OCS Study
MMS 93-0026

STATUS AND PELAGIC DISTRIBUTION OF OTARIID PINNIPEDS IN THE BERING SEA DURING WINTER

by

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funded by

Environmental Studies Section
Minerals Management Service
Alaska OCS Region
Anchorage, AK 99508

using Interagency Agreement number IA-14411

March 1993

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This study was funded in apart by the U. S. Department of the Interior, Minerals Management Service (MMS), through Interagency Agreement No. 14411 with the U. S. Department of Commerce, National Marine Fisheries Service, National Marine Mammal Laboratory, as part of the MMS Alaska Environmental Studies Program.

March 1993

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TABLE OF CONTENTS

	Page
Chapter 1. Review of information on the status of northern fur seals and Steller sea lions and their use of the Bering Sea in winter.	
Status and trends	1
Distribution	3
POP data base	6
Acknowledgments	7
References	8
Figures 1-1...1-6	12
Chapter 2. Use of the Bering Sea during winter by northern fur seals and Steller sea lions using satellite-linked telemetry.	
Abstract	18
Introduction	19
Materials and Methods	20
Results	22
Discussion	26
Acknowledgments	29
References	30
Tables 2-1...2-5	33
Figures 2-1...2-9	38
Chapter 3. Blood chemistry and body condition of Steller sea lion pups at Marmot Island, Alaska	
Abstract	50
Introduction	50
Materials and Methods	51
Results	53
Discussion	54
Acknowledgements	54
References	55
Table 3-1	57
Figure 3-1	58

Chapter 1

REVIEW OF INFORMATION ON THE STATUS OF NORTHERN FUR SEALS AND STELLER SEA LIONS AND THEIR USE OF THE BERING SEA IN WINTER

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The following text on status, trends, and distribution for northern fur seals and Steller sea lions in Alaska was summarized from reports/plans published or in press prepared by the National Marine Fisheries Service. Most of the information is from the draft Conservation Plan for Northern Fur Seals (NMFS 1993) and the Final Steller Sea Lion Recovery Plan (NMFS 1992). Also included is a section titled "POP data base" which summarizes observations of both pinniped species in the Bering Sea from October to February 1971-91. The purpose of this review is to summarize from existing sources the winter pelagic distribution of northern fur seals and Steller sea lions on the Alaskan outer continental shelf.

STATUS AND TRENDS

Northern fur seals

The abundance of fur seals on the Pribilof Islands has fluctuated dramatically since their discovery in 1786 (Roppel 1984). The stock is thought to have been at peak abundance of perhaps 2-3 million in the early to mid-1800s, and at its lowest in the first decade of the 20th century. The greatest decline occurred in the last half of the 1800s and early 1900s because of the commercial harvest, especially of pregnant females. Females were not taken from 1917 to 1955. The period of greatest recovery occurred between 1912 and 1940, when the stock increased from perhaps 300,000 (Lander 1980) to a peak this century of just under 2 million. In 1912, approximately 67,000 pups were born compared with about 469,000 in 1940 (Fowler 1985).

By the early 1940s the rate of population growth of about 8% per year began to slow and leveled off until 1956. The abundance in the early 1950s was estimated by Kenyon et al. (1954) to be 1.8 million and may have been at or close its carrying capacity under a limited commercial harvest for juvenile males. Subsequent analyses by Chapman (1964), Lander (1981), and York (1987b) estimated that, between the early 1940s and 1956, about 450,000-470,000 pups were born annually.

From 1956 to 1968 the Pribilof stock was once again reduced when approximately 23,000 females were harvested annually. The female hunt was terminated in 1968 and the stock again increased between 1970 and 1976. In 1974, the stock was estimated to be 1.25 million with about 326,000 pups born on both Pribilof Islands (Lander 1981). Between 1976 and 1984, the stock began to decline, with pup production declining at a rate of 6.5% to 7.8% per year (York 1987a). The total stock estimate in 1983 was estimated at 877,000 (Briggs and Fowler 1984). Between 1981 and 1990, the number of pups born on the Pribilof Islands has not changed significantly, suggesting that the current stock size has not changed (York and Fowler 1992). The 1992 stock estimate for the Pribilof Islands is 982,000 (Antonelis et al. in review).

<u>Steller sea lion</u>

A total of 36,459 adult and juvenile sea lions were counted in 1991 at 103 trend sites in the area from southeast Alaska through the western Aleutian Islands. This is a decrease of 4.4% from the 38,154 animals counted in the same area in 1990 (Merrick et al. 1992). During 1976-79, 116,804 animals were counted at the trend sites, a decrease to 1991 of 68.8%.

The Kenai to Kiska index area includes the major component of the Steller sea lion population in Alaska. A total of 21,737 animals (59.6% of the total Alaska population) were counted at the 77 trend sites in 1991, a 4.5% decrease from 1990 (22,754). This 61.1% decrease (14.6% per year) from the 55,824 animals counted in 1985 was statistically significant ($r = 0.966$, $P = 0.034$). This was also a significant decline of 75.7% ($r = 0.998$, $P < 0.0001$) from the 89,364 animals counted at the sites during the mid 1970s.

A total of 6,273 sea lions (29% of the total) were counted in 1991 in the central Gulf of Alaska, 3,734 (17%) in the western Gulf of Alaska, 4,231 (19%) in the eastern Aleutian Islands, and 7,499 (35%) in the central Aleutian Islands. Declines are continuing in much of the Gulf of Alaska. However, numbers in the Aleutian Islands did not show a downward trend during 1989-91.

Three other areas were censused in 1991 outside of the Kenai to Kiska area--southeast Alaska, eastern Gulf of Alaska, and western Aleutian Islands. From 1990 to 1991, numbers in southeast Alaska and the western Aleutian Islands remained relatively constant; however, numbers dropped by 15.6% in the eastern Gulf of Alaska. Since 1979, southeast Alaska numbers have increased by 21.0% (from 6,376 to 7,715), although the trend was not statistically significant.

Numbers in the eastern Gulf of Alaska decreased by 15.6% from 1990 to 1991 (from 5,444 to 4,596) and by 34.8% since 1976 (7,053). The trend from 1976 to 1991 was not significant (r = 0.602, P = 0.398); however, the trend from the 7,241 animals counted in 1989 was significant (r = 0.990, P = 0.092).

Western Aleutian Island numbers increased slightly in 1990, but decreased 82.8% (14,011 to 2,411) from 1979 to 1991. The western Aleutian Islands trend since 1979 was significant (r = 0.996, P = 0.059). This pattern follows that of the other Aleutian Island subareas.

The estimated world population of Steller sea lions in 1989 was 90,633 non-pups and 25,891 pups (Loughlin et al. 1992). This total of 116,524 animals was 39-48% of the 240,000-300,000 pups and non-pups estimated 30 years ago (Kenyon and Rice 1961).

The Alaskan population in 1989 was estimated to include 63,823 nonpups (Loughlin et al. 1992). Of this total, 19,033 were in the Aleutian Islands, 887 in the Bering Sea, 31,600 in the Gulf of Alaska, and 12,303 in southeastern Alaska. An additional 5,357 nonpups were in Oregon-California (most of the Washington animals probably migrate from this group of animals or from British Columbia).

DISTRIBUTION

Northern fur seals

Northern fur seals are endemic to the North Pacific Ocean and occur from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan. At least five separate populations are recognized. During the breeding season approximately 74% of all fur seals are found on the Pribilof Islands in the southern Bering Sea, 15% are on the Commander Islands in the western Bering Sea (Russia), 9% are on Robben Island in the Okhotsk Sea (Russia), <2% are on the Kuril Islands in the western North Pacific Ocean (Russia), and <1% are on San Miguel Island off southern California (Lander 1980; Lander and Kajimura 1982). A small colony of fur seals also occurs on Bogoslof Island in the southern Bering Sea (Loughlin and Miller 1989).

Northern fur seals were first discovered in 1786 on the Pribilof Islands. They were discovered to have colonized San Miguel Island, California, in the late 1950s or early 1960s (Peterson et al. 1968). The latest rookery to be discovered was in 1976 on Bogoslof Island (53°56'N, 168°02'W) in the southern Bering Sea (Fiscus 1983). Two pups were first observed in 1980 (Lloyd et al. 1981). The rookery contained 11-13 pups and 18 adult females (78 total animals) in August 1983, and by July 1989 the rookery had increased to 99 pups and 132 adult females (719 total animals) (Loughlin and Miller 1989). Northern fur seals temporarily haul-out onto land at other sites in Alaska, British

Columbia, Canada, and on islets along the coast of the continental United States, but generally only outside the breeding season.

The breeding season lasts about 5 months between June and November and the next 7 months are spent at sea foraging. After pupping and mating, adult females from the Pribilof Islands migrate south through passes in the Aleutian Islands into the North Pacific Ocean. Adult males generally migrate only as far south as the Gulf of Alaska in the east and to northern Japan on the west (Kajimura 1984; Chapter 2). Most pups also travel through Aleutian Islands passes after leaving their birth islands (Ragen 1991) and remain at sea in the North Pacific Ocean before returning to where they were born as two or three-year-olds. The timing of reproduction on San Miguel Island is essentially the same as on the Pribilof and Bogoslof Islands. Fur seals from San Miguel Island spend their winter months feeding at sea in the eastern North Pacific Ocean. The timing and location of feeding by fur seals from Bogoslof Island are unknown, but are presumed to be the same as fur seals from the Pribilof Islands.

We know relatively little about northern fur seal movements at sea and habitat use patterns and it is difficult to locate and follow fur seals at sea. The Pribilof Islands are essential for pupping and mating, and the surrounding feeding grounds out to at least 200-300 km of the Islands are especially important for lactating females (Loughlin et al. 1987; Goebel et al. 1991). Passageways between the Aleutian Islands are also critical for their annual migration between the Bering Sea and North Pacific Ocean (Bigg 1990; Kiyota et al. 1992; Ragen 1990; Chapter 2).

The continental shelf and shelf break from the Bering Sea to California are essential as feeding grounds while some fur seals are at sea. Highest fur seal densities in the open ocean occur in association with major oceanographic features such as sea mounts, valleys, canyons and along the continental shelf break (Lander and Kajimura 1982; Kajimura 1984; Kajimura and Loughlin 1988). It should be noted that principal prey of fur seals may be concentrated or most accessible in such areas and the association may be due to biological, rather than physical factors. Many fur seals (presumably juveniles) have been seen far out to sea even during the breeding season (Zeusler 1936; NMML unpublished data). Nonetheless, there are insufficient data to judge specifically which areas are critical for their survival.

Steller sea lions

The present range of Steller sea lion extends around the North Pacific Ocean rim from the Kuril Islands and Okhotsk Sea, through the Aleutian Islands and southern Bering Sea, along Alaska's southern coast, and south to California (Kenyon and Rice

1961; Loughlin et al. 1984). The centers of abundance and distribution are the Gulf of Alaska and Aleutian Islands. Seal Rocks in Prince William Sound, Alaska, represents the northern-most rookery (60°09'N) and Año Nuevo Island off central California is the southern-most rookery (37°06'N). Most large rookeries are in the Gulf of Alaska and Aleutian Islands (Kenyon and Rice 1961; Calkins and Pitcher 1982; Loughlin et al. 1984; Merrick et al. 1987). A 1989 range-wide survey found 15% of the population in Russia, 70% in Alaska, 9% in British Columbia, and 6% in Oregon and California. (Loughlin et al. 1992)

Rookeries are dispersed from the central Kuril Islands (46°N) to southern California (37°N). Most large rookeries are in southeast Alaska, the Gulf of Alaska, and Aleutian Islands (Calkins and Pitcher 1982; Kenyon and Rice 1961; Loughlin et al. 1992). Steller sea lions are not known to migrate but disperse widely during the postbreeding season and may occur near ice or northern islands in the Bering Sea during fall and winter (Kenyon and Rice 1961; Loughlin et al. 1984; and see below). Animals branded at rookeries in the central Gulf of Alaska have been sighted as far away as the eastern Aleutian Islands, southeast Alaska and British Columbia. Animals marked in Oregon were also seen from northern California to southeast Alaska.

Steller sea lion habitats include marine and terrestrial areas that are used for a variety of purposes. The most well described are the rookeries where adult animals congregate for pupping and breeding from late May to early July. Rookeries are found on the beaches of relatively remote islands, often in areas exposed to wind and waves. Substrates include sand, gravel, cobble, boulder, and bedrock. The rookery may extend across low-lying reefs and islands, or may be restricted to a relatively narrow band by steep cliffs. Rocky points may divide the animals using an area into subgroups.

Sea lions climb steep rocks and sometimes haul out many meters above the water; on rookeries they tend to use relatively level areas above the high tide line. Females appear to select certain places for giving birth that are gently sloping, protected from waves and sun, easy to defend from other animals, and some distance away from territories being defended by adult males (Sandegren 1970). Pups normally stay on land for about two weeks, then spend an increasing amount of time in intertidal areas and swimming nearshore.

While at sea, Steller sea lions frequently are seen near shore and out to the edge of the continental shelf; in the Gulf of Alaska they commonly occur near the 200 m depth contour (Kajimura and Loughlin 1988; Chapter 2). They have been caught on fishing lines at depths of 183 m (Kenyon 1952; Fiscus and Baines 1966). Some individuals may enter rivers in pursuit of prey (Jameson and Kenyon 1977).

During the breeding season adult females remain on land during the day and feed principally at night; territorial males remain on land and fast during the breeding season (Gentry 1970; Sandegren 1970; Spalding 1964; Withrow 1982). Research conducted on foraging behavior of sea lions utilizing a satellite-linked time-depth recorder showed seasonal differences in foraging trips (Merrick et al. in press; Chapter 2). Results of these studies indicated that during summer, females with pups foraged close to rookeries, and made relatively short trips with shallow dives. In winter females had much longer trips and dove deeper than summer animals. (Merrick et al., in press).

POP DATA BASE

The Platforms of Opportunity Program data base (POP) was upgraded in 1975 (but uses data collected back to 1962) to meet the objectives of the U.S. Outer Continental Shelf Environmental Assessment Program and is summarized by Boucher and Boaz (1989). Since then the program has solicited and collected marine mammal sightings from observers aboard various types of vessels from the government and private sector. All sources use the same sighting forms. Observers are cautioned that if their description of a given species is judged inadequate for verifying the sighting, the sighting may be classified as "unidentified." None of the sightings used in this report include unidentified sightings.

All users of the POP data base, and those reading reports using the data base, must recognize the biases associated with the sightings. In most cases the sightings represent opportunistic observations while vessels are underway. There are no effort or distance data collected at the time of the sighting and the observations are, in most cases, not part of a rigorous line-transect study from which density or abundance estimates can be calculated. The observation represents only where the animal was at that point in time. Animals not identified in certain areas does not mean they do not occur there; the data base can only include areas where there were ships with observers. Thus, in the figures to follow, the lack of sightings of either fur seals or sea lions in parts of the Bering Sea during any month (eg., January) could either represent an actual absence of animals or an absence of vessels from which observations could be made.

Sightings of northern fur seals are presented in Figs. 1-1 to 1-3 for all years from 1971-1991. Each sighting represents a single seal. The highest number of northern fur seal sightings occurred in October and the least in December and January. Sightings during October and November in the Bering Sea were primarily over shallow water and along the continental shelf break northwest and southeast of the Pribilof Islands. During December and January most sightings were in the south central

Bering Sea over deep water. Sightings in February were similar to November and primarily north of the Pribilof Islands. It is possible that the February sightings were in association with the ice edge. The relatively low number of fur seal sightings in the Bering Sea supports reports that most fur seals move out to the region in the winter (summarized by Bigg 1990). Due to the limitations of the data collection, it is not possible to reliably determine the sex of fur seals sighted from POP vessels. Available historical records indicate, however, that more males tend to remain in Alaskan waters with increasing age (Bigg 1990).

Steller sea lions observed during October to February are shown in Figs. 1-4 to 1-6. In all years, more sea lions were sighted from ships than for fur seals. Sea lions were seen during all months along the shelf break in the Gulf of Alaska. During October and November observations of sea lions were primarily along the continental shelf and in shallow waters of the southeastern Bering Sea. They were also seen in other areas, but their numbers tended to be a progressively higher in the central Bering Sea during December to February. The tendency for sea lions to occur in deeper water during the winter may be associated with the movement of walleye pollock (Theragra chalcograma) and other potential forage fishes (U. S. Department of Interior 1987; Pola 1985).

ACKNOWLEDGMENTS

J. Lerczak conducted the POP data search and prepared the figures. Staff at the National Marine Mammal Laboratory collected and summarized most of the information for the reports/plans summarized in this review. Principal staff at NMML includes G. Antonelis, H. Braham, J. Baker, K. Chumbley, R. DeLong, C. Fowler, R. Gentry, M. Goebel, R. Merrick, E. Sinclair, and A. York.

