Exxon Valdez Oil Spill
Restoration Project Annual Report

Aerial Survey Support for the APEX Project

Restoration Project 99163T
Annual Report

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Study history: Restoration Project 99163-T was initiated after a round of data sharing between the Sound Ecosystem Assessment (SEA) project, Restoration Project 99320, and the Alaska Predator Ecosystem Experiment (APEX) project, Restoration Project 99163. In the 1998 annual meeting and review for *Exxon Valdez* Oil Spill (EVOS) science the principal investigator of this project present data on broadscale distributions of surface schooling forage fishes in Prince William Sound from 1995-1997. In addition, modelers working with the APEX project found a significant correlation between foraging activity of sea birds and the fish distributions from the aerial surveys. It was decided at that meeting that an aerial component should be added to the APEX program to provide additional information on fish distribution for modelers and other researchers with the APEX umbrella. Therefore, this project was conceived to as a service and data delivery project for that program. The first field season was 1998 and a second (final) field season is anticipated for 1999. This is a continuing project.

Abstract: The objective of this project was to provide information on pelagic schooling fishes in the surface waters of Prince William Sound in order to better understand reproductive and foraging dynamics of various sea bird species. The scope of the project focuses on the study areas of the APEX project within Prince William Sound, Alaska. The individual objectives for this project were completed between the dates of July 1 and August 9, 1998. Preliminary data was delivered to the APEX program via Glen Ford, APEX modeler. Net catches from our survey and other APEX projects were compiled to provide corrections for species identification. Final edited data was delivered on December 14, 1998. We were not able to over fly the acoustics program within APEX due to a non-overlap in over flights and cruises. However, we were able to conduct a single broadscale survey within Prince William Sound during the course of July, 1998. In meeting our objectives, we flew 15 repeat surveys over the northern and central study regions and 5 repeat surveys (coordinating with kittiwake researchers) over the Jackpot study region (coordinating with marbled murrelet researchers).

Key Words: Aerial Surveys, line transects, forage fish, sea birds, kittiwakes, *Clupea pallasi*, Pacific herring, juvenile, *Ammodytes hexapterus*, sand lance, capelin, *Mallotus villosus*, eulachon, *Thaleichthys pacificus*, Prince William Sound, distribution

Project Data: Distribution, abundance, and species composition of forage fish; distribution, abundance and behavior of "white" sea birds; limited alcid (diving bird) and marine mammal distributions; fish lengths; jellyfish distribution and abundance.

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Executive Summary

The objective of this project was to provide data to other Alaska Predator Ecosystem Experiment (APEX) projects on distribution, abundance and species composition of forage fish in Prince William Sound (PWS), Alaska. The data from this project was and is being used to address APEX hypotheses concerning food limitation to seabirds and affects of variability in prey availability on seabird foraging patterns. From research conducted in PWS from 1995-1997, we knew that four forage fish species including Pacific herring (*Clupea pallasi*), sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), and eulachon (*Thaleichthys pacificus*) form distinct schools in surface waters during the summer (June and July) which are easily spotted from aircraft. Data on surface school distribution from those years was significantly correlated to seabird foraging activities during the same years. Using methodology developed in 1995-97, we conducted repeat surveys over known seabird foraging regions within PWS from early July to early August. A total of 160 hours were flown during 28 survey days. A total of 13 repeat surveys were conducted in the North study area and 14 in the Central area. The Jackpot area was surveyed five times (Figure 1, Table 1) during the period beginning July 6 and ending August 11, 1998. An area totaling 9,923.8 km^2 with a lineal distance of 22,103.2 km was surveyed during the study period (Table 2). The average transect width was 449.2 m and transect lengths ranged from 81.3 to 3,653,4 km. 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. A detection model for aerial surveys was developed the probability detection function consisting of the perpendicular distances from the center of the transect to the sightings. The key parameters needed to calculate densities was the probability of detection estimated at 0.83 from previous studies and f(d) estimated at 0.18 for kittiwakes, 0.31 for herring and 0.28 for sand lance. Validations from net catches, diver observations and underwater video segments were collated to correct aerial species identification. Peak counts of key species within the study regions and broadscale survey path were plotted for each survey period or weekly. Total numbers of individual schools or animals sighted were estimated for each survey day. During the survey period, a total of 5,223 alcids , 53,364 kittiwakes, 337 harbor seals, 69 humpback whales, 1,597 sea lions, 1,416 sea otters, 53 capelin schools, 23 eulachon schools, 1,445 herring schools, 1,416 sand lance schools and 770 jellyfish aggregations were sighted. Total surface area of schools and jellyfish were also calculated by day. Total surface area (m^2) of all species over the study period were 1,285.7 for capelin, 4,231.5 for eulachon, 52,117.9 for herring, 109,545.6 for sand lance and 65,465.53 for jellyfish. The data resulting was delivered to APEX modelers and other researchers for use in their respective analyses.

Introduction

The objective of this project is to provide data to other Alaska Predator Ecosystem Experiment (APEX) projects on distribution, abundance and species composition of forage fish in Prince William Sound (PWS), Alaska. This project is a single component of the APEX study complex and addresses food availability as a limitation for recovery of a suite of sea bird species injured for the oil spill.

Little was known about the distribution and relative abundance of juvenile Pacific herring, *Clupea pallasi,* and other forage fish in Prince William Sound (PWS), Alaska prior to the *Exxon Valdez* oil spill in 1989. Herring, sardines, anchovy, capelin, and sand lance are known to 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 pelagic fish are arranged in shoal or school groups (Cram and Hampton 1976; Fiedler 1978). Distribution of herring and capelin is thought to be contiguous. Known areas of seasonal aggregations are unique to a particular population (Templeman 1948; Campbell and Winter 1973; Sinclair 1988; Stocker 1993). Given that these forage species form distinct, easily identifiable schools, the visual aerial technique described in this report is able to provide data on surface schools available for forage food by sea birds. Since 1995, aerial surveys have added considerably to the base of knowledge on forage fish in PWS and the immediate vicinity.

The main foraging species within Prince William Sound (PWS) include Pacific herring, sand lance *(Ammodytes hexapterus)*, capelin *(Mallotus villosus)*, eulachon (*Thaleichthys pacificus*), juvenile pollock (*Theragra chalcogramma*), and juvenile salmon (*Onchorynchus sp.*). The first four species listed form distinct schools in surface waters during the summer (June and July) which are easily spotted from aircraft. However, capelin and eulachon are visible for a narrow window of time (June) after which they disperse and move to deeper waters, becoming invisible to aerial spotters (E.Brown, unpublished data; reflected in APEX catches, Haldorson et al. 1996). Distinct foraging patterns of birds, seen from aircraft, form over post-spawn adult capelin; if those observations are coupled with net catches, information about capelin may be refined (E. Brown, unpublished data). The main target species for this project, therefore, are juvenile herring, sand lance, and post-spawn or juvenile capelin since aerial surveys will be conducted mainly in July.

Methodology for this project was developed in 1995-1996, but the database extends to 1997 (Brown and Norcross 1997; Brown and Borstad 1998; Brown 1998; Brown et al., in prep) and now 1998. Broadscale measurements of forage fish distribution and abundance were completed for June and July, all three years. However, in 1995-1996, other months were also sampled. In addition, fine scale and repeat measurements were taken for a subset of herring nursery bays in eastern, northern , southwestern and central PWS. All of this data has been made available to the APEX project for analyses of earlier data.

