*Exxon Valdez* Oil Spill
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# Ecological Factors Affecting the Distribution and Abundance of Forage Fish in Prince William Sound, Alaska; An APEX Synthesis Product

Restoration Project 00163T

Evelyn D. Brown
Stephanie M. Moreland
Institute of Marine Science
University of Alaska Fairbanks
P.O. Box 757220
Fairbanks, Alaska
99775-7220

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**Study history:** This project was initiated after a round of data sharing between the Sound Ecosystem Assessment (SEA) project, Restoration Project XX320, and the Alaska Predator Ecosystem Experiment (APEX) project, Restoration Project XX163. Ecological modelers for APEX (Project XX163Q) were frustrated by the lack of correlation between APEX acoustic data on forage fish distribution in Prince William Sound (PWS) and sea bird foraging patterns. Data from the SEA aerial surveys were provided to the modelers who documented a significant correlation between that data and the sea bird foraging patterns. The disparity in results between the two fish data sets (acoustic and aerial) was primarily due to the shallow distribution of the two main forage species in PWS (juvenile Pacific herring, *Clupea pallasi*, and juvenile Pacific sand lance, *Ammodytes hexapterus*). The depth limitation of acoustic data acquisition (shallow water < 10m and surface waters < 5m) excluded many of the fish schools from observation; unfortunately, many of these shallow schools were the prime targets for foraging sea birds. The principal investigator of this project was asked to present data on broadscale distributions of surface schooling forage fishes in Prince William Sound (PWS) from 1995-1997 during the 1998 annual meeting and review for *Exxon Valdez* Oil Spill (EVOS) science. She was also asked to participate in 1998-99 field logistic planning for APEX as aerial surveys were determined to be important to research goals for the APEX project. In 1998, a proposal was submitted to include aerial surveys for the final two field seasons of APEX (1998 and 1999). In 1999, this project was expanded to include a synthesis of the SEA and APEX forage fish data. The synthesis product is an ecological analysis of factors affecting distribution and availability (as prey to sea birds) of key forage species in PWS. The synthesis includes oceanographic data, combined acoustic and aerial results, and foraging patterns of sea birds and marine mammals observed from aircraft.

**Abstract:** The main objectives were (1) to document forage fish abundance and distribution in Prince William Sound (PWS), (2) provide data to cooperating studies and (2) determine key environmental factors driving forage fish availability as prey for sea birds. Aerial survey results and validations from 1995-1999 were compiled and data queries were fulfilled. Unlike Gulf of Alaska, PWS sea bird parents rely mainly on juvenile forms of Pacific herring and sand lance. Interannual variability in forage fish availability was due to variations in overall abundance and depth distribution. Weekly variability during the sea bird breeding period was largely due to recruiting events of herring and sand lance to nearshore nursery zones (< 1km). Oceanic and climate conditions during the five year period were reviewed, including the strong 1997 El Niño event. Topographical features and population abundance (geographic spread) are the two most likely factors affecting horizontal distribution. Zooplankton, temperature and predation risk are the factors likely affecting vertical distribution. To quantify factors affecting distribution, aerial

survey results must be combined with acoustic data, along with environmental data to created spatially explicit variables. A two-stage analytical approach is described.
**Key Words:** Aerial surveys, *Ammodytes hexapterus*, capelin, *Clupea pallasi*, distribution, eulachon, forage fish, juvenile, kittiwakes, line transects, *Mallotus villosus*, Pacific herring, Prince William Sound, sand lance, sea bird ecology, *Thaleichthys pacificus*

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## Executive Summary

This study was initiated in support of the Alaska Predator Experiment (APEX) program providing data to answer research questions concerning sea bird production and foraging success. In Prince William Sound (PWS), there was a lack of correlation between acoustic data on forage fish distribution and sea bird foraging patterns. However, a significant correlation was found between aerial survey results and sea bird foraging patterns. The disparity between the two fish data sets (acoustic and aerial) was primarily due to the shallow distribution of the two main forage species in PWS (juvenile Pacific herring, *Clupea pallasi*, and juvenile Pacific sand lance, *Ammodytes hexapterus*). The depth limitation of acoustic data acquisition (shallow water < 10m and surface waters < 5m) excluded many of the fish schools targeted as prey by the sea birds. Consequently, aerial surveys conducted under this project became a key component of the APEX project in PWS.

The main objectives of this study were (1) to document spatial and temporal variability in forage fish abundance and distribution in PWS, (2) to provide other *Exxon Valdez* Oil Spill (EVOS) projects with forage fish, jellyfish, and sea bird distribution data to meet their research objectives, and (3) to synthesize existing data and determine how environmental factors affect forage fish distribution and abundance. The field program consisted of aerial surveys coordinated with ground acoustic surveys, oceanographic surveys, zooplankton tows, other net sampling, and underwater video surveys over a five-year period from 1995-1999. Net catches and video footage was used to validate aerial fish sightings. Although the aerial surveys were originally designed to locate fish schools, other features easily observed from the air were recorded, including sea birds, marine mammals, jellyfish aggregations, and other large fish (e.g. salmon sharks. adult salmon). Methods used are cited or included in this report. Data from the aerial survey database was shared with a diverse array of researchers and has been included in publications on jellyfish, river otters, as well as sea bird foraging dynamics/modeling, sea bird reproduction, and behavior.

A total of 26,532 $km^2$ of effective area (incorporates detection correction) was surveyed for fish schools and 91,227 $km^2$ for kittiwakes and gulls from 1995-1999. Fish school, jellyfish, seabird abundance and proportion of birds observed foraging (from the air) varied by month, year and species in the three APEX study. During June and July, herring density and abundance peaked in 1996 and was lowest in 1999. The relative proportion of herring observed among regions varied from year to year. Prior to 1999, availability of age-1 herring was due to first year survival and depth distribution with a high in 1996 and a low in 1997. Age-0 recruitment peaked in 1997 and remained low through the end of the study. Sand lance abundance was low in 1995, increased by 1996 and peaked in 1997, recruiting a month early that year. Sand lance abundance remained relatively high through 1999. Capelin were episodically observed in abundance during 1995 and 1999. Eulachon were anomalously prevalent in 1997 following an anecdotally high incidental catch in commercial fishing gillnets outside the Copper River,.a known spawning location. Kittiwakes (observed from the air) appeared to increase over the five years period while the proportion of birds observed engaged in foraging behavior declined overall. Weekly variability in fish distribution and abundance observed over a six-week

period in July through early August appeared to be due mainly to variations in temporal staging of age 0 herring and sand lance recruitment. Fish school depth and monthly patterns of depth distribution varied between sites and years. In general, juvenile herring were deeper in May and July, 1997 than May and July, 1996, but shallower in August 1997 vs. August 1996 in all bays except Zaikof. As before, differences in age composition between sites and months did not appear to explain the depth differences observed. Many schools observed from the air were invisible to acoustics and visa versa. This disagreement underscores the need to synthesize both data types to answer the research question concerning availability of forage fish species to birds. Both abundance levels and depth distribution can affect availability.

Oceanic and climatic conditions associated with GOA and APEX regions in PWS varied during the five-year period. The June Bakun upwelling anomalies at Hinchinbrook Entrance indicated stronger downwelling and potentially stronger inflow through PWS from 1995-97 and the opposite in1998. The Aleutian Low Pressure Index (ALPI) anomalies indicated that the atmospheric pressure field driving winds, storms, rainfall, and GOA residual currents were relatively intensified, especially in 1998. The Atmospheric Forcing Index (AFI), based on very similar inputs as the Pacific Decadal Oscillation vacillated near zero during most of the period becoming positive in 1998 mainly in response to the intensified ALPI. The El Niño-Southern Oscillation (ENSO) anomaly was mainly negative but a strong ENSO event occurred in 1997 potentially having a strong impact on temperature and weather patterns. Average zooplankton biomass (from hatchery data) was higher than average in 1995 and 1999, lower from 1996-1998. Peak zooplankton biomass was anomalously low in 1997 coinciding with ENSO; 1998 and 1999 were anomalously high indicating a more intense bloom when it occurred. We expected higher sea surface temperatures (SST) in 1997, but observed them highest at nearshore sites (< 1 km from shore) in 1998 and offshore areas (> 1 km) in 1996. In general, the offshore areas were cooler and less variable than inshore areas and southwestern PWS had the coolest inshore waters. The mean thermocline depth (m) was variable at nearshore sites. The differences between regions were not consistent in relation to one another with no single region standing out as warmer with a deeper or shallower thermocline. However, the two years with the deepest thermocline in the southwest (SW) region were associated with the two years of highest peak zooplankton production at AFK. The deepest thermocline occurred in central PWS in 1996, while the shallowest occurred in 1999.

From the SEA and APEX research, it is highly likely that intraspecific (age 0 and 1 herring) and interspecific (juvenile sand lance, herring, pollock) competition is likely at nearshore nursery zones in PWS affecting growth, survival and distribution patterns observed. Competition is intensified in years of low zooplankton abundance. By combining aerial and acoustic data, it may be possible to examine some of these biological factors. Recruitment of sand lance in 1997, coinciding with the ENSO event, was early (June) and the highest in magnitude recorded over the 5-year period. Peak abundance of age-1 herring in June of 1996 was likely related to above average first-year survival and a shallower depth distribution (compared to 1997). Age-0 herring recruiting in 1996 experienced poor survival (SEA studies) and age-1 abundance the next year was at a three-year low as measured by both aerial and acoustics. It is also possible that herring experienced poor larval survival in 1998 and 1999. We confirm that the juvenile forms prefer the warmer, shallower regions as predicted by behavioral bioenergetic models of growth maximization in smaller fish.

The primary research objective for this project was a spatially explicit analysis of factors affecting availability of forage fish as prey. Completion of this objective was delayed from the original target date to enable rescaling and rebinning of the 5-yr acoustic data set and to compile the zooplankton data. We will identify factors deterministic in 3-d forage fish distribution out of the compiled set of oceanographic and biological variables. To accomplish this, acoustic data must be combined with aerial data and together synthesized with synoptic environmental data. For the analysis, we will use a two-stage geospatial analysis. The first stage is analysis of horizontal distribution (geographic spread by presence or absence in an array of bins); this distribution likely linked to topographic/bathymetric features, abundance, and predation risk. The second stage is analysis in the vertical direction (density and depth distribution), likely linked to zooplankton density and distribution, hydrographic conditions, and predator risk.

## Introduction

This study was initiated to provide information on forage fish distribution, particularly in the upper 20m of the water column, to the Alaska Predator Experiment (APEX) program. Aerial surveys were used to increase spatial and temporal coverage. This information was used to answer research questions concerning sea bird production, foraging success, and jellyfish distribution. In Prince William Sound (PWS), there was a lack of correlation between acoustic data on forage fish distribution and sea bird foraging patterns. However, a significant correlation was found between aerial survey results and sea bird foraging patterns. The disparity between the two fish data sets (acoustic and aerial) was primarily due to the shallow distribution of the two main forage species in PWS (juvenile Pacific herring, *Clupea pallasi*, and juvenile Pacific sand lance, *Ammodytes hexapterus*). The depth limitation of acoustic data acquisition (shallow water < 10m and surface waters < 5m) excluded many of the fish schools targeted as prey by the sea birds. In 1998, aerial surveys became a key field component of the APEX study in PWS.

As in other regions, sea bird productivity in PWS appears to be dependent on the availability and quality of forage fish as prey. Colonies adjacent to the Gulf of Alaska (GOA) appear to rely mainly on adult stages of forage fish while PWS colonies are feeding primarily on juvenile stages. High quality forage prey species include herring, eulachon, capelin and sand lance, all relatively high in lipid as adults. Juveniles are generally lower in energetic content, but may be easier prey for sea birds and therefore more available than adult forms where they occur. From other APEX research it appears that kittiwakes in PWS will select quality (high energy) over quantity and diet is a function of the availability of the preferred species and age-classes (capelin > age-1 herring > age-0 herring > age-0 sand lance). Alcid species, such as puffins and murrelets may prefer and select age-0 herring over age-1s.

This study focused on temporal and spatial variability of schooling, pelagic forage fish species in PWS. In other parts of the world, herring, sardines, anchovy, capelin, and sand lance school in tight aggregations with distinctive shapes and are often found in oceanic surface waters (Mais 1974; Squire 1978; Blaxter and Hunter 1982; Hara 1985; Misund 1993; Carscadden et al. 1994). Many schooling pelagic fish are arranged in shoal or school groups (Cram and Hampton 1976; Fiedler 1978) that are often contiguous in distribution. The visibility of schools from the surface and spatial patchiness of non-random shoals affect seabird and marine mammal foraging behavior and success. In standard ship transect surveys, spatial patchiness and discrete school or shoal structure is often ignored. Fish abundance is provided as an integrated density through the water column (i.e. does not represent what the apex foragers see). However, using broadscale remote sensing techniques, such as visual aerial surveys, the sampling unit is a school or shoal and patchiness can be documented. The schooling pelagic species form seasonal aggregations often in the same areas year after year; these areas are unique to a particular population (Templeman 1948; Campbell and Winter 1973; Sinclair 1988; Stocker 1993). Therefore, temporal and spatial life history knowledge is important in designing abundance surveys. Given that PWS forage fish species formed easily identifiable schools and that a priori knowledge on distribution was available, aerial surveys were able to document seasonal and interannual variation in distribution and abundance of key forage species in PWS, the adjacent Gulf of Alaska (GOA) inner shelf waters, and, to a lesser extent, the Outer Kenai (OK). We were able to survey most of the habitat occupied by the two main forage species and their sea bird predators. Since 1995, aerial surveys have added considerably to the base of knowledge on forage fish in the north central coast of Alaska.

The three main objectives of this study were (1) to document spatial and temporal variability in forage fish abundance and distribution in PWS, (2) to provide other *Exxon Valdez* Oil Spill (EVOS) projects with forage fish, jellyfish, and sea bird distribution data to meet their research objectives, and (3) to synthesize existing data and determine how environmental factors affect forage fish distribution and abundance. The main purpose of this report is: 1) to document the finalized aerial survey information, database, data sharing, and validations (catch and video data), and 2) to provide a preliminary analysis of environmental factors affecting forage fish distribution and abundance.

## Objectives

During the first year of this project (FY99), the primary objective listed in the detailed study plan was:

Provide aerial support for the APEX project, deliver the resulting data, and assist APEX researchers in its use and interpretation.

This was addressed by the following tasks:

1) Coordinate with sea bird and other researchers from the APEX project to develop field survey plans addressing the overall objectives of APEX.

2) Conduct daily repeat surveys over the APEX study area which represents the foraging range of birds from a single; set small catcher and sea bird “chase” skiffs on schools with foraging flocks in order to obtain more detailed observations.

3) Over fly the entire APEX study region during times when acoustic vessels are performing surveys to obtain a broadscale data set, which will include nearshore schools invisible to acoustics.

4) During broadscale flights, coordinate with other sea bird researchers to enable synoptic measurements of bird distributions from ground surveys and fish/bird distributions from the air.

5) Process the data during and after the field season; build into the three-year database of aerial data already in place; obtain a data set of field net-catches.

6) Work with modelers and other researchers to deliver the data appropriately, accurately and in a timely manner.

7) Work with APEX projects to finalize annual reports, prepare presentations and complete publications.

The objective and tasks were completed as given except task number 3. We were not able to coordinate the APEX acoustic survey flyovers in 1998 because of ship survey schedule changes. However, the aerial survey flight paths and schedule were planned to minimize the time lapse and maximize the spatial overlap between aerial and acoustic surveys. In 1999, the aerial surveys were scheduled in coordination with acoustic surveys and 100% overlap in space and time was archived.
For the second year of the project (FY00), the following objectives were added in addition to the ones stated above:

1. Determine and compare the annual spatial coherence between foraging kittiwakes and surface schools of forage fish.

2. Determine how distributions of forage fish in the surface waters co-vary with oceanographic structure and zooplankton concentration.

3. Compare the depth distribution of forage fish for the three years and determine how it is affected by and related to ocean conditions and zooplankton concentrations.

4. Analyze and publish all significant findings.

These objectives were designed to address the following hypotheses:

Foraging patterns of sea birds are dependent on the occurrence and availability of forage fish in surface waters; and

The occurrence and availability of forage fish in surface waters are dependent on ocean conditions and zooplankton distribution and abundance.

The first objective has been completed and is presented here. The last three objectives were postponed until 2001. Resources originally assigned to these objectives in FY00 were reassigned in order to rescale the SEA and APEX acoustic data with the revised target strengths for these species (Thomas and Kirsch, 1999). The two data sets were also rebinned in order to be comparable for analysis. Previously, the APEX data was integrated through all depths in order to produce estimates of fish biomass by transect and region. In order to analyze 3-d fish distribution, the data needed to be binned by depth. In addition, zooplankton data needed for the analysis is still unavailable, but that situation is being rectified this fall.

## Methods

Methodology for the aerial surveys conducted for this project was developed in 1995-1996 and documented beginning in 1997 (Brown and Norcross 1997; Brown and Borstad 1998; Brown 1998; Brown et al., submitted) under the Sound Ecosystem Assessment (SEA) project. Broadscale measurements of forage fish distribution and abundance in PWS, the GOA inner shelf, and the OK were completed for June and July, 1995-1997. In 1995-1996, other months were sampled. A broadscale survey was a single pass over most of the PWS coastline In 1996-7, fine scale and repeat measurements were taken for a subset of herring nursery bays in eastern, northern , southwestern and central PWS in addition to the broadscale survey measurements. For the APEX project, a single broadscale survey was conducted in July, 1998 and 1999. In addition, we conducted daily, repeat surveys (15) over the three APEX study regions in PWS (Northern, Central and Southwest; Figure 1) which represented the foraging range of two Black-legged kittiwake colonies (Shoup Bay and Eleanor) as well as the study sites for APEX and NVP Pigeon Guillemot and APEX Marbled Murrelet projects. A complete flight log of all surveys flown from 1995 to 1999 is listed in Appendix I.

At the start of the APEX field seasons, flight paths were established in the northern, central, and Jackpot APEX study regions (Figure 1). During the survey, the pilot stayed on the established flight path as closely as possible. Both flight path (transect) and features along path were recorded using the DLog program provided by Glen Ford (APEX modeler) A GPS mounted to the dash of the aircraft was connected to a lap top computer and dumped latitude, longitude, and date in 2-second intervals. Time was recorded from the computers internal clock. At the beginning of each flight, header information including weather, water visibility, wind, wind direction, tide stage, wave height and other notes concerning the survey were recorded in the log program. Information or "sightings" such as numbers of fish schools or jellyfish aggregations, species of fish, surface area of schools or jellyfish aggregations, numbers of birds or mammals, and behavior of birds were recorded on the computer log program.

Validations of sightings, performed by this and cooperating projects, were collated (Appendix II). They included dip net, beach seine, small mesh purse seine, and anchovy seine catches as well as underwater video captures and diver observations. A small number of net captures by small mesh purse seine and anchovy purse seine were guided from the aircraft to be used to validate and correct species assignments. Because of the error in separating age 0 herring and sand lance schools during July (Brown and Norcross 1997; Brown et al. submitted), we realized that we needed to increase the sample size of validated nearshore schools. To address this problem in 1999, a small vessel (30 ft) was chartered to perform video validations. The vessel was outfitted with a front-mounted outrigger pole and pulley system. Then, an underwater sea-cam was mounted at the end of the pole and attached to a digital camera system operated from the vessel. We also used a cable sea-cam that could extend to depths beyond the range of the outrigger pole. In order to obtain validations (species identification) of surface schools, the vessel overlapped the aerial survey in a specified target area on a daily basis and set on schools by the surveyors. In areas where acoustic targets were observed (likely to be fish), the cabled camera was lowered to the appropriate depth and "drifted" through the targets. In this manner, we

obtained over 400 sightings of fish schools (about one half synoptic with the aerial surveys) as compared with 21 net catches over the same time period. Examples of synoptic images are provided in Appendix III. The camera method was cheaper, faster, and provided a higher degree of corrections. Other validations were obtained from other projects sampling fish during the time period of the aerial surveys. In that case, matching validations was a post-processing procedure using GIS and matching date codes. Aerial digital video footage of fish schools, foraging flock configurations, and other features were collected and used in identifying validations and evaluating schools shape. Although there are more questions we can answer with the images in terms of sea bird/forage fish school dynamics on smaller scales, further processing of the images was not covered within the scope of this study.
A database of all flight paths and sightings was created and used for data queries and storage (documentation of metadata in Appendix IV). A listing of the queries provided from this data is in Appendix V. Single or double letter codes were developed for fish, bird and mammal species (such as h for herring, sd for sand lance, kw for kittiwakes, hs for harbor seals etc). Bird behavior was recorded as foraging or plunging (pl), resting on water (rw), resting on shore (rs), aggregated tightly on water over school (tw), traveling (tr) or flying in a "broad area search" (bs).

For estimating total school or sea bird density and forage fish abundance available at the surface (not including subsurface fish), the appropriate model is outlined by Quang and Lanctot (1991:

$$\hat{D} = \frac{n\hat{f}(d)}{L}, \ \hat{N} = 2A\hat{D} \ \text{or} \ \hat{N} = \frac{n}{\hat{p}}, \ C = \frac{1}{\hat{p}}$$

where D is density, n is the observed schools or birds, *f*(d) is the maximum height of the probability density function (*f*(x)) of distances (x) at distance d from the center of the transect, L is the length of the transect, N is the total number of animals estimated in the area, A is the area sampled, p is the probability of detection and C is the visibility coefficient. Estimates of variance should include estimates of variance for p and surveyor bias (calculated via double counting, Brown and Norcross 1997; Brown et al., in prep). For this study, only one parameter needed to be estimated (*f*(d)). The estimate of p (0.83) was obtained in an earlier study using independent sampling techniques and is described in a publication in preparation that will appear in the EVOS final report for SEA project 99320T (Brown et al., in prep; also in Brown and Borstad 1998). In order to estimate *f*(d), we collected angles on a subset of sightings. This was accomplished by marking the strut of the aircraft with a series of graduated marks indicating angle off the wing and collecting the angles by flattening the aircraft (using the gyroscope) and taking a measurement. The angles were converted to distance from transect centerline using simple geometry and the frequency distribution of the distances (x) were plotted (i.e. the *f*(x)). In this model, a beta curve best represents the probability density function of x and *f*(d) is obtained from the plot of x. Sampled sizes were sufficient to calculate detection curves for herring and sand lance schools as well as for Black-legged kittiwakes (applicable to any white gull; Figure 2). The probability detection functions resulted in estimates for *f*(d) at approximately 0.18 at d =

700 m for kittiwakes (n = 1019), 0.31 at d = 600 m for herring (n = 345) and 0.28 at d = 600m for sand lance (n=274). Any expressions of density or numbers of birds or schools should reflect these values in the estimates.

Finally, the analytical deliverable of this project has been postponed until 2001.The main objective of this analysis is to determine what factors affect the availability of surface schooling pelagic fish as prey for seabirds. In preparation, aerial data is combined with acoustic data to provide a sub-surface correction factor for aerial data and a measure of variability in vertical distribution. This will be the first time, to our knowledge, that aerial and acoustic results have been combined to answer this type of ecological question. In addition, spatially and temporally appropriate oceanographic variables are being assembled. We will likely adopt a two-stage approach similar to Maravelias (1999)). The first stage addresses presence of absence answering questions about factors forcing horizontal distribution and geographic spread or abundance. Likely forcing variables are topographic/bathymetric features and variability in recruitment; satellite image data may be used. The second stage quantifies factors affecting the density and depth of schools where they occur. Likely variables include hydrographic data, zooplankton density and distribution, predator fields/risk, We will use spatially-explicit non-linear models (e.g. generalized additive modeling and pursuit regressions) to identify the key forcing factors in both horizontal and vertical distribution. The original completion data was moved forward in order to incorporate efforts from the NOAA fish investigators, reformulate acoustic data, and allow more time for compilation of biological oceanographic data. Acoustic data collected by both the SEA and APEX projects prior to 1999 was scaled improperly. A supplemental fund was provided to this project to complete the rescaling of all surveys collected from 1995-98. In addition, APEX data was reprocessed and binned to enable comparisons with the SEA data. The combined SEA/APEX acoustic data will be incorporated into a single database. Raw data files were assembled and edited by Brown and Moreland; while the algorithms to re scale the data were developed by Dr. Ken Coyle (UAF) according to Thomas and Kirsch (1999). The rescaling was completed in November, 2000. The compilation of appropriate hydrographic data included all ctd casts from APEX and SEA, NOAA buoy data, and other data from the IMS database from the period 1995-99 in PWS. All of this data has been complied on a single PWS oceanographic database to facilitate analysis. Satellite data composites will be used to determine variability in scale of ocean features. Zooplankton data is still required, but not yet fully available. A publication will be produced as a co-authored effort of all those who participate in data sharing or analysis.

## Results and Discussion

Based on sea bird diets, the main pelagic prey species in PWS include Pacific herring, sand lance (*Ammodytes hexapterus)*, capelin (*Mallotus villosus)*, eulachon (*Thaleichthys pacificus***)** and other unidentified smelt juvenile pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), juvenile salmon (*Onchorynchus sp.*), and macroinvertebrates (Kuletz et al. 1997; Irons et al. 1999). The first four species listed formed distinct schools in PWS surface waters during the summer, peaking in June and July. Capelin and eulachon were visible for a narrow window of time, generally in June, corresponding to pre-spawning aggregations or post-spawning feeding aggregations. By July, capelin and eulachon schools were either diffuse, in deep water or both and became invisible to aerial spotters (E.Brown, unpublished data; reflected in APEX catches, Haldorson et al. 1996). Distinct foraging patterns of birds (categorized as Type II flocks; Maniscalco and Ostrand, 1997) visible from aircraft appear to form over post-spawn adult capelin (E. Brown, unpublished data; Maniscalco and Ostrand, 1997). The vast majority of fish schools sighted from the air consisted of the two main forage species, juvenile herring and sand lance. Capelin was the third most common fish species recorded, as either schools or distinct avian forging pattern with validated net captures. These results are summarized here.

A total of 26,532 $km^2$ of effective area (incorporates detection correction) was surveyed for fish schools and 91,227 $km^2$ for kittiwakes and gulls over the five year period (Table 1).The average area covered varied from year to year, month to month, and by each APEX area. In order to produce a density and index of abundance estimates for fish, a mean area or expansion factor by month/year strata was calculated over all periods for the Northeast (450 $km^2$), Central (210) and Southwest (250). Average densities were not estimated for kittiwakes.

