Exxon Valdez Oil Spill
Restoration Project Annual Report

Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

Restoration Project 95025
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.

Leslie Holland-Bartels
NVP Project Leaders[1]

National Biological Service
1011 East Tudor Road
Anchorage, Alaska 99503

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[1] **Principal Investigators:** Brenda Ballachey[1], James Bodkin[1], Terry Bowyer[2], Tom Dean[3], Larry Duffy[4], Dan Esler[1], Stephen Jewett[2], Lyman McDonald[5], Chuck O'Clair[6], Alan Rebar[7], Dan Roby[8], Paul Snyder[7], Glenn VanBlaricom[9]

[1] Alaska Science Center, National Biological Service, 1011 East Tudor Road Anchorage, AK 99503
[2] Institute of Arctic Biology, University of Alaska, Fairbanks, AK 99775
[3] Coastal Resources Associates, Inc., 1185 Park Center Dr., Suite A, Vista, CA 92083
[4] Department of Chemistry and Biochemistry, Box 756160, University of Alaska, Fairbanks, AK 99775
[5] Western Ecosystems Technology, Inc., 2003 Central Ave., Cheyenne, WY 82001
[6] National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801
[7] Dept. of Veterinary Pathobiology, Purdue Univ., 1243 Veterinary Pathology Bldg., West Lafayette, IN 47907
NBS, Oregon Cooperative Fish and Wildlife Research Unit, 104 Nash Hall, OSU, Corvallis, OR 97331-3803
BS, Washington Cooperative Fish & Wildlife Research Unit, WH-10, U. of Washington, Seattle, WA 98195

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Study History: This project began with the acceptance of the 5-year study plan by the Trustee Council in March 1995. FY 95 funds were provided to develop sampling protocols, test methodologies and to initiate those portions of the overall study that could begin in late summer. The FY 95 effort underwent program review by the Chief Scientist and Trustee reviewers February 27-28, 1996.

Abstract: The project, Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators (NVP), was approved in March 1995 and a pilot field season was initiated during the summer to develop statistically valid sampling protocols for invertebrates and fish prey items and describe subtidal study area habitats through sidescan sonar technologies so that final protocols could be developed for the full field seasons (1996-1998). In addition to these preliminary efforts, field seasons were initiated for sea otter and harlequin duck components. The NVP study areas are: 1) oiled - northern Knight and Naked Islands, and 2) unoiled - northwestern Montague Island and Jackpot Bay. A full aerial survey of western PWS to estimate sea otter abundance was completed, mortality surveys were conducted to estimate age class distribution of sea otters dying as compared to pre- (1976-84; 1989) and post- (1989-94) spill age distributions, 6 adult sea otters were captured to obtain blood for preliminary investigations of immune response, and surveys were completed to estimate reproductive output of sea otters in the two study areas. On the basis of these preliminary data, 1) continued lower population densities exist in the oiled study area and 2) a relatively high proportion of prime aged animals occurred in the annual mortality in the western sound. Over 200 harlequin ducks from Montague Island and 160 from Knight Island were captured. Body condition of all birds was determined and total body electrical conductivity (TOBEC) was measured on 267 individuals to develop a noninvasive condition index. Finally, eighty-nine of these birds (all adult females) were implanted with radio transmitters and monitored to determine comparative survival between oiled versus non-oiled populations. Differences exist between areas in patterns of body weight variation through molt, winter survival of females, and blood chemistry. In addition to the biological data collection, a detailed data management program and data archives were established and a review of interactions of sea otters and their ecosystems (VanBlaricom et al. 1995) was completed.

Key Words: *Cepphus columa*, *Enhydra lutris*, *Exxon Valdez*, harlequin duck, health, *Histrionicus histrionicus*, *Lutra canadensis*, nearshore ecosystem, pigeon guillemot, population status, river otter, sea otter, trophic

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INTRODUCTION

Background.-- The nearshore marine ecosystem of Prince William Sound (PWS) plays a critical role in the commercial, subsistence, and recreation economy of southcentral Alaska. Because of shorelines and coastal physiography, the nearshore ecosystem served as a repository for much of the oil spilled by the T/V *Exxon Valdez* (EVOS). As a result, many of the injured resources under study by the EVOS Trustee Council are components of the nearshore system. Thus, the Nearshore Vertebrate Predator (NVP) study describes a research approach for assessing the biological and ecological significance of trophic issues and contaminants present in the environment. We focus on the status of system recovery and a suite of injured apex predators as indicators of environmental stress--the invertebrate feeding sea otter and harlequin duck, and fish feeding pigeon guillemot and river otter. NVP takes a multispecies, integrated approach to assess several potential key mechanisms constraining recovery of the nearshore system. For our test species, EVOSTC (1994) suggested that three mechanisms have potential for impacting the nearshore system and constraining recovery:

1) *Recruitment processes are limiting recovery of nearshore resources injured by EVOS;*

2) *Initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on the recovery of benthic foraging predators; and*

3) *EVOS induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators.*

Based on that consensus, the NVP study examines status of recovery of the four selected nearshore vertebrate predators. We measure population density, as well as demographic factors (e.g., size and age distributions, birth rates, survival rates) at both oiled and unoiled sites to examine possible reasons for lack of recovery, and to assess progress toward recovery given demographic restraints. Simply stated, we will ask "are vertebrate populations recovering, and if so, are they recovering as quickly as possible given potential rates of population increase?"

In contrast with these "recovery monitoring" studies, we will address two working hypotheses with respect to possible constraints to the recovery process:

1) *Initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on recovery of benthic foraging predators; and*

2) *Prey availability and competition for prey is constraining recovery of sea otters, river otters, pigeon guillemots, and harlequin ducks.*

In simpler terms, "is it oil?", or "is it food?". These questions will be addressed through evaluation of demographic measures, health assessments, biomarkers of oil exposure, and availability of prey for the four nearshore vertebrate predators.

Overall Approach.-- Our overall intent in this study is to examine the status of recovery of nearshore vertebrate predators believed to still be damaged from EVOS (Table 1). Three factors most likely to be limiting recovery are intrinsic demographic constraints, continued hydrocarbon exposure, and food limitation (Figure 1). Successful assessment of recovery has been limited to date by the diversity and trophic interdependence of the numerous injured resources within the nearshore system and lack of accurate and precise pre-spill population demographic data upon which to judge the progress of restoration. The NVP approach is to assess each of the constraining parameters across a suite of species (with tools and techniques best suited for each species) to create a matrix (Table 2) that allows us to assess ecosystem health despite the above limitations and any specific tool limitations within a given species.

Demography: The rate of recovery of nearshore vertebrate predators may be constrained by oil-related factors (continued toxicity of oil and food availability) as well as non-oil related processes. The latter include death and birth processes as affected by factors such as intrinsic reproductive capacity and mortality due to adverse weather conditions. It may be, for example, that death and birth rates do not differ among injured and non-injured subpopulations of nearshore vertebrate predators, but that the rate of population increase is too slow to have allowed for complete recovery of the injured nearshore vertebrate predator populations.

In NVP, abundance of nearshore vertebrate predators is being measured at oiled and unoiled areas to compare population status. To assess whether recovery is proceeding as quickly as possible, considering no oil related limits to population growth rates, we determine whether population growth rates and demographic parameters are consistent with models predicting growth rates in the absence of oil or food limitation effects. As an example, poor survival of pigeon guillemot chicks at oiled sites, coupled with a lack of preferred food items being brought to the nest at these sites, and a limited supply of these food items in oiled foraging areas would lend strong support to the hypothesis that food is limiting to pigeon guillemot recovery.

Continued Hydrocarbon Exposure: Studies initiated following EVOS (Table 1) suggest continued biochemical effects (Rebar et al. 1996; Ballachey, unpubl. data, Duffy et al. 1994b, Jewett et al. 1994) potentially related to oil toxicity. These initial observations support the hypothesis that continued exposure to crude oil may be affecting animal health through chronic or recurrent infections resulting from diminished immune responses.

Health of predator populations and the related issue of continued oil exposure are assessed in NVP using a variety of measurements. These allow for an assessment of the status of recovery of injured populations that is independent of measures of recovery based on population abundance or demographic data. This independent assessment of recovery may also provide a view of potential for recovery and long term population health that can not be evaluated by abundance or demographic characteristics. Measurements to be collected

Table 1. Injury and evidence for lack of recovery from the *Exxon Valdez* Oil Spill, 1989 in four top nearshore vertebrate species as evidenced through demographic, bioindicator, and trophic evidence.

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/Recovery Strategy
Pigeon Guillemots	**DEMOGRAPHIC** •1,500-3,000 killed by EVOS in 1989. •Populations in PWS have declined from c.15,000 in the 1970s to c.3,000-5,000 in 1993 based on boat surveys. Declines have been greater in oiled vs non-oiled areas of PWS (Klosiewski and Lang, unpubl. data; Sanger and Cody 1993). •Number of breeding pairs on Naked Island (largest guillemot breeding aggregation in PWS) have declined c.50% since the late 1970s and give no evidence of recovery (D.L. Hayes, USFWS, pers. comm.). **BIOINDICATOR** •Average growth rates of chicks have declined since the spill (Oakley and Kuletz 1993) and remained lower at Naked Island (oiled) versus Jackpot Island (non-oiled) during the 1994 breeding season (D.L. Hayes, USFWS, unpubl. data). **TROPHIC** •No direct evidence collected. However, nearshore demersal fish, primary prey of this species, demonstrate a high incidence of hemosiderosis in oiled eelgrass beds of Herring Bay (Jewett et al. 1994). This suggests continued exposure to hydrocarbons. Nearshore demersal fish comprised ~half the diet of chicks on Naked Island. •Sandlance, a schooling fish that burrows in nearshore sandy sediments, formerly comprised c. a third of the diet of chicks on Naked Island. Since the spill, the proportion in the diet has declined.	•Stable or continuing decline. •Conduct research to find out why recovering; likely causes climatic /oceanographic, prey limitations and predation. •Recovery judged by stable or increasing populations.
River Otters	**DEMOGRAPHIC** •Although some were killed, there was no catastrophic mortality--river otters continued to live in areas that were heavily oiled through 1990 (Testa et al. 1994). •Initially modified their use of habitat by avoiding heavily oiled shorelines (Bowyer et al. 1995). Selected habitat differently on oiled versus non-oiled areas by concentrating their activities on steeper tidal slopes and using areas with greater exposure to wave action (Bowyer et al. 1994), where oil was less likely to persist (Wolfe et al. 1994). •In 1990, home ranges in oiled areas were 2x those in non-oiled areas, suggesting a loss of habitat on oiled sites (Bowyer et al. 1995). •Continued exposure has adverse health effects; lower body mass. Lower body mass often related to lower reproductive output in large mammals (Docktor et al. 1987). •Throughout broad areas of PWS, latrine sites (an index of population density) were abandoned at a rate of three times greater on oiled versus non-oiled areas (Duffy et al. 1994a). **BIOINDICATOR** •Continued exposure has adverse health effects; higher haptoglobin (an acute-phase protein indicator of damage) than otters in non-oiled (Duffy et al. 1993). **TROPHIC** •Diets in oiled vs non-oiled areas were similar through 1990, but differed markedly by summer 1991 (Bowyer et al. 1994). A number of taxa were absent from the diet in oiled areas. •Nearshore demersal fish, primary prey of this species, demonstrate a high incidence of hemosiderosis in oiled eelgrass beds of Herring Bay (Jewett et al. 1994). This suggests continued exposure to hydrocarbons.	•Unknown status. •Rely on natural recovery, indications of recovery are when habitat use, food habitats and physiological indices return to prespill conditions.

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/Recovery Strategy
Sea Otters	**DEMOGRAPHIC** •Up to 4,000 acute mortalities. •Various surveys suggest abundance of sea otters has not recovered to pre-spill numbers. •Significant differences in juvenile survival between oiled & unoiled areas in 90/91 and 92/93. •Proportions of prime aged animals among dead returning to pre-spill levels (Ballachey et al. 1994). **BIOINDICATOR** •Hematological and serum chemistries suggest otters in oiled areas had higher incidence of inflammatory and/or infectious conditions.	•Stable, not recovered. •Conduct research to find out why not recovering; hypotheses include continued hydrocarbon ingestion; spill-caused changes in benthic prey.
	TROPHIC •Primary foods include mussels, clams, and urchins, as well as other subtidal organisms. Sea otters feed in the lower intertidal and subtidal areas, areas that were especially contaminated by oil spilled from the *Exxon Valdez* (Wolfe et al. 1994) and may still be exposed to hydrocarbons through their feeding (EVOSTC 1994a). •In areas where recovery has not occurred, increases in sea urchin densities (a preferred prey) have been observed (Jewett pers. comm.).	•Recovery judged when population abundance & distribution are comparable to prespill, & when all ages appear healthy.
Harlequin Ducks	**DEMOGRAPHIC** •1,000 acute mortalities in Harlequins. •875 acute mortalities in other species. •Summer populations of harlequin ducks, which may be year-round residents, were lower than expected in the oiled area of Prince William Sound between 1989 and 1991 (Klosiewski and Laing 1994). **BIOINDICATOR** •Patten (1994) found hydrocarbon metabolites in sea ducks collected in oiled areas and also suggested that reproductive effort and productivity of harlequin ducks were lower in oiled areas. **PREDATOR/PREY** •Although harlequin ducks rely on benthic invertebrates that may continue to transport hydrocarbons through their food chain, no specific assessment evidence of the potential for trophic-related constraints to recovery exists.	•Unknown status. •Conduct research to find out why not recovering; hypothesis related to oil-contaminated prey. •Recovery judged for harlequins when no difference between spill and non-spill areas.

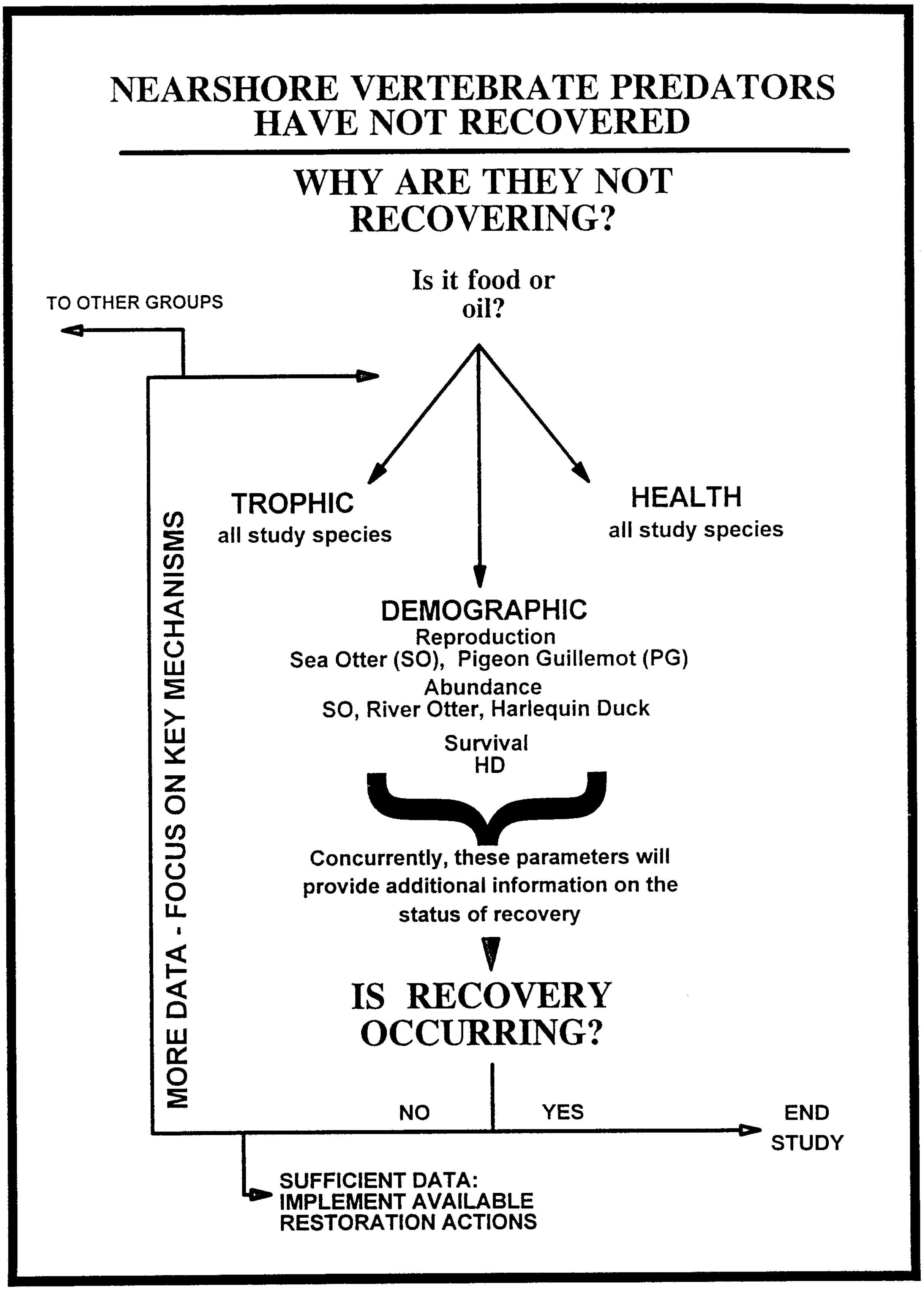


Figure 1 . Graphic depicting general approach taken in the NVP project

Table 2. Summary of overall efforts to be undertaken in the 1995-1998 field seasons of the NVP project, listed by species and approach. Those activities initiated in the 1995 partial field season are marked in bold.

Approach	Sea Otters	Harlequin Ducks	Pigeon Guillemots	River Otters
Demography	• **Aerial Surveys** • Surveys of Annual Repro-duction Rates • Carcass Recovery to Evaluate Mortality Patterns	• Habitat use and Abundance in Oiled and Unoiled Areas • **Overwinter Survival of Females**	• Chick Growth Rates • Repr. Success • Adult Attentive-ness to Chicks • Meal Delivery Rates & Meal Size	• Latrine Site Abandonment as Abundance Index
Health & Oil Exposure	• **Blood & Immune Function Assays** • P450 Assays • Morphometrics & Condition	• **Blood Assays** • **P450 Assays** • **Body Composition**	• Blood Assays • P450 Assays	• Blood, Immune Function Assays • P450 Assays • Morphometrics
Trophic Interactions	• **Abundance, Distribution, Size Class Structure -- Clams, Mussels, Sea Urchins, Crabs** • Prey Selection & Foraging Success • **Factors Affecting Prey Abundance: Variation in Recruitment & Growth of Invertebrate Prey; Compe-ting Predators**	• Abundance & Size Class Distribution of Primary Invertebrate Prey	• **Abundance of Prey Fishes**	• **Abundance of Prey (Demersal Fishes)**

include assays of immune function, hematology and serum chemistry, cytochrome P450 levels (an enzyme indicative of continuing exposure to aromatic hydrocarbons), hydrocarbons, body condition and morphometrics.

Food Availability: There is strong evidence that population densities of many nearshore vertebrate predators including sea ducks, sea otters, and pigeon guillemots are limited by food (Garshelis 1983, Kenyon 1969, Kruuk et al. 1991, Stott and Olsen 1973). In addition, population densities of at least some important vertebrate prey species declined as a result of the EVOS (Highsmith et al. 1993, 1995, Jewett et al. 1994). The possibility of food limitation of vertebrate predators, coupled with the evidence for injury from the EVOS to prey species, suggests that recovery of some vertebrate populations may be food limited.

The hypothesis that food availability may be limiting recovery of nearshore vertebrate predators is addressed primarily by examining abundance of major prey items in oiled and unoiled areas. Evaluation of abundance and size distribution data for prey items also will be useful for providing additional indirect evidence for a lack of recovery of some predator species. However, evidence of lack of recovery of predators based on differences in abundance and/or size of prey may be confounded by several factors, including presence of copredators. To account for these factors, it will be important to assess the relative impact of various predators on prey items, and to assess both recruitment and growth of the prey at the oiled and unoiled sites. Figure 2 presents the general strategy applied to this issue.

One of the major challenges in this aspect of the project will be to define the amount of food available to the predators throughout the study area. As described in the methods below, we have employed sidescan sonar to better define subtidal habitats. This information, coupled with Geographic Information System (GIS) technologies and the estimates of abundance by habitat type described above will lead to a calculated abundance of food in the various study areas (Figure 3). These data can then be used within modelling efforts that will assess predator food needs, food availability, and confounding factors of copredators.

FY 95 Approach.-- Funding was approved in March and received in June 1995. As such, the approach developed for 1995 was to not attempt a full field season but to:

1) initiate trophic assessments by conducting preliminary sampling for invertebrate prey to assess the power of our proposed sampling protocols,

2) better define subtidal habitats through the use of bathymetric models and sidescan sonar to allow stratification of invertebrate collections by habitat and reduce variance in estimates,

3) begin those demographic efforts (Table 2, bold items) that could be initiated in late FY 95, including a) sea otter population, reproduction, and mortality surveys and b) harlequin duck survival,

4) collect samples for health assessments (condition measures in harlequin ducks, blood samples in sea otters and harlequins) and hydrocarbon exposure (P450, harlequins),

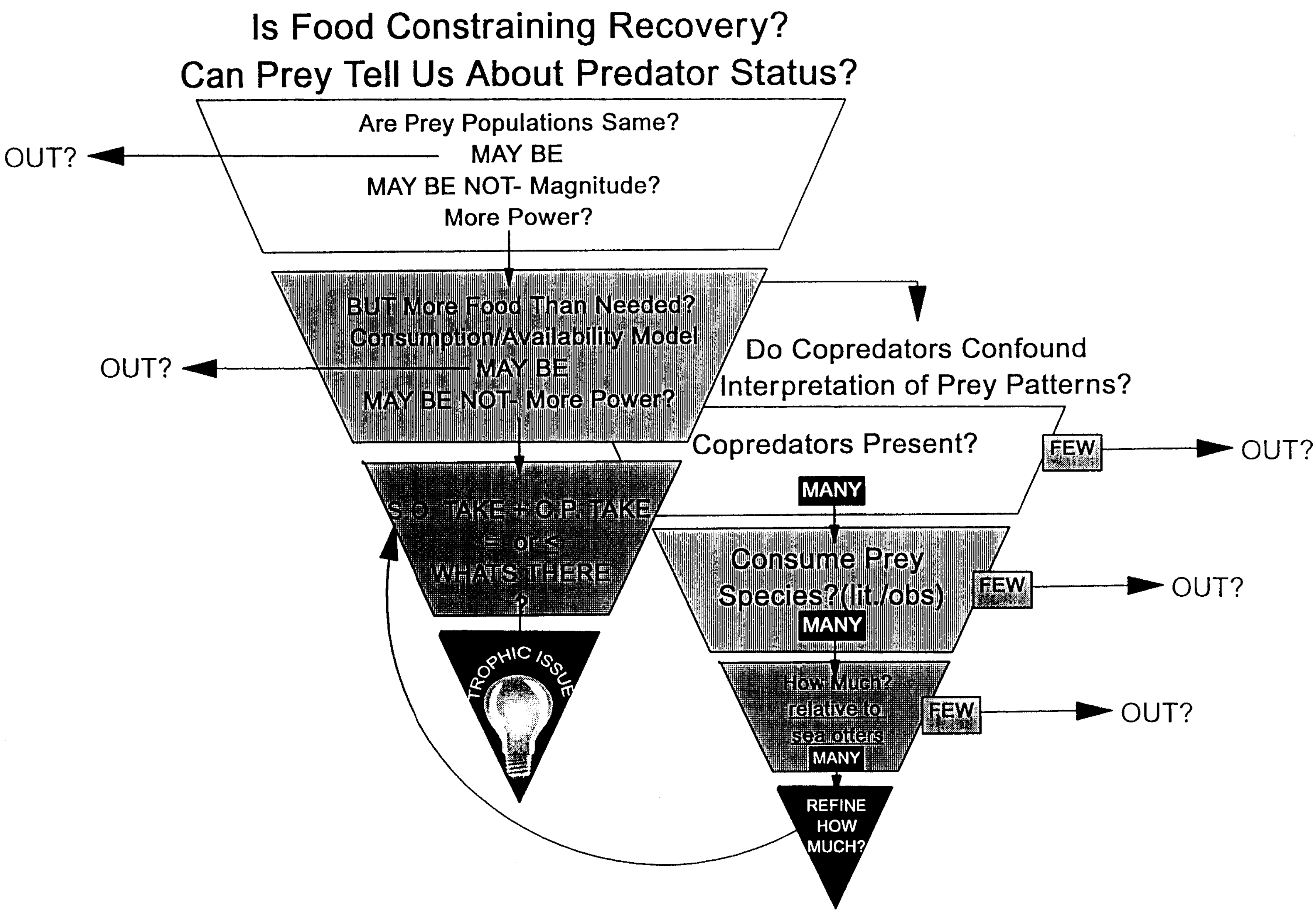


Figure 2. Step-down approach used in NVP project to assess the hypothesis that prey structure can tell us about top predator status of recovery and the approach to determine if trophic issues are constraining recovery of top vertebrate predators. Initial focus is on sea otter populations.

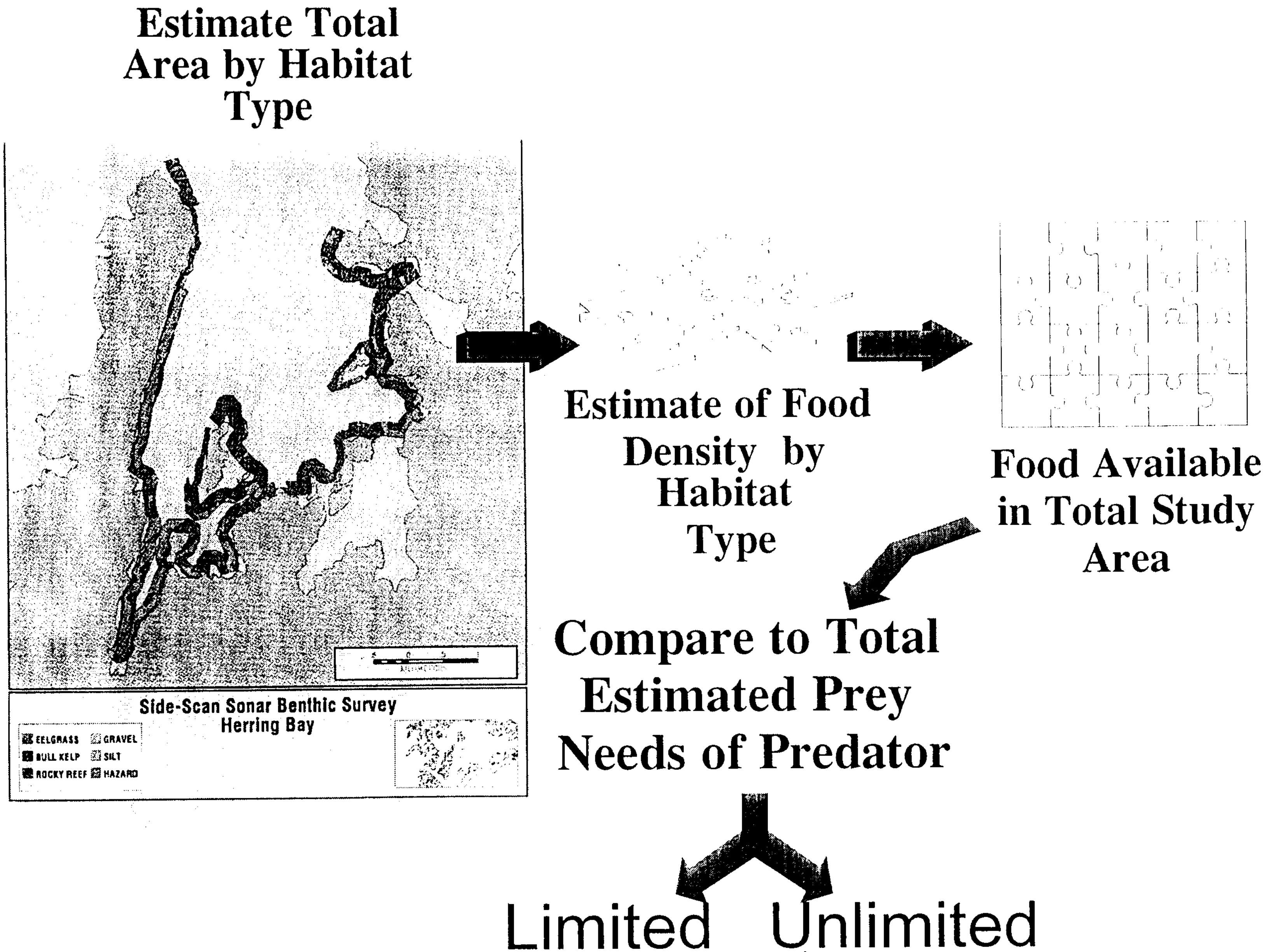


Figure 3. One process to be used to assess if trophic factors are constraining recovery of predators, based on sidescan sonar definition of habitat, GIS generated estimates of area of each habitat, and prey density estimates by habitat type.

5) develop a detailed data management and quality assurance plan that included statistically reviewed standard operating procedures for each component effort of NVP, and

6) establish electronic file serving capabilities to allow project scientists located nationwide to easily communicate and share data.

GENERAL PROJECT OBJECTIVES

Objective 1.-- Determine status of recovery of injured populations of nearshore vertebrate predators by determining if there are differences between oiled and unoiled areas in:

a. Abundance or indices to abundance. (1995: begun for sea otter [so].)

b. Demographic characteristics. (1995: so and harlequin ducks [hd].)

c. Measures of health. (1995: preliminary collections for so and hd.)

d. Abundance or size distribution of prey. (1995: sampling strategies and power analyses.)