For this project, a single broadscale survey was conducted in July, 1999, which will include all of APEX study areas. In addition, we conducted daily, repeat surveys (15) over two APEX study regions in PWS which represented the foraging range of two colonies

(Black-legged kittiwakes). We also directed net catches on schools observed from the air through all regions surveyed for validation. Data collected was made available to all bird researchers within APEX and we coordinated with them to insure that their needs were met. There was no working hypothesis for this project.

Objectives

For FY99, we had the following objective:

Provide aerial support for the APEX project, deliver the resulting data, and assist APEX researchers in its use and interpretation. We addressed that objective with 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 over fly the APEX acoustic survey due to a lack of overlap in the survey/cruise dates.

Methods

Prior to each survey, we established the flight and weather. In order to minimize the effect of survey condition bias on accuracy of the results, criteria were established for determining whether or not to proceed with a survey. We flew if the winds were under 25 knots (creating a sea state of less than 1 Beauport scale and no white capping), if the average ceiling (cloud cover) was at least 250m, and precipitation was either absent or very patchy. Conditions outside the criteria can significantly affect the quality and accuracy of the survey data.

At the start of the field season, 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. 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 were conducted with net catches and aircraft video. 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. However, a number of 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. Digital video images of many schools and foraging flock configurations were collected and used in identifying validations and evaluating schools shape. Although there is more we can accomplish with the images in terms of sea bird/forage fish school dynamics, that analysis was not covered within the scope of this study.

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). We used gridded maps to facilitate communication between aerial and ground crews concerning the location of birds and fish.

Fish schools were counted and surface area estimated using a sighting tube. The sighting tube is constructed of PVC pipe with a grid drawn on mylar on the end. The focal length of the tube is 216 mm and can be calibrated for ground distance covered by reference line (X) for any survey altitude, when length of the grid reference line (L), focal length of the tube (F), and survey altitude (A) are known, by using the equation:

$X = A\,({}^{L}/_{F})$ (Lebida and Whitmore 1985; Brady 1987). (1)

The use of the grid is particularly important for large schools. For elliptical shaped schools, maximum length and maximum width provided a rough estimate of surface area; for irregularly shaped schools (U-shaped, long wavy bands, etc.) length and width of separate sections were measured and combined to give a total estimate. The sighting angle established from fish survey protocols and a detection curve analysis was established at between 20 and 40 degrees from the wing tip with optimal sighting occurring at 30 degrees. The sighting angle for sea birds can be decreased. The swath or effective transect width is calculated using standard geometry from the wing angles and altitude.

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.). In order to expand the estimate to include subsurface distributions, acoustics must be incorporated. That was outside the scope of this study.

Results and Discussion

A total of 13 repeat surveys were conducted in the North study area and 14 in the Central area. The Jackpot area was surveyed five times (Figure 1, Table 1) during the period beginning July 6 and ending August 11, 1998. A area totaling 9,923.8 km^2 with a lineal distance of 22,103.2 km was surveyed during the study period (Table 2). The average transect width was 449.2 m and transect lengths ranged from 81.3 to 3,653,4 km.

We coordinated with sea bird researchers working with radio tagged kittiwakes in the north and central regions, Pigeon guillemot and marbled murrelet researchers in the central region, and marble murrelet researchers in the Jackpot region during each survey day in the appropriate regions. We also reported several sightings of killer whales for the EVOS killer whale researcher (C. Matkin, Project 99012A) in order to facilitate his research. Finally, we conducted double counts on 5 of the survey days to calibrate our estimate of surveyor bias.

The probability detection functions were plotted for kittiwakes, herring and sand lance (Figure 2). The estimates for *f*(d) are 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.

For validations, we were able to use 4 diver observations (Steve Jewett, UAF, unpublished data), 2 underwater video observations and 21 net catches (APEX project) occurring during our survey period to validate 116 sightings (Table 3). We were able to use some catches for multiple sighting validations because schools occurred in school groups or shoals and a single catch may be used to characterize that particular shoal. Ages of fish were only determined when average lengths were supplied. These validations were used to correct some misidentified species. As a result, 36 records were corrected for species, both occurring in the area (Green Island) with major overlap between age-0 herring and sand lance schools (also reflected in the catches; see Haldorson et al., this annual reporting series from APEX).

Peak counts of key species within the study regions and broadscale survey path were plotted for each survey period or weekly (Figures 3-7). Total numbers of individual schools or animals sighted were estimated for each survey day (Table 4). During the survey period, a total of 5,223 alcids , 53,364 kittiwakes, 337 harbor seals, 69 humpback whales, 1,597 sea lions, 1,416 sea otters, 53 capelin schools, 23 eulachon schools, 1,445 herring schools, 1,416 sand lance schools and 770 jellyfish aggregations were sighted. Total surface area of schools and jellyfish were also calculated by day (Table 5). Total surface area (m^2) of all species over the study period were 1,285.7 for capelin, 4,231.5 for eulachon, 52,117.9 for herring, 109,545.6 for sand lance and 65,465.53 for jellyfish.

Finally, the principal investigator participated as co-author in two publications that include the aerial data. A paper on jellyfish (Purcell et al., in prep) is due out this year as well as a paper on a foraging model for kittiwakes by David Ainley and other unknown co-authors (title unknown at this point). This investigator also provided numerous verbal and written comments for the various researchers in APEX to aid in their interpretation, analysis and reporting of their respective studies.

Next year, we are proposing a publication analyzing the three-year distribution of forage fish in PWS in relation to environmental factors such as zooplankton and ocean state (from the SEA data set).

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Table 1. Flight Log for 1998 Aerial Surveys in Prince William Sound, Alaska (next two pages)

