SATELLITE TELEMETRY &
STELLER SEA LION RESEARCH

Prepared by ADF&G & NMFS Steller Sea Lion Research Programs

Introduction

This paper represents an overview of the use of satellite telemetry in research on the Steller sea lion (SSL) in Alaska by the Alaska Department of Fish and Game (ADF&G) and the National Marine Mammal Laboratory (NMML) of the National Marine Fisheries Service (NMFS). The primary intent of this paper is to provide information on the basic operation of satellite telemetry devices deployed on SSLs, the type of data obtained and how it is processed and analyzed, a brief summary of available results and current analyses, and how inferences from satellite telemetry data have been used in developing conservation and management strategies.

Satellite Telemetry Operational overview

Basically, a satellite-linked time-depth recorder (SDR) is composed of a battery pack, conductivity sensor, pressure transducer, miniature computer, and antenna. The conductivity sensor determines if the SDR is either wet (below the surface) or dry (on land or above the surface), whereas the pressure transducer estimates the SDR's depth. The SDR is 'asleep' the majority of the time, yet 'wakes up' every 10 seconds, for only about 25 milli-seconds, to determine it's depth and if it's wet or dry. These data, and other 'dive data', are stored until the SDR sends them through a transmission to the orbiting satellites of the Service-Argos system. The rate (or interval) at which the SDR sends transmissions is dependent on whether the sea lion is 'on land' or 'at sea'; transmission rates are established by Service-Argos. When a sea lion is at sea, the SDR transmission interval is every ~40 seconds, whereas when a sea lion is hauled out on land the transmission interval is every ~90 seconds. The SDR will only transmit when the conductivity switch reads 'dry', including when a sea lion is at sea. If the reading is 'wet' when a transmission is scheduled based on the transmission interval, the transmission is delayed and the SDR will transmit as soon as the sea lion surfaces and the conductivity switch reads dry. Thus, the number of transmissions (and thus messages) while at sea depends on the frequency of the SDR's exposure at the surface.

SDRs do not independently determine their location, and hence sea lion locations are not sent to the orbiting satellites; SDRs do not contain a GPS. Rather, sea lion locations are estimated by the Argos satellites, based on the SDR transmitted messages that contain the dive data. Messages transmitted by SDRs are encoded with a unique identifier on a single radio frequency to the 3-5 Argos polar-orbiting satellites. Each satellite can receive messages from SDRs during a ~10 minute period when they pass over the SDR. The geographic area satellites pass over changes each time they orbit the earth, and the probability that a message will be received is higher when a satellite is directly overhead as opposed to near the horizon. Thus the probability that messages transmitted by SDRs will be received by satellites will vary substantially; when none of the satellites are overhead, SDR messages will not be received. Researchers usually program SDRs to transmit only during the hours with the highest probability of satellite overpass, which is typically two separate 5-hour periods within 24 hours. When at least 2 messages are received during a single satellite overpass, the Argos system attempts to calculate the SDR location, and also assigns an accuracy estimate. SDR locations are calculated using a combination of the known satellite position, the known position of the Earth's surface, and the distance between the SDR and the satellite as computed from the Doppler-shift of the SDR radio signal. With each estimated location, a 'location class' is also reported that represents the estimated accuracy: class 3 is accurate to less than 150 meters, class 2 between 150-350 meters, class 1 between 350-1000 meters, class 0 greater than 1000 meters, class A and B have no accuracy estimates assigned, and class Z is an invalid location.

Although the Argos satellite system provides global and frequent coverage, it has several limitations. Transmissions are currently one-way only, such that SDRs are not able to confirm that their transmitted data are received, and the amount of information that can be sent during a transmission is quite restricted (i.e., 32 sensor data bytes). SDRs are designed to best accommodate these limitations by summarizing dive data before transmission, and transmitting each data unit redundantly. Data collected in this fashion are not guaranteed to be continuous and lack fine temporal resolution. Alternative devices, Time-Depth-Recorders (TDRs), record depth on a much finer temporal scale (e.g., every 10-seconds) thus providing the actual dive 'profile' for each individual dive an animal makes while at-sea. The amount of data recorded by TDRs is too large to be transmitted to an ARGOS satellite, requiring that TDRs must be retrieved in the field such that the data stored within them can be downloaded into a computer. Due to the great difficulty involved in capturing sea lions, the feasibility of using TDRs has been limited because of the low probability that animals could be recaptured. TDRs could be deployed with an attached VHF transmitter, such that when the device fell off a sea lion during the molt it could potentially be located by the VHF signal. Because sea lions make substantial movements at-sea and among haulouts, the device could fall off anywhere within a large geographic range resulting in a low probability of locating the VHF signal.

SDRs used in sea lion research have changed over the last ten years. Initially, some units recorded dive behavior on a fine temporal scale similar to a TDR, but they deployments stopped after several problems could not be solved. Overtime, advances in SDR technology have allowed the units to become smaller and yet have a larger number of transmissions during which dive data can be sent to orbiting satellites. Additional information on SDRs and their capabilities has been reported in Merrick *et al*. (1994) and Merrick and Loughlin (1997). The Agros satellite tracking system is described in detail in Fancy *et al*. (1988), Stewart *et al*. (1989), and Harris *et al*. (1990).

Dive Data

Due to the limited amount of data that can be transmitted in each message to the satellites, detailed information on each individual dive made by sea lions is not obtained by SDRs. Rather, four 6-hour histograms (sampling units) of summarized dive data are collected per day: "dawn" 03:00–09:00, "day" 09:00-15:00, "dusk" 15:00–21:00, and “night” 21:00–03:00 (the following day). These 6-hour periods are based on local longitudinal time, which more closely resembles the actual solar cycle than Alaska Standard Time. Three types of summarized dive behavior data are collected: (1) maximum depth, (2) duration, and (3) time-at-depth; SDRs deployed in the first few years did not record time-at-depth. Researchers program the SDRs to record dive data into separate bins. For example, recent deployments have used the following maximum depth bins: 4-6 m; 6-10 m; 10-20 m; 20-34 m; 34-50 m; 50-74 m; 74-100 m; 100-124 m; 124-150 m; 150-174 m; 174-200 m; 200-250 m; and >250 m. Dive duration bins are usually programmed at one minute intervals; e.g., 0-1 min, 1-2 min, 2-3 min, 3-4 min, etc. Time-at-depth bins typically coincide with maximum depth bins, except the first bin is set to zero in order to record when sea lions are hauled out on land. Time-at-depth is the proportion of time that dives occurred within a particular depth bin of a 6-hour period while at sea. For example, if a sea lion was at sea for 3 hr during a 6 hr period and spent half its dive time in bin 50-74, the value in bin 50-74 would be 25%. The number of bins available for programming has increased in more recently deployed SDRs.

The most reliable information to determine when haulout bouts and at-sea periods begin and end is from the “At-Surface Timeline” data. The conductivity sensor status (“wet” or “dry”) is sampled every 10 seconds, and each 20-minute interval (72 intervals for each 24-hour period) is assigned the majority value of its sensor readings; i.e., wet or dry. The major advantage of these data is that ‘timelines’ are transmitted in a highly redundant fashion, with each timeline transmitted for 2 full transmit-days. Timeline data has been available from SDRs deployed since 1996.

SDRs have a finite number of transmissions, and researchers have several programming options to maximize the type of data they wish to receive. For example, a maximum number of transmissions can be established; e.g., 400/day. Transmissions can be suspended after a sea lion has been hauled out for a specific period of time (e.g., 2 hours), to save transmissions for at-sea periods. Additionally, transmission can be suspended when satellite coverage results in low probability for reception. Finally, SDRs can be ‘duty cycled’ with specific on-off periods (e.g., 4 hr on and 2 hr off, 1 day on and 1 day off) to extend the duration for which data will be obtained.

Data Extraction and Summary

Data relayed from SDRs are received from Argos on a monthly basis. The Argos "Location Service Plus" is available, which provides a primary and alternate solution for each location, numerous diagnostic indicators of signal quality, and locations that fail the standard Argos quality tests (Argos/CLS 1996). This service allows the selection of the correct location solution (primary or alternate) for each location fix, and avoids the 6% error caused when this selection is performed automatically by Argos/CLS. Because SDRs are of relatively low power compared to most Argos transmitters, many locations fail standard Argos quality checks. However, through the editing process described below, many of these locations that would otherwise be discarded by the Argos system can be obtained and included in location databases.

The SATPAK software package (Wildlife Computers, Inc. 2000) is used to process raw Argos data files and extract locations, including the identification of the correct primary/alternate solution for each location fix. SATPAK is also used to extract haulout timelines, land/sea data, daily maximum depth readings, maximum dive depth histograms, duration histograms, time-at-depth histograms, and SDR status diagnostic reports. SATPAK also returns a set of unreadable, corrupted data messages for possible repair.

Once the raw location files have been obtained through SATPAK, location data must be edited or 'filtered' to ensure that reliable locations are used in subsequent analyses. Both NMML and ADF&G have developed software programs to edit location data, based primarily on error indices associated with each location and checking estimated swim speed between successive locations. In general, locations classified invalid by Argos (Location Class "Z") are deleted first. Next, the Keating error index (Keating 1994) is computed for all locations, and locations with an index value > 25 are deleted. Next, locations which exceeded the reasonable movement capabilities of sea lions are deleted, in sequence; e.g., movements of > 10 km/h for > 5 minutes; movements of > 100 km/h for >1 minute; and any movement of > 500 km/h. Finally, the Keating error index is re-computed for the remaining locations, and those locations with index value > 25 are deleted. Valid locations from the data set are not arbitrarily removed based on Argos Location Class alone. Edited locations are then merged with the "Land/Sea" sensor data to classify each location as on-land, at-sea, or unknown.

Available Results and Current Analyses

Summary of Deployments

Through March 2001, 98 and 84 SDRs have been deployed on Steller sea lions in the western and eastern stocks, respectively (Table 1, Figs. 1 & 2). Early deployments were focused on adult females with pups during the breeding season, whereas since 1994 the large majority of deployments in both stocks have been on animals < 2 years of age during both the breeding and non-breeding periods. Nearly equal numbers of male and female pups and juveniles have been tagged, but of the 70 adults tagged only 4 have been males. Mean deployment duration is ~60 days, and a substantial number of units provided data sets too small for analysis; recent deployments have lasted substantially longer (Table 1, Appendix 1). The geographic distribution of tags extends from Russia through Washington State. In Alaska, SDRs have been deployed in all subregions of both stocks: Gulf of Alaska, Aleutian Islands (except western Aleutians), and Southeast Alaska (Figs. 1 & 2). Although sea lions tagged in the western GOA and Aleutian Islands range into the Bering Sea, SDRs have not yet been deployed on sea lions from sites on the Pribilof Islands or further north.

Results

Previously, section 4.8.6.2 of the 30 November 2000 BIOP (page 86) presented an overview of information available on the foraging distribution of sea lions, including that derived from satellite telemetry; the primary publication discussed in the BIOP was Merrick and Loughlin (1997), additional publications include Merrick et al. (1994) and Loughlin et al. (1998). A telemetry workshop convened by the Steller sea lion Recovery Team was held on 8-10 December 1997, in which summaries of recent and current research results were presented, and then discussed by a panel of scientists who made recommendations for future telemetry research (SSL Recovery Team 1997). The primary results from these studies that were used in the designation of no-trawl zones and critical habitat are presented and discussed in a later section.

The NMML and ADF&G continue to coordinate SSL satellite telemetry research in Alaska. The current focus is to analyze the data obtained since that published in Merrick and Loughlin (1997), and preparing manuscripts that will present the results. Following is an overview of the research being conducted by each agency, and status reports of the analyses underway:

NMML

<u>Research Overview</u>

The NMML has been conducting both VHF and satellite telemetry research on Steller sea lions since the mid 1980s. The satellite studies were originally designed to determine locations where sea lion died at sea and included substantial time and effort into the development of the SDRs currently in use. The objective of locating where sea lions died at sea was not achieved, but significant breakthroughs in instrument design facilitated the NMML's efforts to describe sea lion foraging behavior. The first effort focused on adult females at rookeries during the breeding season, which also included a substantial effort to determine appropriate chemicals and dosages for chemical restraint, and attachment of the instruments to the sea lions. The efforts were focused in the Gulf of Alaska and eastern Aleutian Islands, at sites where logistical support was available and where sea lions occurred in high abundance. There were many failures due to instrument malfunction, attachment problems, and animal mortality. But as techniques improved, the NMML was able to access an adequate sample size to describe in sufficient detail Steller sea lion foraging behavior and trip distances for adult female sea lions, and some young-of-the year, to provide a biological basis for designing protective measures used by fisheries managers. The results of these studies have been reported previously (e.g., Merrick et al. 1994; Merrick and Loughlin 1997; Merrick 1995; Loughlin et al. 1998).

The NMML's overall research objectives since the early 1990s follow recommendations by the Steller Sea Lion Recovery Team and the Plan they developed, and by the needs of managers at the NMFS Alaska Region. The Recovery Team also hosted a workshop to review past and present telemetry research (SSL Recovery Team 1997). The workshop report contained recommendations for future work by both NMML and ADFG that provides guidance for the present efforts.

NMML and ADFG presently are addressing issues pertaining to immature Steller sea lions. The NMML continues with their efforts to describe foraging behavior, foraging locations, and the potential conflict between these animals and commercial fisheries. Specific studies include comparison of foraging behavior between the western and eastern stock, amount of foraging effort inside and outside critical habitat or other management areas, and sea lion home range at sea.

<u>Current Analyses - Juvenile movements and dive behavior</u>

Preliminary results of a recent analysis by the NMML of telemetry data obtained from juvenile sea lions revealed three types of movements at-sea: (1) long-range trips

>15 km offshore and lasting >20 hours, (2) short-range trips <15 km offshore and <20 hours duration, and (3) nearshore transits among land sites (i.e., haulouts and rookeries). A preliminary screening of the dive behavior data associated with the at-sea locations suggests relatively more foraging may occur during the long- and short-range trips in contrast to the nearshore transits. For long-range trips, the mean distance from the haulout site at which a sea lion began a trip to the location furthest from that haulout site was 48.7 km (SD=55.7 km; max=240.8 km). Long-range trips represented 6% of all trips to sea, and began when sea lions reached about 9 months of age in March, possibly when the animals were weaned and began foraging independently from their mother. The most numerous trips (87%) were short-range foraging trips that occurred almost daily (0.9 trips/day, n=328 trips) with a mean distance of 3.6 km (SD=0.4 km; max=21.0 km). Transit trips were characterized as the straight line distance from one haulout site to another and began as early as 7 months of age, but occurred more often after 9 months of age when animals were likely weaned. Transit trips represented 6 % of all trips to sea and had a mean distance of 66.6 km (SD=83.7 km; range 6.5-341.9 km).

ADF&G

Research overview

The hypothesis that reduced juvenile survival has been integral to the decline of Steller sea lions in the western stock (York 1994) prompted ADF&G to concentrate satellite telemetry research on juveniles since 1998. Prior to this time, little was known about the life history of juveniles due to the difficulty of capture and studies were limited by small sample sizes and short deployment period (Merrick and Loughlin 1997). Although low juvenile survivorship can partially explain the population decline, it has not been documented and no large mortality events have been observed. Unlike the declining western stock, the Steller sea lion population in Southeast Alaska has been increasing or stable, yet little information is available on juvenile life history traits in either population. Therefore, intensive research on juveniles in Southeast Alaska offered the opportunity to develop methods and collect data useful in understanding the biology of Steller sea lions without requiring the handling of animals in the areas of greatest decline and potentially more sensitive to disturbance. This work has focused on using satellite telemetry, combined with health and condition measurements, in order to describe some of the life history of juveniles. The first step was the design of a safe and efficient method of capturing juveniles. Using SCUBA to capture pups and juveniles in the water has proven to be an effective method that avoids disturbing an entire colony, as with previous beach captures.

Refinement of the capture method during 1999-2000 has allowed ADF&G to concentrate on improving the sample size of juveniles. The overall research objective has been to document the development of diving and movement patterns throughout the first year of life, with the intent of distinguishing differences in the biology and habits of juveniles between the western and eastern stock. Because of transmitter failure and instrument loss due to molting, multiple deployments have been required throughout the calendar year to obtain coverage in all seasons. To date 57 juveniles in the eastern stock (Southeast Alaska) and 14 in the western stock (Prince William Sound) have been instrumented. Two manuscripts summarizing this work are being prepared and are outlined below. Additionally, Dr. Russ Andrews from the University of British Columbia is collaborating with ADF&G to compile a manuscript describing the movement patterns of adult females with dependent pups from a rookery in Southeast Alaska; manuscript publication is anticipated in 2002.

Current Analyses - Movements and Habitat Selection by juveniles

The Alaska Department of Fish and Game began deploying SDRs in Southeast Alaska during March 1998. Additionally, 13 SDRs were deployed in the western stock (PWS) in April and September 2000. Although the primary objective was to investigate the ontogeny of dive behavior in juvenile Steller sea lions, a secondary goal, as outlined here, was to examine juvenile dispersal, movement patterns, and resource selection in relation to age, sex, and season. SDRs were programmed to maximize battery life by duty-cycling (transmitting one day on and one day off). This method provided maximum dive information in relation to age development. However, some location and movement information was sacrificed to meet this objective.

The results of this work will provide the first detailed synthesis of the movement habits of juvenile Steller sea lions in Southeast Alaska. Our purpose is to provide a broad description of spatial and temporal habits of juvenile sea lions in the eastern stock, and where possible to describe the areas of concentrated use within the available habitat. These measures will be constructive in comparing and contrasting juvenile Steller sea lion habitat use in the eastern stock with that in the endangered western stock.

Primary Objectives

- Determine if mean at-sea bout distance and duration change significantly with age, sex, or season. At-sea bout distance will be calculated as the straight-line distance from the departure haulout to the location furthest offshore, whereas duration will be calculated as the interval of time between departure and return to a haulout site.
- Characterize the spatial extent or animal use area for male and female SSLs using methods such as home range analysis, with age and season as covariates.
- Determine if juvenile SSLs select certain habitats based on bathymetric features (e.g., water depth, slope of the seafloor) or if they use a circular area around their haulout site as predicted by a central-place model.
- Determine if the proportion of time spent on land versus at-sea changes with age, season or diel period.

Results as of July 2001

From March 1998 to September 2000, we deployed SDRs on 57 animals in the eastern stock (Southeast Alaska) and 14 animals in the western stock (Prince William Sound). Ages ranged from 1.6 to 22.4 months, with a mean of 8.2 months (SD=5.5). The weaning status of tagged juvenile SSLs is currently uncertain. Animal locations were computed using the Argos system and edited using methods developed by ADF&G and NMML. A total of 11,853 locations were collected including 46% in location classes 1, 2, and 3. Deployment duration averaged 57 days (range = 3-181 days) in the eastern stock and 53 days (range = 10-103 days) in the western stock. Maximum straight-line travel distance from capture haulout to final haulout used prior to transmitter termination was > 1000 km.

Tentative Timeline:

Date	Objectives
July-October 2001	Continue data analyses and interpret results.
November 2001	Manuscript preparation and presentation at the Marine Mammal Conference. Tentative title: "Juvenile Steller sea lions in Alaska: development of dispersal, movements, and resource selection. Authors: K. Raum-Suryan, M. Rehberg, K. Pitcher, T. Gelatt
December 2001	Continue manuscript preparation.
January 2001	Complete draft manuscript for publication, initiate internal review.
March 2001	Revise reviewed manuscript and submit for publication.

