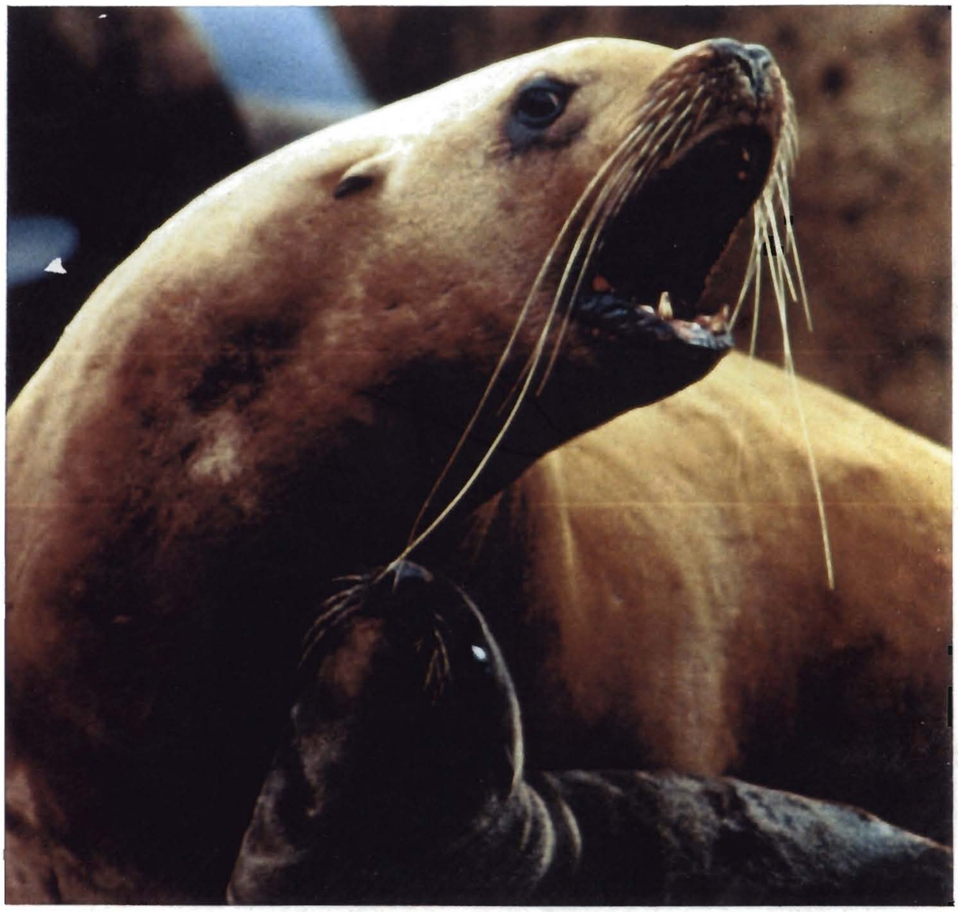
Steller Sea Lion Recovery Investigations in Alaska, 1992-1994

Contributors

T. C. Adams, D. Bradley, E. A. A. Brandon,
D. G. Calkins, M. A. Castellini, R. W. Davis, B. S. Fadely, T. R.
Loughlin, L. L. Milette, D. C. McAllister, G. W. Pendleton,
K. W. Pitcher, B. Porter, L. D. Rea, T. R. Spraker, U. G. Swain
and T. Zenteno-Savin



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ABSTRACT

The United States population of Steller sea lions (SSL), *Eumetopias jubatus*, is classified as "threatened" under the Endangered Species Act" because of a recent 73% decline in numbers. National Marine Fisheries Service (NMFS) has recommended that the US population of SSL be divided into two stocks, with an east-west division at 144° west longitude, based largely on genetic evidence. Since 1992, the Alaska Department of Fish & Game (ADF&G) and NMFS have been the recipients of congressional appropriations to study the decline and develop management strategies for population recovery. The basis for much of the research has been an "experimental/control" approach comparing population characteristics between the depressed western stock and the increasing Southeast Alaska (SEA) portion of the eastern stock. Research then could focus on those factors that are different between stocks to determine their role in the decline and eventually to develop appropriate strategies to enhance population recovery. In addition to ADF&G and NMFS several other scientific groups (cooperators), with specialized expertise, have joined the research effort. In this report we present findings from our research and that of our cooperators.

Counts of SSL pups and nonpups were made at rookery and haulout sites in SEA between 1979 and 1995. Historical data on SSL abundance from earlier in the century were also examined. Counts of both pups and nonpups showed a positive trend (pups = +6.86%/yr, nonpups = +4.83%). The lower rate of increase for nonpups was probably due to the reduced presence of subadults from the depressed western stock. During this period two sites, White Sisters and Hazy Island, developed into significant rookeries. We estimate, based on total counts of pups, that in 1994 the SEA breeding population numbered approximately 17,000 animals. We conclude that SSL are abundant in SEA and are probably at the highest level of this century. These findings question the logic behind classification of the SEA subpopulation as threatened.

Comparisons of composition data from Sugarloaf Island rookery, in the area of decline, and Forrester Island rookery, in an increasing population, showed no differences that indicated reduced juvenile survival. There was an increasing trend in the proportion of adult males at Sugarloaf and a decreasing trend at Forrester. The mean ratio of subadult males was higher for Sugarloaf than for Forrester. Ratios of pups to adult females differed among years at both locations which indicates that annual variations in the environments affect productivity.

We found that pupping dates for SSL at Sugarloaf Island, in the depressed western stock, were about 10 days later than at Forrester Island, in the increasing SEA portion of the eastern stock. Pupping dates also differed between years at Sugarloaf and Forrester. At Sugarloaf Island pupping appeared earlier in 1995 than during 1980. At Forrester, between 1992 and 1995, there was a trend towards later pupping. It had previously been thought that the timing of pupping was synchronous throughout the species range. There are reports in the literature for other pinnipeds that timing of pupping is affected by nutritional status. We suggest that these findings support the hypothesis of undernutrition as a factor in the decline of the western stock but do not discount the presence of a genetic component to birthing dates. Late pupping is likely a symptom of undernutrition rather than a major mechanism behind the decline.

A potential mechanism in aiding the recovery of the western stock of SSL is emigration of animals from the SEA. It is known from other studies that SSL are highly mobile with movements of many hundred and even thousands of kilometers. However, current information indicate adult females show a high degree of fidelity to their site of birth or to nearby areas. We marked 813 pups at the Forrester Island rookery in the increasing SEA portion of the eastern stock during 1994 and 1995. Resightings of the marked animals have been made at sites ranging from Seattle, Washington to Kodiak, Alaska. Between 1998 and 2002 searches for these marked animals will be made on rookeries from Oregon to the Aleutian Islands to determine the rate of emigration. Survivorship rates will be estimated using the resightings of marked animals.

One hypothesis proposed to explain the decline is that juvenile SSL are nutritionally stressed and are experiencing high mortality during winter. It is postulated that activity budgets of juvenile SSL should reflect nutritional status. A comparative behavioural study of juvenile activity budgets was conducted at haulout sites in both the declining western stock (Cape St. Elias) and in the increasing SEA portion of the eastern stock (Timbered Island). Activity data are currently being analyzed and will be reported in a MS thesis from the University of British Columbia. The target date for completion is October 1996.

A comparative study of reproductive behaviours of SSL was conducted at the Sugarloaf Island rookery in the declining western stock and at Forrester Island in SEA, an increasing segment of the eastern stock. During an El Nino event, which resulted in drastic food shortages ranging from Chile to California, a number of reproductive behaviours were noted to change in otariids. Based on findings of field research with otariids and experimental studies of terrestrial mammals, data on the following behavioural, developmental and physical indices were collected at the two sites. These included activity budgets, maternal attendance patterns, male tenure duration and territory size, copulation frequency and time, delayed weaning, early pup development and maternal care postpartum, and the occurrence of fungal patches. Preliminary results indicate that females spend more time nursing their pups, are more aggressive and have a longer perinatal period in the area of decline. Trip durations appear to be shorter in the area of decline. The final results of this study will be reported in a MS thesis from the University of British Columbia. The target date for completion is December 1996.

Indices of adult female reproductive effort, female body condition, and pup growth were studied for Alaskan Steller sea lions. Data from declining populations at Chirikof Island in 1993 (C93), Marmot Island in 1994 (M94), and Fish Island in 1995 (F95) were compared to a stable population at Lowrie Island in 1993 and 1994 (L93, L94). Trip duration of adult females was monitored by deploying VHF transmitters. Female body condition and known-age pup growth, body condition and milk intake were measured during their first 40 days postpartum. There was a significant difference among locations in mean trip duration, the longest at L94 (29.1 hrs) and shortest at C93 (11.2 hrs). There was no significant difference among locations in pup mass at age 0-5 days (mean = 21.0 kg), although males (22.4 kg) were significantly heavier than females (19.5 kg). There was a significant difference among growth rates, with the C93 and F95 pups growing faster in their first 40 days than the M93, L93, and L94 pups. Male and female pups generally grew at the same rate, so male pups remained consistently heavier than females. There was no significant difference in milk composition, lean body mass and total body lipid among pups or adult females at the different locations. Overall, there is no indication for increased female reproductive effort, poor body condition or slower pup growth for females and pups in the area of declining population.

We examined the plasma concentration of the acute phase protein haptoglobin (Hp) from SSL and harbor seals (*Phoca vitulina*) in regions of Alaska where the populations of these pinnipeds were declining and compared the values with concentrations of Hp from the same species in areas where the populations were stable. Samples were collected from 1992 through 1994 at sites in Southeast Alaska, Prince William Sound, the Gulf of Alaska and the Aleutian Islands. Significantly higher levels of Hp were found in the samples from the areas of decline compared to those from stable populations. Based on these findings, we propose that one may be able to distinguish these compromised pinniped populations using Hp as a biomedical indicator.

Studies of the health status of SSL were conducted in both the area of decline (western stock) and an area where numbers were increasing (SEA) in an attempt to identify factors involved in the decline. These studies were organized into three categories: clinical evaluations of live-captured pups and adults; gross necropsies, histological lesions and toxicology of animals found dead;and studies of a specific syndrome characterized by dermal ulceration and alopecia in relatively healthy and robust pups. Hematological data demonstrated that many of the adults had relatively normal blood parameters while many of the clinically normal pups had slightly elevated white blood cell counts. At least 6 serotypes of the San Miguel sea lion virus and a *Chlamydia* sp. are circulating through the sea lion population. Both of these agents could cause abortions under certain circumstances. Based on small sample sizes, only low levels of chlorinated hydrocarbons and polychlorinated biphenyls were present in the blubber of SSL from SEA. Necropsies of 4 adult female SSL indicated all were relatively healthy. The deaths of 4 juveniles were attributed to emaciation (2), capture related drug reaction (1) and blunt trauma (1). Necropsies on 55 SSL pups indicated the primary cause of death was emaciation due to starvation and trauma. A total of 26 aborted fetuses were collected from winter haulout sites and necropsied. Several organisms were identified that could be associated with the abortions including *Chlamydia* sp., *Virio fluvialis, Edwardsiella tarda, Provendencia/Morganella* sp. and perhaps *Streptococcus* spp. Two dermological conditions of SSL pup (often found together) were found characterized alopecia with lice by blisters and/or ulcers located on the flippers, perineal area and prepuce. The ulcerative dermatitis (probably caused by calcivirus) and alopecia (probably associated with lice) is widespread and found in both the declining and increasing portions of the SSL range. No evidence was found that either of these two disease conditions caused mortality of pups.

The diving behaviour of female SSL was investigated using satellite-linked time-depth recorders (SDRs). Fourteen SDRs were deployed during 1992-1993 at 2 rookeries in Southeast Alaska and 1 haulout in the eastern Gulf of Alaska; 12 on adult females in summer, including 1 without a pup, 1 on a yearling female in summer, and 1 on an adult female in winter. Data were received from all 14 SDRs for 21-113 days. During summer, adult females with pups made relatively short foraging trips (mean 19.1 h). Mean trip durations for the adult female without a pup and for the yearling were 31.0 hr and 19.3 hr. In winter; foraging trips by an adult female from the Cape St. Elias haulout in the eastern Gulf of Alaska were longer in duration (mean 56.1 hr, maximum 169 hr). The proportion of time at sea for the winter female was 86% compared to 61% for the yearling female, 47% for the female without a pup, and a mean of 51% for the summer females with pups. Dives for all females were generally short (mean 1.5 min) and shallow (mean 26.1 m). More than 60% of all dives were under 2 min and less than 20 m. The percentages of dives under 1 min ranged from 66% for the yearling, 53% for the winter female, 48% for the summer female without a pup, and a mean of 46% for the females with pups. Mean percent time submerged ranged from 12-29%. Maximum dive depths for individuals ranged from 120 to 424 m, the deepest dive being recorded for the winter female. The winter adult also had a higher percentage of dives deeper than 100 m (14% vs. 2-6%). Overall dive depths for the winter female decreased as dive frequency increased in the spring (7.2 dives/hr in Feb. and March vs. 14.0 dives/hr in April and May). The yearling dove more frequently to depths greater than 100 m (maximum 220 m) in June and July (10.3 dives/day) than in August and September (3 dives total). As dive depths decreased during the summer, dive frequency increased from 13.7 dives/hr to 19.5 dives/hr. For all sea lions except the female without a pup, the frequency of dives was higher at night (2100-0300). Significant diel patterns were also observed for diving behavior of nursing females.

Summer movements and habitat use of female SSL were studied in SEA with the use of satellite-linked depth recorders. Females, believed to have pups on rookeries, remained within about 20 nautical miles of those rookeries. Mean foraging trip distance from the Forrester Island and Hazy Island rookeries for these animals was 14.5 km. An adult female, that apparently without a surviving pup, moved between all 3 rookery sites in SEA. A juvenile female, captured at Forrester Island, moved between Forrester and 2 nearby haulouts and may of been in the process of being weaned. An area north of Forrester was particularly important for feeding adult females. Options for protective fishing closures are discussed.

Results of this research were equivocal in regard to testing the hypothesis that undernutrition was a major factor in the decline of SSL numbers in the western stock. Findings which supported the undernutrition hypothesis included differences in the timing of pupping, reproductive behaviors, levels of haptoglobin, dive rates during foraging trips and foraging effort. However a study of female reproductive effort, female body condition and pup growth gave no indication of reduced nutrition in the declining population. In fact, several of these indicators revealed that the opposite may be true. Interpretation of these comparisons was complicated by uncertainty that the nutritional status of the western stock was the same during the earlier years of the decline and when the data were collected. Certainly, density-dependent relationships have changed substantially in the western stock and to a lesser degree in SEA. Undernutrition could be affecting only certain age classes (i.e. juveniles) or certain seasons. Regardless of what the current factors are controlling the western stock, there is considerable evidence that undernutrition was a major factor in the original decline. Even if nutritional status has improved in the western stock, population numbers are at such a low level that other sources of mortality may be preventing recovery. Recommendations are provided for management and continued research.

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INTRODUCTION

Steller sea lions (*Eumetopias jubatus*) are carnivorous marine mammals belonging to the suborder Pinnipedia and family Otariidae. They occur in the North Pacific Ocean and Bering and Okhotsk Seas. In North America they range from southern California north along the Pacific Coast throughout the Gulf of Alaska, the Bering Sea and the Aleutian Islands. In Asia they range from northern Japan, the Kuril Islands and the Okhotsk Sea, the east coast of the Kamchatka Peninsula to as far south as China's Yellow Sea (NMFS 1995). Mature males and females gather on terrestrial sites known as rookeries during the pupping and breeding seasons; mid-May through mid-July. They also use terrestrial sites known as haulouts to rest throughout the year. Many rookeries have adjoining haulouts, and many rookeries are used as haulouts after pupping and breeding are completed. Steller sea lions repeatedly use the same rookery and haulout locations,thus, these could be considered traditional sites (Calkins and Pitcher 1982). When not hauled out, Steller sea lions range from nearshore to beyond the continental shelf and occasionally occur in rivers and lakes. They are capable of diving to depths exceeding 400 m (ADF&G unpubl. data, 333 Raspberry Road, Anchorage, AK 99518).

Steller sea lions are the largest Otariid; pups were about 1 m long and weighed about 16 to 25 kg at birth; mean adult weights were 566 kg for males and 264 kg for females (Calkins and Pitcher 1982).

Steller sea lions are polygynous and dominant males establish territories on rookeries within which females birth and breed. Males became sexually mature between 5 and 7 years of age (Perlov 1971). Most territorial bulls were between the ages of 9 and 13 years (Thorsteinson and Lensink 1962). Females became sexually mature between 3 and 8 years of age; all mature females ovulated annually. Reproductive failures occurred in about one-third of adult females examined during the 1970s resulting in a birth rate of about 63% (Pitcher and Calkins 1981). In a sample taken in the mid-1980s (Calkins and Goodwin 1988) a slightly lower birth rate was estimated.

Steller sea lions have been described as generalistic predators that feed primarily on fishes and cephalopods (Loughlin et al. 1987). In the Gulf of Alaska, Pitcher (1981) found that major prey included walleye pollock (*Theragra chalcogramma*), Pacific herring (*Clupea harengus*), capelin (*Mallotus villosus*), Pacific cod (*Gadus macrocephalus*), salmon (*Oncorhynchus* spp.), squids (Gonatidae) and octopus (*Octopus* sp.) In the Aleutian Islands, Atka mackerel (*Pleurogrammus monopterygius*) was the most common prey; walleye pollock and Pacific salmon were also found (Merrick 1995). In Southeast Alaska, walleye pollock predominated in a small sample that also included flathfishes (Pleuroncectidae), herring, squid and octopus (Calkins and Goodwin 1988).

While Steller sea lions are not considered migratory in the classical sense (a two-way movement, involving a return to the area originally vacated), they are highly mobile with movements of many hundreds and even thousands of kilometers (Calkins and Pitcher 1982, Calkins 1986, NMFS 1995). Most of these observations were of young animals marked as pups. It is unknown if these wide-ranging animals returned to the general area of their birth when mature or if they were true dispersers resulting in animals breeding in locations distant from their place of birth. Most current information adult females show a considerable degree of breeding fidelity to their site of birth or to nearby areas (Calkins and Pitcher 1982, Loughlin *In* Press).

Recent research, which analyzed mitochondrial DNA, indicated that the worldwide population of Steller sea lions is composed of at least 2 genetically differentiated populations or "stocks" (NMFS 1995, Bickham et al. 1996). These include an eastern population ranging from California through Southeast Alaska and a western population to the north and west. Data from marked animal and population dynamic and morphology studies support this idea (Loughlin *In* Press).

In Alaska, the western population of Steller sea lions has declined by about 81% since the 1960s from about 177,000 nonpups to 33,600 in 1994 (Loughlin et al. 1992, NMFS 1995). The decline was first in the eastern Aleutian Islands in the early 1970s (Braham et al. 1980). Merrick et al. (1987) reported that by 1985 the decline had spread throughout the Aleutian Islands and eastward into the Gulf of Alaska at least to the Kenai Peninsula. The rate of decline increased between 1985 and 1989. By 1990 the decline covered the entire western population from Cape St. Elias to the western Aleutian Islands. The decline has continued since 1989 but has moderated in most areas (NMFS 1995).

In contrast the Alaskan portion of the eastern Steller sea lion stock (Southeast Alaska) has been increasing and is probably at its highest level of this century (see Chapter 1 in this report).

In 1990 National Marine Fisheries Service (NMFS) classified the Steller sea lion as threatened under the Endangered Species Act because of the large decline and concern for the viability of the species. Sea lions were also classified as depleted under the Marine Mammal Protection Act. In 1995, because of the continuing decline, NMFS published a notice in the *Federal Register* soliciting comments on a proposal to designate a western and eastern stock and to change the status of the western stock to endangered leaving the eastern stock listed as threatened.

Also in 1990, NMFS appointed a Steller sea lion recovery team. The primary purpose of the recovery team was to develop a recovery plan to guide restoration of the sea lion population. The recovery team published a recovery plan in 1992 that provides guidelines for investigating causes of the decline and outlines both management and research activities that may aid population recovery. The team also recommended to NMFS areas of critical habitat.

Since the passage of the Marine Mammal Protection Act in 1972, NMFS has been the agency with management responsibility for Steller sea lions. The state of Alaska, through the Alaska Department of Fish and Game (ADF&G), has continued to play a major role in research activities and in making management recommendations to NMFS. Most of the worldwide population is in Alaska and play an important role in the Alaskan marine ecosystem. Steller sea lions are particularly important to Alaskan residents as a subsistence food source for coastal Natives and through interactions with commercial fisheries.

From statehood until 1972, ADF&G was responsible for management of Steller sea lions and had active research and management programs. The focus of these programs was on the commercial harvest of sea lions and on interactions of sea lions with commercial fisheries. After 1972 ADF&G's involvement with sea lion research became somewhat intermittent as research became more dependent on outside funding. In 1973 and 1974 ADF&G conducted studies of sea lion abundance and distribution in Prince William Sound in anticipation of the transport of crude oil through the area. Between 1976 and 1981 research was conducted on sea lions throughout the Gulf of Alaska because of the prospect of oil and gas development. Funding was provided by the Outer Continental Shelf Environmental Assessment Program. NMFS provided funding to conduct aerial surveys and pup counts between 1982 and 1984. In 1985 and 1986 the U.S. Congress provide funding for ADF&G to conduct a study that investigated the Steller sea lion decline. After the Exxon Valdez oil spill in 1989, ADF&G participated in a research program to evaluate damages to the sea lion population caused by the oil spill. Since 1992 Congress, in light of the continuing decline, has appropriated funding for Steller sea lion recovery research and ADF&G has been the recipient of a portion of that funding.

Since 1992, ADF&G has worked in partnership with NMFS, the other recipient of the Congressional appropriation, in investigating the decline with the goals of understanding the cause(s) of the decline and developing management actions tp promote population recovery. Congressional funding has continued through FY 96 and is likely to continue, at least for the near future. Recent research has been guided by the Steller sea lion recovery plan. The major emphasis has been on monitoring population trends, investigating factors which may be causing (or have precipitated) the decline and identifying important habitats. Much of the research has centered on determining if abundance and types of prey have changed and how this may have affected population dynamics.

A general strategy to identify factors involved in the decline has been a comparative "experimental/control" approach. The western population, which has declined greatly over the past 20 years, serves as the experimental area. Data reported on from the western population were collected in the Gulf of Alaska. The SEA portion of the eastern stock, that has increased over the same period, is the control. NMFS has focused their efforts in the western area while ADF&G has worked mainly in the eastern area (Southeast Alaska) and the central and eastern Gulf of Alaska. This approach proposes to compare a number of population characteristics and to identify those that may be different in the two stocks. Research could then focus on those factors to determine their role in the decline and eventually to develop management actions to promote recovery.

In addition to ADF&G and NMFS a number of other groups with specialized expertise have joined the research effort. These cooperators have received logistical support, and in some cases financial support. These include scientists from the North Pacific Universities Marine Mammal Research Consortium, the University of Alaska, Texas A&M University, the Office of Naval Research, the University of British Columbia and Colorado State University.

In this report we present findings of research conducted by ADF&G, and by major cooperators, from 1992 through 1994. In some instances more recent data will be reported when it fits logically with the analyses of earlier work. In the ADF&G research proposals for the years 1992-1994, 19 individual objectives are listed. These objectives have been grouped into categories (chapters) (Table 1). Each chapter is comprised of stand-alone report(s) in manuscript format. A general discussion, synthesizing the findings of the individual chapters along with conclusions and recommendations, concludes this report.

Table 1. ADF&G Steller sea lion research categories (chapters).

Number	Category
One	Distribution and Abundance
Two	Population Composition Comparisons
Three	Dispersal and Rookery Fidelity
Four	Behavioral Comparisons
Five	Physiological Comparisons
Six	Pathological Comparisons
Seven	Movements, Habitat Use and At Sea Behavior

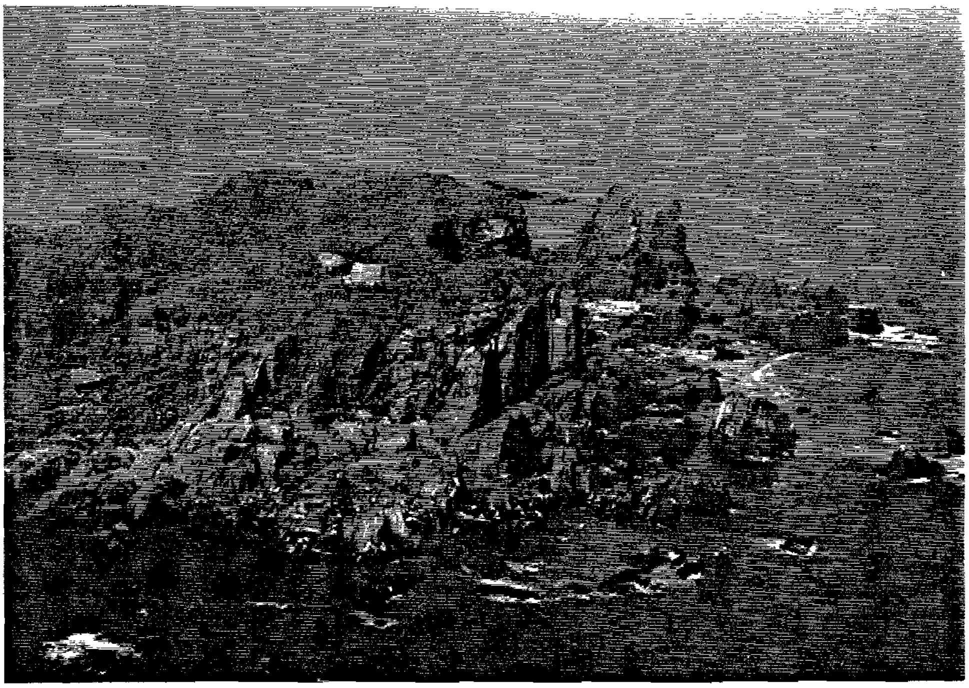
Two peer-reviewed, scientific journal papers, based at least in part on this research program, have been published or are in the process of being published and are cited below.

Heath, R. B., D. G. Calkins, D. C. McAllister, W. B. Taylor and T. R. Spraker. In Press. Telazol and Isoflurene anesthesia in free-ranging Steller sea lions (*Eumetopias jubatus*). Journal of Zoo and Wildlife Medicine.

Merrick, R. L., R. Brown, D. G. Calkins and T. R. Loughlin. 1995. A comparison of Steller sea lion, *Eumetopias jubatus*, pup masses between rookeries with increasing and decreasing populations. Fishery Bulletin 93:753-758.

CHAPTER ONE

Steller Sea Lion Abundance and Distribution



UNA SWAIN

Steller Sea Lion Status and Trend in Southeast Alaska

Donald G. Calkins, Dennis C. McAllister, Grey W. Pendleton
and Kenneth W. Pitcher

Alaska Department of Fish and Game
Division of Wildlife Conservation
333 Raspberry Road
Anchorage, AK 99518

The United States' population of Steller sea lions (SSL) has declined to about 52,000 nonpups over the past 30 years, a reduction of about 73%, and is classified as "threatened" under the Endangered Species Act (NMFS 1995). In Alaska, which at one time contained about 74% of the worldwide population (Loughlin et al. 1992), numbers have declined by about 75%. Here we report on SSL numbers and population trends in Southeast Alaska (SEA) where numbers have not declined.

National Marine Fisheries Service has recently recommended the worldwide population of SSL be divided into two stocks (Figure 1) with an east-west division near Cape Suckling (144 degrees west longitude) in Alaska (NMFS 1995). This recommendation was based on genetic information (Bickham et al. 1996) as well as on population dynamics, the results of marked animal studies and morphological comparisons (Loughlin In Press). This division separates SEA from the declining western stock.

Knowledge of population status and trend information from SEA is meaningful in the context of the proposed division of stocks and the determination of appropriate classifications under the Endangered Species Act. This information is also meaningful, from a comparative viewpoint, in understanding the factors involved in the substantial decline in SSL numbers to the west. Trend information is necessary for making management decisions concerning this subpopulation, particularly in regard to enhancing recovery of the western stock.

Methods

Beginning in 1979, systematic counts were periodically made of SSL in SEA. These counts were of two types. Pups were counted on rookeries after most pups had been born but before they began entering the water, usually between 25 June and 4 July. Pups were counted by herding all nonpups into the water and then counting the pups. Nonpups were counted on rookeries and haulouts from photographs taken during aerial surveys during the breeding period (usually 15 June-15 July).

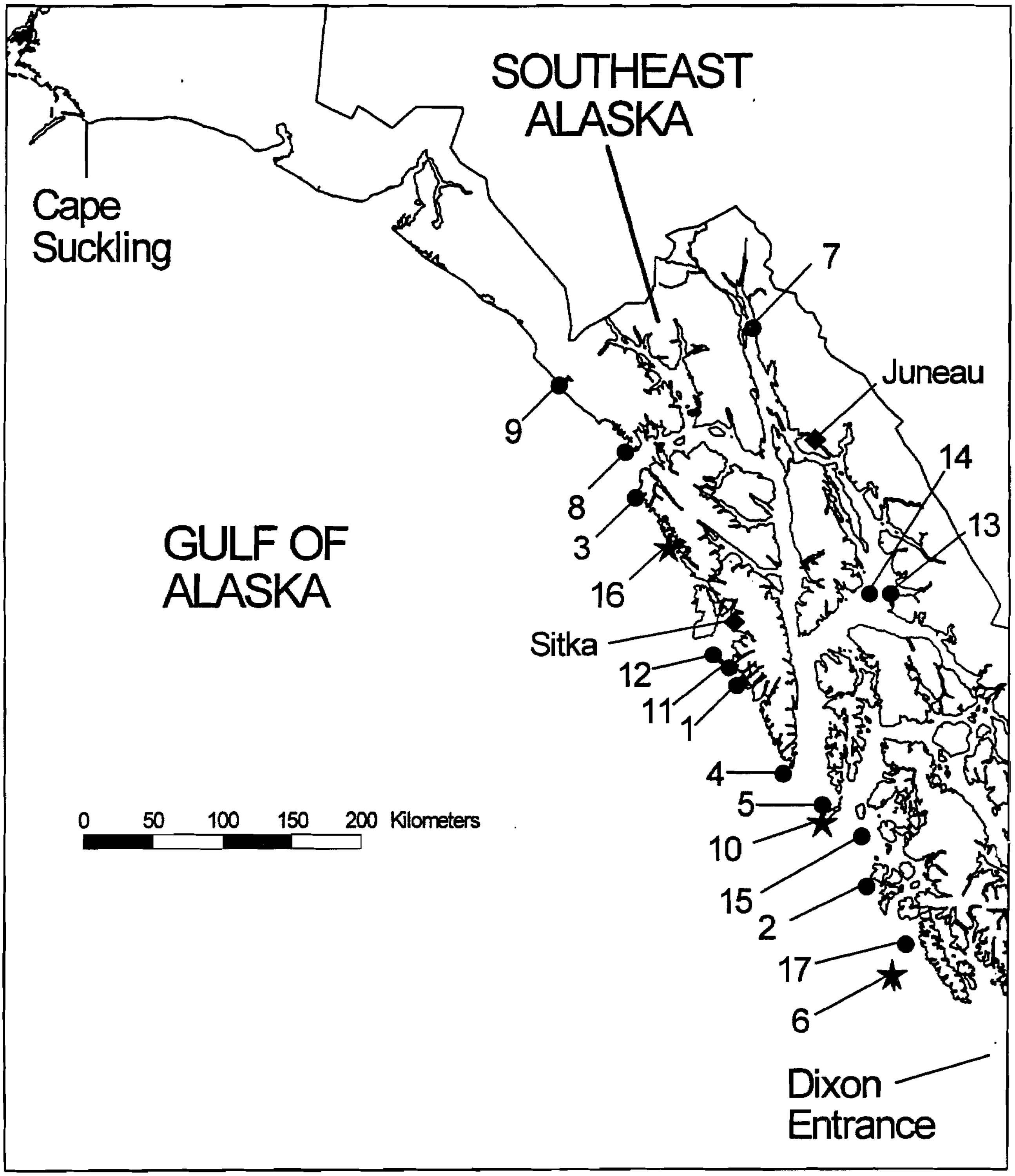


Figure 1. Locations of Steller sea lion rookery and haulout trend sites in Southeast Alaska. Site names and numbers are in Table 1.

Observations of numbers of SSL on rookeries and haulouts, dating back to the early 1900s, were obtained from the literature. These counts were of variable quality as they were generally made with nonstandardized techniques compared to our surveys.

The standardized counts of nonpups on rookeries and haulouts during the breeding season were used for trend analyses (Appendix 1). All 3 rookeries and 14 haulout sites were selected as trend index sites. Selection was based on consistent use during the breeding season. Typically, more than 95% of the total number of SSL counted in SEA during the breeding season were found at these sites. We also analyzed trends in numbers of pups counted at the three rookeries (Appendix 2).

Population trends were estimated using an analysis-of-covariance (ANCOVA) approach similar to that of Geissler and Sauer (1990). This method allows detection probabilities to vary among sites and assumes a constant rate of change. Nonconstant rates of change were investigated by adding a quadratic term to the ANCOVA. Counts were transformed to common logarithms prior to analysis. Because the logarithm of 0 is undefined, 0.5 was added to all 0 counts. Adding this small constant causes little bias when average counts are as large as those in the SSL data sets (Link and Sauer 1994). The combined trend was estimated as a weighted average of the individual trends with weights based on the average count at each site. These weights are appropriate because of evidence that trends differed among sites. Approximate 95% confidence intervals (CI) were estimated as $\mathrm{Tr} \pm t_{\mathrm{df},,\ 0.05}$ *S.E. where Tr is the estimated trend (on the log scale) from the ANCOVA, $t_{\mathrm{df},\ 0.05}$ is the Student's t-value based on alpha = 0.05 and the appropriate degrees of freedom, and SE is the standard error of the trend estimate. Estimates and CI were transformed to the original scale using the procedure of Bradu and Mundlak (1970). P-values from the hypotheses that combined trends were 0 were based on t-statistics associated with the ANCOVA; individual site trends were based on separate linear regressions.

Results

Population trends of nonpup SSL from 17 sites differed among sites ($F_{13,53}=18.73$, p = 0.002). There was little evidence of nonconstant rate of change with a quadratic ANCOVA superior ($p<0.05$) at only 2 sites. For the entire area, the estimated trend is positive with an average annual rate of increase of +4.83%, but the hypothesis of population stability is not rejected (p = 0.356)(Table 1). The variability of trends among sites and variability of trend estimates for individual sites reduced the statistical power for detecting areawide population trends.

Production of pups (Table 2) increased at the 3 rookeries combined (+6.86%/yr) and at all 3 sites (note p = 0.065 at the White Sisters). There were also differences in the trends of pup production at the 3 rookeries ($F_{2,15} = 36.32$, $p<0.001$).

Table 1. Steller sea lion nonpup population trends in Southeast Alaska, 1979-1995.

Site #	Site	Trend (%/yr)	Approximate 95% CI	P(HO: trend = 0)
1	Biali Rocks	-3.24	-6.87 - 0.53	0.078
2	Brothers Complex	-9.00	-66.36 - 146.20	0.863
3	Cape Addington	16.82	4.87 - 30.13	0.016
4	Cape Cross	61.09	30.37 - 99.06	0.002
5	Cape Ommaney	5.47	-3.13 - 14.84	0.157
6	Coronation Island	12.14	-15.95 - 49.61	0.289
7	Forrester Complex[a]	2.15	-0.78 - 5.16	0.119
8	Gran Point	60.00	-79.81 - 1168.04	0.393
9	Graves Rock	-0.67	-30.24 - 41.43	0.973
10	Harbor Point	29.46	-14.46 - 95.93	0.138
11	Hazy Islands[a]	3.54	1.11 - 6.03	0.011
12	Jacob Rock	53.28	8.54 - 116.46	0.024
13	Kaiuchali Island	29.69	-61.95 - 29.92	0.214
14	Sunset Island	34.16	-64.63 - 22.56	0.144
15	Timbered Island	7.36	-13.06 - 32.57	0.418
16	White Sisters[a]	3.06	-5.58 - 12.48	0.423
17	Wolf Rock	53.02	13.30 - 106.24	0.158
	All Rookeries	8.24	-8.93 - 28.67	0.363
	All Haulouts	2.61	-0.53 - 5.84	0.127
	Combined	4.83	-5.21 - 15.92	0.356

[a] = rookery

Table 2. Trends in numbers of pups counted on Steller sea lion rookeries in Southeast Alaska.

Rookery Site	Trend (%/yr)	Approximate 95% CI	P (Ho: trend = 0
Forrester Island	2.31	0.32 - 4.36	0.028
Hazy Islands	26.24	17.73 - 35.37	0.001
White Sisters	40.38	-4.09 - 105.49	0.065
Combined	6.86	4.02 - 9.78	<0.001

Discussion

While these data indicate increasing numbers of SSL in SEA, apparent differences existed in recent trends of pups and nonpups. Pup production at the 3 rookeries combined showed a positive increasing (*p*<0.001) trend (+6.86%/yr) (Table 2). Counts of nonpups at rookeries and haulouts combined suggested an increase (+4.83%/yr) but of nonpups at rookeries and haulouts combined suggested an increase (+4.83%/yr) but the hypothesis of population stability was not rejected (*p* = 0.356) (Table 1). Trends in numbers of nonpups at rookeries combined and haulouts combined both appeared to be increasing but again the hypothesis of population stability was not rejected (+8.24%, *p* = 0.363-rookeries and +2.61%,*p* = 0.127-haulouts) (Table 1).

Some researchers have concluded that counts of pups on rookeries are a better measure of trends of populations than are counts of nonpups (Calkins and Pitcher 1982, Berkson and DeMaster 1985). Most sex and age classes of nonpups spend portions of the time at sea while pups are limited to the rookeries during the census period. For nonpups the variability of trends among sites and the variability of trend estimates for individual sites reduced the statistical power for detecting areawide population trends.

A possible explanation for a precise correlation between trends innonpups and pups could be a reduced presence of animals from the western stock. SSL are known to range widely, particularly young animals (Calkins and Pitcher 1982, NMFS 1995). We know from marked animal studies that animals from the western stock are present during the survey period (Calkins and Pitcher 1982, Calkins 1986, NMFS unpublished data, 7600 Sand Point Way, NE, Seattle, WA 98115). However there are no observations that indicate breeding and pupping in SEA by western stock animals. Because the Alaska portion of the western stock has declined by about 74% since 1979 (NMFS 1995), it follows that the number of western SSL ranging into SEA has diminished accordingly and fewer are being counted in our SEA surveys of nonpups. This could also explain the apparent higher rate of increase of nonpups on rookeries than on haulouts (Table 1).

We believe the "true SEA breeding population" of SSL was increasing as indicated by the counts of pups. Counts of nonpups likely underestimated this increase because fewer western stock animals were counted as that subpopulation declined. The establishment of the Hazy Islands and White Sisters as significant rookeries between 1979 and 1994 could be an indicator of an increasing population. We also observed the establishment of at least 5 new haulouts during this period.

Only sketchy data are available (Table 3) to evaluate earlier population trends. Observations made during the first half of the century indicate a much smaller population (Rowley 1929, Imler and Sarber 1948). However counts made in the 1950s and 1960s (Mathisen and Lopp 1962, Bigg 1985) indicate the presence of a substantial population although probably lower than that of 1979-1995.

An estimate of the total SSL breeding population in SEA can be made from the total number of pups counted on the 3 rookeries. Pitcher and Calkins (1982) calculated the total number of animals in the Gulf of Alaska was 4.5 x the number of pups. This was based on estimates of the sex and age structure of the population and birth rates. This method produces somewhat of an underestimate as some pups are born after the counts are complete and some have died and been scavenged or washed off the rookery before the counts are made. We estimate, using the 1995 count of 3,770 pups, that the SEA breeding population is about 17,000 animals of all ages. This assumes that the SEA and Gulf of Alaska subpopulations have similar sex and age structures and birth rates. We recognize that at any given time sea lions from this subpopulation are probably scattered from at least the Pacific Northwest to the Gulf of Alaska and Aleutian Islands. We also recognize that animals born in these other areas spend time in SEA.

Population trends of SSL in SEA contrast sharply with those of the depressed western stock. Researchers currently investigating the western decline are comparing a number of population level parameters between the subpopulations, including physical condition, juvenile mortality rates, physiology, prey use, behavior, foraging effort and diseases in an attempt to explain the decline.

Table 3. Historical counts of Steller sea lions in Southeast Alaska.

Year	Site	Count	Source
pre-1929	Cape Addington	250	Rowley 1929
1945	Forrester Island	350	Imler and Sarber 1948
1945	Hazy Islands	350	Imler and Sarber 1948
1946	White Sisters	200	Imler and Sarber 1948
1957	Cape Addington	600	Mathisen and Lopp 1962
1957	Cape Ommaney	350	Mathisen and Lopp 1962
1957	Forrester Island	2500	Mathisen and Lopp 1962
1957	Hazy Islands	2500	Mathisen and Lopp 1962
1957	Kaiuchali Island	400	Mathisen and Lopp 1962
1957	Timbered Island	225	Mathisen and Lopp 1962
1961	Forrester Island	1300	Bigg 1985
1973	Forrester Island	3787	Bigg 1985

If just considering the SEA breeding population alone, it seems illogical for it to be classified as "threatened" under the Endangered Species Act. SSL are abundant in SEA and the population is probably larger than at any time during this century. However,because of the severely depleted condition of the adjoining western stock and declines in the California portion of the eastern stock, it may be particularly important to protect and maintain the SEA subpopulation at a high level. The SEA subpopulation could play a role in rebuilding depleted populations through emigration. We are currently conducting research to determine whether significant emigration of SEA SSL to the western stock occurs.

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Appendix 1. Nonpup counts of Steller sea lions on index rookeries and haulouts in southeast Alaska, 1979-1994.

YEAR	ISLAND/SITE	REGION	DAY	MONTH	ADULT CT.
1979	BIALI ROCK	SE AK	0	7	810
1982	BIALI ROCK	SE AK	0	7	722
1984	BIALI ROCK	SE AK	11	2	585
1989	BIALI ROCK	SE AK	22	6	794
1990	BIALI ROCK	SE AK	4	7	596
1991	BIALI ROCK	SE AK	9	7	494
1992	BIALI ROCK	SE AK	0	6	439
1984	CAPE ADDINGTON	SE AK	14	7	209
1989	CAPE ADDINGTON	SE AK	22	6	616
1990	CAPE ADDINGTON	SE AK	4	7	1022
1991	CAPE ADDINGTON	SE AK	20	6	827
1992	CAPE ADDINGTON	SE AK	5	7	907
1994	CAPE ADDINGTON	SE AK	12	6	892
1979	CAPE CROSS	SE AK	12	7	0
1982	CAPE CROSS	SE AK	17	7	0
1989	CAPE CROSS	SE AK	20	6	227
1990	CAPE CROSS	SE AK	8	7	128
1991	CAPE CROSS	SE AK	21	6	141
1992	CAPE CROSS	SE AK	10	6	211
1994	CAPE CROSS	SE AK	14	6	128
1982	CAPE OMMANEY	SE AK	19	7	415
1984	CAPE OMMANEY	SE AK	11	7	
1989	CAPE OMMANEY	SE AK	22	6	363
1990	CAPE OMMANEY	SE AK	4	7	431
1991	CAPE OMMANEY	SE AK	30	6	785
1992	CAPE OMMANEY	SE AK	11	6	696
1994	CAPE OMMANEY	SE AK	0	6	723
1982	CORONATION ISLAND	SE AK	19	7	74
1990	CORONATION ISLAND	SE AK	4	7	374
1991	CORONATION ISLAND	SE AK	30	6	585
1992	CORONATION ISLAND	SE AK	5	7	528
1994	CORONATION ISLAND	SE AK	12	6	142
1979	FORRESTER COMPLEX	SE AK	13	7	3121
1982	FORRESTER COMPLEX	SE AK	19	7	2622
1989	FORRESTER COMPLEX	SE AK	22	6	4648
1990	FORRESTER COMPLEX	SE AK	4	7	3324
1991	FORRESTER COMPLEX	SE AK	20	6	3648
1992	FORRESTER COMPLEX	SE AK	5	7	3508
1994	FORRESTER COMPLEX	SE AK	12	6	4008
1990	GRAN POINT	SE AK	8	8	9
1991	GRAN POINT	SE AK	21	6	101

YEAR	ISLAND/SITE	REGION	DAY	MONTH	ADULT CT.
1992	GRAN POINT	SE AK	10	6	280
1994	GRAN POINT	SE AK	13	6	104
1989	GRAVES ROCK	SE AK	17	6	533
1990	GRAVES ROCK	SE AK	8	7	937
1991	GRAVES ROCK	SE AK	21	6	470
1992	GRAVES ROCK	SE AK	12	6	366
1994	GRAVES ROCK	SE AK	13	6	733
1989	HARBOR POINT	SE AK	17	6	53
1990	HARBOR POINT	SE AK	12	7	92
1991	HARBOR POINT	SE AK	22	6	250
1992	HARBOR POINT	SE AK	10	6	110
1994	HARBOR POINT	SE AK	13	6	243
1979	HAZY ISLANDS	SE AK	13	7	893
1982	HAZY ISLANDS	SE AK	19	7	1268
1984	HAZY ISLANDS	SE AK	14	7	1251
1989	HAZY ISLANDS	SE AK	22	6	1462
1990	HAZY ISLANDS	SE AK	4	7	1187
1991	HAZY ISLANDS	SE AK	30	6	1496
1992	HAZY ISLANDS	SE AK	5	7	1861
1994	HAZY ISLANDS	SE AK	12	6	1615
1979	JACOB ROCK	SE AK	0	7	0
1982	JACOB ROCK	SE AK	0	7	1
1984	JACOB ROCK	SE AK	14	7	0
1989	JACOB ROCK	SE AK	22	6	0
1991	JACOB ROCK	SE AK	30	6	163
1992	JACOB ROCK	SE AK	11	6	147
1994	JACOB ROCK	SE AK	0	6	141
1982	KAIUCHALI ISLAND	SE AK	0	7	240
1984	KAIUCHALI ISLAND	SE AK	0	7	387
1989	KAIUCHALI ISLAND	SE AK	22	6	0
1990	KAIUCHALI ISLAND	SE AK	8	7	4
1991	KAIUCHALI ISLAND	SE AK	20	6	0
1992	KAIUCHALI ISLAND	SE AK	12	6	63
1994	KAIUCHALI ISLAND	SE AK	12	6	19
1982	SUNSET ISLAND	SE AK	17	7	274
1989	SUNSET ISLAND	SE AK	20	6	12
1990	SUNSET ISLAND	SE AK	5	7	120
1991	SUNSET ISLAND	SE AK	20	6	1
1992	SUNSET ISLAND	SE AK	10	6	0
1994	SUNSET ISLAND	SE AK	14	6	10
1982	THE BROTHERS	SE AK	17	7	119
1989	THE BROTHERS	SE AK	20	6	0
1990	THE BROTHERS	SE AK	5	6	2
1991	THE BROTHERS	SE AK	20	6	73

YEAR	ISLAND/SITE	REGION	DAY	MONTH	ADULT CT.
1992	THE BROTHERS	SE AK	5	7	0
1994	THE BROTHERS	SE AK	14	6	422
1982	TIMBERED ISLAND	SE AK	19	7	114
1984	TIMBERED ISLAND	SE AK	14	7	37
1989	TIMBERED ISLAND	SE AK	22	6	385
1990	TIMBERED ISLAND	SE AK	4	7	37
1991	TIMBERED ISLAND	SE AK	20	6	126
1992	TIMBERED ISLAND	SE AK	5	7	142
1994	TIMBERED ISLAND	SE AK	12	6	201
1979	WHITE SISTERS	SE AK	0	7	761
1982	WHITE SISTERS	SE AK	0	7	934
1984	WHITE SISTERS	SE AK	11	2	226
1989	WHITE SISTERS	SE AK	20	6	734
1990	WHITE SISTERS	SE AK	8	7	980
1991	WHITE SISTERS	SE AK	8	7	975
1992	WHITE SISTERS	SE AK	12	6	861
1994	WHITE SISTERS	SE AK	13	6	868
1990	WOLF ROCK	SE AK	4	7	13
1992	WOLF ROCK	SE AK	5	7	21
1994	WOLF ROCK	SE AK	12	6	72

Appendix 2. Counts of pups at Southeast Alaska rookeries, 1979-1995.