Flightpaths	Air-craft	Pilot	V	Notes	GMT date	AST Time
980706a.raw	185	tim	n	North region survey to Tatitlek;test DLOG program; flt path not established	7/6/98	14:00:00
980706b.raw	185	tim	n	North region survey Val. Arm North Shore; test DLOG program; flt path not established	7/6/98	17:00:00
980707a.raw	185	tim	n	North region survey; set flight path today; files a-d	7/7/98	10:00:00
980708a.raw	185	tim	n	North region survey; adjusted flt path; files a-d	7/8/98	12:00:00
-0-	185	tim	n	aborted Central region survey due to weather and vis.	7/9/98	11:00:00
980710a.raw	185	tim	n	First Central region survey; set flt path; project meeting at Eleanor; single file	7/10/98	12:45:00
980711a.raw	185	tim	n	Central region; good complete survey; files a-d	7/11/98	12:00:00
980712a.raw	185	tim	n	Central region; good complete survey; files a-f	7/12/98	10:30:00
980712b.raw	185	tim	n	Central region; good complete survey; files a-f	7/12/98	11:30:00
980712c.raw	185	tim	n	Central region; good complete survey; files a-f	7/12/98	13:43:00
980712c.bs	185	tim	n	Broadscale Survey in Jackpot region and SW	7/12/98	15:16:00
980712e.raw	185	tim	n	Central region; good complete survey; files a-f; file d logon error no data loss	7/12/98	16:02:00
980712f.raw	185	tim	n	Central region; good complete survey; files a-f	7/12/98	17:56:00
980713a.bs	185	tim	n	Broadscale Survey at outer Montague and Latouche	7/13/98	11:21:00
980713b.bs	185	tim	n	Broadscale Survey at SW passes	7/13/98	13:42:00
980714a.raw	185	tim	n	North Area region; survey to Bligh Island only; weathered out rest	7/14/98	14:10:00
980714b.bs	185	tim	n	Attempted Broadscale in the North; aborted due to weather so garbage file	7/14/98	16:19:00
980715a.raw	185	tim	n	North Area region; complete survey files a-c	7/15/98	11:18:00
980715b.raw	185	tim	n	North Area region; complete survey files a-c	7/15/98	13:47:00
980715c.raw	185	tim	n	North Area region; complete survey files a-c	7/15/98	16:07:00
980716a.raw	185	tim	n	North Area region; complete survey files a-c	7/16/98	12:05:00
980716b.raw	185	tim	n	North Area region; complete survey files a-c	7/16/98	14:17:00
980716c.raw	185	tim	n	North Area region; complete survey files a-c	7/16/98	17:07:00
980717a.bs	185	tim	n	North shore and NW PWS broadscale survey files a and b	7/17/98	12:15:00
980717b.bs	185	tim	n	North shore and NW PWS broadscale survey files a and b	7/17/98	14:22:00
980718a.raw	185	tim	n	Central region survey; complete files a-d	7/18/98	11:02:00
980718b.raw	185	tim	n	Central region survey; complete files a-d	7/18/98	12:02:00
980718c.raw	185	tim	n	Central region survey; complete files a-d	7/18/98	13:07:00
980718d.raw	185	tim	n	Central region survey; complete files a-d	7/18/98	15:05:00
980719a.raw	185	tim	n	Central region survey; complete files a-f	7/19/98	11:30:00
980719b.raw	185	tim	n	Central region survey; complete files a-f	7/19/98	12:26:00
980719c.bs	185	tim	n	Broadscale Survey in Jackpot region and SW	7/19/98	12:58:00
980719d.raw	185	tim	n	Central region survey; complete files a-f	7/19/98	14:01:00
980719e.raw	185	tim	n	Central region survey; complete files a-f	7/19/98	14:34:00
980719f.raw	185	tim	n	Central region survey; complete files a-f	7/19/98	15:06:00
980720a.raw	185	tim	n	Central region survey; incomplete survey Naked and Knight files a and b	7/20/98	11:37:00
980720b.raw	185	tim	n	Central region survey; incomplete survey Naked and Knight files a and b	7/20/98	12:35:00
980723a.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/23/98	13:41:00
980723b.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/23/98	15:43:00
980723c.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/23/98	17:33:00
980724a.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/24/98	13:58:00
980724b.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/24/98	16:09:00
980724c.raw	185	tim	n	North Area survey; complete survey files a-c poor survey conditions	7/24/98	17:58:00
980726a.sm	185	tim	n	Central Area partial survey; Stephanie practice excluded Naked and Knight	7/26/98	14:21:00

980726b.sm	185 tim	n	Central Area partial survey; Stephanie practice excluded Naked and Knight	7/26/98	15:27:00
980726c.sm	185 tim	n	Central Area partial survey; Stephanie practice excluded Naked and Knight	7/26/98	17:53:00
980728a.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	13:35:00
980728b.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	14:33:00
980728c.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	15:01:00
980728d.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	15:11:00
980728e.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	15:32:00
980728f.raw	185 davee	n	Central Area survey; complete survey a-f; flight paths flown but GPS off; new aircraft	7/28/98	16:36:00
980730a.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	9:22:00
980730b.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	12:01:00
980730c.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	13:41:00
980730d.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	16:40:00
980730e.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	17:28:00
980730f.raw	185 tim	y	Central Area survey; complete survey a-f with camera	7/30/98	18:35:00
980730a.sm	185 tim	y	Dual count second surveyor	7/30/98	9:22:00
980730b.sm	185 tim	y	Dual count second surveyor	7/30/98	12:01:00
980730c.sm	185 tim	y	Dual count second surveyor	7/30/98	13:56:00
980730d.sm	185 tim	y	Dual count second surveyor	7/30/98	16:37:00
980730e.sm	185 tim	y	Dual count second surveyor	7/30/98	17:28:00
980730f.sm	185 tim	y	Dual count second surveyor	7/30/98	17:32:00
980730g.sm	185 tim	y	Dual count second surveyor; corresponds with 980730f.raw	7/30/98	18:35:00
980731a.sm	185 tim	y	North area complete survey; Stephanie primary files a-d	7/31/98	11:35:00
980731b.sm	185 tim	y	North area complete survey; Stephanie primary files a-d	7/31/98	13:29:00
980731c.sm	185 tim	y	North area complete survey; Stephanie primary files a-d	7/31/98	15:26:00
980731d.sm	185 tim	y	North area complete survey; Stephanie primary files a-d	7/31/98	17:10:00
980801a.sm	185 tim	y	North area complete survey; Stephanie primary files a-c	8/1/98	9:34:00
980801b.sm	185 tim	y	North area complete survey; Stephanie primary files a-c	8/1/98	12:00:00
980801c.sm	185 tim	y	North area complete survey; Stephanie primary files a-c	8/1/98	13:13:00
980803a.raw	185 tim	y	Central region survey double counts; Evelyn primary files a-c	8/3/98	11:28:00
980803b.raw	185 tim	y	Central region survey double counts; Evelyn primary files a-c	8/3/98	12:19:00
980803b.raw	185 tim	y	Central region survey double counts; Evelyn primary files a-c	8/3/98	13:16:00
980803a.sm	185 tim	y	Dual count second surveyor	8/3/98	11:28:00
980803b.sm	185 tim	y	Dual count second surveyor	8/3/98	12:20:00
980803c.sm	185 tim	y	Dual count second surveyor	8/3/98	13:17:00
980804a.sm	185 tim	y	Dual count second surveyor	8/4/98	10:46:00
980804b.sm	185 tim	y	Dual count second surveyor	8/4/98	11:36:00
980804c.sm	185 tim	y	Dual count second surveyor	8/4/98	12:10:00
980804d.sm	185 tim	y	Dual count second surveyor	8/4/98	12:39:00
980804e.sm	185 tim	y	Dual count second surveyor	8/4/98	14:29:00
980804a.raw	185 tim	y	Central region complete survey; double counted primary Evelyn files a-e	8/4/98	10:46:00
980804b.raw	185 tim	y	Central region complete survey; double counted primary Evelyn	8/4/98	11:36:00
980804c.raw	185 tim	y	Jackpot region survey	8/4/98	12:07:00
980804d.raw	185 tim	y	Central region complete survey; double counted primary Evelyn	8/4/98	12:38:00
980804e.raw	185 tim	y	Central region complete survey; double counted primary Evelyn	8/4/98	14:27:00
980805a.raw	185 tim	y	Central region complete survey; last double count survey files a-d	8/5/98	10:03:00
980805b.raw	185 tim	y	Central region complete survey; last double count survey files a-d	8/5/98	10:57:00
980805c.raw	185 tim	y	Central region complete survey; last double count survey files a-d	8/5/98	12:04:00