Objective 2.-- Determine if recovery of nearshore vertebrate predators is constrained by demographic factors unrelated to oil toxicity or food supply. (1995: efforts as described above.)

Objective 3.-- Determine if recovery of nearshore vertebrate predators is constrained by continued oil toxicity by determining if there are differences between oiled and unoiled areas in:

a. Bioindicators of exposure to oil in predator species. (1995: sampling for P450 begun in hd.)

b. Bioindicators of exposure to oil in prey species.

c. Hydrocarbon levels in prey species.

Objective 4.-- Determine if recovery of nearshore vertebrate predators is constrained by food availability. (1995: sampling design efforts for prey begun.)

We will address all major objectives for each of the 4 predators selected for study.

STUDY AREA

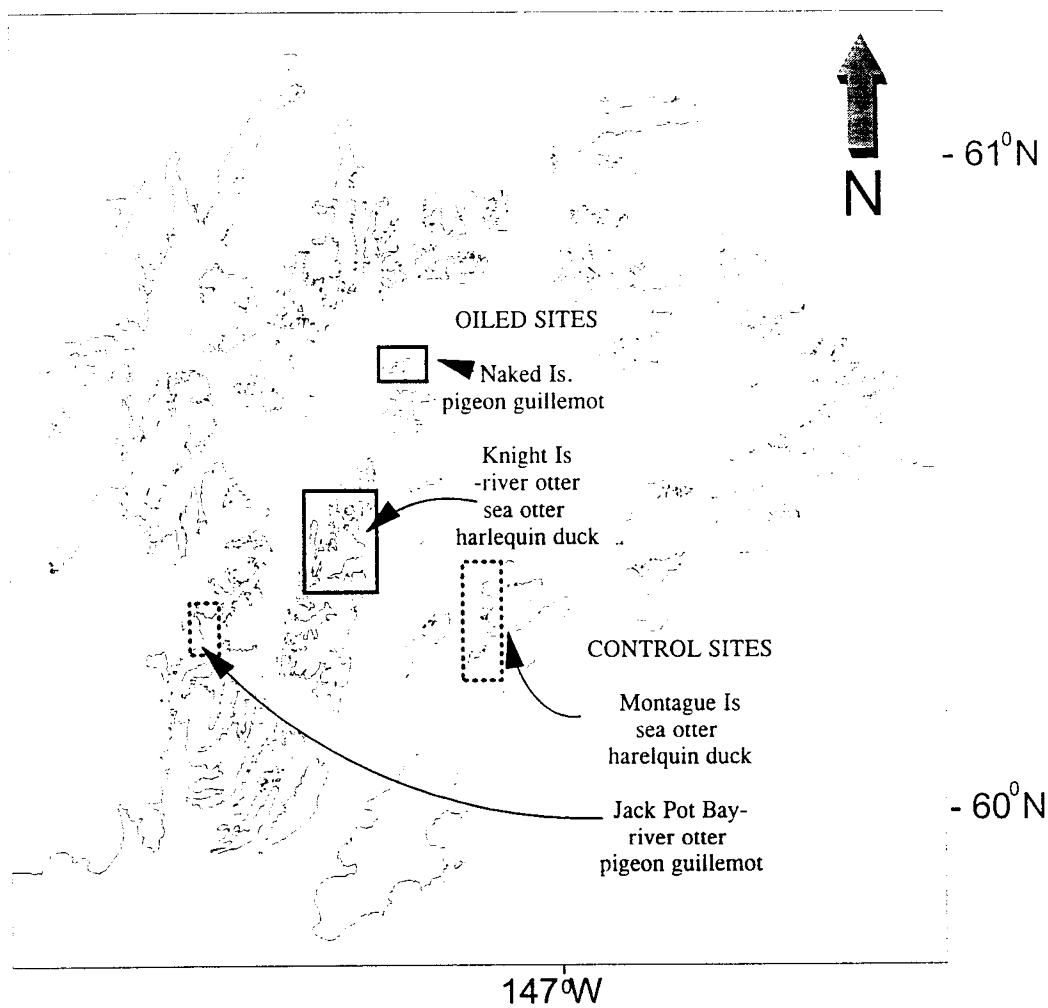
Study areas are within generalized "oiled" and "unoiled" zones (Figure 4). The oiled area is identified as the Naked Island-Northern Knight Island group. Oiling was heaviest here, and population levels of sea otters are much lower here than in other areas of PWS that were not oiled. Harlequin duck densities are lower in this area. The unoiled areas area along the northwestern shore of Montague Island (for sea otters and harlequin ducks) and around Jackpot Island (for river otters and pigeon guillemots). The unoiled areas are on the periphery of oiled areas. More specific study sites will be selected from within each generalized area. For sea otters and harlequin ducks, we focus on two, non-contiguous sites: one in Herring Bay (25 km) and the other in Bay of Isles (25 km) on Knight Island as our oiled area. Our unoiled site is the 50 km northwest shoreline of Montague Island (Figure 4). For pigeon guillemots, selected study locations include approximately 10 km of shoreline which are feeding grounds for the birds. These are within a 4 km radius of two known areas of nesting for pigeon guillemots: one is an oiled area on Naked Island, and the other is an unoiled site near Jackpot Island (Figure 4). For river otters, the selected oiled study location is Herring Bay and unoiled site a 25 km section of shoreline near Jackpot Bay. These both represent reasonable river otter habitat areas with old growth forest to the water's edge. Herring Bay was selected because there are historical data for otters (Bowyer et al. 1994, Testa et al. 1994).

METHODS

Overall NVP methods for FY 1995-1998 field seasons are outlined in detail in Holland-Bartels et al. (1995). Specific activities undertaken in FY 1995 are highlighted in Table 2. In 1995 we developed methods to better define habitat through substrate and bathymetry models, began collection of samples for oil exposure and health determinations for sea otters and harlequin ducks, initiated sampling for prey (both invertebrate and fish), and initiatied demographic assessments for harlequin ducks and sea otters.

Habitat Determination.-- ***Bathymetry Model:*** An existing digital bathymetric model, published in 1990 by the Alaska Department of Natural Resources (DNR), was produced for broad-scale representation of the greater PWS ecosystem. As a result, the only relevant data in this model for near-shore studies is the coastline and a 'generalized' 10-meter bathymetric isocline. In 1995, a pilot study was initiated to investigate the feasibility of developing improved bathymetric models of the NVP study areas. The project's underlying objective is to create the best bathymetric characterization of the NVP study areas, from existing data, to serve as a quantitative basis for extrapolating sub-tidal invertebrate prey abundances that have been sampled within depth strata. Digital bathymetric survey data for the Jackpot Bay and Montague Island study areas were purchased from the National Ocean Service. The data were standardized to common units of measure, reformatted and converted to ARC/INFO GIS databases. Based on the dispersion and depth of the input sample points, and the assumption that the coastline represented zero depth, analytical software was used to generate a continuous interpolated bathymetric surface model for each of the two study areas. Depth readings (n=550) collected along the 1995 sidescan sonar transects were used to assess the

Figure 4. Location of "oiled" and "control" study sites for NVP



preliminary bathymetric models.

Substrate Model: Distribution of habitat types within intertidal regions was determined using a pre-existing Environmental Sensitivity Index GIS database that lists geomorphological habitat types for shorelines throughout PWS (Gundlach et al. 1983). Shoreline types in this database were verified by a visual census of all shorelines within our study areas conducted from a small boat. Shoreline type verification was carried out in conjunction with sidescan sonar surveys of subtidal habitats, described below.

There are no existing data on subtidal habitats, and it is impossible to determine subtidal habitat type from shoreline habitat data. Therefore, we censused all subtidal habitats within our study areas using sidescan sonar to define substrate types. The sidescan sonar system consists of a graphic recorder, digital processor and towed sonar fish. The sonar fish has two sets of linearly focused transducers - one set on each side of the towed fish. Circuitry inside the towed fish energizes the transducers, causing them to project high intensity, high frequency bursts of acoustic energy at 100 kHz in fan-shaped beams, narrow in the horizontal plane and wide in the vertical plane. These sound beams (sonar signals) project along the sea bed on both sides of the moving vessel. Objects, topographic features, and substrate changes on the sea bed reflect the signal back to the towed fish where it is received by the transducers, amplified, and sent up the tow cable to the graphic recorder on the ship.

The digital graphic recorder produces a continuous permanent graphic record of the sea floor by electronically processing and then printing the information (line by line) to produce the sonar image, as well as data from the water column. Signal synchronization is achieved by the recorder generating a trigger pulse and sending it to the towed fish and then waiting for the reflected signals.

Printing is accomplished by a high speed thermal printer in which each individual dot is digitally interpreted in order to produce 16 distinct gray shades on 43.2 cm (17.0") wide graphic recorder paper.

A 100 meter range scale was selected for the described mapping system, using 100 kHz transducers. This combination provides the best compromise between resolution and mapping efficiency. Accurate positioning of the survey vessel was provided using a differential Global Positioning System (GPS) interfaced with a navigation computer. The navigation computer provided a permanent record of the ranges, line and shot number updating, real time, and other related features.

A single boat track was run along the shore, with the boat positioned along the 4-10 m depth contour. The depth range covered by the sonar record depended in part on the slope of the seabed at each location, but generally extend from depths of 12 m to the intertidal zone (0 m).

Demographic.-- ***Sea Otter:*** Mortality Surveys: Mortality patterns, based on age distributions of the dying portion of the population, have been evaluated through recovery of beach-cast sea otter carcasses in western PWS. Beaches in the Green Island area of western

PWS, surveyed for carcasses in 1976-84 by Johnson (1987), and again in 1990-94 (Monson and Ballachey 1996), were surveyed in April, 1995. Data recorded for each carcass included: (1) relative location of carcass on the beach, (2) relative condition and completeness of carcass, (3) position of remains relative to previous year's vegetation, (4) relative age (adult, subadult, pup), (5) sex, and (6) specimens collected (e.g., entire carcass, skull, baculum, none). Skulls (when present) were taken from all carcasses and a tooth extracted for aging (Garshelis 1984). Subsequent to final age analyses, otters were classed as: 1) juvenile: ages 0 and 1; 2) prime: ages 2-8; and 3) older: ages 9 and above. The distribution of age classes were compared with other post-spill collections (1990-94) and pre-spill collections (1976-84), using Fisher's Exact Test (2-tailed).

Aerial Surveys: The aerial sea otter survey methodology consists of two components: (1) strip transect counts and (2) intensive search units. Sea otter habitat was sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. Survey effort was allocated proportional to expected sea otter abundance by adjusting the systematic spacing of transects within each stratum. Transects with a 400 meter strip width on one side of a fixed-wing aircraft were surveyed by a single observer at an airspeed of 65 mph (29 m/sec) and altitude of 300 feet (91 m). The observer searched forward as far as conditions allow and out 400 m, indicated by marks on the aircraft struts, and recorded otter group size and location on a transect map. A group was defined as one or more otters spaced less than three otter lengths apart. Intensive search units (ISU's) were used to estimate the proportion of sea otters not detected on strip transect counts. ISU's were flown at intervals dependant on sampling intensity throughout the survey period, and were initiated by the sighting of a group, then followed by five concentric circles flown within the 400 m strip perpendicular to the group which initiated the ISU.

Reproduction Surveys: Estimates of annual reproduction, as indicated by ratios of independent to dependent sea otters, were obtained from small boat surveys in August, 1995. Sample units correspond to coastline transects established by Irons et al. (1988) and extended offshore out to the 100 m depth contour or 1/2 the distance to the opposing shoreline, whichever is less. A subset of sample units were randomly selected to be surveyed in each of the study sites. The survey vessel maneuvered about 200 to 300 m offshore, and out to the offshore boundary as necessary to observe all otters within each selected sample unit. Two observers used high resolution binoculars to classify otters as either dependent or independent. Crews then recorded the number of dependent and independent sea otters found in each sample unit. Proportions of dependent sea otters were calculated for each transect area and compared.

Harlequin Ducks: Capture: Several project objectives require capture of harlequin ducks. Harlequin ducks, like nearly all Anatids, molt their wing feathers (primaries and secondaries) simultaneously, rendering them flightless. During the molt, harlequin ducks congregate and are susceptible to capture by herding flocks of flightless birds into pens. We used this method to capture harlequin ducks for this study. Capture methods followed those used successfully by researchers in British Columbia and Washington (Clarkson and Goudie 1994). Sea kayaks were used to slowly herd molting flocks towards a trap. The trap consisted of two 100' wings which lead birds into a holding pen in shallow water.

We captured harlequin ducks from 20 August through 16 September 1995. Chronology of harlequin duck molt differs among age and sex cohorts, with males molting earlier than females. We scheduled field work to maximize capture of adult females, which molt from late August through late September.

Captured harlequin ducks were removed from the trap, separated by gender, placed in holding pens, and transported by boat to the main vessel for processing. Birds were banded with USFWS aluminum bands and, for birds captured in oiled areas, with individually coded plastic tarsus bands (orange with white letters), as part of a cooperative effort with the Alaska Department of Fish and Game (ADFG). Sex was identified based on plumage characteristics and age was determined by bursal probing. Adults do not have a bursa; SY birds were distinguished from third year subadults by the depth of the bursa (SY bursa >2 cm; TY bursa <1 cm). All birds were weighed and culmen, diagonal tarsus, and wing length (flattened, straightened, to longest primary) were measured.

We captured ducks on the Montague Island (unoiled) and Knight Island (oiled) study areas. Although harlequin numbers were adequate on Montague Island for this study, densities were very low on the Knight Island sites. Herring Bay held almost no molting harlequins and none were captured. In Bay of Isles, we captured 26 harlequins, including 5 adult females. However, those 26 were the only molters in the entire bay. Following NVP adaptive protocol, we expanded the capture effort beyond the boundaries of the distinct study areas, using information from surveys by Dan Rosenberg, ADFG, to identify possible trap locations. Successful trapping in other oiled areas occurred at Foul Bay, Crafton Island, and Green Island.

Adult Female Survival: Winter survival rates of adult female harlequin ducks were assessed using radio telemetry. We surgically implanted radio transmitters in 97 adult females. Of those, 8 either (1) died within a 2-week census period designed to eliminate handling effects, or (2) their radio failed, resulting in an initial sample size of 89 (40 on the unoiled site and 49 on oiled sites).

We used implantable radio transmitters with external antennas. Battery life was expected to be ≥ 210 days. Transmitters weighed approximately 15 g, which is $\leq 3\%$ of the body weight of the smallest molting female harlequin duck. Transmitters were equipped with temperature sensitive mortality switches; the pulse rate changes from 45 to 90 beats per minute when the transmitter temperature drops below 85 degrees F. Reception distance (ground to air) exceeded 20 km.

Implanted transmitters have been successfully used in waterfowl studies (e.g., Olsen et al. 1992, Haramis et al. 1993) and are less disruptive than backpack transmitters (Pietz et al. 1993, Rotella et al. 1993), especially for diving ducks (Korschegen et al. 1984). Surgeries were conducted by certified veterinarians experienced in avian implant surgeries, following protocol.

We conducted radio telemetry flights at approximately weekly intervals through winter until the end of March. On each flight, status and general location of each radioed bird was sought. For dead birds, we determined more exact locations for subsequent carcass recovery.

We used a Kaplan-Meier staggered entry design to estimate survival probability. These data are still being collected and are updated continuously as flights occur and data are entered and analyzed.

River Otter: No FY 95 field activity was proposed or conducted.

Pigeon Guillemot: No FY 95 field activity was proposed or conducted.

Health.-- ***General Methods for Determining Health and Exposure to Oil:*** We examine a common suite of biomarkers (Table 3) for each of the nearshore vertebrate predator species to determine the health and oil exposure of oiled and unoiled populations. Health is evaluated through hematology and immune function assays as well as morphometrics (weights, lengths, etc.) and in 1995 for harlequin ducks, body composition measurements. Oil exposure is evaluated by measurements of cytochrome P450-1A's, enzymes that are specific indicators of exposure to aromatic hydrocarbons. P450 assays will be done for the four predator species and on vertebrate prey (selected fish species). Additional tests of oil exposure include ELISA assay of pelage or plumage swabs.

In subsequent years, if warranted based on outcome of P450 assays, analysis of hydrocarbon levels in tissue samples may be initiated.

Immune Function Assays: In 1995, 30 ml of blood was collected from each of six adult sea otters, as per our methods outlined in Holland-Bartels (1995). Samples were processed using a technique modified from Truax et al. (1993). Peripheral mononuclear cells were cryopreserved and shipped to Purdue University for analysis.

Cytochrome P450 Assays: We will use two approaches to evaluate cytochrome P450 levels during the course of our study: *1) Immunohistochemistry* and *2) Quantitative RT-PCR*. In 1995, sampling for immunochemistry was initiated. Foot web biopsies from captured harlequin ducks were preserved in 10% neutral buffered formalin immediately after collection and shipped to Wood's Hole Oceanographic Institute for analysis.

Assays of External Oil: Personnel at the California Department of Fish and Game have recently adapted an ELISA assay to detect oil contamination of pelage under field conditions (J. Mazet, CDF&G, pers. comm). Controlled tests of the procedure show sensitivities in the range of less than or equal to 0.7 parts per million. We sampled the plumage of captured harlequin ducks and samples are frozen pending processing in 1996.

Body Composition: In 1995, sampling was initiated for body composition of molting harlequin ducks to assess population health in oiled and unoiled sites in PWS. Body composition of harlequin ducks will be estimated using nondestructive condition indices that incorporate body mass, morphometrics, and measures of total body electrical conductivity (TOBEC; Walsberg 1988, Roby 1991). Although the TOBEC technique is nondestructive, it

Table 3. List of assays, measurements for evaluation of health and oil exposure.

Assay or Biomarker	Laboratory or Location	Sea Otters n=60	Harlequin Ducks n=100	Pigeon Guillemots n=75 nestlings n=25 adults	River Otters n=30	Demersal Fishes n=40
Blood - CBC, WBC	CCL[a]/AVEX[a] /Purdue	X	X	X	X	
Serum Chemistry	CCL/AVEX /Purdue	X	X	X	X	
Interleukin-6	UAF	X	X	X	X	
Haptoglobin	UAF	X	X	X	X	
Immunoglobulin Quantitations	Purdue	X	X			
Serum Electrophoresis	Purdue/UAF	X	X		X	
Lymphocyte Transformation Assay	Purdue	X			X	
Cytochrome P450 Immunohistochemistry	Wood's Hole	X	X	X	X	X
Cytochrome P450 Quantitative PCR	Purdue	X			X	
External oil (ELIZA)	In field/UAF/NBS	X	X	X - Adults	X	
Morphometrics (weights, lengths)	In field	X	X	X	X	
Body Composition	UAF/NBS		X			

[a] CCL, AVEX are commercial diagnostic laboratories.

must be calibrated by sacrificing a sample of subjects of each species for proximate analysis of body composition. TOBEC readings were taken following procedures outlined in the operators manual. We measured TOBEC for 267 birds, including all adult females and nearly all subadult females. Birds were restrained with a velcro strap to ensure a standard position for all individuals during analysis. Six TOBEC readings were taken for each bird.

Derivation of models of body condition will occur after we collect a reference sample of molting females from Kodiak in 1996 and conduct laboratory analyses of carcass composition (as per Esler and Grand 1994).

Although measures of body composition are not yet available, we assessed body weight variation during molt to determine if patterns existed that might indicate effects of oiling treatment on body condition. We regressed body weight by length of the longest primary for adults and subadults of each sex. However, body weight is only a crude predictor of body condition; more refined analyses in the future are necessary.

Trophic Assessments.-- In 1995, we began efforts to determine abundance and size structure of key prey of our top predators.

Sea Otter: Intertidal Clams: Reconnaissance surveys were conducted in July and August 1995 for the purpose of locating potential clam beaches (mixed sand/gravel) and determining the dominant clam species, abundance, and size structure of a representative beach. These surveys were conducted during cruises for subtidal sampling and sidescan sonar. In general, 0.25 m^2 samples were randomly collected from beaches along a 30 m transect at the 0.0 m tidal height. The 30 m transect was randomly placed at the 0.0 m tidal height on the beach. We removed sediment from each sample to a depth of 30 cm and hand-sorted to remove larger bivalves. This sediment depth was needed to obtain the deep-dwelling butter clams. Sediment was then washed through a series of screens (down to 1.5 x 1.5 mm mesh) to obtain smaller clams. The sediment retained by the finest screen was returned to the laboratory and examined for small specimens.

Subtidal clams: Taxa assessed included *Saxidomus giganteus*, *Protothaca staminea*, *Tresus capax*, *Clinocardium* spp., *Mya* spp., *Macoma* spp., and *Serripes groenlandicus*. Based on results of the sidescan sonar habitat survey, we selected the two most prominent unconsolidated substratum types as sample strata. Within each stratum in each study area (i.e., Montague Island and Knight Island) we sampled at two depths, 6 and 12 m, in five replicate sites chosen from within each of the defined strata. Site selection was random, but arbitrary adjustments were made to ensure that site environmental attributes (e.g., exposure, current velocity) were comparable among the two study areas. A complete sample set consisted of 2 study areas x 2 strata x 5 sites x 2 depths = 40 samples.

Individual samples were gathered by SCUBA divers. A temporary 50 m transect line was placed at a pre-determined sample site. Individual sample frames (0.25 m^2 surface area) were placed at random locations along the line and at random distances (5 m maximum) from the line. For obvious clams within each frame, calibrated rods were placed in siphon holes to determine depth of individual clams below the sediment surface. Each sample included a small sediment core taken prior to suction for subsequent determination of grain size distribution and organic carbon content. We cleared each frame by venturi dredge to a depth of at least 50 cm and adjusted as necessary, based on preliminary sampling and rod probing, to ensure collection of all large clams within the frame. Output was filtered through a bag with mesh of approximately 0.5 cm, brought to the surface, live clams sorted by species, and measured (maximum shell length, to nearest mm). Data were analyzed by species to determine mean and variance of density and size per site.

We determined the rate and pattern of recruitment to natural substrata in study sites as indicated above by using small diver-deployed coring devices to sample for newly-settled clams. Cores of about 0.01 - 0.02 m^2 surface area, and located in the same way as sampling frames for suction samples, were sampled to depths of 10-20 cm. Cores were capped with fine mesh screening and inserted gently, by hand, to minimize loss of organisms due to surface disturbance. Once in place, cores were contained and extracted, carried to a surface vessel, washed through a 0.5 mm screen, and retained materials stained and preserved for laboratory sorting. In the laboratory, samples were sorted for juvenile clams and specimens identified.

<u>Sea Urchins</u>: Preliminary sampling was conducted in 1995 to establish the appropriate sampling protocol. Also, we examined data collected between 1990 and 1995 by Jewett et al. (1995) to determine possible differences in sea urchin densities between habitats, and possible temporal trends. Also, in summer 1995, we conducted qualitative assessments of sea urchin abundance over larger areas within Herring Bay, Bay of Isles, Montague Island, and Jackpot Bay regions. The goal of the sampling was to determine the presence or absence of large aggregations of sea urchins. Quantitative sampling was then conducted within several aggregations that were observed in Bay of Isles. Each habitat type was divided into 200 m segments. The size and average density of urchins was determined for any aggregations noted.

<u>Mussels</u>: Mussel abundance was estimated using a stratified random sampling protocol with proportional allocation. Each length of coast was initially divided into five strata based on shoreline type: 1) exposed rocky, 2) sheltered rocky, 3) gravel, 4) sheltered tidal flats, and 5) mixed sand and gravel. Four shoreline segments were sampled in each stratum. A 30 m transect was laid parallel to shore at the median tidal level of mussel distribution at randomly selected mussel beds in each randomly selected segment. Mussel densities were estimated using 500 cm^2 quadrats randomly along each transect. The contents of each quadrat were collected and subsequently washed over a 0.5 mm sieve.

In a subset from each randomly selected mussel bed, mussels were collected and the maximum shell length of each mussel measured to the nearest 0.1 mm. Mussels were dried at 60°C and weighed at 24 h intervals to the nearest 0.001 g on a precision balance. Subsequently, mussel tissue will be digested in 10% potassium hydroxide and the remaining shell dried to a constant weight. Tissue dry weight will be obtained by subtracting shell dry weight from mussel dry weight.

<u>Copredators:</u> *Invertebrate:* Sea otter, sea ducks, and various invertebrates may

overlap broadly in their diets, especially with respect to bivalves. To assess predation pressure of these potential copredators on populations of selected bivalves (mussels and sub- and inter-tidal clams) and possible confounding effects on interpretation of sea otter effects, models including diet and copredator numbers will be derived to estimate numbers, biomass, and size classes of invertebrate prey consumed. In concert with data documenting invertebrate prey abundance and size class and sea otter diets, we can determine the extent of structuring by this predation and its potential confusion with sea otter structuring.

We determined densities and diets of predatory invertebrates with a focus on sea stars (*Pycnopodia helianthoides* and *Evasterias troschelii*), crabs (*Telmessus cheiragonus* and *Cancer* spp.), and snails (*Nucella* spp.). Within each area, this project used the same study sites at the same depths as indicated for the subtidal clam assessments. Sampled transects were placed in adjacent non-overlapping positions to ensure that sampling effort for one project will not be disruptive to the other. In addition, data were gathered from intertidal soft-substratum sites in the vicinity of subtidal sites. Thus a complete subtidal sample consisted of 2 study areas x 2 subtidal strata x 2 depths x 5 sites = 40 samples. A complete intertidal sample consisted consist of 2 study areas x 5 sites = 10 samples.

Subtidal invertebrate predator data were collected during SCUBA dives with a temporary 50-m transect line divided into 10 m segments placed on the bottom. Within each segment, a random point on the line was chosen. A 10-m line extended perpendicularly from the random point in one of two randomly chosen directions. Invertebrate predator species within 1 m of either side of the 10-m line were counted, measured, and examined for dietary information. Thus each 50-m transect provided five separate random subsamples of 20 m^2 each. Sea stars and snails were located by simple visual survey. Sea star size was indexed by measuring the distance from the center of the mouth to the tip of the longest ray, crab size by measuring the maximum carapace width, snail size by measuring the maximum shell dimension. Diet was determined by direct examination during dives for sea stars and snails. *Pycnopodia helianthoides* swallows prey whole, requiring manual probing of the stomach to extract and identify prey. *Evasterias troschelii* and snails process prey externally, thus prey items can be easily removed from the mouth area. Prey items were either identified and measured (maximum shell dimension) during sampling dives, or returned to the surface for later examination. All crabs located in samples were transported to the surface and later dissected to remove stomach contents. Intertidal density data were gathered for sea stars and crabs by counting all predatory invertebrates within 1 m on either side of a 50-m line placed parallel to shore at the tidal datum. Snails were counted by searching 0.25 m^2 frames placed along the 50-m line.

Harlequin Duck: Prey: Harlequin duck prey were collected from three sites, an exposed rocky habitat at Montague Island, a sheltered rocky habitat in Bay of Isles, and an eelgrass bed at Montague. At each site, samples were collected from three 1 m^2 quadrats at each of two depths (0 to 3, and 3 to 6 m). We collected all eelgrass or algae from each plot and counted all mollusks attached to the eelgrass or algae. We also sampled all epibenthos from each quadrat using either airlift (for rocky habitats) or suction dredge (for eelgrass). The common harlequin duck prey were counted and (for only the Montague - rocky sample) the animals were weighed and a dry weight determined. The dry weight data were combined with those collected in the higher intertidal zone by Highsmith et al. (1993) to examine the vertical distribution of harlequin duck prey.

Pigeon Guillemot: Prey: Preliminary sampling and reconnaissance surveys were conducted in summer 1995 to evaluate the proposed sampling methods for benthic and schooling fish. Specific concerns were the feasibility of using diver observations to estimate the abundance of schooling fishes (especially sandlance), and the possible influence of movements of fish during a tidal cycle on abundance estimates. We suspected that benthic fishes may be moving up and down the shoreline with the tide. As a result, sampling within different depth strata may provide biased estimates of abundance within a depth stratum, depending on the tidal level at the time of sampling.

In addition, we examined previously collected data on the relative abundance of fish in the nearshore subtidal habitat, and the relative abundance of fish in the diets of river otters and pigeon guillemot chicks. Data on river otter prey were obtained from previously published data (Bowyer et al. 1994). Data on pigeon guillemot chick diets were unpublished data of D. Roby and L. Hayes. For river otters, fish taxa were ranked by abundance and the relative rankings in river otter diets were compared to ranking in benthic surveys. For pigeon guillemots, we were able to estimate the relative proportions of fish species in the diets of nestlings, and in benthic samples.

Dive reconnaissance surveys were conducted in Sleepy Bay and Jackpot Bay in what were considered possible habitats in which sandlance might bury. In Sleepy Bay, surveys were conducted over a stretch of coastline where divers had observed sandlance emerging from the substrate in previous years. Divers swam transects within this area at approximately four hour intervals from dawn to dusk in an attempt to quantify sandlance abundance. In addition, divers also conducted surveys over approximately 4 to 6 km of coastline in Jackpot Bay in search of sandlance that might be buried in sediments.