<u>Current Analyses – Dive Behavior of juveniles</u>

ADF&G is using data generated from the instrumented animals summarized above to examine the development of dive behavior in juvenile Steller sea lions. Merrick and Loughlin (1997) reported a maximum depth of 72 meters for 5 winter young-of-year Western Stock SSLs. Furthermore, they hypothesized that young animals are more vulnerable than adults to changes in prey availability due to behavioral and/or physiological limitations in diving ability. These results reflect the need for additional research examining the characteristics of juvenile dive behavior as well as the development of indices for recognizing juvenile independence.

Given these constraints in the existing knowledge of juvenile dive development, the ADF&G commenced research into the development of diving behavior by SSL juveniles during the first 2 years of life. Most of this effort was focused within Southeast Alaska on the stable/increasing Eastern Stock. The SDRs used in this work measured dive depth, duration, and time-at-depth, grouped into 10-14 depth or time bins and summarized into 6-hour periods; maximum actual depth reached per day to the 240-250 meter depth resolution of the SDR; and the timing and duration of at-sea activity bouts. SDR deployments were scheduled to provide as complete coverage of the first year-of-life as possible, and no single animal had its dive behavior recorded for the entire year. The continued development and analysis of these data are concurrent with the movement data outlined above (Raum-Suryan et al. in prep) and will provide important context to this analysis.

Primary Objectives

- Determine if dive depth, duration, frequency, and time-at-depth change with age or other covariates.
- Determine if diurnal pattern of diving and at-sea activity changes with age or other covariates.
- Examine variability of diving behavior among individual animals with respect to age.

Results as of July 2001

Between March 1998 and January 2001, SDRs deployed on 71 juvenile sea lions (31 males, 40 females) in Southeast Alaska (n = 57) and Prince William Sound (n = 14) remained operational for 3-181 days (average deployment length 55.9 days). Ages ranged from 1.6 to 22.4 months, with a mean of 8.2 months (SD=5.5). The weaning status of tagged juvenile SSLs is currently uncertain. Dive data histograms were reported for at least 1 6-hour histogram period during 3335 animal-days, and maximum actual dive depth reached per day was reported for 1680 animal-days. Within the Eastern Stock, mean daily dive depth reported for early winter young-of-year SSLs age 5.3-6.3 months was 70 meters (S.D.=21.4, max=94 m, n=7 SSLs); for late Winter young-of-year SSLs age 9.5-10.5 months mean daily dive depth was 139 meters (S.D.=34.1, max=222 m, n=12 SSLs).

Tentative Timeline

Date	Objectives
July – October 2001	Conduct analysis, review analysis, and interpret results.
November 2001	Begin manuscript preparation; Prepare poster/presentation. Tentative title: "Diving behavior of juvenile Steller sea lions in Alaska". Authors: M. Rehberg, K. Raum-Suryan, K. Pitcher, T. Gelatt.
December - January 2001	Complete manuscript for publication and begin internal review of draft.
March 2001	Submit revised manuscript for publication.

The habits of nutritionally dependent and independent young sea lions are closely linked to their food source, and many species typically show an increase in juvenile mortality rate post-weaning. If the decline in the Steller sea lion population hinges on juvenile survival it follows that the period of greatest vulnerability to juveniles may occur at the transition to nutritional independence. Thus, a critical component for describing juvenile life history is the ability to distinguish between weaned juveniles and nursing pup/juveniles still dependent on their mothers for nourishment. ADF&G health and condition experiments have focused on this aspect by collecting a suite of measurements for incorporation in the development of physiological indices of weaning.

Use of satellite telemetry data in designation of no-trawl zones and critical habitat

The satellite telemetry data considered when the spatial extent of no-trawl zones and critical habitat was determined was a result of studies conducted during 1990-1993 on adult females in the Gulf of Alaska and eastern Aleutian Islands during the breeding season (Loughlin and Spraker 1989; Merrick et al. 1994; Merrick and Loughlin 1997). Results from these studies were summarized, in part, by the distance from the rookery from which a female departed to the subsequent location furthest offshore from that site during an at-sea trip. Due to the limited number of transmissions sent to the satellites while animals are at sea, sea lions likely traveled further offshore than indicated by the calculated distance. During the breeding season, adult female Steller sea lions traveled a mean distance of 17 km (~9.2 nm) from the rookeries with a range of 3-49 km (~1.6-26.5

nm); this mean distance remained similar across separate studies. The maximum distance recorded during an individual at-sea trip was 32 km (~17.3 nm) during the earliest studies, yet as more females were studied, the maximum distance increased to 49 km (~26.5 nm). Similar distances were observed in the Kuril Islands, Russia, during June 1991 (Loughlin et al. 1998) and in Southeast Alaska in the early and mid 1990s (Calkins 1997; Swain and Calkins 1997).

These distances were the only data of this type available when the spatial extent of no-trawl zones and critical habitat was being determined. The size of the no-trawl zones was based on the mean distance traveled by adult females with pups during the breeding season; i.e., approximately 17 km (~9.2 nm). In June 1991, NMFS issued an emergency interim rule prohibiting fishing with trawl gear in the EEZ within 10 nm of all 14 sea lion rookeries in the GOA. Subsequently in January 1992, a final rule was implemented that prohibited trawling year-round within 10 nm of 37 rookeries in the GOA and BSAI, and expanded the no-trawl zone to 20 nm for 5 of those rookeries (Sea lion Rocks, and Akun, Akutan, Seguam, and Agligadak Islands) from January 1 through April 15 annually. The extension from 10 to 20 nm was based on the concern that sea lions from the 5 rookeries foraged on the large assemblage of spawning pollock on the continental shelf north of Unimak Island, an area where trawling could increase after statistical area 518 was closed due to concerns about the decline in the size of the Aleutian Basin pollock stock. The distance of 20 nm was based on maximum distances traveled (17 nm and 26 nm recorded during early and later deployments, respectively) offshore from a rookery by a parturient adult female during the breeding season on a feeding bout during the summer months. This same maximum distance of 20 nm was used in the 1993 critical habitat designation. Specifically, an aquatic zone extending seaward 20 nm from each major rookery and haulout west of 144 degrees W longitude in State and Federally managed waters was established.

Studies conducted after critical habitat designation suggest that juveniles and adult females in winter travel much greater distances (i.e. > 60 nm) during feeding bouts and during their movements within their home range (Merrick and Loughlin 1997; Swain and Calkins 1997). In general, the distance traveled away from the rookery during the breeding season appears to reflect the width of the continental shelf near the rookery. In those areas where the shelf is near the rookery females tend to travel shorter distances, and where it is farther offshore, they travel further; variation among individual animals was large. As the female's pup grows and becomes less dependent on frequent nursing bouts, the distance traveled by the female tends to increase, as does the duration of time at sea. After the breeding season, females tend to travel greater distances away from the rookery or haulout site because they are not obligated to return to the rookery frequently to suckle their pup. The maximum distance traveled offshore for adult females in winter was >500 km for adult females in winter, whereas the distance travel among haulouts for young of the year in winter was >320 km.

In 1991, the SSL Recovery Team recommended three large areas/features that may require special management protection. These areas were noted as needing special protection because they provide space, nutrition, shelter, reproductive sites, and habitats free of disturbance. The Team noted the need to protect or manage these habitats in such a way as to minimize impacts of human activities on sea lion distribution, behavior, and productivity. They noted that human activities might affect the suitability of habitats for

Steller sea lion in several ways, including disturbance, pollution, entanglement in fishing nets, and alteration of food availability. The Team went on to recommend three specific areas based on possible affects of fishing. They stated that data on the sea lion diet clearly indicate that from the mid-1970s through the mid-1980s, pollock had been a major food (Lowry et al. 1989). This is true through the 1990s as well (e.g., Merrick and Calkins 1996, Sinclair and Zeppelin, submitted). The Team went on to say that large concentrations of pollock occur in the Shelikof Strait, Bogoslof, and Seguam areas, especially during the spawning season. Large catches of pollock from these areas are near declining Steller sea lion rookeries. The Team recognized that similar relationships occur in other parts of the sea lion's range, but these three sites seem particularly important considering the precipitous decline of sea lions in adjoining areas. The Team recommended these three sites be designated as critical habitat. NMFS reviewed the recommendation by the Team and concurred. Additional information on historical incidental catch and Platform-of-Opportunity sightings data was sufficient to convince the NMFS that these areas need special designation as critical habitat. The satellite telemetry data used in establishing the spatial extent of no-trawl zones and the critical habitat 20 nm aquatic zones around major rookeries and haulouts was not a major consideration in the Teams recommendation of the three special aquatic foraging areas as critical habitat.

Satellite telemetry data request by the RPA Committee

In early 2001, the RPA committee requested a summary of at-sea locations, which was presented in March 2001 as (1) the distance to the nearest landmass and (2) the distance to the capture site. The request provided committee members with an overview of the distribution of SSL at-sea locations to evaluate the spatial overlap with fisheries. All locations within the filtered database were sorted into two groups of bins, representing the distance (nm) to the nearest landmass and the distance to the capture site. The percentage of the total number of locations in each bin was displayed in graphic form as a frequency distribution, including the cumulative percentage across bins on the 2nd (right) y-axis. Frequency distributions were generated for both summer and winter periods in the three main geographic regions (BSAI, GOA, and SE) by age (pup, juvenile, and adult). Overall, the large majority of at-sea locations occurred close to shore (<10 nm) across regions and seasons (Appendix 2; figs 1-8, 18-25). More distant locations were observed for adult females in winter, and in some cases juveniles in summer.

Several important caveats were noted when these data were presented to the RPA Committee: (1) due to a larger proportion of time spent at the surface nearshore, the probability of obtaining at-sea locations near haulouts and rookeries is likely higher than when further offshore when sea lions are diving to depth in deeper waters; (2) at-sea locations do not directly indicate where sea lions are foraging; (3) the large majority of pups, and perhaps most juveniles, were likely still nursing and thus not foraging independently for prey; and (4) telemetry data are lacking for subadults and females without pups. These caveats were presented and discussed relative to interpreting the distribution of locations as the percentage of time SSLs may spend at specific distances offshore, and further inferring that they represent the spatial distribution of where SSLs actively forage, and, subsequently capture prey.

Additional figures prepared by the NMML (Appendix 2; figs 9-12) and presented at the March RPA committee meeting included 2- and 3-dimensional figures of individual foraging bouts by 11-month old male SSLs off Long Island (GOA) and Seguam Island (BSAI). The duration of these two foraging bouts was approximately 4 and 14 days, with mean dive depths (> 4 m) of ~23 and ~18 m, and maximum depths recorded of 152 and 252 m. These figures represent results from the on-going analysis discussed above that integrate at-sea locations and concurrent dive behavior of individual at-sea trips to estimate the foraging behavior of SSLs. Additional figures (Appendix 2; figs 13-15) prepared by NMML displayed the low fidelity of SSLs to the site where they were captured and the SDR was deployed. Preliminary results indicate that pups make extensive movements along the nearshore area, but do not make extensive offshore movements, until perhaps 11 months of age. Once pups and juveniles arrive at a new site, they appear to remain relatively close to the new site and make short distance movements, until they move to the next site (Appendix 2; Fig 14). An additional figure prepared by ADF&G illustrated an extensive offshore foraging trip of an adult female in March and April of 1993 (Appendix 2; fig. 26).

In May 2001, Dr. Russ Andrews of the University of British Columbia made a presentation of his research on the foraging behavior and energetics of adult female SSLs to the RPA Committee. The primary focus of this research was a test of the hypothesis that the current SSL decline is due to nutritional stress, with preliminary results presented previously during a feeding ecology workshop convened by the Recovery Team in 1999 (SSL Recovery Team 1999). His collaborative research integrated three electronic devices that provided detailed fine-scale information on SSL foraging: (1) a stomach temperature transmitter (STT) that indicates when SSLs ingest prey; (2) a data logger that records depth, velocity, and water temperature; and (3) a SDR to determine locations. The combination of data collected from these instruments provides insights to when and where SSLs actively forage and capture prey, and as such, are pertinent to the interpretation of the data presented during the March 2001 RPA Committee meeting.

Based on results from adult females in summer at Forrester Island (SE) and Seguam Island (BSAI) in 1994 and 1997, nearly all prey ingestion occurred when animals repeatedly exhibited deep dives (> 10m). Prey was ingested during all at-sea trips during which such 'foraging dives' occurred. However, long periods of time often elapsed and large distances were covered between successful foraging events (SSL Recovery Team 1999). This preliminary study demonstrated that knowing where sea lions traveled and dove does not necessarily allow one to distinguish productive feeding areas from unproductive ones (SSL Recovery Team 1999). Adult females began 'foraging dives' >10 m within 8-26 minutes after departing a rookery, yet the first prey was not ingested until 0.9 to 5.1 hours after departure.

The at-sea locations of the SSLs while these foraging data were obtained are currently being integrated to provide an estimate of where 'foraging dives' and prey ingestion occurred. Due to the small number of at-sea locations obtained and the relatively large amount of error associated with each location, their spatial resolution is quite low especially when compared to the fine temporal scale of the dive data. Alternatively, assuming the animals swam at a velocity of 1.5 – 2.5 m/sec in a straight line from the rookery, 'foraging dives' would have commenced from 1-5 km offshore, whereas prey ingestion could have occurred from 5-46 km (~3-25 nm) offshore. As the actually speed and direction of sea lions is unknown during such at-sea bouts, reliable estimates of distances from the rookery where 'foraging dives' and prey ingestion occurred cannot be estimated by these calculations.

Results from current analyses by the NMML, ADF&G, and Dr. Andrews will provide a direct means of estimating the spatial and temporal aspects of SSL foraging. However, preliminary results outlined above permit further examination of the frequency distribution of distances (Appendix 2; figs 1-8, 18-25) requested by the RPA Committee. Such an examination is necessary because the distribution of distances could be interpreted as an index to the spatial extent of SSL foraging areas.

SSL at-sea behavior is different near haulout and rookeries than offshore. Specifically, nearshore activity can include resting, sleeping, social interactions, etc. that would result in animals spending a larger proportion of time at the surface in contrast to offshore activity that likely includes a greater proportion of time when sea lions dive to depth in deeper waters. Subsequently, the probability of obtaining at-sea locations near haulouts and rookeries is likely higher than when further offshore because the SDR must be at the surface for a transmission to be sent, and, multiple transmissions must be received within a 10-minute period in order for a satellite to estimate a location. The distance distributions for adult females during the summer breeding period in the GOA (Appendix 2; fig 2) demonstrate this issue, as animals made distant offshore trips >100 nm miles from shore, yet locations were not obtained between 8 and 100 nm. Additionally, the existing data from stomach temperature transmitters (adult females in summer) indicates the first prey ingestion event occurs at least 0.9 hours after departure from a rookery. Assuming SSL travel away from the rookery during some portion of the time prior to the first prey ingestion event, a portion of nearshore at-sea locations do not represent locations where animals successfully obtained prey.

Combined, this information suggests that some portion of the number of locations nearest to shore do not represent locations where SSLs obtain prey, and that the number of locations offshore is biased downward. To explore the potential effect of these biases for SSLs in the western stock, the number of at-sea locations in the first distribution bin (i.e., 0-2 nm) was reduced by 90% from the NMML deployments from 1990-2000, for the GOA and BSAI combined. During summer (breeding period), ~80% of adult, primarily females with pups, locations were within 6 nm from shore, with the remaining ~20% >100 nm from shore (Fig. 3). During the same summer period, ~35% of locations for pups and juveniles were within 6 nm, with ~15% between 8 and 20 nm, and ~50% >20 nm. These results suggest adult females make short at-sea trips in summer when they must nurse their pups on the rookery, yet also make some long-range trips. Pup and juvenile locations were distributed in all bins, with substantial proportions both nearshore and far offshore (>20 nm), suggesting that at least some of these younger animals, likely the juveniles that have been weaned, have begun to make more extensive offshore foraging trips. In winter (Fig. 3), when adult females do not nurse their pups as often, ~55% of locations were distributed among the bins up to 16 nm, with the remaining ~45% >50 nm, suggesting that during the non-breeding period adults make both nearshore and more extensive off-shore trips. Locations of pups and juveniles in winter were distributed among all bins except >100 nm, with a large majority (~90%) within 6 nm, suggesting young SSLs make relatively short at-sea trips. The larger percentage of nearshore locations in winter compared to summer for pups and juveniles may be a result of SDRs being deployed primarily on pre-weaning animals compared to the few post-weaning animals that were tracked during the early summer period.

The purpose of generating Figure 3 was not to suggest the frequency distributions of distances from at-sea locations to the nearest landmass should be used to infer the spatial extent of SSL foraging areas. Rather, the figure represents one illustration of how alternative inferences could be drawn from the data when some of the potential biases have been taken into consideration. Attempting further examples of accounting for the numerous uncertainties associated with the several caveats and potential biases previously mentioned are not recommended. Rather, the current analyses being conducted by NMML and ADF&G (outlined above) that integrate both location and dive behavior data from individual at-sea trips are considered the most direct means to estimate the spatial and temporal foraging patterns of SSLs.

Conclusion

The use of satellite telemetry in Steller sea lion research in Alaska has expanded substantially since the initial deployments by the NMML in the mid 1980s. Advances in telemetry technology and SSL capture techniques have allowed SDRs to be deployed on a relatively large number of animals from which a significant amount of information can be obtained. Knowledge of SSL movements, dive behavior, and site fidelity will continue to increase as data from recent deployments are analyzed. Integrating dive behavior and at-sea locations to estimate the extent and location of key SSL foraging areas is a primary focus of current research. Due to limitations of current satellite telemetry technology, the spatial resolution of SSL at-sea locations is not as fine as the temporal resolution of dive behavior data. Yet, results expected in 2001 and 2002 will provide further refinement of the understanding of SSL foraging activity.

Note: The NMFS Alaska Ecosystem program and the ADF&G Steller sea lion research program have prepared this 'white paper' to provide a general overview of satellite telemetry research on Steller sea lions in Alaska. For additional information pertaining to this information, or for use in any publication or account, please contact the NMFS (Dr. Thomas R. Loughlin, Alaska Ecosystem Program Manager or Dr. Douglas P. DeMaster, Director, National Marine Mammal Laboratory) or ADF&G (Dr. Tom S. Gelatt, Principal Investigator, Steller sea lion program or Dr. Robert J. Small, Marine Mammals Coordinator).

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Appendix 1

Table 1. Satellite transmitters (SDRs) deployed on Steller sea lions by the NMML and ADF&G, 1990-2001. Age class is approximate, with pups/juveniles < 36 months.