980805d.raw	185 tim	y	Central region complete survey; last double count survey files a-d	8/5/98	13:26:00
980805a.sm	185 tim	y	Dual count second surveyor	8/5/98	10:01:00
980805b.sm	185 tim	y	Dual count second surveyor	8/5/98	10:57:00
980805c.sm	185 tim	y	Dual count second surveyor	8/5/98	12:05:00
980805d.sm	185 tim	y	Dual count second surveyor	8/5/98	13:26:00
980807a.sm	185 tim	y	North area survey; Stephanie is primary	8/7/98	9:31:00
980807b.sm	185 tim	y	North area survey; Stephanie is primary	8/7/98	13:22:00
980807c.sm	185 tim	y	North area survey; Stephanie is primary	8/7/98	15:15:00
980808a.sm	185 tim	y	North area survey; Stephanie is primary	8/8/98	9:18:00
980808b.sm	185 tim	y	North area survey; Stephanie is primary	8/8/98	11:54:00
980808c.sm	185 tim	y	North area survey; Stephanie is primary	8/8/98	13:52:00
980809a.sm	185 tim	y	North area survey; Stephanie is primary	8/9/98	9:18:00
980809b.sm	185 tim	y	North area survey; Stephanie is primary	8/9/98	12:13:00
980809c.sm	185 tim	y	North area survey; Stephanie is primary	8/9/98	14:14:00
980810a.sm	185 tim	y	Last Central region survey; Stephanie is primary	8/10/98	11:32:00
980810b.sm	185 tim	y	Last Central region survey; Stephanie is primary	8/10/98	12:22:00
980811a.sm	185 tim	y	Last Central region survey; Stephanie is primary	8/11/98	10:34:00

V = Video taken

Table 2. Summary of flight path (transect) statistics by day.

Date	Total Area Surveyed (km^2)	Average Transect Width (m)	Length of Transect (km)
7/6/98	221.46	486.85	457.90
7/7/98	354.20	455.33	777.90
7/8/98	308.44	445.36	692.78
7/10/98	1,633.60	446.83	3653.36
7/11/98	274.64	451.19	607.82
7/12/98	434.34	454.88	954.78
7/13/98	314.68	456.48	689.26
7/14/98	147.54	435.42	338.58
7/15/98	371.62	454.52	817.62
7/16/98	332.12	454.45	730.85
7/17/98	252.47	452.01	558.44
7/18/98	313.34	455.33	688.16
7/19/98	431.00	455.33	946.57
7/20/98	97.57	444.16	219.80
7/23/98	323.11	455.33	709.62
7/24/98	338.92	455.33	744.34
7/26/98	249.63	444.50	562.18
7/28/98	209.55	455.33	460.22
7/30/98	687.38	455.33	1509.63
7/31/98	371.71	455.33	816.35
8/1/98	245.28	425.13	573.67
8/3/98	305.13	439.44	693.38
8/4/98	343.89	455.33	755.25
8/5/98	248.43	354.30	698.72
8/7/98	325.68	455.33	715.25
8/8/98	326.83	455.33	717.79
8/9/98	324.75	455.33	713.22
8/10/98	99.46	455.33	218.44
8/11/98	37.03	455.33	81.32
Total	9,923.83		22,103.16
Average Width		449.24	

Table 3. Validations collected from net catches, diver observations and underwater video in 1998 (next two pages)

Aerial I.D.	School shape	Validation type	Validation species	Age	Latitude	Longitude	Set No.	Coorproj	Set time	Set date
Sand lance	Round	Diver	Sand lance		60.416	-147.631		NVP		7/10/98
Capelin	Round	Net Catch	Capelin		60.281	-147.263	98020003	APEX	1824	7/11/98
Capelin	Round	Net Catch	Capelin		60.281	-147.263	98020003	APEX	1824	7/11/98
Capelin	Round	Net Catch	Capelin		60.281	-147.263	98020003	APEX	1824	7/11/98
Herring	Round	Diver	Herring	2+	60.449	-147.764		NVP		7/11/98
Sand lance	Oval	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Sand lance	Oval	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Sand lance	Oval	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Sand lance	Oval	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Sand lance	Round	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Sand lance	Streak	Net Catch	Sand lance	0	60.244	-147.491	98020004	APEX	1115	7/12/98
Herring	Oval	Diver	Sand lance		60.070	-147.846		NVP		7/12/98
Sand lance	Oval	Diver	Sand lance		60.070	-147.846		NVP		7/12/98
Sand lance	Oval	Diver	Sand lance		60.070	-147.846		NVP		7/12/98
Sand lance	Round	Diver	Sand lance		60.070	-147.846		NVP		7/12/98
Sand lance	Round	Diver	Sand lance		60.070	-147.846		NVP		7/12/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Herring	Round	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Streak	Net Catch	Sand lance	0-1	60.658	-147.436	98020006	APEX	1149	7/13/98
Sand lance	Oval	Diver	Sand lance		60.293	-147.231		NVP		7/13/98
Sand lance	Round	Diver	Sand lance		60.293	-147.231		NVP		7/13/98
Herring	Round	Net Catch	Herring	0-adult	60.608	-145.859	98020007	APEX	1748	7/14/98
Herring	Round	Net Catch	Herring	0-adult	60.608	-145.859	98020007	APEX	1748	7/14/98
Herring	Round	Net Catch	Herring	0-adult	60.608	-145.859	98020007	APEX	1748	7/14/98
Herring	Oval	Net Catch	Herring	0-1	60.628	-145.891	98020008	APEX	1010	7/15/98
Herring	Round	Net Catch	Herring	0-1	60.628	-145.891	98020008	APEX	1010	7/15/98
Herring	Round	Net Catch	Herring	0-1	60.628	-145.891	98020008	APEX	1010	7/15/98
Herring	Round	Net Catch	Herring	0-1	60.628	-145.891	98020008	APEX	1010	7/15/98
Sand lance	Streak	Net Catch	Sand lance	0	60.653	-147.319		APEX	1545	7/16/98
Sand lance	Oval	Net Catch	Sand lance	0	60.683	-147.550		APEX	1245	7/17/98
Sand lance	Oval	Net Catch	Sand lance	0	60.683	-147.550		APEX	1245	7/17/98
Sand lance	Oval	Net Catch	Sand lance	0	60.683	-147.550		APEX	1245	7/17/98
Sand lance	Oval	Net Catch	Sand lance	0	60.683	-147.550		APEX	1245	7/17/98

Sand lance	Round	Net Catch	Sand lance	0	60.683	-147.550		APEX	1245	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.999	-147.222	98020009	APEX	2130	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Herring	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Round	Net Catch	Herring	1-adult	60.973	-147.271	98020010	APEX	2242	7/17/98
Sand lance	Oval	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Herring	Round	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Herring	Round	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Sand lance	Round	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Sand lance	Round	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Sand lance	Round	Net Catch	Herring	2-adult	60.905	-147.318	98020011	APEX	1100	7/18/98
Sand lance	Round	Net Catch	Herring	2-adult	60.871	-147.400	98020012	APEX	1200	7/18/98
Sand lance	Round	Net Catch	Herring	2-adult	60.871	-147.400	98020012	APEX	1200	7/18/98
Herring	Round	Net Catch	Herring	2	60.344	-148.250	98020015	APEX	1630	7/19/98
Sand lance	Round	Net Catch	Herring	2	60.344	-148.250	98020015	APEX	1630	7/19/98
Sand lance	Round	Net Catch	Herring	2	60.344	-148.250	98020015	APEX	1630	7/19/98
Sand lance	Round	Net Catch	Herring	2	60.344	-148.250	98020015	APEX	1630	7/19/98
Herring	Oval	UW Video	Herring	1	60.820	-146.652		APEX	1350	7/21/98
Sand lance	Oval	Net Catch	Mixed sd,h)	0	60.856	-146.811		APEX	1730	7/21/98
Sand lance	Oval	Net Catch	Mixed sd,h)	0	60.856	-146.811		APEX	1730	7/21/98
Sand lance	Round	Net Catch	Mixed sd,h)	0	60.856	-146.811		APEX	1730	7/21/98
Herring	Oval	Net Catch	Herring		60.569	-147.619		APEX	920	7/24/98
Sand lance	Oval	Net Catch	Sand lance	0	60.525	-147.620		APEX	1400	7/24/98
Sand lance	Oval	Net Catch	Sand lance	0	60.525	-147.620		APEX	1400	7/24/98
Sand lance	Oval	Net Catch	Sand lance	0	60.418	-147.627		APEX	1745	7/24/98