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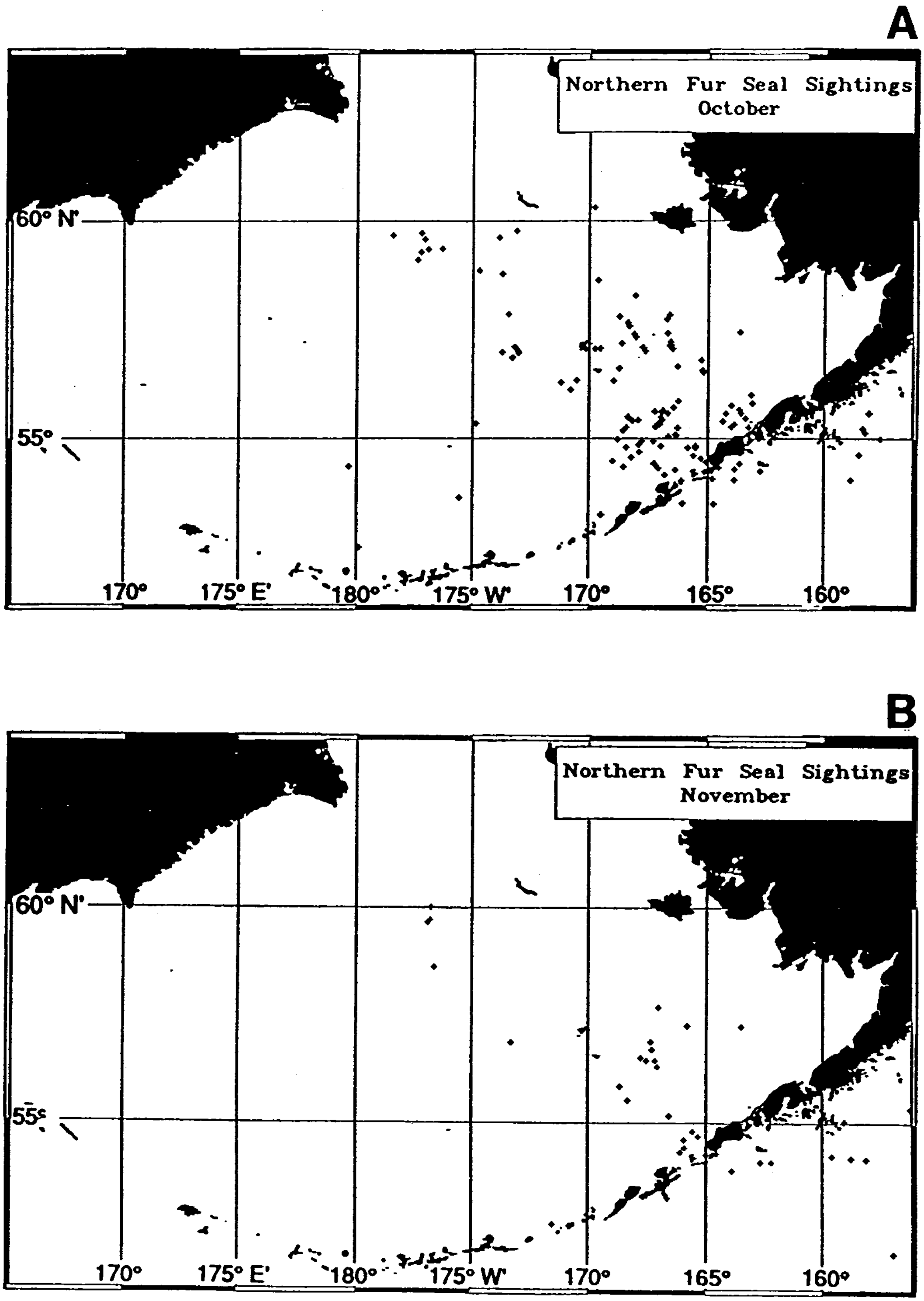


Figure 1-1. Plot of the Platforms of Opportunity data base for northern fur seals for October (A) and November (B). All sightings for the years 1971-91 are combined. Each (+) represents one sighting.

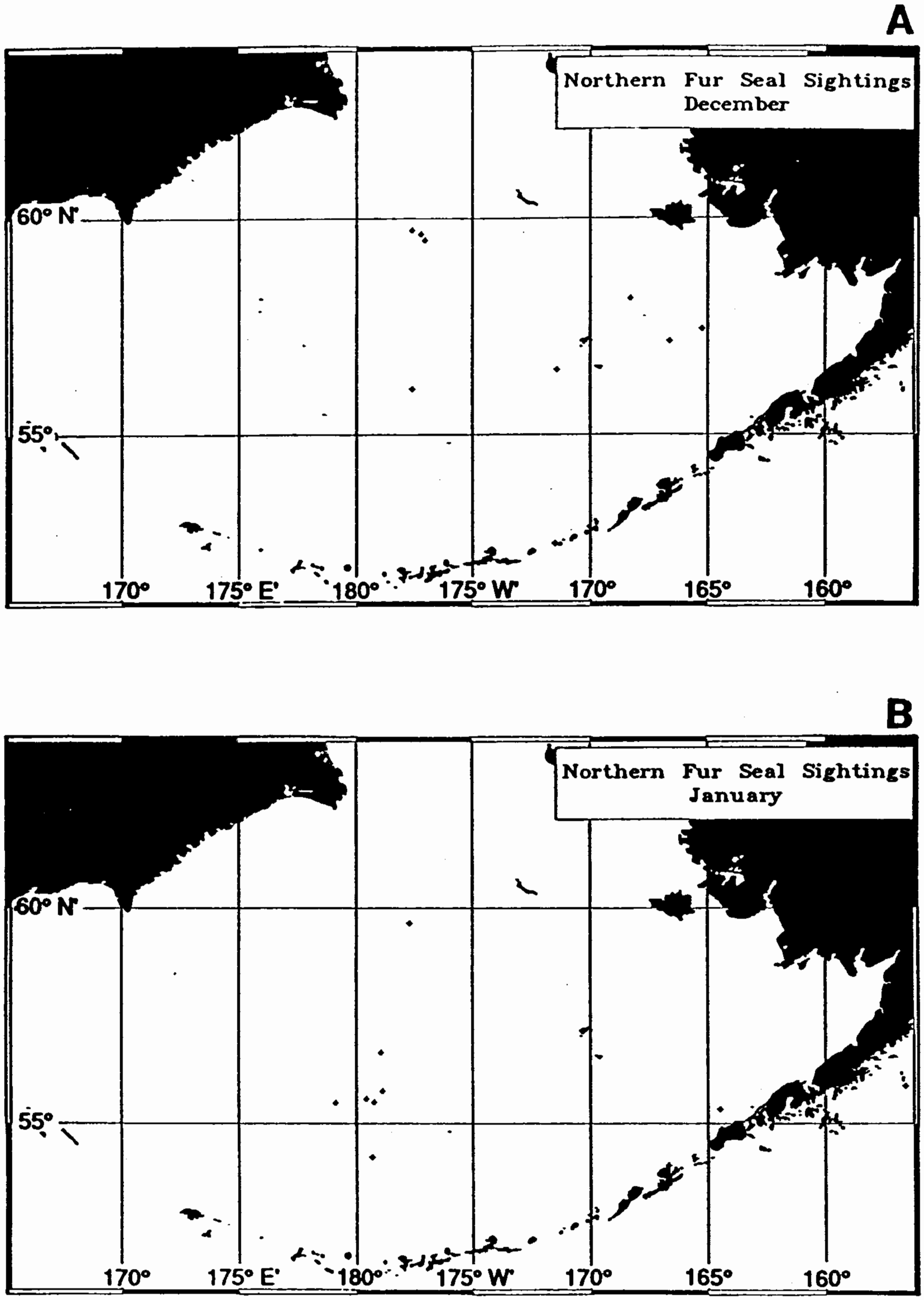


Figure 1-2. Plot of the Platforms of Opportunity data base for northern fur seals for December (A) and January (B). All sightings for the years 1971-91 are combined. Each (+) represents one sighting.

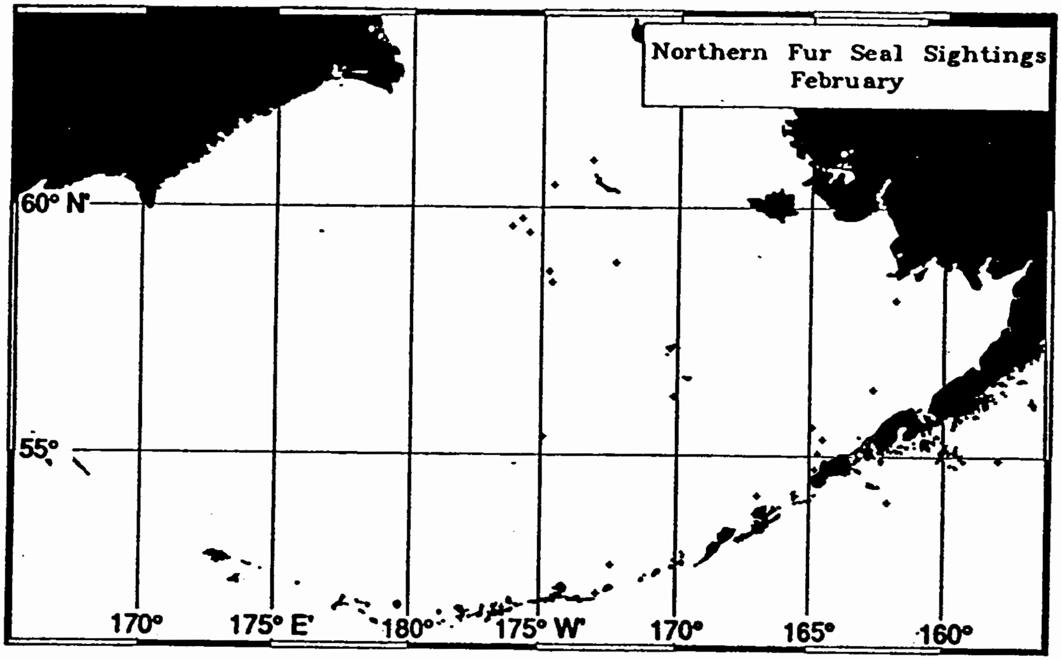
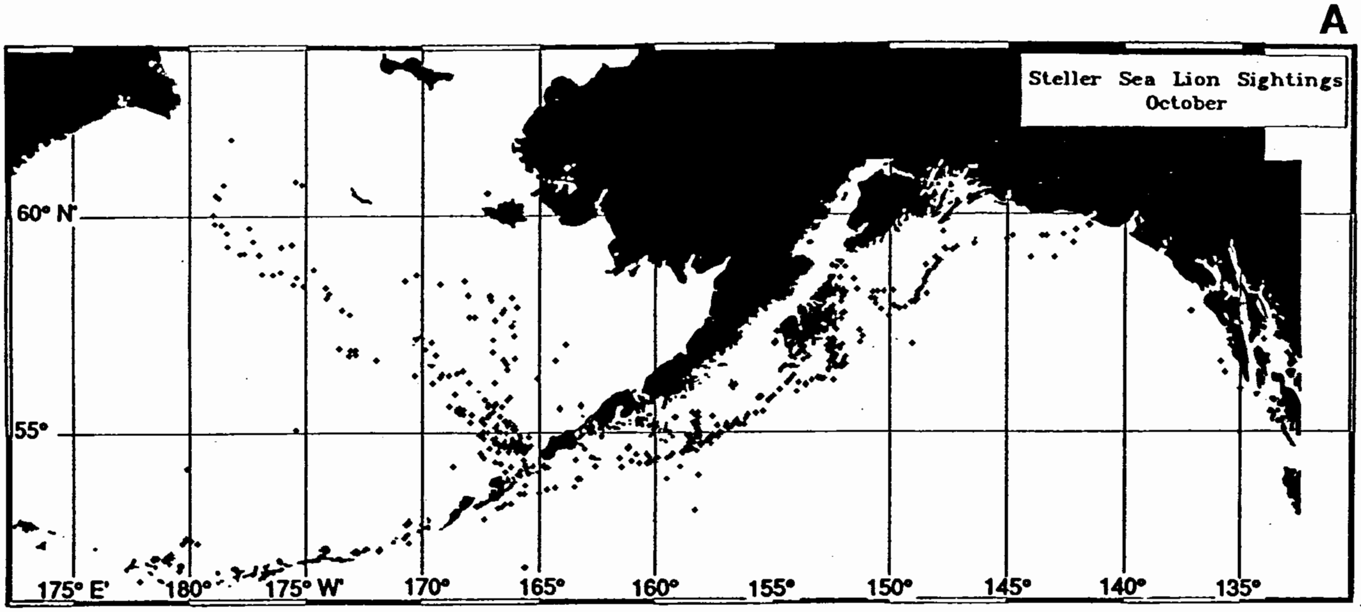


Figure 1-3. Plot of the Platforms of Opportunity data base for northern fur seals for February. All sightings for the years 1971-91 are combined. Each (+) represents one sighting.



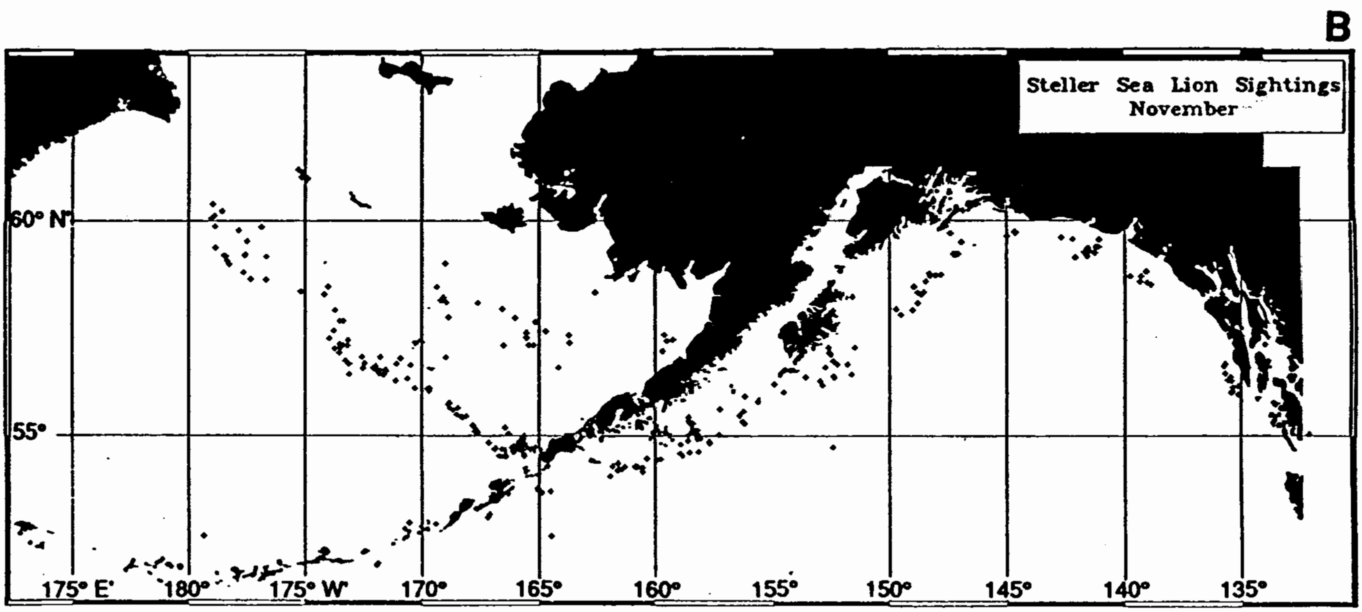
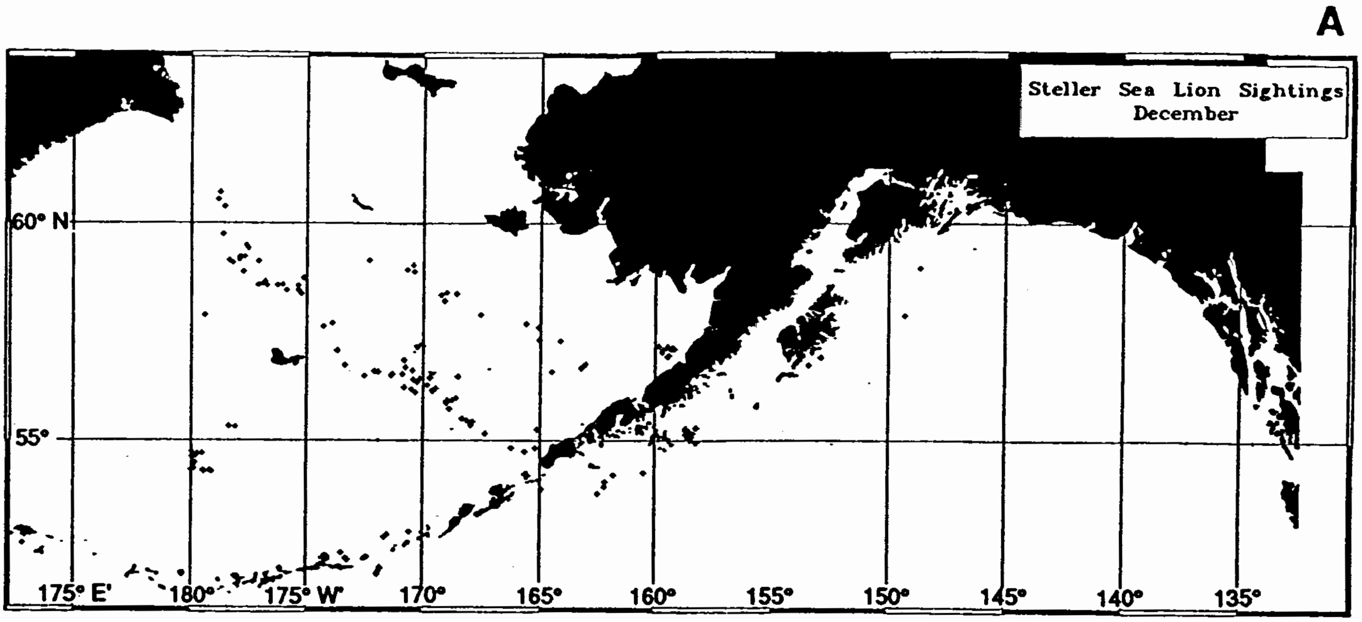


Figure 1-4. Plot of the Platforms of Opportunity data base for Steller sea lions for October (A) and November (B). All sightings for the years 1971-91 are combined. Each (+) represents one sighting.