YEAR	ISLAND/SITE	REGION	DAY	MONTH	PUP COUNT
1979	FORRESTER COMPLEX	SE AK	0	0	2187
1982	FORRESTER COMPLEX	SE AK	1	7	2120
1984	FORRESTER COMPLEX	SE AK	0	0	2568
1986	FORRESTER COMPLEX	SE AK	0	0	1954
1988	FORRESTER COMPLEX	SE AK	0	0	2202
1989	FORRESTER COMPLEX	SE AK	23	6	2844
1990	FORRESTER COMPLEX	SE AK	0	7	2932
1991	FORRESTER COMPLEX	SE AK	7	7	3261
1994	FORRESTER COMPLEX	SE AK	30	6	2757
1995	FORRESTER COMPLEX	SE AK	24	6	2869
1979	HAZY ISLANDS	SE AK	0	0	31
1989	HAZY ISLANDS	SE AK	0	7	349
1990	HAZY ISLANDS	SE AK	27	6	638
1991	HAZY ISLANDS	SE AK	6	7	808
1993	HAZY ISLANDS	SE AK	26	7	759
1994	HAZY ISLANDS	SE AK	7	1	862
1990	WHITE SISTERS	SE AK	8	7	30
1991	WHITE SISTERS	SE AK	8	7	95
1992	WHITE SISTERS	SE AK	26	6	116
1993	WHITE SISTERS	SE AK	11	7	115
1994	WHITE SISTERS	SE AK	2	7	151

CHAPTER TWO

Steller Sea Lion Population Composition

JOEL SARTORI

Steller Sea Lion Population Composition in a Declining Versus an Increasing Population

Donald G. Calkins, Grey W. Pendleton and Kenneth W. Pitcher

Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, AK 99518

In Alaska, the western subpopulation of Steller sea lions (SSL) has declined by about 81% since the 1960s from about 177,000 nonpups to 33,600 in 1994 (Loughlin et al. 1992, NMFS 1995). This has resulted in the classification of the U.S. population as a threatened species under the U. S. Endangered Species Act (NMFS 1995). However in Southeast Alaska (SEA), SSL numbers appear to have been increasing and are probably at the highest level of this century (see chapter on SSL status and trend in SEA in this report). A leading hypothesis of the proximate mechanism behind the decline in the western subpopulation is reduced survival, particularly of juveniles (Merrick 1995, NMFS 1995). Supporting this hypothesis were findings of reduced proportions of juveniles on the Ugamak Island and Marmot Island rookeries (Merrick 1995).

In this paper we compare composition data from Sugarloaf Island (Figure 1), in the depleted western subpopulation, with that from Forrester Island in SEA where numbers have increased. We also compare Sugarloaf Island composition data that was collected in 1978-1980 with data collected in 1995. Data obtained from Cape St. Elias, a haulout in the western stock, in 1978, 1990 and 1995 are presented. Composition data collected in 1995 on Fish Island, a rookery and haulout also in the western subpopulation, are also included.

Methods

Systematic counts were made of SSL at Forrester Island in SEA (1992-95) and at Sugarloaf Island in the Gulf of Alaska (1995) during the pupping and breeding seasons, 24 May through 28 June. Animals were categorized into pups, juveniles, subadult males, adult males and adult females. Comparable data were available for comparison from Sugarloaf Island from 1978-1980 (Smith 1988). Additional composition data were obtained from Cape St. Elias from 22 March through 17 April 1978, 13 April through 12 May 1990 and 25 January through 23 March 1995 and at

Fish Island from 11 June through 11 July 1995.

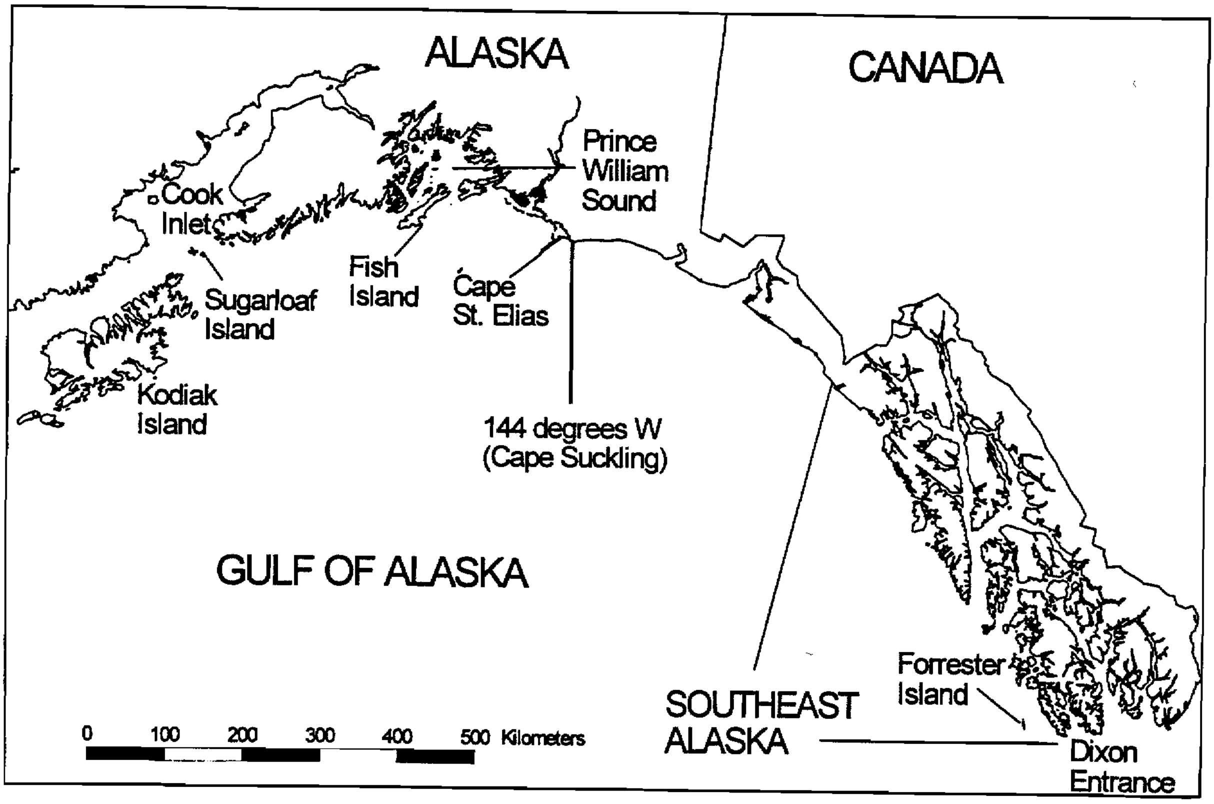

Figure 1. Locations of Steller sea lion rookeries and haulouts where population composition data were collected.

For each year, maximum counts of each sex and age class on a single day were used as an index of abundance for that group. The maximums for each group need not have come from the same day. The maximum was used rather than the mean because the maximum is closer to the true number in each group that used a particular location that year. These analyses assume that the maximum counted for a sex and age class is a constant proportion of the number present each year (constant sighting probability). Mature females were used as the denominator for all ratios as our main interest in these data was to examine temporal and areal comparisons of productivity and early survival . To assess changes in these ratios, they were regressed against year using linear regression. Quadratic regressions (i.e., year-squared was also used included as an explanatory variable) were also used when nonlinear changes were suspected based on residuals. Because the maximum is probably related to the number of counts conducted within a year, each year's data were weighted by the number of counts. For ratios with no time trend, means were compared using unbalanced analysis of variance. Individual observations were weighted by the number of within-year counts. Because of the small number of years of counts, the power of analysis is low and only quite large changes could be detected. The ratios of pups to mature females (PUPS/MFS) was compared among years for Forrester and Sugarloaf Islands using two factor loglinear models (Agresti 1990). Factors used in the model were group (i.e. pup or adult female) and year. The group by year interaction was used to test whether the relative proportion of pups and adult females differed among years. Single degree-of-freedom effects were used to investigate patterns within this interaction (i.e., which years differed).

Results

The ratios of adult males to adult females (MMS/MFS) (Table 1) showed linear trends at both locations although in opposite directions (Forrester: slope=-0.009, p=0.028; Sugarloaf: slope= 0.007, p=0.014). No linear changes were found for the other ratios (p>0.15). Linear trends for composition ratios between the Sugarloaf Island and Forrester Island rookeries differed only between MMS/MFS (slope=0.018, p=0.095).

The mean ratio of subadult males was higher for Sugarloaf than for Forrester (Table 2). There was no difference in the ratios of juveniles and pups between the two sites.

Table 1. Temporal and areal comparisons of Steller sea lion sex and age composition data from Southeast Alaska and the Gulf of Alaska (MMS=mature males, SAMS=subadult males, MFS=mature females, JUVS=juveniles, PUP=pups).

SITE	YEAR	MMS		SAMS		MFS	JUVS		PUPS	
		#	Ratio	#	Ratio	#	#	Ratio	#	Ratio
Forrester	1992	55	0.08			686			792	1.15
	1993	41	0.07	2	0.00	553	13	0.02	380	0.69
	1994	34	0.06	1	0.00	568	13	0.02	403	0.71
	1995	31	0.06	1	0.00	559	14	0.03	459	0.82
Sugarloaf	1978	210	0.07	253	0.08	3055	62	0.02	2946	0.96
	1979	190	0.10	57	0.03	1957	63	0.03	2417	1.24
	1980	195	0.08	190	0.08	2465	31	0.01	1976	0.80
	1995	121	0.20	24	0.04	605	11	0.02	514	0.85
C. St. Elias	1978	52	0.12	67	0.15	440	661	1.50		
	1990	28	0.03	145	0.18	821	795	0.97		
	1995	22	0.13	80	0.47	172	113	0.66		
Fish I.	1995	75	0.23			327	155	0.47	259	0.79

Table 2. Comparisons of mean ratios for SAMS, JUVS and PUPS between the Forrester Island and Sugarloaf Island rookeries.

Ratio	Forrester Mean (n)	Sugarloaf Mean (n)	P-Value
SAMS/MFS	0.002 (3)	0.057 (4)	0.014
JUVS/MFS	0.024 (3)	0.021 (4)	0.566
PUPS/MFS	0.809 (4)	0.965 (4)	0.298

The ratio of pups to mature females differed among years at both locations (Forrester $X^2_3=52.8$, $p<0.001$; Sugarloaf $X^2_3=108.5$, $p<0.001$) (Table 3).

Table 3. Paired comparisons of PUP/MFS ratios among years at Sugarloaf and Forrester Islands.

Site					
Forrester	Year	1992	1993	1994	1995
	Ratio	1.155	0.687	0.710	0.821
	P=0.05[1]	c	a	a	b
Sugarloaf	Year	1978	1979	1980	1995
	Ratio	0.964	1.235	0.802	0.850
	P=0.05[1]	b	c	a	a

[1] Ratios underscored by the same letter do not differ (P>0.005).

Discussion

These data (Table 1) do not indicate reduced juvenile survivorship, as measured by proportions of juveniles, at Sugarloaf Island over time or at Sugarloaf compared to Forrester Island. The apparent decline in the juvenile to adult female ratio (JUV/MFS) at Cape St. Elias (Table 1) must be interpreted cautiously because of seasonal differences in data collection. There was also no indication that pup production differed between sites (Table 2). Therefore these data do not appear to support the hypothesis of reduced juvenile survival or reduced productivity as proximate causes of the decline. There was a significant difference (Table 2) in the ratios of subadult males at Forrester and Sugarloaf. This difference was consistent over all years sampled and may have been a result of different patterns of use of these areas by subadult males.

Much higher proportions of juveniles were seen at Fish Island and Cape St. Elias than at Sugarloaf and Forrester Islands (Table 1). Fish Island and Cape St. Elias are primarily haulout sites with relatively small numbers of pups produced, while Sugarloaf and Forrester Islands are primarily rookeries. It appears that juveniles occur more frequently on haulouts than rookeries. Dating back to 1956, it appears that Fish Island has had a high proportion of juveniles (Sandegren 1969).

The findings of interannual differences in pup/mature females ratios suggests that annual variations in the environment (availability of food?) may affect reproductive performances of female SSL.

The significant increase in MMS/MFS at Sugarloaf Island can probably be explained by the fact that there are normally surplus adult bulls in the population that can only establish rookery territories when rookery density is lowered. Currently a higher proportion of the mature bulls in the population are probably found on Sugarloaf than during 1978-1980 resulting in a higher MMS/MFS ratio.

These composition data appear to have limited value in evaluating SSL population demography. The data are not estimates of population composition but are at best, indices of composition. Strong biases are associated with these counts because different sex and age classes show different haulout patterns and ties to terrestrial sites. It appears that different sites are used in different ways by SSL. Some sites are primarily rookeries, others exclusively haulouts, and yet others are used as combination rookeries and haulouts. The value of PUP/MFS and JUV/MFS ratios to assess productivity and juvenile survival is confounded as it appears that at least some proportion of nonproductive females behave very differently than productive females, spending less time on rookeries and more time on haulouts (see section on summer movements of mature females). A potential problem with the time series at Sugarloaf is that the ultimate and proximate factors that resulted in the decline may have already been in play during the time the 1978-1980 data were collected resulting in reduced juvenile survival during that period as well as during 1995. Also complicating the interpretation is the possibility that chronic reduce juvenile survivorship has resulted in a 1995 age structure identical to that found in the 1970s and therefore reduced juvenile survivorship would not be shown when comparing ratios.

It also must be remembered that because of the low number of years sampled and the large gaps between sampling, the sensitivity of the analysis in detecting change is low. Merrick (1995) found decreased proportions of juveniles on Ugamak Island (eastern Aleutian Islands) and Marmot Island (Gulf of Alaska) based on similar composition data so it is possible that similar changes occurred but were not detected in our analyses.

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Pupping Chronology of Steller Sea Lions in Southeast Alaska and the Gulf of Alaska

Kenneth W. Pitcher, Donald G. Calkins and Grey W. Pendleton

Alaska Department of Fish and Game
Division of Wildlife Conservation
333 Raspberry Road
Anchorage, AK 99518

The United States population of Steller sea lions (SSL) has declined by about 73% over the past 30 years and is classified as a threatened species under the Endangered Species Act (NMFS 1995). In Alaska numbers are only 25% of levels in the 1960s. The decline has occurred in the Gulf of Alaska, the Aleutian Islands and the Bering Sea. SSL numbers in Southeast Alaska (SEA) are probably at their highest level of this century (see Chapter 1). While a clear-cut mechanism behind the decline has not been identified, reduced juvenile and adult survivorship due to undernutrition is the leading hypothesis (Calkins and Goodwin 1988, Merrick 1995, NMFS 1995).

Based on the results of several studies, for at least some pinnipeds, there is a relationship between nutrition and birthing dates, whereby undernutrition can result in extended gestation and later birth dates (Boyd 1991). Boyd (1996) found the duration of pregnancy and the date of parturition varied among years in Antarctic fur seals (*Arctocephalus gazella*), probably a response to changing environmental conditions (low availability of food appeared to increase duration of pregnancy). He hypothesized this was the result of a delay in implantation and/or a reduction in fetal growth rates depending on the stage of gestation when maternal undernutrition occurred. In grey seals (*Halichoerus grypus*) implantation occurred earliest in females with large fat reserves, and pupping occurred earlier in heavy females (Boyd 1984).

This relationship of maternal nutrition and birthdate is not limited to pinnipeds. Several studies found that undernutrition of females during gestation and possibly before breeding resulted in late calving of caribou and reindeer (*Rangifer tarandus*) (Espmark 1980, Reimers et al. 1983, Skogland 1984).

In this paper we examine the possible role of undernutrition in the decline of the western subpopulation through comparisons of pupping dates between Steller sea lions in SEA and the Gulf of Alaska. We also compare pupping dates in the Gulf of Alaska between 1978-1980 when the decline began and in 1995 after the local population had declined by 75%. We also look for a recent trend in mean birth dates at Forrester Island, a rookery that has been increasing.

Methods

Systematic counts of sea lions in 5 sex and age classes (including numbers of pups) were made on the Forrester Island rookery in SEA from 1992-95. Comparable counts were made on Sugarloaf Island in the Gulf of Alaska during 1978-1980 (Smith 1988) and again in 1995. Count data were obtained from Fish Island, in the eastern Gulf of Alaska, from 1967 and 1968 (Sandegren 1970) and again during 1995 (Figure 1).

Estimates of mean dates of pupping were made using the "sigmoid" methodology developed by Trites (1992). This involved fitting either logistic or Gompertz models to repeated counts of SSL pups taken sequentially throughout the pupping season. Estimates of model variance were obtained with nonlinear least-squares. The estimated mean date of pup birth (and its variance) is a function of the model parameter estimates and their estimated variances (Trites 1992). These estimates were negatively biased (mean earlier in the season than the true mean) because no adjustments were made for pup mortalities during the pupping season or for detection probabilities (the probability of counting a pup that is present <1). Estimated mean pupping dates at Fish Island in 1967 and 1968 were obtained by averaging the Julian dates of births observed throughout the season,.assuming that births were equally likely to be observed throughout each season and between years. Mean pupping dates were compared between areas and among years within areas using contrasts (Sauer and Hines 1989, Sauer and Williams 1989). For Forrester Island orthogonal polynomial contrasts were also used to test for linear and nonlinear trends in pupping dates. Bonferroni adjustments were used when evaluating pairwise comparisons of years within areas.

Results

Both the logistic and Gompertz models fit the data very well ($r^2>0.89$) for all areas and years except Forrester in 1992. This data set had several erratic points which weakened the analysis and consequently estimates are probably less reliable. For Sugarloaf and Fish Islands, the Gompertz model fit slightly better for most years, while At Forrester Island the logistic model was slightly better for most years. Mean pupping dates at Forrester were earlier by about 10 days than at Sugarloaf ($X^2_1 = 22.63$, $p<0.001$) and at Fish Island ($X^2_1 = 53.4$, $p<0.001$). There was only weak evidence of a difference between Sugarloaf and Fish Islands ($X^2_1 = 3.11$, $p = 0.078$) (Table 1).

Pupping dates differed among years at both Sugarloaf ($X^2_3 = 28.31$, $p<0.001$ and Forrester Islands ($X^2_3 = 12.52$, $p = 0.006$) but not at Fish Island) $X^2_1 3.79$, $p = 0.15$) (Table 2). At Forrester there was a linear increase in mean pupping date (later pupping) over the 4 year period ($X^2_1 = 6.26$, $p = 0.012$); no quadratic or cubic trends were found ($p>0.10$).

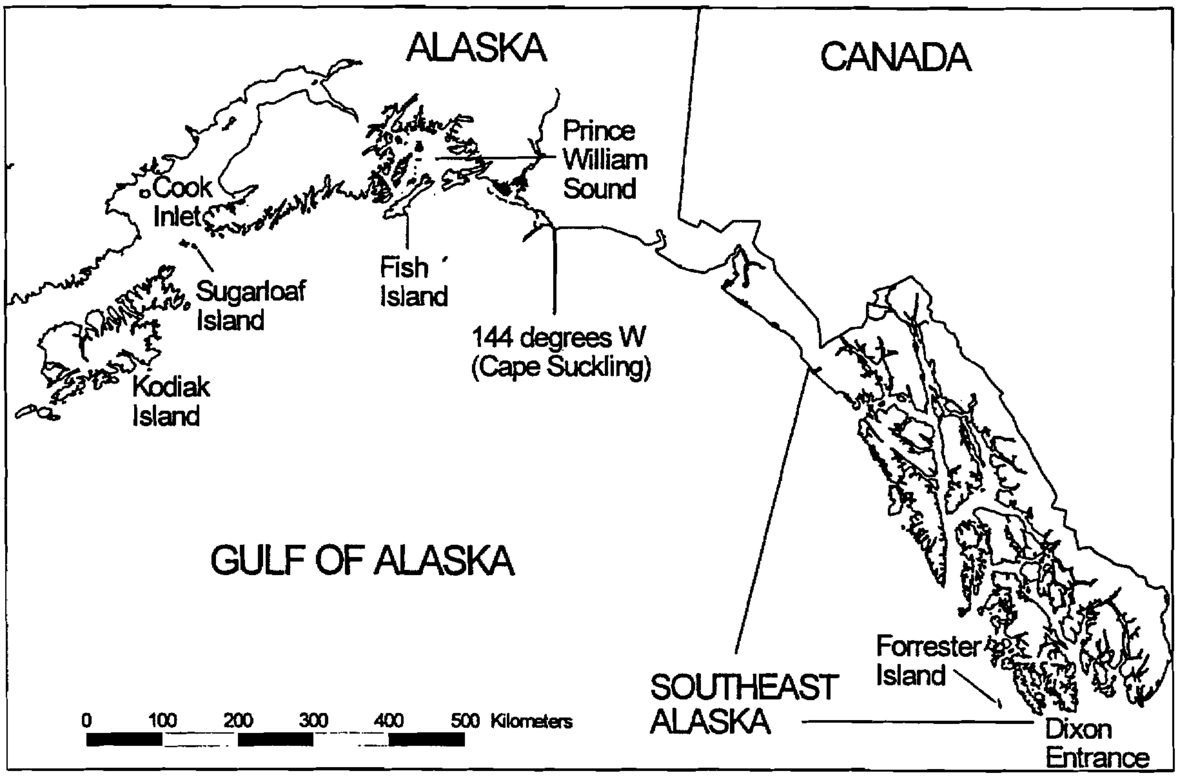

Figure 1. Locations of Alaskan Steller sea lion rookeries where studies of pupping chronology were conducted.

Table 1. Mean pupping dates (Julian date) for the Sugarloaf, Forrester and Fish Island Steller sea lion rookeries.

		LOGISTIC MODEL			GOMPERTZ MODEL		
SITE	YEAR	MEAN DATE	STD. ERROR	95% CI	MEAN DATE	STD. ERROR	95% CI
Sugarloaf	1978	164.8	(0.43)	163.9-165.6	167.7[1]	(0.96)	165.9-169.6
	1979	164.4	(0.56)	163.2-165.5	165.7[1]	(0.87)	164.0-167.4
	1980	166.3	(0.75)	164.8-167.8	167.9[1]	(1.17)	165.6-170.2
	1995	163.3[2]	(0.48)	162.3-164.2	164.5	(1.09)	162.4-166.7
Forrester	1992	152.9[3]	(1.16)	150.6-155.2	152.3	(1.35)	149.9-155.2
	1993	153.3[2]	(0.59)	152.1-154.4	153.1	(0.62)	151.8-154.3
	1994	154.0[2]	(0.42)	153.8-154.9	153.7	(0.44)	152.8-154.6
	1995	155.9	(0.55)	154.8-157.0	156.0[1]	(0.61)	154.9-157.2
Fish	1967	167.5[4]	(1.17)	165.2-169.8			
	1968	165.7[4]	(1.22)	163.4-168.1			
	1995	174.5	(3.85)	166.9-182.0	176.9[1]	(6.24)	164.7-189.2

[1] Fit of Gompertz model slightly better than logistic model.
[2] Fit of logistic model slightly better than Gomperz model.
[3] Fit of model poor; estimates may be inaccurate.
[4] Estimates obtained directly rather than logistic or Gompertz models.

Table 2. Paired comparisons of mean pupping dates among years at Sugarloaf, Forrester and Fish Islands rookeries.

SITE					
Sugarloaf	Year	1995	1979	1978	1980
	Mean Date	163.2	165.7	167.7	167.9
	P = 0.05	a[1]	ab	b	b
Forrester	Year	1992	1993	1994	1995
	Mean Date	152.9	153.3	154.0	156.0
	P = 0.05	ab	a	a	b
Fish	Year	1968	1967	1995	
	Mean Date	165.7	167.5	176.9	
	P = 0.05	a	a	a	

[1] Means underscored by the same letter are not different ($p = 0.05$).

Discussion

It had previously been thought that SSL pupping was synchronous from central California to the Aleutian Islands (Calkins and Pitcher 1982, Merrick et al. 1995). We found substantially earlier pupping in recent years at Forrester Island of the increasing SEA subpopulation than at Sugarloaf Island and Fish Island in the western subpopulation during the time of decline and depletion. If we accept that synchronous pupping dates in SSL are the norm and extrapolate findings from other pinnipeds, it is reasonable to suspect that the difference in pupping dates could be related to poorer nutrition of Sugarloaf and Fish Island females. It appears that pupping is becoming later at Forrester Island and perhaps earlier at Sugarloaf. There is also a suggestion ($p = 0.15$) that pupping is currently later, by about eight days, at Fish Island than before the decline. Because of the bias toward earlier pupping associated with the 1995 estimate (see methods) at Fish Island a change in pupping dates is more likely than statistically shown. SSL in the eastern Gulf of Alaska, which includes Fish Island, now appear to be undergoing a very rapid decline which began about 1989. The mean pupping date at Fish Island in 1995 was the latest recorded for any site in any year. These could indicate nutritional status of females is changing in these areas, possibly because of changes in prey availability and composition, and/or density dependent responses. If so, this also supports the nutritional hypothesis of the decline.

York (1994) concluded that the average age of SSL in the Gulf of Alaska increased between 1975-78 and 1985-86. This shift in age structure may have influenced timing of pupping. However, the shift would likely have been towards earlier pupping as it was found that older female Antarctic fur seals gave birth earlier than younger females (Lunn et al. 1994)

It is also possible that earlier conclusions of synchronous pupping were in error and that differences in pupping dates are genetically controlled and are based on environmental cues such as photoperiod. Bickham et al. (1996) found that SSL from the western stock, which include Sugarloaf and Fish Islands, differed genetically from those of the eastern stock, which includes Forrester Islands. The findings of variable (changing?) pupping dates at Forrester and Sugarloaf and possibly Fish islands argue against strict genetic control. The findings of this study plus reports from the literature lead us to suspect there may be both genetic (Temte 1991) and nutritional components to the timing of SSL pupping in Alaska and that at least temporal comparisons have value in assessing nutritional status in a population.

We suggest that these findings provide additional evidence of nutritional stress in the declining western subpopulation. Previously cited indicators of nutritional stress include decreased body size (Calkins and Goodwin 1988), a concurrent decline in harbor seals which feed on the same prey (Pitcher 1981, Pitcher 1990), changes in size composition of the major SSL prey, walleye pollock (*Theragra chalcogramma*) (Calkins and Goodwin 1988), and changes in the diversity of the SSL diet (Merrick 1995). There are also indications of major changes in the GOA marine ecosystem, dating back to 1976-1978, which have affected the abundance and composition of SSL prey (Francis and Hare 1994, Kerr 1992, Trenberth and Hurrell 1995).

Late pupping at the Sugarloaf and Fish Island rookeries may be an indicator of undernutrition. However it does not, in itself, necessarily provide a direct mechanism for the decline. Timing of birth may be important for the survival of SSL pups, as found for northern fur seals (*Callorhinus ursinus*) (Trites and Antonelis 1994). Late pupping could cause pups to be more vulnerable to harsh weather in the fall or be less successful in foraging going into the winter. Female undernutrition may also be associated with a reduction in birth rates and lowered survival of pups (Duck 1990) as well as a reduced probability of conceiving and carrying a fetus to term (Lunn and Boyd 1993). Both Pitcher and Calkins (1981) and Calkins and Goodwin (1988) reported a high rate (33%-40%) of prenatal mortality in SSL from implantation to pupping in the Gulf of Alaska at the beginning of and during the decline. It is not known if these high rates of reproductive failure are "normal" for SSL or are caused by some factor(s) such as undernutrition and disease. If nutrition is affecting the reproductive cycle of female SSL, it also could play a role in reducing juvenile and adult survival (Merrick 1995, NMFS 1995).

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CHAPTER THREE

Steller Sea Lion Dispersal and Rookery Fidelity

UNA SWAIN

Steller Sea Lion Movements, Emigration and Survival

Donald G. Calkins and Kenneth W. Pitcher

Alaska Department of Fish and Game
Division of Wildlife Conservation
333 Raspberry Road
Anchorage, AK 99518

The United States population of Steller sea lions (SSL) has declined to about 52,000 nonpups over the past 30 years, a reduction of about 73%, and is classified as a threatened species under the Endangered Species Act (NMFS 1995). In Alaska, which at one time contained about 74% of the worldwide population (Loughlin et al. 1992), numbers have declined by 75%. However, in Southeast Alaska (SEA) SSL numbers appear to have been increasing and are probably at the highest level of the past century (see Chapter 1).

National Marine Fisheries Service has recently recommended the worldwide population of SSL be divided into 2 stocks with an east-west division at Cape Suckling (144 degrees W longitude) in Alaska (Figure 1) (NMFS 1995). This recommendation was based on genetic information (Bickham et al. 1996) as well as on population dynamics, marked animal studies and morphological comparisons (Loughlin *In* Press). This division separates the SEA subpopulation from the declining western stock.

A potential mechanism in aiding the rebuilding of the western stock is the emigration of animals from SEA. SSL are highly mobile with movements of many hundreds and even thousands of kilometers (Calkins 1986, Calkins and Pitcher 1982, NMFS 1995). Most current information indicates that adult females show a considerable degree of breeding fidelity to their site of birth or to nearby areas (Calkins and Pitcher 1982, Loughlin In Press). However, it is unknown if significant emigration occurs from an area of high density (SEA) into an adjoining area where numbers have been severely reduced (western subpopulation). Knowledge of the extent of emigration of SEA SSL into the western stock is important for evaluating the NMFS proposal to divide the worldwide SSL population into 2 stocks. It also has important implications in determining an appropriate status for the proposed population stocks under the Endangered Species Act and in the management of these animals.

In this study we are evaluating the extent of emigration of SEA SSL into the western stock. Secondarily, we will gather data on extent of movements and survivorship rates.

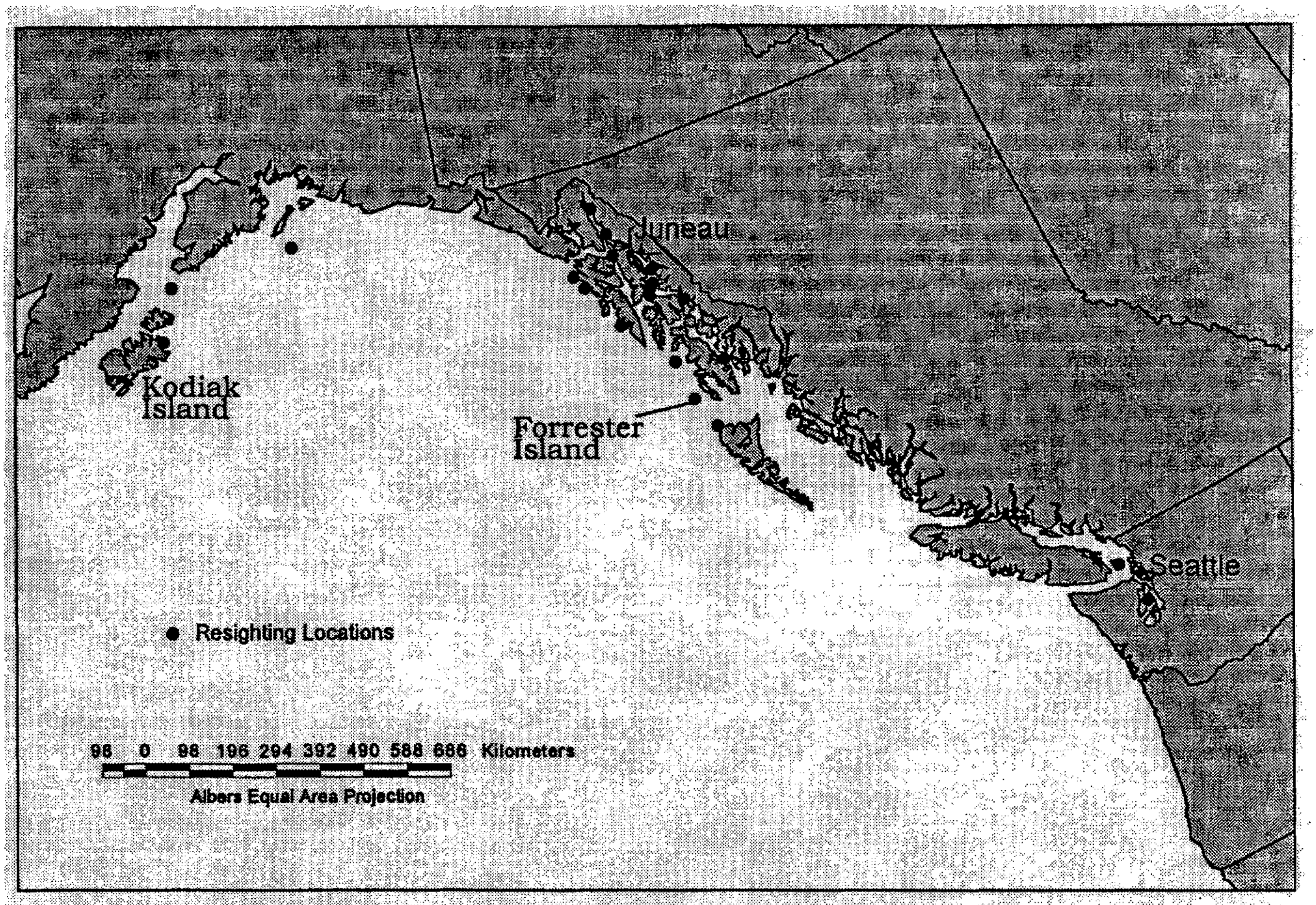

Figure 1. Resighting locations of marked Steller sea lions from Forrester Island, Southeast Alaska.

Methods

SSL pups were marked with individually recognizable hot iron brands at the Forrester Island rookery in SEA in late June during both 1994 and 1995. Allflex tags were applied to the rear margins of the front flippers. Tag numbers corresponded to brand numbers.

To date, brand resights have been collected opportunistically when visiting rookeries and haulouts and from public reports. When the marked animals begin reaching sexual maturity, we will search for the Forrester Island marked animals at all potential breeding rookeries, particularly those in the western stock, to estimate rates of emigration.

We will estimate survivorship rates using resightings of branded animals principally at rookeries. Estimates will be obtained using open-population capture-recapture methods (i.e. Jolly-Seber models) (Pollock et al. 1990. The basic Jolly-Seber will be modified to use a cohort model (Loery et al. 1987, Pollock et al. 1990) which is based on groups of marked individuals with no addition of new marked animals. Both within- and between-year resightings will be used in the "robust design" to help account for temporary emigration and nonconstant resightig probabilities (Pollock et. a. 1990, Kendall and Nichols 1995).

Results

A total of 813 SSL pups were marked at the Forrester Island rookery in 1994 (399) and 1995 (414). Of these animals 45% (368) were females and 55% (445) were males; the proportion of sexes was different ($X^2 = 14.62$, $p = 0.0013$). Resightings of these marked animals have been made at sites ranging from Seattle, Washington to Kodiak Island in Alaska (Figure 1, Appendix 1).

Discussion

The observations made to date support earlier findings that young SSL disperse widely (Calkins and Pitcher 1982, NMFS 1995). Resighting information will continue to be collected on an opportunistic basis until the marked females begin attaining sexual maturity in 1998. Between 1998 and 2002, substantial effort will be made to search for marked animals on rookeries ranging from Oregon to the Aleutian Islands. Rates of emigration and survivorship will be calculated from those data. Males predominated in our sample of marked animals. Calkins and Pitcher (1982) also found that males were more common (51%) in a large sample of marked animals from the Gulf of Alaska in the 1970s. It is unknown if this reflects the sex ratio at birth, higher postnatal mortality of females or biases associated with the capture technique.

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Appendix 1. Resightings of Steller sea lion pups marked on Forrester Island in 1994 and 1995.

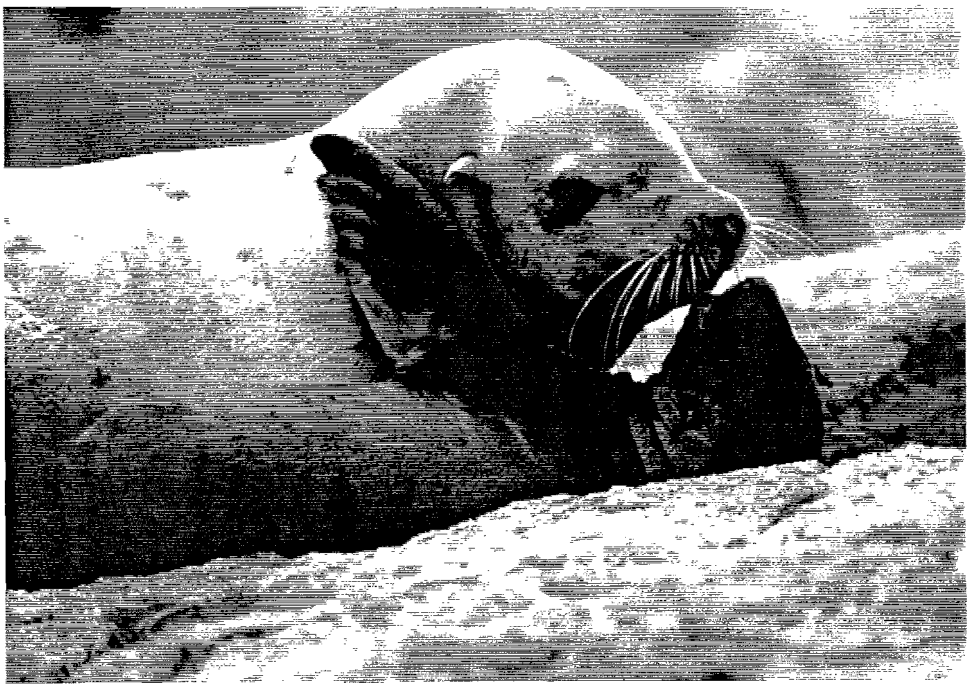
Brand #	Sex	Age (mos)	1995	Day of Year	Resight Location
214	m	1.3	1995	307	Sail I.
217	m	1.3	1995	307	Sail I.
220	m	1	1995	170	Lowrie I.
220	m	1.1	1995	198	Lowrie I.
220	m	1.1	1995	199	Lowrie I.
220	m	1.1	1995	204	Lowrie I.
221	f	1.2	1995	218	Gran Pt.
221	f	1.3	1995	307	Sail I.
226	m	1.6	1996	14	Timbered I.
230	f	1	1995	170	Lowrie I.
230	f	1.1	1995	199	Lowrie I.
234	m	1.1	1995	198	Poundstone Rock
241	m	1	1995	152	Lowrie I.
241	m	1	1995	156	Lowrie I.
241	m	1.1	1995	195	Lowrie I.
242	m	1	1995	160	Lowrie I.
245	m	1.7	1996	39	Benjamin I.
255	m	1.1	1995	208	Langara I. BC
251	m	1.1	1995	188	Fish I.
251	m	1.1	1995	189	Fish I.
251	m	1.7	1996	56	Gran Pt.
259	f	1.3	1995	307	Sail I.
269	f	1	1995	141	Lowrie I.
271	m	1.1	1995	187	Fish I.
302	m	1	1995	157	Seattle Harbor
303	m	1.7	1996	19	W.Brother I.
306	f	1.5	1995	364	W.Brother I.
313	f	1.5	1995	364	W.Brother I
341	f	1.1	1995	187	Gran Pt.
346	f	1.7	1996	39	Benjamin I.
413	m	1.1	1995	218	Kodiak Harbor
435	f	1.1	1995	193	Poundstone Rock
441	m	1.7	1996	34	White Sisters
442	f	1	1995	170	Gran Pt.
443	m	1.3	1995	302	Sail I.
443	m	1.3	1995	307	Sail I.
447	m	1.7	1996	39	Benjamin I.
447	m	1.7	1996	40	Benjamin I.
447	m	1.7	1996	49	Benjamin I.
451	m	1.5	1995	363	Pt. League
451	m	1.5	1995	364	SW.Brothers

Brand #	Sex	Age (mos)	1995	Day of Year	Resight Location
474	f	1.6	1996	19	W.Brothers I.
474	f	1.1	1996	187	Gran Pt.
477	m	1.7	1996	149	Benjamin I.
501	f	1.3	1995	302	Sail Island
502	m	1.6	1996	19	W.Brother I.
530	f	1.7	1996	34	Cape Cross
541	f	1.2	1995	242	Grindall I.
543	m	1	1995	157	Lowrie I.
543	m	1	1995	170	Lowrie I.
559	f	1.2	1995	203	Sugarloaf I.
559	f	1.2	1995	204	Sugarloaf I.
559	f	1.2	1995	207	Sugarloaf I.
559	f	1.2	1995	208	Sugarloaf I.
559	f	1.2	1995	211	Sugarloaf I.
559	f	1.2	1995	212	Sugarloaf I.
569	f	1	1995	187	Gran Pt.
569	f	1.7	1996	56	Gran Pt.
581	m	1.5	1996	3	Benjamin I.
581	m	1.7	1996	49	Benjamin I.
587	m	1.3	1995	307	Sail I.
609	m	0.6	1996	16	Timbered I.
614	m	0.3	1995	307	Sail I.
614	m	0.7	1006	34	Cape Cross
640	f	0.5	1995	364	W.Brother I.
651	f	0.5	1995	364	W.Brother I.
655	f	0.5	1995	364	W.Brother I.
660	m	0.6	1996	14	Timbered I.
689	m	0.7	1996	56	Gran Pt.
712	m	0.7	1996	33	Biali R. R.
728	f	0.3	1995	307	Sail I.
737	m	0.6	1996	19	W.Brother I.
741	m	0.3	1995	307	Sail I.
741	m	0.7	1996	56	Gran Pt.
752	f	0.7	1994	34	Cape Cross
761	f	0.6	1996	16	Timbered I.
767	f	0.5	1995	365	Turnabout I.
768	m	0.7	1996	34	White Sisters
798	f	0.3	1995	307	Sail I.
805	m	0.6	1996	16	Timbered I.
811	f	0.5	1995	364	W.Brother I.
813	m	0.7	1996	40	Benjamin I.
816	m	0.3	1995	307	Sail I.
819	f	0.7	1996	33	Biali R.
823	m	0.7	1996	39	Benjamin I.
828	f	0.7	1996	39	Benjamin I.

Brand #	Sex	Age (mos)	1995	Day of Year	Resight Location
831	m	0.7	1996	39	Benjamin I.
833	f	0.6	1996	19	Timbered I.
835	m	0.7	1996	34	White Sisters
841	m	0.7	1996	56	Gran Pt.
843	f	0.3	1995	307	Sail I.
851	f	0.3	1995	302	Sail I.
851	f	0.3	1995	307	Sail I.
871	f	0.7	1996	49	Benjamin I.
898	m	0.6	1996	19	W.Brother I.
913	m	0.6	1996	16	Timbered I.
931	m	0.6	1996	16	Timbered I.
947	f	0.7	1996	34	White Sisters
949	m	0.6	1996	16	Timbered I.
957	f	0.3	1995	307	Sail I.
973	m	0.5	1995	365	Turnabout I.
983	f	0.5	1995	365	Turnabout I.
?44		0.3	1995	302	Sail I.
34?		1.3	1995	307	Sail I.
34?		1.3	1995	309	Benjamin I.
34?		1	1995	170	Gran Pt.
8?6		0.7	1996	40	Benjamin I.
7??		0.7	1996	40	Benjamin I.

CHAPTER FOUR

Steller Sea Lion Behavioral Comparisons



UNA SWAIN

Preliminary Report
Winter Ecology of Immature Steller Sea Lions

By: Boyd Porter
Alaska Department of Fish and Game and
the University of British Columbia

Abstract

The world population of Steller sea lions (*Eumetopias jubatus*) has been declining since about 1970. One hypothesis explaining this decline is that young Steller sea lions are nutritionally stressed and are experiencing high mortality during winter. Understanding winter ecology during this critical period is essential to resolving the cause of the long term decline.