Sand lance	Oval	Net Catch	Sand lance	0	60.418	-147.627	APEX	1745	7/24/98
Sand lance	Oval	Net Catch	Sand lance	0	60.418	-147.627	APEX	1745	7/24/98
Sand lance	Oval	Net Catch	Mixed h,sd)	0	60.304	-147.355	APEX	1100	7/25/98
Sand lance	Oval	Net Catch	Mixed(h,sd)	0	60.304	-147.355	APEX	1100	7/25/98
Sand lance	Oval	Net Catch	Mixed(h,sd)	0	60.304	-147.355	APEX	1100	7/25/98
Sand lance	Round	Net Catch	Mixed(h,sd)	0	60.304	-147.355	APEX	1100	7/25/98
Sand lance	Round	Net Catch	Mixed(h,sd)	0	60.304	-147.355	APEX	1100	7/25/98
Sand lance	Oval	Net Catch	Herring	0	60.254	-147.408	APEX	1300	7/25/98
Sand lance	Round	Net Catch	Herring	0	60.254	-147.408	APEX	1300	7/25/98
Sand lance	Oval	Net Catch	Herring	0	60.254	-147.408	APEX	1300	7/25/98
Sand lance	Oval	Net Catch	Sand lance	0	60.254	-147.408	APEX	1300	7/25/98
Herring	Oval	Net Catch	Sand lance	0	60.246	-147.434	APEX	1400	7/25/98
Sand lance	Oval	Net Catch	Sand lance	0	60.246	-147.434	APEX	1400	7/25/98
Sand lance	Oval	Net Catch	Sand lance	0	60.246	-147.434	APEX	1400	7/25/98
Sand lance	Round	Net Catch	Sand lance	0	60.246	-147.434	APEX	1400	7/25/98
Sand lance	Round	Net Catch	Sand lance	0	60.246	-147.434	APEX	1400	7/25/98
Sand lance	Oval	UW Video	Herring	0	60.275	-147.334	APEX	1030	7/30/98
Herring	Round	UW Video	Herring	0	60.275	-147.334	APEX	1030	7/30/98
Herring	Round	UW Video	Herring	0	60.275	-147.334	APEX	1030	7/30/98
Herring	Oval	Net Catch	Herring	0	60.298	-147.319	APEX	1045	7/30/98
Herring	Round	Net Catch	Herring	0	60.298	-147.319	APEX	1045	7/30/98
Herring	Round	Net Catch	Herring	0	60.298	-147.319	APEX	1045	7/30/98

Table 4. Total numbers of key species sighted from the air by day, 1998.

Month	Day	Alcids	GW*	Kittiwakes	DP*	HS*	HW*	Orcas	Sea Lions	Sea Otters	Capelin	Eulachon	Herring	Sand Lance	Jellyfish
July	6	3	2	1062		1			7	2			43	2	67
	7	12	11	2119	4	4			161	26			96	26	88
	8			1617					13	35			65	35	40
	10	308		4013	2	51	10		39	34	10	5	41	34	7
	11	3		1698			5		5	36	18		16	36	14
	12	1723		4906		81	2		39	104	18		74	104	47
	13	100		5764	7		1	8	15	107	7	17	124	107	5
	14	17		522					4	5			11	5	11
	15			1552	2				9	17			104	17	52
	16	23		1401					218	16			56	16	45
	17	2		887			1		2	8			49	8	36
	18	224		2384		8	8		60	165		1	25	165	16
	19	164		2492			10		47	185			34	185	133
	20	16		393			1		1	11			2	11	3
	23	22	45	1364				3	18	11			41	11	8
	24	151	37	1550	4	3			224	12			21	12	11
	26	107		4759			7		208	151			9	151	3
	28	110		1267		1	2			157			39	157	42
	30	292	21	3385		2	7	2	135	125			156	125	25
	31	281	7	1552					30	8			11	8	22
July Total		3558	123	44687	19	151	54	13	1235	1215	53	23	1017	1215	675
August	1	209	38	930					7	2			2	2	5
	3	122	1	1885			7		6	71			116	71	15
	4	257		2934		90	3	1	70	61			130	61	39
	5	202	4	2599		96	5		52	50			84	50	14
	7	136	2	1462					20	1			15	1	4
	8	175	4	1467					104				41		1
	9	105	5	1632					84	12			23	12	4
	10	401		612					19	4			17	4	
	11	58		156											13
August Total		1665	54	13677		186	15	1	362	201			428	201	95
Grand Total		**5223**	**177**	**58364**	**19**	**337**	**69**	**14**	**1597**	**1416**	**53**	**23**	**1445**	**1416**	**770**

- GW = Glacous-Winged Gulls, DP = Dahl Porpoise, HW = Humpback Whales, HS = Harbor Seals

Table 5. Total surface area (m^2) of fish schools and jellyfish aggregations sighted along the transects by date, 1998.

Month	Day	Capelin	Eualchon	Herring	Jellyfish	Sand Lance
July	6			1407.63	3767.50	65.53
	7			2948.30	8128.29	431.75
	8			1279.05	4087.43	1315.11
	10	97.54	767.92	1958.24	442.79	2504.71
	11	344.00		455.94	6611.84	3076.81
	12	456.39		4719.25	4453.94	6984.22
	13	387.78	3179.21	5643.89	406.71	15344.92
	14			203.70	905.10	117.56
	15			3334.39	5621.51	445.92
	16			2013.10	4522.62	729.12
	17			3428.27	1263.00	639.93
	18		284.41	473.85	1707.44	13222.81
	19			1592.92	8695.90	10353.65
	20			25.32	212.36	592.06
	23			1235.87	1888.52	456.55
	24			565.79	1220.14	436.98
	26			108.12	0.00	22783.58
	28			849.40	2638.42	9193.62
	30			5531.75	1651.50	8264.11
	31			332.38	1477.06	489.84
July Total		1285.71	4231.54	38107.15	59702.08	97448.78
	1			30.53	86.58	38.72
	3			5948.07	2276.04	4805.00
	4			5087.05	1815.77	4172.37
	5			1300.72	919.52	2252.03
	7			218.17	474.02	2.98
	8			811.89	9.48	
	9			349.96	182.03	778.82
	10			264.33		46.86
	11				0.00	
August Total				14010.71	5763.45	12096.77
Grand Total		**1285.71**	**4231.54**	**52117.86**	**65465.53**	**109545.56**

Figure 1. APEX study regions and established flight paths.