Fish school, jellyfish, seabird abundance and proportion of birds observed foraging (from the air) varied by month, year and species in the three APEX study regions (Table 2). The boundaries for the queries are shown in Figure 5. During June and July (most commonly surveyed months), herring density and abundance peaked in 1996 (note the northeast area bars are over the scale) and was lowest in 1999 (Figure 3). The relative proportion of herring observed among regions varied from year to year. Prior to 1999, availability of age-1 herring was due to first year survival and depth distribution with a high in 1996 and a low in 1997. Age-0 recruitment peaked in 1997 and remained low through the end of the study. Sand lance abundance was low in 1995, increased by 1996 and peaked in 1997 (recruiting a month early). Sand lance abundance remained relatively high through 1999. The recruitment to the northeast in 1997 was particularly noteworthy. Capelin were episodically observed in abundance during 1995 and 1999. Eulachon were anomalously prevalent in 1997 following an anecdotally high incidental catch in commercial fishing gillnets outside the Copper River,.a known spawning location. Kittiwakes (Figure 4) appeared to increase in the numbers observed from the air, but we observed a decline in the proportion of birds engaged in foraging behavior. This may have reflected the decline of juvenile herring availability. The variability in spatial distributions of the fish are illustrated in Figures 5-7 for June and July, 1995-97 and July only, 1998-9. The occurrence of higher herring abundance in June of 1996, over 1995 and 1997, is apparent. Capelin and eulachon formed observable surface schools in June mainly near the entrance and exits of PWS to the adjacent GOA. The massive increase in sand lance from 1996 to 1999 is apparent in all sectors queried, but particularly in central, south central and eastern PWS. All four species of forage fish appear to occur in some areas all years; geographic spread accompanies increases in abundance from these distribution centers. We will characterize these centers of distribution in the geospatial analysis.

Within a six-week period (July 1 to August 8), there was a high degree of weekly variability in distribution and abundance of surface fish schools as well as bird foraging patterns during and between both years (1998-9; Figures 8-11). During the entire interval, there was a high degree of coherence between seabird (kittiwakes and alcids) foraging aggregations and locations of fish schools. Both age-0 sand lance and herring were recruiting to nearshore nursery beaches or bays during this period and therefore, this variability is expected. In both years, herring recruited first to eastern and northern PWS, than to southwestern portion; this timing agrees with the predicted timing of spatial recruitment from a larval drift model for PWS (Norcross et al., in prep). By period 4, herring likely adopt a deeper or more variable distribution as fewer surface schools were observed. This decrease in surface herring schools may be related to the decrease on proportion of foraging kittiwakes observed by August both years (Figure 4). A query of aerial data, within the core and expanded search area for the Shoup Bay kittiwake colony, revealed similar trends in timing. Herring generally peaked in availability during the first two weeks of the period in both the core and expanded areas (Tables 3 and 4) while sand lance peaked in period three. The differences in forage fish densities over the two scales (core vs. expanded) were not significant. Capelin peaked in period four for both years. Although herring abundance over all study areas was lowest in 1999, abundance in the northeast foraging area of the Shoup Bay colony was higher in 1999 than 1998.

Variability in depth distribution likely plays a major role in forage fish availability to sea birds. Aerial counts were compared with synoptic acoustic survey results in four herring nursery bays (SEA data; Figure 12). In general, there was good agreement at two sites (southeastern and southwestern PWS) and poor agreement at the other two (central and northern PWS). The disagreement could not be explained entirely by differences in age structure or month of observation, but the sample sizes may have been too small to identify the causal factor. The broadscale acoustic survey in July, 1996 (SEA) revealed a high degree of variability in both mean depth site-specific variance (Figure 13; Table 5). Three of the six sites with deepest mean distribution patterns were also sites dominated by adult herring (Figure 14); however, the other three were dominated by age 1 or 0 herring and therefore other factors were involved. Temporal variability in depth was observed at the four SEA herring nursery sites (Figure 15; Table 6). Variability in depth and monthly patterns of depth distribution varied between sites and years. In general, juvenile herring were deeper in May and July of 1997 than May and July of 1996, but shallower in August 1997 vs. August 1996 in all bays except Zaikof. As before, differences in age composition between sites and months did not appear to explain the depth differences observed (Figure 16). These mean depths may change as aerial survey is combined with acoustic data; many schools observed from the air were invisible to acoustics and visa versa. This disagreement in the two data sources underscores the need to collect both data types simultaneously in order to answer questions concerning availability of forage fish species to birds. It is clear that both abundance levels and depth distribution can affect availability. This is the same conclusion reached by Cram and Hampton (1976) but rarely have the two survey types been used together. We will attempt the sort out factors forcing variability in depth distribution in the geospatial analysis of the data.

Oceanic and climatic conditions associated with GOA or PWS, as a whole, varied during the five-year period. Within PWS, some regional differences were evident in the temperature profiles as well. The June Bakun upwelling anomaly at Hinchinbrook entrance was very low in 1995, increasingly less so through 1997, then very high in 1998. The ramifications are stronger downwelling and potentially stronger inflow through PWS during the negative phase and the opposite during the positive. The Aleutian Low Pressure Index (ALPI; Beamish et al. 1999) anomaly was mainly in a positive phase during the five-year period with a high in 1998 and a minimum in 1999. This indicates that the atmospheric pressure field driving winds, storms, rainfall, and GOA residual currents was relatively intensified, especially in 1998. The Atmospheric Forcing Index (AFI; Beamish et al. 1999), based on very similar inputs as the Pacific Decadal Oscillation (Mantua et al. 1997), vacillated near zero during most of the period becoming positive in 1998 mainly in response to the intensified ALPI. The El Niño-Southern Oscillation (ENSO) anomaly was mainly negative but a strong ENSO event occurred in 1997 potentially having a strong impact on temperature and weather patterns. The average zooplankton production anomaly, measured at the Armin F. Koernig (AFK) hatchery facility and located in southwestern PWS, represents average zooplankton biomass over the April copepod bloom. This is key for herring since the larvae feed on copepod eggs and the adult copepods are very high quality prey for juvenile fish. It was positive in 1995, negative from 1996-1998, then positive in 1999 indicating higher than average or lower than average copepod production. However, the peak zooplankton biomass (the magnitude of the bloom at its peak) was anomalously low in 1997 coinciding with ENSO; 1998 and 1999 were anomalously high indicating a more intense bloom when it occurred. Zooplankton were sampled at herring and sand lance nursery sites during the SEA and APEX project, they were unavailable at the time this summary was prepared.

We examined average water temperatures during July in PWS both offshore (> 1km from shore) and inshore (< 1 km from shore; Table 8). We expected to find higher than average sea surface water temperatures (SST) in 1997, but this was not evident. At nearshore sites, 1998 has the highest SSTs measured. At the offshore areas, 1996 had higher SSTs at all sites than other years. In general, the offshore areas were cooler and less variable than inshore areas and southwestern PWS had the coolest inshore waters. The mean thermocline depth (m), estimated as the depth where 90% of the temperature change occurred between 0 and 50 m, was variable at nearshore sites. The differences between regions were not consistent in relation to one another with no single region standing out as warmer with a deeper or shallower thermocline. However, it is interesting to note that two years with the deepest thermocline in the southwest (SW) region were associated with the two years of highest peak zooplankton production at AFK. The deepest thermocline occurred in central PWS in 1996, while the shallowest occurred in northeast PWS in 1999.

Understanding key life history events is a pre-requisite for investigating the effects of oceanic conditions on distribution and abundance of juvenile sand lance and herring. Biotic factors such as competition can alter distribution, food availability, and the response to a given set of ocean parameters thereby complicating the interpretation of causal factors. Variation in monthly distribution is mainly a function of recruiting events during the juvenile life stages. In June and early July, age-1 herring dominate the nursery bays and in some cases share these habitats with the highly mobile and migratory adult herring. Based on the literature (Crowder and Magnuson, 1983; Ware 1985; Hughes and Grand, 2000), age-1 herring distribution is very likely affected by the presence of older herring and competition may limit age-1 growth in areas with high overlap. By late June to mid July, age-0 sand lance go through metamorphosis, begin schooling and recruit to mainly gravel or sand beaches where they bury themselves when not feeding. In late July and early August, age-0 herring also metamorphose and begin schooling. They show up in many of the same nursery bays already occupied by age-1 herring but recruitment is spatially variable. Although no cannibalism was observed during the SEA years, there was evidence of density-dependence with the lowest age-0 growth rate observed in the bay with the highest overall juvenile herring abundance (Stokesbury et al. 1999a). In addition, there is some overlap between age-0 herring and age-0 sand lance; where this occurs, it is expected that they compete as evidenced by APEX diet studies (Sturdevant et al. 2000a and b). Finally, juvenile pollock occurred in many of the same bays used by juvenile herring. Diet overlap between the two species is high and it is very possible that competition as well as piscivory limits herring growth and survival; therefore, quality of and availability as prey for sea birds is also affected (Sturdevant et al. 2000a).

It is clear that many variables, biotic and abiotic, affect distribution of the juvenile fish. Some factors are likely deterministic during the larval drift stage of the two species. Others are deterministic once the fish are in place at their nursery sites. Factors affecting herring may be different from those affecting sand lance. The regional variability will be better defined after completion of the spatial analysis is completed. However, a few interesting observations are mentioned. Recruitment of sand lance in 1997, coinciding with the ENSO event, was early (June) and the highest in magnitude recorded over the 5-year period. Peak abundance of age-1 herring in June of 1996 was likely related to above average first-year survival and a shallower depth distribution (compared to 1997). Age-0 herring recruiting in 1996 experienced poor survival (SEA studies) and age-1 abundance the next year was at a three-year low as measured by both aerial and acoustics. It is possible that interspecific competition occurred between sand lance, herring and pollock, especially in years of poor zooplankton production. It is also possible that herring experienced poor larval survival in 1998 and 1999. We confirm that the juveniles forms prefer the warmer, shallower regions as predicted by behavioral bioenergetic models of growth maximization in smaller fish (Neill, 1979; Ware, 1985; Crowder and Magnuson, 1983).

For the analysis of forage fish distribution, we will use all available site-specific hydrographic data binned at a finer spatial scale to sort out the effect of environmental variability on distribution of fish. In the horizontal direction, there are likely "centers" of distribution that have consistently high habitat quality and fish distribution radiates from those points as abundance increases; topographical/bathymetric features and associated predation risk may dictate the locations of these regions. In the vertical direction (at a given site), zooplankton density and distribution, hydrographic characteristics, and associated predation risk are the likely factors forcing forage fish density and distribution. The quantitative spatial analysis planned for 2001 should answer many of these questions and synthesizes much of the fish distribution and oceanographic data collected by both the APEX and SEA programs.

## Conclusions

In summary, using aerial surveys we were able to capture much of the spatial and temporal variability that affect observed sea bird foraging patterns and success. We were also able to document counting error and apply that to estimates of fish density and abundance. We were able to observe the two main forage fish species in PWS, juvenile Pacific herring and sand lance, over the entire period critical to sea bird reproduction. Herring have declined in abundance over the five-year study period while sand lance have increased. Occurrences of capelin and eulachon were more episodic. The weekly variability observed in fish distribution over the sea bird breeding period was largely dictated by spatial and temporal patterns of age 0 recruitment to nearshore nursery zones. The juvenile herring and sand lance tended to occupy warm, shallow, plankton-rich waters and were not mixed with adult forms to any degree. The aerial data was valuable in answering many "top-down" questions concerning sea birds and forage fish. However, since fish availability as prey is dictated by both fish abundance and vertical distribution of schools, we must combine acoustic with aerial survey results to answer "bottom up" questions. It is likely that forage fish distribution is dictated by both abundance (horizontal distribution) and environmental conditions (depth and density). We will adopt a two-stage analytical approach to examine fish distribution in the horizontal direction (stage one), the vertical direction (stage two) in 2001.

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Table 1. Summary of area flown (km$^2$) within each of the three APEX regions for each month and year strata.

| | **April-May** | | | **June** | | | **July** | | | **August** | | | **Totals** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Effective km$^2$ Flown Fish** | **Northeast** | **Central** | **Southwest** | **Northeast** | **Central** | **Southwest** | **Northeast** | **Central** | **Southwest** | **Northeast** | **Central** | **Southwest** | |
| 1995 | 314.12 | 193.97 | 142.14 | 314.12 | 193.97 | 142.14 | 584.60 | 213.40 | 242.86 | 542.81 | 202.37 | 240.63 | **3,327.13** |
| 1996 | 414.59 | 169.10 | 275.91 | 310.67 | 99.25 | 80.88 | 454.59 | 248.29 | 580.87 | 89.09 | 155.22 | 78.05 | **2,956.51** |
| 1997 | | | | 593.39 | 279.30 | 321.80 | 644.66 | 395.60 | 480.81 | | | | **2,715.56** |
| 1998 | | | | | | | 2,934.28 | 2,949.86 | 387.60 | 1,113.13 | 657.57 | 91.18 | **8,133.62** |
| 1999 | | | | | | | 2,586.04 | 1,917.70 | 517.45 | 822.02 | 47.43 | 39.37 | **5,930.01** |
| Average | 364.36 | 181.54 | 209.03 | 406.06 | 190.84 | 181.60 | 561.28 | 285.76 | 434.85 | 315.95 | 178.79 | 159.34 | **3,469.40** |
| **Totals** | **1,093.07** | **544.62** | **627.08** | **1,624.24** | **763.36** | **726.42** | **7,765.45** | **6,010.61** | **2,644.44** | **2,883.00** | **1,241.37** | **608.57** | **26,532.22** |
| | | | | | | | | | | | | | |
| **Expansion Factors** | **450** | **210** | **250** | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Total Effective km$^2$ Flown Birds** | | | | | | | | | | | | | |
| 1995 | 982.26 | 606.55 | 444.46 | 982.26 | 606.55 | 444.46 | 1,828.04 | 667.30 | 759.42 | 1,697.36 | 632.79 | 752.45 | **10,403.89** |
| 1996 | 1,296.42 | 528.79 | 862.78 | 971.45 | 310.34 | 252.92 | 1,421.49 | 776.39 | 1,816.37 | 278.58 | 485.36 | 244.07 | **9,244.95** |
| 1997 | | | | 1,855.53 | 873.38 | 1,006.25 | 2,015.83 | 1,237.03 | 1,503.49 | | | | **8,491.52** |
| 1998 | | | | | | | 9,175.46 | 9,224.17 | 1,212.03 | 3,480.74 | 2,056.21 | 285.12 | **25,433.73** |
| 1999 | | | | | | | 8,086.50 | 5,996.63 | 1,618.06 | 4,066.15 | 24.57 | 78.18 | **19,870.10** |
| Average | 1,139.34 | 567.67 | 653.62 | 1,269.75 | 596.76 | 567.87 | 4,505.46 | 3,580.30 | 1,381.87 | 2,380.71 | 799.73 | 339.95 | **17,783.04** |
| **Totals** | **3,418.02** | **1,703.01** | **1,960.86** | **5,078.99** | **2,387.03** | **2,271.50** | **27,032.79** | **21,481.82** | **8,291.24** | **11,903.54** | **3,998.67** | **1,699.77** | **91,227.23** |

Table 2. Summary of key fish, bird and invertebrate species observed by month and year. Total abundance estimates were expanded by the average area covered by aerial surveys in a given region (not the total area within the region).

| | | | 1995 | | | | 1996 | | | | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Index** | **Area** | **May** | **June** | **July** | **August** | **May** | **June** | **July** | **August** | **June** | **July** | **July** | **August** | **July** | **August** |
| **Herring** | Density by Surface Area | Northeast | 0.00 | 7.10 | 3.02 | 15.15 | 85.06 | 28.10 | 10.52 | 3.40 | 2.11 | 6.78 | 1.83 | 1.27 | 5.34 | 4.95 |
| | (total m$^2$ SA/km$^2$ flown) | Central | 0.85 | 7.11 | 3.44 | 8.74 | 35.60 | 37.99 | 2.32 | 9.07 | 2.16 | 7.62 | 2.69 | 15.91 | 4.72 | 0.52 |
| | | Southwest | 1.16 | 18.21 | 19.26 | 0.00 | 21.57 | 57.92 | 13.79 | 6.32 | 4.06 | 1.57 | 26.56 | 0.39 | 3.61 | 1.99 |
| | Density by No. Schools | Northeast | 0.00 | 0.17 | 0.10 | 0.30 | 0.69 | 0.82 | 0.25 | 0.21 | 0.09 | 0.45 | 0.07 | 0.07 | 0.41 | 0.30 |
| | (no. schools/km$^2$ flown) | Central | 0.01 | 0.18 | 0.09 | 0.10 | 0.15 | 0.33 | 0.78 | 0.50 | 0.04 | 0.21 | 0.09 | 0.47 | 0.22 | 0.02 |
| | | Southwest | 0.01 | 0.47 | 0.51 | 0.00 | 0.14 | 1.25 | 0.33 | 0.27 | 0.09 | 0.08 | 0.43 | 0.01 | 0.08 | 0.05 |
| | Index of Abundance** | Northeast | 0.00 | 3196.84 | 1356.90 | 6818.15 | 38276.75 | 12647.14 | 4733.69 | 1527.96 | 949.20 | 3052.25 | 824.79 | 569.51 | 2404.71 | 2225.94 |
| | (total SA schools m$^2$) | Central | 178.15 | 1492.61 | 723.09 | 1835.50 | 7475.41 | 7978.09 | 487.19 | 1903.98 | 454.03 | 1600.27 | 565.70 | 3340.61 | 991.15 | 108.80 |
| | | Southwest | 289.43 | 4552.90 | 4815.82 | 0.00 | 5391.41 | 14480.38 | 3447.11 | 1580.16 | 1015.21 | 392.49 | 6639.09 | 97.99 | 901.51 | 496.47 |
| **Sand lance** | Density by Surface Area* | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.09 | 10.03 | 2.19 | 23.74 | 1.41 | 0.65 | 5.12 | 12.09 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.82 | 11.22 | 6.98 | 11.87 | 19.15 | 13.22 | 10.50 | 12.50 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.06 | 2.38 | 2.99 | 4.09 | 23.68 | 13.30 | 4.22 | 12.18 |
| | Density by No. Schools | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.09 | 0.55 | 0.05 | 0.01 | 0.40 | 0.66 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.17 | 0.20 | 0.25 | 0.28 | 0.27 | 0.28 | 0.06 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.05 | 0.06 | 0.11 | 0.20 | 0.33 | 0.12 | 0.20 |
| | Index of Abundance** | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1391.71 | 4513.25 | 984.21 | 10684.74 | 635.45 | 294.69 | 2302.91 | 5439.63 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1012.05 | 2355.31 | 1466.22 | 2493.21 | 4020.49 | 2776.21 | 2205.35 | 2624.31 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 514.99 | 595.76 | 746.80 | 1021.79 | 5919.18 | 3324.71 | 1055.64 | 3045.00 |
| **Capelin** | Density by Surface Area* | Northeast | 0.00 | 4.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 1.13 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.17 | 0.00 | 1.66 | 0.00 |
| | | Southwest | 0.00 | 5.10 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 35.96 | 0.00 |
| | Density by No. Schools | Northeast | 0.00 | 0.04 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 0.04 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.03 | 0.00 |
| | | Southwest | 0.00 | 0.11 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 |
| | Index of Abundance** | Northeast | 0.00 | 1799.21 | 0.00 | 489.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 25.76 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 236.53 | 115.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.56 | 35.04 | 0.00 | 347.68 | 0.00 |
| | | Southwest | 0.00 | 1274.09 | 0.00 | 35.72 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8990.81 | 0.00 |

| | | | 1995 | | | | 1996 | | | | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Index** | **Area** | **May** | **June** | **July** | **August** | **May** | **June** | **July** | **August** | **June** | **July** | **July** | **August** | **July** | **August** |
| **Eulachon** | Density by Surface Area* | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.47 | 0.00 | 0.28 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 35.15 | 0.75 | 0.00 | 0.00 | 0.05 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 27.94 | 0.00 | 0.00 | 0.00 | 1.19 | 0.00 |
| | Density by No. Schools | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| | Index of Abundance** | Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2912.54 | 0.00 | 126.75 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7380.53 | 158.11 | 0.00 | 0.00 | 10.19 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6986.18 | 0.00 | 0.00 | 0.00 | 297.87 | 0.00 |
| **Unknown FF** | Density by Surface Area* | Northeast | 0.00 | 0.22 | 0.14 | 1.61 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.12 | 2.67 | 4.02 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 1.49 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Southwest | 0.00 | 0.06 | 0.23 | 0.07 | 0.05 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Density by No. Schools | Northeast | 0.00 | 0.01 | 0.01 | 0.05 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 0.01 | 0.02 | 0.07 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Southwest | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Index of Abundance** | Northeast | 0.00 | 100.27 | 63.62 | 725.43 | 0.00 | 0.00 | 49.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Central | 0.00 | 24.38 | 561.26 | 843.59 | 0.00 | 0.00 | 32.75 | 0.00 | 0.00 | 312.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Southwest | 0.00 | 13.82 | 57.49 | 18.17 | 13.06 | 0.00 | 16.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Jellyfish** | Density by Surface Area* | Northeast | 0.00 | 0.00 | 3.03 | 3.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.13 | 0.08 | 7.65 | 2.00 |
| | | Central | 0.00 | 0.00 | 0.21 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.99 | 3.35 | 0.78 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 0.85 | 2.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 23.57 | 0.00 | 2.84 | 0.00 |
| | Density by No. Schools | Northeast | 0.00 | 0.00 | 0.10 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.09 | 0.02 |
| | | Central | 0.00 | 0.00 | 0.02 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.01 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 0.06 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.00 | 0.05 | 0.00 |
| | Index of Abundance** | Northeast | 0.00 | 0.00 | 1364.68 | 1524.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2310.50 | 37.63 | 3440.93 | 901.24 |
| | | Central | 0.00 | 0.00 | 43.96 | 144.49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 628.25 | 703.64 | 163.43 | 0.00 |
| | | Southwest | 0.00 | 0.00 | 211.55 | 573.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5891.88 | 0.00 | 709.41 | 0.00 |

| | | | 1995 | | | | 1996 | | | | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Index** | **Area** | **May** | **June** | **July** | **August** | **May** | **June** | **July** | **August** | **June** | **July** | **July** | **August** | **July** | **August** |
| **Kitti-wakes** | Total Observed | Northeast | 0 | 1101 | 1616 | 13942 | 1063 | 570 | 997 | 627 | 7089 | 1929 | 16317 | 4923 | 19488 | 5671 |
| | | Central | 80 | 251 | 561 | 767 | 369 | 398 | 521 | 1685 | 867 | 2079 | 13458 | 5647 | 22605 | 819 |
| | | Southwest | 0 | 21693 | 576 | 324 | 1739 | 172 | 989 | 13 | 696 | 395 | 2061 | 236 | 20302 | 48 |
| | Total Foraging | Northeast | 0 | 593 | 1077 | 11618 | 638 | 461 | 814 | 167 | 3630 | 1334 | 5381 | 244 | 8922 | 2274 |
| | | Central | 40 | 207 | 440 | 730 | 302 | 360 | 409 | 0 | 653 | 1398 | 6428 | 750 | 12880 | 603 |
| | | Southwest | 0 | 8397 | 464 | 281 | 1175 | 172 | 853 | 13 | 408 | 263 | 1541 | 76 | 10671 | 18 |
| **Glacous-Winged** | Total Observed | Northeast | 0 | 48 | 3177 | 1501 | 326 | 0 | 1561 | 25 | 1506 | 3 | 94 | 49 | 730 | 88 |
| | | Central | 20 | 4 | 70 | 40 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 467 | 2 |
| | | Southwest | 0 | 1 | 20 | 0 | 5 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 85 | 1 |
| | Total Foraging | Northeast | 0 | 26 | 1324 | 0 | 285 | 0 | 937 | 0 | 602 | 3 | 6 | 0 | 216 | 25 |
| | | Central | 20 | 2 | 23 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 254 | 1 |
| | | Southwest | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 |
| **Unknown Gulls** | Total Observed | Northeast | 0 | 60 | 413 | 568 | 129 | 0 | 337 | 134 | 35 | 14 | 460 | 198 | 930 | 110 |
| | | Central | 505 | 19 | 565 | 60 | 2 | 15 | 459 | 1438 | 56 | 7 | 366 | 1312 | 1825 | 0 |
| | | Southwest | 0 | 158 | 134 | 52 | 13 | 0 | 283 | 102 | 0 | 14 | 0 | 0 | 300 | 25 |
| | Total Foraging | Northeast | 0 | 23 | 283 | 426 | 60 | 0 | 267 | 80 | 16 | 9 | 43 | 22 | 85 | 0 |
| | | Central | 135 | 8 | 391 | 45 | 2 | 0 | 355 | 664 | 28 | 7 | 52 | 195 | 0 | 0 |
| | | Southwest | 0 | 123 | 34 | 17 | 0 | 0 | 222 | 77 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Alcids** | Total Observed | Northeast | 0 | 20 | 0 | 38 | 1208 | 0 | 231 | 5 | 91 | 3 | 2105 | 602 | 1090 | 470 |
| | | Central | 5 | 0 | 0 | 28 | 190 | 0 | 65 | 0 | 0 | 5 | 489 | 399 | 1918 | 0 |
| | | Southwest | 0 | 30 | 0 | 0 | 87 | 0 | 59 | 15 | 2 | 12 | 5 | 58 | 1487 | 0 |

** Expansions to abundance index based in Average km^2 flown per Area of NE, 450; C, 210, and SW, 250

Table 3. Weekly and interannual variability in forage fish surface school density within the core kittiwake foraging area in the northeast; estimates are corrected for sightability error; missing data is denoted by NS for no survey.