Data describing haulout patterns and activity budgets were collected on adult and immature (1-3 yrs.) sea lions during winter (January to April) 1995 at Cape St. Elias, Alaska. Behaviours measured included: resting, suckling, aggression and others that have been reported to change during periods of naturally occurring or induced nutritional stress. Two sampling procedures were used (1) 30 minute interval instantaneous scan sampling, and (2) 15 minute interval focal animal sampling. Activity budgets showed immature animals spend the majority of on-shore time resting (57%), followed by suckling (21%). No diurnal haulout patterns were observed. Haulout behaviour showed a significant correlation ($r = 0.827$, $p < 0.001$) between numbers of mature females on shore and numbers of immatures present. This suggests a high proportion of immatures are not fully behaviorally or physiologically weaned 3-5 months prior to breeding. Work will continue during winter 1996 to compare activity budgets and haulout behaviours at two sites, one in the area of decline (Marmot Island), the other in the area where sea lions are not declining (Timbered Island).

Introduction

Little is known at present about the biology of juvenile Steller sea lions, and minimal work has been done in the past during the winter season. It is possible, and many suspect, that high mortality of young animals may explain the population decline. It may be that mothers are unable to adequately nourish their pups during lactation, or weaned juveniles may not be able to successfully forage on their own.

In theory, activity budgets of Steller sea lions should reflect an animal's nutritional status. Thus, nutritionally stressed sea lions should behave differently from healthy individuals. This study will be measuring a number of behaviours which in other populations of mammals have been linked to natural or induced nutritional stress. For example; animals that are nutritionally stressed should rest more, be more aggressive, and spend more time alone.

Objectives

The purpose of this study is to contrast the winter ecology of immature Steller sea lions from two populations during January to April. To approach this goal I will document the winter behaviour, activity budgets and haulout patterns of immature animals. Three study sites will be compared: two in the declining area and a control site in the area where the population has been increasing.

Work was completed at Cape St. Elias during winter 1995 and preliminary results are included in this report. During January to April 1996 one team will be stationed at Marmot Island northeast of Kodiak, Alaska and another team in southeast Alaska at Timbered Island located west of Prince of Wales Island. These sites were selected for their similar exposure to the open Gulf of Alaska and for the high number of immatures present during the winter.

Cape St. Elias 1995

This site is located east of Prince William Sound on the southern tip of Kayak Island. There is an unoccupied lighthouse near the sea lion haulout with reasonable accommodation facilities. Few pups are born each year at Cape St. Elias, but the area is considered to be a year round haulout site and contains all sex and age classes. This includes a high proportion of juveniles in winter which are a necessary component for my study. A high proportion of the juveniles were associated with mature females. Data gathered in the past at this site, using brand resightings, indicate the majority of the animals are representative of the declining population.

Haulout Behaviour

There are no other rocks near Kayak Island where animals haul out making it easier to determine time spent on and offshore. Changes in sex and age composition of the haulout population were noted over the winter months. Sex and age composition counts were made at one hour intervals over the entire study period to determine daily and seasonal changes. The maximum number of animals present at this site were 135 immatures, 175 mature females, 3 mature bulls, 4 sub adult males (see Figures for count data). These counts indicate a strong correlation ($r = 0.827$, $p < 0.001$) between the numbers of immature animals on shore and adult females present at this site. This may indicate the majority of these immature animals are not behaviorally or physiologically weaned 3-5 months prior to breeding.

Most of the low counts can be explained by bald eagle (*Haliaeetus leucocephalus*) interactions. A large number of eagles overwinter at this site and the birds were observed spooking the animals several times to allow them access to an aborted fetus. This resulted in all the animals on the haulout entering the water, often requiring overnight to fully recover from the disturbance. I will be watching for these behaviors and the incidence of premature pupping at the two sites in 1996.

Group Scans

These scans document, at an instantaneous glance, each animal's activity on the haulout. Starting from left to right across the entire group of animals I break the haulout into natural groups. These groups are further broken down to individual animals. The behaviour at that instant is recorded on the data sheet. The result is a measure of the average behavior for the entire group. These scans are done at 30 minute intervals throughout the observation period. I have a total of 350 hours of group scans from 1995. This resulted in an immature activity budget for the time on shore as follows: 59% rest, 25% suckle, 11% active, and 5% play.

Focal Scans

The focal or known animal information will serve as a measure of individual variation. The immatures are not marked with natural scars or recognizable fungal patches as are the mature animals. The sample of known animals was too small and marking proved futile. I have not yet analyzed the data, but the information may be limited by the small sample size and lack of followed animals. I attempted several methods to mark animals, but due to the distance to the haulout, marking was unsuccessful. The distance between animals and observers should be more conducive to marking and close observation at the two sites in 1996. This should result in an appropriate sample of focal animals.

Night Observations

The only attempts to document night activity in the past involved using vocalization rates during the summer of 1994 at Lowrie Island. This method relied on observers being able to differentiate between individual vocalizations and then interpret the meaning of those calls. For example, a long lasting pup attraction call was an indication the female was coming on-shore. This always caused chaos and many animals would become involved, further complicating an accurate measurement of activity from the vocalizations alone. These measures could only be used when a few animals were present due to the confusion of differentiating which animal made the call. It was also difficult between observers to consistently interpret rates of activity using this method. The initial work done by Kathy Ono's crew on Lowrie indicate the night activity rate is substantial and worth investigation.

Only four attempts were made in 1995 to perform night work due to the extreme distance and position of the animals. These initial observances indicate activity is substantial even during late winter nights, and is worth the additional effort to measure the activity patterns. It requires more manpower since the person writing notes cannot also observe using the night vision equipment. Working with the night scopes is also more labor intense and requires the observer to work in shorter intervals to avoid fatigue. It is not clear whether it will be possible to identify individual focal animals using brands and dye marks at night. Nonetheless, the group scans and counts will allow me to document an average night activity budget. This night information will add to the scope of my activity data to include the entire diel period. I will pursue the night work at the two sites in 1996 using Generation II night vision binoculars on loan from the Canadian Military.

Weather and Sea Conditions

I am collecting information on abiotic conditions including: weather variables, tide, sky and sea conditions. To collect the weather information each study site will be equipped with an Omni II weather station. This station will download weather data at 15 minute intervals into a laptop computer. For the tide data I will be using Alaska Tide Tables on diskette.

I will be looking for relationships associated with numbers of animals hauled on land. It may be that during some combination of weather and sea conditions the animals on the winter haulout are better off thermodynamically to leave the frozen rocks and enter the water. Several times we observed the animals spook during or shortly after a blizzard where driving snow made visibility almost zero. At other times the animals would remain relatively inactive even when covered with snow. This information could be useful for future immature capture work and aerial count surveys during the winter.

Completion Target Dates

I plan to return from field research in early April 1996 and begin entering data. Data entry should be complete by mid-June. The projected date for thesis completion and defense is October 1996.

The Reproductive Behaviour of Steller Sea Lions in Alaska: A Comparison between a Stable and Declining Population

Linda L. Milette
Fisheries Centre
University of British Columbia

Introduction

In 1994, I began a two year behavioural study of Steller sea lions at two sites: a stable population in Southeast Alaska (Lowrie Island) and a declining population near the Kenai Peninsula area (Sugarloaf Island). The goal is to document and compare reproductive behaviours that might indicate if one of the two populations is nutritionally stressed.

My study is focused on behaviours that have been reported to change during periods of naturally occurring or induced nutritional stress. For example, during the 1983 El Nino event, which caused a drastic food shortage between Chile and California (Arntz et al. 1991), adult female otariids were reported to 1) increase time spent foraging at sea, 2) increase time spent away from their pup while on land and 3) increase search effort by decreasing time spent swimming and resting at sea (see Trillmich et al. 1991 for a summary of El Nino effects on pinnipeds in the eastern Pacific). Ono et al. 1987 also found that female California sea lions (*Zalophus californianus)* had a shorter perinatal period and that the activity level of their pups decreased during the El Nino event. Male California sea lions also appeared to copulate less frequently during El Nino (Ono et al. 1987). All of these findings suggest that female attendance patterns as well as activity budgets are likely to change during periods of nutritional stress to meet energy demands. Other effects of El Nino on pinnipeds were decreased reproductive success, reduced lactation and a delay of weaning (see Trillmich et al. 1991). It is also possible that tenure duration among male otariids may decrease during periods of nutritional stress (Gentry, 1991).

Controlled experiments using terrestrial mammals have also demonstrated behavioural, developmental and physical effects of nutritional deficiencies that can be quantified by observation (see Chow and Rider 1973; Zimmerman 1975; Simonson 1979; Levitsky 1979 for behavioural and developmental effects and DeMaeyer 1976; Truswell 1976 for physical effects). In particular, protein-calorie deficiencies can result in hyperaggression, hyperexcitability, lack of curiosity, anti-sociality, growth stunting and a decrease in physical activity. Essential fatty acid deficiencies can cause dermal lesions.

Based on the documented effects of nutritional deficiencies I compared the following behavioural, developmental and physical indices at my two sites:

- activity budgets
- maternal attendance patterns
- male tenure duration/territory size
- copulation frequency/time
- delayed weaning
- early pup development and maternal care postpartum
- fungal patches

Although behavioural differences between the two study sites will not prove that Steller sea lions are nutritionally stressed, strong inference towards this hypothesis can be made based on the documented effects of nutritional deficiencies for experimental mammals as well as for pinnipeds during the 1983 El Nino event.

1994 and 1995 Accomplishments

In 1994, Boyd Porter (ADF&G) and Dave Gummeson (UBC) made behavioural observations at Lowrie Island. They arrived on May 10 and left on August 1. Dave Johnson (ADF&G), Una Swain (ADF&G) and I collected the data at Sugarloaf Island. We arrived on May 16 and left on August 11.

In 1995, Dave Johnson (ADF&G) and Carolyn Cornish (UBC) worked at Lowrie Island, arriving on May 16 and leaving on August 4. Caroline Villeneuve (UBC) and I collected the data at Sugarloaf Island. We arrived on May 10th and left on August 14.

The data collected at each site includes:

1) Activity Budgets

The proportion of time sea lions spent in certain activities is referred to as their activity budget. We quantified the proportion of time sea lions spent in selected activities to determine whether sea lion activity budgets differed between the two study sites.

The study team focused on the activity budgets of adult males and females. Adults were identified by natural markings and brands due to difficulties associated with marking individuals with paint or dye. These known individuals were scanned for activity on a daily basis at 15 minute intervals for 14 hours per day.

On Lowrie Island, 20 lactating females and 18 territorial bulls were followed in 1994. In 1995, observers followed 26 lactating females and 17 territorial bulls.

On Sugarloaf Island, 40 lactating females and 9 territorial bulls were followed in 1994. In 1995, we followed 47 lactating females and 24 territorial bulls.

2) Maternal Attendance Patterns

Attendance patterns were recorded to calculate the perinatal period (the period after birth that a female stays onshore with her pup before leaving on her first trip to sea), and the length of time females are away from the rookery and with their pup onshore. The length of the perinatal period is important because it reflects the energy reserves a female has acquired for the first part of lactation (Bowen 1991).

In 1994, the attendance of known females was monitored at 15 minute intervals for 14 hours most days. On other days, female attendance was recorded every hour for 14 hours. There were five days on Lowrie Island when no data were recorded. On Sugarloaf Island, there were several days when female attendance could only be recorded every 6 hours due to poor weather conditions and logistic circumstances.

In 1995, the attendance of known females was monitored at 15 minute intervals for 14 hours a day, 4 days per week on Lowrie Island and 5 days per week on Sugarloaf Island. On the other days, daily checks of females were made at 6:00 - 9:00, 13:00-14:00, and 17:00 - 20:00. No days were missed at either site in 1995.

In 1995, we obtained data on perinatal periods for 38 females on Sugarloaf Island and 22 females on Lowrie Island.

3) Male Tenure Duration/Territory Size

Like the perinatal period, length of time breeding bulls spend onshore during the breeding season may reflect the amount of energy reserves that they have when they come ashore. It therefore seemed prudent to document any differences that may occur between the two sites. However, Gisiner and Calkins (pers.comm) suspect that tenure may be shorter where conditions are better because fit males are competing with each other. In addition, Gisiner (1985) comments that older, more experienced bulls spend more time on their territories probably because they are less active than newer, inexperienced bulls. Tenure size may depend more on male experience rather than reflect physical condition, since an experienced bull in poor condition may not need to decrease the size of his territory to meet energy demands if he is less active. It is clear that the breeding history of bulls must be considered in order to interpret any changes in tenure duration and size between the two sites.

In 1994, we estimated tenure duration by monitoring the attendance of known bulls at 15 minute intervals on most days. On other days male attendance was recorded once per day. No data were recorded on eight days on Lowrie Island which will force me to make assumptions about the presence or absence of bulls on those days. The Lowrie Island study team was able to document the start of the tenure duration in 1994 for about 18 bulls. On Sugarloaf Island, the start of the tenure for 6 of the 9 bulls identified was missed due to poor weather and a delay in the arrival of our study team.

In 1995, the attendance of known bulls was monitored at 15 minute intervals for 14 hours a day, 4 days per week on Lowrie Island and 5 days per week on Sugarloaf

Island. On the other days, daily checks of bulls were made at 6:00 - 9:00, 13:00-14:00, and 17:00 - 20:00. After all the females and pups had left the study site, we monitored bulls at least once per day until they departed. No days were missed at either site in 1995.

To estimate territory size, the Lowrie Island study team painted 10m x 10m grids onto the 1A rookery in 1994 before the bulls arrived. Bull position was plotted at 15 minute intervals on days when behavioural scans were conducted.

The presence of bulls when we arrived onto Sugarloaf Island in 1994 prevented us from painting grids onto the rookery. However, a rough estimate of territory size on Sugarloaf Island was made using the numerous landmarks on the rookery. We measured these landmarks (such as boulders) after all the sea lions left the area and will use them to estimate territory size. The same methods were employed in 1995 at both sites.

4) Copulation Time/Frequency

In theory, copulation frequency can be used as a measure of reproductive success. In 1994 and 1995, study teams on both Lowrie Island and Sugarloaf Island continuously scanned the rookery for copulations while at the observation site. Lowrie Island timed copulations on both years whereas Sugarloaf Island only timed copulations in 1995.

5) Delayed Weaning

The proportion of juveniles nursing on a rookery may indicate prolonged maternal investment to ensure survival of the offspring (Trivers 1972). In 1994 and 1995, study teams recorded the daily number of nursing juveniles on the rookeries. Numbers of nursing juveniles were recorded at two rookeries on Sugarloaf Island (Area 7 and 10AB) and at one rookery on Lowrie Island (Area 1A).

6) Early Pup Development and Maternal Care Postpartum

It has been previously shown that the offspring of diet-restricted mammalian mothers exhibit delays in development such as eye opening, walking and exploring (Simonson 1979). Thus, in 1994 and 1995, study teams attempted to time how long it took new born pups to vocalize, lift their heads, take a first step, search for teat and nurse. In addition the time it took the mother to grab her pup upon delivery, sniff and lift-drop the pup were also recorded.

7) Fungal Patches

Patches of eroded skin caused by a fungus (T. Spraker pers.comm) are thought to be more numerous in the area of decline. Why fungal patches are more numerous in the declining area is unclear. Given these circumstances, it seemed prudent to quantify the number of adults and sub-adult males that have these patches. In both 1994 and 1995, both study teams recorded the number of adult females, adult males and sub-adult males that had at least one fungal patch or more than two fungal patches. This was done once per week at both sites.

Data Analysis

All of the 1995 data has been key-punched and is currently being analyzed to determine whether postpartum female activity budgets differ between the two study sites. Some of the 1994 data still needs to be key-punched and standardized before a thorough statistical comparison can be made with the 1995 data set. Analysis of the bull data will begin shortly.

Analysis of perinatal period, trip duration, mother-pup association and early pup development/maternal care comparisons between the two sites are complete for 1995. Trip frequencies and the length of time females spent onshore prior to the birth of pup still need to be compared.

Final results for the number of nursing juveniles and fungal patched animals at each site are still pending for both years. The influence of weather and tides on behaviour, the effect of time on trip duration and mother/pup associations for both years has not yet been analyzed.

A final report is expected by December 1996.

Addendum - The following is a summary which updates results of this study.

Preliminary results suggest that females spend more time nursing their pups, are more aggressive and have a longer perinatal period in the are of decline. Trip durations appear to be shorter in the declining area. Male behavioural data have not yet been examined. Additional results for female behaviours are also pending.

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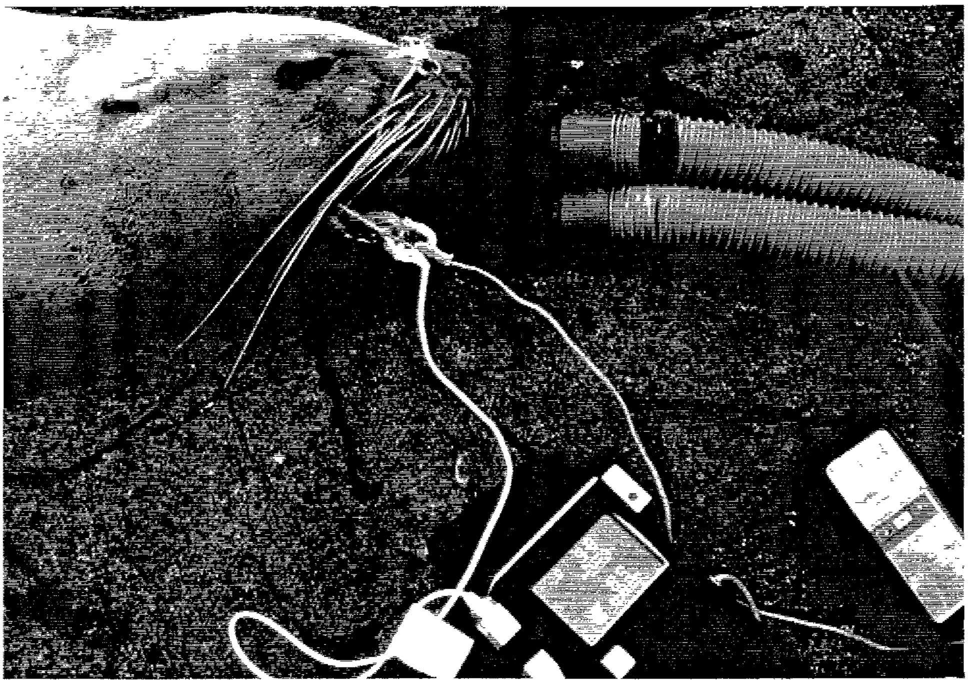
CHAPTER FIVE

Steller Sea Lion Physiological Comparisons



JOEL SARTORI

Indices of Reproductive Effort, Body Condition and Pup Growth for Steller Sea Lions (*Eumetopias jubatus*) in Alaska

Davis, R.W., Brandon, E.A.A., Adams, T.C., Williams[1], T.M., Castellini, M.A.[2], Loughlin, T.R.[3], Calkins, D.G.[4]

Texas A&M University, Galveston, TX 77553; [1]University of California, Santa Cruz, CA 95064; [2]University of Alaska, Fairbanks, AK 99755; [3]NMFS-National Marine Mammal Laboratory, Seattle, WA 98115; [4]Alaska Dept. of Fish and Game, Anchorage, AK 99518.

Abstract

Indices of adult female reproductive effort, female body condition, and pup growth were studied for Alaskan Steller sea lions. Data from declining populations at Chirikof Island in 1993 (C93), Marmot Island in 1994 (M94), and Fish Island in 1995 (F95) were compared to a stable population at Lowrie Island in 1993 and 1994 (L93, L94). Trip duration of adult females was monitored by deploying VHF transmitters. Female body condition and known-age pup growth, body condition and milk intake were measured during their first 40 days postpartum. There was a significant difference among locations in trip duration, the longest at L94 (29.1 hrs) and shortest at C93 (11.2 hrs). There was no significant difference among locations in pup mass at age 0-5 days (mean = 21.0 kg), although males (22.4 kg) were significantly heavier than females (19.5 kg). There was a significant difference among growth rates, with the C93 and F95 pups growing faster in their first 40 days than the L93, and L94 pups. Male and female pups generally grew at the same rate, so male pups remained consistently heavier than females. There was no significant difference in milk composition, lean body mass and total body lipid among pups or adult females at the different locations. Overall, there is no indication for increased female reproductive effort, poor body condition or slower pup growth for females and pups in the area of declining population.

Introduction

The Steller sea lion is the largest of all otariid pinnipeds. This species exhibits pronounced sexual dimorphism, with males attaining an average weight of 968 kg and females an average weight of 333 kg. Breeding populations range from the Kurile Islands, throughout the Aleutian Islands and along the Alaska-Canadian coast down to Ano Nuevo Island.

In 1990, the NMFS determined that the Steller sea lion was a threatened species under the Endangered Species Act. The species was listed throughout its range because of a precipitous decline in abundance. This decline has been concentrated primarily in areas near the Gulf of Alaska and the Aleutian Islands.

In 1995, the NMFS proposed to reclassify the western Steller sea lion population segment to endangered. This includes the area west of 144° W longitude near Cape Suckling along the north-central coast of Alaska. Loughlin et al. (1992) estimated a 70% decrease in the number of adult and juvenile sea lions in this area between the 1960's and 1989. Trend counts for the western population have continued to decline. The NMFS has proposed to leave the eastern segment of the population, which has shown a modest increase of 17% since 1990, under the current status of threatened.

A change in food availability is the leading hypothesis for the cause of the Steller sea lion decline. Reduced juvenile recruitment appears to be the proximate cause of the decline. Although the relationship between commercial fisheries and the ability of Steller sea lions to obtain adequate food is not clear, the Gulf of Alaska, Bering Sea and Aleutian Islands have experienced the greatest decline in Steller sea lions and are also an area where large commercial fisheries have developed. As a result, competition may exist between the commercial fisheries and Steller sea lions for certain finfish such as pollock.

If a change in food availability is causing the Steller sea lion decline, we might expect to see changes in adult body condition, female attendance behavior, pup nutrition and the rate of pup growth. Although caution must be used in using any one of these variables as an index of food availability, taken together they provide a good picture of the nutritional plane of a particular segment of the population at a particular time of year. This has been demonstrated for several otariid species that are influenced by periodic El Nino events in tropical and temperate waters of the eastern Pacific Ocean.

The objective of this study was to measure indices of adult female reproductive effort, female body condition, and pup growth of Steller sea lions in the area of population decline and an area of stable population. The null hypothesis was that indices would not differ for the two areas. The alternative hypothesis was that animals in the area of population decline would show evidence of reduced food availability and malnutrition.

Data from declining populations at Chirikof Island in 1993, Marmot Island in 1994, and Fish Island in 1995 were compared to a stable population at Lowrie Island in 1993 and 1994. Measurements were made in June and July during the period of peak pupping and early pup rearing.

Methods

Adult females were darted with Telazol and anesthetized with Isoflurane using a portable gas anesthesia system. This enabled us to immobilize the animals for up to two hours while we made measurements, took blood samples, injected isotopically labeled water and attached instruments.

The following measurements were made for each female:

- body mass
- standard length
- axillary, chest and mid-trunk girth
- blubber thickness (nine sites)
- total body water
- hematology and blood chemistry
- milk composition

Lean body mass and total body lipid were calculated from total body water.

Female attendance and foraging trip duration were monitored by gluing VHF transmitters to the hair on the back. Transmitter signal reception was automatically recorded for 40 days using an ATS radio receiver and data logger. Females were assumed to have departed from the rookery if the signal was not received for three hours.

Pups were physically restrained. Pup age was estimated from the appearance of the umbilicus. In most cases, only pups with very fresh umbilical cords, some with the placenta still attached, were used. The following measurements were made for known age pups about every two weeks during the first 40 days postpartum:

- body mass
- standard length
- axillary, chest and mid-trunk girth
- total body water
- water turnover rate
- hematology and blood chemistry

Pups were recaptured up to three times during the 40 day period. The lean body mass and total body lipid were calculated from total body water. Growth rates were determined for each pup individually from the changes in mass, standard length and axillary girth with age. Milk intake was estimated from water turnover.

In general, data were analyzed using one-way and two-way ANOVA (Systat), testing for differences by location and by sex (for pup data).

Results

Adult Females

There was no significant difference in the body mass, standard length or axillary girth of females in the area of decline and area of stable population (Table 1). On average adult females weighed 266 kg and had a standard length of 228 cm.

Table 1. Steller sea lion adult female morphometrics.

Location	n	Body Mass (kg)	Standard Length (cm)	Axillary Girth (cm)
Lowrie Island	20	259.8 ± 35.55	228.4 ± 11.73	159.5 ± 19.87
Chirikof Island	10	269.6 ± 38.78	225.4 ± 11.21	160.8 ± 11.43
Fish Island	4	289.0 ± 19.02	231.7 ± 3.59	159.5 ± 2.38

There was no significant difference in the total body water, lean body mass or total body lipid of females from the two areas (Table 2). On average, female total body water was 65% of body weight. Lean body mass was 91.7% of total mass and total body lipid was 8.3% of total mass.

Table 2. Adult female Steller sea lion body composition.

	n	Total Body Water (%mass)	Lean Body Mass (%mass)	Total Body Lipid (%mass)
Lowrie Island	14	64.9 ± 3.15	91.7 ± 4.44	8.3 ± 4.44
Chirikof Island	8	64.6 ± 3.00	91.4 ± 4.26	8.6 ± 4.26
Fish Island	2	65.5 ± 0.57	92.6 ± 0.78	7.3 ± 0.78

There was no significant difference among locations for female attendance on the rookery (Table 3). The mean time ashore between foraging trips was 22.5 hours. There was a significant difference among locations for trip duration. Mean trip duration on Chirikof Island was 11.2 hours and was significantly shorter than the mean trip duration of 26.9 hours for Lowrie Island. There was no difference between Chirikof and Fish Islands. On average, females on Chirikof Island spent 37% of their time at sea while females on Lowrie Island spent 52.7% of their time at sea. This means that females in the area of stable population spent 42% more time at sea foraging than females in the area of decline during the first month postpartum.

Table 3. Adult female attendance pattern means ± SD of means for each location of time spent on shore, at sea, total cycle time, and percentage of the cycle spent on shore and at sea. N is the number of females from each location used in the analysis..

Location	n	Time Onshore (hrs)	Time at Sea (hrs)	Total Cycle Time (hrs)	Pct. of Cycle Time Onshore	Pct. of Cycle Time at Sea
Lowrie Is.	15	22.2 ± 7.38	26.9 ± 7.93	49.4 ± 14.26	47.3 ± 8.93	52.7 ± 8.93
Chirikof Is.	4	20.7 ± 5.57	11.2 ± 3.33	31.7 ± 3.35	63.0 ± 9.51	37.0 ± 9.51
Fish Is.	5	25.0 ± 6.35	18.2 ± 5.16	43.5 ± 6.44	55.1 ± 9.93	44.9 ± 9.93
ANOVA		p = 0.64	*p = 0.0014	p= 0.0492	*p = 0.0165	*p = 0.0165

There was no significant difference in milk composition among locations during the first two weeks postpartum (Table 4). However, sample sizes are small and the contributions of interannual variations in various parameters which might influence milk composition are unknown.

Table 4. Steller sea lion milk composition.

Location	n	% Water	% Solids	% Protein	% Ash	% Lipid
Lowrie Island	8	65.1 ±5.50	34.9 ±5.50	2.87 ±1.05	0.8 ±0.05	31.2 ±4.59
Chirikof Island	9	61.1 ±6.31	38.9 ±6.31	4.12 ±1.30	0.8 ±0.15	34.0 ±5.55
Fish Island	3	54.5 ±1.61	41.0 ±1.61	3.7 ±0.34	0.7 ±0.05	36.6 ±1.43
ANOVA				p>0.15	p<0.05	p>0.50

Pups

Among locations, there was no significant difference in body mass, standard length or axillary girth for pups that were 0-5 days of age (Table 5), although males (22.4 kg) were significantly heavier and than females (19.5 kg).

Table 5. Body mass, standard length, and axillary girth of pups at first capture (0-5 days of age).

Location	n	male	female	male	female	male	female
Lowrie I.	28m	21.99	19.58	98.2	93.4	64.8	65.6
	25 f	±1.96	±1.71	±4.5	±3.7	±3.6	±5.6
Chirikof I.	11m	22.62	19.20	96.2	93.3	68.5	64.0
	9f	±1.69	±2.39	±5.2	±6.4	±3.0	±4.0
Marmot I.	3m	21.73	20.22	101.7	97.4	65.5	61.8
	6f	±1.8	±2.42	±1.5	±2.7	±2.8	±5.4
Fish I.	11m	23.21	19.02	99.1	94.9	62.7	60.1
	9f	±2.59	±1.05	±5.2	2.4±	±3.5	±2.1

There was no significant difference in total body water, lean body mass or total body lipid for pups at the four locations (Table 6). On average, total body water was 74.2% of body mass. Lean body mass was 97.6% of total mass, and total body lipid was 2.4% of total mass. Pups obviously have very little fat reserves when born, which is in agreement with measurements of skinfold thickness.

Table 6. Body composition of Steller sea lion pups 0-5 days of age.

Location	n	Total Body Water (%mass)	Lean Body Mass (%mass)	Total Body Lipid (%mass)
Lowrie Is.	33	74.1 ± 3.47	97.5 ± 4.56	2.5 ± 4.56
Chirikof Is.	12	73.3 ± 1.80	96.5 ± 2.37	3.5 ± 2.37
Marmot Is.	19	75.2 ± 3.29	99.0 ± 4.34	1.0 ± 4.34
Fish Is.	14	73.8 ± 3.84	97.1 ± 5.05	2.9 ± 5.05

There was a significant difference among growth rates (Table 7), with the Chirikof and Fish Island pups growing faster in their first 40 days than the Lowrie Island pups. Male and female pups generally grew at the same rate, so male pups remained consistently heavier than females.

Table 7. Rates of change of mass, standard length, and axillary girth for pups from 0-40 days of age. There were significant differences by location for change in mass (p = 0.0002) and standard length (p = 0.0149) but not for axillary girth. There were no significant differences between male and female pups in growth rates.

Location	n	Mass Rate (kg/day)	Std. Length Rate (cm/day)	Ax. Girth Rate (cm/day)
Lowrie Is.	15	0.20 ± 0.151	0.17 ± 0.392	0.31 ± 0.221
Chirikof Is.	17*	0.45 ± 0.126	0.47 ± 0.171	0.47 ± 0.187
Marmot Is.	6	0.28 ± 0.141	0.22 ± 0.287	0.59 ± 0.510
Fish Is.	13	0.35 ± 0.171	0.22 ± 0.183	0.41 ± 0.235
2-way ANOVA		Lowrie ≠ Chirikof Lowrie ≠ Fish	Lowrie ≠ Chirikof	ns

* n = 16 for AG rate and CI rate

There was no significant difference in total water intake or milk intake among locations (Table 8). However, pups on Lowrie Island had significantly lower rates milk energy intake, which is consistent with their lower growth rates.

Table 8. Steller sea lion pup total water and milk intake rates.

Location	n	Mean Age (days)	Mean Mass (kg)	Total Water Intake (ml/kg/d)	Milk Intake (ml/kg/d)	Energy Intake (kJ/kg/d)
Lowrie Is.	6	9.4 ±3.9	23.37± 3.14	57.5 ±8.70	73.42 ±14.77	940.6 ±189.19
Chirikof Is.	11	13.4 ±1.23	26.61± 2.77	62.73 ±9.99	79.12 ±16.64	1111.8 ±233.88
Fish Is	6	19.19 ±1.4	30.39± 3.74	63.3 ±11.5	83.35 ±19.5	1278.68 ±299.21

p=0.077

Conclusions

Overall, there was no indication of a reduced nutritional state for lactating females and pups during the first 40 days postpartum in the area of decline. In addition, there was no indication of increased female foraging effort if we assume that it is reflected in foraging trip duration. We therefore cannot accept our alternative hypothesis that females and pups in the area of decline show evidence of reduced food availability.

Keeping in mind the small sample size and limited number of sites examined in the area of decline, this is perhaps a surprising result given the dramatic decline in the population. These results may indicate that:

1) diminished food resources are not the cause of the decline

2) diminished food resources were the cause of the decline, but this is not longer the case and food availability is now adequate

3) pregnant and lactating females have access to food resources that are unavailable to juvenile animals

A comparison of otariids affected by El Nino events in the eastern Pacific Ocean has shown the following effects of decreased food availability:

emaciation and increased mortality of adult females and males
increased foraging trip duration and decreased foraging efficiency
decreased pup production
decreased milk transfer from mother to pup
decreased pup growth rates and mortality due to starvation

Of these effects, foraging trip duration and pup growth rate appear to be the best indicators of food availability in otariids. In this study, female foraging trip duration was shorter and pup growth rate was greater in the area of population decline. Enhanced pup growth in the area of decline has also been reported by Merrick et al. (1995). This would indicate that food is not in short supply for lactating females prior to arrival on the rookery and during early pup rearing. It may also indicate that adult females that return to give birth have been able to find adequate food during the winter gestation period. However, females that do not find adequate food during the winter may die or not return to the rookery in the spring to pup. As a result, our results may be biased toward only those animals that survive and are in good health.

York (1994) has indicated that the proximate cause of the population decline is juvenile mortality. However, juveniles are extremely difficult to access, so there is little data on their health and body condition. As with many mammals, the early post-weaning period can be very difficult and high juvenile mortality is common for many species. For marine mammals, the larger adults may have access to prey that are inaccessible to juveniles because of their ability to make longer and deeper dives.

If a female Steller sea lion survives to adulthood, it would appear that she has access to adequate food resources to raise a healthy pup. In fact, lactating females in the area of decline appear to spend less time foraging and their pups grow faster than in the area of stable population. This may be a density dependent effect resulting from the overall population decline in which animals that survive to adulthood have access to abundant prey that is, for some reason, inaccessible to juvenile animals.

Further studies will be necessary to determine whether juvenile Steller sea lions show a reduced nutritional state and whether their diving behavior and prey preference is significantly different from adult females. In addition, it would be useful to assess pup health and body condition during the latter part of the lactation period and to obtain weaning weights. This would enable us to determine whether the lactating females have access to food throughout the lactation period.

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Pup Condition and Growth Rates in Declining and Stable Populations of Steller sea lions in Alaska

E.A.A. Brandon, R.W. Davis, S. Kanatous, D.G. Calkins[1], T.R. Loughlin[2]

Texas A&M University at Galveston, Galveston, TX 77551 [1]-Alaska Dept. of Fish and Game, Anchorage, AK 99518 [2]-National Marine Mammal Laboratory, NMFS, Seattle, WA 98115

The cause of the drastic decline of Steller sea lions (*Eumetopias jubatus*) in Alaska has been hypothesized to be decreased food availability. If food supplies are low, then lactating females would have difficulty finding enough food to nurse their pups. Pup condition at birth would give some indication of the female's condition and ability to find food prior to parturition. Pup growth rate would be an indicator of the female's condition and ability to find food during the lactation period.

We carried out a longitudinal study of Steller sea lion pups at birth and as they grew in their first six weeks of age. We worked at several locations in Alaska: Lowrie Island, which is in an area where the Steller population is table, Chirikof Island, Marmot Island, and Fish Island, which are all in areas where the population is declining (central and western Gulf of Alaska and the Aleutians). We expected to find pups with lower birth weights and slower growth rates in the area of decline.

Methods

Capture locations, dates, and number of pups captured are given in Table 1. We captured pups with umbilical cords which had not yet fallen off and used the freshness of the umbilical cord as a rough estimate of age (0-5 days). Pups were weighed, measured for standard length (SL) and axillary girth (AG), flipper tagged, and marked with hair bleach. We attempted recaptures of pups at 2-3 week intervals for the first 6 weeks of their lives. At recaptures, we weighed and measured the pups.

Table 1. Capture locations, date and numbers of pups capture for pup growth studies.

Location	Dates	n
Lowrie Island	26 May - 5 June	25
(1993)	15 -19 June	5
	3 July	1
Lowrie Island	15 - 22 June	28
(1994)	24 - 30 June	9
	13 - 14 July	3
Chirikof Island	11 - 17 June	20
(1993)	27 - 28 June	14
	7 July	11
	18 July	4
Marmot Island	27 June	9
(1994)	15 July	6
Fish Island	9 -10 June	20
(1995)	24 - 26 June	13
	13 - 14 July	12

Data from the first capture (0-5 days of age) were analyzed by comparing location and by sex using a 2-way ANOVA. Data on pup growth were analyzed by performing a linear regression for each pup to determine its growth rate and extrapolated birth morphometrics. Pup growth rates were analyzed by 2-way ANOVA, again looking for differences by location and by sex. Pups that died during the study were excluded from growth analyses. A condition index (as used by Rea et al. in prep.) was calculated as 100 x AG/SL.

Results Summary

Male-Female Differences

1. Male pups at age 0-5 days had significantly higher mass $p < 0.0001$), SL ($p = 0.0004$), and AG ($p = 0.0168$) than female pups (Table 2).

2. Male and female pups grew at the same rate, in terms of mass, SL, and AG, over the first 40 days after birth (Figure 1).

Table 2. Pup morphometrics at 0-5 days of age.

		Mass (kg(		Standard Length (cm)		Axillary Girth (cm)	
Site	n	male	female	male	female	male	female
Lowrie Is.	28M	21.99	19.58	98.2	93.4	64.8	65.6
	25F	±1.96	±1.71	±4.5	±3.7	±3.6	±5.6
Chirikof Is.	11M	22.62	19.20	96.2	93.3	68.5	64.0
	9F	±1.69	±2.39	±5.2	±6.4	±3.0	±4.0
Marmot Is.	3M	21.73	20.22	101.7	97.4	65.5	61.8
	6F	±1.80	±2.42	±1.5	±2.7	±2.8	±5.4
Fish Is.	11M	23.21	19.02	99.1	94.9	62.7	60.1
	9F	±2.59	±1.05	±5.2	±2.4	±3.5	±2.1

3. Male pups at birth, as extrapolated from growth curves, had significantly higher mass ($p < 0.0001$), SL ($p = 0.0023$), and AG ($p = 0.0004$) than female pups (Table3).

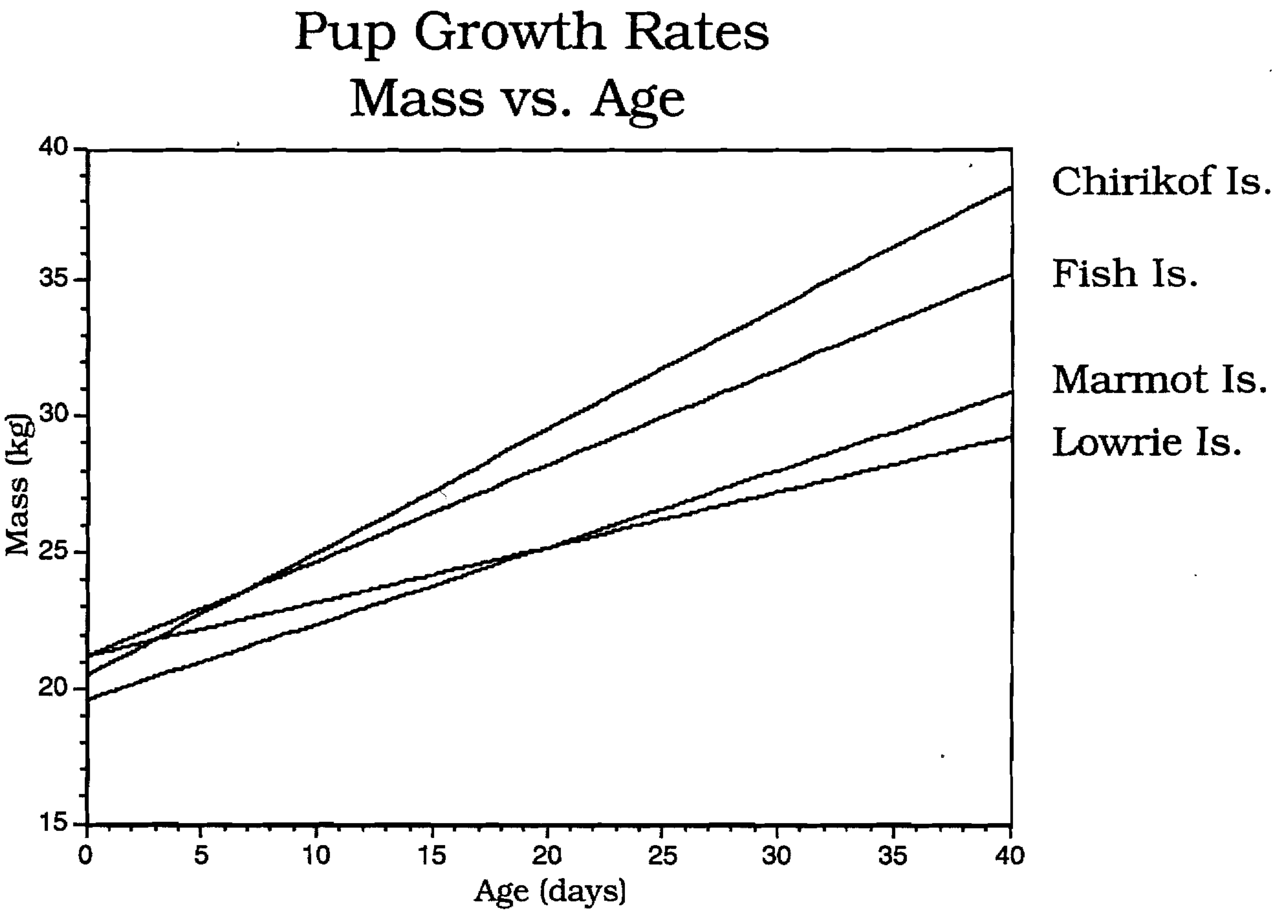

Figure 1. Pup growth rates 0-40 days of age; mass versus age.

3. Male pups at birth, as extrapolated from growth curves, had significantly higher mass ($p < 0.0001$), SL ($p = 0.0023$), and AG ($p = 0.0004$) than female pups (Table 3).

Table 3. Pup morphometrics at birth extrapolated from growth rates.

Location	n	Mass Rate (kg/day)	Std. Length Rate (cm/day)	Ax. Girth Rate (cm/day)
Lowrie Is.	15	0.20 ± 0.151	0.17 ± 0.392	0.31 ± 0.221
Chirikof Is.	17*	0.45 ± 0.126	0.47 ± 0.171	0.47 ± 0.187
Marmot Is.	6	0.28 ± 0.141	0.22 ± 0.287	0.59 ± 0.510
Fish Is.	13	0.35 ± 0.171	0.22 ± 0.183	0.41 ± 0.235
2-way ANOVA		Lowrie _ Chirikof Lowrie _ Fish	Lowrie _ Chirikof	ns

* n = 16 for AG rate and CI rate

4. The condition index did not differ between male and female pups, either at 0-5 days old or at birth (Table 4).

Stable Area-Decline Area Differences

1. There were no differences by location in pup mass or SL at first capture (ages 0-5 days). Pups on Fish had significantly smaller AG's than pups on Lowrie or Chirikof ($p < 0.005$) (Table 2).

2. Pups on Lowrie grew in mass significantly slower than pups on Chirikof ($p = 0.0002$) and on Fish ($p = 0.0471$). SL increased more slowly with age on Lowrie as compared to Chirikof ($p = 0.0175$). Change in AG with age did not differ by location (Figure 1).

3. Pup mass, SL, and AG at birth, as extrapolated from growth rate curves, did not differ among locations (Table 3).

4. The condition index differed by location for pups at 0-5 days old and at birth (extrapolated). Chirikof pups had the highest CI, followed by Lowrie, Marmot, and Fish pups (Table 4).

Table 4. Condition index of pups (AG/SL x 100) at first capture and extrapolated to birth from growth curves.

Location	n	CI at 0-5 days of age	n	CI at birth (extrapolated)
Lowrie Is.	63	68.1 ± 6.2	15	66.7 ± 4.7
Chirikof Is.	20	70.2 ± 5.1	16	70.2 ± 5.0
Marmot Is.	9	63.7 ± 3.5	6	61.4 ± 6.4
Fish Is.	20	63.4 ± 3.7	13	64.6 ± 4.1
2-way ANOVA		Chirikof ≠ Marmot Chirikof ≠ Fish Fish ≠ Lowrie		Chirikof ≠ Marmot Chirikof ≠ Fish

Discussion

Differences between male and female pups are similar to those seen in other otariid pups, although some studies have indicated that male pups grow faster than female pups. Lunn et al. (in press), in studies of Antarctic fur seals, found higher growth rates for male pups when pups were measured cross-sectionally, that is, different, un-marked pups were measured at each capture. However, when growth rates were measured serially, by recapturing marked pups for whom age was less uncertain, male pups appeared to grow at the same rate as females. While we also found no difference in growth rates for male and female pups measured serially, we only captured pups up to 40 days of age. It would be useful to measure pup mass until weaning, if one could get around the difficulties of capturing older pups.

While we expected the pups in the area of decline to be born smaller and to grow more slowly, there appeared to be little difference among locations in the pups' condition at birth, and pups in the area of decline actually grew faster. Thus, there was no indication that the pups in the area of decline were any less well provisioned by their mothers than pups in the stable population area.

Merrick et al. (1995) found higher masses for pups weighed in June and July in the area of decline. These results are similar those reported by T. Adams (see poster), that energy intake rates (calculated from milk intake) were higher for Fish and Chirikof pups than for Lowrie pups. Concurrent radio tracking work on lactating female Steller sea lions gives no indication that females in the area of decline are spending more time foraging for food than females in the stable area (Brandon et al. in prep).

While food availability may be the cause of the Steller sea lion population decline, we have seen no indication that young pups or lactating females are affected by food shortages. Perhaps, as was suggested by York (1994), it is juveniles that are feeling the affect of decreased food availability. It may be that there is food available to adult females that is not accessible to juveniles.