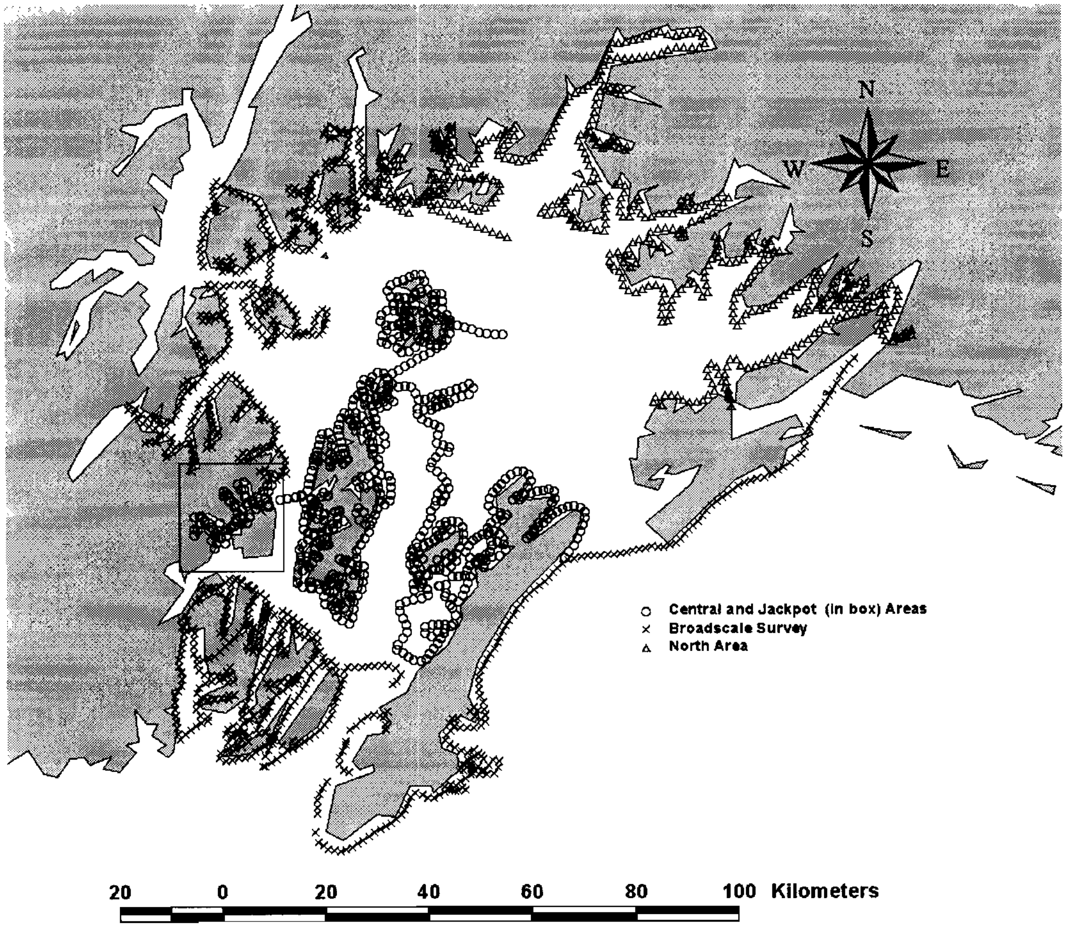
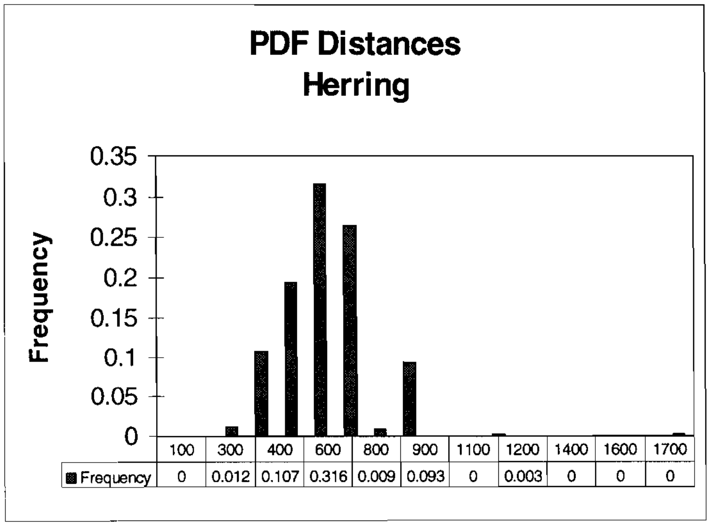
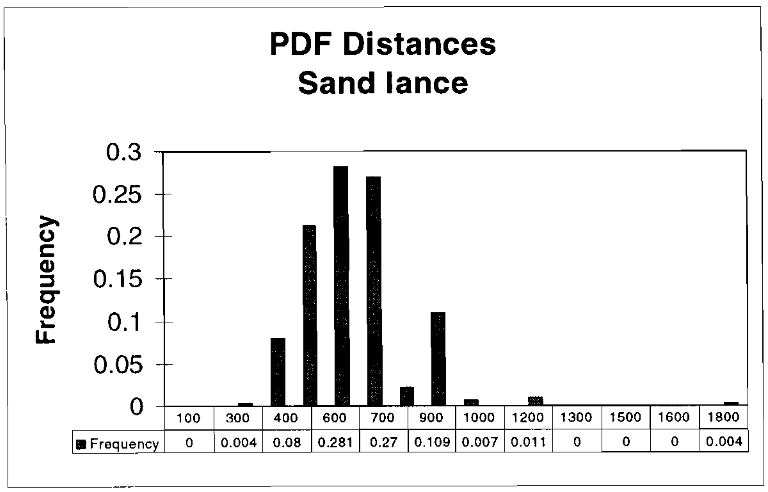


Figure 2. Probability density functions for kittiwakes, herring and sand lance





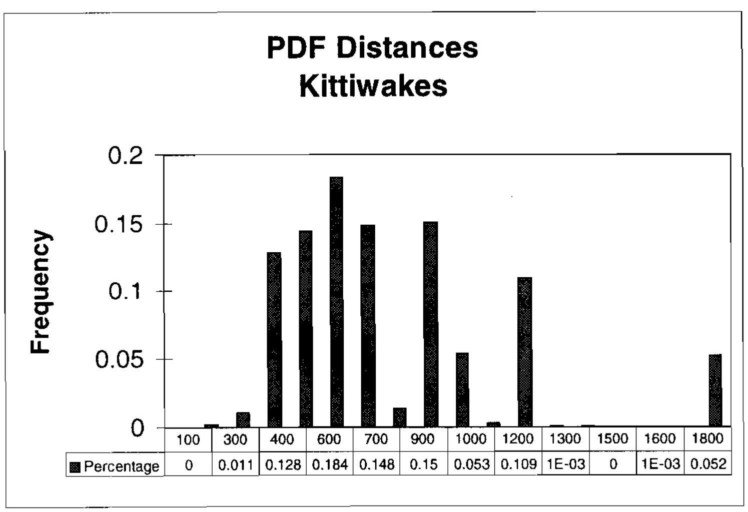


Figure 3. Peak counts of key species sighted in APEX study regions during period 1, 7/6 – 7/13, 1998.

