CHARACTERIZING THE WINTER MOVEMENTS AND DIVING BEHAVIOR OF

SUBADULT STELLER SEA LIONS (*Eumetopias jubatus*) IN THE NORTH-

CENTRAL GULF OF ALASKA

A Thesis

by

HOLLY BETH BRIGGS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2005

Major Subject: Wildlife and Fisheries Sciences

CHARACTERIZING THE WINTER MOVEMENTS AND DIVING BEHAVIOR OF

SUBADULT STELLER SEA LIONS (*Eumetopias jubatus*) IN THE NORTH-

CENTRAL GULF OF ALASKA

A Thesis

by

HOLLY BETH BRIGGS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	Randall Davis
Committee Members,	Douglas Biggs
	Jane Packard
Head of Department,	Robert Brown

December 2005

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Characterizing the Winter Movements and Diving Behavior of Subadult Steller Sea Lions

(*Eumetopias jubatus*) in the North-Central Gulf of Alaska. (December 2005)

Holly Beth Briggs, B.S., University of New Hampshire

Chair of Advisory Committee: Dr. Randall Davis

Recent studies indicate a 70% decrease in the Alaskan Steller sea lion (SSL) population (ca. 5% per year) since the early 1980's.   In accordance with a 1997 status classification of the Western Steller sea lion (WSSL) stock as endangered, the "critical habitat" for the species was to be defined. This habitat has now been designated to include 10-20 nautical mile buffer zones around most rookeries and haulouts in the Gulf of Alaska (GOA) and Aleutian Islands. However, these zones were based on limited, summer, foraging data.

The primary objective of this study was to characterize juvenile SSL diving behavior and habitat use along the Kenai Peninsula and Prince William Sound (PWS) from winter to spring. Fifteen free ranging, subadult SSL of both sexes were captured and equipped with satellite telemeters at five haulout sites in PWS and Resurrection Bay, Alaska. Telemeters transmitted for an average of 122 days (range 38-181 days).   A total of 11,692 locations were received and 217,419 dives recorded.

All sea lions exhibited localized movements parallel or close to shore (3-15 km offshore). Young of the year (YOY) exhibited high site fidelity. Older juvenile sea lion lions were less restricted in their movements and traveled greater distances (200-400km) visiting a variety of islands, buoys, and other locations in PWS.

Most dives were short (mean duration = 1.1 min) and shallow (mean depth = 10.8 m), with animals diving to an average maximum depth of 193 m. During winter (January and

February), many dives ($\geq$40%) occurred during the daytime (0900-1500 LT). However, by April

and May this pattern shifted and the animals made most of their dives ($\geq$40%) during the night

(2100-0300 LT). This relationship was more pronounced for dives deeper than 20 m and

coincided with the seasonal increase in photoperiod.

Subadult SSL, especially YOY, remained within the 20 nautical mile coastal zone during

winter and spring. Shallow, nearshore waters provide important habitat during this critical

period of transition to nutritional independence. However, more conclusive data on SSL

foraging ecology is necessary to better understand locations and depths preferred by the species.

DEDICATION

I am very grateful for the tremendous amount of support I have received throughout my graduate career. However, I am most appreciative for the person who has always provided me inspiration: my mother. Raising five girls on your own while balancing your own flower shop is no small task, however my mother not only did so, she did it with pizzazz. Without her, I would have not learned how to be a strong woman, a smart woman, a successful woman. More important though, she has instilled in me the value of a family dinner, the meaning of a hearty laugh, and the importance in finding a good ice cream cone after a long day at the beach. For all these reasons and more, I dedicate the completion of my Master's work to my mother.

ACKNOWLEDGEMENTS

NOMENCLATURE

SSL	Steller Sea Lion
WSSL	Western Stock of Steller Sea Lions
PWS	Prince William Sound
GOA	Gulf of Alaska
YOY	Young of the Year

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Species overview and population trends

The Steller sea lion (SSL), *Eumetopias jubatus*, is a gregarious, polygynous (dominant males defend territories and mate with many females) pinniped (seals, sea lions and walrus) that inhabits a region extending from California's Channel Islands, up through northwestern Canada, throughout southeast Alaska, the Gulf of Alaska, and the Aleutian Islands, around the Kamchatcka Peninsula in Russia, and into northern Japan (Fig. 1). Most of the world's breeding population is distributed around 39 major rookeries and 250 haulouts in the central GOA and the western Aleutian Islands (Trites and Larkin 1996). The Prince William Sound population of SSL is considered to be the smallest of those located in the GOA and may be a place for young males and females to emigrate to from other, larger populations (Trites and Larkin 1992, Trites and Larkin 1996).

The SSL is the largest of the otarrids (eared pinnipeds), exhibiting marked sexual dimorphism between males and females. Adult males average 566 kg in weight (although they can reach a maximum over 1000 kg) and 2.8-3.3 m in length; adult females average about 263 kg in weight and grow to 2.3 m in length (York et al. 1996). Males reach sexual maturity between 3-7 years of age, females, 3-8 years of age (Pitcher and Calkins 1981). SSL inhabit various terrestrial areas, many of which are exposed rocks and remote islands thought to be in close proximity to foraging resources (Trites and Larkin 1992). They can range seaward as far as the continental shelf break and may be found anywhere within the nearshore waters of the GOA (Calkins and Pitcher 1982). Specific locations are used depending on sea lion age and the season of the year (Hoover 1988). SSL use rookeries for pupping and breeding during late May

---

This thesis follows the style of Marine Ecology Progress Series.

through early June, with peak pupping occurring in mid-June (Pitcher and Calkins 1981). Pups

weigh approximately 16-23 kg at birth and are 1 m in length (York et al. 1996). Adults and

dependent young tend to remain at rookeries until October, dispersing to haulout sites for the

remainder of the year (Hoover 1988). Such sites are used for resting and molting. Although

pups can nurse for more than a year, remaining with their mothers for up to 3 years, most are

weaned before the next breeding season (Pitcher and Calkins 1981).

Over the past twenty years, the population in this region has declined by 70-80% (Porter

1997). Mean body size of animals (weight, girth, and standard length) has also been

significantly reduced since the 1970's (Calkins and Goodwin 1988). Early surveys estimate the

total SSL population in the GOA and Aleutian Islands was about 176,000 animals (Kenyon and

Rice 1961). Further surveys suggest a maximum level of over 200,000 animals through the

1960's and 1970's, with numbers as high as 250,000-280,000 (Trites and Larkin 1996). From

1974-1980, the population was estimated to be around 196,000 individuals, and then the

numbers dropped significantly (Trites and Larkin 1992). There is a directional component to the

decline as it began in the Pribilof Islands and carried into the eastern Aleutian Islands during the

early 1970's (Braham et al. 1980, Calkins and Goodwin 1988), spread through the rest of

Aleutians and further eastward into the GOA in the 1980's. Between 1985 and 1989, the rate of

decline had increased, and population drops in PWS and the eastern GOA were noted. Recent

studies indicate a 70% decrease in the western Alaskan Steller sea lion stock (ca. 5% per year)

since the early 1980's, with current population estimates between 33,000 and 75,000 animals

(Trites and Larkin 1996, Calkins et al. 1999, Loughlin and York 2000, Sease and Taylor 2001).
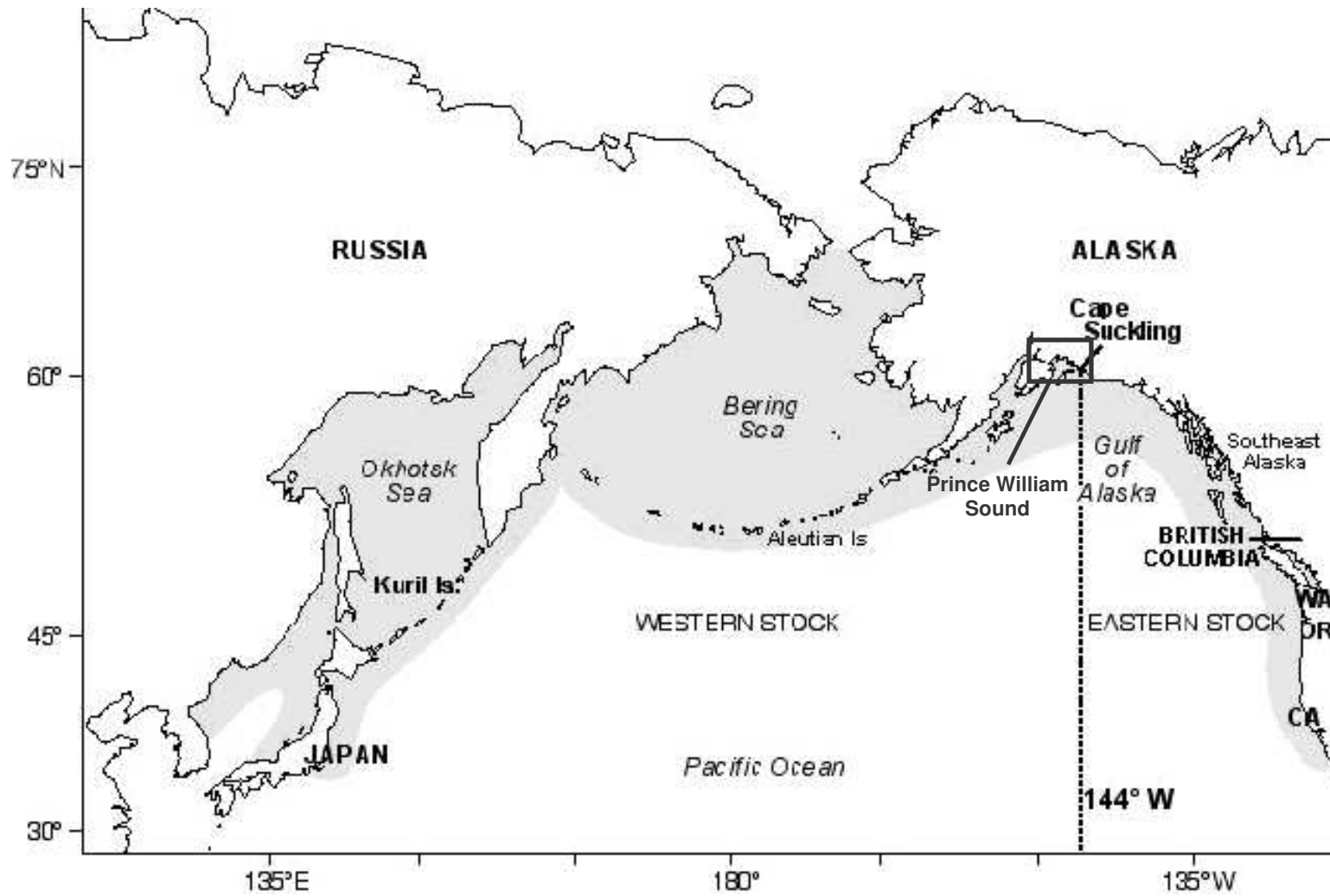
Fig. 1. Current Steller sea lion distribution, indicated by grey areas on the map (NOAA/NMFS/NMML).

The greatest reduction in overall SSL numbers has occurred in the eastern and central GOA and the western Aleutian Islands (Loughlin and York 2000). Declines have also been cited in Russian stocks of SSL, but not in southeastern Alaska or Canada. Instead, increases in population numbers have been found at historically high levels (Calkins et al. 1999). The National Marine Fisheries Service has declared that this stable section of the SSL population is a distinct genetic stock, different than that located west of 144° longitude (Calkins et al. 1999).

Much research is now being focused on the juvenile age class of SSL; studies indicate that the initial population collapse in the 1980's may have resulted from low juvenile survivorship (Holmes and York 2003). It has been hypothesized that the health of these individuals was compromised by behavioral and physical foraging limitations further compounded by prey shifts resulting from ecosystem fluctuations and large-scale fishing, especially of walleye pollock, *Theragra chalcogramma* (York et al. 1996, Merrick and Loughlin 1997). If a regime shift, in addition to any other factors, reduced the abundance and quality of different prey, inexperienced juvenile sea lions may be more at risk as they face extensive foraging challenges and high energy needs when compared to adults (Winship et al. 2002, Trites and Donnelly 2003).

Potential causes for the decline: regime shifts and fisheries interactions

Commercial harvest, natural population fluctuation, predation, parasites, and pollution, have all been proposed as causes for the drastic decline in sea lion numbers (Pascual and Adkison 1994, Trites and Larkin 1996, York et al. 1996, Porter 1997). However, recent research has focused on direct and indirect effects on juvenile mortality due to ecosystem fluctuations and large-scale fishing, especially of walleye pollock (Loughlin and Merrick 1988, York et al. 1996, Trites 1998, Anderson and Piatt 1999, Holmes and York 2003).

For over 200 years, large-scale, low frequency, and sometimes very abrupt changes in the distribution of atmospheric pressure over the North Pacific, called regime shifts, have occurred. Such changes, occurring over multi-year periods, are reflected in ocean system properties and circulation patterns which influence community composition and annual production (Anderson et al. 1997, Hayward 1997, Francis et al. 1998, Hare and Mantua 2000, Benson and Trites 2002, Chavez et al. 2003). Basin-wide effects that occur are similar to those from El Nino and La Nina, but on longer time scales (Chavez et al. 2003). The climatic regime shift that occurred in the Northeast Pacific during the late 1970's has been well described (Hollowed and Wooster 1992, Anderson et al. 1997, Hayward 1997, Francis et al. 1998, Anderson and Piatt 1999, Hare and Mantua 2000, Miller and Schneider 2000, Benson and Trites 2002, Conners et al. 2002, Chavez et al. 2003). A large-scale shift in ocean conditions occurred, causing changes in surface wind stress and atmospheric circulation, and an intensification and southern displacement of the wintertime Aleutian Low. This caused stronger westerly winds and warmer surface temperatures in central Alaskan waters (Anderson and Piatt 1999). Increased precipitation also caused decreased upwelling and stabilized other oceanic conditions (Benson and Trites 2002). The ultimate result was the complete restructuring of the GOA epibenthic community from one that was dominated by pelagic forage species such as shrimp and capelin to one dominated by piscivorous gadids, such as cod and pollock, and pleuronectid flatfish (Anderson et al. 1997, Anderson and Piatt 1999, Benson and Trites 2002, Conners et al. 2002). These benthic or demersal fish, which were absent in inshore bays during the early 1970's, may have benefited from the warming trend as it allowed them to expand winter distributions and forage nearshore instead of migrating offshore when temperatures cooled (Anderson et al. 1997, Conners et al. 2002). For such species as walleye pollock, which exhibit intraspecies

cannibalism, transport of juveniles inshore away from predatory adults may have promoted stock growth (Benson and Trites 2002).

Changes in Pacific climate observed from late 1989 through 2000 suggest that the warming trend in coastal waters may have ended. It is theorized that another regime shift may have occurred in 1989. Satellites show an increase in sea-slope as well as ocean chlorophyll off of California, physical and primary production factors that are consistent with the return to a cooler regime (Chavez et al. 2003). Dramatic increases in fish abundances that had fallen during the warmer regime have been reported since 1999, as well as increases in zooplankton abundance and changes in community structure (Chavez et al. 2003). Despite these trends, however, the shift was not a complete reversal of the climate and ecosystem conditions caused by the 1977 shift (Hare and Mantua 2000, Benson and Trites 2002).

Climatic forcing may indirectly affect marine populations through changes in the distribution and abundance of predators and prey (Benson and Trites 2002). Significant declines in GOA populations of fur and harbor seals and marine birds have been linked to the prey shift that occurred (Trites 1998, Benson and Trites 2002). Management decisions, such as that for salmon and halibut fisheries, have been influenced by the impacts of the 1977 climate flux (Hare and Mantua 2000). However, the possible effects of a regime shift on the SSL population are difficult to interpret due to lags in species' response or complications caused by anthropogenic factors (Francis et al. 1998). If a regime shift had a negative impact on SSL, it probably affected juveniles more than adults (Benson and Trites 2002). The change in fish base may have reduced prey abundance and diversity, which has negative impacts on juvenile foraging as decreased prey abundance could increase competition with experienced adults and decreased diversity could make prey harder to locate (Loughlin and Merrick 1988, Francis et al. 1998, Benson and Trites

2002). Available prey, critical to developing sea lions, may have also been lacking in nutritional value (Trites 1998).

Commercial fishing activities may also influence SSL population trends. Fisheries in the GOA may have affected juvenile SSL due to overlaps in their geographical range and targeted forage species. In addition to this direct competition, fishing activities may also alter the abundance and age-class structures of fish stocks as well as marine habitat (Loughlin and Merrick 1988, Lowry et al. 1988). The presence of fishing vessels and gear may disrupt SSL foraging and/or cause the abandonment of foraging areas used by SSL (Bowen et al. 2001). Vessel traffic may also affect fish distributions, causing them to compress into tighter, deeper schools or slip into smaller concentrations (Fritz and Ferrero 1995).

SSL diet consists of a wide variety of fish that are also targeted by major fisheries, but pollock (*Theragra chalcogramma*) is considered the dominant forage species (Pitcher 1981, Calkins and Pitcher 1982, Merrick and Calkins 1996). The commercial fishery for pollock in the GOA and Bering Sea began in the mid-1900's (Loughlin and Merrick 1988, Lowry et al. 1988, Trites and Larkin 1992). Traditional and early commercial fisheries were mostly near shore, using small scale gear. But, by the early 1950's, a new era of fishing with bigger fleets and larger gear began to evolve and develop rapidly (Trites and Larkin 1992). From the late 1950's to the early 1990's, the total annual removal of Alaskan groundfish increased from approximately 27,000 t to about 2.1 million t (Fritz and Ferrero 1998). Pollock catches alone accounted for 40-80% of all groundfish catches between 1977 and 1992 (Fritz and Ferrero 1995). As the pollock fishery grew and commercial harvest increased, sea lion predation on pollock hypothetically decreased as did overall population numbers (Lowry et al. 1988).

The pollock fishery operates more heavily in fall and winter, in areas that overlap with SSL habitat (Fritz and Ferrero 1998). Zeppelin et al. (2004) found ~69% and ~57% overlap

between the size of fish taken by juvenile SSL and size of fish taken by fisheries during the summer and winter, respectively. However, young SSL usually eat juvenile pollock found at shallow depths in bays and nearshore areas. This age class of pollock may only constitute a small fraction of the commercial catch, as the fishery usually targets larger, mature pollock that occur at deeper depths (Lowry et al. 1988, Fritz and Ferrero 1995, Trites 1998). Although the removal of pollock may have some impact on the local availability of food for juvenile sea lions (Trites and Larkin 1992), fisheries competition may be a greater occurrence in adult sea lions (Trites 1998).

Significance of research

The western stock of SSL was first classified as "threatened" in 1990 under the Endangered Species Act. It was then reclassified in 1997 as "endangered". In accordance with this 1997 status classification, the "critical habitat" for the species was to be designated around rookeries and haulout sites used for reproduction, lactation, molting and resting. Foraging trips occur near shore or distant in relation to these areas (NMFS 2001). SSL critical habitat has since been classified to include 10 to 20 nautical mile (nm) buffer zones around most rookeries and haulouts in the Gulf of Alaska and Aleutian Islands, where no commercial fishing is allowed. However, these buffer zones were based on the movements of lactating females during the summer. Such movements are restricted in their range due to the necessity for females to concentrate foraging in a central location in order to return to the rookery and nurse their pups every 1-3 days (Fiscus and Baines 1966, Merrick and Loughlin 1997, Trites and Porter 2002). Areas designated as "critical habitat" may, therefore, be underestimated.

The specific causes of increased juvenile mortality in SSL populations remain unclear. Moreover, it is hypothesized that the factors that led to the rapid decline in the 1980's may not be the same as those causing the continued decline into the 1990's (Holmes and York 2003).

Prolonged declines in SSL numbers may cause the population to reach a critical state. Models indicate that the next 20 years are crucial to the survival of the SW Alaska sea lion population (York et al. 1996). Rookeries may be reduced to extremely low levels of reproducing adults. After 40 years, localized fragmentation may occur, with the extinction of some populations possible (York et al. 1996).