The influence of tidal state on the distribution and abundance of fishes was examined by sampling along several permanently marked transects at both high and low tidal levels. The sampling was conducted at four locations within Bay of Isles. All locations were along moderately sloping shorelines with similar cobble/boulder substrata in the intertidal. At each site we established four transects. Each was 50 m long and ran parallel to shore along a given depth contour. The transects were set at +1.5 m, -0.5 m, -3.5 m, and -7.5 m (all relative to MLLW). The +1.5 transects were located in the high intertidal dominated by *Fucus* and *Cladophora*. The -0.5 m transects were in either *Laminaria saccharina* or eelgrass, depending on the site. The lower transects were generally dominated by *Agarum* and *L. saccharina*. We counted benthic fish along a 1 m wide swath on each transect. The sites were sampled once at low water (early morning on July 13, and again the following day during high water (on the afternoon of the 14th). The tidal levels at the times of sampling ranged from approximately -1m to -0.1 m on the 13th and +1 to +1.5 m on the 14th. Fish were counted while sorting through the benthic algae.

RESULTS

General.-- As stated above, in FY 1995 we focused on efforts to better define habitat through development of substrate and bathymetry models, initiation of demographic and health assessments for the invertebrate-feeding vertebrate predators, sea otter and harlequin duck, as well as refinement of prey sampling protocols and assessments of statistical power to identify improvements for the full field seasons of FY 1996-1998 (Table 2 bold portions).

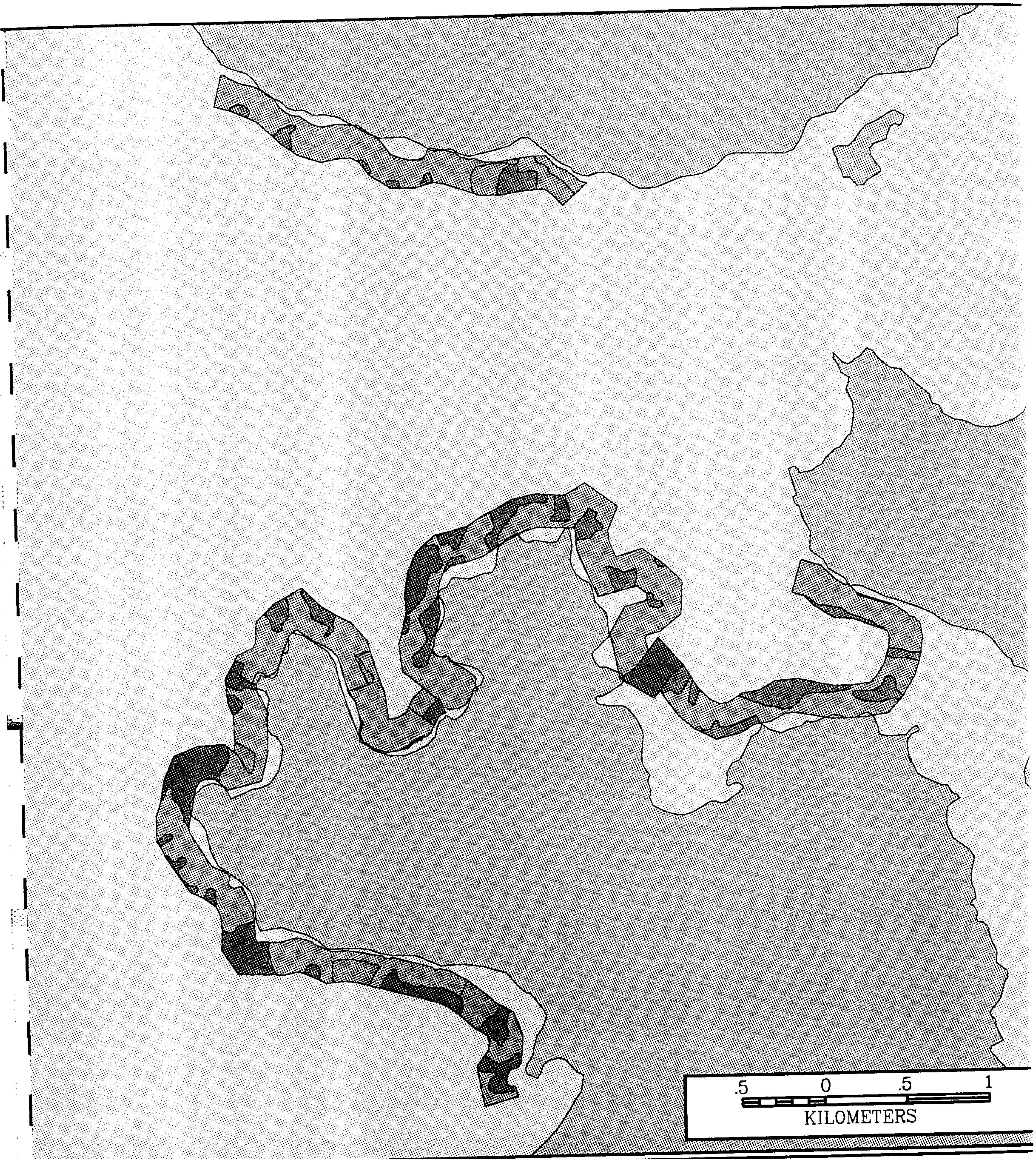
Habitat Determination.-- ***Bathymetry Model:*** While agreement between the two bathymetry models tested (sidescan sonar generated and National Ocean Service data) was generally good, there were segments along the sidescan sonar transects where deviations were relatively exaggerated. Closer examination of these segments suggested that the majority of discrepancy was probably introduced by the fact that the bathymetric model was based largely on interpolation between input data points, which were often separated by more than 100 meters horizontally. In reality, the ocean floor does not likely adhere to such a 'smooth' character, such that when the sidescan sonar transect traversed a relatively large region of interpolated bathymetry, discrepancies with the validation data would not be unexpected. However, comparisons between these bathymetric models and the existing DNR 10-meter model clearly showed improvement in both precision and resolution. Consequently, bathymetric data for the other three study areas have been ordered from the National Ocean Service. These data are only available in 'map' format and will require digitizing before the models can be developed. Final bathymetric models for all study areas are targeted for publication in late 1996.

Substrate Model: The Watson Company (Anchorage, AK) was retained to define seafloor substrate types in the five NVP study locations of PWS by the use of geophysical methods described above. Substrate types were delineated as classified by the Wentworth Grain Size Scale utilizing sand/gravel as a category and with the addition of eelgrass as a category. Substrate types have been intepreted, mapped (examples: Figures 5-9), and a final report and electronic and hardcopy versions of the habitat classifications provided. These products are available for review through the NVP Chief Scientist's office.

Demographic.-- ***Sea Otter:*** <u>Mortality Surveys</u>: Between 11 and 16 April 1995 we surveyed on foot approximately 65 km of shoreline in southwestern PWS to recover beachcast remains of sea otters that died during the previous winter, and estimate age at death based on cementum deposits in teeth or examination of the skeletal remains. Green, Little Green and Channel Islands, as well as the barrier islands northwest of Green were surveyed in their entirety, and a 9 km section of Stockdale harbor, centered at Wilby Island, was surveyed.

Twelve sea otter carcasses were located; teeth for aging were recovered from 10 of these carcasses, and age of one otter was estimated subjectively, based on examination of the carcass. Teeth were submitted to a contracting laboratory for estimation of age based on cementum; results listed in Table 4. Five animals (45%) were considered prime, 4 (35%) were juvenile, and 2 (18%) of the 11 were aged. Although the sample size is small, the

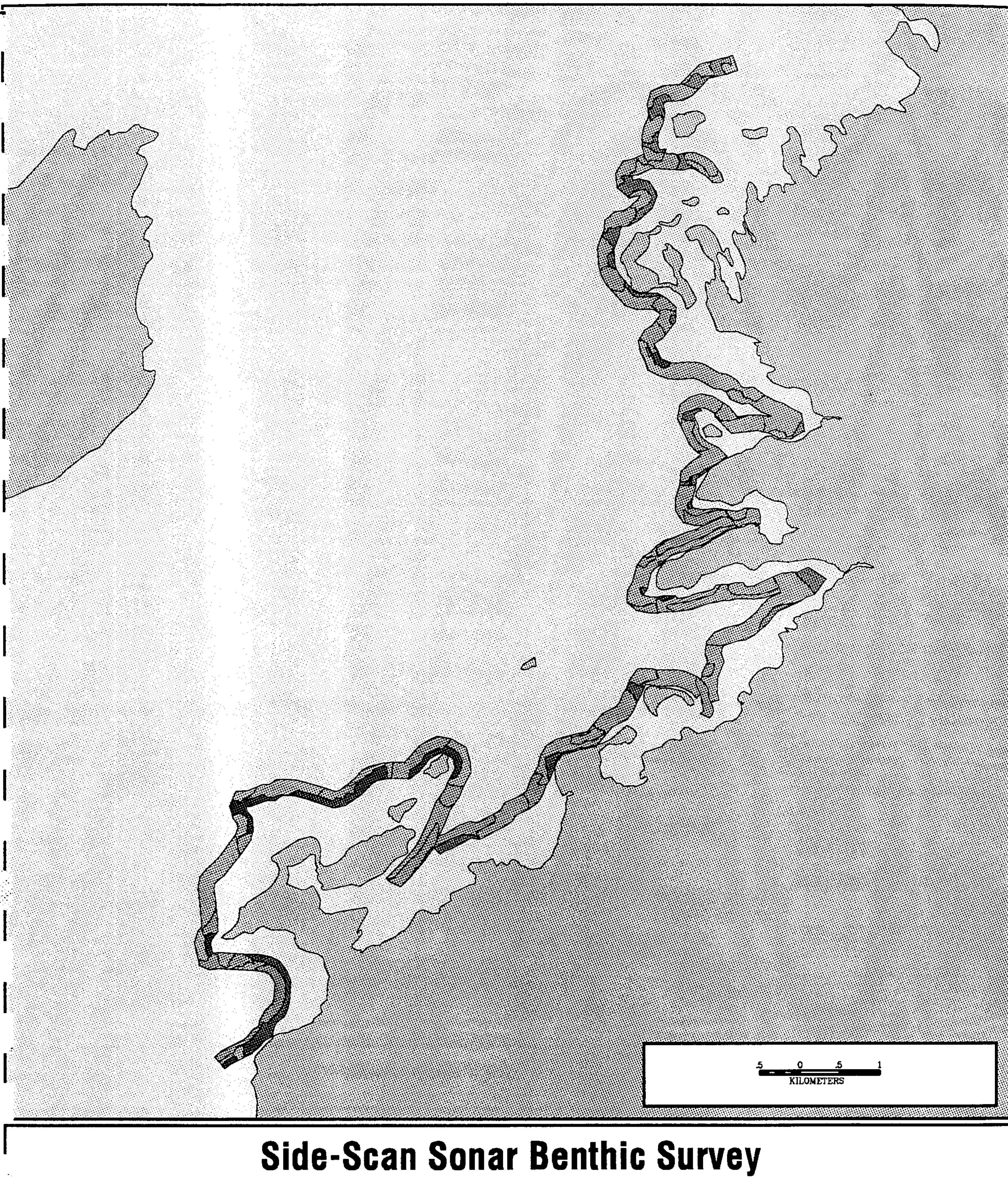
Figure 5. Sidescan sonar benthic survey, Naked Island.



Side-Scan Sonar Benthic Survey
Naked Island

- EELGRASS
- BULL KELP
- ROCKY REEF
- GRAVEL
- SILT
- HAZARD

Figure 6. Sidescan sonar benthic survey, Montague.



Side-Scan Sonar Benthic Survey
Montague

EELGRASS
BULL KELP
ROCKY REEF
GRAVEL
SILT
HAZARD

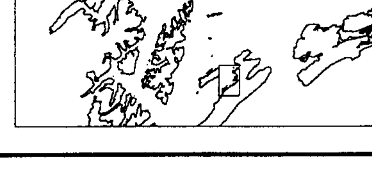
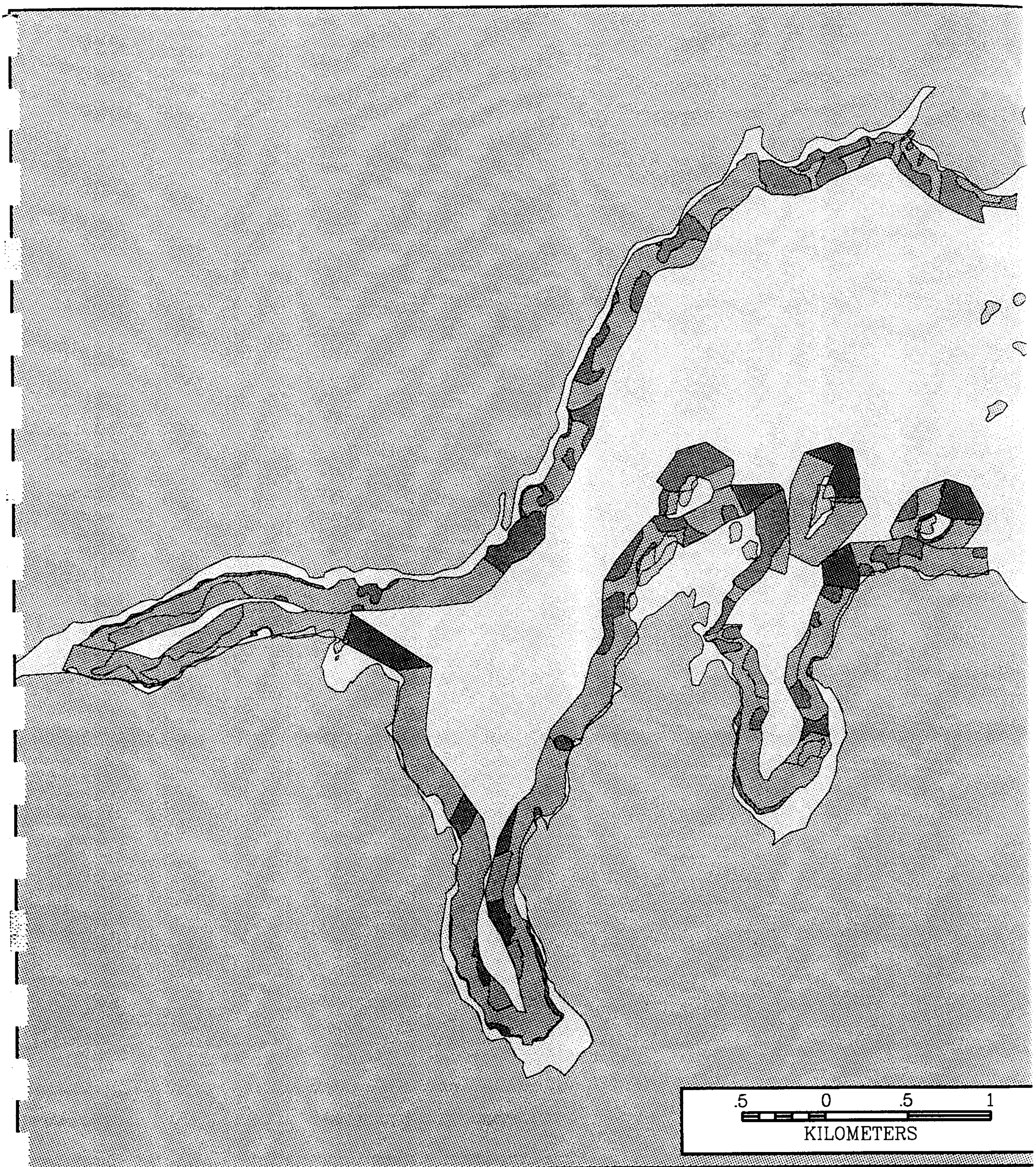


Figure 7. Sidescan sonar benthic survey, Bay of Isles.



Side-Scan Sonar Benthic Survey
Bay of Isles

- EELGRASS
- BULL KELP
- ROCKY REEF
- GRAVEL
- SILT
- HAZARD

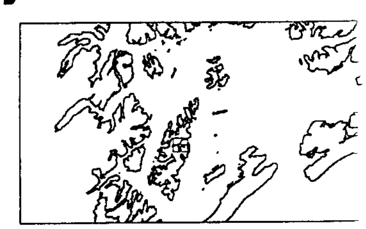
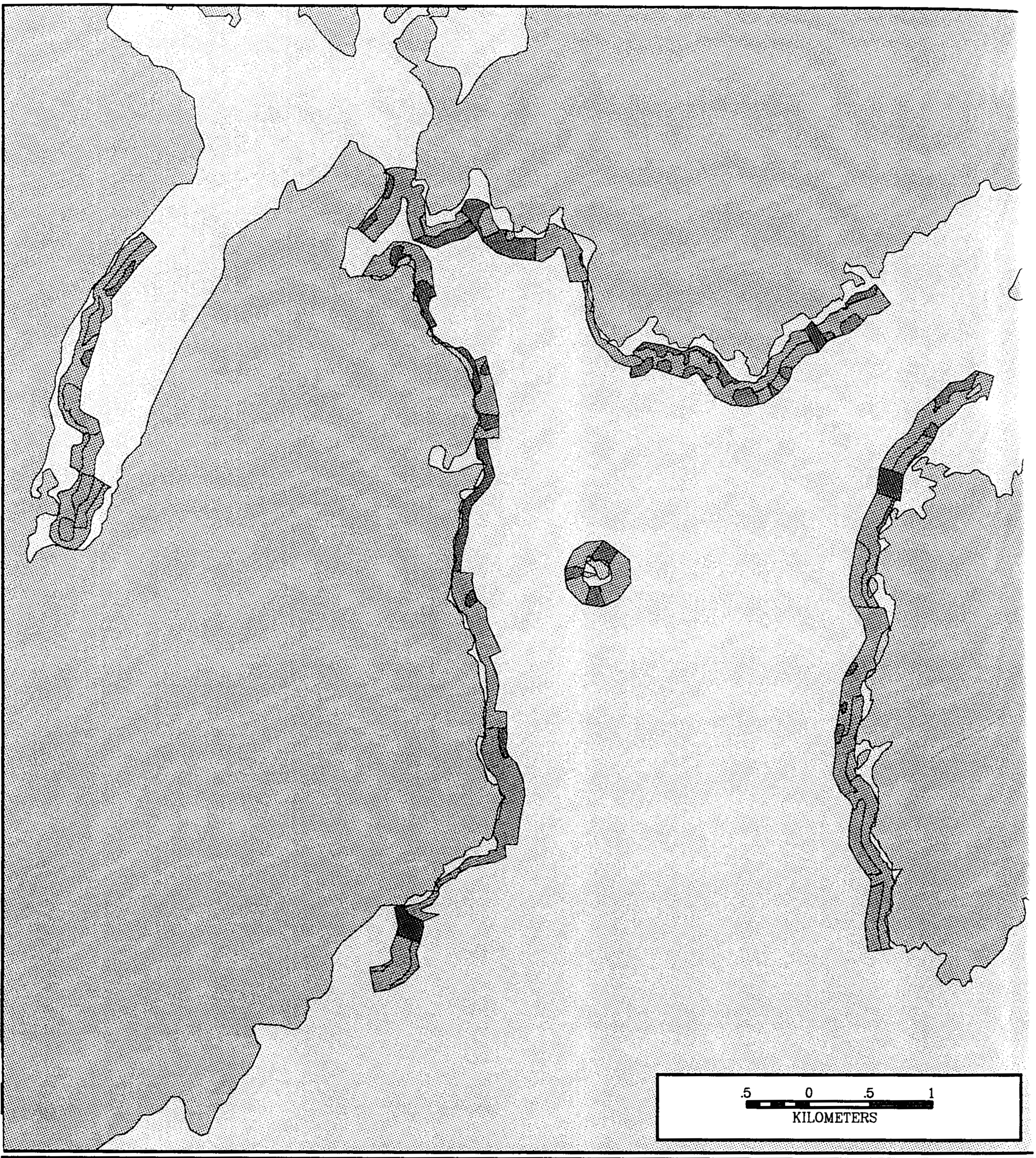


Figure 8. Sidescan sonar benthic survey, Jackpot Bay.



Side-Scan Sonar Benthic Survey
Jackpot Bay

- EELGRASS
- GRAVEL
- BULL KELP
- SILT
- ROCKY REEF
- HAZARD

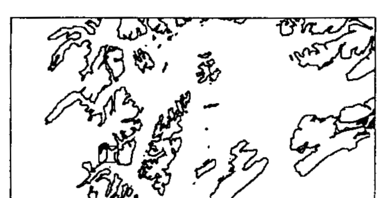
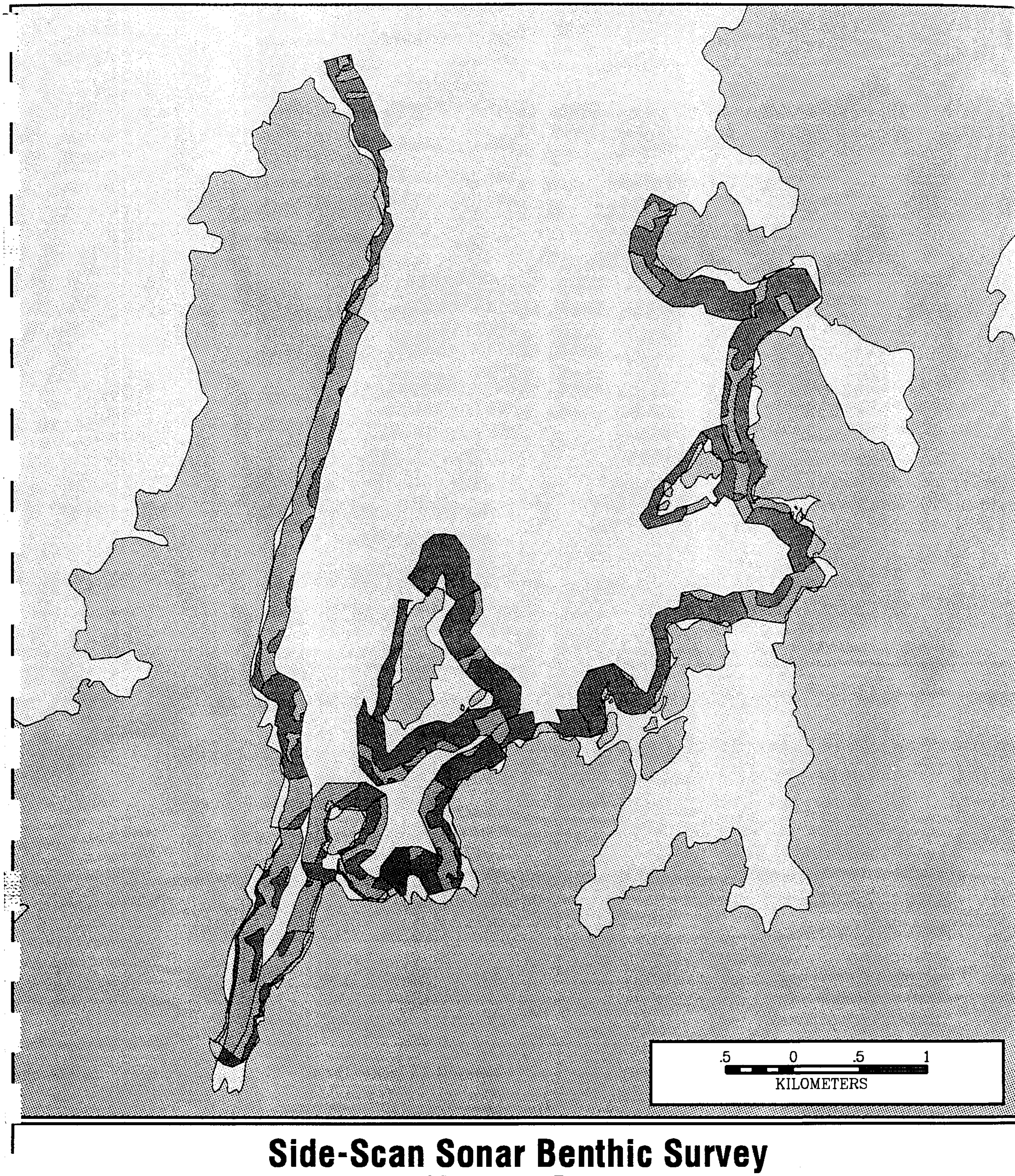


Figure 9. Sidescan sonar benthic survey, Herring Bay.



Side-Scan Sonar Benthic Survey
Herring Bay

EELGRASS
BULL KELP
ROCKY REEF
GRAVEL
SILT
HAZARD

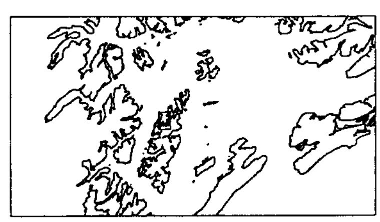


Table 4. Summary of sea otter carcasses recovered from Green Island and vicinity, western PWS, April 1995.

ID #	Location	Relative age[a]	Cementum age	Tooth used	Sex	Collection
BW9501	ss gi	2	5	unk	nd	skull
BW9502	ss gi	2	4	pm2	nd	skull
BW9503	gib anch	1	0	pm1, pm2, inc	nd	none
BW9504	sw gib anch	3	20	pm1, can	nd	part skull
BW9505	gib anch is.	1	0	eruption	nd	mandible
BW9506	stock/mont.	1	0	skull sutures	nd	maxilla
BW9507	green is ck	2	12	pm1	f	skull
BW9508	barrier is	2	6	pm1, can	nd	skull
BW9509	ss gi	2	-	m1	nd	none
BW9510	gibb anch	2	5	pm1 can	nd	skull
BW9511	gibb anch is	1	0	pm2, can	nd	mandible
BW9512	gibb anch	nd	-	none	nd	no data

a 1 = juvenile, 0-1 years of age; 2 = prime, 2-8 years of age, 3 = aged, 9+ years of age.

Table 5. Population estimates from aerial survey of sea otters in western Prince William Sound, July 1995.

Stratum	Area (km^2)	# Transects	Area sampled (km^2)	Unadjusted estimate	Standard error	Prop. se[a]
high	1003	702	335	1389	127	0.09
low	1355	131	110	197	74	0.38
TOTAL	2358	833	445	1586	147	0.09

a Proportional standard error.

proportion of prime age animals is higher than expected (but not significantly different) relative to data from pre- and post-spill collections.

Aerial Surveys: Between 17 and 26 July 1995, we conducted aerial surveys of sea otters in western Prince William Sound which included 2358 km^2, of which 1003 km^2 were considered high density stratum and 1355 km^2 low density stratum. We surveyed 833 transects, 702 in the high stratum (355 km^2) and 131 in the low (110 km^2). The unadjusted population size was estimated at 1,586 (se=147) (Table 5). Thirty-four intensive search units provided a correction factor of 1.36 (se=0.09). The corrected population size estimate was 2,158 sea otters (se=236) (Table 6). During the same period, 5 replicate aerial surveys of sea otters were completed in NVP sites at Montague and N. Knight Islands. The Monatgue Island replicate survey area contained 89.7 km^2, consisting of 69.8 km^2 of high and 19.9 km^2 of low stratum. The Knight Island replicate survey area contained 168.2 km^2, consisting of 74.3 km^2 of high and 94.0 km^2 of low stratum (Table 7). Population size estimates were 301 (se=50) or 3.4/ km^2 for Montague and 89 (se=22) or 0.53/km^2 for Knight. Variation in estimates among replicates, within areas, was high (Table 8). Sea otter location and attribute data currently are being digitized on survey transect and shoreline coverages in ARC-INFO.

Reproduction Surveys: Skiff surveys of oiled and unoiled study areas were conducted on 25-27 August 1995, to provide an index of annual reproduction of sea otters. We observed 134 independent and 68 dependent sea otters in the Montague study area, and 44 independent and 21 dependent sea otters in oiled study area, giving proportions of pups of 0.337 in Montague and 0.323 in Knight/Naked. These values were not significantly different (P=0.96).

Harlequin Duck: Capture: We captured 413 harlequin ducks, including 41 within-year recaptures. Numbers of birds captured by area, age, and sex are listed in Table 9. We were successful in capturing good samples of adults (ATY) and subadults (TY) of both sexes. Samples of juveniles (SY) were low because capture efforts occurred after the bulk of juvenile molt. Timing of capture was good for obtaining adequate samples of adult females for radio work; based on modeling exercises, average wing molt was initiated on 20 August for females and 20 July for males. For both sexes, initiation dates were similar for adult and subadult birds.

Adult Female Survival: We included 89 transmittered birds in survival analyses. As of 27 January 1996, survival probabilities for the unoiled and oiled sites were 94.2 and 86.7%, respectively (Figure 10). Radios will be monitored through March to determine survival for the entire 6-month winter period. Currently there are about 30 radios unaccounted for. We attribute these to radio failure unrelated to fate or bird movement. Extensive surveys have revealed few missing frequencies. Also, winter site fidelity is high (see below).

Radio telemetry also has provided information regarding the scale of movements of adult females between molting and wintering areas and movements during winter. This has important implications for understanding the effects of the oil spill. If birds move back and

Table 6. Adjusted[a] sea otter population size estimate.

Stratum	Population size	std. error	prop. se
high	1890	213	0.11
low	268	102	0.38
TOTAL	2158	236	0.11

[a] Adjusted by correction factor of 1.36, obtained from 34 ISU's.

Table 7. Replicate survey areas and area sampled in each study site, by stratum.

Study Area	Stratum	Area (km^2)	# transects	Area sampled (km^2)
Montague	high	69.82	19	24.33
	low	19.86	3	1.34
N. Knight	high	74.27	55	25.09
	low	93.95	8	7.06

Table 8. Sea otter population estimates from Montague and northern Knight Island from replicate surveys.

Replicate	# ISU's	Correction	Unadjusted est.	Adjusted est.
Montague				
1	2	1	196	196
2	4	1.73	212	367
3	1	1.2	161	193
4	2	1.25	362	453
5	4	2	149	298
Mean (se)				301 (50)
Knight Naked				
1	2	1.33	83	110
2	4	1.29	98	126
3	1	∞	27	-
4	1	1	27	27
5	1	1	93	93
Mean (se)				89 (22)

Table 9. Summary of total harlequin duck captures by sex and age group.

