Exxon Valdez Oil Spill
Restoration Project Annual report

APEX Project: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska

Restoration Project 96163 A - P
Annual Report

This annual report has been prepared for peer review as part of the Exxon Valdez Oil Spill Trustee Council Restoration Program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: Study History: This research project, APEX: the Alaska Predator Ecosystem Experiment, was initiated under Restoration Project 95163, merging together a group of existing bird and forage fish investigations and proposals to provide an integrated research approach that examines the interactions of seabirds and their prey, the reasons that changes in prey might have occurred, and the consequences for seabirds. The primary hypothesis to be tested is that several seabird species have failed to recover from the *Exxon Valdez* oil spill because of shifts that may have occurred independently in the marine ecosystem of Prince William Sound and the northern Gulf of Alaska. The pilot year of APEX was FY 95. This annual report (96163) covers the FY96 field season.

Abstract:

The Alaska Predator Ecosystem Experiment (APEX) is a five-year study of the effect of food resources on the recovery of seabirds from the *Exxon Valdez* oil spill (EVOS) in Prince William Sound and Cook Inlet. The study examines historical data, forage fish resources, seabird reproduction and colony and population dynamics to address this issue. Research to date strongly suggests a basic shift in ecosystem structure occurred after the late 1970's, with a decrease in species nutritious to seabirds and an increase in less rich species. This resulted in population declines for several species and may help explain the subsequent failure of species to recover from EVOS mortality. Current work aims at refining these conclusions, understanding the factors that may trigger such major shifts, identifying critical areas in Prince William Sound for fish and seabird interactions, and developing a means of monitoring the Northern Gulf of Alaska.

Key Words: *Ammodytes*, *Brachyramphus*, Capelin, *Clupea*, Cook Inlet, *Fratercula*, Guillemot, Gulf of Alaska, Herring, Kittiwake, *Mallotus*, Murre, Murrelet, pollock, Prince William Sound, puffin, *Rissa*, sandlance.

Project Data: (will be addressed in the final report)

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Executive Summary

The APEX Project is a five-year study to determine if food has limited the recovery of seabirds affected by the oil spill of the *Exxon Valdez*. The project has three interconnected components that study fish ecology, seabird foraging at sea, and seabird reproductive success and colony dynamics on land.

Historical analysis of fisheries research trawls shows a strong shift in the marine ecosystem from a shrimp/capelin/sandlance system to one dominated by pollock in the late 1970's and early 1980's. The change is associated with an increase in temperature which may have altered recruitment strength and patterns or changed the distributions of predators. While there are differences in depth and proximity to shore between fish species, APEX research shows little evidence to date of major differences in hydrologic tolerances between these species. This suggests that events at or before recruitment may determine numbers and distribution.

Analysis of data from APEX and previous studies suggest that Pigeon Guillemot breeding numbers declined in response to decreases in sandlance, a major prey. Similarly, Black-legged Kittiwake populations in northern Prince William Sound that have depended more on herring and sandlance have been more stable than southern populations, which may have been more capelin dependent.

APEX data show a strong correlation between local fish abundance and some reproductive parameters of kittiwakes. At a more general scale, similar correlations occur between food abundance and colony foraging and success in Lower Cook Inlet and Prince William Sound. Food delivery correlates with growth of young kittiwakes and Pigeon Guillemots. Quality of food is also important; high-lipid foods are necessary for successful growth based on laboratory and field studies.

Because of the complexity of the interplay of forces affecting seabird and fish populations, we are using models to test the importance of different factors and to identify critical processes and sites that should receive management attention. These products will identify the environmental measurements that should be most useful for longterm monitoring of the Sound. They will also identify critical areas that should be protected as development occurs, especially in the western part of Prince William Sound.

INTRODUCTION

The spill from the oil tanker *Exxon Valdez* resulted in significant mortality of several seabirds and in acute massive damage to Prince William Sound (PWS), Cook Inlet (CI) and the Gulf of Alaska (GOA) (Piatt *et al.* 1990). Seven years following the spill in 1996, several species have not recovered. This may be the result of lingering effects of the oil spill (toxicity of prey or sublethal effects of oil exposure to organisms) or inertia in population response. However, other non-oil factors may also be involved, such as predation, climate-driven ecosystem changes (Duffy 1993), or even 'random' perturbations (Wolfe and Kjerfve 1986).

Numerous seabird species have declined between surveys in the 1970's and the 1990's in Prince William Sound: cormorants (*Phalacrocorax* spp.), Black-legged Kittiwake, Glaucous-winged Gull (*Larus glaucescens*), Arctic Tern (*Sterna paradisaea*), Kittlitz's and Marbled murrelets (*Brachyramphus brevirostris* and *B. marmoratus*), Tufted (*Lunda cirrhata*) and Horned (*F. corniculata*) puffins, and Pigeon Guillemot (*Cepphus columba*) (Agler *et al.* 1994 a,b; Klosiewski and Laing 1994).

Colony trends for kittiwakes in Prince William Sound have been inconsistent, with colonies decreasing in the southern portion and increasing in the north (Irons and Suryan, APEX unpubl. data). The population of Pigeon Guillemots in PWS has decreased from about 15,000 in the 1970's to about 3,000 in 1993 (Isleib and Kessel 1973; Sanger and Cody 1993). Based on censuses taken around the Naked Island complex, pre-spill counts were roughly twice as high as post-spill counts (Oakley and Kuletz 1993). Pigeon Guillemots are listed as "Not recovering" in the 1994 *Exxon Valdez* Oil Spill Restoration Plan.

Common Murres (*Uria aalge*) in Cook Inlet were among the species most damaged by the oil spill (Piatt *et al.* 1990). Murres were also listed as "Not recovering" in the 1994 *Exxon Valdez* Oil Spill Restoration Plan, but have been upgraded to "recovering" because productivity has been normal since 1993 (Roseneau *et al.* 1995, 1996).

The best evidence for a shift in trophic resources for seabirds within Prince William Sound comes from Pigeon Guillemots (Kuletz and Hayes in prep.). In 1994, sandlance (*Ammodytes hexapterus*) accounted for only about 1% of prey items fed to guillemot chicks at Jackpot Island and about 8% at Naked Island. In contrast, in 1979 the sandlance component at Naked Island was about 55% (Kuletz 1983; Oakley and Kuletz 1993). Gadids were much more prevalent in the diet of guillemot chicks on Naked Island in the 1990's than they were in 1979-1981 (< 7%) (Kuletz and Hayes in prep.).

The decline in the prevalence of sandlance in the diet of guillemots breeding at Naked Island might be a key element in the failure of this species to recover from the oil spill. The schooling behavior of sandlance, coupled with its high lipid content relative to that of gadids and nearshore bottom fish, might make this species a particularly high-quality forage resource for PWS pigeon guillemots. This is consistent with the observation that other seabird species (e.g., puffins, murres, kittiwakes) experience enhanced reproductive success when sandlance are available (Pearson 1968; Harris and Hislop 1978; Vermeer 1979, 1980; Monaghan *et al.* 1989) .

In addition, the carrying capacity of the forage environment for guillemots in the absence of pelagic forage species such as sandlance or herring is probably low, restricted to benthic fish. The more pelagic fish, the greater the carrying capacity. Kuletz and Hayes (in prep.) found a strong correlation between total numbers of adult guillemots and active nests and the annual percentage of sandlance in chick diets at Naked Island, supporting this hypothesis.

Mechanisms that could cause a reduction in energy-rich forage fish populations remain unknown. Major oceanographic shifts in the northern Gulf of Alaska and North Pacific (Springer 1993; Piatt and Anderson 1995) may have favored wall-eye pollock (*Theragra chalcogramma*), one of the most abundant forage fish species currently available to seabirds (Parks and Zenger 1979; Springer and Byrd 1989; Brodeur and Merati 1993). Pollock may also be an important competitor or predator of other forage fish species and may suppress populations of these species. Similarly, other species-pairs may overlap in diet, such as herring and sandlance (McGurk and Warburton 1992) or pink salmon (*Oncorhynchus gorbuscha*) and sandlance (Sturtevant 1995 and unpubl.), raising the possibility that reductions in the trophic role of one species may 'release' others from competition for food.

Both to aid in the recovery of injured resources and to safeguard the long-term health of Prince William Sound, Cook Inlet, and the upper Gulf of Alaska, we need to understand the ecological processes that control the ecosystem. This project focuses on the trophic interactions of seabirds and the forage species they feed on. We chose food as the focus because:

1) much of seabird population theory and several empirical field tests have identified food as an important limiting factor (Ashmole 1963; Furness and Birkhead 1984; Birt *et al.* 1987; Cairns 1989);

2) seabird/fish researchers in the PWS/GOA complex have concluded that major changes in food have occurred during the period (Springer 1993; Anderson *et al.* 1994; Piatt and Anderson 1995);

3) other factors such as oil toxicity and climate change might express themselves through the food supply; and

4) knowledge of the forage prey base is critical for other apex predators, such as marine mammals and predatory fish (Pitcher 1980, 1981; Lowry *et al.* 1989), as well as for any larger effort to manage the marine resources of Prince William Sound and the Gulf of Alaska in a sustainable manner.

This report documents progress in the study of the distribution and abundance of prey species through acoustic and net sampling in relation to food, environmental conditions and possible competitors, then proceeds to examine the physical, behavioral and competitive factors that limit access to these forage species for seabirds. We examine the reproductive consequences of such limitations for Pigeon Guillemots, Black-legged Kittiwakes, Tufted Puffins, Common Murres, and cormorants at the chick and colony level.

The study uses between-year comparisons within sites and within-year comparisons between sites in Prince William Sound and Lower Cook Inlet, areas that have different food-availability. The comparisons between years allow us to assess the degree of variability of different food regimes, while the between-site comparisons allow us to assess the responses of seabird communities to these same regimes. We use models to relate oceanographic and spatial features of estuaries in the Northern Gulf of Alaska to changes in seabird diet and population trends. We hope to build up a picture of the forage base for the entire seabird community, setting the stage for a long-term, low-cost monitoring program.

Objectives

The APEX Project has as its objective the testing of a general hypothesis:

A shift in the Prince William Sound marine trophic structure has prevented recovery of injured resources.

This is approached through research testing several more specific hypotheses:

1. The trophic structure of PWS and GOA have changed at the decadal scale.
2. Planktivory is the factor determining abundance of the preferred forage species of seabirds.
3. Forage fish species differ in their spatial responses to oceanographic processes.
4. Productivity and size of forage species change the energy potentially available for seabirds.
5. Forage fish characteristics and interactions among seabirds limit availability of seabird prey.
6. Seabird foraging group size and species composition reflect prey patch size.
7. Seabird diet composition and amount reflect changes in the relative abundance and distribution of forage fish at relevant scales around colonies.

8. Changes in seabird productivity reflect differences in forage fish abundance. as measured in adult seabird foraging trips, chick meal-size and chick provisioning-rates.
9. Seabird productivity is determined by differences in forage fish nutritional quality.
10. Seabird species within a community react predictably to different prey bases.
11. Continuing damage from oiling is restricting recovery of some forage fish species.

By testing these hypotheses, we hope to understand how past effects of changes at the ecosystem level continue to affect seabird populations at present. We also hope to determine which environmental measures will be most effective for future monitoring, to help managers take the pulse of the estuaries of the Northern Gulf of Alaska.

Methods

APEX is a complex project, with fifteen subprojects and three main lines of investigation. In many cases, a single project may contribute to two or more such lines. In addition, data flow is equally complex: a project may contribute some of its data to a second project for analysis, while performing analysis and synthesis of its own data, combined with that of a third project. Several projects provide technical support (Project C, I, O).

There are three main field components of APEX:

1. studying the fish community (Projects A, B, C, L, K),
2. studying fish /bird (Projects B, E, F) and harbor seal/fish (Project I) interactions at sea,
3. those studying the effects of food supply on colony size and reproductive success (Projects E, F,G, J, M, N).

In addition, Project Q is modelling the fish/forage/colony interaction and Projects B and I are modelling spatial aspects of the system. Project O provides statistical and modelling advice to a range of projects.

The fish community component (1) has two goals: 1. to understand dynamics, interactions, and modes of change among fish species in the forage community and 2. to estimate the abundance and quality of fish used by seabirds. The fish/bird and harbor seal/fish at sea component (2) attempts to describe the factors that determine seabird and harbor seal access to food. The effects of food supply on colony component (3) attempts to determine the effects of available food on reproductive success and populations of seabirds.

Methods may be found in the detailed project descriptions for each subproject.

Results

The specifics of results are given in the appendices under individual projects. This section highlights results as they bear upon specific hypotheses.

Hypothesis 1. The trophic structure of PWS and GOA have changed at the decadal scale.

Long-term data from trawls from Kodiak analyzed by Project L very clearly show a transition from shrimp and capelin in the early 1970's to pollock and flatfish thereafter. Data from four Kodiak bays show that declines in shrimp and capelin biomass occurred at different times. The data shown no sign of a single-year event associated with concerted change across species.

In a later-starting data set from Kachemak Bay, fish also increased. Shrimp collapsed in the mid 1980's, well after the decline at Kodiak. Several fish species peaked in 1977 - 1978 and 1989, declining afterward. Pollock has been the most abundant and most variable fish species.

Pollock and flatfish population increases did not occur immediately after collapse of shrimp and capelin. These increases might not have occurred until the arrival of a strong year class. Similarly, shifts in spatial and temporal distribution caused by temperature may have placed predators and prey together, preventing recovery of forage species such as shrimp and capelin.

Our data strongly support this hypothesis of past change. Further study by Project L of historical trends in different bays should be directed at the mechanisms for such change . Studies by Project A should allow us to determine the ecological requirements of post recruitment fish. Data from the SEA project will examine recruitment. Understanding these mechanisms may allow us early warning of future 'triggering' events and may allow changes in fisheries management to avoid loss of resources.

Hypothesis 2. Planktivory is the factor determining abundance of the preferred forage species of seabirds.

Data analysis from 1995 by Project C shows that relatively few plankton dominated forage fish diets in PWS, shifting between summer and fall cruises. Large copepods were selected for.

The most interesting data were for pollock and herring, showing a 60 - 80% overlap in diet. The relation appears asymmetrical: herring diets appeared to shift when herring co-occurred with pollock, compared to when they occurred alone. Pollock did not shift. These data suggest that herring are at a competitive disadvantage where they co-occur with pollock, supporting this hypothesis. Competition may occur at the individual fish or within-school level.

Sandlance had highly variable diets; capelin and eulachon stomachs were usually empty: little data could be obtained from these species to test this hypothesis.

Analysis of 1996 data to be reported in the 1997 report may provide a clearer view of the dietary consequences of single and mixed species schooling for forage fish. These data, combined with those for Hypothesis 3, suggest a need to focus on school and within school level ecology and behavior, to test both hypotheses.

Hypothesis 3. Forage fish species differ in their spatial responses to oceanographic processes.

Prince William Sound
Project A has found major differences in distribution and abundance of forage fish between years and between zones in PWS. In 1995 and 1996, acoustic analysis showed that forage fish were more abundant in the Northern sample area, with fewest prey in the Central area. In 1995, young of the year (YOY) pollock were abundant throughout PWS, but they were scarce in 1996.

The first year appears to have been an exceptionally strong pollock year-class. In both years, herring were abundant in the North and to a lesser extent in the South. Herring and sandlance were more common in shallow water than offshore.

In 1995 and 1996, oceanographic conditions were generally similar between sites. Between years, upper layers were more saline in 1996, as expected from reduced runoff resulting from low rainfall during the winter of 1995/1996. In addition, sampling did not reveal any differences in hydrographic structure caused by tides or inshore/offshore location, although offshore locations tended to be warmer and to have higher salinities. Analyses from Project C for summer and fall 1995 also indicate that total zooplankton density was similar across areas, with plankton concentrated in the upper 25 m.

The data do not seem to support the hypothesis at two different scales. At the school scale, local differences in oceanographic structure (temperature and salinity) do not appear to separate the different species. However, depth does appear to be important, with a shallow-water suite of sandlance and herring and a deeper-water suite of pollock and prowfish. For species like sandlance that spend time in the benthos, an inshore preference is understandable, but for other species, this may simply be a reflection of Heincke's Law (1913) that little fish live in shallower water than do bigger fish.

At a larger scale, there were major differences in forage fish species composition and abundance between the three study sites that are not reflected in hydrographic structure or physical parameters such as temperature and salinity.

We have a paradox that forage fish show differences in abundance and species composition between years and between sites, despite a general uniformity of ecological conditions. This suggests that these changes are generated by factors outside either our spatial or temporal sampling framework. For example, pollock year strength may reflect events over the whole GOA area or herring strength may reflect earlier conditions during spawning.

Cook Inlet

In contrast to PWS , Cook Inlet showed strong differences between the three study sites (Project M). Kachemak showed a strong temperature change with water depth, while the Barrens and Chisik did not, the Chisik being much warmer than the other two. Similar depth differences for salinity and density occurred for Kachemak but not for the other two sites. Basically Chisik is an inshore, estuary system while the Barrens are oceanic and Kachemak is stratified, with an upper layer of glacial runoff.

At Chisik Island, no single species dominated either inshore or shelf areas, while sandlance dominated both inshore and shelf waters at Kachemak. In the Barren Islands, sandlance dominated the nearshore, while pollock dominated the offshore. The Barrens had the highest catch per unit effort; Chisik the lowest.

The three Cook Inlet sites show a much greater range of environmental variability than do the Prince William Sound sites. Kachemak Bay is closest to the PWS sites in hydrology and species. While the varied conditions in CI might explain the differences in fish fauna, equally great ranges in fauna occur under much more homogeneous conditions of PWS. This suggests caution in attributing causation. Local differences may reflect extrinsic conditions, not local hydrology. These results and those from Hypothesis 2 suggest a greater need to focus at the within-school level to test this hypothesis, while continuing the ongoing sampling to better describe year-to-year variability. We also need to coordinate with the SEA project to look at other factors that might explain the observed patterns.

Hypothesis 4. Productivity and size of forage species change the energy potentially available for seabirds.

Projects G and M found significant differences in lipid levels of forage fish potentially available to seabirds and marine mammals in Prince William Sound, Cook Inlet and the Gulf of Alaska. Variation seemed to reflect differences in age, sex, reproductive stage, and locale, although the importance of these varied between species. Pollock, a deeper-water species, had low fat levels, while schooling fish such as capelin, sandlance and herring had variable but generally higher levels of lipids. Inshore, benthic species generally were intermediate in their lipid levels.

In addition, Project A, during acoustic surveys, found age/size differences between forage species in the three study areas. Although the Southern Area was intermediate between the Northern and Central areas in terms of prey abundance, the true availability of fish in the Southern area may have been less, because much of their biomass was adult herring, too large for seabirds.

This hypothesis now appears to have been satisfactorily answered, but we will continue to measure this as a component of estimates of food delivery to colonies.

Hypothesis 5. Forage fish characteristics and interactions among seabirds limit availability of seabird prey.

and

Hypothesis 6. Seabird foraging group size and species composition reflect prey patch size.

There appear to be four general forging situations for seabirds in CI and PWS during the midsummer sampling period: 1) An inshore, benthic fish community that is evenly distributed within substrates (primarily rocky vs eel grass (project F). 2) Also inshore, schools of herring and sandlance are present irregularly. 3) Offshore, in deeper water, there may be deeper, diffuse schools of walleye pollock, and 4) Schools of spawning or post spawning capelin may be present off spawning beaches and not far from open ocean waters. School size, in ascending order, goes: benthic < inshore < capelin < pollock. Spatial predictability within a year, in ascending order of unpredictability, probably goes: benthic < pollock <inshore < capelin; while between years, it is probably: benthic < inshore < pollock < capelin.

Project B, working with fish data from Project A, has established a clear difference between the seabirds foraging on inshore, shallow schools of herring and sandlance (Black-legged Kittiwakes and Marbled Murrelets) and on the deeper, offshore walleye pollock schools (Tufted Puffins, Glaucous-winged Gulls). Within inshore flocks, birds chose wider and shallower schools. Project F has shown that guillemots forage on benthic forage fish and occasional inshore schools when they are available.

Kleptoparasitism was strongest against kittiwakes in dense flocks and against alcids in dispersed flocks. Kittiwake plunge-diving appeared to be suppressed by the presence of Glaucous-winged Gulls.

A possible complication for this and other hypotheses at the scale of the individual is the evidence for Pigeon Guillemots (Kuletz, ms; Project F) and kittiwakes (Project E) that individual birds may have narrow and persistent preferences for foraging areas that keep them from responding freely to food availability. At a colony or population scale, such preferences may cancel each other out, so we might expect a better fit of foraging seabirds to resources when considering means of populations, rather than individuals.

The data appear to support these hypotheses; the question now is to what extent such limitations serve as a filter between forage fish and population effects for seabirds and whether we can predict access to fish based on environment, to determine which areas are likely to be critical for seabirds. Project B is addressing these issues in 1997.

Hypothesis 7. Seabird diet composition and amount reflect changes in the relative abundance and distribution of forage fish at relevant scales around colonies.

and

Hypothesis 8. Changes in seabird productivity reflect differences in forage fish abundance as measured in adult seabird foraging trips, chick meal-size and chick provisioning-rates.

Variation in Forage Fish Abundance
In PWS, Project A showed that potential forage fish species of an appropriate size for seabirds were most abundant in the Northern study area. Inshore schools of young herring and sandlance provided the best opportunities for foraging. In contrast, fish were less common in the other two study areas and consisted of adult herring potentially too large for foraging or of species not usually exploited by seabirds (tomcod and salmon). Inshore sampling by purse seine and cast net did not appear to sample the inshore benthic fish community well enough to provide data on relative abundance between areas.

In Cook Inlet, Projects J and M showed significant differences in prey abundance between the three study colonies. At the Chisik Islands, no single fish species dominated either inshore or shelf areas, while sandlance dominated both inshore and shelf at Kachemak. In the Barren Islands, sandlance dominated the nearshore, while pollock dominated the offshore.

Response of Black-legged Kittiwake
An initial analysis of data from projects A, B, E for kittiwake by Project B showed significant relations between fish abundance in inshore acoustic surveys and number of kittiwakes observed during nearshore surveys (Fig 1), between nearshore fish biomass and number of kittiwake chicks produced in each study area in 1996 (Fig 2); between offshore biomass and nests in 1995 and 1996 (Fig 3); and between offshore biomass and number of chicks in 1995 and 1996 (Fig 4). These data are limited and preliminary, but they establish a key condition to testing this hypothesis: there appears to be a strong underlying positive relationship between fish abundance and kittiwake reproduction.

The next step is to examine which features of kittiwake foraging correlate best with fish abundance, for long-term monitoring. These might include adult foraging trip length or distance, chick meal size, chick provisioning rates, and total chick energy intake. These are still being examined for 1995 and 1996 data.

Response of Pigeon Guillemot
For Pigeon Guillemots, sandlance were the principal species in beach seines at Naked Island as well as the second most common prey recovered from or intercepted at nests (Project F). Near Jackpot, herring were the main species caught (Project A) and the main guillemot prey (Project

G). At Kachemak Bay, the diet was mostly blenny and sandlance (Projects G, M), reflected by a dominance by sandlance in inshore fish sampling (Project M).

Within Kachemak Bay, at an even smaller scale, differences in sandlance were significantly correlated with sandlance in guillemot diets (Project M).

The available data support in broad terms a relationship between seabird diet and relative abundance of forage fish. By early 1998, we should have a good idea of the strongest correlations. Further work would then focus on fine-tuning the calibrations and building up statistically-significant sample sizes.

Hypothesis 9. Seabird productivity is determined by differences in forage fish nutritional quality.

We have taken a two-pronged approach to this, using both laboratory studies and field studies. The lab studies allowed us to control foraging rates and diet (Project N). This study fed Black-legged Kittiwakes and Tufted Puffins high-lipid capelin or sandlance and compared growth with that of birds fed low-lipid pollock. Growth in mass was more sensitive than growth in wing length to differences in lipid levels in diets. Since lighter young in other species appear to have lower survival after fledging that do heavier birds, this suggests one mechanism by which low-lipid diets may contribute to the failure of some seabird species to recover from the EVOS.

Project G, in conjunction with Projects E, F, J, M, looked at energy provisioning to Pigeon Guillemots and Black-legged Kittiwakes, For kittiwakes in 1996, the provisioning rate varied by a factor of 2.6, with Shoup Bay showing the highest rate and Chisik Island, the lowest. For guillemots, the provisioning rate varied by a factor of 1.8 for three colonies, combining 1995 and 1996 data.

For logistic and predation reasons, we were not able to get simultaneous provisioning and growth rates for kittiwakes at more than two of six colonies (provisioning rates for four colonies, growth rates for four colonies, overlap at two colonies: Shoup and Eleanor). As predicted from provisioning rates, Shoup had a higher growth than did Eleanor. After reworking the protocols, we expect to be able to compare data from four to six colonies for 1997.

For guillemots, we were able to get growth and provisioning for only Naked Island and Kachemak Bay (Jackpot experienced total reproductive failure because of predation). Again, as predicted from provisioning rates, Kachemak had a higher growth rate than did Naked Island. We hope to protect Jackpot from predation this year.

We have strong support for this hypothesis from both lab and field studies, but the true test will come from interannual comparisons within sites and from expanded data sets for comparisons among sites within years.

Hypothesis 10. Seabird species within a community react predictably to different prey bases.

The main test of this hypothesis will be conducted by Project Q which, while it presented an annual report, did not actually start until after the reporting period. However, several disparate sets of data support this hypothesis. For example, Hays and Kuletz (ms; Projects F), summarizing historical data and data from Project F, found a strong relation between sandlance in diet of guillemots and number of breeding pairs. Projects G and N showed a strong relationship between food quality and growth of young. Projects J and M found a very strong general community response to different levels of food availability within Cook Inlet.

Perhaps the most intriguing result at present is a regional analysis of kittiwake populations in Prince William Sound by Project E. This suggests that a herring/sandlance food base in Northern PWS with its stratified hydrology has allowed a stable population, while the Southern area, vulnerable to intrusions from the Alaska Coastal Current (and perhaps formerly capelin-based), has shown a general decline. While the mechanism is open to discussion, the general regional trends suggest support for the hypothesis.

Next year (FY 97) will represent our first attempt to fully address this hypothesis.

Hypothesis 11. Continuing damage from oiling is restricting recovery of some forage fish species.

Project P examined potential for *Exxon Valdez* oil residue in sandlance, an important prey fish in PWS and an intertidal species expected to be sensitive to continued oiling. Initial results from 1996 indicated EVOS oiling, but further work showed instead a reaction to an unknown compound. Similar studies should be conducted on sandlance and other inshore-spawning species immediately following high-latitude spills, because of this species' importance in marine ecosystems and its potential vulnerability to oiled substrates.

Since eight years have already passed since the spill, further work on sandlance exposure to Exxon Valdez *oil appears unlikely to produce significant results.*

Life-saving

While not formally a part of APEX activities, some of the most gratifying results of the project's activities were two separate incidents where boats involved in Project B and Project M saved eight lives. In the first case, William Ostrand and John Maniscalco brought their small research vessel alongside a burning boat and rescued four people. In the second case, while conducting hydroacoustic surveys, the *Tiglax*, with Kevin Bell as Captain and John Piatt as Lead Researcher, searched for and rescued two children and two adults from the waters of Cook Inlet.

Discussion

After the second year of APEX, some very clear pictures have emerged. APEX has shown that food availability at sea, food abundance, food quality and supply rate to young birds all can affect seabird reproduction in one form or another. We need now to understand their relative contributions to the overall picture.

We also have significant results for Pigeon Guillemot and Black-legged Kittiwakes, suggesting that food can affect size of breeding population and population dynamics. With kittiwakes, we can trace step by step, in preliminary form, a chain from fish in the sea to foraging to reproductive success to colony and regional dynamics. This is perhaps unprecedented in seabird studies. With Pigeon Guillemots, we lack only foraging observations to do the same. We await another year's data and the activities of Project Q to help pull this together. The models may serve two purposes: as a predictive management tool and to 'hindcast' the role that food may have played relative to the

EVOS in affecting populations of these two species.

We are also at a stage where the first descriptive models have been produced for seabird foraging; similar models for fish are expected in 1997. These should allow us to model PWS spatially, predicting where the 'good' areas are for fish of different species and for birds to forage on them. Again these models could be used in two ways. As a hindcast, we can see how much important foraging area was affected by the spill and, for the future, we can predict fish and bird concentrations that should be protected from development. This may prove increasingly important as the Whittier Road is completed, triggering development and the need for infrastructure in Western PWS. Since much of the increase in tourism stems from the EVOS, these models are likely to address a restoration need that is only just emerging.

One important task of the past year was a reworking of the protocols. Our study sites differ so greatly in logistical and physical constraints that not all data could be collected at all sites without exceptional effort. For example, obtaining meal size from kittiwakes on cliffs is a serious challenge, yet it is key to understanding the link between food and reproductive success. The principal investigators spent a great deal of time on this which should improve our data for the 1997 field season.

The Tasks Ahead

It is clear that APEX needs to rework its hypotheses. In the review above, it became evident that several of the hypotheses have essentially been tested to the extent useful for answering APEX's larger hypothesis. Several others appear less effective than when originally developed. Still others have arisen. This turnover is natural in research. This ongoing effort will be concluded over the fall and winter of 1997 - 98.

The next several years may be spent fine-tuning the bird-fish picture, or we may find the situation much more variable than initial sampling suggests. Also, we will be focusing much more on the mechanisms that mediate relative abundance in the forage fish community. Without such understanding of the fish community dynamics, the seabird efforts remain essentially *post hoc.* Coupled together, seabird and fisheries dynamics may offer us much more capability to manage the Northern Gulf estuaries in an ecologically sustainable manner.

For FY 97, we will be expanding efforts to address several gaps in the project, looking at energetics of adult seabirds, interactions of Marbled Murrelet productivity with fish distribution, how juvenile pollock use jellyfish as staging areas, the diets of sharks, and the trophic role of jellyfish. We will conclude the cooperative work (part of Project I) with K. Frost, comparing harbor seal diets and APEX fish data.

The upcoming two years may be especially rewarding. The summer season of 1997 and winter of 1997 - 1998 will occur under El Niño conditions. These may be quite different from what we have sampled so far or may trigger changes in existing conditions that will help deepen our knowledge of the environment for upper-trophic level predators in the estuaries of the Northern Gulf of Alaska.

Conclusions

Coincident with the EVOS, the forage fish situation for seabirds in the Northern Gulf of Alaska and estuaries deteriorated, with a transition from energy-rich capelin and sandlance to a system dominated by the nutritionally poorer walleye pollock. Effects of this can be seen for various seabird species at the level of diet, individual chick growth rate, number of breeding birds, colony reproductive success, and regional population dynamics.

Tasks that remain are 1. to better characterize these effects at the interannual scale of variability; 2. to generate predictive models useful for future monitoring and for 'hind cast' testing of the main hypothesis; 3. to generate spatial models of areas important for fish, birds, and possibly marine mammals; and 4. to develop an understanding of what generates change in the forage community.

Acknowledgments

This project is the result of the work of a large number of investigators, field workers, technicians, and support staff. These are recognized and acknowledged in the individual sections. They worked under conditions that were not always pleasant, dry or warm. They endured the tedium of long field hours, showed courage when fellow Alaskans needed rescuing, and usually found the time to appreciate the beauty of the Northern Gulf and its estuaries.

At the overall program level, A. Gunther, S. Senner, R. Spies, and B. Wright have been extremely helpful in providing moral support, insights, and critical suggestions that have greatly improved the project. The EVOS Scientific Reviewers have also helped greatly with their commentary.

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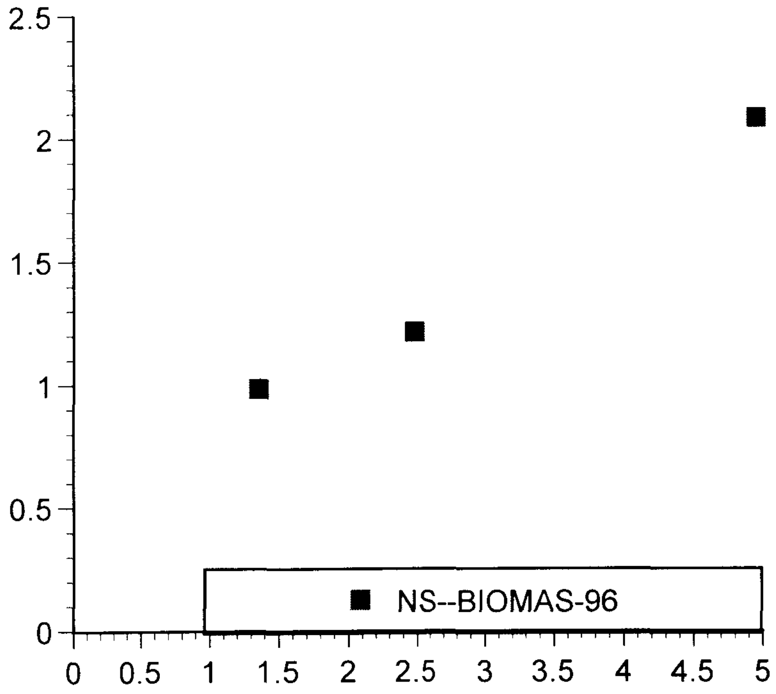
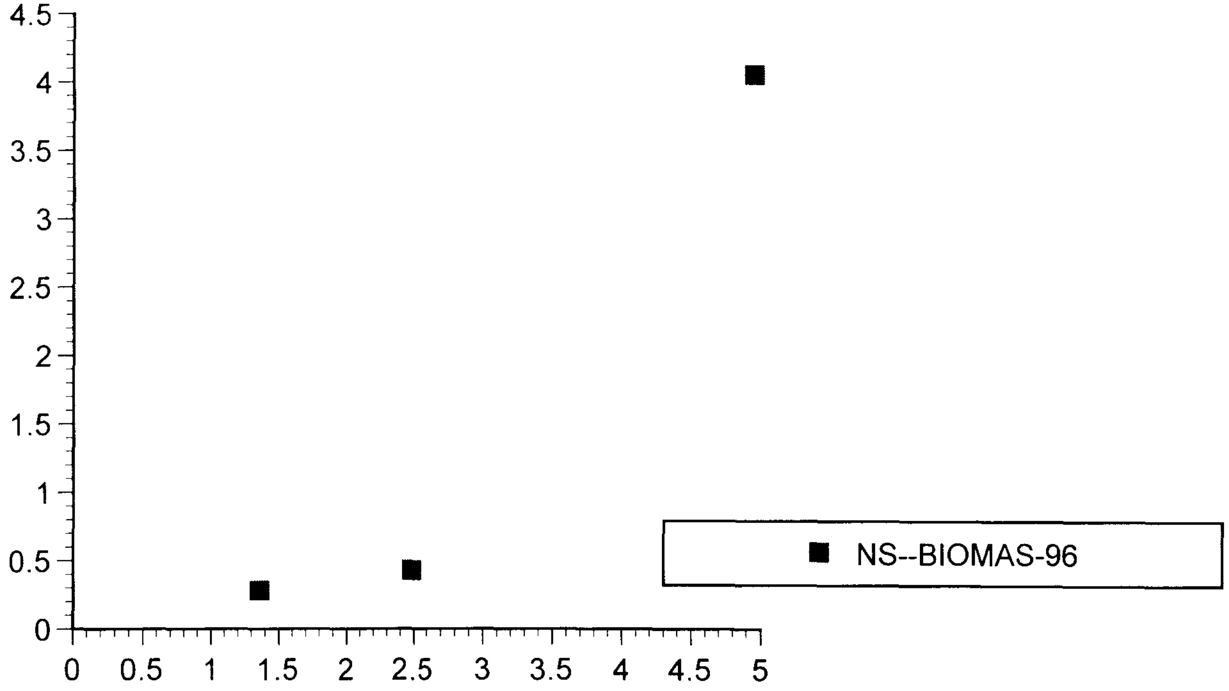
Figure 1. Fish abundance in inshore acoustic surveys and number of kittiwakes observed during nearshore surveys.



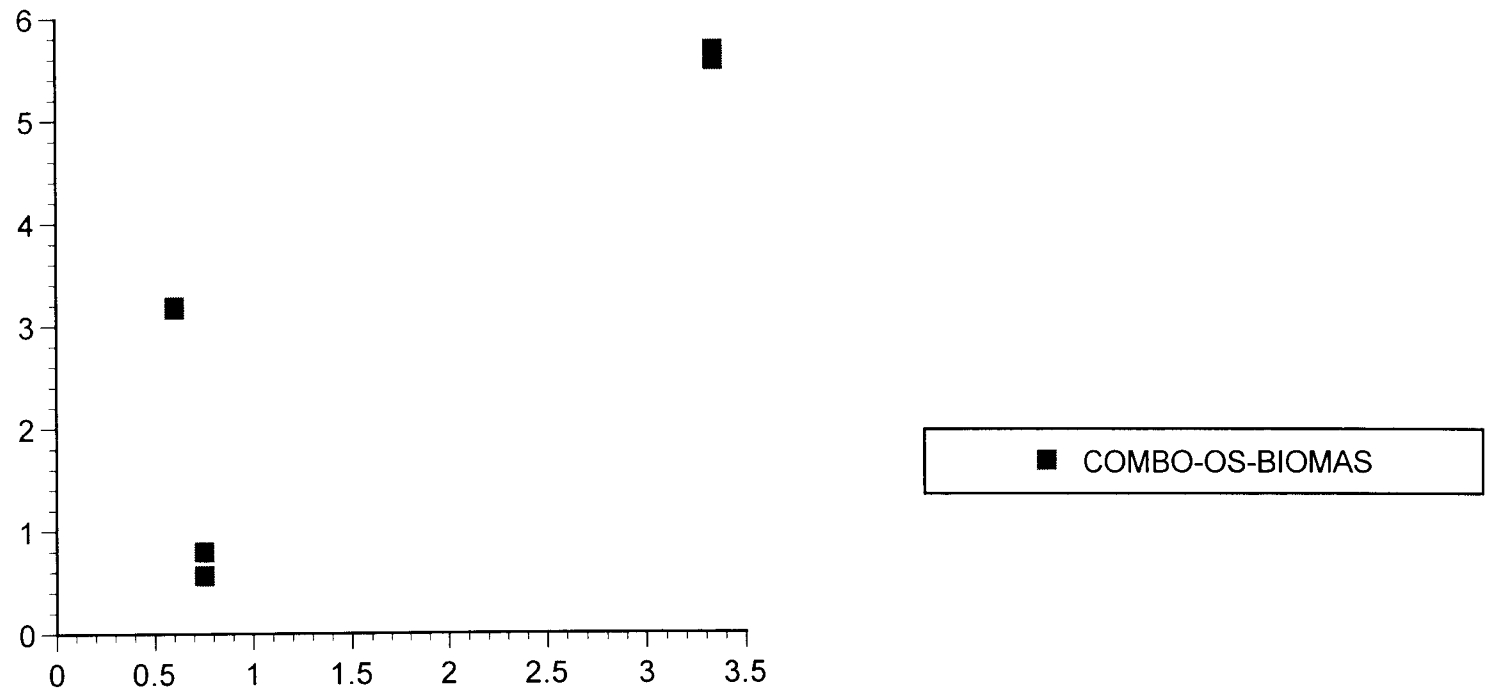
NEARSHORE FISH BIOMAS (X AXIS) VS
MEAN NUMBER OF BLKI OBSERVED
DURING NEARSHORE SURVEY

Figure 2. Nearshore fish biomass and number of kittiwake chicks produced in each study area in 1996.



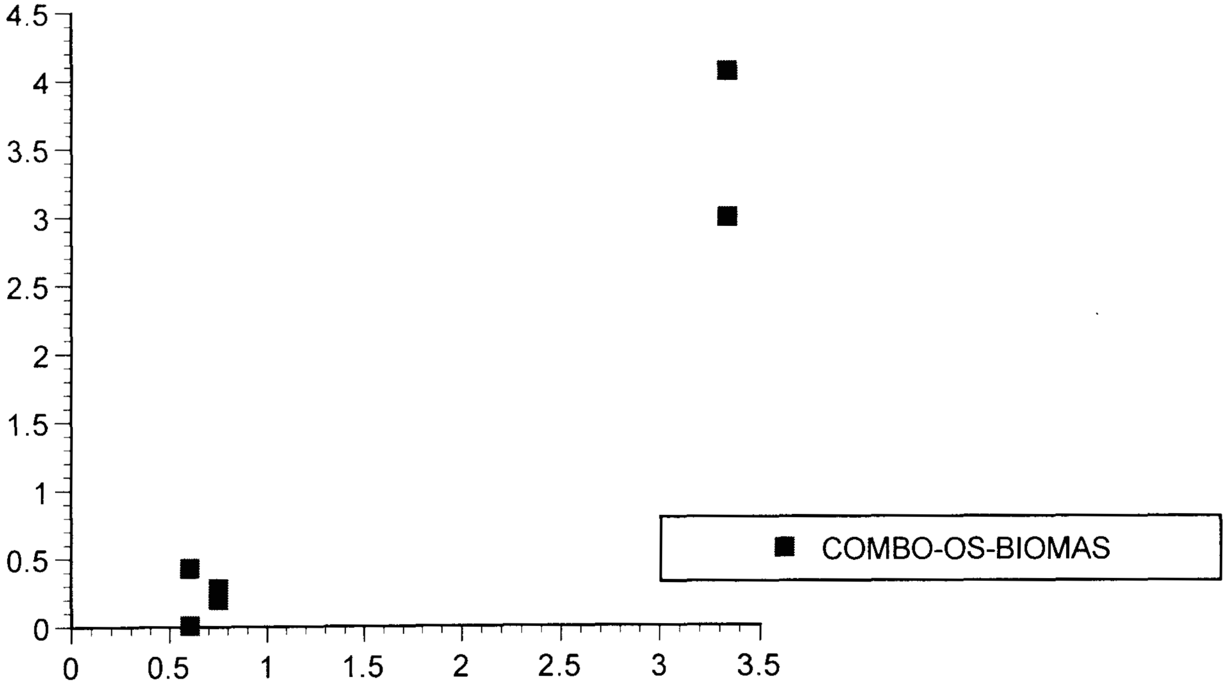
NEARSHORE FISH BIOMAS (X AXIS) VS
NUMBER OF BLKI CHICKS. 1996 DATA

Figure 3. Offshore biomass and nests in 1995 and 1996.



OFFSHORE FISH BIOMAS (X AXIS) VS NO
OF BLKI NESTS. 1995 AND 1996 DATA

Figure 4. Offshore biomass and number of chicks in 1995 and 1996.



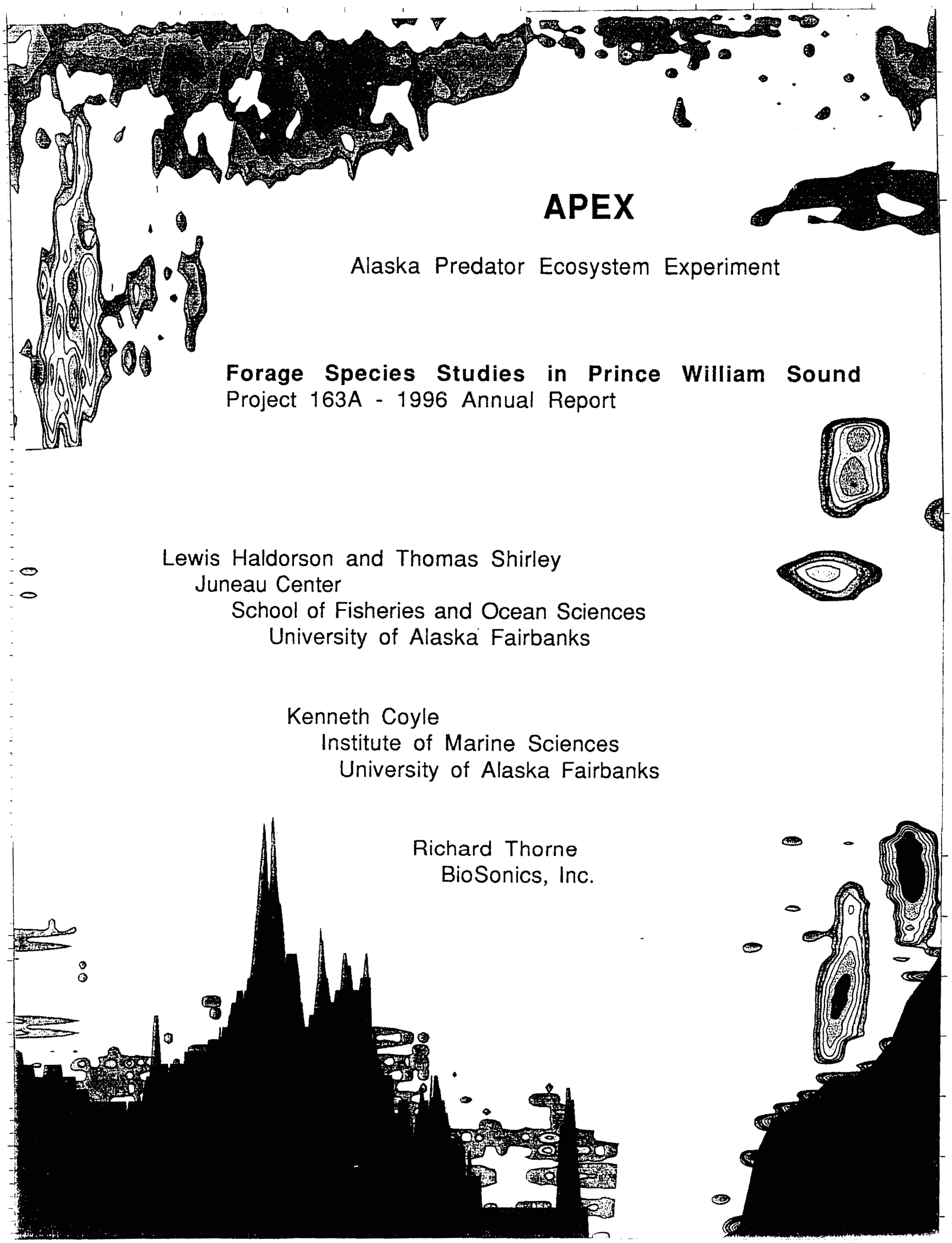
OFFSHORE FISH BIOMAS (X AXIS) VS NUMBER OF BLKI CHICKS. 1995 AND 1996 DATA

APPENDIX

REPORTS OF INDIVIDUAL SUBPROJECTS

APPENDIX A

APEX: 96163A



APEX

Alaska Predator Ecosystem Experiment

Forage Species Studies in Prince William Sound

Project 163A - 1996 Annual Report

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ABSTRACT

The abundance of forage fishes was assessed in three areas of Prince William Sound in July 1996 using acoustic surveys of offshore and nearshore areas, and a beach seine survey for the very shallow nearshore zone. Offshore biomass was similar in depths above and below 25 m, and was about four times higher in the North area than in either the Central or South areas. The only fishes sampled by net in the offshore survey were walleye pollock over 200 mm in length.

Herring were by far the most abundant forage species in the nearshore acoustic survey, based on both net sampling and video observations of acoustic targets. Most herring were juveniles aged 1 or 2 years; however, large schools of young-of-the-year (YOY) herring were found in the North area, and notable numbers of adult herring occurred in the South area. Other species encountered in the nearshore acoustic survey were sand lance and YOY walleye pollock, both in the North study area. Nearshore acoustic biomass was considerably higher in the North study area than in either the South or Central areas. Most nearshore biomass was concentrated in distinct schools of fish that occurred on relatively few transects - from 10% of transects in the South, to 25% of transects in the North. The number of nearshore acoustic transects where large schools (mean transect estimate > 10 g/m^2) were encountered was approximately three times higher in the North study area than the South, and ten times higher than the Central area. Video observations were very valuable in identifying acoustic targets, and allowed confirmation of distinctly different patterns of acoustic return associated with schools of herring, sand lance and YOY walleye pollock.

Beach seine catches were highly variable, but trends were similar to those in the acoustic surveys. More fish were caught in the North - about five and twenty-five times as many as in the South and Central areas, respectively; with approximately equal effort. Nearly all fish caught in the North were herring or sand lance. Some sandlance did occur in catches from the Central area, although they ranked third in total catch after pink salmon and tomcod. In the South herring were about 80% of total catch, followed by tomcod at about 15% of total. In frequency of occurrence (the proportion of seine hauls that had a species present in the catch), herring and sand lance ranked highest

in the North, whereas pink salmon and tomcod ranked one and two in both the South and Central areas.

All surveys (offshore acoustic, nearshore acoustic, beach seine) indicated that forage species were much more abundant in the North than in either the Central or South areas. Herring were the most common and widespread forage fishes, and were most abundant in the North, where many schools of YOY herring and older (age 1 and 2) juveniles occurred. In addition the North area had notable occurrences of sand lance and YOY pollock.

There was no obvious explanation for the dramatic differences we observed in the abundance and distribution of forage fishes in Prince William Sound. Temperature and salinity distributions in the water column were very similar in the three study areas. We examined salinity and temperature distributions along nearshore to offshore transects in all three study areas to determine if nearshore frontal zones could be associated with distributions of forage fishes. In all cases, the pronounced stratification of the water column persisted into very shallow nearshore areas, indicating that the energy of tidal mixing was insufficient to break down stratification in the nearshore areas.

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ACKNOWLEDGMENTS

This research program was conducted with the aid of many individuals. Especially valuable were the contributions in field work by Jennifer Boldt, Cathy Coon, Lee Hulbert, Malcolm McEwen, Jill Mooney, Chris Rooper and Molly Sturdevant. Lyman MacDonald provided very valuable assistance in sampling design and data analyses.

INTRODUCTION

Prince William Sound (PWS) is one of the largest areas of protected waters bordering the Gulf of Alaska (GOA), and provides a foraging area for large populations of apex predators including piscivorous seabirds. These avian predators were severely impacted by the EXXON VALDEZ oil spill (EVOS), and many - especially common murres, marbled murrelets, pigeon guillemots - suffered population declines that have not recovered to pre-EVOS levels (Agler et al. 1994). Piscivorous seabirds in PWS are near the apex of food webs based on pelagic production. They feed on an assemblage of forage species that include several fishes and may also prey on invertebrates such as euphausiids, shrimps and squid. Recovery of apex predator populations in PWS depends on restoration of important habitats and the availability of a suitable forage base. Since the 1970's there has apparently been a decline in populations of apex predators of the pelagic plankton production system, and it is not clear if failure to recover from EVOS-related reductions is due to long-term changes in forage species abundance or to EVOS effects.

Forage species include planktivorous fishes and pelagic invertebrates. Planktivorous fish species that occur in PWS and are known or likely prey of apex predators include Pacific herring, *Clupea pallasi* ; Pacific sand lance, *Ammodytes hexapterus* (Drury et al. 1981, Springer et al. 1984, Wilson and Manuwal 1984); walleye pollock,*Theragra chalcogramma* (Springer and Byrd 1989, Divoky 1981); capelin, *Mallotus villosus* , and eulachon, *Thaleichthys pacificus* (Warner and Shafford 1981, Baird and Gould 1985). Pelagic invertebrates; including euphausiids, shrimp, mysids, amphipods; are found in the diets of sand lance, capelin and pollock, as well as young salmon (Clausen 1983, Coyle and Paul 1992, Livingston et al. 1986, Straty 1972). When aggregated in sufficient densities, macrozooplankton are fed on directly by marine birds (Coyle et al. 1992, Hunt et al 1981, Oji 1980).

We used hydroacoustics to estimate the distribution and abundance of forage fishes. Hydroacoustics measure horizontal and vertical abundance at scales not possible by traditional net sampling techniques, and have been used to quantify fish (Thorne et al. 1977, Thorne et al. 1982, Mathisen et al. 1978) and the spatial patterns of a variety of aquatic populations (Gerlotto 1993; Baussant et al. 1993; Simard et al. 1993). In Alaskan waters, acoustics have been used to measure biomass relative to tidally-generated frontal features (Coyle and Cooney 1993) and the relationship between murre foraging, tidal currents and water masses in the southeast Bering Sea (Coyle et al. 1992). Acoustic sampling cannot positively identify the species of targets; consequently, other sampling must be conducted concurrently with acoustics to identify species and to provide size distribution data necessary for biomass estimations.

This report describes the second year of research that is part of a program (APEX) designed to determine if forage species availability is limiting the recovery of seabird populations that were impacted by the EVOS. In the first year of the study (1995), the most significant aggregation of forage species occurred offshore in the central part of the Sound where large schools of young-of-the year walleye pollock were found at depths from 30 - 70 m. Studies of seabirds in 1995 indicated they foraged principally within 1 km of the shoreline. As a consequence of those observations our research program in 1996 directed much more effort to quantifying the abundance of forage species in the nearshore area, and we added a nearshore acoustic survey and a beach seine survey.

OBJECTIVES

1. Provide an estimate of the abundance and distribution of forage species in nearshore (within 1 km) and offshore zones of three study areas in Prince William Sound.

2. Describe size distributions of the most abundant forage species.

3. Provide samples of forage fishes to NMFS for food habits studies, and other samples of forage species to other APEX and EVOS funded researchers.

4. Describe oceanographic conditions in the study area, and determine if forage fish distributions are associated with hydrographic features such as tidal fronts.

FIELD METHODS

Field studies were conducted in July 1996. The survey was conducted in three areas designated as the north, central and south study sites (Figure 1). The study began on 14 July and ended on 28 July:

14 July	Loaded gear on vessels in Cordova, traveled to South study area
15-19	Conducted surveys in South study area
19-22	Conducted surveys in Central study area
23-27	Conducted surveys in North study area.
28 July	Traveled to Cordova, unloaded equipment.

Offshore Survey.

The offshore survey was conducted from two vessels, an acoustic/bird observation vessel (F/V CAPE ELRINGTON) and a mid-water trawl vessel (F/V CARAVELLE). Surveys were conducted during daylight hours, typically between 0600 and 2000. The acoustic vessel surveyed a series of transects. The transects were in a pattern of parallel transects through each area, terminating at shorelines as close as possible to the shore. Patterns to be run in each area followed a pre-selected series of transects spaced at two mile intervals (Table 1, Figures 2 - 4). Data were collected with a 120 kHz BioSonics Model 101 Scientific Echosounder, with the transducer deployed in down-looking mode from the towed vehicle. Signal processing was accomplished with a BioSonics Model 221 ESP Echo Integrator.

The F/V CARAVELLE collected mid-water trawl samples of targets designated by the acoustic vessel (Table 2). The location of net sampling was determined by acoustic and bird observations. Where acoustic signals or bird activity indicated the presence of forage species, scientists on the acoustic vessel directed the midwater trawl vessel to the location and depth where collections were desired.

CTD profiles were collected at net collection stations and on each transect line (Table 3). A Seabird SEACAT SBE 19 CTD was used to sample the water column from the surface to 200 m depth, or to within 10 m of the bottom at shallower stations.

Nearshore Survey

The F/V MISS KAYLEE conducted a series of hydroacoustic transects in the three study areas, working in the same general area as the offshore survey on each day. On July 26 and 27 the CAPE ELRINGTON conducted the nearshore survey due to failure of acoustic equipment on the MISS KAYLEY. The equipment on the MISS KAYLEE was a Biosonics ESP 420 kHz analog down-looking and side-looking system multiplexed with a 130 kHz DT6000 digital down-looking system. On July 19th the ESP 420 kHz system failed and beginning on July 20th the inshore survey was continued with only the DT6000 system. On July 25th the DT6000 system also failed, and it was replaced with a DT5000 system. The DT5000 system failed almost immediately; consequently, the nearshore survey was completed using the CAPE ELRINGTON and the ESP 120 kHz system.

Inshore transects were in a pattern of zig-zags within 12 km segments of shoreline. The 12 km study site segments were laid out sequentially through the shoreline within each study area. The number of 12 km study sites within each study are: North - 26, Central - 8, South 21 (Figures 5 - 7). Since time constraints precluded sampling all of the shoreline in the North and South areas, a systematic sampling plan was followed, and every other study site segment was sampled, with random removal of additional segments to further reduce the number as necessary. Segments sampled were:

North	1, 3, 5, 7, 9, 13, 15. 17, 19
Central	1-8
South	2, 4, 6, 10, 14, 16, 18, 20

Each 12 km study site was further divided into ten 1.2 km beach sections, with the starting and ending points of each beach section marking the shoreward turning point in a series of 20 transects were laid out following a zig-zag pattern (10 zigs, 10 zags), with each transect about 1.2 km long (Table 4, Figure 8). The acoustic transects are identified by a alpha-numeric designation, for example: N03-02A

N - indicates the North study area
03 - indicates the third 12 km shoreline segment
02 - indicates the second beach section, or second set of zig-zags
A - indicates the first of the two zig-zag transects off beach section 2.

Acoustic targets found by the survey vessel in the inshore study areas were sampled by the F/V PAGAN using purse seine, dip nets, cast nets (Table 5) or a video-equipped ROV (Remote Operated Video) (Table 6).

CTD profiles were collected at representative sites at each 12 km segment sampled acoustically (Table 7). A Seabird SEACAT SBE 19 CTD was used to sample the water column from the surface to 200 m depth, or to within 10 m of the bottom at shallower stations.

Beach-seine survey

Beach seining was conducted in each study area in the same 12 km beach segments that were sampled in the inshore survey. The beach sections within each segment sampled were chosen randomly. The ten 1.2 km sections within each study site segment were randomly ranked, using a random number table (Table 8). The first three ranked sections had one seine haul made on any beach that was thought to be fishable. If there were no fishable beaches in a top-ranked beach section, the next ranked section was used.

Net Sampling methods

A mid-water trawl was the primary sampling tool used to sample acoustic targets offshore. This net is a research-scale version of a mid-water commercial herring trawl used in Canada. Although the absolute net mouth opening is about 100 m^2, the effective opening is about 50 m^2. This size net has proven effective on larger nektonic forage fishes such as herring (Mike Halstead, Research Nets Inc. Seattle, Personal communication). The mesh sizes diminish stepwise from about 2" in the wings to 3/8" (9.5 mm) in the codend. An additional cod end liner with 1/8" (3.2 mm) mesh netting was sewn into the midwater trawl, this inner liner terminated in a plankton bucket with 0.5 mm nytex mesh that retained smaller macroplanktonic organisms. Midwater trawl samples were collected at locations and depths specified by the researchers monitoring the acoustic sampling.

A purse seine was the primary net sampling gear used to collect samples of acoustic targets in the nearshore survey, although dip nets and cast nets were used occasionally to collect fishes very near the surface. The purse seine was 200 m long by 20 m deep with 25 mm stretched mesh.

The beach seine is a 37 m long net equipped with bridles and 30 m long lines attached to each bridle. The net tapers from 5 m depth at the center to 1.5 m depth at the end of each wing. The mesh size is 20 mm stretched mesh except for a center panel 9 m long that has 10 mm stretched mesh.

Sample Processing

MacroInvertebrates.

Gelatinous zooplankton were identified to the lowest possible taxon in the field. All other zooplankton were either frozen for future energetic studies or preserved in buffered 5% formalin.

Fishes.

Fish larger than about 50 mm were identified in the field and sorted to species. All fish were measured (fork length) unless net hauls contain large numbers of individuals of some species. Large catches were randomly subsampled by splitting the catch down to 100 - 200 individuals for measurement. Subsamples of all forage fish species were frozen and returned to the laboratory for future life history and energetics studies.

ANALYTIC AND STATISTICAL METHODS

Acoustic data

Offshore survey.

Averages were caculated for each transect within two depth strata: 1 - 25 m and 26 - 100 m. the deeper stratum exends further than the previous year (100 m ve. 65 m) because of the lower frequency (120 kHz vs. 420 kHz) used in 1996. A scaling factor of - 30 dB/Kg of fish biomass was used to convert echo integration measurements to fish density.

Nearshore survey.

Biomass estimates were developed by scaling down-looking acoustic data based on the length distributions of the dominant fish species collected in each study area. Estimates of the number of individual fish per cubic meter are determined by an equation relating acoustic target strength to fish length. Data were collected using the default target strength of -42.2 dB. Equations to convert fish length (L, in cm, log base 10) to target strength (TS) were:

pollock	$TS = 20 (\log L) - 66$	
herring	$TS = 20 (\log L) - 68$	
sand lance	$TS = 20 (\log L) - 93.7$	(based on 38 kHz system)

Differences between the computed target strength and the default target strength were used to rescale the data.

Estimates of fish numbers were converted to an estimate of biomass per cubic meter using the length-weight relationship for the dominant species. Equations to compute biomass (W - in grams, L - in mm) were:

pollock	$W = (1.89 \times 10^{-6}) L^{3.272}$
herring	$W = (5.007 \times 10^{-6}) L^{3.196}$
sand lance	$W = (4.81 \times 10^{-7}) L^{3.451}$

Biomass per cubic meter estimates were converted to biomass per square meter of surface by integrating the results over the depth of the sampled water column. Length to target strength relationships were taken from the literature, and the length-weight equations were from our unpublished data in PWS.

Geographic distributions of forage species were assessed by developing area plots of biomass density gradients determined through a kriging routine. The kriging method has a gridding algorithm (we used a minimum curvature algorithm) that estimates the data between transect lines based on spatial variation along the transect lines. Therefore, the most accurate point estimates are those occurring closest to the lines in regions where transect density is highest. Land masses were overlaid on the area plots after the gridding algorithm had been run.

Biomass estimates for each of the nearshore 12 km sampling sites were developed by calculating the mean for each set of zigs and zags separately, and an overall estimate was calculated by including all transects (zigs and zags) in the average. The estimate of nearshore biomass in each of the three study areas (North, Central, and South) was produced by averaging the overall estimate from each of the sampling sites.

Depth profiles of temperature, salinity and sigma-t were plotted for all CTD casts. We also evaluated geographic patterns in offshore water structure by plotting isotherm and isohaline lines over series of stations in the North (Valdez Arm), Central (east of Knight Is.) and South (Knight Island Passage) study areas.

Geographic patterns of temperature and salinity were plotted for series of CTD stations extending from nearshore to offshore in the North (Port Fidalgo), Central (MacPherson Passage), and South (Knight Island Passage) study areas to determine if tidal fronts were found in the nearshore areas of the Sound. In addition, two diel CTD stations were sampled every 6 hours over a 24 hour period in Bainbridge Passage to determine if tidal currents were strong enough to break down the vertical stratification of the water column.

RESULTS - OFFSHORE SURVEY

Hydroacoustic

Aggregations of forage fishes were seldom encountered in the offshore survey. This was a sharp contrast to the results from the 1995 survey, when large aggregations of young-of-the-year walleye pollock were found in the Central area east of Knight Island (Figures 9, 10). In most cases densities were low, less than one gram/square meter (Table 9). The North area had average densities of acoustic biomass that were over three times higher than either the Central or South areas (Table 10).

Net Sampling

Midwater trawl samples were collected at twelve stations in the offshore survey (Table 11). The only fish in midwater catches were walleye pollock at stations 65 (Central area, mean fork length 281 mm) and 119 (North area, mean fork length 260 mm), these lengths indicate they were at least two years of age. Jellyfish were the dominant component of midwater trawl catches, the most abundant genera of jellyfish were *Aequorea* and *Cyanea* (Table 11).

Hydrographic

Prince William Sound is a large estuary, with large amounts of freshwater input from rainwater and meltwater from glaciers and snowfields. The resultant salinity gradients are largely responsible for stratification of the water column in the Sound. In the summer of 1996 all three study areas had gradients in temperature and salinity in the upper 50 m, with surface temperatures ranging from 12 - 15 ° C. and salinities from 17 - 30 °/oo (Figure 11). Below about 50 m temperatures were typically <5° C with salinities above 32 °/oo.

Physical conditions in the three study areas were very similar, both in termperature and salinity. Unlike 1995, there was no layer of cold water near the surface in the South, and the Central area was not notably less saline at the surface than the North or South areas. The upper 20 meters of the Sound was generally more saline in 1996 than in 1995. All of these observations are consistent with the lower rainfall that occurred in the Prince William Sound area in 1996, relative to 1995; and the consequent reduction in fresh water run-off into the Sound.

Conditions within a survey area were relatively uniform. In the North area a south to north series of stations on transect lines 2 - 8 (Figure 12, stations are spaced every 2 nautical miles) have quite flat isothermal and isohaline profiles, except for colder surface water near glaciers (station N03A) and colder, less saline water at the north end of the transect. (Figure 13) . In a south to north transect of stations in the Central area (Figure 14), temperatures and salinities are more uniform (Figure 15). At 9 stations through Knight Island Passage in the South area (Figure 16), the water column is colder and more saline at shallow depths at the southern end of the transect (Figures 17).

RESULTS - NEARSHORE SURVEY

Hydroacoustics

Biomass estimates varied among the three major study areas, largely due to the variability in the rate at which schools of forage fishes were encountered. Within each of the 12 km sampling sites, the mean biomass for each set of zigs and zags often differed sharply - reflecting the fact that usually much of the biomass within a sampling site was due to the presence of one or two schools of fish that occurred on one or two of the 20 transects that made up the set of zigs and zags at a site. As a consequence of this pattern the standard errors for each set of zigs and zags are relatively large (Table 12). The distribution of biomass estimates of individual transects provides an index of the number of schools of forage fishes in each of the study areas (Figure 18). The North area had substantially more transects where fish schools were encountered than did the South or Central areas. Large schools on a transect typically resulted in average biomass exceeding 10 g/m2. The North area had 21 such transects, whereas the South and Central areas had 7 and 2 high value transects, respectively. The mean biomass estimates of zigs only, zags only, and total transects were all also higher in the North study area (Table 12).

The geographic distribution of biomass among the transects in the study areas indicated that schools of forage fishes were not randomly distributed (Figures

19, 20, 21). In the North, Port Gravina had the highest concentration of biomass which was comprised of sand lance, YOY herring, and YOY walleye pollock. In the Central area most biomass occurrred around the north end of Knight Island. In the South, biomass was concentrated in Prince of Wales Passage, where schools of juvenile and adult herring occurred.

Acoustic returns from herring, sand lance and walleye pollock displayed distinctively different patterns. Herring schools were typically tightly organized in roughly symetrical oval shapes in the upper water column with high acoustic backscattering (Figure 22). Sand lance schools were widely spread above the bottom with relatively low acoustic backscatter (Figure 23). YOY pollock were found in patchy schools, well off the bottom with moderately high acoustic backscatter (Figure 24).

Net and Video Sampling

Net samples were collected in the three study areas (Tables 13, 14, 15) to identify acoustic targets and to collect samples for size, condition and energetics studies. More samples were collected in the North study area as the acoustic survey found many more schools of forage fishes in that area.

Video sampling was used extensively in all study areas, and proved to be an effective way to identify species of fish schools that were located by the acoustic survey vessel. Herring were by far the most commonly identified species in video sampling of acoustic targets (Table 16).

Fishes collected by the nearshore net/video sampling vessel were mostly herring with size distributions indicating they were young-of-the year (< 100 mm), 1+ years (100 - 130 mm) 2+ years (130 - 170 mm) or older adults (>180 mm). Lengths of fishes sampled varied among the study areas (Table 17).

Hydrographic

Physical conditions in the nearshore were very similar to those in the offshore stations in all three study areas. We examined geographic patterns in temperature and salinity at a series of CTD stations extending from nearshore to offshore to determine if tidal fronts were present nearshore in the Sound. At a series in Port Fidalgo (Figures 25, 26), Naked Island (Figures 27, 28) and Bainbridge/Knight Is. Passage (Figures 29, 30), we found no indication that the strong vertical stratification that exists offshore was being being broken down in the nearshore. Examination of temporal variation in temperature and salinity at two stations in Bainbridge passage on July 18 also indicated that the vertical structure was not disrupted over several tide changes in this narrow passage that experiences considerable tidal flushing (Figures 31, 32, 33). In that series, high tides occurred at about 3:20 AM (+ 12.3 ft) and 4:20 PM (+ 11.2 ft), and low tides at about 9:50 AM (- 0.9 ft) and10:00 PM (+2.5 ft). This date had the greatest tide range that occurred during our field season.

RESULTS - BEACH SEINE SURVEY

Catches in beach seine sampling were highly variable, as most of the fish were caught in a few hauls in each of the three study areas. Among the 73 hauls that comprised the beach seine survey, ten hauls accounted for over 95% of the total catch (Figure 34). Large samples typically occurred when schools of herring or sand lance were intercepted by the seine. Highest catches occurred in the North study area, and fewest in the South (Tables 18, 19, 20). The differences were not tested statistically because of the extremely high variability in catches; however, the data suggest that there were differences in the species composition and abundance among the three areas. The proportions of beach seine samples that included the most commonly occurring species also suggest that there were differences among the three study areas. Pink salmon and tomcod were the most frequently occurring species in the South and Central study areas, whereas herring and sand lance had the highest frequency of occurrence in the North (Figure 34).

DISCUSSION/SUMMARY

Pronounced water column structure in the form of strong vertical gradients in temperature, salinity and density were evident throughout the North, Central and South sampling areas in Prince William Sound in summer 1996. This is expected in an estuarine ecosystem such as PWS which receives large amounts of rain, snowmelt and glacial meltwater discharge. Surface temperatures ranged from 12 - 15 ^{o}C and decreased rapidly with depth. Temperatures below 50 m were 3 - 5 ^{o}C. Surface salinities varied from 19 - 30 ppt, while salinities below 50 m were relatively isohaline at 31-33 ppt. In general, offshore stations had warmer temperatures and higher salinities in surface waters than inshore stations. Surface waters at stations in the North area were generally colder and less saline than stations in the South area, but the proximity of stations to glacial meltwater and riverine discharge introduces considerable variability. Although considerable spatial variability existed, in general waters in PWS during our cruise in summer 1996 were warmer and more saline than in 1995. This is consistent with the lower amounts of rainfall in the area in 1996.

Differences in the relative abundance of birds in the offshore and nearshore areas led to a hypothesis that differences in water column structure from offshore to inshore might explain the larger abundance of seabirds feeding nearshore. Nearshore frontal zones - boundaries between stratified offshore waters and well-mixed nearshore waters - occur when turbulence from tidal currents is strong enough to break down stratification. Such frontal zones may concentrate zooplankton, which could cause planktivorous fishes to aggregate nearshore; and, consequently, result in more birds foraging nearshore.

To examine the possible changes of hydrographic structure from offshore to nearshore waters, a series of CTD transects were established in several locations within the North (Port Fidalgo), Central (McPherson Bay) and South (Bainbridge Passage) areas. In the north and central parts of Bainbridge Passage, CTD samples were collected at 6 hour intervals for 24 hours, spanning two spring cycles.

No differences in hydrographic structure were evident from offshore to inshore, or over tidal cycles. Horizontal thermopleths and halopleths were uniformly smooth between stations located along transects extending from offshore to inshore, indicating that tidal fronts are not consistent features of the nearshore environment. Similarly, only a few deep anomalies in thermal and salinity isopleths are obvious in diel hydrographic sampling over a spring tide series. Although the concept sounds plausible, we found no evidence to support the hypothesis that water column structure might explain changes in availability of forage species to seabirds.

In 1996 we repeated the offshore survey of 1995, and added extensive nearshore acoustic and beach seine surveys. The main difference in the offshore survey in 1996 relative to 1995 was the absence of large schools of young-of-the-year walleye pollock that were a dominant feature of the forage fish complex in 1995. The YOY walleye pollock may have been absent from the 1996 survey if they were located outside the three study areas we surveyed; or, there may have been relatively few pollock produced in Prince William Sound in 1996. Walleye pollock populations in the Gulf of Alaska and the Bering Sea typically have high variability in year-class abundance; consequently, it would not be surprising to observe similar variability in Prince William Sound. We suspect that relatively low numbers of YOY walleye pollock in 1996 was due to a weak year class, although we cannot rule out the possibility that there were large numbers of pollock outside the study areas. Except for the areas where walleye pollock schools occurred in 1995, the acoustic biomass estimates for 1996 were similar in scale to those observed in 1995. As in 1995, the 1996 survey found distinctly higher acoustic biomass in the North study area than in the Central or South areas.

The nearshore acoustic survey found that herring were by far the most abundant forage species in nearshore areas, although there were some differences in herring age and size composition in the three study areas. In all areas, juvenile herring that were probably age 1+ or 2+ were the most commonly encountered sizes; young-of-the-year herring were encountered mainly in the North study area, whereas adult herring occurred mainly in the South. Larger herring are probably less vulnerable to bird predation;

therefore, these observations suggest that the North study area provided enhanced foraging conditions for avian predators.

Acoustic biomass estimates in the nearshore survey were mainly a function of the number of fish schools encountered on transects. The North area had the highest mean biomass estimates, followed by the South and Central areas. This result was due to the substantially higher number of transects with fish schools in the North. The fish schools were principally herring, although the North was the only area where schools of sand lance and schools of YOY pollock were found in the nearshore acoustic survey. It appears that the North study area provided substantially more opportunities for birds to encounter schools of fish in the nearshore area than did the South or Central study areas. Within the North area, schools of fish appeared to be concentrated in Port Gravina and to a lesser extent in the outer parts of Port Fidalgo. Port Gravina was also the area where schools of sand lance and YOY pollock were found.

The beach seine survey provided highly variable results, with total catches dominated by a few hauls that caught schools of forage species. Nevertheless, beach seine data provide indications of forage species distributions that are consistent with the nearshore acoustic results. The beach seine survey caught the highest total of fish in the North study area, followed by the South and Central areas. In addition, the frequency of occurrence of commonly caught species differed among areas, as herring and sandlance were ranked first and second in frequency of occurrence in the North, whereas in the South and Central areas pink salmon and tomcod ranked first and second. Statistically, the beach seine data set has very limited power to identify differences among areas, due mainly to the high variability within areas. Nevertheless, trends in beach seine results are similar to results from the acoustic surveys, and reinforce a conclusion that the North study area, especially waters around Port Gravina, provided substantially enhanced availability of forage fishes within Prince William Sound.

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Table 1. Offshore transect locations in APEX Prince William Sound study areas.

North Area

Transect Number	Latitude	General Location	From/To
N01A	60º 46.2'	S Port Fidalgo	shore to 147º 0'
N02A	60º 48.2'	S Bligh Is.	146º 0.0 to 147º 5'
N03LLB	60º 50.2'	Landlocked Bay	shore to shore
N03TT	60º 50.2'	S Tatitlek Narrows	shore to shore
N03VA	60º 50.2'	Bligh Reef	shore to 147º 0'
N04BB	60º 52.2'	Boulder Bay	shore to shore
N04VA	60º 52.2'	E Glacier Is.	shore to shore
N05VA	60º 54.2'	Valdez Arm	shore to shore
N05GIW	60º 54.2'	W. Glacier Is.	shore to 147º 0'
N06GBE	60º 56.2'	inner Galena Bay	shore to shore
N06GBW	60º 56.2'	outer Galena Bay	shore to shore
N06VA	60º 56.2'	Valdez Arm	shore to shore
N06CB	60º 56.2'	Columbia Bay ent.	shore to shore
N06LB	60º 56.2'	Long Bay ent.	shore to shore
N07VA	60º 58.2'	Valdez Arm	shore to shore
N08VA	61º 0.2'	Valdez Arm	shore to shore
N09VA	61º 2.2'	Valdez Arm/ Jack B.	shore to shore
N10VN	61º 4.2'	Valdez Narrows	shore to shore
N11PV	61º 6.2'	Port Valdez	shore to shore
N12 A	60º 44.2'	Outer Port Fidalgo	146º 50.0' to shore
N13W	60º 42.2'	Goose Island	146º 55.0' to shore
N13E	60º 42.2'	Port Gravina	shore to shore
N14W	60º 40.2'	Port Gravina	146º 45.0' to Red Head
N14E	60º 40.2'	Port Gravina	Red Head east to shore

Central Area

Transect Number	Latitude	General Location	From/To
C01A	60º 22.3'	N Montague St.	147º 12.0' to shore
C02A	60º 24.3'	Manning Rocks	147º 12.0' to shore
C03A	60º 26.3'	N Seal Is.	147º 12.0' to shore
C04A	60º 28.3'	N Knight Is.	147º 12.0' to shore
C05A	60º 30.3'	S Smith Is.	147º 2.0' to shore
C06A	60º 32.3'	N Smith Is.	147º 2.0' to shore
C07E	60º 34.3'	NE Eleanor Is.	147º 2.0' to shore
C07W	60º 34.3'	NW Eleanor Is.	shore to 147º 2.0'
C08A	60º 36.3'	Eleanor Pass.	147º 12.0' to 147º 42.0'
C09E	60º 38.3'	SE Naked Is.	147º 12.0' to shore
C09W	60º 38.3'	SW Naked Is.	shore to 147º 42.0'
C10E	60º 40.3'	E Naked Is.	147º 12.0' to shore
C10C	60º 40.3'	McPherson Bay	shore to shore
C10W	60º 40.3'	W. Naked Is.	shore to 147º 42.0'
C11E	60º 42.3'	E Peak Is.	147º 12.0' to shore
C11W	60º 42.3'	W Peak Is.	shore to 147º 42.0'
C12E	60º 44.3'	E. Storey Is.	147º 12.0' to shore
C12W	60º 44.3'	W. Storey Is.	shore to 147º 42.0'

South Area

Transect Number	Latitude	General Location	From/To
S01E	60º 15.0'	Whale Bay Entr.	148º 5' to shore
S01W	60º 15.0'	Icy Bay	shore to shore
S02W	60º 17.0'	Lower Dang. Pass.	shore to shore
S02E	60º 17.0'	Knight Is Pass.	shore to shore
S03W	60º 19.0'	S Jackpot Is.	shore to shore
S03E	60º 19.0'	Knight Is. Pass.	shore to shore
S04W	60º 21.0'	Dangerous Pass.	shore to shore
S04E	60º 21.0'	Knight Is. Pass	shore to shore
S06W	60º 11.0'	Bainbridge Pass.	shore to shore
S06E	60º 11.0'	Bainbridge Pass.	shore to shore
S07A	60º 09.0'	Shelter Bay to Pt. Helen	shore to shore
S08A	60º 07.0'	So. end Knight Is. Pass.	shore to 147º 46.0'
S09W	60º 23.0'	Dangerous Passage	shore to shore
S09E	60º 23.0'	Knight Is. Pass.	shore to shore

TABLE 2. Midwater trawl samples collected in the offshore survey during APEX cruise 96-1

DATE	TIME	STN #	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)	GEAR DEPTH (m)
15/07	13:51	5		60 07.271	147 50.285	340	40
16/07	11:56	12	Prince of Wales Pass.	60 2.464	148 07.928	76	35
16/07	13:20	12	Prince of Wales Pass.	60 03.872	148 07.668	90	40-50
20/07	12:36	48	C02A	60 24.008	147 32.043	173	70
20/07	13:30	48	C02A	60 24.186	147 28.153	128	60
21/07	14:23	65	C04A	60 28.156	147 21.516	80.6-163	128
23/07	12:23	83	Galena Bay	60 56.429	146 40.391	220	170
23/07	13:51	84	Galena Bay	60 56.350	146 41.557	780	230
25/07	9:50	102	1 km from shore	60 47.51	146 25.84	102	55
25/07	15:46	111	off Knowles Head	60 40.156	146 38.946	31	25
26/07	11:54	119	N01-13E	60 41.855	146 12.848	136	125-130
26/07	14:07	122	N14E	60 40.000	146 17.557	135	60

Table 3. CTD data collected in the offshore survey during APEX cruise 96-1.

DATE	TIME	STN #	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)	GEAR DEPTH (m)
15/07	13:27	5	S08A	60 07.4	147 49.9	292	200
15/07	15:04	6	S07A	60 09.0	147 50	289	200
15/07	16:10	8	S06E	60 10.966	147 55.077	382	200
15/07	16:50	9	S05E	60 12.877	148 0.00	368	200
15/07	17:27	10	S01E	60 14.93	147 59.96	592	200
16/07	17:15	17	S01E	60 15	148 10	324	200
17/07	10:36	19	S02W	60 17	148 09.85	288	200
17/07	11:15	21	S03W	60 19.031	148 10.000	260	200
17/07	12:23	22	S02E	60 16.980	148 00.059	522	200
17/07	12:50	23	S03E	60 18.991	147 57.924	404	200
17/07	13:16	24	S04E	60 20.986	147 57.983	368	200
17/07	13:43	25	S09E; S18-10A	60 22.970	147 57.956	270	200
20/07	9:54	45	C01A	60 22.293	147 30.033	151	140
20/07	10:19	46	C02A	60 24.390	147 29.853	161	140
20/07	10:53	47	C03A	60 26.318	147 30.030	159	140
20/07	15:01	49	C04A	60 28.311	147 29.989	185	180
20/07	15:28	50	C05A	60 30.273	147 30.022	196	180
21/07	8:56	55	C08A	60 36.311	147 15.020	196	180
21/07	9:20	56	C09E	60 38.274	147 14.999	167	160
21/07	9:45	57	C10E	60 40.350	147 15.013	125	120
21/07	10:05	58	C11E	60 42.333	147 15.968	172	160
21/07	10:30	59	C12E	60 44.276	147 14.891	275	200
21/07	15:21	65	C04A	60 28.233	147 18.554	179	160
21/07	16:40	66	C06A	60 32.271	147 29.930	191	180
21/07	17:13	67	C07A	60 34.304	147 30.090	196	180
21/07	18:31	68	C08A	60 36.374	147 35.020	334	200
22/07	8:53	69	C09W	60 38.306	147 34.992	350	200
22/07	9:15	70	C10W	60 40.307	147 34.965	498	200
23/07	8:57	77	N09A	61 02.036	146 43.828	337	200
23/07	9:27	78	N08A	61 00.22	146 47.522	346	200
23/07	9:52	79	N07A	60 58.250	146 50.140	374	200
23/07	10:23	80	N06A	60 56.224	146 53.309	322	200
24/07	9:53	89	N05A	60 54.279	146 56.568	341	200
24/07	10:59	90	N04A	60 52.326	146 56.466	359	200
24/07	11:33	91	N03A	60 50.322	146 59.947	372	200
24/07	11:56	92	N02A	60 48.326	147 00.021	320	200
24/07	12:20	93	N01A	60 46.274	146 59.981	444	200
24/07	12:30	93	N01A	60 46.301	146 59.881	446	200
25/07	14:10	109	N01A	60 46.180	146 40.037	102	100

Table 4. Locations of nearshore transects sampled in APEX cruise 96-1.

TRANSECT	LAT START	LONG START	LAT END	LONG END
N0101A	60 37.25	146 15.6	60 37.4	146 16.9
N0101B	60 37.4	146 16.9	60 37.8	146 16.1
N0102A	60 37.8	146 16.1	60 38.0	146 17.2
N0102B	60 38.0	146 17.2	60 38.45	146 16.4
N0103A	60 38.45	146 16.4	60 38.8	146 17.6
N0103B	60 38.8	146 17.6	60 39.0	146 16.3
N0104A	60 39.0	146 16.3	60 39.6	146 16.5
N0104B	60 39.6	146 16.5	60 39.5	146 15.1
N0105A	60 39.5	146 15.1	60 40.05	146 15.5
N0105B	60 40.05	146 15.5	60 39.9	146 14.5
N0106A	60 39.9	146 14.5	60 40.55	146 14.6
N0106B	60 40.55	146 14.6	60 40.4	146 13.7
N0107A	60 40.4	146 13.7	60 41.0	146 13.6
N0107B	60 41.0	146 13.6	60 40.8	146 12.4
N0108A	60 40.8	146 12.4	60 41.9	146 12.0
N0108B	60 41.9	146 12.0	60 41.35	146 11.3
N0109A	60 41.35	146 11.3	60 41.95	146 11.8
N0109B	60 41.95	146 11.8	60 41.8	146 10.8
N0110A	60 41.8	146 10.8	60 42.45	146 11
N0110B	60 42.45	146 11	60 43.3	146 9.6
N0301A	60 42.8	146 15.4	60 42.3	146 16.3
N0301B	60 42.3	146 16.3	60 42.75	146 16.8
N0302A	60 42.75	146 16.8	60 42.2	146 17.4
N0302B	60 42.2	146 17.4	60 42.75	146 18.1
N0303A	60 42.75	146 18.1	60 42.45	146 19.2
N0303B	60 42.45	146 19.2	60 43.0	146 18.9
N0304A	60 43.0	146 18.9	60 43.3	146 20.8
N0304B	60 43.3	146 20.8	60 43.5	146 19.1
N0305A	60 43.5	146 19.1	60 44.05	146 20.5
N0305B	60 44.05	146 20.5	60 44.2	146 18.8
N0306A	60 44.2	146 18.8	60 44.75	146 19.7
N0306B	60 44.75	146 19.7	60 45.2	146 18.2
N0307A	60 45.2	146 18.2	60 45.95	146 17.8
N0307B	60 45.95	146 17.8	60 45.6	146 19.35
N0308A	60 45.6	146 19.35	60 44.9	146 18.8
N0308B	60 44.9	146 18.8	60 44.8	146 19.6
N0309A	60 44.8	146 19.6	60 43.7	146 17.7
N0309B	60 43.7	146 17.7	60 43.8	146 20.3
N0310A	60 43.8	146 20.3	60 43.2	146 19.8
N0310B	60 43.2	146 19.8	60 42.5	146 21.5
N0501A	60 40.7	146 26.8	60 39.95	146 27.0
N0501B	60 39.95	146 27.0	60 40.35	146 26.9
N0502A	60 40.35	146 26.9	60 39.7	146 28.1
N0502B	60 39.7	146 28.1	60 40.1	146 29.3
N0503A	60 40.1	146 29.3	60 39.4	146 29.7
N0503B	60 39.4	146 29.7	60 40.05	146 30.3
N0504A	60 40.05	146 30.3	60 39.75	146 31.4
N0504B	60 39.75	146 31.4	60 40.5	146 31.2
N0505A	60 40.5	146 31.2	60 40.3	146 32.4
N0505B	60 40.3	146 32.4	60 40.95	146 32.3
N0506A	60 40.95	146 32.3	60 40.35	146 33.1
N0506B	60 40.35	146 33.1	60 41.0	146 33.55
N0507A	60 41.0	146 33.55	60 40.4	146 34.2
N0507B	60 40.4	146 34.2	60 40.9	146 35.1
N0508A	60 40.9	146 35.1	60 40.25	146 35.6
N0508B	60 40.25	146 35.6	60 60.8	146 36.4
N0509A	60 60.8	146 36.4	60 40.15	146 36.9
N0509B	60 40.15	146 36.9	60 40.7	146 37.8
N0510A	60 40.7	146 37.8	60 40.2	146 38.6
N0510B	60 40.2	146 38.6	60 40.8	146 39.0

Table 4. Continued.

N0701A	60 44.0	146 44.55	60 43.4	146 44.5
N0701B	60 43.4	146 44.5	60 43.9	146 43.2
N0702A	60 43.9	146 43.2	60 43.9	146 42.3
N0702B	60 43.9	146 42.3	60 44.3	146 42.3
N0703A	60 44.3	146 42.3	60 44.8	146 43.4
N0703B	60 44.8	146 43.4	60 44.9	146 42.1
N0704A	60 44.9	146 42.1	60 45.4	146 41.3
N0704B	60 45.4	146 41.3	60 44.6	146 40.8
N0705A	60 44.6	146 40.8	60 45.05	146 39.5
N0705B	60 45.05	146 39.5	60 44.4	146 39.4
N0706A	60 44.4	146 39.4	60 44.5	146 38.2
N0706B	60 44.5	146 38.2	60 44.8	146 36.7
N0707A	60 44.8	146 36.7	60 45.45	146 38.2
N0707B	60 45.45	146 38.2	60 45.05	146 37.3
N0708A	60 45.05	146 37.3	60 45.75	146 37.9
N0708B	60 45.75	146 37.9	60 45.75	146 36.0
N0709A	60 45.75	146 36.0	60 46.3	146 35.6
N0709B	60 46.3	146 35.6	60 45.6	146 35
N0710A	60 45.6	146 35	60 45.65	146 33.4
N0710B	60 45.65	146 33.4	60 45.5	146 34.2
N0901A	60 48.4	146 31.9	60 47.4	146 31.15
N0901B	60 47.4	146 31.15	60 48.4	146 30.5
N0902A	60 48.4	146 30.5	60 47.3	146 29.5
N0902B	60 47.3	146 29.5	60 48.15	146 29.1
N0903A	60 48.15	146 29.1	60 46.65	146 28.3
N0903B	60 46.65	146 28.3	60 46.55	146 27.8
N0904A	60 46.55	146 27.8	60 47.2	146 27.5
N0904B	60 47.2	146 27.5	60 46.85	146 26.5
N0905A	60 46.85	146 26.5	60 47.5	146 26.2
N0905B	60 47.5	146 26.2	60 46.95	146 25.1
N0906A	60 46.95	146 25.1	60 47.7	146 24.75
N0906B	60 47.7	146 24.75	60 47.2	146 23.8
N0907A	60 47.2	146 23.8	60 47.75	146 23.25
N0907B	60 47.75	146 23.25	60 47.3	146 22.5
N0908A	60 47.3	146 22.5	60 47.95	146 22.05
N0908B	60 47.95	146 22.05	60 47.5	146 21.05
N0909A	60 47.5	146 21.05	60 48.1	146 20.6
N0909B	60 48.1	146 20.6	60 47.7	146 19.6
N0910A	60 47.7	146 19.6	60 47.85	146 19.9
N0910B	60 47.85	146 19.9	60 48.1	146 18.7
N1301A	60 50.9	146 35.1	60 50.35	146 34.5
N1301B	60 50.35	146 34.5	60 50.35	146 35.95
N1302A	60 50.35	146 35.95	60 49.85	146 35.1
N1302B	60 49.85	146 35.1	60 49.65	146 36.45
N1303A	60 49.65	146 36.45	60 49.15	146 35.7
N1303B	60 49.15	146 35.7	60 49.05	146 36.5
N1304A	60 49.05	146 36.5	60 48.4	146 37.4
N1304B	60 48.4	146 37.4	60 48.9	146 38.3
N1305A	60 48.9	146 38.3	60 48.5	146 39.3
N1305B	60 48.5	146 39.3	60 49.2	146 38.9
N1306A	60 49.2	146 38.9	60 49.45	146 40.0
N1306B	60 49.45	146 40.0	60 49.8	146 38.7
N1307A	60 49.8	146 38.7	60 50.2	146 39.8
N1307B	60 50.2	146 39.8	60 50.65	146 38.7
N1308A	60 50.65	146 38.7	60 51.05	146 39.3
N1308B	60 51.05	146 39.3	60 51.1	146 38.5
N1309A	60 51.1	146 38.5	60 51.7	146 38.6
N1309B	60 51.7	146 38.6	60 51.5	146 37.4
N1310A	60 51.5	146 37.4	60 52.05	146 37.9
N1310B	60 52.05	146 37.9	60 52.7	146 38.0

Table 4. Continued.

N1501A	60 48.65	146 42.5	60 48.0	146 42.5
N1501B	60 48.0	146 42.5	60 48.4	146 43.9
N1502A	60 48.4	146 43.9	60 47.9	146 44.5
N1502B	60 47.9	146 44.5	60 48.45	146 45.3
N1503A	60 48.45	146 45.3	60 47.65	146 45.8
N1503B	60 47.65	146 45.8	60 48.15	146 46.85
N1504A	60 48.15	146 46.85	60 47.5	146 47.1
N1504B	60 47.5	146 47.1	60 48.0	146 48.0
N1505A	60 48.0	146 48.0	60 47.9	146 49.5
N1505B	60 47.9	146 49.5	60 48.6	146 48.9
N1506A	60 48.6	146 48.9	60 48.85	146 50.3
N1506B	60 48.85	146 50.3	60 49.3	146 49.3
N1507A	60 49.3	146 49.3	60 49.65	146 50.45
N1507B	60 49.65	146 50.45	60 50.05	146 49.3
N1508A	60 50.05	146 49.3	60 50.8	146 49.5
N1508B	60 50.8	146 49.5	60 50.3	146 50.65
N1509A	60 50.3	146 50.65	60 50.45	146 52.0
N1509B	60 50.45	146 52.0	60 50.9	146 51.0
N1510A	60 50.9	146 51.0	60 51.55	146 51.4
N1510B	60 51.55	146 51.4	60 51.45	146 50.0
N1701A	60 45.15	146 47.4	60 54.7	146 47.4
N1701B	60 54.7	146 47.4	60 54.0	146 46.25
N1702A	60 54.0	146 46.25	60 54.3	146 44.9
N1702B	60 54.3	146 44.9	60 53.65	146 43.65
N1703A	60 53.65	146 43.65	60 54.35	146 44.4
N1703B	60 54.35	146 44.4	60 54.35	146 44.4
N1704A	60 54.35	146 44.4	60 54.6	146 45.7
N1704B	60 54.6	146 45.7	60 54.9	146 44.4
N1705A	60 54.9	146 44.4	60 55.0	146 45.8
N1705B	60 55.0	146 45.8	60 55.55	146 45.0
N1706A	60 55.55	146 45.0	60 56.2	146 46.45
N1706B	60 56.2	146 46.45	60 56.25	146 45.95
N1707A	60 56.25	146 45.95	60 56.8	146 47.25
N1707B	60 56.8	146 47.25	60 57.4	146 46.55
N1708A	60 57.4	146 46.55	60 57.55	146 47.4
N1708B	60 57.55	146 47.4	60 57.55	146 46.1
N1709A	60 57.55	146 46.1	60 58.1	146 46.6
N1709B	60 58.1	146 46.6	60 58.15	146 45.3
N1710A	60 58.15	146 45.3	60 58.5	146 43.95
N1710B	60 58.5	146 43.95	60 57.8	146 43.95
N1901A	60 55.85	146 36.0	60 55.85	146 37.35
N1901B	60 55.85	146 37.35	60 56.3	146 36.7
N1902A	60 56.3	146 36.7	60 56.25	146 37.9
N1902B	60 56.25	146 37.9	60 56.85	146 37.55
N1903A	60 56.85	146 37.55	60 56.4	146 38.4
N1903B	60 56.4	146 38.4	60 56.95	146 38.8
N1904A	60 56.95	146 38.8	60 56.6	146 39.6
N1904B	60 56.6	146 39.6	60 56.3	146 40.95
N1905A	60 56.3	146 40.95	60 56.5	146 41.05
N1905B	60 56.5	146 41.05	60 57.0	146 42.3
N1906A	60 57.0	146 42.3	60 57.1	146 43.6
N1906B	60 57.1	146 43.6	60 57.65	146 42.8
N1907A	60 57.65	146 42.8	60 56.7	146 44.2
N1907B	60 56.7	146 44.2	60 58.2	146 43.5
N1908A	60 58.2	146 43.5	60 58.6	146 44.6
N1908B	60 58.6	146 44.6	60 59.15	146 43.7
N1909A	60 59.15	146 43.7	60 59.8	146 43.7
N1909B	60 59.8	146 43.7	60 59.45	146 42.55
N1910A	60 59.45	146 42.55	60 59.9	146 43.3
N1910B	60 59.9	146 43.3	61 0.1	146 42.0

Table 4. Continued.

C0101A	60 21.3	147 37.6	60 21.45	147 36.9
C0101B	60 21.45	147 36.9	60 21.85	147 37.9
C0102A	60 21.85	147 37.9	60 22.2	147 35.9
C0102B	60 22.2	147 35.9	60 22.5	147 37.0
C0103A	60 22.5	147 37.0	60 22.8	147 35.9
C0103B	60 22.8	147 35.9	60 23.1	147 37.9
C0104A	60 23.1	147 37.9	60 23.8	147 36.6
C0104B	60 23.8	147 36.6	60 23.65	147 37.9
C0105A	60 23.65	147 37.9	60 23.85	147 39.1
C0105B	60 23.85	147 39.1	60 23.4	147 40.1
C0106A	60 23.4	147 40.1	60 23.9	147 41.1
C0106B	60 23.9	147 41.1	60 24.15	147 40.0
C0107A	60 24.15	147 40.0	60 23.75	147 41.1
C0107B	60 23.75	147 41.1	60 24.5	147 41.1
C0108A	60 24.5	147 41.1	60 23.9	147 40.0
C0108B	60 23.9	147 40.0	60 24.5	147 40.0
C0109A	60 24.5	147 40.0	60 24.05	147 37.8
C0109B	60 24.05	147 37.8	60 24.71	147 37.9
C0110A	60 24.71	147 37.9	60 24.55	147 36.7
C0110B	60 24.55	147 36.7	60 25.25	147 36.8
C0201A	60 25.25	147 36.8	60 25.35	147 35.4
C0201B	60 25.35	147 35.4	60 25.8	147 36.2
C0202A	60 25.8	147 36.2	60 26.5	147 35.9
C0202B	60 26.5	147 35.9	60 26.35	147 37.2
C0203A	60 26.35	147 37.2	60 27.0	147 37.0
C0203B	60 27.0	147 37.0	60 27.05	147 38.6
C0204A	60 27.05	147 38.6	60 27.05	147 37.3
C0204B	60 27.05	147 37.3	60 27.65	147 37.1
C0205A	60 27.65	147 37.1	60 28.1	147 36.2
C0205B	60 28.1	147 36.2	60 28.3	147 37.4
C0206A	60 28.3	147 37.4	60 28.85	147 36.4
C0206B	60 28.85	147 36.4	60 28.9	147 37.5
C0207A	60 28.9	147 37.5	60 29.1	147 37.8
C0207B	60 29.1	147 37.8	60 28.85	147 38.3
C0208A	60 28.85	147 38.3	60 29.2	147 39.6
C0208B	60 29.2	147 39.6	60 28.85	147 36.3
C0209A	60 28.85	147 36.3	60 29.2	147 35.1
C0209B	60 29.2	147 35.1	60 29.5	147 36.2
C0210A	60 29.5	147 36.2	60 30.15	147 35.3
C0210B	60 30.15	147 35.3	60 30.5	147 36.4
C0301A	60 30.5	147 36.4	60 30.5	147 35.3
C0301B	60 30.5	147 35.3	60 31.3	147 35.0
C0302A	60 31.3	147 35.0	60 31.15	147 33.6
C0302B	60 31.15	147 33.6	60 31.75	147 34.0
C0303A	60 31.75	147 34.0	60 31.6	147 32.9
C0303B	60 31.6	147 32.9	60 32.25	147 33.1
C0304A	60 32.25	147 33.1	60 32.1	147 31.9
C0304B	60 32.1	147 31.9	60 32.7	147 30.25
C0305A	60 32.7	147 30.25	60 33.1	147 31.3
C0305B	60 33.1	147 31.3	60 33.35	147 32.6
C0306A	60 33.35	147 32.6	60 33.8	147 31.5
C0306B	60 33.8	147 31.5	60 33.5	147 32.9
C0307A	60 33.5	147 32.9	60 34.55	147 32.0
C0307B	60 34.55	147 32.0	60 34.65	147 33.3
C0308A	60 34.65	147 33.3	60 35.25	147 32.6
C0308B	60 35.25	147 32.6	60 35.25	147 33.9
C0309A	60 35.25	147 33.9	60 35.35	147 35.25
C0309B	60 35.35	147 35.25	60 34.75	147 34.9
C0310A	60 34.75	147 34.9	60 34.65	147 36.1
C0310B	60 34.65	147 36.1	60 34.2	147 35.4

Table 4. Continued.

C0401A	60 38.0	147 23.1	60 38.05	147 24.5
C0401B	60 38.05	147 24.5	60 37.45	147 23.6
C0402A	60 37.45	147 23.6	60 37.05	147 22.6
C0402B	60 37.05	147 22.6	60 37.4	147 21.5
C0403A	60 37.4	147 21.5	60 37.0	147 20.3
C0403B	60 37.0	147 20.3	60 37.7	147 20.2
C0404A	60 37.7	147 20.2	60 37.65	147 18.9
C0404B	60 37.65	147 18.9	60 38.2	147 19.55
C0405A	60 38.2	147 19.55	60 38.2	147 18.2
C0405B	60 38.2	147 18.2	60 38.75	147 18.8
C0406A	60 38.75	147 18.8	60 38.75	147 17.5
C0406B	60 38.75	147 17.5	60 39.35	147 18.1
C0407A	60 39.35	147 18.1	60 39.75	147 17.1
C0407B	60 39.75	147 17.1	60 40.05	147 18.3
C0408A	60 40.05	147 18.3	60 40.65	147 17.8
C0408B	60 40.65	147 17.8	60 40.5	147 19.1
C0409A	60 40.5	147 19.1	60 41.2	147 19.3
C0409B	60 41.2	147 19.3	60 40.8	147 20.4
C0410A	60 40.8	147 20.4	60 40.7	147 21.7
C0410B	60 40.7	147 21.7	60 40.1	147 20.8
C0501A	60 40.15	147 20.8	60 40.5	147 21.9
C0501B	60 40.5	147 21.9	60 39.9	147 22.0
C0502A	60 39.9	147 22.0	60 39.3	147 21.9
C0502B	60 39.3	147 21.9	60 38.85	147 23.2
C0503A	60 38.85	147 23.2	60 40.35	147 21.9
C0503B	60 40.35	147 21.9	60 40.5	147 23.6
C0504A	60 40.5	147 23.6	60 40.5	147 22.2
C0504B	60 40.5	147 22.2	60 41.15	147 22.0
C0505A	60 41.15	147 22.0	60 41.1	147 20.7
C0505B	60 41.1	147 20.7	60 41.7	147 21.2
C0506A	60 41.7	147 21.2	60 41.95	147 19.9
C0506B	60 41.95	147 19.9	60 42.9	147 20.9
C0507A	60 42.9	147 20.9	60 43.1	147 20.0
C0507B	60 43.1	147 20.0	60 43.5	147 21.5
C0508A	60 43.5	147 21.5	60 42.85	147 22.4
C0508B	60 42.85	147 22.4	60 42.85	147 22.8
C0509A	60 42.85	147 22.8	60 43.1	147 24.0
C0509B	60 43.1	147 24.0	60 43.75	147 23.0
C0510A	60 43.75	147 23.0	60 43.95	147 21.6
C0510B	60 43.95	147 21.6	60 44.4	147 22.7
C0601A	60 44.4	147 22.7	60 45.1	147 23.0
C0601B	60 45.1	147 23.0	60 44.6	147 23.8
C0602A	60 44.6	147 23.8	60 45.15	147 24.9
C0602B	60 45.15	147 24.9	60 44.4	147 25.2
C0603A	60 44.4	147 25.2	60 45.0	147 26.2
C0603B	60 45.0	147 26.2	60 44.3	147 26.4
C0604A	60 44.3	147 26.4	60 44.7	147 27.6
C0604B	60 44.7	147 27.6	60 44.05	147 27.8
C0605A	60 44.05	147 27.8	60 44.6	147 28.6
C0605B	60 44.6	147 28.6	60 43.9	147 29.1
C0606A	60 43.9	147 29.1	60 43.5	147 30.3
C0606B	60 43.5	147 30.3	60 43.25	147 29.0
C0607A	60 43.25	147 29.0	60 42.6	147 28.5
C0607B	60 42.6	147 28.5	60 43.05	147 27.6
C0608A	60 43.05	147 27.6	60 42.45	147 27.3
C0608B	60 42.45	147 27.3	60 42.9	147 26.3
C0609A	60 42.9	147 26.3	60 42.55	147 25.1
C0609B	60 42.55	147 25.1	60 42.1	147 26.1
C0610A	60 42.1	147 26.1	60 42.4	147 27.3
C0610B	60 42.4	147 27.3	60 41.9	147 28.0

Table 4. Continued.

C0701A	60 41.9	147 28.0	60 42.05	147 29.4
C0701B	60 42.05	147 29.4	60 41.4	147 29.1
C0702A	60 41.4	147 29.1	60 41.2	147 30.5
C0702B	60 41.2	147 30.5	60 40.75	147 29.4
C0703A	60 40.75	147 29.4	60 40.1	147 29.35
C0703B	60 40.1	147 29.35	60 40.4	147 28.3
C0704A	60 40.4	147 28.3	60 39.8	147 28.7
C0704B	60 39.8	147 28.7	60 39.65	147 29.1
C0705A	60 39.65	147 29.1	60 39.95	147 30.3
C0705B	60 39.95	147 30.3	60 39.3	147 30.25
C0706A	60 39.3	147 30.25	60 38.95	147 31.5
C0706B	60 38.95	147 31.5	60 38.6	147 30.25
C0707A	60 38.6	147 30.25	60 38.05	147 29.5
C0707B	60 38.05	147 29.5	60 38.6	147 28.8
C0708A	60 38.6	147 28.8	60 38.45	147 27.5
C0708B	60 38.45	147 27.5	60 38.4	147 27.5
C0709A	60 38.4	147 27.5	60 38.35	147 28.9
C0709B	60 38.35	147 28.9	60 37.65	147 28.8
C0710A	60 37.65	147 28.8	60 37.6	147 30.3
C0710B	60 37.6	147 30.3	60 37.0	147 29.4
C0801A	60 37.0	147 29.4	60 36.4	147 28.5
C0801B	60 36.4	147 28.5	60 36.95	147 28.0
C0802A	60 36.95	147 28.0	60 36.45	147 27.0
C0802B	60 36.45	147 27.0	60 37.1	147 26.5
C0803A	60 37.1	147 26.5	60 36.8	147 25.2
C0803B	60 36.8	147 25.2	60 37.65	147 25.45
C0804A	60 37.65	147 25.45	60 37.5	147 24.0
C0804B	60 37.5	147 24.0	60 38.2	147 24.7
C0805A	60 38.2	147 24.7	60 38.1	147 23.5
C0805B	60 38.1	147 23.5	60 38.5	147 24.3

Table 4. Continued.

S0201A	60 1.3	147 57.3	60 1.9	147 58.0
S0201B	60 1.9	147 58.0	60 1.85	147 56.7
S0202A	60 1.85	147 56.7	60 2.35	147 57.4
S0202B	60 2.35	147 57.4	60 2.4	147 56.2
S0203A	60 2.4	147 56.2	60 3.1	147 56.4
S0203B	60 3.1	147 56.4	60 3.0	147 55.1
S0204A	60 3.0	147 55.1	60 3.5	147 55.6
S0204B	60 3.5	147 55.6	60 3.4	147 54.4
S0205A	60 3.4	147 54.4	60 3.95	147 54.7
S0205B	60 3.95	147 54.7	60 3.85	147 53.4
S0206A	60 3.85	147 53.4	60 4.5	147 53.8
S0206B	60 4.5	147 53.8	60 4.4	147 52.6
S0207A	60 4.4	147 52.6	60 5.0	147 52.8
S0207B	60 5.0	147 52.8	60 4.85	147 51.5
S0208A	60 4.85	147 51.5	60 5.4	147 51.2
S0208B	60 5.4	147 51.2	59 59.05	148 7.0
S0209A	59 59.05	148 7.0	59 58.95	148 6.0
S0209B	59 58.95	148 6.0	59 59.6	148 6.6
S0210A	59 59.6	148 6.6	59 59.45	148 5.2
S0210B	59 59.45	148 5.2	60 1.15	148 5.7
S0401A	60 3.6	147 58.6	60 3.4	147 57.35
S0401B	60 3.4	147 57.35	60 4.1	147 57.4
S0402A	60 4.1	147 57.4	60 3.85	147 56.1
S0402B	60 3.85	147 56.1	60 4.5	147 56.5
S0403A	60 4.5	147 56.5	60 4.3	147 55.1
S0403B	60 4.3	147 55.1	60 4.95	147 55.5
S0404A	60 4.95	147 55.5	60 4.8	147 54.1
S0404B	60 4.8	147 54.1	60 5.45	147 54.5
S0405A	60 5.45	147 54.5	60 5.2	147 53.1
S0405B	60 5.2	147 53.1	60 5.85	147 53.4
S0406A	60 5.85	147 53.4	60 6.1	147 52.0
S0406B	60 6.1	147 52.0	60 6.5	147 53.1
S0407A	60 6.5	147 53.1	60 6.8	147 52.0
S0407B	60 6.8	147 52.0	60 7.05	147 53.1
S0408A	60 7.05	147 53.1	60 7.65	147 52.6
S0408B	60 7.65	147 52.6	60 7.7	147 53.8
S0409A	60 7.7	147 53.8	60 8.25	147 53.4
S0409B	60 8.25	147 53.4	60 8.2	147 54.8
S0410A	60 8.2	147 54.8	60 8.5	147 55.7
S0410B	60 8.5	147 55.7	60 7.9	147 56.1
S0601A	60 1.05	148 11.3	60 .08	148 10.0
S0601B	60 .08	148 10.0	60 1.45	148 10.3
S0602A	60 1.45	148 10.3	60 1.2	148 9.0
S0602B	60 1.2	148 9.0	60 1.85	148 9.2
S0603A	60 1.85	148 9.2	60 1.75	148 7.9
S0603B	60 1.75	148 7.9	60 2.4	148 8.3
S0604A	60 2.4	148 8.3	60 2.85	148 7.45
S0604B	60 2.85	148 7.45	60 3.4	148 8.1
S0605A	60 3.4	148 8.1	60 3.45	148 6.8
S0605B	60 3.45	148 6.8	60 4.0	148 7.0
S0606A	60 4.0	148 7.0	60 4.05	148 6.3
S0606B	60 4.05	148 6.3	60 4.6	148 6.6
S0607A	60 4.6	148 6.6	60 4.7	148 5.4
S0607B	60 4.7	148 5.4	60 5.2	148 6.2
S0608A	60 5.2	148 6.2	60 5.3	148 4.8
S0608B	60 5.3	148 4.8	60 5.8	148 5.3
S0609A	60 5.8	148 5.3	60 5.9	148 4.1
S0609B	60 5.9	148 4.1	60 6.4	148 5.0
S0610A	60 6.4	148 5.0	60 6.95	148 4.3
S0610B	60 6.95	148 4.3	60 7.0	148 5.6

Table 4. Continued.

S0801A	60 9.9	148 0.04	60 10.3	147 58.9
S0801B	60 10.3	147 58.9	60 10.6	148 0.15
S0802A	60 10.6	148 0.15	60 11.3	147 59.7
S0802B	60 11.3	147 59.7	60 11.2	148 1.0
S0803A	60 11.2	148 1.0	60 11.7	148 1.5
S0803B	60 11.7	148 1.5	60 11.2	148 2.3
S0804A	60 11.2	148 2.3	60 11.8	148 1.9
S0804B	60 11.8	148 1.9	60 12.1	148 3.0
S0805A	60 12.1	148 3.0	60 12.6	148 3.95
S0805B	60 12.6	148 3.95	60 11.95	148 4.2
S0806A	60 11.95	148 4.2	60 12.2	148 5.45
S0806B	60 12.2	148 5.45	60 11.45	148 5.3
S0807A	60 11.45	148 5.3	60 11.2	148 6.5
S0807B	60 11.2	148 6.5	60 10.9	148 5.15
S0808A	60 10.9	148 5.15	60 10.6	148 6.3
S0808B	60 10.6	148 6.3	60 10.25	148 5.1
S0809A	60 10.25	148 5.1	60 10.15	148 6.45
S0809B	60 10.15	148 6.45	60 9.6	148 5.7
S0810A	60 9.6	148 5.7	60 9.2	148 6.7
S0810B	60 9.2	148 6.7	60 8.85	148 5.7
S1001A	60 12.8	148 4.5	60 13.4	148 4.2
S1001B	60 13.4	148 4.2	60 13.35	148 5.4
S1002A	60 13.35	148 5.4	60 14	148 5.1
S1002B	60 14	148 5.1	60 13.8	148 6.45
S1003A	60 13.8	148 6.45	60 14.5	148 5.1
S1003B	60 14.5	148 5.1	60 14.35	148 7.5
S1004A	60 14.35	148 7.5	60 15.05	148 7.9
S1004B	60 15.05	148 7.9	60 14.45	148 8.55
S1005A	60 14.45	148 8.55	60 14.5	148 9.9
S1005B	60 14.5	148 9.9	60 13.9	148 9.4
S1006A	60 13.9	148 9.4	60 13.55	148 10.8
S1006B	60 13.55	148 10.8	60 13.15	148 9.5
S1007A	60 13.15	148 9.5	60 12.95	148 10.9
S1007B	60 12.95	148 10.9	60 12.5	148 9.6
S1008A	60 12.5	148 9.6	60 12.5	148 11.05
S1008B	60 12.5	148 11.05	60 11.9	148 10.4
S1009A	60 11.9	148 10.4	60 11.7	148 11.6
S1009B	60 11.7	148 11.6	60 11.15	148 10.6
S1010A	60 11.15	148 10.6	60 10.9	148 10.7
S1010B	60 10.9	148 10.7	60 10.4	148 10.9
S1201A	60 12.9	148 16.5	60 12.2	148 15.2
S1201B	60 12.2	148 15.2	60 13.8	148 14.5
S1202A	60 13.8	148 14.5	60 13.6	148 13.2
S1202B	60 13.6	148 13.2	60 14.1	148 12.4
S1203A	60 14.1	148 12.4	60 13.75	148 11.2
S1203B	60 13.75	148 11.2	60 13.4	148 11.2
S1204A	60 13.4	148 11.2	60 14.7	148 9.9
S1204B	60 14.7	148 9.9	60 15.15	148 10.9
S1205A	60 15.15	148 10.9	60 15.8	148 10.8
S1205B	60 15.8	148 10.8	60 15.55	148 12.0
S1206A	60 15.55	148 12.0	60 16.3	148 12.4
S1206B	60 16.3	148 12.4	60 15.7	148 13.3
S1207A	60 15.7	148 13.3	60 16.2	148 14.4
S1207B	60 16.2	148 14.4	60 15.5	148 14.6
S1208A	60 15.5	148 14.6	60 15.95	148 15.6
S1208B	60 15.95	148 15.6	60 15.2	148 16.0
S1209A	60 15.2	148 16.0	60 15.7	148 17.3
S1209B	60 15.7	148 17.3	60 15.0	148 17.3
S1210A	60 15.0	148 17.3	60 14.9	148 18.4
S1210B	60 14.9	148 18.4	60 14.35	148 17.5

Table 4. Continued.

S1401A	60 17.8	148 12.0	60 18.25	148 10.9
S1401B	60 18.25	148 10.9	60 18.45	148 12.2
S1402A	60 18.45	148 12.2	60 18.9	148 11.0
S1402B	60 18.9	148 11.0	60 19.2	148 12.3
S1403A	60 19.2	148 12.3	60 19.6	148 11.2
S1403B	60 19.6	148 11.2	60 19.85	148 12.3
S1404A	60 19.85	148 12.3	60 20.5	148 11.9
S1404B	60 20.5	148 11.9	60 20.65	148 13.3
S1405A	60 20.65	148 13.3	60 21.4	148 13.6
S1405B	60 21.4	148 13.6	60 20.9	148 14.5
S1406A	60 20.9	148 14.5	60 20.5	148 15.8
S1406B	60 20.5	148 15.8	60 20.9	148 15.2
S1407A	60 20.9	148 15.2	60 21.4	148 14.4
S1407B	60 21.4	148 14.4	60 20.15	148 11.4
S1408A	60 20.15	148 11.4	60 19.5	148 10.9
S1408B	60 19.5	148 10.9	60 20.15	148 10.0
S1409A	60 20.15	148 10.0	60 19.9	148 8.6
S1409B	60 19.9	148 8.6	60 20.65	148 8.8
S1410A	60 20.65	148 8.8	60 20.15	148 7.7
S1410B	60 20.15	148 7.7	60 20.8	148 7.21
S1601A	60 24.65	148 4.9	60 24.2	148 5.8
S1601B	60 24.2	148 5.8	60 23.75	148 4.8
S1602A	60 23.75	148 4.8	60 23.2	148 5.2
S1602B	60 23.2	148 5.2	60 23.35	148 4.1
S1603A	60 23.35	148 4.1	60 22.75	148 4.9
S1603B	60 22.75	148 4.9	60 23.0	148 3.5
S1604A	60 23.0	148 3.5	60 22.8	148 2.2
S1604B	60 22.8	148 2.2	60 23.4	148 2.9
S1605A	60 23.4	148 2.9	60 22.95	148 1.7
S1605B	60 22.95	148 1.7	60 23.6	148 1.6
S1606A	60 23.6	148 1.6	60 23.35	148 0.3
S1606B	60 23.35	148 0.3	60 24.1	148 0.5
S1607A	60 24.1	148 0.5	60 23.8	147 59.1
S1607B	60 23.8	147 59.1	60 24.5	147 59.3
S1608A	60 24.5	147 59.3	60 24.1	147 58.3
S1608B	60 24.1	147 58.3	60 24.8	147 58.0
S1609A	60 24.8	147 58.0	60 24.8	147 56.6
S1609B	60 24.8	147 56.6	60 25.35	147 57.0
S1610A	60 25.35	147 57.0	60 25.6	147 55.8
S1610B	60 25.6	147 55.8	60 26.0	147 56.5
S1801A	60 16.3	148 1.3	60 15.45	148 0.0
S1801B	60 15.45	148 0.0	60 17.0	148 1.2
S1802A	60 17.0	148 1.2	16 17.3	147 59.6
S1802B	16 17.3	147 59.6	60 17.6	148 0.9
S1803A	60 17.6	148 0.9	60 17.9	147 59.4
S1803B	60 17.9	147 59.4	60 18.3	148 0.6
S1804A	60 18.3	148 0.6	60 18.6	147 59.3
S1804B	60 18.6	147 59.3	60 19.1	148 0.4
S1805A	60 19.1	148 0.4	60 19.3	147 59.1
S1805B	60 19.3	147 59.1	60 19.6	148 0.0
S1806A	60 19.6	148 0.0	60 19.8	147 58.7
S1806B	60 19.8	147 58.7	60 20.4	147 59.6
S1807A	60 20.4	147 59.6	60 20.5	147 58.0
S1807B	60 20.5	147 58.0	60 20.95	147 59.1
S1808A	60 20.95	147 59.1	60 21.4	147 58.1
S1808B	60 21.4	147 58.1	60 21.65	147 59.2
S1809A	60 21.65	147 59.2	60 22.0	147 58.1
S1809B	60 22.0	147 58.1	60 22.3	147 59 .1
S1810A	60 22.3	147 59 .1	60 22.8	147 58.6
S1810B	60 22.8	147 58.6	60 23.0	147 59.6

Table 4. Continued.

S2001A	60 17.35	147 56.8	60 17.1	147 58.2
S2001B	60 17.1	147 58.2	60 16.5	147 57.4
S2002A	60 16.5	147 57.4	60 16.4	147 58.9
S2002B	60 16.4	147 58.9	60 15.8	147 58.0
S2003A	60 15.8	147 58.0	60 15.7	147 59.5
S2003B	60 15.7	147 59.5	60 15.15	147 58.5
S2004A	60 15.15	147 58.5	60 14.65	147 59.6
S2004B	60 14.65	147 59.6	60 14.45	147 58.1
S2005A	60 14.45	147 58.1	60 13.85	147 58.9
S2005B	60 13.85	147 58.9	60 13.75	147 57.6
S2006A	60 13.75	147 57.6	60 13.0	147 57.9
S2006B	60 13.0	147 57.9	60 13.2	147 56.6
S2007A	60 13.2	147 56.6	60 12.5	147 55.9
S2007B	60 12.5	147 55.9	60 13.1	147 55.1
S2008A	60 13.1	147 55.1	60 12.5	147 54.6
S2008B	60 12.5	147 54.6	60 13.0	147 53.6
S2009A	60 13.0	147 53.6	60 12.35	147 53.1
S2009B	60 12.35	147 53.1	60 12.9	147 52.5
S2010A	60 12.9	147 52.5	60 12.3	147 51.6
S2010B	60 12.3	147 51.6	60 12.8	147 50.7

Table 5. Net samples collected by the inshore survey of cruise 96-1.
P - Purse Seine, D - Dip Net, C - Cast Net

DATE	TIME IN	STN #	GEAR	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)
SOUTH STUDY AREA							
15/07	14:46	1	P		60 03.97	147 53.47	47.2
15/07	16:28	2	P	N. end La touche	60 04.97	147 51.14	36.0
16/07	15:48	3	P		60 03.20	148 08.22	35.7
CENTRAL STUDY AREA							
19/07	12:30	18	P	C01-05B	60 23.13	147 40.60	18.3
19/07	15:30	19	P	C01-07B	60 23.85	147 40.38	45.7
20/07	12:00	24	P	C02-10A	60 29.88	147 35.97	76.2
21/07	9:00	26	P	C04-01B	60 37.90	147 23.05	27.4
21/07	12:00	29	P	C04-08A	60 40.20	147 18.20	25.9
NORTH STUDY AREA							
22/07	13:00	38	P	C07-02B	60 40.04	147 29.73	24.4-30.5
23/07	9:30	41	P	N19-09A	60 58.81	146 42.43	16.8
23/07	12:30	44	P	N19-01A	60 55.89	146 36.05	21.3
23/07	17:30	47	C	N17-03A	60 53.29	146 45.16	12.2
23/07	16:15	47	P	N17-03A	60 53.32	146 44.60	7.6
24/07	10:30	48	P	N15-07B	60 49.95	146 49.59	24.4
24/07	15:00	52	P	N13-07B	60 50.40	146 38.87	36.6-38.1
24/07	16:50	55	D		60 49.14	146 36.38	36.6
25/07	13:30	58	P	N09-01A	60 46.59	146 33.13	18.3-24.4
25/07	13:30	59	P	N07-05B	60 44.68	146 39.18	36.6
26/07	9:30	62	P	St. Matthews Bay	60 43.59	146 19.70	33.5-35.1
26/07	19:00	68	P	N07-01B	60 43.94	146 42.96	24.4-27.4
27/07	9:00	69	D	N03-06B	60 45.32	146 18.94	35.1

Table 6. Video samples collected on inshore survey of cruise 96-1

DATE	TIME	STN #	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)	SAMPLE D (m)
SOUTH STUDY AREA							
16/07	15:40	3		60 03.24	148 08.09	33.5	12.2
17/07	9:15	4	Whale Bay	60 12.90	148 10.7	30.5	30.5
17/07	10:14	5	Whale Bay	60 12.51	148 09.45	32.0	30.5
17/07	10:58	6	Whale Bay, S107A	60 12.52	148 10.86	76.2	15.2-18.3
17/07	13:15	7	near S10-02A	60 13.28	148 05.61	31.1	15.2
17/07	15:08	8	S14-01A	60 17.98	148 12.56	36.6	12.2
17/07	17:13	9	S14-08A	60 20.17	148 11.45	32.0	12.2
17/07	17:55	10	S14-09	60 20.55	148 08.96	18.3	16.8
18/07	8:42	11	Paddy Bay	60 24.45	148 04.94	15.2-21.3	12.2-15.2
18/07	9:25	12	S16-04B	60 23.45	148 03.76	10.7-15.2	3.0-4.6
18/07	10:30	13	S6-04B	60 23.72	148 01.63	19.8-24.4	12.2-18.3
18/07	11:06	14	S16-04B	60 23.72	148 01.63		
18/07	11:55	14		60 24.93	147 58.24	36.6	15.2-18.3
18/07	14:12	15	S02-01A	60 17.01	147 56.37	12.2	10.7
18/07	17:06	16	S02-07A	60 13.10	147 52.51	67.1	15.2
18/07	17:33	17	S02-09A	60 12.72	147 51.79	19.8	9.1-15.2
CENTRAL STUDY AREA							
19/07	12:00	18	C01-05B	60 23.13	147 40.06	30.5	12.2-15.2
19/07	14:55	19	C01-07B	60 23.75	147 40.19	67.1	10.7-12.2
19/07	16:45	20	C02-04B	60 27.37	147 38.29		6.1
19/07	17:05	21	C02-04B	60 27.57	147 37.11	85.6	6.1
19/07	18:15	22	C02-06B	60 28.75	147 36.54		12.2-18.3
19/07	18:41	23	C02-06B	60 29.05	147 36.85	33.5	12.2
20/07	11:10	24	C02-10A	60 29.88	147 35.97	76.2	9.1
20/07	14:07	25	C03-08A	60 34.72	147 33.45	22.9	9.1-12.2
20/07	14:35	25	C03-08A	60 34.40	147 33.51	15.2	12.2
20/07	14:55	25	C03-08A	60 34.86	147 33.36	12.2-15.2	18.3
21/07	8:20	26	C04-01B	60 37.81	147 23.11	15.2	12.2
21/07	8:40	26	C04-01B	60 37.90	147 23.05	27.4	9.1
21/07	10:45	27	C04-05B	60 38.64	147 18.71	30.5-39.6	12.2-15.2
21/07	11:15	28	C04-06B	60 39.34	147 18.13	24.4-27.4	15.2
21/07	11:36	29	C04-08A	60 40.20	147 18.20	25.9	12.2-15.2
21/07	12:40	30	McPherson Passage	60 40.88	147 19.87	15.2-30.5	12.2-16.8
21/07	13:36	31		60 39.43	147 22.00	27.4-36.6	30.5
21/07	14:30	32	C05-03A	60 40.30	147 22.36	45.7	18.3-30.5
21/07	15:53	33	C05-10B	60 43.00	147 21.65	22.9	21.3
22/07	8:50	34	C07-10A	60 37.58	147 29.30	30.5-36.6	24.4-36.6
22/07	10:03	35	C07-07A	60 38.65	147 29.29	1.5-9.1	1.5-7.6
22/07	11:10	36	C07-04B	60 39.54	147 27.76	9.1-12.2	7.6-9.1
22/07	11:45	37	C07-03B	60 40.56	147 28.11	3.0-6.1	3.0-6.1
22/07	16:15	39	C07-06A	60 47.63	147 29.69	29.0	18.3
22/07	17:05	40	C06-03B	60 44.59	147 26.49	27.4-36.0	30.5
NORTH STUDY AREA							
23/07	10:00	42		60 57.79	146 43.14	36.6	3.0-6.1
23/07	11:30	43	N19-02B	60 56.48	146 36.46	22.9	3.0-9.1
23/07	11:48	44	N19-01A	60 55.94	146 36.16	25.9	15.2
23/07	12:10	44	N19-01A	60 55.71	146 36.39	16.8	15.2
23/07	14:26	45	N17-05B	60 55.23	146 44.34	24.4	12.2
23/07	14:43	46	N17-04B	60 54.88	146 44.52	45.7-48.8	13.7-15.2
24/07	10:10	48	N15-07B	60 49.95	146 49.59	24.4	9.1-12.2

Table 6. Continued

DATE	TIME	STN #	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)	SAMPLE D (m)
24/07	11:15	49	N15-06A	60 49.93	146 49.14	9.1-10.7	6.1-9.1
24/07	12:12	50	N15-02A	60 48.18	146 44.78	22.9-27.4	12.2-18.3
24/07	13:00	51		60 48.62	146 42.21	30.5-38.1	12.2-15.2
24/07	14:37	52	N13-07B	60 50.40	146 38.87	36.6-38.1	12.2
24/07	15:45	53	N13-05B	60 48.76	146 39.25	45.7	18.3-21.3
24/07	16:00	54	N13-04B	60 48.52	146 38.57	36.6-42.7	21.3
24/07	16:13	54	N13-04B	60 48.58	146 38.12	51.8-53.3	22.9
24/07	17:15	56	N13-03A	60 49.52	146 36.48	30.5	21.3-24.4
25/07	10:07	57	N09-07B	60 47.27	146 23.18	54.7	1.5-4.6
25/07	13:08	58	N09-01A	60 46.59	146 33.13	18.3-24.4	10.7-13.7
25/07	13:15	59	N07-05B	60 44.68	146 39.18	36.6	9.1-13.7
25/07	16:35	60		60 43.55	146 42.64	13.7	10.7
25/07	17:43	61		60 41.01	146 36.35	7.6-10.7	7.6-10.7
26/07	9:03	62	St. Matthews Bay	60 43.59	146 19.70	33.5-35.1	10.7-15.2
26/07	11:04	63	St. Matthews Bay	60 43.82	146 19.87	29.0-30.5	24.4-30.5
26/07	14:00	64	N05-10A	60 40.01	146 27.12	18.3	12.2
26/07	14:18	65	N05-09B	60 40.05	146 28.06	10.7-12.2	4.6-6.1
26/07	16:00	66	N05-06A	60 40.95	146 32.80	9.1-10.7	6.1
26/07	16:20	66	N05-06A	60 40.86	146 33.14	9.1-10.7	4.6
26/07	17:05	67	N05-03A	60 41.02	146 36.30	7.6-9.1	7.6-9.1
26/07	18:51	68	N07-02B	60 43.94	146 42.96	18.3-19.8	6.1-9.1
27/07	9:54	70	N03-05B	60 44.48	146 19.19	42.9	42.7
27/07	12:00	71	N03-08B	60 42.25	146 14.31	121.9	36.6
27/07	12:21	72	N03-09A	60 42.98	146 13.45	70.1	30.5
27/07	13:17	73	N01-10A	60 42.06	146 09.87	29.0-38.1	15.2-18.3
27/07	13:44	74	N01-09A	60 41.85	146 11.39	45.7	15.2-18.3
27/07	14:23	75	N01-07B	60 40.55	146 13.41	38.1-61.0	15.2-30.5

Table 7. CTD data collected in the inshore survey during APEX cruise 96-1

DATE	TIME IN	LOCATION	LATITUDE	LONGITUDE	DEPTH (m)	GEAR D (m)
SOUTH STUDY AREA						
15/07	10:00	Shelter Bay	60 07.580	147 55.564	27	10
15/07	11:41	S02-01A	60 1.93	147 58.0	73	60
15/07	11:57	S04-01A	60 03.4	147 57.3	161	140
15/07	12:53	S02-08A	60 05.36	147 51.24	88	80
15/07	15:32	S04-09A	60 8.25	147 53.4	247	200
16/07	11:38	S06-01A	60 00.9?	148 09.8?	117	100
16/07	14:01	S06-10A	60 07.021	148 04.252	108	100
16/07	14:45	S08-01A	60 10.245	147 58.835	162	140
16/07	16:00	S08-091A	60 09.378	148 06.179	132	120
16/07	16:38	S10-01A	60 13.458	148 04.259	480	200
16/07	17:56	S10-10A	60 10.910	148 11.165	106	100
17/07	10:58	S14-01A	60 18.331	148 11.049	281	200
17/07	14:23	S16-10A	60 25.58	147 55.841	296	200
17/07	15:18	S16-09A	60 23.213	148 04.864	73	60
CENTRAL STUDY AREA						
20/07	8:04	C02-06A	60 28.708	147 37.036	160	140
20/07	8:37	C02-01A	60 25.440	147 34.947	111	100
20/07	9:12	C01-01A	60 21.395	147 36.926	64	60
20/07	16:05	C03-01A	60 30.390	147 34.776	28.6	20
20/07	17:51	C03-07A	60 34.588	147 32.868	191	180
20/07	18:43	C04-02A	60 37.205	147 22.152	29	20
21/07	8:12	C08-03	60 37.522	147 24.940	52	40
21/07	11:08	C05-10A	60 43.915	147 21.676	53	40
21/07	11:41	C05-05A	60 41.113	147 20.529	71	60
21/07	11:53	C05-04A	60 40.545	147 21.858	44	40
21/07	12:14	C04-08A	60 40.685	147 17.864	62	60
21/07	12:37	C04-06A	60 38.862	147 17.302	106	100
22/07	9:59	C07-07A	60 38.108	147 29.652	92	80
22/07	10:33	C07-03A	60 40.111	147 29.408	56	40
22/07	11:00	C07-01A	60 42.028	147 29.270	43	40
22/07	11:12	C06-07A	60 42.563	147 28.530	107	100
22/07	11:38	C06-05A	60 44.557	147 28.557	151	140
NORTH STUDY AREA						
23/07	8:28	N17-08A	61 59.765	146 43.681	338	200
23/07	11:22	N19-05A	60 56.804	146 42.631	210	200
23/07	11:54	N19-02A	60 56.228	146 37.580	106	100
23/07	15:34	N17-08A	60 57.447	146 47.301	348	200
23/07	15:59	N17-06A	60 55.654	146 46.505	252	200
23/07	16:16	N17-01A	60 54.722	146 46.344	66	60
23/07	16:56	N15-10A	60 51.800	146 51.089	68	60
24/07	13:57	N15-08A	60 24.6	146 50.015	66	60
24/07	14:25	N15-05A	60 47.871	146 49.477	40	35
24/07	14:54	N15-01A	60 47.953	146 42.917	81	80
24/07	15:43	N13-10A	60 52.095	146 37.936	51	40
24/07	16:45	N02-01A	60 48.186	146 39.873	79	60
24/07	17:01	N13-04A	60 48.447	146 37.738	103	95
24/07	18:31	N13-01A	60 50.35	146 34.67	94	80
25/07	9:20	N09-01A	60 47.4	146 31.15	197	180
25/07	10:27	N09-05A	60 47.533	146 26.178	186	180
25/07	12:05	N09-01A	60 47.872	146 19.925	182	180
25/07	13:19	N07-10A	60 45.674	146 33.811	36	20
25/07	13:53	N07-05A	60 45.148	146 39.552	43	20
25/07	14:40	N07-01A	60 44.492	146 43.39	41	40
25/07	16:28	N05-10A	60 40.227	146 38.643	26	20
25/07	17:12	N05-05A	60 40.037	146 32.535	21	20
25/07	17:38	N05-01A	60 39.749	146 27.036	21	20
26/07	10:06	N03-01	60 45.449	146 19.013	32	20
26/07	10:36	N03-07	60 43.021	146 20.702	32	20
26/07	11:01	N03-01A	60 42.282	146 16.400	63	60
26/07	11:36	N01-10A	60 42.456	146 11.030	165	160
26/07	12:57	N01-05A	60 40.524	146 15.478	108	100
26/07	13:37	N01-01A	60 37.441	146 17.009	35	20

Table 8. Beach seine samples collected on APEX cruise 96-1

DATE	TIME	STN #	LOCATION	LATITUDE	LONGITUDE
SOUTH STUDY AREA					
15/07	13:15	1	S02-03	60 02.24	147 55.03
15/07	14:30	2	S02-06	60 03.92	147 53.00
15/07	16:00	3	S02-04	60 03.00	148 54.31
15/07	16:30	4	S04-01	60 04.01	147 58.25
15/07	17:20	5	S04-02	60 04.15	147 56.95
15/07	18:15	6	S04-04	60 05.52	147 55.05
16/07	11:05	7	S06-01	60 01.40	148 11.50
16/07	13:00	8	S06-09	60 06.00	148 05.50
16/07	13:35	9	S06-10	60 05.50	148 05.70
16/07	15:30	10	S08-05	60 11.89	148 03.83
16/07	17:25	11	S08-06	60 11.59	148 04.53
16/07	17:40	11	S08-06	60 11.59	148 04.53
17/07	8:30	12	S10-08	60 11.59	148 09.09
17/07	9:35	13	S10-05	60 13.95	148 09.00
17/07	10:10	14	S10-02	60 13.33	148 07.40
17/07	12:30	15	S14-06	60 20.80	148 14.40
17/07	13:30	16	S14-07	60 21.31	148 15.40
17/07	15:25	17	S14-09	60 20.50	148 09.59
17/07	16:30	18	S16-03	60 23.15	148 03.80
17/07	17:30	19	S16-07	60 24.24	148 00.45
17/07	18:42	20	S16-09	60 25.18	147 57.60
18/07	9:10	21	S18-05	60 19.61	148 00.60
18/07	9:40	22	S18-04	60 18.70	148 01.10
18/07	10:40	23	S18-03	60 18.05	148 01.30
18/07	13:00	24	S20-08	60 13.54	147 53.70
18/07	12:35		S20-10		
18/07	15:00	25	S20-04	60 14.44	147 56.80
18/07	15:35	26	S20-03	60 15.40	147 56.41
CENTRAL STUDY AREA					
19/07	11:48	27	C01-05	60 23.60	147 38.20
19/07	13:15	28	C01-06	60 22.11	147 40.00
19/07	15:30	29	C01-10	60 23.26	147 36.91
19/07	17:20	30	C02-03	60 26.54	147 37.26
19/07	17:50	31	C02-04	60 26.47	147 36.96
19/07	19:05	32	C02-01	60 27.89	147 37.29
20/07	9:10	33	C03-03	60 32.54	147 34.47
20/07	9:30	33	C03-03	60 32.54	147 34.47
20/07	11:05	34	C03-07	60 34.28	147 32.70
20/07	12:30	35	C03-09	60 34.67	147 33.13
20/07	14:40	36	C04-02	60 37.67	147 21.10
20/07	15:50	37	C04-05	60 38.69	147 19.69
20/07	16:55	38	C04-07	60 39.60	147 17.31
21/07	8:40	39	C08-01	60 37.13	147 28.10
21/07	9:00	39	C08-01	60 37.13	147 28.10
21/07	10:30	40	C08-03	60 37.15	147 25.99
21/07	11:35	41	C08-04	60 37.77	147 25.70
21/07	13:30	42	C05-01	60 39.90	147 20.77
21/07	14:45	43	C05-02	60 39.16	147 22.64
21/07	15:45	44	C05-03	60 40.22	147 23.75
21/07	16:20	45	C05-04	60 41.07	147 23.17
22/07	9:10	46	C07-03	60 40.77	147 28.68

Table 8. Continued.

DATE	TIME IN	STN #	LOCATION	LATITUDE	LONGITUDE
22/07	9:25	46	C07-03	60 40.77	147 28.68
22/07	9:55	47	C07-05	60 39.32	147 29.41
22/07	10:50	48	C07-01	60 41.26	147 28.79
22/07	12:10	49	C06-08	60 43.20	147 26.95
22/07	12:50	50	C06-09	60 43.13	147 25.55
22/07	11:50	51	C06-07	60 43.20	147 27.62
NORTH STUDY AREA					
23/07	8:28	52	N19-09	60 42.10	146 58.82?
23/07	9:00	53	N19-08	60 58.49	146 43.30
23/07	11:10	54	N19-04	60 58.49	146 43.30?
23/07	12:35	55	N17-06	60 56.33	146 45.10
23/07	13:15	56	N17-05	60 55.42	146 44.13
23/07	13:50	57	N17-03	60 54.28	146 43.50
23/07	15:30	58	N15-08	60 50.39	147 48.91
23/07	17:50	59	N15-03	60 48.42	146 45.81
24/07	9:50	60	N15-07	60 49.78	146 48.89
24/07	11:45	61	N13-02	60 49.90	146 36.90
24/07		62	N13-04	60 49.13	146 37.50
24/07		63	N13-06	60 49.65	146 38.20
24/07		64	N09-05	60 46.72	146 25.40
24/07		65	N09-10	60 47.61	146 19.27
24/07		65	N09-10	60 47.61	146 19.27
24/07		66	N09-09	60 47.32	146 19.30
25/07	9:45	67	N07-09	60 45.68	146 35.96
25/07	10:40	68	N07-04	60 44.60	146 41.68
25/07	11:40	69	N07-02	60 43.41	146 43.49
25/07	13:30	70	N05-07	60 41.43	146 33.20
25/07	14:30	71	N05-06	60 41.40	146 32.00
25/07	15:20	72	N05-05	60 41.30	146 31.11
26/07	8:50	73	N03-09	60 44.39	146 19.90
26/07	9:25	74	N03-07	60 45.30	146 18.38
26/07	10:05	75	N03-05	60 44.09	146 18.61
26/07	11:20	76	N01-09	60 41.65	146 10.61
26/07	12:25	77	N01-08	60 40.92	146 11.90
26/07	13:25	78	N01-01	60 37.58	146 15.51
27/07	8:55	79	N05-05	60 41.30	146 31.11
27/07	11:10	80	N05-06	60 41.40	146 32.00
27/07	13:50	81	N15-03	60 48.42	146 45.81
27/07	14:45	82	N15-07	60 49.78	146 48.89
27/07	17:45	83	N05-05	60 41.30	146 31.11
27/07	18:00	84	N05-06	60 41.40	146 32.00
27/07	20:40	85	N15-07	60 49.78	146 48.89
27/07	21:45	86	N15-03	60 48.42	146 45.81
28/07	4:55	87	N05-05	60 41.30	146 31.11
28/07	6:25	88	N05-06	60 41.40	146 32.00
28/07	9:10	89	N15-07	60 49.78	146 48.89
28/07	9:35	90	N15-03	60 48.42	146 45.81

Table 9. Fish densities (g/square meter) in shallow and deep depth strata in offshore transects in South, Central and North areas.

	Biomass Estimate (g/sq.m)		
Transect	1-25m	26-100m	TOTAL
NORTH STUDY AREA			
N01A-1	3.91	2.11	6.01
N01A-2	0.32	1.66	1.99
N01A-3	0.01	0.19	0.20
N02A-1	0.22	0.15	0.37
N02A-2	13.75	6.97	20.72
N02A-3	0.23	2.85	3.08
NZ02N	0.57	1.32	1.89
NO3A-1	0.70	0.09	0.79
N03A-2	10.36	9.92	20.28
N03A-3	4.22	0.27	4.49
NO3TT	0.08	0.21	0.29
NO3LL	0.07	12.42	12.49
NZ03S	0.60	3.09	3.69
N04A	0.41	1.22	1.62
NZ04N	4.69	0.23	4.92
N05A-1	0.41	0.11	0.51
N05A-2	0.38	0.44	0.83
NZ05S	0.04	1.06	1.10
N06A	0.41	0.24	0.65
NZ06N	0.32	0.06	0.38
NZ06S	2.41	0.86	3.26
N06GBW	0.52	0.93	1.45
N06GBE	0.79	2.36	3.14
N07A	0.26	0.38	0.64
NZ07N	1.18	0.38	1.56
NZ07S	0.59	1.29	1.88
N08A	0.17	0.43	0.60
N09A	7.92	1.53	9.45
N10A	0.71	1.01	1.73
N12A	0.39	0.90	1.29
N13E	0.13	1.70	1.83
N13W	0.38	0.11	0.50
N14E	1.42	2.09	3.51
N14W	0.81	1.48	2.28
CENTRAL STUDY AREA			
C01A-1	0.41	1.07	1.48
C01A-2	0.50	0.04	0.54
CZ01S	0.53	0.06	0.59
C02A-1	0.72	0.44	1.16
C02A-2	0.59	1.84	2.43
CZ02N	0.82	0.06	0.88
CZ02S	0.07	0.50	0.56
C03A-1	0.34	0.21	0.55
C03A-2	0.15	0.45	0.60
CZ03N	0.28	0.61	0.89
C04A-1	0.31	0.45	0.77
C04A-2	0.34	0.08	0.42
CZ04N	0.24	0.35	0.59
CZ04S	0.32	0.00	0.33

Table 9. Continued.

	Biomass Estimate (g/sq.m)		
Transect	1-25m	26-100m	TOTAL
C05A-1	0.35	0.13	0.48
C05A-2	0.19	0.14	0.33
C06A-1	0.49	0.14	0.64
C06A-A	0.53	0.20	0.74
CZ06N	1.32	1.15	2.47
CZ06S	0.11	0.28	0.38
C07W	0.39	0.15	0.54
C07E-1	0.20	0.13	0.32
C07E-2	0.23	0.75	0.98
C08A-1	0.32	0.01	0.33
C08A-2	0.17	0.27	0.44
C09E	0.09	0.40	0.48
C10C	0.17	0.05	0.22
C10W	0.36	0.01	0.37
C10E	0.09	0.05	0.14
C11E	0.28	0.05	0.33
C12E	0.24	0.20	0.44
SOUTH STUDY AREA			
SO1W	1.22	0.09	1.31
S01S	0.20	0.00	0.21
S01E	0.32	0.13	0.45
S01N	0.23	0.04	0.27
S02E	0.22	0.06	0.28
S03N	0.27	0.07	0.34
S03S	0.35	0.01	0.35
S03W	0.12	0.17	0.29
S04E	0.25	0.11	0.36
S04W	0.19	0.00	0.20
S05E	0.24	0.06	0.30
S05W	0.09	0.02	0.11
S06W	0.20	0.13	0.33
S07A	0.17	1.25	1.42
S08A	0.77	0.75	1.52
S09E	0.01	0.01	0.02
S09W	0.08	0.05	0.13

Table 10. Average fish densities (g/square m) for South, Central and North areas

	Biomass Estimate (g/sq.m)		
Depth (m)	North	Central	South
1-25	1.80	0.37	0.29
26-100	1.55	0.38	0.31
TOTAL	3.34	0.75	0.60

Table 11. Fish and jellyfish in midwater trawl samples collected on APEX cruise 96-1 in Prince William sound

Station	Pollock	Aequora	Cyanea	Aurelia	Eutonia	Other Jellyfish
5		960	16			4
12a		109	33			
12b		50	12			
48a		31	2		1	1
48b		35				
65	128	22				
83		7	9	6	4	
84		19	5	6	5	
102			6	3	1	
119	11	37	7			
122		40	1			
TOTAL	139	1310	91	15	11	5

Table 12. Biomass estimates for nearshore study sites in three study areas of Prince William Sound in APEX cruise 96-1.

	ZIGS				ZAGS			
SITE	**MEAN BIOMASS**	**STD DEV**	**N**	**STD ERR.**	**MEAN BIOM**	**STD DEV**	**N**	**STD ERR.**
NORTH STUDY AREA								
N1	0.76	0.91	10	0.29	0.64	0.89	10	0.28
N3	0.25	0.27	10	0.09	0.39	0.6	10	0.19
N5	28.01	24.32	10	7.69	29.21	18.44	10	5.83
N7	15.22	36.31	6	14.82	1.92	2.87	5	1.28
N9	0.12	0.29	10	0.09	0.88	2.37	10	0.75
N13	1.59	4.31	10	1.36	2.28	5.41	10	1.71
N15	0.94	2.59	10	0.82	0.09	0.11	10	0.03
N17	5.38	16.9	10	5.34	0.64	1.82	10	0.58
N19	0.54	1.6	10	0.51	0.24	0.38	10	0.12
MEAN	**5.87**				**4.03**			
STD ERR	**3.21**				**3.16**			
CENTRAL STUDY AREA								
C1	0.28	0.5	10	0.16	1.85	3.16	10	1.00
C2	4.48	12.81	10	4.05	1.27	2.7	10	0.85
C3	0.93	2.09	10	0.66	5.08	15.28	10	4.83
C6	0.16	0.2	10	0.06	1.23	1.81	10	0.57
C7	0.24	0.46	10	0.15	0.2	0.46	10	0.15
C8	0.01	0.01	5	0.00	0.12	0.26	5	0.12
MEAN	**1.02**				**1.63**			
STD ERR	**0.70**				**0.74**			
SOUTH STUDY AREA								
S2	4.05	8.69	10	2.75	3.41	10.02	10	3.17
S4	0.01	0.02	9	0.01	0.27	0.66	10	0.21
S6	0.12	0.15	10	0.05	15.5	32.52	10	10.28
S10	0.55	1.47	10	0.46	0.63	1.17	10	0.37
S14	5.04	15.86	10	5.02	0.06	0.15	10	0.05
S16	0.08	0.13	10	0.04	0.08	0.15	10	0.05
S18	4.79	13.69	10	4.33	0.06	0.13	10	0.04
MEAN	**2.09**				**2.86**			
STD ERR	**0.91**				**2.16**			

TABLE 13. Fish catches in nearshore net sampling in the North Study Area of Prince William Sound on APEX cruise 96-1.

STATION NO.	41	44	47	47	48	52	58	62	68	69	
SITE	N19-09A	N19-01A	N17-03A	N17-03A	N15-07B	N13-07B	N09-01A	ST MATT	N07-01B	N03-06B	
DATE	23-Jul	23-Jul	23-Jul		24-Jul	24-Jul	25-Jul	26-Jul	26-Jul	27-Jul	
											TOTAL
				CAST NET						DIPPNET	
HERRING			176	414				10000	10000	450	21040
PINK SALMON	5				2	7	61				75
POLLOCK		1	2								3
TOM COD		1			2						3
PAC COD			32								32
GREENLING											
GREEN WH SP			1								1
GREEN KELP			1								1
ARCTIC SHANNY			3								3
SNAKE PRICKL											
SCULPIN			3								3
STICKLEBACK	2	4			1	2	200				209
CREST GUNN	1				2	4					7
PROWFISH	2	2	1			1	2				8
WOLFFISH			1								1
ALL FISH	10	8	220	414	7	14	263	10000	10000	450	21386

Table 14. Catches of fish in purse seine samples in the Central Study Area of Prince William Sound on APEX cruise 96-1

STATION NO.	18	19	24	26	29	38	
SITE	C01-05B	C01-07B	C02-10A	C04-01B	C04-08A	C07-02B	
DATE	19-Jul	19-Jul	20-Jul	21-Jul	21-Jul	22-Jul	
							TOTAL
HERRING	1300	2	1				1303
SANDLANCE	28						28
PINK SALMON		2	200				202
COHO SALMON				3			3
CHUM SALMON							
POLLOCK					1	2	3
TOM COD						1	1
LINGCOD					1		1
STICKLEBACK		2					2
CREST GUNN		7					7
PROWFISH		2			1		3
ALL FISH	1328	15	201	3	3		1550

Table 15. Catches of fish in purse seine samples in the South Study Area of Prince William Sound in APEX cruise 96-1.

STATION NO.	1	2	3	
SITE				TOTAL
DATE	15-Jul-96	15-Jul-96	16-Jul-96	
HERRING		3	650	653
PINK SALMON	472	550	78	1100
CHUM SALMON	107	39	19	165
ALL FISH	579	592	747	1918

Table 16. Video samples identifications on inshore survey of cruise 96-1

DATE	TIME	STN #	LOCATION	DEPTH (m)	TARGET IDENTIFICATION
			SOUTH STUDY AREA		
16/07	15:40	3		12.2	NONE
17/07	9:15	4	Whale Bay	30.5	NONE
17/07	10:14	5	Whale Bay	30.5	NONE
17/07	10:58	6	S107A	15.2-18.3	HERRING >100 MM
17/07	13:15	7	near S10-02A	15.2	SALMON SHARKS
17/07	15:08	8	S14-01A	12.2	HERRING >100 MM
17/07	17:13	9	S14-08A	12.2	NONE
17/07	17:55	10	S14-09	16.8	NONE
18/07	8:42	11	Paddy Bay	12.2-15.2	YOY POLLOCK
18/07	9:25	12	S16-04B	3.0-4.6	NONE
18/07	10:30	13	S16-04B	12.2-18.3	ROCKFISH
18/07	11:06	14	S16-04B	15.2 - 18.3	HERRING >100 MM
18/07	14:12	15	S02-01A	10.7	NONE
18/07	17:06	16	S02-07A	15.2	UNIDENTIFIED SCHOOL
18/07	17:33	17	S02-09A	9.1-15.2	HERRING
			CENTRAL STUDY AREA		
19/07	12:00	18	C01-05B	12.2-15.2	HERRING > 100 MM
19/07	14:55	19	C01-07B	10.7-12.2	NONE
19/07	16:45	20	C02-04B	6.1	NONE
19/07	17:05	21	C02-04B	6.1	NONE
19/07	18:15	22	C02-06B	12.2-18.3	HERRING > 100 MM
19/07	18:41	23	C02-06B	12.2	UNIDENTIFIED SCHOOL
20/07	11:10	24	C02-10A	9.1	HERRING > 100 MM
20/07	14:07	25	C03-08A	9.1-12.2	HERRING > 100 MM
20/07	14:35	25	C03-08A	12.2	NONE
20/07	14:55	25	C03-08A	18.3	NONE
21/07	8:20	26	C04-01B	12.2	NONE
21/07	8:40	26	C04-01B	9.1	UNIDENTIFIED SCHOOL
21/07	10:45	27	C04-05B	12.2-15.2	NONE
21/07	11:15	28	C04-06B	15.2	UNIDENTIFIED SCHOOL
21/07	11:36	29	C04-08A	12.2-15.2	HERRING > 100 MM
21/07	12:40	30	McPherson Passage	12.2-16.8	ROCKFISH
21/07	13:36	31		30.5	ADULT SALMON
21/07	14:30	32	C05-03A	18.3-30.5	HERRING > 100 MM
21/07	15:53	33	C05-10B	21.3	ROCKFISH
22/07	8:50	34	C07-10A	24.4-36.6	NONE
22/07	10:03	35	C07-07A	1.5-7.6	ROCKFISH JUVENILES
22/07	11:10	36	C07-04B	7.6-9.1	NONE
22/07	11:45	37	C07-03B	3.0-6.1	GADID - JUVENILE
22/07	16:15	39	C07-06A	18.3	NONE
22/07	17:05	40	C06-03B	30.5	NONE
			NORTH STUDY AREA		
23/07	10:00	42		3.0-6.1	JELLYFISH
23/07	11:30	43	N19-02B	3.0-9.1	JELLYFISH
23/07	11:48	44	N19-01A	15.2	UNIDENTIFIED SCHOOL
23/07	12:10	44	N19-01A	15.2	NONE
23/07	14:26	45	N17-05B	12.2	UNIDENTIFIED SCHOOL
23/07	14:43	46	N17-04B	13.7-15.2	HERRING > 100 MM
24/07	10:10	48	N15-07B	9.1-12.2	UNIDENTIFIED SCHOOL
24/07	11:15	49	N15-06A	6.1-9.1	UNIDENTIFIED SCHOOL

Table 16. Continued

DATE	TIME	STN #	LOCATION	SAMPLE D (m)	IDENTIFICATION
24/07	12:12	50	N15-02A	12.2-18.3	UNIDENTIFIED SCHOOL
24/07	13:00	51		12.2-15.2	HERRING > 100 MM
24/07	14:37	52	N13-07B	12.2	HERRING > 100 MM
24/07	15:45	53	N13-05B	18.3-21.3	HERRING > 100 MM
24/07	16:00	54	N13-04B	21.3	HERRING > 100 MM
24/07	16:13	54	N13-04B	22.9	HERRING > 100 MM
24/07	17:15	56	N13-03A	21.3-24.4	NONE
25/07	10:07	57	N09-07B	1.5-4.6	NONE
25/07	13:08	58	N09-01A	10.7-13.7	HERRING > 100 MM
25/07	13:15	59	N07-05B	9.1-13.7	HERRING > 100 MM
25/07	16:35	60		10.7	NONE
25/07	17:43	61		7.6-10.7	SANDLANCE
26/07	9:03	62	St. Matthews Bay	10.7-15.2	HERRING - YOY
26/07	11:04	63	St. Matthews Bay	24.4-30.5	NONE
26/07	14:00	64	N05-10A	12.2	NONE
26/07	14:18	65	N05-09B	4.6-6.1	NONE
26/07	16:00	66	N05-06A	6.1	NONE
26/07	16:20	66	N05-06A	4.6	NONE
26/07	17:05	67	N05-03A	7.6-9.1	NONE
26/07	18:51	68	N07-02B	6.1-9.1	HERRING > 100 MM
27/07	9:54	70	N03-05B	42.7	NONE
27/07	12:00	71	N03-08B	36.6	NONE
27/07	12:21	72	N03-09A	30.5	NONE
27/07	13:17	73	N01-10A	15.2-18.3	HERRING - YOY
27/07	13:44	74	N01-09A	15.2-18.3	POLLOCK - YOY
27/07	14:23	75	N01-07B	15.2-30.5	NONE

Table17. Mean lengths of dominant species (n >10) in net samples collected by the inshore survey of cruise 96-1.
P - Purse Seine, D - Dip Net, C - Cast Net

DATE	STN #	GEAR	LOCATION	DEPTH (m)	SPECIES	FORK LENGTH (mm)	STAND. DEV.	N
			SOUTH AREA					
15/07	1	P		47.2	Pink Salmon	92.6	6.2	279
15/07	2	P	N. end La touche	36.0	Pink Salmon	99.1	12.6	234
16/07	3	P		35.7	Herring	192	12.2	204
					Pink Salmon	115.3	14.6	78
			CENTRAL AREA					
19/07	18	P	C01-05B	18.3	Herring	125.8	12.1	270
					Sand lance	101.2	2.5	11
20/07	24	P	C02-10A	76.2	Juv. Salmon	111.8	13.4	200
			NORTH AREA					
23/07	47	C	N17-03A	12.2	Herring	118.3	6.0	177
23/07	47	P	N17-03A	7.6	Herring	54.1	2.8	414
25/07	58	P	N09-01A	18.3-24.4	Juv. Salmon	98.7	9.2	61
26/07	62	P	St. Matthews Bay	33.5-35.1	Herring	55.6	2.5	247
26/07	68	P	N07-01B	24.4-27.4	Herring	135.2	9.4	234
27/07	69	D	N03-06B	35.1	Herring	54.8	3.0	220

Table 18 . Composition of beach seine samples collected in the North study area of Prince William Sound in APEX cruise 96-1.

										TOTAL
SITE	N 01	N03	N05	N07	N09	N13	N15	N17	N19	
DATE										
TOTAL HAULS	3	3	3	3	3	3	3	3	3	27
HERRING	1109		597	10	127	1	32006	16	17	33883
SANDLANCE			13500	0	706	52	600			14858
EULACHON			6	1						7
PINK SALMON							4	1	67	72
COHO SALMON										
RED SALMON								3		3
POLLOCK										
TOM COD								17		17
PAC COD										
GREENLING						4		1		5
GREEN WH SP			1							1
GREEN MASK			1					1		2
LINGCOD			2					1		3
SCULPIN						1			1	2
GREAT SCULPIN		1							1	2
STICKLEBACK									3	3
SANDFISH							20			20
PIPEFISH						1		2		3
CREST GUNN						1		2	1	4
GUNNEL										
TUBESNOUT								13		13
OTHER			2							2
ALL FISH	1109	1	14109	11	833	60	32630	57	90	48900

Table 19. Composition of beach seine samples collected in the Central study area of Prince William Sound on APEX cruise 96-1

SITE	C01	C02	C03	C04	C05	C06	C07	TOTAL
DATE								
TOTAL HAULS	3	3	3	3	4	3	3	22
HERRING					1	1		2
SANDLANCE	1			1			262	264
PINK SALMON	6	1	114	500	1	137	65	824
COHO SALMON			2					2
RED SALMON					2	2		4
POLLOCK			10	1	20			31
TOM COD	140		325		29		1	495
PAC COD			33		2			35
GREENLING			1					1
GREEN WH SP	1		1					2
GREEN MASK	1		2					3
LINGCOD	1		20					21
SCULPIN	1		1	1	1			4
GREAT SCULPIN	3							3
SANDFISH			1	4	2			7
TUBESNOUT	1							1
OTHER	1							1
ALL FISH	156	1	510	507	58	140	328	1700

Table 20. Composition of beach seine samples collected in the South study area of Prince William Sound in APEX cruise 96-1.

										TOTAL
SITE	S 02	S 04	S 06	S08	S 10	S14	S16	S18	S20	
DATE										
TOTAL HAULS	3	3	3	1	3	3	3	2	3	24
HERRING		6			36	8001	56	1	48	8148
SANDLANCE			6	33	1				1	41
PINK SALMON	13		2		6	3	48	6	25	103
POLLOCK	1						1			2
TOM COD	98	7			190	904	222	1	31	1453
GREENLING										
GREEN WH SP				2						2
GREEN KELP								10		10
GREEN MASK	1									1
LINGCOD	3	1							1	5
SNAKE PRICKL	1									1
SCULPIN	2				1				1	4
GREAT SCULPIN							7			7
STICKLEBACK							1			1
TUBESNOUT					3	11		2		16
OTHER										
										0
ALL FISH	119	14	8	35	237	8919	335	20	107	9794

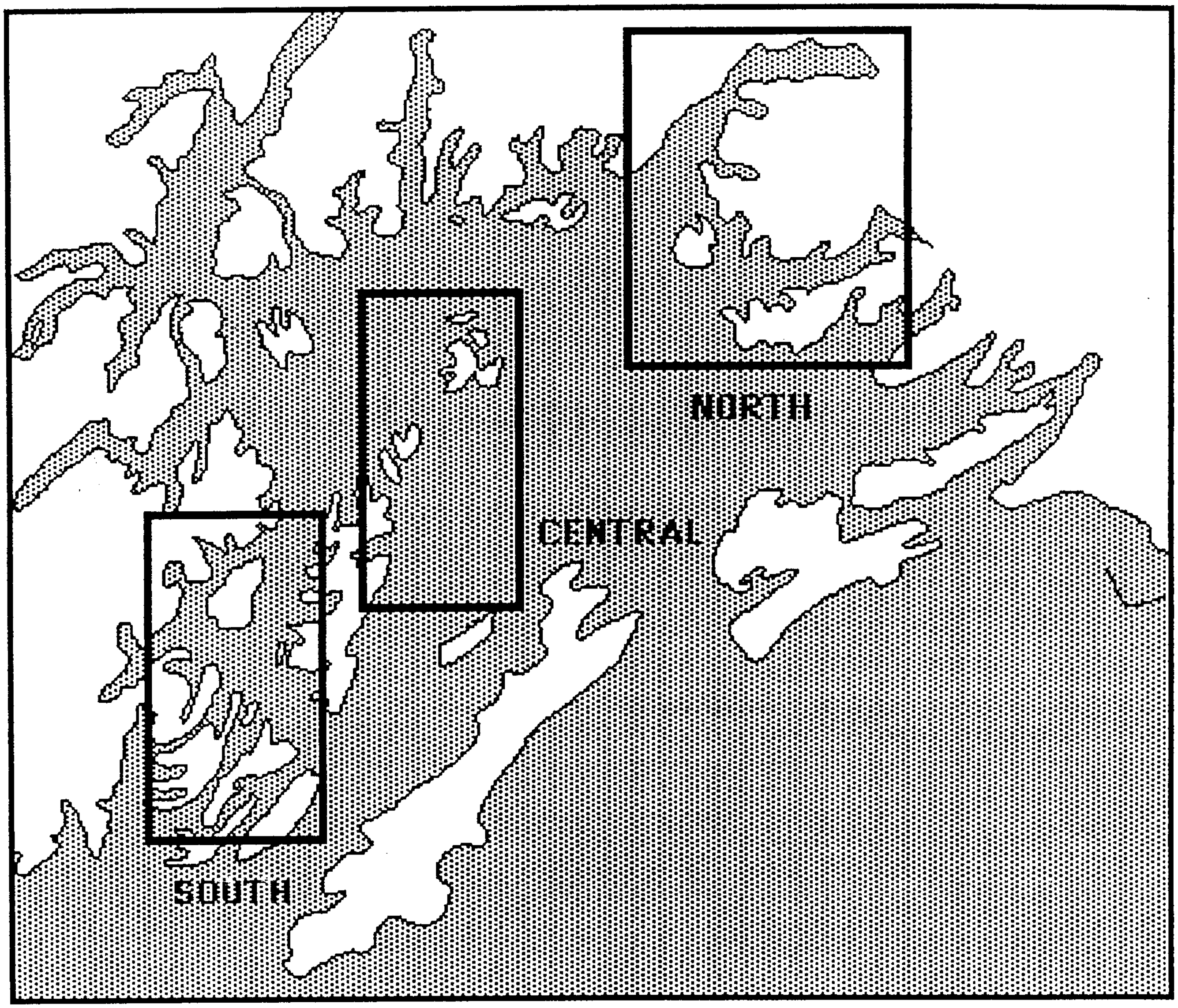


Figure 1. Locations of North, Central and South study areas for the APEX forage fish project.

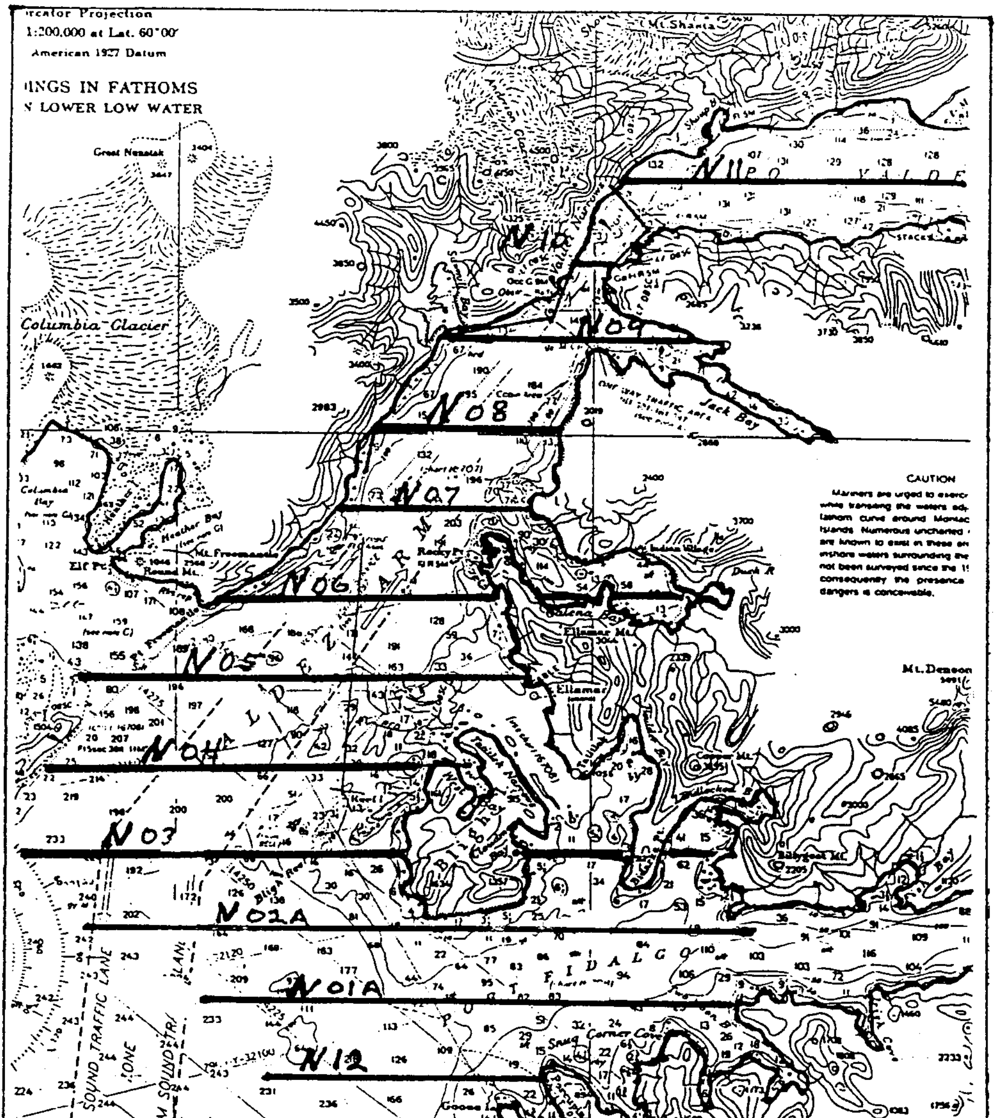


Figure 2. Offshore hydroacoustic transect locations in the North study area of Prince William Sound.

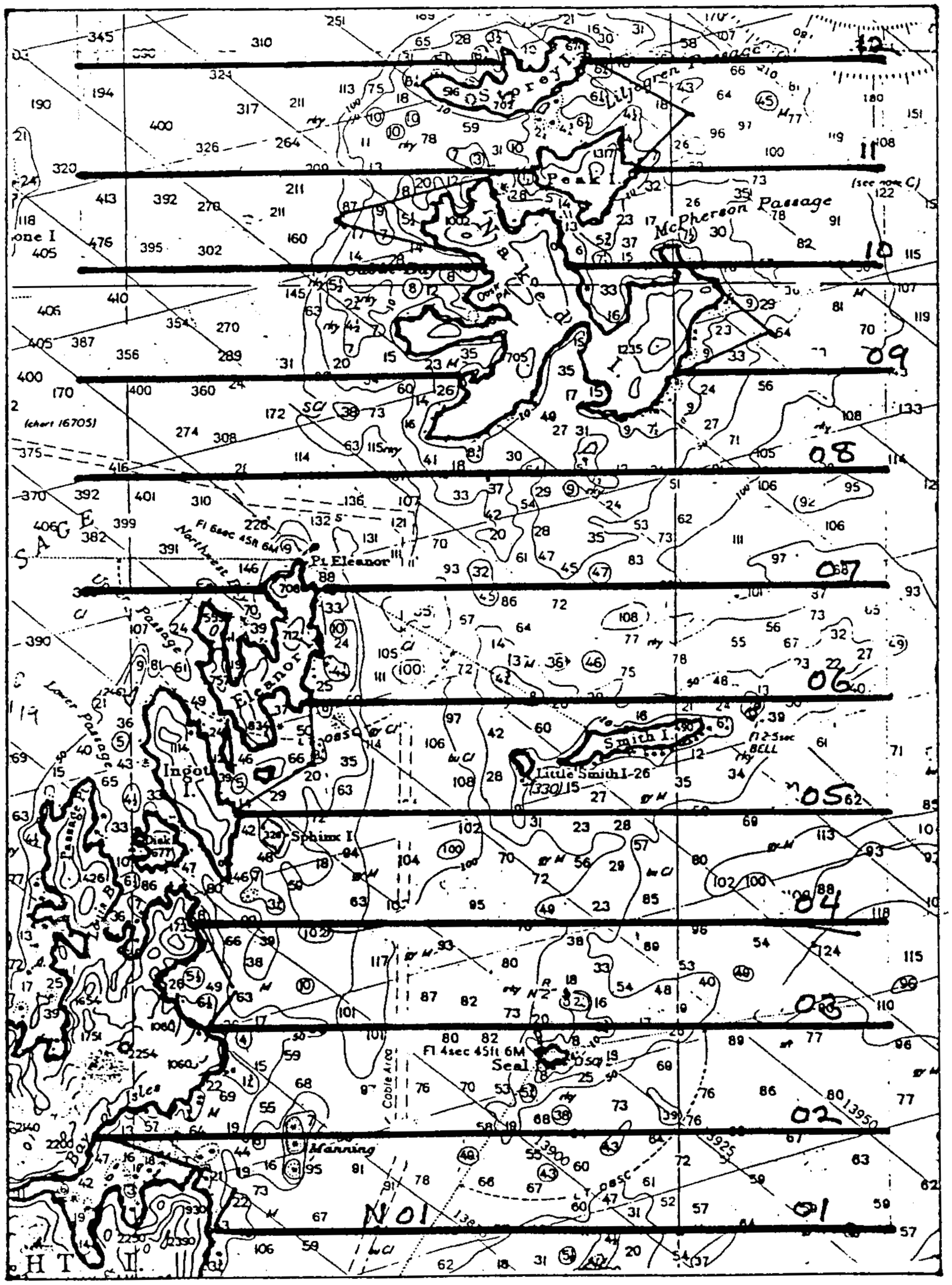


Figure 3. Offshore hydroacoustic transect locations in the Central study of Prince William Sound.

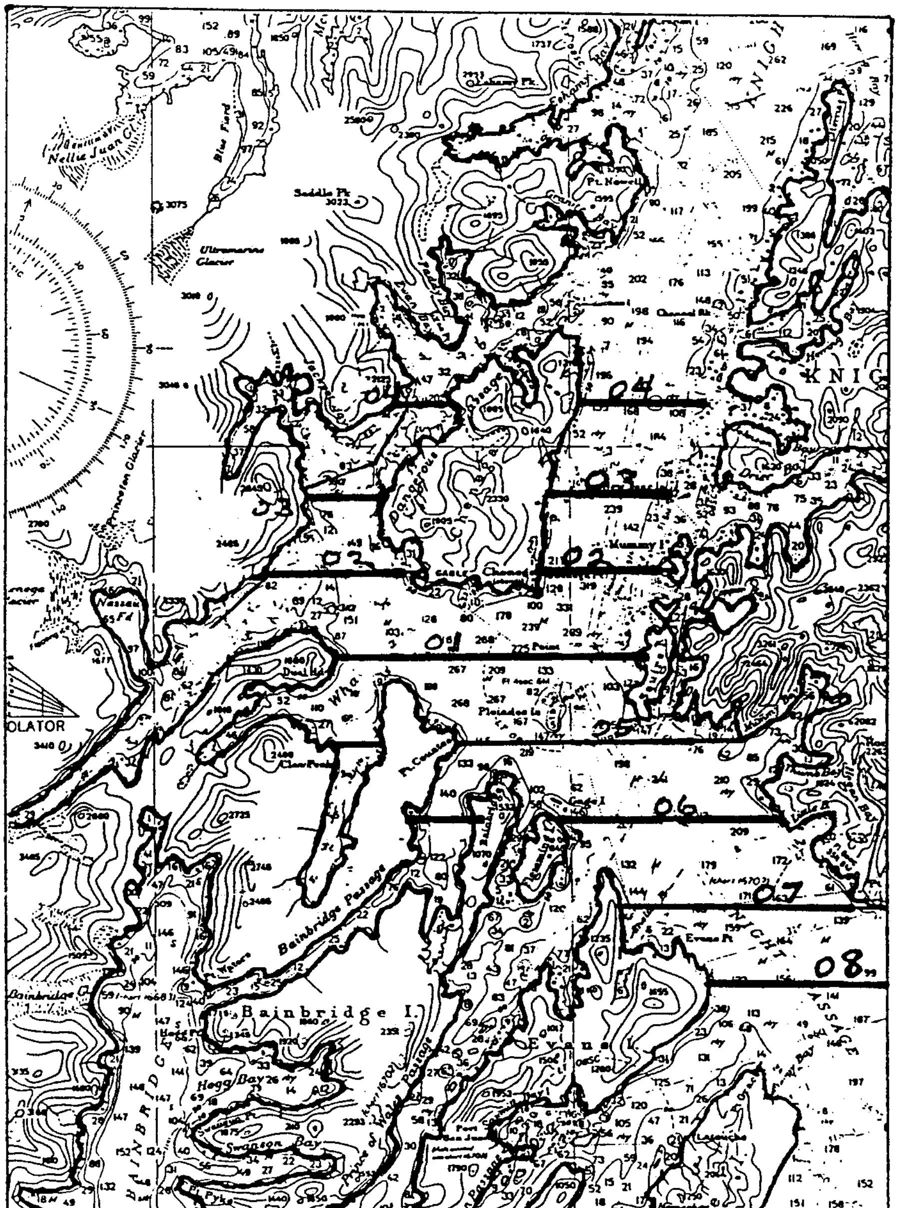


Figure 4. Offshore hydroacoustic transect locations in the South study area of Prince William Sound.

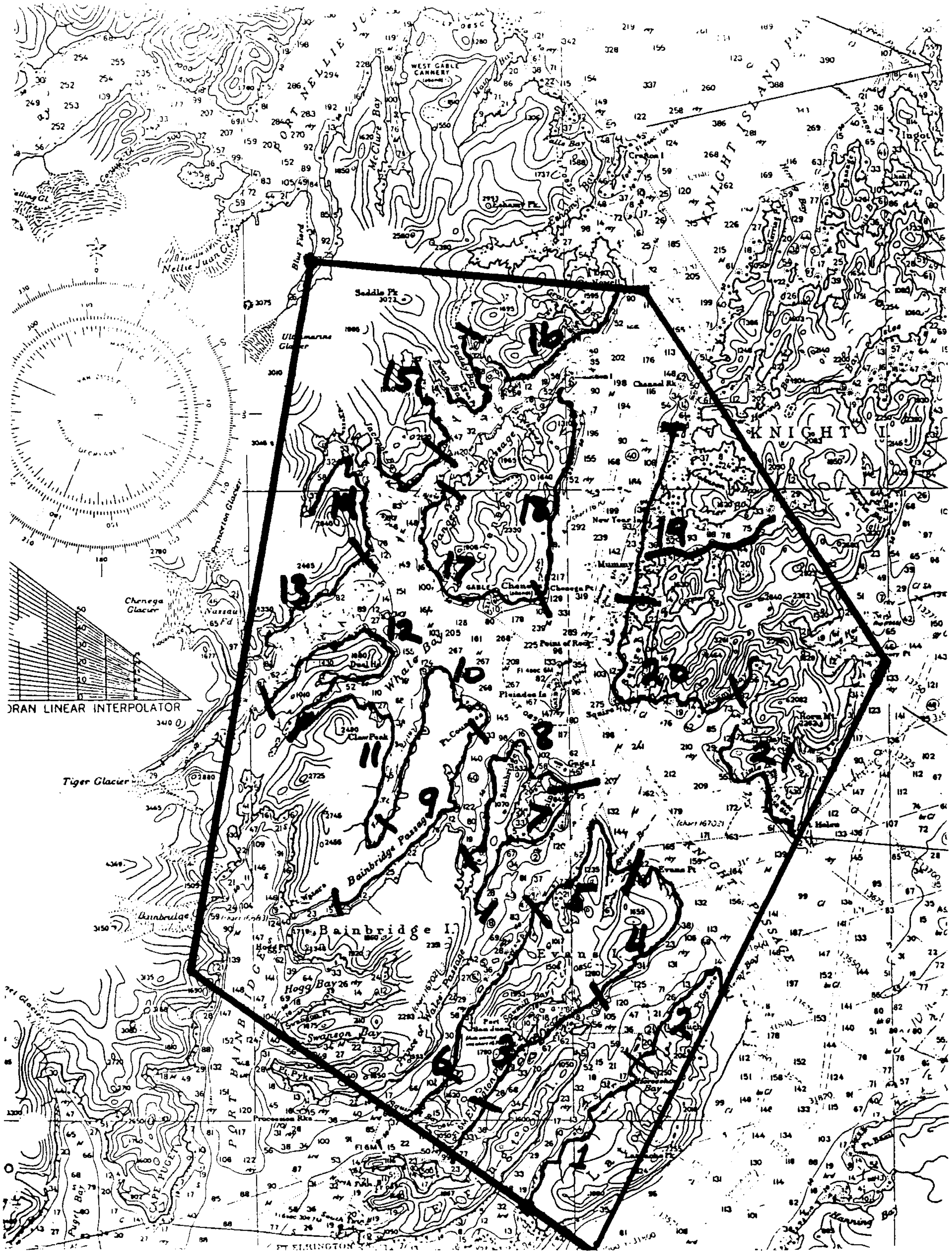


Figure 5. Layout of shoreline segments 12 km in length in the South study area

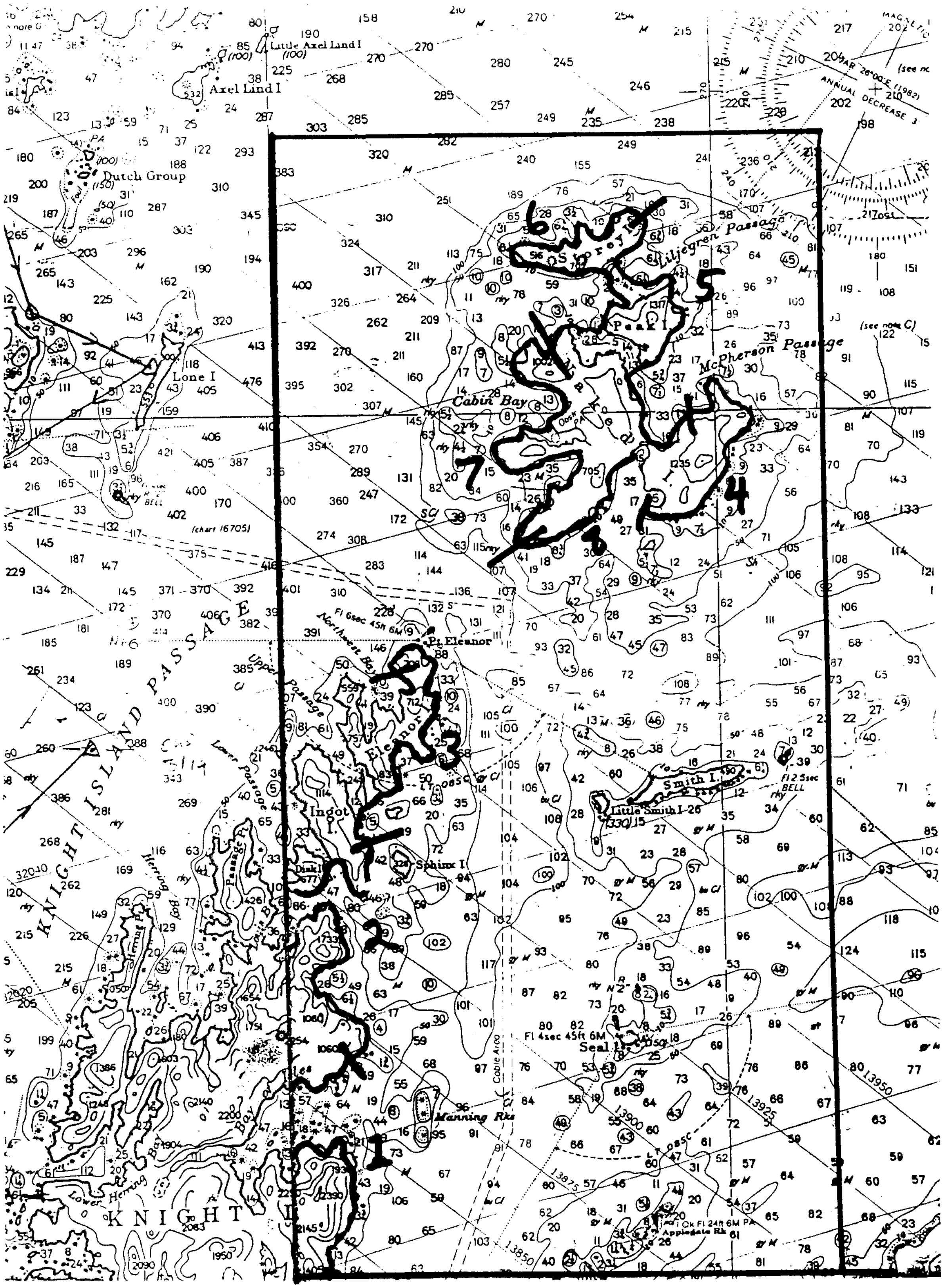


Figure 6. Layout of shoreline segments 12 km in length in the Central study

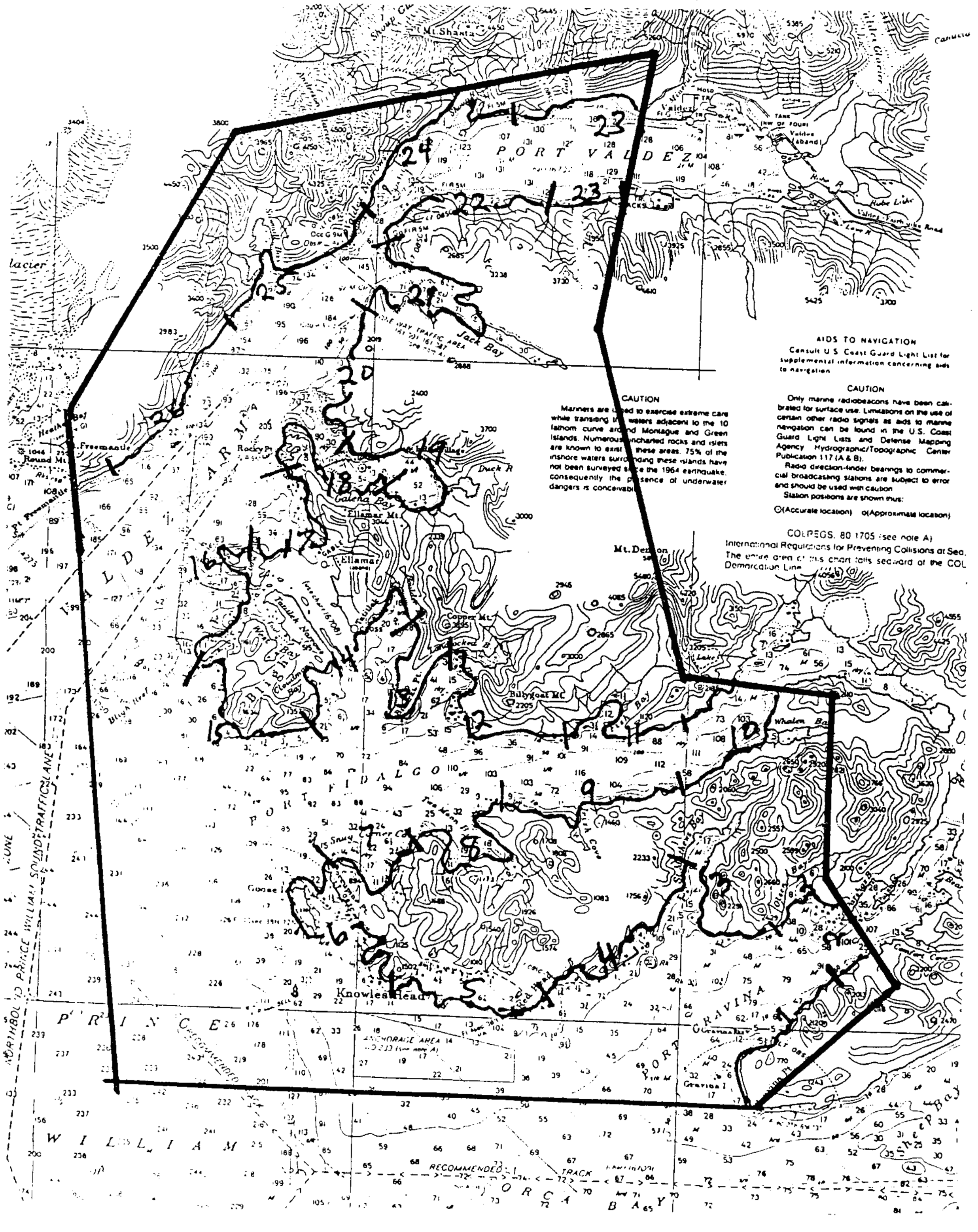


Figure 7. Layout of shoreline sements 12 km in length in the North study area

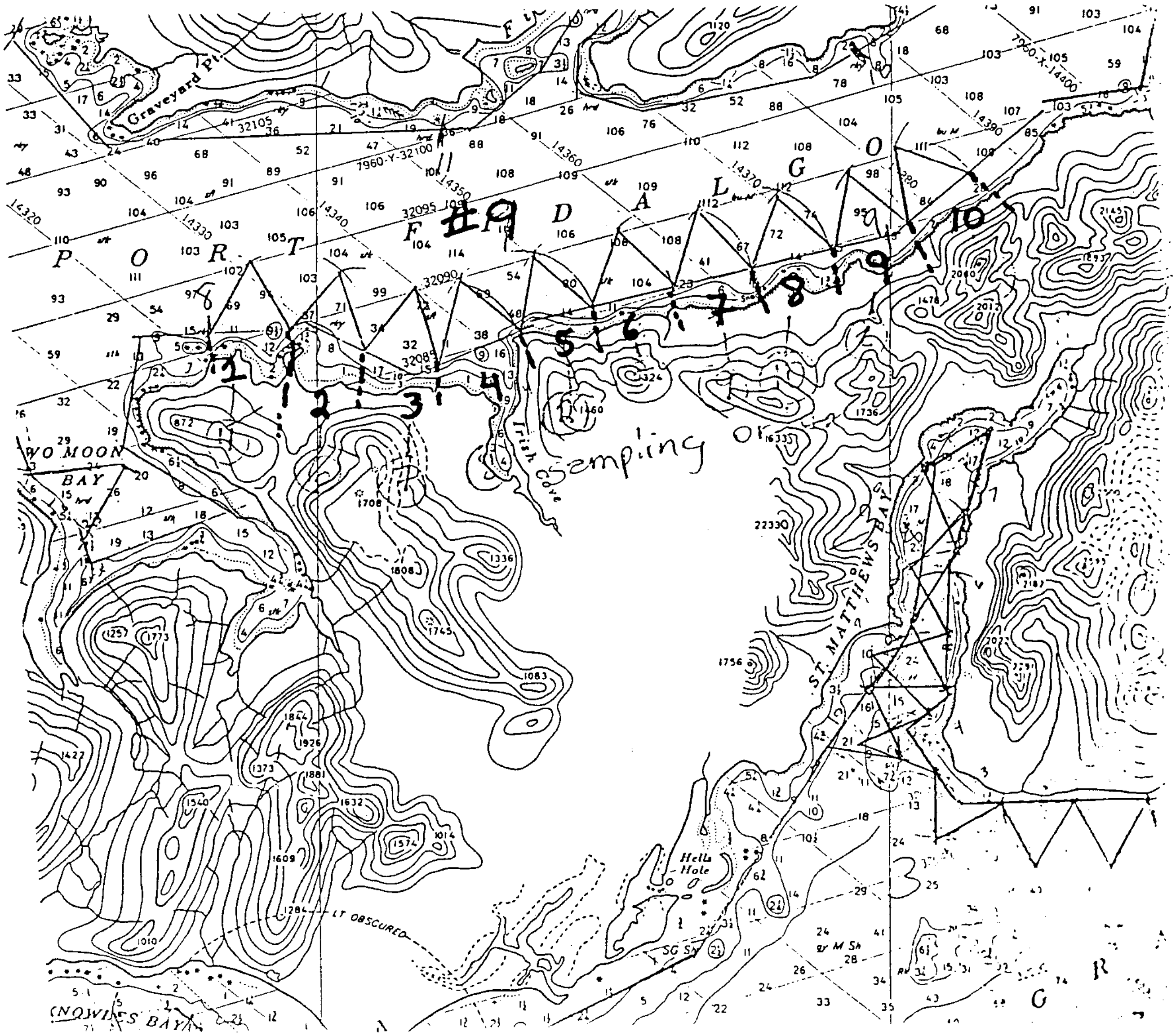


Figure 8. Typical layout of beach sections within a 12 km shoreline segment, with set of zig-zag acoustic transects. Example is segment N09, located on the south side of Port Fidalgo

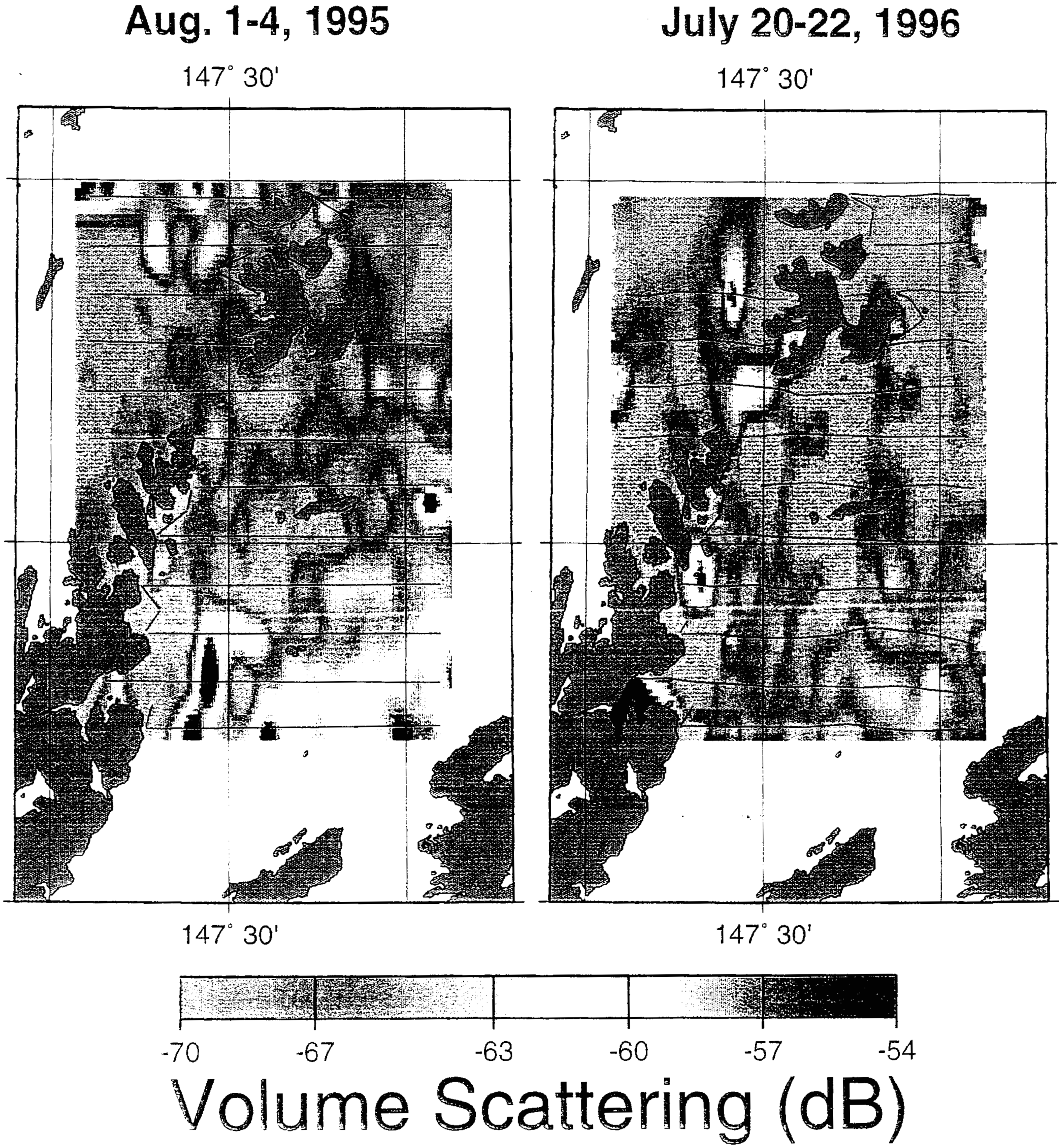


Figure 9. Area plot of acoustic backscatter in offshore surveys of the Central study area in 1995 and 1996.

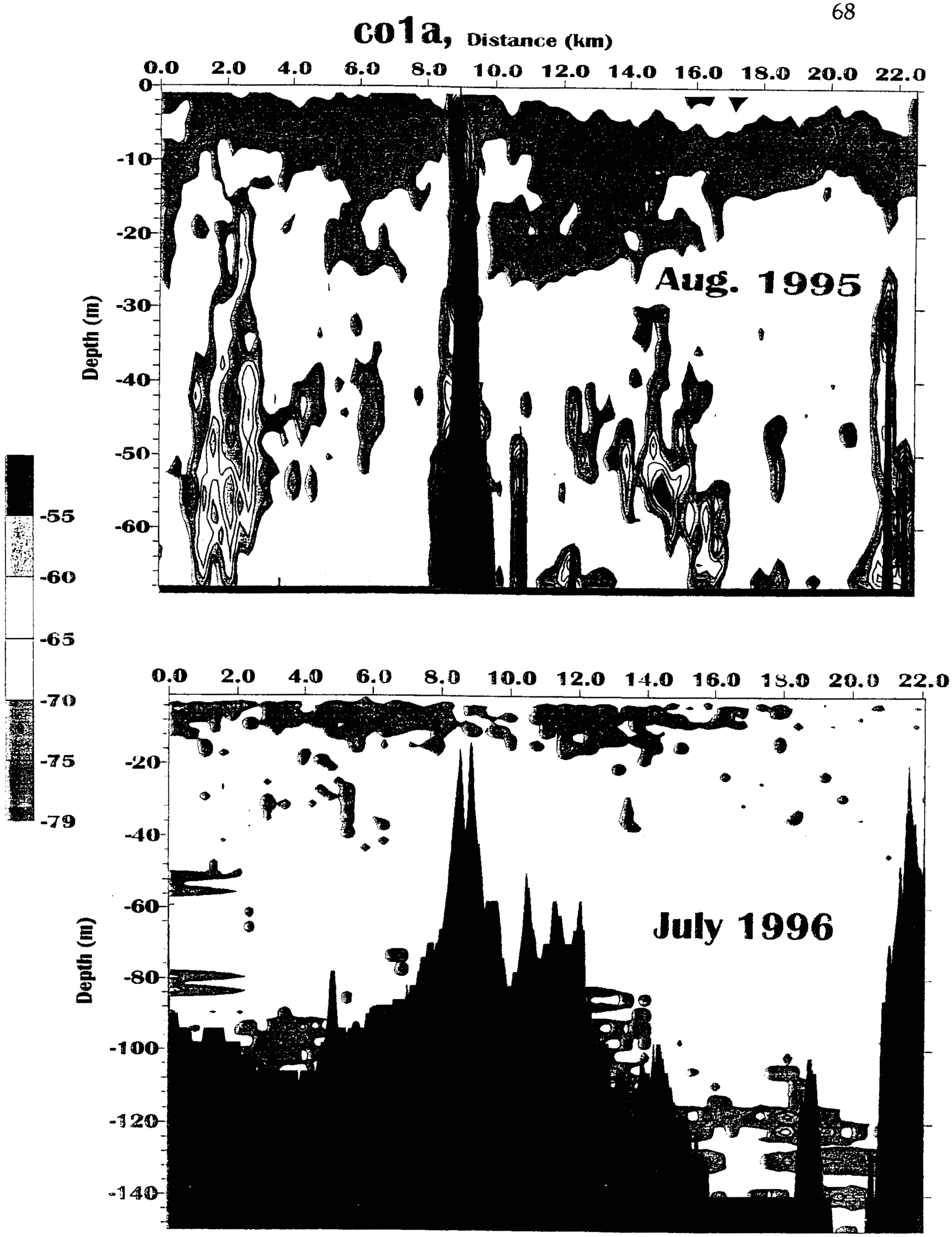


Figure 10. Vertical distribution of acoustic backscatter on transect C01A in the Central study area in 1995 and 1996

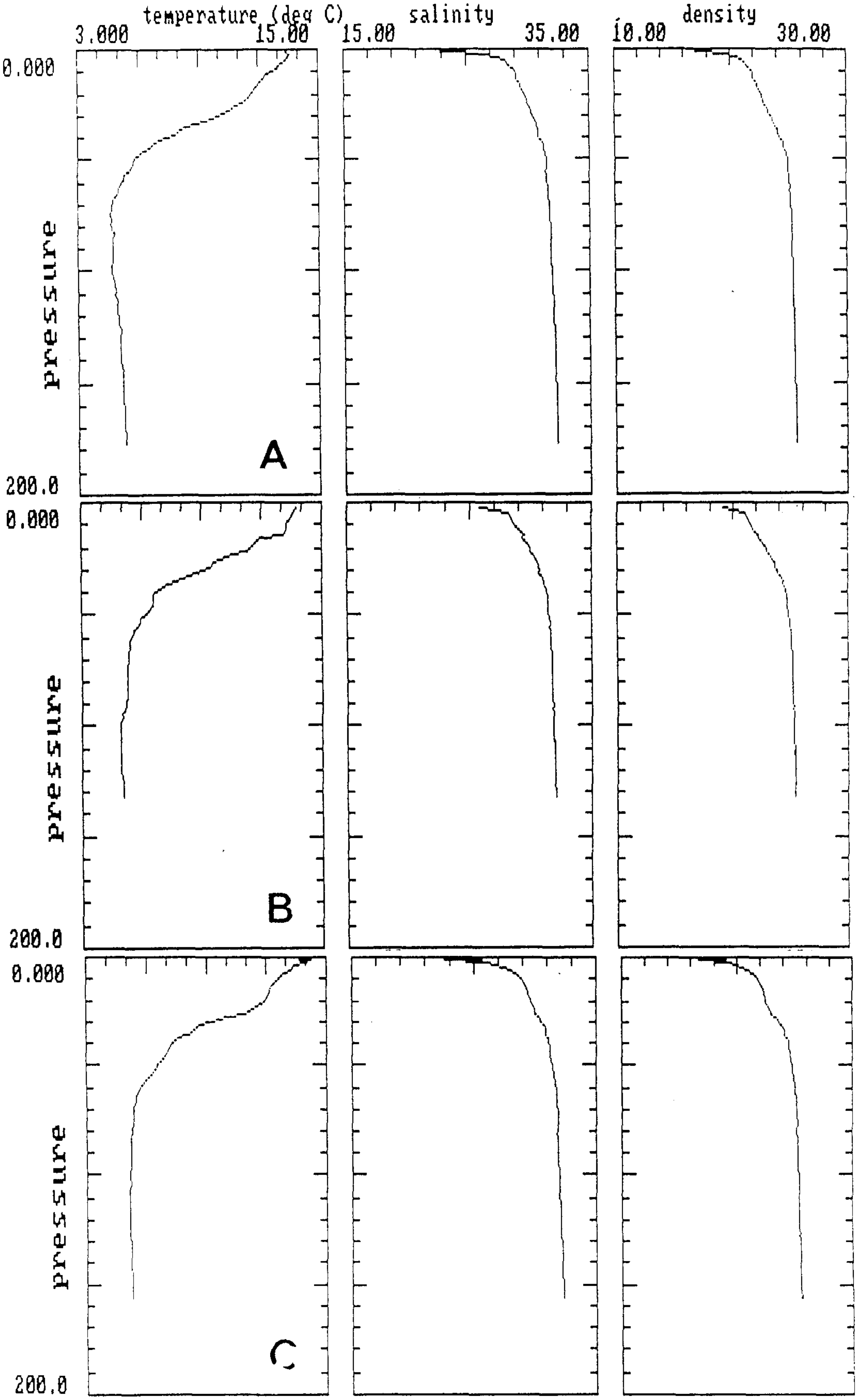


Figure 11. Vertical profiles of temperature, salinity and density at representative stations located in the: A. North. B. Central. C. South.

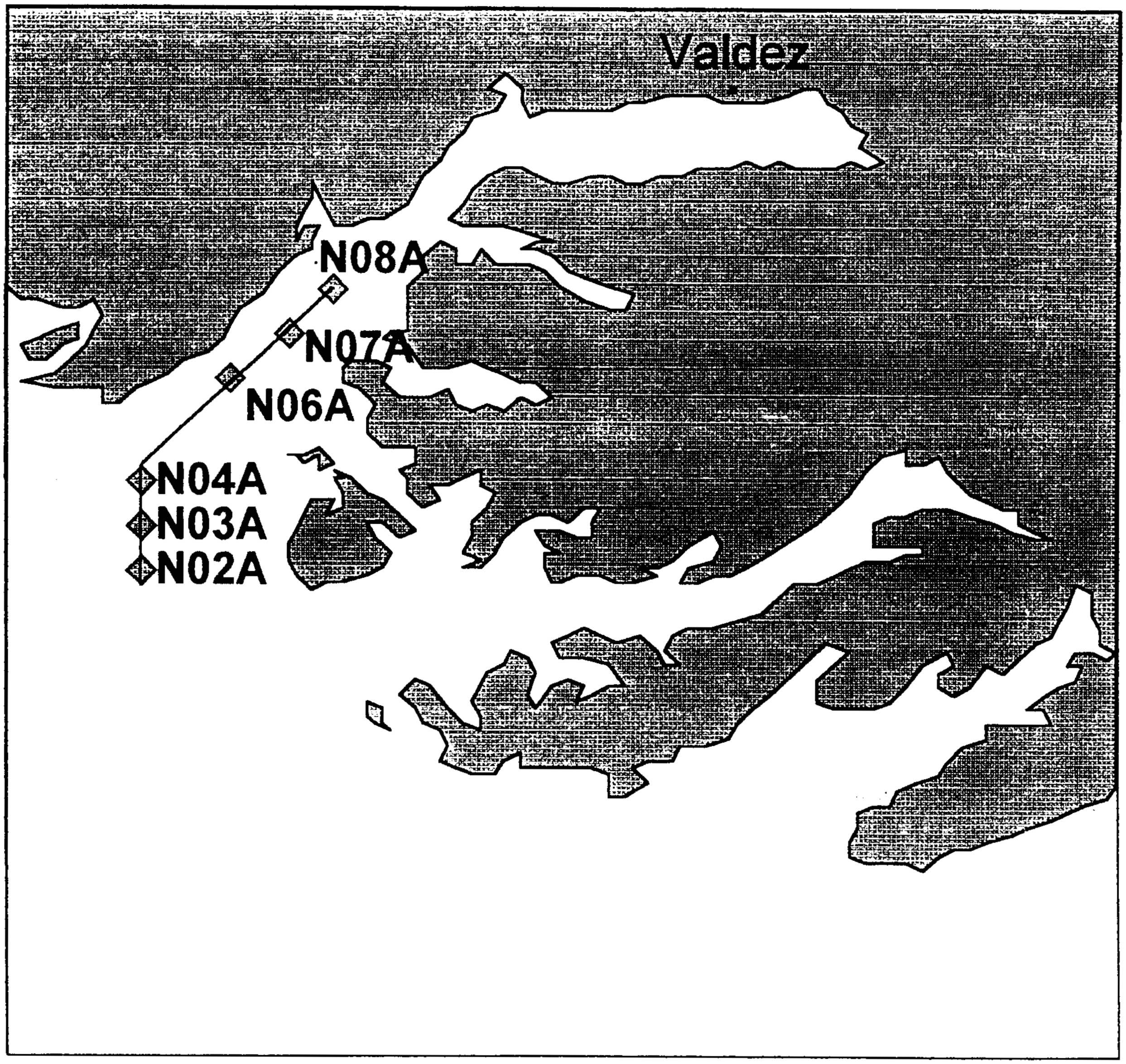


Figure 12. Locations of CTD stations used to examine horizontal variation in the water column in the North study area.

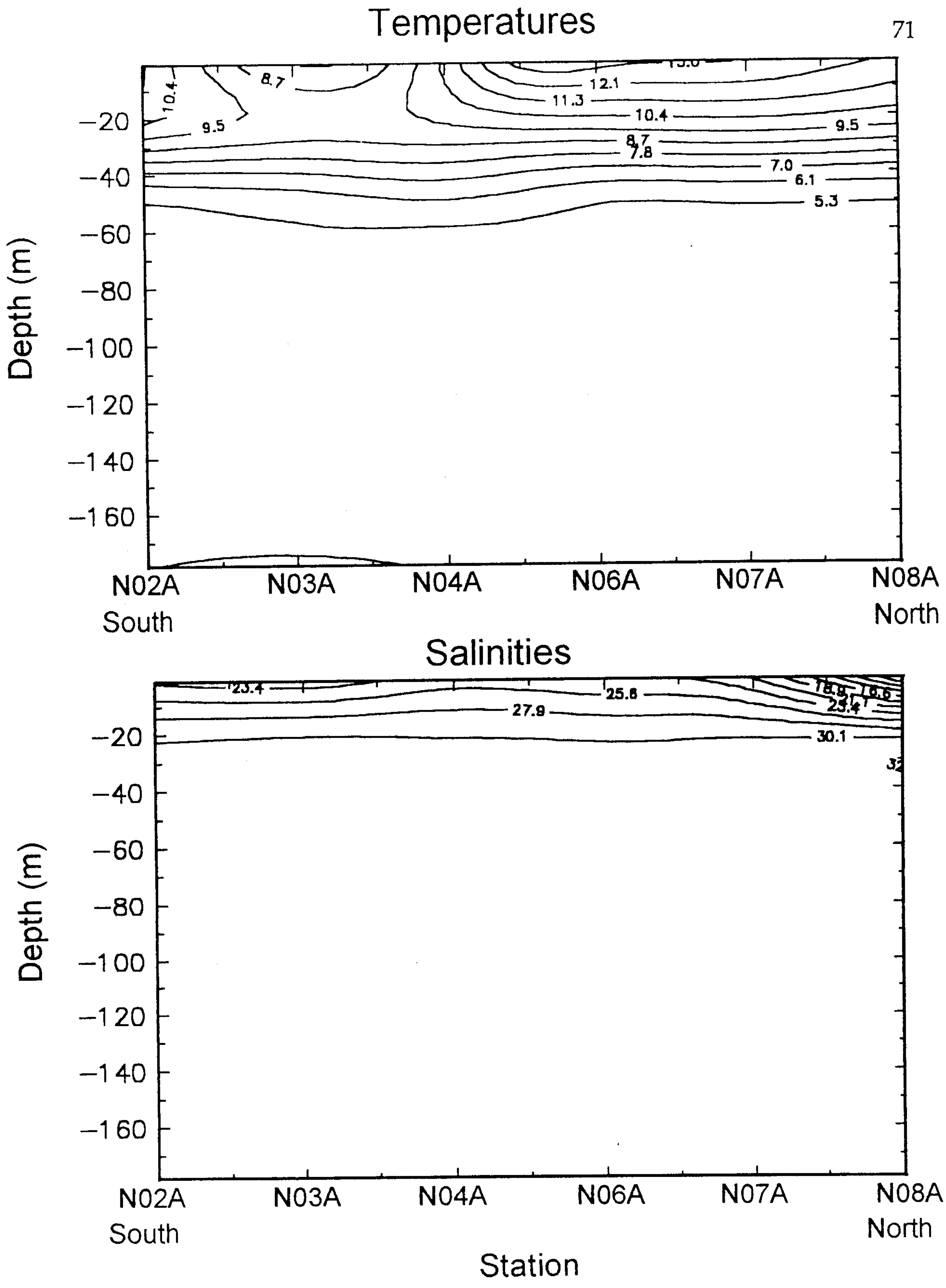


Figure 13. Isothermal and isohaline profiles at CTD stations in the North study area.

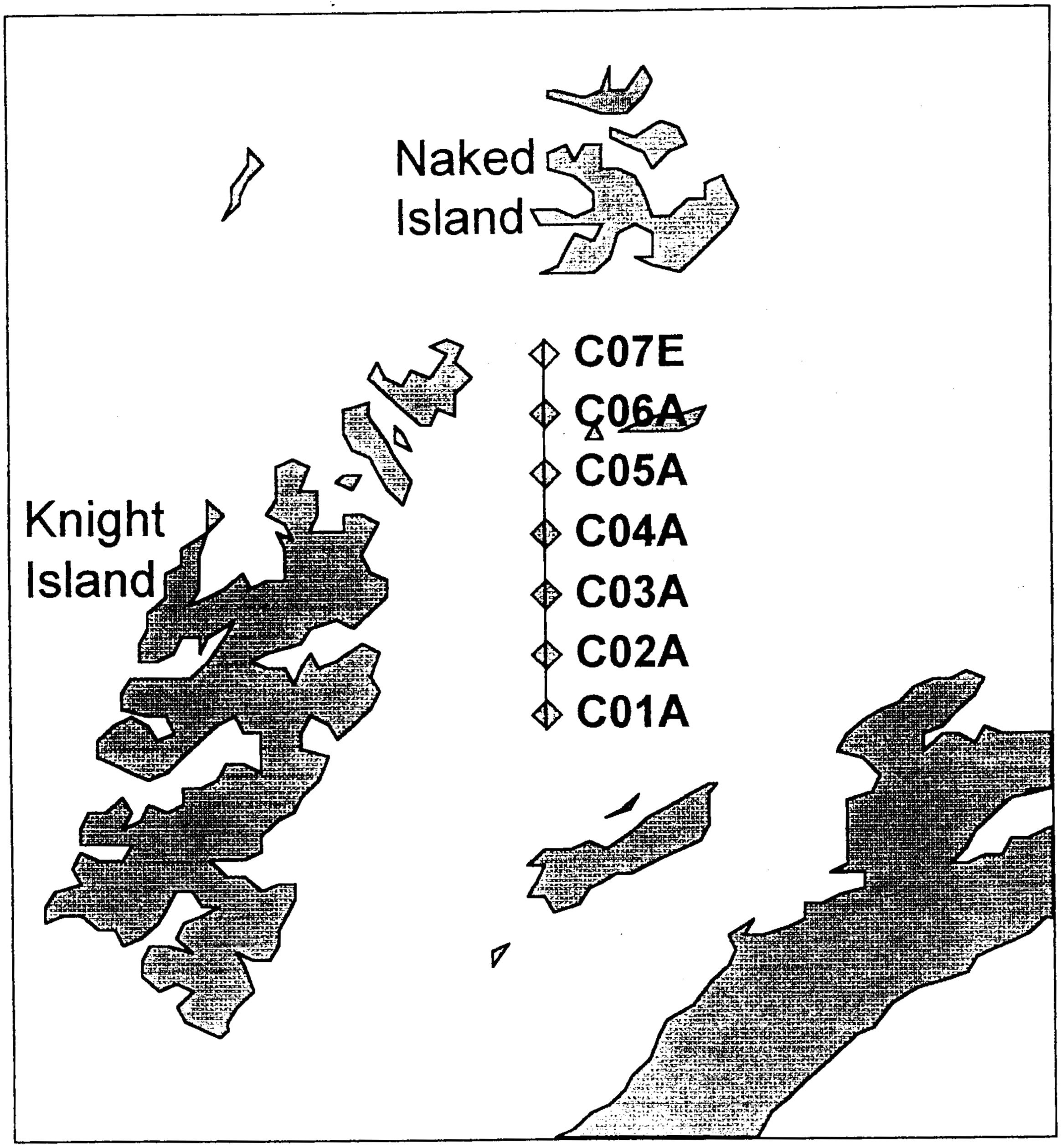


Figure 14. Locations of CTD stations used to examine horizontal variation in the water column in the Central study area.

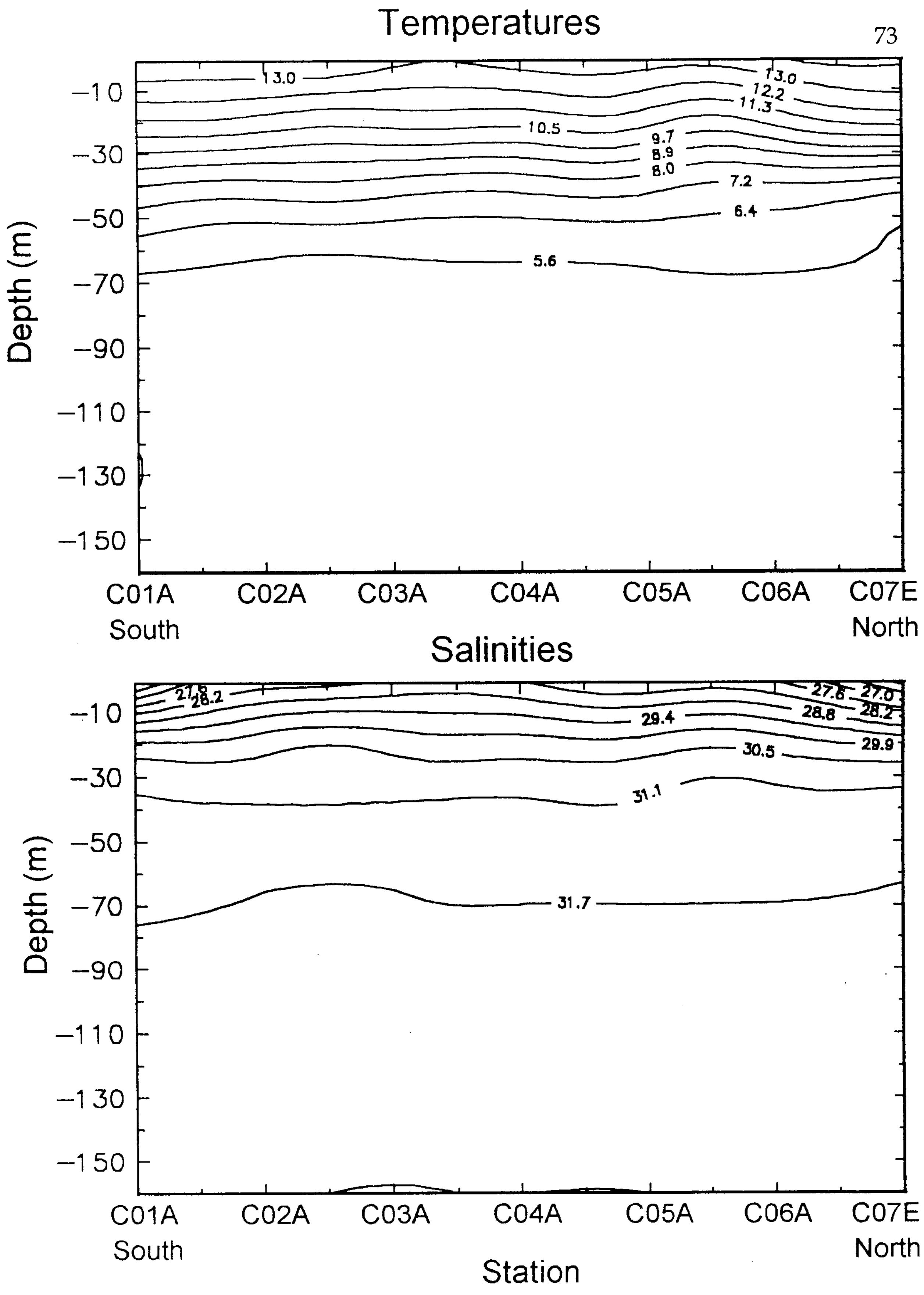


Figure 15. Isothermal and isohaline profiles at CTD stations in the Central study area.

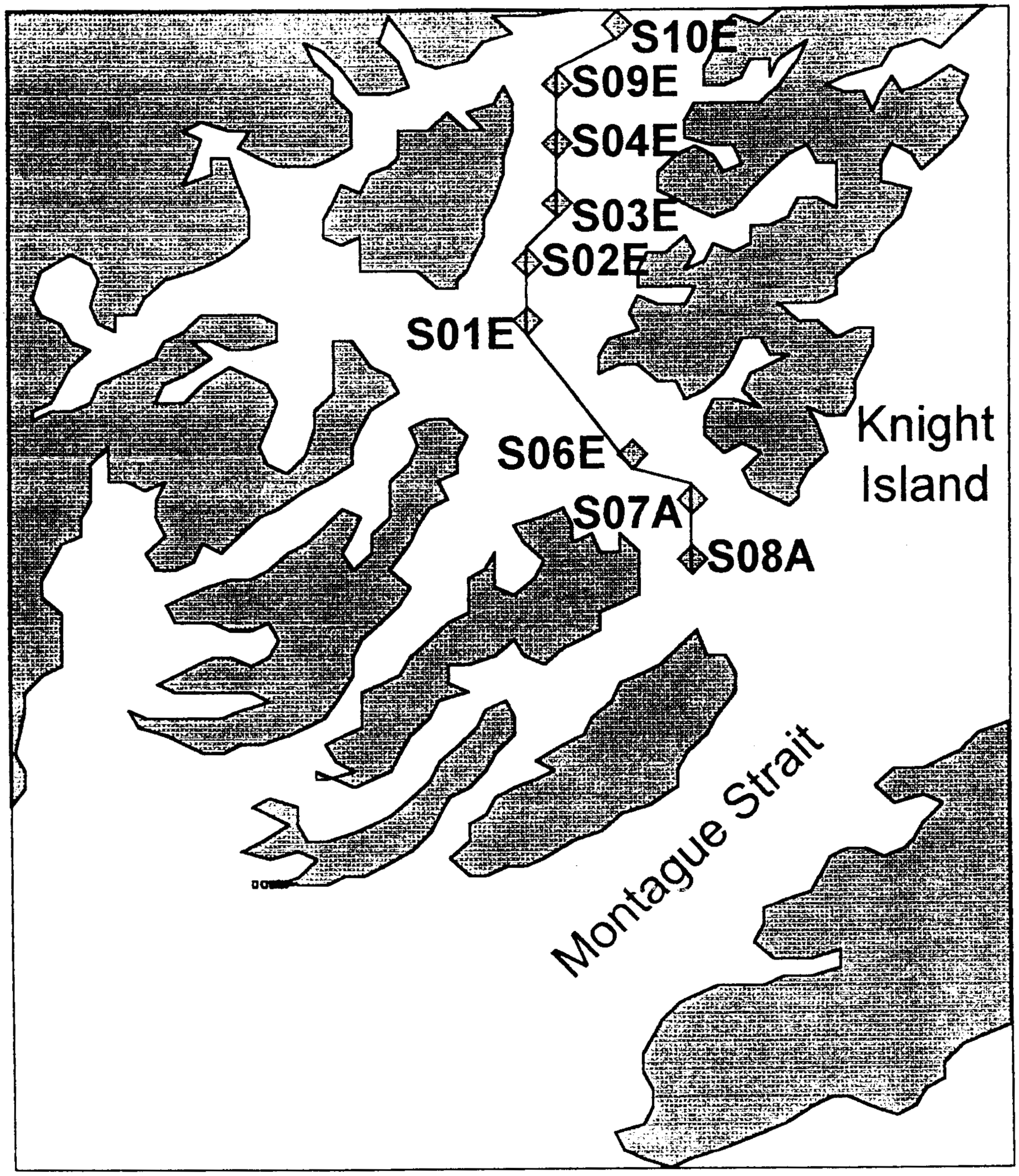


Figure 16. Locations of CTD stations used to examine horizontal variation in the water column in the South study area.

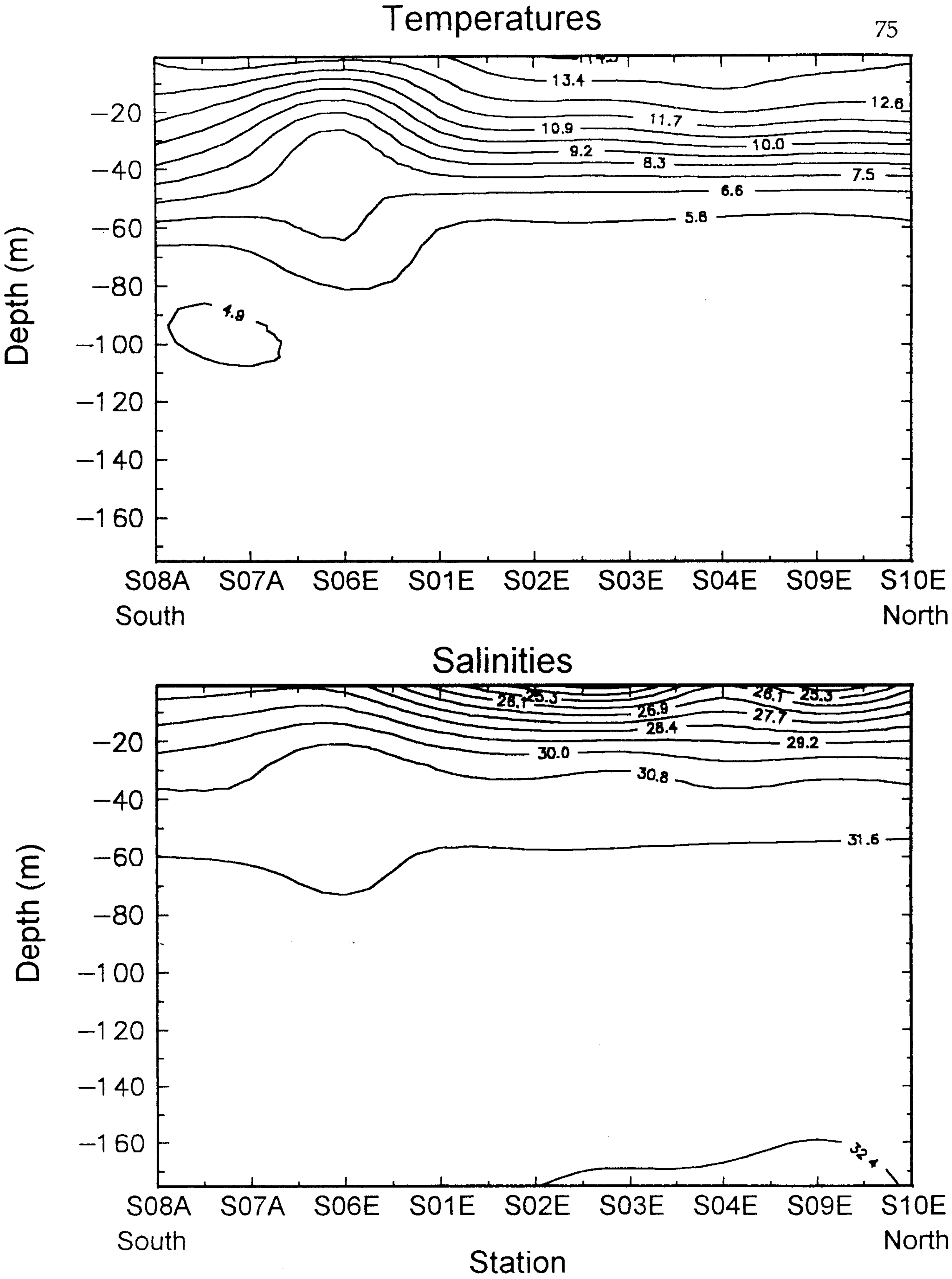


Figure 17. Isothermal and isohaline profiles at CTD stations in the South study area.

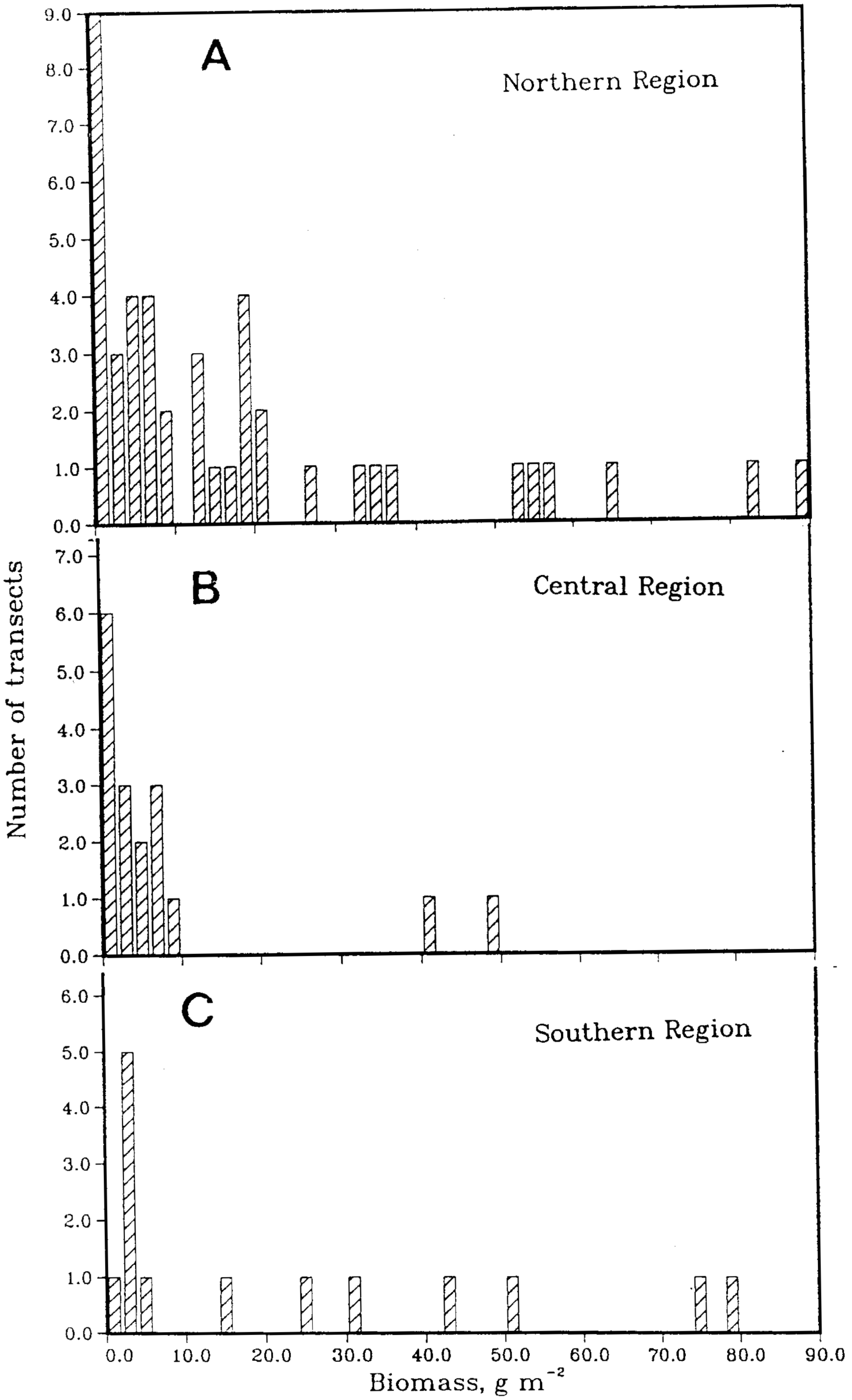


Figure 18. Distribution of biomass on individual transects in the: A. North, B. Central, and C. South study areas.

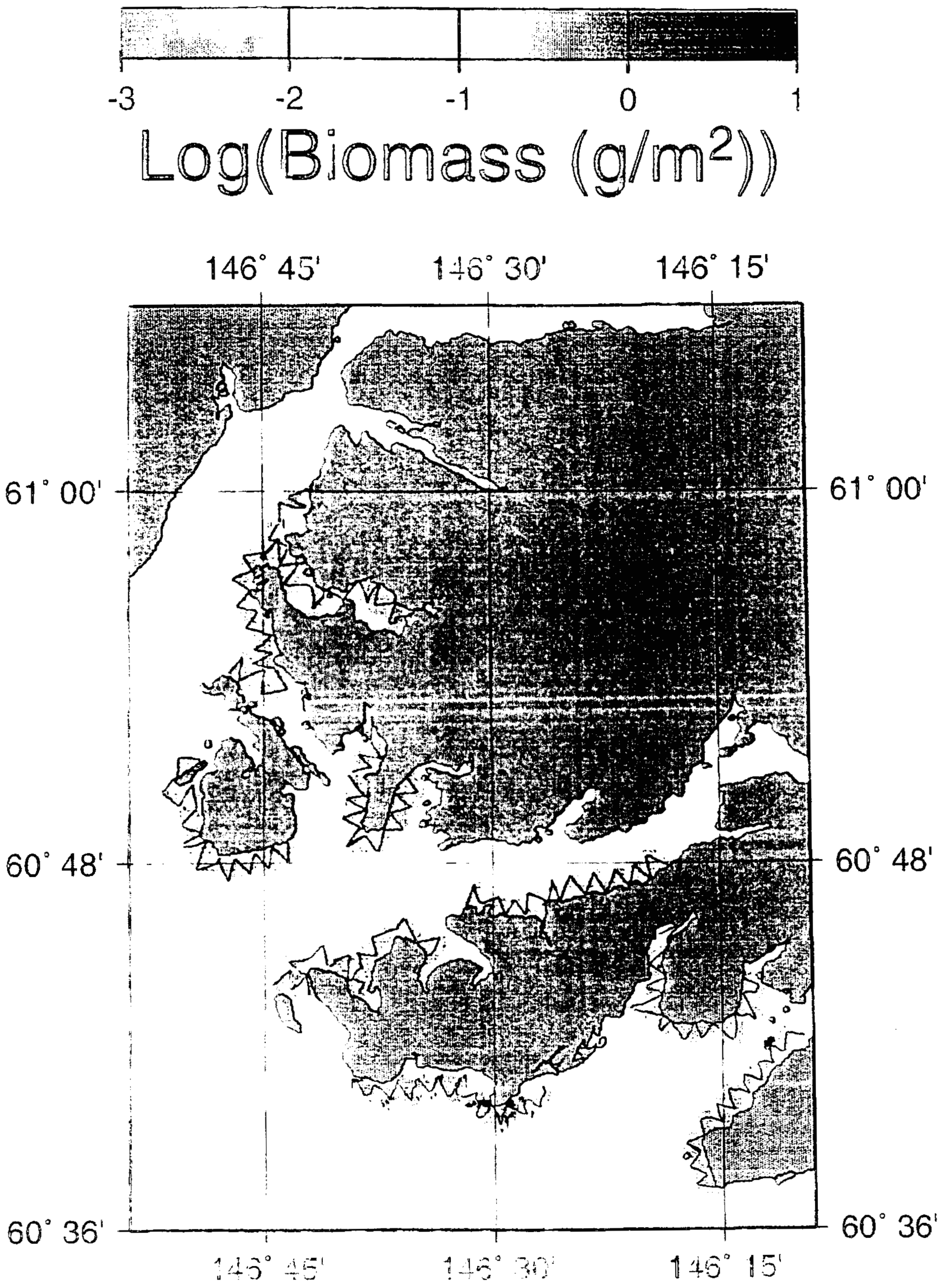


Figure 19. Geographic distribution of biomass on nearshore transects in the North study area.

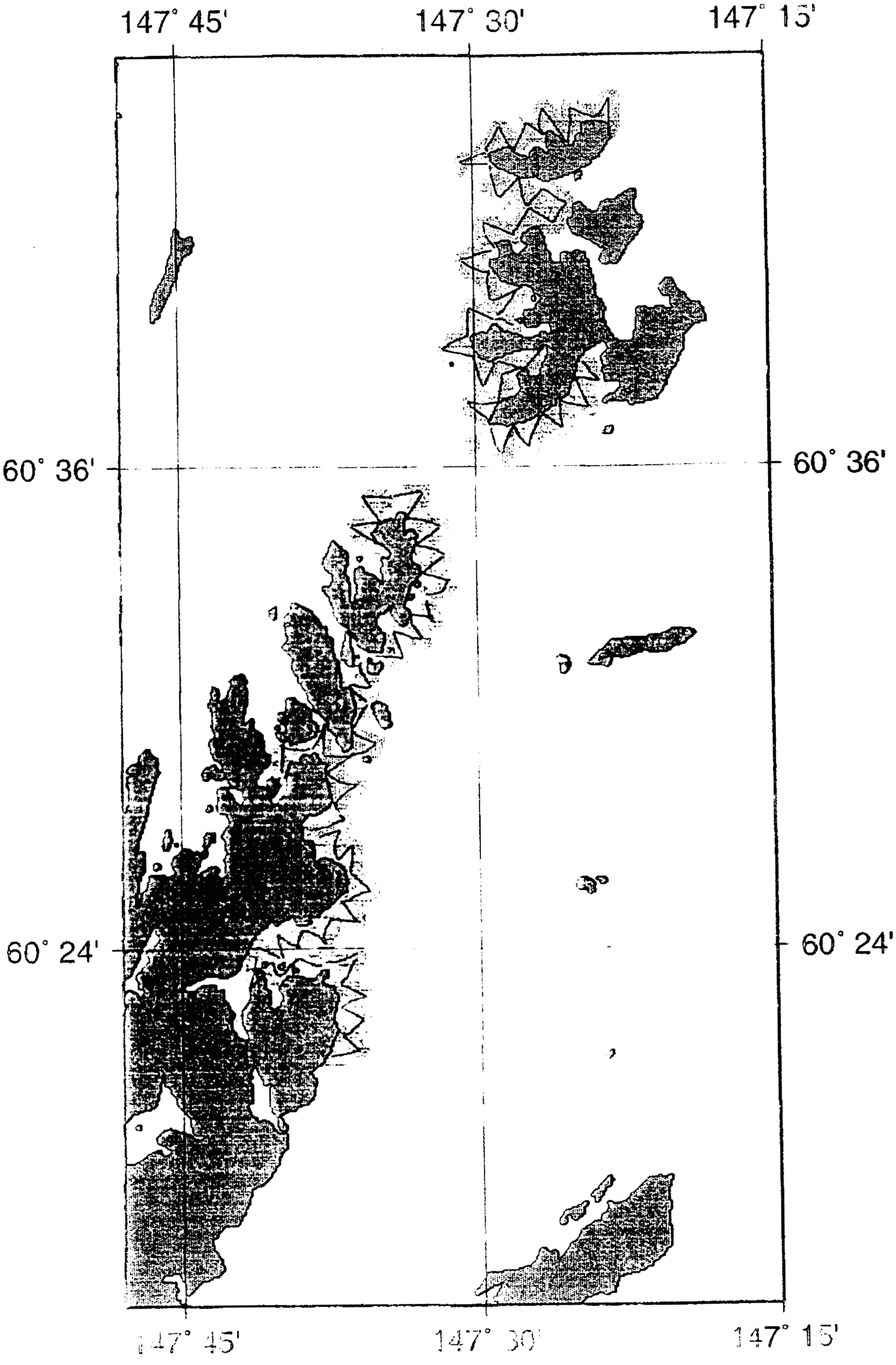


Figure 20. Geographic distribution of biomass along nearshore transects in the Central study area.

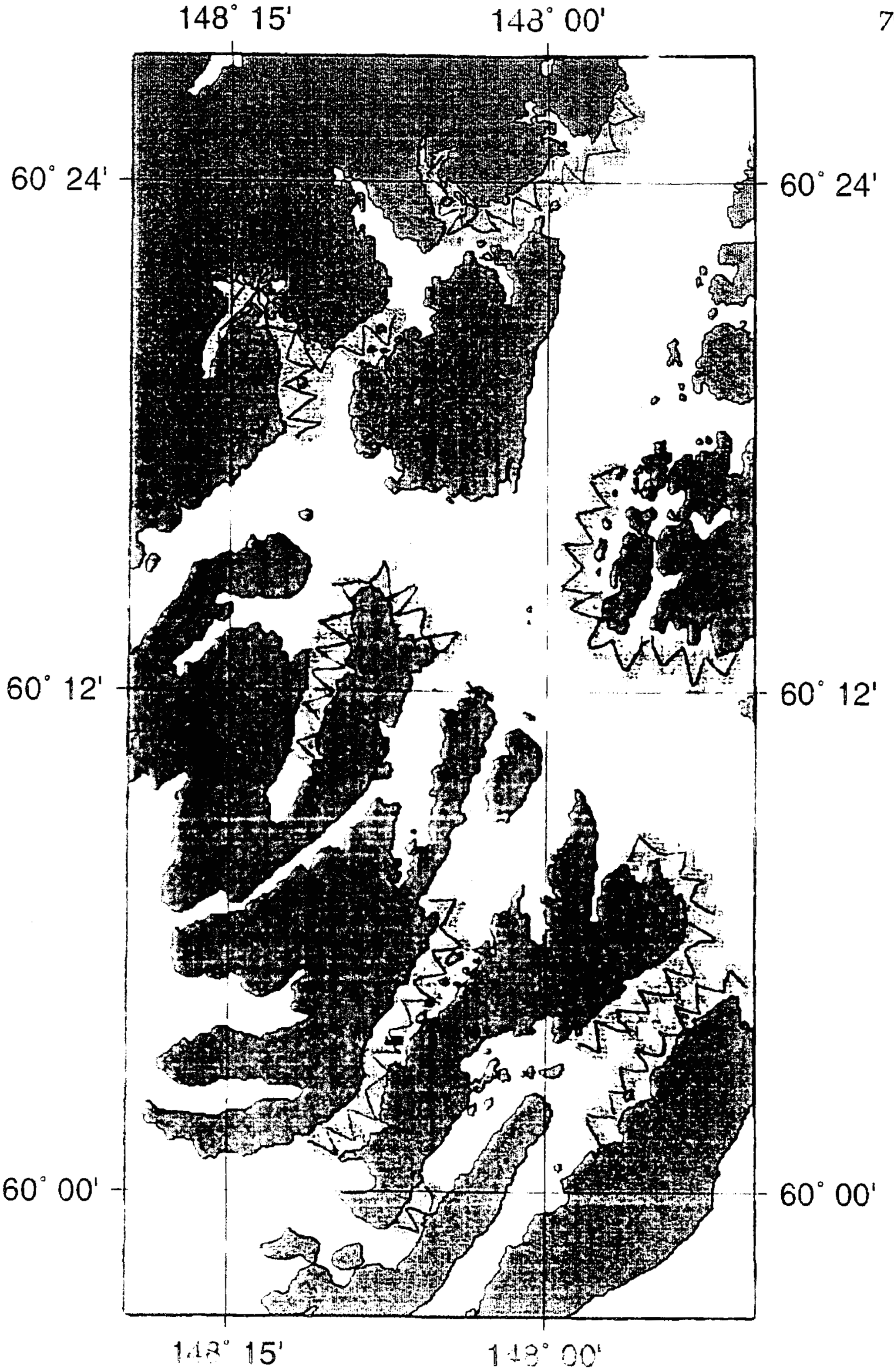


Figure 21. Geographic distribution of biomass along nearshore transects in the South study area.

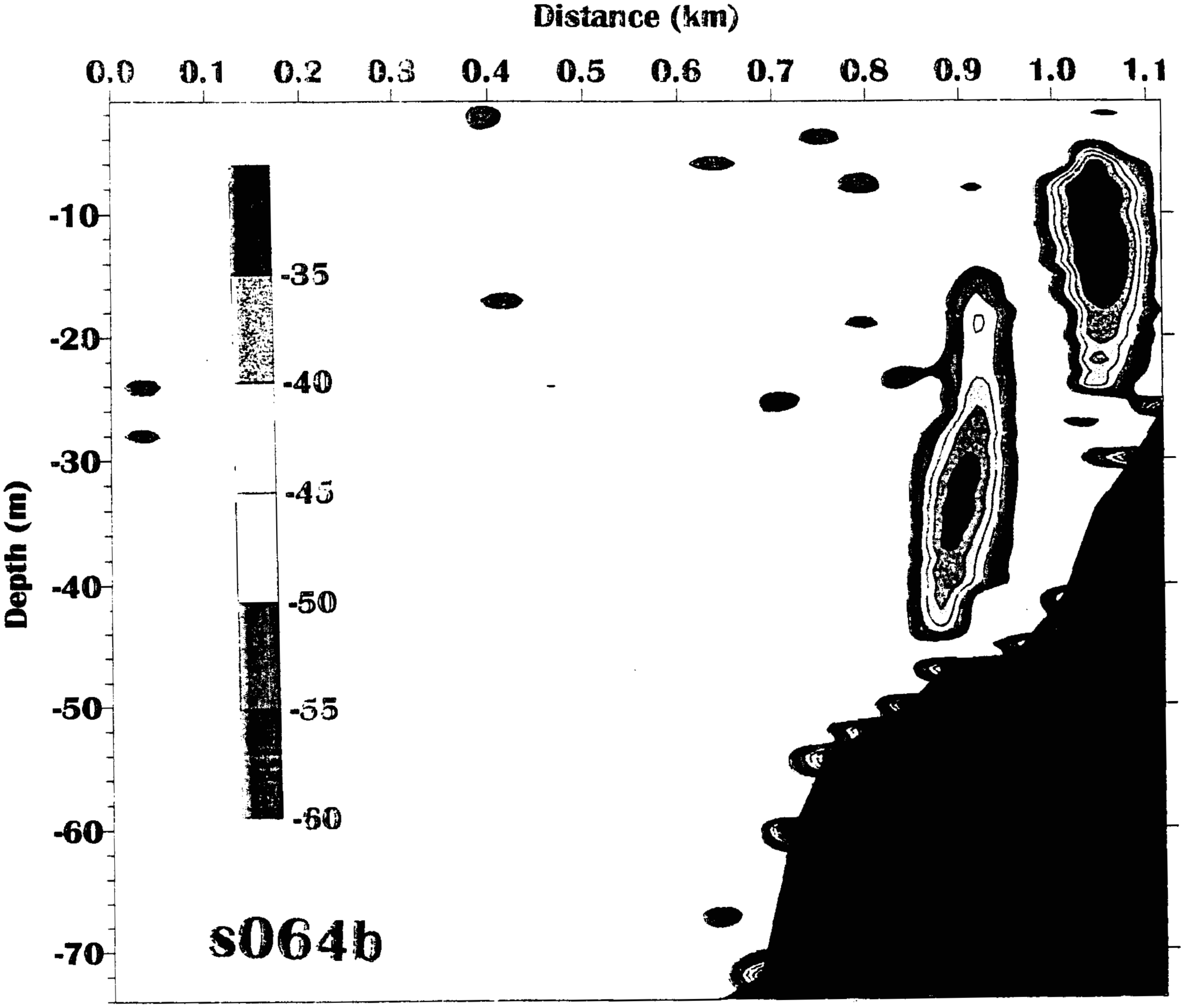


Figure 22. Example of a herring school on an individual nearshore transect (S06-04B) in the South study area.

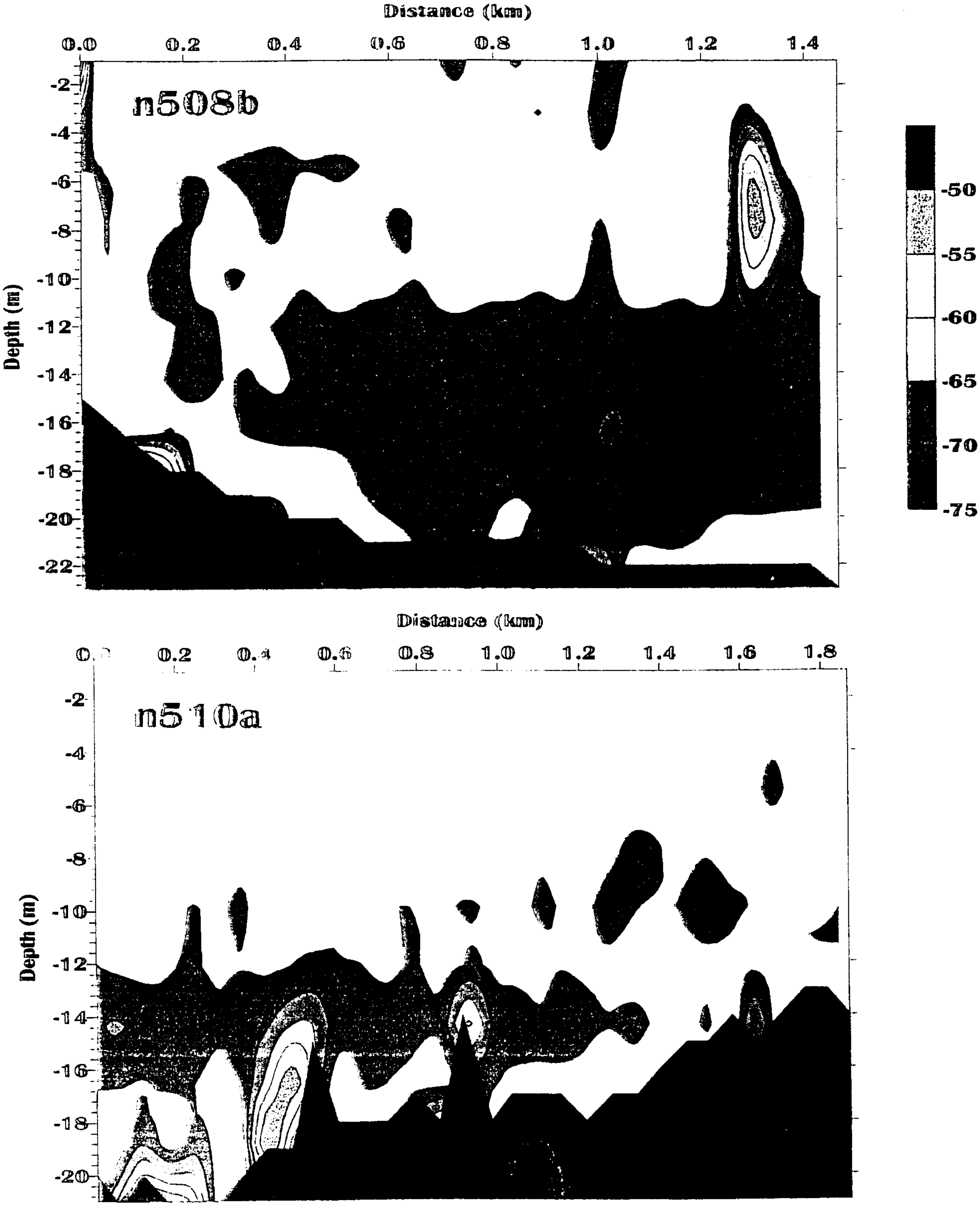
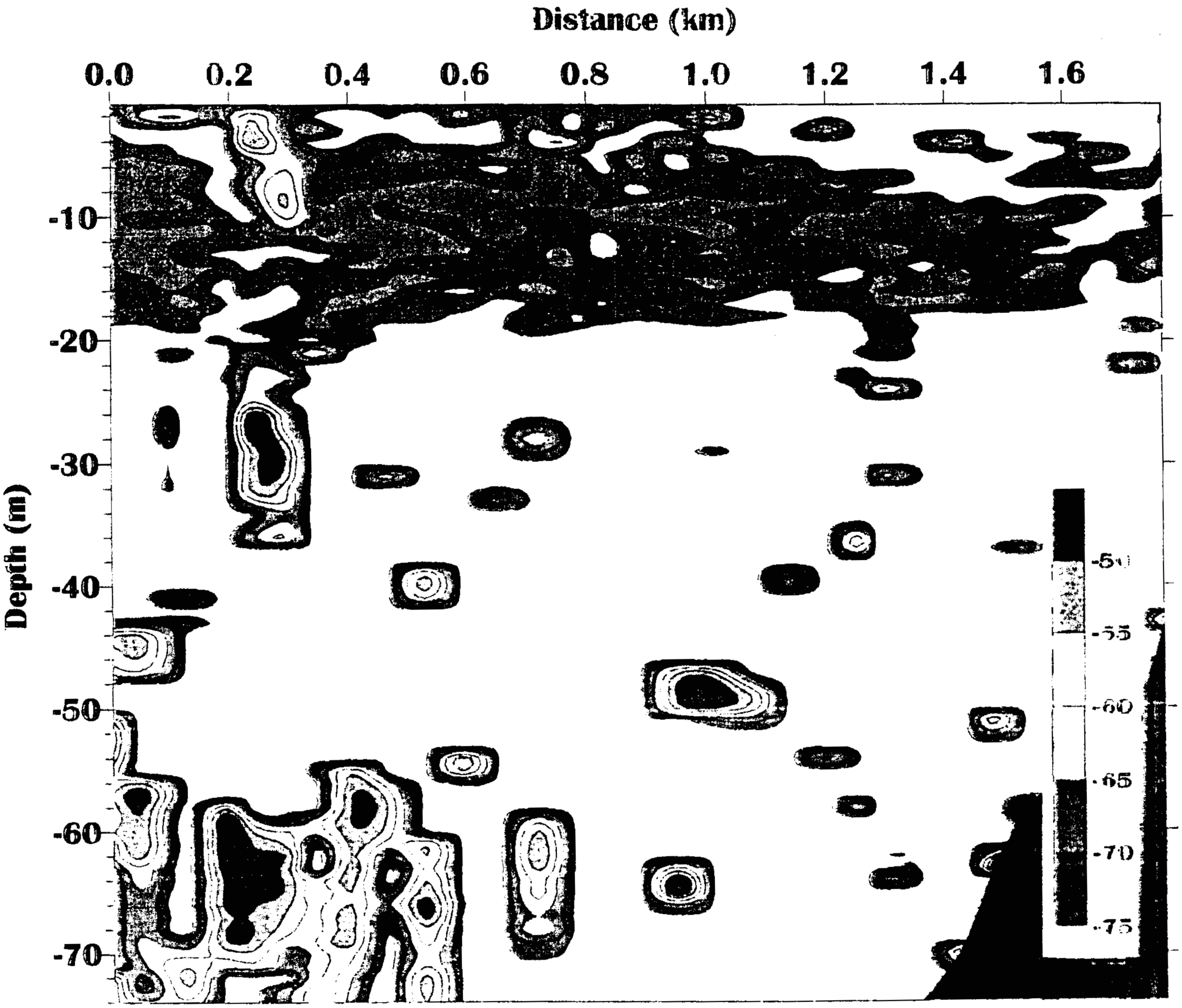


Figure 23. Example of sand lance schools on two nearshore transects (N05-08B, N05-10A) in the North study area.



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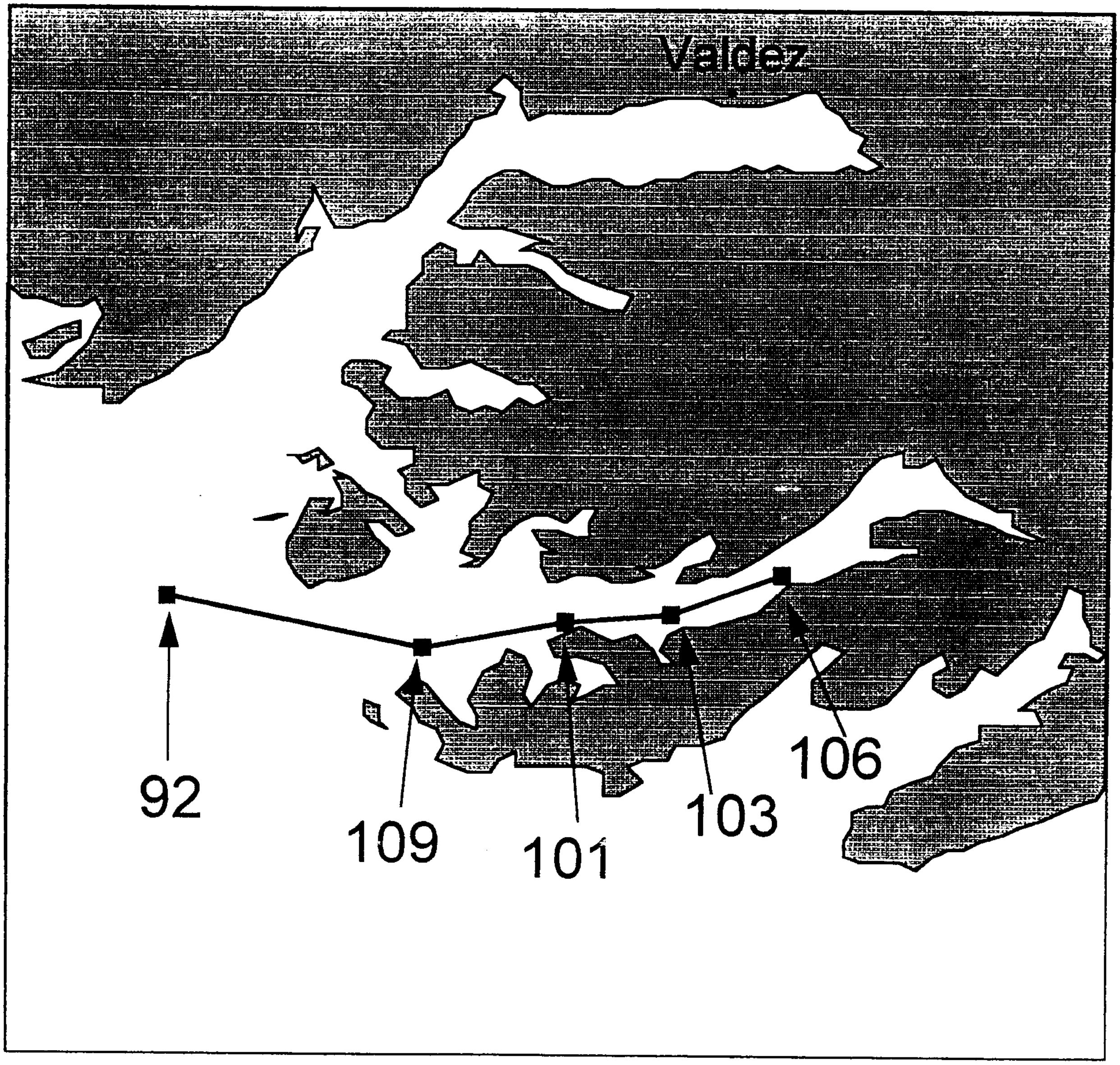

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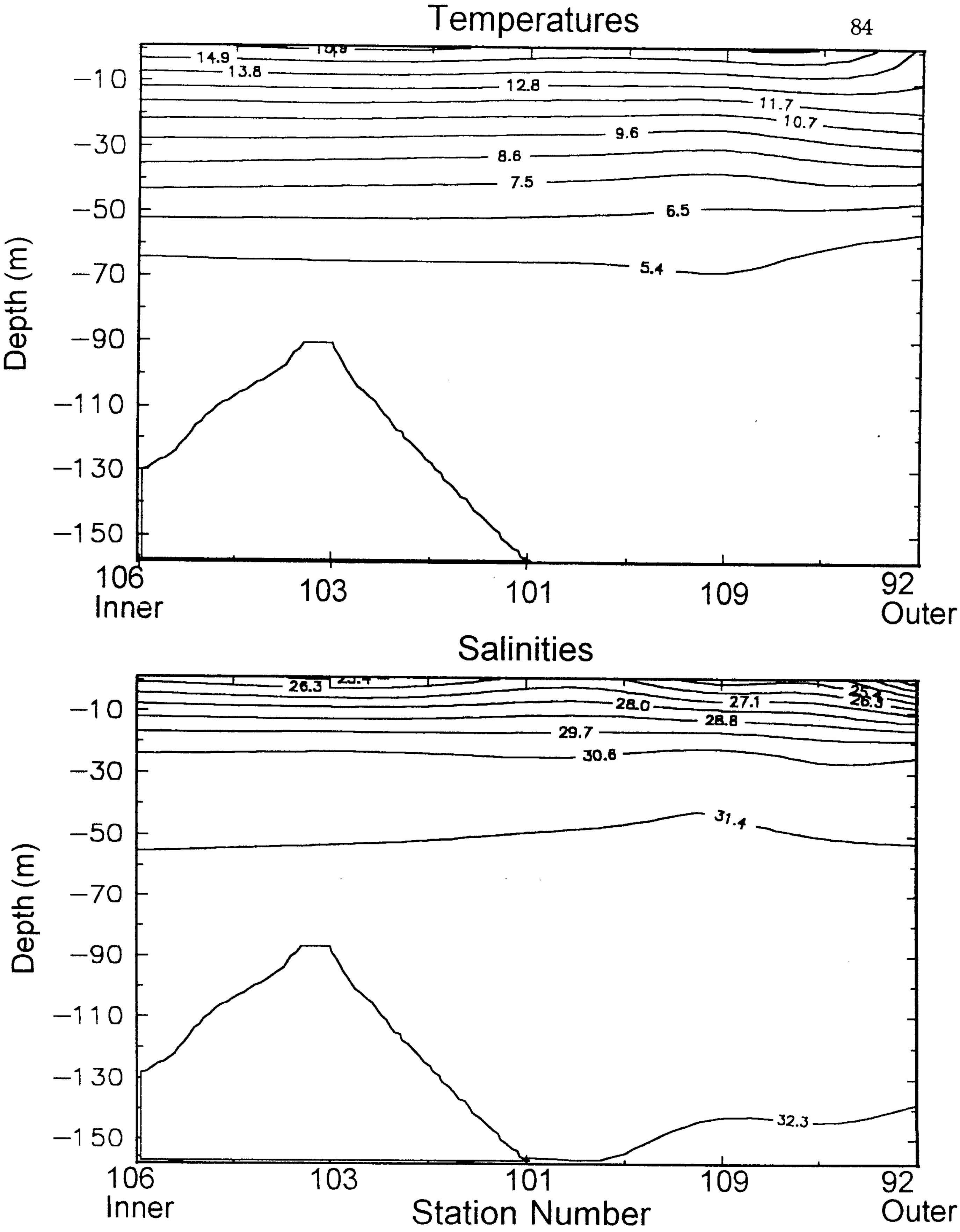

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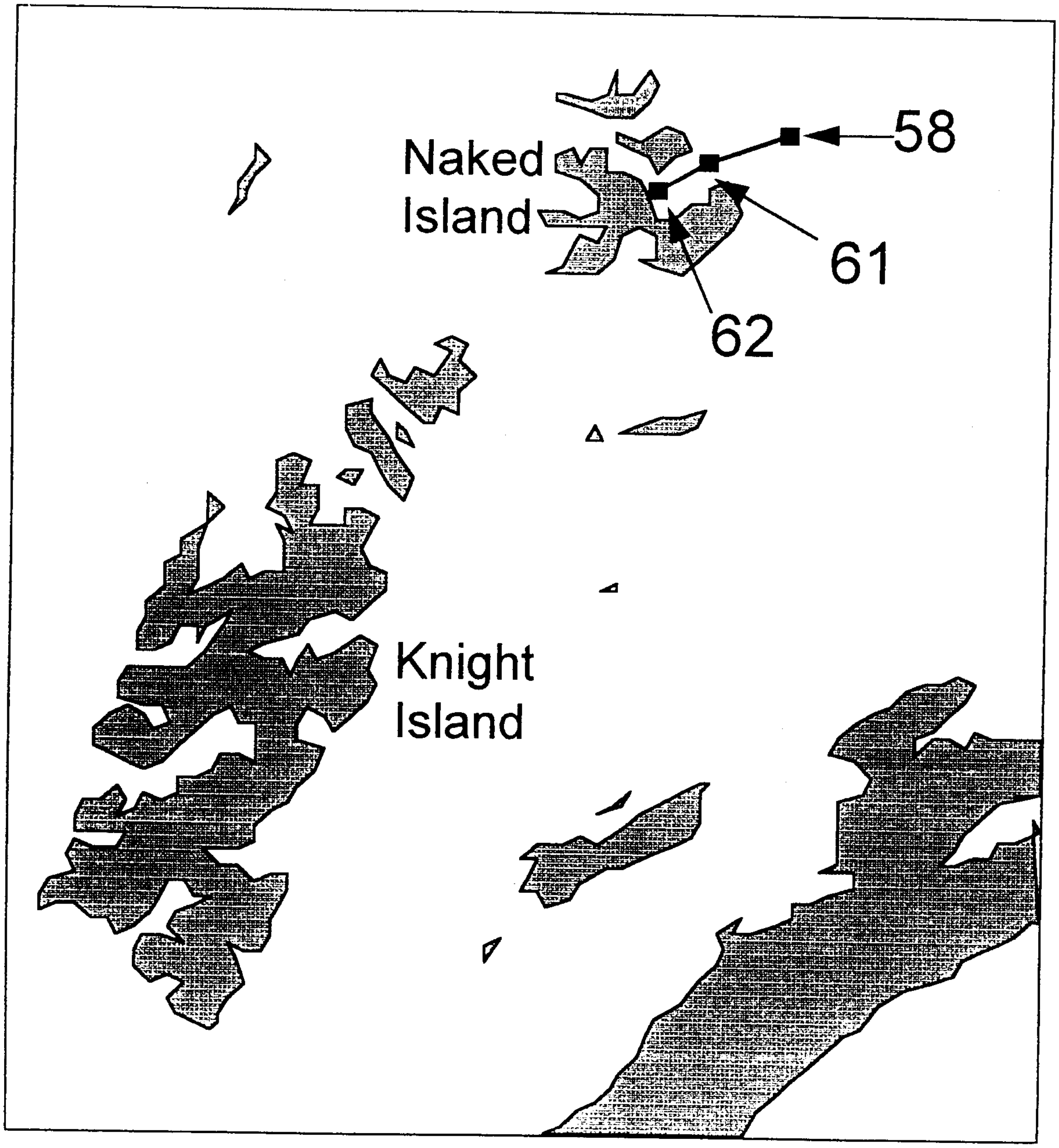

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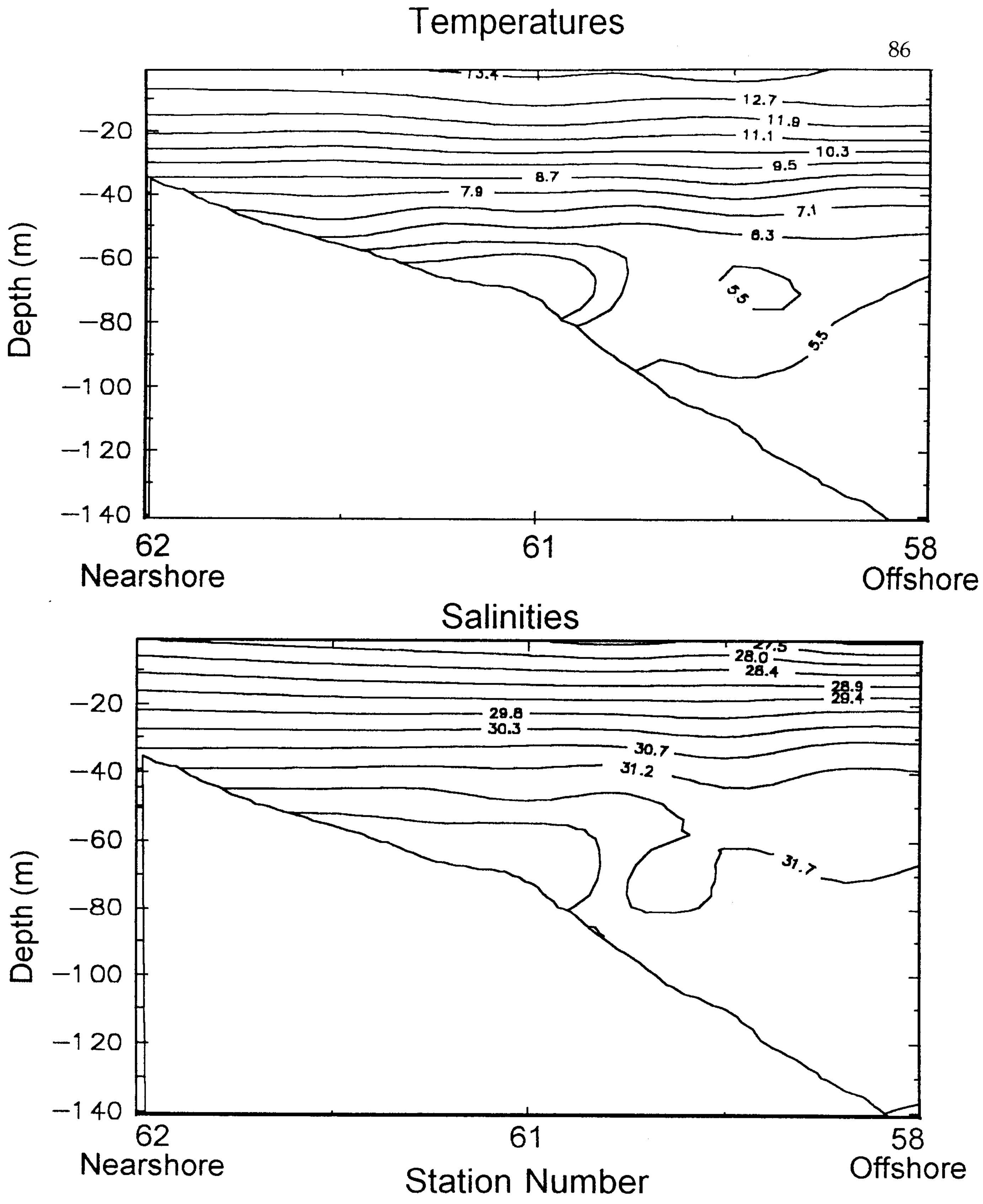
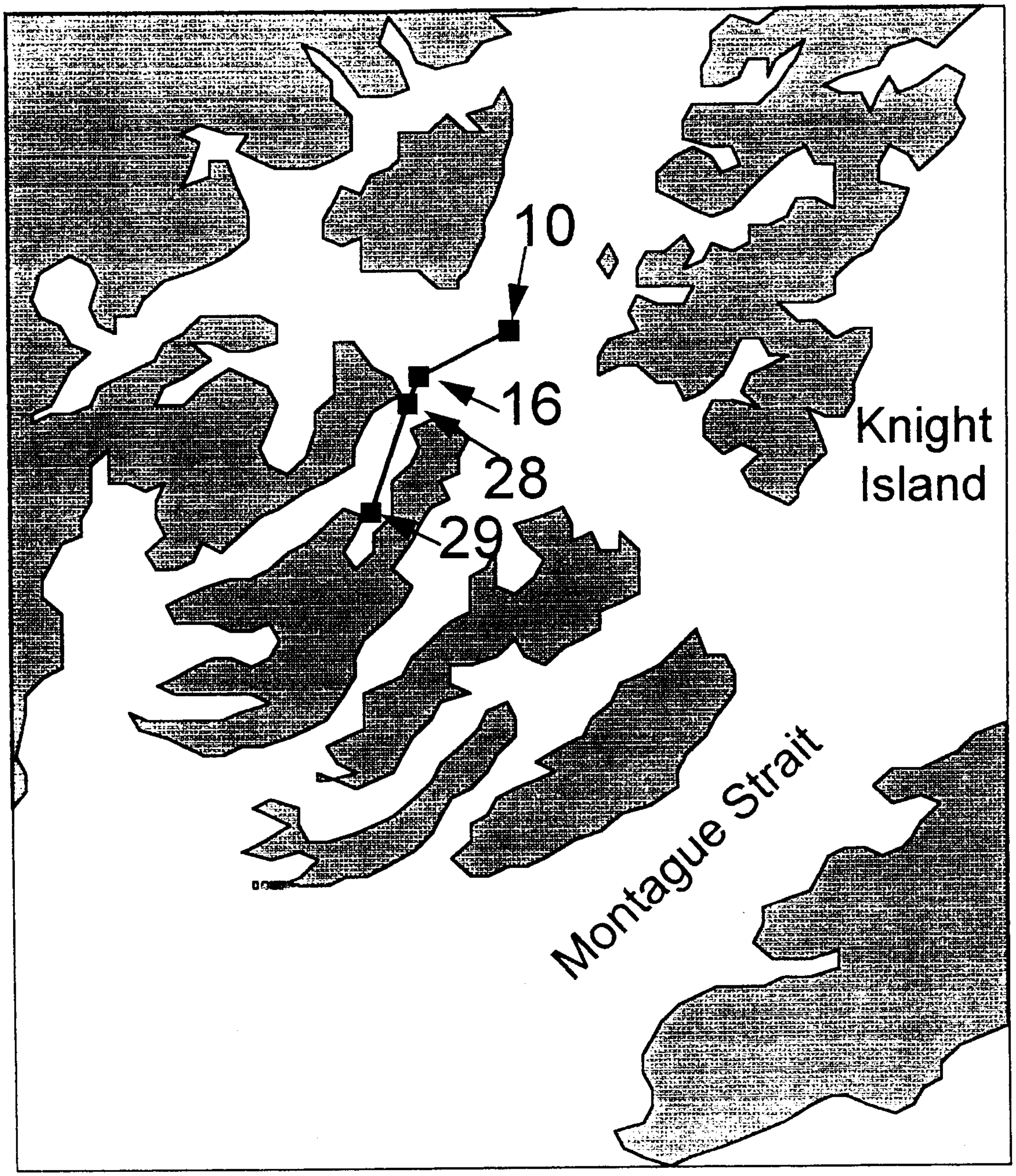


Figure 28. Isotherm and Isohaline profiles along the CTD transect at McPherson Passage in the Central study area.