**Core Area Estimates:**

**Herring:** **Error = +/- 12.0%** (Density by Numbers of Schools) / **Error = +/- 15.2%** (Density by School Surface Area)

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.22 | NS | 0.39 | 0.65 | 1.00 | 7.93 | NS | 10.85 | 26.01 |
| 2 | NS | NS | 0.17 | 0.63 | 2.00 | NS | NS | 2.85 | 16.07 |
| 3 | NS | NS | 0.30 | 0.20 | 3.00 | NS | NS | 7.39 | 5.14 |
| 4 | NS | 0.57 | 0.14 | 0.10 | 4.00 | NS | 11.23 | 3.55 | 1.27 |
| 5 | NS | NS | 0.05 | 0.11 | 5.00 | NS | NS | 1.15 | 2.32 |
| 6 | NS | NS | 0.06 | NS | 6.00 | NS | NS | 0.72 | NS |

**Sand Lance** **Error = +/- 27.7%** (Density by Numbers of Schools) / **Error = +/- 30.9%** (Density by School Surface Area)

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.02 | NS | 0.01 | 0.26 | 1.00 | 3.01 | NS | 0.46 | 9.91 |
| 2 | NS | NS | 0.05 | 0.36 | 2.00 | NS | NS | 1.04 | 11.12 |
| 3 | NS | NS | 0.07 | 0.60 | 3.00 | NS | NS | 2.00 | 19.55 |
| 4 | NS | 0.11 | 0.04 | 0.31 | 4.00 | NS | 5.90 | 1.42 | 7.84 |
| 5 | NS | NS | 0.02 | 0.46 | 5.00 | NS | NS | 0.53 | 10.87 |
| 6 | NS | NS | 0.01 | NS | 6.00 | NS | NS | 0.04 | NS |

**Capelin** no error estimates available

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.00 | NS | 0.00 | 0.00 | 1.00 | 0.00 | NS | 0.00 | 0.00 |
| 2 | NS | NS | 0.00 | 0.00 | 2.00 | NS | NS | 0.00 | 0.00 |
| 3 | NS | NS | 0.00 | 0.00 | 3.00 | NS | NS | 0.00 | 0.54 |
| 4 | NS | 0.00 | 0.00 | 0.03 | 4.00 | NS | 0.00 | 0.00 | 1.66 |
| 5 | NS | NS | 0.00 | 0.00 | 5.00 | NS | NS | 0.00 | 0.00 |
| 6 | NS | NS | 0.00 | NS | 6.00 | NS | NS | 0.00 | NS |

| Periods | Date Range |
|---|---|
| 1 | July 1 - 7 |
| 2 | July 7- 14 |
| 3 | July 15 - 21 |
| 4 | July 22 - 28 |
| 5 | July 29 - Aug. 4 |
| 6 | Aug. 5 - 11 |

Table 4. Weekly and interannual variability in forage fish surface school density within expanded kittiwake foraging area in the northeast; estimates are corrected for sightability error.

**Expanded Area Estimates:**

**Herring:** **Herring:** **Error = +/- 12.0%** **Error = +/- 15.2%**

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.29 | NS | 0.25 | 0.77 | 1.00 | 11.54 | NS | 6.98 | 29.66 |
| 2 | 0.21 | 0.50 | 0.15 | 0.58 | 2.00 | 2.53 | 4.51 | 2.71 | 15.23 |
| 3 | NS | 0.35 | 0.22 | 0.21 | 3.00 | NS | 3.23 | 5.47 | 4.85 |
| 4 | NS | 0.51 | 0.11 | 0.13 | 4.00 | NS | 10.13 | 2.52 | 1.29 |
| 5 | 0.20 | NS | 0.03 | 0.28 | 5.00 | 7.68 | NS | 0.74 | 5.04 |
| 6 | 0.24 | NS | 0.09 | NS | 6.00 | 2.55 | NS | 1.47 | NS |

**Sand Lance** **Error = +/- 27.7%** **Error = +/- 30.9%**

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.01 | NS | 0.05 | 0.32 | 1.00 | 2.12 | NS | 0.65 | 10.00 |
| 2 | 0.19 | 0.00 | 0.10 | 0.39 | 2.00 | 8.73 | 0.00 | 3.02 | 8.39 |
| 3 | NS | 1.64 | 0.05 | 0.55 | 3.00 | NS | 64.56 | 1.39 | 14.36 |
| 4 | NS | 0.09 | 0.03 | 0.33 | 4.00 | NS | 4.95 | 1.03 | 9.74 |
| 5 | 0.00 | NS | 0.02 | 0.63 | 5.00 | 0.00 | NS | 0.81 | 12.07 |
| 6 | 0.00 | NS | 0.01 | NS | 6.00 | 0.00 | NS | 0.74 | NS |

**Capelin** no error estimates available

| Density by Numbers of Schools (#/km^2) | | | | | Density by School Surface Area (m^2/km^2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | 1996 | 1997 | 1998 | 1999 | Period | 1996 | 1997 | 1998 | 1999 |
| 1 | 0.00 | NS | 0.00 | 0.00 | 1.00 | 0.00 | NS | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.03 | 0.00 | 2.00 | 0.00 | 0.00 | 0.66 | 0.00 |
| 3 | NS | 0.00 | 0.00 | 0.00 | 3.00 | NS | 0.00 | 0.00 | 0.33 |
| 4 | NS | 0.00 | 0.00 | 0.02 | 4.00 | NS | 0.00 | 0.00 | 0.98 |
| 5 | 0.00 | NS | 0.00 | 0.00 | 5.00 | 0.00 | NS | 0.00 | 0.00 |
| 6 | 0.00 | NS | 0.00 | NS | 6.00 | 0.00 | NS | 0.00 | NS |

Table 5. Spatial variability in mean depth (m) of juvenile herring schools, standard deviation and 95% confidence interval range during July, 1996 based on acoustic surveys.

| | Mean | SD | 95% CI |
|---|---|---|---|
| **Simpson Head Pt.** | 11.86 | 5.97 | 11.70 |
| **Gravina Landlocked Bay** | 22.59 | 12.84 | 25.17 |
| **Jack Bay** | 7.60 | 6.64 | 13.02 |
| **Valdez Arm** | 13.13 | 1.25 | 2.44 |
| **Wells Bay** | 8.23 | 2.60 | 5.09 |
| **Eaglek** | 19.74 | 7.09 | 13.89 |
| **Culross** | 14.38 | 7.49 | 14.69 |
| **McClure Bay** | 9.88 | 2.31 | 4.52 |
| **Herring Bay** | 15.17 | 10.38 | 20.34 |
| **Whale** | 9.67 | 3.10 | 6.07 |
| **Port San Juan** | 19.57 | 12.61 | 24.71 |
| **Elrington Pass** | 23.71 | 7.29 | 14.30 |
| **Fox Farm** | 30.26 | 2.90 | 5.68 |
| **Hogg Bay** | 18.46 | 5.49 | 10.77 |
| **Zaikof** | 26.48 | 2.54 | 4.98 |

Table 6. Temporal variability in juvenile herring schools depth (m) at four herring nursery sites in PWS.

| Month | Zaikof | sd | 95% | Eaglek | sd | 95% | Simpson | sd | 95% | Whale | sd | 95% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May-96 | 22.87 | 2.89 | 5.659926 | 18.17 | 3.30 | 6.473832 | 12.04 | 1.36 | 2.670699 | 25.82 | 6.20 | 12.15752 |
| Jun-96 | 18.10 | 5.70 | 11.1748 | 12.67 | 7.45 | 14.59922 | 23.94 | 10.58 | 20.7295 | 10.44 | 4.54 | 8.891202 |
| Jul-96 | 26.48 | 2.54 | 4.976629 | 19.74 | 7.09 | 13.88691 | | | 0 | 9.67 | 3.10 | 6.068807 |
| Aug-96 | 21.66 | 2.62 | 5.141553 | 80.12 | 12.23 | 23.97416 | 17.97 | 10.88 | 21.33204 | 22.73 | 3.31 | 6.483419 |
| Oct-96 | 37.93 | 6.88 | 13.47995 | 74.36 | 11.22 | 21.99289 | 22.76 | 13.39 | 26.2484 | 58.43 | 7.76 | 15.19983 |
| | | | | | | | | | | | | |
| May-97 | 28.71 | 4.18 | 8.183845 | 42.50 | 4.93 | 9.661512 | 29.33 | 6.18 | 12.12071 | 39.09 | 6.98 | 13.6754 |
| Jul-97 | 42.50 | 0.71 | 1.385929 | 15.62 | 1.14 | 2.24099 | 27.02 | 5.61 | 10.99209 | 13.48 | 3.60 | 7.058925 |
| Aug-97 | 24.10 | 4.73 | 9.276172 | 55.71 | 1.18 | 2.308329 | 10.91 | 7.98 | 15.63909 | 20.08 | 5.71 | 11.19727 |

Table 7. Normalized climate and production indices for PWS and the north Pacific during the SEA/APEX study years including the June Bakun upwelling index at Hinchinbrook Entrance, the Aleutian Low Pressure Index (ALPI; (Beamish, 1999)), the Atmospheric Forcing Index (AFI-PDO; (Beamish, 1999)), the El Niño Southern Oscillation (ENSO; (Mantua, 1997)), and both the average and peak zooplankton production at the Armin F. Koernig (AFK) salmon hatchery in southwestern PWS.

| | **June Upwell.** | **ALPI** | **AFI(PDO)** | **ENSO** | **Ave.AFK Zoop.** | **Peak AFK Zoop.** |
|---|---|---|---|---|---|---|
| 1995 | -5.283 | 1.515 | -0.645 | -0.392 | 0.432 | 0.197 |
| 1996 | -2.283 | 0.799 | 0.176 | -0.688 | -0.373 | -0.399 |
| 1997 | -0.283 | 0.538 | -0.117 | 1.261 | -0.388 | -1.419 |
| 1998 | 6.717 | 4.707 | 1.360 | 0.331 | -0.644 | 1.642 |
| 1999 | | 0.007 | | -0.436 | 0.480 | 4.363 |

Table 8 Thermocline depth (m) and mean sea surface temperature to 10 m measured at APEX nearshore sites in each of the three study areas (northeast-NE, central-C, and southwest-SW) during July.

| | Mean Thermocline Depth (m) | | | Mean Temperature to 10m | | |
|---|---|---|---|---|---|---|
| **Year** | **NE** | **C** | **SW** | **NE** | **C** | **SW** |
| 1995 | 13.33 | 8.67 | 10.00 | 13.09 | 11.91 | 11.00 |
| 1996 | 6.00 | 21.67 | 2.67 | 10.59 | 12.95 | 11.84 |
| 1997 | 6.00 | 9.33 | 10.00 | 14.27 | 14.91 | 13.03 |
| 1998 | 4.33 | 9.50 | 14.67 | 13.96 | 13.09 | 11.92 |
| 1999 | 1.00 | 2.67 | 16.00 | 14.46 | 16.33 | 13.83 |

Table 9. Mean sea surface temperature and salinity to 20 m at PWS SEA project offshore (> 1 km) sites in regions overlapping the APEX study regions during July.

| **Temperature** | **Northeast** | **Northshore** | **Central** | **Montague St.** | **Southwest** |
|---|---|---|---|---|---|
| 1995 | 5.27 | 6.74 | 6.94 | 5.92 | 7.29 |
| 1996 | 5.84 | 7.29 | 7.96 | 8.11 | 7.98 |
| 1997 | - | 6.10 | 5.79 | 5.57 | 6.21 |
| 1998 | - | - | - | 6.71 | 5.91 |
| 1999 | - | 5.47 | - | 5.60 | 5.34 |
| **Salinity** | | | | | |
| 1995 | 31.09 | 29.34 | 29.10 | 30.78 | 29.19 |
| 1996 | 31.42 | 30.69 | 31.08 | 31.20 | 30.56 |
| 1997 | - | 31.08 | 31.41 | 31.54 | 30.68 |
| 1998 | - | - | - | 30.93 | 30.46 |
| 1999 | - | 31.31 | - | 31.53 | 31.14 |

Figure 1. Flight paths used during the APEX project in 1998-9 for the north region, the central region, and the southwest or Jackpot region;the additional areas covered during the single July broadscale survey are also shown..

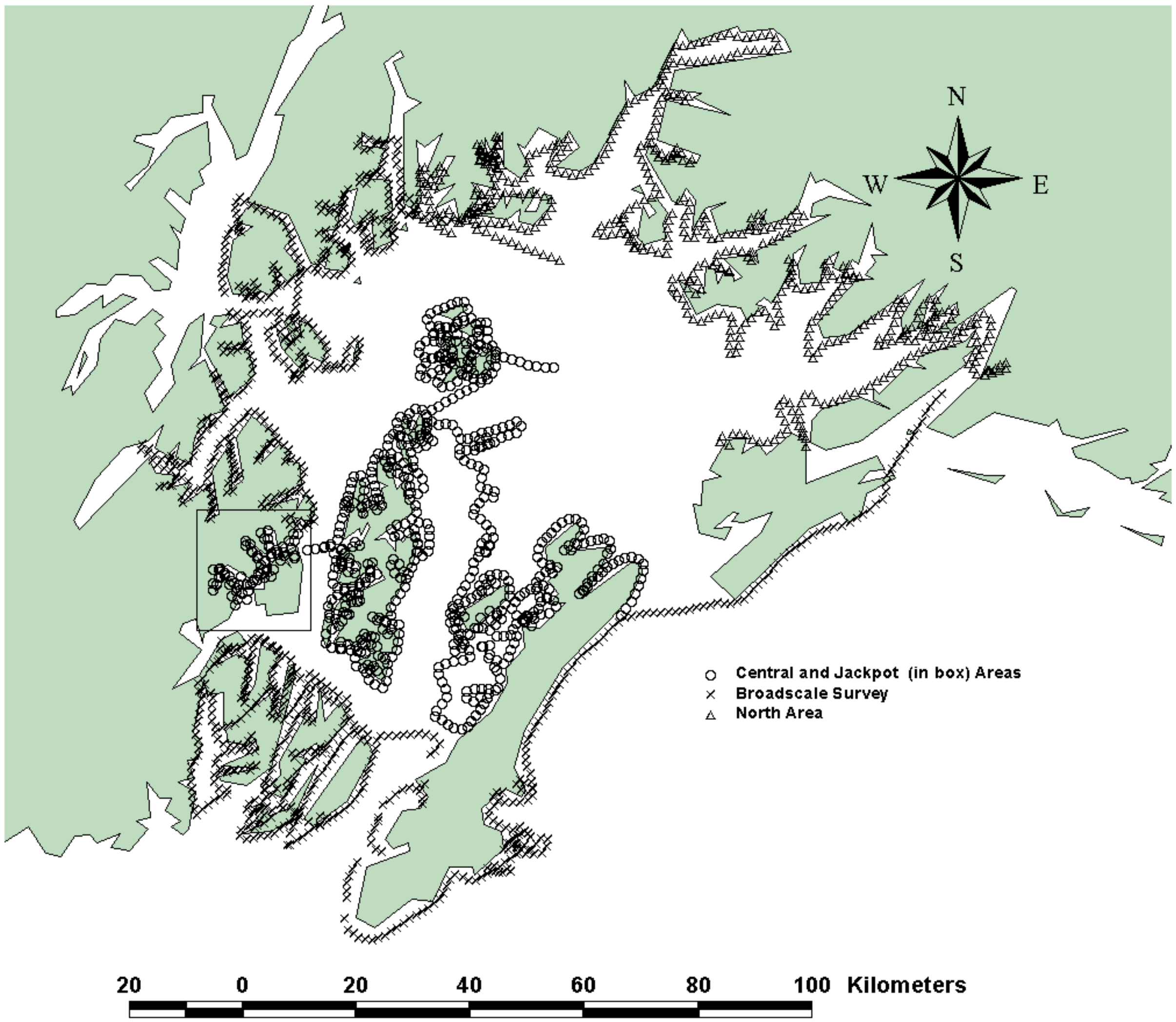


Figure 2.  Probability density functions of sighting distances (estimated from observed angle of sighting from wing) used to estimate effective (sampled) swath width for kittiwakes, herring and sand lance.

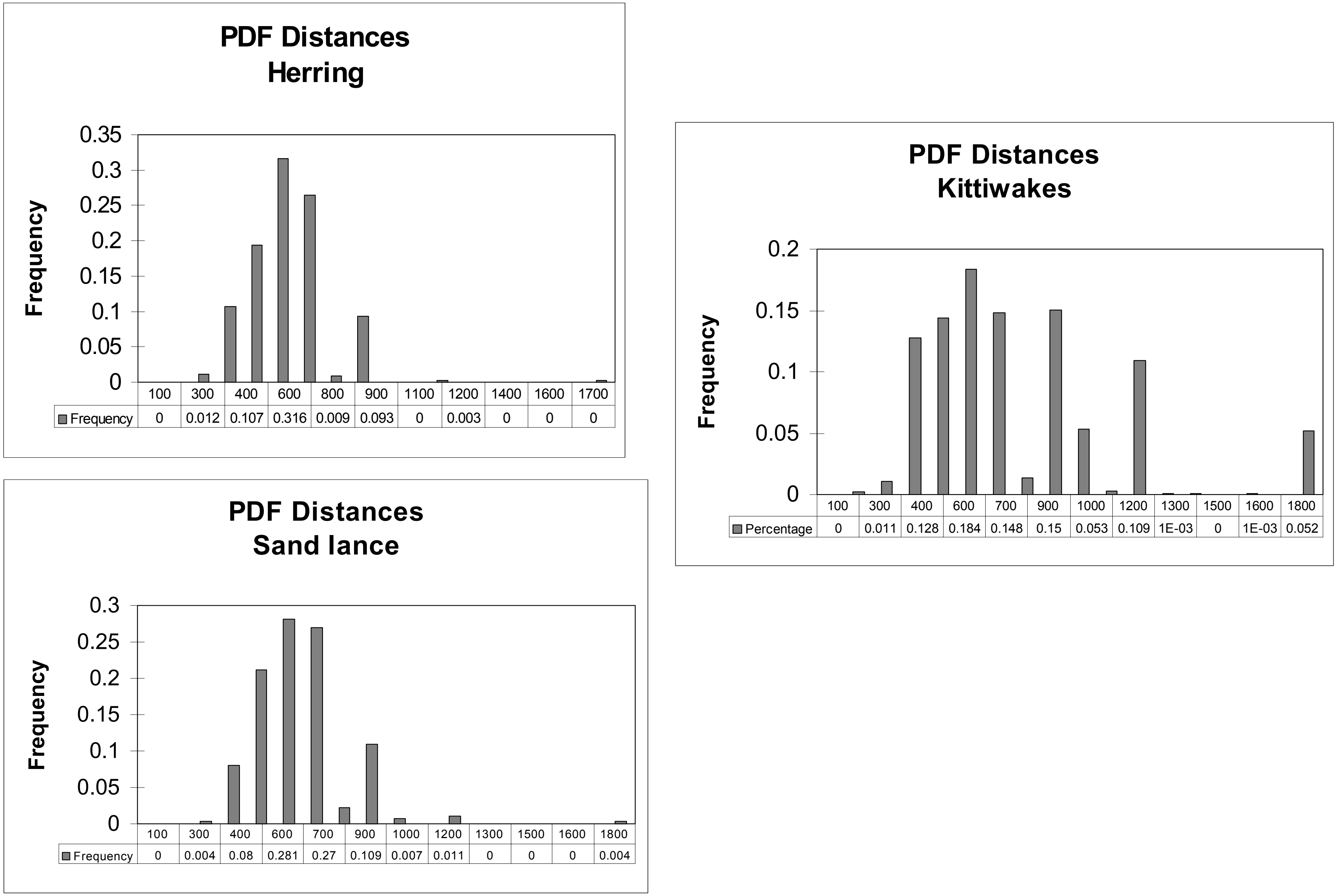


Figure 3. Changes in relative abundance of fish over the months/years surveyed within the APEX study areas (note that herring in the NE are off the scale in May and June of 1996).

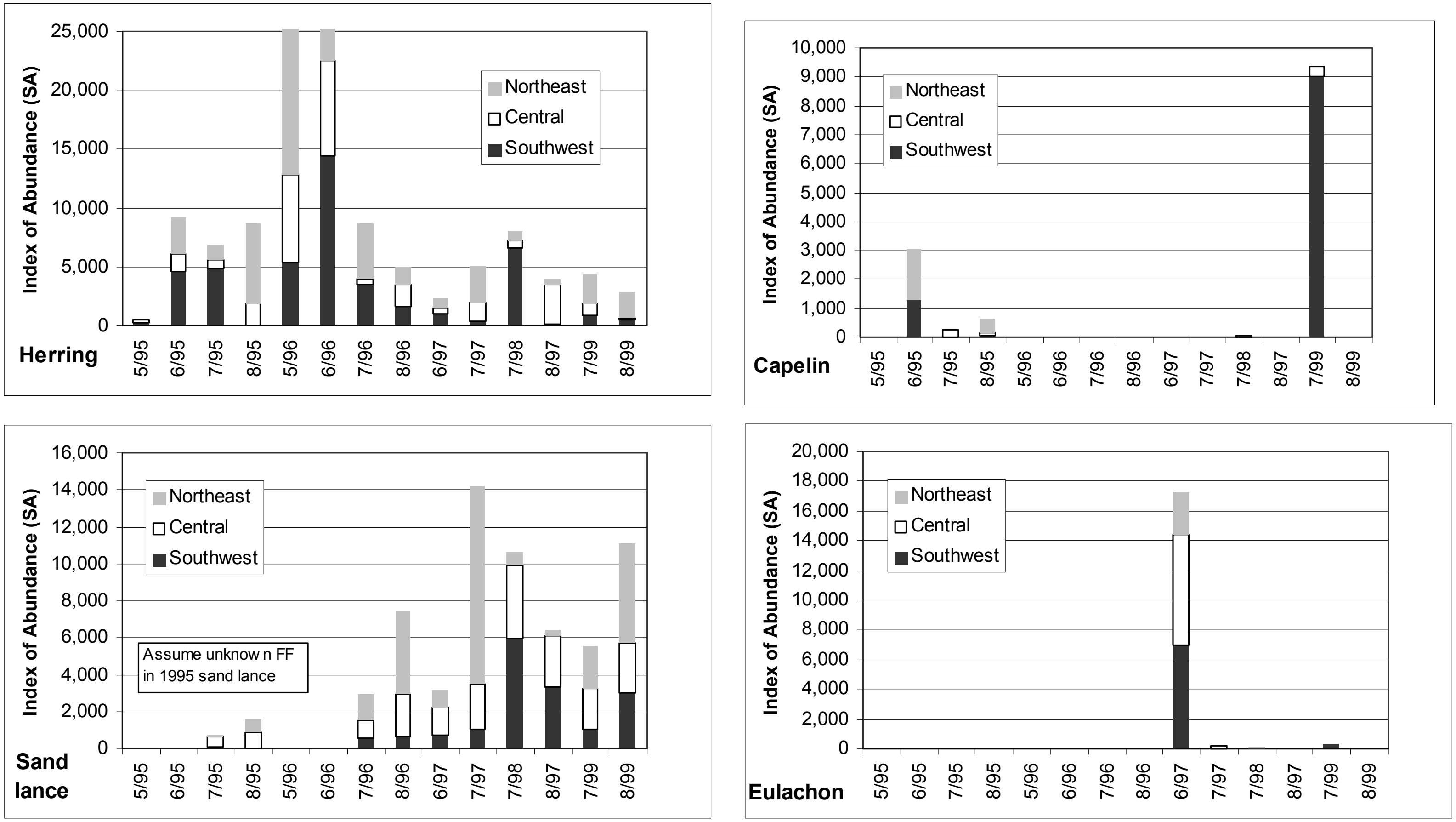


Figure 4. Changes in abundance of kittiwakes (bars) and proportion observed with foraging behaviors (lines) in the three APEX study areas.

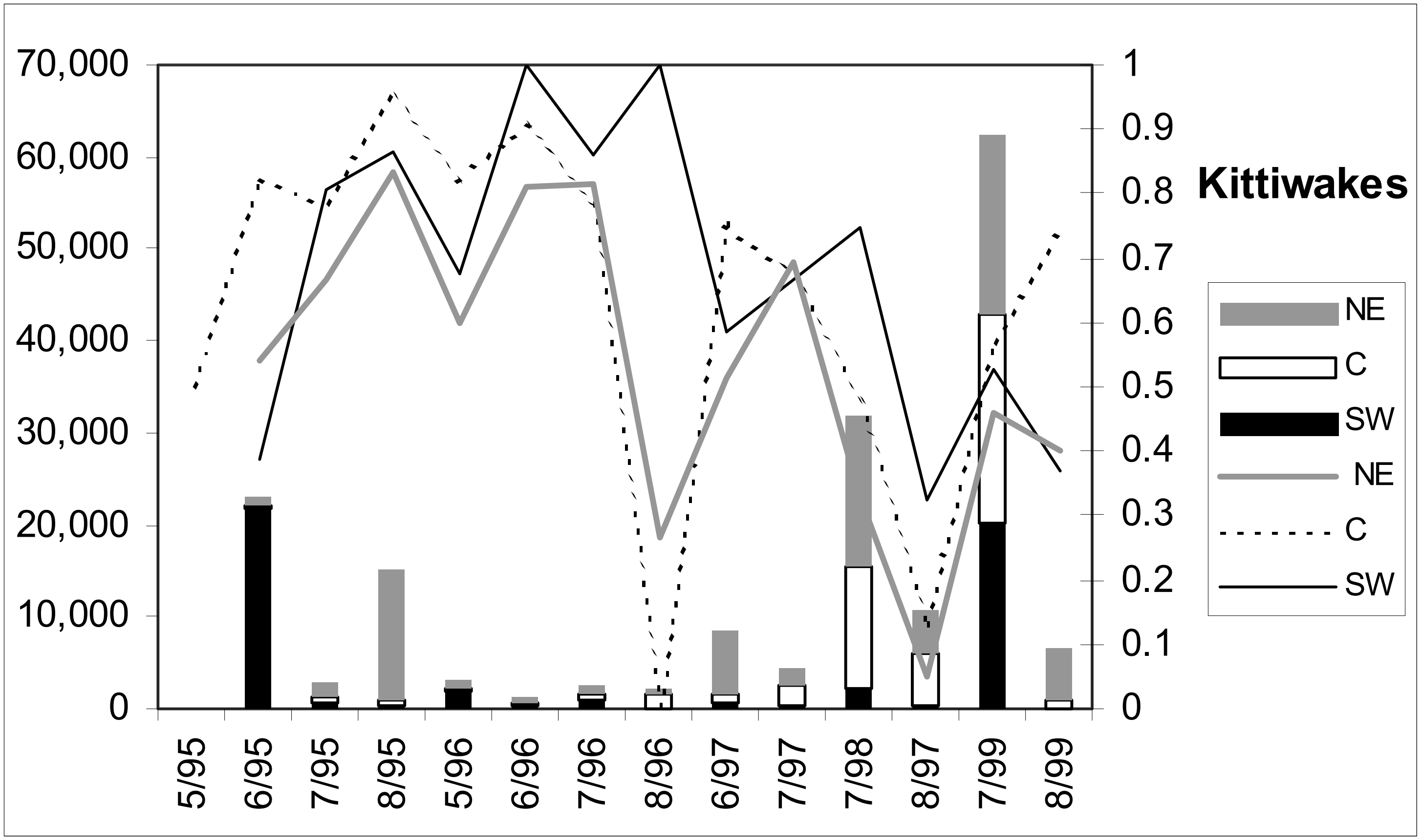


Figure 5. Distribution of forage fish schools by species in June and July of 1995-1996. The black lines denote the geographic query regions for APEX (northeast-NE, Central-C and southwest-SW).