Little is known about SSL ecology during the winter. The first winter following birth is thought to be a critical period as young sea lions shift to independent foraging in April-June (Loughlin and Merrick 1988). Given that young SSL are inexperienced foragers and inferior divers, a reduction in the availability or quality of prey due to a regime shift or other factors, may affect their survival, especially during winter months (Loughlin and Merrick 1988). Although SSL are known to inhabit surface and midwater regions within 45 km of the coast (Kenyon and Rice 1961, Fiscus and Baines 1966), it is unclear if current buffer zones adequately cover the movements of subadult sea lions. Therefore, the objective of this study was to assess the habitat associations and diving patterns of subadult SSL during the winter. Using satellite telemetry, I tracked the daily movements of subadult SSL in PWS and obtained detailed information on their dive behavior.

METHODS

Study site and sample size

Two research cruises took place from February 24-March 5, 2003 and January 9-16 2004. Fifteen free-ranging SSL of both sexes (9M, 6F) were captured, tagged and released at five haulout sites located within Resurrection Bay and PWS, Alaska (Fig. 2, Table 1). PWS is a diverse and complex aquatic ecosystem, consisting of many deep basins, fjords, tidewater glaciers, islands, channels, and estuaries located at the northernmost coastal margin of the Gulf of Alaska (Niebauer et al. 1994, Wang et al. 2001, Cooney et al. 2001). At its center, basin depths reach up to 450 m, but there is also a smaller basin in north-west PWS that reaches an excess of 800 m (Vaughan et al. 2001). The Chugach and Kenai mountains provided a land boundary to the west, north and east, where the Gulf of Alaska creates and ocean boundary to the south (Cooney et al. 2001). PWS exhibits moderate air temperatures, high precipitation rates and strong winds, all of which are influenced by the Aleutian Low (Niebauer et al. 1994). Its circulation patterns are characterized by seasonal flows of Alaskan Coastal Current water entering PWS via the Hinchinbrook Island entrance and flowing out through the Montague Straight, into the Gulf of Alaska. In winter, the system maintains a strong, wind-influenced, cyclonic circulation pattern, causing intense coastal downwelling and heavy flushing through the Montague Straight (Niebauer et al. 1994).

Animal capture and telemeter attachment

The age of the animals could not be determined with precision, but probably ranged from 7-32 months based on presumed birth dates in June, pelage color, standards for size, and the presence/absence and size of permanent canines. Animals were captured by divers using the
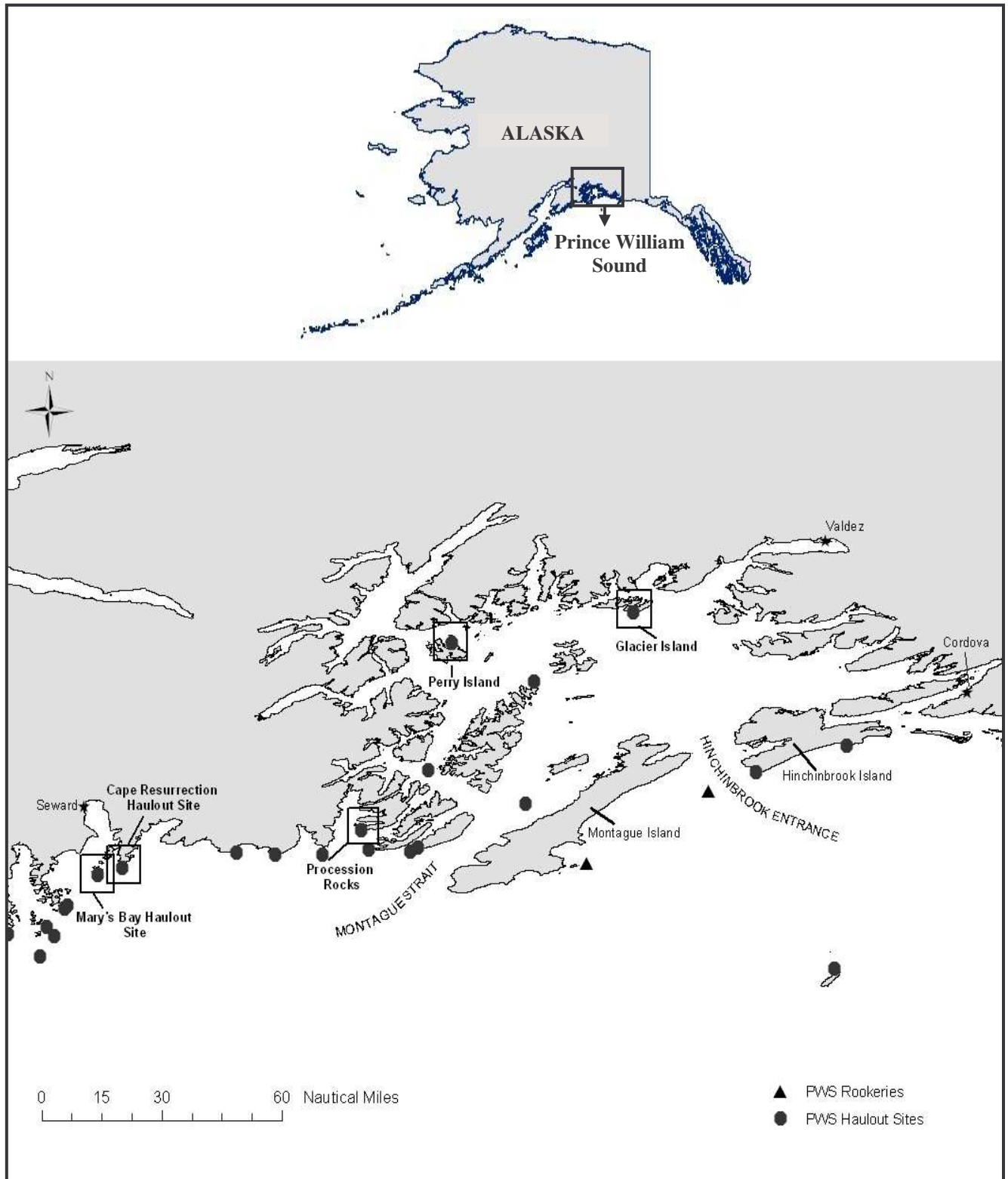
Fig. 2. Map displaying 2003 and 2004 SSL capture sites in PWS and Resurrection Bay, Alaska. Sites included Mary's Bay and Cape Resurrection haulouts at the south of Resurrection Bay, Procession Rocks in SW PWS, Perry Island in NW PWS, and Glacier Island in NE PWS.

Table 1. Capture details and morphometrics for tagged sea lions. Animals estimated to be young of the year are listed first, older individuals, second.

Animal ID	Capture Site (haulout site)	Capture Date	Est. Age	Sex	Mass (kg)	St. Length (cm)
Young of the Year (YOY)						
03	Perry Island	03/01/03	9 months	M	99	160
04	Glacier Island	03/01/03	9 months	M	106	163
05	Procession Rocks	03/03/03	9 months	F	111	164
06	Cape Resurrection	03/04/03	9 months	M	96	162
08	Cape Resurrection	03/04/03	9 months	M	130	168
09	Mary's Bay	03/05/03	9 months	M	121	171
010	Mary's Bay	01/10/04	7 months	F	86	149
011	Perry Island	01/11/04	7 months	F	89	153
013	Glacier Island	01/13/04	7 months	M	118	159
014	Perry Island	01/04/04	7 months	M	110	157
015	Perry Island	01/15/04	7 months	F	82	151
Older Juveniles						
01	Procession Rocks	02/26/03	21months	F	95	162
02	Procession Rocks	02/27/03	32 months	M	179	203
007	Cape Resurrection	03/04/03	21 months	F	88	154
012	Perry Island	01/11/04	30 months	M	187	204

underwater noose method (Alaska Fish and Game), weighed in their capture cage, and anesthetized with isoflurane (Heath et al. 1996). Standard length and girth measurements were taken, as well as blood, fecal and blubber samples.

Two types of satellite telemeters were deployed on each sea lion. A Spot 2 location-only transmitter (83 mm x 45 mm x 34 mm, 185 g; Wildlife Computers, Inc.) was mounted on the animal's head. A Satellite-Linked Time-Depth Recorder (SDR T-16, 168 mm x 81.5 mm x 41 mm, 630 g; Wildlife Computers, Inc.) was mounted in the dorsal axillary region behind the shoulders. During 2003, two mounting techniques were used. Half of the animals received tags that were mounted on neoprene rubber and glued to the fur with neoprene rubber cement. The other tags were attached using 5-minute epoxy (Devcon) with a nylon mesh (Table 1). Telemeters mounted with either of the attachments transmitted for comparable periods of time in 2003. Therefore, only the neoprene mounting technique was used during 2004 because it provides a flexible attachment that bends with the animal as it swims or moves on land.

Animals remained under anesthesia for about two hours, monitored by the veterinary anesthesiologist. Once samples were taken, the telemeters attached and signal transmission verified, and an ID number was painted on the animal's fur with black hair dye, the sea lion was extubated and released. This project was conducted in accordance with Animal Use Protocols at Texas A&M University and under NOAA Marine Fisheries Marine Mammal Permit #800-1664-00.

Instrument description and programming

The Service Argos satellite system was used to track the movements of tagged sea lions and receive data on diving behavior. Argos provides an estimate of location accuracy by assigning each of their locations to one of six classes. Sixty-eight percent of location classes 1,

2, and 3 (abbreviated LC-1, LC-2, and LC-3) are predicted to be within 1.0, 0.35, and 0.15 km, respectively. Location classes 0, A, and B have no predicted accuracy, usually because fewer than three uplinks are received or because there is not enough time between the messages.

The Spot 2 telemeters transmitted every day of every month, for every hour except those with poor satellite coverage. A total allowance of 100 transmissions was allotted to each Spot 2 tag in 2003. The overall number of messages received from all Spot 2 tags was low, hence, the allowance was increased to 350 in 2004. The SDR tags were allocated 400 transmissions per day, with transmissions occurring during all hours of each day/month of the sampling period. Data on dive depths, dive durations, and the amount of time that the animal spent at certain depths was encoded into histograms with programmable ranges of depth and time. The transmit buffer stored 24 h of data in 6 h histogram periods that corresponded to night (2100-0259), dawn (0300-0859), day (0900-1459) and dusk (1500-2059). Separate from the histogram data, maximum dive depth during a 24-hour period was extracted from the SDR status message.

Location data and habitat associations

Argos locations were downloaded daily to a local email account and entered into Excel spreadsheets for each animal. Locations with an LC of B or Z were not used in the analysis due to poor accuracy. Vincent et al. (2002) has suggested that Argos locations of LC A may be equivalent in accuracy to LC 1, and were therefore included in the initial data. A 5 m s^{-1} speed filter was applied to all remaining locations using the Satellite and Tracking Analysis online program (Coyne 2004). These locations, in addition to PWS bathymetric data and other features, were imported into ArcGIS 8.3 (ESRI) with a map of the Alaskan coastline. Animal movements and trip distances were calculated using the Animal Movement Extension (Hooge and Eichenlaub 1997).

Analysis of dive characteristics

Dive data was extracted from Argos and analyzed using SATPAK software (Wildlife Computers). The number of dives was determined for the four 6-hourly periods as well as daily and monthly dive averages. Median dive depths and durations were calculated by using the midpoint of each histogram bin (e.g., 7 m for a 4-10 m bin) (Loughlin et al. 2003). Data from each of the histograms was considered for the subadult age class as a whole, and then data for estimated young of the year (YOY) and juveniles was separated to look for differences between younger and older individuals. To better achieve normality, overall dive percentages were transformed using the arcsine equation:

$$X' = \arcsin\sqrt{p} \text{ (Krebs 1989)}$$

Differences in dive depth and duration between younger and older individuals were then tested using a univariate analysis of variance (ANOVA) with post hoc tests to refine results. To test for diel and seasonal effects on subadult diving behavior, time of day and month were entered as fixed factors into a general linear model (GLM) with percentage of total dives as the dependent variable. P-values less than 0.05 were considered significant. All statistical tests were carried out in SPSS 12.0.1 (SPSS Inc., USA).

RESULTS

Animal movements: overall subadult patterns

Telemeters transmitted for an average of 122 days (range: 38-181 days, Table 2). Antennae breakage rather than transmitter detachment was most likely the cause of tag failure. Several resighted animals had transmitters still attached in the summer of 2003, however the antennae were kinked or curled. In 2004, a more robust antenna was used with the telemeters, but these too were prone to breakage. Many animals were resighted late in 2004 with their telemeters still attached, but with the antennae broken off at their base. Burns et al. (1999) also found high tag failure rates in 1993 and 1994 to be linked primarily to antenna breakage.

A total of 11,692 locations were received during the two years. Of these, 35.5% of the positions were LC B, 25.8% LC A, 7.5% LC 0, 13.9% LC 1, 10.4% LC 2, and 5.5% LC 3. After filtering, 5,932 locations remained for analysis and included those that were LC A or better.

All 15 sea lions exhibited localized, nearshore movements that were within the 20 nm buffer zone (Fig. 3). Ninety-five percent of all locations received were 3 nm (~6 km) or less from shore. Locations also appeared to stay between the 0-100 m isobaths, as animals focused their movements in the shallow waters of PWS instead of deep basin areas.

Animal movements: YOY and juvenile comparison

Animals estimated to be YOY tended to remain longer at the haulout site at which they were captured than older individuals (Fig. 3), displaying a gradual tendency toward offshore movements. Start and end transmissions from satellite tags showed that animals 04, 09, 11, and 14 did not move from their capture site (see Appendix I). Other YOY transited to new haulout sites 9-80 km from their original tagging site. However, once at these locations, most of the YOY did not move again during the study period. Moreover, they remained in coastal waters

within a tight radius (5-10 km) around the haulout site. With the exception of Animal 10, all

tagged juveniles moved from their original haulout site, usually at great distances (70-200+ km)

Older juveniles also tended to travel (transiting) 2-3 times more (km day $^{-1}$) than YOY,

especially during January and February (YOY avg. 7-9 km day $^{-1}$, juv. avg. 25-28 km day $^{-1}$).

This difference decreased over time, with YOY daily distance traveled approaching that of

juveniles by May.

Animal 15 (YOY) and Animal 12 (older juvenile) were tagged at the same site (Perry

Island) within a few days of each other, and their telemeters transmitted for equivalent periods.

Animal 15 remained in nearshore waters $\leq$ 5 nm from the haulout site on Perry Island from

January-March 2004. It did not travel to many locations outside the Perry Island area until

April/May 2004, where the animal moved east to Glacier Island, a popular juvenile haulout site

in the north-central part of the Sound. Here, the animal displayed wider movements up to 15 nm

around the haulout (Fig. 4*a*). In contrast, Animal 12 immediately left Perry Island after capture

in January 2004, moving to a shallow moraine feature around College Fjord, a glacial area in the

northwestern part of PWS. Animal 12 used this area for travels to and from locations up to 60

nm away. Many trips seemed to follow a similar route, with repeated stopovers at the same

islands, outcroppings, and buoys seen in previous trips. By March 2004, most of the sea lion's

movements originated from Glacier Island, with localized trips ($\leq$ 20 nm) and longer trips (>120

nm) outside of PWS to Kayak Island (Fig. 4*b*).

Table 2. Dive characteristics for all study animals

| ID	Length of Transmission (d)	Total Locations (overall)	Total Locations (filtered)	Total Number of Dives	Mean Dive Depth (m)	Max. Dive Depth (m)	Mean Dive Duration (min)
03	159	1013	567	11798	10.45	128	1.11
04	149	607	273	13560	10.21	120	1.03
05	86	553	291	10060	3.24	32	0.73
06	138	721	367	17109	5.61	136	0.73
08	149	903	616	6824	6.82	128	0.77
09	139	785	436	5834	12.53	216	1.16
010	144	368	165	7351	9.18	40	0.89
011	38	464	234	5786	12.74	224	0.96
013	65	686	338	2480	7.98	184	0.74
014	64	920	458	8535	13.56	272	1.10
015	181	1206	568	29876	13.56	360	1.09
01	81	475	220	15011	7.02	112	1.01
02	128	657	287	28863	13.54	264	1.24
07	130	1217	640	22187	9.38	88	1.03
012	181	1117	472	32145	25.47	592	1.51
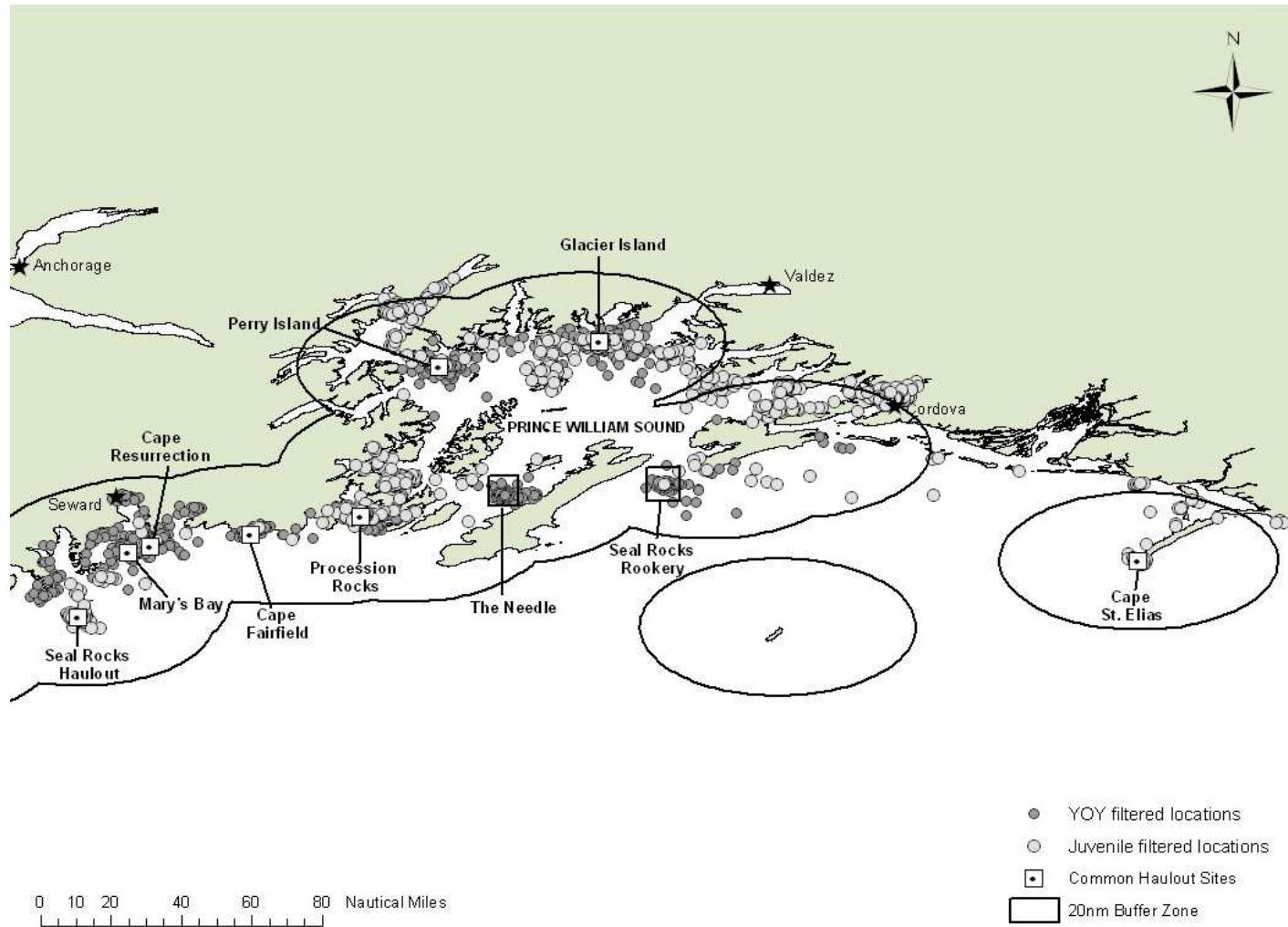
Fig. 3. YOY and juvenile locations for the study period(s) March 1-May 31, 2003, and January 10-May 31, 2004. All locations were nearshore and remained within the 20 nm buffer zone. YOY also remained at capture sites and other recognized haulout sites longer than older juveniles.