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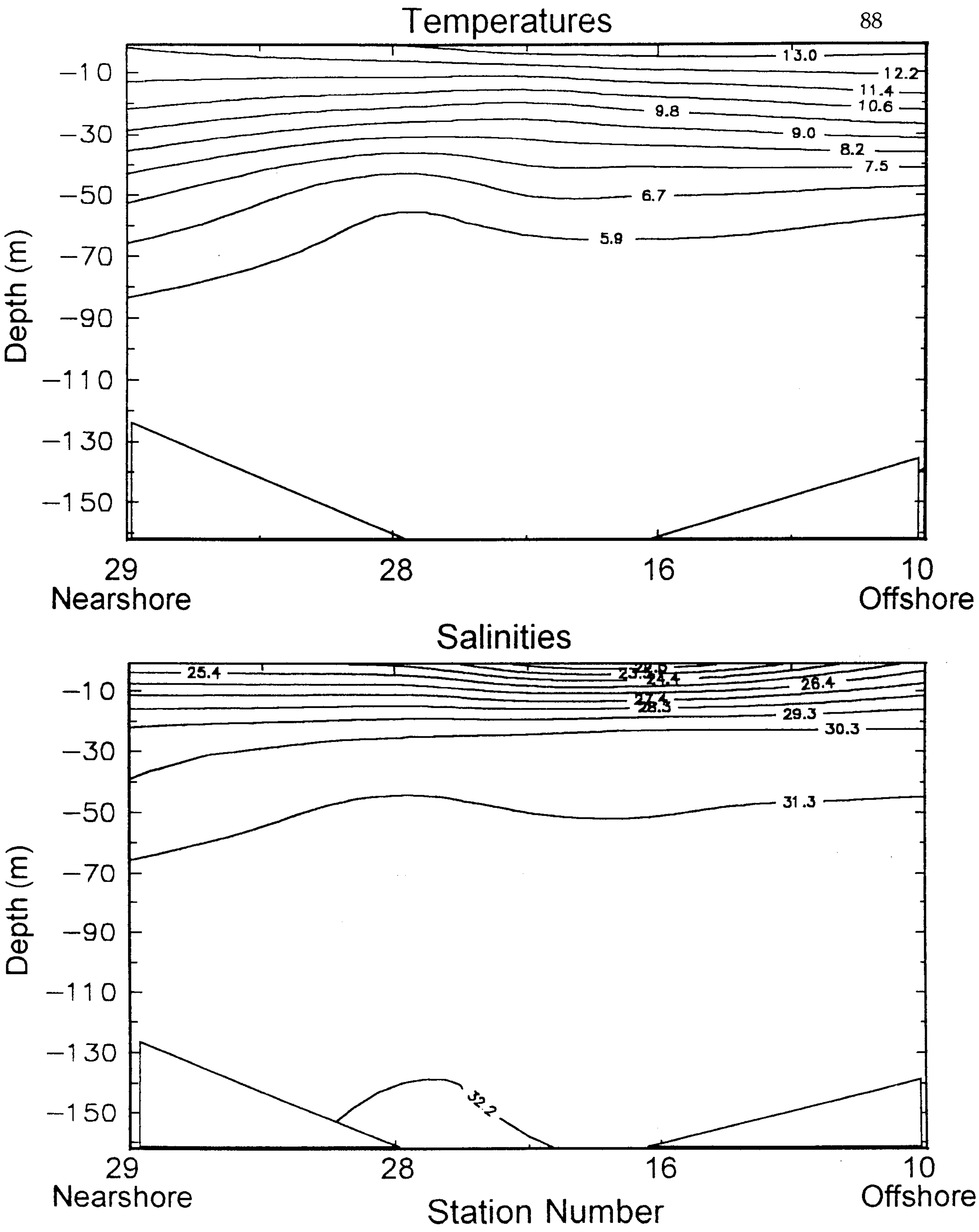

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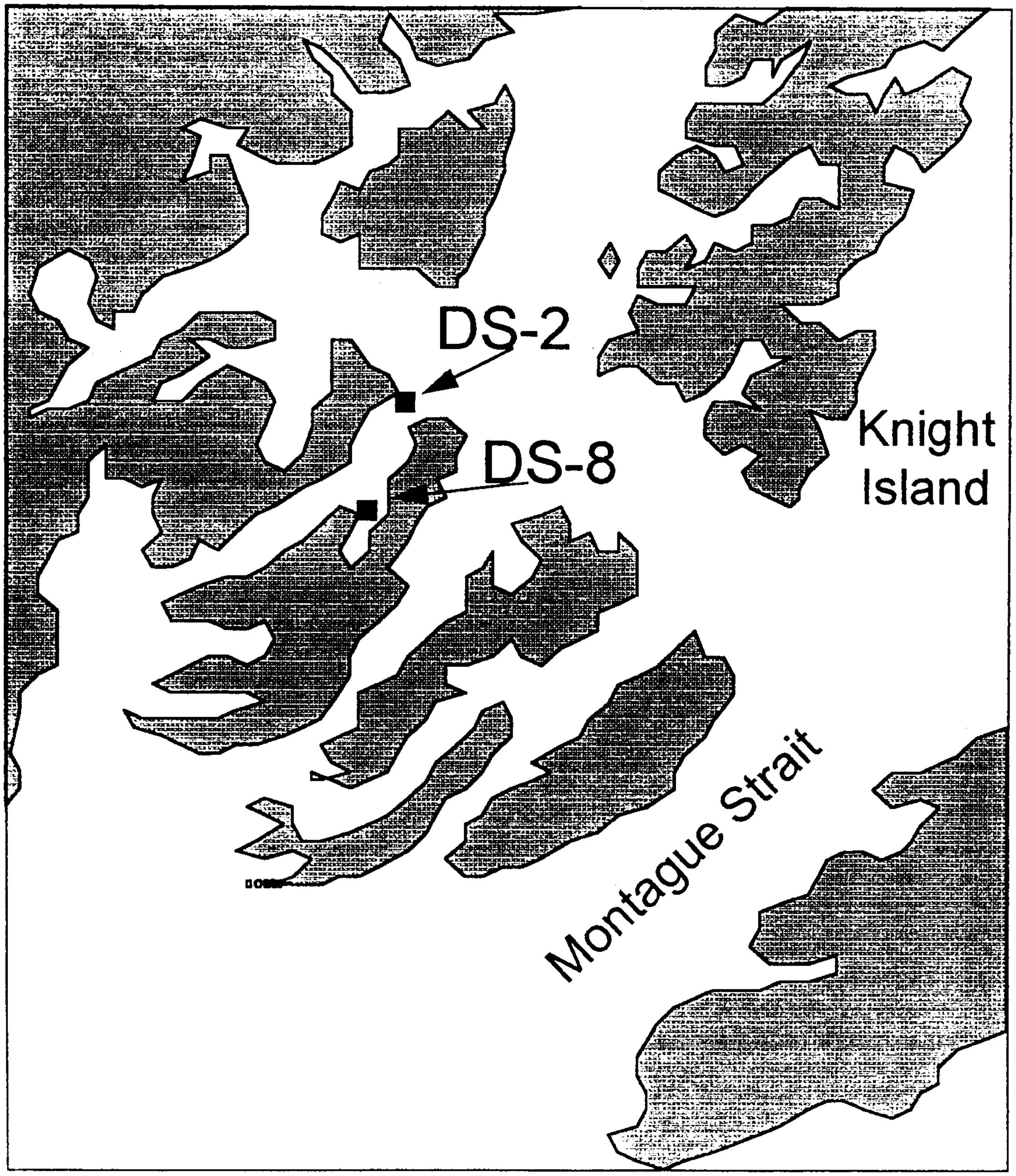

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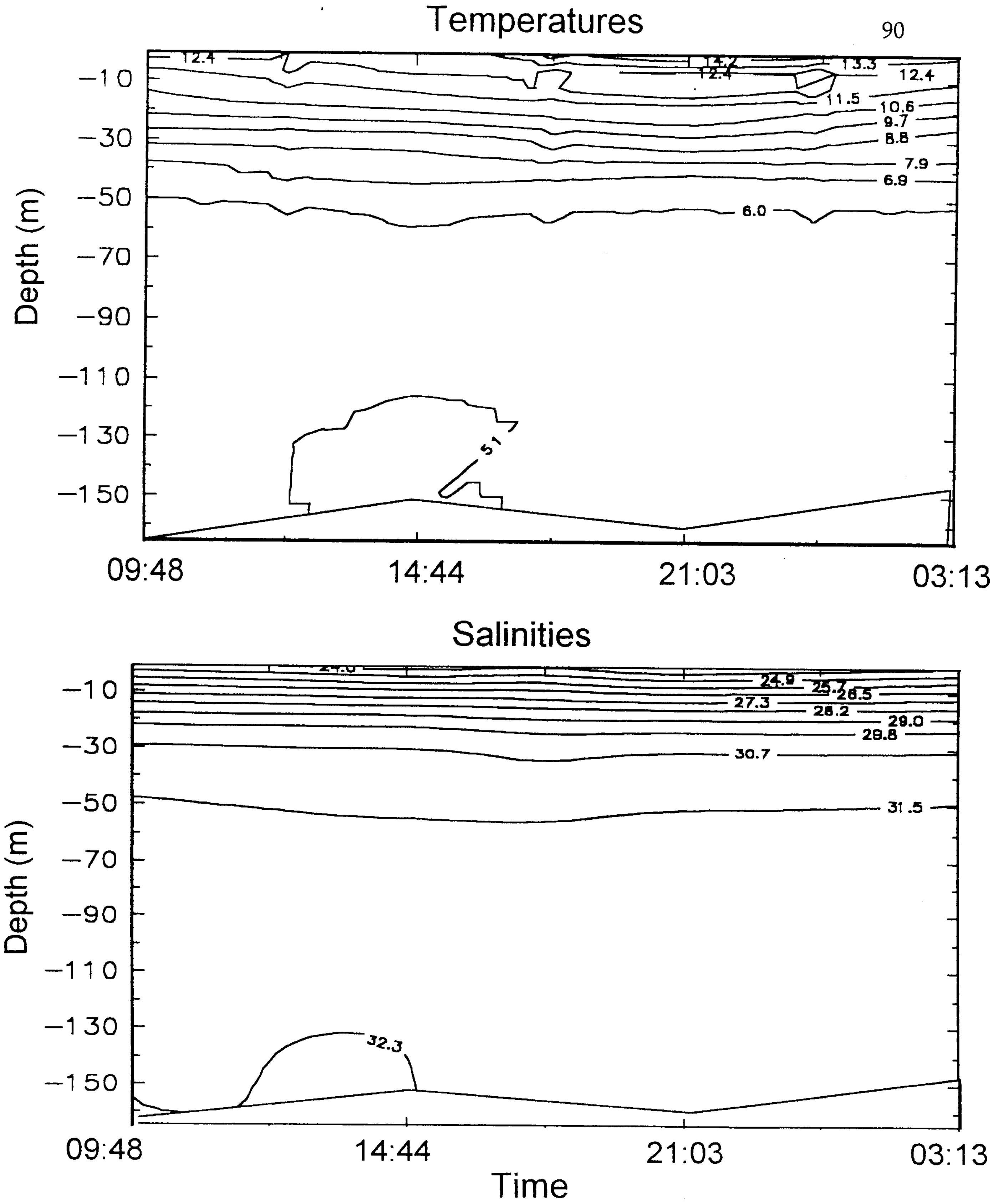

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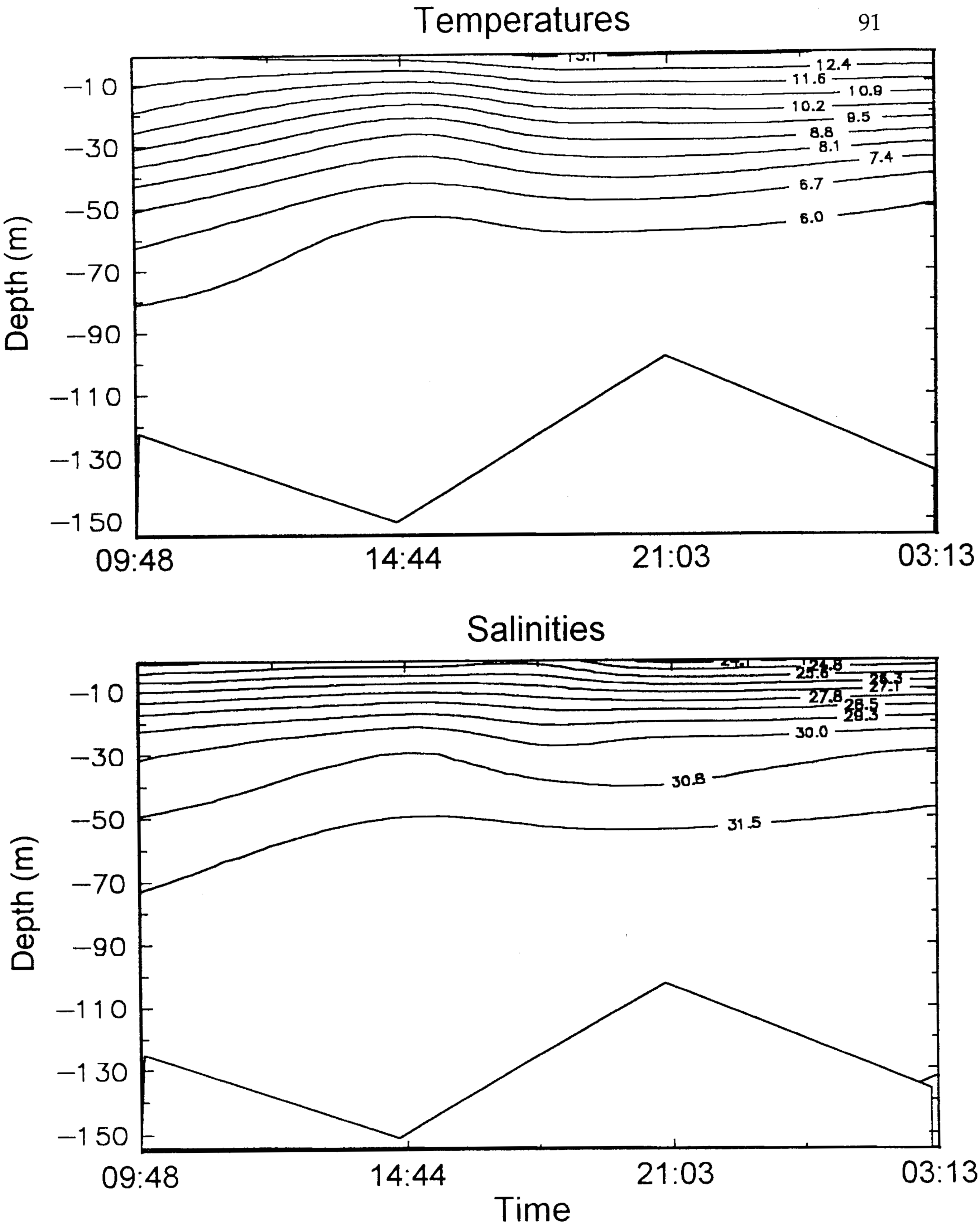

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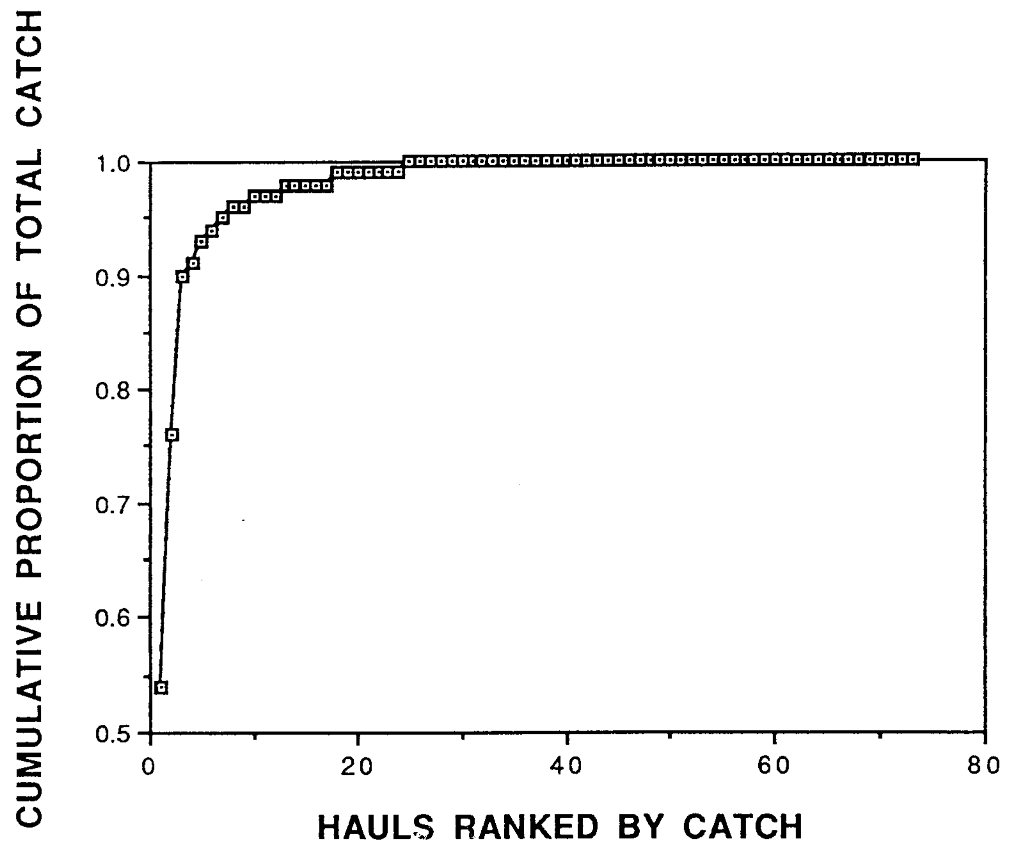

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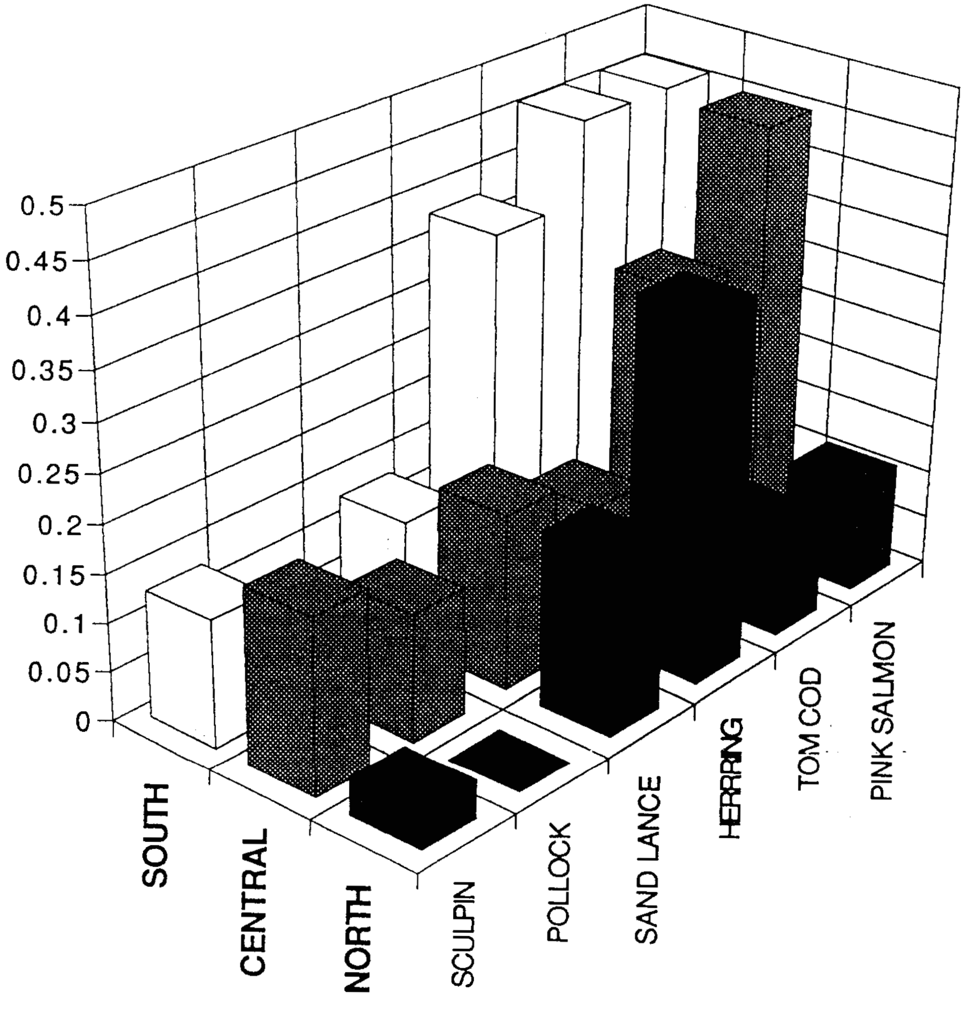

Figure 35. Frequency of occurrence (proportion of samples where a species was present) of most abundant species in beach seine samples from the North, Central and Southern study areas.

APPENDIX B

APEX: 96163B

Exxon Valdez Oil Spill
Restoration Project Annual Report

Seabird/Forage Fish Interactions Component
APEX

Restoration Project Component 96163B
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

William D. Ostrand
John M. Maniscalco

U. S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

April 1997

Seabird/Forage Fish Interactions Component
APEX

Restoration Project Component 96163B
Annual Report

Study History: This is an ongoing study which began with a pilot effort in 1994 to test field methods. In 1995, the study was expanded to look at seabird foraging in several habitats in 3 study sites within Prince William Sound. Data collected in 1994 and 1995 indicated that seabird activity was concentrated in shallow water nearshore. In response to these findings the 1996 study expanded data collection by adding an extensive survey of nearshore habitats.

Abstract: We sought to determine if forage fish characteristics and/or interactions among seabirds limit food availability. We also examined the relationship between seabird foraging groups size and the characteristics of associated forage fish. Additionally, we compared strip transect and telemetry methods of determining the foraging range of black-legged kittiwakes (*Rissa tridactyla*). Seabird/forage fish interactions were monitored by conducting systematically arranged transects, 21 July-11 August 1995 and 14-28 July 1996 in three study areas in Prince William Sound Alaska, Alaska. The study sites were located in Valdez Arm, Naked and Knight Islands, and Jackpot and Icy bays. In 1996 nearshore survey blocks were added in these three areas. Hydroacoustic and bird-observation data were collected simultaneously during these surveys. We collected addition data on seabird/forage fish interactions at 22 mixed species feeding flocks in both 1995 and 1996. We determined that *Brachyrampus* murrelets selected forage fish schools in shallow water habitats, that are generally associated with high energy forage fish that have declined in abundance. Whereas, tufted puffins (*Fratercula cirrhata*) were generalist forages. We speculated that differences in forage selection and life history differences of these species may be linked to the differential response of these species to the *Exxon Valdez* oil spill. We determined that there may be a commensal relationship between black-legged kittiwakes and marbled murrelets (*Brachyrampus marmoratus*) with kittiwakes the beneficiary and a competitive interaction between kittiwakes and glaucous-winged gulls at mixed species feeding flocks. The total number of birds in mixed species feeding flocks was positively related to the chord length of associated fish schools and negatively related to density and depth of water to schools. Our comparison of strip transect and telemetry sampling indicated that a survey design of insufficient size and the declining probability of encountering birds as distance from the colony increase, were major sources of bias associated with the strip transect method.

Key Words: *Brachyramphus marmoratus*, *Exxon Valdez* oil spill, forage fish, foraging, *Fratercula cirrhata*, glaucous-winged gulls, kleptoparasitism, *Larus glaucescens*, marbled murrelets, radio telemetry, randomization, resource selection, seabirds, tufted puffins.

Project Data: *Description of data* - Major data sets of all birds observed during the 1994, 1995 and 1996 on pelagic APEX cruises. Several subsets of the 1995 data give locations of individual species and locations within each study areas. There is an additional data set of bird locations for the 1996 APEX nearshore survey. There are also data sets of behavior data collected on mixed species feeding flocks for 1995 and 1996. We maintain a file of video tapes of mixed species feeding flocks recorded in 1995 and 1996. We developed a data set of the characteristics of fish schools encountered during the 1995 APEX cruise. There are subsets of the fish school set that give characteristics of schools associated with *Brachyrampus* murrelets, tufted puffins (*Fratercula cirrhata*), black-legged kittiwakes (*Rissa tridactyla*), and feeding flocks. We have an unprocessed data set for 1996 on the formation of feeding flocks, that gives location, time and date of occurrence, and initiating species on each flock observed. Format - These data sets are in ASCII text format except the initiators of flocks set which is on field data sheets and the video tape file. *Custodian* - Contact William Ostrand through the Office of Migratory Bird Management, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503 (phone: 907-786-3849, fax: 907-786-3641, or email: William_Ostrand@mail.fws.gov). *Availability* - Copies of all data that are recorded as computer files are available on floppy disc.

Citation: Ostrand, W.D. and J.M. Maniscalco. 1997. Seabird/forage fish interactions. Appendix B in D.C. Duffy, compiler. APEX: Alaska predator ecosystem experiment, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96163), Alaska Natural Heritage Program, University of Alaska, Anchorage, Alaska.

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Executive Summary: The Seabird/Forage Fish Interactions component of APEX has examined several aspects of seabird activity at sea. In the 1996 annual report we have presented our findings on the following topics: 1) A comparison the characteristics of forage fish schools selected by murrelets and tufted puffins with implications on their differential response following the *Exxon Valdez* oil spill. 2) The characteristics of fish schools associated with mixed species feeding flocks. 3) A comparison of radio telemetry and strip transect methods of determining foraging ranges of black-legged kittiwakes. 4) The composition and behaviors at mixed species feeding flocks. 5) A summary of bird data collected during the 1996 nearshore APEX survey.

To compare the characteristics of forage fish schools selected by murrelets and tufted puffins we collected hydroacoustic and bird-observation data simultaneously along transects in three areas in Prince William Sound from 21 July - 11 August 1995. We derived depth to each fish school, area, and density of forage-fish schools and total depth of water, distance to shore, and distance to the nearest seabird colony for each forage-fish school. Subsequently we determined which schools were associated with Tufted Puffins, a species that has been increasing in abundance following the spill, and Brachyramphus murrelets, 2 species with stable populations following the spill. The probability of the association of fish schools with birds was determined through the use of a resource selection function based on logistic regression. Our analysis indicated that Tufted Puffins were generalist foragers which selected fish schools near their colony. Brachyramphus murrelets selected larger, denser fish schools in shallower water when compared to available fish schools. Fish species that were high in energy content were associated with shallow water habitats. There are indications that these fish species have experienced local population declines. Walleye Pollock (Theragra chalcogramma), a low energy content forage species, was abundant in deep water habitats and their biomass has been increasing in the northern Gulf of Alaska. Our study indicated that Brachyramphus murrelets foraged in habitats associated with high energy content forage species. If Walleye Pollock provided sufficient energy for reproduction, we might have expected Brachyramphus murrelets to use a foraging strategy that would have allowed them to maximize their consumption of this abundant species. We suggest that the generalist foraging and the nesting strategies of Tufted Puffins has allowed this species to adjust to ecological change and increase its population. Whereas, Brachyramphus murrelets need for high energy foods and a foraging strategy that selects habitats associated with high energy forage species, that have declined in abundance, may be a major reason for this species failure to recover following the oil spill.

We made comparisons between schools associated with flocking birds and those not associated with flocking birds encounter during the 1995 APEX survey using Wilcoxon rank sum tests and logistic regression analysis. Feeding flocks chose fish schools which were close to shore and in shallow bottom depths, as well as those which had a narrow chord length. However, fish schools found nearshore were significantly more narrow than offshore fish schools suggesting that flocking birds chose feeding habitat rather than school size. At the feeding flocks, bird numbers were positively correlated with fish school chord length and negatively correlated with density and depth to the schools.

We compared strip transect and telemetry methods of determining foraging range by using randomization tests. We evaluated factors that could bias either method and indicate how they may have affected the respective data sets. We also used bootstrap resampling to: determine the effect of reducing our sampling effort for both methods, speculate on the benefits of increased sampling, and compare the time required to obtain similar variability by both methods. The mean distance birds were observed from their colony determined by telemetry were significantly greater than the mean value calculated from strip transects. We determined that this difference was due to 2 sources of bias: 1) a decreasing probability of sighting birds at increasing distance from their colony on strip transect surveys. 2) The maximum distance birds were observed from the colony through telemetry exceeded the extent of the strip transect survey. We compared the observed number of birds seen on the strip transect survey to the predictions of a model of the declining probability of sighting birds at increasing distance from the colony (DPSB). Field data were significantly different from modeled data; however, the field data were consistently equal to or below the model predictions indicating a general conformity to prediction of a DPSB. We concluded that telemetry data provided a more accurate measure of foraging distance than strip transect data for colonial birds. Furthermore, studies that have used strip transect sampling that have not accounted for DPSB may have underestimated foraging range. Variability was less for strip transect sampling and less time was required to collect the data. We concluded that strip transect sampling yielded more precise data whereas telemetry data was more accurate.

We examined the behaviors of seabirds at feeding flocks in Prince William Sound, Alaska during July/August 1995 to determine the factors which may enhance or limit the availability of forage to surface feeding birds. The presence of lairds and alcids at feeding flocks was positively correlated, suggesting complimentary feeding habits. On the other hand, the frequency of kittiwake plunge dives was negatively correlated with the relative presence of larger gulls in the flock. Kittiwakes preferred to plunge-dive for fish while Glaucous-winged Gulls hop-plunged from the water surface to maintain their position at the center of the feeding flock. Kittiwakes had a feeding success of 80.6% and lost 4.8% of their captures to intraspecific piracy and 6.7% to interspecific piracy. Kleptoparasitism was most intense against kittiwakes in tightly aggregated feeding flocks and against alcids in loosely aggregated flocks. Jaegers preferred to kleptoparasitize kittiwakes in the largest flocks.

During July of 1996 we conducted a nearshore survey to assess seabird distributions and examine their behavior at feeding flocks. We systematically selected 12-km blocks of shoreline within which we ran 20 1-km long transects to and from shore at oblique angles. The average number of birds per transect and transect block were 6.62 and 131.57, respectively and were not significantly different among the three study areas ($P > 0.10$ in both cases). However, species composition of the blocks differed significantly among the study areas ($P < 0.001$). Bird flocks were feeding primarily on juvenile herring and sand lance. Flocks in the northeastern area were significantly larger than flocks in the other two areas ($P = 0.01$) and were feeding on herring more often. The feeding rate of black-legged kittiwakes did not increase significantly with the presence of marbled murrelets ($P = 0.3801$), but did decrease significantly with the presence of glaucous-winged gulls ($P = 0.0225$). Changes in flocks from 1995 included; reduced presence of

kittiwakes and tufted puffins, increased presence of marbled murrelets and glaucous-winged gulls, more tightly aggregated feeding flocks, reduced feeding success of kittiwakes and greater feeding success of gulls, reduced kleptoparasitism of kittiwakes and increased kleptoparasitism of gulls. The implications of these changes are discussed briefly.

Introduction: This annual report is comprised of 4 manuscripts, chapters I - IV, that have been prepared for publication in scientific publications. In addition, chapter V presents general findings of the nearshore survey conducted in 1996.

Objectives: The Seabird/Forage Fish Interactions component of APEX had 3 major objectives for 1996:

1) Forage fish characteristics limit availability of seabird prey. This objective is the focus of chapter I and a portion of chapter II.
2) Interactions among seabirds limit availability of seabird prey. This objective is the subject of chapter IV and portions of chapter V.
3) Seabird foraging group size and species composition reflect prey patch size. Findings on this objective are discussed in chapter II.

In addition to these objectives, a comparison between radio telemetry and strip transect methods of determining the foraging range of black-legged kittiwakes is discussed in chapter III.

CHAPTER I: SELECTION OF FORAGE-FISH SCHOOLS BY MURRELETS AND TUFTED PUFFINS IN PRINCE WILLIAM SOUND, ALASKA AS FACTORS IN RECOVERY FOLLOWING THE EXXON VALDEZ OIL SPILL

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Abstract: As of 1996, local populations of 7 piscivorous pursuit diving bird and mammal species had not recovered from the perturbations caused by the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska (PWS). We hypothesized that these species shared a common food limitation and to gain insight into the possible limitation we compared the foraging strategies of injured and non-injured species of birds from the same sub-order. We collected hydroacoustic and bird-observation data simultaneously along transects in three areas in PWS from 21 July - 11 August 1995. We derived depth to each fish school, area, and density of forage-fish schools and total depth of water, distance to shore, and distance to the nearest seabird colony for each forage-fish school. Subsequently we determined which schools were associated with Tufted Puffins (*Fratercula cirrhata*), a non-injured species that has been increasing in abundance following the spill, and *Brachyramphus* murrelets (*Brachyramphus* spp.), 2 injured species with stable population following the spill. The probability of the association of fish schools with birds was determined through the use of a resource selection function based on logistic regression. Our analysis indicated that Tufted Puffins were generalist foragers that selected fish schools that were near their colony. *Brachyramphus* murrelets selected larger, denser fish schools in shallower water when compared to available fish schools. Fish species that were high in energy content were associated with shallow water habitats. There are indications that these fish species have experienced local population declines. Walleye Pollock (*Theragra chalcogramma*), a low energy content forage species, was abundant in deep water habitats and their biomass has been increasing in the northern Gulf of Alaska. Our study indicated that *Brachyramphus* murrelets foraged in habitats associated with high energy content forage species. If Walleye Pollock provided sufficient energy for reproduction, we might have expected *Brachyramphus* murrelets to use a foraging strategy that would have allowed them to maximize their consumption of this abundant species. We suggest that the generalist foraging and the nesting stratagies of Tufted Puffins has allowed this species to adjust to ecological change and increase its population. Whereas, *Brachyramphus* murrelet's need for high energy foods and a foraging stratagy that selects habitats associated with high energy forage species, that have declined in abundance, may be a major reason for of this species failure to recover following the oil spill.
Key words: *Brachyramphus brevirostris*, *Brachyramphus marmoratus*, *Brachyramphus* murrelets, foraging, *Fratercula cirrhata*, Kittletz's Murrelets, Marbled Murrelets, Prince William Sound, resource selection, Tufted Puffins.

On 24 March 1989 the oil tanker M/V *Exxon Valdez* grounded on Bligh Reef in Prince William Sound, Alaska (PWS), resulting in the spill of more than 42,000,000 liters of crude oil (Spies et al. 1996). Seabirds were severely impacted by the spill: 3,400 bird carcasses were recovered from PWS and 30,000 from the total spill affected area. Piatt et al. (1990) estimated total seabird mortality at 100,000 - 300,000. As of 1996, 9 bird and mammal species had not recovered from the population perturbation (*Exxon Valdez* Oil Spill Trustee Council 1996). Seven of these, Pelagic Cormorants (*Phalacrocorax pelagicus*), Red-faced Cormorants (*Phalacrocorax urile*), Doubled-crested Cormorants (*Phalacrocorax auritus*), Common Murres (*Uria aalge*), Marbled Murrelets (*Brachyramphus marmoratus*), Pigeon Guillemots (*Cepphus columba*), and Harbor Seals (*Phoca vitulina*), are piscivorous pursuit diving species. In addition Kittlitz's Murrelet (*Brachyramphus brevirostris*) were injured by the spill and the status of their recovery is unknown (*Exxon Valdez* Oil Spill Trustee Council 1996). All of these species forage on small schooling fishes which suggests that population recovery may be impeded by a common food or energy limitation. Long term affects of the oil spill (Spies et al. 1996) and/or a broader ecological shift in the Alaska Coastal Current (Piatt and Anderson 1996) could have altered the food web, resulting in a food limitation.

Marbled Murrelets were among the most common seabirds within PWS (Agler et al. 1997) and as a study species, provided the greatest potential for obtaining an adequate sample size for a comparative foraging study. A disproportionately high number of dead murrelets, 390, compared to their proportion of the total marine bird population were recovered in PWS after the oil spill (Piatt 1990). Subsequent to the spill, the murrelet population has remained stable and has not recovered (Agler et al. 1997). Tufted Puffins (Fratercula cirrhata), were also common within PWS (Agler et al. 1997) and were not severely impacted by the Exxon Valdez oil spill (Piatt et al. 1990, Exxon Valdez Oil Spill Trustee Council 1996). Following the spill, there has been an upward trend in their population (Agler 1997). The coexistence of these species provided an opportunity to contrast the foraging strategies of 2 alcids, which were affected differently by the oil spill. Differences in the selection of forage resources among these species, would support the food limitation hypothesis and provide insight the mechanisms causing a limitation.

Hydroacoustic sampling of forage resources while simultaneously conducting bird surveys has provided much of our current information on the relationship between seabirds and their prey (Hunt 1988). Several studies using these techniques have correlated seabird and forage abundances. However, the strength of these relationships generally weakened as the scale became finer (Obst 1986, Heinemann et al. 1989, Schneider and Piatt 1986, Erikstad et al. 1990, Hunt et al. 1990, Piatt 1990). Mehlum et al. (1996) correlated Brünnich's Guillemots (Uria lomvia) abundance to forage density at a fine scale by including a prey density threshold that excluded non-preferred food items from their correlation analysis. In examining fine scale relationships between Common Terns (Sterna hirundo) and forage-fish, Safina and Burger (1985) did not find a relationship between predator and prey abundance but did find a significant relationship between birds, depth to prey, and the presence of predatory fish. These studies suggest that marine birds may select patches based upon more factors than prey abundance at fine scales. Furthermore, studies of feeding flocks in the tropics (Duffy 1983) and Alaskan waters (Hoffman 1981) have demonstrated that the species composition of feeding flocks was related to characteristics of associated fish schools. Therefore, we anticipated that differences in the foraging strategies of murrelets and Tufted Puffins would be most apparent if we examined the selection of fish schools by birds through multivariate methods to evaluate several possible factors.

STUDY AREA AND METHODS

We conducted this study in PWS, an inland waterway of 10,000 km^2, located on the southern coast of Alaska. The climate is maritime with record annual precipitation > 8 m and moderate temperatures for the subarctic. The coastline of PWS is rugged, with mountains up to 4-km elevation, and numerous fjords and tidewater glaciers. Three study sites were selected for sampling (Fig. 1): 1) the northern study area which included Valdez Arm and Port Valdez, 2) the central study area which included waters near Naked and Knight Islands, and 3) the southern study area which included Icy and Jackpot Bays.

We collected hydroacoustic and bird location data simultaneously while traveling systematically arranged transects (Anderson et al. 1979, Litvaitis et al. 1994). To locate transects, we randomly selected the starting point from 20 equally spaced points within the first 2' latitude of the southern boundary of each study area. We arranged east-west transects at 2' latitude intervals north of the initial starting latitude and added zigzag transects to increase data collection of nearshore habitats (Fig. 1). Zigzag transects were inserted at points where east-west transects terminated at land. We drew zigzag transects from the end of the previous east-west transect, to a point half the perpendicular distance to the next east-west transect at which the water depth was 100 m. From the 100-m depth point we drew a transect to the beginning of the next east-west transect. Potential transect segments that were < 1 nautical mile were not included, other potential segments were deleted for safety considerations. After deletions, 41 east-west and 25 zigzag transects remained in the survey design. By study area there were 15, 18, and 8 east-west and 8, 9, and 8 zigzag transects in the north, central, and south study areas, respectively. We determined the total length and mean ± standard deviation (SD) of both east-west and zigzag transects (Table 1). We chartered a 24-m vessel, the M/V Pacific Star, to replicate the hydroacoustic/bird transect survey twice during 21 July- 11 August 1995.

Hydroacoustic data were collected with a 420 kHz BioSonics Model 120-121 echo-integration system. The data were integrated for 30-second intervals and over 1-m depth intervals, corrected for calibration, and stored to disk. Transects were run at 6 knots with the transducers towed beside the vessel. The effective range of the equipment was 65 m from the transducers. Global Positioning System (GPS) data were written to each record. Length and species composition information from net samples of the target species (Haldorson et al. 1996) was used with length-target strength relationships (R. Thorne, BioSonics Inc., Seattle, Wash., unpubl. data) to scale the acoustic data. We obtained net-sample data from a separate vessel which was directed by the hydroacoustic vessel to trawl through schools with a Canadian midwater herring trawl (100-m^2 opening). We selected schools for trawling which had the greatest species and/or age class composition uncertainty. These trawls were only effective on the larger schools; therefore, the samples may not have been representative of all schools.

Bird observations were made from the second deck of the M/V Pacific Star, 8-m above the water. Continuous counts were made of all seabirds observed within 100 m of the starboard side of the vessel, the same side from which acoustic data were taken. We assigned the following behavioral codes to each observation: 1) flying, 2) on the water, 3) on a floating object, 4) foraging, and 5) potentially foraging. Foraging was defined as the actual observation of foraging behavior such as diving for food or holding food in the bill. Potential foraging was defined as ≥2 associated birds on the water or circling above. Bird observations were made by scanning ahead of the ship using binoculars. Recorded observations were made prior to the ships presence influencing bird activities. Data were recorded when the ship was closest to the point at which the birds were first observed. We directly recorded data into a computer file using custom software that also recorded the ships position and time for each data entry. GPS data were obtained from the same device accessed by the acoustic system.

Some previous acoustic/seabird studies have not included flying birds in their analysis because of the greater probability that birds on the wing are not associated with acoustic targets (Piatt 1990, Decker 1995). We have adapted this convention for our analysis by including birds foraging, potentially foraging, and on the water. During surveys we were confident that nearly all of observed murrelets were Marbled Murrelets; however, there is a possibility that we have incorrectly identified some kittlitz's as marbled. Therefore, we have chosen to refer to these species collectively as Brachyramphus murrelets.

We displayed acoustic data with contouring and 3 dimensional surface-mapping software (Keckler 1995). These images were then used to determine school density, depth to top of schools, depth to bottom of schools, height of school, chord length of schools, and bottom depth for values < 60 m for each fish school observed. The chord lengths of fish schools were determined by averaging widths measured at 2-m depth intervals. Height of school was multiplied by chord length to approximate a 2 dimensional area. We ascribed categorical density values of low, medium and high for average densities of 0.01-0.20, 0.21-0.35, and > 0.35 g/m^3, respectively. As a result of integrating acoustic data at 30-second intervals, schools with a chord length of < 40 m were either not displayed or were extrapolated to a chord length of 40 m. Therefore, the smallest fish schools were not well represented.

A geographic information system (GIS) was used to examine the spatial relationship between forage-fish schools, depth, distance to shore, and locations of bird colonies. GPS data for fish schools and colony locations were converted into GIS layers. Forage-fish school data were intersected with National Oceanographic and Atmospheric Administration (NOAA) bathymetry data to return depths for each school. Acoustic data had previously recorded depths to 60 m; therefore, GIS data for depth > 60 m were merged with acoustic bathymetric data. Digital NOAA coastline data were used to calculate distance to shore for each forage-fish school. Finally, we used GIS to calculate the distance to the nearest Tufted Puffin colony (U. S. Fish and Wildl. Serv., Anchorage, Alas., unpublished data) for each school. These data sets were then combined with acoustic data on fish school characteristics for analysis.

We used custom software to determined which of the forage-fish schools had Brachyramphus murrelet or Tufted Puffin locations within 100 m of the edge of the school. We selected 100 m as the distance of association to be consistent with other sources of variation: 1) The transect width allows birds up to 100-m distant to be associated with schools beneath the ship. 2) GPS data have an accuracy of about ± 100 m (Leick 1992).

We used resource selection functions based upon logistic regression to model the selection of fish schools by birds (Manly et al. 1993). We checked variables for independence through correlation analysis. Paired variables with a correlation coefficient (r) > 0.50 were not used in the analysis. We incorporated the variables: area, depth to the top of the school, bottom depth, distance to shore, biomass density of the school, area of the school, and distance to the nearest Tufted Puffin colony. The 3-level categorical variable, density, was converted to 3 separate binomial variables, low, medium, or high density, for these analyzes. Only medium and high density levels were used in the models since knowledge of these 2 levels determines the value of low density. Positive coefficients of either medium or high density indicated that selection was in favor of these categories when compared to low density schools. If a coefficient for either medium or high density was significant then both levels remained in the model. For the Brachyramphus murrelets regression, distance to colony was not applicable and not used. We ascribed variables moderately significant and highly significant for $P = 0.15$ to $P = 0.05$ and $P < 0.05$, respectively. We began analysis with all variables in the models and systematically deleted non-significant variables from the regressions singly and ordinally, beginning with highest P values, until all terms in the model were moderately or highly significant. The models selected by this method were checked to determine if they had the lowest Akaike's information criterion (AIC) value (Akaike 1973) of all possible configurations. The AIC statistic describes fit of the model while penalizing for including variables that explain minimal error (Akaike 1973). We considered models to be significant if, based on the likelihood ratio test, the covariates explained 95% of the variation ($P \leq 0.05$).

RESULTS

Of 326 Brachyramphus murrelets and 122 Tufted Puffin sightings, 70 and 9 were associated with forage-fish schools, respectively. The mean number of Brachyramphus murrelets and Tufted Puffins per sighting was 1.7 ± 1.1 SD and 1.2 ± 0.7, respectively. Our forage fish net sampling indicated that the principle species were Walleye Pollock (Theragra chalcogramma), Capelin (Mallotus villosus), Sand Lance (Ammodytes hexapterus), and juvenile Herring (Clupea harengus). For the hydroacousticly sampled forage-fish schools (n = 614) mean values for depth to the top of the school, total depth at the school location, distance to shore, and area (chord length x height of school) were 14.5 ± 17.6 m, 109.2 ± 43.2 m, 2299.2 ± 2051.2 m, and 1842.3 ± 4936.6 m^2, respectively. Correlation analysis indicated that all of the variables included in our modeling were independent ($r \leq 0.5$). The resource selection models were significant (Table 2) and had AIC and concordance values 423.8 and 66.3 % for the Brachyramphus murrelets and 75.2 and 89.9 % for the tufted puffin models.

DISCUSSION

The variables we examined fall into 2 general types: those that describe the location of the school in relation to physical features (distance from the nearest colony, distance from shore, total depth of water), and those that describe characteristics of fish schools (density, area, and depth to the top of schools). Inclusion of only location variables in the resource selection model would indicate that, based on the available data, birds were selecting habitat types and were not discriminating among fish schools. Similarly, a model that contained only characteristics of schools would indicate that birds were foraging broadly for schools that satisfied their search image. Our resource selection model for Brachyramphus murrelets contained both location (depth of water) and school characteristic variables (density and area). Interpretation of this model must be done cognizant of our inability to hydroacousticly sample small schools frequently observed in shallow water, that may have been foraged on extensively by Brachyramphus murrelets (Strachan et al. 1995). When the smallest schools were not considered, Brachyramphus murrelets foraged in shallow water habitats and within those habitats selected larger and denser schools.

The resource selection model for Tufted Puffins contains only a location variable (distance from the nearest Tufted Puffin Colony), suggesting that this species does not discriminate among fish schools and makes selections based only on flight distances. Our level of concordance and AIC value for the Tufted Puffin model indicate that this species was efficient at locating fish schools near their colony. Tufted Puffins prey upon several different fish species (Baird 1990). Hatch and Sangar (1992) have shown that they take Walleye Pollock in proportion to their availability by age class. Although we were not able to identify the species composition of all schools associated with Tufted Puffins, our model is consistent with Hatch and Sangar's (1992) findings of generalized foraging.

Both Tufted Puffins and Brachyramphus murrelets forage extensively as individuals or in small groups. Aside from this common foraging trait, our results suggest that these species used different foraging strategies to find different types of forage-fish schools. During the 1995 survey, large Walleye Pollock schools, identified through trawling, were located in deep water of the central study area (Haldorson et al. 1996). We observed Tufted Puffins associated with these schools but not Brachyramphus Murrelets. Herring, which were the most abundant forage species in shallow water habitats during the 1995 survey of PWS (Haldorson et al. 1996) declined following the spill (Brown et al. 1996) and had not recovered as of 1996 (Exxon Valdez Oil Spill Trustee Council 1996). Sand Lance, also associated with shallow water habitat (Dick 1982) have declined in frequency of occurrence in the diet of Marbled Murrelets and Pigeon Guillemots (Cepphus columba) while Walleye Pollock has increased (Kuletz et al. in press). On a more coarse scale, the ecosystem shift in the Northern Gulf of Alaska (Piatt and Anderson 1966) resulted in an increase in pollock biomass and a decline Capelin (Piatt and Anderson 1966). Capelin were also associated with shallow water habitats during the 1995 survey of PWS (Haldorson 1996). These findings collectively suggest an increase in Pollock and a decline in other major schooling forage fishes.

Our model indicates that although Brachyramphus murrelets adapted to the shift in available forage fishes by incorporating Pollock into their diet; however, their foraging strategy did not maximize consumption of this species. We speculated that this may be the result of less efficient foraging in deep water because of possible downward escape by prey, or because prey are more predictably available due to advection in shallow water (Hunt 1988). These factors did not constrain Tufted Puffins and we were not able to identify biological reasons why they would differentially affect Brachyramphus murrelets. We proposed an alternative explanation based upon energetics.

Roby et al. (1996) determined that in PWS the lipid content and energy density of Herring, Sand Lance, and Capelin were variable but high when compared to Walleye Pollock, which was among the lowest of the sampled fishes. Brachyramphus murrelets, in response to a relatively short nestling period (De Santo and Nelson 1995), rapid chick growth when compared to most alcids, and chick provisioning limited to crepuscular periods (Nelson and Hamer 1995), may require higher energy food to maintain productivity. Murrelets adjusted to the shift in the food web by incorporating Walleye Pollock into their diet, but forage in habitats with the highest quality food items. If Walleye Pollock provided sufficient energy for reproduction, we might have expected Brachyramphus murrelets to use a foraging strategy that would have allowed them to maximize their consumption of this abundant species. In contrast, Tufted Puffins have the longest nestling period of the alcids (De Santo and Nelson 1995), the daily provisioning of nestlings period may extend to 17 hour (Amaral 1977) and their co-genera, the Atlantic Puffin (Fratercula corniculata), is capable of extending the nestling period in times of food stress (Harris 1984). A possible variable length nesting cycle, a nearly unlimited provisioning period, and a generalist foraging strategy should buffer Tufted Puffins from productivity declines due a change in available forage to a greater extent than species with more constrained foraging and nestings strategies. We suggest that the foraging and nesting strategies of Tufted Puffins has allowed this species to adjust to ecological change. Whereas, Brachyramphus murrelet's need for high energy foods and a foraging strategy that selects habitats with high energy forage species, that have declined in abundance, may be a major reason for of this species failure to recover following the oil spill.

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Table I-1. Transect lengths (km) for 3 study areas in Prince William Sound, Alaska. Zigzag transects surveyed nearshore and east-west transects surveyed open water.

Study Area	Northern area	Central area	Southern area	All areas
Total east-west	99.3	152.8	23.3	275.4
$\bar{x}$ ± SD east-west	6.6 ± 4.9	8.5 ± 4.1	2.9 ± 1.9	6.7 ± 4.6
Total zigzag	12.1	15.1	14.4	41.6
$\bar{x}$ ± SD zigzag	1.5 ± 0.7	1.7 ± 0.8	1.8 ± 0.4	1.7 ± 0.7
East-west + zigzag	111.4	168.9	37.7	317.0

Table I-2. Models of the likelihood that fish schools will be associated with diving birds using characteristics of the schools as independent variables.

No. schools not associated with birds	No. schools associated with birds	Model	Model P
545	70	BMurrelets[a] = -0.01TDepth[b](0.0004)[c] + 0.00004Area[d](0.03) + 0.62MDensity[e](0.05) + 0.53HDensity[f](0.12)	0.0002
606	9	TPuffins[g] = -0.00026DColony[h](0.02)	0.0001

[a] The probability of selection by Marbled or Kittlitz's Murrelets.

[b] Total water depth.

[c] P value of the associated independent variable.

[d] The chord length * the mean height of the school.

[e] Selection for medium density fish schools over low density schools. If either medium or high density variables were significant then both were retained in the model.

[f] Selection for high density fish schools over low density schools.

[g] The probability of selection by Tufted Puffins.

[h] Distance to the nearest Tufted Puffin colony.

Fig. I-1. The transects used to conduct acoustic and seabird surveys in Prince William Sound, Alaska.

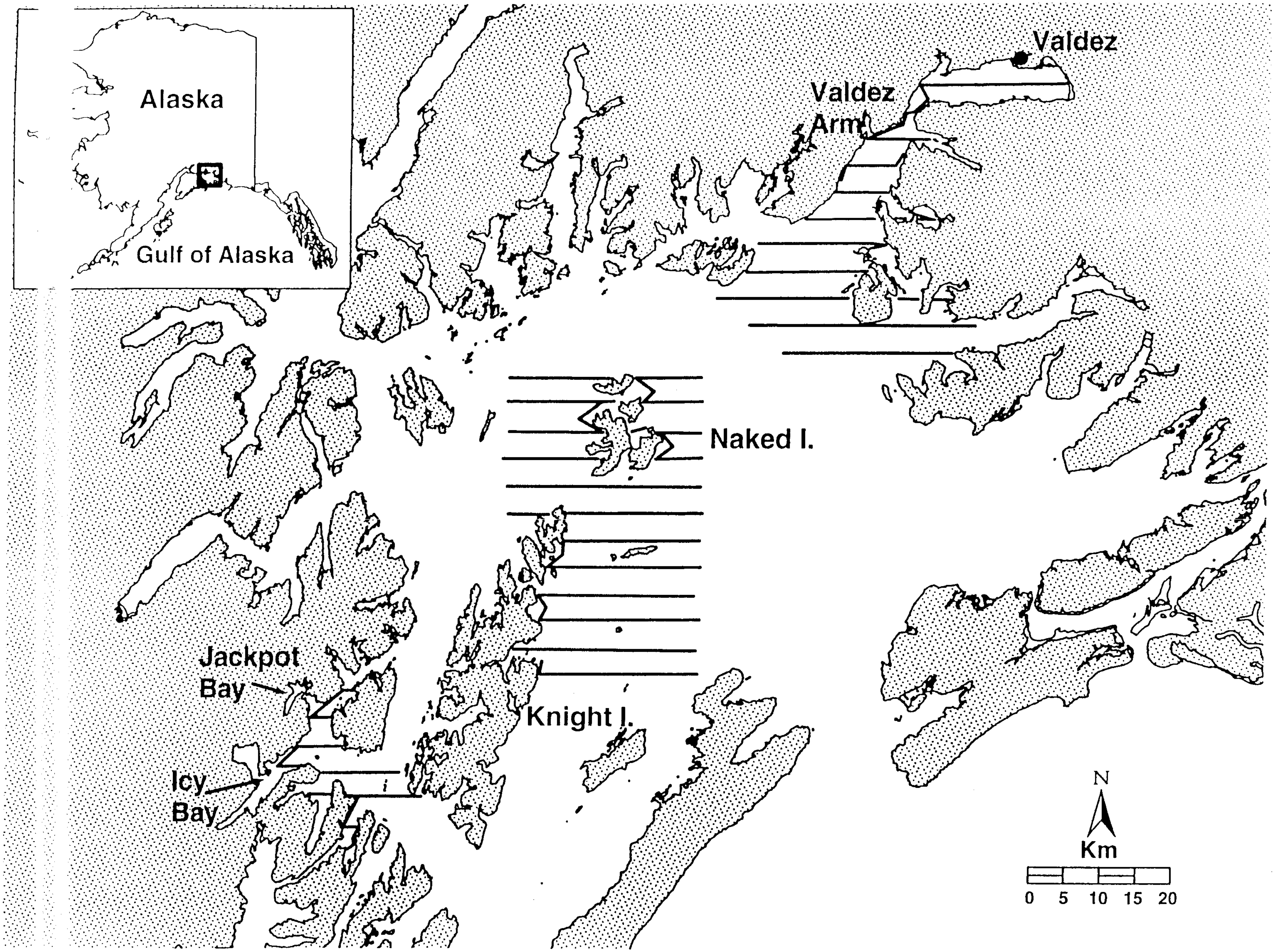
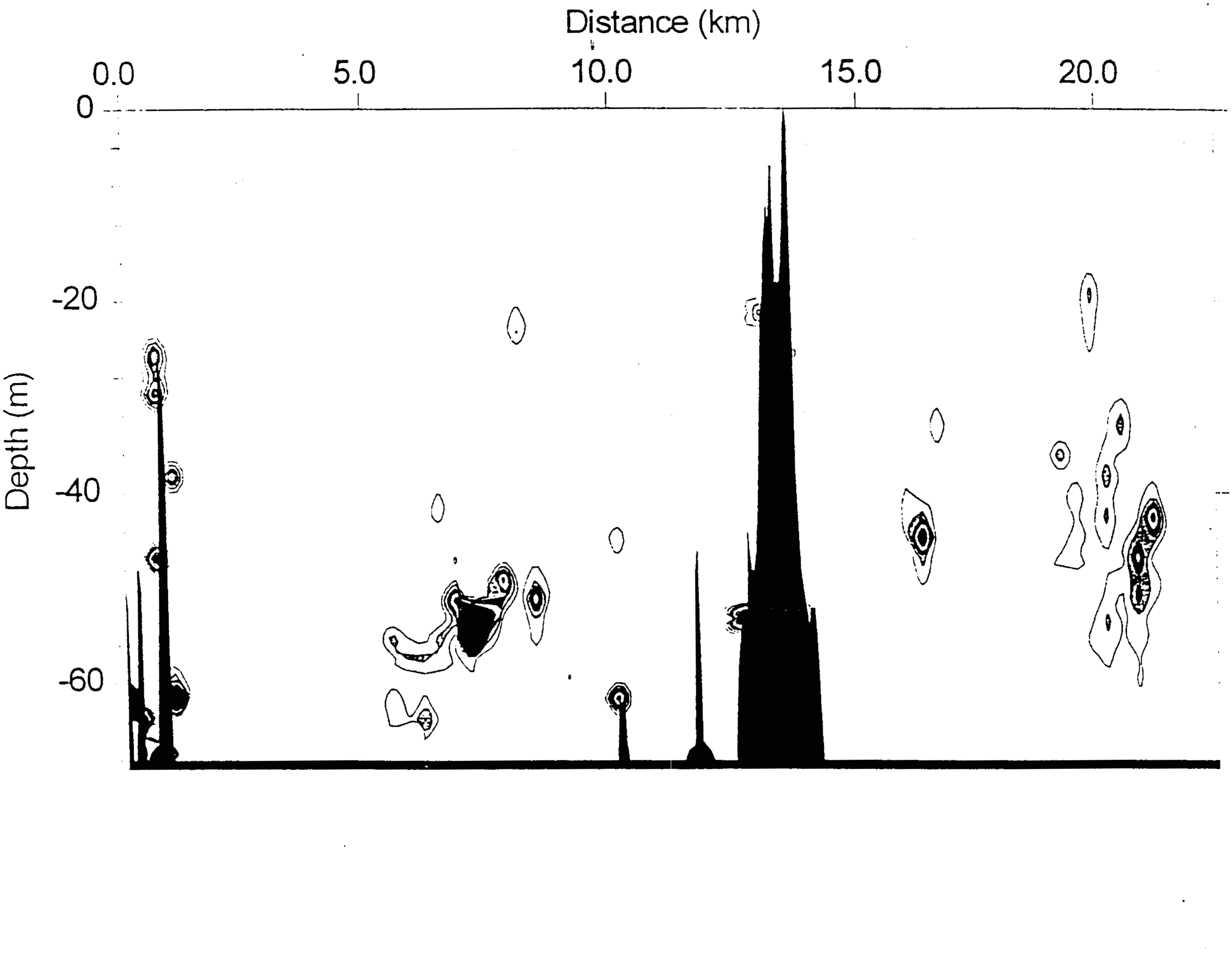

Alaska
Gulf of Alaska
Valdez
Valdez Arm
Naked I.
Jackpot Bay
Knight I.
Icy Bay
N
Km
0 5 10 15 20

Fig. I-2. A 3 dimensional plot of hydroacoustic data collected during a survey of Prince William Sound, Alaska. Black spires represent the bottom. Grey polygons represent fish schools. Darker shades of grey in polygons indicate a greater biomass density.


Distance (km)
0.0
5.0
10.0
15.0
20.0
0
-20
-40
-60
Depth (m)

CHAPTER II: SELECTION OF FISH SCHOOLS BY FLOCKING SEABIRDS IN PRINCE WILLIAM SOUND, ALASKA

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Abstract: We examined the size and location characteristics of fish schools encountered along line transects in Prince William Sound, Alaska during July/August 1995. We made comparisons between schools associated with flocking birds and those not associated with flocking birds using Wilcoxon rank sum tests and logistic regression analysis. Feeding flocks chose fish schools which were close to shore and in shallow bottom depths, as well as those which had a narrow chord length. However, fish schools found nearshore were significantly more narrow than offshore fish schools suggesting that flocking birds chose feeding habitat rather than school size. At the feeding flocks, bird numbers were positively correlated with fish school chord length and negatively correlated with density and depth to the schools.

INTRODUCTION

The marine environment is vast and its biological content is largely hidden from the sight of surface and aerial predators. However, it is here that seabirds must search for prey to sustain themselves and their offspring. Environmental and biological parameters which seabirds may cue on to search for and obtain food have been the topic of much recent research (e.g. Woodby 1984, Heinemann et al. 1989, Erikstad et al. 1990, Piatt et al. 1991). Fish schools that are not utilized by seabirds, may be unavailable (i.e. too deep or too far from nesting colony), of low quality, quantity or density, or they simply have not been discovered by the birds. Describing the characteristics of the available forage may explain otherwise paradoxical distributions of seabirds (Springer et al. 1987). Studies of seabirds, coupled with fisheries hydroacoustics, offer valuable insights to some of the complex relationships that puzzle marine ecologists. Transect surveys at sea have helped to explain the distribution of seabirds with respect to their prey and environmental factors such as depth of water (Vermeer et al. 1989, Stone et al. 1995), distance from land (Vermeer et al. 1989), depth to food source (Hunt et al. 1990), density of the prey (Piatt 1990), water temperature and salinity (Haney 1991, Vermeer et al. 1991), tides and currents (Braune and Gaskin 1982, Coyle et al. 1992), bottom topography (Cairns and Schneider 1990), and the presence of other oceanographic features such as fronts and upwellings (Schneider 1982, Kinder et al. 1983, Brown and Gaskin 1988).

In the aforementioned studies, observations of birds were typically recorded while fisheries hydroacoustics measured prey densities along strip transects. Birds in the air were included in some of these studies, while birds sitting on the water were included in all of them. However, flying birds are not necessarily using the area surveyed for feeding and birds on the water may be inactive or resting after feeding on prey which has moved away (Hoffman et al. 1981). Therefore, these observations may confound correlations between birds and their prey.

In this study, we compared fish schools at which birds were feeding in flocks of three or more with fish schools where birds were not obviously feeding in flocks. Variables of fish schools which were compared included chord length (the horizontal distance traveled over the school), depth to the school, bottom depth, relative density, distance from shore, and distance from the nearest Black-legged Kittiwake (Rissa tridactyla) colony. We also wished to determine if some of these variables would be useful in helping to predict the number of seabirds at feeding flocks.

STUDY AREA

Prince William Sound (PWS), Alaska is a large estuarine embayment of the northern Gulf of Alaska which provides important foraging and breeding habitat for many seabirds (Isleib and Kessel 1973, Irons et al. 1988). Water depths exceed 870 m and the numerous bays and fjords along with more than 150 islands form at least 5000 km of shoreline. High precipitation rates keep the sea-surface salinity low and catabatic winds flowing down the fjords transport this low-salinity (about 25 ppt during this study; Haldorson et al. 1995) water out of PWS, generally through Montague Strait and the smaller straits and passages of the southwestern region. The Alaska coastal current provides the major inflow of marine water through Hinchinbrook Entrance (Royer et al. 1990). Diurnal tidal changes in PWS can also create currents exceeding 5 km/hr through narrow passages.

Seabirds which commonly forage in flocks in PWS during summer include Black-legged Kittiwakes, Glaucous-winged Gulls (Larus glaucescens), Mew Gulls (Larus canus), Marbled Murrelets (Brachyramphus marmoratus), Tufted Puffins (Fratercula cirrhata) and Horned Puffins (F. corniculata). These birds feed on a variety of forage fish including: Pacific herring (Clupea pallasi), capelin (Mallotus villosus), Pacific sand lance (Ammodytes hexapterus), walleye pollock (Theragra chalcogramma), and eulachon (Thaleichthys pacificus) (Sanger 1987, Haldorson et al. 1995). Three focal areas in PWS (Northeastern, Central, Southwestern) were chosen for study because their habitat is critical to these seabird species of interest.

METHODS

Field Procedures

From a random starting point, strip transects were selected along lines of latitude 2 nm apart in the three areas of primary interest. Since many seabirds are often found nearshore or in relatively shallow waters (Vermeer et al. 1989, Stone et al. 1995), we also ran zig-zag transects on a straight line from shore to the halfway point between adjacent transects where water depth was 100 m. From this point, sampling continued to the beginning of the next transect. All transects were replicated once.

The study period (July 20 - Aug. 12) was chosen to include the peak time of chick provisioning for many seabirds in PWS. Seabird observations were made using 8 x 40 binoculars, 6 m above the water line from a 26 m vessel while conducting hydroacoustic surveys to estimate forage fish distributions and abundances. Data on bird observations were entered directly into a computer which was linked to a Global Positioning System (GPS) to record the location of each observation. We departed from our transect lines to more closely examine feeding flocks within 300 m of either side of our vessel.

Hydroacoustic and trawl data were used to determine species composition of fish schools, water depth to the schools, chord lengths (lengths of the horizontal cross sections) and densities of the schools. These data were collected along the main transects and along short transects conducted at feeding flocks. Hydroacoustic measurements were made from the same vessel from which bird surveys were conducted. We used a BioSonics system with 120 and 420 kHz down-looking and 420kHz side-looking transducers to measure deep and near-surface targets, respectively. Both transducers used a single beam with a 6° viewing angle and data were integrated over 1 m depth intervals to a depth of 65 m. The acoustic data were also linked with the GPS to record locations of fish schools along each transect.

Trawl samples were collected from a separate vessel which was directed by the hydroacoustic vessel to schools of forage species. A modified Canadian midwater herring trawl (100 m^2 opening), an improvised pair trawl, and a dip net were used to verify fish school compositions. These trawls were only used on the larger fish schools and hence the fish collected from them were not representative of all schools.

Laboratory Procedures

A BASIC program was written to integrate the acoustic data using calibrated target strengths of fishes and length-weight relationships of captured fish. Acoustic target strengths, which were collected using the default target strength of -42.2 dB, were then scaled using fish species and size estimates from trawl data using the equations:

pollock	$TS = 20 (\log L) -66$	(MacLennan and Simmonds 1992)
herring	$TS = 20 (\log L) -68$	(Thorne et al. 1983)
capelin	$TS = 20 (\log L) -68$	(R. Thorne, pers. comm.)

where TS is the calculated target strength and L is the length of the fish in centimeters (equations provided by BioSonics, Inc.). The estimates of fish numbers were used to compute a biomass estimate per cubic meter using the following length-weight relationships for the dominant species where W = weight in grams and L = length in mm:

pollock	$W = (1.89 \times 10^{-6}) L^{3.272}$	(Haldorson et al. 1995)
herring	$W = (5.007 \times 10^{-6}) L^{3.196}$	(L. Haldorson, pers. comm.)
capelin	$W = (2.5 \times 10^{-6}) L^{3.213}$	(Pahlke 1985)

Hydroacoustic profiles for each transect were printed using Surfer software (Keckler 1995, Figure 1). From those profiles we examined every fish school to determine chord length, depth to the top of the schools, bottom depth (when less than 65 m), and average density. The chord lengths of fish schools were determined to be the average of widths measured at 2 m depth intervals and the density of the fish schools were graded as low, medium and high, based on average densities of 0.01-0.20, 0.21-0.35, and > 0.35 g/m^3, respectively. Distance from shore, depth of water 65 - 150 m, and distance from the nearest bird colonies were obtained from Geographic Information System (GIS) computer analysis. Water depths of greater than 150 m were not available in the latest GIS depth coverage for PWS. Therefore, these data were estimated from National Oceanic and Atmospheric Administration charts (numbers 16701, 16705, and 16708).

Side-looking hydroacoustic data were available for the transects at feeding flocks. These data were analyzed by examination of echograms to determine number of fish schools and their chord lengths. The upper depths of these fish schools were assumed to be at 1 m.

Data Analyses

All data analyses were conducted with S-Plus for Windows 3.1 (Statistical Sciences, Inc. 1993). We determined with stem and leaf and boxplots of the acoustic data that transformations were necessary to reduce outliers and make the data more symmetrical about the medians. Transformations which improved plots of the variables were square root of the upper depth of the fish schools, the cube root of their chord length and depth to bottom, and the fourth root of the distance to shore. We did not transform the categorical variable density. We used Wilcoxon rank sum tests to determine if the above mentioned characteristics of fish schools were significantly different between nearshore schools and offshore schools. Wilcoxon rank sum tests were also used to determine significant differences in characteristics between those schools being fed upon by seabirds in flocks and those not being fed upon. The characteristics which were significantly different or which may have been biologically meaningful were then used in a logistic regression (Hosmer and Lemeshow 1989) to determine the log likelihood of any particular school being fed upon. We also more closely examined the fish schools associated with feeding flocks using multiple linear regression (Kleinbaum et al. 1988). Chord length, depth to school, and relative density were used as independent variables to produce a linear fit which may determine how many birds will flock at a particular fish school. Side-looking hydroacoustic data were available from the transects conducted at feeding flocks. Therefore, we pooled the down- and side-looking data to more closely examine the variables which could help to explain the number of birds at a feeding flock. Distance to shore and bottom depth were not available for the side-scanning hydroacoustic data. Hence, we could not use these variables for further analysis.

The fish school variables were transformed as mentioned above. Whereas, the number of larids and total birds in the flocks were log transformed. Two flocks had no larids participating in them. Therefore, in order to avoid negatively infinite values, we added 0.8 to the entire data set before applying the regression analysis which had total larids as the dependent variable.

RESULTS

Initial comparisons of fish schools

During 18 days and 120 transects totaling 587.7 km, only 22 feeding flocks were encountered which ranged in size from 3 to 1065 birds. From the down-looking hydroacoustic data, we analyzed data on 614 fish schools which were not associated with feeding flocks and 26 fish schools which were associated with feeding flocks (Table 1). One hundred and thirty-two of the 614 schools not associated with flocks were found on the nearshore transects. Fish schools which had a chord length of less than 30 m did not show up on many of the plots which had longer than average transect lengths. Therefore, our estimates for chord length were positively biased. However, this bias was equally applied to fish schools associated with flocks and fish schools which were not associated with flocks.

Nearshore fish schools were associated with significantly shallower bottom depths and were significantly closer to the surface than offshore fish schools (Wilcoxon rank sum test; $P < 0.001$, Table 1). Chord length of the fish schools was also significantly narrower nearshore (Wilcoxon rank sum test; $P < 0.001$, Table 1). Characteristics which were significantly different when comparing fish schools from combined nearshore and offshore transects with the fish schools associated with feeding flocks included chord length, bottom depth, and distance to shore (Figure 2). When just the fish schools from the nearshore transects were compared with the feeding flock fish schools, only bottom depth was significantly different (Figure 3).

Logistic regression analyses of fish schools

Distance to nearest kittiwake colony was eliminated from the logistic regression analysis because of the small difference in this variable and because kittiwakes often fly long distances (> 45 km, Irons 1992) while searching for prey in PWS. Although there was also little difference in the density of the fish schools and depth to them, we felt that these could be important biological variables. Therefore, the initial logistic regression comparing all the fish schools with the fish schools which feeding flocks of birds were associated with included these variables along with chord length, upper depth, bottom depth and distance to shore of each fish school. Of these variables, bottom depth and distance to shore as well as chord length and distance to shore had high degrees of correlation (Table 2). Comparisons of the fish schools from only the nearshore transects with the those at feeding flocks had smaller correlations (Table 3).

Chord length and density of the fish schools did not offer a significant contribution to the initial logistic regression fit. However, examination of the residuals (Table 4) revealed at least five outliers. Four of these were associated with three bird flocks which may not have had an accurate hydroacoustic picture of what they were feeding on because of a great distance between the vessel and the flock. The fifth was a school which did not show up on the software plot when graded with the proper maximum biomass. Those five schools were removed from further analysis. Diagnostic analyses on the reduced data set revealed one more outlier, the only other fish school suspected as being too far from a flock. With the removal of the foregoing six fish schools, density was still an insignificant contributor to the fit. Therefore, we decided to remove this variable from further analysis. An ANOVA of additive models was used to determine that the variables upper depth of fish school and chord length did not add significantly to the fit of the logistic regression. The linear fit for the remaining variables produced the results expressed in Table 5.

We also applied a logistic regression to compare only the fish schools on the nearshore transects with the schools associated with feeding flocks. Through diagnostic analyses, we discovered and removed the same outliers which were associated with the feeding flocks as before. The linear fit was not dissimilar from the fit obtained by the analysis using all the fish schools except that the addition of depth to the fish school was slightly significant (Table 6).

Bird numbers at feeding flocks and associated fish schools

Using linear regression analysis of the fish schools at only the feeding flocks, we were able to learn what might be important variables for determining the size of a feeding flock. Chord length was positively correlated, while density and upper depth of fish schools were negatively correlated with flock size in the best fit regression equation (see below). The upper depth of the fish school was, however, more correlated with flock size than density. Removing density from the analysis resulted in a much higher p-value for upper depth of the school but added little to the overall significance of the regression. We also determined from Cp plots (Mallows 1973) that the best regression equation for these data would include all three of these variables.

The best fit regression equation using characteristics of the fish schools as independent variables and total number of birds as the dependent variable was

$$\ln(\text{total birds}) = 1.484(CL)^{1/3} - 0.348(UD)^{1/2} - 0.574(DE) + 1.158$$

where CL is the chord length of the school, UD is the upper depth of the school, and DE is the relative density of the school ($R^2 = 0.8358$, N = 17, F-stat. = 22.0622 on 3 and 13 df, p-value < 0.001).

Results of a regression analysis using larids as the dependent variable were similar to the results using all birds producing the fit

$$\ln(\text{total larids}) = 1.759(CL) - 0.485(UD) - 0.783(DE) + 0.613$$

($R^2 = 0.8474$; N = 17, F-stat. = 24.9875 on 3 and 13 df, p-value < 0.001).

Three-dimensional perspective plots allowed a visual interpretation of the data (Figure 4). Depth to school and chord length may be important variables considered together (Figure 4a). Density appears to increase with increasing bird numbers when chord length is narrow. Yet, at mid to wider chord lengths total birds decrease at mid densities and increase at low or high densities (Figure 4b). At shallow school depths a similar relationship also appears also appears with density and total bird numbers (Figure 4c).

DISCUSSION

Traditionally, transects are used as the sampling unit to determine correlations between seabirds and their prey. Transects can be easily added together or subdivided to determine the scales on which seabirds select feeding areas (Schneider and Piatt 1986, Hunt and Schneider 1987, Schneider 1993). By using the fish schools as the sampling unit, we hoped to learn the characteristics of those schools that are exploited regardless of the scale. We also examined only fish schools associated with seabird flocks that were obviously feeding and compared those schools with schools not associated with feeding flocks. The anticipated advantage of this method was to determine a better correlation with actively feeding birds and their prey.

Comparisons of fish schools

Feeding seabirds may affect the behavior of fish by changing their distribution in the water column (Logerwell and Hargreaves *in press*), and probably school size and density (Maniscalco and Ostrand, Unpubl. Data). Therefore, it cannot be known if those characteristics of fish schools associated with feeding flocks were the result of the seabirds' preference for those schools or their effect upon the schools. However, the general location of fish schools, which includes distance from shore and bottom depth, are probably not greatly affected by the relatively small and ephemeral feeding flocks of PWS.

Bottom depth, distance to shore, and chord length were significant variables by themselves for the formation of feeding flocks in PWS as determined from our initial comparisons of the fish school characteristics. The significance of the former two variables suggests that the seabirds in PWS are selecting habitat rather than fish schools. Proximity to shore and shallow depths have also been associated with higher densities of alcids and larids in other areas (Vermeer et al. 1989, Gaston and Brown 1990, Stone et al. 1995).

The positive correlation between bottom depth and distance to shore makes it difficult to determine which of these might have been more important. This relationship was the main impetus for reanalyzing the data with only the nearshore transects where the correlation between bottom depth and distance to shore was much smaller (Table 3). Inn that reanalysis, only bottom depth was significant. Areas of upwelling created by shallow bottom depths and irregular bottom topography in conjunction with tidal currents appear to attract alcids and larids regardless of distance to shore (Braune and Gaskin 1982, Cairns and Schneider 1990, Coyle et al. 1992). Several replicate surveys at different tidal stages would be necessary to determine if currents and bottom topography had an effect on the feeding behavior of seabirds in PWS.

The notion that seabirds chose fish schools with narrower chord lengths than normal could be a bit perplexing. However, fish schools nearshore had significantly smaller chord lengths than those farther from shore. Also, chord lengths of nearshore fish schools were not significantly different from chord lengths of the feeding flock fish schools and this variable was not a significant contributor to either logistic regression analysis. Therefore, we believe that seabirds in PWS may not select fish schools for their size nor density, but chose fish in areas where forage is easily accessible. This may be realized by the fact that nearshore fish schools were significantly shallower in the water column. Though, feeding seabirds may have driven the fish deeper into the water (Logerwell and Hargreaves *in press*), giving us a positive correlation with fish depth and flock presence in the logistic regression with only the nearshore fish schools.

Forage fishes in PWS can be found at much deeper depths than are accessible by the local seabirds. Larids typically penetrate the water to only shallow depths (Ashmole 1971). The diving depths of marbled murrelets, Tufted and Horned Puffins are not specifically known. However, the maximum diving depth of the Atlantic puffin, a congener to puffins in PWS, is about 68 m (Burger and Simpson 1986). Marbled Murrelets forage most often in water depths between 20 and 80 m (Strachan et al. 1995) and, based on their size (Burger 1991), probably do not normally dive deeper than 40 m. The average bottom depth at the feeding flocks examined in PWS was 50 m and the average depth to the fish schools was only 16 m (Table 1). Shallow areas which help restrict prey to accessible depths in the water column during predictable times provide a reliable source of food for many coastal seabirds in the northern hemisphere (Springer and Roseneau 1985, Vermeer et al. 1987, Brown and Gaskin 1988, Coyle et al. 1992). Based on these studies and others (e.g. Braune and Gaskin 1982, Cairns and Schneider 1990), shallow bottom depths, especially those which induce upwellings, maybe more important than distances to shore for many birds.

Bird numbers at feeding flocks and associated fish schools

The number of feeding seabirds at fish schools appeared to increase with increasing size and decreasing depths of the fish schools as judged from the perspective plots. This is in accord with a typical numerical repsonse (Hassell and May 1974) where predators will aggregate with an increase of prey availability. Flock size increasing with decreasing depth to the fish schools was also expected. Pursuit diving birds often drive forage to near the surface (Grover and Olla 1983, Mahon et al. 1992) and this frequently attracts plunge-diving birds such as larids (Hoffman et al. 1981, Mahon et al. 1992).

The role that density plays in helping to determine bird numbers at feeding flocks appeared to be somewhat ambiguous. Dense fish schools may have smaller chord lengths and hence would be discovered less frequently by predators than fish schools which are spread out more evenly (Brock and Riffenburgh 1960). Whereas, schools with longer chord lengths might attract more birds because there would be a greater area of attack. Small, tightly aggregated feeding flocks of alcids may also affect the density of fish by breaking off a portion of a fish school and driving it to the sea surface into a tight writhing mass (Grover and Olla 1983).

In conclusion, proximity to shore and shallow bottom depths are likely key features for determining where seabirds will feed in flocks in PWS. Areas such as these which consistently harbor large fish schools, high in the water column can attract many feeding seabirds and should be of special interest to managers who make decisions concerning critical habitat. This research was part of ongoing studies in PWS determining long term changes following the Exxon Valdez oil spill of 1989 and to aid in our understanding of coastal ecosytems. The results presented here should be useful to future researchers in understanding ecosystem relationships between apex predators and their prey.

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Table II-1 - Average characteristics of fish schools from nearshore, offshore, and flock transects.

	Nearshore (n = 132)	Offshore (n = 482)	Flocks (n = 26)
chord length (m)	188.5	350.2	194.8
depth to school (m)	8.9	15.9	15.6
bottom depth (m)	75.8	118.7	50.3
density (scaled 1 - 3)	1.48	1.56	1.69
distance to shore (km)	0.55	2.78	0.48
distance to nearest kittiwake colony (km)	12.4	16.9	13.6

Table II-2 - Correlation matrix of the variables from all of the fish schools (Spearman rho; p-values in parentheses).

	chord length	depth to fish	bottom depth	density	dist. to shore
chord length	1.0000				
depth to fish	-0.032 (0.429)	1.0000			
bottom depth	0.256 (0.000)	0.016 (0.682)	1.0000		
density	0.380 (0.000)	0.118 (0.003)	0.112 (0.005)	1.0000	
dist. to shore	0.491 (0.000)	0.213 (0.000)	0.584 (0.000)	0.180 (0.000)	1.0000

Table II-3 - Correlation matrix of the variables from the nearshore fish schools (Spearman rho; p-values in parentheses).

	chord length	depth to fish	bottom depth	density	dist. to shore
chord length	1.0000				
depth to fish	-0.221 (0.007)	1.0000			
bottom depth	-0.193 (0.018)	0.140 (0.085)	1.0000		
density	0.472 (0.000)	0.144 (0.077)	0.082 (0.316)	1.0000	
dist. to shore	0.008 (0.918)	0.129 (0.113)	0.152 (0.061)	0.092 (0.256)	1.0000

Table II-4 - List of diagnostic plots analyzed for the logistic regression and their results. All identified outliers were removed from further analyses.

Diagnostic Plot	Results
predicted values vs. standard residuals	no outliers detected
predicted values vs. absolute residuals	no outliers detected
index plot of standard deviance residuals	fish school numbers 625, 626, and 635 identified as outliers
quantiles of standard normal distribution with 95% confidence envelope	few points outside the envelope
partial residuals	school number 615 identified as an outlier
index plot of Cook's distances	fish school numbers 106, 616, 625, 626, and 635 identified as outliers
predicted values vs. Cook's distances	fish school numbers 625, 626, and 635 identified as outliers
leverage values (h) vs. predicted values	fish school numbers 616, 625, 626, and 635 identified as outliers
leverage values (h) vs. Pearson chi-square statistic	fish school numbers 625, 626, and 635 identified as outliers
leverage values (h) vs. Cook's distances	fish school numbers 616, 625, 626, and 635 identified as outliers

Table II-5 - Results from the logistic regression analysis using fish schools encountered on all of the transects (Residual Deviance = 96.306 on 630 df).

	Parameter Value	Std. Error	t-value
intercept	11.6099	2.3381	4.9654
distance to shore	-1.6025	0.3339	-4.7999
bottom depth	-1.9358	0.4317	-4.4838

Table II-6 - Results from the logistic regression analysis using fish schools encountered on just the nearshore and feeding flock transects (Residual Deviance = 75.203 on 148 df).

	Parameter Value	Std. Error	t-value
intercept	11.6768	2.7520	4.2430
depth to school	0.48717	0.1820	2.6762
distance to shore	-1.2412	0.3572	-3.4746
bottom depth	-2.6236	0.6125	-4.2834

Figure II-1 - An example of a hydroacoustic profile recorded at a feeding flock on the east side of Peak Island showing a large fish school near the surface and a shallow bottom.

Flock # 4 - East Peak Is.

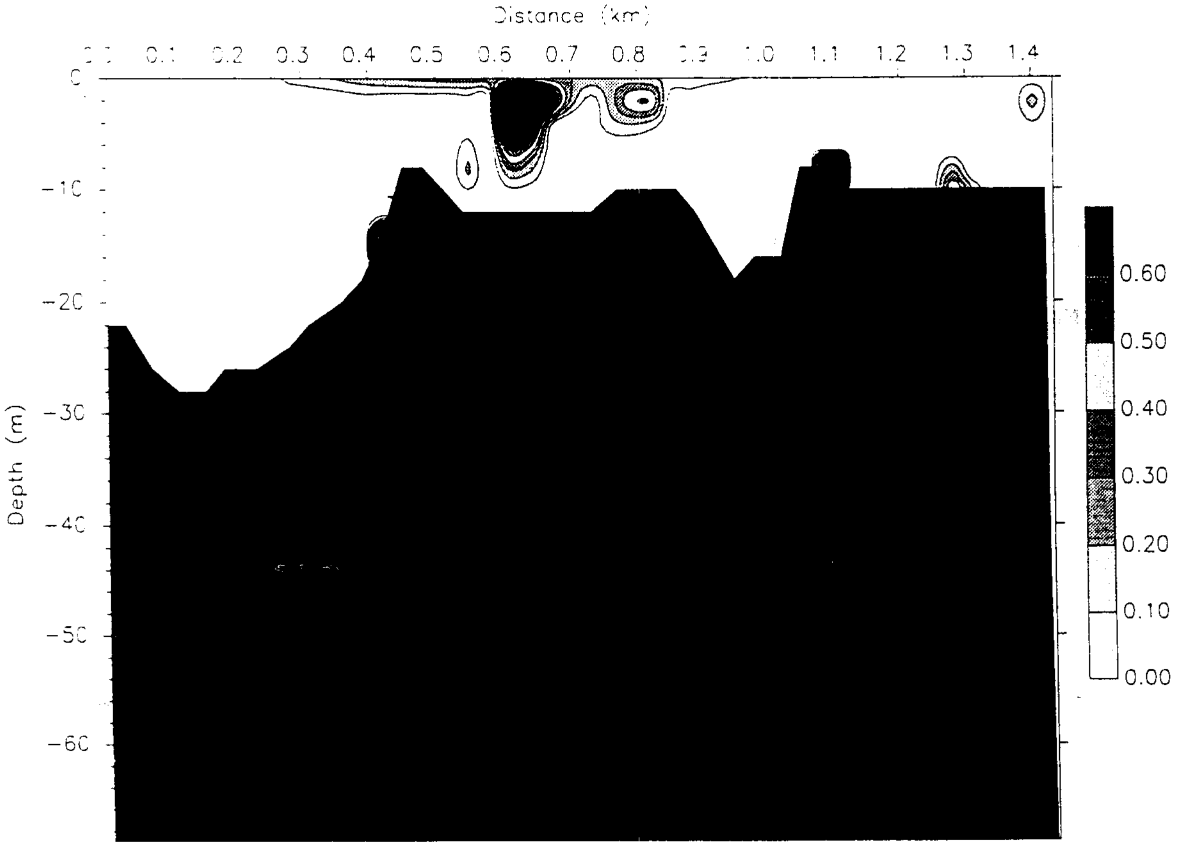


Figure II-2 - Comparisons of fish schools from both nearshore and offshore transects with fish schools at feeding flocks showing standard error bars. See text for transformations.

$^+$ The variable density was relatively scaled (1 to 3) and not transformed.

* $p < 0.05$, ** $p < 0.001$ (Wilcoxon rank sum tests)

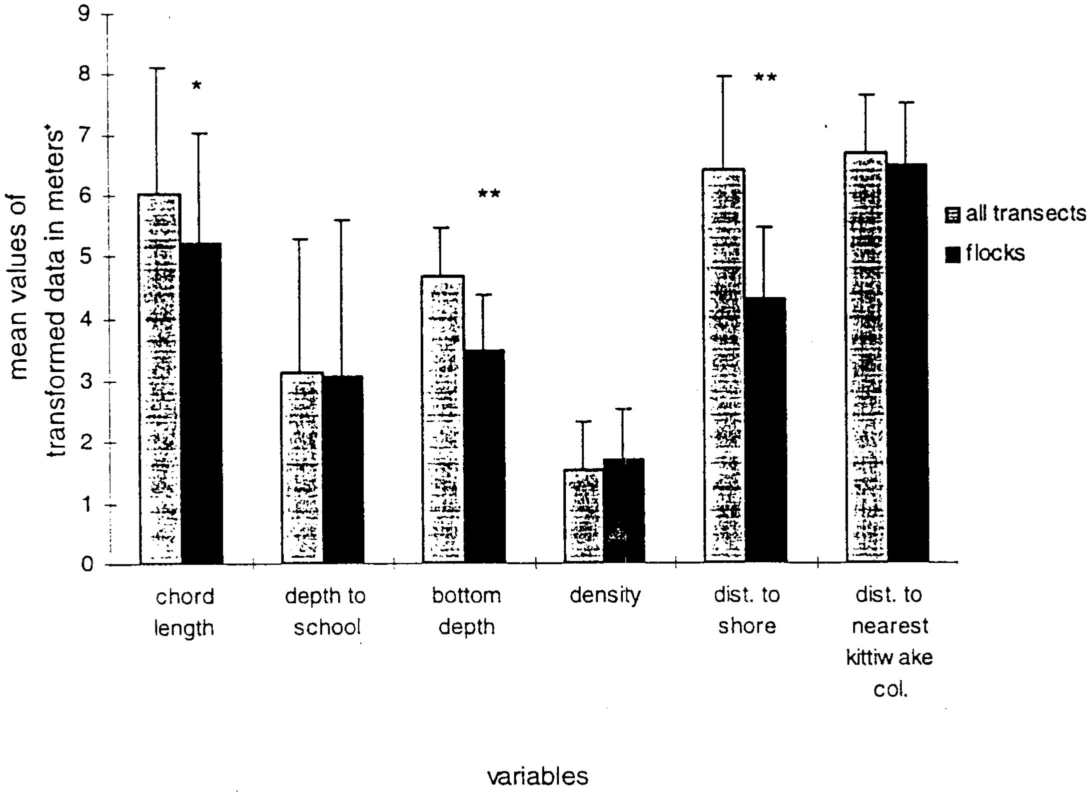

mean values of transformed data in meters*
0
1
2
3
4
5
6
7
8
9
*
**
**
chord length
depth to school
bottom depth
density
dist. to shore
dist. to nearest kittiwake col.
variables
▤ all transects
■ flocks

Figure II-3 - Comparisons of nearshore fish schools with fish schools at feeding flocks showing standard error bars. See text for transformations.

$^{+}$ The variable density was relatively scaled (1 to 3) and not transformed.

** $p < 0.001$ (Wilcoxon rank sum tests)

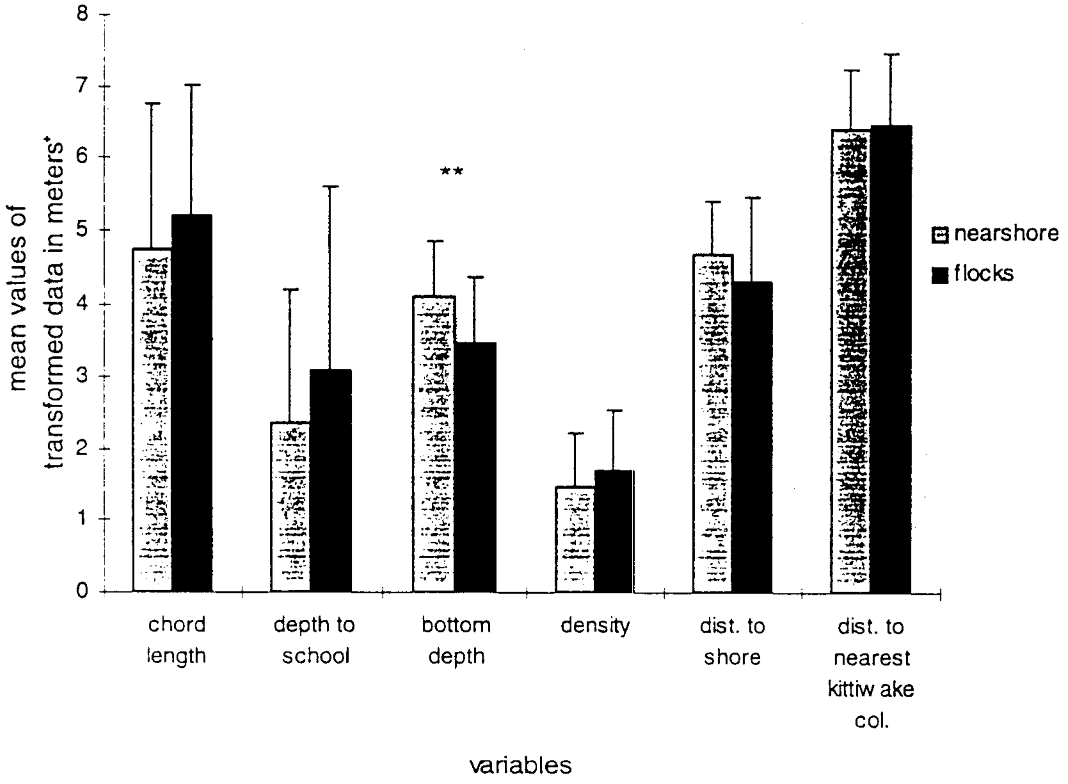
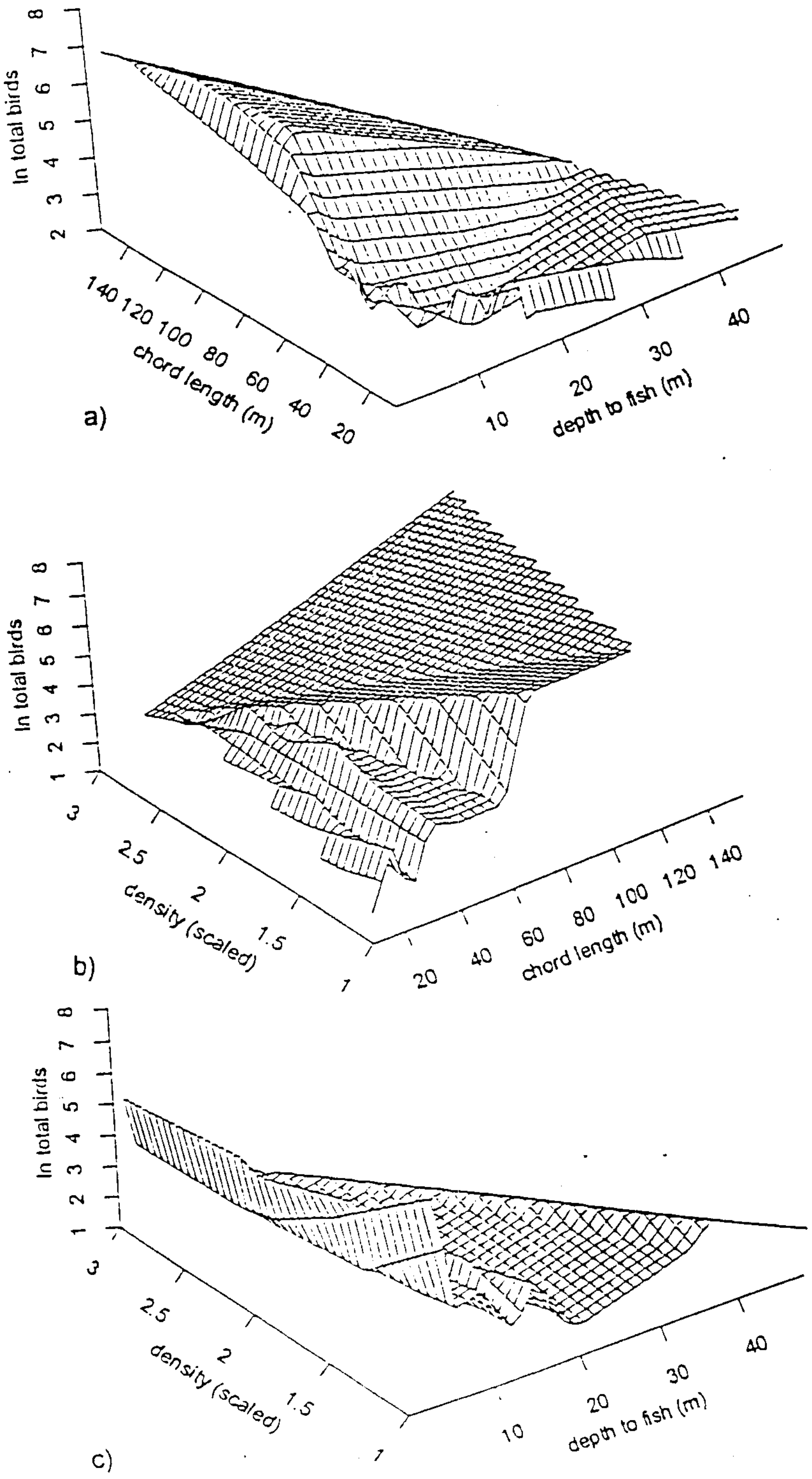

8
7
6
5
4
3
2
1
0
mean values of transformed data in meters*
**
nearshore
flocks
chord length
depth to school
bottom depth
density
dist. to shore
dist. to nearest kittiw ake col.
variables

Figure II-4 - Three-dimensional perspective plots showing the relationship of chord length, depth to fish school, and density on the dependent variable of total number of birds at the feeding flocks.


ln total birds
2
3
4
5
6
7
8
140
120
100
80
60
40
20
chord length (m)
10
20
30
40
depth to fish (m)
a)
ln total birds
1
2
3
4
5
6
7
8
3
2.5
2
1.5
1
density (scaled)
20
40
60
80
100
120
140
chord length (m)
b)
ln total birds
1
2
3
4
5
6
7
8
3
2.5
2
1.5
1
density (scaled)
10
20
30
40
depth to fish (m)
c)

CHAPTER III: RANDOMIZATION EVALUATIONS OF RADIO TELEMETRY AND STRIP TRANSECT METHODS OF DETERMINING FORAGING RANGES OF BLACK-LEGGED KITTIWAKES

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Abstract: We compared strip transect and telemetry methods of determining foraging range by using randomization tests. We evaluated factors that could bias either method and speculated on how they may have affected the respective data sets. We also used bootstrap resampling to: determine the effect of reducing our sampling effort for both methods, speculate on the benefits of increased sampling, and compare the time required to obtain similar variability by both methods. The mean distance birds were observed from their colony determined by telemetry were significantly greater than the mean value calculated from strip transects. We determined that this difference was due 2 sources of bias: 1) a decreasing probability of sighting birds at increasing distance from their colony on strip transect surveys. 2) The maximum distance birds were observed from the colony through telemetry exceeded the extent of the strip transect survey. We compared the observed number of birds seen on the strip transect survey to the predictions of a model of the declining probability of sighting birds at increasing distance from the colony (DPSB). Field data were significantly different from modeled data; however, the field data were consistently equal to or below the model predictions indicating a general conformity to prediction of a DPSB. We concluded that telemetry data provided a more accurate measure of foraging distance than strip transect data for colonial birds. Furthermore, studies that have used strip transect sampling that have not accounted for DPSB may have underestimated foraging range. The simulated reduction of sampling effort for both methods indicated that as sample size was reduced the rate of change in variability was lower for strip transect sampling than telemetry indicating that changes in telemetry sampling efforts would have a greater affect on standard error values. Variability was less for strip transect sampling and less time was required to collect the data. We concluded that strip transect sampling yielded more precise data whereas telemetry data was more accurate.

Key words: Alaska, Black-legged Kittiwakes, bootstrapping, habitat use, Prince William Sound, radio telemetry, randomization tests, Rissa tridactyla, seabirds.

Radio telemetry and strip transects are both commonly used to evaluate resource selection by animals (Litvaitis et al. 1994). However, we found few habitat selection studies for seabirds that utilized telemetry (e.g. Harrison et al. 1981, Trivelpiece et al. 1986, Anderson and Ricklefs 1987) with strip transects the more commonly used method (e.g. Heinemann et al. 1989, Piatt et al. 1989, Erikstad et al. 1990). Consequently comparisons of the techniques have not been made with colonial seabirds as the study subject.

Comparison of these techniques with traditional statistical methods is problematic because of differences in the nature of the data sets. Telemetry consists of locations of individual birds from a known colony which differs greatly from the set of chance encounters of birds obtained by strip transect methods. Computer intensive methods can frequently be applied to problems which cannot be easily addressed by conventional methods (Noreen 1989). We compared telemetry and strip transect data collected on Black-legged Kittiwakes (Rissa tridactyla) in Prince William Sound (PWS), Alaska using randomization tests. We also used bootstrapping methods to simulate the effect of reducing strip transect and telemetry sampling.

We assumed that there would not be significant differences in measures of habitat use determined by both telemetry and strip transect sampling methods, when data were collected on the same population during the same time period. If differences were observed they were probably the result of bias associated with sampling methods and we could speculate on their origin. We also hypothesized that because descriptors of data distribution (variance, standard deviation, and standard error) are exponential functions (Zar 1984), variability of the data would increase exponentially as the sampling effort decreased (Green 1979). By examining how data variability changed with decreasing sampling effort we determined the adequacy of our sampling and the effect of changing sample sizes.

We compared the mean distance birds were observed from their colony as determined by both field methods. We speculated that as the distance from the colony is increased the area in which birds could be observed also increases thereby reducing the probability of sighting birds. We suggest that sighting probability is a function of the area of the marine habitat available to birds for foraging. Island colonies, because they are surrounded by water and thus have the greatest available foraging area, should have the greatest bias associated with strip transect sampling. To describe this bias, we adapted a model from Kinder et al. (1983) and Decker (1995). We considered the available foraging habitat of an island colony as a series of concentric rings. The number of birds expected to be observed (n) in any ring (I) is inversely related to the area of a ring and can be calculated by

$$n_i = N_i a_i / \pi(ro_i^2 - ri_i^2) \qquad \text{formula 1}$$

where N_i is the total number of birds within ring I, ri_i is the inner radius and ro_i is the outer radius of ring I, and a_i is the area surveyed within ring I. Foraging theory suggests that if foraging patches are equal in quality that birds should select patches near the colony (Stephen and Krebs 1986), hence as ri_i and ro_i increases N_i should decrease. If we make a conservative assumption that the number of birds (N_i) remains constant as the distance from the colony increases, then the predicted number of birds observed decreases (n_i). We assume that the probability of sighting birds within rings remains constant, i.e. the birds are randomly distributed within rings. For fjords and bays, as in this study, the above formula can be modified by introducing a variable (j), the proportion of ring I that is marine habitat:

$$n_i = N_i a_i / j_i \, \pi(ro_i^2 - ri_i^2) \qquad \text{formula 2}$$

This equation may be solved to approximate the number of birds within a ring:

$$N_i = n_i j_i \, \pi(ro_i^2 - ri_i^2) / a_i \qquad \text{formula 3}$$

We approximated formula 2 and compared the predicted n_i values to those obtained from strip transect sampling to test our predictions of the diminishing probability of sighting birds as distance from their colony increases (DPSB).

We anticipated 3 additional sources of bias that could have influenced the comparison of flight distances from the colony: 1) Transmitters were only attached to birds with chicks. Birds without chicks, free of provisioning and nest attendance requirements, may be more likely to range further during foraging flights (e.g. Wilson et al. 1988). Observations of non-nesting kittiwakes would tend to increase the mean distance from the colony for the strip transect data set. 2) Gessamen and Nagy (1988) and Gessamen et al. (1991) have demonstrated that the attachment of radio transmitters can increase the energy demands of flight. If the kittiwakes in this study were affected similarly then bird with attached transmitters may have made shorter foraging flights. This source of bias would reduce the mean distance from the colony for the telemetry data set. 3) The potential maximum distance from colony obtained from telemetry was unlimited whereas the furthest point from strip transect data was constrained by the survey design. If the survey did not cover the full extent of the foraging range of kittiwakes from the study colony then a smaller mean distance would be obtained from the strip transect data. If the mean distance from colony, determined by strip transects was greater then bias sources 1 and/or 2 had a greater effect than other factors. If the telemetry data yielded a greater mean distance from colony we planned to reduce the affect of factor 3 by deleting flight distances within the telemetry data set that exceeded the distance to the furthest point on the strip transect survey and repeat the analysis.

METHODS

We conducted this study in PWS, an inland waterway, 10,000 km^2, located on the southern coast of Alaska. The climate is maritime with record annual precipitation > 8 m and moderate temperatures for the subarctic (Royer 1979). The coastline is rugged, with mountains up to 4-km elevation, and numerous fjords and tidewater glaciers. We selected the Black-legged Kittiwake colony located at Shoup Bay (61° 09' N, 146° 35' W), the largest in PWS with 5628 breeding pairs in 1995 (D. B. Irons, US Fish & Wildl. Serv., Anchorage, Alaska, unpubl. data) for the focus of this study. Shoup Bay adjoins Port Valdez and Valdez Arm in northern PWS.

For the telemetry study, birds on accessible nests with eggs or chicks were captured with a noose-pole. Advanced Telemetry Systems, Inc. radio transmitters, 166 to 167 MHZ, were attached to 24 adult birds. The radio packages weighed approximately 9 gm, which is less than 2.5% of a kittiwake's body weight, and were attached under the base of the tail (Anderson and Ricklefs 1987, Irons 1992). Flight tracks were determined by following radio tagged birds in a 8-m boat 14 July - 5 August 1995. Birds were tracked both visually and with telemetry equipment. A following distance of 50 - 100 m was maintained to limit the effect of tracking upon behavior. Bird locations were determined, using a global positioning system instrument (GPS), at foraging sites and where birds changed direction of their flight. Only followings that were successful in determining the furthest point from the colony of the flight were used in analysis (n = 7). Return flight locations were not included the analysis (Fig. 1).

We chose the boundaries for the strip transect study area based upon the expected foraging range of Black-legged Kittiwakes at the Shoup Bay colony. Predictions of foraging ranges were determined using previous radio telemetry studies of Black-legged Kittiwakes from the same colony (Irons 1992). We randomly selected the starting point for transects (n = 24) from 20 points equally spaced within the first 2' of the southern boundary of the study area. We arranged 11 east/west transects at 2' latitude intervals north of the initial starting latitude and 13 zigzag transects to increase data collection of nearshore habitats (Fig. 2). Zigzag transects were inserted where east/west transects terminated at land. From the location at which the previous east-west transect terminated, the zigzag transect extended to the point half the distance to the next east-west transect at which the water depth was 100 m. An additional transect extended to the beginning of the next east-west transect. Potential transect segments that were < 1.0 nautical mile were not included and additional potential segments were deleted for safety considerations.

We replicated the strip transects of the study area twice, 26-28 July and 5-7 August 1995. Observations were made from the second deck, 8-m above the water, on the 24-m vessel, the M/V Pacific Star. Continuous counts were made of all kittiwakes observed within 100 m of the starboard side of the vessel. We used only locations of flying birds for this study (n = 255). Bird observations were made by scanning ahead of the ship using binoculars. Recorded observations were made prior to the ships presence influencing bird activities. Data were recorded when the ship was closest to the point at which the birds were first observed. We recorded data directly into a computer file using custom software that also recorded the ships position and time for each entry. Positions were determined with a GPS.

We developed a set of random locations from the telemetry field data to mimic the chance sightings that were obtained from the strip transects. We assume that the birds flew in a straight line between the GPS locations that had been recorded during flight following. A geographic information system (GIS) was used to convert the GPS locations into contiguous tracts. Then we converted these routes to points with a resolution of approximately 100 m. For each point along tracts we calculated the distance to the study colony. This data set was then used as the pool of potential Black-legged Kittiwake locations from the telemetry method. We also used the GIS to calculate the distance to shore and the distance to the nearest colony from bird observations made along the strip transects.

To compare telemetry and strip transect data we modified a randomization program from Noreen (1989). A random subset (n = 255) was extracted from the telemetry flight data (n = 1504) to yield a data set of equal size to strip transects. Mean distances from the study colony were calculated for the strip transect and telemetry data and the difference for these variables was then determined. We then conducted a randomization test, 1000 shuffles, and used the difference in mean values as the actual test statistic to determine the significance level (Noreen 1989). The number of randomly sampled test statistics greater than or equal to the actual test statistic divided by the number of shuffles provided an approximate probability. We determined the maximum distance from the study colony on the strip transect survey and the greatest distance that radio tagged birds were observed from the colony. To reduce the effect of unequal maximum distances from colony among data sets, all values greater than the smaller maximum value were deleted. We used a randomization test, 1000 shuffles (Noreen 1989) to determine if the deletions resulted in a significant change in the data set. We then reran comparison of the strip transect and telemetry data using the reduced data set.

To test the model of DPSB, we calculated expected values of n_i using formula 2 and compared them to the mean n_i values observed during the 2 replicates of the strip transect survey. We measured the area of available foraging habitat within 12 concentric rings, with widths of 2 nautical miles (Fig. 3), using GIS. The outer most ring contained the furthest distance from the study colony on the strip transect survey. We determined the mean number of kittiwakes observed in each ring during the 2 strip transect surveys. We multiplied the transect length within in each ring by the transect width, 100 m, to determine the area surveyed within each ring. For the inner most ring we used values for area available, area surveyed, and number of birds observed, in formula 3 to determine a value for N_1. To be consistent with our assumption that each ring contained the same number of birds we used the calculated value of N_1 for N_i and the respective values for area surveyed and available area in formula 2 to determine values for n_i for all rings. We compared the expected n_i values calculated using the model with the mean observed values graphically (Fig. 6) and with a chi-square test. Using N_1 for all N_i values ensured that the observed and predicted values of n_1 would be equal thereby facilitating the graphical and statistical comparisons.

To evaluate the effect of reducing the sampling effort we wrote a bootstrapping program that simulated decreased sampling. We randomly selected 48 transects, with replacement, from the strip transect data set and used the kittiwake locations from those transects to create a pseudo survey. Mean distance from the Shoup Bay colony was then calculated for pseudo survey. We then repeated the process for 1000 iterations and calculated the mean of mean distances and standard error. We repeated the randomization with successively fewer number of transects ($\underline{n}$ = 48..1). We applied the same bootstrapping program to the telemetry data set, simulating the affect of reducing the number of kittiwake flights ($\underline{n}$ = 7..1).

RESULTS

The mean distances from the Shoup Bay colony calculated from telemetry and strip transects were 35.5 km and 22.2 km, respectively ($\underline{P}$ = 0.001, $\underline{n}$ = 255, $\underline{NS}$ = 1000). The maximum distance from colony for the telemetry data set and the furthest point from colony on the strip transect survey was 62.3 km and 47.3 km, respectively. We deleted 314 locations from the telemetry data set with values greater than 47.3 km. The mean distance to colony for the telemetry data was reduced significantly to 29.4 km ($\underline{P}$ = 0.001, $\underline{n}_1$ = 1504, $\underline{n}_2$ = 1190, $\underline{NS}$ = 1000). We again randomly selected 255 locations from the reduced data set, reran randomization comparison of sampling methods, and determined the telemetry and strip transect data remained significantly different ($\underline{P}$ = 0.001, $\underline{n}$ = 255, $\underline{NS}$ = 1000).

Our expected number of kittiwakes obtained using formula 2 was significantly different from the number observed in rings ($\underline{X}^2$ = 37.9, df = 11, $\underline{P}$ = 0.001). The observed values were consistently equal to or below the expected values (Fig. 4).

Simulating a reduced sampling effort for both strip transect and telemetry studies resulted in exponentially increasing variability (Fig. 5). SE values for the telemetry data set were greater than those obtained by the strip transect method (2976 and 2628 SE distance to colony, for telemetry and strip transects respectively). SE values most similar to those obtained by the telemetry method were achieved with a reduced sampling effort of 34 transects (2976 and 2891 SE for telemetry and strip transects, respectively) out of 48 transects surveyed.

DISCUSSION

If either the energy cost of carrying radio transmitters and/or the bias associated with using only birds with chicks in the telemetry study had a greater effect than other sources of bias, then we expected strip transect data to yield a greater mean distance from the study colony. However, this was not the case. The greater mean distance from colony calculated from the telemetry data suggests that the differences in maximum distance from colony for each data set and/or DPSB had greater influence. Our adjustment to the telemetry data set and subsequent comparison of the reduced data set to the original isolated a significant bias associated with differences in maximum distances. This problem is the result of underestimating the foraging range of kittiwakes when designing the strip transect survey. However, this source of bias does not account for all of the error. By eliminating distances that were larger than those that could be obtained from strip transects we identified a significant bias associated with DPSB. Both sources of error had an influence on our results.

The model of DPSB did produced significantly different results from field observations. Differences may have resulted from assuming an equal number of birds in all rings and a consistent probability of sighting birds within rings. Kittiwakes within PWS (Irons 1992) and other seabird species elsewhere (e.g. Hunt et al. 1990 and Coyle et al. 1992) have been shown to be associated with areas where forage is consistently available. Our telemetry data also indicated that kittiwake activity was relatively high in a few areas and absent in other areas (Fig. 1). However, in all cases the observed number of birds within each ring was equal to or less than predicted by the model indicating that although the distribution of kittiwakes is patchy, their density does decline to or below predictable levels as distance from their colony increases. These findings indicating a general conformity to the prediction of a DPSB. The results of our randomization comparison and modeling efforts were consistent, confirming our speculation on the bias of strip transect data due to DPSB. We conclude that telemetry data gave a more representative indication of foraging distances than did strip transect sampling. Studies that have used strip transect data to describe the distribution of birds relative to colony location and have not accounted for DPSB (e.g. Wilson et al. 1988, Leopold et al. 1995) were likely to underestimate foraging ranges. This bias could be reduced using weighted averages on the strip transect data as opposed to simple means as we have done. We have used mean distances from colony to make comparisons among our data sets; however, wildlife biologist more frequently use these types of data to determine foraging ranges or foraging distance (e.g. Wilson et al. 1988, Leopold et al. 1995). Weighted means are not applicable to these more common methods of interpretation, yet the DPSB remains a source of bias. In these applications, bias can be reduced by sampling the same proportion of the total area within each ring.

Our simulation of reducing sampling effort resulted in a exponential increases in variability as sample size was decreased for both methods; however, the rate of change in variability was greater for the telemetry data (Fig. 4). These results indicate that we could greatly reduce our strip transect sampling before the standard error increases dramatically. Similarly we can project that a considerable increase in sampling effort would be required to make a relevant reduction in standard error of strip transect data. Variability of the telemetry data is noticeably declining with 7 flight followings. We expect that an increase in our sampling effort would continue to result in a reduction in variability. Similar levels of variability to those obtained by telemetry could have been achieved by a reduced strip transect survey. Strip transect data was collected in 6 days and our simulation indicates that similar variability to telemetry data could be obtained with less time; whereas, the telemetry data was collected in 7 days of following kittiwakes with additional time spent on capturing birds and unsuccessful chases. This comparison indicates that our strip transect sampling yielded similar variability for less time spent sampling.

We have shown that telemetry yields less bias predictions of foraging range. However, we have also demonstrated that telemetry will require greater field time to achieve similar levels of variability to those obtained by the strip transect method. In essence then, the statistical trade off between methods is one of accuracy versus precision.

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Fig. III-1. The flight tracts of 7 Black-legged Kittiwakes followed by boat during telemetry studies conducted in Valdez Arm, Prince William Sound, Alaska.

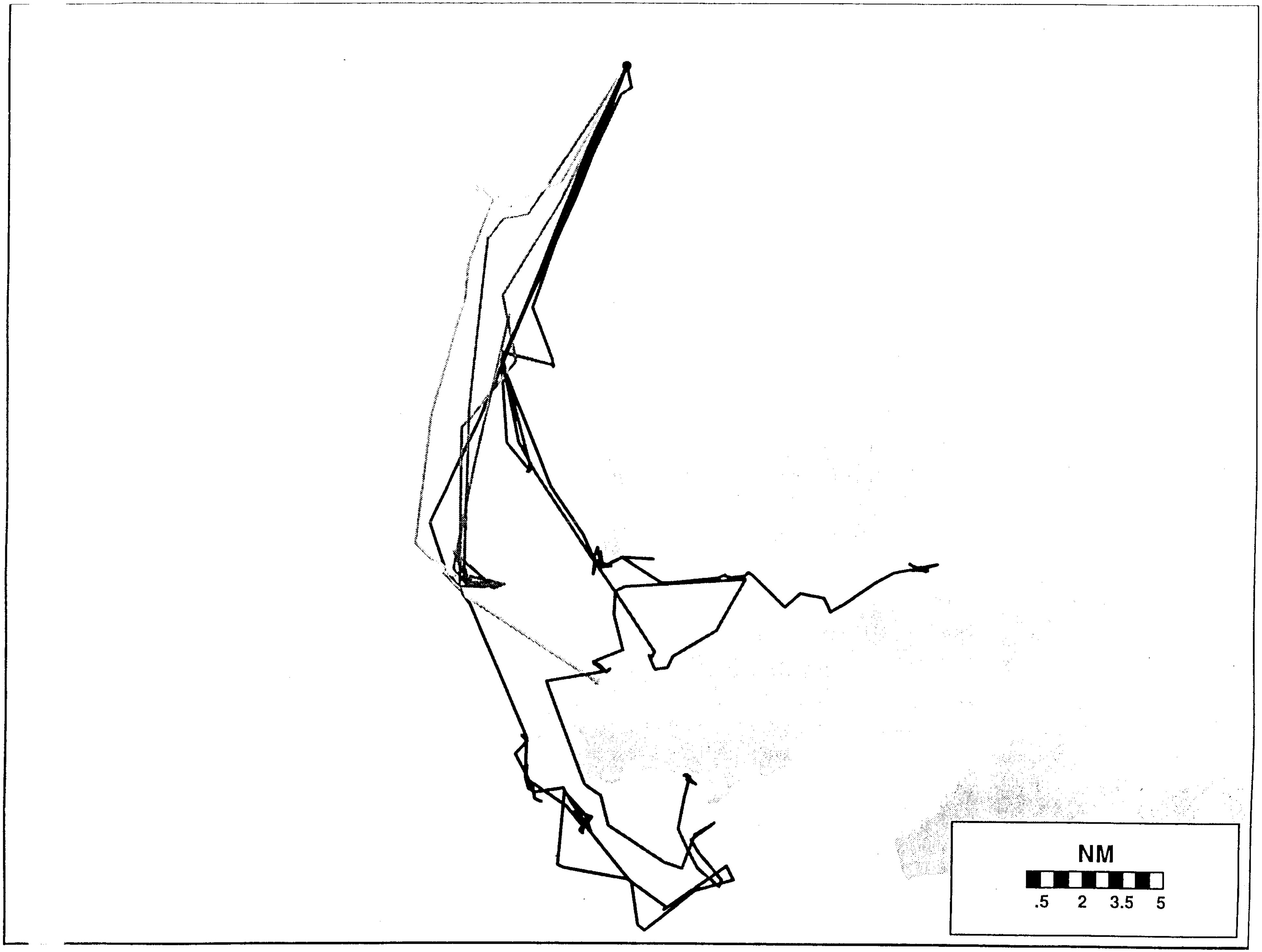

NM
.5
2
3.5
5

Fig. III-2. Transects conducted to obtain location data on Black-legged Kittiwakes in Valdez Arm, Prince William Sound, Alaska.

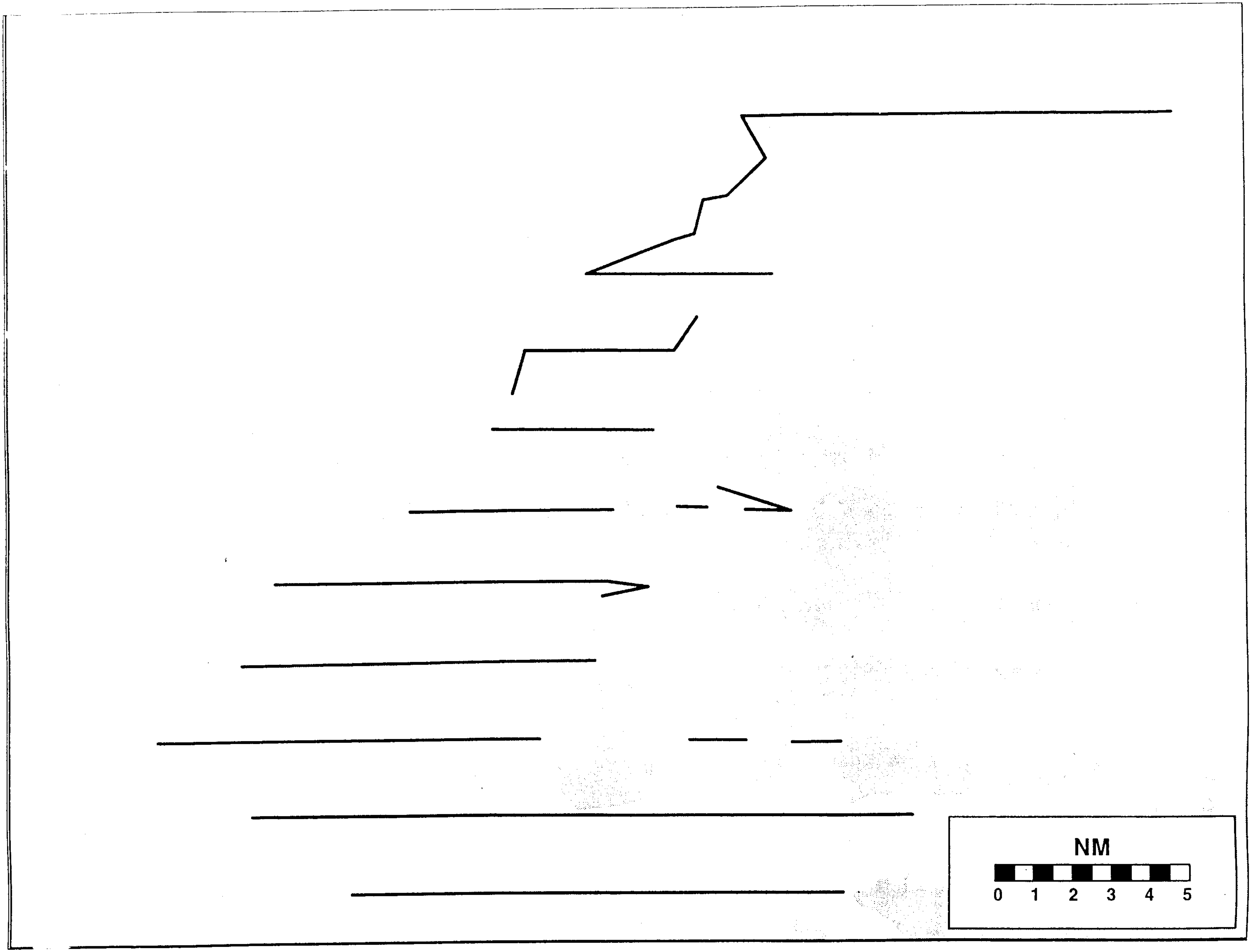

NM
0 1 2 3 4 5

Fig. III-3. Concentric rings extending out at 2 nautical mile intervals from the Shoup Bay colony located in Valdez Arm, Prince William Sound, Alaska.

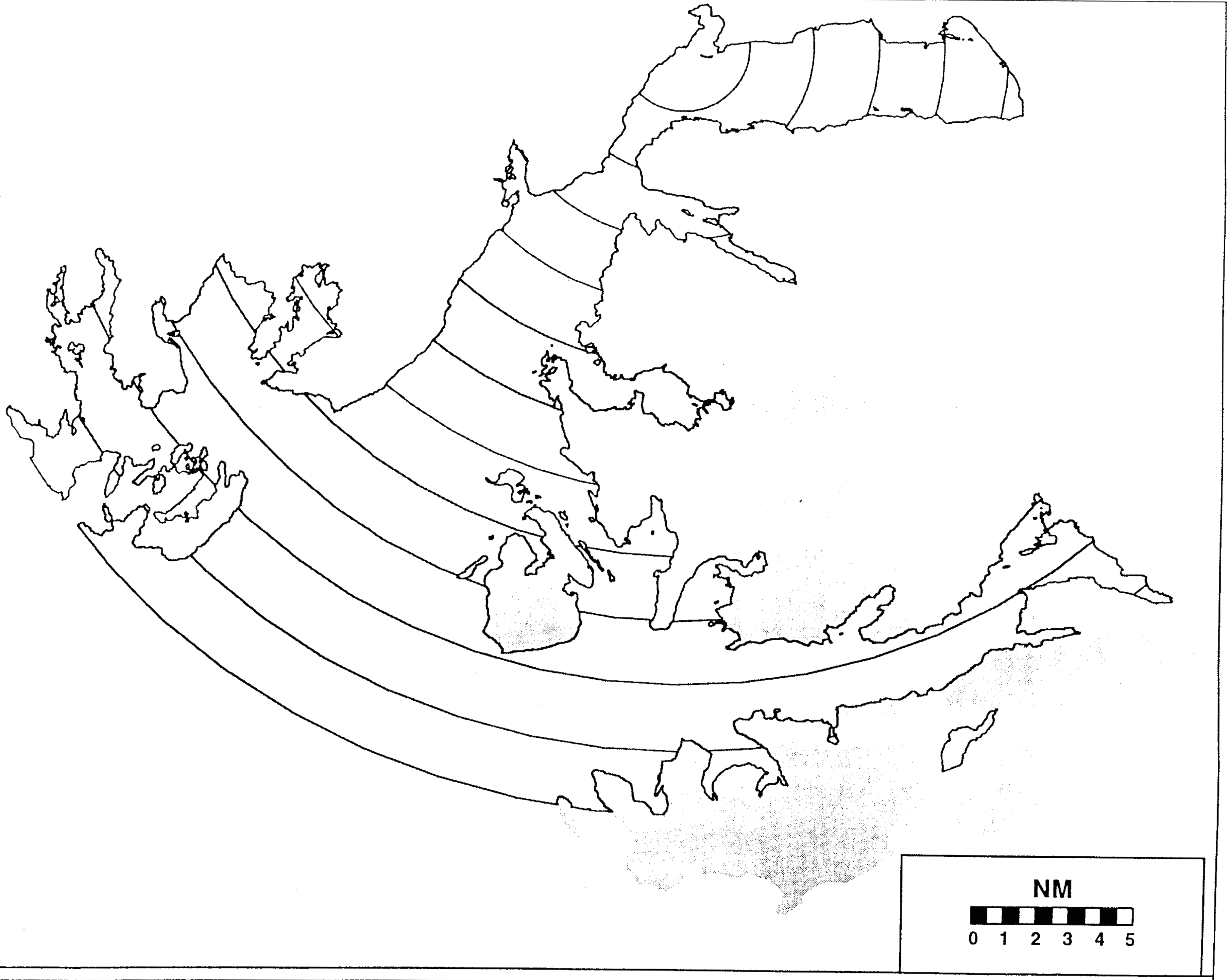

NM
0 1 2 3 4 5

Fig. III-4. Comparison of the number of Black-legged Kittiwakes observed within concentric rings (Fig. 3), extending from the Shoup Bay Colony, Prince William Sound, Alaska, to numbers predicted by a model of diminishing probability of encountering birds at increasing distance from a colony. Observed data was obtained on 2 surveys of systematically arranged transects (Fig. 2).

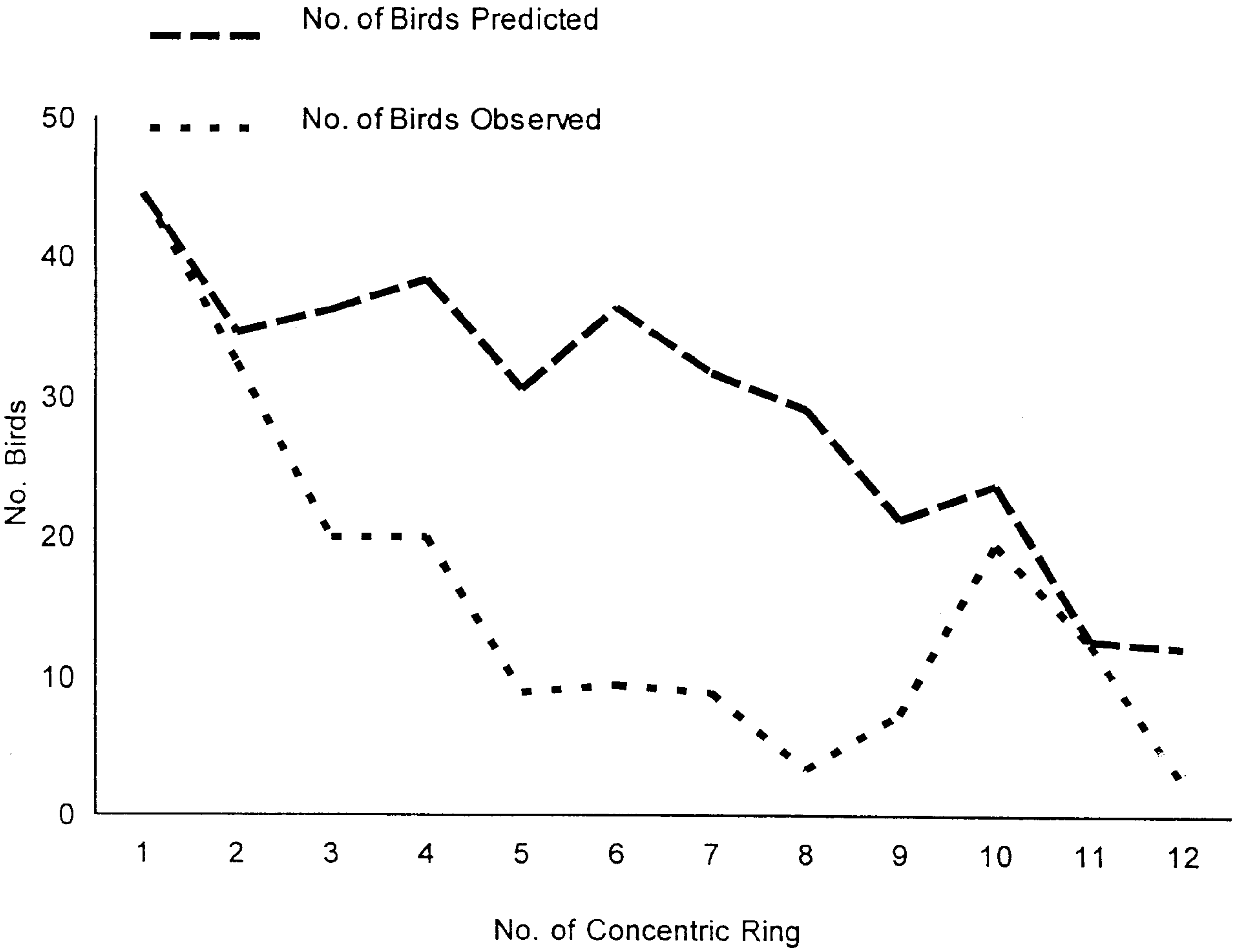
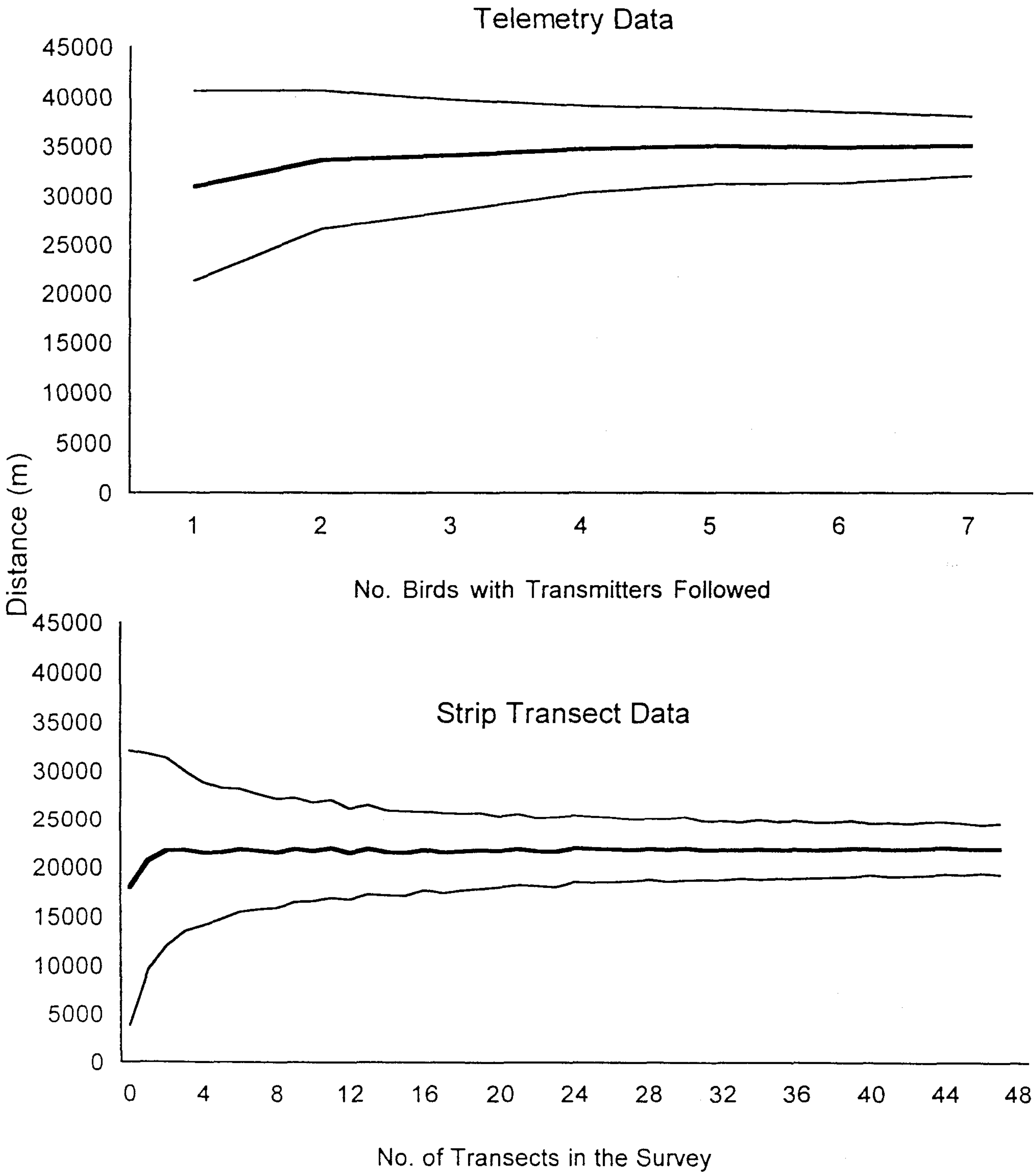

No. of Birds Predicted
No. of Birds Observed
50
40
30
20
10
0
No. Birds
1
2
3
4
5
6
7
8
9
10
11
12
No. of Concentric Ring

Fig. III-5. The results of a bootstrapped simulated reduction of the sampling efforts of telemetry and strip transect studies of Black-legged Kittiwake in Valdez Arm, Prince William Sound, Alaska. The simulation examined how the mean (bold lines) and standard errors (fine lines) values for distance birds were observed from their colony changed as sampling effort was reduced.


Telemetry Data
Distance (m)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
No. Birds with Transmitters Followed
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Strip Transect Data
0
4
8
12
16
20
24
28
32
36
40
44
48
No. of Transects in the Survey

CHAPTER IV: FLOCK COMPOSITION AND SEABIRD BEHAVIORS AT FEEDING ASSEMBLAGES IN PRINCE WILLIAM SOUND, ALASKA

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Abstract: We examined the behaviors of seabirds at feeding flocks in Prince William Sound, Alaska during July/August 1995 to determine the factors which may enhance or limit the availability of forage to surface feeding birds. The presence of larids and alcids at feeding flocks was positively correlated, suggesting complimentary feeding habits. On the other hand, the frequency of kittiwake plunge dives was negatively correlated with the relative presence of larger gulls in the flock. Kittiwakes preferred to plunge-dive for fish while Glaucous-winged Gulls hop-plunged from the water surface to maintain their position at the center of the feeding flock. Kittiwakes had a feeding success of 80.6% and lost 4.8% of their captures to intraspecific piracy and 6.7% to interspecific piracy. Kleptoparasitism was most intense against kittiwakes in tightly aggregated feeding flocks and against alcids in loosely aggregated flocks. Jaegers preferred to kleptoparasitize kittiwakes in the largest flocks.

Key words: seabirds, feeding behaviors, feeding success, kleptoparasitism, Prince William Sound

INTRODUCTION

Seabirds often gather in flocks to exploit patchily distributed prey (Brown 1980, Obst 1985, Heinemann et al 1989). Behavioral studies of seabirds at mixed-species feeding flocks have added substantially to our view of how food is obtained by this group of animals searching in an environment which is generally hidden from sight (e.g. Sealy 1973, Hoffman et al. 1981, Chilton and Sealy 1987, Mahon et al. 1992). Species composition of seabird flocks may vary widely depending on the feeding situation (Duffy 1983). Many seabirds play specific roles in the formation, continuation, or breakup of the flocks (Hoffman et al. 1981, Duffy 1983, Chilton and Sealy 1987, Mahon et al. 1992). The presence or absence of certain key seabirds can affect the availability of forage to a number of other species. For instance, cormorants which dive in the middle of fish schools may have the effect of breaking up the schools and making them unavailable to other seabirds (Hoffman et al. 1981). Duffy (1986) found that roseate terns (*Sterna dougalli*) were more successful when foraging alone in dispersed flocks than in tightly spaced flocks with common terns (*S. hirundo*). Yet, individual foraging success of certain species can increase with the number of birds involved (Gotmark et al. 1986).

Methods by which seabirds feed vary from dipping in petrels to pursuit diving in auks and penguins (Ashmole 1971). Depending upon their feeding circumstances at sea, gulls and kittiwakes may choose to surface seize, plunge-dive, hop-plunge, dip or kleptoparasitize (steal food which had been captured by another animal). These behaviors may depend upon the density of birds in the aggregation or upon how the forage is made available. Both of these factors were used to delineate different types of feeding flocks (Hoffman et al. 1981). The feeding method of a particular seabird species may make forage unavailable to other species through interference competition (Shealer and Burger 1993) or through dispersion of the prey (Hoffman et al. 1981).

Kleptoparasitism is one feeding strategy which is common in many gulls and is a way of life for jaegers (Brockman and Barnard 1979). The success of a kleptoparasite could be dependent on factors such as weather condition, size of prey carried by host, or stage of the breeding season (Furness 1987). Instances of kleptoparasitism in many birds may increase with decreasing access to food (Brockman and Barnard 1979, Duffy 1980, Temeles and Wellicome 1992, Oro and Martinez-Vilalta 1994, Oro 1996). High rates of this feeding strategy in seabirds could adversely affect populations of the host (Furness 1987) and failure of one host species to breed could cause increased pressures on an alternate host (Arnason and Grant 1978).

In this chapter we describe the species composition seabirds at different flock types in Prince William Sound, Alaska. Prey capture techniques by gulls and kittiwakes are compared between the flock types. We further attempt to determine how the behaviors of different seabirds affect the availability, accessibility, and retention of their forage by examining cooperation between alcids and larids, interference competition between gulls and kittiwakes, and kleptoparasitism by jaegers and other larids.

STUDY AREA

Prince William Sound (PWS), Alaska is a large estuarine embayment of the northern Gulf of Alaska which provides important foraging and breeding habitat for many seabirds (Isleib and Kessel 1973, Irons et al. 1988). Water depths exceed 870 m and the numerous bays and fjords along with more than 150 islands form at least 5000 km of shoreline. High precipitation rates keep the sea-surface salinity low and catabatic winds flowing down the fjords transport this low-salinity water out of PWS, generally through Montague Strait and the smaller straits and passages of the southwestern region. The Alaska coastal current provides the major inflow of marine water through Hinchinbrook Entrance (Royer et al. 1990). Diurnal tidal changes in PWS can also create currents exceeding 5 km/hr through narrow passages.

Seabirds which commonly forage in flocks in PWS include black-legged kittiwakes (*Rissa tridactyla*), glaucous-winged gulls (*Larus glaucescens*), mew gulls (*Larus canus*), marbled murrelets (*Brachyramphus marmoratus*), tufted puffins (*Fratercula cirrhata*) and horned puffins (*F. corniculata*). The former three species are members of the family Laridae and the latter three are members of the alcidae. We occasionally refer to these birds as larids and alcids, respectively. Jaegers (*Stercorarius* spp., family: Laridae) kleptoparasitize at these flocks to an unknown extent. Three focal areas in PWS (Figure 1) were chosen for study because of their habitat which is critical to these seabird species of interest.

Some of the forage fish available to nesting seabirds in PWS include, Pacific herring (*Clupea pallasi*), capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), walleye pollock (*Theragra chalcogramma*), and eulachon (*Thaleichthys pacificus*) (Sanger 1987, Haldorson et al. 1995). Herring in PWS did not appear to be seriously affected immediately following the spill. However, in 1993, greatly reduced numbers of herring returned to spawn and many of them had ulcers and hemorrhages of the skin and fins (Meyers et al. 1994, Brown et al. 1996). Declines in sand lance delivered to nestling pigeon guillemots (*Cepphus columba*) following the spill may also reflect a decrease in the abundance of this prey species (Hayes 1995, Oakley and Kuletz 1996).

METHODS

Field Procedures

From a random starting point, we selected transects in the three areas of primary interest along lines of latitude 2 nm apart. Since many seabirds are often found nearshore or in shallow depth gradients (Vermeer et al. 1989, Stone et al. 1995), zig-zag transects were conducted nearshore by sampling on a straight line from shore to the halfway point between adjacent transects where water depth was 100 m. From this point, the ship continued sampling to the beginning of the next transect. The study period (July 20 - Aug. 12) was chosen to include the peak time of chick provisioning for many seabirds in PWS. Observations were made with 8 x 40 binoculars, 6 m above the water line from a 26 m vessel traveling at approximately 5 knots while conducting hydroacoustic surveys to estimate forage fish and seabird distributions and abundances. Transect lines were left to more closely examine feeding flocks within 300 m of either side of our vessel.

Trawl data were collected from a separate vessel which was directed by the hydroacoustic vessel to sample schools of forage species in which there was the most uncertainty as to prey species and/or age class composition. A modified Canadian midwater herring trawl (100 m^2 opening), an improvised pair trawl, and a dip net were used to verify fish school compositions as estimated from the acoustic data. These trawls were only used on the larger fish schools and hence the fish collected from them were not representative of all schools.

We collected behavioral data on feeding flocks upon leaving the transect and continued to do so until the flock broke up naturally or became disturbed by our presence. A feeding flock was defined as an aggregation of three or more seabirds actively feeding as observed by diving alcids with fish in their bill or larids plunge-diving, dipping, or hop-plunging. While at a feeding flock, one observer videotaped the flock for later analysis while another recorded detailed information on the flock, including: location (lat. and long.), date, time, weather conditions, wind speed and direction, sea state, water and air temperatures, area covered by flock in m^2, any noticeable physical features (e.g. upwellings, fronts), flock composition with numbers and locations of each species within the flock, kleptoparasitic and aggressive interactions with as much detail as possible, other feeding methods used and their success, and the duration and fate of the flock if known. We categorized feeding methods as surface-seizing, dipping, surface-diving, plunging, pursuit-plunging, piracy (Ashmole 1971), and hop-plunging (Hoffman et al. 1981). Flock types were loosely classified following Hoffman et al. (1981): I) small, short duration flocks over tightly clumped prey; II) large, persistent flocks over more broadly dispersed prey; III) flocks associated with sites where forage was concentrated by downwelling or other hydrophysical influence, determined by a subjective evaluation of oceanographic features.

After approximately 15 minutes of examining seabird behaviors at the flocks or as soon as the flocks stopped feeding, our vessel was maneuvered through the area of activity to produce an acoustic profile of the forage. This was normally done more than once with the location of greatest feeding activity to the right of the vessel where the side-looking transducer was viewing. However, on a few occasions the forage was in too close to shore for the vessel to maneuver safely.

Data Analyses

Analysis of the videotapes included categorizing the feeding methods used, frequency of these methods, and frequency of kleptoparasitic and aggressive interactions. We computed the independence of the different flock types by species composition using a Chi-square contingency table. The association between kittiwakes and murrelets, murrelets and puffins, and the relationship of kittiwake dive frequencies and gull presence in the flocks was analyzed using Spearman's rank correlation. These data were analyzed in S-Plus (Statistical Sciences, Inc. 1993). Chi-square and Fisher's Exact Test were also used to compare and contrast the behaviors of different seabirds at the different flock types.

RESULTS

Flock types and species composition

In PWS flocks are generally smaller than those encountered in more oceanic regions (e.g. Hoffman et al. 1981, Duffy 1983). During 18 days of hydroacoustic sampling 120 transects totaling 587.7 km, only 22 feeding flocks were encountered and ranged in size from 3 to 1065 birds (mean = 135.8). Fifteen bird species participated in feeding flocks with a maximum of 11 species at a Type II flock (Appendix 4). Species participation in the three flock types was significantly different overall ($\chi^2 = 214.65$, df = 8, $P < 0.001$; Table 4.1). However, species compositions of Type I and II flocks were not significantly different ($\chi^2 = 7.025$, df = 4, $P = 0.135$).

Black-legged kittiwakes and marbled murrelets were the most numerous species in all three flock types (Appendix 4). A scatter plot of their presence in the flocks suggested rank ordering them before analysis. Kittiwake presence in flocks was positively correlated with murrelet presence (Spearman's rho = 0.613, $P = 0.005$, Figure 4.1). Tufted puffins and glaucous-winged gulls were also a predominant species in Type I and II flocks, and the correlation results for all larids and alcids at the flocks were the same as those for kittiwakes and murrelets.

Marbled murrelets and tufted puffins were present together in great numbers in Type II flocks. However, in the only two Type I flocks in which tufted puffins participated, murrelets had a presence of zero and one. A significant negative correlation was not detected, perhaps because of the small sample size.

Type I flocks were composed of 7 to 174 birds (N = 14; Table 4.1; Appendix 4) with the mean number of species being 3.3 (SD = 1.49). At these flocks, we often saw the fish held in tight balls by pursuit-diving birds which dived and resurfaced near the periphery of the flock, as also observed by Hoffman et al. (1981) and Mahon et al. (1992). In some cases, this ball of fish appeared to be only a small portion which was separated from a much larger fish school residing near the bottom of the water column as seen in hydroacoustic plots of the area (Chapter 1). Herring and capelin were found to be common prey at PWS Type I flocks as determined by trawling.

We encountered two Type II flocks of 984 and 1065 birds with 11 and 8 species participating in them, respectively. These were much smaller in size than the Type II flocks described by Hoffman et al. (1981), who described such flocks as ranging in size from 5,000 to 50,000 individuals. However, we still considered them to be Type II flocks because: (1) they were significantly larger than flock Types I and III ($\chi^2 = 1696.1$, d.f. = 2, $P < 0.001$), (2) both of them lasted for at least two days, and (3) they were loosely aggregated assemblages feeding on post-spawning male capelin in one case and either capelin or herring in the second case.Type III flocks were composed of 11 to 168 birds (N = 6; Table 4.1) with the mean number of species being 4.2 (SD = 2.40). Five of these flocks were concentrated around points of land and one at the mouth of a shallow passage. Herring of various age groups were found in a trawl at one of these flocks.

Larid behaviors at flocks

Alcids pursuit-dived from the outskirts of Type I flocks and from throughout Type II and III flocks. We did not concentrate any part of our observations on these birds because of the difficulty of following these birds from where they dived to where they resurfaced.

Glaucous-winged gulls hop-plunged more frequently than any other foraging method at all flock types (Figure 4.2a). At Type I flocks, glaucous-winged gulls normally sat on the water directly over the fish school, while kittiwakes sat on the water around the periphery of the school or circled above it. To maintain their position in this flock type, gulls hop-plunged as opposed to plunge-dived. The latter foraging method was used more often in Type II and Type III flocks (Fisher's exact test; $P < 0.001$). Kittiwakes also hop-plunged more often in Type I flocks than in Type II and III flocks combined ($\chi^2 = 14.356$; $P < 0.001$). Yet, in all flock types, plunge-diving was their preferred method of feeding (Figure 4.2b). We were able to detect a weak but insignificant negative correlation between the frequency of kittiwake plunges and the relative presence of larger gulls in the flock (Spearman rho = -0.5664, P = 0.0587).

Kleptoparasitism

Kittiwakes had an overall feeding success of 80.6% (N = 129) and lost 4.8% of their captures to intraspecific piracy and 6.7% to interspecific piracy. Glaucous-winged gulls had a feeding success of 55.3% (N = 38) and lost no prey to kleptoparasitism.

Kleptoparasitism against kittiwakes occurred more frequently in the tightly aggregated Type I flocks compared to Type II and III flocks combined ($\chi^2 = 83.55$; $P < 0.001$; Table 4.2, Figure 4.3). Intraspecific kleptoparasitic attempts by kittiwakes were observed most often in Type I flocks, while attempts directed against alcids were more commonly seen in Type II flocks (Table 4.2, Figure 4.3). Glaucous-winged gulls attempted to rob alcids only in Type I flocks (Table 4.2, Figure 4.3). Gulls and kittiwakes kleptoparasitized alcids less than expected in Type I flocks ($\chi^2 = 15.32$, d.f. = 1, $P < 0.001$), but not in Type III flocks ($\chi^2 = 1.780$, d.f. = 1, $P = 0.182$).

Jaegers preferred to kleptoparasitize at the large Type II flocks (78% of observed attempts; Figure 4.3). Thirty-one out of 32 observed jaeger robbing attempts were directed toward kittiwakes, and the other toward a juvenile glaucous-winged gull. One large capelin feeding flock had a group of 15 Pomarine and 2 Parasitic Jaegers sitting on the water about 1 km away. They appeared to be making occasional sorties (usually alone) into the feeding flock. Their method of attack in Type II flocks was to concentrate efforts on kittiwakes which had recently caught a fish and those with fish visible in their bill.

DISCUSSION

Flock types and species composition

In PWS flocks are generally smaller than those encountered in more oceanic regions (e.g. Hoffman et al. 1981, Duffy 1983). Feeding flocks of murrelets, kittiwakes, gulls, puffins, and guillemots fed on schools of herring, capelin, and sand lance that were nearshore (Ostrand and Maniscalco, unpubl. data). Conspecifics and congeners of these birds have also been found to be distributed nearshore in other boreal environments (Vermeer et al. 1989, Stone et al. 1995) to obtain easy access to their prey. Our observations on only 22 feeding flocks during 18 days were likely the result of spending a much greater proportion of time on offshore portions of transects.

Seabird prey can be concentrated by upwelling or downwelling in both oceanic and coastal regimes (e.g. Wahl et al. 1989, Schneider et al. 1990, Coyle et al. 1992). Such flow gradients are often found around islands and points of land (Hamner and Hauri 1981, Kinder et al. 1983). These processes may work in PWS during the summer to make herring more vulnerable to seabird predation and forming Type III flocks. Sand lance are also common in shallow waters and nearshores which have sandy substrates and relatively high bottom current velocities (Auster and Stewart 1986). These conditions occur around many of the land masses in PWS. The capelin concentrations discovered nearshore appeared to be post-spawning aggregations which are known to attract alcids (Piatt 1990) and many other seabirds (Hoffman et al. 1981). The hydroacoustic profiles suggest that the predominant concentration of capelin in these schools reside near the bottom of the water column. Alcids appear to be the driving force in Type I flocks where capelin are concentrated in tight balls near the surface and hence become accessible for gulls and kittiwakes (Grover and Olla 1983). In the large Type II flocks, individual capelin appear to separate from the main school for unknown reasons and swim to near the surface where they are vulnerable to plunge-diving birds.

In British Columbia Marbled Murrelets may have been the catalyst in the formation of feeding flocks by forcing fish schools into tight balls and driving them to the surface (Mahon et al. 1992). This is a likely cause for the association between murrelets and kittiwakes at the flocks. Not only do alcids make prey easily available to larids (Grover and Olla 1983), but larids may make the fishes more vulnerable to capture by alcids by plunge-diving into the middle of a school and forcing individual fish outward for easier capture (Major 1978).

Our observations of murrelet participation in flocks were consistent with observations made within intercoastal waters of British Columbia (Mahon et al. 1992) and inconsistent with the low murrelet participation in flocks of outside waters (Porter and Sealy

1981, Chilton and Sealy 1987). Hunt (1995) reviewed these and other studies and was unable to conclude why there was this difference in murrelet flock participation. The relative absence of murrelets in tightly aggregated flocks with many puffins in PWS does suggest, however, that murrelet feeding activity may be inhibited by larger alcids in this type of situation (see also Chilton and Sealy 1987, Piatt 1990).

Larid behaviors at flocks

Glaucous-winged gulls may deter smaller gulls and kittiwakes from feeding at densely aggregated flocks. Porter and Sealy (1982) observed that smaller California gulls usually hovered over flocks and plunge-dived, while glaucous-winged gulls flew directly into the center and hop-plunged or dipped for prey. These behaviors are similar to what we have observed with kittiwakes and gulls in PWS feeding flocks. One feeding flock was encountered which had 12 glaucous-winged gulls sitting on the water over a tight ball of capelin and occasionally plunge-diving. Kittiwakes were entirely absent from this flock, though many were seen within a few kilometers. Interference competition such as this has also been noted in brown noddies (*Anous stolidus*) which deterred the feeding attempts made by roseate terns near Puerto Rico and may have been stronger during periods of food shortage (Shealer and Burger 1993). We observed that kittiwakes partially compensated for the presence of glaucous-winged gulls at densely aggregated Type I feeding flocks by remaining on the water and hop-plunging more often in these flocks but always outside the central core of gulls. The negative correlation we found between kittiwake dive rates and gull presence in the flocks is further suggestive that interference competition does take place amongst larids in PWS. Unfortunately, keeping track of individual birds is difficult in Type I flocks, therefore correlations between feeding success of kittiwakes and gull presence were not possible to determine. Glaucous-winged gulls are unable to dominate the more loosely aggregated fish at Type II and III flocks and hence plunge-dived more often in those situations.

Kleptoparasitism

Densely aggregated Type I flocks promoted kleptoparasitism within the gulls and kittiwakes but did not facilitate piracy by jaegers, perhaps because of their low success rate in this type of flock (Hoffman et al. 1981). Alcids were attacked less frequently in Type I flocks because of their ability to dive and resurface around the outer edge of these flocks and avoid the attacking kittiwakes (Hoffman et al. 1981, Chilton and Sealy 1987). The inability to keep fish tightly balled as in Type II and III flocks causes diving birds to resurface randomly. Without the focal point of a tight fish school, kittiwakes may cue on the resurfacing alcids for feeding opportunities. Our observations of greater numbers of alcid attacks at those flock types supports this hypothesis.

Parasitic and pomarine jaegers were most commonly observed in the largest (Type II) feeding flocks. Kittiwakes were preferentially chased, rather than the larger gulls, probably because kittiwakes were smaller hosts or they delayed the swallowing of their prey or both. On the St. Lawrence River, smaller common terns were chased more often by parasitic jaegers than were black-legged kittiwakes and almost half of the chased terns had fish dangling from the bill, whereas none of the chased kittiwakes carried visible fish

(Belisle and Giroux 1995). A review by Furness (1987), however, suggests that the parameters regarding a bird's susceptibility to chase remain equivocal.

Although most studies of jaeger piracy have been conducted near colonies (e.g. Andersson 1976, Birt and Cairns 1987), these birds are not common raiders at colonies in PWS (David Irons, pers. comm.). The relatively small colony sizes of PWS seabirds (Sowls et al. 1978) may limit kleptoparasitic opportunities at these locations. Foraging at large feeding flocks where bird densities are higher could be more beneficial (Furness 1987), especially when a host has been observed catching a fish (Hoffman et al. 1981).

Evolutionary stable kleptoparasitic interactions may deprive hosts of about 1% of their food (Furness 1987). The estimated loss of secured prey by kittiwakes to interspecific kleptoparasitism in PWS was close to 7%. Increased rates of kleptoparasitism could be indicative of periods of food shortage (Furness 1987). This hypothesis was tested by Oro and Martinez-Vilalta (1994) and Oro (1996) who showed a correlation between a greater number of attempted food robberies by gulls and a trawling moratorium which reduced the accessibility of their food near Spain. On the other hand, changes in food abundance form year to year may be positively, not negatively, correlated with robbing attempts by opportunistic kleptoparasites such as gulls (Rice 1985, 1987). Furness (1987) also argues that high success rates of robbing attempts could indicate that some birds may have been more willing to relinquish their catches when prey was abundant. Therefore, higher food losses to kleptoparasitism such as reported by Hulsman (1976) and this study may not imply much without comparing trends in forage fish abundance.

Intraspecific kleptoparasitism as seen in Kelp Gulls (*Larus domincanus*) at a rate of 15% may benefit this species (Steele and Hockey 1995). Although our data concerning kittiwakes is not directly comparable, kleptoparasitism among kittiwakes in PWS be not be adversely affecting their populations. A significant change in rates of kleptoparasitism in PWS in the coming years may be indicative of changes in the abundance of seabirds and/or their prey.

Physical and biological processes which make forage easily available or difficult to obtain for seabirds in PWS are not necessarily the same as in other ecosystems, although there are some apparent similarities. Seabird behavior is more complex than presented here and all of the aspects analyzed in this paper should be studied further to better understand seabird ecology in PWS and elsewhere.

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Table IV-1 - Total numbers of the most common seabirds and total birds at the different flock types with percent contribution of these species at each flock type (n = number of flocks).

	Type I (n = 14)	Type II (n = 2)	Type III (n = 6)
black-legged kittiwake	277 (43%)	860 (42%)	105 (35%)
glaucous-winged gull	55 (9%)	250 (12%)	13 (4%)
marbled murrelet	141 (22%)	420 (20%)	112 (38%)
tufted puffin	143 (22%)	450 (22%)	12 (4%)
other birds	26 (4%)	69 (3%)	54 (18%)
all birds	642 (100%)	2049 (100%)	296 (100%)

Table IV-2 - Kleptoparasitism of alcids and kittiwakes by all larids combined in Type I and III flocks.

Flock Type	Host	Host total abundance	Host relative abundance	Expected # of chases	Observed # of chases
I	alcid	180	0.4286	12.43	2
I	kittiwake	240	0.5714	16.57	27
III	alcid	143	0.6272	10.66	8
III	kittiwake	85	0.3728	6.34	9

Figure IV-1 - Scatter plot of Marbled Murrelets and Black-legged Kittiwakes at feeding flocks.

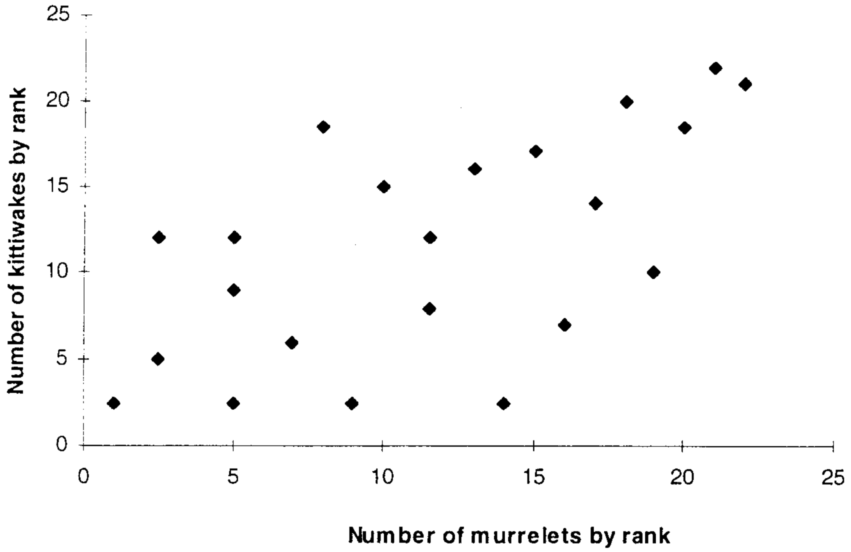
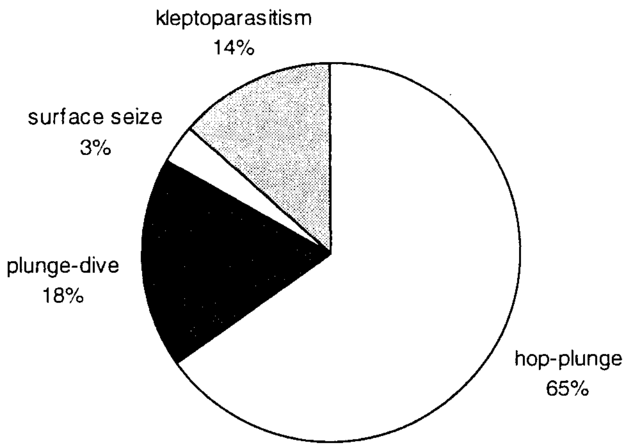

Number of kittiwakes by rank
25
20
15
10
5
0
0
5
10
15
20
25
Number of murrelets by rank

Figure IV-2 - Frequency of feeding techniques used by a) glaucous-winged gulls and b) black-legged kittiwakes at all flock types combined.


a) Glaucous-winged Gulls

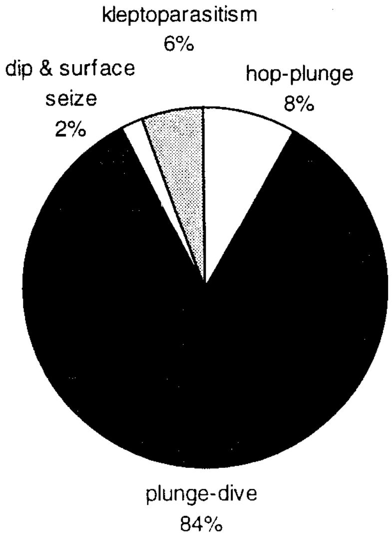
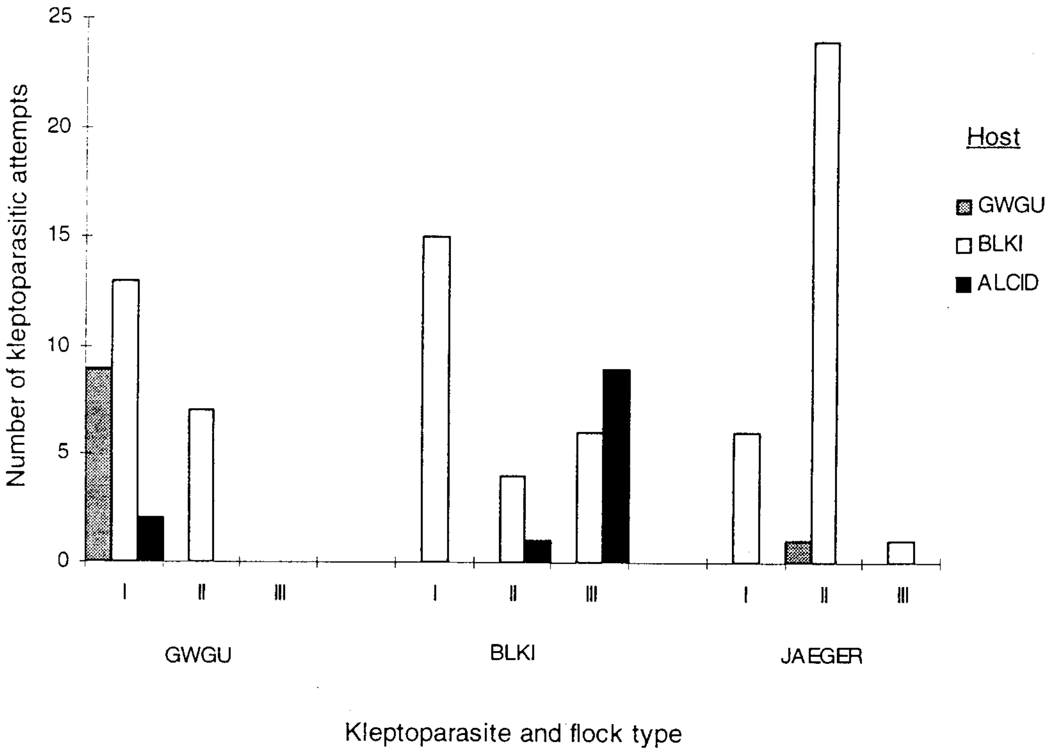

b) Black-legged Kittiwakes

Figure IV-3 - Number of observed kleptoparasitic attempts segregated by flock type and species involved.


Number of kleptoparasitic attempts
25
20
15
10
5
0
I
II
III
I
II
III
I
II
III
GWGU
BLKI
JAEGER
Kleptoparasite and flock type
Host
▨ GWGU
□ BLKI
■ ALCID

Chapter V: July 1996 Species Composition and Behavioral Results from Nearshore Transects and Flocks Observed on Nearshore Transects

John M. Maniscalco
William D. Ostrand

Abstract

We conducted seabird/ hydroacoustic surveys in three different areas (northeast, central, southwest) of Prince Willam Sound, Alaska during July of 1996 to assess seabird distributions and examine their behavior at feeding flocks. We systematically selected 12-km blocks of shoreline within which we ran 20 1-km long transects to and from shore at oblique angles. The average number of birds per transect and transect block were 6.62 and 131.57, respectively and were not significantly different among the three areas ($P > 0.10$ in both cases). However, species composition of the blocks differed significantly among the study areas ($P < 0.001$). Bird flocks found within 300 meters of these transects were feeding primarily on juvenile herring and sand lance. Flocks in the northeastern area were significantly larger than flocks in the other two areas ($P = 0.01$) and were feeding on herring more often. The feeding rate of black-legged kittiwakes did not increase significantly with the presence of marbled murrelets ($P = 0.3801$), but did decrease significantly with the presence of glaucous-winged gulls ($P = 0.0225$). Changes in flocks from 1995 included; reduced presence of kittiwakes and tufted puffins, increased presence of marbled murrelets and glaucous-winged gulls, more tightly aggregated feeding flocks, reduced feeding success of kittiwakes and greater feeding success of gulls, reduced kleptoparasitism of kittiwakes and increased kleptoparasitism of gulls. The implications of these changes are discussed briefly.

Many seabirds in certain regions of the world are commonly distributed near shore and in shallow waters (Vermeer et al. 1989, Stone et al. 1995). Prince William Sound (PWS) is no exception (Chapter II). For this reason and judging from the results of our 1994 and 1995 surveys, we decided to conduct additional surveys nearshore in 1996. We may be able to better determine what factors are important for seabird prey selection by concentrating our efforts in their preffered habitat.

In this chapter we provide preliminary results on the species composition of the nearshore transects and transect blocks from July 1996. We also describe the feeding flock composition and seabird behaviors observed at the flocks during the same period and draw some contrasts with our observations of 1995 feeding flocks.

Methods

Field Procedures

Twelve kilometer sections of shoreline were systematically selected in each of the three study areas in PWS (seven in the southwest, seven and one half in the central, and nine in the northeast). Within each of these shoreline sections 20 one-kilometer transects were surveyed at an oblique angle to and from shore (See annual report by Haldorson et al. for further details). We counted seabirds and recorded their behaviors while surveying these transects with down and side looking hydroacoustics. Fish species and size distributions in the the 12-km sections were determined through purse seining, beach seining, cast netting, dip netting, and visually with an underwater video camera.

The study period (15 - 27 July 1996) was chosen to include the peak time of chick provisioning for many seabirds in PWS. Observations were made with 8 x 40 binoculars, 6 m above the water line from a 26 m vessel traveling at approximately 5 knots while conducting hydroacoustic surveys to estimate forage fish and seabird distributions and abundances. Transect lines were left to more closely examine feeding flocks within 300 m of either side of our vessel.

We collected behavioral data on feeding flocks upon leaving the transect and continued to do so until the flock broke up naturally or became disturbed by our presence. A feeding flock was defined as an aggregation of three or more seabirds actively feeding as observed by diving alcids with fish in their bill or larids plunge-diving, dipping, or hop-plunging. While at a feeding flock, one observer videotaped the flock for later analysis or recorded detailed information on dive types and success into a microcassette recorder. A second observer recorded other information on the flock, including: location (lat. and long.), date, time, weather conditions, wind speed and direction, sea state, water and air temperatures, area covered by flock in m^2, any noticeable physical features (e.g. upwellings, fronts), flock composition with numbers and locations of each species within the flock, kleptoparasitic and aggressive interactions with as much detail as possible, other feeding methods used and their success, and the duration and fate of the flock if known. We categorized feeding methods as surface-seizing, dipping, surface-diving, plunging, pursuit-plunging, piracy (Ashmole 1971), and hop-plunging (Hoffman et al. 1981). Flock types were loosely classified following Hoffman et al. (1981): I) small, short duration flocks over tightly clumped prey; II) large, persistent flocks over more broadly dispersed prey; III) flocks associated with sites where forage was concentrated by downwelling or other hydrophysical influence, determined by a subjective evaluation of oceanographic features.

After approximately 15 minutes of examining seabird behaviors at the flocks or as soon as the flocks stopped feeding, our vessel was maneuvered through the area of activity to produce an acoustic profile of the forage. This was normally done more than once with the location of greatest feeding activity to the right of the vessel where the side-looking transducer was viewing. However, on a few occasions the forage was in too close to shore for the vessel to maneuver safely.

Data Analyses

In the analysis of species composition of transects and transect blocks we included all observed gulls and kittiwakes and alcids and other diving birds such as loons and cormorants if they were recorded as on the water, foraging, or potentially foraging. We deleted the half block from the central area for the analysis of species composition by blocks. We used ANOVA to determine if there were any differences among the three study areas in species numbers observed on transects. Kruskal-Wallis and Chi-square statistics were used to analyze differences among the study areas in species numbers observed in total blocks of transects.

Descriptive statistics were used to summarize feeding flock composition and the behaviors of gulls and kittiwakes at the flocks. We analyzed differences in behaviors between 1995 and 1996 with Chi-square statistics. Linear regression was used to determine the rate of decrease in kittiwake feeding attempts with increased presence of glaucous-winged gulls.

RESULTS

Species composition of the nearshore transects and blocks

The overall average number of birds per transect was 6.62 (± 14.92 SD) with 8.32, 6.16, and 5.34 birds per transect in the central, northeastern, and southwestern areas, respectively (Figure 1). Those differences were not significant (ANOVA, $P = 0.2056$). However, the distribution of bird numbers on transects was not normal (Figure 2). Black-legged kittiwakes and marbled murrelets were the most abundant birds in all three areas (Figure 3). There were no significant differences in the average number of murrelets (ANOVA, $P = 0.9776$) nor kittiwakes (ANOVA, $P = 0.3307$) per transect in the three study areas (Figure 1).

Seven and one half of the 23.5 blocks surveyed were in the central study area and seven and nine were in the southeastern and northeastern study areas, respectively. The average numbers of all bird species per block was 131.57 and was not significantly different among the three study areas (Kruskal-Wallis t-value = 2.0966, $P > 0.10$; Figure 4). Numbers of kittiwakes, glaucous-winged gulls, and marbled murrelets also did not differ significantly between the three study areas (all Kruskal-Wallis P-values > 0.10; Figure 5). However, the overall species composition of the blocks in the study areas did differ significantly ($\chi^2 = 469.4$, d.f. = 10, $P < 0.001$; Figure 6). This difference was due primarily to an abundance of tufted puffins in the central area which were absent from the northeastern and southwestern regions.

Species composition of flocks

In July of 1996 we observed 22 feeding flocks on the nearshore transect series. Twenty of these were Type I flocks and the other two were Type III flocks. We did not observe any large Type II feeding flocks. The flocks ranged in size from 8 to 194 birds (mean = 67.4 ±11.0 SE; Table 1). Many of these flocks consisted of less than fifty birds (Figure 7). We encountered five flocks in the southern area, six flocks in the central area, and 11 flocks in the northern area. The average number of birds participating in the flocks was significantly greater in the northern area (ANOVA, $P = 0.01$; Figure 8).

Based on visual identification, purse seining, beach seining and other fish catching methods we were able to determine with a good degree of certainty what 16 out of the 22 observed flocks were feeding upon. Nine of the flocks were feeding on herring (usually young of the year) and seven of the flocks were feeding on sandlance. Herring was observed as the prey species in seven of the eleven northeastern area flocks; whereas sand lance was more important in the central area, appearing as prey in four out of six flocks (Figure 9). One or more flocks in the southwestern and central areas may have been feeding on juvenile salmon.

The species composition of these flocks was significantly different from the composition of the flocks observed in 1995 ($\chi^2 = 690.88$; Figure 10) as well as just the Type I flocks from 1995 ($\chi^2 = 478.17$; Figure 11). The biggest changes were decreases in the relative presence of kittiwakes and tufted puffins and increases in the relative presence of marbled murrelets and glaucous-winged gulls. The ratio of kittiwakes to glaucous-winged gulls at all of the flocks increased significantly from 0.256 in 1995 to 0.441 in 1996 ($\chi^2 = 25.167$).

Feeding methods, success, and kleptoparasitism

The feeding methods of black-legged kittiwakes were significantly different in 1996 compared to 1995 ($\chi^2 = 34.74$) as were those of glaucous-winged gulls ($\chi^2 = 148.16$). Kittiwakes and gulls plunge-dived less and hop-plunged more in 1996 compared to 1995 (Figure 12).

On average, each kittiwake made 0.0404 feeding attempts per minute or made a feeding attempt once every 24.74 minutes and was successful once every 41.49 minutes at the flocks. Their feeding success was much lower than in 1995 but they lost nothing to interspecific kleptoparastism in 1996 (Figure 13). On average, each glaucous-winged gull made 0.0581 feeding attempts per minute or made a feeding attempt once every 17.2 minutes and was successful once every 19.66 minutes. Their success rate was much higher than observed in 1995 (Figure 14).

The feeding rate of black-legged kittiwakes did not increase significantly with the presence of marbled murrelets ($R^2 = 0.2135$, $P = 0.3801$, n = 19) but did decrease significantly with increasing numbers of glaucous-winged gulls present in the flocks ($R^2 = 0.5201$, $P = 0.0225$, n = 19; Figure 15). However, combining the data from 1995 and 1996 did not improve the regression ($R^2 = 0.3491$; $P = 0.0586$; n = 30).

Kleptoparasitic attempts directed toward kittiwakes decreased from 1995 to 1996 whereas, those directed toward glaucous-winged gulls increased over the same period (Figure 16). Kittiwakes were never observed attempting to rob from glaucous-winged gulls in 1995, but in 1996 kittiwakes would occasionally try to steal from gulls which acquired a mouthful of small sand lance or herring and some of the fish were flopping out. There were no kleptoparasitic attempts directed toward alcids in 1996 as observed in 1995. Kleptoparasitism by jaegers was minimal in 1996 (only two unsuccessful attempts observed at one flock).

Table 2 summarizes the changes in seabird behaviors from 1995 to 1996.

DISCUSSION

Species composition of the nearshore transects and blocks

The lack of difference in numbers of the major bird species among the three study areas may indicate that PWS has a relatively uniform avian ecosystem structure. However, tufted puffins were found only in the central area and this probably lead to our determination of differences in species composition among study areas as analyzed by transect blocks. Further analyses may be necessary to determine that no other statistical differences exist.

Species composition of flocks

We observed the same number of feeding flocks on one survey of the nearshore transects in 1996 as we had on two surveys of the predominantly offshore transects of 1995 (Chapter II this report). Type II flocks were not observed in 1996 probably because the large capelin feeding flocks that we had seen in August of 1995 were not present within the study area during the 1996 cruise. The greater number and average size of the feeding flocks observed in the northeastern study area may have resulted from differences in forage fish abundance, quality, or accessability. The present results show that herring may be fed upon more in the northeastern study area and sand lance in the central area. Both of these have the highest lipid and energy content of the widely available forage fishes in PWS (D. Roby and J. Anthony, unpubl. data). Differences in seabirds' diet among the different areas probably reflect variable abundances of these fishes. We anxiously await the results of the hydroacoustic data to make comparisons.

The reasons for changes in the species composition of flocks are unknown. A decrease in the amount of offal produced by fisheries vessels in PWS may increase the presence of glaucous-winged gulls at the feeding flocks as they look for other feeding opportunities. Decreases in the number of tufted puffins and increases in the number of marbled murrelets at the flocks may have resulted from changes in the distribution or abundance of one or more forage fishes. Other possibilities for these changes include variation because of small sample sizes, and different locations of transects in 1995 and 1996.

Feeding methods, success, and kleptoparasitism

The increase in hop-plunging is partially due to an increase in the number of tightly aggregated Type I flocks which promote this behavior (Chapter IV this report). Marbled murrelets also foster the formation of tightly balled fish (Mahon et al. 1992) which in turn cause the tight formation of feeding flocks. Greater proportionate numbers of murrelets in the feeding flocks of 1996 probably facilitated the formation of tightly balled fish and hence tightly aggregated flocks with a lot of hop-plunging. Larger and more aggressive seabird species can dominate feeding opportunities where food in densely aggregated (Hudson and Furness 1989).

This decrease in the feeding rate of kittiwakes with increases in gull numbers probably explains the decrease in the feeding frequency of kittiwakes from 1995 to 1996 since the relative presence of glaucous-winged gulls at the flocks was much higher in 1996 than in 1995. Larger seabirds can interfere with the ability of smaller seabirds to obtain food (Shealer and Burger 1993).

Glaucous-winged gulls were probably kleptoparasitized more in 1996 than kittiwakes because their capture success was higher than kittiwakes. Birds that are obviously getting food are more likely to be kleptoparasitized than those which are likely to have none (Furness 1978, 1987). The paucity of jaeger kleptoparasitism can be explained by the smaller flocks observed in 1996. Jaegers appeared to favor thievery at the large Type II flocks as observed in 1995 (Chapter IV this report).

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Vermeer, K., K.H. Morgan, G.E.J. Smith, and R.Hay. 1989. Fall distribution of pelagic birds over the shelf off SW Vancouver Island. Col. Waterbirds 12:207-214.

le V-1. Species composition of flocks observed on nearshore transects during July 1996 cruise.

#	796-1	796-2	796-3	796-4	796-5	796-6	796-7	796-8	796-9	796-10	796-11	796-12	796-13	796-14	796-15	796-16	796-17	796-18	796-19	796-20	796-21	796-22	Totals	Means
type	3	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1		
)	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	16	--------	3	--------	6	1	--------	--------	--------	--------	--------	26	1.18
O	--------	--------	--------	--------	--------	--------	--------	--------	1	--------	--------	--------	--------	--------	--------	1	--------	--------	--------	--------	--------	--------	2	0.09
\	--------	--------	--------	--------	--------	1	--------	--------	--------	--------	--------	--------	--------	--------	2	--------	--------	--------	--------	--------	--------	--------	3	0.14
A	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	0	0.00
U	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1	1	0.05
G	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	0	0.00
GU	1	1	3	--------	--------	4	--------	9	1	--------	3	16	1	15	--------	27	28	6	12	20	14	21	182	8.27
	12	3	17	5	3	15	12	45	5	20	22	33	43	16	14	50	26	3	21	45	--------	3	413	18.77
E	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	0	0.00
IU	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1	--------	--------	--------	--------	--------	1	0.05
J	--------	6	--------	--------	--------	--------	--------	1	--------	5	2	--------	--------	1	--------	--------	--------	--------	--------	--------	--------	--------	15	0.68
IU	3	183	2	5	5	13	2	8	6	44	56	32	65	110	22	19	66	3	47	15	17	91	814	37.00
U	--------	1	--------	1	--------	--------	1	5	2	10	4	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	24	1.09
U	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	0	0.00
U	--------	--------	--------	--------	--------	--------	--------	--------	--------	2	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	2	0.09
AL	16	194	22	11	8	33	15	68	15	81	87	97	109	145	38	103	122	12	80	80	31	116		

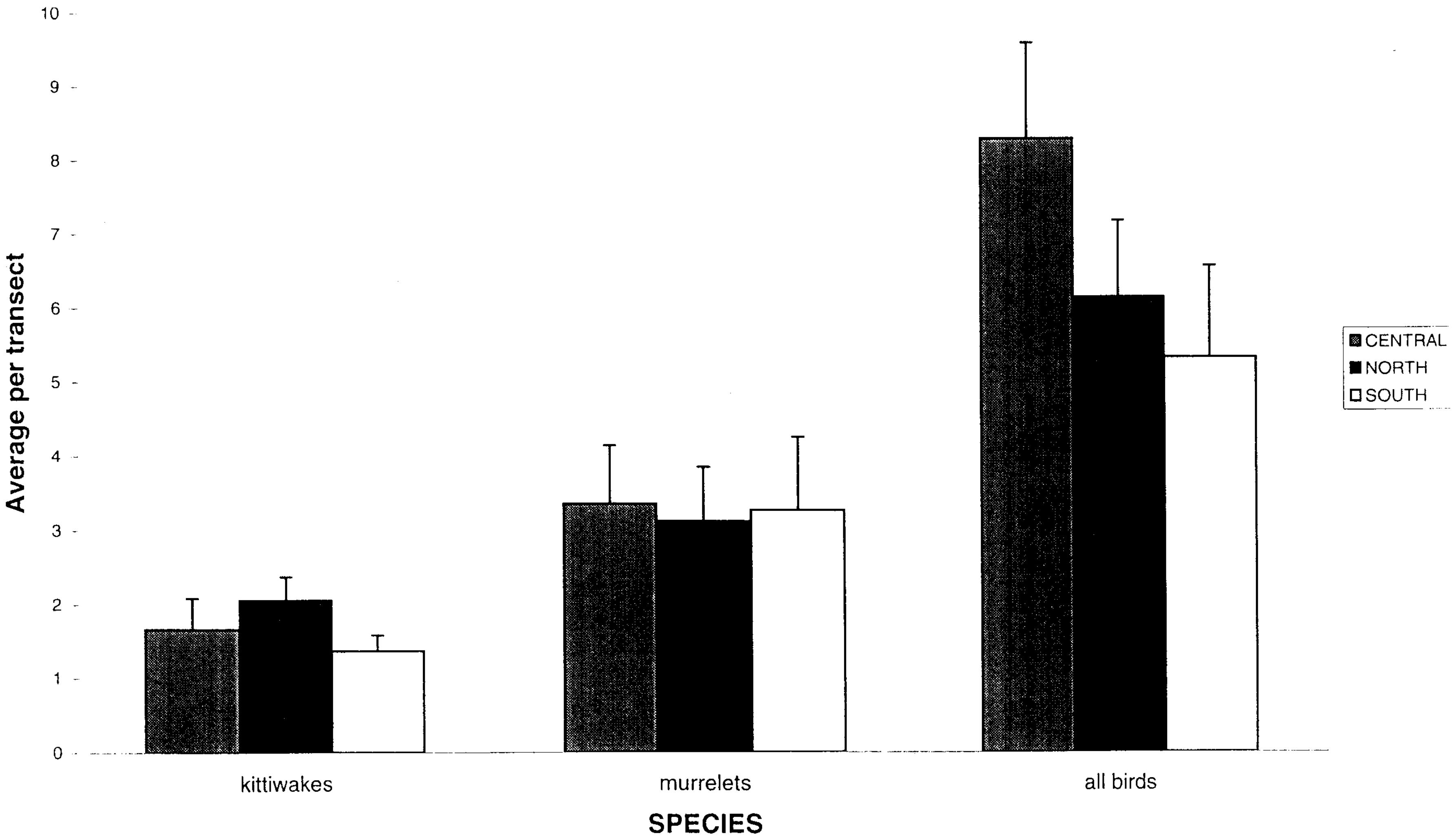
ecies Codes

O = Pacific loon
O = pelagic cormorant
IA = parasitic jaeger
JA = pomarine jaeger
GU = mew gull
G = herring gull
GU = glaucous-winged gull
I = black-legged kittiwake
E = Arctic tern
MU = common murre
U = pigeon guillemot
MU = marbled murrelet
PU = horned puffin
PU = tufted puffin
AU = parakeet auklet

Table V-2. Summary of feeding flock changes between 1995 and 1996 (except for first line).

Ratio of GWGU to BLKI '93 to '96 in PWS (Agler et al.)	↑
Ratio of GWGU to BLKI at feeding flocks	↑
Proportion of small, tightly aggregated feeding flocks	↑
Proportion of MAMU at feeding flocks	↑
Proportion of hop-plunging by BLKI and GWGU	↑
Feeding success of BLKI	↓
Feeding success of GWGU	↑
Kleptoparasitism of BLKI	↓
Kleptoparasitism of GWGU	↑

Figure V-1. Average number of species per nearshore transect in the three study areas during July 1996.



Average per transect
10
9
8
7
6
5
4
3
2
1
0
kittiwakes
murrelets
all birds
SPECIES
▨ CENTRAL
■ NORTH
☐ SOUTH

Figure V-2. Histogram of nearshore transects with "x" number birds on them from July 1996.

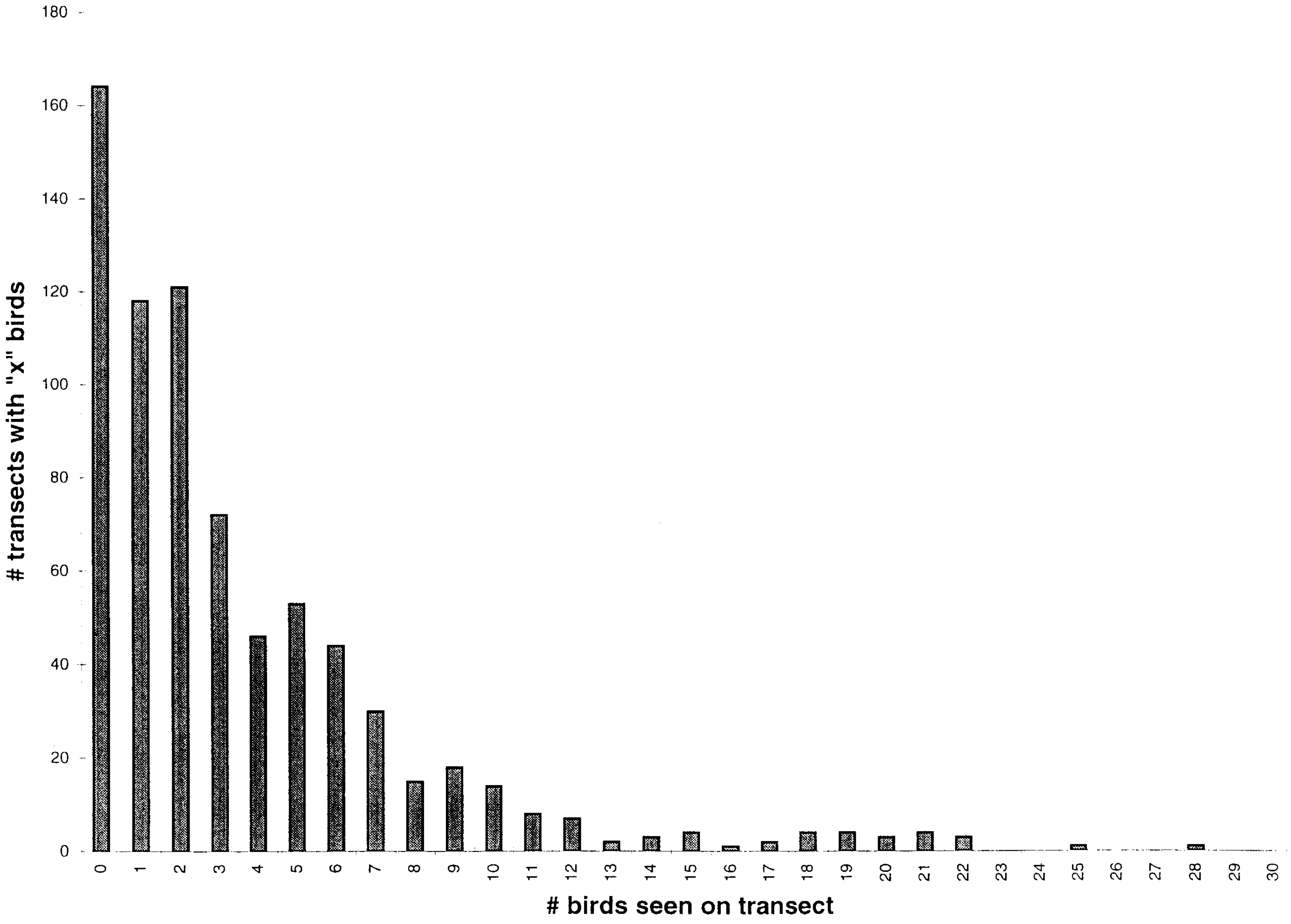

180
160
140
120
100
80
60
40
20
0
transects with "x" birds
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
birds seen on transect

Figure V-3. Cumulative numbers of birds per nearshore transect in the three study areas from July 1996.

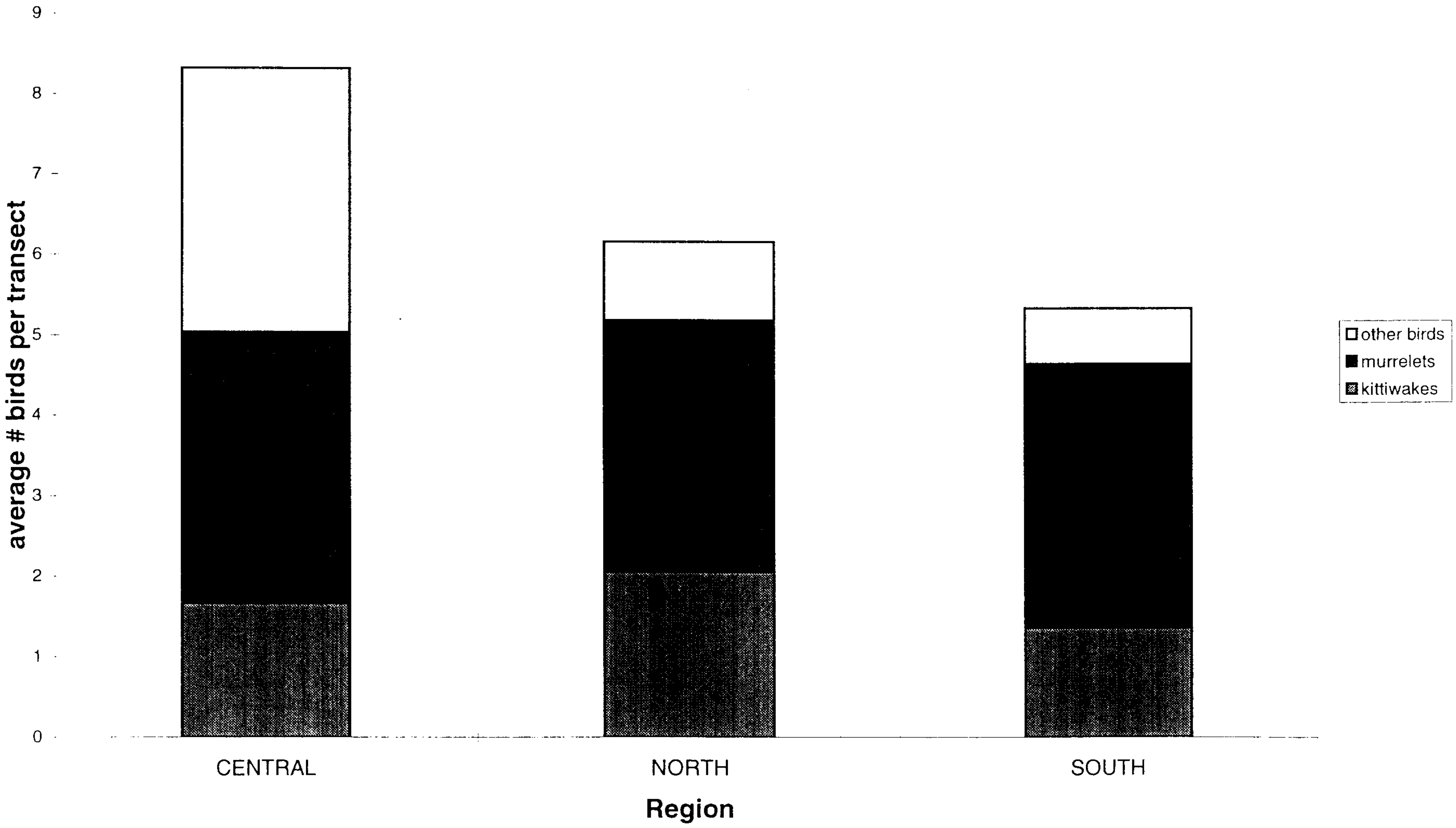

9
8
7
6
5
4
3
2
1
0
average # birds per transect
CENTRAL
NORTH
SOUTH
Region
other birds
murrelets
kittiwakes

Figure V-4. Average numbers of all birds per 12-km nearshore block in the three study areas from July 1996.

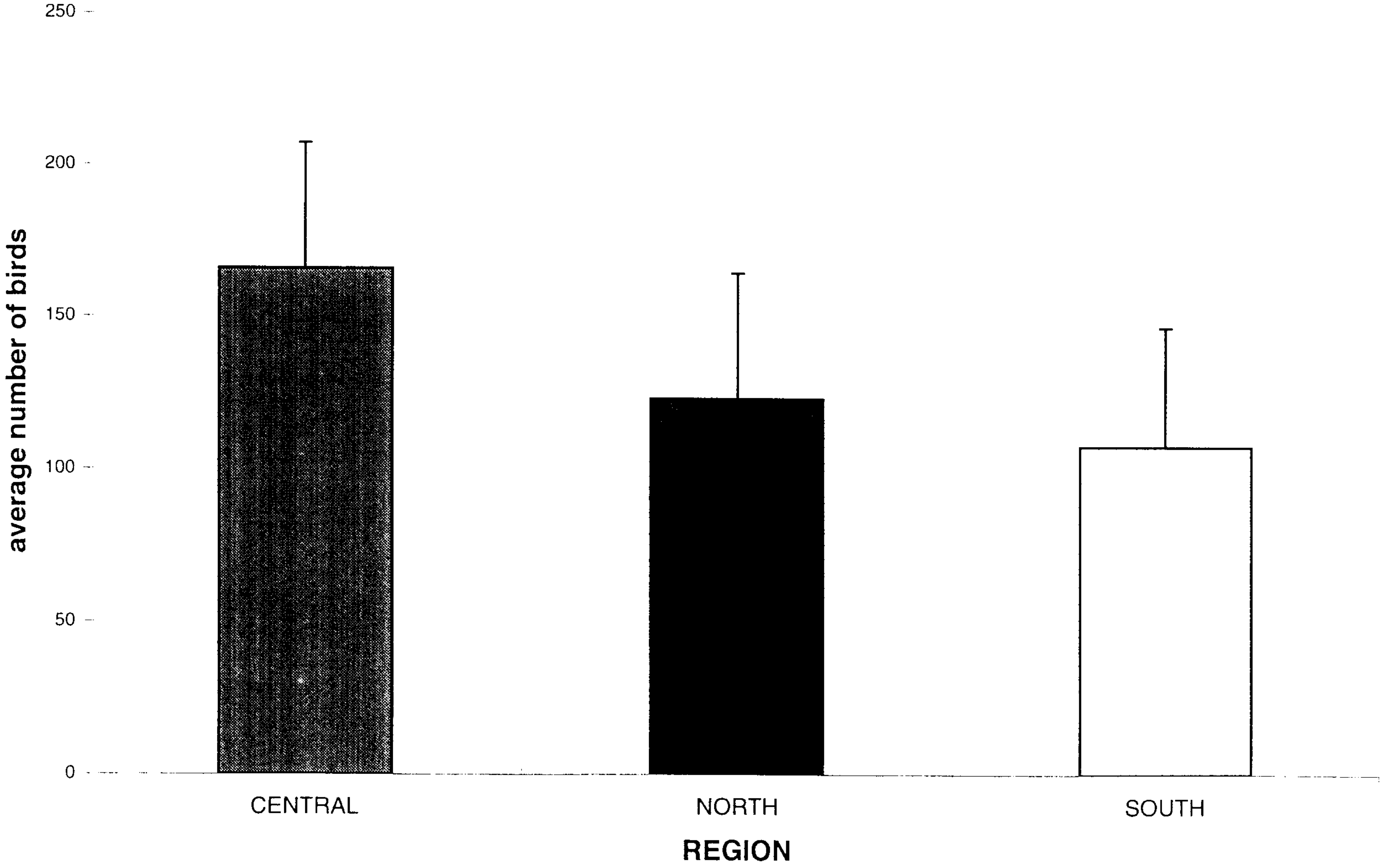

250
200
150
100
50
0
average number of birds
CENTRAL
NORTH
SOUTH
REGION

Figure V-5. Average numbers of black-legged kittiwakes, glaucous-winged gulls, and marbled murrelets per nearshore 12-km block in the three different study areas from July 1996.

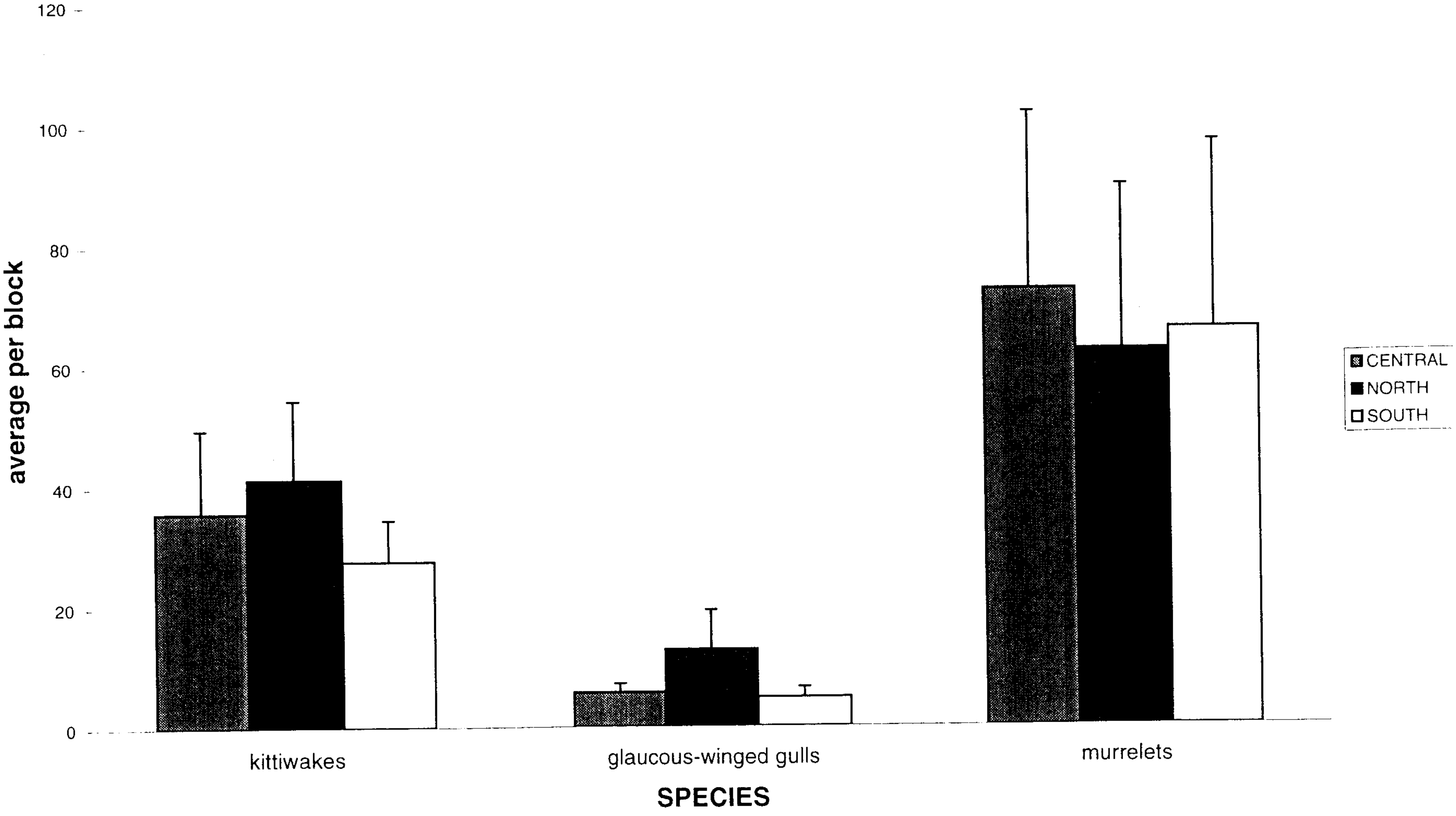

120
100
80
60
40
20
0
average per block
kittiwakes
glaucous-winged gulls
murrelets
SPECIES
▨ CENTRAL
■ NORTH
☐ SOUTH

Figure V-6. Percent species composition of the nearshore study blocks in the three different areas from July 1996. See Table 1 for species codes.

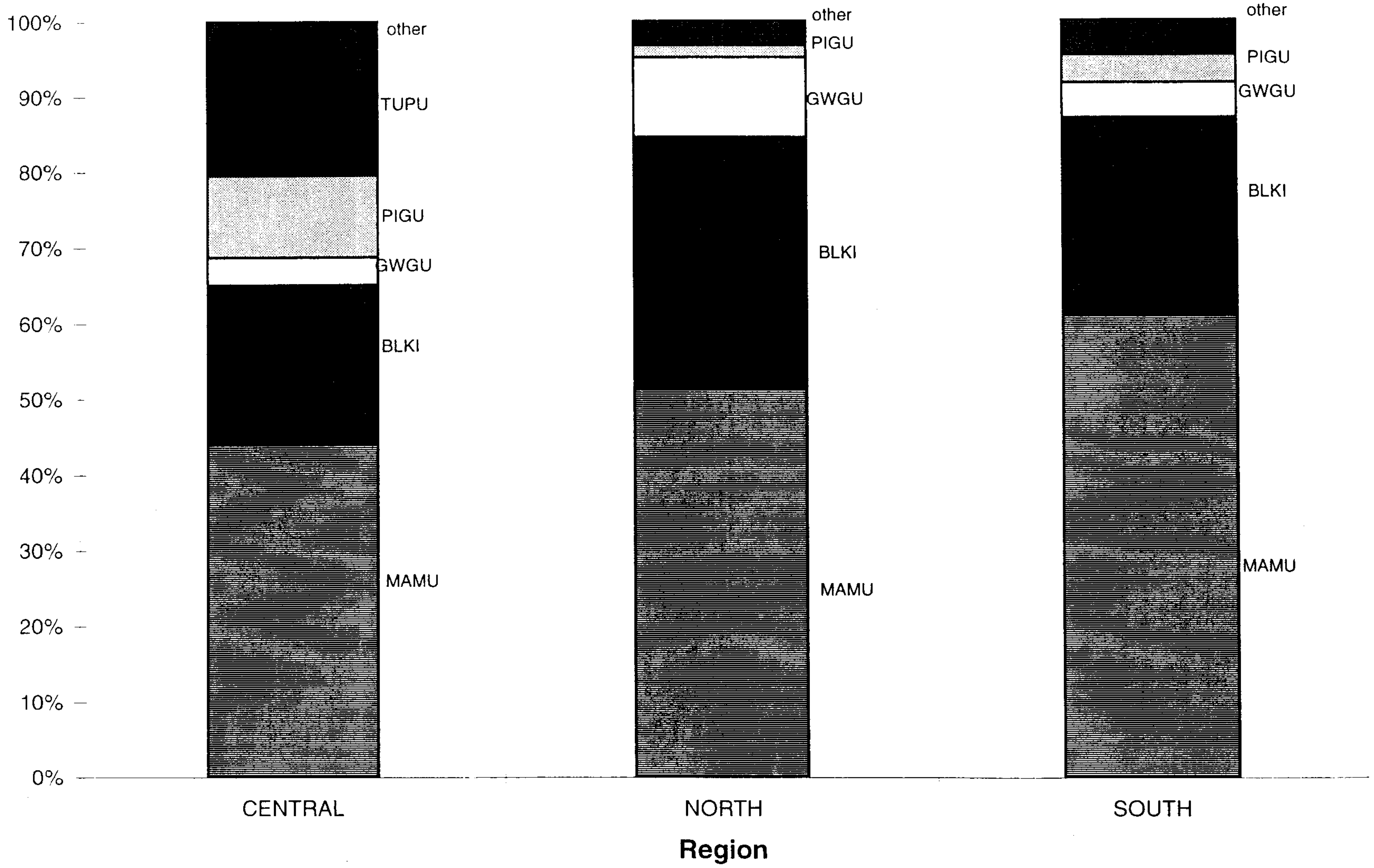

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
other
TUPU
PIGU
GWGU
BLKI
MAMU
other
PIGU
GWGU
BLKI
MAMU
other
PIGU
GWGU
BLKI
MAMU
CENTRAL
NORTH
SOUTH
Region

Figure V-7. Size distribution of flocks observed on nearshore transects during July 1996 forage fish cruise.

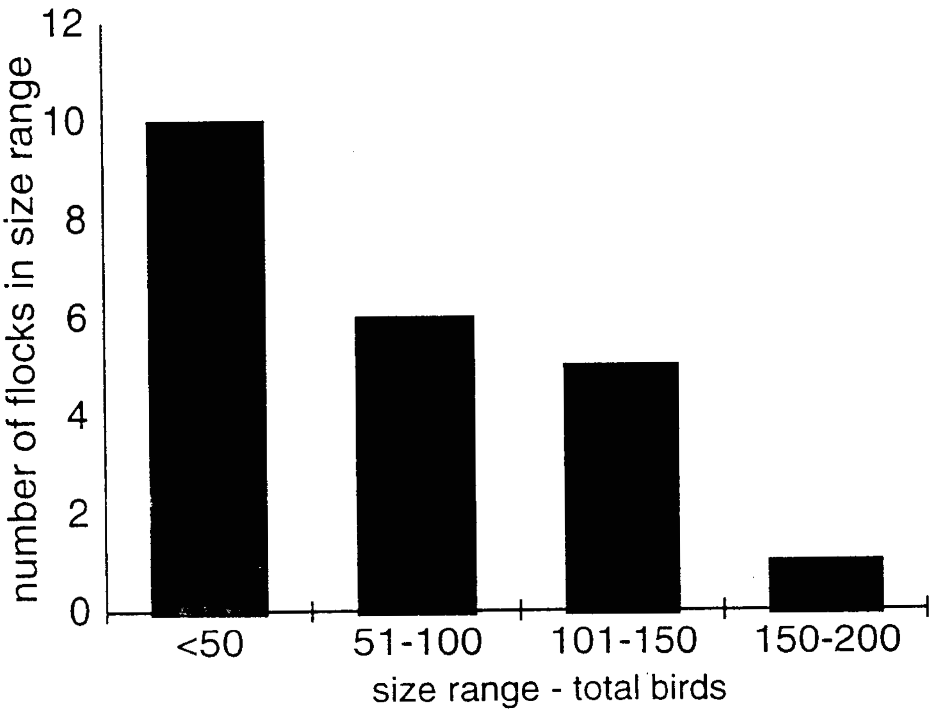

12
10
8
6
4
2
0
number of flocks in size range
<50
51-100
101-150
150-200
size range - total birds

Figure V-8. Average number of birds (flock size) participating in feeding flocks in the three different study areas during July of 1996.

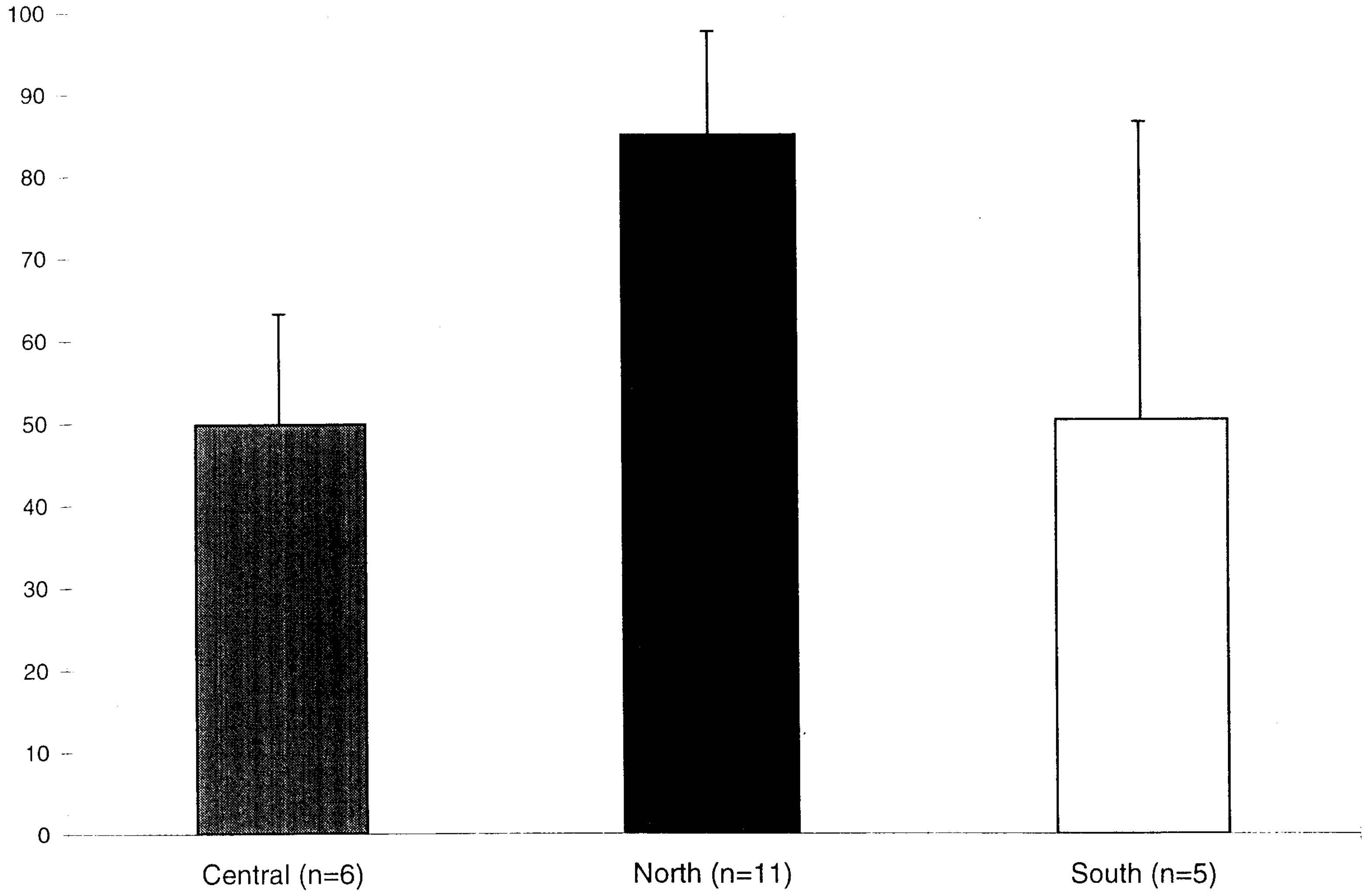

100
90
80
70
60
50
40
30
20
10
0
Central (n=6)
North (n=11)
South (n=5)

Figure V-9. Fish species being fed upon by flocking seabirds in the three different study areas during July of 1996.

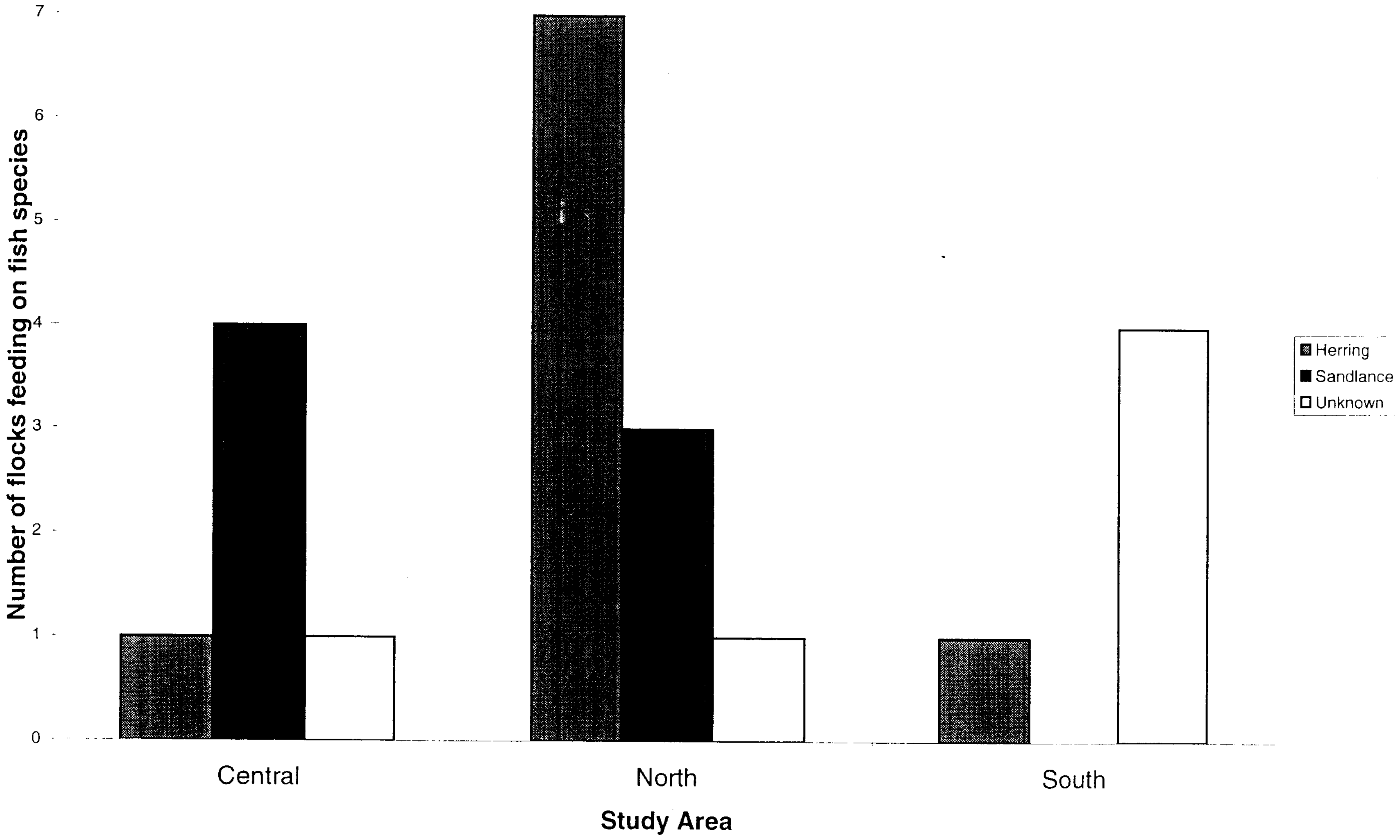

7
6
5
4
3
2
1
0
Number of flocks feeding on fish species
Central
North
South
Study Area
▨ Herring
■ Sandlance
☐ Unknown

Figure V-10. Percent species composition of feeding flocks observed during 1995 and 1996. See Table 1 for species codes.

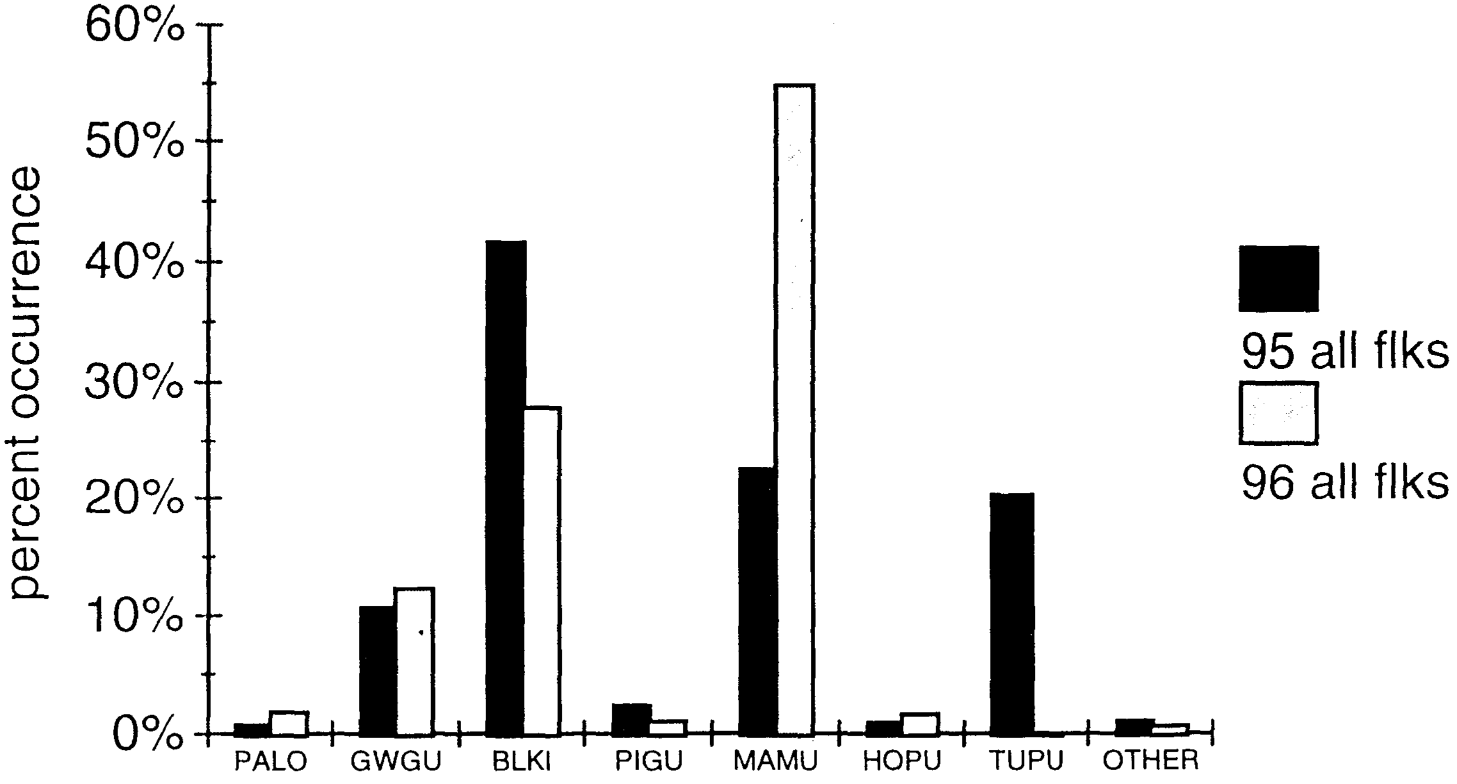

60%
50%
40%
30%
20%
10%
0%
percent occurrence
PALO
GWGU
BLKI
PIGU
MAMU
HOPU
TUPU
OTHER
95 all flks
96 all flks

Figure V-11. Percent species composition of Type I flocks observed during 1995 and 1996. See Table 1 for species codes.

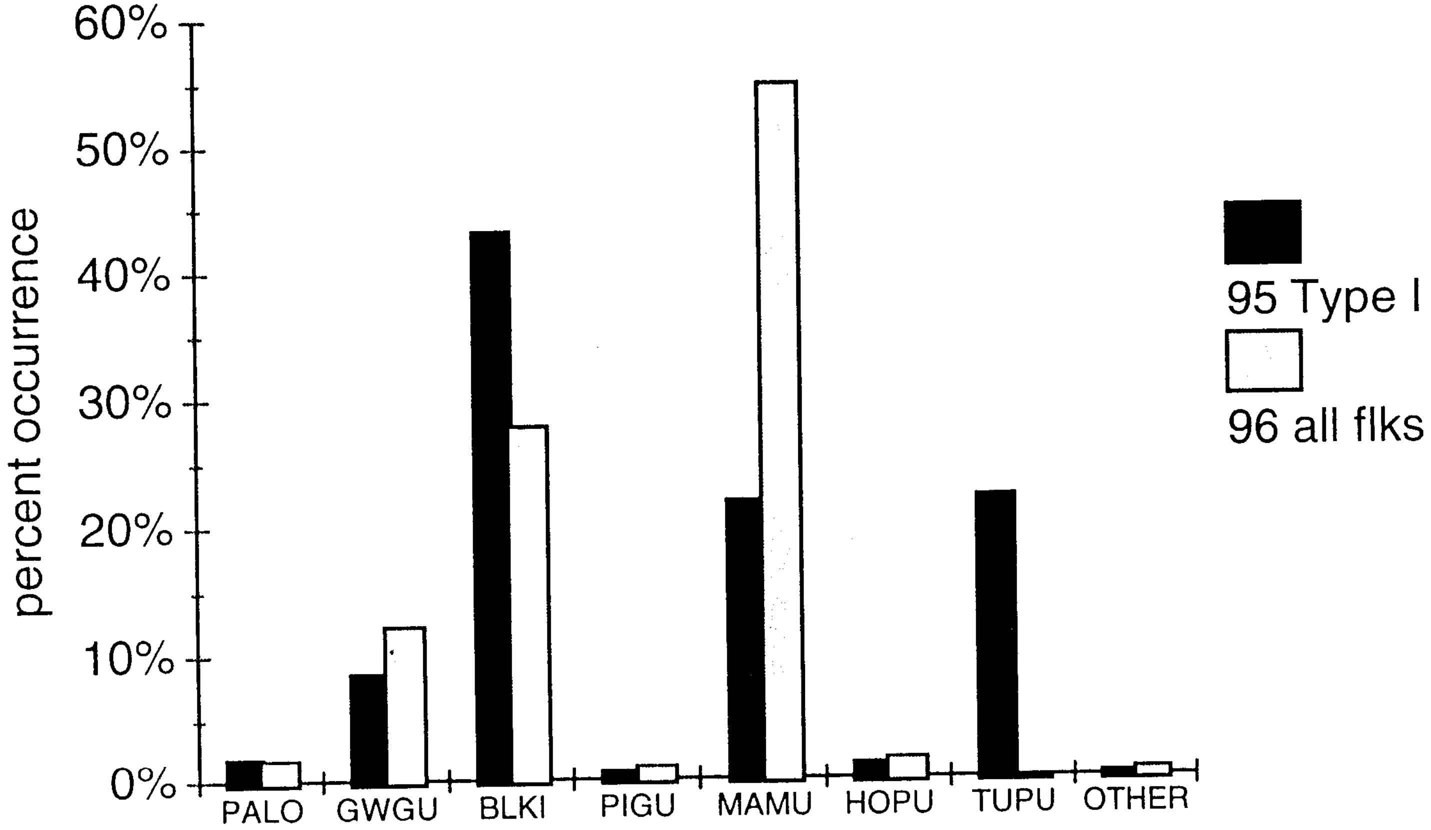

60%
50%
40%
30%
20%
10%
0%
percent occurrence
PALO
GWGU
BLKI
PIGU
MAMU
HOPU
TUPU
OTHER
95 Type I
96 all flks

Figure V-12. Percentage of feeding methods observed by black-legged kittiwakes (BLKI) and glaucous-winged gulls (GWGU) during 1995 and 1996.

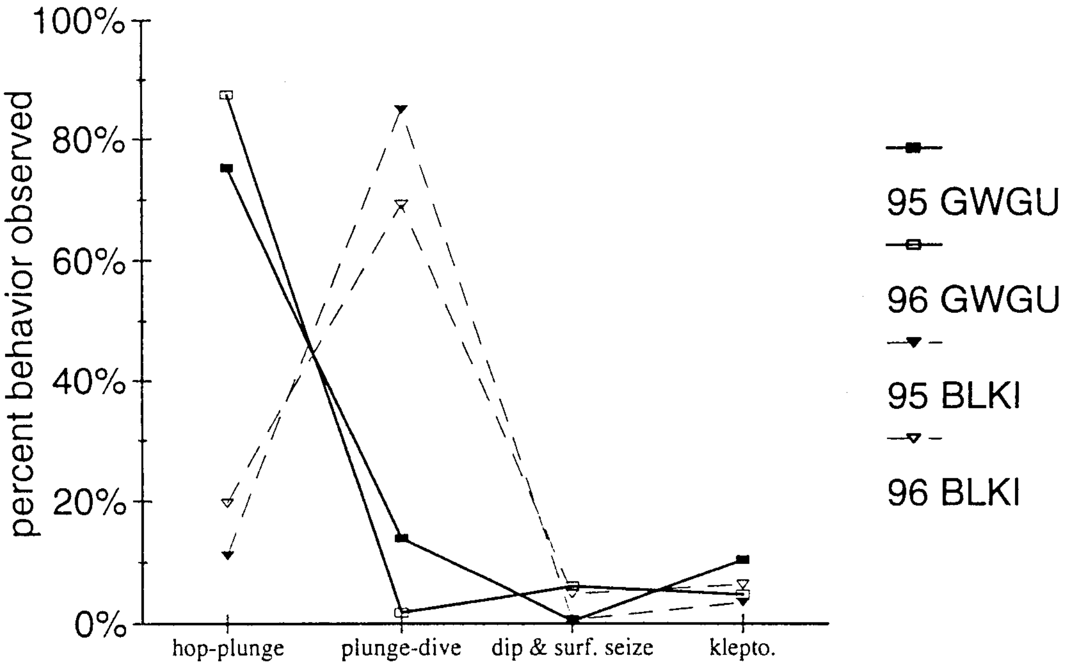

100%
80%
60%
40%
20%
0%
percent behavior observed
hop-plunge
plunge-dive
dip & surf. seize
klepto.
95 GWGU
96 GWGU
95 BLKI
96 BLKI

Figure V-13. Feeding success and losses for black-legged kittiwakes in 1995 and 1996.

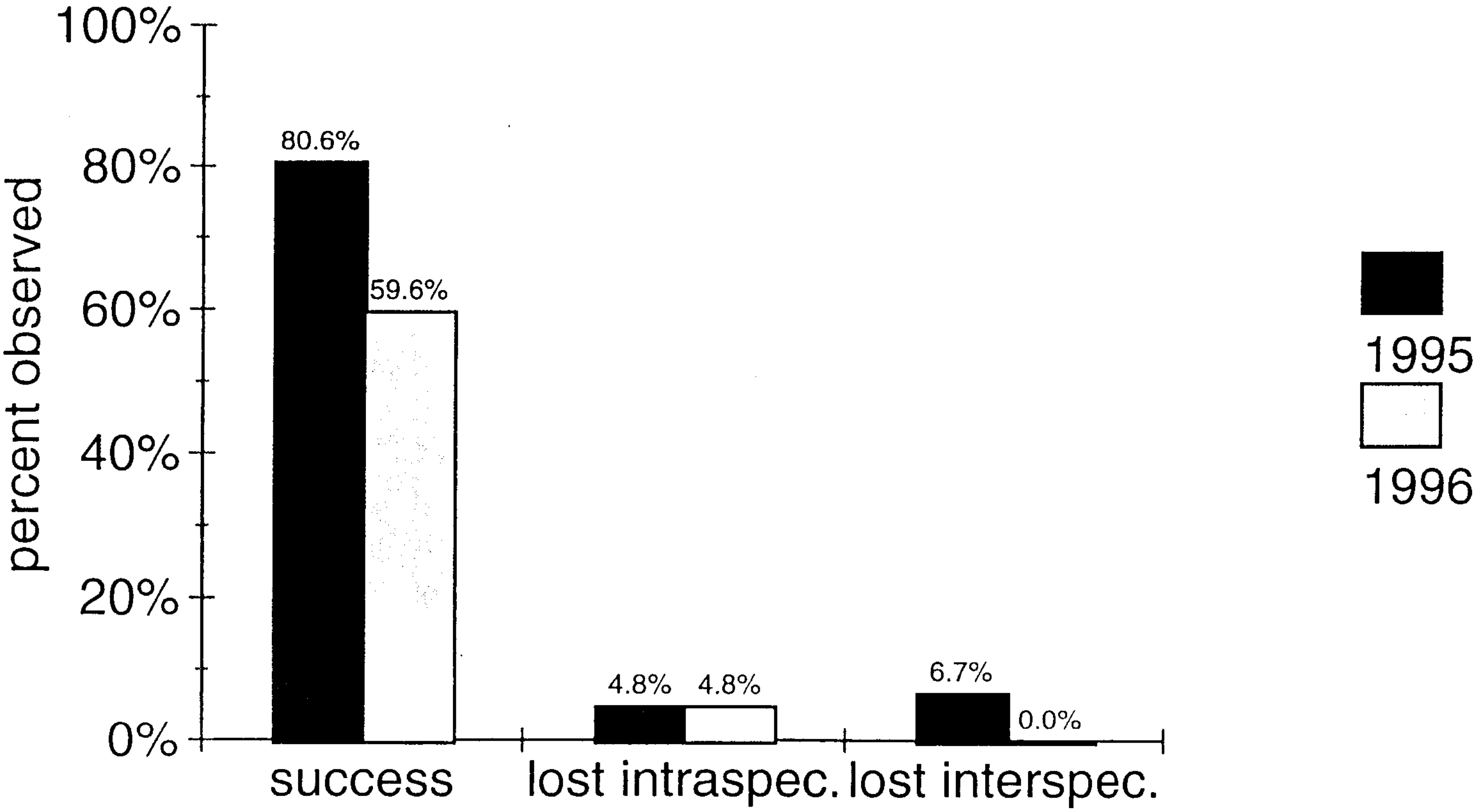

100%
80%
60%
40%
20%
0%
percent observed
80.6%
59.6%
4.8%
4.8%
6.7%
0.0%
success
lost intraspec.
lost interspec.
1995
1996

Figure V-14. Feeding success and losses for glaucous-winged gulls in 1995 and 1996.

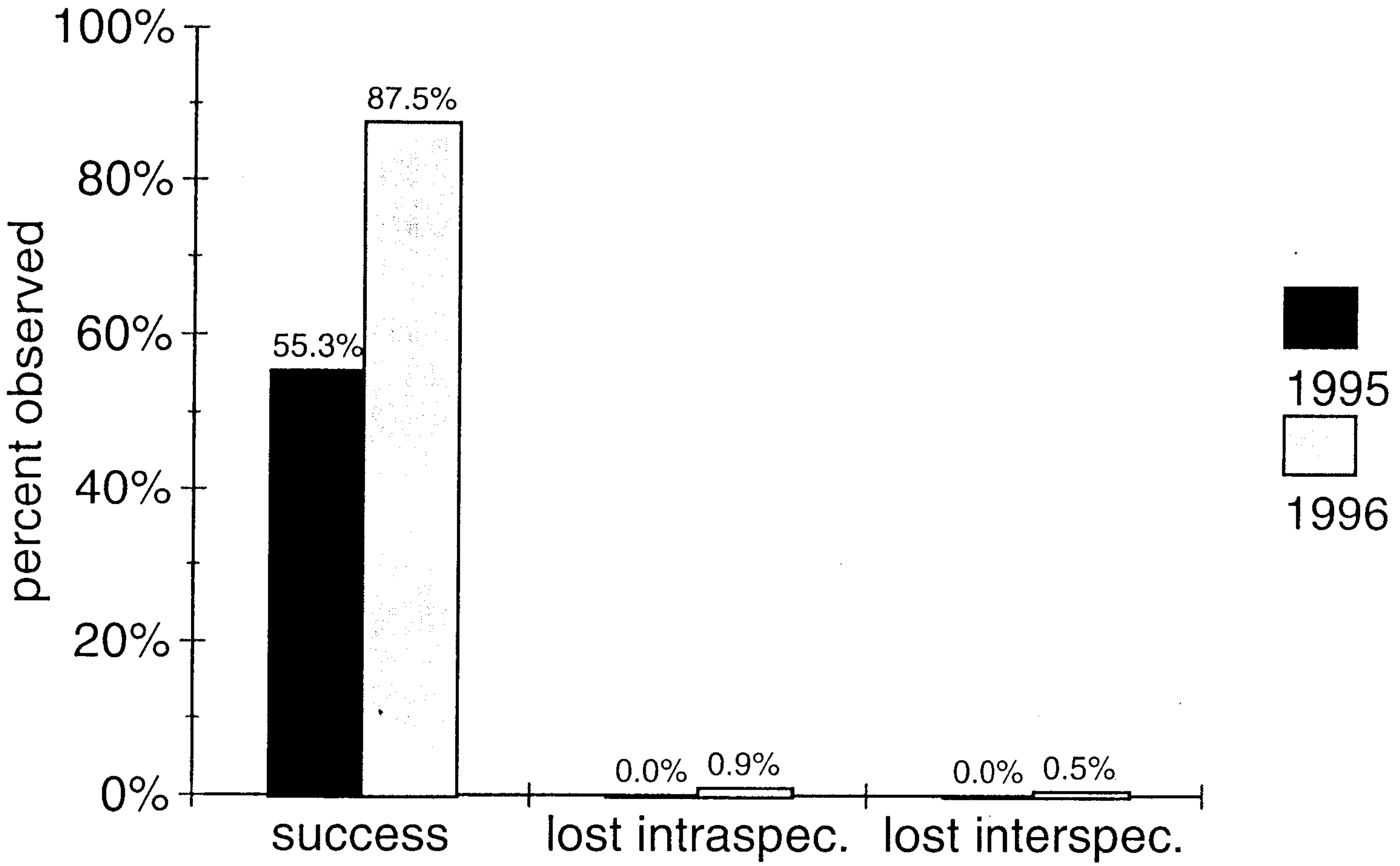

100%
80%
60%
40%
20%
0%
percent observed
55.3%
87.5%
0.0%
0.9%
0.0%
0.5%
success
lost intraspec.
lost interspec.
1995
1996

Figure V-15. Regression of the feeding rate of black-legged kittiwakes (BLKI) on glaucous-winged gull (GWGU) numbers at the flocks from July 1996.

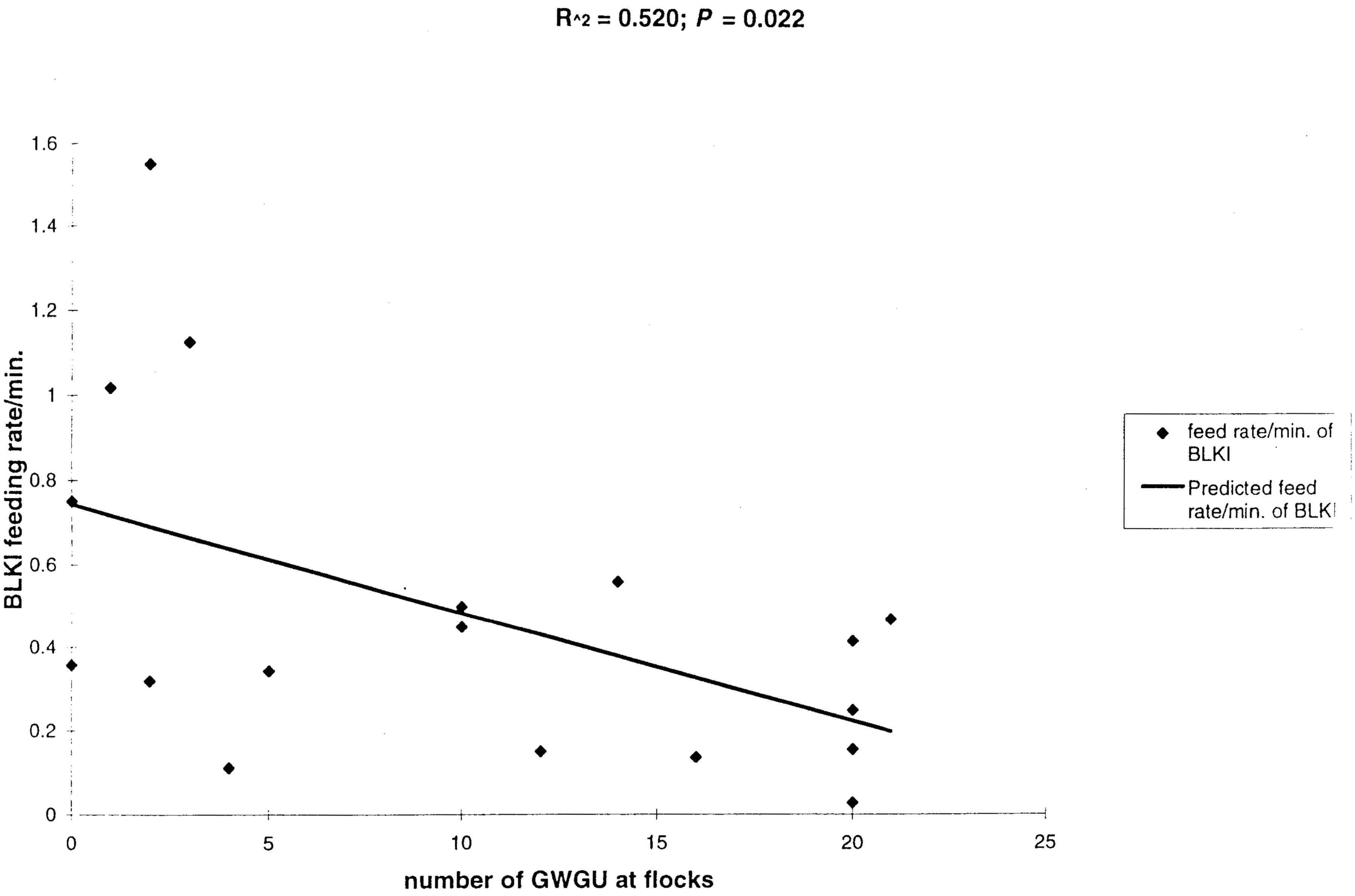
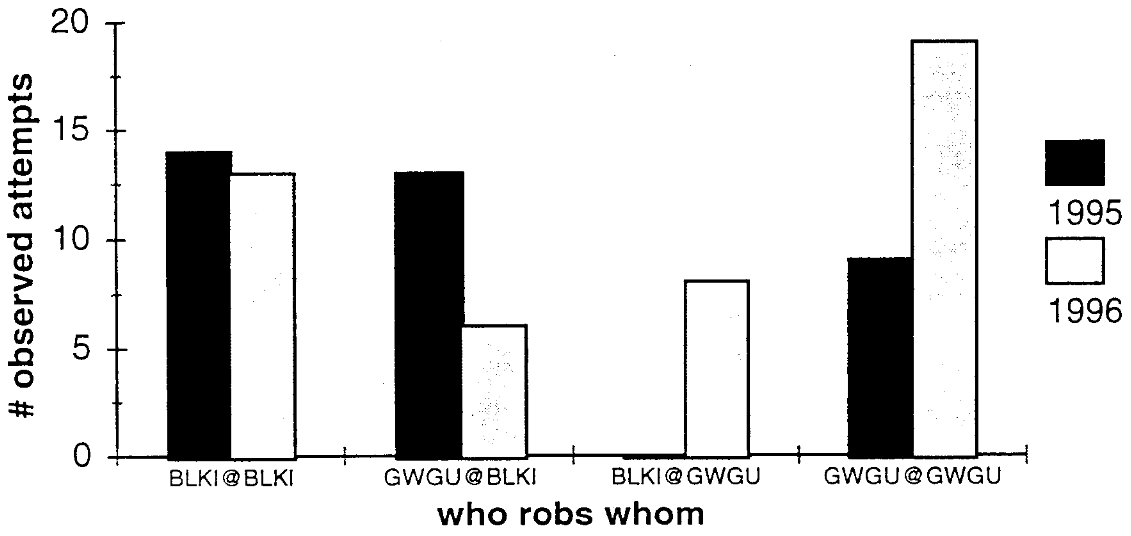

R^2 = 0.520; P = 0.022
BLKI feeding rate/min.
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
number of GWGU at flocks
feed rate/min. of BLKI
Predicted feed rate/min. of BLKI

Figure V-16. Kleptoparasitism of kittiwakes (BLKI) and glaucous-winged gulls (GWGU) in 1995 and 1996.


20
15
10
5
0
observed attempts
BLKI@BLKI
GWGU@BLKI
BLKI@GWGU
GWGU@GWGU
who robs whom
1995
1996

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(Thesis, defended 8 Dec 1996)

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Submitted	Due	April 1996
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Draft	Due	February 1997
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Accepted	Due	September 1996
	Submitted	
Published		

Ostrand, W. D., K. O. Coyle, G. S. Drew, J. M. Maniscalco, D. B. Irons. Selection of forage-fish schools by murrelets and tufted puffins in Prince William Sound, Alaska as factors in recovery following the *Exxon Valdez* oil spill.

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Submitted	Due Submitted	November 199

APPENDIX C

APEX: 96163C

Exxon Valdez Oil Spill
Restoration Project Annual Report

Alaska Predator Ecosystem Study:

Diet overlap, prey selection and potential food competition among forage fish species

Restoration Project 96163C
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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April, 1997

Diet Overlap, Prey Selection and Potential Food Competition among Forage Fish Species

Abstract: The food habits of forage fish, collected principally by trawl, and their prey resources, collected in vertical plankton tows, were examined from the central, southeastern and northeastern areas of Prince William Sound. The diet study is one of several components of the Alaska Predator Ecosystem Study (APEX), which is examining trophic interactions of seabirds injured by the *Exxon Valdez* Oil Spill and their forage species. This report summarizes all forage fish diet and prey resource data from 1994-1995 collections and a subset of sandlance data from 1996, in an attempt to determine whether fish trophic interactions might affect the abundance and quality of prey available to seabirds. Forage fish diet samples were analyzed from fall, 1994 (n = 90), summer 1995 (n = 380), fall, 1995 (n = 200), and summer 1996 (n = 80). Food habits data is presented for multiple species-size groups (primarily young-of-the-year and 1-age, as suggested by mean preserved fork lengths (FL)) of herring and pollock; less data is available for juvenile sandlance, capelin, eulachon, tomcod and pink salmon. Diet composition is presented as percent biomass of pooled prey categories and diet overlap as Schoener Overlap Index calculated from biomass of prey taxa. Prey resources were characterized from 84 zooplankton samples; prey selection was determined using fish and zooplankton samples collected at the same stations.

The mean total density of zooplankters available to planktivores was similar in summer and fall, 1995, in all areas of PWS, Most plankton was found in the upper 20-25 m water column, usually < 1500 animals*m^{-3}. Small calanoid copepods were the dominant taxon in all areas of PWS in both seasons, frequently comprising more than 80% by number. Large copepods *(Metridia pacifica)* were relatively abundant in the fall, particularly in the northeastern area; other relatively abundant taxa included the gastropod, *Limacina helicina*, the pteropod, *Oikopleura dioica*, and bryozoan cyphonautes larvae.

Most dietary biomass was contributed by few prey categories and differences were observed between species, age-classes, seasons and areas. In summer, large and small calanoids and hyperiid amphipods usually contributed the majority of prey biomass. In contrast, fall diets were usually dominated by euphausiids, large calanoids and some hyperiids. Sandlance had the most varied diets, and most capelin and eulachon stomachs were empty. High diet overlap (60-80%) occurred between between sympatric herring and pollock in northeastern and southwestern PWS, but was highly variable. No sets of co-occurring herring and pollock were sampled from central PWS, where pollock were most abundant. Small calanoids were generally avoided or were selected in proportion to their abundance, while large calanoids were selected for. A comparison of prey selection when herring occurred in single species schools vs. when they co-occurred with pollock suggested that diets shifted in the presence of this competitor. Pollock selected large prey whether they co-occurred with herring or in single species schools. These results suggest that, although the prey consumed may change seasonally, herring and pollock compete for food when their distributions overlap. More information is needed to understand the mechanisms for prey partitioning and the nature of trophic interactions between other species of forage fish.

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Figure 14. Frequency of occurrence (percent number of hauls) of prey taxa selected by herring occurring in single species schools (n = 5 allopatric hauls) vs. multi-species schools with pollock (n = 3 sympatric hauls). Specific taxon codes on the x-axis are grouped into the major prey categories indicated (see also Appendix 3). Date represents all possible hauls from fall, 1994 and summer and fall, 1995 APEX collections.

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Appendix 2(A-E). APEX forage fish collected in 1996 for diet analyses from Projects 96163A (PWS Fish Population Sampling), 96163M (Cook Inlet Studies), 96163F (Guillemot Foraging and Reproduction) 96163J (Barrens Nesting Study). Appendix 2 sections are ordered by species of forage fish (A) herring, B) sandlance, C) pollock, D) tomcod and E) pink salmon. Only samples indicated with a * have been processed and summary data is included in this report; the majority of samples have not been processed (see also APEX 1998 DPD). See Table 1 for gear abbreviations. See individual project summaries for further collection details.

Appendix 3. Protocol for Collecting and Processing Samples for APEX Forage Fish Diet Investigations. Appendices A-G are forms and codes used in collection and processing diet samples. A) field checklist, B) fish codes, C) sample log, D) fullness and digestion codes, E) sample labels, F) stomach content data sheet, G) prey codes and weights, and H) zooplankton and epibenthic prey data sheet.

INTRODUCTION

The Alaska Predator Ecosystem Experiment (APEX) is a multi-disciplinary, multi-year study designed to examine the marine food web of Prince William Sound (PWS) and Cook Inlet and its effects on species injured by the *Exxon Valdez* Oil Spill (EVOS). Efforts to restore apex predators injured by the EVOS oil spill, particularly harbor seals, pigeon guillemots, marbled murrelets, and black-legged kittiwake, have been limited by the paucity of information about the biology and population dynamics of their forage fish prey. In 1994, the pilot study "Forage Fish Influence on Recovery of Injured Species" was incorporated into Sound Ecosystem Assessment investigations focusing on salmon and herring. In the next year, that study evolved into APEX, which simultaneously investigates marine bird colonies and forage fish populations in the spill area. As one component of APEX, "Diet Overlap, Prey Selection and Potential Food Competition among Forage Fish Species," investigates the intra- and interspecific trophic interactions of forage fish and their prey in Prince William Sound (PWS) and other areas. Forage fish species include pelagic species in the offshore region as well as demersal nearshore species. Potential prey in offshore assemblages include Pacific herring (*Clupea harengus pallasi*), Pacific sandlance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), northern smoothtongue (*Leuroglossus schmidti*), eulachon (*Thaleichthys pacificus*), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), tomcod (*Microgadus proximus*), juvenile salmon (*Oncorhynchus* spp.) and prowfish (*Zaprora silenus*); potential prey in nearshore assemblages may include these and other species, such as Pacific snake pricklebacks (*Lumpenus sagitta*), Pacific sandfish (*Trichodon trichodon*) and daubed shanny (*L. maculatus*).

The high sea bird mortalities associated with EVOS occurred during a period of decline in several sea bird populations (Piatt and Anderson, 1996). Long-term shifts in the relative population abundances of prominent forage species were noted (Anderson et al., 1994), while, also in the 1970's and 1980's, increasing numbers of juvenile salmonids were released into the sound by enhancement facilities. The environmental conditions, trophic interactions and other factors controlling growth and survival of forage fish, as well as marine birds, are not well understood. However, damage assessment studies since the spill have associated continuing sea bird declines with the availability of forage fish prey. Reproductive failures were documented among black-legged kittiwakes from oiled areas (Irons, 1996) and may be associated with food conditions. Greater declines of pigeon guillemots in oiled areas compared to non-oiled areas were associated with reduced deliveries of sandlance, a high energy prey, to their chicks (Oakley and Kuletz, 1996). These population changes could be reflected in trophic interactions if food availability limits the carrying capacity of PWS (Cooney 1993. Knowledge about forage fish food habits, prey availability and selection, prey partitioning and shifts in prey selection when fish distributions overlap (allopatry vs. sympatry), diel feeding chronology, and other aspects of the feeding ecology, as well as geographic, seasonal and interannual comparisons of such trophic attributes, provide insight into how the population dynamics of these fish affect predation on them by apex predators, and in turn, the health of bird populations.

"Diet Overlap, Prey Selection and Potential Food Competition among Forage Fish Species," is conducted under the general APEX hypothesis that "planktivory is the factor determining abundance of the preferred forage species of seabirds." This project is testing the assumption of planktivory with the objectives of examining: prey availability, food habits, diet overlap between species and prey selection of forage fish species. A companion hypothesis, that "diets of different forage fish species will be different from one another," is being tested by looking for evidence of prey partitioning, ie., low diet overlap between co-occurring species. A finding that "forage fish diets exhibit a high degree of overlap or similarity," the alternative hypothesis, would suggest that food competition is possible when food is limited. Finally, competition between species is principally demonstrated through some kind of behavioral change that results in a negative impact on one species; in lieu of directed sampling, this project uses as a proxy evidence of a shift in diets and prey selection of co-occurring species compared to species in monospecific net hauls. Other kinds of comparisons with temporal and spatial attributes also provide information about interspecific and intraspecific trophic interactions, for a better understanding of ecosystem dynamics. This report summarizes the preliminary findinge of all diet and zooplankton data collected in APEX 1995 and a subset of sandlance data from 1996.

B. Methods

Field Sampling

This report includes only a brief summary of sample collection methods; the reader is referred to APEX 1994-1996 annual reports and "Protocol for Collecting and Processing Samples for APEX Forage Fish Diet Investigations" (see Appendix 3) for further details. Diet samples were collected opportunistically during APEX projects with other principal objectives, primarily the fish population studies in Prince William Sound and Cook Inlet and the food sampling aspects of bird studies. Samples were collected during survey operations for the "Forage Fish Population Sampling" project each year (Project 94163A: Forage Fish Cruise FF94-02, November 7-13, 1994 aboard the R/V Medeia; Project 95163A: APEX Cruise FF95-01, July 20-August 12, 1995 aboard the F/V Caravelle; and APEX Cruise FF95-02, October 5-14, 1995 aboard the R/V Medeia; Project 96163A: APEX Cruise FF96-01, July 14 -28, 1996). In 1994-1996, offshore hydroacoustic surveys were conducted along parallel transects in central, northeastern and southwestern PWS, spaced at two-mile intervals and ending as near shore as possible. Where fish were detected, the vessel either interrupted the survey or returned after the transect was completed to fish on the target. In 1996, samples were also collected with beach seines nearshore by Project 96163A (Cruise 96-01), in trawls and beach seines by Project 96163M (Cook Inlet Studies), by beach seines in 96163F (Guillemot Foraging and Reproduction), and by seines from 96163J (Barrens Nesting Study). In brief, if at least 10 specimens were available, fish samples for diet studies were preserved in 10% formalin-saltwater solution after biological measurements and sample data were recorded.

Project 96163A also conducted nearshore hydroacoustic surveys along zig-zag transects in each area. Various nets were fished on targets to determine species composition and to collect diet and other project samples. Schools detected hydro acoustically in offshore areas were sampled with purse seines and trawls. Schools detected hydro acoustically in shallow nearshore water or visually sighted at the surface were sampled primarily with purse seines, cast nets and dipnets. The beach segment at the base of the hydro acoustically assessed zig-zag was fish blindly; 3 fishable sections of the 10 sections contained in each beach segment were randomly selected. Diet samples were collected during both offshore and nearshore operations whenever fish were captured. An inventory of the samples collected in 1996 is included in Appendices 1 and 2; the majority of them will be analyzed in 1997.

After fall of 1994, prey resource samples (two replicates) were collected whenever diet samples were preserved, and in 1996 they were collected even if few samples were available and all were frozen for other project needs. Zooplankton samples were collected with a ring-net (0.5 m diameter) towed vertically from the depth where fish were sampled to the surface. In 1995, a 303-micron mesh net was used in summer and a 243-micron mesh net was used in the fall. In 1996, only the smaller mesh size was used. In 1995, 3 stations in the northeastern area (81, 84 and 85) were the sites of plankton mesh trials; one 20 m haul each with 105-micron, 243-micron, and 303-micron nets were collected to compare the prey resources sampled by each. Also in 1996, to complement the nearshore fish samples collected by 96163A, epibenthic sled samples were taken in addition to vertical plankton tows to assess prey available to intertidal fish from both epibenthic and pelagic production systems. In the nearshore, zooplankton samples were collected within approximately 100 m of the fish sampling site unless the site was too shallow; the plankton net was towed from 20 m depth to the surface. Epibenthic samples were collected using an epibenthic sled with an attached 0.3-m-diameter, 243-μ-mesh net hauled along a 10-m horizontal area at approximately 0.5-m depth adjacent to the seine location. The sled rested 11-cm above the substrate, thus collecting both epibenthic and planktonic organisms across the integrated micro habitats near the bottom. Replicates of either type of sample were preserved in 5% buffered formaldehyde solution in individual 500 ml sample bottles Few additional plankton samples were collected offshore; however, in some cases, prey samples collected to complement beach seined fish will be used with purse seined fish samples.

Due to gear and time constraints, it has not been possible to conduct directed sampling on specific schools for the proposed investigations of feeding periodicity and comparisons of diets of fish in monospecific and mixed species schools (see objectives in 97163C DPD). However, we attempted to address these objectives at least minimally. First, diel samples were collected during one day of serial beach seining in northeastern PWS at the end of the APEX cruise. Two beach segments (see above) where fish had been successfully seined during surveys just days before were selected (N05, Knowles Bay and N15, Bligh Island). Two replicate sections on each segment were beach seined at least once during each of four, 6-hour diel intervals (I: 10:01-14:00, II: 14:01-20:00, III: 20:01-04:00, and IV: 04:01-10:00). These sections were N0506 and N0505 in Knowles Bay, and N1503 and N1507 on southern and western Bligh Island. These beach sections could not be seined during time interval III at either location. The broad, shallow shelf off Knowles Bay required a long trip by small skiff from the supporting vessel (M/V Ms. Barrett) in semi-darkness, which was determined to be unsafe, and there was no time to return to

Bligh Island. The best subsets of samples obtained from this diel feeding investigation were for sandlance and herring. Sandlance were collected during three intervals at Knowles Bay; in addition, a "pseudo-diel" sample collected at the same site two days earlier during surveys provides a fourth time data point for sandlance. Herring are also available from four times at Knowles Bay. Herring samples were collected at both replicate beach segments in Knowles Bay within the designated diel period and at one of the segments two days earlier during surveys. Additionally, co-occurring herring and sandlance were collected in one of the diel samples. No diel series for a single species was available from Bligh Island replicate segments. The diel samples from Knowles Bay in northeastern PWS and Cabin Bay in central PWS (see below) are the only stomach samples analyzed to date from the 1996 APEX collections (n = 90 fish).

Project 96163M (Lower Cook Inlet Studies) collected nearshore and offshore forage fish samples in a manner similar to the work done in PWS. Plankton samples were not collected. Diet samples obtained from this investigation (Appendices 1 and 2) include beach seine and trawl samples collected from mid-June to mid-September at approximately 2-week intervals. The best subsets available from these samples is a 7-bimonthly time series of sandlance and 3 sets of Pacific cod to compare to collections from Naked Island.

Project 96163F provided fish diet samples (Appendices 1 and 2) by beach seining from the end of June to early August at Cabin Bay on western Naked Island (central PWS). Several sites in the bay were seined approximately weekly to collect guillemot prey samples. These collections provide two subsets of samples that we will use to address temporal aspects of sandlance diets: a 6-week time series spread over five sites in Cabin Bay and a diel series collected at a single station in late July over five diel intervals (four times and one repeat the next day). The time series samples at Cabin Bay were collected over roughly the same time period that diel samples in northeastern PWS (at Bligh Island and Knowles Bay) were collected. A 5-set collection of Pacific cod samples is also available. No plankton samples were collected.

Project 96163J (Barrens Islands Nesting Study) provided diet samples from weekly beach seine operations conducted from early July to early September at Amatouli Cove (Appendices 1 and 2). This sampling was also conducted to determine forage species available to marine birds at the colony sites. Subsamples were preserved for fish diet studies. The best subset of samples available from these collections is a 6-bimonthly time series of sandlance. No plankton samples were collected.

Laboratory Methods

Forage fish stomach samples and prey samples were analyzed at the NMFS Auke Bay Laboratory. The complete methods of handling and analyzing specimens collected for diet studies are described in "Protocol for Collecting and Processing Samples for APEX Forage Fish Diet Investigations" (see Appendix 3). Briefly, in the laboratory, fish were measured and weighed, stomachs were removed and weighed, and semiquantitative indices of stomach fullness and prey digestion were recorded from visual assessment. Relative fullness was recorded as: 1=empty, 2= trace, 3=25%, 4=50%, 5=75%, 6=100% full, and 7=distended. The state of digestion was recorded as: 0=fresh, 1=partially digested, 2=mostly digested, 3=stomach empty. Stomach contents were teased apart and split according to standard subsampling techniques when stomachs were too full to count every prey item (Kask and Sibert 1976). Zooplankton samples were split with a Folsom splitter. Prey were identified to the lowest level possible, enumerated under the microscope, and numbers were expanded. Taxa were identified to allow examination of prey selection by species, sex and life history stage, and within size groups. Large copepods were identifed as those > 2.5 mm total length (TL); small copepods were identified as those $\leq$ 2.5. mm TL; other taxa, such as euphausiid or amphipod species, were similarly defined by length ranges. Appendix 3G lists all prey codes, taxonomic names, and size definitions utilized in this study by their major taxonomic categories.

Data Summary and Statistical Methods

The numerical percentage composition and mean abundance of prey taxa in plankton samples were summarized to characterize the general resources available to planktivores in the northeastern, central and southwestern areas of PWS and at each station. Density of planktonic prey was standardized to 1 m^3 water volume using the number of animals per sample divided by the volume (V) of water sampled:

$$X = \sum x_i*(1/f)/V, \text{ and } V= 3.1742*r^2*D,$$

where x_i = number observed per taxon, f = the fraction of the sample analyzed, r = diameter of the net (0.5m) and D = depth of the tow. Depth of plankton samples were generally between 20-100 m; a 20 m tow filters approximately 16 m^3 of water, while a 100 m tow filters approximately 79 m^3 of water.

Ten fish from each species-size group per stations were analyzed from diet sample collections. Mean preserved fork lengths (FL) for each group was calculated to distinguish between intraspecific size/age groups. Mean fullness index and stomach fullness as mean prey percent body weight (%BW) were also computed:

$$\%BW = [\sum(x_i*w_i)/(BW- \sum x_{(i)}*(w_i))]*100, \text{ for } I = 1 \text{ to n prey taxa,}$$

where x_i = total number of prey per taxon, w_i = the mean weight of each prey taxon in mg, and BW = the fish body weight in mg.

Overall food habits of forage fish species were summarized for the northeastern, central and southwestern areas of PWS by pooling the specific prey taxa identified into major prey categories presented as percent total biomass and percent numbers . The Schoener Index of Overlap, also known as the Percent Similarity Index (PSI), was used as the principal measure of diet overlap (Wieser, 1960; Schoener 1974; Boesch, 1977; Hurlbert 1978; Krebs 1989). The PSI is computed by summing the minimum percentage of all prey taxa shared between two species of forage fish :

$$PSI_{jk} = \sum \min(p_{ij}, p_{ik}) = 1-0.5(\sum|p_{ij} - p_{ik}|),$$

where p is the biomass proportion of the i^th prey taxon in n taxonomic categories consumed by fish species j and k. The PSI is a simple and conservative estimator of diet overlap, yet, in this case, is based on the finest resolution identifications available. It was used to compare general food habits of fish among different regions of PWS and to compare specific diets of forage fish collected sympatrically in the same hauls.

Strauss Linear Selection Index was used as the principal measure of prey selection. This measure compares the numbers of prey taxa consumed by fish to the numbers available in prey resource sample (Ivlev 1961; Krebs 1989; Manly 1986; Strauss 1979). The index is computed by calculating the difference in the mean numerical proportion of a taxon consumed by fish and the mean numerical proportion available in the environment:

$$L_i = (p_i-e_i)*100, \text{ for } i = 1 \text{ to n prey taxa,}$$

where p_i is the numerical proportion consumed and e_i is the numerical proportion in the prey resource sample. Selection values were calculated for fish whose stomach contents could be compared to zooplankton samples collected at the same station; in a few instances, nearby stations were substituted when exact station samples were not available. Selection values were calculated for all taxa observed in either the stomachs or the prey samples. Negative values indicate avoidance, positive values indicate selection, and values near zero indicate predation at a rate proportional to the availability of the taxon.

Competitionwas investigated through diet shifts by comparing prey selection values for forage fish species occurring in the allopatric condition with those for the same species in the sympatric condition. The relative frequency of selection or avoidance of available taxa was used to indicate whether fish diets shifted in the presence of potential competitors.

RESULTS

This preliminary report summarizes the food habits and prey resources of forage fish species-size groups in central, northeastern and southwestern PWS in 1994-1996 in terms of prey biomass and numbers, diet overlap, prey selection, and stomach fullness (Tables 1 and 2; Appendices 1 and 2). All samples are analyzed from 1994-1995, while only a small subset of sandlance samples from 1996 have been completed. Table 1 summarizes the collection data for all fish collected in 1994-1995 for diet studies, with mean size and stomach fullness statistics for each group of 10 fish; minor species, such as prowfish, are not included. Size groups represent "ages" estimated from preserved lengths; this was done for convenience in separating sympatric age-size classes and "ages" have not been confirmed. Fish up to approximately 120 mm were categorized as 0-age, fish between approximately 121-170 mm FL were categorized as 1-age, and fish 171-225 mm were categorized as 2-age. Weights are whole-fish preserved wet weight. Stomach fullness index (1-7) and digestion index (1-3) codes are the mean per species-size group of 10. All samples have been processed.

The locations in southern, central and northeastern regions of PWS where APEX Fish Population Sampling Project obtained diet samples for this study in fall, 1994 and fall and summer, 1995 (Figure 1). A total of 670 fish were analyzed from these collections (Table 1), with n = 90 from fall, 1994; n = 380 from summer , 1995; and n = 200 from fall, 1995. Fish were taken from the surface to depths of 100 m in all three seasons. A total of 69 zooplankton samples were collected in the summer and 15 in the fall of 1995 (Table 2). No plankton was collected in fall, 1994. Replicate plankton samples were hauled from depths near where fish were located; plankton were taken to a depth of 20 m if fish were sampled above that depth. Ten stations in the summer and one station in the fall were sampled for zooplankton at two depths because fish were collected from both.