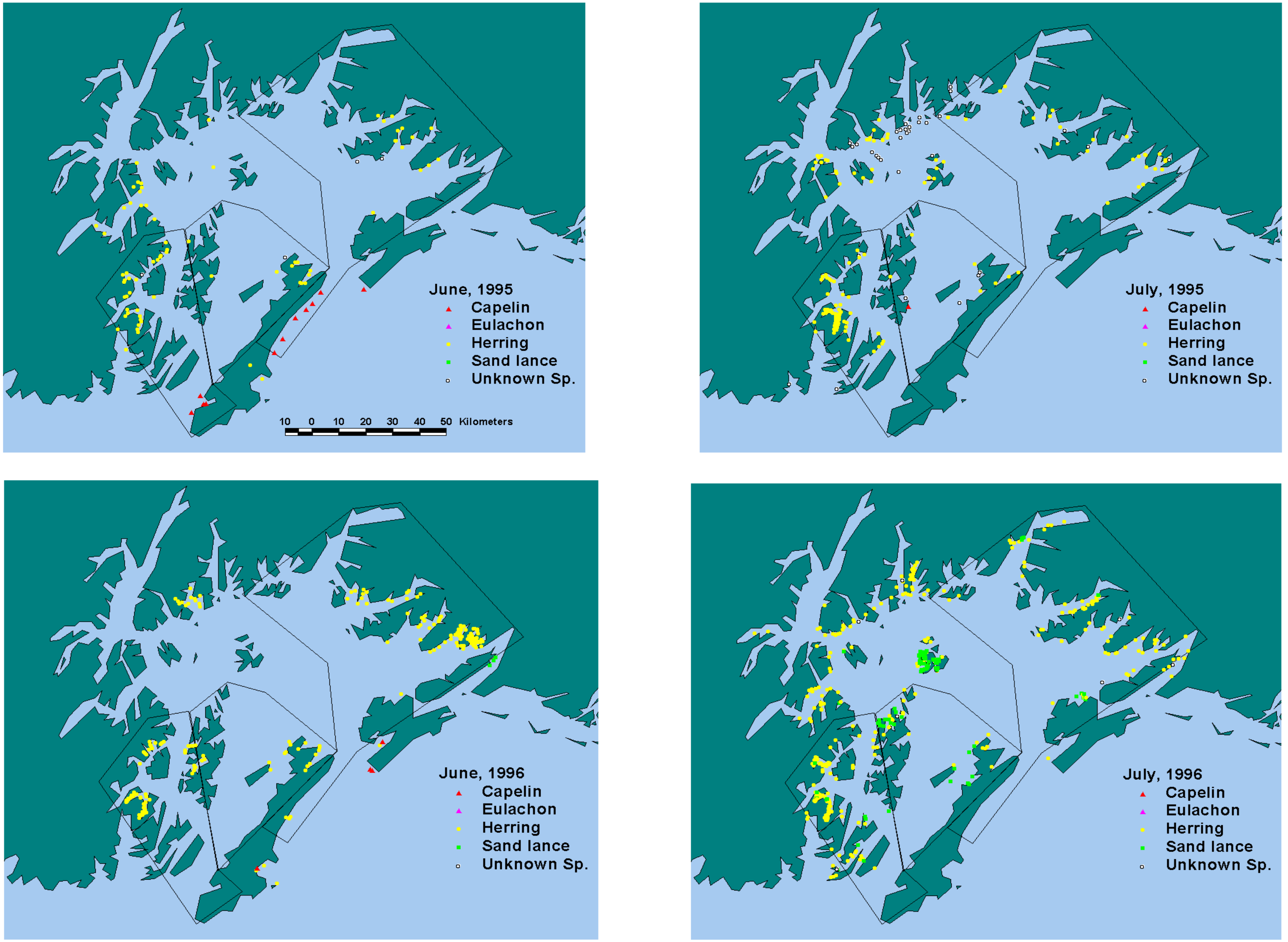
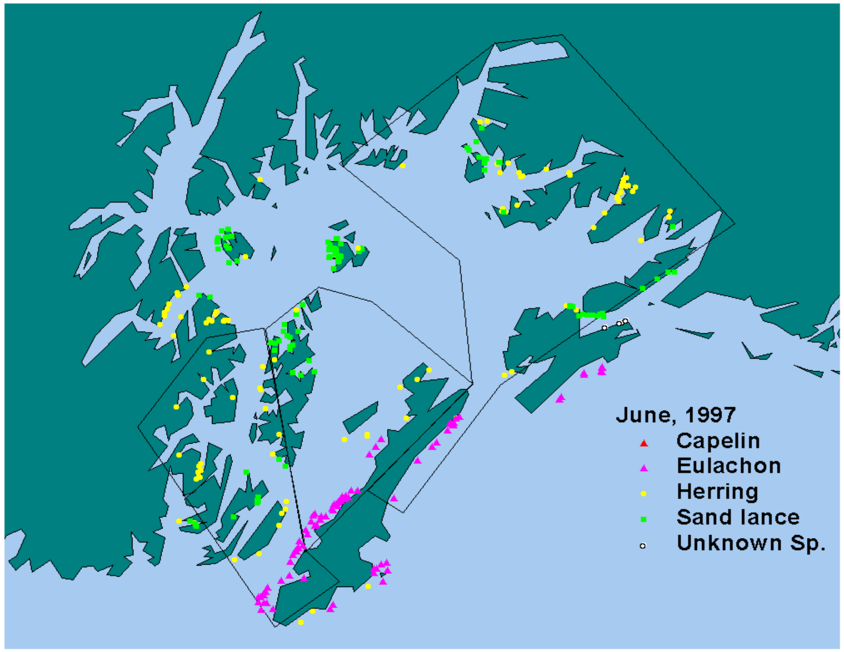


Figure 6. Distribution of forage fish schools by species in June and July of 1997. The black lines denote the geographic query regions for APEX (northeast-NE, Central-C and southwest-SW).



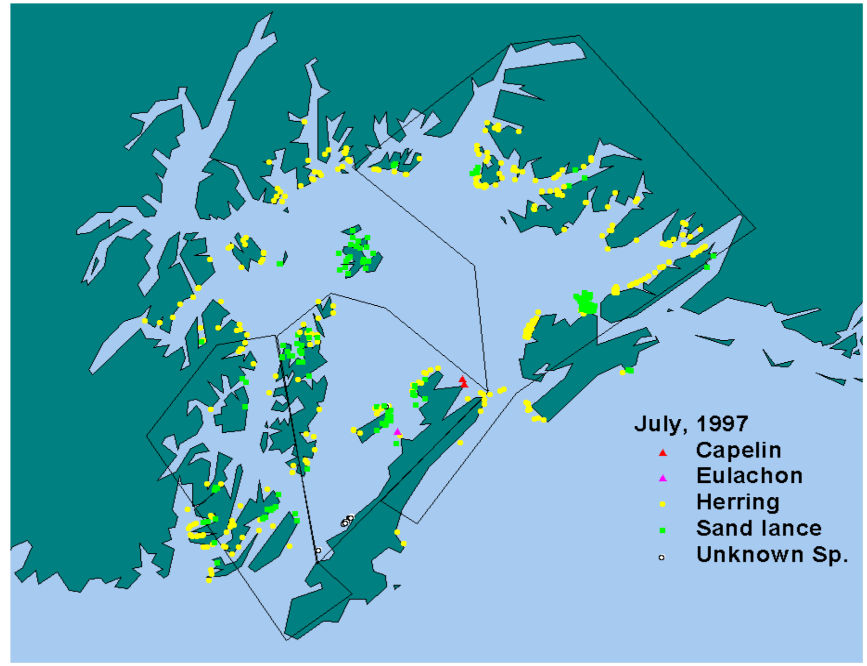



Figure 7. Distribution of forage fish schools by species in July of 1998-9. More schools are mapped than in previous years due to intensive repeat surveys. The table of fish densities shows truer comparisons. The black lines denote the geographic query regions for APEX (northeast-NE, Central-C and southwest-SW).

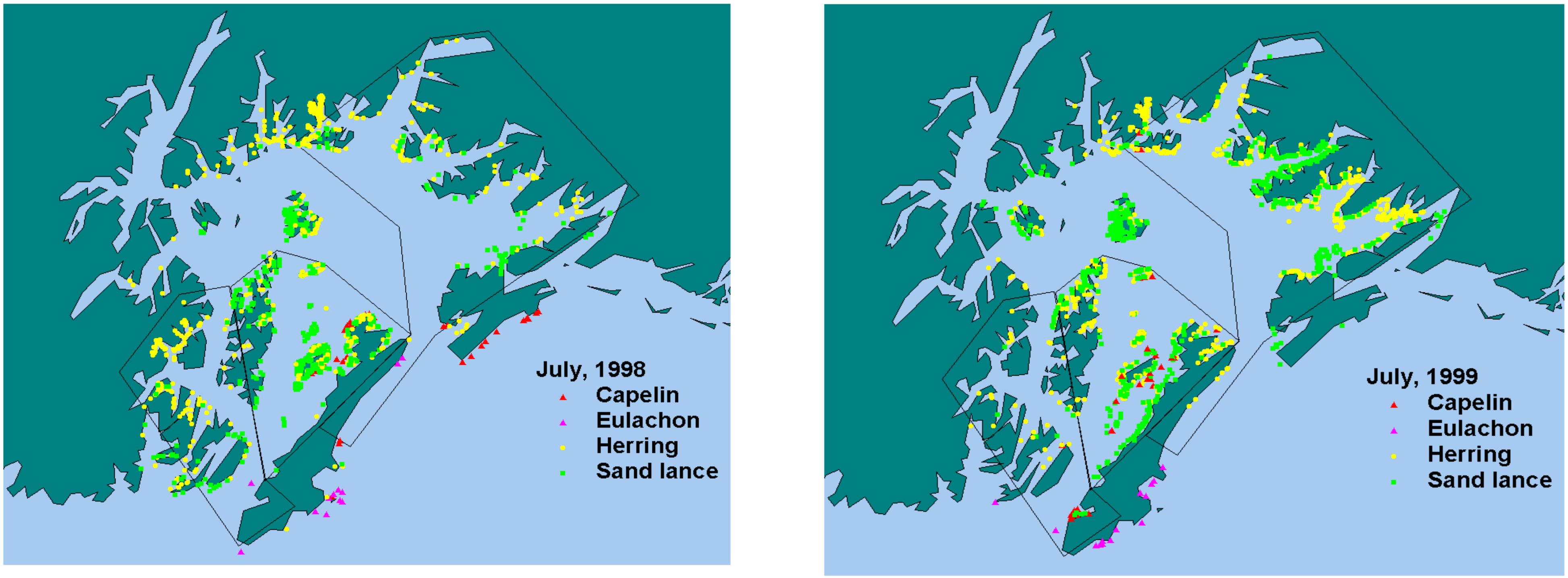


Figure 8. Counts of key species sighted in APEX study regions dring period 1, 7/1 – 7/7, 1998-1999. In 1998, only the northeastern area was surveyed during period 1.

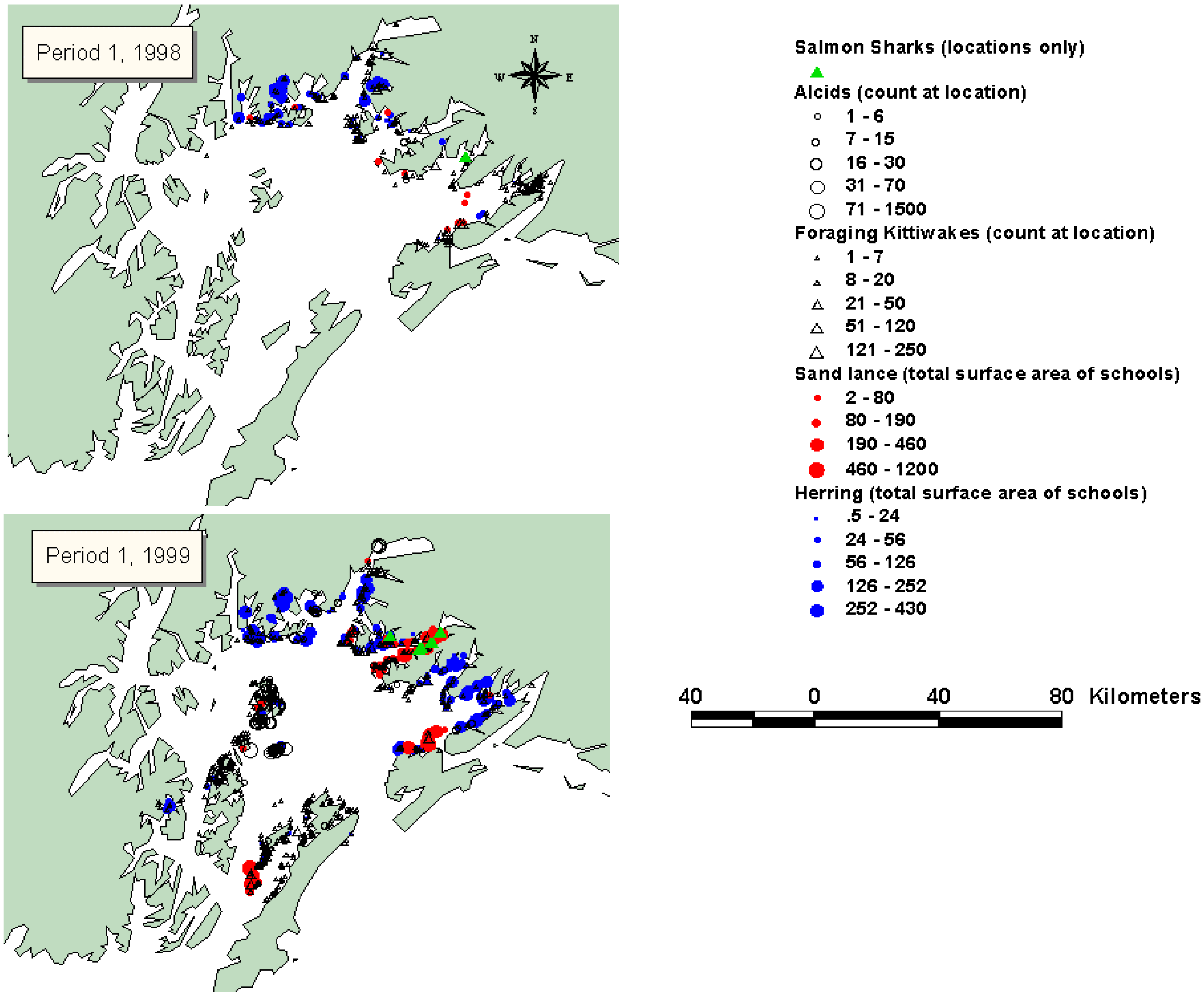


Figure 9. Counts of key species sighted in APEX study regions during period 2, 7/8 - 7/14, and period 3, 7/15 – 7/21, 1998-1999. In addition to the APEX core regions, the broadscale survey was conducted in southwestern and outside PWS during period 2 both years and in northwestern PWS during period 3 of 1998 and periods 2 and 3 of 1999

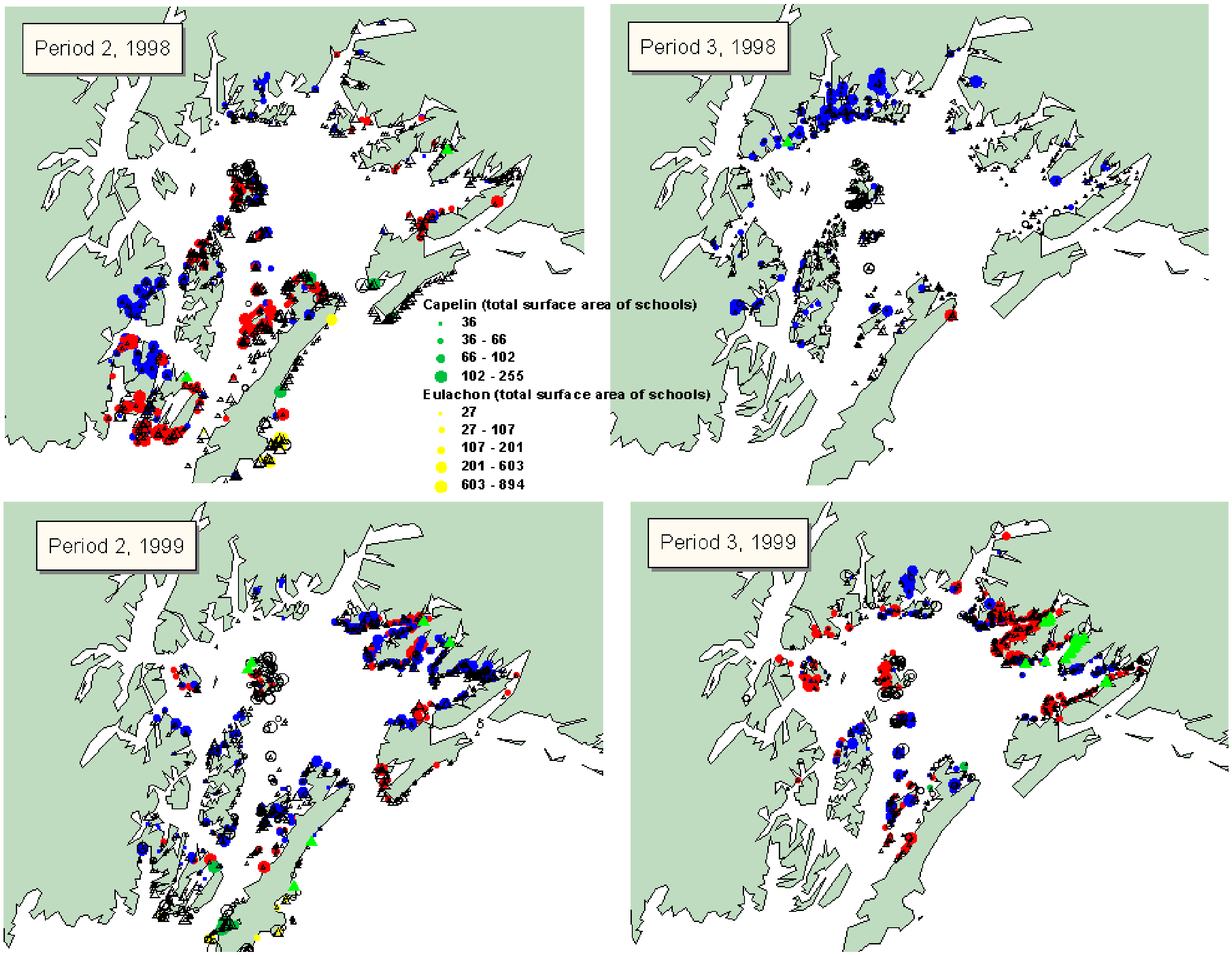


Figure 10. Counts of key species sighted in APEX study regions during period 4, 7/22 – 7/28, and period 5, 7/29 - 8/4 during 1998 and 1999. Only the APEX core regions were flown during these periods.

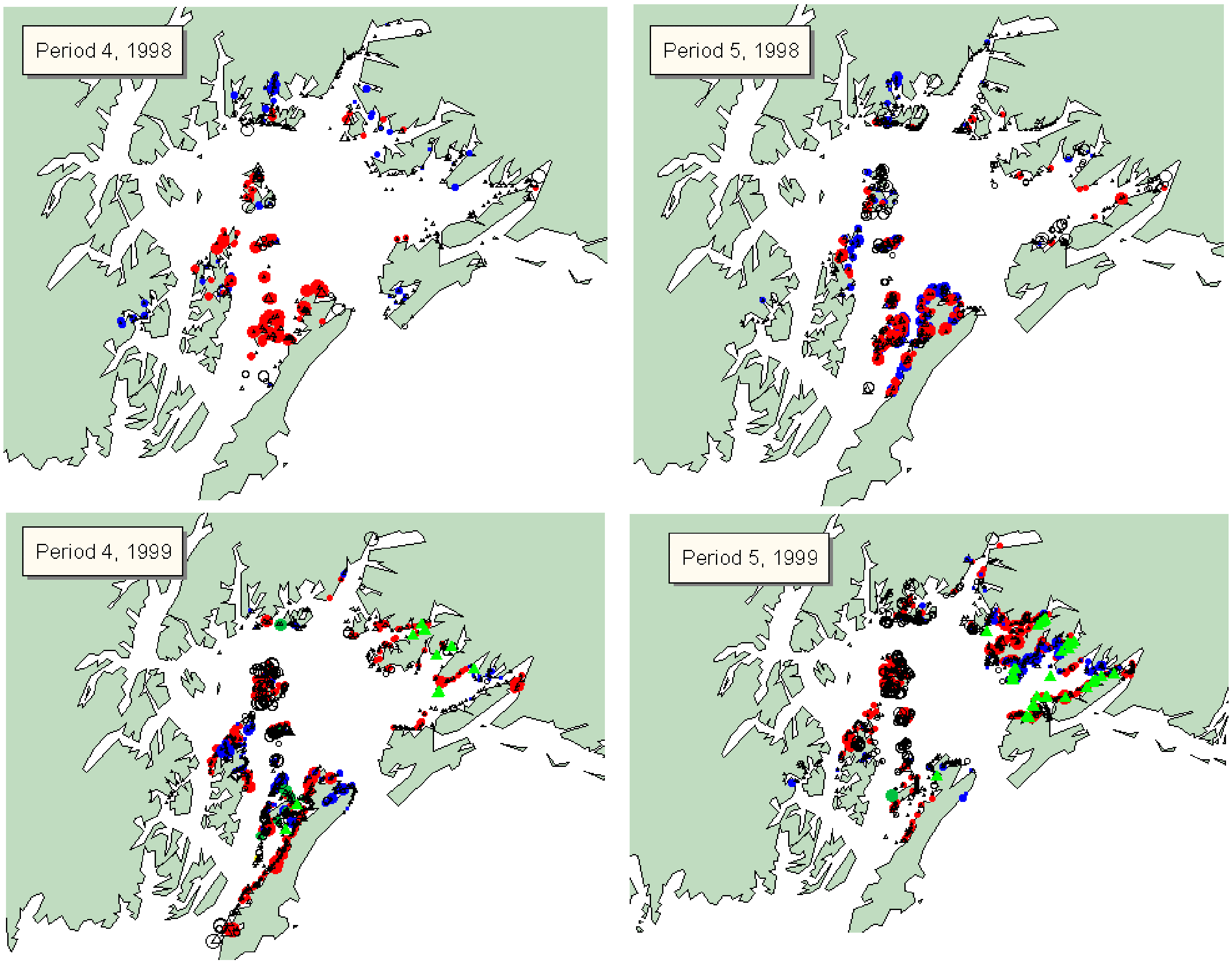


Figure 11. Counts of key species sighted in APEX study regions during period 6, 8/6 - 8/11, 1998. No surverys were flown in period 6 during 1999.

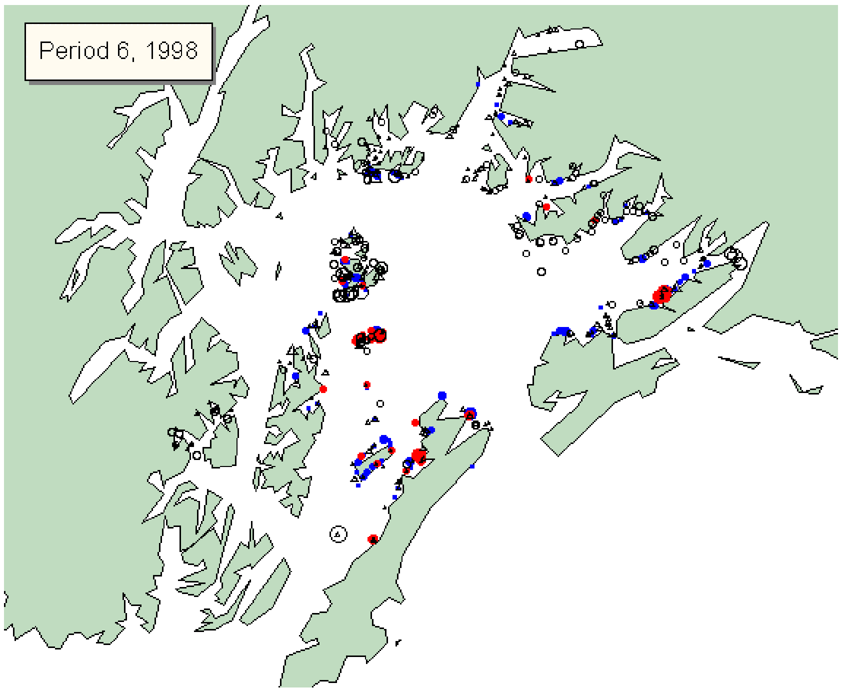


Figure 12. Site-specific relationships between aerial and acoustic fish school counts during 1996-97. Good agreement occurred at Simpson Bay (southeastern PWS) and Whale Bay (southwestern), poor agreement at Zaikof Bay (central) and Eaglek Bay (northern).