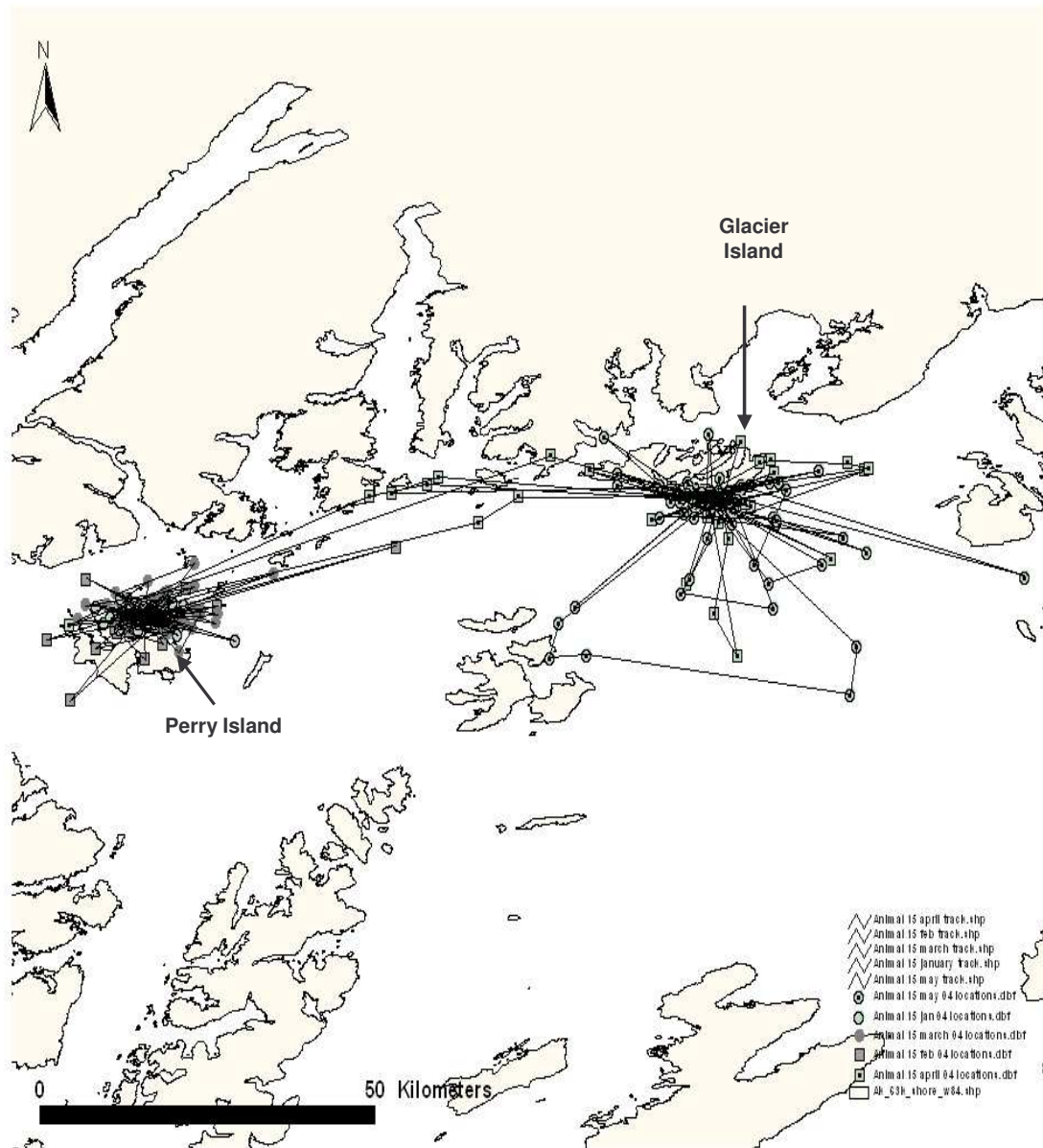Fig. 4a. Movements for Animal 15, a 7-month old YOY, that displayed a gradual increase in offshore travel from January-May. Transits made to and from Glacier Island in April and May are much further away from land than those made at Perry Island during January and February. Although the animal did relocate to the Glacier Island haulout in March, it did move to another site during the study period.
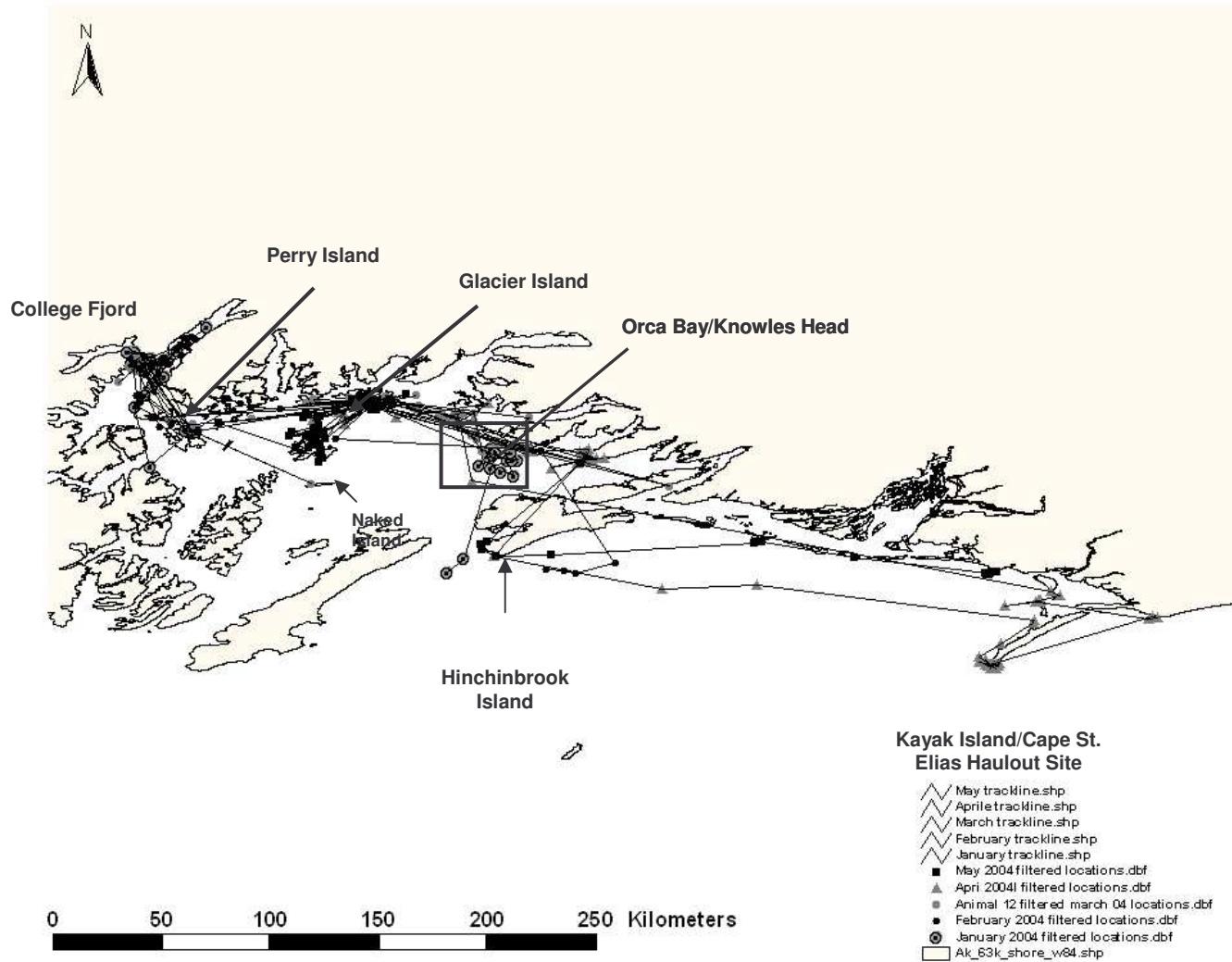
Fig. 4b. In contrast, Animal 12, an older juvenile, traveled to many sites within PWS during the study period. The sea lion also left the Perry Island area immediately after capture and based transits from College Fjord, and area otherwise not known to be occupied by SSl.

Dive behavior

A total of 217,419 dives (mean total dives per animal = 14,495 $\pm$ 9,596 SD; range 2,480 - 32,145) were recorded during the 2 years. Dives were short and shallow for all animals, with a mean depth of 10.8 m and a mean duration of 1.0 min. Animals dove to an average maximum depth of 193 m, with an older juvenile (Animal 12) reaching a depth of close to 600 m (Table 2).

Overall, subadult animals showed a significant preference for shallow dive depths ($p<.001$). Although older animals appeared to make deeper and longer dives than YOY (Fig. 5 and Fig. 6), no significant differences were detected between YOY and older juvenile dive depths ($p=.868$). However, this may be an artifact of my small sample size (n=15), with only four individuals estimated to be one year or older. YOY made a higher proportion of dives at shallow depths, with 85% of all dives less than 20 m. Only 10% of their dives were greater than 20 m, and no dives were deeper than 152 m (Fig. 3). Juveniles did not display as great of a proportion of dives in the 0 - 4 m depth range. About 35% of dives were between 0 - 4 m and 38% 4-20 m in depth. One-to-three year old animals made the deepest dives (up to 200 m) and a higher proportion of dives deeper than 80m than YOY sea lions.

Over the entire depth range, the distribution of dive depths did not significantly differ between the two age classes. However, age did influence dive duration ($p=.001$). Both YOY and older juveniles made a high proportion of dives 1 - 2 min in duration (Fig. 7), however, juveniles made significantly less of these short duration dives ($p<.001$ and $p=.042$ for dives $\leq$ 2 min), and displayed a greater percentage of longer (1 - 7 min) dives.

Season and time of day had a significant effect on subadult dive behavior ($p=.008$ and $p=.022$, respectively). Diving activity during April and May was considerably different than that in earlier months. During winter (January and February), animals made a high proportion of dives (> 40%) during the daytime (0900 – 1500 LT). However, by April and May, this pattern

changed, and the animals made most of their dives (> 40%) during the night (2100-0300 LT).

Activity during dusk and dawn remained approximately the same throughout the 5-month

sampling period, and March appeared to be a transitional month, with dives distributed more

evenly throughout the 24-h day (Fig. 7*a*). This relationship was more pronounced when looking

at dives deeper than 20 m (Fig. 7*b*). The sea lions made $\geq$ 50% of their deeper dives during the

day in the early winter and then switched to deep diving at night at the end of winter/early

spring. This appears to coincide with the seasonal change in photoperiod that occurs at this
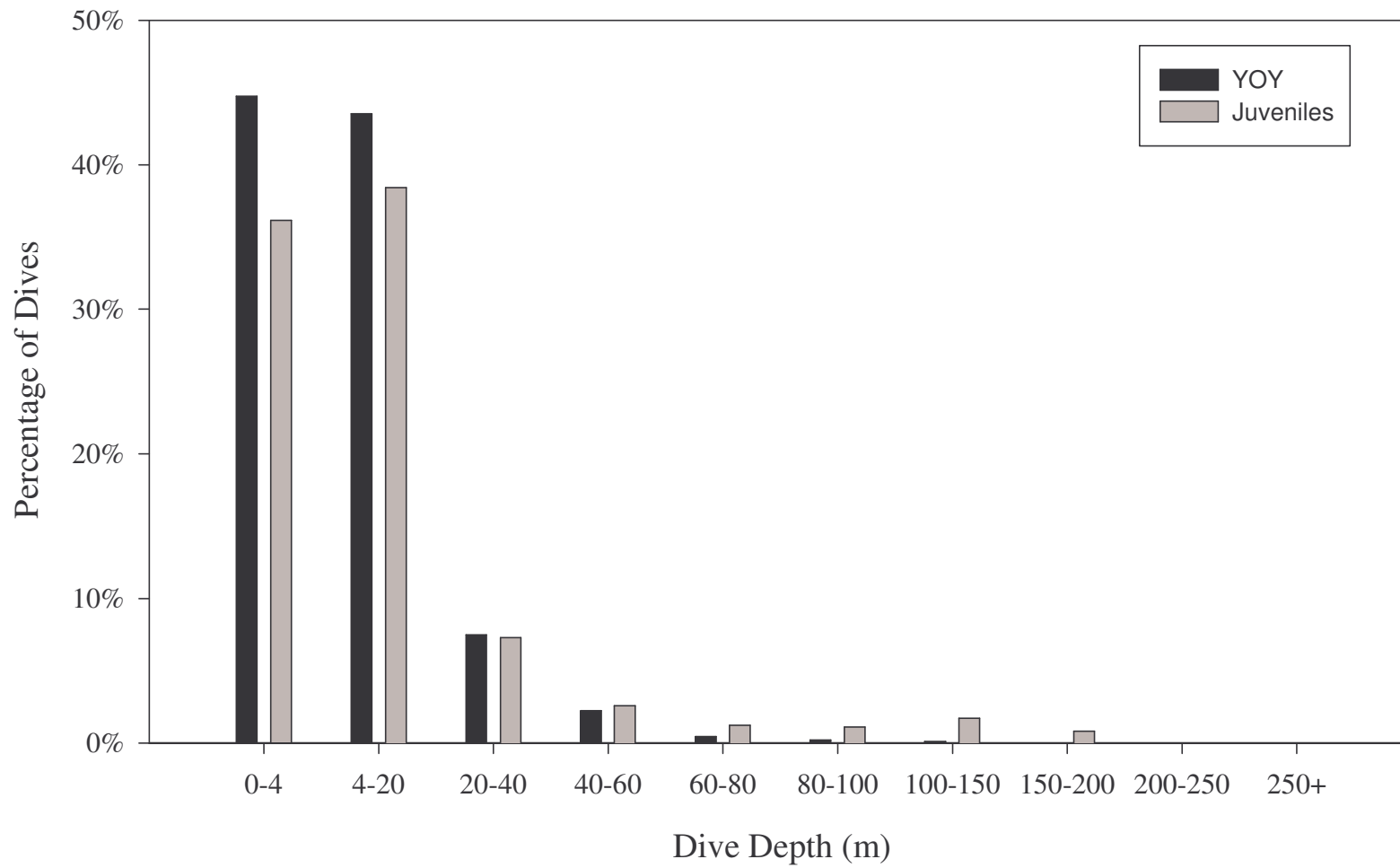
latitude.

Fig. 5. Dive depth distribution for YOY and older, juvenile Steller sea lions. Although no statistical difference was found, YOY exhibited a greater proportion of shallow dives.
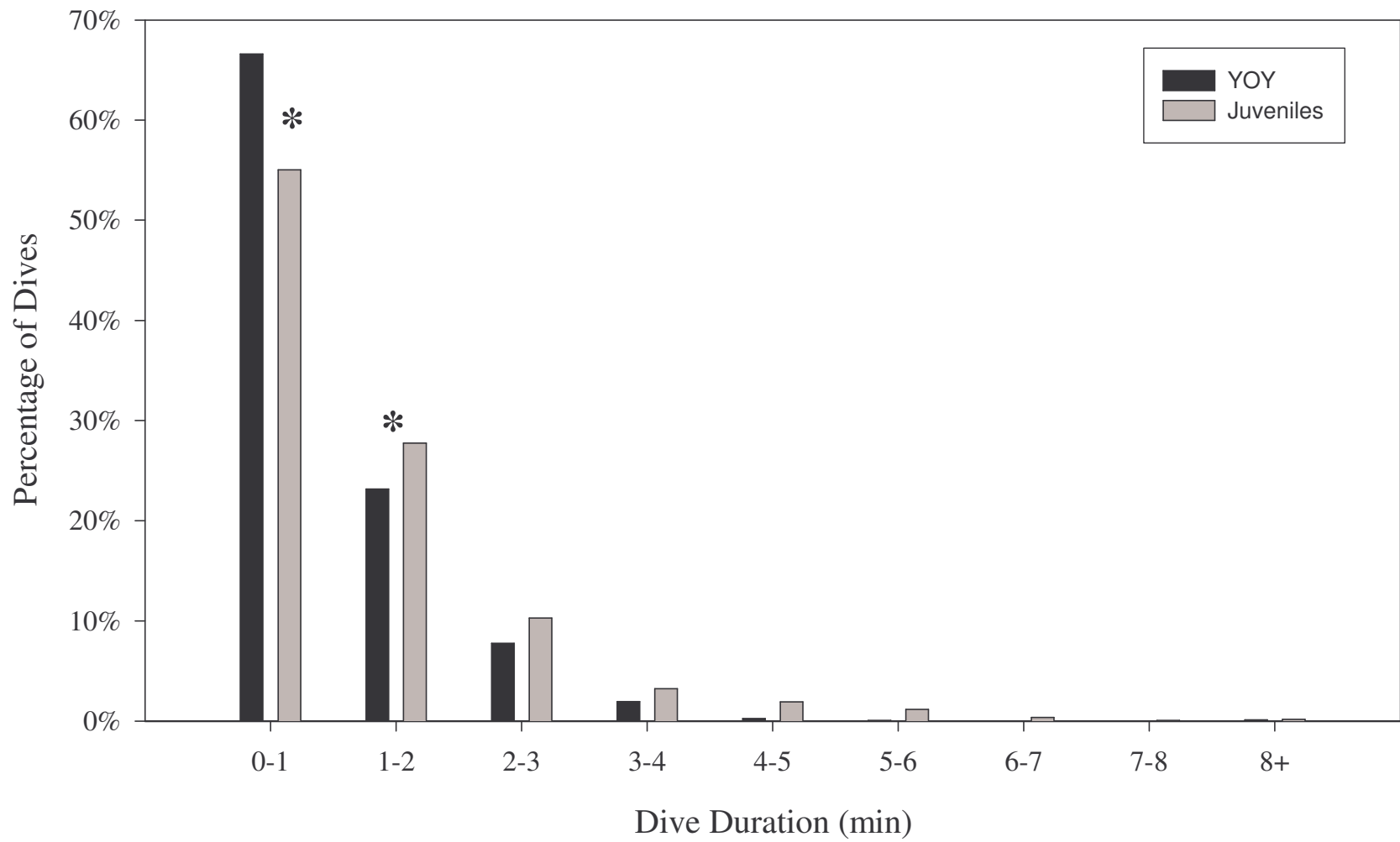
Fig. 6. Dive duration distribution for YOY and older juveniles. YOY exhibited a higher proportion of shorter dives. An asterisk indicates a significant difference
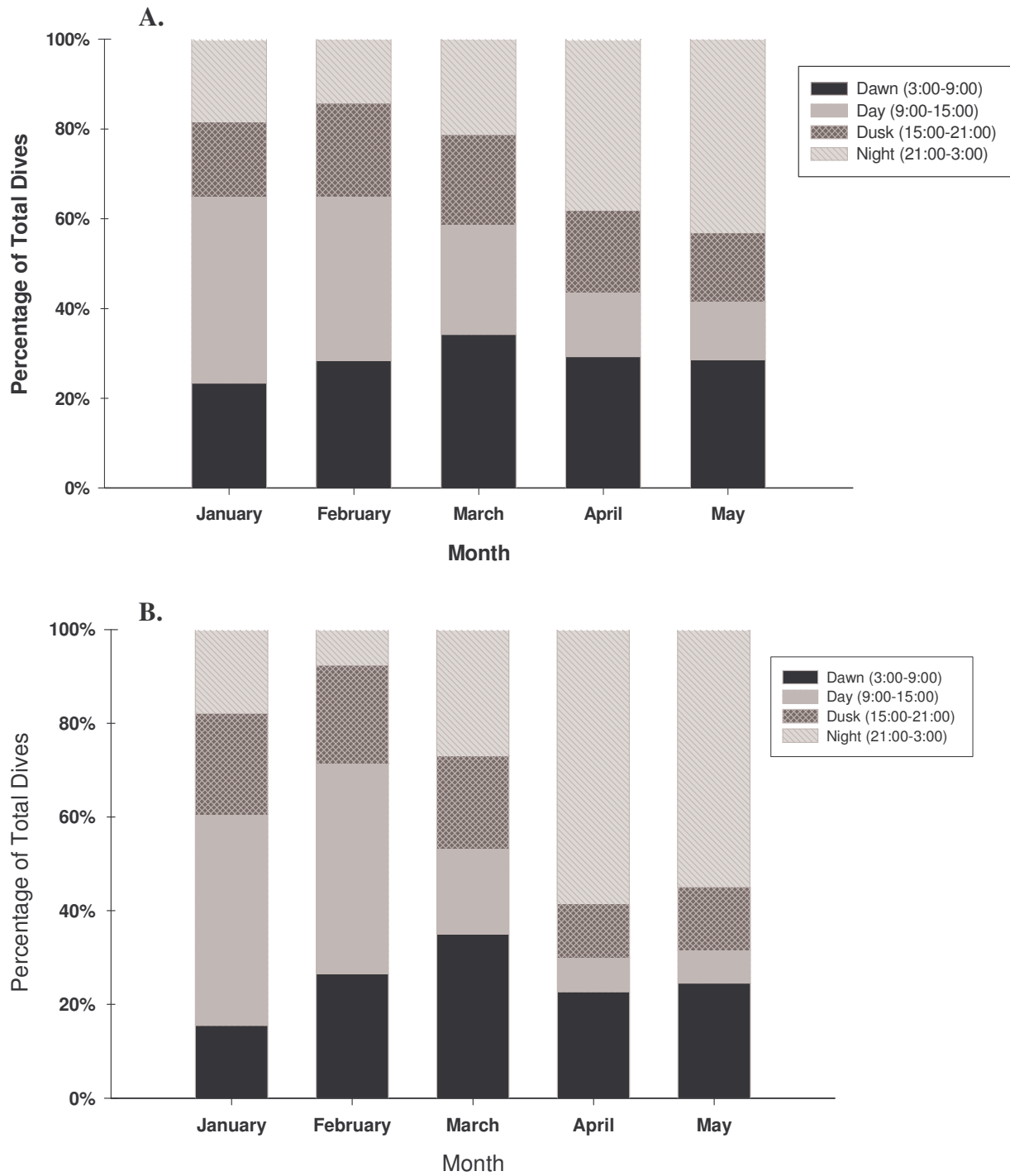
Fig. 7. Distribution of total dives during the 24-hour period, per month, for all subadults tagged. (a) Overall percentage of total dives during the 24-hour period, per month, for all animals. A preference for daytime diving was seen in January and February, and a switch to night diving was noted by early spring. March appears to be a transitional month, as dive activity is more evenly distributed during the 24-hour period. (b) Diving activity at deeper depths ($\geq$20 m) during the 24 hour period, per month, for all animals. A similar but more pronounced pattern is noted.