Fish collections were primarily comprised of multiple size groups of Pacific herring and Walleye pollock (Figure 2, Table 1). Not all size groups were represented in all areas of PWS or in all seasons. Most fish were collected in the summer in the central area; these were primarily pollock in monospecific schools or with small numbers of other species. Herring were collected primarily from the northeastern and southwestern areas of the sound in both summer and fall. Pollock and herring were most often collected together in the fall (see also 96163A annual report). Other species collected in large enough numbers to analyze diets included capelin, pink salmon, sandlance and one set of tomcod from summer, and capelin and eulachon from fall. Fish sizes ranged from capelin approximately 20 mm in FL in summer to herring over 200 mm in the fall. The majority of the fish were young-of-the year on the order of 50 mm FL in summer and over 100 mm in the fall (Figure 2).

The mean density of zooplankters available to planktivores was similar in summer and fall, 1995 in central, northeastern, and southwestern PWS (Figure 3). Most plankton was found in the upper 20-25 m water column, usually at total densities less than 1500 animals per cubic meter, which is well below a typical spring bloom density. The highest mean zooplankton density observed was approximately 3500*m^{-3} plankters in southwestern PWS in summer. The mean density and relative density (percent number) of species pooled into major groups of plankters by station and depth are shown for summer (Table 3) and fall (Table 5) in each area of the sound.

A key to the major prey groups for all zooplankton and diet composition figures to follow is shown in Figure 4. Small calanoid copepods were the dominant taxon in all areas of PWS in both seasons, frequently comprising more than 80% by number (Figure 5). These were primarily *Pseudocalanus* spp. and *Acartia longiremis*. Other taxa combined made up less than 20% of the zooplankton composition. Large copepods were relatively abundant in the fall, particularly in the northeastern area; these were primarily *Metridia pacifica* and some *Calanus pacificus*. Other relatively abundant taxa included the gastropod, *Limacina helicina*, the larvacean, *Oikopleura dioica*, and bryozoan cyphonautes larvae. The composition of zooplankton as mean numbers and percent numbers by species is shown for each area and station in Tables 4 and 6 for summer and fall, respectively.

Examples of forage fish diet composition (percent biomass of major prey groups) are shown in pie diagrams for each season (Figures 6, 7 and 9). Details for each station by area are presented in Tables 7-12 for fall, 1994; Tables 13-18 for summer, 1995; and Tables 19-24 for fall, 1995. In summer, large and small calanoid copepods were the most common prey groups; calanoids made up the largest percentage biomass in the diets of most forage species, while very small hyperiids were sometimes prominent (Tables 7, 13, and 19). Juvenile pink salmon diets varied at the two stations where they were collected, with large calanoids predominate at one station, and larvaceans and fish predominating at the other. In fall of both 1994 and 1995, large calanoids and euphausiids commonly formed large percentages of prey biomass, with larvaceans as smaller proportions (Figures 7 and 9) for herring and pollock. Seasonal changes in diet composition were therefore fairly consistent between years, although the 1994 fall samples were collected approximately one month later than the 1995 fall samples. Euphausiids were more prominent in the October, 1994 samples than the November, 1995 samples. All eulachon and most capelin sampled had stomachs containing only trace amounts of prey (Table 1); those eulachon stomachs containing anything had eaten euphausiids (Figure 9).

Prey selection from zooplankton is shown for the same fish species-size groups for summer and fall, 1995, the only data available to correspond with pie diagrams of prey biomass (Figures 8, 10, and 11). In the prey selection figures, the specific codes for prey taxa are shown along the x-axis (see also Appendix 3G); these are grouped within major taxonomic categories, separated by dashed vertical lines. Strauss Linear Selection values as positive bars indicate selection of the taxon and negative values indicate avoidance of the taxon. Values close to 0 represent prey taxa consumed randomly or in proportion to their abundance in the environment. The example shown (Figures 7 and 8) depicts three stations in northeastern PWS in summer, two in Port Fidalgo and one in Port Gravina. Two groups of YOY herring were caught at the surface and two of YOY sandlance were caught at different depths. These species selected different prey at different stations. At the station where no other fish were caught (Station 27), the herring selected small calanoids, invertebrate eggs and cladocerans. The herring collected with YOY sandlance at Station 118 had empty stomachs (the negative bars in this case only represent the plankters available). Sandlance co-occurring with the herring at Station 118 probably consumed small calanoids slightly less than in proportion to their abundance overall; the calanoids were not identifiable (CAS), but probably consisted mostly of the *Pseudocalanus* stages shown as avoided. The sandlance also selected small amounts of other prey, including barnacle larvae and cladocerans. At the deeper Station 82, however, they primarily selected the large calanoid, *Calanus pacificus.* Although these sandlance and the older pollock collected sympatrically in 100 m of water at Station 82 near East Graveyard Point in outer Port Fidalgo both selected large calanoids, at least some of them were different species (Figure 8); the pollock also selected unidentified crustaceans and chaetognaths. The YOY herring at Station 118 were the only set of that species encountered with empty stomachs; however, while prey consumed by the co-occurring sandlance were diverse, their stomachs were not full (fullness index = 25%; Table 1). Prey selection details are presented for all fish collected at each station by area in Tables 29 and 30.

At Port Fidalgo, northeastern PWS, forage species were collected from two depths at Station 7 in fall, 1995. Both YOY herring and pollock collected at 20 m depth selected small prey (Figure 10). For theseherring, the greatest magnitude positive selection was for oikopleurans (larvaceans). The pollock appeared to heavily select small calanoids, but many of the unidentifiable species shown as selected were probably a mixture of the avoided species shown by the negative bars; the net result was probably consumption of small calanoids in proportion to their abundance. Both YOY herring and pollock tended to select large calanoids in greater proportion than their availability in the plankton. Both YOY species had stomachs approximately 50% full (Table 1). Pollock showed increasing selection for large calanoids with increasing size and depth; pollock deeper in the water column particularly selected *Metridia pacifica* females, a highly migratory species (Figure 10). Overall, the most abundant plankters, the small calanoid *Pseudocalanus* spp. and bryozoan cyphonautes larvae, were avoided. Proportionately fewer small calanoids were available near the surface than at 100 m in the northeastern area in the fall, while proportionately more large calanoids were near the surface than deeper (Figure 5). This is the opposite trend from that observed in the summer in the same area. Euphausiids do not appear to be highly selected for despite their prominence as prey biomass; they may be poorly represented by the sampling gear or the fish may have fed in another area of the water column.

An example of prey selection from southwestern PWS at a station in Whale Bay shows co-occurring 1-age herring and 0- and 1-age pollock collected at 60 m depth in the fall (Figure 11). None of these fish selected small calanoids. As in the last graph, the unidentified, small calanoids (CAS) that appear to be selected by herring were probably *Pseudocalanus* and *Acartia*, species which are shown as avoided. This means that, although small calanoids are present in the diet, they are not consumed in proportion to their abundance. The major differences in prey selection by these species and size groups are that 1) both large and small herring selected the larger oikopleurans from those available, while both large and small pollock avoided oikopleurans; 2) conversely, only large pollock selected large copepods, primarily female *Metridia pacifica*, and they had the greatest selection for large euphausiids and for unidentified crustaceans (which may have been euphausiids); and 3) small pollock selected very high numerical proportions of invertebrate eggs, possibly by non-discriminate filter feeding. Forage fish appear to be opportunistic, selecting different prey in different circumstances; without more of these sympatric samples, it is difficult to tell which variable controls what they eat: prey availability by depth or locale, predator size, presence of other predators, etc. This particular situation suggests that in schools containing mixed herring-pollock, prey resources are at least partitioned by species and age class.

Diet overlap was examined for species pairs collected in the same hauls (Figure 12, Tables 25-28) using Shoener's Index of Overlap. This measure sums the minimum percent biomass shared between fish groups. Each bar represents a species-size pair, including stations where an age class was sampled from two different depths (Table 25). Diet overlap between 0-age herring and pollock ranged from 3% prey biomass to nearly 80% prey biomass. Co-occurring YOY herring and pollock had the highest diet overlap at Port Gravina in the fall of 1994,and area where euphausiids formed most of the prey biomass in both species. Diet overlap was also substantial, between 60-70%, at some stations where different age classes of herring and pollock were paired or where YOY pollock were collected from different depths. These high overlap values occurred in all three seasons and areas. Some of the lowest diet overlap values were observed for species combinations involving older pollock. Little overlap was observed for other forage fish species, although few hauls with large enough samples of species other than herring or pollock were collected in 1994-1995. Capelin and eulachon collected in multi-species hauls primarily had empty stomachs. Juvenile tomcod and 0-age pollock were collected together in a beach seine haul in the summer in the southwest area; however, their diets showed virtually no overlap-- tomcod ate fish and epibenthic gammarids amphipods, while pollock mostly ate small calanoids. As shown in the by selection data in Figure 8, 0-age sandlance and age-2 pollock co-occurring in Port Fidalgo did not have overlapping diets because they selected different large calanoids. Finally, the diets of 0-age sandlance and 0-age herring co-occurring in Port Gravina did not overlap because the herring had empty stomachs.

Figures 13 and 14 show the percent frequency with which prey taxa were selected or avoided by herring and pollock when they occurred in single species schools, versus when they co-occurred with the other species. These figures represent data pooled across all seasons at stations where plankton was sampled with the fish (see also Table 31). The y-axis is the percent frequency of occurrence of the taxa on the x-axis. Only taxa with selection values > 5% or < -5% were included. Pollock occurred as single species schools at 8 stations and co-occurred with herring at 6 stations. Pollock avoided many of the taxa available, notably the small calanoids;however, pollock selected large calanoids both when they occurred alone and when they co-occurred with herring. Compared to herring, pollock also frequently selected various hyperiid amphipods, another energy rich prey group. The five sets in which herring were caught alone are shown at the top of Figure; the three sets in which herring were caught with pollock are shown at the bottom. In both the monospecific and multi-species schools, herring did not select many of the prey types available. However, more than twice as many taxa were selected when herring occurred alone than when they co-occurred with pollock. In contrast to pollock, the calorie dense large calanoids were selected only when pollock were not present. These observations suggest a shift in diet away from the optimum for herring co-occurring with pollock, ie., a negative effect that suggests competition for food.

The last three figures indicate some research goals for the next field season. Directed sampling is needed to address questions about factors and mechanisms that control when co-occurring species exhibit high diet overlap, whether selection of large calanoids or other favorable prey is regulated by density dependent interactions between species, and whether fish partition the available food by feeding at different times of day or in different sections of the water column. Two sets of sandlance collected by beach seining over a diel cycle in July, 1996 in two areas of the sound were analyzed (Figure 15). Time of day is shown on the x-axis, and the mean percent fullness index is on the y-axis. While the stomachs of sandlance from Cabin Bay on west Naked Island had the fullest stomachs in the middle of the day, those from Knowles Head outside Port Gravina had empty stomachs at all times of the day. Plankton has not yet been analyzed to determine what prey fields were available to the fish in these two areas, but data from 1995 does not suggest that total densities differ greatly between the central and northeastern areas. They were all YOY fish, as indicated by the mean FL shown above each time point, although the difference in lengths at different times of day suggests that different schools may have moved into these areas at different times of day. An analysis of the food habits of the Cabin Bay sandlance also suggests that prey consumed changes with time of day (Figure 16). Although small calanoids predominate in the diets, during the times of peak feeding, other prey formed relatively large proportions of the prey biomass; these included larvaceans, decapods, and epibenthic harpacticoid copepods. By contrast, mean stomach fullness of herring and pollock (n = 10 per station) plotted over time for all seasons combined suggest no pattern for peak time of feeding in these species (Figure 17). Mean fullness for the 130 capelin analyzed was "empty" regardless of time of day collected. Finally, total prey expressed as a percent of fish body weight was plotted for all herring and pollockindividuals analyzed from 1994-1995 diet studies and for all sandlance individuals collected at discreet time intervals at Cabin Bay in 1996 for diel feeding studies (Figure 18). Again, no pattern emerges for the herring and pollock, but sandlance appear to feed in the daylight after approximately 08:00. These ambiguous results for herring and pollock suggest that, to examine whether prey are partitioned by time of day of feeding, directed sampling on specific schools of fish over the diel cycle is needed. Summaries of stomach fullness and related statistics for the common forage fish species sampled are shown in Tables 32-36.

Discussion

Seasonal, ontogenetic, spatial or temporal partitioning of prey resources may occur among forage fish species inhabiting the same area. A species preferred foraging habitat may change with changing hydrographic conditions and will reflect foraging behaviors that could also change ontogenetically. Species caught in the same area also may have foraged in different levels of the water column. This spatial segregation will be reflected by low dietary overlap. Niche overlap between age-1 herring and capelin, for example, was highest in the spring when both species foraged in the water column; after the water column stratified, herring switched to a surface foraging mode in response to a newly available prey assemblage (Coyle and Paul 1992). Niche overlap between the two species then decreased as capelin continued to feed in the water column. Such trophic shifts also suggest that species which are not competitors during one season or life history stage may become competitors at another time.

Species sharing the same habitat may also partition resources on a temporaral basis, for example by having different diurnal feeding rhythms. For example, juvenile herring are sometimes observed schooling in shallow water at the head of bays (personal observation, APEX 1995). In these conditions, juvenile herring may compete with sandlance or demersal nearshore species for epibenthic or brackish water prey, or perhaps partition resources by feeding at different tidal stages when the suite of available prey changes. Conversely, herring located in pelagic waters offshore may compete with juvenile pollock for planktonic copepod prey.

Sandlance is an important forage species with the potential for food competition with several other species because of its diel behavioral pattern. Pacific sandlance perform a daily migration between feeding grounds, schooling sites and benthic refuge areas in soft substrates, primarily feeding during daylight (Hobson 1986). This transient behavior and the sandlance's attraction to light (Hobson 1986) suggests that sandlance could feed from both epibenthic and pelagic production systems, intermixing with both schooling and demersal fish species at various times during a 24-hour cycle. Calanoid copepods are commonly reported as the majority of prey weight found in the stomachs of several species of sandlance (e.g., Meyer et al 1979; Craig 1987; Field 1988). Meyer et al. observed that American sand lance (*A. americanus)* feed in schools between midwater and the surface, not on the bottom. Pacific sandlance (*A. hexapterus*), however, consumed a variety of prey taxa, with epibenthic taxa more common in diets during fall and winter (Field 1988). Similarly, epibenthic harpacticoid copepods are commonly observed along with other prey in the stomach contents of sandlance in PWS (Sturdevant, unpub. data; Willette et al. 1995). Diet overlap based on numbers of epibenthic prey is likely to be high between sandlance, tomcod (*Microgadus proximus*) and juvenile salmon (*O. gorbuscha* and *O. keta*), the forage species whose stomach contents commonly contained high numbers, but usually low biomass, of these small epibenthic prey (Sturdevant, unpub. data; Sturdevant et al. 1996; Willette 1996). Collections of a particularly important forage species, sandlance, have been limited in PWS. Although analyses of PWS forage fish diets are not complete, some findings suggest that sandlance trophic interactions could impact several species. Larval sandlance and herring in Port Moller, Alaska shared a diet of various copepod life history stages (McGurk and Warburton, 1992). Willette et al (unpub. data) found that sandlance and pink salmon fry collected together in spring also shared a diet consisting primarily of small copepods, similar to independent observations on these species in other areas (e.g., Craig 1987; Sturdevant et al. 1996). In one net haul, sandlance stomachs contained approximately 10 times the biomass of the pteropod, *Limacina helicina*, and four times the biomass of small copepods as pink salmon in spring. Trophic interactions between sandlance and other forage species may occur over broad spatial and temporal scales, and this study reports on further investigations.

Information on seasonal changes in diet overlap and food competition among forage species is limited. Craig (1987) observed seasonal changes in the principal dietary components (% biomass) of YOY sandlance on the north Aleutian shelf. Copepods predominated in summer (90%), euphausiids predominated in winter (100%), and a mixture of the two taxa predominated in spring (26% copepods and 40% euphausiids). Although seasonal data were not available for the herring from his study, their diets overlapped with sandlance in summer; the predominant prey of both large (28.2 cm) and small (91 mm) herring in summer were copepods, crustacean larvae, and chaetognaths. Hobson (1986), Field (1988) and McGurk and Warburton (1992) also noted the co-occurrence and similarity in diets of Pacific herring and sandlance during several life stages. These observations are similar to our preliminary data from APEX collections in the summer of 1995. We found high diet overlap between sandlance and two size classes of herring, largely based on small copepods (Figures 5 and 6). Likewise, we observed high biomass proportions of euphausiids in the diets of both herring and pollock in November (Figure 7), when sandlance were not caught. Euphausiids predominated in sandlance winter diet on the Aleutian shelf (Craig 1987).

Although "copepods" are commonly reported in fish diets, specific identifications of the prey are not always made and can be important. Both *Epilabidocera longipedata* a surface swarming copepod species (Johnson, 1934) and *Metridia ohkotensis* and *M. pacifica*, diel vertical migrators (Hattori 1989) were consumed by herring and other forage species (Willette et al, unpub. data). The presence of these very different prey organisms in the same spring diets indicates that trophic interactions could occur at several depths in the water column or that oceanographic processes play a large role in determining which prey are available and whether partitioning occurs. The results from analysis of seasonal diet data may also depend on detailed species identifications.

While the APEX project focused on the summer nesting period of marine birds, a complete understanding of the influence of their forage species trophic niche must take into account the fish's entire life history and environment. Ideally, trophic studies should examine seasonal relationships over a broad area, include as many stages of the life history as possible, investigate diel feeding rhythms and behavior, and assess the dynamics of prey resources. These factors may contribute to an explanation of how co-occurring species partition resources and each sustain healthy populations. Competition among species can be inferred from an observed shift in resource use, such as absence from preferred habitat or failure to use a preferred a prey resource (Sogard 1994); the shift is then reflected in some measure of health, such as poor condition or small size. Ultimately, survival may be affected and populations reduced. While a complete investigation of all of these factors is outside the scope of the APEX forage fish diet study, some aspects can be addressed in the 1996 field study. Preliminary information about trophic interactions among forage species was reported in "Forage Fish Influence on Recovery of Injured Species: Forage Fish Diet Overlap" (SEA 94163C; Willette et. al, 1995). Analyses are not complete, but substantial diet overlap among forage species pairs was demonstrated for the late summer season. Juvenile herring-pollock and juvenile pink-chum salmon pairs both had relatively high diet overlap, but partitioned available prey resources; small copepods were the principal prey of juvenile herring and pollock, while fish larvae were the principal prey for juvenile salmon.

During the nearshore work scheduled for the 1996 APEX field season, it is likely that a number of additional nearshore benthic and demersal forage species exhibiting substantial diet overlap with sandlance will be collected. Information from APEX and SEA studies of oceanographic processes and fish dynamics will be important for understanding the food observations. Seasonal and tidal oceanographic processes that affect zooplankton and epibenthic prey abundance and distribution could impact trophic interactions (Field 1988; Hobson 1986). Our observation that both same-age classes (fall) and different age classes (summer) of pollock from different areas of PWS had different diets, for example, suggests that the spatial availability of prey in geographic areas may be one factor affecting the amount of diet overlap observed. A number of behaviors could also influence the degree of overlap in diets. Seasonal and/or diel differences in both horizontal and vertical distribution of the fish (and prey) are likely to affect both observations of fullness and prey selection (see Haldorson 1995; Haldorson et al 1996). The prey available may also affect the relative fullness of stomachs, if different size prey are available in different areas. Simultaneous collections of prey samples will be important to determine whether fish are selecting prey from the resources available where they are caught. Furthermore, because mouth gape increases with fish growth, seasonal differences in prey selection from taxa present year round, such as euphausiids, may be a reflection of both fish distribution and their ability to select larger prey specimens. Other aspects of particular species' biology are also important, such as the habit of capelin to stop feeding during the spawning period, which had likely taken place shortly before our summer sampling period. Systematic collection of diet samples over the diel period will enable us to determine if the preliminary observations of seasonal differences in stomach fullness and the empty stomachs of juvenile eulachon (this report) can actually be attributed to differences in the time of day fish were collected. In addition, the degree of dietary overlap observed among co-occurring species may be explained by other trophic interactions, such as shifts in habitat use like those documented for juvenile cod avoiding predation (sensu Gotceitas et al 1995). A clearer understanding of diel feeding behavior and activity patterns of sandlance and other forage species will be important to explain the simlilarities and differences observed.

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ble 1. Forage fish diet samples collected during fall, 1994 and summer and fall, 1995 fish population sampling
veys (APEX projects 94163A and 95163A), by area, date, station and haul numbers, gear type, general location,
nple time, and gear depth. No fish were collected in the central area in fall, 1994. Fish size and stomach indices
explained in the text. Gear abbreviations: T = midwater trawl, M = methot trawl, B= beach seine, D = dipnet, R
air trawl; U = purse seine; S = cast net.

L 1994 FISH COLLECTIONS

mple ate	station #	haul #	gear code	location	sample time	gear depth	species	size group	mean length (FL, mm)	mean weight (wet wt., g)	number of fish	mean stomach fullness (1-7)	mean stomach digestion (1-3)
heast region PWS													
-Nov	6	1	T	Inner Galena Bay	22:42	20	herring	0	93	6.65	10	1	2
-Nov	6	1	T	Inner Galena Bay	22:42	20	pollock	0	100	6.62	10	3	1
-Nov	7	4	T	Mouth Of Port Gravina	22:30	21	herring	0	97	7.20	10	3	2
Nov	7	4	T	Mouth Of Port Gravina	22:30	21	pollock	0	111	8.63	10	3	2
Nov	7	5	T	Mouth Of Port Gravina	23:25	80	eulachon	0	84	2.76	10	1	2
Nov	8	2	T	Mouth Of Port Gravina	15:10	36	herring	0	123	83.33	1	3	1
Nov	8	2	T	Mouth Of Port Gravina	15:10	36	herring	1	173	49.70	9	2	1
Nov	8	3	T	Mouth Of Port Gravina	16:15	35	herring	0	88	5.31	9	3	2
Nov	8	3	T	Mouth Of Port Gravina	16:15	35	herring	1	147	30.06	1	3	2
hwest region PWS													
lov	3	1	T	Needles Area	13:25	95	herring	2	215	45.77	10	2	2
lov	5	5	T	Icy Bay	15:32	50	pollock	0	111	9.08	10	5	1
											n=90		

MER 1995 FISH COLLECTIONS

ple e	station #	haul #	gear code	location	sample time	gear depth	species	size group	mean length (FL, mm)	mean weight (wet wt., g)	number of fish	mean stomach fullness (1-7)	mean stomach digestion (1-3)
al region PWS													
ul	1	2	T	N.E. Montague	16:40	60	pink salmon	0	76	3.33	10	5	1
ul	3	1	T	Applegate-Knight Island (FFN01A)	12:23	60	pollock	0	59	1.04	10	3	1
ul	5	2	T	Nw Seal Island (FFN03A)	17:04	50	pollock	0	54	0.91	10	4	2
ul	19	1	T	E. Liljegren Pass	15:37	50	pollock	0	58	1.08	10	4	2
g	53	1	T	N. Montague Pt. (East FFN01A)	9:17	60	pollock	0	56	0.94	10	4	2
g	53	2	T	N. Montague Pt. (East FFN01A)	9:55	20	pollock	0	62	1.32	10	5	1
g	54	2	T	E. Of Knight Is. (FFN01A)	12:14	60	pollock	0	54	0.85	10	3	2
g	56	1	T	Seal Island (FFN03A)	15:27	80	pollock	0	58	0.96	10	3	2
g	57	2	T	Seal Island (FFN03A)	17:30	80	pollock	0	58	1.11	10	4	2
g	58	2	T	North Knight Is. (FFN04A)	9:25	80	pollock	0	56	1.03	10	5	2
g	62	1	T	E. Eleanor Island (FFN07A)	14:28	20	capelin	0	21	0.02	10	1	3
g	62	2	T	E. Eleanor Island (FFN07A)	15:16	60	pollock	0	53	0.84	10	4	2

Ta cont.

g	65	1	R	So. Tip Naked Is.	10:45	0	capelin	1	137	19.26	10	1	1
ig	66	2	T	Eleanor Passage (East End FFN08A)	14:49	8	pink salmon	0	118	15.27	10	6	2
ig	67	1	T	East Of Peak Island (N. Naked)	17:06	10	capelin	0	31	0.05	10	1	2
ig	72	1	T	East Of Liljegren Pass.	10:45	15	capelin	0	24	0.03	10	1	2
ug	73	1	T	Ne Peak Island, Liljegren	11:56	80	pollock	0	57	1.09	10	4	1
ug	73	1	T	Ne Peak Island, Liljegren	11:56	80	capelin	0	26	0.03	10	1	3
ug	108	1	T	N. Hogan Bay (Se Knight Is.)	21:57	20	pollock	0	66	1.78	10	6	2
ug	110	1	B	Se Eleanor Island	15:30	0	herring	0	30	0.12	10	3	2
Aug	112	1	T	South Of Naked Island	13:13	80	pollock	0	65	1.72	10	4	2
Aug	114	7	T	Off Montague Point	20:38	15	capelin	1	135	16.94	10	1	2
Aug	999	1	B	Cabin Bay, Naked Is.	-0-	0	sandlance	0	92	2.34	10	7	2
heast region PWS													
-Jul	22	2	T	South Of Bligh Island	11:07	20	herring	1	143	25.99	10	4	2
-Jul	27	1	D	S. Graveyard Pt; Port Fidalgo	19:30	0	herring	0	76	2.93	10	6	1
7-Jul	29	1	T	W. Of Bligh Reef	10:57	80	pollock	2	185	38.14	10	1	2
-Aug	82	1	T	E. Graveyard Pt.; Port Fidalgo	14:25	100	pollock	2	181	37.80	10	4	2
-Aug	82	1	T	E. Graveyard Pt.; Port Fidalgo	14:25	100	sandlance	0	61	0.54	10	4	1
-Aug	116	1	T	Port Gravina	12:10	20	herring	1	127	19.58	10	5	2
1-Aug	118	1	B	Outside Port Gravina	15:30	0	herring	0	71	2.35	10	1	3
1-Aug	118	1	B	Outside Port Gravina	15:30	0	sandlance	0	90	2.30	10	3	1
uthwest region PWS													
30-Jul	43	1	T	Mouth Whale Bay (Dual Head)	12:37	10	herring	0	108	6.03	10	4	1
30-Jul	43	1	T	Mouth Whale Bay (Dual Head)	12:37	10	capelin	0	30	0.05	10	1	2
30-Jul	47	1	T	Pt. Countess (FFJ05E)	16:07	10	capelin	0	33	0.05	10	1	2
31-Jul	51	1	B	Pt. Countess	11:30	6	tomcod	1	163	27.84	10	4	2
31-Jul	51	1	B	Pt. Countess	11:30	6	pollock	0	56	0.87	10	5	2
8-Aug	100	2	T	E. Dual Head (Whale Bay)	13:20	10	capelin	0	27	0.04	10	1	1
8-Aug	107	1	T	South Of Pt. Helen	20:16	20	herring	1	142	27.50	10	6	1
											n=380		

ALL 1995 FISH COLLECTIONS

sample date	station #	haul #	gear code	location	sample time	gear depth	species	size group	mean length (FL, mm)	mean weight (wet wt., g)	number of fish	mean stomach fullness (1-7)	mean stomach digestion (1-3)
Central region PWS													
11-Oct	3	1	T	Applegate Rocks	21:00	60	pollock	0	100	6.64	10	6	1
11-Oct	3	1	T	Applegate Rocks	21:00	60	capelin	0	38	0.15	10	2	2
11-Oct	3	2	T	Applegate Rocks	22:00	60	pollock	2	200	57.22	10	4	2
12-Oct	4	2	T	Smith Island	20:30	50	capelin	0	34	0.09	10	1	2
12-Oct	4	3	T	Smith Island	21:50	60	pollock	0	96	5.88	10	3	2
12-Oct	4	3	T	Smith Island	21:50	60	pollock	2	216	78.17	10	2	2

le 1 cont.													
3-Oct	5	1	T	East Naked Island (3FNZ4S)	11:30	65	herring	0	92	6.77	10	4	1
theast region PWS													
-Oct	6	1	T	Galena Bay (Outer South Shore)	21:42	15	herring	0	84	5.24	10	5	1
-Oct	6	1	T	Galena Bay (Outer South Shore)	21:42	15	pollock	0	93	5.47	10	6	1
-Oct	7	1	T	Landlocked Bay-Fidalgo (Shallow)	21:58	20	herring	0	95	7.67	10	4	2
-Oct	7	1	T	Landlocked Bay-Fidalgo (Shallow)	21:58	20	pollock	0	90	4.43	10	4	1
-Oct	7	2	T	Landlocked Bay-Fidalgo (Deep)	23:20	90	pollock	0	103	5.94	10	4	1
-Oct	7	2	T	Landlocked Bay-Fidalgo (Deep)	23:20	90	pollock	2	179	37.19	10	3	2
-Oct	7	2	T	Landlocked Bay-Fidalgo (Deep)	23:20	90	eulachon	0	39	0.16	10	2	2
-Oct	7	2	T	Landlocked Bay-Fidalgo (Deep)	23:20	90	eulachon	1	106	5.36	10	1	2
-Oct	8	1	N	Goose Island (Port Gravina)	10:42	2	capelin	0	24	0.02	10	1	3
Oct	9	1	N	Knowles Head/Redhead (Port Gravina)	13:05	2	capelin	0	20	0.01	10	1	2
hwest region PWS													
Oct	2	1	T	Whale Bay	19:40	60	herring	0	79	3.51	2	5	2
Oct	2	1	T	Whale Bay	19:40	60	herring	1	143	25.31	8	1	2
Oct	2	1	T	Whale Bay	19:40	60	pollock	0	105	6.05	10	2	2
Oct	2	1	T	Whale Bay	19:40	60	pollock	1	165	27.56	10	2	2
											n=200		

ble 2. Station locations and sampling details for zooplankton samples collected in summer and fall, 1995 in ntral, northeastern and southwestern Prince William Sound for APEX 95163C. No zooplankton samples were llected in 1994. All samples have been processed.

ummer 1995, mesh size 303 μm unless otherwise noted

ample day	station	haul	Location	sample time	gear depth (m)
entral region PWS					
22-Jul	2	3	Nw Montague (FFN01A)	11:00	20
22-Jul	2	4 [1]	Nw Montague (FFN01A)	11:05	20
22-Jul	3	3	Applegate-Knight Island (FFN01A)	14:00	20
22-Jul	3	4	Applegate-Knight Island (FFN01A)	14:03	20
22-Jul	4	3	Manning Rocks (FFN02A)	15:40	20
22-Jul	4	4	Manning Rocks (FFN02A)	15:43	20
22-Jul	5	3	Nw Seal Island (Ffn03A)	17:55	20
22-Jul	5	4	Nw Seal Island (Ffn03A)	18:00	20
24-Jul	11	4	Sw Of Naked Island (North Ffn08A)	12:20	20
24-Jul	11	5	Sw Of Naked Island (North Ffn08A)	12:35	20
24-Jul	12	2	W. Of Naked Island (Ffn09W; Deep)	15:00	60
24-Jul	12	3	W. Of Naked Island (Ffn09W; Deep)	15:08	60
24-Jul	12	4	W. Of Naked Island (Ffn09W; Shallow)	15:16	20
24-Jul	12	5	W. Of Naked Island (Ffn09W; Shallow)	15:21	20
1-Aug	53	4	N. Montague Pt. (East Ffn01A; Shallow)	10:50	20
1-Aug	53	5	N. Montague Pt. (East Ffn01A; Shallow)	10:50	20
1-Aug	53	6	N. Montague Pt. (East Ffn01A; Deep)	10:55	60
1-Aug	53	7	N. Montague Pt. (East Ffn01A; Deep)	11:00	60
1-Aug	54	3	E. Of Knight Is. (Ffn01A; Deep)	12:45	60
1-Aug	54	4	E. Of Knight Is. (Ffn01A; Deep)	12:50	60
1-Aug	54	5	E. Of Knight Is. (Ffn01A; Shallow)	12:55	20
1-Aug	54	6	E. Of Knight Is. (Ffn01A; Shallow)	13:00	20
1-Aug	56	3	Seal Island (Ffn03A; Shallow)	16:05	20
1-Aug	56	4	Seal Island (Ffn03A; Shallow)	16:10	20
1-Aug	56	5	Seal Island (Ffn03A; Deep)	16:12	80
1-Aug	56	6	Seal Island (Ffn03A; Deep)	16:20	80
1-Aug	57	3	Seal Island (Ffn03A; Deep)	18:05	80
1-Aug	57	4	Seal Island (Ffn03A; Deep)	18:10	80
1-Aug	57	5	Seal Island (Ffn03A; Shallow)	18:15	20

able 2 cont.

1-Aug	57	6	Seal Island (Ffn03A; Shallow)	18:20	20		
2-Aug	58	3	N. Knight Is. (Ffn04A; Deep)	10:00	80		
2-Aug	58	4	N. Knight Is. (Ffn04A; Deep)	10:05	80		
2-Aug	58	5	N. Knight Is. (Ffn04A; Shallow)	10:10	20		
3-Aug	58	6	N. Knight Is. (Ffn04A; Shallow)	10:20	20		
2-Aug	62	3	E. Eleanor Island (Ffn07A; Deep)	16:05	60		
2-Aug	62	4	E. Eleanor Island (Ffn07A; Deep)	16:10	60		
2-Aug	62	5	E. Eleanor Island (Ffn07A; Shallow)	16:15	20		
2-Aug	62	6	E. Eleanor Island (Ffn07A; Shallow)	16:20	20		
3-Aug	66	3	Eleanor Passage (E. End Ffn08A)	15:40	20		
3-Aug	66	4	Eleanor Passage (E. End Ffn08A)	15:45	20		
0-Aug	112	3	South Of Naked Island (Shallow)	13:55	20		
0-Aug	112	4	South Of Naked Island (Shallow)	13:58	20		
0-Aug	112	5	South Of Naked Island (Deep)	14:03	80		
0-Aug	112	6	South Of Naked Island (Deep)	14:08	80		
0-Aug	114	5	Off Montague Point	20:17	20		
0-Aug	114	6	Off Montague Point	20:20	20		
ortheast region PWS							
26-Jul	22	6	South Of Bligh Island (Ffv01A)	12:45	20		
26-Jul	22	7	South Of Bligh Island (Ffv01A)	12:50	20		
27-Jul	29	2	W. Of Bligh Reef (Ffv03Va; Deep)	12:00	80		
27-Jul	29	3	W. Of Bligh Reef (Ffv03Va; Deep)	12:10	80		
27-Jul	29	4	W. Of Bligh Reef (Ffv03Va; Shallow)	12:21	20		
27-Jul	29	5	W. Of Bligh Reef (Ffv03Va; Shallow)	12:25	20		
-Aug	81	2	Two Moon Bay (W. End Of Ffv01A)	13:50	20		
-Aug	81	3[1]	Two Moon Bay (W. End Of Ffv01A)	13:55	20		
-Aug	81	4[2]	Two Moon Bay (W. End Of Ffv01A)	13:58	20		
-Aug	82	3	E. Graveyard Pt.; Port Fidalgo (Ffv02A; Shallow)	15:24	20		
-Aug	82	4	E. Graveyard Pt.; Port Fidalgo (Ffv02A; Shallow)	15:30	20		
-Aug	82	5	E. Graveyard Pt.; Port Fidalgo (Ffv02A; Deep)	15:37	80		
-Aug	82	6	E. Graveyard Pt.; Port Fidalgo (Ffv02A; Deep)	15:45	80		
-Aug	84	2	So. Of Bligh Island	18:20	20		
-Aug	84	3[1]	So. Of Bligh Island	18:33	20		
-Aug	84	4[2]	So. Of Bligh Island	18:25	20		
-Aug	85	2	Mid-Valdez Arm (Ffv03Va)	9:38	20		
-Aug	85	3[1]	Mid-Valdez Arm (Ffv03Va)	9:43	20		

le 2 cont.					
-Aug	85	4[2]	Mid-Valdez Arm (Ffv03Va)	9:46	20
1-Aug	116	3	Port Gravina	13:13	20
1-Aug	116	4	Port Gravina	13:17	20
uthwest region PWS					
3-Aug	107	5	South Of Pt. Helen	20:56	20
3-Aug	107	6	South Of Pt. Helen	20:59	20
					n=69
all 1995, mesh size 243 µ					
ample day	**station**	**haul**	**Location**	**sample time**	**gear depth (m)**
entral region PWS					
11-Oct	3	4	Applegate Rocks	23:35	100
11-Oct	3	5	Applegate Rocks	23:45	100
12-Oct	4	5	Smith Island	1:09	75
12-Oct	4	6	Smith Island	1:25	75
13-Oct	5	3	East Naked Island (3Fnz4S)	13:35	80
13-Oct	5	4	East Naked Island (3Fnz4S)	13:50	80
Northeast region PWS					
13-Oct	6	3	Galena Bay (Outer South Shore)	23:00	50
13-Oct	6	4	Galena Bay (Outer South Shore)	23:10	50
14-Oct	7	4	Landlocked Bay-Port Fidalgo (Shallow)	1:25	25
14-Oct	7	5	Landlocked Bay-Port Fidalgo (Shallow)	1:25	25
14-Oct	7	6	Landlocked Bay-Port Fidalgo (Deep)	1:45	100
14-Oct	7	7	Landlocked Bay-Port Fidalgo (Deep)	1:55	100
15-Oct	9[4]	1[3]	Knowles Head/ Redhead Port Gravina	13:05	2
Southwest region PWS					
10-Oct	2	4	Whale Bay	22:25	75
10-Oct	2	5	Whale Bay	22:35	75
					n=15

[1] 243 µm

[2] 105 µm

[3] 500 µm

[4] NIO net, 1 replicate

3 Density (mean total number per cubic meter) and numerical percent composition of major groups of ankters by station and depth in central, northeastern and southwestern PWS in summer, 1995.

al Area

station	2	3	4	5	11	112	112	114	12	12	53	53	54	54	56	56	57	57	58	58	62	62	66
depth (m)	20	30	20	20	20	20	80	20	20	60	20	60	20	60	20	80	20	80	20	80	20	60	20
ODE																							
cle	0.00	0.00	1.02	6.11	8.15	0.00	0.51	12.22	6.11	1.36	4.07	0.00	0.00	0.00	3.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
oid copepod-large	8.15	8.15	12.22	30.43	8.15	24.45	19.39	12.22	16.55	22.11	55.00	21.09	36.16	53.35	79.32	57.04	36.67	14.32	22.41	12.35	4.20	15.70	4.20
oid copepod-small	6038.20	869.88	695.70	1091.93	1183.60	1014.52	315.25	1841.61	954.42	573.81	1114.34	745.61	878.02	641.03	772.09	517.44	1053.22	422.21	835.24	238.35	2558.70	966.98	198.62
ognath	0.00	6.62	4.71	9.17	8.15	5.09	5.25	0.25	7.64	7.47	2.04	6.79	1.15	1.70	4.07	5.60	3.06	3.63	3.06	2.80	1.02	5.01	3.06
cera	0.00	3.06	11.20	172.14	18.33	0.00	1.02	122.23	14.26	10.86	91.67	13.58	19.35	8.15	28.52	9.17	14.26	2.04	20.37	4.07	0.00	4.07	0.00
naute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
od	0.00	1.02	0.00	1.02	0.00	0.00	0.03	49.02	3.06	0.00	0.00	0.00	1.02	1.40	1.02	0.13	0.25	0.06	0.25	0.00	0.00	0.00	0.00
usiid	24.45	1.02	1.02	3.06	2.16	6.11	0.57	16.30	0.00	0.04	2.04	2.76	3.06	4.20	2.29	0.70	2.55	0.51	5.09	1.53	0.00	4.97	3.06
	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.13	0.25	0.04	0.00	0.08	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
erid	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pod	73.34	7.13	50.93	15.28	2.04	65.19	31.58	65.19	33.61	16.98	48.89	50.25	34.63	14.94	114.08	64.71	36.67	15.28	196.59	34.63	199.64	40.06	159.15
id	8.15	0.00	0.00	0.00	2.16	2.04	3.57	0.00	6.37	0.81	8.28	5.90	4.20	0.00	2.04	0.51	5.22	0.13	0.00	1.02	0.00	0.51	0.64
rian/ Ctenophore	0.25	0.13	0.00	1.27	1.27	2.67	0.86	4.84	0.76	1.06	0.51	1.70	0.76	0.51	1.15	0.25	1.78	0.99	2.80	0.16	5.09	3.27	1.66
ean	0.00	0.00	2.16	27.12	34.63	14.39	26.99	52.97	14.51	14.94	2.16	8.15	0.00	1.36	5.09	5.09	4.58	2.20	10.19	5.60	4.84	9.85	8.91
	24.45	34.63	40.74	38.71	6.11	6.11	1.53	0.00	13.24	8.15	4.07	6.79	14.26	6.79	10.19	12.29	28.52	8.18	27.50	6.65	24.45	10.44	13.75
L	6176.98	931.63	819.71	1396.23	1276.93	1140.57	406.54	2176.98	1070.79	657.63	1333.08	862.70	992.62	733.43	1022.92	672.97	1186.78	469.54	1123.50	307.17	2797.94	1060.86	393.05

percent number of zooplankton (per m^3) per station (n=2) in Prince Willam Sound, summer 1995

al Area

station	2	3	4	5	11	112	112	114	12	12	53	53	54	54	56	56	57	57	58	58	62	62	66
depth (m)	20	30	20	20	20	20	80	20	20	60	20	60	20	60	20	80	20	80	20	80	20	60	20
ODE																							
cle	0.00	0.00	0.12	0.44	0.64	0.00	0.13	0.56	0.57	0.21	0.31	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
id copepod-large	0.13	0.87	1.49	2.18	0.64	2.14	4.77	0.56	1.55	3.36	4.13	2.45	3.64	7.27	7.75	8.48	3.09	3.05	1.99	4.02	0.15	1.48	1.07
id copepod-small	97.75	93.37	84.87	78.21	92.69	88.95	77.54	84.59	89.13	87.25	83.59	86.43	88.46	87.40	75.48	76.89	88.75	89.92	74.34	77.60	91.45	91.15	50.53
gnath	0.00	0.71	0.57	0.66	0.64	0.45	1.29	0.01	0.71	1.14	0.15	0.79	0.12	0.23	0.40	0.83	0.26	0.77	0.27	0.91	0.04	0.47	0.78
era	0.00	0.33	1.37	12.33	1.44	0.00	0.25	5.61	1.33	1.65	6.88	1.57	1.95	1.11	2.79	1.36	1.20	0.43	1.81	1.33	0.00	0.38	0.00
naute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
od	0.00	0.11	0.00	0.07	0.00	0.00	0.01	2.25	0.29	0.00	0.00	0.00	0.10	0.19	0.10	0.02	0.02	0.01	0.02	0.00	0.00	0.00	0.00
usiid	0.40	0.11	0.12	0.22	0.17	0.54	0.14	0.75	0.00	0.01	0.15	0.32	0.31	0.57	0.22	0.10	0.21	0.11	0.45	0.50	0.00	0.47	0.78
	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
erid	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pod	1.19	0.77	6.21	1.09	0.16	5.72	7.77	2.99	3.14	2.58	3.67	5.82	3.49	2.04	11.15	9.62	3.09	3.25	17.50	11.27	7.14	3.78	40.49
d	0.13	0.00	0.00	0.00	0.17	0.18	0.88	0.00	0.59	0.12	0.62	0.68	0.42	0.00	0.20	0.08	0.44	0.03	0.00	0.33	0.00	0.05	0.16
an/ Ctenophore	0.00	0.01	0.00	0.09	0.10	0.23	0.21	0.22	0.07	0.16	0.04	0.20	0.08	0.07	0.11	0.04	0.15	0.21	0.25	0.05	0.18	0.31	0.42
ean	0.00	0.00	0.26	1.94	2.71	1.26	6.64	2.43	1.36	2.27	0.16	0.94	0.00	0.19	0.50	0.76	0.39	0.47	0.91	1.82	0.17	0.93	2.27
	0.40	3.72	4.97	2.77	0.48	0.54	0.38	0.00	1.24	1.24	0.31	0.79	1.44	0.93	1.00	1.83	2.40	1.74	2.45	2.17	0.87	0.98	3.50

cont.

astern Area

station	116	22	29	29	81	82	82	84	85
depth (m)	20	20	20	80	20	20	80	20	20
ODE									
cle	2.04	0.00	8.15	0.00	65.19	14.26	0.00	21.81	325.95
oid copepod-large	30.30	18.72	27.76	21.52	42.10	10.19	6.45	23.17	50.67
oid copepod-small	941.18	843.39	825.06	616.25	14353.96	1140.82	146.34	18372.72	44030.81
ognath	0.00	2.04	1.02	4.17	1.36	4.07	2.38	0.42	2.55
cera	122.23	148.71	37.69	15.28	184.70	87.60	8.83	404.72	464.48
onaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.73	0.00
pod	4.20	4.20	1.02	2.36	18.76	0.25	1.02	4.41	0.00
ausiid	10.19	2.16	1.02	7.26	0.34	0.00	0.10	2.72	4.07
	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
merid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
ropod	83.52	35.01	118.16	38.71	262.12	199.64	20.03	821.66	941.18
eriid	4.07	2.16	9.17	6.11	0.17	2.04	0.40	0.08	0.00
arian/ Ctenophore	0.13	0.76	3.69	2.23	0.51	12.73	0.13	1.27	1.02
acean	105.93	81.49	47.87	21.42	152.11	128.34	9.51	723.88	1947.54
er	189.46	46.86	12.61	7.13	635.60	61.12	2.04	567.69	5940.41
AL	1493.25	1185.51	1093.20	742.42	15716.92	1661.06	197.22	20966.39	53708.68

Northeastern Area

station	116	22	29	29	81	82	82	84	85
depth (m)	20	20	20	80	20	20	80	20	20
	0.14	0.00	0.75	0.00	0.41	0.86	0.00	0.10	0.61
	2.03	1.58	2.54	2.90	0.27	0.61	3.27	0.11	0.09
	63.03	71.14	75.47	83.00	91.33	68.68	74.20	87.63	81.98
	0.00	0.17	0.09	0.56	0.01	0.25	1.21	0.00	0.00
	8.19	12.54	3.45	2.06	1.18	5.27	4.48	1.93	0.86
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
	0.28	0.35	0.09	0.32	0.12	0.02	0.52	0.02	0.00
	0.68	0.18	0.09	0.98	0.00	0.00	0.05	0.01	0.01
	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.59	2.95	10.81	5.21	1.67	12.02	10.16	3.92	1.75
	0.27	0.18	0.84	0.82	0.00	0.12	0.20	0.00	0.00
	0.01	0.06	0.34	0.30	0.00	0.77	0.06	0.01	0.00
	7.09	6.87	4.38	2.89	0.97	7.73	4.82	3.45	3.63
	12.69	3.95	1.15	0.96	4.04	3.68	1.03	2.71	11.06

ithwestern Area

station	107
depth (m)	20
MCODE	
rnacle	0.13
lanoid copepod-large	27.50
lanoid copepod-small	3499.87
aetognath	1.40
adocera	12.22
phonaute	0.00
ecapod	2.29
uphausiid	16.55
sh	0.00
ammerid	0.00
astropod	52.97
lyperiid	0.51
nidarian/ Ctenophore	1.15
arvacean	0.89
ther	28.52
OTAL	3644.00

Southwestern Area

station	107
depth (m)	20
	0.00
	0.75
	96.04
	0.04
	0.34
	0.00
	0.06
	0.45
	0.00
	0.00
	1.45
	0.01
	0.03
	0.02
	0.78

le 4. Species composition and density of zooplankters (mean number per cubic meter; mean percent number per
ic meter) by station and depth in central (A), northeastern (B) and southwestern (C) PWS, summer 1995.
ical, 0.5 m-diameter nets with 303- mesh were hauled vertically from the depth indicated to the surface.
ess otherwise noted, two replicate hauls were collected at each station and depth sampled.

Central Area PWS

	station	2	2	3	3	4	4	5	5	11	11	12	12
	depth (m)	20	20	20	20	20	20	20	20	20	20	60	60
D	PREYNAME	#	%	#	%	#	%	#	%	#	%	#	%
NACLE													
	Barnacle, adult molt (cirri)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barnacle, nauplius	0.00	0.00	0.00	0.00	1.02	0.12	6.11	0.44	8.15	0.64	1.36	0.21
-LARGE													
	Calanoid, general large (>2.5 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus sp. copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Neocalanus cristatus V	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	0.00	0.00	1.53	0.11	0.00	0.00	0.04	0.01
	Calanoid, C. marshallae copepodite	0.00	0.00	0.00	0.00	0.00	0.00	2.93	0.21	0.00	0.00	1.61	0.25
	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.03
	Calanoid, Calanus marshallae AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus/Neocalanus copepodids	8.15	0.13	8.15	0.87	12.22	1.49	19.35	1.39	8.15	0.64	14.26	2.17
	Calanoid, Calanus pacificus AF	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.15	0.00	0.00	0.72	0.11
	Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.15	0.00	0.00	1.36	0.21
	Calanoid, Calanus pacificus CV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.26
	Calanoid, Eucalanus bungii, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Euchaeta elongata copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.10
	Calanoid, Epilabidocera longipedata, cop			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, AF			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, gen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, AM			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Metridia pacifica, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.21
	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Neocalanus spp. copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.21	0.03
	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	0.00	0.00	0.00	2.29	0.16	0.00	0.00	0.00	0.00
SMALL													
	Calanoid, Acartia sp.			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia clausi copepodite			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

e 4 cont.													
	Calanoid, Acartia clausi female	0.00	0.00	0.00	0.00	1.02	0.12	6.11	0.44	0.00	0.00	0.00	0.00
	Calanoid, Acartia clausi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia clausi male	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.22	2.04	0.16	0.68	0.10
	Calanoid, Acartia longiremus adult	57.04	0.92	3.06	0.33	7.13	0.87	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia longiremus copepodite	0.00	0.00	2.04	0.22	0.00	0.00	11.20	0.80	6.11	0.48	6.79	1.03
	Calanoid, Acartia longiremis AF	48.89	0.79	57.04	6.12	30.56	3.73	86.58	6.20	38.71	3.03	16.98	2.58
	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia longiremus AM	40.74	0.66	12.22	1.31	5.09	0.62	24.45	1.75	18.33	1.44	6.79	1.03
	Calanoid, Centropages abdominalis, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Calanoid, Centropages abdominalis, copdt	0.00	0.00	0.00	0.00	0.00	0.00	5.09	0.36	0.00	0.00	0.00	0.00
F	Calanoid, Centropages abdominalis, AF	8.15	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.22	0.00	0.00	2.04	0.31
N	Calanoid, general nauplius	16.30	0.26	0.00	0.00	1.02	0.12	0.00	0.00	0.00	0.00	0.00	0.00
S	Calanoid, general small (<2.5 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	Cyclopoid, Oithona copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.10
SF	Cyclopoid, Oithona similis AF	244.46	3.96	3.06	0.33	4.07	0.50	0.00	0.00	0.00	0.00	1.36	0.21
SM	Cyclopoid, Oithona similis AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	Calanoid, Pseudocalanus copepodids I-IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	Calanoid, Pseudocalanus sp., general	2827.60	45.78	244.46	26.24	172.14	21.00	296.41	21.23	193.53	15.16	173.16	26.33
SF	Calanoid, Pseudocalanus AF	2762.41	44.72	545.96	58.60	471.61	57.53	641.71	45.96	910.62	71.31	349.72	53.18
SG	Calanoid, Pseudocalanus GF	32.59	0.53	2.04	0.22	2.04	0.25	10.19	0.73	10.19	0.80	9.51	1.45
SM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHAETOGNAT													
CHT	Chaetognath, species unknown	0.00	0.00	0.00	0.00	4.71	0.57	9.17	0.66	8.15	0.64	7.47	1.14
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	6.62	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CLADOCERA													
EVD	Cladoceran, Evadne sp.	0.00	0.00	3.06	0.33	9.17	1.12	133.44	9.56	10.19	0.80	4.07	0.62
PON	Cladoceran, Podon sp.	0.00	0.00	0.00	0.00	2.04	0.25	38.71	2.77	8.15	0.64	6.79	1.03
DECAPOD													
DCM	Decapod, megalops, unknown crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DGB	Decapod, zoea, Brachyura, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DML	Decapod, megalops, Lithodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DZB	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DZG	Decapod, zoea, general unknown group	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIE	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PAN	Decapod, Pandalidae	0.00	0.00	0.00	0.00	1.02	0.12	4.07	0.29	4.07	0.32	6.11	0.93
PDZ	Decapod zoea, Shrimp, Pandalidae	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.07	0.00	0.00	0.00	0.00
PGZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

le 4 cont.

	Decapod zoea, general shrimp	0.00	0.00	1.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHAUSIID													
	Euphausiid egg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Euphausiid nauplii	0.00	0.00	1.02	0.11	1.02	0.12	1.02	0.07	0.00	0.00	0.00	0.00
	Euphausiid calyptopis	8.15	0.13	0.00	0.00	0.00	0.00	2.04	0.15	2.04	0.16	0.00	0.00
	Euphausiid furcilia	16.30	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.04	0.01
	Euphausiid juvenile, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Euphausiid, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H													
	Fish, juvenile, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01
	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.16	0.00	0.00
MMARID													
	Amphipod, Gammarid, unknown, large	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00
STROPOD													
	Gastropod, juv. snail w/ black pigment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gastropoda, general juvenile (SNAIL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gastropoda, juv. 'snail' in zooplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gastropod, Pteropod, Limacina helicina J	73.34	1.19	7.13	0.77	50.93	6.21	15.28	1.09	2.04	0.16	16.98	2.58
ERIID													
	Amphipod, Hyperiid, unknown adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01
	Amphipod, Hyperiid, unknown small (<2mm)	8.15	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Amphipod, Hyperiid, unknown juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.16	0.72	0.11
	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00
	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y													
	Cnidaria (>2mm), general large jellyfish	0.25	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.89	0.07	0.21	0.03
	Cnidaria (<2mm), general small jellyfish	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.07	0.00	0.00	0.68	0.10
	Ctenophore, general (>2mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cnidaria, Hydrozoan, general hydroid	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	Thaliacea, Salpida unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.03	0.00	0.00
	Cnidaria, Hydrozoa, Siphonophore "larva"	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.17	0.03
/ACEA													
	Larvacea, general	0.00	0.00	0.00	0.00	0.00	0.00	6.11	0.44	0.00	0.00	0.00	0.00
	Larvacea, Oikopleura sp.	0.00	0.00	0.00	0.00	2.16	0.26	21.01	1.50	34.63	2.71	14.94	2.27
ER													
	Polychaeta, Autolytus sp. gravid Female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4 cont.

Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown invertebrate egg, small (<0.2mm)	0.00	0.00	2.04	0.22	38.71	4.72	38.71	2.77	4.07	0.32	8.15	1.24
Unknown invertebrate egg, large (>0.2mm)	24.45	0.40	32.59	3.50	2.04	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaeta, Tomopteris sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.16	0.00	0.00
Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	6176.98	100.00	931.63	100.00	819.71	100.00	1396.23	100.00	1276.93	100.00	657.63	100.00

e 4 cont.

station	12	12	53	53	53	53	54	54	54	54	56	56	56	56
th (m)	20	20	20	20	20	20	60	60	20	20	20	20	80	80
CD	#	%	#	%	#	%	#	%	#	%	#	%	#	%
NACLE														
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.11	0.57	4.07	0.31	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.30	0.00	0.00
-LARGE														
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.45
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.11	0.57	2.04	0.15	0.51	0.06	30.13	4.11	9.04	0.91	17.57	1.72	20.37	3.03
	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.51	0.05	1.53	0.23
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.15
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.04	0.19	52.97	3.97	20.37	2.36	23.09	3.15	26.48	2.67	61.12	5.97	0.00	0.00
	2.29	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	4.07	0.61
	2.93	0.27	0.00	0.00	0.08	0.01	0.04	0.01	0.25	0.03	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.04	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.02	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.99	4.01
	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00
SMALL														
	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.19	0.00	0.00	2.04	0.20	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.21	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.31	3.06	0.30	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4.07	0.38	4.07	0.31	4.07	0.47	0.00	0.00	7.13	0.72	4.07	0.40	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.29	6.43

4 cont.

L	8.15	0.76	0.00	0.00	4.07	0.47	8.15	1.11	5.09	0.51	4.07	0.40	0.00	0.00
L	58.06	5.42	59.08	4.43	42.10	4.88	27.16	3.70	43.80	4.41	85.56	8.36	1.02	0.15
L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L	35.65	3.33	10.19	0.76	12.22	1.42	9.51	1.30	17.32	1.74	16.30	1.59	0.00	0.00
S/	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.15
S/	0.00	0.00	2.04	0.15	4.07	0.47	0.00	0.00	5.09	0.51	3.06	0.30	0.00	0.00
S/	1.02	0.10	4.07	0.31	0.00	0.00	1.36	0.19	0.00	0.00	2.04	0.20	0.00	0.00
C M	2.04	0.19	4.07	0.31	0.00	0.00	0.00	0.00	0.00	0.00	4.07	0.40	2.04	0.30
C N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.38
C S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.15
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.38
C C	2.04	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C F	6.11	0.57	2.04	0.15	2.72	0.31	4.07	0.56	2.04	0.21	0.00	0.00	1.02	0.15
C M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.45
F P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.07	0.61
F A	265.85	24.83	203.72	15.28	251.25	29.12	176.56	24.07	206.77	20.83	146.68	14.34	176.22	26.18
F F	552.08	51.56	804.69	60.36	418.30	48.49	407.44	55.55	577.54	58.18	496.05	48.49	274.51	40.79
F G	15.28	1.43	14.26	1.07	2.72	0.31	1.36	0.19	3.06	0.31	1.02	0.10	5.09	0.76
F M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IAETOGNAT														
IT	7.64	0.71	2.04	0.15	6.79	0.79	1.70	0.23	1.15	0.12	4.07	0.40	1.02	0.15
GE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.58	0.68
LADOCERA														
VD	9.17	0.86	85.56	6.42	12.22	1.42	8.15	1.11	15.28	1.54	22.41	2.19	6.11	0.91
ON	5.09	0.48	6.11	0.46	1.36	0.16	0.00	0.00	4.07	0.41	6.11	0.60	3.06	0.45
ECAPOD														
CM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GB	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	1.02	0.10	0.00	0.00
ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01
ZB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
ZG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PAN	4.07	0.38	6.11	0.46	4.07	0.47	4.07	0.56	5.09	0.51	4.07	0.40	0.00	0.00
PDZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SHR	3.06	0.29	0.00	0.00	0.00	0.00	1.36	0.19	1.02	0.10	0.00	0.00	0.00	0.00
EUPHAUSIID														
EU1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU2	0.00	0.00	0.00	0.00	2.72	0.31	2.72	0.37	0.00	0.00	0.00	0.00	0.10	0.01

T ble 4 cont.

E 3	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.19	3.06	0.31	2.04	0.20	0.00	0.00
E 4	0.00	0.00	2.04	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.25	0.02	0.51	0.08
E J	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.02	0.00	0.00	0.00	0.00	0.10	0.01
E P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F H														
F J	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
MMARID														
G 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G STROPOD														
G B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.08
G Z	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.19	2.04	0.21	0.00	0.00	0.03	0.00
L A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.07	0.41	0.00	0.00	0.00	0.00
L J	33.61	3.14	48.89	3.67	50.25	5.82	13.58	1.85	28.52	2.87	114.08	11.15	64.17	9.54
PERIID														
H A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H P	6.37	0.59	8.28	0.62	5.90	0.68	0.00	0.00	4.20	0.42	2.04	0.20	0.00	0.00
P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.04
P 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.03
J LY														
C	0.38	0.04	0.13	0.01	1.49	0.17	0.08	0.01	0.38	0.04	1.15	0.11	0.13	0.02
C S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SI	0.38	0.04	0.38	0.03	0.21	0.02	0.42	0.06	0.38	0.04	0.00	0.00	0.13	0.02
VACEA														
LF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OI P	14.51	1.36	2.16	0.16	8.15	0.94	1.36	0.19	0.00	0.00	5.09	0.50	5.09	0.76
IER														
AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BV	0.00	0.00	0.00	0.00	1.36	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EG G	13.24	1.24	4.07	0.31	5.43	0.63	6.79	0.93	14.26	1.44	10.19	1.00	0.00	0.00
EG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.22	1.82
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

e 4 cont.

M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
U:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL	1070.79	100.00	1333.08	100.00	862.70	100.00	733.43	100.00	992.61	100.00	1022.92	100.00	672.97	100.00

ble 4 cont.

station	57	57	57	57	58	58	58	58	62	62	62	62	66	66	112	112	112
pth (m)	80	80	20	20	80	80	20	20	60	60	20	20	20	20	20	20	80
SPCD	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
RNACLE																	
IM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
IP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L-LARGE																	
L	0.00	0.00	0.00	0.00	0.51	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.32	0.00	0.00	0.00
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.07	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
i	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.06	0.00	0.00	0.00
IC	5.09	1.08	18.33	1.54	6.65	2.17	12.22	1.09	2.72	0.26	4.07	0.15	2.29	0.58	24.45	2.14	16.81
IF	1.02	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.03	0.00	0.00	2.04
IM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.06	0.00	0.00	0.00
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.43	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	12.22	1.03	0.00	0.00	0.00	0.00	1.36	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.06	0.02	2.04	0.18	1.36	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.00	4.07	0.34	0.00	0.00	2.04	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	0.00	0.00	2.04	0.17	0.03	0.01	4.07	0.36	0.68	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	0.00	0.00	1.02	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	8.15	1.74	0.00	0.00	4.07	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.03
-SMALL																	
	0.00	0.00	0.00	0.00	1.02	0.33	12.22	1.09	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.18	2.04
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	1.02	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	0.00	0.00	2.04	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.51	0.11	16.30	1.37	0.00	0.00	0.00	0.00	19.01	1.79	20.37	0.73	4.58	1.17	0.00	0.00	6.62

e 4 cont.

	4.07	0.87	2.04	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.26	0.00	0.00	0.00
	20.88	4.45	12.22	1.03	5.60	1.82	6.11	0.54	5.43	0.51	40.74	1.46	3.57	0.91	0.00	0.00	1.02
	0.00	0.00	6.11	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.11	1.55	0.00	0.00	0.00
	6.11	1.30	12.22	1.03	2.55	0.83	2.04	0.18	0.68	0.06	4.07	0.15	1.02	0.26	0.00	0.00	0.00
	2.55	0.54	0.00	0.00	0.00	0.00	1.02	0.09	1.36	0.13	0.00	0.00	0.00	0.00	2.04	0.18	0.51
	0.00	0.00	10.19	0.86	0.00	0.00	0.00	0.00	6.79	0.64	0.00	0.00	1.53	0.39	0.00	0.00	0.00
	0.00	0.00	4.07	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	0.00	0.00	6.11	0.51	0.00	0.00	9.17	0.82	6.79	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	0.00	0.00	4.07	0.34	0.00	0.00	0.00	0.00	1.36	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	3.06	0.65	2.04	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.72	0.26	0.00	0.00	0.76	0.19	0.00	0.00	0.00
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	4.07	0.34	2.04	0.66	2.04	0.18	0.00	0.00	0.00	0.00	1.02	0.26	0.00	0.00	0.00
M	1.53	0.33	4.07	0.34	2.04	0.66	0.00	0.00	1.36	0.13	4.07	0.15	5.60	1.43	4.07	0.36	1.02
P	0.00	0.00	10.19	0.86	0.00	0.00	75.38	6.71	21.73	2.05	0.00	0.00	0.51	0.13	0.00	0.00	0.00
A	125.80	26.79	203.72	17.17	76.39	24.87	80.47	7.16	267.55	25.22	558.19	19.95	46.35	11.79	183.35	16.08	80.47
F	251.59	53.58	723.20	60.94	146.17	47.59	556.15	49.50	581.95	54.86	1914.95	68.44	125.54	31.94	818.95	71.80	217.98
G	5.09	1.08	6.11	0.51	2.55	0.83	13.24	1.18	36.67	3.46	16.30	0.58	1.02	0.26	4.07	0.36	5.60
M	0.00	0.00	24.45	2.06	0.00	0.00	77.41	6.89	13.58	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAETOGNAT																	
HT	1.91	0.41	1.02	0.09	2.04	0.66	0.25	0.02	0.85	0.08	0.00	0.00	0.00	0.00	0.76	0.07	0.00
GE	1.72	0.37	2.04	0.17	0.76	0.25	2.80	0.25	4.16	0.39	1.02	0.04	3.06	0.78	4.33	0.38	5.25
LADOCERA																	
VD	1.02	0.22	12.22	1.03	4.07	1.33	17.32	1.54	4.07	0.38	0.00	0.00	0.00	0.00	0.00	0.00	1.02
ON	1.02	0.22	2.04	0.17	0.00	0.00	3.06	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECAPOD																	
CM	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
GB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIE	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PDZ	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGZ	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SHR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EUPHAUSIID																	
EU1	0.00	0.00	0.00	0.00	1.02	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU2	0.00	0.00	0.00	0.00	0.51	0.17	1.02	0.09	2.72	0.26	0.00	0.00	0.76	0.19	4.07	0.36	0.00

le 4 cont.

E 3	0.00	0.00	2.04	0.17	0.00	0.00	4.07	0.36	2.12	0.20	0.00	0.00	1.53	0.39	0.00	0.00	0.54
E 4	0.00	0.00	0.51	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E J	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.76	0.19	2.04	0.18	0.03
E P	0.51	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F H																	
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G MMARID																	
G 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G STROPOD																	
G 3	0.00	0.00	2.04	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.18	0.00
G T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LI A	1.02	0.22	0.00	0.00	1.53	0.50	2.04	0.18	0.00	0.00	0.00	0.00	6.88	1.75	4.07	0.36	3.06
LI	14.26	3.04	34.63	2.92	33.10	10.78	194.55	17.32	40.06	3.78	199.64	7.14	152.28	38.74	59.08	5.18	28.52
H ERIID																	
H A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H P	0.13	0.03	0.00	0.00	1.02	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PS	0.00	0.00	4.97	0.42	0.00	0.00	0.00	0.00	0.51	0.05	0.00	0.00	0.64	0.16	2.04	0.18	2.55
PS	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02
LY																	
CI	0.57	0.12	1.02	0.09	0.13	0.04	0.13	0.01	0.42	0.04	1.02	0.04	1.02	0.26	0.38	0.03	0.10
CI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.72	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	0.00	0.00	0.38	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SI	0.41	0.09	0.38	0.03	0.03	0.01	2.42	0.22	0.13	0.01	4.07	0.15	0.64	0.16	2.29	0.20	0.76
VACEA																	
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DI	2.20	0.47	4.58	0.39	5.60	1.82	10.19	0.91	9.85	0.93	4.84	0.17	8.91	2.27	14.39	1.26	26.99
ER																	
U	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	0.00	0.00	0.00	0.00	0.00	0.00	8.15	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	8.15	1.74	28.52	2.40	6.62	2.16	19.35	1.72	9.68	0.91	24.45	0.87	12.48	3.17	6.11	0.54	1.02
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00

e 4 cont.																	
M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00	1.27	0.32	0.00	0.00	0.51
U	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAL	469.54	100.00	1186.78	100.00	307.17	100.00	1123.50	100.00	1060.86	100.00	2797.94	100.00	393.05	100.00	1140.57	100.00	406.54

Table 4 cont.

station	112	114	114
depth (m)	80	20	20
SPCD	%	#	%
BARNACLE			
BMM	0.13	12.22	0.56
BMP	0.00	0.00	0.00
CAL-LARGE			
CAL	0.00	0.00	0.00
CCP	0.00	0.00	0.00
CCV	0.00	0.00	0.00
CLN	0.00	0.00	0.00
CM	0.00	0.00	0.00
CMC	4.13	12.22	0.56
CMF	0.50	0.00	0.00
CMM	0.00	0.00	0.00
CPA	0.00	0.00	0.00
CPC	0.00	0.00	0.00
CPD	0.00	0.00	0.00
CPF	0.00	0.00	0.00
CPM	0.00	0.00	0.00
CPV	0.00	0.00	0.00
EBC	0.00	0.00	0.00
ECC	0.00	0.00	0.00
EPC	0.00	0.00	0.00
EPF	0.00	0.00	0.00
EPI	0.13	0.00	0.00
EPM	0.00	0.00	0.00
EUB	0.00	0.00	0.00
MPC	0.00	0.00	0.00
MPF	0.00	0.00	0.00
NCP	0.00	0.00	0.00
NEO	0.01	0.00	0.00
CAL-SMALL			
AC	0.50	4.07	0.19
ACC	0.00	0.00	0.00
ACF	0.00	0.00	0.00
ACG	0.00	0.00	0.00
ACM	0.00	0.00	0.00
AL	1.63	57.04	2.62

Table 4 cont.

ALC	0.00	0.00	0.00
ALF	0.25	12.22	0.56
ALG	0.00	0.00	0.00
ALM	0.00	4.07	0.19
CA	0.13	8.15	0.37
CAC	0.00	8.15	0.37
CAF	0.00	4.07	0.19
CAM	0.00	0.00	0.00
CAN	0.00	0.00	0.00
CAS	0.00	0.00	0.00
OS	0.00	8.15	0.37
OSC	0.00	0.00	0.00
OSF	0.00	0.00	0.00
OSM	0.25	16.30	0.75
PCP	0.00	12.22	0.56
PSA	19.79	586.71	26.95
PSF	53.62	1116.37	51.28
PSG	1.38	4.07	0.19
PSM	0.00	0.00	0.00
CHAETOGNAT			
CHT	0.00	0.00	0.00
SGE	1.29	0.25	0.01
CLADOCERA			
EVD	0.25	97.78	4.49
PON	0.00	24.45	1.12
DECAPOD			
DCM	0.01	0.00	0.00
DGB	0.00	44.82	2.06
DML	0.00	0.00	0.00
DZB	0.00	0.00	0.00
DZG	0.00	0.00	0.00
HIE	0.00	0.00	0.00
PAN	0.00	0.13	0.01
PDZ	0.00	0.00	0.00
PGZ	0.00	4.07	0.19
SHR	0.00	0.00	0.00
EUPHAUSIID			
EU1	0.00	0.00	0.00
EU2	0.00	8.15	0.37

Table 4 cont.			
EU3	0.13	8.15	0.37
EU4	0.00	0.00	0.00
EUJ	0.01	0.00	0.00
EUP	0.00	0.00	0.00
FISH			
FSJ	0.00	0.00	0.00
FSL	0.00	0.13	0.01
GAMMARID			
GA3	0.00	0.00	0.00
GASTROPOD			
GSB	0.00	24.45	1.12
GST	0.00	0.00	0.00
GSZ	0.00	0.00	0.00
LMA	0.75	4.07	0.19
LMJ	7.02	36.67	1.68
HYPERIID			
HYA	0.00	0.00	0.00
HYB	0.00	0.00	0.00
HYP	0.00	0.00	0.00
PA1	0.00	0.00	0.00
PA2	0.00	0.00	0.00
PS1	0.63	0.00	0.00
PS2	0.25	0.00	0.00
JELLY			
CNI	0.02	0.38	0.02
CNS	0.00	0.00	0.00
CTE	0.00	0.00	0.00
HYD	0.00	0.00	0.00
SAL	0.00	0.00	0.00
SIP	0.19	4.46	0.20
LARVACEA			
LRV	0.00	0.00	0.00
OKP	6.64	52.97	2.43
OTHER			
AUT	0.00	0.00	0.00
BVL	0.00	0.00	0.00
EGG	0.00	0.00	0.00
EGL	0.25	0.00	0.00
ISP	0.00	0.00	0.00

Table 4 cont.

TOM	0.13	0.00	0.00
UNI	0.00	0.00	0.00
TOTAL	100.00	2176.98	100.00

T le 4 cont.

Northeastern Area PWS

	station	22	22	29	29	29	29	81	81	82	82
	depth (m)	20	20	80	80	20	20	20	20	20	20
CD	PREY NAME	#	%	#	%	#	%	#	%	#	%
nacle											
	Barnacle, cyprid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barnacle, nauplius	0.00	0.00	0.00	0.00	8.15	0.71	65.19	0.18	14.26	0.83
noid copepod-large											
	Calanoid, C. marshallae copepodite	6.24	0.53	3.63	0.49	12.10	1.14	13.58	0.31	6.11	0.34
	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.07	0.27
	Calanoid, Calanus marshallae AF	0.00	0.00	0.35	0.05	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus pacificus AF	0.13	0.01	0.06	0.01	0.13	0.01	0.00	0.00	0.00	0.00
	Calanoid, Calanus pacificus CV	0.13	0.01	1.18	0.16	0.13	0.01	0.00	0.00	0.00	0.00
	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	2.72	0.20	0.00	0.00
	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	2.72	0.20	0.00	0.00
	Calanoid, Calanus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Calanus/Neocalanus copepodids	6.11	0.52	13.24	1.78	14.26	1.30	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, cop	0.00	0.00	0.00	0.00	1.02	0.10	0.00	0.00	0.00	0.00
	Calanoid, Epilabidocera longipedata, gen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, general large (>2.5 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.10	0.00	0.00
	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00
	Calanoid, Metridia pacifica, copepodite	0.00	0.00	1.02	0.14	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Metridia sp. copepodids I-IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Neocalanus plumchrus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Neocalanus spp. copepodite	6.11	0.52	2.04	0.27	0.00	0.00	21.73	0.06	0.00	0.00
oid copepod-small											
	Calanoid, Acartia clausi adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia clausi copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Acartia clausi female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

e 4 cont.

1	Calanoid, Acartia clausi male	4.07	0.34	0.00	0.00	1.02	0.10	21.73	0.06	0.00	0.00	
	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Calanoid, Acartia longiremis AF	38.71	3.27	15.28	2.06	34.63	3.02	110.01	1.58	14.26	0.85	
	Calanoid, Acartia longiremus adult	0.00	0.00	0.00	0.00	0.00	0.00	129.02	3.32	2.04	0.14	
1	Calanoid, Acartia longiremus AM	4.07	0.34	1.02	0.14	4.07	0.42	184.70	0.91	0.00	0.00	
	Calanoid, Acartia longiremus copepodite	0.00	0.00	1.02	0.14	2.04	0.21	76.05	0.61	0.00	0.00	
	Calanoid, Acartia sp.	0.00	0.00	0.00	0.00	0.00	0.00	130.38	0.36	46.86	3.00	
	Calanoid, Centropages abdominalis, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
F	Calanoid, Centropages abdominalis, AF	0.00	0.00	1.02	0.14	0.00	0.00	0.00	0.00	0.00	0.00	
M	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.14	
C	Calanoid, Centropages abdominalis, copdt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
S	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	2716.24	7.56	0.00	0.00	
F	Calanoid, Eurytemora pacifica AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
T	Calanoid, Eurytemora pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
N	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	2477.21	6.90	2.04	0.14	
S	Calanoid, general small (<2.5 mm)	0.00	0.00	0.00	0.00	0.00	0.00	97.78	0.99	0.00	0.00	
F	Calanoid, Pseudocalanus AF	533.74	45.02	453.27	61.04	587.73	53.89	1707.16	27.64	857.65	51.56	
M	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	304.22	3.07	0.00	0.00	
P	Calanoid, Pseudocalanus copepodids I-IV	0.00	0.00	0.00	0.00	0.00	0.00	1044.39	10.64	0.00	0.00	
SG	Calanoid, Pseudocalanus GF	6.11	0.52	7.13	0.96	15.28	1.45	0.00	0.00	2.04	0.14	
SA	Calanoid, Pseudocalanus sp., general	254.65	21.48	136.49	18.38	176.22	16.41	2469.06	13.75	207.79	12.39	
SC	Cyclopoid, Oithona copepodite	0.00	0.00	0.00	0.00	0.00	0.00	10.86	0.11	0.00	0.00	
SF	Cyclopoid, Oithona similis AF	0.00	0.00	0.00	0.00	2.04	0.17	673.63	1.88	4.07	0.25	
SM	Cyclopoid, Oithona similis AM	0.00	0.00	0.00	0.00	0.00	0.00	92.35	0.65	2.04	0.11	
S	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	2109.16	6.61	0.00	0.00	
TS	Cyclopoid, Oithona spinirostris	2.04	0.17	1.02	0.14	2.04	0.17	0.00	0.00	0.00	0.00	
haetognath												
GE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.11	
HT	Chaetognath, species unknown	2.04	0.17	4.17	0.56	1.02	0.10	1.36	0.10	2.04	0.14	
Cladocera												
CLA	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
EVD	Cladoceran, Evadne sp.	8.15	0.69	9.17	1.24	22.41	1.93	73.34	1.11	28.52	1.81	
PON	Cladoceran, Podon sp.	140.57	11.86	6.11	0.82	15.28	1.36	111.37	1.69	59.08	3.41	
Cyphonaute												
CFN	Bryozoa, cyphonautes larva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Decapod												
LIZ	Decapod zoea, Anomuran, Lithodidae	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.10	0.00	0.00	
DZB	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.01	0.25	0.01	
ORG	Decapod zoea, crab, Oregoninae	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.07	0.00	0.00	

C P	Decapod zoea, crab, Pisinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
S R	Decapod zoea, general shrimp	0.00	0.00	1.11	0.15	1.02	0.10	1.36	0.01	0.00	0.00	
F Z	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.01	0.00	0.00	
H	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
F Z	Decapod zoea, Shrimp, Pandalidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C G	Decapod, megalops, Brachyura	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C L	Decapod, megalops, Lithodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C P	Decapod, megalops, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C M	Decapod, megalops, unknown crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C B	Decapod, zoea, Brachyura, general	4.20	0.35	1.24	0.17	0.00	0.00	0.00	0.00	0.00	0.00	
D G	Decapod, zoea, general unknown group	0.00	0.00	0.00	0.00	0.00	0.00	12.22	0.12	0.00	0.00	
S P	Decapod,Shrimp, gen. unknown juv./adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
E	**hausiid**											
E 3	Euphausiid calyptopis	0.00	0.00	1.02	0.14	1.02	0.10	0.00	0.00	0.00	0.00	
E 4	Euphausiid furcilia	0.13	0.01	3.09	0.41	0.00	0.00	0.17	0.01	0.00	0.00	
E J	Euphausiid juvenile, general	0.00	0.00	1.11	0.15	0.00	0.00	0.17	0.01	0.00	0.00	
E 2	Euphausiid nauplii	2.04	0.17	2.04	0.27	0.00	0.00	0.00	0.00	0.00	0.00	
E P	Euphausiid, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
T	Euphausiid, T. longipes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
F H												
F E	Fish egg (~1.0 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
F L	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
G	**nmarid**											
G 2	Amphipod, Gammarid, unknown, medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
G	**stropod**											
V L	Gastropod, general veliger	2.04	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
G 3	Gastropod, juv. snail w/ black pigment	4.07	0.34	4.07	0.55	6.11	0.55	1.36	0.10	50.93	3.25	
L A	Gastropod, Pteropod, Limacina helicina A	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	6.11	0.34	
L J	Gastropod, Pteropod, Limacina helicina J	18.33	1.55	34.63	4.69	110.01	10.02	228.16	2.60	142.60	8.64	
G T	Gastropoda, general juvenile (SNAIL)	10.31	0.87	0.00	0.00	0.00	0.00	32.59	0.33	0.00	0.00	
H M	Gastropoda, juv. 'snail' in zooplankton	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	
H	**eriid**											
P 2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.01	2.04	0.11	
P	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
H P	Amphipod, Hyperiid, unknown juvenile	0.00	0.18	0.00	0.82	0.00	0.78	0.00	0.00	0.00	0.00	
H C	Amphipod, Hyperiid, unknown juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
H 3	Amphipod, Hyperiid, unknown small (<2mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
P	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C	**darian/ Ctenophore**											
C S	Cnidaria (<2mm), general small jellyfish	0.00	0.00	0.00	0.00	3.06	0.27	0.00	0.00	8.15	0.54	
C	Cnidaria (>2mm), general large jellyfish	0.64	0.05	2.13	0.29	0.64	0.06	0.51	0.03	0.51	0.03	

e 4 cont.												
	Cnidaria, Hydrozoa, Siphonophore "larva"	0.13	0.01	0.10	0.01	0.00	0.00	0.00	0.00	4.07	0.22	
acean												
	Larvacea, Oikopleura sp.	81.49	6.87	21.42	2.88	47.87	4.30	152.11	3.49	128.34	7.50	
er												
	Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	0.00	21.73	0.22	0.00	0.00	
C	Harpacticoid, general copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Z	Harpacticoid, general eggsac	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00	0.00	
	Harpacticoid, general, unknown stage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.00	
P	Harpacticoid, Laophontidae, copepodite	2.16	0.00	6.11	0.00	9.17	0.00	0.00	0.00	0.00	0.00	
C	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
C	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
O	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
AE	Malacostraca, eyes only	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
L	Polychaeta, general, juvenile	0.00	0.00	1.02	0.14	0.25	0.02	0.00	0.00	0.00	0.00	
RK	Polychaeta, trochophore larva	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	
NI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
EM	Unknown egg mass	18.33	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
GL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.00	0.00	16.30	0.52	59.08	3.60	
GG	Unknown invertebrate egg, small (<0.2mm)	28.52	2.41	6.11	0.83	12.22	1.09	597.57	1.74	0.00	0.00	
NP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	TOTAL	1185.51	100.00	742.42	100.00	1093.20	100.00	15716.92	100.00	1661.06	100.00	

ble 4 cont.									
Northeastern Area PWS									
	station	84	84	85	85	116	116	82	82
	depth (m)	20	20	20	20	20	20	80	80
CD	PREY NAME	#	%	#	%	#	%	#	%
rnacle									
E IC	Barnacle, cyprid	0.08	0.01	65.19	0.13	0.00	0.00	0.00	0.00
E IP	Barnacle, nauplius	21.73	0.06	43.46	0.09	2.04	0.12	0.00	0.00
lanoid copepod-large									
C IC	Calanoid, C. marshallae copepodite	23.17	0.16	5.94	0.19	22.03	1.54	16.30	2.75
C I	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C IF	Calanoid, Calanus marshallae AF	0.00	0.00	0.08	0.01	0.00	0.00	1.02	0.17
C F	Calanoid, Calanus pacificus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C V	Calanoid, Calanus pacificus CV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C A	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C C	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C G	Calanoid, Calanus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C D	Calanoid, Calanus/Neocalanus copepodids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E F	Calanoid, Epilabidocera longipedata, AF	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00
E M	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E C	Calanoid, Epilabidocera longipedata, cop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	Calanoid, Epilabidocera longipedata, gen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E B	Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.17
C L	Calanoid, general large (>2.5 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C N	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M F	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M F	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M C	Calanoid, Metridia pacifica, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M P	Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.17
M P	Calanoid, Metridia sp. copepodids I-IV	0.00	0.00	0.00	0.00	2.04	0.12	0.00	0.00
M	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N F	Calanoid, Neocalanus plumchrus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N D	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N P	Calanoid, Neocalanus spp. copepodite	0.00	0.00	10.86	0.66	6.11	0.35	0.00	0.00
anoid copepod- small									
A A	Calanoid, Acartia clausi adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A C	Calanoid, Acartia clausi copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A F	Calanoid, Acartia clausi female	0.00	0.00	0.00	0.00	2.04	0.12	0.00	0.00
A M	Calanoid, Acartia clausi male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A G	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4 cont.

	Calanoid, Acartia longiremis AF	8.15	0.65	38.03	1.04	95.75	6.47	3.06	0.52
	Calanoid, Acartia longiremus adult	0.00	0.00	0.00	0.00	0.00	0.00	7.13	1.21
	Calanoid, Acartia longiremus AM	65.19	0.17	4.07	0.25	12.22	0.80	0.00	0.00
	Calanoid, Acartia longiremus copepodite	86.92	0.23	2.72	0.17	8.15	0.47	0.00	0.00
	Calanoid, Acartia sp.	548.68	2.85	169.76	1.46	26.48	1.71	0.00	0.00
	Calanoid, Centropages abdominalis, adult	0.00	0.00	0.00	0.00	4.07	0.28	0.00	0.00
	Calanoid, Centropages abdominalis, AF	65.19	0.17	1.36	0.08	2.04	0.12	0.00	0.00
M	Calanoid, Centropages abdominalis, AM	0.00	0.00	1.36	0.08	2.04	0.12	0.00	0.00
	Calanoid, Centropages abdominalis, copdt	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.34
S	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Eurytemora pacifica AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Calanoid, Eurytemora pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	Calanoid, general nauplius	2814.11	7.38	4479.08	9.28	0.00	0.00	1.02	0.17
S	Calanoid, general small (<2.5 mm)	1825.31	4.77	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Pseudocalanus AF	2330.53	24.53	1401.58	26.54	617.27	41.81	319.84	54.06
M	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	2.04	0.12	0.00	0.00
P	Calanoid, Pseudocalanus copepodids I-IV	21.73	0.09	0.00	0.00	0.00	0.00	0.00	0.00
G	Calanoid, Pseudocalanus GF	24.45	0.31	55.68	0.49	4.07	0.28	1.02	0.17
A	Calanoid, Pseudocalanus sp., general	7322.98	31.07	3496.82	29.40	156.86	10.76	99.82	16.87
SC	Cyclopoid, Oithona copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	Cyclopoid, Oithona similis AF	554.11	1.57	2.72	0.17	4.07	0.28	1.02	0.17
SM	Cyclopoid, Oithona similis AM	249.89	1.07	999.58	2.06	0.00	0.00	2.04	0.34
S	Cyclopoid, Oithona similis, general	2455.48	6.42	4024.19	9.56	4.07	0.28	2.04	0.34
TS	Cyclopoid, Oithona spinirostris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
heatognath									
GE	Chaetognath, Sagitta (elegans)	0.25	0.02	0.42	0.01	0.00	0.00	6.11	1.03
HT	Chaetognath, species unknown	0.17	0.01	0.42	0.03	0.00	0.00	1.02	0.17
ladocera									
LA	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VD	Cladoceran, Evadne sp.	225.45	2.39	115.44	0.64	71.30	4.34	9.17	1.55
ON	Cladoceran, Podon sp.	179.27	1.85	39.39	0.86	50.93	3.39	17.32	2.93
yphonaute									
FN	Bryozoa, cyphonautes larva	21.73	0.06	0.00	0.00	0.00	0.00	0.00	0.00
ecapod									
IZ	Decapod zoea, Anomuran, Lithodidae	1.36	0.11	0.00	0.00	0.00	0.00	0.00	0.00
DZB	Decapod zoea, crab, Brachyrhyncha	2.72	0.22	0.00	0.00	4.07	0.28	0.00	0.00
ORG	Decapod zoea, crab, Oregoninae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DZP	Decapod zoea, crab, Pisinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SHR	Decapod zoea, general shrimp	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00

F Z	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H E	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F Z	Decapod zoea, Shrimp, Pandalidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D IG	Decapod, megalops, Brachyura	0.00	0.00	0.00	0.00	0.13	0.01	3.06	0.52
L iL	Decapod, megalops, Lithodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D IP	Decapod, megalops, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D M	Decapod, megalops, unknown crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D B	Decapod, zoea, Brachyura, general	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00
D G	Decapod, zoea, general unknown group	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S P	Decapod,Shrimp, gen. unknown juv./adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E **phausiid**									
E 3	Euphausiid calyptopis	0.00	0.00	0.00	0.00	4.07	0.24	0.00	0.00
E 4	Euphausiid furcilia	0.00	0.00	1.36	0.08	0.00	0.00	0.19	0.03
E J	Euphausiid juvenile, general	0.00	0.00	0.00	0.00	2.04	0.16	0.03	0.01
E 2	Euphausiid nauplii	2.72	0.22	0.00	0.00	4.07	0.28	0.00	0.00
E P	Euphausiid, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
T	Euphausiid, T. longipes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F H									
F E	Fish egg (~1.0 mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
G **nmarid**									
G 2	Amphipod, Gammarid, unknown, medium	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G **tropod**									
VI	Gastropod, general veliger	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G 3	Gastropod, juv. snail w/ black pigment	334.10	2.86	65.19	0.13	2.04	0.16	9.17	1.55
LN	Gastropod, Pteropod, Limacina helicina A	10.86	0.05	19.01	1.16	0.00	0.00	1.02	0.17
LN	Gastropod, Pteropod, Limacina helicina J	476.70	3.43	229.52	4.08	71.30	4.79	49.91	8.44
G	Gastropoda, general juvenile (SNAIL)	0.00	0.00	0.00	0.00	10.19	0.59	0.00	0.00
H 1	Gastropoda, juv. 'snail' in zooplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hy **eriid**									
PS	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	0.00	4.07	0.32	0.70	0.12
PS	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.09
HN	Amphipod, Hyperiid, unknown juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HZ	Amphipod, Hyperiid, unknown juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN	Amphipod, Hyperiid, unknown small (<2mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cn **arian/ Ctenophore**									
CN	Cnidaria (<2mm), general small jellyfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CN	Cnidaria (>2mm), general large jellyfish	1.19	0.04	0.34	0.01	0.13	0.01	0.38	0.06
SIF	Cnidaria, Hydrozoa, Siphonophore "larva"	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00
a **acean**									

ble 4 cont.

P	Larvacea, Oikopleura sp.	723.88	4.95	649.18	6.02	105.93	7.10	28.52	4.82
ner									
L	Bivalve, larvae	305.58	1.30	43.46	0.09	2.04	0.12	0.00	0.00
C	Harpacticoid, general copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z	Harpacticoid, general eggsac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Harpacticoid, general, unknown stage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	Harpacticoid, Laophontidae, adult	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.00
YP	Harpacticoid, Laophontidae, copepodite	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	Isopod, general	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AE	Malacostraca, eyes only	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RK	Polychaeta, trochophore larva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NI	Unidentified item	10.86	0.05	0.00	0.00	0.00	0.00	0.00	0.00
EM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GL	Unknown invertebrate egg, large (>0.2mm)	55.68	0.30	17.66	1.08	187.42	12.48	6.11	1.03
GG	Unknown invertebrate egg, small (<0.2mm)	184.70	0.57	1917.66	4.09	0.00	0.00	0.00	0.00
NP	Unknown nauplius	10.86	0.05	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	20966.39	100.00	17902.90	100.00	1493.25	100.00	591.67	100.00

ble 4 cont.

Southwestern PWS

	station	107	107
	depth (m)	20	20
'CD	PREYNAME	#	%
rnacle			
1M	Barnacle, adult molt (cirri)	0.13	0.00
1C	Barnacle, cyprid	0.00	0.00
1P	Barnacle, nauplius	0.00	0.00
lanoid copepod-large			
1M	Calanoid, Calanus marshallae AM	0.00	0.00
'F	Calanoid, Calanus pacificus AF	0.13	0.00
'V	Calanoid, Calanus pacificus CV	0.13	0.00
'A	Calanoid, Calanus pacificus, adult	0.00	0.00
'C	*Calanoid, Calanus pacificus, general*	0.00	0.00
;P	Calanoid, Calanus sp. copepodite	4.07	0.11
'M	Calanoid, Epilabidocera longipedata, AM	0.00	0.00
'C	Calanoid, Epilabidocera longipedata, cop	0.13	0.00
'F	Calanoid, Metridia pacifica, AF	0.00	0.00
3	Calanoid, Metridia sp., General	0.00	0.00
1C	Calanoid, C. marshallae copepodite	14.90	0.41
1	Calanoid, Calanus marshallae	0.00	0
1F	Calanoid, Calanus marshallae AF	0.00	0
'G	Calanoid, Calanus sp. general	0.00	0.00
IB	Calanoid, Eucalanus bungii, general	0.00	0
IE	Calanoid, Euchaeta elongata, general	0.00	0
.L	Calanoid, general large (>2.5 mm)	0.00	0.00
N	Calanoid, large, Neocalanus/Calanus	0.00	0.00
;P	Calanoid, Neocalanus spp. copepodite	8.15	0.22
lanoid copepod-small			
'F	Calanoid, Acartia clausi female	8.15	0.22
)S	Calanoid, Copepodite small	0.00	0.00
M	Calanoid, Pseudocalanus AM	81.49	2.25
.V	Calanoid, unknown copepodids	0.00	0.00

le 4 cont.			
C	Cyclopoid, Oithona sp., general	0.00	0.00
A G	Calanoid, Acartia longiremis , General	4.07	0.11
A F	Calanoid, Acartia longiremis AF	44.82	1.23
M	Calanoid, Acartia longiremus AM	44.82	1.23
A C	Calanoid, Acartia longiremus copepodite	16.30	0.45
A	Calanoid, Acartia sp.	0.00	0.00
	Calanoid, Centropages abdominalis, adult	0.00	0.00
AF	Calanoid, Centropages abdominalis, AF	4.07	0.11
AM	Calanoid, Centropages abdominalis, AM	0.00	0.00
AC	Calanoid, Centropages abdominalis, copdt	0.00	0.00
YF	Calanoid, Eurytemora pacifica AF	0.00	0
YT	Calanoid, Eurytemora pacifica, general	0.00	0.00
AN	Calanoid, general nauplius	12.22	0.33
AS	Calanoid, general small (<2.5 mm)	8.15	0.22
SF	Calanoid, Pseudocalanus AF	2717.60	74.59
CP	Calanoid, Pseudocalanus copepodids I-IV	118.16	3.26
SG	Calanoid, Pseudocalanus GF	20.37	0.56
SA	Calanoid, Pseudocalanus sp., general	419.66	11.48
S	Cyclopoid, Oithona similis, general	0.00	0.00
haetognath			
GE	Chaetognath, Sagitta (elegans)	1.27	0.04
HT	Chaetognath, species unknown	0.13	0.00
Cladocera			
CLA	Cladocera, General	0.00	0.00
EVD	Cladoceran, Evadne sp.	12.22	0.33
PON	Cladoceran, Podon sp.	0.00	0.00
Decapod			
DMG	Decapod, megalops, Brachyura	0.00	0
DZB	Decapod zoea, crab, Brachyrhyncha	1.27	0.04
SHR	Decapod zoea, general shrimp	0.00	0.00
PGZ	Decapod zoea, hermit crab, Paguridae	0.25	0.01
HIE	Decapod zoea, Shrimp, Hippolytidae	0.13	0.00
PDZ	Decapod zoea, Shrimp, Pandalidae	0.00	0.00
DMP	Decapod, megalops, Paguridae	0.00	0

ıble 4 cont.

IC	Decapod, Shrimp, Crangonid, general	0.38	0.01
3B	Decapod, zoea, Brachyura, general	0.00	0.00
ZG	Decapod, zoea, general unknown group	0.00	0.00
IY	Decapod,Shrimp, Hippolytid, general	0.25	0.01
ıphausiid			
J3	Euphausiid calyptopis	16.30	0.45
J4	Euphausiid furcilia	0.25	0.01
JJ	Euphausiid juvenile, general	0.00	0.00
JP	Euphausiid, general unknown	0.00	0.00
SH			
F E	Fish egg (~1.0 mm)	0.00	0
F L	Fish larvae, general	0.00	0
F J	Fish, juvenile, general	0.00	0.00
F /2	Fish, walleye pollock, (41-60mm)	0.00	0.00
F /3	Fish, walleye pollock, (61-80mm)	0.00	0.00
mmarid			
C M	Amphipod, Gammarid head	0.00	0.00
C iC	Amphipod, Gammarid, Calliopius	0.00	0.00
C 3	Amphipod, Gammarid, unknown, large	0.00	0.00
C 2	Amphipod, Gammarid, unknown, medium	0.00	0.00
C U	Amphipod, Gammarid, unknown, no size	0.00	0.00
C 1	Amphipod, Gammarid, unknown, small	0.00	0.00
C stropod			
L J	Gastropod, Pteropod, Limacina helicina J	52.97	1.45
L D	Gastropoda, Lacuna sp.	0.00	0.00
ɔeriid			
P 2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00
P 1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00
P 1	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	0.00
P I	Amphipod, Hyperiid, Primno macropa, gen.	0.00	0.00
H P	Amphipod, Hyperiid, unknown juvenile	0.00	0.00
H 3	Amphipod, Hyperiid, unknown small (<2mm)	0.51	0.01
P I	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00

ble 4 cont.			
ect			
L	Insect, Dipteran larvae	0.00	0.00
idarian/ Ctenophore			
IS	Cnidaria (<2mm), general small jellyfish	0.25	0.01
NI	Cnidaria (>2mm), general large jellyfish	0.38	0.01
P	Cnidaria, Hydrozoa, Siphonophore "larva"	0.51	0.01
rvacean			
KP	Larvacea, Oikopleura sp.	0.89	0.02
her			
VP	Bivalve pieces (shell + muscle)	0.00	0.00
VL	Bivalve, larvae	8.15	0.22
MV	Bivalve, Musculus vernicosus	0.00	0.00
CO	Copepod, Caligidae, parasitic copepod	0.00	0.00
UM	Cumacea	0.00	0.00
RC	Harpacticoid, general copepodite	0.00	0.00
EM	Harpacticoid, general eggsac	0.00	0.00
R	Harpacticoid, general, unknown stage	0.00	0.00
RJ	Harpacticoid, Harpacticus copepodite	0.00	0.00
RS	Harpacticoid, Harpacticus sp. general ad	0.00	0.00
SC	Harpacticoid, Tisbe copepodite	0.00	0.00
SB	Harpacticoid, Tisbe sp., adult	0.00	0.00
SG	Harpacticoid, Tisbe sp., gravid female	0.00	0.00
GN	Isopod, Gnorimosphaeroma species	0.00	0.00
MAL	Malacostraca	0.00	0.00
MAE	Malacostraca, eyes only	0.00	0.00
NEM	Nematode	0.00	0.00
PLA	Polychaeta, adult	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00	0.00
EGL	Unknown invertebrate egg, large (>0.2mm)	16.30	0.45
EGG	Unknown invertebrate egg, small (<0.2mm)	4.07	0.11

T le 5. Density (total mean number per cubic meter) and percent numerical composition of major groups of
z plankters in central, northeastern and southwestern PWS in fall, 1995.

theastern Area						**Northeastern Area**				
station	6	7	7	9		station	6	7	7	9
depth (m)	50	100	25			depth (m)	50	100	25	
S MCODE										
B nacle	0.00	0.20	0.00	2.55			0.00	0.02	0.00	0.05
C anoid copepod-large	469.82	175.86	104.10	2770.56			20.98	16.53	8.01	55.54
C anoid copepod-small	1349.43	425.77	685.31	1385.28			60.27	40.01	52.74	27.77
C aetognath	2.75	4.63	1.02	407.44			0.12	0.44	0.08	8.17
C docera	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00
C honaute	182.53	332.47	296.61	0.00			8.15	31.24	22.83	0.00
D apod	0.05	0.03	0.51	2.55			0.00	0.00	0.04	0.05
E hausiid	3.00	2.01	0.71	38.20			0.13	0.19	0.05	0.77
F n	0.00	0.05	0.00	0.00			0.00	0.00	0.00	0.00
G nmerid	5.35	0.69	0.20	0.00			0.24	0.06	0.02	0.00
G stropod	133.69	84.34	140.97	22.92			5.97	7.93	10.85	0.46
H eriid	0.46	1.38	0.51	297.94			0.02	0.13	0.04	5.97
C darian/ Ctenophore	0.61	5.14	1.53	33.10			0.03	0.48	0.12	0.66
L vacean	78.23	22.41	49.71	25.46			3.49	2.11	3.83	0.51
M acostracan	0.00	0.00	0.00	2.55			0.00	0.00	0.00	0.05
C er	13.09	9.12	18.13	0.00			0.58	0.86	1.40	0.00
T TAL	2239.01	1064.09	1299.31	4988.54						
C tral Area						**Central Area**				
station	3	4	5			station	3	4	5	
depth (m)	100	75	80			depth (m)	100	75	80	
S MCODE										
B nacle	2.44	2.17	0.00				0.46	0.39	0.00	
C anoid copepod-large	78.64	50.52	66.81				14.80	9.04	6.31	
C anoid copepod-small	372.60	406.89	851.86				70.12	72.81	80.47	
C etognath	2.70	5.16	4.62				0.51	0.92	0.44	
C docera	0.00	0.00	0.00				0.00	0.00	0.00	
C honaute	13.85	5.43	14.26				2.61	0.97	1.35	
D apod	0.03	0.00	0.00				0.00	0.00	0.00	
E hausiid	2.52	5.30	1.24				0.47	0.95	0.12	
F n	1.04	0.61	0.00				0.20	0.11	0.00	
G nmerid	2.52	0.75	0.41				0.47	0.13	0.04	
G tropod	10.59	23.94	25.46				1.99	4.28	2.41	
H eriid	1.60	2.00	0.80				0.30	0.36	0.08	
C darian/ Ctenophore	14.67	22.88	48.48				2.76	4.09	4.58	
L vacean	11.92	15.69	27.53				2.24	2.81	2.60	

able 5 cont.										
alacostracan	0.00	0.00	0.00				0.00	0.00	0.00	
ther	16.25	17.52	17.09				3.06	3.13	1.61	
TAL	531.37	558.87	1058.57							
outhwestern Area						**Southwestern Area**				
station	2					station	2			
depth (m)	75					depth (m)	75			
UMCODE										
arnacle	2.48						0.20			
alanoid copepod-large	12.49						1.00			
alanoid copepod-small	1008.95						80.83			
haetognath	0.27						0.02			
ladocera	0.41						0.03			
yphonaute	26.75						2.14			
ecapod	0.17						0.01			
uphausiid	0.34						0.03			
ish	0.00						0.00			
ammerid	0.14						0.01			
astropod	17.25						1.38			
yperiid	0.34						0.03			
nidarian/ Ctenophore	10.56						0.85			
arvacean	107.02						8.57			
Malacostracan	0.00						0.00			
Other	61.08						4.89			
TOTAL	1248.25									

ble 6. Species composition, density and percent numbers (mean number per cubic meter; mean percent number r cubic meter) of zooplankters by station in central, northeastern and southwestern PWS, fall 1995. Conical, 0.5 diameter nets with 243- mesh were hauled vertically from the depth indicated to the surface. Unless otherwise ted, two replicate hauls were collected at each station and depth sampled.

area	SW	SW	C	C	C	C	C	C	NE	NE	NE	NE	NE	NE	NE	NE
station	2	2	3	3	4	4	5	5	6	6	7	7	7	7	9	9
epth (m)	75	75	100	100	75	75	80	80	50	50	25	25	100	100	2	2
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
CD																
rnacle																
MC			1.63	0.31	2.17	0.39						0.00	0.20	0.02	0.00	0.00
MM	0.03	0.00	0.81	0.15											2.55	0.05
MP	2.44	0.20													0.00	0.00
lanoid copepod-large																
L		0.00					1.53	0.14	0.00						0.00	0.00
M											0.81	0.06			40.74	0.82
CL							0.03	0.00	0.00						0.00	0.00
CP	10.19	0.82	6.52	1.23	4.89	0.87	2.29	0.22			2.24	0.17	5.09	0.48	366.69	7.35
CV									0.05	0.00					0.00	0.00
N															0.00	0.00
M	0.14	0.01	0.20	0.04	0.27	0.05									0.00	0.00
MC	1.36	0.11	0.61	0.12	1.09	0.19	2.55	0.24	21.59	0.97	0.20	0.02	0.41	0.04	1140.82	22.87
MF					0.27	0.05									122.23	2.45
PC									1.22	0.05					407.44	8.17
PD	0.27	0.02													0.00	0.00
PF			0.61	0.12			0.51	0.05			0.20	0.02			0.00	0.00
PG															611.15	12.25
PM															0.00	0.00
PV							1.27	0.12							0.00	0.00
C					0.27	0.05									0.00	0.00
CC							0.03	0.00	0.20	0.01			0.61	0.06	0.00	0.00
CF									0.10	0.00					0.00	0.00
CM															0.00	0.00
F							0.03	0.00	0.31	0.01			0.43	0.04	0.00	0.00
M									0.15	0.01					0.00	0.00
C			1.43	0.27			0.25	0.02							0.00	0.00
F							0.25	0.02							81.49	1.63
I													0.41	0.04	0.00	0.00
PM			0.61	0.12											40.74	0.82
CP			5.70	1.07											0.00	0.00
CS			17.11	3.22	26.62	4.76	46.09	4.35	169.49	7.58	84.75	6.52	89.64	8.42	0.00	0.00
EP									0.00						0.00	0.00
G		0.00	1.63	0.31					0.00						0.00	0.00
GF		0.00													0.00	0.00

Table 6 cont.																
C			21.80	4.10	12.77	2.28	7.64	0.72	223.68	9.98	12.02	0.93	67.02	6.30	0.00	0.00
F	0.54	0.04	17.11	3.22	4.35	0.78	3.82	0.36	52.15	2.32	4.69	0.36	11.41	1.07	0.00	0.00
M		0.00	5.30	1.00											0.00	0.00
P							0.51	0.05	0.87	0.04			0.81	0.08	0.00	0.00
O															0.00	0.00
F		0.00													0.00	0.00
lanoid copepod-small																
		0.00	1.63	0.31			10.19	0.96							0.00	0.00
P									19.56	0.87					0.00	0.00
					0.54	0.10									0.00	0.00
C	84.75	6.79					4.07	0.38	3.26	0.15	0.81	0.06	3.26	0.31	40.74	0.82
F	155.37	12.45	6.52	1.23	6.52	1.17	25.46	2.41	16.30	0.73	13.04	1.00	18.74	1.76	814.87	16.33
G	68.45	5.48			1.09	0.19	3.06	0.29			14.67	1.13	8.96	0.84	203.72	4.08
M	29.34	2.35	3.26	0.61			12.22	1.15	6.52	0.29	6.52	0.50	1.22	0.11	0.00	0.00
RC	1.36	0.11													0.00	0.00
RF	0.14	0.01					0.03	0.00							0.00	0.00
RG		0.00														
RM	0.95	0.08													0.00	0.00
AC									9.78	0.43	6.52	0.50			0.00	0.00
AF			0.81	0.15							0.81	0.06			0.00	0.00
AN	3.26	0.26	0.81	0.15	1.09	0.19	1.02	0.10	3.26	0.15	3.26	0.25	0.41	0.04	0.00	0.00
AS	5.43	0.44	5.70	1.07	7.61	1.36	27.50	2.60	0.00		13.04	1.00	4.48	0.42	81.49	1.63
GF			0.20	0.04			0.03	0.00							0.00	0.00
OS	3.26	0.26	4.89	0.92					0.00				1.22	0.11	0.00	0.00
EF			3.26	0.61	31.51	5.64	3.31	0.31			1.63	0.13	0.81	0.08	0.00	0.00
EG					22.27	3.99	16.30	1.54	3.26	0.14	3.26	0.25	1.22	0.11	0.00	0.00
IT													64.78	6.09	0.00	0.00
S	304.22	24.37	52.15	9.81	30.42	5.44	115.10	10.87	0.00		137.71	10.60	60.71	5.71	0.00	0.00
SC											1.63	0.13			0.00	0.00
OSF					0.54	0.10	95.75	9.04	322.69	14.44					0.00	0.00
OSG	2.17	0.17													0.00	0.00
OSM					23.90	4.28									0.00	0.00
OTF			0.81	0.15	7.06	1.26									0.00	0.00
OTM															0.00	0.00
OTS			0.81	0.15	4.35	0.78	14.26	1.35	22.82	1.02	4.89	0.38			0.00	0.00
PCP	126.03	10.10	125.49	23.62	40.20	7.19	132.42	12.51			187.42	14.42	121.82	11.45	40.74	0.82
PSA	54.32	4.35	55.41	10.43	104.30	18.66	240.39	22.71	762.72	34.04	58.67	4.52	24.04	2.20	0.00	0.00
PSF	107.56	8.62	81.49	15.34	99.96	17.89	129.36	12.22	179.27	7.99	194.75	14.99	98.19	9.23	122.23	2.45
PSG	13.04	1.04	0.81	0.15			3.06	0.29			2.44	0.19			0.00	0.00
PSM	49.30	3.95	26.89	5.06	11.95	2.14	8.15	0.77			22.82	1.76	11.00	1.03	40.74	0.82
TOR		0.00							0.00		10.59	0.82	4.89	0.46	0.00	0.00
Chaetognath																
CHT		0.00	0.33	0.06			1.85	0.17	2.75	0.12					0.00	0.00
SGE	0.27	0.02	2.37	0.45	5.16	0.92	2.77	0.26			1.02	0.08	4.63	0.44	407.44	8.17

ble 6 cont.																
doceran																
A		0.00													0.00	0.00
D	0.41	0.03													0.00	0.00
N		0.00													0.00	0.00
phonaute																
N	26.75	2.14	13.85	2.61	5.43	0.97	14.26	1.35	182.53	8.17	296.61	22.83	332.47	31.24	0.00	0.00
capod																
G															2.55	0.05
C	0.03	0.00													0.00	0.00
G															0.00	0.00
E	0.07	0.01													0.00	0.00
N															0.00	0.00
Z											0.41	0.03			0.00	0.00
Z													0.03	0.00	0.00	0.00
C			0.03	0.00											0.00	0.00
R	0.03	0.00									0.10	0.01			0.00	0.00
	0.03	0.00													0.00	0.00
phausiid																
E 1															0.00	0.00
E 2															0.00	0.00
E 3															0.00	0.00
E P									0.20	0.01					0.00	0.00
E 2					0.54	0.10									0.00	0.00
E 3			1.02	0.19	2.51	0.45	1.02	0.10					1.63	0.15	0.00	0.00
E 4	0.10	0.01	1.09	0.21	0.88	0.16	0.13	0.01	0.41	0.02	0.41	0.03	0.10	0.01	38.20	0.77
E A									0.05	0.00					0.00	0.00
E B													0.03	0.00	0.00	0.00
E J	0.17	0.01	0.41	0.08	1.32	0.24	0.10	0.01	1.73	0.08	0.31	0.02			0.00	0.00
E P		0.00							0.00						0.00	0.00
T									0.00						0.00	0.00
T)	0.03	0.00			0.03	0.01									0.00	0.00
T													0.03	0.00	0.00	0.00
T F									0.31	0.01			0.05	0.00	0.00	0.00
T G									0.00						0.00	0.00
T M									0.36	0.02			0.20	0.02	0.00	0.00
T	0.03	0.00													0.00	0.00
F n																
F E			1.02	0.19									0.05	0.00	0.00	0.00
F L			0.03	0.00											0.00	0.00
M I					0.61	0.11									0.00	0.00
nmarid																
C C							0.32	0.03	5.35	0.24					0.00	0.00
C G			1.43	0.27	0.71	0.13	0.10	0.01			0.20	0.02	0.69	0.06	0.00	0.00
G I	0.14	0.01	0.81	0.15	0.03	0.01									0.00	0.00

able 6 cont.																
GA2		0.00	0.20	0.04					0.00						0.00	0.00
GA3															0.00	0.00
GAU		0.00													0.00	0.00
DED			0.08	0.01											0.00	0.00
Gastropod																
GCP									0.05	0.00					0.00	0.00
GPC															2.55	0.05
GSB	15.35	1.23	2.44	0.46	3.80	0.68					49.71	3.83	61.12	5.74	0.00	0.00
GST		0.00							0.00		52.15	4.01			20.37	0.41
LMA									0.00						0.00	0.00
LMJ	1.90	0.15	8.15	1.53	20.10	3.60	25.46	2.41	133.64	5.96	39.11	3.01	23.22	2.18	0.00	0.00
VEL					0.03	0.01									0.00	0.00
Hyperiid																
HP			0.23	0.04									0.03	0.00	0.00	0.00
HYA															0.00	0.00
HYB	0.24	0.02	0.66	0.12	1.70	0.30	0.48	0.05			0.31	0.02	0.51	0.05	259.74	5.21
HYP		0.00					0.06	0.01	0.46	0.02					0.00	0.00
PA2			0.48	0.09									0.56	0.05	5.09	0.10
PAA			0.03	0.00											0.00	0.00
PR1															0.00	0.00
PRI					0.27	0.05	0.03	0.00					0.05	0.00	0.00	0.00
PS															0.00	0.00
PS1	0.07	0.01	0.03	0.00			0.19	0.02			0.20	0.02	0.08	0.01	0.00	0.00
PS2	0.03	0.00	0.18	0.03	0.03	0.01	0.03	0.00					0.15	0.01	33.10	0.66
Insect																
DPL									0.00						0.00	0.00
Cnidarian/ Ctenophore																
BCT			0.08	0.01	1.36	0.24	0.32	0.03				0.00	1.22	0.11	0.00	0.00
CNI	0.85	0.07	3.82	0.72	3.53	0.63	6.40	0.60	0.51	0.02	0.81	0.06	0.92	0.09	15.28	0.31
CNS	9.57	0.77	10.47	1.97	16.87	3.02	40.30	3.81			0.61	0.05	1.45	0.14	5.09	0.10
CTE	0.14	0.01					0.16	0.02	0.10	0.00	0.10	0.01	0.13	0.01	7.64	0.15
CTO					0.03	0.01									0.00	0.00
GON			0.15	0.03	1.09	0.19	0.29	0.03					0.46	0.04	0.00	0.00
MES			1.63	0.31	13.58	2.43	10.19	0.96							0.00	0.00
SIP			0.15	0.03			1.02	0.10					0.97	0.09	5.09	0.10
Larvacean																
OI1	80.94	6.48			0.54	0.10			0.00		19.56	1.51	14.26	1.34	0.00	0.00
OKP	26.08	2.09	11.92	2.24	15.14	2.71	27.53	2.60	78.23	3.50	30.15	2.32	8.15	0.77	25.46	0.51
Other																
BVJ			0.92	0.17											0.00	0.00
BVL	5.57	0.45	3.26	0.61	14.12	2.53	8.15	0.77	9.78	0.44	10.59	0.82	2.44	0.23	0.00	0.00
CNC							0.25	0.02			0.20	0.02	0.51	0.05	0.00	0.00
CUM	0.07	0.01	0.03	0.00											0.00	0.00
EBL	2.17	0.17	0.81	0.15			1.02	0.10							0.00	0.00

able 6 cont.

BP	4.35	0.35	1.63	0.31	1.09	0.19	2.04	0.19			0.81	0.06			0.00	0.00
GG	38.03	3.05	2.44	0.46	0.54	0.10	1.02	0.10	0.00		1.63	0.13	0.81	0.08	0.00	0.00
GL	1.22	0.10	0.81	0.15	1.15	0.21	2.29	0.22	0.00				1.63	0.15	0.00	0.00
EM									3.26	0.15					0.00	0.00
R	1.09	0.09							0.00						0.00	0.00
RC		0.00							0.00				0.41	0.04	0.00	0.00
RN													0.41	0.04	0.00	0.00
ZC									0.00						0.00	0.00
ZZ									0.00						0.00	0.00
SC			0.81	0.15							0.10	0.01	0.43	0.04	0.00	0.00
AC			2.44	0.46											0.00	0.00
AE		0.00							0.00						2.55	0.05
AL		0.00							0.00						0.00	0.00
PN	0.07	0.01													0.00	0.00
UJ			0.03	0.00					0.05	0.00					0.00	0.00
YS		0.00													0.00	0.00
EM		0.00			0.03	0.01									0.00	0.00
ER	0.14	0.01													0.00	0.00
IE	1.09	0.09													0.00	0.00
ST	0.14	0.01	1.63	0.31			0.25	0.02							0.00	0.00
CO									0.00						0.00	0.00
EC	5.43	0.44													0.00	0.00
LC			0.03	0.00	0.31	0.05	1.02	0.10							0.00	0.00
LL	0.24	0.02	1.40	0.26					0.00		3.06	0.24	1.25	0.12	0.00	0.00
RK	0.27	0.02			0.27	0.05	1.02	0.10			1.73	0.13			0.00	0.00
EM	0.14	0.01													0.00	0.00
NI		0.00					0.03	0.00							0.00	0.00
NP	1.09	0.09											1.22	0.11	0.00	0.00

le 7. Total numbers and percent numbers of major groups of prey organisms in forage fish stomachs by species-size ıp (n = 10 each) at stations in central, northeastern and southwestern PWS in fall, 1994.

al number										
Region	SW	SW		NE	NE	NE	NE	NE	NE	NE
species	herring	pollock		pollock	herring	herring	pollock	eulachon	herring	herring
size group	2	0		0	0	0	0	0	0	1
station-haul	3-1	5-5		6-1	6-1	7-4	7-4	7-5	8	8
SUMCODE										
alanoid copepod-large	2.00	153.00		3.00	0.00	10.00	4.00	0.00	7.00	1.00
alanoid copepod-small	153.00	616.00		27.00	43.00	78.00	19.00	0.00	227.00	625.00
Chaetognath	0.00	5.00		0.00	0.00	1.00	1.00	0.00	2.00	1.00
Decapod	0.00	1.00		0.00	0.00	0.00	1.00	0.00	0.00	0.00
Euphausiid	2.00	18.00		16.00	3.00	21.00	11.00	1.00	4.00	10.00
Gammarid	0.00	1.00		1.00	0.00	0.00	0.00	0.00	1.00	0.00
Gastropod	0.00	2.00		0.00	2.00	4.00	0.00	0.00	75.00	4.00
Hyperiid	1.00	7.00		0.00	0.00	1.00	4.00	0.00	1.00	1.00
Cnidarian/ Ctenophore	0.00	5.00		1.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	9.00	6402.00		134.00	86.00	200.00	24.00	0.00	786.00	177.00
Malacostracan	1.00	0.00		0.00	1.00	0.00	0.00	1.00	1.00	0.00
Other	6.00	16.00		3.00	2.00	3.00	0.00	0.00	2081.00	36.00
Total	174.00	7226.00		185.00	137.00	318.00	64.00	2.00	3185.00	855.00
ercent number										
Region	SW	SW		NE	NE	NE	NE	NE	NE	NE
species	herring	pollock		pollock	herring	herring	pollock	eulachon	herring	herring
size group	2	0		0	0	0	0	0	0	1
station-haul	3-1	5-5		6-1	6-1	7-4	7-4	7-5	8	8
SUMCODE										
Calanoid copepod-large	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small	87.93	8.52		14.59	31.39	24.53	29.69	0.00	7.13	73.10
Chaetognath	0.00	0.07		0.00	0.00	0.31	1.56	0.00	0.06	0.12
Decapod	0.00	0.01		0.00	0.00	0.00	1.56	0.00	0.00	0.00
Euphausiid	1.15	0.25		8.65	2.19	6.60	17.19	50.00	0.13	1.17
Gammarid	0.00	0.01		0.54	0.00	0.00	0.00	0.00	0.03	0.00
Gastropod	0.00	0.03		0.00	1.46	1.26	0.00	0.00	2.35	0.47
Hyperiid	0.57	0.10		0.00	0.00	0.31	6.25	0.00	0.03	0.12
Cnidarian/ Ctenophore	0.00	0.07		0.54	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	5.17	88.60		72.43	62.77	62.89	37.50	0.00	24.68	20.70
Malacostracan	0.57	0.00		0.00	0.73	0.00	0.00	50.00	0.03	0.00
Other	3.45	0.22		1.62	1.46	0.94	0.00	0.00	65.34	4.21

T le 8. Total numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at st ions in central, northeastern and southwestern PWS in fall, 1994.

	Region	SW	SW	NE	NE	NE	NE	NE	NE	NE
	species	herring	pollock	herring	pollock	herring	pollock	eulachon	herring	herring
	size group	2	0	0	0	0	0	0	0	1
	station-haul	3-1	5-5	6-1	6-1	7-4	7-4	7-5	8	8
S. :D	preyname									
C anoid copepod-large										
C	Calanoid, general large (>2.5 mm)	0.00	6.00	0.00	1.00	2.00	0.00	0.00	3.00	1.00
C l	Calanoid, large, Neocalanus/Calanus	0.00	3.00	0.00	0.00	4.00	1.00	0.00	1.00	0.00
C F	Calanoid, Calanus marshallae AF	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C)	Calanoid, Calanus/Neocalanus copepodids	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C M	Calanoid, Calanus pacificus AM	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E F	Calanoid, Euchaeta elongata, AF	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E M	Calanoid, Euchaeta elongata, AM	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E M	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00
M F	Calanoid, Metridia pacifica, AF	2.00	136.00	0.00	2.00	1.00	2.00	0.00	0.00	0.00
M M	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	1.00	0.00	3.00	0.00
C anoid copepod-small										
A	Calanoid, Acartia clausi adult	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	8.00
A	Calanoid, Acartia longiremus adult	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A	Calanoid, Acartia longiremis AF	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Calanoid, Centropages abdominalis, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
C M	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	4.00
C	Calanoid, general small (<2.5 mm)	75.00	218.00	43.00	7.00	78.00	16.00	0.00	160.00	499.00
LU	Calanoid, Lucicutia flavicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
O	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
O F	Cyclopoid, Oithona similis AF	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00
PC	Calanoid, Pseudocalanus copepodids I-IV	0.00	14.00	0.00	0.00	0.00	0.00	0.00	9.00	31.00
PS	Calanoid, Pseudocalanus sp., general	33.00	87.00	0.00	19.00	0.00	0.00	0.00	15.00	14.00
PS	Calanoid, Pseudocalanus AF	7.00	30.00	0.00	0.00	0.00	0.00	0.00	23.00	40.00
PS 1	Calanoid, Pseudocalanus AM	37.00	261.00	0.00	1.00	0.00	3.00	0.00	18.00	13.00
C etognath										
C	Chaetognath, species unknown	0.00	0.00	0.00	0.00	1.00	1.00	0.00	2.00	0.00
S	Chaetognath, Sagitta (elegans)	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
D apod										
D	Decapod zoea, Shrimp, Crangonidae	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
E hausiid										

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3	Euphausiid calyptopis	0.00	0.00	1.00	1.00	1.00	0.00	0.00	2.00	5.00
4	Euphausiid furcilia	0.00	0.00	2.00	0.00	1.00	2.00	0.00	2.00	2.00
JP	Euphausiid, general unknown	1.00	11.00	0.00	14.00	15.00	7.00	1.00	0.00	3.00
	Euphausiid, Thysannoessa sp., gen. adult	0.00	1.00	0.00	0.00	4.00	2.00	0.00	0.00	0.00
RF	Euphausiid, T. raschii females	1.00	3.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
RM	Euphausiid, T. raschii males	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ammarid										
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
A2	Amphipod, Gammarid, unknown, medium	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
astropod										
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	2.00	0.00	4.00	0.00	0.00	31.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	0.00	2.00	0.00	0.00	0.00	0.00	0.00	44.00	4.00
TP	Gastropoda, Pteropod, unidentified	0.00	5.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
yperiid										
P	Amphipod, Hyperiid, Hyperia sp.	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.00	1.00	0.00	0.00	1.00	3.00	0.00	1.00	1.00
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L2	Amphipod, Hyperiid, P. libellula 2-6.9mm	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
P	Amphipod, Hyperiid/Parath. pacifica gen.	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR1	Amphipod, Hyperiid, Primno macropa, <2mm	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean										
OKI	Larvacea, Oikopleura dioica	9.00	6402.00	86.00	134.00	200.00	24.00	0.00	786.00	177.00
Malacostracan										
MAE	Malacostraca, eyes only	1.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00
MAL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Other										
BVL	Bivalve, larvae	0.00	0.00	1.00	0.00	1.00	0.00	0.00	18.00	2.00
EGG	Unknown invertebrate egg, small (<0.2mm)	0.00	11.00	1.00	0.00	1.00	0.00	0.00	17.00	31.00
EGL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	1.00	0.00	0.00	2040.00	0.00
HZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
ISP	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
NEM	Nematode	2.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
PCO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
PEC	Polychaeta, Pectinariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

ble 8 cont.										
L	Polychaeta, general, juvenile	0.00	2.00	0.00	1.00	0.00	0.00	0.00	3.00	0.00
EM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
II	Unidentified item	4.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
TAL		174.00	7226.00	137.00	185.00	318.00	64.00	2.00	3185.00	855.00

able 9. Percent numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at tations in central, northeastern and southwestern PWS in fall, 1994.

	Region	SW	SW	NE	NE	NE	NE	NE	NE	NE
	species	herring	pollock	herring	pollock	herring	herring	herring	pollock	eulachon
	size group	2	0	0	0	0	0	1	0	0
	station-haul	3-1	5-5	6-1	6-1	7-4	8	8	7-4	7-5
PCD	preyname									
alanoid copepod-large										
AL	Calanoid, general large (>2.5 mm)	0.00	0.08	0.00	0.54	0.63	0.09	0.12	0.00	0.00
LN	Calanoid, large, Neocalanus/Calanus	0.00	0.04	0.00	0.00	1.26	0.03	0.00	1.56	0.00
MF	Calanoid, Calanus marshallae AF	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD	Calanoid, Calanus/Neocalanus copepodids	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Calanus pacificus AM	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECF	Calanoid, Euchaeta elongata, AF	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECM	Calanoid, Euchaeta elongata, AM	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EPM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	1.15	1.88	0.00	1.08	0.31	0.00	0.00	3.13	0.00
MPM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.09	0.00	1.56	0.00
Calanoid copepod-small										
ACA	Calanoid, Acartia clausi adult	0.57	0.00	0.00	0.00	0.00	0.03	0.94	0.00	0.00
AL	Calanoid, Acartia longiremus adult	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis AF	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00
CAM	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.03	0.47	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	43.10	3.02	31.39	3.78	24.53	5.02	58.36	25.00	0.00
LUC	Calanoid, Lucicutia flavicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00
OS	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00
OSF	Cyclopoid, Oithona similis AF	0.00	0.01	0.00	0.00	0.00	0.00	1.05	0.00	0.00
PCP	Calanoid, Pseudocalanus copepodids i-iV	0.00	0.19	0.00	0.00	0.00	0.28	3.63	0.00	0.00
PSA	Calanoid, Pseudocalanus sp., general	18.97	1.20	0.00	10.27	0.00	0.47	1.64	0.00	0.00
PSF	Calanoid, Pseudocalanus AF	4.02	0.42	0.00	0.00	0.00	0.72	4.68	0.00	0.00
PSM	Calanoid, Pseudocalanus AM	21.26	3.61	0.00	0.54	0.00	0.57	1.52	4.69	0.00
Chaetognath										
CHT	Chaetognath, species unknown	0.00	0.00	0.00	0.00	0.31	0.06	0.00	1.56	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	0.07	0.00	0.00	0.00	0.00	0.12	0.00	0.00

able 9 cont.										
ecapod										
ZC	Decapod zoea, Shrimp, Crangonidae	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00
uphausiid										
U3	Euphausiid calyptopis	0.00	0.00	0.73	0.54	0.31	0.06	0.58	0.00	0.00
U4	Euphausiid furcilia	0.00	0.00	1.46	0.00	0.31	0.06	0.23	3.13	0.00
UP	Euphausiid, general unknown	0.57	0.15	0.00	7.57	4.72	0.00	0.35	10.94	50.00
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.01	0.00	0.00	1.26	0.00	0.00	3.13	0.00
RF	Euphausiid, T. raschii females	0.57	0.04	0.00	0.54	0.00	0.00	0.00	0.00	0.00
RM	Euphausiid, T. raschii males	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ammarid										
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
A2	Amphipod, Gammarid, unknown, medium	0.00	0.01	0.00	0.54	0.00	0.00	0.00	0.00	0.00
astropod										
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	1.46	0.00	1.26	0.97	0.00	0.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	0.00	0.03	0.00	0.00	0.00	1.38	0.47	0.00	0.00
yperiid										
P	Amphipod, Hyperiid, Hyperia sp.	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.00	0.01	0.00	0.00	0.31	0.03	0.12	4.69	0.00
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L2	Amphipod, Hyperiid, P. libellula 2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00
P	Amphipod, Hyperiid/Parath. pacifica gen.	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R1	Amphipod, Hyperiid, Primno macropa, <2mm	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TP	Gastropoda, Pteropod, unidentified	0.00	0.07	0.00	0.54	0.00	0.00	0.00	0.00	0.00
arvacean										
KI	Larvacea, Oikopleura dioica	5.17	88.60	62.77	72.43	62.89	24.68	20.70	37.50	0.00
alacostracan										
AE	Malacostraca, eyes only	0.57	0.00	0.73	0.00	0.00	0.03	0.00	0.00	0.00
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
ther										
VL	Bivalve, larvae	0.00	0.00	0.73	0.00	0.31	0.57	0.23	0.00	0.00

T ble 9 cont.

G	Unknown invertebrate egg, small (<0.2mm)	0.00	0.15	0.73	0.00	0.31	0.53	3.63	0.00	0.00
L	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.31	64.05	0.00	0.00	0.00
C	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
P	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
EM	Nematode	1.15	0.04	0.00	0.00	0.00	0.00	0.12	0.00	0.00
O	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00
EC	Polychaeta, Pectinariidae	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
L	Polychaeta, general, juvenile	0.00	0.03	0.00	0.54	0.00	0.09	0.00	0.00	0.00
EM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00
NI	Unidentified item	2.30	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00

ble 10. Total biomass and percent biomass of major groups of prey organisms in forage fish stomachs by species-size group
= 10 each) at stations in central, northeastern and southwestern PWS in fall, 1994.

tal Biomass													
Region	SW	SW		NE	NE	NE	NE	NE	NE	NE			
species	herring	pollock		herring	pollock	herring	pollock	eulachon	herring	herring			
size group	2	0		0	0	0	0	0	0	1			
station-haul	3-1	5-5		6-1	6-1	7-4	7-4	7-5	8	8			
SUMCODE													
ılanoid copepod-large	1.58	139.08		0.00	3.84	19.76	4.03	0.00	9.62	2.26			
lanoid copepod-small	14.23	52.87		3.22	3.29	5.84	1.40	0.00	20.44	50.54			
Chaetognath	0.00	2.20		0.00	0.00	0.44	0.44	0.00	0.88	0.44			
Decapod	0.00	7.58		0.00	0.00	0.00	2.74	0.00	0.00	0.00			
Euphausiid	24.35	213.05		0.95	162.97	215.11	102.73	10.65	1.11	33.56			
Gammarid	0.00	1.34		0.00	1.34	0.00	0.00	0.00	0.65	0.00			
Gastropod	0.00	0.35		0.32	0.00	0.64	0.00	0.00	12.64	0.70			
Hyperiid	1.87	51.33		0.00	0.00	7.86	31.44	0.00	7.86	7.86			
;nidarian/ Ctenophore	0.00	34.70		0.00	6.94	0.00	0.00	0.00	0.00	0.00			
Larvacean	0.30	213.19		2.86	4.46	6.66	0.80	0.00	26.17	5.89			
Malacostracan	0.39	0.00		0.39	0.00	0.00	0.00	12.06	0.39	0.00			
Other	0.18	0.55		0.01	0.09	0.04	0.00	0.00	50.10	0.44			
Total	42.89	716.23		7.75	182.92	256.35	143.57	22.71	129.85	101.69			
rcent biomass													
Region	SW	SW		NE	NE	NE	NE	NE	NE	NE			
species	herring	pollock		herring	pollock	herring	pollock	eulachon	herring	herring			
size group	2	0		0	0	0	0	0	0	1			
station-haul	3-1	5-5		6-1	6-1	7-4	7-4	7-5	8	8			
MCODE													
ılanoid copepod-large	3.68	19.42		0.00	2.10	7.71	2.81	0.00	7.41	2.22			
lanoid copepod-small	33.16	7.38		41.53	1.80	2.28	0.97	0.00	15.74	49.70			
Chaetognath	0.00	0.31		0.00	0.00	0.17	0.31	0.00	0.68	0.43			
Decapod	0.00	1.06		0.00	0.00	0.00	1.91	0.00	0.00	0.00			
Euphausiid	56.77	29.75		12.19	89.09	83.91	71.55	46.90	0.85	33.00			
Gammarid	0.00	0.19		0.00	0.73	0.00	0.00	0.00	0.50	0.00			
Gastropod	0.00	0.05		4.13	0.00	0.25	0.00	0.00	9.73	0.69			
Hyperiid	4.36	7.17		0.00	0.00	3.07	21.90	0.00	6.05	7.73			
;nidarian/ Ctenophore	0.00	4.84		0.00	3.79	0.00	0.00	0.00	0.00	0.00			
Larvacean	0.70	29.77		36.93	2.44	2.60	0.56	0.00	20.16	5.80			
Malacostracan	0.91	0.00		5.03	0.00	0.00	0.00	53.10	0.30	0.00			
Other	0.42	0.08		0.19	0.05	0.01	0.00	0.00	38.58	0.43			

able 11. Total biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at tations in central, northeastern and southwestern PWS in fall, 1994.

	Region	SW	SW	NE	NE	NE	NE	NE	NE	NE
	species	herring	pollock	herring	pollock	herring	pollock	eulachon	herring	herring
	size group	2	0	0	0	0	0	0	0	1
	station-haul	3-1	5-5	6-1	6-1	7-4	7-4	7-5	8	8
SPCD	preyname									
Calanoid copepod-large										
CAL	Calanoid, general large (>2.5 mm)	0.00	13.57	0.00	2.26	4.52	0.00	0.00	6.79	2.26
CLN	Calanoid, large, Neocalanus/Calanus	0.00	6.79	0.00	0.00	9.05	2.26	0.00	2.26	0.00
CMF	Calanoid, Calanus marshallae AF	0.00	1.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPD	Calanoid, Calanus/Neocalanus copepodids	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPM	Calanoid, Calanus pacificus AM	0.00	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECF	Calanoid, Euchaeta elongata, AF	0.00	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECM	Calanoid, Euchaeta elongata, AM	0.00	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EPM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	5.40	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	1.58	107.30	0.00	1.58	0.79	1.58	0.00	0.00	0.00
MPM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.57	0.00
Calanoid copepod-small										
ACA	Calanoid, Acartia clausi adult	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.14
AL	Calanoid, Acartia longiremus adult	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis AF	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
CAM	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.39
CAS	Calanoid, general small (<2.5 mm)	5.62	16.33	3.22	0.52	5.84	1.20	0.00	11.98	37.38
LUC	Calanoid, Lucicutia flavicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
OS	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
OSF	Cyclopoid, Oithona similis AF	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.11
PCP	Calanoid, Pseudocalanus copepodids I-IV	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.21	0.73
PSA	Calanoid, Pseudocalanus sp., general	4.69	12.35	0.00	2.70	0.00	0.00	0.00	2.13	1.99
PSF	Calanoid, Pseudocalanus AF	1.46	6.27	0.00	0.00	0.00	0.00	0.00	4.81	8.36
PSM	Calanoid, Pseudocalanus AM	2.44	17.23	0.00	0.07	0.00	0.20	0.00	1.19	0.86
Chaetognath										
CHT	Chaetognath, species unknown	0.00	0.00	0.00	0.00	0.44	0.44	0.00	0.88	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	2.20	0.00	0.00	0.00	0.00	0.00	0.00	0.44

able 11 cont.										
ecapod										
ZC	Decapod zoea, Shrimp, Crangonidae	0.00	7.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	2.74	0.00	0.00	0.00
uphausiid										
U3	Euphausiid calyptopis	0.00	0.00	0.17	0.17	0.17	0.00	0.00	0.33	0.83
U4	Euphausiid furcilia	0.00	0.00	0.78	0.00	0.39	0.78	0.00	0.78	0.78
UP	Euphausiid, general unknown	10.65	117.15	0.00	149.10	159.75	74.55	10.65	0.00	31.95
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	13.70	0.00	0.00	54.80	27.40	0.00	0.00	0.00
RF	Euphausiid, T. raschii females	13.70	41.10	0.00	13.70	0.00	0.00	0.00	0.00	0.00
RM	Euphausiid, T. raschii males	0.00	41.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ammarid										
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00
A2	Amphipod, Gammarid, unknown, medium	0.00	1.34	0.00	1.34	0.00	0.00	0.00	0.00	0.00
astropod										
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	0.32	0.00	0.64	0.00	0.00	4.96	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	0.00	0.35	0.00	0.00	0.00	0.00	0.00	7.68	0.70
TP	Gastropoda, Pteropod, unidentified	0.00	34.70	0.00	6.94	0.00	0.00	0.00	0.00	0.00
yperiid										
P	Amphipod, Hyperiid, Hyperia sp.	0.00	30.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.00	7.86	0.00	0.00	7.86	23.58	0.00	7.86	7.86
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L2	Amphipod, Hyperiid, P. libellula 2-6.9mm	0.00	0.00	0.00	0.00	0.00	7.86	0.00	0.00	0.00
P	Amphipod, Hyperiid/Parath. pacifica gen.	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R1	Amphipod, Hyperiid, Primno macropa, <2mm	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	7.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
arvacean										
KI	Larvacea, Oikopleura dioica	0.30	213.19	2.86	4.46	6.66	0.80	0.00	26.17	5.89
alacostracan										
AE	Malacostraca, eyes only	0.39	0.00	0.39	0.00	0.00	0.00	0.00	0.39	0.00
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	12.06	0.00	0.00
ther										
VL	Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01

ble 11 cont.

G	Unknown invertebrate egg, small (<0.2mm)	0.00	0.11	0.01	0.00	0.01	0.00	0.00	0.17	0.31
GL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.02	0.00	0.00	43.25	0.00
ZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
P	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.74	0.00
EM	Nematode	0.18	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.09
CO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
EC	Polychaeta, Pectinariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.54	0.00
LL	Polychaeta, general, juvenile	0.00	0.17	0.00	0.09	0.00	0.00	0.00	0.26	0.00
EM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
NI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTAL		42.89	716.23	7.75	182.92	256.35	143.57	22.71	129.85	101.69

ole 12. Percent biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at tions in central, northeastern and southwestern PWS in fall, 1994.

	Region	SW	SW	NE	NE	NE	NE	NE	NE	NE
	species	herring	pollock	herring	pollock	herring	pollock	eulachon	herring	herring
	size group	2	0	0	0	0	0	0	0	1
	station-haul	3-1	5-5	6-1	6-1	7-4	7-4	7-5	8	8
CD	preyname									
lanoid copepod-large										
L	Calanoid, general large (>2.5 mm)	0.00	1.90	0.00	1.24	1.77	0.00	0.00	5.23	2.22
N	Calanoid, large, Neocalanus/Calanus	0.00	0.95	0.00	0.00	3.53	1.58	0.00	1.74	0.00
IF	Calanoid, Calanus marshallae AF	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	Calanoid, Calanus/Neocalanus copepodids	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Calanus pacificus AM	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Euchaeta elongata, AF	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Euchaeta elongata, AM	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.00
F	Calanoid, Metridia pacifica, AF	3.68	14.98	0.00	0.86	0.31	1.10	0.00	0.00	0.00
M	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.44	0.00
lanoid copepod-small										
A	Calanoid, Acartia clausi adult	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13
	Calanoid, Acartia longiremus adult	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Acartia longiremis AF	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Centropages abdominalis, AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
M	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.39
S	Calanoid, general small (<2.5 mm)	13.10	2.28	41.53	0.29	2.28	0.83	0.00	9.23	36.75
C	Calanoid, Lucicutia flavicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
F	Cyclopoid, Oithona similis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
P	Calanoid, Pseudocalanus copepodids I-IV	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.16	0.72
A	Calanoid, Pseudocalanus sp., general	10.92	1.72	0.00	1.47	0.00	0.00	0.00	1.64	1.95
F	Calanoid, Pseudocalanus AF	3.41	0.88	0.00	0.00	0.00	0.00	0.00	3.70	8.22
M	Calanoid, Pseudocalanus AM	5.60	2.41	0.00	0.04	0.00	0.14	0.00	0.91	0.84
aetognath										
T	Chaetognath, species unknown	0.00	0.00	0.00	0.00	0.17	0.31	0.00	0.68	0.00
E	Chaetognath, Sagitta (elegans)	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.43
capod										
C	Decapod zoea, Shrimp, Crangonidae	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	1.91	0.00	0.00	0.00

able 12 cont.										
uphausiid										
U3	Euphausiid calyptopis	0.00	0.00	2.13	0.09	0.06	0.00	0.00	0.25	0.81
U4	Euphausiid furcilia	0.00	0.00	10.06	0.00	0.15	0.54	0.00	0.60	0.77
UP	Euphausiid, general unknown	24.83	16.36	0.00	81.51	62.32	51.92	46.90	0.00	31.42
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	1.91	0.00	0.00	21.38	19.08	0.00	0.00	0.00
RF	Euphausiid, T. raschii females	31.94	5.74	0.00	7.49	0.00	0.00	0.00	0.00	0.00
RM	Euphausiid, T. raschii males	0.00	5.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
ammarid										
A2	Amphipod, Gammarid, unknown, medium	0.00	0.19	0.00	0.73	0.00	0.00	0.00	0.00	0.00
astropod										
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	4.13	0.00	0.25	0.00	0.00	3.82	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	0.00	0.05	0.00	0.00	0.00	0.00	0.00	5.91	0.69
TP	Gastropoda, Pteropod, unidentified	0.00	4.84	0.00	3.79	0.00	0.00	0.00	0.00	0.00
yperiid										
P	Amphipod, Hyperiid, Hyperia sp.	0.00	4.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.00	1.10	0.00	0.00	3.07	16.42	0.00	6.05	7.73
PA1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PL2	Amphipod, Hyperiid, P. libellula 2-6.9mm	0.00	0.00	0.00	0.00	0.00	5.47	0.00	0.00	0.00
PP	Amphipod, Hyperiid/Parath. pacifica gen.	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR1	Amphipod, Hyperiid, Primno macropa, <2mm	4.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean										
OKI	Larvacea, Oikopleura dioica	0.70	29.77	36.93	2.44	2.60	0.56	0.00	20.16	5.80
Malacostracan										
MAE	Malacostraca, eyes only	0.91	0.00	5.03	0.00	0.00	0.00	0.00	0.30	0.00
MAL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00	53.10	0.00	0.00
Other								0.00	0.00	0.00
BVL	Bivalve, larvae	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.07	0.01
EGG	Unknown invertebrate egg, small (<0.2mm)	0.00	0.02	0.13	0.00	0.00	0.00	0.00	0.13	0.30
EGL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	33.31	0.00
HZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
ISP	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11	0.00
NEM	Nematode	0.42	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.09
PCO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
PEC	Polychaeta, Pectinariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.73	0.00

able 12 cont.

LL	Polychaeta, general, juvenile	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.20	0.00
EM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
NI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

le 13. Total numbers and percent numbers of major groups of prey organisms in forage fish stomachs by
ecies-size group (n = 10 each) at stations in central, northeastern and southwestern PWS in summer, 1995.

ntral Area PWS, summer 1995, all fish species except for pollock

tal number

species	herring	pink salmon	pink salmon	capelin	capelin	capelin	capelin	capelin	capelin	sandlance
size group	0	0	0	0	0	0	0	1	1	0
station-haul	110	1-2	66-2	62-1	67-1	72-1	73-1	114	65-1	999
mcode										
arnacle	0.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.00
alanoid copepod-large	0.00	163.00	391.00	0.00	0.00	0.00	0.00	0.00	0.00	65.00
alanoid copepod-small	526.00	348.00	88.00	0.00	2.00	5.00	0.00	0.00	16.00	8948.00
haetognath	0.00	0.00	711.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ladocera	0.00	748.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.00
yphonaute	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ecapod	0.00	21.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
uphausiid	0.00	6.00	123.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
ish	0.00	5.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ammarid	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
astropod	0.00	1062.00	4266.00	0.00	0.00	0.00	0.00	1.00	0.00	10.00
yperiid	0.00	10.00	262.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
nidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
nsect	0.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
arvacean	0.00	0.00	2254.00	0.00	0.00	0.00	0.00	0.00	0.00	8772.00
Malacostracan	0.00	3.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ther	0.00	257.00	48.00	0.00	0.00	0.00	0.00	0.00	4.00	788.00
TOTAL	526.00	2645.00	8172.00	0.00	2.00	5.00	0.00	1.00	20.00	18653.00

Central Area PWS, summer 1995, all fish species except for pollock

% prey number

	herring	pink salmon	pink salmon	capelin	capelin	capelin	capelin	capelin	capelin	sandlance
size group	0	0	0	0	0	0	0	1	1	0
station-haul	110	1-2	66-2	62-1	67-1	72-1	73-1	114	65-1	999
Barnacle	0.00	0.53	0.00	empty	0.00	0.00	empty	0.00	0.00	0.20
Calanoid copepod-large	0.00	6.16	4.78	empty	0.00	0.00	empty	0.00	0.00	0.35
Calanoid copepod-small	100.00	13.16	1.08	empty	100.00	100.00	empty	0.00	80.00	47.97
Chaetognath	0.00	0.00	8.70	empty	0.00	0.00	empty	0.00	0.00	0.00
Cladocera	0.00	28.28	0.00	empty	0.00	0.00	empty	0.00	0.00	0.16
Cyphonaute	0.00	0.08	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00
Decapod	0.00	0.79	0.05	empty	0.00	0.00	empty	0.00	0.00	0.01
Euphausiid	0.00	0.23	1.51	empty	0.00	0.00	empty	0.00	0.00	0.02
Fish	0.00	0.19	0.05	empty	0.00	0.00	empty	0.00	0.00	0.00
Gammarid	0.00	0.08	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00

ıble 13 cont.													
astropod	0.00	40.15	52.20	empty	0.00	0.00	empty	100.00	0.00	0.05			
/periid	0.00	0.38	3.21	empty	0.00	0.00	empty	0.00	0.00	0.00			
ıidarian/ Ctenophore	0.00	0.00	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00			
sect	0.00	0.15	0.06	empty	0.00	0.00	empty	0.00	0.00	0.00			
ırvacean	0.00	0.00	27.58	empty	0.00	0.00	empty	0.00	0.00	47.03			
alacostracan	0.00	0.11	0.20	empty	0.00	0.00	empty	0.00	0.00	0.00			
her	0.00	9.72	0.59	empty	0.00	0.00	empty	0.00	20.00	4.22			
entral Area PWS, summer 1995, just pollock													
ımber													
species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
size group	0	0	0	0	0	0	0	0	0	0	0	0	0
station-haul	108	112	19-1	3-1	5-2	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1
mcode													
ırnacle	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
ılanoid copepod-large	19.00	39.00	26.00	8.00	233.00	0.00	17.00	0.00	0.00	3.00	14.00	15.00	133.00
ılanoid copepod-small	13694.00	41.00	19.00	743.00	48.00	917.00	1838.00	356.00	85.00	184.00	1347.00	88.00	117.00
ıaetognath	2.00	14.00	0.00	2.00	0.00	0.00	1.00	1.00	1.00	2.00	2.00	1.00	0.00
adocera	0.00	0.00	0.00	0.00	0.00	3.00	0.00	16.00	2.00	1.00	11.00	0.00	1.00
phonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
capod	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
ıphausiid	6.00	2.00	6.00	0.00	3.00	1.00	0.00	1.00	2.00	0.00	6.00	0.00	1.00
sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	2.00	0.00
ımmarid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
ıstropod	33.00	0.00	0.00	80.00	1.00	108.00	150.00	4.00	57.00	4.00	471.00	5.00	4.00
periid	4.00	6.00	0.00	2.00	3.00	9.00	18.00	2.00	3.00	22.00	11.00	6.00	22.00
idarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
sect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rvacean	187.00	85.00	71.00	26.00	78.00	73.00	21.00	7.00	3.00	75.00	81.00	36.00	47.00
ılacostracan	0.00	2.00	2.00	0.00	0.00	1.00	1.00	2.00	2.00	4.00	3.00	7.00	2.00
ıer	10938.00	17.00	0.00	849.00	5.00	428.00	630.00	146.00	62.00	148.00	473.00	12.00	5.00
)TAL	24895.00	206.00	124.00	1710.00	371.00	1541.00	2676.00	535.00	218.00	450.00	2420.00	172.00	333.00
ntral Area PWS, summer 1995, just pollock													
number													
species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
size group	0	0	0	0	0	0	0	0	0	0	0	0	0
station-haul	108	112	19-1	3-1	5-2	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1
ncode													
RNACLE	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.04	0.00	0.00
L-LARGE	0.08	18.93	20.97	0.47	62.80	0.00	0.64	0.00	0.00	0.67	0.58	8.72	39.94

ble 13 cont.

L-SMALL	55.01	19.90	15.32	43.45	12.94	59.51	68.68	66.54	38.99	40.89	55.66	51.16	35.14
IAETOGNAT	0.01	6.80	0.00	0.12	0.00	0.00	0.04	0.19	0.46	0.44	0.08	0.58	0.00
ADOCERA	0.00	0.00	0.00	0.00	0.00	0.19	0.00	2.99	0.92	0.22	0.45	0.00	0.30
CAPOD	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
JPHAUSIID	0.02	0.97	4.84	0.00	0.81	0.06	0.00	0.19	0.92	0.00	0.25	0.00	0.30
SH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	1.16	0.00
MMARID	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00
ASTROPOD	0.13	0.00	0.00	4.68	0.27	7.01	5.61	0.75	26.15	0.89	19.46	2.91	1.20
PERIID	0.02	2.91	0.00	0.12	0.81	0.58	0.67	0.37	1.38	4.89	0.45	3.49	6.61
LLY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00
RVACEA	0.75	41.26	57.26	1.52	21.02	4.74	0.78	1.31	1.38	16.67	3.35	20.93	14.11
ALACO	0.00	0.97	1.61	0.00	0.00	0.06	0.04	0.37	0.92	0.89	0.12	4.07	0.60
THER	43.94	8.25	0.00	49.65	1.35	27.77	23.54	27.29	28.44	32.89	19.55	6.98	1.50

ortheast Area PWS, summer 1995

tal number

species	herring	herring	herring	herring	pollock	pollock	sandlance	sandlance
size group	0	0	1	1	2	2	0	0
station-haul	118	27-1	116	22-2	29-1	82-1	118	82-1
umcode								
arnacle	0.00	65.00	0.00	4.00	0.00	0.00	26.00	0.00
alanoid copepod-large	0.00	70.00	57.00	1255.00	77.00	53.00	0.00	106.00
alanoid copepod-small	0.00	45720.00	900.00	27163.00	19.00	10.00	231.00	1.00
haetognath	0.00	0.00	0.00	0.00	2.00	97.00	0.00	0.00
ladocera	0.00	8311.00	27.00	254.00	0.00	0.00	49.00	0.00
yphonaute	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
ecapod	0.00	13.00	41.00	45.00	1.00	2.00	0.00	0.00
uphausiid	0.00	41.00	4.00	21.00	0.00	5.00	0.00	0.00
ish	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
ammarid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
astropod	0.00	66.00	791.00	380.00	0.00	0.00	6.00	0.00
yperiid	0.00	209.00	20.00	49.00	3.00	1.00	1.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	0.00	13864.00	1834.00	12.00	14.00	21.00	0.00
Malacostracan	0.00	5.00	36.00	40.00	1.00	23.00	0.00	0.00
Other	0.00	5185.00	597.00	15039.00	4.00	1.00	51.00	0.00
TOTAL	0.00	59687.00	16337.00	46084.00	119.00	206.00	385.00	107.00

ble 13 cont.

rtheast Area PWS, summer 1995
number

species	herring	herring	herring	herring	pollock	pollock	sandlance	sandlance
size group	0	0	1	1	2	2	0	0
station-haul	118	27-1	116	22-2	29-1	82-1	118	82-1
mcode								
rnacle	empty	0.11	0.00	0.01	0.00	0.00	6.75	0.00
lanoid copepod-large	empty	0.12	0.35	2.72	64.71	25.73	0.00	99.07
lanoid copepod-small	empty	76.60	5.51	58.94	15.97	4.85	60.00	0.93
aetognath	empty	0.00	0.00	0.00	1.68	47.09	0.00	0.00
adocera	empty	13.92	0.17	0.55	0.00	0.00	12.73	0.00
phonaute	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
capod	empty	0.02	0.25	0.10	0.84	0.97	0.00	0.00
phausiid	empty	0.07	0.02	0.05	0.00	2.43	0.00	0.00
sh	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mmarid								
stropod	empty	0.11	4.84	0.82	0.00	0.00	1.56	0.00
periid	empty	0.35	0.12	0.11	2.52	0.49	0.26	0.00
idarian/ Ctenophore								
sect								
rvacean	empty	0.00	84.86	3.98	10.08	6.80	5.45	0.00
alacostracan	empty	0.01	0.22	0.09	0.84	11.17	0.00	0.00
her	empty	8.69	3.65	32.63	3.36	0.49	13.25	0.00

uthwest Area PWS
tal number

species	herring	herring	tomcod	pollock	capelin	capelin	capelin
size group	0	1	1	0	0	0	0
station-haul	43-1	107	51-1	51-1	100	43-1	47-1
sumcode							
Barnacle	10.00	2.00	4.00	5.00	0.00	0.00	0.00
Calanoid copepod-large	10.00	5.00	4.00	7.00	0.00	0.00	0.00
Calanoid copepod-small	10377.00	231294.00	10.00	2954.00	7.00	3.00	8.00
Chaetognath	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera	71.00	150.00	4.00	219.00	0.00	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	21.00	55.00	0.00	0.00	0.00	0.00	0.00
Euphausiid	15.00	11.00	3.00	1.00	0.00	0.00	0.00
Fish	0.00	0.00	4.00	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	267.00	0.00	0.00	0.00	0.00

able 13 cont.

Gastropod	4.00	858.00	0.00	0.00	0.00	0.00	0.00
Hyperiid	235.00	33.00	0.00	9.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Larvacean	0.00	416.00	0.00	0.00	0.00	0.00	0.00
Malacostracan	6.00	2.00	2.00	0.00	0.00	0.00	0.00
Other	3208.00	172356.00	145.00	201.00	3.00	0.00	0.00
TOTAL	13957.00	405182.00	444.00	3396.00	10.00	3.00	8.00

outhwest Area PWS, summer 1995

% number

species	herring	herring	tomcod	pollock	capelin	capelin	capelin
size group	0	1	1	0	0	0	0
station-haul	43-1	107	51-1	51-1	100	43-1	47-1
sumcode							
Barnacle	0.00	0.00	0.90	0.15	0.00	0.00	0.00
Calanoid copepod-large	0.00	0.00	0.90	0.21	0.00	0.00	0.00
Calanoid copepod-small	0.00	57.08	2.25	86.98	70.00	100.00	100.00
Chaetognath	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera	0.00	0.04	0.90	6.45	0.00	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Euphausiid	0.00	0.00	0.68	0.03	0.00	0.00	0.00
Fish	0.00	0.00	0.90	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	60.14	0.00	0.00	0.00	0.00
Gastropod	0.00	0.21	0.00	0.00	0.00	0.00	0.00
Hyperiid	0.00	0.01	0.00	0.27	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	0.23	0.00	0.00	0.00	0.00
Larvacean	0.00	0.10	0.00	0.00	0.00	0.00	0.00
Malacostracan	0.00	0.00	0.45	0.00	0.00	0.00	0.00
Other	0.00	42.54	32.66	5.92	30.00	0.00	0.00

able 14. Total numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at ations in central (A), northeastern (B) and southwestern (C) PWS in summer, 1995.

Central Area PWS, all fish species except for pollock

	species	herring	pink salmon	pink salmon	capelin	capelin	capelin	capelin	capelin	capelin	sand-lance
	size group	0	0	0	0	0	0	0	1	1	0
	station-haul	110-1	1-2	66-2	62-1	67-1	72-1	73-1	114-7	65-1	999-1
cd											
arnacle											
MC	Barnacle, cyprid	0.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
MM	Barnacle, adult molt (cirri)	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
alanoid copepod-large											
AL	Calanoid, general large (>2.5 mm)	0.00	25.00	52.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00
LN	Calanoid, large, Neocalanus/Calanus	0.00	28.00	75.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Calanus marshallae	0.00	0.00	141.00	0.00	0.00	0.00	0.00	0.00	0.00	28.00
MF	Calanoid, Calanus marshallae AF	0.00	1.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PC	Calanoid, Calanus pacificus, general	0.00	1.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	21.00
PF	Calanoid, Calanus pacificus AF	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PC	Calanoid, Epilabidocera longipedata, cop	0.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
PF	Calanoid, Epilabidocera longipedata, AF	0.00	7.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PI	Calanoid, Epilabidocera longipedata, gen	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Epilabidocera longipedata, AM	0.00	8.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
G	Calanoid, Metridia sp., General	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
P	Calanoid, Metridia pacifica, adult	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PF	Calanoid, Metridia pacifica, AF	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
PM	Calanoid, Metridia pacifica, AM	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EO	Calanoid, Neocalanus spp. adult	0.00	11.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
alanoid copepod-small											
C	Calanoid, Acartia sp.	0.00	6.00	5.00	0.00	0.00	0.00	0.00	0.00	4.00	336.00
LC	Calanoid, Acartia longiremus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
LG	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	560.00
A	Calanoid, Centropages abdominalis, gen.	0.00	53.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00
AF	Calanoid, Centropages abdominalis, AF	0.00	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	2.00	4.00	0.00	0.00	1.00	0.00
AS	Calanoid, general small (<2.5 mm)	67.00	214.00	62.00	0.00	0.00	0.00	0.00	0.00	6.00	1668.00
AV		0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
OS	Calanoid, Copepodite small	433.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	Cyclopoid, Oithona sp., general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5696.00
S	Cyclopoid, Oithona similis, general	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	Cyclopoid, Oithona copepodite	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	Calanoid, Pseudocalanus copepodids I-IV	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	Calanoid, Pseudocalanus sp., general	0.00	6.00	15.00	0.00	0.00	0.00	0.00	0.00	2.00	584.00
SF	Calanoid, Pseudocalanus AF	0.00	41.00	6.00	0.00	0.00	0.00	0.00	0.00	1.00	88.00
SM	Calanoid, Pseudocalanus AM	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

able 14 cont.														
haetognath														
GE	Chaetognath, Sagitta (elegans)	0.00	0.00	711.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
ladocera														
LA	Cladocera, General	0.00	141.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
VD	Cladoceran, Evadne sp.	0.00	51.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.00			
ON	Cladoceran, Podon sp.	0.00	556.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00			
yphonaute														
FN	Bryozoa, cyphonautes larva	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
ecapod														
CM	Decapod, megalops, unknown crab	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
GB	Decapod, zoea, Brachyura, general	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
ZB	Decapod zoea, crab, Brachyrhyncha	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
ZG	Decapod zoea, crab, general unknown	0.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
PDZ	Decapod zoea, Shrimp, Pandalidae	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PGZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
SHR	Decapod zoea, general shrimp	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Euphausiid														
EU3	Euphausiid calyptopis	0.00	1.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
EU4	Euphausiid furcilia	0.00	3.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00			
EUP	Euphausiid, general unknown	0.00	2.00	73.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
TH	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
THJ	Euphausiid, Thysannoessa sp. juvenile	0.00	0.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
TL	Euphausiid, T. longipes	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Fish														
FSL	Fish larvae, general	0.00	5.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Gammarid														
GA2	Amphipod, Gammarid, unknown, medium	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Gastropod														
GSB	Gastropod, juv. snail w/ black pigment	0.00	98.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00			
GST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00			
LMA	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	1553.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
LMJ	Gastropod, Pteropod, Limacina helicina J	0.00	964.00	2703.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00			
Hyperiid														
HYB	Amphipod, Hyperiid, unknown small (<2mm)	0.00	6.00	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
HYP	Amphipod, Hyperiid, unknown juvenile	0.00	2.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PR1	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	0.00	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PR2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PR3	Amphipod, Hyperiid, P. macropa, 7+mm	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PRI	Amphipod, Hyperiid, Primno macropa, gen.	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	2.00	102.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	46.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Insect														
DIP	Insect, Dipteran adult	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
INS	Insect, general	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			

able 14 cont.														
arvacean														
KP	Larvacea, Oikopleura sp.	0.00	0.00	2254.00	0.00	0.00	0.00	0.00	0.00	0.00	8772.00			
alacostracan														
AE	Malacostraca, eyes only	0.00	3.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
ther														
VL	Bivalve, larvae	0.00	236.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	62.00			
AP	Amphipod, Caprellidae	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
GG	Unknown invertebrate egg, small (<0.2mm)	0.00	19.00	48.00	0.00	0.00	0.00	0.00	0.00	3.00	712.00			
GL	Unknown invertebrate egg, large (>0.2mm)	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
RC	Harpacticoid, general copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
RJ	Harpacticoid, Harpacticus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
ZZ	Harpacticoid, Zaus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
P	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
LL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00			
SB	Harpacticoid, Tisbe sp., adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00			
SC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.00			
SG	Harpacticoid, Tisbe sp., gravid female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
OTAL		526.00	2645.00	8172.00	0.00	2.00	5.00	0.00	1.00	20.00	18653.00			
entral Area PWS, just pollock														
	species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
	size group	0	0	0	0	0	0	0	0	0	0	0	0	0
	station-haul	108	112	19-1	3-1	5-2	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1
pcd														
arnacle														
MC	Barnacle, cyprid	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
alanoid copepod-large														
AL	Calanoid, general large (>2.5 mm)	8.00	19.00	22.00	6.00	37.00	0.00	2.00	0.00	0.00	3.00	9.00	11.00	24.00
CF	Calanoid, Calanus sp. AF	1.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	Calanoid, Calanus sp. copepodite	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	1.00
LN	Calanoid, large, Neocalanus/Calanus	1.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	0.00
LU	Calanoid, large, NOT Neocalanus/Calanus	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
MC	Calanoid, C. marshallae copepodite	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	10.00
MF	Calanoid, Calanus marshallae AF	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
PA	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
PC	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
PF	Calanoid, Calanus pacificus AF	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PG	Calanoid, Calanus sp. general	0.00	0.00	0.00	2.00	188.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
UB	Calanoid, Eucalanus bungii, general	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EP	Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.00
G	Calanoid, Metridia sp., General	0.00	15.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	2.00

able 14 cont.														
GM	Calanoid, Metridia sp., general male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
PF	Calanoid, Metridia pacifica, AF	7.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	56.00
PM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
alnoid copepod-small														
C	Calanoid, Acartia sp.	16.00	0.00	0.00	3.00	0.00	9.00	19.00	0.00	0.00	0.00	0.00	0.00	1.00
CP	Calanoid, Acartia sp. copepodids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
LF	Calanoid, Acartia longiremis AF	6.00	0.00	0.00	0.00	1.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	1.00
LG	Calanoid, Acartia *longiremis* , General	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A	Calanoid, Centropages abdominalis, gen.	32.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
AM	Calanoid, Centropages abdominalis, AM	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
CAS	Calanoid, general small (<2.5 mm)	5184.00	41.00	19.00	208.00	47.00	768.00	912.00	356.00	84.00	164.00	944.00	78.00	48.00
COS	Calanoid, Copepodite small	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCP	Calanoid, Pseudocalanus copepodids I-IV	668.00	0.00	0.00	45.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
PSA	Calanoid, Pseudocalanus sp., general	4702.00	0.00	0.00	351.00	0.00	127.00	383.00	0.00	0.00	20.00	395.00	10.00	21.00
PSF	Calanoid, *Pseudocalanus* AF	3070.00	0.00	0.00	136.00	0.00	11.00	522.00	0.00	1.00	0.00	7.00	0.00	17.00
PSM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.00
Chaetognath														
CHT	Chaetognath, species unknown	0.00	14.00	0.00	2.00	0.00	0.00	1.00	1.00	1.00	2.00	2.00	1.00	0.00
SGE	Chaetognath, Sagitta (elegans)	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera														
CLA	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
EVD	Cladoceran, Evadne sp.	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	4.00	0.00	0.00
PON	Cladoceran, *Podon sp.*	0.00	0.00	0.00	0.00	0.00	2.00	0.00	15.00	0.00	1.00	7.00	0.00	1.00
Decapod														
DZB	Decapod zoea, crab, Brachyrhyncha	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DZG	Decapod zoea, crab, general unknown	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
SHR	Decapod zoea, general shrimp	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiid														
EU3	Euphausiid calyptopis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
EU4	*Euphausiid furcilia*	6.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
EUJ	Euphausiid juvenile, general	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EUP	Euphausiid, general unknown	0.00	2.00	6.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	1.00
TH	Euphausiid, Thysannoessa sp., *gen. adult*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Fish														
FSL	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	2.00	0.00
Gammarid														
GA1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Gastropod														
LMA	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
LMJ	Gastropod, Pteropod, Limacina helicina J	33.00	0.00	0.00	80.00	1.00	108.00	149.00	4.00	57.00	4.00	471.00	5.00	4.00
PTP	Gastropoda, Pteropod, *unidentified*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Hyperiid														
HPJ	Amphipod, Hyperiid, Hyperia sp. juvenile	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00

able 14 cont.														
YB	Amphipod, Hyperiid, unknown small (<2mm)	2.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	1.00	5.00	0.00	0.00	2.00	5.00	8.00	2.00	3.00	4.00	8.00	2.00	1.00
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	Amphipod, Hyperiid, Parathemisto sp.<2mm	1.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	16.00	2.00	4.00	18.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	2.00	1.00	0.00	3.00
arvacean														
KP	Larvacea, Oikopleura sp.	187.00	85.00	71.00	26.00	78.00	73.00	21.00	7.00	3.00	75.00	81.00	36.00	47.00
alacostracan														
AE	Malacostraca, eyes only	0.00	2.00	2.00	0.00	0.00	0.00	1.00	2.00	2.00	4.00	3.00	7.00	2.00
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ther														
VL	Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	3.00	0.00	1.00	1.00	2.00	1.00	0.00	0.00
GG	Unknown invertebrate egg, small (<0.2mm)	10932.00	16.00	0.00	838.00	5.00	425.00	628.00	145.00	61.00	144.00	472.00	12.00	0.00
GL	Unknown invertebrate egg, large (>0.2mm)	5.00	0.00	0.00	11.00	0.00	0.00	2.00	0.00	0.00	1.00	0.00	0.00	0.00
EM	Nematode	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NI	Unidentified item	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
NP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
	TOTAL	24895.00	206.00	124.00	1710.00	371.00	1541.00	2676.00	535.00	218.00	450.00	2420.00	172.00	333.00

able 14 cont.

) Northeast Area PWS

species		herring	herring	pollock	sandlance	pollock	herring	sandlance	herring
size group		1	0	2	0	2	1	0	0
station-haul		22-2	27-1	29-1	82-1	82-1	116	118	118
pcd	preyname								
arnacle									
MC	Barnacle, cyprid	4.00	48.00	0.00	0.00	0.00	0.00	26.00	0.00
MP	Barnacle, nauplius	0.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
alanoid copepod-large									
AL	Calanoid, general large (>2.5 mm)	748.00	70.00	37.00	0.00	28.00	4.00	0.00	0.00
LN	Calanoid, large, Neocalanus/Calanus	500.00	0.00	11.00	0.00	25.00	4.00	0.00	0.00
M	Calanoid, Calanus marshallae	0.00	0.00	22.00	5.00	0.00	16.00	0.00	0.00
MF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
PG	Calanoid, Calanus sp. general	0.00	0.00	4.00	96.00	0.00	0.00	0.00	0.00
PF	Calanoid, Epilabidocera longipedata, AF	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PI	Calanoid, Epilabidocera longipedata, gen	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Epilabidocera longipedata, AM	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
MG	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
MOF	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	0.00	0.00	3.00	0.00	0.00	28.00	0.00	0.00
NCP	Calanoid, Neocalanus spp. copepodite	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
NEO	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	2.00	0.00	1.00	0.00	0.00
NPF	Calanoid, Neocalanus plumchrus AF	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Calanoid copepod-small									
AC	Calanoid, Acartia sp.	71.00	48.00	0.00	0.00	0.00	27.00	0.00	0.00
ACA	Calanoid, Acartia clausi adult	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
ACC	Calanoid, Acartia clausi copepodite	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
ALG	Calanoid, Acartia longiremis , General	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	Calanoid, Centropages abdominalis, gen.	1.00	1120.00	0.00	0.00	0.00	0.00	1.00	0.00
CAF	Calanoid, Centropages abdominalis, AF	16.00	128.00	0.00	0.00	0.00	0.00	0.00	0.00
CAN	Calanoid, general nauplius	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	19978.00	25508.00	17.00	1.00	10.00	485.00	230.00	0.00
EYF	Calanoid, Eurytemora pacifica AF	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00
EYT	Calanoid, Eurytemora pacifica, general	0.00	84.00	0.00	0.00	0.00	0.00	0.00	0.00
OS	Cyclopoid, Oithona similis, general	112.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
OSF	Cyclopoid, Oithona similis AF	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00

able 14 cont.									
CP	Calanoid, Pseudocalanus copepodids I-IV	296.00	2548.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	Calanoid, Pseudocalanus sp., general	3089.00	11456.00	2.00	0.00	0.00	299.00	0.00	0.00
SF	Calanoid, Pseudocalanus AF	3584.00	4776.00	0.00	0.00	0.00	89.00	0.00	0.00
haetognath									
HT	Chaetognath, species unknown	0.00	0.00	2.00	0.00	97.00	0.00	0.00	0.00
ladocera									
LA	Cladocera, General	2.00	145.00	0.00	0.00	0.00	0.00	0.00	0.00
VD	Cladoceran, Evadne sp.	1.00	94.00	0.00	0.00	0.00	20.00	24.00	0.00
ON	Cladoceran, Podon sp.	251.00	8072.00	0.00	0.00	0.00	7.00	25.00	0.00
yphonaute									
FN	Bryozoa, cyphonautes larva	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
ecapod									
CM	Decapod, megalops, unknown crab	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
GB	Decapod, zoea, Brachyura, general	11.00	0.00	0.00	0.00	0.00	23.00	0.00	0.00
MG	Decapod, megalops, Brachyura	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
ML	Decapod, megalops, Lithodidae	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MP	Decapod, megalops, Paguridae	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
ZB	Decapod zoea, crab, Brachyrhyncha	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	15.00	3.00	0.00	0.00	0.00	5.00	0.00	0.00
ZP	Decapod zoea, crab, Pisinae	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
IE	Decapod zoea, Shrimp, Hippolytidae	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z	Decapod zoea, Anomuran, Lithodidae	4.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
DZ	Decapod zoea, Shrimp, Pandalidae	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
GZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
HP	Decapod,Shrimp, gen. unknown juv./adult	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
HR	Decapod zoea, general shrimp	1.00	5.00	0.00	0.00	0.00	4.00	0.00	0.00
uphausiid									
J3	Euphausiid calyptopis	0.00	37.00	0.00	0.00	0.00	1.00	0.00	0.00
J4	Euphausiid furcilia	20.00	4.00	0.00	0.00	0.00	3.00	0.00	0.00
JP	Euphausiid, general unknown	1.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00
	Euphausiid, T. longipes	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
sh									
SE	Fish egg (~1.0 mm)	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
astropod									
SB	Gastropod, juv. snail w/ black pigment	18.00	50.00	0.00	0.00	0.00	10.00	0.00	0.00
ST	Gastropoda, general juvenile (SNAIL)	34.00	6.00	0.00	0.00	0.00	1.00	2.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	328.00	10.00	0.00	0.00	0.00	780.00	4.00	0.00

Table 14 cont.									
Hyperiid									
HYB	Amphipod, Hyperiid, unknown small (<2mm)	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00
HYP	Amphipod, Hyperiid, unknown juvenile	33.00	209.00	3.00	0.00	1.00	6.00	1.00	0.00
PA2	Amphipod, P. pacifica juvenile, 2-6.9mm	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	13.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean									
OKP	Larvacea, Oikopleura sp.	1834.00	0.00	12.00	0.00	14.00	13864.00	21.00	0.00
Malacostracan									
MAE	Malacostraca, eyes only	38.00	4.00	0.00	0.00	23.00	34.00	0.00	0.00
MAL	Malacostraca	2.00	1.00	1.00	0.00	0.00	2.00	0.00	0.00
Other									
BVL	Bivalve, larvae	9.00	113.00	0.00	0.00	0.00	5.00	15.00	0.00
EGG	Unknown invertebrate egg, small (<0.2mm)	14998.00	5024.00	1.00	0.00	0.00	589.00	4.00	0.00
EGL	Unknown invertebrate egg, large (>0.2mm)	15.00	16.00	0.00	0.00	0.00	2.00	0.00	0.00
HEM	Harpacticoid, general eggsac	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
HR	Harpacticoid, general, unknown stage	0.00	3.00	1.00	0.00	0.00	0.00	12.00	0.00
HRC	Harpacticoid, general copepodite	0.00	16.00	0.00	0.00	0.00	0.00	12.00	0.00
HZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00
LAC	Harpacticoid, Laophontidae, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
LAO	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00
PLL	Polychaeta, general, juvenile	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
TSC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00
UEM	Unknown egg mass	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
UNP	Unknown nauplius	16.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL		46084.00	59687.00	119.00	107.00	206.00	16337.00	385.00	0.00

able 14 cont.								
) Southwest Area PWS								
	species	herring	capelin	capelin	tomcod	pollock	capelin	herring
	size group	0	0	0	1	0	0	1
	station-haul	43-1	43-1	47-1	51-1	51-1	100	107
pcd								
arnacle								
MC	Barnacle, cyprid	2.00	0.00	0.00	4.00	5.00	0.00	2.00
MP	Barnacle, nauplius	8.00	0.00	0.00	0.00	0.00	0.00	0.00
MV		0.00	0.00	0.00	39.00	0.00	0.00	0.00
alanoid copepod-large								
AL	Calanoid, general large (>2.5 mm)	4.00	0.00	0.00	0.00	1.00	0.00	0.00
LN	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	1.00	0.00	0.00
MM	Calanoid, Calanus marshallae AM	2.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	2.00
PC	Calanoid, Calanus pacificus, general	4.00	0.00	0.00	0.00	0.00	0.00	1.00
PG	Calanoid, Calanus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	2.00
PM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	1.00	0.00	0.00	0.00
G	Calanoid, Metridia sp., General	0.00	0.00	0.00	2.00	0.00	0.00	0.00
PF	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	1.00	5.00	0.00	0.00
alanoid copepod-small								
C	Calanoid, Acartia sp.	1.00	0.00	0.00	0.00	47.00	0.00	608.00
LC	Calanoid, Acartia longiremus copepodite	0.00	0.00	0.00	0.00	3.00	0.00	0.00
LF	Calanoid, Acartia longiremis AF	1.00	0.00	0.00	0.00	10.00	0.00	0.00
LG	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	14.00	0.00	0.00
A	Calanoid, Centropages abdominalis, gen.	578.00	0.00	0.00	1.00	129.00	0.00	32.00
AC	Calanoid, Centropages abdominalis, copdt	8.00	0.00	0.00	0.00	0.00	0.00	0.00
AF	Calanoid, Centropages abdominalis, AF	142.00	0.00	0.00	0.00	12.00	0.00	0.00
AM	Calanoid, Centropages abdominalis, AM	8.00	0.00	0.00	0.00	0.00	0.00	0.00
AS	Calanoid, general small (<2.5 mm)	6412.00	3.00	2.00	6.00	2357.00	0.00	193182.00
AV		0.00	0.00	0.00	0.00	5.00	0.00	0.00
OS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	8.00	7.00	0.00
YT	Calanoid, Eurytemora pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	64.00
IT	Cyclopoid, Oithona sp., general	0.00	0.00	0.00	0.00	4.00	0.00	0.00
S	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	2.00	0.00	288.00
CP	Calanoid, Pseudocalanus copepodids I-IV	759.00	0.00	3.00	0.00	10.00	0.00	0.00
SA	Calanoid, Pseudocalanus sp., general	1751.00	0.00	2.00	1.00	266.00	0.00	20608.00
SF	Calanoid, Pseudocalanus AF	717.00	0.00	0.00	1.00	87.00	0.00	16512.00

able 14 cont.								
SG	Calanoid, Pseudocalanus GF	0.00	0.00	1.00	0.00	0.00	0.00	0.00
SM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	1.00	0.00	0.00	0.00
ladocera								
LA	Cladocera, General	2.00	0.00	0.00	0.00	54.00	0.00	130.00
VD	Cladoceran, Evadne sp.	22.00	0.00	0.00	1.00	93.00	0.00	15.00
ON	Cladoceran, Podon sp.	47.00	0.00	0.00	3.00	72.00	0.00	5.00
ecapod								
GB	Decapod, zoea, Brachyura, general	6.00	0.00	0.00	0.00	0.00	0.00	15.00
ZB	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	10.00
ZG	Decapod zoea, crab, general unknown	14.00	0.00	0.00	0.00	0.00	0.00	25.00
DZ	Decapod zoea, Shrimp, Pandalidae	1.00	0.00	0.00	0.00	0.00	0.00	0.00
GZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	1.00
HR	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	4.00
uphausiid								
U3	Euphausiid calyptopis	1.00	0.00	0.00	0.00	0.00	0.00	3.00
U4	Euphausiid furcilia	10.00	0.00	0.00	2.00	0.00	0.00	8.00
UJ	Euphausiid juvenile, general	4.00	0.00	0.00	0.00	1.00	0.00	0.00
EUP	Euphausiid, general unknown	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Fish								
FSJ	Fish, juvenile, general	0.00	0.00	0.00	1.00	0.00	0.00	0.00
FW2	Fish, walleye pollock, (41-60mm)	0.00	0.00	0.00	2.00	0.00	0.00	0.00
FW3	Fish, walleye pollock, (61-80mm)	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Gammarid								
CGC	Amphipod, Gammarid, Calliopius	0.00	0.00	0.00	3.00	0.00	0.00	0.00
GA1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	49.00	0.00	0.00	0.00
GA2	Amphipod, Gammarid, unknown, medium	0.00	0.00	0.00	124.00	0.00	0.00	0.00
GA3	Amphipod, Gammarid, unknown, large	0.00	0.00	0.00	61.00	0.00	0.00	0.00
GAM	Amphipod, Gammarid head	0.00	0.00	0.00	16.00	0.00	0.00	0.00
GAU	Amphipod, Gammarid, unknown, no size	0.00	0.00	0.00	14.00	0.00	0.00	0.00
Gastropod								
LMJ	Gastropod, Pteropod, Limacina helicina J	4.00	0.00	0.00	0.00	0.00	0.00	858.00
Hyperiid								
HYB	Amphipod, Hyperiid, unknown small (<2mm)	132.00	0.00	0.00	0.00	6.00	0.00	0.00
HYP	Amphipod, Hyperiid, unknown juvenile	3.00	0.00	0.00	0.00	3.00	0.00	27.00
PA1	Amphipod, P. pacifica juvenile, <2mm	4.00	0.00	0.00	0.00	0.00	0.00	0.00
PR1	Amphipod, Hyperiid, Primno macropa, <2mm	1.00	0.00	0.00	0.00	0.00	0.00	1.00
PRI	Amphipod, Hyperiid, Primno macropa, gen.	2.00	0.00	0.00	0.00	0.00	0.00	0.00
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	91.00	0.00	0.00	0.00	0.00	0.00	5.00

able 14 cont.								
'S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	2.00	0.00	0.00	0.00	0.00	0.00	0.00
ısect								
)PL	Insect, Dipteran larvae	0.00	0.00	0.00	1.00	0.00	0.00	0.00
.arvacean								
)KP	Larvacea, Oikopleura sp.	0.00	0.00	0.00	0.00	0.00	0.00	416.00
lalacostracan								
IAE	Malacostraca, eyes only	6.00	0.00	0.00	0.00	0.00	0.00	2.00
IAL	Malacostraca	0.00	0.00	0.00	2.00	0.00	0.00	0.00
)ther								
;VL	Bivalve, larvae	43.00	0.00	0.00	3.00	20.00	0.00	25.00
;VP	Bivalve pieces (shell + muscle)	0.00	0.00	0.00	2.00	0.00	0.00	0.00
:UM	Cumacea	0.00	0.00	0.00	19.00	1.00	0.00	0.00
:GG	Unknown invertebrate egg, small (<0.2mm)	3163.00	0.00	0.00	0.00	174.00	2.00	172032.00
:GL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	1.00	0.00	0.00	299.00
IEM	Harpacticoid, general eggsac	0.00	0.00	0.00	6.00	0.00	0.00	0.00
IR	Harpacticoid, general, unknown stage	1.00	0.00	0.00	4.00	0.00	0.00	0.00
IRC	Harpacticoid, general copepodite	0.00	0.00	0.00	1.00	4.00	0.00	0.00
IRJ	Harpacticoid, Harpacticus copepodite	0.00	0.00	0.00	0.00	1.00	0.00	0.00
IRS	Harpacticoid, Harpacticus sp. general ad	0.00	0.00	0.00	26.00	0.00	0.00	0.00
3N	Isopod, Gnorimosphaeroma species	0.00	0.00	0.00	5.00	0.00	0.00	0.00
.AO	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	2.00	0.00	0.00	0.00
IUV	Mytiloida, Musculus vernicosus							
IEM	Nematode	0.00	0.00	0.00	0.00	1.00	0.00	0.00
'CO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	4.00	0.00	0.00	0.00
'LA	Polychaeta, adult	0.00	0.00	0.00	3.00	0.00	0.00	0.00
'LL	Polychaeta, general, juvenile	1.00	0.00	0.00	23.00	0.00	0.00	0.00
SB	Harpacticoid, Tisbe sp., adult	0.00	0.00	0.00	1.00	0.00	0.00	0.00
SC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	1.00	0.00	0.00	0.00
SG	Harpacticoid, Tisbe sp., gravid female	0.00	0.00	0.00	5.00	0.00	0.00	0.00
JNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	1.00	0.00
ɔtal		13957.00	3.00	8.00	444.00	3396.00	10.00	405182.00

able 15. Percent numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at tations in central (A), northeastern (B) and southwestern (C) PWS in summer, 1995.

) Central Area PWS, all fish species except for pollock

	species	pink salmon	capelin	capelin	pink salmon	capelin	capelin	capelin	herring	capelin	sand-lance
	size group	0	0	1	0	0	0	0	0	1	0
	station-haul	1-2	62-1	65-1	66-2	67-1	72-1	73-1	110	114	999
spcd											
Barnacle											
BMC	Barnacle, cyprid	0.49	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.19
BMM	Barnacle, adult molt (cirri)	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01
Calanoid copepod-large											
CAL	Calanoid, general large (>2.5 mm)	0.95	empty	0.00	0.64	0.00	0.00	empty	0.00	0.00	0.05
CLN	Calanoid, large, Neocalanus/Calanus	1.06	empty	0.00	0.92	0.00	0.00	empty	0.00	0.00	0.00
CM	Calanoid, Calanus marshallae	0.00	empty	0.00	1.73	0.00	0.00	empty	0.00	0.00	0.15
CMF	Calanoid, Calanus marshallae AF	0.04	empty	0.00	0.22	0.00	0.00	empty	0.00	0.00	0.00
CPC	Calanoid, Calanus pacificus, general	0.04	empty	0.00	0.86	0.00	0.00	empty	0.00	0.00	0.11
CPF	Calanoid, Calanus pacificus AF	0.00	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.00
EPC	Calanoid, Epilabidocera longipedata, cop	2.61	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.02
EPF	Calanoid, Epilabidocera longipedata, AF	0.26	empty	0.00	0.07	0.00	0.00	empty	0.00	0.00	0.00
EPI	Calanoid, Epilabidocera longipedata, gen	0.19	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
EPM	Calanoid, Epilabidocera longipedata, AM	0.30	empty	0.00	0.15	0.00	0.00	empty	0.00	0.00	0.01
MG	Calanoid, Metridia sp., General	0.00	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.00
MOF	Calanoid, Metridia ochotensis AF	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01
MP	Calanoid, Metridia pacifica, adult	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	0.19	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01
MPM	Calanoid, Metridia pacifica, AM	0.08	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
NEO	Calanoid, Neocalanus spp. adult	0.42	empty	0.00	0.15	0.00	0.00	empty	0.00	0.00	0.00
Calanoid copepod-small											
AC	Calanoid, Acartia sp.	0.23	empty	20.00	0.06	0.00	0.00	empty	0.00	0.00	1.80
ALC	Calanoid, Acartia longiremus copepodite	0.00	empty	5.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
ALG	Calanoid, Acartia longiremis , General	0.00	empty	5.00	0.00	0.00	0.00	empty	0.00	0.00	3.00
CA	Calanoid, Centropages abdominalis, gen.	2.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.09
CAF	Calanoid, Centropages abdominalis, AF	0.83	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
CAN	Calanoid, general nauplius	0.00	empty	5.00	0.00	100.00	80.00	empty	0.00	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	8.09	empty	30.00	0.76	0.00	0.00	empty	12.74	0.00	8.94
CAV		0.00	empty	0.00	0.00	0.00	20.00	empty	0.00	0.00	0.00
COS	Calanoid, Copepodite small	0.00	empty	0.00	0.00	0.00	0.00	empty	82.32	0.00	0.00
OIT	Cyclopoid, Oithona sp., general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	30.54
OS	Cyclopoid, Oithona similis, general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.57	0.00	0.00
OSC	Cyclopoid, Oithona copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	4.37	0.00	0.00
PCP	Calanoid, Pseudocalanus copepodids I-IV	0.08	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00

ble 15 cont.														
A	Calanoid, Pseudocalanus sp., general	0.23	empty	10.00	0.18	0.00	0.00	empty	0.00	0.00	3.13			
F	Calanoid, Pseudocalanus AF	1.55	empty	5.00	0.07	0.00	0.00	empty	0.00	0.00	0.47			
M	Calanoid, Pseudocalanus AM	0.15	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
aetognath														
E	Chaetognath, Sagitta (elegans)	0.00	empty	0.00	8.70	0.00	0.00	empty	0.00	0.00	0.00			
adocera														
A	Cladocera, General	5.33	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
D	Cladoceran, Evadne sp.	1.93	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.10			
N	Cladoceran, Podon sp.	21.02	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.05			
phonaute														
N	Bryozoa, cyphonautes larva	0.08	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
ecapod														
M	Decapod, megalops, unknown crab	0.00	empty	0.00	0.02	0.00	0.00	empty	0.00	0.00	0.00			
GB	Decapod, zoea, Brachyura, general	0.30	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
B	Decapod zoea, crab, Brachyrhyncha	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
G	Decapod zoea, crab, general unknown	0.23	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.01			
Z	Decapod zoea, Shrimp, Pandalidae	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
Z	Decapod zoea, hermit crab, Paguridae	0.00	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.00			
R	Decapod zoea, general shrimp	0.19	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
phausiid														
3	Euphausiid calyptopis	0.04	empty	0.00	0.20	0.00	0.00	empty	0.00	0.00	0.01			
4	Euphausiid furcilia	0.11	empty	0.00	0.06	0.00	0.00	empty	0.00	0.00	0.01			
P	Euphausiid, general unknown	0.08	empty	0.00	0.89	0.00	0.00	empty	0.00	0.00	0.00			
	Euphausiid, Thysannoessa sp., gen. adult	0.00	empty	0.00	0.13	0.00	0.00	empty	0.00	0.00	0.00			
J	Euphausiid, Thysannoessa sp. juvenile	0.00	empty	0.00	0.16	0.00	0.00	empty	0.00	0.00	0.00			
	Euphausiid, T. longipes	0.00	empty	0.00	0.06	0.00	0.00	empty	0.00	0.00	0.00			
sh														
L	Fish larvae, general	0.19	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.00			
ammarid														
2	Amphipod, Gammarid, unknown, medium	0.08	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
astropod														
B	Gastropod, juv. snail w/ black pigment	3.71	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.03			
T	Gastropoda, general juvenile (SNAIL)	0.00	empty	0.00	0.12	0.00	0.00	empty	0.00	0.00	0.02			
A	Gastropod, Pteropod, Limacina helicina A	0.00	empty	0.00	19.00	0.00	0.00	empty	0.00	0.00	0.00			
J	Gastropod, Pteropod, Limacina helicina J	36.45	empty	0.00	33.08	0.00	0.00	empty	0.00	100.00	0.00			
periid														
B	Amphipod, Hyperiid, unknown small (<2mm)	0.23	empty	0.00	0.56	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, unknown juvenile	0.08	empty	0.00	0.07	0.00	0.00	empty	0.00	0.00	0.00			
1	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	empty	0.00	0.69	0.00	0.00	empty	0.00	0.00	0.00			
2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.00			
3	Amphipod, Hyperiid, P. macropa, 7+mm	0.00	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.00			
I	Amphipod, Hyperiid, Primno macropa, gen.	0.00	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.00			

Table 15 cont.														
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.08	empty	0.00	1.25	0.00	0.00	empty	0.00	0.00	0.00			
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	empty	0.00	0.56	0.00	0.00	empty	0.00	0.00	0.00			
Insect														
DIP	Insect, Dipteran adult	0.15	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
INS	Insect, general	0.00	empty	0.00	0.06	0.00	0.00	empty	0.00	0.00	0.00			
Larvacean														
OKP	Larvacea, Oikopleura sp.	0.00	empty	0.00	27.58	0.00	0.00	empty	0.00	0.00	47.03			
Malacostracan														
MAE	Malacostraca, eyes only	0.11	empty	0.00	0.20	0.00	0.00	empty	0.00	0.00	0.00			
Other														
BVL	Bivalve, larvae	8.92	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.33			
CAP	Amphipod, Caprellidae	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
EGG	Unknown invertebrate egg, small (<0.2mm)	0.72	empty	15.00	0.59	0.00	0.00	empty	0.00	0.00	3.82			
EGL	Unknown invertebrate egg, large (>0.2mm)	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
HRC	Harpacticoid, general copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
HRJ	Harpacticoid, Harpacticus copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
HZZ	Harpacticoid, Zaus sp. general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
ISP	Isopod, general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
PLL	Polychaeta, general, juvenile	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.02			
TSB	Harpacticoid, Tisbe sp., adult	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
TSC	Harpacticoid, Tisbe copepodite	0.00	empty	5.00	0.00	0.00	0.00	empty	0.00	0.00	0.02			
TSG	Harpacticoid, Tisbe sp., gravid female	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
A) Central Area PWS, just pollock														
	species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
	size group	0	0	0	0	0	0	0	0	0	0	0	0	0
	station-haul	3-1	5-2	19-1	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1	108	112
spcd														
Barnacle														
BMC	Barnacle, cyprid	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BMP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Calanoid copepod-large														
CAL	Calanoid, general large (>2.5 mm)	0.35	9.97	17.74	0.00	0.07	0.00	0.00	0.67	0.37	6.40	7.21	0.03	9.22
CCF	Calanoid, Calanus sp. AF	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCP	Calanoid, Calanus sp. copepodite	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
CLN	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	1.16	0.00	0.00	1.94
CLU	Calanoid, large, NOT Neocalanus/Calanus	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM	Calanoid, Calanus marshallae	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
CMC	Calanoid, C. marshallae copepodite	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00
CMF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
CPA	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00

Table 15 cont.														
PC	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
PF	Calanoid, Calanus pacificus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PG	Calanoid, Calanus sp. general	0.12	50.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00
UB	Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
EP	Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.61	0.00	0.00
G	Calanoid, Metridia sp., General	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.60	0.00	7.28
GM	Calanoid, Metridia sp., general male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00
PF	Calanoid, Metridia pacifica, AF	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	16.82	0.03	0.00
PM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00
alnoid copepod-small														
C	Calanoid, Acartia sp.	0.18	0.00	0.00	0.58	0.71	0.00	0.00	0.00	0.00	0.00	0.30	0.06	0.00
CP	Calanoid, Acartia sp. copepodids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
LF	Calanoid, Acartia longiremis AF	0.00	0.27	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.30	0.02	0.00
LG	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A	Calanoid, Centropages abdominalis, gen.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.13	0.00
AM	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
AN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
AS	Calanoid, general small (<2.5 mm)	12.16	12.67	15.32	49.84	34.08	66.54	38.53	36.44	39.01	45.35	14.41	20.82	19.90
OS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
CP	Calanoid, Pseudocalanus copepodids I-IV	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	2.68	0.00
SA	Calanoid, Pseudocalanus sp., general	20.53	0.00	0.00	8.24	14.31	0.00	0.00	4.44	16.32	5.81	6.31	18.89	0.00
SF	Calanoid, Pseudocalanus AF	7.95	0.00	0.00	0.71	19.51	0.00	0.46	0.00	0.29	0.00	5.11	12.33	0.00
SM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.91	0.00	0.00
haetognath														
HT	Chaetognath, species unknown	0.12	0.00	0.00	0.00	0.04	0.19	0.46	0.44	0.08	0.58	0.00	0.00	6.80
GE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
ladocera														
LA	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00
VD	Cladoceran, Evadne sp.	0.00	0.00	0.00	0.06	0.00	0.19	0.00	0.00	0.17	0.00	0.00	0.00	0.00
ON	Cladoceran, Podon sp.	0.00	0.00	0.00	0.13	0.00	2.80	0.00	0.22	0.29	0.00	0.30	0.00	0.00
ecapod														
ZB	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
GZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00
HR	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
uphausiid														
U3	Euphausiid calyptopis	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U4	Euphausiid furcilia	0.00	0.27	0.00	0.06	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.02	0.00
UJ	Euphausiid juvenile, general	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UP	Euphausiid, general unknown	0.00	0.00	4.84	0.00	0.00	0.00	0.92	0.00	0.04	0.00	0.30	0.00	0.97
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00

able 15 cont.														
ish														
SL	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	1.16	0.00	0.00	0.00
ammarid														
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00
astropod														
MA	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	4.68	0.27	0.00	7.01	5.57	0.75	26.15	0.89	19.46	2.91	1.20	0.13	0.00
TP	Gastropoda, Pteropod, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
yperiid														
HPJ	Amphipod, Hyperiid, Hyperia sp. juvenile	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HYB	Amphipod, Hyperiid, unknown small (<2mm)	0.06	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
HYP	Amphipod, Hyperiid, unknown juvenile	0.00	0.54	0.00	0.32	0.30	0.37	1.38	0.89	0.33	1.16	0.30	0.00	2.43
PA1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.26	0.00	0.00	0.00	3.56	0.08	2.33	5.41	0.00	0.00
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.04	0.00	0.90	0.00	0.49
Larvacean														
OKP	Larvacea, Oikopleura sp.	1.52	21.02	57.26	4.74	0.78	1.31	1.38	16.67	3.35	20.93	14.11	0.75	41.26
Malacostracan														
MAE	Malacostraca, eyes only	0.00	0.00	1.61	0.00	0.04	0.37	0.92	0.89	0.12	4.07	0.60	0.00	0.97
MAL	Malacostraca	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other														
BVL	Bivalve, larvae	0.00	0.00	0.00	0.19	0.00	0.19	0.46	0.44	0.04	0.00	0.00	0.00	0.00
EGG	Unknown invertebrate egg, small (<0.2mm)	49.01	1.35	0.00	27.58	23.47	27.10	27.98	32.00	19.50	6.98	0.00	43.91	7.77
EGL	Unknown invertebrate egg, large (>0.2mm)	0.64	0.00	0.00	0.00	0.07	0.00	0.00	0.22	0.00	0.00	0.00	0.02	0.00
NEM	Nematode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.49
UNP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.30	0.00	0.00

able 15 cont.									
) Northeast Area PWS									
	species	herring	herring	pollock	pollock	sandlance	herring	herring	sandlance
	size group	1	0	2	2	0	1	0	0
	station-haul	22-2	27-1	29-1	82-1	82-1	116	118	118
pcd									
arnacle									
MC	Barnacle, cyprid	0.01	0.08	0.00	0.00	0.00	0.00	empty	6.75
MP	Barnacle, nauplius	0.00	0.03	0.00	0.00	0.00	0.00	empty	0.00
alanoid copepod-large									
AL	Calanoid, general large (>2.5 mm)	1.62	0.12	31.09	13.59	0.00	0.02	empty	0.00
LN	Calanoid, large, Neocalanus/Calanus	1.08	0.00	9.24	12.14	0.00	0.02	empty	0.00
M	Calanoid, Calanus marshallae	0.00	0.00	18.49	0.00	4.67	0.10	empty	0.00
MF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.93	0.01	empty	0.00
PG	Calanoid, Calanus sp. general	0.00	0.00	3.36	0.00	89.72	0.00	empty	0.00
PF	Calanoid, Epilabidocera longipedata, AF	0.01	0.00	0.00	0.00	0.00	0.00	empty	0.00
PI	Calanoid, Epilabidocera longipedata, gen	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	0.00	0.01	empty	0.00
G	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.00	0.00	0.01	empty	0.00
OF	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.01	empty	0.00
PF	Calanoid, Metridia pacifica, AF	0.00	0.00	2.52	0.00	0.00	0.17	empty	0.00
CP	Calanoid, Neocalanus spp. copepodite	0.00	0.00	0.00	0.00	0.93	0.00	empty	0.00
EO	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	0.00	1.87	0.01	empty	0.00
PF	Calanoid, Neocalanus plumchrus AF	0.00	0.00	0.00	0.00	0.93	0.00	empty	0.00
alanoid copepod-small									
C	Calanoid, Acartia sp.	0.15	0.08	0.00	0.00	0.00	0.17	empty	0.00
CA	Calanoid, Acartia clausi adult	0.00	0.01	0.00	0.00	0.00	0.00	empty	0.00
CC	Calanoid, Acartia clausi copepodite	0.00	0.01	0.00	0.00	0.00	0.00	empty	0.00
LG	Calanoid, Acartia longiremis , General	0.03	0.00	0.00	0.00	0.00	0.00	empty	0.00
A	Calanoid, Centropages abdominalis, gen.	0.00	1.88	0.00	0.00	0.00	0.00	empty	0.26
AF	Calanoid, Centropages abdominalis, AF	0.03	0.21	0.00	0.00	0.00	0.00	empty	0.00
AN	Calanoid, general nauplius	0.00	0.01	0.00	0.00	0.00	0.00	empty	0.00
AS	Calanoid, general small (<2.5 mm)	43.35	42.74	14.29	4.85	0.93	2.97	empty	59.74
YF	Calanoid, Eurytemora pacifica AF	0.00	0.03	0.00	0.00	0.00	0.00	empty	0.00
YT	Calanoid, Eurytemora pacifica, general	0.00	0.14	0.00	0.00	0.00	0.00	empty	0.00
S	Cyclopoid, Oithona similis, general	0.24	0.01	0.00	0.00	0.00	0.00	empty	0.00
SF	Cyclopoid, Oithona similis AF	0.00	0.02	0.00	0.00	0.00	0.00	empty	0.00
CP	Calanoid, Pseudocalanus copepodids I-IV	0.64	4.27	0.00	0.00	0.00	0.00	empty	0.00

able 15 cont.

SA	Calanoid, Pseudocalanus sp., general	6.70	19.19	1.68	0.00	0.00	1.83	empty	0.00
SF	Calanoid, Pseudocalanus AF	7.78	8.00	0.00	0.00	0.00	0.54	empty	0.00
haetognath									
HT	Chaetognath, species unknown	0.00	0.00	1.68	47.09	0.00	0.00	empty	0.00
ladocera									
LA	Cladocera, General	0.00	0.24	0.00	0.00	0.00	0.00	empty	0.00
VD	Cladoceran, Evadne sp.	0.00	0.16	0.00	0.00	0.00	0.12	empty	6.23
ON	Cladoceran, Podon sp.	0.54	13.52	0.00	0.00	0.00	0.04	empty	6.49
yphonaute									
FN	Bryozoa, cyphonautes larva	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
ecapod									
CM	Decapod, megalops, unknown crab	0.00	0.00	0.84	0.00	0.00	0.00	empty	0.00
GB	Decapod, zoea, Brachyura, general	0.02	0.00	0.00	0.00	0.00	0.14	empty	0.00
MG	Decapod, megalops, Brachyura	0.00	0.00	0.00	0.49	0.00	0.00	empty	0.00
ML	Decapod, megalops, Lithodidae	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
MP	Decapod, megalops, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
ZB	Decapod zoea, crab, Brachyrhyncha	0.03	0.00	0.00	0.00	0.00	0.00	empty	0.00
ZG	Decapod zoea, crab, general unknown	0.03	0.01	0.00	0.00	0.00	0.03	empty	0.00
ZP	Decapod zoea, crab, Pisinae	0.00	0.00	0.00	0.00	0.00	0.02	empty	0.00
HIE	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
LIZ	Decapod zoea, Anomuran, Lithodidae	0.01	0.00	0.00	0.00	0.00	0.01	empty	0.00
PDZ	Decapod zoea, Shrimp, Pandalidae	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PGZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.02	empty	0.00
SHP	Decapod,Shrimp, gen. unknown juv./adult	0.00	0.00	0.00	0.49	0.00	0.00	empty	0.00
SHR	Decapod zoea, general shrimp	0.00	0.01	0.00	0.00	0.00	0.02	empty	0.00
Euphausiid									
EU3	Euphausiid calyptopis	0.00	0.06	0.00	0.00	0.00	0.01	empty	0.00
EU4	Euphausiid furcilia	0.04	0.01	0.00	0.00	0.00	0.02	empty	0.00
EUP	Euphausiid, general unknown	0.00	0.00	0.00	1.94	0.00	0.00	empty	0.00
TL	Euphausiid, T. longipes	0.00	0.00	0.00	0.49	0.00	0.00	empty	0.00
Fish									
FSE	Fish egg (~1.0 mm)	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gastropod									
GSB	Gastropod, juv. snail w/ black pigment	0.04	0.08	0.00	0.00	0.00	0.06	empty	0.00
GST	Gastropoda, general juvenile (SNAIL)	0.07	0.01	0.00	0.00	0.00	0.01	empty	0.52
LMJ	Gastropod, Pteropod, Limacina helicina J	0.71	0.02	0.00	0.00	0.00	4.77	empty	1.04

able 15 cont.									
yperiid									
YB	Amphipod, Hyperiid, unknown small (<2mm)	0.00	0.00	0.00	0.00	0.00	0.06	empty	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.07	0.35	2.52	0.49	0.00	0.04	empty	0.26
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
S1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.03	0.00	0.00	0.00	0.00	0.02	empty	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
arvacean									
KP	Larvacea, Oikopleura sp.	3.98	0.00	10.08	6.80	0.00	84.86	empty	5.45
alacostracan									
AE	Malacostraca, eyes only	0.08	0.01	0.00	11.17	0.00	0.21	empty	0.00
AL	Malacostraca	0.00	0.00	0.84	0.00	0.00	0.01	empty	0.00
ther									
VL	Bivalve, larvae	0.02	0.19	0.00	0.00	0.00	0.03	empty	3.90
GG	Unknown invertebrate egg, small (<0.2mm)	32.54	8.42	0.84	0.00	0.00	3.61	empty	1.04
GL	Unknown invertebrate egg, large (>0.2mm)	0.03	0.03	0.00	0.00	0.00	0.01	empty	0.00
EM	Harpacticoid, general eggsac	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
R	Harpacticoid, general, unknown stage	0.00	0.01	0.84	0.00	0.00	0.00	empty	3.12
RC	Harpacticoid, general copepodite	0.00	0.03	0.00	0.00	0.00	0.00	empty	3.12
ZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.52
AC	Harpacticoid, Laophontidae, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.26
AO	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.78
LL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.01	empty	0.00
SC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.52
EM	Unknown egg mass	0.00	0.00	0.00	0.49	0.00	0.00	empty	0.00
NI	Unidentified item	0.00	0.00	1.68	0.00	0.00	0.00	empty	0.00
NP	Unknown nauplius	0.03	0.02	0.00	0.00	0.00	0.00	empty	0.00

ble 15 cont.								
Southwest Area PWS								
	species	herring	capelin	capelin	tomcod	pollock	capelin	herring
	size group	0	0	0	1	0	0	1
	station-haul	43-1	43-1	47-1	51-1	51-1	100	107
ocd								
arnacle								
MC	Barnacle, cyprid	0.01	0.00	0.00	0.90	0.15	0.00	0.00
MP	Barnacle, nauplius	0.06	0.00	0.00	0.00	0.00	0.00	0.00
MV		0.00	0.00	0.00	8.78	0.00	0.00	0.00
alanoid copepod-large								
AL	Calanoid, general large (>2.5 mm)	0.03	0.00	0.00	0.00	0.03	0.00	0.00
LN	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.03	0.00	0.00
MM	Calanoid, Calanus marshallae AM	0.01	0.00	0.00	0.00	0.00	0.00	0.00
PA	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PC	Calanoid, Calanus pacificus, general	0.03	0.00	0.00	0.00	0.00	0.00	0.00
PG	Calanoid, Calanus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EPM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.23	0.00	0.00	0.00
MG	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.45	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	0.23	0.15	0.00	0.00
Calanoid copepod-small								
AC	Calanoid, Acartia sp.	0.01	0.00	0.00	0.00	1.38	0.00	0.15
ALC	Calanoid, Acartia longiremus copepodite	0.00	0.00	0.00	0.00	0.09	0.00	0.00
ALF	Calanoid, Acartia longiremis AF	0.01	0.00	0.00	0.00	0.29	0.00	0.00
ALG	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.41	0.00	0.00
CA	Calanoid, Centropages abdominalis, gen.	4.14	0.00	0.00	0.23	3.80	0.00	0.01
CAC	Calanoid, Centropages abdominalis, copdt	0.06	0.00	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis, AF	1.02	0.00	0.00	0.00	0.35	0.00	0.00
CAM	Calanoid, Centropages abdominalis, AM	0.06	0.00	0.00	0.00	0.00	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	45.94	100.00	25.00	1.35	69.41	0.00	47.68
CAV		0.00	0.00	0.00	0.00	0.15	0.00	0.00
COS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.24	70.00	0.00
EYT	Calanoid, Eurytemora pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.02
OIT	Cyclopoid, Oithona sp., general	0.00	0.00	0.00	0.00	0.12	0.00	0.00
OS	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.06	0.00	0.07
PCP	Calanoid, Pseudocalanus copepodids I-IV	5.44	0.00	37.50	0.00	0.29	0.00	0.00
PSA	Calanoid, Pseudocalanus sp., general	12.55	0.00	25.00	0.23	7.83	0.00	5.09
PSF	Calanoid, Pseudocalanus AF	5.14	0.00	0.00	0.23	2.56	0.00	4.08
PSG	Calanoid, Pseudocalanus GF	0.00	0.00	12.50	0.00	0.00	0.00	0.00

able 15 cont.								
SM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.23	0.00	0.00	0.00
ladocera								
LA	Cladocera, General	0.01	0.00	0.00	0.00	1.59	0.00	0.03
VD	Cladoceran, Evadne sp.	0.16	0.00	0.00	0.23	2.74	0.00	0.00
ON	Cladoceran, Podon sp.	0.34	0.00	0.00	0.68	2.12	0.00	0.00
ecapod								
GB	Decapod, zoea, Brachyura, general	0.04	0.00	0.00	0.00	0.00	0.00	0.00
ZB	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	0.10	0.00	0.00	0.00	0.00	0.00	0.01
DZ	Decapod zoea, Shrimp, Pandalidae	0.01	0.00	0.00	0.00	0.00	0.00	0.00
GZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HR	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00
uphausiid								
U3	Euphausiid calyptopis	0.01	0.00	0.00	0.00	0.00	0.00	0.00
U4	Euphausiid furcilia	0.07	0.00	0.00	0.45	0.00	0.00	0.00
UJ	Euphausiid juvenile, general	0.03	0.00	0.00	0.00	0.03	0.00	0.00
UP	Euphausiid, general unknown	0.00	0.00	0.00	0.23	0.00	0.00	0.00
sh								
SJ	Fish, juvenile, general	0.00	0.00	0.00	0.23	0.00	0.00	0.00
W2	Fish, walleye pollock, (41-60mm)	0.00	0.00	0.00	0.45	0.00	0.00	0.00
W3	Fish, walleye pollock, (61-80mm)	0.00	0.00	0.00	0.23	0.00	0.00	0.00
ammarid								
GC	Amphipod, Gammarid, Calliopius	0.00	0.00	0.00	0.68	0.00	0.00	0.00
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	11.04	0.00	0.00	0.00
A2	Amphipod, Gammarid, unknown, medium	0.00	0.00	0.00	27.93	0.00	0.00	0.00
A3	Amphipod, Gammarid, unknown, large	0.00	0.00	0.00	13.74	0.00	0.00	0.00
AM	Amphipod, Gammarid head	0.00	0.00	0.00	3.60	0.00	0.00	0.00
AU	Amphipod, Gammarid, unknown, no size	0.00	0.00	0.00	3.15	0.00	0.00	0.00
astropod								
MJ	Gastropod, Pteropod, Limacina helicina J	0.03	0.00	0.00	0.00	0.00	0.00	0.21
yperiid								
YB	Amphipod, Hyperiid, unknown small (<2mm)	0.95	0.00	0.00	0.00	0.18	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.02	0.00	0.00	0.00	0.09	0.00	0.01
A1	Amphipod, P. pacifica juvenile, <2mm	0.03	0.00	0.00	0.00	0.00	0.00	0.00
R1	Amphipod, Hyperiid, Primno macropa, <2mm	0.01	0.00	0.00	0.00	0.00	0.00	0.00
RI	Amphipod, Hyperiid, Primno macropa, gen.	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.65	0.00	0.00	0.00	0.00	0.00	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.01	0.00	0.00	0.00	0.00	0.00	0.00

able 15 cont.								
nsect								
PL	Insect, Dipteran larvae	0.00	0.00	0.00	0.23	0.00	0.00	0.00
arvacean								
KP	Larvacea, Oikopleura sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.10
alacostracan								
AE	Malacostraca, eyes only	0.04	0.00	0.00	0.00	0.00	0.00	0.00
AL	Malacostraca	0.00	0.00	0.00	0.45	0.00	0.00	0.00
ther								
VL	Bivalve, larvae	0.31	0.00	0.00	0.68	0.59	0.00	0.01
VP	Bivalve pieces (shell + muscle)	0.00	0.00	0.00	0.45	0.00	0.00	0.00
UM	Cumacea	0.00	0.00	0.00	4.28	0.03	0.00	0.00
GG	Unknown invertebrate egg, small (<0.2mm)	22.66	0.00	0.00	0.00	5.12	20.00	42.46
GL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.23	0.00	0.00	0.07
HEM	Harpacticoid, general eggsac	0.00	0.00	0.00	1.35	0.00	0.00	0.00
HR	Harpacticoid, general, unknown stage	0.01	0.00	0.00	0.90	0.00	0.00	0.00
HRC	Harpacticoid, general copepodite	0.00	0.00	0.00	0.23	0.12	0.00	0.00
HRJ	Harpacticoid, Harpacticus copepodite	0.00	0.00	0.00	0.00	0.03	0.00	0.00
HRS	Harpacticoid, Harpacticus sp. general ad	0.00	0.00	0.00	5.86	0.00	0.00	0.00
IGN	Isopod, Gnorimosphaeroma species	0.00	0.00	0.00	1.13	0.00	0.00	0.00
LAO	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.45	0.00	0.00	0.00
MUV	Mytiloida, Musculus vernicosus							
NEM	Nematode	0.00	0.00	0.00	0.00	0.03	0.00	0.00
PCO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.90	0.00	0.00	0.00
PLA	Polychaeta, adult	0.00	0.00	0.00	0.68	0.00	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00	0.00	0.00	5.18	0.00	0.00	0.00
TSB	Harpacticoid, Tisbe sp., adult	0.01	0.00	0.00	0.23	0.00	0.00	0.00
TSC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.23	0.00	0.00	0.00
TSG	Harpacticoid, Tisbe sp., gravid female	0.00	0.00	0.00	1.13	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	10.00	0.00

ble 16. Total biomass and percent biomass of major groups of prey organisms in *forage fish stomachs*
species-size group (n =10 each) at stations in central, northeastern and southwestern PWS in summer, 1995.

ntral Area, all fish other than pollock

tal biomass

species	herring	pink salmon	pink salmon	capelin	capelin	capelin	capelin	capelin	capelin	sandlance
size group	0	0	0	0	0	0	0	1	1	0
station-haul	110	1-2	66-2	62-1	67-1	72-1	73-1	114	65-1	999
sumcode										
Barnacle	0.00	7.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.94
Calanoid copepod-large	0.00	312.01	616.99	0.00	0.00	0.00	0.00	0.00	0.00	81.29
Calanoid copepod-small	15.51	35.32	8.17	0.00	0.02	0.07	0.00	0.00	1.13	335.35
Chaetognath	0.00	0.00	312.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera	0.00	29.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13
Cyphonaute	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	44.33	25.92	0.00	0.00	0.00	0.00	0.00	0.00	2.74
Euphausiid	0.00	22.64	1080.06	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Fish	0.00	250.00	200.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammarid	0.00	2.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod	0.00	178.02	2305.81	0.00	0.00	0.00	0.00	0.17	0.00	1.24
Hyperiid	0.00	17.07	560.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	1.76	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	0.00	75.06	0.00	0.00	0.00	0.00	0.00	0.00	292.11
Malacostracan	0.00	1.17	6.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	2.71	0.48	0.00	0.00	0.00	0.00	0.00	0.10	11.02
TOTAL	15.51	904.22	5198.54	0.00	0.02	0.07	0.00	0.17	1.23	739.76

ntral Area, all fish other than pollock

biomass

species	herring	pink salmon	pink salmon	capelin	capelin	capelin	capelin	capelin	capelin	sandlance
size group	0	0	0	0	0	0	0	1	1	0
station-haul	110	1-2	66-2	62-1	67-1	72-1	73-1	114	65-1	999
sumcode										
Barnacle	0.00	0.81	0.00	empty	0.00	0.00	empty	0.00	0.00	1.88
Calanoid copepod-large	0.00	34.51	11.87	empty	0.00	0.00	empty	0.00	0.00	10.99
Calanoid copepod-small	0.00	3.91	0.16	empty	100.00	100.00	empty	0.00	91.88	45.33
Chaetognath	0.00	0.00	6.02	empty	0.00	0.00	empty	0.00	0.00	0.00
Cladocera	0.00	3.23	0.00	empty	0.00	0.00	empty	0.00	0.00	0.15
Cyphonaute	0.00	0.00	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00

le 16 cont.

Decapod	0.00	4.90	0.50	empty	0.00	0.00	empty	0.00	0.00	0.37
Euphausiid	0.00	2.50	20.78	empty	0.00	0.00	empty	0.00	0.00	0.13
Fish	0.00	27.65	3.85	empty	0.00	0.00	empty	0.00	0.00	0.00
Gammarid	0.00	0.30	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00
Gastropod	0.00	19.69	44.36	empty	0.00	0.00	empty	100.00	0.00	0.17
Hyperiid	0.00	1.89	10.78	empty	0.00	0.00	empty	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	empty	0.00	0.00	empty	0.00	0.00	0.00
Insect	0.00	0.19	0.13	empty	0.00	0.00	empty	0.00	0.00	0.00
Larvacean	0.00	0.00	1.44	empty	0.00	0.00	empty	0.00	0.00	39.49
Malacostracan	0.00	0.13	0.12	empty	0.00	0.00	empty	0.00	0.00	0.00
Other	0.00	0.30	0.01	empty	0.00	0.00	empty	0.00	8.12	1.49

entral Area, summer 1995, pollock only

tal biomass

species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
size group	0	0	0	0	0	0	0	0	0	0	0	0	0
station-haul	108	112	19-1	3-1	5-2	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1
sumcode													
Barnacle	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.19	0.00	0.00
Calanoid copepod-large	29.45	66.41	52.64	15.15	242.69	0.00	20.15	0.00	0.00	6.79	27.04	30.92	133.20
Calanoid copepod-small	1718.60	3.07	1.42	94.99	3.59	78.22	232.48	26.66	6.50	15.12	128.36	7.26	11.87
Chaetognath	0.88	6.16	0.00	0.88	0.00	0.00	0.44	0.44	0.44	0.88	0.88	0.44	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.62	0.08	0.04	0.43	0.00	0.04
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	31.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59
Euphausiid	2.34	21.30	63.90	0.00	7.67	0.39	0.00	0.17	21.30	0.00	25.91	0.00	10.65
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	300.00	0.00	100.00	0.00
Gammarid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00
Gastropod	5.76	0.00	0.00	13.96	0.17	18.85	27.18	0.70	9.95	0.70	82.19	0.87	0.70
Hyperiid	8.37	47.16	0.00	8.03	15.89	39.98	65.33	15.72	23.58	49.86	71.08	16.40	34.48
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.94	0.00	0.00	0.00
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	6.23	2.83	2.36	0.87	2.60	2.43	0.70	0.23	0.10	2.50	2.70	1.20	1.57
Malacostracan	0.00	0.78	0.78	0.00	0.00	12.06	0.39	0.78	0.78	1.56	1.17	2.73	0.78
Other	109.52	0.16	0.00	8.61	0.05	4.26	6.32	1.45	0.61	1.48	4.72	0.12	0.01
TOTAL	1912.49	147.87	121.11	142.48	272.66	156.59	352.99	46.78	63.99	385.87	344.66	159.94	194.88

le 16 cont.													
ntral Area, pollock only													
iomass													
species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
size group	0	0	0	0	0	0	0	0	0	0	0	0	0
station-haul	108	112	19-1	3-1	5-2	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1
SUMCODE													
Barnacle	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.06	0.00	0.00
Calanoid copepod-large	0.00	44.91	43.47	10.63	89.01	0.00	5.71	0.00	0.00	1.76	7.84	19.33	68.35
Calanoid copepod-small	0.00	2.08	1.18	66.67	1.32	49.95	65.86	57.00	10.16	3.92	37.24	4.54	6.09
Chaetognath	0.00	4.17	0.00	0.62	0.00	0.00	0.12	0.94	0.69	0.23	0.26	0.28	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.07	0.00	1.33	0.12	0.01	0.12	0.00	0.02
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82
Euphausiid	0.00	14.40	52.76	0.00	2.81	0.25	0.00	0.35	33.29	0.00	7.52	0.00	5.46
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	77.75	0.00	62.53	0.00
Gammarid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00
Gastropod	0.00	0.00	0.00	9.80	0.06	12.04	7.70	1.49	15.54	0.18	23.85	0.55	0.36
Hyperiid	0.00	31.89	0.00	5.64	5.83	25.53	18.51	33.60	36.85	12.92	20.62	10.25	17.69
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	1.91	1.95	0.61	0.95	1.55	0.20	0.50	0.16	0.65	0.78	0.75	0.80
Malacostracan	0.00	0.53	0.64	0.00	0.00	7.70	0.11	1.67	1.22	0.40	0.34	1.71	0.40
Other	0.00	0.11	0.00	6.05	0.02	2.72	1.79	3.11	0.96	0.38	1.37	0.08	0.01
theastern Area													
al Biomass													
species	herring	herring	herring	herring	pollock	pollock	sandlance	sandlance					
size group	0	0	1	1	2	2	0	0					
station-haul	118	27-1	116	22-2	29-1	82-1	118	82-1					
sumcode													
Barnacle	0.00	17.05	0.00	1.15	0.00	0.00	7.49	0.00					
Calanoid copepod-large	0.00	158.36	71.46	2835.95	145.56	119.90	0.00	92.00					
Calanoid copepod-small	0.00	4738.83	98.15	2698.35	1.56	0.75	17.33	0.07					
Chaetognath	0.00	0.00	0.00	0.00	0.88	42.68	0.00	0.00					
Cladocera	0.00	324.13	1.05	9.91	0.00	0.00	1.91	0.00					
Cyphonaute	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00					
Decapod	0.00	31.12	85.53	146.55	10.80	18.85	0.00	0.00					
Euphausiid	0.00	7.67	1.34	18.45	0.00	62.60	0.00	0.00					
Fish	0.00	6.59	0.00	0.00	0.00	0.00	0.00	0.00					

able 16 cont.

Gammarid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod	0.00	7.71	137.27	64.48	0.00	0.00	1.02	0.00
Hyperiid	0.00	35.32	49.53	278.91	23.58	7.86	7.86	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	0.00	461.67	61.07	0.40	0.47	0.70	0.00
Malacostracan	0.00	13.62	37.38	38.94	12.06	8.97	0.00	0.00
Other	0.00	52.53	6.04	150.60	0.10	0.02	2.19	0.00
TOTAL	0.00	5392.94	949.42	6304.35	194.94	262.10	38.49	92.08
Northeastern Area								
% Biomass								
species	herring	herring	herring	herring	pollock	pollock	sandlance	sandlance
size group	0	0	1	1	2	2	0	0
station-haul	118	27-1	116	22-2	29-1	82-1	118	82-1
SUMCODE								
Barnacle	empty	0.32	0.00	0.02	0.00	0.00	19.45	0.00
Calanoid copepod-large	empty	2.94	7.53	44.98	74.67	45.75	0.00	99.92
Calanoid copepod-small	empty	87.87	10.34	42.80	0.80	0.29	45.01	0.08
Chaetognath	empty	0.00	0.00	0.00	0.45	16.28	0.00	0.00
Cladocera	empty	6.01	0.11	0.16	0.00	0.00	4.96	0.00
Cyphonaute	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	empty	0.58	9.01	2.32	5.54	7.19	0.00	0.00
Euphausiid	empty	0.14	0.14	0.29	0.00	23.88	0.00	0.00
Fish	empty	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Gammarid	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod	empty	0.14	14.46	1.02	0.00	0.00	2.64	0.00
Hyperiid	empty	0.65	5.22	4.42	12.10	3.00	20.42	0.00
Cnidarian/ Ctenophore	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	empty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	empty	0.00	48.63	0.97	0.20	0.18	1.82	0.00
Malacostracan	empty	0.25	3.94	0.62	6.19	3.42	0.00	0.00
Other	empty	0.97	0.64	2.39	0.05	0.01	5.69	0.00
Southwestern Area								
Total Biomass								
species	herring	herring	tomcod	pollock	capelin	capelin	capelin	
size group	0	1	1	0	0	0	0	
station-haul	43-1	107	51-1	51-1	100	43-1	47-1	

able 16 cont.							
sumcode							
Barnacle	2.10	0.58	1.15	1.44	0.00	0.00	0.00
Calanoid copepod-large	13.89	3.20	4.02	8.47	0.00	0.00	0.00
Calanoid copepod-small	981.42	20875.36	0.96	250.87	0.16	0.22	0.71
Chaetognath	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera	2.77	5.85	0.16	8.54	0.00	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	56.65	148.44	0.00	0.00	0.00	0.00	0.00
Euphausiid	18.63	3.62	11.43	3.64	0.00	0.00	0.00
Fish	0.00	0.00	5048.00	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	1449.39	0.00	0.00	0.00	0.00
Gastropod	0.70	149.72	0.00	0.00	0.00	0.00	0.00
Hyperiid	87.51	214.94	0.00	24.59	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	0.35	0.00	0.00	0.00	0.00
Larvacean	0.00	13.85	0.00	0.00	0.00	0.00	0.00
Malacostracan	2.34	0.78	24.12	0.00	0.00	0.00	0.00
Other	32.02	1726.78	222.78	2.44	0.02	0.00	0.00
TOTAL	1198.02	23143.10	6762.36	300.00	0.18	0.22	0.71
outhwestern Area							
biomass							
species	herring	herring	tomcod	pollock	capelin	capelin	capelin
size group	0	1	1	0	0	0	0
station-haul	43-1	107	51-1	51-1	100	43-1	47-1
SUMCODE							
Barnacle	0.17	0.00	0.02	0.48	0.00	0.00	0.00
Calanoid copepod-large	1.16	0.01	0.06	2.82	0.00	0.00	0.00
Calanoid copepod-small	81.92	90.20	0.01	83.62	89.16	100.00	100.00
Chaetognath	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera	0.23	0.03	0.00	2.85	0.00	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	4.73	0.64	0.00	0.00	0.00	0.00	0.00
Euphausiid	1.55	0.02	0.17	1.21	0.00	0.00	0.00
Fish	0.00	0.00	74.65	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	21.43	0.00	0.00	0.00	0.00
Gastropod	0.06	0.65	0.00	0.00	0.00	0.00	0.00
Hyperiid	7.30	0.93	0.00	8.20	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Insect	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table 16 cont.

Larvacean	0.00	0.06	0.00	0.00	0.00	0.00	0.00						
Malacostracan	0.20	0.00	0.36	0.00	0.00	0.00	0.00						
Other	2.67	7.46	3.29	0.81	10.84	0.00	0.00						

e 17. Total biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at ons in central (A), northeastern (B) and southwestern (C) PWS in summer, 1995.

entral Area PWS, summer 1995, pollock only

species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
size group	0	0	0	0	0	0	0	0	0	0	0	0	0
station-haul	3-1	5-2	19-1	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1	108	112
acle													
Barnacle, cyprid	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
noid copepod-large													
Calanoid, general large (>2.5 mm)	13.57	83.71	49.77	0.00	4.52	0.00	0.00	6.79	20.36	24.89	54.30	18.10	42.98
Calanoid, Calanus sp. AF	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00
Calanoid, Calanus sp. copepodite	0.00	0.00	0.00	0.00	3.09	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00
Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.52	4.52	0.00	2.26	9.05
Calanoid, large, NOT Neocalanus/Calanus	0.00	4.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Calanus marshallae	0.00	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00
Calanoid, C. marshallae copepodite	0.00	0.00	0.00	0.00	12.53	0.00	0.00	0.00	0.00	0.00	12.53	0.00	0.00
Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.73	1.73	0.00
Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71	0.00	0.00
Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00
Calanoid, Calanus pacificus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00
Calanoid, Calanus sp. general	1.57	147.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.89	0.00	0.00
Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.62
Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.76	0.00	0.00
Calanoid, Metridia sp., General	0.00	0.00	2.87	0.00	0.00	0.00	0.00	0.00	2.15	0.00	1.43	0.00	10.76
Calanoid, Metridia sp., general male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00
Calanoid, Metridia pacifica, AF	0.00	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	44.18	5.52	0.00
Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	0.00	0.00
noid copepod-small													
Calanoid, Acartia sp.	0.09	0.00	0.00	0.26	0.54	0.00	0.00	0.00	0.00	0.00	0.03	0.45	0.00
Calanoid, Acartia sp. copepodids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Calanoid, Acartia longiremis AF	0.00	0.07	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.07	0.44	0.00
Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Centropages abdominalis, gen.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	3.14	0.00
Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00
Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Calanoid, general small (<2.5 mm)	15.58	3.52	1.42	57.52	68.31	26.66	6.29	12.28	70.71	5.84	3.60	388.28	3.07
Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
Calanoid, Pseudocalanus copepodids I-IV	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	15.70	0.00
Calanoid, Pseudocalanus sp., general	49.84	0.00	0.00	18.03	54.39	0.00	0.00	2.84	56.09	1.42	2.98	667.68	0.00
Calanoid, Pseudocalanus AF	28.42	0.00	0.00	2.30	109.10	0.00	0.21	0.00	1.46	0.00	3.55	641.63	0.00
Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.00
etognath													
Chaetognath, species unknown	0.88	0.00	0.00	0.00	0.44	0.44	0.44	0.88	0.88	0.44	0.00	0.00	6.16
Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00

le 17 cont.

\	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
docera														
)	Cladoceran, Evadne sp.	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.16	0.00	0.00	0.00	0.00
N	Cladoceran, Podon sp.	0.00	0.00	0.00	0.08	0.00	0.59	0.00	0.04	0.27	0.00	0.04	0.00	0.00
:apod														
B	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.87	0.00
G	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.39	0.00
Z	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	0.00	0.00
R	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
phausiid														
J3	Euphausiid calyptopis	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J4	Euphausiid furcilia	0.00	0.39	0.00	0.39	0.00	0.00	0.00	0.00	1.56	0.00	0.00	2.34	0.00
JJ	Euphausiid juvenile, general	0.00	7.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JP	Euphausiid, general unknown	0.00	0.00	63.90	0.00	0.00	0.00	21.30	0.00	10.65	0.00	10.65	0.00	21.30
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.70	0.00	0.00	0.00	0.00
sh														
SL	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	300.00	0.00	100.00	0.00	0.00	0.00
ammarid														
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00
astropod														
MA	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	13.96	0.17	0.00	18.85	26.00	0.70	9.95	0.70	82.19	0.87	0.70	5.76	0.00
yperiid														
IPJ	Amphipod, Hyperiid, Hyperia sp. juvenile	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IYB	Amphipod, Hyperiid, unknown small (<2mm)	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00
IYP	Amphipod, Hyperiid, unknown juvenile	0.00	15.72	0.00	39.30	62.88	15.72	23.58	31.44	62.88	15.72	7.86	7.86	39.30
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.68	0.00	0.00	0.00	2.70	0.34	0.68	3.04	0.17	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	7.86	0.00	0.00	0.00	0.00	0.00	0.00	15.72	7.86	0.00	23.58	0.00	7.86
TP	Gastropoda, Pteropod, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.94	0.00	0.00	0.00	0.00	0.00
arvacean														
KP	Larvacea, Oikopleura sp.	0.87	2.60	2.36	2.43	0.70	0.23	0.10	2.50	2.70	1.20	1.57	6.23	2.83
Malacostracan														
MAE	Malacostraca, eyes only	0.00	0.00	0.78	0.00	0.39	0.78	0.78	1.56	1.17	2.73	0.78	0.00	0.78
MAL	Malacostraca	0.00	0.00	0.00	12.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other														
BVL	Bivalve, larvae	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
EGG	Unknown invertebrate egg, small (<0.2mm)	8.38	0.05	0.00	4.25	6.28	1.45	0.61	1.44	4.72	0.12	0.00	109.32	0.16
EGL	Unknown invertebrate egg, large (>0.2mm)	0.23	0.00	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.11	0.00
NEM	Nematode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UNP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
TOTAL		142.48	272.66	121.11	156.59	352.99	46.78	63.99	385.87	344.66	159.94	194.88	1912.49	147.87

le 17 cont.

entral Area PWS, summer 1995, all fish except for pollock

species	pink salmon	capelin	capelin	pink salmon	capelin	capelin	capelin	herring	capelin	sandlance
size group	0	0	1	0	0	0	0	0	1	0
station-haul	1-2	62-1	65-1	66-2	67	72-1	73-1	110	114	999
nacle										
Barnacle, cyprid	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.37
Barnacle, adult molt (cirri)	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.57
noid copepod-large										
Calanoid, general large (>2.5 mm)	56.56	0.00	0.00	117.64	0.00	0.00	0.00	0.00	0.00	20.36
Calanoid, large, Neocalanus/Calanus	63.34	0.00	0.00	169.67	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Calanus marshallae	0.00	0.00	0.00	201.63	0.00	0.00	0.00	0.00	0.00	40.04
Calanoid, Calanus marshallae AF	1.73	0.00	0.00	31.05	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Calanus pacificus, general	0.49	0.00	0.00	34.11	0.00	0.00	0.00	0.00	0.00	10.23
Calanoid, Calanus pacificus AF	0.00	0.00	0.00	2.62	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Epilabidocera longipedata, cop	124.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40
Calanoid, Epilabidocera longipedata, AF	12.60	0.00	0.00	10.80	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Epilabidocera longipedata, gen	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Epilabidocera longipedata, AM	14.40	0.00	0.00	21.60	0.00	0.00	0.00	0.00	0.00	1.80
Calanoid, Metridia sp., General	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88
Calanoid, Metridia pacifica, adult	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Metridia pacifica, AF	3.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58
Calanoid, Metridia pacifica, AM	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Neocalanus spp. adult	24.89	0.00	0.00	27.15	0.00	0.00	0.00	0.00	0.00	0.00
noid copepod-small										
Calanoid, Acartia sp.	0.17	0.00	0.11	0.14	0.00	0.00	0.00	0.00	0.00	9.54
Calanoid, Acartia longiremus copepodite	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Acartia longiremis , General	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	29.06
Calanoid, Centropages abdominalis, gen.	5.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57
Calanoid, Centropages abdominalis, AF	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, general nauplius	0.00	0.00	0.01	0.00	0.02	0.04	0.00	0.00	0.00	0.00
Calanoid, general small (<2.5 mm)	16.03	0.00	0.45	4.64	0.00	0.00	0.00	5.02	0.00	124.93
	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.18	0.00	0.00
Cyclopoid, Oithona sp., general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	68.92
Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
Cyclopoid, Oithona copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00
Calanoid, Pseudocalanus copepodids I-IV	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid, Pseudocalanus sp., general	0.85	0.00	0.28	2.13	0.00	0.00	0.00	0.00	0.00	82.93
Calanoid, Pseudocalanus AF	8.57	0.00	0.21	1.25	0.00	0.00	0.00	0.00	0.00	18.39
Calanoid, Pseudocalanus AM	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
etognath										
Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	312.84	0.00	0.00	0.00	0.00	0.00	0.00

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docera														
A	Cladocera, General	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
D	Cladoceran, Evadne sp.	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74			
N	Cladoceran, Podon sp.	21.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39			
phonaute														
N	Bryozoa, cyphonautes larva	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
capod														
M	Decapod, megalops, unknown crab	0.00	0.00	0.00	21.59	0.00	0.00	0.00	0.00	0.00	0.00			
B	Decapod, zoea, Brachyura, general	20.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
B	Decapod zoea, crab, Brachyrhyncha	3.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
G	Decapod zoea, crab, general unknown	16.43	0.00	0.00	2.74	0.00	0.00	0.00	0.00	0.00	2.74			
Z	Decapod zoea, Shrimp, Pandalidae	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Z	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.00			
HR	Decapod zoea, general shrimp	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
phausiid														
U3	Euphausiid calyptopis	0.17	0.00	0.00	2.64	0.00	0.00	0.00	0.00	0.00	0.17			
U4	Euphausiid furcilia	1.17	0.00	0.00	1.95	0.00	0.00	0.00	0.00	0.00	0.78			
UP	Euphausiid, general unknown	21.30	0.00	0.00	777.45	0.00	0.00	0.00	0.00	0.00	0.00			
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.00	0.00	150.70	0.00	0.00	0.00	0.00	0.00	0.00			
HJ	Euphausiid, Thysannoessa sp. juvenile	0.00	0.00	0.00	47.32	0.00	0.00	0.00	0.00	0.00	0.00			
L	Euphausiid, T. longipes	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00			
ish														
SL	Fish larvae, general	250.00	0.00	0.00	200.00	0.00	0.00	0.00	0.00	0.00	0.00			
ammarid														
A2	Amphipod, Gammarid, unknown, medium	2.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
astropod														
SB	Gastropod, juv. snail w/ black pigment	9.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60			
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.64			
MA	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	1832.54	0.00	0.00	0.00	0.00	0.00	0.00			
MJ	Gastropod, Pteropod, Limacina helicina J	168.22	0.00	0.00	471.67	0.00	0.00	0.00	0.00	0.17	0.00			
Hyperiid														
HYB	Amphipod, Hyperiid, unknown small (<2mm)	1.01	0.00	0.00	7.77	0.00	0.00	0.00	0.00	0.00	0.00			
HYP	Amphipod, Hyperiid, unknown juvenile	15.72	0.00	0.00	47.16	0.00	0.00	0.00	0.00	0.00	0.00			
PR1	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	0.00	0.00	104.72	0.00	0.00	0.00	0.00	0.00	0.00			
PR2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	0.00	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.00			
PR3	Amphipod, Hyperiid, P. macropa, 7+mm	0.00	0.00	0.00	3.99	0.00	0.00	0.00	0.00	0.00	0.00			
PRI	Amphipod, Hyperiid, Primno macropa, gen.	0.00	0.00	0.00	15.96	0.00	0.00	0.00	0.00	0.00	0.00			
PS1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.34	0.00	0.00	17.24	0.00	0.00	0.00	0.00	0.00	0.00			
PS2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	361.56	0.00	0.00	0.00	0.00	0.00	0.00			
Insect														
DIP	Insect, Dipteran adult	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
INS	Insect, general	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00			
Larvacean														
OKP	Larvacea, Oikopleura sp.	0.00	0.00	0.00	75.06	0.00	0.00	0.00	0.00	0.00	292.11			
Malacostracan														
MAE	Malacostraca, eyes only	1.17	0.00	0.00	6.24	0.00	0.00	0.00	0.00	0.00	0.00			

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er														
E L	Bivalve, larvae	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30			
C P	Amphipod, Caprellidae	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
E G	Unknown invertebrate egg, small (<0.2mm)	0.19	0.00	0.03	0.48	0.00	0.00	0.00	0.00	0.00	7.12			
E L	Unknown invertebrate egg, large (>0.2mm)	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
H C	Harpacticoid, general copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05			
H J	Harpacticoid, Harpacticus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04			
H Z	Harpacticoid, Zaus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03			
I	Isopod, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.74			
P L	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35			
T B	Harpacticoid, Tisbe sp., adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10			
T C	Harpacticoid, Tisbe copepodite	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.21			
T G	Harpacticoid, Tisbe sp., gravid female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07			
TAL		904.22	0.00	1.23	5198.54	0.02	0.07	0.00	15.51	0.17	739.76			

ble 18. Percent biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at
ıtions in central (A), northeastern (B) and southwestern (C) PWS in summer, 1995.

Central Area PWS, pollock only

	species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock
	size group	0	0	0	0	0	0	0	0	0	0	0	0	0
	station-haul	3-1	5-2	19-1	53-1	53-2	54-2	56-1	57-2	58-2	62-2	73-1	108	112
꞉cd														
arnacle														
MC	Barnacle, cyprid	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
alanoid copepod-large														
AL	Calanoid, general large (>2.5 mm)	9.53	30.70	41.10	0.00	1.28	0.00	0.00	1.76	5.91	15.56	27.86	0.95	29.07
CF	Calanoid, Calanus sp. AF	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
CP	Calanoid, Calanus sp. copepodite	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
LN	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31	2.83	0.00	0.12	6.12
LU	Calanoid, large, NOT Neocalanus/Calanus	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	Calanoid, Calanus marshallae	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
MC	Calanoid, C. marshallae copepodite	0.00	0.00	0.00	0.00	3.55	0.00	0.00	0.00	0.00	0.00	6.43	0.00	0.00
MF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.09	0.00
PA	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00
PC	Calanoid, Calanus pacificus, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00
PF	Calanoid, Calanus pacificus AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
PG	Calanoid, Calanus sp. general	1.10	54.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM	Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	0.00	0.00
UB	Calanoid, Eucalanus bungii, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45
MEP	Calanoid, Metridia pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.52	0.00	0.00
MG	Calanoid, Metridia sp., General	0.00	0.00	2.37	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.74	0.00	7.28
MGM	Calanoid, Metridia sp., general male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	22.67	0.29	0.00
MPM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00
Calanoid copepod-small														
AC	Calanoid, Acartia sp.	0.06	0.00	0.00	0.16	0.15	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00
ACP	Calanoid, Acartia sp. copepodids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
ALF	Calanoid, Acartia longiremis AF	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00
ALG	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	Calanoid, Centropages abdominalis, gen.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.16	0.00
CAM	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
CAN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	10.93	1.29	1.18	36.74	19.35	57.00	9.83	3.18	20.51	3.65	1.84	20.30	2.08
COS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCP	Calanoid, Pseudocalanus copepodids I-IV	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.82	0.00
PSA	Calanoid, Pseudocalanus sp., general	34.98	0.00	0.00	11.52	15.41	0.00	0.00	0.74	16.27	0.89	1.53	34.91	0.00
PSF	Calanoid, Pseudocalanus AF	19.95	0.00	0.00	1.47	30.91	0.00	0.33	0.00	0.42	0.00	1.82	33.55	0.00
PSM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00
Chaetognath														
CHT	Chaetognath, species unknown	0.62	0.00	0.00	0.00	0.12	0.94	0.69	0.23	0.26	0.28	0.00	0.00	4.17
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00

ble 18 cont.

adocera														
A	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
D	Cladoceran, Evadne sp.	0.00	0.00	0.00	0.02	0.00	0.08	0.00	0.00	0.05	0.00	0.00	0.00	0.00
N	Cladoceran, Podon sp.	0.00	0.00	0.00	0.05	0.00	1.25	0.00	0.01	0.08	0.00	0.02	0.00	0.00
capod														
B	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
G	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00
Z	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00
R	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
phausiid														
3	Euphausiid calyptopis	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Euphausiid furcilia	0.00	0.14	0.00	0.25	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.12	0.00
J	Euphausiid juvenile, general	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	Euphausiid, general unknown	0.00	0.00	52.76	0.00	0.00	0.00	33.29	0.00	3.09	0.00	5.46	0.00	14.40
	Euphausiid, Thysannoessa sp., gen. adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.97	0.00	0.00	0.00	0.00
sh														
L	Fish larvae, general	0.00	0.00	0.00	0.00	0.00	0.00	0.00	77.75	0.00	62.53	0.00	0.00	0.00
mmarid														
1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00
stropod														
A	Gastropod, Pteropod, Limacina helicina A	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J	Gastropod, Pteropod, Limacina helicina J	9.80	0.06	0.00	12.04	7.37	1.49	15.54	0.18	23.85	0.55	0.36	0.30	0.00
periid														
J	Amphipod, Hyperiid, Hyperia sp. juvenile	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	Amphipod, Hyperiid, unknown small (<2mm)	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
P	Amphipod, Hyperiid, unknown juvenile	0.00	5.77	0.00	25.10	17.81	33.60	36.85	8.15	18.24	9.83	4.03	0.41	26.58
1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.70	0.10	0.42	1.56	0.01	0.00
2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	5.52	0.00	0.00	0.00	0.00	0.00	0.00	4.07	2.28	0.00	12.10	0.00	5.32
P	Gastropoda, Pteropod, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	0.00	0.00
rvacean														
P	Larvacea, Oikopleura sp.	0.61	0.95	1.95	1.55	0.20	0.50	0.16	0.65	0.78	0.75	0.80	0.33	1.91
lacostracan														
E	Malacostraca, eyes only	0.00	0.00	0.64	0.00	0.11	1.67	1.22	0.40	0.34	1.71	0.40	0.00	0.53
L	Malacostraca	0.00	0.00	0.00	7.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
her														
L	Bivalve, larvae	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
G	Unknown invertebrate egg, small (<0.2mm)	5.88	0.02	0.00	2.71	1.78	3.10	0.95	0.37	1.37	0.08	0.00	5.72	0.11
L	Unknown invertebrate egg, large (>0.2mm)	0.16	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
M	Nematode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

e 18 cont.

entral Area PWS, all fish except for pollock

	species	pink salmon	capelin	capelin	pink salmon	capelin	capelin	capelin	herring	capelin	sandlance
	size group	0	0	1	0	0	0	0	0	1	0
	station-haul	1-2	62-1	65-1	66-2	67	72-1	73-1	110	114	999
d											
nacle											
C	Barnacle, cyprid	0.41	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	1.40
M	Barnacle, adult molt (cirri)	0.39	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.48
anoid copepod-large											
L	Calanoid, general large (>2.5 mm)	6.25	empty	0.00	2.26	0.00	0.00	empty	0.00	0.00	2.75
N	Calanoid, large, Neocalanus/Calanus	7.01	empty	0.00	3.26	0.00	0.00	empty	0.00	0.00	0.00
i	Calanoid, Calanus marshallae	0.00	empty	0.00	3.88	0.00	0.00	empty	0.00	0.00	5.41
IF	Calanoid, Calanus marshallae AF	0.19	empty	0.00	0.60	0.00	0.00	empty	0.00	0.00	0.00
C	Calanoid, Calanus pacificus, general	0.05	empty	0.00	0.66	0.00	0.00	empty	0.00	0.00	1.38
F	Calanoid, Calanus pacificus AF	0.00	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.00
C	Calanoid, Epilabidocera longipedata, cop	13.74	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.73
F	Calanoid, Epilabidocera longipedata, AF	1.39	empty	0.00	0.21	0.00	0.00	empty	0.00	0.00	0.00
I	Calanoid, Epilabidocera longipedata, gen	1.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
M	Calanoid, Epilabidocera longipedata, AM	1.59	empty	0.00	0.42	0.00	0.00	empty	0.00	0.00	0.24
G	Calanoid, Metridia sp., General	0.00	empty	0.00	0.01	0.00	0.00	empty	0.00	0.00	0.00
OF	Calanoid, Metridia ochotensis AF	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.25
P	Calanoid, Metridia pacifica, adult	0.05	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
PF	Calanoid, Metridia pacifica, AF	0.44	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.21
PM	Calanoid, Metridia pacifica, AM	0.04	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
EO	Calanoid, Neocalanus spp. adult	2.75	empty	0.00	0.52	0.00	0.00	empty	0.00	0.00	0.00
alanoid copoepod-small											
C	Calanoid, Acartia sp.	0.02	empty	9.23	0.00	0.00	0.00	empty	0.00	0.00	1.29
LC	Calanoid, Acartia *longiremus* copepodite	0.00	empty	1.03	0.00	0.00	0.00	empty	0.00	0.00	0.00
LG	Calanoid, Acartia longiremis , General	0.00	empty	4.22	0.00	0.00	0.00	empty	0.00	0.00	3.93
A	Calanoid, Centropages abdominalis, gen.	0.57	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.21
AF	Calanoid, Centropages abdominalis, AF	0.46	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
AN	Calanoid, general nauplius	0.00	empty	0.87	0.00	100.00	64.56	empty	0.00	0.00	0.00
AS	Calanoid, general small (<2.5 mm)	1.77	empty	36.50	0.09	0.00	0.00	empty	32.36	0.00	16.89
AV		0.00	empty	0.00	0.00	0.00	35.44	empty	0.00	0.00	0.00
OS	Calanoid, Copepodite small	0.00	empty	0.00	0.00	0.00	0.00	empty	65.61	0.00	0.00
IT	Cyclopoid, Oithona sp., general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	9.32
S	Cyclopoid, Oithona similis, general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.23	0.00	0.00
SC	Cyclopoid, Oithona copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	1.79	0.00	0.00
CP	Calanoid, *Pseudocalanus* copepodids I-IV	0.01	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus sp., general	0.09	empty	23.07	0.04	0.00	0.00	empty	0.00	0.00	11.21
PSF	Calanoid, Pseudocalanus AF	0.95	empty	16.97	0.02	0.00	0.00	empty	0.00	0.00	2.49
PSM	Calanoid, Pseudocalanus AM	0.03	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00
Chaetognath											
SGE	Chaetognath, Sagitta (elegans)	0.00	empty	0.00	6.02	0.00	0.00	empty	0.00	0.00	0.00
Cladoceran											
CLA	Cladocera, General	0.61	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00

T	e 18 cont.													
E	Cladoceran, Evadne sp.	0.22	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.10			
P	Cladoceran, Podon sp.	2.40	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.05			
C	**honaute**													
C	Bryozoa, cyphonautes larva	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
D	**apod**													
D	Decapod, megalops, unknown crab	0.00	empty	0.00	0.42	0.00	0.00	empty	0.00	0.00	0.00			
D	Decapod, zoea, Brachyura, general	2.32	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
D	Decapod zoea, crab, Brachyrhyncha	0.43	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
D	Decapod zoea, crab, general unknown	1.82	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.37			
P	Decapod zoea, Shrimp, Pandalidae	0.29	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
P	Decapod zoea, hermit crab, Paguridae	0.00	empty	0.00	0.03	0.00	0.00	empty	0.00	0.00	0.00			
S	Decapod zoea, general shrimp	0.05	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
E	**hausiid**													
E	Euphausiid calyptopis	0.02	empty	0.00	0.05	0.00	0.00	empty	0.00	0.00	0.02			
E	Euphausiid furcilia	0.13	empty	0.00	0.04	0.00	0.00	empty	0.00	0.00	0.11			
E	Euphausiid, general unknown	2.36	empty	0.00	14.96	0.00	0.00	empty	0.00	0.00	0.00			
T	Euphausiid, Thysannoessa sp., gen. adult	0.00	empty	0.00	2.90	0.00	0.00	empty	0.00	0.00	0.00			
T	Euphausiid, Thysannoessa sp. juvenile	0.00	empty	0.00	0.91	0.00	0.00	empty	0.00	0.00	0.00			
T	Euphausiid, T. longipes	0.00	empty	0.00	1.92	0.00	0.00	empty	0.00	0.00	0.00			
Fi														
F	Fish larvae, general	27.65	empty	0.00	3.85	0.00	0.00	empty	0.00	0.00	0.00			
G	**merid**													
G	Amphipod, Gammarid, unknown, medium	0.30	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
G	**tropod**													
G	Gastropod, juv. snail w/ black pigment	1.08	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.08			
G	Gastropoda, general juvenile (SNAIL)	0.00	empty	0.00	0.03	0.00	0.00	empty	0.00	0.00	0.09			
L	Gastropod, Pteropod, Limacina helicina A	0.00	empty	0.00	35.25	0.00	0.00	empty	0.00	0.00	0.00			
L	Gastropod, Pteropod, Limacina helicina J	18.60	empty	0.00	9.07	0.00	0.00	empty	0.00	100.00	0.00			
H	**eriid**													
H	Amphipod, Hyperiid, unknown small (<2mm)	0.11	empty	0.00	0.15	0.00	0.00	empty	0.00	0.00	0.00			
H	Amphipod, Hyperiid, unknown juvenile	1.74	empty	0.00	0.91	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	empty	0.00	2.01	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	empty	0.00	0.04	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, P. macropa, 7+mm	0.00	empty	0.00	0.08	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, Primno macropa, gen.	0.00	empty	0.00	0.31	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.04	empty	0.00	0.33	0.00	0.00	empty	0.00	0.00	0.00			
P	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	empty	0.00	6.96	0.00	0.00	empty	0.00	0.00	0.00			
In	**ct**													
D	Insect, Dipteran adult	0.19	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
IN	Insect, general	0.00	empty	0.00	0.13	0.00	0.00	empty	0.00	0.00	0.00			
L	**acean**													
O	Larvacea, Oikopleura sp.	0.00	empty	0.00	1.44	0.00	0.00	empty	0.00	0.00	39.49			
M	**costracan**													
M	Malacostraca, eyes only	0.13	empty	0.00	0.12	0.00	0.00	empty	0.00	0.00	0.00			
O	**r**													
B	Bivalve, larvae	0.13	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.04			
C	Amphipod, Caprellidae	0.15	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			

able 18 cont.

GG	Unknown invertebrate egg, small (<0.2mm)	0.02	empty	2.44	0.01	0.00	0.00	empty	0.00	0.00	0.96			
GL	Unknown invertebrate egg, large (>0.2mm)	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
RC	Harpacticoid, general copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
RJ	Harpacticoid, Harpacticus copepodite	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
ZZ	Harpacticoid, Zaus sp. general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.00			
SP	Isopod, general	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.37			
LL	Polychaeta, general, juvenile	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.05			
SB	Harpacticoid, Tisbe sp., adult	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			
SC	Harpacticoid, Tisbe copepodite	0.00	empty	5.69	0.00	0.00	0.00	empty	0.00	0.00	0.03			
SG	Harpacticoid, Tisbe sp., gravid female	0.00	empty	0.00	0.00	0.00	0.00	empty	0.00	0.00	0.01			

able 18 cont.

) Northeast Area PWS

	species	herring	herring	pollock	pollock	sandlance	herring	sandlance	herring
	size group	1	0	2	2	0	1	0	0
	station-haul	22-2	27-1	29-1	82-1	82-1	116	118	118
pcd									
arnacle									
MC	Barnacle, cyprid	0.02	0.26	0.00	0.00	0.00	0.00	19.45	empty
MP	Barnacle, nauplius	0.00	0.06	0.00	0.00	0.00	0.00	0.00	empty
alanoid copepod-large									
AL	Calanoid, general large (>2.5 mm)	26.84	2.94	42.94	24.17	0.00	0.95	0.00	empty
LN	Calanoid, large, Neocalanus/Calanus	17.94	0.00	12.77	21.58	0.00	0.95	0.00	empty
M	Calanoid, Calanus marshallae	0.00	0.00	16.14	0.00	7.77	2.41	0.00	empty
MF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	1.87	0.18	0.00	empty
PG	Calanoid, Calanus sp. general	0.00	0.00	1.61	0.00	82.01	0.00	0.00	empty
PF	Calanoid, Epilabidocera longipedata, AF	0.14	0.00	0.00	0.00	0.00	0.00	0.00	empty
PI	Calanoid, Epilabidocera longipedata, gen	0.03	0.00	0.00	0.00	0.00	0.00	0.00	empty
PM	Calanoid, Epilabidocera longipedata, AM	0.03	0.00	0.00	0.00	0.00	0.19	0.00	empty
1G	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.00	0.00	0.08	0.00	empty
1OF	Calanoid, Metridia ochotensis AF	0.00	0.00	0.00	0.00	0.00	0.20	0.00	empty
1PF	Calanoid, Metridia pacifica, AF	0.00	0.00	1.21	0.00	0.00	2.33	0.00	empty
ICP	Calanoid, Neocalanus spp. copepodite	0.00	0.00	0.00	0.00	0.90	0.00	0.00	empty
IEO	Calanoid, Neocalanus spp. adult	0.00	0.00	0.00	0.00	4.91	0.24	0.00	empty
IPF	Calanoid, Neocalanus plumchrus AF	0.00	0.00	0.00	0.00	2.46	0.00	0.00	empty
alanoid copepod-small									
C	Calanoid, Acartia sp.	0.03	0.03	0.00	0.00	0.00	0.08	0.00	empty
CA	Calanoid, Acartia clausi adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
CC	Calanoid, Acartia clausi copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
LG	Calanoid, Acartia longiremis , General	0.01	0.00	0.00	0.00	0.00	0.00	0.00	empty
A	Calanoid, Centropages abdominalis, gen.	0.00	2.04	0.00	0.00	0.00	0.00	0.25	empty
AF	Calanoid, Centropages abdominalis, AF	0.05	0.45	0.00	0.00	0.00	0.00	0.00	empty
AN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
AS	Calanoid, general small (<2.5 mm)	23.74	35.43	0.65	0.29	0.08	3.83	44.76	empty
YF	Calanoid, Eurytemora pacifica AF	0.00	0.02	0.00	0.00	0.00	0.00	0.00	empty
YT	Calanoid, Eurytemora pacifica, general	0.00	0.12	0.00	0.00	0.00	0.00	0.00	empty
S	Cyclopoid, Oithona similis, general	0.02	0.00	0.00	0.00	0.00	0.00	0.00	empty
SF	Cyclopoid, Oithona similis AF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
CP	Calanoid, Pseudocalanus copepodids I-IV	0.11	1.11	0.00	0.00	0.00	0.00	0.00	empty
SA	Calanoid, Pseudocalanus sp., general	6.96	30.16	0.15	0.00	0.00	4.47	0.00	empty

able 18 cont.									
SF	Calanoid, Pseudocalanus AF	11.88	18.51	0.00	0.00	0.00	1.96	0.00	empty
haetognath									
HT	Chaetognath, species unknown	0.00	0.00	0.45	16.28	0.00	0.00	0.00	empty
ladocera									
LA	Cladocera, General	0.00	0.10	0.00	0.00	0.00	0.00	0.00	empty
VD	Cladoceran, Evadne sp.	0.00	0.07	0.00	0.00	0.00	0.08	2.43	empty
ON	Cladoceran, Podon sp.	0.16	5.84	0.00	0.00	0.00	0.03	2.53	empty
yphonaute									
FN	Bryozoa, cyphonautes larva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
Decapod									
DCM	Decapod, megalops, unknown crab	0.00	0.00	5.54	0.00	0.00	0.00	0.00	empty
DGB	Decapod, zoea, Brachyura, general	0.46	0.00	0.00	0.00	0.00	6.35	0.00	empty
DMG	Decapod, megalops, Brachyura	0.00	0.00	0.00	2.59	0.00	0.00	0.00	empty
DML	Decapod, megalops, Lithodidae	0.17	0.00	0.00	0.00	0.00	0.00	0.00	empty
DMP	Decapod, megalops, Paguridae	0.00	0.40	0.00	0.00	0.00	0.00	0.00	empty
DZB	Decapod zoea, crab, Brachyrhyncha	0.74	0.07	0.00	0.00	0.00	0.00	0.00	empty
DZG	Decapod zoea, crab, general unknown	0.65	0.00	0.00	0.00	0.00	1.44	0.00	empty
DZP	Decapod zoea, crab, Pisinae	0.00	0.00	0.00	0.00	0.00	0.14	0.00	empty
HIE	Decapod zoea, Shrimp, Hippolytidae	0.08	0.00	0.00	0.00	0.00	0.00	0.00	empty
LIZ	Decapod zoea, Anomuran, Lithodidae	0.22	0.00	0.00	0.00	0.00	0.37	0.00	empty
PDZ	Decapod zoea, Shrimp, Pandalidae	0.00	0.10	0.00	0.00	0.00	0.00	0.00	empty
PGZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.67	0.00	empty
SHP	Decapod,Shrimp, gen. unknown juv./adult	0.00	0.00	0.00	4.60	0.00	0.00	0.00	empty
SHR	Decapod zoea, general shrimp	0.00	0.01	0.00	0.00	0.00	0.04	0.00	empty
Euphausiid									
EU3	Euphausiid calyptopis	0.00	0.11	0.00	0.00	0.00	0.02	0.00	empty
EU4	Euphausiid furcilia	0.12	0.03	0.00	0.00	0.00	0.12	0.00	empty
EUP	Euphausiid, general unknown	0.17	0.00	0.00	16.25	0.00	0.00	0.00	empty
TL	Euphausiid, T. longipes	0.00	0.00	0.00	7.63	0.00	0.00	0.00	empty
Fish									
FSE	Fish egg (~1.0 mm)	0.00	0.12	0.00	0.00	0.00	0.00	0.00	empty
Gastropod									
GSB	Gastropod, juv. snail w/ black pigment	0.03	0.09	0.00	0.00	0.00	0.11	0.00	empty
GST	Gastropoda, general juvenile (SNAIL)	0.09	0.02	0.00	0.00	0.00	0.02	0.83	empty
LMJ	Gastropod, Pteropod, Limacina helicina J	0.91	0.03	0.00	0.00	0.00	14.34	1.81	empty
Hyperiid									
HYB	Amphipod, Hyperiid, unknown small (<2mm)	0.00	0.65	0.00	0.00	0.00	0.18	0.00	empty
HYP	Amphipod, Hyperiid, unknown juvenile	4.11	0.00	12.10	3.00	0.00	4.97	20.42	empty

able 18 cont.									
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.03	0.00	0.00	0.00	0.00	0.00	0.00	empty
S1	Amphipod, Hyperiid, Parathemisto sp.<2mm	0.03	0.00	0.00	0.00	0.00	0.07	0.00	empty
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.25	0.00	0.00	0.00	0.00	0.00	0.00	empty
arvacean									
KP	Larvacea, Oikopleura sp.	0.97	0.00	0.20	0.18	0.00	48.63	1.82	empty
alacostracan									
AE	Malacostraca, eyes only	0.24	0.03	0.00	3.42	0.00	1.40	0.00	empty
AL	Malacostraca	0.38	0.22	6.19	0.00	0.00	2.54	0.00	empty
ther									
VL	Bivalve, larvae	0.00	0.01	0.00	0.00	0.00	0.00	0.19	empty
GG	Unknown invertebrate egg, small (<0.2mm)	2.38	0.93	0.01	0.00	0.00	0.62	0.10	empty
GL	Unknown invertebrate egg, large (>0.2mm)	0.01	0.01	0.00	0.00	0.00	0.00	0.00	empty
EM	Harpacticoid, general eggsac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
R	Harpacticoid, general, unknown stage	0.00	0.01	0.05	0.00	0.00	0.00	2.81	empty
RC	Harpacticoid, general copepodite	0.00	0.02	0.00	0.00	0.00	0.00	1.65	empty
ZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.26	empty
AC	Harpacticoid, Laophontidae, copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.08	empty
AO	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.23	empty
LL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.01	0.00	empty
SC	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.36	empty
EM	Unknown egg mass	0.00	0.00	0.00	0.01	0.00	0.00	0.00	empty
NI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty
NP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty

ab 18 cont.

uthwest Area PWS, summer 1995

	species	herring	capelin	capelin	tomcod	pollock	capelin	herring
	size group	0	0	0	1	0	0	1
	station-haul	43-1	43-1	47-1	51-1	51-1	100	107
pC								
acle								
M	Barnacle, cyprid	0.05	0.00	0.00	0.02	0.48	0.00	0.00
M	Barnacle, nauplius	0.13	0.00	0.00	0.00	0.00	0.00	0.00
M		0.00	0.00	0.00	1.79	0.00	0.00	0.00
noid copepod-large								
A	Calanoid, general large (>2.5 mm)	0.76	0.00	0.00	0.00	0.75	0.00	0.00
L	Calanoid, large, Neocalanus/Calanus	0.00	0.00	0.00	0.00	0.75	0.00	0.00
M 1	Calanoid, Calanus marshallae AM	0.24	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Calanus pacificus, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Calanus pacificus, general	0.16	0.00	0.00	0.00	0.00	0.00	0.00
F	Calanoid, Calanus sp. general	0.00	0.00	0.00	0.00	0.00	0.00	0.01
EF	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.03	0.00	0.00	0.00
MC	Calanoid, Metridia sp., General	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Mi	Calanoid, Metridia pacifica, AF	0.00	0.00	0.00	0.01	1.32	0.00	0.00
noid copepod-small								
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.00	0.44	0.00	0.07
AL	Calanoid, Acartia longiremus copepodite	0.00	0.00	0.00	0.00	0.01	0.00	0.00
AL	Calanoid, Acartia longiremis AF	0.01	0.00	0.00	0.00	0.25	0.00	0.00
AL	Calanoid, Acartia longiremis , General	0.00	0.00	0.00	0.00	0.24	0.00	0.00
C	Calanoid, Centropages *abdominalis*, gen.	4.73	0.00	0.00	0.00	4.21	0.00	0.01
C C	Calanoid, Centropages abdominalis, copdt	0.02	0.00	0.00	0.00	0.00	0.00	0.00
C	Calanoid, Centropages abdominalis, AF	2.26	0.00	0.00	0.00	0.76	0.00	0.00
C M	Calanoid, Centropages abdominalis, AM	0.07	0.00	0.00	0.00	0.00	0.00	0.00
C S	Calanoid, general small (<2.5 *mm*)	40.09	100.00	21.00	0.01	58.85	0.00	62.52
C V		0.00	0.00	0.00	0.00	0.04	0.00	0.00
C S	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.06	89.16	0.00
E T	Calanoid, Eurytemora pacifica, general	0.00	0.00	0.00	0.00	0.00	0.00	0.02
O	Cyclopoid, Oithona sp., general	0.00	0.00	0.00	0.00	0.02	0.00	0.00
C	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.01	0.00	0.02
P P	Calanoid, Pseudocalanus copepodids I-IV	1.49	0.00	9.88	0.00	0.08	0.00	0.00
P A	Calanoid, Pseudocalanus sp., general	20.75	0.00	39.81	0.00	12.59	0.00	12.64
P F	Calanoid, Pseudocalanus AF	12.51	0.00	0.00	0.00	6.06	0.00	14.91
F G	Calanoid, Pseudocalanus GF	0.00	0.00	29.30	0.00	0.00	0.00	0.00

Table 18 cont.								
F 3N	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladoceran								
C LA	Cladocera, General	0.01	0.00	0.00	0.00	0.70	0.00	0.02
E /D	Cladoceran, Evadne sp.	0.07	0.00	0.00	0.00	1.21	0.00	0.00
F ON	Cladoceran, Podon sp.	0.15	0.00	0.00	0.00	0.94	0.00	0.00
Decapod								
D GE	Decapod, zoea, Brachyura, general	1.31	0.00	0.00	0.00	0.00	0.00	0.17
D ZE	Decapod zoea, crab, Brachyrhyncha	0.00	0.00	0.00	0.00	0.00	0.00	0.17
D ZC	Decapod zoea, crab, general unknown	3.20	0.00	0.00	0.00	0.00	0.00	0.30
F DZ	Decapod zoea, Shrimp, Pandalidae	0.22	0.00	0.00	0.00	0.00	0.00	0.00
F GZ	Decapod zoea, hermit crab, Paguridae	0.00	0.00	0.00	0.00	0.00	0.00	0.01
S HF	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiid								
E J3	Euphausiid calyptopis	0.01	0.00	0.00	0.00	0.00	0.00	0.00
E J4	Euphausiid furcilia	0.33	0.00	0.00	0.01	0.00	0.00	0.01
E JJ	Euphausiid juvenile, general	1.22	0.00	0.00	0.00	1.21	0.00	0.00
E JF	Euphausiid, general unknown	0.00	0.00	0.00	0.16	0.00	0.00	0.00
Fish								
F J	Fish, juvenile, general	0.00	0.00	0.00	15.08	0.00	0.00	0.00
F V2	Fish, walleye pollock, (41-60mm)	0.00	0.00	0.00	25.70	0.00	0.00	0.00
F V3	Fish, walleye pollock, (61-80mm)	0.00	0.00	0.00	33.86	0.00	0.00	0.00
Gammarid								
C GC	Amphipod, Gammarid, Calliopius	0.00	0.00	0.00	1.82	0.00	0.00	0.00
G A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.47	0.00	0.00	0.00
G A2	Amphipod, Gammarid, unknown, medium	0.00	0.00	0.00	2.46	0.00	0.00	0.00
G A3	Amphipod, Gammarid, unknown, large	0.00	0.00	0.00	16.25	0.00	0.00	0.00
G AM	Amphipod, Gammarid head	0.00	0.00	0.00	0.15	0.00	0.00	0.00
G AU	Amphipod, Gammarid, unknown, no size	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Gastropod								
L IJ	Gastropod, Pteropod, Limacina helicina J	0.06	0.00	0.00	0.00	0.00	0.00	0.65
Hyperiid								
H B	Amphipod, Hyperiid, unknown small (<2mm)	1.86	0.00	0.00	0.00	0.34	0.00	0.00
H F	Amphipod, Hyperiid, unknown juvenile	1.97	0.00	0.00	0.00	7.86	0.00	0.92
P 1	Amphipod, P. pacifica juvenile, <2mm	0.06	0.00	0.00	0.00	0.00	0.00	0.00
P 1	Amphipod, Hyperiid, Primno macropa, <2mm	0.16	0.00	0.00	0.00	0.00	0.00	0.01
P I	Amphipod, Hyperiid, Primno macropa, gen.	0.67	0.00	0.00	0.00	0.00	0.00	0.00
P 1	Amphipod, Hyperiid, Parathemisto sp.<2mm	1.28	0.00	0.00	0.00	0.00	0.00	0.00
P 2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	1.31	0.00	0.00	0.00	0.00	0.00	0.00

T le 18 cont.								
ect								
D L	Insect, Dipteran larvae	0.00	0.00	0.00	0.01	0.00	0.00	0.00
vacean								
C P	Larvacea, Oikopleura sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.06
lacostracan								
M E	Malacostraca, eyes only	0.20	0.00	0.00	0.00	0.00	0.00	0.00
M L	Malacostraca	0.00	0.00	0.00	0.36	0.00	0.00	0.00
ner								
B L	Bivalve, larvae	0.02	0.00	0.00	0.00	0.03	0.00	0.00
B P	Bivalve pieces (shell + muscle)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C M	Cumacea	0.00	0.00	0.00	0.07	0.09	0.00	0.00
E G	Unknown invertebrate egg, small (<0.2mm)	2.64	0.00	0.00	0.00	0.58	10.84	7.43
E L	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.03
H M	Harpacticoid, general eggsac	0.00	0.00	0.00	0.01	0.00	0.00	0.00
H	Harpacticoid, general, unknown stage	0.01	0.00	0.00	0.01	0.00	0.00	0.00
H C	Harpacticoid, general copepodite	0.00	0.00	0.00	0.00	0.07	0.00	0.00
H J	Harpacticoid, Harpacticus copepodite	0.00	0.00	0.00	0.00	0.01	0.00	0.00
H S	Harpacticoid, Harpacticus sp. general ad	0.00	0.00	0.00	0.04	0.00	0.00	0.00
I N	Isopod, Gnorimosphaeroma species	0.00	0.00	0.00	1.33	0.00	0.00	0.00
L O	Harpacticoid, Laophontidae, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N M	Nematode	0.00	0.00	0.00	0.00	0.03	0.00	0.00
P O	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P A	Polychaeta, adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P L	Polychaeta, general, juvenile	0.01	0.00	0.00	0.03	0.00	0.00	0.00
T B	Harpacticoid, Tisbe sp., adult	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T C	Harpacticoid, Tisbe copepodite	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T G	Harpacticoid, Tisbe sp., gravid female	0.00	0.00	0.00	0.01	0.00	0.00	0.00
U I	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 19. Total numbers and percent numbers of major groups of prey organisms in forage fish stomachs by *species-size group (n = 10 each) at stations in central, northeastern and southwestern PWS in fall, 1995.*

Central Area PWS							
Total number							
species	capelin	pollock	pollock	capelin	pollock	pollock	herring
size group	0	0	2	0	0	2	0
station-haul	3-1	3-1	3-2	4-2	4-3	4-3	5-1
SUMCODE							
Barnacle	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	1738.00	373.00	0.00	130.00	8.00	981.00
Calanoid copepod-small	10.00	59.00	8.00	28.00	32.00	4.00	657.00
Chaetognath	0.00	74.00	11.00	0.00	2.00	0.00	26.00
Cladocera	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	1.00	0.00	3.00	0.00	2.00
Euphausiid	4.00	108.00	223.00	2.00	3.00	4.00	54.00
Fish	0.00	1.00	1.00	0.00	0.00	2.00	0.00
Gammarid	0.00	0.00	0.00	0.00	1.00	1.00	1.00
Gastropod	0.00	3.00	0.00	0.00	0.00	0.00	29.00
Hyperiid	0.00	9.00	9.00	0.00	0.00	5.00	18.00
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	0.00	2.00	0.00	2.00	0.00	1945.00
Malacostracan	0.00	0.00	19.00	0.00	10.00	1.00	19.00
Other	6.00	3.00	7.00	1.00	1.00	4.00	127.00
TOTAL	20.00	1995.00	654.00	31.00	185.00	29.00	3859.00
Central Area PWS							
% Number							
species	capelin	pollock	pollock	capelin	pollock	pollock	herring
size group	0	0	2	0	0	2	0
station-haul	3-1	3-1	3-2	4-2	4-3	4-3	5-1
SUMCODE							
Barnacle	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	87.12	57.03	0.00	70.27	27.59	25.42
Calanoid copepod-small	50.00	2.96	1.22	90.32	17.30	13.79	17.03
Chaetognath	0.00	3.71	1.68	0.00	1.08	0.00	0.67
Cladocera	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	0.15	0.00	1.62	0.00	0.05

Table 19 cont.										
Euphausiid	20.00	5.41	34.10	6.45	1.62	13.79	1.40			
Fish	0.00	0.05	0.15	0.00	0.00	6.90	0.00			
Gammarid	0.00	0.00	0.00	0.00	0.54	3.45	0.03			
Gastropod	0.00	0.15	0.00	0.00	0.00	0.00	0.75			
Hyperiid	0.00	0.45	1.38	0.00	0.00	17.24	0.47			
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Larvacean	0.00	0.00	0.31	0.00	1.08	0.00	50.40			
Malacostracan	0.00	0.00	2.91	0.00	5.41	3.45	0.49			
Other	30.00	0.15	1.07	3.23	0.54	13.79	3.29			
Northeastern Area										
Total Number										
species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
size group	0	0	0	0	0	2	0	1	0	0
station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Calanoid copepod-large	133.00	618.00	1352.00	42.00	362.00	336.00	0.00	0.00	0.00	0.00
Calanoid copepod-small	694.00	114.00	192.00	351.00	56.00	11.00	3.00	0.00	0.00	4.00
Chaetognath	1.00	1.00	0.00	0.00	5.00	4.00	0.00	0.00	0.00	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute	62.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiid	14.00	27.00	2.00	7.00	10.00	22.00	5.00	2.00	0.00	0.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammarid	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod	8.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Hyperiid	0.00	0.00	52.00	2.00	4.00	16.00	0.00	0.00	0.00	0.00
Insect	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	8264.00	11.00	3712.00	40.00	49.00	1.00	0.00	0.00	0.00	0.00
Malacostracan	0.00	7.00	6.00	7.00	0.00	0.00	0.00	1.00	0.00	0.00
Other	96.00	3.00	102.00	19.00	2.00	6.00	1.00	0.00	0.00	0.00
TOTAL	9273.00	783.00	5422.00	468.00	488.00	397.00	9.00	4.00	0.00	4.00
Northeastern Area PWS										
% Numbers										
species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
size group	0	0	0	0	0	2	0	1	0	0

Table 19 cont.										
station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	empty	0.00
Calanoid copepod-large	1.43	78.93	24.94	8.97	74.18	84.63	0.00	0.00	empty	0.00
Calanoid copepod-small	7.48	14.56	3.54	75.00	11.48	2.77	33.33	0.00	empty	100.00
Chaetognath	0.01	0.13	0.00	0.00	1.02	1.01	0.00	0.00	empty	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Cyphonaute	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Decapod	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	empty	0.00
Euphausiid	0.15	3.45	0.04	1.50	2.05	5.54	55.56	50.00	empty	0.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gammarid	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gastropod	0.09	0.13	0.00	0.00	0.00	0.00	0.00	25.00	empty	0.00
Hyperiid	0.00	0.00	0.96	0.43	0.82	4.03	0.00	0.00	empty	0.00
Insect	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Larvacean	89.12	1.40	68.46	8.55	10.04	0.25	0.00	0.00	empty	0.00
Malacostracan	0.00	0.89	0.11	1.50	0.00	0.00	0.00	25.00	empty	0.00
Other	1.04	0.38	1.88	4.06	0.41	1.51	11.11	0.00	empty	0.00
Southwestern Area PWS										
Total number										
species	herring	herring	pollock	pollock						
size group	0	1	0	1						
station-haul	2-1	2-1	2-1	2-1						
n	2	8	10	10						
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00						
Calanoid copepod-large	0.00	0.00	6.00	27.00						
Calanoid copepod-small	812.00	11.00	36.00	1.00						
Chaetognath	0.00	0.00	3.00	3.00						
Cladocera	1.00	0.00	1.00	0.00						
Cyphonaute	1.00	0.00	0.00	0.00						
Decapod	0.00	0.00	0.00	0.00						
Euphausiid	0.00	4.00	3.00	6.00						
Fish	0.00	0.00	0.00	0.00						
Gammarid	0.00	0.00	0.00	4.00						
Gastropod	9.00	0.00	0.00	0.00						
Hyperiid	0.00	1.00	3.00	0.00						

Table 19 cont.