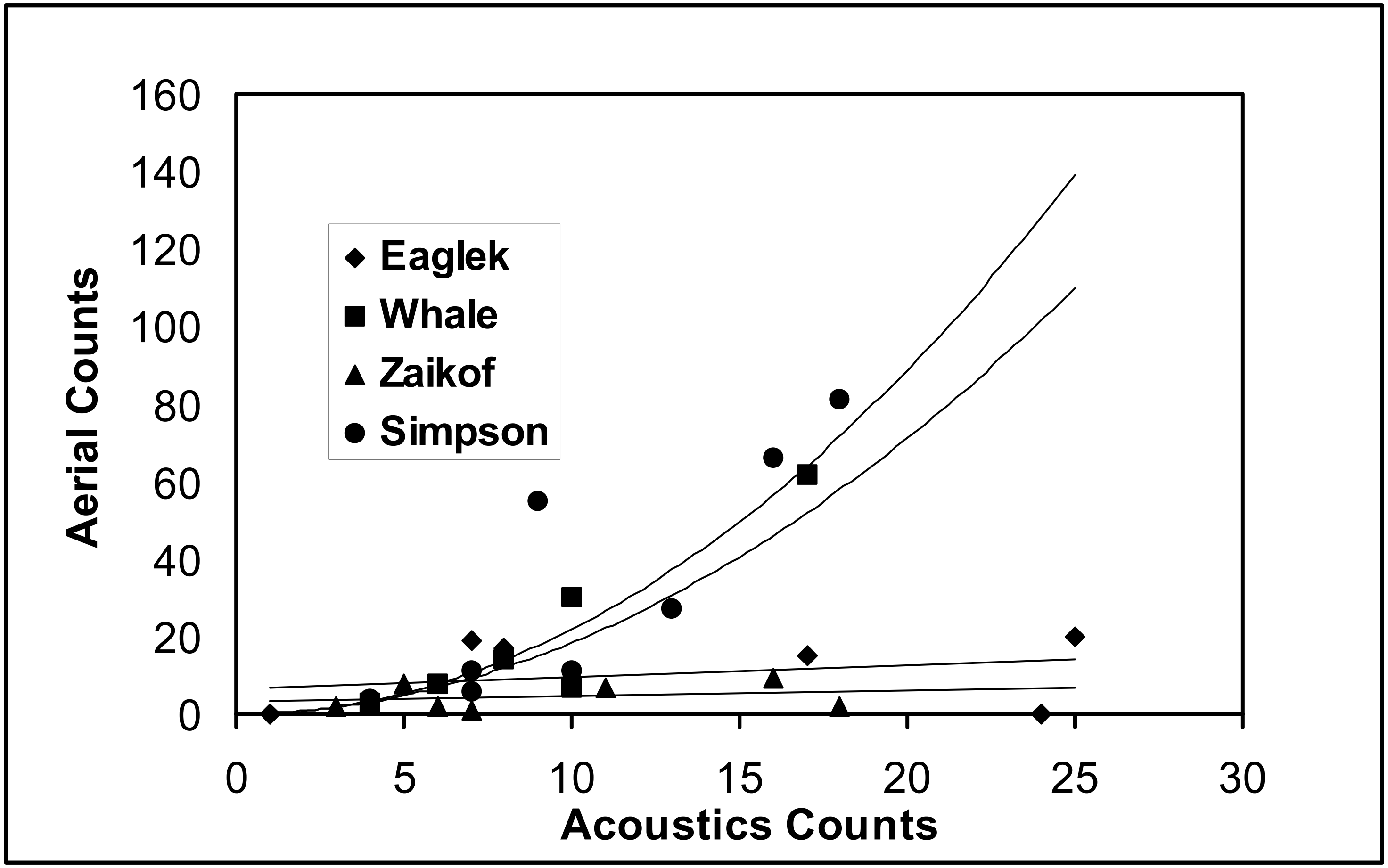


Figure 13. Spatial variation in depth distribution of juvenile herring in July, 1996 starting from eastern PWS (Pt. Gravina) counter-clockwise to southwestern PWS (Fox Farm), just west of PWS at the eastern edge of the Outer Kenai Penisula (Hogg Bay) then to central PWS (Zaikof).

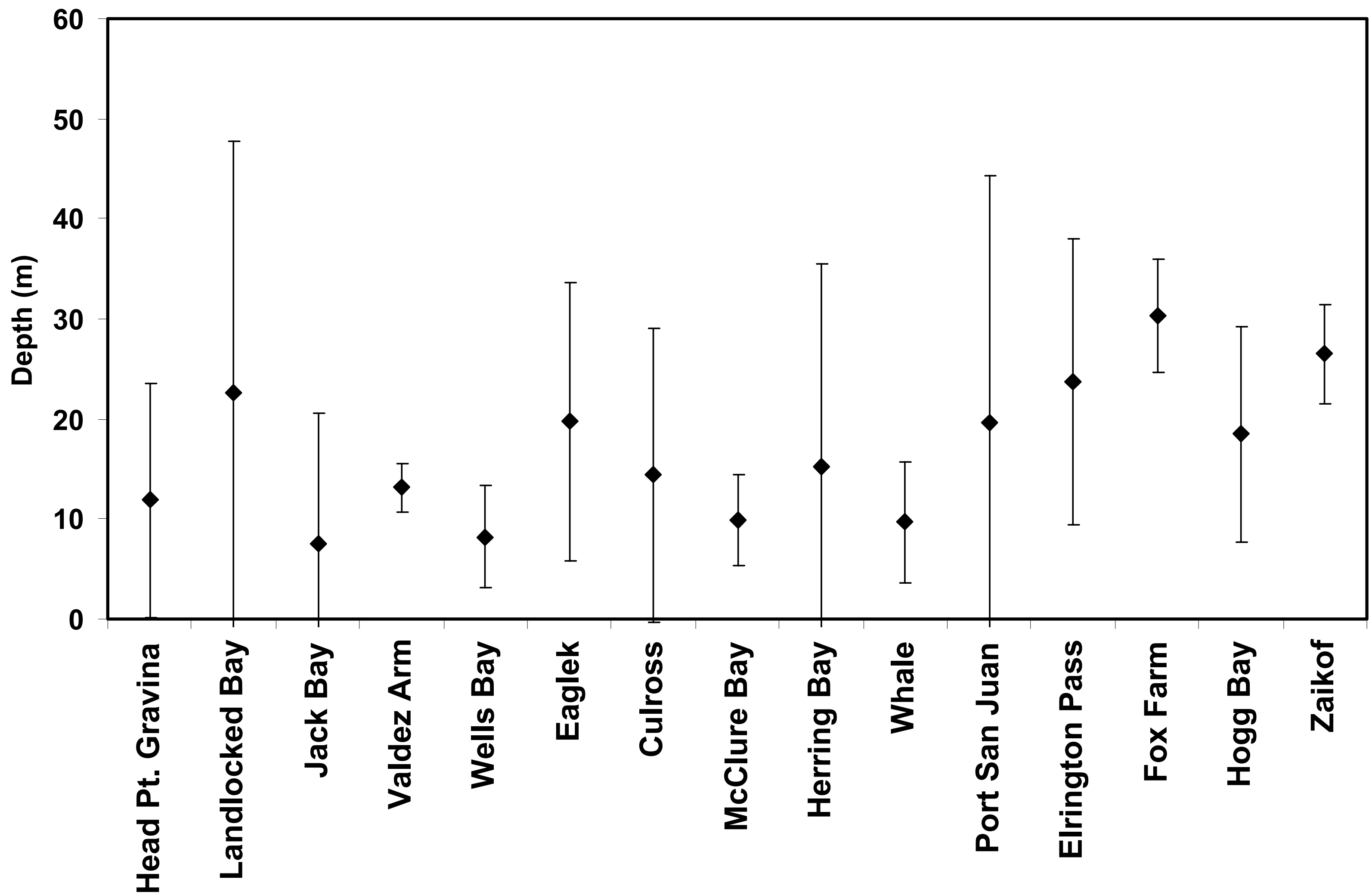


Figure 14. Spatial variability in age structure at PWS herring nursery sites (mainly bays) in July, 1996.

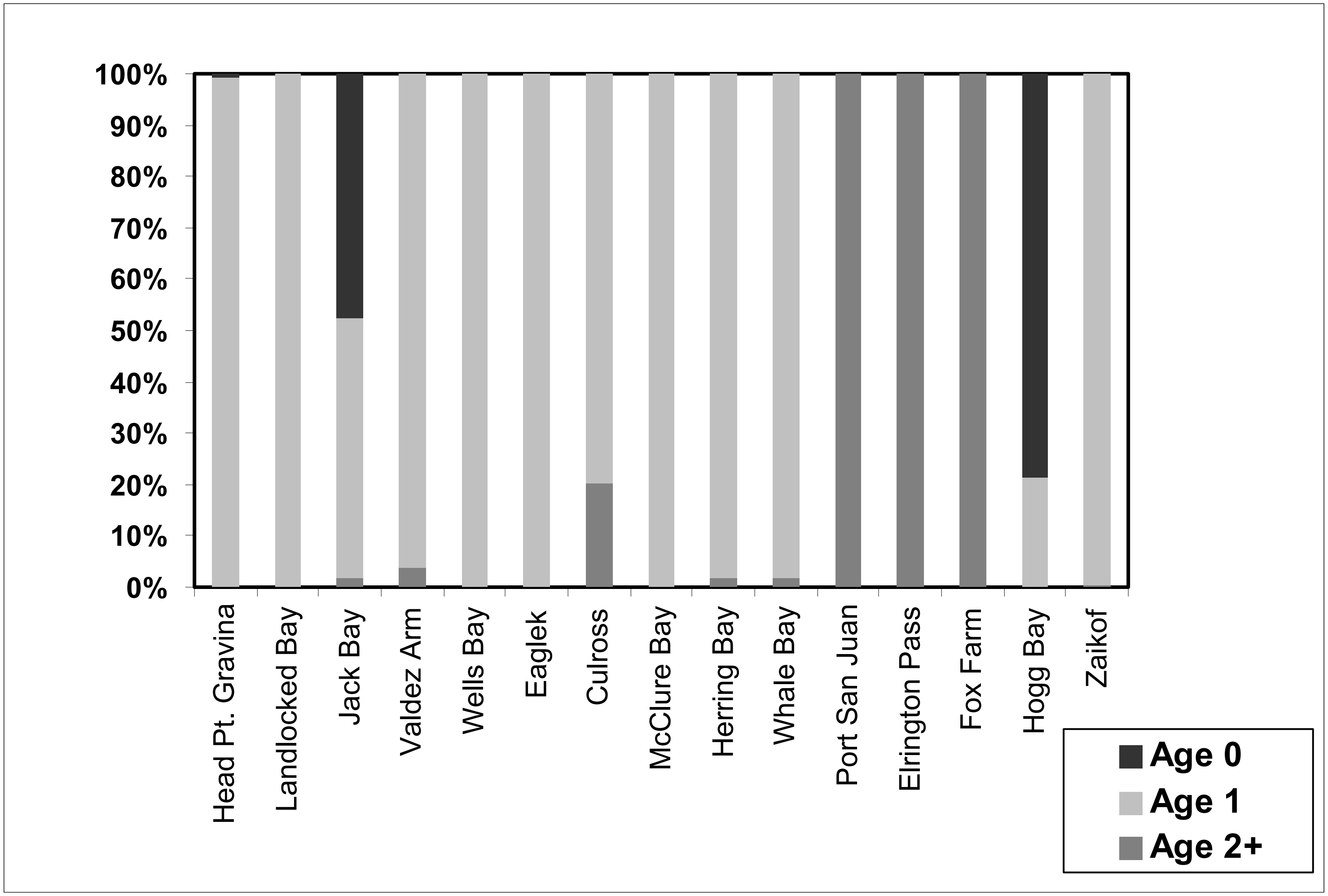


Figure 15. Site-specific temporal variability in PWS juvenile herring depth distribution.

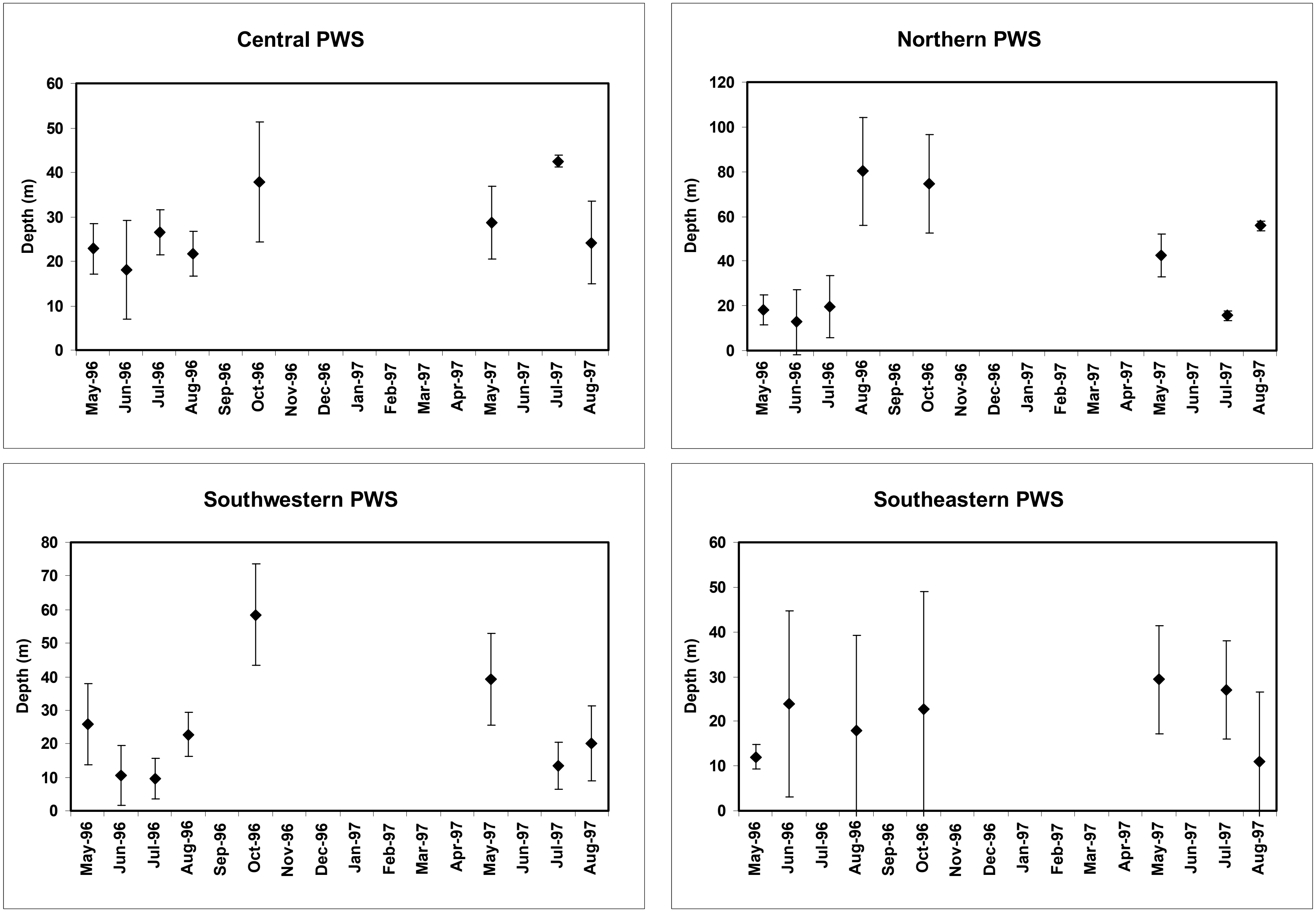
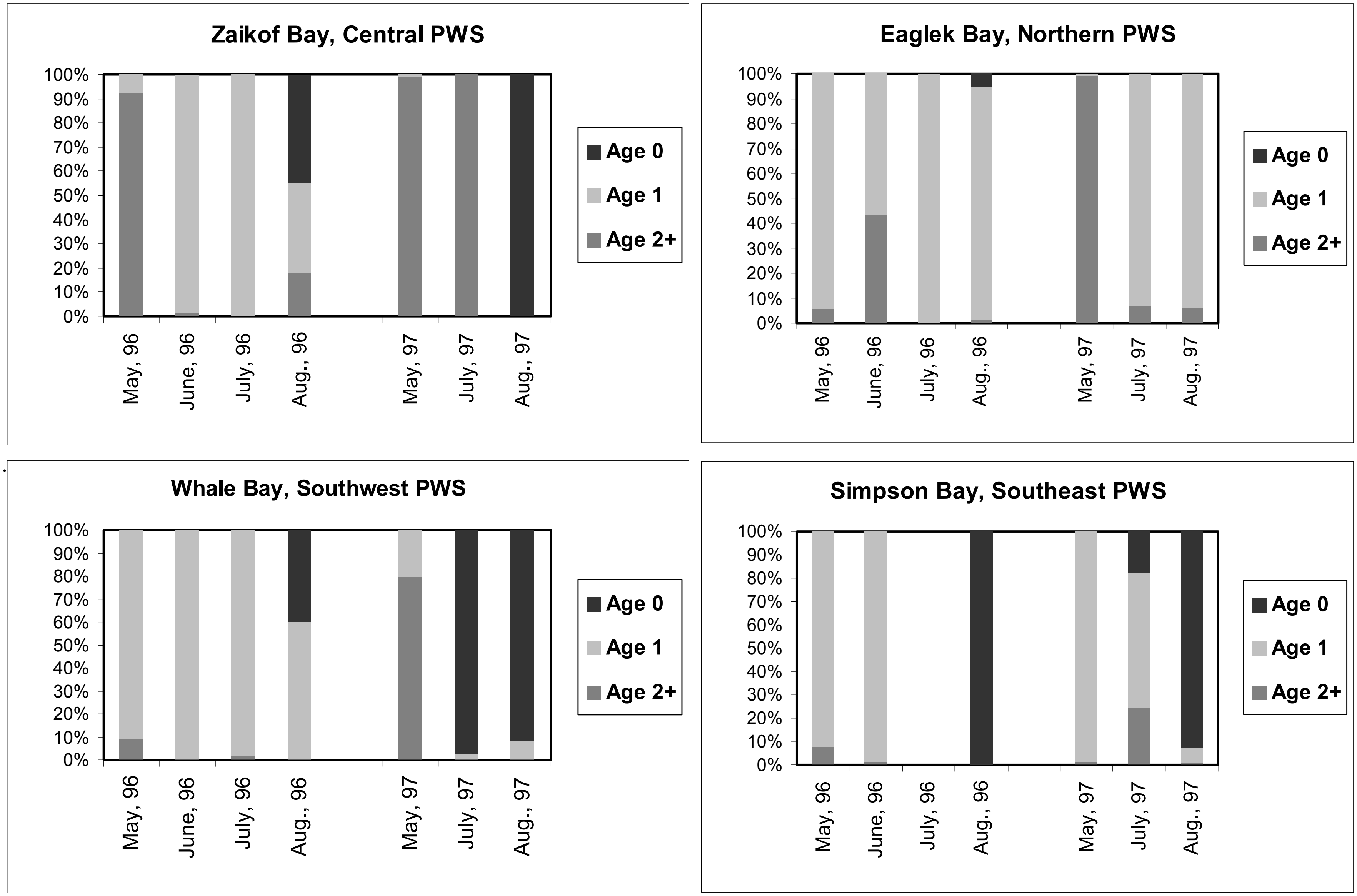


Figure 16. Temporal variability in age structure at PWS herring nursery bays.



APPENDIX I. Summary of flights conducted from 1995 to 1999 including the lineal distance flown per survey (km), the effective swath width for fish and white sea birds (km), and the effective area surveyed ($km^2$) by flight file. Keys for the letter codes are listed at the bottom of the table.