DISCUSSION

Subadult SSL movements

Subadult SSL habitat use can be characterized by localized, nearshore movements 3 nm or less from shore. It was originally anticipated that animals would leave PWS and interact with cyclonic features in the Gulf of Alaska, however all animals, except Animal 12, remained within PWS and the coastal waters of Cape Resurrection. Moreover, young SSL did not disperse randomly in PWS, but appeared to concentrate their activities in coastal areas and revisited common sites when migrating. PWS harbor seals have also been found to focus their activites close to haulout shorelines; Lowry et al. (2001) found 90% of all at-sea distances to be $\leq$ 25 km from shore, and 97% to be $\leq$ 50 km, suggesting that the seals fed primarily near haulout sites. Highly localized habitat use may be correlated with physical features of the environment which provide protection from predators, aid in navigation, and/or create areas of predictable prey (Burns et al. 2004). Coastal areas were preferred by grey seals and weaned Weddell seal pups as a means of protection from possible killer whale attacks (McConnell et al 1992, Burns et al. 1999, McConnell et al. 1999). Predation pressure from killer whales in PWS may also be a factor in subadult SSL habitat choice. Transient killer whales, which feed on marine mammals, inhabit PWS and present a substantial predation threat for young SSL. Members of the AT1 transient group have been sighted year-round in PWS and Resurrection and Aialik Bays; Gulf of Alaska transients have also been sited in these waters (Saulitis et al. 2000). Foraging killer whales have been found to remain within 20 m of shore, entering bays and narrow passages. The majority of marine mammal takes by killer whales usually occur in nearshore waters (Heimlich-Boran 1988, Saulitis et al. 2000). If killer whales are posing a threat to subadult SSL, proximity to the coast may be a quick way to escape potential attacks.

The spatial distribution of fish can be influenced by bathymetry, temperature, salinity, currents, and sediment type (Tollit et al. 1998). Nearshore areas may thus provide features that increase foraging efficiency and the predictability of prey. Seabed structure and gradient significantly affected bottlenose dolphin foraging efficiency, where steep bathymetric gradients acted like a bottleneck to channel fish, increasing prey density, and enhancing foraging (Ingram and Rogan 2002, Hastie et al. 2004). Grey seals maximized their feeding efforts in areas with steep slopes, as herring schools were more stationary in these areas, and patches became concentrated, making catching prey easier (Sjoberg and Ball 2000). Further studies on the bottom topography and gradient of coastal areas occupied by young SSL need to be conducted to investigate similar effects of physical features on the distribution of SSL prey.

In addition to predation and near-shore foraging, age appeared to influence SSL distributions in PWS. YOY SSL remained in coastal areas longer than older individuals, with offshore movements gradually increasing over time. Young animals also showed a greater residency period at known haulout sites. Raum-Suryan et al. (2002) found similar results when comparing dispersal distances between SSL pups and older juveniles; animals less than one year in age remained close to their natal rookery while branded juveniles dispersed widely and were resighted up to 1,700 km from their natal rookery. SSL pups and yearlings have been found to stay on or near haulout sites while their mothers are out foraging. Weaning in SSL usually occurs before the first year of life, and has not been found to occur during the winter (Pitcher and Calkins 1981, Trites and Porter 2002). By 2-4 months, SSL pups are proficient swimmers, capable of trips up to 400 km, and can accompany their mothers out to sea during foraging trips (Hoover 1988, Trites and Porter 2002, Raum-Suryan et al. 2004). Such trips may provide information to young SSL about foraging locations and potential prey. Harbor seal pups have been found to follow their mothers to sea during the lactation period (Bowen et al. 1999).

Although it was unlikely that the pups were attempting to forage during bouts of diving with their mothers, it was more likely they were traveling with their mother to maintain contact, and possibly more importantly, to learn where and on what their mother was feeding (Bowen et al. 1999). Hence, movements made by YOY may reflect the dispersal of mother-pup pairs, or may be independent trips made by the young SSL while their mothers were out foraging. Wider movements may also coincide with weaning, where the transition to nutritional independence may force young SSL to explore other areas to forage. Loughlin et al. (2003) found sea lions 10 months of age to travel a mean distance of 7 km when at sea, and those >10 months of age traveled a mean distance 24.6 m. They concluded that trip distance increased with age and that longer transits indicated foraging trips, beginning at around 9 months of age.

In contrast to YOY, older juveniles displayed widespread movements, traveling to areas other than known SSL haulout sites in PWS. Juveniles also traveled greater distances, often crossing PWS. It is possible that Animal 12's preference for the College Fjord area may have been due to the presence of a winter food resource; the glacial area may be ideal for overwintering age-0 herring and hence provide a predictable prey patch for SSL (personal communication Thorne 2005). Another shallow outcropping that was used by older juveniles in transit was Middle Ground Shoal, which is located in between Hinchinbrook and Hawkins Islands in southeastern PWS. Such features may provide predictable haul outs for SSL. Extended trips to certain sites made by older animals may also indicate an awareness of major foraging zones and prey patches that are otherwise unavailable to younger conspecifics. Once an animal learns where profitable patches are located, it may become easier to relocate and exploit prey (Bonadonna et al. 2001). The preference by older juveniles to visit certain locations, some of which contained previously uknown haulout sites, may have been related to prior foraging experience, where individuals return to exploit prey patches in areas where they were previously

successful (Tollit et al. 1998). They may also be a responding to the seasonal, nearshore

spawning nature of fish. Spawning aggregations of prey provide important seasonal food

resources for many marine predators (Macleod et al. 2004, Sigler et al. 2004). Strong patterns

have been noted in SSL consumption of prey, where they capitalize on seasonal concentrations

of fish, usually in nearshore waters less than 180 m in depth (Fiscus and Baines 1966, Calkins

and Pitcher 1982, Sinclair and Zeppelin 2002). Pacific herring (*Clupea pallasi*) is found

throughout PWS, but becomes locally abundant during spawning from March-June (Brown and

Carls 1998, Norcross et al. 2001). After spawning, adults disperse and return to deeper, offshore

waters to feed. Inshore bays and harbors become protected nursery grounds and are important

habitat for juvenile herring for at least the first year of life. However, variable habitat quality

among the bays in PWS causes spatial variation in the densities of juvenile herring, as each bay

represents a unique nursery area with differing biological and physical conditions (Norcross et

al. 2001). Juvenile SSL may exploit coastal areas with greater densities of herring and return to

these sites throughout the spawning season. Herring also complete about 75% of their somatic

growth in these nursery areas (Stokesbury et al. 1999). Thus, if SSL are exploiting this resource,

they may be gaining substantial energy from it.

Subadult SSL diving behavior

Young pinnipeds cannot remain submerged as long as adults due to their small size,

higher metabolic rates, and lowered oxygen stores (Burns 1999*a*). The short and shallow nature

of all subadult SSL dives in this study may be indicative of these physiological constraints. It

may also signify the availability of prey and the animal's ability to catch it. Feeding depths and

the time available for search are physiologically limited by available oxygen stores in the blood

and muscle and metabolic rate, which influences the decisions that marine predators make in

locating and pursing their prey (Feldkamp et al. 1989). Food availability and accessibility also

determine an individual's foraging success, in conjunction with its diving abilities (Horning and Trillmich 1997). Young sea lions may thus forage on prey that is easier to catch or found in shallow waters where it is locally abundant.

Fish comprise the majority of SSL diet, with walleye pollock and Pacific herring (*Clupea pallisi*) ranked as top prey (Pitcher 1981, Calkins and Pitcher 1982, Merrick and Calkins 1996). Juvenile pollock is considered to be the predominant fish species consumed by young SSL, although herring, squid, capelin and salmon were found to be extensively used by sea lions in PWS. Harbor seals have also been found to use more herring and squid in PWS than other areas (Pitcher 1981, Calkins and Pitcher 1982, Calkins and Goodwin 1988).

YOY walleye pollock and YOY Pacific herring are found at the same locations and depths during at least part of the year (Studevant et al. 2001). SSL diving to depths between 10 and 20 m would encounter both juvenile and adult herring and juvenile pollock (at night). The near-shore orientation and the geographic distribution of juvenile sea lions (northeast and southwest PWS) may overlap juvenile herring distributions (pers. obs. Thorne 2005). In addition, the sea lion locations did not overlap the major adult herring locations around northern Montague Island or within Port Fidalgo and Port Gravina. It may be that younger sea lions feed on juvenile herring, while the mature animals are able to encounter adult herring more frequently (pers. obs. Thorne 2005). However, further research is needed on the vertical and horizontal distributions of herring and pollock in PWS, especially during non-spawning periods. Larger data sets on subadult SSL movements in PWS will provide insight on potential overlaps with their prey.

Just as seasonality in prey patches may affect SSL movements, it also appears to influence their diving patterns. Season and time of day were found to significantly affect subadult dive patterns. The majority of dives, including deep dives (≥ 20 m), occurred during

the daytime in the winter and then switched to a nightly distribution during the spring. This

change in diving behavior may reflect available daylight. The Alaskan photoperiod increases

during the late winter and spring (increasing by approx. 3 hours per month for the Seward, AK

region). During the study period, the earliest date of transmission was January 11 (sunrise 09:50,

sunset: 16:19), and the latest date was May 31 (sunrise: 03:50 sunset: 21:59). In January and

February, 6-9 hours of daylight was available; by April and May the photoperiod had nearly

doubled to 14-17 hours towards the end of spring.

Many marine predators have been found to follow the daily patterns of their prey

(Feldkamp et al. 1989, Wilson et al. 1993, Nordoy et al. 1995, Burns et al. 1999, Bost et al.

2002, Harcourt et al. 2002, Burns et al. 2004). Herring and pollock perform diel vertical

migrations (DVM), ascending and descending in the water column in response to various factors

such as food availability and water temperature (Sogard and Olla 1996, Schabestberger et al.

2000). Such movements are directly influenced by the amount of light available and are thus

indirectly linked to photoperiod length.

Juvenile pollock and herring both depend on small calanoid prey in PWS throughout

their range; the distribution of these copepods influences fish distributions (Ryer and Olla 1995,

Sturdevant et al. 2001). Peak zooplankton abundance varies with time of day (available light).

Zooplankton densities have been found to be highest during summer in shallow waters. At this

time, pollock occur between 50-80 m (usually above the thermocline), and herring are found in

waters less than 50 m or at the surface (Carlson 1980, Sogard and Olla 1993). In autumn, both

fish species are found around 30 m. Zooplankton biomass decreases from October-February,

and most plankton species remain at depth throughout the winter. Herring rely on stored energy

reserves and do not actively feed during the winter. Fish therefore remain concentrated in dense

schools at depth during the day and disperse into surface waters at night. Herring continue to

move to deeper depths from January through March. Although pollock continue to feed through the winter, their depth distributions also increase towards winter, and adult fish disperse further offshore. Like herring, juvenile pollock reside in deep layers during the day and migrate toward the surface, forming loose aggregations, at night (Schabetsberger et al. 2000). Herring begin to concentrate at shallower depths in April or May as daylight increases, the spring plankton bloom occurs, and spawning commences (Carlson 1980, Livingston 1993, Sturdevant et al. 2001).

SSL dive patterns may change as the vertical migrations of their prey break down and species become less abundant and unavailable to subadult SSL. The aggregated nature of herring at depth during the day in winter may make it easier for prey capture by subadult SSL. Although it takes more energy and time to forage at depth, the dispersed nature of prey at night may make it too difficult for subadult SSL to efficiently forage. Such behavior may explain the high proportion of diving during daylight hours throughout the winter. In contrast, when surface waters are abundant with fish in April and May, SSL may switch to diving predominately at night in response to the increased vertical migration of their prey. Sjoberg et al. (1995) found a Baltic grey seal to forage more during the daytime, and thought it was capitalizing on dense schools of Baltic herring forming near bottom during the day (Sjoberg et al. 1995). Burns et al. (1999) also found weaned Weddell seal dive depths to increase during afternoon periods in the winter, and thought this was in response to a lack in vertical movement displayed by prey during winter months.

Diving behavior in pinnipeds has been found to develop and change with age (Horning and Trillmich 1997, Burns 1999*b*, Burns et al. 1999, Loughlin et al. 2003). Juvenile dive behavior continues to develop during the winter as nursing pups begin to grow and mature (Burns et al. 1999). During this study, older juveniles exhibited deeper dives and significantly longer dive durations than YOY. Trites and Porter (2002) also found the dive profiles of

dependent, immature SSL to be shallower and shorter compared to older independent sea lions. Differences in dive characteristics in this study may reflect experience with age. The occurrence of dives during the day in winter may also result from the development of diving in young SSL. Perhaps availability of light makes foraging easier, whereas YOY SSL rely on visual cues at the early stages of diving, improving their foraging abilities over time. This would mean performing most dives during maximum light, which throughout late winter occurs during the day. As prey become more abundant in surface waters later in the day, photoperiod lengthens, and diving proficiency improves, animals may be able to switch to a more nightly distribution in diving.

CONCLUSION

Habitat preferences are important in defining critical areas and establishing protective zones. For subadult SSL, it appears that nearshore areas within the 20 nm buffer zones are important habitat to young SSL that are maturing to nutritional independence. This was evident by the proximity to shore maintained by all tagged sea lions as well as the short and shallow natures of their dives. Such regions may provide protection and seasonal patches of predictable prey for inexperienced foragers. Spawning aggregations of prey are likely an important food source for subadult SSL. Animals appear to shift their vertical and horizontal distributions during the winter and spring in response to the seasonal movements of this prey base. Monthly shifts in movements and dive behavior may have also reflected the development of dive behavior in SSL, where animals displayed expanded movements with longer transits and deeper dives as they matured through the winter.

Although it is clear that nearshore waters are critical to maturing SSL, in order to improve conservations strategies and further understand SSL ecology, the distribution and behavior of sea lions needs to be correlated to the productivity and behavior of PWS fish species, especially juvenile herring and pollock. Species, sizes, and quantities of prey consumed by subadult SSL need to be correlated seasonally with fish distributions in PWS. Further oceanographic surveys should also be performed where young SSL occur to investigate the effects of habitat features on prey patches. Without complete, current information on the spatial distribution of fish in PWS and the factors that influence their movements, it is hard to make links between predator and prey distributions.

LITERATURE CITED

Anderson, P.J., Blackburn, J.E., and Johnson A.B. (1997) Declines of forage species in the Gulf of Alaska, 1972-1995, as an indicator of regime shift. *In:* Proceedings: Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program. 531-543

Anderson, P.J. and Piatt, J.F. (1999) Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series. 189: 117-123.

Benson, A.J., and Trites, A.W. (2002) Ecological effects of regime shifts in the Bering Sea and eastern North Pacific Ocean. Fish and Fisheries. 3: 95-113.

Bonadonna, F., Lea, M., Dehorter, O. and Guinet, C. (2001) Foraging ground fidelity and route-choice tactics of a marine predator: the Antarctic fur seal *Arctocephalus gazella*. Marine Ecology Progress Series. 223: 287-297.

Bost, C.A., Zorn, T., Le Maho, Y. and Duhamel, G. (2002) Feeding and diving predators and diel vertical migration of prey: king penguins' diet versus trawl sampling at Kerguelen Islands. Marine Ecology Progress Series. 227: 51-61.

Bowen, W.D., Boness, D.J., and Iverson S.J. (1999) Diving behavior of lactating harbor seals and their pups during maternal foraging trips. Canadian Journal of Zoology. 77: 978-988.

Bowen, W.D., Harwood, J., Goodman, D., Swartzman, G.L. (2001) Review of the November 2000 biological opinion and incidental take statement with respect to the Western stock of the Steller sea lion. Interim Report, North Pacific Fishery Management Council.

Braham, H.W., Everitt, R.D., Rugh, D.J. (1980) Northern sea lion population decline in the eastern Aleutian Islands. Journal of Wildlife Management. 44(1): 25-33.

Brown, E.D. and Carls, M.G. (1998) Pacific herring, Clupea pallisi. Exxon Valdez Oil Spill Trustee Council Restoration Notebook. 1-8.

Burns, J.M. (1999a) Movements and diving behavior of weaned Weddel seal (*Leptonychotes weddellii*) pups. Polar Biology. 21: 23-36.

Burns, J.M. (1999b) The development of diving behavior in juvenile seals; pushing physiological limits in order to survive. Canadian Journal of Zoology. 77: 737-747.

Burns, J.M., Castellini, M.A., Testa. (1999) Movements and diving behavior of weaned Weddell seal (*Leptonychotes weddelli*) pups. Polar Biology. 21: 23-36.

Burns, J.M., Costa, D.P., Fedak, M.A., Hindell, M.A., Bradshaw, C.J.A., Gales, N.J., McDonald, B., Trumble, S.J., and Crocker, D.E. (2004) Winter habitat use and foraging behavior of crabeater seals along the Western Antarctic Peninsula. Deep-Sea Research II. 51: 2279-2303.

Calkins, D.G. and Pitcher, K.W. (1982) Population assessment, ecology, and trophic relationships of Steller sea lions in the Gulf of Alaska.   Outer Continental Shelf Environmental Assessment Program. United States Department of the Interior. Bureauof Land Management.

Calkins, D.G. and Goodwin, E. (1988) Investigation of the declining sea lion population in the Gulf of Alaska. Technical Report, Alaska Department of Fish and Game.

Calkins, D.G., McAllister, D.C., and Pitcher, K.W. (1999) Steller sea lion status and trend in Southeast Alaska: 1979-1997. Marine Mammal Science. 15(2): 462-477.