Stock/ Region	Capture Period	Age class: Pups / Juveniles M	Pups / Juveniles F	Adults M	Adults F	Total No. SDRs Deployed	Mean deployment duration/range (days)
Western Stock							
NMML							
Russia	Jun-91				9	9	10 (1-22)
Central Aleutians	Jul-90; Feb-00	1	3		5	9	43 (0-104)
Eastern Aleutians	Jun-90; Jul/Nov-91,	4	3		8	15	38(1-67)
Western Gulf of AK[a]	Jul-91,93; Mar-96	1	1		6	8	28(0-52)
Central Gulf of AK[a] (Kodiak Region)	Jun/Dec-90; Jun-91; Feb/Jul-92; Feb-93; Dec-94; Jan-96; Mar-01	7	3		21	31	45(0-174)
Southeast AK	Jul-91				1	1	<1
Washington State	Jun-95; Oct-97; May-99; Jan/Mar-00			4	3	7	55(14-83)
Total		13	10	4	53	80	
Eastern Gulf of AK	Jan-93				1	1	114
Eastern Gulf of AK	Jan-95	1	1			2	129 (113-145)
Eastern Gulf of AK	Jun-95	1	0			1	11
Prince William Sound	April-00	4	4			8	42.5 (10-78)
Prince William Sound	April-00	0	2			2	64 (54-74)
Prince William Sound	Aug-00	1	3			4	67.8 (51-103)
Total		7	10		1	18	
Eastern Stock							
Southeast AK-North	Nov-98	5	5			10	44.6 (12-119)
Southeast AK-North	Jan-00	2	5			7	81.6 (60-138)
Southeast AK-North	Jan-00	2	1			3	146.7 (120-181)
Southeast AK-North	May-01	2	2			4	[b]
Southeast AK-North	May-01	1	1			2	[b]
Southeast AK-Central	Mar-98	7	5			12	81.7 (30-143)
Southeast AK-Central	Aug-99	4	6			10	5.6 (3-13)
Southeast AK-Central	Sept-00	3	2			5	106 (82-114)
Southeast AK-Central	May-01	3	2			5	[b]
Southeast AK-Central	May-01	1	1			2	[b]
Southeast AK-Central	May-01	1	0			1	[b]
Southeast AK-South	May/Jul-92	0	1		5	6	40 (28-84)[c]
Southeast AK-South	Jun/Jul-93				7	7	28 (21-36)[c]
Southeast AK-South	July-98	3	7			10	21.1 (11-34)
Total		34	38		12	84	

[a]NMML deployed 10 satellite transmitters at Unimak pass and ADF&G and NMML collaborated to deploy 13 transmitters around Kodiak Island in March, 2001.
[b]Data collection in progress.
[c]Feeding trips for summer-captured adult females with pups are being analyzed for Andrews et al. (in prep); locations outside feeding trips not used.

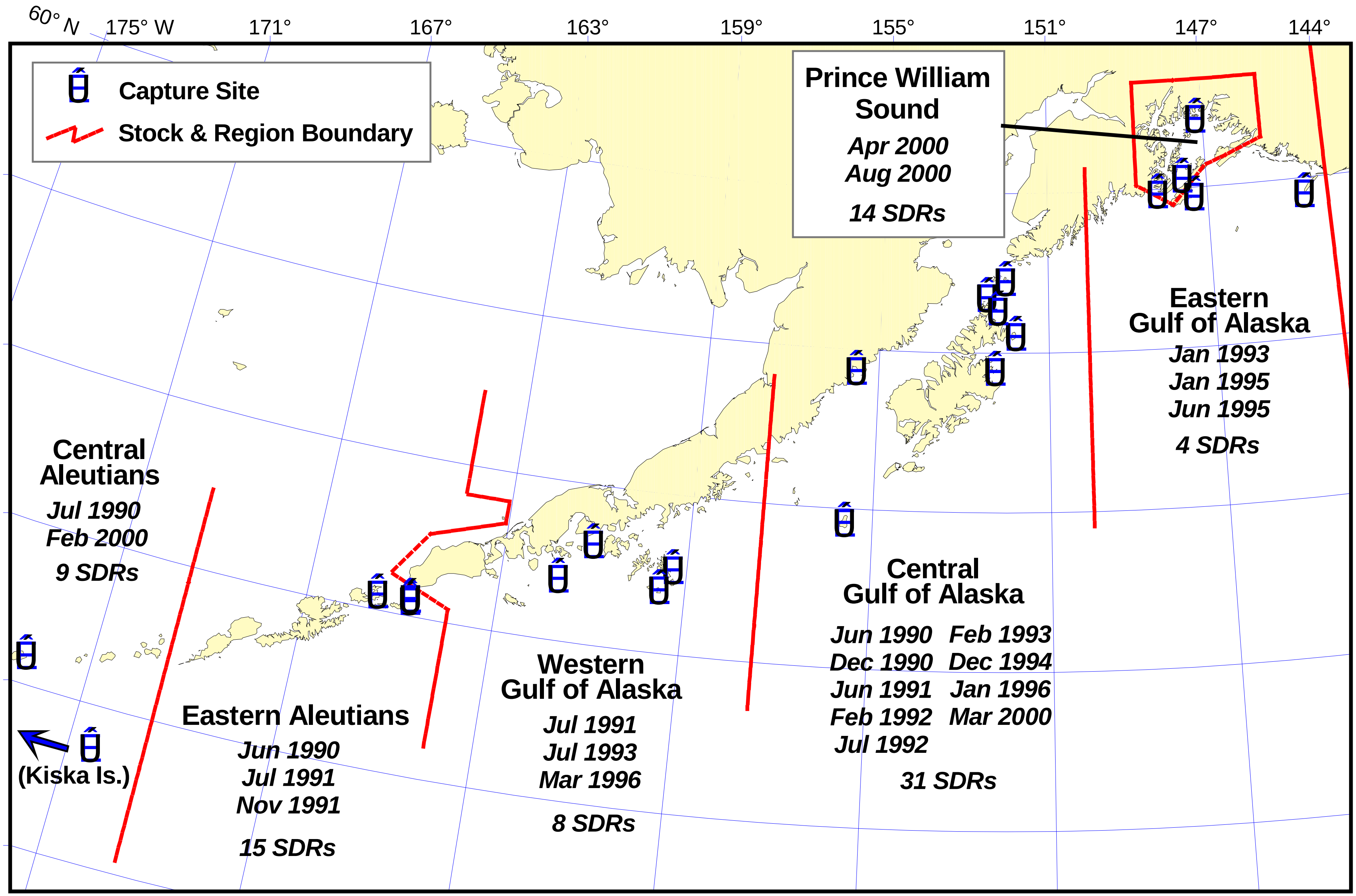


Fig 1. Spatial distribution of satellite tags (SDRs) deployed on Steller sea lions in the Western Stock, by GOA and AI region.

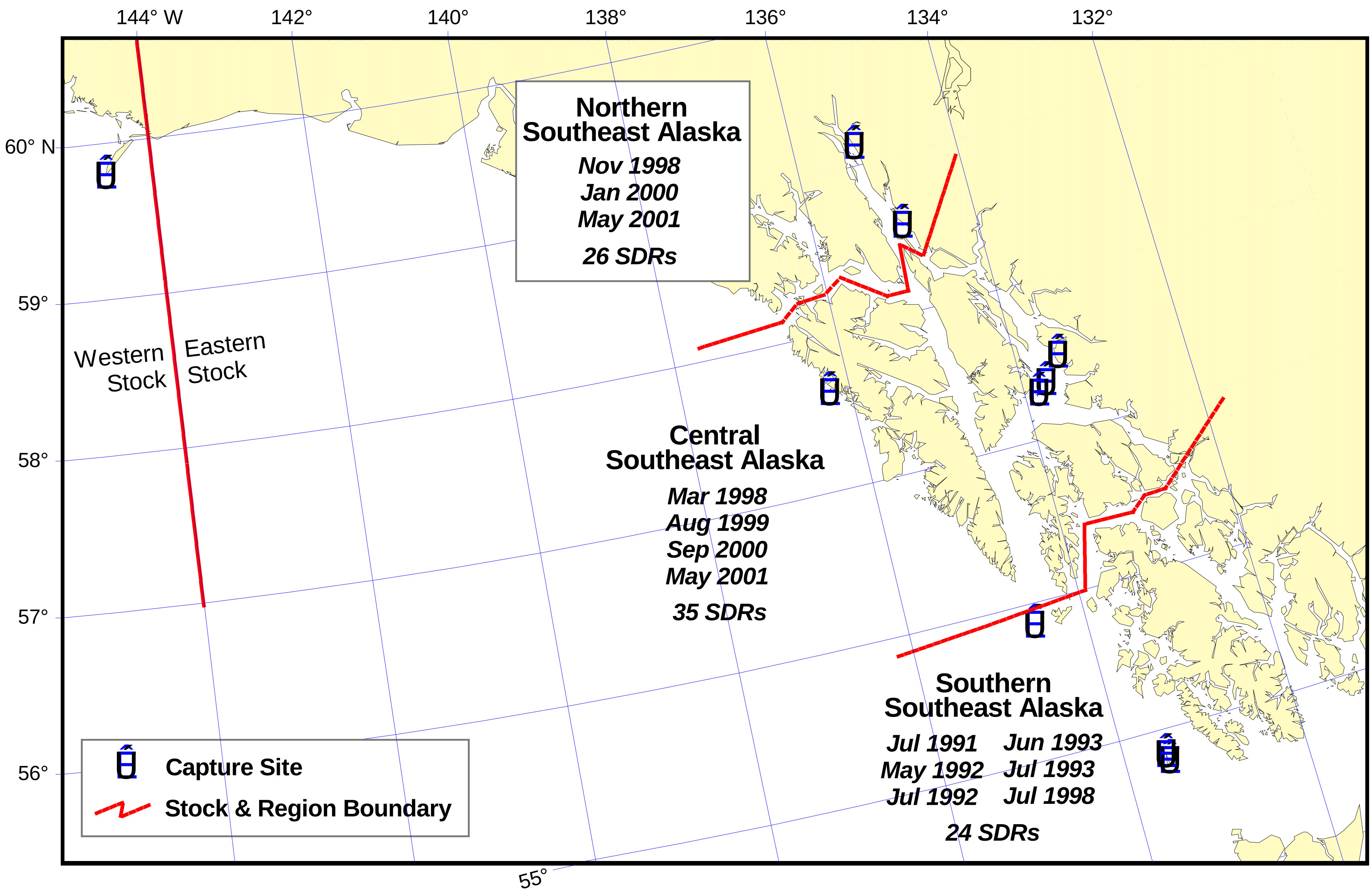


Fig 2. Spatial distribution of satellite tags (SDRs) deployed on Steller sea lions in the Eastern Stock, by Southeast Alaska region.

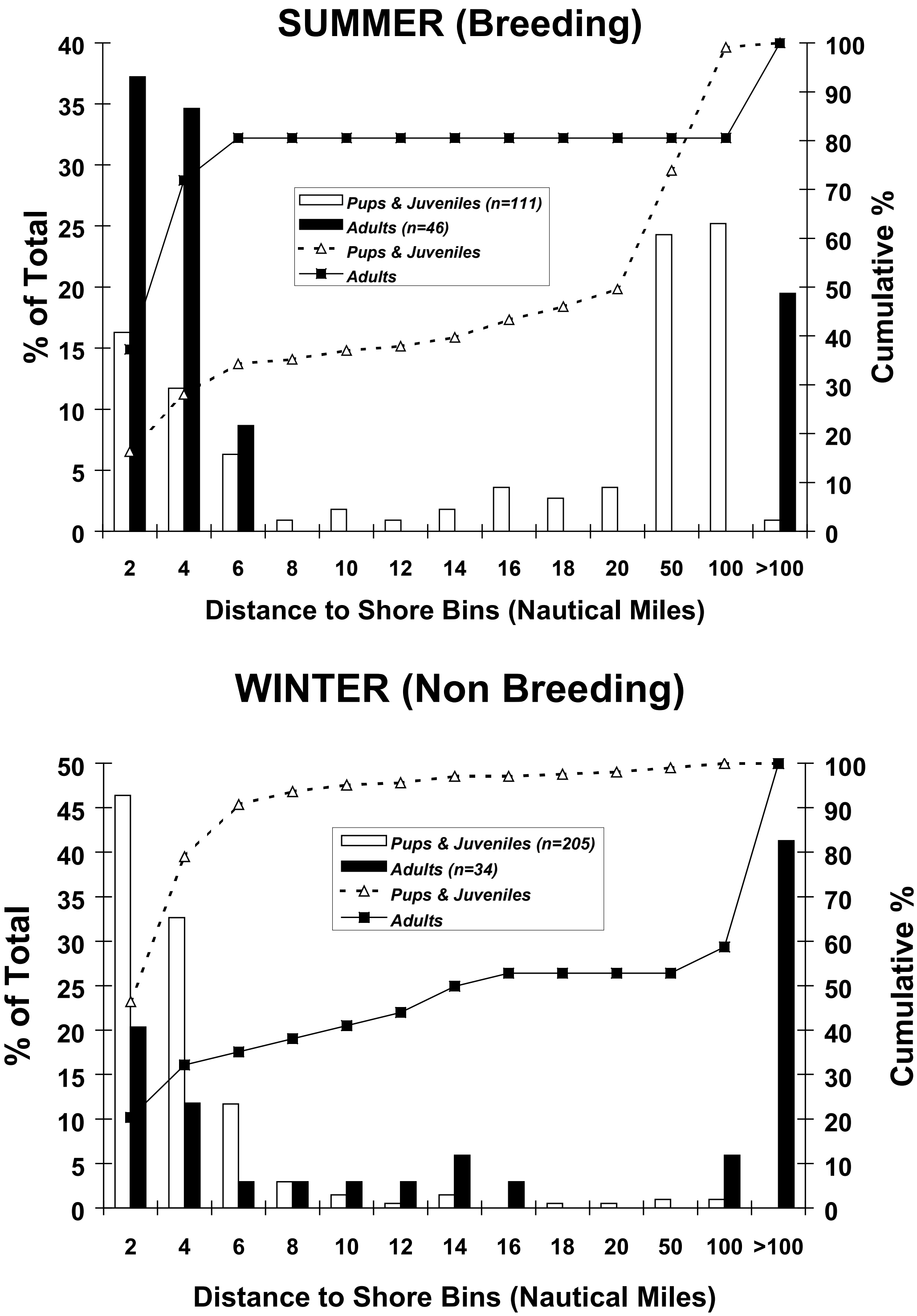
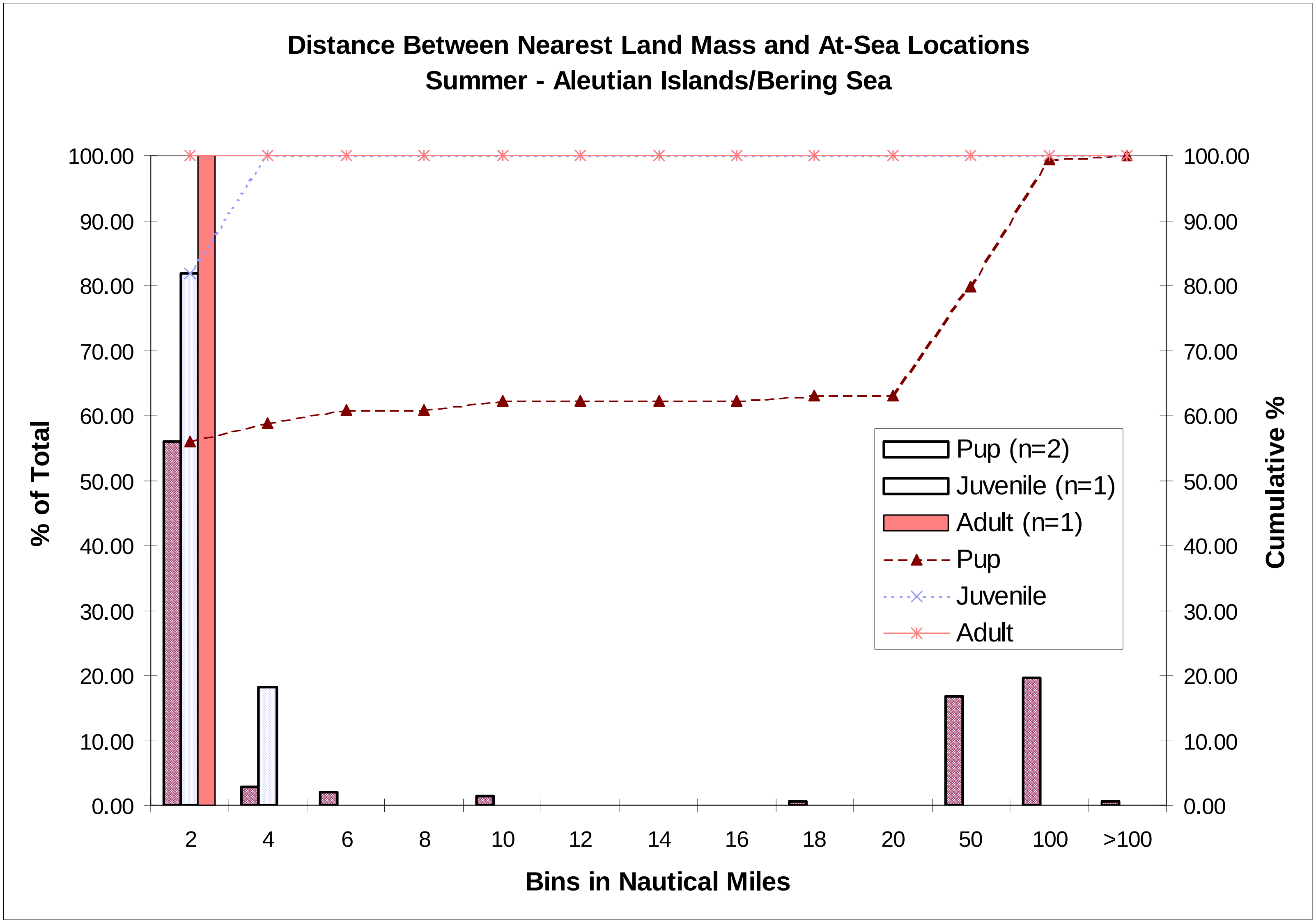
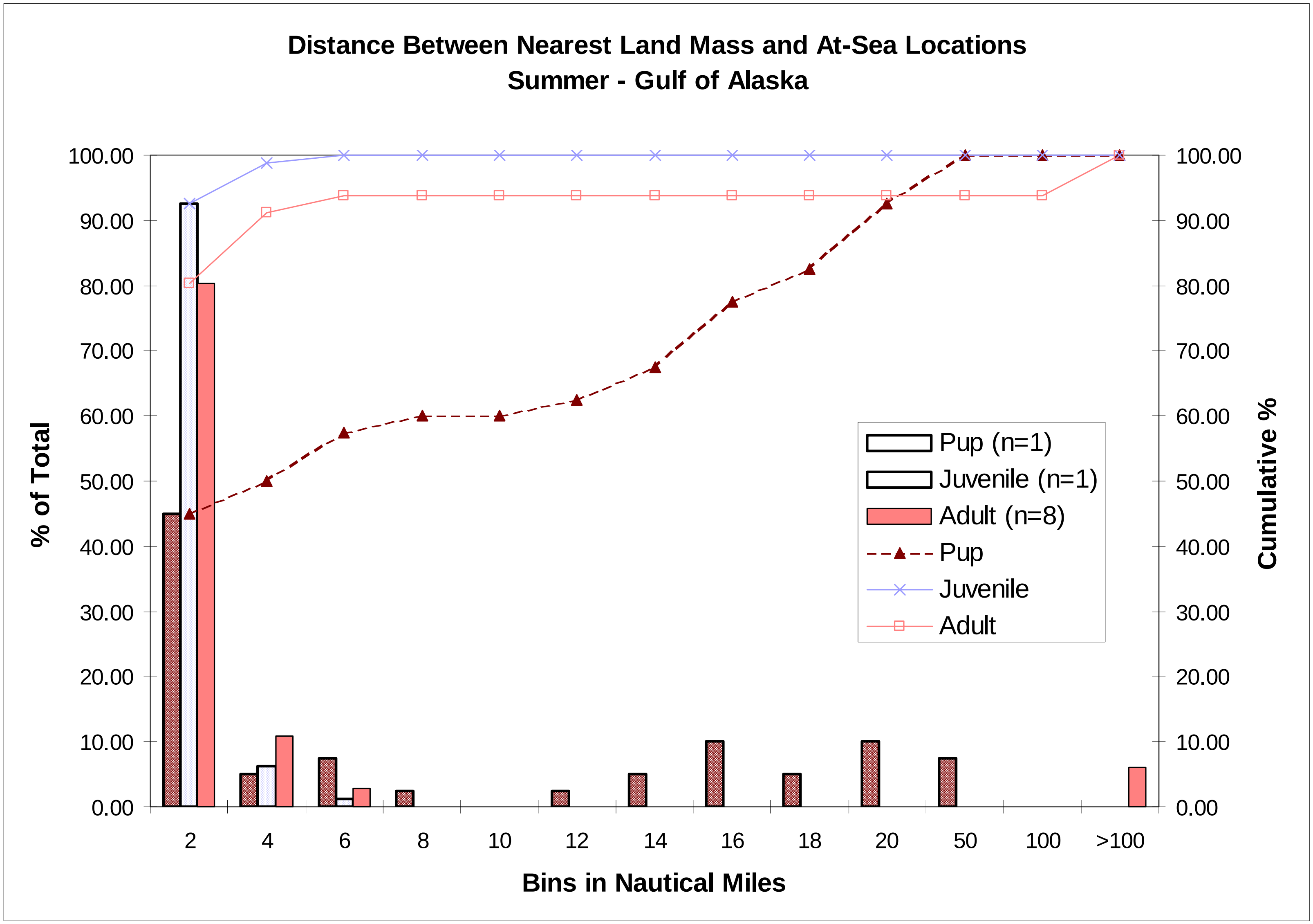