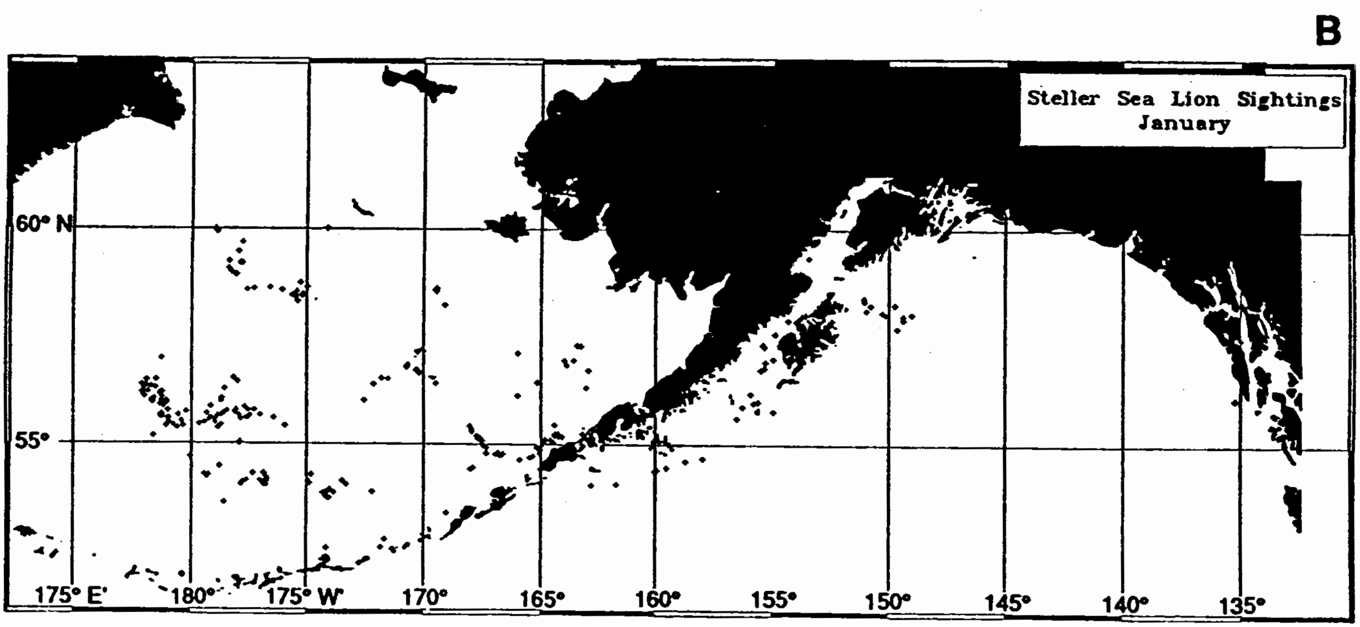


Figure 1-5. Plot of the Platforms of Opportunity data base for Steller sea lions for December (A) and January (B). All sightings for the years 1971-91 are combined. Each (+) represents one sighting.

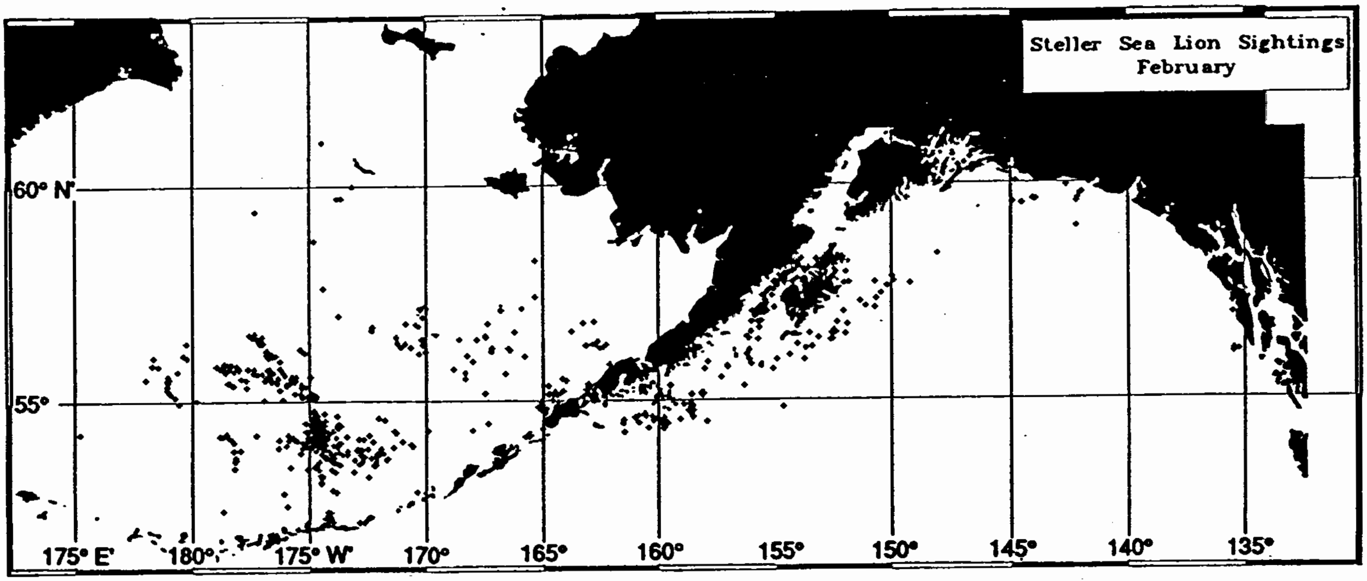


Figure 1-6. Plot of the Platforms of Opportunity data base for Steller sea lions for February. All sightings for the years 1971-91 are combined. Each (+) represents one sighting.

Chapter 2

USE OF THE BERING SEA DURING WINTER BY NORTHERN FUR SEALS AND STELLER SEA LIONS USING SATELLITE-LINKED TELEMETRY

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ABSTRACT

We studied foraging ecology and movements of northern fur seals (Callorhinus ursinus) and Steller sea lions (Eumetopias jubatus) during winter to characterize pelagic areas of importance. Data on location at sea and dives (depth and duration) were collected by satellite-linked time-depth recorders (SLTDR) glued to the backs of fur seals and sea lions and monitored during October to November 1991 and 1992. A total of 22 SLTDRs were deployed, 14 on male fur seals and four each on adult female and pup Steller sea lions. Once at sea male fur seals utilized oceanic areas and the outer domain of the continental shelf of the Bering Sea from about St. Matthew Island south and from about the 100 m isobath on the continental shelf west to Shirshov Ridge in the western Bering Sea. They left the Bering Sea usually by January and fed either in the eastern Pacific Ocean and Gulf of Alaska or to the west off the Kuril Islands and Japan. The mean duration in the Bering Sea after SLTDR attachment was 30.3 days (n = 8, sd = 12.3 days). Steller sea lions generally stayed within 60 km of the haulout site but were capable of movements >300 km. Sea lion foraging locations were over the continental shelf (<200 m), although infrequent sorties occurred into deeper water. Adults foraged both to the north and south of Unimak Island.

Male northern fur seal dives (83%) were between 4 and 100 m and the remaining 17% between 101 and 350 m. No dives was >350 m. Sixty eight percent of all dives were between 4 and 50 m and 14% were between 51 and 100 m. Only 2.5% of the dives were greater than 250 m. Dive duration was <6 minutes (90%), with 43% being 1 min or less and <1% over 11 min. Steller sea lion adult females (n = 3) dove to significantly deeper depths ($\bar{x}$ = 23.4 m; t = 2.015, df = 5) than pups (n = 4, $\bar{x}$ = 7.8 m). A greater proportion of dives by pups (88.8%) were in the 4-10 m range than for adult females (46.1%); there were no dives by pups >50 m,

while adult animals dove close to 200 m. Mean dive depth for all dives >10 m for pups was 17.1 m, and for adult females it was 46.3 m. Both pups and adults can dive longer than 6 min, but the proportion of dives by pups less than one minute (75%) was significantly greater than for adults (34.5%; $chi^2 = 2853$, $P<0.01$). The average duration of adult dives (1.8 min) was greater than for pups (0.9 min) but pups had numerous short dives.

INTRODUCTION

Recent population censuses of the Steller sea lion (*Eumetopias jubatus*) have documented significant declines through most of it's range (Merrick et al. 1987; Loughlin et al. 1992). Northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands also declined during the 1970s but the population has been stable since about 1983 (Loughlin et al. in press). These declines have resulted in the listing of both species as depleted under the U. S. Marine Mammal Protection Act and Steller sea lions as threatened under the U. S. Endangered Species Act.

The cause(s) of these declines remain unknown; however, one hypothesis is that changes in the abundance or quality of preferred prey have contributed to the declines (Merrick et al. 1987; Loughlin and Merrick 1989). Much is known about prey preferences of the two species, but foraging ecology (e.g., feeding locations and depths), particularly for Steller sea lions, remains largely unstudied. A major reason for this lack of information has been the difficulty of obtaining data on foraging locations and diving of free ranging marine animals. Instruments which record diving depths over time (time-depth recorder or TDR) have existed since the 1970s and have allowed researchers to track some pinniped movements vertically in the water column during foraging trips (Gentry and Kooyman 1986). Coupled with a separate VHF radio transmitter and a ship or aircraft with which to track the animal, it was possible to obtain at least a partial picture of northern fur seals' foraging movements for 1 trip (Antonelis et al. 1990; Loughlin et al. 1987; Goebel et al. 1991). Application of this technique has received limited use due at least in part to the high costs of aircraft and ship time, and the need to recapture the animal to recover the TDR.

Recent developments in satellite telemetry allow tracking of marine animals using satellite-linked transmitters (Hill et al. 1987; Hills 1987; Mate et al. 1987; Stewart et al. 1989; Heidi-Jorgensen et al. 1991). Through the Service-Argos system on board NOAA Tiros-series satellites, it is possible to track and retrieve data from free-ranging animals using uplink communications between satellite transmitters attached to animals and receivers onboard satellites. Locations at sea are determined from the Doppler shift of the frequencies of a series of signals received by the satellite (Fancy et al. 1988; Stewart et al. 1989).

By combining a satellite transmitter and TDR it is possible to simultaneously determine locations and collect diving information while the animal is at sea. The TDR collects dive data which can be reported by the transmitter while the animal is at sea or saved for later reporting while the animal is on land. This is particularly important for animals like Steller sea lions which inhabit relatively inaccessible areas, return to their tagging site on an infrequent basis, and are difficult to capture to retrieve the TDR.

In this report we describe our use of a satellite-linked time-depth recorder (SLTDR) developed for pinnipeds (Merrick et al. in press) and provide information gained from these instruments on free-ranging northern fur seals and Steller sea lions in the Bering Sea. We describe their movements and foraging behavior during October through February 1991 and 1992.

MATERIALS AND METHODS

SLTDR Protocol

Two types of SLTDR were used, a 1 watt size (type 2) and ½ watt size (type 3). Unit software controlled three functions--data collection, summarization, and transmission. Data were collected only while the animals were at sea. Once the animal had gone to sea the unit collected data on location and depth readings at 10-second intervals throughout the trip. The animal was considered to be diving after a threshold depth had been exceeded. Depths from the first dive of each hour were collected and stored in their entirety for later transmission. For all other dives, only the maximum depth, and both dive and surface durations were saved. Thus, at the end of the trip a complete sequential record of surface times, dive times, and maximum dive depths, was available for transmission. The SLTDR allows for storage of dive information to within ± 2 m in six bins. For example, dive depth information for fur seals in 1992 was placed into depths of 4-50 m, 51-100 m, 101-150 m, 151-250 m, 251-350 m, and >350 m. Dive duration in 1992 was similarly partitioned between six bins ranging from 0-1 minute, 1-6 minutes, 6-11 minutes, 11-16 minutes, 16-21 minutes, and > 21 minutes.

Two transmission protocols were used: at-sea and on-land. While the animal was at sea, a 32 bit data message was transmitted at 45 second intervals whenever the animal surfaced (as determined by a conductivity sensor, "saltwater switch"). This message included location and a histogram of earlier dives.

Each day was subdivided into four six-hour periods (2100-0200 hrs, 0300-0800 hrs, 0900-1400 hrs, and 1500-2000 hrs, which corresponded to local sunrise and sunset). Histograms were separately summarized for dive depths and durations for each of the preceding four complete six-hour periods (a total of eight histograms).

The on-land protocol was used for transmission of the hourly dive profiles, and a chronological record of duration, maximum depth, and duration of subsequent surface intervals. Fur seals are pelagic after leaving the Pribilof Islands until they return the following breeding season. They usually remain at sea for 6-8 months, thus greatly reducing the possibility of obtaining dive profile information during the on-land protocol of the SLTDR.

Service-Argos classifies the accuracy of locations as follows--class 3 is accurate to 150 m, class 2 is accurate to 350 m, class 1 is accurate to 1 km, and class 0 has no accuracy assigned (Service-Argos 1984). Differences between class 1 and class 3 fixes were around 0.5 km, while class 2 and 3 fixes were essentially identical. Most locations received during this study were class 1 and 0.

Data were received from Service-Argos on floppy diskettes and formatted using software developed by Wildlife Computers. Statistical analysis of dive parameters for Steller sea lions were performed using SYSTAT (Wilkinson 1990).

Time at sea was calculated as the time (hours) between the first at-sea transmission and the first on-land transmission. Average dive depths were calculated from histograms. At-sea information for northern fur seals is presented as track lines over time representing numerous locations at sea. Conversely, the Steller sea lion data are presented as individual transmissions or locations at sea.

<u>SLTDR Attachment Summary</u>

A total of 22 SLTDRs were deployed in this study, 14 on fur seals and eight on Steller sea lions. Male northern fur seals were studied because females and pups migrate out of the Bering Sea in November and occur as far south as California during winter. In October 1991 one type 2 and one type 3 SLTDR were attached to two adult males on St. Paul Island and in October and November 1992 four type 2 and eight type 3 SLTDRs were attached to males on St. Paul (Table 2-1). The males were immobilized with Telazol injected remotely with a 5 cc dart fired from a pneumatic dart gun (Kiyota et al. 1992). The SLTDR was then attached directly to the animal's back using 5-minute epoxy glue (Loughlin et al. 1987).

No SLTDRs were attached to male sea lions because the animals are too large for immobilizing with current techniques and are difficult to approach. Two SLTDRs were attached to adult females and two to pups (one male and female) at Ugamak Island (eastern Aleutian Islands) in November 1991; one was attached to an adult female and one to a female pup at Akun Island (eastern Aleutian Islands) during March 1992; and one was attached to an adult female and one to a female pup at Latax Rock during February 1992 (Table 2-2). We generally focused our efforts in the eastern Aleutian Islands but weather commonly prohibited access to the animals. We chose Latax Rocks (near Kodiak Island) as a secondary site for inter-area comparisons. Sea lions were immobilized using the same methods as with fur seals but with lower Telazol dosages (Loughlin and Spraker 1989).

RESULTS

Location and movements

Northern fur seals:

During 1991 location data were received from the 1 watt SLTDR from Julian Date (JD) 299-065 and from JD 296-337 for the ½ watt SLTDR (Table 2-1). During 1992 the 1 watt SLTDRs did not work well and most data were provided by the ½ watt SLTDRs (Table 2-1).

The duration of time on land by the males after SLTDR attachment varied from a few days to a month or more. However, once at sea the seal did not return to land during the monitoring period (Figs. 2-1 to 2-3).

While at sea fur seals utilized most oceanic areas and the outer domain of the continental shelf of the Bering Sea from about St. Matthew Island south and from about the 100 m isobath on the continental shelf west to Shirshov Ridge in the western Bering Sea (Figs 2-1 to 2-3). None used the shallow waters of the eastern Bering Sea shelf. Some animals moved erratically while others moved in direct lines to feeding locations. Eventually all male fur seals for which we have adequate data left the Bering Sea and fed either in the eastern Pacific Ocean and Gulf of Alaska (Fig. 2-2) or to the west off the Kuril Islands and Japan (Fig. 2-1). In 1991 information on the movement out of the Bering Sea is available for one of the two seals. This male (SLTDR 2338) left the Bering Sea after 127 days; the other (SLTDR 2320) stopped transmission after about 42 days while he was still in the Bering Sea. In 1992, seven of the twelve fur seals left the Bering Sea by January. One (SLTDR 14102) left after just 14 days while another (SLTDR 14104) left after 45 days. The mean duration in the Bering Sea after SLTDR attachment was 30.3 days (n = 8, sd = 12.3 days). Data are not available for the remaining five SLTDRs.