Carlson, H.R. (1980) Seasonal distribution and environment of Pacific herring near Auke Bay, Lynn Canal, Southeastern, Alaska. Transactions of the American Fisheries Society. 109: 71-78.

Chavez, F.P., Ryan, J., Lluch-Cota, S.E., and Niquen, M.C. (2003) From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science. 299: 217-221.

Conners, M.E., Hollowed, A.B., and Brown, E. (2002) Retrospective analysis of Bering Sea bottom trawl surveys: regime shift and ecosystem reorganization. Progress in Oceanography. 55: 209-222

Cooney, R.T., Coyle, C.O., Stockmar, E., and Stark, C. (2001) Seasonality in surface-layer net zooplankton communities in Prince William Sound, Alaska. Fisheries Oceanography. 10(Suppl. 1): 97-109

Coyne, M.S. (2004) Satellite tracking and analysis tool. SEATURTLE.ORG, Inc. http://www.seaturtle.org/tracking/.

Feldkamp, A.D., Delong, R.L., and Antonelis, G.A. (1989) Diving patterns of California sea lions, *Zalophus califonianus*. Canadian Journal of Zoology. 67: 872-883.

Fiscus, C.H. and Baines, G.A. (1966) Food and feeding behavior of Steller and California sea lions. Journal of Mammalogy. 47(2): 195-200.

Francis, R.C., Hare, S.R., Hollowed, A.B., and Wooster, W.S. (1998) Effects of interdecadal climate variability on the oceanic systems of the NE Pacific. Fisheries Oceanography. 7:1-21.

Fritz, L.W. and Ferrero, Ri.C. (1995) The threatened status of Steller sea lions, *Eumetopias jubatus*, under the Endangered Species Act: effects on Alaska groundfish fisheries management. Marine Fisheries Review. 57(2): 14-28.

Fritz, L.W. and Ferrero, R.C. (1998) Options in Steller sea lion recovery and groundfish fishery management. Biosphere Conservation. 1(1): 7-19.

Harcourt, R.G., Bradshaw, C.J.A., Dickson, K., and Davis, L.S. (2002) Foraging ecology of a generalist predator, the female New Zealand fur seal. Marine Ecology Progress Series. 227: 11-24.

Hare, S.R., and Mantua, N.J. (2000) Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography. 47: 103-145.

Hastie, G.D., Wilson, B., Wilson, L.J., Parsons, K.M., Thompson, P.M. (2004) Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. Marine Biology. 144: 397-403.

Hayward, Thomas. (1997) Pacific Ocean climate change: atmospheric forcing, ocean circulation and ecosystem response. Trends in Evolution and Ecology. 12(4): 150-154.

Heath, R.B., Calkins, D., McAllister, D., Taylor, W. (1996) Telazol and isoflurane field anesthesia in free-ranging Steller sea lions (*Eumetopias jubatus*). Journal of Zoo and Wildlife Medicine. 27(1): 35-43.

Heimlich-Boran, J.R. (1988) Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Canadian Journal of Zoology. 66: 565-578.

Hollowed, A.B. and Wooster, W.S. (1992) Variablity of winter ocean conditions and strong year classes of Northeast Pacific groundfish. ICES Marine Science Symposia. 195: 433-444.

Holmes, E.E. and York, A.E. (2003) Using age structure to detect impacts on threatened populations: a case study with Steller sea lions. Conservation Biology. 17(6): 1794-1806

Hooge, P.N. and Eichenlaub, B. (1997) Animal movement extension to arcview. Ver. 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK.

Hoover, A. (1988) Steller sea lion (*Eumetopias jubatus*). Selected marine mammals of Alaska: species accounts with research and management recommendations. Jack W. Lentfer (editor). Washington, D.C.: Marine Mammal Commission.

Horning, M. and Trillmich, F. Ontogeny of diving behaviour in the Galapagos fur seal. (1997) Behaviour. 134: 1211-1257.

Ingram, S.N. and Roger, E. (2002) Identifying critical areas and habitat preferences of bottlenose dolphins *Tursiops truncatus*. Marine Ecology Progress Series. 244: 247-255.

Kenyon, K.W. and Rice, D.W. (1961) Abundance and distribution of the Steller sea lion. Journal of Mammalogy. 42: 223-234.

Krebs, C. J. (1989) Ecological methodology. Harper Collins, New York.

Loughlin, T.R., and Merrick, R.L. (1988) Comparison of commercial harvest of walleye pollock and northern sea lion abundance in the Bering Sea and Gulf of Alaska. In : Proceedings of the International Symposium on the Biology and Management of walleye pollock, November 1988, Anchorage, Alaska. Lowell Wakefield Fisheries Symposium. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Alaska. p. 679-700.

Loughlin, T.R. and York, A.E. (2000) An accounting of the sources of Steller sea lion, *Eumetopias jubatus*, mortality. Marine Fisheries Review. 62(4): 40-45.

Loughlin, T.R., Sterling, J.T., Merrick, R.L., Sease, J.L., and York, A.E. (2003) Diving behavior of immature Steller sea lions (*Eumetopias jubatus*). Fisheries Bulletin. 101:566-582.

Lowry, L.F., Frost, K.J., and Loughlin, T.R. (1988) Importance of walleye pollock in the diets of marine mammals in the Gulf of Alaska and Bering Sea, and implications for fishery management. In Proceedings of the International Symposium on the Biology and Managemetn of walleye pollock, November 1988, Anchorage, Alaska. Lowell Wakefield Fisheries Symposium. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Alaska. p. 701-736.

Lowry, L.F, Frost, K., Ver Hoef, J.M., and Delong, R.A. (2001) Movements of satellite-tagged subadultand adult harbor seals in Prince William Sound, Alaska. Marine Mammal Science. 17: 835-861.

Macleod, K., Fairbairns, R., Gill, A., Fairbairns, B., Gordon, J., Blair-Myers, C., Parsons, E.C.M. (2004) Seasonal distribution of minke whales *Balaenoptera acutorostrata* in relation to physiography and prey off the Isle of Mull, Scotland. Marine Ecology Progress Series. 277: 263-274.

McConnell, B.J., Chambers, C., Nicholas, K.S., and Fedak, M.A. (1992) Satellite tracking of grey seals (*Halichoerus grypus*). Journal of Zoology. 226: 271-282.

McConnell, B.J., Fedak, M.A., Lovell, P., and Hammond, P.S. (1999) Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology. 36: 573-590.

Merrick, R.L., and Loughlin, T.R. (1997) Foraging behavior of adult female and young-of-the-year Steller sea lions in Alaskan waters. Canadian Journal of Zoology. 75, 776-786.

Miller, A.J., and Schneider, N. (2000) Interdecadal climate regime dynamics in the North Pacific Ocean: theories, observations and ecosystem impacts. Progress in Oceanography. 47: 355-379.

National Marine Fisheries Service. (2001) Steller sea lion protection measures. Chapter three: affected environment. Final supplemental environmental impact statement, Anchorage, Alaska.

Niebauer, H.J., Royer, Thomas C., and Weingartner, Thomas J. (1994) Circulation of Prince William Sound, Alaska. Journal of Geophysical Research. 99(C7): 14,113-14,126.

Norcross, B.L., Brown, E.D., Foy, R.J., Frandsen, M., Gay, S.M., Cline, T.C. Jr., Mason, D.M., Patrick, E.V, Paul, A.J., and Stokesbury, K.D.E. (2001) A synthesis of the life history and ecology of juvenile Pacific herring in Prince William Sound, Alaska. Fisheries Oceanography. 10 (Suppl. 1): 42-57.

Nordoy, E.S., Folkow, L, and Blix, A.S. (1995) Distribution and diving behavior of crabeater seals (*Lobodon carcinophagus*). Polar Biology. 15: 261-268.

Pascual, M.A. and Adkison, M.D. (1994) The decline of the Steller sea lion in the Northeast Pacific: demography, harvest, or the environment? Ecological Applications. 4(2): 393-403.

Pitcher, K.W. (1981) Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fishery Bulletin. 79: 467-472.

Pitcher, Kenneth W. and Calkins, Donald G. (1981) Reproductive biology of Steller sea lions in the Gulf of Alaska. Journal of Mammalogy. 62(3): 599-605.

Porter, Boyd. (1997) Winter ecology of Steller sea lions (*Eumetopias jubatus*) in Alaska. Masters Thesis. University of Alaska, Anchorage. Anchorage, Alaska.

Raum-Suryan, K., Pitcher, K.W., Calkins, D.G., Sease, J.L, Loughlin, T.R. (2002) Dispersal, rookery fidelity, and metapopulation structure of Steller sea lions (*Eumetopias jubatus*) in an increasing and decreasing population in Alaska. Marine Mammal Science. 18(3): 746-764

Raum-Suryan, K., Rehberg, M., Pendelton, G.W., Pitcher, K.W., and Gelatt, T.S. (2004) Development of dispersal, movement patterns, and haul-out use by pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. Marine Mammal Science. 20(4): 823-850.

Ryer, C.H. and Olla, B.L. (1995) Influences of food distribution on fish foraging behaviour. Animal Behaviour. 49: 411-418.

Saulitis, E., Matkin, C., Barrett-Lennard, L., Heise, K., and Ellis, G. (2000) Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. Marine Mammal Science. 16(1): 94-109.

Schabetsberger, R., Brodeur, R.D., Ciannelli, L., Napp, J.M., and Swartzman, G.L. (2000) Diel vertical migration and interaction of zooplankton and juvenile walleye pollock (*Theragra chalcogramma*) at a frontal region near the Pribilof Islands, Bering Sea. ICES Journal of Marine Science. 57: 1283-1295.

Sease, J.L., and Taylor, W.P. (2001) Aerial survey of adult and juvenile Steller seal lions in Alaska, June 2000. In: B.S. Fadley, editor, Steller Sea Lion Investigations, 2000. U.S. Department of Commerce, Seattle, WA. (AFS Processed Report 2000-05) p. 514.

Sigler, M.F., Womble, J.N., Wollenweider, J.J. (2004) Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: a prespawning aggregation of eulachon (*Thaleichthys pacificus*). Canadian Journal of Fisheries and Aquatic Science. 61: 1475-1484.

Sinclair, E.H., and Zeppelin, T.K. (2002) Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*).   Journal of Mammalogy. 83(4): 973-990.

Sjoberg, M. Fedak, M.A. and McConnell, B.J. (1995) Movements and diurnal behavior in a Baltic grey seal (*Halichoerus grypus*). Polar Biology. 15: 593-595.

Sjoberg, M. and Ball, John P. (2000) Grey seal, *Halichoerus grypus*, habitat selection around haulout sites in the Baltic Sea: bathymetry or central-place foraging? Canadian Journal of Zoology. 78: 1661-1667.

Sogard, S.M. and Olla, B.L. (1993) Effects of light, thermoclines and predator presence on vertical distribution and behavioral ineractions ofjuvenile walleye pollock, *Theragra chalcogramma* Pallas. Journal of Experimental Marine Biology and Ecology. 167: 179-195.

Sogard, S.M. and Olla, B.L. (1993) Effects of light, thermoclines, and predator presence on vertical distribution and behavioral interactions of juvenile walleye pollock, *Theragra clacogramma* Pallas. Journal of Experimental Marine Biology and Ecology. 167: 179-195.

Sogard, S.M. and Olla, B.L. (1996) Diel Pattern of behavior in juvenile walleye pollock, *Theragra chalcogramma*. Environmental Biology of Fishes. 47: 379-386.

Stokesbury, K.D.E., Foy, R.J., and Norcross, B.L. (1999) Spatial and temporal variability in juvenile Pacific herring, *Clupea pallasi*, growth in Prince William Sound, Alaska. Environmental Biology of Fishes. 56: 409-418.

Sturdevant, M.V., Brase, A.L.J., Hulbert, L.B. (2001) Feeding habits, prey fields, and potential competition of young-of-the-year walleye pollock (*Theragra chalcogramma*) and Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, 1994-1995. Fisheries Bulletin. 99: 482-501.

Tollit, D.J., Black, A.D., Thompson, P.M., Mackay, A., Corpe, H.M., Wilson, Bl, Van Parijs, S.M., Grellier, Kl, and Parlane, S. (1998) Variations in harbour seal *Phoca vitulina* diet and dive depths in relation to foraging habitat. Journal of Zoology. 244: 209-222.

Trites A.W., and Larkin, P.A. (1992) The status of Stellers sea lion populations and the development of fisheries in the Gulf of Alaska and Aleutian Islands. Report to the Pacific States Marine Fisheries Commission, 133p. Fisheries Centre, University of British Columbia, Vancouver, B.C., Canada.

Trites, A.W. and Larkin, P.A. (1996) Changes in the abundance of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1956 to 1992: how many were there? Aquatic Mammals. 22(3): 153-166.

Trites, A.W. (1998) Steller sea lions (*Eumetopias jubatus*): causes for their decline and factors limiting their restoration. Unpublished manuscript, 24p. Marine Mammal Research Unit, Fisheries Centre, University of British Columbia, Vancouver, B.C., Canada.

Trites, A.W. and Porter, B.T. (2002) Attendance patterns of Steller sea lions (*Eumetopias jubatus*) and their young during winter. Journal of Zoology. 256: 547-556.

Trites, A. W., and Donnelly, C.P. (2003) The decline of the Steller sea lions *Eumetopias jubatus* in Alaska: a review of the nutritional stress hypothesis. Mammal Review. 33: 3-28

Vaughan, S.L, Mooers, C.N.K., and Gay, S.M. III. (2001) Physical variability in Prince William Sound during the SEA study (1994-1998). Fisheries Oceanography. 10(Suppl. 1): 58-80.

Vincent, C., McConnell, B.J., Ridoux, V., and Fedak, M.A. (2002) Assessment of Argos location accuracy from satellite tags deployed on captive grey seals. Marine Mammal Science. 18(1): 156-166.

Wang, J., Meibing, J., Patrick, E.V., Allen, J.R., Eslinger, D.L., Mooers, C.N.K., and Cooney, T.R. (2001) Numerical simulations of the seasonal circulation patterns and thermohaline structures of Prince William Sound, Alaska. Fisheries Oceanography. 10(Suppl. 1): 132-148.

Wilson, R.P., Puetz, K., Bost, C.A., Culik, B.M., Bannasch, R., Reins, T., and Adelung, D. (1993) Diel dive depth in penguins in relation to the diel vertical migration of prey: whose dinner by candle-light? Marine Ecology Progress Series. 94: 101-104.

Winship, A.J., Trites, A.W. and Rosen, D.A.S. (2002) A bioenergetic model for estimating the food requirements of Steller sea lions, *Eumetopias jubatus,* in Alaska, USA. Marine Ecology Progress Series. 229: 291-312.

York, A.E., Merrick, R.L., and Loughlin, T.R. (1996) An analysis of the Steller sea lion metapopulation in Alaska. In: Dale R. McCullough (editor), Metapopulations and Wildlife Conservation. Island Press. Covello, California. Pp. 259-292.

Zeppelin, T.K., Tollit, D.J., Call, K.A., Orchard, T.J. (2004) Sizes of walleye pollock (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus monopterygius*) consumed by the western stock of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1998-2000. 2004. Fisheries Bulletin. 102: 509-521.