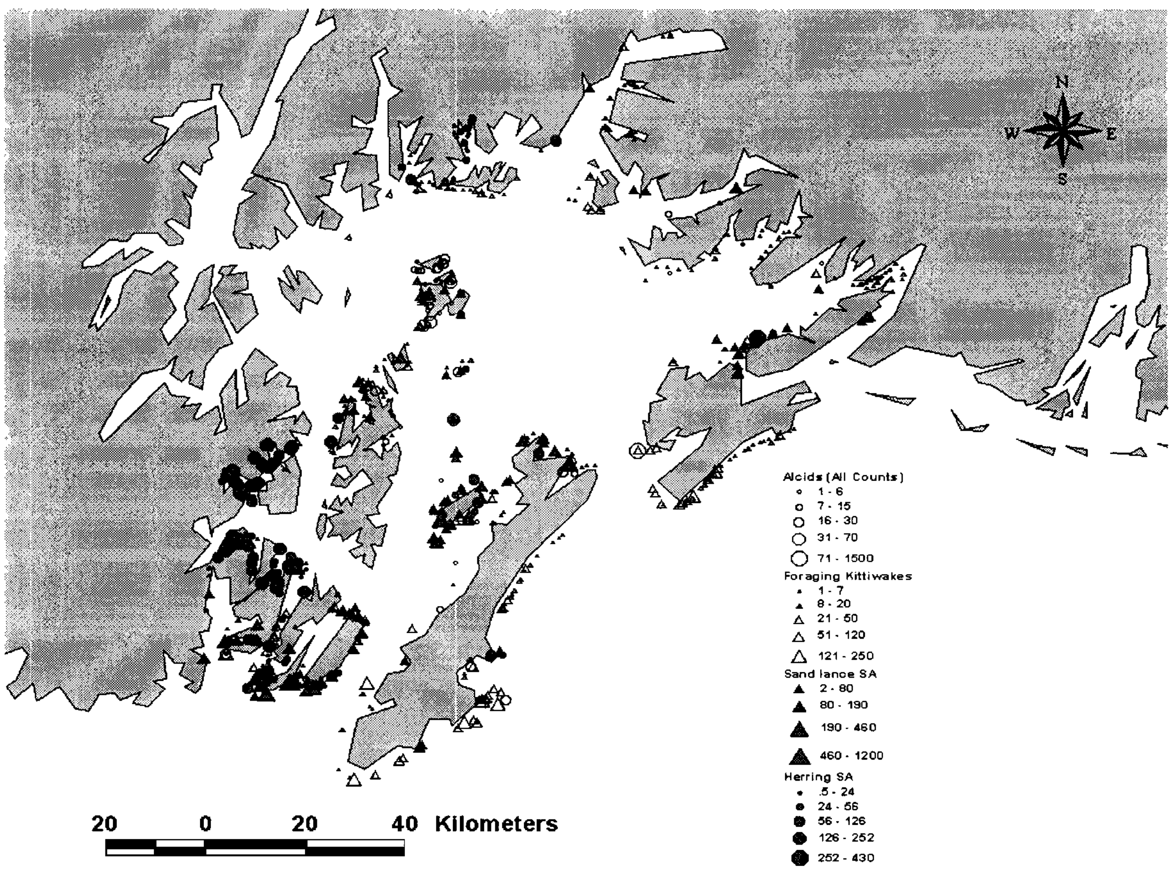


Figure 4. Peak counts of key species sighted in APEX study regions during period 2, 7/14 – 7/20, 1998.

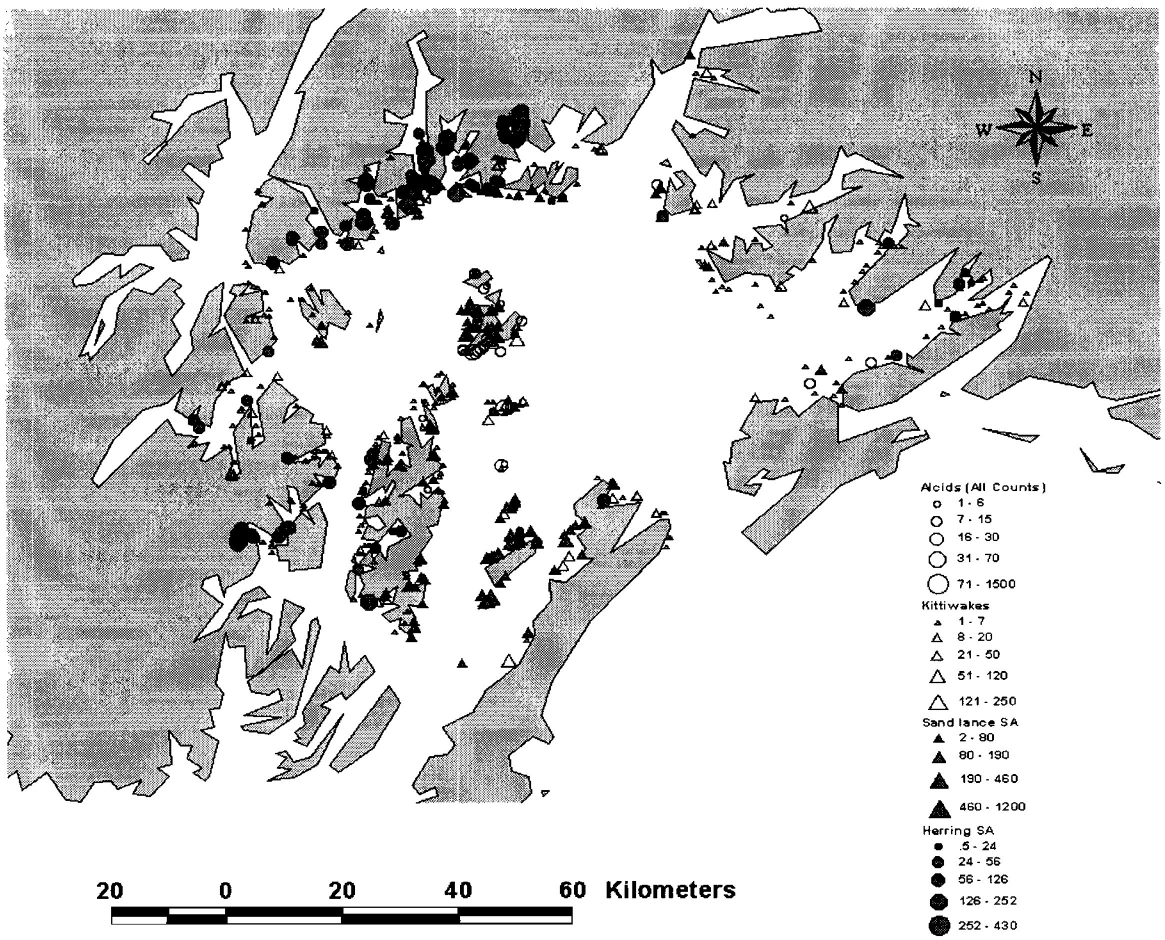


Figure 5. Peak counts of key species sighted in APEX study regions during period 3, 7/23 – 7/30, 1998.