While in the Bering Sea, male fur seals foraged in areas associated with the outer domain of the continental slope, or underwater ridges and sea mounts, such as Bower's Ridge, a large, crescent shaped ridge extending north and west from Semisopochnoi Island, and northwest of the Pribilof Islands on the continental shelf in water from 100-250 m deep. Relatively little time was spent over deep water masses (>1000 m) of the Bering Sea. One animal in 1991 (SLTDR 2320) and four in 1992 (SLTDRs 14100, 14103, 14106, and 14107) spent a few days west of St. Matthew Island over the shelf and shelf break diving in water <100 m, but the time spent in shallow water was minimal.

The seals entered the North Pacific Ocean from the Bering Sea through Aleutian Island passes from Unimak Pass west to the Commander Islands (Figs. 2-1 to 2-3). In 1991, SLTDR 2338 passed through Amchitka Pass. In 1992, three of seven used Unimak Pass; one used Samalga Pass; one passed through near Kiska Island, and two passed through near the Commander Islands. PTT 2338, monitored in 1991, was resighted on St. Paul Island during July 1992 with the inoperative SLTDR attached; the date that it re-entered the Bering Sea is not known. None of those monitored in 1992 had re-entered the Bering Sea by the end of the study period (February 1993).

Steller sea lion:

The SLTDR on Steller sea lions transmitted from zero to 67 days ($\bar{x}$ = 37.5 days, n = 7, sd = 23.4) and provided both location and dive data. Unlike fur seals which stayed at sea after leaving the Pribilof Islands, Steller sea lions alternate between on land and at sea trips. For the adult female sea lions, a total of 28 trips to sea were recorded with a mean duration ranging from 26 to 57 days which accounted for about one third of their time (Table 2-2). Pups spent much less time at sea with mean duration ranging from 3 to 17 days (Table 2-2).

While at sea, the sea lions stayed closer to land and the haulout site than fur seals, but both pups and adult sea lions are capable of long movements (Figs. 2-4 to 2-6). One pup (SLTDR 2322) moved 340 km in November 1991 from Akun Island (eastern Aleutian Islands) to St. George Island (Pribilof Islands). However, aside from this movement, pups appear to stay within 60 km of their haulout site while adults frequently make farther movements.

Most foraging locations were over the continental shelf (<200 m), although infrequent sorties occurred into deeper water (Figs. 2-4 to 2-6). In the eastern Aleutian Islands, the entire Krenitzen group appears to contain important foraging areas. The area from Akun Island to Unimak Island appeared to be most important for pups. Adults foraged both to the north and south of Unimak Island, however each animal tended to feed on one side or the other. SLTDR 14072 fed principally on the north side while SLTDR 2324 fed on the south.

There was interchange between haulout sites (Table 2-3). It seems that, at least in winter, eastern Aleutian Island sea lions intermix. Sea lions instrumented at Ugamak Island in November were recorded at Akun Island, and animals instrumented at Akun during March were recorded at Ugamak. These inter-island movements for adult females have not been observed during other times of the year.

At Latax Rock the adult and pup behaved similarly to the eastern Aleutian Island sea lions. The female foraged further from the haulout site than the pup which stayed within 60 km.

Dive depth and duration

Northern fur seal:

The two seals monitored in 1991 showed different modes in their diving behavior. SLTDR 2320 remained over the continental shelf and had shallow dives (31.5% of dives were <10 m) and deep dives (49% were 50-250 m); SLTDR 2338 spent most time in deep water and 54% of its dives were >100 m. Its dives were longer in duration (>90% were longer than 4 min) where SLTDR 2320 had 98% of its dives <1 min.

During 1992/93, most dives (mean 83%, n = 8, sd = 20.17) were between 4 and 100 m and the remaining 17% between 101 and 350 m. None were >350 m. Sixty eight percent of all dives were between 4 and 50 m and 14% were between 51 and 100 m. Only 2.5% of the dives were greater than 250 m.

Concomitant with predominant shallow dive depths, the duration of most dives was <6 minutes (90%), with 43% being one minute or less. The proportion of dive duration over 11 minutes was <1%, as expected, since few deep dives were recorded.

Individual animal variation in both dive depth and duration occurred. SLTDRs 14102, 14104 and 14105 dove primarily between 4-50 m with a few dives between 51-100 m, and even fewer between 101-150 m (Fig. 2-7). SLTDRs 14103 an 14107 also had numerous shallow dives, but they also had many deep dives. SLTDR 14103 had 19% of its dives in 151-250 m; 14107 had 7% in 151-250 m and 16% in 251-350 m (Fig. 2-7). SLTDR 14107 was the only seal with >15% of dives >250 m.

As with dive depth and dive duration, the time of day when diving occurred varied with individual. However, dives occurred at all times of the day during both 1991 and 1992/93. About 21% of the dives occurred between 2100-0200 hrs, 23% from 0300-0800 hrs, 24% from 0900-1400 hrs, and about 30% from 1500-2000 hrs.

Dives to all depths and for all durations occurred during all periods of the day (eg., shallow dives occurred during night and day). The only exception is that for both SLTDRs 14103 and 14107, the largest proportion of deep dives occurred between 0900-1400 hrs.

Steller sea lion:

Steller sea lion adult females and pups dove to shallower depths than did fur seals (Fig. 2-8). Average dive depth for pups (n = 4) was 7.8 m, which was significantly less than for adult females (n = 3, $\bar{x}$ = 23.4 m; t = 2.015, df = 5). A greater proportion of dives by pups (88.8%) were in the 4-10 m range than for adult females (46.1%). Dives in this range are significantly greater for pups than for adults (chi^2 = 5219.8, P<0.01). It is not clear whether these shallow dives are foraging dives or if the animals are merely exploring and moving within the water column. However, there were no dives by pups >50 m, while adult animals dove close to 200 m. Mean dive depth for all dives >10 m for pups was 17.1 m, and for adult females it was 46.3 m (Table 2-4).

There was also a difference in dive duration for pups compared to adult females (Table 2-5). Pups (n = 2) and adults (n = 2) can dive longer than six minutes, but the proportion of dives by pups less than one minute (75%) was significantly greater than for adults (34.5%; chi^2 = 2853, P<0.01) (Fig. 2-9). The average duration of adult dives (1.8 min) was greater than for pups (0.9 min). However, this difference is heavily influenced by the high number of short dives <1 min. If just dives >1 min are considered, the mean dive durations were similar (pups = 2.1 min, adults 2.5 min).

Adults spent a longer time at sea (35.8%) than did the pups (18.8%). Mean trip length for pups was 10.2 hrs and adults 39.9 hrs.

We summarized the few data available for Steller sea lions at sea to estimate the amount of time spent under water for pups and adults. For each hour at sea, pups spent much more time under water (32 min) than adults (12 min). During a day pups still dove more (146 min) than adults (100 min), but the greater amount of time adults spent at sea compensates somewhat for this difference.

DISCUSSION

SLTDR summary

The type 2 SLTDR transmits at-sea locations superior in number and quality to those of earlier experiences with a satellite transmitter only (Merrick et al. in press). The deployment of SLTDR 14080 (on a Steller sea lion) at Latax Rocks yielded 100 at-sea locations during March 1992 (31 days), and 22.0% were class 2 or better. Many location fixes from SLTDRs on fur seals showed in similar results.

Simultaneously, data obtained on dive parameters was virtually identical to that produced by a conventional TDR (eg., Goebel et al., 1991). Even though a full profile for every dive is not obtained, the combination of chronological records and hourly profiles provides all the data typically used for analysis of dive parameters (Gentry and Holt, 1986). These data can also be linked with locations by date and time to determine where the diving occurred. Thus, it is possible to determine whether the animal was foraging in the water column or at the bottom.

The only limitation of the SLTDR compared to a conventional TDR is that it does not provide a complete record of all diving. This is because of the difficulty of transmitting all dive data to satellites during the brief times animals are ashore or on the water surface with the antenna in the air and satellites are in view (around 8 min at 55° N latitude). Many more dives are reported from the histogram records (e.g., 3,040 for SLTDR 14080) than are reported in the chronological records (e.g., 1,216 for 14080). This is because it takes much longer to transmit a comparable number of dives in the chronological record format. For example, if 140 dives were made in a 24 hour period, only eight unique messages would need to be received by the satellite to complete the histogram record of the 24 hour period. Twenty chronological records would have to be received to transmit the detailed information on dive parameters. Also, data must be transmitted 15-20 times to ensure that it is received because satellite coverage is limited with polar orbiting satellites. This further prolongs the time required to transmit all data. Thus missing chronological and profile data were used as histograms describing the total number of dives made. The chronological (and profile) records were then considered to represent a subsample of the characteristics of the total population of dives.

Histogram records also ensure that some data were recovered from all animals, even if they did not return to land. This makes the SLTDR a powerful tool for studying winter foraging behavior of fur seals and sea lions which spend prolonged periods of time at sea in the winter.

Movements

Male fur seals from St. Paul Island equipped with SLTDR fed in many of the same areas that females did during the breeding season. Loughlin et al. (1987) and Goebel et al. (1991) showed that females fed on the outer domain of the continental shelf northwest of St. Paul Island and in deep water west and south of the Pribilof Islands. During winter when males were in these areas most females had already left the Pribilof Islands for their winter migration south and out of the Bering Sea (Kiyota et al. 1992). None of the females monitored in the early studies fed as far west in the Bering Sea as did the males monitored in this study (eg., SLTDRs 2238, 14103, 14104, 14106). Thus, during winter there seems to be very little overlap in foraging activities of male and female fur seals in the Bering Sea.

Studies on the fall movements of pups migrating from the Pribilof Islands showed that as they moved south they moved through a number of different eastern Aleutian Island passes as they moved into the eastern and central Pacific Ocean (Ragen 1990). These pups left the rookeries in November and spent, on average, about ten days swimming to the Aleutian Islands, entering the North Pacific in early November to mid December (Ragen 1990). Four males that we monitored in this study also used these passes at about the same time as the pups, however most pups had likely migrated beyond the Aleutian Islands before arrival of the males monitored in this study. Adult males and pups probably feed on different size prey and dive to different depths to feed and are probably not competing for similar prey resources.

Information collected during this study on adult male fur seals, and in earlier studies on adult females and pups (Kiyota et al. 1992; Ragen 1990) suggests that all ages and both sexes of fur seals leave the Bering Sea during winter (February-March). However, unpublished observer reports suggest that some male fur seals haul out onto ice in the Bering Sea during late March and April (NMML, unpublished data). Whether these animals had remained in the Bering Sea throughout winter or moved back after foraging in the North Pacific is equivocal. The proportion of the male population that remains in the Bering Sea is unknown. In our study all males (for which the SLTDR transmitted long enough to provide the data) left the Bering Sea before January and had not returned by the end of February.

Other than Merrick et al. (in press) there are no previous studies on the movements of Steller sea lions. Our study showed that Steller sea lion pups are capable of making long distance movements, although their foraging range is somewhat restricted compared to adult females which forage close to land in summer (within 20 km), make brief trips (<2 days), and dive to shallow depths (<30 m) (Merrick et al., in press). However, in winter trips are much longer in distance (>300 km) and duration (up to several months). Dives are also deeper (often >250 m). Sea lion pups by their sixth month are able to range more than 250 kilometers, although their dives remain shallow (<20 m) and brief (<1 min).

The entire Krenitzen area of the eastern Aleutian Islands out to the continental shelf break, as well as areas on the north and south sides of Unimak Island, were important foraging areas for adult females and pups. Movements of sea lions in the Krenitzen area between islands and the intermixing between haulout sites, suggests that sea lions in this area are one population.

Diving

Diving depths of male fur seals in this study were similar to those recorded for adult females (Gentry and Kooyman 1986; Goebel et al. 1991). Maximum dive depth for males in our study rarely exceeded 200 m, even when over very deep water. Individual variability occurred in both dive depth and duration (as with females) but generally followed the form of shallow diving (<50 m) and deep diving (>100-<200 m) characteristics. In this context "deep" diving is a relative term when compared to shallow dives by fur seals. The deepest dives by northern fur seals are shallow when compared to northern elephant seals which commonly dive to 400 m and may dive to >1,500 m (DeLong and Stewart 1991).

Northern fur seal dives last about 1-6 min, with a few lasting as long as 16 min. Similarly, Steller sea lion dives are brief and generally last 1-6 min; the maximum duration was 11 min. Galapagos sea lions (Zalophus californianus) and other fur seal species (Arctocephalus) have average dive durations of about 2 min with maximum duration of about 7 min (Gentry and Kooyman 1986). For comparison, northern elephant seals, the deepest-diving mammal, dive on average 21-24 min with the longest lasting 77 min (Delong and Stewart 1991).

Foraging depths of sea lion pups are clearly less than that for adult females. The maximum depth for pups was much shallower than for adults, and the proportion of shallow dives (<10 m) was greater than for adult females.

Adult sea lions spent more time at sea and made longer but fewer dives than pups. While pups are capable of staying under water as long as adults, they did so less often. However, even though pups spent less time at sea, their greater diving rate resulted in a foraging effort similar to adults.

These results indicate that fur seals and sea lions dive most frequently to depths of 4-50 m and for durations usually less than 6 min. The two species may feed on similar prey, but there is no winter foraging information to examine this possibility. If there is overlap in the diet of fur seals and sea lions during the winter, it probably occurs in locations such as Bowers Ridge or the Aleutian Island passes when the fur seals are migrating south into the north Pacific Ocean.

ACKNOWLEDGMENTS

We express our appreciation to S. Insley, S. Mello, L. Rea, R. Ream, J. Sease, for the help attaching the SLTDRs. Minerals Management Service provided financial support through Interagency Agreement IA-14411. Steller sea lions and northern fur seals were handled under MMPA permit numbers 584 and 598 to the Alaska Fisheries Science Center.

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Table 2-1. Deployment record of satellite-linked time depth recorders (SLTDR) attached to male northern fur seals at St. Paul Island during winter 1991 and 1992.

SLTDR	Type	Date Deployed	Date Out Of Bering Sea	No. Days	Data Loc.	Received Dive	Est. Age (yrs)
2320	.5 W	10/23/91	[1]	41	Y	Y	5-6
2338	1 W	10/26/91	3/01/92	131	Y	Y	10-11
14100	.5 W	10/22/92	[1]	75	Y	Y	10-11
14101	.5 W	10/24/92	11/13/92	>98	Y	Y	9-11
14102	.5 W	10/24/92	11/07/92	58	Y	Y	8-9
14103	.5 W	10/26/92	12/07/92	>96	Y	Y	10-11
14104	.5 W	10/27/92	12/09/92	47	Y	Y	7-8
14105	.5 W	10/27/92	11/16/92	30	Y	Y	10-11
14106	.5 W	10/27/92	12/13/92	>93	Y	Y	10-11
14107	.5 W	10/28/92	12/01/92	84	Y	Y	8-9
14115/16	1 W	10/29/92	[1]	6	Y	?	7-8
14117/18	1 W	10/29/92	[1]	3	?	?	7-8
14119/20	1 W	10/30/92	[1]	>14	Y	Y	10-11
14121/22	1 W	11/01/92	[1]	5	?	?	11-12

[1] Satellite tag stopped transmitted while in Bering Sea

Table 2-2. Deployment record for satellite-linked time depth recorders (SLTDR) attached to Steller sea lion pups and adult females during November 1991 and February-May 1992.

Animal		SLTDR	Deployment			Trips		Percent	Dives
ID	Sex	Type	Location	Date	Duration (Days)	Sample Size	Mean Distance (km)	Time At-Sea	Per Hour At-Sea
Pups:									
2321	Female	0.5W	Ugamak	11/06	50	18	3	4.5	23
2322	Male	0.5W	Ugamak	11/12	25	12	12	24.0	7
2325	Female	0.5W	Latax Rk	2/17	37	13	8	11.7	57
2326	Male	0.5W	Akun	3/08	57	28	17	34.8	19
Adults:									
2324	Female	0.5W	Ugamak	11/14	12	4	26	36.1	9
14070	Female	1.0W	Ugamak	11/12	0	na	na	na	na
14072	Female	1.0W	Akun	3/08	52	14	32	35.9	5
14080	Female	1.0W	Latax Rk	2/27	67	10	57	35.4	8

Table 2-3. General haul-out locations of Steller sea lion pups (n=4) and adult females (n=3) during November 1991 and February-May 1992.

Animal ID	Observation day From	To	Favored haul-out location
Pups:			
2321	1	5	Ugamak Island
	6	50	Rocks north of Tigalda
2322	1	9	Ugamak Island
	10	13	Akun Island - Billings Head
	13	15	Transit
	16	20	St. George Island
	21	25	St. Paul and Walrus Islands
2325	1	37	Latax Rocks
2326	1	6	Akun Island - Billings Head
	7	57	Ugamak and Aiktak Islands, and rocks north of Tigalda Island
Adults:			
2324	1	12	Ugamak
14072	1	5	Akun Island - Billingshead
	6	10	Tanginak Island
	11	17	Unimak Island - Sennett Point
	18	46	Akun Island - Billings Head
	47	55	Amak Island
	56	61	Unimak Island - Otter Point
	62	67	Amak Island
14080	1	35	Latax Rocks
	36	39	Kodiak Island - Steep Cape
	40	67	Latax Rocks

Table 2-4. Dive depths calculated from SLTDR's attached to Steller sea lion pups (n=4) and adult females (n=3) during November 1991 and February-May 1992.