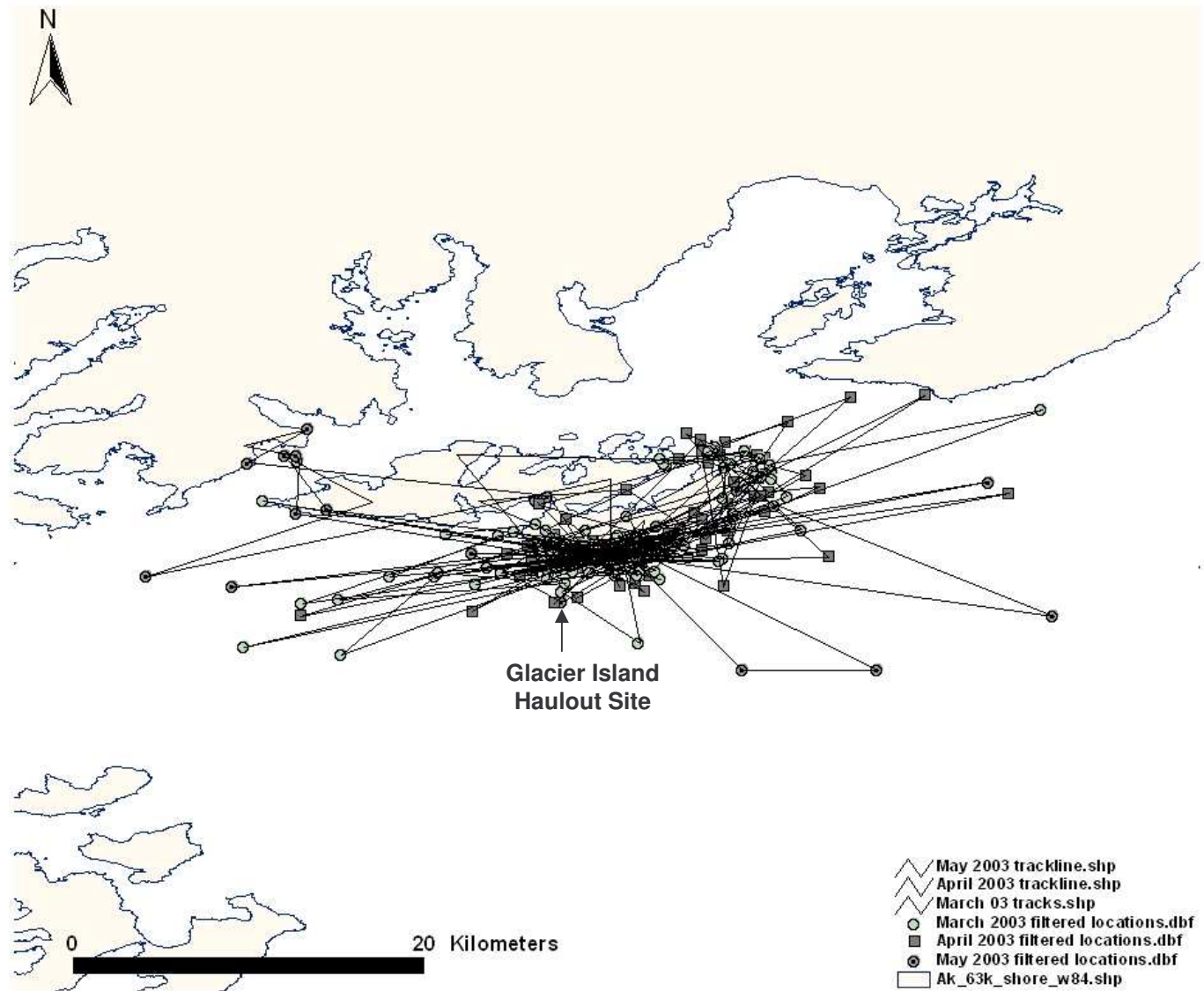**Maps and Movements for All Animals**
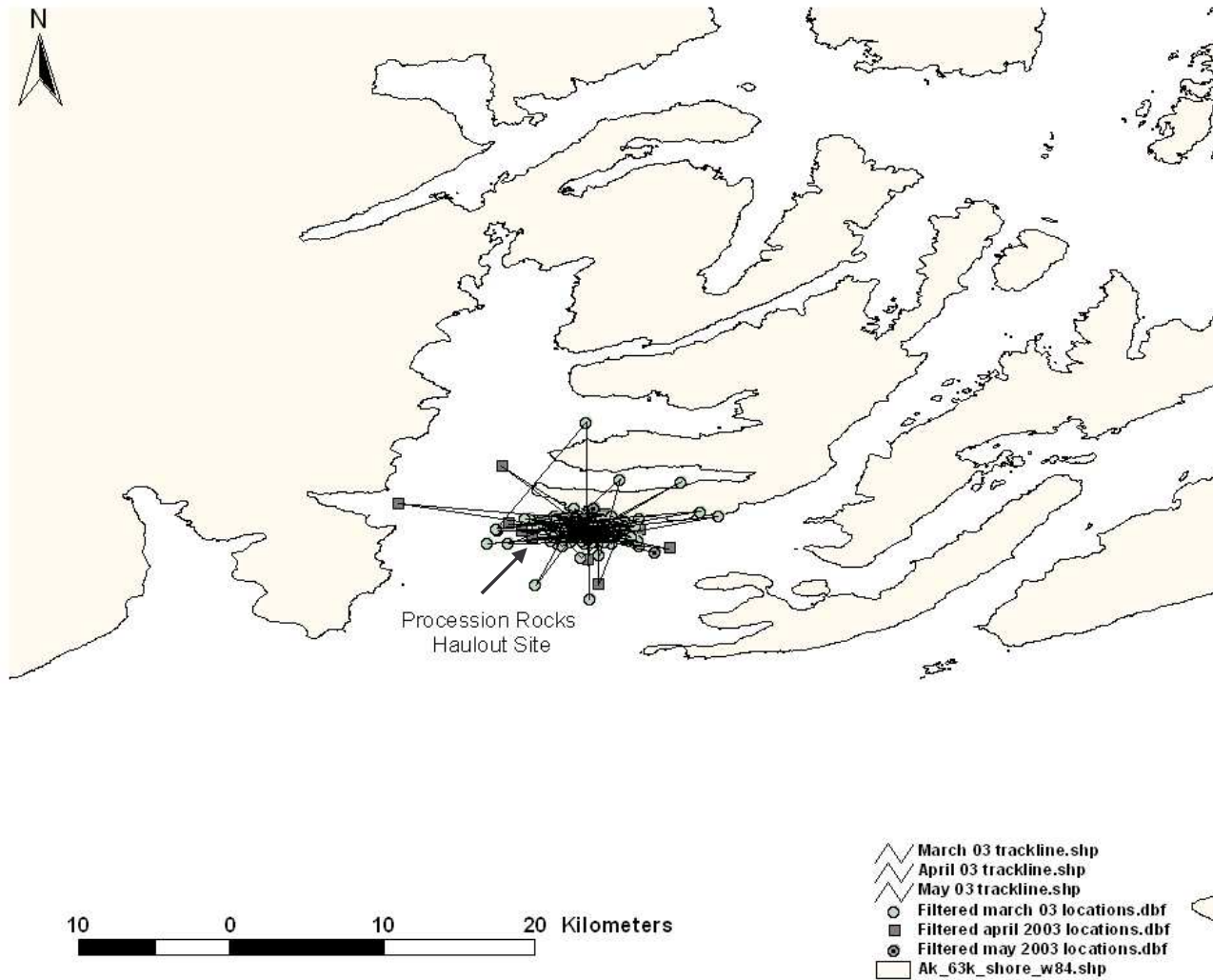
Map 1. Movements for Animal 01 from March 1st-May 30th, 2003. Although the animal was estimated to be a yearling, it did not leave it's capture site at Procession Rocks during they study period. It also stayed within a tight radius (<10km) around the site.
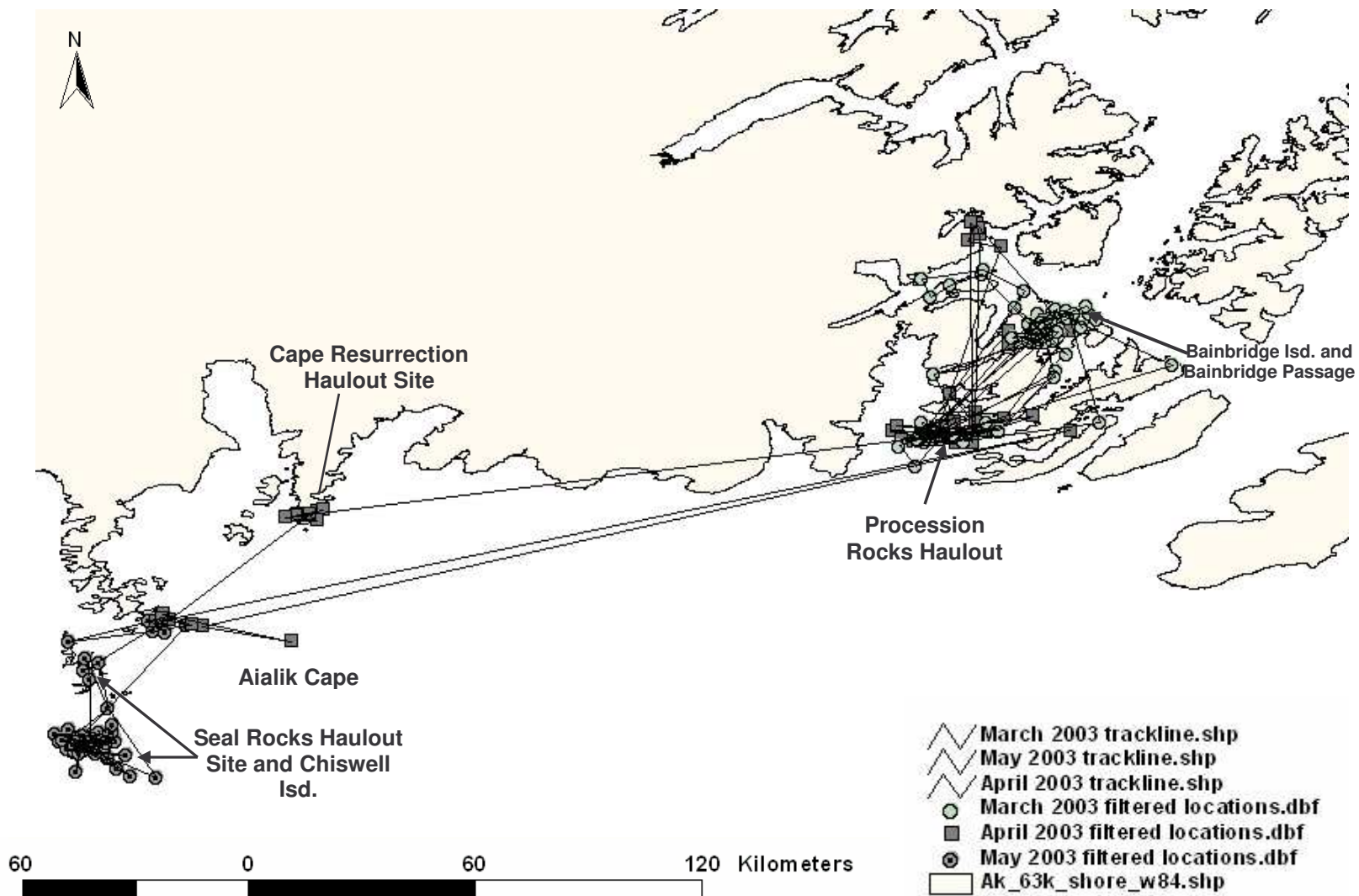
Map 2. Movements for Animal 02, an older juvenile estimated to be 2.5 years in age. The animal remained in the area of Procession Rocks, its capture site, for the month of March, with other activities concentrated around the NE tip of Bainbridge Island and associated waters, including Icy Bay and Whale Bay. By April, the sea lion moved to the southwest, to the Cape Resurrection haulout site, and then was located off of Seal Rockss and Chiswell Island by the end of the study period in May 2003.
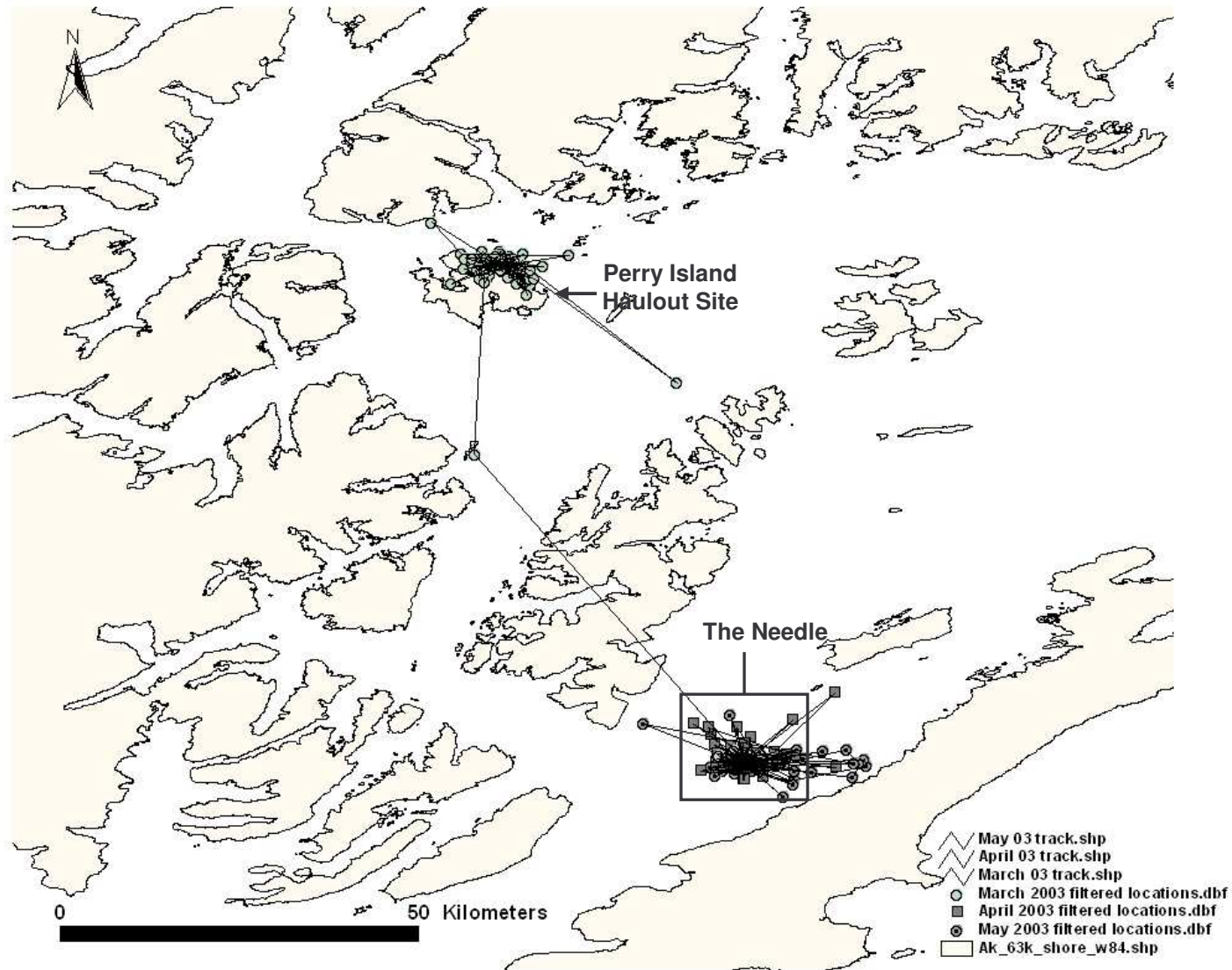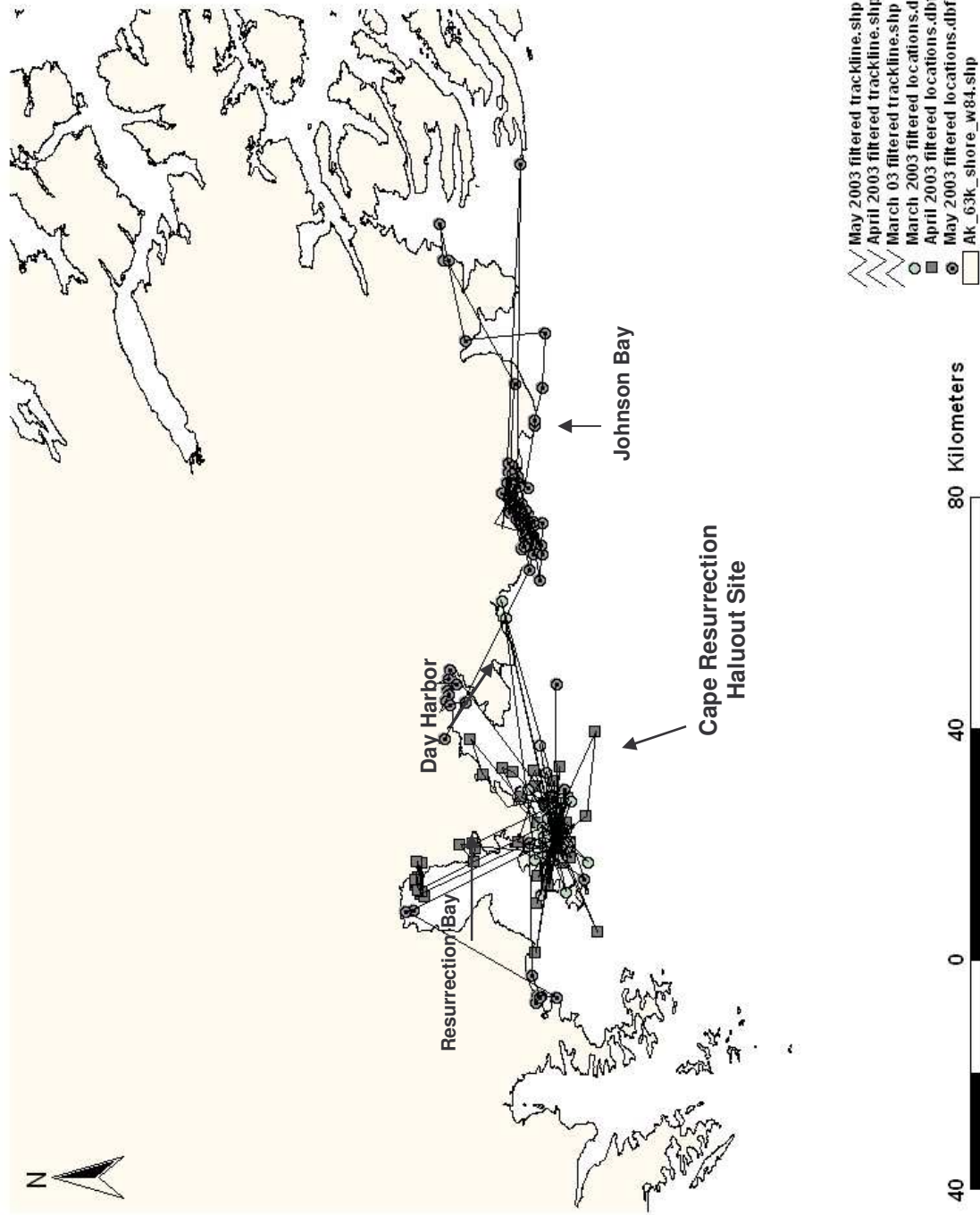
Map 3. Movements for Animal 03, estimated to be a 9-month-old YOY. The animal was tagged in early March at the Perry Island haulout site and remained here for the rest of the month. It then made a direct migration ($\geq$50km) to The Needle, an outcropping of rocks off the NW coast of Montague Island. The sea lion remained in a tight radius ($\leq$5km) around both haulouts. It may have been traveling with its mother at this time and followed her as she moved from one haulout to another.

**Glacier Island
Haulout Site**

Legend:
- May 2003 trackline.shp
- April 2003 trackline.shp
- March 03 tracks.shp
- March 2003 filtered locations.dbf
- April 2003 filtered locations.dbf
- May 2003 filtered locations.dbf
- Ak_63k_shore_w84.shp