Acknowledgments

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Comparisons Of Milk Composition And Intake Rates For Steller Sea Lion Pups In Areas Of Stable And Declining Populations

Adams, T.C.[1], Davis, R.W.[1], Brandon, E.A.A.[1] , and Calkins, D.G.[2]

[1]Texas A&M University at Galveston, Galveston, TX 77551
[2]Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518

ABSTRACT

Since the late 1960s the population of Steller sea lions has declined by more than 50% in the western Gulf of Alaska and the Aleutian Islands, but has remained relatively stable in southeast Alaska. Although the cause of the population decline remains unknown, one hypothesis is a decline in prey availability for lactating females, which might decrease the nutritional quality and quantity of milk delivered to pups. To test this hypothesis, we sampled the milk of lactating females and measured the milk intake rates of pups during the first four weeks postpartum on Chirikof and Fish Islands (area of population decline) and Lowrie Island (area of stable population). Milk samples were collected from anesthetized females following injection of 10 ml oxytocin and kept frozen until analysis for percent water, total solids and ash. Milk intake of known-age pups was estimated from labeled water turnover following injection with 10 ml 99% deuterium oxide. The mean total milk solids, %ash, %protein, and %lipid were not significantly different ($p > 0.05$) among islands. The mean milk intake rate of pups was also not significantly different ($p > 0.05$) among islands and averaged 79.14 ml/kg/d ± 16.35 S.D. ($n=23$). However, the energy intake rates did differ significantly ($p<0.05$) between locations. Assuming these measurements are an indication of food availability and the capacity of females to provision their pups and that the physiological processes in the production of milk do not differ among females, the data suggest potential differences in the abundance or nutritional quality of prey items between sites sampled. Concurrent studies of foraging trip duration did not indicate that females in the area of decline were working harder to obtain energy for themselves and their pups. These studies additionally showed pups in the area of decline to have higher growth rates than pups in the area of stable population. Additional data are needed from the area of population decline to more accurately assess the effects of prey availability on lactating females and their ability to provision their pups. Also needed are milk samples and intake rates for the period beyond the fourth week postpartum, as weaning does not occur until about six months.

Introduction

The population of Alaskan Steller sea lions (*Eumetopias jubatus*) has declined by more than 50% since the late 1960's. They are currently listed as threatened but it has been proposed to upgrade the population west of Cape Suckling, Alaska to endangered while the population east of this site remains as threatened.

Although the precise cause of the decline remains unknown, recent studies suggest it may be food related (Castellini 1993). Measurements of indices of physiological condition, growth and energy metabolism, and female reproductive effort are being compared for animals in the area of declining population with those from animals in an area where the population remains stable.

Methods

In 1993 and 1994, samples were obtained from animals on Lowrie Island in the eastern Gulf of Alaska as a site representative of the area of stable population. Chirikof and Fish Islands, in the western Gulf of Alaska, were sampled in 1993 and 1995 respectively, as sites representing the area of declining population.

Milk samples were obtained from 25 females for proximate compositional analysis. The percentage of water and total solids was determined gravimetrically after lyophilization to a constant weight. The ash content was determined from incineration of lyophilized samples. The protein content of milk was determined by digestion of fluid samples with a modified Kjeldahl method. The amount of lipid in the milk samples was estimated as that portion of the total solids not accounted for by protein or ash. This assumes the contribution of carbohydrates to the total solids is negligible (Oftedal, 1984). Energetic content of the milk was calculated using energy values of 9.4 kcal/g for lipid and 4.3 kcal/g for protein (Schmidt-Nielsen, 1983).

Milk intake rates of 23 pups were estimated as the difference between total water influx and metabolic water production, divided by the water content of the milk. The total water influx for each pup was determined from labeled water turnover following injection with 99% deuterium oxide. The metabolic water production used in the calculations was determined from the average field metabolic rate of a previous season's pups. Energy intake rates were then determined from the calculated energetic content of the milk.

Results

Table 1 summarizes the results of the proximate compositional analysis of the milk samples. There were no significant differences in any of the measured components.

Table 1. Composition of milk from adult female Steller sea lions.

Location	n	% Water	% Solids	% Ash	% Protein	% Lipid
Chirikof 1993	9	61.09 ±6.31	38.91 ±6.31	0.82 ±0.15	4.11 ±1.30	33.98 ±5.55
Lowrie 1993	5	52.69 ±1.73	40.86 ±1.73	0.83 ±0.04	3.79 ±0.89	36.24 ±2.00
Lowrie 1994	8	65.09 ±5.50	34.91 ±5.50	0.80 ±0.05	2.87 ±1.05	31.25 ±4.59
Fish 1995	3	54.52 ±1.61	41.03 ±1.61	0.71 ±0.05	3.73 ±0.34	36.58 ±1.43

Table 2 shows pup intake rates of total water, milk, and energy. The milk intake rates of pups averaged 79.14 ml/kg/day (±16.35 S.D.) and were not significantly different between islands. The energy intake rates were significantly different ($p<0.05$) between Lowrie 1994 and Fish 1995. There was no significant difference ($p>0.05$) between the energy intake rates of Chirikof 1993 and Lowrie 1994 nor between Chirikof 1993 and Fish 1995. The mean age of pups sampled was 13.97 days (± 4.59 S.D.) with an average mass of 26.56 kg (± 3.99 S.D.).

Table 2. Total water, milk and energy intake rate of Steller sea lions

Site	n	Mean Age	Mean Mass	Total Water Intake	Milk Intake
		(days)	(kg)	(ml/kg/day)	(ml/kg/d)
Chirikof 1993	3F:8M	13.36	26.61	62.73	79.12
		±1.23	±2.77	±9.99	±16.64
Lowrie 1994	3F:3M	8.83	23.37	57.51	73.42
		±4.10	±3.14	±8.70	±14.77
Fish 1995	1F:5M	19.17	30.39	63.30	83.35
		±1.40	±3.74	±11.50	±19.50

There is a significant (r^2=0.61) association between pup growth rates and energy intake rates as indicated in Figure 2.

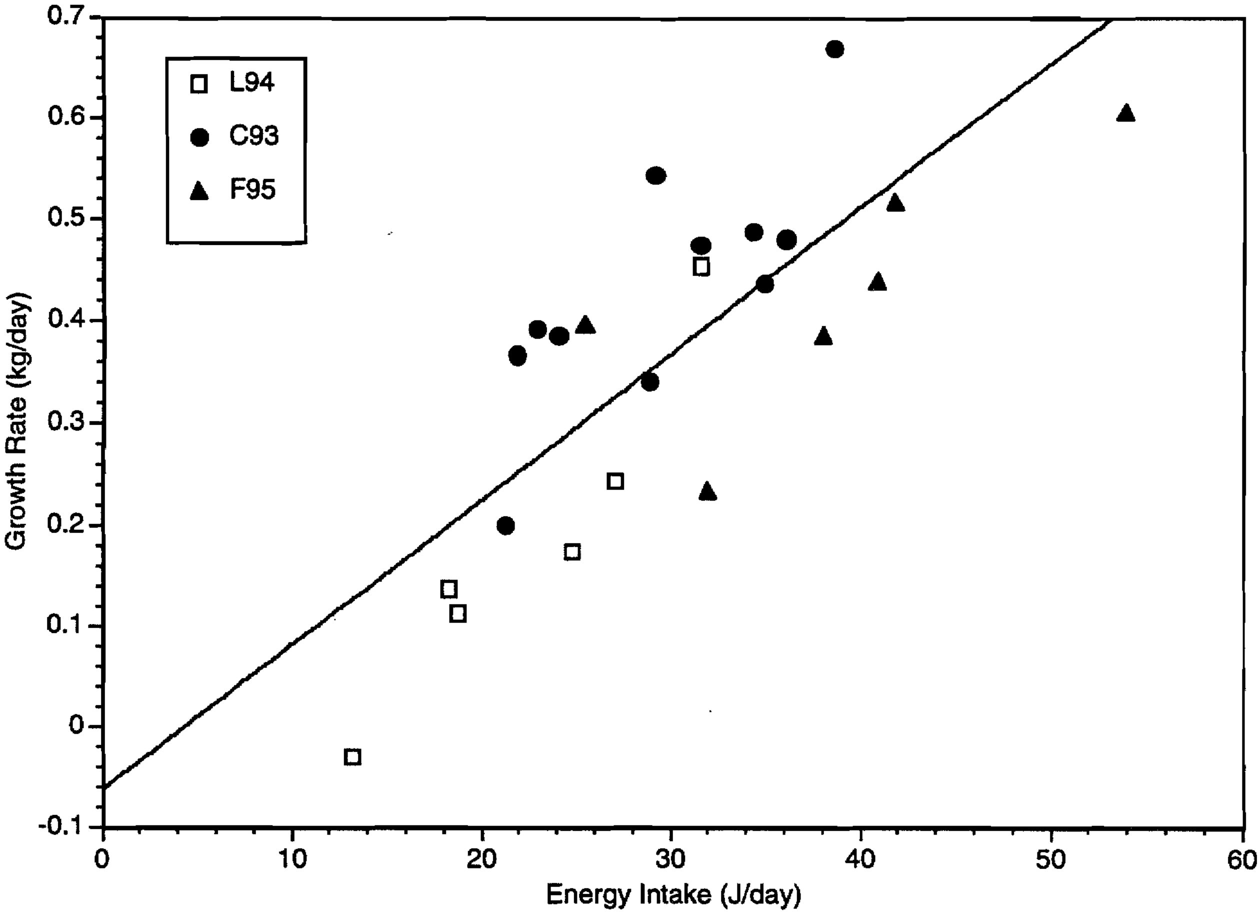
Conclusions

Although the differences in the proximate composition of milk and milk intake rates between locations were not significant, when combined they were different enough to yield energy intake rates that varied significantly between some locations. The trend was for energy intake rates to be higher in the areas of decline. These results could indicate differences in the abilities of females at different islands to provision their young.

The composition of milk is known to change over the course of lactation; in sea lions the percentage of water is presumed to decrease over time. Because the stage of lactation of females sampled was not known it is possible that differences in milk solids are not due to differences in access to prey between islands but are an effect of variations resulting from different stages of lactation. However, the average age of pups was approximately the same for each island at the time of sampling, so it is likely that all adult females sampled were in the same stage of lactation. Hence, the differences in the composition of milk solids between islands could be attributed to differences in prey composition between areas sampled. However, sample sizes are small and the contributions of interannual variations in various parameters which might influence milk content are unknown.

Given the current hypothesis that the decline of Alaskan Steller sea lion populations is related to food availability, it is likely that although females in all areas appear to be supplying their pups with similar quantities of milk, the quality of this milk varies in terms of protein and lipid content due, perhaps, to differences in the types or nutritional quality of prey available to females in the regions sampled. Evidence in support of this assumption comes from concurrent studies of foraging trip duration and pup growth rates. These studies indicate that females in the areas of decline were not working harder than females in the stable population area to obtain energy for themselves and their pups. They also indicate that pups in the area of decline have higher growth rates than pups in the area of stable population.

FIGURE 2: Pup Growth Rates vs. Energy Intake Rates by Location



Further study including larger sample sizes as well as concurrent samples from both areas of stable and declining population are needed. In addition milk samples and intake rates for the period beyond the fourth week postpartum are needed, as weaning does not occur until about six months.

Acknowledgments

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Plasma Haptoglobin Levels in Threatened Alaskan Pinniped Populations

Tania Zenteno-Savin, Michael A. Castellini, Lorrie D. Rea and Brian S. Fadely.
Institute of Marine Science, University of Alaska Fairbanks, P.O. Box 757200,
Fairbanks, Alaska, 99775-7220, USA.

Corresponding author:
Dr. Michael A. Castellini.
Institute of Marine Science, University of Alaska Fairbanks, P.O. Box 757200, Fairbanks,
Alaska, 99775-7220, USA.

ABSTRACT: We examined the plasma concentration of the acute phase protein haptoglobin (Hp) from Steller sea lions (*Eumetopias jubatus*) and harbor seals (*Phoca vitulina*) in regions of Alaska where the populations of these pinnipeds were declining and compared the values with concentrations of Hp from the same species in areas where the populations were stable. Samples were collected from 1992 through 1994 at sites in Southeast Alaska, Prince William Sound, the Gulf of Alaska and the Aleutian Islands. Significantly higher levels of Hp were found in the samples from the areas of decline compared to those from stable populations. Based on these findings, we propose that one may be able to distinguish these compromised pinniped populations using Hp as a biomedical indicator.

Key words: Steller sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*), blood chemistry, health, disease.

Introduction

Haptoglobin (Hp) belongs to a group of blood proteins that increases considerably in response to infection, inflammation, tumor, or trauma in what is known as the acute phase reaction. The analysis of Hp concentration is a very sensitive, although non-specific, indicator of disease used for diagnostic assessments in human and veterinary medicine. It is an $\propto_{2}$- glycoprotein which binds free hemoglobin)Hb) in a stable complex, both in vivo and in vitro (Nguyen, 1989). Haptoglobin prevents the loss of Hb from the plasma and blocks the exchange of heme between methemoglobin and albumin (Koj, 1974).

As one of the acute phase proteins, Hp has been shown to increase in cases of inflammatory and infectious diseases, trauma, myocardial infarction, active rheumatoid arthritis, cancer, leukemia, and tuberculosis (Gordon and Koj, 1985; Echersall et al. 1989; Cross et al. 1991). The Hp concentration is useful in the determination of acute hepatitis, anemia and other hemolytic episodes, in which the plasma concentration of Hp is significantly reduced (Laurell and Gronwall, 1962). Reduced Hp levels are also observed during paroxysmal memoglobinuria, malaria, chronic liver disease, cirrhosis and mononucleosis (Giblett, 1974).

The application of acute phase protein analyses to wild populations to assess potential stressors is relatively new. Duffy et al. (1993, 1994) found elevated Hp levels in river otters (*Lutra canadensis*) that were exposed to oil from the Exxon Valdez oil spill in Prince William Sound. This change in blood chemistry persisted for several years beyond the exposure event.

To assess the potential use of Hp analyses for population health studies of marine mammals, Steller sea lions (*Eumetopias jubatus*) and harbor seals (*Phoca vitulina*) from Alaska (USA) were examined. For the past 20 years the populations of Steller sea lions and harbor seals in Alaska have been declining (Pitcher, 1990; Loughlin et al. 1992), and a portion of the Steller sea lion population has recently been proposed as endangered (Federal Register, 1995). There is no known obvious cause for these declines. In routine hematological studies of Alaskan Steller sea lion pups Castellini et al. (1993) and Rea (1995) found no indications in the clinical blood chemistries to suggest gross physiological or metabolic disturbances. Since Hp may be a much more sensitive indicator of disease or sublethal damage, Hp levels in plasma samples of Steller sea lions from the Gulf of Alaska and the Aleutian Islands, and of harbor seals from Prince William Sound, Alaska (all sites where significant population declines are occurring) were compared to samples from Steller sea lions and harbor seals captured in Southeast Alaska (where the populations are stable: Loughlin et al. 1992; Small and DeMaster, 1995). Based on these results, we propose that the areas of decline are characterized by one or more factors causing plasma Hp levels to increase significantly over control populations.

Materials and Methods

Blood samples were taken from Steller sea lions at rookeries in the Aleutian Islands and the Gulf of Alaska during the summers of 1992, 1993 and 1994. Harbor seals were sampled in Prince William Sound, Alaska in 1994. As comparative controls, Steller sea lions and harbor seals were sampled in Southeast Alaska during the summers of 1992, 1993 and 1994. Additionally, blood samples were obtained from healthy Steller sea lions that were captured from the wild as pups in 1994 and reared at Vancouver Aquarium (Vancouver, British Columbia, Canada). We collected a total of 128 plasma samples from Steller sea lions (19 pups from the Aleutian Islands; 13 newborns, 41 pups and 14 adults from different rookeries in the Gulf of Alaska; 6 newborns, 22 pups, 4 juveniles and 5 adults from Southeast Alaska, including Forrester Island; 4 juveniles from Vancouver Aquarium), and 63 harbor seals (12 juveniles and 20 adults from Prince William Sound, Alaska; 9 juveniles and 22 adults from Southeast Alaska). Approximate age of harbor seals and Steller sea lions was estimated from morphometric data. In addition, Steller sea lions were classified as newborn when the umbilicus was attached, and as a pup if the umbilicus was no longer present but the animal was still nursing. Detailed age information was available for a subset of Steller sea lion pups which had been tagged within two days of birth. Steller sea lion adults and juveniles were darted with Telazol® (Loughlin and Spraker, 1989) and some of the adults were anesthetized further with Halothane® (Heath et al. 1993). Steller sea lion pups were manually restrained. Some harbor seals (Prince William Sound) were anesthetized with ketamine/diazepam at standard doses (Geraci et al. 1981) and others (Southeast Alaska) were manually retrained. Blood samples were taken by venipuncture from either a hind flipper vein, the extradural vein, or the dorsal pelvic vein, and collected in heparinized vacuum tubes (Vacutainer, Beckton, Dickinson, Rutherford, New Jersey, USA) and stored on ice. All animals were captured in collaboration with National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game (ADFG) field projects.

In all cases, plasma was separated by centrifugation within 4 hr, and samples were stored frozen at -20 C until assayed. The Hp content of plasma samples was determined as the Hb-binding capacity of Hp, using a high resolution electrophoresis kit (Helena Laboratories, Beaumont, Texas, USA) (Moors, 1978). A known excess of a 10% solution of homologous Hb was added to each plasma sample and allowed to mix for 5 min. Samples were then applied to an agarose plate and electrophoresed (Wide Mini Sub Cell with model 3000 xi power supply, BioRad, Palo Alto, California, USA) at 110 V for 30 min. After fixing the protein complex by drying at 60 C for 15 min, the gels were stained with o-dianisidine (Valeri at al. 1965). The Hp-Hb complex, which migrates in a different region from Hb, was quantified in a densitometer (model 620, BioRad, Palo Alto, California, USA). Results were expressed as mg of Hb-binding capacity per 100 ml of plasma. Data were analyzed by using non-paired t-tests with Bonferroni adjustment for multiple comparisons, and are presented as mean ± SE (Shott, 1990). Statistical significance was assumed when $\underline{P}<0.05$.

A separate set of control tests were carried out to consider the possibility that handling methods and time lag until sampling might have affected Hp levels. This hypothesis was tested in several ways: first, differences in Hp concentrations between anesthetized and manually restrained harbor seals was tested. Second, changes in Hp concentrations with time elapsed between capture and sampling in harbor seals in Southeast Alaska were examined. Third, correlations between Hp levels and known biochemical indices of short-term handling stress, including creatinine phosphokinase (CPK), alanine aminotransferase (ALT), alkaline phosphatasse (AP), aspartate aminotransferase (AST) and albumin-to-immunoglobulin G (A/G) rations in harbor seals and Steller sea lions from Southeast Alaska were analyzed. Concentrations of these metabolites were determined using routine clinical procedures. Clinical chemistry profiles were run on a Kodak Ektachem analyzer at Fairbanks Memorial Hospital

(Fairbanks, Alaska, USA). Fourth, the effect of time-lag between capture and blood sampling on Hp concentration in five healthy northern elephant seal pups (*Mirounga angustirostris*) fitted with indwelling venous catheters was evaluated. Differences between time interval samples were assessed using an ANOVA for repeated measures and post-hoc analysis with use of a Tukey's multiple range test (Zar, 1984). Statistical significance was assumed when $\underline{P}<0.05$.

Results

No statistically significant differences in Hp concentrations were found between anesthetized (mean ± SE Hp: 136.3 ± 11.2 mg/100 ml, n=20) and non-anesthetized (123.7 ± 10.5 mg/100 ml, n=12) harbor seals (T=-0.76, $\underline{P}=0.455$). Similarly, Hp concentrations did not change with time between capture and sampling in harbor seals in Southeast Alaska. In parallel studies, Hp levels showed no correlation with biochemical indices of short-term handling stress in harbor seals (CPK, $\underline{r}=o.077$, $\underline{P}=0.545$; AST, $\underline{r}=0.146$, $\underline{P}=0.250$; ALT, $\underline{r}=0.138$, $\underline{P}=0.276$; AP, $\underline{r}=0.019$, $\underline{P}=0.880$) or Steller sea lions (CPK, $\underline{r}=0.259$, $\underline{P}=0.122$; AST, $\underline{r}=0.205$, $\underline{P}=0.223$: ALT, $\underline{r}=0.257$, $\underline{P}=0.125$; AP, $\underline{r}=0.292$, $\underline{P}=0.079$). Finally, in northern elephant seal pups with indwelling venous catheters, ANOVA for repeated measures and Tukey's post-hoc analysis showed that there was no significant effect of time between capture, catheterization and blood sampling on Hp concentration for up to 8 hr (mean ± SE Hp at catheterization, 80.7 ± 7.0 mg/100 ml; 1 hr later, 93.6 ± 4.4 mg/100 ml; 2 hr, 113.5 ± 7.1 mg/100 ml; 3 hr, 103.2 ± 14.9 mg/100 ml; 5 hr, 114.4 ± 14.9 mg/100 ml; 7 hr, 104.1 ± 10.2 mg/100 ml).

In Steller sea lions, significantly higher Hp concentrations were found in samples from the Gulf of Alaska and the Aleutian Islands than in those from Southeast Alaska (Table 1). The Hp levels in the four Steller sea lions held at Vancouver Aquarium were comparable to those in sea lions from Southeast Alaska. Similarly, harbor seals sampled in Prince William Sound had significantly higher Hp levels than those sampled in Southeast Alaska.

Table 1. Haptoglobin concentration (mg Hb bound/100 ml) in plasma of Steller sea lions and harbor seals. Newborns = < 5 days old; Pups = 1-10 weeks old; Juveniles = 1-3 years old; Adults = > 4 years old (age classification based on estimated age at sampling).

Site	Age	Mean	SE	Number Sampled
STELLER SEA LIONS				
Southeast Alaska	Adults	143.1	13.5	5
	Juveniles	97.8	14.1	4
	Pups	87.2	13.8	22
	Newborns	35.4[a]	4.6	6
Aleutian Islands	Pups	253.6[b]	16.7	19
Gulf of Alaska	Adults	250.7[b]	20.7	14
	Pups	263.0[b]	10.3	41
	Newborns	68.6[a]	21.8	13
Vancouver Aquarium	Juveniles	73.8	11.2	4
HARBOR SEALS				
Southeast Alaska	Adults	82.9	11.3	22
	Juveniles	73.9	9.1	9
Prince William Sound	Adults	133.1[b]	11.4	20
	Juveniles	130.1[b]	10.8	12

[a] Significantly (P<0.05) different compared to adult animals

[b] Significantly (P<0.05) different compared to animals from Southeast Alaska

The Hp levels in Steller sea lions from Southeast Alaska generally increased with age (Fig. 1), with the exception that newborns (estimated <5 days old) had relatively high Hp levels compared to animals estimated to be 10 days old (Figure 1).

In Steller sea lion pups, A/G ratios showed a weak negative relationship with Hp levels (A/G ratio = 1.723 - 0.001 * Hp, R^2=0.358). This was found to be due to a decrease in the albumin content. It is interesting to note that no correlation was found between Hp levels and A/G ratio in plasma samples from harbor seals (r=0.059, P=0.643).

Discussion

Based on the control studies, we believe that the differences in Hp seen in Steller sea lion and harbor seal populations were probably not due to handling differences. Furthermore, restraining harbor seals, white-tailed deer (*Odocoileus virginianus*), black bears (*Ursus americanus*), and raccoons (*Procyon lotor*) immobile for over 6 hrs did not result in changes in Hp levels (Seal et al. 1971). In humans, the first signs of increased synthesis of Hp after injury appear after a delay of 3 to 6 hours and the maximum level

is reached about 5 to 7 days after the onset of the reaction (Nguyen, 1989). All animals included in this study were typically sampled within 3 hrs of capture.

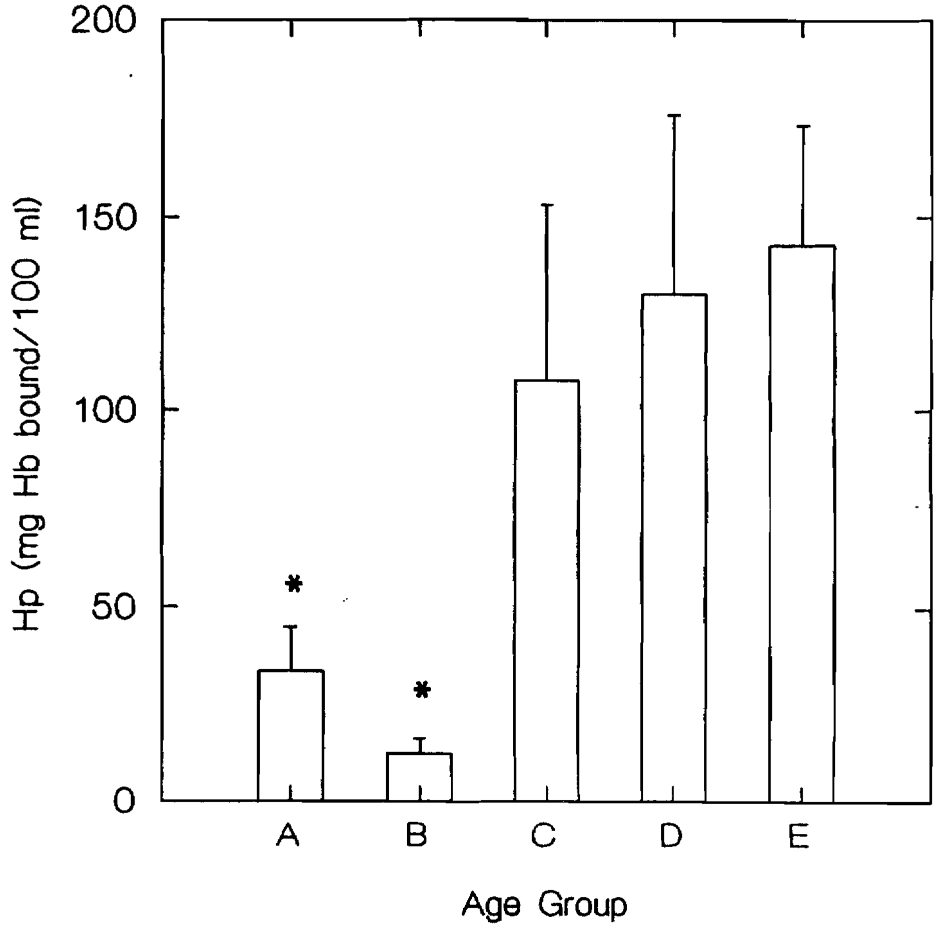

FIGURE 1. Mean circulating haptoglobin (Hp) levels in Steller sea lions from Southeast Alaska. A = newborn (<5 days old), B = pup (5-15 days old), C = pup (1-10 weeks old), D = juvenile (1-3 years old); E = adult (>4 years old). Vertical lines indicate ± S.E. * = significantly ($P<0.05$) different compared to adult animals.

Discussion

Based on the control studies, we believe that the differences in Hp seen in Steller sea lion and harbor seal populations were probably not due to handling differences. Furthermore, restraining harbor seals, white-tailed deer (*Odocoileus virginianus*), black bears (*Ursus americanus*), and raccoons (*Procyon lotor*) immobile for over 6 hrs did not result in changes in Hp levels (Seal et al. 1971). In humans, the first signs of increased synthesis of Hp after injury appear after a delay of 3 to 6 hours and the maximum level is reached about 5 to 7 days after the onset of the reaction (Nguyen, 1989). All animals included in this study were typically sampled within 3 hrs of capture.

The mean ± SE Hp concentrations in plasma samples from adult Steller sea lions and harbor seals in Southeast Alaska (Table 1) fell within the ranges for healthy adult humans (93 ± 40 mg/100 ml, n=152; Kirk, 1968; about 150 mg/100 ml; Oliviero et al. 1987). Haptoglobin levels were significantly ($P<0.05$) higher in Steller sea lions sampled in the Gulf of Alaska and the Aleutian Islands than in sea lions sampled in Southeast Alaska and were comparable to the mean ± SE Hp concentrations reported in serum from mice subjected to an acute phase response (297.6 ± 9.3 mg/100 ml; Waites et al. 1983). In harbor seals, Hp concentration was higher in samples from Prince William Sound than in those obtained at Southeast Alaska. Albeit elevated relative to harbor seals from Southeast Alaska, Hp concentration in samples from harbor seals at Prince William Sound did not reach the levels observed in samples from Steller sea lions at the Aleutian Islands and the Gulf of Alaska, nor the values reported for mice during the induced acute phase response.

Elevated Hp levels are clinical indicators of infection and disease in humans and other mammals (Henry et al. 1974; Gordon and Koj, 1985; Echersall et al. 1989). Increases in the acute-phase proteins including Hp, have been associated to physical, psychological and environmental stress (Aikawa et al. 1990; Kalmovarin et al., 1991; Singh et al. 1991; Boosalis et al. 1992). In river otters (L. Canadensis) that were exposed to crude oil from the Exxon Valdez oil spill, Hp levels were also elevated compared to animals that were not impacted (Duffy et al. 1993; 1994). Based on these data, we suggest that the Steller sea lion and harbor seal populations in the Gulf of Alaska and the Aleutian Islands may be faced with a stressor, or a group of stressors, that are inducing an acute phase reaction, as indicated by elevated Hp levels.

In a previous study, mean ± SE Hp levels in adult harbor seal serum samples, collected in 1989 and 1990 following the Exxon Valdez oil spill, were not significantly different for oiled and non-oiled areas of Prince William Sound, or from non-oiled areas of the Gulf of Alaska (125.1 ± 11.4, n=5; 148.4 ± 24.7, n=7, respectively) (Frost and Lowry, 1994). However, the mean ± SE Hp level (133.0 ± 11.3, n=19) for these animals, sampled in 1989 and 1990, is similar to the values from this study for Prince William Sound adult harbor seals (Table 1).

In Steller sea lion pups, Hp was detectable within the first week of life. The developmental variation in Hp concentration observed in the Steller sea lion pup samples is normal in mammals. In newborn mice, serum Hp was about 50% of the adult levels; the Hp levels dropped quickly and remained at 10 to 30% of the adult range during the first 2 wk of life (Loeb and Quimby, 1989). In humans, Hp is first detected in 14 day old infants and increases gradually with the maximum value seen by about the 20th year (Kirk, 1968; Loeb and Quimby, 1989). Hypohaptoglobinemia is characteristic of most human newborns and the normal range for Hp levels in infants is 1 to 30 mg Hb bound/100 ml (Adinolfi and Adinolfi, 1974; Giblett, 1974). The Hp concentrations in all Steller sea lion pups were higher than in healthy human infants, suggesting that this species is immunologically precocious compared to humans. Shaughnessy (1974) found Hp bands in electrophoretic analyses of serum samples from 1 day old southern elephant seals (*M. Leonina*) and concluded that they were more immunologically advanced at birth than most mammals.

Haptoglobin acts as an immunomodulator in man and cattle (Oh et al. 1990; Murata and Yamamoto, 1993). The negative relationship between A/G ratios and Hp levels in Steller sea lion pups may indicate impairment of the immune system in these animals and is consistent with the suppression of lymphocyte blastogenesis reported for bovine calves (Murata and Yamamoto, 1993). Albumin deficiency is characteristic of various liver diseases, including cirrhosis, as well as parasitic infections, chronic inflammation, and malignancy (Vido and Rezai, 1975; Keshgegian, 1984; Monzon and Villavisencio, 1990).

There are many possible disease states that could induce a higher Hp level in the Steller sea lions and harbor seals. Future work will need to address the relationship between Hp concentrations and known disease states in these species. However, the data suggest that some event has occurred which differentiates the declining and stable pinniped populations on the basis of Hp levels.

Beyond disease states, it is possible that these differences in Hp concentrations may reflect differences in genetic composition or biology and natural history of harbor seals and Steller sea lions. Sufficient evidence (behavioral, phenotypic and genotypic) has been recently found to distinguish the Steller sea lions in Alaska as two distinct stocks separated east and west of Cape Suckling, Alaska (144°W longitude) (Bickham et al. In press; Loughlin, in press). All the Southeast Alaska, as well as the Vancouver Aquarium Steller sea lions analyzed in this study, were sampled east of Cape Suckling while those from Gulf of Alaska and Aleutian Islands were sampled west of Cape Suckling. Harbor seals at Grand Island, Southeast Alaska, were sampled during August 1994, at which time they were molting. Further research is needed to address the possibility that differences in Hp levels found between pinnipeds in the Gulf of Alaska, Aleutian Islands and Prince William Sound and those in Southeast Alaska reflect genetic isolation between stocks, and to study changes in Hp levels related to different stages in the life cycle (such as molting and fasting) of these species.

In summary, plasma concentrations of Hp from Steller sea lions and harbor seals in stable populations (Southeast Alaska) and healthy Steller sea lions (Vancouver Aquarium) were within the range reported for humans and other mammals. Compared to reported values for newborn and infant humans, Steller sea lion pups had higher Hp levels, suggesting these animals are born with an immune system developed to a higher degree than humans. Steller sea lions and harbor seals sampled at sites where populations are declining (Aleutian Islands and Gulf of Alaska, and Prince William Sound, respectively) had elevated levels of plasma Hp relative to individuals from stable populations. This is the first indication that these stocks can be separated on the basis of an acute phase reaction that is consistent with declining Alaskan pinniped populations.

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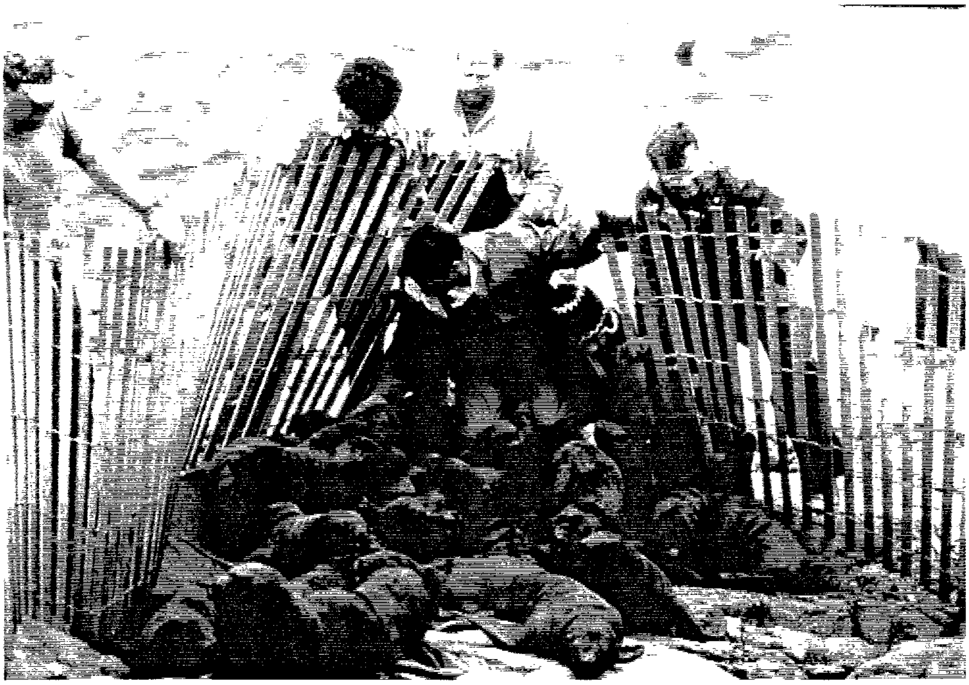
CHAPTER SIX

Steller Sea Lion Pathological Comparisons



JOEL SARTORI

Investigations into the Health Status of Steller Sea Lions, *Eumetopias jubatus*, from 1992 to 1995.

Terry R. Spraker and Denise Bradley

Veterinary Diagnostic Laboratory
Colorado State University
Fort Collins, CO 80523

INTRODUCTION

In the late 1960's Steller sea lions *(Eumetopias jubatus)* were abundant in the eastern Aleutian Islands with some rookeries containing over 15,000 adults and juveniles. In the early 1970's the abundance of Steller sea lions inhabiting the Aleutian Islands had declined (Braham et al. 1980). The population continued to decline throughout the Aleutian Islands. The decline became evident in the Gulf of Alaska, at least to the Kenai Peninsula in the mid 1980s (Merrick et al. 1987). The rate of decline increased between 1985 to 1989. After 1989 the decline continued to spread eastward as far as Prince William Sound. The Alaska population, which was estimated to have been 157,000 adults and juveniles in the 1970s, had now declined to less than 64,000 animals by 1989 (Loughlin et al. 1992). The Steller sea lion population throughout central and southern California has also declined from the 1940's by at least 50% (Loughlin et al. 1992).

Because of this rapid decline in Steller sea lion numbers, on April 5, 1990, the National Marine Fisheries Service (NMFS) classified the animals as a threatened species under the provisions of the Endangered Species Act. The NMFS appointed the Steller Sea Lion Recovery Team that reviewed the problem and suggested a series of management and research projects to be done to determine possible causes of decline. This project dealing with diseases is one of many to attempt to define the possible causes of decline of Steller sea lions.

The general outline of this chapter will be divided into three main categories: Clinical evaluation of captured adults and pups using hematological parameters, bacterial isolation findings, serology, toxicology and visual examination. The second category will summarize the gross necropsies, histological lesions and toxicology in animals found dead. These animals were divided into four age groups: adults, juveniles, pups and fetuses and each will be covered separately. The third category will cover a specific syndrome characterized by dermal ulceration and alopecia in relatively healthy and robust pups.

MATERIALS AND METHODS

In order to examine this population of Steller sea lions for evidence of diseases every opportunity was taken to examine animals both alive and dead. All of the adults and many of the pups that were captured were examined and sampled. Samples taken from live animals included blood for complete blood counts and serology and swabs for bacteriology. Selected skin samples were taken for virology and histopathology. All animals that were found dead were necropsied and a selected number were examined histologically.

Bacterial cultures were taken clinically on adults and pups. The sites cultured included nasal passages, rectum, vagina and throat. Additional sites included skin lesions, abscesses and conjunctival sacs of the eyes. Bacterial cultures also were taken on selected necropsy cases in pups and fetuses. Sites cultured in pups included intestine, abdomen, abscesses, brain, thoracic cavity and skin lesions. Sites cultured in fetuses included lungs, stomach contents, amniotic fluid, liver and placenta. Cultures were taken using a sterile swab placed in clear Amies media for transport. Swabs were held at environmental temperature from one to six hours. Depending on site cultured and any special fastidious bacterial suspected, swabs were plated onto one or more of the following media:

Blood agar with 5% sheep blood
Columbia agar base with 5% sheep blood with colistin and Nalidixic acid
MacConkey Agar
Selenite broth
Salmonella-Shigella agar
Urea agar
Brucella agar base with 5% sheep blood, cefoperazone, vancomycin and amphotericin B
Cycloserine-sefotoxin-fructose Agar
Mycoplasma media
Sabourauds dextrose agar
Thiosulfate-citrate bile sucrose agar
Leptospirosis media

Gram stains were done on all swabs. Cultures were incubated at environmental temperature, 37° C and 42° C. Both aerobic and microaerophilic environments were provided. Identification of bacteria was accomplished using standard morphology and biochemical tests in conjunction with gram staining.

Tissues were evaluated for the presence of *Chlamydia* sp. by standard tissue culture techniques and by fluorescent antibody staining on selected fetal tissues.

Blood was collected on all adults and on many of the pups for complete blood counts. Vacutainers with EDTA (LTT) were appropriately filled with whole blood. Samples were kept cool until they could be processed, one to six hours. Packed cell volume as determined by placing the blood collected in the EDTA in a microhematocrit tube and centrifuging for 5 minutes. White cell counts were done using the manual Unipette hemocytometer method (Becton-Dickson, Rutherford, NJ). Blood film slides for differential white cell counts were made, air dried and transported. The slides were stained with a Wright Giemsa stain and a differential count was done.

Serum was analyzed for the presence of antibody against 10 serotypes of calicivirus virus and *Chlamydia psittaci* by the National Veterinary Services Laboratory, Ames, Iowa using standard techniques. Serum will be analyzed for other viral diseases (morbillivirus-phocine and canine, herpes and influenza) and bacterial diseases (*Brucella* sp., *Chlamydia* sp. and *Leptospira* sp.).

All animals found dead were necropsied. Selected tissues were collected and fixed in 10 to 15% neutral buffered formalin or glutaraldehyde. Selected tissues were embedded in paraffin, sectioned at 5 to 6 um, stained with hematoxylin and eosin and examined under light microscopy. Selected tissues collected in 1994 were embedded in epoxy, thin sections made and examined under electron microscopy.

Blubber and brain from Steller sea lion adults (n=12), juveniles (n=3) and fetuses (N=5) were analyzed with gas chromatograph/electron capture detector (GC-ECD) for the presence of organochlorine pesticides and polychlornated biphenols (PCB's).

EVALUATION OF THE HEALTH STATUS OF STELLER SEA LIONS: HEMATOLOGY, BACTERIOLOGY, SEROLOGY AND TOXICOLOGY

Hematology and Bacteriology

In May of 1992 an adult female Steller sea lion was captured and sampled. This animal appeared to be clinically healthy. Her packed cell volume was 46% and her white blood cell count was 9,000 cells/ul. Pathogenic bacterial organisms were not isolated from the nasal cavity, eye, pharynx, vagina and rectum from this female.

During June of 1992, 7 Steller sea lions were darted, captured and sampled from Forrester Island, Alaska. All of these females were clinically healthy and had healthy pups at the time of capture. The packed cell volume of these 7 animals ranged from 35% to 50% with an overall average of 43%. The white blood cell count ranged from 6,200 to 14,100 cells/ul with an overall average of 9,900 cells/ul. Of these 7 adult females 2 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Microfilaria were not found in blood from any of these animals. The pup of one female (92SSL-8) was captured by hand and bled, its packed cell volume was 35% and its white blood cell count was 10,100 cells/ul. Areas cultured on adult females for bacterial pathogens included nasal cavity, pharynx, trachea, eye, vagina, rectum, liver and heart blood. A total of 43 cultures were done. Only one potentially pathogenic organism was found and that was *Edwardsiella tarda* that was isolated from the vagina and rectum from 92SSL-4 and from the mouth and rectum from 92SSL-8P.

In July of 1992, 11 Steller sea lion pups were captured and bled from Marmot Island, Alaska. The reason these pups were captured was due to the presence of an infectious disease that was causing alopecia and dermal ulceration. These pups had not been previously captured, tagged or manipulated in any fashion prior to us capturing them for the purpose to investigate this disease. These pups were captured at random. All pups appeared to be large and robust except for the fact that 10 of these pups had dermal ulcers and/or alopecia with lice. The packed cell volume of these 11 pups ranged from 33% to 40% with an overall average of 37%. The white blood cell count ranged from 6,200 to 11,000 cells/ul with an overall average of 8,100 cells/ul. Of these 11 pups, none were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Microfilaria were not found in any of these animals. Potentially pathogenic bacteria were not isolated from the rectum and nasal cavity from these 11 pups.

On 26 January, 1993 an adult female Steller sea lion (93SSL-19) was darted and sampled on Cape St. Elias, Alaska. This female appeared to be in good body condition. Her packed cell volume was 44% and her white blood cell count was 12,200 cells/ul. Microfilaria were not found in blood from this animal. Pathogenic bacterial organisms were not isolated from the nasal cavity, vagina or rectum of this female. Rectal and nasal swabs were cultured for chlamydia, but were negative.

On 6 February 1993, an 8 month old male Steller sea lion was darted on Long Island, Kodiak Island, Alaska. This animal appeared to be clinically healthy and in good body condition. His packed cell volume was 46% and his white blood cell count was 9,570 cells/ul. Microfilaria were not found in blood from this animal. Pathogenic bacterial organisms were not isolated from the nasal cavity, but a moderate growth of *Listeria* sp. and alpha *Streptococcus* sp. and non-hemolytic *Streptococcus* sp. were isolated from the rectum of this young male. *Listeria* sp. are known to cause encephalitis and abortion in mammals and is believed to cause abortion in northern fur seals (*Callorhinus ursinus*).

In June of 1994, 12 adult female Steller sea lions were captured and bled from Forrester Island, Alaska. One animal was captured and bled twice. All of these adult females appeared healthy at the time of capture. The packed cell volume of these 12 animals ranged from 34% to 49% with an overall average of 42%. The white blood cell count ranged from 8,100 to 23,600 cells/ul with an overall average of 12,300 cells/ul. The one animal that was captured twice (94Ej-69) had an extremely elevated count of 23,000 cells/ul on 18 June 1994 and 23,300 cells/ul on 22 June, 1994. Of these 12 adult females 5 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Microfilaria were not found in blood from any of these animals. Pathogenic bacterial organisms were not isolated from the nasal cavity, vagina and rectum in any of these females. All of these females were clinically normal and had healthy pups.

In June of 1994, 35 Steller sea lion pups were captured and bled from Forrester Island, Alaska. Most of these pups had been previously captured, tagged and manipulated or handled in some fashion for various research projects or were considered to be sick for some reason. These pups were not captured at random as were pups in 1995. The packed cell volume of these 35 pups ranged from 33% to 57% with an over all average of 42%. The white blood cell count ranged from 10,100 to 47,400 cells/ul with an overall average of 23,400 cells/ul. Of these 35 pups 29 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Microfilaria were not found in any of these animals. The only important bacteria isolated from these pups was a *Bordatella bronchiseptica* in two pups (94Ej-88/89 and 94Ej-114/115). All other cultures were considered to be normal flora.

In June of 1995, 7 adult female Steller sea lions were captured and bled from Fish Island, Alaska. All of these adult females appeared healthy at the time of capture and had healthy pups. Their packed cell volume ranged from 42% to 48% with an overall average of 45%. The white blood cell count ranged from 8,800 to 15,500 cells/ul with an overall average of 11,700 cells/ul. Microfilaria were not found in any of the animals. Pathogenic bacterial organisms were not isolated from the nasal cavity, vagina and rectum from any of these females.

In June of 1995, 23 Steller sea lion pups were captured and bled on Fish Island, Alaska. These pups had not been captured, tagged or manipulated in any way prior to this initial capture nor had this rookery been disturbed prior to this capture. The packed cell volume of these 23 pups ranged from 35% to 58% with an overall average of 48%. The white blood cell count ranged from 7,700 to 23,500 cells/ul with an overall average of 14,000 cells/ul. Of these 23 pups 14 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). If pups were placed into three categories: clinically normal pups, pups with ulcers on the flippers and pups with infections or abscesses, the overall white blood cell counts differed. Of the 15 pups that were considered clinically normal, the packed cell volume ranged from 43% to 58% with an average of 49%. The range of the WBC was 7,700 to 17,300 cells/ul with an overall average of 12,400 cells/ul. Of these 16 pups 8 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Of the 4 pups that were considered clinically normal but also had ulcers on the flippers, the packed cell volume ranged from 35% to 52% with an average of 44%. The range of the WBC's in these pups was 13,500 to 23,500 cells/ul with an overall average of 19,000 cells/ul. Of these 4 pups with ulcers on their flippers all 4 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Of the 3 pups that had obvious infections, their packed cell volume ranged from 41% to 53% with an overall average of 49%. The range of their WBC was 10,400 to 20,200 cells/ul with an overall average of 15,600 cells/ul. Of these 3 pups with infections, two were considered to have an elevated white blood cell counts (WBC>13,000 cells/ul). Microfilaria were not found in the blood of any of these animals.