	All dives		Dives >10 m		Max
		mean		Mean	depth
SLTDR	n	(m)	n	(m)	(m)
Pups:					
2321	1218	7.5	82	15.0	< 20
2322	996	7.3	27	19.4	< 50
2325	5978	7.3	219	15.2	< 50
2326	8857	9.1	1588	18.8	< 50
Adults:					
2324	922	27.2	301	69.0	150-250
14072	2409	22.4	1011	39.4	174
14080	4378	20.6	2843	30.7	198

Table 2-5. Dive durations (minutes) from SLTDR's attached to Steller sea lion pups (n=2) and adult females (n=2) during February-May 1992.

SLTDR	All dives n	All dives mean (min)	Dives >1 min n	Dives >1 min Mean (min)	Max duration (min)	Dive time per hour at sea	Dive duration per day
Pups:							
2325	6025	0.8	1856	1.8	>6	44	123
2326	8645	1.1	2517	2.4	>6	20	168
Adults:							
14072	2319	2.0	1672	2.5	7.3	10	84
14080	4743	1.7	2795	2.5	11.0	14	115

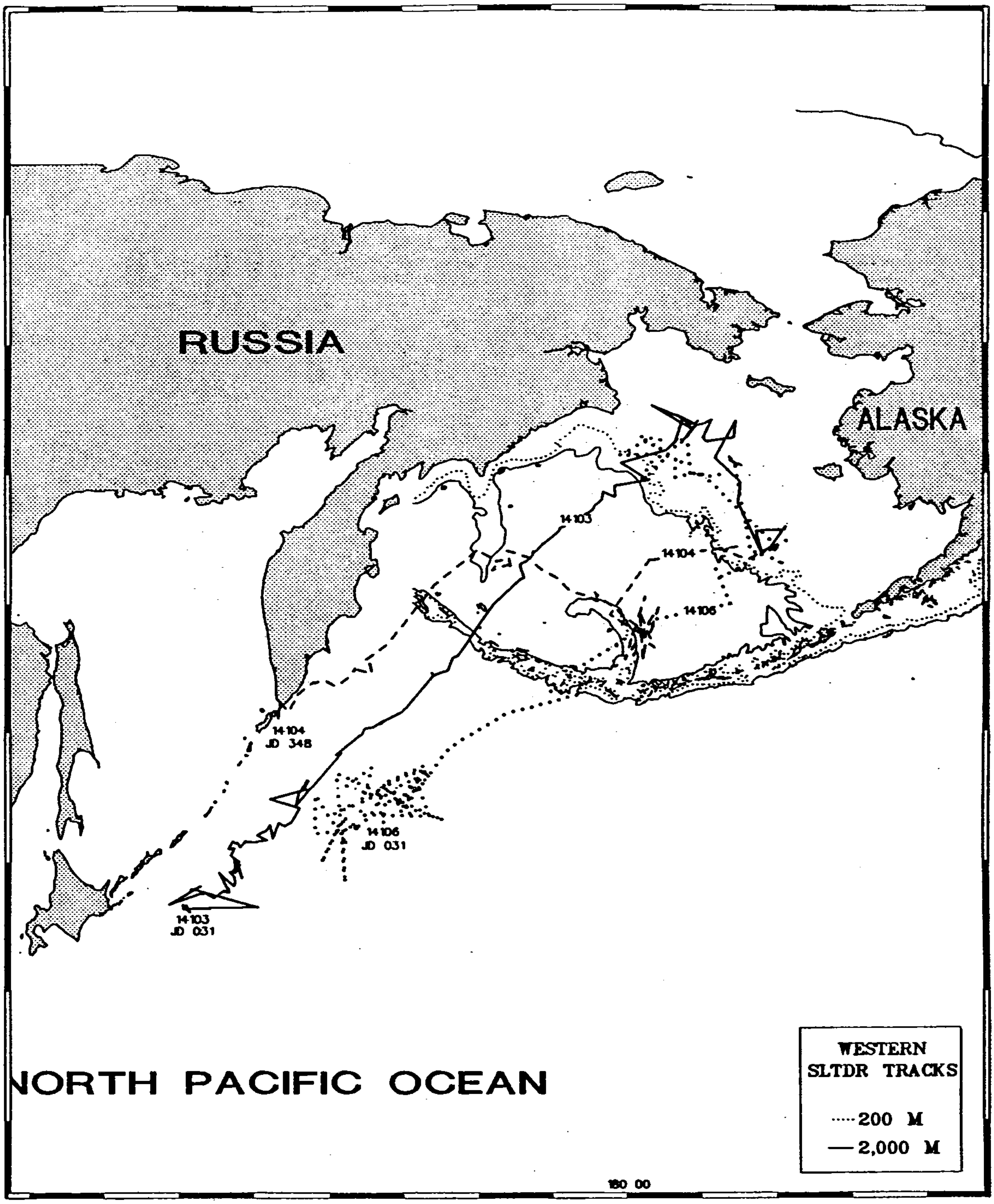
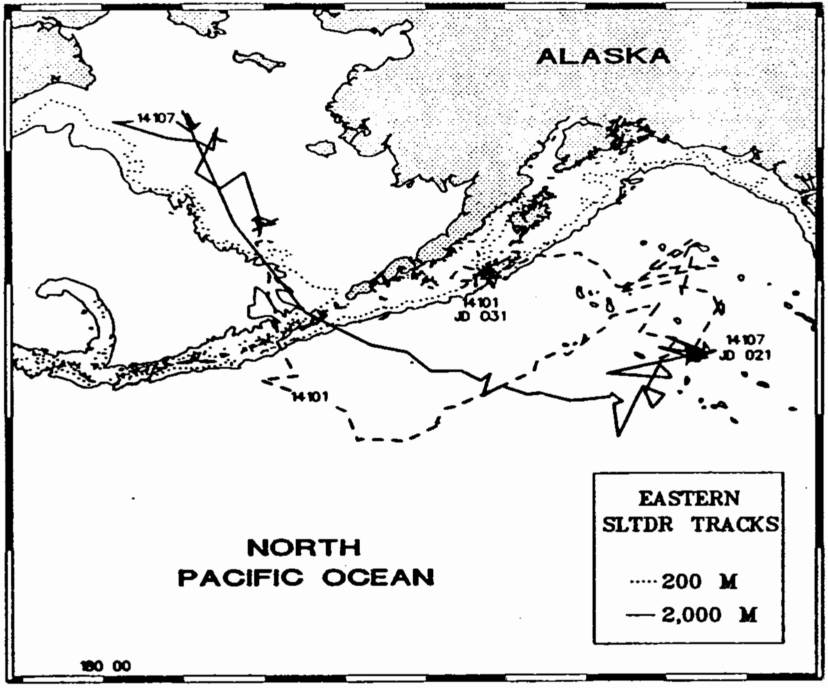


Figure 2-1. Movements of three northern fur seals equipped with SLTDRs in 1992. Each track begins at the Pribilof Islands in the southeastern Bering Sea. Only fur seals that swam to the western Pacific Ocean are shown. SLTDR number (eg. 14103, 14104, and 14106) and Julian Date (JD) of last reception are shown.



B

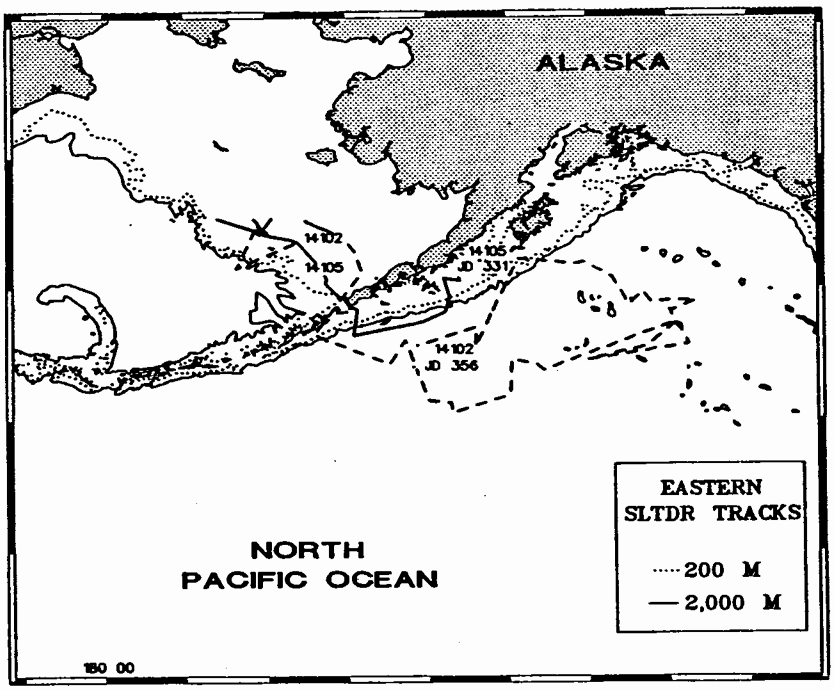


Figure 2-2. Movements of four northern fur seals equipped with SLTDRs in 1992. Each track begins at the Pribilof Islands in the southeastern Bering Sea. Only fur seals that swam to the eastern Pacific Ocean are shown. SLTDR number 14101 and 14107 (A), 14102 and 14105 (B), and Julian Date (JD) of last reception are shown.

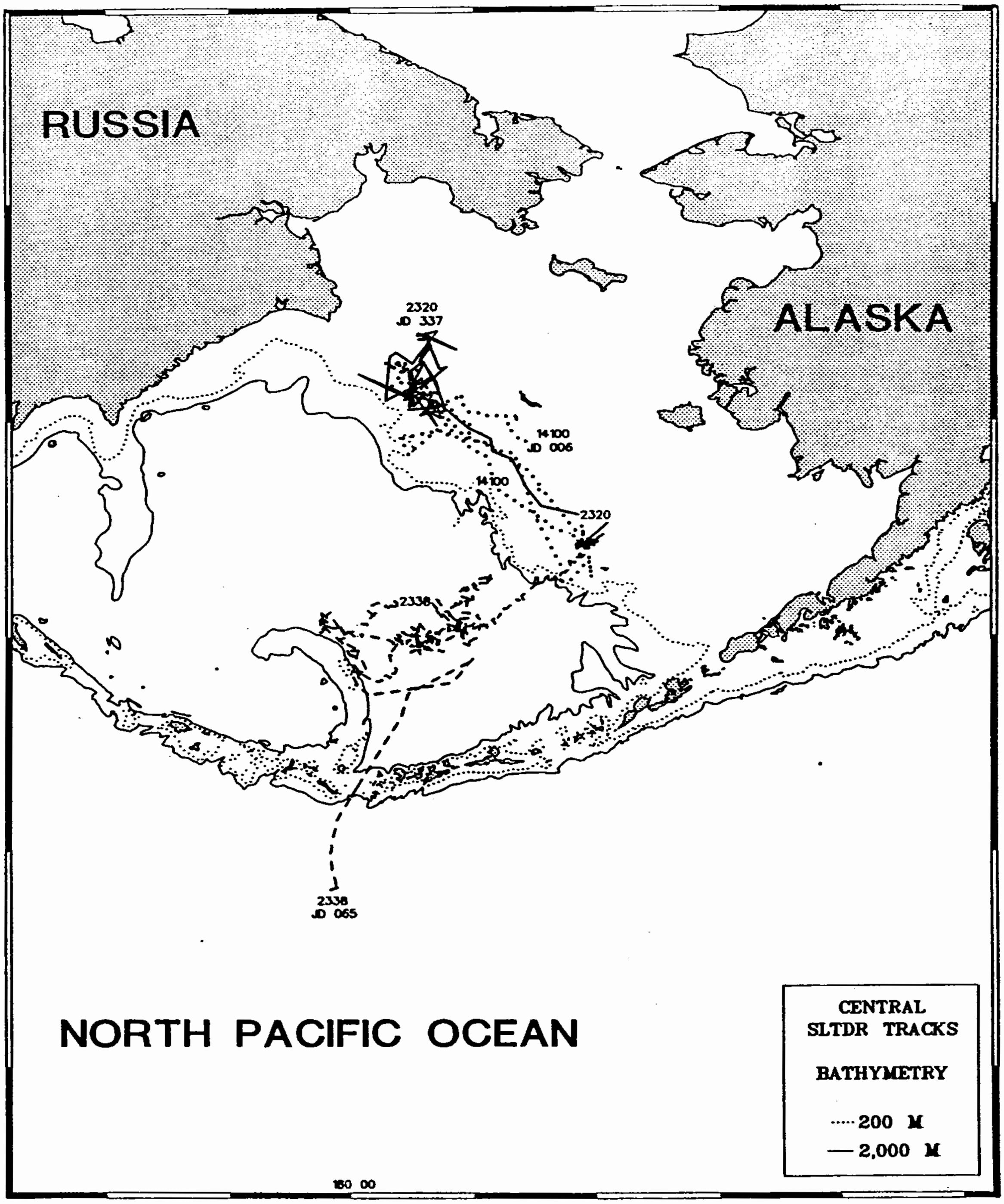


Figure 2-3. Movements of three northern fur seals equipped with SLTDRs in 1991 and 1992. Each track begins at the Pribilof Islands in the southeastern Bering Sea. Only fur seals in which the SLTDR stopped operating early or stayed within the Bering Sea are shown. SLTDR number (1991--2320 and 2338; 1992-14100) and Julian Date (JD) of last reception are shown.

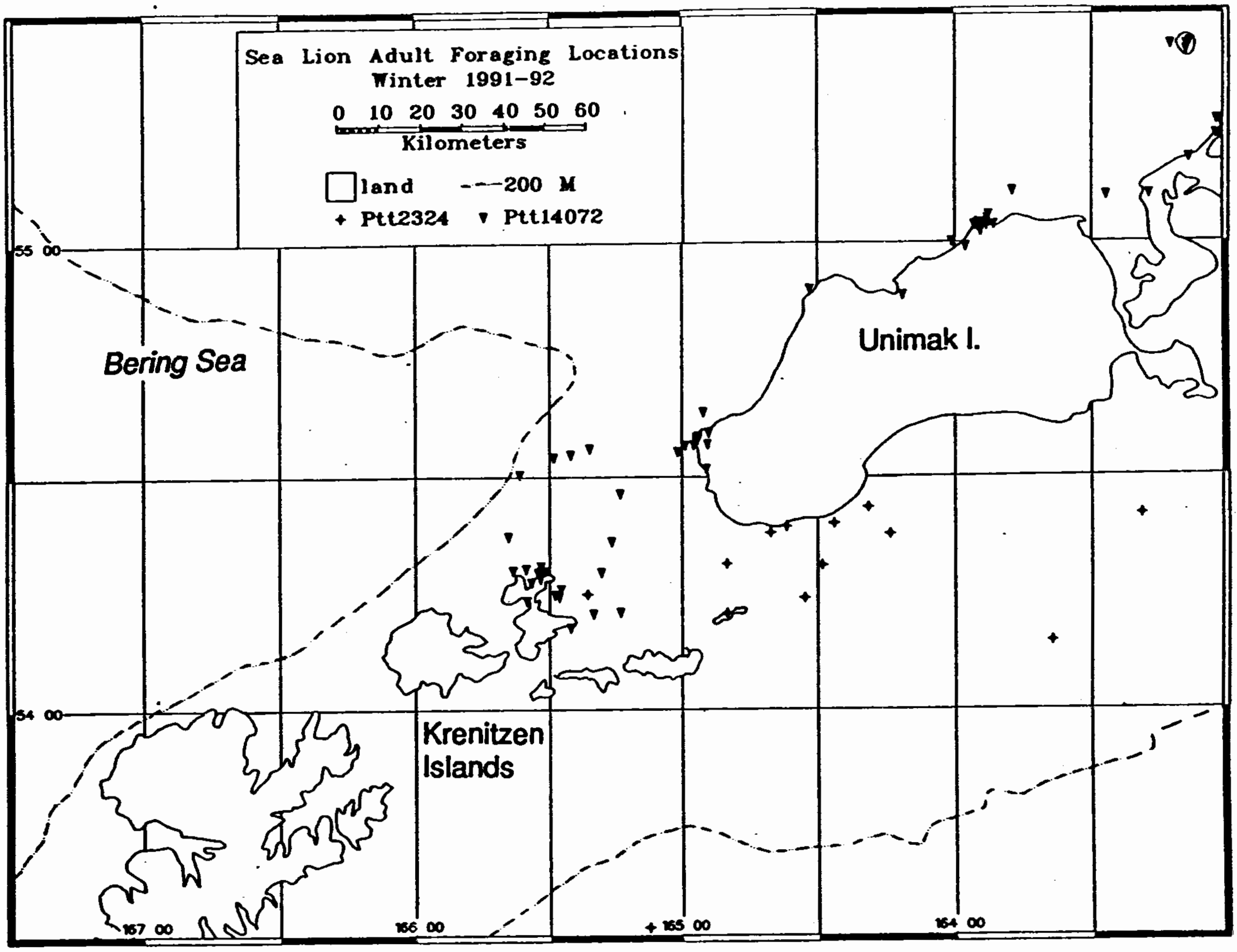


Figure 2-4. Map depicting locations for Steller sea lions equipped with SLTDRs during 1991-92 in the eastern Aleutian Islands. Each mark represents one transmission/reception. Two adult female sea lions are depicted, SLTDRs 2324 and 14072 (in legend PTT = SLTDR number).