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 950320 | 03/20/95 | 1.55 | 1000 | 189.76 | 455.33 | 86.40 | 1423.82 | 270.17 | B | | | N | y |
| 950327 | 03/27/95 | 2.72 | 1000 | 316.44 | 455.33 | 144.09 | 1423.82 | 450.56 | B | | | N | y |
| 950330 | 03/30/95 | 3.43 | 1000 | 706.89 | 455.33 | 321.87 | 1423.82 | 1006.48 | B | | | N | y |
| 950414 | 04/25/95 | 1.94 | 1000 | 298.34 | 455.33 | 135.85 | 1423.82 | 424.79 | B | | | N | y |
| 950430A | 04/30/95 | | | | | | | | B | | | Y | y |
| 950505B | 05/05/95 | | | | | | | | B | | | Y | y |
| 950506 | 05/06/95 | | | | | | | | B | D | X | Y | n |
| 950609 | 06/09/95 | 3.34 | 1000 | 535.55 | 455.33 | 243.85 | 1423.82 | 762.53 | B | | | N | n |
| 950610 | 06/10/95 | 4.20 | 1059 | 645.70 | 482.02 | 311.22 | 1507.28 | 973.18 | B | | | N | n |
| 950612 | 06/12/95 | 3.94 | 761 | 532.17 | 346.74 | 190.61 | 1084.24 | 596.03 | B | | | N | n |
| 950614 | 06/14/95 | 4.21 | 1000 | 674.31 | 455.33 | 307.04 | 1423.82 | 960.10 | B | | X | Y | n |
| 950709 | 07/09/95 | 7.68 | 1053 | 999.14 | 479.56 | 517.18 | 1499.57 | 1617.21 | B | | | N | n |
| 950710 | 07/10/95 | 3.54 | 948 | 558.73 | 431.77 | 240.41 | 1350.13 | 751.75 | B | | | N | n |
| 950715 | 07/15/95 | 0.17 | 1000 | 28.71 | 455.33 | 13.07 | 1423.82 | 40.88 | B | | | N | n |
| 950715B | 07/15/95 | 1.88 | 1000 | 235.57 | 455.33 | 107.26 | 1423.82 | 335.41 | B | | | N | n |
| 950716 | 07/16/95 | 0.74 | 1040 | 124.83 | 473.55 | 58.87 | 1480.78 | 184.07 | B | | | N | n |
| 950721 | 07/21/95 | 3.80 | 1000 | 710.36 | 455.33 | 323.45 | 1423.82 | 1011.43 | B | | | N | n |
| 950727 | 07/27/95 | 3.90 | 1029 | 571.32 | 468.68 | 269.74 | 1465.57 | 843.46 | B | | X | N | n |
| 950728 | 07/28/95 | 4.71 | 1001 | 654.69 | 455.98 | 298.49 | 1425.84 | 933.38 | B | | X | N | n |
| 950802 | 08/02/95 | 0.15 | 1000 | 23.63 | 455.33 | 10.76 | 1423.82 | 33.64 | B | | | N | n |
| 950804 | 08/04/95 | 0.11 | 1000 | 0.37 | 455.33 | 0.17 | 1423.82 | 0.52 | B | | | N | n |
| 950805 | 08/05/95 | 4.78 | 1000 | 465.22 | 455.33 | 211.83 | 1423.82 | 662.40 | B | | | N | n |
| 950806 | 08/06/95 | 1.48 | 1000 | 214.82 | 455.33 | 97.82 | 1423.82 | 305.87 | B | | | N | y |
| 950805B | 08/06/95 | 0.82 | 1000 | 148.17 | 455.33 | 67.47 | 1423.82 | 210.96 | B | | | N | n |
| 950808 | 08/08/95 | 2.13 | 941 | 270.57 | 428.65 | 116.81 | 1340.40 | 365.28 | B | | | N | y |
| 950809 | 08/09/95 | 2.18 | 866 | 407.53 | 394.16 | 162.00 | 1232.53 | 506.56 | B | | | N | y |
| 950811 | 08/11/95 | 5.52 | 900 | 789.66 | 409.80 | 323.60 | 1281.44 | 1011.88 | B | | | N | y |
| 950815 | 08/15/95 | 6.52 | 900 | 987.75 | 409.80 | 404.78 | 1281.44 | 1265.74 | B | | | N | y |
| 950819 | 08/19/95 | 3.80 | 900 | 465.34 | 409.80 | 190.70 | 1281.44 | 596.33 | B | | | N | n |
| 950820 | 08/20/95 | 1.29 | 400 | 108.64 | 182.13 | 19.79 | 569.53 | 61.88 | B | | X | N | n |
| 950822 | 08/22/95 | 3.58 | 1000 | 515.63 | 455.33 | 234.78 | 1423.82 | 734.14 | B | | | N | n |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 951004 | 10/04/95 | 4.45 | 1000 | 739.27 | 455.33 | 336.62 | 1423.82 | 1052.60 | B | | X | N | y |
| 960416a | 04/16/96 | 1.27 | 1000 | 172.47 | 455.33 | 78.54 | 1423.82 | 245.58 | B | | | N | y |
| 960418a | 04/18/96 | 2.76 | 1192 | 403.68 | 542.97 | 218.43 | 1697.87 | 683.03 | B | | | N | y |
| 960419a | 04/19/96 | 2.18 | 1106 | 372.68 | 503.47 | 188.85 | 1574.36 | 590.53 | B | | | N | y |
| 960424a | 04/24/96 | 1.03 | 1182 | 303.22 | 538.02 | 167.03 | 1682.39 | 522.29 | B | | | Y | n |
| 960509a | 05/09/96 | 3.33 | 1147 | 393.02 | 522.24 | 206.00 | 1633.04 | 644.17 | BD | | X | N | n |
| 960509b | 05/10/96 | 0.90 | 1042 | 138.51 | 474.38 | 65.60 | 1483.39 | 205.12 | B | | | N | n |
| 960510a | 05/10/96 | 0.28 | 794 | 30.49 | 361.67 | 11.00 | 1130.92 | 34.40 | BD | R | X | N | n |
| 960510b | 05/11/96 | 1.12 | 1063 | 53.59 | 484.00 | 26.05 | 1513.47 | 81.45 | BD | R | X | Y | n |
| 960511a | 05/11/96 | 1.88 | 1104 | 259.88 | 502.57 | 134.58 | 1571.54 | 420.83 | BD | | X | N | n |
| 960511b | 05/12/96 | 2.31 | 1055 | 263.87 | 480.23 | 125.69 | 1501.67 | 393.04 | BD | R | X | N | n |
| 960512a | 05/12/96 | 2.21 | 1047 | 324.02 | 476.65 | 154.64 | 1490.47 | 483.56 | BD | R | X | N | n |
| 960513a | 05/13/96 | 2.34 | 1105 | 369.50 | 503.13 | 186.19 | 1573.28 | 582.22 | BD | R | X | N | n |
| 960514a | 05/14/96 | 3.65 | 1067 | 501.17 | 485.88 | 243.43 | 1519.34 | 761.22 | BD | R | X | N | n |
| 960610a | 06/10/96 | 0.86 | 999 | 97.46 | 454.90 | 44.31 | 1422.45 | 138.56 | BD | R | X | N | n |
| 960611a | 06/11/96 | 0.73 | 988 | 95.54 | 449.64 | 42.88 | 1406.03 | 134.08 | BD | | X | N | n |
| 960612a | 06/12/96 | 1.08 | 1068 | 174.59 | 486.27 | 85.03 | 1520.56 | 265.88 | BD | | X | N | n |
| 960613a | 06/13/96 | 1.78 | 1106 | 272.18 | 503.63 | 136.99 | 1574.86 | 428.38 | B | R | X | N | n |
| 960614a | 06/14/96 | 1.88 | 1100 | 279.30 | 500.87 | 139.89 | 1566.21 | 437.43 | BD | R | X | N | n |
| 960615a | 06/15/96 | 2.73 | 1100 | 381.56 | 500.87 | 191.11 | 1566.21 | 597.61 | B | R | X | N | n |
| 960702a | 07/02/96 | 1.52 | 983 | 248.99 | 447.37 | 111.25 | 1398.93 | 347.89 | B | | X | N | n |
| 960703a | 07/03/96 | 1.48 | 935 | 206.78 | 425.66 | 87.46 | 1331.04 | 273.50 | B | | X | N | n |
| 960704a | 07/04/96 | 1.98 | 907 | 233.19 | 413.04 | 98.32 | 1291.57 | 307.46 | B | | X | N | n |
| 960705b | 07/05/96 | 3.42 | 887 | 427.16 | 403.71 | 170.72 | 1262.39 | 533.83 | B | | X | N | n |
| 960706a | 07/06/96 | 2.88 | 1005 | 413.59 | 457.70 | 189.36 | 1431.21 | 592.12 | B | | X | N | n |
| 960707a | 07/07/96 | 4.08 | 904 | 483.53 | 411.85 | 202.68 | 1287.83 | 633.78 | B | | X | N | n |
| 960708a | 07/08/96 | 5.04 | 1000 | 482.64 | 455.33 | 219.77 | 1423.82 | 687.22 | B | R | X | N | n |
| 960709a | 07/09/96 | 2.01 | 798 | 260.93 | 363.14 | 94.75 | 1135.53 | 296.29 | B | R | X | N | y |
| 960710a | 07/10/96 | 2.03 | 1000 | 298.51 | 455.33 | 135.92 | 1423.82 | 425.02 | B | R | X | N | n |
| 960711a | 07/11/96 | 2.51 | 927 | 336.54 | 422.31 | 141.00 | 1320.57 | 440.92 | B | | X | N | n |
| 960717a | 07/17/96 | 3.64 | 992 | 356.03 | 451.80 | 160.70 | 1412.77 | 502.52 | B | R | X | N | y |
| 960718a | 07/18/96 | 3.06 | 918 | 348.72 | 418.21 | 143.71 | 1307.75 | 449.37 | B | R | | N | y |
| 960720a | 07/20/96 | 1.33 | 904 | 168.51 | 411.51 | 69.93 | 1286.78 | 218.67 | B | R | X | N | y |
| 960721a | 07/21/96 | 3.28 | 740 | 280.21 | 337.11 | 104.03 | 1054.14 | 325.30 | B | R | X | N | y |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 960801a | 08/01/96 | 0.34 | 529 | 55.35 | 240.68 | 13.27 | 752.59 | 41.50 | BD | D | X | N | n |
| 960802a | 08/02/96 | 0.45 | 800 | 70.86 | 364.27 | 25.81 | 1139.06 | 80.72 | B | RD | X | N | n |
| 960802b | 08/03/96 | 1.53 | 997 | 231.13 | 453.85 | 104.79 | 1419.18 | 327.68 | B | R | X | N | n |
| 960804a | 08/04/96 | 1.28 | 1000 | 177.37 | 455.33 | 80.76 | 1423.82 | 252.54 | B | R | X | N | n |
| 960804b | 08/05/96 | 0.79 | 1000 | 91.34 | 455.33 | 41.59 | 1423.82 | 130.05 | B | RD | X | N | n |
| 960805a | 08/06/96 | 0.48 | 900 | 87.57 | 409.80 | 35.89 | 1281.44 | 112.22 | B | RD | X | N | y |
| 960806a | 08/06/96 | 0.50 | 1000 | 78.52 | 455.33 | 35.75 | 1423.82 | 111.80 | B | R | X | N | n |
| 970612a | 06/12/97 | 2.07 | 1000 | 284.58 | 455.33 | 129.57 | 1423.82 | 405.18 | BD | D |  | N | n |
| 970613a1 | 06/13/97 | 1.38 | 1000 | 187.72 | 455.33 | 85.48 | 1423.82 | 267.29 | B | D |  | N | n |
| 970613a2 | 06/13/97 | 0.30 | 968 | 60.31 | 440.57 | 26.48 | 1377.65 | 82.82 | B | D |  | N | n |
| 970613b | 06/13/97 | 0.18 | 639 | 41.46 | 291.02 | 12.02 | 910.01 | 37.58 | B | D | X | N | n |
| 970614a | 06/14/97 | 4.12 | 1000 | 439.13 | 455.33 | 199.96 | 1423.82 | 625.26 | B | D | X | N | n |
| 970615a | 06/15/97 | 2.78 | 1000 | 211.06 | 455.33 | 96.11 | 1423.82 | 300.54 | B | D | X | N | n |
| 970616a | 06/16/97 | 2.78 | 1000 | 304.80 | 455.33 | 138.79 | 1423.82 | 433.99 | B | D |  | N | y |
| 970617a | 06/17/97 | 3.23 | 1018 | 466.22 | 463.43 | 216.67 | 1449.14 | 677.54 | B |  |  | N | n |
| 970617b | 06/17/97 | 0.38 | 1000 | 68.35 | 455.33 | 31.12 | 1423.82 | 97.32 | B |  |  | N | n |
| 970618a | 06/18/97 | 3.28 | 1000 | 518.36 | 455.33 | 236.03 | 1423.82 | 738.06 | B | D |  | N | n |
| 970619a | 06/19/97 | 2.65 | 828 | 398.32 | 376.83 | 150.50 | 1178.34 | 470.62 | B | D |  | N | n |
| 970620a | 06/20/97 | 3.34 | 1000 | 447.79 | 455.33 | 203.90 | 1423.82 | 637.58 | B | D | X | N | n |
| 970621a | 06/21/97 | 5.19 | 997 | 484.14 | 454.09 | 281.46 | 1419.95 | 880.13 | B | D | X | N | n |
| 970709a | 07/09/97 | 1.00 | 1000 | 143.43 | 455.33 | 65.31 | 1423.82 | 204.21 | BD | DC | X | N | n |
| 970709b | 07/09/97 | 1.36 | 1000 | 152.14 | 455.33 | 69.28 | 1423.82 | 216.62 | BD | RDC | X | N | c |
| 970709c | 07/10/97 | 1.28 | 1000 | 74.55 | 455.33 | 33.94 | 1423.82 | 106.14 | BD | RDC | X | N | c |
| 970713a | 07/13/97 | 0.29 | 514 | 42.78 | 233.99 | 9.97 | 731.69 | 31.17 | BD | D |  | N | c |
| 970713b | 07/13/97 | 0.60 | 1000 | 52.30 | 455.33 | 23.82 | 1423.82 | 74.47 | B | DC |  | N | c |
| 970714a | 07/14/97 | 0.60 | 1000 | 91.91 | 455.33 | 41.85 | 1423.82 | 130.87 | B | D |  | N | n |
| 970714b | 07/14/97 | 1.08 | 927 | 130.47 | 422.31 | 54.80 | 1320.57 | 171.35 | B | DC |  | N | c |
| 970715a | 07/15/97 | 2.36 | 1000 | 239.89 | 455.33 | 109.23 | 1423.82 | 341.57 | B | DC |  | N | c |
| 970715b | 07/15/97 | 1.94 | 1000 | 197.43 | 455.33 | 89.90 | 1423.82 | 281.12 | B | DC |  | N | c |
| 970717a | 07/17/97 | 1.93 | 942 | 319.23 | 429.13 | 137.29 | 1341.89 | 429.29 | BA | D |  | N | y |
| 970718a | 07/18/97 | 3.39 | 1014 | 409.22 | 461.81 | 189.78 | 1444.06 | 593.43 | BA | D | X | N | y |
| 970719a | 07/19/97 | 4.39 | 1013 | 468.16 | 461.11 | 211.88 | 1441.89 | 662.55 | BA | D | X | N | y |
| 970720a | 07/20/97 | 4.31 | 1000 | 494.90 | 455.33 | 225.35 | 1423.82 | 704.65 | BA | D |  | N | n |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 970721a | 07/21/97 | 5.79 | 1000 | 479.57 | 455.33 | 218.38 | 1423.82 | 682.87 | BA | D | X | N | n |
| 970722a | 07/22/97 | 5.23 | 989 | 558.89 | 450.33 | 250.77 | 1408.18 | 784.15 | BA | D | X | N | n |
| 970723a | 07/23/97 | 3.21 | 1000 | 69.17 | 455.33 | 31.50 | 1423.82 | 98.49 | BA | D | X | Y | n |
| 970723b | 07/23/97 | 0.90 | 1000 | 93.88 | 455.33 | 42.54 | 1423.82 | 133.01 | BA | D | X | Y | n |
| 970723c | 07/23/97 | 0.73 | 1000 | 63.29 | 455.33 | 25.40 | 1423.82 | 89.57 | BA | D | X | Y | n |
| 970723d | 07/23/97 | 0.03 | 1000 | 11.43 | 455.33 | 5.20 | 1423.82 | 16.27 | BA | D | X | Y | n |
| 970723e | 07/23/97 | 0.06 | 1000 | 12.49 | 455.33 | 3.13 | 1423.82 | 17.73 | BA | D | X | Y | n |
| 970724a | 07/23/97 | 3.05 | 1000 | 79.30 | 455.33 | 3.53 | 1423.82 | 110.23 | BA | D | | Y | n |
| 970725a | 07/25/97 | 4.06 | 1000 | 476.13 | 455.33 | 216.80 | 1423.82 | 677.95 | BA | D | X | N | n |
| 970725b | 07/25/97 | 0.56 | 1000 | 76.41 | 455.33 | 34.79 | 1423.82 | 108.79 | BA | D | X | N | y |
| 980706a.raw | 07/06/98 | 0.58 | 1146 | 67.97 | 522.03 | 35.68 | 1632.38 | 111.56 | AN | | X | N | n |
| 980706b.raw | 07/06/98 | 0.79 | 1092 | 125.97 | 497.07 | 62.57 | 1554.34 | 195.64 | AN | | X | N | n |
| 980706c.raw | 07/06/98 | 0.11 | 1200 | 10.51 | 546.40 | 5.74 | 1708.59 | 17.95 | AN | | | N | n |
| 980706d.raw | 07/06/98 | 1.54 | 1018 | 253.46 | 463.66 | 117.47 | 1449.85 | 367.33 | AN | | | N | n |
| 980707a.raw | 07/07/98 | 3.24 | 1000 | 528.13 | 455.33 | 240.48 | 1423.82 | 751.97 | AN | | X | N | n |
| 980707b.raw | 07/07/98 | 0.74 | 1000 | 648.70 | 455.33 | 54.90 | 1423.82 | 171.67 | AN | | | N | n |
| 980707c.raw | 07/07/98 | 0.06 | 1000 | 660.87 | 455.33 | 5.54 | 1423.82 | 17.32 | AN | | | N | n |
| 980707d.raw | 07/07/98 | 0.48 | 1000 | 83.98 | 455.33 | 53.29 | 1423.82 | 166.63 | AN | | | N | n |
| 980708a.raw | 07/08/98 | 0.00 | 1000 | 0.00 | 455.33 | 0.00 | 1423.82 | 0.00 | AN | | X | N | n |
| 980708b.raw | 07/08/98 | 3.54 | 974 | 592.07 | 443.58 | 262.58 | 1387.06 | 821.07 | A | | X | N | n |
| 980708c.raw | 07/08/98 | 0.62 | 1000 | 100.72 | 455.33 | 45.86 | 1423.82 | 143.41 | A | | | N | n |
| 980710a.raw | 07/10/98 | 3.78 | 981 | 624.50 | 446.83 | 1633.60 | 1397.23 | 5108.24 | ACB | | X | N | n |
| 980711a.raw | 07/11/98 | 0.88 | 998 | 137.43 | 454.48 | 62.54 | 1421.16 | 195.57 | ACB | | X | N | n |
| 980711b.raw | 07/11/98 | 0.43 | 1000 | 211.78 | 455.33 | 33.85 | 1423.82 | 105.86 | ACB | | | N | n |
| 980711c.raw | 07/11/98 | 0.45 | 918 | 282.36 | 418.08 | 29.62 | 1307.33 | 92.62 | ACB | | | N | n |
| 980711d.raw | 07/11/98 | 1.91 | 1003 | 607.81 | 456.62 | 148.62 | 1427.85 | 464.74 | ACB | | | N | n |
| 980712c.bs | 07/12/98 | 1.51 | 1000 | 386.51 | 455.33 | 111.41 | 1423.82 | 348.38 | ACB | | X | N | n |
| 980712a.raw | 07/12/98 | 1.03 | 994 | 158.39 | 452.78 | 71.72 | 1415.85 | 224.26 | ACB | | X | N | n |
| 980712b.raw | 07/12/98 | 0.88 | 1000 | 141.83 | 455.33 | 64.58 | 1423.82 | 201.93 | ACB | | X | N | n |
| 980712d.raw | 07/12/98 | 0.72 | 1000 | 509.64 | 455.33 | 56.07 | 1423.82 | 175.33 | B | | X | N | n |
| 980712e.raw | 07/12/98 | 0.68 | 1000 | 635.16 | 455.33 | 57.15 | 1423.82 | 178.71 | ACB | | X | N | n |
| 980712f.raw | 07/12/98 | 0.95 | 1000 | 796.37 | 455.33 | 73.41 | 1423.82 | 229.55 | ACB | | X | N | n |
| 980713a.bs | 07/13/98 | 2.26 | 1005 | 368.90 | 457.51 | 168.81 | 1430.63 | 527.87 | B | | X | N | n |
| 980713b.bs | 07/13/98 | 2.03 | 1000 | 689.26 | 455.33 | 145.87 | 1423.82 | 456.14 | B | | X | N | n |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 980714b.bs | 07/14/98 | 0.03 | 1000 | 338.58 | 455.33 | 2.38 | 1423.82 | 7.45 | AC | | X | N | n |
| 980714a.raw | 07/14/98 | 2.08 | 956 | 333.35 | 435.11 | 145.16 | 1360.57 | 453.90 | B | | X | N | n |
| 980715a.raw | 07/15/98 | 2.32 | 996 | 360.66 | 453.54 | 163.55 | 1418.21 | 511.41 | AC | | X | N | n |
| 980715b.raw | 07/15/98 | 2.27 | 1000 | 363.52 | 455.33 | 165.52 | 1423.82 | 517.58 | AC | | X | N | n |
| 980715c.raw | 07/15/98 | 0.54 | 1000 | 93.45 | 455.33 | 42.55 | 1423.82 | 133.07 | ACB | | X | N | n |
| 980716a.raw | 07/16/98 | 2.16 | 996 | 333.64 | 453.41 | 151.26 | 1417.80 | 472.99 | ACB | | X | N | n |
| 980716b.raw | 07/16/98 | 2.03 | 1000 | 646.25 | 455.33 | 142.34 | 1423.82 | 445.10 | ACB | | X | N | n |
| 980716c.raw | 07/16/98 | 0.51 | 1000 | 84.60 | 455.33 | 38.52 | 1423.82 | 120.46 | ACB | | X | N | n |
| 980717a.bs | 07/17/98 | 2.11 | 988 | 332.34 | 449.78 | 149.52 | 1406.45 | 467.55 | B | | X | N | n |
| 980717b.bs | 07/17/98 | 1.42 | 1000 | 558.44 | 455.33 | 102.95 | 1423.82 | 321.93 | B | | X | N | n |
| 980718a.raw | 07/18/98 | 0.99 | 1000 | 156.15 | 455.33 | 71.10 | 1423.82 | 222.32 | AC | | X | N | n |
| 980718b.raw | 07/18/98 | 1.04 | 1000 | 321.31 | 455.33 | 75.21 | 1423.82 | 235.17 | AC | | X | N | n |
| 980718c.raw | 07/18/98 | 1.98 | 1000 | 615.67 | 455.33 | 134.03 | 1423.82 | 419.11 | AC | | X | N | n |
| 980718d.raw | 07/18/98 | 0.46 | 1000 | 688.16 | 455.33 | 33.01 | 1423.82 | 103.22 | AC | | X | N | n |
| 980719c.bs | 07/19/98 | 1.03 | 1000 | 411.07 | 455.33 | 80.81 | 1423.82 | 252.68 | AC | | X | N | n |
| 980719a.raw | 07/19/98 | 0.93 | 1000 | 147.88 | 455.33 | 67.34 | 1423.82 | 210.57 | AC | | X | N | n |
| 980719b.raw | 07/19/98 | 0.52 | 1000 | 233.60 | 455.33 | 39.03 | 1423.82 | 122.05 | B | | X | N | n |
| 980719d.raw | 07/19/98 | 0.53 | 1000 | 514.06 | 455.33 | 46.89 | 1423.82 | 146.63 | AC | | X | N | n |
| 980719e.raw | 07/19/98 | 0.53 | 1000 | 606.61 | 455.33 | 42.14 | 1423.82 | 131.78 | AC | | X | N | n |
| 980719f.raw | 07/19/98 | 2.10 | 1000 | 946.56 | 455.33 | 154.79 | 1423.82 | 484.04 | AC | | X | N | n |
| 980720a.raw | 07/20/98 | 0.94 | 965 | 153.91 | 439.36 | 67.57 | 1373.87 | 211.30 | AC | | X | N | n |
| 980720b.raw | 07/20/98 | 0.40 | 1000 | 65.88 | 455.33 | 30.00 | 1423.82 | 93.81 | AC | | X | N | n |
| 980723a.raw | 07/23/98 | 2.02 | 1000 | 328.36 | 455.33 | 149.51 | 1423.82 | 467.52 | AC | | X | N | n |
| 980723b.raw | 07/23/98 | 1.83 | 1000 | 621.34 | 455.33 | 133.41 | 1423.82 | 417.16 | AC | | X | N | n |
| 980723c.raw | 07/23/98 | 0.57 | 1000 | 88.27 | 455.33 | 40.19 | 1423.82 | 125.69 | AC | | X | N | n |
| 980724a.raw | 07/24/98 | 2.18 | 1000 | 352.81 | 455.33 | 160.64 | 1423.82 | 502.33 | AC | | X | N | n |
| 980724b.raw | 07/24/98 | 1.81 | 1000 | 644.64 | 455.33 | 132.88 | 1423.82 | 415.53 | AC | | X | N | n |
| 980724c.raw | 07/24/98 | 0.58 | 1000 | 99.69 | 455.33 | 45.39 | 1423.82 | 141.94 | AC | | X | N | n |
| 980726a.sm | 07/26/98 | 0.81 | 922 | 125.04 | 420.02 | 52.48 | 1313.41 | 164.10 | AC | D | X | N | n |
| 980726b.sm | 07/26/98 | 2.40 | 991 | 501.62 | 451.08 | 169.58 | 1410.52 | 530.28 | AC | D | X | N | n |
| 980726c.sm | 07/26/98 | 0.38 | 1000 | 562.17 | 455.33 | 27.57 | 1423.82 | 86.21 | AC | D | X | N | n |
| 980728a.raw | 07/28/98 | 0.84 | 1000 | 108.68 | 455.33 | 49.49 | 1423.82 | 154.74 | AC | | X | N | n |
| 980728b.raw | 07/28/98 | 0.46 | 1000 | 188.23 | 455.33 | 36.22 | 1423.82 | 113.27 | AC | | X | N | n |
| 980728c.raw | 07/28/98 | 0.14 | 1000 | 214.53 | 455.33 | 11.97 | 1423.82 | 37.44 | AC | | X | N | n |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 980728d.raw | 07/28/98 | 0.38 | 1000 | 277.08 | 455.33 | 28.49 | 1423.82 | 89.08 | AC | | X | N | n |
| 980728e.raw | 07/28/98 | 1.05 | 1000 | 457.59 | 455.33 | 82.19 | 1423.82 | 257.01 | AC | | X | N | n |
| 980728f.raw | 07/28/98 | 0.01 | 1000 | 460.21 | 455.33 | 1.19 | 1423.82 | 3.73 | AC | | X | N | n |
| 980730a.raw | 07/30/98 | 2.03 | 1000 | 351.25 | 455.33 | 159.94 | 1423.82 | 500.12 | AC | | X | N | y |
| 980730b.raw | 07/30/98 | 1.65 | 1000 | 284.19 | 455.33 | 250.40 | 1423.82 | 783.01 | AC | | X | N | y |
| 980730c.raw | 07/30/98 | 0.53 | 1000 | 97.95 | 455.33 | 44.60 | 1423.82 | 139.45 | AC | | X | N | y |
| 980730d.raw | 07/30/98 | 0.76 | 1000 | 134.82 | 455.33 | 61.39 | 1423.82 | 191.97 | AC | | X | N | y |
| 980730e.raw | 07/30/98 | 1.12 | 1000 | 336.55 | 455.33 | 91.85 | 1423.82 | 287.20 | AC | | X | N | y |
| 980730f.raw | 07/30/98 | 0.97 | 1000 | 510.50 | 455.33 | 79.21 | 1423.82 | 247.69 | AC | | X | N | y |
| 980731a.sm | 07/31/98 | 1.86 | 1000 | 326.96 | 455.33 | 148.88 | 1423.82 | 465.53 | AC | D | X | N | y |
| 980731b.sm | 07/31/98 | 0.16 | 1000 | 355.25 | 455.33 | 12.88 | 1423.82 | 40.28 | AC | D | X | N | y |
| 980731c.sm | 07/31/98 | 1.43 | 1000 | 610.28 | 455.33 | 116.13 | 1423.82 | 363.13 | AC | D | X | N | y |
| 980731d.sm | 07/31/98 | 1.09 | 1000 | 103.03 | 455.33 | 93.83 | 1423.82 | 293.40 | AC | D | X | N | y |
| 980801a.sm | 08/01/98 | 1.80 | 1000 | 324.02 | 455.33 | 147.54 | 1423.82 | 461.35 | AC | D | X | N | y |
| 980801b.sm | 08/01/98 | 0.89 | 757 | 475.60 | 344.87 | 53.09 | 1078.41 | 166.02 | AC | D | X | N | y |
| 980801c.sm | 08/01/98 | 0.58 | 1000 | 98.07 | 455.33 | 44.65 | 1423.82 | 139.63 | AC | D | X | N | y |
| 980803a.raw | 08/03/98 | 0.83 | 887 | 141.47 | 403.88 | 57.17 | 1262.93 | 178.77 | AC | | X | N | y |
| 980803b.raw | 08/03/98 | 0.93 | 956 | 310.02 | 435.41 | 73.41 | 1361.53 | 229.55 | AC | | X | N | y |
| 980803c.raw | 08/03/98 | 2.09 | 1000 | 693.37 | 455.33 | 174.55 | 1423.82 | 545.83 | AC | | X | N | y |
| 980804a.raw | 08/04/98 | 0.81 | 1000 | 139.90 | 455.33 | 63.70 | 1423.82 | 199.19 | AC | | X | N | y |
| 980804b.raw | 08/04/98 | 0.51 | 1000 | 228.74 | 455.33 | 40.45 | 1423.82 | 126.50 | AC | | X | N | y |
| 980804c.raw | 08/04/98 | 0.51 | 1000 | 314.49 | 455.33 | 39.04 | 1423.82 | 122.09 | AC | | X | N | y |
| 980804d.raw | 08/04/98 | 0.89 | 1000 | 475.39 | 455.33 | 73.26 | 1423.82 | 229.10 | AC | | X | N | y |
| 980804e.raw | 08/04/98 | 1.58 | 1000 | 755.25 | 455.33 | 127.43 | 1423.82 | 398.47 | AC | | X | N | y |
| 980805a.raw | 08/05/98 | 0.88 | 790 | 146.76 | 359.59 | 52.90 | 1124.42 | 165.42 | AC | | X | N | y |
| 980805b.raw | 08/05/98 | 1.11 | 795 | 332.04 | 361.89 | 67.30 | 1131.62 | 210.45 | AC | | X | N | y |
| 980805c.raw | 08/05/98 | 0.98 | 839 | 502.53 | 382.21 | 65.13 | 1195.17 | 203.65 | AC | | X | N | y |
| 980805d.raw | 08/05/98 | 1.21 | 705 | 698.73 | 320.92 | 63.10 | 1003.50 | 197.31 | AC | | X | N | y |
| 980807a.sm | 08/07/98 | 1.93 | 1000 | 333.84 | 455.33 | 152.01 | 1423.82 | 475.33 | AC | | X | N | y |
| 980807b.sm | 08/07/98 | 1.60 | 1000 | 619.34 | 455.33 | 130.00 | 1423.82 | 406.50 | AC | | X | N | y |
| 980807c.sm | 08/07/98 | 0.58 | 1000 | 95.91 | 455.33 | 43.67 | 1423.82 | 136.56 | AC | | X | N | y |
| 980808a.sm | 08/08/98 | 1.91 | 1000 | 334.39 | 455.33 | 152.26 | 1423.82 | 476.12 | AC | | X | N | y |
| 980808b.sm | 08/08/98 | 1.67 | 1000 | 623.62 | 455.33 | 131.70 | 1423.82 | 411.82 | AC | | X | N | y |
| 980808c.sm | 08/08/98 | 0.63 | 1000 | 94.17 | 455.33 | 42.88 | 1423.82 | 134.07 | AC | | X | N | y |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 980809a.sm | 08/09/98 | 1.92 | 1000 | 329.98 | 455.33 | 150.25 | 1423.82 | 469.83 | AC | | X | N | y |
| 980809b.sm | 08/09/98 | 1.71 | 1000 | 623.92 | 455.33 | 133.84 | 1423.82 | 418.52 | AC | | X | N | y |
| 980809c.sm | 08/09/98 | 0.51 | 1000 | 89.29 | 455.33 | 40.66 | 1423.82 | 127.14 | AC | | X | N | y |
| 980810a.sm | 08/10/98 | 0.36 | 1000 | 62.16 | 455.33 | 28.30 | 1423.82 | 88.51 | AC | | X | N | y |
| 980810b.sm | 08/10/98 | 0.90 | 1000 | 156.27 | 455.33 | 71.16 | 1423.82 | 222.51 | AC | | X | N | y |
| 980811a.sm | 08/11/98 | 0.49 | 1000 | 81.33 | 455.33 | 37.03 | 1423.82 | 115.79 | AC | | X | N | y |
| 990701a.raw | 07/01/99 | 2.00 | 1000 | 355.62 | 455.33 | 161.93 | 1423.82 | 506.34 | AN | | | N | n |
| 990701b.raw | 07/01/99 | 0.78 | 1000 | 141.74 | 455.33 | 64.54 | 1423.82 | 201.81 | AN | | | N | n |
| 990702a.raw | 07/02/99 | 2.29 | 974 | 389.08 | 443.29 | 173.68 | 1386.16 | 543.09 | AN | | X | N | n |
| 990702b.raw | 07/02/99 | 1.59 | 1000 | 270.82 | 455.33 | 123.31 | 1423.82 | 385.60 | AN | | X | N | n |
| 990702c.raw | 07/02/99 | 0.47 | 1000 | 87.77 | 455.33 | 39.96 | 1423.82 | 124.96 | AN | | X | N | n |
| 990703a.raw | 07/03/99 | 2.10 | 1000 | 351.52 | 455.33 | 160.05 | 1423.82 | 500.49 | AN | | | N | y |
| 990703b.raw | 07/03/99 | 1.38 | 1000 | 237.94 | 455.33 | 108.35 | 1423.82 | 338.80 | AN | | | N | y |
| 990703c.raw | 07/03/99 | 0.53 | 1000 | 96.36 | 455.33 | 43.88 | 1423.82 | 137.21 | AN | | | N | y |
| 990706a.raw | 07/06/99 | 1.49 | 835 | 251.21 | 380.33 | 96.03 | 1189.29 | 300.28 | AC | | | N | n |
| 990706b.raw | 07/06/99 | 1.96 | 881 | 320.26 | 401.31 | 129.11 | 1254.90 | 403.74 | AC | | | N | n |
| 990707a.raw | 07/07/99 | 1.39 | 994 | 239.13 | 452.62 | 108.24 | 1415.35 | 338.48 | AC | | XUW | N | n |
| 990707b.raw | 07/07/99 | 0.42 | 1000 | 70.77 | 455.33 | 32.22 | 1423.82 | 100.76 | AC | | XUW | N | n |
| 990707c.raw | 07/07/99 | 0.33 | 1000 | 59.93 | 455.33 | 27.29 | 1423.82 | 85.33 | AC | | XUW | N | n |
| 990707d.raw | 07/07/99 | 1.99 | 1000 | 346.18 | 455.33 | 157.63 | 1423.82 | 492.90 | AC | | XUW | N | n |
| 990708.bs | 07/08/99 | 0.62 | 1000 | 102.35 | 455.33 | 46.60 | 1423.82 | 145.73 | AC | | | N | n |
| 990708a.raw | 07/08/99 | 1.30 | 1000 | 220.06 | 455.33 | 100.20 | 1423.82 | 313.31 | AC | | | N | n |
| 990708b.raw | 07/08/99 | 0.87 | 1000 | 144.59 | 455.33 | 65.83 | 1423.82 | 205.86 | AC | | | N | n |
| 990708c.raw | 07/08/99 | 1.46 | 1000 | 255.57 | 455.33 | 116.37 | 1423.82 | 363.88 | B | | | N | n |
| 990709a.bse | 07/09/99 | 3.37 | 986 | 606.15 | 449.09 | 272.59 | 1404.31 | 852.38 | B | | | N | n |
| 990709b.bse | 07/09/99 | 0.71 | 1000 | 131.59 | 455.33 | 59.92 | 1423.82 | 187.36 | B | | | N | n |
| 990710.bs | 07/10/99 | 1.88 | 1000 | 325.40 | 455.13 | 148.08 | 1423.20 | 463.05 | AN | | XUW | N | n |
| 990710a.raw | 07/10/99 | 2.04 | 955 | 364.90 | 434.97 | 158.22 | 1360.16 | 494.74 | AN | | XUW | N | n |
| 990710b.raw | 07/10/99 | 0.51 | 1000 | 97.08 | 455.33 | 44.20 | 1423.82 | 138.23 | B | | X | N | n |
| 990711a.raw | 07/11/99 | 0.96 | 1000 | 152.15 | 455.33 | 69.28 | 1423.82 | 216.63 | AN | | XUW | N | y |
| 990711b.raw | 07/11/99 | 1.20 | 997 | 204.76 | 454.08 | 92.97 | 1419.90 | 290.72 | AN | | XUW | N | y |
| 990711c.raw | 07/11/99 | 0.34 | 1000 | 56.45 | 455.33 | 25.70 | 1423.82 | 80.38 | AN | | XUW | N | y |
| 990711d.raw | 07/11/99 | 0.25 | 1000 | 44.52 | 455.33 | 20.27 | 1423.82 | 63.38 | AN | | XUW | N | y |
| 990712a.raw | 07/12/99 | 2.10 | 994 | 327.71 | 452.54 | 148.20 | 1415.10 | 463.43 | AN | | XUW | N | y |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 990712b.raw | 07/12/99 | 0.33 | 1000 | 51.41 | 455.33 | 23.41 | 1423.82 | 73.20 | AN | | XUW | N | y |
| 990712c.raw | 07/12/99 | 0.63 | 1000 | 114.78 | 455.33 | 52.26 | 1423.82 | 163.42 | AN | | XUW | N | y |
| 990713a.bs | 07/13/99 | 1.48 | 987 | 229.83 | 449.19 | 103.22 | 1404.63 | 322.78 | B | | XUW | N | y |
| 990713b.bs | 07/13/99 | 1.07 | 1000 | 174.92 | 455.33 | 79.65 | 1423.82 | 249.06 | B | | XUW | N | y |
| 990713c.raw | 07/13/99 | 0.60 | 1000 | 107.12 | 455.33 | 48.77 | 1423.82 | 152.52 | ACB | | XUW | N | y |
| 990714a.raw | 07/14/99 | 1.68 | 1000 | 279.85 | 455.33 | 127.43 | 1423.82 | 398.46 | AC | | XUW | N | y |
| 990714b.raw | 07/14/99 | 0.58 | 1000 | 95.99 | 455.33 | 43.71 | 1423.82 | 136.67 | AC | | XUW | N | y |
| 990714c.raw | 07/14/99 | 0.63 | 1000 | 85.01 | 455.33 | 38.71 | 1423.82 | 121.03 | AC | | XUW | N | y |
| 990714d.raw | 07/14/99 | 0.50 | 1000 | 80.89 | 455.33 | 36.83 | 1423.82 | 115.17 | AC | | XUW | N | y |
| 990715a.raw | 07/15/99 | 1.05 | 1000 | 158.03 | 455.33 | 71.96 | 1423.82 | 225.01 | AC | | XUW | N | y |
| 990715b.raw | 07/15/99 | 1.08 | 1000 | 176.55 | 455.33 | 80.39 | 1423.82 | 251.38 | AC | | XUW | N | y |
| 990715c.raw | 07/15/99 | 1.29 | 1000 | 214.74 | 455.33 | 97.78 | 1423.82 | 305.75 | AC | | XUW | N | y |
| 990716a.raw | 07/16/99 | 0.71 | 850 | 117.68 | 387.03 | 45.54 | 1210.25 | 142.41 | B | | XUW | N | y |
| 990716b.raw | 07/16/99 | 2.23 | 900 | 356.02 | 409.89 | 145.57 | 1281.71 | 455.21 | B | | XUW | N | y |
| 990716c.raw | 07/16/99 | 0.15 | 1000 | 25.58 | 455.33 | 11.65 | 1423.82 | 36.42 | B | | XUW | N | y |
| 990717a.raw | 07/17/99 | 1.72 | 1000 | 278.16 | 455.33 | 126.66 | 1423.82 | 396.05 | ANB | | XUW | N | y |
| 990717b.raw | 07/17/99 | 0.84 | 1000 | 134.23 | 455.33 | 61.12 | 1423.82 | 191.12 | ANB | | XUW | N | y |
| 990717c.raw | 07/17/99 | 0.46 | 1000 | 82.92 | 455.33 | 37.76 | 1423.82 | 118.06 | ANB | | X | N | y |
| 990718a.raw | 07/18/99 | 2.58 | 1000 | 422.67 | 455.33 | 192.46 | 1423.82 | 601.81 | AN | | X | N | y |
| 990718b.raw | 07/18/99 | 1.64 | 1000 | 264.71 | 455.33 | 120.53 | 1423.82 | 376.89 | AN | | X | N | y |
| 990718c.raw | 07/18/99 | 0.57 | 1000 | 92.63 | 455.33 | 42.18 | 1423.82 | 131.89 | AN | | X | N | y |
| 990719a.raw | 07/19/99 | 2.10 | 995 | 334.40 | 453.17 | 151.54 | 1417.07 | 473.85 | AN | | X | N | y |
| 990719b.raw | 07/19/99 | 1.88 | 1027 | 319.92 | 467.77 | 149.52 | 1462.71 | 467.54 | AN | | X | N | y |
| 990719c.raw | 07/19/99 | 0.48 | 1000 | 96.61 | 455.33 | 43.99 | 1423.82 | 137.55 | AN | | X | N | y |
| 990721a.raw | 07/21/99 | 1.92 | 1000 | 341.54 | 455.33 | 155.51 | 1423.82 | 486.29 | AC | | | N | y |
| 990722a.raw | 07/22/99 | 1.45 | 1000 | 238.96 | 455.33 | 108.80 | 1423.82 | 340.23 | ACJ | | | N | y |
| 990722b.raw | 07/22/99 | 0.41 | 1000 | 73.61 | 455.33 | 33.52 | 1423.82 | 104.81 | ACJ | | | N | y |
| 990722c.raw | 07/22/99 | 0.91 | 1000 | 164.46 | 455.33 | 74.89 | 1423.82 | 234.17 | ACJ | | | N | y |
| 990722d.raw | 07/22/99 | 1.60 | 1000 | 285.33 | 455.33 | 129.92 | 1423.82 | 406.25 | ACJ | | | N | y |
| 990723a.raw | 07/23/99 | 1.93 | 1000 | 323.37 | 455.33 | 147.24 | 1423.82 | 460.42 | AC | | | N | y |
| 990723b.raw | 07/23/99 | 1.98 | 1000 | 335.89 | 455.33 | 152.94 | 1423.82 | 478.24 | AC | | | N | y |
| 990725a.raw | 07/25/99 | 1.88 | 994 | 329.41 | 452.73 | 149.18 | 1415.67 | 466.50 | AN | | XUW | N | y |
| 990725b.raw | 07/25/99 | 1.10 | 896 | 187.48 | 408.09 | 76.66 | 1276.09 | 239.70 | AN | | | N | y |
| 990725c.raw | 07/25/99 | 0.52 | 1000 | 89.27 | 455.33 | 40.65 | 1423.82 | 127.10 | AN | | | N | y |