In June of 1995, 53 Steller sea lion pups were captured and anesthetized with isoflurane and then bled and branded on Forrester Island, Alaska. These pups had not been captured, tagged or manipulated in any way prior to this initial capture nor had this rookery been disturbed prior to this capture. The packed cell volume of these 53 pups ranged from 32% to 53% with an overall average of 39%. The white blood cell count ranged from 4,700 to 35,300 cells/ul with an overall average of 15,000 cells/ul. If pups were placed into three categories: clinically normal pups, pups with ulcers on the flippers and pups with abscesses or infections, the overall white blood cell counts differed. Of the 30 pups that were considered clinically normal the packed cell volume ranged from 34% to 53% with an average of 40%. The range of the WBC was 4,700 to 23,900 cells/ul with an overall average of 13,200 cells/ul. Of these 30 pups 12 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Of the 21 pups that were considered clinically normal but also had ulcers on the flippers, the packed cell volume ranged from 32% to 47% with an average of 38%. The range of the WBC was 6,100 to 35,300 cells/ul with an overall average of 16,900 cells/ul. Of these 20 pups with ulcers on their flippers 14 were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Of the 2 pups that had obvious abscesses, both of them had a packed cell volume of 38%. The range of their WBC was 13,300 to 26,500 cells/ul with an overall average of 19,900 cells/ul. Of these 2 pups with subcutaneous abscesses both were considered to have an elevated white blood cell count (WBC>13,000 cells/ul). Microfilaria were not found in the blood of any of these animals.

In summary the hematological data do demonstrate that many of the adults had relatively normal blood parameters, but many of the clinically normal pups had slightly elevated white blood cell counts and that a few of the pups were mildly to severely dehydrated. Also pups with obvious infections and dermal ulceration were responding to the infection with a elevated white blood cell counts (Table 1).

Serology

A total of 58 serum samples from Steller sea lions were sent to National Veterinary Services Laboratory, Ames, Iowa, for detection of antibody to 10 serotypes of calicivirus including BCV, SMSV-1, SMSV-2, SMSV-4, SMSV-5, SMSV-6, SMSV-7, SMSV-8, SMSV-13 and SMSV-14. Of the 58 serum samples, 44 animals were negative to all 10 serotypes, but 14 were positive for one to three of the serotypes. The results are the following: two positive to SMSV-1, five positive to SMSV-2, two positive to SMSV-5, two positive to SMSV-6, one positive to SMSV-8, six positive to SMSV-13 and one was positive to a bovine calicivirus. Positive sera was not found to SMSV-4, SMSV-7 and SMSV-14.

Table 1. Summary of hematological values found in adult and pup Steller sea lions (PCV=packed cell volume, WBCC=white blood cell count).

Year/Location	# of Animals and Age	PCV Range	PCV Mean	WBCC Range	WBCC Mean
92-Forrester	1-adult		46		9.0
92-Forrester	7-adult	35/50	43	6.0/14.1	9.0
92-Marmot	11-pup	30/40	37	6.2/11.0	8.1
92-Forrester	1-pup		35		10.1
93-Cape St. Elias	1-adult		44		12.2
93-Kodiak	1-juvenile		46		9.5
94 Forrester	12-adult	34/49	42	8.1/23.3	12.3
94-Forrester	35-pup	33/57	42	10.1/47.4	23.4
95-Fish	7-adult	42/48	45	8.8/15.5	11.7
95-Fish	23-pup	35/58	48	7.7/23.5	14.0
Normal Pups	16-pup	43/58	49	7.7/17.3	12.4
Ulcer Pups	4-pup	35/42	44	13.5/23.5	19.0
Infection Pups	3-pup	41/53	49	10.4/20.2	15.6
95-Forrester	53-pup	32/53	39	4.7/53.3	15.0
Normal Pups	30-pup	34/53	40	4.7/23.4	13.2
Ulcer Pups	21-pup	32/47	38	6.1/35.3	16.9
Infection Pups	2-pup	38	38	13.3/26.5	19.9

Packed cell volume = percentages
White blood cell count units =10.0 x 103 cells/ael

A total of 41 serum samples from Steller sea lions were sent to the National Veterinary Services Laboratory, Ames, Iowa, for detection of antibody to *Chlamydia psittaci*. Tests were negative for 13 serum samples, positive for 22 and non specific for 6.

In summary, this serological data suggest that at least 6 serotypes of calicivirus (SMSV-1, SMSV-2, SMSV-5, SMSV-6, SMSV-8 and SMSV-13) and a *Chlamydia* sp. that has similar antigenicity to *Chlamydia psittaci* are circulating through the Steller sea lion population. It has not been proven, but probably both of these agents under the right circumstances could cause abortion.

Toxicology

Analysis of 12 blubber samples from adult female Steller sea lions collected from Southeast Alaska has been completed by John Stein and Karen Tilbury, Northwest Fisheries Science Center, Montlake Boulevard, Seattle, Washington. The samples were analyzed for selected chlorinated hydrocarbons (CH's) by a screening method using high performance liquid chromatography coupled with photodiode array detection (Krahn et al. 1994). The CH analytes included selected PCB congeners, DDT's and their metabolites (e.g., DDE's and DDD's), and hexachlorobenzene (HCB) as these analytes are potentially toxic, persist in the environment and are bioaccumulated by marine mammals. The results thus far show that the sum (mean + standard error) of the PCB congeners #138 and #153, which can comprise up to 50% of the total PCB's in marine mammal blubber, was 870 + 220 ng/g wet weight for these females adult Steller sea lions. The sum of the DDT's was 5,300 + 990 ng/g wet weight and the pesticide HCB was not detected in most of the samples. As means of comparison, the mean concentration of the sum of congeners #138 and #153 and the sum of the DDT's in blubber samples from which data are available in the database at the Northwest Fisheries Science Center, Seattle, Washington, are 2,600 + 1,600 and 21,000 + 13,000 ng/g wet weight, respectively, in adult and young (<5 years) Steller sea lions (females; n=6, males; n=2) samples that were also collected from Alaskan waters (Varanasi et al. 1993).

In summary, the small amount of data obtained thus far suggest that the level of PCB's and CH's in Southeastern Alaskan waters is relatively low, however these values should be compared to animals from the areas of decline.

POST MORTEM EVALUATION OF STELLER SEA LIONS

Adult Steller Sea Lion Necropsy Findings

Three adult female Steller sea lions from Forrester Island (92Ej-M1, 93Ej-M1, 94Ej-M1) and one adult female from Fish/Wooded Island (95Ej-WI-M1) have been necropsied. Three (1 in 1992, 1 in 1993, 1 in 1995) died following injection of Telazol at an estimated dosage of 1.0 mg/pound body weight. One animal died under isoflurane anesthesia probably due to hypoxia.

The first animal (92Ej-M1) was successfully darted, but went down in a pool of water and when we approached her another female with a fresh pup lying near her would not allow us to approach the immobilized female. She drowned before we could pull her from the water. The second female (93Ej-M-1) was darted with Telazol and went down nicely, but she was between the waters edge and a large pool of water. As we approached her two large waves (approximately 20 feet high) hit her and us, knocking her and us into the pool of water. She drowned before we could recover and pull her from the pool. The third animal died about 15 minutes after she was put on isoflurane. The cause of her death was believed to be due to a faulty exhaust valve in the gas machine resulting in hypoxia. The fourth animal (95Ej-WI-M-1 or 95WP50) died 15 minutes after being darted with Telazol.

The gross lesions found in these animals were all similar. They were all in good body condition and had 10 to 15 mm of sternal blubber. A few nematodes were present in the stomach and tapeworms were found in the small intestines. The nasal turbinates were covered by a few flecks of mucoid exudate and nasal mites. Lungs were collapsed, edematous and dark red. Excessive fluid was found in the lungs of 92Ej-M1 (SSL-92-M1) and 93Ej-M-1, because both of these animals drowned following immobilization. The uterine horns suggested that all 4 of these females had given birth within the past week. Mammary glands were well developed and lactation was evident. Blood work was done on 94Ej-M1 and the results are the following: packed cell volume-37%, white blood cell count-14,800 cells/ul and microfilaria were not found.

Histopathology was done on 3 animals. Lesions included mild microcavitory degeneration in the cuneate nucleus of the brain stem (92Ej-M1, 94Ej-M1), ulcerative gastritis (92Ej-M1, 94Ej-M1, 95Ej-M1), mild suppurative rhinitis (92Ej-M1, 94Ej-M1, 95Ej-M1), multifocal pneumonia associated with lungworms (94Ej-M1), lungworms without pneumonia (92Ej-M1), encephalitis and myocytis associated with a heavy infection of a protozoan compatible to *Sarcocyst* sp. (95Ej-M1) and mild parasitism, small intestine, trematodes (94Ej-M1, 95Ej-M1).

The two most significant histological lesions found in these females were a mild degree of microcavitary degeneration of the nuclei of the brain stem and the encephalitis and myocytis caused by the severe sarcocyst infection. The cause of the lesion in the brain stem was not determined, but I have seen this lesion in Steller sea lions and harbor seals killed during the Exxon Valdez oil spill. Occasionally marine mammals are found to be infected with Sarcocyst, but this is extremely unusual. Heavy infections of *Sarcocyst* sp. can cause abortion, encephalitis, myocarditis and myocytis in terrestrial mammals. However, this particular female with the heavy infection had mild encephalitis and myocytis associated with a heavy *Sarcocyst* sp. infection, did have had a normal involuting uterus, the pup of this female was not positively identified. Finding the suppurative rhinitis associated with nasal mites and the multifocal pneumonia due to lungworms is common in Steller sea lions (Spraker unpublished data 1986 and 1989). Overall, the general health status of the adults that we examined was fairly healthy.

Juvenile Steller Sea Lion Necropsy Findings

Between 1992 to 1995, four juvenile Steller sea lions were necropsied. The first juvenile was a male (92SSL-H1) that was found near Homer, Alaska. This animal was necropsied by a local veterinarian, who sent the tissues to us for histological examination. His primary gross necropsy findings on this animal were severe emaciation. On histopathology a moderate degree of atrophy of muscle and hepatocytes, lymphoid depletion of lymphoid tissue and mild granulomatous gastritis were found. No other histological lesions or any evidence of infection were found in this animal. The most likely cause of death in this animal was emaciation probably secondary to malnutrition.

The second juvenile (93CSE-1) was darted on 24 January 1993 on Cape St. Elias. This was a large male (150 pounds) that died within approximately 10 minutes of being darted with 150 mg of Telazol. The dart hit the animal in the lower neck region between the anterior dorsal aspect of the scapula and the thoracic vertebra. Blood work revealed a packed cell volume of 46% and a white blood cell count was 7,000 cells/ul. On gross examination the animal was in excellent body condition with a sternal blubber layer of 30 mm. All internal organs were normal except for a few bite wounds over the shoulder and one small (2 mm) ulcer on one of the flippers. Histological lesions included a small healing dermal ulcer on the flipper, dermatitis (probably associated with the bite wound) and mild rhinitis, tracheitis and bronchitis caused by nasal mites. Bacterial cultures grew *E. coli* and alpha *Streptococcus* sp. from the pharynx and prepuce and *Salmonella* sp. *E. coli* and alpha *Streptococcus* sp. from the rectum. The *Salmonella* sp. isolation is important, and has been isolated from both sick and asymptomatic California sea lions and Northern fur seals.

The third juvenile was a 100 pound female (93SSL-K1) that had been seen in the Kodiak harbor for a week in January 1993 before she was found dead. She was then frozen until mid February when she was thawed and necropsied. This animal was emaciated and had 5 mm of sternal blubber. All the lymph nodes were small and the thymus was totally atrophied. One nematode, but no ulcers were found in the stomach. The liver was small a dark and the skeletal muscle was atrophied. On histopathology a moderate degree of atrophy of muscle and hepatocytes, lymphoid depletion of lymph nodes and thymus, and mild granulomatous gastritis associated with nematodes were found. The most likely cause of death in this animal was emaciation probably secondary to malnutrition.

Liver and kidney were analyzed in two of these juveniles (93CSE-1 and 93SSL-K1) for mercury (Hg), thallium (Tl), arsenic (As), molybdenum (Mo), zinc (Zn), lead (Pb), cadmium (Cd), Nickel (Ni), manganese (Mn), iron (Fe), chromium (Cr), aluminum (Al), vanadium (V), beryllium (Be), copper (Cu) and barium (Ba) and all were within normal limits. Brains from these two juveniles were analyzed with a gas chromatograph/electron capture detector (GC-ECD) for the presence of organochlorine pesticides and polychlorinated biphenols (PCB's). The brains of both of these juveniles had no detectable levels of organochlorine pesticides or polychlorinated biphenols. Brain and blubber from the juvenile from Homer were analyzed for organochlorine pesticides and polychlorinated biphenols (PCB's) by Global Tech Laboratories, Colorado Springs, Colorado using gas chromatography. Low levels of 4,4'-DDE (46.6 ppm), 4,4'-DDT (19.0 ppm), B-BHC (5.74 ppm), dieldrin (4.23 ppm), endosulfan I (11.4 ppm), heptachlor epoxide (5.02 ppm) and a-BHC (8.03 ppm) were found in the brain. Low levels of 4,4'-DDE (1590 ppm), 4,4'-DDT (265 ppm), B-BHC (112 ppm), dieldrin (103 ppm), heptachlor epoxide (117 ppm) and a-BHC (14.5 ppm) were found in the blubber. Evidence of PCB's was not detected in brain or blubber.

One yearling male Steller sea lion was found dead near East Landing on St. Paul Island, Pribilof Islands in July 1995. This animal was in excellent body condition. The cause of death in this animal was suppurative peritonitis secondary to multiple ruptures of the small intestine. This lesion was most likely caused from severe blunt trauma to the abdomen. What caused the severe blunt trauma to the abdomen was not determined.

In summary, the primary cause of death in two of these juveniles (92SSL-H1 and 93SSL-K1) was due to emaciation probably secondary to malnutrition, the third (93CSE-1) due to a Telazol problem and the fourth severe blunt trauma. The last two animals were in excellent body condition. The degree of parasitism in these animals was considered to be within normal limits and no evidence of any infectious diseases were found. Analysis for heavy metals and trace elements from three animals were all within normal limits. Significant detectable levels of organochlorine pesticides or polychlorinated biphenols were not found in the brain (n=3) or blubber (n=1) of these animals.

Pup Steller Sea Lion Necropsy Findings

Steller sea lion pups were necropsied from Forrester Island and the Hazy Islands in June and July of 1994 and 1995. During these two summer field seasons a total of 55 pups (24 females and 31 males) were examined, 38 (16 females and 22 males) in 1994 and 17 (8 females and 9 males) in 1995. The general causes of death were divided into 8 categories: 1) emaciation, 2) stillbirths, 3) neonatal mortality, 4) sharp trauma, 5) blunt trauma, 6) infections, 7) environmental accidents (drownings, falling from rocks or falling into crevices) and 8) killed during round-up of pups (Table 2).

Table 2. Gross necropsy findings of 55 Steller sea lion pups from Forrester and Hazy Islands, 1994-1995.

Condition	1994	1995
Emaciation	25	6
Thymic Atrophy	7	2
Trauma	7	4
Infection	11	0
Stillborns	1	2
Neonatal Mortality	4	0
Sharp Trauma (bite wound)	2	1
Blunt Trauma	2	1
Pneumonia & Omphalophlebitis	1	1
Drowning	1	0
Fell (from cliff or between rocks)	1	1
Killed During Roundups	0	5
Total	38	17

The most common cause of death in 1994 (25 of 37 pups) and 1995 (6 of 17 pups) was emaciation. Trauma was also found in 7 of these 25 pups in 1994 and in 4 of the 6 pups in 1995. It is easy to visualize how weak emaciated pups could be traumatized. Of these 25 emaciated pups in 1994, 11 also had infections. The most likely cause of emaciation was probably starvation.

One pup was found stillborn in 1994 and two were found in 1995. The most common cause of stillbirths are dystocia and intrauterine infections. No evidence of infection was found on histopathology in two of these fetuses, however this does not rule out an infectious agent. Neonatal mortality is defined as pups that die within 24 hours of birth. In 1994, four pups were diagnosed as neonatal mortality (three from Forrester Island and one from the Hazy Islands) and none in 1995. Some of the causes of neonatal mortality include dystocia, weak pups at the time of birth, trauma during the birthing process, infections and other causes. Accurate determination of the causes of stillbirths and neonatal mortality is extremely difficult and was not determined in these two cases of stillbirths and two cases of neonatal mortality.

Two healthy pups in 1994 and one in 1995 died from massive bite wounds to the head, neck and/or chest. These wounds are caused by adult animals throwing pups. Blunt trauma is caused by adult animals trampling over the pup. Blunt trauma was found in 3 of the 37 pups in 1994 and in 1 of the 17 pups in 1995.

Systemmic infections were found in one pup each year. One pup had a suppurative pneumonia and omphalophlebitis in 1994 and one pup had a suppurative pneumonia in 1995. In both cases a hemolytic *E. coli* was isolated from the lungs and from the infected umbilicus. Seeing only two of 54 pups with an infection is low and suggest that the immune status of these Steller sea lions is relatively good.

Two of the 37 pups in 1994 died from environmental accidents (one drowned and one fell into a deep crevice and could not escape) and one in 1995 was killed by falling off of a cliff. These pups were all in good body condition and showed no evidence of disease.

Five pups died during the pup round-up for branding on North Rocks, Forrester Island in 1995. These pups were crushed and smothered in pile ups. These pups were all in excellent body condition and only one of these pups showed evidence of disease (dermal ulceration).

In summary, the primary cause of death in these 55 Steller sea lion pups was emaciation probably due to starvation and trauma. The most likely cause of the starvation was abandonment by the female and the trauma/environmental accidents were due to disturbance weather natural or iatrogenic. The degree of infectious diseases were extremely minimal.

Fetal Steller Sea Lion Necropsy Findings

Fetuses (n=26) were collected from winter haulout areas in Alaskan waters from 1990 to 1995. Specific winter haulout areas included Cape St. Elias (1990, n=6; 1992, n=6;

1993, n=7 and 1995, n=4), eastern Aleutians (1994, n=1) and from Kodiak (1994 n=2). All fetuses were necropsied and sampled when possible.

During three weeks in March, 1990 six fetuses were found and necropsied. The gender was not recorded in these fetuses. No gross or histological lesions were found in any of these fetuses. During a 10 day trip to Cape St. Elias in early March 1992, six fetuses were found. The gender of these fetuses was 1 female, 3 males and 2 undetermined. Of these fetuses, five had no gross or histological lesions. One fetus (92CSE-2F) did have numerous small white foci, erosions and ulcers in the skin that grossly looked like a viral disease. A few small ulcers were found on histopathology, however inflammation was not found around these small dermal ulcers. The gross and histological lesions found in this fetus were suggestive of a viral infection, however viral isolation was negative. Swabs of lung, stomach fluids, liver, kidney, placenta and amniotic fluid were plated and cultured for bacterial organisms from 4 fetuses. A *Staphylococcus* sp. was isolated from the amniotic fluid and *E. coli*, *Streptococcus* sp. and a *Staphylococcus* sp. were isolated from the placenta from 92CSE-1F. *Edwardsiella tarda* and a *Staphylococcus* sp. was isolated from the lung and a Staphylococcus sp. was isolated from the stomach from 92CSE-2F. *Streptococcus* spp. (exhibiting alpha, beta, and gamma hemolysis) were isolated from the lung and *Pseudomonas* sp. was isolated from the kidney of 92CSE-3F. An *Enterobacter* sp. and *Provendencia/Morganella* sp. were isolated from the lung and liver and a S*treptococcus* sp. was isolated from the lung and placenta from 92CSE-6F.

During last 10 days in January 1993, 7 abortions were confirmed on Cape St. Elias of which five were collected and examined. The gender of these fetuses was 3 females, 2 males and 2 undetermined. Gross lesions were not found in any of these fetuses. A mild placentitis was found in the placenta of four fetuses. A *Chlamydia* sp. was isolated from the tissues of one fetus (93CSE-3F). *Edwardsiella tarda*, *E. coli*, beta *Streptococcus* sp. and a nonhemolytic *Streptococcus sp*. were isolated from the placenta and a alpha *Streptococcus* sp. was isolated from the lung from 93CSE-1F. *Enterococcus faecalis* was isolated from the lung, stomach and placenta, *Vibrio fluvialis* and *Serratia marcescans* were also isolated from the placenta and an alpha *Streptococcus* sp. was also isolated from the lungs of 93CSE-2F. *Edwardsiella tarda*, *E. coli*, *Streptococcus* sp. were isolated from the placenta, *Edwardsiella tarda*, and beta S*treptococcus* sp. were isolated from the stomach and *Enterococcus faecalis* were isolated from the lungs from 93CSE-3F. *Edwardsiella tarda*, *E. coli* and *Lactobacillus* sp. were isolated from the placenta of 93CSE-4F. *Edwardsiella tarda* was isolated from the lungs in 93CSE-5F. Organisms that may possibility cause abortion include *Chlamydia* sp., *Vibrio fluvialis*, *Edwardsiella tarda* and perhaps the *Streptococcus* spp. and *Sarcocyst* sp..

Liver and kidney were analyzed in these five fetuses from Cape St. Elias for mercury (Hg), thallium (Tl), arsenic (As), molybdenum (Mo), zinc (Zn), lead (Pb), cadmium (Cd), Nickel (Ni), manganese (Mn), iron (Fe), chromium (Cr), aluminum (Al), vanadium (V), beryllium (Be), copper (Cu) and barium (Ba) and all were within normal limits. Brains from these five fetuses were analyzed with a gas chromatograph/electron capture detector (GC-ECD) for the presence of organochlorine pesticides and polychlorinated biphenols (PCB's). The brains of all five fetuses had no detectable levels of organochlorine pesticides or polychlorinated biphenols.

In the spring of 1993, Richard Merrick from the National Marine Mammal Laboratory, Seattle, Washington sent a frozen male Steller sea lion fetus to the Colorado State Diagnostic Laboratory, Fort Collins, Colorado for necropsy. This fetus was found in the eastern Aleutian Islands, Alaska. This was a large full term male fetus in good body condition. No gross or histological lesions were found in this fetus. Bacterial agents were not found in tissues of this fetus. The cause of this stillborn was not determined.

In May of 1994, two fetuses (gender not recorded) were necropsied by Richard Merrick from the National Marine Mammal Laboratory, Seattle, Washington. These fetuses were found near Kodiak Island, Alaska. No gross or histological lesions were found in these fetuses.

Between 9 and 23 January, 1995 four female fetuses were found on Cape St. Elias. Three were intact and one consisted only of muscle and skeleton. Gross lesions were not found in the fetuses. On histopathology one fetus (95SSL-CSE-4F) did have plaques and perhaps early ulcers of the skin. These lesions were somewhat suggestive of a viral infection. Cell culture of the kidney from this fetus was done and it was successful. The tissue cultures are kept frozen at the Diagnostic Laboratory, Colorado State University, Fort Collins, Colorado. Viral and chlamydial isolation from these fetuses were negative.

In summary, a total of 26 Steller sea lion fetuses were necropsied from various locations from Alaska. Placentitis was found in the placenta of 4 fetuses. The most common causes of placentitis include bacterial and chlamydial infections. Bacterial agents and a *Chlamydia* sp. were isolated from fetuses. Both of these types of organisms could be associated with abortion. This is especially true for *Chlamydia* sp. since this organism is a known abortifacient and positive serology to *Chlamydia* sp. has been reported in Steller sea lions (Calkins and Goodwin, 1988). Bacterial organisms that may possibility cause abortion include *Vibrio fluvialis*, *Edwardsiella tarda*, *Provendencia/Morganella* sp. and perhaps the *Streptococcus* spp.

Abortion problems are extremely difficult to diagnose because the cause of the abortion may be confined within the female and not be found in the aborted fetus. Investigations into the causes of abortion in Steller sea lions should be continued. Work should include viral, chlamydial and bacterial isolation, gross and histopathology and analysis for environmental toxins.

ULCERATIVE DERMATITIS AND ALOPECIA IN STELLER SEA LIONS

Introduction

In order to evaluate the rapid decline in Steller sea lion numbers in the North Pacific, investigations were carried out to determine the presence of infectious diseases in the Steller sea lion population in the Gulf of Alaska and to a much lesser degree in the Bering Sea. During this investigation two dermological conditions in Steller sea lion pups (often occurring together) characterized by blisters and/or ulcers located on the flippers, perineal area and prepuce and alopecia with lice were found.

Materials and Methods

During the summers of 1987, 1992, 1993, 1994 and 1995, personnel of the Alaska Department of Fish and Game, Anchorage, Alaska and of the National Marine Mammal Laboratory, NMFS/NOAA, Seattle, Washington observed a disease characterized by ulceration of the fore and hind flippers and alopecia in Steller sea lion pups. This condition was observed on Marmot Island in 1987 and 1992, on Forrester Island in 1992, 1994 and 1995, White Sisters in 1994, Walrus Island (one of the Pribilof Islands) in 1994, Kayak Island (Cape St. Elias) in 1995 and on Fish Island in the Fish Island in 1995 (Table 3).

Table 3. Dates and locations in which ulcerative dermatitis and alopecia were found in Steller sea lions pups in the Southeast Alaska, the Gulf of Alaska and the Bering Sea.

Date	Locations	Lesions
August 1987	Marmot Island	Ulcers
July 1992	Marmot Island	Ulcer and Alopecia
August 1992	Forrester Island	Ulcers and Alopecia
July 1993	Marmot Island	Ulcers and Alopecia
July 1993	Forrester Island	Ulcers and Alopecia
July 1994	Forrester Island	Ulcers and Alopecia
July 1994	Hazy Islands	Ulcers
July 1994	White Sisters	Ulcers
July 1994	Walrus Island, Bering Sea	Ulcers
June 1995	Fish Island	Ulcers
July 1995	Forrester Island	Ulcers and Alopecia

Selected animals were opportunistically sampled in order to describe and delineate the causes of these conditions. Samples collected included blood and biopsies of dermal and prepucial lesions. Skin biopsies were taken from 7 pups from Marmot Island in 1992, from 6 pups in 1994 and 3 pups in 1995 from Forrester Island, 2 pups from the

White Sisters in 1994, one juvenile from Kayak Island in 1995 and 2 pups from Fish Island in 1995. Biopsy samples were fixed in 10% neutral buffered formalin or glutaraldehyde. Tissues were embedded in paraffin, sectioned at 5 um and stained with hematoxylin and eosin. Tissues collected in 1994 also were embedded in epoxy and thin section were made.

Blood was collected from pups from Marmot Island 1992, Forrester Island in 1994 and 1995 and Fish Island in 1995. Serum samples have not yet been analyzed for evidence of antibodies to a viral agent.

Biopsies samples of ulcers from pups from Marmot Island 1992 and Forrester Island 1994 were placed in Minimal Essential Media (MEM) and frozen on dry ice. Skin samples from 1992 were placed on kidney cell lines and went through 2 passages. Skin samples from 1992 and 1995 were placed on kidney cell lines and went through 2 to 4 passages. All 1994 virus samples thawed during transportation and were therefore rendered unsuitable for virus isolation. Skin biopsies of blisters and fluid aspirated from blisters located on the fore flippers of 2 pups from Fish Island 1995 were collected, frozen on liquid nitrogen and transported to the Colorado State Diagnostic Laboratory College of Veterinary Medicine, Fort Collins CO. These samples were cultured on porcine kidney cells and passed 4 times.

Results

Two previously undescribed dermological conditions of Steller sea lion pups and juveniles characterized by blisters and/or ulcers and by areas of alopecia were observed during this study. In most affected animals both conditions occurred together, but occasionally only one condition was found on an affected animal.

The ulcerative dermatitis was characterized by ulcerative lesions located on the fore and hind flippers and on the mucocutaneous junction of the perineal region and around the prepuce were found on five islands in the Gulf of Alaska and on one island in the Bering Sea in the summers of 1987-1995 (Table 3).

This condition was first seen on Marmot Island in 1987 in which several pups were observed to have blisters and/or ulcers on their flippers during a pup censusing project.

The disease was next observed in mid July 1992 on Marmot Island. Eleven pups were captured at random from Marmot Island during the second week of July, 1992 and examined. Two of 11 pups had ulcers on the flippers, three of seven males had ulcers on their prepuce and/or umbilical area, one of four females had ulcers on the umbilical area, five of 11 pups had areas of alopecia on their backs or abdomens and two of 11 pups had a moderate infestation of lice. All of these 11 pups appeared to be otherwise healthy.

The disease was observed the next year (1993) on Forrester and Marmot Islands, but no samples were taken.

In 1994 the disease was found on Forrester Island, White Sisters and the Hazy Islands in Southeast Alaska and Walrus Island (Pribilof Islands) in the Bering Sea.

In 1995 this ulcerative disease was observed in two of 30 pups examined on Fish Island. Both of these pups had numerous blisters primarily on the fore flippers. One of these pups was estimated to be under 36 hrs old and the other was estimated to be 3 to 5 days old. In July, 1995 on Forrester Island, 200 pups were examined for ulcers and 16 were observed. These pups otherwise appeared healthy.

Clinically, this ulcerative disease was characterized by blisters and/or ulcerative lesions of the skin on the fore and/or hind flippers and on the mucocutaneous junction of the perineal region and the prepuce. All of these pups with this ulcerative disease were in good condition and appeared healthy except the one pup that was < 36 hr old on Fish Island, 1995. This pup appeared to be weak, was dyspneic and coughing. This pup was not observed again after sampling. Blisters were small, two to five mm circular, raised, foci filled with a slightly reddish opaque fluid. Ulcerated areas were two to 15 mm in diameter, had a reddened bed surrounded by a pale zone.

Dermal lesions were examined histologically from flippers and mucocutaneous junction of perineal and prepucial areas in 15 pups and one juvenile. Blisters were found in pups from Fish Island and from Forrester Island. The earliest histological changes of blisters were characterized by mild swelling and spongiosis of the epidermis associated with moderate superficial dermal edema. This type of lesion progressed to a blister characterized by extensive necrosis of the stratum germitivum, stratum spinosum and stratum granulosum, but appeared to spare the stratum lucidum and stratum corium. There was a mild to moderate infiltration of neutrophils with a few lymphocytes and plasma cells around the bed of these blisters. The fluid within blisters contained necrotic keratocytes admixed with a few neutrophils, erythrocytes and fibrin. Ulcerative lesions were characterized histologically by necrosis and sloughing of the epidermis and marked inflammation within the upper dermis. Inflammation within the dermis was characterized by infiltration of neutrophils, lymphocytes, macrophages and a few plasma cell.

The second type of dermological lesion observed in Steller sea lion pups was characterized by alopecia and darkening of the skin of the chest, back, flank and/or abdomen. This condition was first noticed in 1992 on Marmot Island. When this condition was first noticed the underlying skin was reddened, but as the disease progresses the skin turned black and corrugated. Eleven pups were captured and examined in 1992 from Marmot Island. Of the eleven animals captured 5 pups had alopecia and 2 had lice. This condition was also observed on Forrester Island in 1993, 1994 and 1995. Clinically these lesions were characterized by alopecia with darkening and mild corrugation of the skin. Severe to mild alopecia was found on the chest, abdomen, back and flank. This disease was observed in pups under 2 months of age.

Lice were associated with these areas of alopecia. Histologically these lesions were characterized by mild to moderate acanthosis and mild inflammation within the superficial dermis. The inflammatory reaction consisted of a mild infiltration of neutrophils, lymphocytes, macrophages, plasma cells and mast cells. Lice were identified as *Antarctophthirus* sp at the Parasitology Department, Colorado State Diagnostic Laboratory, Fort Collins, Colorado.

Electron microscopy of five dermal lesions revealed similar lesions as observed with light microscopy, but viral agents were not observed.

Complete blood cell counts were done on the 11 pups from Marmot Island captured in July 1992. Their packed cell volume ranged from 33% to 40% with an average of 37%. The white blood cell counts ranged from 6,200 to 8,100 ul with an average of 8,100 ul. All of these pups appeared to be large, robust and healthy except for the dermal ulcers. Rectal and nasal swabs were collected and cultured for bacterial organism, but only normal flora were isolated.

Complete blood cell counts were done on eight pups from Forrester Island in 1994. Their packed cell volume ranged from 33 to 46% with an average of 38%. The white blood cell counts ranged from 10,100 to 29,000 cells/ul with an average of 17,600 cells/ul. Of the eight pups sampled five were considered to have an elevated white cell counts (WBC >13,000 cells/ul).

Complete blood cell counts were done on 53 pups from Forrester Island in 1995. The packed cell volume of the pups with ulcers ranged from 32 to 47% with an average of 38%. The packed cell volume of the pups without ulcers ranged from 34 to 53% with an overall average of 39%. The white blood cell counts of the pups with ulcers ranged from 6,100 to 35,300 cells/ul with an average of 16,400 cells/ul. Of the 20 pups in which WBC's were counted 15 were considered to have an elevated white cell counts (WBC >13,000 cells/ul). The white blood cell counts of the pups without ulcers ranged from 4,700 to 26,500 cells/ul with an average of 13,300 cells/ul. Of the 29 pups in which WBC's were done 14 were considered to have an elevated white cell counts (WBC >13,000 cells/ul).

Complete blood cell counts were done on 21 pups from Fish Island in 1995. The packed cell volume of four pups with ulcers ranged from 35 to 52% with an average of 44%. The packed cell volume of the 17 pups without ulcers ranged from 45 to 58% with an overall average of 49%. The white blood cell counts of 4 pups with ulcers ranged from 17,500 to 23,500 cells/ul with an average of 19,000 cells/ul. Of the four pups with ulcers in which WBC's were counted all four were considered to have an elevated white cell counts (WBC >13,000 cells/ul). The white blood cell counts of 17 clinically normal pups without ulcers ranged from 7,700 to 20,200 cells/ul with an average of 13,200 cells/ul. Of these 17 clinically normal pups 8 were considered to have an elevated white blood cell counts (WBC >13,000 cells/ul).

All viral cultures of ulcers were negative.

Evaluation of serum from these pups for various viral will be completed in the near future.

Discussion

Few studies have addressed pup mortality of Steller sea lions, but available literature suggests that less than 10% mortality occurs during the first 2 months postpartum (Gentry 1970; Sandegren 1970; Merrick et al. 1988). Causes of pup mortality that have been suggested include drowning, starvation (caused by separation from the dam), blunt trauma (crushing by adult animals), sharp trauma (bite wounds), predation and probably diseases. (Orr and Poulter, 1967; Edie 1977).

This ulcerative dermatitis is though to be of viral etiology, possibly a marine calicivirus. Al Smith, Oregon State University has isolated calicivirus from Steller sea lions and suggests that calicivirus does cause ulcers in this species. The incidence and prevalence of this disease was not determined, however on one rookery (North Rocks, Forrester Island - 1995) in which 200 pups were examined, 16 pups were noted with this condition, although the actual incidence is probably much higher. All of these affected pups were robust and appeared healthy. This ulcerative dermatitis appears to be a relatively wide spread, nonfatal infectious disease that is present throughout part of the Steller sea lion range and was found in both declining and stable population regions. The second dermological condition characterized by alopecia was believed to be associated with *Antarctophthirus* sp. of lice, but may also be associated with a epithelial trophic or dermal viral infection. The incidence and prevalence of louse infestation with alopecia was not determined but was common on Forrester Island (1994 & 1995) and on Marmot Island (1992).

This ulcerative dermatitis (probably caused by calicivirus) and alopecia (probably associated with lice) appears to be two relatively wide spread, nonfatal infectious diseases that are present throughout at least part of the Steller sea lion range. This disease was found in both declining and stable regions of Steller sea lion range. No evidence was found that either of these two disease conditions caused mortality in pups.

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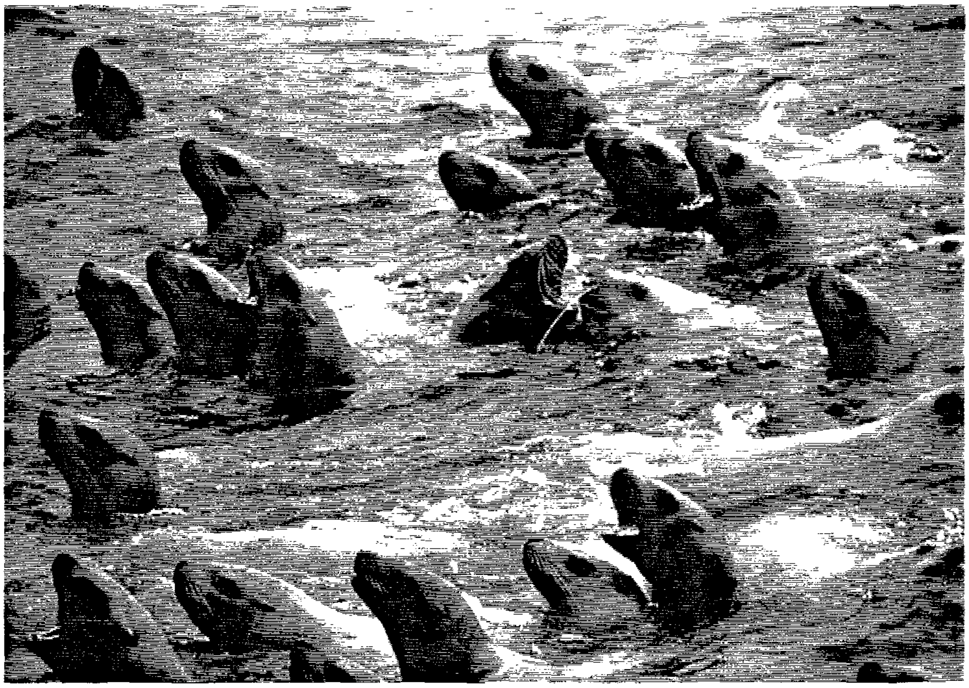
CHAPTER SEVEN

Steller Sea Lion Movements, Habitat Use and Foraging Behavior



JOEL SARTORI

Movements and Habitat Use of Female Steller Sea Lions In Southeastern Alaska

Donald G. Calkins

Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, Alaska 99518

Steller sea lions (SSL) (*Eumetopias jubatus)* are major marine predators in the North Pacific Ocean ecosystem. Sea lions are found in Alaskan waters from Dixon Entrance, through the Gulf of Alaska, throughout the Aleutian Islands and north into the Bering Sea. They were abundant throughout their range during the late 1960s but began declining in the eastern Aleutian Islands about 1970. This decline continued and spread throughout the Gulf of Alaska and the Aleutian Islands. By 1989, a range-wide survey conducted by National Marine Fisheries Service (NMFS) showed that SSL in Alaska, west of Prince William Sound, had declined severely. In 1991 the entire U. S. population was classified as threatened under the Endangered Species Act because of that decline.

Sea lions are opportunistic feeders, able to modify their diet according to prey availability (Pitcher 1981). While they prey on a wide variety of taxa, the most important are off-bottom schooling fish species and cephalopods including squid and octopus (Pitcher 1981, Calkins and Goodwin 1988). Throughout Alaska, walleye pollock (*Theragra chalcogramma*) is the single most important prey species, composing greater than 50% of the diet in most areas (Pitcher 1981, Calkins and Goodwin 1988, ADF&G unpublished data).

The most plausible hypothesis to explain the decline is nutritional stress, first hypothesized by Calkins and Goodwin 1988. One of the objectives proposed in this study was to determine movements, feeding patterns, diving behavior, habitat use, and patterns and significance of interactions between SSL and commercial fisheries and to test the hypothesis these relationships differ between the eastern and western stocks. This objective has been a part of the Alaska Department of Fish and Game SSL studies since 1992, addressing several tasks identified in the SSL Recovery Plan.

This report addresses the movements, feeding patterns and habitat use of female sea lions fitted with satellite-linked depth recorders in 1992 and 1993.

Methods

One juvenile and 9 adult female SSL were fitted with satellite-linked depth recorders (SDRs) at the Forrester rookery complex during June and July 1992 and 1993 (Table 1). Two adult females were fitted with SDRs at the Hazy Islands rookery, 1 in 1992 and 1 in 1993. Signals broadcast by the SDRs were received by polar-orbiting NOAA satellites. Adult females were captured by darting with a tranquilizer and placed on gas anesthesia (Heath et al. 1996). After the first capture in these studies on May 13, 1992, an attempt was made to identify and capture post-parturient females. SDRs were glued to the hair in the mid-dorsal region using fast setting epoxy glue (Fedak et al. 1984, Stewart et al. 1989). SDRs remained attached until the hair became brittle and broke as the molt approached. Most SDRs were shed within 4 to 6 weeks. The SDRs were manufactured by Wildlife Computers (Redmond, WA), and produced 0.5 watts of power. The units measured 14.8 x 10.0 x 3.8 cm, weighed about 750 g and were powered by 4 lithium C cells.

SDRs were equipped with conductivity and pressure sensors and built-in programmable microprocessors that collected and summarized data for periods when animals were diving and that stored data for later transmission, as has been done for spotted seals (*Phoca largha*), crabeater seals (*Lobodon carcinophagus*), and SSL in other studies (Lowry et al. 1994*a,b,* Hill et al. 1987, Bengtson et al. 1993, Merrick et al. 1994). Data were stored in six hour blocks (0300-0900 hrs, 0900-1500 hrs, 1500-2100 hrs, and

Table 1. Female Steller sea lions captured, tagged, sampled and fitted with SDRs in 1992 and 1993 during summer in southeastern Alaska and during winter at Cape St. Elias.

Flipper Tag Number	**Date Captured**	**Location Captured**	**Age Class**	**SDR Number**
61	6/30/93	Hazy Is.	Adult	2084
1	5/13/92	Hazy Is.	Adult	2085
6	6/30/92	Lowrie I.	Adult	2086
7	6/30/92	Lowrie I.	Adult	2087
23	6/26/93	Sea Lion Rks.	Adult	2088
8	7/1/92	Lowrie I.	Adult	2089
5	6/29/92	Sea Lion Rks.	Adult	2090
21	6/4/93	Sea Lion Rks.	Adult	2091
2	6/22/92	Sea Lion Rks.	Yrlng	2094
62	7/2/93	Sea Lion Rks.	Adult	2095
24	6/26/93	Cape Horn Rks.	Adult	2099
22	6/5/93	Lowrie I.	Adult	11036
25	6/28/93	North Rocks	Adult	11038

2100-0300 hrs local time) and transmitted to the satellite once the 6-hour period was complete. Data from four periods were stored in memory providing at least a 24-hour window for transmission before the data were lost.

Each SDR transmitted information to a National Oceanic and Atmospheric Administration polar-orbiting satellite whenever, sea lion was hauled out,or when the antenna broke the surface, and the satellite was positioned to receive the signal. Transmissions occurred at about 90 sec. intervals while on land and 45 sec. intervals while at sea. These units had a projected capacity of about 100,000 transmissions. During summer the units were programmed to transmit continuously while above the surface.

Satellite Tag Data Analysis

Data from satellite tagged sea lions were collected from Service ARGOS. The ARGOS system recorded date and time of each uplink and calculated a location for the SDR based on Doppler shift whenever sufficient signals were received during a satellite pass. When only one uplink occurred during a satellite pass, sensor data were recorded but no location was calculated. Fancy et al. (1988), Stewart et al. (1989) and Mate (1987) provide additional description and analysis of the ARGOS system and its application to marine mammal tracking.

For analysis and presentation of data, dates and times reported by Service ARGOS were converted to true local time from Greenwich mean time by subtracting 9 hours. The minus 9 correction accounts for the actual position of the sun and makes midday occur at approximately 1200 hours.

The accuracy of location calculations varies based in part on the number of uplinks that occur during a satellite pass. Service ARGOS assigns a quality ranking to each location. Prior to June 1994 locations resulting from standard data processing were ranked as 1, 2, or 3, with quality 3 the best. Special data processing provided locations from satellite passes with few uplinks or other potential problems. Such locations were assigned a quality of 0 and given a location indicator value of 0 to -10.

Records that failed validation tests performed by ARGOS (given location indicators -6 to -10) were deleted from the database. Then, an error index value (KEI) was calculated for each remaining record according to the equation described in Keating (1994). This value takes into account the distances and relative directions between sequential location fixes and is used to identify erroneous locations based on the assumption that records indicating a single, relatively large movement followed immediately by a return to a point near the origin are likely to be in error. All location records that had a KEI value greater than 25 were then removed. The next step in screening records was to locate and remove erroneous locations based on the apparent movement speeds of the sea lions. To do this, time, distance, and speed between each sequential pair of fixes were calculated for all location records remaining in the database. A three-stage process was used to flag records that produced improbable movements: 1) apparent speeds of greater than 10 km/hr for a period of greater than 5 minutes 2) apparent speeds of greater than 100 km/hr for a period of greater than 1 minute and 3) apparent speeds of greater than 500 km/hr for any length of time. The parameters in 1) are based on the likely sustained swim speeds of harbor seals (*Phoca vitulina*) (Williams and Kooyman 1985), while the latter 2 identify records that may be erroneous but were too close together in time to be flagged by the first set of criteria. Flagged records were inspected visually, and the locations that were most distant from adjacent records were removed from the database. As a final step, the KEI values were recalculated for the remaining records, and any records with a KEI greater than 25 were deleted. Numbers of location records referred to in this report include only those records that remained after the complete screening process.

With each transmission, SDRs reported the sea lions as hauled out or at sea based on the status of conductivity sensors. A data file was created that indicated the times when sensors showed that haulouts began and ended. The land-sea sensor data were merged with location records to produce a data file that included SDR number, date, time, latitude, longitude, location quality, and sensor indications the sea lion was on land or at sea. A computer program calculated from this data file the average location of the sea lion during each haulout bout and the average daily position for at-sea locations. The program also calculated the distance between each sequential pair of average positions. The result was saved as an average position data file.

The all-location and average-position data files were used to produce geographic information system coverages in ARCINFO, and data sets were selected and displayed using ARCVIEW. Figures shown in this report are from both the average position and all-location data files.

Maximum trip distance was determined by measuring the distance from the rookery where the sea lion was tagged to the single furthest location point in a trip. Only those trips were used that had 2 or more at-sea locations within the same trip.