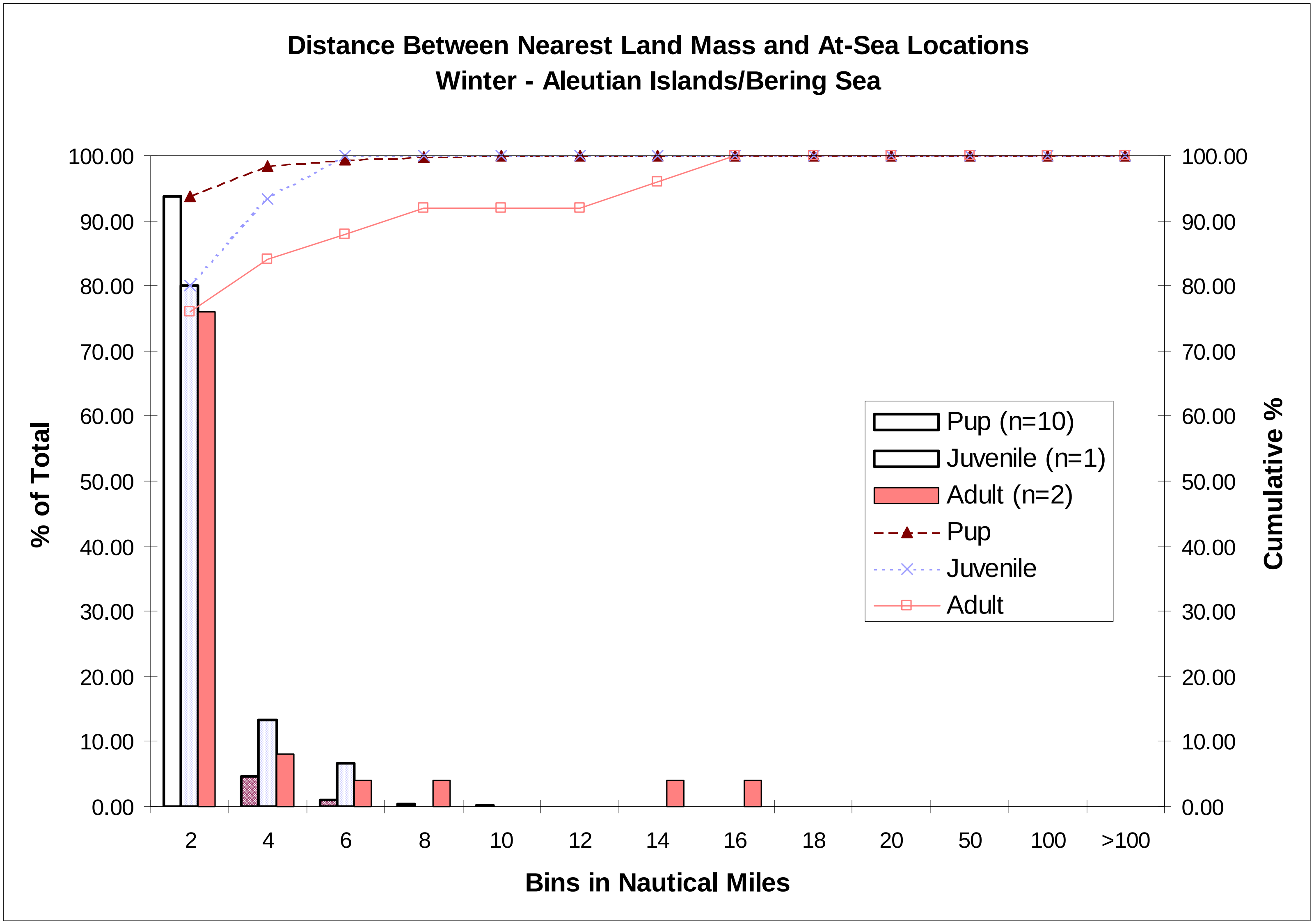
Figure 3. The distribution of distances (nm) from Steller sea lion at-sea locations to the nearest point of land, for NMML deployments in the GOA and BSAI from 1990-2000. The number of locations in the first bin (0-2 nm) was reduced by 90% from the total number of locations obtained (see text). Horizontal bars represent the percentage of the total number of locations in each bin, whereas lines represent the cumulative percentage. The number of locations for both pups and juveniles, and adults, is in parentheses in the figure legends.

Appendix 2

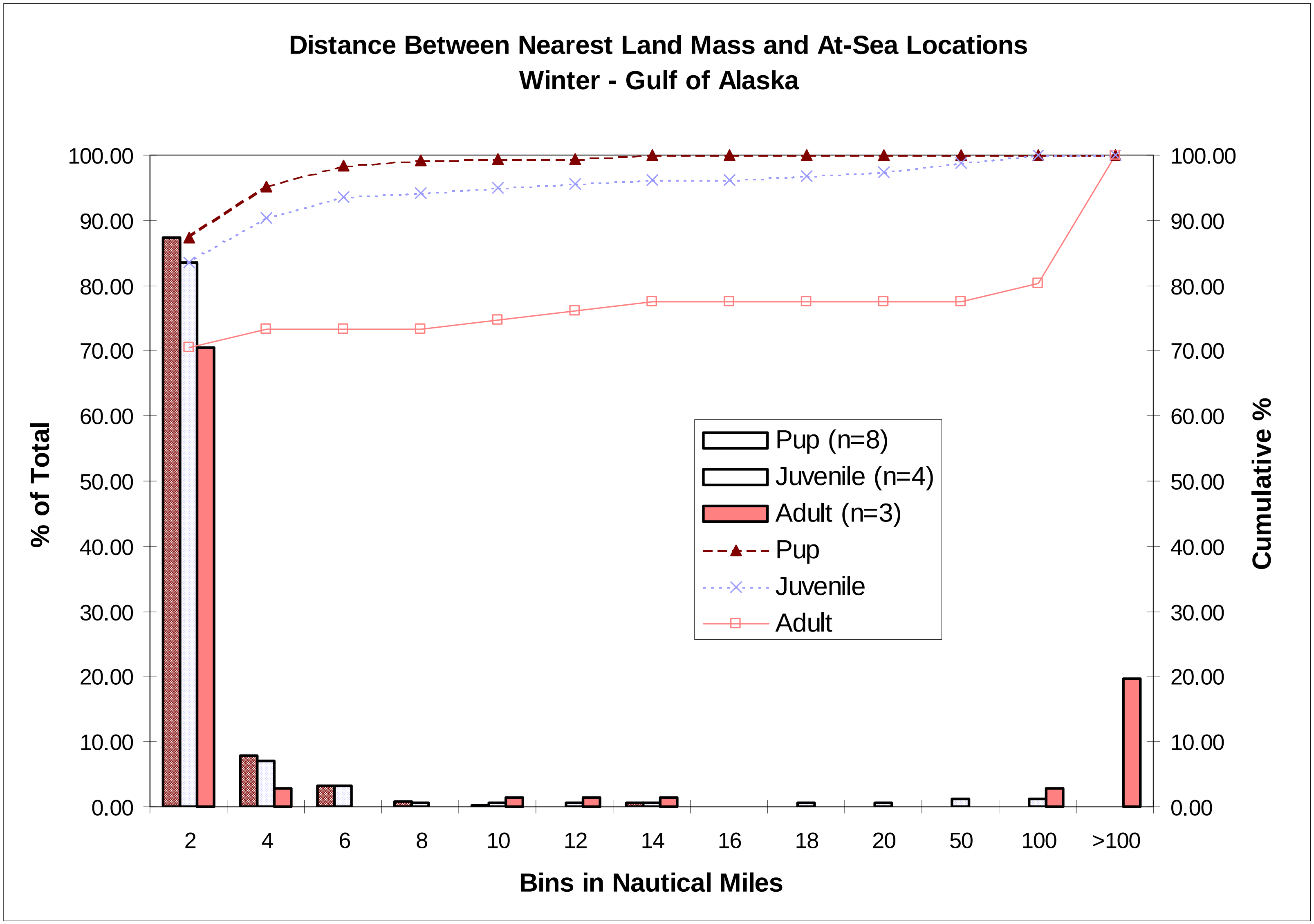

Distance Between Nearest Land Mass and At-Sea Locations
Summer - Aleutian Islands/Bering Sea
% of Total
Cumulative %
Bins in Nautical Miles
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n=2)
Juvenile (n=1)
Adult (n=1)
Pup
Juvenile
Adult

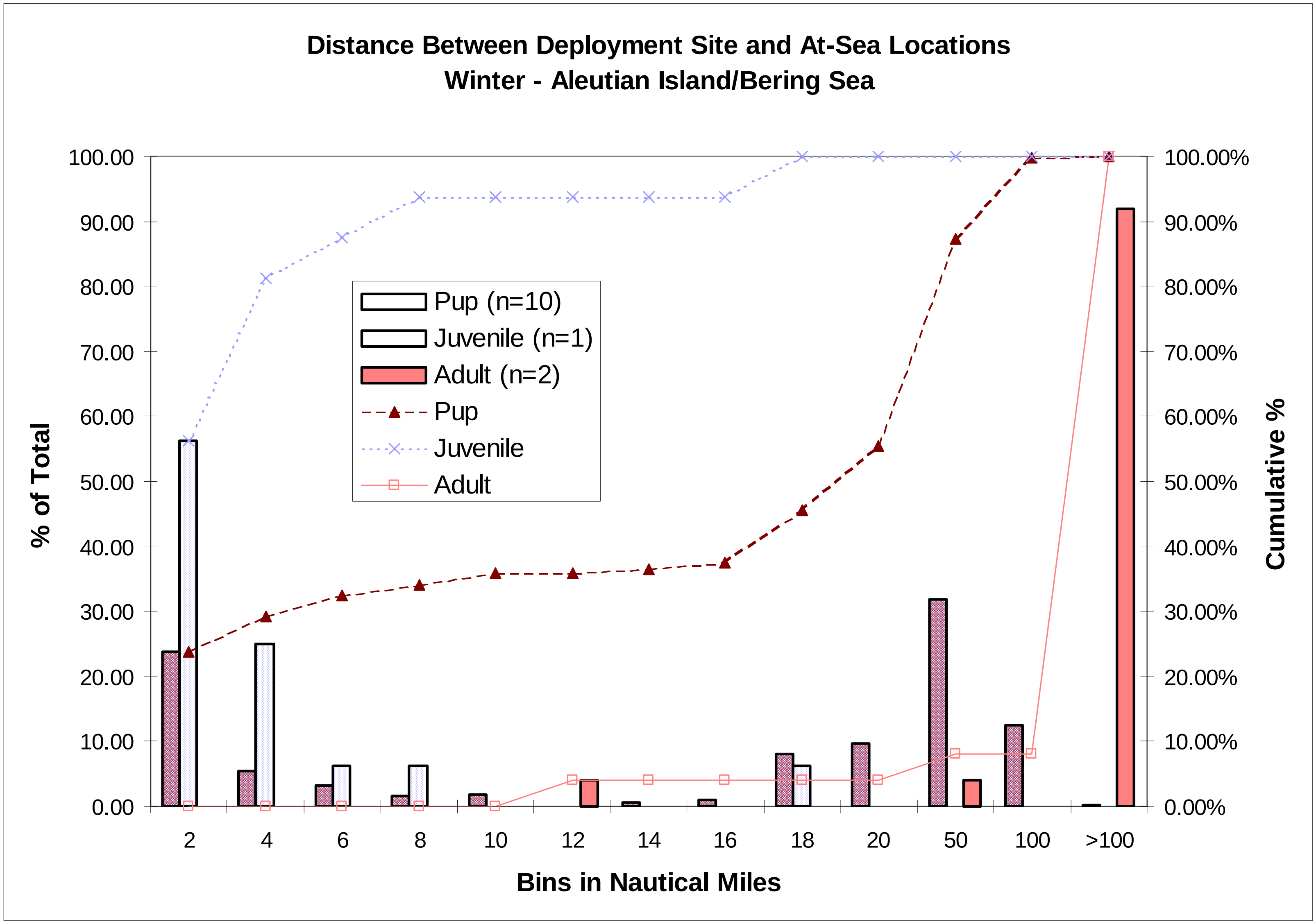


Distance Between Nearest Land Mass and At-Sea Locations
Summer - Gulf of Alaska
% of Total
Cumulative %
Bins in Nautical Miles
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n=1)
Juvenile (n=1)
Adult (n=8)
Pup
Juvenile
Adult



Distance Between Nearest Land Mass and At-Sea Locations
Winter - Aleutian Islands/Bering Sea
% of Total
Cumulative %
Bins in Nautical Miles
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n=10)
Juvenile (n=1)
Adult (n=2)
Pup
Juvenile
Adult


Distance Between Nearest Land Mass and At-Sea Locations
Winter - Gulf of Alaska
% of Total
Cumulative %
Bins in Nautical Miles
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n=8)
Juvenile (n=4)
Adult (n=3)
Pup
Juvenile
Adult


Distance Between Deployment Site and At-Sea Locations
Winter - Aleutian Island/Bering Sea
% of Total
Cumulative %
Pup (n=10)
Juvenile (n=1)
Adult (n=2)
Pup
Juvenile
Adult
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
90.00%
100.00%
2
4
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12
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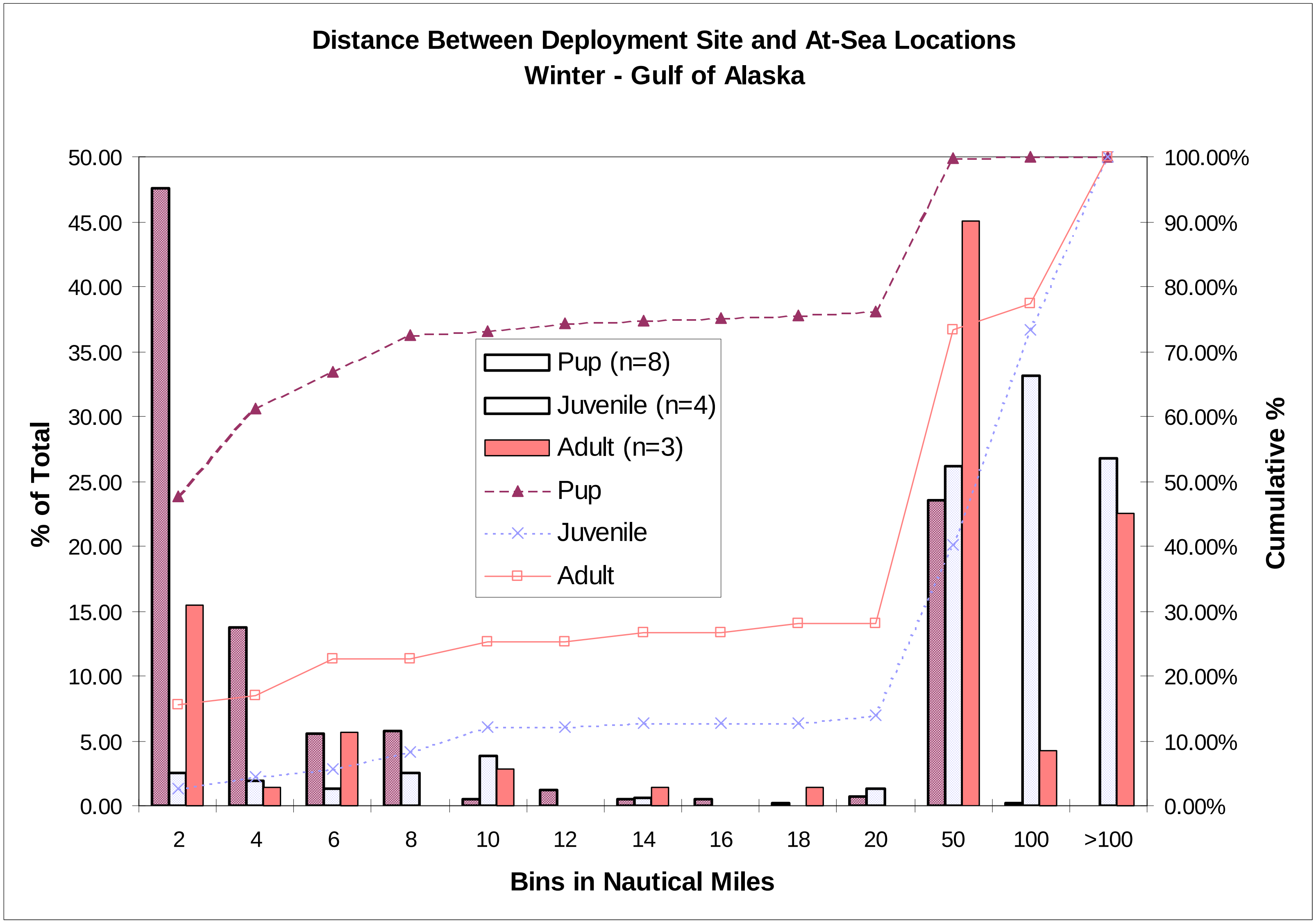
100
>100
Bins in Nautical Miles