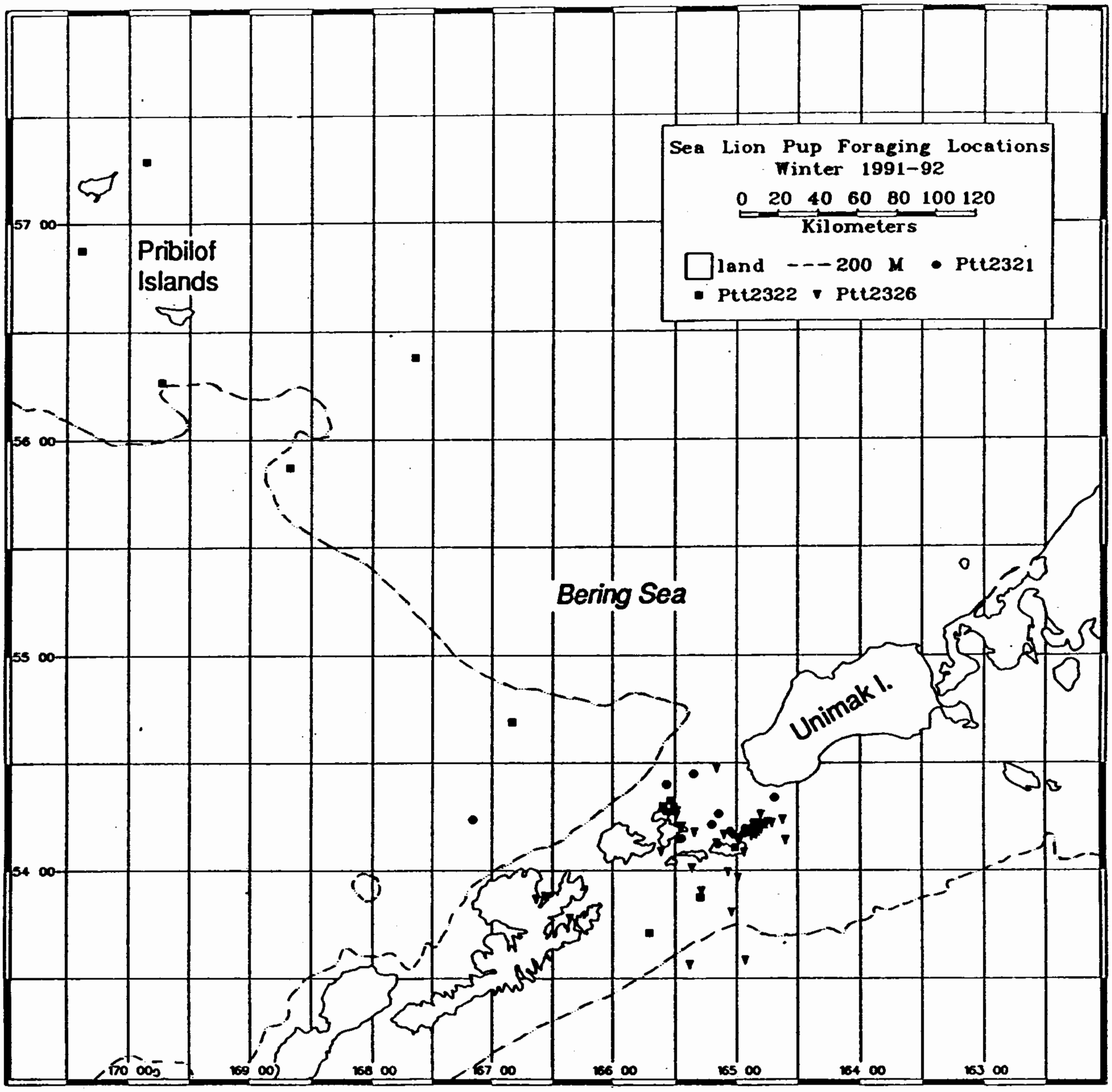


Figure 2-5. Map depicting locations for Steller sea lion pups equipped with SLTDRs during 1991-92 in the eastern Aleutian Islands. Each mark represents one transmission/reception. Two pups are depicted, SLTDRs 2322 and 2326 (in legend PTT = SLTDR number). Note trip to the Pribilof Islands by pup SLTDR 2322.

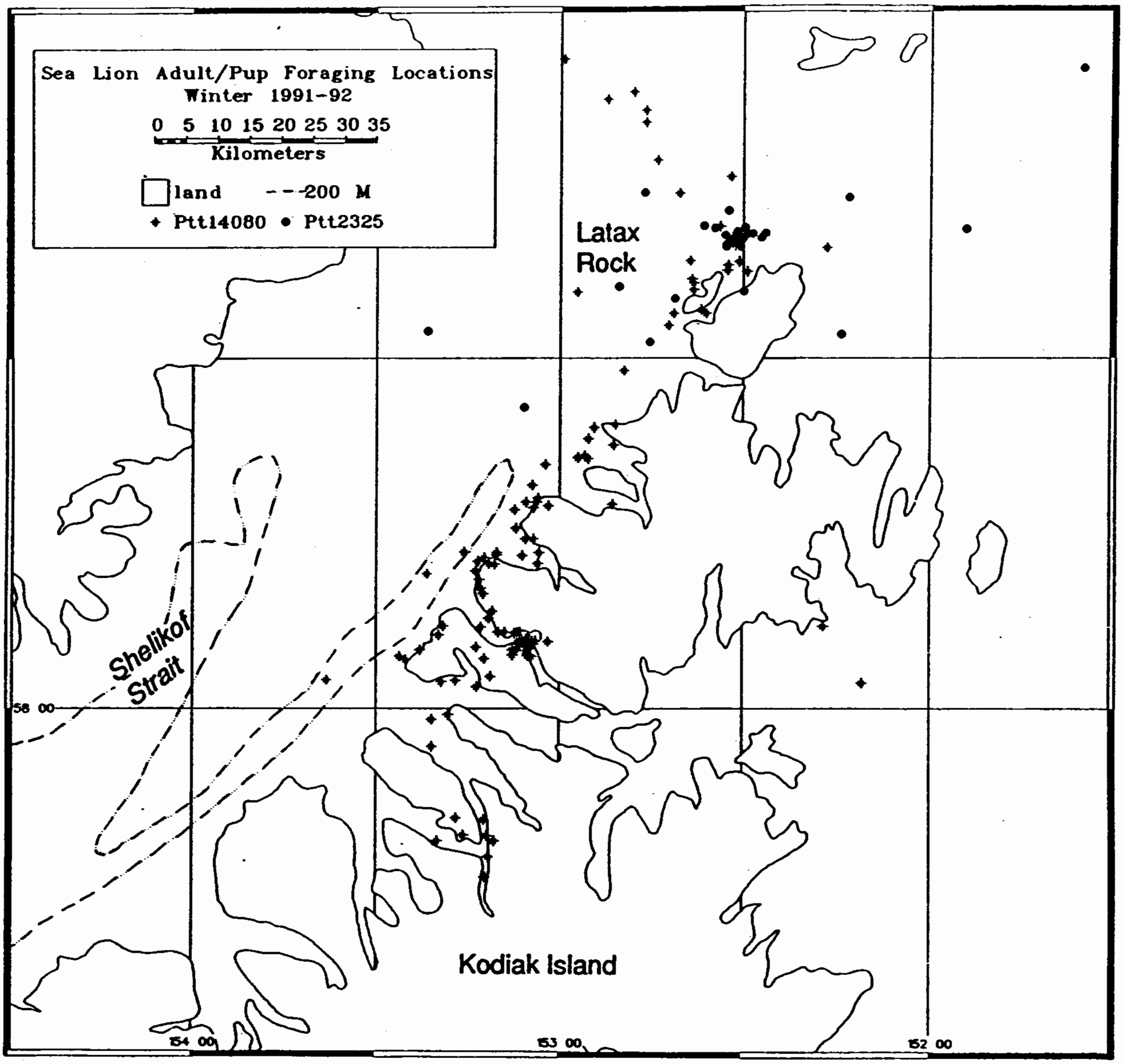
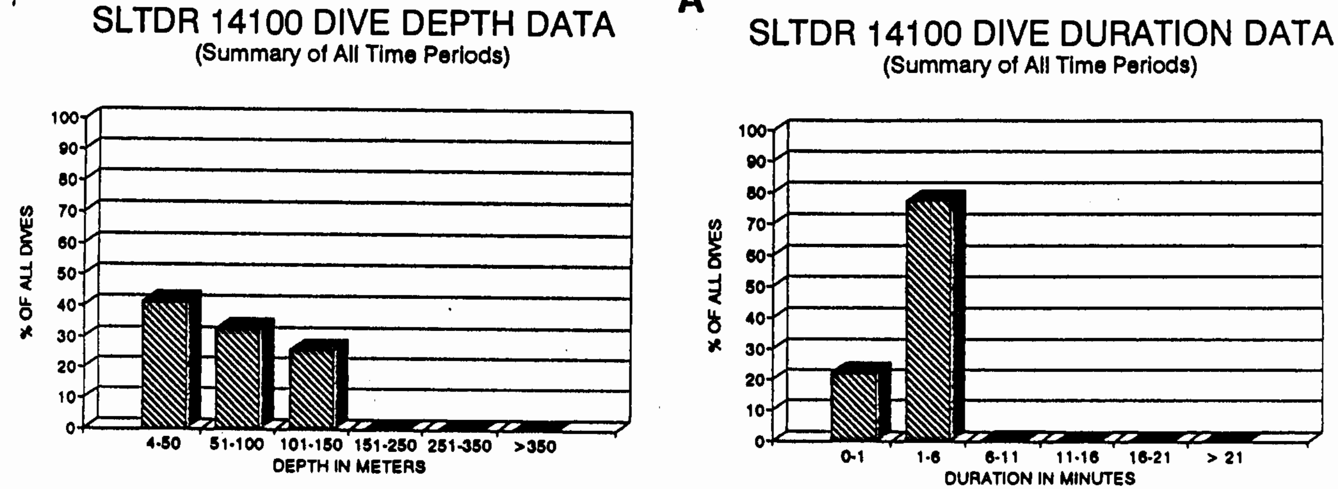


Figure 2-6. Map depicting locations for Steller sea lions equipped with SLTDRs during 1991-92 at Latax Rocks near Kodiak Island, Gulf of Alaska. Each mark represents one transmission/reception. One pup (SLTDR 2325) and one adult female (SLTDR 14080) are depicted (in legend PTT = SLTDR number).

A



B

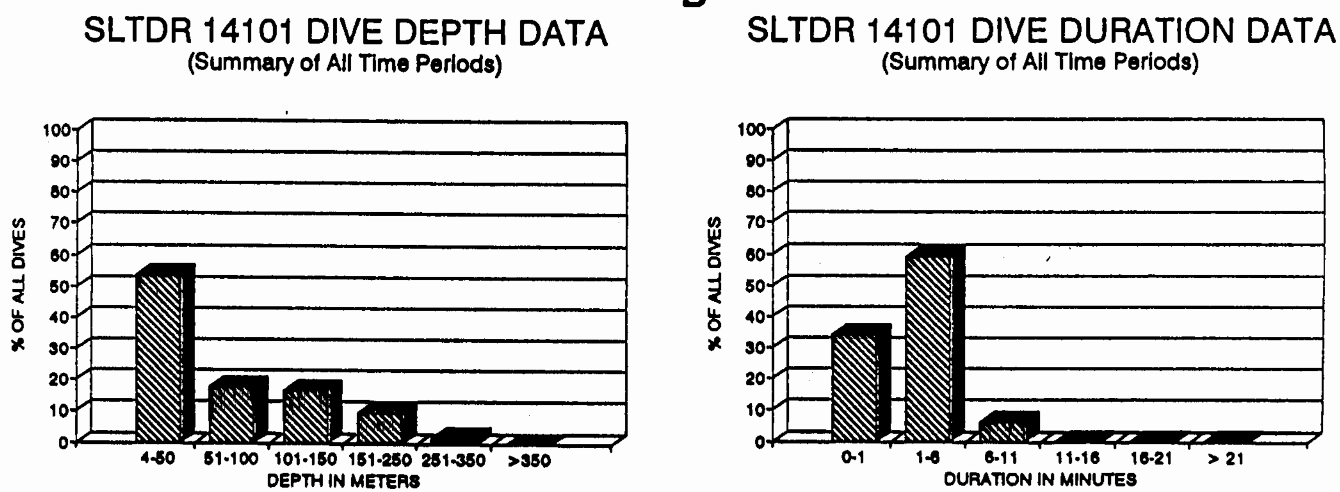
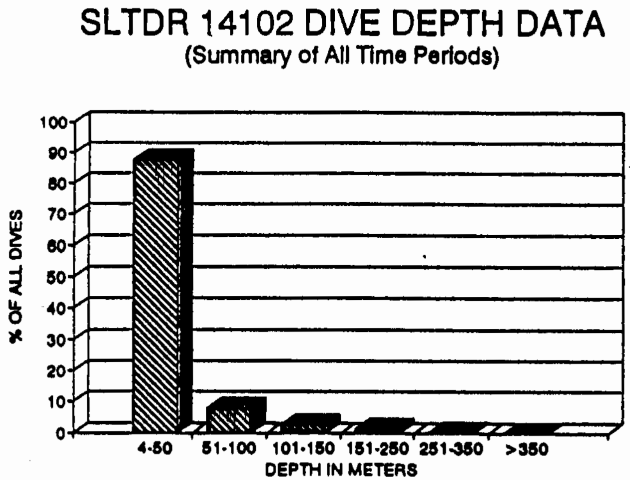
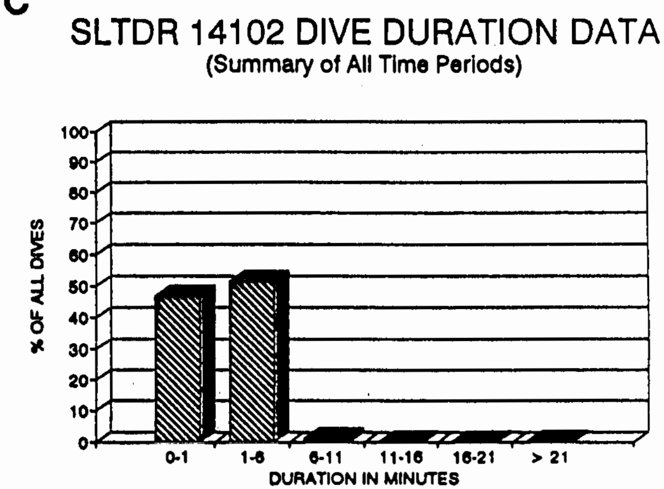
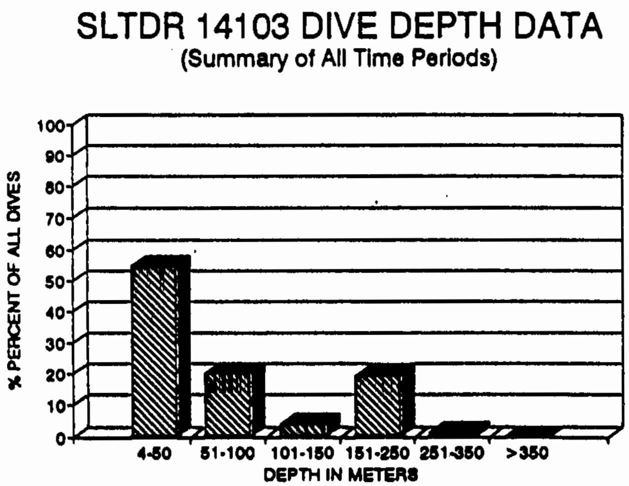


Figure 2-7 (A) to (H). Summary of percentage of dives at depths and duration of dives for eight northern fur seal equipped with a SLTDR in 1992.



C





D

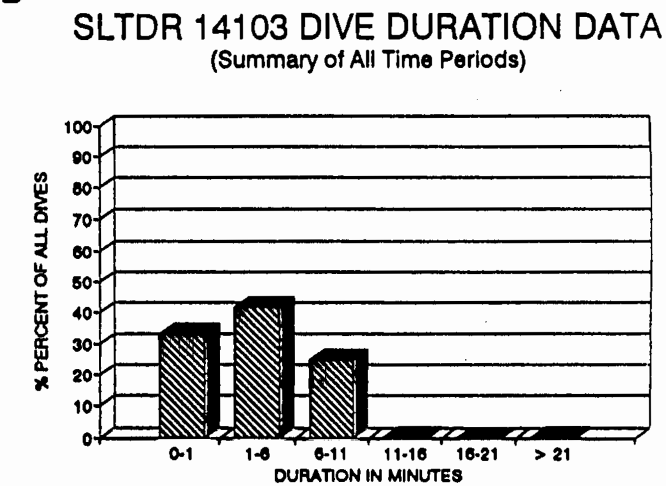


Figure 2-7 (continued).