Insect	0.00	0.00	0.00	0.00
Larvacean	841.00	14.00	24.00	1.00
Malacostracan	1.00	0.00	0.00	8.00
Other	9659.00	1.00	4.00	5.00
TOTAL	11324.00	31.00	80.00	55.00
Southwestern Area PWS				
% Number				
species	herring	herring	pollock	pollock
size group	0	1	0	1
station-haul	2-1	2-1	2-1	2-1
n	2	8	10	10
SUMCODE				
Barnacle	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	0.00	7.50	49.09
Calanoid copepod-small	7.17	35.48	45.00	1.82
Chaetognath	0.00	0.00	3.75	5.45
Cladocera	0.01	0.00	1.25	0.00
Cyphonaute	0.01	0.00	0.00	0.00
Decapod	0.00	0.00	0.00	0.00
Euphausiid	0.00	12.90	3.75	10.91
Fish	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	0.00	7.27
Gastropod	0.08	0.00	0.00	0.00
Hyperiid	0.00	3.23	3.75	0.00
Insect	0.00	0.00	0.00	0.00
Larvacean	7.43	45.16	30.00	1.82
Malacostracan	0.01	0.00	0.00	14.55
Other	85.30	3.23	5.00	9.09

able 20. Numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at stations
central, northeastern and southwestern PWS in fall, 1995.

Region	SW	SW	SW	SW	C	C	C	C	C	C	C	NE	NE	NE	NE	NE	NE	NE	NE
Station-haul	2-1	2-1	2-1	2-1	3-1	3-1	3-2	4-2	4-3	4-3	5-1	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2
n	8	8	2	2															
size group	1	1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	1	0	2
species	herring	pollock	pollock	herring	capelin	pollock	pollock	capelin	pollock	pollock	herring	herring	pollock	herring	pollock	eulachon	eulachon	pollock	pollock
SPCD																			
AC				8.00								0.00	1.00	0.00	13.00	0.00			
AL																			
ALC																			
ALF				4.00										0.00	1.00	0.00		1.00	0.00
ALG																			
ALM			1.00	0.00															
BCT																			
BMC																			
BMM																			
BMP																		0.00	1.00
BRC			1.00	0.00															
BRF			1.00	0.00															
BRG			1.00	0.00															
BVJ																			
BVL				5.00				1.00				25.00	0.00	5.00	0.00	0.00			
CA														0.00	60.00	0.00			
CAC														0.00	3.00	0.00			
CAF											3.00			0.00	2.00	0.00			
CAL	0.00	6.00	3.00	0.00	0.00	53.00	16.00	0.00	93.00	4.00	56.00	11.00	54.00	41.00	15.00	0.00		27.00	15.00
CAM														0.00	34.00	0.00			
CAN														0.00	3.00	0.00		1.00	0.00
CAS	11.00	1.00	18.00	793.00	0.00	49.00	8.00	0.00	28.00	3.00	226.00	629.00	73.00	96.00	223.00	3.00		45.00	11.00
CCC																			
CCG																			
CCL												1.00	0.00						
CCP	0.00	1.00	0.00		0.00	32.00	4.00				20.00								
CFN				1.00								62.00	0.00						
CGF																			
CHT	0.00	2.00	0.00		0.00	7.00	10.00	0.00	2.00	0.00	3.00	1.00	1.00			0.00		4.00	2.00
CLA				1.00															
CLN					0.00	14.00	2.00	0.00	10.00	0.00	25.00								
CM					0.00	1.00	0.00												
CMC						0.00	1.00					0.00	1.00	0.00	2.00	0.00		2.00	0.00
CMF					0.00	2.00	0.00												
CNC																			
CNI																			
CNS	0.00	1.00	0.00																
COS				7.00	10.00			28.00	0.00	0.00	6.00	9.00	0.00						
CPC					0.00	5.00	0.00												
CPF					0.00	117.00	4.00				27.00			4.00	0.00	0.00			

Table 20 cont.																			
CPM					0.00	2.00	0.00												
CPV																			
CUM	0.00	2.00	1.00	0.00															
CTE																			
CTO																			
DPL												1.00	0.00						
DZG								0.00	2.00	0.00				2.00	0.00	0.00			
EBC																			
EBL																			
EBP																			
ECC											1.00								
ECF											2.00								
ECM					0.00	2.00	0.00												
EEF											2.00								
EGG				9652.00	6.00						122.00	8.00	1.00	45.00	15.00	1.00			
EGL												36.00	1.00						
EP1						0.00	114.00	0.00	0.00	1.00									
EP2					0.00	2.00	0.00												
EP3					0.00	4.00	4.00	0.00	0.00	1.00									
EPC											2.00								
EPF											3.00								
EPI																			
EPM																			
EPP						0.00	1.00					0.00	3.00					0.00	1.00
EU2								0.00	1.00	0.00									
EU3								2.00	0.00	0.00	1.00								
EU4	1.00	0.00			0.00	46.00	4.00				11.00								
EUB																			
EUE																0.00		1.00	3.00
EUJ	2.00	5.00	0.00		1.00	34.00	88.00				42.00			1.00	5.00	5.00	1.00	0.00	20.00
EUP	1.00	1.00	3.00	0.00	0.00	17.00	8.00	0.00	2.00	2.00		5.00	9.00	0.00	1.00	0.00		4.00	1.00
FSE																			
FSL					0.00	1.00	1.00	0.00	0.00	2.00									
GA1	0.00	1.00	0.00																
GA2	0.00	1.00	0.00									0.00	1.00						
GA3								0.00	0.00	1.00									
GAU	0.00	2.00	0.00					0.00	1.00	0.00	1.00								
GON																			
GSB																			
GST				9.00							3.00	8.00	0.00						
HIE											2.00								
HP					0.00	2.00	0.00												
HR												6.00	1.00	0.00	2.00	0.00		1.00	0.00
HRC				1.00								1.00	0.00						
HRN																			
HYA								0.00	0.00	1.00									
HYB					0.00	2.00	3.00				2.00			4.00	0.00	0.00		2.00	0.00

Table 20 cont.																			
HYP	1.00	0.00	3.00	0.00	0.00	2.00	2.00	0.00	0.00	3.00	6.00			20.00	2.00	0.00		1.00	9.00
HZC												8.00	0.00						
HZZ												9.00	0.00						
ISC											1.00								
ISP														1.00	0.00	0.00			
LAC																			
LMA												0.00	1.00						
LMJ					0.00	3.00	0.00				26.00						1.00		
MAE	0.00	6.00	0.00	1.00		0.00	19.00	0.00	10.00	1.00	19.00	0.00	5.00	2.00	5.00	0.00	1.00		
MAL	0.00	2.00	0.00									0.00	2.00	1.00	0.00	0.00			
MCP																			
MCS											17.00	0.00	146.00			0.00		1.00	0.00
MEF								0.00	0.00	1.00	20.00								
MEG											11.00	1.00	0.00						
MEP					0.00	203.00	84.00	0.00	0.00	2.00	313.00	43.00	0.00			0.00		2.00	0.00
MES											10.00								
MG	0.00	2.00	0.00									0.00	4.00						
MGF			2.00	0.00															
MP																		0.00	64.00
MPC					0.00	107.00	5.00				312.00	61.00	338.00	0.00	4.00	0.00		16.00	5.00
MPF	0.00	16.00	1.00	0.00	0.00	1150.00	257.00	0.00	26.00	2.00	201.00	17.00	75.00	631.00	21.00	0.00		313.00	249.00
MPM	0.00	1.00	0.00		0.00	48.00	0.00												
MUJ																			
MYA														0.00	2.00	0.00			
MYS	0.00	2.00	0.00																
MVI																			
NCP																			
NEM	1.00	0.00	1.00	0.00	0.00	3.00	7.00	0.00	1.00	4.00								0.00	1.00
NEO					0.00	2.00	0.00	0.00	1.00	0.00									
NPF	0.00	1.00	0.00																
OED																			
OI1				113.00								7304.00	0.00						
OIT																			
OKI																			
OKP	14.00	1.00	24.00	728.00		0.00	2.00	0.00	2.00	0.00	1945.00	960.00	11.00	1856.00	40.00	0.00		49.00	1.00
OS								0.00	1.00	0.00	18.00	9.00	0.00						
OSC																			
OSF																			
OSM																			
OST																			
OTF																			
OTS																			
PAA																			
PA2					0.00	2.00	1.00				3.00					0.00		1.00	2.00
PAN						0.00	1.00												
PCO												1.00	0.00						
PCP											81.00								

able 20 cont.																			
PDZ																			
PGZ								0.00	1.00	0.00									
PLA																0.00		1.00	0.00
PLC																			
PL3																		0.00	1.00
PLL				1.00							1.00	2.00	0.00					0.00	2.00
PON			1.00	0.00				0.00	1.00	0.00									
PRI											2.00								
PR1											2.00								
PR2																		0.00	3.00
PS						0.00	1.00												
PS1								0.00	0.00	1.00	3.00								
PS2					0.00	1.00	2.00											0.00	1.00
PSA			7.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	122.00	32.00	13.00	0.00	7.00	0.00		3.00	0.00
PSF			5.00	0.00	0.00	5.00	0.00	0.00	1.00	0.00	160.00	13.00	27.00	0.00	3.00	0.00		6.00	0.00
PSG																			
PSM			1.00	0.00	0.00	3.00	0.00							0.00	2.00	0.00			
PUN																		0.00	2.00
SGE		1.00	3.00	0.00	0.00	67.00	1.00				23.00					0.00		1.00	2.00
SHC																			
SHR														1.00	0.00	0.00			
SIP																			
TL																			
TH					0.00	2.00	1.00					2.00	5.00	0.00	1.00	0.00		5.00	0.00
THJ					3.00	2.00	2.00												
TOR			1.00	0.00								1.00	0.00						
TRF												1.00	0.00				1.00		
TRG												1.00	10.00						
TRK																			
TRM												5.00	0.00			0.00		1.00	0.00
TS					0.00	1.00	1.00												
UNI			1.00	0.00										0.00	2.00	0.00		0.00	1.00
UNP			1.00	0.00															
VEL																			

able 21. Percent numbers of prey species observed in forage fish stomachs by species-size group (n = 10 each) at tations in central, northeastern and southwestern PWS in fall, 1995.

Region	SW	SW	SW	SW	C	C	C	C	C	C	C	NE	NE	NE	NE	NE	NE	NE	NE
Station-haul	2-1	2-1	2-1	2-1	3-1	3-1	3-2	4-2	4-3	4-3	5-1	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2
n	8	8	2	2															
size group	1	1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	1	0	2
species	herring	pollock	pollock	herring	capelin	pollock	pollock	capelin	pollock	pollock	herring	herring	pollock	herring	pollock	eulachon	eulachon	pollock	pollock
SPCM																			
AC	0.00	0.00	0.00	0.07	0.00	0.00	0.00				0.00	0.00	0.13	0.00	2.78	0.00	0.00	0.00	0.00
AL								0.00	0.00	0.00									
ALC											0.00			0.00	0.00	0.00	0.00	0.00	0.00
ALF	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.21	0.00	0.00	0.20	0.00
ALG								0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
ALM	0.00	0.00	1.25	0.00	0.00	0.00	0.00				0.00			0.00	0.00	0.00	0.00	0.00	0.00
BCT					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
BMC					0.00	0.00	0.00	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.00	0.00
BMM					0.00	0.00	0.00												
BMP														0.00	0.00	0.00	0.00	0.00	0.25
BRC	0.00	0.00	1.25	0.00															
BRF	0.00	0.00	1.25	0.00							0.00								
BRG	0.00	0.00	1.25	0.00															
BVJ					0.00	0.00	0.00												
BVL	0.00	0.00	0.00	0.04	0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.27	0.00	0.18	0.00	0.00	0.00	0.00	0.00
CA														0.00	12.82	0.00	0.00	0.00	0.00
CAC														0.00	0.64	0.00	0.00	0.00	0.00
CAF					0.00	0.00	0.00				0.08			0.00	0.43	0.00	0.00	0.00	0.00
CAL	0.00	10.91	3.75	0.00	0.00	2.66	2.45	0.00	50.27	13.79	1.45	0.12	6.90	1.51	3.21	0.00	0.00	5.53	3.78
CAM														0.00	7.26	0.00	0.00	0.00	0.00
CAN					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.64	0.00	0.00	0.20	0.00
CAS	35.48	1.82	22.50	7.00	0.00	2.46	1.22	0.00	15.14	10.34	5.86	6.78	9.32	3.54	47.65	33.33	0.00	9.22	2.77
CCC											0.00								
CCG					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
CCL											0.00	0.01	0.00						
CCP	0.00	1.82	0.00	0.00	0.00	1.60	0.61	0.00	0.00	0.00	0.52			0.00	0.00	0.00	0.00	0.00	0.00
CFN	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CGF					0.00	0.00	0.00				0.00								
CHT	0.00	3.64	0.00	0.00	0.00	0.35	1.53	0.00	1.08	0.00	0.08	0.01	0.13	0.00	0.00	0.00	0.00	0.82	0.50
CLA	0.00	0.00	0.00	0.01															
CLN					0.00	0.70	0.31	0.00	5.41	0.00	0.65								
CM					0.00	0.05	0.00	0.00	0.00	0.00									
CMC					0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.43	0.00	0.00	0.41	0.00
CMF					0.00	0.10	0.00	0.00	0.00	0.00									
CNC											0.00			0.00	0.00	0.00	0.00	0.00	0.00
CNI					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
CNS	0.00	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
COS	0.00	0.00	0.00	0.06	50.00	0.00	0.00	90.32	0.00	0.00	0.16	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPC					0.00	0.25	0.00												
CPF					0.00	5.86	0.61				0.70			0.15	0.00	0.00	0.00	0.00	0.00
CPM					0.00	0.10	0.00												
CPV											0.00								
CUM	0.00	3.64	1.25	0.00	0.00	0.00	0.00												
CTE											0.00			0.00	0.00	0.00	0.00	0.00	0.00

able 21 cont.																			
CTO								0.00	0.00	0.00									
DPL												0.01	0.00						
DZG								0.00	1.08	0.00				0.07	0.00	0.00	0.00	0.00	0.00
EBC								0.00	0.00	0.00									
EBL					0.00	0.00	0.00				0.00								
EBP					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
ECC											0.03			0.00	0.00	0.00	0.00	0.00	0.00
ECF											0.05								
ECM					0.00	0.10	0.00												
EEF											0.05			0.00	0.00	0.00	0.00	0.00	0.00
EGG	0.00	0.00	0.00	85.23	30.00	0.00	0.00	0.00	0.00	0.00	3.16	0.09	0.13	1.66	3.21	11.11	0.00	0.00	0.00
EGL					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.13	0.00	0.00	0.00	0.00	0.00	0.00
EP1					0.00	0.00	17.43	0.00	0.00	3.45									
EP2					0.00	0.10	0.00												
EP3					0.00	0.20	0.61	0.00	0.00	3.45									
EPC					0.00	0.00	0.00				0.05								
EPF											0.08								
EPI														0.00	0.00	0.00	0.00	0.00	0.00
EPM					0.00	0.00	0.00												
EPP					0.00	0.00	0.15					0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.25
EU2								0.00	0.54	0.00									
EU3					0.00	0.00	0.00	6.45	0.00	0.00	0.03			0.00	0.00	0.00	0.00	0.00	0.00
EU4	3.23	0.00	0.00	0.00	0.00	2.31	0.61	0.00	0.00	0.00	0.29			0.00	0.00	0.00	0.00	0.00	0.00
EUB														0.00	0.00	0.00	0.00	0.00	0.00
EUE														0.00	0.00	0.00	0.00	0.20	0.76
EUJ	6.45	9.09	0.00	0.00	5.00	1.70	13.46	0.00	0.00	0.00	1.09			0.04	1.07	55.56	25.00	0.00	5.04
EUP	3.23	1.82	3.75	0.00	0.00	0.85	1.22	0.00	1.08	6.90		0.05	1.15	0.00	0.21	0.00	0.00	0.82	0.25
FSE					0.00	0.00	0.00							0.00	0.00	0.00	0.00	0.00	0.00
FSL					0.00	0.05	0.15	0.00	0.00	6.90									
GA1	0.00	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00									
GA2	0.00	1.82	0.00	0.00	0.00	0.00	0.00					0.00	0.13						
GA3								0.00	0.00	3.45									
GAU	0.00	3.64	0.00	0.00				0.00	0.54	0.00	0.03								
GON					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
GSB					0.00	0.00	0.00	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.00	0.00
GST	0.00	0.00	0.00	0.08							0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIE											0.05								
HP					0.00	0.10	0.00							0.00	0.00	0.00	0.00	0.00	0.00
HR												0.06	0.13	0.00	0.43	0.00	0.00	0.20	0.00
HRC	0.00	0.00	0.00	0.01								0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HRN														0.00	0.00	0.00	0.00	0.00	0.00
HYA								0.00	0.00	3.45									
HYB					0.00	0.10	0.46	0.00	0.00	0.00	0.05			0.15	0.00	0.00	0.00	0.41	0.00
HYP	3.23	0.00	3.75	0.00	0.00	0.10	0.31	0.00	0.00	10.34	0.16			0.74	0.43	0.00	0.00	0.20	2.27
HZC								0.00				0.09	0.00						
HZZ												0.10	0.00						
ISC					0.00	0.00	0.00				0.03			0.00	0.00	0.00	0.00	0.00	0.00
ISP														0.04	0.00	0.00	0.00	0.00	0.00
LAC					0.00	0.00	0.00												
LMA												0.00	0.13						
LMJ					0.00	0.15	0.00	0.00	0.00	0.00	0.67			0.00	0.00	0.00	25.00	0.00	0.00

Table 21 cont.																			
MAE	0.00	10.91	0.00	0.01	0.00	0.00	2.91	0.00	5.41	3.45	0.49	0.00	0.64	0.07	1.07	0.00	25.00	0.00	0.00
MAL	0.00	3.64	0.00	0.00								0.00	0.26	0.04	0.00	0.00	0.00	0.00	0.00
MCP					0.00	0.00	0.00												
MCS					0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	18.65	0.00	0.00	0.00	0.00	0.20	0.00
MEF					0.00	0.00	0.00	0.00	0.00	3.45	0.52			0.00	0.00	0.00	0.00	0.00	0.00
MEG								0.00	0.00	0.00	0.29	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEP					0.00	10.18	12.84	0.00	0.00	6.90	8.12	0.46	0.00	0.00	0.00	0.00	0.00	0.41	0.00
MES					0.00	0.00	0.00	0.00	0.00	0.00	0.26								
MG	0.00	3.64	0.00	0.00	0.00	0.00	0.00					0.00	0.51						
MGF	0.00	0.00	2.50	0.00															
MP														0.00	0.00	0.00	0.00	0.00	16.12
MPC					0.00	5.36	0.76	0.00	0.00	0.00	8.09	0.66	43.17	0.00	0.85	0.00	0.00	3.28	1.26
MPF	0.00	29.09	1.25	0.00	0.00	57.64	39.30	0.00	14.05	6.90	5.21	0.18	9.58	23.28	4.49	0.00	0.00	64.14	62.72
MPM	0.00	1.82	0.00	0.00	0.00	2.41	0.00												
MUJ					0.00	0.00	0.00												
MYA														0.00	0.43	0.00	0.00	0.00	0.00
MYS	0.00	3.64	0.00	0.00															
MVI								0.00	0.00	0.00									
NCP											0.00			0.00	0.00	0.00	0.00	0.00	0.00
NEM	3.23	0.00	1.25	0.00	0.00	0.15	1.07	0.00	0.54	13.79				0.00	0.00	0.00	0.00	0.00	0.25
NEO					0.00	0.10	0.00	0.00	0.54	0.00									
NPF	0.00	1.82	0.00	0.00															
OED					0.00	0.00	0.00												
OI1	0.00	0.00	0.00	1.00								78.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OIT														0.00	0.00	0.00	0.00	0.00	0.00
OKI								0.00	0.00	0.00									
OKP	45.16	1.82	30.00	6.43	0.00	0.00	0.31	0.00	1.08	0.00	50.44	10.35	1.40	68.49	8.55	0.00	0.00	10.04	0.25
OS					0.00	0.00	0.00	0.00	0.54	0.00	0.47	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OSC														0.00	0.00	0.00	0.00	0.00	0.00
OSF								0.00	0.00	0.00	0.00								
OSM								0.00	0.00	0.00									
OST					0.00	0.00	0.00				0.00								
OTF					0.00	0.00	0.00	0.00	0.00	0.00									
OTS					0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
PAA					0.00	0.00	0.00												
PA2					0.00	0.10	0.15				0.08			0.00	0.00	0.00	0.00	0.20	0.50
PAN					0.00	0.00	0.15												
PCO												0.01	0.00						
PCP					0.00	0.00	0.00	0.00	0.00	0.00	2.10			0.00	0.00	0.00	0.00	0.00	0.00
PDZ														0.00	0.00	0.00	0.00	0.00	0.00
PGZ								0.00	0.54	0.00				0.00	0.00	0.00	0.00	0.00	0.00
PLA														0.00	0.00	0.00	0.00	0.20	0.00
PLC					0.00	0.00	0.00	0.00	0.00	0.00	0.00								
PL3														0.00	0.00	0.00	0.00	0.00	0.25
PLL	0.00	0.00	0.00	0.01	0.00	0.00	0.00				0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.50
PON	0.00	0.00	1.25	0.00				0.00	0.54	0.00									
PRI								0.00	0.00	0.00	0.05			0.00	0.00	0.00	0.00	0.00	0.00
PR1											0.05								
PR2														0.00	0.00	0.00	0.00	0.00	0.76
PS					0.00	0.00	0.15												
PS1					0.00	0.00	0.00	0.00	0.00	3.45	0.08			0.00	0.00	0.00	0.00	0.00	0.00

Table

cont.																			
PS2					0.00	0.05	0.31	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.25
PSA	0.00	0.00	8.75	0.00	0.00	0.10	0.00	0.00	1.08	0.00	3.16	0.35	1.66	0.00	1.50	0.00	0.00	0.61	0.00
PSF	0.00	0.00	6.25	0.00	0.00	0.25	0.00	0.00	0.54	0.00	4.15	0.14	3.45	0.00	0.64	0.00	0.00	1.23	0.00
PSG					0.00	0.00	0.00				0.00			0.00	0.00	0.00	0.00	0.00	0.00
PSM	0.00	0.00	1.25	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00			0.00	0.43	0.00	0.00	0.00	0.00
PUN														0.00	0.00	0.00	0.00	0.00	0.50
SGE	0.00	1.82	3.75	0.00	0.00	3.36	0.15	0.00	0.00	0.00	0.60			0.00	0.00	0.00	0.00	0.20	0.50
SHC					0.00	0.00	0.00												
SHR														0.04	0.00	0.00	0.00	0.00	0.00
SIP					0.00	0.00	0.00				0.00			0.00	0.00	0.00	0.00	0.00	0.00
TL														0.00	0.00	0.00	0.00	0.00	0.00
TH					0.00	0.10	0.15					0.02	0.64	0.00	0.21	0.00	0.00	1.02	0.00
THJ					15.00	0.10	0.31	0.00	0.00	0.00									
TOR	0.00	0.00	1.25	0.00								0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRF												0.01	0.00	0.00	0.00	0.00	25.00	0.00	0.00
TRG												0.01	1.28						
TRK								0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
TRM												0.05	0.00	0.00	0.00	0.00	0.00	0.20	0.00
TS					0.00	0.05	0.15												
UNI											0.00			0.00	0.43	0.00	0.00	0.00	0.25
UNP																			
VEL								0.00	0.00	0.00									

able 22. Biomass and percent biomass of major groups of prey organisms in forage fish stomachs by species-size roup (n = 10 each) at stations in central, northeastern and southwestern PWS in fall, 1995.

entral Area

otal biomass

species	capelin	pollock	pollock	capelin	pollock	pollock	herring
size group	0	0	2	0	0	2	0
station-haul	3-1	3-1	3-2	4-2	4-3	4-3	5-1
SUMCODE							
Barnacle	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	1308.06	291.92	0.00	255.79	11.61	612.36
Calanoid copepod-small	0.24	5.20	0.60	0.66	2.60	0.88	97.38
Chaetognath	0.00	32.56	4.84	0.00	0.88	0.00	11.44
Cladocera	0.00	0.00	0.00	0.00	0.04	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	12.06	0.00	7.07	0.00	10.48
Euphausiid	14.56	589.13	1558.21	0.33	21.32	74.20	157.34
Fish	0.00	50.00	50.00	0.00	0.00	100.00	0.00
Gammarid	0.00	0.00	0.00	0.00	1.34	18.02	1.34
Gastropod	0.00	0.52	0.00	0.00	0.00	0.00	5.02
Hyperiid	0.00	87.84	41.42	0.00	0.00	36.84	64.56
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	0.00	0.00	0.07	0.00	0.07	0.00	64.77
Malacostracan	0.00	0.00	7.41	0.00	3.90	0.39	7.41
Other	0.06	0.27	0.63	0.00	0.09	0.36	1.50
TOTAL	4.86	2073.57	1967.15	0.99	293.10	242.29	1033.58

Central Area

% biomass

species	capelin	pollock	pollock	capelin	pollock	pollock	herring
size group	0	0	2	0	0	2	0
station-haul	3-1	3-1	3-2	4-2	4-3	4-3	5-1
SUMCODE							
Barnacle	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	63.08	14.84	0.00	87.27	4.79	59.25
Calanoid copepod-small	1.58	0.25	0.03	66.27	0.89	0.36	9.42
Chaetognath	0.00	1.57	0.25	0.00	0.30	0.00	1.11
Cladocera	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Cyphonaute	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 22 cont.										
Decapod	0.00	0.00	0.61	0.00	2.41	0.00	1.01			
Euphausiid	98.01	28.41	79.21	33.24	7.27	30.62	15.22			
Fish	0.00	2.41	2.54	0.00	0.00	41.27	0.00			
Gammarid	0.00	0.00	0.00	0.00	0.46	7.44	0.13			
Gastropod	0.00	0.03	0.00	0.00	0.00	0.00	0.49			
Hyperiid	0.00	4.24	2.11	0.00	0.00	15.20	6.25			
Insect	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Larvacean	0.00	0.00	0.00	0.00	0.02	0.00	6.27			
Malacostracan	0.00	0.00	0.38	0.00	1.33	0.16	0.72			
Other	0.40	0.01	0.03	0.49	0.03	0.15	0.14			
Northeastern area PWS										
Total biomass										
species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
size group	0	0	0	0	0	2	0	1	0	0
station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Calanoid copepod-large	73.38	260.15	593.23	53.79	318.55	274.24	0.00	0.00	0.00	0.00
Calanoid copepod-small	55.45	12.99	7.19	28.62	5.14	0.82	0.22	0.00	0.00	0.24
Chaetognath	0.44	0.44	0.00	0.00	2.20	1.76	0.00	0.00	0.00	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod	0.00	0.00	5.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiid	176.55	309.90	3.64	42.55	124.80	86.30	18.20	17.34	0.00	0.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammarid	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod	1.28	1.18	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
Hyperiid	0.00	0.00	157.88	15.72	9.81	100.52	0.00	0.00	0.00	0.00
Insect	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean	275.19	0.37	61.80	1.33	1.63	0.03	0.00	0.00	0.00	0.00
Malacostracan	0.00	26.07	12.84	25.57	0.00	0.00	0.00	0.39	0.00	0.00
Other	2.41	0.12	3.21	0.33	0.18	10.26	0.01	0.00	0.00	0.00
TOTAL	586.29	612.55	845.37	167.91	462.31	474.13	18.43	17.90	0.00	0.24

Table 22 cont.										
Northeastern Area PWS										
% biomass										
species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
size group	0	0	0	0	0	2	0	1	0	0
station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	empty	0.00
Calanoid copepod-large	12.52	42.47	70.17	32.04	68.91	57.84		0.00	empty	0.00
Calanoid copepod-small	9.46	2.12	0.85	17.04	1.11	0.17	1.22	0.00	empty	100.00
Chaetognath	0.08	0.07	0.00	0.00	0.48	0.37	0.00	0.00	empty	0.00
Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Cyphonaute	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Decapod	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	empty	0.00
Euphausiid	30.11	50.59	0.43	25.34	27.00	18.20	98.73	96.85	empty	0.00
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gammarid	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gastropod	0.22	0.19	0.00	0.00	0.00	0.00	0.00	0.97	empty	0.00
Hyperiid	0.00	0.00	18.68	9.36	2.12	21.20	0.00	0.00	empty	0.00
Insect	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Larvacean	46.94	0.06	7.31	0.79	0.35	0.01	0.00	0.00	empty	0.00
Malacostracan	0.00	4.26	1.52	15.23	0.00	0.00	0.00	2.18	empty	0.00
Other	0.41	0.02	0.38	0.20	0.04	2.16	0.05	0.00	empty	0.00
Southwestern Area PWS										
Total biomass										
species	herring	herring	pollock	pollock						
size group	0	1	0	1						
station-haul	2-1	2-1	2-1	2-1						
SUMCODE										
Barnacle	0.00	0.00	0.00	0.00						
Calanoid copepod-large	0.00	0.00	10.25	30.70						
Calanoid copepod-small	60.08	0.82	4.90	0.07						
Chaetognath	0.00	0.00	1.32	1.32						
Cladocera	0.04	0.00	0.04	0.00						
Cyphonaute	0.02	0.00	0.00	0.00						
Decapod	0.00	0.00	0.00	0.00						
Euphausiid	0.00	18.32	31.95	28.85						

Table 22 cont.				
Fish	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	0.00	4.67
Gastropod	1.44	0.00	0.00	0.00
Hyperiid	0.00	7.86	23.58	0.00
Insect	0.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.11
Larvacean	28.01	0.47	0.80	0.03
Malacostracan	0.39	0.00	0.00	26.46
Other	96.68	0.09	0.36	24.14
TOTAL	186.66	27.56	73.20	116.36
Southwestern Area				
% Biomass				
species	herring	herring	pollock	pollock
size group	0	1	0	1
station-haul	2-1	2-1	2-1	2-1
SUMCODE				
Barnacle	0.00	0.00	0.00	0.00
Calanoid copepod-large	0.00	0.00	14.00	26.39
Calanoid copepod-small	32.19	2.99	6.69	0.06
Chaetognath	0.00	0.00	1.80	1.13
Cladocera	0.02	0.00	0.05	0.00
Cyphonaute	0.01	0.00	0.00	0.00
Decapod	0.00	0.00	0.00	0.00
Euphausiid	0.00	66.47	43.65	24.79
Fish	0.00	0.00	0.00	0.00
Gammarid	0.00	0.00	0.00	4.01
Gastropod	0.77	0.00	0.00	0.00
Hyperiid	0.00	28.52	32.21	0.00
Insect	0.00	0.00	0.00	0.00
Cnidarian/ Ctenophore	0.00	0.00	0.00	0.10
Larvacean	15.00	1.69	1.09	0.03
Malacostracan	0.21	0.00	0.00	22.74
Other	51.80	0.33	0.49	20.75

Table 23. Biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at stations in central (A), northeastern (B) and southwestern (C) PWS in fall, 1995.

A) Central Area PWS

	species	herring	pollock	pollock	pollock	pollock	capelin	capelin
	size group	0	0	0	2	2	0	0
	station-haul	5-1	3-1	4-3	3-2	4-3	3-1	4-2
SPCD	n	10	10	10	10	10	10	10
Calanoid copepod-large								
CAF	Calanoid, Centropages abdominalis	0.57	0.00	0.00	0.00	0.00	0.00	0.00
CAL	Calanoid, general large (>2.5 mm)	126.69	119.90	210.39	36.20	9.05	0.00	0.00
CCP	Calanoid, Calanus sp. copepodite	12.38	19.80	0.00	2.48	0.00	0.00	0.00
CLN	Calanoid, large, Neocalanus/Calanus	56.56	31.67	22.62	4.52	0.00	0.00	0.00
CM	Calanoid, Calanus marshallae	0.00	1.43	0.00	0.00	0.00	0.00	0.00
CMC	Calanoid, C. marshallae	0.00	0.00	0.00	1.25	0.00	0.00	0.00
CMF	Calanoid, Calanus marshallae	0.00	3.45	0.00	0.00	0.00	0.00	0.00
CPC	Calanoid, Calanus pacificus	0.00	2.44	0.00	0.00	0.00	0.00	0.00
CPF	Calanoid, Calanus pacificus	17.69	76.64	0.00	2.62	0.00	0.00	0.00
CPM	Calanoid, Calanus pacificus	0.00	0.96	0.00	0.00	0.00	0.00	0.00
ECC	Calanoid, Euchaeta elongata	3.95	0.00	0.00	0.00	0.00	0.00	0.00
ECF	Calanoid, Euchaeta elongata	4.60	0.00	0.00	0.00	0.00	0.00	0.00
ECM	Calanoid, Euchaeta elongata	0.00	10.60	0.00	0.00	0.00	0.00	0.00
EEF	Calanoid, Euchaeta elongata	7.90	0.00	0.00	0.00	0.00	0.00	0.00
MCS	Calanoid, Metridia pacifica	1.02	0.00	0.00	0.00	0.00	0.00	0.00
MEP	Calanoid, Metridia pacifica	153.15	99.33	0.00	41.10	0.98	0.00	0.00
MPC	Calanoid, Metridia pacifica	60.84	20.87	0.00	0.98	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica	158.59	907.35	20.51	202.77	1.58	0.00	0.00
MPM	Calanoid, Metridia pacifica	0.00	9.10	0.00	0.00	0.00	0.00	0.00
NEO	Calanoid, Neocalanus spp.	0.00	4.52	2.26	0.00	0.00	0.00	0.00
EPC	Calanoid, Epilabidocera longipedata	3.60	0.00	0.00	0.00	0.00	0.00	0.00
EPF	Calanoid, Epilabidocera longipedata	5.40	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small								
CAS	Calanoid, general small (<2.5mm)	16.93	3.67	2.10	0.60	0.22	0.00	0.00
COS	Calanoid, Copepodite small	0.14	0.00	0.00	0.00	0.00	0.24	0.66
MEF	Calanoid, Mesocalanus tenuicornis	13.10	0.00	0.00	0.00	0.66	0.00	0.00

Table 23 cont.									
MEG	Calanoid, Mesocalanus tenuicornis	7.21	0.00	0.00	0.00	0.00	0.00	0.00	
MES	Calanoid, Mesocalanus tenuicornis	6.55	0.00	0.00	0.00	0.00	0.00	0.00	
PSA	Calanoid, Pseudocalanus spp.	17.32	0.28	0.28	0.00	0.00	0.00	0.00	
PSF	Calanoid, Pseudocalanus spp.	33.44	1.05	0.21	0.00	0.00	0.00	0.00	
PSM	Calanoid, Pseudocalanus spp.	0.00	0.20	0.00	0.00	0.00	0.00	0.00	
OS	Cyclopoid, Oithona similis	0.22	0.00	0.01	0.00	0.00	0.00	0.00	
PCP	Calanoid, Pseudocalanus spp.	1.90	0.00	0.00	0.00	0.00	0.00	0.00	
Cladoceran									
PON	Cladoceran, Podon sp.	0.00	0.00	0.04	0.00	0.00	0.00	0.00	
Chaetognath									
CHT	Chaetognath, species unknown	1.32	3.08	0.88	4.40	0.00	0.00	0.00	
SGE	Chaetognath, Sagitta (elegans)	10.12	29.48	0.00	0.44	0.00	0.00	0.00	
Decapod									
DZG	Decapod, zoea, general unknown	0.00	0.00	5.48	0.00	0.00	0.00	0.00	
HIE	Decapod zoea, Shrimp, Hippolytidae	10.48	0.00	0.00	0.00	0.00	0.00	0.00	
PAN	Decapod, Pandalidae	0.00	0.00	0.00	12.06	0.00	0.00	0.00	
PGZ	Decapod zoea, hermit crab	0.00	0.00	1.59	0.00	0.00	0.00	0.00	
Euphausiid									
EP1	Euphausiid, E. pacifica small	0.00	0.00	0.00	934.80	8.20	0.00	0.00	
EP2	Euphausiid, E. pacifica medium	0.00	39.20	0.00	0.00	0.00	0.00	0.00	
EP3	Euphausiid, E. pacifica large	0.00	178.80	0.00	178.80	44.70	0.00	0.00	
EU2	Euphausiid nauplii	0.00	0.00	0.02	0.00	0.00	0.00	0.00	
EU3	Euphausiid calyptopis	0.17	0.00	0.00	0.00	0.00	0.00	0.33	
EU4	Euphausiid furcilia	4.29	17.94	0.00	1.56	0.00	0.00	0.00	
EUJ	Euphausiid juvenile, general	152.88	123.76	0.00	320.32	0.00	364.00	0.00	
EUP	Euphausiid, general unknown	0.00	181.05	21.30	85.20	21.30	0.00	0.00	
EPP	Euphausiid, Euphausia pacifica	0.00	0.00	0.00	2.85	0.00	0.00	0.00	
TH	Euphausiid, Thysannoessa sp.,	0.00	27.40	0.00	13.70	0.00	0.00	0.00	
THJ	Euphausiid, Thysannoessa sp.	0.00	7.28	0.00	7.28	0.00	10.92	0.00	
TS	Euphausiid, Thysanoessa spinifera	0.00	13.70	0.00	13.70	0.00	0.00	0.00	
Fish									
FSL	Fish larvae, general	0.00	50.00	0.00	50.00	100.00	0.00	0.00	
Gammarid									
GA3	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	18.02	0.00	0.00	

Table 23 cont.									
GAU	Amphipod, Gammarid, unknown	1.34	0.00	1.34	0.00	0.00	0.00	0.00	
Gastropod									
GST	Gastropoda, general juvenile	0.48	0.00	0.00	0.00	0.00	0.00	0.00	
LMJ	Gastropod, Pteropod, Limacina	4.54	0.52	0.00	0.00	0.00	0.00	0.00	
Hyperiid									
HP	Amphipod, Hyperiid, Hyperia sp	0.00	60.70	0.00	0.00	0.00	0.00	0.00	
HYA	Amphipod, Hyperiid, unknown	0.00	0.00	0.00	0.00	13.09	0.00	0.00	
HYB	Amphipod, Hyperiid, unknown	0.34	0.34	0.00	0.51	0.00	0.00	0.00	
HYP	Amphipod, Hyperiid, unknown	47.16	15.72	0.00	15.72	23.58	0.00	0.00	
PR1	Amphipod, Hyperiid, Primno macropa	3.74	0.00	0.00	0.00	0.00	0.00	0.00	
PRI	Amphipod, Hyperiid, Primno macropa	7.98	0.00	0.00	0.00	0.00	0.00	0.00	
PS	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.00	7.86	0.00	0.00	0.00	
PS1	Amphipod, Hyperiid, Parathemisto	0.51	0.00	0.00	0.00	0.17	0.00	0.00	
PS2	Amphipod, Hyperiid, Parathemisto	0.00	7.86	0.00	15.72	0.00	0.00	0.00	
PA2	Amphipod, P. pacifica juvenile	4.83	3.22	0.00	1.61	0.00	0.00	0.00	
Larvacean									
OKP	Larvacea, Oikopleura sp.	64.77	0.00	0.07	0.07	0.00	0.00	0.00	
Malacostracan									
MAE	Malacostraca, eyes only	7.41	0.00	3.90	7.41	0.39	0.00	0.00	
Other									
BVL	Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
EGG	Unknown invertebrate egg, small	1.22	0.00	0.00	0.00	0.00	0.06	0.00	
NEM	Nematode	0.00	0.27	0.09	0.63	0.36	0.00	0.00	
ISC	Isopod, (Epicarid)	0.19	0.00	0.00	0.00	0.00	0.00	0.00	
PLL	Polychaeta, general, juvenile	0.09	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL		1033.58	2073.57	293.10	1967.15	242.29	14.86	0.99	

Table 23 cont.

B) Northeastern Area PWS

	species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
	size group	0	0	0	0	0	2	0	1	0	0
	station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
	n	10	10	10	10	10	10	10	10	10	10
SPCD	depth	15 m	20 m	20 m	15 m	90 m	20 m	90 m	90 m		
Barnacle											
BMP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Calanoid copepod-large											
CAL	Calanoid, general large (>2.5mm)	24.89	122.16	92.75	33.93	61.08	33.93	0.00	0.00	0.00	0.00
CCL	Calanoid, Candacia columbiae	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CMC	Calanoid, C. marshallae	0.00	1.25	0.00	2.51	2.51	0.00	0.00	0.00	0.00	0.00
CPF	Calanoid, Calanus pacificus	0.00	0.00	2.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MCS	Calanoid, Metridia pacifica	0.00	8.77	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
MEP	Calanoid, Metridia pacifica	21.04	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
MG	Calanoid, Metridia sp.	0.00	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MP	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	31.32	0.00	0.00	0.00	0.00
MPC	Calanoid, Metridia pacifica	11.90	65.91	0.00	0.78	3.12	0.98	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica	13.41	59.18	497.86	16.57	246.96	196.46	0.00	0.00	0.00	0.00
EUE	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	3.85	11.55	0.00	0.00	0.00	0.00
Calanoid copepod-small											
AC	Calanoid, Acartia sp.	0.00	0.03	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
CA	Calanoid, Centropages abdominalis	0.00	0.00	0.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00
CAC	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00
CAM	Calanoid, Centropages abdominalis	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus spp.	4.54	1.85	0.00	0.99	0.43	0.00	0.00	0.00	0.00	0.00
PSF	Calanoid, Pseudocalanus spp.	2.72	5.64	0.00	0.63	1.25	0.00	0.00	0.00	0.00	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
MEG	Calanoid, Mesocalanus tenuicornis	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COS	Calanoid, Copepodite small	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAN	Calanoid, general nauplius	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.01
CAS	Calanoid, general small (<2.5 mm)	47.11	5.47	7.19	16.70	3.37	0.82	0.22	0.00	0.00	0.22
OS	Cyclopoid, Oithona similis	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOR	Calanoid, Tortanus discaudatus	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute											
CFN	Bryozoa, cyphonautes larva	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaetognath											
CHT	Chaetognath, species unknown	0.44	0.44	0.00	0.00	1.76	0.88	0.00	0.00	0.00	0.00

able 23 cont.

GE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.44	0.88	0.00	0.00	0.00	0.00
ecapod											
ZG	Decapod, zoea, general unknown	0.00	0.00	5.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HR	Decapod zoea, general shrimp	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
uphausiid											
PP	Euphausiid, Euphausia pacifica	0.00	8.55	0.00	0.00	0.00	2.85	0.00	0.00	0.00	0.00
UJ	Euphausiid juvenile, general	0.00	0.00	3.64	18.20	0.00	72.80	18.20	3.64	0.00	0.00
UP	Euphausiid, general unknown	53.25	95.85	0.00	10.65	42.60	10.65	0.00	0.00	0.00	0.00
TH	Euphausiid, Thysannoessa sp.,	27.40	68.50	0.00	13.70	68.50	0.00	0.00	0.00	0.00	0.00
TRF	Euphausiid, T. raschii	13.70	0.00	0.00	0.00	0.00	0.00	0.00	13.70	0.00	0.00
TRG	Euphausiid, T. raschii	13.70	137.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRM	Euphausiid, T. raschii	68.50	0.00	0.00	0.00	13.70	0.00	0.00	0.00	0.00	0.00
Gammarid											
GA2	Amphipod, Gammarid, unknown	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod											
GST	Gastropoda, general juvenile	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LMA	Gastropod, Pteropod, Limacina	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LMJ	Gastropod, Pteropod, Limacina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
Hyperiid											
HYB	Amphipod, Hyperiid, unknown	0.00	0.00	0.68	0.00	0.34	0.00	0.00	0.00	0.00	0.00
HYP	Amphipod, Hyperiid, unknown	0.00	0.00	157.20	15.72	7.86	70.74	0.00	0.00	0.00	0.00
PA2	Amphipod, P. pacifica juvenile	0.00	0.00	0.00	0.00	1.61	3.22	0.00	0.00	0.00	0.00
PL3	Amphipod, Hyperiid, P. libellula	0.00	0.00	0.00	0.00	0.00	13.09	0.00	0.00	0.00	0.00
PR2	Amphipod, Hyperiid, P. macropa	0.00	0.00	0.00	0.00	0.00	5.61	0.00	0.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathemisto sp.	0.00	0.00	0.00	0.00	0.00	7.86	0.00	0.00	0.00	0.00
Insect											
DPL	Insect, Dipteran larvae	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean											
OI1	Larvacea, Oikopleura < 2mm	243.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OKP	Larvacea, Oikopleura sp.	31.97	0.37	61.80	1.33	1.63	0.03	0.00	0.00	0.00	0.00
Malacostracan											
MAE	Malacostraca, eyes only	0.00	1.95	0.78	1.95	0.00	0.00	0.00	0.39	0.00	0.00
MAL	Malacostraca	0.00	24.12	12.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MYA	Mysidae, general	0.00	0.00	0.00	23.62	0.00	0.00	0.00	0.00	0.00	0.00
Other											
BVL	Bivalve, larvae	0.12	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EGG	Unknown invertebrate egg, small	0.08	0.01	0.45	0.15	0.00	0.00	0.01	0.00	0.00	0.00
EGL	Unknown invertebrate egg, large	0.76	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HR	Harpacticoid, general, unknown	0.54	0.09	0.00	0.18	0.09	0.00	0.00	0.00	0.00	0.00
HRC	Harpacticoid, general copepodite	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HZC	Harpacticoid, Zaus copepodite	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

able 23 cont.

ZZ	Harpacticoid, Zaus sp.	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	Isopod, general	0.00	0.00	2.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EM	Nematode	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
NI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	Copepod, Caligidae, parasitic	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA	Polychaeta, adult	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
LL	Polychaeta, general, juvenile	0.17	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
UN	Polychaeta, unknown large	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00
OTAL		586.29	612.55	845.37	167.91	462.31	474.13	18.43	17.90	0.00	0.24

Table 23 cont.

C) Southwestern Area PWS

	species	herring	herring	pollock	pollock
	size group	0	1	0	1
	station-haul	2-1	2-1	2-1	2-1
SPCD	n	2	8	10	10
Calanoid copepod-large					
BRC	Calanoid, Bradyidius saanichi	0.00	0.00	0.00	0.00
BRF	Calanoid, Bradyidius saanichi	0.00	0.00	0.66	0.00
BRG	Calanoid, Bradyidius saanichi	0.00	0.00	0.66	0.00
CAL	Calanoid, general large (>2.5mm)	0.00	0.00	6.79	13.57
CCP	Calanoid, Calanus sp.	0.00	0.00	0.00	0.62
MG	Calanoid, Metridia sp.	0.00	0.00	0.00	1.43
MGF	Calanoid, Metridia general	0.00	0.00	2.67	0.00
MPF	Calanoid, Metridia pacifica	0.00	0.00	0.79	12.62
MPM	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.19
TOR	Calanoid, Tortanus discaudatus	0.00	0.00	0.10	0.00
NPF	Calanoid, Neocalanus plumchrus	0.00	0.00	0.00	2.26
Calanoid copepod-small					
AC	Calanoid, Acartia sp.	0.23	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis	0.30	0.00	0.00	0.00
ALM	Calanoid, Acartia longiremus	0.00	0.00	0.03	0.00
CAS	Calanoid, general small (<2.5mm)	59.40	0.82	1.35	0.07
COS	Calanoid, Copepodite small	0.16	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus spp.	0.00	0.00	0.99	0.00
PSF	Calanoid, Pseudocalanus spp.	0.00	0.00	1.05	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.07	0.00
Chaetognath					
CHT	Chaetognath, species unknown	0.00	0.00	0.00	0.88
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	1.32	0.44
Cnidarian/ Ctenophore					
CNS	Cnidaria (<2mm), general small	0.00	0.00	0.00	0.11
Cyphonaute					
CFN	Bryozoa, cyphonautes larva	0.02	0.00	0.00	0.00

Table 23 cont.					
Cladoceran					
PON	Cladoceran, Podon sp.	0.00	0.00	0.04	0.00
Euphausiid					
EU4	Euphausiid furcilia	0.00	0.39	0.00	0.00
EUJ	Euphausiid juvenile, general	0.00	7.28	0.00	18.20
EUP	Euphausiid, general unknown	0.00	10.65	31.95	10.65
Gammarid					
GA1	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.65
GA2	Amphipod, Gammarid, unknown	0.00	0.00	0.00	1.34
GAU	Amphipod, Gammarid, unknown	0.00	0.00	0.00	2.68
Gastropod					
GST	Gastropoda, general juvenile	1.44	0.00	0.00	0.00
Hyperiid					
HYP	Amphipod, Hyperiid, unknown juv.	0.00	7.86	23.58	0.00
Larvacean					
OI1	Larvacea, Oikopleura < 2mm	3.76	0.00	0.00	0.00
OKP	Larvacea, Oikopleura sp.	24.24	0.47	0.80	0.03
Malacostracan					
MAE	Malacostraca, eyes only	0.39	0.00	0.00	2.34
MAL	Malacostraca	0.00	0.00	0.00	24.12
MYS	Mysidae, general adult	0.00	0.00	0.00	23.62
Other					
BVL	Bivalve, larvae	0.02	0.00	0.00	0.00
CLA	Cladocera, General	0.04	0.00	0.00	0.00
CUM	Cumacea	0.00	0.00	0.26	0.52
EGG	Unknown invertebrate egg, small	96.52	0.00	0.00	0.00
HRC	Harpacticoid, general copepodi	0.05	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00
UNP	Unknown nauplius	0.00	0.00	0.01	0.00
NEM	Nematode	0.00	0.09	0.09	0.00
PLL	Polychaeta, general, juvenile	0.09	0.00	0.00	0.00
TOTAL		186.66	27.56	73.20	116.36

Table 24. Percent biomass of prey species observed in forage fish stomachs by species-size group (n = 10 each) at stations in central (A), northeastern (B) and southwestern (C) PWS in fall, 1995.

A) Central Area

	species	capelin	pollock	pollock	capelin	pollock	pollock	herring
	size group	0	0	2	0	0	2	0
	station-haul	3-1	3-1	3-2	4-2	4-3	4-3	5-1
SPCD	n	10	10	10	10	10	10	10
Calanoid copepod-large								
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00	0.00	0.06
CAL	Calanoid, general large (>2.5 mm)	0.00	5.78	1.84	0.00	71.78	3.73	12.26
CCP	Calanoid, Calanus sp. copepodite	0.00	0.95	0.13	0.00	0.00	0.00	1.20
CLN	Calanoid, large, Neocalanus/Calanus	0.00	1.53	0.23	0.00	7.72	0.00	5.47
CM	Calanoid, Calanus marshallae	0.00	0.07	0.00	0.00	0.00	0.00	0.00
CMC	Calanoid, C. marshallae	0.00	0.00	0.06	0.00	0.00	0.00	0.00
CMF	Calanoid, Calanus marshallae	0.00	0.17	0.00	0.00	0.00	0.00	0.00
CPC	Calanoid, Calanus pacificus	0.00	0.12	0.00	0.00	0.00	0.00	0.00
CPF	Calanoid, Calanus pacificus	0.00	3.70	0.13	0.00	0.00	0.00	1.71
CPM	Calanoid, Calanus pacificus	0.00	0.05	0.00	0.00	0.00	0.00	0.00
ECC	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00	0.38
ECF	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00	0.45
ECM	Calanoid, Euchaeta elongata	0.00	0.51	0.00	0.00	0.00	0.00	0.00
EEF	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00	0.76
MCS	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	0.00	0.10
MEP	Calanoid, Metridia pacifica	0.00	4.79	2.09	0.00	0.00	0.40	14.82
MPC	Calanoid, Metridia pacifica	0.00	1.01	0.05	0.00	0.00	0.00	5.89
MPF	Calanoid, Metridia pacifica	0.00	43.76	10.31	0.00	7.00	0.65	15.34
MPM	Calanoid, Metridia pacifica	0.00	0.44	0.00	0.00	0.00	0.00	0.00
NEO	Calanoid, Neocalanus spp.	0.00	0.22	0.00	0.00	0.77	0.00	0.00
EPC	Calanoid, Epilabidocera longipedata	0.00	0.00	0.00	0.00	0.00	0.00	0.35
EPF	Calanoid, Epilabidocera longipedata	0.00	0.00	0.00	0.00	0.00	0.00	0.52
Calanoid copepod-small								
CAS	Calanoid, general small (<2.5mm)	0.00	0.18	0.03	0.00	0.72	0.09	1.64
COS	Calanoid, Copepodite small	1.58	0.00	0.00	66.27	0.00	0.00	0.01
MEF	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.27	1.27
MEG	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.70
MES	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.00	0.63
PSA	Calanoid, Pseudocalanus spp.	0.00	0.01	0.00	0.00	0.10	0.00	1.68
PSF	Calanoid, Pseudocalanus spp.	0.00	0.05	0.00	0.00	0.07	0.00	3.24

Table 24 cont.										
PSM	Calanoid, Pseudocalanus spp.	0.00	0.01	0.00	0.00	0.00	0.00	0.00		
OS	Cyclopoid, Oithona similis	0.00	0.00	0.00	0.00	0.00	0.00	0.02		
PCP	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.18		
Cladoceran										
PON	Cladoceran, Podon sp.	0.00	0.00	0.00	0.00	0.01	0.00	0.00		
Chaetognath										
CHT	Chaetognath, species unknown	0.00	0.15	0.22	0.00	0.30	0.00	0.13		
SGE	Chaetognath, Sagitta (elegans)	0.00	1.42	0.02	0.00	0.00	0.00	0.98		
Decapod										
DZG	Decapod, zoea, general unknown	0.00	0.00	0.00	0.00	1.87	0.00	0.00		
HIE	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00	0.00	0.00	0.00	1.01		
PAN	Decapod, Pandalidae	0.00	0.00	0.61	0.00	0.00	0.00	0.00		
PGZ	Decapod zoea, hermit crab	0.00	0.00	0.00	0.00	0.54	0.00	0.00		
Euphausiid										
EP1	Euphausiid, E. pacifica small	0.00	0.00	47.52	0.00	0.00	3.38	0.00		
EP2	Euphausiid, E. pacifica medium	0.00	1.89	0.00	0.00	0.00	0.00	0.00		
EP3	Euphausiid, E. pacifica large	0.00	8.62	9.09	0.00	0.00	18.45	0.00		
EU2	Euphausiid nauplii	0.00	0.00	0.00	0.00	0.01	0.00	0.00		
EU3	Euphausiid calyptopis	0.00	0.00	0.00	33.24	0.00	0.00	0.02		
EU4	Euphausiid furcilia	0.00	0.87	0.08	0.00	0.00	0.00	0.42		
EUJ	Euphausiid juvenile, general	24.50	5.97	16.28	0.00	0.00	0.00	14.79		
EUP	Euphausiid, general unknown	0.00	8.73	4.33	0.00	7.27	8.79	0.00		
EPP	Euphausiid, Euphausia pacifica	0.00	0.00	0.14	0.00	0.00	0.00	0.00		
TH	Euphausiid, Thysannoessa sp.,	0.00	1.32	0.70	0.00	0.00	0.00	0.00		
THJ	Euphausiid, Thysannoessa sp.	73.51	0.35	0.37	0.00	0.00	0.00	0.00		
TS	Euphausiid, Thysanoessa spinifera	0.00	0.66	0.70	0.00	0.00	0.00	0.00		
Fish										
FSL	Fish larvae, general	0.00	2.41	2.54	0.00	0.00	41.27	0.00		
Gastropod										
GST	Gastropoda, general juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.05		
LMJ	Gastropod, Pteropod, Limacina	0.00	0.03	0.00	0.00	0.00	0.00	0.44		
Gammarid										
GA3	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	0.00	7.44	0.00		
GAU	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	0.46	0.00	0.13		
Hyperiid										
HP	Amphipod, Hyperiid, Hyperia sp	0.00	2.93	0.00	0.00	0.00	0.00	0.00		
HYA	Amphipod, Hyperiid, unknown	0.00	0.00	0.00	0.00	0.00	5.40	0.00		

Table 24 cont.										
HYB	Amphipod, Hyperiid, unknown	0.00	0.02	0.03	0.00	0.00	0.00	0.03		
HYP	Amphipod, Hyperiid, unknown	0.00	0.76	0.80	0.00	0.00	9.73	4.56		
PR1	Amphipod, Hyperiid, Primno macropa	0.00	0.00	0.00	0.00	0.00	0.00	0.36		
PRI	Amphipod, Hyperiid, Primno macropa	0.00	0.00	0.00	0.00	0.00	0.00	0.77		
PS	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.40	0.00	0.00	0.00	0.00		
PS1	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.00	0.00	0.00	0.07	0.05		
PS2	Amphipod, Hyperiid, Parathemisto	0.00	0.38	0.80	0.00	0.00	0.00	0.00		
PA2	Amphipod, P. pacifica juvenile	0.00	0.16	0.08	0.00	0.00	0.00	0.47		
Larvacean										
OKP	Larvacea, Oikopleura sp.	0.00	0.00	0.00	0.00	0.02	0.00	6.27		
Malacostracan										
MAE	Malacostraca, eyes only	0.00	0.00	0.38	0.00	1.33	0.16	0.72		
Other										
BVL	Bivalve, larvae	0.00	0.00	0.00	0.49	0.00	0.00	0.00		
EGG	Unknown invertebrate egg, small	0.40	0.00	0.00	0.00	0.00	0.00	0.12		
NEM	Nematode	0.00	0.01	0.03	0.00	0.03	0.15	0.00		
ISC	Isopod, (Epicarid)	0.00	0.00	0.00	0.00	0.00	0.00	0.02		
PLL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.01		

Table 24 cont.											
Northeastern Area PWS											
	species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
	size group	0	0	0	0	0	2	0	1	0	0
	station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
	n	10	10	10	10	10	10	10	10	10	10
SPCD	depth	15 m	15 m	20 m	20 m	90 m	20 m	90 m	90 m		
Barnacle											
BMP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	empty	0.00
Calanoid copepod-large											
CAL	Calanoid, general large (>2.5mm)	4.24	19.94	10.97	20.21	13.21	7.16	0.00	0.00	empty	0.00
CCL	Calanoid, Candacia columbiae	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
CMC	Calanoid, C. marshallae	0.00	0.20	0.00	1.49	0.54	0.00	0.00	0.00	empty	0.00
CPF	Calanoid, Calanus pacificus	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	empty	0.00
MCS	Calanoid, Metridia pacifica	0.00	1.43	0.00	0.00	0.01	0.00	0.00	0.00	empty	0.00
MEP	Calanoid, Metridia pacifica	3.59	0.00	0.00	0.00	0.21	0.00	0.00	0.00	empty	0.00
MG	Calanoid, Metridia sp.	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
MP	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	6.60	0.00	0.00	empty	0.00
MPC	Calanoid, Metridia pacifica	2.03	10.76	0.00	0.46	0.67	0.21	0.00	0.00	empty	0.00
MPF	Calanoid, Metridia pacifica	2.29	9.66	58.89	9.87	53.42	41.44	0.00	0.00	empty	0.00
EUE	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.83	2.44	0.00	0.00	empty	0.00
Calanoid copepod-small											
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	empty	0.00
ALF	Calanoid, Acartia longiremis	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.00	empty	0.00
CA	Calanoid, Centropages abdominalis	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	empty	0.00
CAC	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	empty	0.00
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	empty	0.00
CAM	Calanoid, Centropages abdominalis	0.00	0.00	0.00	1.98	0.00	0.00	0.00	0.00	empty	0.00
PSA	Calanoid, Pseudocalanus spp.	0.78	0.30	0.00	0.59	0.09	0.00	0.00	0.00	empty	0.00
PSF	Calanoid, Pseudocalanus spp.	0.46	0.92	0.00	0.37	0.27	0.00	0.00	0.00	empty	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	empty	0.00
MEG	Calanoid, Mesocalanus tenuicornis	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
COS	Calanoid, Copepodite small	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
CAN	Calanoid, general nauplius	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	empty	4.55
CAS	Calanoid, general small (<2.5 mm)	8.04	0.89	0.85	9.95	0.73	0.17	1.22	0.00	empty	95.45
OS	Cyclopoid, Oithona similis	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
TOR	Calanoid, Tortanus discaudatus	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Cyphonaute											
CFN	Bryozoa, cyphonautes larva	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Chaetognath											
CHT	Chaetognath, species unknown	0.08	0.07	0.00	0.00	0.38	0.19	0.00	0.00	empty	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.10	0.19	0.00	0.00	empty	0.00
Decapod											
DZG	Decapod, zoea, general unknown	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	empty	0.00
SHR	Decapod zoea, general shrimp	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	empty	0.00

Table 24 cont.											
Euphausiid											
EPP	Euphausiid, Euphausia pacifica	0.00	1.40	0.00	0.00	0.00	0.60	0.00	0.00	empty	0.00
EUJ	Euphausiid juvenile, general	0.00	0.00	0.43	10.84	0.00	15.35	98.73	20.33	empty	0.00
EUP	Euphausiid, general unknown	9.08	15.65	0.00	6.34	9.21	2.25	0.00	0.00	empty	0.00
TH	Euphausiid, Thysannoessa sp.,	4.67	11.18	0.00	8.16	14.82	0.00	0.00	0.00	empty	0.00
TRF	Euphausiid, T. raschii	2.34	0.00	0.00	0.00	0.00	0.00	0.00	76.52	empty	0.00
TRG	Euphausiid, T. raschii	2.34	22.37	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
TRM	Euphausiid, T. raschii	11.68	0.00	0.00	0.00	2.96	0.00	0.00	0.00	empty	0.00
Gammarid											
GA2	Amphipod, Gammarid, unknown	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gastropod											
GST	Gastropoda, general juvenile	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
LMA	Gastropod, Pteropod, Limacina	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
LMJ	Gastropod, Pteropod, Limacina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	empty	0.00
Hyperiid											
HYB	Amphipod, Hyperiid, unknown	0.00	0.00	0.08	0.00	0.07	0.00	0.00	0.00	empty	0.00
HYP	Amphipod, Hyperiid, unknown	0.00	0.00	18.60	9.36	1.70	14.92	0.00	0.00	empty	0.00
PA2	Amphipod, P. pacifica juvenile	0.00	0.00	0.00	0.00	0.35	0.68	0.00	0.00	empty	0.00
PL3	Amphipod, Hyperiid, P. libellula	0.00	0.00	0.00	0.00	0.00	2.76	0.00	0.00	empty	0.00
PR2	Amphipod, Hyperiid, P. macropa	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	empty	0.00
PS2	Amphipod, Hyperiid, Parathemisto sp.	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	empty	0.00
Insect											
DPL	Insect, Dipteran larvae	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Larvacean											
OI1	Larvacea, Oikopleura < 2mm	41.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
OKP	Larvacea, Oikopleura sp.	5.45	0.06	7.31	0.79	0.35	0.01	0.00	0.00	empty	0.00
Malacostracan											
MAE	Malacostraca, eyes only	0.00	0.32	0.09	1.16	0.00	0.00	0.00	2.18	empty	0.00
MAL	Malacostraca	0.00	3.94	1.43	0.00	0.00	0.00	0.00	0.00	empty	0.00
MYA	Mysidae, general	0.00	0.00	0.00	14.07	0.00	0.00	0.00	0.00	empty	0.00
Other											
BVL	Bivalve, larvae	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
EGG	Unknown invertebrate egg, small	0.01	0.00	0.05	0.09	0.00	0.00	0.05	0.00	empty	0.00
EGL	Unknown invertebrate egg, large	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HR	Harpacticoid, general, unknown	0.09	0.01	0.00	0.11	0.02	0.00	0.00	0.00	empty	0.00
HRC	Harpacticoid, general copepodite	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HZC	Harpacticoid, Zaus copepodite	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HZZ	Harpacticoid, Zaus sp.	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
ISP	Isopod, general	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	empty	0.00
NEM	Nematode	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	empty	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PCO	Copepod, Caligidae, parasitic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PLA	Polychaeta, adult	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	empty	0.00
PLL	Polychaeta, general, juvenile	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.00	empty	0.00

Table 24 cont.											
PUN	Polychaeta, unknown large	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	empty	0.00

Table 24 cont.											
B) Northeastern Area PWS											
	species	herring	pollock	herring	pollock	pollock	pollock	eulachon	eulachon	capelin	capelin
	size group	0	0	0	0	0	2	0	1	0	0
	station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	8-1	9-1
	n	10	10	10	10	10	10	10	10	10	10
SPCD	depth	15 m	15 m	20 m	20 m	90 m	20 m	90 m	90 m		
Barnacle											
BMP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	empty	0.00
Calanoid copepod-large											
CAL	Calanoid, general large (>2.5mm)	4.24	19.94	10.97	20.21	13.21	7.16	0.00	0.00	empty	0.00
CCL	Calanoid, Candacia columbiae	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
CMC	Calanoid, C. marshallae	0.00	0.20	0.00	1.49	0.54	0.00	0.00	0.00	empty	0.00
CPF	Calanoid, Calanus pacificus	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	empty	0.00
MCS	Calanoid, Metridia pacifica	0.00	1.43	0.00	0.00	0.01	0.00	0.00	0.00	empty	0.00
MEP	Calanoid, Metridia pacifica	3.59	0.00	0.00	0.00	0.21	0.00	0.00	0.00	empty	0.00
MG	Calanoid, Metridia sp.	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
MP	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	6.60	0.00	0.00	empty	0.00
MPC	Calanoid, Metridia pacifica	2.03	10.76	0.00	0.46	0.67	0.21	0.00	0.00	empty	0.00
MPF	Calanoid, Metridia pacifica	2.29	9.66	58.89	9.87	53.42	41.44	0.00	0.00	empty	0.00
EUE	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.83	2.44	0.00	0.00	empty	0.00
Calanoid copepod-small											
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	empty	0.00
ALF	Calanoid, Acartia longiremis	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.00	empty	0.00
CA	Calanoid, Centropages abdominalis	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	empty	0.00
CAC	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	empty	0.00
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	empty	0.00
CAM	Calanoid, Centropages abdominalis	0.00	0.00	0.00	1.98	0.00	0.00	0.00	0.00	empty	0.00
PSA	Calanoid, Pseudocalanus spp.	0.78	0.30	0.00	0.59	0.09	0.00	0.00	0.00	empty	0.00
PSF	Calanoid, Pseudocalanus spp.	0.46	0.92	0.00	0.37	0.27	0.00	0.00	0.00	empty	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	empty	0.00
MEG	Calanoid, Mesocalanus tenuicornis	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
COS	Calanoid, Copepodite small	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
CAN	Calanoid, general nauplius	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	empty	4.55
CAS	Calanoid, general small (<2.5 mm)	8.04	0.89	0.85	9.95	0.73	0.17	1.22	0.00	empty	95.45
OS	Cyclopoid, Oithona similis	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
TOR	Calanoid, Tortanus discaudatus	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Cyphonaute											
CFN	Bryozoa, cyphonautes larva	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Chaetognath											
CHT	Chaetognath, species unknown	0.08	0.07	0.00	0.00	0.38	0.19	0.00	0.00	empty	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.10	0.19	0.00	0.00	empty	0.00
Decapod											
DZG	Decapod, zoea, general unknown	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	empty	0.00
SHR	Decapod zoea, general shrimp	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	empty	0.00

Table 24 cont.

Euphausiid											
EPP	Euphausiid, Euphausia pacifica	0.00	1.40	0.00	0.00	0.00	0.60	0.00	0.00	empty	0.00
EUJ	Euphausiid juvenile, general	0.00	0.00	0.43	10.84	0.00	15.35	98.73	20.33	empty	0.00
EUP	Euphausiid, general unknown	9.08	15.65	0.00	6.34	9.21	2.25	0.00	0.00	empty	0.00
TH	Euphausiid, Thysannoessa sp.,	4.67	11.18	0.00	8.16	14.82	0.00	0.00	0.00	empty	0.00
TRF	Euphausiid, T. raschii	2.34	0.00	0.00	0.00	0.00	0.00	0.00	76.52	empty	0.00
TRG	Euphausiid, T. raschii	2.34	22.37	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
TRM	Euphausiid, T. raschii	11.68	0.00	0.00	0.00	2.96	0.00	0.00	0.00	empty	0.00
Gammarid											
GA2	Amphipod, Gammarid, unknown	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Gastropod											
GST	Gastropoda, general juvenile	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
LMA	Gastropod, Pteropod, Limacina	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
LMJ	Gastropod, Pteropod, Limacina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	empty	0.00
Hyperiid											
HYB	Amphipod, Hyperiid, unknown	0.00	0.00	0.08	0.00	0.07	0.00	0.00	0.00	empty	0.00
HYP	Amphipod, Hyperiid, unknown	0.00	0.00	18.60	9.36	1.70	14.92	0.00	0.00	empty	0.00
PA2	Amphipod, P. pacifica juvenile	0.00	0.00	0.00	0.00	0.35	0.68	0.00	0.00	empty	0.00
PL3	Amphipod, Hyperiid, P. libellula	0.00	0.00	0.00	0.00	0.00	2.76	0.00	0.00	empty	0.00
PR2	Amphipod, Hyperiid, P. macropa	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	empty	0.00
PS2	Amphipod, Hyperiid, Parathemisto sp.	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	empty	0.00
Insect											
DPL	Insect, Dipteran larvae	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
Larvacean											
OI1	Larvacea, Oikopleura < 2mm	41.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
OKP	Larvacea, Oikopleura sp.	5.45	0.06	7.31	0.79	0.35	0.01	0.00	0.00	empty	0.00
Malacostracan											
MAE	Malacostraca, eyes only	0.00	0.32	0.09	1.16	0.00	0.00	0.00	2.18	empty	0.00
MAL	Malacostraca	0.00	3.94	1.43	0.00	0.00	0.00	0.00	0.00	empty	0.00
MYA	Mysidae, general	0.00	0.00	0.00	14.07	0.00	0.00	0.00	0.00	empty	0.00
Other											
BVL	Bivalve, larvae	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
EGG	Unknown invertebrate egg, small	0.01	0.00	0.05	0.09	0.00	0.00	0.05	0.00	empty	0.00
EGL	Unknown invertebrate egg, large	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HR	Harpacticoid, general, unknown	0.09	0.01	0.00	0.11	0.02	0.00	0.00	0.00	empty	0.00
HRC	Harpacticoid, general copepodite	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HZC	Harpacticoid, Zaus copepodite	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
HZZ	Harpacticoid, Zaus sp.	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
ISP	Isopod, general	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	empty	0.00
NEM	Nematode	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	empty	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PCO	Copepod, Caligidae, parasitic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	0.00
PLA	Polychaeta, adult	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	empty	0.00
PLL	Polychaeta, general, juvenile	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.00	empty	0.00

able 24 cont.											
UN	Polychaeta, unknown large	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	empty	0.00

able 24 cont.					
) Southwestern Area PWS					
	species	herring	herring	pollock	pollock
	size group	0	1	0	1
	station-haul	2-1	2-1	2-1	2-1
PCD	n	2	8	10	10
alanoid copepod-large					
RC	Calanoid, Bradyidius saanichi	0.00	0.00	0.00	0.00
RF	Calanoid, Bradyidius saanichi	0.00	0.00	0.90	0.00
RG	Calanoid, Bradyidius saanichi	0.00	0.00	0.90	0.00
AL	Calanoid, general large (>2.5mm)	0.00	0.00	9.27	11.67
CP	Calanoid, Calanus sp.	0.00	0.00	0.00	0.53
G	Calanoid, Metridia sp.	0.00	0.00	0.00	1.23
GF	Calanoid, Metridia general	0.00	0.00	3.65	0.00
PF	Calanoid, Metridia pacifica	0.00	0.00	1.08	10.85
PM	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.16
OR	Calanoid, Tortanus discaudatus	0.00	0.00	0.13	0.00
PF	Calanoid, Neocalanus plumchrus	0.00	0.00	0.00	1.94
alanoid copepod-small					
C	Calanoid, Acartia sp.	0.12	0.00	0.00	0.00
LF	Calanoid, Acartia longiremis	0.16	0.00	0.00	0.00
LM	Calanoid, Acartia longiremus	0.00	0.00	0.04	0.00
AS	Calanoid, general small (<2.5mm)	31.82	2.99	1.84	0.06
OS	Calanoid, Copepodite small	0.09	0.00	0.00	0.00
SA	Calanoid, Pseudocalanus spp.	0.00	0.00	1.36	0.00
SF	Calanoid, Pseudocalanus spp.	0.00	0.00	1.43	0.00
SM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.09	0.00
ladoceran					
ON	Cladoceran, Podon sp.	0.00	0.00	0.05	0.00
haetognath					
HT	Chaetognath, species unknown	0.00	0.00	0.00	0.76
GE	Chaetognath, Sagitta (elegans)	0.00	0.00	1.80	0.38
nidarian/ Ctenophore					
NS	Cnidaria (<2mm), general small	0.00	0.00	0.00	0.10
yphonaute					
FN	Bryozoa, cyphonautes larva	0.01	0.00	0.00	0.00
uphausiid					

Table 24 cont.					
EU4	Euphausiid furcilia	0.00	1.42	0.00	0.00
EUJ	Euphausiid juvenile, general	0.00	26.41	0.00	15.64
EUP	Euphausiid, general unknown	0.00	38.64	43.65	9.15
Gammarid					
GA1	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.56
GA2	Amphipod, Gammarid, unknown	0.00	0.00	0.00	1.15
GAU	Amphipod, Gammarid, unknown	0.00	0.00	0.00	2.30
Gastropod					
GST	Gastropoda, general juvenile	0.77	0.00	0.00	0.00
Hyperiid					
HYP	Amphipod, Hyperiid, unknown juv.	0.00	28.52	32.21	0.00
Larvacean					
OI1	Larvacea, Oikopleura < 2mm	2.02	0.00	0.00	0.00
OKP	Larvacea, Oikopleura sp.	12.99	1.69	1.09	0.03
Malacostracan					
MAE	Malacostraca, eyes only	0.21	0.00	0.00	2.01
MAL	Malacostraca	0.00	0.00	0.00	20.73
MYS	Mysidae, general adult	0.00	0.00	0.00	20.30
Other					
BVL	Bivalve, larvae	0.01	0.00	0.00	0.00
CLA	Cladocera, General	0.02	0.00	0.00	0.00
CUM	Cumacea	0.00	0.00	0.36	0.45
EGG	Unknown invertebrate egg, small	51.71	0.00	0.00	0.00
HRC	Harpacticoid, general copepodi	0.03	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00
UNP	Unknown nauplius	0.00	0.00	0.01	0.00
NEM	Nematode	0.00	0.33	0.12	0.00
PLL	Polychaeta, general, juvenile	0.05	0.00	0.00	0.00

Table 25. Diet overlap (Schoener Overlap Index) values for co-occurring pollock and herring in PWS, 1994-1995.

station-haul (season year)	species								
	0 pollock	2 pollock	1 herring	1 herring	1 herring	0 pollock	0 pollock	0 pollock	0 pollock	
	0 herring	0 herring	0 herring	0 pollock	1 pollock	0 pollock	0 pollock	1 pollock	2 pollock	
6-1 (F94)	3.00	64.00	31.00	70.00	25.00	42.00	42.00	20.00	40.00	
7-4 (F94)	78.00								39.00	
6-1 (F95)	26.50								12.00	
7-1 (F95)	32.00								0.00	
7-1 (F95)		0.00								
7-2 (F95)		0.00								
8-2 (F94)			0.00							
8-3 (F94)			0.00							
2-1 (S95)				0.00						
2-1 (S95)					0.00					
7-1 (F95)						0.00				
7-1 (F95)						0.00				
53-1 (S95)							0.00			
53-2 (S95)							0.00			
2-1 (S95)								0.00		
7-2 (F95)									0.00	
3-1 (F95)									0.00	
3-2 (F95)									0.00	
4-3 (F95)									0.00	

Table 26. Diet overlap (Schoener Overlap Index) of sympatric forage fish species-size groups (n = 10 each) at stations in northeastern PWS in fall, 1994.

Northeastern Area PWS

	station-haul	6	7	7	7	8
	species	0 herring	0 herring	0 herring	0 pollock	0 herring
		0 pollock	0 pollock	0 eulachon	0 eulachon	1 herring
SPCD	*preyname*					
Calanoid copepod-large						
CAL	Calanoid, general large (>2.5 mm)	0.00	0.00	0.00	0.00	2.22
CLN	Calanoid, large, Neocalanus/Calanus	0.00	1.58	0.00	0.00	0.00
CMF	Calanoid, Calanus marshallae AF	0.00	0.00	0.00	0.00	0.00
CPD	Calanoid, Calanus/Neocalanus copepodids	0.00	0.00	0.00	0.00	0.00
CPM	Calanoid, Calanus pacificus AM	0.00	0.00	0.00	0.00	0.00
ECF	Calanoid, Euchaeta elongata, AF	0.00	0.00	0.00	0.00	0.00
ECM	Calanoid, Euchaeta elongata, AM	0.00	0.00	0.00	0.00	0.00
EPM	Calanoid, Epilabidocera longipedata, AM	0.00	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica, AF	0.00	0.31	0.00	0.00	0.00
MPM	Calanoid, Metridia pacifica, AM	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small						
ACA	Calanoid, Acartia clausi adult	0.00	0.00	0.00	0.00	0.01
AL	Calanoid, Acartia longiremus adult	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis AF	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis, AF	0.00	0.00	0.00	0.00	0.00
CAM	Calanoid, Centropages abdominalis, AM	0.00	0.00	0.00	0.00	0.08
CAS	Calanoid, general small (<2.5 mm)	0.29	0.83	0.00	0.00	9.23
LUC	Calanoid, Lucicutia flavicornis	0.00	0.00	0.00	0.00	0.00
OS	Cyclopoid, Oithona similis, general	0.00	0.00	0.00	0.00	0.00
OSF	Cyclopoid, Oithona similis AF	0.00	0.00	0.00	0.00	0.00
PCP	Calanoid, Pseudocalanus copepodids I-IV	0.00	0.00	0.00	0.00	0.16
PSA	Calanoid, Pseudocalanus sp., general	0.00	0.00	0.00	0.00	1.64
PSF	Calanoid, Pseudocalanus AF	0.00	0.00	0.00	0.00	3.70
PSM	Calanoid, Pseudocalanus AM	0.00	0.00	0.00	0.00	0.84
Chaetognath						
CHT	Chaetognath, species unknown	0.00	0.17	0.00	0.00	0.00

able 26 cont.						
GE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00
ecapod						
ZC	Decapod zoea, Shrimp, Crangonidae	0.00	0.00	0.00	0.00	0.00
ZG	Decapod zoea, crab, general unknown	0.00	0.00	0.00	0.00	0.00
uphausiid						
U3	Euphausiid calyptopis	0.09	0.00	0.00	0.00	0.25
U4	Euphausiid furcilia	0.00	0.15	0.00	0.00	0.60
UP	Euphausiid, general unknown	0.00	51.92	46.90	46.90	0.00
H	Euphausiid, Thysannoessa sp., gen. adult	0.00	19.08	0.00	0.00	0.00
RF	Euphausiid, T. raschii females	0.00	0.00	0.00	0.00	0.00
RM	Euphausiid, T. raschii males	0.00	0.00	0.00	0.00	0.00
ammarid						
A1	Amphipod, Gammarid, unknown, small	0.00	0.00	0.00	0.00	0.00
A2	Amphipod, Gammarid, unknown, medium	0.00	0.00	0.00	0.00	0.00
astropod						
ST	Gastropoda, general juvenile (SNAIL)	0.00	0.00	0.00	0.00	0.00
MJ	Gastropod, Pteropod, Limacina helicina J	0.00	0.00	0.00	0.00	0.69
TP	Gastropoda, Pteropod, unidentified	0.00	0.00	0.00	0.00	0.00
yperiid						
P	Amphipod, Hyperiid, Hyperia sp.	0.00	0.00	0.00	0.00	0.00
YP	Amphipod, Hyperiid, unknown juvenile	0.00	3.07	0.00	0.00	6.05
A1	Amphipod, P. pacifica juvenile, <2mm	0.00	0.00	0.00	0.00	0.00
A2	Amphipod, P. pacifica juvenile, 2-6.9mm	0.00	0.00	0.00	0.00	0.00
L2	Amphipod, Hyperiid, P. libellula 2-6.9mm	0.00	0.00	0.00	0.00	0.00
P	Amphipod, Hyperiid/Parath. pacifica gen.	0.00	0.00	0.00	0.00	0.00
R1	Amphipod, Hyperiid, Primno macropa, <2mm	0.00	0.00	0.00	0.00	0.00
R2	Amphipod, Hyperiid, P. macropa, 2-6.9mm	0.00	0.00	0.00	0.00	0.00
S2	Amphipod, Hyperiid, Parathem. sp.2-6.9mm	0.00	0.00	0.00	0.00	0.00
arvacean						
KI	Larvacea, Oikopleura dioica	2.44	0.56	0.00	0.00	5.80
alacostracan						
AE	Malacostraca, eyes only	0.00	0.00	0.00	0.00	0.00
AL	Malacostraca	0.00	0.00	0.00	0.00	0.00

Table 26 cont.

Other						
BVL	Bivalve, larvae	0.00	0.00	0.00	0.00	0.01
EGG	Unknown invertebrate egg, small (<0.2mm)	0.00	0.00	0.00	0.00	0.13
EGL	Unknown invertebrate egg, large (>0.2mm)	0.00	0.00	0.00	0.00	0.00
HZC	Harpacticoid, Zaus copepodite	0.00	0.00	0.00	0.00	0.00
ISP	Isopod, general	0.00	0.00	0.00	0.00	0.00
NEM	Nematode	0.00	0.00	0.00	0.00	0.00
PCO	Copepod, Caligidae, parasitic copepod	0.00	0.00	0.00	0.00	0.00
PEC	Polychaeta, Pectinariidae	0.00	0.00	0.00	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00
UEM	Unknown egg mass	0.00	0.00	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00
TOTAL		2.82	77.67	46.90	46.90	31.42

Table 27. Diet overlap (Schoener Overlap Index) of sympatric forage fish species-size groups (n = 10 each) at stations in central, northeastern and southwestern PWS in summer, 1995.

Region	NE	NE	SW	SW	C	C	C
station-haul	118-1	82-1	51-1	43-1	53-1 and 53-2	62-1 and 62-2	73-1
species	0 herring	2 pollock	0 pollock	0 herring	60m 0 pollock	20m 0 pollock	80m 0 pollock
	0 sandlance	0 sandlance	1 tomcod	0 capelin	20m 0 pollock	20m 0 capelin	80m 0 capelin
spcd							
AC	herring empty	0.00	0.00	0.00	0.15	capelin empty	capelin empty
ACA	herring empty	0.00					
ACC	herring empty	0.00					
ACP					0.00	capelin empty	capelin empty
ALC			0.00	0.00		capelin empty	capelin empty
ALF			0.00	0.00	0.00	capelin empty	capelin empty
ALG	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
BMC	herring empty	0.00	0.02	0.00	0.00	capelin empty	capelin empty
BMM						capelin empty	capelin empty
BMP	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
BMV			0.00	0.00			
BVL	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
BVP			0.00	0.00			
CA	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
CAC			0.00	0.00			
CAF	herring empty	0.00	0.00	0.00		capelin empty	capelin empty
CAL	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
CAM			0.00	0.00	0.00	capelin empty	capelin empty
CAN	herring empty	0.00			0.00	capelin empty	capelin empty
CAP						capelin empty	capelin empty
CAS	herring empty	0.08	0.01	40.09	19.35	capelin empty	capelin empty
CAV			0.00	0.00		capelin empty	capelin empty
CCF					0.00	capelin empty	capelin empty
CCP					0.00	capelin empty	capelin empty
CFN	herring empty	0.00				capelin empty	capelin empty
CGC			0.00	0.00			
CHT	herring empty	0.00			0.00	capelin empty	capelin empty
CLA	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
CLN	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty
CLU					0.00	capelin empty	capelin empty
CM	herring empty	0.00			0.00	capelin empty	capelin empty

Table 27 cont.

CMC					0.00	capelin empty	capelin empty	
CMF	herring empty	0.00			0.00	capelin empty	capelin empty	
CMM			0.00	0.00				
COS			0.00	0.00	0.00	capelin empty	capelin empty	
CPA			0.00	0.00	0.00	capelin empty	capelin empty	
CPC			0.00	0.00	0.00	capelin empty	capelin empty	
CPF					0.00	capelin empty	capelin empty	
CPG	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
CPM					0.00	capelin empty	capelin empty	
CUM			0.07	0.00				
DCM	herring empty	0.00				capelin empty	capelin empty	
DGB	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
DIP						capelin empty	capelin empty	
DMG	herring empty	0.00						
DML	herring empty	0.00						
DMP	herring empty	0.00						
DPL			0.00	0.00				
DZB	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
DZG	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
DZP	herring empty	0.00						
EGG	herring empty	0.00	0.00	0.00	1.78	capelin empty	capelin empty	
EGL	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
EPC						capelin empty	capelin empty	
EPF	herring empty	0.00				capelin empty	capelin empty	
EPI	herring empty	0.00				capelin empty	capelin empty	
EPM	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
EU3	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
EU4	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
EUB					0.00	capelin empty	capelin empty	
EUJ			0.00	0.00	0.00	capelin empty	capelin empty	
EUP	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
EVD	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
EYF	herring empty	0.00						
EYT	herring empty	0.00	0.00	0.00				
FSE	herring empty	0.00						
FSJ			0.00	0.00				
FSL					0.00	capelin empty	capelin empty	
FW2			0.00	0.00				

Table 27 cont.								
FW3			0.00	0.00				
GA1			0.00	0.00	0.00	capelin empty	capelin empty	
GA2			0.00	0.00		capelin empty	capelin empty	
GA3			0.00	0.00				
GAM			0.00	0.00				
GAU			0.00	0.00				
GSB	herring empty	0.00				capelin empty	capelin empty	
GST	herring empty	0.00				capelin empty	capelin empty	
HEM	herring empty	0.00	0.00	0.00				
HIE	herring empty	0.00						
HPJ					0.00	capelin empty	capelin empty	
HR	herring empty	0.00	0.00	0.00				
HRC	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
HRJ			0.00	0.00		capelin empty	capelin empty	
HRS			0.00	0.00				
HYB	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
HYP	herring empty	0.00	0.00	0.00	17.81	capelin empty	capelin empty	
HZC	herring empty	0.00						
HZZ						capelin empty	capelin empty	
GN			0.00	0.00				
NS						capelin empty	capelin empty	
SP						capelin empty	capelin empty	
LAC	herring empty	0.00						
LAO	herring empty	0.00	0.00	0.00				
LIZ	herring empty	0.00						
LMA					0.00	capelin empty	capelin empty	
LMJ	herring empty	0.00	0.00	0.00	7.37	capelin empty	capelin empty	
MAE	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
MAL	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
MEP					0.00	capelin empty	capelin empty	
MG	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
MGM					0.00	capelin empty	capelin empty	
MOF	herring empty	0.00				capelin empty	capelin empty	
MP						capelin empty	capelin empty	
MPF	herring empty	0.00	0.01	0.00	0.00	capelin empty	capelin empty	
MPM					0.00	capelin empty	capelin empty	
NCP	herring empty	0.00						
NEM			0.00	0.00	0.00	capelin empty	capelin empty	

Table 27 cont.

NEO	herring empty	0.00				capelin empty	capelin empty	
NPF	herring empty	0.00						
OIT			0.00	0.00		capelin empty	capelin empty	
OKP	herring empty	0.00	0.00	0.00	0.20	capelin empty	capelin empty	
OS	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
OSC						capelin empty	capelin empty	
OSF	herring empty	0.00						
PA1			0.00	0.00	0.00	capelin empty	capelin empty	
PA2	herring empty	0.00						
PCO			0.00	0.00				
PCP	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
PDZ	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
PGZ	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
PLA			0.00	0.00				
PLL	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
PON	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
PR1			0.00	0.00		capelin empty	capelin empty	
PR2						capelin empty	capelin empty	
PR3						capelin empty	capelin empty	
PRI			0.00	0.00		capelin empty	capelin empty	
PS1	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
PS2	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
PSA	herring empty	0.00	0.00	0.00	11.52	capelin empty	capelin empty	
PSF	herring empty	0.00	0.00	0.00	1.47	capelin empty	capelin empty	
PSG			0.00	0.00				
PSM			0.00	0.00	0.00	capelin empty	capelin empty	
PTP					0.00	capelin empty	capelin empty	
SGE					0.00	capelin empty	capelin empty	
SHP	herring empty	0.00						
SHR	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	
TH					0.00	capelin empty	capelin empty	
THJ						capelin empty	capelin empty	
TL	herring empty	0.00				capelin empty	capelin empty	
TSB			0.00	0.00		capelin empty	capelin empty	
TSC	herring empty	0.00	0.00	0.00		capelin empty	capelin empty	
TSG			0.00	0.00		capelin empty	capelin empty	
UEM	herring empty	0.00						
UNI	herring empty	0.00	0.00	0.00	0.00	capelin empty	capelin empty	

Table 27 cont.								
UNP	herring empty	0.00			0.00	capelin empty	capelin empty	
TOTAL	herring empty	0.08	0.12	40.09	59.65	capelin empty	capelin empty	

Table 28. Diet overlap (Schoener Overlap Index) of sympatric forage fish species-size groups (n = 10 each) at stations in central (A), northeastern (B) and southwestern (C) PWS in fall, 1995.

A) Central Area PWS			Station 3			Station 4	
		0 pollock	0 pollock	0 capelin	0 pollock	0 pollock	0 capelin
SPCD		2 pollock	0 capelin	2 pollock	2 pollock	0 capelin	2 pollock
Calanoid copepod-large							
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00	0.00
CAL	Calanoid, general large (>2.5 mm)	1.84	0.00	0.00	3.73	0.00	0.00
CCP	Calanoid, Calanus sp. copepodite	0.13	0.00	0.00	0.00	0.00	0.00
CLN	Calanoid, large, Neocalanus/Calanus	0.23	0.00	0.00	0.00	0.00	0.00
CM	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	0.00	0.00
CMC	Calanoid, C. marshallae	0.00	0.00	0.00	0.00	0.00	0.00
CMF	Calanoid, Calanus marshallae	0.00	0.00	0.00	0.00	0.00	0.00
CPC	Calanoid, Calanus pacificus	0.00	0.00	0.00	0.00	0.00	0.00
CPF	Calanoid, Calanus pacificus	0.13	0.00	0.00	0.00	0.00	0.00
CPM	Calanoid, Calanus pacificus	0.00	0.00	0.00	0.00	0.00	0.00
ECC	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00
ECF	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00
ECM	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00
EEF	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00	0.00
MCS	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	0.00
MEP	Calanoid, Metridia pacifica	2.09	0.00	0.00	0.00	0.00	0.00
MPC	Calanoid, Metridia pacifica	0.05	0.00	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica	10.31	0.00	0.00	0.65	0.00	0.00
MPM	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	0.00
NEO	Calanoid, Neocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
EPC	Calanoid, Epilabidocera longipedata	0.00	0.00	0.00	0.00	0.00	0.00
EPF	Calanoid, Epilabidocera longipedata	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small							
CAS	Calanoid, general small (<2.5mm)	0.03	0.00	0.00	0.09	0.00	0.00
COS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00
MEF	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.00
MEG	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.00
MES	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
PSF	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
OS	Cyclopoid, Oithona similis	0.00	0.00	0.00	0.00	0.00	0.00
PCP	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00

Table 28 cont.								
Cladoceran								
PON	Cladoceran, Podon sp.	0.00	0.00	0.00		0.00	0.00	0.00
Chaetognat								
CHT	Chaetognath, species unknown	0.15	0.00	0.00		0.00	0.00	0.00
SGE	Chaetognath, Sagitta (elegans)	0.02	0.00	0.00		0.00	0.00	0.00
Decapod								
DZG	Decapod, zoea, general unknown	0.00	0.00	0.00		0.00	0.00	0.00
HIE	Decapod zoea, Shrimp, Hippolytidae	0.00	0.00	0.00		0.00	0.00	0.00
PAN	Decapod, Pandalidae	0.00	0.00	0.00		0.00	0.00	0.00
PGZ	Decapod zoea, hermit crab	0.00	0.00	0.00		0.00	0.00	0.00
Euphausiid								
EP1	Euphausiid, E. pacifica small	0.00	0.00	0.00		0.00	0.00	0.00
EP2	Euphausiid, E. pacifica medium	0.00	0.00	0.00		0.00	0.00	0.00
EP3	Euphausiid, E. pacifica large	8.62	0.00	0.00		0.00	0.00	0.00
EPP	Euphausiid nauplii	0.00	0.00	0.00		0.00	0.00	0.00
EU2	Euphausiid calyptopis	0.00	0.00	0.00		0.00	0.00	0.00
EU3	Euphausiid furcilia	0.00	0.00	0.00		0.00	0.00	0.00
EU4	Euphausiid juvenile, general	0.08	0.00	0.00		0.00	0.00	0.00
EUJ	Euphausiid, general unknown	5.97	5.97	16.28		0.00	0.00	0.00
EUP	Euphausiid, Euphausia pacifica	4.33	0.00	0.00		7.27	0.00	0.00
TH	Euphausiid, Thysannoessa sp.,	0.70	0.00	0.00		0.00	0.00	0.00
THJ	Euphausiid, Thysannoessa sp.	0.35	0.35	0.37		0.00	0.00	0.00
TS	Euphausiid, Thysanoessa spinifera	0.66	0.00	0.00		0.00	0.00	0.00
Fish								
FSL	Fish larvae, general	2.41	0.00	0.00		0.00	0.00	0.00
Gammarid								
GA3	Amphipod, Gammarid, unknown	0.00	0.00	0.00		0.00	0.00	0.00
GAU	Amphipod, Gammarid, unknown	0.00	0.00	0.00		0.00	0.00	0.00
Gastropod								
GST	Gastropoda, general juvenile	0.00	0.00	0.00		0.00	0.00	0.00
LMJ	Gastropod, Pteropod, Limacina	0.00	0.00	0.00		0.00	0.00	0.00
Hyperiid								
HP	Amphipod, Hyperiid, Hyperia sp	0.00	0.00	0.00		0.00	0.00	0.00
HYA	Amphipod, Hyperiid, unknown	0.00	0.00	0.00		0.00	0.00	0.00
HYB	Amphipod, Hyperiid, unknown	0.02	0.00	0.00		0.00	0.00	0.00
HYP	Amphipod, Hyperiid, unknown	0.76	0.00	0.00		0.00	0.00	0.00
PR1	Amphipod, Hyperiid, Primno macropa	0.00	0.00	0.00		0.00	0.00	0.00
PRI	Amphipod, Hyperiid, Primno macropa	0.00	0.00	0.00		0.00	0.00	0.00

Table 28 cont.								
PS	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.00		0.00	0.00	0.00
PS1	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.00		0.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathemisto	0.38	0.00	0.00		0.00	0.00	0.00
PA2	Amphipod, P. pacifica juvenile	0.08	0.00	0.00		0.00	0.00	0.00
Larvacean								
OKP	Larvacea, Oikopleura sp.	0.00	0.00	0.00		0.00	0.00	0.00
Malacostracan								
MAE	Malacostraca, eyes only	0.00	0.00	0.00		0.16	0.00	0.00
Other								
BVL	Bivalve, larvae	0.00	0.00	0.00		0.00	0.00	0.00
EGG	Unknown invertebrate egg, small	0.00	0.00	0.00		0.00	0.00	0.00
NEM	Nematode	0.01	0.00	0.00		0.03	0.00	0.00
ISC	Isopod, (Epicarid)	0.00	0.00	0.00		0.00	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00	0.00	0.00		0.00	0.00	0.00
total		39.35	6.32	16.65		11.94	0.00	0.00

Table 28 cont.						
B) Northeastern Area PWS		station 6	station 7	station 7	station 7	station 7
			20 m	20 & 90 m	20 m	20 m
		0 herring	0 herring	0 pollock	2 pollock	0 herring
SPCD		0 pollock	0 pollock		0 pollock	2 pollock
Barnacle						
BMP	Barnacle, nauplius	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-large						
CAL	Calanoid, general large (>2.5mm)	4.24	10.97	13.21	7.16	7.16
CCL	Calanoid, Candacia columbiae	0.00	0.00	0.00	0.00	0.00
CMC	Calanoid, C. marshallae	0.00	0.00	0.54	0.00	0.00
CPF	Calanoid, Calanus pacificus	0.00	0.00	0.00	0.00	0.00
MCS	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00
MEP	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00
MG	Calanoid, Metridia sp.	0.00	0.00	0.00	0.00	0.00
MP	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00
MPC	Calanoid, Metridia pacifica	2.03	0.00	0.46	0.21	0.00
MPF	Calanoid, Metridia pacifica	2.29	9.87	9.87	9.87	41.44
EUE	Calanoid, Euchaeta elongata	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small						
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis	0.00	0.00	0.02	0.00	0.00
CA	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00
CAC	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00
CAF	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00
CAM	Calanoid, Centropages abdominalis	0.00	0.00	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus spp.	0.30	0.00	0.09	0.00	0.00
PSF	Calanoid, Pseudocalanus spp.	0.46	0.00	0.27	0.00	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00
MEG	Calanoid, Mesocalanus tenuicornis	0.00	0.00	0.00	0.00	0.00
COS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00
CAN	Calanoid, general nauplius	0.00	0.00	0.00	0.00	0.00
CAS	Calanoid, general small (<2.5 mm)	0.89	0.85	0.73	0.17	0.17
OS	Cyclopoid, Oithona similis	0.00	0.00	0.00	0.00	0.00
TOR	Calanoid, Tortanus discaudatus	0.00	0.00	0.00	0.00	0.00
Chaetognat						
CHT	Chaetognath, species unknown	0.07	0.00	0.00	0.00	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00

Table 28 cont.							
Cyphonaute							
CFN	Bryozoa, cyphonautes larva	0.00		0.00	0.00	0.00	0.00
Decapod							
DZG	Decapod, zoea, general unknown	0.00		0.00	0.00	0.00	0.00
SHR	Decapod zoea, general shrimp	0.00		0.00	0.00	0.00	0.00
Euphausiid							
EPP	Euphausiid, Euphausia pacifica	0.00		0.00	0.00	0.00	0.00
EUJ	Euphausiid juvenile, general	0.00		0.43	0.00	10.84	0.43
EUP	Euphausiid, general unknown	9.08		0.00	6.34	2.25	0.00
TH	Euphausiid, Thysannoessa sp.,	4.67		0.00	8.16	0.00	0.00
TRF	Euphausiid, T. raschii	0.00		0.00	0.00	0.00	0.00
TRG	Euphausiid, T. raschii	2.34		0.00	0.00	0.00	0.00
TRM	Euphausiid, T. raschii	0.00		0.00	0.00	0.00	0.00
Gammarid							
GA2	Amphipod, Gammarid, unknown	0.00		0.00	0.00	0.00	0.00
Gastropod							
GST	Gastropoda, general juvenile	0.00		0.00	0.00	0.00	0.00
LMA	Gastropod, Pteropod, Limacina	0.00		0.00	0.00	0.00	0.00
LMJ	Gastropod, Pteropod, Limacina	0.00		0.00	0.00	0.00	0.00
Hyperiid							
HYB	Amphipod, Hyperiid, unknown	0.00		0.00	0.00	0.00	0.00
HYP	Amphipod, Hyperiid, unknown	0.00		9.36	1.70	9.36	14.92
PA2	Amphipod, P. pacifica juvenile	0.00		0.00	0.00	0.00	0.00
PL3	Amphipod, Hyperiid, P. libellula	0.00		0.00	0.00	0.00	0.00
PR2	Amphipod, Hyperiid, P. macropa	0.00		0.00	0.00	0.00	0.00
PS2	Amphipod, Hyperiid, Parathemisto sp.	0.00		0.00	0.00	0.00	0.00
Insect							
DPL	Insect, Dipteran larvae	0.00		0.00	0.00	0.00	0.00
Larvacean							
OI1	Larvacea, Oikopleura < 2mm	0.00		0.00	0.00	0.00	0.00
OKP	Larvacea, Oikopleura sp.	0.06		0.79	0.35	0.01	0.01
Malacostracan							
MAE	Malacostraca, eyes only	0.00		0.09	0.00	0.00	0.00
MAL	Malacostraca	0.00		0.00	0.00	0.00	0.00
MYA	Mysidae, general	0.00		0.00	0.00	0.00	0.00
Other							
BVL	Bivalve, larvae	0.00		0.00	0.00	0.00	0.00
EGG	Unknown invertebrate egg, small	0.00		0.05	0.00	0.00	0.00

Table 28 cont.

EGL	Unknown invertebrate egg, large	0.00		0.00	0.00	0.00	0.00
HR	Harpacticoid, general, unknown	0.01		0.00	0.02	0.00	0.00
HRC	Harpacticoid, general copepodite	0.00		0.00	0.00	0.00	0.00
HZC	Harpacticoid, Zaus copepodite	0.00		0.00	0.00	0.00	0.00
HZZ	Harpacticoid, Zaus sp.	0.00		0.00	0.00	0.00	0.00
ISP	Isopod, general	0.00		0.00	0.00	0.00	0.00
NEM	Nematode	0.00		0.00	0.00	0.00	0.00
UNI	Unidentified item	0.00		0.00	0.00	0.00	0.00
PCO	Copepod, Caligidae, parasitic	0.00		0.00	0.00	0.00	0.00
PLA	Polychaeta, adult	0.00		0.00	0.00	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00		0.00	0.00	0.00	0.00
PUN	Polychaeta, unknown large	0.00		0.00	0.00	0.00	0.00
Total		26.46		32.42	41.77	39.86	64.12

Table 28 cont.

C) Southwestern Area PWS

SPCD		0 herring	0 herring	0 herring	1 herring	1 herring	0 pollock
Calanoid copepod-large		1 herring	0 pollock	1 pollock	0 pollock	1 pollock	1 pollock
BRC	Calanoid, Bradyidius saanichi	0.00	0.00	0.00	0.00	0.00	0.00
BRF	Calanoid, Bradyidius saanichi	0.00	0.00	0.00	0.00	0.00	0.00
BRG	Calanoid, Bradyidius saanichi	0.00	0.00	0.00	0.00	0.00	0.00
CAL	Calanoid, general large (>2.5mm)	0.00	0.00	0.00	0.00	0.00	9.27
CCP	Calanoid, Calanus sp.	0.00	0.00	0.00	0.00	0.00	0.00
MG	Calanoid, Metridia sp.	0.00	0.00	0.00	0.00	0.00	0.00
MGF	Calanoid, Metridia general	0.00	0.00	0.00	0.00	0.00	0.00
MPF	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	1.08
MPM	Calanoid, Metridia pacifica	0.00	0.00	0.00	0.00	0.00	0.00
TOR	Calanoid, Tortanus discaudatus	0.00	0.00	0.00	0.00	0.00	0.00
NPF	Calanoid, Neocalanus plumchrus	0.00	0.00	0.00	0.00	0.00	0.00
Calanoid copepod-small							
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.00	0.00	0.00
ALF	Calanoid, Acartia longiremis	0.00	0.00	0.00	0.00	0.00	0.00
ALM	Calanoid, Acartia longiremus	0.00	0.00	0.00	0.00	0.00	0.00
CAS	Calanoid, general small (<2.5mm)	2.99	1.84	0.06	1.84	0.06	0.06
COS	Calanoid, Copepodite small	0.00	0.00	0.00	0.00	0.00	0.00
PSA	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
PSF	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
PSM	Calanoid, Pseudocalanus spp.	0.00	0.00	0.00	0.00	0.00	0.00
Chaetognat							
CHT	Chaetognath, species unknown	0.00	0.00	0.00	0.00	0.00	0.00
SGE	Chaetognath, Sagitta (elegans)	0.00	0.00	0.00	0.00	0.00	0.38
Cladocera							
PON	Cladoceran, Podon sp.	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute							
CFN	Bryozoa, cyphonautes larva	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiid							
EU4	Euphausiid furcilia	0.00	0.00	0.00	0.00	0.00	0.00
EUJ	Euphausiid juvenile, general	0.00	0.00	0.00	0.00	15.64	0.00
EUP	Euphausiid, general unknown	0.00	0.00	0.00	38.64	9.15	9.15
Gammarid							
GA1	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	0.00	0.00
GA2	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	0.00	0.00

Table 28 cont.							
GAU	Amphipod, Gammarid, unknown	0.00	0.00	0.00	0.00	0.00	0.00
Gastropod							
GST	Gastropoda, general juvenile	0.00	0.00	0.00	0.00	0.00	0.00
Hyperiid							
HYP	Amphipod, Hyperiid, unknown juv.	0.00	0.00	0.00	28.52	0.00	0.00
Cnidarian/ Ctenophore							
CNS	Cnidaria (<2mm), general small	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean							
OI1	Larvacea, Oikopleura < 2mm	0.00	0.00	0.00	0.00	0.00	0.00
OKP	Larvacea, Oikopleura sp.	1.69	1.09	0.03	1.09	0.03	0.03
Malacostracan							
MAE	Malacostraca, eyes only	0.00	0.00	0.21	0.00	0.00	0.00
MAL	Malacostraca	0.00	0.00	0.00	0.00	0.00	0.00
MYS	Mysidae, general adult	0.00	0.00	0.00	0.00	0.00	0.00
Other							
BVL	Bivalve, larvae	0.00	0.00	0.00	0.00	0.00	0.00
CLA	Cladocera, General	0.00	0.00	0.00	0.00	0.00	0.00
CUM	Cumacea	0.00	0.00	0.00	0.00	0.00	0.36
EGG	Unknown invertebrate egg, small	0.00	0.00	0.00	0.00	0.00	0.00
HRC	Harpacticoid, general copepodi	0.00	0.00	0.00	0.00	0.00	0.00
UNI	Unidentified item	0.00	0.00	0.00	0.00	0.00	0.00
UNP	Unknown nauplius	0.00	0.00	0.00	0.00	0.00	0.00
NEM	Nematode	0.00	0.00	0.00	0.12	0.00	0.00
PLL	Polychaeta, general, juvenile	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL		4.68	2.93	0.30	70.22	24.89	20.33

Table 29. Prey selection (Strauss Linear Selection values, L) by forage fish species-size groups (n = 10 each) at stations in central and in northeastern and southwestern PWS in summer, 1995.

Region	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
species	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pollock	pink salmon	pollock	pollock	capelin	capelin
size group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
station-haul	3-1	5-2	53-1	53-2	54-2	56-1	56-1	57-2	57-2	58-2	58-2	62-2	62-2	66-2	112-1	112-1	62-1	114-7
depths (m)	60/20	50/20	60/60	20/20	60/60	80/20	80/80	80/20	80/80	80/20	80/80	60/20	60/60	8/20	80/20	80/80	20/20	15/20
SPCD																		
AC	0.18	0.00	0.71	-0.21	0.00	-0.21	0.00	0.00	0.00	-0.34	-1.36	0.00	0.00	0.06	-0.21	-0.42	empty	empty
ACC				0.00	-0.19												empty	empty
ACF	0.00	-0.38	0.00	0.00	-0.30	-0.29	0.00	-0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
ACG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
ACM	0.00	-0.10	-0.31	0.00	-0.69	-0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
ACP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
AL	-0.36	0.00	0.00	0.00	0.00	0.00	-6.35	-0.14	-1.12	0.00	0.00	-1.21	-0.66	-1.04	0.00	-2.01	empty	empty
ALC	-0.24	-0.67	0.00	-1.16	-0.52	-0.37	0.00	-0.71	-0.22	0.00	0.00	0.00	0.00	-0.23	0.00	0.00	empty	empty
ALF	-6.10	-3.87	-4.34	-3.63	-4.52	-8.46	-0.15	-4.30	-1.17	-1.64	-0.63	-1.00	-2.06	-0.81	0.00	-0.21	empty	empty
ALG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.67	0.00	0.00	0.00	0.00	-1.78	0.00	0.00	empty	empty
ALM	-1.28	-0.58	-0.76	-1.33	-1.71	-1.65	0.00	-1.07	-1.33	-0.75	-0.14	-0.12	-0.21	-0.23	0.00	0.00	empty	empty
AUT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
BMC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
BMM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.11	empty	empty
BMP	0.00	-0.58	-0.31	0.00	0.00	-0.29	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	empty	empty
BVL	0.00	-0.12	0.00	0.19	0.19	0.46	0.46	0.44	0.44	0.04	0.04	0.00	0.00	0.00	0.00	0.00	empty	empty
CA	0.00	0.00	0.00	0.00	0.00	0.00	-0.15	-0.70	0.00	0.04	-0.08	-0.09	0.00	0.00	-0.21	-0.15	empty	empty
CAC	0.00	-0.21	-0.15	0.00	-0.50	-0.29	0.00	0.00	-0.78	0.00	0.00	-1.08	0.00	-0.35	0.00	0.00	empty	empty
CAF	0.00	0.00	-0.31	-0.17	0.00	-0.19	0.00	0.00	-0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CAL	0.35	9.74	0.07	0.00	0.00	0.00	0.00	0.67	0.67	0.19	0.37	6.40	6.40	0.64	9.22	9.22	empty	empty
CAM	0.00	-2.56	-0.31	0.00	0.00	-0.40	-0.29	0.00	-0.56	0.00	-0.70	0.43	0.00	0.00	0.00	0.00	empty	empty
CAN	0.00	0.00	0.00	0.00	0.00	0.00	-0.38	0.00	-0.44	0.00	0.00	-0.09	0.00	0.00	0.00	0.00	empty	empty
CAP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CAS	12.16	11.61	34.08	66.54	66.54	38.53	38.39	35.91	36.22	39.01	39.01	45.35	45.35	0.76	19.90	19.90	empty	empty
CAV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CFN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CCF	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CCP	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.37	0.00	0.00	empty	empty

Table 29 cont.																		
CCV	0.00	-0.01	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CHT	0.12	-0.26	-0.11	-0.06	0.19	0.05	0.31	0.11	0.33	-0.52	0.06	0.49	0.58	0.00	6.74	6.80	empty	empty
CLA	0.00	0.00	0.00	0.00	0.00	0.92	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CLN	0.00	0.00	0.00	0.00	0.00	0.00	-0.44	0.00	0.00	0.08	0.08	0.90	1.16	0.92	1.94	1.94	empty	empty
CLU	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CM	0.00	-0.11	0.00	0.00	-0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.65	0.00	0.00	empty	empty
CMC	0.00	-0.11	0.22	-4.49	0.00	-1.76	-2.92	-1.39	-1.26	-2.39	-1.46	-0.17	-0.21	-0.57	-2.23	-4.22	empty	empty
CMF	0.00	0.00	0.00	0.00	0.00	-0.05	-0.22	-0.18	0.00	0.00	0.00	0.00	0.00	0.19	0.00	-0.52	empty	empty
CMM	0.00	-0.12	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	0.00	0.00	empty	empty
CNI	-0.01	0.00	-0.01	-0.01	0.00	-0.12	-0.02	-0.15	-0.11	-0.05	-0.02	-0.04	-0.05	-0.27	-0.03	-0.03	empty	empty
CNS	0.00	-0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
COS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CPA	0.00	0.00	0.00	0.00	0.00	0.00	-0.16	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	empty	empty
CPC	0.00	0.00	0.00	0.00	-2.76	0.00	0.00	0.00	-1.33	0.00	0.00	-0.25	0.00	0.86	0.00	0.00	empty	empty
CPD	-0.88	-1.04	-3.97	-3.16	0.00	-5.84	0.00	0.00	0.00	0.00	-0.14	0.00	0.00	0.00	0.00	0.00	empty	empty
CPF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.14	-0.25	0.00	0.05	0.00	0.00	empty	empty
CPG	0.12	50.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
CPM	0.00	0.00	0.00	-0.01	-0.03	0.00	-0.58	0.00	-0.44	0.00	-0.14	0.00	0.00	0.00	0.00	0.00	empty	empty
CPV	0.00	-0.10	0.00	-0.01	0.00	0.00	0.00	0.00	-0.22	-0.01	-0.29	-0.12	0.00	0.00	0.00	0.00	empty	empty
CTE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.17	0.00	0.00	0.00	0.00	empty	empty
CTO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.02			empty	empty
DCM				0.00	0.00									0.00	0.00	-0.01	empty	empty
DGB	0.00	0.00	0.00	-0.01	0.00	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
DML	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
DZB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
DZG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	empty	empty
EBC	0.00	-0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
ECC	0.00	-0.12	0.00	0.00	-1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
DIP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
EGG	48.81	-0.69	23.16	26.11	27.10	27.02	27.98	32.00	32.00	19.50	18.93	6.98	6.98	0.59	7.77	7.77	empty	empty
EGL	-2.98	0.00	0.07	0.00	-0.01	0.00	-1.81	-1.70	-2.15	-2.31	-1.82	-0.96	-0.86	-3.17	-0.57	-0.31	empty	empty
EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
EPC	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
EPF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	empty	empty
EPI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.11	empty	empty
EPM	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	empty	empty

Table 29 cont.																		
EU1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
EU2	-0.12	-0.10	0.00	-0.41	-0.30	0.00	-0.01	0.00	0.00	-0.19	-0.12	-0.17	0.00	-0.22	-0.31	0.00	empty	empty
EU3	0.00	0.00	0.00	0.02	0.19	-0.19	0.00	0.00	-0.22	0.00	-0.29	-0.38	0.00	-0.15	0.00	-0.16	empty	empty
EU4	0.00	0.27	-0.15	0.00	0.00	-0.02	-0.08	0.00	-0.06	0.17	0.17	0.00	0.00	0.06	0.00	0.00	empty	empty
EUB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.49	0.49	empty	empty
EUJ	0.00	0.54	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.01	0.00	-0.22	-0.16	-0.01	empty	empty
EUP	0.00	0.00	0.00	0.00	-1.54	0.92	0.92	-0.14	0.00	0.04	0.04	0.00	0.00	0.89	0.97	0.97	empty	empty
EVD	-0.36	-5.96	-6.40	-0.90	0.19	-2.19	-0.90	-0.18	-1.25	-1.25	-1.41	-0.42	0.00	0.00	0.00	-0.21	empty	empty
FSJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
FSL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	1.33	0.00	0.00	1.16	1.16	0.05	0.00	0.00	empty	empty
GA1	0.00	0.00	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
GA2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
GA3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
GSB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.14	0.00	0.00	0.00	0.00	0.00	-0.21	0.00	empty	empty
GST	0.00	-0.12	0.00	0.00	-0.22	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	empty	empty
GSZ	0.00	0.00	0.00	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HIE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	empty	empty
HPJ	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HRC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HRJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HYA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HYB	0.06	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	empty	empty
HYD	0.00	-4.71	0.00	0.00	-0.40	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
HYP	0.00	0.54	-0.32	0.37	0.37	1.16	1.38	0.87	0.89	0.03	0.33	1.16	1.16	0.07	2.43	2.43	empty	empty
HZZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
INS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	empty	empty
ISP	0.00	0.00	0.00	0.00	-0.39	0.00	0.00	0.00	0.00	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	empty	empty
LMA	0.00	0.00	0.04	0.00	-2.86	0.00	0.00	-0.18	0.00	-0.52	-0.24	0.00	0.00	17.43	-0.41	-0.68	empty	empty
LMJ	3.92	-0.02	1.89	-1.05	0.75	14.84	16.68	-2.10	-2.15	8.43	2.36	-1.51	-3.64	6.08	-5.15	-7.33	empty	empty
LRV	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
MAE	0.00	0.00	0.04	0.37	0.37	0.92	0.92	0.89	0.89	0.12	0.12	4.07	4.07	0.20	0.97	0.97	empty	empty
MAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
MEP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
MG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.01	7.28	7.28	empty	empty
MGM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.00	0.00	0.00	empty	empty
MOF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty

Table 29 cont.																		
MP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
MPC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
MPF	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.00	0.00	0.00	empty	empty
MPM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
NEM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
NCP	0.00	-0.01	0.00	0.00	0.00	0.00	-4.17	-1.42	0.00	-1.20	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
NEO	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.15	0.00	-0.01	empty	empty
OIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
OKP	1.52	20.47	0.62	1.14	1.31	0.90	0.60	16.27	16.17	1.48	2.43	19.94	20.69	25.02	39.80	34.94	empty	empty
OS	0.00	0.00	0.00	0.00	0.00	0.00	-0.39	0.00	0.00	0.00	0.00	-0.17	0.00	-0.22	0.00	0.00	empty	empty
OSC	0.00	0.00	0.00	0.00	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
OSF	-0.32	0.00	-0.15	-0.58	0.00	0.00	-0.15	0.00	-0.36	-0.67	-0.14	0.00	0.00	-0.26	0.00	0.00	empty	empty
OSM	0.00	-0.71	0.00	0.00	-0.52	0.00	-0.44	-0.42	-0.36	-0.74	0.00	-0.09	-0.21	-1.46	-0.36	-0.26	empty	empty
OTS	0.00	-0.54	-0.46	-0.54	0.00	-0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			empty	empty
PAN				0.00	0.00										0.00	0.00	empty	empty
PA1	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
PA2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
PCP	2.63	0.00	0.00	0.00	0.00	0.00	-0.58	0.00	-1.11	0.00	-5.36	-3.82	0.00	-0.15	0.00	0.00	empty	empty
PDZ	0.00	-0.22	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
PGZ	0.00	-0.87	0.00	0.00	-0.41	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	empty	empty
PLL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
PON	0.00	-1.92	-0.46	2.80	2.80	-0.59	-0.45	0.04	0.08	0.29	0.02	0.00	0.00	0.00	0.00	0.00	empty	empty
PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	empty	empty
PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	empty	empty
PR3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	empty	empty
PRI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	empty	empty
PS1	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	3.56	3.18	0.08	0.08	2.26	2.33	1.10	-0.21	-0.53	empty	empty
PS2	0.06	0.00	0.00	0.00	-20.73	0.00	-0.03	0.44	0.44	0.04	0.04	0.00	0.00	0.56	0.49	0.18	empty	empty
PSA	-5.49	-10.10	-0.99	-24.08	-58.26	-14.30	-26.38	-22.28	-11.19	-8.15	6.94	-12.46	-14.38	-11.65	-15.58	-19.30	empty	empty
PSF	-50.66	-21.67	-40.85	-55.10	-0.33	-47.90	-40.33	-54.06	-60.33	-47.26	-49.50	-57.53	-67.88	-31.26	-71.88	-53.85	empty	empty
PSG	-0.24	-0.38	-1.07	-0.21	0.00	-0.11	-0.75	-1.09	-0.50	-0.86	-1.09	-3.30	-0.64	-0.26	-0.31	-1.26	empty	empty
PSM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.66	0.00	-5.50	-2.49	0.00	0.00	0.00	0.00	empty	empty
PTP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
SAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
SGE	-0.74	0.00	0.00	0.00	-0.11	0.00	-0.68	-0.47	-0.22	-0.28	-0.33	-0.39	-0.05	7.89	-0.41	-1.35	empty	empty
SHR	-0.12	0.00	0.00	-0.21	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty

Table 29 cont.																		
SIP	0.00	-1.07	-0.03	-0.06	0.00	0.00	-0.02	-0.10	-0.04	-0.01	-0.29	-0.01	-0.21	-0.14	-0.23	-0.18	empty	empty
TH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.13	0.00	0.00	empty	empty
THJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	empty	empty
TL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	empty	empty
TOM	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.01	0.00	-0.32	0.00	-0.15	empty	empty
TSB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
TSC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
TSG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty
UNI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.49	empty	empty
UNP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	empty	empty

Table 29 cont.

Region	SW		NE	NE	NE	NE	NE	NE	NE	NE
species	herring		herring	pollock	pollock	pollock	pollock	sandlance	sandlance	herring
size group	1		1	2	2	2	2	0	0	1
station-haul	107-1		22-2	29-1	29-1	82-1	82-1	82-1	82-1	116-1
depths (m)	20/20		20/20	80/80	80/20	100/20	100/80	100/20	100/80	20/20
SPCD										
Barnacle										
BMM	0.00									
BMC	0.00		0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BMP	0.00		0.00	0.00	-0.71	-0.83	0.00	-0.83	0.00	-0.12
Calanoid copepod-large										
CM			0.00	18.49	18.49	-0.27	0.00	4.40	4.67	0.10
CMF			0.00	-0.05	0.00	0.00	-0.17	0.93	0.76	0.01
CMM	0.00									
CPF	0.00		-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
CPV	0.00		-0.01	-0.16	-0.01	0.00	0.00	0.00	0.00	0.00
CPA	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPC	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPD			-0.52	-1.78	-1.30	0.00	0.00	0.00	0.00	0.00
CPG	0.00		0.00	3.36	3.36	0.00	0.00	89.72	89.72	0.00
CCP	-0.11									
CMC	-0.41		-0.53	-0.49	-1.14	-0.34	-2.75	-0.34	-2.75	-1.54
EPM	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
EPC	0.00		0.00	0.00	-0.10	0.00	0.00	0.00	0.00	0.00
EPF			0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
EPI			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EUB			0.00	0.00	0.00	0.00	-0.17	0.00	-0.17	0.00
MPF	0.00		0.00	2.52	2.51	0.00	0.00	0.00	0.00	0.17
MG	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CAL	0.00		1.62	31.09	31.09	13.59	13.59	0.00	0.00	0.02
CLN	0.00		1.08	9.24	9.24	12.14	12.14	0.00	0.00	0.02
MOF			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
MPC			0.00	-0.14	0.00	0.00	0.00	0.00	0.00	0.00
MEP			0.00	0.00	0.00	0.00	-0.17	0.00	-0.17	0.00

Table 29 cont.										
MCP			0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.12
NPF			0.00	0.00	0.00	0.00	0.00	0.93	0.93	0.00
NEO			0.00	0.00	0.00	0.00	0.00	1.87	1.87	0.01
NCP	-0.22		-0.52	-0.27	0.00	0.00	0.00	0.93	0.93	-0.35
Calanoid copepod-small										
ACA			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACC			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACF	-0.22		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.12
ACM			-0.34	0.00	-0.10	0.00	0.00	0.00	0.00	0.00
ALF	-1.23		-3.27	-2.06	-3.02	-0.85	-0.52	-0.85	-0.52	-6.47
ALG	-0.11		0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL			0.00	0.00	0.00	-0.14	-1.21	-0.14	-1.21	0.00
ALM	-1.23		-0.34	-0.14	-0.42	0.00	0.00	0.00	0.00	-0.80
ALC	-0.45		0.00	-0.14	-0.21	0.00	0.00	0.00	0.00	-0.47
AC	0.15		0.15	0.00	0.00	-3	0	-3	0	-1.54
CA	0.01		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.28
CAF	-0.11		0.03	-0.14	0.00	0.00	0.00	0.00	0.00	-0.12
CAM	0.00		0.00	0.00	0.00	-0.14	0.00	-0.14	0.00	-0.12
CAC	0.00		0.00	0.00	0.00	0.00	-0.34	0.00	-0.34	0.00
COS	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAV	0.00									
CAN	-0.33		0.00	0.00	0.00	-0.14	-0.17	-0.14	-0.17	0.00
CAS	47.45		43.35	14.29	14.29	4.85	4.85	0.93	0.93	2.97
EYF			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EYT	0.02		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PSF	-70.51		-37.24	-61.04	-53.89	-51.56	-54.06	-51.56	-54.06	-41.27
PSM	-2.25		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.12
PCP	-3.26		0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PSG	-0.56		-0.52	-0.96	-1.45	-0.14	-0.17	-0.14	-0.17	-0.28
PSA	-6.39		-14.78	-16.70	-14.73	-12.39	-16.87	-12.39	-16.87	-8.93
OIT	0.00									
OS	0.07		0.24	0.00	0.00	0.00	-0.34	0.00	-0.34	-0.28
OSC			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OSF			0.00	0.00	-0.17	-0.25	-0.17	-0.25	-0.17	-0.28

Table 29 cont.										
OSM			0.00	0.00	0.00	-0.11	-0.34	-0.11	-0.34	0.00
OTS			-0.17	-0.14	-0.17	0.00	0.00	0.00	0.00	0.00
Chaetognath										
SGE	-0.04		0.00	0.00	0.00	-0.11	-1.03	-0.11	-1.03	0.00
CHT	0.00		-0.17	1.12	1.58	46.95	46.92	-0.14	-0.17	0.00
Cladoceran										
EVD	-0.33		-0.69	-1.24	-1.93	-1.81	-1.55	-1.81	-1.55	-4.22
PON	0.00		-11.31	-0.82	-1.36	-3.41	-2.93	-3.41	-2.93	-3.35
CLA	0.03		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute										
CFN			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapod										
LIZ			0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
DZB	-0.03		0.03	0.00	0.00	-0.01	0.00	-0.01	0.00	-0.28
ORG			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DZP			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
SHR	0.00		0.00	-0.15	-0.10	0.00	0.00	0.00	0.00	0.02
PGZ	-0.01		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
HIE	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PDZ	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SHC	-0.01									
DGB	0.00		-0.33	-0.17	0.00	0.00	0.00	0.00	0.00	0.14
DMG			0.00	0.00	0.00	0.49	-0.03	0.00	-0.52	-0.01
DML			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DMP			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DCM			0.00	0.84	0.84	0.00	0.00	0.00	0.00	0.00
DZG	0.01		0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
SHY	-0.01									
SHP			0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00
Euphausiid										
EU2			-0.17	-0.27	0.00	0.00	0.00	0.00	0.00	-0.28
EU3	-0.45		0.00	-0.14	-0.10	0.00	0.00	0.00	0.00	-0.23
EU4	-0.01		0.03	-0.41	0.00	0.00	-0.03	0.00	-0.03	0.02
EUJ	0.00		0.00	-0.15	0.00	0.00	-0.01	0.00	-0.01	-0.16

Table 29 cont.

EUP	0.00		0.00	0.00	0.00	1.94	1.93	0.00	-0.01	0.00
Fish										
FSE			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TL			0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00
FSJ	0.00									
FSL			0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00
FW2	0.00									
FW3	0.00									
Gammerid										
GAM	0.00									
CGC	0.00									
GA3	0.00									
GA2	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GAU	0.00									
GA1	0.00									
Gastropod										
GSB			-0.30	-0.55	-0.55	-3.25	-1.55	-3.25	-1.55	-0.10
GST			-0.80	0.00	0.00	0.00	0.00	0.00	0.00	-0.58
GSZ			0.00	0.00	-0.17	0.00	0.00	0.00	0.00	0.00
VEL			-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAO	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LMA			-0.02	0.00	0.00	-0.34	-0.17	-0.34	-0.17	0.00
LMJ	-1.24		-0.83	-4.69	-10.02	-8.64	-8.44	-8.64	-8.44	-0.01
Hyperiid										
PS1	0.00		0.03	0.00	0.00	0.00	-0.09	0.00	-0.09	0.02
PS2	0.00		0.00	0.00	0.00	-0.11	-0.12	-0.11	-0.12	-0.32
PRI	0.00									
PR1	0.00									
HYP	0.01		-0.11	1.70	1.74	0.49	0.49	0.00	0.00	0.04
HYB	-0.01		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
PA1	0.00									
PA2			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DPL	0.00									

Table 29 cont.									
Cnidarian/ Ctenophore									
CNS	-0.01		0.00	0.00	-0.27	-0.54	0.00	-0.54	0.00	0.00
CNI	-0.01		-0.05	-0.29	-0.06	-0.03	-0.06	-0.03	-0.06	-0.01
Larvacean									
SIP	-0.01		-0.01	-0.01	0.00	-0.22	0.00	-0.22	0.00	0.00
OKP	0.08		-2.89	7.20	5.79	-0.70	1.98	-7.50	-4.82	77.76
Malacostracan									
MAL	0.00		0.00	0.84	0.84	0.00	0.00	0.00	0.00	0.01
MAE	0.00		0.08	0.00	0.00	11.17	11.17	0.00	0.00	0.21
Other									
BVP	0.00									
BVL	-0.22		0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.09
BMV	0.00									
PCO	0.00									
CUM	0.00									
HEM	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HR	0.00		0.00	0.84	0.84	0.00	0.00	0.00	0.00	0.00
HRC	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HRJ	0.00									
HRS	0.00									
TSB	0.00									
TSG	0.00									
IGN	0.00									
LAC			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TSC	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HZC			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ISP			0.00	0.00	0.00	-0.14	0.00	-0.14	0.00	0.00
NEM	0.00									
PLA	0.00									
PLL	0.00		0.00	-0.14	0.00	0.00	0.00	0.00	0.00	0.01
EGL	-0.37		0.03	0.00	0.00	-3.60	-1.03	-3.60	-1.03	-12.46
EGG	42.35		30.14	0.01	-0.25	0.00	0.00	0.00	0.00	3.61
TRK			0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00
UNI			0.00	1.68	1.67	0.00	0.00	0.00	0.00	0.00

Table 29 cont.										
UEM			-1.55	0.00	0.00	0.49	0.49	0.00	0.00	0.00
UNP			0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 30. Prey selection (Strauss Linear Selection values, L) by forage fish species-size groups (n = 10 each) at stations in central and southwestern (A) and northeastern (B) PWS in fall, 1995.

	Region	SW	SW	SW	SW	C	C	C	C	C	C	C
	Station-haul	2-1	2-1	2-1	2-1	3-1	3-1	3-2	4-2	4-3	4-3	5
	n	8	8	2	2	10	10	10	10	10	10	10
	size group	1	1	0	0	0	0	2	0	0	2	0
SPCD	species	herring	pollock	pollock	herring	capelin	pollock	pollock	capelin	pollock	pollock	herring
Barnacle												
BMM	Barnacle, adult molt	0.00	0.00	0.00	0.00	-0.15	-0.15	-0.15				
BMC	Barnacle, cyprid					-0.31	-0.31	-0.31	-0.39	-0.39	-0.39	
BMP	Barnacle, nauplius	-0.20	-0.20	-0.20	-0.20							
Calanoid copepod-large												
CM	Calanoid, Calanus marshallae	-0.01	-0.01	-0.01	-0.01	-0.04	0.01	-0.04	-0.05	-0.05	-0.05	
CMF	Calanoid, Calanus marshallae					0.00	0.10	0.00	-0.05	-0.05	-0.05	
CPF	Calanoid, Calanus pacificus					-0.12	5.75	0.50				0.65
CPM	Calanoid, Calanus pacificus					0.00	0.10	0.00				
CPV	Calanoid, Calanus pacificus											-0.12
CPC	Calanoid, Calanus pacificus					0.00	0.25	0.00				
CCP	Calanoid, Calanus sp.	-0.82	1.00	-0.82	-0.82	-1.23	0.38	-0.62	-0.87	-0.87	-0.87	0.30
CPD	Calanoid, Calanus/Neocalanus	-0.02	-0.02	-0.02	-0.02							
CCL	Calanoid, Candacia columbia											0.00
CMC	Calanoid, C. marshallae	-0.11	-0.11	-0.11	-0.11	-0.12	-0.12	0.04	-0.19	-0.19	-0.19	-0.24
EPF	Calanoid, Epilabidocera longipedata											0.05
EPM	Calanoid, Epilabidocera longipedata					-0.12	-0.12	-0.12				
EPC	Calanoid, Epilabidocera longipedata					-0.27	-0.27	-0.27				0.03
EBC	Calanoid, Eucalanus bungii,								-0.05	-0.05	-0.05	
ECC	Calanoid, Euchaeta elongata											0.02
ECF	Calanoid, Euchaeta elongata											0.05
ECM	Calanoid, Euchaeta elongata					0.00	0.10	0.00				
EEF	Calanoid, Euchaeta elongata											0.05
CAL	Calanoid, general large (>2 mm)	0.00	10.91	3.75	0.00	0.00	2.66	2.45	0.00	50.27	13.79	1.31
CLN	Calanoid, large, Neocalanus					0.00	0.70	0.31	0.00	5.41	0.00	0.65
MGF	Calanoid, Metridia general	0.00	0.00	2.50	0.00							
MCS	Calanoid, Metridia pacifica					-3.22	-3.22	-3.22	-4.76	-4.76	-4.76	-3.91
MPF	Calanoid, Metridia pacifica	-0.04	29.05	1.21	-0.04	-3.22	54.42	36.08	-0.78	13.28	6.12	4.85
MPM	Calanoid, Metridia pacifica	0.00	1.82	0.00	0.00	-1.00	1.41	-1.00				
MPC	Calanoid, Metridia pacifica					-4.10	1.26	-3.34	-2.28	-2.28	-2.28	7.37
MEP	Calanoid, Metridia pacifica					0.00	10.18	12.84	0.00	0.00	6.90	8.12
MCP	Calanoid, Metridia sp.					-1.07	-1.07	-1.07				
MG	Calanoid, Metridia sp.	0.00	3.64	0.00	0.00	-0.31	-0.31	-0.31				
NPF	Calanoid, Neocalanus plumchrus	0.00	1.82	0.00	0.00							
NEO	Calanoid, Neocalanus sp.					0.00	0.10	0.00	0.00	0.54	0.00	

Table 30 cont.												
NCP	Calanoid, Neocalanus sp.											-0.05
CCL	Candacia columbiae											
CCV	Neocalanus cristatus											
Calanoid copepod-small												
EEM	Euchaeta elongata											
ALF	Calanoid, Acartia longiremus	-12.45	-12.45	-12.45	-12.41	-1.23	-1.23	-1.23	-1.17	-1.17	-1.17	-2.41
ALG	Calanoid, Acartia longiremus	-5.48	-5.48	-5.48	-5.48				-0.19	-0.19	-0.19	-0.29
AL	Calanoid, Acartia longiremus								-0.10	-0.10	-0.10	
ALM	Calanoid, Acartia longiremus	-2.35	-2.35	-1.10	-2.35	-0.61	-0.61	-0.61				-1.15
ALC	Calanoid, Acartia longiremus	-6.79	-6.79	-6.79	-6.79							-0.38
AC	Calanoid, Acartia sp.	0.00	0.00	0.00	0.07	-0.31	-0.31	-0.31				-0.96
BRF	Calanoid, Bradyidius saanichi	-0.01	-0.01	1.24	-0.01							0.00
BRG	Calanoid, Bradyidius saanichi	0.00	0.00	1.25	0.00							
BRM	Calanoid, Bradyidius saanichi	-0.08	-0.08	-0.08	-0.08							
BRC	Calanoid, Bradyidius saanichi	-0.11	-0.11	1.14	-0.11							
CAC	Centropages abdominalis											
CAF	Calanoid, Centropages abdominalis					-0.15	-0.15	-0.15				0.08
CGF	Calanoid, Chiridius gracilis					-0.04	-0.04	-0.04				0.00
COS	Calanoid, Copepodite small	-0.26	-0.26	-0.26	-0.20	49.08	-0.92	-0.92	90.32	0.00	0.00	0.16
CAN	Calanoid, general nauplius	-0.26	-0.26	-0.26	-0.26	-0.15	-0.15	-0.15	-0.19	-0.19	-0.19	-0.10
CAS	Calanoid, general small (<2 mm)	35.05	1.38	22.06	6.57	-1.07	1.38	0.15	-1.36	13.77	8.98	3.26
MEF	Calanoid, Mesocalanus tenuicornis					-0.61	-0.61	-0.61	-5.64	-5.64	-2.19	0.21
MEG	Calanoid, Mesocalanus tenuicornis								-3.99	-3.99	-3.99	-1.25
PSF	Calanoid, Pseudocalanus spp.	-8.62	-8.62	-2.37	-8.62	-15.34	-15.08	-15.34	-17.89	-17.35	-17.89	-8.07
PSM	Calanoid, Pseudocalanus spp.	-3.95	-3.95	-2.70	-3.95	-5.06	-4.91	-5.06	-2.14	-2.14	-2.14	-0.77
PCP	Calanoid, Pseudocalanus spp.	-10.10	-10.10	-10.10	-10.10	-23.62	-23.62	-23.62	-7.19	-7.19	-7.19	-10.41
PSG	Calanoid, Pseudocalanus spp.	-1.04	-1.04	-1.04	-1.04	-0.15	-0.15	-0.15				-0.29
PSA	Calanoid, Pseudocalanus spp.	-4.35	-4.35	4.40	-4.35	-10.43	-10.33	-10.43	-18.66	-17.58	-18.66	-19.54
TOR	Calanoid, Tortanus discaudatus	0.00	0.00	1.25	0.00							
OSC	Cyclopoid, Oithona sp.											
OSF	Cyclopoid, Oithona similis								-0.10	-0.10	-0.10	-9.04
OSM	Cyclopoid, Oithona similis								-4.28	-4.28	-4.28	
OSG	Cyclopoid, Oithona similis	-0.17	-0.17	-0.17	-0.17							
OS	Cyclopoid, Oithona similis,	-24.37	-24.37	-24.37	-24.37	-9.81	-9.81	-9.81	-5.44	-4.90	-5.44	-10.41
OTS	Cyclopoid, Oithona spiniros					-0.15	-0.15	-0.15	-0.78	-0.78	-0.78	-1.35
OTF	Cyclopoid, Oithona spiniros					-0.15	-0.15	-0.15	-1.26	-1.26	-1.26	
Chaetognath												
SGE	Chaetognath, Sagitta	-0.02	1.80	3.73	-0.02	-0.45	2.91	-0.29	-0.92	-0.92	-0.92	0.33
CHT	Chaetognath, species unknown	0.00	3.64	0.00	0.00	-0.06	0.29	1.47	0.00	1.08	0.00	-0.10
Cladocera												
EVD	Cladoceran, Evadne sp.	-0.03	-0.03	-0.03	-0.03							

Table 30 cont.												
PON	Cladoceran, Podon sp.	0.00	0.00	1.25	0.00				0.00	0.54	0.00	
CLA	Cladocera, General	0.00	0.00	0.00	0.01							
Cyphonaute												
CFN	Bryozoa, cyphonautes larva	-2.14	-2.14	-2.14	-2.13	-2.61	-2.61	-2.61	-0.97	-0.97	-0.97	-1.35
Decapod												
SHR	Decapod zoea, general shrimp	0.00	0.00	0.00	0.00							
PGZ	Decapod zoea, hermit crab								0.00	0.54	0.00	
EUA	Shrimp, Hippolytid, Eualus sp.											
DZC	Decapod zoea, Shrimp	0.00	0.00	0.00	0.00							
HIE	Decapod zoea, Shrimp	-0.01	-0.01	-0.01	-0.01							0.05
PAN	Decapod, Pandalidae					0.00	0.00	0.15				
SHC	Decapod, Shrimp, Crangonid					0.00	0.00	0.00				
DZG	Decapod, zoea, general								0.00	1.08	0.00	
SPI	Decapod, Shrmp	0.00	0.00	0.00	0.00							
Euphausiid												
EU3	Euphausiid calyptopis					-0.19	-0.19	-0.19	6.00	-0.45	-0.45	-0.07
EU4	Euphausiid furcilia	3.22	-0.01	-0.01	-0.01	-0.21	2.10	0.41	-0.16	-0.16	-0.16	0.27
EUJ	Euphausiid juvenile, general	6.44	9.08	-0.01	-0.01	4.92	1.63	13.38	-0.24	-0.24	-0.24	1.08
EU2	Euphausiid nauplii								-0.10	0.44	-0.10	
EPP	Euphausiid, Euphausia pacifica					0.00	0.00	0.15				
EP3	Euphausiid, Euphausia pacifica					0.00	0.20	0.61	0.00	0.00	3.45	
EP2	Euphausiid, Euphausia pacifica					0.00	0.10	0.00				
EP1	Euphausiid, Euphausia pacifica					0.00	0.00	17.43	0.00	0.00	3.45	
EUP	Euphausiid, general unknown	3.23	1.82	3.75	0.00	0.00	0.85	1.22	0.00	1.08	6.90	
THJ	Euphausiid, Thysannoessa sp.	0.00	0.00	0.00	0.00	15.00	0.10	0.31	-0.01	-0.01	-0.01	
TH	Euphausiid, Thysannoessa sp.					0.00	0.10	0.15				
TS	Euphausiid, Thysanoessa sp.	0.00	0.00	0.00	0.00	0.00	0.05	0.15				
TRF	Thysannoessa raschii											
TRG	Thysannoessa raschii											
TRM	Thysannoessa raschii											
EPP	Euphausia pacifica											
Fish												
FSE	Fish egg (~1.0 mm)					-0.19	-0.19	-0.19				
FSL	Fish larvae, general					0.00	0.05	0.15	0.00	0.00	6.90	
MVI	Fish, Mallotus villosus								-0.11	-0.11	-0.11	
Gammarid												
CCG	Amphipod, Gammarid					-0.27	-0.27	-0.27	-0.13	-0.13	-0.13	-0.01
CCC	Amphipod, Gammarid											-0.03
OED	Amphipod, Gammarid					-0.01	-0.01	-0.01				
GA3	Amphipod, Gammarid, unknown								0.00	0.00	3.45	
GA2	Amphipod, Gammarid, unknown	0.00	1.82	0.00	0.00	-0.04	-0.04	-0.04				

Table 30 cont.												
GAU	Amphipod, Gammarid, unknown								0.00	0.54	0.00	0.03
GA1	Amphipod, Gammarid, unknown	-0.01	1.81	-0.01	-0.01	-0.15	-0.15	-0.15	-0.01	-0.01	-0.01	
Gastropod												
GCP	Pteropoda, Clione sp.											
GST	Gastropoda, general juvenile	0.00	0.00	0.00	0.08							0.08
VEL	Gastropoda, general veliger								-0.01	-0.01	-0.01	
GSB	Gastropod, juv. snail	-1.23	-1.23	-1.23	-1.23	-0.46	-0.46	-0.46	-0.68	-0.68	-0.68	
LMA	Pteropod, Limacina helicina											
LMJ	Pteropod, Limacina helicina	-0.15	-0.15	-0.15	-0.15	-1.53	-1.38	-1.53	-3.60	-3.60	-3.60	-1.73
Hyperiid												
HP	Amphipod, Hyperiid, Hyperia					-0.04	0.06	-0.04				
PS	Amphipod, Hyperiid, Parathemisto					0.00	0.00	0.15				
PS1	Amphipod, Hyperiid, Parathemisto	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	3.45	0.06
PS2	Amphipod, Hyperiid, Parathemisto	0.00	0.00	0.00	0.00	-0.03	0.02	0.27	-0.01	-0.01	-0.01	0.00
PRI	Amphipod, Hyperiid, Primno								-0.05	-0.05	-0.05	0.05
PR1	Amphipod, Hyperiid, Primno											0.05
HYA	Amphipod, Hyperiid, unknown								0.00	0.00	3.45	
HYP	Amphipod, Hyperiid, unknown	3.23	0.00	3.75	0.00	0.00	0.10	0.31	0.00	0.00	10.34	0.15
HYB	Amphipod, Hyperiid, unknown	-0.02	-0.02	-0.02	-0.02	-0.12	-0.02	0.33	-0.30	-0.30	-0.30	0.01
PAA	Amphipod, Hyperiid/Parathemisto					0.00	0.00	0.00				
PA2	Amphipod, P. pacifica					-0.09	0.01	0.06				0.08
Cnidarian/ Ctenophore												
CNS	Cnidaria (<2mm)	-0.77	1.05	-0.77	-0.77	-1.97	-1.97	-1.97	-3.02	-3.02	-3.02	-3.81
CNI	Cnidaria (>2mm)	-0.07	-0.07	-0.07	-0.07	-0.72	-0.72	-0.72	-0.63	-0.63	-0.63	-0.60
BCT	Cnidaria, Hydrozoa					-0.01	-0.01	-0.01	-0.24	-0.24	-0.24	-0.03
GON	Cnidaria, Hydrozoa					-0.03	-0.03	-0.03	-0.19	-0.19	-0.19	-0.03
SIP	Cnidaria, Hydrozoa					-0.03	-0.03	-0.03				-0.10
MES	Cnidaria, Melicertum sp.					-0.31	-0.31	-0.31	-2.43	-2.43	-2.43	-0.70
CTO	Ctenophore, general (<2mm)								-0.01	-0.01	-0.01	
CTE	Ctenophore, general (>2mm)	-0.01	-0.01	-0.01	-0.01							-0.02
Larvacean												
OKI	Larvacea, Oikopleura dioica								-0.10	-0.10	-0.10	
OKP	Larvacea, Oikopleura sp.	43.07	0.27	27.91	4.34	-2.24	-2.24	-1.94	-2.71	-1.63	-2.71	47.84
OI1	Larvacea, Oikopleura < 2mm	-6.48	-6.48	-6.48	-5.49							
Other												
BVJ	Bivalve, general juvenile					-0.17	-0.17	-0.17				
MUJ	Bivalve, juvenile mussel					0.00	0.00	0.00				
BVL	Bivalve, larvae	-0.45	-0.45	-0.45	-0.40	-0.61	-0.61	-0.61	0.70	-2.53	-2.53	-0.77
OIE	Copepod, Oithona egg cases	-0.09	-0.09	-0.09	-0.09							
CUM	Cumacea	-0.01	3.63	1.24	-0.01	0.00	0.00	0.00				
EBL	Echinodermata, Bipinnaria	-0.17	-0.17	-0.17	-0.17	-0.15	-0.15	-0.15				-0.10

Table 30 cont.												
EBP	Echinodermata, Brittlestar	-0.35	-0.35	-0.35	-0.35	-0.31	-0.31	-0.31	-0.19	-0.19	-0.19	-0.19
HRC	Harpacticoid, general copep	0.00	0.00	0.00	0.01							
HR	Harpacticoid, general, unkn	-0.09	-0.09	-0.09	-0.09							
LAC	Harpacticoid, Laophontidae					-0.46	-0.46	-0.46				
ISC	Isopod, (Epicarid) Cryptoni					-0.15	-0.15	-0.15				0.03
MAL	Malacostraca	0.00	3.64	0.00	0.00							
MAE	Malacostraca, eyes only	0.00	10.91	0.00	0.01	0.00	0.00	2.91	0.00	5.41	3.45	0.49
MYS	Mysidae, general adult	0.00	3.64	0.00	0.00							
MPN	Mysidae,Pacifacanthomysis	-0.01	-0.01	-0.01	-0.01							
NEM	Nematode	3.23	0.00	1.25	0.00	0.00	0.15	1.07	-0.01	0.53	13.79	
CNC	Ostracod, Conchoecia sp.											-0.02
OST	Ostracod, general unknown	-0.01	-0.01	-0.01	-0.01	-0.31	-0.31	-0.31				-0.02
PLC	Pleuro cercoid larvae					0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.10
PLL	Polychaeta, general, juvenile	-0.02	-0.02	-0.02	-0.01	-0.26	-0.26	-0.26				0.03
NER	Polychaeta, Nereidae	-0.01	-0.01	-0.01	-0.01							
PEC	Polychaeta, Pectinariidae	-0.44	-0.44	-0.44	-0.44							
TRK	Polychaeta, trochophore larva	-0.02	-0.02	-0.02	-0.02				-0.05	-0.05	-0.05	-0.10
UNI	Unidentified item	0.00	0.00	1.25	0.00							0.00
UEM	Unknown egg mass	-0.01	-0.01	-0.01	-0.01							
EGL	Unknown invertebrate egg	-0.10	-0.10	-0.10	-0.10	-0.15	-0.15	-0.15	-0.21	-0.21	-0.21	-0.22
EGG	Unknown invertebrate egg	-3.05	-3.05	-3.05	82.19	29.54	-0.46	-0.46	-0.10	-0.10	-0.10	3.07
UNP	Unknown nauplius	-0.09	-0.09	1.16	-0.09							

Table 30 cont.															
				From 25 m zooplankton						From 100 m zooplankton					
	Region	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Station-haul	6-1	6-1	7-1	7-1	7-2	7-2	7-2	7-2	7-1	7-1	7-2	7-2	7-2	7-2
	n	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	size group	0	0	0	0	0	1	0	2	0	0	0	1	0	2
SPCD	species	herring	pollock	herring	pollock	sandlance	sandlance	pollock	pollock	herring	pollock	sandlance	sandlance	pollock	pollock
Barnacle															
BMC	Barnacle, cyprid			0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	0.00	0.00	0.00	0.00
BMP	Barnacle, nauplius			0.00	0.00	0.00	0.00	0.00	0.25	-0.31	-0.31	-0.31	-0.31	-0.31	0.31
Calanoid copepod-large															
CPF	Calanoid, Calanus pacificus			0.13	-0.02	-0.02	-0.02	-0.02	-0.02	-0.84	-0.84	-0.84	-0.84	-0.84	0.84
CPC	Calanoid, Calanus pacificus	-0.05	-0.05												
CCP	Calanoid, Calanus sp.			-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.11	-0.11	-0.11	-0.11	-0.11	0.11
CMC	Calanoid, C. marshallae cop	-0.97	-0.84	-0.02	0.41	-0.02	-0.02	0.39	-0.02	-0.11	-0.11	-0.11	-0.11	-0.11	0.11
EPI	Calanoid, Epilabidocera longipedata			0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	0.02
ECC	Calanoid, Euchaeta elongata	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.23	-0.23	-0.23	-0.23	0.23
ECF	Calanoid, Euchaeta elongata	0.00	0.00												
EEF	Calanoid, Euchaeta elongata	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.82	0.00	0.00	0.00	0.00
EEM	Euchaeta elongata	-0.01	-0.01												
EUB	Calanoid, Eucalanus bungii			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
EUE	Calanoid, Euchaeta elongata			0.00	0.00	0.00	0.00	0.20	0.76	0.00	0.64	0.00	0.00	0.00	3.00
CAL	Calanoid, general large (>2 mm)	0.12	6.90	1.51	3.21	0.00	0.00	5.53	3.78	0.00	0.43	0.00	0.00	0.00	0.00
MCS	Calanoid, Metridia pacifica	-7.58	11.06	-6.52	-6.52	-6.52	-6.52	-6.32	-6.52	-1.76	-1.55	-1.76	-1.76	-1.56	-1.76
MP	Calanoid, Metridia pacifica			0.00	0.00	0.00	0.00	0.00	16.12	1.51	3.21	0.00	0.00	5.53	3.78
MPF	Calanoid, Metridia pacifica	-2.14	7.26	22.92	4.13	-0.36	-0.36	63.78	62.36	0.00	7.26	0.00	0.00	0.00	0.00
MPC	Calanoid, Metridia pacifica	-9.32	33.19	-0.93	-0.07	-0.93	-0.93	2.35	0.33	-0.04	0.60	-0.04	-0.04	0.17	0.04
MEP	Calanoid, Metridia pacifica	0.46	0.00	0.00	0.00	0.00	0.00	0.41	0.00	3.12	47.23	32.91	-0.42	8.80	2.35
MG	Calanoid, Metridia sp.	0.00	0.51												
NCP	Calanoid, Neocalanus sp.	-0.04	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	-0.06	-0.06	-0.06	-0.06	0.06
CCL	Candacia columbiae	0.01	0.00												
CCV	Neocalanus cristatus	0.00	0.00												
Calanoid copepod-small															
ALF	Calanoid, Acartia longiremus	-0.73	-0.73	-1.00	-0.79	-1.00	-1.00	-0.80	-1.00	-31.24	-31.24	-31.24	-31.24	-31.24	-31.24
ALG	Calanoid, Acartia longiremus			-1.13	-1.13	-1.13	-1.13	-1.13	-1.13	0.00	0.00	0.00	0.00	0.82	0.50
ALM	Calanoid, Acartia longiremus	-0.29	-0.29	-0.50	-0.50	-0.50	-0.50	-0.50	-0.50	-0.04	0.39	-0.04	-0.04	0.37	0.04
ALC	Calanoid, Acartia longiremus	-0.15	-0.15	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05	0.05
AC	Calanoid, Acartia sp.	0.00	0.13	0.00	2.78	0.00	0.00	0.00	0.00	-0.09	-0.09	-0.09	-0.09	-0.09	0.09
CA	Centropages abdominalis			0.00	12.82	0.00	0.00	0.00	0.00	-0.14	-0.14	-0.14	-0.14	-0.14	0.14
CAC	Centropages abdominalis	-0.43	-0.43	-0.50	0.14	-0.50	-0.50	-0.50	-0.50	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
CAF	Centropages abdominalis			-0.06	0.36	-0.06	-0.06	-0.06	-0.06	-0.11	-0.11	-0.11	-0.11	-0.11	0.11
COS	Calanoid, Copepodite small	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
CAM	Centropages abdominalis			-0.06	7.20	-0.06	-0.06	-0.06	-0.06	0.15	0.00	0.00	0.00	0.00	0.00
CAN	Calanoid, general nauplius	-0.15	-0.15	-0.25	0.39	-0.25	-0.25	-0.05	-0.25	0.00	0.00	0.00	0.00	0.00	0.00
CAS	Calanoid, general small (<2 mm)	6.78	9.32	2.54	46.65	32.33	-1.00	8.22	1.77	-0.06	-0.06	-0.06	-0.06	-0.06	0.06
MEF	Calanoid, Mesocalanus tenuicornis			-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.04	-0.04	-0.04	-0.04	-0.04	0.04
MEG	Calanoid, Mesocalanus tenuicornis	-0.13	-0.14	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	1.58	3.13	11.03	-0.08	-0.08	0.08
PSF	Calanoid, Pseudocalanus	-7.85	-4.55	-14.99	-14.35	-14.99	-14.99	-13.76	-14.99	-0.15	-0.15	-0.15	-0.15	-0.15	0.15
PSM	Calanoid, Pseudocalanus			-1.76	-1.33	-1.76	-1.76	-1.76	-1.76	0.00	0.00	0.00	0.00	0.00	0.00
PCP	Calanoid, Pseudocalanus			-14.42	-14.42	-14.42	-14.42	-14.42	-14.42	-0.04	-0.04	-0.04	-0.04	-0.04	0.04
PSG	Calanoid, Pseudocalanus			-0.19	-0.19	-0.19	-0.19	-0.19	-0.19	0.00	0.00	0.00	0.00	0.00	0.25

Table 30 cont.																	
PSA	Calanoid, Pseudocalanus sp.	-33.70	-32.38	-4.52	-3.02	-4.52	-4.52	-3.90	-4.52	-0.15	-0.15	-0.15	-0.15	-0.15	0.15
TOR	Calanoid, Tortanus discauda	0.01	0.00	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
OS	Cyclopoid, Oithona similis			-10.60	-10.60	-10.60	-10.60	-10.60	-10.60	0.00	0.00	0.00	0.00	0.20	0.76
OIT	Cyclopoid, Oithona similis			0.00	0.00	0.00	0.00	0.00	0.00	-0.48	-0.48	-0.48	-0.48	-0.48	0.48
OSC	Cyclopoid, Oithona sp.			-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	0.00	0.00	0.00	0.00	0.00	0.00
OSF	Cyclopoid, Oithona similis	-14.44	-14.44												
OS	Cyclopoid, Oithona similis	0.10	0.00												
OTS	Cyclopoid, Oithona spiniros	-1.02	-1.02	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	0.04	1.07	55.56	25.00	0.00	5.04
Chaetognath															
SGE	Chaetognath, Sagitta			-0.08	-0.08	-0.08	-0.08	0.13	0.43	0.00	0.21	0.00	0.00	0.82	0.25
CHT	Chaetognath, species unknown	-0.11	0.00	0.00	0.00	0.00	0.00	0.82	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Cyphonaute															
CFN	Bryozoa, cyphonautes larva	-7.50	-8.17	-22.83	-22.83	-22.83	-22.83	-22.83	-22.83	-0.04	-0.04	-0.04	-0.04	-0.04	0.04
Decapod															
SHR	Decapod zoea, general shrimp			0.03	-0.01	-0.01	-0.01	-0.01	-0.01	-5.74	-5.74	-5.74	-5.74	-5.74	-5.74
PGZ	Decapod zoea, hermit crab			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PDZ	Decapod, zoea, crab			-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
DZG	Decapod, zoea, shrimp, Pandalidae			0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.20	0.00
EUA	Shrimp, Hippolytid, Eualus sp.	0.00	0.00												
Euphausiid															
EU3	Euphausiid calyptopis			0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.04	-0.04	-0.04	0.96	0.04
EU4	Euphausiid furcilia	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.04	-0.04	-0.08	-0.08	0.04
EUJ	Euphausiid juvenile	-0.08	-0.08	0.01	1.04	55.53	24.98	-0.02	5.01	0.10	-0.05	-0.05	-0.05	0.36	0.05
EPP	Euphausiid, Euphausia pacifica			0.00	0.00	0.00	0.00	0.00	0.25	0.74	0.43	0.00	0.00	0.20	2.27
EP3	Euphausiid, E. pacifica	-0.87	-0.87												
EUP	Euphausiid, general unknown	0.05	1.15	0.00	0.21	0.00	0.00	0.82	0.25	-0.04	-0.04	-0.04	-0.04	-0.04	0.04
THJ	Euphausiid, Thysannoessa sp														
TH	Euphausiid, Thysannoessa sp	0.02	0.64	0.00	0.21	0.00	0.00	1.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00
TL	Thysannoessa longipes			0.00	0.00	0.00	0.00	0.00	0.00	-2.18	-2.18	-2.18	22.82	-2.18	-2.18
TRF	Thysannoessa raschii	0.00	-0.01	0.00	0.00	0.00	25.00	0.00	0.00	0.07	1.07	0.00	25.00	0.00	0.00
TRG	Thysannoessa raschii	0.01	1.28												
TRM	Thysannoessa raschii	0.04	-0.02	0.00	0.00	0.00	0.00	0.20	0.00	0.04	0.00	0.00	0.00	0.00	0.00
EPP	Euphausia pacifica	-0.01	0.37												
Fish															
FSE	Fish egg (~1.0 mm)			0.00	0.00	0.00	0.00	0.00	0.00	-8.42	-8.42	-8.42	-8.42	-8.22	-8.42
Gammarid															
CCG	Amphipod, Gammarid			-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.08	-0.08	-0.08	-0.08	-0.08	0.08
CCC	Amphipod, Gammarid	-0.24	-0.24												
GA2	Amphipod, Gammarid	0.00	0.13												
Gastropod															
GCP	Pteropoda, Clione sp.	0.00	0.00												
GST	Gastropoda, general juvenile	0.09	0.00	-4.01	-4.01	-4.01	-4.01	-4.01	-4.01	-0.11	-0.11	-0.11	-0.11	-0.11	0.11
VEL	Gastropod, general veliger														
GSB	Gastropod, juv. snail			-3.83	-3.83	-3.83	-3.83	-3.83	-3.83	0.00	0.00	0.00	0.00	0.41	0.00
LMA	Pteropod, Limacina helicina	0.00	0.13												
LMJ	Pteropod, Limacina helicina	-5.96	-5.96	-3.01	-3.01	-3.01	21.99	-3.01	-3.01	0.00	0.00	0.00	0.00	0.00	16.12
Hyperiid															
HP	Amphipod, Hyperiid, Hyperia			0.00	0.00	0.00	0.00	0.00	0.00	-6.30	-5.44	-6.30	-6.30	-3.02	-5.04
PL3	Amphipod, Hyperiid, Parathemisto libellula			0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.25
PS1	Amphipod, Hyperiid, Parathemisto sp.			-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	22.21	3.42	-1.07	-1.07	63.07	61.65

Table 30 cont.															
PS2	Amphipod, Hyperiid, Parathemisto sp.			0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.43	0.00	0.00	0.00	0.00
PRI	Amphipod, Hyperiid, Primno macropa			0.00	0.00	0.00	0.00	0.00	0.00	-0.08	-0.08	-0.08	-0.08	-0.08	0.08
PR2	Amphipod, Hyperiid, Primno macropa			0.00	0.00	0.00	0.00	0.00	0.76	-1.34	-1.34	-1.34	-1.34	-1.34	-1.34
HYP	Amphipod, Hyperiid, unknown	-0.02	-0.02	0.74	0.43	0.00	0.00	0.20	2.27	-6.09	-6.09	-6.09	-6.09	-6.09	-6.09
HYB	Amphipod, Hyperiid, unknown			0.12	-0.02	-0.02	-0.02	0.39	-0.02	67.72	7.78	-0.77	-0.77	9.28	0.51
PA2	Amphipod, *P. pacifica juvenile*			0.00	0.00	0.00	0.00	0.20	0.50	-5.71	-5.71	-5.71	-5.71	-5.71	-5.71
Cnidarian/ Ctenophore															
CNS	Cnidaria (<2mm), general			-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.00	0.00	0.00	0.00	0.00	0.00
CNI	Cnidaria (>2mm), general	-0.02	-0.02	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
BCT	Cnidaria, Hydrozoa			0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05	0.15	0.45
GON	Cnidaria, Hydrozoa			0.00	0.00	0.00	0.00	0.00	0.00	-11.45	-11.45	-11.45	-11.45	-11.45	-11.45
SIP	Cnidaria, Hydrozoa			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CTE	Ctenophore, general (>2mm)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
Larvacean															
OKP	Larvacea, Oikopleura sp.	6.85	-2.09	66.17	6.23	-2.32	-2.32	7.72	-2.07	0.00	0.00	0.00	0.00	0.20	0.00
OI1	Larvacea, Oikopleura < 2mm	78.77	0.00	-1.51	-1.51	-1.51	-1.51	-1.51	-1.51	0.00	0.00	0.00	0.00	0.00	0.25
Other															
MUJ	Bivalve, juvenile mussel	0.00	0.00												
BVL	Bivalve, larvae	-0.17	-0.44	-0.63	-0.82	-0.82	-0.82	-0.82	-0.82	0.00	0.00	0.00	0.00	0.00	0.00
EBP	Echinodermata, Brittlestar			-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	0.00	0.00	0.00	0.00	0.00	0.76
HRC	Harpacticoid, general copepodite	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
HR	Harpacticoid, general, unknown	0.06	0.13	0.00	0.43	0.00	0.00	0.20	0.00	-2.26	-0.76	-2.26	-2.26	-1.64	-2.26
HRN	Harpacticoid, general, nauplius			0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.24
ISC	Isopod, (Epicarid)			-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
ISP	Isopoda, general			0.04	0.00	0.00	0.00	0.00	0.00	-9.23	-17.82	-9.23	-9.23	-8.00	-9.23
MAL	Malacostraca	0.00	0.26	0.04	0.00	0.00	0.00	0.00	0.00	-1.03	-1.64	-1.03	-1.03	-1.03	-1.03
MAE	Malacostraca, eyes only	0.00	0.64	0.07	1.07	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
MYA	Mysidae, general unknown			0.00	0.43	0.00	0.00	0.00	0.00	-0.44	-0.44	-0.44	-0.44	-0.23	0.07
NEM	Nematode			0.00	0.00	0.00	0.00	0.00	0.25	0.04	0.00	0.00	0.00	1.00	0.00
CNC	Ostracod, Conchoecia sp			-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.09	-0.09	-0.09	-0.09	-0.09	0.09
PLA	Polychaeta, general, adult			0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PLL	Polychaeta, general, juvenile	0.02	0.00	-0.24	-0.24	-0.24	-0.24	-0.24	0.27	0.00	0.21	0.00	0.00	0.00	0.00
TRK	Polychaeta, trochophore larva			-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.46	-0.46	-0.46	-0.46		0.46
UNI	Unidentified item			0.00	0.43	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
EGL	Unknown invertebrate egg	0.39	0.13	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02	-0.19	0.02
EGG	Unknown invertebrate egg	0.09	0.13	1.54	3.08	10.99	-0.13	-0.13	-0.13	-0.11	0.31	-0.11	-0.11	-0.11	0.14
HEM	Harpacticoid, general eggsac	-0.15	-0.15												
HZC	Harpacticoid, Zaus sp.	0.09	0.00												
HZZ	Harpacticoid, Zaus sp.	0.10	0.00												
PCO	Caligidae, parasitic copepod	0.01	0.00												
DPL	Dipteran larva	0.01	0.00												
PUN	Polychaeta, unknown			0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	25.00	0.00	0.00

Table 31. Stations used to compare pollock and herring frequencies of prey selection when in single species (allopatric) versus sympatric (co-occurring, multi-species) schools.

	Single Species Stations		Multi-Species Stations	
	Herring	Pollock	Herring and Pollock Co-occurring	
Fall 1994				
station-haul	(3-1T)* (8-2T) (8-3T)	(5-5T)	(6-1T) (7-4T)	(6-1T) (7-4T)
Summer 1995				
station-haul	107-1T 22-2T 27-1D 116-1T (110-1B)*	3-1T 5-2T (19-1T) 29-1T 54-2T 56-1T 57-2T 58-2T (108-1T) 112-1T	-0-	-0-
Fall 1995				
station-haul	5-1T	-0-	2-1T 6-1T 7-1T	2-1T** 6-1t 7-1T 7-2T**

*sets in parentheses without zooplankton

**2 age classes present

Table 32. Summary of stomach fullness statistics for all APEX pollock specimens analyzed 1994-1995. See also Figures 17 and 18.

Sample date	Sample time	species-size group-station-haul-gear	specimen number	Fish length (mm)	Fish weight (g)	Fish stomach weight (g)	Total prey weight (mg)	stomach fullness code (1-7)	stomach digestion code (1-3)	Percent body weight
Southwestern Area PWS										
11/8/94	15:32	270-0-5-5T	5071	111	8.92	0.10	54.91	5	1	0.62
11/8/94	15:32	270-0-5-5T	5072	109	8.79	0.34	125.71	7	1	1.45
11/8/94	15:32	270-0-5-5T	5073	107	8.32	0.16	85.10	6	1	1.03
11/8/94	15:32	270-0-5-5T	5074	115	10.05	0.07	28.60	5	2	0.29
11/8/94	15:32	270-0-5-5T	5075	114	10.39	0.11	48.28	6	1	0.47
11/8/94	15:32	270-0-5-5T	5076	118	10.19	0.05	21.15	5	1	0.21
11/8/94	15:32	270-0-5-5T	5077	109	8.81	0.12	74.81	6	1	0.86
11/8/94	15:32	270-0-5-5T	5078	118	10.55	0.16	89.82	6	1	0.86
11/8/94	15:32	270-0-5-5T	5079	103	7.38	0.19	62.25	6	1	0.85
11/8/94	15:32	270-0-5-5T	5080	106	7.42	0.22	133.45	6	1	1.83
Northeastern Area PWS										
11/10/94	22:42	270-0-6-1T	5061	94	4.52	0.01	1.37	3	1	0.03
11/10/94	22:42	270-0-6-1T	5062	113	9.59	0.16	66.30	7	2	0.70
11/10/94	22:42	270-0-6-1T	5063	96	5.15	0.01	0.60	2	2	0.01
11/10/94	22:42	270-0-6-1T	5064	107	8.95	0.02	17.69	4	2	0.20
11/10/94	22:42	270-0-6-1T	5065	90	5.32	0.00	0.03	2	3	0.00
11/10/94	22:42	270-0-6-1T	5066	98	5.90	0.03	0.89	2	2	0.02
11/10/94	22:42	270-0-6-1T	5067	109	8.61	0.03	13.97	4	1	0.16
11/10/94	22:42	270-0-6-1T	5068	93	4.81	0.02	0.76	3	2	0.02
11/10/94	22:42	270-0-6-1T	5069	88	4.20	0.01	3.05	3	2	0.07
11/10/94	22:42	270-0-6-1T	5070	114	9.18	0.13	78.26	6	1	0.86
11/12/94	22:30	270-0-7-4T	5041	115	9.88	0.04	21.52	4	2	0.22
11/12/94	22:30	270-0-7-4T	5042	116	9.63	0.12	93.18	7	2	0.98
11/12/94	22:30	270-0-7-4T	5043	108	7.33	0.02		1	3	0.00
11/12/94	22:30	270-0-7-4T	5044	99	5.94	0.02	0.95	3	2	0.02
11/12/94	22:30	270-0-7-4T	5045	108	8.36	0.02		1	3	0.00
11/12/94	22:30	270-0-7-4T	5046	112	9.41	0.01		1	3	0.00
11/12/94	22:30	270-0-7-4T	5047	115	10.59	0.01	1.89	3	1	0.02

Table 32 cont.										
11/12/94	22:30	270-0-7-4T	5048	107	8.06	0.05	21.85	6	2	0.27
11/12/94	22:30	270-0-7-4T	5049	116	9.56	0.01	0.82	2	1	0.01
11/12/94	22:30	270-0-7-4T	5050	109	7.51	0.01	24.20	3	2	0.32
Central Area PWS										
7/22/95	12:23	270-0-3-1	5660	59	1.02	0.00	0.17	2	1	0.02
7/22/95	12:23	270-0-3-1	5661	56	1.09	0.00		1	3	0.00
7/22/95	12:23	270-0-3-1	5662	59	0.99	0.00	10.35	3	2	1.06
7/22/95	12:23	270-0-3-1	5663	64	1.52	0.01	0.17	2	2	0.01
7/22/95	12:23	270-0-3-1	5664	64	1.22	0.00	0.34	2	2	0.03
7/22/95	12:23	270-0-3-1	5665	51	0.62	0.01	76.64	6	1	14.24
7/22/95	12:23	270-0-3-1	5666	60	1.05	0.01	8.48	4	2	0.81
7/22/95	12:23	270-0-3-1	5667	52	0.68	0.00	8.10	3	1	1.20
7/22/95	12:23	270-0-3-1	5668	64	1.13	0.01	6.85	4	2	0.61
7/22/95	12:23	270-0-3-1	5669	62	1.10	0.02	31.37	6	2	2.94
7/22/95	17:04	270-0-5-2	5850	54	0.88	0.00		1	3	0.00
7/22/95	17:04	270-0-5-2	5851	60	1.24	0.01	0.14	2	2	0.01
7/22/95	17:04	270-0-5-2	5852	50	0.82	0.00		1	3	0.00
7/22/95	17:04	270-0-5-2	5853	49	0.72	0.01	24.54	6	2	3.53
7/22/95	17:04	270-0-5-2	5854	53	0.84	0.00	10.62	4	2	1.28
7/22/95	17:04	270-0-5-2	5855	59	1.32	0.01	115.22	6	2	9.56
7/22/95	17:04	270-0-5-2	5856	51	0.81	0.02	91.88	7	2	12.79
7/22/95	17:04	270-0-5-2	5857	56	0.98	0.00	0.79	2	2	0.08
7/22/95	17:04	270-0-5-2	5858	54	0.87	0.02	33.18	6	2	3.96
7/22/95	17:04	270-0-5-2	5859	49	0.64	0.01	12.02	5	2	1.91
7/25/95	15:37	270-0-19-1	5590	67	1.90	0.02	0.60	6	2	0.03
7/25/95	15:37	270-0-19-1	5591	64	1.48	0.04	10.93	6	2	0.75
7/25/95	15:37	270-0-19-1	5592	57	1.11	0.00	10.65	2	2	0.97
7/25/95	15:37	270-0-19-1	5593	60	1.29	0.05	41.36	6	2	3.33
7/25/95	15:37	270-0-19-1	5594	57	0.69	0.01	13.21	4	2	1.94
7/25/95	15:37	270-0-19-1	5595	52	0.70	0.00	0.07	2	2	0.01
7/25/95	15:37	270-0-19-1	5596	51	0.67	0.01	3.15	3	2	0.48
7/25/95	15:37	270-0-19-1	5597	61	1.31	0.07	39.77	7	2	3.12
7/25/95	15:37	270-0-19-1	5598	56	0.92	0.01	1.17	4	2	0.13
7/25/95	15:37	270-0-19-1	5599	51	0.72	0.00	0.20	3	2	0.03

Table 32 cont.										
Northeastern Area PWS										
7/27/95	10:57	270-2-29-1	5600	188	39.46	0.12	62.05	3	2	0.16
7/27/95	10:57	270-2-29-1	5601	196	47.71	0.07		1	3	0.00
7/27/95	10:57	270-2-29-1	5602	197	46.69	0.11	52.90	3	2	0.11
7/27/95	10:57	270-2-29-1	5603	182	34.92	0.04	20.55	2	2	0.06
7/27/95	10:57	270-2-29-1	5604	184	36.04	0.08		1	3	0.00
7/27/95	10:57	270-2-29-1	5605	189	41.55	0.05	25.67	2	2	0.06
7/27/95	10:57	270-2-29-1	5606	185	35.88	0.05		1	3	0.00
7/27/95	10:57	270-2-29-1	5607	175	29.47	0.04		1	3	0.00
7/27/95	10:57	270-2-29-1	5608	164	24.62	0.05	7.50	2	2	0.03
7/27/95	10:57	270-2-29-1	5609	193	45.01	0.06	3.19	2	2	0.01
Southwestern Area PWS										
7/31/95	11:30	270-0-51-1	5840	59	0.98	0.01	6.13	4	2	0.63
7/31/95	11:30	270-0-51-1	5841	54	0.94	0.01	23.77	5	2	2.59
7/31/95	11:30	270-0-51-1	5842	54	0.74	0.01	18.24	6	2	2.53
7/31/95	11:30	270-0-51-1	5843	51	0.75	0.01	25.72	7	2	3.55
7/31/95	11:30	270-0-51-1	5844	58	0.96	0.02	33.00	6	2	3.56
7/31/95	11:30	270-0-51-1	5845	54	0.99	0.01	29.22	6	2	3.04
7/31/95	11:30	270-0-51-1	5846	58	0.88	0.01	29.41	7	2	3.46
7/31/95	11:30	270-0-51-1	5847	55	0.76	0.01	30.35	6	2	4.16
7/31/95	11:30	270-0-51-1	5848	59	1.06	0.02	114.50	6	2	12.11
7/31/95	11:30	270-0-51-1	5849	54	0.63	0.00	13.25	5	2	2.15
Central Area PWS										
8/1/95	15:27	270-0-56-1	5570	56	1.03	0.01		1	3	0.00
8/1/95	15:27	270-0-56-1	5571	64	1.52	0.03	14.90	6	2	0.99
8/1/95	15:27	270-0-56-1	5572	56	0.91	0.00	0.46	2	2	0.05
8/1/95	15:27	270-0-56-1	5573	60	1.01	0.02	13.75	6	2	1.39
8/1/95	15:27	270-0-56-1	5574	49	0.60	0.00		1	3	0.00
8/1/95	15:27	270-0-56-1	5575	68	1.52	0.01	22.34	5	2	1.50
8/1/95	15:27	270-0-56-1	5576	51	0.58	0.00	1.12	4	2	0.20
8/1/95	15:27	270-0-56-1	5577	56	0.82	0.01	3.90	4	2	0.48
8/1/95	15:27	270-0-56-1	5578	57	0.82	0.00		1	3	0.00
8/1/95	15:27	270-0-56-1	5579	58	0.84	0.00		1	3	0.00
8/1/95	12:14	270-0-54-2	5620	55	0.91	0.00	0.66	3	2	0.07

Table 32 cont.

8/1/95	12:14	270-0-54-2	5621	51	0.83	0.02	27.79	6	2	3.47
8/1/95	12:14	270-0-54-2	5622	62	1.45	0.00		1	3	0.00
8/1/95	12:14	270-0-54-2	5623	61	1.19	0.01	0.75	3	2	0.06
8/1/95	12:14	270-0-54-2	5624	48	0.53	0.01	2.95	5	2	0.56
8/1/95	12:14	270-0-54-2	5625	57	0.88	0.01		1	3	0.00
8/1/95	12:14	270-0-54-2	5626	47	0.52	0.02	13.53	6	2	2.70
8/1/95	12:14	270-0-54-2	5627	53	0.79	0.01		1	3	0.00
8/1/95	12:14	270-0-54-2	5628	49	0.64	0.01	16.82	4	2	2.72
8/1/95	12:14	270-0-54-2	5629	52	0.81	0.00		1	3	0.00
8/1/95	9:17	270-0-53-1	5640	61	1.36	0.01	3.48	4	2	0.26
8/1/95	9:17	270-0-53-1	5641	57	0.82	0.01	8.08	4	2	0.99
8/1/95	9:17	270-0-53-1	5642	55	0.94	0.01	28.20	5	2	3.11
8/1/95	9:17	270-0-53-1	5643	60	1.17	0.01	7.98	4	2	0.69
8/1/95	9:17	270-0-53-1	5644	56	0.99	0.01	20.35	6	2	2.11
8/1/95	9:17	270-0-53-1	5645	54	0.83	0.01	28.98	5	2	3.64
8/1/95	9:17	270-0-53-1	5646	52	0.78	0.01	7.24	5	2	0.93
8/1/95	9:17	270-0-53-1	5647	54	0.86	0.01	21.08	5	2	2.50
8/1/95	9:17	270-0-53-1	5648	50	0.69	0.01	18.58	6	2	2.77
8/1/95	9:17	270-0-53-1	5649	57	0.99	0.01	5.27	5	2	0.54
8/1/95	17:30	270-0-57-2	5650	67	1.54	0.09	267.99	7	2	21.08
8/1/95	17:30	270-0-57-2	5651	61	1.37	0.02	55.32	5	2	4.21
8/1/95	17:30	270-0-57-2	5652	63	1.38	0.01	6.94	2	2	0.51
8/1/95	17:30	270-0-57-2	5653	40	0.32	0.00		1	3	0.00
8/1/95	17:30	270-0-57-2	5654	53	0.79	0.01	2.32	3	2	0.30
8/1/95	17:30	270-0-57-2	5655	63	1.36	0.01	32.61	4	2	2.47
8/1/95	17:30	270-0-57-2	5656	65	1.60	0.02	20.19	6	2	1.28
8/1/95	17:30	270-0-57-2	5657	58	1.05	0.01	18.08	5	2	1.75
8/1/95	17:30	270-0-57-2	5658	56	0.97	0.01	13.41	5	2	1.40
8/1/95	17:30	270-0-57-2	5659	50	0.70	0.01	0.46	3	2	0.07
8/1/95	9:55	270-0-53-2	5780	69	1.90	0.05	11.90	5	2	0.63
8/1/95	9:55	270-0-53-2	5781	62	1.28	0.02	35.42	6	2	2.85
8/1/95	9:55	270-0-53-2	5782	63	1.36	0.03	57.12	5	1	4.38
8/1/95	9:55	270-0-53-2	5783	59	1.09	0.01	43.25	6	2	4.13
8/1/95	9:55	270-0-53-2	5784	62	1.39	0.01	26.83	5	2	1.97

Table 32 cont.										
8/1/95	9:55	270-0-53-2	5785	59	1.25	0.01	31.01	5	2	2.54
8/1/95	9:55	270-0-53-2	5786	59	0.98	0.01	13.07	4	2	1.35
8/1/95	9:55	270-0-53-2	5787	59	1.08	0.01	43.18	5	2	4.17
8/1/95	9:55	270-0-53-2	5788	56	0.97	0.02	105.89	7	2	12.25
8/1/95	9:55	270-0-53-2	5789	68	1.86	0.02	48.21	7	2	2.66
8/2/95	15:16	270-0-62-2	5510	56	1.11	0.03	82.57	6	2	8.01
8/2/95	15:16	270-0-62-2	5511	58	0.98	0.01	8.93	4	2	0.92
8/2/95	15:16	270-0-62-2	5512	48	0.61	0.01	1.94	5	2	0.32
8/2/95	15:16	270-0-62-2	5513	56	0.91	0.02	56.06	4	2	6.57
8/2/95	15:16	270-0-62-2	5514	56	0.88	0.01	6.15	4	2	0.71
8/2/95	15:16	270-0-62-2	5515	50	0.73	0.01	0.32	5	2	0.04
8/2/95	15:16	270-0-62-2	5516	51	0.75	0.01	0.03	2	2	0.00
8/2/95	15:16	270-0-62-2	5517	55	0.82	0.01	1.33	3	2	0.16
8/2/95	15:16	270-0-62-2	5518	54	0.88	0.02	17.91	5	2	2.08
8/2/95	15:16	270-0-62-2	5519	50	0.76	0.01	0.39	3	2	0.05
8/2/95	9:25	270-0-58-2	5520	55	0.93	0.03	119.51	7	2	14.84
8/2/95	9:25	270-0-58-2	5521	50	0.77	0.01	27.31	6	2	3.70
8/2/95	9:25	270-0-58-2	5522	51	0.82	0.01	21.87	7	2	2.73
8/2/95	9:25	270-0-58-2	5523	49	0.75	0.01	11.12	6	2	1.51
8/2/95	9:25	270-0-58-2	5524	50	0.77	0.02	29.95	6	2	4.05
8/2/95	9:25	270-0-58-2	5525	66	1.80	0.09	59.94	5	2	3.45
8/2/95	9:25	270-0-58-2	5526	59	1.09	0.01	4.85	4	2	0.45
8/2/95	9:25	270-0-58-2	5527	55	1.05	0.03	84.02	5	2	8.67
8/2/95	9:25	270-0-58-2	5528	67	1.08	0.01	10.96	6	2	1.02
8/2/95	9:25	270-0-58-2	5529	60	1.27	0.02	22.46	6	2	1.81
8/4/95	11:56	270-0-73-1	5740	63	1.38	0.03	12.67	5	1	0.93
8/4/95	11:56	270-0-73-1	5741	60	1.27	0.03	15.65	5	1	1.25
8/4/95	11:56	270-0-73-1	5742	59	1.18	0.02	21.76	6	1	1.88
8/4/95	11:56	270-0-73-1	5743	57	1.07	0.01	11.70	4	1	1.11
8/4/95	11:56	270-0-73-1	5744	60	1.26	0.02	16.91	5	1	1.36
8/4/95	11:56	270-0-73-1	5745	60	1.28	0.02	16.82	5	1	1.33
8/4/95	11:56	270-0-73-1	5746	48	0.62	0.01	28.72	4	2	4.86
8/4/95	11:56	270-0-73-1	5747	56	0.85	0.02	33.17	5	1	4.06
8/4/95	11:56	270-0-73-1	5748	56	0.98	0.02	28.35	4	1	2.98

Table 32 cont.										
8/4/95	11:56	270-0-73-1	5749	55	0.98	0.03	17.01	6	1	1.77
Northeastern Area PWS										
8/5/95	14:25	270-2-82-1	5540	181	36.97	0.31	98.94	6	2	0.27
8/5/95	14:25	270-2-82-1	5541	172	32.19	0.17	26.16	4	2	0.08
8/5/95	14:25	270-2-82-1	5542	186	40.83	0.11	2.34	2	2	0.01
8/5/95	14:25	270-2-82-1	5543	172	33.44	0.11	12.89	3	2	0.04
8/5/95	14:25	270-2-82-1	5544	174	28.43	0.10	27.02	3	2	0.10
8/5/95	14:25	270-2-82-1	5545	194	44.21	0.02	30.65	5	2	0.07
8/5/95	14:25	270-2-82-1	5546	193	46.46	0.20	20.61	5	2	0.04
8/5/95	14:25	270-2-82-1	5547	179	41.79	0.11	6.88	2	2	0.02
8/5/95	14:25	270-2-82-1	5548	190	42.13	0.18	29.03	5	2	0.07
8/5/95	14:25	270-2-82-1	5549	167	31.57	0.17	15.44	5	2	0.05
Central Area PWS										
8/8/95	21:57	270-0-108-1	5870	74	2.09	0.07	200.04	7	2	10.58
8/8/95	21:57	270-0-108-1	5871	61	1.29	0.05	223.00	7	2	20.90
8/8/95	21:57	270-0-108-1	5872	67	1.80	0.07	244.39	7	2	15.71
8/8/95	21:57	270-0-108-1	5873	61	1.17	0.04	157.73	6	2	15.58
8/8/95	21:57	270-0-108-1	5874	65	1.60	0.03	170.44	6	2	11.92
8/8/95	21:57	270-0-108-1	5875	64	1.55	0.07	301.13	7	2	24.11
8/8/95	21:57	270-0-108-1	5876	68	2.06	0.02	123.90	6	2	6.40
8/8/95	21:57	270-0-108-1	5877	66	2.02	0.04	164.90	6	2	8.89
8/8/95	21:57	270-0-108-1	5878	73	2.56	0.02	52.16	5	2	2.08
8/8/95	21:57	270-0-108-1	5879	63	1.64	0.05	255.27	7	2	18.43
8/10/95	13:13	270-0-112-1	5610	65	1.89	0.02	35.11	5	2	1.90
8/10/95	13:13	270-0-112-1	5611	64	1.63	0.01	8.85	5	2	0.55
8/10/95	13:13	270-0-112-1	5612	70	2.19	0.01	2.10	3	2	0.10
8/10/95	13:13	270-0-112-1	5613	58	1.16	0.01	0.07	2	2	0.01
8/10/95	13:13	270-0-112-1	5614	65	1.79	0.02	20.21	5	2	1.14
8/10/95	13:13	270-0-112-1	5615	60	1.33	0.01	2.06	5	2	0.16
8/10/95	13:13	270-0-112-1	5616	68	1.97	0.02	11.10	5	2	0.57
8/10/95	13:13	270-0-112-1	5617	67	1.97	0.01	1.05	3	2	0.05
8/10/95	13:13	270-0-112-1	5618	67	1.79	0.02	80.24	6	2	4.71
8/10/95	13:13	270-0-112-1	5619	64	1.47	0.03	26.36	5	2	1.83

Table 32 cont.										
Southwestern Area PWS										
10/10/95	19:40	270-0-2-1T	6031	109	7.47	0.03	15.97	2	2	0.21
10/10/95	19:40	270-0-2-1T	6032	112	5.44	0.02		1	3	0.00
10/10/95	19:40	270-0-2-1T	6033	107	6.81	0.03	2.22	3	1	0.03
10/10/95	19:40	270-0-2-1T	6034	105	6.75	0.02	1.32	3	2	0.02
10/10/95	19:40	270-0-2-1T	6035	96	4.28	0.02	2.40	3	2	0.06
10/10/95	19:40	270-0-2-1T	6036	109	7.08	0.02	16.48	4	2	0.23
10/10/95	19:40	270-0-2-1T	6037	92	4.81	0.04	31.95	4	2	0.67
10/10/95	19:40	270-0-2-1T	6038	106	6.73	0.01	21.01	3	2	0.31
10/10/95	19:40	270-0-2-1T	6039	104	5.97	0.02	3.97	2	2	0.07
10/10/95	19:40	270-0-2-1T	6040	110	5.20	0.00	1.44	2	2	0.03
10/10/95	19:40	270-1-2-1T	6041	175	34.92	0.08	9.70	3	2	0.03
10/10/95	19:40	270-1-2-1T	6042	170	30.02	0.11	11.28	3	2	0.04
10/10/95	19:40	270-1-2-1T	6043	159	23.99	0.04	2.30	2	2	0.01
10/10/95	19:40	270-1-2-1T	6044	165	23.53	0.07	21.11	4	2	0.09
10/10/95	19:40	270-1-2-1T	6045	166	27.07	0.07	2.21	4	2	0.01
10/10/95	19:40	270-1-2-1T	6046	153	22.71	0.06	12.25	2	2	0.05
10/10/95	19:40	270-1-2-1T	6047	179	34.74	0.06	33.65	3	2	0.10
10/10/95	19:40	270-1-2-1T	6048	173	32.03	0.08	0.79	2	2	0.00
10/10/95	19:40	270-1-2-1T	6049	159	25.93	0.05	6.07	2	2	0.02
10/10/95	19:40	270-1-2-1T	6050	150	20.70	0.06	17.01	4	2	0.08
Central Area PWS										
10/11/95	21:00	270-0-3-1T	6001	104	6.84	0.26	206.35	7	2	3.11
10/11/95	21:00	270-0-3-1T	6002	99	6.31	0.30	312.62	7	2	5.21
10/11/95	21:00	270-0-3-1T	6003	100	6.21	0.34	452.62	7	1	7.86
10/11/95	21:00	270-0-3-1T	6004	111	9.29	0.05	65.68	5	2	0.71
10/11/95	21:00	270-0-3-1T	6005	101	6.65	0.09	121.40	6	2	1.86
10/11/95	21:00	270-0-3-1T	6006	109	8.92	0.33	201.96	7	2	2.32
10/11/95	21:00	270-0-3-1T	6007	91	5.21	0.31	166.14	7	2	3.29
10/11/95	21:00	270-0-3-1T	6008	93	5.14	0.20	171.36	7	2	3.45
10/11/95	21:00	270-0-3-1T	6009	88	4.56	0.24	170.54	7	2	3.89
10/11/95	21:00	270-0-3-1T	6010	106	7.28	0.42	220.63	7	2	3.13
10/11/95	22:00	270-2-3-2T	6061	213	75.02	1.04	32.45	4	2	0.04
10/11/95	22:00	270-2-3-2T	6062	205	53.86	0.17	24.26	3	2	0.05

Table 32 cont.										
10/11/95	22:00	270-2-3-2T	6063	227	87.95	4.74	763.92	7	2	0.88
10/11/95	22:00	270-2-3-2T	6064	165	31.88	1.45	396.17	6	2	1.26
10/11/95	22:00	270-2-3-2T	6065	200	49.86	0.27	149.89	5	2	0.30
10/11/95	22:00	270-2-3-2T	6066	199	55.75	0.28	192.19	5	2	0.35
10/11/95	22:00	270-2-3-2T	6067	178	40.86	0.23	103.26	4	2	0.25
10/11/95	22:00	270-2-3-2T	6068	219	67.71	0.22	69.24	3	2	0.10
10/11/95	22:00	270-2-3-2T	6069	202	59.84	0.91	148.46	6	2	0.25
10/11/95	22:00	270-2-3-2T	6070	193	49.47	0.33	103.05	5	2	0.21
10/12/95	21:50	270-0-4-3T	6051	109	8.98	0.07	18.75	4	2	0.21
10/12/95	21:50	270-0-4-3T	6052	96	6.02	0.06	19.01	4	2	0.32
10/12/95	21:50	270-0-4-3T	6053	101	6.73	0.06	47.87	5	2	0.72
10/12/95	21:50	270-0-4-3T	6054	88	4.50	0.03	22.60	3	2	0.50
10/12/95	21:50	270-0-4-3T	6055	98	5.84	0.04	35.32	3	2	0.61
10/12/95	21:50	270-0-4-3T	6056	91	4.76	0.03	10.70	4	2	0.23
10/12/95	21:50	270-0-4-3T	6057	92	5.38	0.05	13.75	4	2	0.26
10/12/95	21:50	270-0-4-3T	6058	98	6.05	0.05	23.36	4	2	0.39
10/12/95	21:50	270-0-4-3T	6059	97	5.82	0.08	75.04	4	2	1.31
10/12/95	21:50	270-0-4-3T	6060	89	4.73	0.04	21.21	3	2	0.45
10/12/95	21:50	270-2-4-3T	6091	222	81.29	0.09		1	3	0.00
10/12/95	21:50	270-2-4-3T	6092	215	71.00	0.15	8.29	3	2	0.01
10/12/95	21:50	270-2-4-3T	6093	228	98.34	0.14	0.15	2	2	0.00
10/12/95	21:50	270-2-4-3T	6094	239	100.48	0.39	155.42	4	2	0.15
10/12/95	21:50	270-2-4-3T	6095	202	63.68	0.08		1	3	0.00
10/12/95	21:50	270-2-4-3T	6096	210	90.15	0.32	35.36	2	2	0.04
10/12/95	21:50	270-2-4-3T	6097	218	75.07	0.19	0.09	2	2	0.00
10/12/95	21:50	270-2-4-3T	6098	178	39.37	0.07	27.01	2	2	0.07
10/12/95	21:50	270-2-4-3T	6099	232	93.15	0.17	0.00	2	2	0.00
10/12/95	21:50	270-2-4-3T	6100	217	69.21	0.19	42.09	2	2	0.06
Northeastern Area PWS										
10/13/95	21:42	270-0-6-1T	6081	95	5.33	0.14	80.50	6	2	1.53
10/13/95	21:42	270-0-6-1T	6082	89	4.69	0.05	44.19	5	1	0.95
10/13/95	21:42	270-0-6-1T	6083	106	8.64	0.17	162.67	6	1	1.92
10/13/95	21:42	270-0-6-1T	6084	89	4.44	0.04	28.33	6	1	0.64
10/13/95	21:42	270-0-6-1T	6085	105	7.82	0.03	17.23	5	1	0.22

Table 32 cont.										
10/13/95	21:42	270-0-6-1T	6086	86	4.59	0.04	48.40	5	1	1.07
10/13/95	21:42	270-0-6-1T	6087	104	7.02	0.04	18.83	7	1	0.27
10/13/95	21:42	270-0-6-1T	6088	91	5.06	0.09	111.23	7	2	2.25
10/13/95	21:42	270-0-6-1T	6089	85	3.53	0.03	51.18	7	1	1.47
10/13/95	21:42	270-0-6-1T	6090	82	3.56	0.03	49.99	7	1	1.42
10/14/95	21:58	270-0-7-1T	6021	92	4.55	0.01	24.35	3	1	0.54
10/14/95	21:58	270-0-7-1T	6022	90	4.35	0.03	15.99	3	2	0.37
10/14/95	21:58	270-0-7-1T	6023	92	4.54	0.02	11.50	5	2	0.25
10/14/95	21:58	270-0-7-1T	6024	98	5.57	0.01		1	3	0.00
10/14/95	21:58	270-0-7-1T	6025	71	2.19	0.01	4.85	4	2	0.22
10/14/95	21:58	270-0-7-1T	6026	97	5.41	0.03	21.59	5	1	0.40
10/14/95	21:58	270-0-7-1T	6027	88	4.09	0.01	37.20	5	1	0.92
10/14/95	21:58	270-0-7-1T	6028	93	4.91	0.06	43.84	5	2	0.90
10/14/95	21:58	270-0-7-1T	6029	91	4.76	0.01	8.22	4	2	0.17
10/14/95	21:58	270-0-7-1T	6030	87	3.93	0.03	16.09	6	2	0.41
10/14/95	23:20	270-0-7-2T	6111	108	7.33	0.04	32.30	5	2	0.44
10/14/95	23:20	270-0-7-2T	6112	108	6.42	0.04	89.21	6	2	1.41
10/14/95	23:20	270-0-7-2T	6113	88	3.12	0.01	13.70	3	1	0.44
10/14/95	23:20	270-0-7-2T	6114	100	5.06	0.01	9.65	2	2	0.19
10/14/95	23:20	270-0-7-2T	6115	108	6.66	0.02	17.07	3	2	0.26
10/14/95	23:20	270-0-7-2T	6116	96	4.92	0.04	51.32	6	2	1.05
10/14/95	23:20	270-0-7-2T	6117	107	7.72	0.05	105.45	6	2	1.38
10/14/95	23:20	270-0-7-2T	6118	94	5.02	0.05	89.05	6	2	1.81
10/14/95	23:20	270-0-7-2T	6119	109	5.77	0.02	27.37	5	2	0.48
10/14/95	23:20	270-0-7-2T	6120	109	7.39	0.03	35.05	5	2	0.48
10/14/95	23:20	270-2-7-2T	6171	165	30.77	0.16	98.99	3	2	0.32
10/14/95	23:20	270-2-7-2T	6172	190	40.85	0.14	5.54	2	2	0.01
10/14/95	23:20	270-2-7-2T	6173	187	45.66	0.10	10.25	3	2	0.02
10/14/95	23:20	270-2-7-2T	6174	183	38.86	0.14	51.48	3	2	0.13
10/14/95	23:20	270-2-7-2T	6175	174	32.27	0.22	66.49	3	2	0.21
10/14/95	23:20	270-2-7-2T	6176	189	41.21	0.35	216.14	4	2	0.53
10/14/95	23:20	270-2-7-2T	6177	188	38.90	0.15	9.05	2	2	0.02
10/14/95	23:20	270-2-7-2T	6178	176	32.87	0.22	46.08	5	2	0.14
10/14/95	23:20	270-2-7-2T	6179	185	47.17	0.44	19.46	5	2	0.04

Table 32 cont.										
10/14/95	23:20	270-2-7-2T	6180	155	23.30	0.12	21.39	2	2	0.09

Table 33. Summary of stomach fullness statistics for all APEX herring specimens analyzed 1994-1995. See also Figures 17 and 18.

Sample date	Sample time	species- size group-station-haul-gear	specimen number	Fish length (mm)	Fish weight (g)	Fish stomach weight (g)	Total prey weight (mg)	stomach fullness code (1-7)	stomach digestion code (1-3)	Percent body weight
Southwestern Area PWS										
11/7/94	13:25	233-2-3-1T	5081	230	64.92	0.34	25.86	2	2	0.04
11/7/94	13:25	233-2-3-1T	5082	198	81.13	0.08	1.09	2	2	0.00
11/7/94	13:25	233-2-3-1T	5083	234	35.83	0.20	4.38	2	2	0.01
11/7/94	13:25	233-2-3-1T	5084	219	20.15	0.09	2.56	2	2	0.01
11/7/94	13:25	233-2-3-1T	5085	219	18.82	0.10	0.35	2	2	0.00
11/7/94	13:25	233-2-3-1T	5086	212	4.59	0.31	0.99	2	2	0.02
11/7/94	13:25	233-2-3-1T	5087	220	29.49	0.63	1.24	2	2	0.00
11/7/94	13:25	233-2-3-1T	5088	184	69.59	0.14	3.68	2	2	0.01
11/7/94	13:25	233-2-3-1T	5089	232	43.92	0.09	0.22	2	2	0.00
11/7/94	13:25	233-2-3-1T	5090	206	89.23	0.07	2.54	2	2	0.00
Northeastern Area PWS										
11/10/94	22:42	233-0-6-1T	5051	97	7.23	0.02		2	2	0.00
11/10/94	22:42	233-0-6-1T	5052	100	7.20	0.00		1	3	0.00
11/10/94	22:42	233-0-6-1T	5053	110	10.27	0.00		1	3	0.00
11/10/94	22:42	233-0-6-1T	5054	98	7.82	0.00		1	3	0.00
11/10/94	22:42	233-0-6-1T	5055	81	4.20	0.01	3.26	3	2	0.08
11/10/94	22:42	233-0-6-1T	5056	94	5.61	0.00		1	3	0.00
11/10/94	22:42	233-0-6-1T	5057	82	4.87	0.01	0.07	2	2	0.00
11/10/94	22:42	233-0-6-1T	5058	73	3.07	0.01		1	3	0.00
11/10/94	22:42	233-0-6-1T	5059	111	12.64	0.01		1	3	0.00
11/10/94	22:42	233-0-6-1T	5060	81	3.63	0.01	4.43	3	2	0.12
11/12/94	22:30	233-0-7-4T	5031	118	13.14	0.01		1	3	0.00
11/12/94	22:30	233-0-7-4T	5032	113	10.13	0.01		1	3	0.00
11/12/94	22:30	233-0-7-4T	5033	98	7.76	0.13	129.35	6	1	1.69
11/12/94	22:30	233-0-7-4T	5034	76	3.22	0.01	25.00	3	2	0.78
11/12/94	22:30	233-0-7-4T	5035	93	5.69	0.02	3.89	3	2	0.07
11/12/94	22:30	233-0-7-4T	5036	92	5.22	0.01	9.76	3	2	0.19
11/12/94	22:30	233-0-7-4T	5037	92	6.23	0.02	13.53	3	2	0.22

Table 33 cont.										
11/12/94	22:30	233-0-7-4T	5038	108	9.87	0.12	53.25	5	2	0.54
11/12/94	22:30	233-0-7-4T	5039	95	6.68	0.04	29.05	3	2	0.44
11/12/94	22:30	233-0-7-4T	5040	80	4.01	0.00	0.38	2	2	0.01
11/13/94	16:15	233-0-8	5001	87	4.82	0.02	1.46	2	2	0.03
11/13/94	16:15	233-0-8	5002	88	5.18	0.02	0.84	2	2	0.02
11/13/94	16:15	233-0-8	5003	90	5.39	0.03	23.94	3	2	0.45
11/13/94	16:15	233-0-8	5004	83	4.48	0.02	5.94	3	2	0.13
11/13/94	16:15	233-0-8	5005	98	7.45	0.04	20.18	4	2	0.27
11/13/94	16:15	233-0-8	5006	86	4.95	0.05	28.45	4	2	0.58
11/13/94	16:15	233-1-8	5007	147	30.06	0.08	53.01	3	2	0.18
11/13/94	16:15	233-0-8	5008	92	5.76	0.05	6.16	4	2	0.11
11/13/94	16:15	233-0-8	5009	83	4.68	0.03	12.80	3	2	0.27
11/13/94	16:15	233-0-8	5010	87	5.08	0.02	27.60	4	2	0.55
11/13/94	15:10	233-0-8	5011	123	83.33	0.18	10.33	3	1	0.01
11/13/94	15:10	233-1-8	5012	178	46.52	0.20	1.17	2	1	0.00
11/13/94	15:10	233-1-8	5013	173	44.37	0.17	24.58	3	2	0.06
11/13/94	15:10	233-1-8	5014	197	84.46	0.26	0.90	2	2	0.00
11/13/94	15:10	233-1-8	5015	175	44.03	0.09	10.46	3	2	0.02
11/13/94	15:10	233-1-8	5016	164	43.48	0.39	4.23	2	2	0.01
11/13/94	15:10	233-1-8	5017	160	41.90	0.09	6.38	2	1	0.02
11/13/94	15:10	233-1-8	5018	157	41.33	0.10	6.31	2	2	0.02
11/13/94	15:10	233-1-8	5019	173	44.80	0.11	1.59	2	1	0.00
11/13/94	15:10	233-1-8	5020	179	56.37	0.17	0.91	2	1	0.00
7/26/95	19:30	233-0-27-1	5500	78	3.19	0.14	918.00	6	2	40.35
7/26/95	19:30	233-0-27-1	5501	87	3.78	0.18	511.27	7	2	15.65
7/26/95	19:30	233-0-27-1	5502	73	2.56	0.14	739.76	7	2	40.60
7/26/95	19:30	233-0-27-1	5503	76	3.19	0.12	538.19	6	2	20.30
7/26/95	19:30	233-0-27-1	5504	63	1.42	0.04	176.36	6	2	14.24
7/26/95	19:30	233-0-27-1	5505	75	2.79	0.10	414.51	7	2	17.48
7/26/95	19:30	233-0-27-1	5506	73	2.53	0.09	605.05	6	2	31.42
7/26/95	19:30	233-0-27-1	5507	78	3.02	0.11	544.63	6	2	21.97
7/26/95	19:30	233-0-27-1	5508	83	4.11	0.03	408.92	6	2	11.05
7/26/95	19:30	233-0-27-1	5509	74	2.76	0.12	536.27	7	1	24.13
7/26/95	11:07	233-1-22-2	5530	148	34.73	0.18	222.49	4	2	0.64

Table 33 cont.										
7/26/95	11:07	233-1-22-2	5531	142	25.29	0.11	272.85	3	2	1.09
7/26/95	11:07	233-1-22-2	5532	140	24.38	0.20	457.13	5	2	1.91
7/26/95	11:07	233-1-22-2	5533	140	23.69	0.35	1054.87	6	2	4.66
7/26/95	11:07	233-1-22-2	5534	143	27.51	0.33	1058.29	6	2	4.00
7/26/95	11:07	233-1-22-2	5535	136	22.20	0.13	613.66	5	2	2.84
7/26/95	11:07	233-1-22-2	5536	142	27.20	0.30	651.86	4	2	2.46
7/26/95	11:07	233-1-22-2	5537	147	24.47	0.09	79.05	3	2	0.32
7/26/95	11:07	233-1-22-2	5538	140	23.58	0.25	927.20	5	2	4.09
7/26/95	11:07	233-1-22-2	5539	147	26.85	0.39	672.06	4	2	2.57
Southwestern Area PWS										
7/30/95	12:37	233-0-43-1	5830	98	3.89	0.06	142.46	5	2	3.80
7/30/95	12:37	233-0-43-1	5831	112	8.98	0.05	62.94	4	2	0.71
7/30/95	12:37	233-0-43-1	5832	114	6.72	0.03	3.92	2	1	0.06
7/30/95	12:37	233-0-43-1	5833	117	7.86	0.08	216.24	4	2	2.83
7/30/95	12:37	233-0-43-1	5834	113	4.70	0.06	28.69	3	2	0.61
7/30/95	12:37	233-0-43-1	5835	91	3.94	0.08	332.65	6	2	9.22
7/30/95	12:37	233-0-43-1	5836	109	6.73	0.06	218.51	6	2	3.36
7/30/95	12:37	233-0-43-1	5837	93	4.58	0.01	0.12	2	1	0.00
7/30/95	12:37	233-0-43-1	5838	116	5.27	0.04	54.75	4	2	1.05
7/30/95	12:37	233-0-43-1	5839	120	7.67	0.13	122.97	6	2	1.63
8/8/95	20:16	233-1-107-1	5580	139	26.85	0.93	5148.85	7	2	23.73
8/8/95	20:16	233-1-107-1	5581	159	37.55	0.90	2932.53	6	2	8.47
8/8/95	20:16	233-1-107-1	5582	135	23.35	0.52	1681.42	6	1	7.76
8/8/95	20:16	233-1-107-1	5583	136	23.23	0.68	1795.41	6	2	8.38
8/8/95	20:16	233-1-107-1	5584	140	24.83	0.62	2734.00	7	2	12.37
8/8/95	20:16	233-1-107-1	5585	144	26.58	0.44	1697.87	6	2	6.82
8/8/95	20:16	233-1-107-1	5586	149	30.68	0.72	2029.72	6	2	7.08
8/8/95	20:16	233-1-107-1	5587	141	27.69	0.77	2507.60	6	2	9.96
8/8/95	20:16	233-1-107-1	5588	146	29.64	0.37	1283.09	6	2	4.52
8/8/95	20:16	233-1-107-1	5589	133	24.64	0.46	1056.33	5	2	4.48
Central Area PWS										
8/9/95	15:30	233-0-110-1	5800	29	0.12	-0-		1	3	0.00
8/9/95	15:30	233-0-110-1	5801	28	0.09	-0-		1	3	0.00
8/9/95	15:30	233-0-110-1	5802	29	0.10	-0-	0.15	2	2	0.15

Table 33 cont.										
8/9/95	15:30	233-0-110-1	5803	31	0.14	-0-	2.55	3	2	1.88
8/9/95	15:30	233-0-110-1	5804	30	0.13	-0-	6.32	6	2	5.19
8/9/95	15:30	233-0-110-1	5805	29	0.09	-0-	2.32	4	2	2.56
8/9/95	15:30	233-0-110-1	5806	28	0.07	-0-	0.38	4	2	0.52
8/9/95	15:30	233-0-110-1	5807	31	0.16	-0-	0.52	3	2	0.32
8/9/95	15:30	233-0-110-1	5808	30	0.14	-0-		1	3	0.00
8/9/95	15:30	233-0-110-1	5809	30	0.12	-0-	3.28	5	2	2.76
Northeastern Area PWS										
8/11/95	12:10	233-1-116-1	5630	123	11.36	0.14	37.75	5	2	0.33
8/11/95	12:10	233-1-116-1	5631	136	22.12	0.26	147.78	5	2	0.67
8/11/95	12:10	233-1-116-1	5632	138	26.91	0.30	195.49	7	2	0.73
8/11/95	12:10	233-1-116-1	5633	141	25.99	0.22	107.16	4	2	0.41
8/11/95	12:10	233-1-116-1	5634	112	15.00	0.09	68.74	5	2	0.46
8/11/95	12:10	233-1-116-1	5635	125	18.98	0.19	56.44	4	2	0.30
8/11/95	12:10	233-1-116-1	5636	130	20.96	0.12	70.55	3	2	0.34
8/11/95	12:10	233-1-116-1	5637	123	18.21	0.17	84.29	6	2	0.47
8/11/95	12:10	233-1-116-1	5638	119	17.53	0.18	115.05	6	2	0.66
8/11/95	12:10	233-1-116-1	5639	123	18.74	0.25	99.64	5	2	0.53
8/11/95	15:30	233-0-118-1	5790	58	0.79	0.01		1	3	0.00
8/11/95	15:30	233-0-118-1	5791	112	8.34	0.04		1	3	0.00
8/11/95	15:30	233-0-118-1	5792	82	3.24	0.03		1	3	0.00
8/11/95	15:30	233-0-118-1	5793	75	2.34	0.02		1	3	0.00
8/11/95	15:30	233-0-118-1	5794	73	2.39	0.02		1	3	0.00
8/11/95	15:30	233-0-118-1	5795	57	0.84	0.01		1	3	0.00
8/11/95	15:30	233-0-118-1	5796	60	1.03	0.00		1	3	0.00
8/11/95	15:30	233-0-118-1	5797	64	1.35	0.00		1	3	0.00
8/11/95	15:30	233-0-118-1	5798	74	2.40	0.03		1	3	0.00
8/11/95	15:30	233-0-118-1	5799	58	0.77	0.00		1	3	0.00
Southwestern Area PWS										
10/10/95	19:40	233-1-2-1T	6161	152	28.13	0.04		1	3	0.00
10/10/95	19:40	233-1-2-1T	6162	146	23.28	0.03	10.65	2	2	0.05
10/10/95	19:40	233-1-2-1T	6163	147	33.37	0.02	0.37	2	2	0.00
10/10/95	19:40	233-1-2-1T	6164	142	22.21	0.02		1	3	0.00
10/10/95	19:40	233-1-2-1T	6165	141	25.06	0.02	20.06	2	2	0.08

Table 33 cont.										
10/10/95	19:40	233-1-2-1T	6166	138	20.08	0.01	0.07	2	2	0.00
10/10/95	19:40	233-1-2-1T	6167	135	21.31	0.01		1	3	0.00
10/10/95	19:40	233-0-2-1T	6168	93	5.15	0.03	51.82	5	2	1.02
10/10/95	19:40	233-0-2-1T	6169	64	1.87	0.02	134.84	6	2	7.77
10/10/95	19:40	233-1-2-1T	6170	145	29.04	0.01	4.26	2	2	0.01
Central Area PWS										
10/13/95	11:30	233-0-5-1T	6101	85	5.70	0.06	42.70	3	1	0.75
10/13/95	11:30	233-0-5-1T	6102	89	7.04	0.09	51.85	4	1	0.74
10/13/95	11:30	233-0-5-1T	6103	96	8.87	0.15	175.72	4	1	2.02
10/13/95	11:30	233-0-5-1T	6104	97	8.03	0.08	54.44	3	1	0.68
10/13/95	11:30	233-0-5-1T	6105	86	7.67	0.12	118.27	3	1	1.57
10/13/95	11:30	233-0-5-1T	6106	89	5.28	0.10	196.62	5	2	3.87
10/13/95	11:30	233-0-5-1T	6107	95	6.53	0.10	197.01	5	1	3.11
10/13/95	11:30	233-0-5-1T	6108	90	6.34	0.07	70.47	4	2	1.12
10/13/95	11:30	233-0-5-1T	6109	96	6.38	0.13	139.05	5	1	2.23
10/13/95	11:30	233-0-5-1T	6110	93	5.83	0.04	34.65	4	1	0.60
Northeastern Area PWS										
10/13/95	21:42	233-0-6-1T	6071	96	7.43	0.13	69.19	6	1	0.94
10/13/95	21:42	233-0-6-1T	6072	68	2.69	0.02	17.31	5	2	0.65
10/13/95	21:42	233-0-6-1T	6073	98	7.56	0.02	26.35	3	2	0.35
10/13/95	21:42	233-0-6-1T	6074	79	3.99	0.01	8.13	2	2	0.20
10/13/95	21:42	233-0-6-1T	6075	98	7.50	0.10	65.08	4	1	0.88
10/13/95	21:42	233-0-6-1T	6076	90	6.32	0.11	87.04	6	2	1.40
10/13/95	21:42	233-0-6-1T	6077	94	6.66	0.12	80.52	6	1	1.22
10/13/95	21:42	233-0-6-1T	6078	64	2.26	0.03	53.48	6	2	2.42
10/13/95	21:42	233-0-6-1T	6079	66	2.70	0.05	128.71	6	2	5.01
10/13/95	21:42	233-0-6-1T	6080	83	5.30	0.02	50.49	6	2	0.96
10/14/95	21:58	233-0-7-1T	6011	97	7.97	0.04	298.56	6	2	3.89
10/14/95	21:58	233-0-7-1T	6012	93	6.69	0.03	113.23	4	2	1.72
10/14/95	21:58	233-0-7-1T	6013	95	7.37	0.05	61.05	5	2	0.84
10/14/95	21:58	233-0-7-1T	6014	92	6.84	0.03	64.16	4	2	0.95
10/14/95	21:58	233-0-7-1T	6015	93	7.25	0.03	18.00	4	2	0.25
10/14/95	21:58	233-0-7-1T	6016	97	7.43	0.02	1.45	4	2	0.02
10/14/95	21:58	233-0-7-1T	6017	114	13.21	0.22	1350.23	6	2	11.38

Table 33 cont.										
10/14/95	21:58	233-0-7-1T	6018	74	3.75	0.01		1	3	0.00
10/14/95	21:58	233-0-7-1T	6019	93	6.47	0.04	64.03	5	2	1.00
10/14/95	21:58	233-0-7-1T	6020	106	9.70	0.02	24.17	4	2	0.25

Table 34. Summary of stomach fullness statistics for all sandlance diet specimens analyzed to date from collections by APEX Projects 95163A (non-diel), 96163A and 96163F (diel samples) in PWS. See also Figure 18.

Sample date	Sample time	species-size group-station-haul	specimen number	Fish length (mm)	Fish weight (g)	Fish stomach weight (g)	Total prey weight (mg)	stomach fullness code (1-7)	stomach digestion code (1-3)	Percent body weight
Central Area PWS										
8/16/95	-0-	517-0-999-1	5724	94	2.89	0.20	143.72	7	2	5.24
8/16/95	-0-	517-0-999-1	5725	94	2.71	0.23	77.28	7	2	2.93
8/16/95	-0-	517-0-999-1	5726	94	2.39	0.06	48.83	7	2	2.09
8/16/95	-0-	517-0-999-1	5727	89	1.88	0.08	56.89	7	2	3.13
8/16/95	-0-	517-0-999-1	5728	95	2.68	0.07	58.97	7	2	2.25
8/16/95	-0-	517-0-999-1	5729	93	2.08	0.07	55.04	7	2	2.72
8/16/95	-0-	517-0-999-1	5730	85	1.81	0.09	80.64	7	2	4.68
8/16/95	-0-	517-0-999-1	5731	82	1.45	0.04	21.78	7	2	1.52
8/16/95	-0-	517-0-999-1	5732	98	2.91	0.17	113.26	7	2	4.06
8/16/95	-0-	517-0-999-1	5733	100	2.59	0.14	85.33	7	2	3.41
Northeastern Area PWS										
8/5/95	14:25	517-0-82-1	5820	60	0.52	-0-	7.15	5	2	1.40
8/5/95	14:25	517-0-82-1	5821	64	0.68	-0-	8.69	4	1	1.29
8/5/95	14:25	517-0-82-1	5822	65	0.63	-0-	10.03	5	1	1.61
8/5/95	14:25	517-0-82-1	5823	61	0.56	-0-	12.01	3	1	2.21
8/5/95	14:25	517-0-82-1	5824	64	0.60	-0-	7.08	4	2	1.20
8/5/95	14:25	517-0-82-1	5825	60	0.50	-0-	7.77	3	2	1.59
8/5/95	14:25	517-0-82-1	5826	58	0.46	-0-	6.29	5	2	1.40
8/5/95	14:25	517-0-82-1	5827	62	0.53	-0-	12.59	4	1	2.44
8/5/95	14:25	517-0-82-1	5828	61	0.52	-0-	11.80	5	2	2.31
8/5/95	14:25	517-0-82-1	5829	56	0.39	-0-	8.65	5	2	2.25
8/11/95	15:30	517-0-118-1	5550	91	2.65	0.01	0.32	2	1	0.01
8/11/95	15:30	517-0-118-1	5551	100	2.99	0.02	3.41	4	2	0.11
8/11/95	15:30	517-0-118-1	5552	97	2.79	0.01	4.41	3	2	0.16
8/11/95	15:30	517-0-118-1	5553	80	1.59	0.01	0.72	3	2	0.05
8/11/95	15:30	517-0-118-1	5554	94	2.47	0.01	13.94	4	2	0.57
8/11/95	15:30	517-0-118-1	5555	80	1.67	0.00	0.09	2	2	0.01
8/11/95	15:30	517-0-118-1	5556	92	2.46	0.01	0.37	2	2	0.02

Table 34 cont.										
8/11/95	15:30	517-0-118-1	5557	81	1.75	0.01	10.72	5	2	0.62
8/11/95	15:30	517-0-118-1	5558	90	1.95	0.00	1.50	2	2	0.08
8/11/95	15:30	517-0-118-1	5559	91	2.68	0.01	3.00	3	2	0.11
All sandlance stomachs processed from 1996 (all collected from Cabin Bay, Naked Island, by project 96163F)										
Central Area PWS										
7/21/96	19:55	517-0-F1D8	9000	86	0.72	0.00	-0-	1	3	0.00
7/21/96	19:55	517-0-F1D8	9001	72	1.19	0.00	7.16	5	2	0.61
7/21/96	19:55	517-0-F1D8	9002	69	0.89	0.00	0.21	2	2	0.02
7/21/96	19:55	517-0-F1D8	9003	66	0.80	0.00	0.03	2	1	0.00
7/21/96	19:55	517-0-F1D8	9004	60	0.74	0.03	41.45	6	2	5.93
7/21/96	19:55	517-0-F1D8	9005	66	0.82	0.00	-0-	1	3	0.00
7/21/96	19:55	517-0-F1D8	9006	67	0.82	0.00	-0-	1	3	0.00
7/21/96	19:55	517-0-F1D8	9007	65	0.84	0.00	-0-	1	3	0.00
7/21/96	19:55	517-0-F1D8	9008	69	1.11	0.02	106.60	5	2	10.62
7/21/96	19:55	517-0-F1D8	9009	69	0.91	0.00	0.15	2	2	0.02
7/22/96	8:00	517-1-F1D12	9010	124	6.66	0.06	68.47	7	1	1.04
7/22/96	8:00	517-1-F1D12	9011	120	6.27	0.02	16.71	4	2	0.27
7/22/96	8:00	517-1-F1D12	9012	125	7.40	0.14	82.55	7	1	1.13
7/22/96	8:00	517-1-F1D12	9013	116	5.02	0.04	49.67	5	1	1.00
7/22/96	8:00	517-1-F1D12	9014	129	7.52	0.11	143.04	6	2	1.94
7/22/96	8:00	517-1-F1D12	9015	118	6.02	0.09	110.42	7	1	1.87
7/22/96	8:00	517-1-F1D12	9016	95	2.82	0.03	15.73	4	1	0.56
7/22/96	8:00	517-1-F1D12	9017	130	7.31	0.11	94.20	6	1	1.31
7/22/96	8:00	517-1-F1D12	9018	92	2.70	0.01	25.14	3	1	0.94
7/22/96	8:00	517-1-F1D12	9019	92	2.71	0.03	35.09	6	1	1.31
7/22/96	12:10	517-0-F2D13	9020	61	0.66	0.00	19.46	5	1	3.04
7/22/96	12:10	517-0-F2D13	9021	70	0.90	0.00	3.10	3	2	0.32
7/22/96	12:10	517-0-F2D13	9022	62	0.68	0.00	23.12	4	2	3.52
7/22/96	12:10	517-0-F2D13	9023.	59	0.62	0.00	13.95	5	2	2.30
7/22/96	12:10	517-0-F2D13	9024	69	0.88	0.01	37.31	5	2	4.43
7/22/96	12:10	517-0-F2D13	9025	60	0.62	0.01	25.83	5	2	4.35
7/22/96	12:10	517-0-F2D13	9026	59	0.63	0.01	39.01	5	1	6.60
7/22/96	12:10	517-0-F2D13	9027	54	0.46	0.01	46.30	7	2	11.19
7/22/96	12:10	517-0-F2D13	9028	49	0.35	0.01	35.26	7	2	11.20

Table 34 cont.										
7/22/96	12:10	517-0-F2D13	9029	68	0.83	0.02	56.96	7	1	7.37
7/22/96	16:05	517-0-F1D15	9030	79	1.48	0.00	15.14	4	2	1.03
7/22/96	16:05	517-0-F1D15	9031	80	1.33	0.01	2.76	3	2	0.21
7/22/96	16:05	517-0-F1D15	9032	78	1.29	0.00	2.06	3	2	0.16
7/22/96	16:05	517-0-F1D15	9033	76	1.18	0.01	35.80	6	2	3.13
7/22/96	16:05	517-0-F1D15	9034	76	1.47	0.00	5.17	3	2	0.35
7/22/96	16:05	517-0-F1D15	9035	68	0.95	0.01	89.57	5	2	10.41
7/22/96	16:05	517-0-F1D15	9036	77	1.27	0.01	31.80	5	2	2.57
7/22/96	16:05	517-0-F1D15	9037	70	0.93	0.01	33.61	6	2	3.75
7/22/96	16:05	517-0-F1D15	9038	70	0.94	0.00	71.33	5	2	8.21
7/22/96	16:05	517-0-F1D15	9039	61	0.62	0.01	90.09	6	2	17.00
7/22/96	20:15	517-0-F2D16	9040	90	2.48	0.00	-0-	1	3	0.00
7/22/96	20:15	517-0-F2D16	9041	72	1.04	0.00	1.04	2	2	0.10
7/22/96	20:15	517-0-F2D16	9042	71	0.99	0.00	1.02	2	2	0.10
7/22/96	20:15	517-0-F2D16	9043	76	1.22	0.00	0.79	2	2	0.06
7/22/96	20:15	517-0-F2D16	9044	64	0.71	0.00	25.66	6	2	3.75
7/22/96	20:15	517-0-F2D16	9045	75	1.11	0.00	0.60	2	2	0.05
7/22/96	20:15	517-0-F2D16	9046	64	0.74	0.00	0.31	2	2	0.04
7/22/96	20:15	517-0-F2D16	9047	71	1.04	0.00	3.45	2	2	0.33
7/22/96	20:15	517-0-F2D16	9048	70	0.97	0.00	0.13	2	1	0.01
7/22/96	20:15	517-0-F2D16	9049	71	0.92	0.00	0.37	2	1	0.04
Northeastern Area PWS										
7/27/96	11:10	517-0-80-D1	7011	76	1.11	0.00	0.11	2	1	0.01
7/27/96	11:10	517-0-80-D1	7012	85	1.65	0.01	0.71	3	1	0.04
7/27/96	11:10	517-0-80-D1	7013	86	1.70	0.00	0.64	2	1	0.04
7/27/96	11:10	517-0-80-D1	7014	87	1.73	0.00	0.25	2	2	0.01
7/27/96	11:10	517-0-80-D1	7015	77	1.20	0.00	0.66	2	1	0.05
7/27/96	11:10	517-0-80-D1	7016	76	1.30	0.00	0.21	2	1	0.02
7/27/96	11:10	517-0-80-D1	7017	70	0.96	0.00	0.26	2	2	0.03
7/27/96	11:10	517-0-80-D1	7018	62	0.59	0.00	0.59	3	2	0.10
7/27/96	11:10	517-0-80-D1	7019	65	0.64	0.00	4.09	4	2	0.64
7/27/96	11:10	517-0-80-D1	7020	71	0.99	0.00	0.99	3	2	0.10
7/27/96	18:00	517-0-84-D2	7021	80	1.26	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7022	87	1.62	0.00	0.00	1	3	0.00

Table 34 cont.										
7/27/96	18:00	517-0-84-D2	7023	83	1.50	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7024	72	0.91	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7025	78	1.36	0.00	0.05	2	1	0.00
7/27/96	18:00	517-0-84-D2	7026	86	1.64	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7027	66	0.71	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7028	63	0.59	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7029	72	0.95	0.00	0.00	1	3	0.00
7/27/96	18:00	517-0-84-D2	7030	68	0.77	0.00	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7040	132	7.89	0.00	1.44	2	2	0.02
7/28/96	6:35	517-1-88-D4	7041	113	3.34	0.02	0.65	2	2	0.02
7/28/96	6:35	517-1-88-D4	7042	100	2.57	0.00	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7043	111	4.32	0.01	0.09	2	2	0.00
7/28/96	6:35	517-1-88-D4	7044	102	2.99	0.00	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7045	97	2.46	0.00	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7046	111	3.59	0.02	1.95	2	2	0.05
7/28/96	6:35	517-1-88-D4	7047	105	3.27	0.01	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7048	107	3.49	0.00	0.00	1	3	0.00
7/28/96	6:35	517-1-88-D4	7049	118	5.75	0.00	0.00	1	3	0.00

Table 35. Summary of stomach fullness statistics for all APEX capelin specimens (n=130) analyzed from 1994-1995 collections. See also Figure 17.

Sample date	Sample time	species-size group-station haul	specimen number	Fish length (mm)	Fish weight (g)	Fish stomach weight (g)	Total prey weight (mg)	stomach fullness code (1-7)	stomach digestion code (1-3)	Percent body weight	
Southwestern Area PWS											
7/30/95	12:37	516-0-43-1T	5810	30	0.05	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5811	35	0.09	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5812	32	0.05	-0-	0.07	2	2	0.14	
7/30/95	12:37	516-0-43-1T	5813	28	0.05	-0-	0.15	2	2	0.31	
7/30/95	12:37	516-0-43-1T	5814	32	0.06	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5815	26	0.02	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5816	31	0.03	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5817	28	0.04	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5818	32	0.06	-0-	0.00	1	3	0.00	
7/30/95	12:37	516-0-43-1T	5819	23	0.02	-0-	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5890	38	0.05	0.00	0.07	2	2	0.16	
7/30/95	16:07	516-0-47-1T	5891	34	0.05	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5892	34	0.07	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5893	31	0.03	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5894	31	0.05	0.00	0.05	2	2	0.09	
7/30/95	16:07	516-0-47-1T	5895	28	0.04	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5896	34	0.06	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5897	32	0.05	0.00	0.00	1	3	0.00	
7/30/95	16:07	516-0-47-1T	5898	34	0.06	0.00	0.02	2	2	0.04	
7/30/95	16:07	516-0-47-1T	5899	33	0.06	0.00	0.57	3	2	1.02	
8/8/95	13:20	516-0-100-2T	5770	39	0.13	0.00	0.00	2	2	0.00	
8/8/95	13:20	516-0-100-2T	5771	30	0.05	0.00	0.02	2	2	0.05	
8/8/95	13:20	516-0-100-2T	5772	34	0.08	0.00	0.00	1	1	0.00	
8/8/95	13:20	516-0-100-2T	5773	26	0.03	0.00	0.07	2	1	0.24	
8/8/95	13:20	516-0-100-2T	5774	29	0.05	0.00	0.02	2	2	0.05	
8/8/95	13:20	516-0-100-2T	5775	24	0.02	0.00	0.00	1	3	0.00	

Table 35 cont.											
8/8/95	13:20	516-0-100-2T	5776	24	0.03	0.00	0.05	2	1	0.19	
8/8/95	13:20	516-0-100-2T	5777	25	0.02	0.00	0.00	1	3	0.00	
8/8/95	13:20	516-0-100-2T	5778	23	0.02	0.00	0.02	2	1	0.13	
8/8/95	13:20	516-0-100-2T	5779	19	0.01	0.00	0.00	1	3	0.00	
Central Area PWS											
8/2/95	14:28	516-0-62-1T	5760	24	0.02	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5761	20	0.01	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5762	23	0.02	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5763	24	0.03	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5764	20	0.01	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5765	21	0.02	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5766	20	0.01	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5767	21	0.02	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5768	22	0.02	0.00	0.00	1	3	0.00	
8/2/95	14:28	516-0-62-1T	5769	19	0.01	0.00	0.00	1	3	0.00	
8/3/95	10:45	516-1-65-1R	5693	137	20.23	0.04	0.12	2	1	0.00	
8/3/95	10:45	516-1-65-1R	5694	131	16.12	0.02	0.40	2	1	0.00	
8/3/95	10:45	516-1-65-1R	5695	140	19.80	0.02	0.00	1	3	0.00	
8/3/95	10:45	516-1-65-1R	5696	141	20.03	0.06	0.49	2	1	0.00	
8/3/95	10:45	516-1-65-1R	5697	143	21.38	0.05	0.07	2	1	0.00	
8/3/95	10:45	516-1-65-1R	5698	128	15.04	0.00	0.00	1	3	0.00	
8/3/95	10:45	516-1-65-1R	5699	143	21.75	0.03	0.08	2	1	0.00	
8/3/95	10:45	516-1-65-1R	5700	138	21.15	0.01	0.00	1	3	0.00	
8/3/95	10:45	516-1-65-1R	5701	135	17.97	0.02	0.00	1	3	0.00	
8/3/95	10:45	516-1-65-1R	5702	135	19.17	0.01	0.07	2	1	0.00	
8/3/95	17:06	516-0-67-1T	5860	37	0.09	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5861	33	0.06	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5862	26	0.02	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5863	32	0.05	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5864	36	0.08	-0-	0.01	2	2	0.01	
8/3/95	17:06	516-0-67-1T	5865	27	0.04	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5866	32	0.04	-0-	0.00	1	3	0.00	

Table 35 cont.											
8/3/95	17:06	516-0-67-1T	5867	38	0.08	-0-	0.01	2	2	0.01	
8/3/95	17:06	516-0-67-1T	5868	28	0.04	-0-	0.00	1	3	0.00	
8/3/95	17:06	516-0-67-1T	5869	23	0.01	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5880	27	0.04	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5881	24	0.03	-0-	0.01	2	2	0.04	
8/4/95	10:45	516-0-72-1T	5883	22	0.01	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5884	26	0.03	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5885	27	0.04	-0-	0.01	2	2	0.03	
8/4/95	10:45	516-0-72-1T	5886	23	0.03	-0-	0.01	2	2	0.04	
8/4/95	10:45	516-0-72-1T	5887	23	0.04	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5888	22	0.01	-0-	0.00	1	3	0.00	
8/4/95	10:45	516-0-72-1T	5889	22	0.02	-0-	0.01	2	2	0.05	
8/4/95	11:56	516-0-73-1T	5750	26	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5751	31	0.06	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5752	25	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5753	25	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5754	25	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5755	24	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5756	24	0.02	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5757	25	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5758	27	0.03	0.00	0.00	1	3	0.00	
8/4/95	11:56	516-0-73-1T	5759	26	0.03	0.00	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5560	134	17.84	0.02	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5561	138	21.49	0.04	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5562	137	15.47	0.02	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5563	135	18.12	0.03	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5564	141	17.73	0.03	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5565	132	14.78	0.01	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5566	124	13.27	0.03	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5567	134	16.86	0.03	0.00	1	3	0.00	
8/10/95	20:38	516-1-114-7T	5568	140	18.38	0.03	0.17	2	2	0.00	
8/10/95	20:38	516-1-114-7T	5569	134	15.50	0.03	0.00	1	3	0.00	

Table 35 cont.											
Central Area PWS											
10/11/95	21:00	516-0-3-1T	6121	44	0.21	0.00	0.00	1	3	0.00	
10/11/95	21:00	516-0-3-1T	6122	40	0.22	0.00	7.28	5	1	3.50	
10/11/95	21:00	516-0-3-1T	6123	39	0.19	0.00	3.64	4	1	1.94	
10/11/95	21:00	516-0-3-1T	6124	36	0.12	0.00	3.86	4	2	3.30	
10/11/95	21:00	516-0-3-1T	6125	37	0.13	0.00	0.02	2	2	0.02	
10/11/95	21:00	516-0-3-1T	6126	37	0.14	0.00	0.02	2	1	0.02	
10/11/95	21:00	516-0-3-1T	6127	38	0.15	0.00	0.00	1	3	0.00	
10/11/95	21:00	516-0-3-1T	6128	37	0.13	0.00	0.00	1	3	0.00	
10/11/95	21:00	516-0-3-1T	6129	37	0.15	0.00	0.00	1	3	0.00	
10/11/95	21:00	516-0-3-1T	6130	37	0.12	0.00	0.02	2	2	0.02	
10/12/95	20:30	516-0-4-2T	6131	37	0.10	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6132	35	0.10	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6133	28	0.05	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6134	40	0.15	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6135	29	0.05	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6136	36	0.14	0.00	0.92	5	2	0.67	
10/12/95	20:30	516-0-4-2T	6137	37	0.11	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6138	29	0.04	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6139	33	0.06	0.00	0.00	1	3	0.00	
10/12/95	20:30	516-0-4-2T	6140	38	0.11	0.00	0.07	2	2	0.07	
Northeastern Area PWS											
10/15/95	10:42	516-0-8-1N	6181	19	0.01	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6182	25	0.03	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6183	25	0.03	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6184	27	0.03	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6185	30	0.04	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6186	26	0.03	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6187	23	0.01	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6188	26	0.03	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6189	21	0.01	-0-	0.00	1	3	0.00	
10/15/95	10:42	516-0-8-1N	6190	21	0.02	-0-	0.00	1	3	0.00	

Table 35 cont.											
10/15/95	13:05	516-0-9-1N	6193	22	0.02	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6194	23	0.02	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6195	22	0.02	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6196	23	0.02	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6197	20	0.01	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6198	19	0.01	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6199	20	0.01	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6200	19	0.01	0.00	0.00	1	3	0.00	
10/15/95	13:05	516-0-9-1N	6201	17	0.01	0.00	0.24	3	2	4.08	
10/15/95	13:05	516-0-9-1N	6202	17	0.01	0.00	0.00	1	3	0.00	

Table 36. Summary of stomach fullness statistics for all APEX eulachon specimens (n=30) analyzed from 1994-1995 collections.

Sample date	Sample time	species-size group-station-haul	specimen number	Fish length (mm)	Fish weight (g)	Fish stomach weight (g)	Total prey weight (mg)	stomach fullness code (1-7)	stomach digestion code (1-3)	Percent body weight
Northeastern Area PWS										
11/12/94	23:25	511-0-7-5T	5021	93	3.66	0.01	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5022	93	3.99	0.07	10.65	4	1	0.27
11/12/94	23:25	511-0-7-5T	5023	76	1.93	0.00	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5024	79	2.33	0.01	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5025	81	2.43	0.01	12.06	3	2	0.50
11/12/94	23:25	511-0-7-5T	5026	82	2.63	0.01	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5027	84	2.79	0.00	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5028	93	3.64	0.00	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5029	86	2.67	0.00	0.00	1	3	0.00
11/12/94	23:25	511-0-7-5T	5030	72	1.56	0.01	0.00	1	3	0.00
Northeastern Area PWS										
10/14/95	23:20	511-0-7-2T	6141	37	0.12	0.00	0.00	1	3	0.00
10/14/95	23:20	511-0-7-2T	6142	42	0.22	0.00	3.64	3	2	1.70
10/14/95	23:20	511-0-7-2T	6143	39	0.15	0.00	3.64	4	1	2.50
10/14/95	23:20	511-0-7-2T	6144	38	0.15	0.00	3.64	4	1	2.42
10/14/95	23:20	511-0-7-2T	6145	40	0.16	0.00	3.64	4	1	2.31
10/14/95	23:20	511-0-7-2T	6146	33	0.07	0.00	0.23	3	2	0.32
10/14/95	23:20	511-0-7-2T	6147	46	0.32	0.00	0.00	1	3	0.00
10/14/95	23:20	511-0-7-2T	6148	39	0.13	0.00	0.00	1	3	0.00
10/14/95	23:20	511-0-7-2T	6149	34	0.10	0.00	0.00	1	3	0.00
10/14/95	23:20	511-0-7-2T	6150	37	0.16	0.00	3.64	3	2	2.34
10/14/95	23:20	511-1-7-2T	6151	95	3.67	0.01	0.00	1	3	0.00
10/14/95	23:20	511-1-7-2T	6152	108	5.49	0.02	0.00	1	3	0.00
10/14/95	23:20	511-1-7-2T	6153	115	6.87	0.06	13.87	5	1	0.20
10/14/95	23:20	511-1-7-2T	6154	110	5.66	0.03	0.00	1	3	0.00
10/14/95	23:20	511-1-7-2T	6155	105	5.51	0.03	0.00	1	3	0.00

Table 36 cont.										
10/14/95	23:20	511-1-7-2T	6156	105	5.47	0.02	0.39	4	1	0.01
10/14/95	23:20	511-1-7-2T	6157	110	5.42	0.01	0.00	1	3	0.00
10/14/95	23:20	511-1-7-2T	6158	103	4.49	0.03	0.00	1	3	0.00
10/14/95	23:20	511-1-7-2T	6159	111	6.81	0.12	3.64	3	2	0.05
10/14/95	23:20	511-1-7-2T	6160	96	4.16	0.08	0.00	1	3	0.00

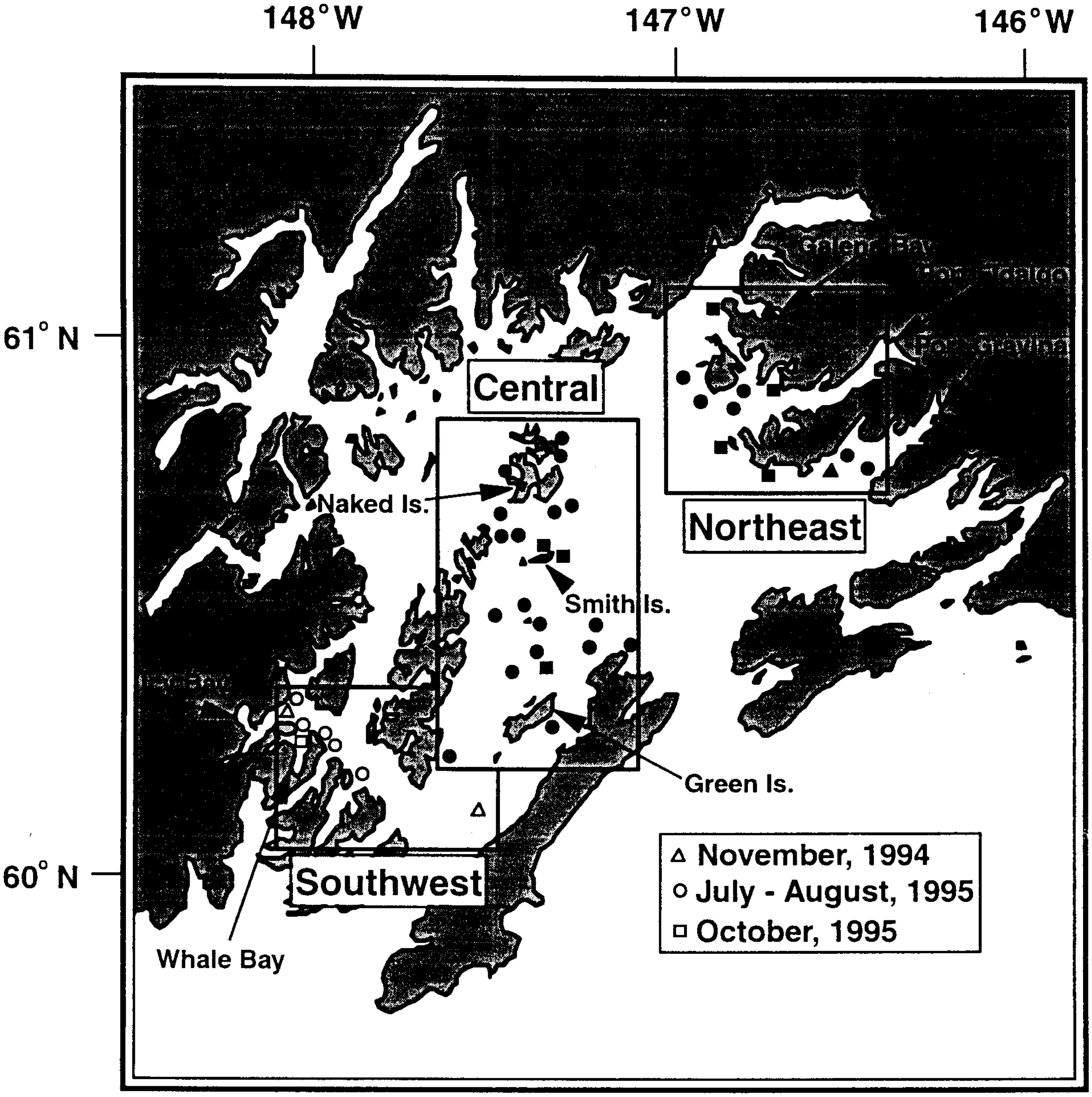

Figure 1. Map of APEX sampling locations where forage fish were successfully collected for diet studies in fall, 1994 and summer and fall, 1995, in central (gray symbols), northeastern (black symbols) and southwestern (open symbols) Prince William Sound, Alaska. For further detail about collections, see APEX 95163A annual report.

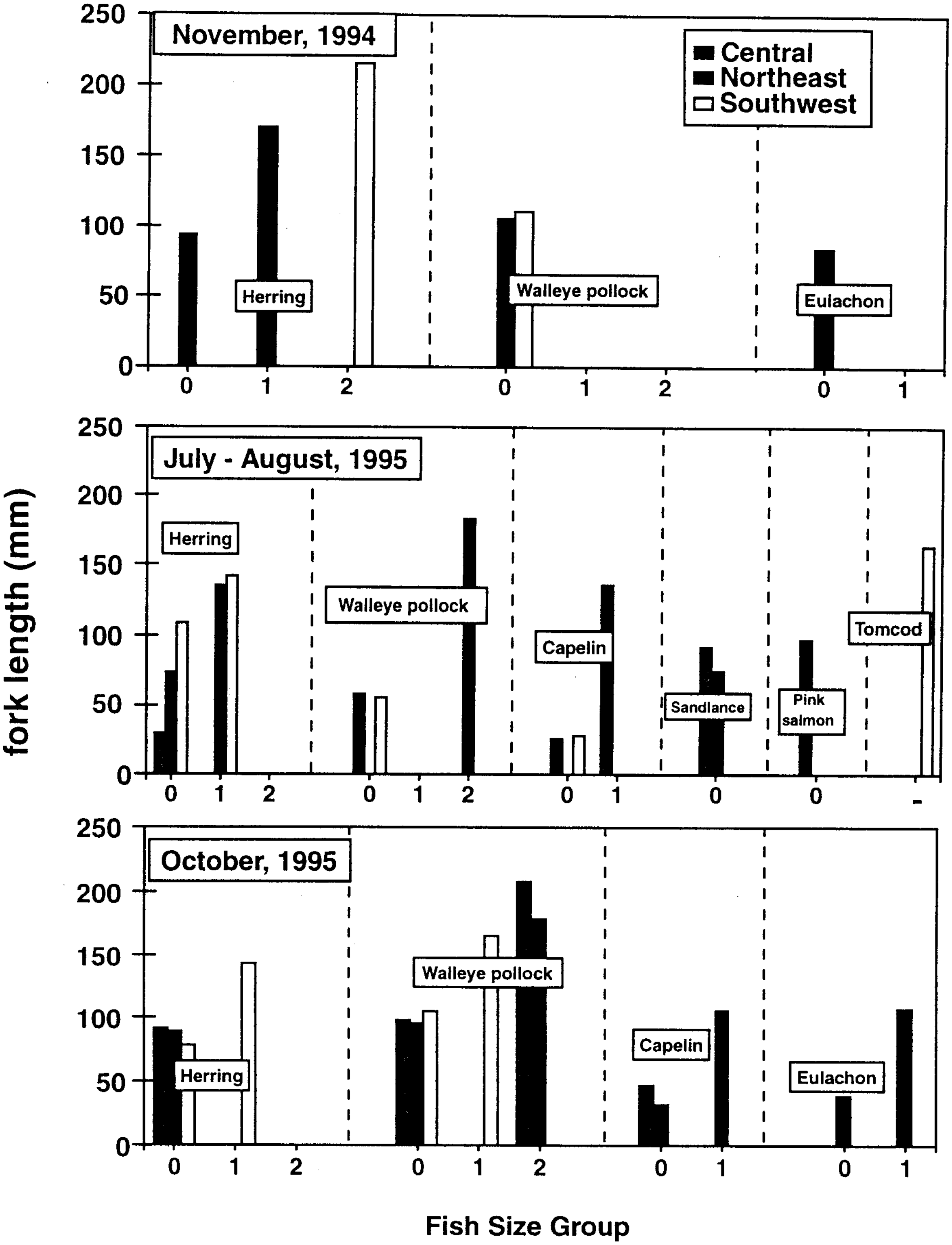

Figure 2. Mean size of preserved forage fish species-size groups analyzed for APEX diet studies in central, northeastern and southwestern in fall, 1994 and summer and fall, 1995 (n = 90, n = 280 and n = 200, respectively). Size groups on the x-axis represent estimated ages (0 - 2). See Table 1 for a summary of fish size by station location.

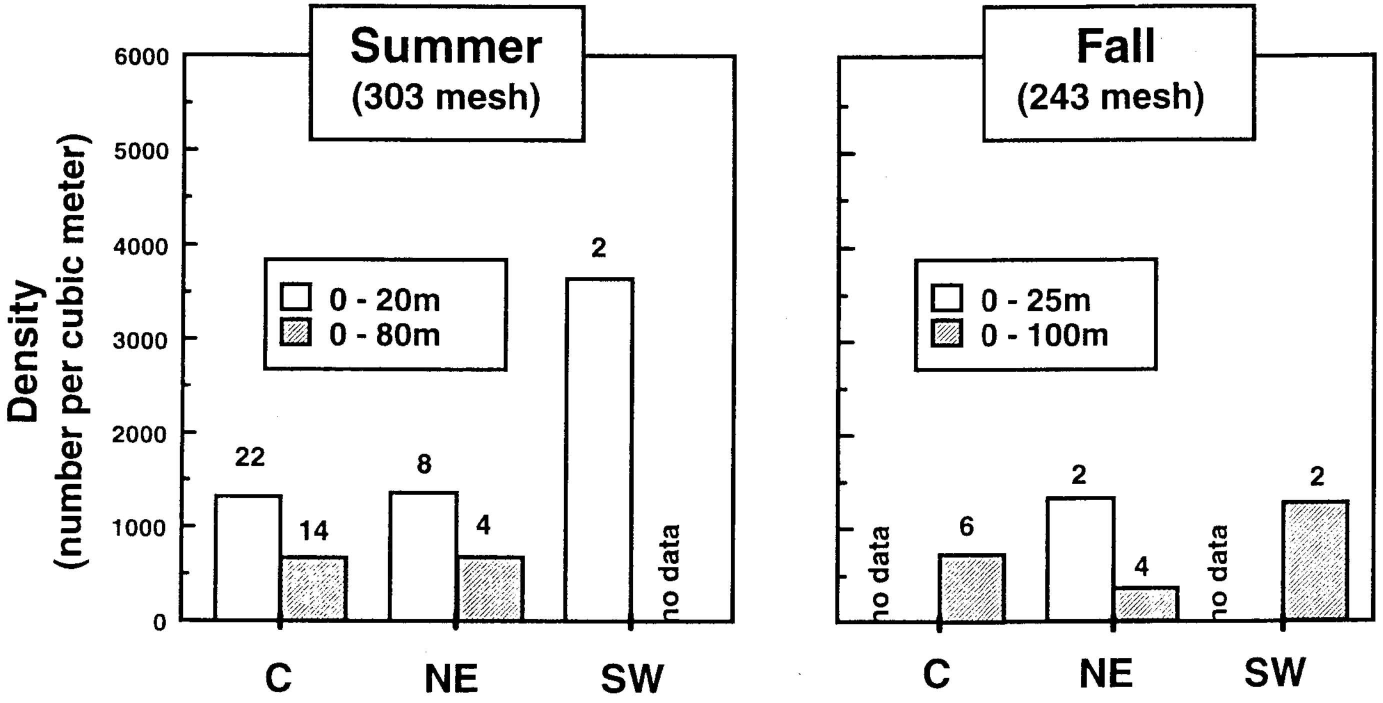

Figure 3. Mean zooplankton density (number per cubic meter) in central, northeastern and southwestern PWS at sample stations where forage fish were collected for APEX diet analyses in summer and fall, 1995. Numbers above bars indicate number of hauls represented. Zooplankton was collected at two depths only if fish were collected at multiple depths. See Table 2 for mean densities at each station and depth per sample area.

Major Prey Categories

▨ Small Calanoids (SC)
▤ Other (OTH)
■ Larvaceans (LAR)
■ Large Calanoids (LC)
▦ Ctenophores & Cnidarians
▦ Hyperiid Amphipods (HYP)
□ Gastropods (GST)
■ Gammarid Amphipods

▦ Fish (FIS)
▦ Euphausiids (EUP)
■ Decapod larvae (DEC)
▧ Bryozoan larvae (BRY)
▦ Cladoceran (CLA)
■ Chaetognaths (CHT)
▩ Barnacle larvae (BAR)
■ Unid. Malacostracans

Figure 4. Key to major categories of zooplankton or prey observed in stomach contents. Key represents all figures of zooplankton or diet composition which follow.

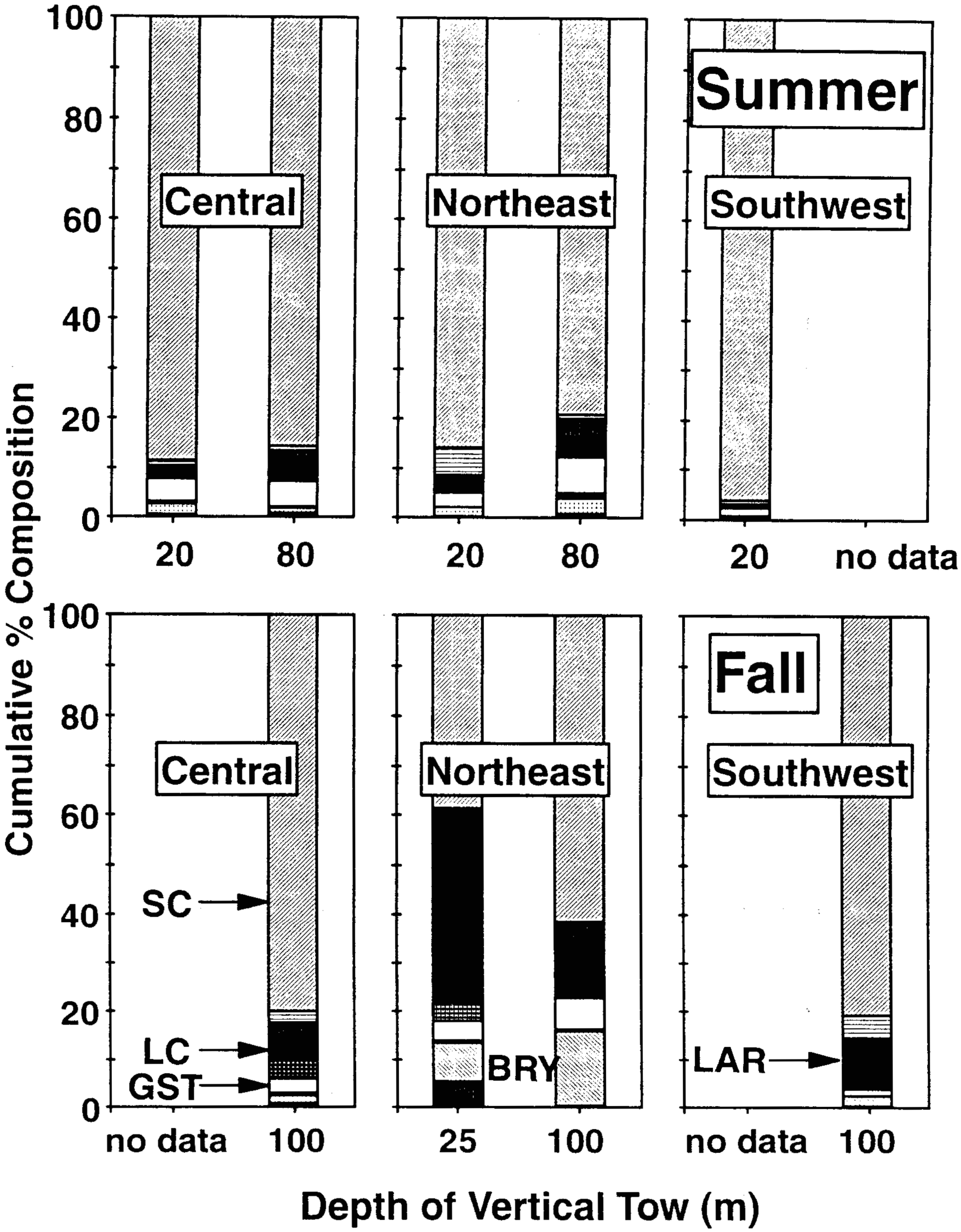

Figure 5. Zooplankton composition (mean percent number in major taxonomic catagories) in PWS by depth and area, summer and fall, 1995. See Figure 4 for key. See Table 2 for mean zooplankton densities at each station and depth per sample area.

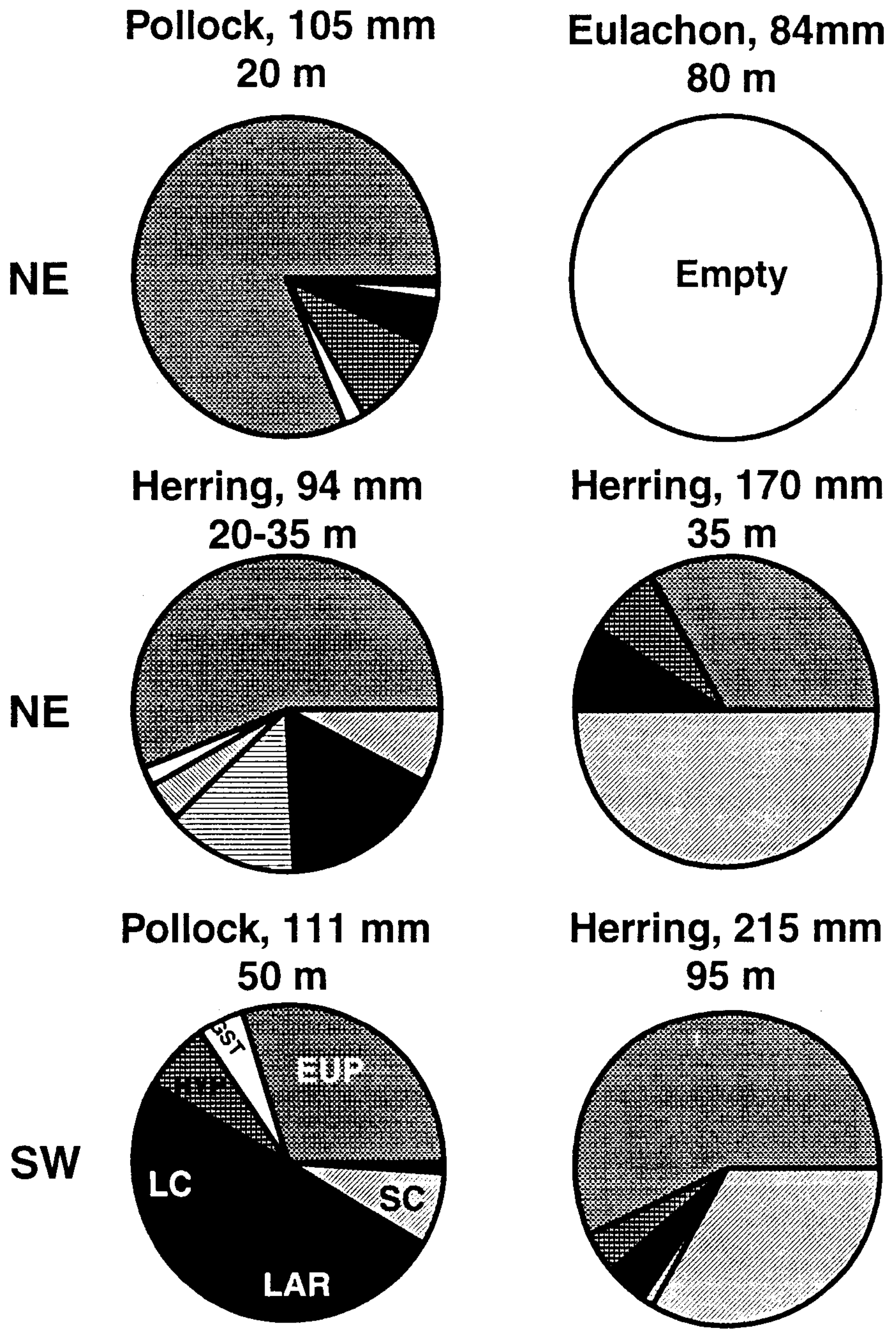

Figure 6. Diet composition of all forage fish species-size groups from fall, 1994 collections, as percent biomass of major prey categories. Fish were collected in northeastern and southwestern PWS only. Species, mean FL and depth fished are shown above each pie. See Figure 4 for key.