Results

At-sea location plots for adult females are shown in figures 1 through 11 for individual SDRs. Figures 1 through 9 are plots of movements of adult females fitted with SDRs at the Forrester Island rookery in 1992 and 1993 and figures 10 and 11 are plots of adult females fitted with SDRs at the Hazy Islands rookery in 1992 and 1993. Numbers of at-sea locations for individual SDRs calculated by Service ARGOS ranged from 0 (SDR 11036) to 45 (SDR 2085) and averaged 13. SDR 2091 (Figure 8) was fitted to an adult female sea lion on June 4, 1993 at Sea Lion Rocks, a part of the Forrester Island rookery complex. This animal only transmitted one at-sea location on June 22 from near the White Sisters rookery. This rookery was 190 nautical miles from the tagging location. This was the only at-sea location recorded for this animal. However she was located several times onland, hauled out at the Hazy Islands rookery and at the White Sisters rookery. In fact this animal was tagged at the Forrester Island rookery complex on June 4, moved to the area of Biali Rocks or Jacob Rock haulout on June 17 and was located at the White Sisters Rookery on June 18. She remained at White Sisters until June 28 and was relocated at Biali /Jacob Rock on July 1 and 2 and back at Forrester Rookery on July 7, where she apparently remained until her last transmission on July 10. From this unusual movement pattern we have concluded that she did not have a live pup on Forrester Island. She may have given birth and the pup died or she may have experienced reproductive failure earlier in the year. Therefore, movements of this animal are not considered typical of females tending pups.

The plot of movements for the juvenile female (SDR 2094) tagged at Sea Lion Rocks on June 22, 1992 is shown in figure 14. This plot only includes those locations recorded for June and July, including both the at-sea and hauledout locations. The juvenile female hauled out at the Forrester Island complex from June 23 to June 29, moved to the area of Wolf Rocks July 2 and 3 back to Forrester July 5 to 8, Wolf Rocks July 8 to 16, Forrester July 18 through 21, Wolf Rocks July 22 and 23 and moved to Cape Addington on July 24, remaining there until the end of the month.

The plot for the sea lion tagged at the Hazy Islands rookery on May 13, 1992 (SDR 2085) is divided into 2 types of location plots. The close diamond symbol represents movements of this animal before May 23 and the open box symbol represents movements after May 24. We have distinguished between these two days because we do not believe this animal produced a pup until about May 23.

Trip distances were measured for 14 total trips made by 5 different sea lions. Mean trip distance for 10 trips from Forrester Island made by 3 sea lions was 11.5 km. Mean trip distance for 4 trips made by the 2 sea lions from Hazy Islands was 21.5 km. the mean of all 14 trips combined was 14.5 km.

Discussion and Conclusions

Frequency of at-sea location data on SSL in southeastern Alaska was highly variable by individual. This could be attributed to placement of the transmitter on the back of the individuals, but in most cases placement was very similar. Differences in the numbers of locations recorded per individual is most likely due to individual differences in behavior. No at-sea locations were recorded for SDR 11036 although this transmitter provided dive data and hauled-out locations from June 5, 1993 through July 6, 1993. The on-land location data received from SDR 11036 indicate this sea lion remained in the vicinity of Forrester Island during the entire time, and the dive data indicates she foraged in a manner similar to the other adult females attending pups at rookeries in southeastern Alaska.

SDR 2085 was fitted to an adult female sea lion at the Hazy Islands rookery on May 13, 1992 but movement data received from that transmitter indicated that she did not have a pup at that time. This was the second animal captured in this study and the protocol was not completely set for determining whether or not an animal had given birth to a pup before capture. She foraged before she gave birth (possibly June 23 to 25) in a manner similar to a sea lion that is not attending a pup on the rookery. Location data suggests she traveled to an area over 110 km from Hazy Islands prior to May 23 (Figure 2). After May 23 she confined her foraging near the rookery, although her diving behavior suggested seemed to indicate that she did not remain on land for the standard perinatal period.

The adult female tagged at the Forrester complex that did not seem to have a surviving pup (SDR 2094, Figure 8) and behaved and moved in an entirely different manner than any of the other adult females tagged in southeastern Alaska. Because she did not have a pup she was able to travel long distances away from the capture location. It is interesting to note she visited all of the rookeries in southeastern Alaska and at least 1 other haulout while she carried the transmitter. All of this occurred during the breeding season so she may have visited these locations for breeding. Little is known about the specific behavior of adult females that do not produce viable pups in summer but this constitutes a significant portion of the population. Up to 33% of pregnant females failed to produce pups in the 1970s in the Kodiak area (Calkins and Pitcher 1982) and up to 40% failed in the 1980's (Calkins and Goodwin 1988)

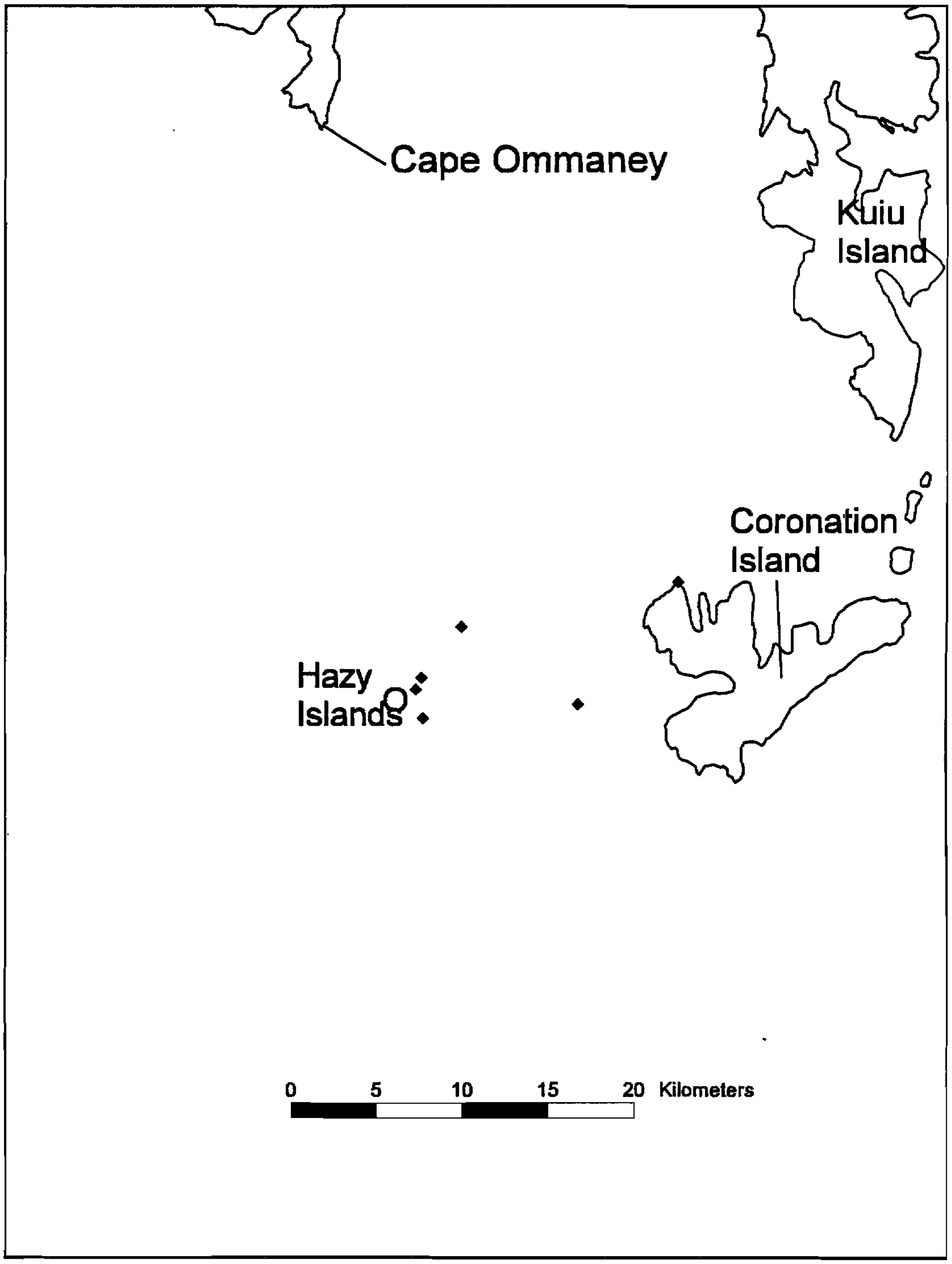


Figure 1. At-sea locations for SDR 2084, July 7 through July 21, 1993. Capture location = Hazy Islands.

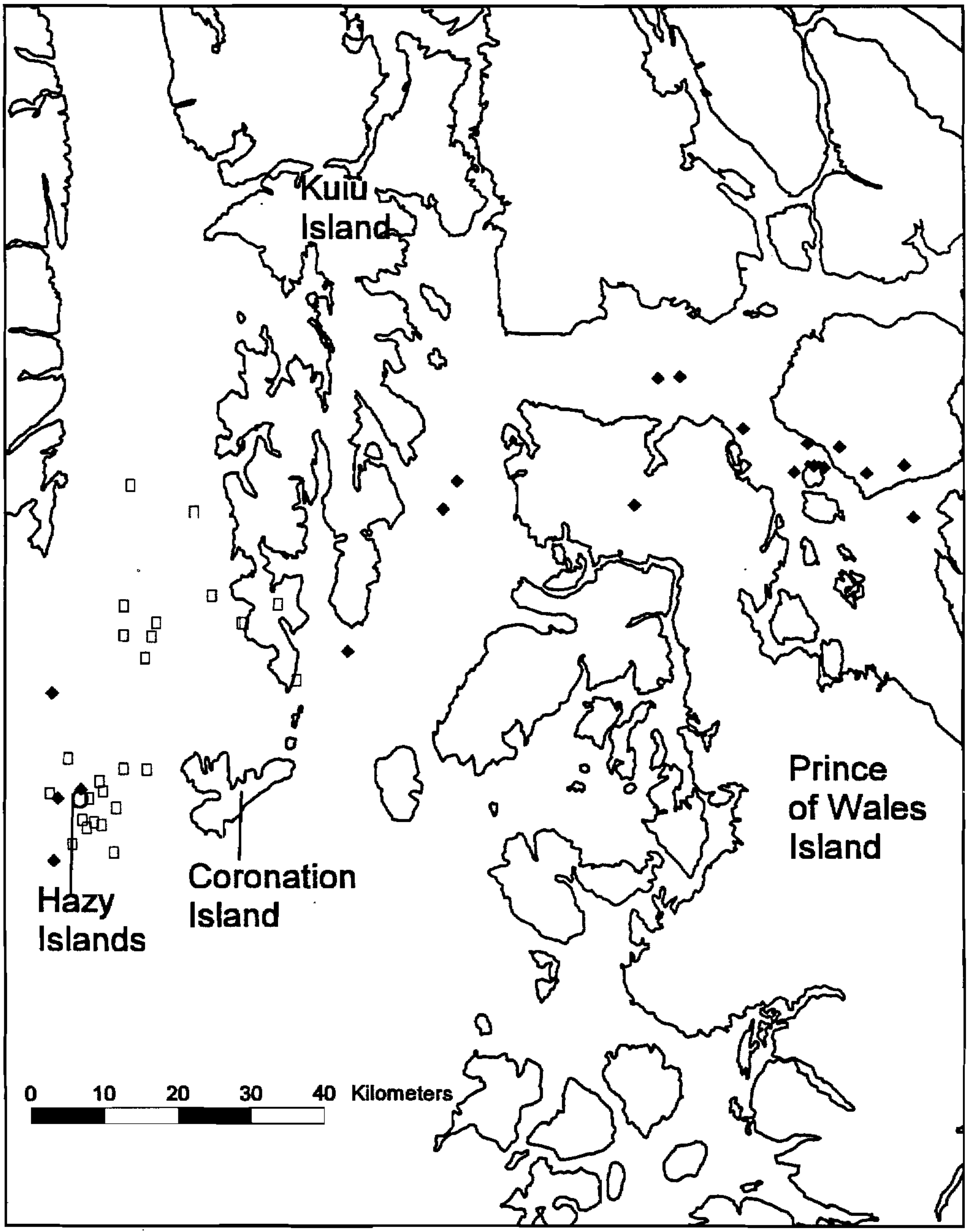


Figure 2. At-sea locations for SDR 2085, May 14, 1992 - June 25, 1992. Capture location = Hazy Islands.

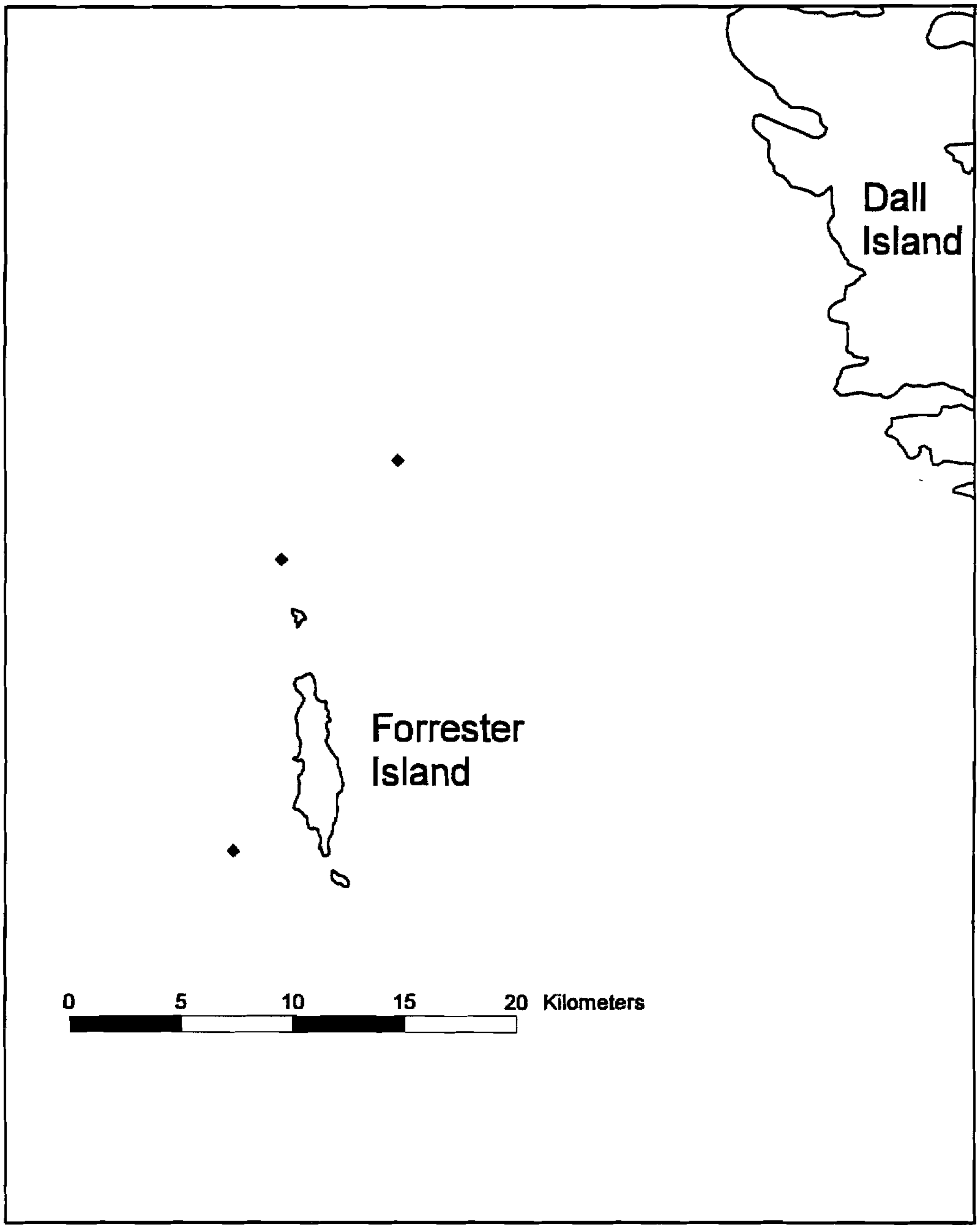


Figure 3. At-sea locations for SDR 2086, July 6 through July 24, 1993. Capture location = Forrester Island.

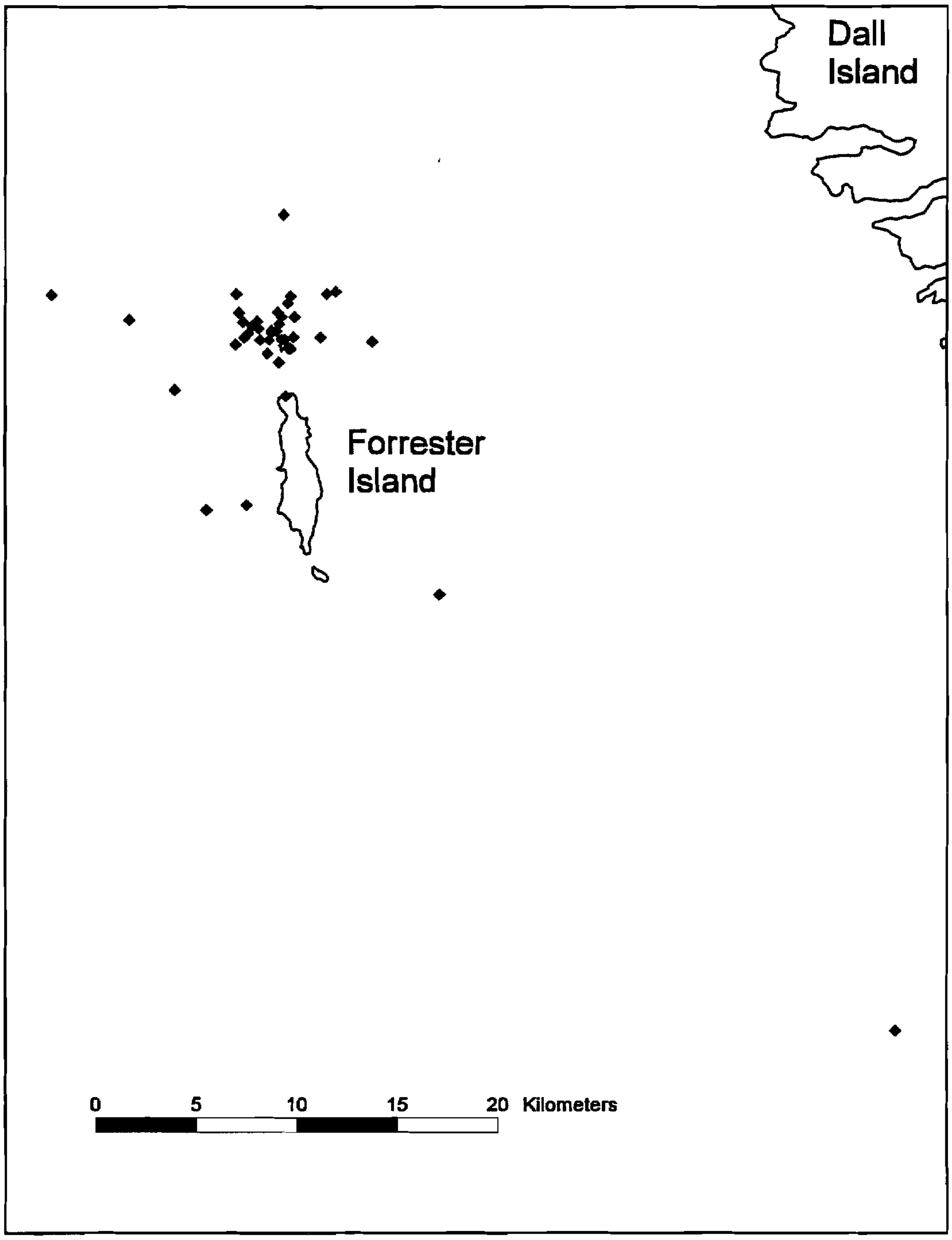


Figure 4. At-sea locations for SDR 2087, July 1 through July 29, 1992. Capture location = Forrester Island.

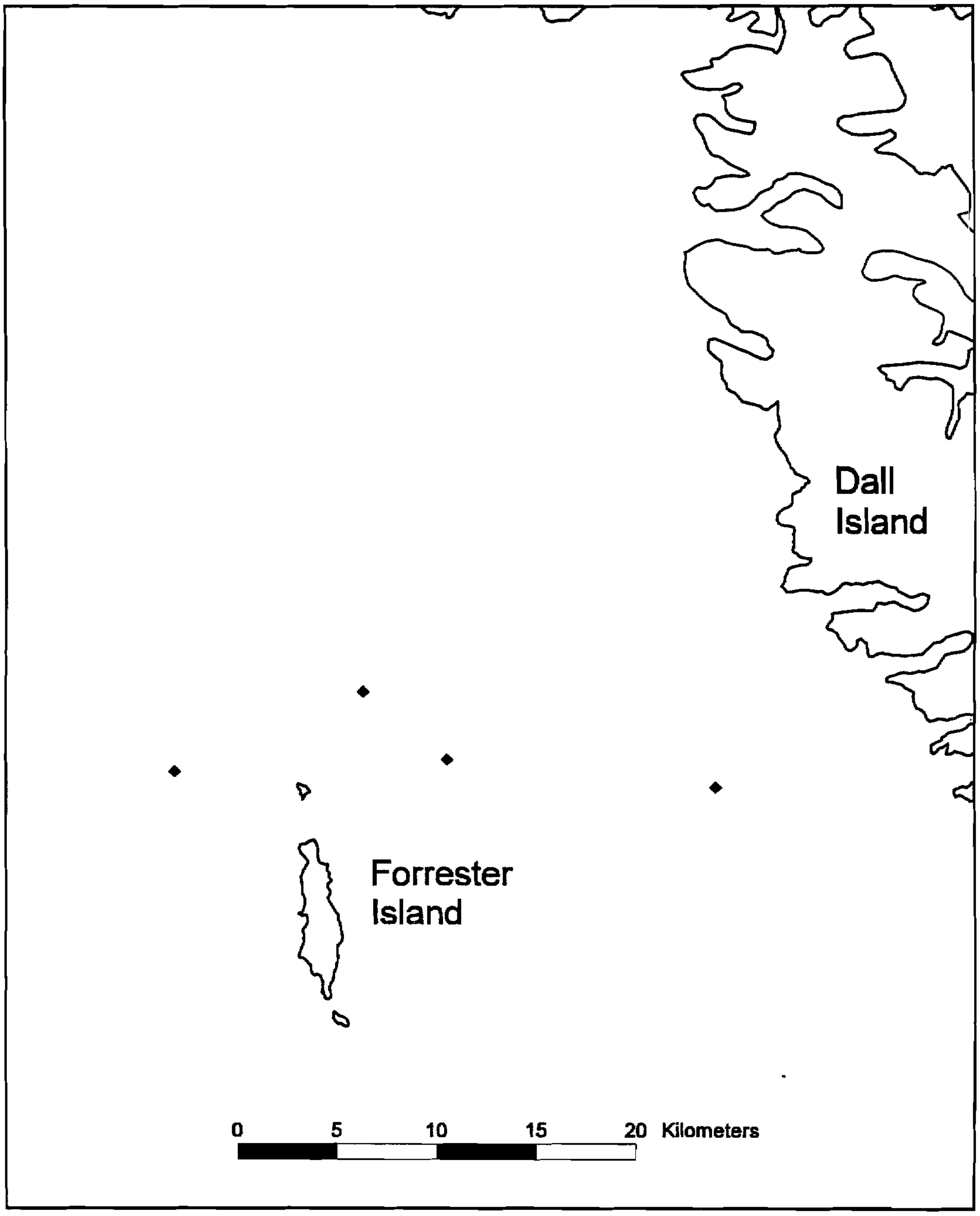


Figure 5. At-sea locations for SDR 2088, June 22 through July 20. Capture location = Forrester Island.

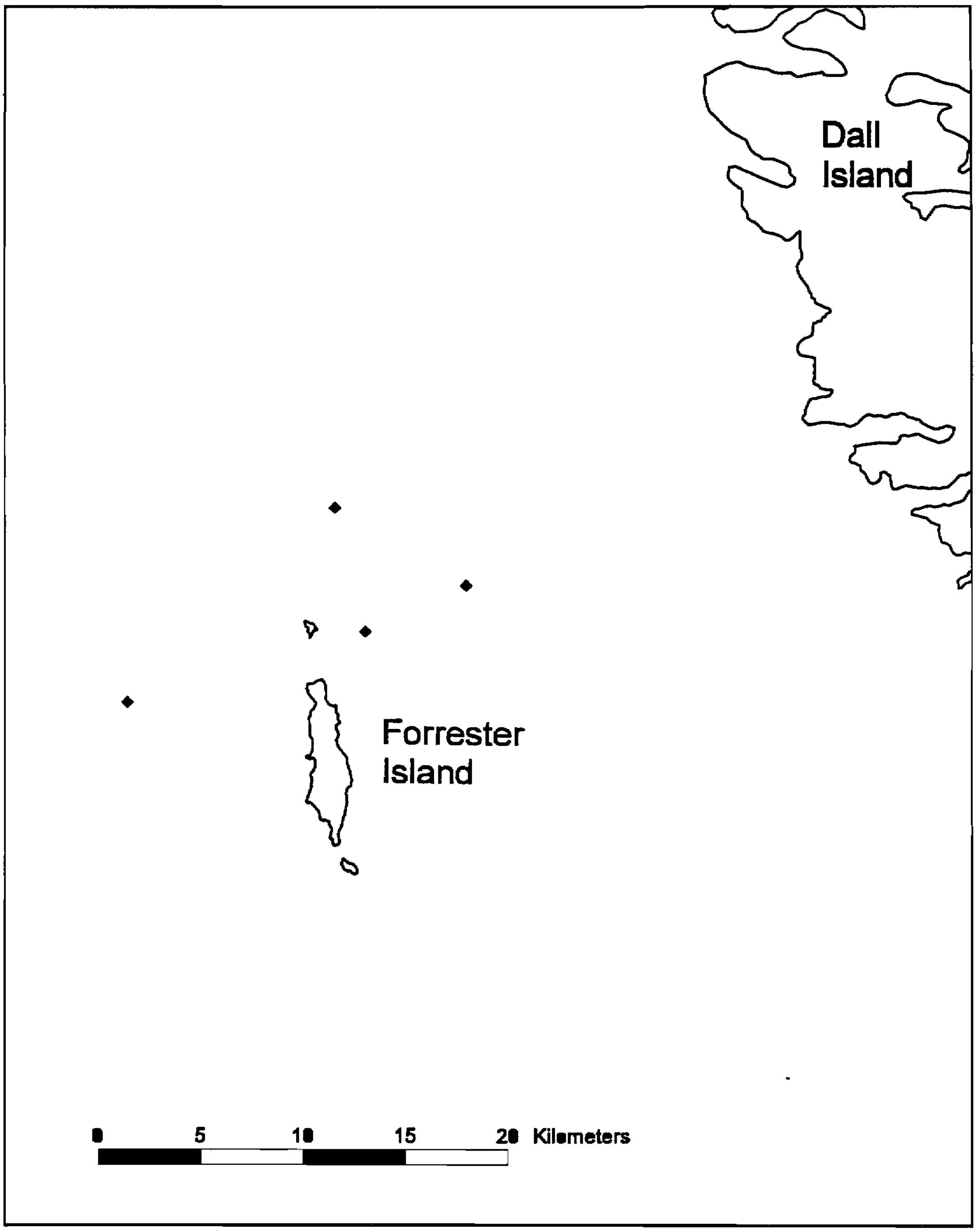


Figure 6. At-sea locations for SDR 20890, July 16 through July 30, 1992. Capture Location = Forrester Island.

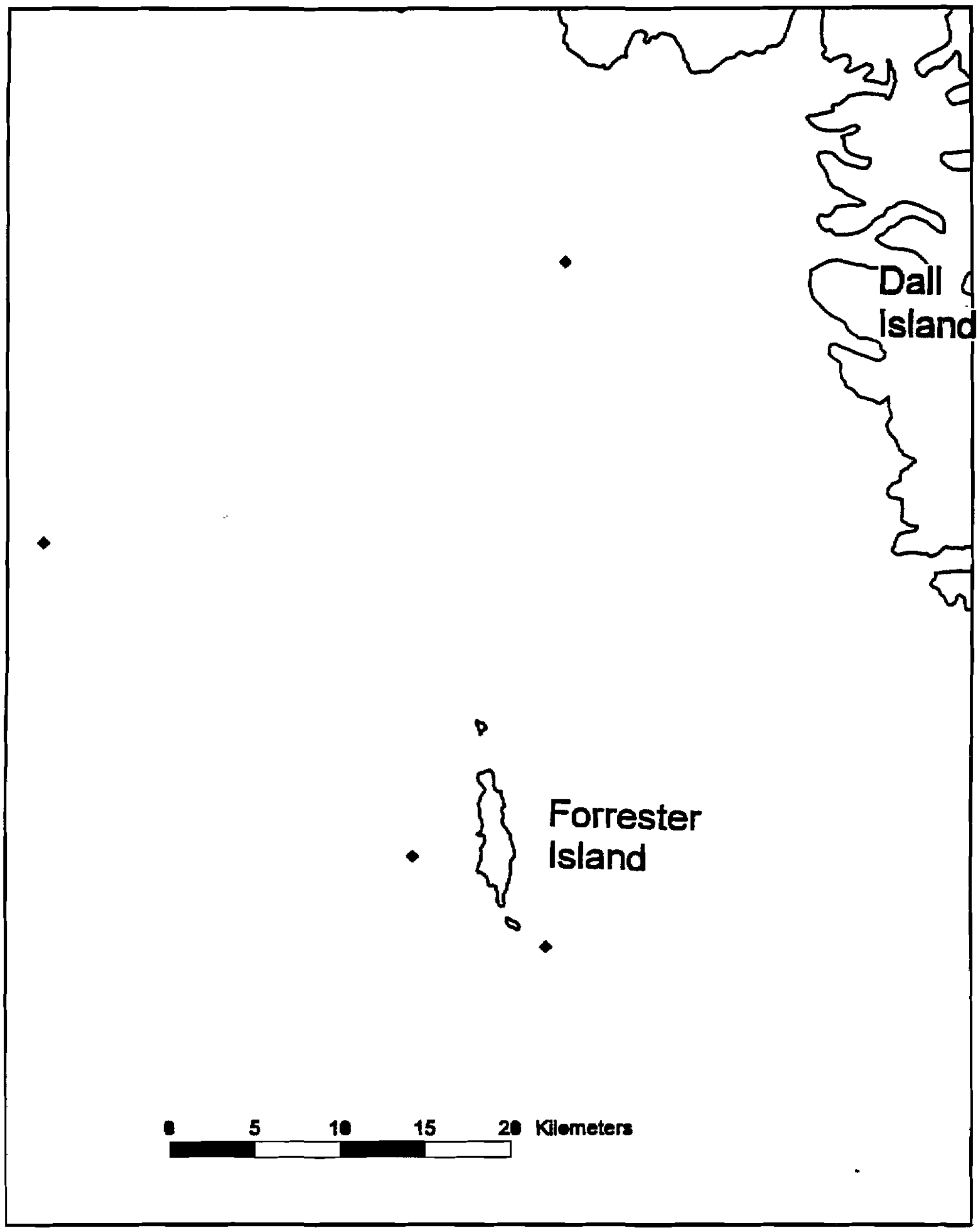


Figure 7. At-sea locations for SDR 2090, July 7 through July 25, 1992. Capture Location = Forrester Island.

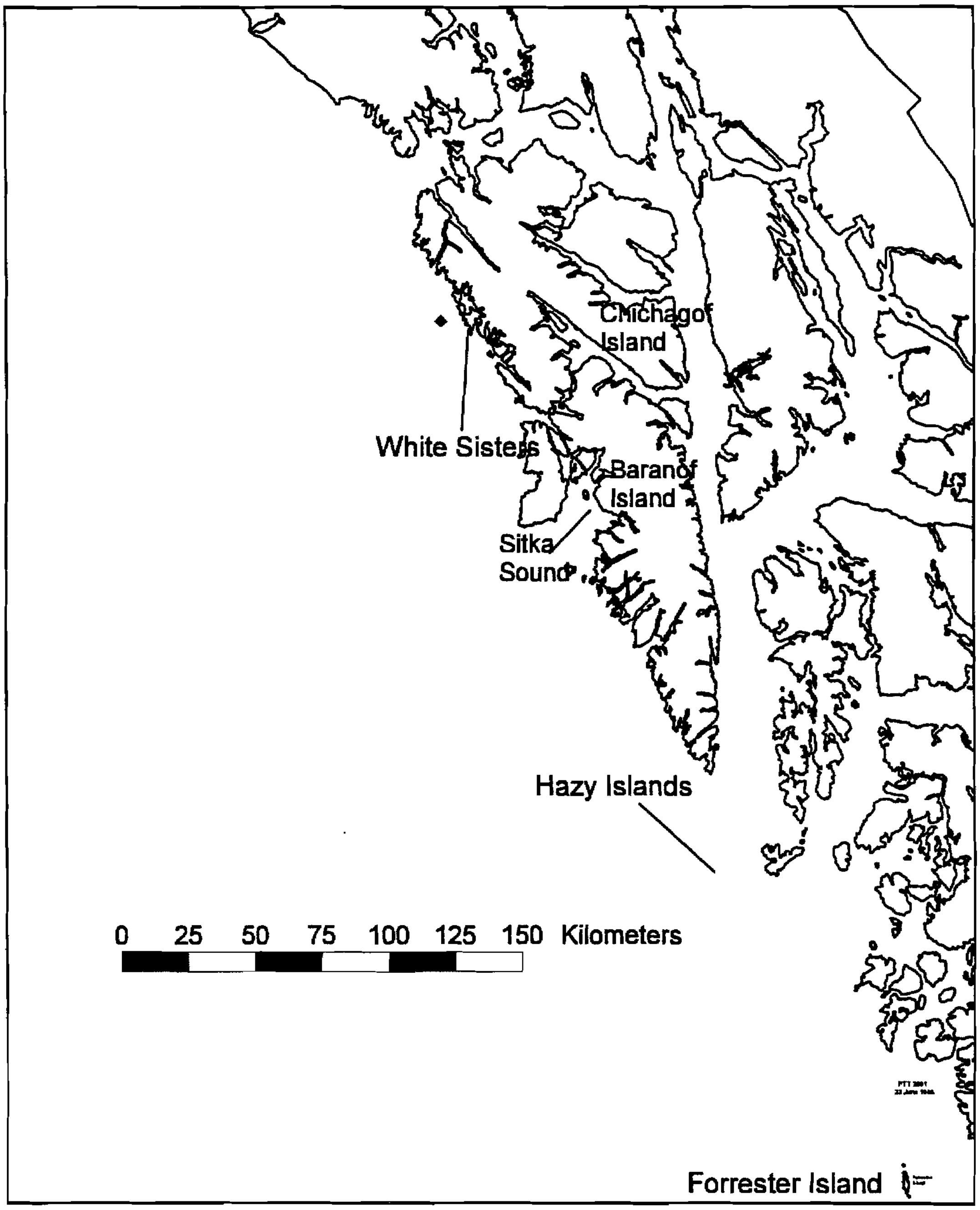


Figure 8. At-sea locations for SDR 2091, June 4 through July 10, 1993. Capture location = Forrester Island.

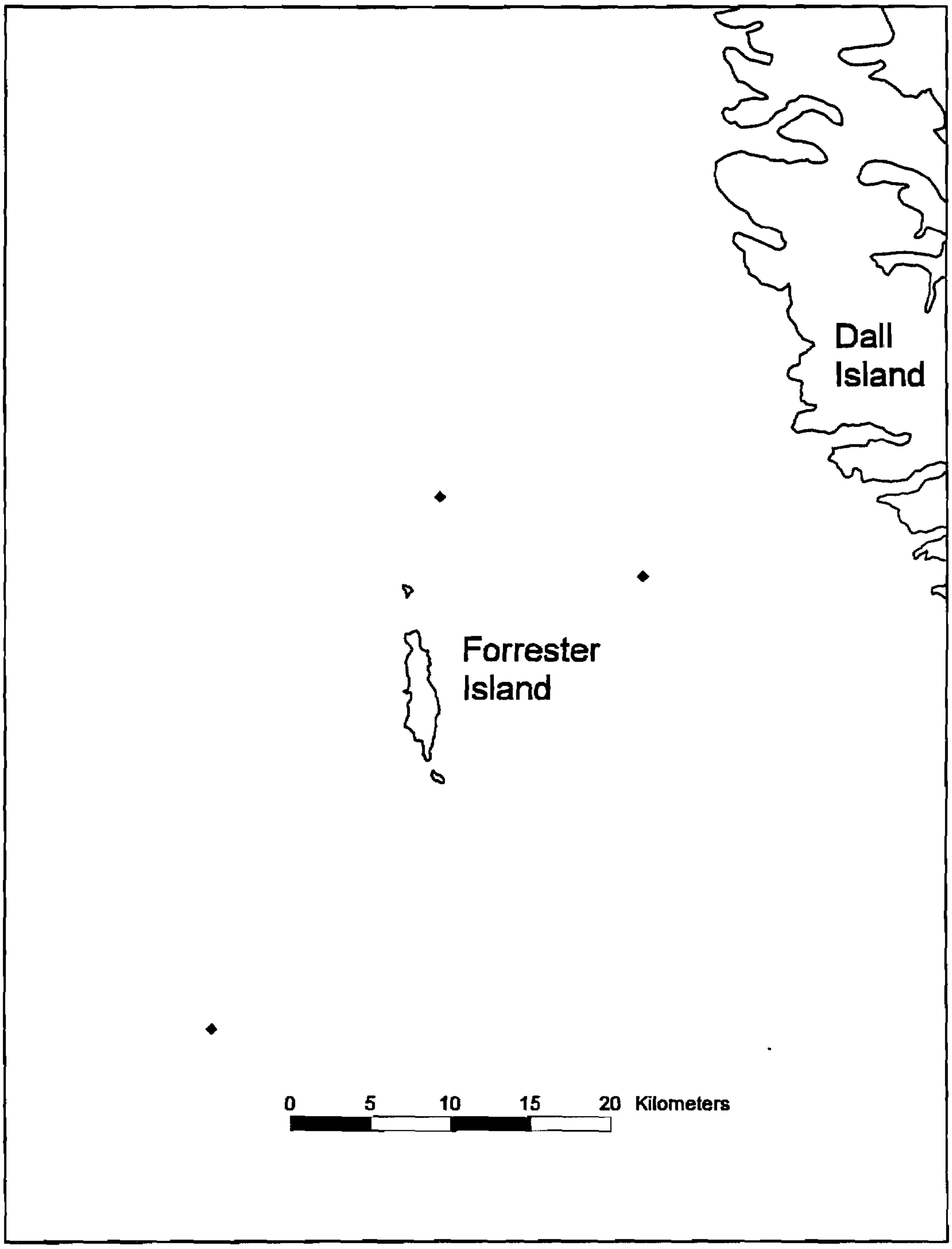


Figure 9. At-sea locations for SDR 2095, July 6 through July 23, 1993. Capture location = Forrester Island.

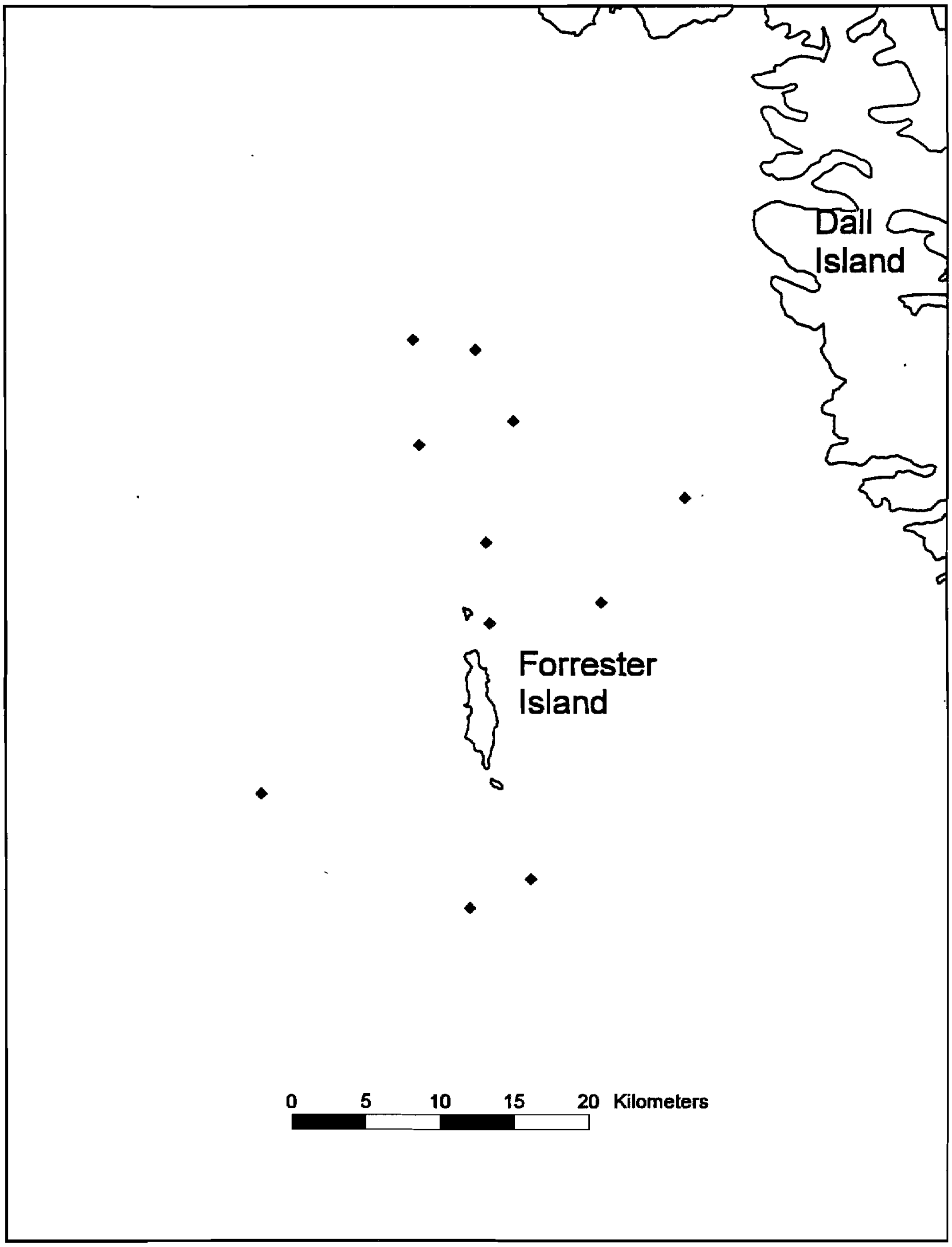


Figure 10. At-sea locations for SDR 2099, July 5 through July 20. Capture location = Forrester Island.

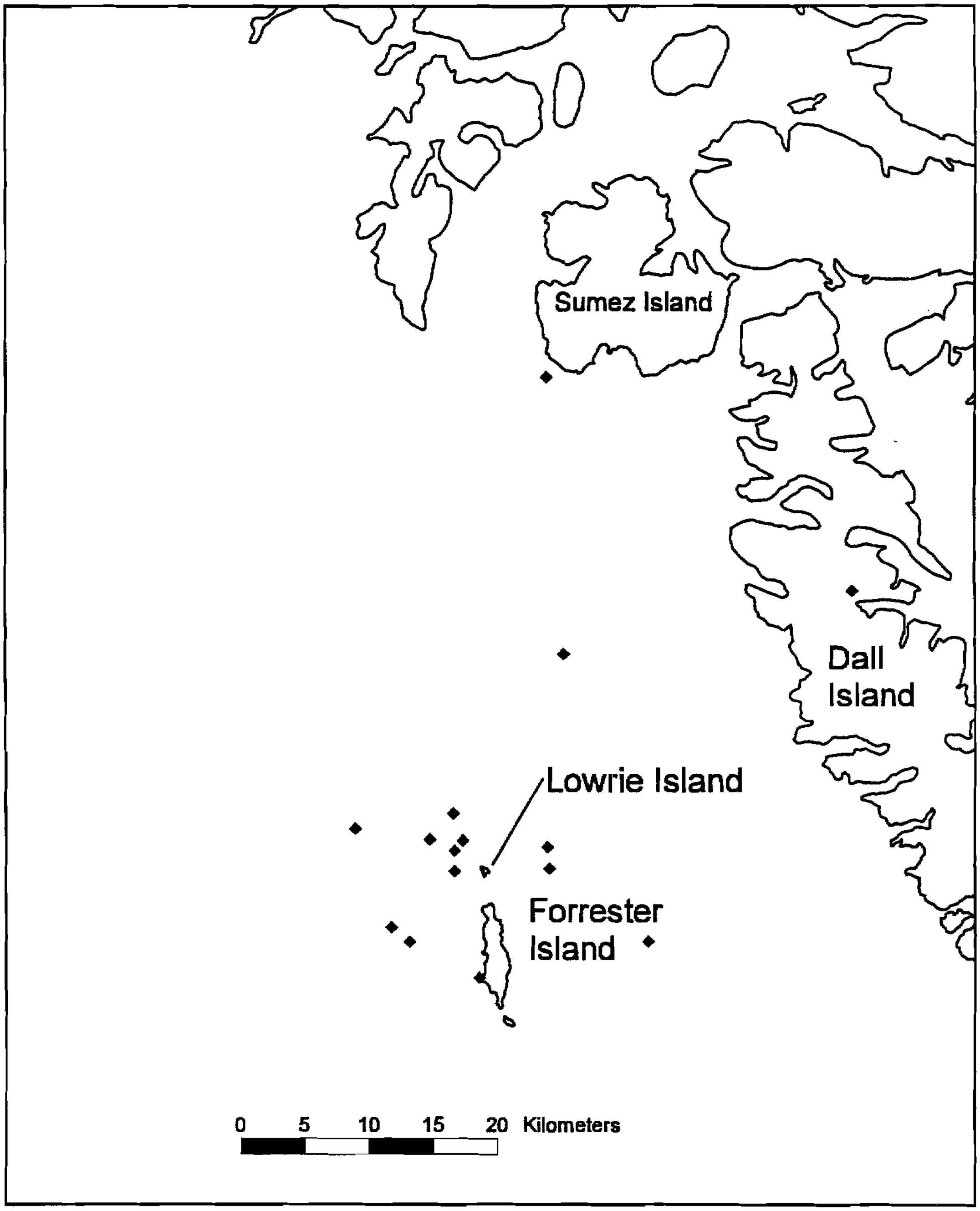


Figure 11. At-sea locations for SDR 11038, June 29 through July 26, 1993. Capture location = Forrester Island.