Distance Between Deployment Site and At-Sea Locations
Winter - Gulf of Alaska
% of Total
Cumulative %
Bins in Nautical Miles
Pup (n=8)
Juvenile (n=4)
Adult (n=3)
Pup
Juvenile
Adult
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
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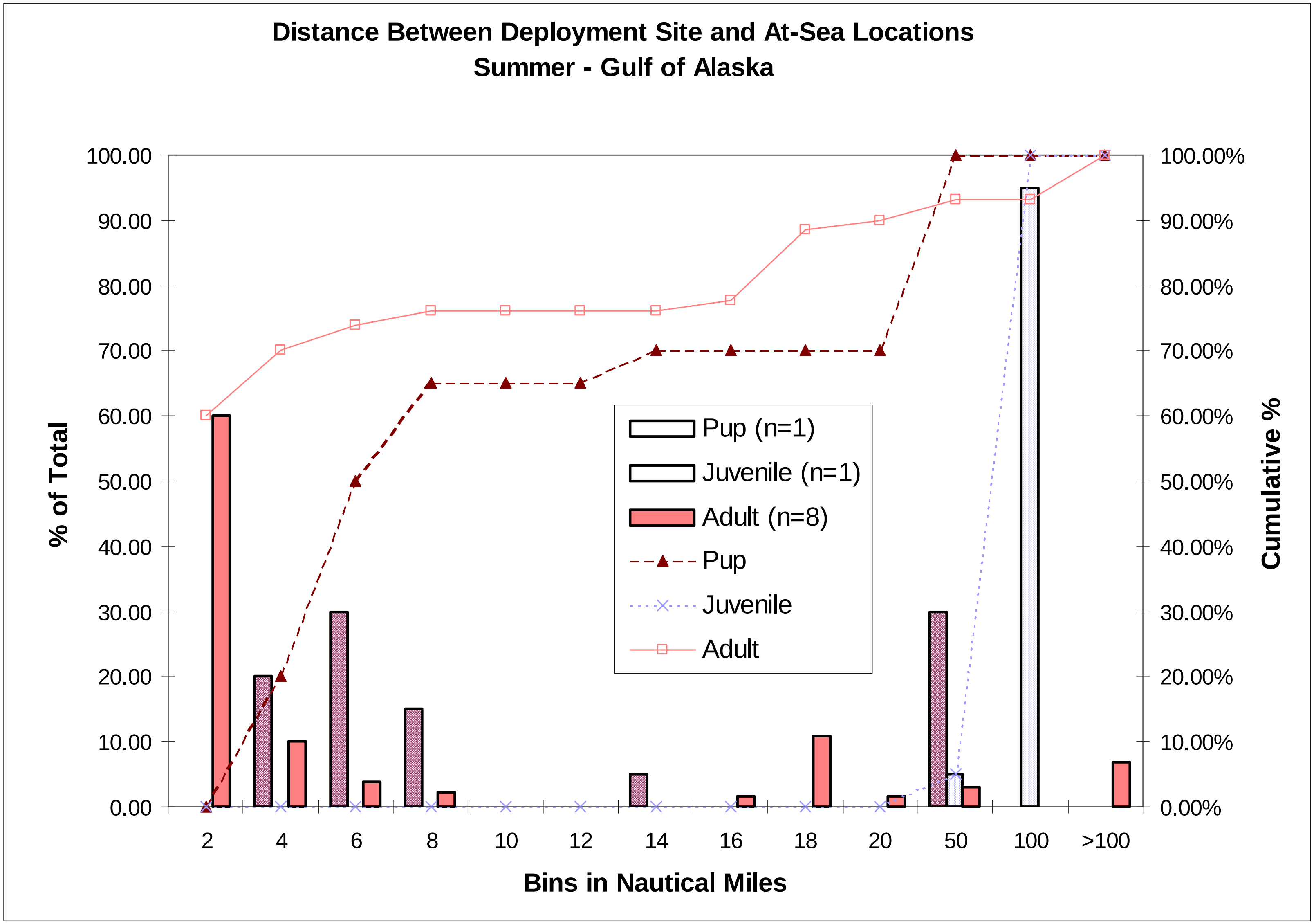
100
>100


Distance Between Deployment Site and At-Sea Locations
Summer - Gulf of Alaska
% of Total
Cumulative %
Bins in Nautical Miles
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00%
90.00%
80.00%
70.00%
60.00%
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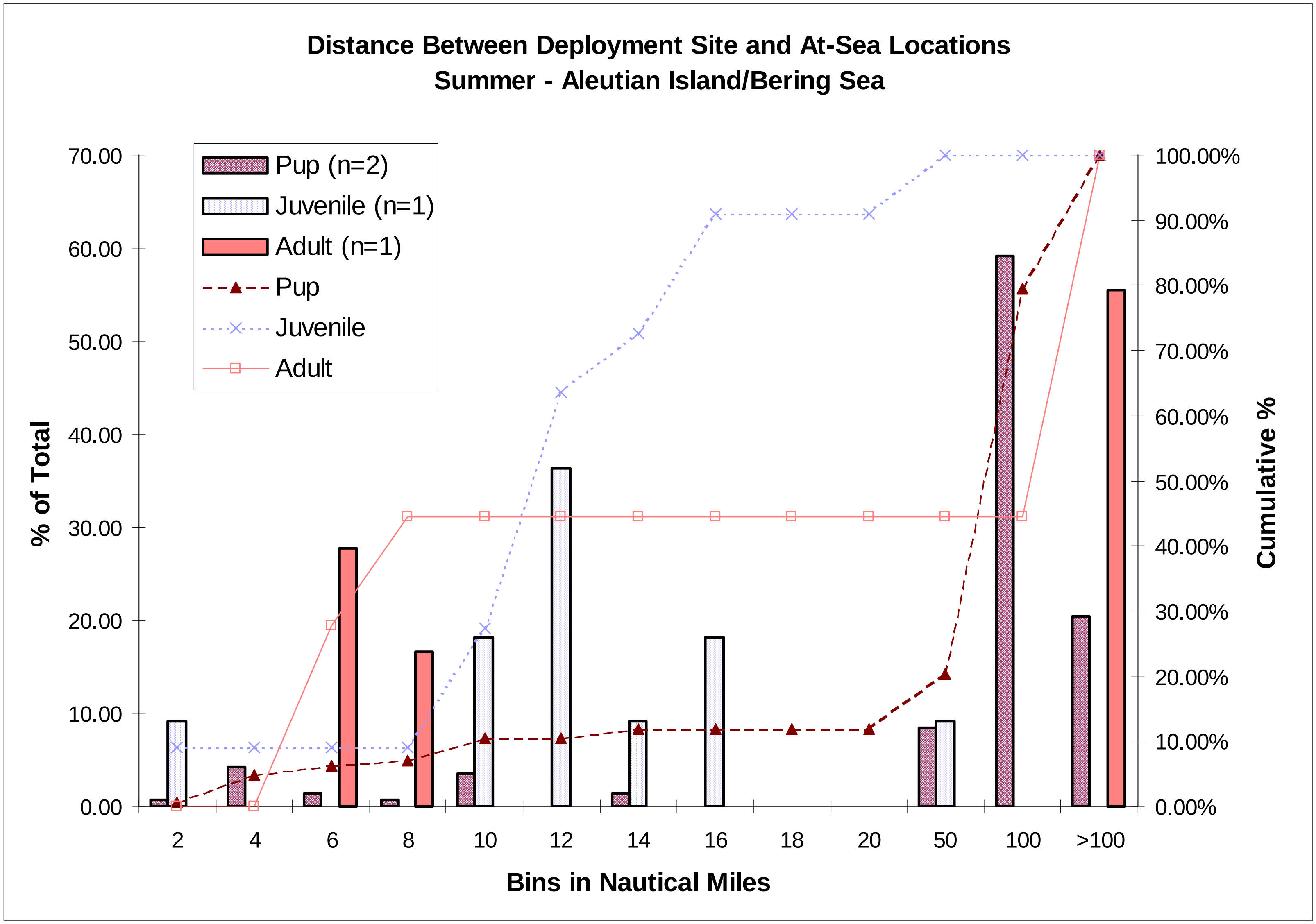
>100
Pup (n=1)
Juvenile (n=1)
Adult (n=8)
Pup
Juvenile
Adult



Distance Between Deployment Site and At-Sea Locations
Summer - Aleutian Island/Bering Sea
Pup (n=2)
Juvenile (n=1)
Adult (n=1)
Pup
Juvenile
Adult
% of Total
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Cumulative %
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
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16
18
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100
>100
Bins in Nautical Miles

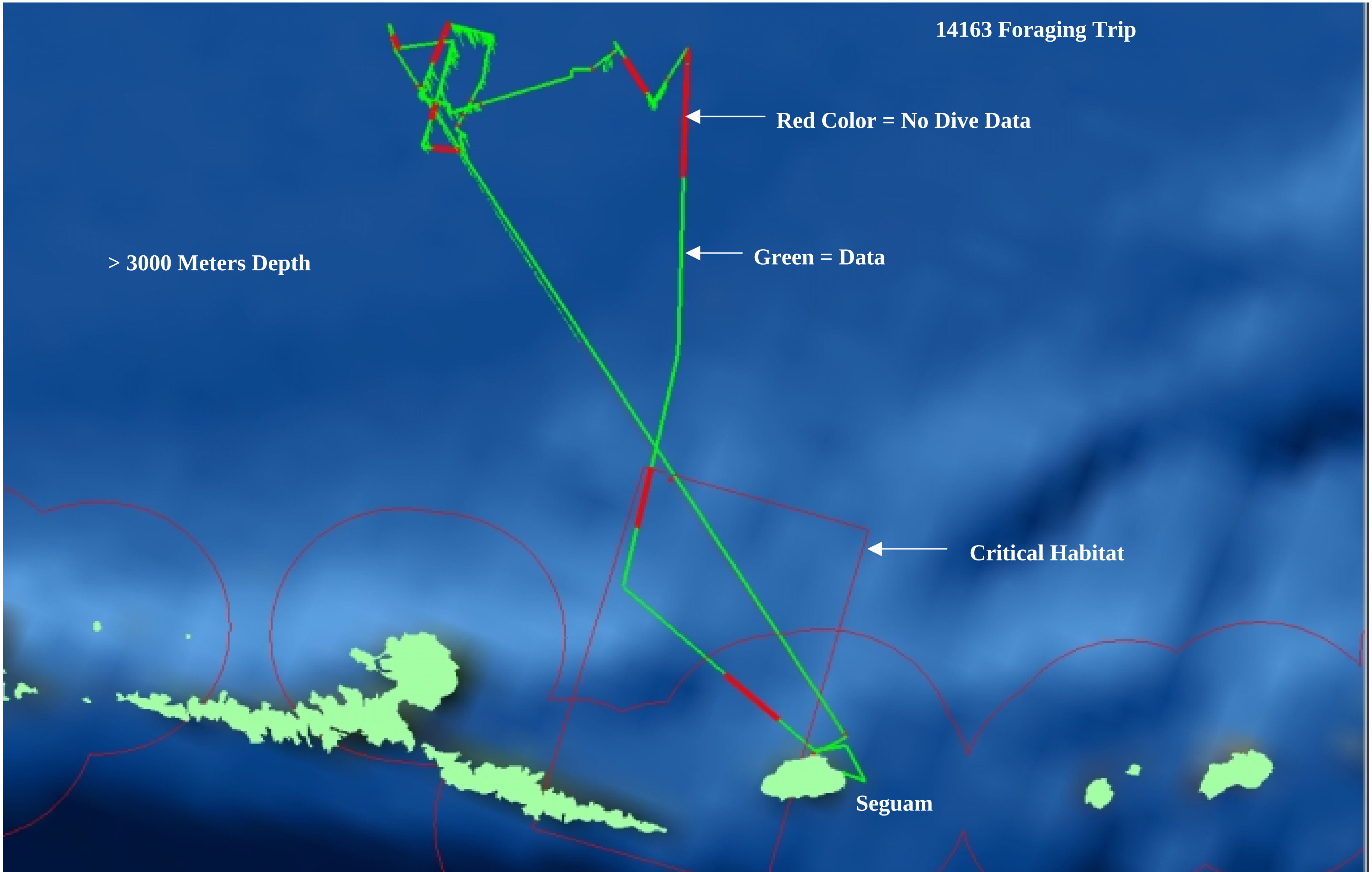


Figure 1. A 14.33 day foraging trip of an 11 month old male Steller sea lion during the month of May, 2000. 3463 dives >4 meters occurred in 31, 6 hour periods. Mean dive depth was 18.04 meters and the maximum dive depth recorded was 252 meters.

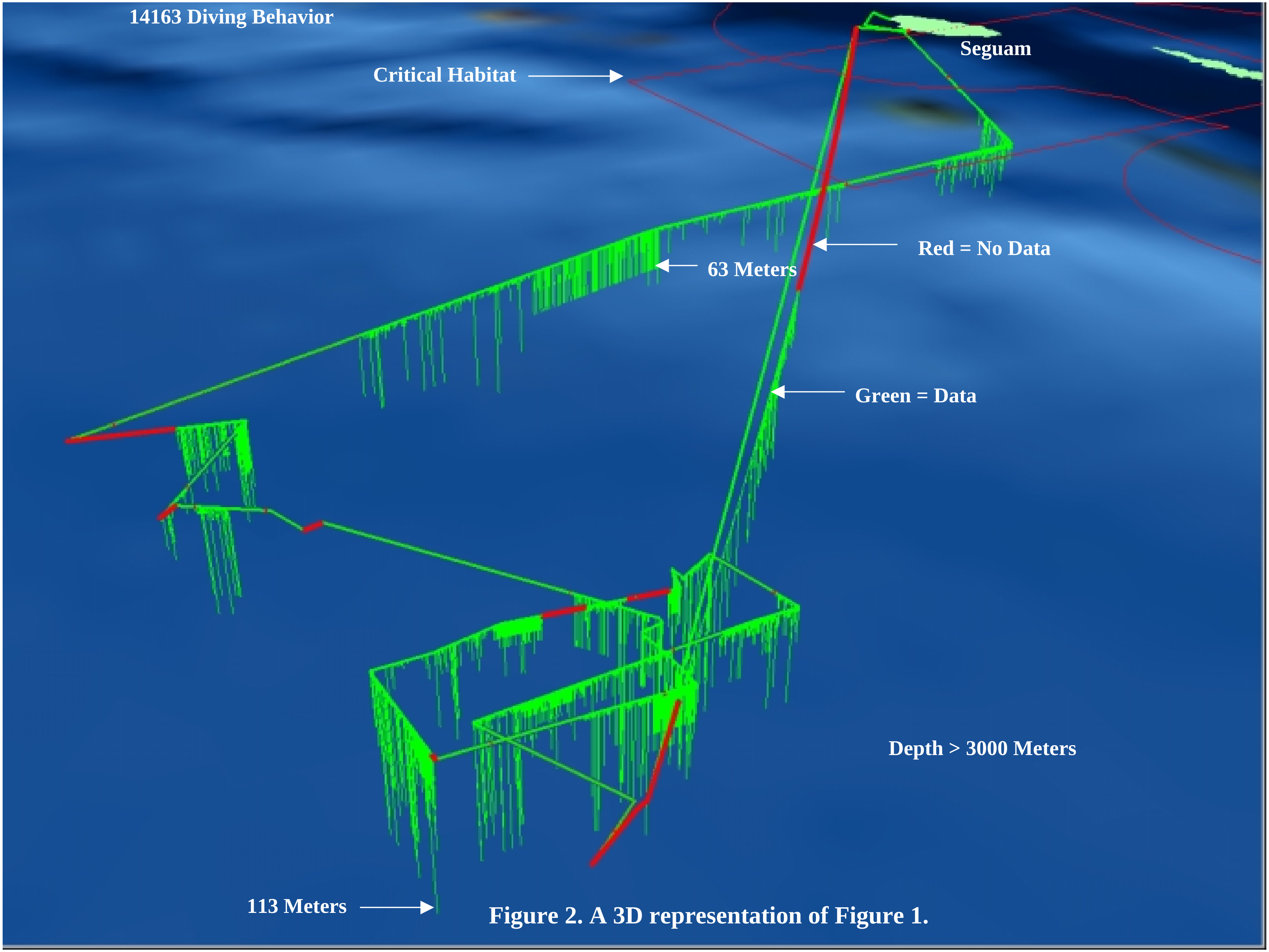


Figure 2. A 3D representation of Figure 1.

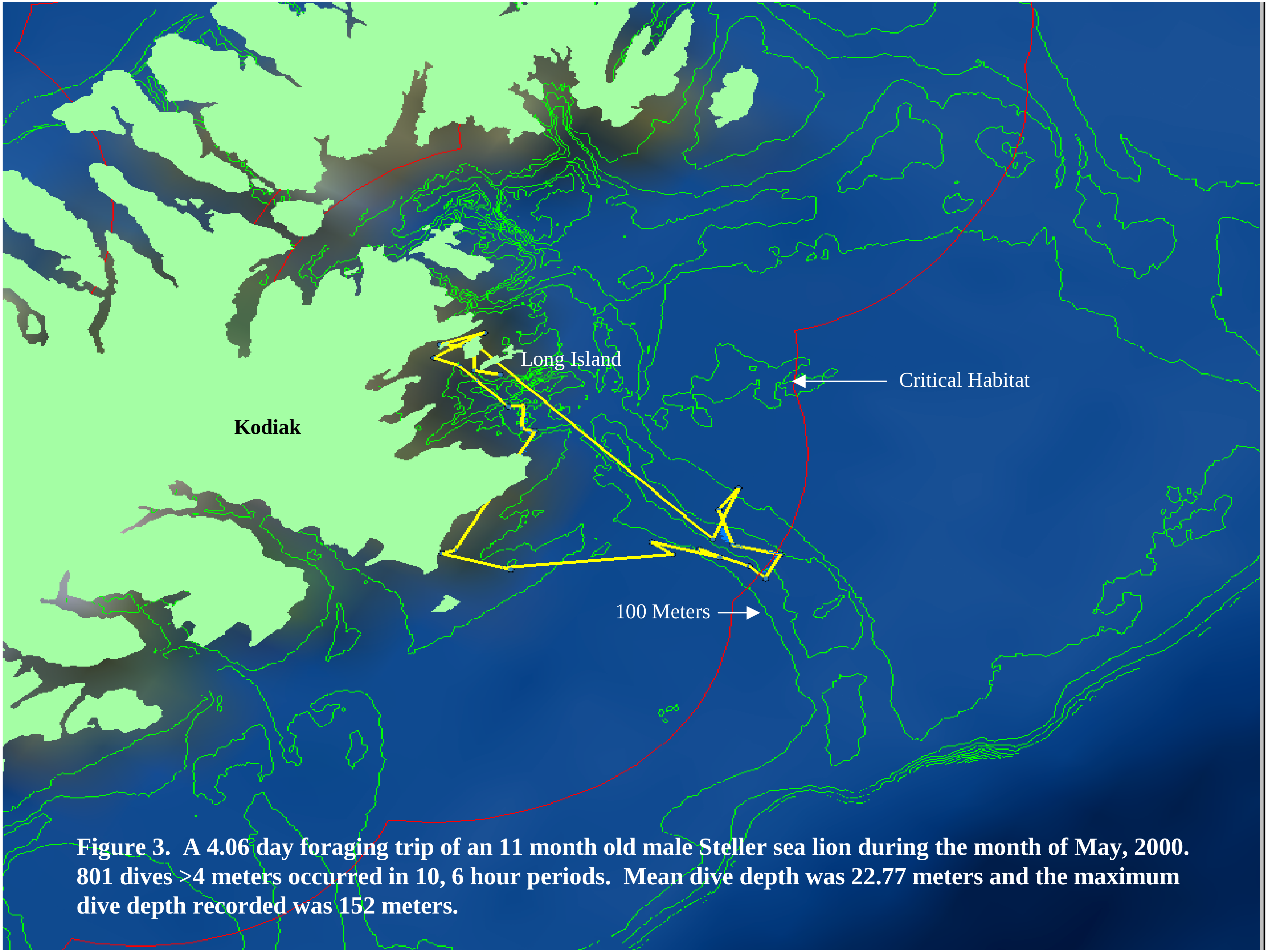


Figure 3. A 4.06 day foraging trip of an 11 month old male Steller sea lion during the month of May, 2000. 801 dives >4 meters occurred in 10, 6 hour periods. Mean dive depth was 22.77 meters and the maximum dive depth recorded was 152 meters.