| Filename | GMT Date | Duration (hrs) | Ave. Altitude (ft) | Total km Flown | Ave. Fish Swath (m) | Total Fish Area ($km^2$) | Ave. Bird Swath (m) | Total Bird Area ($km^2$) | Survey Type | Error Est. | Validation Catches | Digitized | Video Taken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 990728a.raw | 07/28/99 | 1.39 | 988 | 241.35 | 449.91 | 108.83 | 1406.87 | 340.32 | AC | | XUW | N | y |
| 990728b.raw | 07/28/99 | 0.16 | 1000 | 27.37 | 455.33 | 12.46 | 1423.82 | 38.97 | AC | | XUW | N | y |
| 990728c.raw | 07/28/99 | 0.24 | 1000 | 43.13 | 455.33 | 19.64 | 1423.82 | 61.40 | AC | | XUW | N | y |
| 990729a.raw | 07/29/99 | 2.01 | 1000 | 342.68 | 455.33 | 156.03 | 1423.82 | 487.91 | ANJC | | XUW | N | y |
| 990729b.raw | 07/29/99 | 0.63 | 1000 | 113.77 | 455.33 | 51.80 | 1423.82 | 161.99 | ANJC | | XUW | N | y |
| 990731a.raw | 07/31/99 | 1.48 | 1000 | 248.10 | 455.33 | 112.97 | 1423.82 | 353.26 | AC | | X | N | y |
| 990731b.raw | 07/31/99 | 0.94 | 1000 | 162.06 | 455.33 | 73.79 | 1423.82 | 230.75 | AC | | X | N | y |
| 990731c.raw | 07/31/99 | 1.61 | 1000 | 278.28 | 455.33 | 126.71 | 1423.82 | 396.21 | AC | | X | N | y |
| 990801a.raw | 08/01/99 | 1.91 | 996 | 320.42 | 453.35 | 145.29 | 1417.63 | 454.34 | AN | | | N | n |
| 990801b.raw | 08/01/99 | 1.47 | 1000 | 250.64 | 455.33 | 114.12 | 1423.82 | 356.86 | AN | | | N | n |
| 990801c.raw | 08/01/99 | 0.55 | 1000 | 100.44 | 455.33 | 45.73 | 1423.82 | 143.00 | AN | | | N | n |
| 990802a.raw | 08/02/99 | 2.02 | 1000 | 346.91 | 455.33 | 157.96 | 1423.82 | 493.95 | AN | | | N | n |
| 990802b.raw | 08/02/99 | 1.41 | 1000 | 243.69 | 455.33 | 110.96 | 1423.82 | 346.97 | AN | | | N | n |
| 990802c.raw | 08/02/99 | 0.47 | 1000 | 85.00 | 455.33 | 38.70 | 1423.82 | 121.02 | AN | | | N | n |
| 990803a.raw | 08/03/99 | 0.33 | 1000 | 55.34 | 455.33 | 25.20 | 1423.82 | 78.79 | AN | | | N | n |
| 990803b.raw | 08/03/99 | 1.48 | 1000 | 249.80 | 455.33 | 113.74 | 1423.82 | 355.67 | AN | | | N | n |
| 990803c.raw | 08/03/99 | 1.38 | 1000 | 241.04 | 455.33 | 109.76 | 1423.82 | 343.21 | AN | | | N | n |
| 990803d.raw | 08/03/99 | 0.51 | 1000 | 84.24 | 455.33 | 38.36 | 1423.82 | 119.94 | AN | | | N | n |
| 990804a.raw | 08/04/99 | 0.45 | 1000 | 86.52 | 455.33 | 39.40 | 1423.82 | 123.19 | ANJC | | X | N | n |
| 990804b.raw | 08/04/99 | 0.46 | 1000 | 86.46 | 455.33 | 39.37 | 1423.82 | 123.11 | ANJC | | X | N | n |
| 990804c.raw | 08/04/99 | 0.64 | 955 | 108.90 | 434.90 | 47.43 | 1359.93 | 148.31 | ANJC | | X | N | n |

Key Codes:

| | |
|---|---|
| A | Survey Type; APEX process studies |
| N,C or J | Survey Type; APEX areas (north, central or Jackpot) |
| D, B | Survey Type; herring nursery bay or broadscale |
| R,D,C | Error Estimation; Repeat survey, dual count, or CASI survey |
| X, UW | Validation Catches; catches exist; UW = underwater camera |
| Y | Digitized flight path (gps error) |
| y, n | Video taken; yes or no |

APPENDIX II. **Net catches and underwater video observations used as species validation for aerial survey data; three catch modes are shown in cases of mixed age samples with the first mode as most predominant age.**

| Species i.d. from aerial | Distance to shore (m) | Validation Type | Actual Species | First Mode Age of Fish | Avg. length | Second Mode Age | Avg. length | Third Mode Age | Avg. length | Latitude | Longitude | Set date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| h | 25 | c | h | 2 | 119.67 | 3 | 170.17 | | | 60.7325 | 146.089 | 7/3/96 |
| h | 10 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 20 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 15 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 75 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 15 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 50 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 50 | c | h | 2 | 107.68 | 1 | 78 | | | 60.7983 | 146.312 | 7/4/96 |
| h | 15 | c | h | | | | | | | 60.717 | 146.344 | 7/3/96 |
| h | 25 | c | h | | | | | | | 60.715 | 146.352 | 7/3/96 |
| h | 25 | c | h | 2 | 128.6 | 3 | 168.82 | | | 60.7758 | 146.483 | 7/4/96 |
| h | 25 | c | h | 2 | 128.6 | 3 | 168.82 | | | 60.7758 | 146.483 | 7/4/96 |
| h | 25 | c | h | 2 | 128.6 | 3 | 168.82 | | | 60.7758 | 146.483 | 7/4/96 |
| h | 30 | c | h | 2 | 128.6 | 3 | 168.82 | | | 60.7758 | 146.483 | 7/4/96 |
| sd | 10 | c | h | | | | | | | 61.0543 | 146.707 | 7/5/96 |
| sd | 15 | c | h | | | | | | | 61.0543 | 146.707 | 7/5/96 |
| sd | 15 | c | h | | | | | | | 61.0543 | 146.707 | 7/5/96 |
| sd | 10 | c | h | | | | | | | 61.0543 | 146.707 | 7/5/96 |
| h | 15 | c | h | 2 | 129.01 | 3 | 167.06 | | | 61.047 | 146.789 | 7/5/96 |
| h | 25 | c | h | 2 | 129.01 | 3 | 167.06 | | | 61.047 | 146.789 | 7/5/96 |
| h | 25 | c | h | 2 | 129.01 | 3 | 167.06 | | | 61.047 | 146.789 | 7/5/96 |
| h | 25 | c | h | 2 | 129.01 | 3 | 167.06 | | | 61.047 | 146.789 | 7/5/96 |
| h | 75 | c | sd | | 81 | | | | | 60.8688 | 147.456 | 7/5/96 |
| h | 50 | c | h | 2 | 111 | | | | | 60.9187 | 147.456 | 7/6/96 |
| h | 75 | c | h | 2 | 111 | | | | | 60.9187 | 147.456 | 7/6/96 |
| h | 25 | c | h | 2 | 118.55 | | | | | 60.9472 | 147.466 | 7/6/96 |
| h | 10 | c | h | 2 | 118.55 | | | | | 60.9472 | 147.466 | 7/6/96 |
| h | 25 | c | h | 2 | 118.55 | | | | | 60.9472 | 147.466 | 7/6/96 |
| h | 75 | c | h | 2 | 118.55 | | | | | 60.9472 | 147.466 | 7/6/96 |
| h | 75 | c | h | 2 | 118.55 | | | | | 60.9472 | 147.466 | 7/6/96 |
| h | | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 20 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 15 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 15 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 25 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 25 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 50 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 100 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 75 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 50 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 20 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 15 | c | h | 2 | 115.1 | | | | | 60.9623 | 147.486 | 7/6/96 |
| h | 35 | c | h | 2 | 118.15 | 3 | 172 | | | 60.2668 | 147.103 | 7/11/96 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sd | 3 | d | sd | | | | | | | 60.6531 | 147.3641 | 7/21/96 |
| sd | 3 | d | sd | | | | | | | 60.6531 | 147.3641 | 7/21/96 |
| sd | 3 | d | sd | | | | | | | 60.6531 | 147.3641 | 7/21/96 |
| sd | 5 | d | h | | | | | | | 60.6519 | 147.379 | 7/21/96 |
| sd | 5 | d | h | | | | | | | 60.6519 | 147.379 | 7/21/96 |
| h | 10 | d | h | | | | | | | 60.6519 | 147.379 | 7/21/96 |
| h | 5 | d | sd | | | | | | | 60.6519 | 147.379 | 7/21/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 3 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 3 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 3 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 3 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 3 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | d | sd | | | | | | | 60.6737 | 147.4502 | 7/20/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 3 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| sd | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| h | 5 | c | sd | 1 | 64.8 | | | | | 60.6876 | 147.4798 | 7/22/96 |
| h | 20 | c | h | 1 | 31.42 | | | | | 60.6648 | 145.87 | 8/6/96 |
| h | 20 | c | h | 1 | 31.42 | | | | | 60.6648 | 145.87 | 8/6/96 |
| h | 25 | c | h | 1 | 62.11 | | | | | 60.6227 | 145.879 | 8/5/96 |
| h | 25 | c | h | 1 | 62.11 | | | | | 60.6227 | 145.879 | 8/5/96 |
| h | 25 | c | h | 1 | 55.89 | 2 | 112.04 | 3 | 175 | 60.6635 | 145.894 | 8/6/96 |
| h | 25 | c | h | 1 | 33.67 | | | | | 60.6747 | 145.895 | 8/6/96 |
| sd | 10 | c | sd | | 83.6 | | | | | 60.2972 | 146.993 | 8/4/96 |
| sd | 15 | c | sd | | 83.6 | | | | | 60.2972 | 146.993 | 8/4/96 |
| sd | 10 | c | sd | | 83.6 | | | | | 60.2972 | 146.993 | 8/4/96 |
| sd | 10 | c | sd | | 83.6 | | | | | 60.2972 | 146.993 | 8/4/96 |
| sd | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 10 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 10 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| h | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 10 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| sd | 10 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| h | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| h | 15 | c | sd | | 85.2 | | | | | 60.2745 | 147.061 | 8/4/96 |
| h | 10 | c | h | 2 | 123.21 | 3 | 170.33 | | | 60.6377 | 145.858 | 7/9/97 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| h | 100 | c | h | 2 | 127.59 | 3 | 175.42 | | | 60.6612 | 145.881 | 7/9/97 |
| h | 50 | c | h | 2 | 127.59 | 3 | 175.42 | | | 60.6612 | 145.881 | 7/9/97 |
| h | 50 | c | h | 2 | 127.59 | 3 | 175.42 | | | 60.6612 | 145.881 | 7/9/97 |
| h | 20 | c | h | 2 | 121.16 | | | | | 60.6438 | 145.894 | 7/9/97 |
| h | 15 | s | h | 1 | | | | | | | | 7/9/97 |
| h | 15 | s | h | 1 | | | | | | | | 7/9/97 |
| h | 15 | s | h | 1 | | | | | | | | 7/9/97 |
| h | 20 | s | h | 1 | | | | | | | | 7/9/97 |
| sd | 10 | d | sd | | | | | | | 60.6905 | 147.438 | 7/22/97 |
| sd | 10 | d | sd | | | | | | | 60.6905 | 147.438 | 7/22/97 |
| sd | 10 | d | sd | | | | | | | 60.6745 | 147.4755 | 7/22/97 |
| sd | 15 | c | sd | | | | | | | | | 7/19/97 |
| sd | 15 | c | sd | | | | | | | | | 7/19/97 |
| sd | 15 | c | sd | | | | | | | | | 7/19/97 |
| sd | 5 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 5 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 5 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 5 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 5 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 25 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 25 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 10 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 10 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 10 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 10 | v | sd | J | | | | | | | | 7/21/97 |
| sd | 10 | v | sd | J | | | | | | | | 7/21/97 |
| h | 35 | c | h | | 75.4 | | | | | 60.945 | 146.6741 | 7/25/97 |
| h | 50 | c | h | | 75.4 | | | | | 60.945 | 146.6741 | 7/25/97 |
| h | 30 | c | h | | 75.4 | | | | | 60.945 | 146.6741 | 7/25/97 |
| h | 15 | c | h | | 75.4 | | | | | 60.945 | 146.6741 | 7/25/97 |
| h | 25 | c | h | | 65.9 | | | | | 60.8985 | 146.734 | 7/25/97 |
| h | 15 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 15 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 15 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 25 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 10 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 10 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 10 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 20 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 20 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 20 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| h | 20 | v | h | 0+ | | | | | | 60.7971 | 146.789 | 7/25/97 |
| H | 5 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 5 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 10 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 5 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 5 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 15 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 5 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 15 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |
| H | 15 | c | sd | | 80.3 | | 120.9 | | | 60.658 | -147.436 | 7/13/98 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 500 | c | c | | 98 | | | | | 60.281 | -147.263 | 7/11/98 |
| C | 1000 | c | c | | 98 | | | | | 60.281 | -147.263 | 7/11/98 |
| C | 100 | c | c | | 98 | | | | | 60.281 | -147.263 | 7/11/98 |
| SD | 25 | d | sd | | | | | | | 60.2926 | -147.231 | 7/13/98 |
| SD | 10 | d | sd | | | | | | | 60.2926 | -147.231 | 7/13/98 |
| H | 35 | c | h | | 167.5 | | 50.6 | | | 60.6081 | -145.859 | 7/14/98 |
| H | 0 | c | h | | 167.5 | | 50.6 | | | 60.6081 | -145.859 | 7/14/98 |
| SD | 100 | c | h | | 127.7 | | 180 | | | 60.8705 | -147.4 | 7/18/98 |
| SD | 100 | c | h | | 127.7 | | 180 | | | 60.8705 | -147.4 | 7/18/98 |
| SD | 5 | c | sd | yoy | | | | | | 60.6525 | -147.318 | 7/16/98 |
| SD | 75 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| SD | 50 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| H | 75 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| H | 25 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| SD | 250 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| SD | 5 | c | h | | 132.8 | | 179.9 | | | 60.9048 | -147.318 | 7/18/98 |
| H | 35 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| H | 50 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| H | 35 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| SD | 25 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| SD | 35 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| SD | 15 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| SD | 50 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| H | 50 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| SD | 100 | c | h | | 105.1 | | 187.9 | | | 60.9726 | -147.271 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 75 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 35 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 25 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 15 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 20 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 100 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 35 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 100 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 25 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 30 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 25 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| H | 50 | c | h | | 105.9 | | 188.3 | | | 60.9988 | -147.222 | 7/17/98 |
| SD | 10 | c | sd,h | yoy | | | | | | 60.856 | -146.811 | 7/21/98 |
| SD | 10 | c | sd,h | yoy | | | | | | 60.856 | -146.811 | 7/21/98 |
| SD | 0 | c | sd,h | yoy | | | | | | 60.856 | -146.811 | 7/21/98 |
| SD | 5 | v | h | 1 | 150 | | | | | 60.82017 | -146.652 | 7/21/98 |
| H | 0 | c | h | | 46.2 | | 111 | | | 60.6276 | -145.891 | 7/15/98 |
| H | 0 | c | h | | 46.2 | | 111 | | | 60.6276 | -145.891 | 7/15/98 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 15 | c | h | | 46.2 | | 111 | | | 60.6276 | -145.891 | 7/15/98 |
| H | 5 | c | h | | 46.2 | | 111 | | | 60.6276 | -145.891 | 7/15/98 |
| H | 50 | c | h | | 167.5 | | 50.6 | | | 60.6081 | -145.859 | 7/14/98 |
| H | 3 | c | sd | yoy | | | | | | 60.24617 | -147.434 | 7/25/98 |
| SD | 0 | c | sd | yoy | | | | | | 60.24617 | -147.434 | 7/25/98 |
| SD | 3 | c | sd | yoy | | | | | | 60.24617 | -147.434 | 7/25/98 |
| SD | 5 | c | sd | yoy | | | | | | 60.24617 | -147.434 | 7/25/98 |
| SD | 5 | c | sd | yoy | | | | | | 60.24617 | -147.434 | 7/25/98 |
| SD | 40 | c | h | yoy | | | | | | 60.25416 | -147.408 | 7/25/98 |
| SD | 3 | c | h | yoy | | | | | | 60.25416 | -147.408 | 7/25/98 |
| SD | 3 | c | h | yoy | | | | | | 60.25417 | -147.408 | 7/25/98 |
| SD | 4 | c | sd | yoy | | | | | | 60.25417 | -147.408 | 7/25/98 |
| SD | 1 | c | h,sd | yoy | | | | | | 60.3035 | -147.355 | 7/25/98 |
| SD | 2 | c | h,sd | yoy | | | | | | 60.3035 | -147.355 | 7/25/98 |
| SD | 100 | c | h,sd | yoy | | | | | | 60.3035 | -147.355 | 7/25/98 |
| SD | 10 | c | h,sd | yoy | | | | | | 60.3035 | -147.355 | 7/25/98 |
| SD | 15 | c | h,sd | yoy | | | | | | 60.3035 | -147.355 | 7/25/98 |
| SD | 15 | v | h | yoy | | | | | | 60.27516 | -147.334 | 7/30/98 |
| SD | 10 | v | h | yoy | | | | | | 60.27516 | -147.334 | 7/30/98 |
| SD | 10 | v | h | yoy | | | | | | 60.27516 | -147.334 | 7/30/98 |
| SD | 25 | c | h | yoy | | | | | | 60.29783 | -147.319 | 7/30/98 |
| H | 15 | c | h | yoy | | | | | | 60.29783 | -147.319 | 7/30/98 |
| SD | 15 | c | h | yoy | | | | | | 60.29783 | -147.319 | 7/30/98 |
| H | 100 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| H | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| H | 100 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| H | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.5105 | -146.403 | 7/11/99 |
| H | 100 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 30 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 40 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| SD | 2000 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 100 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 30 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 40 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| SD | 0 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| SD | 2000 | V | sd | yoy | | | | | | 60.516 | -146.402 | 7/11/99 |
| H | 250 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |
| H | 400 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |
| H | 500 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |
| H | 250 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |
| H | 400 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |
| H | 500 | V | h | yoy | | | | | | 60.8217 | -146.711 | 7/17/99 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD | 1000 | V | sd | yoy | | | | | | 60.7078 | -146.685 | 7/17/99 |
| SD | 1000 | V | sd | yoy | | | | | | 60.7078 | -146.685 | 7/17/99 |
| H | 600 | C | h | yoy | 58.9 | sd | 91.5 | gad | 46.4 | 60.6815 | -146.572 | 7/18/99 |
| SD | 1000 | C | h | yoy | 58.9 | sd | 91.5 | gad | 46.4 | 60.6815 | -146.572 | 7/18/99 |
| H | 600 | C | h | yoy | 58.9 | sd | 91.5 | gad | 46.4 | 60.6815 | -146.572 | 7/18/99 |
| SD | 1000 | C | h | yoy | 58.9 | sd | 91.5 | gad | 46.4 | 60.6815 | -146.572 | 7/18/99 |
| SD | 100 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 100 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 30 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 100 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 100 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 30 | C | gad | yoy | 57.1 | sa | 121 | | | 60.755 | -146.568 | 7/17/99 |
| SD | 150 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 100 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 75 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 150 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 100 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 75 | C | gad | yoy | 55.7 | sa | 76.4 | | | 60.7882 | -146.381 | 7/17/99 |
| SD | 400 | C | h | yoy | 48.6 | | | | | 60.7493 | -146.327 | 7/18/99 |
| SD | 400 | C | h | yoy | 48.6 | | | | | 60.7493 | -146.327 | 7/18/99 |
| SD | 400 | V | sd | yoy | | | | | | 60.524 | -147.329 | 7/28/99 |
| SD | 400 | V | sd | yoy | | | | | | 60.524 | -147.329 | 7/28/99 |
| SD | 400 | V | sd | yoy | | | | | | 60.524 | -147.329 | 7/28/99 |
| SD | 400 | V | sd | yoy | | | | | | 60.524 | -147.329 | 7/28/99 |
| SD | 600 | V | sd | yoy | | | | | | 60.2077 | -147.32 | 7/28/99 |
| SD | 600 | V | sd | yoy | | | | | | 60.2077 | -147.32 | 7/28/99 |
| H | 100 | V | h | yoy | | 1 | | | | 60.867 | -147.255 | 7/26/99 |
| H | 100 | V | h | yoy | | 1 | | | | 60.867 | -147.255 | 7/26/99 |
| SD | 400 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 0 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 0 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 800 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 200 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 400 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 0 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 0 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 800 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| SD | 200 | C | sd | | | | | | | 60.357 | -147.399 | 7/31/99 |
| | | | | | | | | | | | | |
| | | key: | | age | | | | | | | | |
| | | C= | net catch | yoy= | young of the year | | | | | | | |
| | | D= | dip net | or age no. in years | | | | | | | | |
| | | V= | video shot | | | | | | | | | |