	Females			Males			
TOTAL	ATY	TY	SY	ATY	TY	SY	
Montague							
# Capture Events	55	50	13	48	63	3	232
# Recaptures	5	3	1	3	7	0	19
# Unique Individuals	50	47	12	45	56	3	213
Knight							
Capture Events	60	64	13	18	25	3	183
# Recaptures	7	15	0	1	0	0	23
# Unique Individuals	53	49	13	17	25	3	160

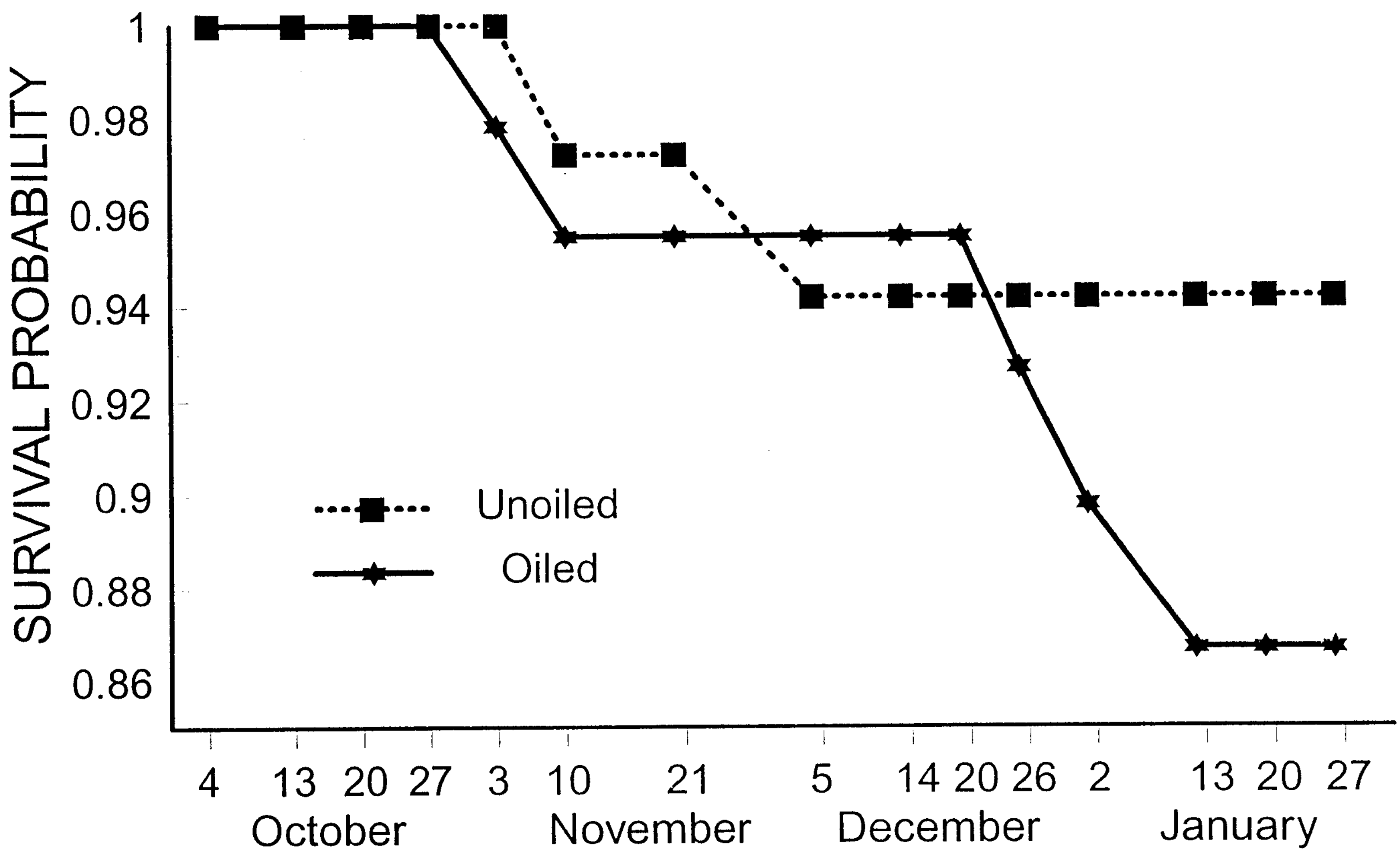


Figure 10. Adult female harlequin duck survival

forth between oiled and unoiled areas, the oiling would affect a larger segment of the population than if they stay in a specific area. Most (92%) of the birds stayed near their molt site (within approximately 20 km). Of 7 birds that moved from their molt site, 4 changed oiling treatments. No consistent direction or pattern was evident. Again, we assume that missing radios represent radio failure and not movements.

River Otter: No FY 95 field activity was proposed or conducted.

Pigeon Guillemot: No FY 95 field activity was proposed or conducted.

Health.-- *Sea Otter*: Blood Chemistry and Immune Function Assays: On 17 and 18 August 1995, 6 adult sea otters (5 female, 1 male) were captured in Deep Bay, near Cordova in eastern Prince William Sound (Table 10). In addition, 1 dependent pup was captured, but it was not sedated or otherwise handled. The six adults were sedated with fentanyl and valium. Once immobilized, blood samples (30 cc from each animal) were collected for chemistry and immune function assays. Additionally, serum samples were submitted to Corning Clinical Laboratory for chemistry analysis. One premolar tooth was extracted from each adult sea otter for aging. We also collected pelage swabs to familiarize ourselves with the ELISA assay for determination of external hydrocarbons. Body lengths, weights, and canine widths were recorded. No flipper tags were attached; however, left flippers were punched in the 2:3 position to prevent multiple sampling due to recaptures. Crystiban was administered as an antibiotic. Anesthetized individuals were reversed with Naltrexone. Processing time averaged 22 minutes per animal. All individuals appeared alert and active at release.

Blood samples were processed to obtain plasma and cellular components. Plasma samples were frozen at collection and subsequently submitted to Corning Clinical Laboratories for chemistry analyses; results are presented in Table 11. Peripheral blood mononuclear cells were harvested and cryopreserved, and shipped to Purdue for evaluation of methods to be used in the immune function assays.

Harlequin Duck: Body Condition Variation: Body weight of adult females was similar between treatments at the beginning of molt, but declined more rapidly through molt on the sites (Figure 11). Similarly, body weights of subadult females were lower at all stages of molt on the oiled side than the unoiled side (Figure 12). No obvious patterns existed for males; more data are needed for early molt stages.

Blood Chemistry: Blood chemistry profiles were examined by Dr. Alan Rebar. Most parameters were similar between treatments. However, eosinophil levels were elevated in some individuals from the oiled site (Figure 13), indicating a systemic hypersensitivity reaction. This result was also observed in sea otters in western Prince William Sound in 1990 and 1992 (Rebar et al. 1996, B. Ballachey unpubl. data).

River Otter: No FY 95 field activity was proposed or conducted.

Pigeon Guillemot: No FY 95 field activity was proposed or conducted.

Table 10. Summary information on adult sea otters captured in Deep Bay, eastern PWS, August 1995.

CAPTURE DATE	OTTER #	SEX	WEIGHT (kg)	LENGTH (cm)	CANINE WIDTH (mm)
8/17/95	NVP9501	f	23.6	115	7.3
8/17/95	NVP9502	f	20.9	113	7.5
8/17/95	NVP9503	m	43.6	135	9.3
8/17/95	NVP9504	f	21.8	114	7.4
8/18/95	NVP9505	f	26.6	118	7.2
8/18/95	NVP9506	f	20.9	117	7.3

Table 11. Blood chemistry of sea otters collected in eastern PWS, August 1995.

	Otter # NVP:					
	9501	9502	9503	9504	9505	9506
Glucose, *mg/dL*	110	95	108	90	84	83
BUN, *mg/dL*	58	41	65	42	51	36
Creatinine, Serum, *mg/dL*	0.5	0.6	0.5	0.5	0.4	0.4
Uric Acid, *mg/dL*	2.5	3.3	2.8	2.9	2.4	2.4
Sodium, *mEq/L*	148	149	153	149	151	149
Potassium, *mEq/L*	4.5	4.2	4.6	4.5	4.6	4.3
Chloride, *mEq/L*	111	111	116	113	112	111
Calcium, *mg/dL*	9.4	8.9	7.9	9.4	9.3	9.1
Phosphorus, *mg/dL*	3.8	3.4	4.3	5.6	4.5	4.7
Total Protein, *g/dL*	6.3	6.4	6.2	6.4	6	6.5
Albumin, *g/dL*	3	3.2	2.4	3.4	3	2.9
Globulin, *g/dL*	3.3	3.2	3.8	3	3	3.6
A/G Ratio	0.9	1	0.63	1.13	1	0.8
Triglycerides, *mg/dL*	79	56	117	43	73	65
Cholesterol, *mg/dL*	151	191	116	174	154	152
HDL, *mg/dL*	134	161	105	161	142	131
VLDL, *mg/dL*	16	11	23	9	15	13
LDL, *mg/dL*	1	19	—	4	—	8
Chol/HDL Ratio	1.13	1.19	1.1	18	18	1.16
Bilirubin, Total, *mg/dL*	0.3	0.5	0.3	0.5	0.3	0.4
Bilirubin, Direct, *mg/dL*	0	0	0	0	0	0.1
GGT, *U/L*	18	15	19	12	18	17
Alkaline Phosphatase, *U/L*	177	122	84	160	122	140
LDH, *U/L*	325	361	341	283	285	297
SGOT, *U/L*	135	168	466	150	136	153
SGPT, *U/L*	166	194	313	164	162	158

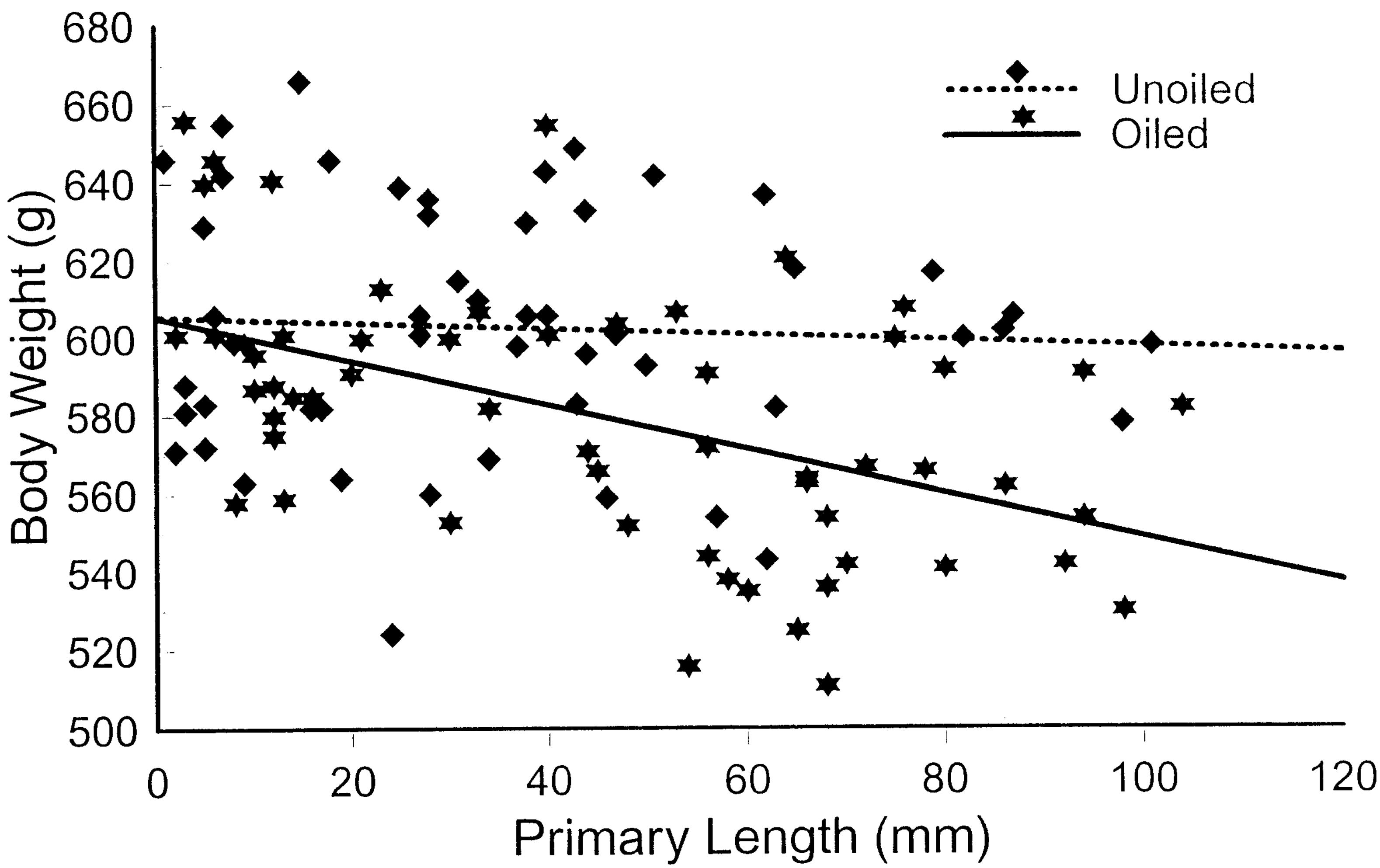


Figure 11. Body weight variation in adult female harlequin ducks through molt.

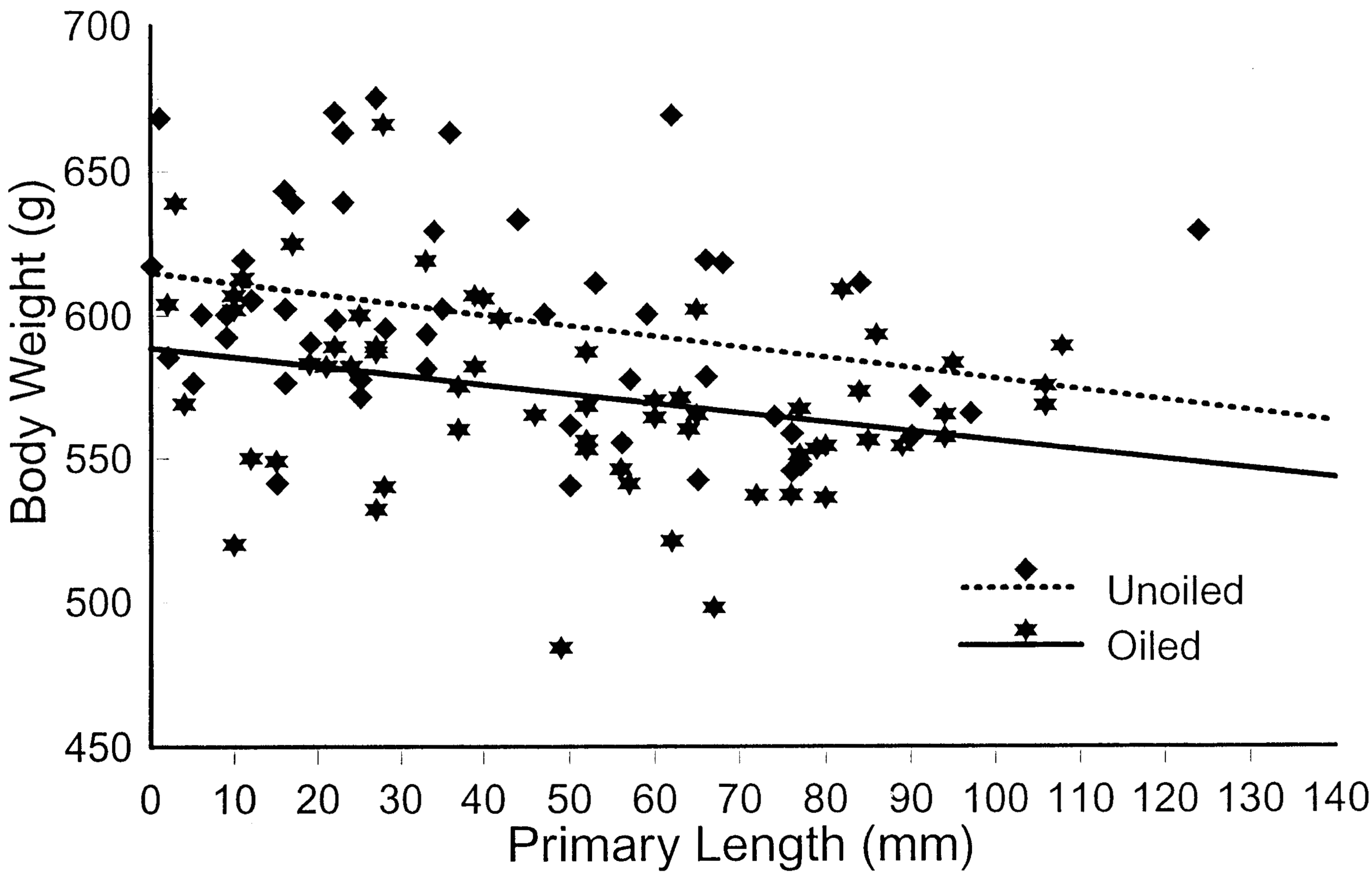


Figure 12. Body weight variation through molt for subadult female harlequin ducks

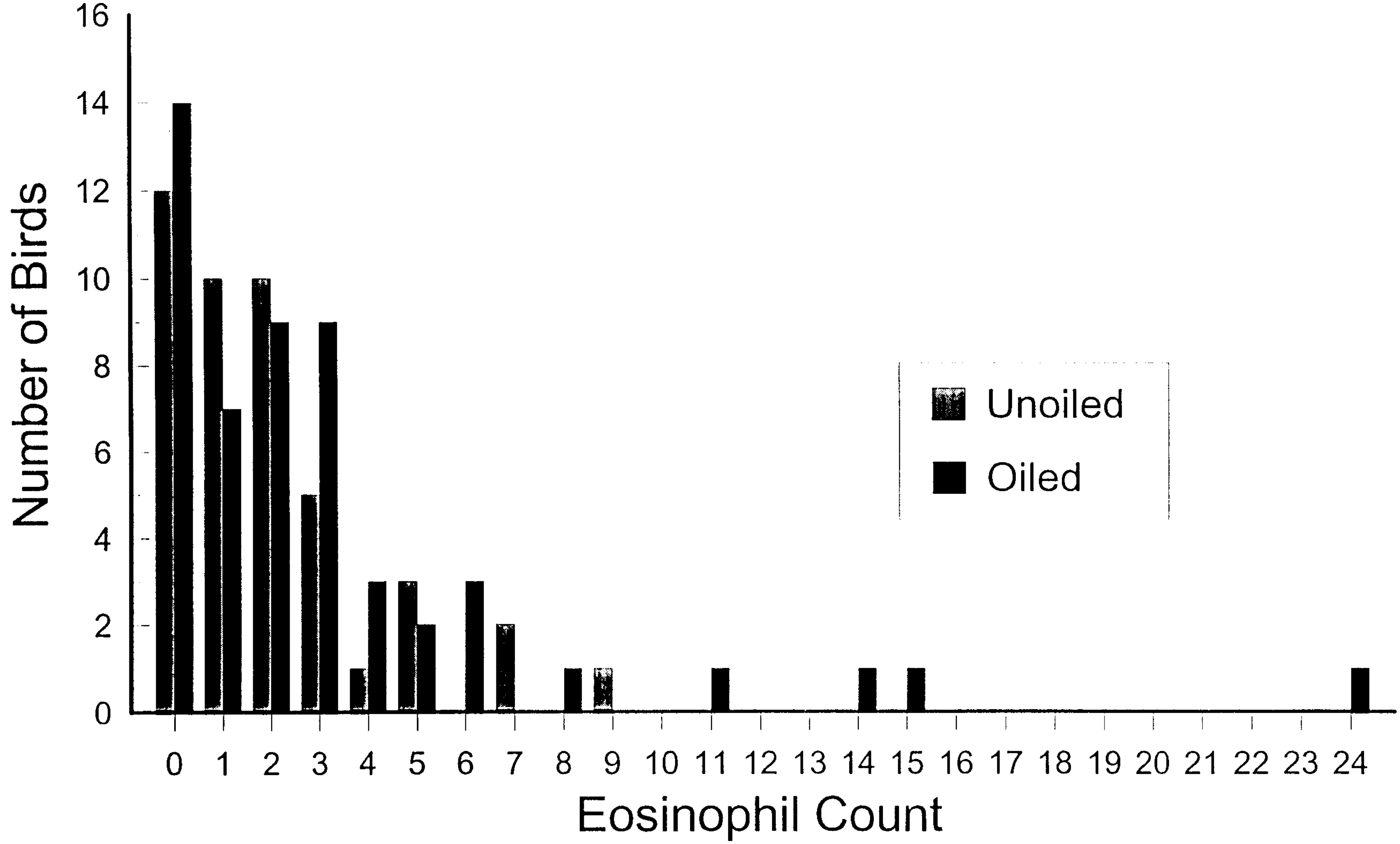


Figure 13. Eosinophil levels in molting harlequin ducks

Trophic Assessments.-- *Sea Otter*: Intertidal clams: We identified only 5 beaches in the unoiled northwest Montague Island vicinity (Figure 14a). In the oiled regions of Bay of Isles and Herring Bay, we found 6 and 0 potential clam beaches, respectively. All beaches were at least 300 m long (Figure 14b). The total amount of potential clam beaches in the Montague Island and Bay of Isles areas was 3900 m and 3500 m, respectively. The upper and lower extremes of the intertidal distribution of littleneck clams are between the tidal heights of +0.73 and -0.76 m (+2.4 and -2.5 ft), respectively, similar to Paul and Feder (1973) as presented here in Figure 15. Maximum densities tend to occur near the 0.0 m tidal height (mean lower low water). The greatest densities of larger clams (>20 mm in length: 4-12 years old) tend to occur between tidal heights of +0.43 and -0.43 m, while the greatest densities for smaller individuals (<20 mm: <4 years old) occur between -0.43 and -0.64 m. Their maximum depth in the sediment is approximately 8 cm.

Intertidal clams were collected in July 1995 from a broad, unoiled beach on western Montague Island (adjacent to Green Island). Ten 0.25 m^2 quadrats were collected along a 100 m transect at zero tidal height. All material to a depth of 10 cm was sieved through 0.25 inch mesh; finer material was returned to Fairbanks for sorting of small clams. The littleneck clam, *Protothaca staminea*, an important food of sea otters, was the only dominant clam. Only a few butter clams, *Saxidomus giganteus*, were found. Although the density of this clam was high, tremendous variability existed (Figure 16, 17).

Subtidal clams: Sampling for subtidal clams was done from July 2-9, 1995 to test sampling equipment and collect preliminary samples in preparation for full scale sampling in 1996. A scientific crew of six used the *M/V Good Times* and sampled areas in Herring Bay, Bay of Isles, and near Mooselips Bay (Montague Island).

In each area, six to seven potential study sites were picked for a series of quick observational dives. These 5 to 15 minute dives qualitatively evaluated the substratum for potential bivalve populations. Two to three of the sites evaluated as potentially the best areas to sample bivalves were then chosen for sampling by diver-held corers and a Venturi dredge. At each sampling site a transect tape 50 m long was laid along the 25-30 ft depth contour parallel to shoreline. A random starting point for sampling was chosen and quadrats (0.5 m x 0.5 m) were placed every 3 m apart for dredge sampling. Clams were collected by slowly winnowing the sediment within the quadrat to uncover larger sized clams. Each quadrat took about 20-30 minutes to completely sample to a depth of 20-30 cm.

A summary of suction dredge samples and core samples is shown in Table 12. A total of 33 suction dredge samples were taken from all areas: 7 from Herring Bay (1 test sample and 6 quantitative samples), 11 from Bay of Isles, and 15 from Mooselips Bay, Montague Island. Montague Island had the highest mean number of clams excavated while Herring Bay and Bay of Isles had similar densities (Table 13). Number of clams excavated from each 0.5 x 0.5 m quadrat ranged from 0 to 4. Clam species that were collected and number collected included *Macoma nasuta* (7), *Protothaca staminea* (2), *Humilaria kennerleyi* (2), *Mya truncata* (2), *Mya arenaria* (1), *Spisula polynyma* (1), *Saxidomus gigantea* (3), *Lucinoma annulata* (3), and one unknown species (1). A total of 59 infaunal cores for biology were taken; however two of the cores were broken in transit so a total of 57 cores are available

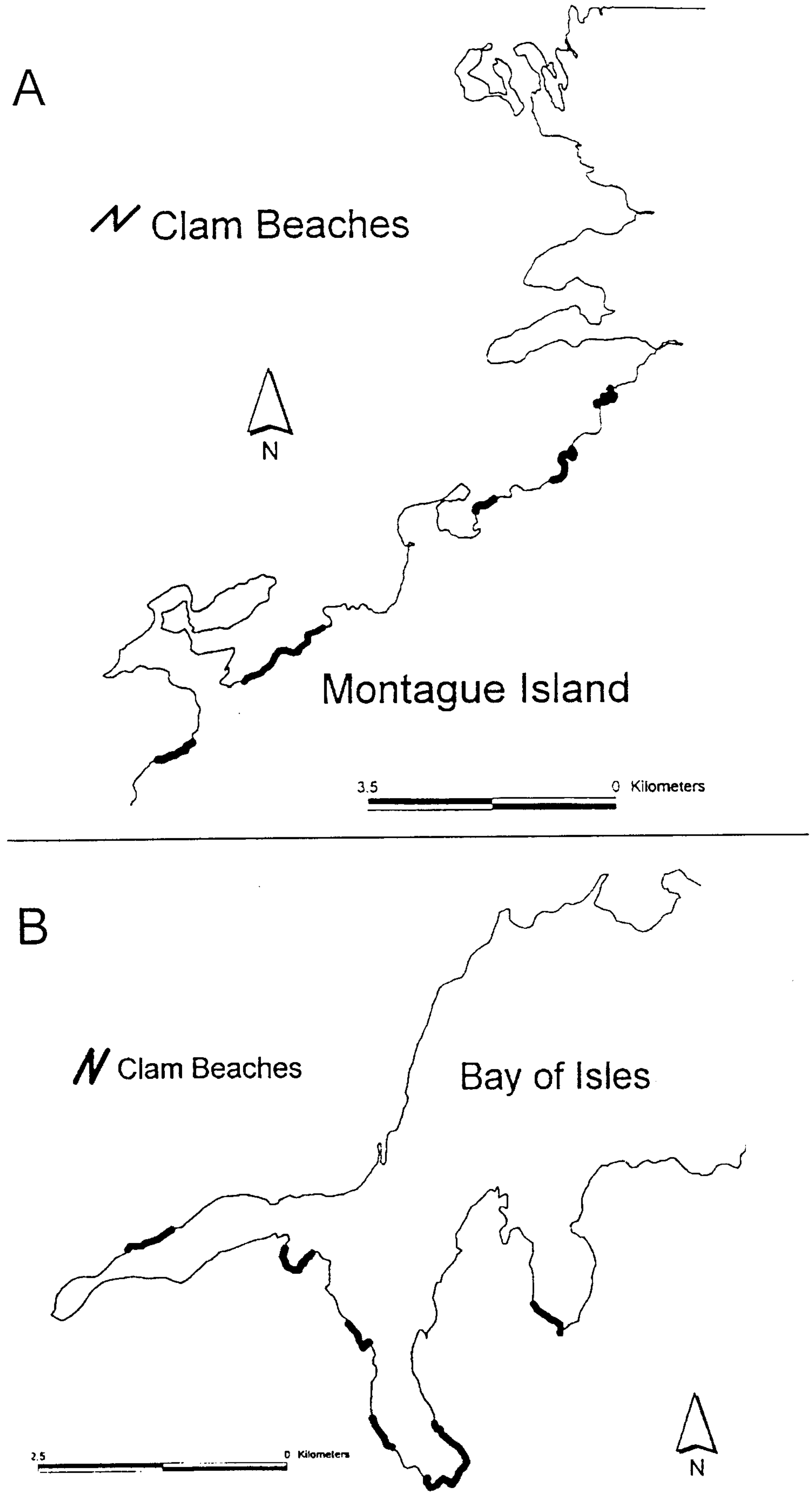


Figure 14. Locations of intertidal clam beaches found during the 1995 reconnaissance surveys of the NVP study areas