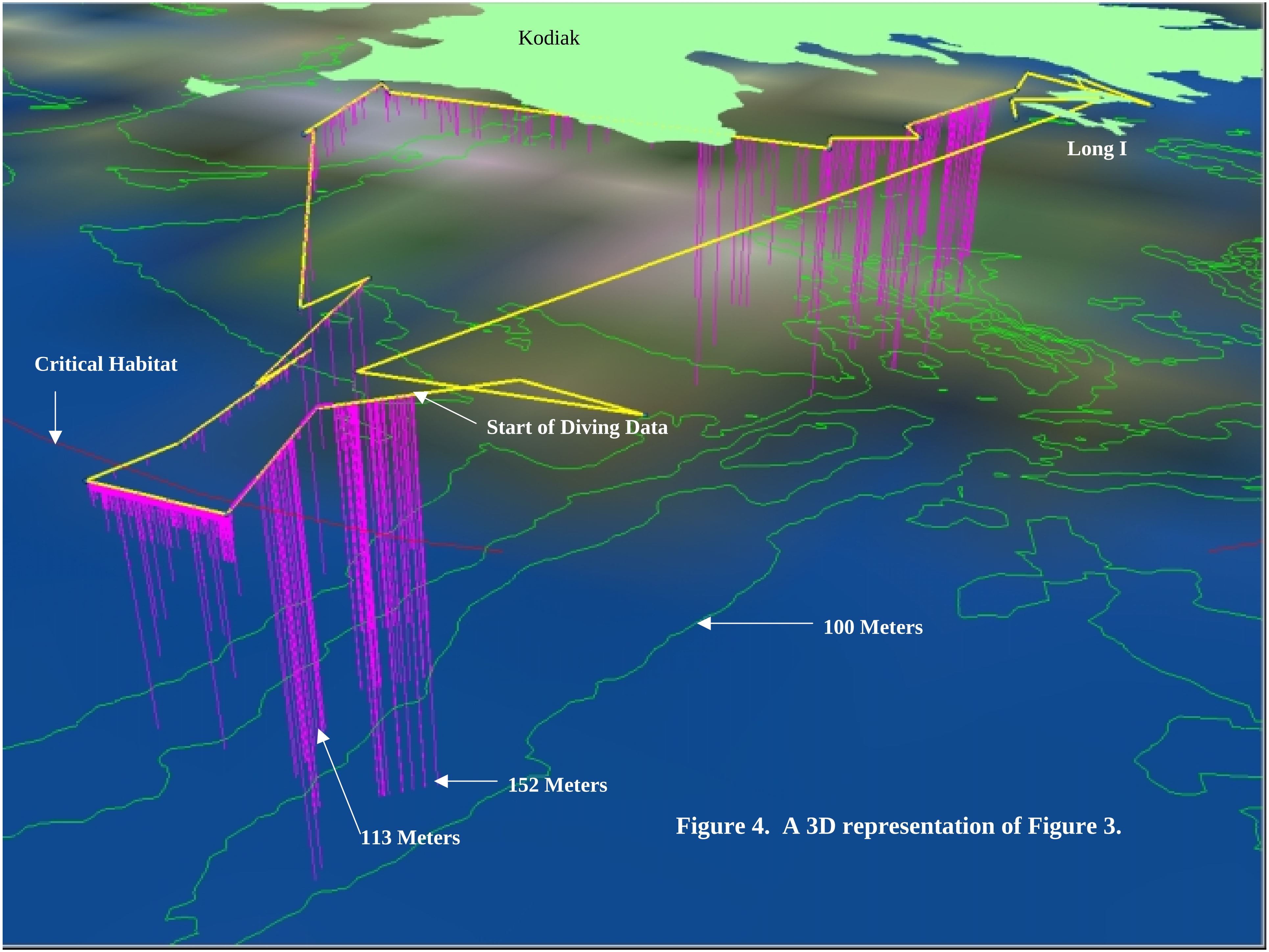
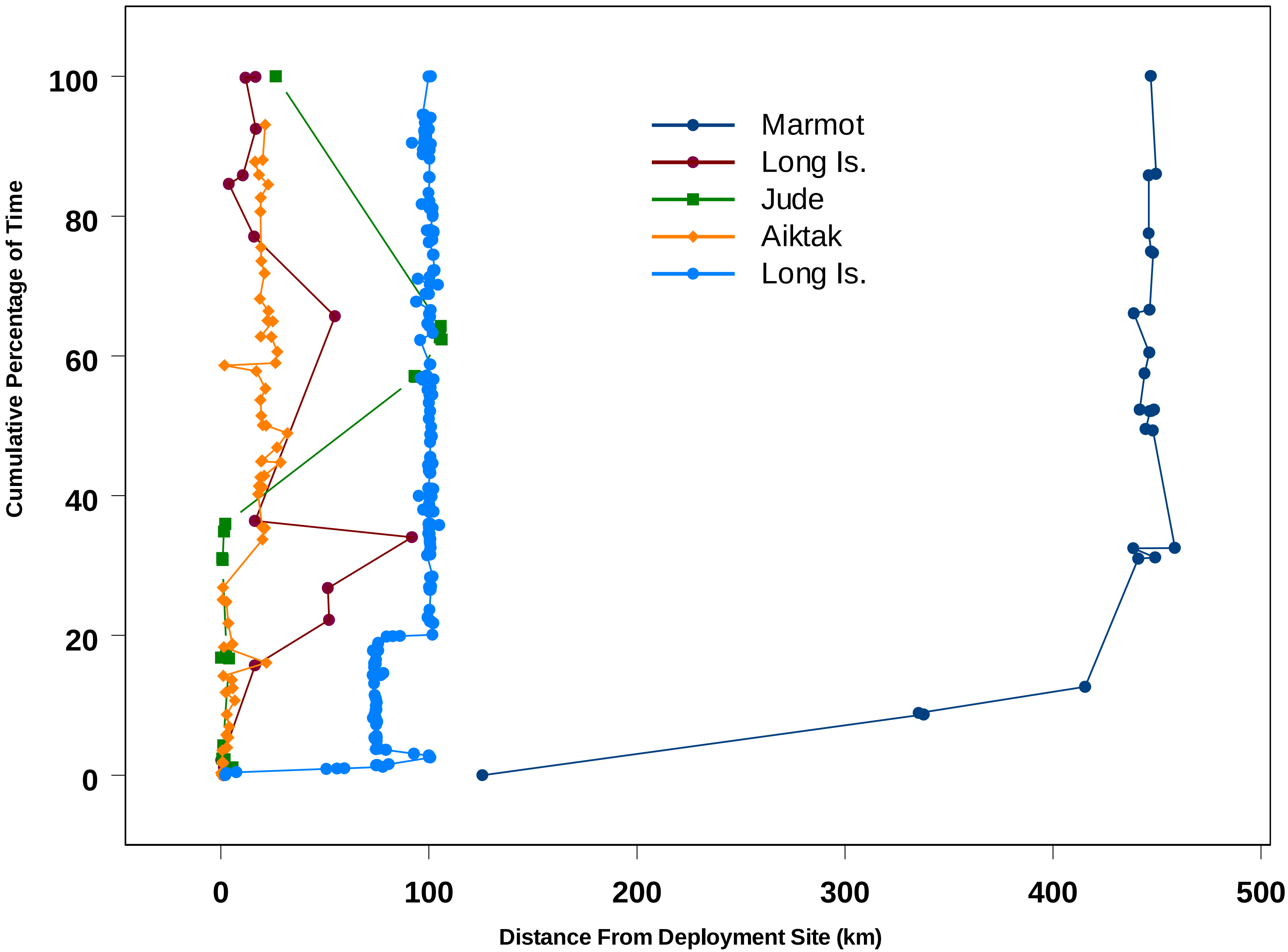
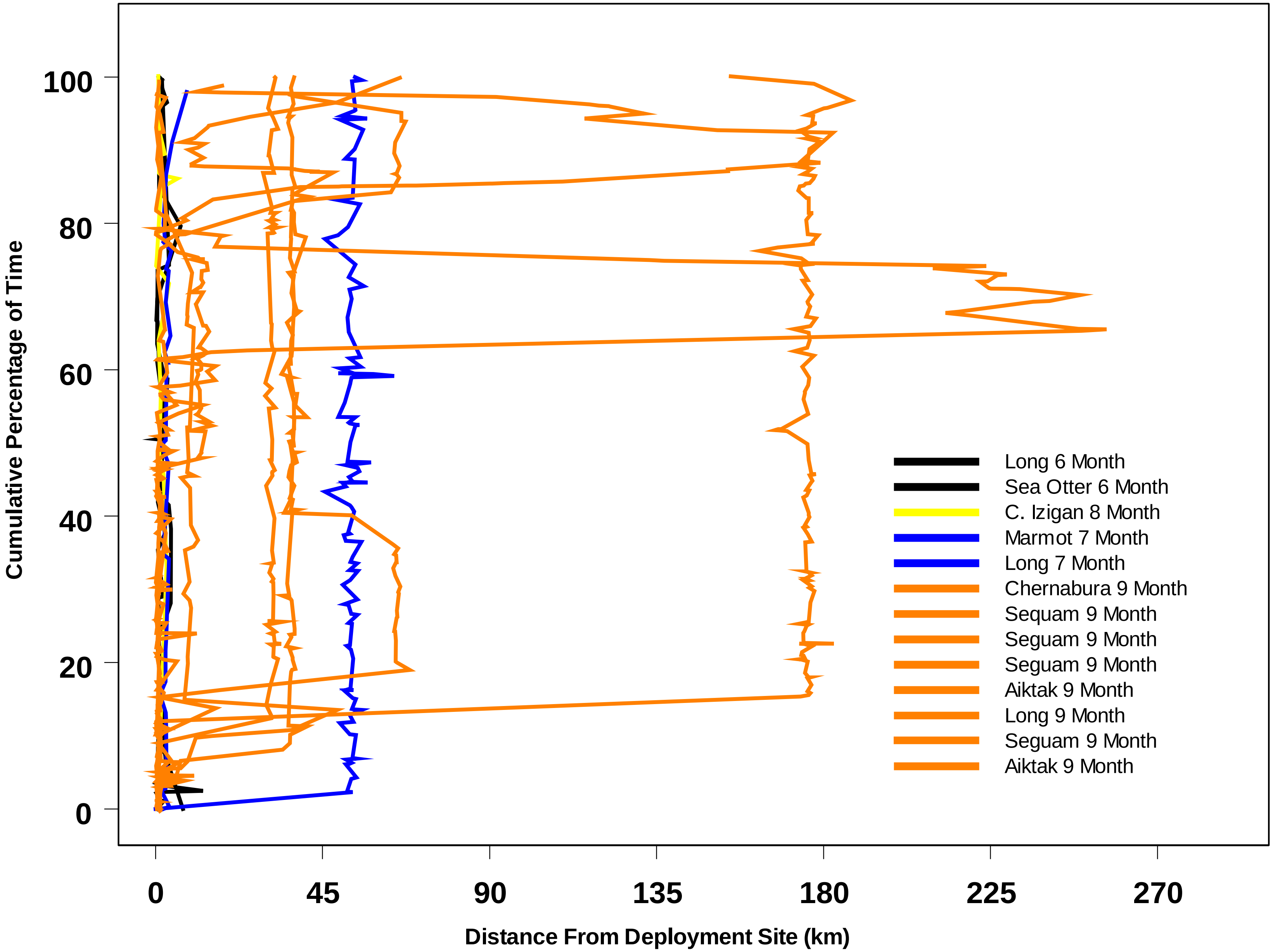


Figure 4. A 3D representation of Figure 3.

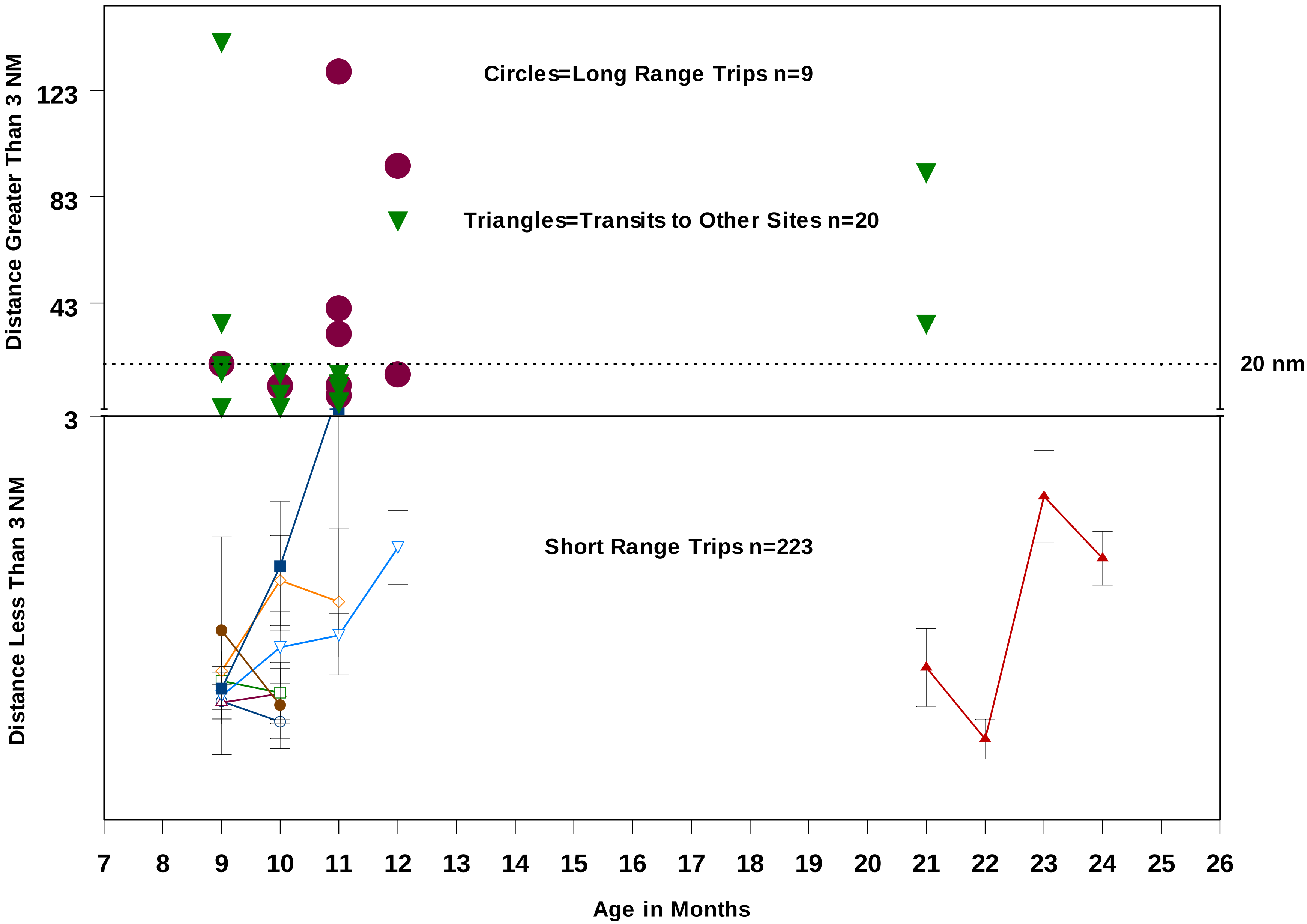
Cumulative Frequency Distribution of Locations
Juvenile Alaska Animals n=5