## APPENDIX III. **Aerial Survey Database Documentation**

**Updated October 20 2000**

```
Number of Tables in Database AERIAL is 29.
Number of Columns in Database AERIAL is 286.
Number of Indexes in Database AERIAL is 14.

   Tables in the Database AERIAL

   Name               Columns   Rows        Name               Columns   Rows

   notes                    6   1581        FlightPath              13  55119
   Sighting9899            25  21560        KeyCodes                 2     16
   Weather                 15    533        KeySpecies               2     35
   Valid                   32    715        gridlist                15   3467
   CASI                     8    799        Sighting9597            27   6756
   FlightLog               13    318        keyshape                 2      9
   keybehavior              2      9        FishSurfaceAreas        16   8125


   Table: KeyCodes             No Lock(s)
   Descr: Codes for Flightlog
 No. Column Name        Attributes
 --- ------------------ ---------------------------------------------------
   1 KCode              Type   : TEXT 3
                        Default: B
                        Comment: Code used in Flightlog table
   2 KNotes             Type   : TEXT 35
                        Comment: Definition for code
   Current number of rows:     16


   Table: KeySpecies           No Lock(s)
   Descr: Species codes
 No. Column Name        Attributes
 --- ------------------ ---------------------------------------------------
   1 spcode             Type   : TEXT 4
                        Comment: 2 letter species code
   2 spname             Type   : TEXT 25
                        Comment: long name for species
   Current number of rows:     35


   Table: keyshape             No Lock(s)
   Descr: key for school shape codes
 No. Column Name        Attributes
 --- ------------------ ---------------------------------------------------
   1 shpcode            Type   : TEXT 4
                        Comment: 1-3 letter shape code
   2 shpdesc            Type   : TEXT 25
                        Comment: description of shape
   Current number of rows:      9
```

```
  Table: keybehavior          No Lock(s)
  Descr: key codes for bird behavior
No. Column Name        Attributes
--- ------------------ -------------------------------------------------------
  1 behcode            Type   : TEXT 4
                       Comment: 2 letter behavior code in Act_ columns
  2 behavior           Type   : TEXT 25
                       Comment: type of behavior coded
  Current number of rows:      9


  Table: FlightLog            No Lock(s)
  Descr: List of all surveys conducted
No. Column Name        Attributes
--- ------------------ -------------------------------------------------------
  1 FileName           Type   : TEXT 13
                       Comment: Flightpath file and/or sighting filename
  2 Flightpath         Type   : TEXT 13
                       Comment: Filename for flightpaths associated with
                                survey
  3 Stype              Type   : TEXT 5
                       Default: B
                       Comment: Type of survey conducted
  4 VType              Type   : TEXT 4
                       Default:
                       Comment: Type of Validation Made
  5 VCatch             Type   : TEXT 3
                       Default:
                       Comment: Validation Catches Made
  6 Digitized          Type   : TEXT 3
                       Default: N
                       Comment: File was digitized or not (Y or N)
  7 Airplane           Type   : TEXT 6
  8 Pilot              Type   : TEXT 15
  9 Video              Type   : TEXT 1
 10 AirNote            Type   : TEXT 80
 11 GMTDate            Type   : DATE
 12 GMTTime            Type   : TIME
 13 ASTTime            Type   : TIME
                       Default: 00:00:00
                       Comment: Alaska Standard Time
  Current number of rows:    318
```

```
  Table: Weather              No Lock(s)
  Descr: Weather log for surveys
No. Column Name        Attributes
--- ------------------ -----------------------------------------------------
  1 filename           Type   : TEXT 13
  2 SeaState           Type   : TEXT 4
                       Comment: Beaufort scale of sea state
  3 Direction          Type   : TEXT 4
                       Comment: Wind direction - coming from
  4 WindSpeed          Type   : TEXT 4
                       Comment: wind speed estimate in knots (by water
                                surface)
  5 Cloud              Type   : TEXT 4
                       Comment: cloud cover in % cover of sky
  6 Visibility         Type   : TEXT 4
                       Comment: visibility code; see key
  7 TideStage          Type   : TEXT 4
                       Comment: flood, ebb, slack high, slack low, etc codes
  8 WaveHT             Type   : TEXT 8
                       Comment: estimated wave height in feet
  9 Altitude           Type   : INTEGER
                       Comment: altitude of aircraft in feet
 10 EnvNote            Type   : TEXT 80
                       Comment: notes about weather/survey conditions
 11 Latitude           Type   : REAL
 12 Longitude          Type   : REAL
 13 GMTTime            Type   : TIME
 14 ASTTime            Type   : TIME
                       Default: 00:00:00
                       Comment: Alaska Standard Time
 15 GMTDate            Type   : DATE
  Current number of rows:    533


  Table: notes                No Lock(s)
No. Column Name        Attributes
--- ------------------ -----------------------------------------------------
  1 filename           Type   : TEXT 13
  2 Notettext          Type   : TEXT 100
  3 latitude           Type   : REAL
  4 longitude          Type   : REAL
  5 GMTTime            Type   : TIME
  6 GMTDate            Type   : DATE
  Current number of rows:   1581
```

```
  Table: FlightPath           No Lock(s)
  Descr: Processed Flight Path Data
No. Column Name        Attributes
--- ------------------ ---------------------------------------------------
  1 Filename           Type   : TEXT 13
                       Comment: Raw data filename
  2 Latitude           Type   : REAL
  3 longitude          Type   : REAL
  4 GMTTime            Type   : TIME
  5 ASTTime            Type   : TIME
                       Default: 00:00:00
                       Comment: Alaska Standard Time
  6 GMTDate            Type   : DATE
  7 YEAR               Type   : INTEGER
  8 MONTH              Type   : INTEGER
  9 Altitude           Type   : INTEGER
 10 Distkm             Type   : REAL
 11 TtlKm              Type   : REAL
 12 Swath              Type   : REAL
                       Compute: ((tan(70)-tan(50))*Altitude/3.2808)
                       Comment: Aerial swath in meters
 13 Area               Type   : REAL
                       Compute: (Distkm*Swath/1000)
                       Comment: Flight path bin in km^2
  Current number of rows:  55119
```

```
  Table: Sighting9597         No Lock(s)
  Descr: All aerial sightings from 95-97
No. Column Name        Attributes
--- ------------------ -----------------------------------------------------
  1 FileName           Type   : TEXT 13
  2 Latitude           Type   : REAL
  3 Longitude          Type   : REAL
  4 GMTTime            Type   : TIME
  5 GMTDate            Type   : DATE
  6 NumSchool          Type   : INTEGER
  7 Size               Type   : TEXT 4
  8 tickdiam           Type   : REAL
  9 tickedge           Type   : REAL
 10 Shape              Type   : TEXT 4
 11 Species            Type   : TEXT 4
 12 Validate           Type   : TEXT 4
 13 DistShore          Type   : TEXT 4
 14 bird1              Type   : TEXT 4
 15 NumBird1           Type   : INTEGER
 16 bird2              Type   : TEXT 4
 17 Numbird2           Type   : INTEGER
 18 bird3              Type   : TEXT 4
 19 Numbird3           Type   : INTEGER
 20 Act1               Type   : TEXT 4
 21 Act2               Type   : TEXT 4
 22 Act3               Type   : TEXT 4
 23 Feature            Type   : TEXT 8
 24 SightNote          Type   : TEXT 80
 25 extrap             Type   : TEXT 3
 26 ttlkm              Type   : REAL
 27 Altitude           Type   : INTEGER
  Current number of rows:   6756
```

```
  Table: Sighting9899         No Lock(s)
  Descr: Sightings for 1998-99 using Dlog Program
No. Column Name        Attributes
--- ------------------ ---------------------------------------------------
  1 FileName           Type   : TEXT 13
  2 Latitude           Type   : REAL
  3 Longitude          Type   : REAL
  4 Hour               Type   : INTEGER
                       Default: 00
                       Comment: Alaska Standard Hour
  5 Minute             Type   : INTEGER
                       Default: 00
                       Comment: Alaska Standard Time minute
  6 Second             Type   : INTEGER
                       Default: 00
                       Comment: Alaska Standard Time second
  7 Year               Type   : INTEGER
  8 Month              Type   : INTEGER
  9 Day                Type   : INTEGER
 10 IDNumber           Type   : INTEGER
                       Default: 000
                       Comment: Dlog ID sighting number
 11 Species            Type   : TEXT 4
 12 NumSchool          Type   : INTEGER
                       Comment: Number of species objects sighted
 13 Act1               Type   : TEXT 4
                       Comment: behavior of bird
 14 BehavDiam          Type   : REAL
                       Comment: Diameter of foraging pattern for kw (m)
 15 tickdiam           Type   : REAL
                       Comment: diameter of school in sighting tube ticks
 16 Shape              Type   : TEXT 4
 17 tickedge           Type   : REAL
                       Default: 00
                       Comment: width of non-circular schools in tube ticks
 18 Distance           Type   : REAL
                       Comment: distance from water line in meters
 19 Angle              Type   : REAL
                       Comment: Sighting angle from ticks on wing
 20 Link               Type   : TEXT 5
                       Comment: Electronic program link to previous sighting
 21 TideStage          Type   : TEXT 4
                       Comment: Stage of the tide letter code
 22 Altitude           Type   : INTEGER
                       Comment: Altitude in feet
 23 Direction          Type   : TEXT 4
                       Comment: Wind direction source
 24 WindSpeed          Type   : TEXT 4
                       Comment: Wind speed in knots
 25 Conditions         Type   : TEXT 15
                       Comment: Survey Conditions qualitative
  Current number of rows:  21560
```

```
  Table: FishSurfaceAreas     No Lock(s)
  Descr: School statistics by lat and long; surface area
No. Column Name        Attributes
--- ------------------ ------------------------------------------------------
  1 Latitude           Type   : REAL
                       Comment: decimal degrees
  2 Longitude          Type   : REAL
                       Comment: decimal degrees
  3 hour               Type   : INTEGER
                       Comment: AST time integer hour
  4 minute             Type   : INTEGER
                       Comment: AST time integer minute
  5 year               Type   : INTEGER
                       Comment: four digit year
  6 month              Type   : INTEGER
                       Comment: integer month
  7 day                Type   : INTEGER
  8 numschool          Type   : INTEGER
                       Comment: Number of schools at that lat and long and
                                size
  9 shape              Type   : TEXT 4
                       Comment: school shape descripter
 10 species            Type   : TEXT 4
                       Comment: text code for species
 11 distshore          Type   : TEXT 4
                       Comment: distance of school to shore (m)
 12 altitude           Type   : INTEGER
                       Comment: Altitude at sighting in feet
 13 length             Type   : REAL
                       Comment: length (diameter) of school(m)
 14 breadth            Type   : REAL
                       Comment: width of school (or cross diameter) (m)
 15 SA                 Type   : REAL
                       Comment: surface area of school (a/2*b/2)PI elipse
                                (m^2)
 16 TotSA              Type   : REAL
                       Comment: Total surface area of all schools at location
  Current number of rows:   8125
```

```
  Table: Valid                No Lock(s)
  Descr: Validations
No. Column Name        Attributes
--- ------------------ -------------------------------------------------------
  1 datecode           Type   : TEXT 8
                       Comment: Code for year and month of validation
  2 filename           Type   : TEXT 13
                       Comment: Filename of raw data file
  3 latitude           Type   : REAL
                       Comment: lat. of sighting
  4 longitude          Type   : REAL
                       Comment: longitude of sighting
  5 GMTdate            Type   : DATE
  6 GMTtime            Type   : TIME
  7 ASTTime            Type   : TIME
                       Default: 00:00:00
                       Comment: Alaska Standard Time
  8 Schlref#           Type   : INTEGER
                       Comment: Reference number for mapped schools
  9 Altitude           Type   : INTEGER
                       Comment: Alt. of sighting
 10 NumSchool          Type   : INTEGER
                       Comment: Number of schools at that location
 11 Size               Type   : TEXT 4
                       Comment: Size category of school
 12 tickdiam           Type   : REAL
                       Comment: Diameter or length of school in tube ticks
 13 tickedge           Type   : REAL
                       Comment: Width of school in tube ticks for oblong
                                schools
 14 Shape              Type   : TEXT 4
                       Comment: Shape of aerial school
 15 Species            Type   : TEXT 4
                       Comment: Species identified from the air
 16 Validate           Type   : TEXT 4
                       Comment: Sighting coded as validated in real time y
                                or n
 17 DistShore          Type   : TEXT 4
                       Comment: Distance in meters from water line
 18 Vcode              Type   : TEXT 4
                       Comment: Validated by catch, video or diver
 19 Species2           Type   : TEXT 4
                       Comment: Actual species by validation observation
 20 Age1               Type   : TEXT 3
                       Comment: Length mode number,age category of most
                                abundant
 21 Avelen1            Type   : REAL
                       Comment: Average length of most abundant mode
 22 Age2               Type   : TEXT 3
                       Comment: Length mode or species of second most
                                abundant
 23 Avelen2            Type   : REAL
                       Comment: Ave. length of second most abundant mode or
                                species
 24 Age3               Type   : TEXT 3
                       Comment: Length mode or species of third most
                                abundant in ca

 25 Avelen3            Type   : REAL
                       Comment: Ave. length of third most abundant mode or
                                species
```

```
 26 Validlat           Type   : REAL
                       Comment: Lat. of validation
 27 Vallong            Type   : REAL
                       Comment: Longitude of validation
 28 Setno              Type   : TEXT 13
                       Comment: Set or reference number of catch or
                                validation
 29 Catref#            Type   : INTEGER
                       Comment: Catch reference number for mapping
 30 Coorproj           Type   : TEXT 8
                       Comment: Coordinating project on the ground
 31 Settime            Type   : TIME
                       Comment: Time of validation set
 32 Setdate            Type   : DATE
                       Comment: Date of validation set
  Current number of rows:    715


  Table: CASI                 No Lock(s)
  Descr: CASI sightings
No. Column Name        Attributes
--- ------------------ -----------------------------------------------------
  1 Tape               Type   : INTEGER
                       Comment: Number of electronic CASI tape
  2 Lineno             Type   : INTEGER
                       Comment: Line number within a specific tape
  3 latitude           Type   : REAL
  4 longitude          Type   : REAL
  5 GMTdate            Type   : DATE
  6 NumSchool          Type   : INTEGER
                       Comment: Number of schools at that coordinate
  7 SA                 Type   : REAL
                       Comment: Surface area of schools at that sighting
  8 rownum             Type   : INTEGER
  Current number of rows:    799
```

```
   Table: gridlist             No Lock(s)
   Descr: Gridded data for CASI/Visual Analysis; scale study
 No. Column Name        Attributes
 --- ------------------ -----------------------------------------------------
   1 Tape               Type   : INTEGER
                        Comment: tape number CASI image is from
   2 Lineno             Type   : INTEGER
                        Comment: Line or transect number for image within tape
   3 latitude           Type   : REAL
                        Comment: dec. degrees of center of grid block
   4 longitude          Type   : REAL
                        Comment: dec. degrees of center of grid block
   5 GMTdate            Type   : DATE
   6 NumSchool          Type   : INTEGER
                        Comment: number of schools identified within the block
   7 SA                 Type   : REAL
                        Comment: total surface area of schools within block
   8 Rownum             Type   : INTEGER
                        Comment: row number of sighting
   9 region             Type   : TEXT 10
                        Comment: region number for grid
  10 gridsize           Type   : INTEGER
                        Comment: size of grid in km lineal length
  11 gridnum            Type   : INTEGER
                        Comment: number of individual grid
  12 stlat              Type   : REAL
                        Comment: starting latitude of grid
  13 stlong             Type   : REAL
                        Comment: starting long. of grid
  14 enlat              Type   : REAL
                        Comment: ending lat. of grid
 No. Column Name        Attributes
 --- ------------------ -----------------------------------------------------
  15 enlong             Type   : REAL
                        Comment: ending longitude of grid
   Current number of rows:   3467
```

**Coding Information and Keys:**

Note: many columns are shared between tables; keys for each column are given only once.

**GPS Data** Collected continuously using NMEA 183b from 1995-1997, NMEAc from 1998-1999

**Weather Table**:

| | |
|---|---|
| Seastate | <0-Calm, 0.5-Slight,1, 2-Choppy> |
| Wind Direction | <N,S,E,W,NE,..> |
| Wind speed (MPH) | |
| Cloud cover; percentage cover | <1..100> |
| Visibility | <Distance in nautical miles> |
| Tidestage | <SL-Slack Low,E-Ebb,SH-Slack High,F-Flood> |

**Sighting9597 Table**

| | |
|---|---|
| Size (if not null) | < D 1-3.5m, S 3.5-6.5m, M 6.5-14m, L 14m in diameter, SP Spawn> |
| Tickdiam; tickedge | <Direct reading of tick measurements fromtube; sizing depends on altitude; first entry only if school is circular (diameter) second entry if school oblong (length X width)> |
| Shape | <R-round, O-oblong, U-Ushaped,J-Jumpers S-S Shaped, I-irregular, ST, str-Streak, SP-Spawning Schools> |
| Species | <H-Herring, C-Capelin, SD-Sandlance,SA-Salmon, J-Jellies, UF-Unidentified Forage Fish, JS-Juvenile Salmon, PO-Pollock, E-Eulachon (candlefish)> |
| Validated | <Y+ or Y, positive id, Y- negative id, Ya acoustic measurement, N, not validated or default > |
| Distshore | <N-nearshore (<500m), M-Midshore (500-1800m),O-Offshore (>1800m)>1996-1997 data, give actual distance estimate in meters |
| Bird1, bird2, bird3 | <KW-Kittiwake, UD-Unknown duck, UG-Unknown gull, SE-Specled Eider, CO-Comorants, SB-Shorebirds, GW-Glaucous wing, AL-Alcid or Diving duck, LWB-Little white birds, BE-Eagle, BH-Blue Heron, SL-Sealion, SO-Sea otter, OR-Orca or Killer whale, MW-Minke Whale,HW-Humpback Whale, UW-Unknown Whale, DP-Dahl Porpoise, SS-Salmon shark, UB-Unknown bird (not gull or duck), CG-Canada geese, CR-Cranes, AT-Arctic Tern, PJ - Parasitic Jaeger> |
| Act1, act2, act3 | <BS-Broad area search, TR-Traveling, PL-Plunging or Foraging, RS-Rest on shore, RW-Rest on water, TW-Tight aggregation on water, ML-Milling> note: in 98-99, these codes were combined in a single column when multiple behaviors were observed |
| Feature | <TR-tide rip> note: this is in species column in 98-99 data |
| Note | <Misc.,physical features, altitude change> |

**Sighting9899 Table:**

| | |
|---|---|
| Species | <now all fish, birds and mammal codes here; see above> |
| **Numschool** | **<numbers of schools or individuals of this species>** |
| **Act1** | **<Behavior codes of birds; in order of most common observed; see above>** |

Valid Table:

| | |
|---|---|
| Sch. Ref # | <1-1000> Reference to mapped sightings only |
| Validated | <y+ or y, positive id, ya acoustic measurement, n not validated or Default> y for 1998-99 means validations recorded in real time |
| Vcode | <c=catch, d=diver, scam=camera skiff, v=video> |
| Species2 | Species of validation observation; primary or predominant in catch/observation |
| Age1 | <1=size mode 1 (yoy), 2=size mode 2 (1+), 3=size mode 3 (adults), a=adults, j=juveniles>Primary size mode of 1st predominant species |
| Avelen1 | Avg length of 1st predominant species |
| Age 2 | Species of 2nd predominant species or secondary size mode of 1st predominant species |
| Avelen2 | Avg length of 2nd predominant species or size mode |
| Age3 | Species of 3rd predominant species or tertiary size mode of primary species |
| Avelen3 | Avg length of 3rd predominant species or size mode |
| Validlat | latitude of validation |
| Vallong | longitude of validation |

| | |
|---|---|
| Setno. | Set number or reference number of catch/observation |
| Catref # | Reference to catches mapped only |
| Coorproj | <APEX, SEA, MAMU, NVP, UAF> |
| Settime | AST time of catch |
| Setdate | AST date of catch10 chars |

Flightpath Table

| | |
|---|---|
| Distkm | Distance along the transect (calculated while processing flight path) in km |
| Ttlkm | Cumulative distance along the transect in km |
| Swath | Area in m calculated by: (Tan(70)-Tan(50)) * Altitude) / 3.2808 ft/m |
| Area | Flightpath bin calculated by: Distkm * Swath / 1000 in $km^2$ |

FishSurfaceAreas

| | |
|---|---|
| Length | Length or diameter of school in meters (measures and coverted from tube ticks) |
| Breadth | Width or secondary diameter of oblong, rectagular or irregularly shaped schools |
| SA | Surface Area caculated using formula for an elipse: (Length/2) * (Breadth/2) * PI |

APPENDIX IV. **Geographic queries provided during the APEX project from the aerial survey database.**

| Name | Project | Month and Year |
|---|---|---|
| Tracey Gotthardt, USFWS | Harbor seals/Marine Mammals | Jan. 1998 |
| Bill Ostrand, USFWS | Sand lance habitat project | Jan. 1998 |
| Dan Rosenberg, ADFG | Scoter/sea duck query | Feb. 1998 |
| Jenny Purcell, U Maryland | Jellyfish analysis/publication | May, 1998 |
| Thomas Okey, UBC | Ecopath Project | Nov., 1998 |
| Lee Hulbert, NMFS | Shark query | Nov. 1998 |
| Kathy Kuletz, USFWS | Marbled murrelet foraging regions | Feb. 1999 |
| Pam Seiser, UAF | Pigeon guillemot foraging regions | March 2000 |
| Rob Suryan, USFWS | Kittiwake foraging regions/weekly | March 2000 |
| Gail Blundell, UAF | River otter foraging regions | March 2000 |
| Rob Suryan, Dave Irons, Jay Johnson, USFWS | General APEX regions/block query | Sept. 2000 |

APPENDIX V. **Identifying Seasonal Spatial Scale for the Ecological Analysis of Herring and Other Forage Fish in Prince William Sound, Alaska.**

**Brown, Wang, Vaughan and Norcross.**