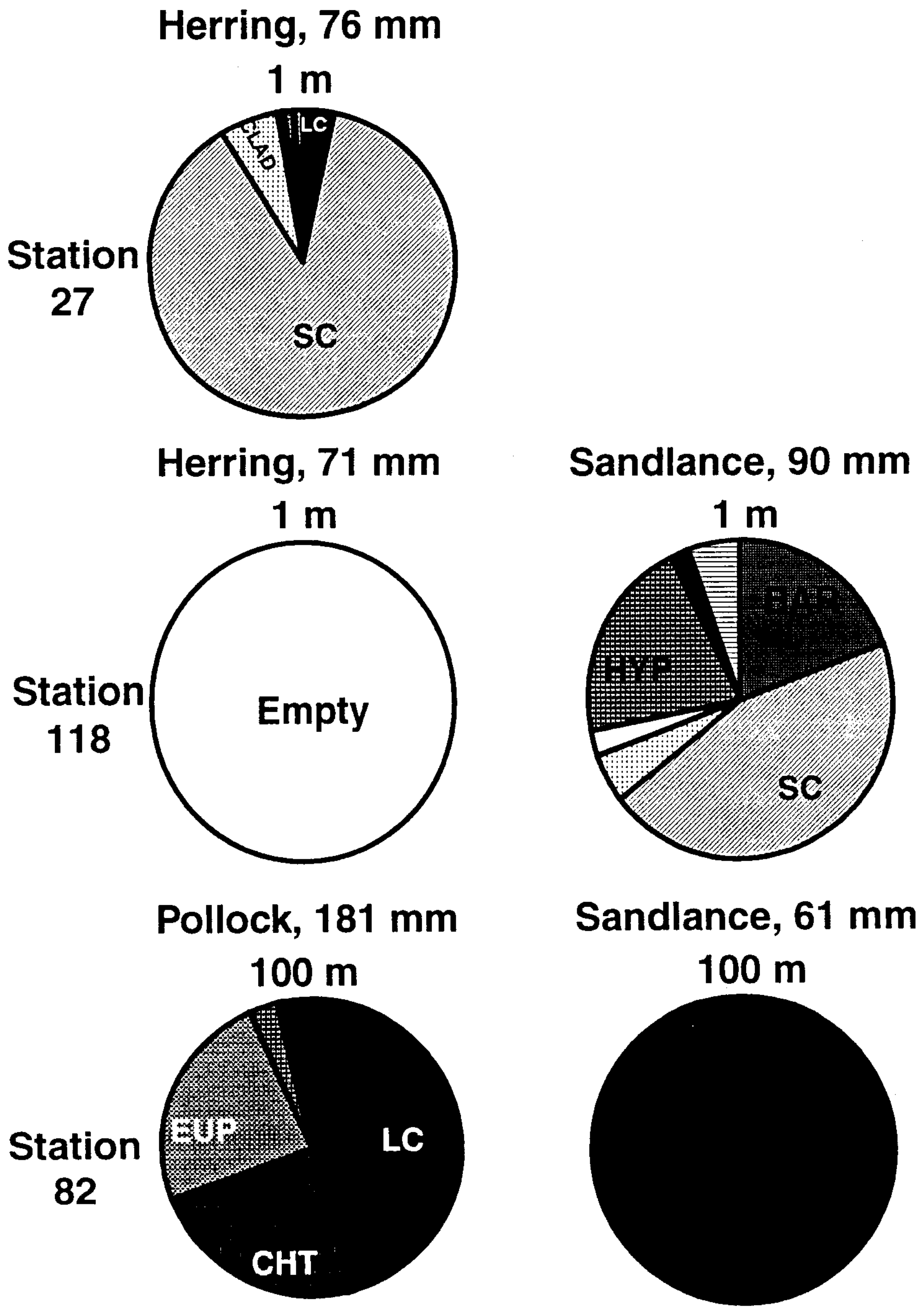

Figure 7. Diet composition (percent biomass of major prey catagories) of forage fish species-size groups from 3 station in Port Fidalgo, northeastern PWS, in summer, 1995. Species, mean FL and depth fished are shown above each pie. See Figure 4 for key.

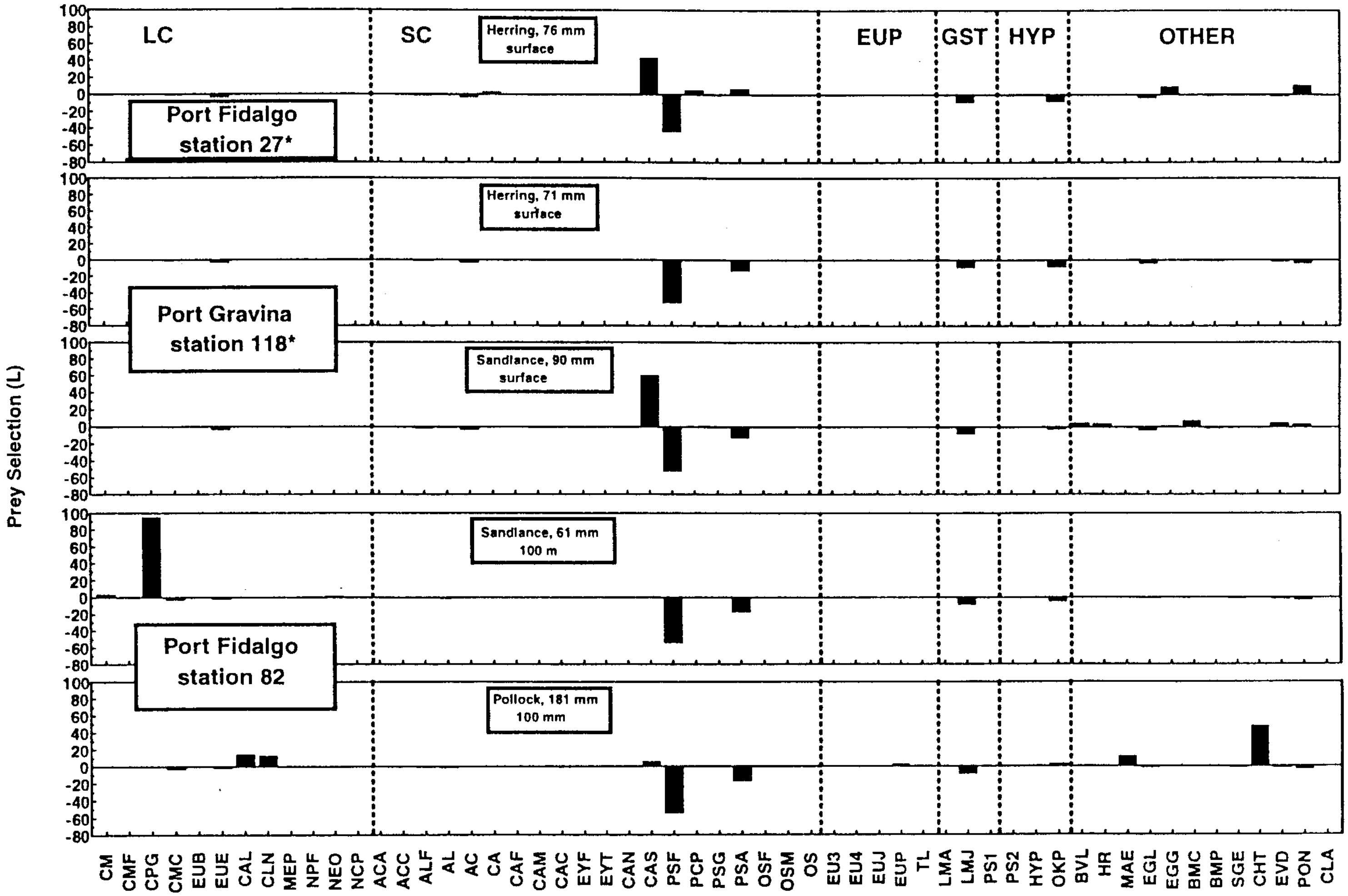

Figure 8. Forage fish prey selection at Port Fidalgo, northeastern PWS, in summer 1995. Values on the y-axis are Strauss Linear Selection, L, calculated from diet and zooplankton data collected at the same station. Specific taxon codes on the x-axis are grouped into the major prey categories indicated (see also Appendix 3). Figure represents the same species-size groups at stations depicted in Figure 7.

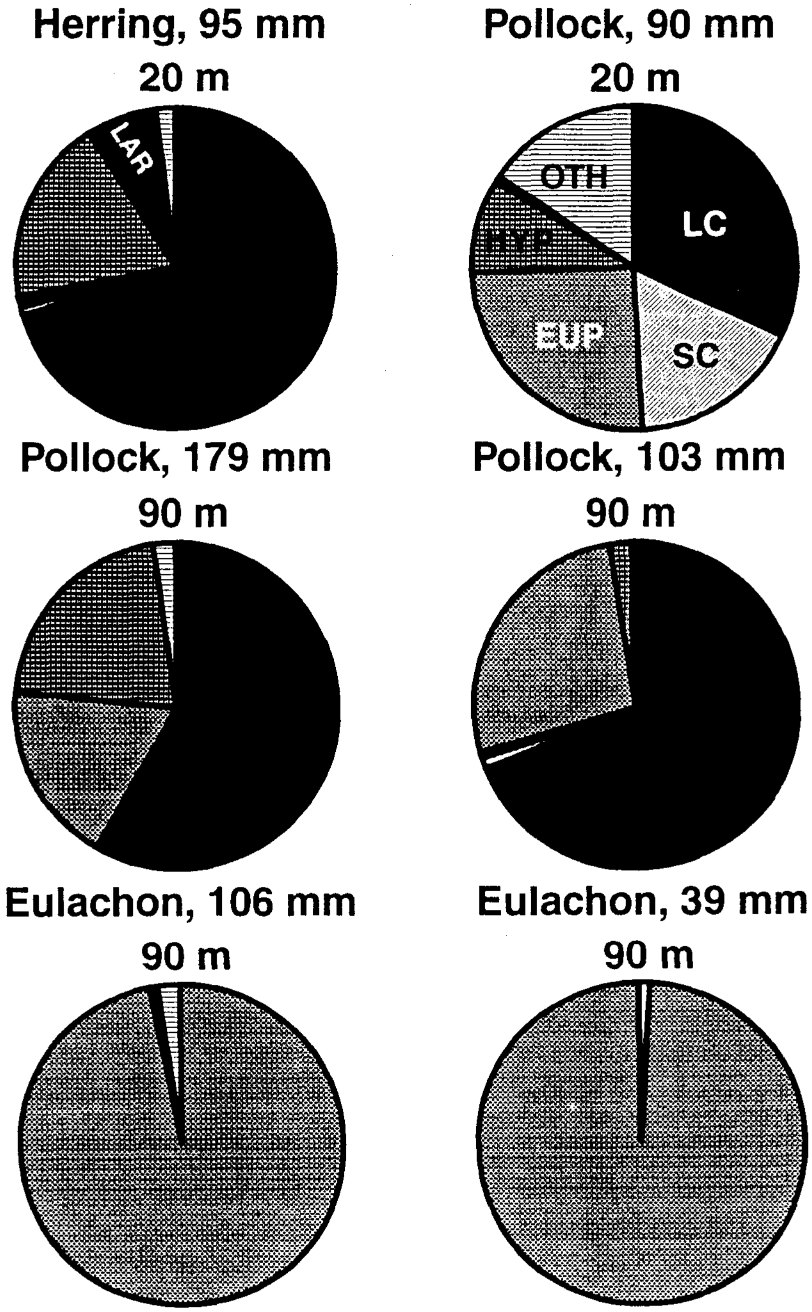

Figure 9. Diet composition (percent biomass of major prey categories) of forage fish species-size groups from two depths at Station 7 in Port Fidalgo, northeastern PWS, in fall, 1995. Species, mean FL and depth fished are shown above each pie. See Figure 4 for key.

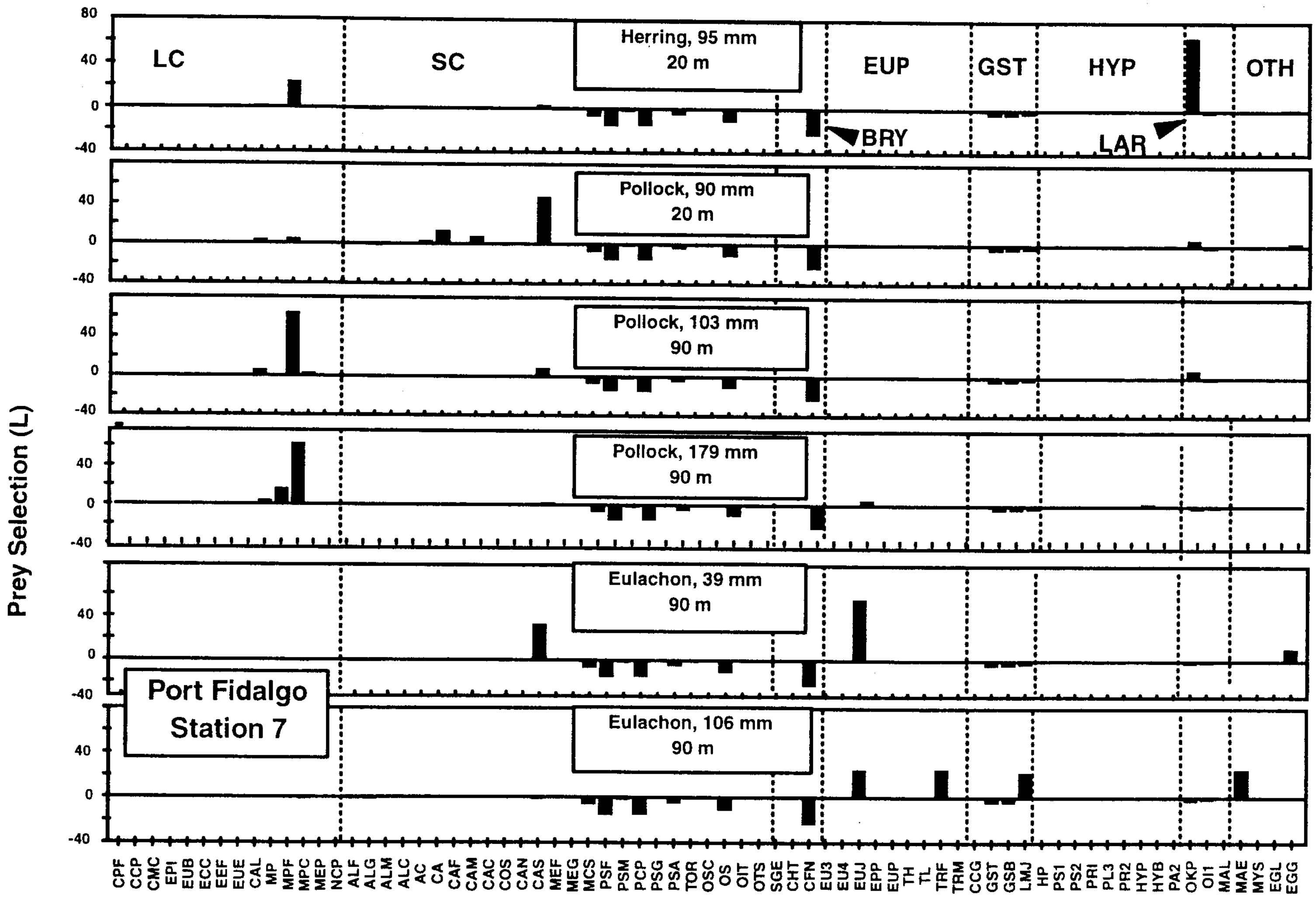

Figure 10. Forage fish prey selection at Station 7, northeastern PWS, in fall, 1995. Values on the y-axis are Strauss Linear Selection, L, calculated from diet and zooplankton data collected at the same station. Specific taxon codes on the x-axis are grouped into the major prey categories indicated (see also Appendix 3). Data represents the same species-size groups depicted in Figure 9.

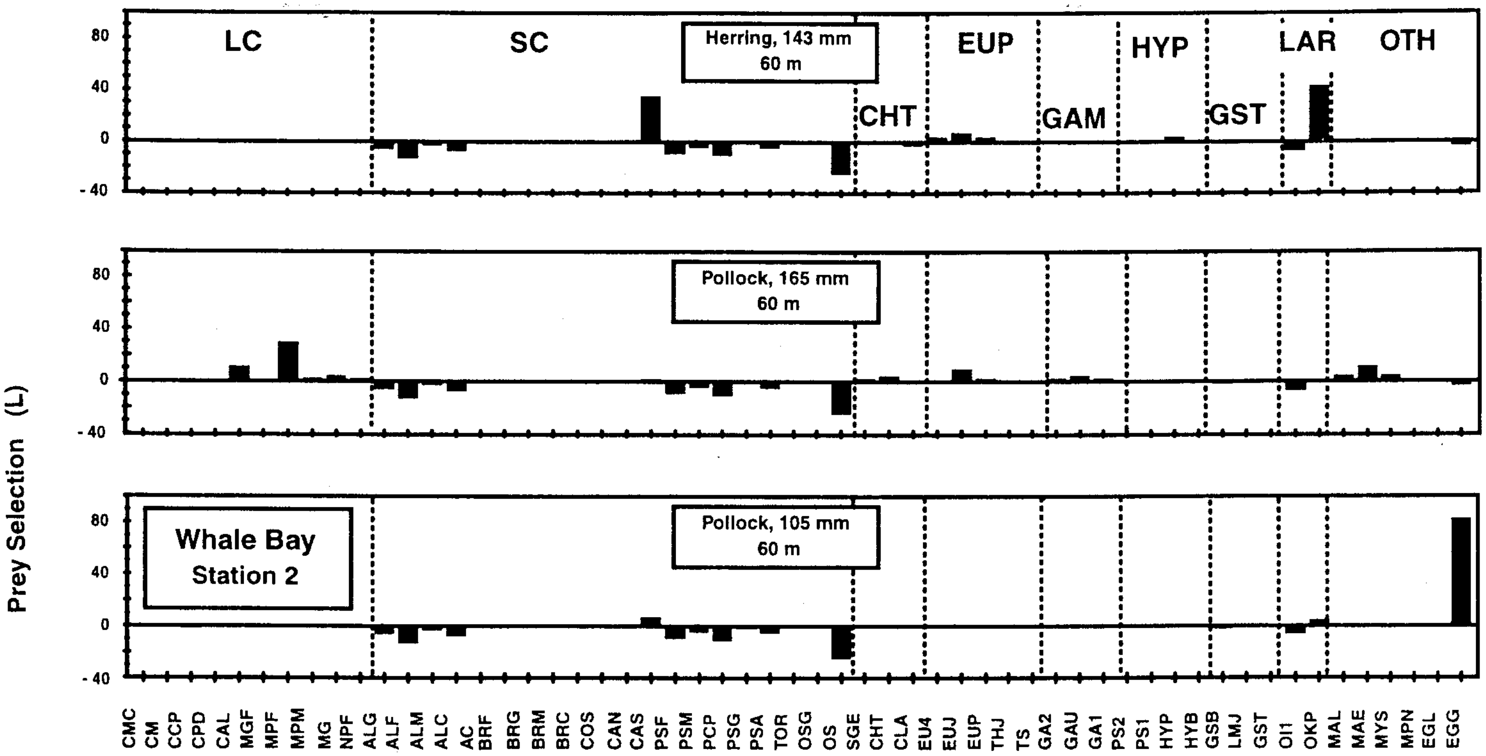

Figure 11. Forage fish prey selection at Station 2, southwestern PWS, in fall, 1995. Values on the y-axis are Strauss Linear Selection, L, calculated from diet and zooplankton data collected at the same station. Specific taxon codes on the x-axis are grouped into the major prey catagories indicated (see also Appendix 3).

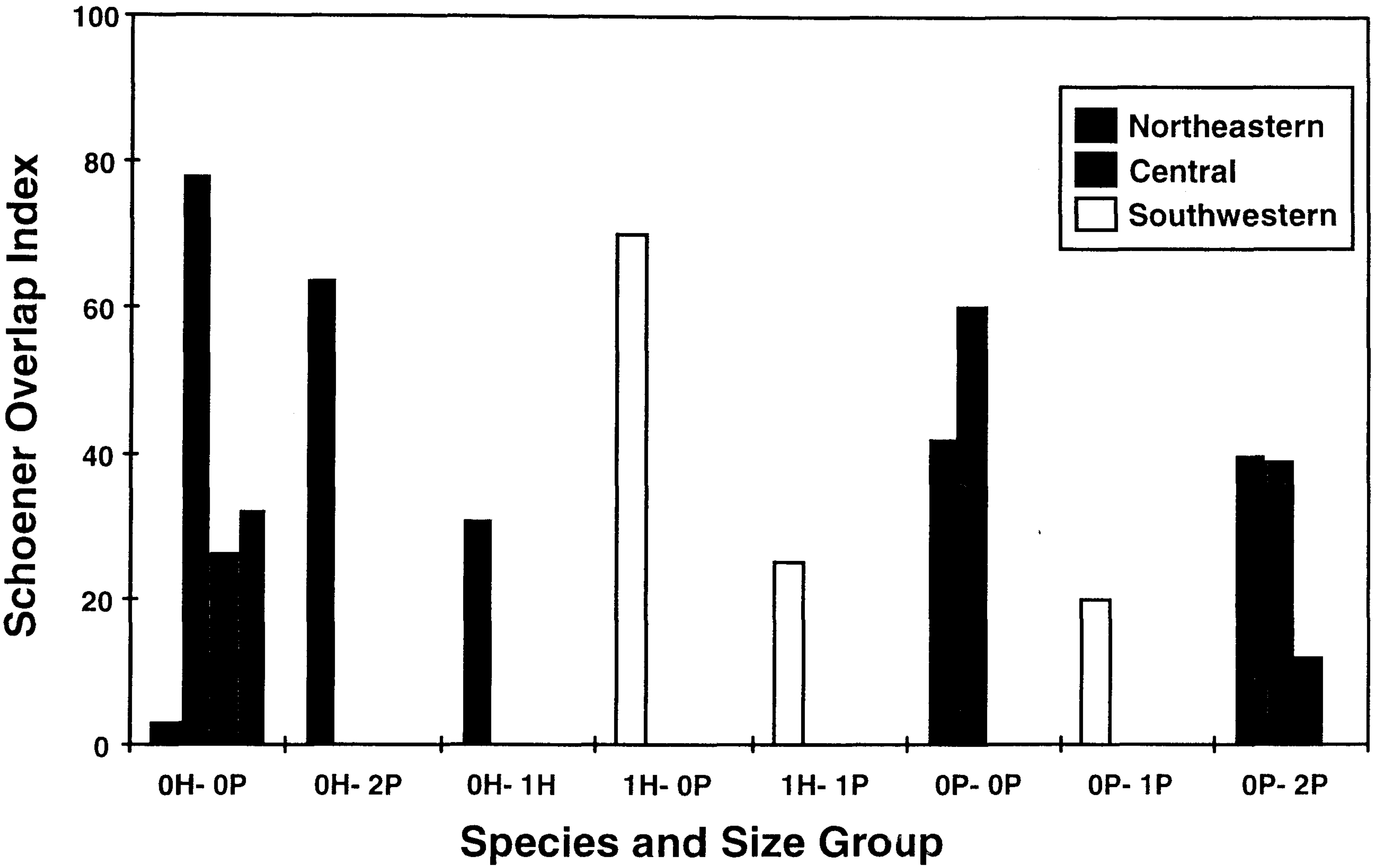

Figure 12. Diet overlap (Schoener Overlap Index by prey biomass) of sympatric herring (H) and pollock (P) collected for APEX diet studies, 1994-1995. Ages (0 - 2) are estimated from mean lengths. Each bar represents overlap between 10 fish of each species at one station (see also Tables 25 - 27).

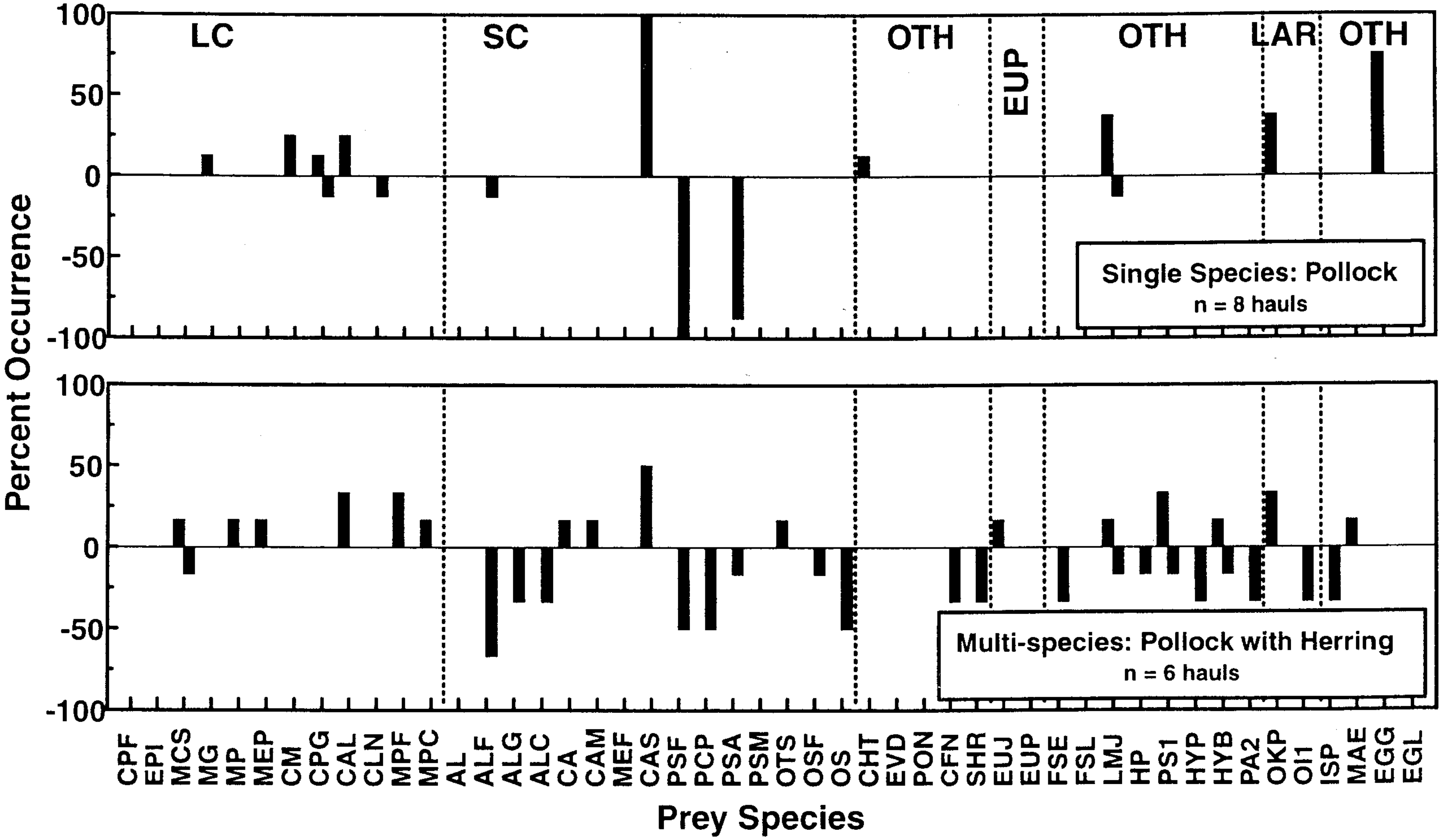

Figure 13. Frequency of occurrence (y-axis: percent number of hauls) of prey taxa selected by pollock occurring in single species schools (n = 8 allopatic hauls) vs. mult-species schools with herring (n = 6 sympatric hauls). Specific taxon codes on the x-axis are grouped into the major prey categories indicated (see also Appendix 3). Data represents all possible hauls from fall, 1994 and summer and fall, 1995 APEX collections.

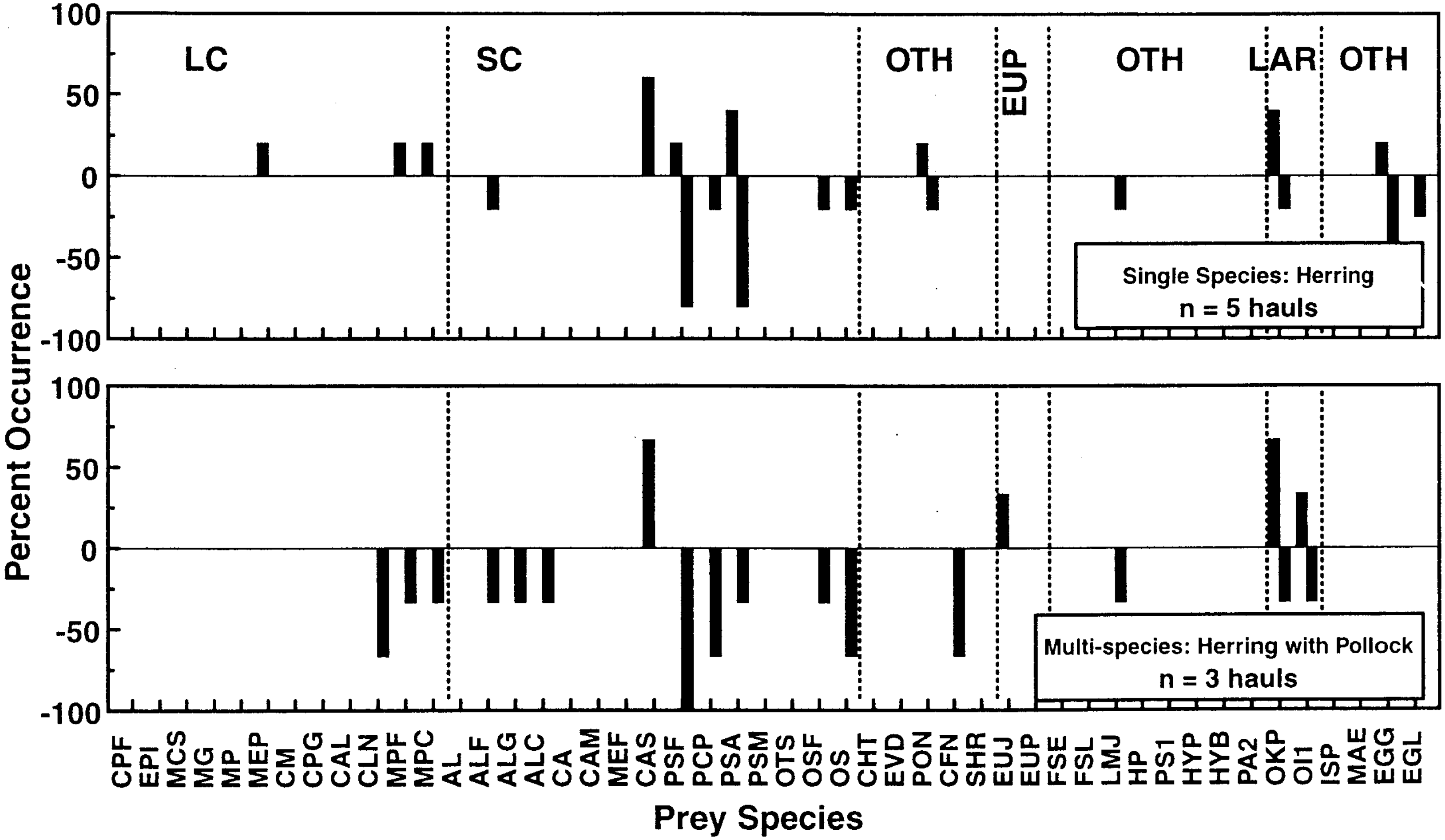

Figure 14. Frequency of occurrence (percent number of hauls) of prey taxa selected by herring occurring in single species schools (n = 5 allopatric hauls) vs. multi-species schools with pollock (n = 3 sympatric hauls). Specific taxon codes on the x-axis are grouped into the major prey categories indicated (see also Appendix 3). Data represents all possible hauls from fall, 1994 and summer and fall, 1995 APEX collections.

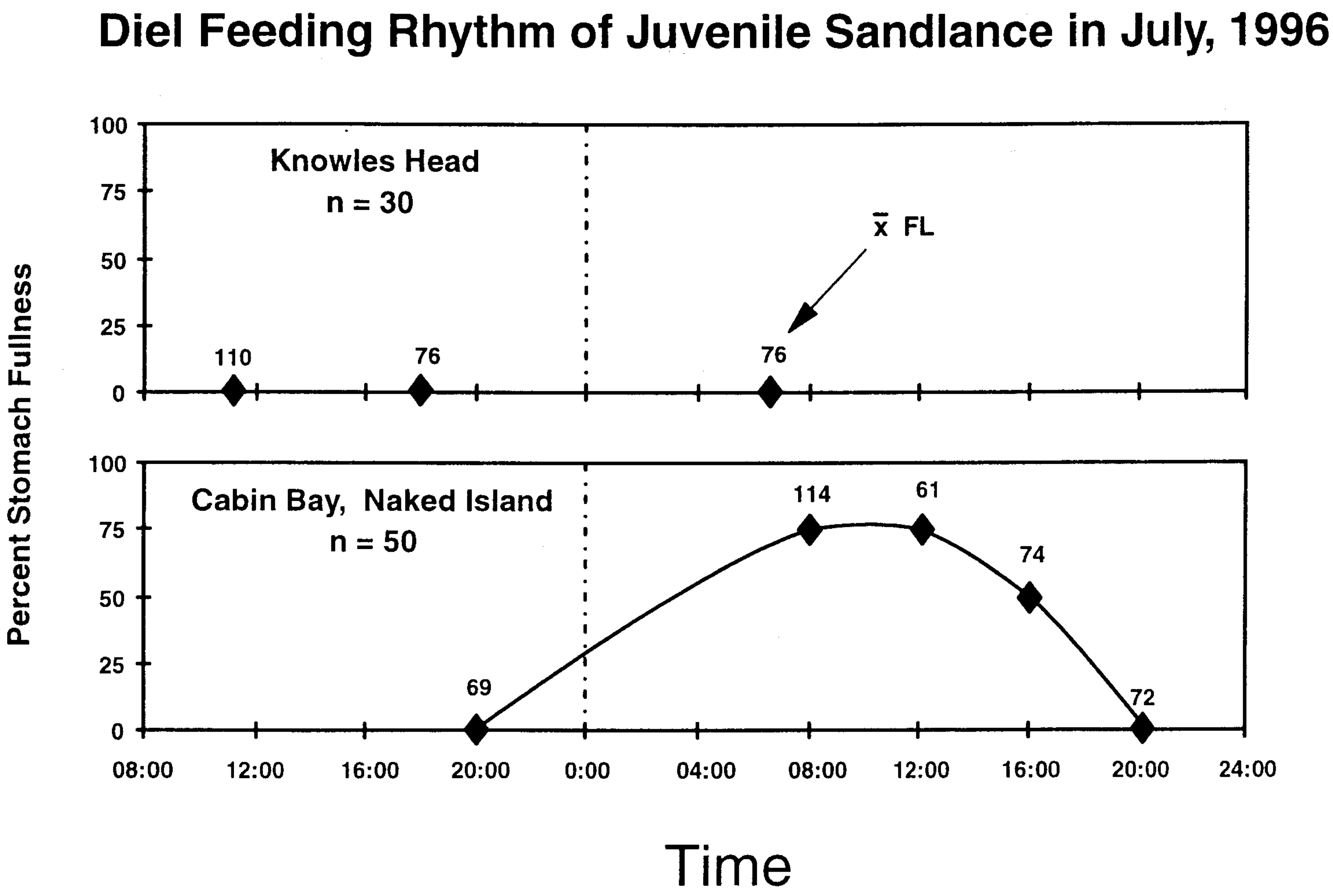

Figure 15. Diel feeding rhythm (mean percent fullness index) of juvenile sandlance collected at two stations in two areas of PWS in July, 1996. Mean FL of the 10 specimens are shown for each time of day (n = 30 from Knowles Head, northeastern PWS and n = 40 from Cabin Bay, Naked Island, central PWS.

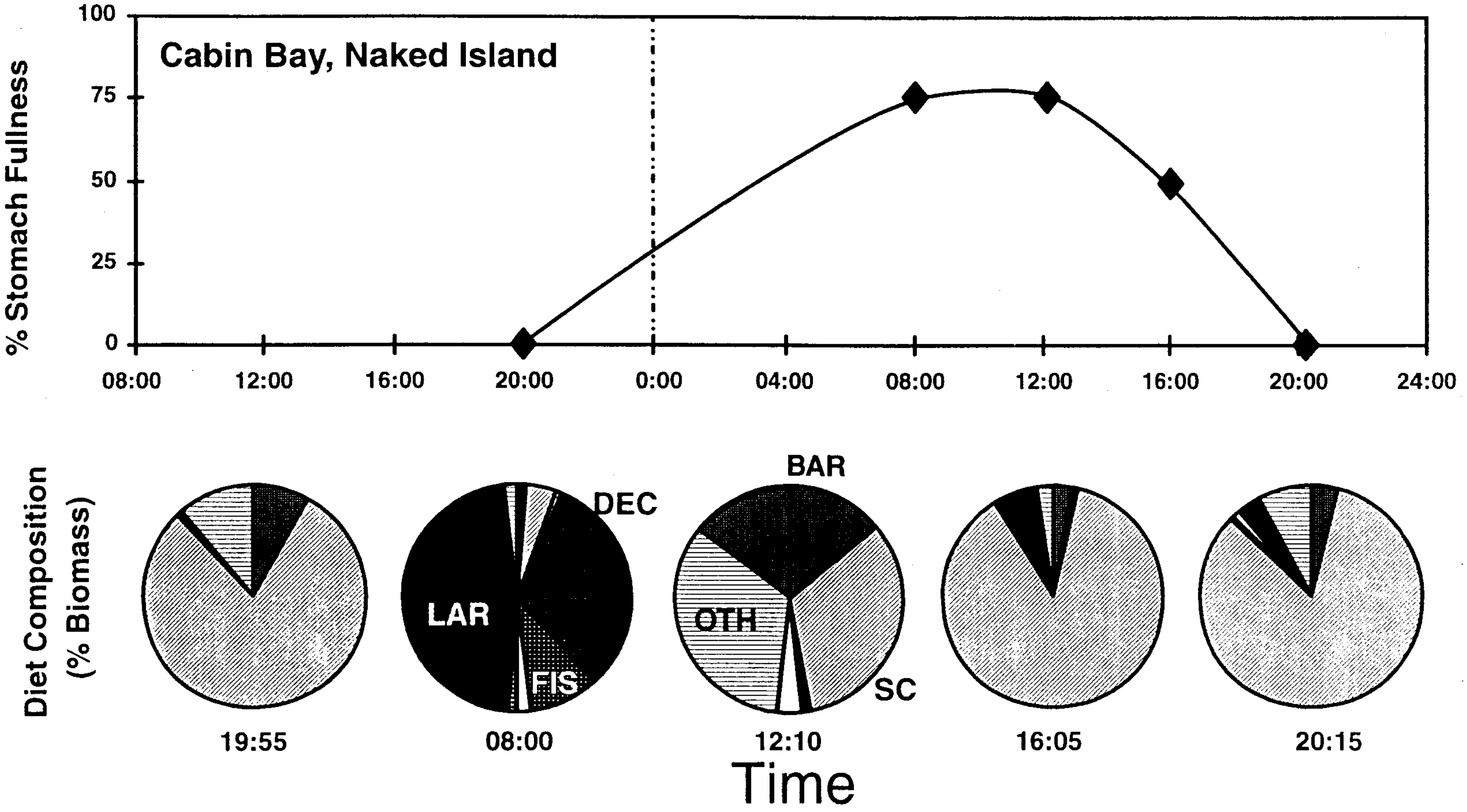

Figure 16. Diel feeding rhythm of juvenile sandlance collected at Cabin Bay, Naked Island, July 1996 (top: mean percent fullness index; bottom: percent biomass of major prey categories).

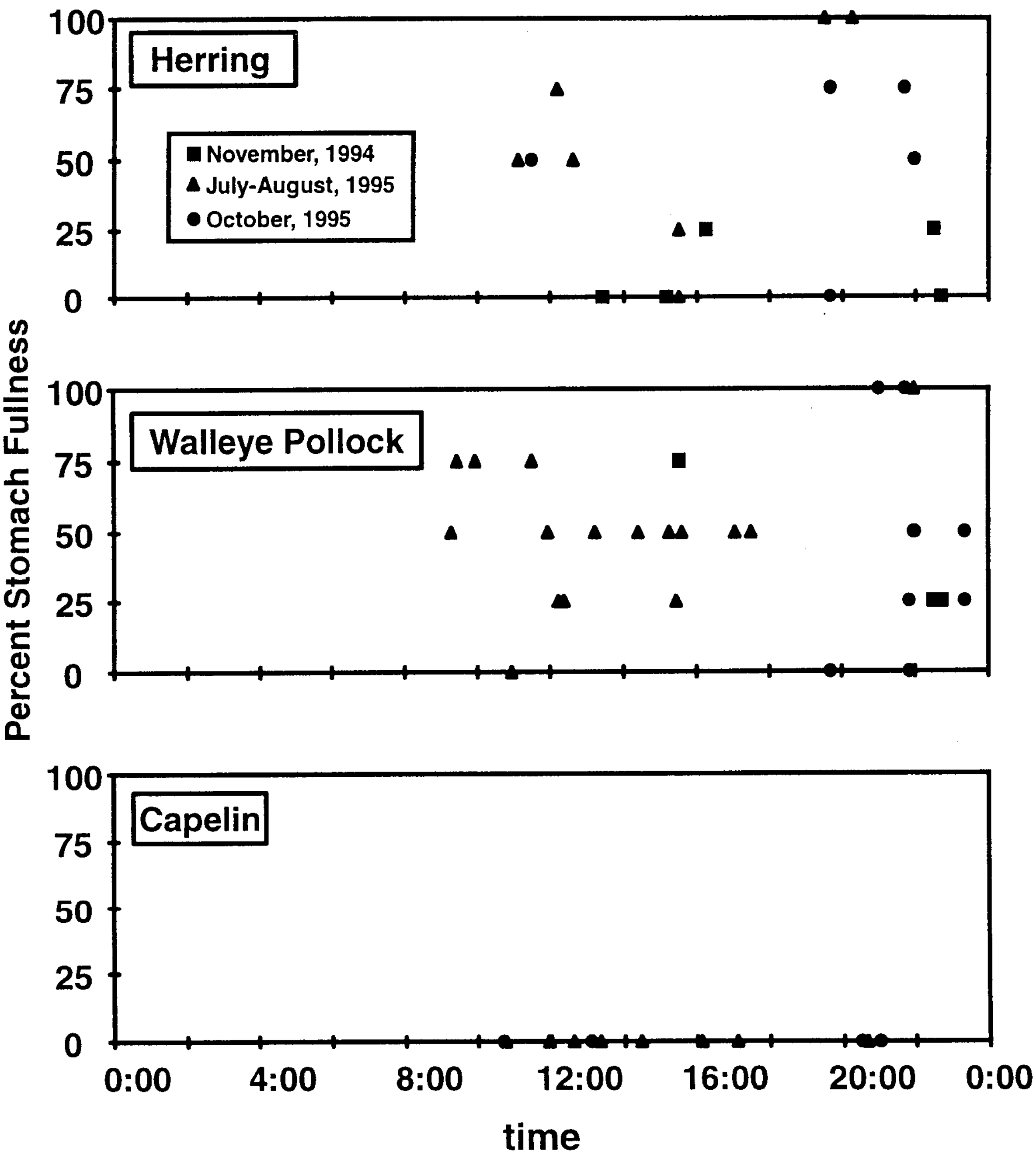

Figure 17. Mean stomach fullness index of herring (top) , pollock (middle) and capelin (bottom) collected at all times of day for APEX diet studies, fall, 1994 and summer and fall, 1995. Each data point represents 10 fish from one haul. (See also Table 31, 32 and 34).

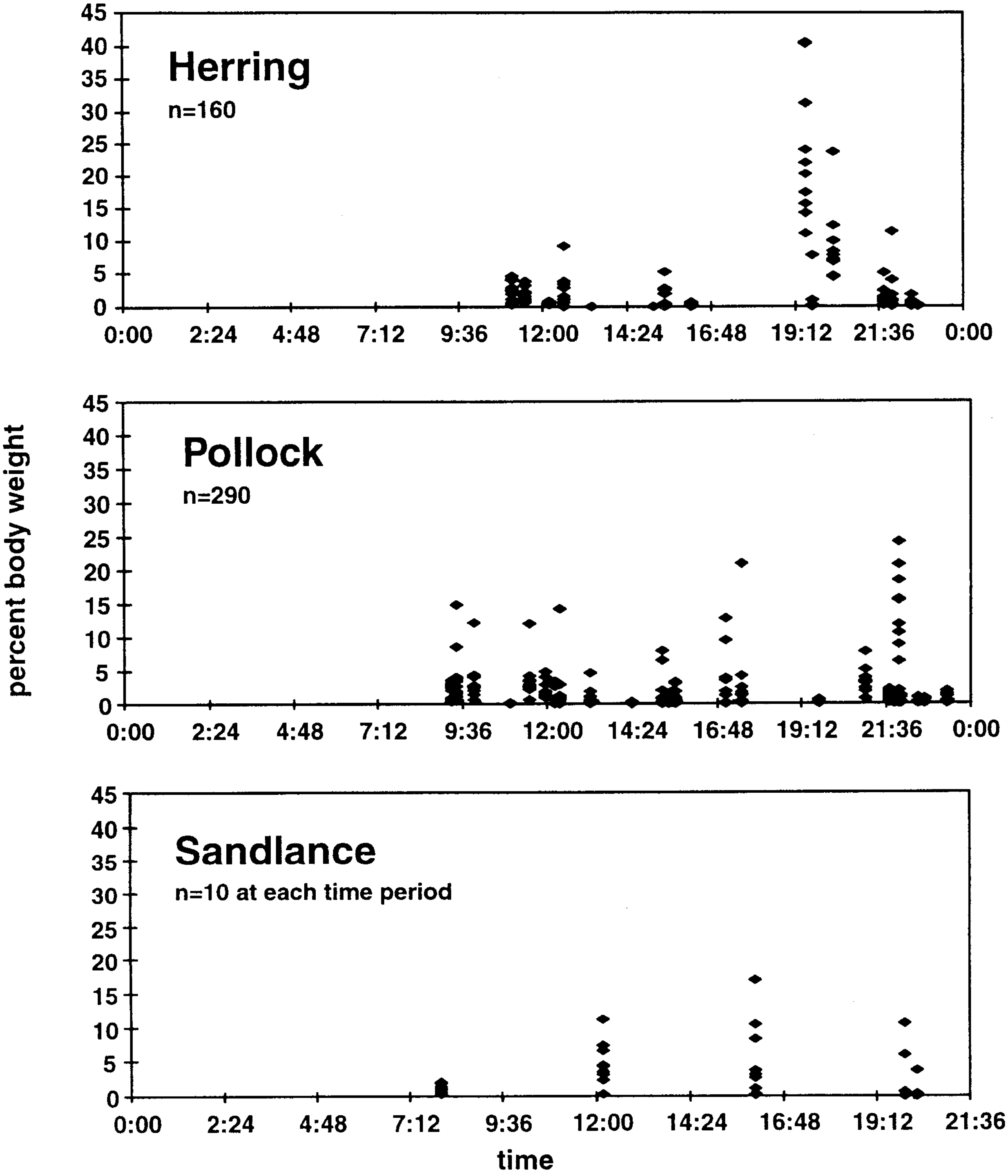

Figure 18. Stomach fullness (prey percent body weight) of all individual herring (top) and pollock (middle) specimens collected for APEX diet studies in fall, 1994 and summer and fall, 1995 at all times of day, and sandlance (bottom) specimens collected for diel feeding rhythm studies at discreet time intervals in 1996. Each data point represents one fish. (See also Table 31 - 33).

Appendix 1A. Co-occurring forage fish species and associated prey samples collected in PWS in non-diel hauls in 1996.

APEX 96163A
Southwest Region PWS

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	tomcod	13:20
7-15	1-1-beach	pink salmon	13:21
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Point Grace (Latouche Is.)			
7-15	2-1-purse	pink salmon	16:28
7-15	2-1-purse	chum salmon	16:28
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Latouche Is.			
7-16	1-1-purse	pink salmon	14:46
7-16	1-1-purse	chum salmon	14:46
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Bainbridge Point			
7-16	10-1-beach	herring	15:30
7-16	10-1-beach	pink salmon	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Prince of Wales Passage			
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30

date	station-haul -gear	species	time
Whale Bay			
7-17	12-1-beach	herring	8:30
7-17	12-1-beach	tomcod	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05
West of Point Countess			
7-17	14-1-beach	herring	10:10
7-17	14-1-beach	tomcod	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Number of fish stomachs=220
Number of epibenthic samples=6
Number of plankton samples=10

Appendix 1A, continued.

Northeast Region PWS

date	station-haul -gear	species	time
Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32
West Bligh Island			
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00
Knowles Bay, Redhead			
7-25	71-1-beach	sandlance-lrg	14:30
7-25	71-1-beach	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50
Knowles Bay			
7-27	84-1-beach	herring**	18:00
7-27	84-1-beach	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42

**stomach ID completed

Number of fish stomachs=90
Number of epibenthic samples=4
Number of plankton samples=10

Central Region PWS

date	station-haul -gear	species	time
South side of Pt. Eleanor			
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	tomcod	11:05
7-20	34-1-beach	pollock	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25
SE Bass Harbor (Naked Is.)			
7-20	36-1-beach	pink salmon-sml	14:40
7-20	36-1-beach	pink salmon-lrg	14:40
7-20	36-2	epibenthic	14:55
7-20	36-3	plankton	14:50
7-20	36-4	plankton	14:55
S. McPherson Bay			
7-21	42-1-beach	pollock	13:30
7-21	42-1-beach	tomcod	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45
point off of N arm of Cabin Bay			
7-22	48-1-beach	pink salmon	10:50
7-22	48-1-beach	sandlance	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Number of fish stomachs=90
Number of epibenthic samples=4
Number of plankton samples=8

Appendix 1B. Single species forage fish and associated prey samples collected in PWS in non-diel hauls in 1996.

APEX 96163A

Central Region PWS

date	station-haul -gear	species	time
large bay on SE Eleanor Is.			
7-20	33-1-beach	tomcod	9:30
7-20	33-2	epibenthic	9:40
7-20	33-3	plankton	9:45
7-20	33-4	plankton	9:50
SW arm of Naked Island			
7-21	39-2-beach	pink salmon	9:00
7-21	39-3	epibenthic	9:10
7-21	39-4	plankton	9:25
7-21	39-5	plankton	9:30
SW Naked Island			
7-21	40-1-beach	pink salmon	10:30
7-21	40-2	epibenthic	10:45
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00

Central Region PWS

date	station-haul -gear	species	time
Bass Harbor (Naked Is.)			
7-21	41-1-beach	pink salmon	11:35
7-21	41-2	epibenthic	11:50
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00
SW Cabin Bay			
7-22	47-1-beach	sandlance	9:55
7-22	47-2	epibenthic	10:08
7-22	47-3	plankton	10:10
7-22	47-4	plankton	10:15

Southwest Region PWS

date	station-haul -gear	species	time
Jackpot Bay			
7-17	16-1-beach	herring	13:30
7-17	16-3	plankton	13:45
7-17	16-4	plankton	13:55
Paddy Bay			
7-17	18-1-beach	tomcod	16:30
7-17	18-2	epibenthic	16:40
7-17	18-3	plankton	16:45
7-17	18-4	plankton	16:50
inside Bainbridge Pt.			
7-16	11-2-beach	sandlance	17:40
7-16	11-3	epibenthic	17:55
7-16	11-4	plankton	18:15
7-16	11-5	plankton	18:25

Northeast Region PWS

date	station-haul -gear	species	time
Tatitlek Narrows			
7-23	55-1-beach	tomcod	12:35
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Appendix 1C. Diel series of forage fish diet samples collected in PWS in 1996.

Cabin Bay, Naked Island, 1996			
Beach seines (APEX 96163F)			
no plankton samples available			
date	**station-haul**	**species**	**time**
7-21	F-1	sandlance**	19:55
7-22	F-1	sandlance**	8:00
7-22	F-2	sandlance**	12:10
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	20:15

Northeast Region PWS, 1996

Knowles Bay (replicate 1)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

Knowles Bay (replicate2)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

"pseudo-diels" at Knowles Bay
collected at diel station two days earlier

7-25	71-1	sandlance-lrg	14:30
7-25	71-1	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

7-25	72-1	herring	15:20
7-25	72-2	epibenthic	15:50

****stomach ID completed**

Appendix 1D. Miscellaneous forage fish species collected for diet samples from PWS, Cook Inlet and Barrens Islands in 1996.

Northeast region PWS, miscellaneous species

date	station-haul -gear	species	time
N. Galena Bay			
7-23	53-1-beach	pink salmon	9:00
7-23	53-2	epibenthic	9:05
7-23	53-3	plankton	10:30
7-23	53-4	plankton	10:35
Port Fidalgo			
7-24	66-1-beach	sandlance	18:05
7-24	66-2	epibenthic	18:20
7-24	66-3	plankton	18:20
7-24	66-4	plankton	18:25
Boulder Bay (inside Bidarka Pt.)			
7-24	63-1-beach	sandlance	13:35
7-24	63-2	epibenthic	13:50
7-24	63-3	plankton	13:50
7-24	63-4	plankton	13:55
Irish Cove, Port Fidalgo			
7-24	64-1-beach	sandlance	15:20
7-24	64-2	epibenthic	15:25
7-24	64-3	plankton	15:30
7-24	64-4	plankton	15:35
Galena Bay W. of Narrows			
7-23	54-1-beach	herring	11:10
7-23	54-2	epibenthic	11:20
7-23	54-3	plankton	11:35
7-23	54-4	plankton	11:40

date	station-haul -gear	species	time
Tatitlek Narrows			
7-23	55-1-beach	tomcod	12:35
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32
W. Landlocked Bay, Bidarka Pt.			
7-24	61-1-beach	herring	11:45
7-24	61-2	epibenthic	12:00
7-24	61-3	plankton	12:00
7-24	61-4	plankton	12:05
Port Fidalgo			
7-24	65-2-beach	herring	17:00
7-24	65-3	epibenthic	17:30
7-24	65-4	plankton	17:25
7-24	65-5	plankton	17:20
Inner Port Fidalgo			
7-26	62-2-purse	herring	9:30
		no plankton	
N. Port Gravina			
7-26	76-1-beach	herring	11:20
7-26	76-2	epibenthic	11:35
7-26	76-3	plankton	11:35
7-26	76-4	plankton	11:40
St. Matthews Bay			
7-27	69-1-dipnet	herring	9:00
		no plankton	

Appendix 1D, continued.

Central region PWS
Miscellaneous gear (APEX 96163A)

date	station-haul -gear	species	time
South inside of Bay of Isles			
7-19	27-1-beach	tomcod	11:48
7-19	27-2	epibenthic	12:00
7-19	27-3	plankton	12:10
7-19	27-4	plankton	12:15
North side Bay of Isles			
7-19	29-1-beach	tomcod	16:30
7-19	29-2	epibenthic	16:45
7-19	29-3	plankton	16:55
7-19	29-4	plankton	17:00
North side Bay of Isles			
7-19	18-2-purse	herring	12:30
		no plankton	
South Smith Is.			
7-21	65-1-trawl	pollock	15:09
7-21	65-2	plankton	15:35
7-21	65-3	plankton	15:45
South Storey Is.			
7-22	49-1-beach	pink salmon	12:10
7-22	49-2	epibenthic	12:20
7-22	49-3	plankton	12:20
7-22	49-4	plankton	12:25

Southwest region PWS

date	station-haul -gear	species	time
East Chenega Is.			
7-18	22-1-beach	greenling	9:40
		no plankton	

Appendix 1D, continued.

Cabin Bay, Naked Island, PWS 1996 (APEX 96163F)			
Beach seines, all species			
date	station-haul	species	time
6-28	F-1	unkn salmon	16:20
6-28	F-1	unkn salmon	16:20
7-14	G-1	sandlance	15:30
7-14	I-1	sandfish	12:00
7-14	I-1	pacific cod	12:00
7-21	F-1	pacific cod	0:00
7-21	F-1	pacific cod	0:00
7-21	F-1	sandlance	19:55
7-21	F-1	sandlance**	19:55
7-22	A-1	sandlance	0:00
7-22	F-1	pacific cod	4:00
7-22	F-1	sandlance**	8:00
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	12:10
7-22	F-2	sandlance**	20:15
7-27	F-1	sandlance	10:35
7-28	I-1	pacific cod	19:20
7-6	F-1	sandlance	15:20
8-1	B-2	herring	16:01
8-1	B-2	herring	16:01
8-1	C-1	herring	13:28
8-13	A-1	sandlance	17:40
8-13	B-1	herring	18:23
8-9	R-1	unk. gadid	17:45

**stomach ID completed

Lower Cook Inlet, 1996 APEX 96163M)			
Miscellaneous gear, all species			

date	station-gear	species	time
6-14	ST-beach	sandlance	15:35
6-16	NF-beach	sandlance	8:30
6-16	NF-beach	sandlance	8:30
6-28	CP1-beach	pink salmon	6:45
6-29	HS-beach	herring	7:45
6-29	HS-beach	eelpout	7:45
6-29	HS-beach	sandlance	8:40
7-1	BF-beach	hagfish	10:20
7-8	CP2-beach	sandlance	15:45
7-16	trawl	pollock	13:43
7-16	trawl	pacific cod	13:43
7-17	trawl	capelin	missing
7-18	trawl	pink salmon	missing
7-18	trawl	sandlance	missing
7-25	trawl	sandfish	missing
8-6	EP-beach	capelin	15:00
8-7	SS-beach	sandlance	9:45
8-7	SS-beach	sandlance	9:30
8-25	missing	herring	missing
8-25	missing	pacific cod	missing
8-27	CP4-beach	sandlance	8:50
8-27	PB-beach	pacific cod	7:27
8-27	PB-beach	pacific cod	7:45
8-27	PC-beach	sandlance	8:10
9-12	ST-beach	smelt	15:20
9-13	PB-beach	sandlance	16:10

Appendix 1D, continued.

Sandfish, all areas PWS, 1996			
Beach seines (APEX 96163A)			
date	**station-haul**	**number**	**time**
7-20	34-1	1	11:05
7-20	36-1	4	14:40
7-21	44-1	1	15:45
7-21	42-1	1	13:30
7-21	41-1	3	11:35
7-24	59-1	1	17:50
7-24	60-1	19	9:50
7-27	82-1	1	15:00
7-27	85-1	3	20:40
7-27	86-1	1	21:45

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	**set #**	**species**
7-2	1	tomcod
7-2	1	sandlance
7-9	3	surf smelt
7-17	1	pink salmon
7-17	1	sandlance
7-23	1	tomcod
7-23	2	sandlance
7-23	2	sandlance-lrg
7-24	3	sandlance
7-24	3	pink salmon
8-16	3	capelin
8-16	3	sandlance
8-23	1	sandlance
9-8	1	sandlance

Appendix 1E. Forage fish diet samples and associated prey samples collected in PWS at adjacent sites or with multiple fishing gear types at one site in 1996.

Northeast region PWS
Multiple gear

date	station-haul -gear	species	time
NE Bligh Island			
7-23	47-1-purse	herring	16:15
7-23	47-2-cast	herring	17:30
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15

Central region PWS
Multiple gear

North Eleanor Is.			
7-20	35-1-beach	pink salmon	12:30
7-20	24-2-purse	pink salmon	12:06
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Northeast region PWS
Adjacent sites

date	station-haul -gear	species	time
Knowles, Redhead			
7-25	71-1-beach	sandlance-lrg	14:30
7-25	71-1-beach	sandlance-sml	14:30
7-25	72-1-beach	herring	15:20
7-25	72-2	epibenthic	15:50
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40

Tatitlek Narrows along Black Pt.			
7-23	56-1-beach	herring	13:15
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Multiple gear and adjacent sites

outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-1-beach	herring	10:40
7-26	68-5-purse	herring	19:00
7-25	68-2	epibenthic	10:55
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Appendix 2A. APEX collections of herring and associated prey samples for diet studies, 1996.

Southwest Region PWS, co-occurring species

date	station-haul -gear	species	time
Bainbridge Point			
7-16	10-1-beach	herring	15:30
7-16	10-1-beach	pink salmon	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Prince of Wales Passage			
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Whale Bay			
7-17	12-1-beach	herring	8:30
7-17	12-1-beach	tomcod	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05

date	station-haul -gear	species	time
West of Point Countess			
7-17	14-1-beach	herring	10:10
7-17	14-1-beach	tomcod	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Northeastern PWS

West Bligh Island			
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15

Apopendix 2A, continued.

Single Species

Southwest PWS

Jackpot Bay			
7-17	16-1-beach	herring	13:30
7-17	16-3	plankton	13:45
7-17	16-4	plankton	13:55

Miscellaneous

Central PWS

North side Bay of Isles			
7-19	18-2-purse	herring	12:30
		no plankton	

Cabin Bay, Naked Island, PWS, 1996			
Beach seines (APEX 96163F)			
date	station-haul	species	time
8-1	B-2	herring	16:01
8-1	B-2	herring	16:01
8-1	C-1	herring	13:28
8-13	B-1	herring	18:23
		no plankton	

Lower Cook Inlet 1996			
APEX 96163M			
date	station-gear	species	time
6-29	HS-beach	herring	7:45
8-25	missing	herring	missing
		no plankton	

Miscellaneous

Northeastern PWS

Galena Bay W. of Narrows			
7-23	54-1-beach	herring	11:10
7-23	54-2	epibenthic	11:20
7-23	54-3	plankton	11:35
7-23	54-4	plankton	11:40
W. Landlocked Bay, Bidarka Pt.			
7-24	61-1-beach	herring	11:45
7-24	61-2	epibenthic	12:00
7-24	61-3	plankton	12:00
7-24	61-4	plankton	12:05
Port Fidalgo			
7-24	65-2-beach	herring	17:00
7-24	65-3	epibenthic	17:30
7-24	65-4	plankton	17:25
7-24	65-5	plankton	17:20
Inner Port Fidalgo			
7-26	62-2-purse	herring	9:30
		no plankton	
N. Port Gravina			
7-26	76-1-beach	herring	11:20
7-26	76-2	epibenthic	11:35
7-26	76-3	plankton	11:35
7-26	76-4	plankton	11:40
St. Matthews Bay			
7-27	69-1-dipnet	herring	9:00
		no plankton	

Appendix 2A, continued.
Northeast region PWS

dual gear (APEX 96163A)

date	station-haul -gear	species	time
NE Bligh Island			
7-23	47-1-purse	herring	16:15
7-23	47-2-cast	herring	17:30
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15

Northeast region PWS

adjacent sites (APEX 96163A)

date	station-haul -gear	species	time
Knowles, Redhead			
7-25	71-1-beach	sandlance-lrg	14:30
7-25	71-1-beach	sandlance-sml	14:30
7-25	72-1-beach	herring	15:20
7-25	72-2	epibenthic	15:50
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

Tatitlek Narrows along Black Pt.			
7-23	56-1-beach	herring	13:15
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28

date	station-haul -gear	species	time
Porcupine Pt., Goose Is.			
7-25	68-1-beach	herring	10:40
7-26	68-5-purse	herring	19:00
7-25	68-2	epibenthic	10i:55
7-25	68-3	plankton	10:55
7-25	68-4	plankton	11:00

Apopendix 2A, continued.

Northeast Region PWS, diels (APEX 96163A)
Knowles Bay (replicate 1)
all beach seines

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

**stomach ID completed

Knowles Bay (replicate2)

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

Appendix 2B. APEX collections of sandlance and associated prey samples for diet studies, 1996.

Co-occurring Species
Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
West Bligh Island			
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15
Beach seine, Knowles, Redhead			
7-25	71-1-beach*	sandlance-lrg	14:30
7-25	71-1-beach*	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

*also pseudo-diel

Central PWS (APEX 96163A)

date	station-haul -gear	species	time
point off of N arm of Cabin Bay			
7-22	48-1-beach	sandlance	10:50
7-22	48-1-beach	pink salmon	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Northeastern PWS (APEX 96163A)
Adjacent sites

Knowles, Redhead			
7-25	71-1-beach*	sandlance-lrg	14:30
7-25	71-1-beach*	sandlance-sml	14:30
7-25	71-1-beach*	herring	15:20
7-25	72-2	epibenthic	15:50
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

Appendix 2B, continued.

Single Species

Central PWS (APEX 96163A)

date	station-haul -gear	species	time
SW Cabin Bay			
7-22	47-1-beach	sandlance	9:55
7-22	47-2	epibenthic	10:08
7-22	47-3	plankton	10:10
7-22	47-4	plankton	10:15

Southwestern PWS (APEX 96163A)

inside Bainbridge Pt.			
7-16	11-2-beach	sandlance	17:40
7-16	11-3	epibenthic	17:55
7-16	11-4	plankton	18:15
7-16	11-5	plankton	18:25

Miscellaneous

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Port Fidalgo			
7-24	66-1-beach	sandlance	18:05
7-24	66-2	epibenthic	18:20
7-24	66-3	plankton	18:20
7-24	66-4	plankton	18:25
Boulder Bay (inside Bidarka Pt.)			
7-24	63-1-beach	sandlance	13:35
7-24	63-2	epibenthic	13:50
7-24	63-3	plankton	13:50
7-24	63-4	plankton	13:55
Irish Cove, Port Fidalgo			
7-24	64-1-beach	sandlance	15:20
7-24	64-2	epibenthic	15:25
7-24	64-3	plankton	15:30
7-24	64-4	plankton	15:35

Appendix 2B, continued.

Cabin Bay, Naked Island, PWS, 1996			
Beach seines (APEX 96163F)			
date	**station-haul**	**species**	**time**
7-6	F-1	sandlance	15:20
7-14	G-1	sandlance	15:30
7-21	F-1	sandlance	19:55
7-21	F-1	sandlance**	19:55
7-22	A-1	sandlance	0:00
7-22	F-1	sandlance**	8:00
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	12:10
7-22	F-2	sandlance**	20:15
7-27	F-1	sandlance	10:35
8-13	A-1	sandlance	17:40

**stomach ID completed

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	**set #**	**species**
7-2	1	sandlance
7-17	1	sandlance
7-23	2	sandlance
7-23	2	sandlance-lrg
7-24	3	sandlance
8-16	3	sandlance
8-23	1	sandlance
9-8	1	sandlance

Lower Cook Inlet 1996			
Miscellaneous gear (APEX 96163M)			
date	**station-gear**	**species**	**time**
6-14	ST-beach	sandlance	15:35
6-16	NF-beach	sandlance	8:30
6-16	NF-beach	sandlance	8:30
6-29	HS-beach	sandlance	8:40
7-8	CP2-beach	sandlance	15:45
7-18	trawl	sandlance	missing
8-7	SS-beach	sandlance	9:45
8-7	SS-beach	sandlance	9:30
8-27	CP4-beach	sandlance	8:50
8-27	PC-beach	sandlance	8:10
9-13	PB-beach	sandlance	16:10

Appendix 2B, continued.

Diel Samples (APEX 96163A)
Northeastern PWS
Knowles Bay (replicate 1)
Beach seines

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

**stomach ID completed

Knowles Bay (replicate2)
Beach seines

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

West Bligh Island
Beach seines

date	station-haul	species	time
7-27	82-1	sandlance	15:00
7-27	82-2	epibenthic	15:30
7-27	82-3	epibenthic	15:32
7-27	82-4	plankton	15:15
7-27	82-5	plankton	15:20

Appendix 2C. **APEX collections of pollock and associated prey samples for diet studies, 1996.**

Central Region PWS (APEX 96163A)

Co-occurring Species

date	station-haul -gear	species	time
South side of Pt. Eleanor			
7-20	34-1-beach	pollock	11:05
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	tomcod	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25

S. McPherson Bay			
7-21	42-1-beach	pollock	13:30
7-21	42-1-beach	tomcod	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45

Miscellaneous (APEX 96163A)

date	station-haul -gear	species	time
South Smith Is.			
7-21	65-1-trawl	pollock	15:09
7-21	65-2	plankton	15:35
7-21	65-3	plankton	15:45

Lower Cook Inlet, 1996 (APEX 96163M)			
date	**station-gear**	**species**	**time**
7-16	trawl	pollock	13:43
		no plankton	

Appendix 2D. APEX collections of tomcod and associated prey samples for diet studies, 1996.

Co-occurring Species

Southwestern PWS (APEX 96163A)

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	tomcod	13:20
7-15	1-1-beach	pink salmon	13:21
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Whale Bay			
7-17	12-1-beach	tomcod	8:30
7-17	12-1-beach	herring	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05
West of Point Countess			
7-17	14-1-beach	tomcod	10:10
7-17	14-1-beach	herring	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Italian Bay			
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35
Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Central PWS (APEX 96163A)

South side of Pt. Eleanor			
7-20	34-1-beach	tomcod	11:05
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	pollock	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25
S. McPherson Bay			
7-21	42-1-beach	tomcod	13:30
7-21	42-1-beach	pollock	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45

Appendix 2D, continued.

Central PWS (APEX 96163A), single species

date	station-haul -gear	species	time
large bay on SE Eleanor Is.			
7-20	33-1-beach	tomcod	9:30
7-20	33-2	epibenthic	9:40
7-20	33-3	plankton	9:45
7-20	33-4	plankton	9:50

Southwestern PWS (APEX 96163A)

Paddy Bay			
7-17	18-1-beach	tomcod	16:30
7-17	18-2	epibenthic	16:40
7-17	18-3	plankton	16:45
7-17	18-4	plankton	16:50

Northeastern PWS (APEX 96163A)
Diel Station

South Bligh Is.			
7-27	86-1-beach	tomcod	21:45
7-27	86-2	epibenthic	22:00
7-27	8603	epibenthic	22:02
7-27	8604	plankton	22:25
7-27	86-5	plankton	22:28

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	**set #**	**species**
7-2	1	tomcod
7-23	1	tomcod
		no plankton

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Tatitlek Narrows			
7-23	55-1-beach	tomcod	12:35
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Central PWS (APEX 96163A)

South inside of Bay of Isles			
7-19	27-1-beach	tomcod	11:48
7-19	27-2	epibenthic	12:00
7-19	27-3	plankton	12:10
7-19	27-4	plankton	12:15
North side Bay of Isles			
7-19	29-1-beach	tomcod	16:30
7-19	29-2	epibenthic	16:45
7-19	29-3	plankton	16:55
7-19	29-4	plankton	17:00

Northeastern PWS (APEX 96163A)
Adjacent sites

Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	56-1-beach	herring	13:15
7-23	57-1-beach	unid. greenling	13:50
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Appendix 2E. APEX collections of pink salmon and associated prey samples for diet studies, 1996.

Co-occurring species (APEX 96163A)
Southwestern PWS

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	pink salmon	13:21
7-15	1-1-beach	tomcod	13:20
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Point Grace (Latouche Is.)			
7-15	2-1-purse	pink salmon	16:28
7-15	2-1-purse	chum salmon	16:28
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Latouche Is.			
7-16	1-1-purse	pink salmon	14:46
7-16	1-1-purse	chum salmon	14:46
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Bainbridge Point			
7-16	10-1-beach	pink salmon	15:30
7-16	10-1-beach	herring	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30

date	station-haul -gear	species	time
Prince of Wales Passage			
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Paddy Bay			
7-17	20-1-beach	pink salmon	18:42
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	pink salmon	13:00
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Appendix 2E, continued.

Co-occurring Species (APEX 96163A)

Northeastern PWS

date	station-haul -gear	species	time
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Central PWS

date	station-haul -gear	species	time
SE Bass Harbor (Naked Is.)			
7-20	36-1-beach	pink salmon-sml	14:40
7-20	36-1-beach	pink salmon-lrg	14:40
7-20	36-2	epibenthic	14:55
7-20	36-3	plankton	14:50
7-20	36-4	plankton	14:55
point off of N arm of Cabin Bay			
7-22	48-1-beach	pink salmon	10:50
7-22	48-1-beach	sandlance	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Single Species (APEX 96163A)

Central PWS

date	station-haul -gear	species	time
SW arm of Naked Island			
7-21	39-2-beach	pink salmon	9:00
7-21	39-3	epibenthic	9:10
7-21	39-4	plankton	9:25
7-21	39-5	plankton	9:30
SW Naked Island			
7-21	40-1-beach	pink salmon	10:30
7-21	40-2	epibenthic	10:45
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00
Bass Harbor (Naked Is.)			
7-21	41-1-beach	pink salmon	11:35
7-21	41-2	epibenthic	11:50
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00
Ingot Is.			
7-20	24-2-purse	pink salmon	12:06
		no plankton	

N. Eleanor Is.

date	station-haul -gear	species	time
7-20	35-1-beach	pink salmon	12:30
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Appendix 2E, continued.

Dual gear
Central PWS

date	station-haul -gear	species	time
North Eleanor Is.			
7-20	35-1-beach	pink salmon	12:30
7-20	24-2-purse	pink salmon	12:06
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Dual gear and adjacent sites
Northeastern PWS

date	station-haul -gear	species	time
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-1-beach	herring	10:40
7-26	68-5-purse	herring	19:00
7-25	68-2	epibenthic	10:55
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Miscellaneous hauls (APEX 96163A)
Northeastern PWS

date	station-haul -gear	species	time
N. Galena Bay			
7-23	53-1-beach	pink salmon	9:00
7-23	53-2	epibenthic	9:05
7-23	53-3	plankton	10:30
7-23	53-4	plankton	10:35

Central PWS

South Storey Is.			
7-22	49-1-beach	pink salmon	12:10
7-22	49-2	epibenthic	12:20
7-22	49-3	plankton	12:20
7-22	49-4	plankton	12:25

Miscellaneous hauls

Lower Cook Inlet 1996 (APEX 96163M)			
date	**station-gear**	**species**	**time**
6-28	CP1-beach	pink salmon	6:45
7-18	trawl	pink salmon	missing
		no plankton	

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	**set #**	**species**
7-17	1	pink salmon
7-24	3	pink salmon

APPENDIX E

APEX: 96163E

Exxon Valdez Oil Spill
Restoration Project Annual Report

KITTIWAKES AS INDICATORS OF FORAGE FISH AVAILABILITY

Restoration Project 96163E
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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February 1996

STUDY HISTORY

Field work for project 95163E began during the summer of 1995 and consisted of detailed studies of the reproductive biology and foraging ecology of Black-Legged Kittiwakes in Prince William Sound (PWS), Alaska. In 1995, studies were conducted at one colony in northeastern (Shoup Bay) and two colonies (Eleanor Island and Seal Island) in central PWS. Research at Shoup Bay was conducted in conjunction with ongoing studies funded by the U.S. Fish and Wildlife Service (USFWS). In 1996, we expanded the study to include North Icy Bay rather than Seal Island, thereby having sites representing northeastern (Shoup Bay), central (Eleanor Island), and southwestern (North Icy Bay) PWS. Additionally, we can make comparisons with long-term demographic (Shoup Bay) and population studies (all of PWS) conducted by the USFWS. This allows us to more accurately address relationships of variation in prey and decadal trends in populations.

ABSTRACT

The distribution of Black-legged Kittiwakes (*Rissa tridactyla)* nesting in Prince William Sound (PWS), Alaska has changed dramatically since the early 1970's. Sixty-three percent of the population now nests in northern PWS compared to 30% in 1972. Population analyses indicated that between 1984 and 1996, productivity at five northern colonies ($n = 9$) was sufficient to maintain a stable or net population increase (fledgling production ≥ adult mortality) while productivity at all southern colonies ($n = 18$) was insufficient to maintain the population (fledgling production < adult mortality). These changes and trends corresponded with a decrease in the availability of high quality forage fishes in the Gulf of Alaska (GOA). We hypothesize that these changes in the GOA primarily affected kittiwakes in the southern PWS where oceanographic conditions and prey associated with the Alaska Coastal Current are more similar to those found at colonies in the GOA. This resulted in a shift of the nesting population to the north where local forage fish production (primarily Pacific herring, *Clupea pallasi*, and Pacific sand lance, *Ammodytes hexapterus*) allowed high kittiwake productivity in PWS compared to the GOA. As part of the APEX project we are conducting detailed studies of three kittiwake colonies located in northeastern (Shoup Bay), central (Eleanor Island), and southwestern (North Icy Bay) PWS. Based on the above hypothesis, we would expect the Shoup Bay colony to be most successful followed by Eleanor Island and North Icy Bay. Our results for 1996 partially support this hypothesis and, in cooperation with other APEX components, will allow us to further examine the relationship between PWS and GOA ecosystems. Additionally, results of these studies will help determine factors limiting the productivity of kittiwakes in portions of PWS.

In 1990, the year following the *T/V Exxon Valdez* oil spill, productivity of Black-legged Kittiwakes in Prince William Sound (PWS) decreased and had not recovered as of 1995. Studies during this period indicated the decline in productivity resulted from decreased food availability and increased predation. Data collected in 1996 provided the first evidence that food availability may have been similar to conditions prior to 1990.

Data collected during this study and Irons (1992) will allow us to model relationships of reproductive success, chick diets, chick growth rates, and foraging effort, as indicators of relative prey quality and availability. By working with other APEX components and the SEA project (EVOS project #320), the above parameters can be used to predict the effects of changes in oceanographic conditions and forage fish availability on population dynamics of kittiwakes in PWS.

INTRODUCTION

Seabirds have been recognized as potentially useful indicators of marine resources by many authors (Ashmole 1971, Boersma 1978, Crawford and Shelton 1978, Anderson and Gress 1984, Ricklefs et al. 1984, Cairns 1987, Croxall et al. 1988, Monaghan et al. 1989, Harris and Wanless 1990, Furness and Barrett 1991, Furness and Nettleship 1991, Hamer et al. 1991, Hunt et al. 1991). Availability of food resources affect foraging success, which in turn affects reproductive output. Several reproductive parameters have been proposed as useful indicators: breeding phenology, clutch size, breeding success, chick diets, chick growth rates, adult colony attendance, adult activity budgets, foraging trip duration, and adult mass (Cairns 1987, Croxall et al. 1988).

Although foraging behavior partially determines reproductive output, the nature of this relationship may be complex. Optimal foraging models predict precise behaviors that are assumed to maximize fitness (Schoener 1971, 1987, Pyke 1984, Stephens and Krebs 1986). In contrast to the idea of optimality, evidence indicates there is a range of foraging effort over which reproductive output is not affected (Costa and Gentry 1986, Burger and Piatt 1990, Irons 1992). For example, Cairns (1987) suggested that adult survivorship changes only when food is in very short supply while activity budgets change only during medium and high levels of food availability. The phenomenon responsible for this uncoupling of foraging effort and reproductive output above threshold levels of food abundance has been termed a "buffer" (Cairns 1987, Burger and Piatt 1990). A buffer can be defined as the surplus capacity to forage. Buffers can be used to compensate for periods of low food availability so that reproductive output is maintained even though food is less available. Cairns (1987) also pointed out that activity budgets may be better than reproductive parameters as indicators of changes in food supply; the effects that changes in food supply have on reproductive output may be reduced by parents altering their foraging behavior to compensate for shortages. Burger and Piatt (1990) and Irons (1992) found evidence of this in common murres (*Uria aalge*) and black-legged kittiwakes, respectively.

In addition to understanding how food shortages affect productivity of seabirds, it is important to understand how seabirds find their food in order to identify which processes break down during a food shortage. Many species of seabirds, including black-legged kittiwakes and marbled murrelets (*Brachyramphus marmoratus*), forage in flocks (Sealy 1973, Hoffman et al. 1981, Duffy 1983, Harrison et al. 1991) which apparently increase foraging efficiency (Lack 1968, Morse 1970, Sealy 1973, Hoffman et al. 1981, Wittenburger and Hunt 1985, Gotmark et al. 1986, Harrison et al. 1991). The formation of seabird feeding flocks is enhanced by a form of information transfer termed "network foraging" (Wittenburger and Hunt 1985), which results in seabirds learning of and joining feeding flocks by observing the flight of other seabirds as they fly toward a feeding flock (Gould 1971, Sealy 1973, Hoffman et al. 1981). However, the importance of flock foraging has been questioned by Irons (1992), who found that much foraging by breeding kittiwakes occurred outside of foraging flocks.

During the 1995 and 1996 nesting season, productivity, chick diets, and foraging of kittiwakes were monitored at three colonies in PWS. We addressed three of the ten APEX project hypotheses:

1) Seabird diet reflects changes in relative abundance and distribution of forage fishes around colonies.
2) Changes in seabird productivity reflect changes in availability of forage fishes as measured in foraging trips, chick meal size, and chick provisioning rates.
3) Seabird species within a community react predictably to different prey bases.

METHODS

Study Area

This study was conducted in Prince William Sound (PWS), a 10,000 km^2 inland marine/estuarine waterway located along the north coast of the Gulf of Alaska (Fig. 1). The abundant fjords, bays, and islands in PWS provide shoreline habitat in excess of 4000 km. This area is also characterized by heterogeneous bathymetry and large tide height variation causing eddies and upwelling which likely affect the distribution of forage fishes and availability to seabirds (Irons 1992).

Population Dynamics

Estimates of the nesting population of Black-legged Kittiwakes in PWS were first conducted in 1972 by Isleib and Kessel (1973). In 1984, David Irons (1996) began collecting annual population (nest counts in mid June) and productivity (chick counts in early August) data from all colonies (n = 27) in PWS (total of 13 years including 1996). Additionally, an intensive banding effort was initiated at Shoup Bay in 1988. This consisted of color-banding 500 kittiwake chicks each year. In 1991, about 850 were captured and color-banded for individual identification and annual resighting efforts (1991 to 1996) have been conducted to estimate adult survival rates (Golet et al. in review). By using these data and treating individual colonies (initially) and PWS (secondarily) as closed populations (assuming no immigration or emigration) we addressed the working hypothesis:

1) Demographic parameters can be used to explain observed changes in populations at individual colonies and PWS as a whole.

Recruitment required to maintain a population at equilibrium is defined by :

$$fecundity = \frac{1 - FSR_{adult}}{FSR_{juv}}$$

where fecundity is the number of female offspring/female/year, FSR_{adult} is the finite survival rate of adults and FSR_{juv} is the finite survival rate of juveniles (Ricklefs 1973). Estimates of adult survival were obtained from kittiwakes at Shoup Bay, PWS (mean = 0.922; Golet et al. in review). We are in the process of calculating juvenile survival and mean age at first breeding for kittiwakes at Shoup Bay. For these analyses, however, we used first year survival (0.79; Coulson and White 1959) and mean age at first breeding (4 to 5 years; Wooler and Coulson 1977; Porter and Coulson 1987) from studies at the North Shields colony in Scotland. We used adult survival rate as a conservative estimate for juvenile survival from age 1 to breeding age and a fledgling sex ratio of 50:50. Given these demographic parameters, a population would have to produce 0.24 to 0.27 young per nest (or female) for the population to replace itself. Therefore, a productivity (fledglings/nest) of > 0.27 produced a net population increase, < 0.24 produced a net decrease, and 0.24 to 0.27 was considered a stable population.

Treating each colony as a closed population, we determined if immigration or emigration occurred by comparing projected colony sizes to actual counts between 1984 and 1996. Estimated colony sizes were determined by using a population projection matrix (birth pulse model for a post-breeding census; Leslie 1945, 1948) with the above demographic parameters, and number of fledglings produced each year. For initial analyses we assumed a probability of breeding of 100%.

Colony Studies

Primary Black-legged Kittiwake colonies studied during the 1996 nesting season in PWS were located near Shoup Bay, Eleanor Island, and North Icy Bay. In 1996, Shoup Bay was the largest kittiwake colony (6537 nests, an increase of 5106 nests since 1984) in PWS, Eleanor Island was a relatively small colony (268 nests, relatively stable since 1984), and North Icy Bay was of moderate size (1877 nests, an increase of 1680 nests since 1984).

Between 2 June and 16 August, the contents of Black-legged Kittiwake nests were recorded every three to seven days at colonies near Shoup Bay (206 nests in 12 plots), Eleanor Island (286 nests, entire colony), and North Icy Bay (162 nests; 11 plots). Only nests built before 20 June were included in the plots.

To determine growth rates, measurements of chicks were recorded every four (Shoup Bay and Eleanor Island) to eight days (North Icy Bay) from hatching to fledgling. Recorded measurements included head plus bill (± 0.1 mm), tarsus (± 0.1 mm), wingchord (±1 mm), tenth primary (±1 mm), and total mass (±1 g) of bird. Growth was calculated as mass gain per day during the near-linear growth phase of 60 to 300 g; producing results that are virtually identical to

Ricklef's (1967) maximum instantaneous growth rates (Galbraith 1983). Additional measures of growth will be evaluated during further data analyses.

Chick diet samples (regurgitations) were collected while handling chicks, weighed to the nearest 0.01 g on an Ohaus top-loading balance, and frozen. Typically, no more than one sample was collected per chick. Prey were identified using otoliths (all species) and scales (Pacific herring).

Adult Black-legged Kittiwakes were captured at their nests using a noose pole or leg noose and radio transmitters (Advanced Telemetry Systems, Inc (ATS), 166 - 167 MHZ, 10 g) were attached to 38 birds at Shoup Bay, 24 birds at Eleanor Island, and 20 birds at North Icy Bay. At Shoup Bay and Eleanor Island, each transmitter had a unique frequency. At North Icy Bay, three transmitters for each frequency were differentiated by pulse widths of 145, 185, and 195 milliseconds. Transmitters were attached (using two plastic cable ties and Loctite 494 instant adhesive) to the ventral surface at the base of tail feathers (Anderson and Ricklefs 1987; Irons 1992). Head, breast, tail and underwings of radio-tagged kittiwakes were dyed (Nyanzol D and Rhodomine B) one of three unique color combinations. The dye permitted easy identification of kittiwakes during tracking.

A remote receiving station (RRS) recorded the presence of radio-transmittered kittiwakes at Shoup Bay, Eleanor Island, and North Icy Bay colonies. A RRS consisted of an ATS data collection computer (DCC) connected to an ATS receiver and a dipole (Shoup Bay and Eleanor Island) or two element "H" antenna (North Icy Bay). A reference transmitter was placed on the colony to verify continuous operation of the DCC. Frequencies beyond the range of transmitters ("dummy frequencies") were input into the DCC to test for radio interference. The RRS was powered by an 80 amp/hr deep cycle, lead-acid battery, which was charged by a three amp solar panel. The DCC's at Shoup Bay and Eleanor Island continuously scanned each frequency (including high/low brackets ± 2 KHz, reference transmitter, and three dummy frequencies) for approximately twenty seconds every ten minutes. DCC's at North Icy Bay continuously scanned each frequency for approximately one minute every ten minutes. The DCC at Shoup Bay required a little less than 45 min for a complete scan of all frequencies (including high/low brackets, allowing three opportunities to receive each frequency). A kittiwake was, therefore, considered absent from the nest if the transmitter signal was not received for > 45 min.

Foraging trip duration, distance, location, and behavior were determined while tracking radio-tagged kittiwakes from a 7.3 m Boston Whaler with an ATS receiver and a four element yagi antenna. Kittiwakes rearing chicks were selected for tracking. Observers waited near the colony until a radio-tagged bird left, then attempted to keep the kittiwake in view until it returned to the colony. Behaviors recorded included traveling (straight flight), searching for prey (back and forth flight), foraging (surface plunge or surface seize; Ashmole 1971), resting, and lost (bird out of view) . Since duration of pursuit and handling of prey for kittiwakes is negligible compared to search time (Irons 1992), foraging was combined with searching in final analyses. Observers also recorded locations of foraging flocks and whether the radio-tagged kittiwake joined or passed the foraging flock. Foraging flocks included any seabird species and were divided into three categories; 1) foraging flock (≥ 2 birds flying back and forth with at least two surface plunge or surface seize locations less than 10 m apart), 2) dispersed foraging flock (≥ 2 birds foraging in an area > 10 m and < 500 m), and 3) potential foraging flock (≥ 2 birds flying back and forth with < 2 foraging attempts within a 500 m diameter). Locations of foraging kittiwakes, foraging flocks, and flight paths of radio-tagged kittiwakes were determined using a Lowrance LMS-350A geographic positioning system receiver (GPS). The computer program Atlas GIS was used to plot foraging trip locations and measure distance to shore for foraging kittiwakes, maximum foraging distance from colony (shortest distance without intersecting land), and total trip distance.

In addition to tracking efforts at Shoup Bay and North Icy Bay colonies, we also used a series of telemetry surveys to obtain at-sea locations of birds from these colonies. The telemetry surveys consisted of traveling by boat along a designated route encompassing expected foraging ranges and monitoring radio frequencies for presence or absence of radio-tagged birds.

In addition to adult kittiwakes captured for radio-tagging, adults were also captured during the late chick rearing period at the three colonies. Morphometrics obtained from these birds were used to compare body condition between incubation and chick rearing and among sites. Principal components analysis (SAS 1988) was used to calculate body size indices which were plotted against corresponding masses. A regression of body size index versus mass was calculated to compare mean residual mass between early and late season and among sites.

RESULTS

Analyses of data collected are not complete and considered preliminary. Final results will be subjected to additional statistical analyses.

Population Dynamics

There are 27 colonies of Black-legged Kittiwakes located throughout PWS (Fig 1). Colony size ranges from < 20 to over 6500 nests. Since 1972, the nesting population at certain colonies has greatly increased while others have greatly decreased or been abandoned. Overall, distribution of the nesting population in PWS has changed dramatically since the early 1970's. Sixty-three percent of the population now nests in northern PWS compared to 55% in 1985 and 30% in 1972. For this comparison, northern and southern PWS are divided by a line intersecting Port Nellie Juan in western, Naked Island in central, and Bligh Island in eastern PWS (northern PWS comprises those colonies with foraging ranges more likely associated with oceanographic conditions specific to PWS waters vs. GOA influences in southern PWS; Fig 1). Population analyses indicated that between 1984 and 1996, productivity at five northern colonies (n = 9) was sufficient to maintain a stable or net population increase at those colonies (fledgling production ≥ adult mortality) while productivity at all southern colonies (n = 18) was insufficient to compensate adult mortality (fledgling production < adult mortality; Fig 2). For PWS as a whole, productivity was sufficient to maintain a net population increase between 1984 and 1989. Decreased productivity, however, between 1990 and 1995 was insufficient to maintain the population. When evaluated by regions during 1984 through 1996, however, it was only the northern colonies that maintained sufficient productivity to compensate adult mortality. Whereas, productivity at the southern colonies was insufficient to maintain populations during this period (Table 1).

There was evidence of immigration at 44% of northern (n = 9) and only 28% (n = 18) of southern colonies (Fig 3). Suprisingly, these included colonies where fledgling production was ≥ adult mortality and where fledgling production was < adult mortality. Passage Canal was the only colony that had evidence of juvenile emigration (projected population was > actual counts). Six colonies in southern PWS had evidence of emigration of adults (population declined at a rate greater than what could be explained by adult mortality alone). There was evidence for immigration into PWS during several years. Based on demographic parameters, the kittiwake population in PWS should decline over the next couple of years if immigration is not occurring.

Colony Studies

In 1996, productivity (fledglings/nest) was greatest at Shoup Bay (0.73) followed by Eleanor Island (0.53) and North Icy Bay (0.28). Compared to 1995, productivity was less at Shoup Bay and greater at Eleanor Island in 1996. Laying success (≥ 0.87 of nest structures having ≥ 1 egg) and mean clutch size (≥ 1.73 eggs) was relatively high at all three sites. Therefore, low productivity at North Icy Bay resulted from loss of eggs and chicks over the nesting period. Overall productivity for kittiwakes in PWS was the greatest (0.35 fledglings/nest) since 1989; in contrast to the last six years (1990 to 1995) of reduced productivity.

Chick growth rates were greatest at Shoup Bay and least at North Icy Bay, although these differences were smaller than anticipated (< 0.6 g/day). Chick growth rates at Eleanor Island and North Icy Bay were slightly greater in 1996 compared to 1995.

When reproductive and foraging parameters were compared with previous years, some interesting trends became apparent. At Shoup Bay, foraging trip distance, chick growth, productivity, and chick diets were similar during three of four years (Fig 4). In 1990, however, a dramatic change in diet (significantly less herring, and more walleye pollock, *Theragra chalcograma*) resulted in greater foraging trip distances, reduced chick growth, and decreased productivity. These data indicated the additional time and energy required to obtain food was beyond the adults ability to buffer their chicks against variability in prey resources. At Eleanor Island, two of three years were similar among these measurements. In this case, a significant change was observed in 1996 with a dramatic change in diet (markedly less herring and more capelin, *Mallotus villosus*) and corresponding increase in foraging trip distance (Fig 5). This increased effort, however, did not result in decreased productivity or chick growth, indicating that the adults were able to obtain sufficient quantities of good quality food and that the increased effort was within the limits for the adults to buffer their young. The relatively few adult kittiwakes at North Icy Bay that were able to obtain sufficient quantities of high quality food (herring, sand lance, and capelin) produced chicks with good growth rates (Fig 6). Their estimated foraging trip distances, however, were long; approaching the limit observed for kittiwakes at Shoup Bay in 1990 and may have contributed to reduced productivity. This increased effort at North Icy Bay corresponded with adults being slightly lighter (1.5 - 4%) than those at Eleanor Island and Shoup Bay. These differences were not as great as expected, but may reflect increased energetic requirements of adults at North Icy Bay and reduced abundance of good quality prey.

At-sea locations of kittiwakes from Shoup Bay in 1996 were similar to locations obtained in 1995 (Fig 7c). The only exception appears to be more locations around Glacier Island in 1996, west of the entrance to Valdez Arm. These are consistent with similar foraging trip durations and diets between the two years. In contrast, there was a change in foraging areas used by kittiwakes from Eleanor Island. In 1996, the significantly greater foraging trip durations and distances and change in diet corresponded with more trips to Green Island where large schools of capelin were observed (Fig 7a). One kittiwake from North Icy Bay was tracked south to Pt. Elrington (Fig 7b) where it was observed foraging on a large school of capelin. Foraging flocks associated with the capelin schools were much larger (100's to 1000's of birds) than those typically found in PWS. Although foraging flocks were commonly encountered while tracking, adult kittiwakes that successfully raised young were observed foraging alone > 50% of the time when foraging flocks were present. Distance to shore of foraging locations was on average within 1 km of shore, consistent with data from previous years.

Data from continuous monitoring by the DCCs indicated mean daily trip duration changed over the chick rearing period (Fig 8a,b). At Shoup Bay and Eleanor Island, mean trip duration increased markedly and became more variable around the third week in July. The increased trip duration was observed for adults with chicks of various ages and for one adult without chicks; indicating potential responses to variation in prey availability. Trip duration among adults raising chicks at North Icy Bay was considerably more variable (Fig 8c) and may reflect limited or unpredictable food resources.

Using these measures of reproductive and foraging effort obtained over years with variable prey diversity and abundance, we can build theoretical frameworks for estimating quality and relative abundance of prey as outlined in Table 2. These estimations could then be compared to data collected by the fisheries investigators (APEX component A).

DISCUSSION

Morrison (1986) and Temple and Wiens (1989) argued that avian population measures are not useful to monitor environmental change because of the difficulties involved in establishing direct cause-and-effect relationships. Also, the appearance of the effects may be buffered by time-lags caused by intermediate stages in the cause-effect relationship or the site-fidelity of breeding birds (Temple and Wiens 1989). This is a reasonable conclusion when addressing change over time periods that are short in relation to life hisories of seabirds, which are typically long-lived species that experience delayed maturity, low reproductive rates (Lack 1967), and breeding site-fidelity. However, when considering environmental change on the decadal scale, such as that described in the GOA (Piatt and Anderson 1996), changes in seabird populations would likely reflect these conditions. Until recently, there has been little information on the relationship of oceanographic processes in PWS and the GOA. Because of this, it is not known how changes in the GOA since the late-1970's may have affected oceanographic conditions in PWS. Researchers from the SEA project (EVOS project 320) are in the process of collecting data to model the Alaska Coastal Current and its effect on the oceanography of PWS. Long term monitoring of kittiwake populations and demography in PWS may provide valuable information for correlating population trends with environmental changes. Between 1984 and 1989, kittiwake productivity in the GOA was at a low of 0.19 fledglings/nest (Hatch et al.1992), similar to those colonies in southern PWS. In contrast, productivity at colonies in northern PWS were significantly greater, indicating availability of prey resources to maintain productivity. Diets of kittiwake chicks in the GOA consist of primarily capelin and sand lance, in contrast to northern PWS where herring and sand lance are the dominant prey items. Reduced productivity of kittiwakes and other piscivorous seabirds in the GOA are likely related to changes in oceanographic conditions and subsequent decline in abundance of capelin and, potentially, sand lance since the late 1970's. We hypothesize that the proposed regime shift in the GOA primarily affected kittiwakes in southern PWS where oceangraphic conditions and prey associated with the Alaska Coastal Current are more similar to those found at colonies in the GOA. This resulted in a shift of the nesting population to the north where local forage fish production (primarily herring and sand lance) allowed greater kittiwake productivity in PWS compared to the GOA.

Cairns (1987) described relationships between population and behavioral parameters of a generalized seabird and its food supply. These parameters--adult survivorship, breeding success, chick growth, colony attendance, and activity budgets--are sensitive to different ranges of food availability and indicate responses on the order of hours (time budgets) to years (survivorship). A confounding factor is the ability of an adult to buffer their chick(s) from variability in food supply (Burger and Piatt 1990). As food supply decreases, however, a maximum limit of foraging effort is reached at which point adults can no longer buffer their chicks from reduced prey availability (Irons 1992). Therefore, to use seabirds as indicators of food availability requires integration of measures from all parameters and a standard by which to compare; as can only be obtained from long-term studies.

For example, based on the above parameters for data acquired for kittiwakes in PWS, we would estimate relative prey quality and availability as depicted in Table 2. If reproductive parameters, diet quality, and chick growth are good and foraging trip effort (distance/duration) is within limits of the buffer, we conclude that available prey is of high quality and availability (as for Shoup Bay in 1989, '95, '96, and Eleanor Island 1996). If measurements of parameters were all poor, then prey quality and availability is presumed low, as with Shoup Bay in 1990. If all parameters were good except productivity (Eleanor 1989, '95) we would conclude that factors other than food quality and availability limited productivity (e.g. predation, weather, anthropogenic influences). If, however, foraging effort was unusually high in association with low productivity, as with North Icy Bay in 1996, this indicates that relative abundance of prey may have been low (Table 2). With sufficient data, theoretical relationships (such as proposed in Table 2) can be developed into predictive models.

Further development of these relationships (conceptually and numerically) in conjuction with other APEX components will provide powerful tools for future monitoring of factors affecting reproductive success and foraging effort.

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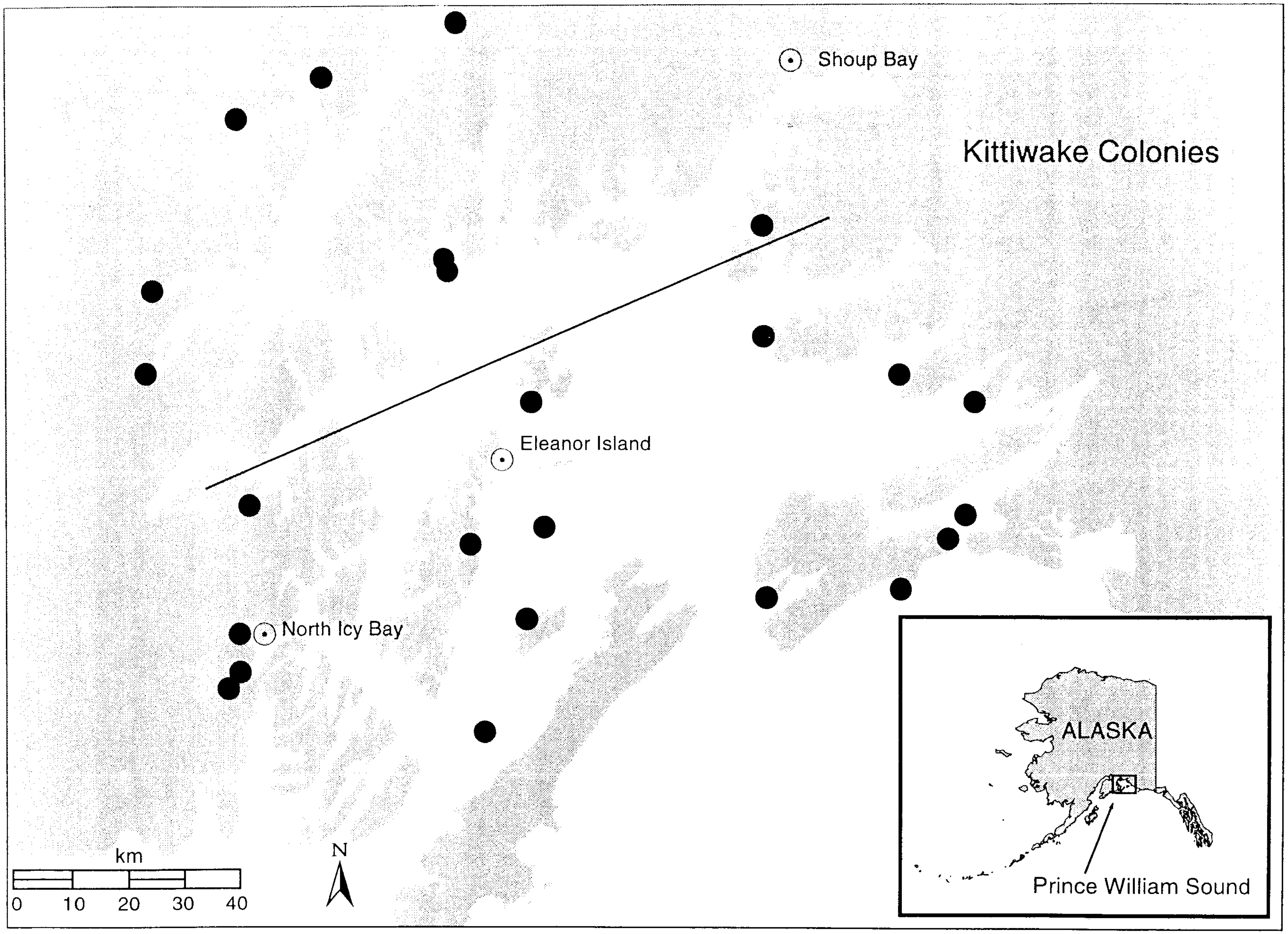
Table 1. Productivity (fledglings/nest) of kittiwakes nesting at colonies in northern vs. southern PWS from 1984 to 1989.

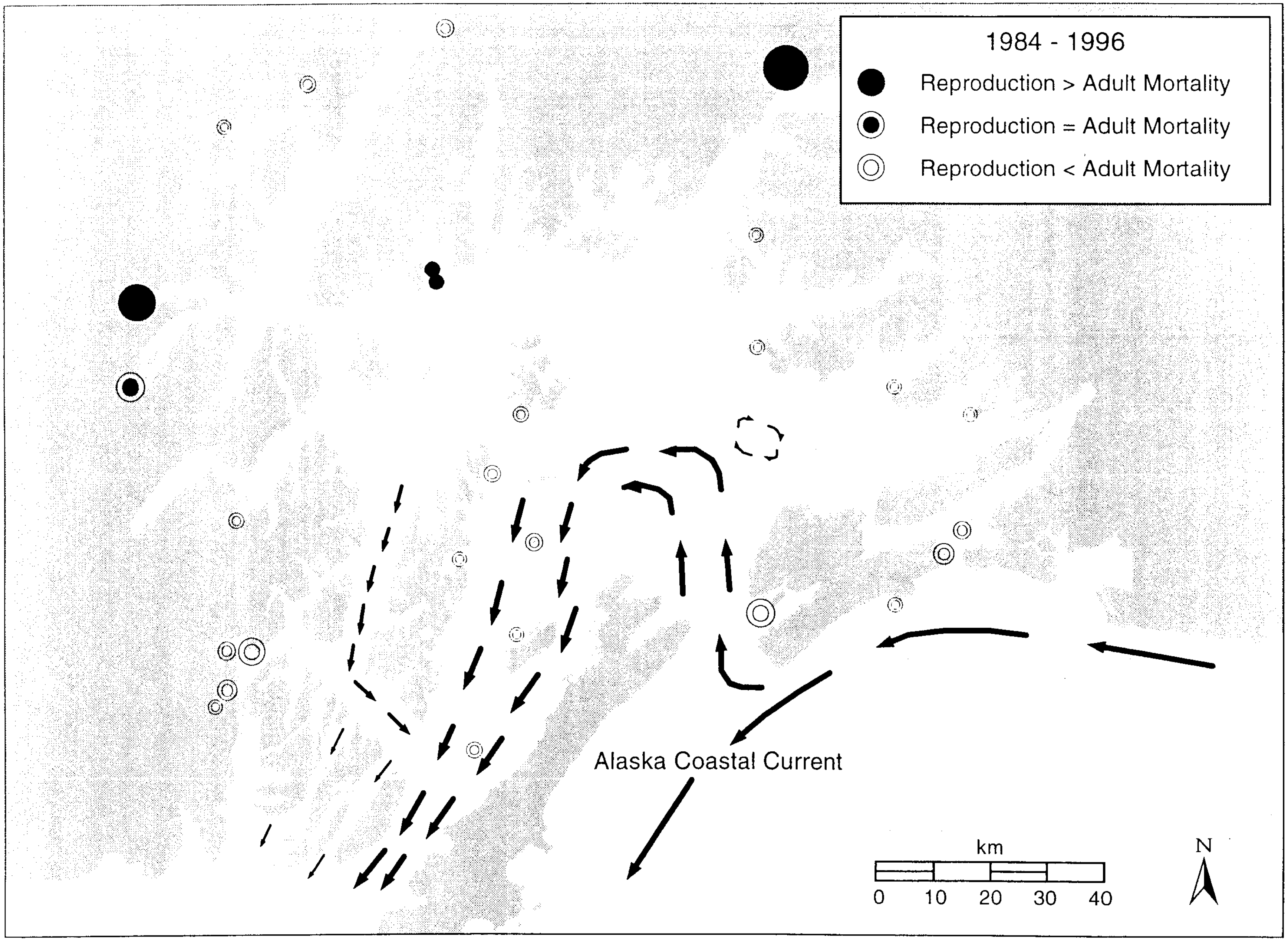
	1984	1985	1986	1987	1988	1989
North	0.44	0.47	0.48	0.45	0.46	0.54
South	0.09	0.03	0.13	0.19	0.16	0.09

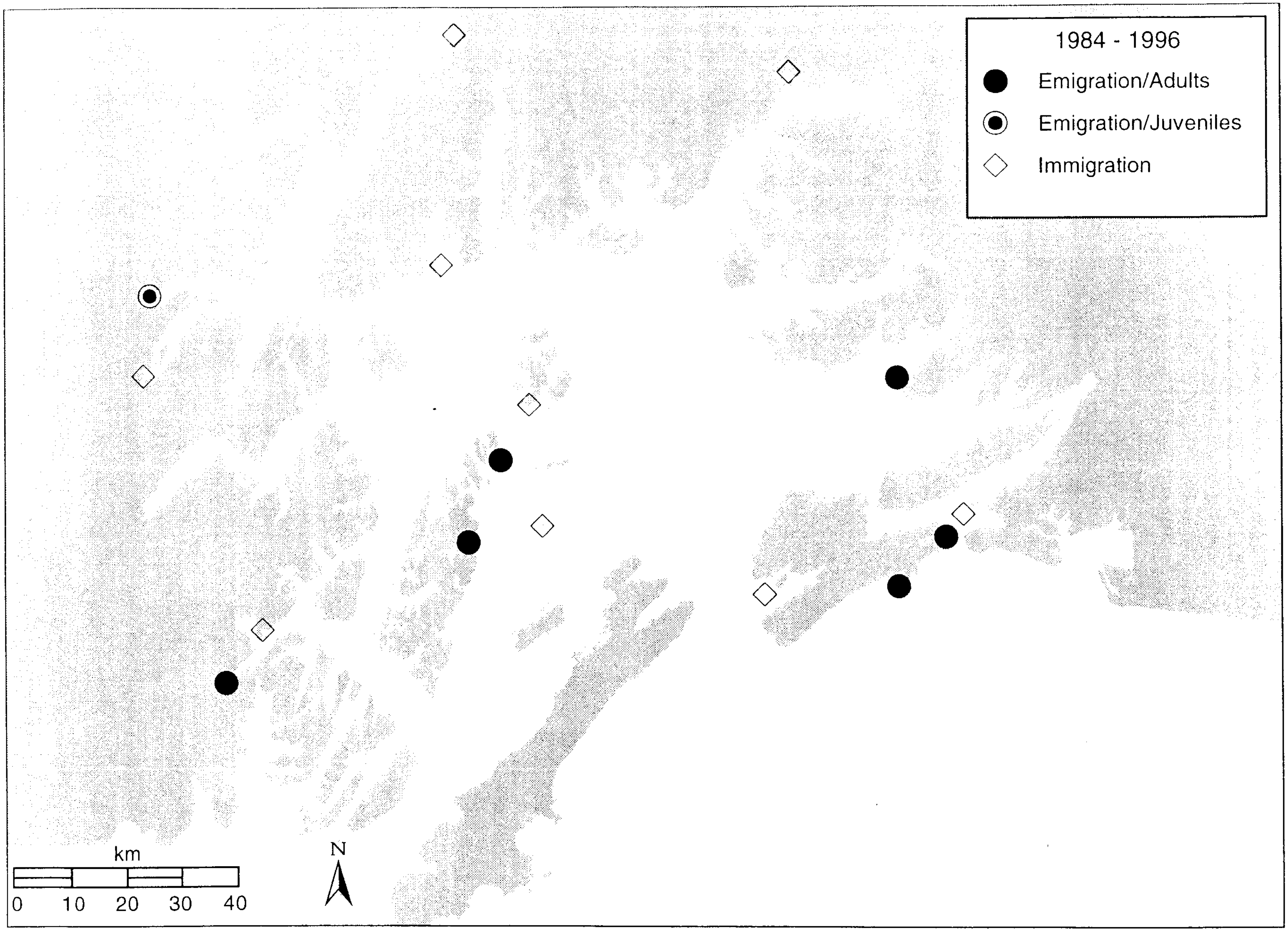
Table 2. Conceptual framework for estimating quality and abundance of prey available to kittiwakes based on measures (+:good, -: poor, =: average) of productivity, diet quality, chick growth, and trip distance (+:within estimated buffer, -:at or near limit of buffering ability).

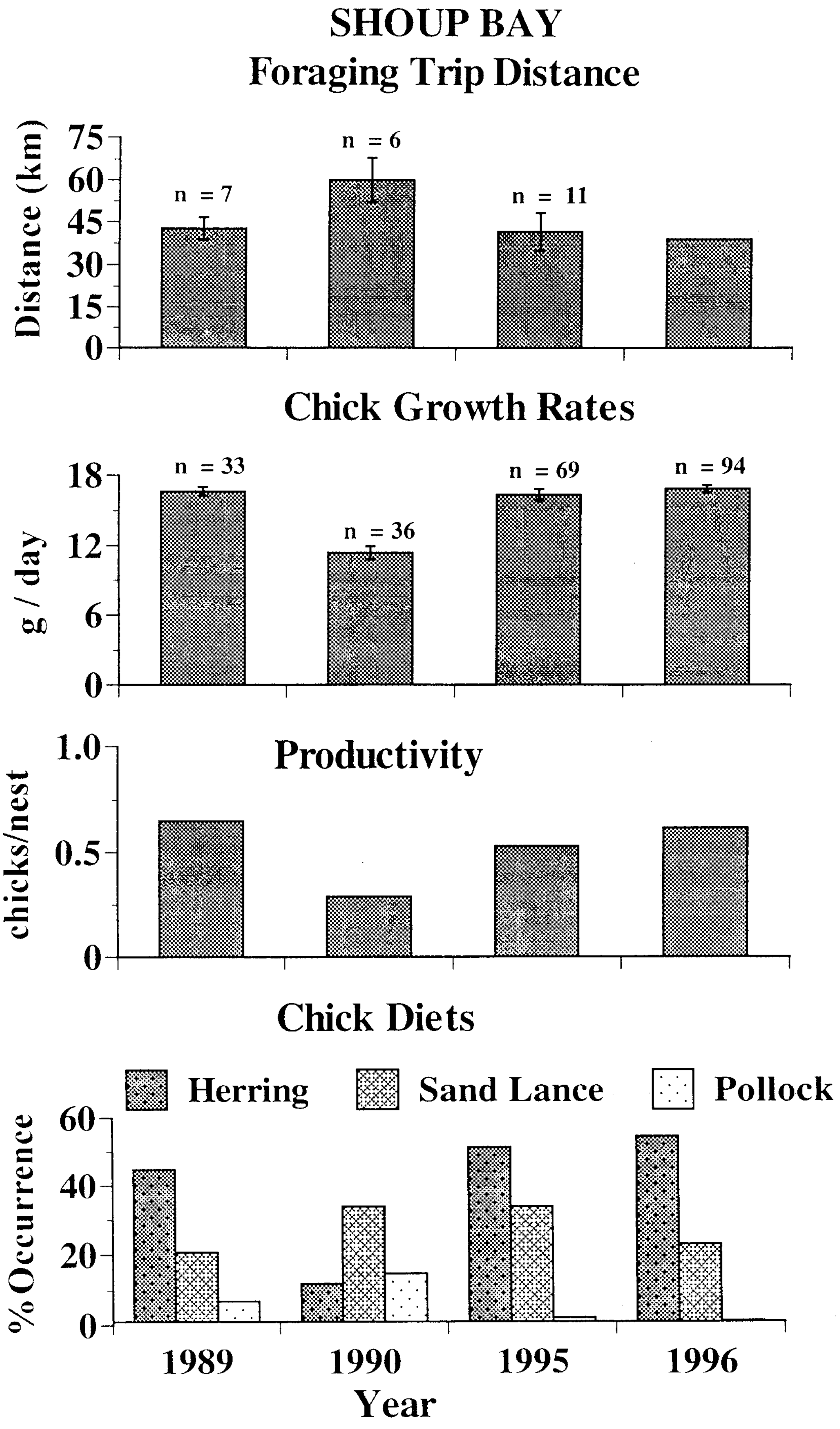
	Shoup '89, '95, '96 Eleanor '96	Eleanor '89, '95	North Icy Bay '96	Shoup '90
Productivity	+	-	-	-
Diet Quality	+	+	+	= -
Chick growth	+	+	+	-
Trip Distance	+	+	-	-
Estimated Prey Availability				
Quality	high	high	high	mod / low
Abundance	high	high	low	low
Comments		Not Food Related		

LIST OF FIGURES


Kittiwake Colonies
Shoup Bay
Eleanor Island
North Icy Bay
km
0
10
20
30
40
N
ALASKA
Prince William Sound


1984 - 1996
● Reproduction > Adult Mortality
◉ Reproduction = Adult Mortality
◎ Reproduction < Adult Mortality
Alaska Coastal Current
km
0
10
20
30
40
N


1984 - 1996
● Emigration/Adults
◉ Emigration/Juveniles
◇ Immigration
km
0
10
20
30
40
N



SHOUP BAY

Foraging Trip Distance

Chick Growth Rates

Productivity

Chick Diets

Figure 4

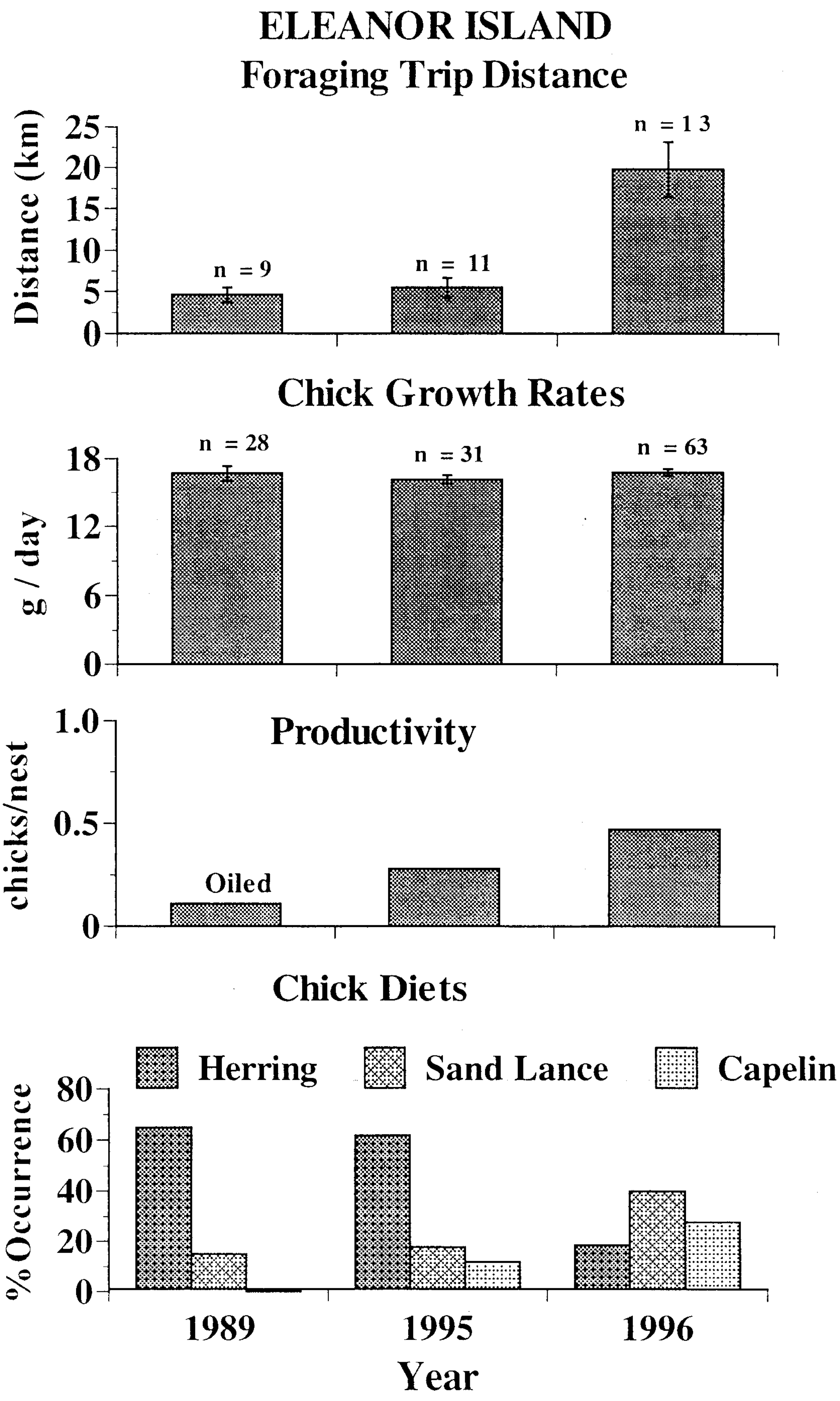

ELEANOR ISLAND
Foraging Trip Distance
Distance (km)
25
20
15
10
5
0
n = 9
n = 11
n = 13
Chick Growth Rates
g / day
18
12
6
0
n = 28
n = 31
n = 63
Productivity
chicks/nest
1.0
0.5
0
Oiled
Chick Diets
Herring
Sand Lance
Capelin
% Occurrence
80
60
40
20
0
1989
1995
1996
Year

Figure 5.

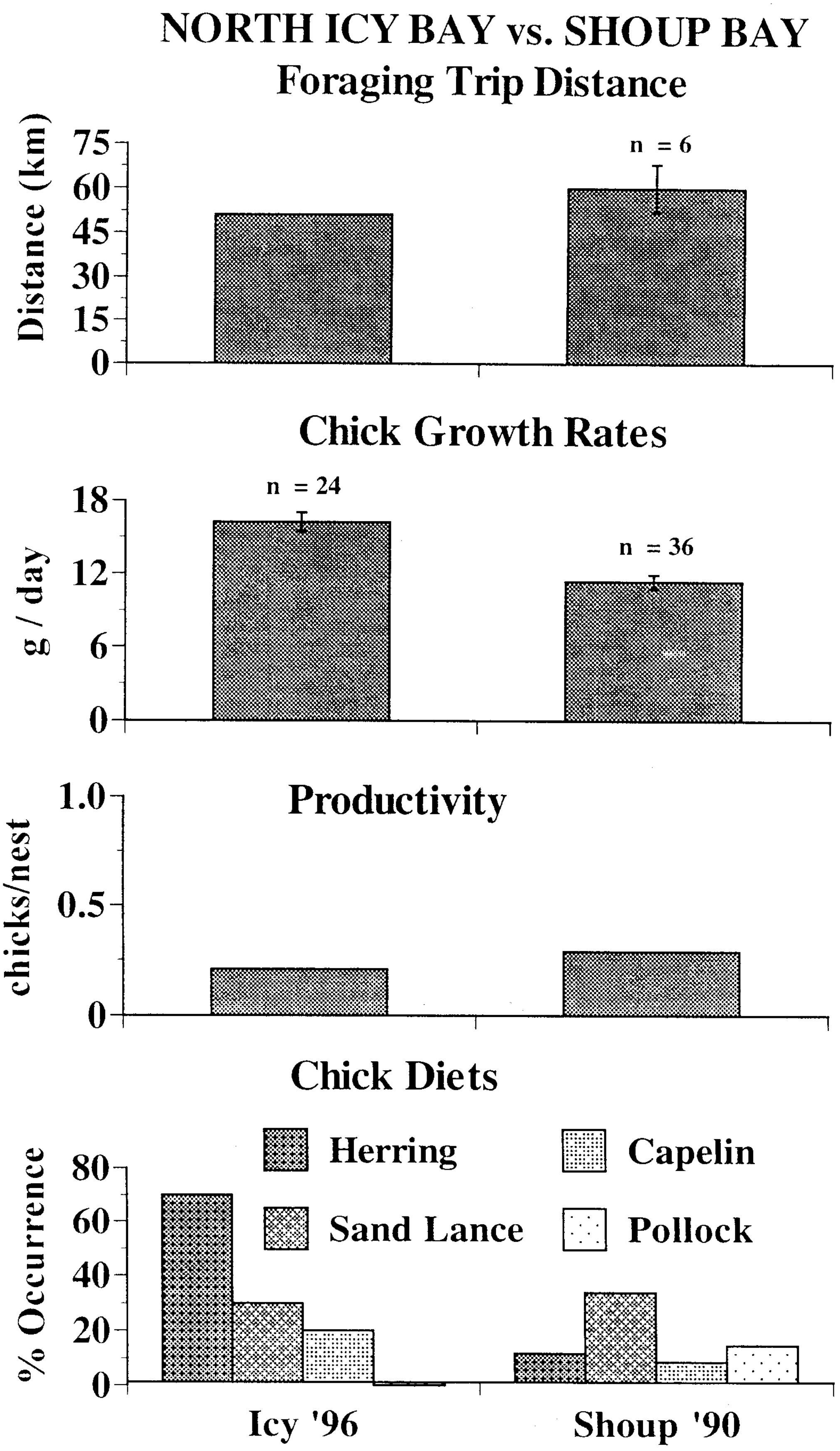
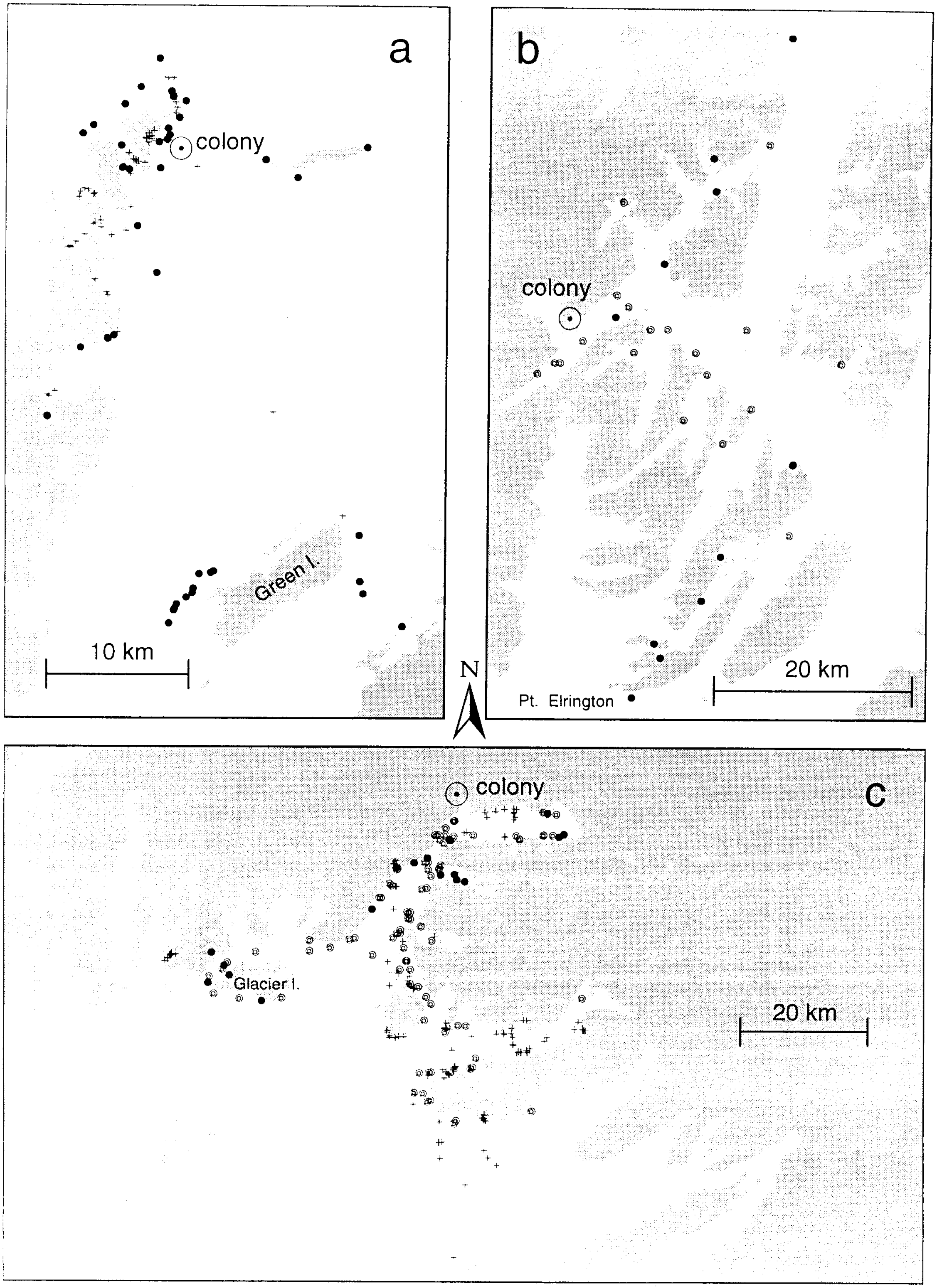

NORTH ICY BAY vs. SHOUP BAY
Foraging Trip Distance
Distance (km)
75
60
45
30
15
0
n = 6
Chick Growth Rates
g / day
18
12
6
0
n = 24
n = 36
Productivity
chicks/nest
1.0
0.5
0
Chick Diets
% Occurrence
80
60
40
20
0
Herring
Capelin
Sand Lance
Pollock
Icy '96
Shoup '90

Figure 6.


a
colony
Green I.
10 km
b
colony
20 km
Pt. Elrington
N
c
colony
Glacier I.
20 km

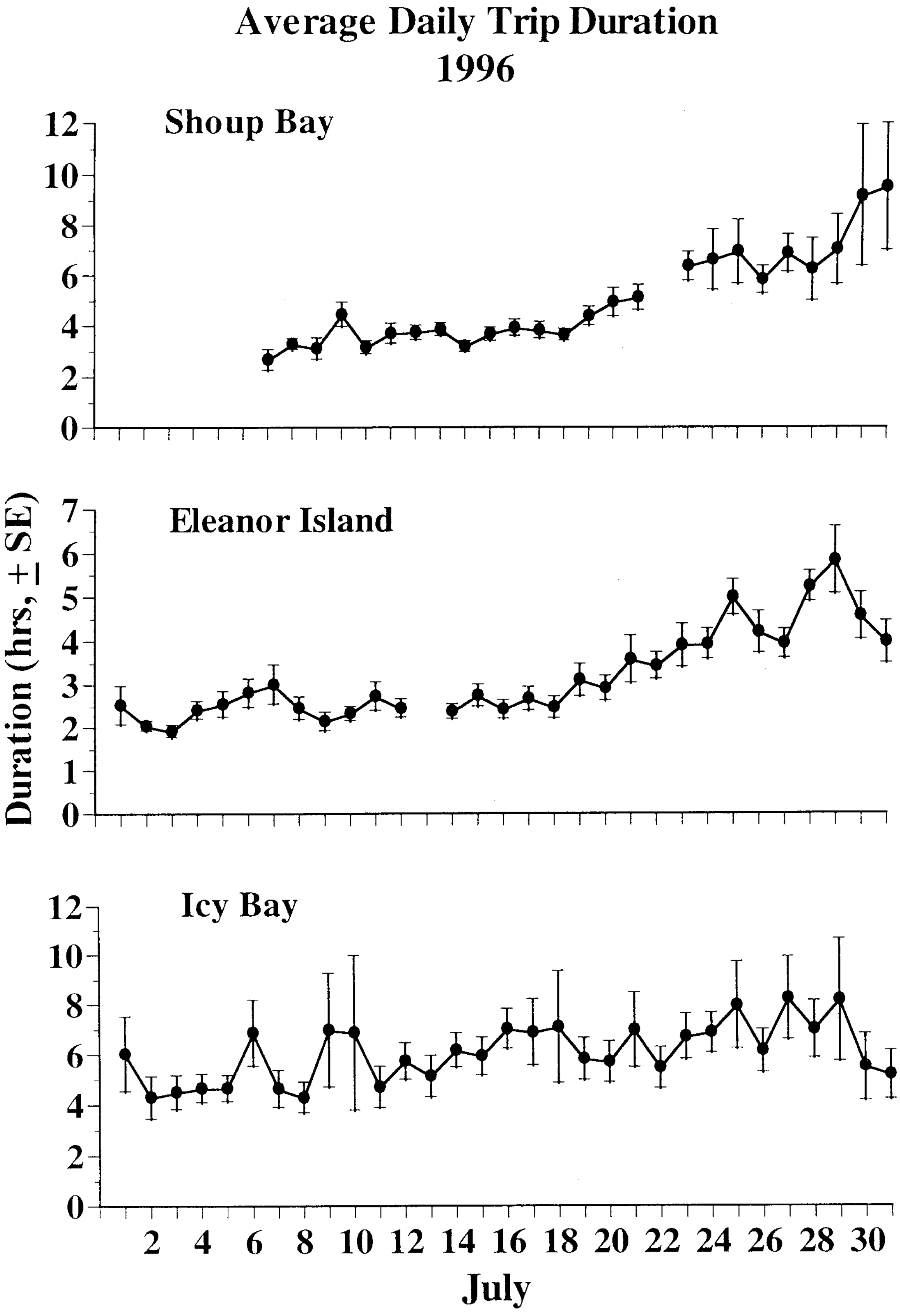

Average Daily Trip Duration
1996
Shoup Bay
Eleanor Island
Icy Bay
Duration (hrs, ± SE)
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
July

Figure 8.

Completed and Proposed Publication List for Irons and Suryan March 15, 1997

Completed

1. Foraging area fidelity of individual seabirds in relation to tidal cycles and flock feeding. (revision of diss. chapter). Revised for Ecology, Irons, March 1997

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3. Cost of chick-rearing in black-legged kittiwakes. Submitted to the J. Of Animal Ecology, Golet, Irons, Estes, March 1997

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11. Dispersal and recruitment rates of black-legged kittiwakes in PWS. Sauer, Irons, Suryan and Gilbert March 2000.

12. Change in kittiwake productivity in PWS, AK: a test of the river/lake hypothesis. Irons Duffy, Cooney, March 2000

13. Scales of variation in productivity and size of Gulf of Alaska black-legged kittiwake colonies. Condor, Irons, Suryan, Hatch, Piatt, Slater Nov 2000..

14. Relationship between forage fish abundance and kittiwake foraging behavior and reproductive performance. Condor, Irons, Suryan, Coyle, Halderson, March 2001.

15. Genetic structure of kittiwakes in the GOA. ?, Suryan, Irons, Hatch, Byrd, Piatt?

16. Observations of predation at PWS kittiwake colonies. Colonial Waterbirds, Suryan and Irons

Plus all the other publications that we are not first author on (Roby, Anthony, Ostrand, Duffy)

APPENDIX F

APEX: 96163F

The Breeding and Feeding Ecology of Pigeon Guillemots at Naked Island in Prince William Sound, Alaska

Results of the 1996 field season

APEX Component 96163F

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Study History: The field work for APEX subproject 96163F was conducted during the summer of 1996. Previous related field work was conducted during the summer of 1995 as part of APEX subproject 95163F. A similar effort was made in 1994 as Project 94173. Previous related projects have been funded by the Trustee Council. Oakley and Kuletz (1996) undertook a study in 1989-1990 to compare various population and reproductive parameters of pigeon guillemots before (Oakley and Kuletz 1979, Kuletz 1981, 1983, Oakley 1981) and after the spill. Also, Project 93034, an extensive survey of pigeon guillemot colonies throughout Prince William Sound, was conducted during the summer of 1993 (Sanger and Cody 1994).

Abstract: The objective of this component was to evaluate the breeding and feeding ecology of pigeon guillemots (*Cepphus columba*) with respect to the abundance and availability of forage fish in the near shore environment. We monitored the reproductive success of 50 guillemot nests at Naked Island, Prince William Sound. Data from numerous sources indicate that there has been a change in the Gulf of Alaska marine ecosystem that began around the late 1970s, which in turn has probably affected marine bird populations. The population of pigeon guillemots in Prince William Sound decreased from about 15,000 in the early 1970s to less than 5,000 in the 1990s. Study colonies at Naked Island and four neighboring islands in Prince William Sound have shown a similar trend since the late 1970s. During this period, the diet of pigeon guillemot chicks on Naked Island also changed. In the late 1970s Pacific sand lance (*Ammodytes hexapterus*), a schooling forage fish, dominated the chick diet. In the 1990s chick diet has been dominated by fish that live on or near the bottom, such as gunnels, pricklebacks, sculpins, and cod-like fish. The correlation between percent sand lance in the chick diet and the total guillemot population is strong, and we suggest that there is a link between the change in diet and the population decline.

Key Words: Alaska, *Ammodytes hexapterus,* breeding ecology, *Cepphus columba,* foraging ecology, Naked Island, oil spill, pigeon guillemot, population, predation, Prince William Sound, sand lance.

Project Data: Information was gathered on pigeon guillemot population and colony attendance, banding and morphometrics, nesting chronology and productivity. Also, chick provisioning, diet, growth, fledging weights, adult foraging effort, and fish types caught in traps and seines. The data is contained in either Paradox database, Quatro pro spreadsheet, or Word perfect programs, with accompanying graphs and figures. The permanent contact for the data is Dave Irons, 1011 East Tudor, Anchorage, Alaska, 99503. Phone: (907) 786-3376, Fax: (907) 786-3641. The data is available with permission.

Citation: Hayes, D.L. and T Spencer. 1997. The breeding and feeding ecology of pigeon guillemots at Naked Island in Prince William Sound, Alaska. Results of the 1996 field season, APEX Component 96163F, U.S. Fish and Wildlife Service, Anchorage,Alaska.

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Executive Summary

The objective of this component was to evaluate the breeding and feeding ecology of pigeon guillemots (*Cepphus columba*) with respect to the abundance and availability of forage fish in the near shore environment. We monitored the reproductive success of 50 guillemot nests at Naked Island, Prince William Sound. Using binoculars and spotting-scopes, we determined the diet of guillemot chicks by identifying fish carried to the nests by adult birds.

The population of pigeon guillemots in Prince William Sound decreased from about 15,000 in the early 1970s to less than 5,000 in the 1990s. Study colonies at Naked Island and four neighboring islands in Prince William Sound have shown a similar trend since the late 1970s. During this same period, the diet of pigeon guillemot chicks on Naked Island also changed. In the late 1970s Pacific sand lance (*Ammodytes hexapterus*), a schooling forage fish, dominated the chick diet. In the 1990s chick diet has been dominated by fish that live on or near the bottom, such as gunnels (*Pholididae*), pricklebacks (*Stichaeidae*), and sculpins (*Cottidae*). Also more prevalent are the cod-like fish (*Gadidae*) in chick diets. The correlation between percent sand lance in the chick diet and the total guillemot population is strong, and we suggest that there is a link between the change in diet and the population decline.

The productivity of guillemots at Naked Island was lower, but not significantly so, in the 1990s than it was in the late 1970s. After 1989, predation was more prevalent at our study colonies than it was previously, and was the cause of numerous failed nesting attempts. Guillemots at Naked Island are doing better than guillemots in other regions. The weighted average productivity of guillemots on Naked Island (0.81 fledgling/nest) is higher than the combined weighted average, from numerous studies, of guillemots in British Columbia, Washington, and Oregon (0.65 fledgling/nest). Thus low productivity for birds attempting to nest is not an obvious factor in the population decline in Prince William Sound.

Data from numerous sources indicate that there has been a change in the Gulf of Alaska marine ecosystem that began around the late 1970s, which in turn has probably affected marine bird populations. The populations of many species of piscivorous marine birds and mammals have declined in Prince William Sound since the early 1970s. This ecosystem shift and the accompanying changes in the food web may account for many of the observed population declines. Besides the 1989 oil spill, other possible contributing factors are winter mortality of adults and juveniles, and low proportions of birds attempting to breed. However, these factors are also likely food-related and thus linked to changes in the ecosystem.

In 1996, we observed more schools of sand lance and more seabird foraging flocks around Naked Island than in either of the two previous years. This may indicate a strong year class for sand lance and possibly future increases in their abundance. The percent of sand lance in the chick diet was 17% in 1996 compared to 10% for each of two the two previous years. This component of the APEX study will further investigate the link between the diet, population and productivity of guillemots and the abundance and distribution of forage fish in Prince William Sound.

The Breeding and Feeding Ecology of Pigeon Guillemots at Naked Island in Prince William Sound, Alaska

INTRODUCTION

During the 1996 breeding season, we studied the breeding and feeding ecology of pigeon guillemots nesting on Naked I. in the western part of Prince William Sound (PWS). Pigeon guillemots were chosen for study by Alaska Predator Ecosystem Experiment (APEX) and Nearshore Vertebrate Predator Project (NVP) because 1) they constitute an injured resource affected by the oil spill, 2) they forage near shore in shallow water on fish and invertebrates particularly vulnerable to oil accumulations, 3) there exists prespill data for this species in PWS, and 4) they are relatively easy to study for population, diet, and productivity data.

Pigeon guillemots (*Cepphus columba*) are cavity-nesting, pursuit-diving seabirds that forage mostly in the near shore environment on both demersal and schooling fish (Storer 1952). Guillemots nest in small scattered colonies or in solitary pairs in natural cavities along rocky shorelines. Unlike most other members of the family Alcidae, the pigeon guillemot typically lays a clutch of two eggs. The chicks are semiprecocial, usually spending about 35 to 45 days in the nest. During the daylight hours, they are fed by both parents, which return to the nest with one prey item (usually fish) at a time in their bills.

The population of pigeon guillemots in PWS has decreased from about 15,000 in the 1970's (Dwyer et al. ND) to less than 5,000 in the 1990's (Agler et al. 1994, Sanger and Cody 1994). There is some evidence suggesting that this population was in decline before the *T/V Exxon Valdez* oil spill in March of 1989 (Oakley and Kuletz 1996).

Demersal fish such as gunnels (Pholidae), pricklebacks (Stichaeidae), and sculpins (Cottidae) have always been an important component of chick diet, and their relative contribution has increased since 1989. The proportions of Gadidae and schooling fish such as Pacific herring (*Clupea harengus*) capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*) have varied widely from year to year.

Numerous studies have shown that changes in the availability of prey species can result in widespread reproductive failure of seabirds (Vermeer et al. 1979, Anderson et al. 1982, Springer et al. 1986, Safina et al. 1988, Uttley et al. 1989, Furness and Barrett 1991; but see Burger and Piatt 1990). We hypothesized that pigeon guillemot numbers may be limited by the availability of suitable forage fish such as Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea harengus*) and capelin (*Mallotus villosus*). Adult survival, recruitment, breeding, and foraging parameters were investigated to try and determine if food availibility is a limiting factor to overall populations. Although results are still preliminary and more data from future years is planned, the correlation between percent sand lance in the chick diet and the total guillemot population at Naked Island is strong, and we suggest that there is a link between the change in diet and the population decline.

OBJECTIVES

1. Determine if availability of food is limiting reproductive success of guillemots by collecting the following kinds of data:
    a. Measuring breeding parameters, including phenology, chick growth rates, fledging weights, and reproductive success at several colonies on Naked I.
    b. Measuring foraging parameters, including diet and provisioning rates of chicks, and locations of foraging areas.

METHODS

Study Area

Our field season extended from 6 June through 22 August 1996. All of our study colonies were located on Naked I. in PWS (Fig. 1). We chose Naked I. in 1994 as one of our principal study sites and as a base of operations because of the high number of breeding pigeon guillemots present (almost one third of the population in PWS) and the accessibility of the nest sites. Also it has an excellent anchorage and it had been used previously as a base camp for other guillemot studies (Eldridge and Kuletz 1980, Oakley 1981, Kuletz 1983, Oakley and Kuletz 1996). The camp has been used consectutive seasons since 1994. Naked I. (ca. 3,862 ha) has a maximum elevation of 400 m and is part of a group of three main islands. Much of the shoreline of Naked I. is characterized by low cliffs and cobble or boulder beaches; higher, steep, exposed cliffs occur along portions of the eastern shore. The island is forested to its summit; the principal species of tree are Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and mountain hemlock (*T. mertensiana*). Naked I. is part of the Chugach National Forest.

Naked I., about 30 km southwest of the site where the *T/V Exxon Valdez* ran aground on Bligh Reef, was one of the first areas to be oiled (see Fig. 1, Kuletz 1996:772). Between 27 March and 2 April, 1989, portions of the eastern, northern, and northwestern shorelines were oiled. The prevailing winds moved most of the oil to the south, away from the island, but between 7 and 9 April, southerly winds brought the oil into contact with the southern and western shorelines of Naked I. again.

Censusing: Population and Colony Attendance

Pigeon guillemot populations at Naked, Peak, Storey, Smith, and Little Smith Islands (the Naked Island complex, Fig. 1) were censused by circumnavigating each island in a small boat at a distance of between 50 m and 100 m from the shore when the weather was good and the tides were near high. We censused Naked I. on 7 June and the other islands of the complex on 8 June. These censuses were conducted at approximately the same time of day (0600-1200

Alaska Daylight Time) and at the same time of year that previous censuses of the this area were made. Also, throughout the breeding season, but mostly during the chick-rearing period, we counted the maximum number of guillemots present at a particular colony at 15-minute intervals whenever that colony was being monitored from a boat or a blind. To examine colony attendance as a function of time of day , we made two continuous 24-h watches at the Nomad colony (12-13 and 18-19 June) from noon to noon on each watch. Observation shifts were four hours.

Nest Sites and Monitoring

We monitored those nests used in 1994 and 1995 plus several new ones found during the 1996 breeding season. Most were at colonies along the western shoreline. Because of their inaccessibility or our inability to determine their contents, some of these nests were monitored only during feeding observations and were not used as part of our productivity sample. Nest sites were classified according to one of three types of habitat in which they occurred: tree root systems, rock crevices, or talus piles.

To reduce the risk of nest abandonment due to our activities, we checked nests at five-day intervals (less frequently than during previous seasons) until near fledging. When a chick reached an age of 30 days, then that nest was checked and the chick weighed and measured on a daily basis until it fledged.

Banding and Morphometrics

Some adults were caught by hand at the nest or with a mist net as they attempted to deliver food to their chicks. Adults were banded on the left foot with a USFWS metal band (bottom) and a color plastic cohort band (top), and on the right foot with a unique combination of two color plastic bands. Chicks were banded on the right foot with a USFWS metal band (bottom) and a color plastic cohort band (top) and on the left foot with a unique combination of two color plastic bands. The 1996 cohort plastic band was white.

We measured all adults that we handled and all accessible chicks. We measured maximum wing chord and length of the fifth and outer primaries with a rule to the nearest millimeter. We weighed birds with Pesola^{TM} spring scales (0-100 g x 1 g, 0-500 g x 5 g, or 0-1 kg x 10 g). Newly hatched chicks were marked on the right foot and on the down of their head with permanent markers to distinguish between alpha (first-hatched) and beta (second-hatched) chicks until they were large enough to be banded.

Nesting Chronology and Productivity

We did not have enough information on hatch dates to construct a complete nesting chronology as in previous years. However, we determined fledging dates for many chicks to within one day.

We estimated productivity only from those nests that were found in the egg stage and followed through fledging. During the incubation stage, a nest was considered to be active and included in our sample if it contained at least one egg and if an adult was seen in that nest at least once. If we knew two eggs had been laid in a nest but saw only one chick and no sign of the other egg, we assumed that both eggs hatched and one chick died. It seems unlikely that a predator entering an active nest would take only one egg and leave the other intact. Also, based on other guillemot studies (G. Divoky, pers. comm.; D.L. Hayes, pers. obs.), the proportion of two-egg nests in which only one egg hatches is fairly low.

Measures of productivity were defined as follows: hatching success (eggs hatched/eggs laid), fledging success (chicks fledged/eggs hatched), and overall productivity (chicks fledged/eggs laid). Thirty days is approximately the minimum time spent in the nest by guillemot chicks; the actual time is often much longer. For purposes of estimating fledging, however, any chick surviving in the nest for 30 days was assumed to have fledged. Other measures of productivity (mean clutch size, number of chicks hatched per nest, and number of chicks fledged per nest) were used for comparison with previous years' data from Naked I. and from other regions.

Predation

If eggs disappeared from nests between visits, we assumed that predation was the cause. If chicks too young to fledge (i.e., younger than 30 days) disappeared from nests between visits, we assumed predation was the cause only if we were reasonably certain that no chick was still in some hidden corner of the nest. In some instances, where the nest cavity was too long or labyrinthine, it was not possible to make this determination. If after repeated visits to this type of nest, we never saw the chick(s) again or never found direct evidence of predation, we listed the cause of failure as unknown.

Chick Growth and Fledging Weights

We calculated the growth rates of chicks as the change in body mass (g/d) during the linear phase of their growth, which is the period eight to 18 days after hatching (Koelink 1972). We estimated the age of some chicks by comparing their body mass to that of known-age chicks from the 1995 field season, or from other clues such as the appearance of the down. Fledging weight was assumed to be the last recorded weight of a chick that was measured within 24 hours of fledging.

Chick Provisioning and Diet

Either from blinds or from boats we observed adult guillemots bringing food items to their chicks throughout the chick-rearing period (total observation time = 256 h). Feeding watches ranged from 2 h to 18 h; shifts lasted up to 5 h. Usually only one observer was in the blind at a time. Binoculars and spotting scopes were used to identify prey items in the bills of guillemots to the lowest possible taxon or "type" of prey. When time and visibility permitted, we also estimated the length of the prey item as a multiple of the guillemot's bill to the nearest half-bill length. We recorded the time an adult returned to the colony with a fish or the time it was first seen with a fish on the water in front of the colony. We also recorded the time of each delivery and the number of the nest to which the prey was delivered. We obtained additional information about chick diet by retrieving fish found in the nests or by intercepting fish at or near the nest entrance with a mist net.

To test whether deliveries were distributed more or less evenly throughout the daylight hours, the day was divided into three equal periods: early (0600-1120), mid-day (1120-1640), and late (1640-2200). Although a few deliveries occurred very early and very late, when it was often too dark to make reliable observations, the period used for analysis was truncated at both ends in accordance with the times listed above. Using a Chi-square goodness-of-fit test, the actual number of deliveries observed during each of the three periods was compared to the expected number of deliveries in those periods if they had been distributed evenly throughout the day.

Provisioning rates were determined for chicks of 15-35 days of age at both one- and two-chick nests. Only deliveries recorded during continuous observations made between 0600 and 2200 were used in determining delivery rates.

Sampling of Fish

We occasionally sampled waters (< ca. 15 m) around Naked I. with fish traps set on or above the bottom to collect specimens for identification and laboratory analysis.

We used a beach seine at several beaches around the island (Fig. 1). Beach seining was conducted using a 14 ft inflatable boat. The net configuration was a 120 ft floating seine, 16 ft deep in the middle tapering to 5 ft at each end. Mesh size was 0.25 in the middle 30 feet and 0.5 in on the ends. Attached to each end was a bridle with a 110 ft length of .75 in polypropylene line. The net was usually deployed using the parallel method. This was accomplished by holding one length of the polypropylene line on shore while the boat reversed out 100 feet perpendicular to the shore. Then the net was set parallel to the shore and the trailing line brought back perpendicular to the shore. The net was pulled in evenly (two people on each end) to the beach. An alternative method (round haul) was sometimes used. One end of the net was anchored at the beach while the net was set perpendicular to the beach. While the outer end was still attached to the boat, the net was then swept through an arc of 90 degrees back to the beach. When space permitted, two sets on adjacent sections of shoreline were made. When large numbers of schooling fish were caught, numbers were estimated volumetrically with containers that held a known quantity of the fish. We kept subsamples from the fish traps and beach seines, releasing the remaining fish. We measured wet weight and standard length of all fish that were kept. Beach seine sets were usually made at or near high tide and at beaches having substrates not likely to snag the net as it was pulled in. The operation was not always smooth because of snagging or other problems and some schools may have escaped before we closed the net. Few benthic fish were caught in the nets, either because they could escape under the net, or because the beaches we selected were not the appropriate habitat. Therefore, results of beach seines should not be considered quantitative.

Data Analysis

Data from the 1996 field season were not compared statistically with that from any particular year in the past, but were tabulated with appropriate data from all previous years of study at Naked I. All means are reported as the mean plus or minus one standard deviation, unless otherwise noted. The level of significance was set at $\alpha = 0.05$.

RESULTS

Population Counts and Colony Attendance

In 1996, 809 pigeon guillemots were counted around the shorelines of the Naked Island complex during the censuses on 7 and 8 June (Table 1). Maximum counts of pigeon guillemots usually occurred in the early morning, shortly after first light, or sometimes later in the day at or around the high tide (Figures 2 and 3). After first light, the birds were typically detected in rafts a considerable distance from shore; then they gradually moved closer to the colony.

Nesting Chronology and Productivity

The median fledging date for guillemots on Naked I. in 1996 was 2 August (n = 30). The earliest fledging date was 27 July and the latest fledging date was 19 August.

The mean clutch size was 1.80 ± 0.38 (n = 41). Hatching success (chicks hatched/eggs laid) was 0.82. Of a total of 74 eggs, 61 hatched, three were depredated, three were abandoned, and seven were incubated but failed to hatch. Fledging success (chicks fledged/chicks hatched) was 0.49. Of a total of 61 chicks, 30 fledged, 11 were depredated, four were found dead in the nest, and the fate of 12 others was unknown (though predation was suspected for many of those). Four other chicks from two nests were found dead in the nest, their deaths probably being related to the death of a parent; an adult carcass with wounds to the neck was found in each of these nests. Overall productivity (chicks fledged/eggs laid) was 0.41. Twenty-three of the 41 nests (0.56) in our productivity sample at Naked I. produced at least one fledgling. The most successful type was rock crevice. The proportion of successful nests (i.e. those from which at least one chick fledged) for each nest type was as follows: rock crevice (15/23 = 0.65), tree root (6/12 = 0.50), and talus (2/6 = 0.33).

In 1996, the mean number of hatchlings per nest was 1.49 ± 0.12 (n =41) and the mean number of fledglings per nest was 0.73 ± 0.12 (n = 41). Mean clutch size and number of hatchlings per nest were slightly higher, while mean number of fledglings per nest was slightly lower than in 1995. These values are within the range of values reported for Naked I. in previous years (Table 2).

Predation

Of the 41 nests monitored from the egg stage through fledging, eggs were depredated in two and one or both chicks were depredated in nine. Also, of nine other nests that failed for unknown reasons, predation was suspected as the cause of failure for eight. Thus the predation rate was at least 27% and may have been as high as 46%. We observed other nests not in our productivity sample that also showed clear signs of predation. The Tuft colony at the southwest end of Naked I. was devastated by predation in 1996. At two nests, guillemot adults were found dead in the nest. The carcasses were intact except for small puncture wounds to the neck. In both nests, the chicks died too, in most instances probably from starvation, as the adult carcass was blocking the nest entrance. In one of these nests, however, one chick had also been bitten in the neck. Guillemots at the Tuft colony nest sympatrically with parakeet auklets (*Cyclorrhynchus psittacula*). Several auklet carcasses were found in the area, either intact, except for the head being cleanly chewed off, or with feathers scattered in the vicinity.

Chick Growth and Fledging Weights

The mean growth rate during the linear phase of growth (i.e. 8 - 18 days posthatch) of chicks at Naked I. was 20.9 ± 5.4 g/d (n = 20, range = 11.6 - 32.0 g/d; see Table 3 for comparison with growth rates from previous years). The mean fledging weight of chicks at Naked I. was 456 ± 58 g (n = 23, range = 328 - 560 g; see Table 4 for comparison with fledging weights from previous years).

Chick Provisioning

Collectively, guillemots delivered fish to their chicks throughout the daylight hours at Naked I. (n = 535 total, n = 492 between 0600 and 2200; Fig. 4). The distribution was not significantly different from a theoretical even distribution of deliveries made throughout the day ($\chi^2 = 3.671$, df = 2, $P > 0.10$).

Based on nine feeding observations lasting at least 17.5 h, delivery rates to guillemot nests ranged from 0.22 to 1.56/nest/h for chicks of any age. For chicks between the ages of 15 and 35 days, the mean delivery rate was 0.67 ± 0.16/nest/h (n = 10, range = 0.33 - 0.89/nest/h) to one-chick nests and 0.88 ± 0.34/nest/h (n = 13, range = 0.44 - 1.56/nest/h) to two-chick nests. At any particular nest, there were sometimes periods of several hours in which no deliveries were made.

The mean time that guillemots spent on the water between arrival at the colony with a fish and delivery of that fish was 13.5 minutes (SD = 19.5 minutes, range = 0 - 215 minutes, n = 650). The time between consecutive deliveries to the same nest was not considered.

Chick Diet

In 1996, the diet of pigeon guillemot chicks at Naked I. was dominated by demersal fish (Fig. 5). Schooling fish, mostly sand lance, accounted for about 21% of the chick diet. The proportions of sand lance, sculpins, and gadids in the chick diet was higher than in 1995, while the proportions of herring/smelt and blennies was lower. A relatively large proportion (ca. 22% in 1996) of fish could not be identified. Crescent gunnels, then sand lance were the most common types of fish recovered from, or intercepted at, the guillemot nests (Table 5).

Chick Diet Relative to Population Size

At Naked I., the percent of sand lance in the diet of chicks was positively related to the number of guillemots ($R^2 = 0.74$, $P = 0.013$; Fig. 6) over the years in which population and diet data was available. The number of active nests (R2 =n 0.69, $P = 0.010$; Fig. 7) was also positively related to the percent of sand lance in the diet.

Foraging

During observation periods, pigeon guillemots at Naked I. sometimes foraged directly in front of their colony in water less than 15 m deep. However, usually they flew out of sight to nearby bays or to the broad, shallow-water (< 25 m deep) shelf surrounding Naked I to forage. These distances were typically more than 2 kilometers away.

Fish Types Caught in Traps and Beach Seines

Shrimp (mostly *Pandalus danae* and *Eualus gaimardii*) were the most frequently taken animal in the fish traps at Naked I. Arctic shannies (*Stichaeus punctatus*) and crescent gunnels (*Pholis laeta*) were the most likely fish to be caught in traps, except when traps were set among some eel grass beds in Cabin Bay, where crescent gunnels and pricklebacks (*Lumpenus* spp.) were most commonly caught.

Relatively few benthic fish were caught with the beach seines. Sand lance, gadids (mostly Pacific Tomcod *Microgadus proximus*), and herring (*Clupea harengus*) were the most frequently caught fish with beach seines in descending order of frequency of occurrence (Table 6; see Fig. 1 for locations of beach seine sets).

DISCUSSION

Censusing

King and Sanger (1979) considered the pigeon guillemot to be one of the birds that is most vulnerable to oil spills because of its near shore foraging habits. Several studies have reported sublethal toxic effects of oil on marine birds (Peakall et al. 1980, Peakall et al. 1982, 1983 as cited in Oakley and Kuletz 1996). Marked declines in populations of the pigeon guillemot or its congener, the black guillemot (*C. grylle*) have been attributed to oil pollution (Ainley and Lewis 1974, Asbirk 1978, Ewins and Tasker 1985). Over 600 guillemot carcasses were recovered throughout the spill zone (135 in PWS) after the spill, but this might represent only 10-30% of the actual number killed (Piatt et al. 1990). Based on censuses taken around the Naked Island complex (Naked, Peak, Storey, Smith, and Little Smith Islands), prespill counts (ca. 2,000 guillemots) were roughly twice as high as postspill counts (ca. 1,000 guillemots; Oakley and Kuletz 1996). Also, on Naked I., the relative decline in the numbers of guillemots was greater along oiled shorelines than along unoiled shorelines (Oakley and Kuletz 1996).

However, censusing data in 1980 indicates that standardized early season counts of pigeon guillemots in the Naked Island complex suggest that their population had decreased considerably from counts in 1978 and 1979 before the oil spill (Table 1). This decline in guillemot numbers appears to be continuing through 1996 counts. Vermeer et al. (1993a) reported that the optimal time to determine the population of nesting guillemots was at high tide in the morning. Observed colony attendance patterns of guillemots at Naked I. during the 1994-

1996 seasons also indicate that the time of day can be important when conducting pigeon guillemot censuses. Replicate counts at the appropriate time of day and tidal cycle, and perhaps starting slightly earlier in the breeding season would increase our confidence in our estimates of the numbers of guillemots in the Naked Island complex.

Nesting Chronology

The median fledging date at Naked I. in 1996 was earlier than in 1995 and earlier than in 1994. Nesting chronology data obtained for black-legged kittiwakes (*Rissa tridactyla*) in PWS during the 1996 season indicate that the median hatching date for this species was earlier and the median fledging date was earlier than in 1995 (R. Suryan, pers. comm.).

Productivity

The ideal and most straightforward method of calculating productivity is from a sample of known nests that are followed from before egg-laying through fledging. We did have known nests on Naked I. that had been found in 1994 and 1995, but because of when we arrived at the study sites (6 June, when some eggs had already been laid), we had to include nests monitored from incubation through fledging as well. It is important to note that the nests used for measuring productivity do not constitute a "sample" in the true sense of the word. On Naked I., they represent all of the nests that we were able to find and then reach, not a random sample of nests on the island. We can only assume that they are fairly representative of the island as a whole.

Productivity (as measured by number of fledglings per nest) of pigeon guillemots at Naked I. in recent years is lower than what it was in the late 1970s (Table 2). After 1989, predation was more prevalent than it was previously, and was the cause of numerous failed nesting attempts. The weighted average productivity of guillemots for 10 years at Naked I. was 0.81 fledglings/nest (n = 215). The combined weighted average in British Columbia, Washington, and Oregon was 0.65 fledglings/nest (n = 941; Ewins 1993 and references therein). At the Farallon Islands off California, productivity averaged 0.9 fledglings/nest for a period of 13 years, but was extremely variable from year to year, the birds failing to breed in one of the years (Ainley and Boekelheide 1990). This comparison suggests that guillemots at Naked I. are doing relatively well compared to their conspecifics in other regions. However, the populations may be declining in these other regions as well.

In addition to predation, investigator disturbance may be responsible for some of the decline in productivity. More intensive research efforts at the Naked I. colonies in recent years have probably increased the level of disturbance. Several investigators at guillemot colonies elsewhere have observed reduced productivity that was apparently associated with human disturbance (Bergman 1971, Cairns 1980, Vermeer et al. 1993b).

Predation

Since the oil spill, and especially in the last few years, predation has become a factor contributing to the lower reproductive success of guillemots on Naked I. (Hayes 1995, 1996, Oakley and Kuletz 1996). Studies at other guillemot colonies have related lowered productivity or emigration to the presence of mammalian predators (Asbirk 1978, Petersen 1979, Cairns 1985, Ewins 1985, 1989).

Oakley and Kuletz (1996) noted that the primary difference in productivity of pigeon guillemots on Naked I. that they observed following the oil spill was lowered nesting success, which was the result of nest predation during the chick stage. Increased predation pressure relative to that in the past appears to be a continuing problem on Naked I. (Table 7).

Potential nest predators include the river otter (*Lutra canadensis*), mink (*Mustela vison*), northwestern crow (*Corvus caurinus*), common raven (*C. corax*), Steller's jay (*Cyanocitta stelleri*), glaucous-winged gull (*Larus glaucescens*), and black-billed magpie (*Pica pica*). Bald eagles (*Haliaeetus leucocephalus*), peregrine falcons (*Falco peregrinus*), and other raptors might be predatory on adult and fledgling guillemots.

Although we have witnessed only avian predation, the available evidence strongly suggests that mammalian predators are responsible for some of the disappearances of eggs or young guillemot chicks. River otters were seen frequently in the vicinity of our study colonies in all years and are the most likely mammalian predator, but evidence found in 1996 indicates that mink may also be involved. Intact carcasses of guillemot adults and chicks with wounds to the neck and headless carcasses of parakeet auklets in the same area are suggestive of mink predation. Ewins (1985) reported that on the island of Mousa in Shetland, otters (*Lutra lutra*) killed both chicks and incubating adults, and that decapitated carcasses were a sure sign of these predators. Ewins also noted that there were few nests inaccessible to them. Crows and magpies are the likeliest avian predators on eggs and chicks. Other studies indicate that crows are a major source of egg predation and sometimes take young chicks as well (Emms and Verbeek 1989, Ewins 1989). Adults, and especially fledglings, are probably sometimes taken by large raptors. Bald eagles are known predators of adult guillemots in British Columbia (Vermeer et al. 1989 as cited in Ewins et al. 1993). Beaks of guillemots were found beneath an eagle's nest on Naked I. during a previous study (K. Kuletz, pers. comm.). Predators can affect local population levels of guillemots (Asbirk 1978, Petersen 1979, Cairns 1984).

Chick Growth

In 1996, our estimates of growth rates (20.9 g/d) during the linear phase of growth were similar to those of Oakley and Kuletz (1996) at Naked I. (range = 16.6 - 23.8 g/d), as were our estimates of fledging weights. Growth rates were slightly higher than those reported by Koelink (1972) for Mandarte Island (15.9 g/d) and Ainley and Boekelheide (1990) for the Farallon Islands (16.5 g/d). It is important that caution be used when making comparisons based on these data; the sample sizes are relatively small in most instances.

Chick Provisioning

Members of the genus *Cepphus* typically lay two eggs. Most other alcids lay only a single egg, but the near-shore foraging habits of guillemots probably account for their ability to raise two chicks. Mehlum et al. (1993) maintain that long-distance foraging by black guillemots, which typically raise two-chick broods and have a high wing loading relative to most other seabirds, is too energetically demanding and might exceed their maximum sustainable working level. In Iceland, artificial triplets fledged at lower mean weights than chicks from normal broods (Petersen 1981 as cited in Harris and Birkhead 1985). Koelink (1972) argues this same point for chick-rearing pigeon guillemots. In his study, although artificial broods of three were successfully raised to fledging, there was a proportional decrease in the amount of food delivered per chick throughout the nestling period.

Our measured rates of food deliveries to individual nests (range = 0.33 - 0.89/nest/hr at one-chick nests; range = 0.44 - 1.56/nest/h at two-chick nests) are comparable to those of other studies of *Cepphus* guillemots (Thoresen and Booth 1958, Bergman 1971, Asbirk 1979 as cited in Harris and Birkhead 1985, Cairns 1981, 1987, Kuletz 1983). However the mean delivery rate of 0.67 ± 0.16/nest/h and (n = 10, range = 0.33 - 0.89/nest/h) to one-chick nests are somewhat lower than pre spill years. The values we used to calculate the means reported above represent minimum delivery rates as it is likely that we occasionally missed deliveries.

Foraging

The maximum diving depth of black guillemots is about 50 m (Piatt and Nettleship 1985). The pigeon guillemot probably has similar diving capabilities, and if foraging on benthic fish must be limited to using the broad, shallow-water shelf surrounding Naked I. and the neighboring islands (see Fig. 14 in Hayes 1995). Kuletz (1983) reported that the guillemots breeding on Naked I. generally foraged around the island, usually within about 600 m of the shore and in water shallower than 25 m. Benthic fish in this environment probably constitute a more dispersed though less ephemeral resource. In the absence of large schools of forage fish, guillemots might have to compete for these benthic resources. After numerous hours of observing guillemots on their foraging grounds, however, we saw few interactions between conspecifics that would suggest they were competing for a resource or defending a feeding territory.

At the Igloo colony on the east side of Naked I., we saw most of the adults flying away from the colony through the narrows between Naked and Peak Islands, presumably to forage. Most deliveries to the Igloo colony came from this direction and consisted of mostly demersal fish. This behavior seemed surprising to us because our regular beach seining efforts as well as anecdotal observations consistently indicated the presence of a large concentration of sand lance in MacPherson Bay just to the south of the Igloo colony. This suggests that guillemots have preferred foraging areas as noted with tagged birds in previous studies (Kuletz, 1983).

Chick Diet

Since the late 1970s and early 1980s there has been a dramatic change in the diet of pigeon guillemot chicks at Naked I. In the years 1979-1981 Pacific sand lance were the single largest component (42%) of the diet, while in the five years 1989-1990 and 1994-1996, sand lance accounted for a much smaller fraction (13%) of the diet. The increase in the proportion of gadids has been equally dramatic, from 4% to 21% for these same periods. Demersal fish such as gunnels (Pholidae), pricklebacks (Stichaeidae), and sculpins (Cottidae) have always been an important component of the diet although their relative contributions have varied widely from lance accounted for a much smaller fraction (13%) of the diet. The increase in the proportion of gadids has been equally dramatic, from 4% to 21% for these same periods. Demersal fish such as gunnels (Pholidae), pricklebacks (Stichaeidae), and sculpins (Cottidae) have always been an important component of the diet although their relative contributions have varied widely from year to year.

The proportion of high-quality forage fish such as sand lance, herring, capelin, and smelt in the diet of chicks might be related to the ephemeral nature of schools of these fish and their presence within the foraging range of guillemots. Their capture might occur only coincidentally when behavioral factors (e.g., spawning) or oceanographic factors (e.g., currents, up welling) bring these prey into shallower near shore waters. On a broader time scale though, these fish may not be as abundant in PWS as they were previously, suggesting that a possible shift in the marine ecosystem has occurred. Data from numerous sources indicate that there has been a change in the Gulf of Alaska marine ecosystem that began around the late 1970s, which in turn has probably affected marine bird populations (Piatt and Anderson 1996 and references therein).

Guillemots forage near their colonies and in shallow water less than about 50 meters. This limits foraging adults at Naked Is. to the broad, shallow-water shelves surrounding the Naked Island complex when foraging on demersal fish. Demersal fish in this limited area may not be abundant enough to support higher numbers of breeding guillemots (Hayes and Kuletz, 1996). When sand lance numbers are low, switching to alternate demersal prey species has allowed breeding Naked Is. guillemots to maintain their productivity. However, guillemot population declines appear to be related to availability or abundance of sand lance. This relationship between sand lance in chick diet and population suggest that availability of high-quality forage fishes are important for maintaining large, productive colonies of pigeon guillemots in Alaska (Hayes and Kuletz, 1996). Also, guillemots that specialized in sand lance (and perhaps other surface fish), did not easily switch to alternative prey, so as the availability of sand lance declined in the late 1980s, the guillemot population could not maintain historic numbers (Kuletz and Hayes, 1996).

Fish Types Caught in Traps and Seines

Although arctic shannies were the most common fish caught in the traps, they were infrequently seen being delivered to guillemot chicks and were not among the samples obtained at the nests. Aside from crescent gunnels,which were consistently captured, the catch in fish traps did not correlate to chick diet. Only when traps were placed in eel grass did the benthic fish captured (more gunnels and pricklebacks) resemble chick diets more closely. Schooling fish (mostly sand lance) dominated the catch in beach seine sets. Over 20% of chick diets for Naked Island included schooling fish, so the correlation between seine catch and diet seems better. However, because of bias in sampling due to problems retaining fish (especially benthic) in the seine, overall abundance of species can not be inferred from this.

Compared to other areas with long stretches of sand or gravel beaches, the shoreline of Naked I. had few beaches suitable for seining. If seining is continued in the future around Naked I., we suggest that it be limited to locations A, B, C, F, and possibly I (Fig. 1). The substrate at these beaches seemed relatively suitable for seining and fish were frequently caught when we seined there. The other beaches either yielded very little fish or the substrate was such that it was particularly difficult to seine there and the chance of fish escaping was high.

CONCLUSIONS

The population of pigeon guillemots at Naked I. and four neighboring islands have shown a decreasing trend since the late 1970s similar to that of PWS guillemot population. During this same period, the diet of pigeon guillemot chicks on Naked I. also changed from one that was previously dominated by sand lance to one that is now dominated by demersal fish. We believe there may be a link between the change in chick diet and the population decline.

The productivity of pigeon guillemots was lower, but not significantly so, in the 1990s than it was in the late 1970s. After 1989, predation was more prevalent at our study colonies than it was previously, and was the cause of numerous nesting failures. However, the pigeon guillemots on Naked I. appear to be doing better than their conspecifics in other regions. Thus low productivity is not likely to be the cause of the population decline.

The Gulf of Alaska ecosystem shift may account for the observed decline in populations of pigeon guillemots and other piscivorous marine birds. Switching to alternate prey species, however, has allowed remaining guillemots at Naked I. to maintain their productivity. Chick diet, seine attempts, aerial surveys by Evelyn Brown, and anecdotal evidence indicate an increase in the numbers of sand lance around Naked Island. If the trend continues, we can track this sand lance increase and see if the population of guillemots changes in response to it. Also, if the guillemot population does increase with increasing sand lance abundance, we can monitor if and when they reach historical population levels.

ACKNOWLEDGMENTS

We thank Mark Russell and Bryan Duggan for their help in the field and Burt Pratte for help with logistics during the 1996 field season. The U.S. Forest Service granted us permission to use Naked Island as our base of operations while in the field. We also thank Steve Kendall for making the maps. Discussions with David Duffy, George Divoky, David Irons, Kathy Kuletz, and Dan Roby regarding various aspects of this project have been most helpful.

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Kuletz, K.. Personal communication.

Suryan, R.. Personal communication.

FIGURE CAPTIONS FOR 1996 APEX GUILLEMOT REPORT

Figure 1. Naked Island complex (Naked, Peak, Storey, Smith, and Little Smith Islands), Prince William Sound, Alaska. Distribution of pigeon guillemot study colonies (circles) and beach seining locations (triangles) on Naked Island. Study colonies: Igloo (1), Nomad (2), Thumb (3), Row (4), North Cabin (5), South Cabin (6), Outer Cabin (7), North Outside (8), Inside Outside (9), Hook (10), Tuft (11). Beach seining locations: MacPherson Isthmus (A), MacPherson Narrows (B), East Bob Day Bay (C), North Cabin Bay (D), Division Point (E), Fuel Cache Beach (F), Outer Cabin Bay (G), Outer Cabin Point (H), Inside Outside Bay (I), East Outside Bay (J), West Outside Bay (K), and Hook II (L).

Figure 2. Attendance patterns of pigeon guillemots at Nomad and Thumb colonies on Naked Island, Prince William Sound, Alaska (12-13 June, 1996).

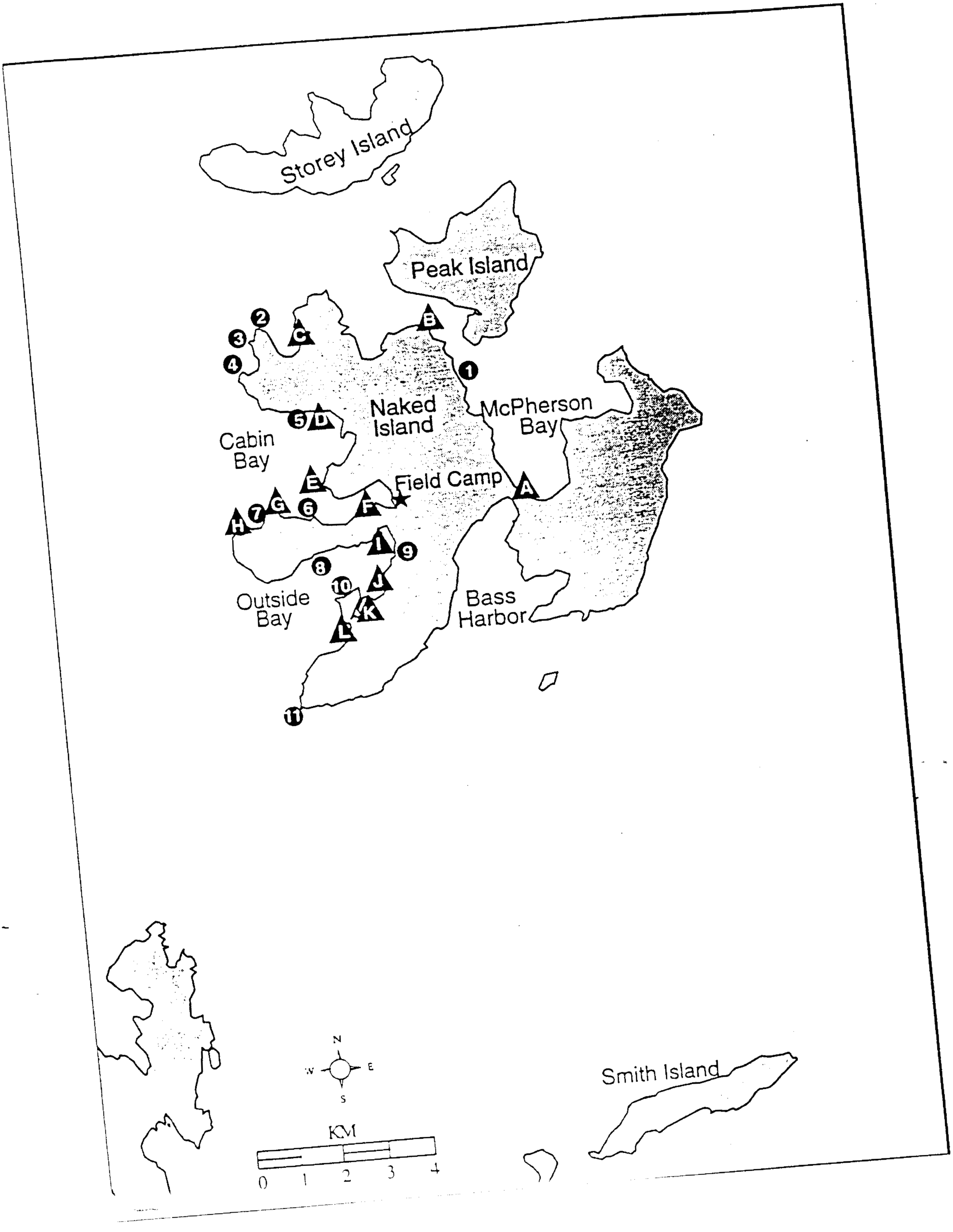
Figure 3. Attendance patterns of pigeon guillemots at Nomad and Thumb colonies on Naked Island, Prince William Sound, Alaska (18-19 June, 1996).

Figure 4. Temporal distribution of food deliveries (n = 535) by adult pigeon guillemots at several colonies on Naked Island, Prince William Sound, Alaska. Observations made between 3 July and 7 August, 1996 (9 colony-days, 43 nest-days). Sampling effort was not equal for periods before 0600 and after 2200.

Figure 5. Diet history of pigeon guillemot chicks on Naked Island, Prince William Sound, Alaska. Numbers above bars are sample sizes. Blennies include mostly gunnels and pricklebacks. Other includes flatfish, greenling, sandfish, rockfish, and a few other types.

Figure 6. Regression of pigeon guillemot population on percent of sand lance in chick diet for Naked Island, Prince William Sound, Alaska.

Figure 7. Regression of number of active pigeon guillemot nests on percent of sand lance in chick diet for Naked Island, Prince William Sound, Alaska.


Storey Island
Peak Island
Naked Island
McPherson Bay
Cabin Bay
Field Camp
Outside Bay
Bass Harbor
Smith Island
A
B
C
D
E
F
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H
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K
L
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1
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3
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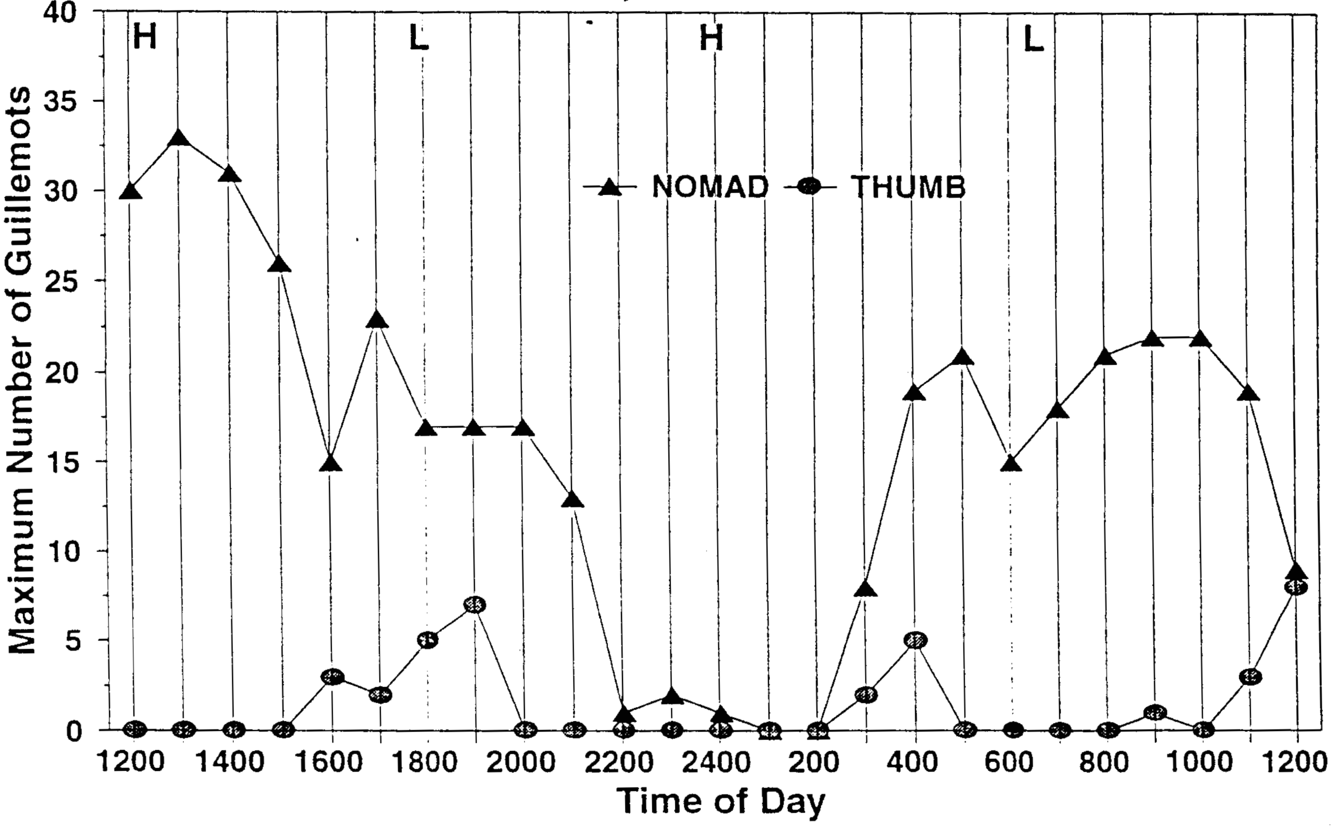
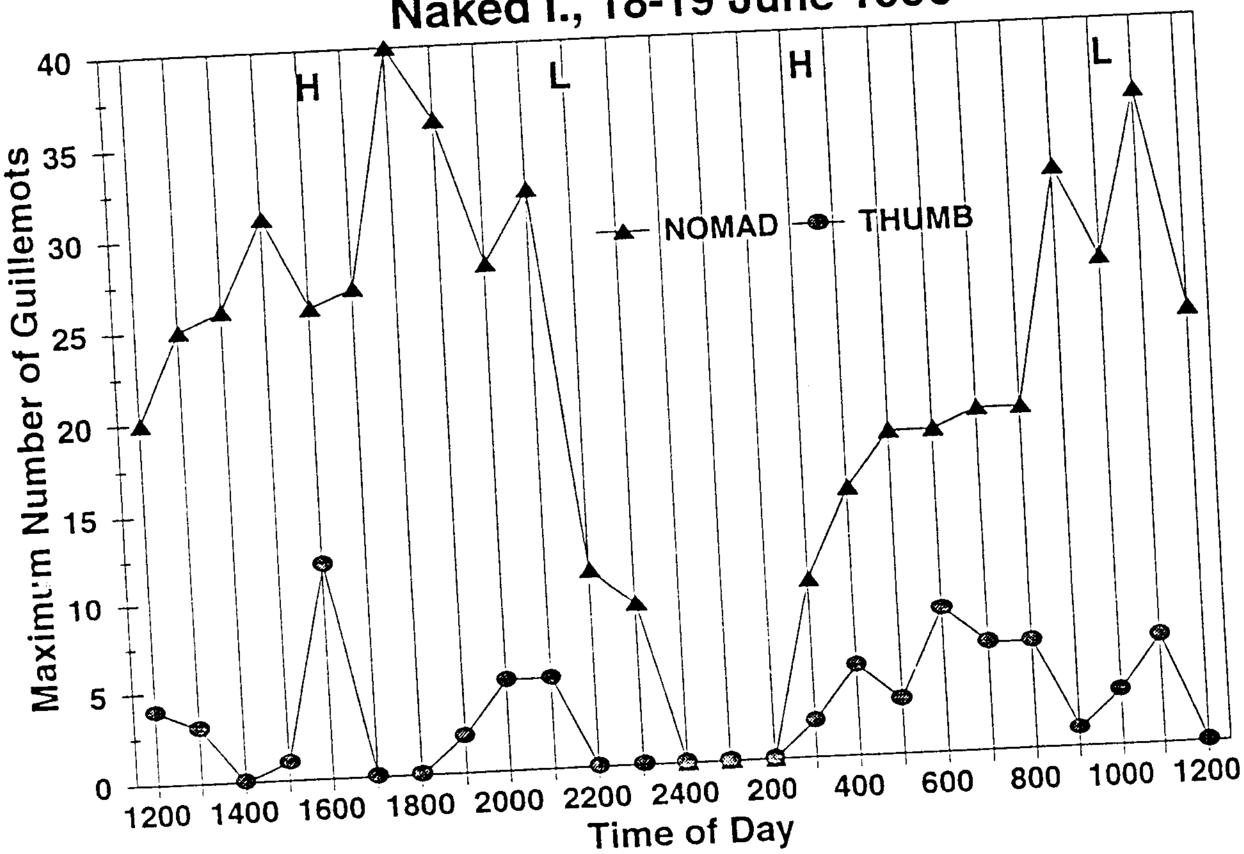
Colony Attendance

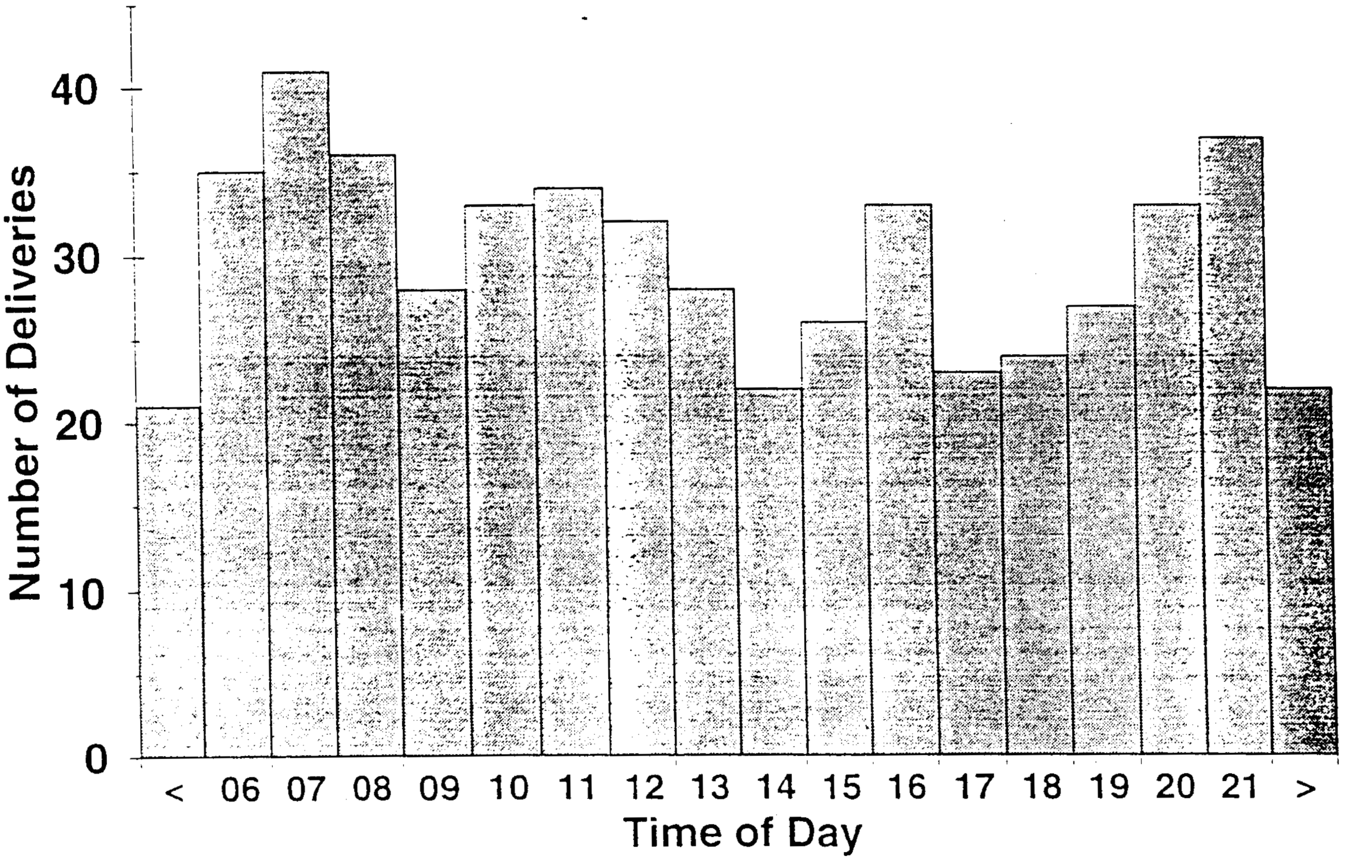
Naked I., 12-13 June 1996



Colony Attendance

Naked I., 18-19 June 1996

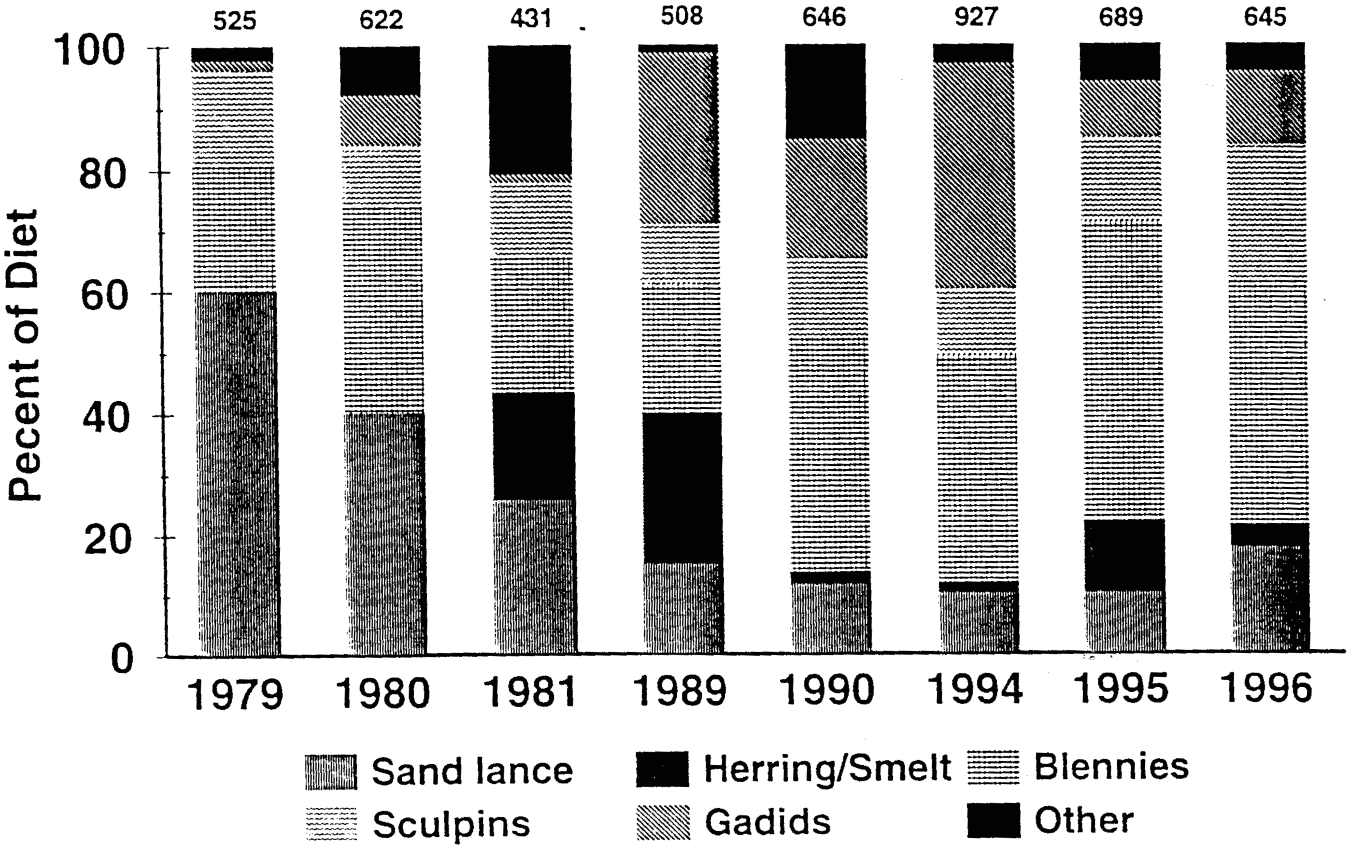


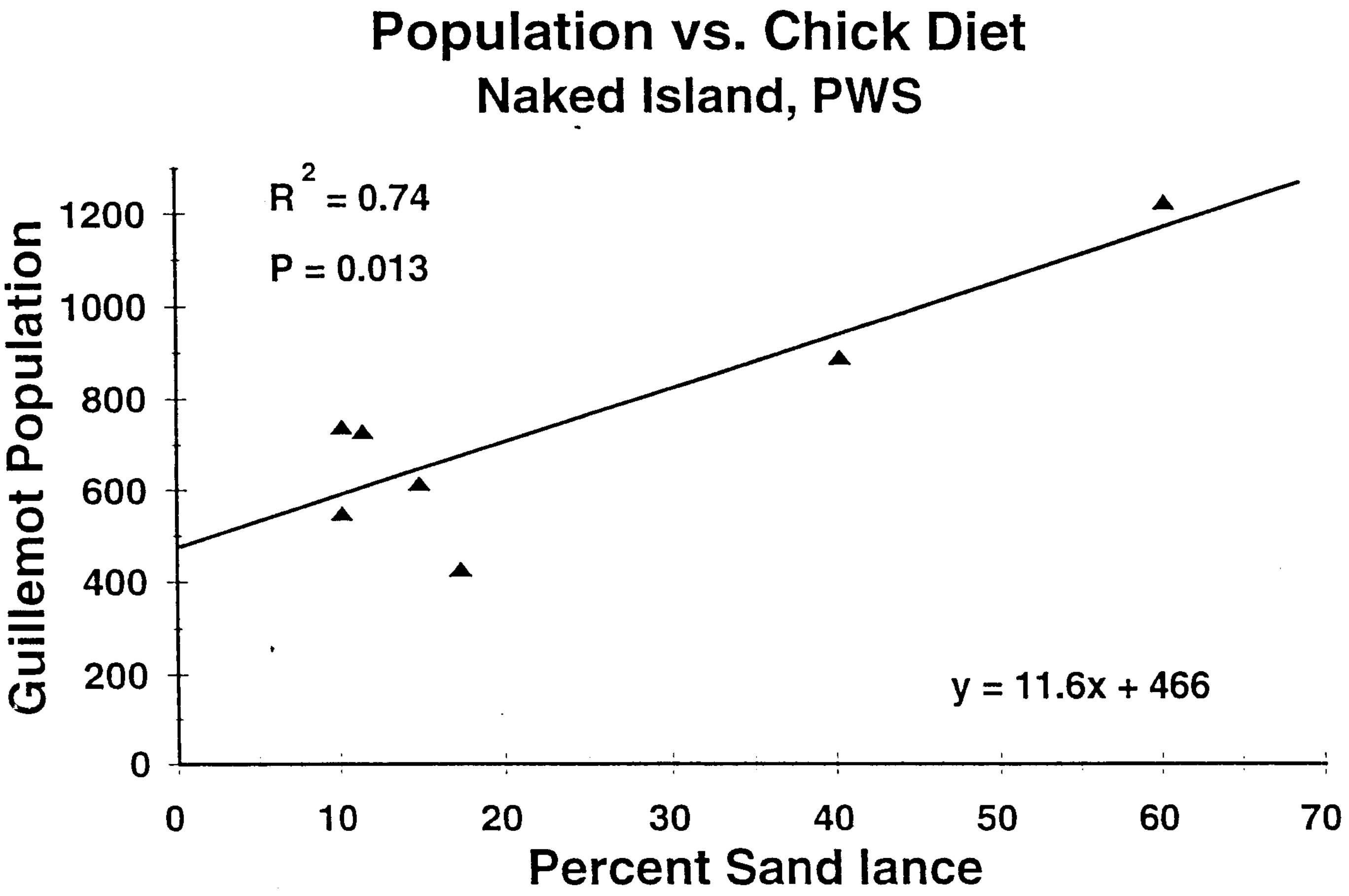


Temporal Distribution of Deliveries

Naked Island -- 1996

Pigeon Guillemot Chick Diet
Naked Island, PWS




Population vs. Chick Diet
Naked Island, PWS
$R^2 = 0.74$
P = 0.013
y = 11.6x + 466
Guillemot Population
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
Percent Sand lance

Active Nests vs. Chick Diet
Naked Island, PWS

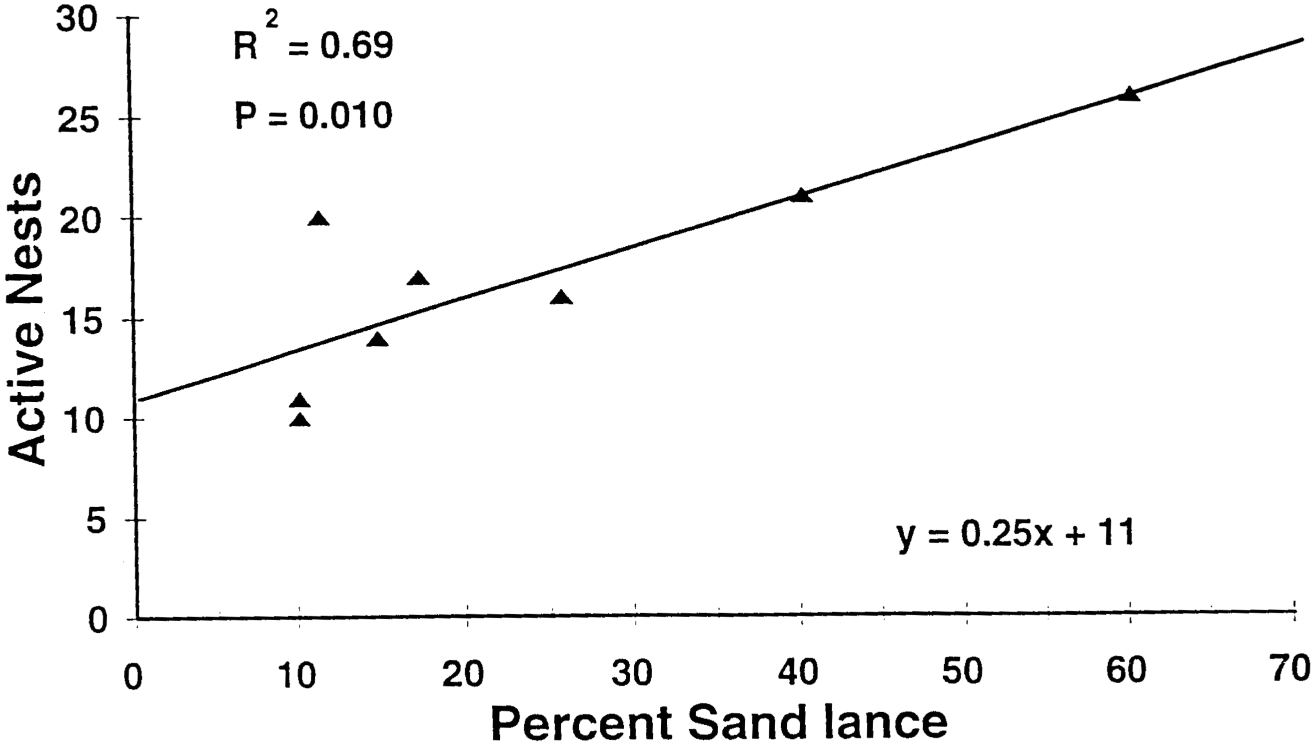


Table 1. Counts of pigeon guillemots during early season censuses at Naked, Peak, Storey, Smith, and Little Smith Islands, Prince William Sound, Alaska. Censuses conducted in the morning between 30 May and 14 June unless otherwise noted. Dashes indicate no surveys were conducted.

Year	Naked Island	Storey Island	Peak Island	Smith Island	Little Smith Island	Total
1978	1115	392	94	175	72	1848
1979	1226	495	150	301	58	2230
1980	891	--	--	--	--	--
1989	615	193	73	--	--	--
1990	729	293	102	124	31	1279
1991	755	293	102	76	35	1261
1992	586	266	87	100	23	1062
1993[a]	385	242	94	75	32	828
1994	739	298	81	121	23	1262
1995	550	165	38	111	23	887
1996	428	185	57	116	23	809

[a] Not all counts made in the morning.

Note: Data for 1978-1992 from Table 1 (Oakley and Kuletz 1996).

Table 2. Mean clutch size, mean rates of hatching (hatchlings/nest) and fledging (fledgings/nest) of pigeon guillemots on Naked Island, Prince William Sound, Alaska.

	Clutch Size			Hatching Success			Fledging Success		
Year	Mean	n	SE	Mean	n	SE	Mean	n	SE
1978	1.54	13	0.14	1.22	9	0.28	1.25	8	0.20
1979	1.85	33	0.06	1.34	32	0.15	1.13	30	0.13
1980	1.78	27	0.08	1.05	20	0.20	0.61	18	0.20
1981	1.59	22	0.11	1.14	21	0.17	0.74	19	0.17
1984	1.86	7	0.14	1.43	7	0.37	1.00	7	0.28
1989	1.57	7	0.20	1.43	7	0.30	0.50	6	0.34
1990	1.78	27	0.10	1.28	25	0.16	0.68	24	0.16
1994	1.70	23	0.10	1.52	23	0.15	0.78	23	0.17
1995	1.77	39	0.07	1.41	39	0.13	0.77	39	0.13
1996	1.80	41	0.06	1.49	41	0.12	0.73	41	0.12

Table 3. Growth rates of pigeon guillemot chicks raised on Naked Island, Prince William Sound, Alaska.

Year	Number of Chicks	Mean Growth Rate (g/d)[a]	SE	Minimum Growth Rate (g/d)[a]	Maximum Growth Rate (g/d)[a]
1978	15	19.6	1.4	7.4	31.7
1979	16	23.8	1.2	17.1	32.0
1981	11	19.2	1.8	11.4	34.3
1989	5	18.1	2.5	11.5	23.4
1990	12	16.6	1.2	10.1	23.6
1994	10	15.7	2.1	5.0	29.0
1995	13	19.5	1.2	11.8	26.7
1996	20	20.9	1.2	11.6	32.0

[a] Mean number of grams gained per day during the linear phase of growth (8-18 days posthatching; Koelink 1972).

Table 4. Fledging weights[a] of pigeon guillemot chicks raised on Naked Island, Prince William Sound, Alaska.

Year	Number of Chicks	Mean Fledging Weight (g)	SE	Minimum Fledging Weight (g)	Maximum Fledging Weight(g)
1978	29	467	9	291	542
1979	17	506	12	427	590
1980	2	517	52	466	569
1981	13	428	29	202	546
1989	10	507	16	420	570
1990	13	438	16	310	510
1994	17	453	13	357	525
1995	22	455	16	311	561
1996	23	456	12	328	560

[a] Fledging weight was considered to be the last weight obtained within one week (1978-1994) and within 24 hours (1995-1996) of fledging.

Table 5. Types of fish and numbers (n=67) recovered from or intercepted at guillemot nests on Naked Island, Prince William Sound, Alaska, in 1996.

Pacific Sand Lance (*Ammodytes hexapterus*)	13
Slender Eelblenny (*Lumpenus fabricii*)	3
Crescent Gunnel (*Pholis laeta*)[a]	24
Daubed Shanny (*Lumpenus maculatus*)	3
Snake Prickleback (*Lumpenus sagitta*)	5
Black Prickleback (*Xiphister atropurpureus*)	1
Ribbed Sculpin (*Triglops pingeli*)	1
Lingcod (*Ophiodon elongatus*)	1
Pacific Sandfish (*Trichodon trichodon*)	1
Shrimp (*Pandalus* sp.)	1
Walleye Pollock (*Theragra chalcogramma*)	2
Rex Sole (*Glyptocephalus zachirus*)	3
Northern Ronquil (*Ronquilus jordani*)	1
Slim Sculpin (*Radulinus asprellus*)	1
Tidepool Sculpin (*Oligocottus maculosus*)	6
Plain Sculpin (*Myoxocephalus jaok*)	1

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[a] Most Crescent Gunnels were collected from the same nest (NO1 in Outside Bay).

Table 6. Fish caught in beach seine sets made around Naked Island, Prince William Sound, Alaska, in 1996. SAN=sand lance, GAD=gadids, SAL=salmonids, SND=sandfish, HEX=Hexagrammidae, HER=herring, SCU=sculpins. See Figure 1 for locations.

LOCATION	TIME	SAN	GAD	SAL	SND	HEX	HER	SCU	OTHER
A									
06 JUL	1520	3100							1
01 AUG	1445	2					12	3	
13 AUG	1750	3385	1					1	
B									
01 AUG	1601	29					62		
13 AUG	1830	7				2	78		5
C									
01 AUG	1320	3					79		
D									
14 JUL	1625		1	3		1			
E									
14 JUL	1550	1							
F									
28 JUN	1630		7	141				2	2
14 JUL	0950	1	4	1	3			1	3
21 JUL	2000	97						4	1
22 JUL	0815	46						2	1
22 JUL	1205	18	2	3		1			8
22 JUL	1605	10000							
22 JUL	1955	31							
27 JUL	1035	5500							
13 AUG	1940	3				1			3
G									
14 JUL	1530	7			2		1		
H									
27 JUL	1126			3					
I									
14 JUL	1215		61		106	17	2	1	
28 JUL	1927		417	1	1	18			19
J									
28 JUL	1835		2	1	3			1	4
K									
28 JUL	1900								0
L									
14 JUL	1110			2					
28 JUL	1755								1
Total		22230	495	155	115	40	234	15	48

Table 7. Causes of nesting failure of pigeon guillemots at Naked Island, Prince William Sound, Alaska.

Year	Number of Nests	Unhatched Egg[a]	Young Chick Death[b]	Predation of Egg	Predation of Chick	Starvation or Exposure	Unknown Reason
		Number of nests in which at least one egg failed to hatch or at least one chick failed to fledge.					
1978	32	4	0	0	0	0	2
1979	30	6	1	2	1	1	4
1980	19	5	0	2	0	4	2
1981	22	6	1	2	0	6	0
1989	15	3	1	1	4	0	0
1990	38	2	1	3	4	1	5
1994	23	1	1	2	7	1	4
1995	39	7	2	3	1	3	9[c]
1996	41	7	0	2	9	1	9[d]

[a] Includes eggs which failed to hatch due to infertility, embryo death, or nest desertion.

[b] Refers to chicks, less than one week old, dying in the nest for no apparent reason.

[c] Predation suspected in 8 instances.

[d] Predation suspected in 6 instances.

APPENDIX G

APEX: 96163G

Exxon Valdez Oil Spill
Restoration Project Annual Report

Diet Composition, Reproductive Energetics, and Productivity of Seabirds Damaged by the *Exxon Valdez* Oil Spill

Restoration Project 96163 G

Annual Report

Start-up Date: April 1996

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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March 1997

STUDY HISTORY

Restoration Project 96163 G is similar to the research described in the original proposal submitted as 95118-BAA to be a component of the Alaska Predator Ecosystem Experiment Project (APEX), for which funding was first approved by the Trustee Council in April 1995. This research examines the effects of diet composition on the reproductive energetics and productivity of piscivorous seabirds in the northern Gulf of Alaska. Black-legged kittiwakes, pigeon guillemots, and tufted puffins were studied as bioindicators of the distribution and abundance of forage fishes to further understand the recovery of injured seabird resources. Study sites were at Shoup Bay, and Eleanor, Naked, Jackpot, and Seal islands in Prince William Sound and at Kachemak Bay, Gull, Chisik, and the Barren islands in Lower Cook Inlet. In 1996, this research continued without the tufted puffin component and with the shift from Seal Island to North Icy Bay for black-legged kittiwakes. To date, this project has produced new information advancing our knowledge of the comparative biochemical composition and physiological condition of forage fishes available to seabird, marine mammal, fish, and human predators; the influence of location, age, gender, and reproductive status on the nutritional quality of forage fishes; foraging strategy responses of breeding seabirds to shifts in prey availability; and the energetic consequences of foraging on different prey with different energy contents.

ABSTRACT

A shift in marine trophic structure of the *Exxon Valdez* oil spill (EVOS) area may have prevented recovery of injured seabird resources, especially pigeon guillemots, common murres, and marbled murrelets. We studied potential energetic factors (diet composition, diet quality, meal size, delivery rate) constraining seabird productivity in the EVOS area, focusing on pigeon guillemots and black-legged kittiwakes in oiled, non-oiled, and reference sites. Lipid content of fish prey in diets varied from 3% dry mass in juvenile walleye pollock to 48% in some juvenile herring. Seabirds can potentially experience a four-fold difference in energy intake based on fish quality. Guillemots preyed mostly on blennies and sculpins at Naked Island, herring at Jackpot Island, and sandlance and blennies at Kachemak Bay. Coincident with less sandlance in the diet, guillemot growth performance at Kachemak Bay declined in 1996 compared to 1995, and was not different than at Naked Island. Kittiwakes fed their young mostly herring and sandlance in Prince William Sound and sandlance and capelin in Lower Cook Inlet. Kittiwake growth and brood size were highest at Shoup Bay. Kittiwakes and guillemots require access to high-quality, schooling forage fishes to maintain high nesting densities.

KEY WORDS

energetics, energy, *Exxon Valdez*, fish, lipid, proximate composition, seabird, reproduction, trophic

EXECUTIVE SUMMARY

This restoration research project is a component of the Alaska Predator Ecosystem Experiment Project (APEX), which is investigating whether low food abundance and quality contributes to the failure of some seabird and marine mammal populations to recover from the *Exxon Valdez* Oil Spill (EVOS). The basic premise of APEX is that a shift in the marine trophic structure of the EVOS area has prevented recovery of injured seabird resources. Specifically, this research component of APEX addresses whether changes in diet quality may have constrained reproduction in pigeon guillemots (*Cepphus columba*), common murres (*Uria aalge*), and marbled murrelets (*Brachyramphus marmoratus*), all resources injured by the spill. The major hypothesis tested is that differences in the nutritional quality of forage fishes are a primary determinant of energy provisioning rates to seabird nestlings, which influence not only the growth and survival of young, but also other factors that regulate seabird populations (e.g., post-fledging survival and recruitment rates).

Pigeon guillemots and black-legged kittiwakes (*Rissa tridactyla*) were the focal piscivorous seabirds studied during the 1995 and 1996 breeding season. In cooperation with other APEX projects, we collected samples of nestling meals and measured nestling growth rates, provisioning rates, and nesting success in relation to diet. The two guillemot study sites in Prince William Sound (PWS) were located at Naked Island (an oiled site) and Jackpot Island (a non-oiled site), and were compared with one site in Kachemak Bay (a reference site). Three study sites for kittiwakes in PWS were located at Eleanor Island (an oiled site), North Icy Bay (a non-oiled site), and Shoup Bay (a non-oiled site), and were compared with three study sites in Lower Cook Inlet (LCI) at Gull, Chisik, and the Barren islands (all reference sites). In addition, forage fishes collected using a variety of methods were analyzed in the lab to determine quality as seabird prey.

The primary factor determining the energy density of forage fishes is lipid content (% dry mass); lipid has twice the energy density of protein and carbohydrates. The lipid content of forage fishes varied from a low of 3% dry mass in some juvenile walleye pollock (*Theragra chalcogramma*) to intermediate values of 22% in sand lance (*Ammodytes hexapterus*) and 37% in capelin (*Mallotus villosus*), to highs of 48% in some juvenile herring (*Clupea harengus pallasii*) and 52% in eulachon (*Thaleichthys pacificus*). Intraspecific variation in lipid content of forage fishes was related to location, age, gender, and reproductive status. Of those fishes present in the diets of kittiwakes and guillemots, herring, sand lance, and capelin had the highest energy density, nearshore demersal fishes (e.g., gunnels, pricklebacks, eelblennies, shannies) were intermediate, and gadids (e.g., walleye pollock, Pacific cod (*Gadus macrocephalus*), Pacific tomcod (*Microgadus proximus*)) were lowest in energy. Energy densities of fresh forage fishes ranged from 2.8 kJ/g wet mass in pollock, 6.3 kJ/g in sand lance, 7.4 kJ/g in capelin, to 10.0 kJ/g in eulachon and some herring. Consequently, piscivorous seabirds can experience a four-fold difference in energy intake based solely on the quality of forage fishes consumed.

The diets of guillemot nestlings were composed primarily of blennies and sculpins at Naked Island, herring at Jackpot Island, and sand lance and blennies at Kachemak Bay. The energy density of guillemot nestling diets was higher in Kachemak Bay than in Prince William Sound from 1994 through 1996. Coincident with less sand lance in the diet, guillemot growth

performance at Kachemak Bay was lower in 1996 compared with 1995. Unlike 1995, growth was not higher than at Naked Island. These results support the hypothesis that breeding guillemots in the EVOS area are constrained by the availability of high-quality forage fishes, especially sand lance.

Kittiwakes fed their young high energy schooling forage fishes, which were in decline and are now rebounding. In 1996, nestling diets were dominated by herring and sand lance in PWS and sand lance and capelin in LCI. The energy density of kittiwake nestling diets were higher at Shoup Bay than at Eleanor Island, and higher in 1996 than in 1995 for both sites. Shoup Bay kittiwakes also transported larger meals back to the colony to feed their chicks, when compared to those in the other study sites. Also, kittiwake growth performance and average brood size were higher at Shoup Bay than at Eleanor Island or North Icy Bay. Kittiwake parents at Shoup Bay selected higher quality prey and provided larger food loads for larger brood sizes and better growth rates for their chicks than parents at the other colonies in PWS and LCI. Our results support the hypothesis that breeding kittiwakes in the EVOS area are constrained by the availability of high quality forage fishes.

In summary, results from the 1996 season of field work support the APEX hypotheses structuring this project (4, 8, and 9). The species composition and abundance of fish used as prey by seabirds nesting in the EVOS area has changed. Kittiwakes and guillemots apparently require access to high quality, schooling forage fishes to maintain high nesting densities in the EVOS area. Productivity and size of forage species appear to change the energy potentially available for nesting seabirds. Changes in seabird reproductive productivity appear to reflect differences in forage fish abundance as measured in adult seabird foraging trip duration, brood meal size, and brood provisioning rates. Seabird reproductive productivity appears to be determined in part by differences in forage fish nutritional quality. By implication, the productivity of two other seabird species that were injured by the spill (specifically, common murres and marbled murrelets) may also be constrained by availability of high quality forage fishes.

INTRODUCTION

Reproductive success in seabirds is largely dependent on foraging constraints experienced by breeding adults. Previous studies on the reproductive energetics of seabirds have indicated that productivity is energy-limited, particularly during brood-rearing (Roby 1991). Also, the young of most seabird species accumulate substantial fat stores prior to fledging, an energy reserve that can be crucial for post-fledging survival in those species without post-fledging parental care (Perrins et al. 1973; but see Schreiber 1994). Data on foraging habitats, prey availability, and diet composition are critical for understanding the effects of changes in the distribution and abundance of forage fish resources on the productivity and dynamics of seabird populations.

The composition of forage fishes is particularly relevant to reproductive success, because it is the primary determinant of the energy density of meals delivered to nestlings. Parent seabirds that transport brood meals in their stomachs (e.g., kittiwakes) or in a specialized pouch (e.g., auklets) normally transport meals that are close to the maximum load. Seabirds that transport brood meals as single prey items held in the bill (e.g., guillemots, murres, murrelets) experience additional constraints on meal size if optimal-sized prey are not readily available. Consequently, seabird parents that provision their young with fish high in lipids are able to support faster growing chicks that fledge earlier and with larger fat reserves. This is because the energy density of lipid is approximately twice that of protein and carbohydrate. Also, forage fish are generally very low in carbohydrate, and metabolism of protein as an energy source requires the energetically expensive process of excreting the resultant nitrogenous waste. While breeding adults can afford to consume prey that are low quality (i.e., low-lipid) but abundant, reproductive success may depend on provisioning young with high quality (i.e., high-lipid) food items. If prey of adequate quality to support normal nestling growth and development are not available, nestlings either starve in the nest or prolong the nestling period and fledge with low fat reserves.

Forage fish vary considerably in lipid content, lipid:protein ratio, energy density, and nutritional quality. In some seabird prey, such as lanternfishes and eulachon, lipids may constitute over 50% of dry mass (A. R. Place, unpubl. data; J. Piatt, unpubl. data; S. Payne, unpubl. data); while in other prey, such as juvenile walleye pollock and Pacific cod, lipids are frequently less than 5% of dry mass (J. Wejak, unpubl. data; J. Piatt, unpubl. data). This means that a given fresh mass of lanternfishes or eulachon may have 3 to 4 times the energy content of the same mass of juvenile pollock or Pacific cod. By increasing the proportion of high-lipid fish in brood diets, parents can increase the energy density of brood meals in order to compensate for the low frequency of brood feeding (Ricklefs 1984, Ricklefs et al. 1985).

Three seabird species that were damaged by the *Exxon Valdez* oil spill are failing to recover at an acceptable rate: pigeon guillemot, common murre, and marbled murrelet. Damage from the spill to a fourth species of seabird, black-legged kittiwake, is equivocal, but recent reproductive failures of kittiwakes within the spill area may be due to longer term ecosystem perturbation related to the spill (D. B. Irons, pers. comm.). The status of pigeon guillemots and marbled murrelets in PWS and LCI has been of concern for nearly a decade due to declines in numbers of adults observed on survey routes (Laing and Klosiewski 1993, D. Zwiefelhofer, pers. comm.). All of these damaged or potentially damaged seabirds are piscivorous and rely to a greater or lesser extent on pelagic schooling fishes during the breeding season.

One prevalent hypothesis for the failure of these seabirds to recover is that changes in the abundance and species composition of forage fish resources within the spill area has resulted in reduced availability and quality of food for breeding seabirds. Concurrent population declines in some marine mammals, particularly harbor seals and Steller sea lions, have also been blamed on food limitation. Seabirds, unlike marine mammals, offer the possibility of directly measuring diet composition and feeding rates, and their relation to productivity. Thus, the piscivorous seabirds breeding in PWS and LCI present an opportunity to assess the relationship between the relative availability of various forage fishes and the productivity of apex predators. Whether these changes in forage fish availability are related to or have been exacerbated by EVOS is unknown.

This study is relevant to EVOS Restoration work because it is designed to develop a better understanding of how shifts in the diet of seabirds breeding in EVOS area affect reproductive success. By monitoring the composition and provisioning rates of seabird nestling diets, prey preferences can be assessed. Measuring provisioning rates is crucial because even very poor quality prey may constitute an acceptable diet if it can be supplied at a high rate without increased parental investment. Understanding the diet composition, foraging niche, and energetic constraints on seabirds breeding within the spill area will be crucial for designing management initiatives to enhance productivity in species that are failing to recover from EVOS. If forage fish that are high in lipids are an essential resource for successful reproduction, then efforts can be focused on assessing stocks of preferred forage fish and the factors that impinge on the availability of these resources within foraging distance of breeding colonies in the EVOS area. As long as the significance of diet composition is not understood, it will be difficult to interpret shifts in the utilization of forage fishes and develop a management plan for effective recovery of damaged species.

Guillemots are the most neritic members of the marine bird family Alcidae (i.e., murres, puffins, and auks), and like the other members of the family, capture prey during pursuit-dives. Pigeon guillemots are a well-suited species for monitoring forage fish availability for several reasons: (1) they are a common and widespread seabird species breeding in the EVOS area (Sowls et al. 1978); (2) they primarily forage within 5 km of the nest site (Drent 1965); (3) they raise their young almost entirely on fish; (4) they prey on a wide variety of fishes, including schooling forage fishes (e.g., sand lance, herring, pollock) and subtidal/nearshore demersal fishes (e.g., blennies, sculpins; Drent 1965, Kuletz 1983); and (5) the one- or two-chick broods are fed in the nest until the young reach adult body size. Guillemots carry whole fish in their bills to the nest-site crevice to feed their young. Thus, individual prey items can be identified, weighed, measured, and collected for composition analyses. In addition, there is strong evidence of a major shift in diet composition of guillemot pairs breeding at Naked Island. Sand lance were the predominant prey fed to young in the late 1970s (Kuletz 1983), but currently sand lance is a minor component of the diet (D. L. Hayes, unpubl. data). In contrast, guillemots breeding in Kachemak Bay continue to provision their young predominately with sand lance, and sand lance is particularly prevalent in the diet at breeding sites that support high densities of nesting guillemots (A. Prichard, unpubl. data).

Black-legged kittiwakes also breed abundantly in the spill area and rely largely on forage fish during reproduction. Unlike guillemots, kittiwakes are efficient fliers, forage at considerable distances from the nest, and capture prey at or near the surface. Although kittiwakes are highly colonial, cliff-nesting seabirds, they construct nests and can be readily studied at the breeding colony without causing substantial egg loss and chick mortality. Like guillemots, kittiwakes can raise one- or two-chick broods, and chicks remain in the nest until nearly adult size. Kittiwake breeding colonies at Shoup Bay, Eleanor Island, and North Icy Bay in PWS are easily accessible so that chicks can be weighed regularly without resorting to technical climbing. Kittiwake colonies at Gull Island, Chisik Island, and the Barren Islands in LCI are not as accessible as the PWS colonies, but acquiring sufficient data on reproductive performance for comparison with PWS colonies is feasible.

This study is one component of the APEX Project, working in conjunction with EVOS Projects 95163A-P, to test the overall hypothesis that a shift in the marine trophic structure of the EVOS area has prevented recovery of injured resources and 12 more specific hypotheses related to this. The three specific hypotheses of this study are:

1. Productivity and size of forage species change the energy potentially available for seabirds (APEX Hypothesis 4).

2. Changes in seabird reproductive productivity reflect differences in forage fish abundance as measured in adult seabird foraging trips, brood-meal size, and brood-provisioning rates (APEX Hypothesis 8).

3. Seabird reproductive productivity is determined in part by differences in forage fish nutritional quality (APEX Hypothesis 9).

These hypotheses address the two primary determinants of energy provisioning rates to nestling seabirds, which in turn have a direct bearing on fitness through variation in reproductive output. Another variable, parental investment, is assumed to remain constant among breeding sites and years. This assumption will be tested in 1997 and 1998 by measuring parental energy expenditure rates during chick-rearing.

OBJECTIVES

The overall objective of this research is to determine the energy content and nutritional value of various forage fishes used by seabirds breeding in the EVOS area, and to relate differences in prey quality and availability to nestling growth performance and productivity of breeding adults. The research in 1996 emphasized pigeon guillemots and black-legged kittiwakes.

Objective 1. To determine the proximate composition of various forage fish species consumed by seabirds in the EVOS area as a function of size, sex, age class, and reproductive status, including:

  a) lipid content
  b) water content
  c) ash-free lean dry matter (protein) content
  d) energy density (kJ/g wet mass)

Objective 2. To determine dietary parameters of pigeon guillemot and black-legged kittiwake chicks in the EVOS area, including:

  a) provisioning rate (meal size X delivery rate)
  b) taxonomic composition of diets
  c) biochemical composition of diets
  d) energy density of diets

Objective 3. To determine the relationship between diet and the growth, development, and survival of seabird nestlings. Variables measured will include:

  a) growth rates of total body mass
  b) rates and patterns of wing and flight feather growth
  c) fledgling body mass
  d) fledging age

Objective 4. To determine the contribution of specific forage fish resources to the overall productivity of seabird breeding pairs and populations, including:

a) relative contribution of each forage fish species to overall energy intake of nestlings
b) gross foraging efficiency of parents
c) conversion efficiency of food to biomass in chicks
d) net production efficiency of the parent/offspring unit
e) estimates of population-level requirements for forage fish resources during brood-rearing

STUDY AREAS

Data collection from the field occurred in Prince William Sound (Naked, Jackpot, and Eleanor islands, and Shoup and North Icy bays) and Lower Cook Inlet (south shore of Kachemak Bay, Gull, Chisik, and the Barren islands) during the 1996 breeding season. These sites were identical to those seabird breeding sites that were used by other components of APEX.

Field work on pigeon guillemots was conducted at breeding colonies on Naked Island (oiled area), Jackpot Island (non-oiled area, both in PWS), and in Kachemak Bay (reference site). Approximately 500 guillemots nest along the shores of Naked Island (Sanger and Cody 1993), supporting a large proportion of the total breeding population of guillemots in PWS. The field camp in Cabin Bay served as the base camp for field studies of guillemots nesting on the western and northern shorelines of Naked Island (see APEX Component 96163 F). Naked Island has been the site of long term studies of guillemot reproductive ecology since 1979 by the U.S. Fish and Wildlife Service (Kuletz 1983).

Jackpot Island is a small island in southwestern PWS that supports the highest known breeding density of guillemots in the Sound (G. Sanger, D. L. Hayes, pers. comm.). Jackpot Island has been the site of intensive studies of guillemot nesting success since 1994 and is located in a non-oiled portion of PWS. Kachemak Bay served as a third study site for guillemots. Since 1994, the breeding population of guillemots on the south shore of Kachemak Bay (from Mallard Bay in the northeast to Seldovia in the southwest) has been studied intensively. Results in 1994 suggested that the guillemot prey base in Kachemak Bay is largely sand lance, and is perhaps similar to the prey base at Naked Island 15-20 years ago. Consequently, the Kachemak Bay guillemot study site provides an excellent reference site for guillemot studies in PWS.

Field work on black-legged kittiwakes in PWS was conducted at three breeding colonies: (1) Shoup Bay in Port Valdez (non-oiled area), the largest kittiwake colony in PWS consisting of c. 6500 breeding pairs, (2) Eleanor Island in central PWS near Knight Island (oiled area) with c. 200 breeding pairs, and (3) North Icy Bay in southeast PWS and a non-oiled area with c. 500 breeding pairs. The Shoup Bay colony is the site of continuing long-term studies of kittiwake nesting ecology in PWS by the U.S. Fish and Wildlife Service, and Eleanor Island has been selected as a site for intensive study for comparison purposes (see APEX Component 96163 E). In Lower Cook Inlet, kittiwake breeding colonies at the Barren Islands (high productivity), Gull Island (moderate productivity), and Chisik Island (low productivity) were monitored for diet and reproductive success (see APEX Component 96163 M) .

METHODS

Field Data Collection

The research approach utilized a combination of sample/data collection in the field (in conjunction with other APEX components in PWS and LCI) and laboratory analyses of forage fish samples. A minimum of 40 active and accessible nests of each species were located and marked prior to hatching at each of the study colonies, and these nests were closely-monitored until the young fledged or the nesting attempt failed. Samples of forage fishes were collected concurrently with data on seabird reproduction during the 1996 breeding season.

Fresh samples of forage fishes used by guillemots were collected for determination of species composition and proximate composition of the diet. Guillemot diet samples were collected by capturing adults in scraps of mist net as they entered the nest crevice with a chick meal held in their bill and opportunistically when dropped meals were discovered in or near nest crevices. Supplemental samples of fishes fed to guillemot chicks were collected using beach seines and minnow traps deployed in guillemot foraging areas and by netting specimens at low tide during spring tide series.

Adult kittiwakes transport brood meals in the stomach and esophagus, so diet samples consist of semi-digested food. Most kittiwake diet samples were collected when chicks regurgitated during routine weighing and measuring. Additional diet samples were collected by capturing adult kittiwakes as they returned to feed their young and encouraging them to regurgitate the contents of their esophagus. Fresh specimens of forage fishes used by kittiwakes were provided by mid-water trawl (APEX Component 96163 A).

Puffin bill loads from the Barren Islands were also used as a source of prey samples. Guillemot brood meals, kittiwake regurgitations, puffin bill loads, and fresh fish samples were weighed (± 0.1 g) in the field on battery-powered, top-loading balances, placed in whirl-paks, and immediately frozen in small, propane-powered freezers that were maintained at each of the study sites. Samples of fresh forage fish, guillemot brood meals, puffin bill loads, and kittiwake regurgitations were shipped frozen to Dr. A. Springer's laboratory at the Institute of Marine Science, UAF, where K. Turco sorted, identified, sexed, aged, measured, and determined reproductive status of specimens in preparation for proximate analysis. Some kittiwake regurgitations were shipped frozen to the University of California Santa Cruz, where the semidigested material was sorted and identified to species to the extent possible by G. Golet.

Proximate analysis of all samples was conducted by the first author and Heather Zollinger in the second author's laboratory at the Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, OSU. Forage fish specimens and brood meals were reweighed on an analytical balance (± 0.1 mg), and dried to constant mass in a convection oven at 60°C to determine water content. Lipid content of dried samples was determined by solvent extraction using a soxhlet apparatus and 7:2 hexane/isopropyl alcohol (v:v) as the solvent system. Lean dry samples were transferred from extraction thimbles to glass scintillation vials and ashed in a muffle furnace at 550°C in order to calculate ash-free lean dry mass (protein) by subtraction. Energy density (kJ/g wet mass) and energy content of forage fishes and brood meals were calculated from their composition (water, lipid, ash-free lean dry matter, and ash), using published energy equivalents of these fractions (Schmidt-Nielsen 1990).

Brood provisioning rates for pigeon guillemots and black-legged kittiwakes at each of the study sites were determined by monitoring active nests for meal delivery rates (meals/ nest day) throughout the 24 hour period (dawn to dusk watches). Average meal mass was determined for guillemots using the sample of individual prey items collected at nest sites. Average meal mass for black-legged kittiwakes was estimated using the periodic weighing technique. Nestlings were weighed in a sample of nests at 2-hour intervals during concurrent watches to determine meal delivery rates. The mass increment between weighings of chicks that were fed was corrected for mass loss between weighings and feedings by adding the average of mass loss in the previous 2-hour period and mass loss in the subsequent 2-hour period to the observed mass increment. This corrected mass increment was used as an estimate of meal size. The product of average meal size (g) and average meal delivery rate (meals/day) was used as an estimate of average quantity of food delivered to a nest daily by a pair of adults (g/(nest day)). The taxonomic and proximate composition of the diet was used to calculate average energy density of brood diets for each species at each site. Finally, the product of average energy density of brood diets (kJ/g wet mass) and average quantity of food delivered (g/nest day) was calculated as an estimate of energy provisioning rates (kJ/nest day) for each species at each site.

Active guillemot and kittiwake nests were checked daily or every other day during the hatching period in order to determine hatching date. In the case of two-chick broods, siblings were marked soon after hatching so that individual growth rates could be monitored throughout the nestling period. Nestling growth rates were determined by weighing and measuring chicks (known-age, in most cases) on a regular basis (every three days, if possible) throughout the nestling period. Nestling survival rates were calculated from the results of periodic nest checks, using the Mayfield method. During the fledging period, we attempted to weigh nestlings every other day in order to more precisely determine fledging mass and age. Data on nestling body mass, wing chord, and primary feather length were separated by colony for each species.

Breeding adult guillemots and kittiwakes that were captured at the nest were weighed, measured, and banded for future identification.

RESULTS AND DISCUSSION

Objective 1: Proximate Composition of Forage Fishes

Specimens of the following forage fish taxa (and two invertebrates) were subjected to proximate analysis in 1995 and 1996:

Schooling fishes:
juvenile walleye pollock (*Theragra chalcogramma*)
juvenile Pacific cod (*Gadus macrocephalus*)
juvenile Pacific tomcod (*Microgadus proximus*)
Pacific sand lance (*Ammodytes hexapterus*)
capelin (*Mallotus villosus*)
Pacific herring (*Clupea harengus pallasii*)
Pacific sandfish (*Trichodon trichodon*)
eulachon (*Thaleichthys pacificus*)
lanternfish (Myctophidae)
Pacific salmon (*Onchorhynchus* spp.)
lingcod (*Ophiodon elongatus*)
prowfish (*Zaprora silenus*)
surf smelt (*Hypomesus pretiosus*)
kelp greenling (*Hexagrammos decagrammus*)

Nearshore demersal fishes:
crescent gunnel (*Pholis laeta*)
slender eelblenny (*Lumpenus fabricii*)
snake prickleback (*Lumpenus sagitta*)
daubed shanny (*Lumpenus maculatus*)
black prickleback (*Xiphister atropurpureus*)
northern ronquil (*Ronquilus jordani*)
crested sculpin (*Blepsias bilobus*)
silverspotted sculpin (*Blepsias cirrhosus*)
four horned sculpin (*Myoxocephalus quadricornis*)
plain sculpin (*Myoxocephalus jaok*)
padded sculpin (*Artedius fenestralis*)
ribbed sculpin (*Triglops pingeli*)
roughspine sculpin (*Triglops macellus*)
slim sculpin (*Radulinus asprellus*)
tidepool sculpin (*Oligocottus maculosus*)
arctic shanny (*Stichaeus punctatus*)

Other:
shrimp (*Pandalus* spp.)
dover sole (*Microstomus pacificus*)
rex sole (*Glyptocephalus zachirus*)
squid (unknown species)

Several patterns in the proximate composition of these forage fishes were revealed by inter-specific comparison (Figure 1). First, lanternfishes and eulachon had the highest lipid content, and therefore the highest energy density (kJ/g wet mass) of the forage fishes analyzed. Herring, sand lance, and capelin had the highest values for forage fishes observed in the diets of seabirds in this study. Gadid species (pollock, cod, tomcod) and prowfish consistently had the lowest lipid content and, consequently, the lowest energy density. There is a clear dichotomy in quality among the schooling forage fishes: gadids are generally low quality and herring, sand lance, and capelin are relatively high quality. No such dichotomy in quality was revealed among the nearshore demersal species (Figure 1). Nearshore demersal fishes (blennies, sculpins, pricklebacks) were intermediate in energy density.

Intraspecific comparisons of proximate composition revealed differences related to age, location, gender and reproductive status. The lipid content of herring increased dramatically from age class 0+ to older fish (Figure 2). Lipid content was highly variable within an age class, which was suggestive of wide variation in the condition of juvenile herring from PWS. Some of this variation could be attributed to differences between collection sites in the average lipid content of herring (Figure 2). Variability in lipid content within an age class was less pronounced in sand lance compared to herring. Surprisingly, the lipid content of 1+ sand lance was somewhat greater than in 2+ sand lance. Female 2+ sand lance had higher lipid content and higher energy density than male 2+ sand lance. Juvenile pollock exhibited a different pattern of lipid content as a function of age: 0+ pollock had slightly higher lipid content than 1+ or 2+ pollock (but lower than 0+ herring or sand lance).

The observed inter- and intra-specific differences in lipid content of forage fishes reflect differences in life history as they influence reliance on stored energy reserves for survival or reproduction. For example, sand lance spawn in the fall (Dick and Warner 1982), and adults, especially females, presumably deposit lipid reserves during summer for later investment in gametes. Juvenile pollock, however, feed year-round and selection has favored allocation of assimilated energy to rapid somatic growth over storage of lipid during the juvenile period.

The energy densities for those schooling and nearshore demersal fishes that were collected and analyzed in 1995 and 1996 differed by a factor of up to four. A parent seabird breeding in PWS could potentially increase its rate of energy provisioning to its brood by a factor of as much as four by selecting prey based on quality, given similar availability. Such an increase in energy provisioning rate could dramatically enhance fitness.

Objective 2: Dietary Parameters of Nestling Seabirds

Data collected in 1996 built on the data set that began in 1995 to broaden our understanding of how seabirds compensate prey availability, diet quality, prey selection, meal size, and feeding frequency to maximize energy provisioning rates to the brood. The patterns are beginning to appear in the second year of this four-year field study: the importance of certain high-quality schooling forage fishes, the flexibility of meal size in response to shifting prey availability, and the trade-off between increasing feeding frequency and meal size. Pigeon guillemots and black-legged kittiwakes have demonstrated different foraging strategies to deal with reproducing under shifting conditions of food availability and quality.

Pigeon Guillemots

Pigeon guillemots have a diverse diet, composed of poorly-known nearshore demersal fishes, as well as relatively well-known schooling forage fishes. Blennies and sculpins were the primary prey of nestlings at Naked Island in 1996 (Figure 3), whereas the proportion of gadids has decreased since 1994. At Kachemak Bay, nestlings were fed mostly sand lance and blennies in 1996, but the proportion of sand lance in the diet decreased from 1995. Pacific herring and gunnels were the main prey for nestlings at Jackpot Island in 1996, although sample size was small due to intense nest predation by a mink and a resultant high rate of nest failure. The proportion of schooling forage fishes in 1996 diets was greatest at Jackpot Island (46%), followed by Kachemak Bay (36%) and Naked Island (21%).

One hundred and one pigeon guillemot brood meals, composed of individual fish, were collected in 1996: 73 at Naked Island, 25 at Kachemak Bay, and 3 at Jackpot Island. These samples were generally representative of nestling diets at the respective study sites, as indicated by the species composition of fish observed delivered to the nest by adults (Figure 3). The average mass of brood meals collected from Naked Island was similar in 1995 and 1996 (Table 1). Sample size of brood meals at Jackpot Island was small in 1996, so no estimate of average meal size could be made. In 1995 and 1996, average meal size at Naked Island was smaller than at Jackpot Island in 1995. The average mass of brood meals collected at Kachemak Bay (11.4, s.d. = 7.9, n = 25) was slightly less than at Naked Island (14.2, s.d. = 11.6, n = 73; t = 4.02, one-tailed, p = 0.09).

Diet quality appears to be an important factor influencing energy provisioning rates to pigeon guillemot nestlings. The average energy density of brood meals was similar at Naked and Jackpot islands in both 1995 and 1996 (Table 1). An increase in the proportion of sand lance in guillemot diets at Naked Island from 1995 to 1996 may have been compensated by a decrease in capelin. At Jackpot Island, energy density of brood meals was moderate in both years, despite a high incidence of herring in the diet. This is apparently due to geographical differences in lipid content of juvenile herring; herring from northeast PWS had higher lipid content and energy density than herring from southwest or central PWS. Brood meals at Kachemak Bay had higher average energy densities than the other sites in 1994, 1995, and 1996, due to the high proportion of sand lance in the diet. The average energy density of guillemot brood meals from Kachemak Bay declined in 1996, coincident with a decline in the proportion of sand lance in the diet.

Guillemot feeding frequency (brood meals delivered per nest day) was highest at Jackpot Island (1995), intermediate at Kachemak Bay (1996), and lowest at Naked Island (1995, 1996; Table 1). The feeding frequency at Naked Island was similar in 1995 and 1996 (means adjusted for proportions of nests containing one- and two-chick broods). Consequently, the estimated mass of food delivered to guillemot nests at Jackpot Island (330 g/nest day, 1995) were almost twice those at Naked Island (170 g/nest day, 1996) or Kachemak Bay (162 g/nest day, 1996).

Energy provisioning rates (kJ/nest day) can be estimated from measurements of feeding frequency (meals/nest day), meal size (g wet mass), and energy density of meals (kJ/g wet mass). Energy provisioning rates for guillemots were almost twice as high at Jackpot Island (1,394 kJ/nest day, 1995) than at Naked Island (750 kJ/nest day, 1996) and Kachemak Bay (826 kJ/nest day, 1996; Table 1). Limited data for 1996 suggests that feeding frequency was about 17.6 meals/nest day at Jackpot Island, which was similar to 1995. If the small sample of meal size data was representative, the energy provisioning rate at Jackpot Island (847 kJ/nest day, estimated for 1996) would be slightly higher than Naked Island (1995, 1996) and Kachemak Bay (1996). If the 1996 meal size data from Jackpot Island were biased low and average meal size was closer to 20.0 grams (as observed in 1995), then the energy provisioning rate at Jackpot Island in 1996 would be about twice as high as the other two study sites (1,584 kJ/nest day). Guillemots nesting at Kachemak Bay provisioned their young with energy at a higher rate than at Naked Island. They compensated for low average meal size and moderate feeding frequency with high energy density of prey. At Naked Island, where the energy density of brood meals was moderate, guillemots delivered moderate-sized fishes at a lower feeding frequency compared to the other two sites. Consequently, energy provisioning rates to broods at Naked Island were lower than at the other two study sites.

Black-legged Kittiwakes

In 1996, the diet of black-legged kittiwake nestlings in PWS was composed primarily of herring and sand lance (Figure 4). Capelin supplemented the diet, more so in the central and southwestern portions of the Sound. Some kittiwakes at Eleanor Island also consumed salmon smolts, while others at Shoup Bay fed on offal from fish processors. In comparison with 1995, nestling diets at Shoup Bay showed a small increase in herring and a small decrease in sand lance and capelin. At Eleanor Island, nestlings were fed less herring and more salmon smolts in 1996 compared to 1995. Sand lance and capelin figured prominently in kittiwake diets from LCI (Figure 4). Kittiwake nestlings at Gull Island fed their young sand lance, supplemented with herring. The sample size for kittiwake diets from Chisik Island was very small. At the Barren Islands, sand lance was more important than capelin in 1996, which was a reversal from the diet composition in 1995.

By filling the esophagus and stomach with forage fishes, black-legged kittiwake parents can maximize meal size for their nestlings and potentially increase the efficiency of foraging trips. Different average meal sizes among colonies contributed to intercolony differences in energy provisioning rates (Table 2). Shoup Bay in 1995 provides the best example of a kittiwake colony where large meal size compensated for longer foraging trips. In 1996, meal size at Shoup Bay was larger than at any other kittiwake colony, while meal size at North Icy Bay, Chisik Island, and Eleanor Island was moderate. Gull Island had the smallest average meal size. Meal sizes were similar at Shoup Bay and Eleanor Island in both 1995 and 1996 (Table 3).

Parent kittiwakes in PWS and LCI fed their broods food with average energy densities of 3 to 5 kJ/g wet mass (Table 2). Average energy densities of brood regurgitations were higher at Gull Island, Shoup Bay, and North Icy Bay than at Eleanor, Chisik, and the Barren islands. The energy density of kittiwake regurgitations was higher at Shoup Bay than at Eleanor Island, and higher in 1996 than in 1995 at both sites (Table 3). Shoup Bay diets had a predominance of herring with high average lipid contents, compared to a more diverse diet of herring, sand lance, capelin, and salmon smolt at Eleanor Island.

Feeding frequencies (brood meals delivered per nest day) were highest at Gull Island and Eleanor Island, intermediate at Shoup Bay, and lowest at Chisik and the Barren islands (Table 2; means adjusted for proportions of nests that contained one- and two-chick broods). Intercolony differences in the rates of food delivery to broods were driven by meal size and/or feeding frequency. The estimated rate of food delivery to kittiwake nests at Shoup Bay (132 g/nest day) and Eleanor Island (106 g/nest day) were greater than at Gull Island (81 g/nest day) and almost twice that at Chisik Island (68 g/nest day). Delivery rates at Shoup Bay were a third higher in 1996 than in 1995, while delivery rates were about the same at Eleanor Island each year. Shoup Bay had a lower average food delivery rate than Eleanor Island in 1995 (96 vs. 104 g/nest day), and a higher rate in 1996 (132 vs. 106 g/nest day).

Energy provisioning rates, calculated from the product of meal size, energy density, and feeding frequency, were highest at Shoup Bay, intermediate at Eleanor and Gull islands, and lowest at Chisik Island (Table 2). Energy provisioning rates to nestlings were higher at Shoup Bay than at Eleanor Island in 1996, but provisioning rates were similar at the two colonies in 1995 (Table 3). Energy provisioning rates were higher at Shoup Bay in 1996 than in 1995. Energy was provisioned to broods at Shoup Bay at a rate more than twice that at Chisik Island. The estimated energy provisioning rate at Gull Island was comparatively low, however, because average meal size was low. Based on foraging trip durations (APEX Component 96163 E), the feeding frequency at North Icy Bay was estimated at about 4 meals/nest day. This frequency would produce an energy provisioning rate of 441 kJ/nest day, lower than at Shoup Bay and higher than at Eleanor Island. Average meal size at the Barren Islands would have to be around 40 grams for an energy provisioning rate similar to Eleanor and Gull islands, colonies with similar productivity to the Barren Islands. Limited data on meal size at the Barren Islands suggest that this estimate may be larger than the meals actually delivered.

Objective 3: Diet and Nestling Growth and Survival

Pigeon Guillemots

Data on body mass of nestling guillemots were plotted as a function of wing length for each of the study sites. By taking the square root of body mass and the square root of the log of wing length, this relationship was linearized and homogeneity of variance was achieved. The slope of the resultant least squares regression line can serve as an index to growth performance of nestlings over the entire pre-fledging period.

The growth performance of guillemot nestlings at Naked Island in 1996 was similar to 1995 (Figure 5). Growth performance at Kachemak Bay declined from 1995 to 1996, coincident with a lower proportion of sand lance in the diet. Growth at Kachemak Bay was not significantly different than at Naked Island in 1996. Nest predation by a mink at Jackpot Island resulted in no successful fledging from that colony, and a limited data set for nestling growth.

Growth performance of guillemot nestlings paralleled patterns in energy provisioning rates, determined by energy density, feeding frequency, and meal size. Slightly more energy was delivered to Kachemak Bay nestlings than those at Naked Island in 1996, and the growth index was slightly greater. The average energy provisioning rate at Kachemak Bay was lower in 1996 than at Jackpot Island in 1995, and the growth performance index was lower as well. Inter-colony differences in the growth performance index appear to be related to the quality of diets provisioned to nestlings.

Black-legged Kittiwakes

Nestling growth performance was similar among kittiwake colonies in 1996 (Figure 6). Gull Island growth performance was similar to those of the PWS colonies, and Chisik Island growth was lower than at the Barren Islands. A combination of herring and sand lance in the diets in PWS and mostly sand lance at Gull Island in LCI provided the energy density to support high growth rates. Breeding adults at Chisik Island were unable to provision their young with sufficient energy to support growth rates as high as at the other colonies, but some chicks did survive to fledging.

Kittiwake nesting productivity was highest at the Shoup Bay colony in 1996. This colony demonstrated the highest nestling growth performance, lowest incidence of brood reduction, and a high productivity (0.73 fledglings/nest). Breeding adults at Shoup Bay fed their nestlings a higher quality diet and larger brood meals, although the range and duration of foraging trips were high compared to other colonies. Confronted with low food availability, kittiwakes at Chisik Island had the lowest nesting success, with low growth performance, more single chick broods, and low productivity (0.05 fledglings/ nest).

Kittiwakes nesting at North Icy Bay provisioned their young with high-quality prey, although herring in southwestern PWS have a lower energy density than in the northeastern region where Shoup Bay kittiwakes forage. Nonetheless, the energy density of the diet at North Icy Bay was high; meal size was fairly large; and the estimated energy provisioning rate was intermediate between Shoup Bay and Chisik Island. Associated with this foraging strategy, growth performance was low to intermediate, brood size was low, and productivity was low (0.28). High laying success (87% of nest structures with ≥ 1 egg) and mean clutch size (≥ 1.73 eggs) suggest loss of eggs and chicks (see APEX Component 96163 E) to predation, disease, or another factor.

Objective 4: Contribution of Forage Fish Resources to Seabird Productivity

Energy provisioning rates were higher for pigeon guillemots than for black-legged kittiwakes in 1995 and 1996. Guillemots provisioned their young with energy (average: 788 to 986 kJ/day) at about twice the rate for kittiwakes (average: 413 kJ/day) in both years. Yet, these two species have similar average brood sizes. Several factors may contribute to this pattern. Guillemots forage close to the colony and capture prey during pursuit dives, so they can prey on fishes throughout the water column. Kittiwakes forage at considerable distances from the colony and capture prey at or near the surface.

Growth rates of nestlings paralleled the patterns in energy provisioning rates. The growth rates for guillemot nestlings (average = 21 g/day, Naked Island) were higher than for kittiwakes (average = 17 g/day, Shoup Bay). Guillemot nestlings fledged at a higher mass (456 g, Naked Island) than kittiwakes (396 g, Shoup Bay), despite similar fledging ages. This leads to the inference that the mass specific metabolic rate for guillemot nestlings is higher than kittiwakes, and their maintenance costs are likely higher. Guillemot nestlings appear to be less efficient in growth, as their average energy provisioning rate was about twice those for kittiwakes.

Guillemots in the EVOS area fed their nestlings schooling forage fishes and nearshore demersal fishes. Kittiwakes fed primarily on high-quality, schooling forage fishes during chick-rearing. Diet quality was higher for kittiwake nestlings than for guillemots, and the high energy density of brood meals helped compensate for low feeding frequencies. The high energy density of kittiwake chick diets suggests that breeding adults are selecting prey based at least partly on quality. In support of this, energy provisioning rates at Shoup Bay were close to those for guillemots. High energy provisioning rates are associated with higher growth performance, which would be expected to lead to higher survival and, in turn, to higher nesting densities.

The species composition and abundance of fishes consumed by seabirds breeding in the EVOS area has changed over time. The prevalence of herring, sand lance, and capelin in kittiwake and guillemot diets coincides with rebounding populations of these species since the early 1990s. Both guillemots and kittiwakes in the northern Gulf of Alaska apparently require access to these high-quality, schooling forage fishes to maintain high nesting densities. Juvenile herring and adult sand lance were the primary energy sources for piscivorous seabirds in PWS, whereas sand lance and capelin were important in LCI. By implication, the productivity of common murres and marbled murrelets, injured by the spill and slow to recover, may also be constrained by availability of high quality forage fishes.

CONCLUSIONS

Objective 1: Proximate Composition of Forage Fishes

- Myctophids and eulachon had the highest energy densities of sampled forage fishes (Figure 1).
- Herring, capelin, and sand lance had the highest average energy densities of those forage fishes found in seabird diets (Figure 1).
- Pollock, Pacific tomcod, and prowfish had the lowest average energy densities of sampled forage fishes (Figure 1).
- Nearshore demersal fishes (blennies, sculpins) had intermediate energy densities (Figure 1).
- Differences in location, age, gender, and reproductive state lead to intraspecific differences in energy density of forage fishes (Figure 2).
  - Herring from northeastern Prince William Sound had higher energy densities than in the central or southwestern Sound, demonstrating regional differences in lipid content.

- Age 1+ and 2+ herring and sand lance had higher energy densities than conspecific age 0+ fish.

Objective 2: Dietary Parameters of Nestling Seabirds

- Guillemots fed their young mostly blennies and sculpins at Naked Island, herring at Jackpot Island, and sand lance and blennies at Kachemak Bay in 1996 (Figure 3).
- The energy density of guillemot nestling diets was higher in Kachemak Bay than in Prince William Sound from 1994 through 1996 (Table 1).
- Kittiwakes fed mostly on herring and sand lance in Prince William Sound and sand lance and capelin in Lower Cook Inlet (Figure 4).
- In 1996, herring was the dominant prey item for kittiwakes breeding in Prince William Sound and sand lance was dominant in Lower Cook Inlet (Figure 4).
- The energy density of kittiwake nestling diets was higher at Shoup Bay than at Eleanor Island, and higher in 1996 than in 1995 for both sites (Table 2).

Objective 3: Diet and Nestling Growth and Survival

- Guillemot growth performance at Kachemak Bay declined in 1996 compared with 1995, and was not significantly higher than at Naked Island (Figure 5).
- The lower growth performance of guillemots at Kachemak Bay in 1996 was coincident with less sand lance in the diet, compared to 1995 (Figure 5).
- Kittiwake growth performance was higher at Shoup Bay than at Eleanor Island or North Icy Bay (Figure 6), coincident with herring of higher quality in the diet.
- Kittiwakes in Prince William Sound had higher productivity in 1996 compared with 1995, coincident with more herring, capelin, and sand lance in the diet - all high quality forage fishes.

Objective 4: Contribution of Forage Fish Resources to Seabird Productivity

- The species composition and abundance of fish used as prey by seabirds nesting in the EVOS area has changed. The prevalence of herring, capelin, and sand lance in seabird diets has increased, corresponding to rebounding populations of these forage fishes since the early 1990s.
- Guillemots apparently require access to high quality, schooling forage fishes (herring, sand lance) to maintain high nesting densities in the EVOS area.

- Productivity of kittiwakes in the EVOS area also appears dependent on availability of high quality forage fishes (herring, sand lance, capelin).

- In Prince William Sound, juvenile herring and adult sand lance are the primary energy sources for piscivorous seabirds.

- Outside the Sound, sand lance and capelin are the primary energy sources for piscivorous seabirds in the EVOS area.

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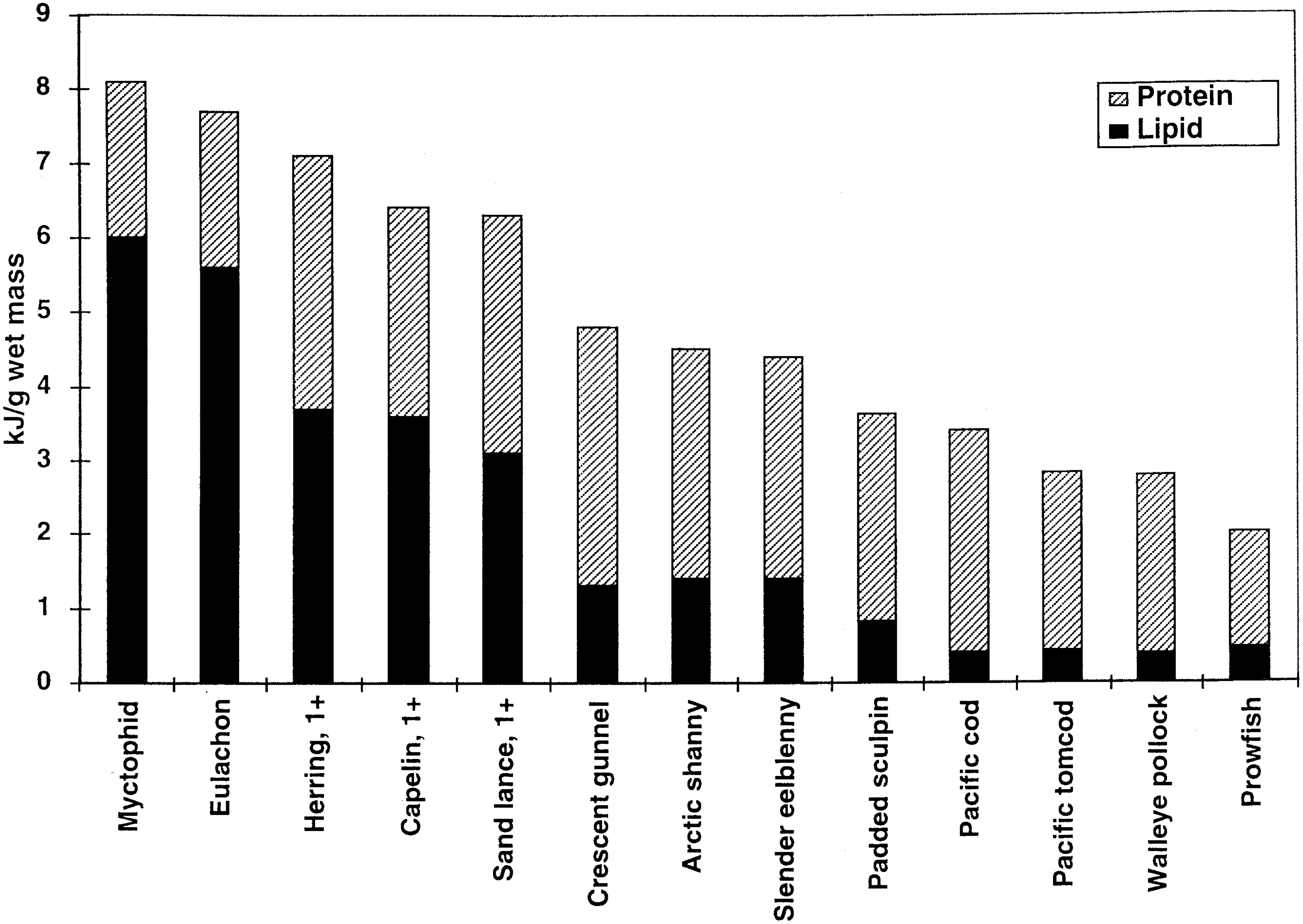
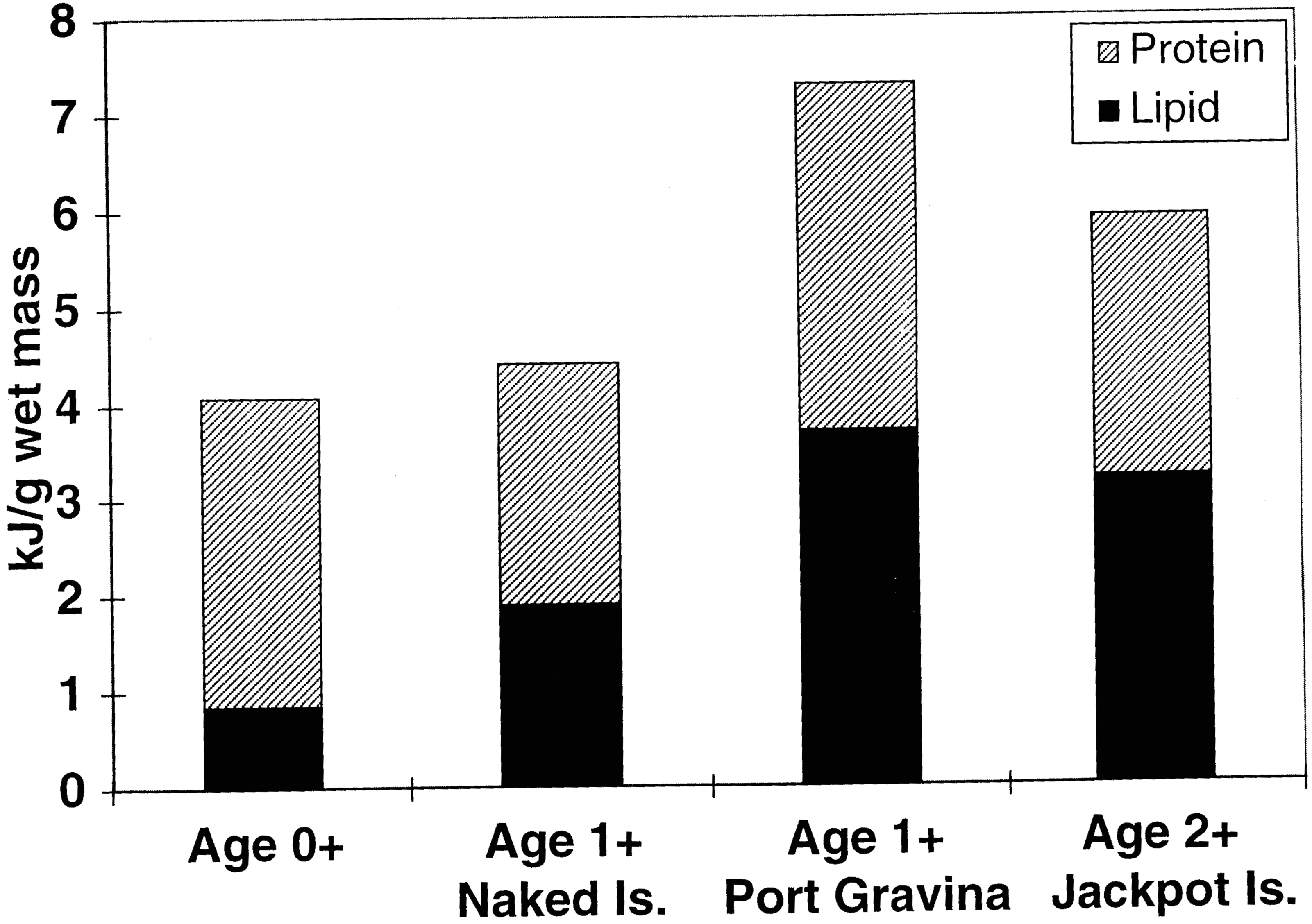


Figure 1. Energy density (kJ/g wet mass) and relative energy content in lipid vs. protein for forage fishes sampled in the northern Gulf of Alaska in 1995 and 1996.



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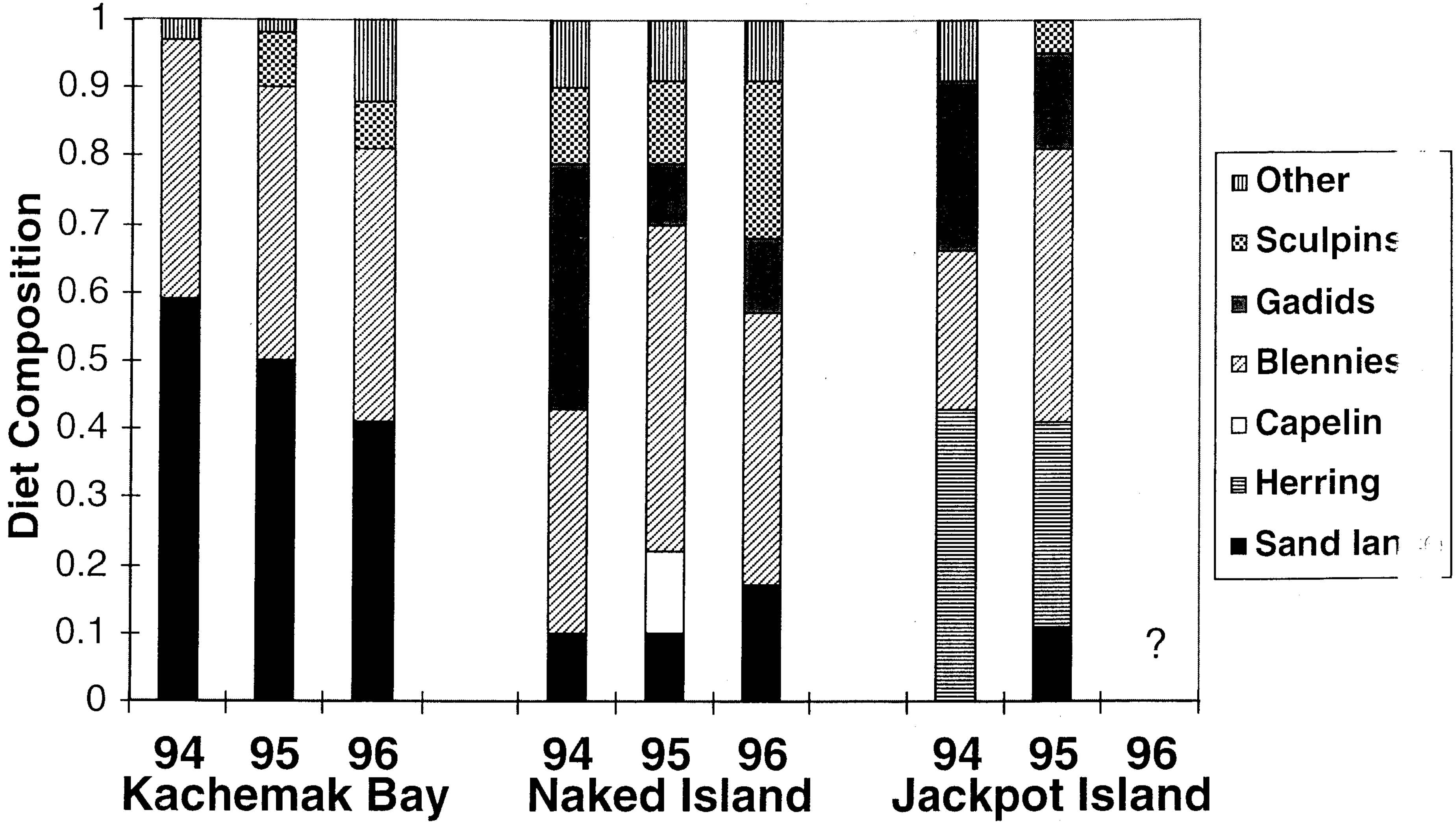

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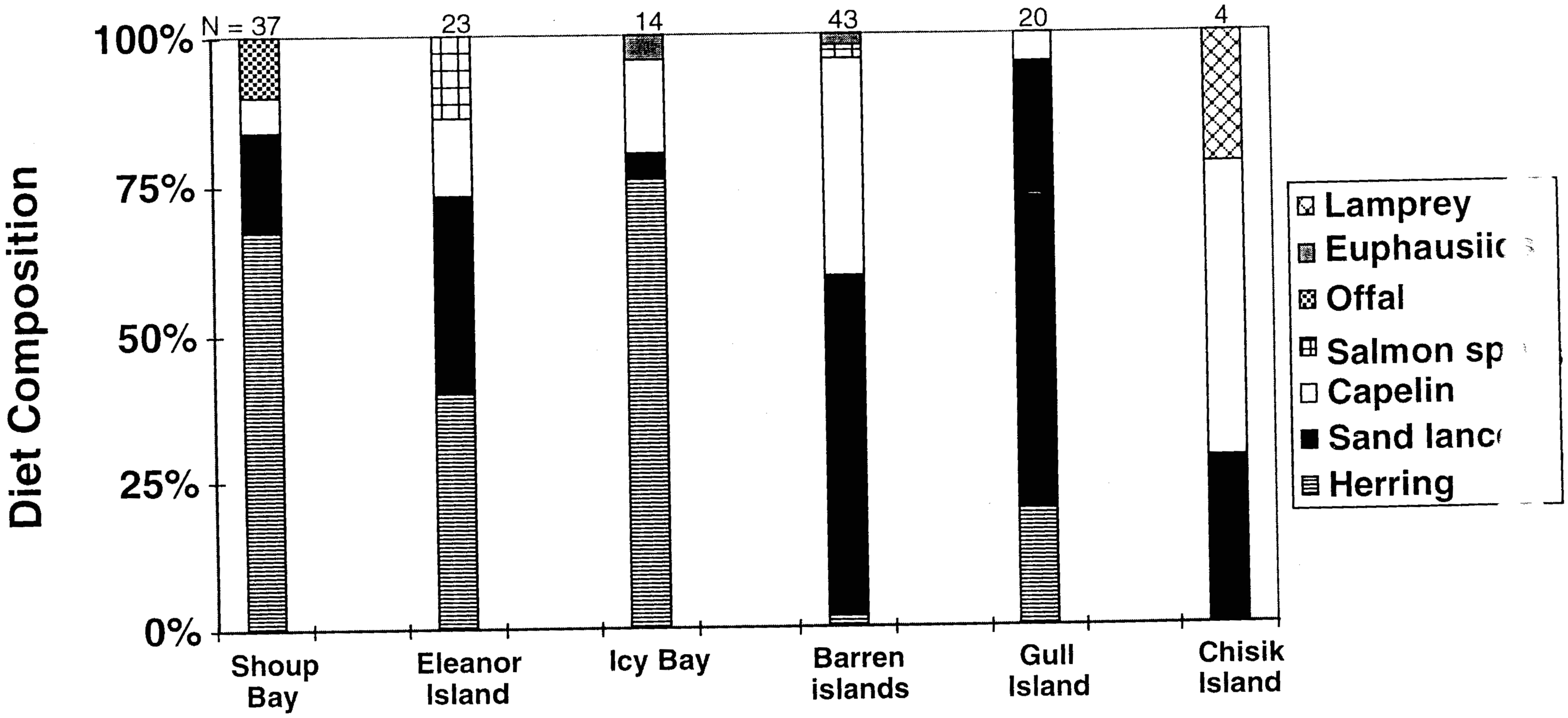

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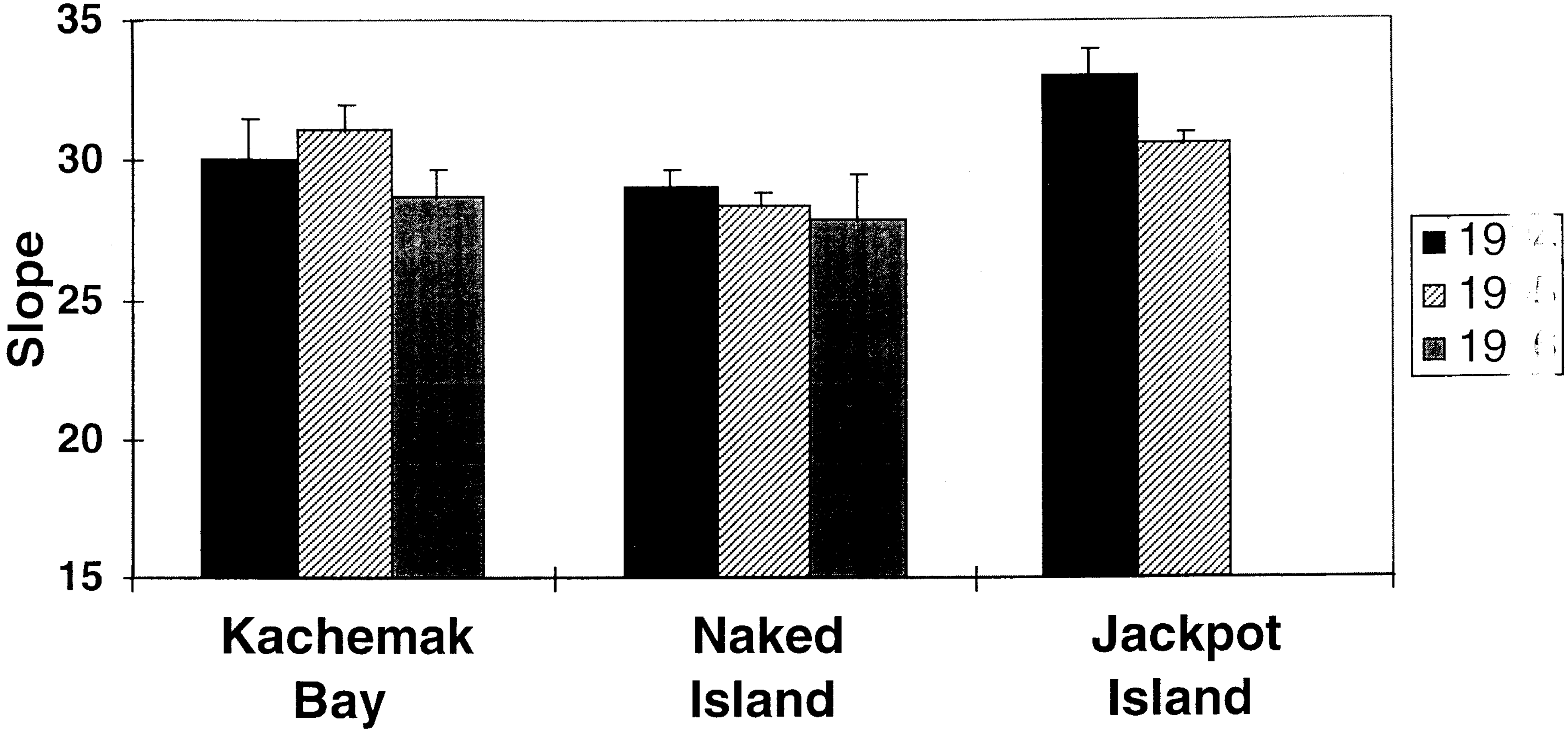

Figure 5. Index to growth performance for pigeon guillemot nestlings at three sites from 1994 through 1996. The growth performance index is the slope of the least squares regression line for the square root of body mass vs. the square root of the natural log of wing length.