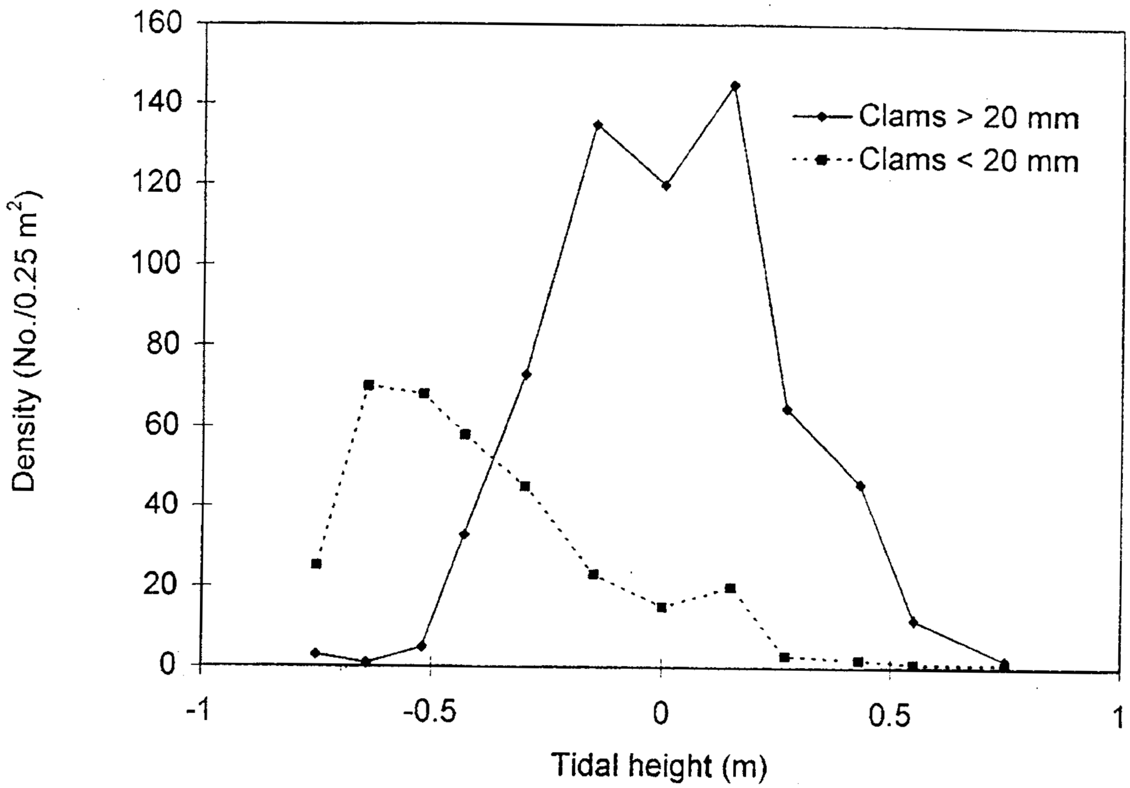


Figure 15. Intertidal distribution of Protothaca staminea in Galena Bay, PWS from Paul and Feder 1973)

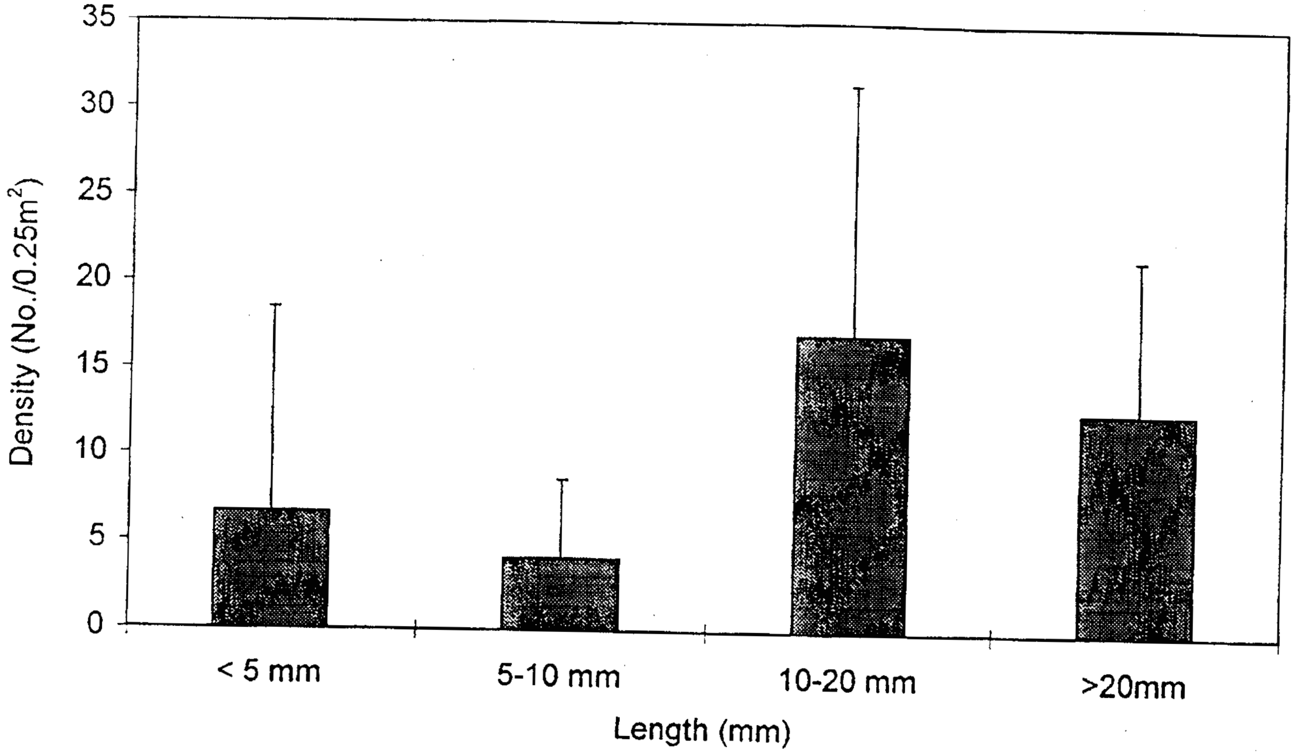


Figure 16. *Protothaca staminea* density by size from 10 0.25 m2 quadrats at 0.0m tidal height, West Montague Island, July 12, 1995

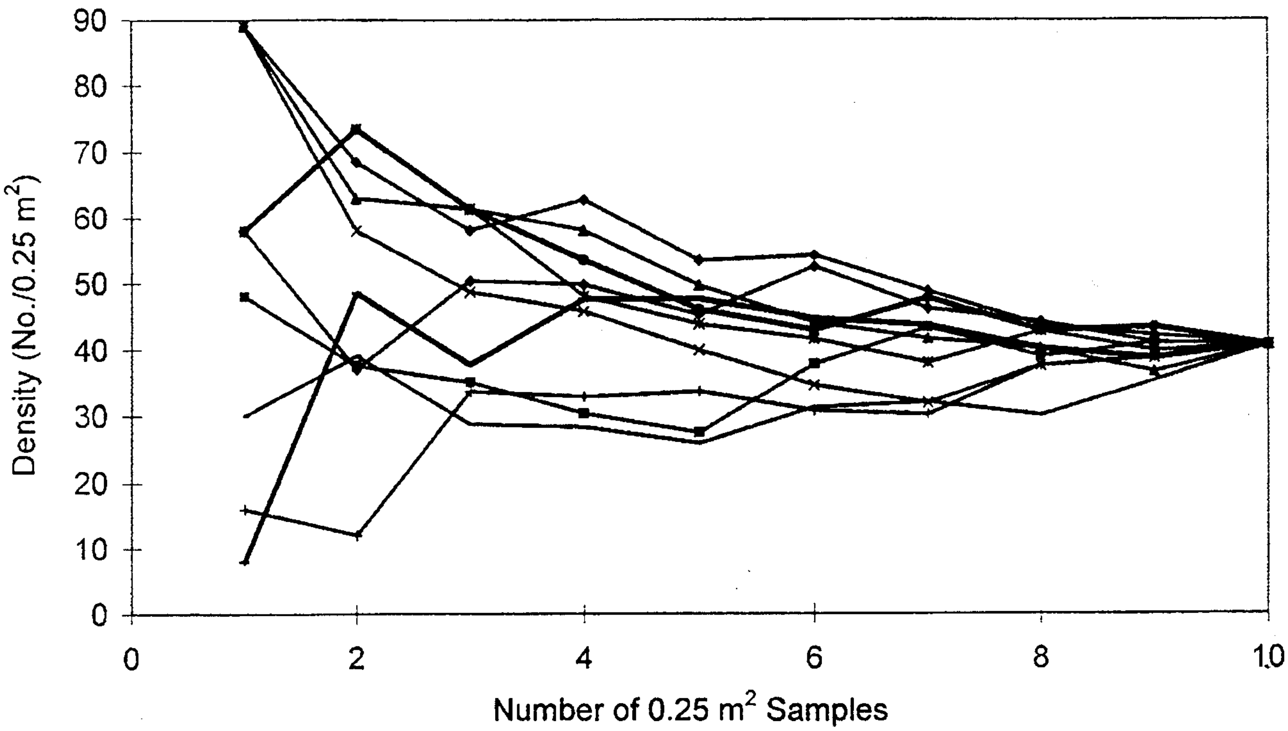


Figure 17. Cumulative mean density of *Protothaca staminea* in 10 0.25m2 quadrats at 0.0m tidal height, West Montague Island, July 12, 1995, randomized ten times to determine optimal numbers of replicates to sample.

Table 12. Summary of sampling done in 1995 for subtidal clams in Prince William Sound, Alaska.

	Location	Venturi dredge samples	Cores for biology	Cores for grain size TOC
Herring Bay	Site T-1	1 (qual)	5	1
	Site T-4	6	10	1
Bay of Isles	Site T-4	7	10	1
	Site T-5	4	10	1
Montague Island	Site T-1	3	4	1
	Site T-3	6	10	1
	Site T-4	6	10	1
Total		33	59	7

Table 13. Summary of bivialves collected in Venturi dredge samples, July 1995.

Location	No. samples	Total clams	Mean per 1/4 m^2	SD	Range
Herring Bay	6	4	0.67	0.82	0-2
Bay of Isles	11	8	0.67	0.98	0-3
Montague Is.	15	11	0.79	1.12	0-4

for analyses. A total of 15 cores were taken in Herring Bay, 20 cores in Bay of Isles, and 22 cores at Montague Island. All cores were sieved through a 0.5 mm screen in the field and preserved in a 10% buffered formalin solution. They were transferred to 70% ethanol after 1-3 weeks of preservation. Additional single cores were collected at each site for grain size analyses and total organic carbon analyses. These cores are currently frozen.

Mussels: To determine the sample size required to discriminate differences in mussel density and size-frequency distribution between our study areas, we sampled mussels in the intertidal region of both areas in July 1995. The study areas were Montague Island and Knight Island (includes only Herring Bay and Bay of Isles). Each area was stratified on the basis of substrate into 1) rocky (including bedrock and boulder and areas) and 2) unconsolidated or mixed substrate (including various mixtures of sand, granules, pebbles and cobble). Within each area, shore segments were chosen randomly for sampling from those segments listed in the collection of Impact Maps and Summary Reports of Shoreline Surveys of the *Exxon Valdez* Spill Site compiled by the Alaska Department of Environmental Conservation. From seven to 10 vertical transects were laid systematically (after the first randomly placed transect) at 20 m intervals within each shore segment. Mussels were sampled (all live mussels collected) with 500 cm^2 quadrat/transect. Estimates of mussel coverage (%) both within the mussel zone and within each quadrat were obtained at each transect. A total of 104 500-cm^2 quadrats (23 from Montague; 81 from Naked/Knight) were sampled along 14 shore segments (3 at Montague; 11 at Naked/Knight) in the two study areas. In the laboratory mussels were counted and their maximum shell lengths measured with a digital caliper linked to a datalogger or with an image analysis system (mussels <6 mm in length).

Results of this preliminary mussel sampling indicate that the mean densities of mussels at the two study areas differed by 33.5 indiv./500 cm^2 (Figure 18). The mean coefficient of variation (CV) of the entire mussel population was 116.2%. This CV was somewhat less than that calculated from the data of Highsmith et al. (1993; mean CV = 126.1%) for July 1990 (Figure 19), and appears to be a realistic estimate of the CV for mussel density over a modest range in quadrat size. Using standard sample-size estimation techniques for two-group contrasts we estimated that to detect a difference of 33 mussels/500 cm^2 at the $\alpha =$ 0.05 level of significance with power $1-\beta = 0.8$ would require a sample size of $n \geq 80$ shore segments in each study area (Figure 20A). This sample size can be achieved within the 1996 projected cruise schedule and within the 1996 budget for mussel sampling (Figure 20B). Analysis of the preliminary data on mussel length-frequency indicates that the study areas are similar in one important respect; large mussels (maximum shell length >40 mm) appear to have been relatively rare. In this respect both areas were similar to VanBlaricom's (1988) study site at Green Island where large mussels were rare in the presence of intense predation by sea otters, especially females with dependent pups and independent juveniles (Figure 21). However, because the results are preliminary and reflect a small sample size with limited geographical coverage they should be viewed with caution. Results from the analysis of mussel density by stratum indicated that variability in *Mytilus* density was greater on rocky than on unconsolidated (mixed) shores (Figure 22).

Urchins: Sampling and reconnaissance surveys were conducted between July

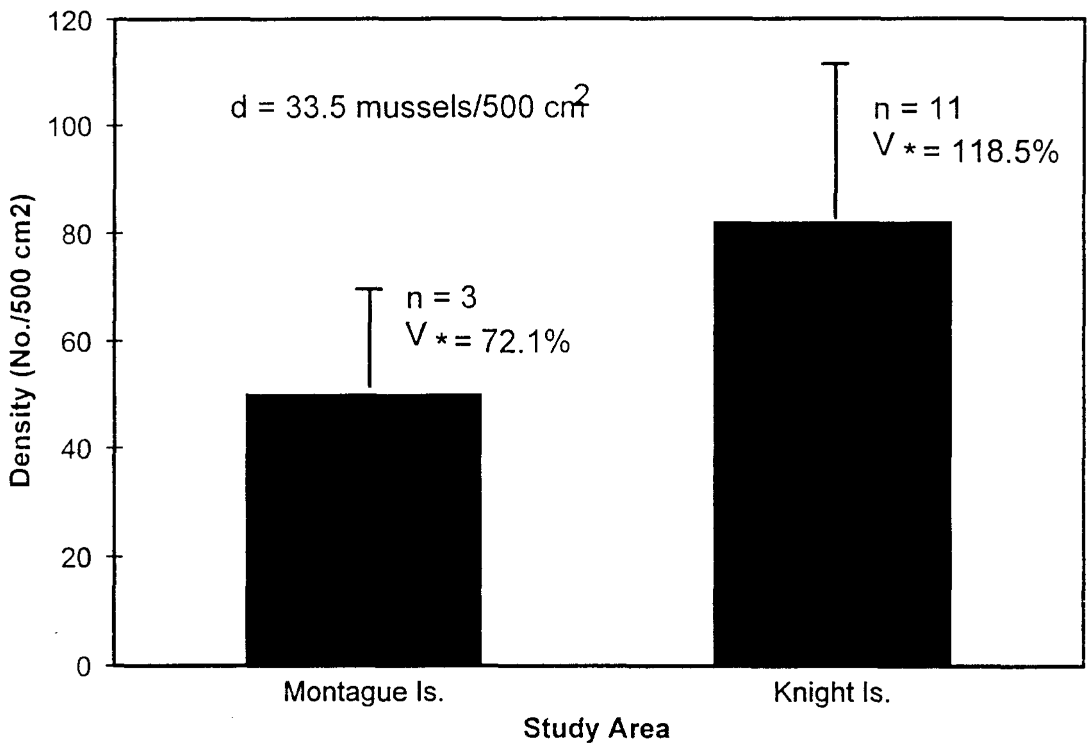


Figure 18. Mean density of mussels in two study areas in July 1995. Error bars are one standard error of the mean. Abbreviations are as follows: d, the difference in mean density of mussels between the two areas; n, the number of shore segments sampled in each area; V*, the unbiased estimate of the coefficient of variation.

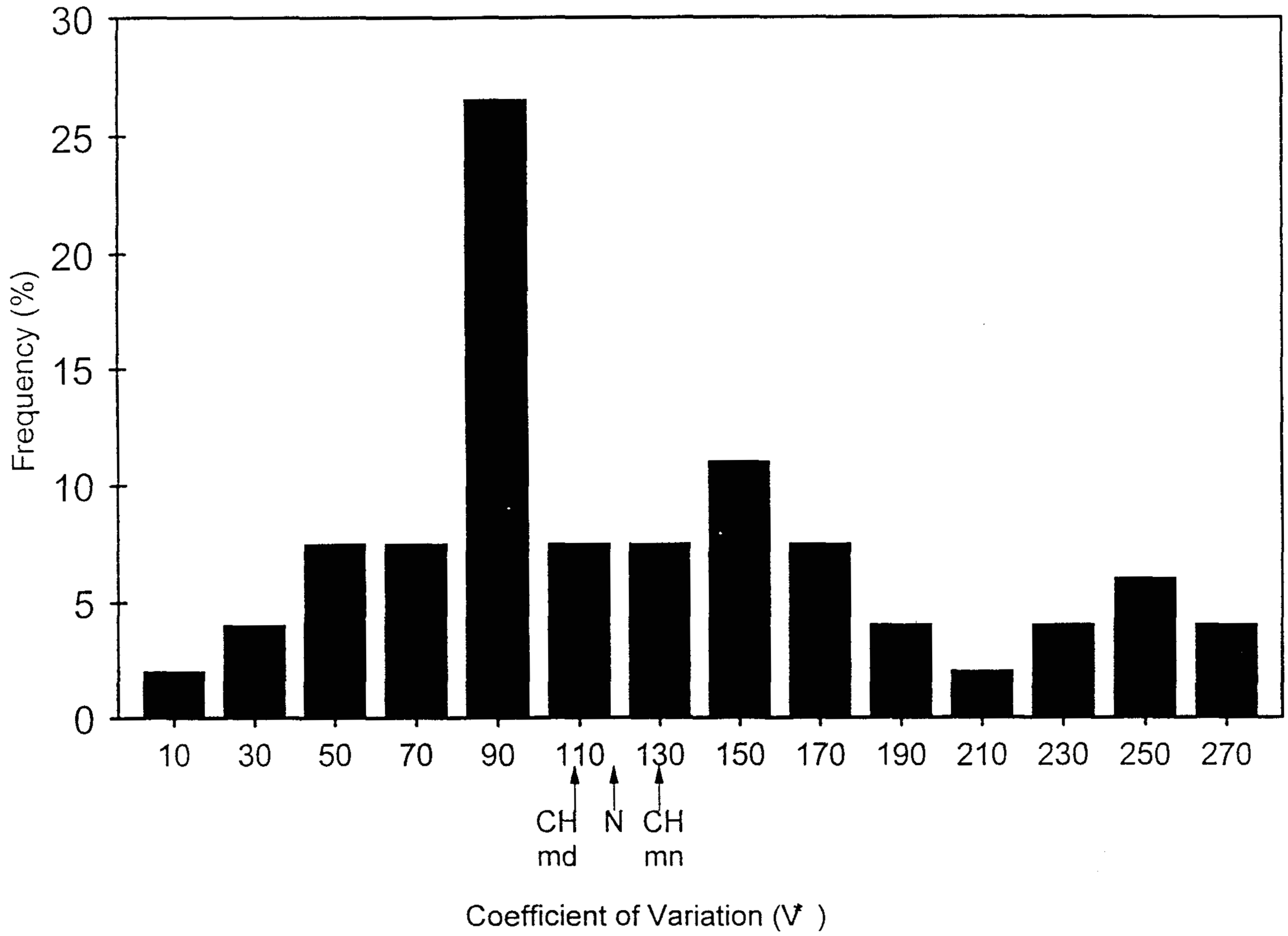


Figure 19. Frequency distribution of the coefficient of variation of mussel density calculated from Coastal Habitat Study Number 1 (CH1) data collected in July 1990. Abbreviations are: n, number of sites for which means and standard errors of the mean were reported (n = 30); md, the median coefficient of variation for the CH1 data; N, the coefficient of variation of mussel density from 1995 Nearshore Vertebrate Predator data.

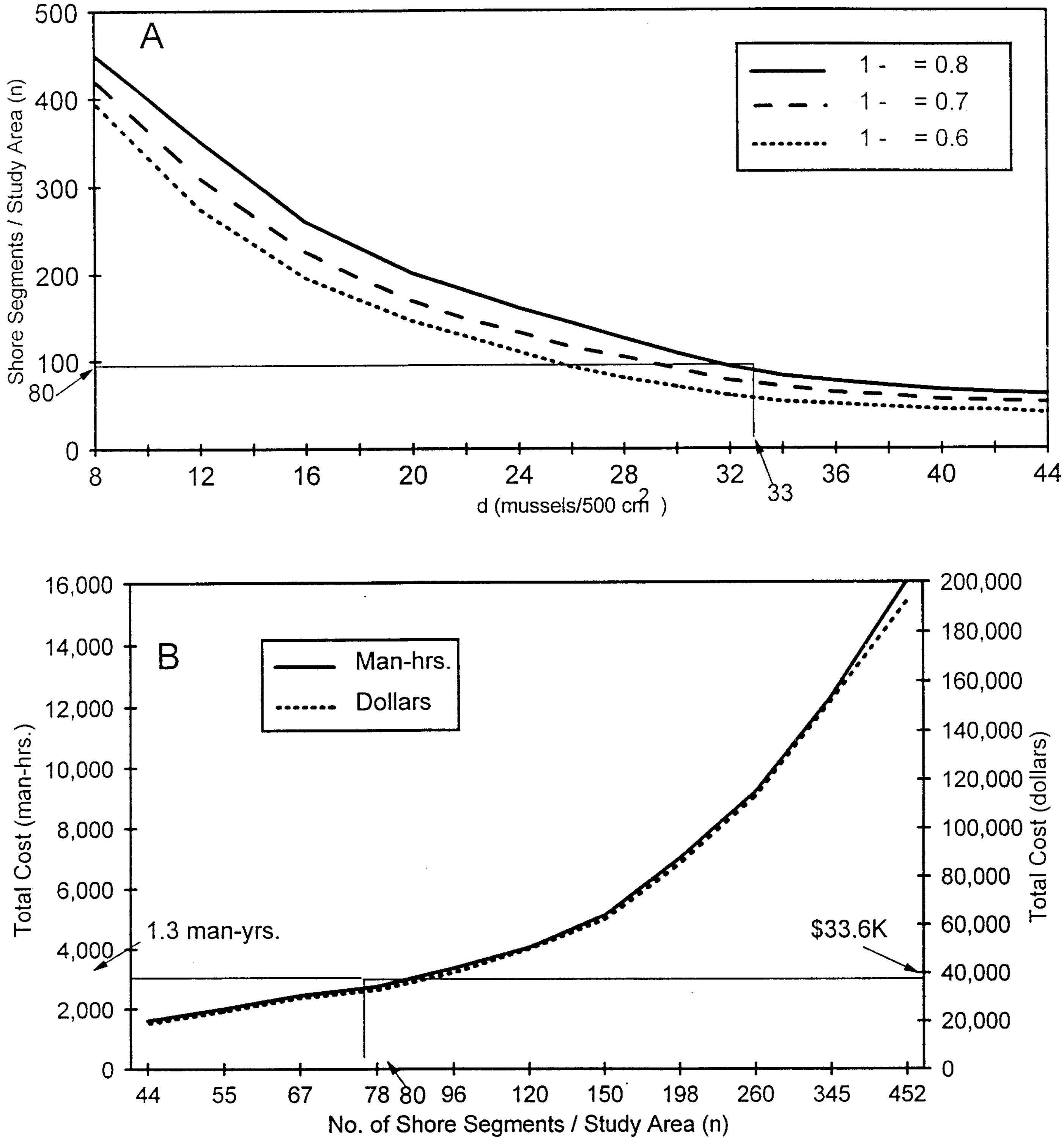


Figure 20. Sample size (A) and cost (B) estimates for detection of a difference in mussel density (d) at a significance level of alpha = 0.05 at three levels of power.

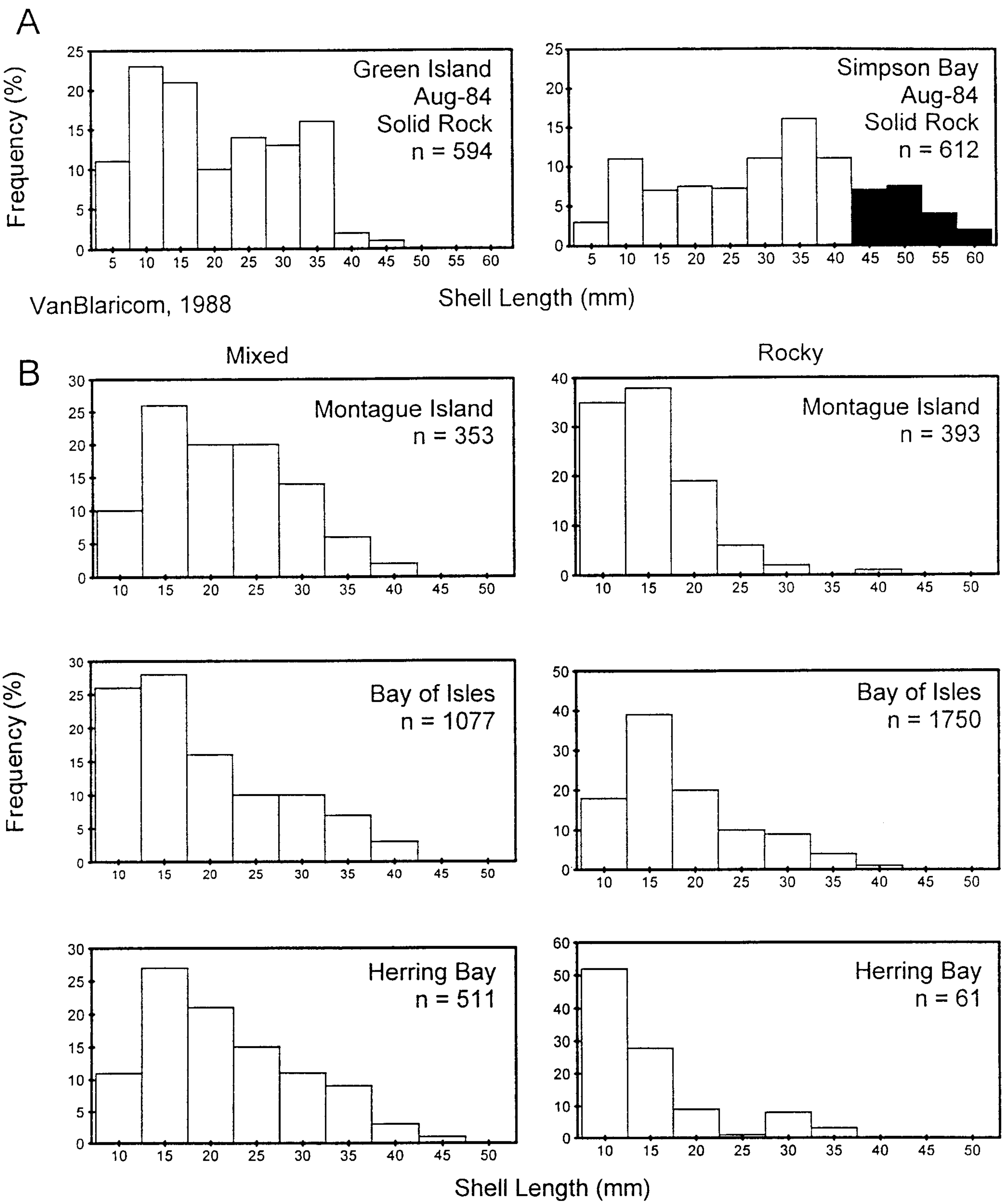


Figure 21. Length-frequency of mussels studied at two locations by VanBlaricom (1988) in August 1984 (A) compared with the length-frequency of mussels from Nearshore Vertebrate Predator preliminary sampling in two strata (mixed and rocky substrates) at three locations in 1995 (B). n = the number of mussels measured.

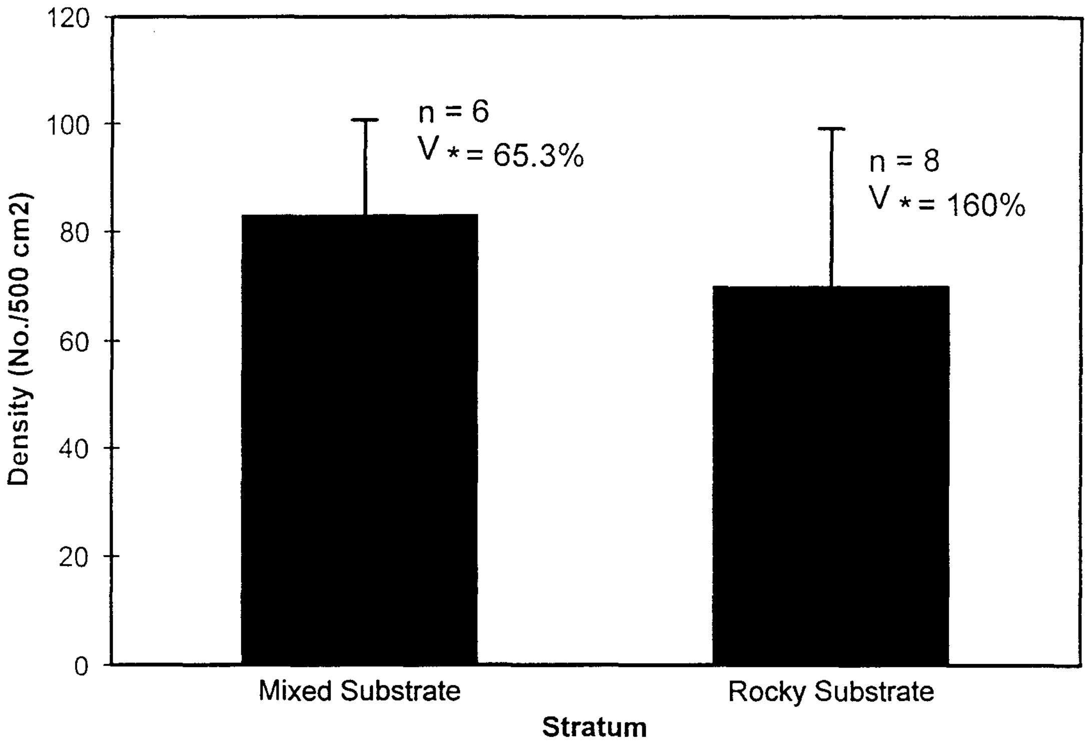


Figure 22. Mean density of mussels in two strata (mixed and rocky substrates) in July 1995. Error bars are one standard error of the mean. Abbreviations are as follows: n, the number of shore segments sampled in each stratum; V , the unbiased estimate of the coefficient of variation.