0   20 Kilometers

Map 4. Movements for Animal 04, estimated to be a 9-month-old YOY. The animal remained at its capture site, Glacier Island, and surrounding waters through the study period, March 1st-May 31st, 2003.
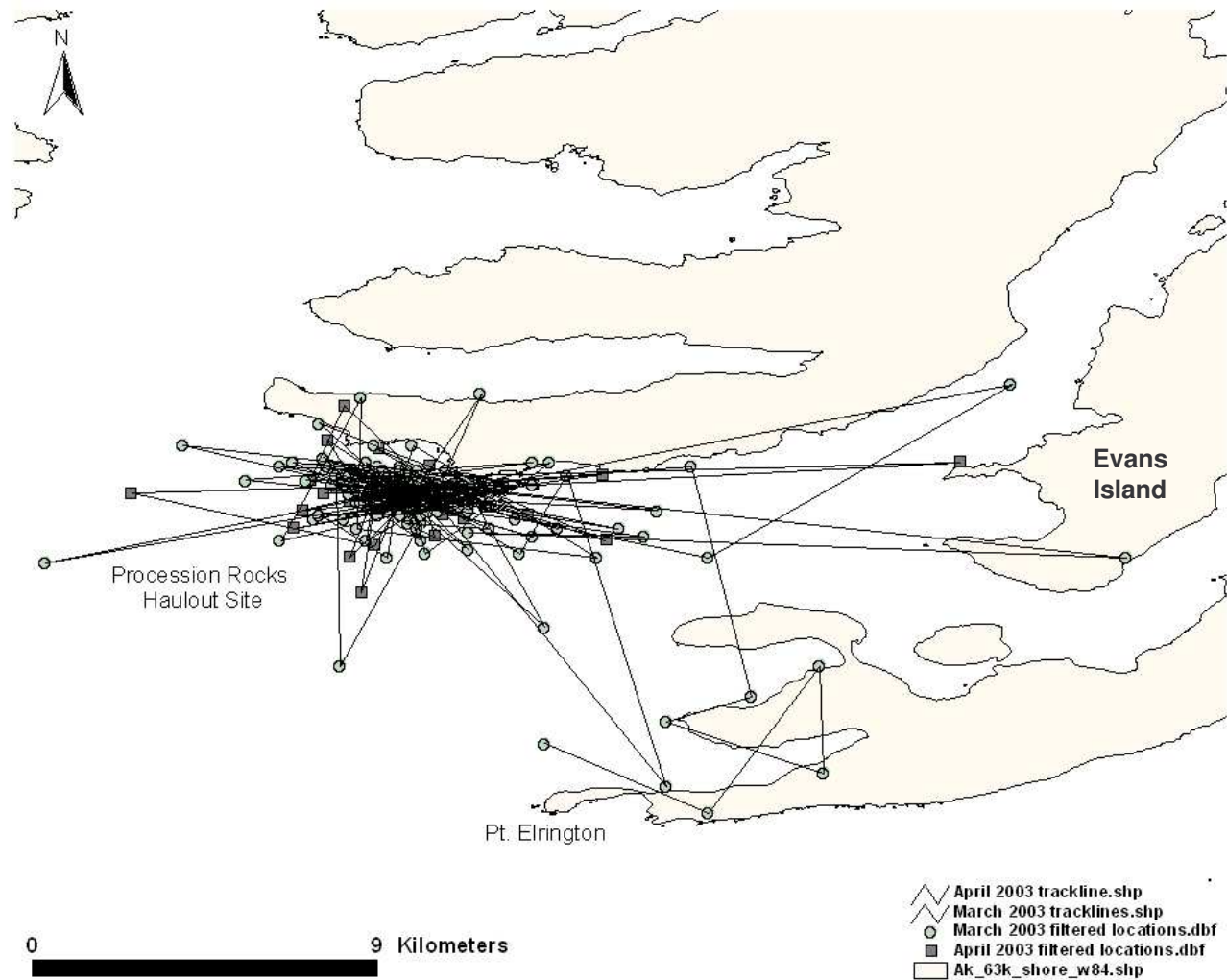
Map 5. Movements for Animal 05, estimated to be a 9-month-old YOY. The sea lion did not move from its capture site during the study period of March 3rd-May 31st, 2003. Although there are some scattered locates around Pt. Elrington and the southern tip of Evans island, the sea lion basically remained in waters ≤5km from the haulout.
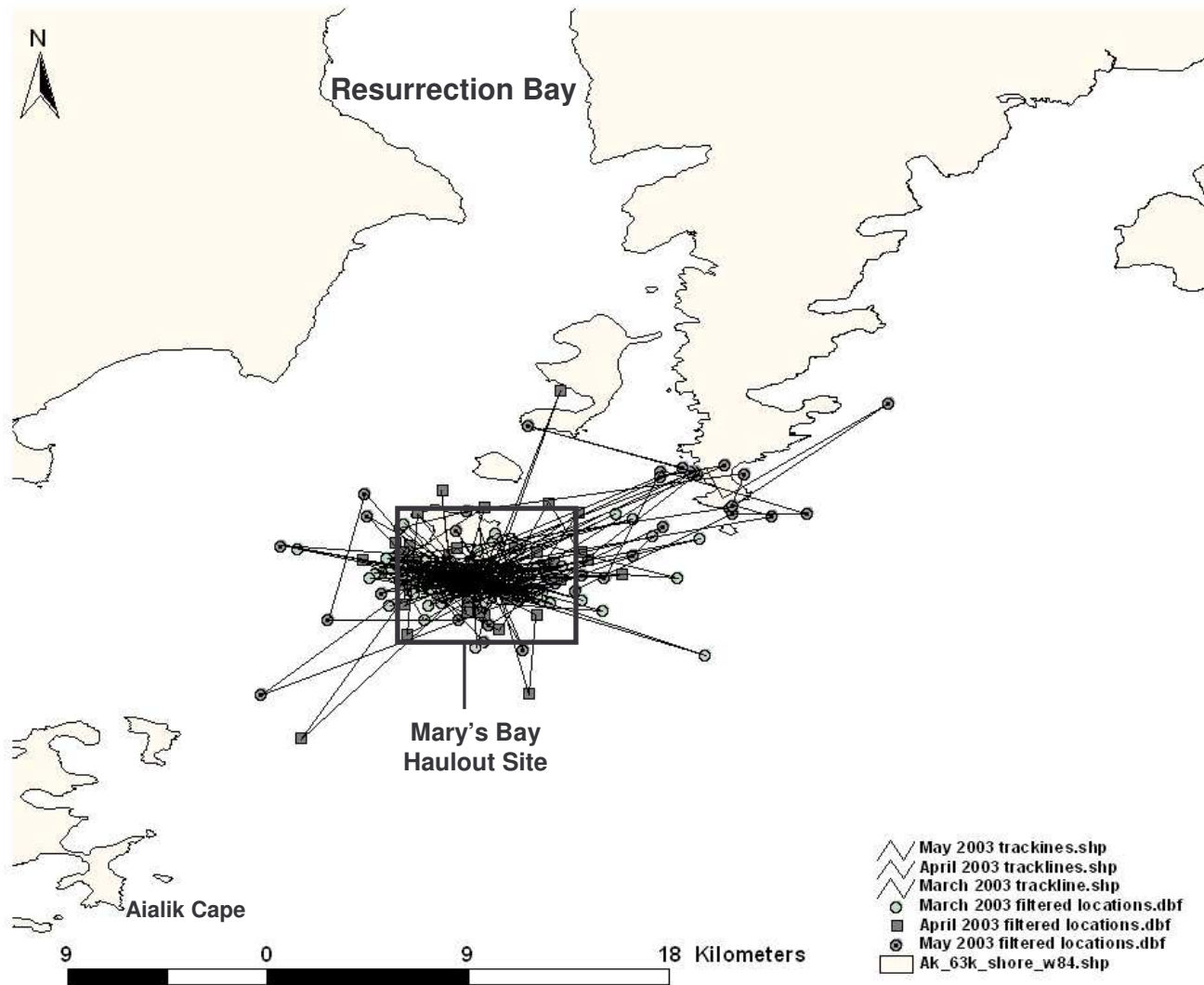
Map 06. Movements for Animal 06, estimated to be a 9-month-old YOY. The animal was tagged on March 4th, 2003 at the Cape Resurrection haulout, where it remained for most of the month. April movements included short trips ($\leq$ 20km) north into Resurrection Bay; the animal may have associated with buoys and channel markers in the bay. By April and May, the seal lion was making larger movements to the east, with stops in Day Harbor and Johnson Bay. The animal was associated with two haulout sites near Johnson Bay by May 31st, 2003: Cape Fairfield and Cape Johnson.
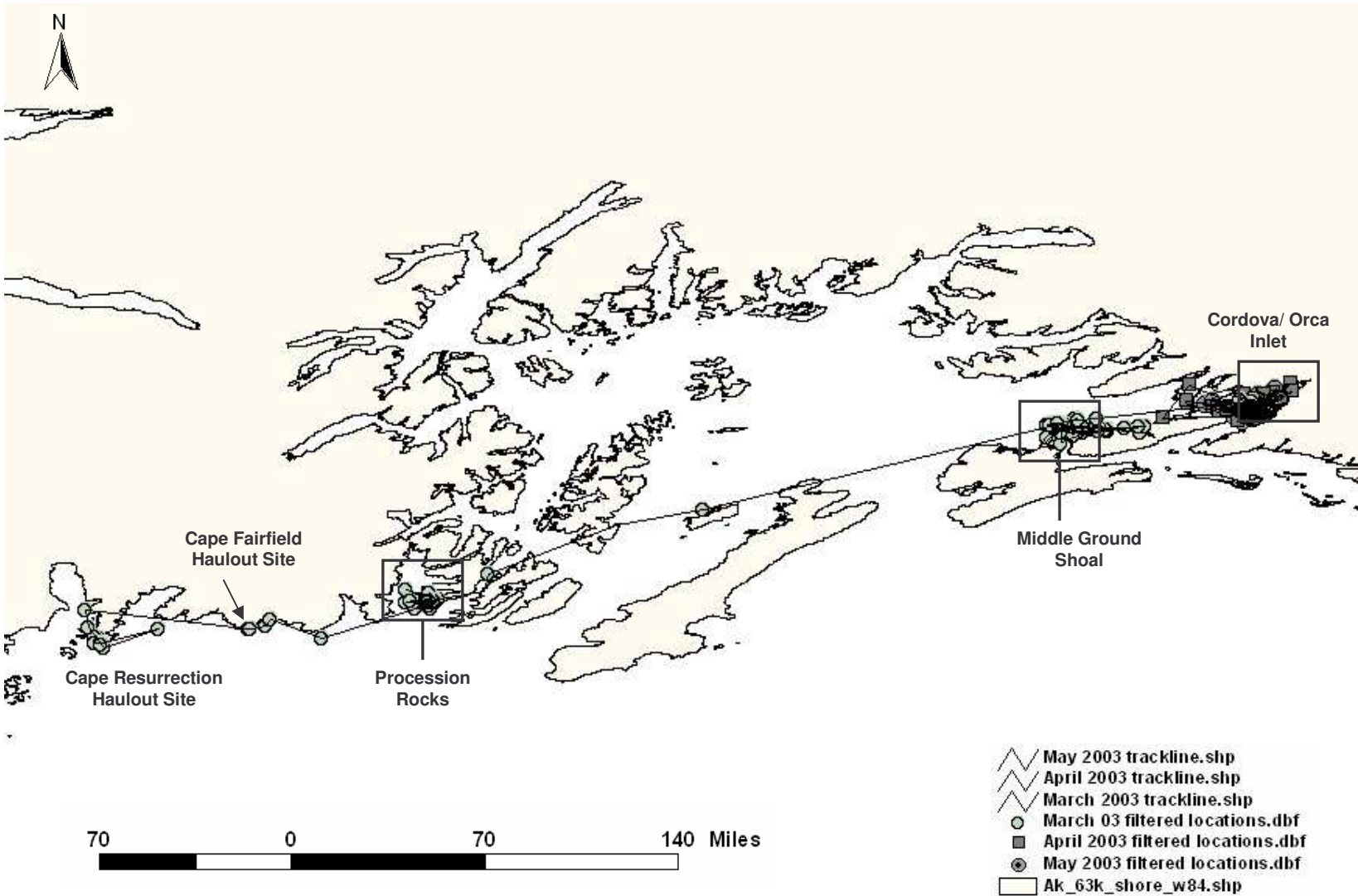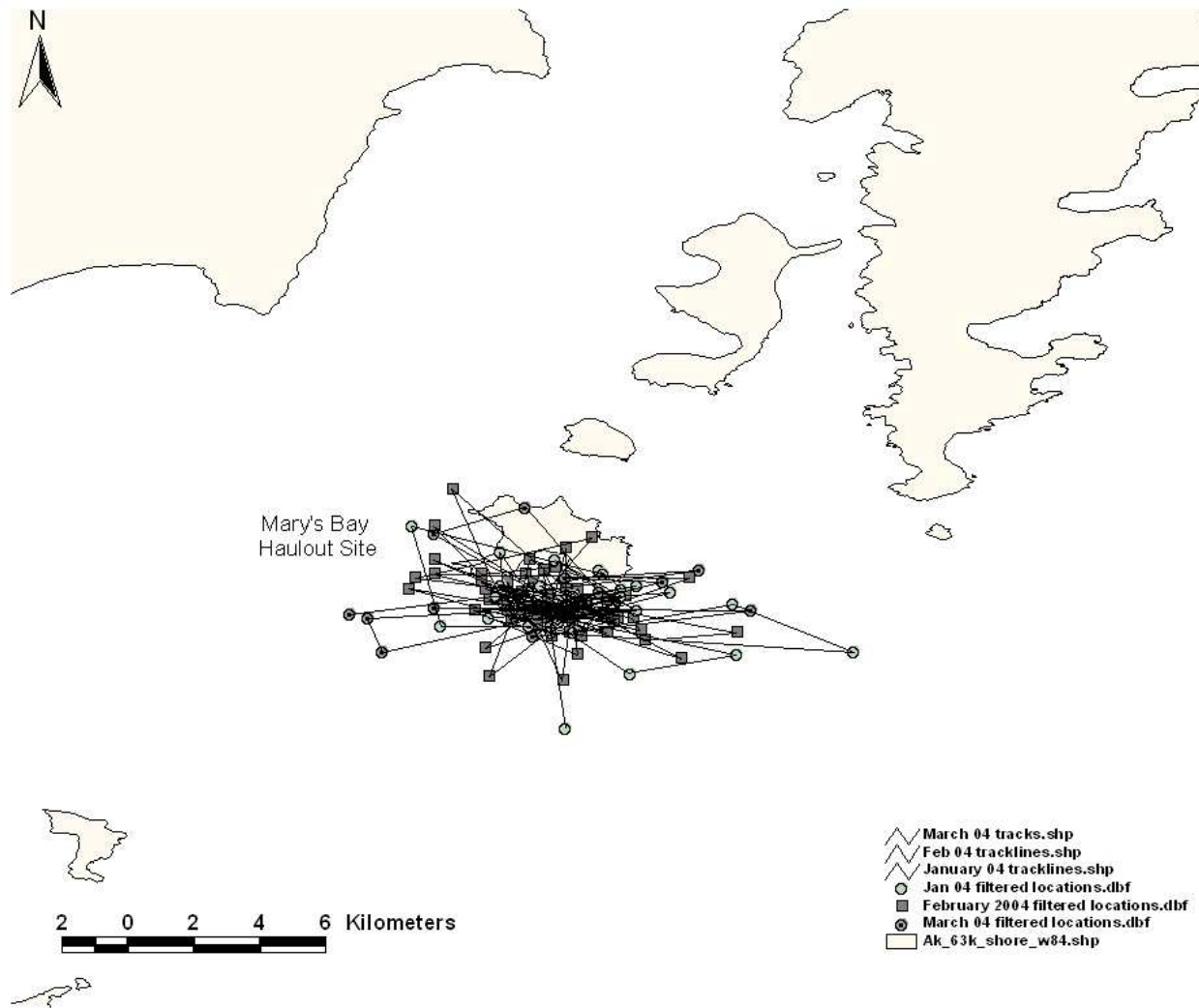
Map 7. Movements for juvenile SSL from March 4th-May 31st, 2003. The animal was tagged at Cape Resurrection, however it did not stay in this area for very long. Within a week of capture, the sea lion began to migrate towards the E/NE across PWS. From March 11th-18th, the animal hauled out at Procession Rocks. By March 24th, the sea lion was hauling out on a buoy at Middle Ground Shoal, a shallow outcropping between Hinchinbrook and Hawkins Islands. The sea lion then continued its travels to the northeast, occupying two buoys outside of Cordova for the remainder of the study period.
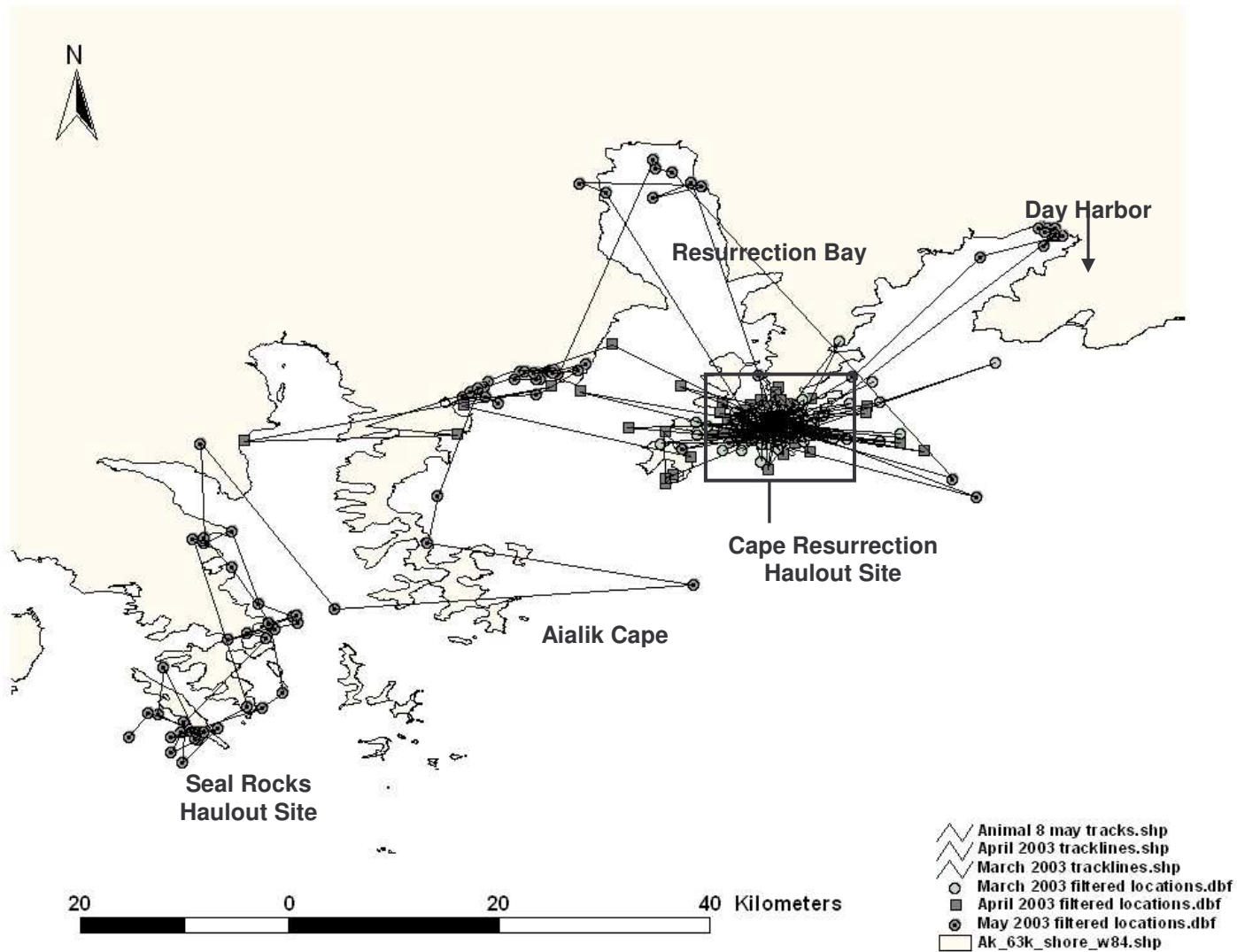
Map 8. Movements for YOY sea lion 08, captured at Cape Resurrection on March 4th, 2003. The sea lion remained in waters surrounding this haulout site for most of the study period, although movements did get wider in April. By May, the sea lion moved into Day Harbor and Resurrection Bay. By the end of the study period, May 31st, the sea lion was associated with haulout sites at Seal Rocks and Chiswell Island, approx. 40+ km from its capture site.
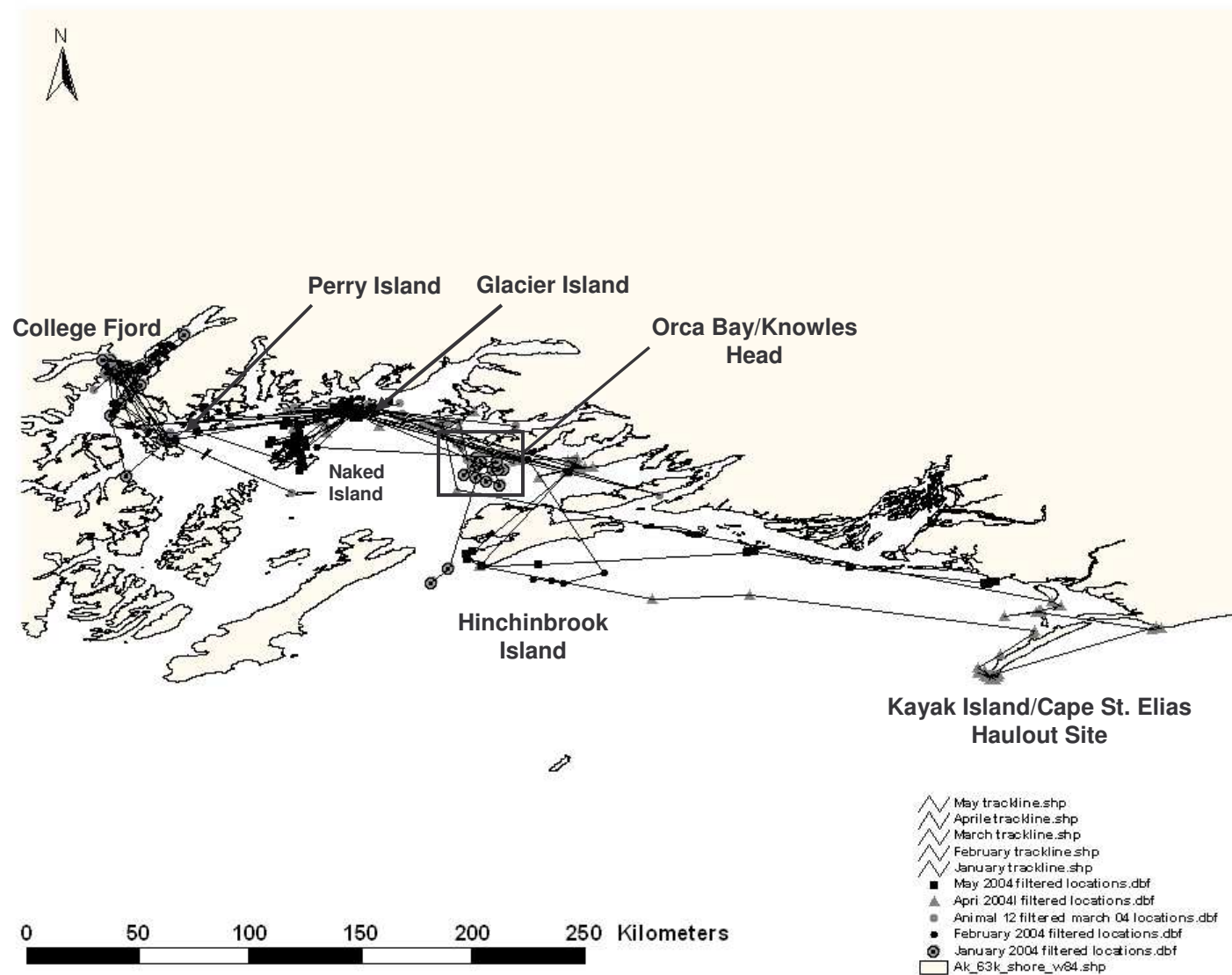
Map 9. Movements for Animal 09, estimated to be a 9-month-old YOY. The animal did not move from its capture site at Mary's Bay Haulout for the duration of the study period, March 5th-May 31st, 2003. However, the animal did increase the range of its movements over time, with trips ≥9 km by the end of May.