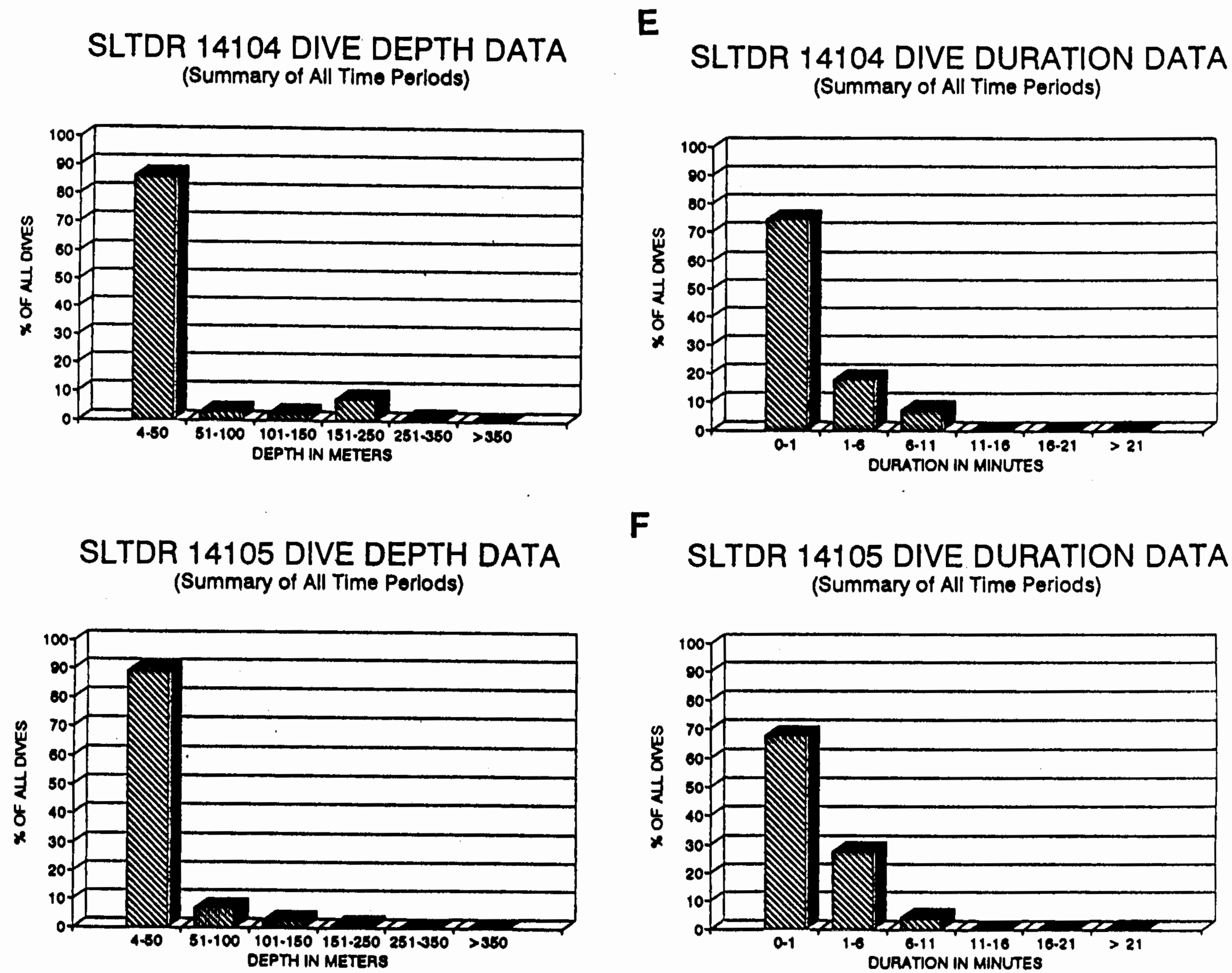
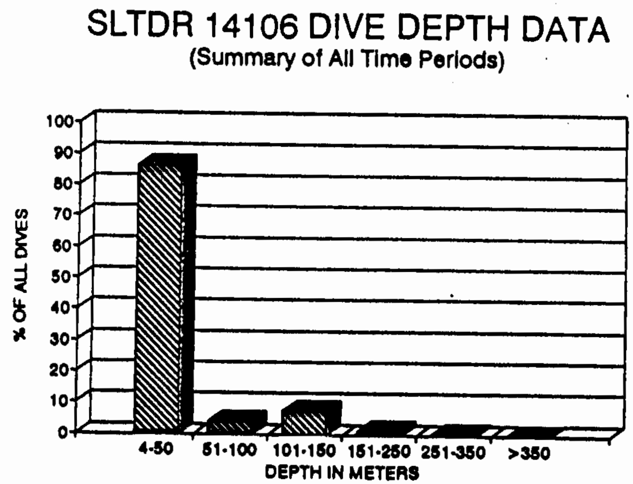
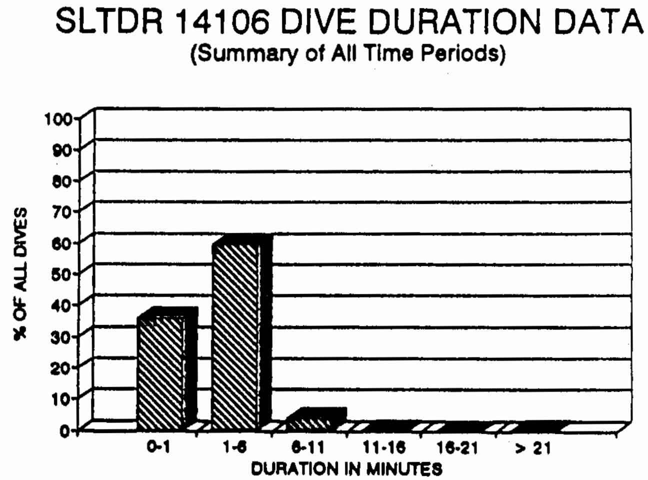
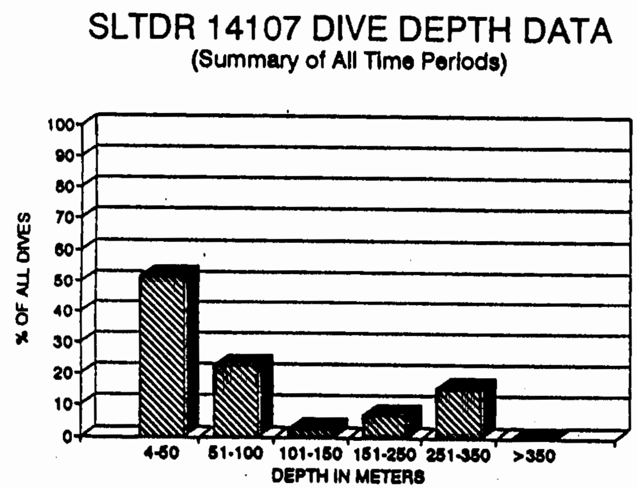


Figure 2-7 (continued).



G





H

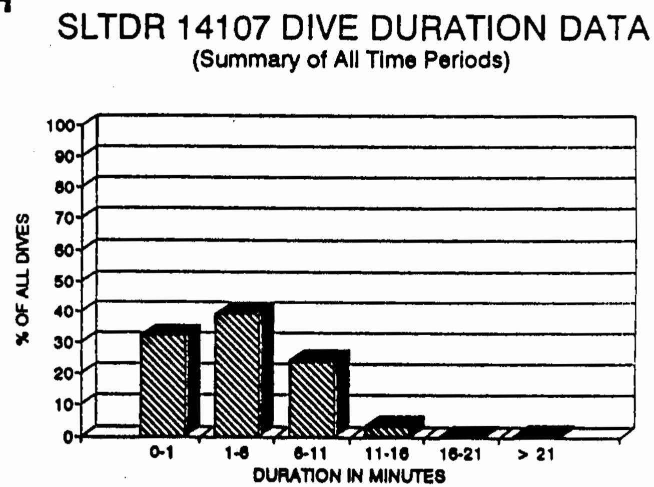


Figure 2-7 (continued).

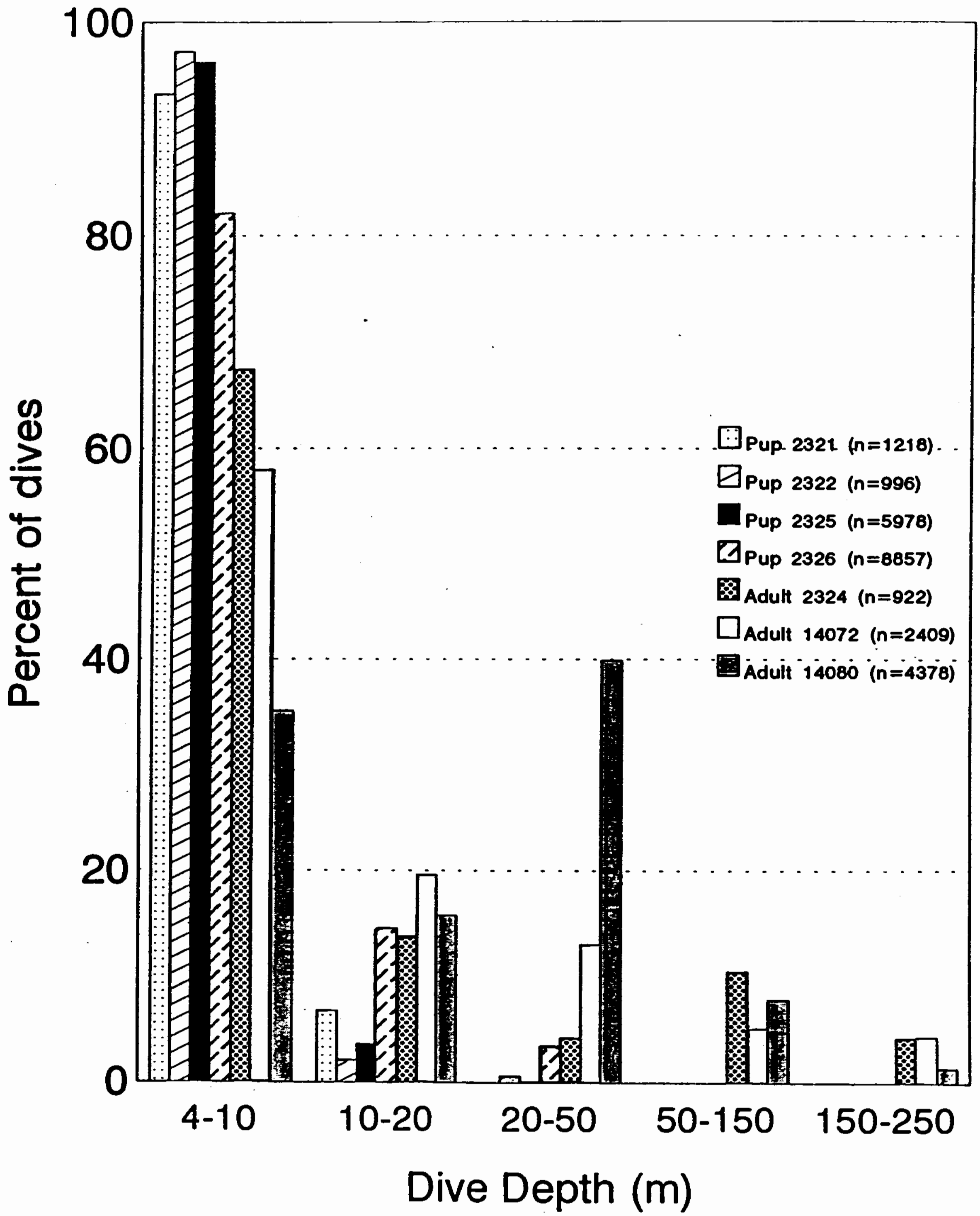


Figure 2-8. Summary of percentage of dives by depth for Steller sea lion pups and adult females during 1991 and 1992.

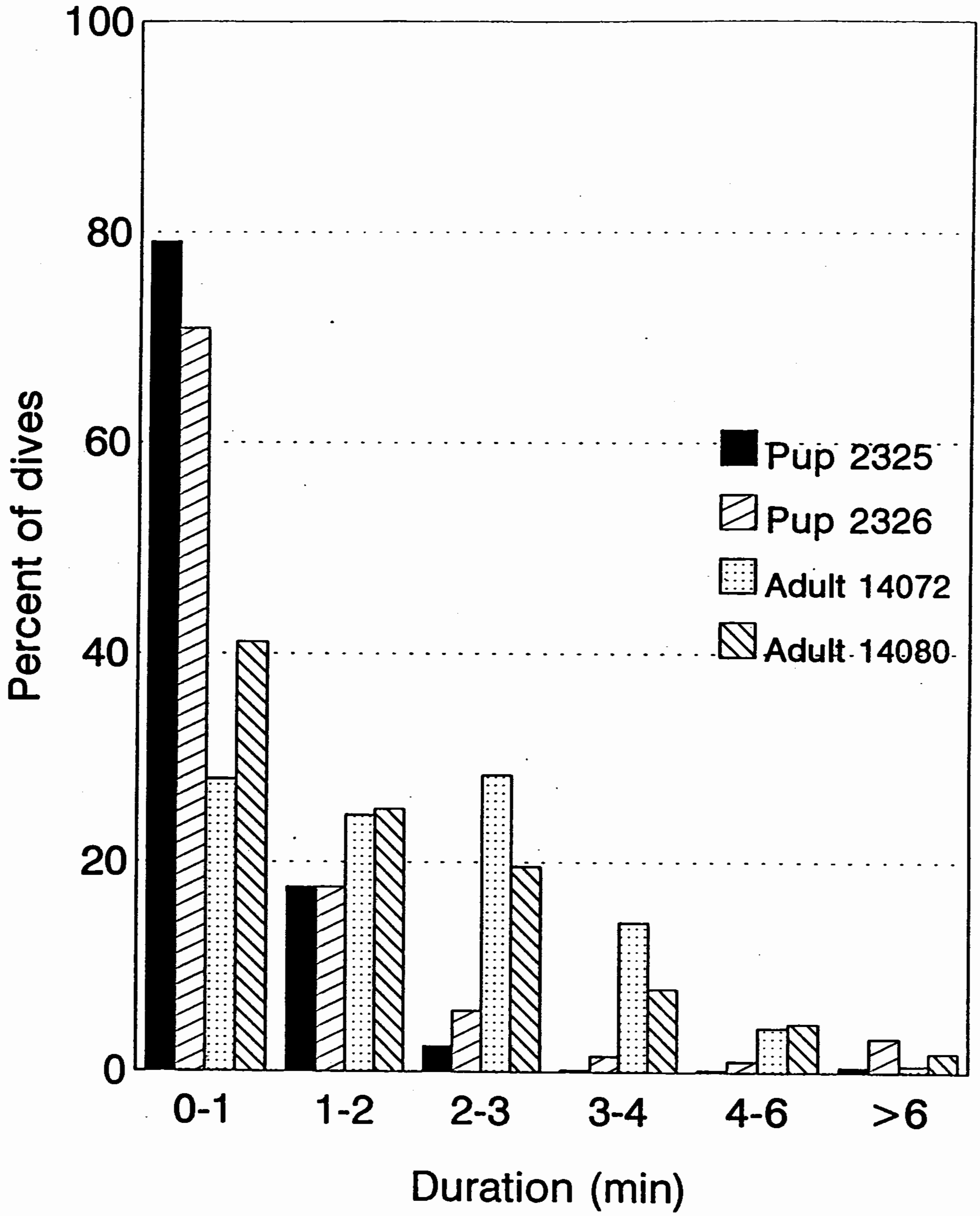


Figure 2-9. Summary of percentage of dives by duration for Steller sea lion pups and adult females during 1991 and 1992.

Chapter 3

BLOOD CHEMISTRIES AND BODY CONDITION OF STELLER SEA LION PUPS AT MARMOT ISLAND, ALASKA

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ABSTRACT

Physiological or metabolic disorders in Steller sea lions (Eumetopias jubatus) could be affecting them as newborns resulting in reduced survival. Four physiological parameters were measured to determine health status: hydration state, blood metabolite chemistry, blood oxygen chemistry and blubber depth. Eighteen Steller sea lion pups (2-3 weeks postpartum) were studied on Marmot Island, Alaska, in June and July, 1990 and 1991. Results showed that whole blood, plasma and red cell (RBC) values of water content and specific gravities were normal compared to other pinnipeds and appeared to be higher in hydration state. No obvious differences were noted in hematocrit or hemoglobin levels or in the amount of hemoglobin per RBC. Blood glucose and free fatty acid levels were in the range of reference values and gave no gross indicator of carbohydrate or lipid irregularities. Blood urea nitrogen levels were lower than reference values. The average dorsal blubber thickness at mid-trunk was 3 ± 1 mm; skin and blubber were being laid down with increasing pup size. The normal values obtained for blood chemistries and blubber thickness in these Steller sea lion newborns do not indicate metabolic or physiological problems.