6 and July 23, 1995 in order to evaluate the proposed sampling design and sampling methods to be used in the 1996 NVP sampling program. In addition, data gathered as part of prior injury assessment studies were evaluated to examine temporal and spatial patterns in sea urchin abundance.

In summer 1995, we also conducted qualitative assessments of sea urchin abundance over larger areas within Herring Bay, Bay of Isles, Montague Island, and Jackpot Bay regions. The goal of the sampling was to determine the presence or absence of large aggregations of sea urchins. Quantitative sampling was then conducted within several aggregations that were observed in Bay of Isles.

Past studies in Prince William Sound indicate that sea urchins are rare. In quantitative random sampling over about 17,000 m^2 in the shallow subtidal from 1990 through 1995, we found only 49 urchins, a density of about 3 per 1,000 m^2. In a survey of several habitats conducted in 1990, a few sea urchins were found in rocky habitats (represented by bays, points, and *Nereocystis* beds) and none were found in eelgrass habitats (Figure 23). Within the bay habitat, there was an indication of a slight increase in density over time (Figure 24).

Several large aggregations of urchins were observed in 1993 and 1995, with densities of greater than $40/m^2$, and covering hundreds of square meters. Two large aggregations were observed in the shallow subtidal; one an eelgrass bed and another on a cobble bottom, and several aggregations were observed in intertidal areas. In the intertidal, the urchins were generally found under small cobbles. Quantitative sampling within these aggregations indicated that the density of urchins decreased with depth (Figure 25), and the average size of urchins increased with depth (Figure 26).

Copredators: *Invertebrate*-- Field work for this project was conducted 2-9 July and 27 November-19 December 1995. During the summer field period, 98 research person-dives were logged and qualitative surveys were made at 28 locations within the study areas. In addition, quantitative surveys were made at 6 sites: 2 at Herring Bay, 2 at Bay of Isles, and 2 at Montague Island. Subtidal observations were made with SCUBA on density, diet and activity of all invertebrate predators in oiled and unoiled study areas in Prince William Sound. All invertebrate predator species observed during the summer are listed in Table 14. *Pycnopodia helianthoides* was observed in the greatest densities at all study areas (Table 15). During the summer, *Telmessus cheiragonus* was the second most observed invertebrate predator.

During subtidal sampling, prey species were recorded when invertebrate predators were observed feeding. *Pycnopodia* and *Telmessus* were collected and dissected to obtain stomach contents. Stomach analysis was conducted on 48 *Pycnopodia* and 13 *Telmessus* collected during the summer (Table 16). Prey varied among sites and ranged from primarily polycheates (by number) in Herring Bay, gastropods in Bay of Isles, and crustacea at Montague sites. About 38% of all stomachs were empty. *Telmessus* also preyed on a variety of foods with snails and clams predominant in Herring Bay and Montague, respectively. Only one sample was collected in Bay of Isles with algae the only food item identified. About 15% of the 13 samples were empty in this prelininary sampling.

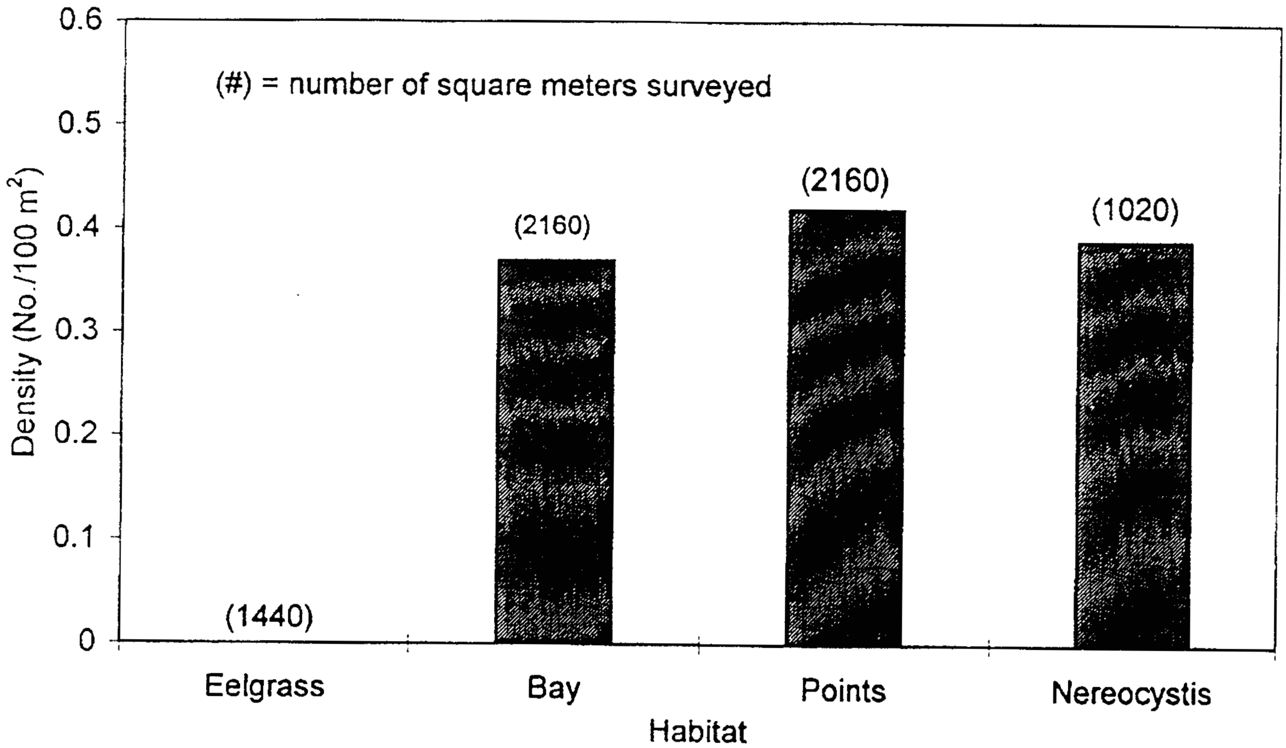


Figure 23. Urchin density by habitat based on 1990 data from PWS (Jewett pers. comm.)

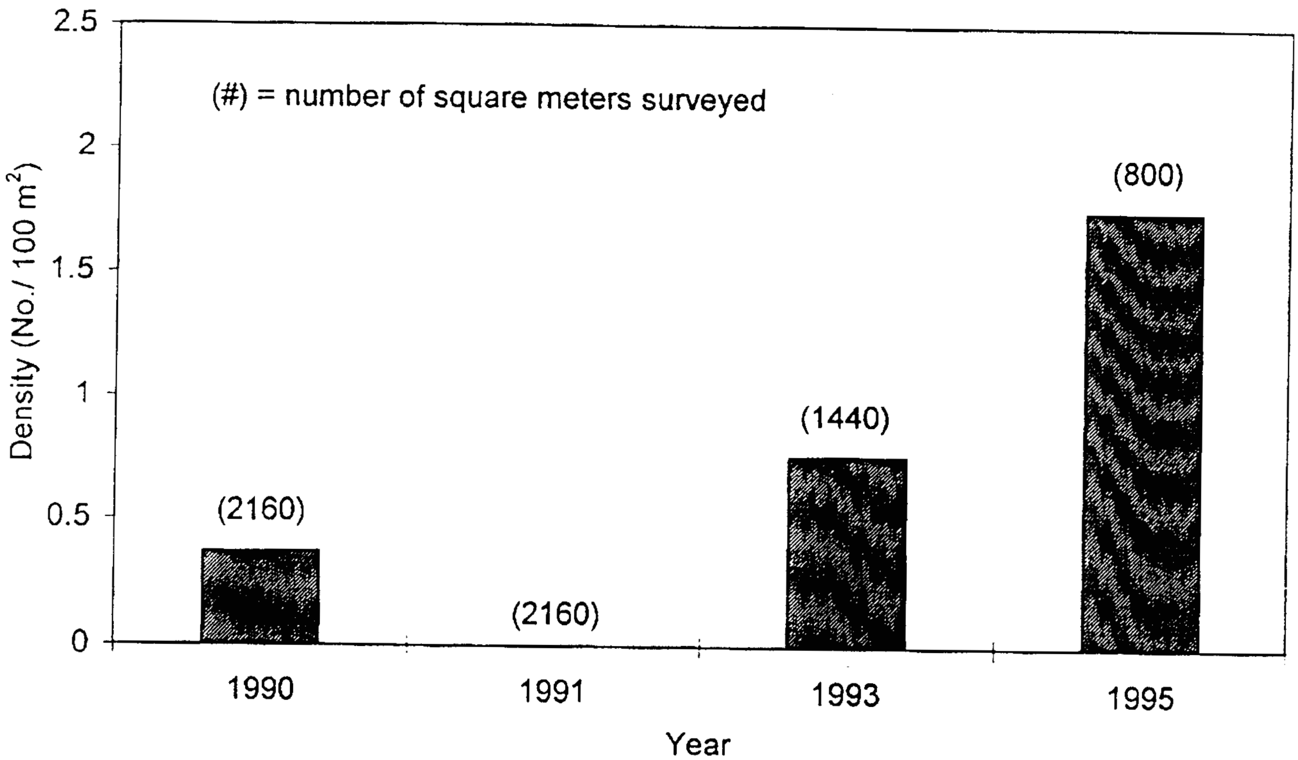


Figure 24. Urchin density by year within bay habitats, based on previously collected data by Jewett (pers. comm.)

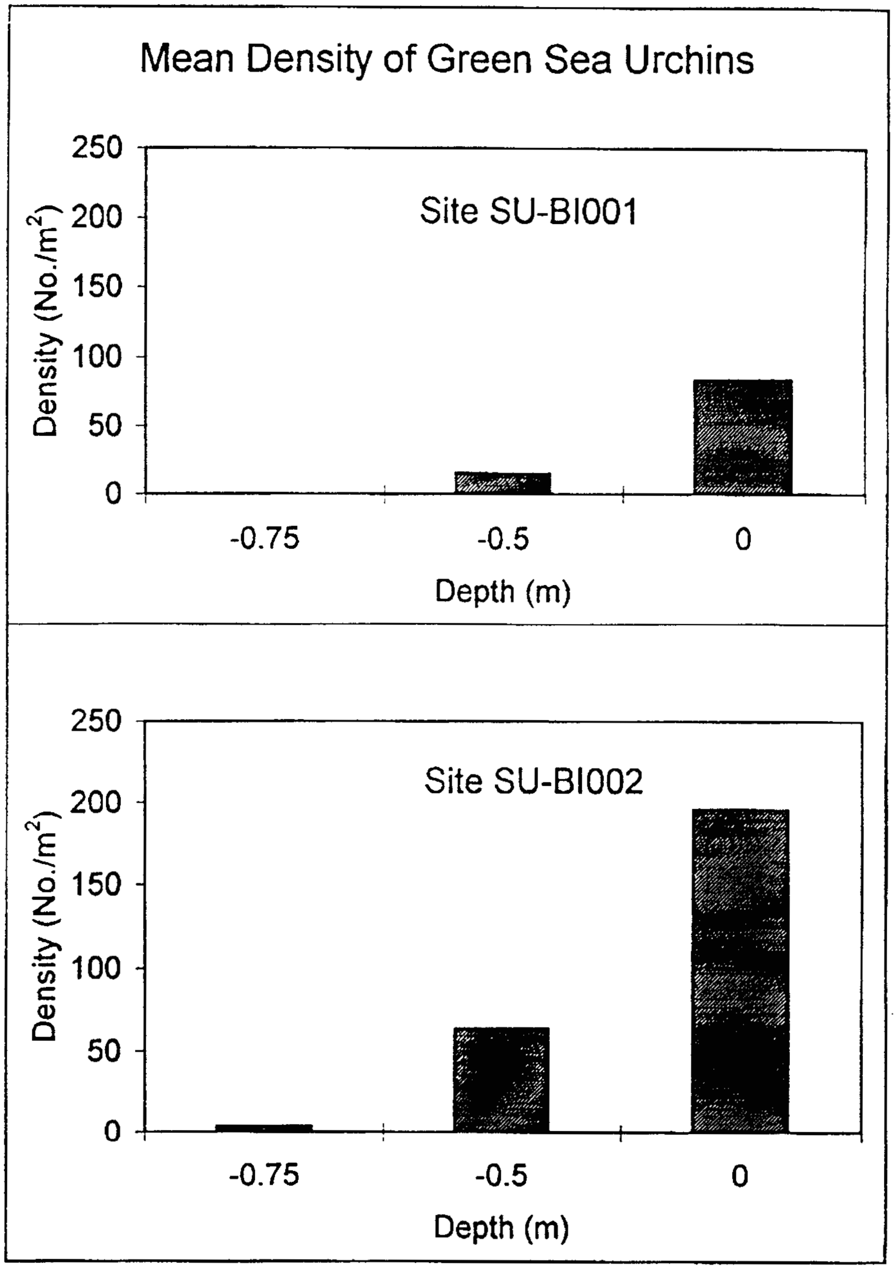


Figure 25. Mean density of sea urchins from two sites in the NVP study area showing density of urchins at various depths.

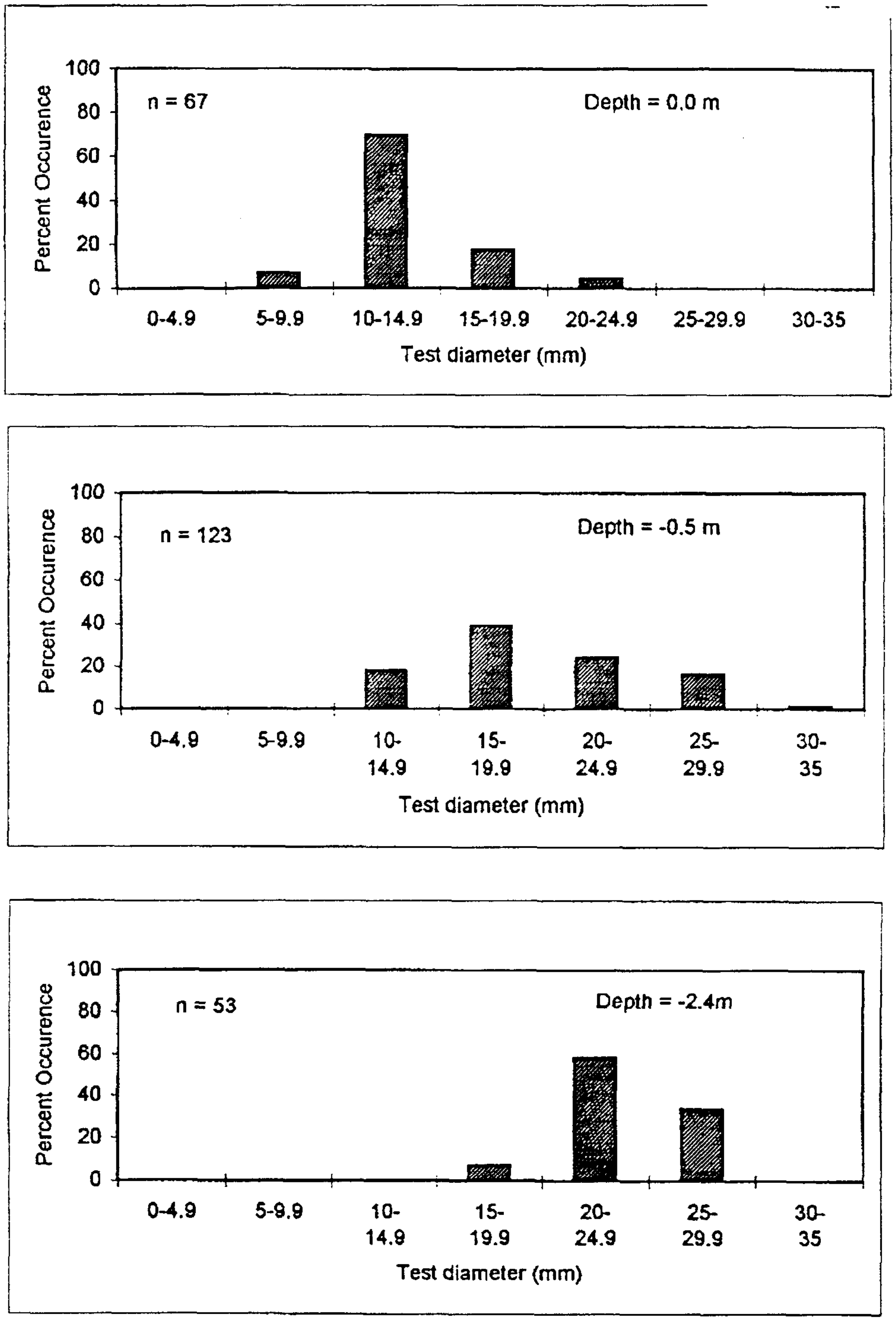


Figure 26. Size frequency distributions of sea urchins at three sites in Bay of Isles

Table 14. Invertebrate predators observed in Prince William Sound during the summer field season, June 1995.

Cancer magister (crab)
Chionoecetes bairde (crab)
Dermasterias imbricata (sea star)
Evasterias troschelii (sea star)
Hemigrapus nudus (crab)
Nucella lima (snail)
Oregonia gracilis (crab)
Orthesterias imbricata (sea star)
Pisaster ochraceus (sea star)
Pycnopodia helianthoides (sea star)
Telmessus cheiragonus (crab)

Table 15. Observed densites of individual predators per square meter in Prince William Sound, Summer 1995.

	Herring Bay	**Bay of Isles**	**Montague**	**Oiled**	**Unoiled**
Pycnopodia	0.18	0.25	0.06	0.22	0.06
	(0 - 0.45)	(0 - 0.65)	(0 - 0.2)	(0 - 0.65)	(0 - 0.2)
	n=15	n=15	n=20	n=30	n=20
Telmessus	0.01	0.03	0.02	0.02	0.04
	(0 - 0.1)	(0 - 0.25)	(0 - 0.15)	(0 - 0.25)	(0 - 0.15)
	n=15	n=15	n=20	n=30	n=20

Table 16. Percent occurrence of prey found in *Pycnopodia* and *Telmessus* stomachs from preliminary samples, Summer 1995. B: Bivalve; G: Gastropoda; P: Polycheate.

	Herring Bay	Bay of Isles	Montague	Combined
Telmessus	N=6	N=1	N=6	N=13
Pectinaria (P)	16.7	0	66.7	38.5
clam (B)	33.3	0	83.3	53.8
limpets (G)	33.3	0	0	15.4
snail (G)	50	0	50	46.1
crustacea	16.7	0	33.3	30.8
algae	33.3	100	33.3	38.5
empty	33.3	0	0	15.4
Pycnopodia	N=9	N=18	N=21	N=48
Olivella baetica (G)	11.1	38.9	9.5	20.8
Pectinaria granulata (P)	33.3	16.7	0	12.5
Searlesia dira (G)	11.1	5.5	9.5	8.3
Musculus (B)	0	16.7	4.8	8.3
clam (B)	0	11.1	9.5	6.3
crustacea	11.1	11.1	14.3	12.5
empty	44.4	16.7	52.4	37.5

Harlequin Duck: Prey: Epibenthic invertebrates that are common prey of harlequin ducks (chitons, limpets, snails, and epibenthic mussels) were sampled from various sites in order to evaluate sampling techniques. At the one rocky site for which there are biomass data, limpets, chitons, *Musculus*, and *Lacuna* were abundant in the deeper subtidal (-2.2 m depth. Figure 27). *Mytilus* and littorines were not very abundant subtidally, but were the dominant prey items in the intertidal zone.

Pigeon Guillemot: Prey: Based on the literature, pigeon guillemots eat a wider variety of fish than river otters, and schooling fishes can comprise a relatively high proportion of chick diets (Figure 28). However, of the benthic fish taken, the relative rankings are what would be expected based on a non-selective feeding behavior.

Attempts to sample sandlance abundance by counting the number emerging from the substrate were not successful. While several schools of sandlance were observed, we did not see any emerging from the substrate.

Fish abundance data from the series of transects sampled at Bay of Isles suggest that there was relatively little vertical movement of either fishes over the tidal cycle (Figure 29). There were clear patterns with respect to the vertical zonation of fishes at each site, but there were no significant differences in the abundance of fish within a stratum at low vs. high water. As expected, there were few fishes observed in the intertidal (+1.5 and -0.5) transects at low.

River Otter: Based on the literature, river otters appear to eat nearshore benthic fishes in proportion to their relative abundance in the nearshore zone. The ranking of abundance of fish within the nearshore benthic zone is very similar to the ranking of fish in the diets of river otters. The only discrepancies are a relative under representation of arctic shanny, and an over representation of sandlance in river otter diets. Arctic shanny are probably too small to be taken by otters, and sandlance are not sampled well by divers.

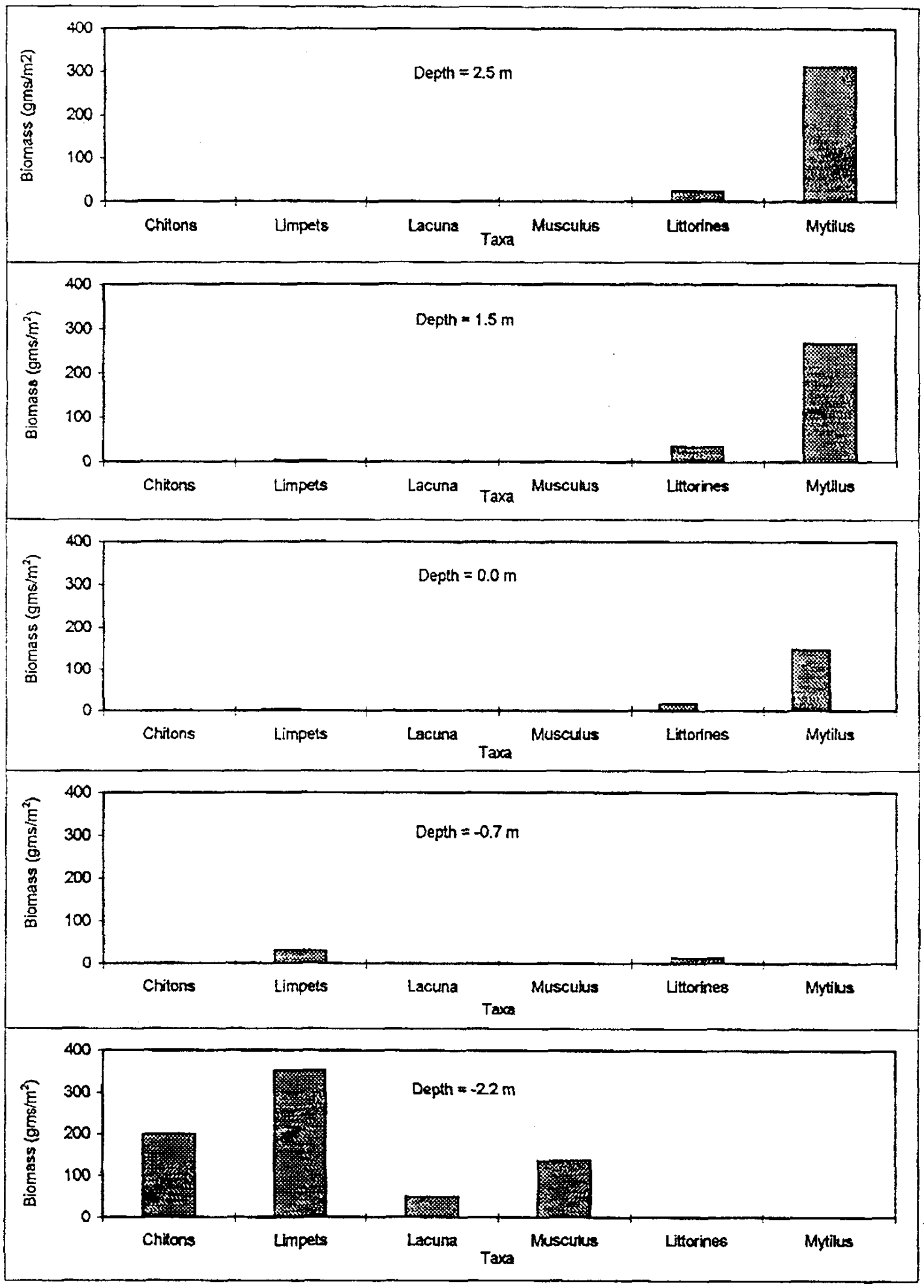


Figure 27. Biomass estimates of various prey items by depth important to harlequin ducks.

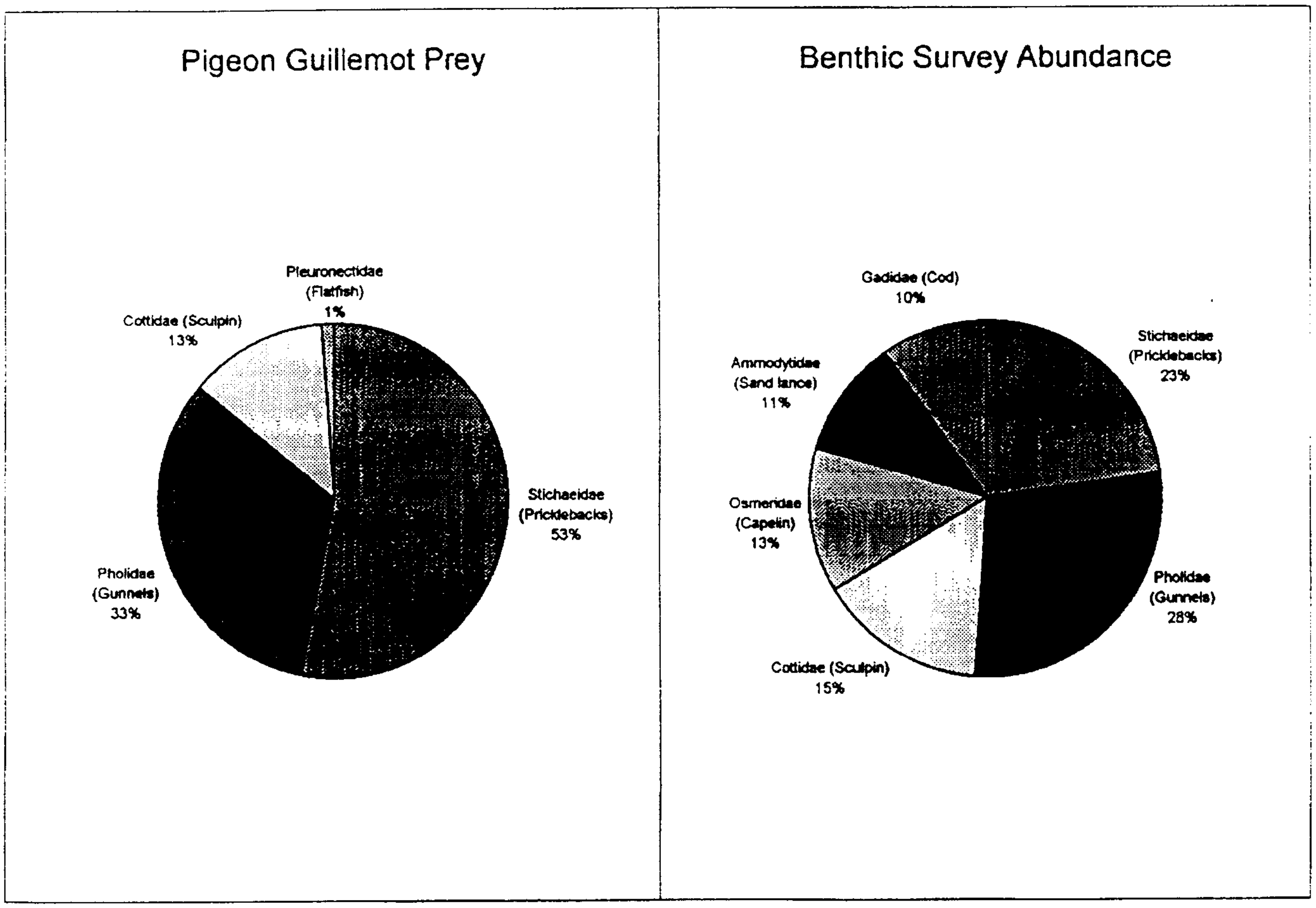


Figure 28. Comparison of prey consumption by pigeon guillemot versus prey availability.