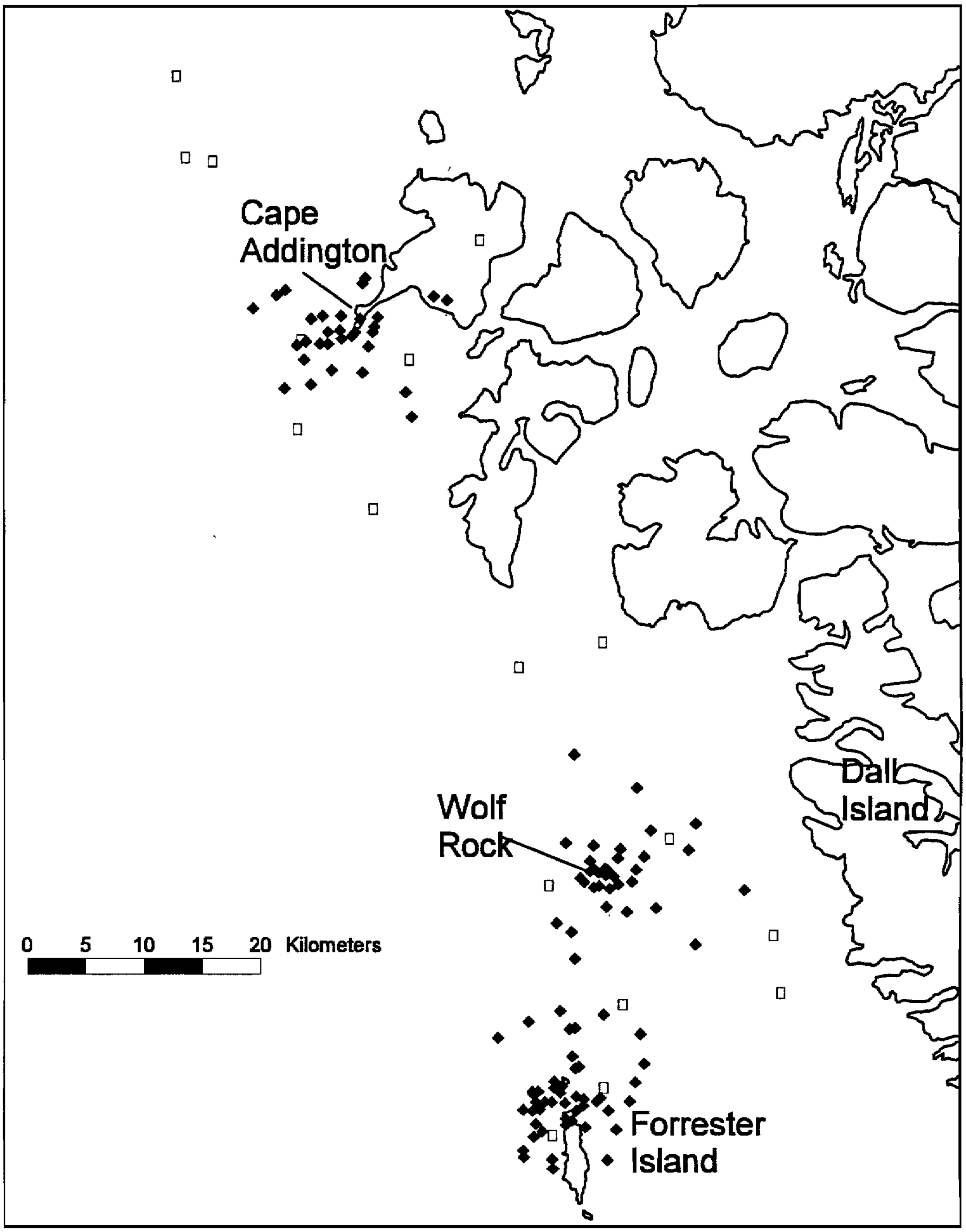


Figure 12. At-sea locations for SDR 2094, June 23 through July 31, 1992. Capture location = Forrester island.

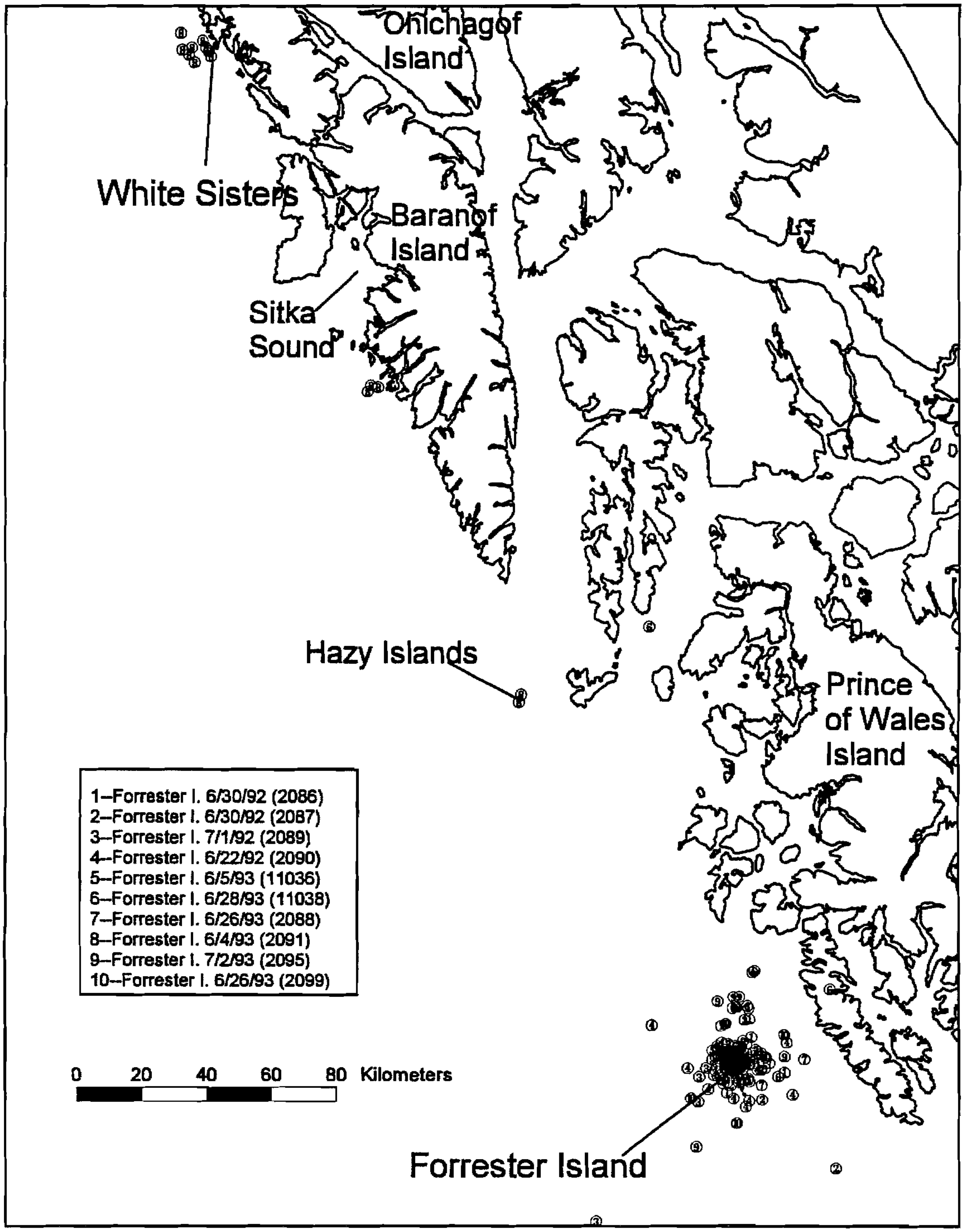


Figure 13. All average daily locations of adult females tagged at Forrester Island, June and July, 1992 and 1993.

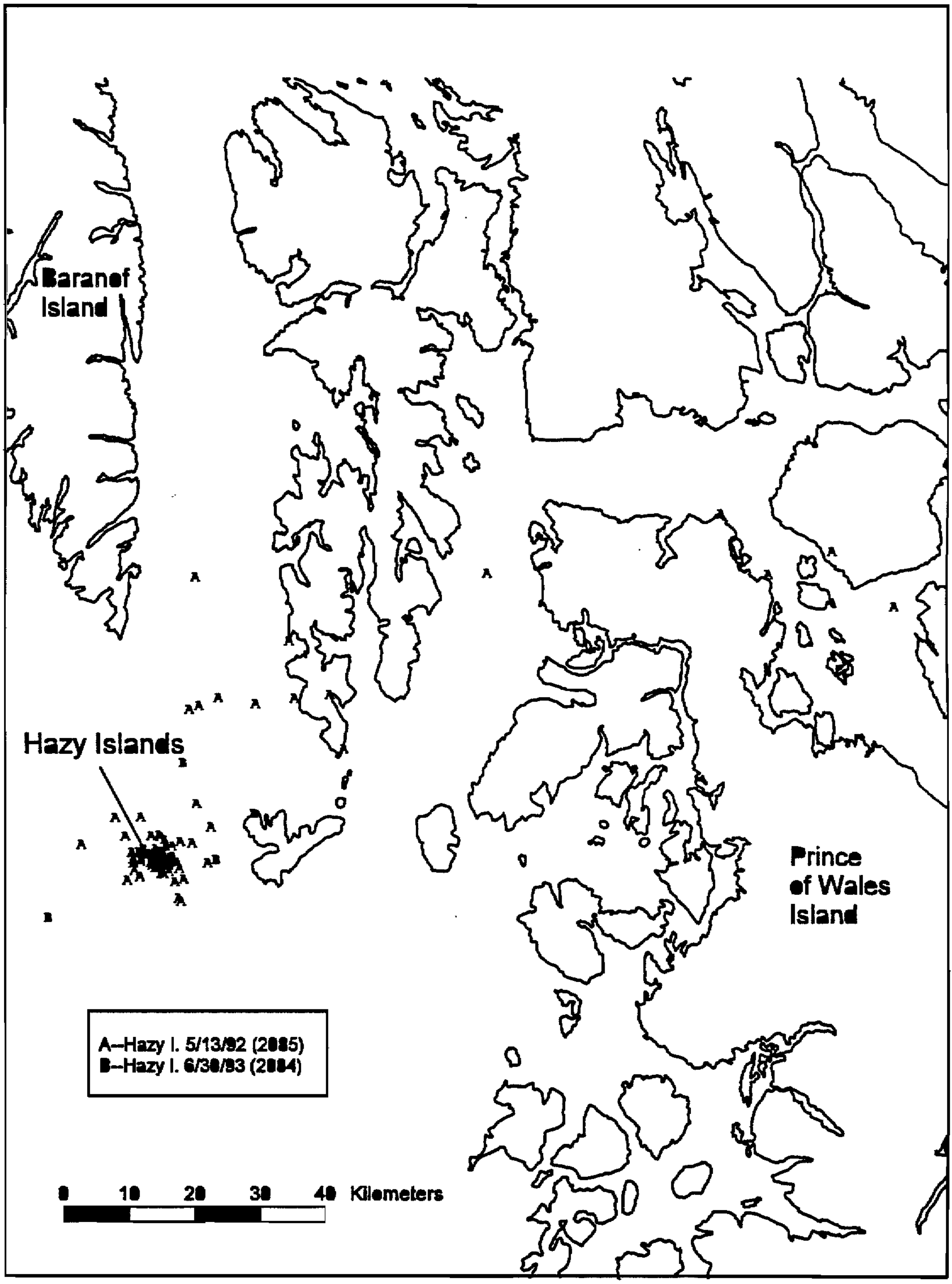


Figure 14. All average daily locations of sea lions tagged at Hazy Islands, June and July, 1992 and 1993.

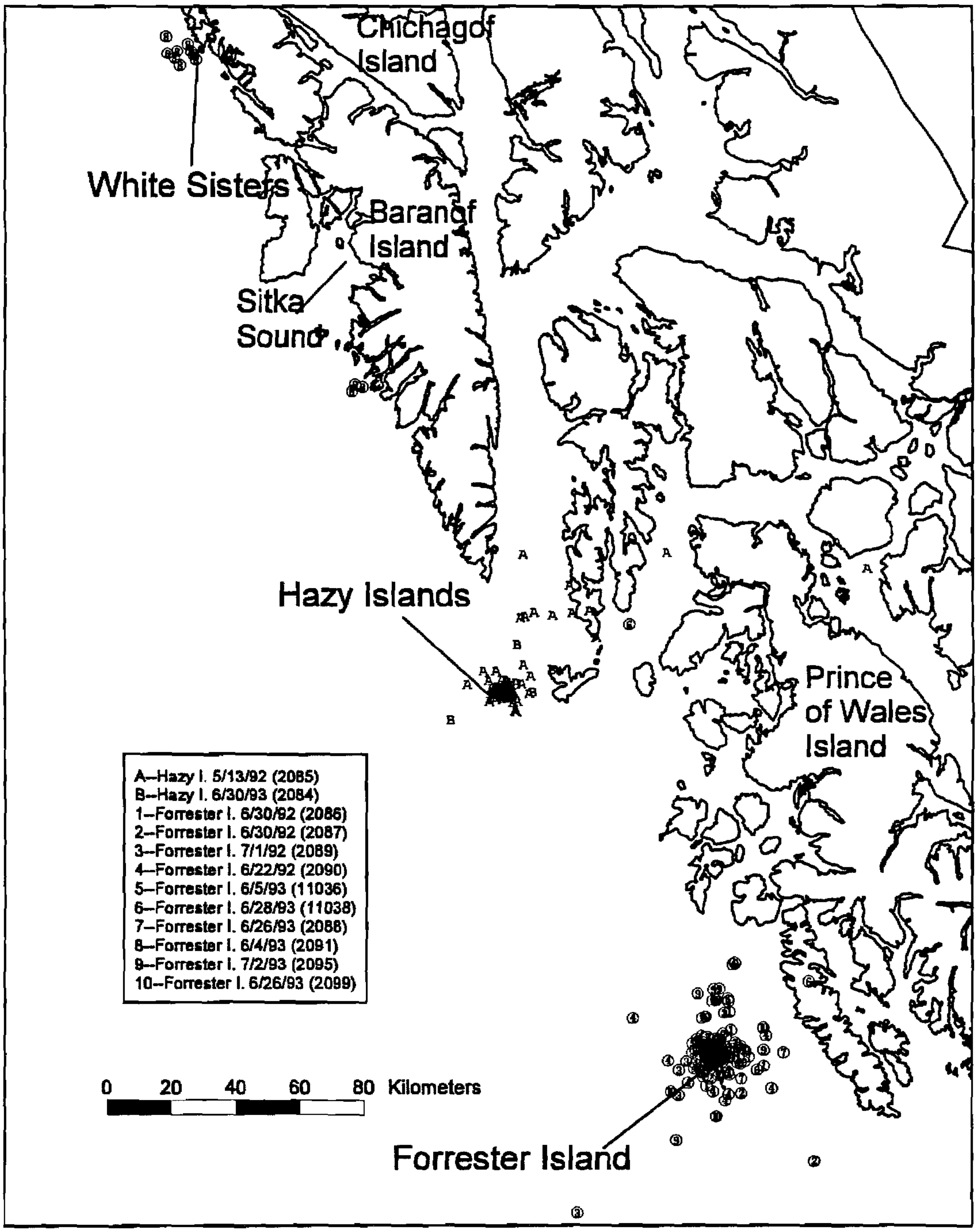


Figure 15. All average daily locations of adult female sea lions tagged in 1992 and 1993.

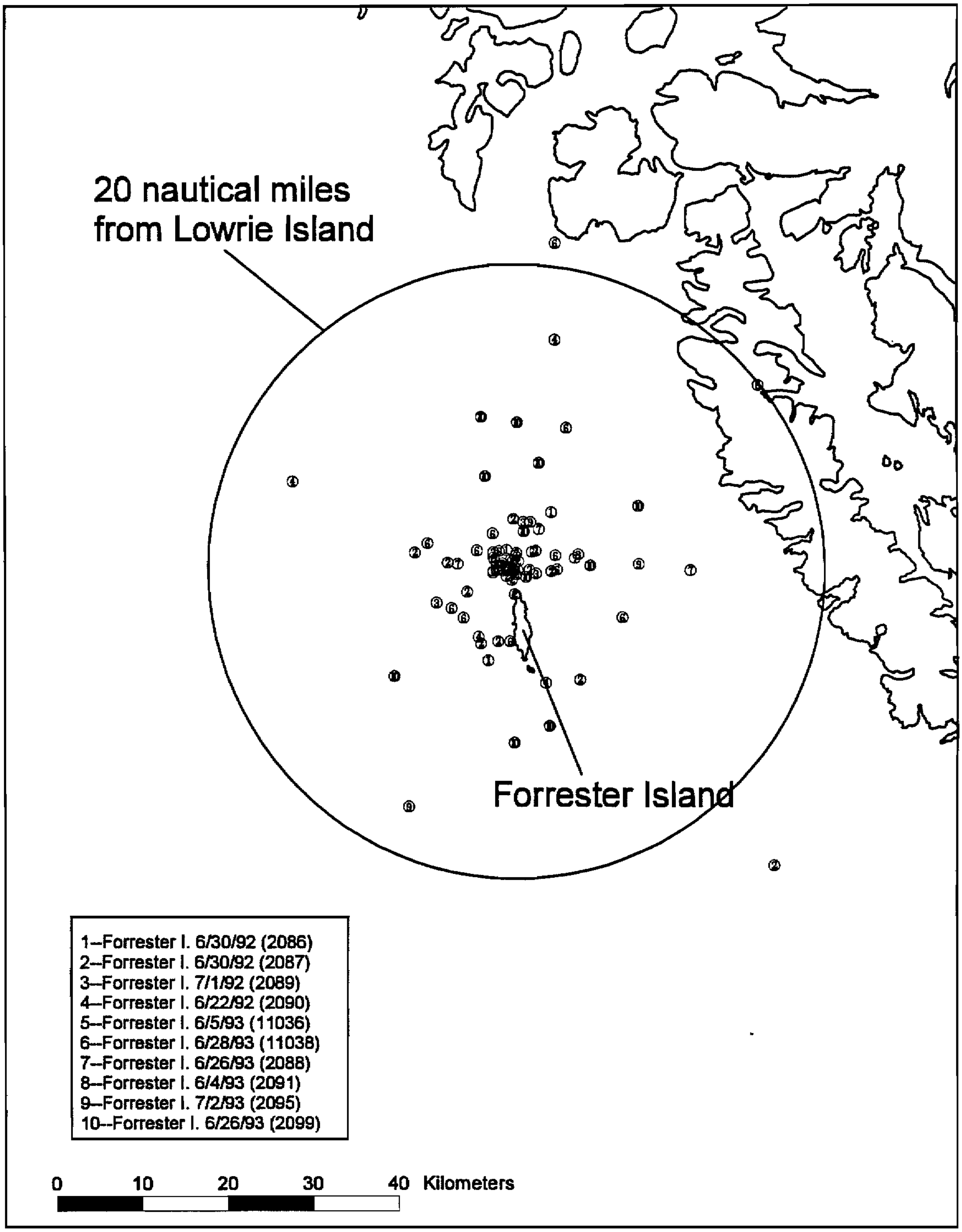


Figure 16. All at-sea locations of all adult females tagged at Forrester Island in 1992 and 1993 with circle drawn at 20 nautical mile radius from the rookery complex.

It seems likely that after losing their pup, females still may visit a rookery for breeding as that is where the most fit males will be found. Little can be said about the foraging locations of this female because the SDR only transmitted one good at-sea location during the entire time she was monitored (Figure 8).

The juvenile female (SDR 2094, Figure 14) moved between the Forrester rookery complex and Wolf Rocks several times after she was tagged. Most juveniles seen at rookeries during the breeding season are usually nursing and either partially or entirely dependent on and accompanied by an adult female. It seems likely these animals are weaned soon after the adult produces a pup unless they are able to displace the pup (Sandegren 1970). Movements of the tagged juvenile female suggest that it accompanied a female to Forrester Island, was weaned probably near the time we captured it, and foraged between Forrester and Wolf Rocks for a time after that. It may be that she made additional attempts to reestablish the parent-offspring bond when she returned to Forrester Island. Location information indicated that she hauled out on at the Forrester complex on several occasions after hauling out on Wolf Rocks. The move to Cape Addington at the end of July probably signaled a permanent end to the parent-offspring bond.

Adult female sea lions that were attending pups at Forrester Island remained and foraged in the vicinity of Forrester Island (Figure 13). The same was true for adult females tagged at Hazy Islands rookery (Figure 14) that appeared to be attending a pup. Both figure 13 and 14 are average daily locations for individual SDRs so they do not depict all locations but do include both hauled-out and at-sea locations. This is typical foraging behavior for an otariid with a nonswimming, nursing young at a rookery.

Mean trip distances of females with pups on the rookery were not significantly different ($t = -1.33$, $p = 0.21$) between Forrester Island and Hazy Islands. It is possible that sea lions may have to travel further away from Hazy Islands to forage than they do at Forrester; however, sample sizes were relatively small, particularly at Hazy Islands with only 2 animals. The mean of all trip distances measured in southeastern Alaska (14.5 km) was similar to that found by Merrick (1995) for summer females in the western stock (17.1 km).

Sea lions were located in the water all around Forrester Island but they particularly frequented an area off the north end of the rookery complex (Figure 16). This likely indicates a rich feeding area that probably contains a concentration of prey resources. While working at the rookery during summer, we noticed several humpback (*Megaptera novaengliae*)and minke (*Balaenoptera acutorostrata)* whales that were probably feeding in this area also.

The average daily location plot of all adult female sea lions tagged in the summers of 1992 and 1993 (Figure 15) shows that animals with pups remained and foraged near their individual rookeries. Only one adult female visited other rookeries or haulouts during this breeding season. That was the female that apparently did not have a viable pup. In fact, the majority of the at-sea locations of adult females during summer were within 20 nautical miles of the rookery as shown by figure 16 for Forrester Island. Apparently it is rarely necessary for females with idependent pups on the rookery to forage more than 20 nautical miles away from the rookery in southeastern Alaska. This argues strongly in favor of protective status for areas within 20 nautical miles of rookeries in southeastern Alaska. However, the Forester Island rookery is not an important haulout during winter. This area is used by less than 200 sea lions during much of the winter and would not require protective status at that time.

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Foraging Behaviour of Female Steller Sea Lions in Southeast Alaska and the Eastern Gulf of Alaska

Una G. Swain

Alaska Department of Fish and Game
Division of Wildlife Conservation
333 Raspberry Rd.
Anchorage, Alaska 99518

Steller sea lions (SSL) (*Eumetopias jubatus*) are found throughout the North Pacific Ocean rim from northern Japan and Russia, along Alaska's coast, and south to Canada and California (Kenyon and Rice 1961; Loughlin et al. 1984). Their numbers are declining throughout most of their range in Alaska and Russia (Loughlin et al. 1992). SSL populations have declined by 78% in the western Gulf of Alaska and the Aleutian Islands since the late 1970s, while the population in Southeast Alaska (SEA) has been increasing (National Marine Fisheries Service (NMFS) 1995); see Chapter 1). Genetic evidence has identified a western and eastern stock in Alaska, corresponding to these differences in population dynamics (Bickham et al. 1996). One of the principal causes of the recent declines in abundance is hypothesized to be a decrease in prey availability which could be caused by environmental changes and/or commercial fishing activities (Loughlin and Merrick 1989, Lowry et al. 1989, Merrick 1995). Support for this hypothesis comes from observations on the condition of sea lions in the Gulf of Alaska, as expressed by body mass, which has declined from the mid-1970s to the mid-1980s (Calkins and Goodwin 1988). In addition, significant changes have occurred in the abundance of some prey species since the late 1970's (Merrick and Calkins in press).

Recent developments in instrumentation have allowed new methods to measure movements and diving behaviour at sea (*e.g.*, Croxall et al.1985, Kooyman et al.1986, Stewart et al. 1989, Hindell et al. 1991, Bengston et al. 1993) and to use these data to interpret food availability and distribution (Costa et al. 1989, Boyd and Arnbom 1991, Boyd 1996). Foraging theory predicts an animal should optimize its behaviour in order to maximize energy intake under changing environmental conditions (Stephens and Krebs 1986); thus, foraging behaviour would be expected to vary in response to changes in prey distribution and abundance. Past research indicates attendance patterns and activity budgets of otariids are likely to change during periods of nutritional stress to meet energy demands (*e.g.*, Ono et al. 1987, Croxall et al. 1988). Differences in foraging patterns of adult female otariids are evident in years of varying prey abundances as a result of El Nino events (Trillmich et al. 1991). Antarctic fur seals (*Arctocephalus gazella*) show a significantly greater investment in foraging effort during periods of reduced prey abundance by increasing both the time spent foraging and the activity during foraging (Boyd et al. 1994). In species like fur seals, diving is thought to be an accurate measure of foraging activity (Boyd and Croxall 1992). These species spend much of their at-sea time at the surface traveling and resting; dives are, therefore, considered to be foraging events.

Few data about the foraging behaviour of SSL are available. Much of the previous research on foraging focused on behavioural observations of foraging trip durations of lactating females during the summer (Sandegren 1969, Gentry 1970, Higgins et al. 1988). Merrick (1995) investigated the foraging behaviour of adult female and young-of-year SSL in western Alaska. Loughlin et al. (in review) described the dive characteristics of adult females in the Kuril Islands, Russia, during the breeding season. Studies on the foraging behaviour of SSL in SEA, where the population is increasing, are restricted to observational studies on attendance patterns of lactating adult females (Brandon et al. 1995; see Chapters 4 and 5). Differences in the prey available to the increasing and decreasing populations of SSL could lead to different foraging strategies and prey utilization which could influence the divergent population dynamics of the 2 stocks.

The aim of this study was to enhance our understanding of the foraging ecology of SSL and, in particular, to investigate the foraging behaviour of sea lions in SEA for comparison to central and western Alaska (Merrick 1995, Merrick and Loughlin, in review). We examined the foraging behaviour of SSL, primarily of lactating females during the first two months postpartum, by using satellite linked time-depth recorders (SDRs) to collect information on at-sea behaviour. The main objectives of the study were to describe the diving behaviour, investigate behavioural indices of foraging effort, and attempt a preliminary determination whether differences in diving behaviour (and presumably foraging behaviour) could indicate differences in prey availability for the two populations.

Methods

SSL were captured and satellite linked time-depth recorders (SDRs) were attached at the two largest rookeries in southeastern Alaska (Hazy and Forrester islands) and at the Cape St. Elias haulout in the eastern Gulf of Alaska (Figure 1). Sea lions in southeastern Alaska represent the increasing population, while sea lions using the haulout at Cape St. Elias are considered to be at the eastern edge of the declining population, which has declined sharply since 1989 (NMFS 1995). Two adult females were captured at Hazy Islands, the second largest rookery in SEA, in May 1992 and June 1993. Ten adult females and 1 yearling female were captured at the Forrester Island rookery in June and July

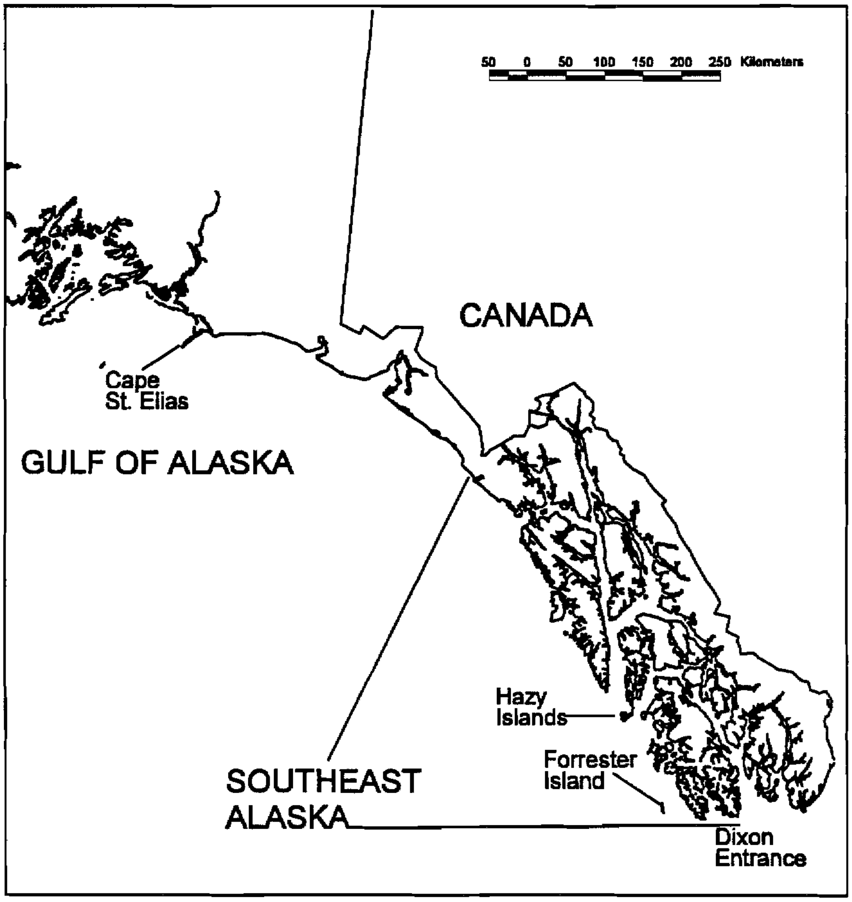


Figure 1. Locations in Southeast Alaska where Steller sea lions were instrumented during 1992 - 93.

1992-93, and one adult female was captured at Cape St. Elias in January 1993. Adult females captured in summer were mostly postpartum with dependent pups. The winter female did not appear to be lactating.

The sea lions were chemically immobilized with Telazol® injected intramuscularly by a dart fired from a pneumatic gun (Loughlin and Spraker 1989). Once the sea lion was immobilized, it was intubated and placed on a semi-closed anesthetic machine delivering only oxygen. When the animal began to recover from the Telazol, isofluorane gas was introduced through the machine as a sedative.

SDRs were used to investigate movements, diving behaviour, and habitat use, as has been done for several pinniped species (e.g., Bengston et al. 1993, Merrick et al. 1994, Lowry et al. 1994). SDRs were glued with netting and fast-setting epoxy resin (Fedak et al. 1984) to the fur of the mid-dorsal region of the sea lion. The 0.5 watt ST-6 transmitters, packaged as Type III SDRs (Wildlife Computers), measured 19 cm x 12 cm x 2.8 cm and weighed approximately 620 g. The epoxy attachments were lost when the sea lion molted in late July for summer most adult females. The loss of the SDR, however, seemed also to be dependent upon the duration of attachment. Most summer females lost their transmitters one month after attachment regardless of date. The SDRs are equipped with pressure sensors to determine depths and salinity (conductivity) sensors to determine whether the SDR was immersed in water or dry (i.e., whether the sea lion was hauled out). Pressure transducers were capable of measuring depths from 0-500 m with 2 m resolution. The pressure sensor was sampled at 10-s intervals, but these data were summarized prior to transmission. Programmable microprocessors collected and summarized data on maximum dive depths and durations and stored it for later transmissions.

The SDRs merged generalized time-depth recorder (TDR) capabilities with the data-relaying capabilities of the Service Argos data collection and location system (Fancy et al. 1988, Keating et al. 1991). The SDRs transmitted information to 2 polar-orbiting satellites administered by the National Oceanic and Atmospheric Administration. Information could only be transmitted when the sea lion was hauled out on land or at the ocean surface and when the satellite was in direct line of sight of the transmitter. For analysis and presentation of the data, Greenwich dates and times, as reported by Argos, were converted to local solar time by subtracting 9 hours.

The Type III SDRs stored, summarized, and transmitted data as histograms. A histogram is a set of "bins," each of which contained counts for a given range of depth or time. The counts are accumulated over a 6-hr "histogram period," and each day was divided into 4 of these periods (2100-0300, 0300-0900, 0900-1500, 1500-2100 local sun time). Dive depths and durations were summarized separately within the same 4 periods and stored in a "transmit buffer" that contained the previous four histogram periods (24 hours). Each histogram recorded dive information into 6 separate bins which were set before deployment. The minimum depth for a dive was 4 m based on earlier studies in Alaska (Merrick et al. 1994). Dive-depth and dive-duration bins differed among transmitters. The dive-depth bins for all 6 of the summer 1992 SDRs (5 adult females, 1 yearling female) were 4-10 m, 10-20 m, 20-50 m, 50-100 m, 100-250 m, and > 250 m. Corresponding dive-duration bins were 0-1 min, 1-2 min, 2-4 min, 4-8 min, 8-16 min, and >16 min. As the majority of dives were shorter and shallower than anticipated, the bin categories were changed in 1993. Six of the 1993 SDRs (5 summer adult females, 1 winter adult female) summarized data in depth bins of 4-10 m, 10-20 m, 20-50 m, 50-100 m, 100-150 m, and > 50 m and in duration bins of 0-1 min, 1-2 min, 2-4 min, 4-6 min, 6-8 min, and >8 min (4 summer adult females) and in duration bins of 0-1 min, 1-2 min, 2-3 min, 3-4 min, 4-6 min, and >6 min (1 summer adult female, 1 winter adult female). Depth bins for 1 summer 1993 adult female were defined as 4-10 m, 10-20 m, 20-50 m, 50-100 m, 100-200 m, and >200 m with duration bins defined as 0-1 min, 1-2 min, 2-4 min, 4-6 min, 6-8 min, and >8 min. In addition, a maximum depth field gave the precise maximum depth recorded for each 24 hours.

Analyses

Records from all 14 instruments were used for analysis, and bin data on dive depth and duration was summarized into standard bins. Sea lions were grouped into 4 categories: lactating summer adult females (n = 11), a summer adult female without a pup (n = 1), a summer yearling female (n = 1), and a winter adult female (n = 1). Observations at the rookery and movement data indicated that adult female 2091 probably had a pup in early June 1993 but certainly did not keep the pup when she left the Forrester Island rookery on June 15 and traveled north 350 km, only to return to Forrester 3 weeks later (see Chapter 7: Movements and habitat use). Adult female 2085 was captured in mid-May, most likely before pupping. Movement and behavioural data indicate she pupped and was tied to the rookery from May 23 onward (see Chapter 7: Movements and habitat use), so only records following this date were used for many of the analyses on this animal.

Duration of time at sea and on land

The SDRs reported with each transmission whether the sea lion was on land or at sea based on the status of the salinity sensor. The length of time a sea lion spent at sea or on land was then determined from an analysis of these transmissions. The first on-land or at-sea period was excluded from the analysis. A sea lion was considered to be on land between the first and last on-land transmission and at sea from the last on-land transmission to the first on-land transmission. The "land/sea" status of the sea lion during the period between the last on-land transmission and the first at-sea transmission was really unknown; however, it was assumed to be at sea because of the greater probability of signal reception by the satellite when the animal is on land.

To determine duration of time at sea and to use it as a measure of foraging trip duration, it was necessary to account for "wet" transmissions which simply represented brief excursions into the water or lounging in the water at the edge of the rookery. Research on foraging trip duration in lactating SSL using VHF radiotransmitters (Chapter 4) interpreted a foraging trip to be a minimum of 3 hours based on the frequency distribution of gap duration in the signal record, as in Boyd et al. (1991). A frequency distribution of at-sea trip duration from our data showed one a minimum between 2 and 3 hours. To be consistent and to take into account behavioural observations of short, 3-hr trips to sea, trips exceeding three hours were interpreted as representing genuine foraging trips.

Dive depth and duration

The total number of dives in each depth and duration bin were summed for each 6-hr period prior to transmission to the satellite. Mean dive depths and durations were determined for individual sea lions by using the midpoint of a bin to represent the average for all dives in that bin (e.g. 7 m for a 4-10 m bin). For the deepest and longest open-ended bins, the minimum depth or duration was used to calculate the average (e.g., 250 m for a > 250 m bin).

Dive frequency, foraging effort, and time submerged

Dive frequencies were calculated directly from the duration histograms by summing the number of dives for each 6-hr period and by dividing by the number of periods which contained at least 1 dive. Mean dive frequencies were determined for individual sea lions and by period.

Foraging effort (FE) was defined by Merrick (1995) as time spent diving in a day and was calculated as follows:

FE = (mean dives per hour)(mean dive duration)(proportion of time at sea)(24)

This was calculated for each sea lion and then for the group of lactating females.

Because of inherent problems in determining the proportion of time at sea due to data collection constraints, time submerged was also determined and considered as an index of foraging effort. Time submerged is the actual time spent diving (without considering any interdive intervals) and thus represents an estimate of time spent foraging. Time submerged was calculated by multiplying the number of dives by the midpoint of the duration bin and then by summing the time of all dives in each 6-hr period. Time submerged was determined for only those days in which data from all 4 periods were available. Mean daily time submerged was also used to determine percent time diving. Percent time at sea was calculated from time submerged and allowed comparison with the percent time at sea ascertained from the "land/sea" messages determined by the salinity sensor. Sea lions were considered to be at sea during 6-hr periods when time submerged exceeded 30 min. During 6-hr periods with 0-30 min spent underwater, sea lions were considered on land during the entire period.

Statistical techniques

Data analysis in part followed that of Merrick (1995) to allow comparisons of foraging behaviour with SSL from the declining population. Comparisons between groups of sea lions were not undertaken because only one sea lion was represented in three of the groups (summer yearling female, summer adult female without a pup, and winter adult female). Differences in dive frequencies by time of day for these individual sea lions were tested using a one-way ANOVA and Tukey's multiple comparisons. Comparisons of mean times at sea among lactating females were also performed using a one-way ANOVA.

Five variables were analyzed to compare diving behaviour among locations (Hazy Islands and Forrester Island) and time of day (2100-0300, 0300-0900, 0900-1500, 1500-2100) for adult female sea lions with pups during the breeding season. These variables were number of dives (in a 6-hr period), average dive duration, average dive depth, average time submerged and dive diversity. For each observation, average dive duration and average dive depth were calculated as the number of dives in each of the duration or depth bins multiplied by the midpoint of the category, all divided by the total number of dives in the observation period. Because the number of dives generally declined as duration was longer or depth deeper, using the midpoints will result in a small positive bias in average durations and depths. Dive diversity was calculated using Shannon's diversity index (Odum 1971:144); this was used to assess how evenly the dive effort was distributed across the dive bins. All of these measures were compared across locations and time periods using analysis of variance procedures appropriate for unbalanced data (SAS type III and IV; Milliken and Johnson 1984). Individual animals, nested within locations and samples (i.e., single day with 4 periods for an individual animal), nested within animals and locations, and interactions involving theses factors were included as random effects in the analyses. Satterthwaite's approximation (Milliken and Johnson 1984) was used to adjust hypothesis tests for the unbalanced data. For the analyses of dive duration, depth, and diversity, observations were weighted by the number of dives in the interval under the assumption that more dives resulted in better (i.e., more precise) measures of the variable of interest. Also, observations with no dives were deleted for analysis of these three variables. Least-squares means of time periods were compared using the Tukey procedure.

Results

The 11 SDRs on summer adult females with pups studied during May-July yielded data during an average deployment of 29.3 days. Data were calculated for 36, 84, and 113 days from the SDR-equipped summer adult female without a pup (June-July), summer yearling female (June-Sept.), and winter adult female (Jan.-May), respectively. The foraging behaviour was described for all individual sea lions; however, comparisons among sea lions were restricted to lactating females because of the limited (1) sample size for the other groups. Results for these sea lions are presented.

Duration of time at sea and on land

The 11 summer adult females with pups (SAF) spent a mean of 19.1 hr (SD = 6.4) at sea during 185 trips and a mean of 14.2 hr (SD = 4.5) on land during 249 haulouts (Table 1). Data were available for an additional 65 trips to sea for the SAF; however, these trips were excluded from the analysis of mean time at sea because they were < 3 hr and were not considered to represent true foraging trips. An additional 5 trips for sea lion 2085 were excluded from the analysis because these were undertaken before May

23 when she was presumed to have pupped. Mean trip duration before May 23 was 34.0 hr compared to 27.9 hr when her movements were concentrated around the Forrester Island rookery. Mean on-land duration was similar before and after birth of her pup (12.6 hr vs. 11.6 hr). Mean trip duration varied considerably for individual females with pups (F=2.61, $p < 0.0056$) and ranged from 11.3 hr to 27.9 hr. Mean time on land ranged from 9.5 hr to 25.6 hr. The proportion of time at sea averaged 50.9% (SD = 10.4) and ranged from 34.7% to 65.6% for individuals.

The summer adult female with no pup and the winter adult female (WAF) had longer trips to sea with mean trip durations of 31.0 hr (SD = 17.4, range = 3.3 - 56.6 hr) and 56.1 hr (SD = 50.4, range = 3.1 - 168.9 hr), respectively (Table 1). Corresponding mean haulout durations were 28.4 hr (SD = 31.4, max = 107.8 hr) and 8.0 hr (SD = 9.0, max = 55.9 hr). The mean proportion of time at sea for the summer female without a pup was 46.7% and for the winter adult female 85.7%, which was the greatest of any of the sea lions. The yearling female (YF) spent a mean of 19.3 hr (SD = 13.5, range 4.9 - 66.3 hr) at sea during 61 trips and a mean of 11.1 hr (SD = 9.2, max = 49.3 hr) on land during 69 visits. Mean proportion of time at sea for the YF was 61.1%.

Dive depth

Depth histograms summarized data from 97,925 dives (Table 2). The number of dives containing duration information differed because of the difference in the number of depth and duration histograms successfully transmitted to the satellite. Mean dive depths for all dives greater than 4 m was 26.1 m (SD = 8.22)

Table 1. Duration of deployments, haulouts, and at-sea trips of 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-93.

			Haulout		Trip		Percent at sea
SDR	Location	Deployment Dates	n	mean (hr)	n	mean (hr)	
Adult females in summer with pups							
2084	Hazy I.	6/30-7/25 93	26	14.0	15	11.4	34.7
2085	Hazy I.	5/13-6/25 92	23	11.6	18	27.9	65.6
2086	Forrester I.	6/30-7/27 92	23	14.8	16	16.6	45.3
2087	Forrester I.	6/30-7/29 92	23	10.2	15	27.0	63.8
2088	Forrester I.	6/27-7/28 93	27	14.2	20	16.5	47.2
2089	Forrester I.	7/1-7/ 31 92	33	9.5	26	12.0	51.4
2090	Forrester I.	6/29-7/28 92	14	25.6	14	19.1	43.0
2095	Forrester I.	7/2-7/23 93	21	14.4	15	11.3	37.4
2099	Forrester I.	6/26-7/2393	19	13.2	18	18.1	56.8
11036	Forrester I.	6/5-7/6 93	16	17.9	12	27.0	54.0
11038	Forrester I.	6/28-7/26 93	24	10.3	16	23.4	61.1
		All	249	14.2	185	19.1	50.9
Adult female in summer without a pup (SE)							
2091	Forrester I.	6/4-7/10 93	14	28.4	11	31.0	46.7
Yearling female in summer (SE)							
2094	Forrester I.	6/22-9/14 93	69	11.1	61	19.3	61.1
Adult female in winter (EGOA)							
2096	Cape St. Elias	1/28-5/21 93	48	8.0	41	56.1	85.7

and 49% (SD = 14.10) of all dives were less than 10 m. The maximum dive depth recorded was 424 m. The WAF dove the deepest (mean = 29.5 m, SD = 43.2). Mean dive depths were 26.4 m (SD = 9.01, max = 236 m) for the SAF, 26.6 m (SD = 33.02, max = 308 m) for the summer female without a pup, and 18.0 m (SD = 24.81, max = 220 m) for the yearling female (Table 2).

The proportion of dives in the 4-10 m depth strata ranged from 28.3% to 72.4 % for the SAF with a mean of 46.3% (SD = 14.88). Dives between 4-10 m represented 57.4%, 57.7%, and 61.1% of all dives for the summer female without a pup, the yearling female, and the WAF, respectively (Table 2; Fig. 2).

Table 2. Dive depths for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-93. The number of dives in the deepest depth category (bin) is given in ().

		Depth		Percentage of Dives					
SDR	No. of Dives	Mean (m)	Max (m)	4-10 m	10-20 m	20-50 m	50-100 m	100-150 m	> 150 m
Adult females in summer with pups (SE)									
2084	3931	19.7	108	37.88	29.84	28.97	3.26	0.05 (2)	
2085	6876	40.2	216	28.26	14.53	26.22	27.41		
2086	4492	28.2	212	34.64	23.78	30.08	8.46		
2087	7529	17.4	232	72.43	7.05	15.58	2.87		
2088	4882	23.5	180	51.52	15.96	20.26	10.08	1.84	0.35 (17)
2089	3410	42.9	224	41.61	10.15	18.39	20.18		
2090	2996	29.4	236	33.51	22.03	29.24	13.15		
2095	4067	13.7	120	72.04	10.82	14.83	2.04	0.27 (11)	
2099	4175	26.2	188	47.45	15.19	20.43	15.47	1.27	0.19 (8)
11036	3891	28.8	200	37.42	16.73	20.43	19.87		5.55 (216)[a]
11038	5262	20.4	180	52.96	21.36	17.22	6.44	1.62	0.40 (21)
All	51,511	26.4		46.34	17.04	21.97	11.75	2.90 % of dives > 100	
Adult female in summer without a pup (SE)									
2091	4557	26.6	308	57.38	8.65	18.30	10.03	4.48	1.16 (53)
Yearling female in summer (SE)									
2094	25,338	18.0	220	57.70	21.52	16.28	2.87		
Adult female in winter (EGOA)									
2096	16,519	29.5	424	61.14	13.90	8.37	3.01	9.48	4.10 (677)

[a] Depth bin is 100-200 m.