INTRODUCTION

The number of Steller sea lions (Eumetopias jubatus) in the North Pacific Ocean has declined over the last 20 years to such an extent that the species has been designated as "threatened" under the United States Endangered Species Act (Federal Register, November 26, 1990). The cause(s) of the decline are unknown, but may be linked to redistribution, disease, environmental perturbations (which may influence the quality or quantity of prey), the synergistic effects of fisheries, or other unknown causes (Braham et al. 1980; Merrick et al. 1987; Loughlin and Merrick 1989; Loughlin et al. 1992). Calkins and Goodwin (1988) suggested that adult female Steller sea lions in the Gulf of Alaska during 1985-1986 were anemic and smaller in body size than animals sampled ten years earlier, possibly as a result of food limitations. The best population models currently suggest that the decline in sea lion numbers results from a reduction in survival of juveniles or breeding females, or both (York, pers comm).

The work reported here considered the possibility that physiological or metabolic disorders could be affecting the animals as newborns and that their early survival would therefore be compromised. Four separate levels of health status which might be altered by such disorders were considered: hydration state, blood metabolite chemistry, blood oxygen chemistry and blubber depth.

MATERIALS AND METHODS

Hydration state was measured by determining the water content and specific gravity of the plasma and the whole blood, factors which respond readily to alterations in water balance in pinnipeds (Castellini et al. 1990). Plasma chemistry assays focused on indicators of excessive protein metabolism that would be caused by starvation (increases in blood urea nitrogen), on breakdowns in lipid metabolic regulation (free fatty acids and ketone bodies), and on carbohydrate levels (glucose), all of which are altered in pinnipeds that are fasting for extended periods or have begun to starve (Castellini and Rea 1992). Blood oxygen chemistry was determined by monitoring the hematocrit, total hemoglobin and the hemoglobin content per red cell. For many of these values, comparative data were available that were collected from captive Steller sea lion pups over 20 years ago in California (Hubbard 1968). Blubber and skinfold thickness were determined to investigate potential gross problems with nutrition or thermoregulation.

Eighteen newborn (2-3 weeks postpartum) Steller sea lion pups were studied on Marmot Island, northeast of Kodiak Island, in the Gulf of Alaska in late June and early July, 1990 and 1991. Nine pups were studied each year. Historically, Marmot Island is a breeding area for Steller sea lions but population levels have dropped over 67% in the last 10 years (Loughlin et al. 1992). We studied pups near their nursing areas by herding their mothers into the surf zone and then working with the pups that remained on the beach. The pups were placed in a small hoop net, weighed to the nearest 0.5 kg on a hanging scale and then moved back onto the sand where they were manually restrained while body measurements and blood samples were taken. Blood samples (about 10 ml) were drawn from the pelvic venous plexus with 18gx2 needles into heparinized syringes and then transferred into heparinized blood collection tubes. The blood was immediately sampled for hematocrit (Hct) and hemoglobin (Hb) and then chilled on ice. In 1990, blubber thickness was measured using a portable ultrasound transducer (Ultrasonics, Inc.; accuracy ± 1 mm) at six key locations around the body (dorsal and lateral at the chest, axillary and mid-trunk). In 1991, skinfold calipers were used to measure blubber and skin thickness and were plotted against body weight to test whether blubber was being laid down with increasing size. The entire procedure for each pup was completed within 10-15 min.

At the field camp, the chilled blood samples were warmed and an aliquot removed for whole blood water content analysis. The remaining whole blood was then centrifuged to separate the red blood cells and aliquots of the plasma were prepared for analysis of water content, ketone body concentration (β-hydroxybutyrate; β-HBA), plasma glucose, non-esterified free fatty acid (FFA) concentration and blood urea nitrogen (BUN). The prepared aliquots of whole blood and plasma were frozen in liquid nitrogen for return to the University of Alaska, Fairbanks. The samples prepared on the beach for Hb concentration were returned to Fairbanks in a chilled and dark container. Hematocrit values were measured in duplicate using standard clinical micro-hematocrit centrifugal techniques at the remote site.

Hemoglobin levels were determined using cyanmethemoglobin spectrophotometric assay techniques (SIGMA kit #525). Mean corpuscular hemoglobin concentration (MCHC) was calculated by dividing the hemoglobin concentration by the Hct. All other plasma chemical assays were carried out using enzymatic end point determinations on a Milton-Roy 1201 spectrophotometer using the following reactions or kits: Plasma glucose was assayed using a modified reaction of the hexokinase-glucose-6-phosphate dehydrogenase assay (Castellini and Castellini 1989). Free fatty acids were assayed using the NEFA-C assay kit by WAKO Pure Industrial Chemicals. Blood urea nitrogen was measured using SIGMA kit #66-20. β-HBA was assayed using a modified form of the β-hydroxybutyrate dehydrogenase reaction (Castellini and Costa 1990).

Water concentrations in the plasma and whole blood were determined using dry weight/wet weight techniques and red blood cell (RBC) water was determined using relationships between plasma and whole blood water concentration, Hct levels and the specific gravity of plasma and whole blood (Castellini and Castellini 1989; Castellini et al. 1990). Specific gravity of the plasma and whole blood was determined by measuring the mass of 200 fl of sample on a 4 place electronic scale (Harris et al. 1987; Castellini et al. 1990).

There are a variety of diseases or nutritional deficiencies that are indicated by gross changes in blood chemistries. For example, in northern fur seal pups, malnutrition is marked by low values for subcutaneous blubber, dehydration in all tissues and viscous blood (Keyes 1965). Hubbard (1968) reported that the BUN level in an anorexic Steller juvenile was off-scale at over 160 mg%, compared to a normal range of about 9-30 mg%. In seals, extreme fasting can increase blood ketone levels to over 1.5 mM, although not to values as high as seen in other fasting mammals (Castellini and Costa 1990). In general, increases in Hct or Hb are indicative of dehydration while decreases can signal anemia, leukemia, iron metabolic disorders or nutritional problems; a decrease in MCHC can suggest anemia or iron deficiency; increases in BUN can suggest dehydration or renal disease while low values can be due to liver pathology or starvation; glucose levels can be elevated due to diabetes or lowered due to systemic disease or malnutrition and plasma lipids can increase due to pancreatic disease or decrease due to starvation (for review of marine mammal clinical blood pathology, see Bossart and Dierauf 1990). Using these clinical precedents, gross changes in the measured blood parameters could indicate a variety of pathological or nutritional problems.

RESULTS

Table 6 contains the measured values and mean (±SD) values for all the blood assay data. Not all values could be collected for every sea lion. For comparative purposes, the table also has values from 11 Steller pups sampled over 22 years ago and reference values for other pinnipeds. Whole blood, plasma and red cell (RBC) values of water content and specific gravities for the Steller sea lion pups were normal compared to other pinnipeds and if anything, appeared to be higher in hydration state. No obvious differences were noted in hematocrit or hemoglobin levels or in the amount of hemoglobin per RBC. Blood glucose and free fatty acid levels were in the range of reference values and gave no gross indicator of carbohydrate or lipid irregularities. Ketone levels in pinnipeds have only recently been investigated, but the low levels do not indicate ketosis brought about by starvation. Similarly, the blood urea nitrogen levels appear lower than reference values and therefore do not indicate excessive protein catabolism that could be brought on by starvation chemistry.

The average dorsal blubber thickness at mid-trunk (skin subtracted) for the nine pups in 1990 was 3 ± 1 mm. In 1991, skinfold thickness was plotted against body weight (Figure 3-1) and indicated that skin and blubber were being laid down with increasing pup size.

DISCUSSION

The normal values obtained for blood chemistries and blubber thickness in these Steller sea lion newborns do not indicate metabolic or physiological problems. This conclusion is based on temporal comparisons with blood values taken from Steller sea lion pups over 2 decades earlier, on comparisons with other species of young sea lions and with clinical values for normal animals (Table 6). Blubber thickness values for healthy newborn fur seal pups (Scheffer 1961; Blix et al. 1979) were recorded to be about 3mm, the same depth as obtained in this study. Unfortunately, these are the only information available on blubber thickness in newborn otariids.

The normal blood values and blubber thickness for these pups suggest several conclusions about relationships between health status and the population decline of Steller sea lions. First, the pups appear to be healthy during their early period of suckling and there is no indication that they are severely compromised. These pups appeared healthy to us in that they were strong, agile and active. Second, there does not seem to be any indication of some sort of disease in neonatal sea lions in this region of Alaska that impacts blood metabolite chemistry, blood chemistry associated with iron metabolism and oxygen carrying capacity or hydration state.

The limitations of this study are that not all possible metabolic disorders were screened, although it seems unlikely that a serious problem would have escaped detection. There was no indication that these 18 pups were the survivors from earlier mortality as there has not been any increase in the numbers of carcasses on the beaches that would indicate a spreading disease (Loughlin, pers. obs.). It is important to realize that these data reflect the health status of pups during their first few weeks of life. It is conceivable that a metabolic problem could be occurring at the juvenile stage and this question is currently being addressed. The most critical point is that it does not appear that Steller sea lion pups are born with a significant metabolic or physiological problem that disables them as newborns.

ACKNOWLEDGEMENTS

Thanks to L. Rea for chemical analysis of some of the samples and to G.A.J. Worthy for computer analysis of the morphometric data. R. Merrick was instrumental in field work during 1991. The Steller sea lions were handled under MMPA permit number 584 to the Alaska Fisheries Science Center. Minerals Management Service provided financial support through Interagency Agreement IA-14411.

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Table 3-1. Blood chemistries from Steller pups at Marmot Island, Alaska, and reference values.

SAMPLE DATE	SUBJECT ID#	Mass (kg)	SG PL (gm/ml)	SG PL (gm/ml)	Plasma % Water	Blood % Water	RBC % Water	HCT (%)	Hb (gm%)	MCHC	Ketones (mM)	Glucose (mM)	FFA (mM)	BUN (mg%)
6/26/90	801	17	1.049	1.021	94.3	78.3	66.9	60.0	19.4	32.3	0.32	3.9	1.75	14.1
6/27/90	802	28	1.061	1.024	94.0	83.7	70.8	46.5	15.3	32.9	0.44	8.4	0.69	10.2
6/27/90	803	27	1.049	1.018	93.3	80.5	68.3	53.0	18.1	34.2	0.15	9.1	0.22	16.2
6/27/90	904	27	1.042	1.021	93.6	81.0	67.4	50.0	16.7	33.4	0.27	8.1	0.42	14.0
6/27/90	805	21	1.055	1.018	93.1	83.4	70.2	44.7	14.8	33.1	0.21	12.4	0.59	11.0
6/27/90	806	21	1.044	1.022	94.2	82.9	67.7	44.7	14.8	33.1	0.43	7.7	0.57	16.0
6/27/90	807	21		1.018	93.8			55.0	17.5	31.8	0.45	5.9	0.54	10.9
6/27/90	808	33		1.019	93.6			51.5	17.0	33.0	0.31	7.2	0.79	4.8
6/27/90	809	32		1.014	94.1			48.5	16.2	33.4	0.24	8.2	0.37	8.3
7/04/91	301	25		1.016	92.9						0.24	8.8	1.5	11.5
6/30/91	303	20		1.019	93.1						0.15	9.8	0.36	17.6
6/30/91	305	22		1.012	93.2						0.16	9.9	1.42	12.9
7/04/91	307	25		1.016	92.9						0.24	7.9	1.93	19.6
7/04/91	309	28		1.012	92.7						0.13	7.5	2.15	7.0
7/04/91	311	24		1.013	93.1						0.13	7.7	2.11	11.8
6/30/91	313	21		1.013	93.1						0.19	10.6	1.64	15.7
6/30/91	315	19		1.018	93.3						0.11	7.8	2.05	23.5
7/04/91	317	14		1.018	93.5						0.35	6.2	3.3	15.4
Mean			1.050	1.017	93.4	81.6	68.5	50.4	16.6	33.0	0.25	8.2	1.2	13.4
Standard Deviation			0.006	0.003	0.5	1.9	1.5	4.8	1.5	0.6	0.11	1.8	0.8	4.4
(a) Steller pups (1968)			na	na	na	na	na	48.6	16.2	33.3	na	5.9	na	21.3
(b) Northern fur seal			na	na	91.1	77.1	70.9	46.3	16.3	35.3	na	8.3	na	40.8
(c) California sea lion			1.063	1.025	90.3	77.2	69.8	48	12-20	32-38	na	8.6	na	17.5
(d) Suckling elephant seal pups			1.071	1.022	90-93	72.9	67-68	48.4	18-22	33-39	0.1	7-9	1-3	15-35

References:
(a) Hubbard 1968
(b) Hubbard 1968, Castellini and Castellini 1989
(c) Hubbard 1968, Castellini and Castellini 1989, Bossart and Dierauf 1990
(d) Costa and Ortiz 1982, Castellini and Castellini 1989, Castellini and Costa 1990, Castellini et al. 1990, Castellini and Rea 1992.

Key: SG = specific gravity; WB = whole blood; PL = plasma; RBC = red blood cells; HCT = hematocrit; Hb = hemoglobin;
MCHC = mean corpuscular hemoglobin concentration; FFA = free fatty acids; BUN = blood urea nitrogen this page (56) is the table which is on another file (chpt3.tbl)

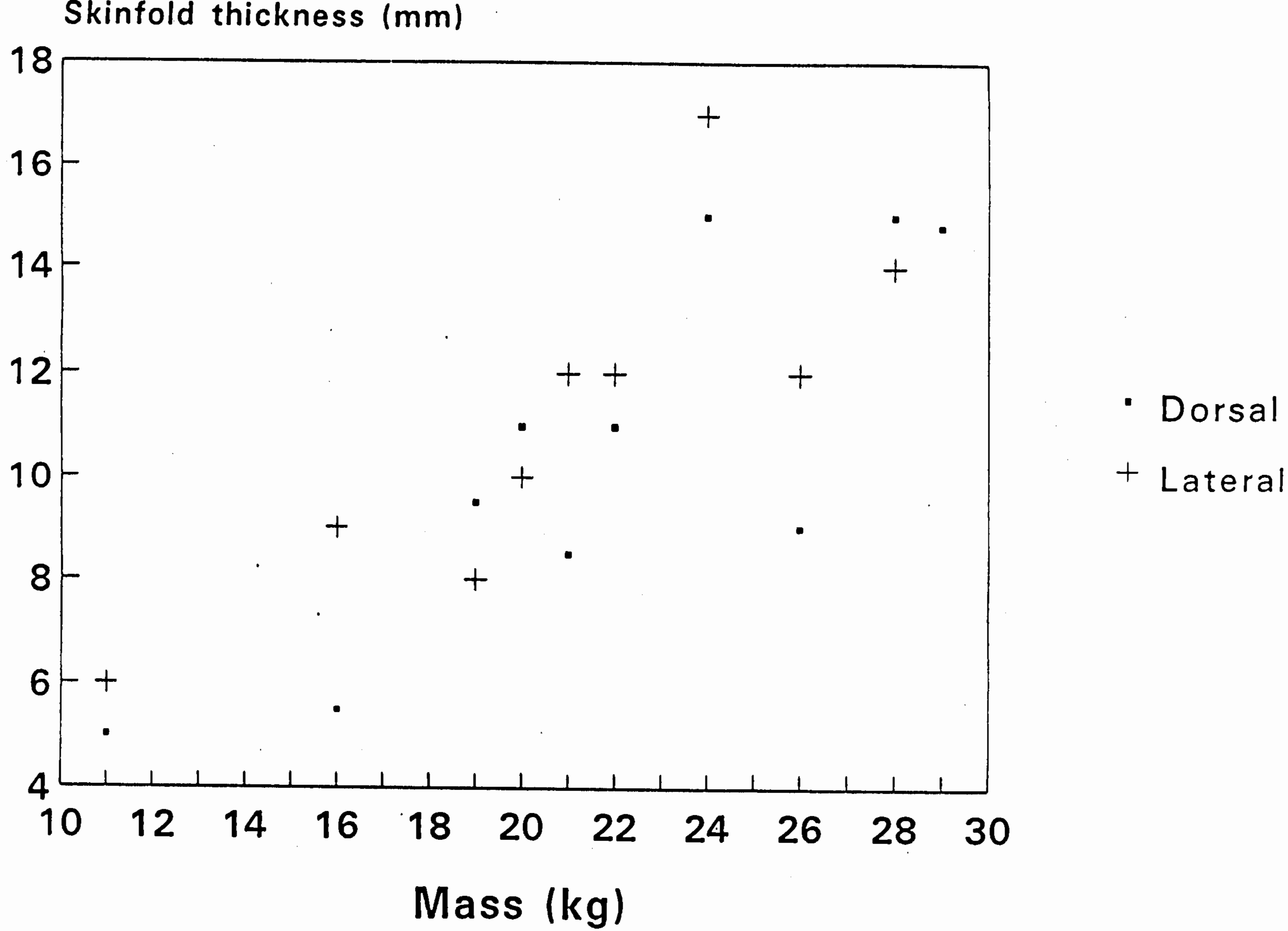

Figure 3-1. Plot of axillary skinfold thickness against body mass for Steller sea lion pups in 1991.