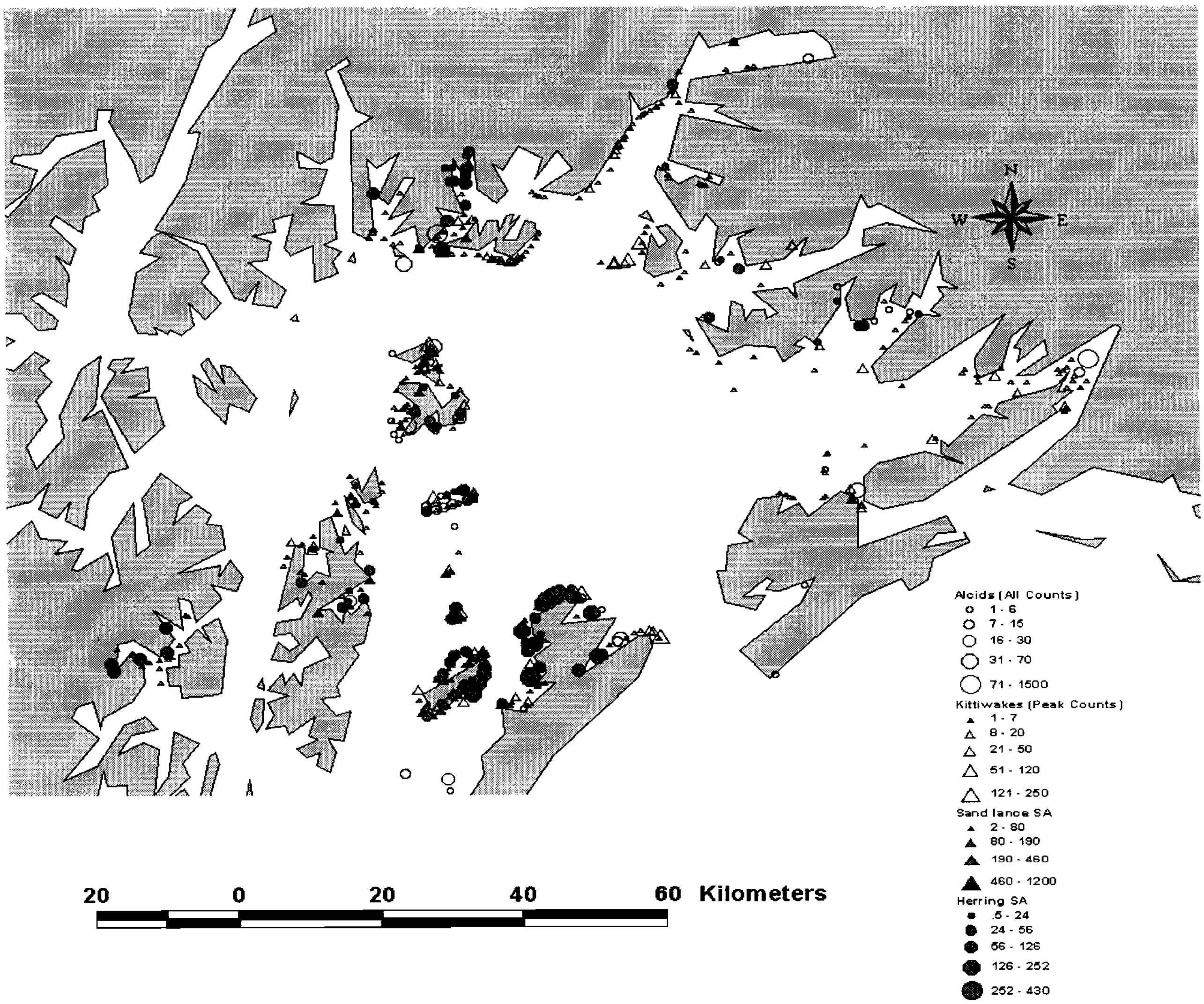


Figure 6. Peak counts of key species sighted in APEX study regions during period 4, 7/31 – 8/5, 1998.

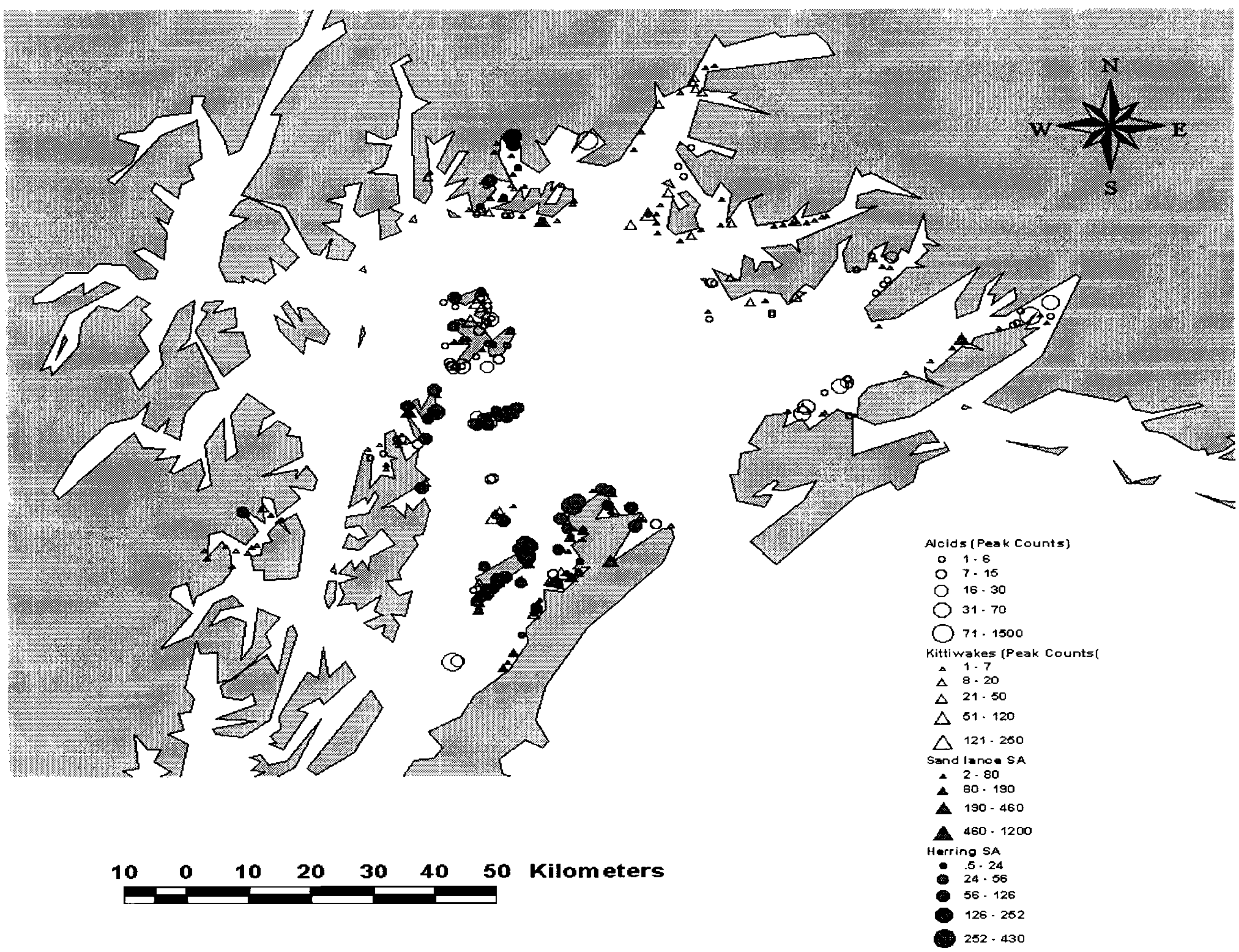


Figure 7. Peak counts of key species sighted in APEX study regions during period 5, 8/7 – 8/11, 1998.