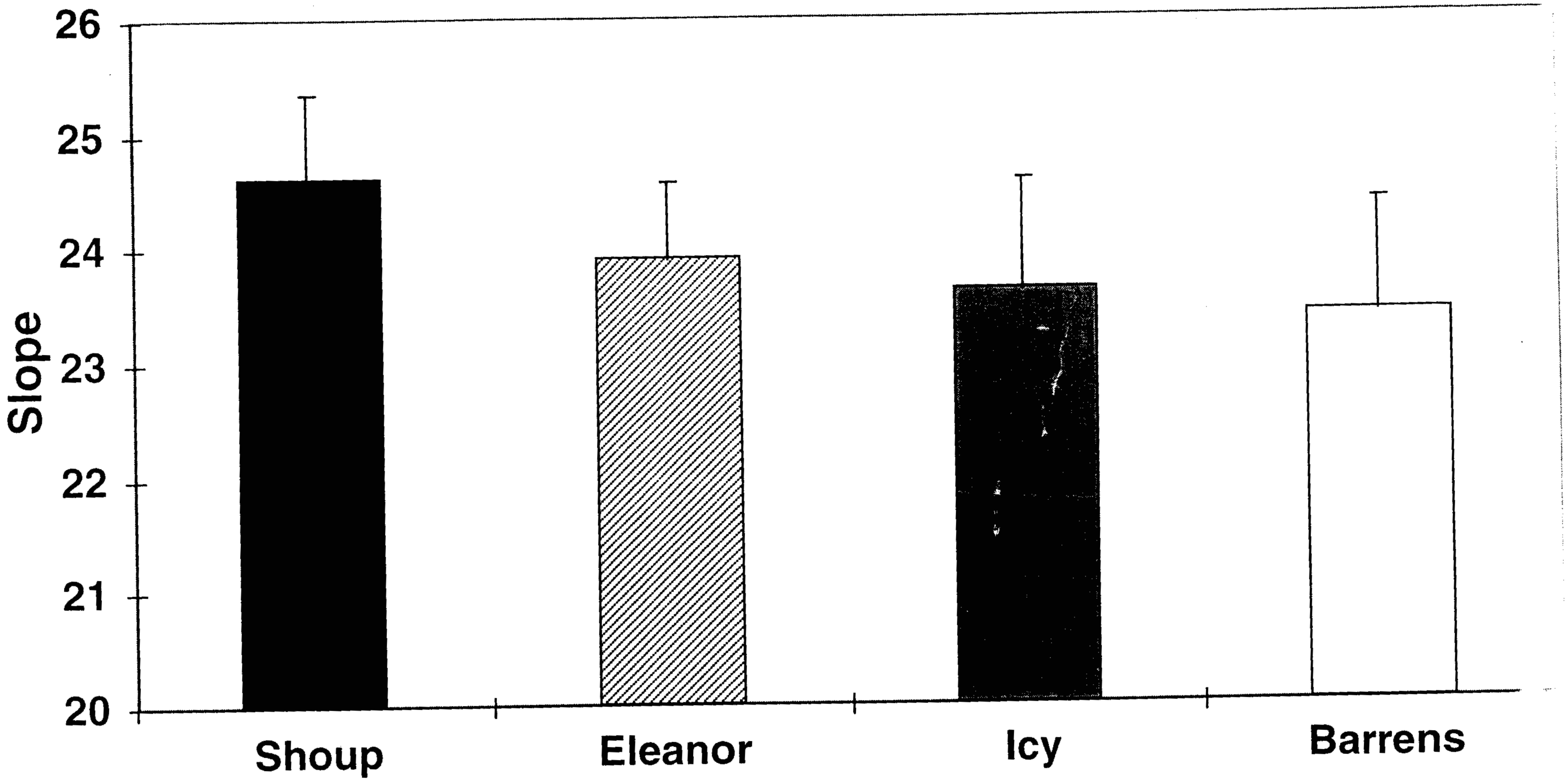

Figure 6. Index to growth performance for black-legged kittiwake nestlings at four sites, 1996. The growth performance index is the slope of the least squares regression line for the square root of body mass vs. the squar root of the natural log of wing length

Table 1. Feeding frequency, meal size, and energy density in determining energy provisioning rates to pigeon guillemot nestlings in the northern Gulf of Alaska, 1994-1996.

	Meal Size (g wet mass)	Energy Density (kJ/g wet mass)	Feeding Frequency (meals/nest day)	Energy Provisioning Rate (kJ/nest day)
Naked Island				
1994	?	4.0	?	?
1995	**14.7**	**4.4**	**11.4**	**737**
1996	**14.2**	**4.4**	**12.0**	**750**
Jackpot Island				
1994	?	4.5	?	?
1995	**20.0**	**4.2**	**16.6**	**1,394**
1996	**10.7**	**4.5**	**?**	**?**
Kachemak Bay				
1994	?	5.5	?	?
1995	**?**	**5.2**	**?**	**?**
1996	**11.4**	**5.1**	**14.2**	**826**

Table 2. Energy Provisioning Rates to Black-legged Kittiwake Nestlings in the Northern Gulf of Alaska, 1996.

	Meal Size (g wet mass)	Energy Density (kJ/g wet mass)	Feeding Frequency (meals/nest day)	Energy Provisioning Rate (kJ/nest day)
Shoup Bay	**30.6**	**4.7**	**4.3**	**618**
Eleanor Island	**23.1**	**3.8**	**4.6**	**404**
North Icy Bay	**24.5**	**4.5**	**?**	**?**
Barren islands	**?**	**4.0**	**2.4**	**?**
Gull Island	**17.2**	**4.9**	**4.7**	**396**
Chisik Island	**24.4**	**3.4**	**2.8**	**232**

Table 3. Energy Provisioning Rates to Black-legged Kittiwake Nestlings in the Northern Gulf of Alaska, 1995-1996.

	Meal Size (g wet mass)	Energy Density (kJ/g wet mass)	Feeding Frequency (meals/nest day)	Energy Provisioning Rate (kJ/nest day)
Shoup Bay				
1995	29.0	4.8	3.3	463
1996	30.6	4.7	4.3	618
Eleanor Island				
1995	21.3	4.2	4.9	441
1996	23.1	3.8	4.6	404

APPENDIX I

APEX: 96163I

96163 I

APEX Project Leader

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This project was created to provide scientific oversight and coordination among the subprojects of the Alaska Predator Ecosystem Experiment or APEX Project. The past year was spent working with the P.I.'s to undertake our first full season of field work, primarily by shifting effort to the nearshore for sampling and fine-tuning projects' goals in response to our initial year of work. We also brought in two new projects, 96163 H and 96136 Q, to undertake analysis of fish samples and to provide initial modelling of the relation between forage fish and seabird reproduction, and we greatly increased support to 96163 M, in Cook Inlet.

Within the project, we supported a graduate student to work with K. Frost of ADF&G and with APEX PI's, to examine the relation between harbor seal diving and fish distribution. To date most of effort has been expended on preparing the data for ArcView and INFOCAD.

In addition, we have undertaken a project with USFWS's seabird atlas to examine whether the distribution of seabird colonies in Prince William Sound may be determined by food, with the predictions that bigger colonies should be farther apart and that colonies with less demand for food within their exclusive foraging zones should do better than colonies with overlap. Data layers have been acquired and brought into ARCINFO. Analysis is underway.

Some time has also been devoted to planning for a symposium on change in Pacific seabirds to be held in 1998. This will allow for the first time a comparison of events in the Sound with those of the rest of the Pacific.

Finally, much of the project is involved in the generation of reports, coordinating research efforts and methods, and in discussions of future needs that appear as the APEX project matures.

The results of the APEX research are discussed in the abstracts for projects 96163 A, B, C, E, F, G, J, K, L, M, N, O, and P.

APPENDIX J

APEX: 96163J

Exxon Valdez Oil Spill
Restoration Project Annual Report

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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March 1997

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

Study History: Barren Islands APEX seabird studies were initiated in 1995 (Project 95163J; see Roseneau *et al.* 1996a, Barren Islands seabird studies, 1995). In 1996, these studies became Project 96163J (see the APEX FY 96 detailed project description).

Abstract: Data on breeding and foraging parameters of common murres *(Uria aalge)*, black-legged kittiwakes *(Rissa tridactyla)*, and tufted puffins *(Fratercula cirrhata)* were obtained by the same collection and analysis methods used at the Barren Islands in 1995. Murre and kittiwake productivity was high and normal, respectively, and similar to 1994-1995. Although Pacific sand lance *(Ammodytes hexapterus)* replaced capelin *(Mallotus villosus)* as the dominant prey fed to kittiwake chicks, and chick regurgitation weights were lower, nestling growth rates were normal and similar to 1995. Murre and puffin chick diets were similar to 1995: murres received about 90% capelin (*Mallotus villosus*), and puffins were primarily fed capelin, Pacific sand lance *(Ammodytes hexapterus)*, and walleye pollock (*Theragra chalcogramma*). However, puffin bill-load weights and chick growth rates were lower, and fewer puffin chicks fledged than in 1995. Murre and kittiwake chick feeding rates were similar among days and to 1995 levels, but puffin chick rates (a variable not obtained in 1995) differed between 1996 observation dates. Although murre attendance varied between days both within and between years, kittiwake attendance was similar to 1995. Kittiwake foraging trips lasted longer, and murres made fewer 2-4 hour-long trips, compared to the previous year. Nesting chronology of kittiwakes was similar to 1994-1995, but murres nested earlier than in all previous postspill years. The trend toward earlier timing in murre nesting chronology since 1993 may have resulted from changing environmental conditions and/or the increasing age and experience of the breeding birds.

Key Words: Barren Islands, black-legged kittiwake, common murre, East Amatuli Island, East Amatuli Light Rock, *Exxon Valdez*, forage fish, *Fratercula cirrhata*, oil spill, Prince William Sound, *Rissa tridactyla*, tufted puffin, *Uria aalge*.

Project Data: (To be addressed in the final report)

Citation: Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1997. Barren Islands seabird studies, 1996. Unpubl. annual rept. by the Alaska Maritime National Wildlife Refuge, Homer, Alaska for the *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska (APEX Project 96163J). 26 pp. (plus appendices).

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INTRODUCTION

This study is a component of the Alaska Predator Ecosystem Experiment (APEX). The APEX project, initiated in 1995, is composed of 15 related studies designed to determine whether forage fish availability and quality are limiting the recovery of seabird populations injured by the T/V *Exxon Valdez* oil spill. Over the course of the 5-year project, data on a variety of seabird breeding parameters and distribution, abundance, and energy content of forage fish will be compared among species, years, and study sites in Prince William Sound and lower Cook Inlet-Kachemak Bay to provide insight into how ecosystem processes may be affecting populations of seabirds nesting in the spill area.

The Barren Islands were included in the APEX seabird-forage fish project for several reasons. The islands support some of the largest concentrations of black-legged kittiwakes *(Rissa tridactyla)*, common murres *(Uria aalge)*, and tufted puffins *(Fratercula cirrhata)* nesting in the spill area, and some information on these species was available from past studies (e.g., Bailey 1975a,b and 1976; Manual 1978, 1980; Manual and Boersma 1978; Nysewander and Dippel 1990, 1991; Dippel and Nysewander 1992; Nysewander *et al.* 1993; Dragoo *et al.* 1995; Boersma *et al.* 1995; Erikson 1995; Roseneau *et al.* 1995, 1996a,b). Also, the offshore location of the islands provided opportunities to compare data from an oceanic environment with results from APEX studies in Prince William Sound and Minerals Management Service (MMS) and other APEX research in lower Cook Inlet-Kachemak Bay. Furthermore, capelin *(Mallotus villosus)*, an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (Piatt and Anderson 1995), were abundant near the islands during 1993-1994 (Roseneau *et al.* 1995, 1996b). Large stocks of these fish and the presence of other forage species, including Pacific sand lance *(Ammodytes hexapterus)* and young cods (e.g., 0-1 age-class walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus*) in surrounding waters provided an opportunity to explore seabird - forage fish relationships that might help explain why populations of some seabird species have not increased in the spill area.

Data collected at the Barren Islands are being used to help test three APEX hypotheses:[1]

Hypothesis 7: Composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near nesting colonies.

Hypothesis 8: Changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks.

Hypothesis 9: Seabird productivity is determined by differences in forage fish nutritional quality.

In 1996, we collected data on kittiwake, murre, and puffin productivity and nesting chronology; types and amounts of prey fed to kittiwake, murre, and puffin chicks; growth rates of kittiwake and puffin chicks and fledging size of murres; feeding frequencies of kittiwake, murre, and puffin chicks; and time-activity budgets of kittiwake and murre adults. We also obtained information that can be used to help track trends in population size of the these species (trends in Barren Islands murre numbers are being studied in greater detail by Projects 96144 and 97144; see the FY 96 and FY 97 common murre population monitoring project descriptions).

Data were compared with results from the 1993-1994 EVOS-sponsored Barren Islands common murre restoration monitoring projects (Projects 93049 and 94039; see Roseneau *et al.* 1995,

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[1] APEX hypotheses are currently undergoing review; they may be modified to better address questions raised by the T/V *Exxon Valdez* oil spill.

1996b) and the 1995 APEX Barren Islands seabird studies (see Roseneau *et al.* 1996a). Information was also shared with other APEX investigators to allow comparisons to be made among colonies (e.g., D. Irons, Project 96163E; J. Piatt, Project 96163M; D. Roby, Project 96163G). Prey samples were sent to D. Roby for energy content and density analyses, to D. Schell (University of Alaska-Fairbanks) for isotope analysis, and to M. Sturdevant (Project 96163C) for studies of fish diets. Also, 40 beach-seine sets were made during the 1996 field season using the same methods employed at Gull and Chisik islands (Project 96163M). Data from these activities were sent to J. Piatt to allow comparisons to be made among study sites (see Robards and Piatt, in press).

OBJECTIVES

Objectives of the 1996 Barren Islands seabird studies were to:

1. Determine the productivity of common murres (fledglings per egg laid), black-legged kittiwakes (fledglings per nest), and tufted puffins (percent of occupied burrows containing chicks).

2. Determine the nesting chronology of common murres, black-legged kittiwakes, and tufted puffins (median hatch date).

3. Determine the growth rates of black-legged kittiwake and tufted puffin chicks (grams per day).

4. Determine the types of prey fed to common murre chicks (composition by number), and black-legged kittiwake and tufted puffin chicks (composition by number and weight).

5. Determine provisioning rates for common murre and black-legged kittiwake chicks (feedings per hour), and tufted puffin chicks (feedings per day).

6. Determine the amounts of food fed to black-legged kittiwake and tufted puffin chicks (grams per chick regurgitation and grams per nest screen, respectively).

7. Determine adult activity budgets for common murre and black-legged kittiwake adults (foraging trip duration, minutes per hour both adults were present at nests, minutes per hour both adults were absent from nests).

8. Sample near-shore forage fish populations throughout the season by making regular beach seine sets using Project 96163M methods.

9. Collect forage fish samples from kittiwake regurgitations and tufted puffin burrow screenings.

METHODS

Study Area

The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula (Fig. 1). The study was conducted at East and West Amatuli islands, and Amatuli Cove camp served as base of operations (Fig. 2). Data were collected during 18 June - 13 September by a team of four to five people. Team members commuted to murre and kittiwakes study sites in outboard-powered, 4.8-m-long, rigid-hulled inflatable boats, and to puffin study areas by boating and hiking.

Productivity

Murres: Murre productivity data were collected at 9 of the 10 East Amatuli Island - Light Rock plots established for this purpose in 1993-1995 (see Roseneau *et al.* 1995, 1996a,b) and one plot set up to replace another that had become difficult to see. The plots, containing about 25-50 nest sites (sites with eggs) each (1996 nest site total = 266), were viewed through 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather permitted (range = 1-6 days). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. Plot checks consisted of searching for eggs and chicks and adults in incubation and brooding postures, and counting adults. Each plot was checked about 28 times during 23 June - 4 September, from before eggs were laid until most chicks had gone to sea. Plots were treated as sample units and productivity was calculated as fledglings per egg laid. These data were also used to calculate hatching and fledging success (see Roseneau *et al.* 1995, 1996a,b). Differences among 1993-1996 results were tested by ANOVA.

Kittiwakes: Data on kittiwake productivity were collected from 11 East Amatuli Island plots, including four established 1993 and seven set up in 1995 (see Roseneau *et al.* 1995, 1996a,b). The plots, located on the same headlands as the murre productivity plots, contained 25-50 nests each (1996 nest total = 312; 285 contained eggs). Methods for collecting and analyzing data were similar to those used for murres, and were compatible with methods used by Projects 96163E and 96163M. Nest checks consisted of searching for eggs and chicks, and counting adults (adult postures were not used to determine kittiwake nest content). Each plot was checked about 28 times during 23 June - 4 September, from just after laying began until most chicks had fledged. Plots were treated as sample units and productivity was calculated as fledglings per nest site. Information on hatching and fledging success was not obtained in 1996, because poor weather conditions made it impossible to collect sufficient data during the hatching period. Differences among 1993-1996 results were tested by ANOVA.

Puffins: Puffin productivity data were obtained from four study plots established by University of Washington personnel in 1990 to collect information on chick growth rates (see growth rates below), and four transects totaling 270 m^2 established by FWS crews in 1986 to monitor numbers and occupancy of burrows (see Nishimoto 1990). Burrows in the plots were searched for signs of activity (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and nestlings during 23 July - 25 July, when most chicks were about one week old. A 35-cm-long flexible scoop was used to help determine presence/absence of nestlings. After the initial visit, burrows containing chicks were checked every five days until 8 September. Active and inactive burrows and nestlings were also counted once on the transects on 28 August, just prior to fledging. Burrows were treated as sample units and productivity was calculated as the percentage of active burrows containing chicks just prior to fledging. The difference between 1995-1996 results was checked with Pearson's Chi-square test. Data on hatching success were obtained from a plot containing 36 burrows marked for this purpose. Burrows were checked three times during the nesting season: once just before and once just after hatching, and once just before most chicks fledged.

Nesting Chronology

Murres: Median hatch date, derived from productivity plot data, was used as the primary measurement of murre nesting chronology (see Roseneau *et al.* 1995, 1996b). Median dates were calculated for the plots and values were averaged to describe timing of nesting events. Because laying and hatching of eggs and fledging of chicks were rarely observed, the date that nest sites changed status (i.e., from eggs to chicks) was estimated to be the midpoint between the closest pre- and post-event observation dates. Two methods were used to maintain precision during analysis. Nest sites with data gaps of more than seven days between pre- and post-event laying and hatching observation dates were excluded from the data set. Also, for nest sites where the range of possible laying dates was smaller than the range of possible hatching dates, hatching dates were calculated by adding 32 days to laying dates (32 days is the average incubation time—see Byrd 1986, 1989; Roseneau *et al.* 1995, 1996a,b). Plots were treated as sample units and differences among 1993-1996 results were tested by ANOVA.

Kittiwakes: Median hatch date, derived from productivity plot data, was used to measure kittiwake nesting chronology (see Roseneau *et al.* 1996a). Methods for calculating this variable were the same as those described for murres, except that 27 days (rather than 32) were added to laying dates at sites where the range of possible laying dates was smaller than the range of possible hatching dates (see Byrd 1986, 1989). Plots were treated as sample units and differences among 1993-1996 results were tested by ANOVA.

Puffins: Median hatch date was used to measure puffin nesting chronology. The date was derived from wing measurements of chicks instead of laying or hatching information, because burrows were not visited until the chicks were about one week old (visiting burrows prior to this time can result in abandonment of eggs or chicks). Chicks were treated as sample units and the date was obtained by estimating the ages of 44 chicks from first wing measurements and a growth equation reported by Amaral (1977), and then calculating the median of the nestlings' estimated hatch dates. The difference between 1995-1996 results was checked with a two-tailed *t*-test.

Chick Growth Rates

Murres: Data on murre chick growth rates were not obtained during the study, because disturbing birds to weigh and measure chicks could have caused high levels of chick mortality. However, 46 nestlings were dip-netted from the water and weighed (to nearest whole g) and measured (culmen, tarsus, and wing chord to nearest whole mm) just after they left the cliffs and went to sea (captured chicks were released immediately after data were collected). Chicks were captured at night to prevent predation by glaucous-winged gulls *(Larus glaucescens)*. Average chick weight provided an index of sea-going size.

Kittiwakes: To obtain information on kittiwake chick growth rates, 40 chicks from 38 broods were weighed (to nearest whole g) and measured (e.g., wing chord, culmen, tarsus, and back of head to tip of bill to nearest 0.1 mm) every 5-7 days, from shortly after hatching until they were about 32 days old. Growth rate calculations followed Project 95163E protocol. Average daily increases in weight were calculated for each chick from the most linear section of the growth curve (from 60 to 300 g) by dividing the difference in weight between the first and last measurements by the number of days between measurements. Resulting values were then used to calculate average growth rates for 'A' chicks (chicks in single-chick nests plus first to hatch chicks in 2-chick nests; n = 33) and 'B' chicks (the second-hatched chicks in 2-chick nests; n = 2). The difference between 1995-1996 'A' chick growth rates was checked with a two-tailed *t*-test.

Puffins: Thirty-three puffin chicks on three of the five study plots (see productivity above) were weighed (to nearest whole g) and measured (culmen, wing chord, and tarsus to nearest 0.1 mm) every five days, from the time they were about one week old until they were almost ready to fledge. To check the effects of more frequent visits on growth, 12 additional nestlings were weighed and measured three times on the remaining study plots. Weight was used as the primary indicator of growth. Data were analyzed by fitting a simple linear model to the 150-450 g section of each chick's growth curve (the portion that is nearly linear), and then calculating the average daily weight gain for each chick by using the slope of the line and numbers of days between first and last measurements. The final grams per day rate was the mean of the 33 chick values. The difference between 1995-1996 growth rates was checked with a two-tailed *t*-test.

Chick Diets

Murres: Prey items delivered to murre chicks were observed on seven different days during 12 August-1 September. Identifications were made using 7 x 42 binoculars and field guides. In total, 236 prey items, all fish, were recorded during deliveries, and 226 (96%) fish were identified to species or family groups (e.g. Gadidae) on the basis of color and body and fin shapes (e.g., caudal, anal, adipose fins). Data were analyzed by calculating percentages by number for five categories of prey: capelin, Pacific sand lance, cods (Gadidae), salmonids *(Oncorhynchus* spp.*)*, and unidentifiable fish species.

Kittiwakes: Samples of prey brought to kittiwake nestlings were obtained when growth study chicks regurgitated before, during, and after measurements. A total of 84 regurgitations were obtained on 15 days during 14 July - 9 August, when nestlings were about 1-4 weeks old. Samples were frozen shortly after collection and weighed (to nearest whole g) in the Homer lab. Individual prey items were weighed and identified by K.R. Turco at the University of Alaska-Fairbanks. Data were analyzed by calculating percentages by number and weight for seven categories of prey: capelin, Pacific sand lance, Pacific herring *(Clupea harengus pallasi)*, walleye pollock, salmonids, euphausiids *(Thyssanoessa* spp.*)*, and unidentifiable items.

Puffins: Samples of prey brought to puffin chicks were collected by temporarily blocking nesting burrows with squares of hardware cloth (screens). One hundred thirty-nine potential chick meals containing 446 prey items were obtained on six screening days at East Amatuli Island and four at West Amatuli Island during 23 July - 7 September. Prey were identified in the field using taxonomic keys and field guides, and then frozen. Preserved items were thawed, cleaned, and weighed (to nearest whole g) in the Homer lab. Data were analyzed by calculating percentages by number and weight for nine categories of prey: capelin, Pacific sand lance, walleye pollock, Pacific cod, prowfish *(Zaprora silenus)*, larval daubed shannies *(Lumpenus maculatus)*, pink salmon *(Oncorhynchus gorbuscha)*, squids (Cephalopoda), and other species.

Chick Provisioning Rates

Murres: Data on murre chick provisioning rates were collected from a plot containing 10 nest sites near one of the productivity plot observation posts. The plot was located in a flat rock-strewn area near the top of a cliff containing some of the productivity plots. Food deliveries were recorded during three 14-hr-long (0700-2100) watches on 12, 17, and 24 August. Data were analyzed by calculating the average number of feedings per hour for the three observation periods. Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA.

Kittiwakes: Kittiwake chick provisioning rate data were obtained from 12 chicks in eight nests that were located in one of the kittiwake productivity plots (see productivity above). Most information was collected by viewing nests through 7 x 42 binoculars from about 20 m away and recording times of feeding events during three 14-hr-long (0700-2100) watches on 16, 26, and 30 July. Some data were also obtained by recording activities on video tape (using two modified 8-mm Sony HandyCam camera/recorders) and reviewing the tapes in camp (in 1995, no differences were found between data collected simultaneously by the two methods). Observations began when nestlings were about nine days old and ended when they were about 23 days old. Because chicks are often fed several times after foraging adults return to their nests, and because adults sometimes leave their nests for short periods of time without foraging at sea, only first feedings after trips lasting 30 minutes or more were counted as feeding events. Data were analyzed by dividing the data into 1- and 2-chick nests, and calculating the average number of feedings per hour for the three observation periods. Differences between 1- and 2-chick nests on the five 1995-1996 observation dates were checked with two-tailed *t*-tests (if nest-types differed, annual indices were calculated for each type). Differences among the five observation dates were tested by ANOVA.

Puffins: Data on puffin chick provisioning rates were collected by observing adults returning to 10 marked burrows in one of the chick growth rate study plots during two 16-hr-long dawn-to-dusk watches (0600-2200) on 31 August and 2 September. Observations were made with 7 x 42 binoculars from a blind located about 50 m from the nesting burrows. Data consisted of adult departure and return times, and notes on activities in the vicinity of the burrows that might have affected the behavior of returning and departing birds (e.g., visits by aerial predators). Days were treated as sample units and the difference between observation dates was checked with a paired-sample *t*-test.

Amounts of Food Fed to Chicks

Murres: Data on amounts of food fed to murre chicks were not collected during the study, because disturbing the birds to collect and weigh fish could have caused high levels of chick mortality.

Kittiwakes: Information on amounts of food fed to kittiwake chicks was obtained from regurgitated samples (see chick food types above). Because amounts of food fed to nestlings increased until they were about 20 days old, the average weight of 33 samples collected from 20-day-old or older chicks were used to calculate meal-size. The difference between 1995-1996 results was checked with a two-tailed *t*-test.

Puffins: Data on amounts of food fed to puffin chicks were obtained from burrow screening samples (see chick food types above). Weights of the screened samples were averaged to obtain the meal-size index for this variable, and the difference between 1995-1996 results was checked with a two-tailed *t*-test.

Activity Budgets of Adults

Murres: Data on murre activity budgets were obtained during the three 14-hr-long observation periods used to collect chick feeding frequency information (0700-2100 hrs) on 12, 17, and 24 August; see chick provisioning rates above) and three additional 14-hr-long watches made during the incubation period (0700-2100 hrs on 15, 21, and 31 July). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks), were recorded for each nest site. Bird-minutes per hour were used to measure the amount of time nest sites were attended by one or two adults. For example, if one adult was present at its nest site for 60 minutes and the second adult was present for 30 minutes during the same hour-long block of time, the nest was assigned 90 bird-minutes of attendance for that hour. Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA. Average foraging trip time was obtained by treating trips made during the nestling period as sample units and calculating the mean trip duration during the three dawn-to-dusk watches that ended in chick feedings (n = 85 trips). Nest-days were used as sample units and the difference between 1995-1996 results was checked with a two-tailed *t*-test. The frequency of trips in 2-hr blocks of time (0-2, 2-4, 4-6 and 6-8 hrs) was also computed and between-years differences were checked with a Chi-square test.

Kittiwakes: Kittiwake activity budget information was obtained during chick feeding frequency observations at eight nests (see chick provisioning rates above) and one incubation period watch. Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded for each nest. Bird-minutes per hour were used to measure the amount of time adults spent at their nests each day (see murres, above). Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA. Average foraging trip time was obtained by treating trips made during the nestling period as sample units and calculating the mean duration of trips that ended in chick feedings and left another adult at the nest (because adults were not marked; n = 23 trips). Nest-days were used as sample units and the difference between 1995-1996 results was checked by a two-tailed *t*-test.

Puffins: During the two dawn-to-dusk watches made to obtain chick provisioning rate data, adult puffins stayed at their nesting burrows about 30 seconds or less to deliver fish to chicks. Because adults left the burrows unattended and were not marked, it was not possible to determine the duration of the foraging trips made by individual birds.

Population Counts

Murres: Murres were counted 16 times on the productivity plots on 16 different dates between the peak of laying and the first sea-going of chicks. Methods for collecting and analyzing data were the same as those used during the 1993-1994 Barren Islands murre restoration monitoring studies (see Roseneau *et al.* 1995, 1996b) and the 1995 Barren Islands APEX seabird project (see Roseneau *et al.* 1996a). Counts were averaged to obtain an annual estimate of birds on the plots and differences among the 1993-1996 scores were tested by ANOVA. *Note: Trends in Barren Islands murre numbers are being studied in greater detail by Project s96144 and 97144.*

Kittiwakes: Kittiwakes were counted 12 times on the productivity plots on 12 different dates before numbers began declining near the onset of fledging. Methods for collecting and analyzing data were the same as those used during 1993-1995 (D.G. Roseneau and A.B. Kettle, unpubl. data). Counts were averaged to obtain an annual estimate of birds on the plots and differences among the 1993-1996 scores were tested by ANOVA.

Puffins: The number of active puffin burrows on the three chick growth rate study plots and four transects were calculated to provide an annual index of population size. Plots and transects were treated as sample units and the difference between 1995-1996 results was checked with a Wilcoxon signed-ranks test.

RESULTS

Productivity

Murres: Murre productivity was high (0.77 fledglings per egg, SD = 0.14; Table 1, Fig. 3a; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.73 and 0.77 fledglings per egg, respectively; Roseneau *et al.* 1995, 1996a,b); however, all of these values were higher than the 1993 results (0.55 fledglings per egg; $P = 0.011$, 0.001, and 0.002, respectively). Fledging success followed an identical pattern: it was high (0.90 chicks per egg, SD = 0.12; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.93 and 0.91 chicks per egg, respectively), and results from all three years were higher than the 1993 value (0.79 chicks per egg; $P = 0.014$, 0.035, and 0.063, respectively). Hatching success exhibited a slightly different pattern: although it was also high (0.85 chicks per egg, SD = 0.10; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.85 and 0.79 chicks per egg, respectively), only 1995-1996 values were higher than the 1993 results (0.70; $P = 0.023$ and 0.022, respectively).

Kittiwakes: Productivity of kittiwakes was high (0.71 fledglings per nest, SD = 0.19; Table 1, Fig. 3b; see Hatch *et al.* 1993) and similar to 1994 and 1995 levels (0.64 and 0.81 fledglings per nest, respectively; see Roseneau *et al.* 1996a). These values differed sharply from 1993, when nesting pairs failed early in the nesting season and reproductive success was zero (no eggs or chicks were present on the four East Amatuli Island plots, Roseneau *et al.* 1995).

Puffins: Just prior to fledging, 0.31 (SD = 0.16) chicks were found per occupied burrow on the three growth rate plots and group of four transects (Table 1). This was a significantly lower ($P <$

0.001) than in 1995 (0.53 chicks per occupied burrow; see Roseneau *et al.* 1996a). Hatching success, obtained from a plot established for this purpose, was 0.5 chicks per egg. This figure was lower than most values reported from other Alaskan colonies (see Byrd *et al.* 1993).

Nesting Chronology

Murres: Based on the median hatch date (4 August, SD = 4; Table 1), hatching occurred 5, 7, and 12 days earlier than in 1995, 1994, and 1993, respectively. These dates differed significantly from one another, with the exception the 1994-1995 dates. Also, the 1993 hatch date was earlier than the reported 1992 Nord Island and 1991 East Amatuli Light Rock dates (see Dragoo *et al.* 1995 and Boersma *et al.* 1995, respectively).

Kittiwakes: The median hatch date was 7 July (SD = 7; Table 1); this was similar to 1994-1995 results (10 and 8 July, respectively).

Puffins: The median hatch date for puffins was 16 July (SD = 5; Table 1). This was significantly earlier than in 1995 (21 July, $P<0.001$).

Chick Growth Rates

Murres: The average weight of the 46 murre chicks dip-netted from the sea was 240 grams (SD = 24; Table 1).

Kittiwakes: The average growth rate of kittiwake chicks, for all chicks combined (n = 35), was 17.5 grams per day (SD = 5.8; Table 1). 'A' chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 33) gained 17.6 grams per day (SD = 5.9), while 'B' chicks (the second-hatched chicks in 2-chick nests; n = 2) grew at a rate of about 14.9 grams per day (SD = 1.6). The 'A' chick rate was similar to the 1995 value (19.4 g per day).

Puffins: Puffin chicks in the three main study plots gained an average of 3.3 grams per day (SD = 1.6 g, n = 32; Table 1), while chicks visited only three times during the same period gained 3.1 grams per day (SD = 1.3, n = 12). The difference between these rates was not significant. The combined growth rate for all chicks was 3.2 grams per day (SD = 1.5; n = 44), a rate that was low for puffins, and considerably lower than the 1995 value of 11.4 grams per day ($P < 0.001$).

Chick Diets

Murres: Prey items delivered to murre chicks consisted solely of small fish (n = 236), most of which were capelin (91% by number; Fig. 4a). Adults also fed nestlings a few unidentified cods (Gadidae, probably walleye pollock and Pacific cod) and Pacific sand lance, and one unidentified salmonid (3%, 2%, and <1% by number, respectively). Ten fish (4%) could not be identified to group or species. Results were similar to 1995: capelin were clearly the primary component in chick diets.

Kittiwakes: By weight, 29% of the contents in the 84 kittiwake chick regurgitation samples could not be identified (Fig. 4b). However, Pacific sand lance (40%) and capelin (21%) were apparently the primary sources of food, while other prey types, including Pacific herring (6%), walleye pollock (1%), salmon (1%), and euphasiids (1%) were less important. Based on these data, chicks were apparently fed a larger proportion of sand lance and a smaller proportion of capelin, compared to 1995. However, methods used to identify the contents of the regurgitation samples differed somewhat from the previous year (otoliths recovered from the samples were saved, but not identified as they had been in 1995). This difference is being resolved, and a more detailed comparison between 1995-1996 results will be made in the next annual report.

Puffins: Prey deliveries (n = 139 screen samples) to puffin chicks contained 446 items (Fig. 5). By weight, capelin (37%), Pacific sand lance (27%), and walleye pollock (18%) were clearly the primary sources of food, while other types of prey, including pink salmon 6 (%), larval daubed shannies (4%), Pacific cod (2%), prowfish (2%), squid (2%), and other fish and invertebrates (2%), were less important. Based on this information, chicks received larger amounts of capelin and sand lance, and much smaller amounts of prowfish, compared to 1995. Chicks were also fed somewhat smaller amounts of pollock, compared to the previous year; however, this decrease (6%) was equivalent to the new pink salmon component (6%), which was not present in 1995.

Chick Provisioning Rates

Murres: During the three all-day observation periods, chicks averaged 0.26 feedings per hour (SD = 0.05, n = 3 d; Table 1, Fig 7a), a figure similar to the overall 1995 value (0.29 feedings per hour). No differences were found among the five 1995-1996 all-day watches.

Kittiwakes: During the three all-day observation periods, single-chick nests averaged 0.19 feedings per hour (SD = 0.03, n = 3 d; Table 1, Fig. 7b), and nests containing two chicks averaged 0.24 feedings per hour (SD = 0.08, n = 3 d). Although this difference was not significant, the difference between 1- and 2-chick nests was significant in 1995 (1- and 2-chick nests = 0.21 and 0.40 feedings per hour, respectively; $P = 0.015$). As a result, the 1995-1996 1- and 2-chick nest values were compared separately; however, no significant differences occurred among the five 1995-1996 all-day observation periods.

Puffins: All puffins returning to burrows were carrying fish. The number of feedings per burrow differed between the two all-day watches (31 Aug = 7.20, SD = 2.25; 2 Sep = 3.80, SD = 1.55; $P < 0.001$; Table 1), and there was a pronounced diurnal pattern on both dates: chicks were fed more often in the early morning hours than during other parts of the day (see Fig. 8).

Amounts of Food Fed to Chicks

Kittiwakes: Kittiwake chick regurgitation weights increased with nestling age (based on median hatch date). Weights averaged 10.1 grams (SD = 5.7, n = 18), 16.6 grams (SD = 11.0, n = 32), and 20.8 grams (SD = 13.3, n = 33) when chicks were less than 10 days old, 10-20 days old, and 20 days old or older, respectively. Only data from the 20-day-old and older chicks were used to compute this index. The average meal-size of 20.8 grams (SD = 13.3; Table 1) was lower than 1995 results (27.7 g, SD 11.5, n = 37; $P = 0.2$).

Puffins: The average weight of 109 screen samples collected during the nestling period was 6.9 grams (SD = 6.8, Table 1). This was significantly lower than the average weight of 110 samples obtained in 1995 (10.3 g; SD = 12.8; n = 110).

Activity Budgets of Adults

Murres: *(Nest Attendance)* -- During the incubation period, at least one adult murre always attended each nest site, and both pair members were present an average of 19.5 minutes per hour (79.5 bird-min/hr; SD = 6.0; n = 3 d; Table 1, Fig. 9a). During the nestling period, at least one adult was also always attended each site, and both birds were present an average of 9.6 minutes per hour (69.6 bird-minutes/hr; SD = 4.1; n = 3 d); this was similar to the 1995 figure (66.4 bird-min/hr). Testing by ANOVA showed that there was a significant difference among observation dates, and a Tukey post-hoc test indicated that two days were marginally different in 1996 (12 and 17 August; $P = 0.055$), as were one in 1995 (24 August) and one in 1996 (15 August; $P = 0.069$). These results indicated that differences between days were as great as differences between years.

(Duration of Foraging Trips) -- During the nestling period, murre foraging trips averaged 150 minutes (SD = 78, n = 85 trips; Table 1), a figure similar to 1995 results (158 minutes). However, the frequency of trips between 0-2 and 2-4 hrs differed between years (see Figs. 10 and 11; $\chi^2 = 17.14$, $P = 0.001$); shorter trips were more common in 1995.

Kittiwakes: *(Nest Attendance)* -- Adult kittiwakes rarely left eggs unattended during the incubation period, and during the same interval, it was even rarer for members of pairs to tend nests together. During the nestling period, as in 1995, members of pairs also rarely attended nests together. In 1996, chicks were occasionally left alone: both adults left 1- and 2-chick nests for an average of 1.0 minutes per hour (SD = 1.4, n = 3 d; Table 1, Fig. 9b) and 5.4 minutes per hour (SD =4.5). respectively. Although within day differences between 1- and 2-chick nests were not significant, 2-chick nests were consistently left alone more often than 1-chick nests (1-chick nests, 59.0 bird-min/hr/nest, SD = 1.43; 2-chick nests, 54.6 bird-min/hr/nest, SD = 4.48). As a result, data were analyzed separately; however, no differences in attendance were detected among days at 1- and 2-chick nests.

(Duration of Foraging Trips)-- Kittiwake foraging trips averaged 326 minutes during the nestling period (SD = 91 min, n = 23 trips; Table 1). This was significantly longer than in 1995 (237 min; $P = 0.01$).

Population Counts

Murres: Murre counts on the productivity plots averaged 407 birds (SD = 24.3; Table 1). This estimate was similar to the 1993, 1994, and 1995 scores of 435, 404, and 392 individuals, respectively (see Roseneau *et al.* 1995, 1996a,b).

Kittiwakes: Kittiwake counts on the four productivity plots that could be compared among years averaged 183 individuals (SD = 8.2, n = 12; Table 1). This estimate was similar to the 1994 and 1995 scores of 192 (SD = 10.3) and 201 (SD = 8.7) birds, respectively, but higher than the 1993 count of 120 individuals (SD = 50.3; $P < 0.001$).

Puffins: The number of occupied puffin burrows on the three growth rate study plots and group of four transects were similar between years (142 active burrows in 1996, Table 1; and 125 active burrows in 1995).

DISCUSSION

In 1995-1996, availability of forage fish to black-legged kittiwakes and common murres was apparently high enough in the vicinity of the Barren Islands to allow these species to reproduce at average and above average levels, respectively. In contrast, tufted puffin productivity was normal in 1995, but quite low in 1996. The lack of concordance between murres and puffins, both diving species, may in part, reflect differences in chick-rearing strategies. Puffin chicks remain in nesting burrows about twice as long as murre chicks stay at nest sites, and prey, including forage fish, need to be available to adult puffins for longer periods of time to ensure continued growth and survival of nestlings to fledging age. Foraging behavior also differs between puffins and murres: puffins tend to forage in flocks less often than murres; this trait might help explain why puffin chick diets were much more diverse than diets of murre chicks in 1995-1996.

During 1995-1996, growth rates of kittiwake and puffin chicks mirrored productivity (murre growth rates were not obtained during the study). However, while growth rates of kittiwake chicks were normal and similar between years, puffin chick growth rates were normal in 1995, but quite low in 1996. Again, differences in chick-rearing strategies and foraging behaviors might partially explain this difference. However, the low growth rate of puffin chicks in 1996 also suggested that these seabirds were having a harder time finding food during the chick-rearing period than in the previous year.

Capelin, generally considered to be relatively high quality prey, were by far the most common item fed to murre chicks in 1995-1996, and nestling diets were similar between years. Murres also reproduced at similar above average levels in 1995-1996. Capelin, in combination with Pacific sand lance, another high quality prey species, also played an important role in the diets of kittiwake and puffin chicks; however, by weight, percentages varied between years and were higher in 1995 than in 1996. Sand lance use followed an opposite pattern: percentages by weight in the chick diets of both species varied between years, but were higher in 1996 than in 1995. However, despite these dietary differences, kittiwake chick growth rates and productivity were normal and similar between years.

Puffin chick diets were the most diverse among the three seabird species. The percentage of prowfish fed to nestling puffins was relatively high in 1995, but markedly lower in 1996, when larger percentages of capelin and sand lance were delivered to burrows, compared to the previous year. Prowfish are generally considered to be poorer-quality prey than sand lance or capelin; however, nestling growth rates and productivity were normal in 1995, but quite low in 1996, when chicks received higher percentages of higher quality prey species. This difference suggested that a change in prey availability, rather than a change in food type, was responsible for the lower chick growth rates and productivity of puffins in 1996.

Seabird productivity and chick growth rates can be altered by availability of prey. The size of meals delivered to nestling kittiwakes was lower in 1996 than in 1995, and the duration of foraging trips was longer, compared to the previous year. These differences suggested that food was more difficult to acquire, and more effort was needed to feed chicks in 1996. However, by working harder, kittiwakes were apparently able to compensate for changes in prey availability and provide food to their nestlings at a frequency similar to the previous year—thereby preventing growth rates and productivity from dropping below 1995 levels.

Murres may have also worked harder to obtain food for chicks in 1996: fewer short foraging trips were made, compared to the previous year, although average trip duration was similar to 1995, and nest attendance and chick provisioning rates did not differ between years. Because murres are capable of diving and foraging throughout the water column, they are less susceptible to changes in oceanographic conditions that can affect surface-feeding kittiwakes by causing prey to remain below this specie's feeding depths.

Puffins delivered significantly smaller meals to chicks in 1996, compared to 1995. Again, this difference suggested these birds were having a more difficult time finding food than in the previous year. Changes in prey availability and amounts of food fed to chicks, rather than changes in types of prey, probably accounted for the lower chick growth rate and productivity of puffins in 1996.

Murre nesting chronology has been getting steadily earlier in the Barren Islands since 1993 (and also apparently since 1991). While the possibility exists that changes in food supplies and environmental conditions may be involved in this in timing change, the pattern is typical for populations undergoing increases in age and experience of breeding individuals— something that might be expected after a major mortality event, such as the *Exxon Valdez* oil spill (see Nysewander *et al.* 1993). Factors that may be responsible for the change in timing of murre nesting events may be identified by continuing to explore relationships among breeding parameters and food supplies of murres and other seabirds at the Barren Islands colonies.

CONCLUSIONS (To be addressed in the final report)

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Table 1. Results from Barren Islands Seabird Studies, 1996.

Variable	Common murre		Black-legged kittiwake		Tufted puffin	
Productivity	Eggs hatched / eggs laid	0.85 (0.10)[1]	Chicks fledged / nests built:	0.71 (0.19)	Chicks / occupied burrow	0.31(0.16)
	Chicks fledged / eggs hatched	0.90 (0.12)				
	Chicks fledged / eggs laid	0.77 (0.14)				
Nesting chronology	Median hatch date:	4 Aug (4)	Median hatch date:	7 Jul (7)	Median hatch date:	16 Jul (5)
Chick growth rate	Fledging weight (g):	240 (24)	Grams / day (all chicks):	17.5 (5.8)	Grams / day:	3.3 (1.6)
			("A" chicks):	17.6 (5.9)		
			("B" chicks):	14.9 (1.6)		
Chick feeding freq.	Feedings / chick / hr (0700-2100):	0.26 (0.05)	Feedings/nest/hr (0700-2100) (1 ch):	0.19 (0.03)	Feedings/nest/d (0600-2200):	7.2 (2.2) - 3.8 (1.5)
			(2 ch):	0.24 (0.08)		
Adult trip duration	Minutes / trip:	150 (78)	Minutes / trip:	326 (91)	*No data*	
Time no ad. on nest	Minutes / hour:	0.0	Minutes / hour (1 chick):	1.0 (1.4)	*Not yet analyzed*	
			(2 chicks):	5.4 (4.5)		
Time 2 ad. on nest:	Minutes / hour (incubation):	19.5 (6.0)	Minutes / hour (1 chick):	0.0	*Not yet analyzed*	
	(nestling period):	9.6 (4.1)	(2 chicks):	0.0		
Chick meal size	*no data*		Regurgitant weight (g):	20.8 (13.3)	Screen samp. wt. (g):	6.9 (6.8)
Population size	Productivity plots (no. of birds):	407 (24)	Productivity plots (no. of birds):	183 (8.2)	Number of burrows:	142

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[1] Standard deviation in parentheses

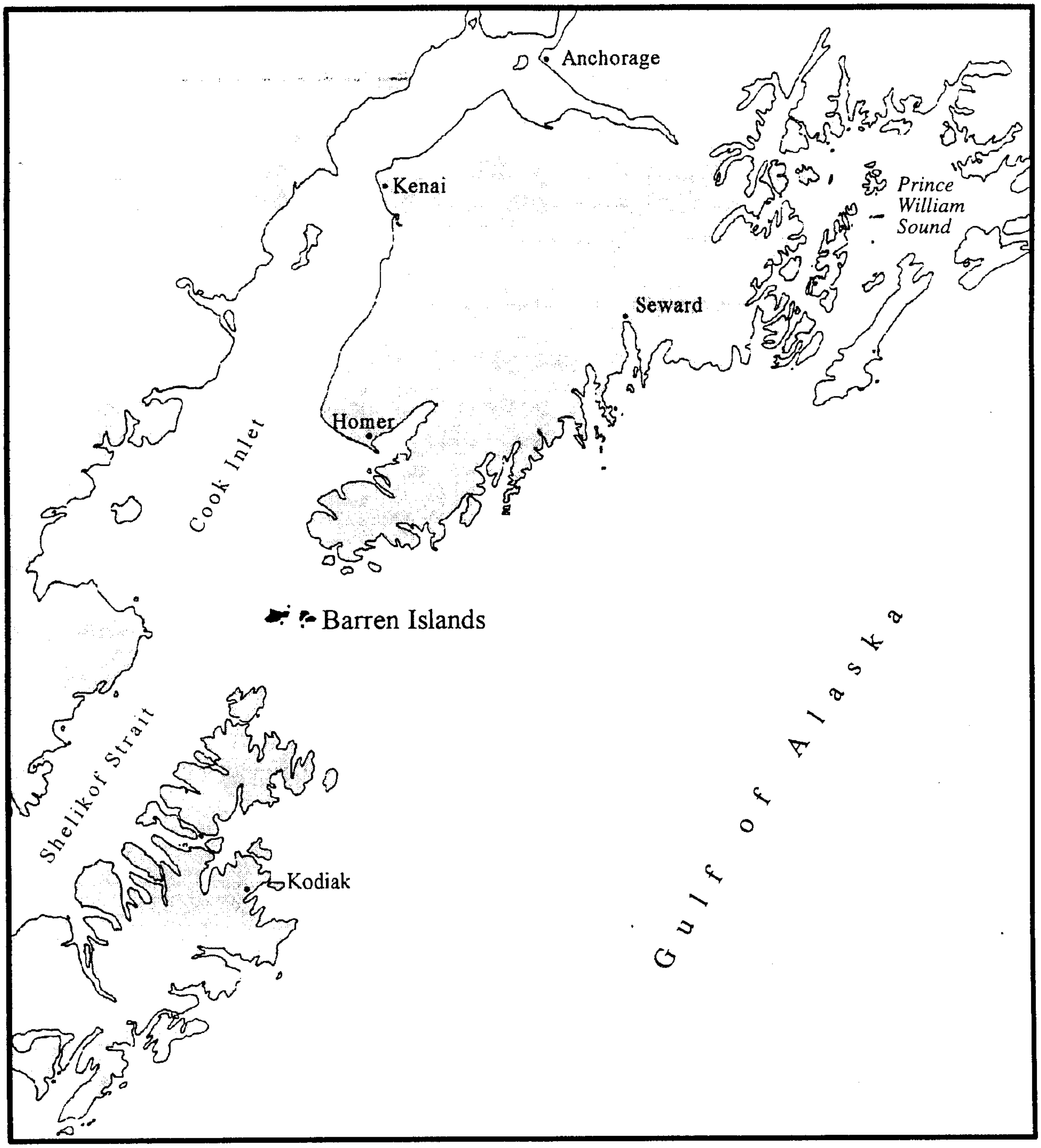


Figure 1. Location of the Barren Islands, Alaska

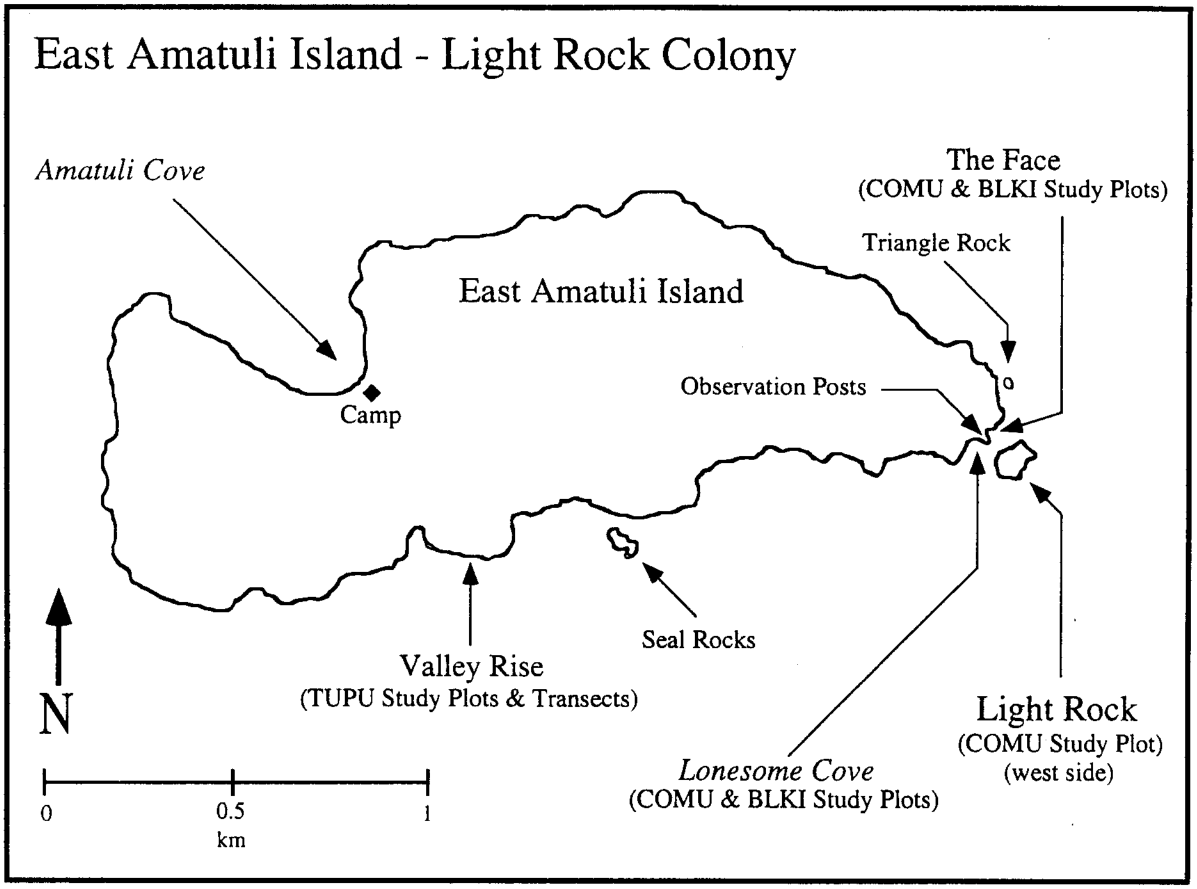


Figure 2. The East Amatuli Island study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

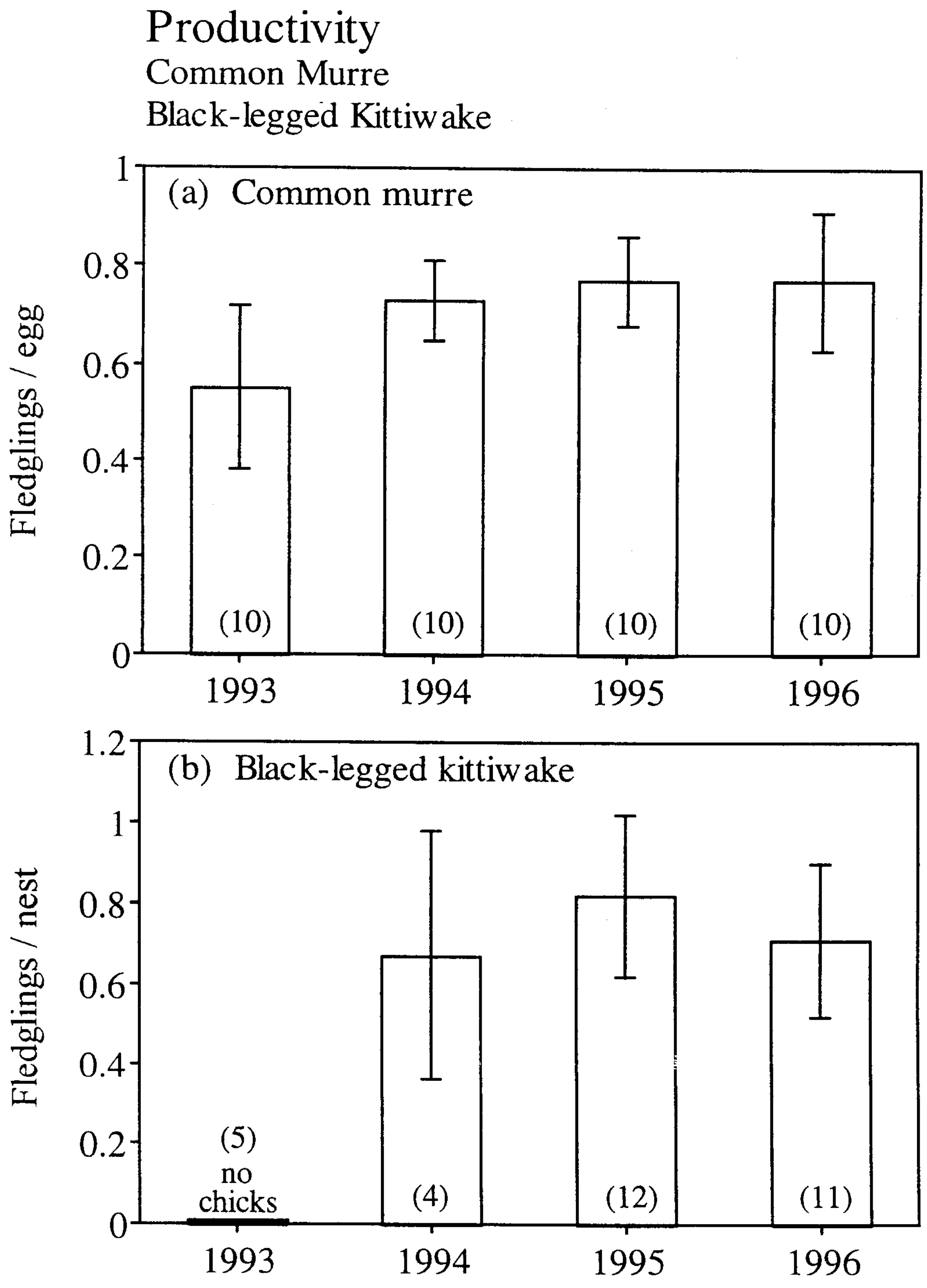
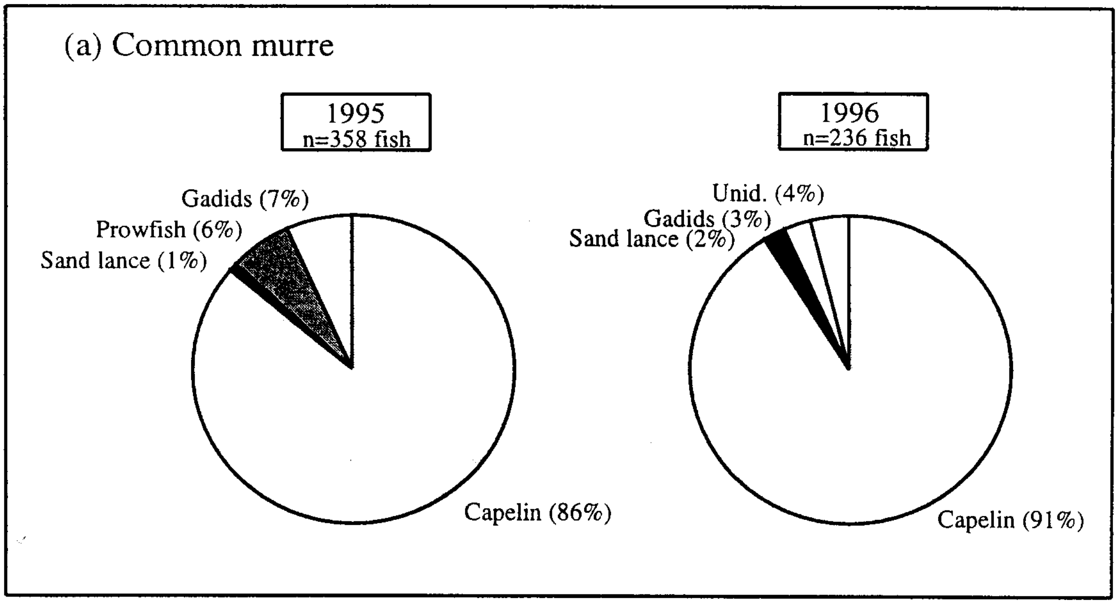


Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1996 (number of plots shown in parentheses; error bars = standard deviation).

Chick diet

Common murre

Black-legged kittiwake



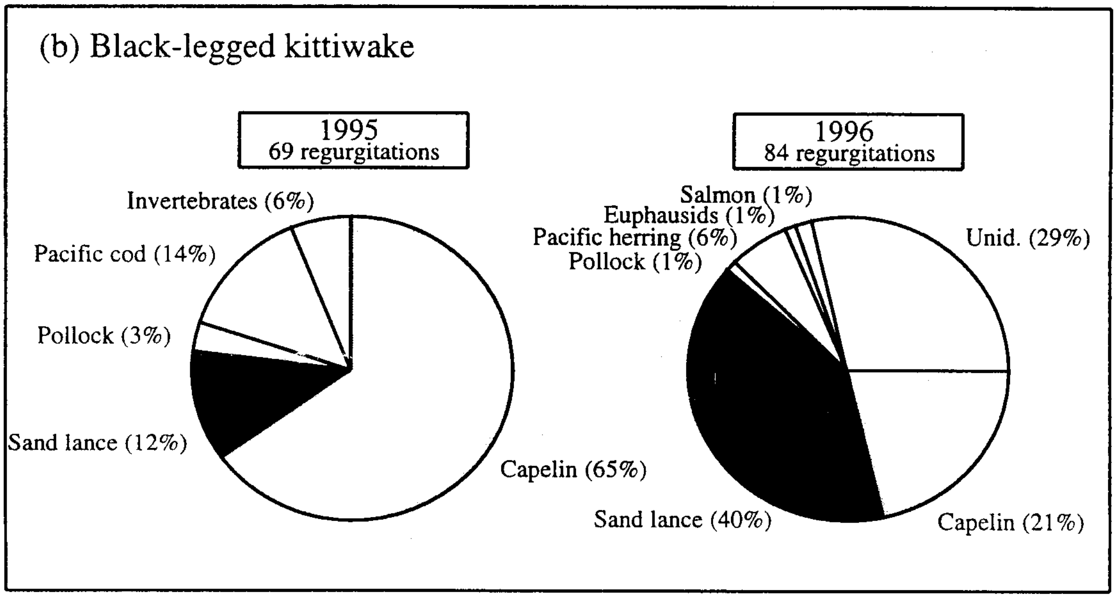


Figure 4. Types of prey fed to (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996: Composition of prey by (a) number and (b) weight.

Chick diet

Tufted puffin

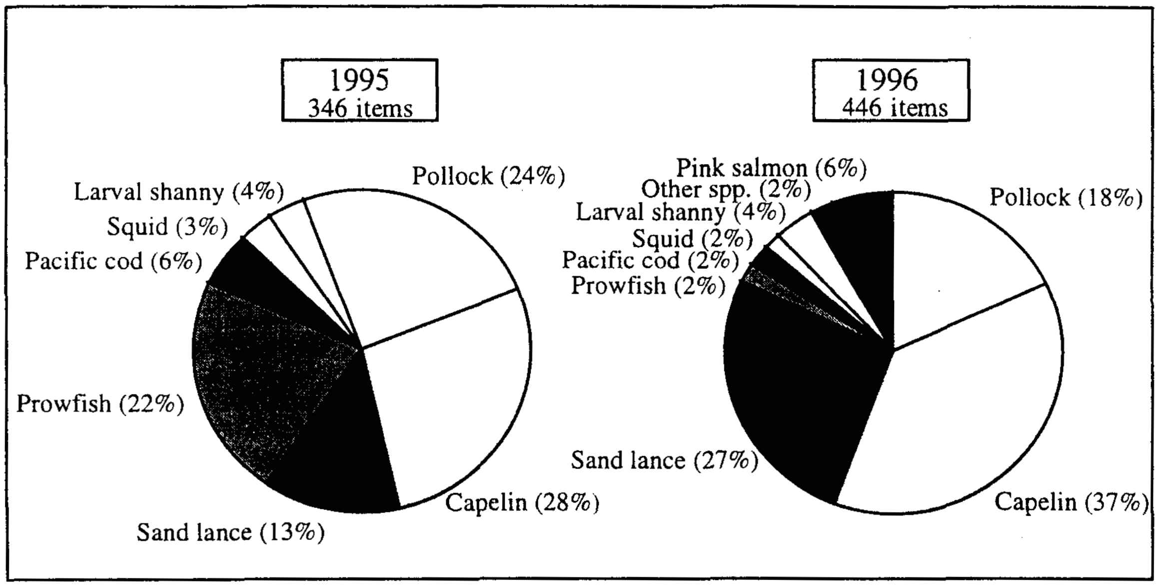


Figure 5. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (composition by weight).

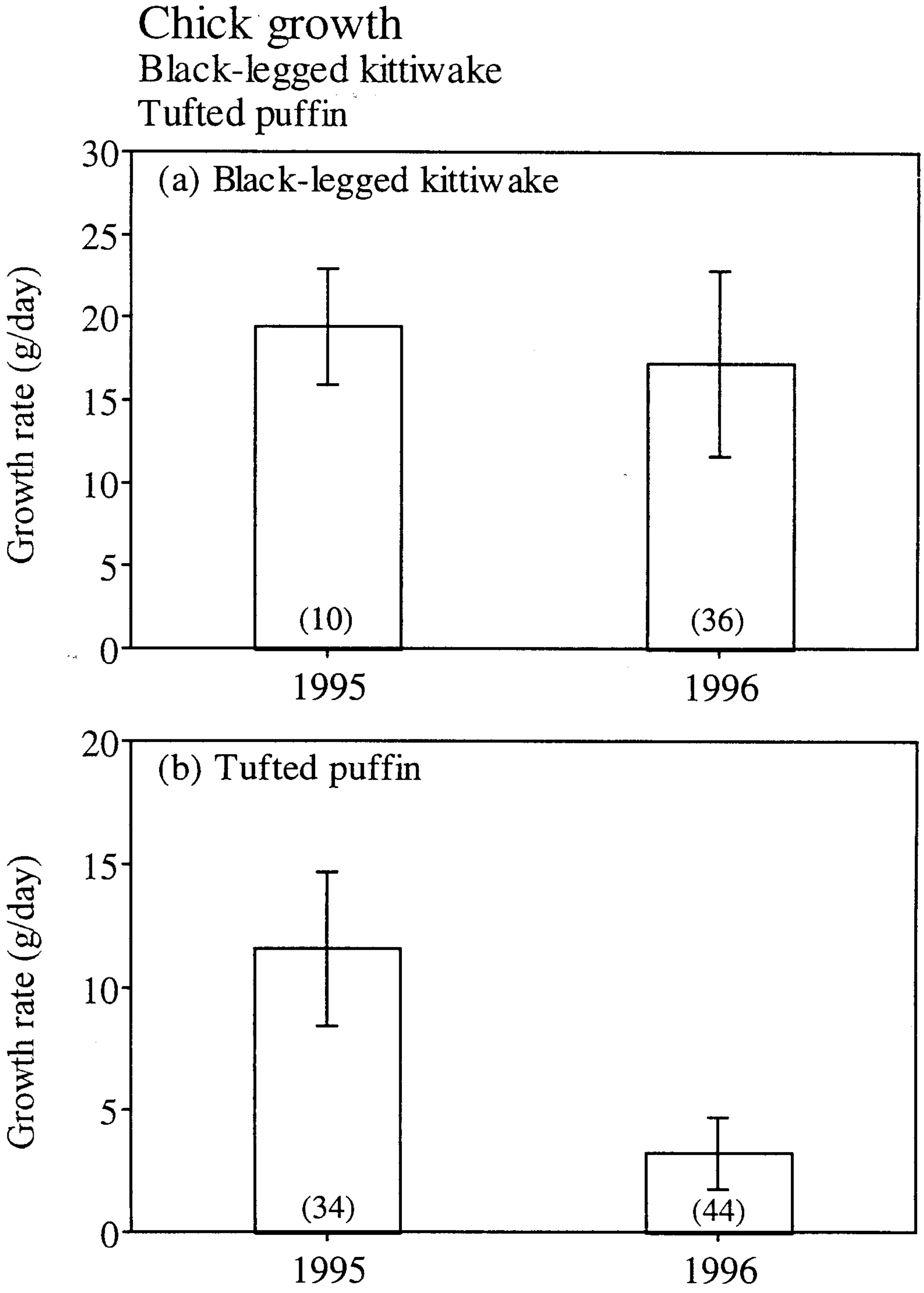
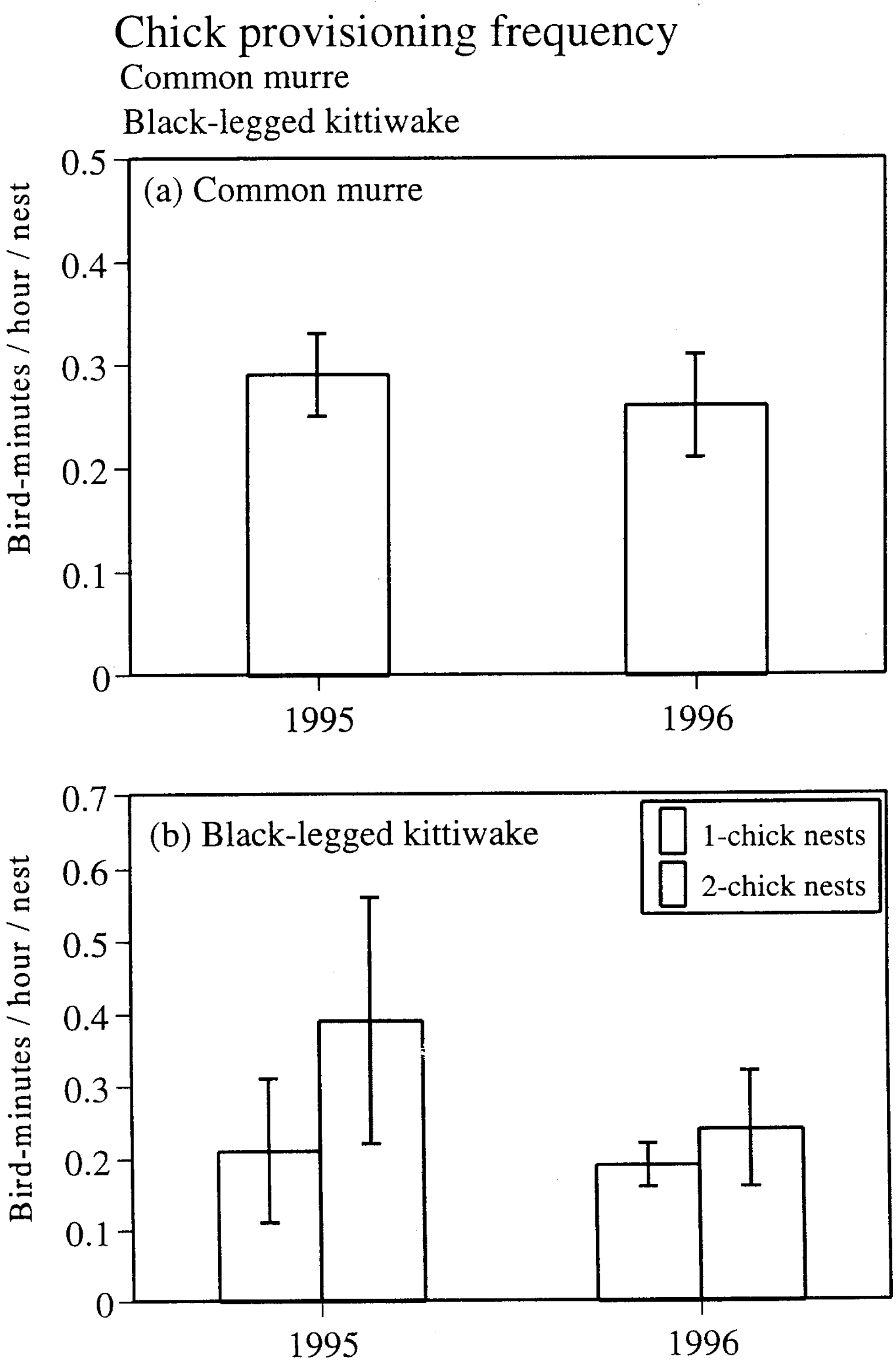


Figure 6. Growth rates of (a) black-legged kittiwake and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (number of chicks shown in parentheses; error bars = standard deviation).



Chick provisioning frequency

Common murre

Black-legged kittiwake

Figure 7. Provisioning rates of (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (n = 2 days in 1995 and 3 days in 1996; error bars = standard deviation).

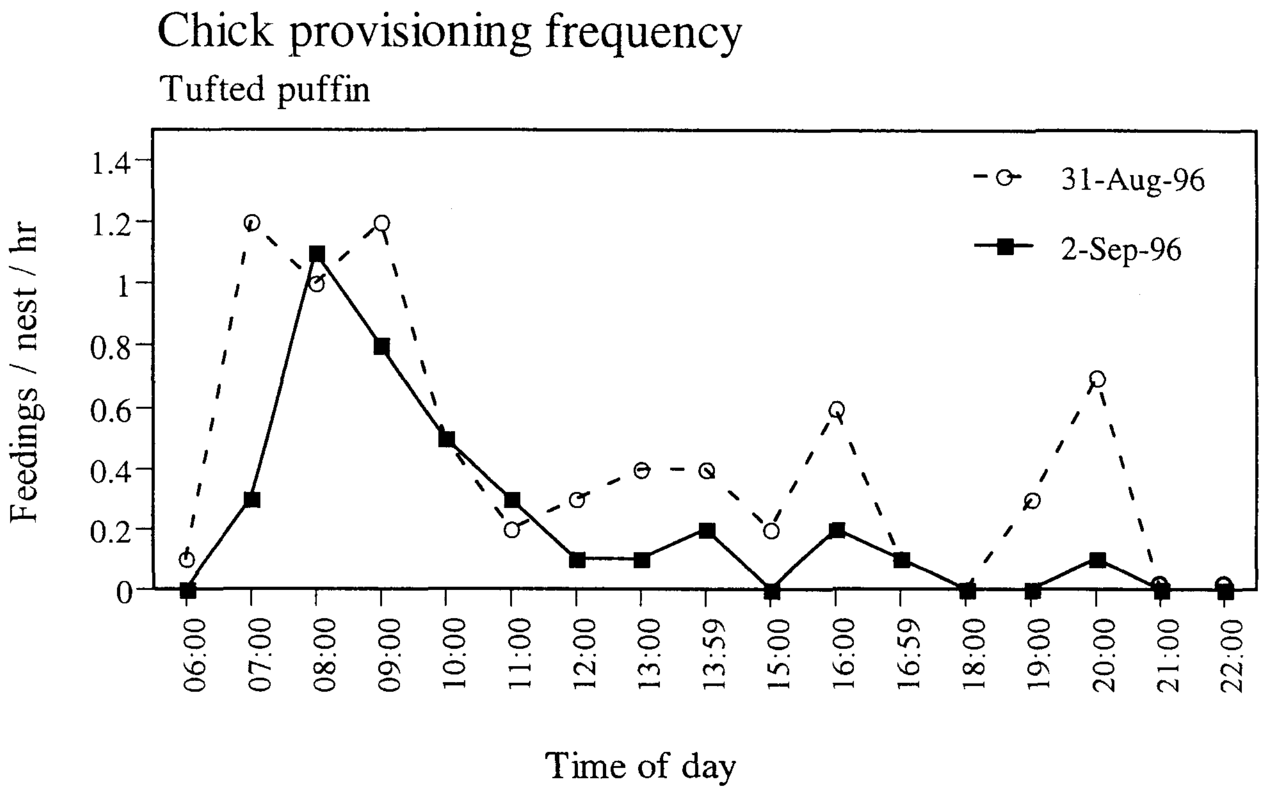


Figure 8. Number of times adult puffins brought prey to burrows at East Amatuli Island, Barren Islands, Alaska during two dawn-to-dusk observation periods in 1996 (calculated as returns per nest per hour, for a sample of 10 nests with chicks; hours are start times for corresponding data points).

Nest attendance -- nestling period
Common murre
Black-legged kittiwake

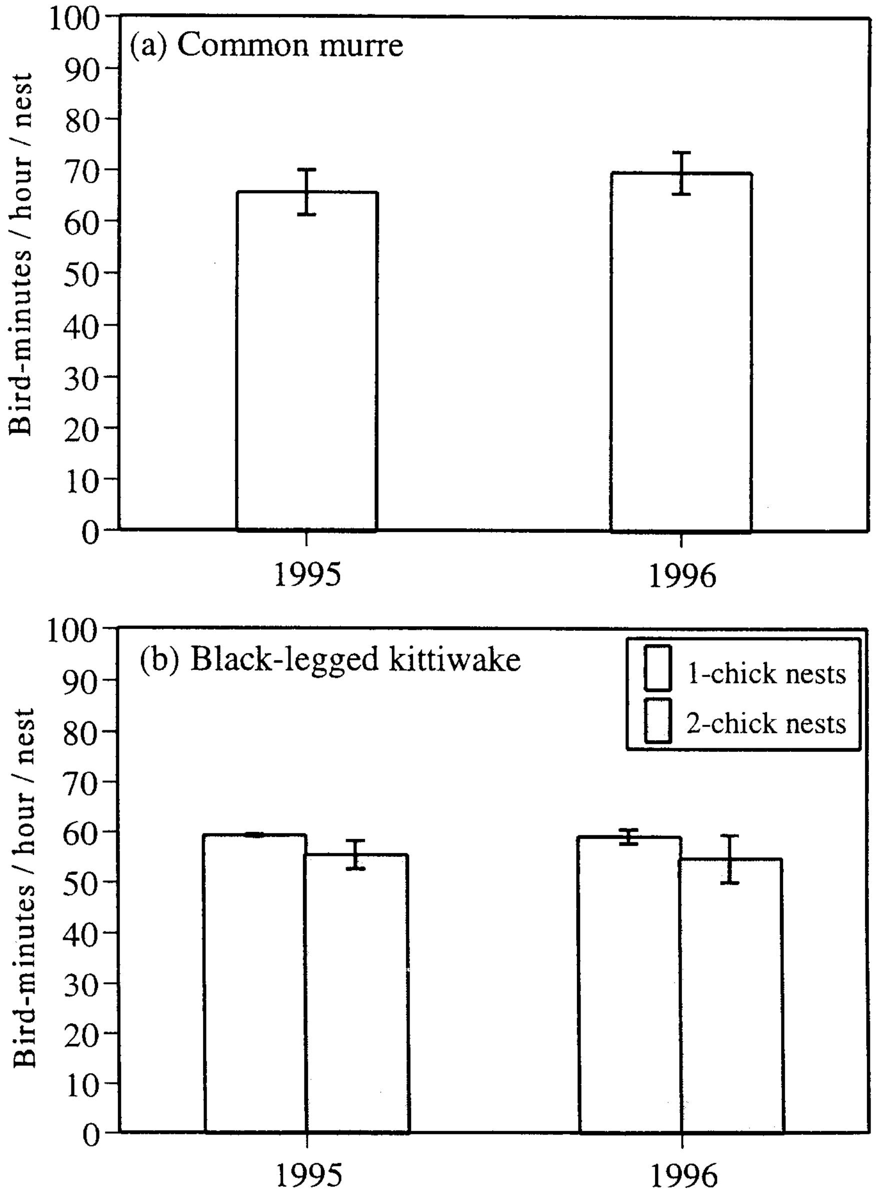


Figure 9. Number of minutes per hour spent at nests by (a) common murre and (b) black-legged kittiwake adults during the chick rearing period at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (n = 2 days in 1995 and 3 days in 1996; error bars = standard deviation).

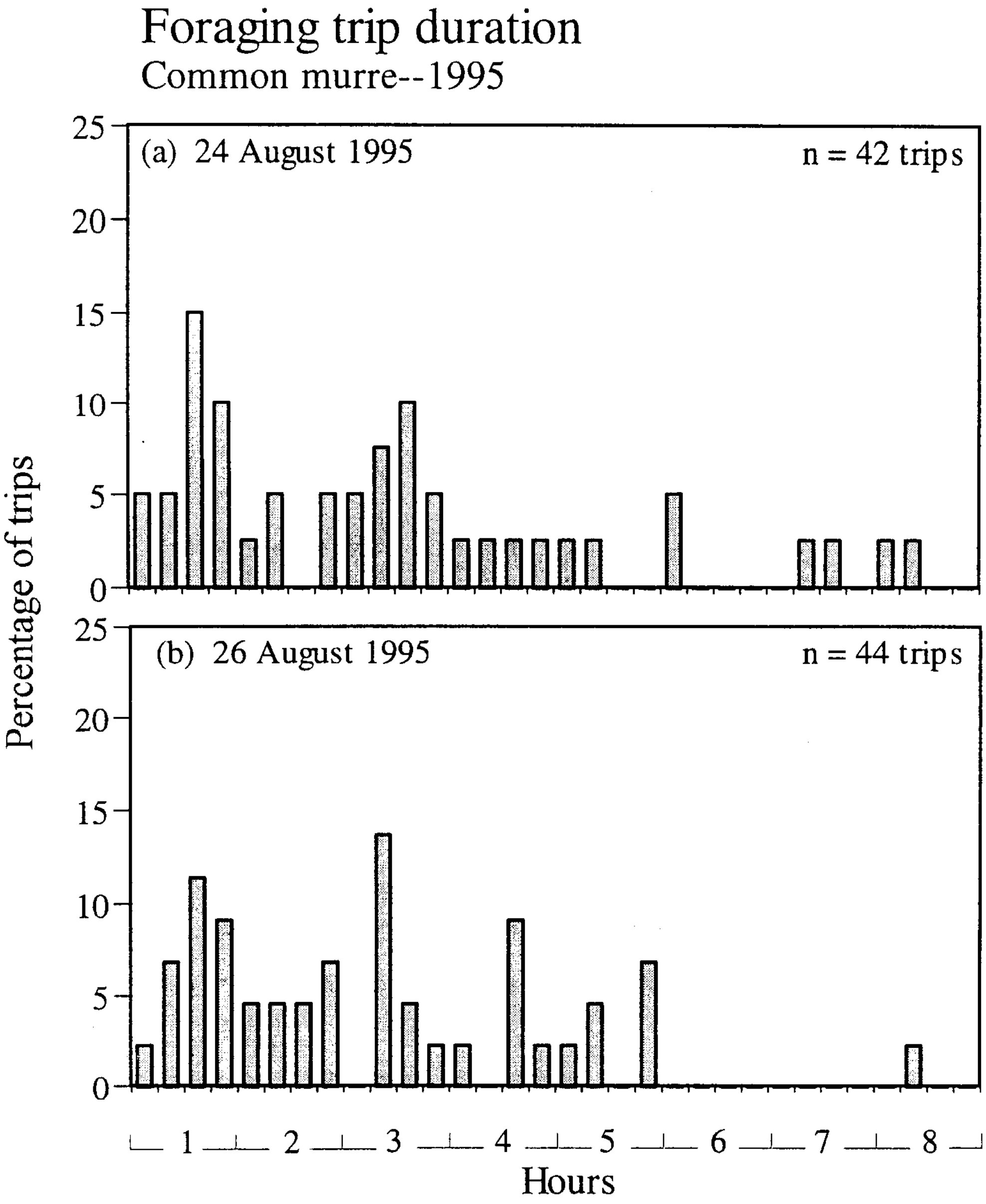


Figure 10. Duration of foraging trips by common murres from 12 nest sites at East Amatuli Island, Barren Islands, Alaska during two days in 1995: (a) 24 August and (b) 26 August.

Appendix 1

Protocol for APEX Common Murre Studies

Protocol for APEX Common Murre Studies

Barren Islands
Gull Island
Chisik Island

Arthur Kettle, John Piatt, Dave Roseneau, and Stephani Zador
17 April 1997

Productivity and Hatch Dates

Murre productivity and hatch dates are calculated from data recorded during regular observations of nest sites grouped into plots.

Field work: Generally, clusters of 20-40 nest sites (sites with eggs) on cliff faces or sections of flat-topped offshore rock are considered plots. At least 7 plots are subjectively selected (to include different habitat types) at each study location (E. Amatuli, Gull, Duck). Plot boundaries are defined by recognizable, permanent features of the substrate.

If possible, the same plots are used each year. When it is possible to identify nest sites used in previous years, nest site numbers are retained. New nest sites receive new numbers (or the number of an adjacent site plus a letter). Observations of each plot are made from a marked point that is used each year. Plot boundaries are clearly marked on photographs taken from the observation point, and on hand-drawn maps that show recognizable features of the terrain.

Plots are checked about every 3 days, from before eggs are laid until nest fates can be determined. During each check, codes are used to describe for each nest site the status of adults and, if visible, the nest content. Since it is often difficult to see underneath a murre to determine whether an egg or chick is present, distinct adult postures are used as indicators of the presence of eggs or chicks (see "Data analysis"). Codes for these data follow:

Adult codes

S	Standing and not in incubation or brooding posture.
L	Laying down and not in incubation or brooding posture.
IP	Incubation posture. A distinct posture assumed by most murres when incubating eggs. Adult sits forward with back humped, tail held down, and wings slightly dropped with tips uncrossed.
BP	Brooding posture. A distinct posture assumed by most murres when brooding chicks. Characterized by wing-mantling--the wing sheltering the chick is dropped.

P Adult present. Can't classify posture as any of the above.

N No adult present.

Example: "2S" means that 2 adults were standing

Nest content codes

E An egg is seen

C A chick is seen

0 There is no egg or chick

U Undetermined nest content

Examples: "SL0" means that one adult stood, another lay, and there was no egg or chick.

"NC" is an unattended chick

"N0" is an empty nest site

Data analysis: For each plot we calculate productivity (chicks fledged[1] per nest site), hatching success (chicks hatched per nest site), fledging success (chicks fledged per chick), and median hatch date. The mean and standard deviations of plot values provide the point estimate for a study location for each year. Data are analyzed according to the procedures in appendices 1 and 2.

Plot estimates (n >= 7 per site) are the sample for comparison among sites and years with ANOVA and Tukey pairwise mean comparison. Trends among years are tested with Kendall's tau rank correlation analysis.

Chick Growth

Gull and Chisik islands

Field work: On Gull and Chisik islands, fifteen to thirty unmarked murre chicks of unknown age are weighed and measured three times. Personnel visit the colonies before dawn or after sunset during early, mid, and late chick-rearing periods and attempt to measure a sample that represents

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[1] The term "fledge" in this protocol refers to the departure of a chick from its nest site, rather than the ability of flight or independence from parental care.

chicks of varying ages. Data recorded are mass (to 1 g), flattened wing chord (to 1 mm), and culmen (to 0.1 mm). Personnel time in the colony is limited to 30 min.

Data analysis: Mean mass as a function of wing length is plotted for all data, and the linear phase of mass increase is determined. For all measurements within this linear phase, mass is divided by wing length to derive an index of body condition. These values are then averaged for each island.

East Amatuli Island

Field work: At East Amatuli Island, if sea conditions allow it (as they did in 1996), fledglings will be weighed and measured just after they jump from the nesting cliffs. Fledglings are scooped from the water, weighed, measured, and released one at a time. A dip net is used to capture the chicks. Wing chord is measured to 1 mm, culmen to 0.1 mm, and mass to 1 g. Wing chord is measured on a flattened wing. If the weighing platform is a boat, a 500-g Pesola scale, rather than a 300-g scale, will be used to minimize bounce. To maintain boating safety and precision of weights, this parameter will be measured only in very calm sea conditions.

Data analysis: Mean mass, wing chord, and culmen are averaged as annual indices. Differences among years are tested with ANOVA and Tukey pairwise mean comparison.

In 1997, personnel at Gull and Chisik will assess the feasibility of measuring murre fledgling size, and the crew at East Amatuli Island will assess the feasibility of measuring more pre-fledging samples (one sample of 33 chicks was measured late in the nestling period in 1996).

Chick Food Types

Field work: We identify prey items brought to chicks by observing, with binoculars, prey in the bills of adults as they return to the nest. Identification is based on the color and shape of the item, and of the caudal, anal, adipose fins of fish. "A field guide to common murre bill loads" (John Piatt) and other keys is used to identify prey.

Observation periods can occur at any time of day and be of any specified length of time, but the time is set aside specifically for this purpose. We do not include fish haphazardly observed during productivity checks; this practice may skew observations toward large fish. At least 50 positive identifications will be obtained during each week of the nestling period. When possible, days of observations will be synchronized among Gull, Chisik, and East Amatuli islands. Only prey fed to chicks are recorded (not fish brought in for "display"). Each observation is recorded as one of the following three categories: (1) "Not Seen" (a feeding occurred, but because the return was too fast or was obscured, no identification was possible), (2) "Unknown" (a view sufficient for identification was obtained, but positive identification was not made) and the reason why identification was not made (e.g., not enough of the fish was available for identification), or (3) the fish is identified to the lowest practical taxonomic level.

When nest sites are visited for chick measurements, the area is searched for dropped prey items;

any found are collected.

Data analysis: Percentage of occurrence will be calculated for "unknown" and for each taxon of prey. The "not seen" category will be excluded.

Adult Time Budgets
Chick Provisioning Frequency
Nest Attendance by Adults
Foraging Trip Duration

Field work: Adult time budgets are calculated from day-long observations of a plot of 10 nest sites at each study location. So that variation among both nest sites and days can be calculated, the same nest sites are used for all observation-days within a year, if possible (although some nests for attendance observations will be different from nests used for the nesting period, if eggs fail to produce chicks). The observation post provides a view of chick feeding for each nest site. The time of all adult arrivals, deliveries of prey to chicks, exchanges of incubation or brooding duty, and adult departures are recorded. Each observation-day begins as close to first light as possible and ends as close to dark as possible. Because at East Amatuli Island a commute by boat is necessary, early-morning and late-night observations are recorded by video and later analyzed at camp. At least three observation-days occur during incubation and three during the nestling period. The observations sample the early, middle, and late parts of the incubation and nestling periods. When possible observation days are synchronized among study locations. If observation nests must change between years we will choose nests near the previous ones, to minimize the possibility of confounding among-plot effects with among-year effects.

In 1997 we will attempt to color-mark with a squirt gun and dye one adult at each nest site.

Data analysis: Nest attendance is measured as bird-minutes per nest per hour (e.g., a nest with one bird attending for a full hour and its mate attending for half of the hour has 90 bird-minutes that hour), and we calculate separately nest attendance during incubation and during the nestling period. Adult provisioning frequency is measured as feedings per nest per hour. Adult duty exchange frequency is calculated as exchanges per nest per hour. A trip from the nest begins when an adult leaves the nest and ends when it returns. Values are calculated separately for trips made during incubation, trips during the nestling period, and trips that ended with chick provisioning. Only complete trips are counted--not trips that were in progress when the observation period started or ended.

Within each year, among-nest and among-day differences in attendance, and in provisioning and exchange frequency are analyzed using the nest-day value as the sample. For example, to test differences among nests, the number of feedings for Nest 1 on the first, second, and third observation-day are compared with the three values for Nest 2, etc. To test differences among days, the number of feedings for nests 1-10 on Day 1 are compared with the ten values on Day 2, etc. Differences are tested with repeated-measures ANOVA and Tukey pairwise mean comparison.

Because there are not enough complete trips from each nest each day for us to obtain an average daily trip duration that is representative of each nest, the sample for comparisons among days is the individual trip; trips from all nests are pooled. Differences among days are tested with ANOVA and Tukey pairwise mean comparison.

For among-year comparisons of attendance, and of provisioning and exchange frequency, the sample is the mean among nests for an observation-day. For trip duration, the sample is the per-day mean of all trips. The annual index of each parameter is the mean and standard deviation of the per-day values. Comparisons among years are tested with ANOVA and Tukey pairwise mean comparisons; trends among years are tested with Kendall's tau rank correlation test.

Population Counts

Field work: Murres are counted on all productivity plots each day that they are checked. Murres on an additional set of larger attendance plots are counted 5-10 times during the season.

Counts are made between 1100 and 2000 hours on East Amatuli (the time during daylight hours when attendance is most stable [see Birkhead and Nettleship 1980; D.E. Dragoo, unpubl. data; Boersma *et al.* 1995; Roseneau *et al.* 1995]), and between 1000 and 1600 hours on Chisik and Gull Islands.

Data analysis: The sample for obtaining the annual mean for each type of plot set is the daily total count of all the plots. The annual index for comparing population size among years is the mean and standard deviation of the samples for all days between the peak of egg-laying and the start of fledging. If plots are added or subtracted between years, we will maintain a sample of plots for which counts can be compared among all the years of the study.

Differences among years and sites are tested with ANOVA followed by Tukey pairwise mean comparison. Trends are tested with Kendall's tau rank correlation analysis.

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Roseneau, D.G., A.B. Kettle, and G.V. Byrd, 1995. Common murre restoration monitoring in the Barren Islands, 1993. Restoration Project No. 93049. Unpubl. final rept., U.S. Fish Wildl. Serv., Homer, AK.

Appendix 1. Rules used for analysis of APEX common murre productivity and nesting chronology data

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1. Sites without observations of eggs and postures that indicate the presence of an egg (see [3.], below) are excluded from all productivity analyses, whether or not a chick is seen.

2. Sites with data that are not logical (e.g., an observation of "no nest content" between sightings of a chick) are excluded from analyses.

3. Observation of an incubation posture (IP) during three nest checks without an intervening observation of (1) no nest content; or (2) one adult, standing, without an egg sighting; or (3) two adults, standing, without an egg sighting, constitutes an egg at that sight first "seen" on the day of the first IP. For this rule, an egg sighting is equivalent to an IP after the first IP (e.g., if there are sightings of "IP, E, E" then the egg was first "seen" on the date of the IP).

    a. This rule is also used to determine the last day that an egg is present.

4. An observation of a brooding posture (BP) constitutes a chick first "seen" on that day.

    a. This rule is also used to determine the last day that a chick is present.

5. Because laying and hatching of eggs and fledging of chicks are rarely observed during plot checks, the date that a nest site changes status (i.e. "no egg" to "egg," "egg" to "chick," or "chick" to "no chick") is estimated to be the midpoint between the closest pre- and post-event observation dates. If the number of days between the two visits is even or is zero, the even Julian date closest to the midpoint is used in place of the midpoint.

    a. On the day that a nest's status changes from "egg" to "chick," the chick's age is zero. The day that the status changes from "chick" to "no chick" is included in the chick's age. Simply subtracting of the hatch date from the "disappeared" date will age the chick according to these rules.

6. In nests with relaid eggs, only the first egg is used for hatch date calculations and only the second for determination of breeding success.

7. Two methods are used to improve hatch date calculation precision.

    a. Each nest site with a "data gap" of more than seven days between pre- and post-event observations for both laying and hatching is excluded from calculations involving hatch dates or chick ages. Since this rule acts only on nests that produce chicks, it has the potential to artificially reduce the chicks-to-eggs ratio. For analyses that involve the proportion of eggs that produced chicks, the number of egg-only nests should be reduced by the proportion of chick-nests that were excluded (e.g., if 15 percent of the nests with chicks were excluded, the number of egg-only nests is reduced by 15 percent).

b. If the data gap for laying is smaller than the gap for hatching, we calculate the hatch date by adding 32 days (the incubation period) to the laying date.

8. Nests with more than 7 days between the last sighting of the chick and the first sighting of no chick are excluded from calculations involving the number of fledglings.
9. Chicks that disappeared at age 15 days[2] or older are considered fledged. Nests with data insufficient for determination of whether chicks died or fledged are excluded from fledging analyses.

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[2] Other studies have used similar conventions for fledging age:

Study	Observation interval (days)	Midpoints used for fledge date?	Minimum chick age for fledging (days)
Hunt, *et al.* 1981	3-4	no	16
Byrd 1989	3-5	no	15
Hatch and Hatch 1990	2	no	16
Dragoo and Dragoo 1994	3	yes	15
Roseneau *et al.* 1995	1-7	yes	15

Appendix 2. Information included on forms for collection and analysis of APEX murre productivity and nesting chronology data

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Data collection form

Each page of the field data collection forms is labeled with the island name and the year, species, and plot. Data fields (columns) are the nest site and the plot check dates; data records (rows) are listed by nest site. Observation codes are entered for each date, by nest site. Forms are printed on waterproof paper.

Data analysis form

Each page of the form used for analysis of nest status change dates is labeled with the island name and the year, species, and plot. Each record in the form contains the calculations for one nest site. Suggested data fields are:

Parameter abbreviation	Short for:	Data needed for calculation:
1. Nest site		
2. ENL	"Egg No Last":	the last "no egg" observation date
3. EY1	"Egg Yes 1st":	the first "yes egg" observation date
4. EYL	"Egg Yes Last":	the last "yes egg" observation date
5. CY1	"Chick Yes 1st":	the first "chick yes" observation date
6. CYL	"Chick Yes Last":	the last "chick yes" observation date
7. CN1	"Chick No 1st":	the first "chick no" observation date
8. #E	"# Eggs"	the number of eggs produced on the plot
9. #C	"# Chicks"	for murres, a "0" or a "1."
10. ELR	"Egg Lay Range"	EY1 minus ENL
11. CHR	"Chick Hatch Range"	CY1 minus EYL
12. BHR	"Best Hatch Range"	Lowest of ELR and CHR
13. BHD	"Best Hatch Date"	EYL + (CY1 minus EYL) / 2, unless ELR < CHR; then BHD = ENL + 32 + (EY1 minus ENL) / 2
14. CGR	"Chick Gone Range"	CN1 minus CYL
15. CGD	"Chick Gone Date"	if CGR =< 8: CYL + (CN1 minus CYL) / 2; otherwise leave blank
15. CGA	"Chick Gone Age"	if CGR =< 8: CGD minus BHD; otherwise leave blank
16. FA	"Fledge Age"	CGA if CGA >= 15; otherwise leave blank
17. DA	"Dead Age"	CGA if CGA < 15; otherwise leave blank

Exxon Valdez Oil Spill
Restoration Project Annual Report

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Restoration Project 96163J
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Study History: Most of the monitoring methods used in this project were also employed during 1995, at the same study sites, by Project 95163J. A report of that study was appended to the 1995 annual report for APEX Project 95163.

Much of the information generated from both the 1995 and 1996 studies is directly comparable with information gathered at the same study site in 1993-1994 during Restoration Projects 93049 and 94039 (see Roseneau *et al.* 1995, 1996).

Abstract: This 1996 APEX component continued methods of Project 95163J (1995) for monitoring the breeding and foraging parameters of common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrhata*) at the Barren Islands, Alaska. Many of the results are directly comparable with results from 1993-1994 restoration studies at the Barren Islands, and some are comparable with results from earlier studies. Breeding productivity (the number of chicks fledged per nest) of murres and kittiwakes was relatively high and normal, respectively, at East Amatuli Island in 1996; these results were similar to those of the previous two years. Growth rates of kittiwake chicks were normal and not significantly different from those of 1995, although the mass of chick regurgitant samples was lower in 1996. Kittiwake chick diet had a greater proportion of sand lance and a lower proportion of capelin in 1996 than in the previous year. The composition of murre and puffin chick diets in 1996 was similar to that of 1995: murre chicks were fed about 90% capelin (*Mallotus villosus*), and puffin chicks received mainly capelin, walleye pollock (*Theragra chalcogramma*), and Pacific sand lance (*Ammodytes hexapterus*). However, puffins fledged fewer chicks in 1996 than in 1995, and the growth rate of puffin chicks was very low. The mean mass of puffin bill-load samples was lower in 1996 than in 1995. Further analysis of the data may indicate whether the food shortage occurred during all or just part of the nesting season, and why the reproductive success of only puffins and not that of murres and kittiwakes was affected.

There were no significant differences among days in 1995 and 1996 in the frequency that murre and kittiwake chicks were fed. There was a significant difference in puffin provisioning frequency between the two days we observed this in 1996. We found differences in nest attendance for murres between days both within and between years, but found no differences for kittiwakes.

Mean foraging trip duration was longer for kittiwakes in 1996 than in 1995. For murres, there were fewer short trips of 2-4 hours of duration in 1996 than in 1995.

Common murres on East Amatuli Island have laid and hatched their eggs earlier each year since 1993. Breeding chronology in 1993 was, in turn, earlier than during previous post spill years (Dragoo *et al.* 1994; Boersma *et al.* 1995). This trend may be caused by environmental conditions or by increasing age and experience of breeding murres. Further analysis, including examination of other species' breeding chronology, will explore these and other possible factors.

Key Words: Barren Islands, black-legged kittiwake, common murre, East Amatuli Island, East Amatuli Light Rock, *Exxon Valdez*, forage fish, *Fratercula cirrhata*, oil spill, Prince William Sound, *Rissa tridactyla*, tufted puffin, *Uria aalge*.

Project Data: (will be addressed in the final report)

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INTRODUCTION

This study is a component of the Alaska Predator Ecosystem Experiment (APEX). APEX began in 1995 and is an association of 18 study components designed to determine whether low prey quality or abundance is limiting the recovery of populations of seabirds that were damaged in the *Exxon Valdez* oil spill. By comparing measurements of seabird activity among years, species, and sites, and with results from studies of forage fish distribution, abundance, and energy content, we hope to learn more about how ecosystem processes affect the population dynamics of seabird colonies.

The Barren Islands study was included in the APEX seabird-forage fish project for several reasons. First, the Barrens provide nest sites for the largest groups of common murres (*Uria aalge*)[1] and tufted puffins in the oil spill area. The majority of dead seabirds were found near or downstream from the Barrens. Common murres are being monitored for recovery. Second, some information on these species was already available from the colony (E.G. Bailey 1975a, b and 1976; Manual 1978, 1980; Manual and Boersma 1978; Nysewander and Dippel 1990, 1991; Dippel and Nysewander 1992; Nysewander *et al.* 1993; Dragoo *et al.* 1994; Boersma *et al.* 1995; Erikson 1995; Roseneau *et al.* 1995, 1996). Third, the island group's offshore location provided opportunities to compare data from an oceanic environment with results from APEX studies in Prince William Sound and Minerals Management Service (MMS) and other APEX research in lower Cook Inlet-Kachemak Bay. Finally, capelin (*Mallotus villosus*), an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (Piatt and Anderson 1995), were abundant near the islands during 1993-1994 (Roseneau *et al.* 1995, 1996). Large stocks of these fish and the presence of other forage species, including sand lance (*Ammodytes hexapterus*) and young cods (e.g., 0-1 age-class walleye pollock [*Theregra chalcogramma*] and Pacific cod [*Gadus macrocephalus*]) in surrounding waters provided an opportunity to study seabird - forage fish relationships that might help explain why populations of some seabird species have not increased in the T/V *Exxon Valdez* oil spill area.

Data collected during the study are being used to test three APEX hypotheses:

> Hypothesis 7: Composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near nesting colonies.
>
> Hypothesis 8: Changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks.
>
> Hypothesis 9: Seabird productivity is determined by differences in forage fish nutritional quality.

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[1] Although a few thick-billed murres (*Uria lomvia*) breed in the Barren Islands, In this report, "murre" refers to the common murre.

We collected data on kittiwake, murre, and puffin productivity and nesting chronology; types and amounts of prey fed to kittiwake, murre, and puffin chicks; growth rates of kittiwake and puffin chicks and fledging size of murres; feeding frequencies of kittiwake, murre, and puffin chicks; and time-activity budgets of kittiwake and murre adults. We also collected information for analysis of population trends of the three species. The status of murre population size at both East Amatuli and Nord Islands are covered more broadly by *Exxon Valdez* Oil Spill Trustee Council Project 96144, Common Murre Population Monitoring .

We have compared our results with data from the 1993-1994 EVOS-sponsored Barren Islands common murre restoration monitoring projects (Projects 93049 and 94039; see Roseneau *et al.* 1995, 1996). Results from this study have been shared with other APEX investigators for comparisons among colonies (e.g., D. Irons, Project 96163E, and J. Piatt, Project 96163M; D. Roby, Project 96163G). Prey samples have been provided to D. Roby for energy content and density analyses, to D. Schell (Project ____) for isotope analysis, and to M. Sturdevant (Project 96163C) for studies of fish diets. The Barrens field crew made 40 beach-seine sets during the season; protocol and methods were the same as for crews on Gull and Chisik islands. The results of this activity were sent to J. Piatt, who reported comparisons among sites (Robards and Piatt, submitted).

OBJECTIVES

Objectives for this 1996 study at the Barren Islands were (units of measure are in parentheses):

1. Determine the breeding productivity of the common murre (fledglings per egg-site), black-legged kittiwake (fledglings per nest), and tufted puffin (percent of occupied burrows containing chicks).

2. Determine the nesting chronology of the common murre, black-legged kittiwake, and tufted puffins (median hatch date).

3. Determine the growth rates of black-legged kittiwake and tufted puffin chicks (grams per day).

4. Determine the types of prey fed to chicks of the common murre (species composition by number), black-legged kittiwake (species composition by number and weight), and tufted puffin (species composition by number and weight).

5. Determine chick provisioning frequencies of common murres, black-legged kittiwakes, and tufted puffins (feedings per hour).

6. Determine the amounts of food fed to chicks of the black-legged kittiwake (grams per chick regurgitation) and tufted puffin (grams per nest screen).

7. Determine adult activity budgets for the common murre and black-legged kittiwake (foraging trip duration, minutes per hour both adults were present at nests, minutes per hour both adults were absent from nests).

8. Sample near-shore forage fish by regularly setting a beach seine, using methods shared with Project 96163M. Measure samples of each species caught, throughout the season.

9. Collect samples of forage fish from tufted puffin burrows, kittiwake regurgitant, and beach seines.

METHODS

Study Area

The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula (Fig 1). The study was conducted at East Amatuli and West Amatuli islands, and personnel stayed at the Amatuli Cove camp (Fig 2). Four to five people occupied the camp during 18 June - 13 September. They commuted to murre and kittiwake study sites in outboard-powered, 4.8-m-long, rigid-hulled inflatable boats, and to puffin study areas by boating and hiking.

Productivity

Murres: Murre productivity data were collected at 9 of the 10 East Amatuli Island - Light Rock plots used for this purpose in 1993-1995 (see Roseneau *et al.* 1995, 1996b) and one plot established to replace another that had been difficult to see. The plots, containing about 25-50 nest sites (sites with eggs) each (1996 nest site total = 266), were inspected with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather allowed (range = 1-6 days). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. Plot checks consisted of searching for eggs and chicks and adults in incubation and brooding postures, and counting adults. Each plot was checked about 28 times during 23 June - 4 September, from before eggs were laid until most chicks had left the cliffs. Using the plot as the sample unit, breeding productivity was calculated as fledglings per nest site; we also calculated hatching and fledging success (see Roseneau *et al.* 1995, 1996b). Differences among 1993-1996 results were tested with ANOVA.

Kittiwakes: Kittiwake productivity data were collected from 11 East Amatuli Island plots; four have been used in studies since 1993, and the other seven since 1995. The plots, located on the same headlands as the murre productivity plots, contained 25-50 nests each (1996 nest total = 312; 285 contained eggs). Methods for collecting and analyzing data were similar to those used for murres; methods were also compatible with those used in other APEX studies in Cook Inlet, and those in Prince William Sound . Nest checks consisted of searching for eggs and chicks, and counting adults (adult postures were not used to determine kittiwake nest content). Each plot was checked approximately 28 times during 23 June - 4 September, from just after egg-laying began until most chicks had fledged. Using the plot as the sample unit, breeding productivity was calculated as fledglings per nest site. Hatching and fledging success were not calculated for 1996 because weather prevented us from obtaining enough data during the egg-hatching period. Differences in productivity among 1993-1996 results were tested with ANOVA, with the plot as the sample unit.

Puffins: Puffin productivity data were obtained from four study plots established by University of Washington personnel in 1990 to collect information on chick growth rates (see "Growth Rates" below), and four transects totaling 270 m^2 established by FWS crews in 1986 to monitor numbers and occupancy of burrows (Nishimoto 1990; Table 2). Burrows in the growth rate plots were searched for signs of activity (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and chicks during 23 July - 25 July, when most nestlings were about one week old. A 35-cm-long flexible scoop was used to help determine presence/absence of chicks. After the initial visit, all burrows containing nestlings were checked every five days until 8 September. Burrows in the transects were checked once on 28 August, just prior to chick fledging, to count all burrows, active burrows, and nestlings. Productivity for both the growth rate plots and the transects was calculated as the proportion of active burrows containing chicks just prior to fledging. Using the burrow as the sample unit, a productivity index (i.e., pre-fledging chicks per active burrow) was calculated and compared between years with Pearson Chi-square.

We measured tufted puffin hatching success in a plot of 36 burrows marked for this purpose. We checked this plot once just before eggs hatched, again just after they hatched, and a third time just before chicks fledged.

Nesting Chronology

Murres: From the productivity plot data, we calculated median hatch date to measure murre nesting chronology (see Roseneau *et al.* 1995, 1996b). The median hatch date was calculated for each plot. These dates were then averaged. Because laying and hatching of eggs and fledging of chicks were rarely observed on the productivity plots, the date that nest sites changed status (i.e., from eggs to chicks) was estimated to be the midpoint between the closest pre- and post-event observation dates. Two methods were used to maintain precision during data analysis. First, each nest site with a "data gap" of more than seven days between pre- and post-event observations for both laying and hatching was excluded from the data set. Second, at each nest site with a smaller data gap for laying than for hatching, we calculated the hatch date by adding 32 days (the incubation period) to laying the date (see Byrd 1986, 1989; Roseneau *et al.* 1995, 1996b). Using the plot as the sample unit, we tested for differences among the years 1993-1996 with ANOVA.

Kittiwakes: Median hatch date was used to measure kittiwake nesting chronology. Data analysis methods were the same as described above for murres, except that an incubation period of 27 days (rather than 32) was added to laying dates when the laying date calculation was more precise than the hatch date calculation (see Byrd 1986, 1989). Using the plot as the sample unit, we tested for differences among the years 1993-1996 with ANOVA.

Puffins: Median hatch date was used to measure puffin nesting chronology. Wing measurements, rather than laying or hatching information, were used to determine the hatch date for each chick, because burrows were not visited until the chicks were about one week old (visiting them prior to this time can result in abandonment of eggs or chicks). The hatch date was calculated for each chick in the growth study by estimating the age of the chick at the first wing measurement with a growth equation reported by Amaral (1977). The median hatch date among the chicks was then determined. The difference between 1995 and 1996 results were compared with a t-test, using the hatch date of each chick as the sample unit.

Chick Growth Rate

Murres: We weighed and measured 33 chicks on Light Rock just before the start of fledging. This was performed at night to prevent predation of the chicks by glaucous-winged gulls (*Larus glaucescens*). We also weighed and measured 46 fledging murre chicks by dipnetting them from the water as they jumped from cliffs. Murre chick measurements included culmen, tarsus, and wing chord (to 1 mm), and mass (to 1 g). As an index of fledgling size for 1996, we calculated the mean fledging weight.

Kittiwakes: We weighed (to 1 g) and measured (e.g. wing chord, culmen, tarsus, and back of head to tip of bill, all to 0.1 mm) 40 kittiwake chicks from 38 broods every 5-7 days, from near hatching until they were about 32 days old. Methods for calculating growth rates followed the protocol for APEX Project 96163E in Prince William Sound. The daily increase in mass was calculated for each chick for the most linear section of the growth curve (from 60 to 300 g), by first calculating the difference in mass between the first and last measurements within the "linear phase" and then dividing the result by the number of days between those measurements. These values were then used to calculate the mean growth rates for "A" chicks (chicks in single-chick nests plus chicks first to hatch in 2-chick nests; n = 33) and "B" chicks (the second-hatched chicks in 2-chick nests; n = 2). Differences between 1995 and 1996 growth slopes were compared with a t-test, using each "A" chick's growth slope as the sample unit.

Puffins: Thirty-three puffin chicks in three of the five study plots (see productivity above) were weighed (to 1 g) and measured (culmen, wing chord, and tarsus, all to 0.1 mm) every five days, from the time they were about one week old until we left the island, when most chicks were old enough to fledge. To check for the effect on growth of more frequent measurement, 12 additional nestlings were weighed and measured only 3 times on the two other study plots. Average daily mass change was chosen as the primary measurement of growth. Data were analyzed by fitting a simple linear model to the 150-450 g section of each chick's growth curve (the portion that is nearly linear), using the slope of the line as the measure of average daily mass change, and then averaging the slopes among the chicks to represent the annual index and to calculate variation. Differences in the slopes between 1995 and 1996 were compared with a t-test.

Chick Diet

Murres: Prey items delivered to murre chicks were identified during observation periods on 7 days. Prey were identified with 7 x 42 binoculars and field guides. In total, 236 prey items, all fish, were observed during 12 August-1 September. Two hundred twenty-six (96%) of the fish were identifiable to species or family groups (e.g. *Gadidae*) on the basis of color and body and fin shapes (e.g., caudal, anal, adipose fins). Data were analyzed by calculating percentages by number of items for five categories of prey: capelin (*Mallotus villosus*); sand lance, (*Ammodytes hexapterus*); salmonids, (*Oncorhynchus*); and cods, (*Gadidae*).

Kittiwakes: Samples of prey brought to kittiwake chicks were obtained when growth study chicks regurgitated before, during, and after measurements. A total of 84 samples was obtained on 15 days during 14 July - 9 August, when chicks were about 1-4 weeks old. Samples were frozen the same day they were collected and weighed (to 1 g) when we returned to Homer.

Prey items were analyzed by K.R. Turco and A.M. Springer, Institute of Marine Sciences, University of Alaska-Fairbanks. Samples were thawed, then separated into identified and unidentified portions. Identified prey were separated by species or lowest possible taxon. All component groups were weighed. Composition of the diet was summarized by listing the proportion of the total mass represented by the mass of each component group.

Puffins: Samples of prey brought to puffin chicks were collected by temporarily blocking burrows with squares of hardware cloth (screens). One hundred thirty-nine chick meals containing 446 items were obtained during six screening days at East Amatuli Island and four at West Amatuli Island during 23 July - 7 September. Samples were frozen. Specimens were identified in the field using field guides and taxonomic keys. Frozen prey items were cleaned and weighed (to 1 g) in the lab when we returned to Homer. Data were analyzed by calculating percentages by number and weight of identifiable prey items.

Chick Provisioning Frequency

Murres: We collected murre chick provisioning frequency data from a plot of 10 nest sites near one of the productivity plot observation posts. The plot was located in a flat rock-strewn area near the top of a cliff that contained some of the productivity plots. Food deliveries were recorded on the plots during three 14-hr-long (0700-2100) watches during the nestling period (12, 17, and 24 August). We tested for differences among these three days in 1996 and the two observation-days in 1995, using the nest-day as the sample unit, with ANOVA.

Kittiwakes: Kittiwake chick provisioning frequency data were obtained from eight nests in one of the kittiwake productivity plots (see Productivity, above). The nests contained 12 chicks. Most of the data were collected by watching the nests with 7 x 42 binoculars from about 20 m away and recording times of feeding events. Some data were also obtained by recording these activities on video tape (using two modified 8-mm Sony HandyCam camera/recorders) and reviewing the tapes in camp (during analysis in 1995, no differences were found between data collected simultaneously by the video and direct observation methods). Observations began when the nestlings were about nine days old. Because chicks may be fed several times after a foraging adult returns to the nest, and because adults sometimes leave their nests for short periods of time without foraging at sea, only first feedings after trips lasting 30 minutes or more were counted as "provisioning" events. Food deliveries were recorded on the plots during three 14-hr-long (0700-2100) watches during the nestling period (16, 26, and 30 July).

We compared the difference between in feeding rates between 1-chick and 2-chick nests for each of the five observation days during the two years. We used t-tests, with the nest-day as the sample unit. If we found a difference between the two types of nest, we would calculate an annual index for each type of nest, rather than combining them. We tested for differences among days, using the nest-day as the sample unit, with ANOVA.

Puffins: During 31 August and 2 September we measured the provisioning frequency of tufted puffin chicks by observing adults returning to 10 nests in one of the tufted puffin chick growth study plots. Observations were made from a blind located about 50 m from the nests. Nests were marked with numbered flags. We made two dawn-to-dark watches (0600-2200), from before the adults were flying until after they had stopped. Binoculars were used to observe whether returning adults were carrying fish. We noted the time of each adult's return and departure, and any activities in the vicinity that may have been affecting the return or departure behaviors and times (e.g., visits by aerial predators). Using the nest-day as the sample unit, we compared the chick provisioning frequencies of the two days with a paired-sample t-test.

Amount Fed to Chicks

Murres: We did not collect data on the size of murre chick meals.

Kittiwakes: An annual index of the size of meals fed to kittiwake chicks was obtained from regurgitated samples (see Chick Food Types, above). Because the amount of food fed to nestlings increased until they were about 20 days old, we used as the annual index the average mass of 33 samples collected from chicks that were about 20 or more days old. Using the regurgitant sample as the sample unit, we compared the masses in 1996 with those in 1995, with a t-test.

Puffins: An annual index of the size of meals fed to puffin chicks was obtained by averaging the masses of burrow screening samples (see chick food types above). The 1996 samples were compared with those of 1995 with a t-test.

Activity Budgets of Adults (Nest attendance, Foraging trip duration)

Murres: Data to describe adult murre activity budgets were recorded during the 14-hr observations used for feeding frequency (see above) and three 14-hr periods during the incubation period (15, 21, and 31 July; 0700-2100 hrs). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest site.

We used "bird-minutes per hour" to measure the proportion of time that the nest was attended by one or two adults. If during one hour a nest was attended by one adult for the entire hour and the second adult for half the hour, the nest had 90 bird-minutes of attendance that hour. The sample unit for comparisons among years was the nest-day. We compared among the five nest-days over the two years, with ANOVA.

Average foraging trip time was obtained by treating trips as sample units and calculating the mean duration of all trips made by birds during the three dawn-to-dusk watches during the nestling period, that ended with a chick feeding ($n = 85$ trips). Using the trip as the sample unit, we compared the duration of trips in 1996 with trips in 1995, with a t-test. We also calculated the frequency of trips in 2-hr blocks of time (0-2, 2-4, 4-6 and 6-8 hr), and compared these frequencies in 1996 with those in 1995, with a Chi-square test.

Kittiwakes: Kittiwake activity budget information was obtained during chick feeding frequency observations of 10 nests (see Chick Provisioning Frequencies, above) and one incubation watch. Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest. We calculated the amount of time spent by adults at each nest, for each day (using "bird-minutes," as with murres, above). Using the nest-day as the sample unit, we compared differences among the observation days of 1995-1996 with ANOVA.

We calculated mean foraging trip duration for kittiwakes, during the nestling period. Only trips that resulted in a chick-feeding, and only trips that left another adult attending the nest were used (because adults were unmarked). As for murres, the sample for obtaining an index of the season was the individual trip. We compared trips in 1996 with those in 1995, with a t-test.

Puffins: During the two days of observations, puffin adults did not stay at the study nests longer than the approximately 30 seconds used to deliver fish to the chicks. Because adults left the nests unattended and adults were unmarked, we could not determine the duration of foraging trips of individual birds.

Population Counts

Murres: Murres were counted on the productivity plots almost every time the plots were checked (19 counts). To calculate an annual index we averaged the 16 counts made between median lay date and the start of fledging. Methods for collecting and analyzing these data were the same as those used during the 1993-1995 Barren Islands restoration monitoring studies (see Roseneau *et al.* 1995, 1996b). Using the plot-set count as the sample unit, we compared the annual means of 1993-1996 with ANOVA. More extensive counts of murres in the Barren Islands were made by Project 96144.

Kittiwakes: Kittiwakes were counted on the productivity plots almost every time the plots were checked (23 counts). To obtain an annual index for the year we first graphed the data and marked visually the date when adult counts began to decline near the start of fledging. We then averaged the daily plot-set counts made before that date (we used 12 counts for the 1996 average).

These counts were made and analyzed by the same procedures used during 1993-1995 (D.G. Roseneau and A.B. Kettle, unpubl. data). Counts were compared among years with ANOVA, using the daily plot-set count as the sample unit.

Puffins: We used the number of active burrows in the three tufted puffin chick growth plots and the four transects as an index of the population size for each year. We compared the number of active burrows between the two years with a Wilcoxon signed rank test, using the plots and transects as sample units.

RESULTS

Productivity

Murres: Common murre productivity was high in 1996 (0.77 fledglings per egg, SD = 0.14; Table 1, Fig. 3a) and similar to the 1994-1995 results (0.73 and 0.77 fledglings per egg, respectively; Roseneau *et al.* 1995, 1996b). Values from 1994, 1995, and 1996 were significantly higher than in 1993 (0.55 fledglings per egg, P = 0.011, 0.001, and 0.002, respectively; Roseneau *et al.* 1996).

Fledging success was also high (0.90 chicks per egg, SD = 0.12; see Byrd *et al.* 1993 for comparisons) and similar to the 1994-1995 levels (0.93 and 0.91, respectively). Results from 1994, 1995, and 1996 were higher than the 1993 value (0.79; P = 0.014, 0.035, and 0.063, respectively).

Hatching success exhibited a slightly different pattern; the 1996, 1995 and 1994 figures (0.85 (SD = 0.10), 0.85, and 0.79 chicks per egg, respectively) were similar to each other (and were also high values, see Byrd *et al.* 1993), but only the 1995 and 1996 values were significantly higher than the 1993 figure (0.70; P = 0.023 and 0.022, respectively).

Kittiwakes: Productivity of kittiwakes was high in 1996 (0.71 fledglings per nest, SD = 0.19; Table 1, Fig. 3b; see Hatch *et al.* 1993 for comparisons in the Gulf of Alaska) and similar to the 1994 and 1995 levels (0.64 and 0.81 fledglings per nest, Roseneau *et al.* 1995). These results were in sharp contrast to 1993, when nesting pairs failed early in the nesting season and reproductive success was zero (no eggs or chicks were present on the four East Amatuli Island plots, Roseneau *et al.* 1995).

Puffins: Just prior to fledging in 1996, 0.31 (SD = 0.16) chicks per active burrow were found in the 3 growth plots and the group of 4 transects. This was a significantly lower ($P < 0.001$) result than in 1995 (0.53, SD = 0.12).

Hatching success, from data obtained in the plot established for this purpose, was 0.5 chicks per egg. This was lower than reported for most years in other colonies of Alaska (Byrd *et al.* 1993).

Nesting Chronology

Murres: Based on the median hatch date (4 August, SD = 4; Table 1), hatching in 1996 occurred five days earlier than in 1995, seven days earlier than in 1994, and 12 days earlier than in 1993. Each of the years 1993-1996 were significantly different from the others, except for the 1994-1995 comparison. Hatching in 1993, in turn, occurred earlier than during 1992 at nearby Nord Island (Dragoo *et al.* 1994) and 1991 on East Amatuli Light Rock (Boersma *et al.* 1995).

Kittiwakes: The average median hatch date was 7 July (SD = 7; Table 1); this was similar to that of 1995 (8 July) and 1994 (10 July).

Puffins: The median chick hatch date for tufted puffins in the study plots was 16 July (SD = 5). This was significantly earlier than for 1995 (21 July, $P<0.001$).

Chick Growth Rate

Murres: The average weight of the 46 fledging murre chicks was 240 g (SD = 24).

Kittiwakes: The average growth rate of kittiwake chicks, for all chicks combined (n = 35), was 17.5 g per day (SD = 5.8; Table 1). "A" chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 33) gained 17.6 g per day (SD = 5.9), while "B" chicks (the second-hatched chicks in 2-chick nests; n = 2) grew at a rate of about 14.9 g per day (SD = 1.6). The mean growth rate for "A" chicks in 1996 was not significantly different from the 1995 mean (19.4 g per day).

Puffins: Puffin chicks in the three main study plots gained an average of 3.3 g per day (SD = 1.6 g, n = 32; Table 1). In the "control" plots (where chicks were measured only 3 times during the same period), they gained 3.1 g per day (SD = 1.3, n = 12). The difference between the two groups was not significant. The growth rate for the two groups combined was 3.2 g per day (SD

= 1.5; n = 44). This rate was very low for puffins in general, and was much lower than last year's rate of 11.4 g per day (P<0.001).

Chick Diet

Murres: Prey items delivered to murre chicks consisted solely of small fish (n = 236), most of which were capelin (91%; Fig. 4a). Adults also fed nestlings unidentified cods (*Gadidae*, probably primarily walleye pollock and Pacific cod), sand lance, and an unidentified salmonid, but in much lower numbers (3%, 2%, and <1%, respectively). We were unable to identify 10 fish (4%) of those observed. These results were similar to last year's (see Fig. 4a).

Kittiwakes: The unidentified portion of the samples made up 29 percent of the total mass, and 29 of the 84 samples were unidentified. One and one-half percent of the identified portion was classified as euphausid shrimp (euphausids were present in two of the samples). The remainder was composed of forage fish. Of the identified portion, sand lance made up 40 percent of the total; capelin 21 percent; pacific herring 6 percent, salmon 1.6 percent; and walleye pollock 1.6 percent.

It appears that there was a higher proportion of sand lance and lower proportion of capelin in the diet of kittiwake chicks than in 1995. Differences between this and last year's methods of analyzing the regurgitant samples are being resolved before more detailed comparisons in diet are made.

Puffins: Prey deliveries (n = 139 screen samples) to puffin chicks contained 446 items (Fig. 5). Capelin, sand lance, and pollock were by weight the largest components of the samples (37%, 27%, and 18% of the total, respectively), followed by pink salmon (*Oncorhynchus gorbuscha*), pacific cod, squid, and larval fish (probably daubed shanny [*Lumpenus maculatus*]). By number, the larval fish were the largest component (44%), followed by walleye pollock, sand lance, capelin (23%, 15%, and 13%, respectively) and in lower proportions: squid, pink salmon, sculpin, greenling, prowfish, pacific cod, octopus, and larval flatfish. The main difference in prey deliveries between 1995 and 1996 was that in 1995 prowfish were the third most important species by weight; this year there was only one prowfish found.

Chick Provisioning Frequency

Murres: During the three observation-days of the 1996 nestling period, chicks averaged 0.26 feedings per hour (SD = 0.05, n = 3 d; Table 1, Fig 7a). There were no significant differences among the results from the five observation days in 1995-1996 (the 1995 mean was 0.29).

Kittiwakes: During the three observation days of the nestling period, single-chick nests averaged 0.19 feedings per hour (SD = 0.03, n = 3 d; Table 1, Fig. 7b), and nests containing two chicks averaged 0.25 feedings per hour (SD = 0.09, n = 3 d). This difference was not significant; however, the difference between 1- and 2-chick nests in 1995 was significant (1-chick nests =

0.21 feedings/nest/hour; 2-chick nests = 0.40; P = 0.015). Therefore, in comparing feeding rates between 1995 and 1996, we chose to compare 1-chick nests and 2-chick nests separately.

The number of feedings per nest per hour for 1-chick nests and for 2-chick nests were not significantly different among any of the five observation days during 1995 and 1996.

Puffins: All returning adults were carrying fish. The number of feedings per nest was different between the two days ($P < 0.001$; 31 Aug = 7.20, SD = 2.25; 02 Sep = 3.80, SD = 1.55).

There was a pronounced diurnal pattern of feeding on both days--there were more feedings early in the morning than during the rest of the day (Fig. 8).

Amount Fed to Chicks

Kittiwakes: The mass of kittiwake chick regurgitations increased with collection date. When (according to the median hatch date) chicks were less than 10 days old, the mean regurgitant mass was 10.1 g (SD = 5.7, n = 18); when 10 -20 days old, the mass was 16.6 g (SD = 11.0, n = 32); when older than 20 d: 20.8 g (SD = 13.3; n = 33). The latter mass was used as the annual index in 1996 and 1995. The 1996 masses were significantly lower (P = 0.02) than those of 1995 (27.7 g; SD 11.5, n = 37).

Puffins: The average weight of the 109 screen samples collected during the nestling period was 6.9 g (SD = 6.8, Table 1). This was significantly lower than the mean of the 110 samples collected in 1995 (10.3 g; SD = 12.8; n = 110).

Activity Budgets of Adults

Murres: *Nest attendance* -- During the incubation period, at least one adult was always present at each site, and both birds were present an average of 19.5 minutes per hour per nest (79.5 "bird-min/hr;" SD = 6.0; n = 3 d; Fig. 9a). During the nestling period, at least one adult was always present at each site, and both birds were present an average of 9.6 minutes per hour per nest (69.6 bird-minutes/hr; SD = 4.1; n = 3 d); this was similar to the 1995 figure (66.4 bird-min/hr). The ANOVA showed a significant difference among the observation days; the Tukey post-hoc test showed that two of the days in 1996 were marginally different (12 and 17 August; P = 0.055), as were one day in 1995 (24 August) and one in 1996 (15 August; P = 0.069). These results show that differences between days were as great as differences between the two years, for the given sample size.

Foraging trip duration -- The average duration of murre foraging trips during the nestling period was 150 minutes (SD = 78 min.; n = 85 trips). This was similar to the 1995 mean of 158 minutes. However, the frequency of trips between 0-2 hour and 2-4 hour were different (Fig.11 and 11; $\chi^2 = 17.14$, P = 0.001); the shorter trips were more common in 1995.

Kittiwakes: *Nest attendance* -- Incubated eggs were very rarely left unattended, and it was even rarer for two adults to tend the nest together during incubation. During the nestling period, as in 1995, there were very rarely two adults on a nest. Chicks were occasionally left unattended in 1996; both adults were absent from 1-chick nests for an average of 1.0 minutes per hour per nest (SD = 1.4, n = 3 d; Fig. 9b); from 2-chick nests: 5.4 minutes per hour per nest (SD =4.5). Although within each day, the differences between 1- and 2-chick nests were not significant, 2-chick nests were consistently abandoned more often than were 1-chick nests (1-chick nests: 59.0 bird-min/hr/nest, SD = 1.43; 2-ch nests: 54.59 bird-min/hr/nest; SD = 4.48), so we analyzed the data separately, when looking for among-day differences.

There were no differences among days, for 1-chick nests or 2-chick nests.

Foraging Trip Duration -- We calculated a mean foraging trip duration for kittiwakes of 326 minutes(SD = 91 min, n = 23 trips). This was significantly longer than the mean duration in 1995 (237 min; P = 0.01).

Population Counts

Murres: The average number of murres counted on the productivity plot sample was 407 (SD = 24.3). In 1993, 1994, and 1995, the average counts were 435, 404, and 392, respectively. While there were no significant differences among years in these counts, the general pattern of the counts across years agreed with the counts of larger plots counted at East Amatuli Island in other projects in previous years, and in Project 96144.

Kittiwakes: Counts on the sample of four kittiwake plots for which we can compare for the years 1993-1996 averaged 183 in 1996 (SD = 8.2; n = 12). This average was similar to that for 1995 (201; SD = 8.7) and 1994 (192; SD = 10.3); the results for all three of these years were higher than those for 1993 (120; SD = 50.3; P<0.001).

Puffins: There was no significant difference in the number of active tufted puffin burrows in the seven productivity plots between 1996 (total = 142 active burrows) and 1995 (125 active burrows).

DISCUSSION

Forage fish near the Barren Islands in 1995 and 1996 apparently provided adequate prey to support average or higher productivity for kittiwakes and murres. Tufted puffins produced normally in 1995, but had reduced success in 1996. The lack of concordance between murres and puffins, both divers, may reflect their different chick-rearing strategies. Puffin chicks are fed approximately twice as long at nest sites as are murre chicks, so forage fish would have to be available at adequate densities for a longer period. There also are differences in feeding behavior between puffins and murres. Puffins tend to feed less often in flocks; this may have resulted in puffins collecting more diverse prey than did murres in 1995 and 1996.

Chick growth rates of kittiwakes and puffins in 1995 and 1996 mirrored their productivity (we had no 1995 growth data for murres). Growth rates for kittiwake chicks in 1995 and 1996 were similar (they were slightly, but not significantly, lower in 1996) and normal. Puffin chicks grew normally in 1995 but had very low growth rates in 1996.

Capelin was the most important prey item for murres in 1995 and 1996 in the Barren Islands. This forage fish, along with sand lance, was also important to kittiwakes and puffins. The proportion of sand lance brought to kittiwake chicks was higher in 1996 than in 1995. Puffin chick diets were the most diverse of the three species. There was a substantial reduction in the amount of prowfish in the puffin diets from 1995 to 1996. Capelin and sand lance are relatively high in lipid content and are generally considered high-quality prey for seabirds. In contrast, prowfish are low in lipids and would not be considered high-quality prey.

Productivity and chick growth are affected by factors other than prey type. The size of meals delivered to kittiwake chicks was lower in 1996 than in 1995, and the duration of forage trips was longer in 1996. Although these results indicate that adult kittiwakes were working harder in 1996 than in 1995, they managed to feed chicks at relatively similar frequencies in the two years, thus keeping growth rates and productivity from being significantly reduced in 1996. Murres also may have worked harder in 1996. They made fewer short foraging trips in 1996 than in 1995, although mean trip durations were similar. There were no significant differences between years in murre nest attendance or chick provisioning frequency. Murres have access to prey throughout the water column, so they are likely to obtain food more easily than are surface-feeding kittiwakes. Puffins delivered significantly smaller meals to chicks in 1996 than in 1995. This reduction in meal size, rather than a change in prey type, probably accounted for reduced chick growth and productivity of puffins in 1996.

The timing of the onset of nesting has been gradually getting earlier for murres in the Barren Islands since at least 1993. While it is possible that changes in food supply could be involved, this pattern would be expected for a population undergoing an increase in the age or experience of breeders, as would occur after a mortality event, such as the *Exxon Valdez* oil spill (see Nysewander et al. 1992). By more closely examining the timing of breeding of murres and other species on the Barren Islands, and by continuing our examination of the effects of changes in food supply on these species, we will explore the potential causes of this pattern in breeding chronology.

ACKNOWLEDGMENTS

We thank Stephanie Zuniga, Carrie Alley, Jonathan Maletta, and Margi Blanding for making the 1996 APEX Barren Islands seabird project a success. Their constant dedication to the work allowed us to safely collect data in spite of sometimes hostile weather and sea conditions.

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Table 1. Results from Barren Islands Seabird Studies, 1996.

Variable	Common murre		Black-legged kittiwake		Tufted puffin	
Productivity	Eggs hatched / eggs laid	0.85 (0.10)[1]	Chicks fledged / nests built:	0.71 (0.19)	Chicks / occupied burrow	0.31
	Chicks fledged / eggs hatched	0.90 (0.12)				
	Chicks fledged / eggs laid	0.77 (0.14)				
Nesting chronology	Median hatch date:	4 Aug (4)	Median hatch date:	7 Jul (7)	Median hatch date:	16 Jul (5.1)
Chick growth rate	Fledging weight (g):	240 (24)	Grams / day (all chicks):	17.5 (5.8)	Grams / day:	3.3 (1.6)
			("A" chicks):	17.6 (5.9)		
			("B" chicks):	14.9 (1.6)		
Chick feeding freq.	Feedings / chick / hr (0700-2100):	0.26 (0.05)	Feedings/nest/hr (0700-2100) (1 ch):	0.19 (0.03)	Feedings/nest/hr (0600-2200):	
			(2 ch):	0.25 (0.09)		7.2 (2.2) - 3.8 (1.5)
Adult trip duration	Minutes / trip:	150 (78)	Minutes / trip:	326 (91)	*No data*	
Time no ad. on nest	Minutes / hour:	0.0	Minutes / hour (1 chick):	1.0 (1.4)	*Not yet analyzed*	
			(2 chicks):	5.4 (4.5)		
Time 2 ad. on nest:	Minutes / hour (incubation):	19.5 (6.0)	Minutes / hour (1 chick):	0.0	*Not yet analyzed*	
	(nestling period):	9.6 (4.1)	(2 chicks):	0.0		
Chick meal size	*no data*		Regurgitant weight (g):	20.8 (13.3)	Screen samp. wt. (g):	6.9 (6.8)
Population size	Productivity plots (no. of birds):	407 (24)	Productivity plots (no. of birds):	183 (8.2)	Number of burrows:	142

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[1] Standard deviation in parentheses

Table 2. Results from searches of four tufted puffin transects at East Amatuli Island, Barren Islands, Alaska, 1993-1996. Total area = 270 m^2

Year	Burrows	Active burrows	Active / total burrows	Chicks	Chicks / active burrows
1993	58	25	0.43	15	0.60
1994	44	17	0.39	8	0.47
1995	63	25	0.40	13	0.52
1996	61	24	0.39	4	0.17
Average	57	23	0.40	10	0.44
St. Dev.	9	4	0.02	5	0.19

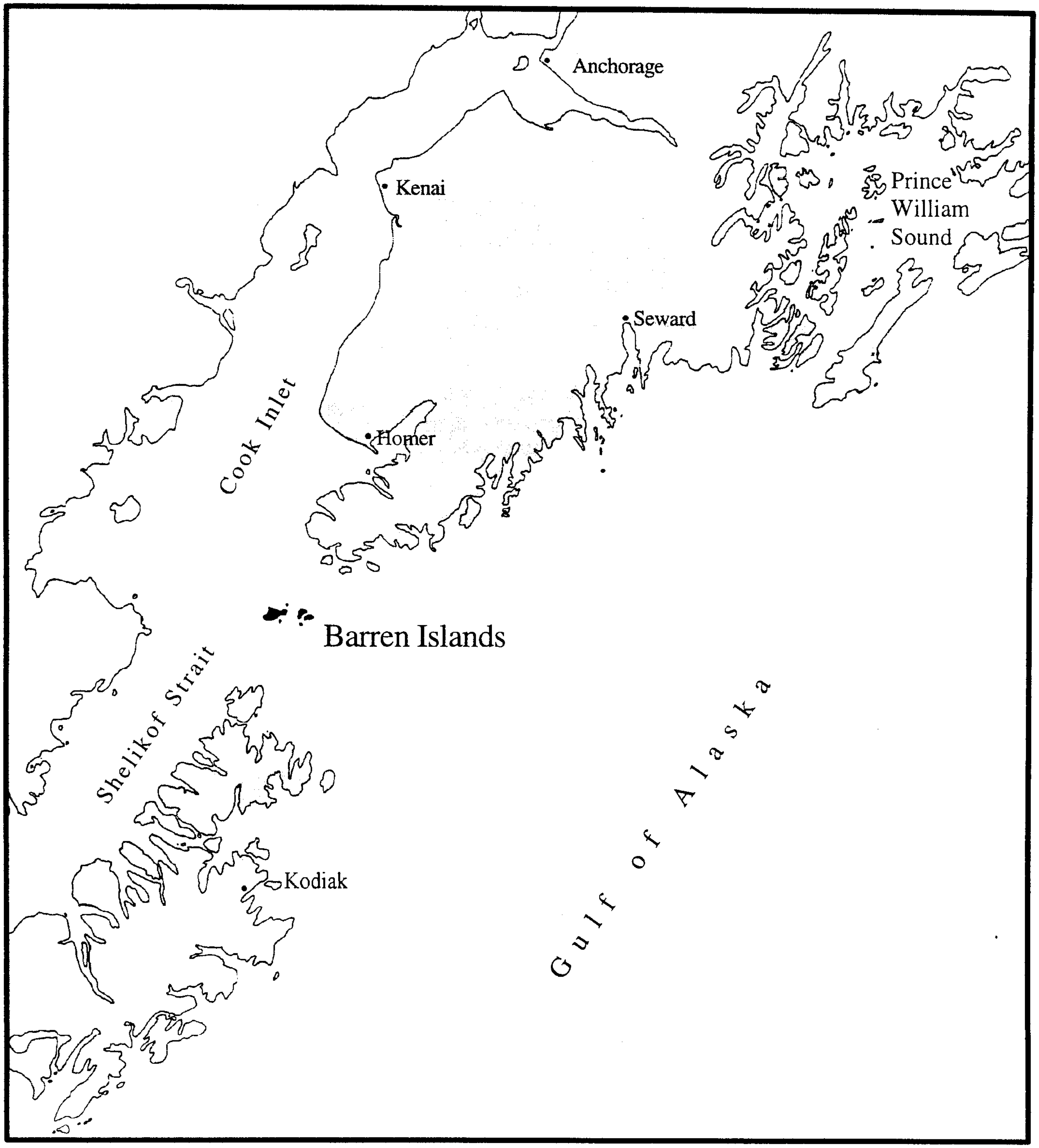


Figure 1. Location of the Barren Islands, Alaska.

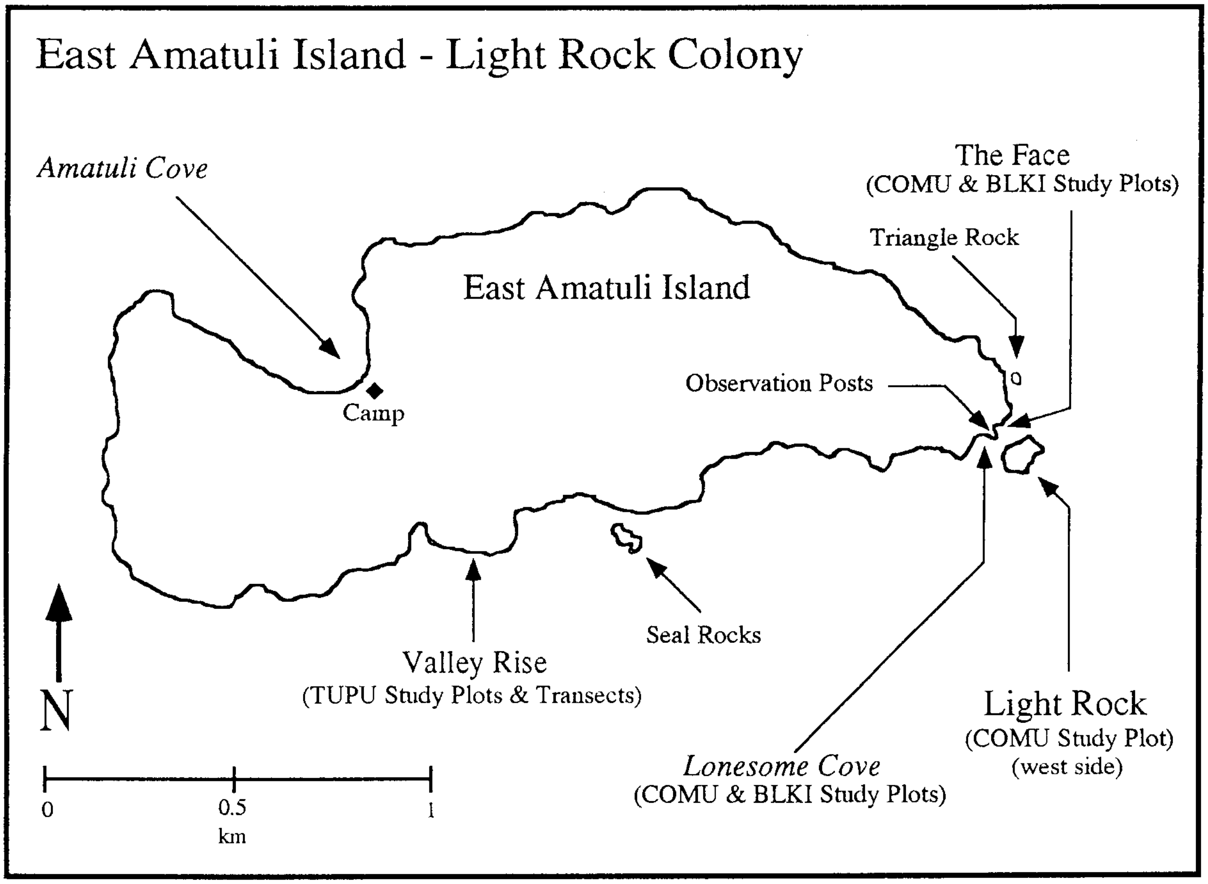


Figure 2. The East Amatuli Island study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

Productivity
Common Murre
Black-legged Kittiwake

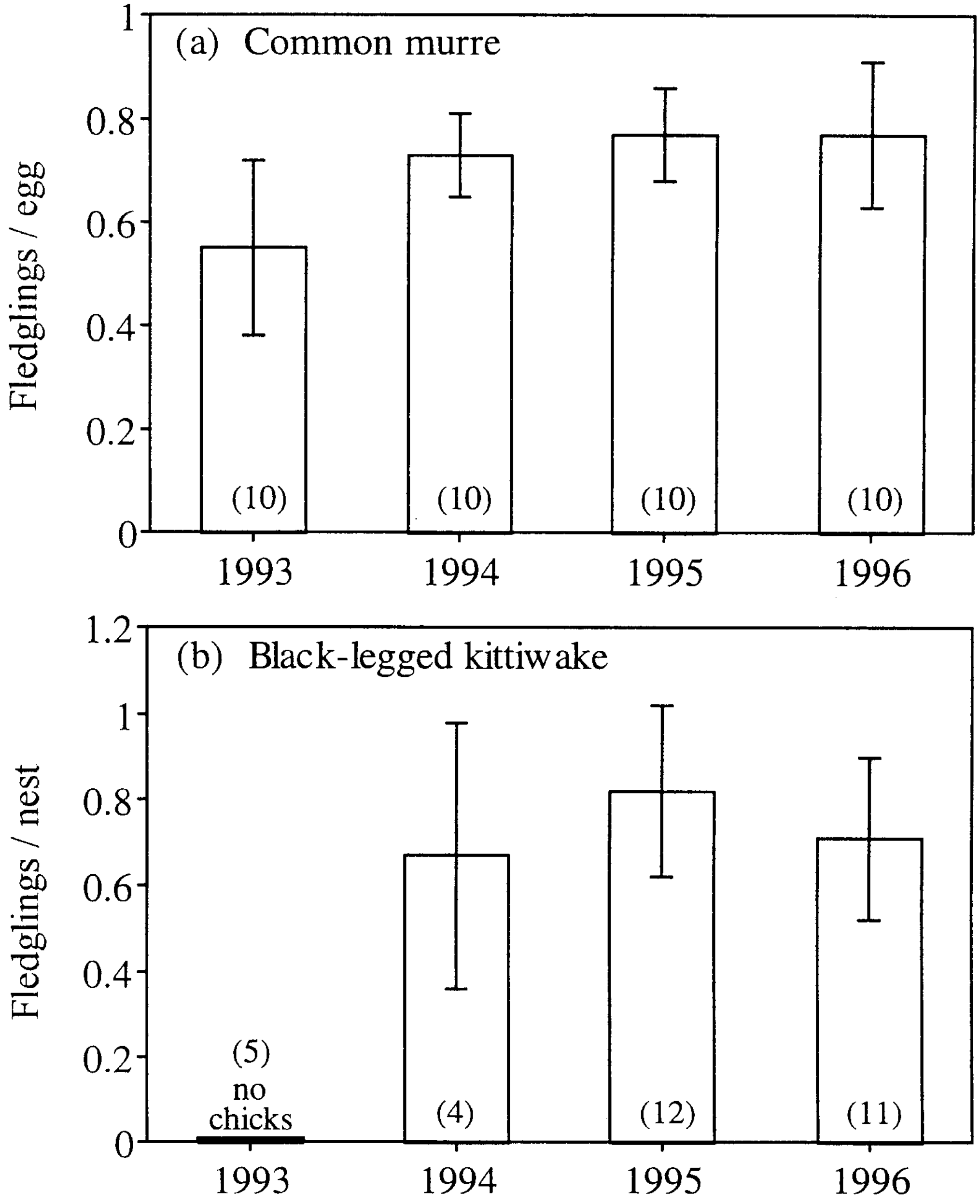
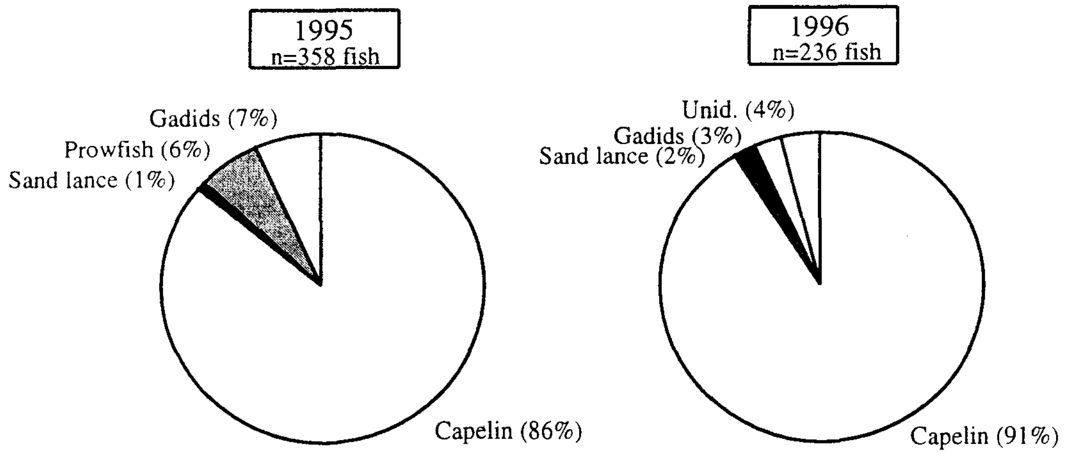


Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1996. Number of plots in parentheses; error bars = standard deviation.

Chick diet

Common murre
Black-legged kittiwake

(a) Common murre



(b) Black-legged kittiwake

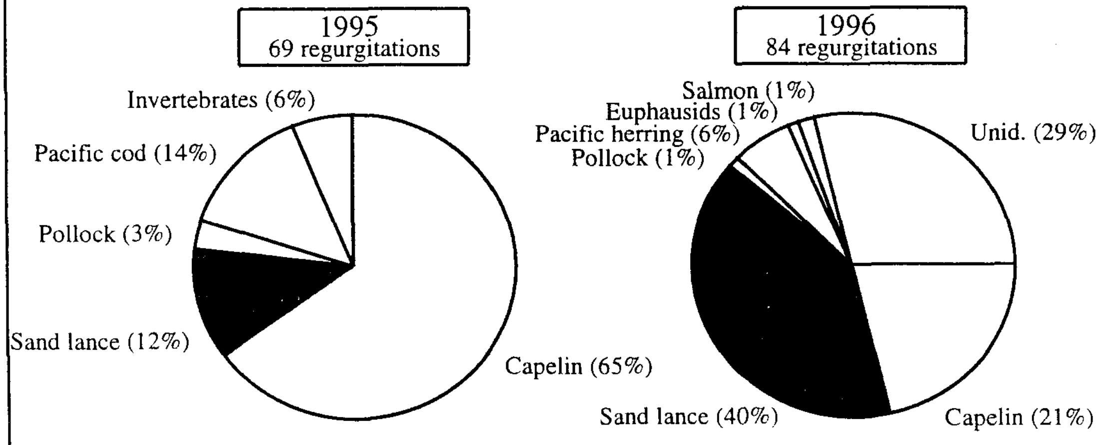


Figure 4. Types of prey fed to (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Composition of prey by (a) number of fish and (b) mass.

Chick diet
Tufted puffin

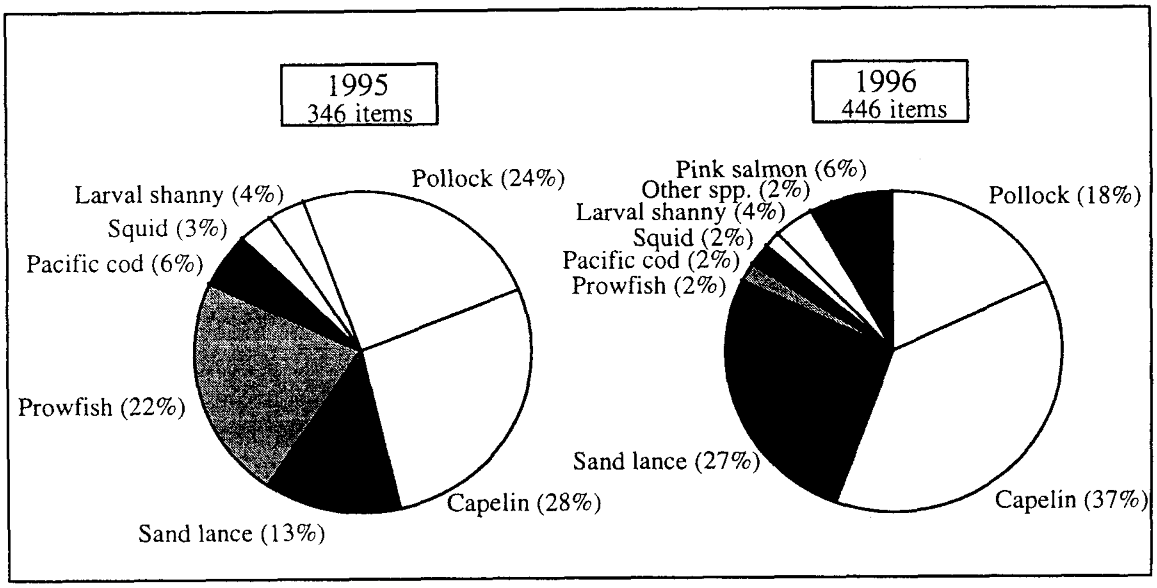


Figure 5. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995 and 1996. Composition of prey by mass.

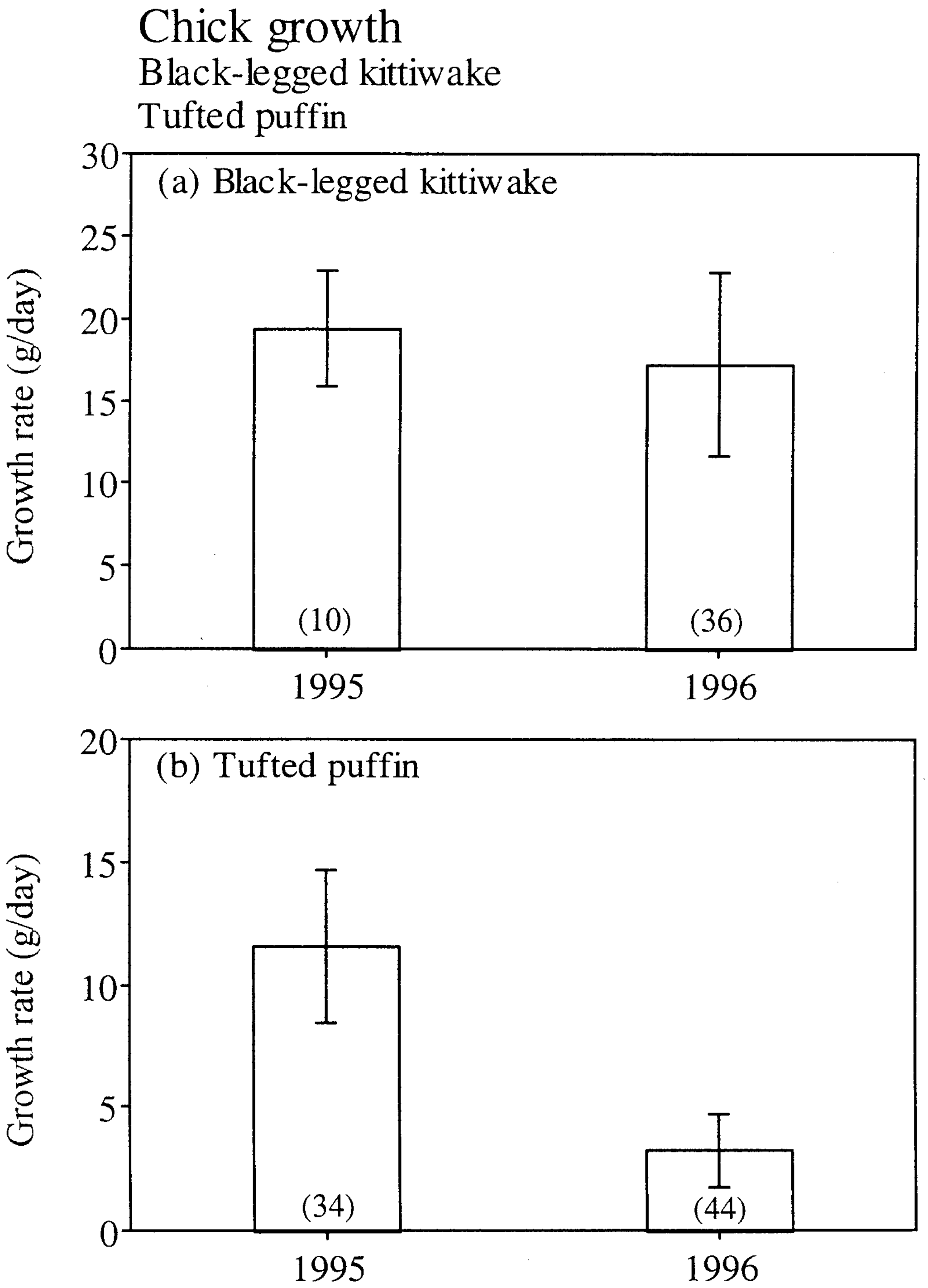


Figure 6. Growth rate of (a) black-legged kittiwake chicks and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Number of chicks on parentheses, error bars = standard deviation.

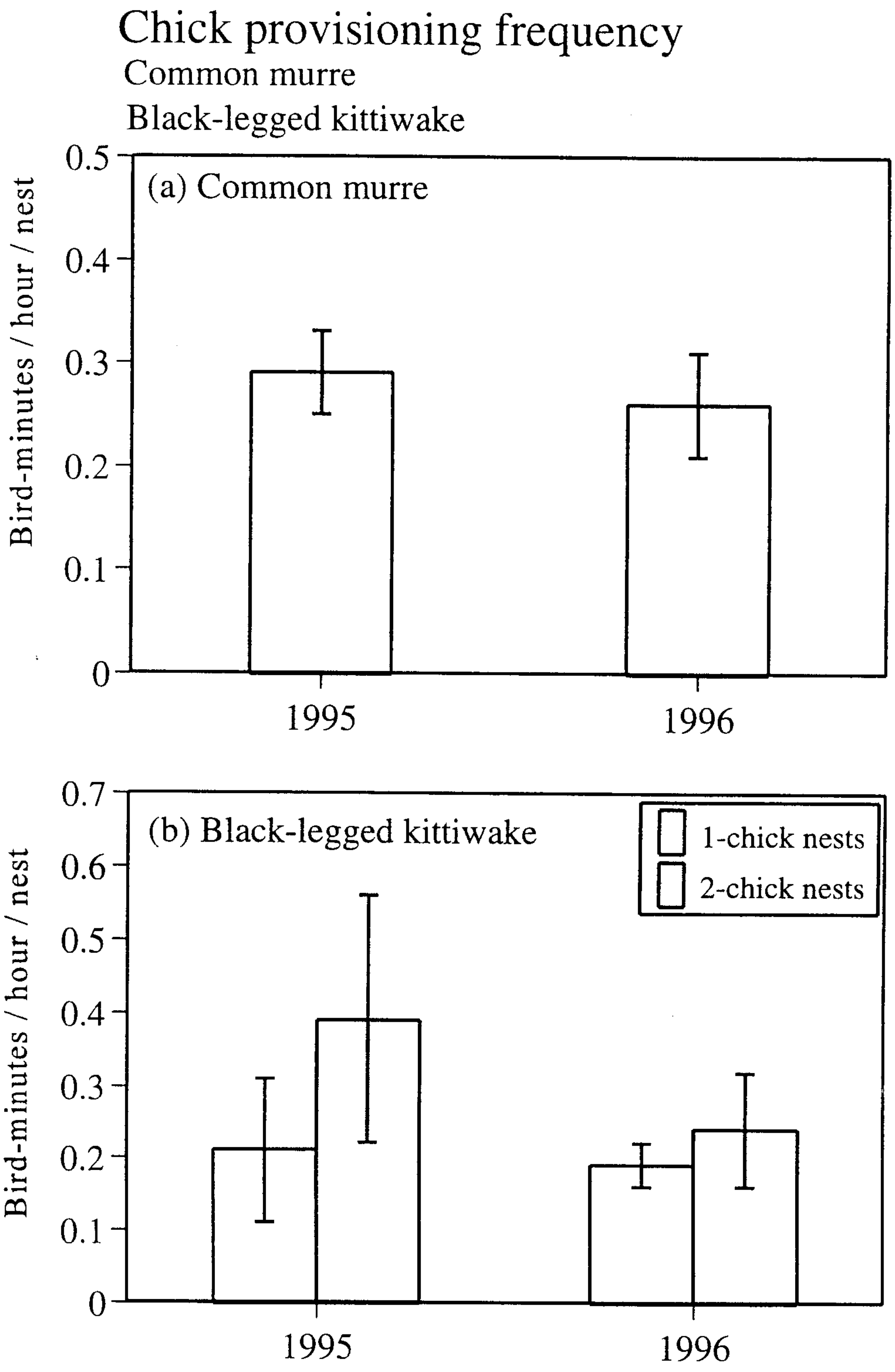


Figure 7. Chick provisioning frequency of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Sample size = 2 days in 1995 and 3 days in 1996; error bars = standard deviation.

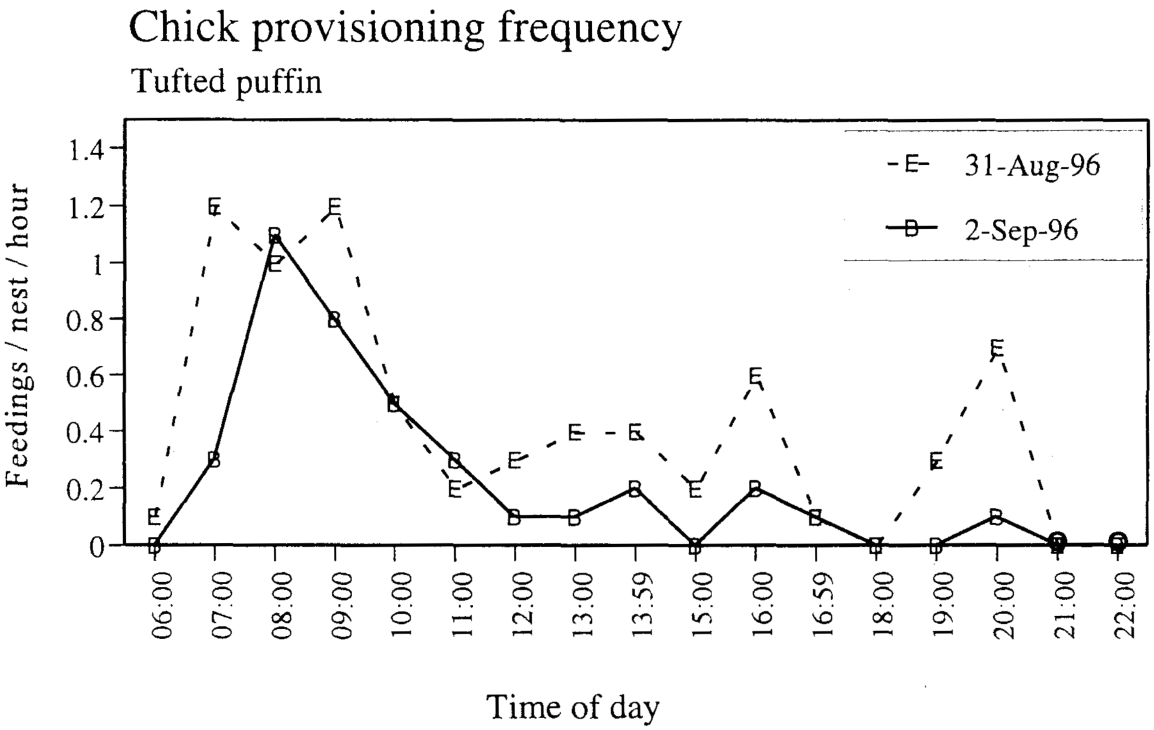


Figure 8. Number of times adult puffins returned to nests with fish at East Amatuli Island, Barren Islands, Alaska during two dawn-to-dusk observation periods in 1996. Calculated as returns per nest per hour, for a sample of 10 nests with chicks. Hours listed are start times for the corresponding data points.

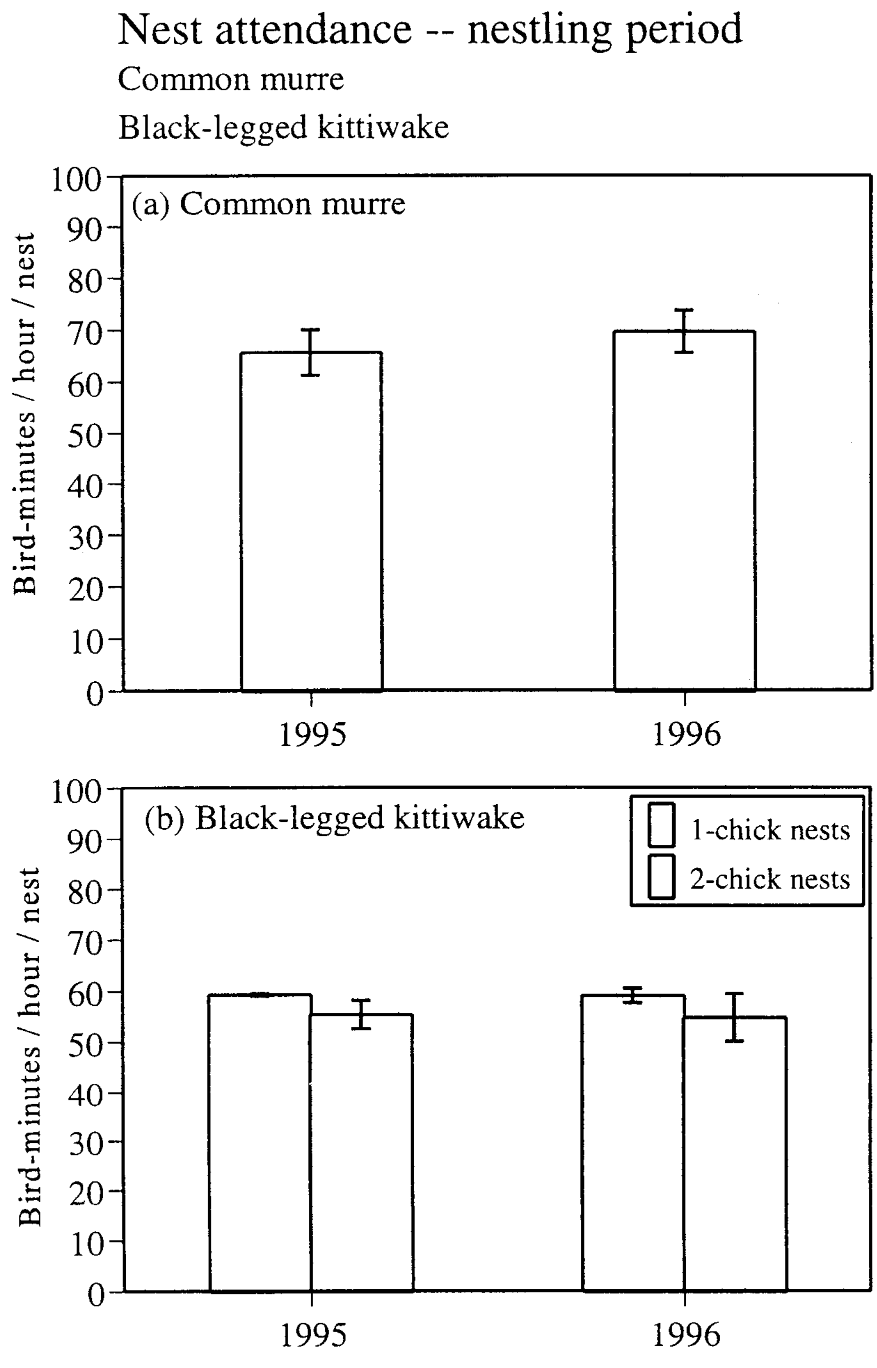


Figure 9. Number of minutes per hour spent at the nest by adults (e.g., 2 adults with full attendance = 120 bird-minutes per hour) of (a) common murre, and (b) black-legged kittiwake, during chick rearing at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Sample size = 2 days in 1995 and 3 days in 1996; error bars = standard deviation.

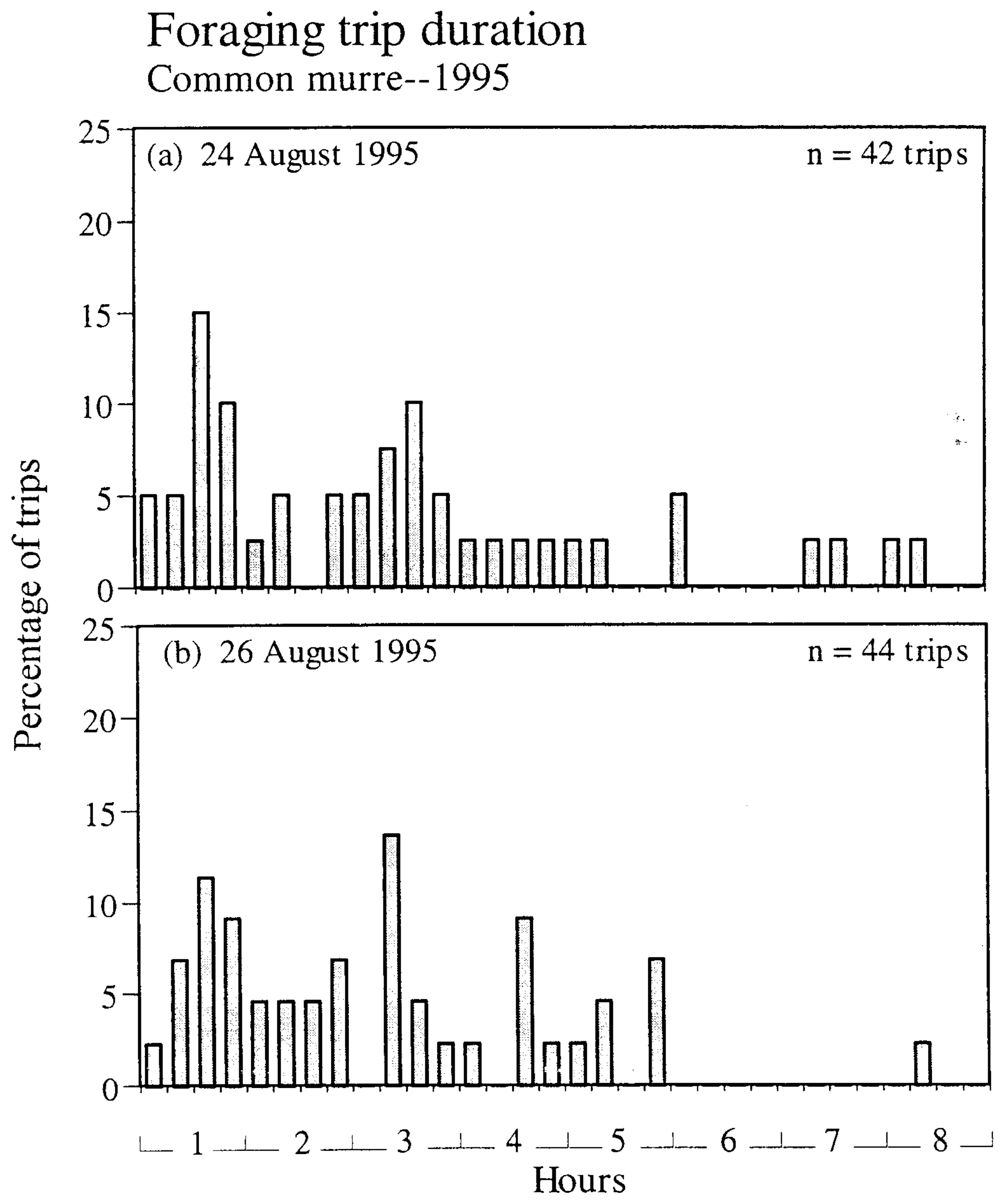


Figure 10. Duration of trips by common murres, by frequency of occurrence, from 12 nests at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August and (b) 26 August, 1995.

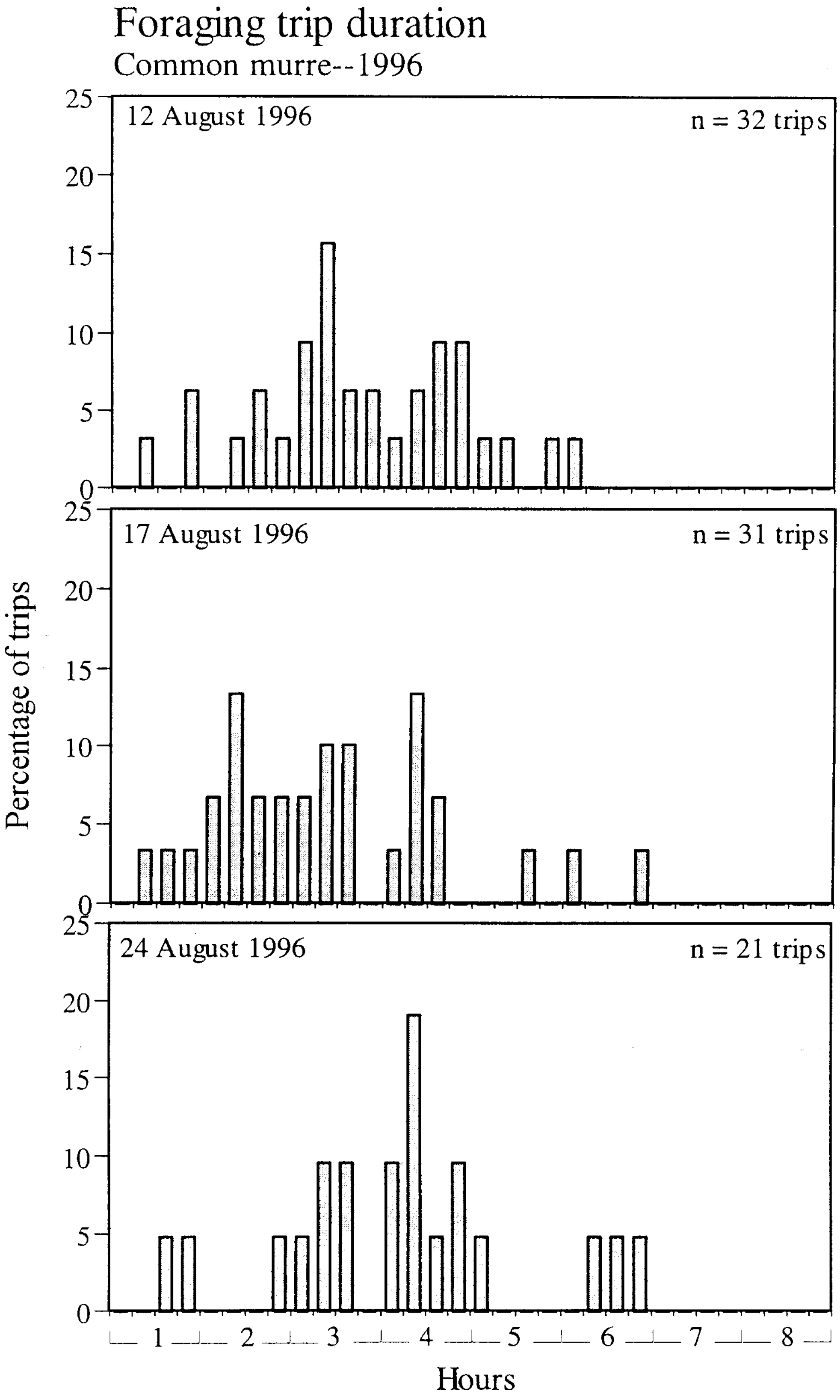


Figure 11. Duration of trips by common murres, by frequency of occurrence, from 10 nests at East Amatuli Island, Barren Islands, Alaska, during three days in 1996.

APPENDIX L

APEX: 96163L

Synthesis and Analysis Gulf of Alaska of Small-Mesh Trawl Data
1953 to 1996
and Gulf of Alaska Forage Fish Icthyoplankton Analysis
1972 to 1996

by
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Abstract

Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in composition and abundance of forage species may be responsible for the decline of these predator populations and their chronic low population levels. In an effort to delineate changes in forage species and a trophic regime shift, if any, over the last several decades, we have gathered together historical fishery-independent scientific survey data to address this question. This report includes three manuscripts submitted for publication from recent analysis of information and data from small-meshed trawl studies conducted in the Gulf of Alaska by the Alaska Department of Fish and Game and the National Marine Fisheries Service and its predecessor agencies from 1953 through 1996. Nearly 10,000 individual sampling tows are in the current database of the two agencies. The need for moving this project into a monitoring status is discussed. Preliminary analysis of an icthyoplankton time series is presented with relevancy toward APEX project goals.

Introduction

This project pursues analysis of small-mesh trawl sampling results from near-shore surveys in the Gulf of Alaska conducted by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G). The data for analysis was collected starting in 1953 and continues through 1996. This report includes two manuscripts that will be published this summer dealing with specific areas and analysis that was completed during the past project year. Only general background material concerning this part of the project will be discussed in this section. The reader is referred to the two enclosed manuscripts for details of the methodology and analysis used with this portion of the data. Additional items discussed in this narrative is the need for moving this project data collection into the monitoring category and analysis of the icthyplankton time series for Shelikof Strait.

Recently there has been information presented that the Gulf of Alaska ecosystem has undergone some abrupt and significant changes (Piatt and Anderson, 1996). The extent and degree of these changes is poorly documented and is important in determining future strategies for management of the marine ecosystem. Analysis of the historic data is a first step in gaining an appreciation for the rapid and abrupt changes that have occurred in the marine species complex in the last five decades. The data from small-mesh shrimp trawl cruises provides an opportunity to review changes in the composition of forage species that occurred through time in the Gulf of Alaska.

Historically, there is evidence of major abundance changes in the fish/crustacean community in the western Gulf of Alaska. Fluctuations in Pacific cod availability on a generational scale was reported for coastal Aleutian communities by Turner (1886). Similarly, landings from the near-shore Shumagin Islands cod fishery (Cobb, 1927) showed definite periods of high and low catches with the fishery peaking in late 1870s. King crab commercial catches in the Gulf of Alaska show two major peaks of landings, one in the mid 1960s and another in 1978-1980 (Blau, 1986). All of the area was closed to fishing in response to low population levels in 1983 (Blau, 1986) and has yet to reopen. By the 1960s there was evidence of high pandalid shrimp abundance in these same areas (Ronholt 1963). One of the highest densities of pandalid shrimp known in the world was to spur the development of a major shrimp fishery (Anderson and Gaffney, 1977). By the late 1970s the shrimp population density had declined radically and was accompanied by a closure of the shrimp fishery and the return of cod to inshore areas (Albers and Anderson, 1985). Catches of almost all salmon stocks of Alaskan origin suddenly increased to unprecedented levels in the 1980's (Francis and Hare, 1994, Hare and Francis, 1995). These changes, witnessed over the last century, imply dynamic fluctuations in abundance of commercially fished species. Managers, fisherman, and processors should be aware of these dynamics and their impacts on the ecology and economy.

Area of Coverage

The study area includes the continental shelf (0 - 200 m.) and upper slope (201 - 400 m.) from 144° W. longitude (in the vicinity of Kayak Island) westward to 168° W. longitude (vicinity of Unalaska Island, eastern Aleutians). This area is characterized as having a relatively broad shelf which is punctuated with numerous islands, separated by deep gullies and large inlets, sounds, and fjords. Most of the data was collected in trawlable locations associated with the numerous gullies and bays that are associated with this bathymetry. The study area covers the entire affected zone of the EVOS.

Icthyoplankton Analysis

Our small-mesh trawls catch most of the species of direct interest to the APEX project except for one critical component, Pacific Sand Lance. We do however capture sand lance larvae in significant numbers during our icthyplankton surveys, both by bongo and neuston sampling gear. FY97 was the first year we have attempted to quantify the changes in relative density of sand lance larvae. Some of the preliminary analysis of this new aspect of the project is discussed.

Sand lance and capelin which together make up a significant amount of the forage base in the Gulf of Alaska have a high affinity for near-shore sediments for spawning. Potential damage to these critical near-shore habitats could have occurred as a result of the EXXON Valdez oil spill, especially along the fine sediment Katmai coast and sandy beaches on the eastern coast of Kodiak Island. We propose to study the early life history and variation in production before and after the spill of sand lance larvae from NMFS collected icthyoplankton data base. Additional studies will be proposed to fund work on analyzing the capelin portion of this data.

Sand Lance are one of the main prey for marine birds, further, 0+ sand lance are a major component of nestling diet and may indicate a linkage between ocean production and nesting success of seabird colonies (Bertram and Kaiser 1993). We propose to study past abundance and test hypothesis concerning changes in abundance of the early life history of sand lance in the vicinity of Kodiak. We propose to analyze a long-term database (1972 - 1995) of an icthyoplankton collection containing sand lance for the Kodiak and Shelikof region of the Gulf of Alaska to develop hypothesis concerning observed changes in density and distribution. Preliminary analysis will focus on the critical spawning (Oct -Jan) and over wintering (Nov - March) state of sand lance and how it might relate to larval survival and year-class strength.

Methods

Larval sand lance were collected from lower Cook Inlet to Unimak Pass with two types of sampling devices. The neuston layer was sampled using a "Sameoto sampler" (Sameoto and Jaroszyinski, 1969), with an opening of .3m by .5m and a mesh of 0.505mm. The water column from near-bottom to the surface was sampled using a MARMAP bongo sampler (Posgay and Marak, 1980) with 0.6m diameter opening and either 0.333 or 0.505mm mesh nets. Depths and position were recorded for each deployment of the sampling gear. Samples of sand lance and other planktonic species were preserved using 5% formalin-seawater solution buffered with either calcium carbonate or sodium tetraborate. Specimens were separated, counted, and up to 50 individuals of sand lance were measured to the nearest 0.1mm SL (Rugen, 1990).

Results

Out of the sixty-six taxa identified in the neuston samples, *Ammodytes hexapterus* were the fifth most abundant in terms of number caught for all sampling made between April 1972 and May 1986 (1,546 neuston stations sampled). For the bongo samples they were the second most abundant during the same time period (2,414 bongo samples) out of 118 taxa. In the months of March through the early part of May Pacific sand lance were the single most abundant species in bongo samples. This peak abundance of sand lance larvae in the spring samples is also reflected well in the neuston samples where their peak relative abundance was found during the first half of June. Sand lance were absent from neuston samples after August and from bongo samples after June sampling periods.

Large numbers of larvae from bongo samples were spatially located close to Kodiak Island with higher concentrations located to the northeast and southwest of the island in March. This distribution pattern held steady in later time periods except for a tendency of larvae to even out there distribution in Shelikof strait. Larvae captured with neuston nets showed relatively large catches later in the year and were found close to Kodiak Island or above the slope. Lengths of larvae were larger in the neuston tows (9.6-29.7 mm SL) than in the bongo samples (5.4-18.7 mm SL).

Discussion

Pacific sand lance are one of the most, important larval fish components of the icthyoplankton around Kodiak Island during the spring period. The only larval fish component that outnumbers sand lance in bongo samples was the walleye pollock, *Theragra chalcogramma*. The analysis of total numbers of larvae captured showed that pollock larvae were nearly 20 times more abundant (233,762) overall than sand lance (13,739). The next most abundant species was *Bathymaster* sp. only accounted for 80 total individuals caught in the 1972-1986 bongo samples.(Rugen, 1990)

Walleye pollock, *Theragra chalcogramma*, are also a locally prominent component of the icthyoplankton during the same period as sand lance larvae and may compete with them for food. Distribution of pollock larvae is concentrated in lower Shelikof strait during the March which is quite different then that of sand lance during the same time period. Also there is indication that as the larvae age and attain a larger size sand lance are more commonly found in the neuston layer than pollock (Bodeur and Rugen, 1995) which suggests a different vertical distribution in the water column. Therefore it seems likely that sand lance may only be a competitor with pollock during the early spring at only a few localized areas mainly in lower Shelikof strait.

Future Direction of Analysis

1. Determine relative year-class strength of sand lance in study area. Do this by examining larval size data and adjusting for differences in hatch dates and growth between years.

2. Inshore migration dynamics and vertical distribution changes and how these might relate to year-class strength.

3. Examin neuston samples to determine timing of in-shore migration.

4. Compare density estimates from neuston samples with those of the same yearset for bongo sampling to investigate the feasability of determining a relative survival index amoung year-classes.

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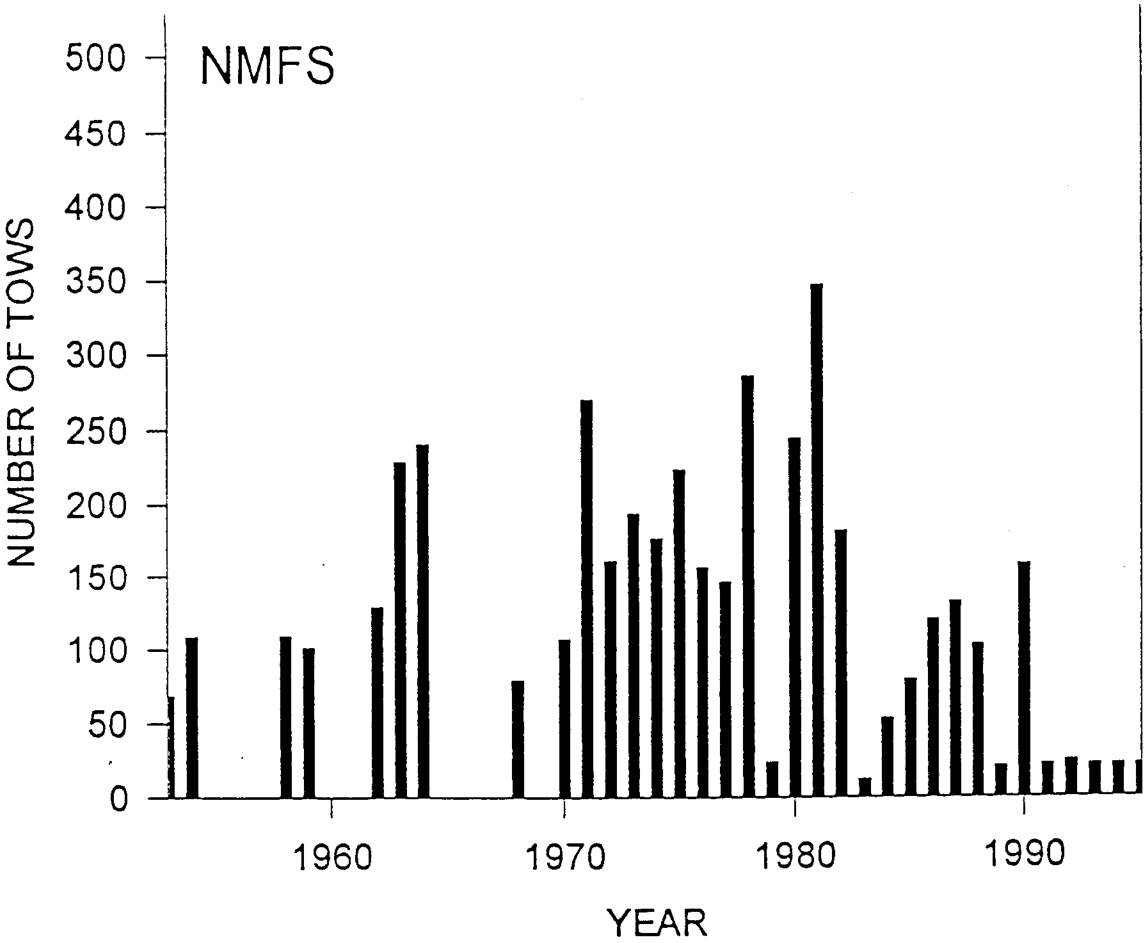
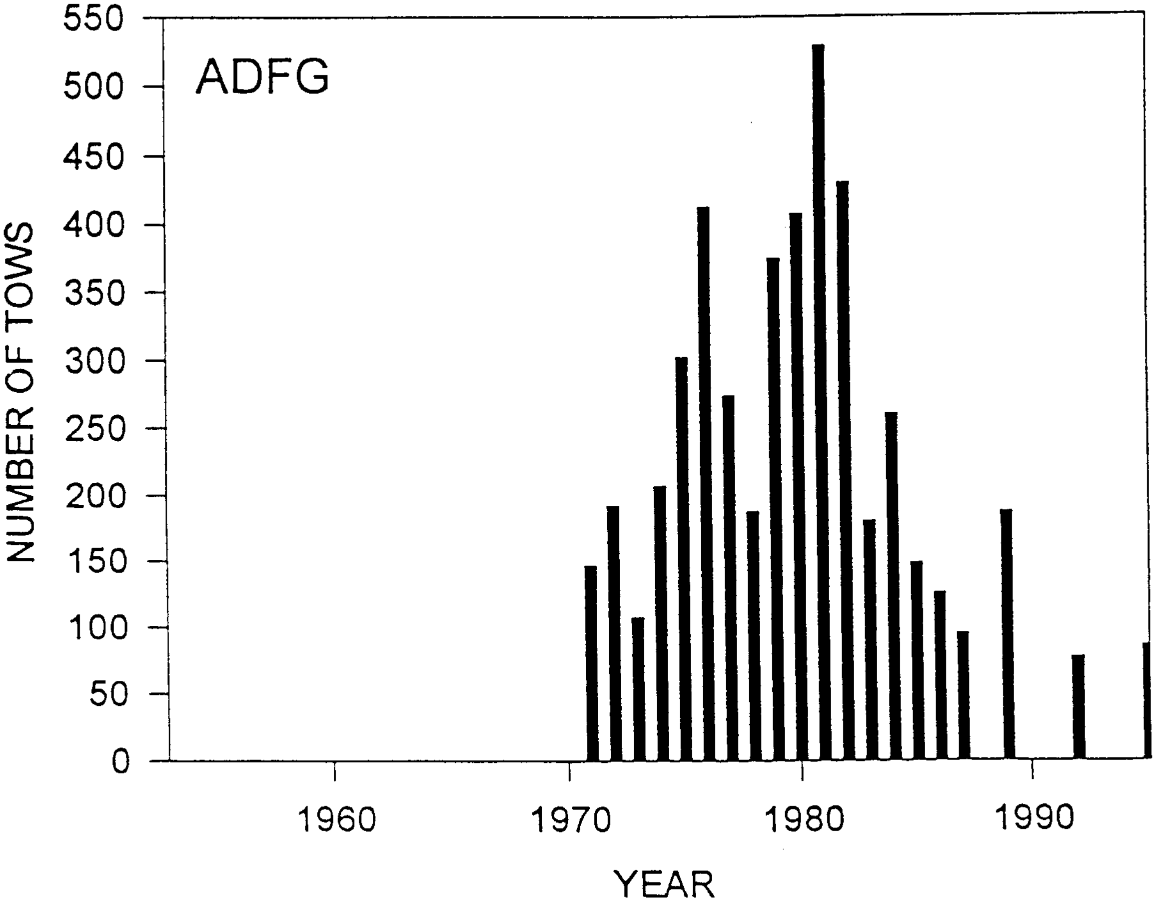
FIGURES

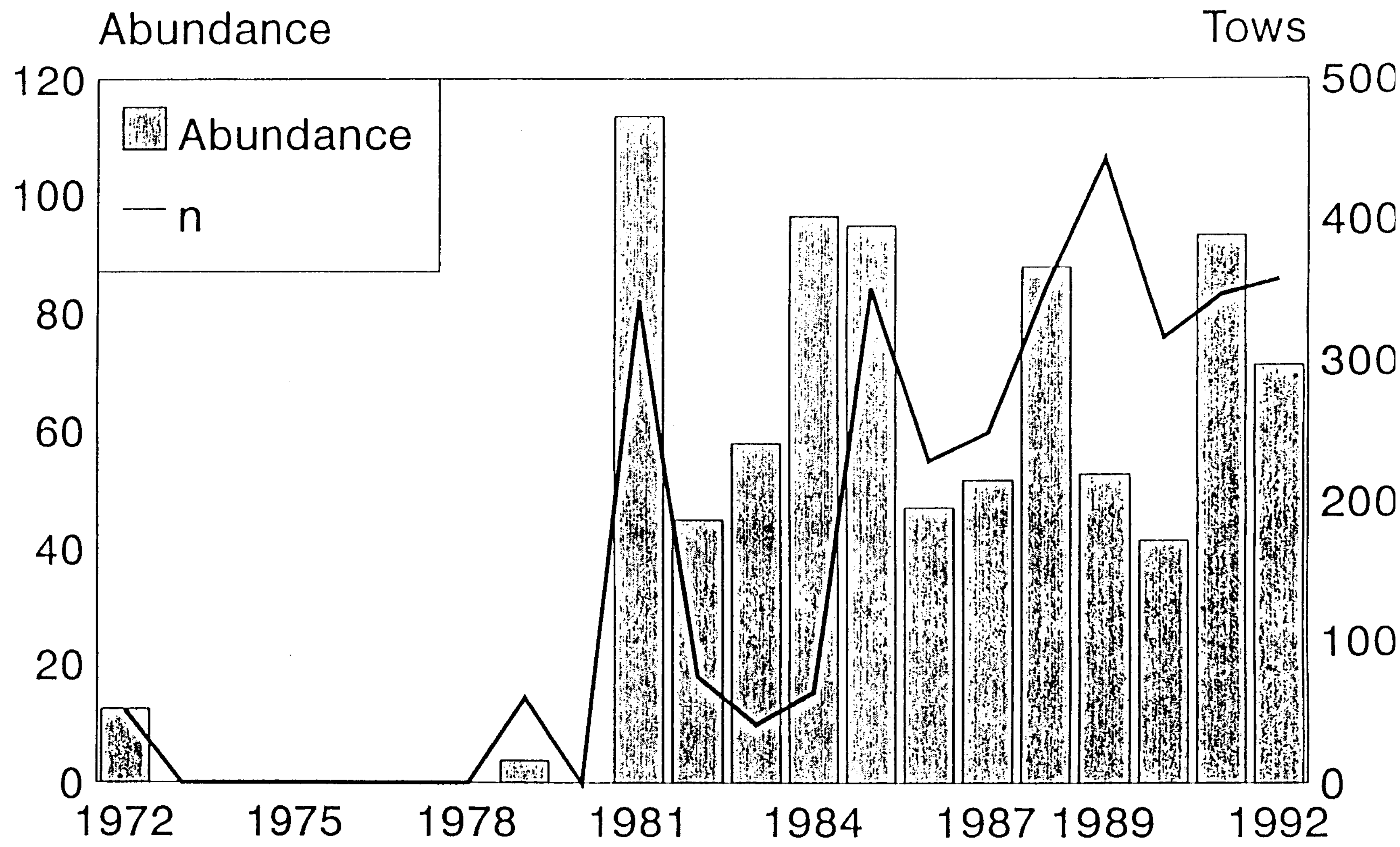
Figure 1. Annual number of small-mesh survey sampling from 1953 to 1994 in the Gulf of Alaska by NMFS and ADFG. All NMFS tows since 1990 conducted in Pavlof Bay only.

Figure 2. Relative density of Pacific sand lance larvae in the Kodiak - Shelikof Strait region 1971 - 1992. Density values in numbers per 10 meter^2.


NMFS
NUMBER OF TOWS
500
450
400
350
300
250
200
150
100
50
0
1960
1970
1980
1990
YEAR


ADFG
NUMBER OF TOWS
550
500
450
400
350
300
250
200
150
100
50
0
1960
1970
1980
1990
YEAR

.6 m Bongo 1972-92



March - June (number per 10 sq. meters)

APPENDIX

Three manuscripts submitted by project investigators for inclusion in: Proceedings of the Role of Forage Fishes in Marine Ecosystems. Expected publication date is summer 1997. These manuscripts are submitted as completed portion of project studies for FY96 & FY97.

Exxon Valdez Oil Spill
Restoration Project Annual Report

Analysis of Small-Mesh Trawl Data

Restoration Project (APEX) 96163L

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March 1997

Analysis of Small-Mesh Trawl Data

Restoration Project(APEX) 96163L
Annual Report

Study History: Restoration Project 96163L was initiated as part of the APEX project that is studying the relationship between changes in forage species composition and marine birds in the spill affected area. Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in composition and abundance of forage species may be responsible for the decline of these predator populations and their chronic low population levels. In an effort to delineate changes in forage species and a trophic regime shift, if any, over the last several decades, we have gathered together historical fishery-independent scientific survey data to address this question. This part of the annual report includes one manuscript submitted for publication from recent analysis of information and data from small-meshed trawl studies conducted in the Gulf of Alaska by the Alaska Department of Fish and Game and the National Marine Fisheries Service and its predecessor agencies from 1953 through 1996.

Abstract: Twenty-four years (1972-95) of shrimp trawl survey catch data was analyzed in order to reveal changes in the species composition of demersal biomass in the Gulf of Alaska. A shrimp-dominated crustacean species community (mostly *Pandalus goniurus* and *P. borealis*) came to an end in the late 1970's and has not yet regained its former level of biomass. Changes in community structure continued with the decline of capelin (*Mallotus villosus*) in the late-1970s, followed by a build-up of gadid fishes in 1978-83 and pleuronectid fishes in 1984 to the present. Overall, the biomass index, as represented by shrimp sampling trawl, has declined to less than one-half of its former size under the recent fish-dominated environment. This epibenthic regime shift was accompanied by a rapid increase in water temperature which may largely be responsible for the observed abrupt temporal change in species composition.

Key Words: Regime Shift, Gulf of Alaska, Forage Species, osmerids, capelin, pandalid shrimp, gadids, pleuronectids, epibenthic, benthic, biomass index, community structure.

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Declines of Forage Species in the Gulf of Alaska, 1972-95, as an Indicator of Regime Shift

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*Abstract

Twenty-four years (1972-95) of shrimp trawl survey catch data was analyzed in order to reveal changes in the species composition of demersal biomass in the Gulf of Alaska. A shrimp-dominated crustacean species community (mostly *Pandalus goniurus* and *P. borealis*) came to an end in the late 1970's and has not yet regained its former level of biomass. Changes in community structure continued with the decline of capelin (*Mallotus villosus*) in the late-1970s, followed by a build-up of gadid fishes in 1978-83 and pleuronectid fishes in 1984 to the present. Overall, the biomass index, as represented by shrimp sampling trawl, has declined to less than one-half of its former size under the recent fish-dominated environment. This epibenthic regime shift was accompanied by a rapid increase in water temperature which may largely be responsible for the observed abrupt temporal change in species composition.

*Introduction

Simultaneous and abrupt declines of crustacean populations, most notably shrimp of the genus Pandalus, and smelt of the family Osmeridae, have occurred in the Gulf of Alaska along with increasing densities of gadid fishes and many species of pleuronectid flatfishes. These concurrent changes in several species suggest that they are causally connected in affecting commercial (Anderson 1991) and non-commercial species (Piatt and Anderson 1996) alike, and thus represent a regime shift (Steele 1996). Implicit in the concept of a regime shift is that changes occur throughout the ecosystem and a new community structure is formed. A crustacean/forage fish epibenthic community changed to the current regime dominated by fishes during a brief time period between 1978 and 1981 in the central and western Gulf of Alaska. This shift is well documented by results from a long-term small-mesh trawl survey series conducted before and after the shift (Piatt and Anderson 1996). This paper describes the results from these surveys and presents hypotheses for the observed regime shift.

*Methods

Data used in this study were collected during small-mesh trawl surveys which targeted shrimp as their primary species. The data set is a compilation of nearly 10,000 trawl samples by the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADF&G). Most of the sampling was done with a small-mesh net with 32 mm stretched mesh throughout

(Anderson 1991). Survey tows were conducted during daylight in water deeper than 50 m since preliminary surveys had shown low shrimp densities in shallow water (Anderson 1991). Most tows covered an average length of 1 to 2 km.

Survey catches were sorted by species and all species were weighed separately. Occasionally, catches were so large that subsampling of the catch was employed after the method described by Hughes (1976). Subsamples were counted to obtain the average weight of individuals. All shrimp, juvenile fish (mostly Pleuronectidae) were combined, weighed, and subsampled for species composition. The subsampled species groups were then counted and weighed to the nearest gram using a triple-beam scale. The extrapolated juvenile weights of each species were added to those of the adults of the same species.

Organism counts and weights were converted to density values expressed as either number or kilograms caught per kilometer towed by the sampling gear (catch per unit of effort [CPUE]). Converting density values in this way minimizes possible bias associated with sampling tows of unequal distance or duration. Abundance comparisons for species among years and areas all use CPUE rather than actual catch values.

Sampled locations were mapped using the computer program ARCINFO and data distribution was outlined graphically to define the sampled area over the time series. Species density by area was determined by combining CPUE values for each area by year and computing the mean. Eight bays were chosen for detailed study

(Fig. 1) representing a broad coverage of the Gulf of Alaska inshore bay ecosystem.

We have abstracted major components from the total biomass in order to simplify our analysis for density trends. Two groups of forage species, which include shrimps mainly of the family Pandalidae and smelts of the family Osmeridae made up of mostly capelin *Mallotus villosus,* and to a lesser extent eulachon *Thaleichthys pacificus*, and small amounts of other miscellaneous smelts composed the forage species complex. For this study, we consider the smelts and shrimps as trophospecies, a species group that shares similar prey and predators. Flatfishes (Pleuronectidae) were treated as a group and include five species, arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides elassodon*), yellowfin sole (*Pleuronectes asper*), rock sole (*Pleuronectes bilineatus*), and Pacific halibut (*Hippoglossus stenolepis*). Gadid fishes include Pacific cod (*Gadus macrocephalus*) and walleye pollock (*Theragra chalcogramma*). All other species, which made up the remainder of the catch biomass, was treated as a combined element for this study.

*Results

Combined biomass of all species declined in seven of the eight study areas to the lowest CPUE during the 1985-89 period. One area, Two-headed Island gully, showed low total biomass during the early 1970-74 time period. Since most of the data for this time period had to be discarded due to incomplete catch sorting, we feel that the low total biomass for this period distorts the results. If this data point is discarded, then the trend of low overall abundance of all organisms fits the same pattern observed for the other areas (Table 1). All areas sampled showed an increase in total biomass as measured by our sampling gear in the latest period (1990-95).

In order to remove fluctuations associated with seasonal on-shore and off-shore movements of biomass components, we selected catch data from the August through November time period to study changes in total biomass. Anderson (1991) hypothesized that shrimp density was most stable at this time of year because of mating aggregations. Ketchen (1961) indicated that inshore cod populations were probably more available in the summer and fall because of wamer temperatures before winter cooling. Highest total biomass was 493.1 kg/km (mean CPUE n=873, SD=470.2) during the 1972-80 time period before declining to 176.1 kg/km (mean CPUE n=342, SD=158.3) in 1985-88. Based on the recent 1991-95 sampling period total biomass has recovered to 373.6 kg/km (mean CPUE n=215, SD=229.3) (Fig. 2).

The two main forage species groups, shrimp and osmerids, declined from relatively high levels of abundance in 1970-84 to uniformly low abundance during 1985-95. Three areas, Chiniak, Pavlof, and Ugak Bays, all showed high levels of osmerids and shrimp simultaneously. In two areas, Pavlof and Chiniak Bays, high forage species abundance was coincident with high total biomass. Chignik bay showed highest osmerid abundance earlier than observed maximum shrimp abundance (Table 1).

In the Osmerid group, capelin alone composed 84% of total group biomass prior to 1981 and declined thereafter leaving eulachon the major species in the group. Capelin maximum mean CPUE for late summer and fall surveys was in 1972 at 23.7 kg/km; other peaks in abundance occurred in 1976 at 21.2 kg/km and again in 1980 at 15.9 kg/km. Abundance has remained at less than 0.1 kg/km since 1987 and shows no sign of recovery (Fig. 3).

Results indicate a close relationship between high total biomass and high forage species abundance. In contrast, low total biomass is related to both low abundance of forage species and high levels of flatfish abundance (Table 1). In order to explore these observed relationships, we used a "slug trace" plot (Ramsey 1988) to illustrate periods of biomass regime shift for our study areas. This technique uses bivariate time plots of the studied species groups in two dimensions accompanied by a univariate scatter plot. The relationship between the two forage species is shown in Figure 4. The arrow line on the corresponding plots signals the regime shift observed in the survey data. It is clear from these plots that the relationship of shrimp and osmerid abundance changed between 1976-83, signaling the shift to a new community structure.

*Discussion

A major shift in the physical regime of the Gulf of Alaska occurred in 1976-77 (Royer 1989, Kerr 1992, Trenberth and Hurrell 1995) and is reflected in the observed shift in species composition data from trawl surveys of inshore bays over a broad region in this study (Fig. 5). Other studies have shown increased landings of Pacific salmon (Beamish and Bouillon 1992), possibly due to enhanced ocean survival which may be the direct result of increased zooplankton abundance (Brodeur and Ware 1992) or more favorable temperature. Kodiak Island near-shore (10.7 m) water temperature in March averaged -0.48 to 2.01 degrees C during 1971-76, 2.90 to 5.09 degrees C during 1977-88, and 2.14 to 3.33 degrees C during 1989-94 (S. F. Blau, pers. comm.). Increases in near-shore water column temperature may possibly affect productivity for shrimp and forage fish in a negative way. Aquatic communities integrate the totality of environmental factors that they are exposed to. Our contention is that the physical regime shift co-occurred with the shift from the crustacean/forage fish regime to the current epibenthic community now dominated by cod, pollock, and pleuronectid flatfishes, and was the primary mechanism that caused the epibenthic community shift.

Shrimp declined uniformly throughout all study areas, but one species (*Pandalus goniurus*) that was formerly a significant part of the shrimp biomass became nearly extinct (Fig. 6) while the other primary species (*P. borealis*) has declined, but not to levels of near-extinction. This observed change demonstrates that some species are more vulnerable to being extinguished from the near-shore ecosystem as a result of regime shift. This species was not heavily targeted by commercial shrimpers, and declines after closure of commercial fisheries continued. We hypothesize that the near-extinction of *P. goniurus* was caused by sustained higher winter temperatures that took place in the late 1970s (Royer 1989). This species is found in relatively shallower waters than *P. borealis* and is subject to areas of high residual winter cooling. These distribution traits along with abrupt changes in winter temperatures may explain the region-wide regime shift.

Influxes of Pacific cod into the inshore bays and gullys where dense shrimp and osmerid populations occurred was a destabilizing factor on those populations and was partially responsible for the observed ecosystem regime shift in the Gulf of Alaska. Cod were virtually absent in inshore bays during the early 1970s (Albers and Anderson 1985) (Fig. 5). We believe that warming water column temperatures may allow cod to remain in our study areas throughout the winter instead of migrating offshore when temperatures are cooler (Ketchen 1961). This increased contact with the forage base probably contributed further to the observed decline of shrimps and osmerids that continued well after the end of most in-shore shrimp trawl fisheries in the late 1970s (Albers and Anderson 1985).

In conclusion, our analysis shows a marked decline in the available biomass after the shift from the crustacean regime to the regime dominated by fishes (Fig. 2 and 5). The declines in epibenthic biomass, as observed in this study, were opposite of the increase in landings and abundance of many species of Pacific salmon (Beamish and Bouillon 1993). Also coincident with the regime shift was a change in the higher trophic levels and composition of zooplankton (Brodeur and Ware 1992). Since many forage species, including capelin and shrimp, are planktivores this observed change in plankton composition could explain the uniform decline of these species.

Abrupt changes in the physical regime with concurrent or slightly delayed reaction from the epibenthic ecosystem had an extreme effect on the inshore fishing fleet and processing of the central and western Gulf of Alaska. The regime shift, as described in this paper, occured rapidly and may shift again from a fish-dominanted to another community regime. These species composition shifts are preceded by changes in the physical environment. Monitoring water column temperature and changes in the epibenthic organisms in many areas of the Gulf of Alaska could be used to forecast future changes and perhaps lead to less disruption in the fishing industry when these regime shifts occur.

*Acknowledgements

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Table 1. Mean catch in kilograms per kilometer trawled of selected species groups by study area and selected time periods (ns = not sampled).

Alitak Bay					
Period	Total	Shrimp	Osmerids	Flatfish	Cod
1970-74	ns	358.63	ns	ns	ns
1975-79	312.32	233.38	7.00	22.3	0.56
1980-84	221.44	106.75	6.12	27.61	16.14
1985-89	113.24	14.25	0.57	19.95	9.96
1990-95	141.11	2.81	0.31	27.08	17.68
Chignik Bay					
1970-74	483.45	345.31	5.22	11.54	1.56
1975-79	476.31	360.88	3.52	10.83	18.36
1980-84	333.71	94.99	2.64	60.37	45.04
1985-89	134.70	16.73	0.40	54.71	6.90
1990-95	210.03	38.90	1.91	80.49	6.48
Chiniak Bay					
1970-74	ns	ns	ns	ns	ns
1975-79	490.43	253.69	2.74	88.52	5.47
1980-84	303.54	126.48	0.78	95.86	13.90
1985-89	166.16	17.34	0.77	78.08	5.91
1990-95	320.62	23.40	0.29	163.30	5.64
Kiliuda Bay					
1970-74	ns	362.29	.07	2.85	0.09
1975-79	511.95	366.80	7.24	36.15	9.91
1980-84	345.52	34.92	27.97	59.08	22.34
1985-89	260.56	9.18	1.08	108.70	22.10
1990-95	476.97	7.56	7.67	141.91	15.30

Table 1. Continued

Marmot Bay					
Period	Total	Shrimp	Osmerids	Flatfish	Cod
1970-74	ns	171.78	ns	ns	ns
1975-79	229.10	110.11	2.72	29.40	2.22
1980-84	298.08	89.07	6.36	117.83	9.39
1985-89	177.36	18.75	0.21	59.75	18.98
1990-95	262.05	54.78	0.12	104.38	5.95
Pavlof Bay					
1970-74	795.59	695.35	21.25	5.20	0.03
1975-79	735.57	373.63	11.73	22.21	225.69
1980-84	402.90	20.49	6.70	70.40	141.84
1985-89	289.18	6.31	0.09	131.04	20.39
1990-95	441.78	14.67	0.04	159.53	32.73
Two-headed					
1970-74	199.05	537.24	4.64	8.45	8.46
1975-79	406.39	297.52	7.44	28.47	13.16
1980-84	319.08	95.68	17.53	75.09	18.28
1985-89	314.45	9.82	1.10	147.45	19.10
1990-95	401.24	20.60	0.39	126.46	4.82
Ugak Bay					
1970-74	ns	90.24	ns	ns	ns
1975-79	304.93	209.60	29.72	23.64	0.27
1980-84	337.13	111.59	13.45	43.54	72.47
1985-89	240.70	9.88	3.70	73.13	20.45
1990-95	ns	ns	ns	ns	ns

*List of Figures

1. Location of bays and near-shore sampling sites for small-mesh trawl surveys 1970-95. Note: "Chignik-Castle" is a group of three bays; Chignik, Kujulik, and Castle Bays.

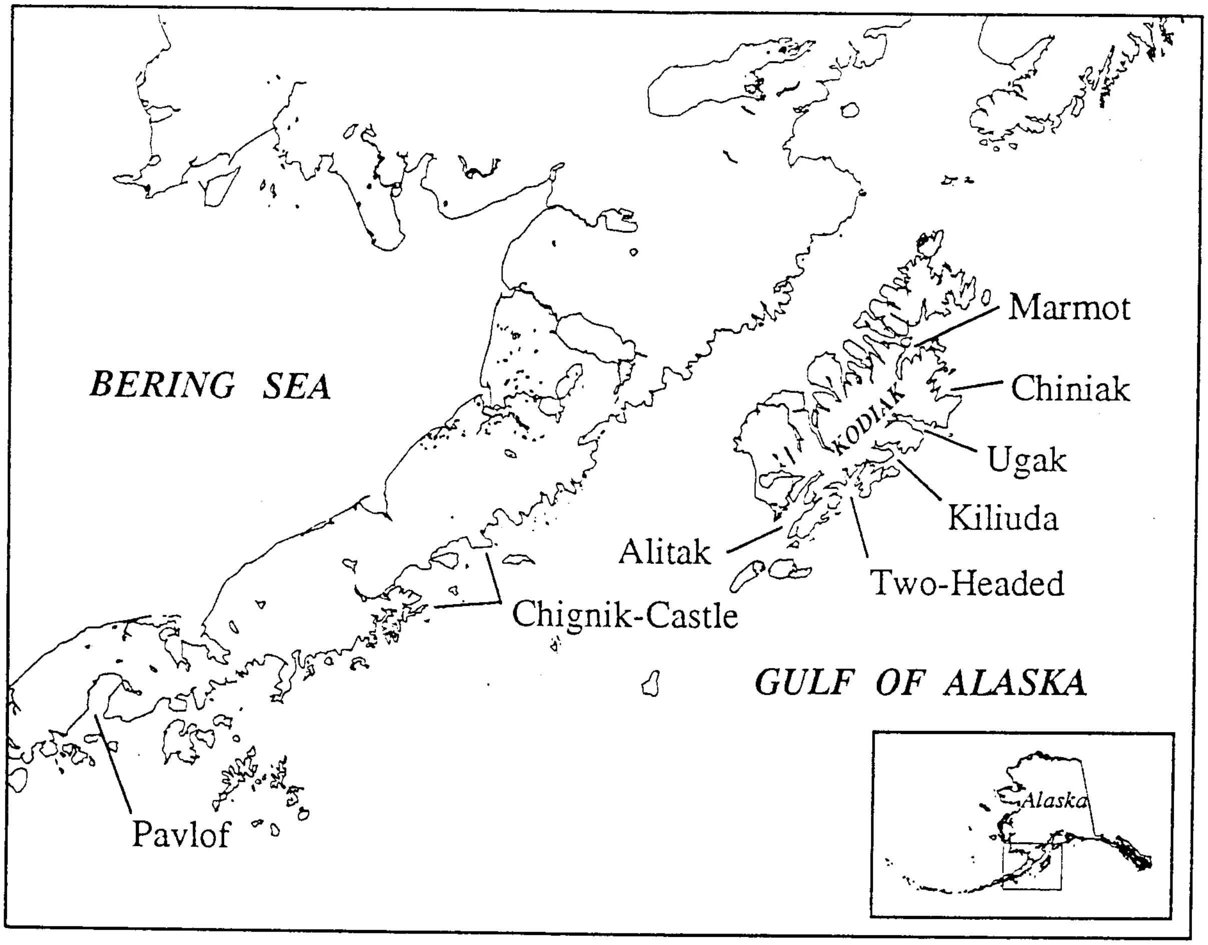
2. Mean CPUE (expressed as kilograms caught per kilometer trawled) of total biomass for the months August through November, 1972-95 . All 8 sampling sites combined.

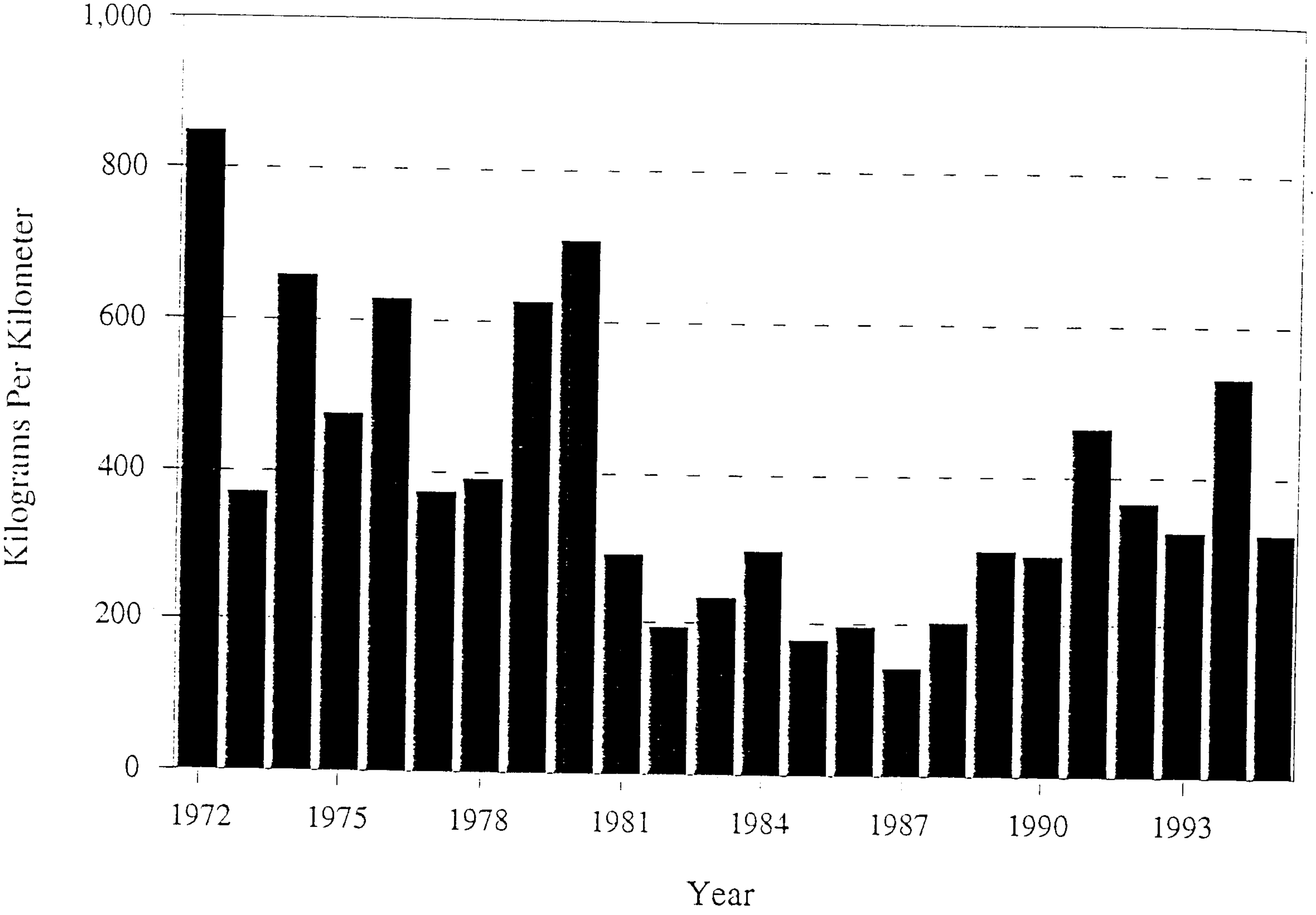
3. Mean CPUE of capelin from August through November trawl surveys in all sampling locations combined.

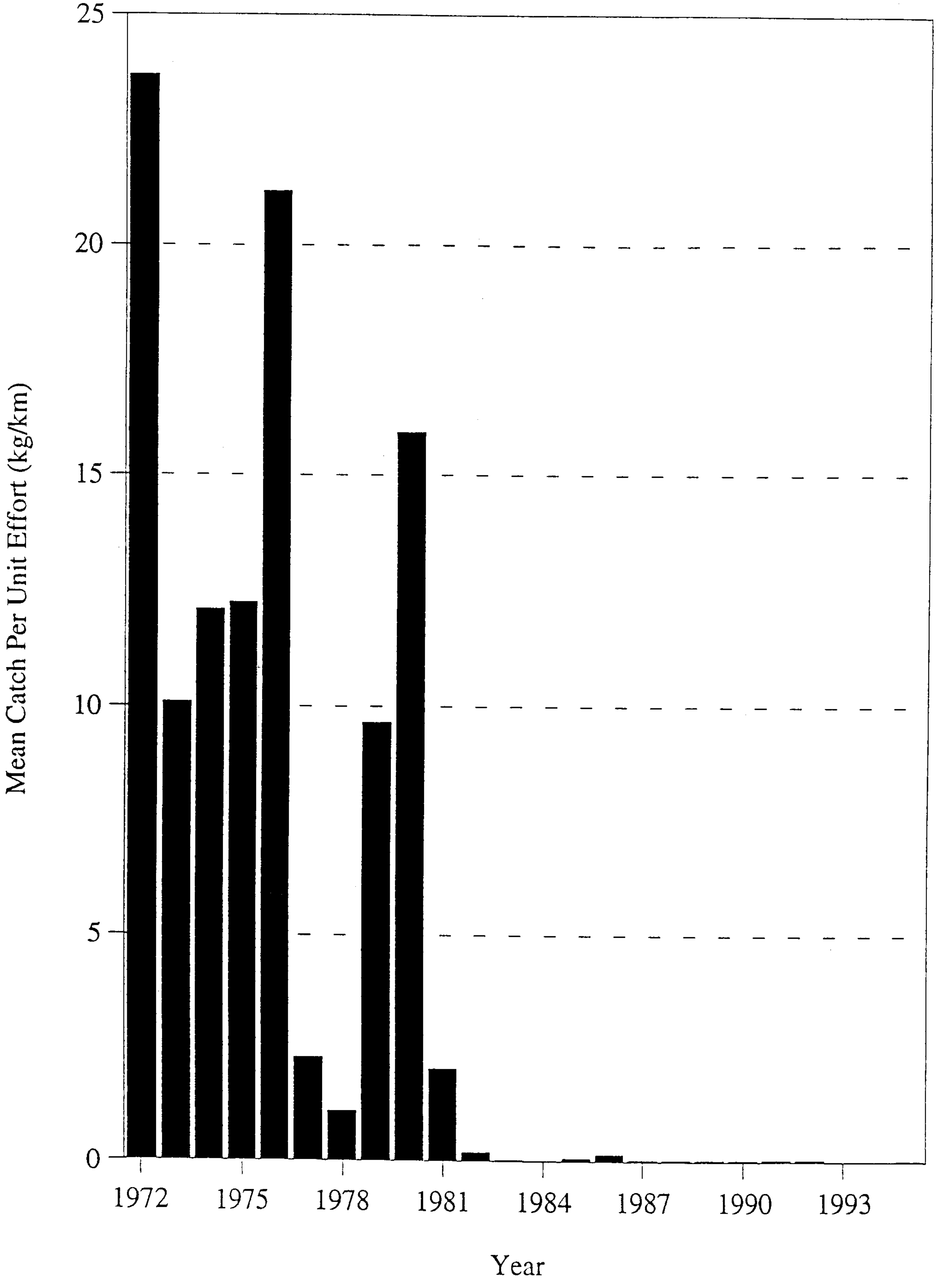
4. Slug traces of shrimps and Osmerids from several bays; regime shift identified by arrow line on scatterplots. (Please note difference in scales of mean CPUE for species groups in bivariate time plots).

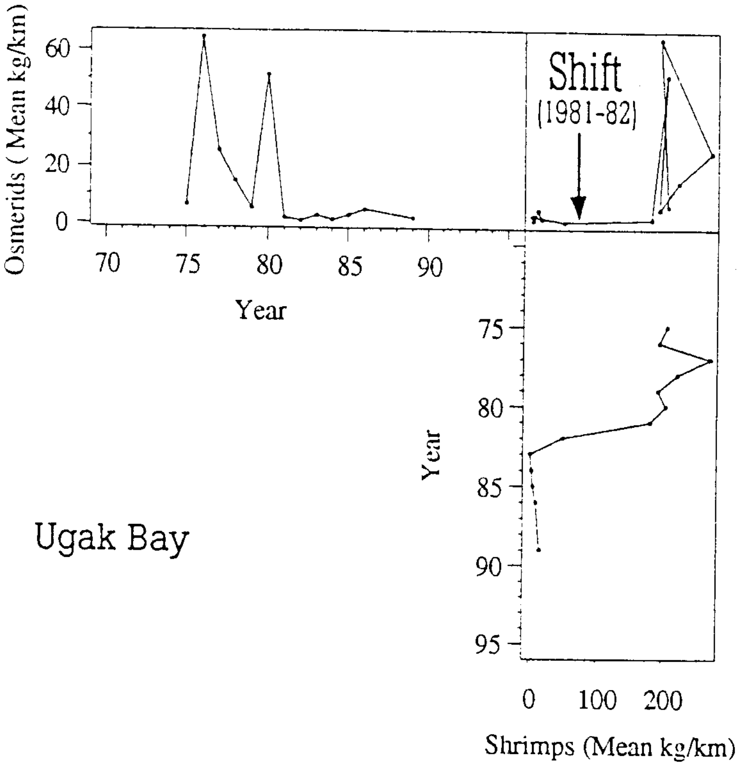
5. Species composition represented by proportional contribution in August through November total biomass in all sampling sites combined.

6. Mean CPUE of *Pandalus borealis* and *P. goniurus* from all sampling areas, 1972-95.

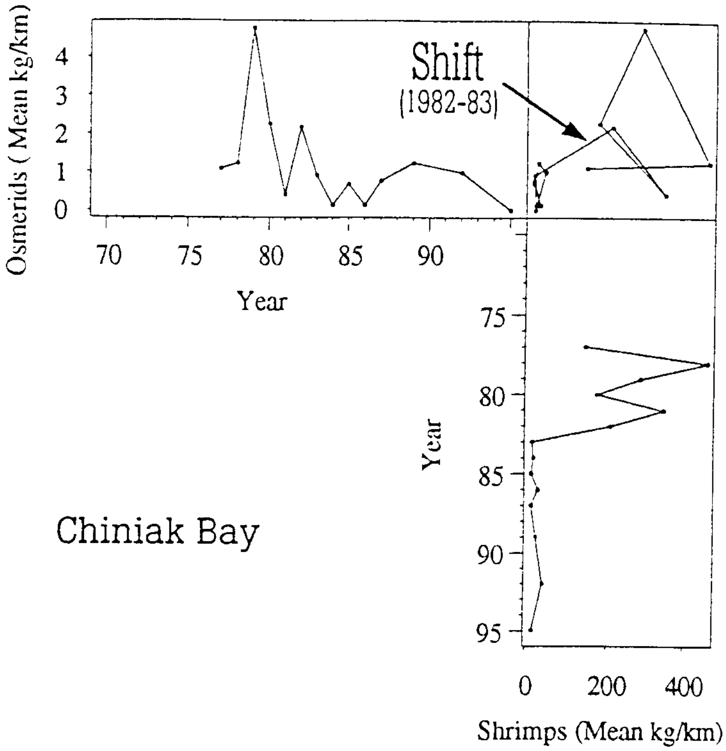

BERING SEA
Marmot
Chiniak
KODIAK
Ugak
Kiliuda
Alitak
Two-Headed
Chignik-Castle
GULF OF ALASKA
Pavlof
Alaska


1,000
800
600
400
200
0
Kilograms Per Kilometer
1972
1975
1978
1981
1984
1987
1990
1993
Year

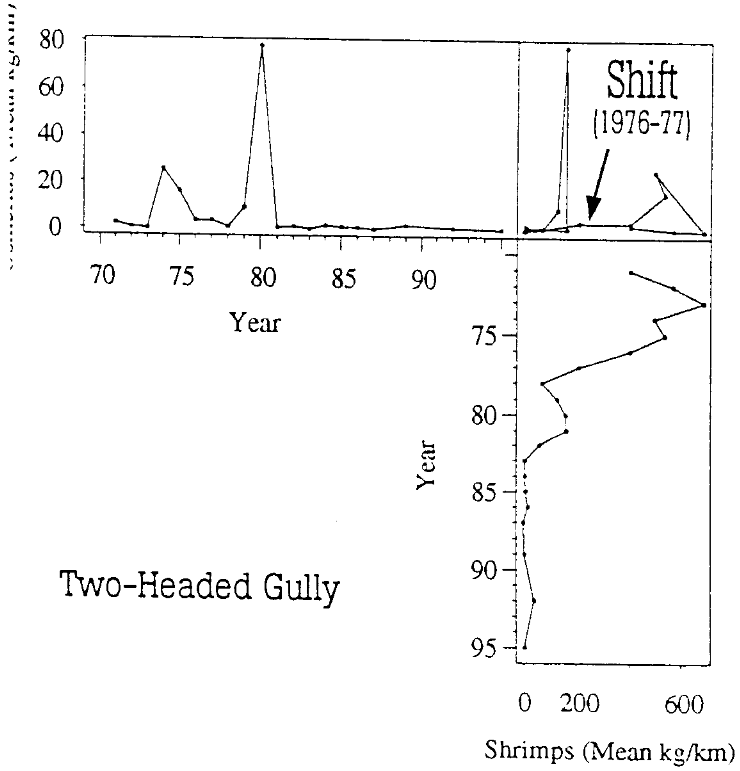

25
20
15
10
5
0
Mean Catch Per Unit Effort (kg/km)
1972
1975
1978
1981
1984
1987
1990
1993
Year



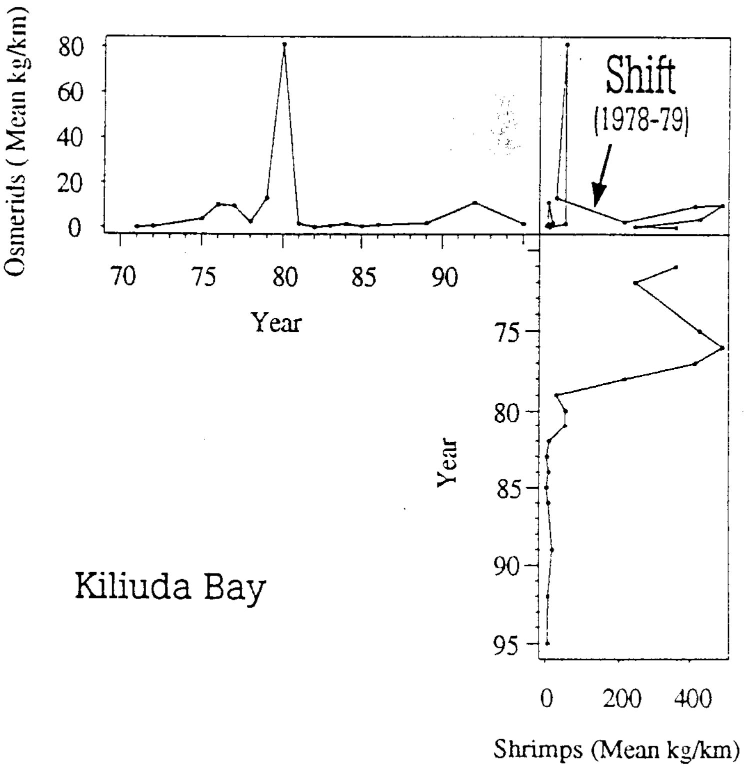
Osmerids (Mean kg/km)
60
40
20
0
70
75
80
85
90
Year
Shift
(1981-82)
75
80
85
90
95
Year
0
100
200
Shrimps (Mean kg/km)
Ugak Bay



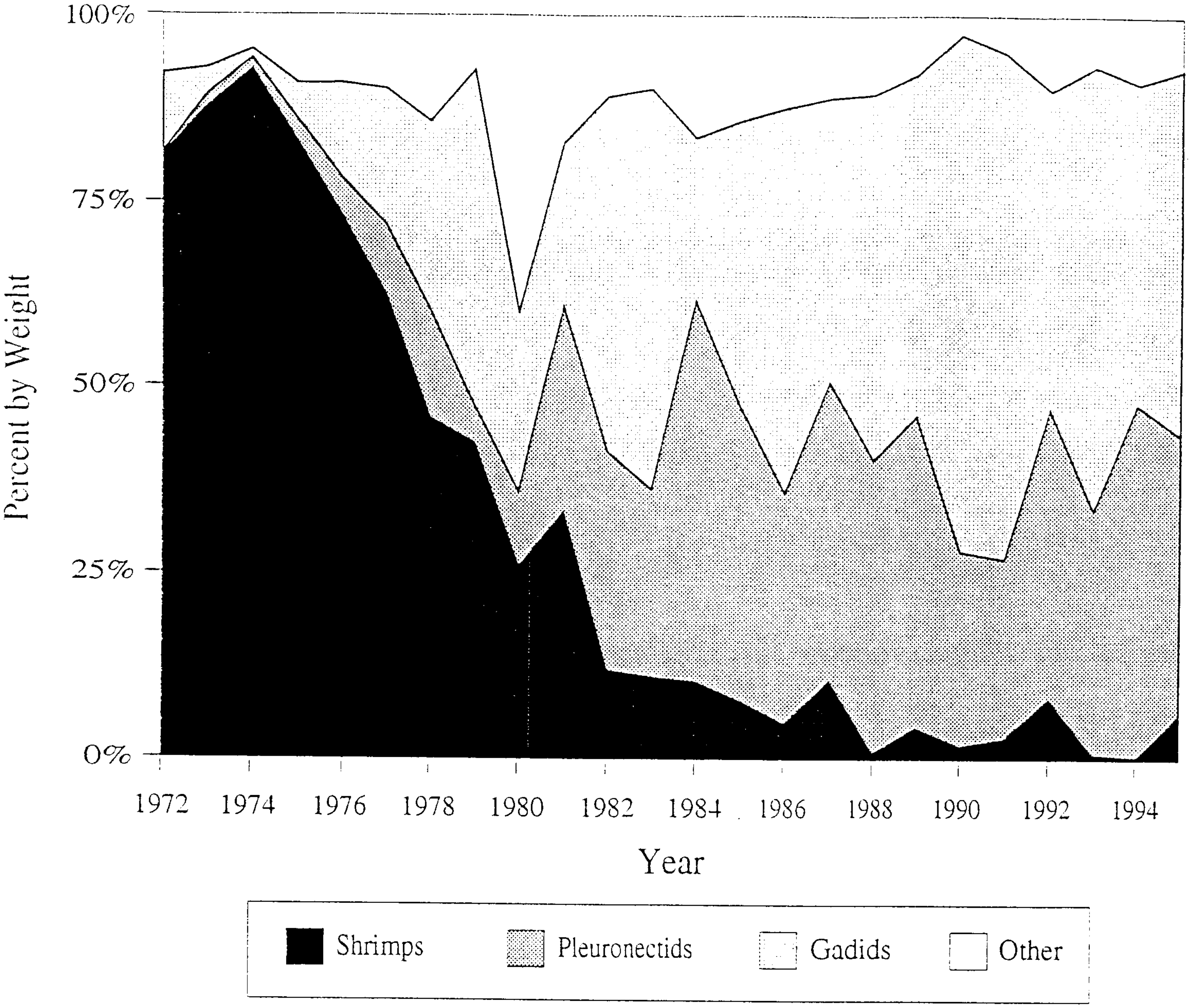
Osmerids (Mean kg/km)
4
3
2
1
0
70
75
80
85
90
Year
Shift
(1982-83)
75
80
85
90
95
Year
0
200
400
Shrimps (Mean kg/km)
Chiniak Bay

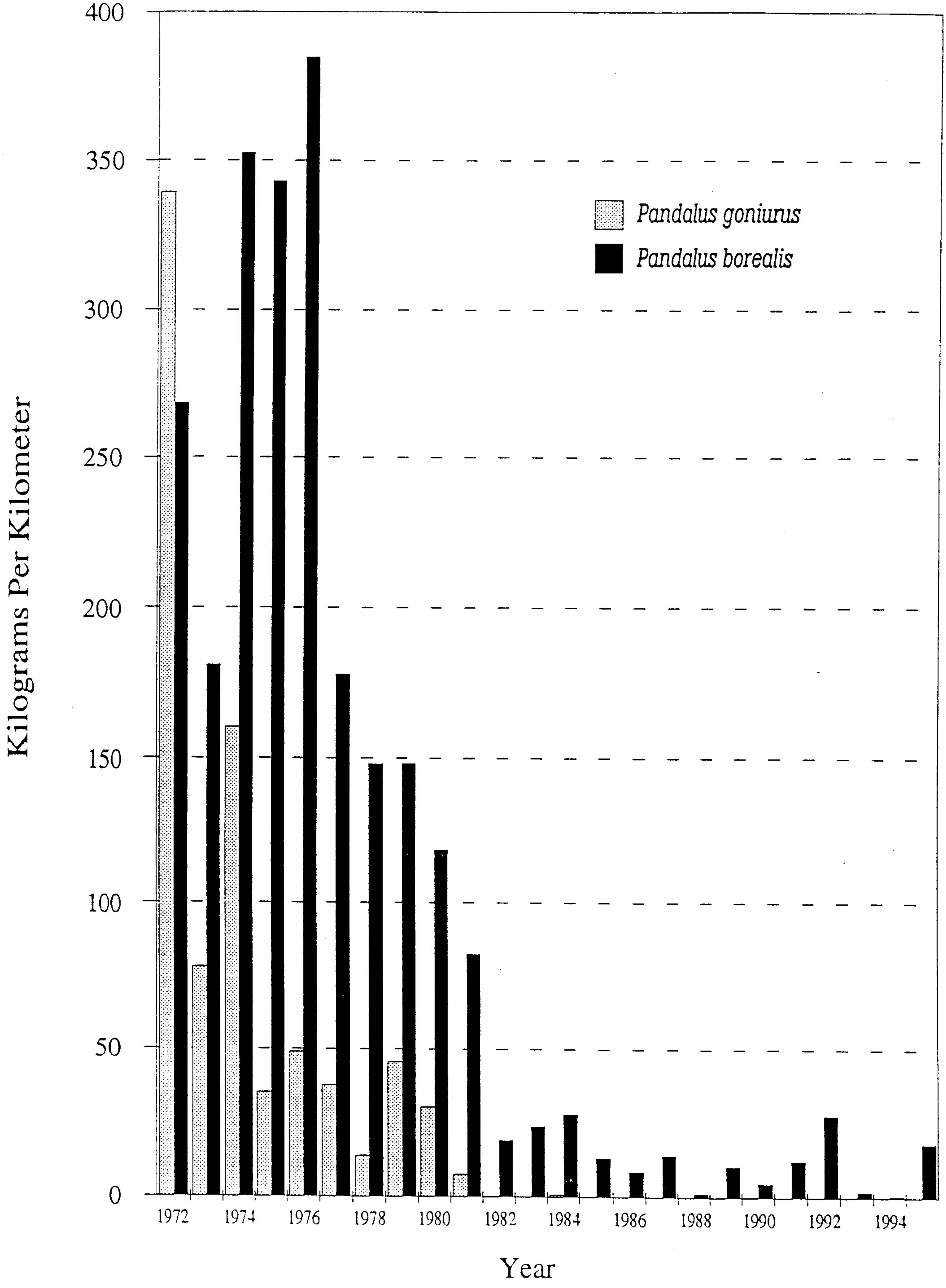


80
60
40
20
0
70
75
80
85
90
Year
Shift
(1976-77)
75
80
85
90
95
Year
0
200
600
Shrimps (Mean kg/km)
Two-Headed Gully



Osmerids (Mean kg/km)
80
60
40
20
0
70
75
80
85
90
Year
Shift
(1978-79)
75
80
85
90
95
Year
0
200
400
Shrimps (Mean kg/km)
Kiliuda Bay


100%
75%
50%
25%
0%
Percent by Weight
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
Shrimps
Pleuronectids
Gadids
Other


400
350
300
250
200
150
100
50
0
Kilograms Per Kilometer
Pandalus goniurus
Pandalus borealis
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year

Exxon Valdez Oil Spill
Restoration Project Annual Report

Analysis of Small-Mesh Trawl Data

Restoration Project (APEX) 96163L

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March 1997

Analysis of Small-Mesh Trawl Data

Restoration Project(APEX) 96163L
Annual Report

Study History: Restoration Project 96163L was initiated as part of the APEX project that is studying the relationship between changes in forage species composition and marine birds in the spill affected area. Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in composition and abundance of forage species may be responsible for the decline of these predator populations and their chronic low population levels. In an effort to delineate changes in forage species and a trophic regime shift, if any, over the last several decades, we have gathered together historical fishery-independent scientific survey data to address this question. This part of the annual report includes one manuscript submitted for publication from recent analysis of information and data from small-meshed trawl studies conducted in the Gulf of Alaska by the Alaska Department of Fish and Game and the National Marine Fisheries Service and its predecessor agencies from 1953 through 1996.

Abstract: A Twenty year (1976-95) of shrimp trawl survey catch data was analyzed in order to reveal changes in the species composition of demersal biomass in Kachemak Bay. A shrimp-dominated crustacean species community (mostly *Pandalus goniurus* and *P. borealis*) came to an end in the late 1970's and has not yet regained its former level of biomass. Despite a complete closure of the commercial shrimp fishery in 1987, no rebuilding of shrimp resource has occurred. Walleye pollock occurrence declined to 22% in the mid-1980's, and have since increased to over 90% of tows in the 1990's. Smelt, as a group, declined from 893.1 per tow in 1978 to 8.9 per tow by 1989. Capelin have appeared to increase their distribution in the sampled area in recent surveys while relative abundance has declined.

Key Words: Kachemak Bay, Forage Species, osmerids, capelin, pandalid shrimp, gadids, Walleye pollock, biomass index, community structure.

Citation: Bechtol, W.R. 1997. Changes in Forage Fish Populations in Kachemak Bay, Alaska, 1976 to 1995. *In* Baxter, B.R. (ed) Proceedings of the Symposium on the Role of Forage Fish in the Marine Ecosystem. Alaska Sea Grant College Program AK-SG-97-01, 1997 (In Press).

Changes in Forage Fish Populations in Kachemak Bay, Alaska, 1976 to 1995

Note: This manuscript is currently under review as a contribution to the Proceedings from the Symposium on the Role of Forage Fishes in Marine Ecosystems, to be published by the Alaska Sea Grant College Program.

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INTRODUCTION

Relationships between different components of the Kachemak Bay marine ecosystem are poorly understood, yet fish and shellfish populations in this area have undergone significant changes since the mid-1970's. For example pandalid shrimp (*Pandalus* sp.) and red king crab (*Paralithodes camtschaticus*), once commercially important in this area, declined to low levels in the 1980's and have shown no evidence of rebuilding even though the fisheries have been closed since that time (Davis 1982; Gustafson 1994; Kimker 1996;). In particular, the collapse of the pandalid shrimp resource, especially the failure of this population to rebuild after a decade without commercial fishing pressure, indicated the magnitude of ecosystem change and the need to examine changes in other marine species. For example, some fish species, such as walleye pollock (*Theragra chalcogramma*), were reported to have dramatically increased.

A 20 year database of ADF&G surveys with small-mesh bottom trawls existed for the Cook Inlet area. Although the primary goal of these surveys was to assess pandalid shrimp resources (e.g. Gustafson 1994), some information was also collected on other captured species. As part of an *Exxon Valdez* oil spill study, the Alaska Predator Ecosystem Experiment (APEX; Duffy 1996), I examined the occurrence and abundance of fishes captured during these trawl surveys. This paper presents results of my analyses on selected species that might be described as either forage fish, i.e., species that might serve as an important prey item for other marine organisms , or as species potentially having a significant impact on the available forage base.

METHODS

From 1976 to 1995, the Alaska Department of Fish and Game (ADF&G) conducted bottom trawl surveys to assess shrimp populations in Kachemak Bay, Alaska, an embayment centered approximately at 59°35'N, 151°52'W in the northern Gulf of Alaska (Figure 1). Spring surveys were conducted annually in May from 1976 to 1993, then shifted to alternate years beginning in 1993. Fall surveys occurred annually from 1976 to 1990, and a single winter survey occurred in 1979. ADF&G made 16 to 45 tows within a season and year stratum, with a total of 1,200 survey tows in the historical database (Table 1).

Surveys involved tows of a 32 mm mesh net with a mouth rising 18.3 m and a 17 m tickler chain (Davis 1982). Tows were typically 1.0 nautical mile long. Following each tow, the tared catch weight was obtained as the catch was dumped on deck. Prior to 1989, all large non-fish objects were removed from the catch and the remaining catch was subsampled to estimate the shrimp to non-shrimp composition. In many cases the species composition of the non-shrimp catch was only described qualitatively. Beginning in 1989, the tared catch weight was obtained, then the entire catch was sorted, counted, and weighed by species or major species group with the total catch subsampled as necessary.

For this analysis, field data sheets were processed into an electronic database. All data were summarized according to shrimp and non-shrimp components. Subsample data on species composition were entered if available. However, sampling emphasis and methods changed somewhat over the survey time series. In particular, little sampling effort was applied to non-shrimp species during the mid-1980's and quantitative data were not recorded for non-shrimp species during most survey tows. If quantitative data were not available, qualitative data were entered during my subsequent analysis. All catch data were converted to 1.0 nm equivalents and summarized within a tow and season. General fish catch was estimated as kg/nm and percent catch composition. I calculated frequency of occurrence and mean tow abundance for three fish families, eelpouts (Zoracidae), poachers (Agonidae), and smelt, excluding capelin (Osmeridae); and four fish species, capelin (*Mallotus villosus*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), and Pacific tomcod (*Microgadus proximus*). I calculated frequency of occurrence for one more family, ronquils and searchers (Bathymasteridae), but did not estimate mean tow abundance because this family was encountered in catches only infrequently.

RESULTS

Relative and Absolute Increases in Fish Catches

Fish comprised an increasing portion of the mean tare weight in Kachemak Bay shrimp surveys since 1976. As the shrimp population declined in the 1980's, the fish component of Cook Inlet shrimp survey catches increased dramatically from less than 20% of the catch biomass in the late 1970's to more than 80% in recent years (Figures 2 and 3). Fish contribution in the fall was generally greater than in the spring. Although representing only a single winter assessment, fish composition in the 1979 winter survey was greater than any other seasonal contribution prior to the fall of 1981.

The aggregate catch biomass of all fish species also changed substantially over time as fish biomass per tow was again greater in fall than spring, and the single winter catch in 1979 was greater than spring or fall catches prior to 1981 (Figure 4). Spring fish catches generally averaged less than 60 kg/nm through 1983, then doubled to nearly 120 kg/nm in 1986 and 1987, and in the 1990's ranged from 264 to 395 kg/nm. Fall fish catches ranged from 87 to 112 kg/nm in the 1970's, and from 123 to 665 kg/nm between 1980 and 1990. The mean winter catch in 1979 was 163 kg/nm. Thus, not only has the overall finfish component of the survey catches increased, but the total fish biomass also increased. In addition, in years when multiple surveys were conducted, more fish were available in the fall than in the spring.

Frequency of Occurrence

The frequency of occurrence changed dramatically for all families and species examined (Table 2; Figure 5). Although the occurrence of ronquils and searchers increased slightly in the 1990's, these species were present in less than 10% of the tows. Poachers occurred in 10% or less of the survey tows during the late 1970's, but increased to nearly 25% of all survey tows since 1989. Eelpouts occurred in a maximum of 35% of the annual survey tows prior to 1981, but have steadily increased since 1989, reaching a peak of 77% of the tows in the 1995 survey. Capelin and other smelt species are more typically regarded as forage fish (NMFS 1996). The annual occurrence of capelin was quite variable during 1976 to 1983, ranging from 0% to 31% with a mean frequency of 8.4%. The annual occurrence of capelin during 1987 to 1993 exhibited similar variability, ranging from 6% to 29% with mean occurrence increasing to 14.4%. No capelin were reported from the 1995 survey. The occurrence of the three gadid species has also increased in recent years. Neither Pacific cod nor Pacific tomcod exceeded 10% of the annual survey tows for most years prior to the mid-1980's. Although some variability is evident, the occurrence of both species increased dramatically in recent years. The peak occurrence of Pacific cod in tows , 53%, was reported from the 1993 survey while the peak occurrence of Pacific tomcod, 92%, was reported from the 1992 survey. Both historically and in recent years, walleye pollock has been the most frequently occurring gadid species. Prior to 1981, walleye pollock occurred in 41% to 71% of tows during annual surveys. Walleye pollock occurrence declined to 22% of tows during annual surveys in the mid-1980's, and increased to over 90% of the tows in 1990's surveys. In fact, this species occurred in 100% of tows in both the 1991 and 1995 surveys.

Mean Catch Abundance

Mean catch abundance, expressed as the average number of fish-per-tow, changed considerably during the survey time series for the families and species examined (Table 3; Figure 6). Many species exhibited peak mean abundance in late 1977 or 1978, and again in 1989. Catches of walleye pollock have been the greatest, and one of the most variable, of all the fish examined from the Kachemak Bay surveys. Walleye pollock abundance ranged from a low of 34.1 per tow in 1993 to a high of 1,280.5 per tow in 1977. For most years in which forage fish data were available, pollock catch rates exceeded 300 catch per tow. Pacific tomcod mean abundance, while also quite variable, was generally greater in the 1990's than in the 1970's. The peak catch of Pacific tomcod was 115.6 per tow in 1989. Although Pacific tomcod catch rates declined to 6.1 per tow in 1992, they have increased to 30.7 per tow in the 1995 survey. Pacific cod abundances have been greater in the 1990's, averaging 11.4 per tow after 1988, than for previous years, which averaged 2.6 per tow. However, the catch abundance of Pacific cod has generally declined since 1989, falling to only 2.0 per tow in 1995. Catch rates of both poachers and eelpouts peaked in 1989, but have been relatively low in recent years, particularly for eelpouts. Mean capelin abundances peaked at 280.4 per tow in 1978, declined to 1.4 per tow in 1989, increased to 13.4 per tow in 1992, and has since declined precipitously; no capelin were reported during the 1995 survey. Smelt exhibited a similar trend. This group declined from a peak of 893.1 per tow in 1978 to 8.5 per tow in 1989, and then increased to 19.5 per tow in 1992 before decreasing to 2.7 per tow in 1995.

DISCUSSION

It is apparent that some major changes have occurred within the Kachemak Bay ecosystem during 1976 to 1995, the time series encompassed by ADF&G surveys with small-mesh bottom trawls. From 1969 to 1982, pandalid shrimp harvests ranged from 1,800 to 2,800 mt annually, then decreased to 200 to 1,400 mt during 1983 to 1986 (Figure 2). Despite a complete closure of the commercial fishery since 1987, the shrimp population has failed to rebuild (Gustafson 1994). In contrast, the mean fish contribution to survey tows and the aggregate fish biomass both increased beginning in the mid-1980's (Figures 3 and 4). In years when surveys were conducted in more than one season, fish catches were greater in fall than spring. I could not determine from available information whether these seasonal changes in fish catches resulted from growth of young fish, mortality of older fish, or migration patterns. The lack of reliable forage fish abundance data during the entire time series inhibited a more complete understanding of ecosystem changes. In particular, survey data from the mid-1980's reflected a limitation in the sampling technique and should be regarded as suspect. In addition, the species I included in this analysis comprise only a portion of the Kachemak Bay biomass and some species, such as flatfish, may have increased over the time series while pelagic species such as Pacific herring have decreased (W. Bucher, Alaska Department of Fish and Game, Homer, Alaska, personal communication).

Substantial interannual variation in both frequency of occurrence and mean catch abundance was apparent for most fishes examined. Pacific cod, Pacific tomcod, and walleye pollock generally occurred more frequently in tows made during the 1990's than in previous years, but their mean catch rates have actually declined since 1989 (Figures 5 and 6). An increasing frequency of occurrence coupled with decreasing catch rates may be the result of a large number of small, young fish (i.e. an abundance year class) growing, subject to annual mortality, into fewer, but wider-dispersed large, old fish. The recent trend in walleye pollock abundance may illustrate this well. The relatively large catches of this species obtained in 1989 and 1990 would correspond to age-1 and -2 walleye pollock from the strong 1988 year class also documented in Gulf of Alaska commercial fisheries (Hollowed et al. 1996). The decline in Kachemak Bay survey catches of walleye pollock would result from mortality and migration of this large year class. Some pre-recruit indices for walleye pollock in the Gulf of Alaska suggest that the 1994 year class may be more abundant than the 1988 year class (Hollowed et al. 1996). If the 1994 year class is also abundant in Cook Inlet, age-2 walleye pollock should be very abundant in the 1997 Kachemak Bay trawl survey catches.

Although the frequency of occurrence of poachers in survey tows increased from about 4% prior to 1981 to nearly 25% after 1988, mean catch rates have remained below 10 per tow in the 1990's. This suggests that poachers may have expanded their distribution with little increase in overall abundance. Eelpouts also appeared more frequently in tows while their catch rates declined between early and more recent portions of the survey time series. This may again indicate an expanded distribution with little or no increase in abundance.

Smelt, an important forage species for fish, birds and marine mammals (NMFS 1996), were commonly captured throughout the survey time series. Smelt frequency of occurrence in recent years was exceeded only by walleye pollock and Pacific cod. However, the relative abundance of smelt declined over the time series, indicating these species have also become more widely dispersed but not relatively more abundant. Capelin, the only smelt for which data was recorded at the species level, followed a similar pattern. Capelin appeared to increase their distribution in recent years, while their relative abundance has declined even more extensively and this species was not recorded from a single tow during the 1995 survey.

Despite the limitations of the historical trawl survey data, analyses indicated that the biomass of many fish species increased while biomass for many invertebrate species, notably pandalid shrimp and red king crab (Gustafson 1994; Kimker 1996), decreased. In addition, not all fishes continued to increase in abundance. For example, Pacific cod and walleye pollock, both large gadid species, increased in distribution and relative abundance, but the relative abundance of important forage species such as capelin and smelt decreased (Figures 5 and 6). Thus, large predatory fishes appear to have benefited from ecosystem changes while small forage fishes, as well as shrimp and crabs, appear to have been adversely affected. It is possible that the ecosystem has now reached a relative stability in which predator species suppress the production of prey species that are limited in abundance (May 1977).

Unfortunately, the trawl survey was not originally designed to monitor fishes, and sampling for fishes have been somewhat inconsistent. While I feel that observed trends in distribution and abundance reflect the true underlying population and not just sampling artifacts, one must be careful in using this data set to examine fishes. Only slight modifications to these surveys in the future would greatly improve their usefulness for examining fish populations. For example, random sampling of the entire survey catch instead of only the target species, and obtaining information on fish size, particularly for the gadid species, could provide valuable information on the population dynamics of many fishes.

ACKNOWLEDGMENTS

Alan Davis, Richard Gustafson, and Alan Kimker were responsible for most of the data collection. I'd like to extend my appreciation to the *Exxon Valdez* Oil Spill Trustee Council for partial funding under APEX project 96163L, and also to the efforts of John Piatt for funding coordination. Carla Milburn and Richard Gustin provided the bulk of computer data entry from archived field data sheets. Scott Meyer, Ted Otis, and Steve Fried reviewed this manuscript.

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Table 1. Number of tows by season during bottom trawl surveys for pandalid shrimp in Kachemak Bay, Alaska, from 1976 to 1995.

	Number of Tows					Number of Tows			
Year	Winter	Spring	Fall	Total	Year	Winter	Spring	Fall	Total
1976		36	33	69	1986		36	46	82
1977		40	36	76	1987		38	37	75
1978		37	32	69	1988		44	38	82
1979	38	41	32	111	1989		45	44	89
1980		40	33	73	1990		43	44	87
1981		40	32	72	1991		44		44
1982		40	34	74	1992		38		38
1983		40	16	56	1993		36		36
1984				0	1994				0
1985			37	37	1995		30		30
					Total	38	668	494	1,200

Table 2. Mean frequency of occurrence for selected fish during trawl surveys in Kachemak Bay, Alaska from 1976 to 1995.

Year	Pollock	Pacific Cod	Pacific Tomcod	Poachers	Capelin	Ronquils/ Searchers	Eelpouts	Smelt
	Percent Occurrence							
1976	42.0	14.5	1.4	10.1	4.3	0.0	26.1	34.8
1977	71.1	9.2	0.0	7.9	0.0	0.0	32.9	31.6
1978	59.4	2.9	0.0	1.4	7.2	2.9	20.3	66.7
1979	40.5	2.7	1.8	2.7	30.6	0.9	9.0	55.9
1980	42.5	5.5	0.0	1.4	21.9	0.0	19.2	52.1
1981	4.2	0.0	1.4	0.0	1.4	0.0	1.4	1.4
1982	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0
1983	12.5	10.7	0.0	0.0	1.8	0.0	1.8	1.8
1984	No Survey							
1985	21.6	16.2	Data Lacking					
1986	36.6	14.6	Data Lacking					4.9
1987	76.0	37.3	18.7	0.0	9.3	1.3	0.0	13.3
1988	80.5	48.8	18.3	2.4	6.1	0.0	2.4	11.0
1989	86.5	60.7	36.0	23.6	7.9	2.2	31.5	36.0
1990	83.9	72.4	44.8	21.8	11.5	8.0	33.3	44.8
1991	100.0	63.6	31.8	27.3	20.5	9.1	47.7	50.0
1992	92.1	92.1	23.7	10.5	28.9	0.0	44.7	68.4
1993	97.2	86.1	52.8	25.0	16.7	8.3	55.6	72.2
1994	No Survey							
1995	100.0	86.7	40.0	33.3	0.0	6.7	76.7	53.3

Table 3. Mean catch of selected fish species during trawl surveys in Kachemak Bay, Alaska from 1976 to 1995.

Year	Pollock	Pacific cod	Pacific Tomcod	Poachers	Capelin	Eelpouts	Smelt
			Mean Catch (fish/nautical mile)				
1976	318.2	10.3	0.1	1.0	0.9	15.4	8.7
1977	1,280.5	1.3	<0.1	4.2		54.5	37.4
1978	1,238.7	1.1	<0.1	1.0	280.4	51.9	893.1
1979	305.0	0.2	0.2	4.1	52.2	34.5	121.4
1980	173.0	0.1	<0.1	0.6	11.8	20.9	38.7
1981	6.1		3.2			0.3	
1982				Data Lacking			
1983				Data Lacking			
1984				No Survey			
1985				Data Lacking			
1986				Data Lacking			
1987				Data Lacking			
1988				Data Lacking			
1989	620.8	27.3	115.6	36.8	1.4	74.0	8.5
1990	817.3	18.9	79.7	6.3	2.1	33.5	11.3
1991	89.7	6.4	17.5	4.6	12.1	7.8	17.0
1992	459.6	10.9	6.1	0.3	13.4	8.2	19.5
1993	34.1	2.7	7.8	0.3	0.4	1.2	3.3
1994				No Survey			
1995	82.5	2.0	30.7	2.0	0.0	3.5	2.7

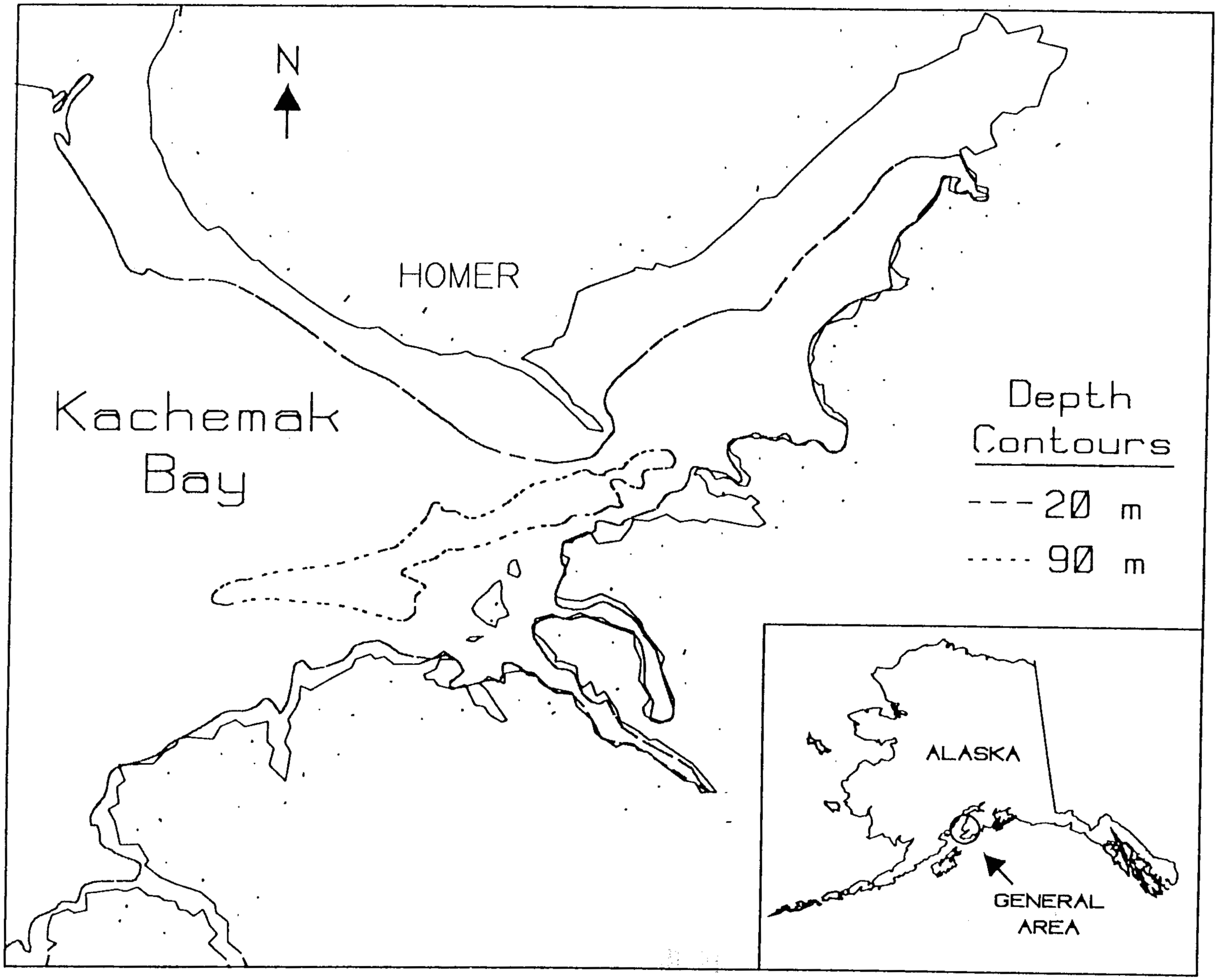

Figure 1. General study area for trawl shrimp surveys of Kackemak Bay, Alaska during 1976 to 1995.

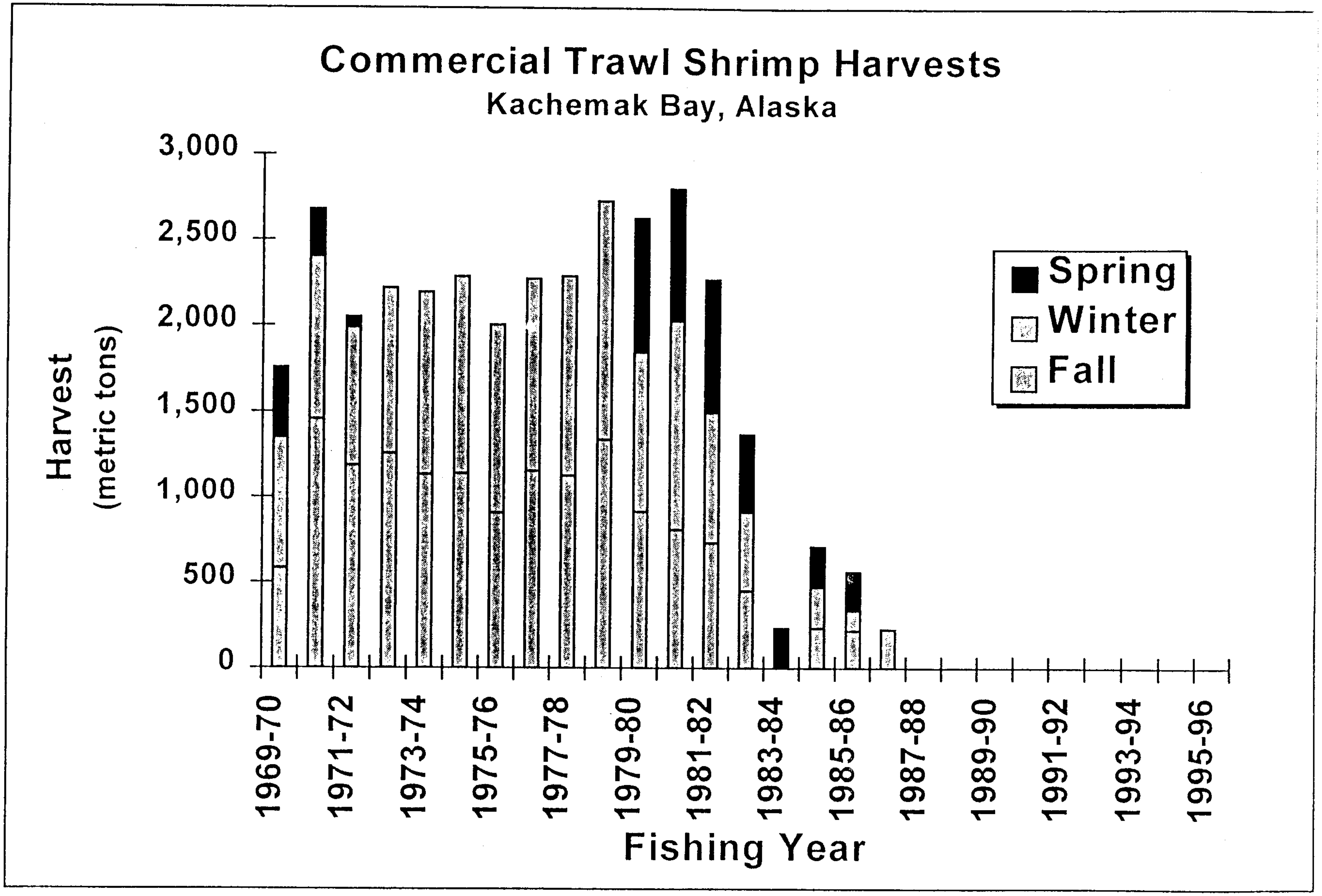

Figure 2. Commercial trawl shrimp harvests from Cook Inlet, Alaska during 1969 to 1996.