N

Mary's Bay
Haulout Site

2   0   2   4   6   Kilometers

March 04 tracks.shp
Feb 04 tracklines.shp
January 04 tracklines.shp
Jan 04 filtered locations.dbf
February 2004 filtered locations.dbf
March 04 filtered locations.dbf
Ak_63k_shore_w84.shp

Map 10. Movements for Animal 10, estimated to be a 7-month-old YOY. Like animal 09, animal 10 did not move from its capture site at Mary's Bay Haulout for the duration of the study period, January 10th-May 31st, 2004. It made very short trips around the site, gradually increasing in distance by February and March. However, all trips were ≤6 km.
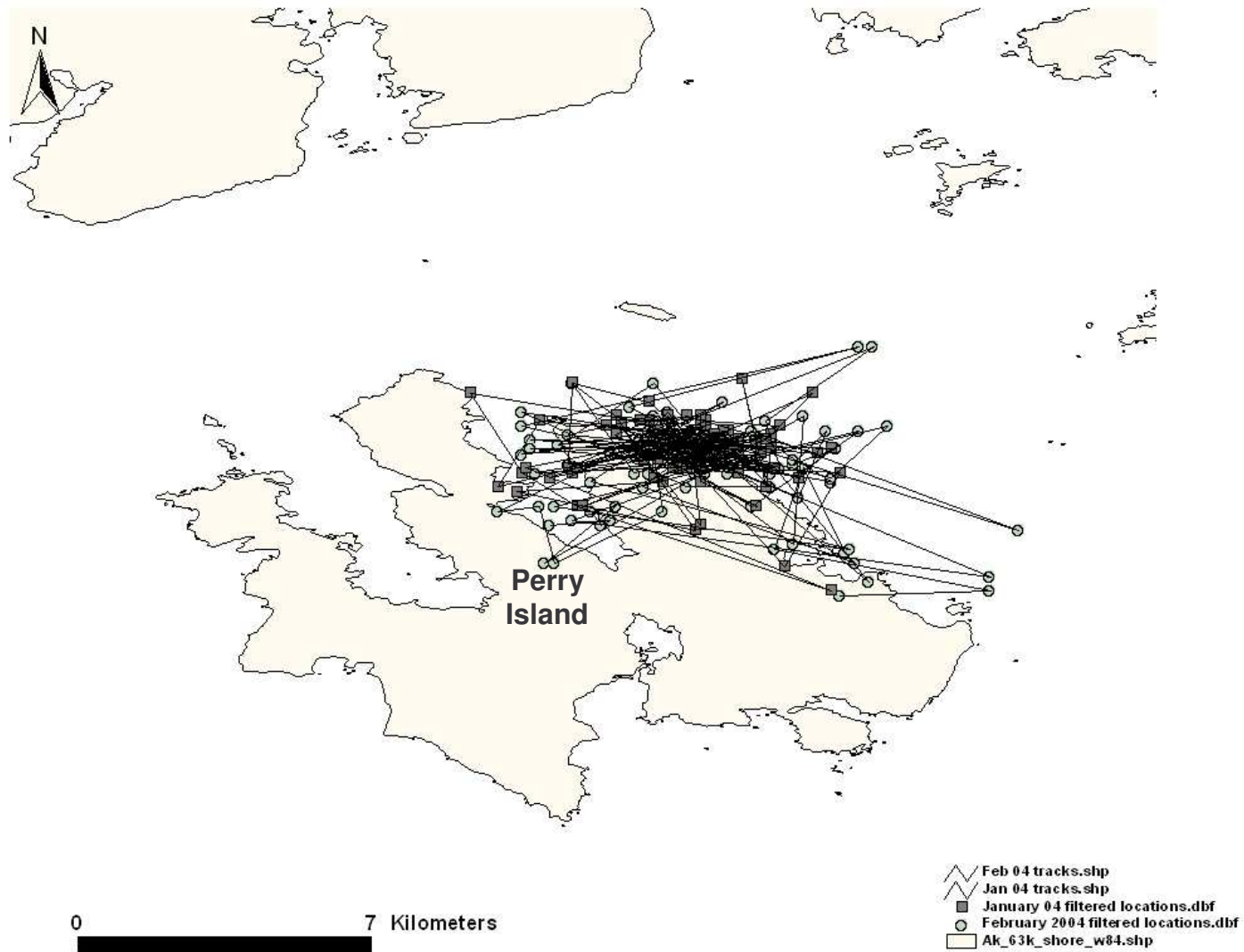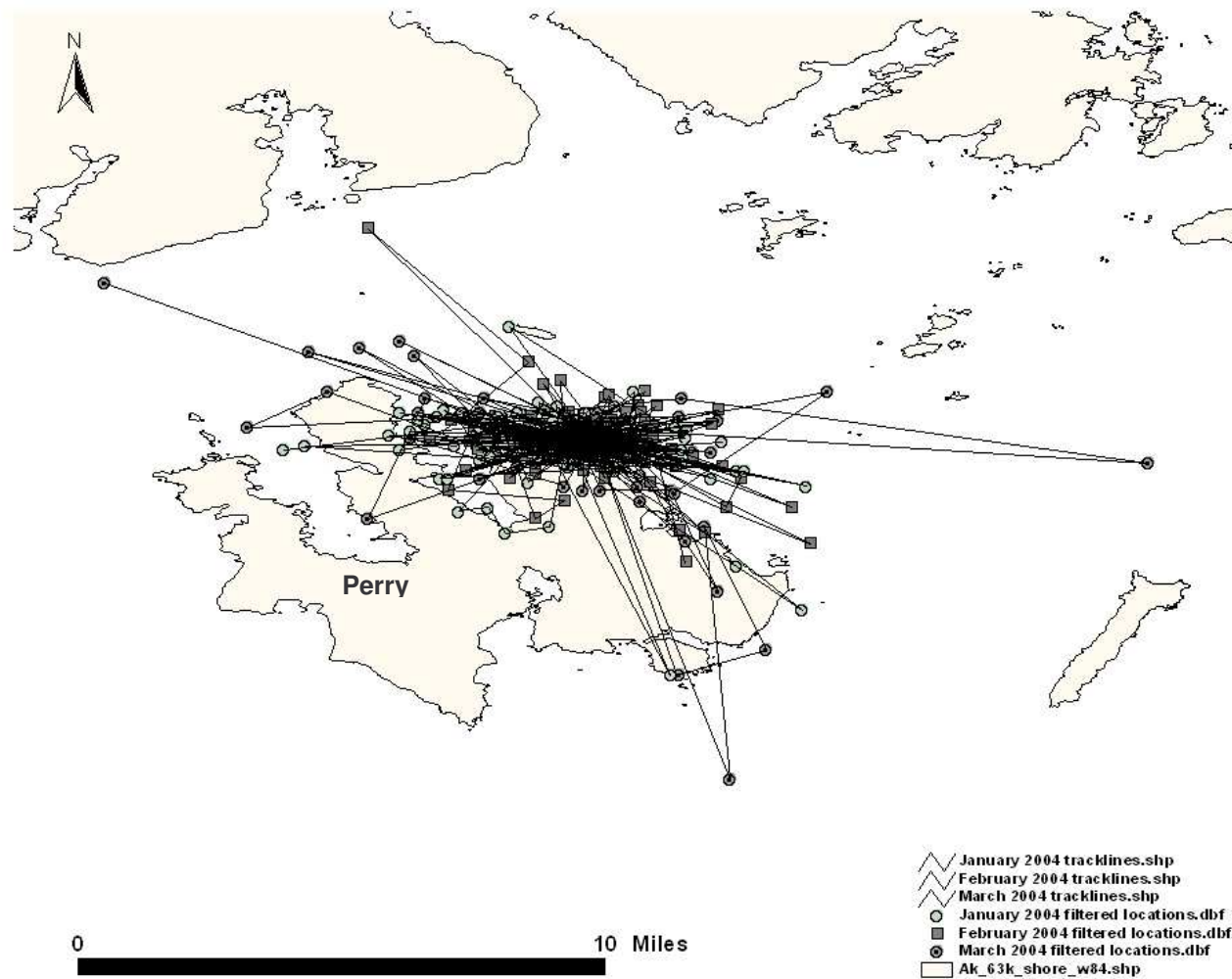
Map 11. Movements for Animal 11, a 7-month-old YOY tagged at Perry Island. The animal did not leave the area, but remained in waters around the haulout from January 11th- February 18th, 2004 (early tag failure).

N

College Fjord

Perry Island   Glacier Island

Orca Bay/Knowles
Head

Naked
Island

Hinchinbrook
Island

Kayak Island/Cape St. Elias
Haulout Site

0   50   100   150   200   250   Kilometers

Map 12. Movements for Animal 12, the oldest sea lion (almost 3 years in age) tagged during the study. This sea lion also made the most significant movements across PWS. The animal immediately left its capture site at Perry Island and based travels out of Pt. Pakenham and College Ford in NW PWS. From here, the sea lion made short transit trips, but also extensive trips to and from Knowles Head. In February, the animal made even longer trips ($\geq$150 km) outside the sound, remaining in waters on the SE coast of Hinchinbrook Island. By March, the animal was making similar trips, however the activity was based out of Glacier Island instead of College Fjord. In April, the sea lion moved to a haulout site outside of PWS, at Cape St. Elias, 300+ km from its original capture site. In May most activites were centered around Naked Island, in the north-central part of the sound.
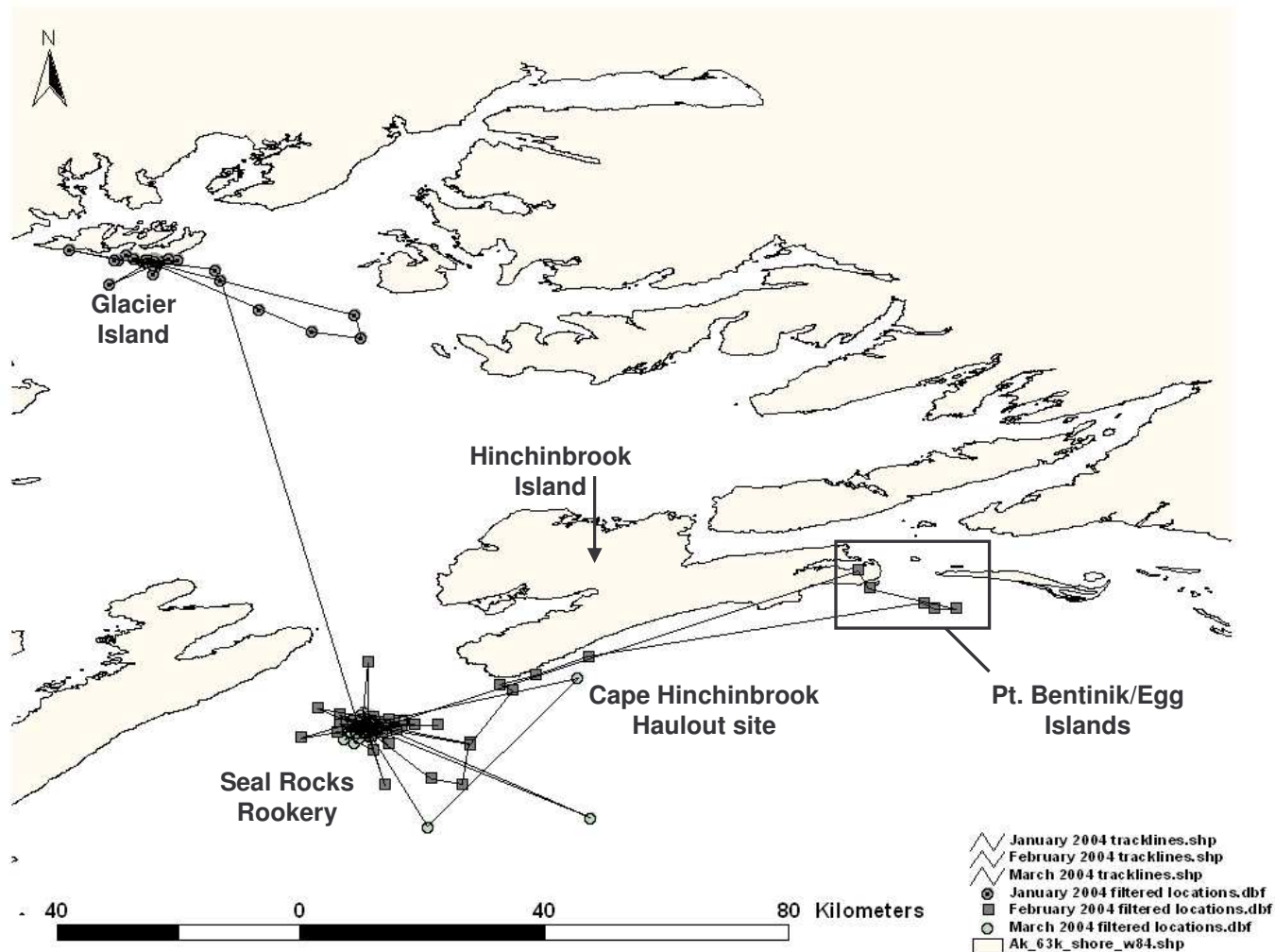
Map 13. Movements for Animal 13, a 7-month-old YOY. This sea lion was tagged at the Glacier Island haulout site on January 13th, 2004. It remained at this site and within coastal waters, until the end of the month, where it made a direct migration to the Seal Rocks Rookery located just outside of PWS to the south. The sea lion remained at this site for the duration of the of the study period, March 19th, 2004 (early tag failure). Like animal 03, this YOY may have also been traveling with its mother as she moved to a rookery with breeding season growing near. However, unlike animal 03, this sea lion made a fairly distant trip (≥50 km) from the site in Febraruy, traveling to the Cape Hinchinbrook haulout and along the southeast coast of Hinchinbrook Island, toward a sand flat area surrounding the Egg Islands.

Map 14. Movements for Animal 14, a 7-month-old YOY. Like Animal 11, this sea lion did not leave the Perry Island area for the duration of the study period, January 14th-March 19th, 2004 (early tag failure). However, movements did gradually increase in distance over time.
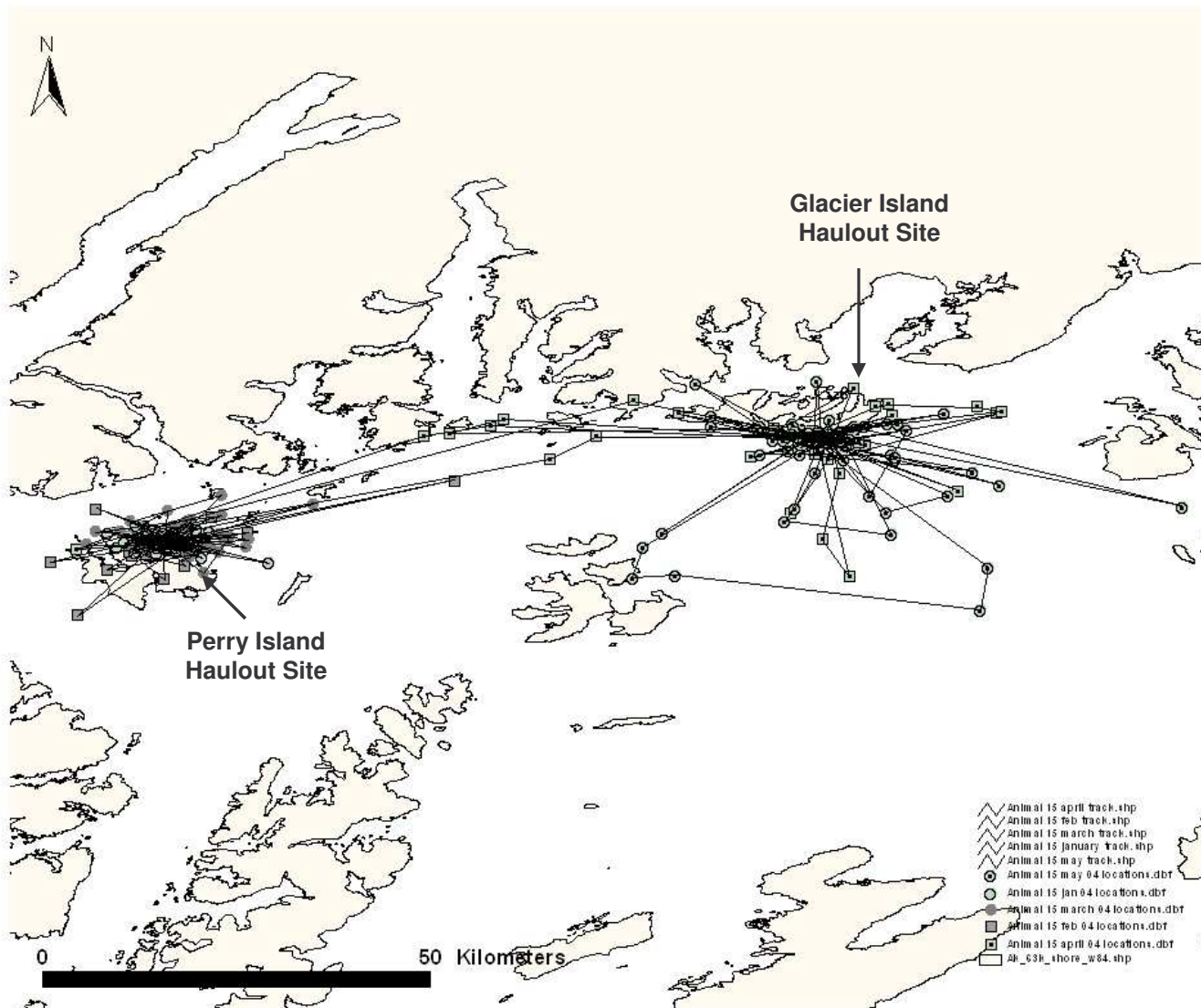
Map 15. Movements for Animal 15, estimated to be a 7-month-old YOY. This was the only YOY whose satellite tags did not prematurely fail. The animal was tagged at Perry Island, where it remained from January through February. Movements increased in distance over time, and by April, the sea lion was moving to the NE towards Glacier Island. It remained at this haulout site and its surrounding waters for the duration of the study period (till May 31st, 2004). Here, the sea lion moved further offshore, traveling in a much greater radius around the haulout (when compared to movements at Perry Island).

VITA

Holly Beth Briggs
366 East Street
Sharon, MA 02067
Cell phone: (409) 457-7811
Email: hb_briggs@hotmail.com

EDUCATION

M.S., Wildlife and Fisheries Sciences, Texas A&M University, December, 2005.

B.S., Marine and Freshwater Biology, University of New Hampshire, May, 2000.

HONORS AND AWARDS

Graduate Second Place: "Critical habitat assessment for juvenile Steller sea lions in the North Central Gulf of Alaska". First Annual Student Research Symposium, Texas A&M University, Galveston. April 2005.

Graduate First Place: "Winter habitat associations and diving patterns of Steller Sea Lions in Prince William Sound and Resurrection Bay, Alaska." Pathways of Research Symposia, Texas A&M University, Galveston. November 2003.

PRESENATIONS AND PUBLICATIONS

Briggs, H.B, Calkins, D. Davis R. (2005). Oral presentation: "Habitat associations and diving activity of subadult Steller sea lions (*Eumetopias jubatus*) during the winter and spring in the North-central Gulf of Alaska". Society for Mammalogy Biennial Conference, San Diego, CA.

Briggs, H.B, Calkins, D. Davis R. (2004). Poster presentation: "Critical habitat assessment for juvenile Steller sea lions in the North Central Gulf of Alaska". Sea Lions of the World Conference, Alaska SeaGrant Program. Anchorage, AK.

Briggs, H.B., Calkins, D, Davis R. (2003). Poster presentation: "Winter habitat associations and diving patterns of Steller Sea Lions in Prince William Sound and Resurrection Bay, Alaska." Society for Mammalogy Biennial Conference, Greensboro, N.C.

RELATED EXPERIENCE

Graduate Researcher: Texas A&M University, Department of Wildlife and Fisheries Science. 2001-2005.

Graduate Teaching Assistant: Texas A&M University, Department of Wildlife and Fisheries Science/Department of Marine Biology. 2001-2005.

Marine Mammal Camp Coordinator: Sea Camp, Texas A&M University, Galveston. Summer(s) 2003 and 2002.