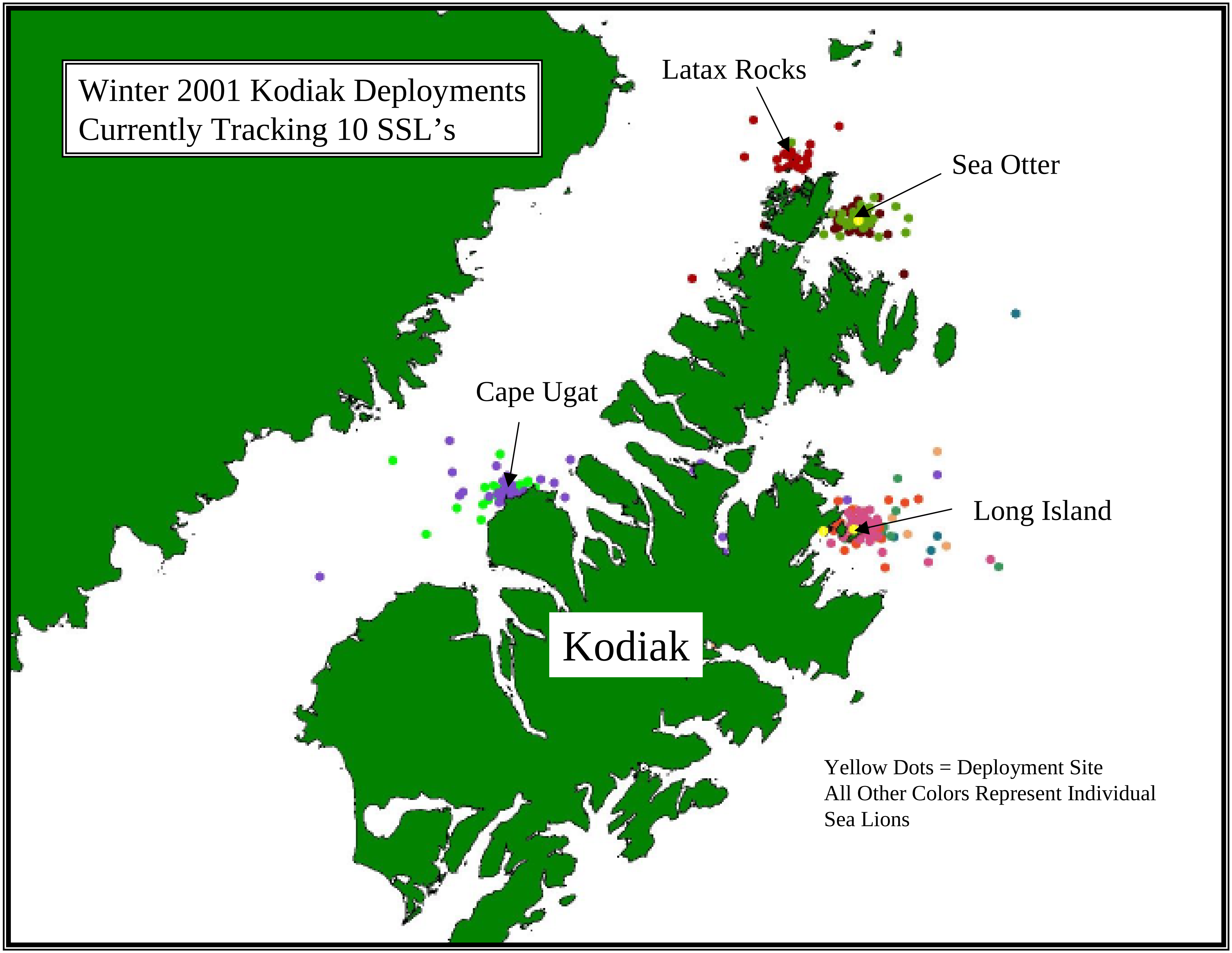


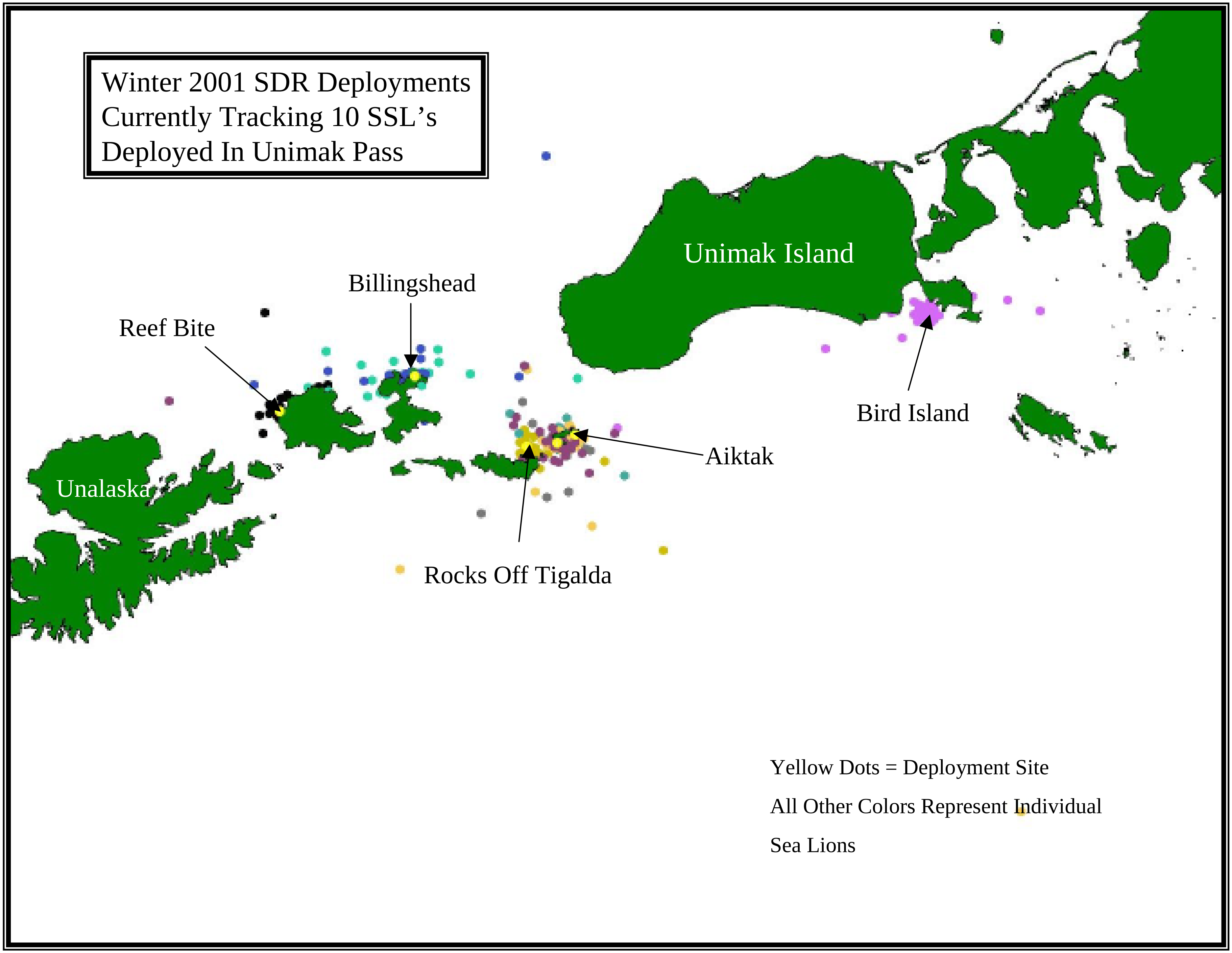
Cumulative Frequency Distribution of Locations
Young of the Year Alaska Animals n=13

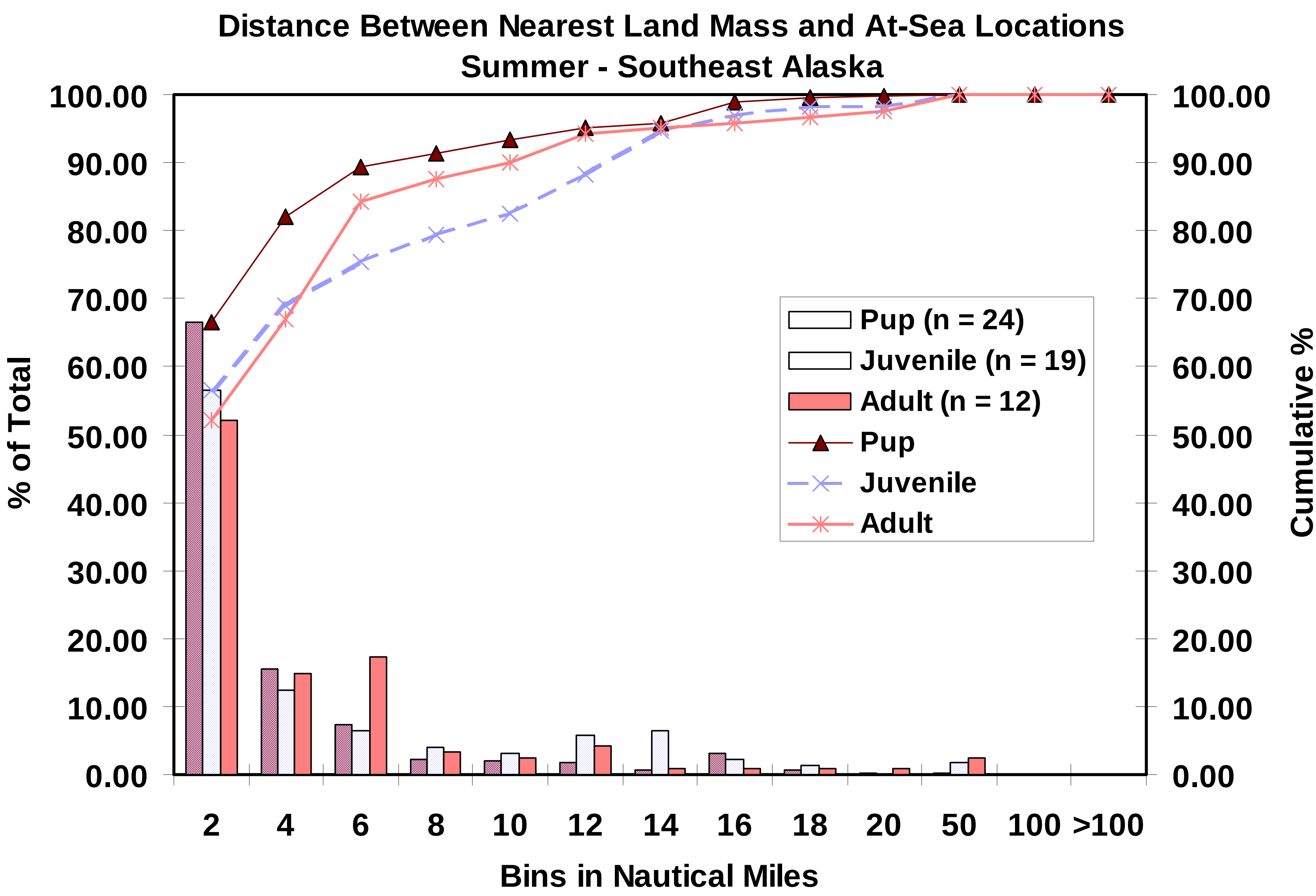


Winter 2000 Alaska Trip Distances
n=8

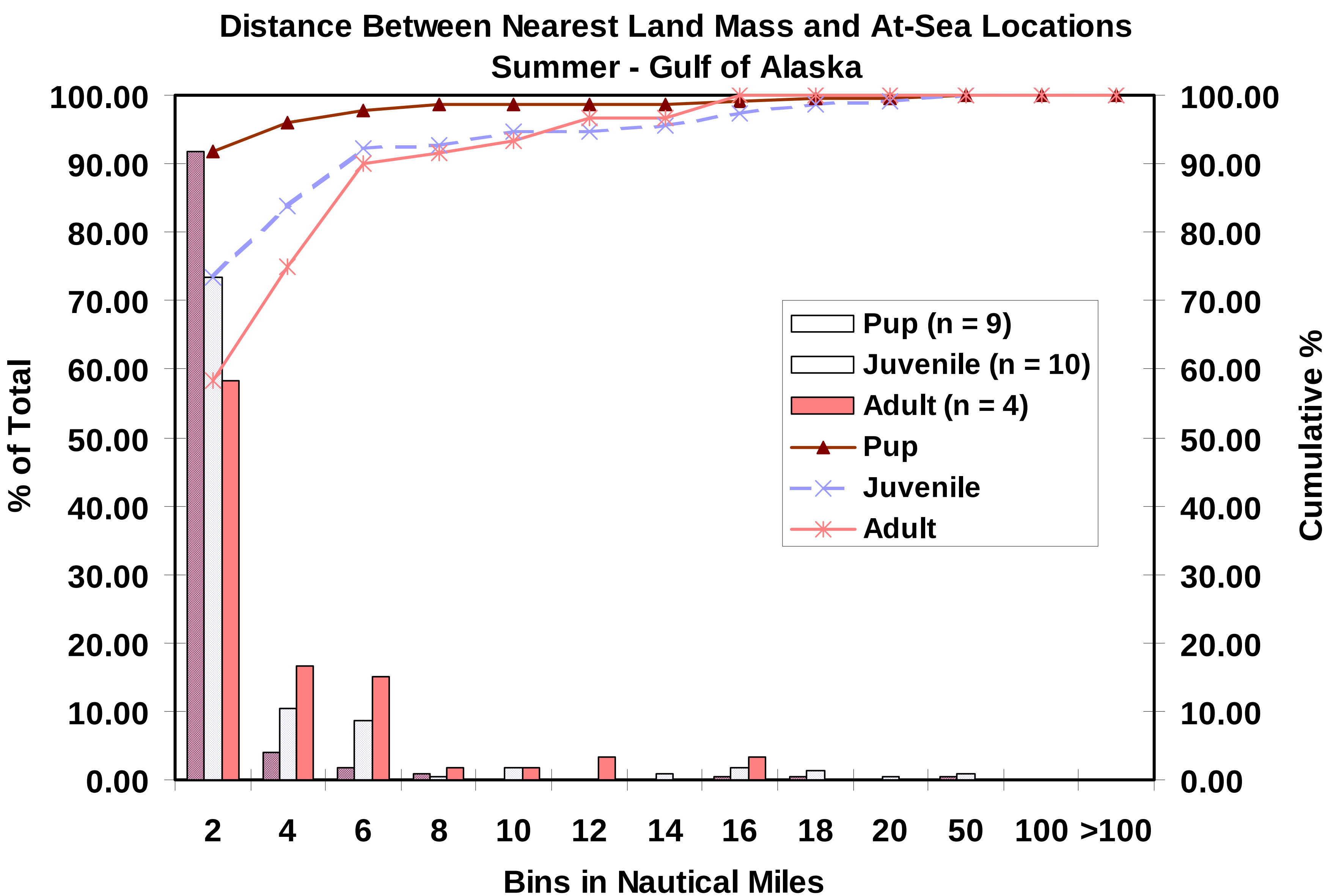



Winter 2001 Kodiak Deployments
Currently Tracking 10 SSL's
Latax Rocks
Sea Otter
Cape Ugat
Long Island
Kodiak
Yellow Dots = Deployment Site
All Other Colors Represent Individual
Sea Lions

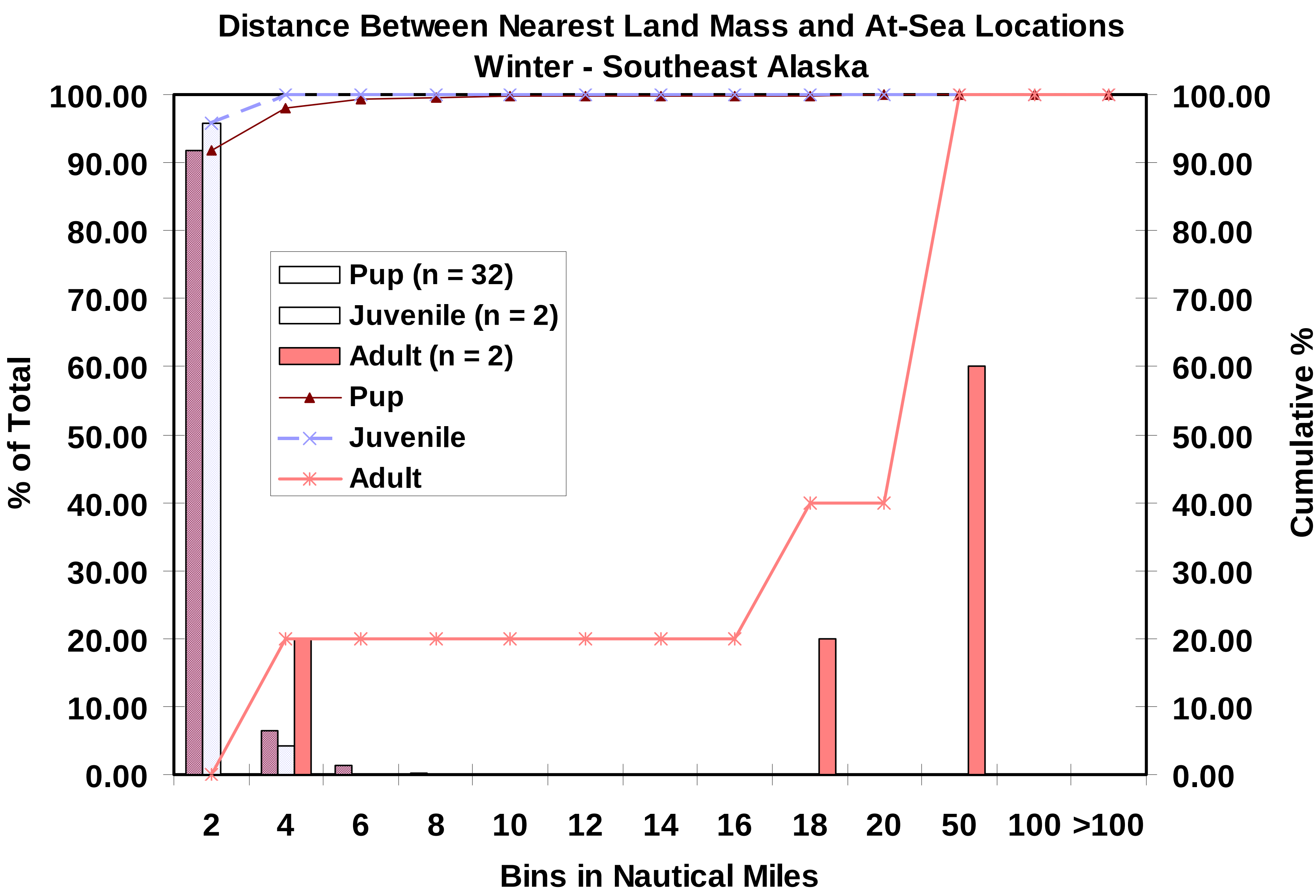

Winter 2001 SDR Deployments
Currently Tracking 10 SSL's
Deployed In Unimak Pass
Unimak Island
Billingshead
Reef Bite
Bird Island
Aiktak
Unalaska
Rocks Off Tigalda
Yellow Dots = Deployment Site
All Other Colors Represent Individual
Sea Lions



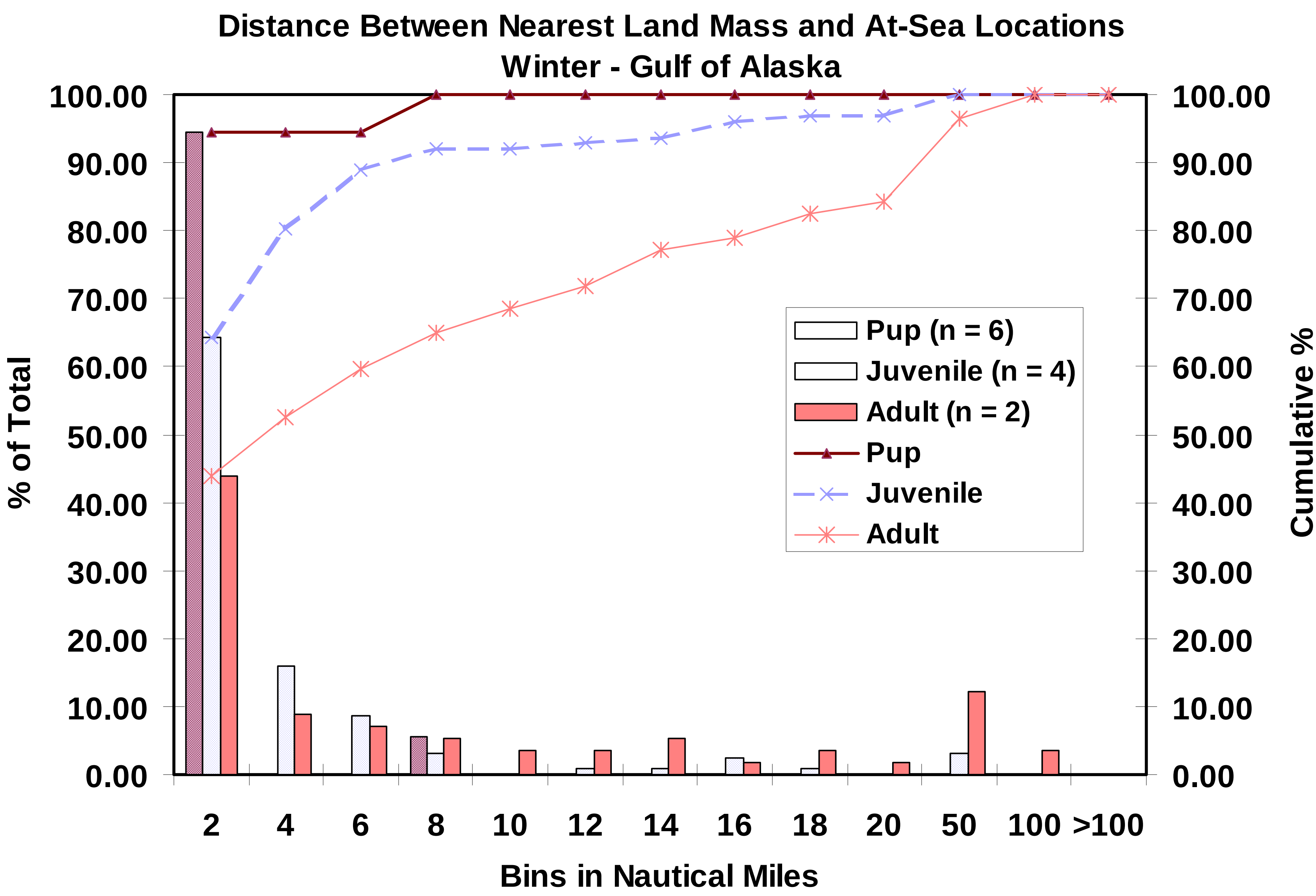
Distance Between Nearest Land Mass and At-Sea Locations
Summer - Southeast Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles
Pup (n = 24)
Juvenile (n = 19)
Adult (n = 12)
Pup
Juvenile
Adult