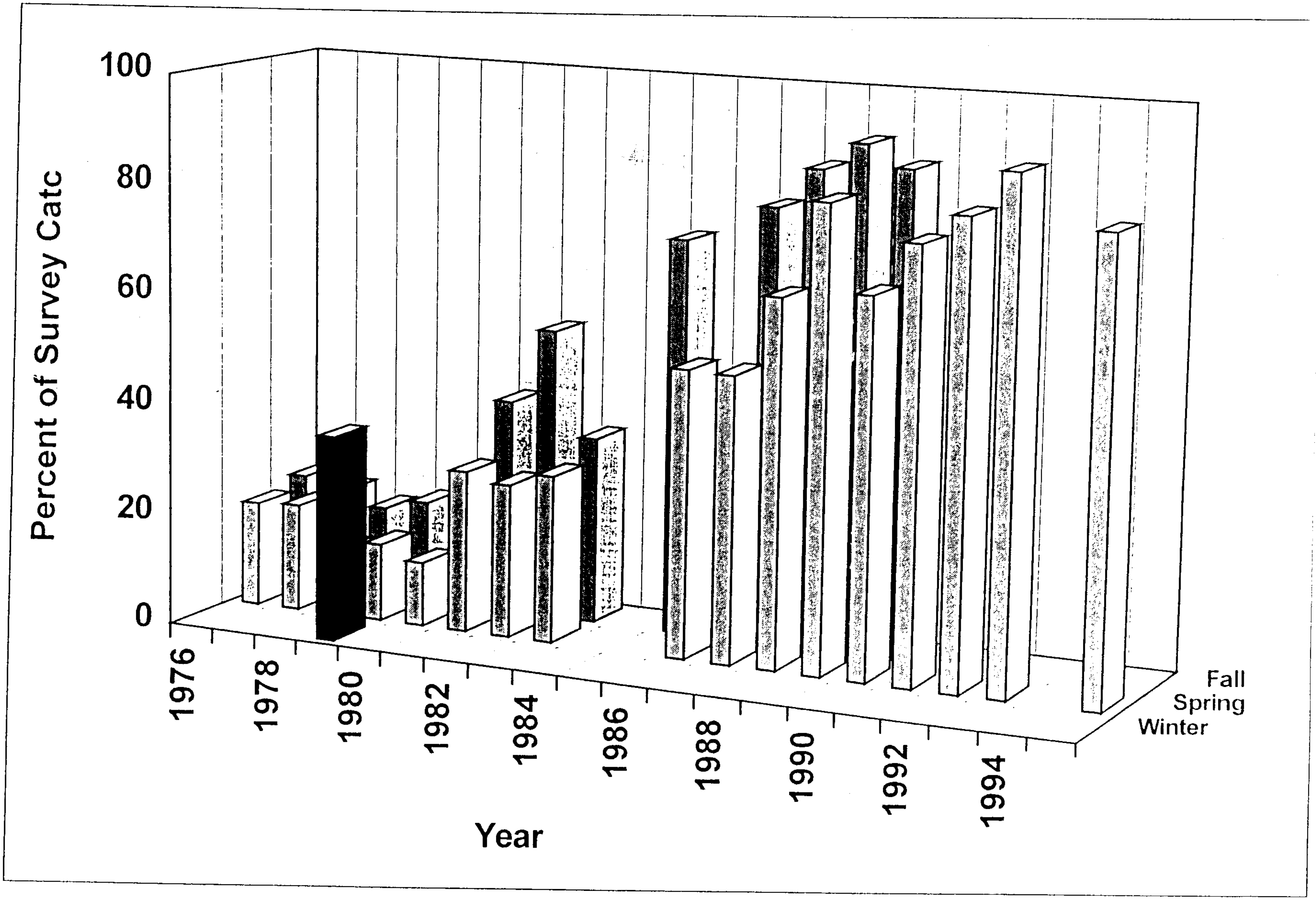

Figure 3. Changes in the fish component of trawl survey biomass in Kachemak Bay, Alaska from 1976 to 1995.

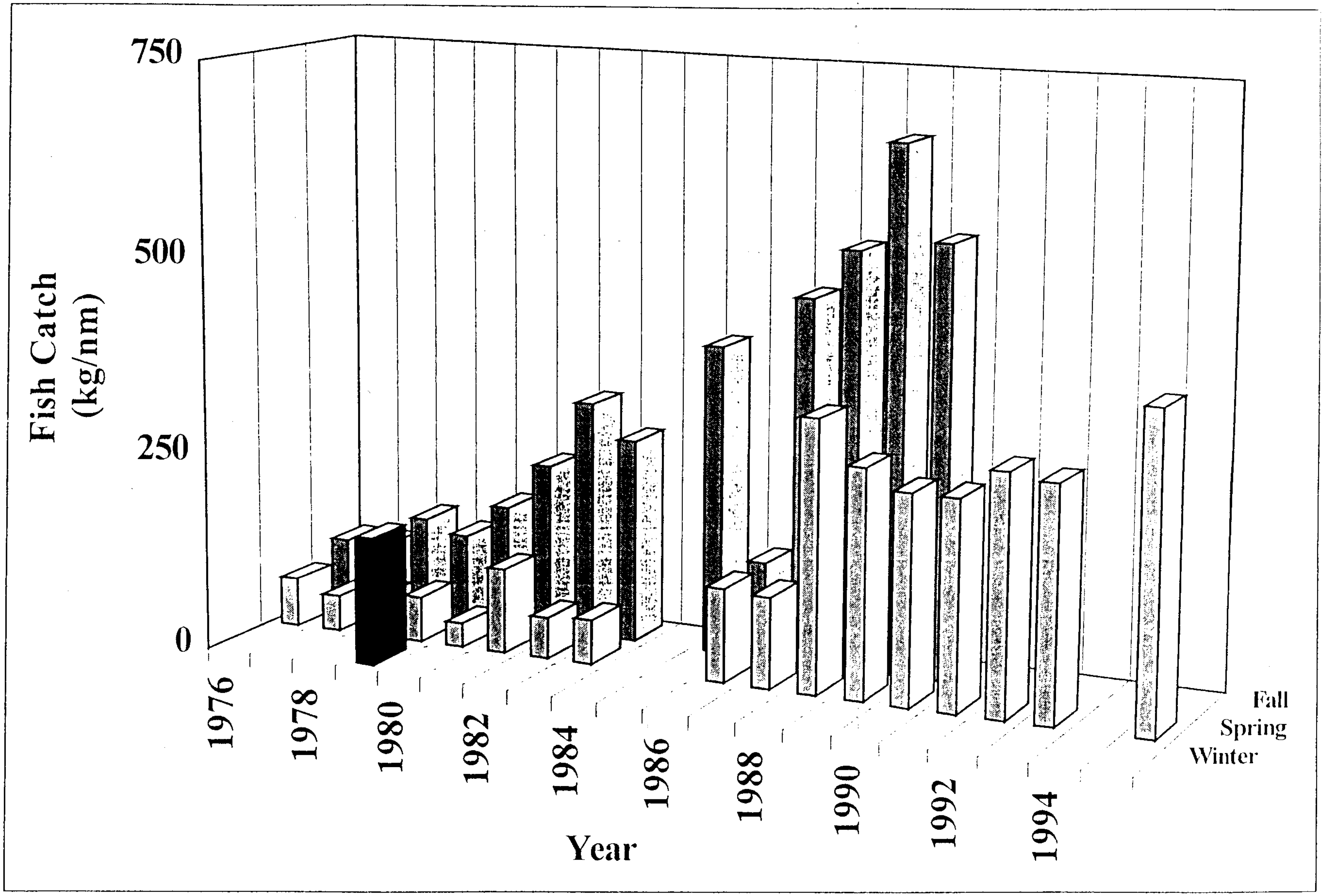

Figure 4. Changes in mean fish biomass during trawl surveys of Kachemak Bay, Alaska from 1976 to 1995.

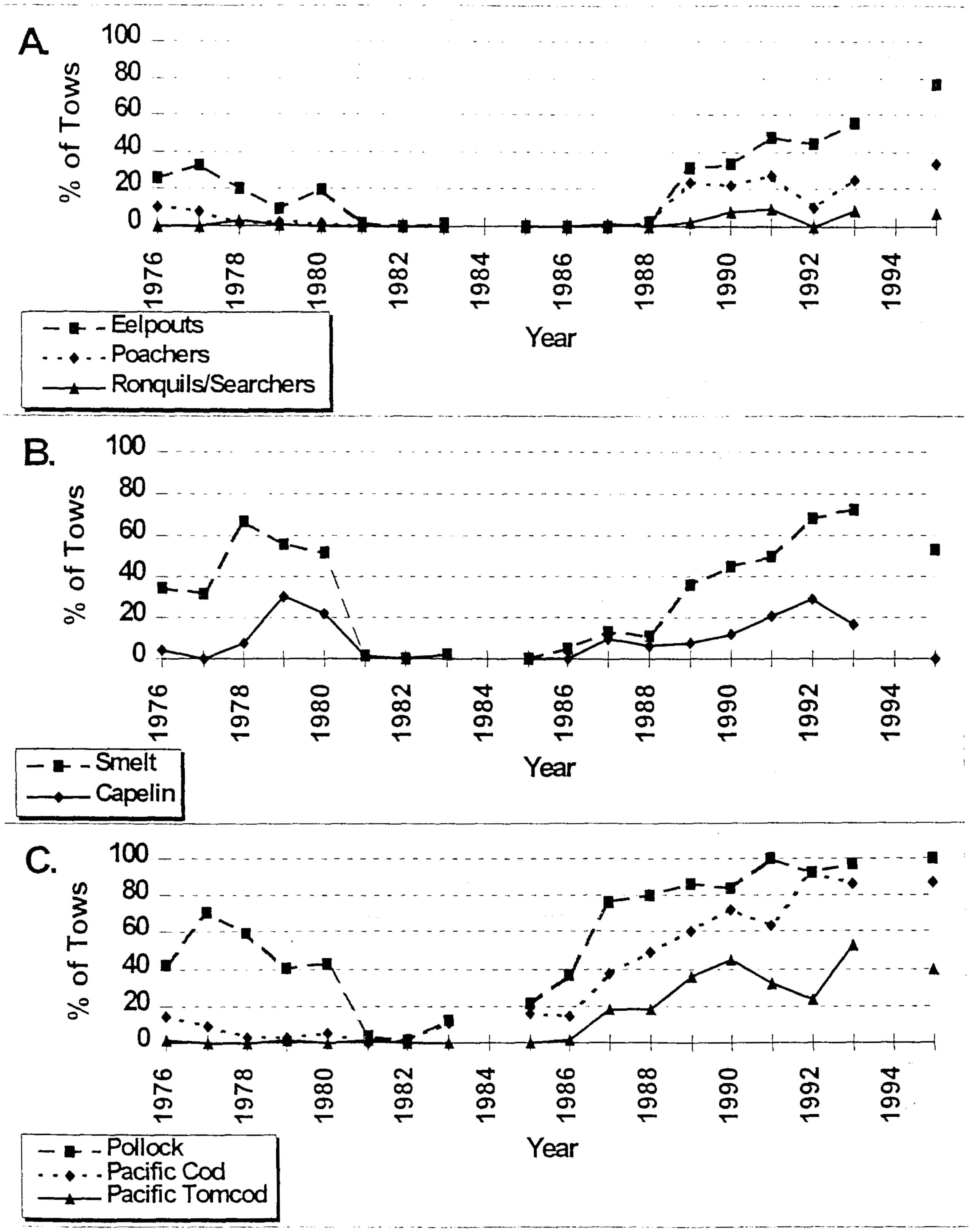

Figure 5. Frequency of occurrence for selected fish species during trawl surveys in Kachemak Bay, Alaska from 1976 to 1995.

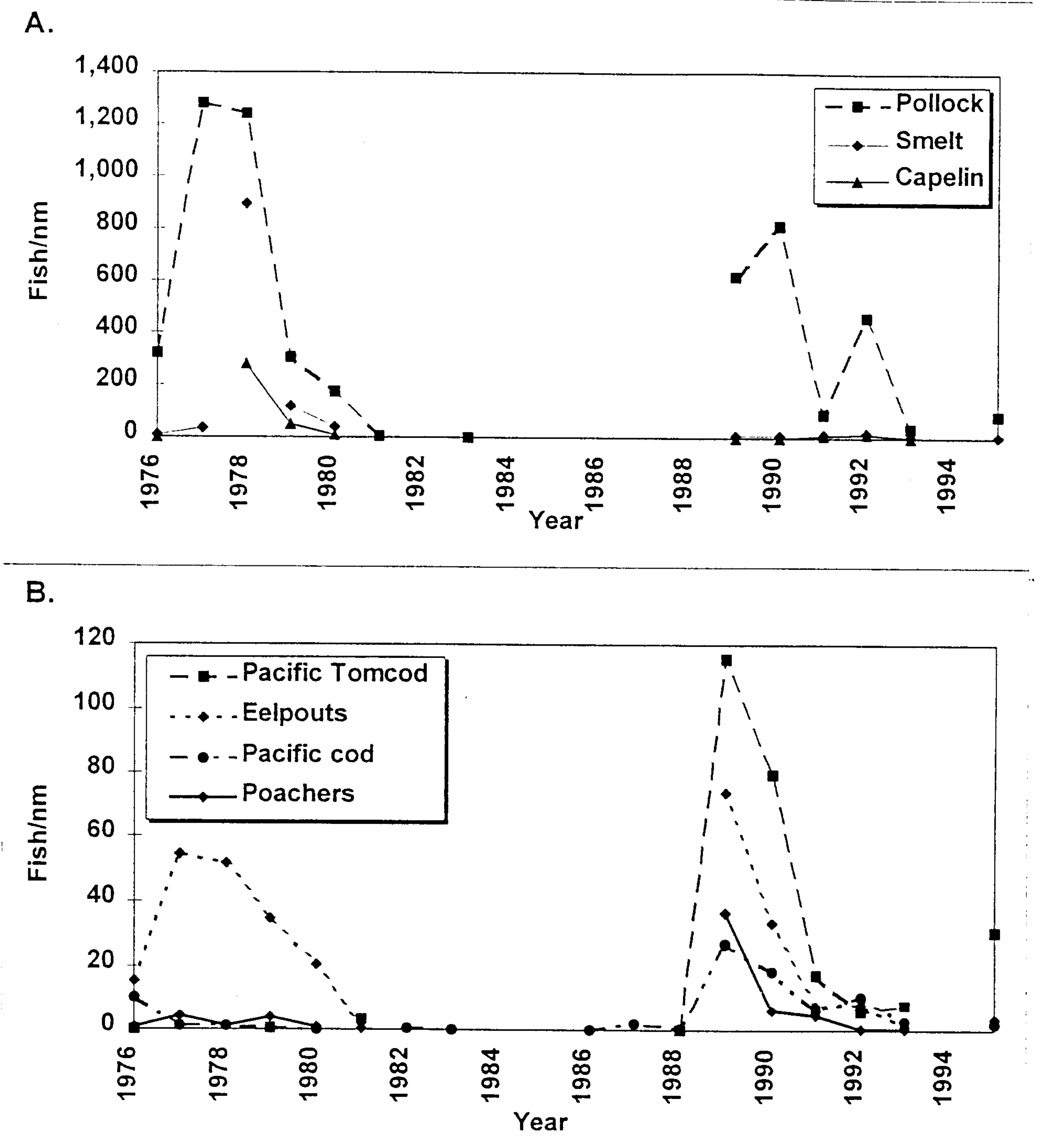

Figure 6. Mean catch of selected fish species during trawl surveys in Kachemak Bay, Alaska from 1976 to 1995.

Exxon Valdez Oil Spill
Restoration Project Annual Report

Analysis of Small-Mesh Trawl Data

Restoration Project (APEX) 96163L

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March 1997

Analysis of Small-Mesh Trawl Data

Restoration Project(APEX) 96163L
Annual Report

Study History: Restoration Project 96163L was initiated as part of the APEX project that is studying the relationship between changes in forage species composition and marine birds in the spill affected area. Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. Changes in composition and abundance of forage species may be responsible for the decline of these predator populations and their chronic low population levels. In an effort to delineate changes in forage species and a trophic regime shift, if any, over the last several decades, we have gathered together historical fishery-independent scientific survey data to address this question. This part of the annual report includes one manuscript submitted for publication from recent analysis of information and data from small-meshed tow and beach seining studies conducted in Cook Inlet and around Kodiak Island in 1976 and 1978 by the Alaska Department of Fish and Game.

Abstract: A small-mesh surface tow net and beach seine were used to sample the near-shore fishes on the west side of Kodiak and in Cook Inlet in late 1976 and 1978. Sampling was conducted from March through November, lowest catches occurring in March and November, and highest catches in May through September. The growth of sand lance (*Ammodytes hexapterus*) based on length frequencies indicated August mean size of 87 mm for age 0 and 136 mm for age 1 in the Kodiak area. Very little growth occurred between August and the following May. In Cook inlet both growth and catch rates were lower than Kodiak, with August mean size of 57mm for age 0 (age 1 average size was not available due to insufficient data). During August-September the abundance increased in inshore areas and in Cook Inlet, where growth was restricted, changes in size distribution occurred in a pattern which strongly suggested movement of the age 0 fish into near-shore waters. Catches stratified by tidal stage were not significantly different but suggested real differences exist that were not detected. Catch variability among samples were extremely high, coefficients of variation typically from 4 to 6. A few fish in spawning condition were found from August through November. Food habits from Cook Inlet showed more than 90% by weight of the food was calanoid copepods during the summer; more variety in diet was evident during different times.

Key Words: Cook Inlet, Kodiak Island, Pacific sand lance, growth, and seasonal movements.

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TITLE PAGE

Pacific Sand Lance (*Ammodytes hexapterus* Pallas) Growth, Seasonal Availability, Movements, Catch Variability, and Food in the Kodiak-Cook Inlet area of Alaska

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ABSTRACT

A small-mesh surface tow net and beach seine were used to sample the near-shore fishes on the west side of Kodiak and in Cook Inlet in 1976 and 1978. Sampling was conducted from March through November, lowest catches occurring in March and November, and highest catches in May through September. The growth of sand lance (*Ammodytes hexapterus*) based on length frequencies indicated August mean size of 87 mm for age 0 and 136 mm for age 1 in the Kodiak area. Very little growth occurred between August and the following May. In Cook Inlet both growth and catch rates were lower than Kodiak, with August mean size of age 0 of 57 mm (size of age 1 was not well documented in August in Cook Inlet). During August-September the abundance increased in inshore areas and in Cook Inlet, where growth was restricted, changes in size distribution occurred in a pattern which strongly suggested movement of the age-0 fish into the near-shore waters. Catches stratified by tidal stage were not significantly different but suggested real differences exist that were not detected. Catch variability among samples was extremely high, coefficients of variation typically from 4 to 6. A few fish in spawning condition were found from August through November. Food habits from Cook Inlet showed more than 90% by weight of the food was calanoid copepods during summer; more variety of items in the diet occurred at other times.

*Introduction

Little is known of the biology of the Pacific sand lance (*Ammodytes hexapterus* Pallas), although the species typically forms large schools (Trumble 1973) and is locally abundant in the near-shore waters of the North Pacific. Pacific sand lance are a major component of the diet of many marine birds, including tufted puffins (*Fratercula cirrhata*; Baird and Hatch 1979), horned puffins (*Fratercula corniculata*; Jones and Peterson 1979), black legged kittiwakes (*Rissa tridactyla*; Baird and Hatch 1979; Jones and Peterson 1979), glaucous winged gulls (*Larus glaucescens*; Baird and Hatch 1979), and rhinoceros auklet chicks (*Cerorhinca monocerata*; Verveer and Westrheim 1984). During winter in Kachemak Bay, Pacific sand lance were important to oldsquaw (*Clangula hyemalis*; Sanger et al. 1979; Sanger and Jones 1984) and less so to common murres (*Uria aalge*) and marbled murrelets (*Brachyramphus marmoratus*; Sanger et al. 1979). Pacific sand lance were important to Pacific cod (*Gadus macrocephalus*; Moiseev 1953; Kasahara 1961) and chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*), lingcod (*Ophiodon elongatus*), halibut (*Hippoglossus stenolepis*), and fur seals (*Callorhinus ursinus*; Hart 1973).

Trumble (1973) reviewed the sand lance family, Ammodytidae, and reported their strong association with clean sandy bottoms, probably related to their habit of burrowing. All species of sand lance live in shallow water, rarely exceeding 100 m depth. Very little information is available on seasonal distribution or migration. Kendall and Dunn (1985) reported that sand lance larvae were found in winter, spring, and summer near Kodiak, although they were most abundant in the spring, when they occurred throughout the study area.

Seasonal migration is common for Ammodytidae but has not been demonstrated in all areas (Trumble 1973). Citing Andriyashev (1954), Trumble stated that the Murman population moves into the coast beginning in mid June, where they remain until August or occasionally September, and then return to deep water for the winter. Trumble (1973) cited incomplete information from which it was deduced the North Sea sand lance migrate seasonally whereas those in the western Atlantic do not.

The purpose of this paper is to present information on the growth of sand lance, seasonal movements, seasonal availability, catch variability, spawning condition, and food in the Kodiak-Cook Inlet region of Alaska.

*Study Area

The study area included lower Cook Inlet from the Forelands south including Kachemak and Kamishak Bays and four bays on the east side of Kodiak: Izhut, Kalsin, Kiliuda, and Kaiugnak Bays (Figure 1). The Kodiak bays are more marine in character than Cook Inlet which is estuarine. In Cook Inlet the net flow consists of marine waters that enter between the Kenai Peninsula and the Barren Islands and flow north along the eastern shore. Water freshened by runoff and heavily laden with particulate matter flows south along the west side of the inlet and exits past Cape Douglas (Larrance et. al. 1977). Strong tidal currents are superimposed on the net flow. Primary productivity and chlorophyll *a* concentrations were consistently up to 2 times greater in Kachemak Bay than elsewhere in lower Cook Inlet, and primary productivity in Kamishak Bay was 10-50% that of Kachemak Bay(Larrance et al. 1977).

The ebb and flood of waters across vast intertidal deposits of silt present around the upper inlet and most of the lower inlet results in large temperature changes effected by prolonged solar heating during summer. This results in extreme fluctuations in environmental conditions, which are greatest on the west side of the inlet due to the current pattern. Near-shore water temperatures in Kamishak Bay in August 1978 ranged from 11.5^0 to 17^0 C.

*Materials and Methods

Samples for this study were collected in 1976 and 1978 as part of extensive studies of lower Cook Inlet and Kodiak. The survey of lower Cook Inlet in 1976 was designed to cover the greatest possible area once each month from June through September. In contrast, 1978 collections in Cook Inlet were designed to cover a smaller area twice each month.

In 1976, samples were taken from a pair of 5.1-m outboard skiffs. The eastern shore was accessed from the Homer boat harbor and transport by boat trailer. The western shore was reached by transporting the two skiffs on the deck of a larger vessel. Once there, two personnel in each skiff, traversed the survey area, and began collecting samples, camping nights until they rendezvoused with the larger vessel after 3-5 d.

In 1978 tow-net samples in Cook Inlet were taken using a 6.4-m outboard skiff and a 10.6-m vessel. In April the field personnel operated from Homer and in October from the Kasitsna field station. During May through September they lived in a field camp in Cottonwood Bay on the west side of the inlet.

The Kodiak field crew lived aboard and worked from a vessel, the 19.8-m M/V YANKEE CLIPPER during April through August. The R/V COMMANDO was used during November and March. A 5.7-m outboard skiff was used to pull one side of the tow net, and the larger vessel pulled the other side. The outboard was used for beach seining.

The beach seine was 47.25-m long by 3.6-m deep, was constructed of knotless nylon throughout, and was hung to float. It consisted of a rectangular center section, 10.6-m long by 3.6-m deep of 6-mm (1/4-in) ace web. amd two identical wings, tapered from the depth of the center section to 0.9-m deep at the ends, that were constructed of 6.1-m wide panels of 13-mm (1/2-in) ace webbing next to the center and 12.2-m wide panels of 38-mm (1-1/2-in) ace webbing to the ends. Ace webbing is woven, not to be confused with tied net material.

The beach was approached by a small outboard-powered boat, and the net was set within a few minutes and then immediately retrieved. The beach seine was set in an arc with each end of the net within about 3 m of the waters edge, which made escape around the ends unlikely. At nearly all locations fished the net reached bottom along its full length, preventing escape. The beach seine spanned about 30 m of beach and sampled about 370 sq m of water.

The tow net used during 1976 was 2.7 m square at the mouth and 8.2 m long. It was made of a 2.4-m forward section of 38-mm stretch mesh, a 2.7-m midsection of 13-mm stretch mesh, a 3.0-m cod end of 6-mm stretch mesh with a 3-mm (1/8-in) stretch mesh cod end liner in the last 0.6 m and a zipper on the cod end to access the catch. The net was held open vertically by spreader bars and horizontally by a towing vessel on each side. The net was pulled at the surface for 10 min at approximately 5 km/h by two 5.1-m skiffs with 70 hp outboards; each skiff was attached to the net with 20-m of cable.

The larger tow net used in 1978 was 6.1 m wide by 3.1 m deep at the mouth. It was constructed of a 4.6-m panel of 76-mm stretch mesh, a 2.2-m panel of 38-mm stretch mesh, a 2.5-m panel of 19-mm #126 web, and a 5.6-m panel of 6-mm #63 web, the last 1.2 m of which were lined with 3-mm web. The nets were deployed in a manner similar to that of the smaller tow net described above, except that one of the towing vessels was larger, 9.7 m in Cook Inlet and 19.8 m in Kodiak.

In early summer small sand lance larvae were too small to be sampled quantitatively. When larval fish were first caught in 1976 no attempt was made to identify them. During July they were first included in the catch data, and in 1978, larval sand lance were recorded throughout the study. The beach seine was spread on the beach and thoroughly examined for fish at the end of each set. Larval fish the size of sand lance were quite easily seen and recovered. When larval sand lance were caught in the tow net, often they were tangled in the meshes and only those in the cod end were readily recovered.

In 1976 in Cook Inlet, collections were made in four areas, at the same time each month. In Kachemak Bay samples were late in the month from May through September. On the west side of Cook Inlet from Cape Douglas to Chinitna Bay, samples were collected during the period of 6th to 14th of each month from June through September. Collections were made on the east side of Cook Inlet between Anchor Point and the Forelands during about 19th to 23rd from June through September. In the South Kenai area, southwest of Tutka Bay to Port Graham, collections were taken in early August and September. Length (total length in milimeters) frequencies were obtained from fish preserved in formalin for one to seven days.

In 1978, collections were taken from Kachemak Bay in April and October and from Kamishak Bay during May through September. Larval fish were routinely preserved, identified, and counted. Age-0 sand lance were usually recorded separately from large ones on catch forms. Length (total length in centimeters) frequencies were obtained from most samples of fresh fish. Stomach samples were taken from collections in Cook Inlet in 1978.

In Kodiak, samples were taken each month from April through August. Kalsin Bay was sampled from the 1st to 7th, Izhut Bay 8th to 15th, Kiliuda Bay 16th to the 23rd, and Kaiugnak Bay 24th through the end of the month. During November 1978 and March 1979 the sequence did not change but the time of month varied. A sample (selected without known bias) of fish was measured to the nearest centimeter total length at the time of capture. Unidentified larvae were routinely preserved and later sorted and recorded.

All samples collected in 1978 were classified by tidal stage using one hour before and one hour after tide change as the breaking points for low, flood, high, and ebb tide classifications. A statistical test of differences by tidal stage used a generalized linear model with binomial error and presence/absence as the dependent variable.

*Results

There were 1,449 gear sets completed in the three surveys; 437 of the sets caught sand lance, and lengths were sampled from 263 of these (Table 1). We caught 261,932 sand lance, and measured 4,676 for lengths (Table 1). Sand lance were numerically predominant in all areas except the west side of Cook Inlet in 1978, where herring were more numerous.

**Seasonality

The monthly catch rates for the tow net and beach seine (Figure 2) were highest in the Kodiak area, Kachemak Bay rates were lower, and the east and west sides of Cook Inlet had the lowest rates (Figure 2). Catch rates were low in the earliest (March and April) and latest months (November), and highest from May through September.

**Growth

The samples from Kodiak (Figure 3) contained 20-30-mm sand lance (age 0) in May, which grew about 20 mm per month to modes at 70 mm in July and 90 mm in August. A mode at 90 mm in March (age 1) progressed about 10 mm per month to 120-140 mm in July, and 130-140 mm in August and November, (note: the mode in August was hidden by the high abundance of the age-0 fish; Figure 3). If age-2 fish were present, they should have appeared at about 130-140-mm in March; there was a weak mode of the fish that progressed from that size to about 150 mm in June and was not seen later (Figure 3). Little growth occurred between August and April (Figure 3).

The samples from Cook Inlet in 1978 (Figure 4) show similar features. Age-0 sand lance 20-50 mm appeared in June and progressed to 80-90 mm by October (Figure 4). Age-1 fish, about 90-100 mm, appeared in June beach seine samples, grew for the next 2 months, but then were too infrequent to follow(Figure 4). A mode at 120 mm in May and June tow-net samples might have been age-2 fish (Figure 4). Careful examination of the July through September catches of age-0 fish (Figure 4) shows a relatively slow growth during July until the first week of August. During August and September there was a pronounced broadening of the size range of age-0 fish then a sudden shift to a much larger modal size (Figure 4). The fish in Kachemak Bay in October were about the same size as those on the west side in September (Figure 4). Monthly average sizes from the different areas indicate minimal growth between August and May (Figure 5).

The 1976 samples from Cook Inlet displayed a growth pattern similar to 1978, although several different areas were sampled (Figure 6). Kachemak Bay and South Kenai age-0 fish grew to a September size of about 73-78 mm, and those on the east and west sides grew to about 60 mm. The age-1 fish which appeared in late May in Kachemak at about 78-88 mm, grew to about 103 mm in late July and to 118-128 mm in late August. Age-1 fish from the east side appeared to be about 85 mm in late July but later growth was not clear.

**Inshore Movement

On the west side of Cook Inlet in 1978 age-0 sand lance increased in size between August and September (Figure 4), and the catch rate was substantially higher in September (Figure 2). The size mode increased from 50 mm in August to 80 mm in September, too great a change to be accounted for as growth. This suggests that the west side received an influx of larger fish (Figure 4). The west side of Cook Inlet in 1976 had neither a large increase in abundance (Figure 2) nor an increase in size of sand lance (Figure 5), indicating an influx of fish did not occur before the last samples in September that year.

In Kodiak there was neither an increase in size nor an increase in heterogeneity of sizes in August 1978 (Figure 3); however, consistent with an inshore movement there was a substantial increase in the beach seine catch rate and a decline in the tow-net catch rate (Figure 2). Catch in August was also more concentrated toward the inner portions of bays than at other times (Table 2).

Kachemak and South Kenai are essentially the inner part and outer part of the same bay. The age-0 sand lance from these areas averaged 57-58 mm in late July-early August (Figure 6). This size is consistent with 11-mm per month growth and a probable hatch date of about March 1. By one month later (late August-early September), Kachemak fish averaged 67 mm, but the South Kenai fish averaged 76 mm, much larger than expected with 11-mm per month growth (Figure 6). In late September, Kachemak fish averaged 75 mm. There was a substantial increase in catch per sample (Figure 2) in the beach seine in both the South Kenai and Kachemak areas simultaneously with the increases in size. The only likely explanation is a late August invasion of the area by larger fish, from oceanic areas, where growth was similar to that in Kodiak (Figure 6), with the larger fish first appearing in the outer part of the bay.

**Catch by Tidal Stage

Catches classified by tidal stage appeared to be different only during July and August. The trends were similar in Cook Inlet and Kodiak samples but higher Kodiak catches facilitate discerning trends. The beach seine catch rates in July and August were generally lowest on ebb and low tide and highest on flood and high stages (Table 3), whereas tow-net catch rates were higher on the ebb tide. Differences by tide stage were not statistically significant. (In an analysis by bay, tide, and gear each factor was significant but the interaction terms were also significant, masking any real effects). Both the statistical tests and the consistency suggest the differences are real, but do not establish it.

**Variability of Catch Rate

Variability of sand lance catches was typically very high. The monthly values for coefficient of variation of samples from Kodiak ranged from 2.9 to 6.4 for the beach seine and 1.8 to 5.4 for the tow net. Similar values were obtained in the Cook Inlet samples. High variability in catches per sample effected wide confidence ranges making comparisons difficult. The distributions of catch numbers per sample (Figure 7) are helpful. They convincingly show seasonality. And, the grouping of multiple catches with large values during the summer, especially in August beach seine, demonstrates repeatability in the catches.

**Spawning

Maturing ova and sperm were present in the body of larger sand lance from Kachemak Bay in September 1976. In Kodiak in 1978 maturing gametes were observed as early as late July. In late August one sample included one mature (free flowing) and two spent fish. Samples in November yielded 58 sand lance with extrudable gametes (Table 4). Mature fish were not seen at any other time of year. The 83 maturing and spawning fish captured in August and November ranged from 104 to 155 mm, and the 29 fish judged to be immature ranged from 62 to 114 mm. There were few fish between 104 and 114mm suggesting that no age-0 fish were mature and that all age-1 and older fish were mature.

**Food Habits

Sand lance from Cook Inlet were sampled for food habits during three periods in 1978. The 191 specimens had consumed 26 different taxa (Table 5). Copepods composed 43-91% by weight of the diets. Non-calanoids were eaten in April, whereas mostly calanoids were consumed from May through October. Barnacle (cirripede) nauplii composed 12% of the diet in April through mid June. Barnacle cyprids were very frequent but composed 3% or less of the diet. Larvaceans composed 23% of the diets late in the year (Figure 8). Shrimp larvae were 22% of the diet in April through mid June. Fish larvae (including herring) composed 3% of the April-mid June diet and chaetognaths (arrow worms) composed 4% of the September-October diet. Also consumed were fish eggs, cladocera, cumacea, polychaetes, diatoms, gammarid amphipods, bivalve larvae, crab larvae (6 taxa), gastropod veligers, mysids, unidentified crustacea, and adult insects.

The food during both early and late summer was much more diverse than during mid summer (mid June through August).

*Discussion

Catches of sand lance were high from May through September, but catches were largest and most frequent during August and September, especially for beach seines. In general, age-1 and older sand lance were a greater proportion of the catch early in the summer, age 0 becoming more important in July-August. The late summer increase in beach seine catch rate of age-0 sand lance was due in part to their growing to a size that could be captured, but that size was attained by the cohort in July, implying that further increase in catch rate was due to inshore movement. The interruption of studies in Kodiak between August and November precluded documenting details of the transition to low winter abundance. In Cook Inlet sand lance were still common in September though decreasingly abundant into October. The decreased abundance is probably due to the fish spending increasing amounts of time buried in the refuge of the sand. The minimal growth between August and May supports this interpretation. Fish were not captured in March in Kodiak, were rarely taken in April, and became fairly common in May. Growth of age-1 and older fish began in June, when abundance was high.

Catches in the tow net from Kodiak were a different pattern; they were mostly age 0, were highest in May, and declined through August. This is consistent with sampling at the pelagic extreme of a life history where the youngest are pelagic and dispersed, then become closely associated with shallow sandy areas.

Sand lance apparently spawn in sandy areas inside bays, especially near the outlets of rivers and creeks (Dick and Warner, 1982). The larvae would be dispersed by the currents, and as they grow, become increasingly mobile. The massive inshore migration documented here is a logical necessity to make the transition to winter residence in the refuge of sand. The larval dispersion is supported by Kendall and Dunn (1985) who found small larvae most abundant nearer shore and a bit more widely dispersed as larger juveniles. Offshore spawning or wintering areas may exist, although we have no evidence of such, and suitable offshore habitat is very limited in the Kodiak area.

The increased size of age-0 sand lance in Cook Inlet noted in September and October was probably due to larger fish moving into the area. Apparently these fish did not move back out the following summer since a decrease in size of age 1 was not observed early in summer.

The inshore migration provides an important food source to predators for a relatively short portion of the year. Many studies cite the use of sand lance during July and August as food of birds (Baird and Hatch, 1979; Jones and Peterson, 1979; Verveer and Westrheim, 1984). Moiseev (1953) states, that in Anadyrski Bay cod concentrate and feed heavily on sand lance between the middle of August and end of October when the sand lance are all over the littoral region.

*Acknowledgements

Any study of this size requires the hard work, talents and dedication of a number of people. Those involved in these studies include Peter Jackson, Leslie Watson, Mark Buckley, Tom Bledsoe, Kelly Meeusen, Bill Johnson, Larry Holyoke, Wes Bucher, Dave Anderson, Bob Mielke, Steve Pint, Don Seagren, Phil Smith, Karen Anderson, Jay Field, Robert Sanderlin, Jim Sicina, Dan Locke, and Harry Dodge; also Fisheries Research Institute of the University of Washington staff working under Don Roger, Chris Wilson, Michael Gross, and Steven Quinnell.

This study was supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multiyear program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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Table 1. Descriptive statistics of effort, catch of sand lance, and sampling of sand lance by gear and study from three independent studies.

Area and Gear	Number of Sets	Sets With Catch	Catch Sampled	Number Caught	Number Measured
KODIAK 1978/79					
Beach Seine	418	138	118	150,775	2,475
Tow Net	214	48	19	54,369	295
Cook Inlet 1976					
Beach Seine	241	81	14	34,432	187
Tow Net	214	76	23	16,818	318
Cook Inlet 1978					
Beach Seine	256	78	73	4,711	967
Tow Net	106	16	16	827	434
Total	1,449	437	263	261,932	4,676

Table 2. Mean number of sand lance per sample by month for the four bays sampled in Kodiak from May through November. Catches during March and April were too low to be meaningful for the purposes of this table.

	BEACH SEINE					TOW NET				
	MAY	JUN	JUL	AUG	NOV	MAY	JUN	JUL	AUG	NOV
Kalsin Bay										
Inner	0	0	25	5569	NS	2008	0	NS	0	0
Outer	0	0	0	725	0	125	0	NS	0	0
Izhut Bay										
Inner	0	10	197	4967	0	NS	35	0	350	0
Inner mid	1	4	2594	157	0	NS	300	0	1	0
Outer mid	3	0	723	0	0	NS	1000	0	0	0
Outer	NS	NS	NS	NS	NS	NS	525	0	0	0
Kiliuda Bay										
Inner	8	1	1	1	0	6	0	0	82	0
Inner mid	3	3	10	416	15	4	NS	4842	0	0
Outer mid	75	0	6	187	0	NS	NS	2765	0	0
Outer	0	16	1	188	1	NS	NS	0	0	0
Kaiugnak Bay										
Inner	230	453	0	6043	3	NS	NS	0	963	0
Outer	3	0	0	4552	0	NS	NS	0	0	0

Table 3. Catch per haul and frequency of occurrence in percent of sand lance catches from Kodiak and Cook Inlet in 1978 by gear and tidal stage.

		TIDAL STAGE			
Gear/Region	Month	HIGH	EBB	LOW	FLOOD
		Catch Per Haul			
Beach Seine					
Kodiak	Jul	118	67	1	604
Kodiak	Aug	2930	438	1668	2425
Cook Inlet	Jul	8	4	0	13
Cook Inlet	Aug	0	3	0	4
Tow Net					
Kodiak	Jul	0	1528	0	0
Kodiak	Aug	0	148	0	93
Cook Inlet	Jul	0	20	15	0
Cook Inlet	Aug	0	0	0	0
		Percent Frequency of Occurrence(Number of Samples)			
Beach Seine					
Kodiak	Jul	33 (6)	37(19)	11 (9)	40(30)
Kodiak	Aug	45(11)	47(17)	75 (8)	67(30)
Cook Inlet	Jul	40(15)	27(15)	33 (3)	33 (6)
Cook Inlet	Aug	21(14)	57(14)	0 (2)	24(17)
Tow Net					
Kodiak	Jul	0 (4)	32(19)	0 (1)	0(14)
Kodiak	Aug	0 (7)	15(26)	0 (2)	50(14)
Cook Inlet	Jul	0 (3)	20(10)	100 (2)	12(16)
Cook Inlet	Aug	0 (3)	0(21)	0 (4)	0 (7)

Table 4. Number of fish recorded at each stage of maturity by date in Kodiak in 1978.[a]

Gonadal	JULY		AUGUST		NOVEMBER	
Stage	1-15	16-31	1-15	16-31	1-8	12-18
Maturing		1	1	18		1
Spawning				1	10	48
Spent				2		2
Inactive		6	3			

---

[a] The project objectives did not include documenting spawning so the methods of determining hese stages were those of the field biologists. Spawning was defined as sperm or ovulated eggs readily extruded

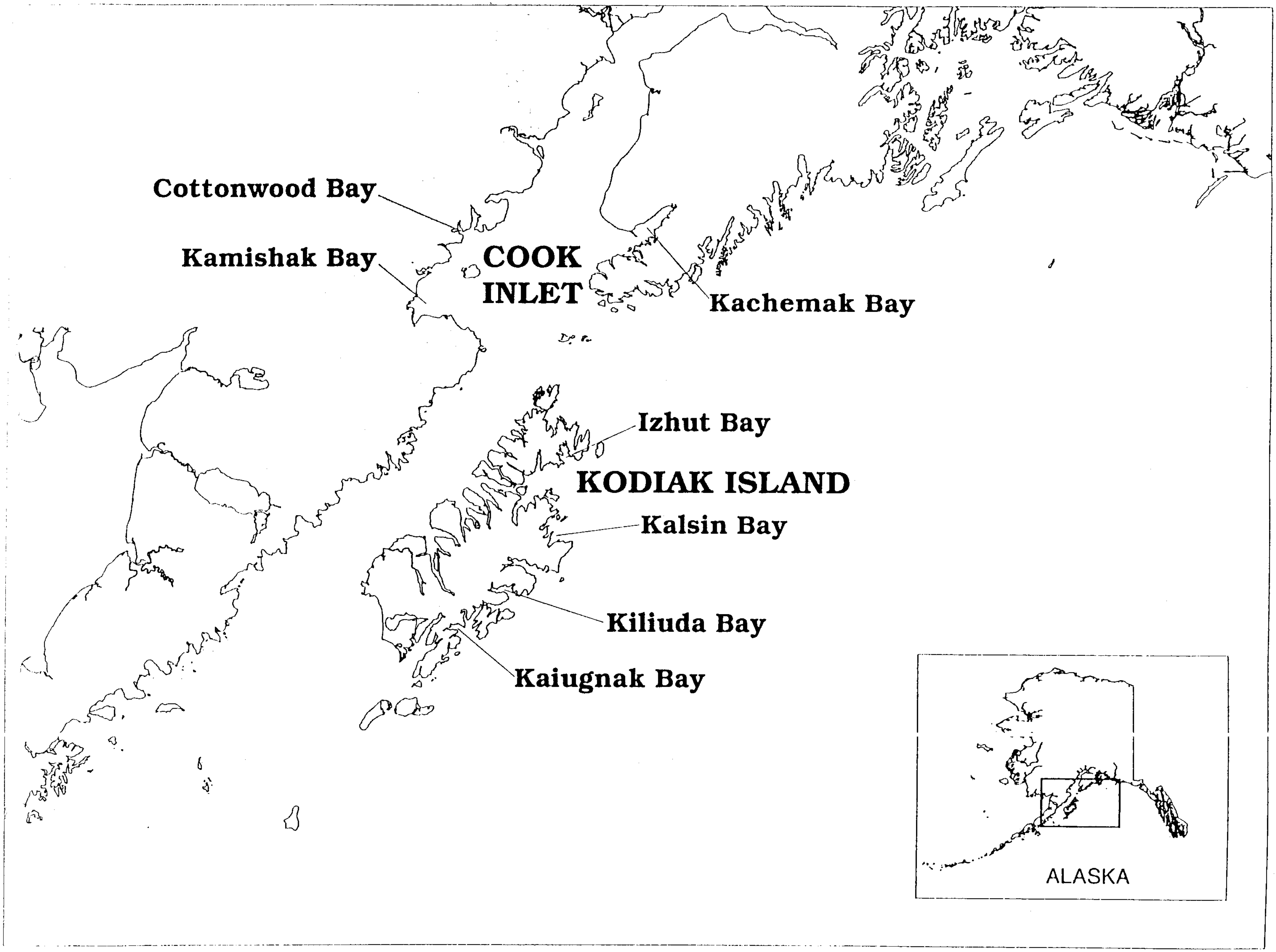
Table 5. Pacific sand lance (*Ammodytes hexapterus*) diet composition in percent occurrence, percent by numbers, and percent by weight by major food item and time of year from Lower Cook Inlet in 1978. April and October fish were from Kachemak Bay and others were from Kamishak Bay.[a]

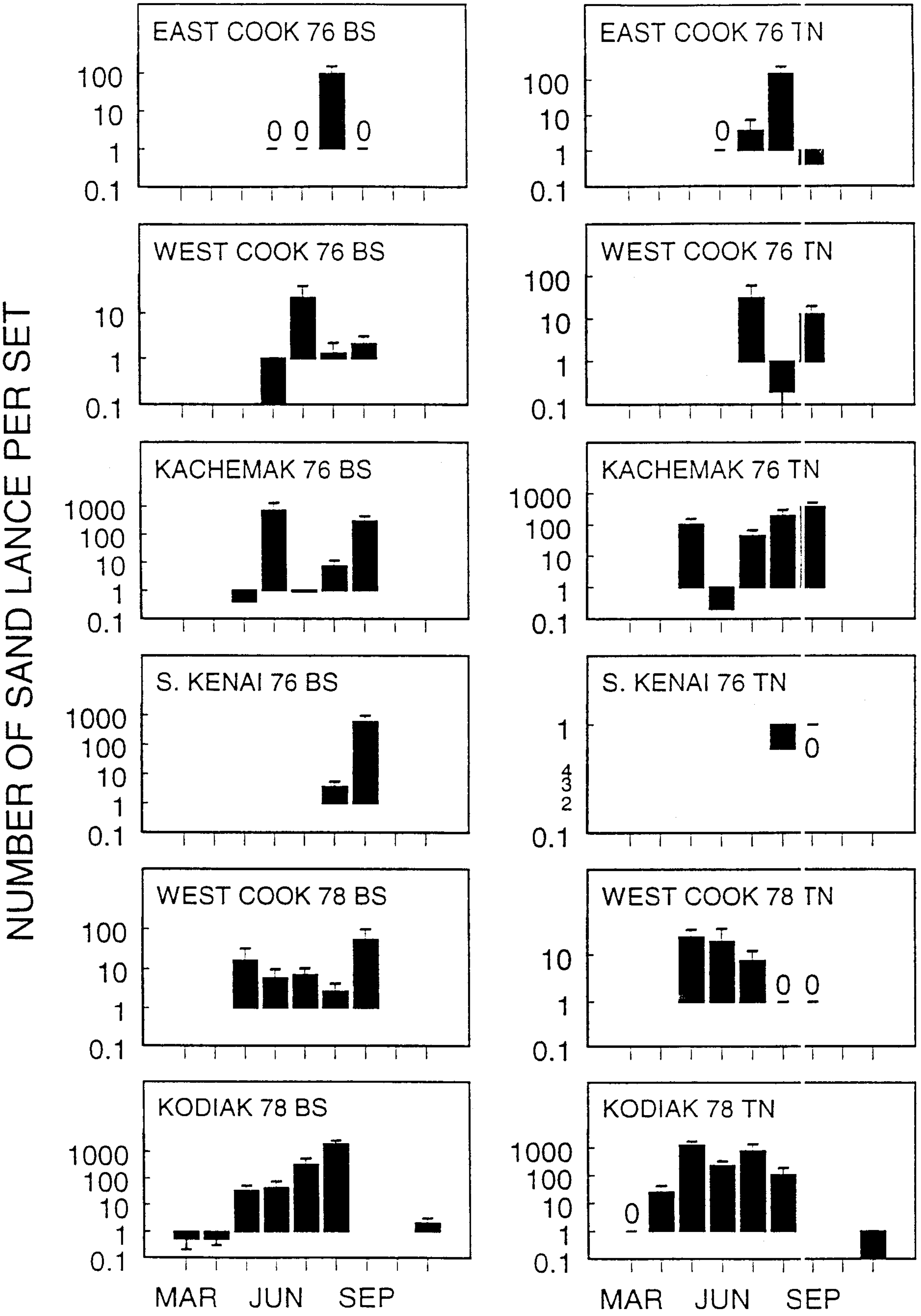
Food Item	April 11 through June 15			June 16 through Aug. 31			Sep. 1 through Oct. 31		
	% Occur.	% By Number	% By Weight	% Occur.	% By Number	% By Weight	% Occur.	% By Number	% By Weight
Copepod, calanoid	78	35	43	89	93	91	84	73	68
Copepod, other	59	10	12	11	0	0	13	0	0
Cirripedia nauplii	86	34	12	37	5	2	18	1	1
Cirripedia cyprids	90	4	3	41	1	1	18	0	0
Shrimp Larvae	29	5	22	1	0	3	4	0	1
Polychaetes	32	0	0	6	0	0	20	1	1
Fish Eggs	42	1	1	0	0	0	0	0	0
Fish Larvae	7	0	3	5	0	1	0	0	0
Gastropod veligers	2	0	0	38	0	1	13	0	1
Chaetognaths	0	0	0	2	0	0	9	0	4
Larvaceans	0	0	0	1	0	0	36	25	23
Other	75	12	3	23	0	0	11	0	0
Number of Fish		59			87			45	
Number Empty		1			7			7	
Predator Size Range		66-147 mm			57-130 mm			56-100 mm	

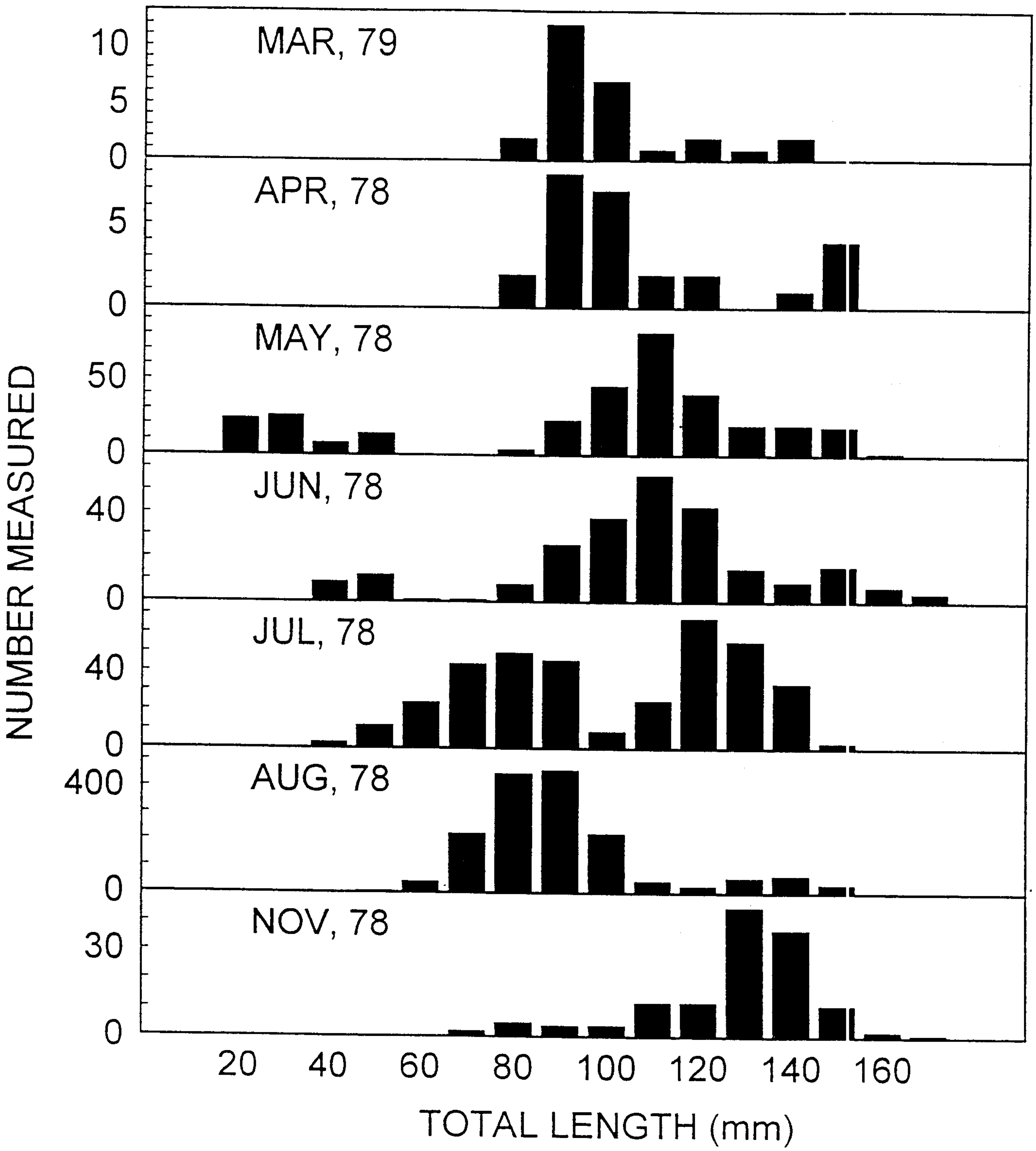
---

[a] Sampling was from 12 periods (April, half-monthly from May through September, then all of October) and these have been grouped here based on periods of consistency.

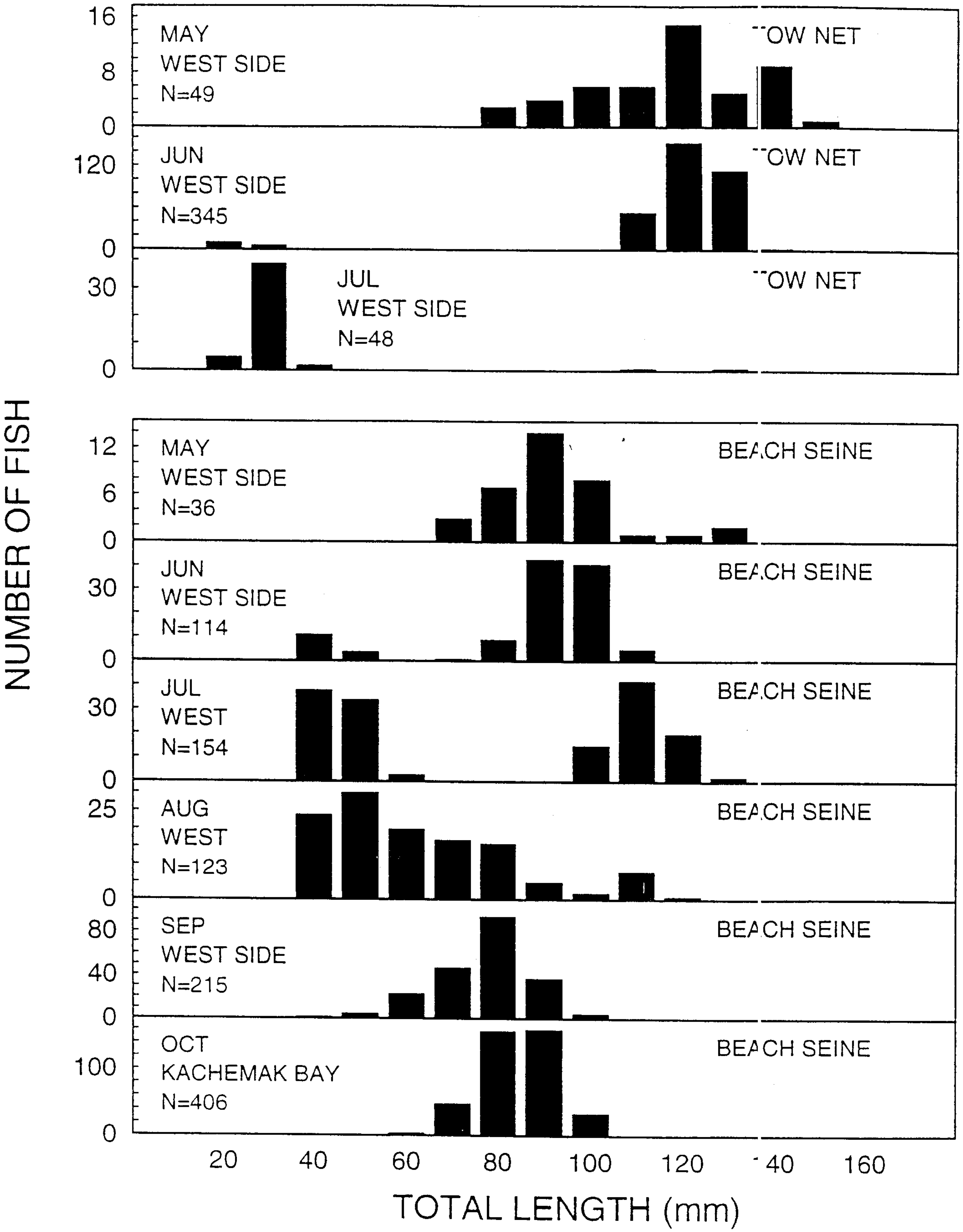
*List of Figures


Cottonwood Bay
Kamishak Bay
COOK INLET
Kachemak Bay
Izhut Bay
KODIAK ISLAND
Kalsin Bay
Kiliuda Bay
Kaiugnak Bay
ALASKA

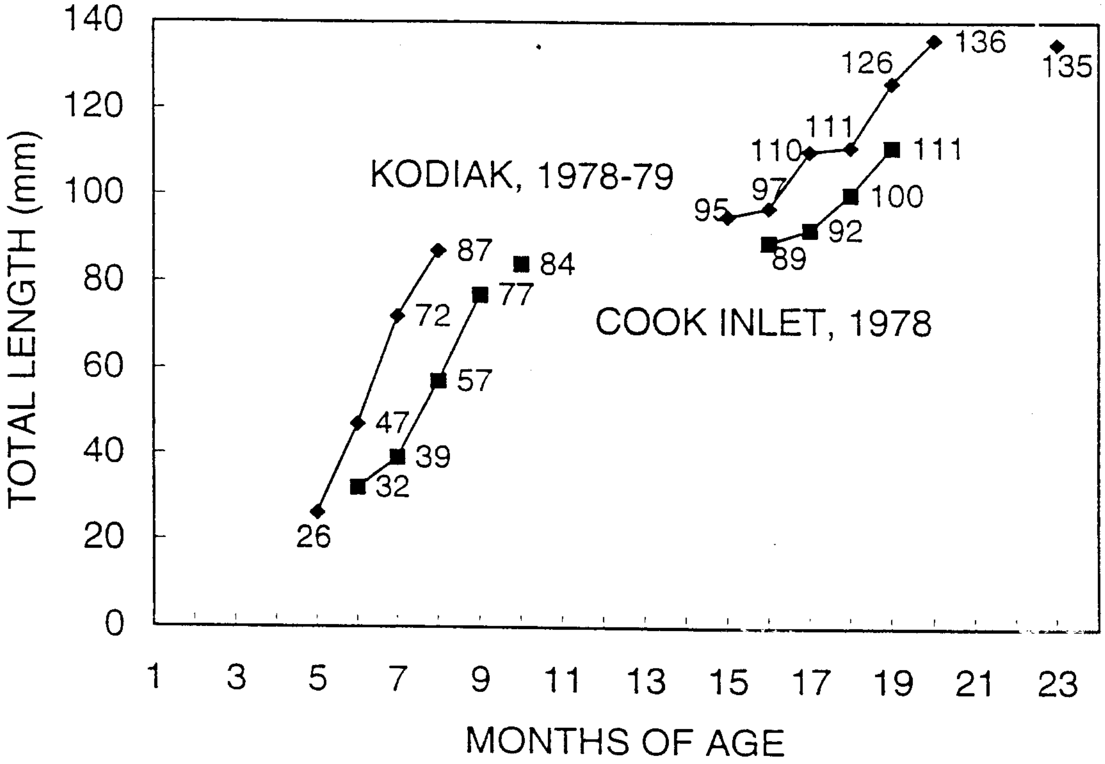

NUMBER OF SAND LANCE PER SET
EAST COOK 76 BS
EAST COOK 76 TN
WEST COOK 76 BS
WEST COOK 76 TN
KACHEMAK 76 BS
KACHEMAK 76 TN
S. KENAI 76 BS
S. KENAI 76 TN
WEST COOK 78 BS
WEST COOK 78 TN
KODIAK 78 BS
KODIAK 78 TN
1000
100
10
1
0.1
0
4
3
2
MAR
JUN
SEP
MAR
JUN
SEP

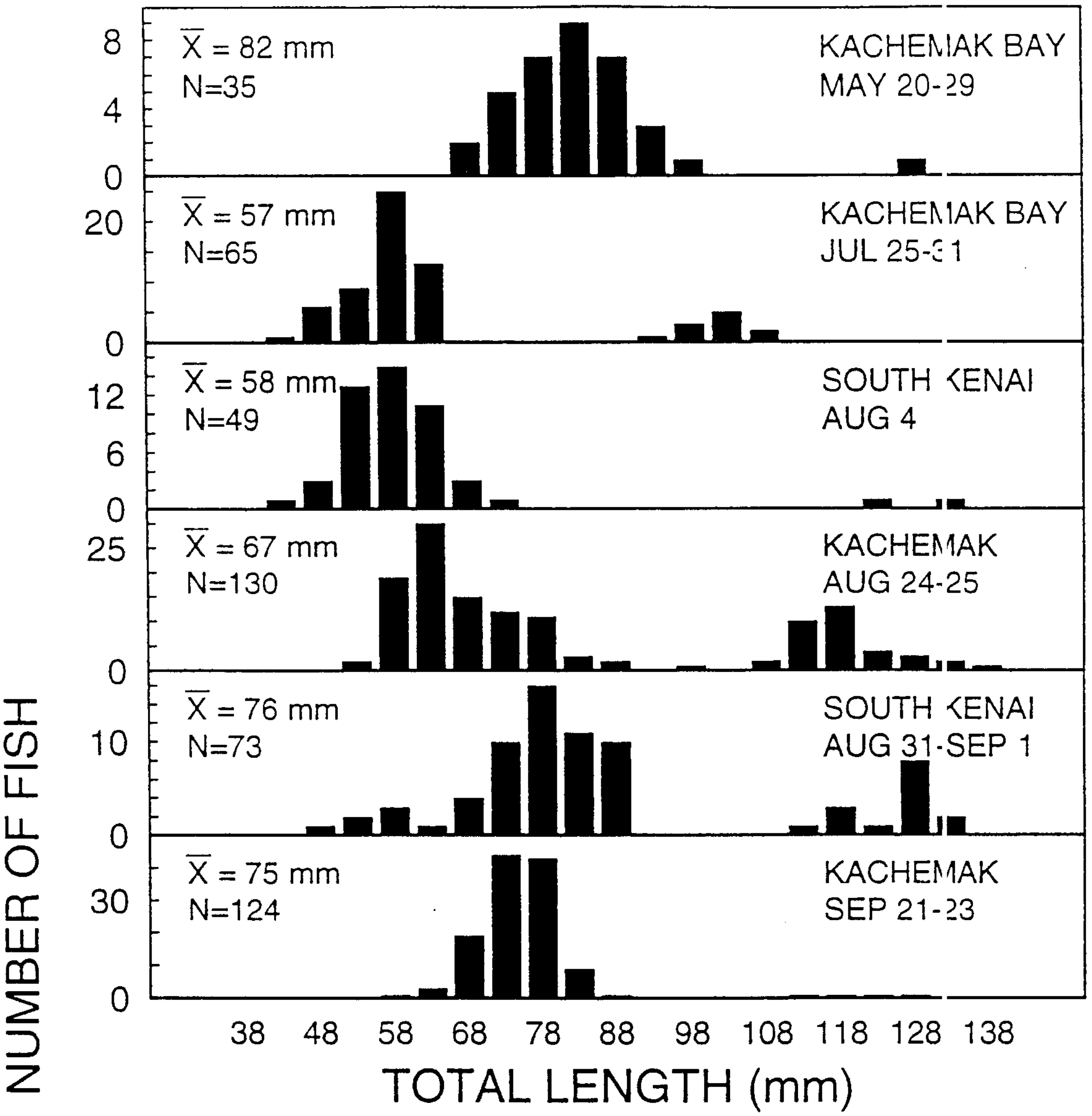


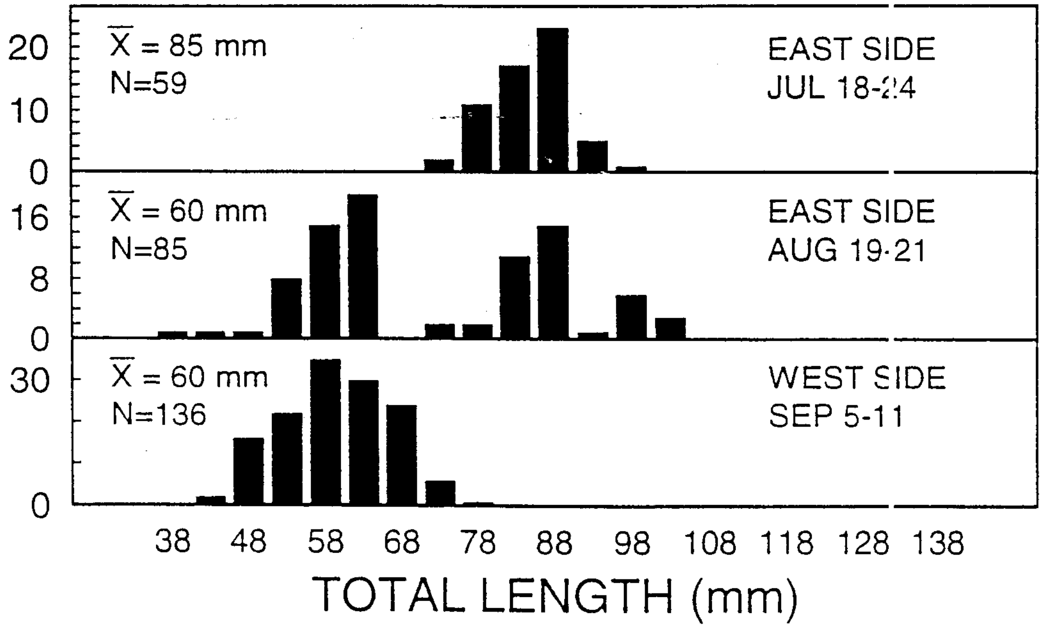
MAR, 79
APR, 78
MAY, 78
JUN, 78
JUL, 78
AUG, 78
NOV, 78
10
5
0
5
0
50
0
40
0
40
0
400
0
30
0
NUMBER MEASURED
20
40
60
80
100
120
140
160
TOTAL LENGTH (mm)

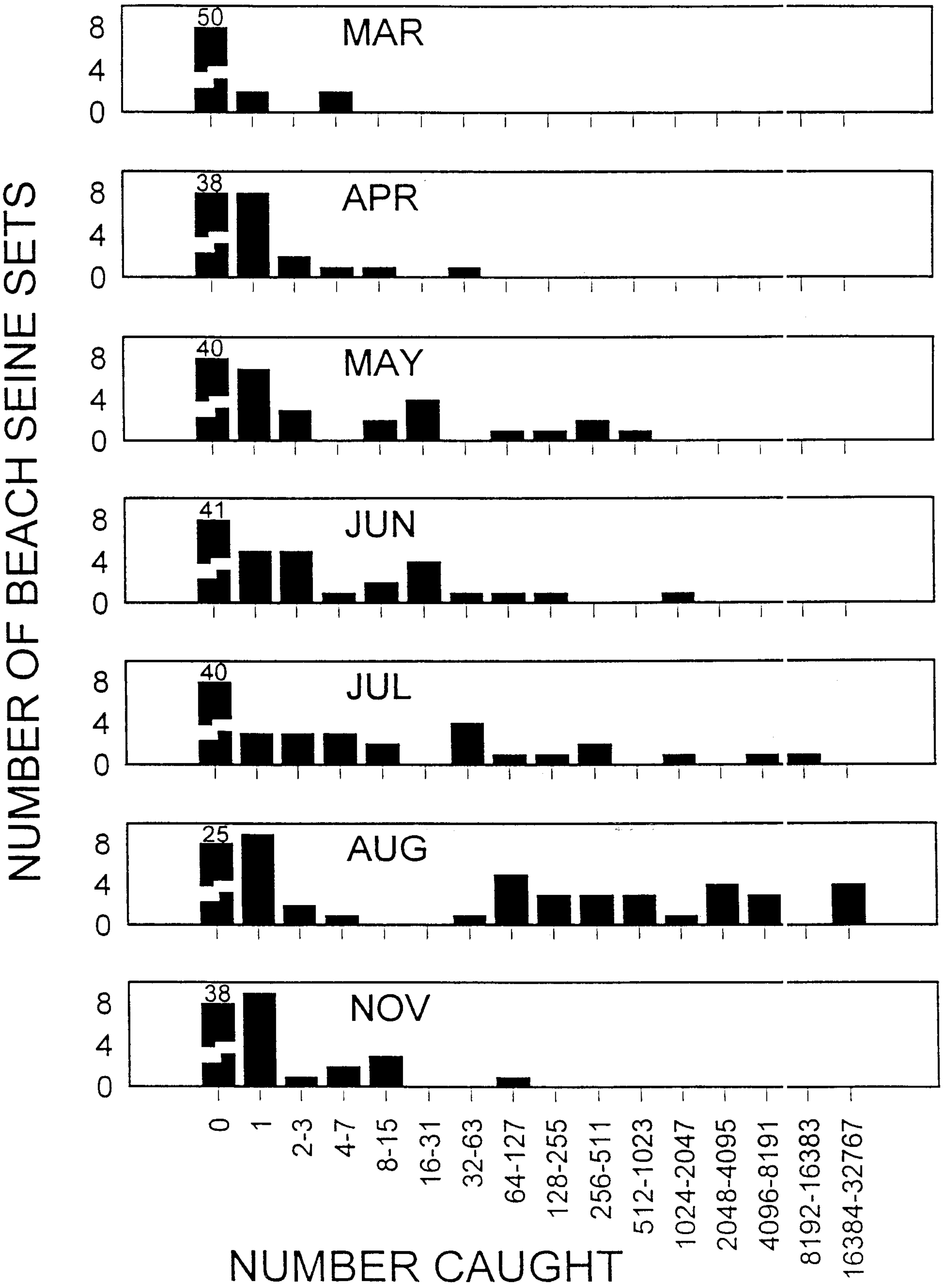


16
8
0
MAY
WEST SIDE
N=49
¨OW NET
120
0
JUN
WEST SIDE
N=345
¨OW NET
30
0
JUL
WEST SIDE
N=48
¨OW NET
12
6
0
MAY
WEST SIDE
N=36
BEACH SEINE
30
0
JUN
WEST SIDE
N=114
BEACH SEINE
30
0
JUL
WEST
N=154
BEACH SEINE
25
0
AUG
WEST
N=123
BEACH SEINE
80
40
0
SEP
WEST SIDE
N=215
BEACH SEINE
100
0
OCT
KACHEMAK BAY
N=406
BEACH SEINE
NUMBER OF FISH
20
40
60
80
100
120
140
160
TOTAL LENGTH (mm)


TOTAL LENGTH (mm)
140
120
100
80
60
40
20
0
1
3
5
7
9
11
13
15
17
19
21
23
MONTHS OF AGE
KODIAK, 1978-79
COOK INLET, 1978
26
47
72
87
32
39
57
77
84
95
97
110
111
126
136
135
89
92
100
111


X̄ = 82 mm
N=35
KACHEMAK BAY
MAY 20-29
X̄ = 57 mm
N=65
KACHEMAK BAY
JUL 25-31
X̄ = 58 mm
N=49
SOUTH KENAI
AUG 4
X̄ = 67 mm
N=130
KACHEMAK
AUG 24-25
X̄ = 76 mm
N=73
SOUTH KENAI
AUG 31-SEP 1
X̄ = 75 mm
N=124
KACHEMAK
SEP 21-23
0
4
8
0
20
0
6
12
0
25
0
10
0
30
0
NUMBER OF FISH
38
48
58
68
78
88
98
108
118
128
138
TOTAL LENGTH (mm)


X̄ = 85 mm
N=59
EAST SIDE
JUL 18-24
X̄ = 60 mm
N=85
EAST SIDE
AUG 19-21
X̄ = 60 mm
N=136
WEST SIDE
SEP 5-11
20
10
0
16
8
0
30
0
38
48
58
68
78
88
98
108
118
128
138
TOTAL LENGTH (mm)


NUMBER OF BEACH SEINE SETS
8
4
0
50
MAR
38
APR
40
MAY
41
JUN
40
JUL
25
AUG
38
NOV
0
1
2-3
4-7
8-15
16-31
32-63
64-127
128-255
256-511
512-1023
1024-2047
2048-4095
4096-8191
8192-16383
16384-32767
NUMBER CAUGHT

APPENDIX M

APEX: 96163M

Exxon Valdez Oil Spill
Restoration Project Report

Cook Inlet Seabird and Forage Fish Studies

Restoration Project (APEX) 96163M
Annual Report

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March 1997

Cook Inlet Seabird and Forage Fish Studies

Restoration Project (APEX) 96163M
Annual Report

Study History: Since the late 1970's, seabirds in the Gulf of Alaska have shown signs of food stress: population declines, decreased productivity, changes in diet, and large-scale die-offs. Small-mesh fishing trawls conducted during the past 30 years reveal that a major shift in fish community composition occurred in the late 1970's: some forage species (e.g., capelin) virtually disappeared, while predatory fish (e.g., pollock) populations increased markedly. Restoration Project 96163M was initiated as part of APEX in 1995 to characterize relationships between seabird population dynamics, foraging behavior, and forage fish densities in lower Cook Inlet--the area in which most seabirds were killed by the EVOS. CISeaFFS is a collaborative project of the Alaska Science Center and the Alaska Maritime National Wildlife Refuge, with major funding and logistic support from the EVOS Trustees (APEX), the MMS, USGS, USFWS, ADF&G and the University of Alaska, Fairbanks.

Abstract: In 1995 and 1996, populations, productivity, diets and foraging behavior of 6 seabird species (murre, kittiwake, guillemot, puffin, cormorant, gull) were studied at three seabird colonies in lower Cook Inlet (Chisik, Gull and Barren islands). Oceanographic measurements, seabird and hydroacoustic surveys, trawls, and beach seines were conducted in waters around (<40 km) each colony. Offshore and southern waters of Cook Inlet were dominated by juvenile walleye pollock and capelin, important prey for murres and puffins. Nearshore waters of Cook Inlet were dominated by sandlance, which were consumed by seabirds (e.g., kittiwakes, guillemots, murres) in proportion to their local abundance. Halibut consumed large numbers of capelin in southern areas, and more sandlance in the north. Forage fish densities ranged from 10's fish/cubic m (pollock) to 100's and 1000's of fish/cubic m (sandlance). Acoustically-measured forage fish biomass was lowest around Chisik Island, moderate in Kachemak Bay, and highest around the Barren Islands. Correspondingly, seabird densities at sea and seabird breeding success ranged from relatively low in the Chisik Island area to relatively high in the Barren Islands area. Populations of seabirds at Chisik Island continued a long-term decline, whereas populations at Gull and Barren islands are stable or increasing. Behavioral studies revealed that seabirds worked harder (longer foraging trips, less "free" time) at colonies where nearby fish densities were lower. Capelin and sandlance had higher energy loads (fat content) than pollock or cod, and in areas where these fish were observed in high densities, seabirds consumed large quantities and had the highest breeding success. Experiments further revealed that kittiwake and puffin chick growth was better in chicks raised on oil-rich sandlance or capelin, than on relatively lean pollock.

Key Words: Cook Inlet, murre, kittiwake, guillemot, forage fish, diet, pollock, capelin, sandlance, reproduction, growth rate, hydroacoustic, trawl, seine, *Exxon Valdez*, Kachemak Bay.

Citation: Piatt, J., M. Robards, S. Zador, M. Litzow, and G. Drew. 1997. Cook Inlet Seabird and Forage Fish Studies. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 96163M), Biological Resources Division, U.S. Geological Survey, Anchorage, Alaska.

The 1997 Annual Report for the Cook Inlet Seabird and Forage Fish Study (CISeaFFS) is comprised of several related papers (in following order):

1) *APEX Project 97163M: Cook Inlet Seabird and Forage Fish Studies (CISeaFFS).* Summary document that integrates all aspects of the project, from oceanography to seabird productivity, and reviews hypotheses under examination in CISeaFFS. 8 pp.

2) *Temporal and Geographic Variation of Fish Populations in Nearshore and Shelf Areas of Lower Cook Inlet, Alaska.* Manuscript under review for submission to Estuarine, Coastal and Shelf Science. 50 pp.

3) *Seabird Populations, Productivity, and Behavior at Gull and Chisik Islands, Cook Inlet, in 1996.* Report of seabird biology at study colonies for EVOS Trustees and Minerals Management Service. 30 pp.

4) *Time-budgets of Common Guillemots (Uria aalge) at declining and increasing colonies in Alaska.* Manuscript under review for submission to Ibis. 12 pp.

5) *Breeding Biology and Feeding Ecology of Pigeon Guillemots at Kachemak Bay, Alaska, in 1996.* Report of Pigeon Guillemot biology for CMI funded research (University of Alaska Fairbanks, Minerals Management Service) and EVOS Trustees.

APEX Project 97163M: Cook Inlet Seabird and Forage Fish Studies (CISeaFFS)

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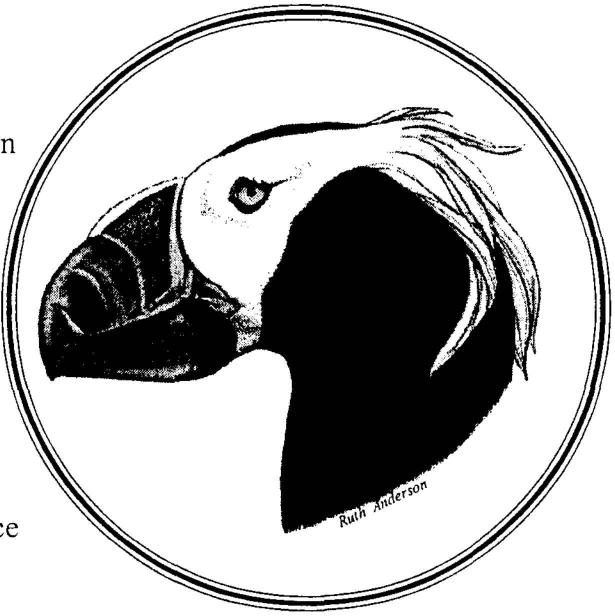


PARTNERS

Exxon Valdez Oil Spill Trustee Council (APEX Projects 97163-J,K,L,M,N 97144, & 97306), U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. Minerals Management Service, Alaska Dept. of Fish and Game, National Marine Fisheries Service, University of Alaska Fairbanks

It is difficult to assess the potential for recovery of seabirds from the Exxon Valdez oil spill (EVOS) and other human impacts (e.g., gill-nets, harvest, commercial fisheries, etc.) because long-term changes in the marine environment were apparently also affecting seabirds at the time of the spill, and during subsequent years. Since the late 1970's, seabirds in the Gulf of Alaska have shown signs of food stress: population declines, decreased productivity, changes in diet, and large-scale die-offs. Small-mesh fishing trawls conducted during the past 30 years reveal that a major shift in fish community composition occurred in the late 1970's: some forage species (e.g., capelin) virtually disappeared, while predatory fish (e.g., pollock) populations increased markedly. These changes correlate with long-term cycles in seawater temperature. It is not known whether fish communities will return to their previous composition and population levels.

CISeaFFS ("Sisyphus") was initiated in 1995 as a long-term research project to characterize relationships between seabird population dynamics, foraging behavior, and forage fish densities in lower Cook Inlet— the area in which most seabirds were killed by the EVOS. CISeaFFS is a multidisciplinary research project of the Alaska Science Center and the Alaska Maritime National Wildlife Refuge, which has management responsibility for most seabird colonies in Alaska.

METHODS

In 1995 and 1996, populations, productivity, diets and foraging behavior of seven seabird species (Common Murre, Black-legged Kittiwake, Pigeon Guillemot, Tufted Puffin, Horned Puffin, Pelagic Cormorant, Glaucous-winged Gull) were studied at three seabird colonies in lower Cook Inlet (Chisik, Gull and Barren islands). Oceanographic measurements (SST's, CTD's), seabird transects and hydroacoustic surveys for fish, mid-water and benthic trawls, and beach seines were conducted in core study areas around (<40 km) each colony (Figure 1, next page). In 1996, surveys extended throughout lower Cook Inlet, as far south as Shuyak Island. Also in 1996, coastal transects were added to the survey of core areas to increase sampling of the productive nearshore zone.

OCEANOGRAPHY

The Alaska Coastal Current flows west and north into Cook Inlet (Figure 2), and upwelling of cold, nutrient-rich water occurs around islands and on shallow coastal shelves (Figure 3). Satellite imagery shows this cold water extending well north into Cook Inlet and Kachemak Bay (Figure 3). Vertical CTD salinity and temperature profiles of the water column (Figure 4), and continuously recording temperature probes (Figure 5), reveal that water around the Barrens is completely mixed, cold, and highly saline. Water in Kachemak Bay has a shallow layer of warm, low-salinity water overlaying cold, saline water like that observed at the Barrens. Water near Chisik Island, on the west side of Cook Inlet, is much warmer and less saline, because south-flowing currents carry warm, fresh water from the head of Cook Inlet. The difference in oceanographic regimes between the east and west side of Cook Inlet has important implications for the forage fish and seabirds residing in each area.

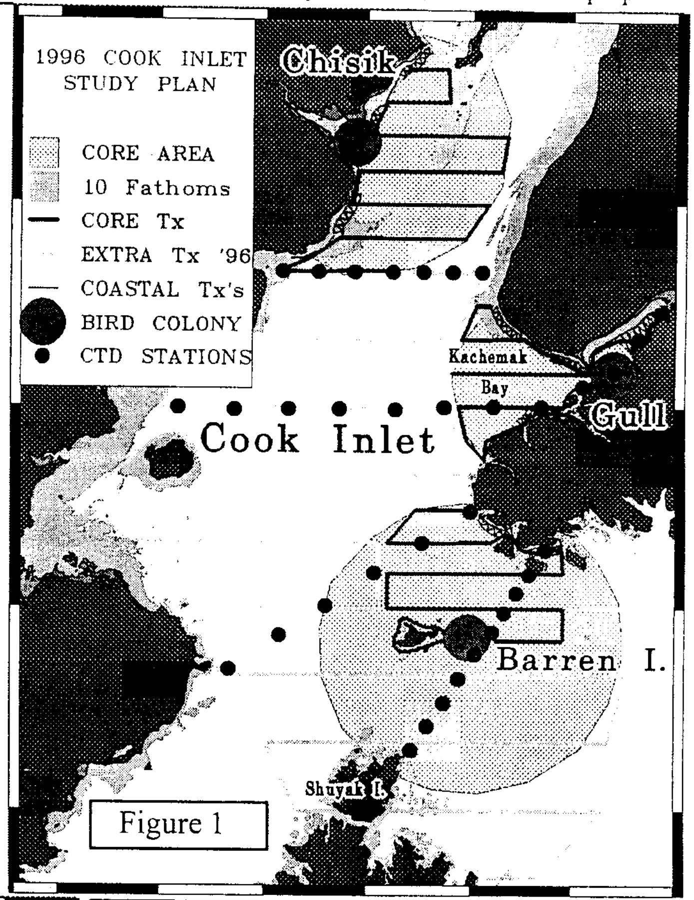
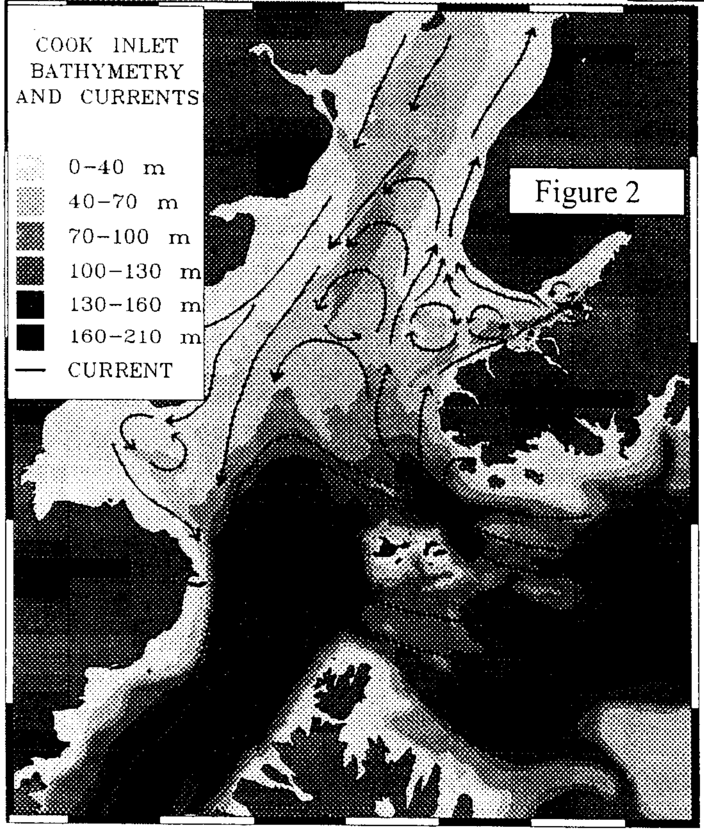


Figure 1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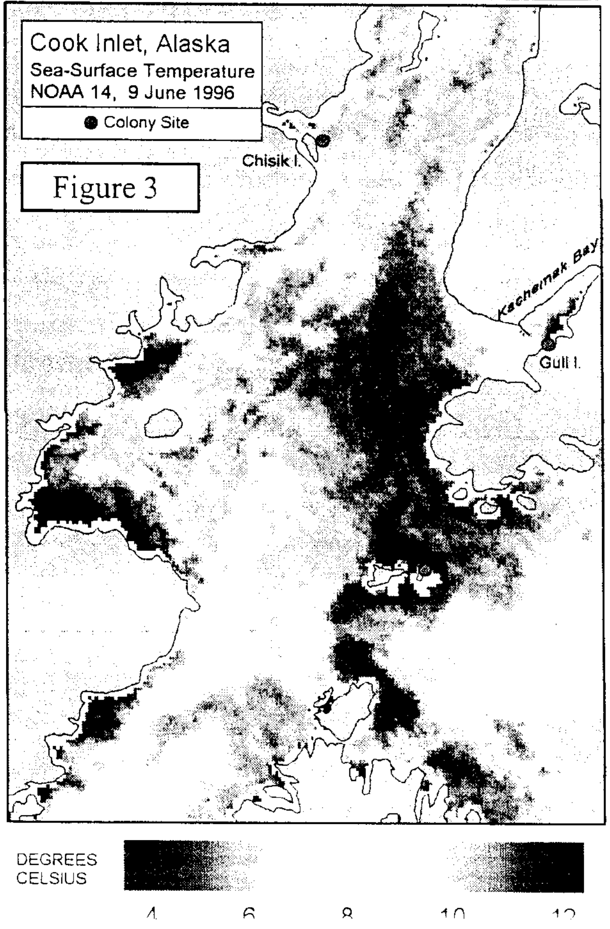
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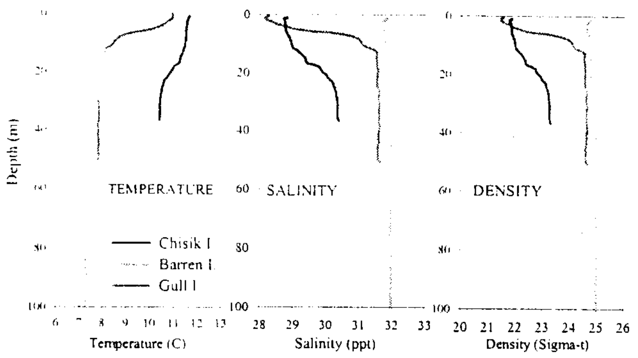


Figure 4. Temperature, salinity and density profiles of the water column at the three study colonies obtained from CTD casts in July, 1996

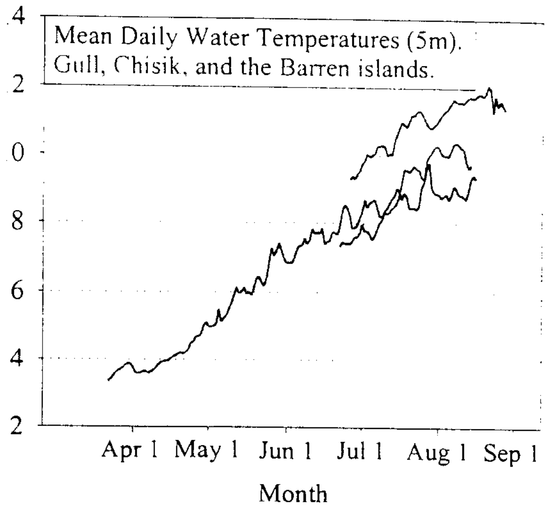


Figure 5. Mean daily water temperatures at 5 m depth obtained from continuously recording temperature probes at the three study colonies in Cook Inlet.

FISH

The abundance and species composition of fish in Cook Inlet were examined by conducting mid-water and benthic trawls (Figures 6&8), beach seines (Figures 7&8), and hydroacoustic surveys (Figures 9&10). Pelagic forage fish abundance increased by about an order of magnitude (Fig. 10), and diversity decreased (Fig. 8), as we sampled from North (Chisik) to South (Barrens). Benthic trawls revealed a similar pattern for bottom fishes. Pacific sandlance dominated in both coastal and offshore waters around Gull Island (Kachemak Bay), although capelin and pollock were also common offshore. Around the Barrens, juvenile pollock and capelin dominated offshore catches, while coastal beach seines caught sandlance almost exclusively. The abundance of fish in coastal waters varied seasonally (Figure 7), with peak seine catches in June-August for most species.

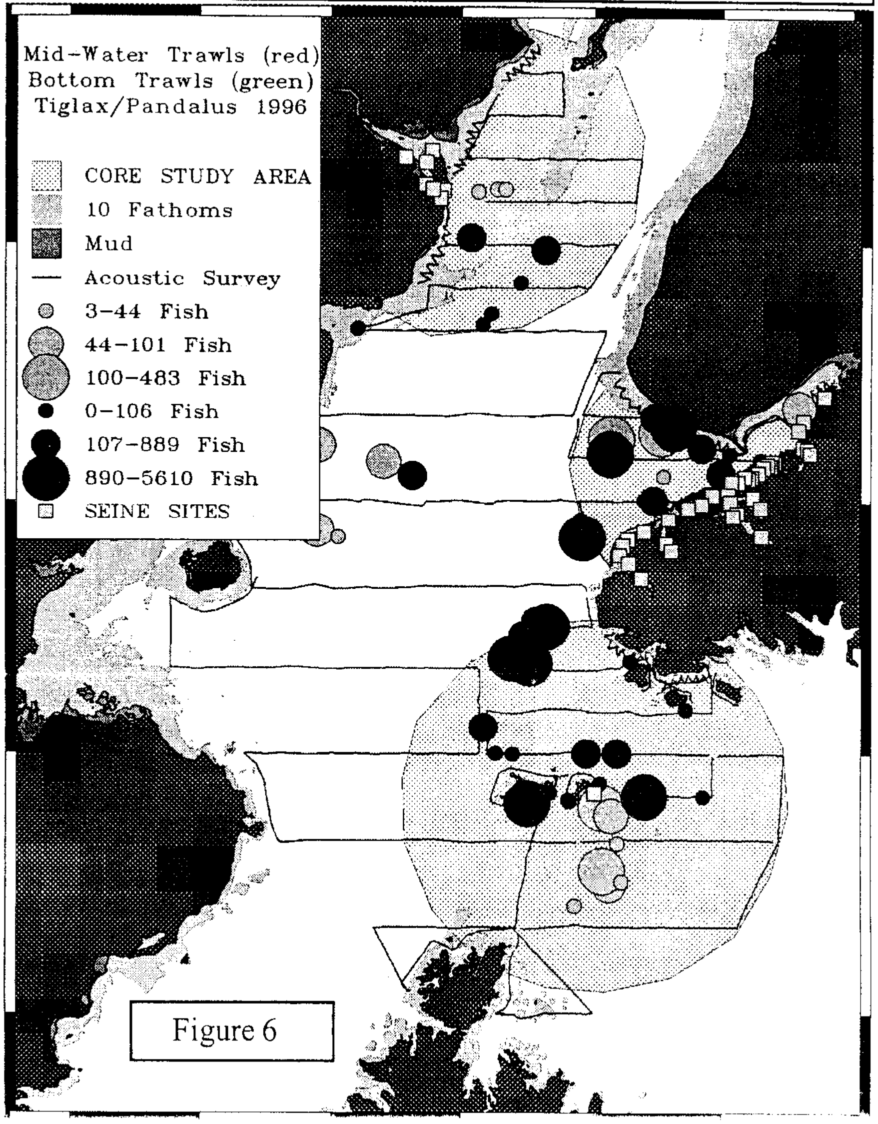


Figure 6

"The Mighty Sandlance", watercolor by William Spear (1994)

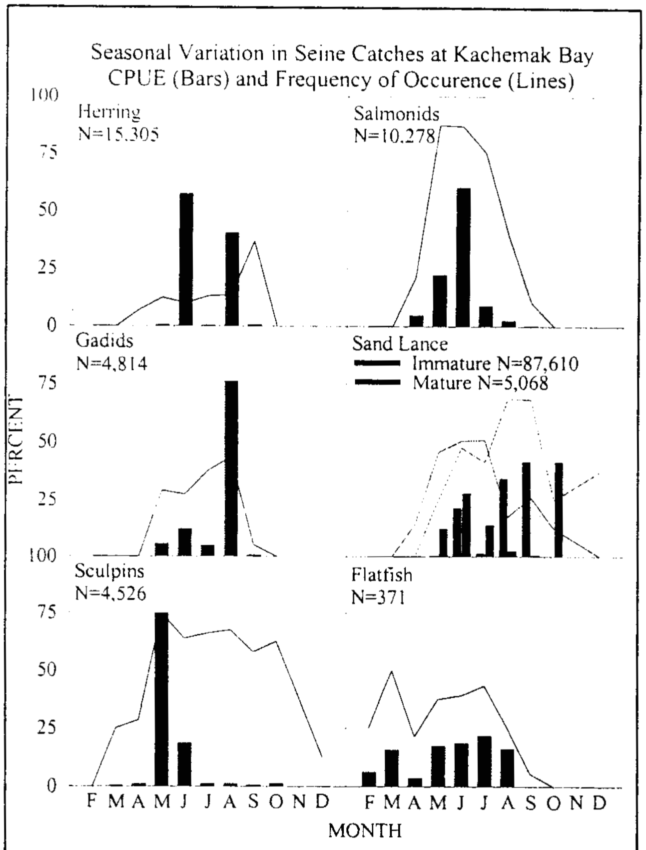
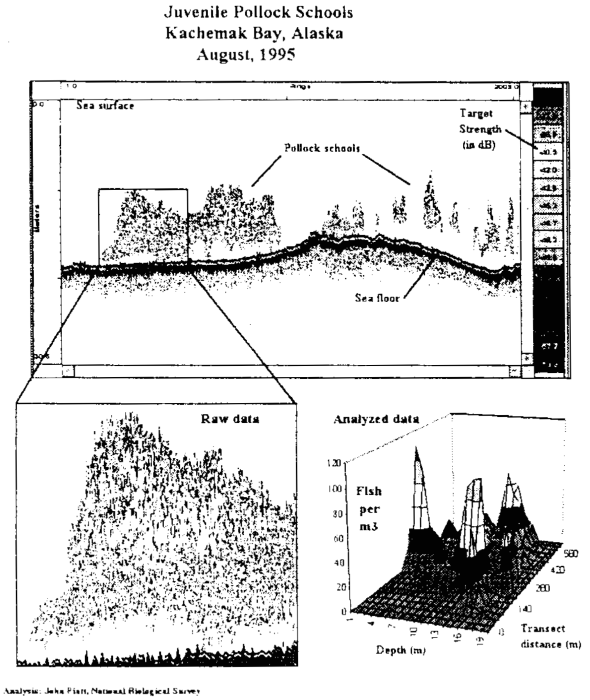


Figure 7. Catch per unit effort (CPUE) and frequency of occurrence of fish caught in beach seines in Kachemak Bay, 1996.



Analysis: John Piatt, National Biological Survey

Figure 9. Example of fish schools recorded on a Biosonics DT4000 Digital Echosounder, and integration to obtain absolute fish densities.

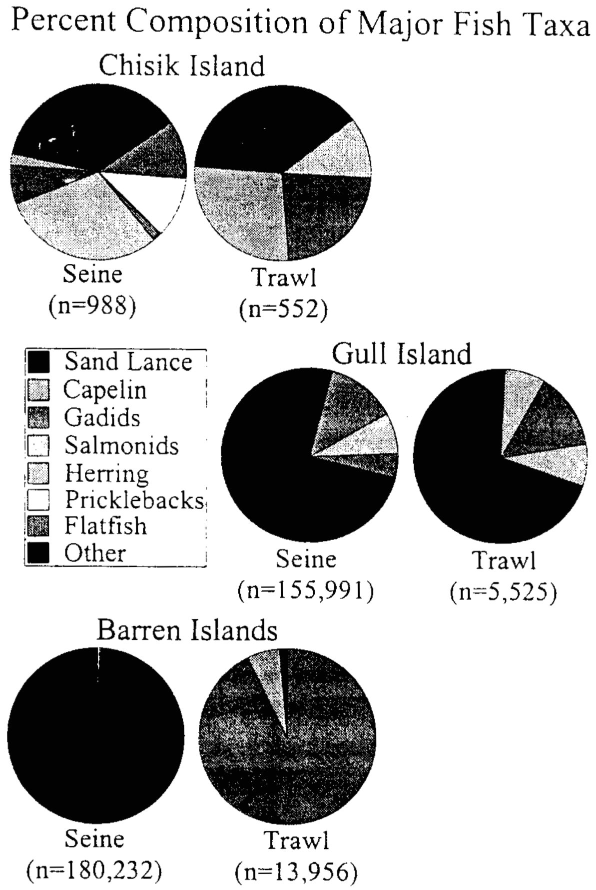


Figure 8. Species composition of fish catches in mid-water trawls and beach seines in lower Cook Inlet, summer 1996.

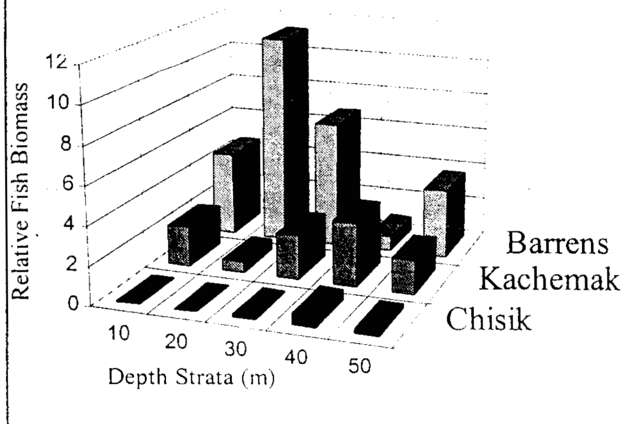


Figure 10. Relative abundance of fish in each of the three core colony study areas (Fig. 1) as determined by hydroacoustic surveys in summer, 1995. (Similar results in 1996).

SEABIRDS AT SEA

The abundance and distribution of fish-eating seabirds corresponded to patterns of oceanography and fish distribution in lower Cook Inlet. Seabirds were concentrated around the Barrens (Fig. 11), northeast along the Kenai coast, and in Kachemak Bay. Shallow coastal habitats were particularly rich, whereas birds were conspicuously scarce in the west half of lower Cook Inlet. A detailed look at Common Murre distribution (Figure 12) reveals that high-density murre foraging areas are close to Gull Island in Kachemak Bay, and further away from the Barrens in several directions. Chisik murres forage little in the vicinity of Chisik Island, and appear to fly southeast to good foraging areas in Kachemak Bay. Kittiwakes reveal a similar pattern (Figure 13), except many appear to forage within 40-50 km of Chisik, and birds from the Barrens forage a long distance north along the coast of the Kenai Peninsula.

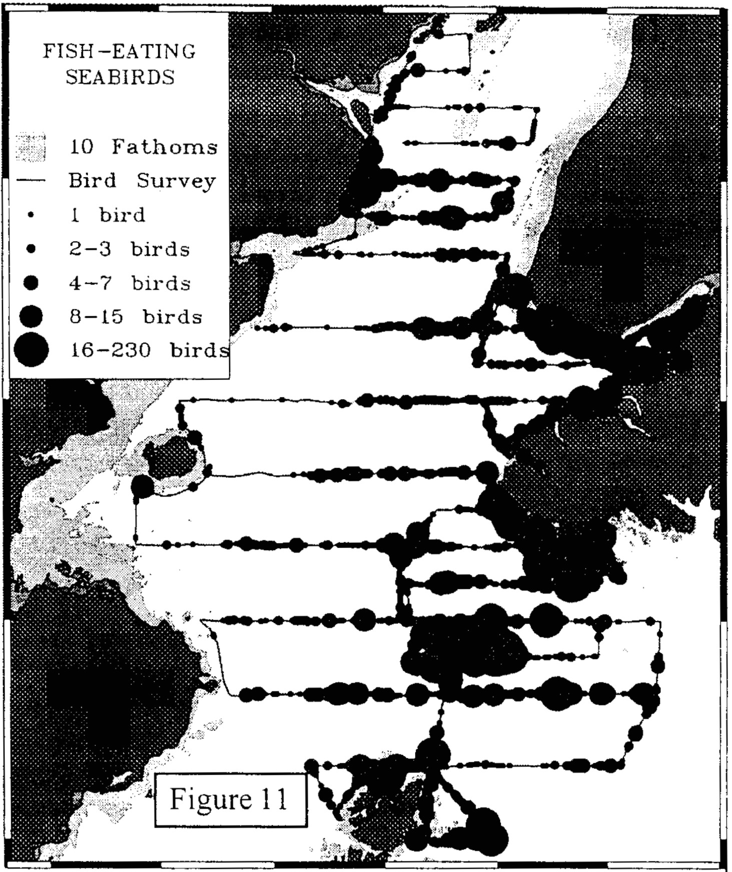


Figure 11

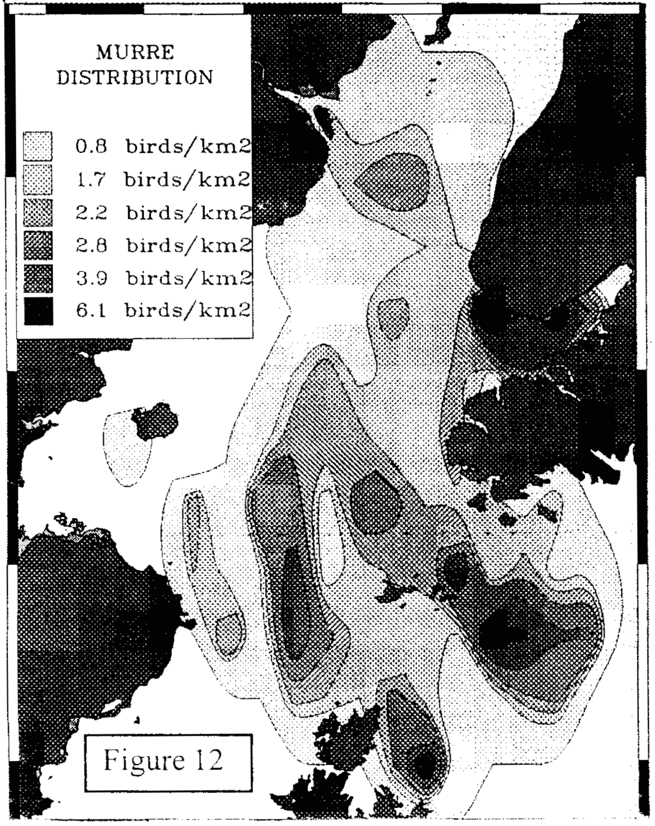


Figure 12

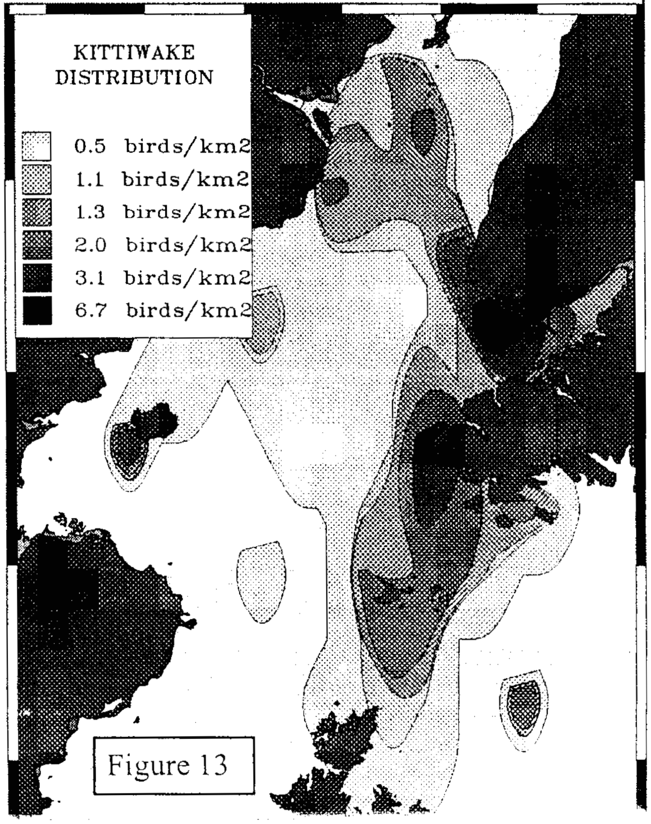
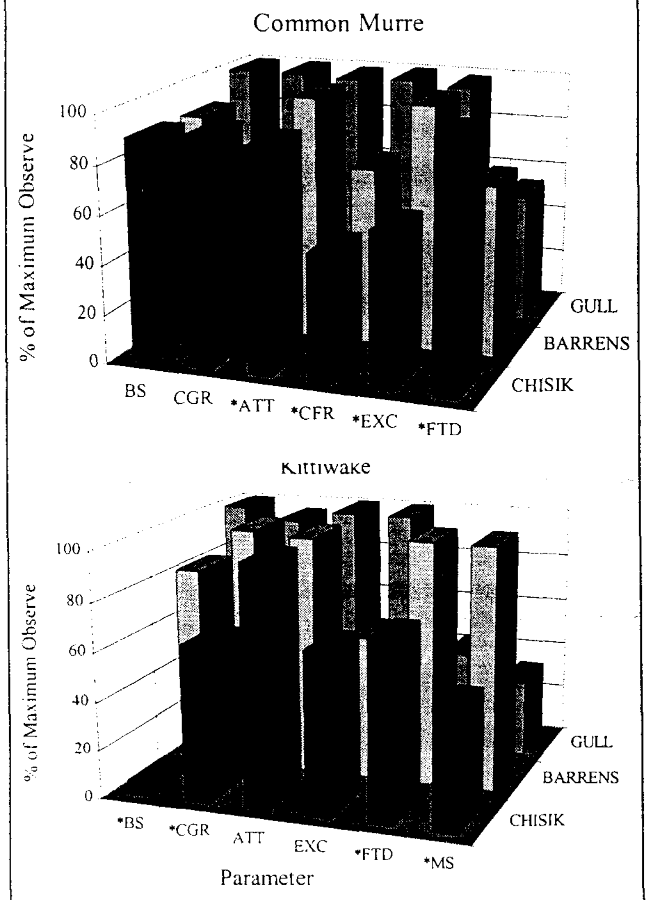


Figure 13

SEABIRDS AT COLONIES
— THE BOTTOM LINE—

We consider here preliminary analyses of data on Common Murres and Black-legged Kittiwakes. Diets of chicks fed by adults in 1996 (Figure 14) reflect the patterns observed from fish and bird surveys at sea. Diet diversity decreases from North to South. Kittiwakes feed chicks more on sandlance in coastal areas (especially in the North), whereas murre chick diets include more offshore species such as capelin and pollock (especially in the South). Adult murres preferentially feed chicks energy-rich capelin. In 1996, adult diets comprised more than 70% pollock, while chicks were fed more than 90% capelin (Figure 14).

Figure 15. Variation in different parameters of breeding and behavior for murres and kittiwakes at each of 3 study colonies in 1996.



Parameters: BS- Breeding Success, CGR- Chick Growth Rate, ATT- Attendance by Adults, CFR- Chick Feeding rate, EXC- Exchange Rate of Brooding Adults, FTD- Foraging Time Duration, MS- Mean Meal Size. Asterisk (*) indicates significant difference in parameter values between colonies.

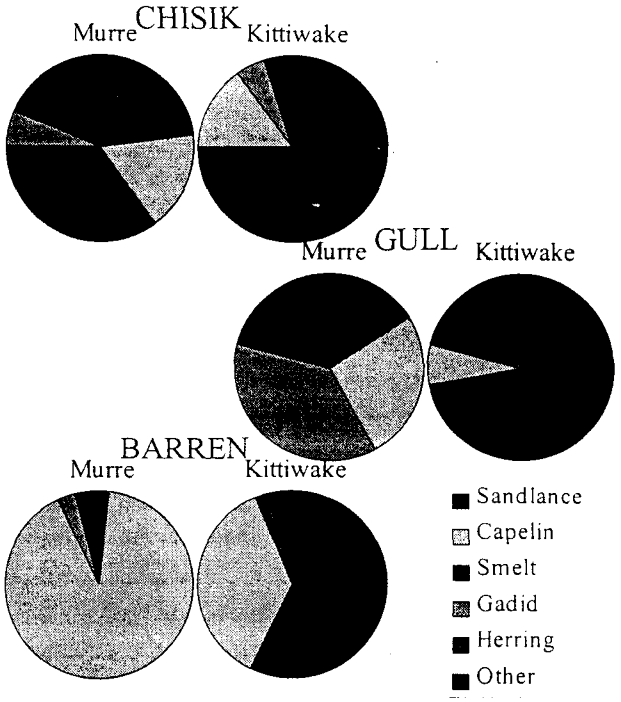


Figure 14. Diet composition of Common Murre and Black-legged Kittiwake chicks in lower Cook Inlet, summer, 1996.

The results of studies at colonies and at sea can be integrated by contrasting murre and kittiwake population parameters at the three study colonies. Data are expressed as percentages of highest observed parameter values (Figure 15). For example, murre breeding success was highest at Gull Island (100%=0.87 chicks/pair), and proportionally lower at Chisik (0.78 ch/pr) and the Barrens (0.77 ch/pr). There was no statistical difference in chick production between colonies, despite the apparent regional differences in fish availability. Murre chick growth rates also did not differ between Chisik and Gull islands (no data from Barrens). However, murres at Chisik spent more time foraging (mean trip = 243 min), fed chicks less frequently (only 2.58 meals/day), and had fewer brooding exchanges (usually after feeding chicks), than murres at the Barrens or Gull Island. As one indication of this extra effort, murres at Chisik spent less time in attendance ("loafing") at nest-sites compared to Gull Island (Figure 16). However, even Gull Island birds appeared stressed during late chick-rearing (29 August). Despite the extra effort required at Chisik, murres there managed to maintain high chick production.

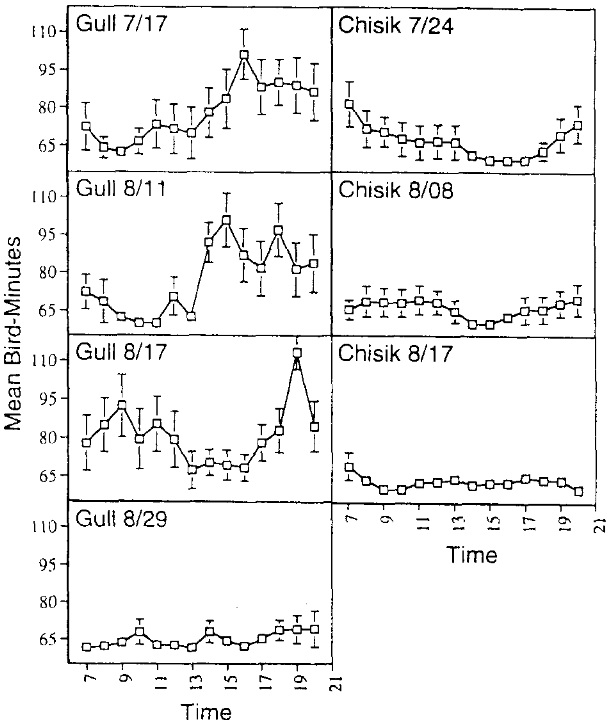


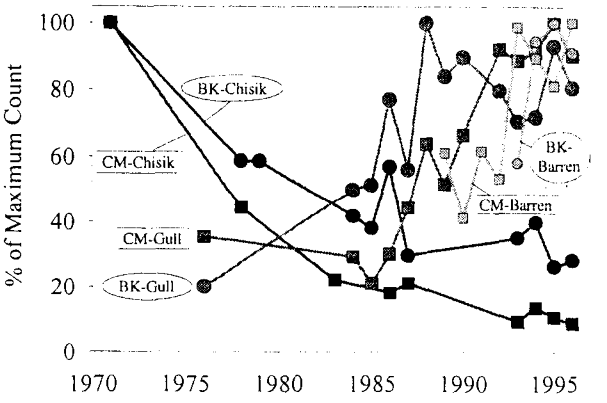
Figure 16. Diurnal attendance patterns of murres at Gull and Chisik Islands during incubation (July) and chick-rearing (August). Note >60 bird-minutes = "Loafing"

Kittiwakes exhibited a very different response (Figure 15). While productivity was high at Gull Island (0.87 ch/pr), kittiwakes almost failed to fledge chicks at Chisik. Similarly, chick growth rates were much lower at Chisik (11.1 g/day). Attendance at nest-sites did not vary between colonies, but this is because rarely was more than one bird present at a nest (unlike murres where the "off-duty" bird often spent hours "loafing" at the site). Chick meal deliveries are difficult to measure as kittiwakes regurgitate many times at "one feeding", but brooding exchange rates were low at both Chisik and the Barrens compared to Gull Island. Correspondingly, Barrens (mean=5.4 h) and Chisik (4.0 h) kittiwakes spent far more time away on foraging trips. Unlike murres, which can carry only one fish at a time, kittiwakes may carry many fish in their crop to regurgitate later to chicks. It appears that Gull Island kittiwakes make many short foraging trips, and deliver many small loads to chicks. Barrens kittiwakes make fewer and much longer foraging trips, but deliver large loads (mean=18.3 g). Chisik kittiwakes make long foraging trips, but deliver loads only slightly bigger than those at Gull Island. Apparently, the latter combination was inadequate to support chick production.

In summary, murres can compensate for shortage of food in adjacent waters by flying further, and using some of their "loafing time" to feed chicks. Kittiwakes may compensate by flying further, and carrying larger loads back to the colony— if prey are available within some threshold distance (ca. <45 km, which is less than for murres, ca. <70 km). Such was not the case at Chisik in 1996, and this problem may account for the steady decline in populations there over the past 25 years (Fig. 17). Kittiwakes have produced almost no chicks during this period. In contrast, murres at Chisik have had high breeding success during the past two years (only data available), and yet their population has been declining at a rate similar to kittiwakes. It may be that the stress of chick-rearing at Chisik increases over-winter mortality of adult murres. Alternatively, adult murres and kittiwakes may be emigrating from Chisik to Gull Island, where populations have increased substantially during the past 20 years.

Figure 17

Population Trends of Common Murres (CM) and Black-legged Kittiwakes (BK) at Chisik, Gull, and Barren Islands



HYPOTHESIS TESTING - PROGRESS

In our Detailed Project Description (1995/1996) we proposed to examine several hypotheses about how seabirds respond to changes in forage fish abundance and distribution in lower Cook Inlet:

1) **Seabird recovery from the EVOS is limited by present-day forage fish densities.** To date, our studies suggest that seabirds at 'oil-affected' colonies at Barren and Gull islands were not limited by food supplies in 1995-96, whereas they were at Chisik Island. However, the numerical response of populations occurs at decadal time scales, and many more years of study are required to assess the form and density threshold of response curves.

2) **Seabird breeding failures and population declines are due to long-term changes in forage fish abundance or species composition.** Assessment of this hypothesis requires comparison of long-term data on seabird population biology and forage fish trends. Data for lower Cook Inlet are patchy for seabirds, and still being analysed for forage fish (APEX Project 97163L). Preliminary evidence suggests that at least the converse of the hypothesis is true in Kachemak Bay: a major shift in forage fish abundance and composition occurred in Kachemak Bay during the early 1980's, leading to an increase in local seabird productivity and population size.

3) **Seabird species respond to different threshold densities of prey abundance.** Our data appear to confirm this hypothesis. Kittiwakes fail to thrive on prey densities at which murres and puffins are capable of rearing chicks. However, prey switching may modulate the form of responses and the threshold densities at which responses occur may depend on prey type.

3) **Large seabirds have more 'free time' to adjust foraging effort as prey densities fluctuate.** Our data appear to confirm this hypothesis. Murres (ca. 1000g) can adjust foraging effort to compensate for lower prey densities, whereas kittiwakes (ca. 500g) appear to have little or no 'spare time'

4) **Prey density or distribution near the sea surface is influenced by depth of the thermocline (or pycnocline).** We have not examined data yet to test this hypothesis. However, waters in lower Cook Inlet (LCI) are very well-mixed and forage fish are abundant at many depth levels, so this environmental factor may not be important in lower Cook Inlet.

5) **Weather (wind, sea state) affects foraging success of seabirds, and annual variability in seabird breeding success is influenced by weather.** Two years of data are insufficient to test this hypothesis.

6) **Kittiwake foraging success (and hence breeding success) is limited by availability of prey at the sea surface (as opposed to overall prey abundance).** We have not examined the data yet to explicitly test this hypothesis. However, evidence suggests that overall prey abundance has a strong influence on foraging success. Prey abundance and availability at the surface may be correlated.

7) **Forage fish prey differ in quality (primarily energy content), and therefore seabird chick growth may be limited by diet composition.** In collaboration with Dan Roby, and from previous studies, we know that different prey have markedly different nutritional value. Experiments conducted in Kachemak Bay in 1996 (APEX Project 97163N) clearly demonstrated that chick growth is markedly affected by prey type. The energy content of prey is a very important determinant of chick growth, but other factors may also influence subsequent chick survival (fat deposition, stress).

8) **Seabirds work harder (adjust time spent foraging) when feeding on low quality prey.** This hypothesis is supported by observations of longer feeding trips and fewer chick meal deliveries by murres at the Barren islands (where adults eat mostly pollock) compared to murres at Gull I. (where adults eat mostly sandlance). Data still need to be analysed by pro-rating foraging invest-

Temporal and Geographic Variation of Fish Populations in Nearshore and Shelf Areas of Lower Cook Inlet, Alaska.

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Abstract

The nearshore and shelf fish communities of Lower Cook Inlet, Alaska were studied at 3 locations (Kachemak Bay, Chisik Island, and the Barren Islands). The Barren Island waters are largely oceanic, Kachemak Bay receives largely oceanic water but has a significant freshwater runoff component, and Chisik Island waters are predominantly estuarine in nature. Beach seines and mid-water trawls were the primary capture methods at all sites. Kachemak Bay was sampled over the course of two years (1995 &

1996), whereas Chisik Island and the Barren Islands were only sampled in the summer of 1996.

The study areas support a diverse nearshore fish community of at least 52 species. Of these species, 50 were caught in Kachemak Bay, 24 at Chisik Island, and 12 at the Barren Islands. Pacific sand lance was clearly the dominant nearshore species at the Barren Islands and Kachemak Bay comprising 99% and 71% of the total individuals respectively. The nearshore fish community at Chisik Island did not show any clear dominance by a single species, which was paralleled by an increased community diversity over the other two sites. Significant changes have occurred in the nearshore fish community of Kachemak Bay between 1976 and the present with increased diversity, particularly in regard to gadids which were almost absent in 1976. A strong seasonality of the nearshore community was noted with a paucity of species and individuals present in the winter. Several species were only present for a portion of the summer. Significant differences in the nearshore community were noted between high and low tides but not between consecutive sets or years (1995 and 1996).

Shelf waters were less diverse in their species assemblages than for nearshore areas. Of at least 26 species found, 14 were present at Kachemak Bay, 19 at Chisik Island, and 7 at the Barren Island. Similar trends in community structure to nearshore areas was noted with no clear dominance and high diversity at Chisik Island compared to a markedly dominated community at both Kachemak Bay and the Barren Islands. However, the Barren Island shelf areas showed a paradoxical situation over nearshore areas with walleye pollock the dominant species, as opposed to sand lance being dominant for both nearshore and shelf areas of Kachemak Bay.

Introduction

The main purpose of this study was to assess in terms of abundance, diversity, and species composition, the changes in the nearshore fish community over 20 years and between three geographically distinct locations within Lower Cook Inlet. In addition, concurrent offshore fish sampling allowed comparisons to be made between shelf and nearshore fish communities.

Blackburn (1980) surveyed the nearshore fish of Kachemak Bay during the summer of 1976, which until the present was the most comprehensive investigation for this area. The current study was designed to sample the nearshore habitat of Kachemak Bay as comprehensively as possible over the course of two summers at the same sites investigated by Blackburn to establish if temporal changes have taken place.

The importance of inshore coastal marine habitats as nursery areas for juveniles of many marine fish species is well documented, and it has been shown that many species are dependent on these areas during the juvenile phase of their life cycles (Poxton *et al.*, 1983; Orsi & Landingham, 1985; Bennett, 1989; Blaber *et al.*, 1995; Santos & Nash, 1995; Dalley & Anderson, 1997). Many studies have also described seasonal variation in shallow water fish assemblages (e.g., Horn, 1980; Allen, 1982; Nash & Gibson, 1982; Nash, 1988; Bennett, 1989). However, there is a paucity of information available concerning seasonal variation of nearshore fish assemblages in Alaska, due largely to the difficult working conditions and logistics of winter fieldwork.

This study is a component of the Exxon Valdez Oil Spill (EVOS) Trustee Council funded project in the northern Gulf of Alaska, which is currently researching forage fish/vertebrate predator interactions. Profound changes in seabird populations have been linked to shifts in the abundance and composition of forage fish stocks in the Gulf of Alaska over the past twenty years (Piatt & Anderson, 1996). Coincident with cyclical fluctuations in sea-water temperatures, the abundance of several forage species such as capelin (*Mallotus villosus*) declined precipitously in the late 1970s while populations of large predatory fish such as walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus pacifica*) increased dramatically. Correspondingly, seabird diets shifted from mostly capelin in the 1970s to mostly Pacific sand lance and juvenile pollock in the late 1980s. Furthermore, a variety of seabirds and marine mammals have exhibited signs of food stress through the 1980s and early 1990s (Piatt & Anderson 1996). Three main study areas were identified in the Lower Cook Inlet centered around seabird colonies; Gull Island in Kachemak Bay, Chisik Island on the west side of Cook Inlet, and the Barren Islands in the mouth of Cook Inlet. Gull Island is an increasing colony, Chisik is failing (Slater *et al.*, 1994), and the Barren Islands are regarded as stable (Roseneau *et al.*, 1995). Investigation of fish communities in nearshore and shelf areas around these colonies provide information to relate differing forage fish abundance and composition to seabird diets and productivity.

Materials and methods

Study sites

Lower Cook Inlet (Figure 1) is located in the southcentral region of Alaska. The area supports several important seabird colonies, numerous marine mammals, a large overwintering and summer bald eagle (*Haliaeetus leucocephalus*) population, major staging areas for migrating shorebirds, as well as commercially and recreationally important fisheries including salmon (*Oncorhynchus Spp.*) and halibut (*Hippoglossus stenolepis*).

Kachemak Bay is situated at the southern tip of the Kenai Peninsula in Alaska. The bay is 38km wide at its entrance, defined as a line from Anchor Point on the north to Point Pogibshi on the south, and is approximately 62km long. The upper 6km are mud flats which are exposed most of the time. Depths in the bay are relatively shallow, ranging from about 35 to 90m, with deeper areas (100 to 165m) between Gull and Yukon islands on the south side of the bay. Water entering the bay is largely oceanic, originating from the Gulf of Alaska via the Kennedy entrance at the southern end of the Kenai Peninsula.

Chisik Island is located on the western side of Cook Inlet (Figure 1). The island is 10.5km long and about 3.6km wide at its northern end but narrows to less than 0.4km at its southernmost point. It lies in the mouth of the glacially fed Tuxedni Bay. Water passing the island is estuarine, having passed up the east side of Cook Inlet before circulating around and down the west side past Chisik Island. Although a navigable channel is present on the west side of the island (Snug harbor) the nearshore habitat around the island is dominated by shallow glacial silt and mud flats exposed at low tides, and rocky substrates with few sandy beaches present.

The Barren islands are located at the entrance to Cook Inlet (Figure 1) and mark the transition between deep oceanic Gulf of Alaska waters and the estuarine Cook Inlet. The Alaska Coastal Current enters Cook Inlet past the Barren Islands leading to intense upwelling of cold, nutrient-rich waters onto the shallow shelf areas of southeast Cook Inlet (Piatt, 1994). The islands are renowned for storm conditions and tidal rips as water moves in and out of the Cook Inlet (second highest tidal range in North America).

Field sampling

In Kachemak Bay, sampling occurred between 16 June and 26 July, 1995, and from February 8 until December 10, 1996. Weather and sea conditions prevented samples being collected in January and November of 1996. Sampling at Chisik Island occurred between July 3 and August 17, 1996, and at the Barren islands between June 26 and September 8, 1996.

Beach seining was the primary method of capture for nearshore fish in this study. This method of fishing provides a very effective, non-selective method for sampling shallow, inshore waters with sandy, or smooth bottom environments (Cailliet *et al.*, 1986). Out of a total of 305 sets made in 1995/96 between spring (May) and fall (September) only 4 sets caught no fish.

Beach seining during the summer of 1995/96 utilized a 44m long variable mesh beach seine. The net had 4m deep, 3 mm knotless nylon stretch mesh (sm) for the middle 15.3m and tapered to 2.3m deep with 13 mm knotted nylon sm in the wings. Thirty meters of rope was attached to each end of the seine for use in deployment. The net was set parallel to shore at a distance of 25 meters as described by Cailliet *et al.* (1986). Samples were collected approximately every two weeks from May to September and once per month through the winter. The beach seine used in the Barren Islands was smaller in size; 36.7m long by 4.9m deep, tapering to 1.0m deep at the wings. This net was constructed with a 4mm sm bag for the middle 9.1m, 13mm sm for the 3.0m inner wings, and 32mm sm for the outer 10.8m wings.

Beach seines in the 1976 season were made with a net 47.3m long by 3.7m deep, tapered to 1.0m deep in the wings. The 10.7m wide cod end was constructed of 7mm sm knotless nylon. The tapered wings were variable mesh with a 6.1m length of 13 mm sm followed by a 12.2m tapered outerwing of 38 mm sm. The net was deployed closer to shore (10m as opposed to 25m in 1995/96) which probably resulted in the increased catch per unit effort (CPUE) from 305 fish per set in 1976 to 511 fish per set in 1995/96.

Beach seining was carried out at 38 sites within Kachemak Bay. These sites were chosen as they were also visited by Blackburn (1980). Some sites visited by Blackburn were not sampled, either due to unsuitable substrates now being present (such as mussel beds) or from new beach-front housing development. Beach seining was carried out at eight sand substrate sites on the west side of the Chisik Island. Beach seining at the Barren Islands was carried out at one site (East Amatuli Cove) which provided the only logistically feasible location.

Beach seining was conducted within a one hour window either side of high or low tide to allow comparisons between the tidal states. To reduce habitat and tidal range variability, high tide/low tide comparisons were made during periods of maximum tidal range at a limited number of sites (6), which were sampled at the same time and frequency each month. Allen *et al.* (1992) state that a single seine haul provides a good representation of species richness and rank for the dominant species. To increase the representation of low-dominance species and to decrease the chance of missing schooling species that are moving along shorelines, each seining event consisted of two consecutive sets made adjacent to each other. Seining was not conducted in swells of over 0.5m which prevented the net being retrieved without the lead line repeatedly leaving the bottom (rolling) allowing fish to escape.

Once onto the beach, fish were immediately sorted by species and subsampled (by volume) if necessary. Fish needed for further analysis were placed into labeled plastic bags and subsequently either frozen or preserved in 10% formalin. All other fish were released alive. Lengths (fork-length in mm) and weights (0.01g) of collected fish were recorded. Species were identified using the keys of Hart (1973), Eschmeyer (1983), and Kessler (1985).

Comparisons with the nearshore beach seining samples were made with fish data collected by other methods. Cast netting (2.4m diameter, 13mm monofilament sm) was used to sample fish schools found close offshore being preyed on by feeding mellées of seabirds (usually black-legged kittiwakes *(Rissa tridactyla)*). Minnow traps and diver observations were used over neighboring rocky substrates to assess other fish species present that were not represented in beach seines. Mid-water trawls were used to sample the shelf environment using the Alaska Department of Fish and Game research vessel *Pandalus*. On transects of the study areas, forage fish abundance was recorded with a DT4000 digital 120kHz echosounder. Significant fish aggregations identified by these hydroacoustics were fished using a 9m-wide mouth modified herring trawl lined with a 3mm cod-end with collecting bucket. Mid-water trawling was monitored using a Furuno-net sounding system. Tow duration ranged from 20-60 minutes depending on fish concentrations. Recovered fish were identified, measured, and samples frozen for later analysis.

Water temperatures at the three study areas were collected using Onset Computer Corporation Optic StowAway temperature loggers (Version 2.02). These loggers were calibrated and programmed to read water temperature every 10 minutes. Weighted loggers were placed at 5m water depth below chart datum at 60 Foot Rock (Kachemak Bay), Snug Harbor (Chisik Island), and East Amatuli Cove (Barren Islands), moored either with line or 3mm stainless steel cable attached to a stainless steel expansion bolt drilled into rock. Information for the logger in Kachemak Bay was downloaded approximately every six months. Temperature loggers at Chisik Island and the Barren Islands were left in the water only for the duration of the field season. Sea surface temperature and salinity data (measured using the practical salinity scale) for shelf areas were recorded during CTD casts digitally on a Seabird SBE21 thermosalinograph.

Analyses

Four diversity indices were calculated. The Shannon-Wiener index (H') (Pielou, 1977) which increases as both the number of species (richness) and the equitability of species abundance (evenness) increase. For the species 'richness component' of diversity, Margalef's index (D) was calculated (Margalef,1969). For the equitability of species abundance, Pielou's evenness function (J') was used (Pielou,1977). Similarity between species lists from different sampling periods was tested using the Jaccard similarity coefficient for presence and absence data (Boesch, 1977). All diversity calculations are based on numbers of individuals and the use of natural logs ($\log_e$). Species assemblages were statistically compared using the Mann-Whitney rank sum test. All species were used for these calculations that occurred in at least one of the two communities being compared.

Results

Physical Environment

The only physical variable measured in the nearshore was temperature. Temperatures are depicted in Figure 2. The different effective depth of the loggers at spring and neap tides (due to being fixed to the substrate) explains the periodicity noted in the graphs. Kachemak Bay temperatures peaked at 10.4°C in early August and dropped to a minimum of (??) in ?? Cold oceanic water entering the Cook Inlet from the Gulf of Alaska, warms as it moves around the Cook Inlet past Kachemak Bay and subsequently past Chisik Island (Figure 1) which is observed in the nearshore temperature profiles (Figure 2).

Analysis of CTD results showed Cook Inlet waters to be well mixed except for Kachemak Bay where a notable summer thermocline exists at approximately 5m water depth due to freshwater glacial runoff into the bay (Figure 3). Shelf temperatures were similar in the Barren Islands and Kachemak Bay, but were notably warmer at Chisik Island. Salinities of shelf waters were highest in the Barren Islands (31-32), followed by Kachemak Bay (29-31), and then Chisik Island (29-30).

Temporal Comparison of the nearshore fish in Kachemak Bay between 1976 and 1995/96

Beach seines from the 1995/1996 period were limited to May 16 to September 27 (305 beach seines) to coincide with the 1976 sampling season (Blackburn, 1980). This data set was also used to compare between areas.

A total of 155,991 fish of 50 species were identified in Kachemak Bay during the May to September seasons of 1995 and 1996 (Table 1). Of these species 35 were caught primarily in their juvenile form. No species were caught in the winter that were not represented in the summer. Of the fish collected, Pacific sand lance was the most numerous comprising 71% of the total individuals. Along with Pacific sand lance, three other species, Pacific herring, Pink salmon, and Pacific cod comprised over 92 % of the total individuals. Great sculpins and Pacific sand lance were the most frequently caught fish during 1995/1996 occurring in over 50 percent of all catches. Dolly Varden were the third most commonly occurring species occurring in over 46 percent of catches.

Biomass results were collected in 1995 only. Of the species collected, Salmonids dominated the biomass comprising nearly 73% of the total. Of the remaining biomass Pacific sand lance and Pacific herring comprised nearly 60 percent. However, except for Dolly Varden, the results for salmonids are highly biased from one beach seine in Port Graham on 23 July when over 296 Kg of pink and chum salmon were caught (52% of biomass for all 60 beach seines conducted in 1995). Dolly Varden were consistently the dominant biomass in the nearshore environment throughout the summer until their departure into freshwater streams and rivers.

A total of 39,927 fish of at least 28 species (greenling and sculpins were not always identified to species) were collected during the 1976 field season in 131 sets (Table 1). For comparisons with 1995/96 data, all sculpin and greenling species were combined.

Of the fish collected, Pacific sand lance, as in 1995/96 was the most numerous comprising 81% of the total individuals. Pacific sand lance and Pacific herring alone made up over 93 % of the total individuals in 1976 compared to the four species in 1995/96. Four of the five dominant species by number caught in 1976 were the same as in 1995 (Pacific sand lance, Pacific herring, Dolly Varden, and pink salmon). Pacific sand lance and Pacific herring were the number one and two most numerous fish in both years of study. During 1976, only 4 (0.01%) of fish were gadids (3 saffron cod and 1 pacific cod). This figure increased to 7012 out of 155,991 (4%) in 1995/96 with Pacific cod the fourth most numerous fish caught for the time period. All four species of gadid exhibited a marked increase in frequency of capture (Table 1) indicating a dramatic increase in gadid populations between the time periods. Dolly Varden was the most important fish in relation to biomass in 1976. Rock sole as in 1995/96 was the most common flatfish caught in seines. As for gadids, rock sole appear to have also increased in number (both in relation to frequency of capture and numbers caught) since the 1970s.

Species diversity indices are summarized in Table 2 for the two time periods. The Shannon-Wiener index (H') was greater in the 1995/96 season compared to 1976 and reflects the large number of gadids only present during the 1990s (accounting for two thirds of the difference in H'). Species richness (D) was also higher in the 1995/96 season compared to 1976 as a result of four species comprising 92% of individuals in 1995/96 compared to 2 species comprising 93% in 1976. The low equitabilities (J') in both time periods reflect the high level of dominance in both of these assemblages by Pacific sand lance.

Jaccard's similarity coefficient indicated only a moderate (59%) similarity between the two time periods. Increased effort during the 1990s may partly explain this with 10 species caught only in one or two seines out of a total 305 which were not caught in 1976. These species may have been too rare in the nearshore to have been sampled by the 1976 sampling effort.

A significant difference in the species assemblages of 1976 and 1995/96 was noted for CPUE, percent composition, and frequency of capture (Mann-Whitney rank sum test; P=0.007, 0.018, 0.033 respectively).

Seasonal investigation of the Kachemak Bay nearshore fish community

Results from all 283 beach seines (130,325 fish of 46 species) made only in 1996 were used for the investigation of seasonal trends to alleviate inter-annual variation.

Winter beach seines showed the nearshore waters to be almost devoid of fish with no schools caught or observed between December and March. Juvenile rock sole and great sculpins were the most abundant fish in the nearshore during February and March. Numbers of juvenile great sculpins increased rapidly in the spring with an influx of small juveniles (<20mm). The occupance of these juveniles dropped by the end of June leaving a relatively steady inshore population of 2nd. year sculpins throughout the rest of the summer (Figure 4). Flatfish were caught at a similar rate throughout the spring and summer but were not found after October (Figure 4). In April Dolly Varden moved into the nearshore environment where they remained through July before following salmon into their freshwater natal systems to overwinter (as described by Isakson *et al.*, 1971, Orsi & Landingham, 1985).

During May, diversity within the nearshore rapidly increased with 20 species identified (Figure 5). Although the nearshore environment is dominated throughout the summer by Pacific sand lance, a diverse community is present with 31 species collected in June and July, and 34 in August. Fish move offshore in September with CPUE (Figure 6) dropping rapidly by October paralleled by a decline in species present from 34 in August to 3 in December (Figure 5).

Only one capelin was caught in 1976, 1995, and 1996 Kachemak Bay beach seines until October 1996 when 1586 1st. year capelin (and 1 2nd year) capelin were collected in three seines. Many other capelin in several large schools were visually observed at the same time. Capelin were also caught in 3 out of 8 seines during December.

Seasonal results for selected taxa are summarized in Figure 4. All species were present to a greater proportion during the summer months indicating an inshore migration to take place as the water warms in spring and an offshore migration at the end of summer. Pacific sand lance as noted by Blackburn (1980) move out of the nearshore in July with fewer numbers being caught at this time. Pacific herring also displayed this trend. However, only five herring catches of over 100 individuals in June and four in August at Halibut Cove contributed almost 99 percent of the total herring numbers for the year. The low frequency of capture of herring schools and resultant possibility of missing schools at a very limited range of sites (only the three Halibut Cove sites) may account for the low herring catch in July.

Catch per Unit Effort (CPUE) drops dramatically in mid-July for the nearshore community (Figure 6) as was also noted in 1976 (Blackburn, 1980). This is largely driven by the offshore Pacific sand lance migration but is compounded by two other species, pink salmon and Pacific cod. Large catches of juvenile pink salmon increase CPUE for June as they migrate along shorelines (Orsi & Landingham,

1985) but tail off rapidly in July as they move offshore (Blackburn, 1980). Large catches of gadids (particularly Pacific cod and walleye pollock) that do not appear in large numbers until August (Figure 4) increase the August CPUE. Adult Pacific sand lance appear to remain offshore longer, with August sand lance numbers dominated by 1st. year individuals; it is not until October that adult Pacific sand lance return to inshore waters to spawn (Blackburn, 1980; Dick & Warner, 1982).

Seasonal community indices are summarized in Figure 5. The Shannon-Wiener diversity index (H') and the Margalef index show diversity and species richness to steadily climb through the season, peaking in July before dropping rapidly through August to September and then increasing (although with vastly fewer individuals and species) into the winter. Evenness (J') drops throughout the season as Pacific sand lance dominate the nearshore summer community rising again in the fall with decreased number of species and individuals.

Comparisons between adjacent sets, tides, and years

Table 3 summarizes results of sets made immediately after the first during 1996 for selected species based on their abundant or common status (Table 1). The impact of disturbance from the first of a double set on an area may scare fish away or attract fish to a disturbed prey source. Results need to be analyzed for both frequency of occurrence as well as for CPUE. For densely schooling fishes, differing school size can markedly impact CPUE as seen for Pacific sand lance which were caught at a similar frequency at the 1st. and 2nd. set of low or high tide, but displayed markedly different CPUE results. This result may also be a function of disturbance disrupting school structure, so a less dense school is present in the nearshore for the second set. Although numbers of individuals caught on first and second sets varied, little difference was noted for frequency of capture, and no significant differences were observed for total catch, CPUE, or frequency of capture for consecutive sets at high or low tide (Mann-Whitney rank sum test; P>0.05).

Figure 7 displays results of sets made at adjacent high and low tides at the same sites. On high tides, 27 species were collected compared to 41 on low tides. Gadids were collected at almost twice the frequency at low tide as compared to high tide as well as in greater numbers. Juvenile Pacific sand lance displayed the most notable difference between high and low tide catches being caught both more frequently at high (47%) than low (30%), as well as in far greater numbers; cpue being approximately 7 times greater at high tide. Adult sand lance did not show this level of disparity between tides, being collected at a similar frequency and in similar numbers at either tidal state. Sculpins (predominately great sculpin) were collected more commonly and in greater numbers at low tide. The low tide result is strongly influenced by juvenile fish (<20mm) which were collected in large numbers at low tides during May and June. Flatfish (predominately rock sole) were collected in low numbers at high and low tide. However, they commonly occurred (over 50% of sets) in the low tide sets as compared to occasionally (13%) in high tide sets.

Species diversity index was higher at low tide compared to high tide (1.55 and 1.00 respectively). Species richness at high and low tides was similar (2.42 and 2.53 respectively). The equitability indices for high and low tides (0.30 and 0.42) indicated a higher degree of dominance for the high tide community resulting from the high proportion of Pacific sand lance in high tide sets.

Jaccard's similarity coefficient indicated a 62 percent similarity between the species assemblages of the two tidal states. A significant difference in the high and low tide species assemblages was noted for percent composition (Mann-Whitney rank sum test; P=0.031).

During June and July 1995, 27,944 fish of 42 species were caught in 60 beach seines. During June and July of 1996, 50,859 fish of 37 species were caught in 283 beach seines. Table 4 displays results of the comparison between sets made in June and July of 1995 and 1996. Forty four species were collected over the course of the two years in June and July of which 30 were caught in both years. Species diversity index (H') was similar for both 1995 and 1996 (1.21 and 1.22 respectively) as was species richness (D) (3.61 and 3.43 respectively) and equitability (J') (0.34 in both years).

Jaccard's similarity coefficient indicated a 68 percent similarity between the species assemblages of the two time periods. The species not represented in either year were generally rare species occurring in only a few seines. No significant difference in the species assemblages between 1995 and 1996 was noted for percent composition (Mann-Whitney rank sum test; P=0.815). The significant similarity between the 1995 and 1996 surveys as well as the close community indices supports the validity of beach seines for nearshore comparisons and the significance of the disparity between the 1976 and 1995/96 species assemblages.

Impact of substrate type in Kachemak Bay

Seining was restricted to the habitat types of sand and gravel. Areas of cobble were generally accompanied by boulders and bedrock causing snagging, and areas of substrates finer than sand were generally low angled mudflats of too shallow a depth to seine. This resulted in little variation in substrate type. However, one sheltered site at the south end of Halibut Cove was markedly different from the other sites in having a large mud component to the substrate. This site accounted for 78 percent of the total herring (juvenile) catch for the entire 1996 sampling period. The site is historically an important herring area in Kachemak Bay (Bucher and Hammarstrom, 1996).

Beach seines sample nearshore sandy substrates and were not used on neighboring rocky beaches or areas with mussel beds and other potentially net-snagging terrain. In conjunction with beach seining, fish traps and diver observations were used to assess presence of other species in areas close to those beach seined. The northern ronquil (*Ronquilus jordani*) was commonly seen by divers or found in fish traps over rocky substrates. This represented the only species observed in the nearshore, not caught in beach seines and is directly related to its habitat preference.

Cast netting was used in areas close offshore at sites of feeding mellées. Net avoidance is readily observable with cast netting which requires fish to be at the surface both to aim the cast as well as to allow the net to catch them. Of eight successful casts, five contained Pacific sand lance, and three capelin. Average numbers of capelin were much higher (2900 per cast) than for sand lance (774 per cast) which may reflect the greater ability of sand lance to avoid this type of capture. The occupance of large numbers of capelin close to shore (within 1km) shows them to be an important summer nearshore fish although not found in direct proximity to the littoral habitat sampled by beach seines.

The nearshore fish community of Chisik Island and the Barren Islands

A total of 988 fish of 24 species were caught in 30 seines in the nearshore waters of Chisik Island during the field season of 1996 (July 3 to August 17). The fish are listed in Table 5 and the corresponding common and scientific names given. Of the fish collected, Dolly Varden was the most numerous comprising 30% of the total individuals and frequently caught occurring in 63% of seines. Pacific sand lance did not dominate the community as seen in Kachemak Bay and the Barren Islands comprising 24% of the total individuals and occurring in 33% of seines. Pacific snake pricklebacks comprised 12% of the total individuals and Pacific cod 8%. The large amounts of mud in this system probably account for the low numbers of Pacific sand lance which require clean sand and gravel substrates in which to rest during periods of inactivity (Dick & Warner, 1982). Sculpins as for Kachemak Bay and the Barren Islands were frequently caught occurring in 53 percent of seines. Starry flounder although not the most numerically abundant flatfish (rock sole) was the second most frequently caught species occurring in 47% of seines exclusively as juveniles.

A total of 180,232 fish of at least 12 species (482 unidentified sculpins, 1 unidentified flatfish and 1 unidentified greenling) were caught in 40 seines in the nearshore waters of the Barren Islands during the field season of 1996 (June 26 to September 8). The Barren Island beach seine catches were dominated by Pacific sand lance (Table 5, Figure 8) which comprised over 99 percent of the catch (predominately juveniles) and occurred in 90 percent of all seines. Pacific cod occurred in over 50 percent of seines ranking 2nd., followed by sculpins occurring in over 40 percent of seines and butter sole (the dominant flatfish) occurring in 18 percent of seines. Pacific cod and pink salmon were the 2nd. and 3rd. numerically dominant species (503 and 449 individuals respectively).

CPUE results showed the Barren Islands to be the most productive nearshore waters of the three study areas followed by Kachemak and Chisik Island. The productivity (represented by CPUE) was vastly less at Chisik Island with only six percent and less than one percent of the CPUE found at this location. Chisik Island and Kachemak Bay displayed greater diversity and species richness than the Barren islands

(Table 2). The colder oceanic domain present in the Barren Islands appeared to reduce species diversity as compared to the warmer increasingly estuarine domains of Kachemak Bay and Chisik Island. Equity (J') was much greater at Chisik Island showing this community to be much less dominated by a particular species.

Comparison of nearshore and shelf communities

Mid-water trawls were made during July of 1996 at each of the study areas. Results are detailed in Table 6 and are summarized in Figure 8. Nine species were collected in mid-water trawls that were not present in any of the beach seine collections (Table 6). Mid-water trawls were much less diverse in the number of species present than for beach seines (Table 6). Kachemak Bay displayed similar proportions of the most abundant taxa between trawls and beach seines with Pacific sand lance dominating catches.. Mid-water trawls made at Chisik Island as for beach seines displayed no clear dominance with low numbers of all the most common species. The shelf environment of the Barren Islands was dominated by walleye pollock contrasting the dominance by sand lance in the nearshore where only a single walleye pollock individual was caught.

CPUE at Chisik Island was 27% and 11% of that found respectively at Kachemak Bay or the Barren Islands (Table 7) paralleling CPUE result for beach seines (Table2). Community diversity indices displayed similar trends to those found for nearshore beach seines (Table 2). Shannon-Wiener (H') diversity index and species richness (D) were highest for Chisik Island followed by Kachemak Bay and a large drop in diversity at the Barren Islands. Equity (J') was highest at Chisik Island followed by Kachemak Bay and a high level of dominance found in the Barren Islands.

The most notable difference between the different study zones was the large component of walleye pollock in shelf areas compared to sand lance in the nearshore areas. Overall for all shelf trawls walleye pollock occurred in 88% of sets compared to 3% of beach seines. Walleye pollock does not appear to use the nearshore environment as a nursery area as observed for related species such as the Pacific cod.

Discussion

Limitations of Study

The scope of the study, was affected by limitations of the equipment used. Sampling the nearshore environment with a beach seine is limited to sandy to cobble substrates. Mussel beds and rocky substrates prevent recovery of the net without snagging occurring, which allows fish to escape. Periods of high current or inshore swells of over 0.5m generally prevented effective retrieval of the net, thus fish preferring surf zone habitat may also be under represented. The surf zone is important or preferentially used by some species due to the low number of predators and food rich waters (Bennett, 1989). Fish that stay preferentially in these areas are therefore under represented by this study.

Allen *et al.* (1992) stated that beach seine catches of burrowing fish would be reduced due to their ability to escape under the net. Dick & Warner (1982) and Gordon & Leavings (1984) also raised doubt as to the adequacy of the beach seine as a sampling tool for sand lance with large schools observed avoiding the beach seine. Therefore Pacific sand lance, the dominant species within the nearshore areas of Kachemak Bay and the Barren Islands may occur to a greater degree than was observed by this study. Juvenile (both 0 and 1 group) cod have been shown to spend the day in deeper waters, moving into the nearshore at night (Keats, 1990; Methven & Bajdik, 1994). Therefore cod (as well as the other gadids) may be under-represented by our catches (made during daylight hours).

Nearshore fish community

The number of species collected in Kachemak Bay was high in comparison to other temperate nearshore investigations using beach seines as a sampling method. In Alaska, Hancock (1975) caught 17 species at Clam Lagoon, Adak, Isakson *et al.* (1971) found 40 species in the nearshore waters of Amchitka, and Orsi & Landingham found 42 species at southeast Alaska sites. Thorman (1986*a*) found 18 species in the Bothnian sea (Sweden), Allen & Horn (1975), Horn (1979), and Allen (1982) found 23, 21, and 32 species respectively in nearshore Californian locations. Nash (1988) found 33 and 23 species respectively at Ellingstad and Hvervenbukta in southern Norway.

Several investigators of northeast Pacific bay, estuarine, and inshore fish populations (e.g., Allen & Horn, 1975; Hancock, 1975; Horn, 1980; Allen, 1982; Gordon & Leavings, 1984; Orsi & Landingham, 1985) have observed five or fewer species usually comprise 75% or more of the total fishes sampled even though total number of species may be much larger. Our results dramatically highlighted this result with 4 species comprising over 92% of total numbers in 1995/96, and 2 species comprising over 93% in 1976 at Kachemak Bay. In the Barren Islands, 99% of total numbers was from sand lance alone. Chisik Island showed a different pattern with five species making up 79% of total numbers. These fish as stated by Allen (1982) were generally low in the trophic structure as would be expected by ecological patterns of relative abundance.

Great variation in diversity was noted in Kachemak Bay on a seasonal basis due to the paucity of species in the winter months. High latitude temperate fish assemblages, particularly those of shallow water habitats are subject to large seasonal variations in temperature and day length. These physical factors impart a strong natural seasonality to community structure (Nash, 1988) with fish leaving shallow waters in the winter at their lower thermal tolerance seeking warmer water offshore, as well as for some species to leave this area in the summer months as their upper thermal tolerance is reached. Results for Kachemak Bay paralleled many studies including Allen and Horn (1975), Allen (1982), and Bennett (1989) which have observed a general pattern of increased numbers of species and numbers of individuals during the late spring through fall period in nearshore waters. In the Gulf of Mexico fish were almost absent from the surf-zone during the winter months (Ross *et al.*, 1987), and Bennett (1989) only found about half the number of species to be present in winter on the southwestern Cape coast of South Africa. Livingston (1976), Horn (1980), Allen (1982), Thorman (1986*b*), and Methven & Bajdik (1994) in addition, also observed a summer depression in abundance between peaks in spring and fall. This was clearly observed in the CPUE for beach seines in Kachemak Bay although was not paralleled by a reduction in species number as seen by Thorman (1986*b*).

Allen (1982) states that the composition of fish assemblages in shallow areas depends to a great extent on water temperature and salinity. Temperature and salinity accounted for 83% of the variation in abundance of individual species collected in upper Newport Bay, California (Allen, 1982). Seasonal declines in catch during July at Kachemak Bay are probably related to temperature and salinity of nearshore waters, as well as to biological responses to predation, feeding, or spawning. Thorman (1986*a*) suggested that fish in exposed areas may avoid the shallowest regions remaining in slightly deeper less disturbed waters. This may be a factor, as well as temperature in the low numbers of individuals and species present in the nearshore during winter when there is generally increased wave action. The storm-prone nearshore areas of the Barren Islands displayed lower species number supporting Thorman (1986*a*) as well as Horn (1980) who stated unstressed fish assemblages tend to be higher in diversity.

Thorman (1986*b*) noted the average number of fish species is positively correlated with minimum salinity and total abundance is positively correlated with increased temperature. The increased diversity of Chisik Island over the Barren Islands or Kachemak Bay coincides with this observation. We expect that with a similar effort at Chisik to Kachemak Bay a similar or greater number of species would have been collected. However, our results contrast Thorman (1986*b*) in that the Barren Islands with the coldest waters had the highest abundance of fish. Thorman (1986*b*) states temperature to be the primary factor regulating abundance and recruitment of juveniles. Pacific sand lance, may be positively rather than negatively influenced by the cooler waters of the Barren Islands.

Chisik Island and Kachemak Bay, both heavily influenced by freshwater influence and characterized by substrates ranging from rock to mud exhibit the greatest range of habitat diversity of the three sites. These sites also exhibited the greatest number of species in accordance with Blaber *et al.* (1995) who suggested numbers of species present in inshore zones was positively correlated to increasing habitat diversity. Nearshore sampling in the Barren Islands was limited to one site reducing the diversity of sites being sampled. However, this site is one of the few sheltered sites in the islands with other beaches exposed to high wave action. These exposed, high energy beaches would not be expected to hold a high diversity species assemblage (Horn, 1980; Thorman, 1986*a*).

Salmonids as for other Alaskan nearshore studies were an important component of the nearshore community. Salmonids were the third ranked most important species by percent composition in

Kachemak Bay. Pink Salmon were second ranked by percent composition occurring in 23 percent of seines in a study of Clam Lagoon, Adak (Hancock, 1975). Orsi & Landingham (1985) found salmonids to be the dominant nearshore species in southeastern Alaska. Between March and June of 1981 and 1982 pink salmon fry dominated their catches comprising over 83 percent of the catch in both years.

Large catches of capelin by cast net, their occurrence in mid-water trawls, and in seabird (Reference) and halibut (Roseneau & Byrd, 1996) diets show them to be numerous in Cook Inlet waters, although not generally found in the nearshore zone. Capelin is of prime interest in this area due to its importance as a forage fish. Apart from three seines in October, 1996 in Kachemak Bay there has been little evidence of capelin occurring in the nearshore areas of Cook Inlet. Seasonal usage of the nearshore by capelin may impact catches, with this species occupying inshore waters outside the range of beach seines but inside our mid-water trawl survey area during the summer months. This may be a result of competition with sand lance in the nearshore environment. Capelin were documented sharply declining in the 1970s (Piatt & Anderson, 1996) and have been documented as returning to Cook Inlet waters during the 1990s (Roseneau *et al.*, 1996) and may become more prevalent in the nearshore in subsequent years as their numbers increase.

The apparent increase in gadids during the 1995/96 sampling period over 1976 was the most dramatic temporal difference between the species assemblages of Kachemak Bay. Gadids were not caught in significant numbers in the whole of Lower Cook Inlet during the 1976 survey, ranking ninth and comprising 0.2% (85 individuals in 262 seines) of the total catch (Blackburn, 1980). The increase in gadids between the 1970s and 1990s corresponds with a concurrent increasing trend in frequency of capture of gadids from the 1970s to present in offshore trawls (Bechtol, 1997). Houghton (1987) in a study of inshore fish habitats north of the Alaska peninsula (Bering sea coast) found walleye pollock, unlike for Kachemak Bay or Amchitka (Isakson *et al.*, 1971) to only occur offshore, whereas Pacific cod were also found inshore. Kachemak Bay's oceanic influence may explain the presence of pollock in the nearshore areas. Methven and Bajdik (1994) noted seasonal abundance of cod to peak in April to June and mid-August to November. Our results showed a small peak in gadid abundance in June with the proportion of gadids being caught in August supporting these results. The seasonality of fish such as Pacific cod needs to be taken into account in nearshore studies. Houghton (1987) studied consecutive years and found Pacific cod to be a numerically dominant species in 1984, but was not present in 1985. This was related to the shorter field season in 1985 which finished before the inshore migration of juvenile cod.

Pacific sand lance were the dominant inshore species north of the Alaska peninsula comprising 63% of the total catch (Houghton 1987) as was found in Kachemak Bay and the Barren Islands. Utilizing other fishing methods they found sand lance to be most abundant close to shore within the 6m isobath and were distributed widely and irregularly. Larger sand lance appeared to occur offshore which coincides with the apparent offshore movement of adult sand lance in midsummer before spawning inshore during early winter. Ganssle (1973) states that adults of the northern anchovy (*Engraulis mordax*) are less available in inshore waters during periods of warming and that young-of-the-year fish seem to tolerate higher temperatures than adults. This appeared to parallel the result noted for Pacific sand lance where adult sand lance were not caught throughout the period of maximum sea temperatures although first year fish were still present, although in much reduced numbers. This phenomenon of reduced adult sand lance numbers in mid-summer has also been noted via interpretation of seabird diets for Atlantic sand lance (Monaghan *et al.*, 1996). This period is a time of maximum predation by chick-rearing seabirds and mature sand lance may also avoid the nearshore and surface areas to avoid this predation.

Sculpins, as for Kachemak Bay were the most commonly caught species in studies of Clam Lagoon (Hancock, 1975) and Amchitka in the western Aleutians (Isakson *et al.*, 1971). However, unlike Clam Lagoon, they were not the numerically most important species in Kachemak Bay. Sculpins ranked second at Chisik Island and third at the Barren Islands for frequency of occurrence in beach seines.

Flatfish as for gadids displayed increased numbers and frequency of capture over results for the 1970s. This was in accordance with trends noted for the Gulf of Alaska by Piatt & Anderson (1996) with a general increase of the flatfish catch over the past twenty years.

Implications to Seabirds

Piatt & Anderson (1996) suggested forage fish abundance is directly related to seabird productivity. Large numbers of high quality, schooling, nearshore forage fish at the Barren Islands and Kachemak Bay provide a large easily accessible food base for seabirds. At Chisik Island, no large agregations of forage fish were observed in the nearshore or offshore areas. This forces Chisik Island seabirds to forage further afield with a resultant drop in nesting success. Pritchard ( ), Sirean & Irons, ( ) and Kuletz ( ) have all linked sand lance abundance to seabird productivity in areas of Prince William Sound, Alaska and Kachemak Bay. Sand lance abundance parallels the productivity for black-legged kittiwakes (a species using sand lance as it's primary food) noted at the three study areas. Sand lance due to their nearshore densely aggregated distribution and high energy value may be the principle component in 'sand lance selective' seabird productivity in the current system.

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Table 1. Totals and frequency of occurrence by species for the 1976 (May 21-September 29) and 1995/96 (May 16-September 27) sampling periods.

			1976[1] (131 Sets)		1995/96 (305 sets)	
STATUS	COMMON NAME	LATIN NAME	Total Fish	% Occurrence	Total Fish	% Occurrence
Abundant >50% of sets in at least one of the time periods	Dolly Varden	*Salvelinus malma*	790	51.1	1635	46.6
	Pacific Sand Lance	*Ammodytes hexapterus*	32490	40.5	110800	50.8
	Great Sculpin	*Myoxocephalus polyacanthocephalus*	120	32.8	484	56.7
Common 10-50% of sets in at least one of the time periods	Pink Salmon	*Oncorhynchus gorbuscha*	804	24.4	8589	39.0
	Rock Sole	*Lepidopsetta bilineata*	43	15.3	379	30.2
	Pacific Herring	*Clupea harengus pallasi*	4666	14.5	19808	17.4
	Pacific Cod	*Gadus macrocephalus*	1	0.8	4419	27.2
	Whitespotted Greenling	*Hexagrammos stelleri*	33	10.7	208	17.0
	Tubenose Poacher	*Pallasina barbata aix*	9	5.3	128	15.7
	Threespine Stickleback	*Gasterosteus aculeatus*	35	13.0	42	6.2
	King Salmon	*Oncorhynchus tshawytscha*	288	12.2	77	5.6
	Surf Smelt	*Hypomesus pretiosus pretiosus*	178	11.5	48	4.9
	Silverspotted Sculpin	*Blepsias cirrhosus*	1	0.8	156	13.8
Occasional 1-10% of sets in at least one of the time periods	Pacific Snake Prickleback	*Lumpenus sagitta*	54	6.9	177	5.6
	Chum Salmon	*Oncorhynchus keta*	8	3.1	786	7.5
	Saffron Cod	*Eleginus gracilis*	3	1.5	523	8.9
	Pacific Staghorn Sculpin	*Leptocottus armatus*	12	6.1	13	3.3
	Red Salmon	*Oncorhynchus nerka*	1	0.8	774	8.5
	Pacific Tomcod	*Microgadus proximus*	0	0.0	660	9.2
	Crescent Gunnel	*Pholis laeta*	5	2.3	59	4.9
	Starry Flounder	*Platichthys stellatus*	7	3.8	45	2.6
	Pacific Sandfish	*Trichodon trichodon*	0	0.0	45	6.2
	Kelp Greenling	*Hexagrammos decagrammus*	0	0.0	46	4.6
	Buffalo Sculpin	*Enophrys bison*	2	0.8	25	3.6
	Slender Eelblenny	*Lumpenus fabricii*	0	0.0	268	4.3
	Masked Greenling	*Hexagrammos octogrammus*	20	3.8	3	0.3
	Rock Greenling	*Hexagrammos lagocephalus*	0	0.0	47	3.6
	Lobefin Snailfish	*Polypera greeni*	0	0.0	16	3.3
	Lingcod	*Ophiodon elongatus*	2	1.5	5	1.3
	Butter Sole	*Isopsetta isolepis*	2	1.5	4	1.3
	Walleye Pollock	*Theragra chalcogramma*	0	0.0	1410	2.6
	Coho Salmon	*Oncorhynchus kisutch*	66	1.5	4	0.7
	Warty Sculpin	*Myoxocephalus verrucosus*	0	0.0	13	2.0
	Sablefish	*Anoplopoma fimbria*	0	0.0	52	1.6
	Longnose Prickleback	*Lumpenus longirostris*	8	1.5	0	0.0
	Northern Rockfish	*Sebastes polyspinis*	1	0.8	2	0.7
	Daubed Shanny	*Lumpenus maculatus*	0	0.0	7	1.3
	Flathead Sole	*Hippoglossoides elassodon*	0	0.0	6	1.3
	Sawback Poacher	*Sarritor frenatus*	1	0.8	1	0.3
Rare <1% of sets in at least one of the time periods	Soft Sculpin	*Gilbertidia sigalutes*	0	0.0	5	1.0
	Petrale Sole	*Eopsetta jordani*	0	0.0	12	1.0
	Prowfish	*Zaprora silenus*	0	0.0	2	0.7
	Padded Sculpin	*Artedius fenestralis*	0	0.0	3	0.7
	Pacific Halibut	*Hippoglossus stenolepis*	0	0.0	4	0.7
	Lemon Sole	*Parophrys vetulus*	0	0.0	2	0.7
	Capelin	*Mallotus villosus*	0	0.0	1	0.3
	Arctic Shanny	*Stichaeus punctatus*	0	0.0	1	0.3
	Yellow Irish Lord	*Hemilepidotus jordani*	0	0.0	1	0.3
	Ribbed Sculpin	*Triglops pingeli*	0	0.0	1	0.3
	Smooth Alligatorfish	*Anoplagonus inermis*	0	0.0	1	0.3
	Smooth Lumpsucker	*Aptocyclus ventricosus*	0	0.0	1	0.3

[1] 1976 data also includes: 28% sets with unidentified sculpins and 25% sets with unidentified greenlings.

Table 2. Summary of nearshore community parameters for Kachemak Bay (1976 & 1995/96), Chisik Island, and the Barren Islands.

Location	Year	CPUE	H’	J’	D
Kachemak Bay	1976	305	0.74	0.23	2.27
Kachemak Bay	1995/96	511	1.05	0.29	3.26
Chisik Island	1996	33	2.13	0.67	3.34
Barren Islands	1996	4506	0.06	0.03	0.91

Table 3. CPUE and (Frequency of Occurrence) on consecutive sets for high and low tidal states at Kachemak Bay for selected species.

Species	High Tide (142 Sets)		Low Tide (96 Sets)	
	Set 1	Set 2	Set 1	Set 2
Pacific Herring	1.7 (10)	0.7 (11)	0.2 (4)	35.3 (10)
Pink Salmon	37.3 (28)	21.4 (23)	3.0 (48)	17.8 (35)
Dolly Varden	3.0 (39)	8.5 (37)	5.7 (40)	2.8 (44)
Pacific Cod	3.4 (11)	4.7 (17)	18.5 (29)	13.5 (25)
1st. Year Sand Lance	892.9 (54)	156.6 (61)	67.5 (35)	11.7 (29)
Mature Sand Lance	5.2 (27)	9.5 (28)	48.4 (40)	4.6 (42)
Whitespotted Greenling	0.1 (6)	0.1 (6)	0.4 (23)	1.6 (25)
Silverspotted Sculpin	0.0 (0)	0.1 (3)	1.6 (25)	0.5 (27)
Great Sculpin	0.3 (44)	1.4 (56)	1.8 (58)	0.9 (50)
Tubenose Poacher	0.07 (7)	0.1 (8)	0.3 (17)	0.3 (10)
Rock Sole	0.1 (6)	0.3 (16)	3.0 (63)	2.4 (50)

Table 4. Comparison of nearshore fish catch at Kachemak Bay between 1995 and 1996 for species occuring in over 10 percent of seines.

	1995			1996		
Species	Frequency of Capture	% of Total Catch	CPUE	Frequency of Capture	% of Total Catch	CPUE
Sand Lance	75.0	66.6	310.2	67.2	60.0	250.1
Dolly Varden	68.3	1.8	8.5	55.7	1.8	7.5
Great Sculpin	68.3	0.7	3.2	49.2	0.2	1.0
Pink Salmon	51.7	3.0	14.0	52.5	13.8	57.4
Rock Sole	33.3	0.2	1.0	36.9	0.4	1.5
Pacific Cod	41.7	7.4	34.4	18.9	0.5	2.2
Herring	30.0	16.1	75.1	11.5	16.5	68.8
Whitespotted Greenling	20.0	0.2	0.9	21.3	0.1	0.5
Tubenose Poacher	31.7	0.3	1.3	11.5	>0.1	0.2
Silverspotted Sculpin	20.0	0.2	0.8	17.2	0.1	0.5

Table 5. Numbers of individuals caught in beach seines at Chisik Island and the Barren Islands.

		Chisik Island 30 Sets	Barren Islands 40 Sets
Pacific Herring	*Clupea harengus pallasi*	18	0
Pink Salmon	*Oncorhynchus gorbuscha*	21	449
Coho Salmon	*Oncorhynchus kisutch*	1	0
Red Salmon	*Oncorhynchus nerka*	1	0
Dolly Varden	*Salvelinus malma*	297	5
Surf Smelt	*Hypomesus pretiosus pretiosus*	0	22
Capelin	*Mallotus villosus*	13	135
Eulachon	*Thaleichthys pacificus*	3	0
Longfin Smelt	*Spirinchus thaleichthys*	5	0
Pacific Cod	*Gadus macrocephalus*	74	503
Pacific Tomcod	*Microgadus proximus*	2	0
Walleye Pollock	*Theragra chalcogramma*	0	1
Threespine Stickleback	*Gasterosteus aculeatus*	10	0
Pacific Sandfish	*Trichodon trichodon*	0	0
Pacific Snake Prickleback	*Lumpenus sagitta*	119	0
Crescent Gunnel	*Pholis laeta*	11	0
Prowfish	*Zaprora silenus*	0	0
Pacific Sand Lance	*Ammodytes hexapterus*	233	178601
Rock Greenling	*Hexagrammos lagocephalus*	1	1
Kelp Greenling	*Hexagrammos decagrammus*	0	5
Whitespotted Greenling	*Hexagrammos stelleri*	22	0
Lingcod	*Ophiodon elongatus*	0	13
Silverspotted Sculpin	*Blepsias cirrhosus*	2	0
Padded Sculpin	*Artedius fenestralis*	2	0
Pacific Staghorn Sculpin	*Leptocottus armatus*	2	0
Great Sculpin	*Myoxocephalus polyacanthocephalus*	32	0
Unidentified Sculpins		0	482
Sawback Poacher	*Sarritor frenatus*	5	0
Pacific Halibut	*Hippoglossus stenolepis*	1	0
Butter Sole	*Isopsetta isolepis*	0	13
Rock Sole	*Lepidopsetta bilineata*	62	0
Starry Flounder	*Platichthys stellatus*	51	0
Total Fish		988	180,232
Total Species		24	12

Table 6. Numbers of fish caugh in mid-water trawls at Kachemak Bay, Chisik Island, and the Barren Islands.

Common Name	Latin Name	Kachemak Bay 16 Sets	Chisik Island 6 Sets	Barren Islands 17 Sets
Walleye Pollock	*Theragra chalcogramma*	456	123	12,912
Pacific Sand Lance	*Ammodytes hexapterus*	3857	132	195
Capelin	*Mallotus villosus*	441	141	840
Pink Salmon	*Oncorhynchus gorbuscha*	413	44	0
Pacific Cod	*Gadus macrocephalus*	317	4	1
Pacific Sandfish	*Trichodon trichodon*	0	59	0
King Salmon	*Oncorhynchus tshawytscha*	0	19	0
Tadpole Sculpin	*Psychrolutes paradoxus*	16	0	0
Snailfish Spp.	*Cyclopteridae*	1	4	0
Eulachon	*Thaleichthys pacificus*	0	10	0
Prowfish	*Zaprora silenus*	9	0	1
Rock Sole	*Lepidopsetta bilineata*	2	1	6
Flatfish Spp.	*Pleuronectidae*	6	0	0
Armorhead Sculpin	*Gymnocanthus galeatus*	0	5	0
Sculpin Spp.	*Myoxocephalus Spp.*	2	0	1
Sculpin Spp.	*Gymnocanthus Spp.*	2	0	0
Dover Sole	*Microstomus pacificus*	0	2	0
Poacher Spp.	*Bathyagonus Spp.*	2	0	0
Smooth Alligatorfish	*Anoplagonus inermis*	0	2	0
Pacific Herring	*Clupea harengus pallasi*	0	1	0
Spinyhead Sculpin	*Dasycottus setiger*	0	1	0
Northern Sculpin	*Icelinus borealis*	0	1	0
Ribbed Sculpin	*Triglops pingeli*	0	1	0
Arrowtooth Flounder	*Atheresthes stomias*	0	1	0
Starry Flounder	*Platichthys stellatus*	1	0	0
Pacific Lamprey	*Lampetra tridentatus*	0	1	0
Total Fish		5525	552	13,956
Total Species		14	19	7

Table 7. Summary of shelf community parameters for Kachemak Bay, Chisik Island, and the Barren Islands.

	CPUE	H'	J'	D
Kachemak Bay	345	1.07	0.40	1.51
Chisik Island	92	1.89	0.64	2.85
Barren Islands	821	0.31	0.16	0.63

Figure 1. Map of lower Cook Inlet showing the three study areas and oceanography.

Figure 2. Seasonal variation in 1996 water temperatures at 5 m depth at Kachemak Bay (1), Chisik Island (2) and the Barren Islands (3).

Figure 3. Depth variations in physical parameters for shelf areas at Kachemak Bay (—), Chisik Island (····) and the Barren Islands (----).

Figure 4. Seasonal variations in nearshore abundance for selected species at Kachemak Bay. CPUE by month (bar graph) and frequency of occurrence (line graph).

Figure 5. Seasonal fluctuations of community parameters [number of species, species diversity (H'), evenness (J'), and species richness (D)] for the nearshore fish community of Kachemak Bay.

Figure 6. Seasonal variation in nearshore CPUE during 1976 (••••) and 1996 (—) at Kachemak Bay.

Figure 7. CPUE of major taxa caught in the nearshore on adjacent high (■ N=93) and low tides (□ N=90) during 1996 (February-October). Numbers are percent frequency of occurrence.

Figure 8. Percent composition of major taxa in the nearshore (■) and shelf (□) areas of Kachemak Bay, Chisik Island, and the Barren Islands.

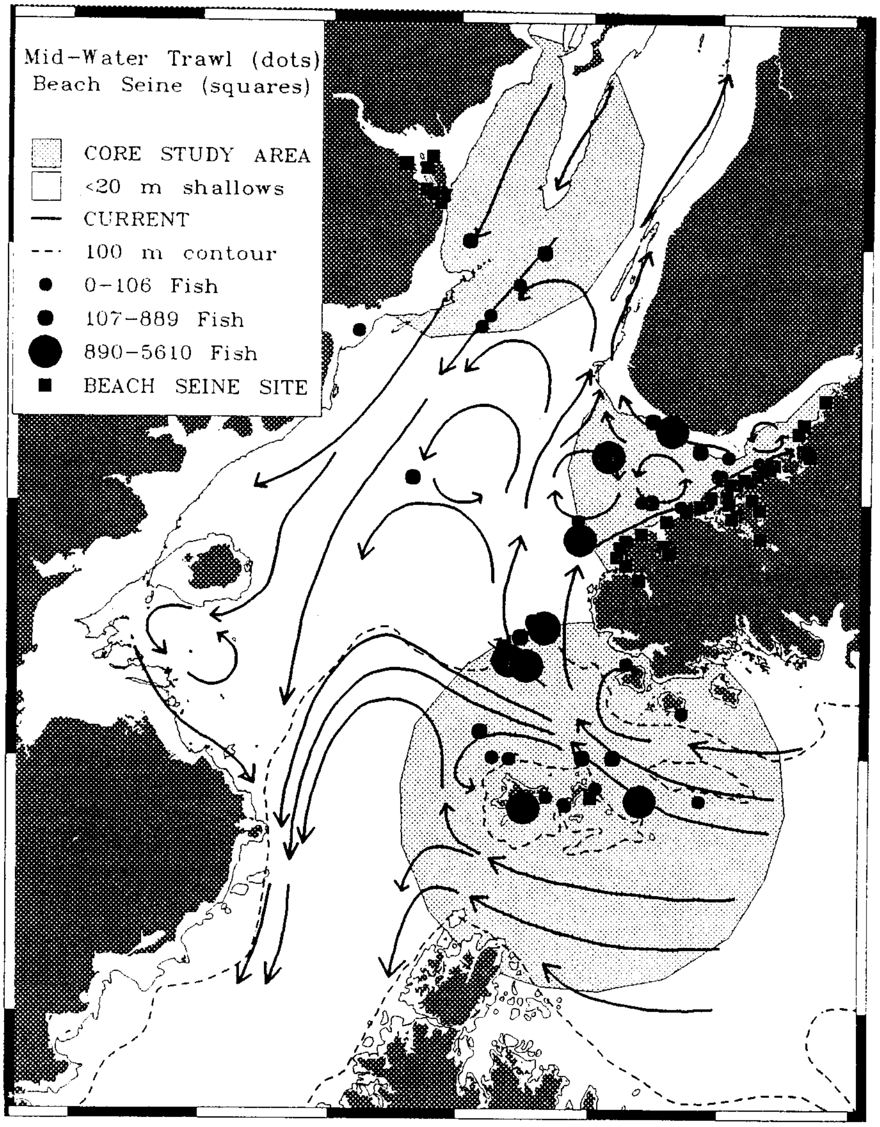
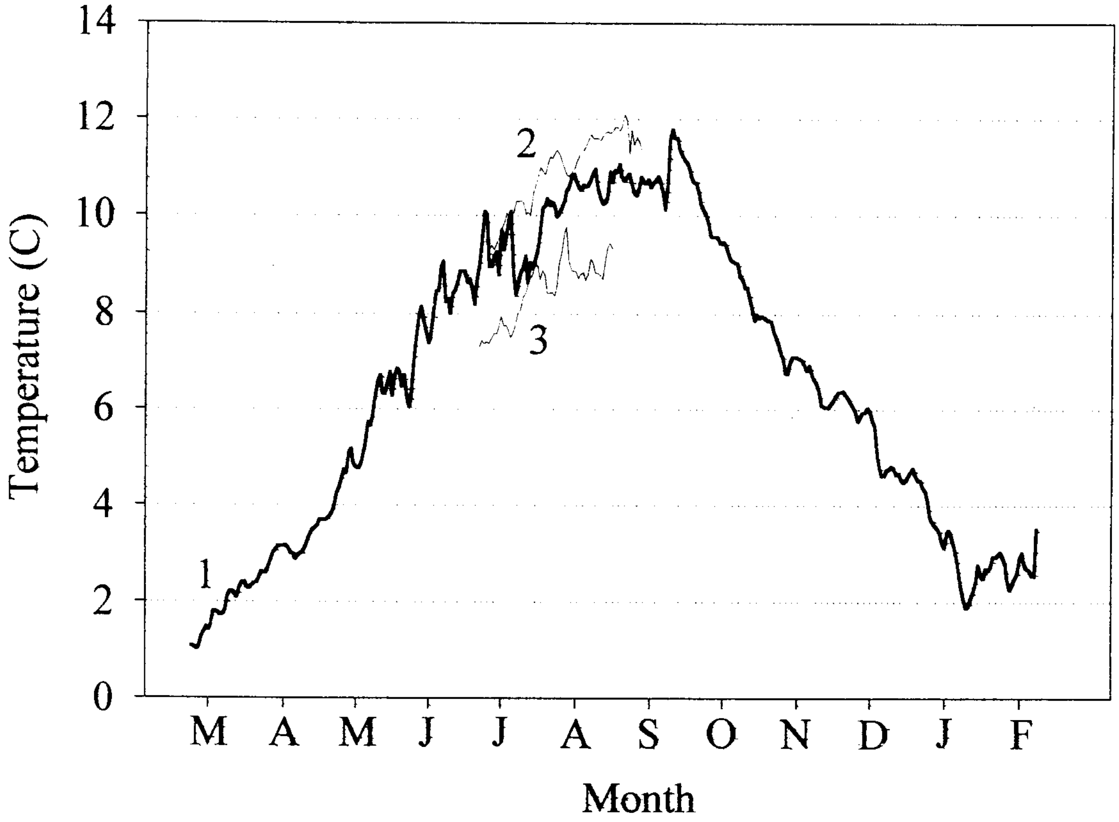

Mid-Water Trawl (dots)
Beach Seine (squares)
CORE STUDY AREA
<20 m shallows
CURRENT
100 m contour
0-106 Fish
107-889 Fish
890-5610 Fish
BEACH SEINE SITE

Figure 2



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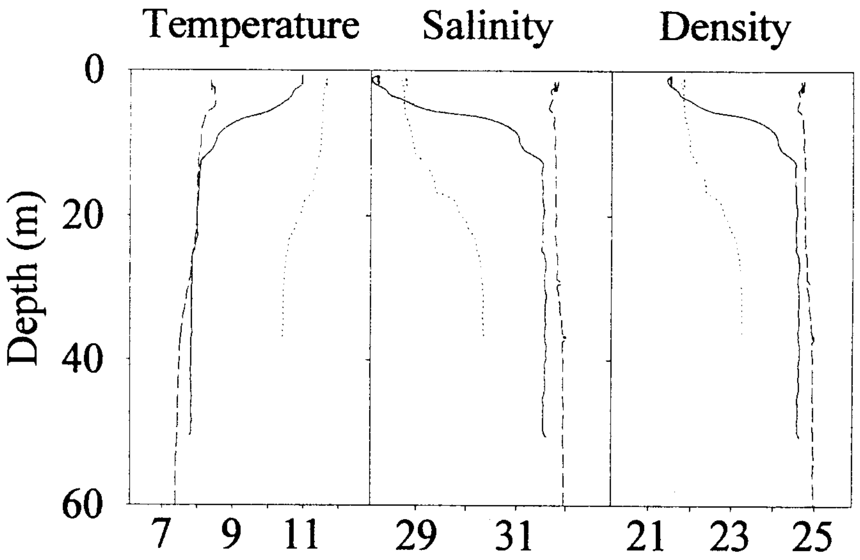
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Salinity
Density
Depth (m)
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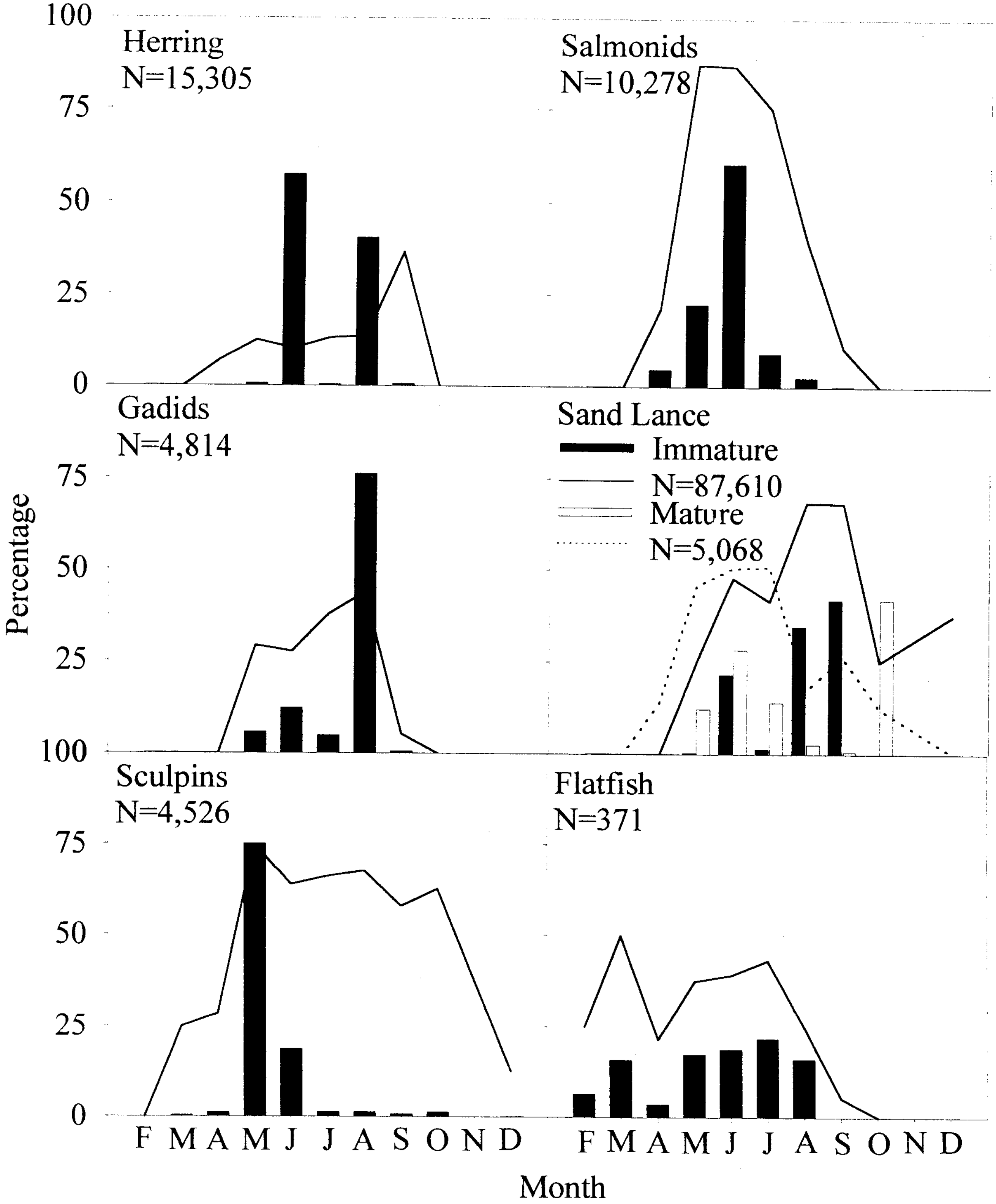
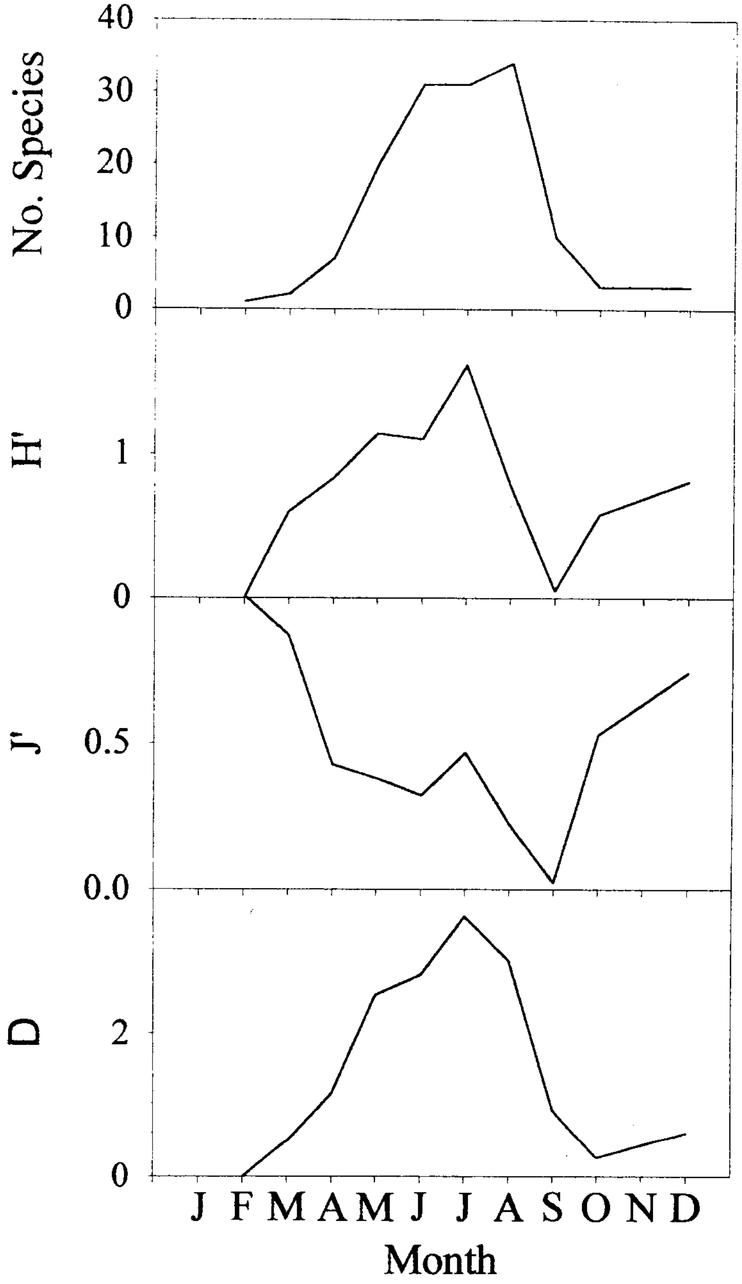
40
60
7
9
11
29
31
21
23
25



Herring
N=15,305
Salmonids
N=10,278
Gadids
N=4,814
Sand Lance
Immature
N=87,610
Mature
N=5,068
Sculpins
N=4,526
Flatfish
N=371
100
75
50
25
0
Percentage
F M A M J J A S O N D
F M A M J J A S O N D
Month

Figure [illegible]



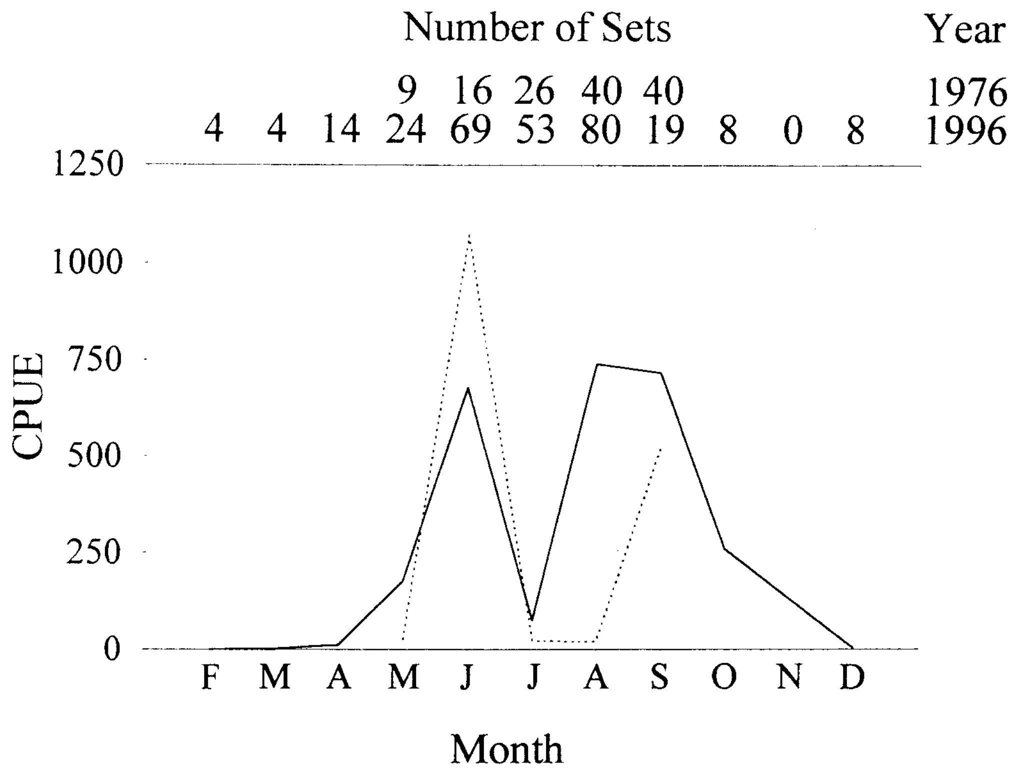
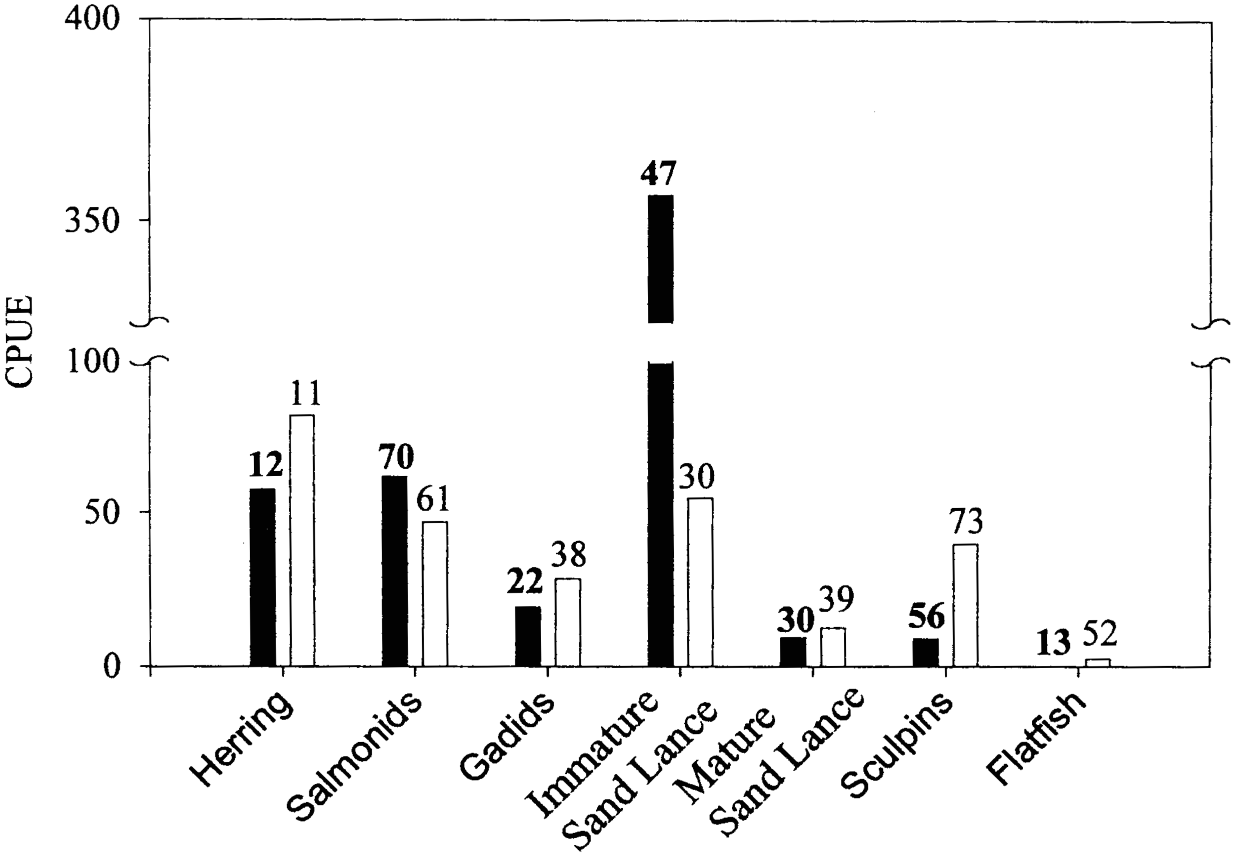
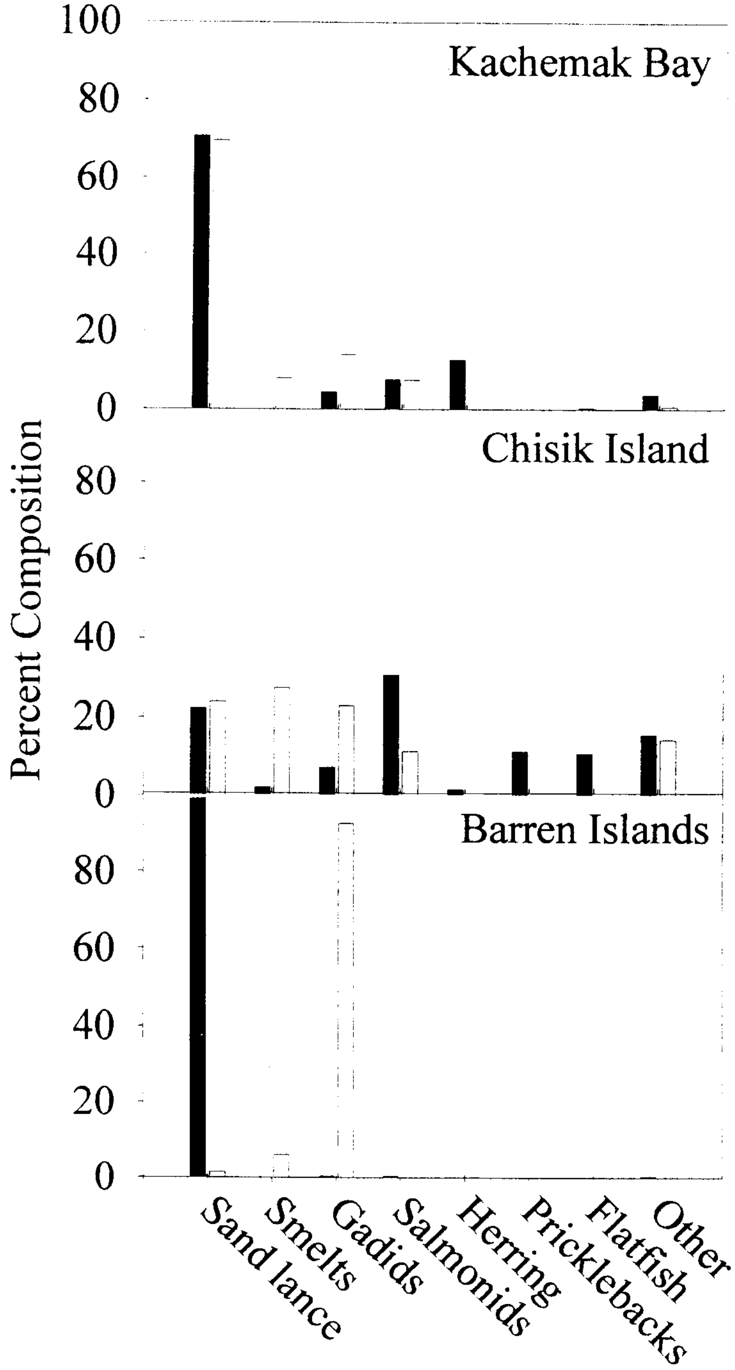

Number of Sets
Year
9 16 26 40 40
1976
4 4 14 24 69 53 80 19 8 0 8
1996
1250
1000
750
500
250
0
CPUE
F M A M J J A S O N D
Month

Figure 7



400
350
100
50
0
CPUE
47
12
11
70
61
22
38
30
30
39
56
73
13
52
Herring
Salmonids
Gadids
Immature Sand Lance
Mature Sand Lance
Sculpins
Flatfish



Percent Composition
100
80
60
40
20
0
Kachemak Bay
80
60
40
20
0
Chisik Island
80
60
40
20
0
Barren Islands
Sand lance
Smelts
Gadids
Salmonids
Herring
Pricklebacks
Flatfish
Other

Seabird Populations, Productivity and Behavior at Gull and Chisik Islands, Cook Inlet, in 1996

Stephani Zador, John F. Piatt, and Ann Harding

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Anchorage AK 99503

DRAFTof PRELIMINARY
RESULTS: November 1996

INTRODUCTION

Some seabird populations in the Gulf of Alaska have declined markedly during the past few decades (Hatch and Piatt 1995; Piatt and Anderson 1996). Whereas human impacts such as those from the *Exxon Valdez* oil spill can account for some proportion of these declines (Piatt et al. 1990), natural changes in the abundance and species composition of forage fish stocks have also affected seabird populations (Decker et al. 1994; Piatt and Anderson 1996). Marine fish communities in the Gulf of Alaska changed dramatically during the past 20 years (Anderson et al. 1994). Coincident with cyclical fluctuations in sea-water temperatures, the abundance of small forage fish species such as capelin (*Mallotus villosus*) declined precipitously in the late 1970's while populations of large predatory fish such as walleye pollock (*Theragra chalcogramma*) and cod (*Gadus pacifica*) increased dramatically. Correspondingly, capelin virtually disappeared from seabird diets in the late 1970's, and were replaced by juvenile pollock and other species in the 1980's (Piatt and Anderson 1996). Seabirds and marine mammals exhibited several signs of food stress (population declines, reduced productivity, die-offs) throughout the 1980's and early 1990's (Merrick et al. 1987; Piatt and Anderson 1996). Similar trends in oceanography, seabird population biology and prey availability have been noted in the Bering Sea, although the cycle there appears to be offset by 4-5 years from events in the Gulf of Alaska (Decker et al. 1994, Springer 1992).

Factors that regulate seabird populations are poorly understood, but food supply is clearly important (Cairns 1992). In many cases, anthropogenic impacts on seabird populations cannot be distinguished from the consequences of natural variability in food supplies (Piatt and Anderson 1996). Thus, 'management' of seabird populations remains an uncertain exercise. For example, how can we enhance recovery of seabird populations lost to the *Exxon Valdez* oil spill if food supplies in the Gulf of Alaska limit reproduction? Would commercial fishery closures reduce or increase food availability to seabirds? What are the minimum forage fish densities required to sustain seabirds?

We are attempting to answer some of these questions by studying seabird and forage fish interactions in lower Cook Inlet. Upwelling of oceanic water at the entrance to Cook Inlet creates a productive marine ecosystem that supports about 2-3 million seabirds during summer. More seabirds breed here than in the entire northeast Gulf of Alaska (including Prince William Sound) and concentrations at sea (up to 90 kg/km^2) are among the highest in Alaska (Piatt 1994). For these reasons, the greatest damage to seabirds from the *Exxon Valdez* oil spill occurred in lower Cook Inlet (Piatt et al. 1990).

Pilot studies were initiated in 1995. The overall objective was to quantify and contrast seabird-forage fish relationships at three seabird colonies in lower Cook Inlet: Chisik Island, Gull Island (Kachemak Bay), and the Barren Islands. The abundance and species composition of forage fish schools around each colony were quantified with hydroacoustic surveys, mid-water trawls, and beach seines. At each colony, we measured breeding success, diet composition, and foraging effort of several seabird species including: common murres, black-legged kittiwakes, pigeon guillemots, pelagic cormorants, glaucous-winged gulls, tufted puffins and horned puffins. Preliminary analyses indicate that the types and quantities of forage fish available to seabirds at each colony differed significantly, and this influenced breeding success of seabirds at each colony.

In 1996, this research program was refined and expanded where appropriate. For example, we increased hydroacoustic sampling of nearshore habitats, tried some new fishing techniques (pair trawls, cast-nets), increased study effort on some species of seabirds (pigeon guillemots, puffins, cormorants) and forage fish (sandlance), and increased coordination of seabird studies at the three colonies (for example, we synchronized feeding watches and census counts with respect to breeding phenology). The basic components of this study have not changed, however, and we will measure the same fundamental parameters of forage fish and seabird biology for the duration of the 10-year study (1995-2005).

This report details some of the results obtained at Gull and Chisik Islands, including population trends, breeding success, and time-activity budgets for several of the key species breeding at these islands. Results presented here will eventually be combined with those from the Barren Islands (data presently being analysed by the Alaska Maritime National Wildlife Refuge).

METHODS

Study Areas

Chisik: Chisik and Duck Islands (collectively referred to as Chisik) are located on the western side of lower Cook Inlet at about 60° 09' N, 152° 34' W (fig 1). Both are part of the Alaska Maritime National Wildlife Refuge. Chisik Island encompasses about 2606 ha, has a peak elevation of 815 m, and is located about 0.8 km from the mainland. Duck Island is 0.4 km east of Chisik, covers about 2.4 ha and reaches a maximum elevation of 49 m. Common murres (*Uria aalge*), black-legged kittiwakes (Rissa *tridactyla*), horned puffins (Fratercula *corniculata*), and in smaller numbers pelagic cormorants (Phalacrocorax *pelagicus*), double-crested cormorants (*P. auritus*), tufted puffins (F. *cirrhata*) glaucous-winged gulls (Larus *glaucescens*) and parakeet auklets (Cyclorrhynchus *psittacula*) nest on cliffs and talus slope of the islands. The gulls also nest throughout the vegetated interior portions of the island. The majority of the study was conducted at Duck Island, and personnel stayed at the Duck Island Camp. Two - three people occupied the camp from 22 June - 7 September. They commuted to study areas on Chisik by a 13' outboard- powered inflatable boat. All study sites on Duck were accessed by foot.

Gull: Gull Island is located in Kachemak Bay on the eastern side of lower Cook Inlet (fig 1). The island is situated 5 km southeast of the tip of Homer Spit at 59° 35' 10" N, 151° 19' 45" W and is owned by the Seldovia Native Corporation. This small island is composed of four rocky portions which connect at extremely low tides. The island is largely composed of steep rocky cliffs with a small vegetated area across the top. Murres, kittiwakes, pelagic cormorants, tufted puffins and in smaller numbers red-faced cormorants and horned puffins nest on the cliff faces and upper edges of the island. Gulls nest in all areas, but dominate the vegetated areas. The study was conducted on all accessible portions of the island, both by foot and from an outboard-powered, 4.8 m rigid-hulled inflatable boat. Due to limited accessibility and space, personnel commuted daily to the island by boat from a remote field camp 7 June - 4 September. Some monitoring was also conducted at 60-foot Rock, a small rocky island about 6 km south of the Homer Spit, which is part of the Alaska Maritime National Wildlife Refuge.

Productivity

Murres

Murre productivity data were collected at 7 study plots established in 1995 and 1996 on Chisik and Gull. These plots, each containing 7- 21 nest sites (defined as sites with eggs), were checked with 8 X 42 or 10 X 42 binoculars or 15 X 60 spotting scope every 2 - 4 days, weather depending. Each plot was checked from a specific observation point or blind; viewing distances varied between 3 - 200 m. Nest sites were mapped by hand and plots photographed. On each visit, nest sites were checked for adults, eggs, chicks, or adults in incubation or brooding postures. Plot checks were initiated when murres began to lay eggs (Chisik: 28 June, Gull: 30 June) and sites were followed until nest fates could be determined. Chicks last seen at age 15 days or older were considered to have fledged (Hatch and Hatch 1990). Mean productivity (chicks fledged per egg), hatching success (chicks hatched per egg), and standard errors were calculated by using plots as sample units. Differences were tested using t-tests.

On Gull Island an index of murre productivity was also calculated by counting the number of chicks per adult on a single visit to large subcolonies (69 - 103 chicks) just prior to peak fledging period.

Kittiwakes

Kittiwake productivity data were collected at 9 study plots on Chisik and 10 study plots on Gull established in 1995 and 1996. The majority of these plots, each containing 6 - 35 nests (defined as nest structures which contain eggs at some point during the breeding season), were checked with 8 X 42 or 10 X 42 binoculars and 15 X 60 spotting scope every 3-10 days during early incubation and every 3 - 5 days when chicks began to hatch. Four plots on Chisik were checked by using an extendable mirror pole held just above each nest to reflect the contents to the observer holding the pole below. Methods for mapping plots and collecting data were similar to those used for murres. Plot checks were initiated during the incubation period when personnel arrived at the colonies, and nests were followed until their fates could be determined. Chicks last seen at age 34 days or older were considered to have fledged (Hatch and Hatch 1990). Mean productivity (chicks fledged per nest), hatching success (chicks hatched per nest), clutch size, and standard errors were calculated using plots as sample units. Differences were tested using t-tests.

An index of productivity (chicks per active nest) was also calculated for kittiwakes on Chisik and Gull. Counts were taken through binoculars by two observers in a boat 5 - 30 m off shore. All nests on Gull and a large sample of nests on Chisik were counted 26 - 29 June at the period of mid-incubation. Active nests were defined as those which appeared to contain eggs, mainly inferred from adult incubation posture. The same areas were surveyed similarly for visible chicks 4 - 6 August, prior to peak fledging. Counts were averaged between observers.

Cormorants

Six double-crested cormorant nests on Chisik Island were monitored from Duck Island through a spotting scope 29 July - 12 August. Due to the great distance, observations were limited to counts of adults, nests, and chicks large enough to see over the nest rims. One additional nest on Duck was monitored similarly. Maximum productivity was calculated as the greatest number of chicks seen per active nest (defined as nests with adults seen in incubating posture for at least three consecutive checks).

On Gull, the contents of eighteen pelagic cormorant nests were checked with 8 X 42 or 10 X 42 binoculars three times during the incubation cycle and every 4 - 6 days during the chick-rearing period. Methods for collecting and analyzing data were similar to those used for kittiwakes on Gull, except means and standard errors are calculated using individual nests as sample units. Chicks last seen at age 41 days or older were considered to have fledged (Hatch and Hatch 1990).

Two pelagic cormorant nests on Chisik were checked by boat through binoculars nine times from 7 July through 2 September. Productivity was inferred by the observation of a chick in one nest during four consecutive checks.

An index of productivity (chicks per active nest) was calculated for all pelagic cormorant nests on Gull Island. Methods used were similar to those used for the kittiwake index count. Nests were counted 5 July, at mid-incubation, and all visible chicks were counted 23 August, just prior to the fledging period.

Puffins

Horned puffin productivity data were collected from fifty-five nests in four plots at Duck Island. All accessible nest sites were checked 4 - 5 July, during the period of mid-incubation. Those with both adults and eggs that could be directly observed were followed. Additional sites were added as found at later dates. Nests were checked for adults, eggs, chicks, or evidence of occupancy (fresh digging, guano, trampled vegetation) every 4 - 5 days or until nest fate could be determined. Chicks last seen at age 36 days or older were considered to have fledged. Mean productivity (chicks per egg), hatching success (chicks hatched per egg), and standard errors were calculated as for murres.

Gulls

On Gull Island, data on gull hatching success were collected from five plots that were established in 1995. Each plots contained 18 - 33 individually marked nests. Plots were checked every five days during incubation for nest contents and every 2 - 3 days when chicks were expected to hatch. Hatching success was determined as possible for each egg. Because chicks were not individually marked, only chicks which could be assigned to a nest by occupation or proximity were recorded as successfully hatched. Eggs with unknown fates due to chicks leaving the nest bowl were not included in hatching success calculation. Limited gull productivity data were collected at Chisik. During the late incubation/early chick-rearing period areas on Duck Island known to contain nesting gulls were searched for nests. Contents of all nests found 24 June were recorded, and nest containing eggs were revisited 29 June to determine egg fate. Due to the unknown number of eggs laid, an index of hatching success (chicks seen per nest) was calculated. The same index was calculated with Gull Island nests for comparative purposes. Differences were tested using t-tests.

Phenology

Median hatch date was chosen as the primary measure of nesting chronology. When the events were not observed, laying and fledging dates were determined using previously established ranges in incubation and chick departure days (Hatch and Hatch 1990). When nest status changed from egg to chick between nest checks, the mid- date between checks was used to establish hatch date. When an even number of days passed between observed status change, the later date was used. When greater than nine days between status change elapsed, hatching dates were not calculated. Hatching dates for cormorants on Chisik were not estimated because nest contents were never observed.

Populations

On Chisik Island, murres were counted 6 - 9 times on two previously established and three newly established population plots. Counts were taken between early incubation and early hatching periods by two observers with binoculars from a boat or a land-based observation point. Counts were taken between 1000 and 1600 hours, weather permitting, and averaged between observers. Mean plot populations were calculated using replicate counts as sample units. On Gull Island, murres were counted 8 - 10 times on twelve previously established population plots. A single count was also taken at ten new population plots established and photographed this year. Counts were made and data analyzed using similar methods to those used at Chisik.

On Chisik and Gull, kittiwakes, cormorants, and gulls were counted 6 - 10 times on 8 and 12 plots respectively. All counts were made by observers in a boat. Gulls were also counted 6 times on two gull population plots (one counted from land, one from a boat) established on Duck Island this year. Counts were made and data analyzed using similar methods to those used for murres.

Horned and tufted puffins on and around Duck Island were counted twice during the late incubation/early hatching period. Counts were taken between 2100 - 2135, the period of highest estimated activity, by two observers circumnavigating the island by foot. All birds in the air and on the water within 200 m of the shore were counted. Counts were averaged for mean population indices.

Time-Activity Budgets

Murres

On Chisik Island, continuous diurnal observations of incubating and brooding murres were conducted by observers alternating shifts in a blind 8 - 30 m away. Observations of arrivals, departures, incubation and brooding shift exchanges, feeding, and prey type and size, if possible, were made through 8 X 42 or 10 X 42 binoculars. Activity was recorded to the nearest minute. Three watches were conducted between 0500 - 2259 on 11 sites with incubating murres . Seven watches were conducted between 0600 - 2159 on 7 - 10 sites during the chick-provisioning period. Total numbers of arrivals, departures, and nest exchanges were recorded for each site each day. Total numbers of chick feedings and minutes of adult attendance were recorded for each site each hour and totaled for each watch. Hourly adult attendance was recorded in bird-minutes, derived from the total number of minutes each adult spent at the nest site in an hour (e.g. a site continuously occupied by 1- 2 adults would have a range of 60 - 120 bird-minutes of attendance). Nest exchanges that occurred between two adults within one minute were not recorded as additional nest attendance. Foraging trip lengths, the number of minutes elapsed between each observed adult departure and subsequent arrival, were calculated and analyzed for all sites in each watch. Diurnal patterns of adult attendance and numbers of chick feedings were analyzed for each site for each watch.

On Gull Island, a time-lapse video camera was used to record the same murre activities observed on Chisik. The camera was set to include 10 viewable murre sites within the picture frame, and the connected video recorder taped four still frames per second from 0600 - 2159. Personnel pre-programmed the camera to record and retrieved the videotape when taping was completed. The tapes were later viewed on a color monitor by 2 - 4 observers. All visible activities at the nest sites were recorded to the nearest full minute. Data were summarized and analyzed as described for the murre activity watches at Chisik.

Mean adult attendance, chick feeding rates, adult trip lengths, and number of next exchanges were compared between colonies. Differences in time-activity budgets were tested with analysis of variance (ANOVA), Kruskal-Wallis ANOVA, Mann-Whitney Rank Sum Tests, and t-tests. Correlations with time were tested by Pearson Product Moment Correlation (PPMC).

Kittiwakes

On Chisik Island, kittiwake nests were observed from 0500 - 2259 once during incubation, once during late incubation/early chick provisioning (nests analyzed separately), and three times during the chick provisioning period. Six to ten nests were observed in each watch. On Gull

Island, activity data at kittiwake nests were recorded from 0600 - 2159 twice during incubation and three times during the chick provisioning period. Eight to twelve nests were observed in each watch. Data were collected and analyzed using similar methods as described for murres on each island. Only the first bout of chick feeding from an adult that had previously been away from the nest for more than 30 minutes was recorded. As chick feeding was often difficult to discern on the videotapes, all apparent attempts were recorded at Gull Island but not included in the analyses. Differences in time-activity budgets were tested with ANOVA and t-tests.

Cormorants

On Gull Island, activity data at two pelagic cormorant nests were recorded from 0600 - 2159 four times during the incubation period and twice during the chick provisioning period. Data were collected using the same methods as described for murres on Gull and have not yet been analyzed.

Chick Growth Rates

Murres

On Chisik and Gull Islands, a sample of 15 - 30 unmarked murre chicks of unknown age were weighed and measured three times. Personnel visited the colonies at dawn or after sunset during the early, mid, and late chick-rearing periods and attempted to measure a representative sample of chicks of varying ages. Weight in grams, flattened wing chord to the nearest millimeter, and culmen to the nearest 0.1 millimeter were recorded for each chick. Personnel time in the colony was limited to 30 minutes. Mean mass as a function of wing length was plotted for all data. The linear phase of mass increase was determined to be between wing lengths of 30 - 40 mm by plotting mean mass as a function of wing length. For all measurements within the linear phase, mass was divided by wing length to derive an index of body condition. These values were averaged for each island and differences compared using t-tests.

Kittiwakes

On Chisik and Gull Islands, individually marked and/or known kittiwake chicks were weighed and measured every five days. Chicks with unknown hatch dates were aged using data from known-age kittiwake chicks in Shoup Bay, AK. Growth rate data were collected on 11 kittiwake chicks at Chisik and 34 chicks on Gull. Weight to the nearest gram, flattened wing chord to the nearest millimeter, and culmen and head-plus-bill length to the nearest 0.1 millimeter were recorded on each visit. Chicks at Gull Island were banded with stainless steel USFWS bands when they weighed over 250 g to distinguish twins and identify any chick movement between nests. Chicks were followed until their fates were determined. The linear growth phase was determined to be between 6 - 22 days by plotting mean mass at each age and choosing the period with the most linear increase. Least squares regression were calculated for each chick within the linear phase and values averaged for each island. Differences between islands were compared by t-tests.

Puffins

Nineteen horned puffin chicks at Duck were weighed and measured every 4 - 5 days until their fates were determined. Weight in grams, flattened wing chord to the nearest millimeter, and culmen to the nearest 0.1 millimeter were recorded on each visit. The linear growth phase was determined to be between 8 - 32 days by plotting mean mass at each age and choosing the period with the most linear increase. Least squares regression were calculated for each chick within the linear phase and values averaged for the island.

Chick Diets

Murres

On Chisik and Gull Islands, murre chick diet composition was determined from sample collections and provisioning observations. Murre chicks meals were collected opportunistically when personnel were in the colonies to measure chicks. All fish seen on the colony substrate were collected, identified, and preserved. Additionally, adults carrying fish were observed with binoculars from blinds or observation points. Personnel recorded every meal delivery into the colony and identified the prey type to lowest practical taxonomic level and estimated prey size in relation to murre bill length when possible. Unidentified prey were included to avoid biases towards easily identifiable species. Percent composition was calculated for all items collected on each island. Differences between islands were tested using Z tests with Yates correction.

Kittiwakes

Kittiwake chick regurgitants were collected opportunistically while handling chicks or induced through gentle throat massage. Special effort was taken to collect samples throughout the chick provisioning period. All samples were placed in individual bags, numbered, and preserved shortly after collection. Data have not yet been analyzed.

Puffins

Samples of horned puffin chick meals were collected on Duck Island throughout the chick provisioning period. Two methods were used. In one method, wire mesh screens were placed over nest crevice entrances to block returning adults and cause them to drop any prey items. The other method involved spreading a fine mesh gill net over an area with several puffin nest entrances in hopes of temporarily entangling returning adults and causing them to drop their prey. Both screens and nets were in place for 1.5 - 2 hours, then collected along with any samples. In additions, opportunistic sightings of dropped prey were collected. All samples were bagged, numbered, labeled with collection method, and preserved. Diet composition was calculated by individual fish and by bill load for all items collected.

Statistical Analyses

All statistical analyses were performed using SigmaStat (v. 2.0, Jandel Scientific Software). All means are reported pus or minus one standard error.

RESULTS

Productivity

Murres

Murre productivity was high at both Chisik (0.78 ± 0.04, n = 7) and Gull (0.87 ± 0.05, n = 7). There was no significant difference between the two values (t-test, df = 12, p = 0.185). Hatching success was similarly high at both colonies (Chisik: 0.82 ± 0.04, n = 7; Gull: 0.92 ± 0.03, n = 7). There was no significant difference between the colonies (t-test, df = 12, p = 0.069). The hatching success value at Gull may be a maximum value, since early egg loss may have been unaccounted for as nest observations were initiated as active sites were found.

Productivity appeared low at Gull based on index estimates. The mean number of chicks per adult in a single visit to two additional plots was 0.22 (n = 169 chicks).

Kittiwakes

Kittiwakes exhibited near reproductive failure at Chisik (0.05 ± 0.03 chicks fledged per nest, n = 9), but produced many fledglings at Gull (0.87 ± 0.10, n = 10) (t-test, df = 17, p = <0.001). At Chisik, great loss occurred during the chick stage. There was no significant difference in hatching success in the same plots at each island (Chisik: 0.71 ± 0.04; Gull: 0.71 ± 0.04; t-test, df = 17, p = 1.0). Mean clutch sizes were significantly higher at Chisik (1.85 ± 0.02) than at Gull (1.69 ± 0.05) (t-test, df = 17, p = 0.011)

The index productivity estimate at Chisik (0.05 chicks per nest, n = 2489) reflected productivity in the closely monitored plots. On Gull, the index productivity estimate (0.56, n = 5152) was somewhat lower than that seen in the plots.

Cormorants

An estimate of pelagic cormorant productivity at Chisik was limited to one nest which appeared to fledge a single chick. A second nest which disappeared early in the season likely did not contain any eggs. Pelagic cormorant productivity at closely monitored nests at Gull was high (1.83 ± 0.31, n = 18) and not significantly different from estimated productivity for all cormorants on the island (1.59 ± 0.14, n = 87)(t-test, df = 103, p = 0.48). Hatching success was also high in the closely monitored nests (0.77 ± 0.08, n = 20). Clutch size in these nests varied (3.1 ± 0.25, n = 20).

Estimated red-faced cormorant productivity at Gull was high (2.75 ± 1.11, n = 4).

Double crested cormorants appeared productive at Chisik. A maximum production value of 1.71 was estimated from the greatest number of large chicks discerned in eight nests.

Puffins

Horned puffin productivity at Chisik was fairly high (0.66 ± 0.07, n = 4), only somewhat lower than hatching success in the same plots (0.86 ± 0.07). Based on observed adult activity and the sighting of a large chick, the two horned puffin nests at Gull most likely fledged chicks.

Gulls

Based on an estimate of chicks per nest, gull hatching success per nest at Chisik (1.81 ± 0.16, n = 32) was significantly higher than a similar estimate at Gull (1.19 ± 0.10, n = 124)(t-test, df = 154, p = 0.004). However, hatching success per egg in closely monitored plots at Gull was lower (0.68 ± 0.03, n = 5). Mean clutch size in all nests was 2.37 ± 0.08 (n = 124).

Phenology

Murres

The median hatch date at Chisik was 10 August (range: 28 July - 20 August) and at Gull was 13 August (range: 3 August - 3 September). Murres at Chisik hatched significantly earlier than those at Gull (Mann-Whitney Rank Sum Test, p = <0.001).

Kittiwakes

The median hatch date at Chisik was 2 July (range: 27 June - 25 July) and at Gull was 8 July (range: 28 June - 29 July). Kittiwakes at Chisik hatched significantly earlier than those at Gull (Mann-Whitney Rank Sum Test, $p = <0.001$).

Cormorants

The median hatch date for pelagic cormorants at Gull was 10 July (range: 8 July - 5 August). Hatching was not be observed at Chisik.

Puffins

The median hatch date at Duck was 23 July (range: 15 July - 5 August). Hatching was not observed at Gull.

Gulls

Although early hatching was not observed at Chisik, hatching appeared to be much earlier at Chisik than at Gull. The median hatch date at Gull was 2 July (range: 28 June - 18 July). In contrast, all eggs on Chisik had hatched by 29 June.

Populations

Murres

The mean number of murres on plots at Chisik was 162 ($n = 9$). This value continues a declining trend from previous years (fig 2). The mean number of murres in newly established plots was 76 ($n = 6$). Expanding our monitoring effort in newly established plots will further document this trend. The mean number of murres on plots at Gull was 327 ($n = 10$). This value has decreased slightly in the past year, but continues a generally increasing trend in numbers in the past ten years (fig 3).

Kittiwakes

Mean numbers of kittiwakes (741, $n = 6$) and nests (714, $n = 3$) in plots at Chisik have increased slightly in the past year, continuing an unclear trend in population fluctuations (fig 4). Overall numbers of adults and nests have declined from counts in 1986. Mean numbers of kittiwakes (1175, $n = 10$) and nests (816, $n = 6$) on plots at Gull decreased slightly, yet overall numbers continue to remain stable (fig 5).

Cormorants

Mean numbers of pelagic cormorants (31, n = 10) and nests (20, n = 6) in plots at Gull declined in the past year. However, excluding a substantial drop in 1992, numbers of cormorants and nests have remained generally stable in the past ten years (fig 6).

Puffins

The mean number of horned puffins counted on Duck Island was 864 ± 67.38 (n = 2). The mean number of tufted puffins counted was 9 ± 2.13 (n = 2).

Time-Activity Budgets

Murres

For all watches combined, murres at Gull spent on average 68.9 ± 0.81 minutes per hour at the nest sites (n = 92), while murres at Chisik spent 62.9 ± 0.49 minutes per hour at the nest site (n = 163) (fig 7). Breeding murres at Gull spent significantly more time at their nest sites than those at Chisik (t-test, df = 14, p = 0.036). Patterns of attendance over the season were similar between islands. Both islands showed highest average attendance in watches during early incubation. Attendance declined at both colonies as the season progressed. Mean hourly attendance on the final watch at Chisik (52.7 ± 1.77) dropped below sixty minutes due to repeated desertion of chicks by some adults.

Daily patterns generally show higher mean attendance in the latter half of the day. Highest hourly values for all watches at Gull occurred between 1500 and 2159. During incubation, Chisik murre attendance showed the same general pattern as on Gull, but during the chick-rearing stage, highest hourly attendance occurred between 0700 - 1259.

Both chick feeding rates and adult trip durations showed strikingly different patterns between islands. For the entire provisioning period, the mean feeding rate at Gull was 5.03 ± 0.82 deliveries per chick per hour (n = 3) and at Chisik was 2.58 ± 0.29 (n = 3)(fig 8). Murre chicks at Gull were fed significantly more often than those at Chisik (Mann-Whitney Rank Sum Test, p = 0.009). Daily mean feeding rates at Gull differed significantly (Kruskal-Wallis ANOVA on ranks, p = 0.028) and increased as the season progressed (PPMC, r = 0.439, $p < 0.050$). The daily mean feeding rate at Chisik on one day (20 August) was significantly higher than that on two other days (12 and 19 August)(ANOVA, $P < 0.05$), but there were no other significant differences between days. Daily mean feeding rates were not correlated with date (PPMC, r = 0.119, p = 0.399). Rates remained relatively level over the season.

Over the same period, mean adult trip duration at Gull was 129.37 ± 9.45 minutes (n = 127) and at Chisik was 242.9 ± 20.56 (n = 107)(fig 9). Murres at Gull spent significantly less time away from their nest sites that those at Chisik (Kruskal-Wallis ANOVA by ranks, P = <0.001). Daily mean trip durations at Gull differed significantly between watches (Kruskal-Wallis ANOVA on ranks, p = 0.001) and decreased as the season progressed (Pearson Correlation, p < 0.001). At Chisik there was no significant difference between daily mean trip durations (Kruskal-Wallis, p = 0.234), nor any correlation between feeding rates and date (Pearson Correlation, p = 0.959).

There was no significant difference between the mean number of exchanges of incubation duty between adults at the nest sites at Chisik (0.94 ± 0.14, n = 33) and Gull (1.17 ± 0.14, n = 35)(t-test, df = 66, p = 0.250). However, the number of exchanges during the brooding period at Gull (3.27 ± 0.73, n = 30) was significantly higher than that at Chisik (2.07 ± 0.15, n = 61)(t-test, df = 89, p = 0.032).

Kittiwakes

Adult kittiwakes at both islands spent little time at the nests when not incubating or brooding. Average hourly nest attendance at Chisik was 58.84 ± 0.46 minutes per hour (n = 88) and at Gull was 59.85 ± 0.40 (n = 68). A t-test detected no significant difference between the values (df = 154, p = 0.111). Daily mean values generally remained constant over the season, but dropped below sixty during the mid and late chick-rearing period at Chisik (59.2 ± 0.6; 54.1 ± 1.91) and late chick-rearing period at Gull (56.6 ± 4.04), when chicks were periodically left unattended.

The mean number of adult exchanges at the nests during the mid - late chick-rearing period at Chisik was 2.75 ± 0.52 (n = 12) and Gull was 4.11 ± 0.55 (n = 18) An ANOVA detected no significant difference between the values (p = 0.099).

During the mid-late chick-rearing period, the average time spent away from the nest site by the off-duty kittiwakes at Chisik was 215.17 ± 29.77 minutes per trip (n = 29), whereas at Gull the average duration was 137.6 ± 8.49 minutes (n = 90). Kittiwakes at Chisik were away for significantly longer periods of time than those at Gull (ANOVA, p = 0.030).

Cormorants

Data have not yet been analyzed.

Chick Growth Rates

Murres

During the linear growth phase, chick body condition at Chisik was 3.93 ±0.12 grams per mm wing length (n = 44), while those at Gull were 4.25 ± 0.19 grams per mm wing length (n = 25). A t-test detected no significant difference between values at each island (df = 67, p = 0.139).

Kittiwakes

During the linear growth phase, the average growth rate of all chicks at Chisik was 11.07 ± 1.87 grams per day (n = 11), while the average rate at Gull was 16.64 ± 0.61 grams per day (n = 34). Growth rates were significantly higher at Gull than at Chisik (t-test, df = 43, p = <0.001).

Puffins

During the linear growth phase, the average Horned Puffin chick growth rate was 9.43 ± 0.79 grams per day (n = 14).

Chick Diets

Murres

Murre chick diets at Chisik and Gull Islands comprised mainly capelin, sandlance, gadids, salmonids, and to a lesser degree, pricklebacks, genus *Lumpenus* (n = 368). Smelt and sandfish were prevalent in chick diets at Chisik only, comprising 33% and 7% of identifiable prey items respectively. There was no significant difference between islands in the proportion of capelin, sandlance, gadids and salmonids in total identified prey. Proportion of *Lumpenus* in diets at Chisik (1%) and Gull (3%) differed significantly (z-test with Yate's correction, p = 0.002).

Kittiwakes

Collections have not yet been analyzed.

Puffins

Sandlance dominated horned puffin chick meals at Chisik. Ninety-three percent of fish delivered to chicks were sandlance. The remainder were mainly capelin (4%) and salmonids (2%). Seventy-six percent of bill loads were completely sandlance. Fourteen percent contained more than one type of prey. The remainder contained only capelin (4%), salmonids (3%), and others (3%).

DISCUSSION

Discussion of results is focused on differences between colonies in the 1996 breeding season. Some comparisons in population trends are made with data from past monitoring efforts. This year, the scope of this project expanded to include more behavioral, diet, and productivity monitoring. With greater effort in coming years, detailed inter-annual analyses will become possible.

Murres

Common murres lay a single egg in dense colonies and have been shown to dive as deep as 200m and range as far as 100 km while provisioning chicks (Piatt 1987). Murres have been shown to adjust their foraging behavior in response to a changes in food supply (Burger and Piatt 1990, Monaghan et al. 1994). High productivity at both Chisik and Gull Islands suggest murres were able to utilize available resources successfully this year.

However, differences in adult behavior parameters between colonies suggest that murres at Chisik were working harder than those at Gull to achieve the same results. Murres at Gull made shorter foraging trips and non-brooding adults spent more time at the nest site, suggesting that murres at Gull may have been foraging closer to the colony than those at Chisik. These differences in behavior seemed to compensate for any differences in food supply, allowing high reproductive success.

Although resources were within threshold limits at Chisik for birds to fledge young, behavior adjustments suggest that food supply may have been be sub-optimal. The population decline suggests that while these resources supported production this year, they have not been great enough to sustain population growth.

Kittiwakes

Black-legged kittiwakes are a highly colonial species that typically lay one or two eggs in each nest (Hatch et al. 1993). They are surface feeders and forage close to the nesting colony. Variability in prey densities within their limited foraging range has been shown to have direct effects on nest success at the colonies (Uttley et al. 1994). Kittiwakes frequently experience complete colony reproductive failure, yet can fledge more than one chick per nest when conditions are favorable (Hatch et al. 1993).

High clutch sizes and hatching success rates at both Chisik and Gull suggest conditions were initially favorable to kittiwakes for reproduction. However, nest desertion and high chick loss at

Chisik shortly after hatching suggest adults were not able to provision chicks successfully. The near complete reproductive failure illustrates the extent of the chick loss. At Gull, kittiwakes continued to do well throughout the fledging period, suggesting that the forage base within the adults' range was favorable. The difference between colonies in time spent away by the provisioning adult reflected difference in foraging effort. The longer trips at Chisik may have surpassed a threshold limit for successful provisioning.

Fluctuations in kittiwake populations at Chisik may be influenced by fluctuations in reproductive success. Whereas at Gull, the stable population size may reflect a more consistent food supply, and hence, more consistent reproductive success.

CONCLUSION

At Chisik Island, foraging strategy seemed to be a crucial factor in reproductive success. Murres and horned puffins, species which have extended foraging ranges, bred successfully this year, while kittiwakes, a species with a restricted foraging range, did not. However, at Gull, both the far-ranging species and near-ranging species did well. This pattern suggests far-ranging species were better able to respond to changes in food supply.

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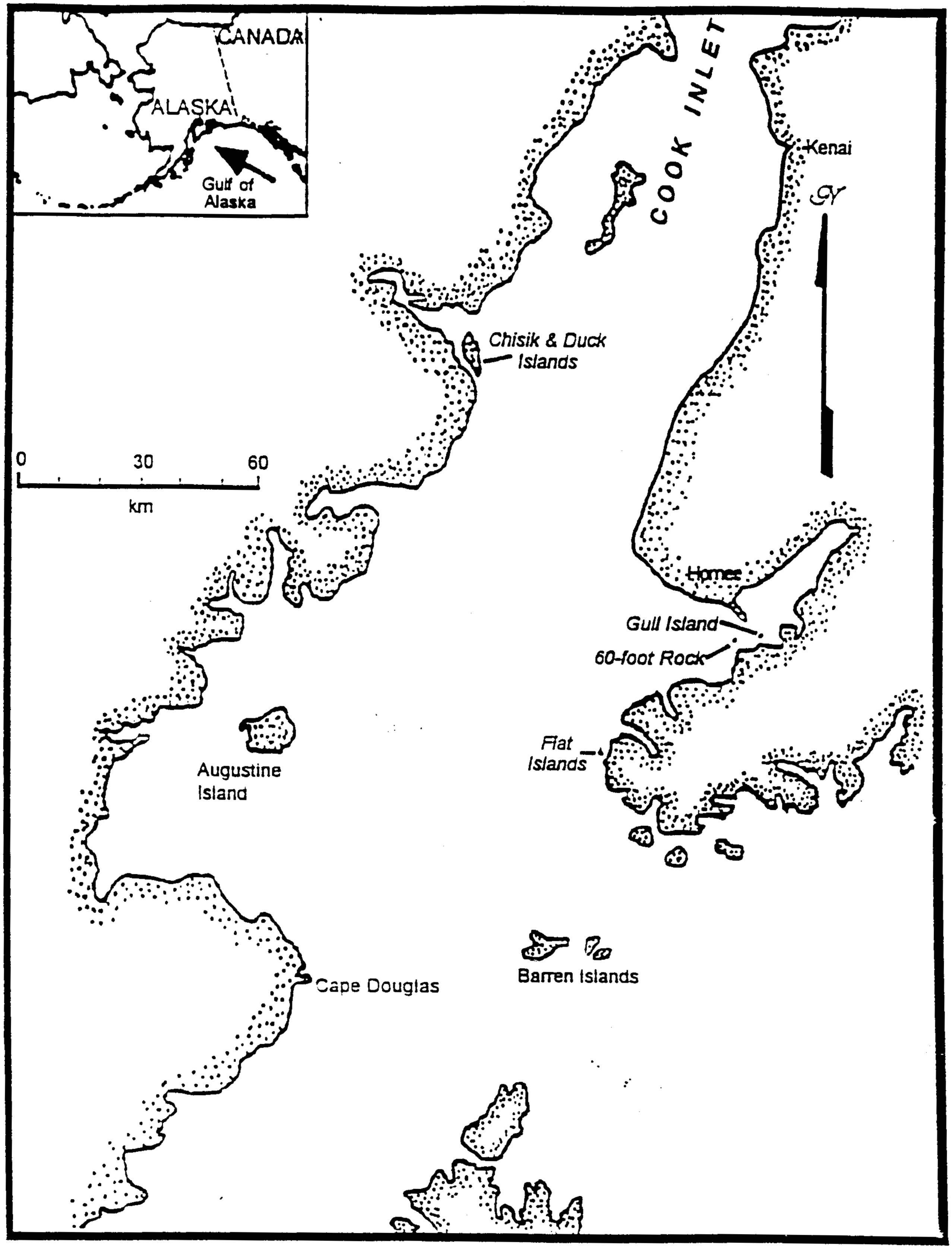

Figure 1. Study locations in lower Cook Inlet, Alaska.

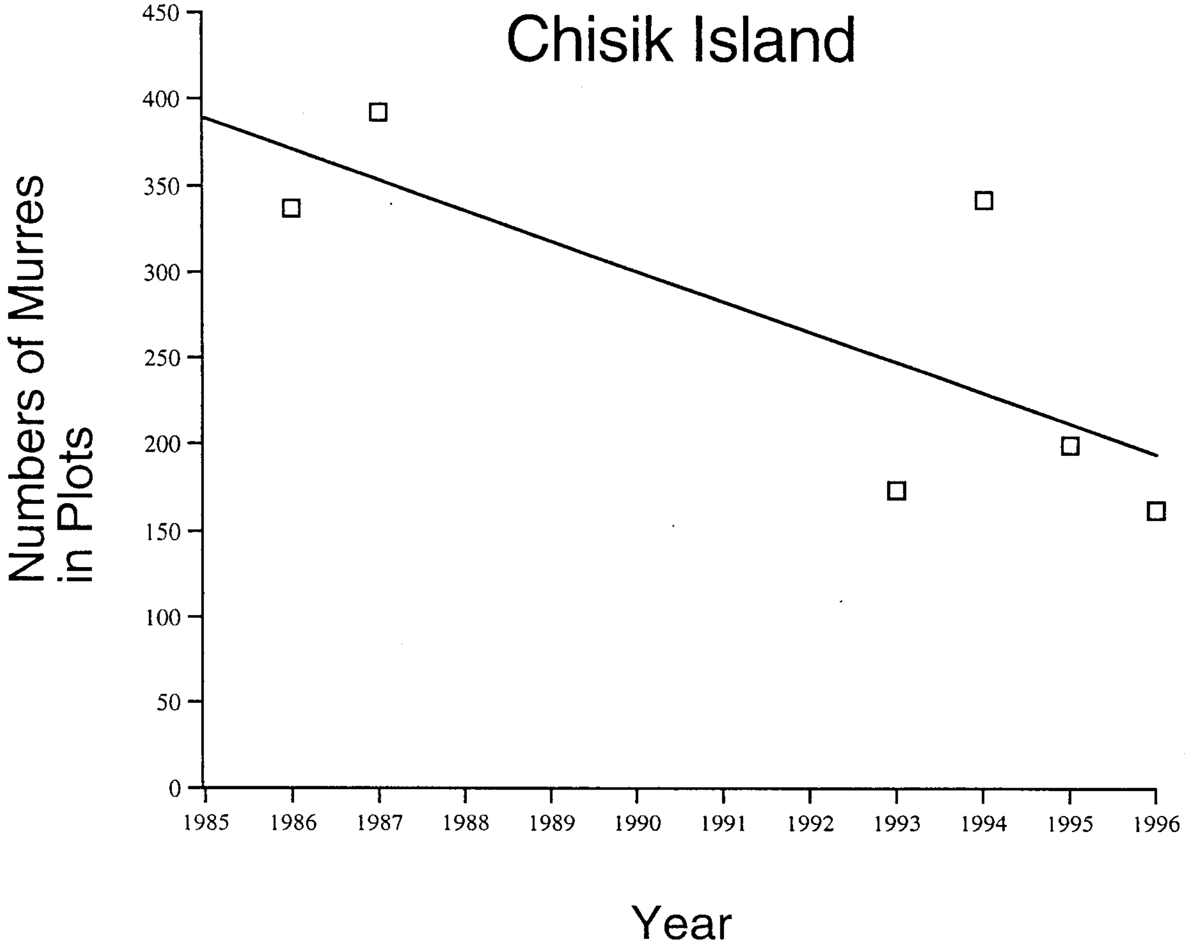

Fig 2. Numbers of common murres in plots 1 - 7 at Chisik Island.

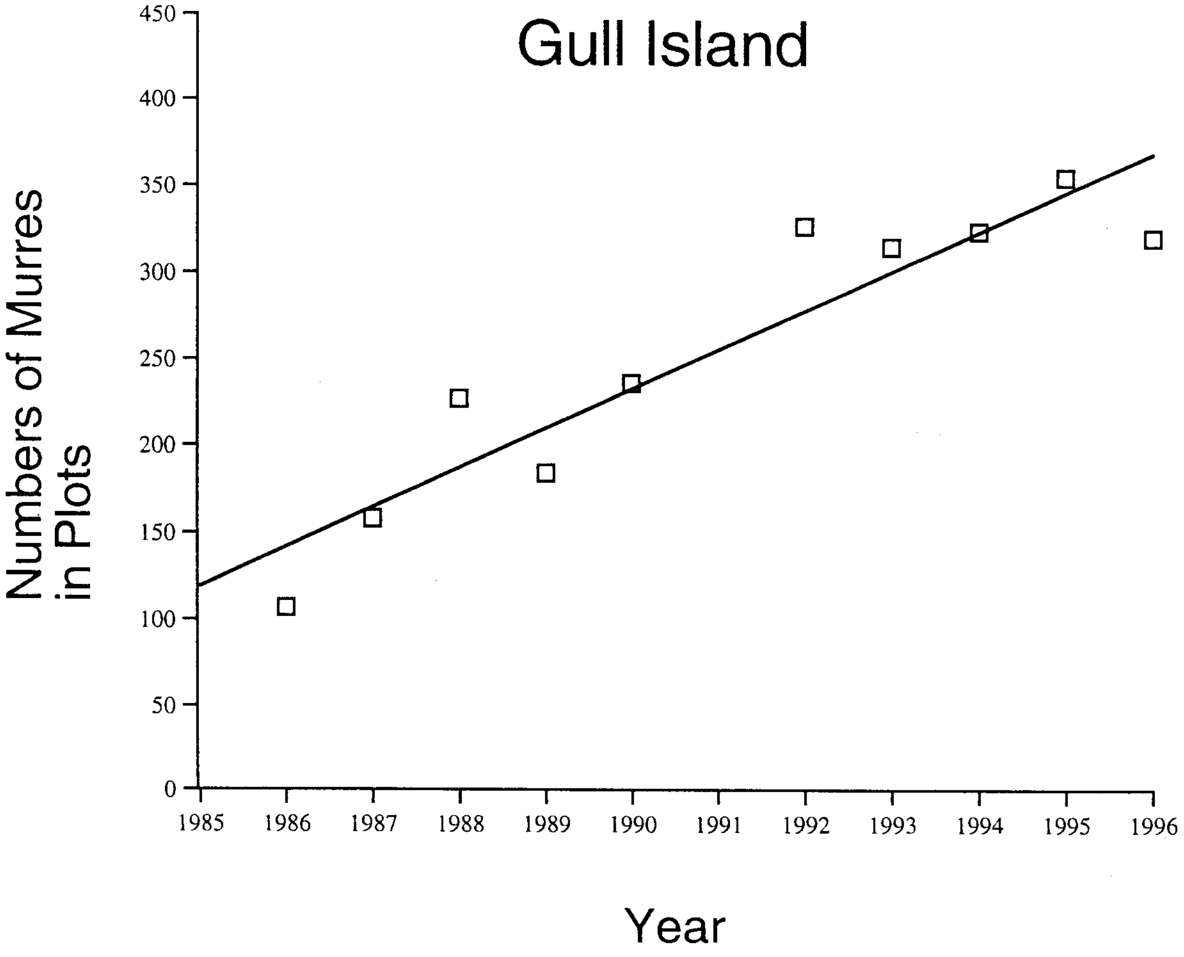

Fig 3. Numbers of common murres in plots 1 - 8 at Gull Island.

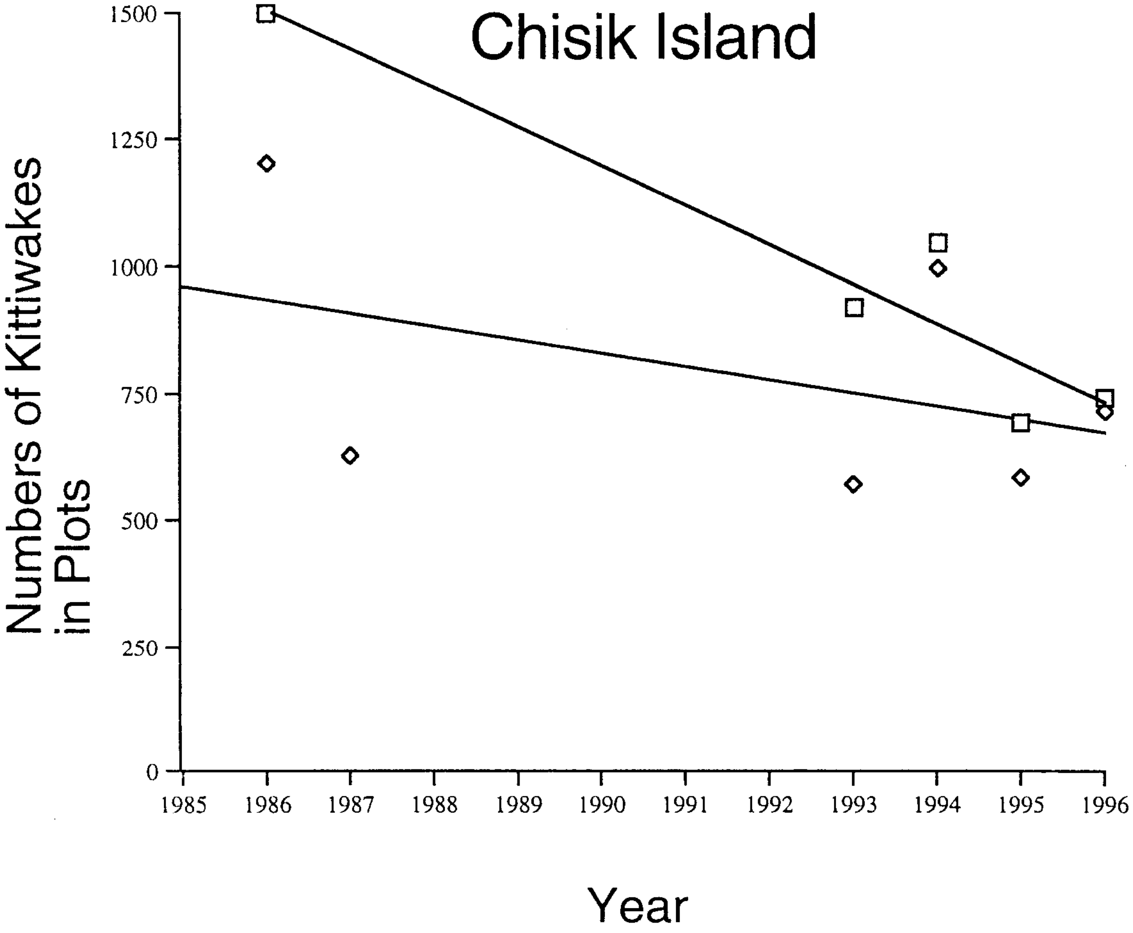

Fig 4. Numbers of black-legged kittiwakes (□) and nests (◇) on plots 1 - 7 at Chisik Island.

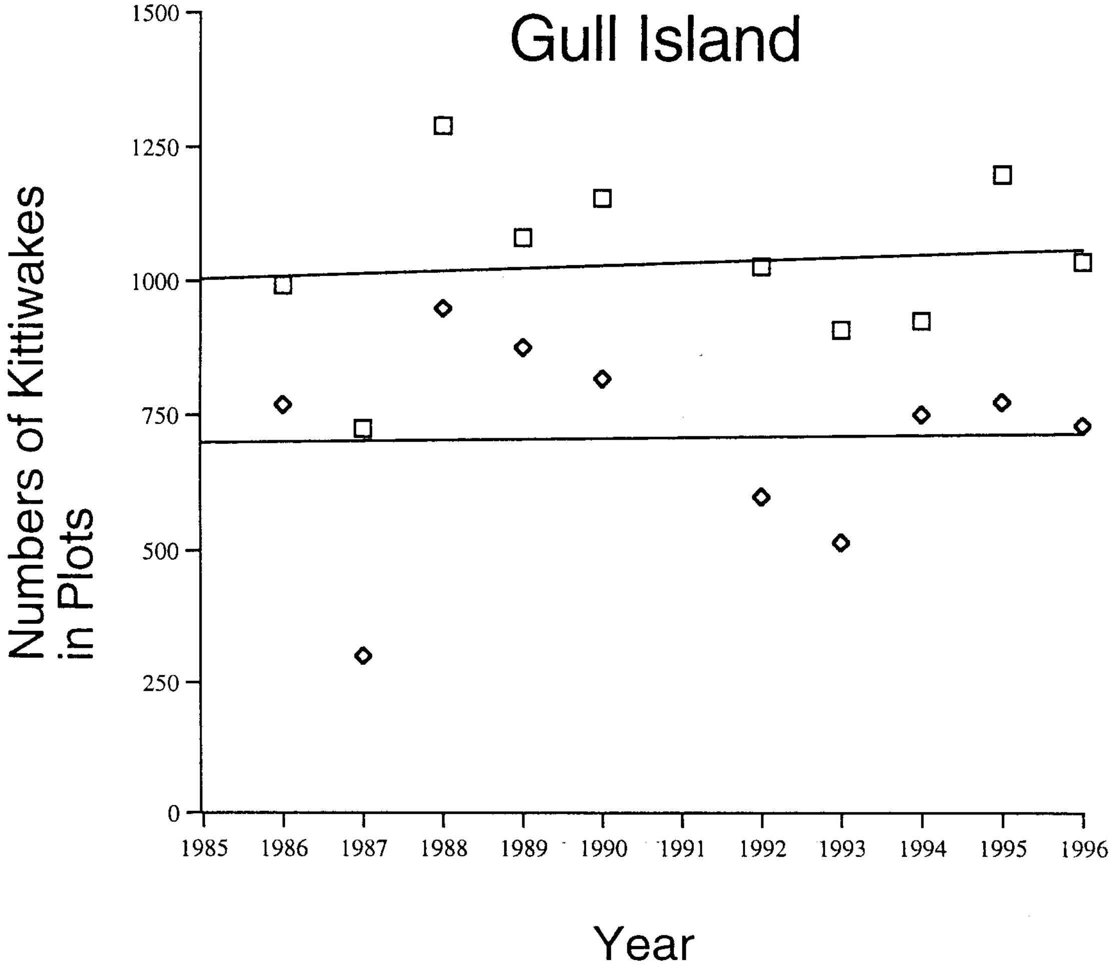

Fig 5. Numbers of black-legged kittiwakes (□) and nests (◇) in plots 1 - 8 at Gull Island.

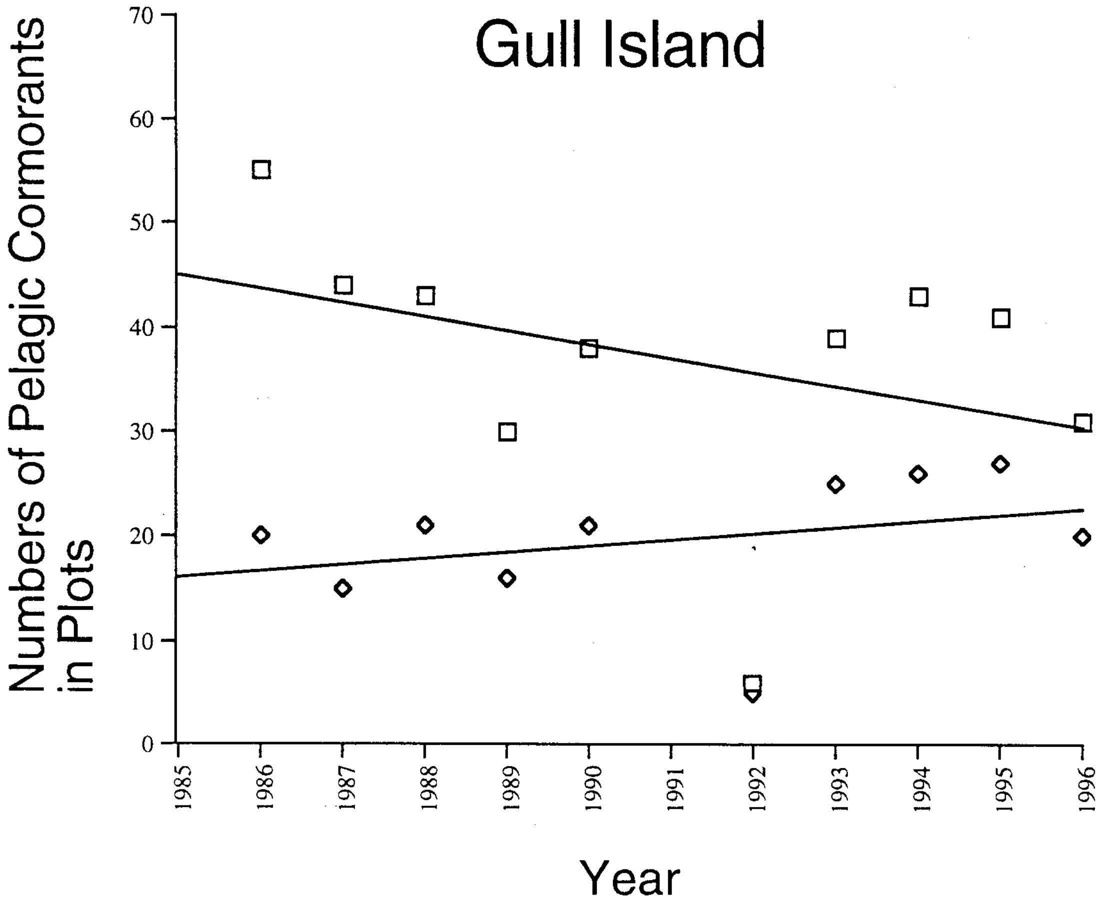

Fig 6. Numbers of pelagic cormorants (□) and nests (◇) in plots 1 - 8 at Gull Island.

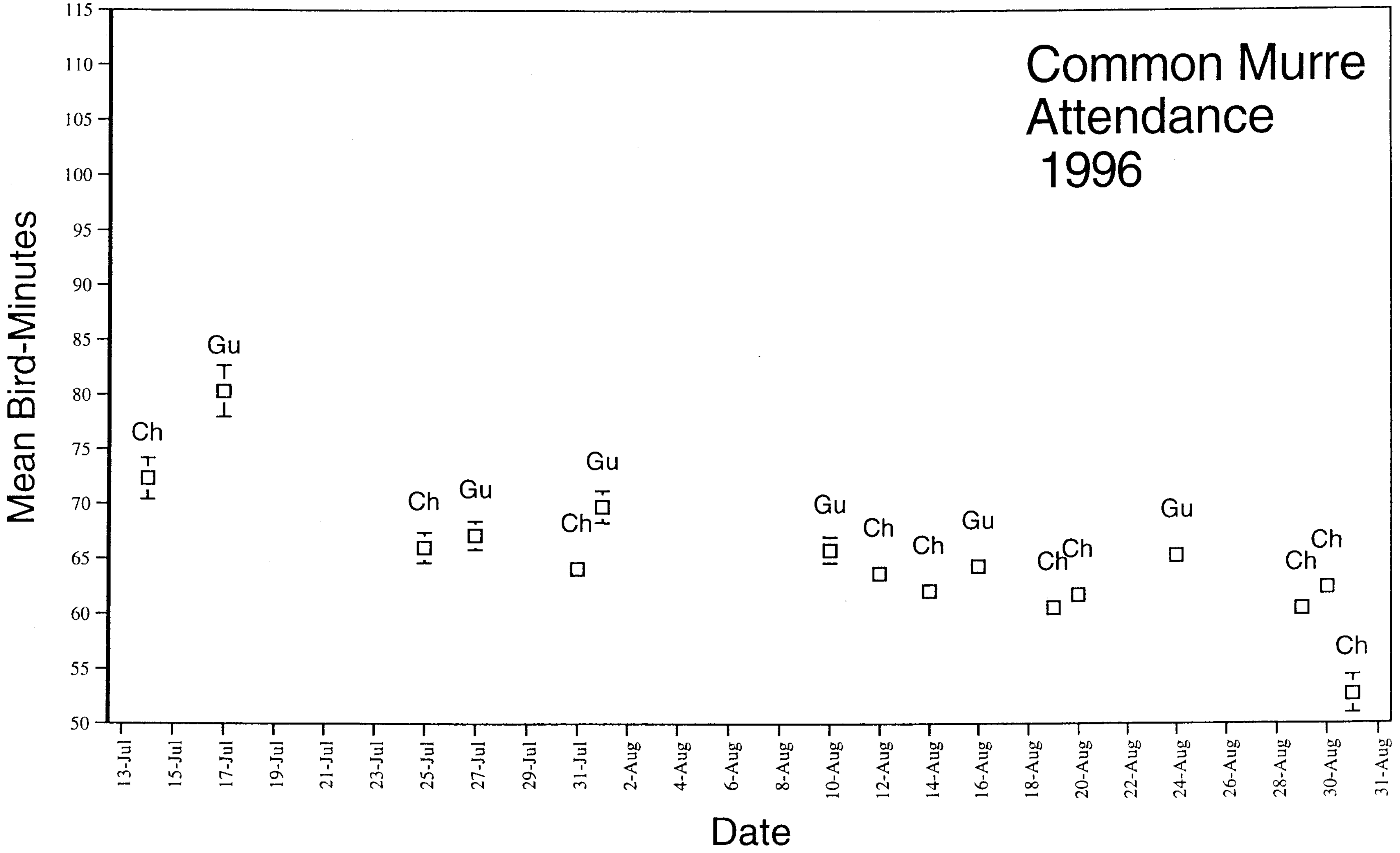

Fig 7. Mean hourly attendance (± s.e.) per all-day watch at common murre nest sites on Chisik and Gull Islands.

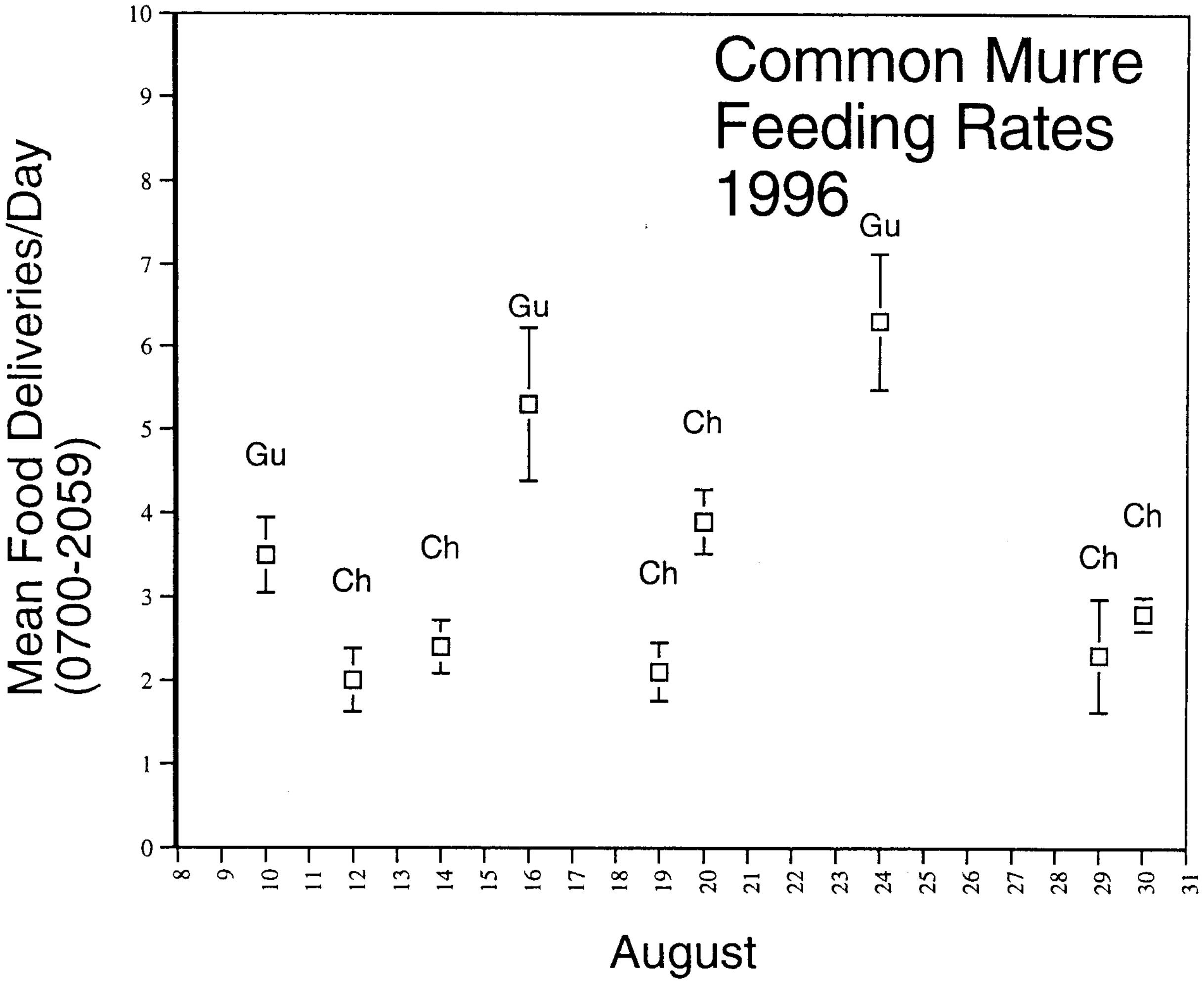

Fig 8. Mean number of food deliveries (± s.e.) to common murre chicks at Chisik and Gull Islands.

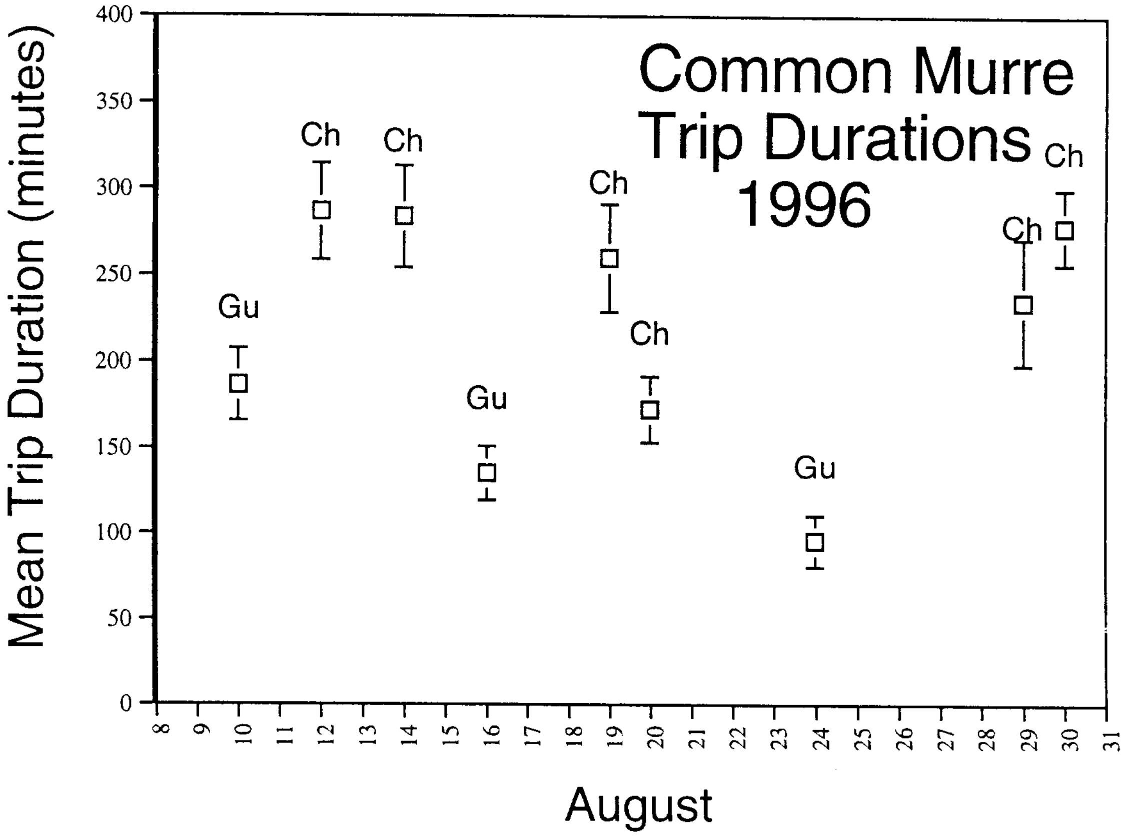

Fig 9. Mean length of time (± s.e.) spent away from nest sites by common murres at Chisik and Gull Islands.

ppendix 1. Productivity summary 1996

	Plots	Total Nests	Nests/plot	Mean Clutch Size	Hatching Success	Productivity	Median Hatch Date	Hatch Range	Index Prod	Nests	Count Dates	
HISIK ISLAND												
LKI	9	111	(6-19)	1.85 (0.02)	0.71 (0.05)	0.05 (0.03)	2-Jul	6/27-7/25	0.05	2489	8/6,6/27	
OMU	7	110	(8-21)	x	0.82 (0.04)	0.78 (0.04)	10-Aug	(7/28-8/20)	x	x	x	
ECO	x	note a	x	x	x	1	note b	x	x	x	x	
CCO	x	8	x	x	x	1.71(max)	x	note c				
WGU	x	32	x	x	1.81 (0.16)*	x	note d	(?-6/29)	x	x	x	
OPU	4	55	(7-18)	x	0.86 (0.07)	0.66 (0.07)	23-Jul	(7/15-8/5)	x	x	x	
ULL ISLAND												
LKI	10	261	(22-35)	1.69 (0.05)	0.71 (0.04)	x	8-Jul	(6/28-7/29)	0.56	5152	8/4,6/29	
	10	220	(16-28)	x	x	0.87 (0.10)						
OMU	7	84	(7-15)	x	0.92 (0.03)	0.87 (0.05)	13-Aug	(8/3-9/3)	0.22 (e)	103, 69	27-Aug	
ECO	x	18	x	3.1 (0.25)	0.88	1.83	10-Jul	(7/8-8/5)	1.66	87	8/23,7/5	
WGU	5	124	(18-33)	2.37 (0.08)	0.68 (0.03) 1.19 (0.10)*	x	2-Jul	(6/28-7/18)	x	x	x	
FCO	x	8	x	x	x	x			1.8	5	8/23,7/5	Gorilla Rock only
IGU	x	60	x	1.80(0.05)	x	x	28-Jun	(6/21-7/23)				
	x	55	x	x	0.54	x						
	x	50	x	x	x	0.59						

Time-budgets of Common Guillemots (Uria aalge) at declining and increasing colonies in Alaska

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INTRODUCTION

Common Guillemots Uria aalge and Atlantic Puffins Fratercula arctica have non-linear, threshold foraging responses to fluctuations in prey density (Piatt 1987, 1990). Cairns (1987, 1992) proposed that other parameters such as adult survivorship, breeding success, colony attendance, and adult time-activity budgets should also exhibit non-linear responses to fluctuating food supplies. In support of this, Burger and Piatt (1990) showed that Common Guillemots were able to buffer against effects of variable prey abundance and maintain high levels of productivity by adjusting foraging effort. When prey are abundant, adult Guillemots spend more time attending nest sites (Furness and Barrett 1985, Burger and Piatt 1990). Conversely, when prey are scarce, Guillemots increase time spent foraging at the expense of time spent ashore (Monoghan 1994). In a companion study, Uttley (1994) showed that the largest difference in time-activity budgets between years with varying food supply was reflected in time spent at the colony by the non-brooding adult.

We investigated patterns of parental attendance in two Guillemot colonies, one in which the population has been declining and one in which the population has been expanding during the past 20 years (Slater et al 1995). Evidence suggests that these trends are due to differences in food availability between the two colonies, which are located about 100 km apart on opposite sides of Cook Inlet, Alaska (Piatt and Roseneau 1996). We tested the hypothesis that Guillemots in the declining colony would reflect food stress by minimizing time spent at the colony. We expected to find higher parental attendance by Guillemots in the expanding colony.