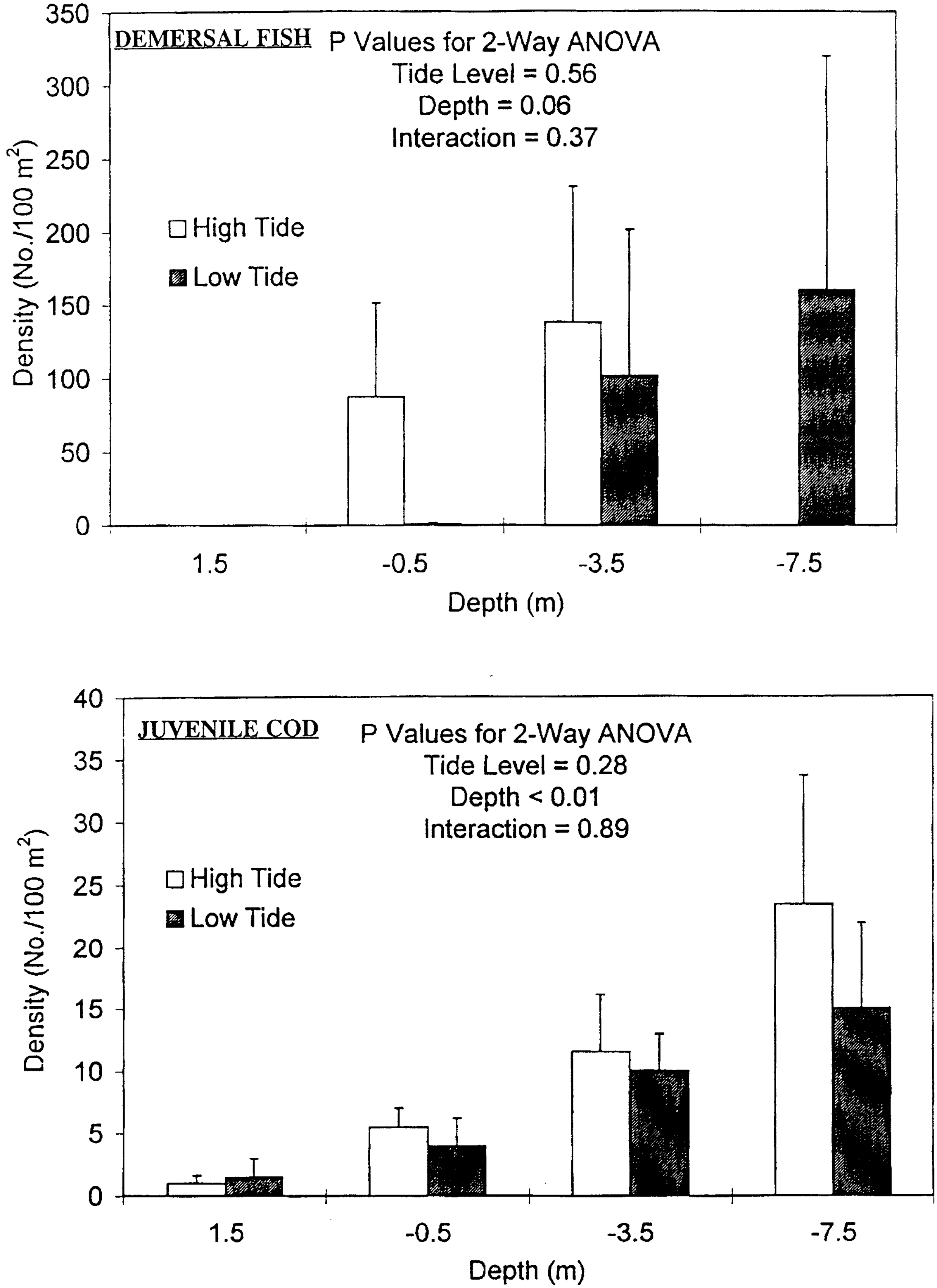


Figure 29. Mean density of fish by depth and tide level.

DISCUSSION

The Nearshore Vertebrate Predator Project (95025) received Trustee approval in March 1995, and project funding in early summer. Our 1995 effort focused on six primary tasks, two that dealt with data management and four related to project hypotheses that could be initiated late in the year. These were 1) establish electronic data file serving capabilities to facilitate data sharing among project scientists, 2) develop a detailed data management and quality assurance plan that included statistically reviewed standard operating procedures and common file formats, 3) better define subtidal habitats through the use of bathymetric and substrate models (sidescan sonar), 4) assess sampling protocols for prey to ensure sufficient power in analyses, 5) initiate some demographic assessments, including sea otter population, reproduction, and mortality surveys and harlequin duck survival studies, and 6) begin sample collections for health assessments and hydrocardon exposure (P450). Each of these elements was successfully initiated in 1995 and key elements are discussed below.

Data Management.-- The NVP project is an integrated effort that assesses nearshore ecosystem status through three parameters (demographics, health, trophic), each with multiple components, examined over a suite of four top predators. As such, a complex matrix of data are to be generated. In addition, these various components are being studied under the leadership of some fourteen scientists, few of whom are collocated. This project depends heavily on each scientist having access to all project data, irrespective of who the particular investigator is or their location, and that scientists have confidence in the quality of the provided data and understand data status and limitations. Therefore, it was critical to successfully complete the two data management tasks listed above prior to the project's first full field season (1996).

Data archiving and electronic data serving capabilities were established in 1995. NVP received access to an Internet accessible FTP site donated by the Alaska Science Center, National Biological Service. A passworded file system was established per the protocol described in the NVP Data Management Plan (see below). The system allows "read only" and off-loading access for all investigators to all files in the system. However, "write only" access is limited by password so that only the assigned investigator has "write" permission to his or her own directory. This was instituted to minimize unauthorized alterations to data files. The FTP site can also be accessed through the Alaska Science Center's WEB site and uses homepage technologies to facilitate access. Not only are project data served through this site, but the NVP Data Management Plan, reports, project field schedules, site information, and general "mail". With this approach, project investigators' access to information is not limited by business hours or having to request information from the project Data Manager. It is 24 hours a day, seven days a week. Also, this site serves as the NVP data archive. The system is online and functioning well.

The Data Management Plan was completed in draft September 1995, with some later additions in December. The Plan is located on the FTP site described above to facilitate updates and ensure that project investigators are reminded of protocols for data handling. The plan is attached as Appendix A without project-specific data sheets or file formats that are included in the full plan. Such information is available upon request from the NVP Data

Manager. The data management plan specifies file formats, metadata specifications, and structure of history files such that any project scientist can understand any other's data input. The history files represent a critical component of this effort since they keep project scientists up-to-date on any changes that may have occurred in a specific file due to additions of data or editing. It should be noted here that our intent in developing this data management system was not to eliminate the need for direct communication among the investigators about their data, but to facilitate a "sharing" process by ensuring that all NVP scientists clearly understand what data are available and what their limitations might be.

Habitat Determination.-- In 1995, we attempted to better define subtidal habitats through 1) sidescan sonar, to allow more informed stratification of our prey sampling, thereby reducing sampling variance, size needs and costs, and 2) bathymetric models, to define the bounds of what really is accessible habitat for foraging sea otters and harlequin ducks (both restricted in foraging depth abilities), once again allowing us to better focus our sampling efforts. In 1995 we were successful in better defining subtidal habitats. However, as expected, both tools at our disposal had limitations.

The ability of sidescan sonar to define subtidal habitats was limited by 1) restrictions on boat path and therefore access to very nearshore zones, and 2) the level of refinement in our ability to translate sonar readings into various sediment classifications. The first issue was particularly evident at the Montague study area (Figure 6), where the subtidal zone is shallowly sloped. As such, very nearshore zones were not assessed by the sonar. A similar issue is evident for small sections of Herring Bay (Figure 9). However, we believe that the slightly offshore data obtained at the Montague area are likely representative of habitat in our "gaps" and, therefore we can "fill" in those gaps in our habitat maps during 1996 sampling with a combination of dive transects and shore observations. The second limitation is only a limitation in that we were unable to delineate habitat as precisely as we had hoped. However, we are able to stratify our sampling into eelgrass, bull kelp, rocky reef, gravel, and silt with the present analysis. Project investigators will continue to record substrate types more precisely, but they will also record their best judgement as to how each sampling site fits into the sidescan sonar habitat classification. Our contractor has made a number of recommendations that may allow us to better delineate material types in the sand/gravel category (Appendix B). However, we will assess the need for this additional effort based on the results of the 1996 field collections.

Our second effort to better focus data collection related to what habitats are generally used during foraging by sea otters and harlequin ducks. In previous work by Bodkin (pers. comm.) we've found that >80% of otters are located within the 40 m bathymetry contour. In addition, various unpublished accounts suggest that harlequin ducks forage mainly within 10 m of the shoreline. For each species, this information can be used as per the general approach presented in Figure 3 to better define "available" habitat and therefore focus our calculations of total prey in those habitats (both defined by substrate type, depth, and/or distance from shore). Because the level of assessment in this portion of the analysis is broad (e.g., depth <40 m or distance from shore <10 m) the limitations identified in the bathymetry model are minor and should not add significant uncertainty to our prey availability models.

Demographic.-- *Sea Otter:* The proportion of prime age beach-cast animals was higher than expected based on previous collections we view as reflecting normal mortality patterns (1976-1984; 1992-1994). However, the 1995 pattern was not significantly different from those observed in "normal" years, perhaps due to the small 1995 sample size (n=11).

Three previous surveys of sea otter abundance in western PWS were completed prior to 1995 (1992-1994). Estimates from 1993 (2054) and 1994 (2228) are statistically similar to the 1995 estimate (2157). Although the 1992 point estimate (3493) is higher than those in subsequent years, variance from the 1992 survey was high (se=937) and we are cautious about drawing conclusions from this comparison.

Within western PWS, however, differences in sea otter densities continue to be observed. The Montague study area had nearly an order of magnitude greater density ($3.4/km^2$) than did the Knight Island area ($0.53/km^2$).

Although reproduction surveys did not find significant differences between oiled and unoiled areas, reproductive potential is one of the last population parameters to decline. In fact, pervious NRDA studies did not demonstrate decreased reproductive performance of sea otters in oiled areas (Monnett and Rotterman 1992).

We conclude, based on our total demographic findings for 1995, recovery of sea otters is not apparent. Therefore, we believe that continuation of the sea otter element of NVP is warranted.

Harlequin Duck: Our 1995 collection and surgery protocols were successful and allowed us to implement the female survival component of NVP. We have included data generated from the 1995 telemetry and subsequent monitoring of survival into 1996 in this report to demonstrate the success of our approach. The difference in patterns of adult female survival between treatments is particularly important. Female survival is a critical factor affecting population dynamics of species, like harlequin ducks, that are long-lived and have relatively low annual productivity (Goudie et al. 1994). Breeding philopatry of sea ducks is thought to be high (e.g., Savard and Eadie 1989). If wintering site fidelity also is high (see Limpert 1980), winter survival would directly influence annual changes in specific populations.

Models have demonstrated that population dynamics of harlequin ducks are extremely sensitive to changes in adult survival (Goudie et al. 1994). Annual survival rates of stable populations are estimated to be about 85%; survival rates of birds on the unoiled site seem to be consistent with that figure, while those on the oiled sites are low. Because harlequin ducks may be particularly sensitive to environmental perturbations due to their small body size, effects of the oil spill on their health or food source could have significant population ramifications.

We conclude, based on our total demographic findings for 1995, recovery of harlequin ducks is not apparent. Therefore, we believe that continuation of the harlequin duck element of NVP is warranted.

River Otter: No FY 95 field activity was proposed or conducted.

Pigeon Guillemot: No FY 95 field activity was proposed or conducted.

Health.-- *Sea Otter:* The methods used for isolation of peripheral blood mononuclear cells from heparinized sea otter blood samples for immune function assays were shown to be valid. The procedure resulted in well defined cell bands that were easily harvested. The cells froze down as expected and methods used to transport the cells appeared to maintain them at a somewhat constant temperature. However, a small liquid nitrogen tank (Dewar, CP 65) will be used to hold and transport cells in future work, to insure that samples are maintained at a constant temperature. Assessment of cell viability and number at Purdue University gave satisfactory results and optimal conditions for evaluating cell mediated immunity using isolated cells have been determined. In summary, this method can be applied to sample collections for sea otters and river otters as planned in 1996.

Serum chemistry values on the six sea otters caught in eastern PWS were within ranges previously observed and appeared normal. These specimens provide an additional control data set for continuing blood sample collections.

Harlequin Duck: We also were successful in applying TOBEC methods to assess body condition in harlequin ducks. Harlequin ducks may be particularly sensitive to body condition effects because of the severe weather encountered in northern wintering areas (Goudie and Ankney 1986) and we know that body composition affects reproduction through initiation date and clutch size effects in other duck species (Esler and Grand 1994). Although body weight does not directly reflect body composition, the differences we have found to date in body weight dynamics of female harlequin ducks through molt indicates that assessing body condition dynamics will lend critical insights into harlequin duck recovery. Therefore, with the calibration of the TOBEC after the approved 1996 take of harlequin ducks, we will have a valuable tool to assess condition factor, its relationship to survival and reproduction, and the overall health of this species.

River Otter: No FY 95 field activity was proposed or conducted.

Pigeon Guillemot: No FY 95 field activity was proposed or conducted.

Trophic Assessments.-- The 1995 NVP field season concentrated on refining methods to accurately and cost effectively estimate the abundance of key prey items of our top vertebrate predators. In particular, much effort was expended to assess invertebrate abundance, size class distributions and sources of variability. Based on the 1995 effort, the standard operating protocols for collection of the various invertebrate prey have been modified and gone through subsequent statistical review. Because each of the key prey items requires specific sampling protocols for best efficiency, key sampling points and recommendations are made separately for each below.

Intertidal Clams: Our efforts to identify intertidal clam sites and test methods were successful in 1995. We identified 11 hardshelled clam beaches within our study areas during our 1995 reconnaissance surveys. Based on power analyses of data in Houghton et al. (1993), 37 sites are needed to detect 50% effect with 80% power. However, this is logistically impractical. Therefore, we will sample 24 randomly located 100 m-long sites during an 8-day low tide series in June and July 1996; 12 sites will be located in Bay of Isles and 12 along Montague Island. This equates to >30% of the clam habitat of the respective sites. We also examined the number of optimal replicate quadrates to sample (Figure 17). It appears that, in general, the cumulative densities seem to moderate after 5-7 replicates. Therefore, 5 replicates will be collected from each site. The littleneck clam is the target species since it was the predominant species in our study areas and only a few *Saxidomus giganteus* were collected.

Subtidal Clams: Although clams are a common component of sea otter diets in our study areas (Bodkin pers. comm.), few subtidal clams were collected with the protocols in place for the brief sampling conducted July 2-9, 1995. Never >4 clams nor an average density of 0.8 per 1/4 m^2 was collected. In addition, sample variability was high (e.g. Montague, average 0.79, sd=1.12). Modifications of the 1995 protocol have been implemented to determine if clams are if fact rare or their apparent rarity is an artifact of a highly clumped distribution coupled with an insufficient sampling effort.

Mussels: The coefficient of variation of mussel density for rocky shores was nearly 2.5 times that for mixed shores leading one to conclude that stratification with optimal allocation is warranted for mussel sampling in 1996. Other modifications in the sampling protocol for mussels proposed for 1996 are as follows. Shore segments will be of uniform length (200 m) and will be selected for sampling using a systematic sampling scheme. Mussel coverage along each vertical transect and within each sampling plot will be estimated using a quadrat subdivided into 1/16's. The number of times points of intersection of the lines subdividing the quadrat cover a mussel will be summed and converted to a percentage to estimate mussel coverage.

Urchins: Past studies in Prince William Sound indicate that sea urchins are rare. Their status can be summarized as follows: 1) urchins are rare, 2) distributions are highly clumped, 3) there has been a possible increase in density since 1990, 4) in the intertidal, urchins are generally found in shallow sloping cobble/gravel beds at between + 0.5 and - 0.5 m, 5) there are no apparent "preferred" habitats in the subtidal, 6) urchins density decreases and size increases with depth, and 7) many animals are cryptic and hide beneath rocks. These observations have lead us to a staged sampling approach in 1996; consisting of random sampling, as well as more intensive sampling of urchins within intertidal habitats and aggregations. In 1996, we will sample 30 randomly selected sites in each of two areas: Montague and Herring Bay/Bay of Isles. We will sample within 3 depth strata at each site. In addition, we will intensively sample randomly selected "preferred" intertidal habitats as well as any aggregations observed during our random sampling.

Copredators of Sea Otter Prey: We proposed to examine the distribution and food habitats of a number of copredators of sea otters to determine if they could potentially confound our interpretation of data for the hypothesis that food availability is constraining recover of sea otters. We originally proposed to examine a suite of invertebrate predators and several sea ducks. Subsequent to our original proposal and action of the Trustee Council in December 1995, an additional array of potential avian copredators have been add for examination. In 1995, however, we collected information related only to invertebrate copredators. We found that our proposed methodologies were adequate. The seastar *Pycnopodia helianthoides* was observed in the greatest densities at all study areas, while the crab *Telmessus cheiragonus* was the second most observed invertebrate predator. However, subsequent collections in winter found few *Telmessus*. Power analyses were completed for densities of *Pycnopodia helianthoides* that suggest large sample sizes will be required to adequately determine if densities differ between the study areas. Further adjustments in protocols are being considered to reduce sample size needs.

Harlequin Duck Prey: Only one rocky site was assessed for biomass data of harlequin duck food. Methods appear sufficient to obtain adequate estimates and a complete sampling protocol will be implemented in 1996 per reviewed operating procedures.

Pigeon Guillemot and River Otter Prey: Very preliminary work was conducted to assess fish prey for these two top predators in 1995. We have initiated coordination and cooperation with both SEA and APEX to deal with the commonly shared problem of estimating nearshore demersal and schooling fish. Our 1996 work will be done in conjunction with those programs with NVP concentrating on nearshore demersal components of the issue.

CONCLUSIONS

The six major tasks proposed for initiation in the 1995 Nearshore Vertebrate Predator work plan were successfully completed. We are comfortable that demographic and health protocols are sufficient to provide desired data. Prey sampling issues have been examined and either protocols determined adequate or modified to provide better estimates of food density and size composition. The data management plan, statistical oversight, and data serving objectives set forth for 1995 were met and are capable of supporting this dynamic project through its completion in 1999.

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APPENDIX A: Data Management Plan: Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators, Draft.

Data Management Plan

Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

Draft of 12-21-95

Prepared for:

National Biological Service
Alaska Science Center
1011 East Tudor Road
Anchorage, AK 99503-6199

Dr. Leslie Holland-Bartels
Chief Scientist

Prepared by:

Coastal Resources Associates, Inc.
1185 Park Center Drive, Ste. A
Vista, CA 92083

Dr. Thomas A. Dean
Project Leader

Table of Contents

Section 2. File Directories, Flow Charts, Field and Laboratory Data Sheets, and Raw Data File Formats for each project. Also included is a Data Dictionary that describes variables used in raw data files.

Data Management Plan

Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

1.0 Introduction

The study of injury to, and recovery of, nearshore vertebrate predators (NVPs) following the *Exxon Valdez* oil spill (EVOS) is a multi-disciplinary project, involving scientists with varied areas of expertise representing several organizations. The success of the project (hereafter termed NVP) depends in large part on the exchange of information among scientists within the program, between the NVP project and other projects sponsored by the *Exxon Valdez* Oil Spill Trustee Council, and between the project and the community. Effective communication of information can only be achieved through the use of a data management plan that provides a common language for the data gathered, a common means of information transfer, and a mechanism for public access to the data.

The following provides an outline of the data management plan to be used by the NVP project and gives steps for implementation of the plan. The specific goals of the plan are:

1. Ensure accuracy and maintain integrity of the data as gathered by each investigator.
2. Provide for an efficient exchange of information among investigators and between the NVP and other projects.
3. Provide a mechanism by which data and reports can be archived.
4. Provide a framework by which analyses presented in reports can be traced to the underlying data obtained during the initial data collection.
5. Provide a mechanism by which managers and the public can gain access to the information obtained.

There are several keys to the successful implementation of such a plan. First, the plan must be a written document. Second, there must be a management framework that clearly defines responsibilities for the plan's implementation. Third, all Principal Investigators and their staffs must be trained to ensure that all data are obtained and transferred as specified by the plan.

It should be stressed that the following is an initial version of the plan. This document will provide a framework by which a more complete plan can be produced and implemented as the project progresses. The complete plan will include Standard Operating Procedures, Field Data Sheets, Data Standards Documents, and Data Dictionaries for each of the individual projects. Here we provide preliminary versions of field data sheets, raw data files, and data dictionaries (see attachments). The Plan is intended to be a "living" document that will change as procedures are modified according to the needs of each investigator. While we have attempted to anticipate all of the possible permutations, there are almost always changes required. One seldom is able to anticipate all of the potential problems associated with field studies, and the subtleties of the data being gathered.

This preliminary plan does not provide details as to the physical means of information transfer, or protocols for such transfer. These will be described at a later date.

2.0 Project Management and Information Flow

The project organization is outlined in Table 1. Dr. Leslie Holland-Bartels will act as Chief Scientist for the NVP project. Her responsibilities with respect to data management, will include selecting a Data Manager and ensuring that all Principal Investigators adhere to the data management plan. All data collected by individual Principal Investigators will remain their intellectual property. However, it is also understood that all data will be accessible to each of the Principal Investigators and the Chief Scientist. After collection and timely review, all data files will be submitted by the Principal Investigators to a central data clearinghouse maintained by the NVP Data Manager.

It will also be the responsibility of the Chief Scientist to ensure that hardware and software are provided for the transfer and archiving of information, and for the development of transfer protocols.

It will be the responsibility of the Data Manager to maintain the central database, and to provide an updated index or metadatabase to Principal Investigators, the Chief Scientist, to the Trustee Council, and to the public upon request. The Data Manager will also be responsible for dissemination of information in the database to the Chief Scientist or to other Principal Investigators upon request. Any use of the data by persons other than the Principal Investigators, either in presentations, reports, or publications will require the permission of the Principal Investigator who gathered the data. All such requests and subsequent approvals or denials for use will be routed through the Data Manager and reviewed by the Chief Scientist.

It will be the responsibility of each Principal Investigator to ensure that the data presented to the Data Manager is in an appropriate, pre-determined format, and is an accurate representation of the data as collected. The Principal Investigators will designate specific persons on her/his staff who have authority to submit data or request data from the Data Manager.

3.0 Written Documentation

Written documentation will primarily be provided in the form of Standard Operating Procedures (SOPs). An example of an SOP is given in Appendix A. All procedures, including field operations, laboratory analyses, data management, data distribution, report production, and the archiving of files will be provided. In many cases, SOPs will be project specific and will be provided by individual Principal Investigators. Other SOPs (e.g., procedures for transfer of data files) will be generic to all projects and will be produced by the Data Manager.

All Standard Operating Procedures will contain the author's name, the draft number, the effective date of the SOP, a brief statement of its purpose, and the specific training required to use the SOP.

4.0 Training

Before an SOP can be used, all of those persons who will utilize the procedure must be trained. The level of training will be dependent on the procedure and will be at the discretion of the Principal Investigator. At a minimum, all users will be required to have read the SOP, and to have demonstrated their understanding of it. More elaborate training procedures involving hands on training and proficiency testing may be required in some instances.

5.0 Structure of the Data

5.1 Introduction

In order to maintain a common database and to ensure efficient dissemination of data, a common format of the data will be required of all individual projects. The following provides guidelines on the structure of files and their format.

5.2 Types of Files

There will be seven types of files maintained (Table 2). These include:

1. Field or laboratory data files - Data as initially recorded on field sheets, lab notebooks, etc.

2. Raw data files - Computer file with the edited data from field or laboratory data sheets

3. History files - Computer text files associated with each raw file that contains of history of when data were entered and/or edited, and a description of edits

4. Analysis files - Computer files that are used to manipulate or provide summaries of statistical analyses of the raw data

5. Metadata file - Computer text files that describe the contents of each raw, analysis, or output file

6. Output files - Computer output provided by analysis

7. Report file - Computer word processing, spreadsheet, or image files that make up a particular report

A brief description of these files and specifications for associated file names and file types are given in Table 3.

All files will be maintained by Principal Investigators. A copy of the raw data files and associated history and metadata files will also be placed in a common database maintained by the Data Manager.

Each individual principal investigator will create and maintain raw data files, using software of her/his choosing. However, all files presented to the Data Manager will be either in ASCII or ArcInfo format. Investigators may wish to use DBMS copy software to create ASCII files from those produced using other tools (e.g., SAS).

5.3 Analysis Flow Charts

Any presentation of data in a report will be accompanied by an appendix containing a flow diagram that describes the steps taken in producing the table or figure (Table 4). This flow chart will allow one to trace the summary presentation back to field or laboratory data sheets. The diagram will indicate all the names of any intermediate databases used in the production of the final table or figure, as well as the names of all analysis files.

5.4 File Structure

An example of each file type represented in the flow diagram described above (Table 4) is given in tables 5 through 9. Each variable contained in raw files (Table 6) will be described in an associated data dictionary that gives the format, acceptable range, and a brief description of each variable in the file (Table 10). The variables used in raw data files can be unique to a given project or can be shared by several projects. All projects are to be consistent in their naming of variables, so that data can be easily shared among projects.

In addition, there will be a database that describes the location of all sampling sites (Table 10). This "site location" database will list all sites sampled by each of the projects, and will describe the location of the sampling sites based on a coordinate system that is the same for all projects. A separate site location database will be maintained by each project. These databases will be named using the two letter project code followed by "SITLOC'. The site location databases will be updated as new sites are added, and updated site location databases for each project will be forwarded to the Data Manager. The Data Manager will maintain a "common" site location database that is a combination of all the individual site location databases from each project. This database is critical to future linking of information from separate projects. For example, it may allow for the efficient determination of prey abundance within a certain region for which we also have estimates of river otter abundance. In addition, this database will allow us to easily place all sampling sites on a common map.

The site location database will contain a unique name for each site sampled. The sites will be named using the two letter project code, followed by a two letter location code, and a three digit number for sites within that area that are sampled by the given project.

5.5 Metadata

Metadatabases will be developed to facilitate access to information in raw files, intermediate databases, and analysis files. Separate metadatabases will be developed for geospatial data (GIS coverages) and for non-geospatial data. These will contain descriptions of each file, the geographic range and time scales covered within each file, and information that would allow for the initial evaluation of source data (Tables 12 and 13). It is anticipated that software will be produced that will allow for efficient searching and access of information contained in the files. Principal investigators will be responsible for updating metadata information sheets associated with each file and forwarding these to the data manager.

6.0 A Time Line for Data Management Procedures

The following is a time line for critical events in the data management process.

- Chief Scientist selects Data Manager
- PIs select individual data managers for their project
- PIs and Data Manager write SOPs, including field/laboratory data sheets, raw data file structure, and associated data dictionaries
- Data Manager reviews and approves SOPs
- Field data collected
- Data from field sheets are entered into a raw data file

- The raw file is checked and edited if necessary

- A history file is produced

- The raw file and associated history file are submitted to the Data Manager

- The Chief Scientist and Data Manager create metadatabase software for searching and access of files

- The Chief Scientist and Data Manager provide hardware, software, and protocols for the transfer of information to the Data Manager, and from the Data Manager to Principal Investigators, Mangers, and to the public

- Metadata information sheets are produced by Principal Investigators and are forwarded to the Data Manager

- At monthly intervals, the PIs submit newly created or edited raw files, history files, or metadata sheets to the Data Manager. If no new or edited files are available, the PI will supply the Data Manager with a short written statement to that effect

- PIs or their designees conduct analyses and prepare flow charts for same PIs write reports and submit to the Chief Scientist along with flow diagrams PIs archive field data, raw data files, history files, analysis files, and reports

- Data Manager archives raw data files, history files, analyses flow diagrams, metadata, and overall project report

7.0 Checklist for submissions to the Data Manager

The following is a list of items that each Principal Investigator will submit to the Data Manager.