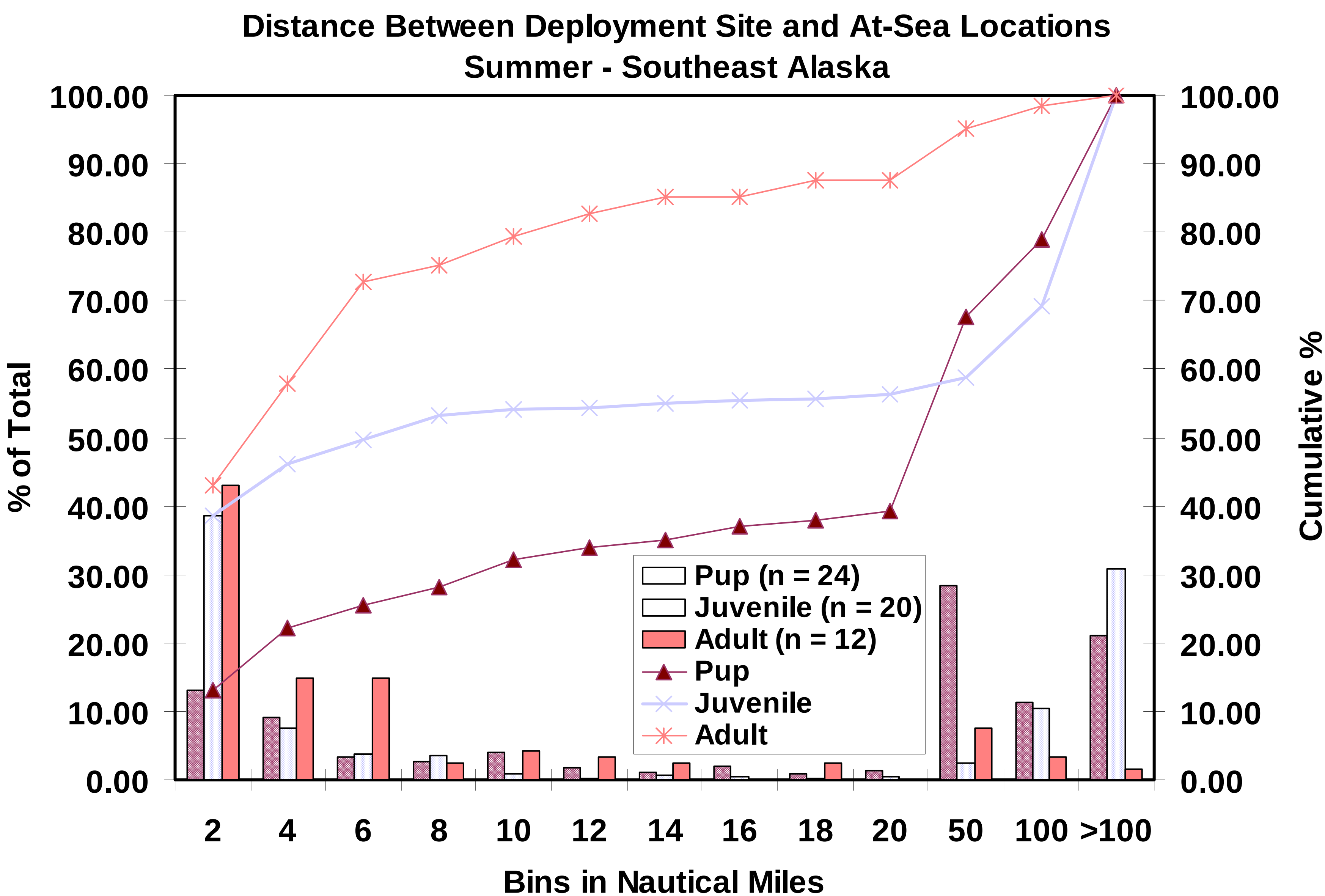
Distance Between Nearest Land Mass and At-Sea Locations
Summer - Gulf of Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles
Pup (n = 9)
Juvenile (n = 10)
Adult (n = 4)
Pup
Juvenile
Adult

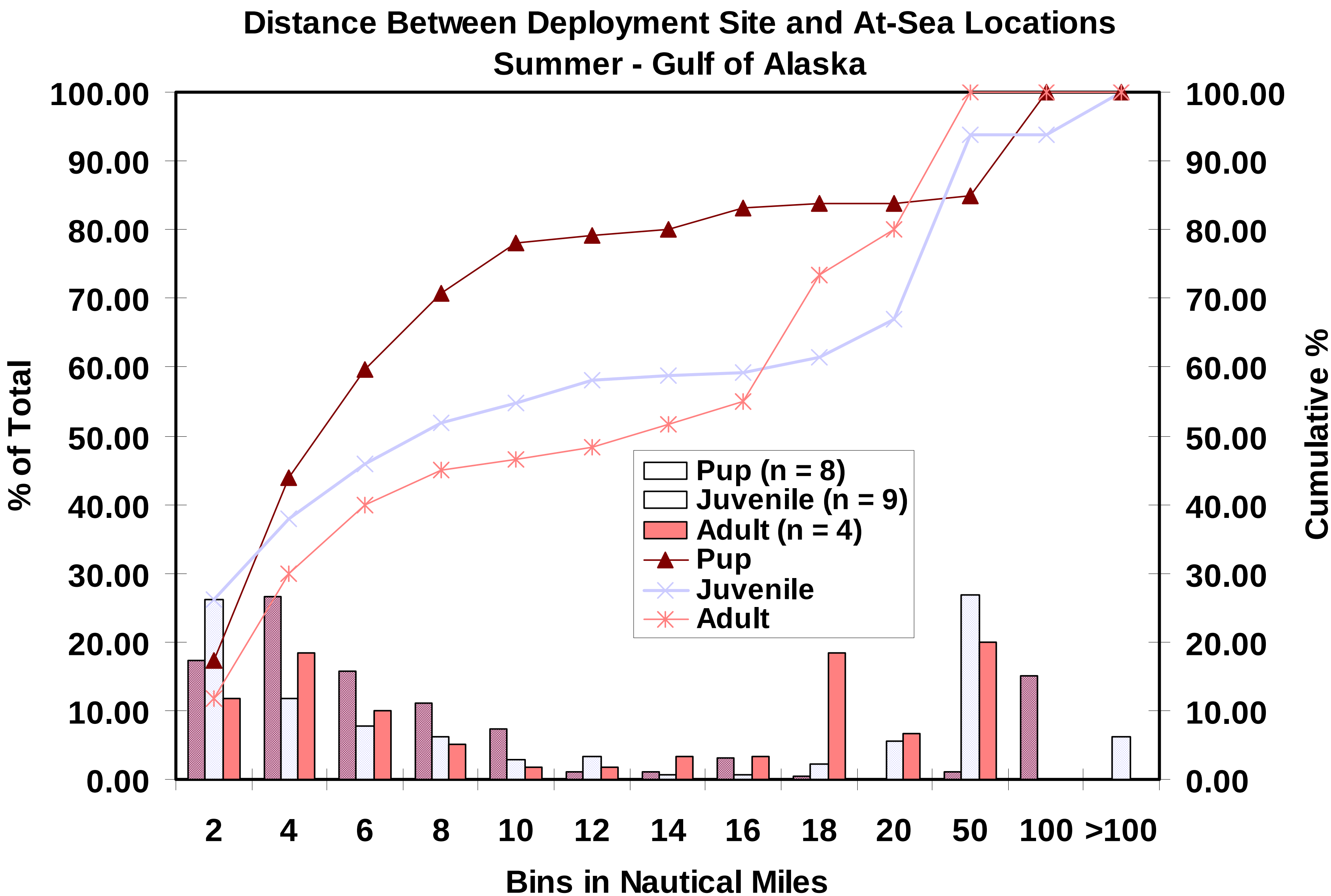


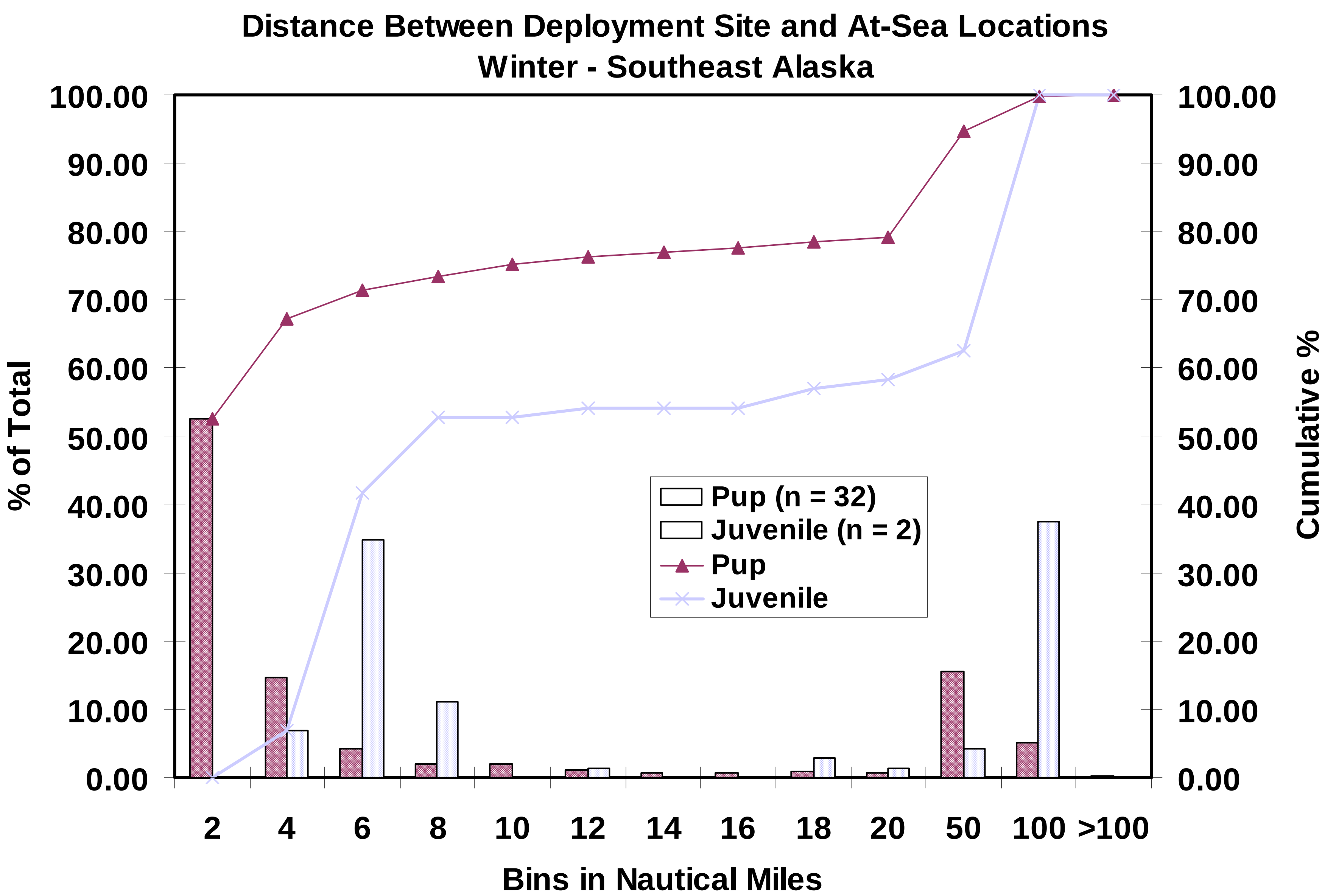
Distance Between Nearest Land Mass and At-Sea Locations
Winter - Southeast Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Pup (n = 32)
Juvenile (n = 2)
Adult (n = 2)
Pup
Juvenile
Adult
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles



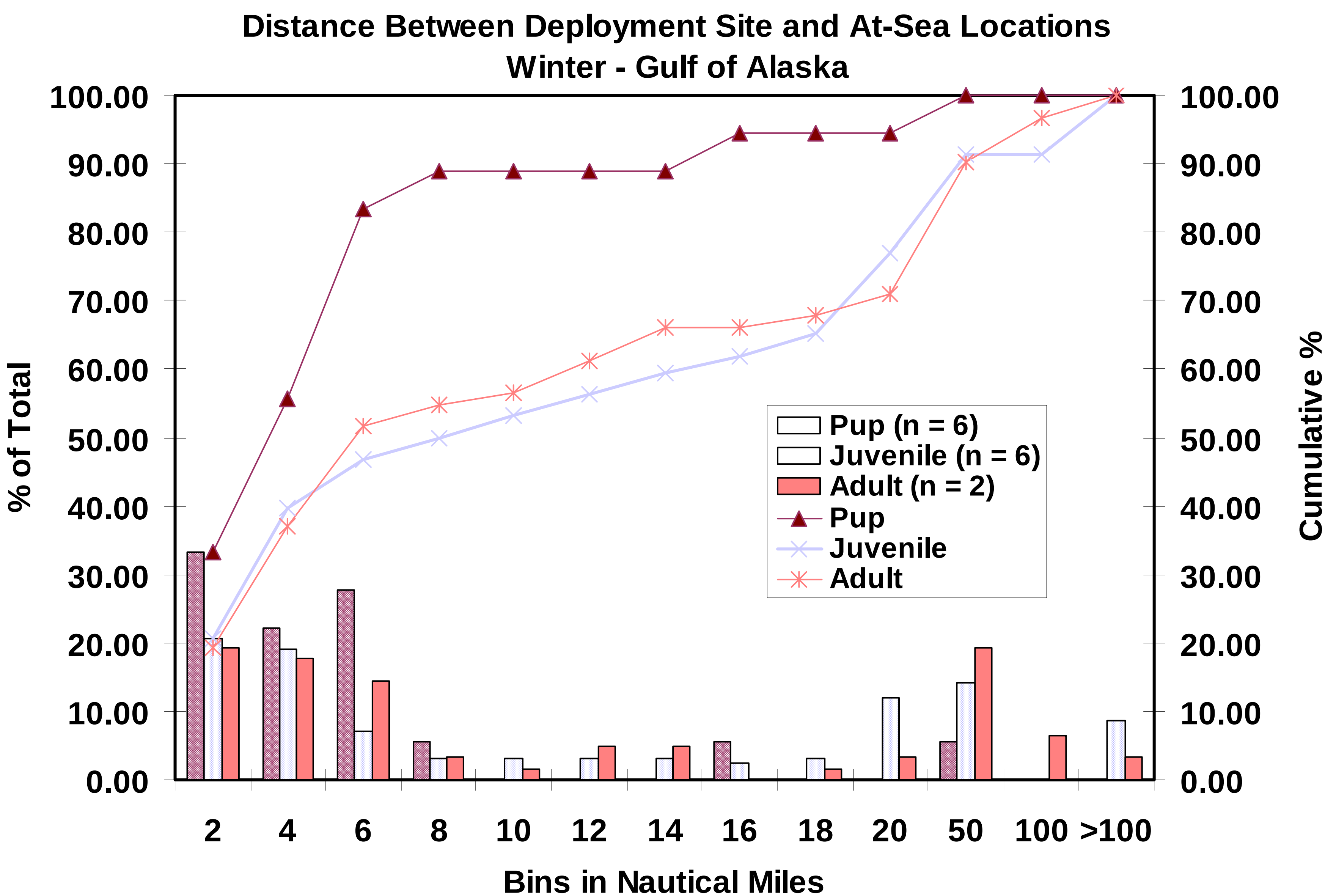
Distance Between Nearest Land Mass and At-Sea Locations
Winter - Gulf of Alaska
% of Total
Cumulative %
Bins in Nautical Miles
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n = 6)
Juvenile (n = 4)
Adult (n = 2)
Pup
Juvenile
Adult

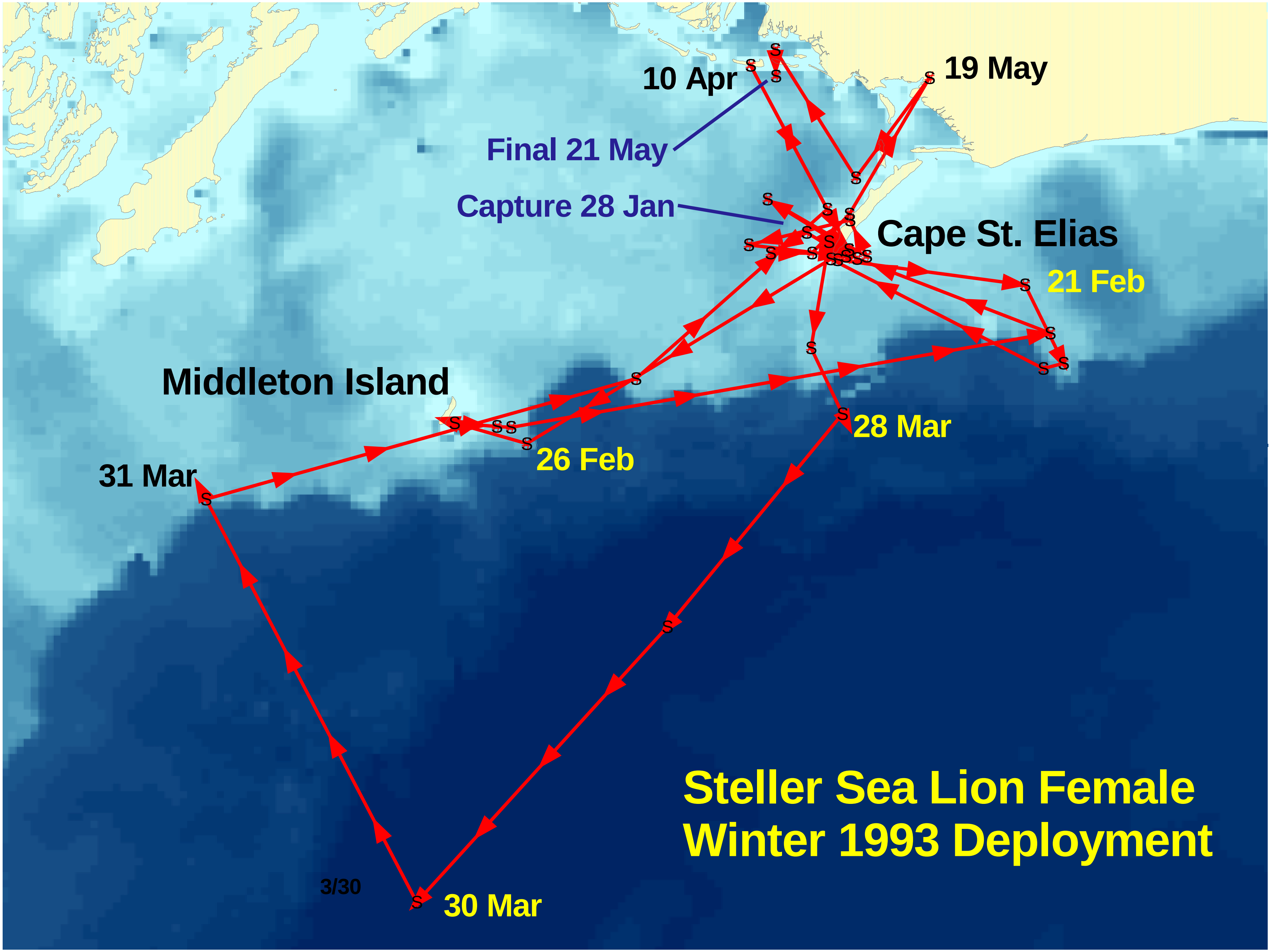

Distance Between Deployment Site and At-Sea Locations
Summer - Southeast Alaska
% of Total
Cumulative %
Bins in Nautical Miles
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Pup (n = 24)
Juvenile (n = 20)
Adult (n = 12)
Pup
Juvenile
Adult


Distance Between Deployment Site and At-Sea Locations
Summer - Gulf of Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles
Pup (n = 8)
Juvenile (n = 9)
Adult (n = 4)
Pup
Juvenile
Adult



Distance Between Deployment Site and At-Sea Locations
Winter - Southeast Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Pup (n = 32)
Juvenile (n = 2)
Pup
Juvenile
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles


Distance Between Deployment Site and At-Sea Locations
Winter - Gulf of Alaska
% of Total
Cumulative %
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Pup (n = 6)
Juvenile (n = 6)
Adult (n = 2)
Pup
Juvenile
Adult
2
4
6
8
10
12
14
16
18
20
50
100
>100
Bins in Nautical Miles


10 Apr
19 May
Final 21 May
Capture 28 Jan
Cape St. Elias
21 Feb
Middleton Island
28 Mar
26 Feb
31 Mar
Steller Sea Lion Female
Winter 1993 Deployment
3/30
30 Mar