METHODS

The study was conducted on Gull and Chisik Islands in lower Cook Inlet, Alaska. These islands support large breeding populations of Common Guillemots, Black-legged Kittiwakes

Rissa tridactyla, Glaucous-winged Gulls Larus glaucescens, and, on Chisik Island, Horned Puffins Fratercula corniculata. Chisik Island (60° 09' N, 152° 34' W) is located in an area of shallow water on the western side of Cook Inlet. Guillemot populations at Chisik Island have declined by about 90% during the past 20 years (Slater et al. 1995, J.F. Piatt, unpubl. data). Gull Island (59° 35' N, 151° 19' W) is located on the eastern side of the inlet, in Kachemak Bay, an area of deep water and variable bathymetry. Guillemot populations at Gull Island have increased by about 80% during the same time period (Slater et al. 1995, J.F. Piatt, unpubl. data).

On Chisik Island, continuous diurnal activity watches were conducted from 0700 - 2100 h on incubating and brooding guillemots by observers alternating shifts in a blind 8 - 30 m away. Observations of arrivals, departures, incubation and brooding shift exchanges, feeding, and prey type and size, if possible, were made with 8 X 42 or 10 X 42 binoculars. On Gull Island, a high-quality time-lapse video camera was used to record Guillemot activities. The camera was positioned to include 6 - 8 viewable Guillemot sites within the picture frame, and the connected video recorder taped four still frames per second. Personnel programmed the camera to record at appropriate time intervals and retrieved the videotape when taping was complete. The tapes were later reviewed with an editing machine equipped with a color monitor.

Watches were conducted at each island once during early/mid incubation (July) and once during late incubation (early August). During the chick-rearing stage (late August), watches were conducted twice at Gull Island and three times at Chisik Island. Total numbers of arrivals, departures, chick feedings, and nest duty exchanges were recorded for each site each day. Hourly attendance was recorded in bird-minutes, derived from the total number of minutes each adult spent at the nest site in an hour (e.g., a site continuously occupied by 1 - 2 adults would have a range of 60 - 120 bird-minutes of attendance). Nest exchanges that occurred between two adults within one minute were not recorded as additional nest attendance. Seasonal and diurnal patterns of adult attendance were analyzed for each site for each watch. Adult trip durations were calculated from the time elapsed between departures and arrivals at each site. Feeding rates were calculated for each chick from the mean number of food deliveries per hour.

All statistical analyses were performed using SigmaStat (v. 2.0, Jandel Scientific Software). Differences in attendance patterns were tested with Kruskal-Wallis analysis of variance (ANOVA) on ranks. Correlations with time were tested by Pearson Product Moment Correlations. All means are reported ± 1 s.e.

RESULTS

Patterns of adult attendance at nest sites showed striking differences between colonies. Nest sites at Chisik Island were rarely occupied by more than one adult. Overall mean attendance at Chisik Island was 65.44 ± 0.59 bird-minutes ($n = 70$), while at Gull Island was 75.41 ± 1.65 bird-minutes ($n = 56$). Guillemots breeding at Gull Island spent significantly more time at their nest sites than those at Chisik Island(Kruskal-Wallis ANOVA, $p = <0.001$) (Fig. 1).

Mean daily attendance at Gull Island varied significantly over the season (Kruskal-Wallis ANOVA, $p = <0.001$) and decreased as the season progressed ($r^2 = -0.303, p = 0.023$). The same patterns were observed at Chisik Island. Attendance varied significantly (Kruskal-Wallis ANOVA, $p = 0.005$) and decreased as the season progressed ($r^2 = -0.346, p = 0.003$). Attendance at Gull Island during the late chick-rearing period dropped sharply. Mean attendance at Gull Island at the end of the season was not significantly different from daily values at Chisik Island throughout the season.

Attendance at Gull Island during incubation and early chick-rearing was higher and more variable in the latter half of the day (Fig. 2). Mean hourly attendance was positively correlated with time of day ($r^2 = 0.445, p = <0.001$, differences in means n.s.). In the late chick-rearing stage, the diurnal attendance pattern at Gull Island resembled those at Chisik Island throughout the season. Hourly mean values did not vary significantly at Chisik Island and tended to decrease with time of day ($r^2 = -0.332$, $p = 0.005$).

We detected no significant differences between chick feeding rates or trip durations at each island. Chicks at Gull Island were fed 0.34 ± 0.02 fish per hour (n = 13 nests) while those at Chisik Island were fed 0.26 ± 0.02 fish per hour (n = 16 nests). Guillemots at Gull Island left their nest sites for 120 ± 14.21 minutes per trip (n = 49), while those at Chisik Island left their nest sites for 154 ± 16.04 minutes (n = 55).

DISCUSSION

Investigations of seabirds as indicators of marine resources are growing in scope and number (Burger & Piatt 1990, Cairns 1987, 1992, Hatchwell 1991, Monaghan et al. 1989, 1994, 1996, Springer et al. 1996, Utteley et al. 1994, Williams & Rothery 1990). The non-linear relationships between seabird parameters and prey availability must be described to predict seabird responses to changes in their prey base. Responses vary in time and scale. Population trends may reflect large-scale changes in food supply which have long-term effects on adult survivorship and recruitment. Breeding success can provide a measure of food supply over a single breeding season. However, this parameter will only reflect extremes in food supply in species where adult behavior can ameliorate the effects of changes in prey availability (Burger & Piatt 1990). Adult behavior, measured in attendance at the colony and activity at sea, can reflect daily changes in prey availability and provide a more sensitive measure of current foraging conditions (Burger and Piatt 1990, Cairns 1987).

We are currently investigating forage fish abundance in lower Cook Inlet, within potential foraging range of birds nesting at Gull and Chisik Islands. Preliminary results suggest more prey is available to birds from Gull Island than from Chisik Island. Differences in forage fish abundance were found in mid-water trawls conducted on targets identified on acoustic surveys

[Gull: 345.3 fish/set (n = 16); Chisik: 92.0 fish/set (n = 6)]. Beach seines showed similar patterns [Gull: 511 fish/set (n = 238); Chisik: 33 fish/set (n = 30)]. Hydro-acoustic surveys indicated that relative biomass was approximately an order of magnitude greater around Gull Island than around Chisik Island (J.F. Piatt, in prep). These differences have been observed over two years (1995, 1996) and are consistent with the seabird population changes observed in each area.

We predicted correctly that Guillemots nesting in the declining colony at Chisik Island would reflect food stress by minimizing time spent at the colony. Rarely did more than one adult Guillemot attend each nest-site at Chisik Island. In contrast, during incubation and chick-rearing both members of breeding adult pairs at Gull Island spent considerable time together at the nest site, especially during the latter half of the day. Gaston & Nettleship (1982)observed that the attendance of Brünnich's Guillemot (Uria lomvia) also varied with food availability: attendance decreased as distance to prey increased. Uttley et al.(1994)observed both seasonal and annual differences in attendance at a Guillemot colony during two years of varying food supply. Off-duty birds spent more time at the colony in the year of greater prey abundance.

Although time spent at the colony is not a direct (inverse) measure of foraging effort, it is a direct measure of time not devoted to foraging. Our data suggest Guillemots nesting at Gull Island devoted less time to foraging than those at Chisik Island. Guillemots at Gull Island appear to be less stressed and have more discretionary time ashore than those at Chisik Island. Attendance in the latter half of the day at Gull Island appeared to be "loafing" time, which was redirected to foraging when chick food demands increased.

The decline in attendance through the season at both colonies suggests that energetic demands on the adults increased as they began to provision chicks. However, consistently low daily attendance at Chisik Island suggests the birds were approaching a limit in foraging effort. When chicks were largest and energetic demands on the adults greatest, the attendance pattern at Gull Island dropped to levels resembling patterns at Chisik Island throughout the season. However, Guillemots at Chisik Island were able to maintain similar chick feeding rates to those at Gull Island. Guillemots in Shetland in a year of extremely low prey availability were not able to provision chicks successfully (Uttley et al. 1994). Prey availability was below a threshold limit where increased time spent foraging could not buffer the effects of poor food supply. Food stress was reflected at the colony: attendance, fledging rates, and chick weights were lower than when food supply was higher.

We expected to find differences in adult trip durations between colonies. Two reasons may have contributed to the lack of significant difference: (1) Sample sizes may have been too small to detect differences; or (2) activity budgets at sea may have differed. Guillemots at Gull Island may have spent more time "loafing" away from the colony. We did not investigate activity budgets at sea.

Differences in attendance clearly suggest Guillemots are adjusting their time and activity budgets to reflect food supply and maximize reproductive success (Burger and Piatt 1990). With further confirmation of the correlation between colony attendance and food supply, attendance can serve as a valuable monitoring tool. Attendance is a relatively simple and inexpensive parameter to measure and is sensitive to daily, seasonal, and annual changes in prey availability. Studies of colony attendance may augment or substitute for at-sea research in areas where marine work is prohibitively expensive or logistically impossible.

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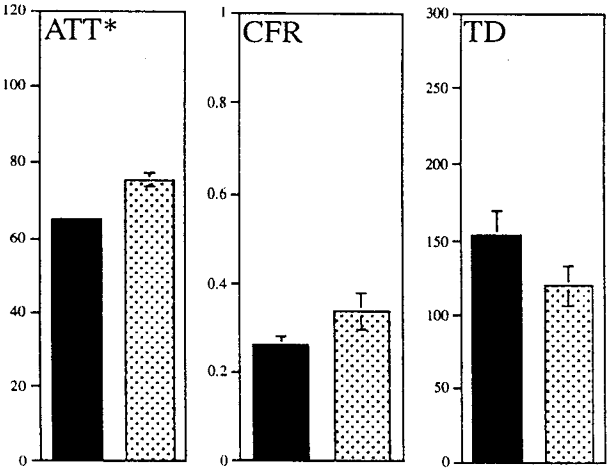
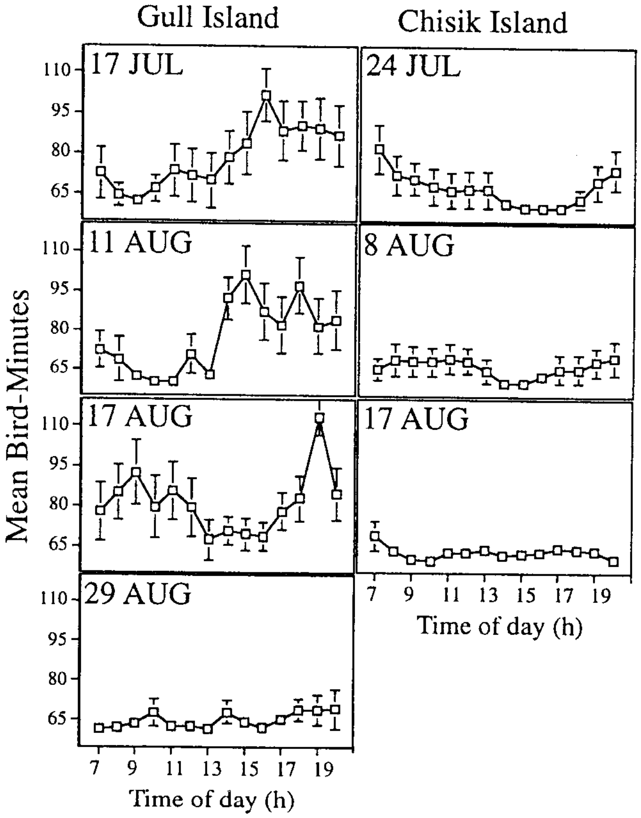
Figure 1. Attendance (ATT) in mean bird-minutes, chick feeding rates (CFR) in mean fish chick^{-1} hour^{-1}, and adult trip durations (TD) in minutes at Chisik Island (solid histogram) and Gull Island (shaded histogram), Alaska, in 1995. Means are shown ± 1 s.e. Significant difference is denoted with an asterisk.

Figure 2. Representative attendance patterns during incubation (17 Jul - 11 Aug), early-chick-rearing (17 Aug), and late chick-rearing (29 Aug) at Chisik and Gull Islands, Alaska, in 1995. Means are shown ± 1 s.e.


ATT*
120
100
80
60
40
20
0
CFR
1
0.8
0.6
0.4
0.2
0
TD
300
250
200
150
100
50
0


Gull Island
Chisik Island
17 JUL
24 JUL
11 AUG
8 AUG
17 AUG
17 AUG
29 AUG
Mean Bird-Minutes
110
95
80
65
7
9
11
13
15
17
19
Time of day (h)

Breeding Biology and Feeding Ecology of Pigeon Guillemots at Kachemak Bay, Alaska, in 1996

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Draft Report
December 1996

Abstract

We studied the breeding biology and chick diet of pigeon guillemots *Cepphus columba* nesting in Kachemak Bay, Alaska, in summer 1996, while simultaneously assessing the availability of forage fish around study colonies using beach seines and bottom trawls. Average breeding success was 0.56 chicks fledged per nest. Productivity was higher in areas where the diet included pacific sandlance *Ammodytes hexapterus*, but nest predation may have been more important than diet in determining reproductive success. Nest abandonment during incubation was also an important influence on reproductive success. Average growth was 17.4 g/d for chicks age 8-18 days. The average mass of 30 day old chicks (± 1 day) was 395.7 g. Non-schooling benthic fish made up 57% of chick diet, based on visual observations. Sandlance ranged from 45% to 0% of the diet at different colonies. Breeding adults rested more during chick provisioning in areas where sandlance were available. Beach seines were useful in assessing near shore forage fish communities, and our bottom trawl data established a baseline for monitoring benthic fish populations around guillemot colonies. We began color-banding chicks to collect data on annual survival and recruitment, and began a guillemot population-monitoring program based on repetitive colony counts.

Introduction

The Pigeon Guillemot (*Cepphus columba*) is a small crevice-nesting seabird of the family Alcidae. Guillemots may lay either one or two egg clutches, and their nests may be aggregated into small colonies or widely dispersed. Guillemots forage near shore on benthic and schooling fish within a few kilometers of their nests (Drent 1965).

Six hundred pigeon guillemot carcasses were recovered in Prince William Sound after the Exxon Valdez oil spill (EVOS), and this probably represents a small fraction of the total killed by the spill (Hayes 1995; Piatt and Ford 1996). Attempts to understand the effects of the spill on guillemot populations are complicated because these populations may have already been declining at the time of the spill (Oakley and Kuletz 1996). Populations may have declined in response to long term changes in forage fish populations throughout the Gulf of Alaska (Piatt and Anderson, 1996). Recent research on pigeon guillemots in Alaska has focused on how changes in forage fish populations may have affected guillemot populations.

We examined the breeding biology of guillemots nesting in Kachemak Bay, Alaska while studying aspects of their feeding ecology and the abundance of prey in their foraging areas. Chick diet was determined by visual observations and by collecting fish that were delivered to nests by adults. Forage fish populations were assessed with minnow traps, beach seines, and bottom trawls. We developed a censusing protocol for the area to assess future population trends, and examined the effect of diet by measuring breeding success and chick growth rates. In order to assess the behavioral response of guillemots to variable forage fish populations, we measured colony attendance, breeding phenology, chick provisioning rates, and adult time budgets.

Although nesting guillemots were studied over a large area in Kachemak Bay, data on chick diet and provisioning rates were obtained at three colonies: Moosehead Point, Yukon Island, and Seldovia Bay (Fig. 1). Since guillemots at these three sites have different diets, comparisons of the effects of different foraging regimes are possible from a single year's data. Guillemots in Kachemak Bay were also the subject of a University of Alaska, Fairbanks study in 1994 and 1995 (Prichard

1996). Most of the colonies and nest sites that we followed were located during the course of that study, and additional comparisons with data from that study are presented in Appendix 1.

Methods

Study Area

Kachemak Bay is located in south-central Alaska, on the eastern shore of lower Cook Inlet. The southern shore of the bay is bordered by mountains and glaciers, and this rugged coastline is characterized by cliffs and rocky headlands which provide suitable nesting habitat for pigeon guillemots. We studied guillemots from Seldovia Bay in the west to Mallard Bay in the east (Fig. 1). Our three main study areas were chosen because they offered relatively accessible nest sites, and locations where we could observe provisioning at several nests simultaneously. The nests that we studied at Seldovia Bay were all within 100 meters of each other. Growth data for the Yukon Island colony all came from nests within one kilometer of each other. We included data on clutch size and egg survival from nearby Hesketh Island in our analysis of productivity at Yukon, since the two groups are close and have had similar diets in past years (Prichard 1996). We included nests in China Poot Bay with our analysis of Moosehead Point birds because we observed that breeding adults from both colonies forage in the same area.

Population Monitoring

We counted guillemots along the south shore of Kachemak Bay between Seldovia Bay and Bear Cove from during 8-10 June, 1996, following the methods of Sanger and Cody (1996). Sadie Cove and Tutka Bay were excluded from the survey because of time constraints and the low numbers of guillemots observed in these bays in earlier years. We surveyed guillemots along the coast, using a small skiff traveling at 4-8 knots approximately 50m from shore. All guillemots on land and within 100 meters of shore were counted. This one-time survey was used to compare with data collected by Prichard (1996) in 1995.

We also conducted repetitive colony counts during the incubation period (31 May - 9 July). Standard census zones (n= 26) were established around colonies from Mallard Bay in the east to roughly two nautical miles west of Pt. Naskowhak in the west. We counted guillemots on land and within 100 meters of shore in these zones. Counts were taken either within two and a half hours of a morning high tide or within one and a half hours of an afternoon high tide, when attendance is known to peak (Prichard 1996). Between six and nine replicate counts were made for each area.

Banding

All chicks that survived to age 25 days were banded with a steel U.S.F.W.S. band on the right leg. These chicks were also banded with a brown plastic color band above the steel band to mark their cohort year, and a unique color band combination on the left leg.

Productivity and Phenology

During incubation (May and early June) we observed guillemot colonies during high tide to locate active nest sites. In order to minimize disturbance and nest abandonment, we visited nests only once during incubation to confirm that they were active. Nests were generally accessed by rappelling from the cliff top. Regular nest checks were begun in late June, when we expected the first eggs to begin hatching. We attempted to visit nests every five days throughout the chick rearing period to assess their status.

Because we began following most nests just before hatching, we necessarily missed nests that failed early in the incubation stage, and therefore our productivity estimates could be biased. To account for this bias, we employed the Mayfield method to estimate productivity (Johnson 1979). This method compares the number of eggs lost with the number of days that eggs have been exposed to risk to calculate a daily survival rate (DSR) using the following formula:

$$\text{DSR} = 1 - (\text{Number of Losses} / \text{Number of Exposure Days})$$

The chance of an egg surviving incubation was calculated as:

$$\text{Chance of Survival} = \text{DSR}^{\text{length of incubation (days)}}$$

We used 31 days as the standard incubation period for our calculations.

Productivity was estimated as the product of three variables: the chance of an egg surviving incubation, the chance that a surviving egg would hatch, and the chance of a chick surviving to fledge. We considered any bird that was missing from the nest after age 30 days to have fledged unless there was evidence of predation. We did not use the Mayfield Method to calculate nestling survival because we discovered all but one of the nests in this study before eggs had hatched.

The chance of an egg hatching was estimated by dividing the number of eggs that survived incubation but failed to hatch by the total number of eggs that survived incubation. Eggs that failed to hatch were considered exposed to risk a maximum of 31 days for purposes of the Mayfield Method. If one egg in a clutch failed to hatch it was considered exposed to risk until two days after the other egg hatched.

Growth Rates

We weighed and measured chicks every five days, and known-age birds that survived to fledge were also weighed at 30 days (± one day) to obtain a standard measurement of peak nestling mass. Chicks were weighed with 100g, 500g, or 1kg Pesola scales. We also measured flattened wing chord and the length of the tenth primary from its emergence from the skin to the tip, excluding down.

Growth rates at different colonies were compared using three methods. The first was to compare growth rates during the linear phase of chick growth, 8-18 days (Koelink 1972). Growth rates during this period were calculated for every nestling as the slope of the least squares fit of the regression of mass on age.

Growth rates were also compared by considering mass as a function of wing chord during the period that these two variables share a linear relationship (35mm - 140 mm). Rates for each chick were again calculated as the slope of the least-squares regression line. This method allows us to use more data than the first because unknown-age chicks can be used, and more measurements are used from each chick.

It is possible to linearize the relationship between mass and wing chord for the entire nestling period by comparing the square root of mass with the square root of the natural log of wing chord (Prichard 1996; Roby et al 1995). We used the resulting slope of mass on wing chord as the third method for assessing growth rates. This method allows the use of all growth data.

No measurements were made of adults.

Chick Diet and Provisioning Rates

When provisioning their chicks, pigeon guillemots carry fish singly in their bills, and often spend long periods of time on the water in front of the colony before delivering to the nest. We observed guillemots provisioning their chicks from land (Moosehead Point) and anchored skiffs (Seldovia Bay and Yukon Island). Using binoculars and a spotting scope, we identified fish to the lowest possible taxonomic level as they were being carried by birds, and estimated prey size to the nearest half bill length. For each nest we recorded delivery time and the time elapsed between arrival on the water in front of the colony and delivery. Delivery rates were calculated for nests containing chicks aged 8 to 30 days. We observed provisioning either all day (0600-2200) or in eight hour blocks starting at 0600 or 1400. Additionally, we attempted to identify fish that we saw during the course of other field activities. Unsuccessful attempts to identify fish were recorded to avoid biasing our diet composition estimates towards easily identified species.

Some fish were collected in order to confirm our visual identifications. We employed two methods: intercepting delivering adults with scraps of mist net placed across nest entrances, and preventing chicks from swallowing fish with choke collars made from pipe cleaners. These fish were sent to Kathy Turco, University of Alaska Fairbanks, for species identifications and proximate body composition analysis. We also collected fish that we found while visiting nests to collect other data.

Prey Assessment

Minnow traps were occasionally placed in shallow water near colonies to capture locally available benthic fish. Additionally, a number of sites near guillemot colonies were sampled with beach seines (47 meter net) throughout the chick rearing period. Salmonids, larval sandlance, and larval sculpins were excluded from our analysis of beach seine data because these three groups are almost entirely absent from guillemot chick diets. Some beach seines were also conducted in 1995. A Pearson Product Moment correlation was used to compare the proportion of sandlance in beach seines with the proportion of sandlance in the diet of chicks at nearby colonies in 1995 (Prichard 1996) and 1996. A similar comparison was made between seasonal changes in diet and catches at Moosehead Point in 1996. Beach seine catches were also used for a qualitative assessment of the availability of various demersal fishes to guillemots.

Benthic fish in deeper water were sampled by bottom trawling on 8-9 August in waters less than 25 meters deep where we suspected that guillemots foraged. We used a 3.05 m plumbstaff beam trawl with a 7 mm square mesh net and a 4 mm mesh codend liner. Each fish was identified to the lowest possible taxonomic level, usually species, and total body length was measured. Representative size classes for analysis were chosen based on the lengths of fish collected at nests: *Lumpenus* spp. 40 - 250 mm; all others, 40 - 150 mm. Raw data from these trawls were extrapolated to obtain an estimate of catch per unit effort (CPUE, number per 1000 m^2 area trawled).

Blood Samples

We took blood samples from known-age chicks as a continuation of a Minerals Management Service project to identify the response of marker proteins to hydrocarbon contamination (L. Duffy, Univ. Alaska Fairbanks). We took blood by puncturing the brachial vein with a hypodermic syringe and letting the blood flow into an eppendorf container. When possible, each chick was bled at age 20, 25, and 30 days. Blood samples were spun down in a centrifuge and the plasma was separated and frozen for later analysis. Most samples were 1 cc, but we took 2 cc from some 30 day old chicks.

Results

Population Monitoring

We counted 467 guillemots during our one-time survey of the southern shore of Kachemak Bay. Five hundred and eighteen individuals were counted in the same area in 1995 (Prichard 1996). Results of our repetitive colony counts are presented in Table 1.

Banding

We banded thirty four chicks. If this effort continues, information on recruitment, survival rates, nest-site tenacity, and colony fidelity may eventually be available.

Phenology

Eggs hatched between 21 June and 23 July, with a median hatch date of 28 June. Based on a 31 day incubation period, we estimate median laying date as 27 May. Since we were visiting nests every five days, no accurate information on fledging dates is available.

Productivity

We were able to determine the fate of sixty nests. Productivity for Kachemak Bay as a whole in 1996 was 0.31 chicks fledged per egg laid. By multiplying by the average clutch size (1.80), we estimate productivity to be 0.56 fledglings per breeding pair. Clutch size did not vary significantly among colonies (ANOVA, $df_{1,59}$, F= 0.963, P= 0.468). Hatch success was 0.49, chick survival was 0.64., and these values varied among different locations (Table 2). Productivity at Moosehead was significantly higher than at Yukon (z-test, z = 1.992, P = 0.046).

Hatch failure and egg predation accounted for roughly two thirds of nest failures (Figure 2). Chick mortality was distributed throughout the nestling period (Figure 3). Moosehead Pt. did better Yukon I. and Seldovia Bay in terms of hatch success (z-test, z = 2.220; P = 0.026) and chick survival (z = 2.364, P = 0.018). Neptune Bay, a productive area in previous years (Prichard 1996), experienced widespread nest abandonment and low overall productivity (0.10 chicks fledged per egg). Nest abandonment was also a cause of low productivity in Seldovia Bay. Of the four chicks that hatched at the colony, two were preyed upon and one died of other causes. Birds in Halibut Cove also fared poorly (0.20 chicks fledged per egg).

Survival was higher in two chick nests (0.69, n = 36 chicks) than in one chick nests (0.20, n = 5 chicks), but the difference was not significant (z test, z = 1.655, P = 0.098).

Growth Rates

The mean growth rate for all chicks in Kachemak Bay during the linear growth phase was 17.36 g/d (s.d.= 5.11, n = 37). Rates for individual colonies differed (Table 3), but an ANOVA detected no significant differences between colonies ($df_{3,25}$, F= 0.761, P = 0.528). A t-test detected no significant difference between the colony with the highest growth rate, Moosehead Point, and all other colonies as a group ($t= 1.262$, $P = 0.219$).

The average slope of mass as a function of wing length during the linear period (35 - 140mm) for all chicks was 2.68 (s.d.= 0.946, n = 34.) The three areas with the largest sample sizes were indistinguishable from each other (Moosehead, Yukon/Seldovia, Kasitsna/Herring, ANOVA, $df_{2,27}$, $F< 0.001$, $P = 1.00$).

The average slope of transformed mass and wing chord data was 30.72 (s.d. = 0.39, n = 49). Again, there was no significant difference between areas (ANOVA, d.f. $_{3,39}$, $F= 0.451$, $P = 0.718$).

The mean peak nestling weight was 395.67 g (s.d. = 88.53, n = 15). At Moosehead Point the mean peak was 403.73 g (s.d.= 82.90, n = 11), at Kasitsna Bay it was 434.50 (s.d. = 17.68, n = 2), and on Yukon Island it was 312.50 (s.d.= 152.03, n = 2). There was no significant difference between these colonies (ANOVA, $df_{2,14}$, $F= 1.144$, $P = 0.351$).

Chick Diet

Non-schooling benthic fish accounted for 57% of guillemot diets during our observations (n= 592). The most prevalent benthic fish were gunnels and pricklebacks (Stichaeidae and Pholidae, 35%), sculpins (Cottidae, 6 %), and flatfish (Pleuronectiformes, 6%). Schooling fish, primarily sandlance (*Ammodytes hexapterus*) accounted for 36% of observations. We were unable to identify 6% of the fish we saw. Greenling (Hexagrammidae) accounted for the remaining 1%.

The percentage of various fish species in guillemot diets differed at the three study locations (Figure 5). The proportion of sandlance in the diet was significantly higher at Moosehead Point (45%) than at Yukon Island (0%, z-test, $z= 6.9$, $P< 0.01$) or Seldovia Bay (21%, $z= 3.7$, $P< 0.01$).

Twenty nine fish were collected from nests (Table 4). Since no systematic effort was made to gather samples equally from different areas, and because diet varied so much within Kachemak Bay, no comparison was made between the composition of this collection and our observations.

Adults delivered food to one-chick nests at an average rate of 0.81 fish per hour (s.e = 0.17, n = 6 nests), and to two-chick nests at an average of 0.97 fish an hour (s.e.= 0.15, n = 10 nests). There was no significant difference between one- and two-chick nests, and no significant difference between the three study locations (ANOVA,$df_{2,15}$, $F=0.551$, $P= 0.593$).

Average resting time for each observation period is presented in Figure 9. Birds spent more time on the water with fish towards the end of the day; rest time and time after sunrise were significantly correlated (Pearson correlation, $r^2= 0.115$, $P= 0.032$). Tide also had a significant effect on loaf time (Kruskall-Wallis, $H= 32.691$, $P< 0.001$). Birds rested on the water less during high and ebb tides than they did during low and flood tides. There was also significant geographic variation in resting time (ANOVA,$df_{2,285}$, $F=4.419$, $P= 0.013$). Moosehead Point birds rested an average of 14.87 minutes (s.e.= 1.30, n= 189) and Yukon Island birds an average of 8.12 minutes (s.e.= 1.27, n= 61). The difference is significant (Tukey, $q=4.053$, $P< 0.05$). The average resting time in Seldovia Bay was 10.97 minutes (s.e.= 2.26, n= 36).

Prey Assessment

Beach seine results from 1995 and 1996 are compared in Figure 6. The sites that we seined around Moosehead Pt. were well distributed in the area where we observed local birds foraging, and seine catches could accurately predict chick diet at this colony: the proportion of sandlance in nestling diet and seine catches was significantly correlated through the season (Pearson Product Moment, $r^2=$

0.967, P= 0.033, Figure 7). Sculpins declined from 1995 to 1996 in both seines and chick diet and Moosehead and Yukon. The highest proportions of flatfish in seines and diet both occurred in Seldovia Bay.

Bottom trawls can be replicated in future years and CPUE values used to assess changes in demersal fish populations around guillemot colonies. A comparison of diet and trawl data for Moosehead Point and Yukon Island from this year indicates that guillemots prey on gunnels and pricklebacks more often than sculpins, even though sculpins were more common at our trawl stations (Figure 8). The same pattern was also seen in seine and diet data from Seldovia Bay.

Discussion

Productivity

Predation and nest abandonment were the biggest influences on reproductive success in Kachemak Bay this year. Suspected predators include northwestern crows (*Corvus caurinus*), ravens (*C. corax*), black-billed magpies (*Pica pica*), mink (*Mustela vison*), and river otters (*Lutra canadensis*). Overall breeding success (0.31 chicks fledged per egg) was slightly higher than in 1994 and 1995 (0.19 and 0.25, respectively, Prichard 1996), but this average value conceals large differences among colonies within Kachemak Bay.

Although we observed no egg predation at Neptune Bay, hatching success was estimated at 0.308, largely because of nest abandonment. Nests were visited less often during incubation this year than in previous years, so our activity cannot account for the increase in abandonment.

Moosehead Point birds did significantly better than Yukon birds in terms of hatch success and chick survival, and it is tempting to explain these differences as the result of the presence of high-lipid sandlance in the diet of chicks at the former colony and their absence in the diet at the latter. However, the nests at Moosehead are on much higher cliffs than those on Yukon, and height above the water has been shown to have a significant positive correlation with nesting success (Prichard 1996), so the Moosehead birds may simply be better protected from predation.

Growth Rates

The linear phase growth rate that we observed (17.4 g/day), falls in the middle of the range of reported values from Prince William Sound in 1994 and 1995 (15.7 - 20.3 g/day, Hayes 1995, 1996). Chicks at Moosehead Point on average grew three grams a day faster during this phase than birds at Yukon Island. This difference was not significant (probably because of small sample sizes), but it follows the trend of differences between Moosehead Point and Outer Kachemak Bay observed in 1994 and 1995 (Prichard 1996), and may reflect the presence of sandlance in the diet at Moosehead. Sandlance have the highest lipid content and energy value of all guillemot forage fish in Kachemak Bay (Roby et al, 1995).

Although we were unable to record actual fledging mass, we did weigh chicks at age thirty days as a measure of peak mass. These results will allow for comparisons with other areas and other years in Kachemak Bay.

Chick Diet and Provisioning

There were clear differences between the diets fed to chicks at the three main study locations.

Sandlance were the most common species in the diet of Moosehead Point birds, even though they made up less than half of the diet. Sandlance made up less of a quarter of the diet in Seldovia Bay and were absent at Yukon Island. Gunnels and Pricklebacks were the dominant benthic group in Moosehead and Yukon diets, but were less common than flatfish and sculpins in Seldovia Bay.

Hayes (1996) found that pigeon guillemots in Prince William Sound fail to provision two-chick nests at twice the rate of one-chick nests. Presumably this means that singleton chicks are being fed at an optimal rate, but that both chicks in a two chick nest are not. We found that one-chick and two-chick nests were not provisioned at significantly different rates, which suggests that forage conditions were sub-optimal around all three study colonies.

It has been demonstrated that Common Murres (*Uria alge)* have flexible time budgets that allow breeding birds to respond to changing forage fish availability with changes in time spent foraging (Burger and Piatt 1990). In contrast, Black-legged Kittiwakes (*Rissa tridactyla*) in Cook Inlet have no such flexibility; even when forage fish are plentiful, breeding adults have little or no resting time at the colony (Piatt et al, unpublished data). We measured the time elapsed between a guillemot's arrival on the water in front of the colony and delivery to the nest in an attempt to determine if this resting time was part of a flexible time budget during chick provisioning. If time spent foraging and resting are inversely related and fluctuate in relation to prey availability, then resting time would provide an index of foraging effort and foraging conditions.

Provisioning birds spent significantly more time resting in front of the colony at Moosehead Point than at Yukon Island. This is consistent with observations that Moosehead birds have a ready supply of concentrated schooling fish (sandlance) to feed on, whereas Yukon birds rely on dispersed benthic fish. However, the higher Moosehead value is the result of the very high average resting time (36.67 minutes) recorded on 4 August. If this watch is excluded, there was no significant difference between colonies in resting time (Kruskall-Wallis, H= 5.15, P= 0.08). In any case, comparisons with data from future breeding seasons should demonstrate whether resting time has any value as an index of foraging effort.

Prey Assessment

The strong correlation between sandlance proportions in seines and chick diets at Moosehead Point suggests that seines can be used to follow seasonal changes in the availability of schooling fish. Seine catches also reflected the decrease of sandlance in the diet at Moosehead from 1995 to 1996 (Appendix). Seines also have some usefulness in measuring benthic fish availability. Beach seines correctly reflected declines in sculpin consumption by guillemots at Moosehead Point and Yukon Island in 1995 and 1996 (Appendix), and the high incidence of flatfish in the diet in Seldovia Bay in 1996.

Bottom trawling is a promising method of sampling benthic fish, since it operates in deeper water further from shore. The trawl stations that we established this year will allow us to monitor benthic fish populations in future years. Data from this year indicate that although sculpins were more common than gunnels and blennies around Moosehead and Yukon (trawl data) and Seldovia (seine data), guillemots fed chicks blennies more often than sculpins at all three colonies. Blennies have a higher energetic value than sculpins (Roby et al, 1995), and guillemots may preferentially seek out these higher quality prey items when foraging for their chicks. It is also possible that sculpins' large heads and spines make them unpalatable prey.

Population Monitoring

The results of our one-time survey of the south shore of Kachemak Bay are slightly lower than those from the 1995 count, but this difference cannot be evaluated statistically. We established a protocol for repetitive colony counts to more accurately monitor population trends. These counts were made at high tide, when colony attendance peaks in Kachemak Bay (Prichard 1996) and they will provide a baseline for future monitoring efforts. Because of the variability in counts, the maximum number of guillemots counted may be a good measure of each colony's population. A comparison of the mean and maximum counts provides an index of colony attendance. Changes in the relationship between these two value could represent changes in colony attendance, and might provide an index of foraging effort and food availability during incubation.

Conclusions and Recommendations

1) Because feeding ecology varies markedly between colonies, Kachemak Bay is an ideal locale to study the interactions between pigeon guillemots and their prey. Future research should concentrate on the three main study colonies in order to increase sample sizes for statistical comparisons. Data on breeding biology and diet have been collected in Kachemak Bay for three consecutive years, providing an excellent baseline for future study. Additionally, prey populations have been assessed around guillemot colonies for the past two years.

2) One-time counts are inadequate to monitor population changes, so we have established a protocol of repetitive colony counts which will allow us to accurately monitor population trends throughout Kachemak Bay on a fine spatial scale. These counts also provide an index of foraging effort during incubation.

3) Differences in breeding biology may be related to diet, as birds with access to sandlance were more successful then those relying on benthic fish. However, predation is also an important factor influencing reproductive success, and more study is needed to distinguish the effects of diet and predation. Chick growth rates were not significantly different between colonies, but larger sample sizes may help elucidate the relationship between diet and nestling growth.

4) Beach seines and bottom trawling are both useful in assessing prey abundance, though both methods have limitations. Future research should increase sampling effort around the three main study areas and synchronize sampling with guillemot diet watches. Alternate methods such as scuba and video may allow prey populations to be accurately quantified.

5) Foraging effort during incubation and time budgets during chick provisioning may provide useful indices of the predator/prey relationship. Birds at Moosehead Point spent more time at rest during chick provisioning than birds at the other study sites, and this may reflect the local abundance of sandlance. Better comparisons of time budgets at the three key study areas could be obtained by establishing simultaneous all-day watches at the three sites. This would require the efforts of at least six observers. Better data on time budgets could be obtained if we marked wing patches to identify individual birds. Radio telemetry would provide data on foraging effort and would allow us to

determine the foraging range of birds at the three study areas and to focus our prey sampling efforts in these areas.

6) The banding program that we began this year will eventually allow us to monitor annual adult survival and chick recruitment, and to compare these population parameters in the context of different foraging regimes.

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Appendix: Inter-annual Comparisons

Introduction

Pigeon guillemots in Kachemak Bay were the subject of a Minerals Management Service study during the summers of 1994 and 1995 (Prichard 1996). Although that study concentrated on the response of blood marker proteins to hydrocarbon exposure in an attempt to develop guillemots as a bio-indicator species for marine oil pollution, data on feeding ecology and reproductive success were also collected. These data included chick diet composition and provisioning rates, chick growth rates, and productivity estimates. Reliable diet data aren't available for 1994, so this comparison will concentrate on results from the 1995 and 1996 field seasons.

Results and Discussion

Productivity

Estimates of breeding success in Kachemak Bay as a whole were 0.19 chicks fledged per egg in 1994, 0.25 in 1995, and 0.31 in 1996 (Figure 10). These averaged values conceal dramatic changes in productivity at individual colonies (Figures 11-14). Productivity at Moosehead Pt. increased from 0.18 fledglings/egg in 1995 to 0.54 fledglings/egg in 1996 (z-test, $z= 2.963$; $P= 0.003$). This increase is probably the result of decreased nest abandonment during incubation and decreased nest predation. Productivity values were not significantly different in nests from Yukon I. to Seldovia Bay (1995= 0.16, 1996= 0.21, $z= 0.254$; $P= 0.800$). Productivity declined at Halibut Cove (1995= 0.51, 1996= 0.20, $z= 1.499$; $P= 0.134$) because of increased egg predation and nest abandonment. Breeding success also declined at Neptune Bay (1995= 0.60, 1996= 0.08, $z= 2.566$; $P= 0.010$). Fifty seven percent of the nests at this colony were apparently abandoned during incubation in 1996.

Chick Growth

Because of low productivity at Halibut Cove and Neptune Bay in 1996, sample sizes were adequate for statistical inter-annual comparisons of chick growth only at Yukon I. and Moosehead Pt. (Figure 15). The mean slope of transformed mass and wing chord data at Moosehead Pt. declined from 31.06 in 1995 (s.e.= 0.64, n= 17) to 28.67 in 1996 (s.e.= 1.02, n= 15, $t= -2.04$, $P=0.05$). There were no significant differences in outer Kachemak Bay (Yukon I.-Seldovia Bay).

Chick Diet

The results of diet watches in 1995 and 1996 are presented in Figure 16. The most obvious difference between years was the sharp decline in sandlance in the Moosehead Point diet, from 83% of observations to 45% (z test, $z= 8.832$, $P< 0.001$). This decline was accompanied by an increased reliance on gunnels and pricklebacks, and the appearance in the diet of significant numbers of sculpins. This shift from sandlance to benthic fish represents a decline in the lipid content and energy density of prey items being fed to chicks (Roby et al, 1995).

Inter-annual variation at Yukon Island probably has more to do with the way data were collected than differences in what chicks were being fed. In 1994 diet observations were generally divided into four categories: sandlance, gunnel/prickleback, sculpin, and flatfish. In 1995 we made a more concerted effort to identify different taxonomic groups in the diet, and found that fish that probably would have been placed in the gunnel/prickleback category in 1994 included gadids, ronquils, searchers, and greenlings. Therefore we placed gunnel/prickleback observations from 1994 in the unidentified demersal fish category. The only apparent change in chick diet between the two years was the decline in sculpins, from 24% to 6% (z-test, $z= 2.565$; $P= 0.010$).

Conclusions

1) Low predation pressure was responsible for an increase in productivity at Moosehead Pt. in 1996. Nest abandonment during incubation was a significant factor in reproductive failure elsewhere in Kachemak Bay. Future research on foraging effort and prey availability during incubation may elucidate the relationship between food availability and nest abandonment.

2) Chicks grew more slowly when sandlance were less prevalent in the diet at Moosehead Pt. At Yukon I., where there was no apparent change in the energetic quality of available forage fish, there was also no change in chick growth rates.

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Table 1. Pigeon guillemot repetitive colony count results, Kachemak Bay, summer 1996.

Census Area	Maximum	Mean	SE	n (counts)
Moosehead Pt.				
China Poot	14	7.86	1.40	7
Motherload	51	35.86	4.53	7
N. Moosehead	19	11.00	2.13	7
Peterson Side	47	41.29	1.92	7
Yukon I.				
Hesketh I.	41	29.88	4.34	8
S.W. Yukon	11	3.63	1.05	8
Yukon I.	26	12.25	3.13	8
Sub-Yukon	14	2.75	1.68	8
Seldovia Bay				
Naskowhak Pt.	16	10.75	1.15	8
Lemon Cliffs	4	3.33	0.33	6
Gray Cliffs	16	9.25	1.47	8
Seldovia Bay	34	26.25	1.49	8
Sub-Seldovia	20	12.67	1.84	9
Seldovia Pt.	45	28.89	4.54	9
Other Areas (East to West)				
Mallard Bay	16	13.14	0.94	7
Goshawk	5	2.88	0.44	8
Triangle Rock	18	10.88	1.55	8
Sea Cliff	7	3.88	0.93	8
Ismailof	7	3.25	1.01	8
Peterson Pt.	9	2.50	0.96	8
E. Peterson	8	5.13	0.81	8
The Nose	8	5.75	0.67	8
N. Neptune	43	30.17	2.90	6
S. Neptune	14	8.43	1.29	7
Kasitsna Cliffs	15	7.44	1.30	9
Guillemot Meadows	50	33.88	3.30	8

Table 2. Pigeon guillemot productivity in Kachemak Bay, 1996. Hatch success is based on Mayfield estimates of egg survival and the percentage of surviving eggs that hatched. Chick survival rates were obtained by the traditional cohort method.

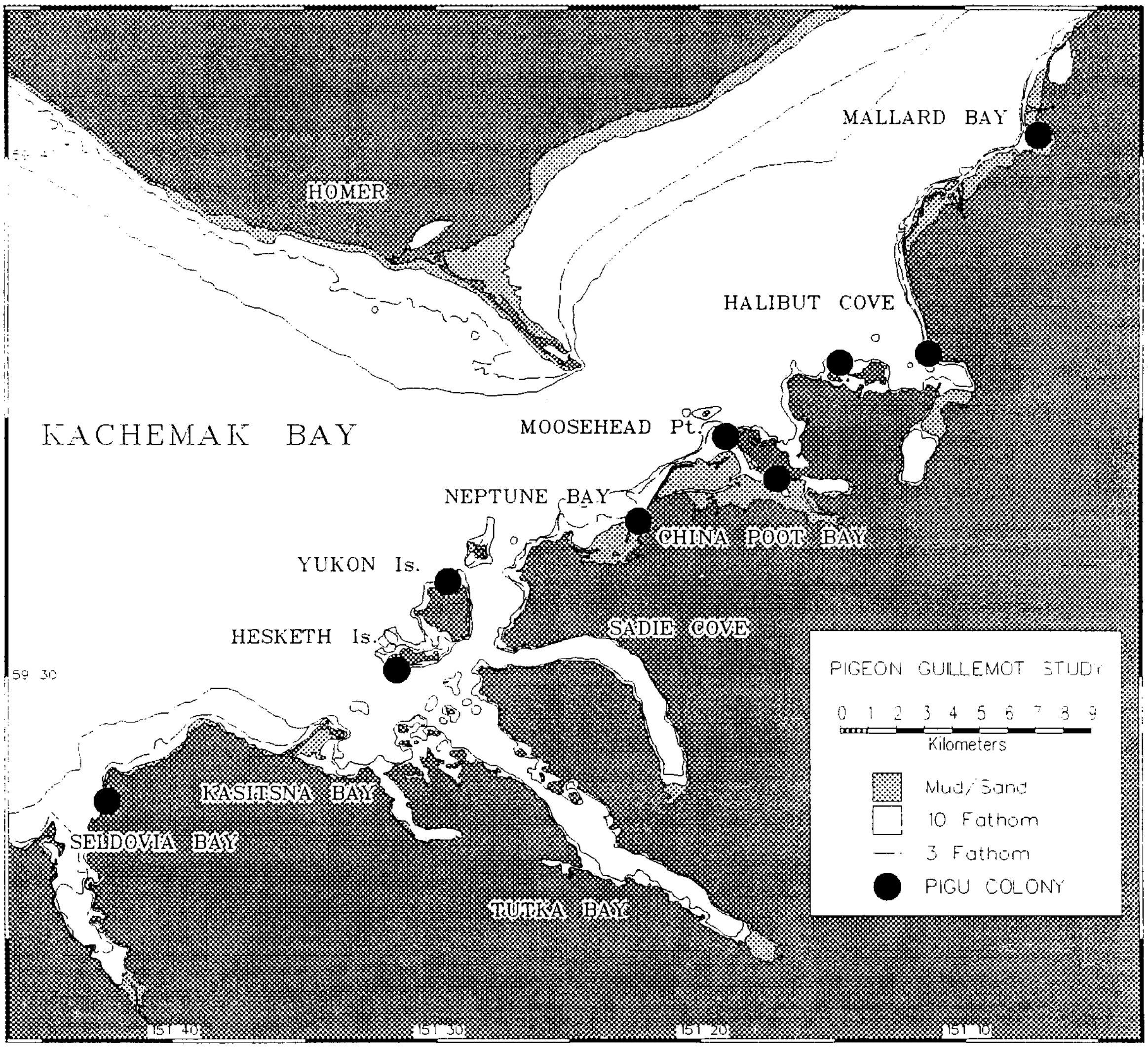
Colony	Mean Clutch Size (SE)	n (nests)	Hatch Success	n (eggs)	Chick Survival	n (chicks)	Chicks Fledged per Egg	Chicks Fledged per Nest
Moosehead Pt.	1.84 (0.09)	19	0.64	29	0.85	20	0.54	1.00
Neptune Bay	1.86 (0.14)	7	0.31	13	0.25	4	0.08	0.14
Yukon I., Hesketh I.	1.91 (0.09)	11	0.35	18	0.33	6	0.12	0.22
Kasitsna Bay	1.50 (0.50)	2	1.00	3	0.67	3	0.67	1.00
Herring Is.	1.67 (0.33)	3	0.41	5	0.75	4	0.31	0.51
Halibut Cove	1.67 (0.17)	9	0.26	15	0.80	5	0.20	0.34
Seldovia Bay	2.00 (0.00)	5	0.27	12	0.33	3	0.09	0.18
Mallard Bay	1.50 (0.29)	4	0.80	7	0.00	2	0.00	0.00
Kachemak Bay	1.80 (0.05)	60	0.49	104	0.64	47	0.31	0.56

Table 3. Three methods of assessing growth rates of pigeon guillemot nestlings in Kachemak Bay, 1996. The linear phase method relies on known age birds, which results in a smaller sample size.

	Linear Rate (g/day)			Transformed Slope			Slope of Mass on Wing Length (35-140 mm)		
Colony	Mean	SE	n	Mean	SE	n	Mean	SE	n
Moosehead Pt.	18.43	1.45	15	28.67	1.02	15	2.68	0.21	19
Neptune Bay				30.89	2.34	2	3.43	0.56	2
Yukon Island	15.42	1.98	5	29.14	2.64	5	2.86	0.67	3
Seldovia Bay				35.98	4.19	2	2.58		1
Kasitsna Bay	13.63	2.38	2	28.84	1.75	3	3.27	0.12	2
Herring Is.	17.43	3.05	3	28.00	1.20	3	2.81	0.16	3
Halibut Cove				32.71	0.31	4	3.80		1
Mallard Bay							1.64		1
Kachemak Bay	17.36	0.84	25	29.60	0.67	34	2.68	0.17	32

Table 4. Taxa and standard length of fish collected from pigeon guillemot nests, Kachemak Bay, summer 1996

Taxon	Standard Length (mm)
Flatfish	107
Flatfish	242
Flatfish	107
Flatfish	93
Flatfish	97
Flatfish	97
Flatfish	99
Gunnel	
Gunnel	
Gunnel	188
Gunnel	145
Gunnel	157
Gunnel	102
Gunnel	145
Gunnel	188
Lumpenus sp.	221
Lumpenus sp.	155
Lumpenus sp.	242
Lumpenus sp.	243
Ronquil/Searcher	136
Ronquil/Searcher	
Ronquil/Searcher	106
Ronquil/Searcher	152
Ronquil/Searcher	85
Sandlance	134
Sandlance	134
Sculpin	102
Sculpin	102
Sculpin	107


MALLARD BAY
HOMER
HALIBUT COVE
KACHEMAK BAY
MOOSEHEAD Pt.
NEPTUNE BAY
CHINA POOT BAY
YUKON Is.
HESKETH Is.
SADIE COVE
59 30
KASITSNA BAY
SELDOVIA BAY
TUTKA BAY
151 40
151 30
151 20
151 10
PIGEON GUILLEMOT STUDY
0 1 2 3 4 5 6 7 8 9
Kilometers
Mud/Sand
10 Fathom
3 Fathom
PIGU COLONY

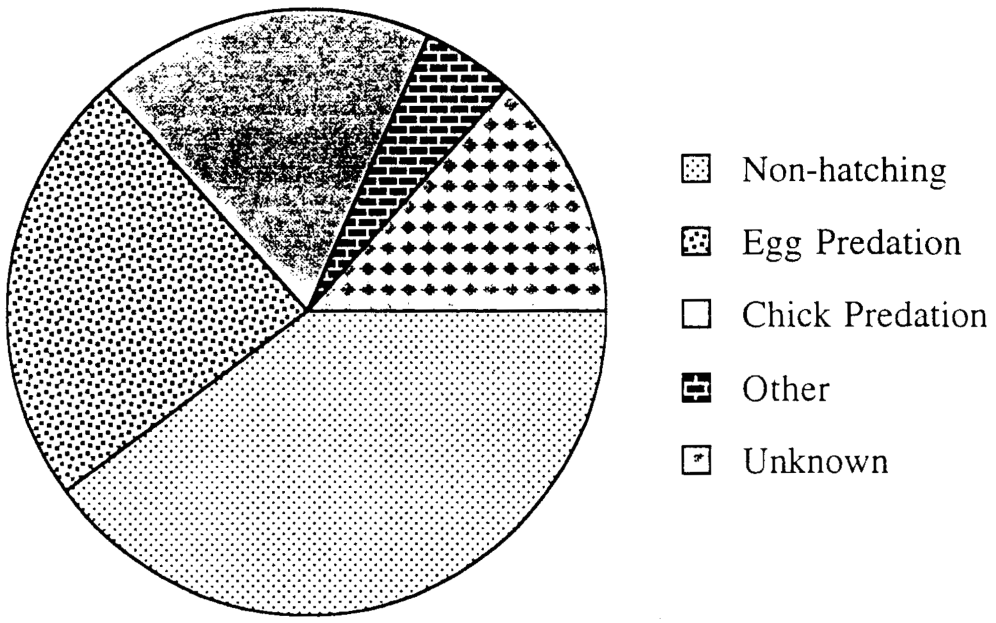


Figure 2. Causes of failure for pigeon guillemot nests in Kachemak Bay, 1996 (n= 63 eggs and chicks).

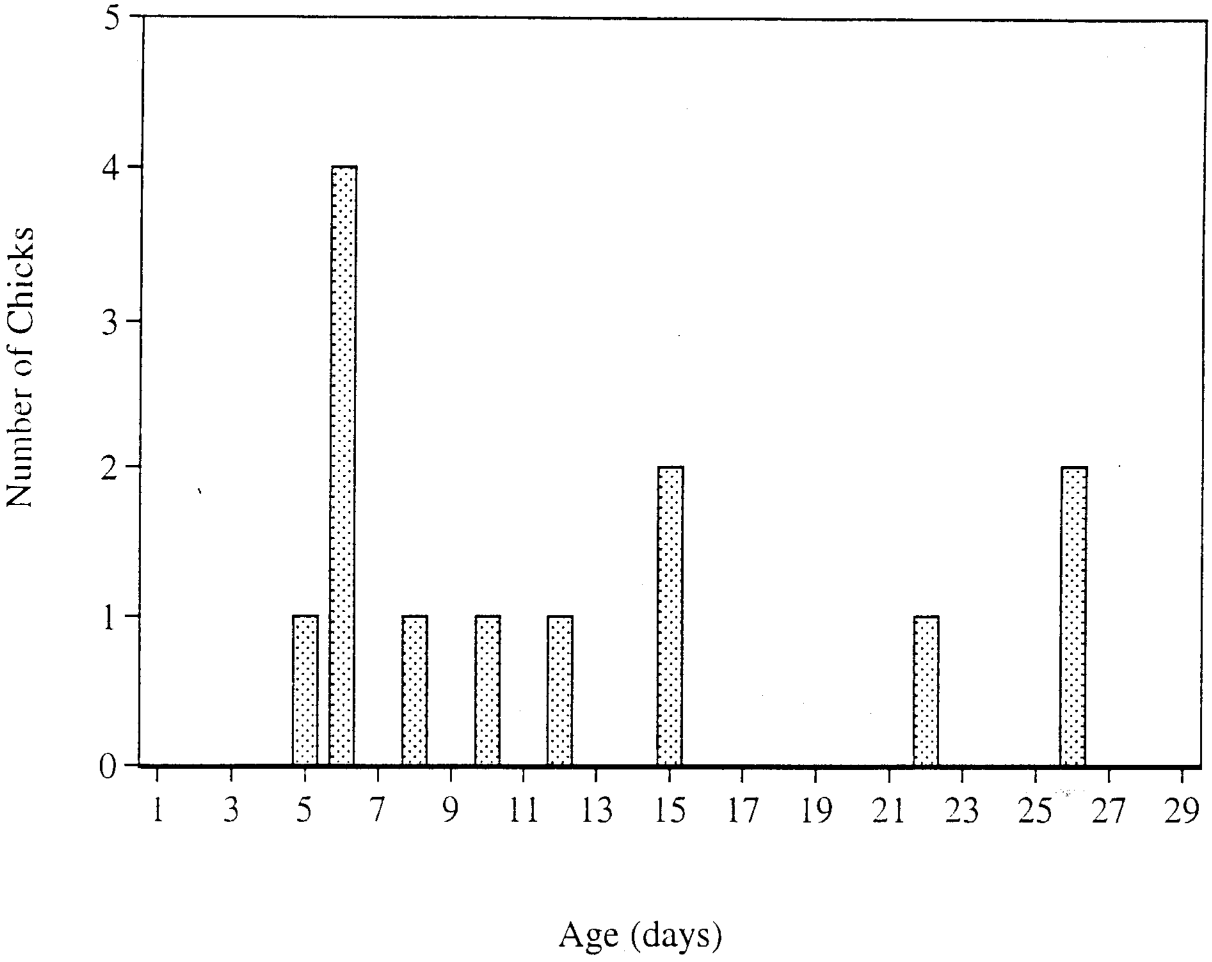


Figure 3. Pigeon guillemot chick mortality by age, Kachemak Bay 1996.

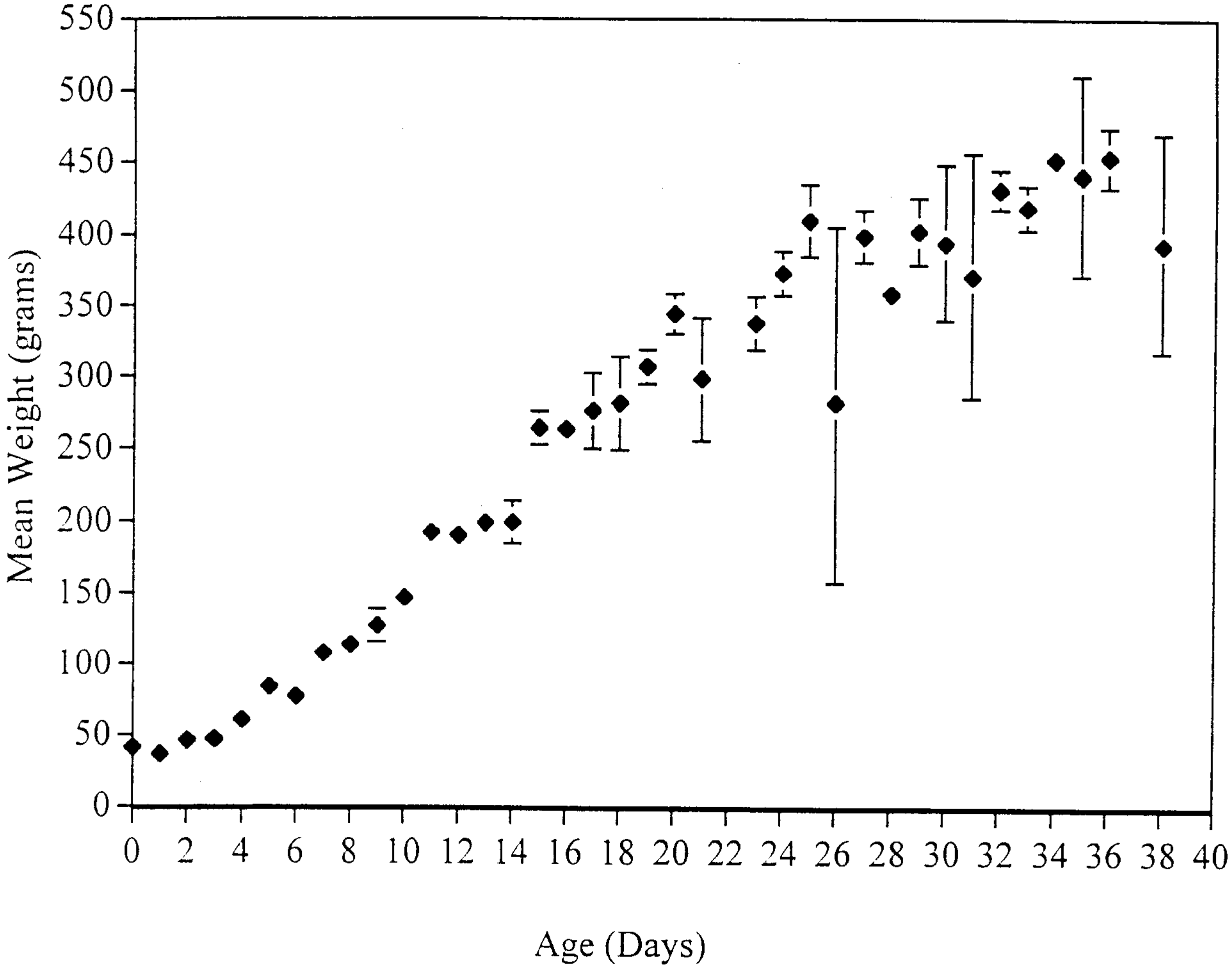


Figure 4. Growth curve of known-age pigeon guillemot nestlings in Kachemak Bay, summer 1996. Error bars equal one standard error.

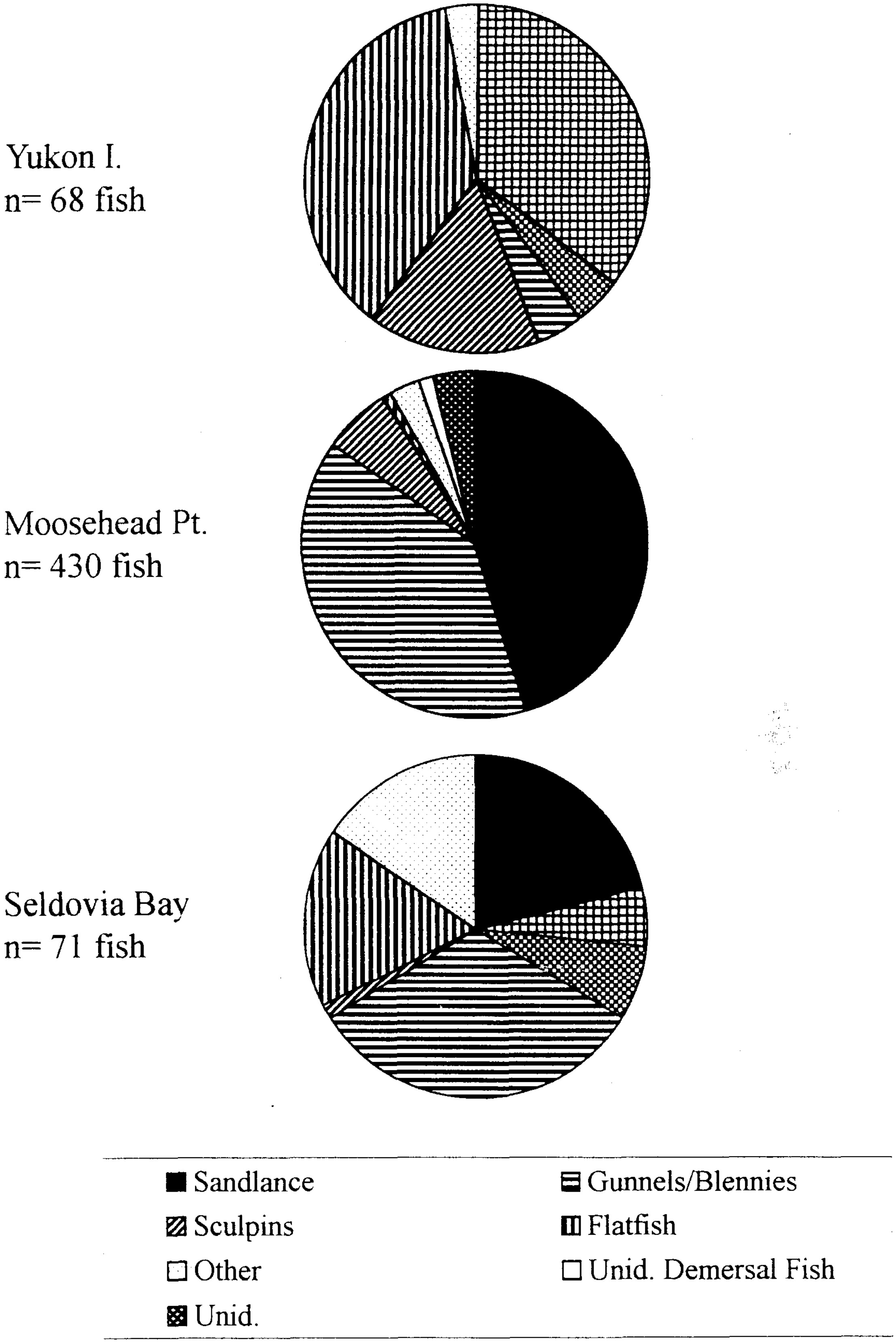


Figure 5. Pigeon guillemot nestling diet in Kachemak Bay, summer 1996.

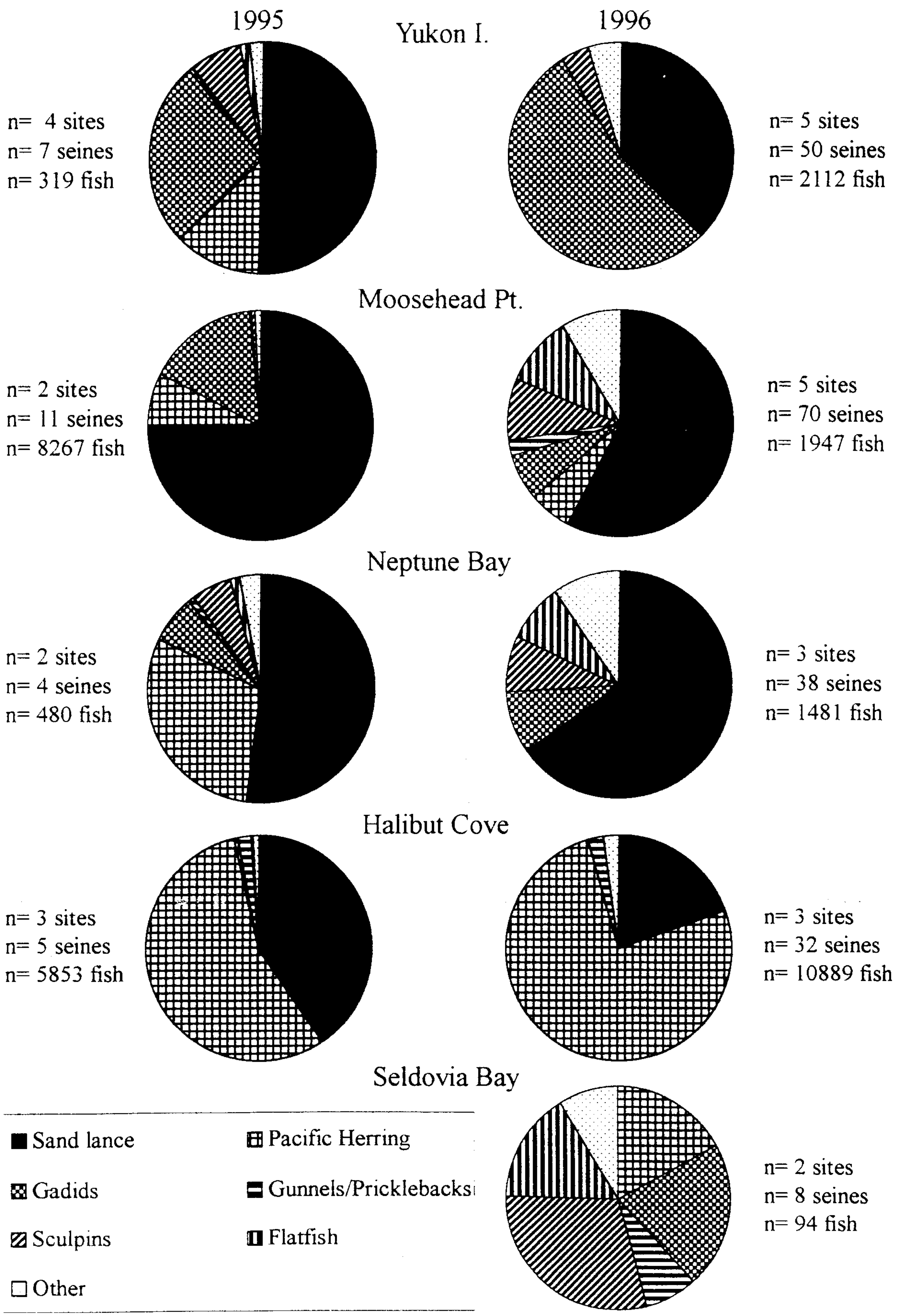


Figure 6. Beach seine results around Kachemak Bay pigeon guillemot colonies, 1995-1996.

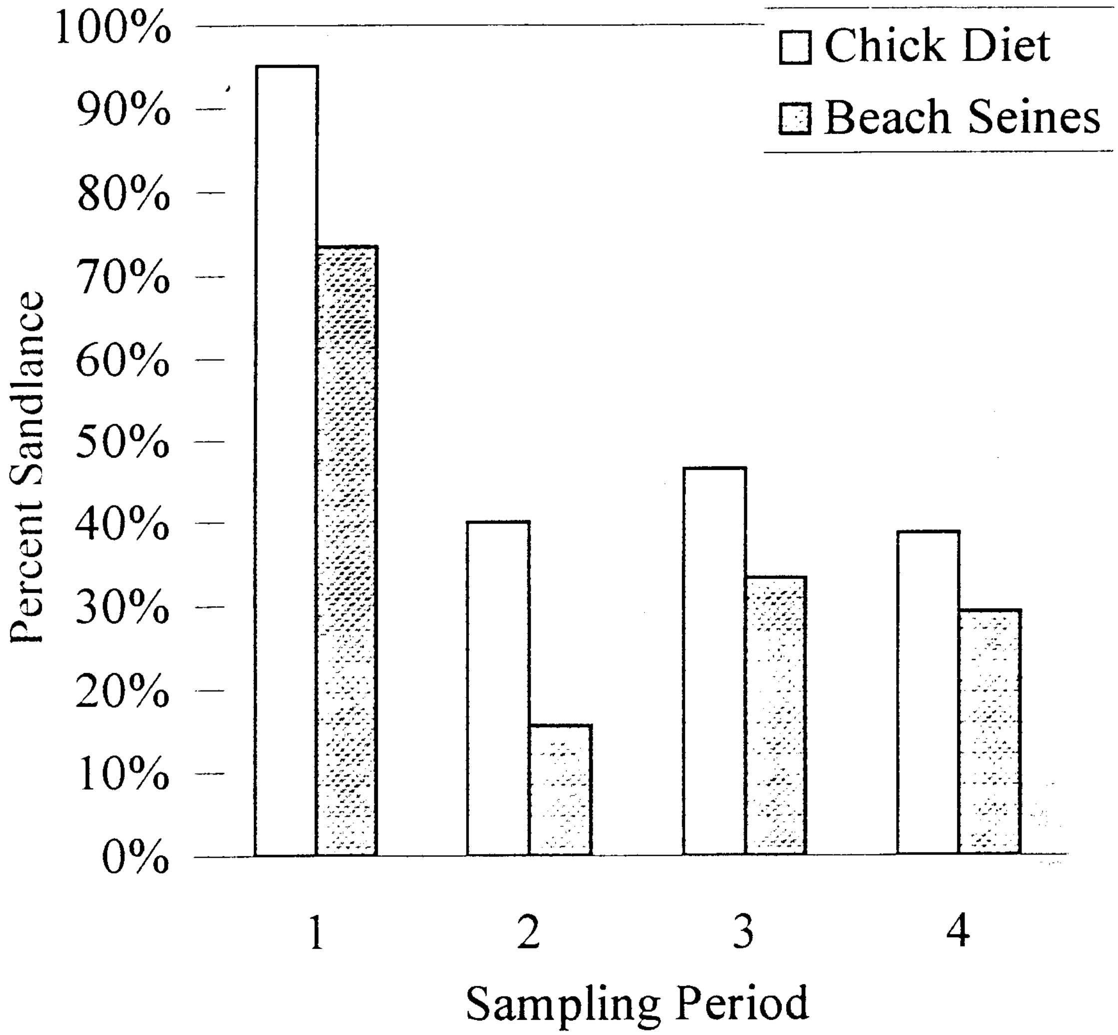
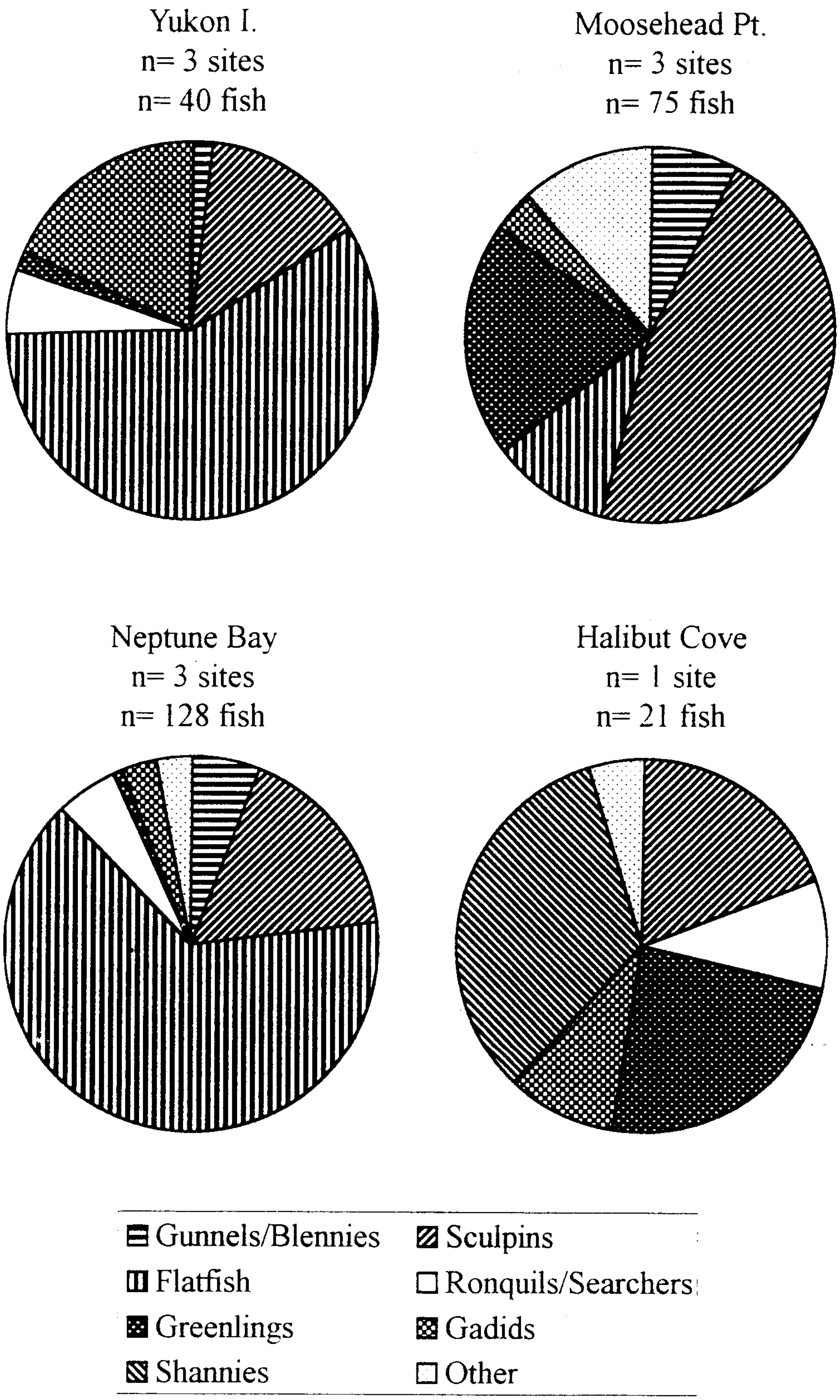


Figure 7. Sandlance in pigeon guillemot nestling diet at Moosehead Pt. and nearby beach seines, Kachemak Bay, summer 1996. Sampling periods: 1= 2-6 July (n= 19 chick meals, n= 4 seines, n= 328 fish caught), 2= 22-25 July (n= 115 meals, n= 7 seines, n= 64 fish), 3= 31 July - 4 August (n= 97 meals, n= 4 seines, n= 6 fish), 4= 10-12 August (n= 43 meals, n= 12 seines, n= 359 fish).



Yukon I.
n= 3 sites
n= 40 fish

Moosehead Pt.
n= 3 sites
n= 75 fish

Neptune Bay
n= 3 sites
n= 128 fish

Halibut Cove
n= 1 site
n= 21 fish

Figure 8. Bottom trawls around pigeon guillemot colonies in Kachemak Bay, 8-9 August, 1996. Includes *Lumpenus* spp. 40-250 mm total length, all other fish 40-150 mm total length.

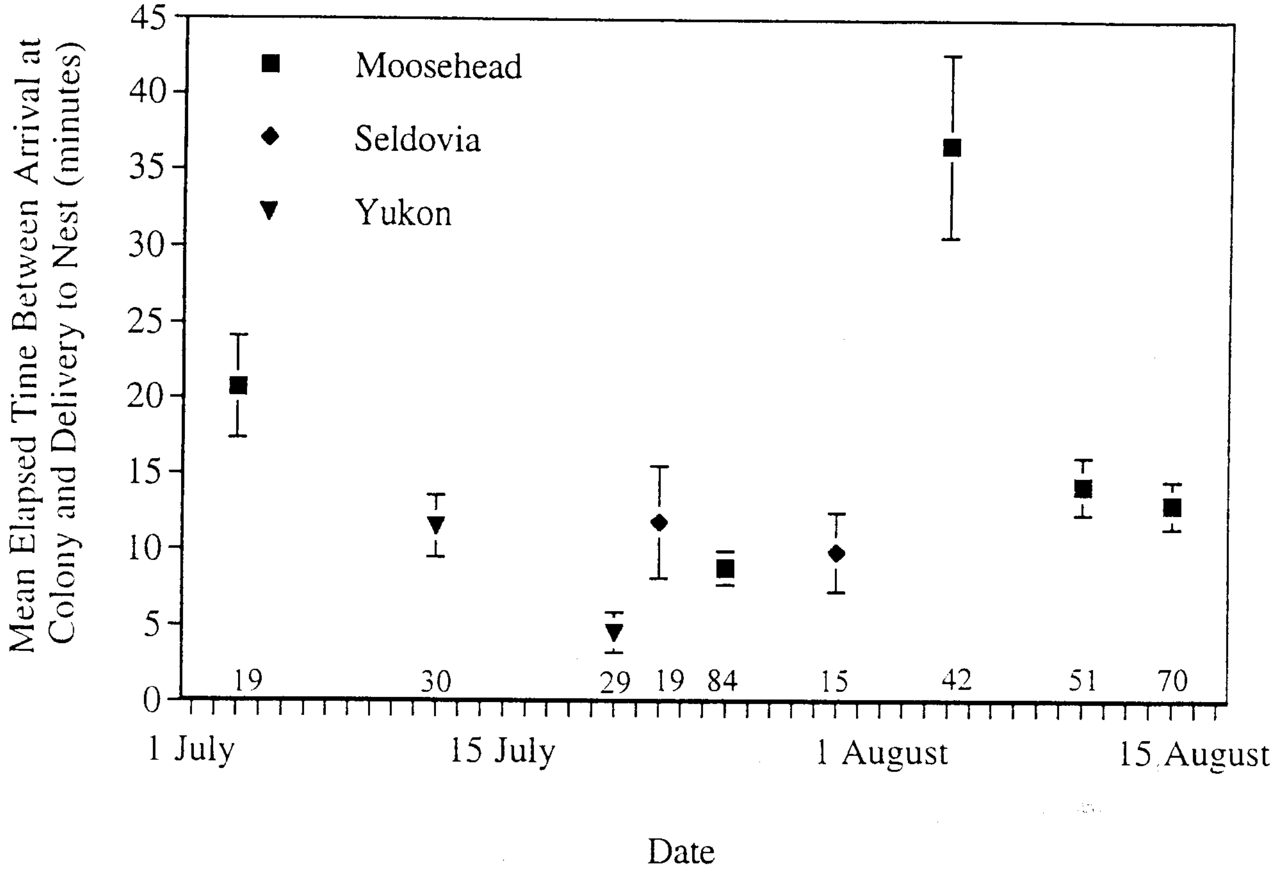


Figure 9. Pigeon Guillemot resting time during chick provisioning, Kachemak Bay, 1996. Error bars are one standard error, and sample sizes (number of deliveries observed) are shown along the x axis.

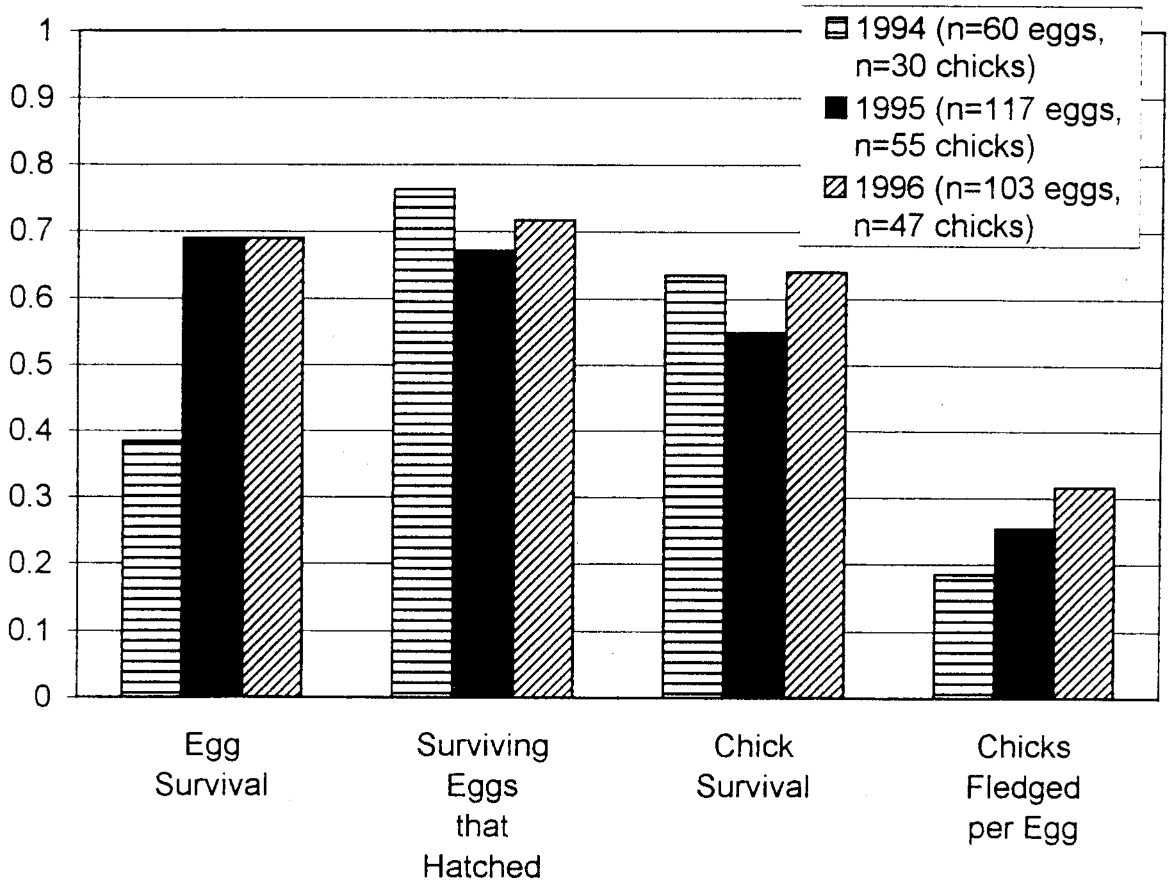


Figure 10. Pigeon guillemot breeding success in Kachemak Bay, 1994-1996.

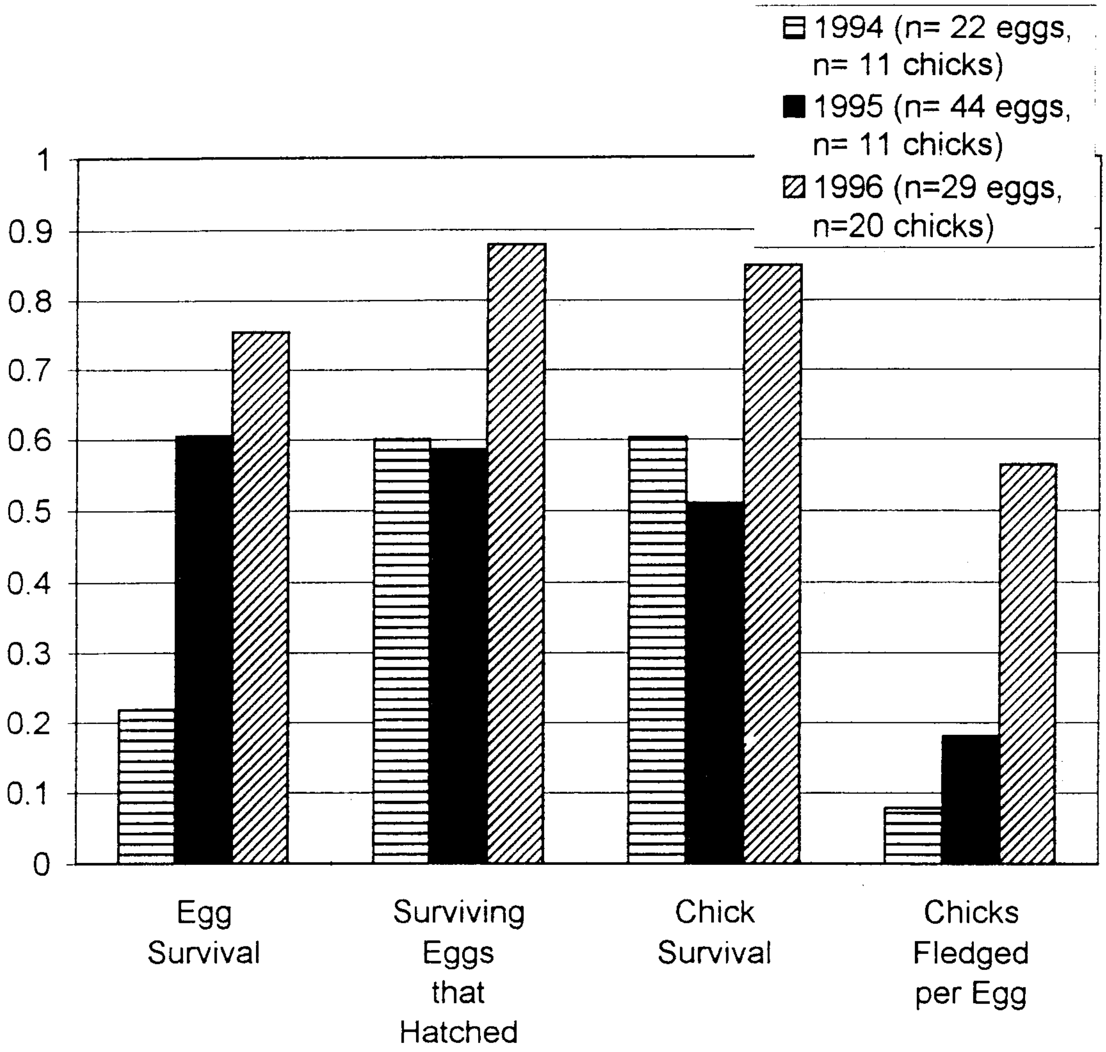


Figure 11. Pigeon guillemot breeding success at Moosehead Point, 1994-1996.

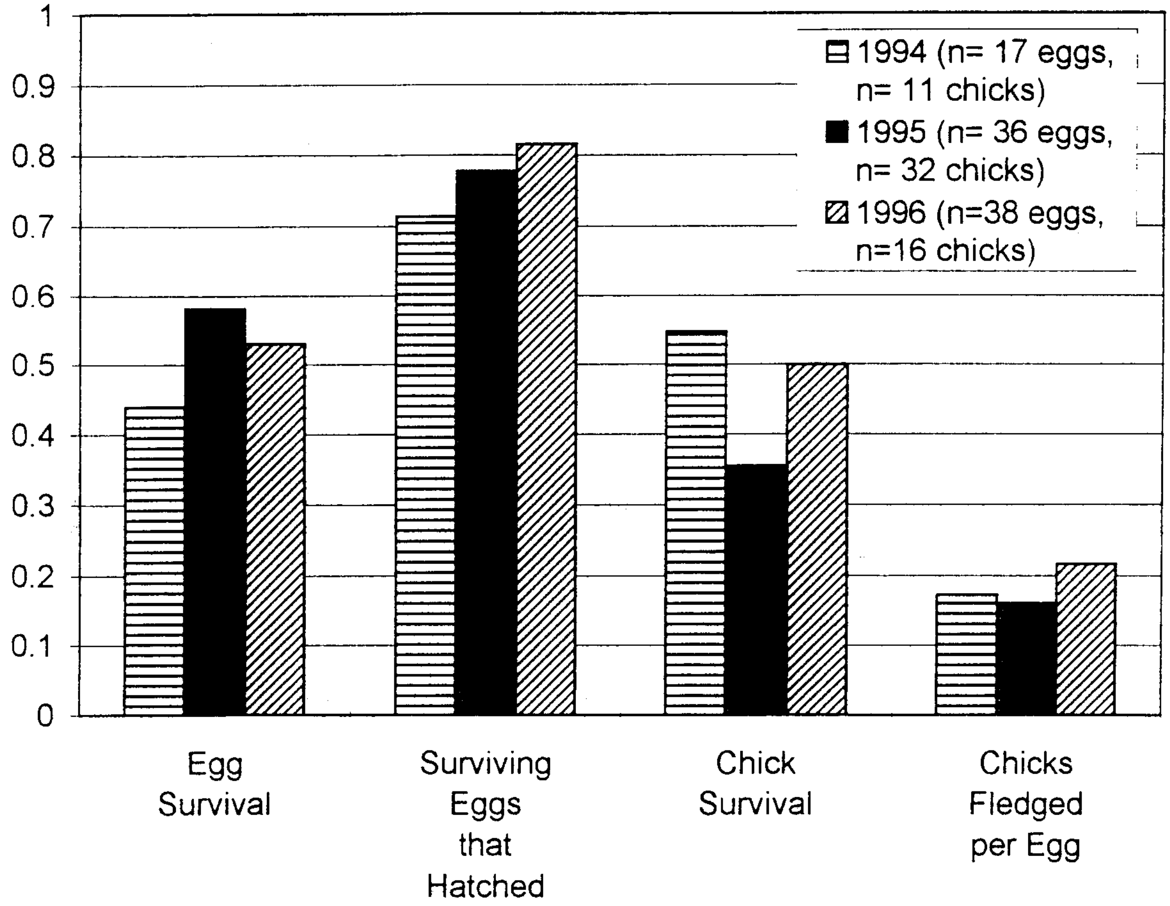


Figure 12. Pigeon guillemot breeding success in outer Kachemak Bay (Yukon I. to Seldovia Bay), 1994-1996.

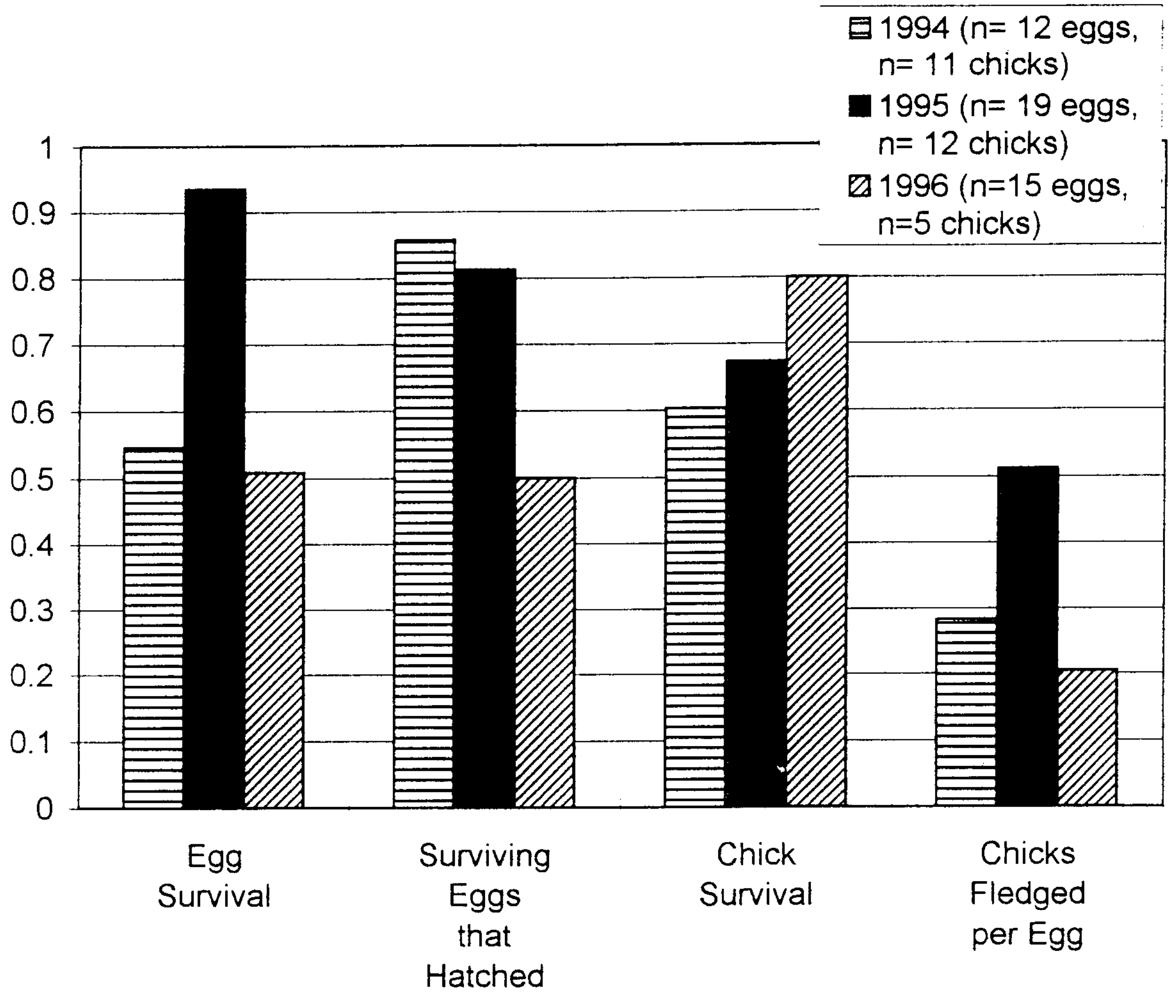


Figure 13. Breeding success of pigeon guillemots in Halibut Cove, 1994-1996.

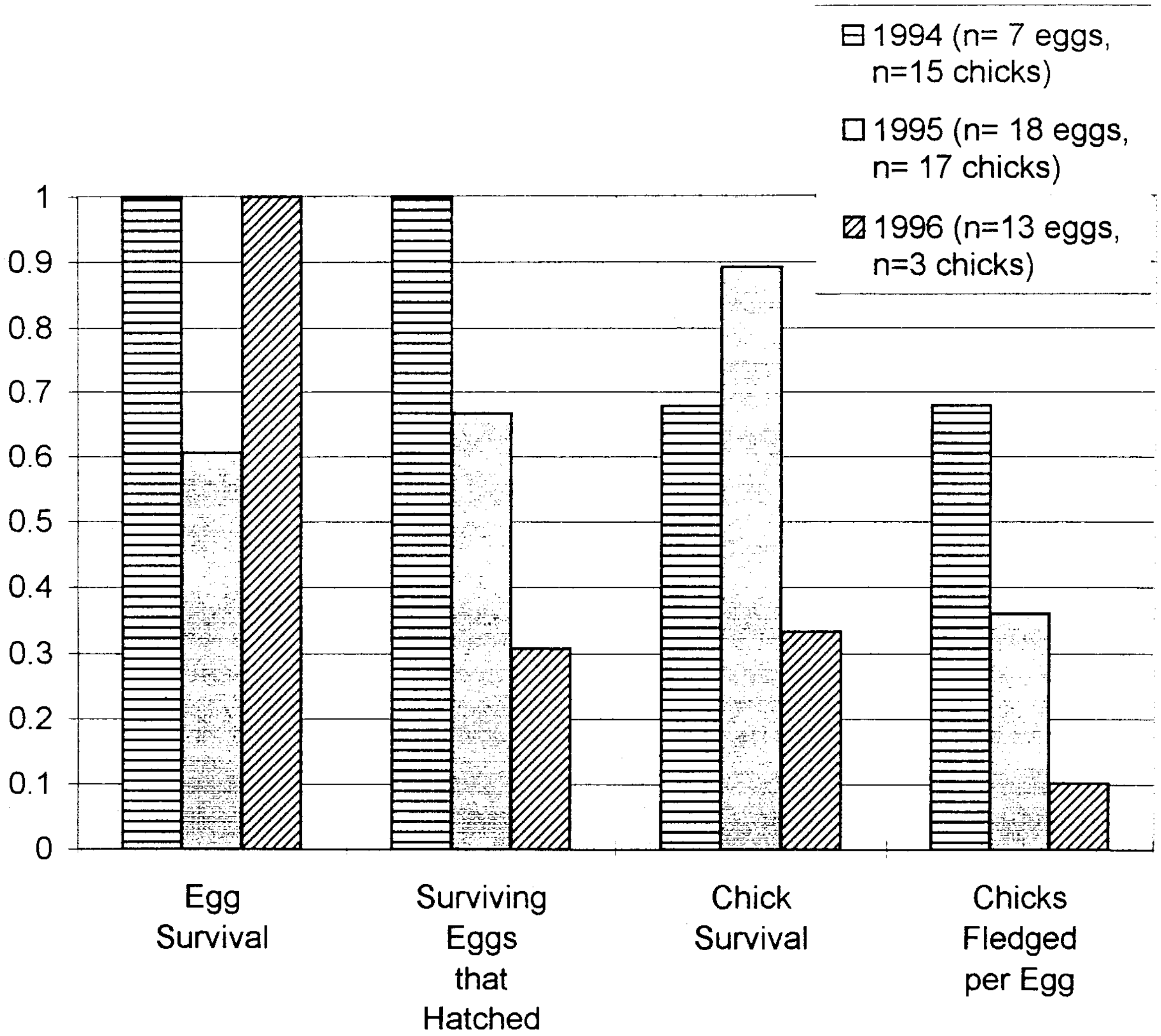


Figure 14. Pigeon guillemot breeding success in Neptune Bay, 1994-1996.

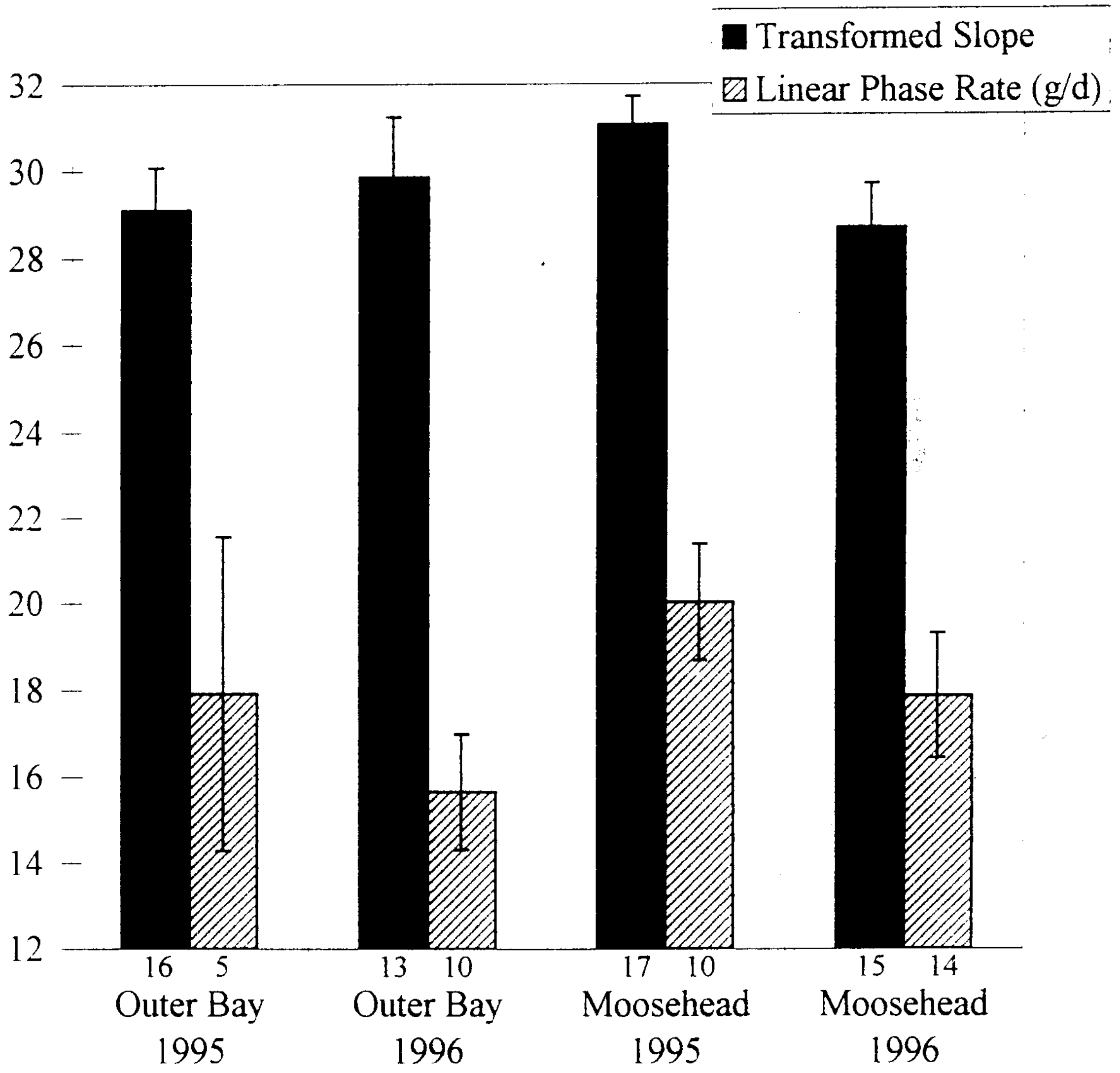


Figure 15. Pigeon guillemot nestling growth in Kachemak Bay, 1995-1996. Outer bay includes nests from Yukon I. to Seldovia Bay. Sample sizes are given at the base of each column. Error bars equal one standard error.

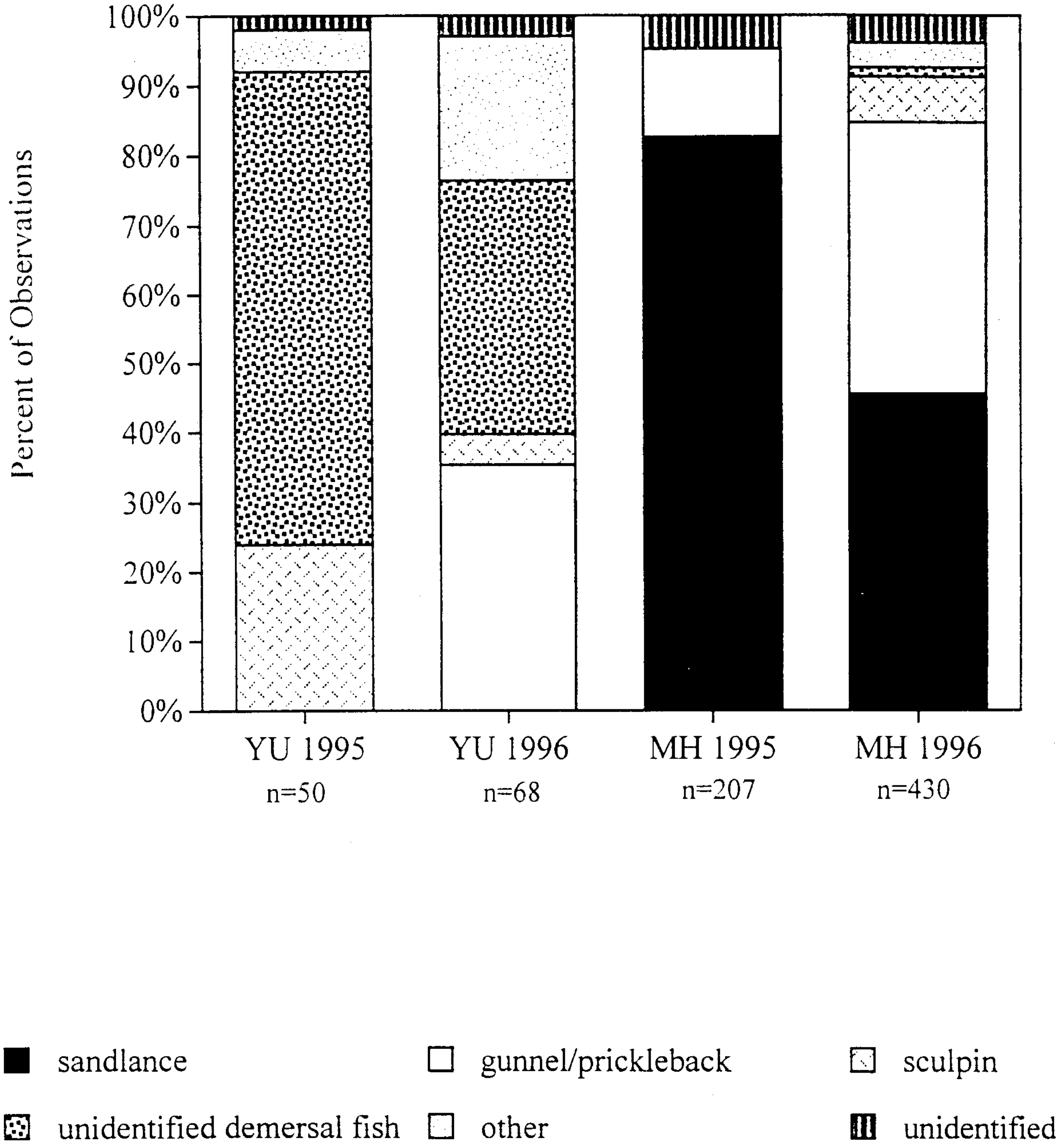


Figure 16. Diet composition at Yukon Island and Moosehead Point in 1995 and 1996.

APPENDIX N

APEX: 96163N

Exxon Valdez Oil Spill
Restoration Project Annual Report

EFFECTS OF DIET QUALITY ON POST-NATAL GROWTH OF SEABIRDS: CAPTIVE FEEDING TRIALS

Restoration Project 96163N

Start-up Date: April 1996

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ABSTRACT

Declines in the availability of certain schooling forage fishes (Pacific sand lance *Ammodytes hexapterus*, Pacific herring *Clupea harengus pallasi*, capelin *Mallotus villosus*) have potentially contributed to the lack of recovery of some fish-eating seabirds (Pigeon Guillemots *Cepphus columba*, Common Murres *Uria aalge*, Marbled Murrelets *Brachyramphus marmoratus*) that were injured by the *Exxon Valdez* oil spill. These forage fishes tend to have high lipid content and, consequently, are assumed to have high nutritional value as food for nestling seabirds. This study tests the hypothesis that composition of the diet is one factor constraining the growth and development of piscivorous seabirds.

We raised seabird nestlings (Black-legged Kittiwakes *Rissa tridactyla* and Tufted Puffins, *Fratercula cirrhata*) in captivity on rations of either capelin or sand lance as representative of high-quality forage fish, or walleye pollock (*Theragra chalcograma*) as representative of low-quality forage fish. Lipid content of capelin diets (31% dry mass) and sand lance diets (22% dry mass) were considerably higher than that of pollock diets (9% dry mass). Experimental diets consisted of iso-biomass and iso-caloric rations of low- and high-lipid fish types.

Seabird nestlings fed rations of either sand lance or capelin had much higher growth rates of body mass and somewhat higher growth rates of wing length than nestlings fed the same biomass of pollock. Puffin chicks fed iso-caloric rations of pollock or capelin showed little difference in rates of mass or wing growth, but the capelin fed chicks deposited larger fat reserves than the chicks fed pollock. In this iso-caloric (ca. 330 kJ/day) comparison, puffin chicks had to be fed 80 g of pollock / day to receive the same calories as 45 g of capelin / day. Differences in mass gain between nestlings fed the different rations were more pronounced than differences in wing growth, suggesting that undernourished nestlings allocate food intake more to structural development than body mass.

We conclude that when provisioning rates of seabirds to their young are constrained, the lipid content and nutritional quality of forage fish fed to nestlings has a marked effect on growth rates and, potentially, on reproductive success. One consequence of subsisting on pollock instead of lipid-rich forage species is that predators must expend more energy and catch more prey to meet the energy requirements of their offspring. In addition, nestlings fed lower lipid diets deposit less fat reserves, potentially reducing post-fledging survival. These conclusions provide more support for the hypothesis that recovery of seabird resources that were injured by the Exxon Valdez oil spill is dependent on recovery of certain key forage fish stocks, especially capelin, sand lance, and herring.

INTRODUCTION

Recent declines among populations of top trophic level predators in the Northern Gulf of Alaska have been linked to decreasing availability of forage fishes (Merrick et al. 1987, Hatch et al. 1993, Piatt and Anderson 1996). Several species of seabirds, including Marbled Murrelets (Brachyramphus marmoratus), Common Murres (*Uria aalge),* and Pigeon Guillemots (*Cepphus columba),* have experienced population declines in the Exxon Valdez oil spill area in recent years. Total failure of breeding seabirds has been recorded at several sites (Chisik I., Middleton I., etc.), and a lack of high quality, lipid-rich forage species to provision nestlings has been hypothesized as a factor in low productivity.

A major change in the taxonomic composition of diets of several seabird species has been observed in the Northern Gulf of Alaska during the past 20 years. Specifically, some species have switched from diets dominated by oily fishes, like capelin (*Mallotus villosus*) and sand lance (*Ammodytes hexapterus),* to diets dominated by juvenile walleye pollock (*Theragra chalcograma*) and other gadids (Piatt and Anderson 1996). Due to lower lipid content and energy density (kJ/g), juvenile pollock are lower quality than other prey commonly found in diets of nestling seabirds, such as capelin or sand lance (Baird 1991, Roby et al. 1996, Van Pelt et al. in review). The energy density of capelin or sand lance is almost twice that of juvenile pollock, depending on sex and age class (Roby et al. 1996, Van Pelt et al. in review).

One of the key hypotheses that the APEX project is investigating states that reproductive success in seabirds is directly related to nutritional quality of forage fishes. Adult seabirds that rely on low quality prey to provision their young may experience lower productivity (Nettleship 1990, Martin 1989). As an example, Irons (1996) argues that recent reproductive failures among black-legged kittiwakes in oiled areas of Prince William Sound are linked to food conditions. Reproductive success in seabirds is dependent, in part, on the parents ability to provision the brood with energy (Roby 1991). If an adult were to provide the same amount of energy to its young in the form of juvenile pollock as it could by provisioning with sand lance or capelin, it would have to deliver nearly twice as much food. This may not be possible due to time and energy constraints, unless pollock are readily available close to the colony. Consequently, slower growth and lower fledging weights would be expected in nestlings fed primarily low energy diets. The potential result would be fewer nestlings surviving to fledge and lower post-fledging survival.

This research is designed to provide a better understanding of the relationship between diet quality and seabird productivity. Captive nestlings fed controlled rations of either pollock, sand lance, or capelin are being used to compare the effects of biomass intake, caloric intake, and lipid:protein ratio of the diet on growth and development. By comparing results of captive feeding trials on two different seabird species (a larid vs. an alcid), we are also investigating differences in energy and nutrient management between seabird taxa.

METHODS

The research design utilizes a combination of captive feeding experiments and laboratory analyses. The captive-rearing experiment was conducted at the Kasitsna Bay Laboratory of the Institute of Marine Science, University of Alaska Fairbanks, during the summer of 1996. Chicks used in the study were collected from either East Amatuli Island in the Barren Islands group or colonies in Kachemak Bay. A sample of Black-legged Kittiwake chicks (N = 22) and Tufted Puffin chicks (N = 21) were removed from their nests at 6-10 days post-hatch and 5-18 post-hatch, respectively. Kittiwake thermoregulation is well-developed at 6-8 days post-hatch (Barrett 1978). Puffin chicks are independent of parental brooding at 5 days post-hatch (Wehle 1983) and thereafter can be maintained in captivity at normal ambient temperatures without an artificial heat source. All chicks were placed in individual indoor cages for captive feeding experiments. Cages consisted of covered plastic buckets with the bottom cut out and replaced with a floor of galvanized hardware cloth. This design made cage cleaning easier. By placing a pan underneath each bucket, we were able to conveniently collect excreta. We made one collection of kittiwake excrement and four collections of puffin excrement. Each collection was made for all subjects over a 24-hour period. These samples will be analyzed for energy content during the spring of 1997.

The sample of kittiwake chicks was evenly divided into three diet treatment groups, each receiving a daily ration of one of the following: (1) 100 g of juvenile walleye pollock, (2) 43 g of Pacific sand lance, (3) 100 g of Pacific sand lance. The 43 g sand lance ration was expected to be similar in caloric content to the 100 g pollock diet, based on published values of energy density in the two species of forage fish. Variables that were measured daily in kittiwake chicks included: (1) total body mass (measured with an Ohaus triple beam balance, +/- 0.1 g), (2) wing length (measured flat on a ruler, +/- 1 mm), and (3) head/bill length (measured with calipers, +/- 0.1 mm).

The sample of puffin chicks was also divided into three diet treatment groups, with each receiving a daily ration of one of the following: (1) 80 g of juvenile walleye pollock (2) 45 g of capelin, (3) 80 g of capelin. The 45 g capelin ration was designed to be similar in caloric content to the 80 g pollock diet (approx. 325 kJ/day) based on published values for energy density in the two forage fishes. Variables that were measured daily in puffins included: (1) body mass (measured with an Ohaus triple beam balance, +/- 0.1 g), (2) wing length (measured flat on a ruler, +/- 1 mm), (3) culmen length (measured with calipers, +/- 0.1 mm), and (4) tarsus length (measured with calipers, +/- 0.1 mm).

When captive-reared chicks reached early fledging age (31 days post-hatch for kittiwakes and 40 days post-hatch for puffins), they were sacrificed and frozen for later body composition analysis in the lab at Oregon State University. Total body water, lean mass, total body fat, ash-free lean dry mass, ash mass, and fat index were determined for each chick. To calculate a fat index, total body fat was divided by lean dry body mass.

Carcasses were weighed, partially thawed, plucked, and reweighed to determine plumage mass. Plucked carcasses were air-dried to constant mass at 60° C in a forced convection oven in order to determine moisture content. Dried carcasses were ground and homogenized by passing repeatedly through a meat grinder. Aliquots of the dried homogenate were extracted in a soxhlet apparatus using petroleum ether as the solvent system in order to determine fat content and ash-free lean dry mass by subtraction. Extracted aliquots were ashed in a muffle furnace at 550°C to determine ash content. Body composition of chicks from the captive-feeding experiments were compared to determine the effects of energy intake and diet composition on the allocation of assimilated resources to growth in lean mass and fat reserves. Preliminary results of these analyses are presented here.

Samples of juvenile pollock, sand lance, and capelin that were fed to captive kittiwake and puffin chicks were shipped frozen to the laboratory at Oregon State University, where they were subjected to proximate analysis. In the lab, forage fish specimens were dried to constant mass in a convection oven at 60° C to determine water content. Lipid content of the dried forage fish was determined by solvent extraction using a soxhlet apparatus and hexane/isopropyl alcohol 7:2 (v:v) as the solvent system. Lean dry fish samples were then ashed in a muffle furnace at 550°C in order to calculate ash-free lean dry mass by subtraction. Energy content of chick diets was calculated from the composition (water, lipid, ash-free lean dry matter [protein], and ash) of forage fish along with published energy equivalents of these fractions (39.4 kJ/g lipid; 17.8 kJ/g protein)(Schmidt-Nielsen 1990:171).

RESULTS

All captive subjects appeared to adjust quickly to captivity, survived for the duration of the experiment and exhibited little variation in growth and development rate within each diet treatment group. All kittiwake and puffin chicks readily consumed whole prey from the first feeding; no force feeding was required. Small aluminum pans were used to weigh out each meal and then the pans were placed in the cages and the chicks generally consumed the meal within 2-3 minutes. On a few occasions, primarily early in the captive feeding trials, individual fish had to be held with tweezers and presented to certain kittiwake chicks to encourage consumption. Puffin chicks did not require this encouragement; most chicks consumed their meals completely within a minute of being fed.

The kittiwakes chicks used as subjects for the experiment were estimated to be from 6-10 days old when first removed from their nests. Each chick was aged using a regression equation derived from data on known-age kittiwake chicks from Prince William Sound, Alaska (D.B. Irons, unpubl. data). Tufted puffin chicks used in the experiment were estimated to be 5-18 days old when they were removed from their nest burrows, with most being less than 12 days old. Puffin chicks were aged using a regression equation derived from data from known-age chicks on Aiktak Island, Alaska (Piatt and Romano, unpubl. data). Because of logistical constraints, we were forced to use puffins from a wider range of ages at the start of the captive feeding trials than we had intended. The primary drawback of including older chicks in the study was they were not allowed to habituate as long to captivity before being placed on their experimental ration as were the younger chicks.

Average energy density of fishes used in the study was 4.07 kJ/g for pollock, 6.85 kJ/g for sand lance, and 7.36 kJ/g for capelin. These values were used to estimate daily energy intake of each experimental group. Estimates of daily energy intake for puffins fed presumed "iso-caloric" diets of capelin or pollock were similar. Puffins fed the pollock ration (80 g/day) received an estimated 326 kJ/day and the "iso-caloric" capelin ration (45 g/day) was an estimated 331 kJ/day. In contrast, puffins fed the iso-biomass capelin ration (80 g/day) received an estimated 589 kJ/day.

Kittiwakes fed the pollock ration (100 g/day) received approximately 407 kJ/day, whereas kittiwakes on the "iso-caloric" sand lance ration (43 g/day) received only about 294 kJ/day. Kittiwakes fed the iso-biomass sand lance ration (100 g/day) received approximately 685 kJ/day. Thus, kittiwake growth could be compared for equal biomass rations of high and low lipid fish, but a comparison of growth on rations of equal caloric content was not possible.

Results of the comparison of growth on iso-biomass rations were similar for both seabird species. Subjects fed the high-lipid diet (capelin for puffins, sand lance for kittiwakes) experienced much higher rates of body mass gain and higher rates of structural development than subjects fed the low-lipid diet (pollock)(Figs. 2-6 for puffins, Figs. 7-10 for kittiwakes). Differences in body mass gain among the three diet groups were much more pronounced than differences in structural development (i.e., wing, culmen, head/bill and tarsus growth).

Tufted puffins fed pollock had slightly but significantly higher average body mass at the end of the feeding trial than those fed an iso-caloric ration diet of capelin. There was no significant difference in wing growth between the two groups (Fig. 6). There were no differences in culmen or tarsus growth between the two diet groups (Figures 4 and 5). However, average fat index for the two groups was very different. Fat index is used to compare body fat reserves among subjects while controlling for differences in body size. The pollock group had an average fat index of 0.0725, whereas the iso-caloric capelin group had an average fat index of 0.1500, more than twice that of the pollock group.

The comparison of kittiwake growth on iso-caloric diets of pollock and sand lance is ambiguous because the diets were not actually similar in energy content. The pollock group (100 g/day) was fed 38% more kJ/day than the sand lance group (43 g/day). Kittiwakes fed the pollock ration experienced significantly higher growth rates of body mass, wing length and head\bill length than kittiwakes fed the 43 g/day sand lance ration.

DISCUSSION

Both kittiwakes and puffins gained mass and grew at a higher rate on a diet of high-lipid fish as opposed to the equivalent biomass of low-lipid fish. This result was predicted because subjects on the high-lipid rations received an estimated 68.3% and 80.7% more kJ/day for kittiwakes and puffins, respectively. These findings support APEX hypothesis #9, that seabird reproductive productivity is determined by forage fish nutritional quality. Several APEX projects have obtained results from field studies that support the hypothesis, but this is the first controlled experimental study that has shown this conclusively.

Differences in mass gain among diet groups were much more pronounced than differences in structural growth. An extreme example of this appears in the kittiwake group receiving the 43 g/day sand lance ration. The average mass gain for chicks in this group was less than 25 g over the course of the 19-day experiment, yet wing growth averaged 75 mm for the same time period (Figs. 7 and 8). This suggests that undernourished seabird chicks preferentially allocate food energy intake to structural development over mass gain. This may be especially significant for kittiwakes, where sibling competition may exact a heavy toll on young that fail to grow on limited resources.

Work on Atlantic Puffins (*Fratercula arctica*) has shown that productivity is closely tied to availability of energy-rich forage fish prey. Nettleship (1984) found that Atlantic Puffins depending primarily on capelin to provision their young experienced high productivity when this forage fish was available. In contrast, during years when capelin was scarce productivity was reduced. Martin (1989) observed a similar pattern in an Atlantic Puffin colony that relied heavily on sand lance. Despite the fact that Martin identified 13 different prey species in the diet, breeding puffins were not able to obtain sufficient alternative food when sand lance stocks declined. The result was a severe breeding failure when sand lance became unavailable.

Adult seabirds can increase their short-term foraging effort when prey is scarce in order to provide sufficient food for development of their young. Work with kittiwakes in Prince William Sound has shown that breeding adults have the potential to buffer their chicks against variable prey resources by traveling further and transporting larger food loads to provision young (Irons 1992). If adult seabirds can increase their foraging effort and provide more biomass of low-lipid prey, will the chicks develop at the same rate as chicks whose parents are able to provide the same amount of calories yet less biomass of a lipid-rich prey? This is the question we are addressing with the iso-caloric comparisons.

A large part of the energy content of sand lance and capelin is in the form of lipid, whereas in low-lipid fish, like pollock, most of the energy content is in the form of protein. Protein is much less energy dense than lipid and utilizing it as an energy source requires excretion of the resultant nitrogenous waste products. The growth and development of tufted puffin chicks, however, does not seem to be affected by the source of energy (i.e., lipid vs. protein). In the iso-caloric comparison the growth and development of both groups was similar. The group receiving 80 g/day of pollock had a slight edge in mass gain over the group receiving 45 g/day of capelin, but structural growth (wing, culmen and tarsus) was not significantly different. Fat index was significantly higher (more than double), however, for the capelin group versus the pollock group, indicating that nestlings fed pollock did not store as much body fat. This could have a significant influence on survival of these chicks after they fledge and are foraging for themselves.

Low availability of high-quality forage fishes could have adverse effects on nestling growth and development of piscivorous seabirds. If parental foraging is constrained, the availability of high-quality forage fish is necessary to compensate for reductions in biomass of prey provided to nestlings. If foraging is not constrained, adults should still preferentially choose high-quality prey to provision nestlings, even if this means providing less total biomass. Provisioning young with high-quality prey will generally result in nestlings that gain body mass and develop structurally more rapidly, and that fledge with greater energy reserves.

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Fig. 1. Daily energy consumption of Tufted Puffin and Black-legged Kittiwake nestlings on experimental diets.

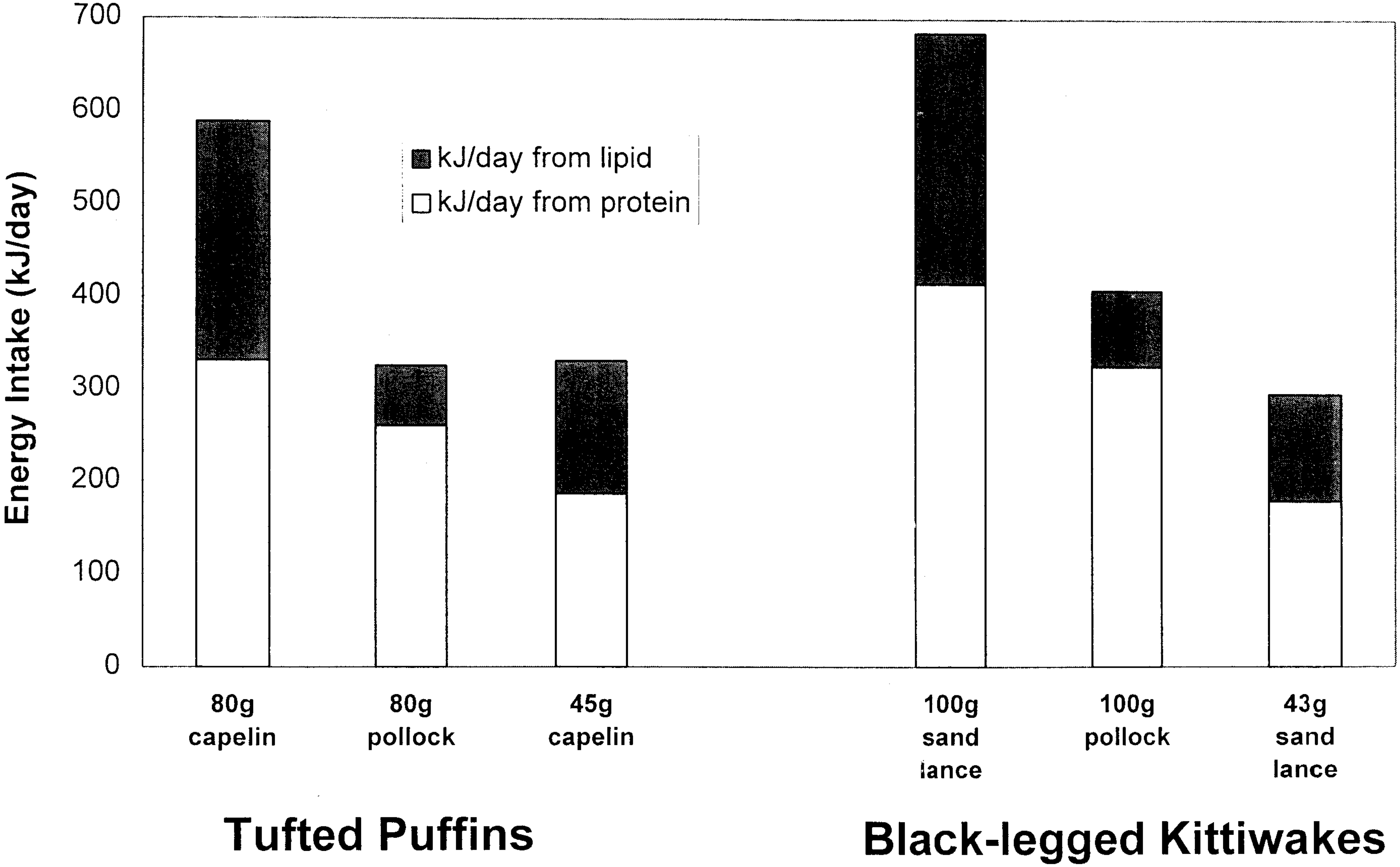


Fig. 2. Growth in body mass of Tufted Puffin nestlings raised on three different experimental diets.

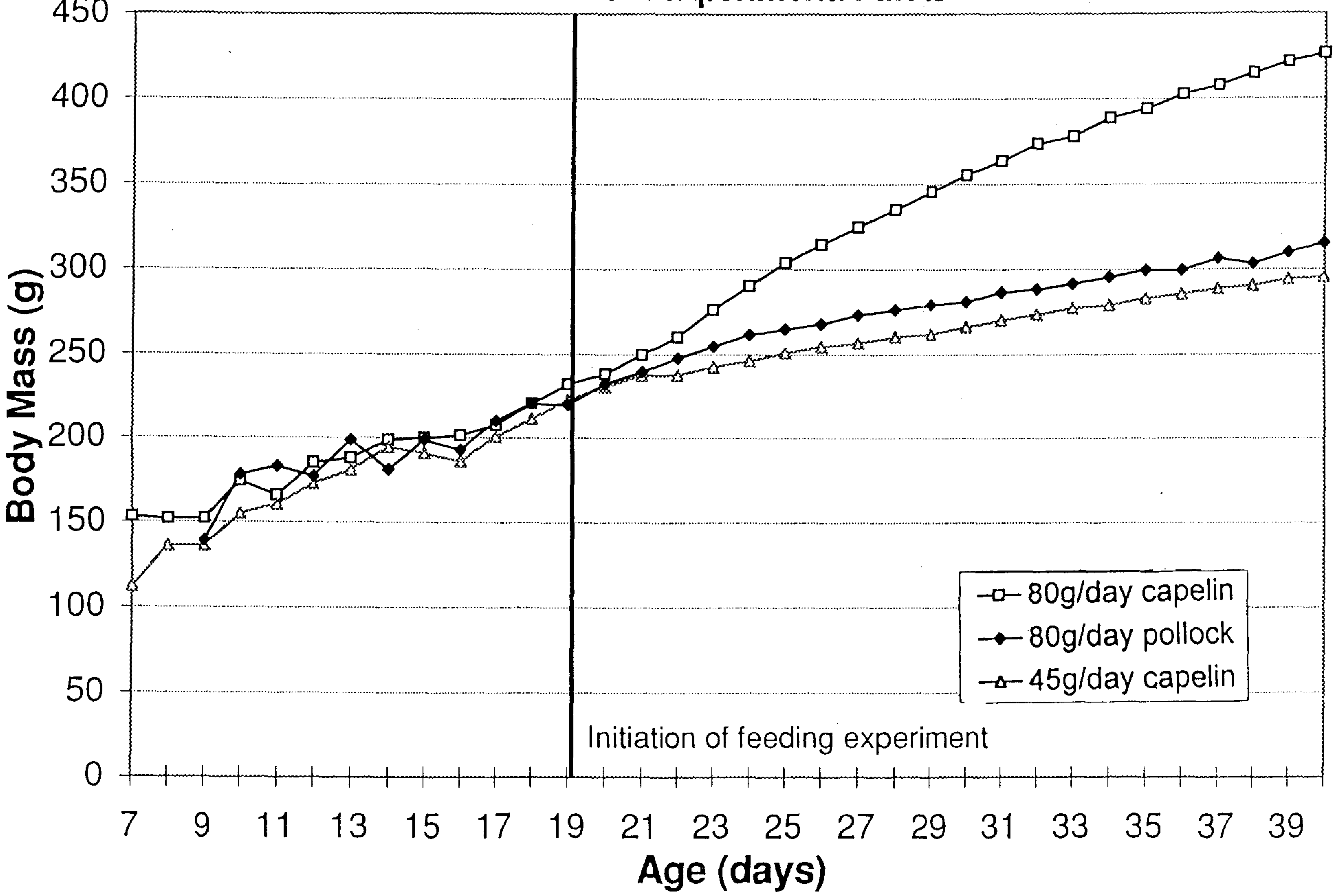


Fig. 3. Growth in wing length of Tufted Puffin nestlings raised on three different experimental diets.

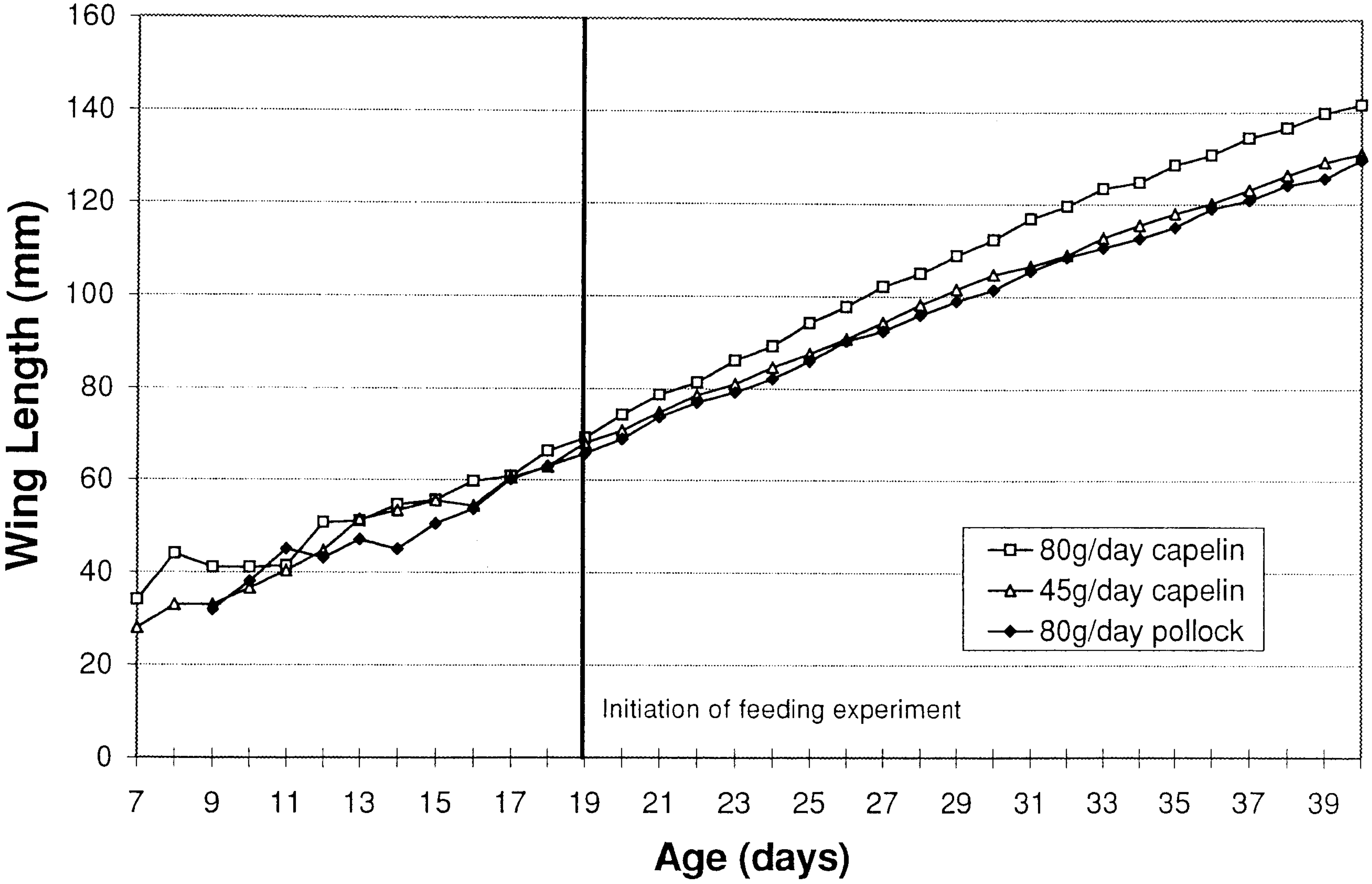


Fig. 4. Growth in culmen length of Tufted Puffin nestlings raised on three different diet treatments.

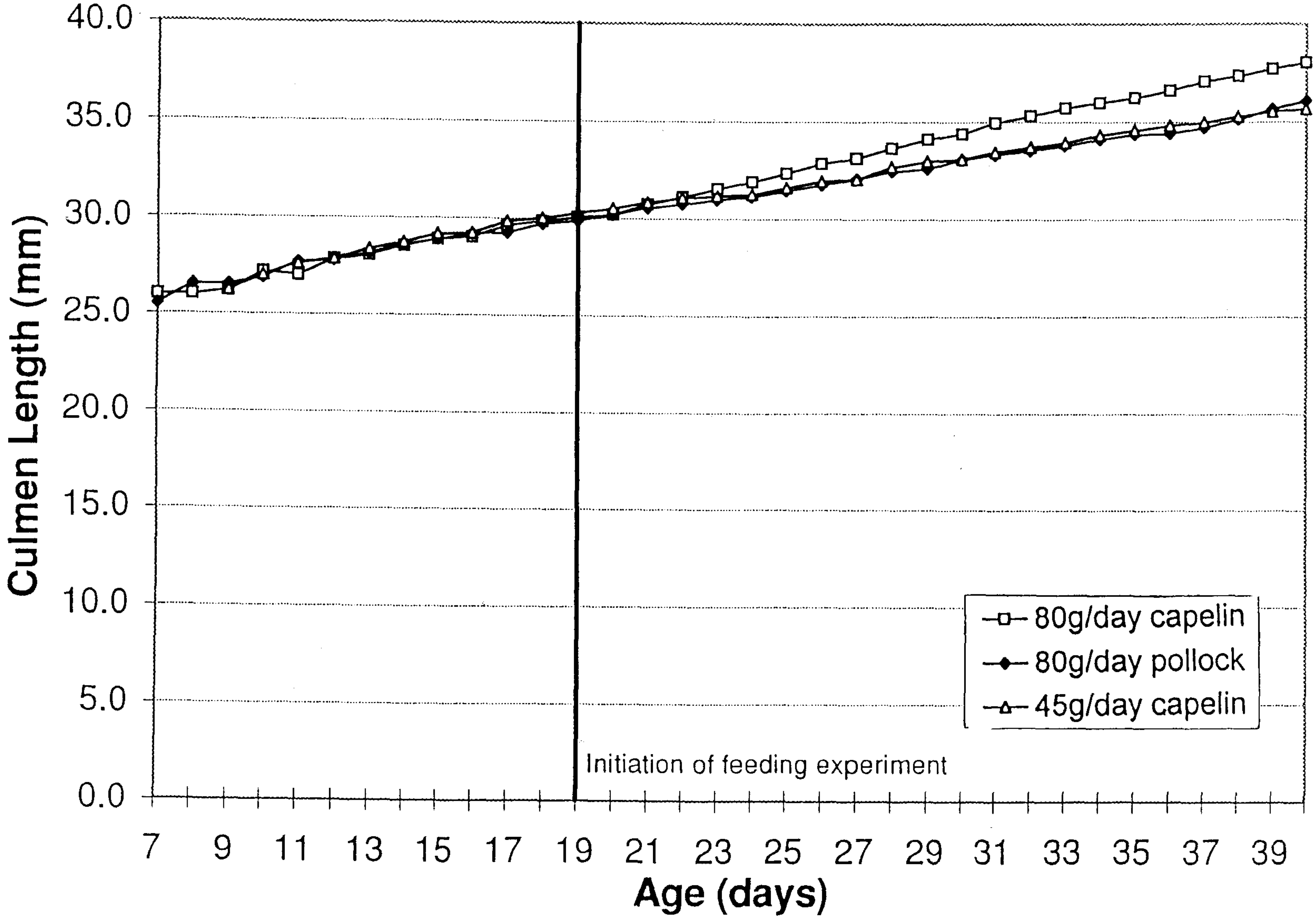


Fig. 5. Growth in tarsus length of Tufted Puffin nestlings raised on three different experimental diets.

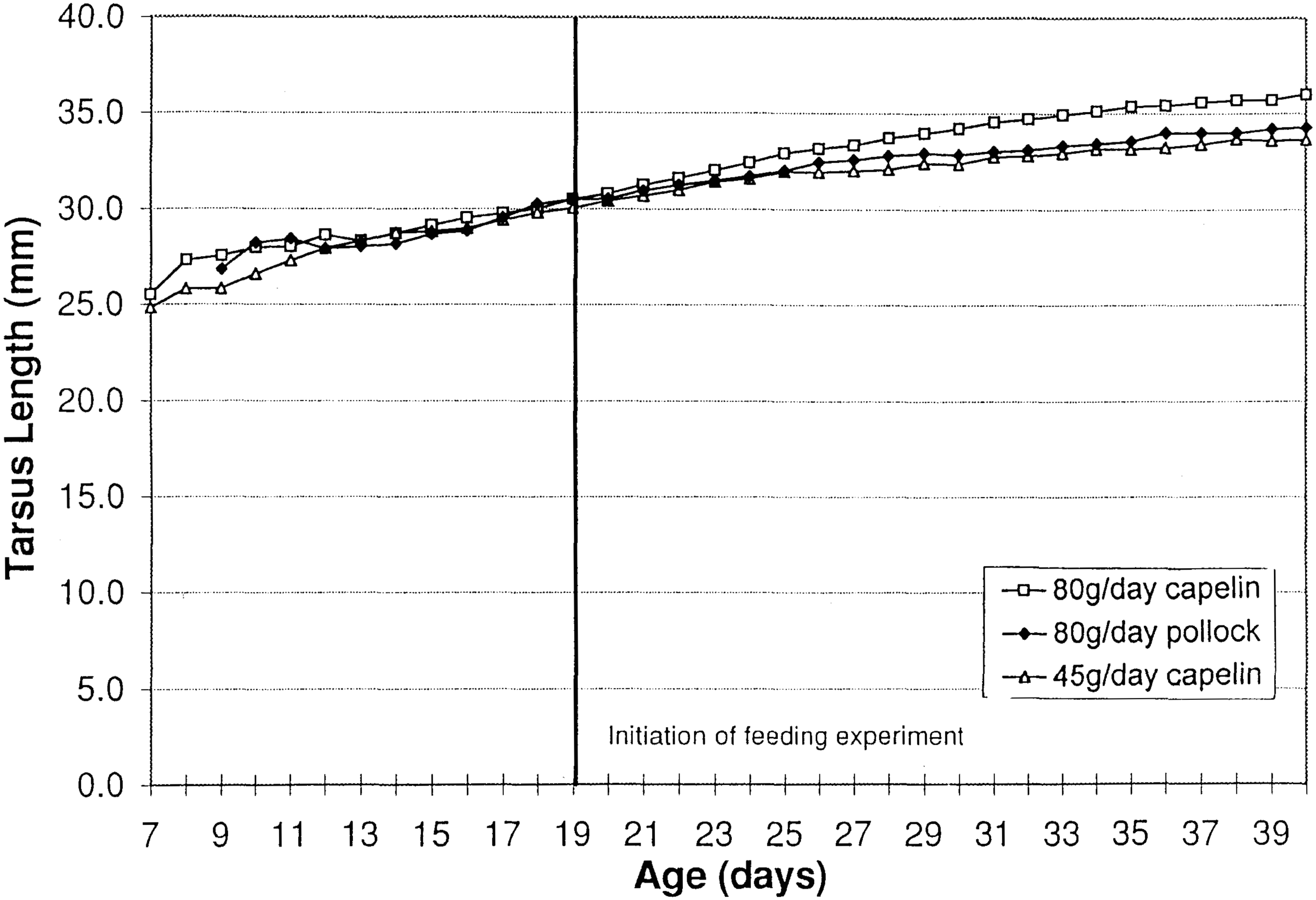


Fig. 6. Average body mass and wing length of Tufted Puffin fledglings (40 days post-hatch) raised on three different experimental diets.

(error bars indicate 95% confidence interval;
breaks in horizontal bars indicate significant differences between means)

Fig. 7. Growth in body mass of Black-legged Kittiwake nestlings raised on three different experimental diets.

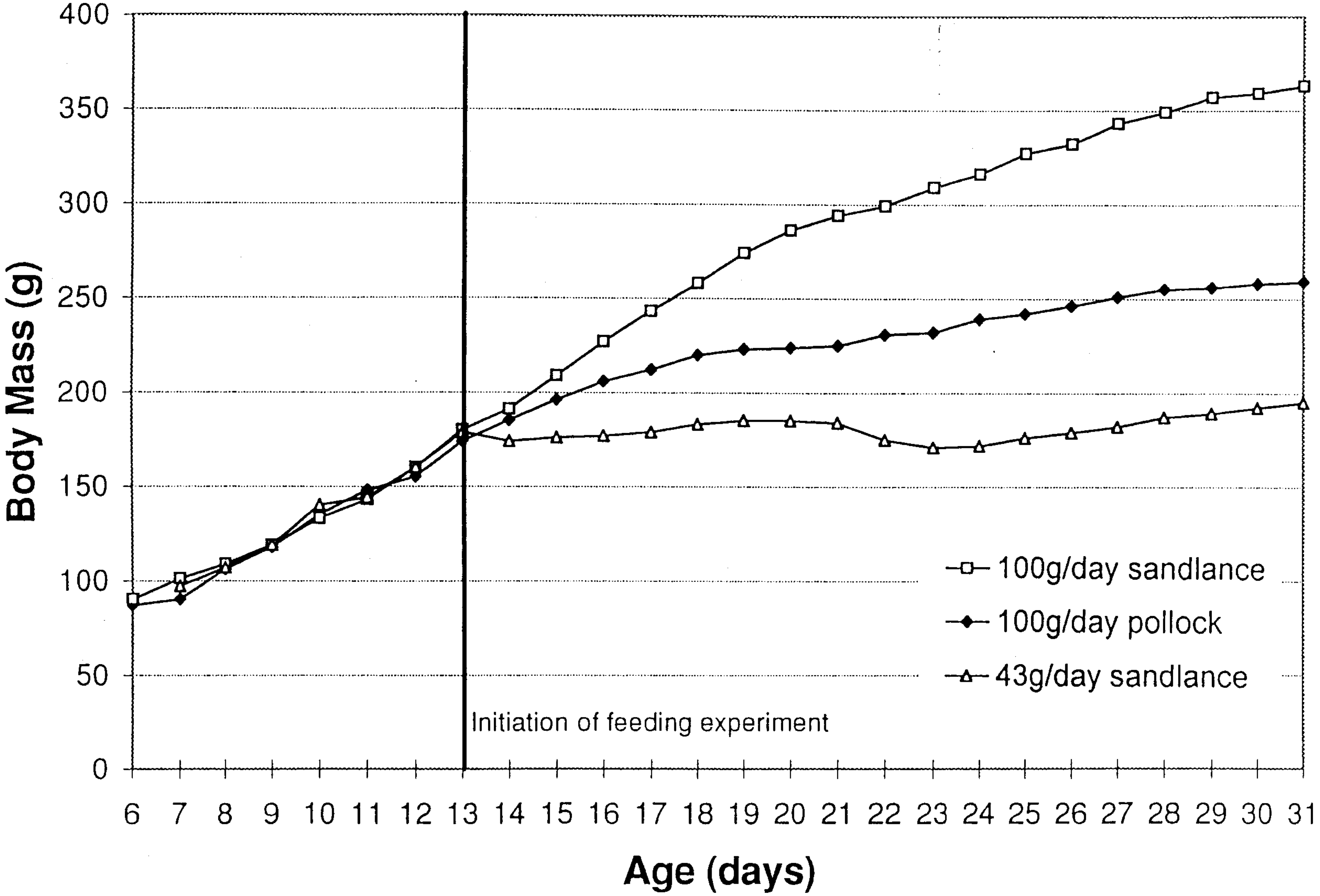


Fig. 8. Growth in wing length of Black-legged Kittiwake nestlings raised on three different experimental diets.

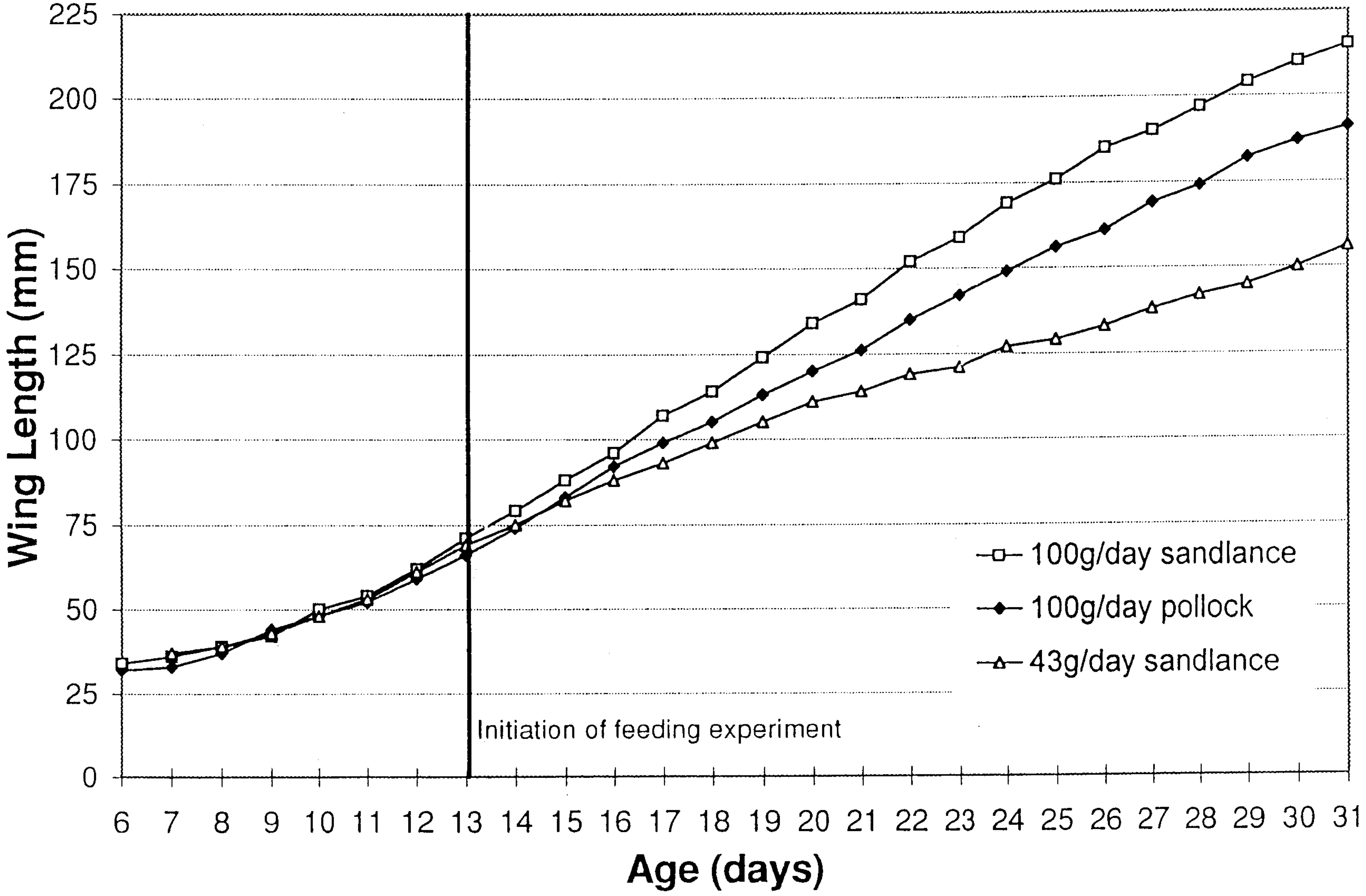


Fig. 9. Growth in head-bill length of Black-legged Kittiwake nestlings raised on three different experimental diets.

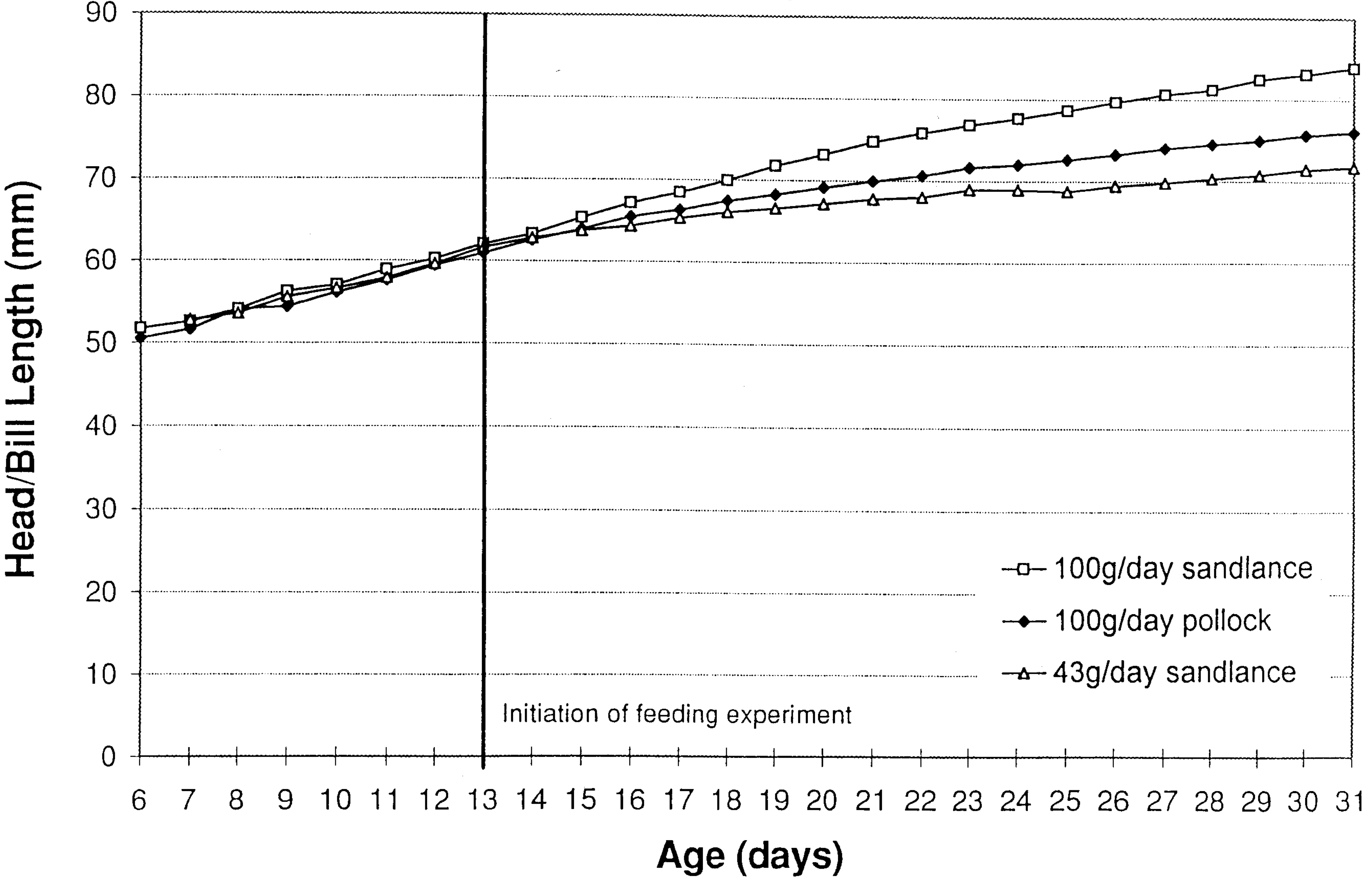
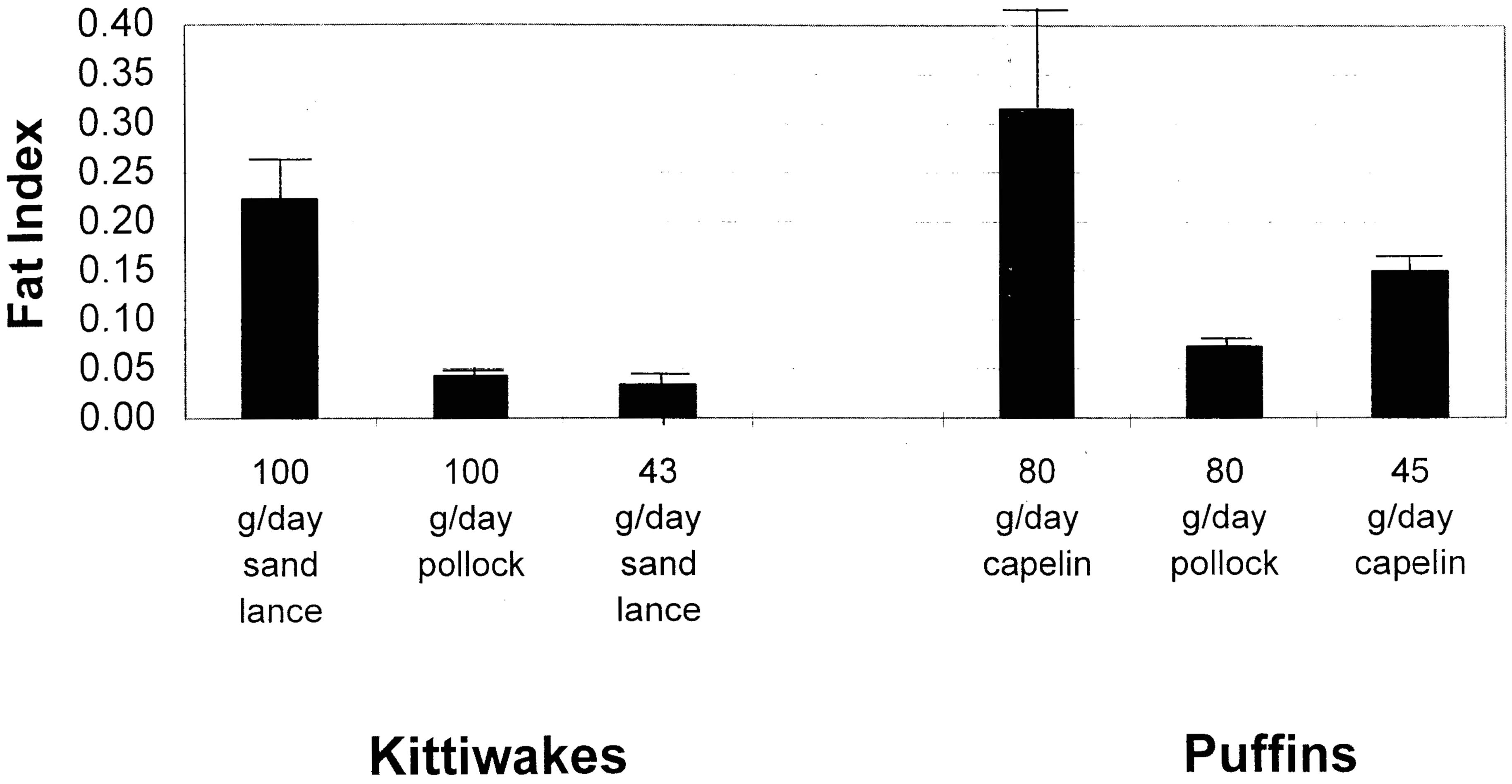


Fig. 10. Average body mass and wing length of Black-legged Kittiwake fledglings (31 days post-hatch) raised on three different experimental diets.

(error bars indicate 95% confidence interval;
breaks in horizontal bars indicate significant differences between means)

Fig. 11. Fat Index of Tufted Puffin and Black-legged Kittiwake nestlings raised on different experimental diets.



APPENDIX O

APEX: 96163O

Statistical Review of APEX Study Designs and Analyses: 1996

Project Number: 97163 O

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March 19, 1997

Study History: The Alaska Predator Ecosystem Experiment (APEX) in Prince William Sound, Alaska required use of sampling designs whose analyses are not commonly available for biological field studies. The design included systematically located unequal length transects and collection of spatially correlated data on abundance, distribution, and biomass of forage fish and abundance and distribution of sea birds. Analyses include estimation of resource selection functions and adjustment for the correlated data. Beginning in 1995, we provided review of and advice for the non-standard study designs in order to help insure that appropriate statistical inferences can be made during the analysis phase of the studies. We also provided advice and assistance during statistical analyses of 1995 data and report preparation for some of the individual projects within APEX.

Abstract: Modifications were made in sampling designs and overall study protocols for the 1997 field season in collaboration with Principal Investigators of the other APEX projects. Custom computer software was developed for analysis of spatially correlated acoustic survey data. Statistical analyses were recommended for some of the APEX projects to insure that statistical inferences are justified by the 1995 and 1996 data collection procedures. Results of interactions with the APEX projects are included in the annual reports, study protocols, and detailed project descriptions submitted by the Principal Investigators.

Key Words: statistical analysis, spatially correlated data, protocols, study design.

Modifications were made in the sampling design for collection of the 1996 acoustic survey data to included random placement of survey blocks in the near-shore areas of Prince William Sound in collaboration with Dr. Lew Haldorson and Dr. Tom Shirley, Project 97163A, Forage Fish Distribution. These blocks were sampled with transects running at approximately 45 degrees to the shoreline during the acoustic survey. The off-shore acoustic survey in 1996 was conducted according to the same design as used in 1995 to provide comparable data. We developed custom software for analysis of the spatially correlated data collected in 1995 and 1996. These computer programs were used by Mr. Ken Coyle for assistance in analysis of the 1995 acoustic data and are currently being used for analysis of the 1996 near-shore and off-shore acoustic data. Analyses for abundance and distribution foraging sea birds in relation to schooling fish followed statistical procedures specifically developed for study of resource selection by animals in collaboration with Dr. William Ostrand, Project 97163B.

Interaction with these and other APEX projects included review of study protocols for the 1997 field season and general advise on statistical analysis for data collected in 1995 and 1996

The individual Principal Investigators are primarily responsible for issuing the reports on 1995 and 1996 data from the various projects within APEX. Results of our interactions with the Principal Investigators are contained within those reports.

APPENDIX Q

APEX: 96163Q

Exxon Valdez Oil Spill
Restoration Project Annual Report

The Factors That Limit Seabird Recovery In The EVOS Study Area: A Modeling Approach

Restoration Project 97163Q
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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March 1997

The Factors That Limit Seabird Recovery In The EVOS Study Area: A Modeling Approach

Restoration Project 97163Q
Annual Report

Study History: The project effort was initiated in February 1997 as a new project. Field work is not direct component of this project, which relies on the data gathered by all other APEX projects as well as data in the literature.

Abstract: We use mathematical models to assess ways in which food supply could be affecting recovery of seabirds in the EVOS study area. The models address foraging effort and success as it relates to breeding productivity. In the first year of effort we will concentrate on developing models for Pigeon Guillemots and Black-legged Kittiwakes in Prince William Sound. Results will test the degree to which food limitation is affecting recovery, indicate the mechanisms by which this could come about, and identify the scale at which interactions are occurring between food availability and the colonies being studied by APEX. Moreover, results should help to "aim" the APEX research effort so that sufficient data are collected to fulfill the overriding APEX objective: to understand the ways in which food supply is limiting seabird recovery.

Key Words: *Exxon Valdez*, Pigeon Guillemots, Black-legged Kittiwakes, foraging effort, population growth, mathematical modeling.

Project Data: (will be addressed in the final report)

Citation: Ainley, D. G., R. G. Ford and D. C. Schneider. 1997. The factors that limit seabird recovery in the EVOS study area: a modeling approach., *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 97163Q), Anchorage, Alaska.

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Executive Summary

We use mathematical models to assess ways in which food supply could be affecting recovery of seabirds in the EVOS study area. Thus, we are addressing the main APEX (Alaska Predator Experiment) hypothesis that food supply is limiting recovery of certain avian populations from the *Exxon Valdez* oil spill. We present here the general outline of the mathematical models, with lists of parameters to be included. Eventually data inputs will comprise information from the field components of APEX. supplemented with data published elsewhere.

Introduction

The general hypothesis of the APEX project is that a change in the relative abundance of forage fish species has prevented recovery of injured avian populations in Prince William Sound. Within this general hypothesis a series of ten working hypotheses are being investigated. The data being collected to test these hypotheses differ in temporal and spatial scale. Some additional data at the time scale of decades exist. However, most of the data are at much smaller scales than the general hypothesis, which is at the scale of decades (time for recovery in long-lived species) and at the spatial scale of the entire sound. Statistical inference can be used to bridge some but not all of the gap. The remainder will be bridged by the same methods used in oceanography (Figure 1), where hypotheses are stated at a specific scale, hypotheses are constrained by conservation laws, and ratios of rates are used to identify the importance of competing processes. This approach integrates the available information, bridges the gap from data to the hypothesis, and identifies variables that need to be linked. The model output will allow avian recovery rates to be evaluated in relation to prey availability, using data and knowledge gathered for this ecosystem.

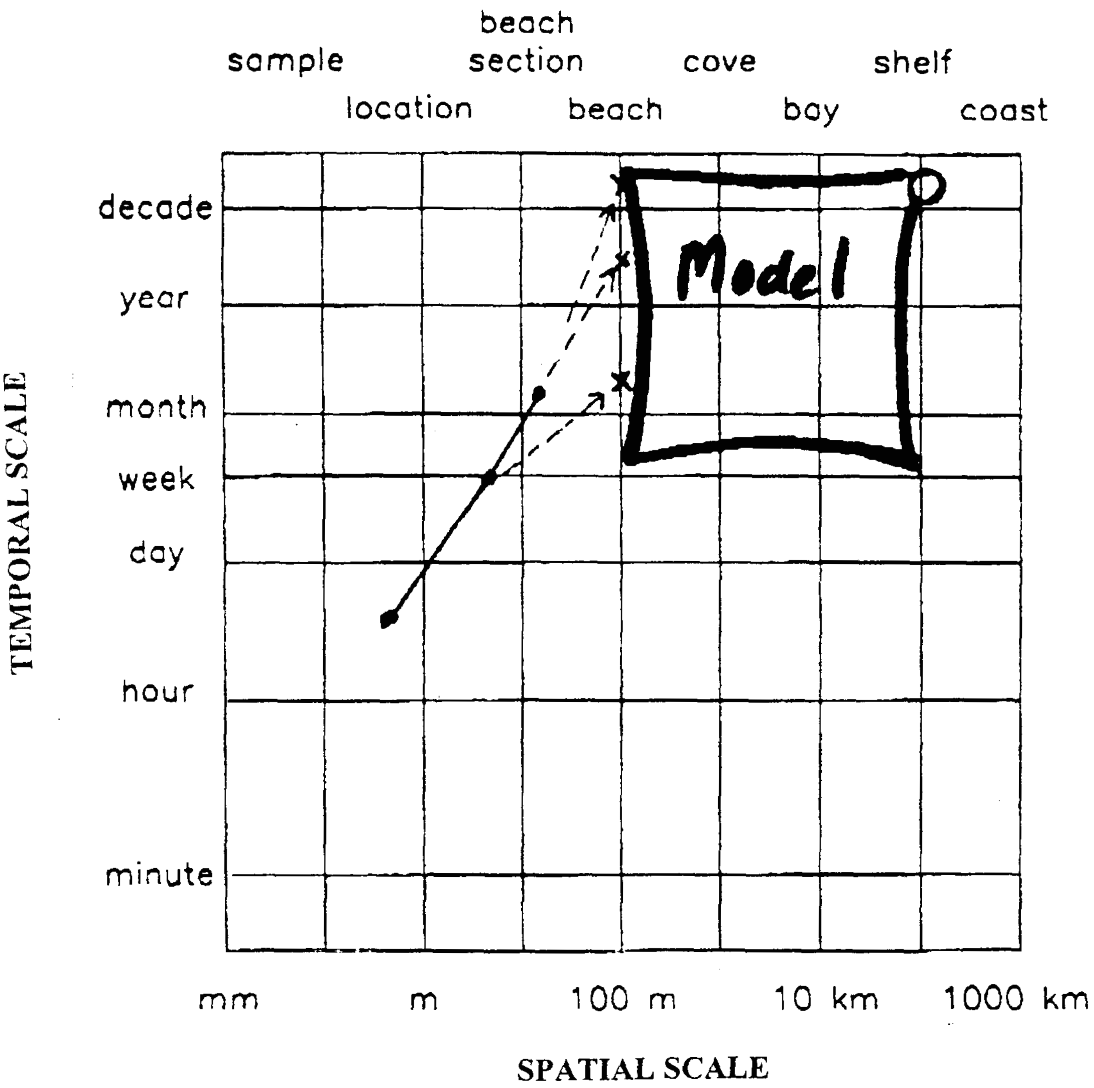
Objectives

Hypotheses to be evaluated by mathematical modeling using existing data, under the null hypothesis:

1. Annual survivorship, age of first breeding, foraging range, feeding frequency of chicks, and reproductive success are not related to food availability. We hypothesize that feeding frequency of chicks and breeding success in large colonies should be lower than in small colonies.

2. No differences in 1 will be evident in pre- and post-spill comparisons, where possible.

Figure 1. Scope of APEX general hypothesis (circle), of available data on Pigeon Guillemot feeding rate (solid lines), of statistical inference (dotted line), and of the model (box).



Methods

The approach will be iterative, beginning with existing verbal models of population dynamics and foraging distribution, including recent findings by APEX investigators. From this a preliminary outline for an integrated computational model will be developed and presented to the APEX investigators and referees. The model will consist of a demographically structured spatial model linked to a spatially structured foraging model. The model will be revised as needed, then data sources for each functional relation in the model will be listed. The model will then be coded. Initial runs will be used to identify relative sensitivity to parameters. Which relationships, for example, have the largest influence on population change and rates of recovery? These results will be presented for discussion and revision as needed. The revised model will be used to guide further testing of working hypotheses. The model will then be used to quantify rates of recovery relative to changes in prey base. Because the model is based on dynamics, it can be used to calculate energy exchange from prey to avian populations through time, including average energy exchange before and after 1989.

Results and Discussion

A demographically structured model linked to a spatially structured foraging model was chosen for several reasons. First and most importantly, the APEX general hypothesis concerns demographics (recovery) in relation to prey distribution. Further, such an approach was successfully applied by Ford et al (1982) for the Pribilof Island colonies and by Nur et al. (1993) for central California colonies. Finally, it is recognized that any long term monitoring program must include demographics, which prevail over other sources of change in avian density at decadal time scales (see below).

Based on findings by APEX investigators, the following conceptual changes were made in the model developed by Ford et al (1982). First, longer term optimality, based on learning or territoriality, was introduced as an alternative to search based on short-term optimality. Evidence for consistent patterns of foraging site usage comes from work in Prince William Sound (PWS) on Pigeon Guillemots (Kuletz 1983) and Black-legged Kittiwakes (Irons 1992). Second, new habitat variables were introduced, notably distance from shore, depth, and substrate type. Pertinent evidence includes the observed restriction of foraging to nearshore areas in PWS, the absence of a strong advective regime in the inner part of the sound, the association of sandlance and juvenile herring with specific habitats in shallow water, and linkage of kittiwakes to shallow water features that increase the local rate of prey resupply near the sea surface. Deeper water species (notably murres and procellariids) are absent from PWS suggesting that foraging mechanisms in relation to habitat differ from the system of shelf break currents and shallow sea fronts that were modeled at the Pribilof colonies. Third, conservation laws were used to make complete listings of processes that alter seabird density at multiple scales. Important components were then identified by comparing rates at the scale of the hypothesis.

Black-legged Kittiwakes and Pigeon Guillemots were chosen because more data exists on these than other species. The guillemot is listed by the EVOS trustees as not recovered.

Spatial scale. A 5 km^2 grid was considered sufficiently detailed for PWS, which extends roughly 100 km from north to south and east to west. A smaller grid scale may be necessary within 10 km of the coast, based on the finding that the bulk of foraging on energy rich fish species occurs in this habitat, with much lower foraging activity offshore.

Time scale: Available data limited the model to time steps of two seasons (breeding vs non-breeding) with a 10 day time step during the breeding season.

Once the avian species, spatial scope, and temporal scope of the model were identified, the components of the general hypothesis were quantified.

BOX 1. Quantification of the APEX general hypothesis.

"Change in forage fish has prevented recovery of some avian populations."

"Avian population" was defined as the number of a species within grid cell of area $A = 5 \text{ km}^2$, where:

$$N = \text{count}/5 \text{ km}^2 = \#/5 \text{ km}^2$$

"Change in avian population" was defined as an instantaneous rate, resulting in components ($r = b - z$) consistent with the demographic literature, where:

$$\text{dotN} = 1/N * dN/dt = \%/\text{unit time}$$

"Forage fish" from the point of view of predators was defined as the energy available to a bird species within the area of each grid cell, where:

$$\mathbf{E} = \text{Sum over depth of } \mathbf{spE} * \mathbf{B.prey} = \text{kJ/g} * \text{g/m}^3 = \text{kJ}/5 \text{ km}^2$$

E for kittiwakes was defined as the energy density within the surface layer, 1 m by 5 km, based on acoustic estimates immediately below this layer. **spE** is the specific energy (kJ/g) of the resource, **B.prey** is the biomass concentration (g/m^3) of the resource. **E** for Pigeon Guillemots was defined as the energy density either within the water column or at the bottom, in water less than 50 m in depth.

"Change in forage fish" was defined as the instantaneous rate of change in energy density available to a bird species within the finite area of each grid cell, again to produce component variables consistent with the demographic literature:

$$\mathbf{dotE} = 1/E * dE/dt = \%/\text{time within each grid cell.}$$

The general hypothesis was cast in quantitative terms on a fixed (Eulerian) grid, where dynamics were computed in discrete time steps within finite volumes. This means that dynamics are first expressed as instantaneous rates, such as the familiar expressions for instantaneous mortality (**z** in the fisheries literature), recruitment (**b** in the ecological literature), or net rate of increase (**r** = b - z). These rates are then integrated over finite volumes and areas to obtain averages over volumes or areas (r.o = b.o - z.o). Conservation laws for numbers, mass, and energy were used to obtain a complete listing of concomitant rates. An expression for energy exchange was written for each bird species and each of its important prey. The relative importance of these concomitant rates was evaluated by taking ratios at the scale of the hypothesis. Application of a conservation law for numbers and energy produces a complete listing of all sources of change in avian density **dotN.o** and change in resource density **dotE.o** of fish.

dotN.o = b.o - z.o + F.o
= recruitment - mortality + movement(flux)
change in density = demographic change + kinematic change

dotE.o	= dot spE	+	dotM	+	b.o	-	z.o	+	F.o
	change in specific energy with age	+	somatic growth	+	recruitment from parent cohort	-	death within known cohort	+	movement

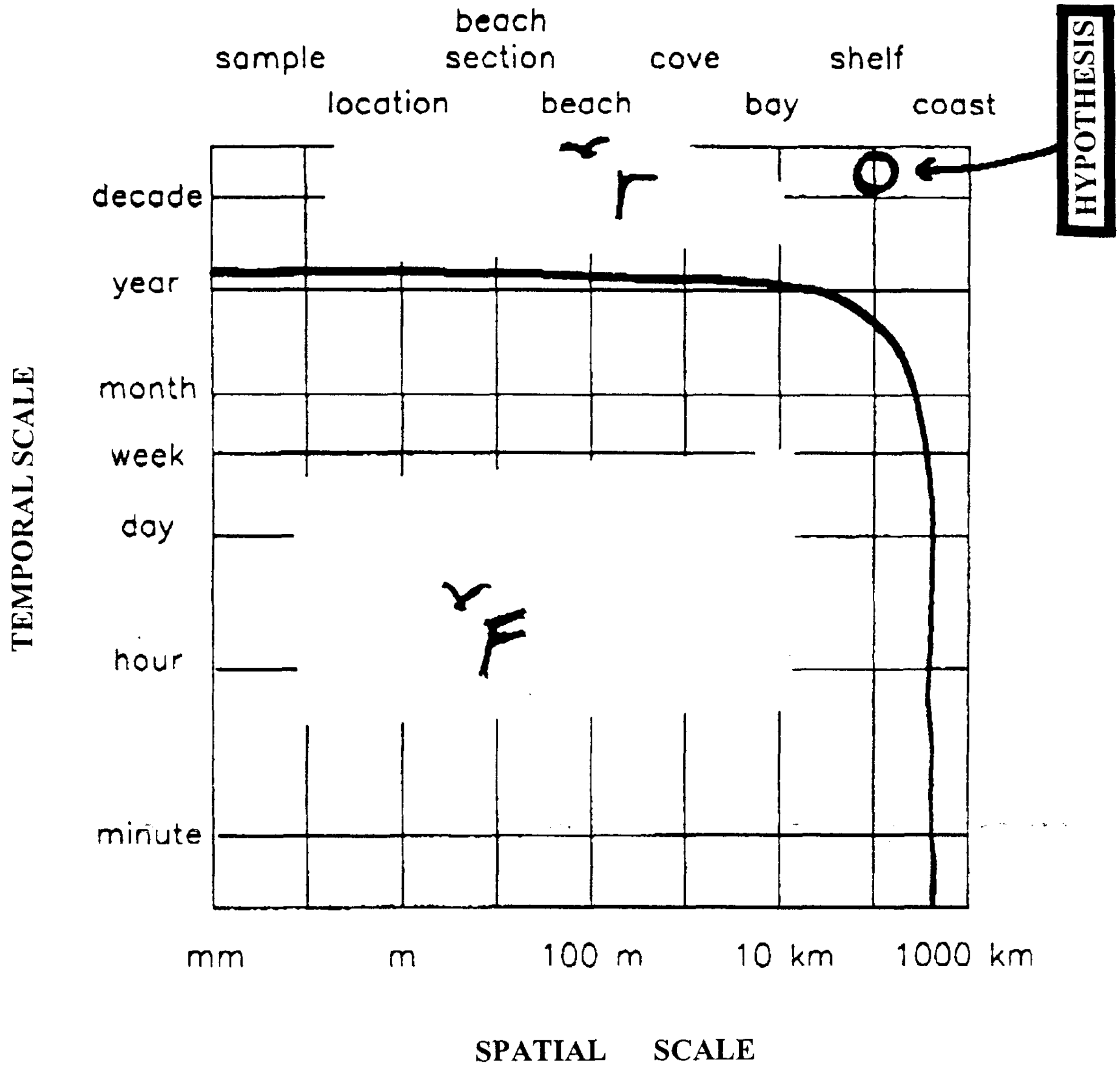
Once a complete listing was obtained, the next step was to identify which components could be treated as constants at the time and space scale of the hypothesis. Order of magnitude values were assigned to each component of change in resource density **dotE.o**, based on knowledge of the biology of sand lance, herring, and capelin.

dot spE = <1%/decade (limited decadal change in kJ/g)
dotM = <10%/decade (limited decadal change in body size)
b.o = >100%/decade (100% change in recruitment possible)
F.o = >100%/decade (doubled migration into PWS possible)

The conclusion from this was that specific energy **spE** and body mass **M** could be taken as single values for each prey species. For **spE** and **M**, short term measurements (lower left part of Figure 1) could be applied at scale of the hypothesis (upper right part of Figure 1). For prey that do not migrate into and out of PWS (possibly sand lance), recruitment **b.o** and mortality **z.o** will be more important than movement, **F.o**, which can be ignored at the scale of PWS. At smaller scales, within PWS, redistribution at decadal scales would need to be considered. For highly migratory species such as capelin and herring, both demographics (**b.o - z.o**) and movements at the scale of PWS would need to be considered.

Similar analysis was made for the components of **dotN.o**, change in avian density, at the scale of the hypothesis. At the time scale of a half year, 100% of a migratory population vacates the breeding range, while mortality will be of the order of 10% during the nonbreeding season. The ratio **r/F** = (10%/halfyear)/(100%/halfyear). At this time scale, movements prevail (**r/F** < 1). At the time scale of a year or more seabird colonies change little in distribution; a figure as high as 1%/year would be surprising in any breeding population in PWS. At the time scale of a year, **r/F** = (10%/year)/(1%/5 year). The ratio **r/F** exceeds unity and demographics prevail over kinematics (movements). For Black-legged Kittiwakes, Figure 2 shows the relative importance of movement and demographics as a function of space and time scale. The conclusion from this analysis was that demographics cannot be ignored, at the scale of the APEX general hypothesis.

Figure 2. Scope diagram for demographics vs kinematics of Black-legged Kittiwakes.



The data available for marine birds were sufficiently detailed to allow an age or stage specific treatment of recruitment and death. The demographic model was structured around the transition points listed in Table 1. A stage was defined as the time between two transition points. Survival within each stage was defined as proportion surviving from one transition point to the next (Table 2). Death rate, **D**, within a stage was defined as the proportion removed. Recruitment rates, **b**, total mortality rates **ztot**, and predation rates **zpred** were calculated from survival and mortality, as shown in Table 3. Instantaneous rates were calculated because these, unlike crude survival and death rates, can be summed over areas, over sources, and over time periods.

Table 1. Transition points used in age structured model of population size.

attempts = nest built
eggs = egg laid
hatch = chick hatched live
fledge = check departed nest alive
new adults = chick returned alive to breed
adult@fledge = adult alive at date of fledge
adult@next attempt = adult returned alive after breeding

Table 2. Stage specific survival and death rates used in the age structured model of avian population size.

SURVIVAL RATES

S.nest = attempts = #nests/pair in colony
S.egg = egg production = number eggs/nest
S.chick = egg hatch = number hatch/number eggs
S.subad = chick production = number fledged/number hatched
S.ad1 = subadult survival = first breeders/number fledged
S.ad2 = breeding survival = returned breeders/first breeders
S.ad.n = adult survival = breeders at age n/breeders at n-1

DEATH RATES

D.nest = nest failure = failed pairs/total pairs
D.egg = egg loss = eggs lost/eggs laid
D.chick = chick loss = chicks lost/chicks hatched
D.subad = subadult loss = subadults lost/chicks fledge
D.ad1 = 1st breeder loss = 1st breeders lost/1st breeders marked
D.ad2 = 2nd breeder loss = 2nd breeders lost/2nd breeders marked
D.ad.n = breeder loss = breeders lost/breeders marked

Table 3. Instantaneous rates of recruitment **b**, total mortality **ztot**, and predatory mortality **zpred** computed from the proportions in Table 2.

RECRUITMENT

b.egg = ln S.nest + ln S.egg
= eggs/pair
b.subad = yr^{-1} * (lnS.nest + lnS.egg + lnS.chick + lnS.subad).
= subadults/pair

MORTALITY

ztot.nest = -ln S.nest
ztot.chick = -ln S.chick
ztot.subad = -ln S.subad
ztot.ad1 = -ln S.ad1
ztot.ad2 = - ln S.ad2
ztot.ad.n = - ln S.ad.n

LOSS RATES

nest failure = ztot.nest - 1 = (nest - pair)/pair
egg loss = ztot.chick - 1 = (hatch - eggs)/eggs
chick loss = ztot.subad - 1 = (fledge - hatch)/hatch
subadult loss = ztot.ad1 - 1 = (return - fledge)/fledge
first breeder loss = ztot.ad2 - 1 (return - 1st tries)/1st tries
breeder loss = ztot.ad.n - 1 (returned - breeder)/breeders

PREDATION RATES

zpred.egg
zpred.chick
zpred.subad
zpred.ad1
zpred.ad2
zpred.ad.n

These demographic rates are related to prey resource density **E** via adult intake rates (**dotE.int** = kJ/day) and delivery rates to chicks (**dotE.deliv** = kJ/day), as in Table 4. The quantitative relation between avian demographic rates (including recovery) and fish resource density **E** was then expressed in both verbal (Table 5) and graphical (Figure 3) forms.

Table 4. Definition of adult intake **dotE.int** and chick delivery **dotE.deliv**.

dotE.int = F.rate * C.att * C.succ * C.energy = kJ/day

F.rate = trips/day = foraging rate

C.att = attempt/trip = capture attempts

C.succ = captures/attempt = capture success

C.energy = kJ/capture = energy value of capture

dotE.deliv = F.rate * M.meal * spE.meal = kJ/day

F.rate.deliv = trips/day = foraging rate

M.meal = g/trip = meal size

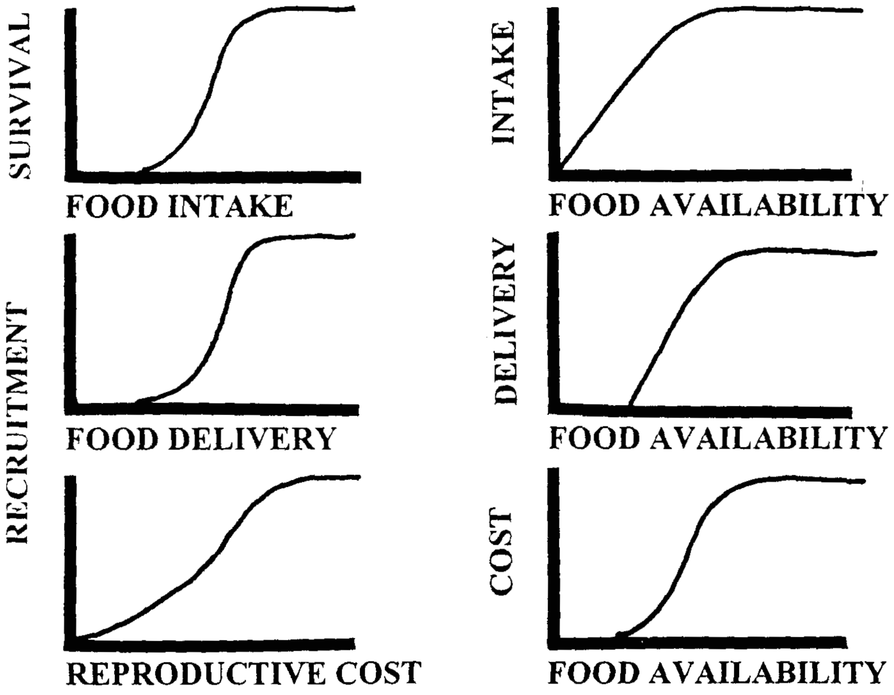
spE.meal = kJ/g = meal value

Table 5. Verbal statement of relation of variables, for APEX general hypothesis.

A1. Survival to next stage depends on (intake, predation, other)
A2. Recruitment depends on (delivery, predation, other)

B1. Intake depends on (resource quality spE, density E, other)
B2. Delivery depends on (resource quality spE, density E, other)
B3. Delivery depends on (distance from colony, other costs)

Figure 3. Graphical expressions of the relation of variables, for the APEX general hypothesis; shapes of curves provisional.



Based on discussions with APEX investigators, several variables (Table 6) were considered potentially important in affecting intake and delivery rates of food. These variables were resource distribution **E**, relative abundance of prey with high specific energy **spE** = kJ/g, and costs of food delivery, including time to find food. Travel time will in turn depends on foraging tactics (information center, traplining, etc).

Table 6. Variables considered to be potentially important in affecting food intake **dotE.int** by birds, or delivery **dotE.deliv** to chicks.

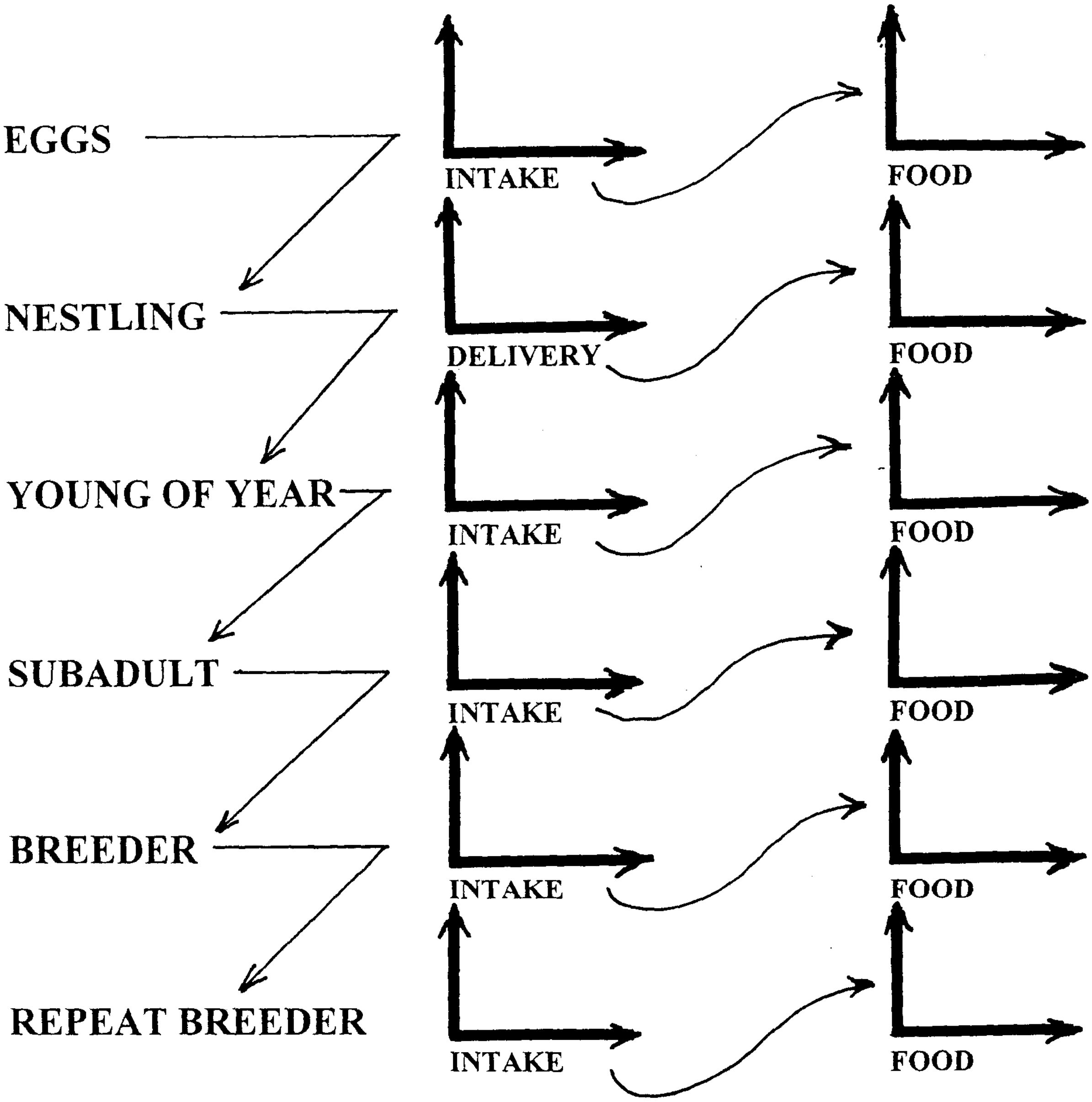
E = resource density = kJ/5 km^2
B.prey.pel = local resource concentration in water = g/m^3
B.prey.benth = local resource concentration at bottom = g/m^3
spE.high/spE.low = ratio of high to low energy density species = (kJ/g)/(kJ/g)

Cost of capture (kJ/day)
  L.prey = distance between prey = m
  A.school = school area = m^2
  FMR = field metabolic rate = kJ/day

Cost of delivery (kJ/delivery)
  L.colony = distance from colony = km

These variables and relationships were developed in discussion with several investigators before the APEX review in February 1997. The resulting model structure was presented to APEX investigators and referees during the February review meeting. The model was presented first in rough outline (Table 5, Figure 3), then in more detailed form, shown in Figure 4.

Figure 4. Age structured model, showing relation of survival (or recruitment) to intake (or delivery), together with relation of intake (or delivery) to resource distribution E (food).



Investigators agreed on the concept of using non-linear relations between demographic rates and intake/delivery. The preferred form of the relation was generally sigmoidal ("buffers"), following those sketched by Cairns (1987). The available data (Ainley et al. 1995; Anker-Nilsson 1996) are consistent with this form of relation. Based on et al. 1995; Anker-Nilsson 1996) are consistent with this form of relation. Based on comments from investigators, a few modifications were made. Three additional variables (Table 7) were suggested as being important, via effects on subsequent survival.

Table 7. Hypotheses concerning variables that potentially affect future survival.

Hypotheses

C1. post breeding survival depends on (effort to breed)

C2. post breeding survival depends on (weight loss)

C3. sub adult survival depends on (weight at fledge)

C4. sub adult survival depends on (condition at fledge)

Variables

dotE.effort = kJ/season (delivered + ingested) = effort to breed

deltaM.adult = g/adult - mean(g/adult) = weight loss (gain)

dotM.chick = g/day = chick growth rate

M.subad = g/fledgling = weight at fledge

cond.fledge = gram/cm = condition at fledge

The third variable in Table 7 corrects weight at fledging for degree of development, measured as wing length at time of fledging, a rough proxy for age. A derived measure (with units of $\text{gram}^2/(\ln(\text{cm}))^2$) is also being used. An effort will be made to find a more biologically interpretable measure. One possibility is to use wing length as a proxy for age, then fit the chick growth data to model with biologically interpretable parameters, such as a von Bertalanffy growth curve.

Once the model was identified, the next step was to list the available data. These data (Tables 8,9,10) will be used to define the form of the relation between variables, to estimate average values of each variable, and to estimate parameters relating one variable to another.

Table 8. Data for Black-legged Kittiwakes in Prince William Sound. Source is either no data, historical data, or APEX protocols for data collection and reporting, listed by sub-project letter. JD = Julian date; (A) = archeology (will require time to assemble).

SYMBOL	UNITS	SOURCE	LOCATION	TIME
POPULATION SIZE AND TRENDS				
N.colony	pairs/colony	E,hd	all colonies	JD
N.sea	birds/km^2	E,hd	coastline	JD
SURVIVAL				
S.nest	egg success/nest built	E	3 colonies	JD
S.egg	clutch size/nest with eggs	E	3 colonies	JD
S.chick	eggs hatched/eggs laid	E	3 colonies	JD
S.subad	fledged/chicks hatched	E	3 colonies	JD
S.ad1	adults returning/chicks fledged	E	1 colony	JD
S.ad2	---		-	
S.ad.n	adults returning/adults banded	E	1 colony	JD
MORTALITY DUE TO PREDATORS				
Dpred.nest	----	-		
Dpred.egg	losses/egg laid	D.Irons(A)	3 colonies	JD
Dpred.chick	losses/chick hatched	D.Irons(A)	3 colonies	JD
Dpred.subad	----	-		
Dpred.ad1	----	-		
Dpred.ad2	----	-		
Dpred.ad.n	losses/breeding pair	F.Bassett(Th.)	1 colony	JD

Table 8. Continued....

SYMBOL	UNITS	SOURCE	LOCATION	TIME
OTHER VARIABLES				
deltaM.adult	g/adult (end of season)	E	1 colony	JD
dotM.chick	g/day	E	3 colonies	JD
M.subad	g/fledgling	E	3 colony	JD
cond@fledge	gram/cm (winglength)	E	3 colony	JD
dotE.effort	kJ/season	E(A)		
dotE.int	kJ/day	E(A)		
F.rate	trips/day	D.Irons	1 colony	JD
C.att	attempt/trip	E	1 colony	JD
C.succ	captures/attempt	B	lat/long	JD
C.energy	kJ/capture	B,E	PWS	JD
dotE.deliv	kJ/d	(A)		
F.rate.deliv	trips/day	B,E	PWS	JD
M.meal	g/trip	E	1 colony	JD
spE.meal	kJ/g	E	1 colony	JD
L.prey	km	E,B	1 colony	JD
A.school	km^2	B	PWS	JD
FMR	kJ/kg	D.Irons	1 colony	JD
L.colony	km	E	1 colony	JD

Table 9. Data for Pigeon Guillemots in Prince William Sound. Source is either no data, historical data from K.Kuletz at one colony (KK), colony atlas (FWS), or APEX protocols for data collection and reporting, listed by subproject letter. JD = Julian date; (A) = archeology (will require time to assemble).

SYMBOL	UNITS	SOURCE	LOCATION	TIME
POPULATION SIZE AND TRENDS				
N.colony	pairs/colony	FWS	all colonies	
N.colony	pairs/colony	F,G,KK	2 colonies	JD
N.sea	$birds/km^2$	E,F,KK	coastline	JD

Table 9. Continued....

SYMBOL	UNITS	SOURCE	LOCATION	TIME
SURVIVAL				
S.nest	egg sites/pair	F,G,KK	2 colonies	JD
S.egg	eggs/site	F,G,KK	2 colonies	JD
S.chick	chicks/nest site	F,G,KK	2 colonies	JD
S.subad	fledged/chicks hatched	F,G	2 colonies	JD
S.ad1	adults returning/chicks fledged	F,G,KK	2 colonies	JD
S.ad2	---		-	
S.ad.n	adults returning/adults banded	F,G,KK	2 colonies	JD
MORTALITY DUE TO PREDATORS				
Dpred.nest	----		-	
Dpred.egg	egg loss/nest site	F,KK	1 colonies	JD
Dpred.chick	chick loss/nest site	F,KK	1 colonies	JD
Dpred.subad	----		-	
Dpred.ad1	----		-	
Dpred.ad2	----		-	
Dpred.ad.n	losses/pair	F,KK	1 colony	JD
OTHER VARIABLES				
deltaM.adult	g/adult (end of season)	G	2 colony	JD
dotM.chick	g/day	F,G	2 colony	JD
M.subad	g/fledgling	F,G	2 colony	JD
cond@fledge	gram/cm (winglength)	F,G	2 colony	JD
dotE.effort	kJ/season	(A)		
dotE.int	kJ/day			
F.rate	trips/day	F,G	2 colony	JD
C.att	attempt/trip			
C.succ	captures/attempt	B	lat/long	JD
C.energy	kJ/capture	B	PWS	JD
dotE.deliv	kJ/day	G	2 colonies	JD
F.rate.deliv	trips/day	F,G	2 colonies	JD
M.meal	g/trip	F,G	2 colonies	JD
spE.meal	kJ/g	(A)		
L.prey	km	B	lat/long	JD
A.school	km^2	B	lat/long	JD
FMR	kJ/day			
L.colony	km	E,B	lat/long	JD

Table 10. Prey data for Black-legged Kittiwakes and Pigeon Guillemots in Prince William Sound. Source is either no data, NVP = nearshore vertebrate predator protocol, SEA project, or APEX protocols for data collection and reporting, listed by subproject letter. JD = Julian date; (A) = archeology (will require time to compile).

SYMBOL	UNITS	SOURCE/TYPE	LOCATION	TIME
M.prey.pel	g/m^3	A/acoustic	3 block	JD
		B/acoustic	PWS	JD
		SEA/aerial	PWS	JD
spE.pel	kJ/g	G		
M.prey.benth	g/m^2	NVP/acoustic (A)	PWS	JD
		NVP/seine (A)	PWS	JD
		F/seine (A)	1 colony	JD
		W.Barbour/quadrat (A)	intertidal	JD
		ADF&G/shrimp trawl (A)		
		UAF (A)	kelp beds	
spE.benth	kJ/g	G		

Discussion and Conclusions

1. The APEX general hypothesis could be readily cast in quantitative terms.

2. In seabirds, demographic rates prevail over kinematic (movement) rates at the scale of the APEX general hypothesis. Demographic variables will need to be estimated, in relation to prey intake and delivery, in order to test the APEX general hypothesis.

3. Data exist to estimate nearly all demographic parameters in 3 colonies of Black-legged Kittiwakes and 2 colonies of Pigeon Guillemots in Prince William Sound.

4. Post fledging and post breeding mortality (s.ad1, s.ad.n) need to be estimated in multiple years, starting in 1997.

5. Concomitant data are needed to estimate parameters relating uptake/delivery to small scale resource density E, for both species. Concomitant measures of the following variables need to be made in multiple years, starting in 1997.

-Capture rates (C.att, C.succ, C.energy) in relation to prey density E = kJ/area.

-Prey intake (dotE.int = kJ/day) and delivery rates (dotE.deliv = kJ/day) relative to variation in resource density E and quality (spE.high/spE.low).

6. Prey intake (dotE.int) by adults needs to be estimated for the pre-breeding, incubation, chick rearing, and post breeding periods.

7. The feasibility of use field metabolic rate (FMR) to measure prey intake of both species in relation to resource density, delivery rate, and energy content (spE) of chick meals should be examined.

Acknowledgments

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APPENDIX P

APEX: 96163P

ASSESSMENT OF THE PAH CONTAMINATION OF POPULATIONS OF THE FORAGE FISH, SAND LANCE (*Ammodytes hexapterus*), INHABITING CLEAN AND OIL-IMPACTED SEDIMENTS

PROJECT NUMBER 96163P

FINAL REPORT

TO THE

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
RESTORATION OFFICE
ANCHORAGE, AK

AND

NOAA
OFFICE OF OIL SPILL
AUKE BAY, AK

FOR WORK ORDER 40ABNF601216

FROM

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Columbia Analytical Services
6060 Corte del Cedro, Carlsbad, CA 92009

January 16, 1997

ASSESSMENT OF THE PAH CONTAMINATION OF POPULATIONS OF THE FORAGE FISH, SAND LANCE (*Ammodytes hexapterus*), INHABITING CLEAN AND OIL-IMPACTED SEDIMENTS

ABSTRACT

APEX investigators collected samples of sand lance from Northwest Block Island, Southeast Eleanor Island, North Cabin Bay, and East Bob Day Bay. Sediments were collected from Southeast Eleanor Island, Northwest Block Island, MacPherson Isthmus, Fuel Cache Beach, MacPherson Narrows, and East Bob Day Bay. All samples were extracted by EPA methods (3540, 3550) to produce dichloromethane (DCM) extracts, and small aliquots of these were applied to human liver cancer cells (101L), which produce a luminescent enzyme (luciferase) if dioxins, furans, coplanar PCBs and polycyclic aromatic hydrocarbons (PAHs) are present. The amount of luciferase produced (light) is measured with a luminometer, and the intensity is a function of the concentrations and potency of the planar organic compounds present in the extract. This test simulates the response of mammals and fish which may ingest contaminated *Ammodytes*. Tissue extracts were from composites of several whole fish, with the combined dry weight per sample of between 0.5 and 2.9 grams. Previous investigations with fish tissue collected in Southern California have detected levels of PAHs of from 0.3 to 4.0 µg of Benzo(a)pyrene Equivalents per g (ppm) in muscle, liver and ovary tissues. In this study, sediments were found to contain between 0.2 and 3.5 µg B(a)PEq/g. Levels of approximately 3 µg B(a)PEq/g were found in sediments collected at Eleanor Island SE and Block Island NW. Many of the sand lance samples did not show any significant contamination, but other samples ranged from 2 to 16 µg B(a)PEq/g. A few samples of fish from Block Island NW contained 5.5 to 16.2 µg B(a)PEq/g, and one sample from East Bob Day Bay contained 3.3 µg B(a)PEq/g. When the data are expressed as µg B(a)PEq/g lipid, values as high as 82 were observed. There appears to be significant contamination in some of the fish and sediment samples, which is likely from high molecular weight PAHs. These data will need to be discussed with the investigators who collected the samples and others with knowledge of the levels of oiling at these sites during the spill. Extracts can be sent to an analytical laboratory for confirmation.

INTRODUCTION

Sand lance (*Ammodytes hexapterus*) are marine fish inhabiting the coastal Northeast Pacific. They are an important trophic link to tertiary fish and mammals in this ecosystem. When not foraging on zooplankton in the water column, these fish bury themselves in bottom sediments to avoid predation. Because of this, sand lance may be important indicators of sediment contamination, including that following the Exxon Valdez oil spill in Prince William Sound (PWS), Alaska in March of 1989.

Given the persistant nature of petroleum hydrocarbons in sediment, levels of PAH contamination in sediments collected from some sites in PWS even in 1996 may be significant. Collier *et al* (1996) found that, in contrast to species in the littoral zone, nearshore benthic fish species in Prince William Sound showed continuing oil exposure through the first two field seasons after the spill, and there was some evidence of increased exposure even after more than two years. Sand lance, though prefering to burrow into clean sand, may be exposed to oil-impacted sediments in these shallow subtidal zones (Pinto *et al* 1984). Contaminant levels in tissue extracts of fish collected at these sites, as compared to those from sites where oiling did not occur, may indicate this exposure. In this study, sand lance as well as sediments were collected from several sites in PWS.

Induction of the cytochrome P450 system in fish in response to petroleum hydrocarbon contamination in sediments has been well characterized (Collier *et al*, 1995, 1996). These contaminants, including polycyclic aromatic hydrocarbons (PAHs) are known to bind to an intracellular cytosolic protein referred to as the Ah receptor . This complex is translocated to the nucleus of the cell, where it interacts with elements in the promoter of the CYP1A1 gene and causes transcription of the P450 enzyme system. While many of these enzymes are involved in metabolic detoxification pathways, epoxidation of benzo[a]pyrene by the P450 enzyme system produces a reactive metabolite, actually enhancing its carcinogenicity (Varanasi *et al* 1987).

To determine possible contamination which may be related to toxicity and carcinogenicity, extracts of sediments and fish tissues collected from PWS were analyzed by a P450 Reporter Gene System (RGS) (APHA, ASTM 1997). This assay utilizes a human cell line, know as 101L, into which a plasmid has been stably integrated. This plasmid contains the CYP1A1 promoter linked to a reporter gene, firefly luciferase. When compounds that induce transcription of P450 by the CYP1A1 gene are present in these cells, the enzyme luciferase is produced. Luciferase acts on the substrate luciferin to produce light. P450 induction can therefore be measured by a simple assay that measures relative light units in a luminometer. In tissue extracts from mussels deployed in San Diego Bay, P450 RGS-estimated Benzo[a]Pyrene Equivalents were highly correlated to Toxic Equivalents (TEQs) based on chemical analytical data of these mussel tissues (Anderson *et al* 1997).

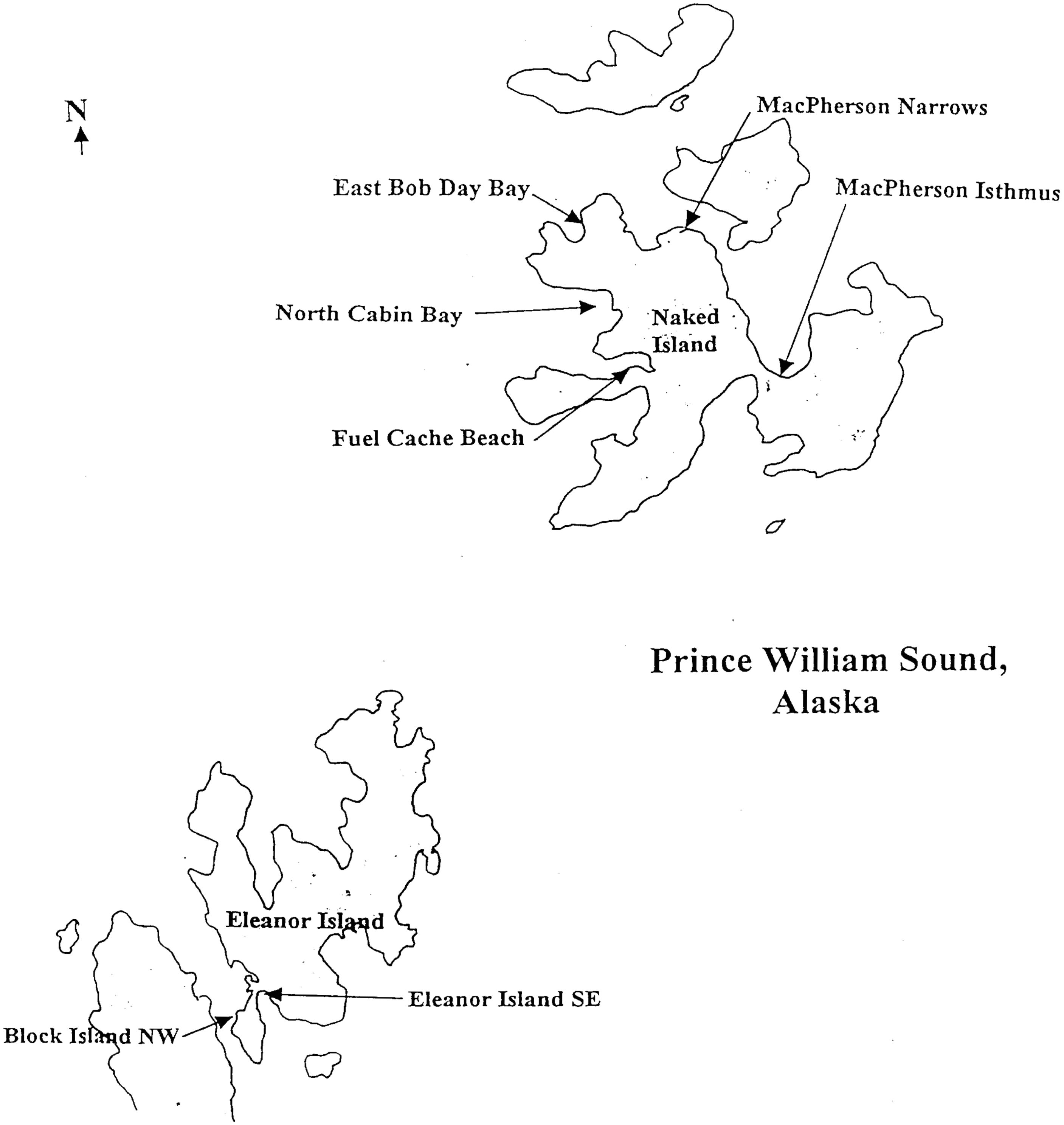
METHODS

Sediments

Approximately 40 grams of sediment from six stations in Prince William Sound (see map) were extracted by EPA method 3540 to produce 1 mL dichloromethane (DCM) extracts containing the extractable organic compounds. Two of these six stations were considered oiled, while the other four were thought to be relatively unoiled sites. Per cent solids were obtained for each sample.

Tissues

Sand lance were collected from six locations (two oiled and four unoiled) in PWS. Fish varied in length and mass, and some samples consisted of composites of four or five small fish. Because of this, samples were given a size classification, so that fish greater than 130



Prince William Sound, Alaska

mm in standard length were assigned to Class A, from 100 mm to 130mm to Class B, and fish less than 100 mm in length, including composites of such fish, to Class C. Tissue samples were weighed and extracted as described above. Percent solids as well as percent lipids were determined for three samples, one from each of the three size classes.
Because of their flocculent lipid content, tissue extracts were centrifuged at 6000 rpm. The resulting supernatent was then decanted and saved. The lipid pellet was resuspended in fresh DCM, mixed, centrifuged again and the supernatents combined. In order to assure that no organic compounds were being harbored in the lipid pellet, one sample was spiked with the reference inducer TCDD and analyzed by the P450 RGS assay before and after several resuspensions in DCM. From this, it was determined that two resuspensions and centrifugations were sufficient to assure that little or no organic content of the sample was lost with the discarded lipid pellet.

Following this, tissue extracts were allowed to evaporate at room temperature to dryness, then taken up in 500 µL of DMSO. DMSO is a more favorable solvent to the cells and the plastic tissue culture plates than DCM when addition of 10 to 20 µL is necessary for optimum analysis of tissue samples. This exchange was unnecessary with sediment extracts since only 5 µL of DCM was applied.

P450 RGS Analysis

The detailed methodology used in this study has been described elsewhere (Anderson *et al* 1995, 1996). Small portions of extracts were applied to approximately one million human liver cancer cells contained in three replicate wells with 2 mL of culture medium. After a 16-hour incubation, the cells were washed, lysed, the solution centrifuged, and 50 µL of the supernatant was measured for luminescence. With each sample run, a solvent blank (using a volume of DCM or DMSO equal to the extract volume being tested) and a reference toxicant (2,3,7,8-dioxin at a concentration of 2 ng/mL) were applied to three replicate wells each. Fold induction of the solvent blank was set equal to 1, and the fold induction of each sample and the reference toxicant was determined by dividing the relative light units (RLUs) produced by that sample by the RLUs produced by the solvent blank.

In order to produce benzo[a]pyrene equivalents (B[a]PEq) for each sample, fold induction values were divided by 60, a value derived from previous studies showing that 1 µg/mL (ppm) of B[a]P produces approximately a 60 fold induction in this P450 RGS assay. Further multiplication by a factor that brings the volume applied up to the total extract volume and then division by the dry weight (in grams) for both the sediment and tissue samples, and by the lipid weight of the tissues yielded B[a]P Eq values in µg/g dry and µg/g lipid, respectively.

Quality Assurance/Quality Control

After each test run, responses to the solvent blank and dioxin were compared to the those values in a control chart to assure that they were within two standard deviations of a running mean. Additional quality control procedures included spiking samples with benzo[a]pyrene, along with analysis of standard curves for both B[a]P and a quantified

PAH mixture. The luminometer was calibrated using a luciferase standard curve of relative light units vs. enzyme concentration.

RESULTS

The results of this project are summarized in the following tables and figures and in Excel PC files on the enclosed disk.

Table 1 below shows the results of the seven different runs of the RGS assay, listing the mean of the triplicate luminometer readings for the dichloromethane (DCM), dimethylsulfoxide (DMSO), and dioxin (TCDD). In the first run, only sediment extracts in DCM were tested, so no DMSO blank was run. The tissue extracts, exchanged into DMSO, were run with a DMSO and usually a DCM blank, and the fold induction with both solvents is listed where applicable. All data points fell within 2 standard deviations of the means.

Table 1. Variability of Fold Induction in Multiple Runs.

DATE	DCM	DMSO	TCDD	FOLD (DCM)	FOLD (DMSO)
10/22/96	0.103	NA	10.706	103.9	NA
10/24/96	0.100	0.062	11.773	117.7	189.9
10/25/96	NA	0.055	10.001	NA	181.8
10/29/96	0.108	0.069	8.121	75.2	117.7
11/4/96	NA	0.060	10.663	NA	177.7
11/5/96	0.153	0.118	11.329	74.0	96.0
11/7/96	0.116	0.088	12.885	111.1	146.4
MEAN	0.116	0.075	10.783	96.4	151.6
S.D.	0.022	0.024	1.495	20.5	38.3
2S.D.	0.043	0.048	2.99	40.9	76.6
Upper C.L.	0.159	0.123	13.773	137.3	228.2
Lower C.L.	0.073	0.028	7.792	55.5	75.0
n	5	6	7	5	6

Table 2 lists the wet weights, percent solids, and subsequent dry weights of the six sediment samples as determined by the Columbia Analytical Services laboratory in Kelso, Washington.

Table 2. Dry Weight Calculations of Sediment Samples.

CAS ID#	Wet wt. (g)	%Solid	Dry wt. (g)
6369-1	40.2	96.7	38.9
5793-48	41.1	94.1	38.6
5793-49	40.7	79.3	32.3
5793-50	40.5	91.3	37.0
5793-51	40.5	94.2	38.1
5793-52	40.9	90.9	37.2

Table 3 lists the wet weights, percent solids, and percent lipids of the thirty-eight tissue samples also determined by the Columbia Analytical Services laboratory in Kelso, Washington. It also presents the subsequent dry weights and lipid weights of all tissue samples. The percent solids were based on analysis of two samples, both of which were found to be 28%. Percent lipids were based on analysis of three samples, one from each of the three fish size classes, and each sample was assigned a percent lipid value based on that classification, as explained in Methods.

Table 4 shows the triplicate luminometer readings in relative light units (RLUs), and the calculated fold induction and benzo[a]pyrene equivalents (B[a]PEq) for all samples. Fold induction was calculated as the mean RLU value of the sample divided by the mean RLU of the solvent blank (either DCM or DMSO). All values for % of the mean (coefficient of variation) are less than 20%, indicating little variation among the triplicates. B[a]PEq were calculated using the following formula:

$\mathrm{B[a]PEq} = (\mathrm{fold}/60)*(V_e/V_a)/\mathrm{wt}$
where 60 = B[a]P conversion factor (see Methods)
V_e = total extract volume
V_a = volume of extract applied to cells
wt = dry or lipid weight of sample

This gives a B[a]PEq in µg per gram of either dry weight or lipid weight.

To summarize the data, Table 5 and Figures 1 and 2 present the B[a]PEq by sample, including the sample description and collection site.

Tissues

A sand lance tissue sample (CAS #6) from Eleanor Island SE was found to contain the highest amount of compounds that induce P450 RGS, calculated as 16 µg B[a]PEq per g dry weight and 82 µg B[a]PEq per g lipid weight. The majority of all tissue samples were lower in µg B[a]PEq per dry weight: 55% were < 2.0, 26% were between 2.0 and 5.0, and 18%, including the highest sample, were >5.0.

Sediments

A sediment extract from Block Island NW (CAS #48) was determined to have the highest level of B[a]PEq at 3.5 µg/g. Most of the sediment extracts (71%) had <1.0 µg B[a]PEq per g dry weight.

Table 3. Weight Calculations of Tissue Samples.

CAS I.D #	size class*	wet wt. (g)	%solid	dry wt. (g)	%lipid	lipid wt. (g)
K5793-2	A	10.37	28	2.9	10.9	1.13
3	B	2.72	28	0.8	8.4	0.23
4	C	1.37	28	0.4	5.6	0.08
5	C	2.65	28	0.7	5.6	0.15
6	C	0.94	28	0.3	5.6	0.05
7	A	10.67	28	3.0	10.9	1.17
8	A	8.88	28	2.5	10.9	0.97
9	B	3.43	28	1.0	8.4	0.29
11	B	5.56	28	1.6	8.4	0.47
12	C	1.97	28	0.6	5.6	0.11
13	B	6.36	28	1.8	8.4	0.54
14	C	1.70	28	0.5	5.6	0.09
15	A	7.74	28	2.2	10.9	0.85
16	B	3.56	28	1.0	8.4	0.30
17	C	1.00	28	0.3	5.6	0.06
18	C	1.70	28	0.5	5.6	0.09
19	C	2.18	28	0.6	5.6	0.12
20	B	3.25	28	0.9	8.4	0.27
21	A	8.70	28	2.4	10.9	0.95
22	B	3.52	28	1.0	8.4	0.30
23	A	8.27	28	2.3	10.9	0.90
24	B	8.01	28	2.2	8.4	0.68
25	C	2.87	28	0.8	5.6	0.16
26	A	9.74	28	2.7	10.9	1.06
27	C	2.05	28	0.6	5.6	0.11
28	A	9.13	28	2.6	10.9	1.00
29	B	4.63	28	1.3	8.4	0.39
30	B	4.88	28	1.4	8.4	0.41
31	A	8.60	28	2.4	10.9	0.94
33	B	7.74	28	2.2	8.4	0.65
36	A	10.00	28	2.8	10.9	1.09
37	A	10.10	28	2.8	10.9	1.10
39	A	10.54	28	3.0	10.9	1.15
41	C	4.71	28	1.3	5.6	0.26
42	A	9.90	28	2.8	10.9	1.08
43	C	10.60	28	3.0	5.6	0.59
44	C	10.50	28	2.9	5.6	0.58
45	C	10.00	28	2.8	5.6	0.56

*Size classes:

A: Standard length ≥130mm

B: Standard length between 100 and 130mm

C: Standard length ≤100mm

Table 4. Triplicate RLUs and Calculated B[a]P Equivalents.

Test Date	CAS #	Solvent	Applied Volume (μL)	type*	RLU1	RLU2	RLU3	MEAN	S.D.	%MEAN	FOLD	B[a]P Eq. (μg/g dry)	B[a]P Eq. (μg/g lipid)
10/22/96	MB	DCM	5	NA	0.144	0.169	0.155	0.156	0.013	8.0	1.5	0.1	NA
10/22/96	6369-1	DCM	5	sed	4.068	3.783	3.375	3.742	0.348	9.3	36.3	3.1	NA
10/22/96	5793-48	DCM	5	sed	4.099	4.208	4.274	4.194	0.088	2.1	40.7	3.5	NA
10/22/96	49	DCM	5	sed-oiled	0.201	0.212	0.209	0.207	0.006	2.7	2.0	0.2	NA
10/22/96	50	DCM	5	sed	0.231	0.221	0.187	0.213	0.023	10.8	2.1	0.2	NA
10/22/96	51	DCM	5	sed-oiled	0.358	0.434	0.453	0.415	0.050	12.1	4.0	0.4	NA
10/22/96	52	DCM	5	sed	0.264	0.286	0.267	0.272	0.012	4.4	2.6	0.2	NA
10/22/96	43	DCM	10	SL-oiled	0.071	0.064	0.111	0.082	0.025	30.9	**0.8**	<1.1	<5.7
10/24/96	9	DMSO	10	SL	0.158	0.159	0.149	0.155	0.006	3.5	2.5	4.3	14.4
10/24/96	16	DMSO	10	SL-oiled	0.144	0.152	0.145	0.147	0.004	3.0	2.4	4.0	13.2
10/25/96	3	DMSO	10	SL	0.078	0.073	0.067	0.0727	0.006	7.6	1.3	2.9	9.6
10/25/96	4	DMSO	10	SL	0.074	0.071	0.068	0.071	0.003	4.2	1.3	5.6	28.3
10/25/96	5	DMSO	10	SL	0.097	0.101	0.101	0.0997	0.002	2.3	1.8	4.1	20.5
10/25/96	17	DMSO	10	SL-oiled	0.074	0.069	0.072	0.0717	0.003	3.5	1.3	7.8	39.1
10/25/96	18	DMSO	10	SL-oiled	0.116	0.125	0.111	0.1173	0.007	6.0	2.1	7.5	37.7
10/25/96	19	DMSO	10	SL-oiled	0.132	0.145	0.167	0.148	0.018	12.0	2.7	7.3	37.1
10/25/96	20	DMSO	10	SL-oiled	0.114	0.119	0.113	0.1153	0.003	2.8	2.1	3.8	12.8
10/25/96	22	DMSO	10	SL	0.070	0.072	0.061	0.0677	0.006	8.7	1.2	2.1	6.9
10/29/96	2	DMSO	5	SL	0.070	0.056	0.063	0.063	0.007	11.1	**0.9**	<1.43	<3.66
10/29/96	21	DMSO	5	SL-oiled	0.075	0.076	0.065	0.072	0.006	8.4	1.0	1.4	3.7
11/4/96	6	DMSO	5	SL	0.130	0.140	0.122	0.131	0.009	6.9	2.6	16.2	81.9
11/4/96	7	DMSO	5	SL	0.109	0.098	0.097	0.101	0.007	6.6	2.0	1.1	2.8
11/4/96	8	DMSO	5	SL	0.095	0.097	0.092	0.095	0.003	2.7	1.9	1.2	3.2
11/4/96	11	DMSO	5	SL	0.143	0.133	0.117	0.131	0.013	10.0	2.6	2.7	9.1
11/4/96	12	DMSO	5	SL	0.137	0.137	0.127	0.134	0.006	4.3	2.6	7.9	40.0
11/4/96	13	DMSO	5	SL	0.097	0.084	0.083	0.088	0.008	8.9	1.7	1.6	5.4
11/4/96	14	DMSO	5	SL	0.082	0.082	0.078	0.081	0.002	2.9	1.6	5.5	27.9
11/4/96	15	DMSO	5	SL	0.090	0.093	0.089	0.091	0.002	2.3	1.8	1.4	3.5
11/4/96	23	DMSO	5	SL	0.090	0.089	0.084	0.088	0.003	3.7	1.7	1.2	3.2
11/4/96	24	DMSO	5	SL	0.080	0.078	0.074	0.077	0.003	4.0	1.5	1.1	3.7
11/4/96	25	DMSO	5	SL	0.110	0.119	0.123	0.117	0.007	5.7	2.3	4.8	24.1
11/4/96	26	DMSO	5	SL	0.092	0.096	0.109	0.099	0.009	9.0	1.9	1.2	3.0
11/4/96	33	DMSO	5	SL	0.085	0.086	0.083	0.085	0.002	1.8	1.7	1.3	4.2
11/4/96	36	DMSO	5	SL	0.078	0.079	0.071	0.076	0.004	5.7	1.5	0.9	2.3
11/5/96	27	DMSO	5	SL	0.088	0.094	0.122	0.101	0.018	17.9	**0.9**	<1.22	<4.07
11/5/96	28	DMSO	5	SL	0.091	0.124	0.089	0.101	0.020	19.4	**0.9**	<1.22	<4.07
11/5/96	29	DMSO	5	SL	0.111	0.117	0.109	0.112	0.004	3.7	1.0	0.20	0.4
11/5/96	30	DMSO	5	SL	0.097	0.092	0.094	0.094	0.003	2.7	**0.8**	<1.22	<4.07
11/5/96	31	DMSO	5	SL	0.103	0.107	0.111	0.107	0.004	3.7	**0.9**	<1.22	<4.07
11/5/96	37	DMSO	5	SL	0.095	0.092	0.096	0.094	0.002	2.2	**0.8**	<1.22	<4.07
11/7/96	39	DMSO	5	SL	0.092	0.095	0.086	0.094	0.002	2.3	1.1	0.6	1.5
11/7/96	41	DMSO	5	SL	0.253	0.250	0.280	0.252	0.002	0.8	2.9	3.6	18.2
11/7/96	42	DMSO	5	SL	0.087	0.092	0.074	0.090	0.004	4.0	1.0	0.6	1.6
11/7/96	44	DMSO	5	SL	0.134	0.127	0.129	0.131	0.005	3.8	1.5	0.8	4.2
11/7/96	45	DMSO	5	SL-oiled	0.498	0.462	0.387	0.480	0.025	5.3	5.5	3.2	16.4

*type: SL=Sandlance tissue sample; SL-oiled= Sandlance tissue sample from oiled site;
sed= Sediment sample; sed-oiled = sediment sample from oiled site

Fold values in bold are <1.0, and are assigned B[a]PEq = < what a 1.0 fold would give.

Table 5. Summary of B[a]P Equivalents in APEX Samples.

CAS # K5793-	Description	Location	B[a]PEq.* (µg/g dry)	B[a]PEq.* (µg/g lipid)
2	SL	Block Island NW	<1.43	<3.66
3	SL	Block Island NW	2.9	9.6
4	SL	Block Island NW	5.6	28.3
5	SL	Block Island NW	4.1	20.5
6	SL	Block Island NW	16.2	81.9
7	SL	Block Island NW	1.1	2.8
8	SL	Block Island NW	1.2	3.2
9	SL-oiled	Block Island NW	4.3	14.4
11	SL	Block Island NW	2.7	9.1
12	SL	Block Island NW	7.9	40.0
13	SL	Block Island NW	1.6	5.4
14	SL	Block Island NW	5.5	27.9
15	SL	Block Island NW	1.4	3.5
16	SL-oiled	Block Island NW	4.0	13.2
17	SL-oiled	Block Island NW	7.8	39.1
18	SL-oiled	Block Island NW	7.5	37.7
19	SL-oiled	Block Island NW	7.3	37.1
20	SL-oiled	Block Island NW	3.8	12.8
21	SL-oiled	Block Island NW	1.4	3.7
22	SL	Eleanor Island SE	2.1	6.9
23	SL	Eleanor Island SE	1.2	3.2
24	SL	Eleanor Island SE	1.1	3.7
25	SL	Eleanor Island SE	4.8	24.1
26	SL	Eleanor Island SE	1.2	3.0
27	SL	Eleanor Island SE	<1.22	<4.07
28	SL	Eleanor Island SE	<1.22	<4.07
29	SL	Eleanor Island SE	1.2	4.1
30	SL	Eleanor Island SE	<1.22	<4.07
31	SL	Eleanor Island SE	<1.22	<4.07
33	SL	Eleanor Island SE	1.3	4.2
36	SL	Eleanor Island SE	0.9	2.3
37	SL	Eleanor Island SE	<1.22	<4.07
39	SL	Eleanor Island SE	0.6	1.5
41	Composite of SL #32,34,35,38,40	Eleanor Island SE	3.6	18.2
42	SL	Eleanor Island SE	0.6	1.6
43	SL-oiled	MacPherson Isthmus	<1.1	<5.7
44	SL	North Cabin Bay	0.8	4.2
45	SL-oiled	East Bob Day Bay	3.2	16.4
Sediment	**Type**	**Location**		
Blank	NA	NA	0.1	
K6369-1	sed	Eleanor Island SE	3.1	
K5793-48	sed	Block Island NW	3.5	
49	sed-oiled	MacPherson Isthmus	0.2	
50	sed	Fuel Cache Beach	0.2	
51	sed-oiled	East Bob Day Bay	0.4	
52	sed	MacPherson Narrows	0.2	

*Differences in detection limits result from variability among sample weight and fold induction values of blanks.

Figure 1. P450 RGS-estimated B[a]P Equivalents in Sand Lance Tissues from Prince William Sound, Alaska

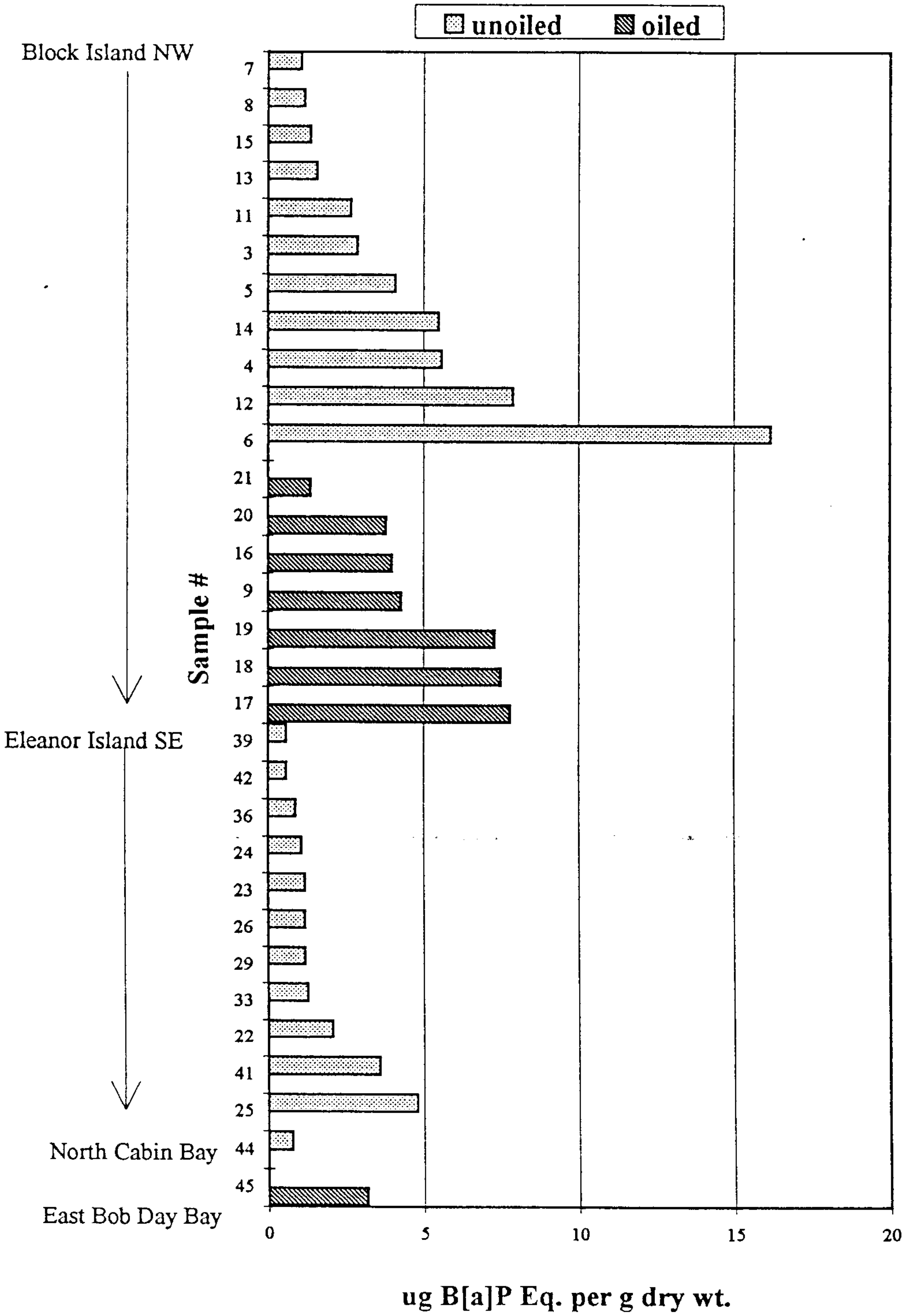
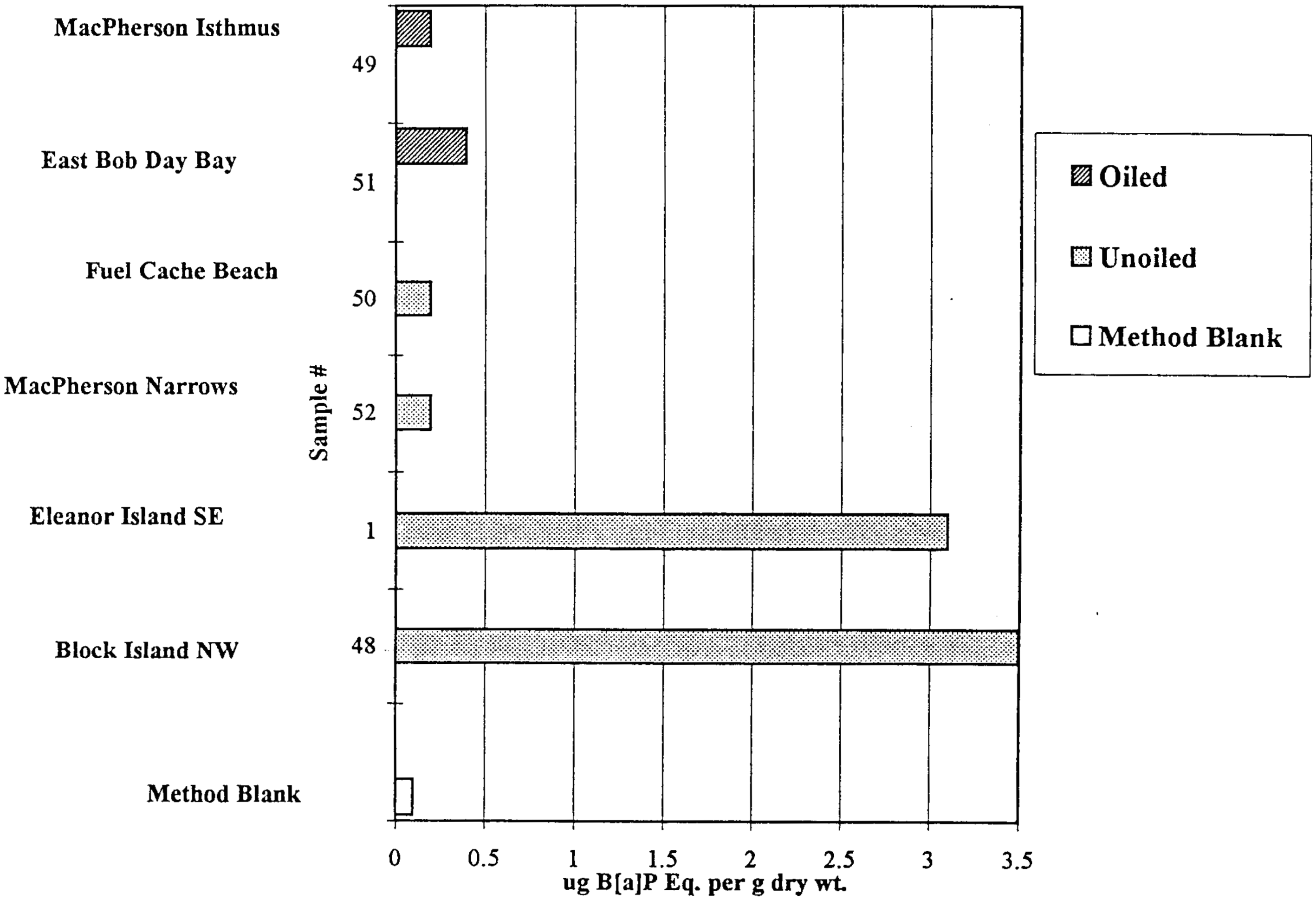


Figure 2. P450 RGS-estimated B[a]P Equivalents in Sediments from Prince William Sound, Alaska



Statistical Analysis

A t-test was used to determine differences between the mean B[a]P Equivalency values of tissues from oiled and unoiled collection sites (Microsoft Excel 5.0). One data point from unoiled Eleanor Island SE (CAS #6) was not used in this analysis. This value was an extreme outlier, greater than three standard deviations above the mean B[a]PEq for unoiled samples. Using a two-tailed t-test with unequal variances, the mean B[a]PEq from the oiled sample set was found to be significantly greater than that from the unoiled set at the 95% confidence level ($p < 0.02$).

Table 6. Results of Statistical Analysis on B[a]PEqs from Sand Lance Tissues.

Variable	N	mean	S.D.
unoiled	22	2.43	2.0
oiled	8	4.93	2.3

$p < 0.021$

QA/QC

Figure 3 shows the dioxin control chart used to assure quality control of the P450 RGS assay. After every test run, the fold induction produced by dioxin at 2 ng/mL is entered into an Excel spreadsheet that adds that day's dioxin performance to obtain a running mean. From this, a confidence interval (shown on the chart by dashed horizontal lines at two standard deviations above and below the most recent value for the running mean) is determined and the test run is evaluated. All dioxin fold induction values obtained in this study (data points from 10/22 to 11/7) were within two standard deviations of the running mean, and were therefore acceptable.

In addition, a sediment extract method blank was tested along with the sediment samples. This extract yielded a 1.5 fold induction and 0.1 µg B[a]PEq per g dry weight (of sodium sulfate used in the extraction method). This gives a baseline value upon which B[a]PEqs calculated from true sediment samples can be analyzed.

Figure 3. P450 RGS TCDD (2 ng/mL) Control Chart

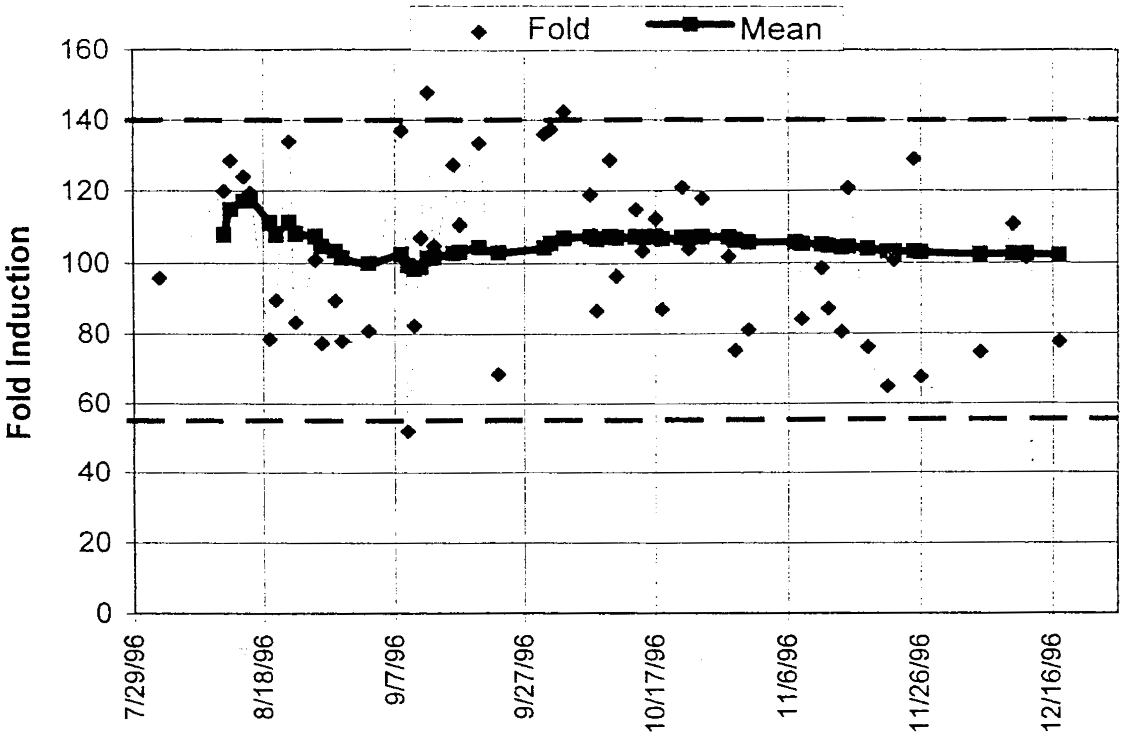


Figure 4. P450RGS Induction from Benzo[a]Pyrene

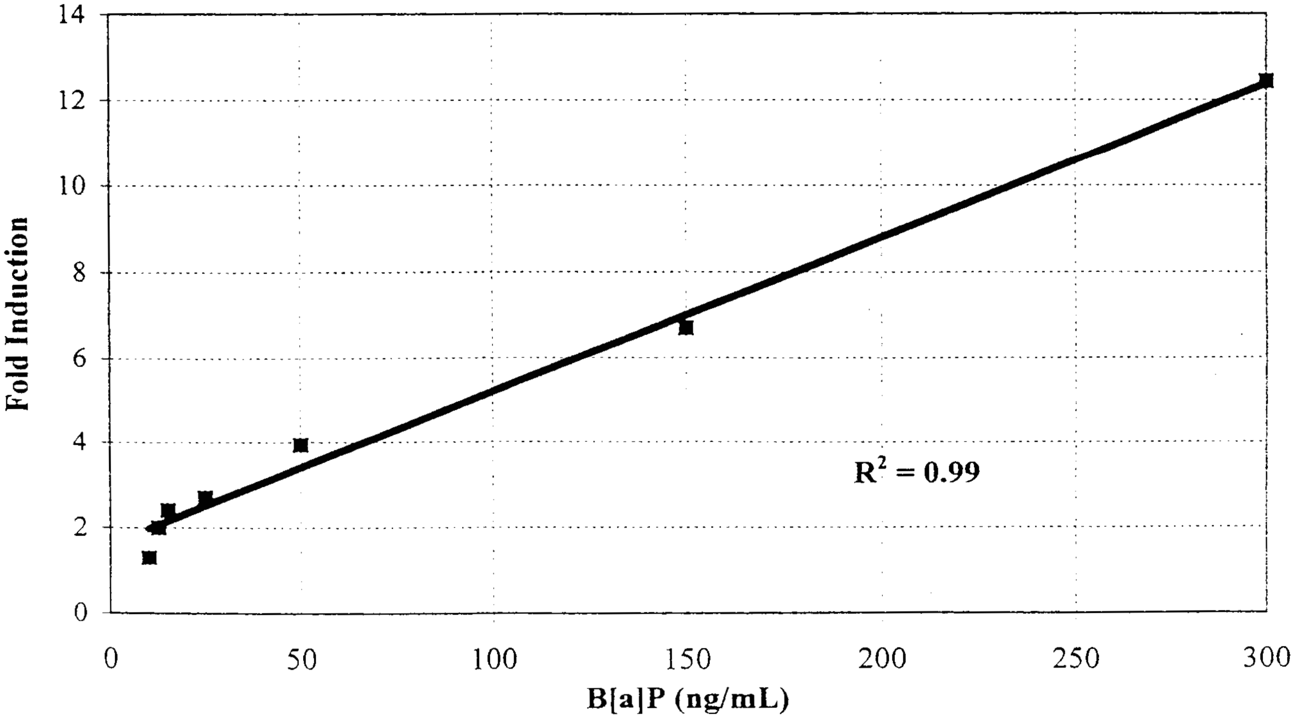


Figure 5. P450 RGS Induction from PAH Mixture

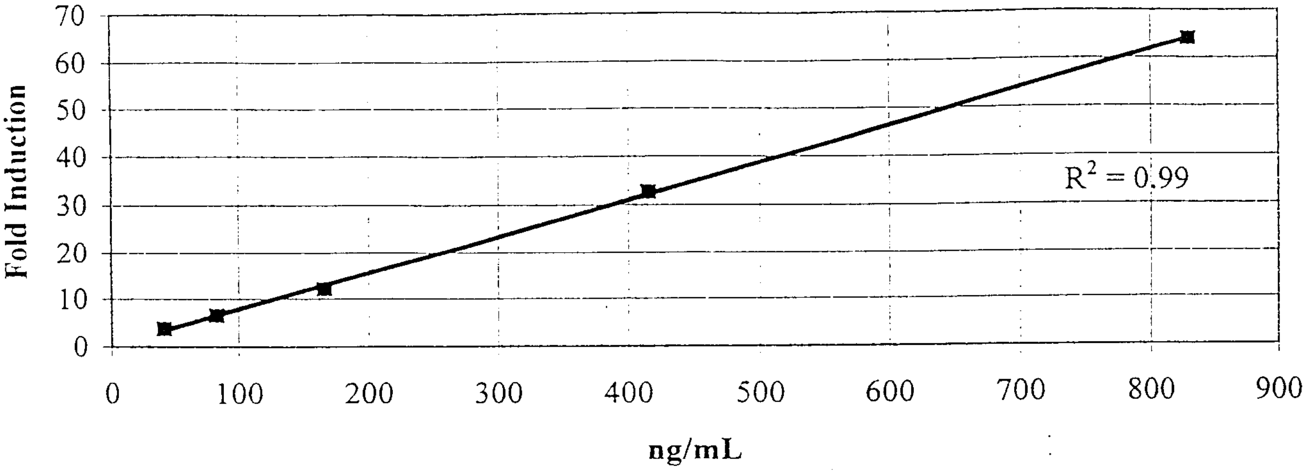


Figure 6. Luciferase Standard Curve (11/6/96)

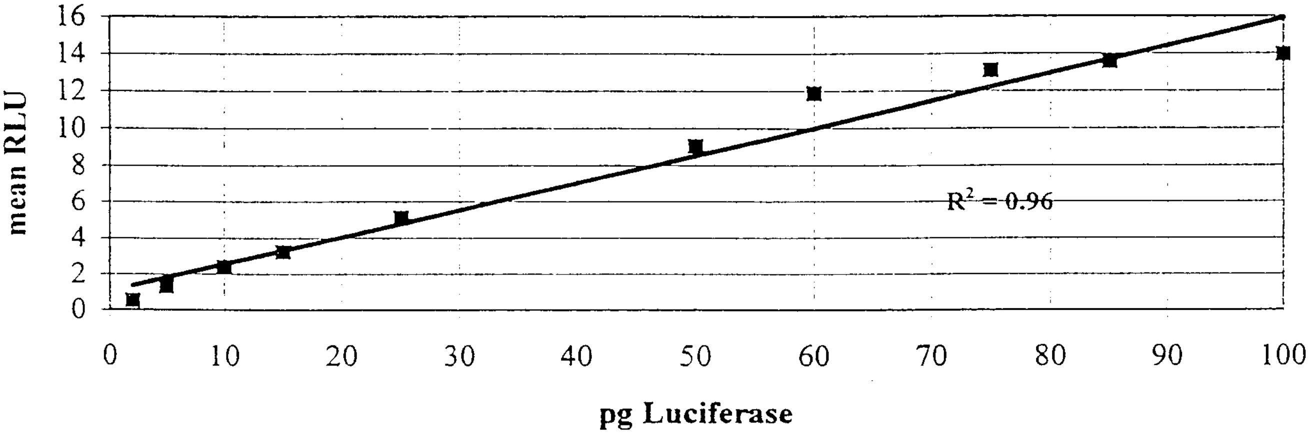
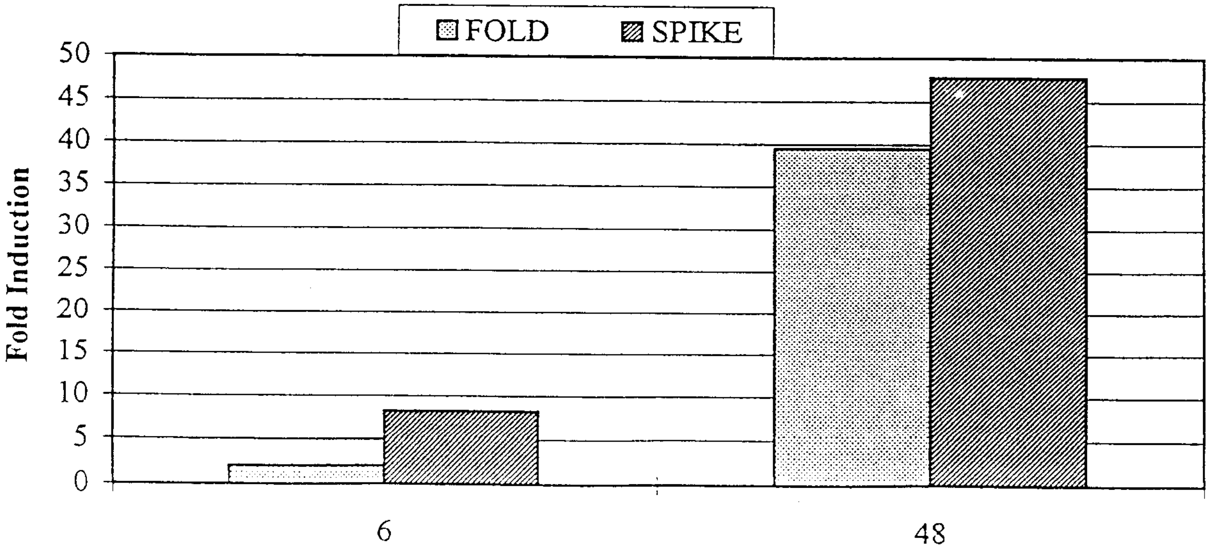


Figure 7. P450 RGS Fold Induction Response to Spike with 300 ng/mL B[a]P



Standard curves for Benzo[a]Pyrene and a commercially obtained PAH mixture are shown in Figures 4 and 5, respectively. Along with this, a luciferase standard curve (Figure 6) shows the lower detection limit of the luminometer and the strong linear correlation between RLUs and enzyme concentration, indicating the sensitivity and precision of the instrument.

Results from the spiking study are shown in Table 7 and Figure 7. Three samples were spiked: the sediment sample showing the highest induction (CAS #48) and two tissue samples (CAS #6 and CAS #36). Sample #48 and # 6 were spiked with 300 ng/mL B[a]P, while sample #36 (not shown in Figure 7) was spiked with only 50 ng/mL B[a]P (see Table 7).

Table 7. Results of Spiking Study with B[a]P.

CAS ID#	B[a]P Spike (ng/mL)	FOLD Sample alone	FOLD B[a]P spike	FOLD Sample + spike
5793-6	300	1.5	9.4	8.2
36	50	0.7	3.0	1.8
48	300	38.2	9.4	47.8

In cases where the fold induction of samples is ≤ 1.0 (equal or less than that of the solvent blank), as with many of the sand lance tissue extracts in this study, the B[a]P EQ are expressed as < what would result from a 1.0 fold induction. From previous studies using very low concentrations of 2,3,7,8-dioxin, the lower endpoint of detection with the P450 RGS assay is approximately 0.001 ng/mL, yielding between 1 and 2-fold. From the luciferase standard curve (Figure 6), detection of as little as 5 picograms of luciferase is possible. Preliminary studies with a PAH mixture (Figure 5) indicate that at least 40 ng/mL yields a reproducible detection of between 2 and 4-fold, and B[a]P concentrations as low as 10 ng/mL have been detected (Figure 4). Other individual PAH compounds, particularly benzo[k]fluoranthene, have even lower detection limits.

DISCUSSION AND CONCLUSIONS

The induction of luciferase production in the 101L cell line used in the P450 RGS assay, as measured by relative light units of cell lysates, indicates that the applied sample contains chemicals that act upon the CYP1A1 gene and cause transcription of cytochrome P450. This response is known to be associated with human and aquatic organism health effects, including carcinogenesis. These inducing chemicals include PAHs, PCBs, and dioxins, and are present, likely as mixtures, as environmental contaminants. As a result of the Exxon Valdez oil spill, Prince William Sound sediments are known to have significant levels of primarily PAH contamination. While this contamination can be measured directly using chemical analysis (GC/MS, HPLC, etc.) of sediment and pore water, this is a tedious and costly process, and the impact of the quantified chemicals on wildlife remain unclear. The P450 RGS analysis is a valid and useful, as well as quick and inexpensive, screening tool to assess the potential of contaminated sediment to have deleterious health effects on humans and wildlife via the Ah-mediated pathway.

In addition, analysis of tissue extracts by P450 RGS enables a further investigation into exposure and food web transfer of contaminants. While PAHs are metabolized by fish, many invertebrates accumulate these chemicals, leading to the transfer of much higher levels to organisms that ingest them.

This study investigates the potential for tissue extracts of sand lance, a fish that may be particularly susceptible to sediment-associated contamination during burrowing, to induce cytochrome P450. Such induction would presumably occur in organisms ingesting sand lance tissue. The results of this study indicate that the induction potential of these tissue samples was not necessarily correlated with the estimated level of oiling in the collection areas. For example, the strongest-inducing tissue sample came from an area that was presumed to be relatively clean. It must be noted here, however, that this particular sample extract (CAS #6) came from the tissue sample of lowest mass, contributing to its higher B[a]PEq value. Given that only five of the thirty-eight tissue samples analyzed were collected from oiled sites, the implications of this are unclear.

Sediment analyses also yielded results inconsistent with assumptions of oiling levels in collection sites. The two extracts that produced the strongest induction were from presumably clean sites. Obviously, there are many factors, including fish movement as well as contaminant patchiness, contributing to the difficulties in interpreting these findings.

In this study, the main focus was on investigating the potential of the P450 RGS assay as a screening tool for detecting PAH contamination in both fish tissues and sediments in a wide area, such as Prince William Sound. In previous studies, P450 RGS-estimated B[a]PEq have been found to be highly correlated with calculated toxic equivalency values determined from chemical analysis of extracts. Follow-on studies using P450 RGS and chemical analysis should investigate Sand Lance tissues and sediments from sites in Prince William Sound yielding high induction response in this study.

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ASSESSMENT OF THE PAH CONTAMINATION OF POPULATIONS OF THE FORAGE FISH, SAND LANCE (*Ammodytes hexapterus*), INHABITING CLEAN AND OIL-IMPACTED SEDIMENTS

PROJECT NUMBER 96163P

ADDENDUM TO THE

FINAL REPORT

TO THE

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
RESTORATION OFFICE
ANCHORAGE, AK

AND

NOAA
OFFICE OF OIL SPILL
AUKE BAY, AK

FOR WORK ORDER 40ABNF601216

FROM

Jack W. Anderson and Jennifer M. Jones
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APRIL 15, 1997

ASSESSMENT OF THE PAH CONTAMINATION OF POPULATIONS OF THE FORAGE FISH, SAND LANCE (*Ammodytes hexapterus*), INHABITING CLEAN AND OIL-IMPACTED SEDIMENTS

RESULTS

Investigators Marie Larsen, Jeff Short, and Stan Rice, of the Auke Bay NOAA laboratory, graciously analyzed extracts of the sand lance and sediments used in our investigation (data enclosed). The tissue extracts from composites of several whole fish, with the combined dry weights per sample of between 0.5 and 2.9 grams, were not found to contain detectable amounts of the higher molecular weight PAHs. These 4- to 6-ring aromatic compounds are those that would be expected to produce the P450 RGS responses observed. We recognized that any measured concentrations would be quite low, as the RGS responses were just above background. Apparently, the induction of CYP1A1 observed was from uncharacterized natural compounds present in the tissues. Previous investigations with fish tissue collected in Southern California have detected levels of PAHs of from 0.3 to 4.0 μg of Benzo(a)pyrene Equivalents per g (ppm) in muscle, liver and ovary tissues.

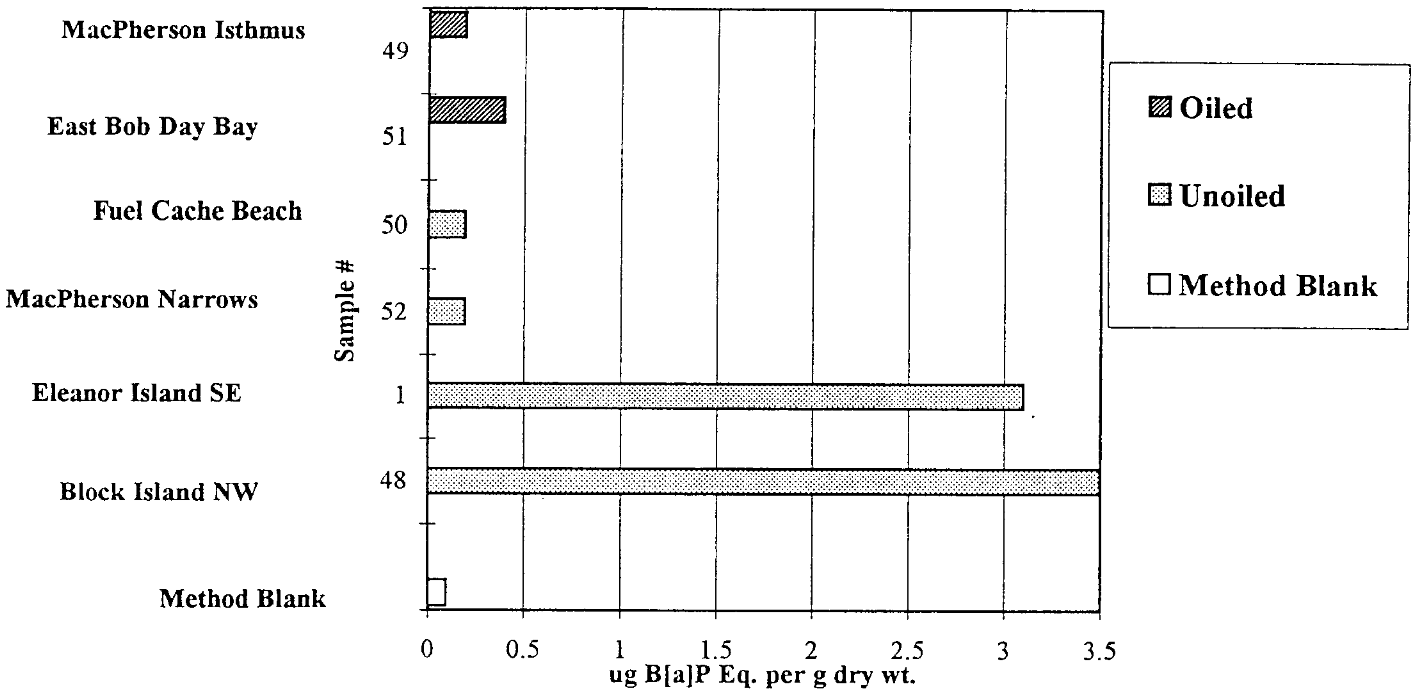
The RGS assay indicated that two sediment samples (Figure 2), collected at Eleanor Island SE and Block Island NW contained low but detectable amounts of PAHs (3.1 to 3.5 μg B(a)PEq/g). Chemical analyses by the Auke Bay scientists demonstrated that the content of high molecular weight PAH in these two sediment samples were 100 and 208 ng/g, respectively (see table). The other two sediment samples analyzed by NOAA (Fuel Cache Bay and MacPherson Narrows) showed no detectable levels of any PAH, which agrees with the baseline values reported for the P450 RGS assay. Using the Toxic Equivalency Factors (TEFs) for specific PAHs generated in our laboratory, the analytical data for the two samples were converted to estimated Toxic Equivalency values (in μg B(a)PEq/g). These values compare very favorably (correlation of 0.86) with the estimates of toxic equivalency produced earlier by the RGS assay.

CONCLUSIONS

While we feel that sand lance can be important indicators of sediment contamination, including that following an oil spill, it is apparent that by 1996 no residual contamination from the 1989 Exxon Valdez oil spill is present in their tissues. Very low levels of sediment contamination were identified in two samples by the P450 RGS assay, and this finding has now been confirmed by detailed chemical analyses.

The P450 Reporter Gene System has demonstrated the ability to determine which of many sediment samples should be further evaluated for petroleum contamination. In the case of RGS responses to tissue extracts, we do not know what substances induced the measured responses. The relatively low level of response observed does not warrant the type of research effort that would be required to evaluate the chemistry of these extracts.

Figure 2. P450 RGS-estimated B[a]P Equivalents in Sediments from Prince William Sound, Alaska



Analyses of Sediment Samples by the Auke Bay NOAA Lab and Comparison									
to P450 RGS Analyses of the Extracts									
				#47					
	5793-48	5793-50	5793-52	6369-1	Calculation of Chemical TEFs				
	BI NW	Fuel C B	MacP Nar	El I SE			5793-		#47
PAH Compounds	unoiled	unoiled	unoiled	unoiled	RGS TE	48	50	52	6369-1
Benzo[a]anthracene	13.0	0.0	0.0	0.0	0.4	5.2	0.0	0.0	0.0
Benzo[a]pyrene	0.0	0.0	0.0	0.0	1	0.0	0.0	0.0	0.0
Benzo[b]fluorathene	54.5	0.0	0.0	23.4	3	163.4	0.0	0.0	70.1
Benzo[g,h,i]perylene	24.2	0.0	0.0	16.1	0.02	0.5	0.0	0.0	0.3
Benzo[k]fluoranthene	0.0	0.0	0.0	0.0	25	0.0	0.0	0.0	0.0
Dibenzo[a,h]anthracene	10.7	0.0	0.0	0.0	4	42.7	0.0	0.0	0.0
Chrysene	94.0	0.0	0.0	61.1	0.4	37.6	0.0	0.0	24.4
Ideno[1,2,3-cd]pyrene	11.5	0.0	0.0	0.0	3	34.4	0.0	0.0	0.0
Total HMW PAHs (ng/mL)	207.7	0.0	0.0	100.5					
B[a]PEQ (ug/g)	**3.5**	**0.2**	**0.2**	**3.1**					
Chem TEQ (ug/mL)	0.3	0.0	0.0	0.1		283.7	0	0	94.9
Sample Dry Weight (g)	38.6	37.0	37.2	38.9					
Chem TEQ (ng/g)	7.3	0.0	0.0	2.4					
Correlation	0.86								

March 14, 1997

This worksheet contains the *aromatic hydrocarbon* data results from the analysis of Sandlance tissues in DMSO. These samples were sent to ABL from Jack Anderson of Columbia Analytical Services.

We have no sample weights so the data are reported in ng. These data have been *filtered* according to a tissue mdl and the data below detection limits have been edited.

id =	5793-9	5793-16	5793-17	5793-18	5793-19	5793-20	5793-23	5793-24	5793-28	5793-29	5793-36	5793-39	5793-45	AREF	BREF	MBLK	NISTARO	NISTARC
qcbatch =	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247	R02247
drywt =	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
wetwt =	1	1	1	1	1	1	1	1	1	1	1	1	1	10	10	1	1	1
matrix =	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANC	SANDLANCE					
submatrix =	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	DMSO	QCTISSUE	QCTISSUE	QCBLANK	QCCALI	QCCALI
Surrogate Recoveries (%)																		
NAPHTHALENE d-8	72.78	69.90	68.59	68.07	66.06	70.47	76.61	76.60	72.22	75.33	76.43	69.17	80.26	73.87	71.18	57.36	101.12	100.99
ACENAPHTHENE d-10	83.93	76.09	75.44	74.47	73.65	75.74	83.09	83.00	79.68	83.00	88.69	80.98	89.90	82.30	80.29	60.97	100.00	100.72
PHENANTHRENE d-10	102.78	91.76	90.85	90.75	87.41	89.41	84.94	87.84	96.00	98.37	106.28	95.05	107.14	86.71	96.36	39.25	98.34	98.27
ANTHRACENE d-10	102.83	103.87	99.72	100.03	98.24	99.62	102.29	106.19	108.25	107.32	108.65	96.76	111.38	85.45	106.19	85.29	96.63	99.33
BENZ-a-ANTHRACENE	96.71	93.71	86.03	87.83	80.51	82.42	93.29	102.49	104.76	104.66	108.91	87.80	111.04	86.23	108.59	74.48	89.31	95.79
CHRYSENE d-12	93.66	80.77	78.03	81.60	75.72	78.74	86.03	96.24	91.30	95.49	104.47	94.13	108.38	93.12	102.64	91.92	94.30	100.42
BENZO-a-PYRENE d-1	68.58	55.09	52.94	59.76	53.38	56.80	64.19	76.65	74.87	75.56	91.48	79.91	99.23	71.74	90.18	48.43	83.55	97.23
PERYLENE d-12	72.15	60.11	57.44	62.92	56.53	60.96	68.17	80.68	76.41	78.65	93.81	82.07	101.57	77.30	90.64	58.76	85.64	96.09
Analyte Concentrations (ng)																		
naphthalene	0.00	28.65	33.06	26.00	35.25	38.29	52.97	68.21	71.24	49.16	45.49	65.76	40.69	47.56	47.21	0.00	342.06	344.51
2-methylnaphthalene	0.00	0.00	32.97	20.37	24.16	27.47	50.31	77.78	69.28	48.22	41.46	58.97	49.89	49.08	48.91	0.00	380.59	388.94
1-methylnaphthalene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.49	33.26	0.00	0.00	0.00	0.00	51.41	51.26	0.00	396.42	402.08
2,6-dimethylnaphthalen	7.55	0.00	10.44	7.63	9.72	10.17	15.32	27.42	21.71	14.76	14.29	20.74	19.86	40.92	40.62	0.00	359.37	354.32
C-2 naphthalenes	23.77	14.97	28.33	21.72	33.60	30.45	48.38	83.40	67.10	47.30	40.83	68.89	62.60	41.46	41.43	0.00	362.76	356.11
2,3,5-trimethylnaphthale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.96	39.87	0.00	328.96	324.47
C-3 naphthalenes	0.00	0.00	0.00	0.00	8.01	0.00	16.70	29.59	27.33	19.57	23.75	33.50	38.40	40.81	39.68	0.00	326.96	325.80
C-4 naphthalenes	0.00	0.00	0.00	0.00	0.00	0.00	9.46	21.25	99.93	17.09	38.10	29.09	7.35	0.00	0.00	0.00	9.42	9.42
biphenyl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	351.95	351.04
acenaphthylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.74	39.24	0.00	345.46	348.68
acenaphthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.33	43.47	0.00	360.12	362.20
fluorene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.35	44.74	0.00	348.63	355.51
C-1 fluorenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.78	0.00	0.00	0.00	22.57	22.59
C-2 fluorenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.35	16.35
C-3 fluorenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.35	16.35
dibenzothiophene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	407.67	412.65
C-1 dibenzothiophenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-31.28	-31.28
C-2 dibenzothiophenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-31.28	-91.28
C-3 dibenzothiophenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-31.28	-31.28
phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.44	38.19	37.37	0.00	349.18	350.68
1-methylphenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.83	37.82	0.00	350.73	346.00
C-1 phenanthrenes/anth	0.00	0.00	0.00	22.94	31.51	27.23	0.00	28.94	41.98	32.87	28.06	22.16	39.32	38.83	38.10	0.00	353.27	348.20
C-2 phenanthrenes/anth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-3 phenanthrenes/anth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-4 phenanthrenes/anth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.80	41.02	0.00	385.89	390.36
fluoranthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.82	32.62	0.00	291.89	290.14
pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.42	32.16	0.00	290.77	286.73
C-1 fluoranthenes/pyren	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benz-a-anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.68	19.02	0.00	171.58	171.31
chrysene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.92	37.23	0.00	349.71	345.16
C-1 chrysenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-2 chrysenes	0.00	0.00	0.00	0.00	0.00	0.00	13.07	16.80	0.00	0.00	0.00	14.16	0.00	0.00	0.00	0.00	0.00	0.00
C-3 chrysenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-4 chrysenes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
benzo-b-fluoranthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	278.44	257.07
benzo-k-fluoranthene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.10	30.51	0.00	277.15	267.80
benzo-e-pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.57	32.59	0.00	307.07	279.98
benzo-a-pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.58	37.17	0.00	342.65	335.16
perylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.61	38.60	0.00	356.75	360.24
indeno-123-cd-pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.41	27.67	0.00	272.59	298.12
dibenzo-a,h-anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	22.40	0.00	209.12	238.51
benzo-g,h,i-perylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	243.86	251.22