1. Standard Operating Procedures for collection of data

2. A flow diagram describing the path from collection of field data through production of a chart or table in a report

3. Raw data files (including a site location database)

4. A history file corresponding to each raw data file

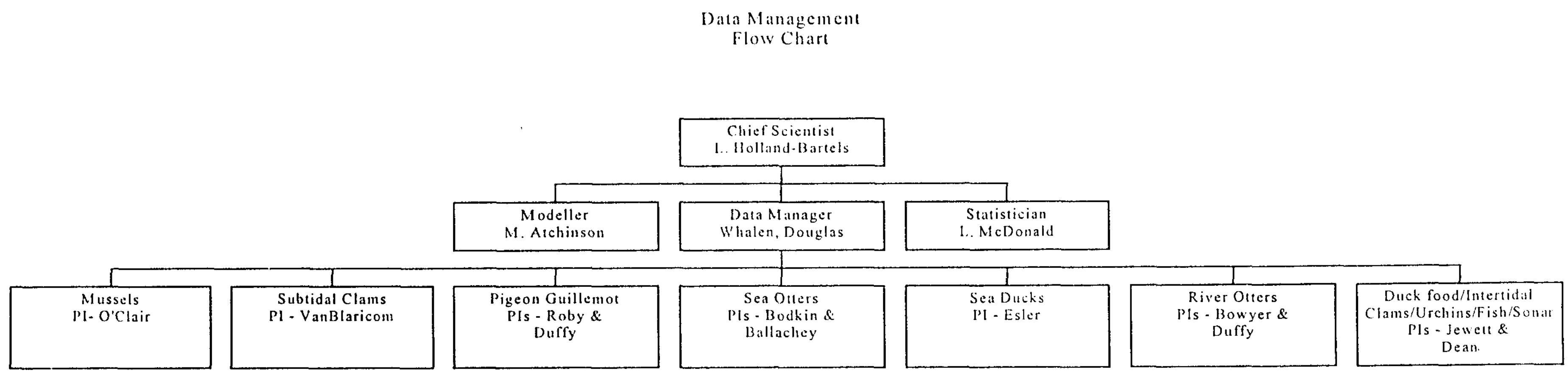
5. A metadata file corresponding to each raw data, intermediate database, and analysis file

6. Updates to the data dictionary

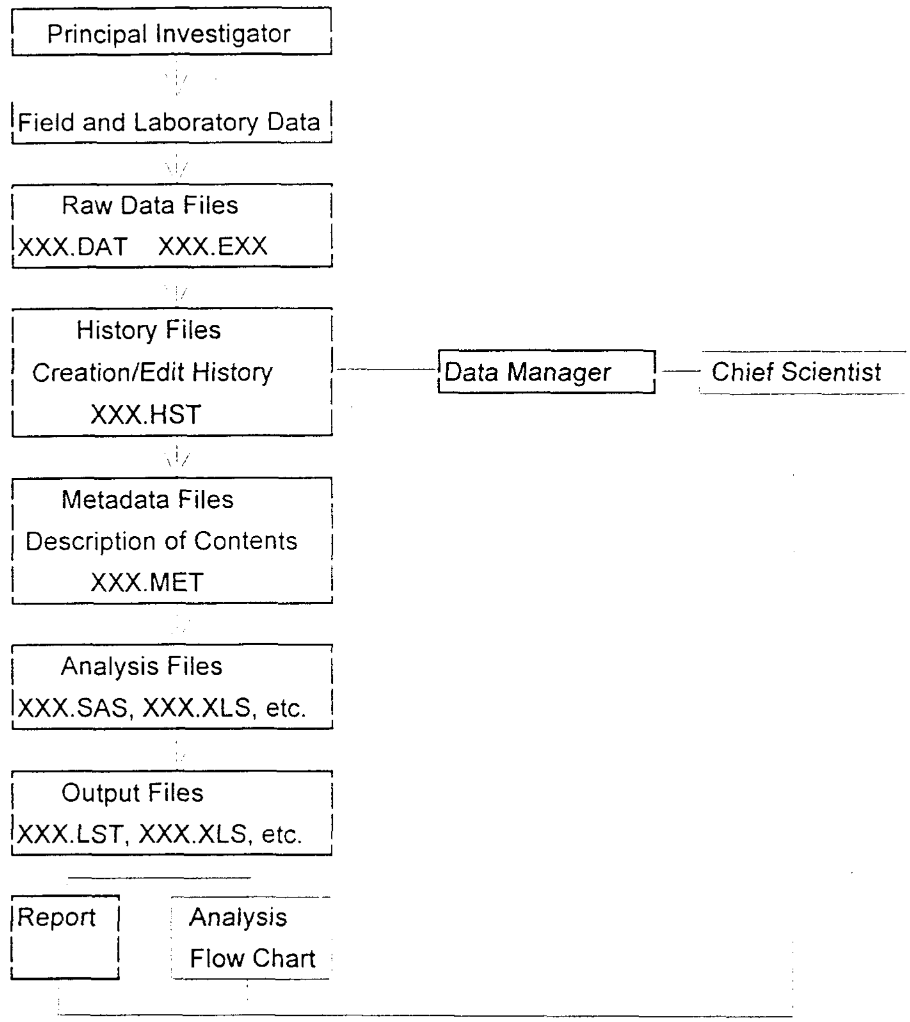
7. Updates to the list of codes for variables in the data dictionary

8. Reports as requested by the Chief Scientist

Appendix A. Table 1. Flow chart for data management of the Nearshore Vertebrate Predator project.



Appendix A. Table 2. Flow chart showing file types and flow of data for NVP project.



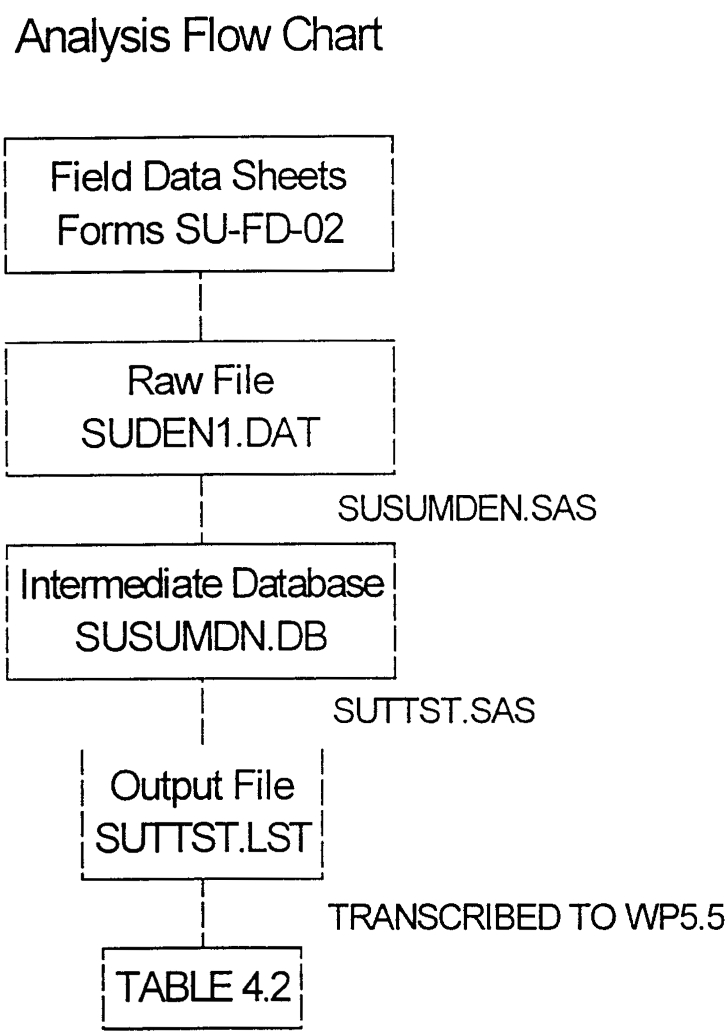
Appendix A. Table 3. Description of file types used in the Nearshore Vertebrate Predator project.

Category	File Name	File Type	Description
Field/Lab Data	None specified	None specified	Field data sheets, notebooks, data tapes, sonar records, etc.
Raw Data	Project code as first 2 digits	.dat (for ASCII) or .exx (for ArcInfo)	Computer file with data from field that has been entered, checked, and edited [1]
History	Same as corresponding Raw file	.hst	A text file (ASCII) containing date raw file was created, name of person who created file, date edits were made, who edited the data, and a short description of edits
Analysis	None specified	determined by software (e.g. .sas, .xls, .wk1)	Any file which produces analyses, tables, charts, graphs, etc. For example, a SAS or EXCEL file that computes mean abundance from raw data
Output File	None specified	none specified	Output from analysis program (In some cases, output may be embedded in analysis file)
Metadata File	Same as corresponding raw file	.met	A text file (ASCII) summarizing information contained in a raw data, intermediate database, or analysis file.
Report File	AAAXXXXA(2)	WP	First 2 letters are the project code. 3rd letter is the code for type of report- (M = monthly, Q = quarterly, A = annual, F=final). Numbers are the month and year of the initial draft of the report. Last letter indicates draft number - (a = 1, b = 2, etc.).

[1] Note: All raw files should be "sparsed". That is, all zero values should be included. For example, if no harlequin ducks were observed on a particular bird transect, then a "0" value (not a blank or missing value) should be entered. A " • " should appear in raw files for data that are truly missing. [2] Format conventions: A = Alpha code, N = Numeric code.

Appendix A . Table 4. Example of an analysis flow chart.

Report: SUQ0995A.WP
Author: Dean et al.
Date: 15Sep95
Output: Table 4.2



Appendix A. Table 5. Example of a field data sheet.

Sea Urchin and Sea Star Densities on Transects
Form SU-FD-01

Name:______________________________ Date:____________________

Site number:________________________________ Depth Stratum:___________

Depth (ft) Actual:____________________ Depth (ft) Adjusted to MLLW:__________

Time In:_____________________________ Time Out:________________

Transect Coordinates (WGS 84)

LAT 1.________ 2.________ 3.________ 4.________ 5.________

(start) (end)

LONG 1.________ 2.________ 3.________ 4.________ 5.________

Transect width (m)_______

Distance	Quad Size	Taxa	Vegetation Type	Substrate Type	Count	Notes

Appendix A. Table 6. Example of a raw data file.

SUDEN.DAT

SITENO	DATE	TRANSDIS	QUADSZ	VEGTYPE	DEPTH	CNT
SU-BI005	14-Jul-95	0.5	0.25	CL	-0.75	0
SU-BI005	14-Jul-95	5.5	0.25	CL	-0.50	2
SU-BI005	14-Jul-95	10.5	0.25	CL	-0.50	3
SU-BI005	14-Jul-95	15.5	0.25	NA	0.00	23
SU-BI005	14-Jul-95	20.5	0.25	NA	0.50	34
SU-BI005	14-Jul-95	25.5	0.25	NA	0.00	24
SU-BI005	14-Jul-95	30.5	0.25	CL	-0.50	13
SU-BI005	14-Jul-95	35.5	0.25	CL	-0.50	4
SU-BI005	14-Jul-95	40.5	0.25	CL	-0.75	0
SU-BI005	14-Jul-95	0	4	NA	-0.50	115
SU-BI006	15-Jul-95	0.5	0.25	CL	-0.75	1
SU-BI006	15-Jul-95	5.5	0.25	CL	-0.50	0
SU-BI006	15-Jul-95	10.5	0.25	NA	-0.50	32
SU-BI006	15-Jul-95	15.5	0.25	NA	0.00	49
SU-BI007	15-Jul-95	0	1	ZM	-3.00	52

Appendix A. Table 7. Example of a history file.

File Name - SUDEN.HST

Date	Name	Action	Description
04JAN96	T. Dean	entered data	none
05JAN96	T. Dean	checked data	no errors found
08JAN96	T. Dean	edited data	changed zero to missing value for sea urchin density, J #3
23MAY97	T. Dean	edited data	changed depth from -2.8 to -2.5 for data of 06JUL95. Tide corrections were applied incorrectly.

Appendix A. Table 8. Example of an intermediate database.

Mean Sea Urchin Densities
File name - SUSUMDN.DB

Site	Date	Depth	Depth	Habitat	Transect	#			# on			
		(m-MLLW)	Stratum	Type	Area (m^2)	J	HG	A	Rock	Cobble	Gravel	Sand
BI-1	6-Jul-95	2.8	S	SR	192.6	8	1	2	1	10	0	0
BI-2	7-Jul-95	2.1	S	SR	185.6	0	1	0	1	0	0	0
BI-3	7-Jul-95	3.0	S	SR	208.8	0	0	0	0	0	0	0
KI-1	8-Jul-95	1.0	S	SR	219.3	0	6	2	2	7	0	0

Appendix A. Table 9. Example of table output.

Sea Urchin and Sea Star Densities

Table 4.2 Mean densities (no. m^{-2}) of sea urchins at shallow oiled (without sea otters) and nonoiled reference (with sea otters) sites in Prince William Sound in 1995.

	number m^{-2}			
Habitat	Oiled	Reference	n	P
Sheltered rocky	0.01	0.02	4	0.99
Sheltered cobble/gravel	0.05	0.01	4	0.92
Sheltered mud/sand	0.81	0.04	4	0.02
Exposed rocky	0.05	0.00	4	0.99
Exposed cobble/gravel	0.00	0.00	4	----

Appendix A. Table 10. Example of data dictionary for raw data files.

DATA DICTIONARY FOR
RAW DATA FILES

Variable Code	Variable	Format	Example	Range	Notes	Project
ACTIVE	Animal or latrine site active	A	Y	Y, N	Y = yes, N = no	RO
AGE	Age	AAA	A	A, J, U, SY, TY, ATY	A = Adult, large body size & grizzled head color J = Juvenile & young-of-the-year otters, determined by small body and dark coloration (juvenile) and pup-like pelage for POY U = undetermined SY = Second year TY = Third year ATY = After third year	SO, RO, SD, PG
AGECLASS	Age class	AAA	POY	POY, JUV, AD, AA, UN	POY = Pup of year, 0-1 years old JUV = Juvenile, 1-2 AD = Adult, 2-8 AA = Aged Adult, > 9 UN = Unknown	SO
AGEEST	Age estimate	XX	10	0 - 15	in years	SO, RO

Appendix A. Table 11. Example of a site location database.

SUSITLOC.DAT

SITEN0	AREA	TIDEZONE	TIDEZON2	HABTYPE	OILCAT	SEGTYPE	BUFFER	AUTME	AUTMN	POSMTD
DF-MI001	MI	S	I	ER	R	PT	30	482981	6674721 ..	MAP
DF-MI002	MI	S	I	ER	R	PT	30	482004	6674809 ..	MAP
DF-MI003	MI	S	.	SR	R	PT	30	484456	6675678 ..	DGPS

Appendix A. Table 12. Examples of Metadata information sheet for non-geospatial data.

SUNDEN1.MET

Data set name:	SUDEN1.DAT
Date:	1 June 1997
Originator:	T.A. Dean, Coastal Resources Associates, Inc.
Description:	Density data for sea urchins, sea stars, and crabs.
File Type:	Raw
Source(s):	Field Data Sheets - SU-FD-02
Date(s) of Source Data:	8 July 1995 - 31 July 1996
Data Processing:	None
Data Structure:	ASCII File
Data Processing:	None
Analysis Software:	None
Area Covered:	MON, KNI.
Source Information:	Diver observations on randomly selected transects (200 m long x 2 wide) at randomly selected sites, within each of 2 depth strata (0-3 m and 3-6 m).

Appendix A. Table 13. Example of Metadata information sheet for geospatial data.

SUBSTRATE.EX000

Data set name:	SUBSTRATE
Originator:	T. A. Dean, Coastal Resources Associates, Inc.
Description:	Map of subtidal substrate distributions in western PWS.
Area Covered:	Approximately 150 km x 200 m, including parts of Montague Knight, Naked, Chenega Islands, and the Jackpot Bay area.
Attribute Accuracy:	To be determined
Minimum Mapping Unit:	50 m x 50 m
Positional Accuracy: GPS.	± 10 m. Navigational fixes were determined using differential and were recoded every 100 m.
Source Info:	Side-scan sonar record produced by Watson Co.
Date of Sources Data:	August, 1995
Scale of Source Data:	N/A
Data Processing:	Data were obtained by hand digitization of sonar records. The digitized data were entered into a DXF file, using AUTOCAD and later imported to PC ARC/INFO.
Data Structure:	Polygon
Attributes:	Substrate types of rock, gravel, sand, silt, eelgrass, and bull kelp. Substrate size distributions correspond roughly to size distributions that are:

Rock	=	> 50 mm
Gravel	=	≥ 1 mm < 50 mm
Sand	=	≥ 0.0.25 mm < 1 mm
Mud	=	< 0.0125 mm

Eelgrass (*Zostera marina)* and bull kelp (*Nereocystis luetkaena*) are plants that provide strong sonar returns and can obscure underlying substrate. Eelgrass generally grows on sand or silt, and bull kelp grows on rock reefs.

APPENDIX B: Seafloor Material Substrate Investigation, Final Report.

FINAL REPORT

NATIONAL BIOLOGICAL SERVICE - UNIVERSITY OF ALASKA FAIRBANKS

PRINCE WILLIAM SOUND
SEAFLOOR MATERIAL SUBSTRATE INVESTIGATION

A Component Of

"MECHANISMS OF IMPACT AND POTENTIAL RECOVERY OF NEARSHORE VERTEBRATE PREDATORS"

REPORT No. WC95A05.01

1995

Prepared For: National Biological Service - University Of Alaska Fairbanks

Submitted By: Watson Co.
2440 East Tudor Road, #1141
Anchorage, Alaska 99507

SEAFLOOR MATERIAL SUBSTRATE INVESTIGATION

A Component Of
"Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators"

1.0 INTRODUCTION

1.1 General

Watson Company was retained by the National Biological Service and the University of Alaska, in support of the study "Mechanisms of Impact and Potential Recovery Of Nearshore Vertebrate Predators (NVP)" to provide technical services to investigate seafloor substrate types at five locations in Prince William Sound, Alaska. The project required the investigation of seafloor substrate types by the use of geophysical methods. The areas surveyed, as specified by the scope of work, were portions of Montague Island, Bay of Isles, Herring Bay, Jackpot Bay, and Naked Island. Additional areas were surveyed as field time allowed and consisted of seven small islands, a portion of Storey Island and an extension of the coverage for Naked Island.

The substrate types delineated within the scope of this program are specified as predominant as classified by the Wentworth Grain Size Scale utilizing sand/gravel as a category. Due to the extremely well mixed nature of the seafloor materials it was necessary to employ sand/gravel as a broad category.

An integral part of this report is to present recommendations for further analysis of the data set. This additional analysis can be accomplished utilizing an image processor to record signatures from the data, and then correlating these with seafloor samples, to delineate materials contained within the sand/gravel category.

1.2 Purpose

The purpose of this program was to investigate a method to delineate predominant substrate types to enable the project biologists to make correlations between seafloor material types and biota. Specifically, this data set was collected to provide information that can be used to study the impact and recovery of nearshore vertebrate predators due to the effects of the 1989 oil spill.

1.3 Scope of Services

The original scope of services for the seafloor substrate type program included site specific data acquisition in five locations. The seafloor investigation at the Montague Island location consisted of surveying approximately 50 kilometers of coastline and nearshore environment. Herring Bay was surveyed and consisted of approximately 35 kilometers of coastline and nearshore environment. Bay of Isles and Jackpot Bay were surveyed and consisted of approximately 25 kilometers of coastline and nearshore environment each. Naked Island seafloor investigation consisted of approximately 20 kilometers of coastline and nearshore environment. It should be noted that the extent of coverage for Herring Bay and Naked Island was increased.

The expanded scope of services included Jackpot Island, three small unnamed islands in the vicinity of the Bay of Isles, three small unnamed islands in the vicinity of Herring Bay, a small portion of Chenega Island, and a small portion of Storey Island.

1.4 Report Format

The accompanying seafloor substrate type program report is presented with the following format and order. The program introduction, its purpose and scope of services are covered in the preceding text. The seafloor investigation equipment is in Section 2.0. Section 3.0 discusses tidal reduction and site specific findings. Section 4.0 is a recommendation for the further analysis of the data and subsequent benefits of the additional analytical work for the NVP project, to be executed by the National Biological Service and the University of Alaska, Fairbanks. Section 5.0 has our conclusions regarding the project. The closure is at the end of this report in Section 6.0.

Within Section 3.0 of the report reference is made to specific figures. The figures are numerically progressive and accompany the report.

1.5 Limitation of Services

This report is intended for use only in accordance with the purpose described herein. It should be understood that the presentations contained within this report are based on the data set collected in the field, and controlled by assumptions such as travel time of sound through water, water turbulence, and approximate location coordinates. Therefore, our analysis is limited, as actual site conditions may vary. It should be noted that the findings within this report are apparent as seafloor samples were not collected for all areas.

1.6 Acknowledgments

We appreciate this opportunity to present the findings of this program to the investigators of the NVP project. We hope this program is of value to you. Watson Company would like to acknowledge the support and service provided by Mr. Stephen Jewett of University of Alaska, Dr. Tom Dean of Coastal Resource Associates, Dr. Holland-Bartels and Mr. Jim Bodkin of the National Biological Service. We would also like to acknowledge Captain Henry Tomingas and his crew.

Watson Company would like to acknowledge Mr. Glenn Aronwits and Ms. Sharon Swendseid for their valuable contribution to this program.

2.0 DATA ACQUISITION

2.1 General

Watson Company performed seafloor imaging and bathymetric data acquisition at the locations within Prince William Sound, Alaska, aboard Fairweather Marine's vessel the R/V Pacific Star. The side scan sonar towfish was housed in a hydrodynamically designed towbody and deployed from the R/V Pacific Star's mechanical platform. An operational summary will be presented later in this section.

2.2 Operational Support by University of Alaska, Fairbanks

University of Alaska's commitment and involvement with the Watson Company's data acquisition consisted of the utilization of their contract vessel the R/V Pacific Star, the use of onboard electronics, including radar and compass to aid in navigation relative to the shoreline. Operations were coordinated with the University of Alaska's representatives Mr. Stephen Jewett and Dr. Tom Dean. The Watson Company representative was kept informed as to the operational priorities of the vessel.

2.3 R/V Pacific Star

The R/V Pacific Star is owned and operated by Fairweather Marine and is under contract to the University of Alaska, Fairbanks. The primary functions of the vessel were to provide a platform for geophysical data acquisition and diver operations and to provide accommodations for the science party and vessel crew. The R/V Pacific Star is a 70-foot fiberglass hulled ocean research vessel. The vessel's covered available aft deck provided adequate area to support the geophysical and diver operations. The Watson Company representative conducted data acquisition during periods when the vessel was not performing other tasks.

2.4 Seafloor Survey Systems

Below is a description of the geophysical equipment utilized for the offshore survey as well as deployment methodology and operations summary.

2.4.1 Odom Precision Fathometer

Bathymetry of the seafloor was acquired with the Odom Echotrack Digital precision depth sounder. A narrow beam transducer was utilized in order to keep acoustic side lobes to a minimum.

The Odom depth sounder has a thermal paper recorder that displays the water depth in meters. The depth sounder transducer is corrected for draft and for the speed of sound in water. The Odom numerically displays the depth on the front panel and outputs the information to the navigation logging device.

The Odom Echotrack Thermal precision fathometer is one of the highest quality commercial digital depth sounders available. The fathometer has an adjustable power output, sequential eventing, and gating capabilities. Illuminated LCD displays and an easy to read thermal recorder with selectable ranges allow for ease of operation.

2.4.2 Digital Side Scan Sonar

Imagery of the seafloor was obtained using the E.G.&G. Model 260 Thermal Image Correcting Digital Side Scan Sonar with the Model 272-TD dual frequency towfish. The towfish operates at 100 kHz or 390 kHz, and transmits two simultaneous "fan-shaped" sonar beams oriented perpendicular to the towfish direction of travel.

An advantage to digitizing side scan sonar data is that the image can be corrected in the axis perpendicular to the direction of travel. The E.G.&G. Model 260 has a bathymetric channel that displays the depth of water under the towfish. This information is used to calculate the horizontal distance to seafloor features from points directly under the towfish.

2.4.3 Deployment Methodology

A side scan sonar towfish was deployed in a hydrodynamic towbody, that was tethered to a stainless steel support cable that was married to the block and tackle line onboard the R/V Pacific Star. The instrument towbody was deployed at a depth of approximately 1 meter below the water surface to optimize towing considerations. The R/V Pacific Star block and tackle is located on the starboard side approximately halfway between the vessel superstructure and the fantail. The towbody was deployed approximately 3 meters from the vessel hull.

2.5 Operations Summary

Mobilization efforts for the program began on July 10, 1995 with hardware and software testing in Anchorage. Transportation to the R/V Pacific Star in Whittier was coordinated through Fairweather Marine's representative Captain Henry Tomingas. Watson personnel and equipment departed Portage, Alaska via train to the vessel location and arrived at the dock in Whittier, Alaska on August 14, 1995.

The weather throughout operations was favorable, with the exception of occasional morning fog. The vessel and geophysical equipment functioned properly throughout the effort, hence no down time was logged.

The vessel radar was utilized to locate the R/V Pacific Star at approximately 100 meters from shore where possible. The captain maintained the vessel in approximately 10 meters of water, or more, where the seafloor relief was steep. Position information was recorded using GPS and indexed with the bathymetry and sonar data at a maximum of 100 meter intervals utilizing Watson Company software. It must be noted due to a number of factors that positioning the vessel 100 meters or less from shore was not possible. Positions from shore were maintained to the best ability of the vessel captain throughout operations. Positioning error was encountered due to shadowing effects of land structures from the differential transmitters. Positioning error was found to be within 20 meters, on average, in comparison with the Rockwell Global Positioning System furnished by the National Biological Service. The differential transmitters were located at Cape Hinchinbrook (LAT 60° 14' 18", LON 146° 38' 48") and Potato Point (LAT 60° 14' 18", LON 146° 42' 00"). The absolute accuracy of the positioning has not been determined. It should be noted that many navigational hazards were encountered and the vessel was required to interrupt the survey to avoid boulders.

Demobilization at the Whittier dock commenced on August 23, 1996 and was appreciatively conducted by all project personnel.

3.0 FIELD STUDY RESULTS

3.1 Tidal Data Reduction

The bathymetry data on the project has been corrected to a standard vertical datum in order to compensate for tidal variation. The bathymetry data was collected at a maximum interval of 100 meters and has an accuracy of better than 15 centimeters, not corrected for tides. Tide gauges were not deployed to collect site specific data during the survey. The bathymetry data was vertically corrected to MLLW utilizing the Micronautics "Rise and Fall" program. This program utilizes predicted tidal constituents and regional information to predict tides for specific locations. The tidal correction was made for specific data-sets based on the nearest location available. The accuracy of the tide corrected depth data is estimated to better than one meter. Sources of error for utilizing predicted tidal data are site offsets, wind surge and local physical influences. The following sections detail site specific information including operation start times and tidal correction locations.

3.2 Site Specific Findings

Target size as specified by project scientists within the data reduction of this program was limited to approximately 100 meters by 100 meters as a high threshold. In most cases minimum target size was considerably less. It should be noted that Watson Company recorded some of the sonar data to magnetic tape for potential postprocessing. The sites that had some of the data recorded are Naked Island, Bay of Isles, Jackpot Bay, Montague Island and to a lesser degree Herring Bay.

The data reduction process included the digitization of the sonar records with a scale of 1 inch equals 25 meters, within the Autocad (computer aided drafting) program. Position error introduced when digitizing data points to the Autocad program were less than 25 meters. All position information, with offsets, was reduced to a workable format in a spreadsheet prior to input into Autocad. It should be noted that subjective seafloor material classifications were made. Diver observations were used to define and verify the subjective classifications. The classifications of predominant substrates for the included figures were made with a high degree of confidence The final product included maps printed on D size drawings and written to disk. The CAD files written to disk are in DXF format for ease of use in standard GIS format.

The survey results included three seafloor classifications that were not initially in the work description. These are eelgrass, bull kelp and shore. The standard classifications are mud (clay-silt), sand/gravel and rock reef. Due to the well mixed seafloor materials the sand/gravel classification, as per the Wentworth Scale, is a category encompassing a wide variation in particle sizes. It is important to note that predominant describes that a particular region has within it's boundaries particles of a specified grain size class.

The project scope of work was expanded to include offshore islands that were surveyed at the request of the project scientists. The additional scope of work included a segment of Storey Island, a segment of Chenega Island, extending the planned coverage for Naked Island, Jackpot Island, three small unnamed islands in Bay of Isles and three small unnamed islands in Herring Bay.

Due to good weather and proper functioning vessel and geophysical equipment the additional scope of work did not add time to the scheduled field work. The additional scope of work did contribute markedly to the data analysis portion of the program.

3.2.1 Montague Island

Field data acquisition commenced on August 15, 1995 at Montague Island. The predicted tidal correction for this area was from Port Chalmers. 60° 14' LAT. 147° 14' LON. The RV Pacific Star returned to Montague Island August 22 to complete area survey. Montague Island is contained within Figure 1 of this report.

3.2.2 Herring Bay

Operations began at 1730 hours on August 17. 1995 at Herring Bay. The predicted tidal correction for this area was from Port Audrey. 60° 20' LAT 147° 46' LON. Herring Bay is contained within Figure 2 of this report.

3.2.3 Jackpot Bay and Chenega Island

Operations were started at Jackpot Bay and Chenega Island area at 1300 hours on August 20. 1995. The predicted tidal correction for this area was from Port Audrey. 60° 20' LAT. 147° 46' LON. Jackpot Bay is contained within Figure 3 of this report.

3.2.4 Bay of Isles

Operations commenced at 0930 hours on August 19. 1995 at Bay of Isles. The predicted tidal correction for this area was from Port Audrey. 60° 20' LAT. 147° 46' LON. Bay of Isles is contained within Figure 4 of this report.

3.2.5 Naked Island

Operations began at approximately 0800 hours on August 17. 1995 at Naked Island. The predicted tidal correction for this area was from McPherson Passage. 60° 40' LAT. 147° 24' LON. Naked Island is contained within Figure 5 of this report.

3.2.6 Storey Island

Operations began at 1130 hours on August 17. 1995 at Storey Island. The predicted tidal correction for this area was from McPherson Passage. 60° 40' LAT. 147° 24' LON. Storey Island is contained within Figure 5 of this report.

4.0 RECOMMENDATIONS FOR FURTHER ANALYSIS

It has been brought to our attention that further analysis may be directed to determine if a specific particle size in the sand/gravel classification is contained within a particular area. A summary of the methods and technology required to execute this is explained below. The following sections briefly describe basic sonar theory and methodologies in the analysis of sonar data and how it would be applied if directed by NBS and UAF.

4.1 Basic Sonar Theory

As the transmitted side scan sonar signals insonify the seafloor, the energy is reflected from the features present. The reflected sonar signals are received by the transducers and amplified and filtered yielding an image analogous to a photograph of the seafloor.

The higher the amplitude of the return signal the harder or more dense the seafloor feature is. An analogy to this would be a tennis ball thrown against a concrete wall where the return would be hard, whereas to throw the ball against a mattress would have a soft return. A hard return or high amplitude signal is reflected from materials such as steel or rock, while a soft return or low amplitude signal is reflected from mud or other unconsolidated materials.

4.2 Signal Processing

While a complete technical description of side scan data processing is not appropriate to this report, the following discussion outlines the principle of signal strength analysis.

The more dense the seafloor material the higher the amplitude of acoustic signal back to the side scan receiver. Return signals can be digitized and corrected for signal attenuation and other physical parameters, including beam angle correction and seafloor grazing angle correction, during processing.

This analysis recognizes extremely fine distinctions in signal amplitude (signal strength) that may then be considered the distinguishing characteristic of a specific seafloor material. In subsequent computer image generation, contrasting colors are assigned to characteristic amplitudes, illuminating the presence of specific materials.

Each seafloor material density has a distinct return amplitude or hardness signature that can be mapped using pseudo colorization utilizing the advanced image processing techniques of the Watson Geophysical Mapping System (WGMS).