Only 2.9% of the dives by the SAF were greater than 100 m compared to 5.6% for the summer female without a pup, 1.6% for the yearling female, and 13.6% for the WAF (Figure 2). Overall dive depths changed during the deployment period for both the yearling female (June - Sept.) and the WAF (Jan. - May). The yearling dove more frequently to depths greater than 100 m (maximum 220 m) in June and July (10.3 dives/day) than in August and September (3 dives total). For the WAF, 13.2% and 10.0% of all dives during February and March were greater than 150 m whereas dives of this depth represented only 0.4% and 1.9% of dives in April and May.

Dive duration

Duration histogram data were collected on 99,784 dives (Table 3). Mean dive duration for all dives was 1.52 min (SD = 0.31). Most dives were short: 48.1% were less than 1 considered equal to that of the longest bin which contained dives. The maximum dive duration was greater than 16 min. This was recorded for 4 SAF and the yearling female; however, these were the only sea lions whose SDRs were programmed with a duration bin of >16 min. Duration bins for all other sea lions were shorter.

Mean dive durations were 1.64 min (SD = 0.28) for SAF, 1.33 min for the summer female without a pup, and 1.25 min for the WAF (Table 3). The yearling female made the shortest dives (mean = 1.06 min) and had the highest percentage of dives between 0-1 min (66.3%). The proportion of dives in the 0-1 min duration bin ranged from 25.3% to 64.3% for the SAF with a mean of 46.1% (SD = 11.63). Dives lasting 0-1 min represented 48.4% and 52.9% of all dives for the summer female without a pup and the WAF, respectively (Table 3; Figure 2). Only 3.9% of the dives by the SAF were longer than 4 min compared to 9.1% for the summer female without a pup, 1.2% for the yearling female, and 9.0% for the WAF (Figure 2).

Overall dive depths were shallow, dive durations were short, and depth and duration showed a correspondence (positive relationship) in the distribution of the proportion of dives in the various depth and duration bins. Generally, sea lions with a high proportion of shallow dives had a high proportion of short dives (Table 3). The highest proportion of dives were 0-1 min for all sea lions except 2085 (SAF); 44.8% of all her dives were 2-4 min, and this sea lion had a higher proportion of dives between 100-250 m. As with dive depths, dive durations changed during the deployment period for both the yearling female and the WAF. In June and July 4.3% and 2.8% of the yearling females dives lasted longer than 4 min, while dives of this duration represented less than 0.1% of all dives in August and September. The WAF made longer dives during Jan.-

Table 3. Dive durations for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-93. The number of dives in the longest duration category (bin) is given in brackets ().

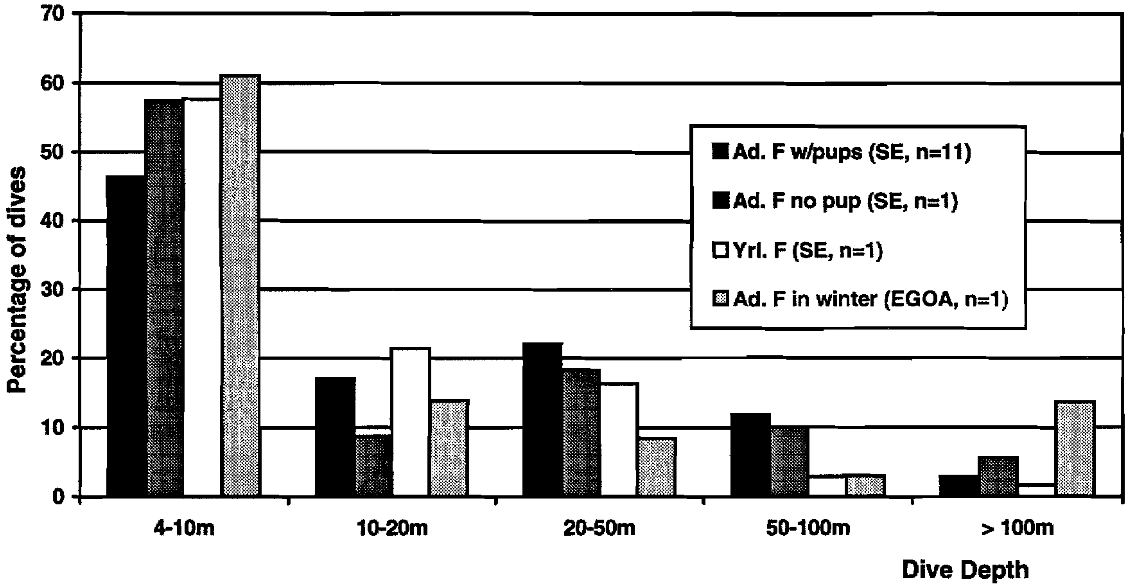
		Duration		Percentage of Dives								
SDR	No. of Dives	Mean (min)	Max (min)	0-1 min	1-2 min	2-4 min	4-6 min	4-8 min	6-8 min	> 8 min	8-16 min	> 16 min
Adult females in summer with pups (SE)												
2084	3931	1.22	> 8	51.21	34.80	13.25	0.64		0.03	0.08 (3)		
2085	6709	2.16	> 16	25.34	25.64	44.84		3.56			0.30	0.33 (22)
2086	4428	1.71	8-16	38.41	27.46	31.37		2.69			0.07	
2087	7778	1.49	> 16	64.34	11.82	17.40		5.34			0.72	0.40 (31)
2088	4964	1.47	> 8	48.13	29.01	19.22	2.46		0.18	1.01 (50)		
2089	3454	2.00	> 16	42.33	16.44	31.88		8.98			0.23	0.14 (5)
2090	3552	1.71	> 16	43.30	23.62	28.55		4.39			0.06	0.08 (3)
2095	4225	1.40	> 8	60.24	17.42	17.80	1.94		0.45	2.15 (91)		
2099	4113	1.67	> 8	38.61	30.25	27.96	2.21		0.49	0.49 (20)		
11036	4429	1.58	6- 8	36.85	36.04	25.20	1.87		0.05 (2)			
11038	4795	1.22	> 8	57.75	24.00	17.04	1.02		0.13	0.06 (3)		
	52,378	1.64		46.05	25.14	24.96		3.30 % of dives 4-8 min		0.55 % of dives > 8 min		

Table 3 continued.

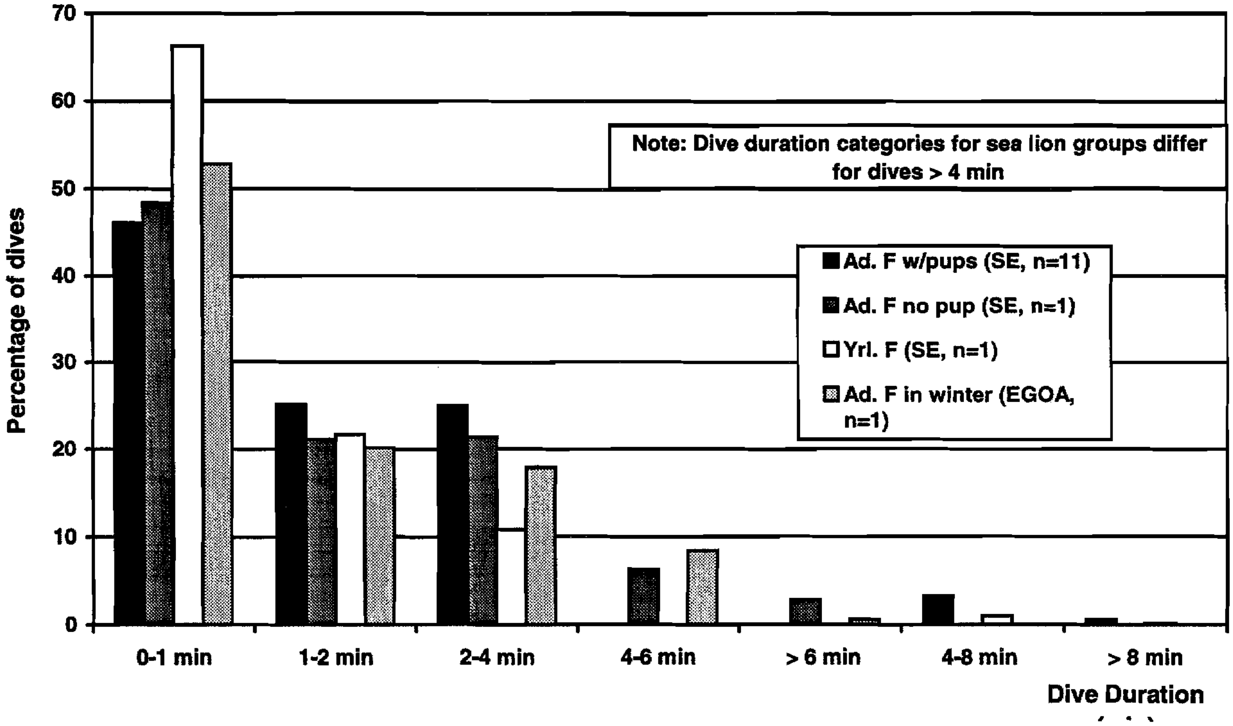
		Duration		Percentage of Dives								
SDR	No. of Dives	Mean (min)	Max (min)	0-1 min	1-2 min	2-4 min	4-6 min	4-8 min	6-8 min	> 8 min	8-16 min	> 16 min
Adult female in summer without a pup (SE)								> 6 min				
2091	4497	1.33	> 6	48.39	21.08	21.44	6.27	2.82 (127)[a]				
Yearling female in summer												
2094	26,148	1.06	> 16	66.30	21.73	10.83		0.99			0.10	0.06 (15)
Adult female in winter (EGOA)								> 6 min				
2096	16,761	1.25	> 6	52.88	20.21	17.94	8.35	0.63 (106)[a]				

[a] Note different duration bin: > 6 min.

DIVE DEPTH



DIVE DURATION



Note: Dive duration categories for sea lion groups differ for dives > 4 min

Figure 2. Proportion of dives in depth and duration categories (bins) for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during summer and winter 1992-93.

March: 21.8% of all dives were longer than 4 min compared to 3.1% of all dives during April and May.

Dive frequency

Data were collected on 52,378 dives from the SAF, 4,497 dives from the summer adult female without a pup, 26,148 dives from the YF, and 16,716 dives from the WAF (Table 4). Mean dive frequencies for individual SAF ranged from 6.3 to 15.1 dives per hour (mean = 9.9 dives per hour, SD = 2.40) compared to 8.3, 16.9, and 10.8 dives per hour for the summer female without a pup, the yearling female, and the winter female, respectively. The highest dive frequencies were recorded for the yearling (54.7 dives per hour) and the WAF (53.7 dives per hour), although a high dive frequency was also observed for the SAF (max = 47.0 dives per hour) and the female without a pup (max = 34.8 dives per hour).

Table 4. Dive frequencies for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-93.

SDR	No. of dives	No. of 6-hr periods[a]	Dive frequency (mean no. per hr)
Adult females in summer with pups (SE)			
2084	3931	58	11.3
2085	6709	118	9.4
2086	4428	74	10.0
2087	7778	86	15.1
2088	4964	100	7.7
2089	3454	92	6.3
2090	3552	65	9.1
2095	4225	74	9.5
2099	4113	80	8.3
11036	4429	54	12.6
11038	4795	76	10.3
All	52,378	877	9.9
Adult female in summer without a pup (SE)			
2091	4497	90	8.3
Yearling female in summer (SE)			
2094	26,148	250	16.9
Adult female in winter (EGOA)			
2096	16,761	256	10.8

[a] Number of 6-hr periods which contained at least one dive, as in Merrick (1995).

There are significant diurnal patterns in dive frequency (Figure 3). Sea lions, except the summer female without a pup, dove most frequently at night (2100-0300). The mean frequency of dives for SAF was 15.4 dives per hour compared to 7.5 dives per hour in the morning (0300-0900), 8.1 dives per hour during the day (0900-1500), and 8.6 dives per hour in the late afternoon (1500-2100) (see *Comparison of dive behaviours among lactating females* below). Significant diurnal patterns were also evident for the summer female without a pup (F = 3.61, P = 0.02), yearling female (F = 132.51, P < 0.0001), and winter female (F = 17.52, P < 0.0001) (Table 5).

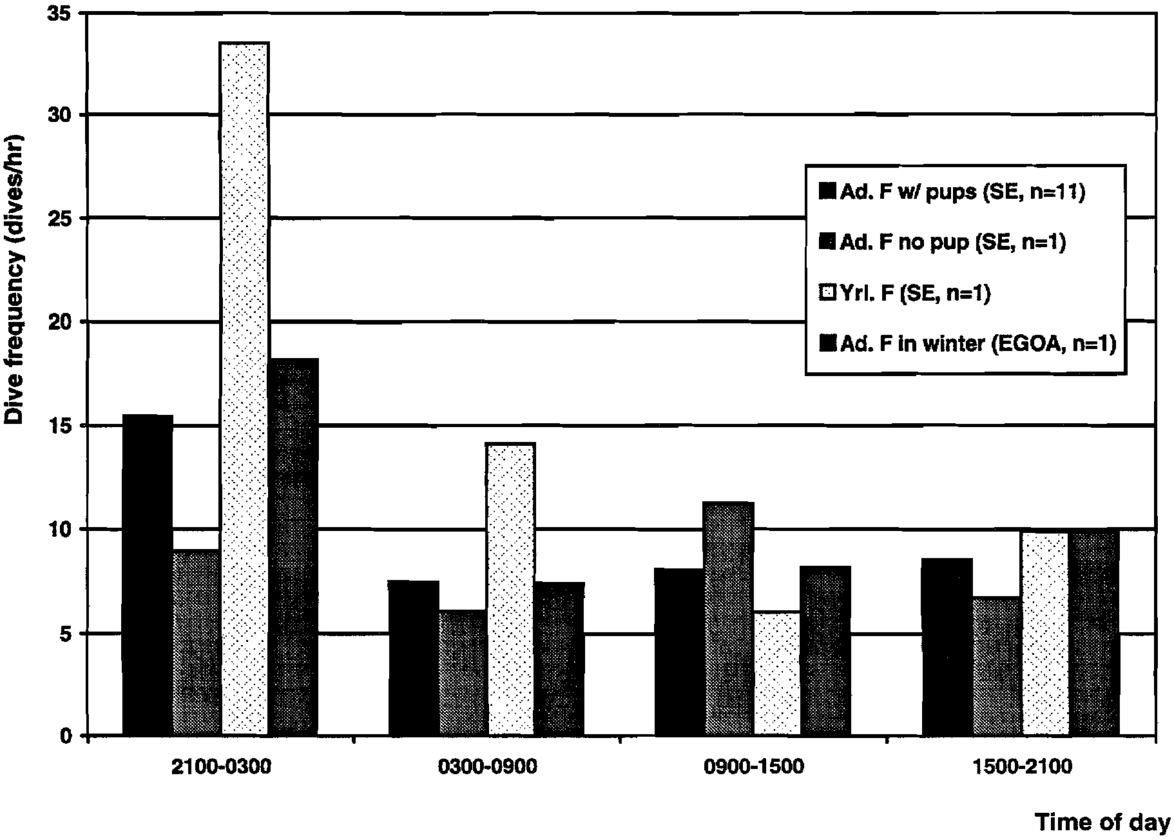


Figure 3. Dive frequency by time of day for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during summer and winter 1992-93.

A seasonal effect on the frequency of dives was observed for the yearling female and the WAF. Both dove more frequently later in the summer and winter (Figures 4 and 5). As dive depths decreased during the summer, a trend of increasing dive frequency was observed for the yearling female; dive frequency was considerably higher in August (18.5 dives per hour) and September (22.6 dives per hour) than in June (11.4 dives per hour) and July (14.1 dives per hour). The WAF dove more frequently in April (14.4 dives per hour) and May (13.4 dives per hour) than in

February (6.5 dives per hour) and March (7.9 dives per hour), corresponding to a decrease in overall dive depths. The WAF showed a dramatic increase in diving at night (2100-0300) during April.

Table 5. Dives per hour by time of day for 3 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-1993.

	Mean dive frequency by time of day (dives/hr)			
SDR	2100-0300	0300-0900	0900-1500	1500-2100
Adult female in summer without a pup (SE)				
2091	8.97^{ab}	6.07^{b}	11.25^{a}	6.75^{ab}
Yearling female in summer (SE)				
2094	33.54^{a}	14.12^{b}	9.92^{c}	6.05^{c}
Adult female in winter (EGOA)				
2096	18.18^{a}	9.90^{b}	8.21^{b}	7.41^{b}

^{abc} Means with different superscripts are significantly different ($P < 0.05$).

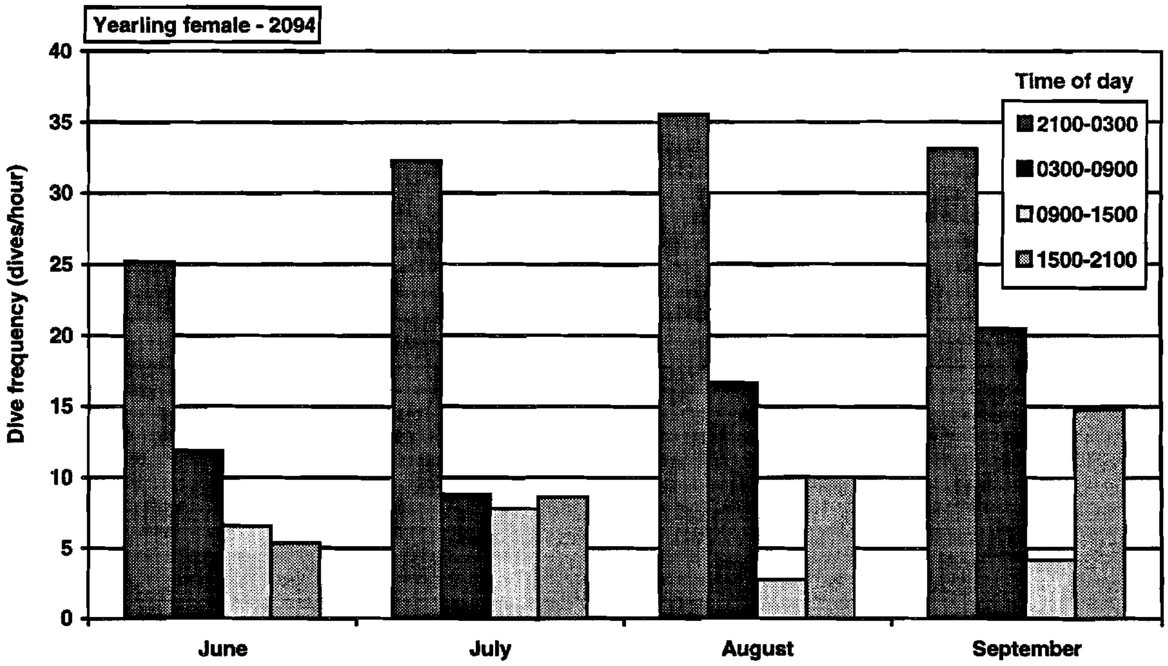


Figure 4. Monthly dive frequency by time of day for a yearling SDR-tagged Steller sea lion in Southeast Alaska during summer 1993.

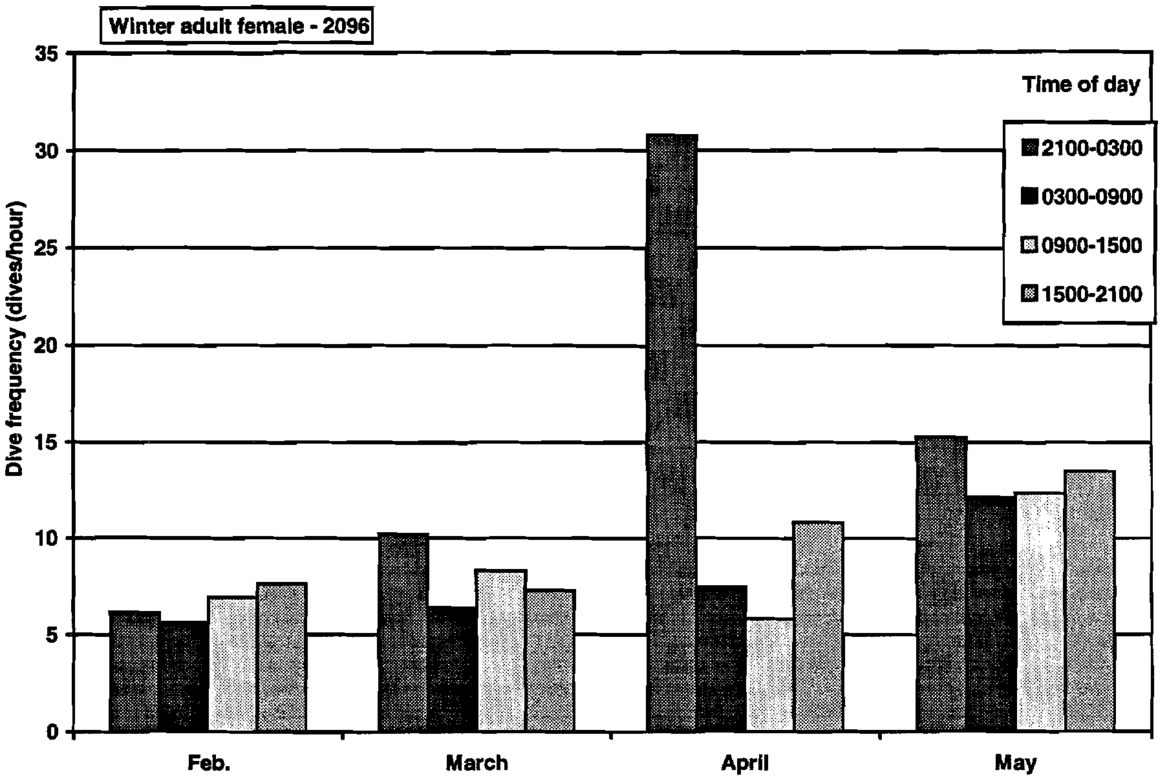


Figure 5. Monthly dive frequency by time of day for an adult female SDR-tagged Steller sea lion in the Eastern Gulf of Alaska during winter and spring 1993.

Foraging effort and time submerged

Mean foraging effort for SAF was 3.26 hrs per day (SD = 1.30) compared to 2.06 hrs per day for the summer adult female without a pup, 4.36 hrs per day for the yearling female, and 4.64 for the WAF (Table 6).

Data were collected for all sea lions on 389 days in which all 4 periods (times of day) were represented. The mean number of hours per day spent submerged or diving was 4.8 hrs (SD = 3.13, range 2.9 - 6.9 hrs) (Table 6). The yearling female and WAF spent more time submerged (5.7 hrs per day) than the summer adult female without a pup (3.9 hrs per day). Mean time submerged for SAF was 4.3 hrs per day (SD = 1.32) which represented an average of 18.0% of their day spent underwater. The proportion of time submerged for the other sea lions was 16.2% for adult female without a pup and 23.8% for the yearling female and WAF (Table 4). Four of the SAF (2085, 2088, 2095, and 11038) never spent an entire day without any time underwater; the minimum time submerged for 3 of these animals (2085, 2088, 11038) was negligible (1.5 - 3.5 min), but 2095 spent at least 49 min diving each day. The minimum daily time submerged for the winter adult female was 64 min.

Table 6. Time submerged and foraging effort for 14 SDR-tagged Steller sea lions in Southeast Alaska (SE) and the eastern Gulf of Alaska (EGOA) during 1992-93.

SDR	No. of 24-hr periods[a]	Time submerged (hrs/day)	Percent time submerged	Foraging effort[b] (hrs/day)
Adult females in summer with pups				
2084	24	3.19	13.3	1.91
2085	30	6.51	27.1	5.31
2086	21	5.03	21.0	3.09
2087	26	6.85	28.6	5.73
2088	24	3.84	16.0	2.14
2089	24	3.69	15.4	2.57
2090	18	2.90	12.1	2.68
2095	19	4.60	19.2	1.99
2099	21	4.15	17.3	3.13
11036	21	3.24	13.5	4.28
11038	17	3.56	14.6	3.08
All	245	4.32	18.0	3.26
Adult female in summer without a pup (SE)				
2091	22	3.88	16.2	2.06
Yearling female in summer (SE)				
2094	70	5.71	23.8	4.36
Adult female in winter (EGOA)				
2096	52	5.71	23.8	4.64

[a] No. of complete days for which data is available from all 4 periods (2100-0300, 0300-0900, 0900-1500, 1500-2100); i.e., all periods are represented in the 24-hr period.

[b] Foraging effort (FE) or time spent diving in a day, as defined by Merrick (1995):
$FE = D * T_D * P_T * 24$, where: D = Mean no. of dives per hour
T_D= Mean dive duration in minutes
P_T= Proportion of time at sea

If time submerged is used to estimate proportion of time at sea by assuming any 6-hr period with greater than 30 min submerged classifies the sea lion as at sea, the mean proportion of time at sea for SAF was 51.5% (SD = 10.86) which was similar to the proportion estimated from the land/sea sensor data (50.9%). By using the same criteria for time submerged, the proportions of time at sea for the summer female without a pup, for the yearling female, and the WAF were estimated as 59.1%, 68.6%, and 72.1%, respectively.

Comparison of dive behaviours among lactating females

The averages of none of the variables differed (p>0.5) between the two locations, although the power could be low because there were only 2 sea lions from Hazy Islands. The interaction of location and time period was also not important (p>0.25). Location was subsequently omitted from the analyses of time periods. Difference in time-of-day means were found for all variables except dive depth (Table 7). In general, the time period from 2100-0300 differed the most from other periods. There were individual animal by time period interactions for all of the variables (p<0.001), indicating substantial variation among individuals in how their behavior related to the time periods. However, in averages across time periods, there were differences (p<0.10) among animals only for depth (*p* = 0.032).

Table 7. Comparison of dive behaviours among time-of-day periods for 11 SDR-tagged adult female SSL with pups in SEA during summer 1992-93.

Variable	Time periods				P-value
	2100-0300	0300-0900	0900-1500	1500-2100	
Number of dives	72.98^{a}	33.28^{b}	33.08^{b}	43.83^{b}	< 0.001
Duration (min)	1.39^{a}	1.70^{ab}	1.62^{ab}	1.84^{b}	0.002
Depth (m)	24.29	27.26	24.55	26.67	0.720
Time submerged (min)	102.8	61.1	54.2	78.6	< 0.001
Diversity	0.937^{a}	0.822^{ab}	0.667^{b}	0.858^{ab}	0.002

^{ab} Least square means of periods with different superscripts are significantly different.

Discussion

The foraging behaviour of adult female SSL in SEA is characterized by relatively brief trips to sea that represent about half their time and by fairly frequent, short and shallow dives that occur mostly at night. These characteristics are similar to those described for sea lions in areas experiencing declines (Merrick 1995; Loughlin, in review). Research by Merrick (1995) in the Gulf of Alaska and eastern Aleutians showed that adult female SSL during the breeding season spent about half their time at sea on relatively brief foraging trips (18-20 hr). Dives tended to be short (1.4 min), shallow (21 m), and frequent (13/hr). Foraging trip distances are also similar (see Chapter 7: Movements and habitat use).

Duration of time at sea and on land

Mean durations of foraging trips and on land visits for SDR-equipped SSL from the declining population were 17.8 hr and 15.4 hr (Merrick 1995). Sea lions in SEA spent a comparable time at sea (19.1 hr) and on land (14.2). A variety of studies have used foraging trip duration as an index of foraging effort (e.g., Trillmich and Ono 1991). SSL in California were shown to spend more time at sea during an El Nino event (Costa et al. 1991). For Antarctic fur seals, whose foraging behaviour is closely tied to the abundance and distribution of krill (Croxall et al. 1985), periodic reductions in prey availability in South Georgia result in increased foraging trip durations for lactating females (Croxall et al. 1988, Boyd et al. 1994). Our results do not indicate that lactating females in SEA spend less time foraging at sea than females from the declining population which would be expected if there were differences in prey availability. In fact, data collected using radiotelemetry (Brandon et al.1995; Chapter 5) indicated females in the area of decline had significantly shorter foraging trip durations than females at the Forrester Island rookery. Preliminary behavioural data from Sugarloaf and Forrester Island rookeries may also indicate trip durations are shorter in the declining area (Millette et al. 1995; Chapter 4). The mean time at sea for adult females at Forrester Island (26.9 hr), as determined by radiotelemetry, was considerably longer than that determined from the SDR-collected data, as was the case for 4 adult females instrumented with conventional time-depth recorders (TDRs), whose mean trip duration was 32.3 hr (n = 7 trips) (Andrews, unpubl. data). Times at sea determined from behavioural observations were also quite different (Sandegren 1969, Merrick et al. 1988). Differences in results could be artifacts of the methodologies.

Foraging trip duration may not be a sufficiently sensitive aspect of foraging behaviour for comparison; nor does it provide any information on energy intake within a period of foraging. A sea lion could be at sea longer yet encounter considerably more prey and have a higher net energy intake. Costa and Gentry (1986) found northern fur seals to have significantly different field metabolic rates between years without changes in trip duration, while trip duration proved a good energetic index for Antarctic fur seals (Costa et al. 1989). The amount of milk delivered to pups by lactating Antarctic fur seals, was not related to foraging trip length (Arnould 1996). Differences in foraging trip duration, may also be masked by the high variability among females.This may simply reflect different individual foraging strategies and adjustments to local and temporal conditions.

Interpretation of results (foraging trip duration and proportion of time at sea) is further complicated by the limitations of the land/sea sensor data. Information on whether a sea lion is on land or at sea at a particular time is limited to the times of the satellite overpasses. The information is further biased by incomplete satellite coverage and the greater probability of signal reception when the sea lion is on land. It is possible for an animal to go out to sea, for no signals to reach the satellite, and for the animal to return to land without any record of the at-sea time in the land/sea sensor data.

Because of these limitations in the data collection, several different methods for estimating the proportion of time at sea were developed. The alternative estimates used dive histogram data not subject to these biases because the data are not linked to actual transmission times. Dive histogram data is collected and summarized over 6-hr periods and then transmitted over the next 24-hours; i.e., data is stored for 24 hrs before they are lost, maximizing the chance of a successful transmission. One estimate of the proportion of time at sea was derived by assuming a sea lion was at sea during any 6-hr period where time submerged exceeded 30 min. The other estimate was based on TDR data from adult female SSL in SEA that indicate 33% of the at-sea time is spent submerged, while the remaining time is spent at the surface (Andrews, unpubl. data). Therefore, to estimate percent time at sea, I assumed time submerged represented 33% of the time at sea.

A comparison of the different estimates is presented in Table 8. The mean proportions of time at sea estimated by these different methods were very similar for the summer adult females with pups (51 - 55%), although individual proportions varied considerably. The different estimates for the percent time at sea for the individual sea lions were also similar: 47 -59% for the summer adult female without a pup, 61 - 72% for the yearling female, and 72 - 86% for the winter adult female. None of the estimates resulted in consistently higher or lower estimates. When land/sea sensor data were used, the time at sea was most likely underestimated. When dive histogram data was used, the amount of time was probably overestimated because using the midpoints of the duration bins for determining time submerged will result in a small positive bias in average duration. It is interesting that the different methods produced similar results. The proportion of time spent submerged is a minimum estimate of time at sea and ranged from 13 - 29% for all sea lions. Although none of these methods is very satisfactory for determining the actual amount of time spent at sea, the estimates do have comparative value, particularly if identical methodologies are employed. Overall time spent at sea on foraging trips by Alaskan adult female SSL in both the western and eastern stocks was similar (54% vs 51%) (Merrick 1995). Kuril Island adult females also spent about half

Table 8. Comparison of proportion of spent at sea determined from land/sea data and from time submerged

SDR	Percent time at sea (land/sea sensor data) [a]	Percent time at sea (histogram data) [b]	Percent time at sea (T_s = 33% time at sea) [c]	Percent t (T_s)
Adult females in summer with pups				
2084	34.7	43.8	40.3	13.3
2085	65.6	65.0	84.9	27.1
2086	45.3	54.8	63.5	21.0
2087	63.8	65.4	86.5	28.6
2088	47.2	53.1	48.5	16.0
2089	51.4	49.0	46.5	15.4
2090	43.0	44.4	36.7	12.1
2095	37.4	67.1	58.1	19.2
2099	56.8	46.4	52.4	17.3
11036	54.0	34.5	40.9	13.5
11038	61.1	42.6	44.9	14.6
All	50.9	51.5	54.8	18.0
Adult female in summer without a pup (SE)				
2091	46.7	59.1	49.0	16.2
Yearling female in summer (SE)				
2094	61.1	68.6	72.1	23.8
Adult female in winter (EGOA)				
2096	85.7	72.1	72.1	23.8

[a] Determined from the at-sea or on-land status of the SDR transmissions.

[b] Determined from the 6-hr periods of dive histogram data: The sea lion was considered at sea during any 6-hr period where $T_s > 30$ min.

[c] Determined from dive histogram data: T_s was considered to represent 33% of the time at sea.

their time at sea (Loughlin in review), and radiotelemetry data indicated adult females at the Forrester Island rookery also spent a similar proportion (53%) of their trip cycle at sea (Chapter 5).

Dive depth and duration

The main features of the diving behaviour of adult female SSL in SEA are that the majority of dives last less than 2 min and are to depths of less than 20 m and that dives occur most frequently at night (2100-0300). Mean dive depths were similar for SSL throughout Alaska: 26.4 m in SEA and 21.0 m in southwestern Alaska (Merrick 1995). Sea lions rarely dove deeper than 50 m with 85% (SEA) and 96%

1995). Sea lions rarely dove deeper than 50 m with 85% (SEA) and 96% (southwestern Alaska) of all dives less than 50 m. Differences in the proportion of dives to different depths by sea lions of the 2 stocks may simply reflect differences in bathymetry. In SEA 39% of all dives were 10-50 m compared with 61% of all dives in southwestern Alaska. Data from lactating females suggest that the sea lions during the breeding season were feeding on or near the bottom (Andrews and Calkins 1996). Adult females from the Kuril Islands showed similar dive characteristics with 81% of all dives less than 50 m (Loughlin, in review).

As expected, sea lions with deeper mean depths generally had longer mean durations. Dive duration for female sea lions in Southeast Alaska was 1.6 min compared with 1.3 min for females in southwestern Alaska and 1.5 min for females in the Kuril Islands. In this study, 46% of all dives were < 1 min and 70% were < 2 min with only 4% of all dives lasting longer than 4 min. Similar proportions were evident for sea lions in the rest of Alaska (45% < 1 min, 78% < 2 min, 2% > 4 min) and in Russia (55% < 1 min, 70% < 2 min, 5% > 4 min). Dives > 4 min were the only dives that exceeded the theoretical aerobic dive limit (ADL). The ADL is the amount of time an animal can dive without relying on anaerobic metabolism and lactic acid appearing in the blood (Kooyman et al. 1980). When lactic acid accumulates, the diving animal must extend the time between dives in order to process the lactic acid, thereby reducing foraging efficiency (Kooyman 1985). Based on equations developed by Kooyman et al. (1983) and Perez et al. (1990), Merrick and Loughlin (unpublished data) estimated the ADL of an adult female Steller sea lion to be 5.2 min. Steller sea lions dive well below their ADL, as has been reported for other otariids (Gentry and Kooyman 1986). It has been suggested that cost-benefit considerations based on prey availability and encounter rate may be more important than physiological limits in determining the foraging patterns of California sea lions (Feldkamp et al. 1988). Foraging patterns of Antarctic fur seals were attributed to energetic efficiency as deep diving (> 30 m) incurred costs in terms of reduced foraging time and increased surface time, since deep dives were also long dives (Boyd et al 1995). Similar energetic considerations may explain why mean dive depths and durations were fairly shallow and brief for Steller sea lions.

Dive frequency, time submerged and foraging effort

Although the foraging behaviour of adult female Steller sea lions throughout Alaska during the breeding season is similar in several respects, there are differences. Dive frequency and foraging effort both are lower in the Southeast Alaska than in the rest of Alaska. Mean dive frequency for female sea lions from the increasing population was 9.9 dives/hr compared with 13.3 dives/hr for females from the population experiencing declines, while foraging effort, defined here as time spent diving in a day (Merrick 1995), was 3.3 hrs/day and 3.9 hrs/day. Dive frequency and time submerged are also measures of foraging effort and show considerable variation among individuals. Mean time submerged for adult females in Southeast Alaska was 4.3 hrs/day which estimates daily time spent actively diving, and presumably foraging. At times, sea lions spend a considerable proportion of their day submerged; the maximum daily time spent underwater was 18.1 hrs and the mean daily maximum for all females was 10.2 hrs. Similarly, the frequency of dives, as recorded over 6-hr periods, can be very high. Dive frequencies ranged up to 47 dives/hour for individual lactating females, while maximum dive frequencies for the winter adult female and the yearling female were even higher (55 and 54 dives/hr, respectively).

Significant diurnal patterns in dive frequency were evident for sea lions. The frequency of dives at night (15.4 dives/hr) was twice that observed during morning (7.5 dives/hr), day (8.1 dives/hr), and late afternoon (8.6 dives/hr). Female Steller sea lions during the breeding season in the Gulf of Alaska and the Kuril Islands dove most frequently in the late afternoon (1500-2100) and night (2100-0300) (Merrick 1995, Loughlin, submitted). Consistent diurnal variations in dive patterns imply that prey availability strongly influences diving. The high mean number of dives undertaken by female sea lions in Southeast Alaska during the 6-hr night period (92.5 dives) could indicate sea lions are pursuing vertically migrating prey. Herring and walleye pollock are two of the most common prey species in Southeast Alaska during the summer (Calkins and Trites, unpubl. data), both having vertical migrations. Although the depth and duration of dives were not significantly shallower or shorter (different) at night, mean dive depths and durations were lowest during that period. Dive durations were significantly longer, however, during the late afternoon. Dive diversity, which assessed how evenly the dive effort was distributed across the different depth and duration bins, was greatest at night and in the morning.

Percentage of time spent at sea, percentage of time spent diving or submerged, total number of dives or dive frequency, and foraging trip duration are all potential indices of foraging effort. Alternatively, a combination of these parameters can be used to develop an index (Merrick 1995). Because of the inherent problems with time at sea estimates due to data collection constraints, other indices of foraging effort which did not rely on percentage of time at sea were also considered in this study. These included dive frequency and time submerged.

A comparison of several of these indices of foraging effort (Tables 4 and 6) did not generally show a correlation among indices, although in broad terms individuals with high dive frequencies spent more time submerged and had greater foraging efforts, calculated as in Merrick 1995. Estimates of the different measures of foraging effort were not consistently higher or lower. The discrepancy between Merricks foraging effort and time submerged is interesting since both estimate the amount of time Steller sea lions spend diving. It seems time spent diving in a day is underestimated by using the calculation developed by Merrick, especially since it includes surface time between dives. His method is likely to be less sensitive since mean dive frequencies and durations were used in addition to percent time at sea. Furthermore, time submerged was calculated in this study only for days for which all 4 6-hr time-of-day periods were available; thus, the daily dive record was taken into consideration. Given the nature of the satellite data, time submerged could be a better index of foraging effort. There is less bias than in the land/sea sensor data, and otariids do appear to adjust time spent diving to maximize foraging time and minimize time spent at the surface between dives (Boyd et al. 1995).

Future analyses will investigate other potential indices of foraging effort. One possibility would be to scale time spent feeding (*i.e.*, submerged) by the number of dives to account for vertical distances traveled by sea lions. Mean daily cumulative dive depth may provide a sensitive index of foraging effort. The possibility of linking dive duration with depth will be investigated. Boyd et al. (1991) selected depth traveled per unit time (dive rate in m/hr) as the best index of foraging effort because it integrated time submerged and distance traveled searching for prey. SDRs with newer software versions provide time-at-depth as well as time at surface which will allow determination of time at surface and better estimation of time at sea and foraging depths.

Foraging characteristics of other sea lions

We can only infer from the data collected from the single summer adult female without a pup, the summer yearling female (YF), and the winter adult female (WAF).

The female without a pup spent a similar proportion of time at sea as the lactating females; however, trips to sea and on-land visits were considerably longer. Lactating females are restricted in foraging range and time because of the necessity of returning to their pups at regular intervals (Oftedal et al. 1987). Lower indices of foraging effort would be expected without the cost of lactation, as indicated by the data. Dive depths and durations were similar, although the female without a pup had a greater percentage of dives > 100 m and > 4 min. This female is the only sea lion to dive significantly more during the day.

The WAF in the eastern Gulf of Alaska spent considerably more time at sea on relatively long foraging trips (mean 56 hrs). Winter adult females in the central Gulf of Alaska and eastern Aleutian Islands spent a similar proportion of time at sea (89%), and foraging trips were long (mean 206 hrs) (Merrick 1995). Overall dive characteristics were similar. Maximum dive depth (424 m) was recorded for the WAF. Proportions of deep and long dives were greater than for summer adult females, although more than half the dives were < 10 m and < 1 min. Results indicated time submerged and foraging effort were greater for the WAF than for the summer adult females in Southeast Alaska. There was a marked increase in diving at night, especially in April with dive frequencies as high as 54 dives/hr (324 dives in 6 hours). The increased frequency of shorter and shallower dives in late spring indicated the WAF may have been foraging on spawning fish such as herring.

The diving abilities of the yearling female in Southeast Alaska during the summer were similar in many respects to that of the adult females. Foraging trip duration (19 hrs) was similar although the proportion of time spent at sea appeared higher. Mean dive durations and depth were somewhat lower and the proportion of dives > 50 m and > 4 min lower, but the data did not indicate the size-based physiological constraints evident in young-of-year sea lions studied during Nov.-April in the eastern Aleutians and central Gulf of Alaska (Merrick 1995). The older yearling female spent more time at sea, and overall dives were longer and deeper, yet theoretical aerobic dive limits were only exceeded on 1% of dives. Maximum depth and durations were similar to that of adult females. Dive frequency was considerably greater for the yearling female (17 dives/hr), and significantly higher at night, than for young-of-year animals (8 dives/hr) which showed no consistent diurnal patterns in dive frequency. The yearling had the highest dive frequency. Less developed foraging skills would require more dives to successfully obtain prey. Other indices of foraging effort also are higher for the yearling than for summer adult females and are comparable to those of the winter female. By contrast, young-of-year sea lions from the declining population were reported to expend less energy in foraging than adult females; however, these animals may still have been nursing. Population modeling based on analyses of population age structure indicated that decreased juvenile survival is the most likely cause for the Steller sea lion decline (York 1994). If juvenile sea lions expend more effort in foraging, they are more likely to be affected by changes in prey resources. This has been postulated to be the most likely cause of the decline in juvenile survival (Merrick 1995).

Conclusions

Diving varied widely among individuals. Seasonal and diel variations in diving patterns indicate the frequency, depth and duration of individual dives are influenced by the rate of prey encounter, as in California sea lions (Feldkamp et al. 1988). Considerable variation in foraging behaviour between individuals also indicates that individuals can adjust their foraging strategies and that behavioural indices of foraging effort may be able to discern differences in prey availability. Some individual Antarctic fur seals show far more intensive foraging than others (Boyd et al. 1994) which may explain the variation found in energy expenditures of lactating females (Costa et. al. 1989). However, differences in foraging patterns are evident in years of varying prey abundance (Croxall et al. 1988).

The predictive value of foraging behaviour in terms of prey distribution and abundance has been well-documented for otariids (e.g., Bengston 1988; Costa et al 1991; Trillmich and Ono 1991; Boyd et al. 1994); however, the measures need to be sensitive enough to discriminate large variations between individuals. Steller sea lions show a plasticity in behavioural responses which may indicate that individuals have a suite of foraging repertoire that they adjust to changing local conditions. Individual strategies may differ but translate to the same net energy intake. Behavioural parameters measured thus far may not be adequately sensitive to discern differences in prey distribution and abundance. We should pursue a finer discrimination and analysis of foraging behaviour to discover potential differences in prey availability between the eastern and western stocks that are difficult to determine by other means.

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Discussion

The analyses of SSL count data (1979 to 1995) from SEA showed an average mean rate of increase of 4.8% for nonpups and 6.9% for pups. This confirms the validity of using this subpopulation as a "control" for comparative studies of the declining western subpopulation. It was concluded that the SEA subpopulation is probably at its highest level of this century.

Most components of this research were designed to evaluate the hypothesis that undernutrition was a (major) factor in the decline. Results were of uncertain significance.

The findings of differences in timing of pupping between Sugarloaf in the western population and Forrester in the eastern population seemed to support the undernutrition hypothesis. Suggestions that pupping is becoming later at Forrester and earlier at Sugarloaf could indicate changing nutritional status at these locations; this could result from density dependent responses or absolute changes in prey composition or abundance.

Preliminary results of a study on reproductive behaviors indicated that females in the area of decline spent more time nursing their pups, are more aggressive, and have a longer perinatal period. These are all suggestive of nutritional limitation in the western stock.

Findings of higher levels of the acute phase protein haptoglobin in SSL from the area where numbers were declining compared with the area where they were increasing may indicate that some environmental factor such as disease or reduced food availability is affecting the declining population.

Disease and pathology studies did not result in definitive differences between increasing and decreasing populations. The apparent high abortive rate in SSL in conjunction with the identification of several potentially abortive pathogens could indicate a nutritionally stressed population susceptible to diseases that normally are not significant to the population.

The initial analysis of data on foraging trips of adult females with pups from the Forrester Island rookery was somewhat ambiguous when compared with similar data from the western subpopulation (Merrick 1995). Distances traveled on foraging trips were similar in the two areas. Mean foraging trip duration was also nearly identical. Dive frequency did seem greater in the area of decline as did an index to foraging effort (Merrick 1995). More extensive analyses of these data are warranted to ensure data sets and their treatment are comparable between areas and researchers.

We found no differences in juvenile survival between Forrester Island and Sugarloaf Island based on ratios of juvenile to adult females from population composition data. However, a number of factors complicated the interpretation of these data, and it is not possible to draw firm conclusions. There are suggestions of varying annual rates of pup production which may indicate environmental influences on productivity.

The results of a study on adult female reproductive effort, female body condition and pup growth gave no indication of reduced nutrition in the declining population. In fact several indicators showed the opposite of what was expected. Female foraging trip length was greater at Forrester Island in SEA where numbers were increasing at Chirikof Island where numbers have declined substantially. Pup growth rates were also higher at 2 rookeries in the area of decline than at Forrester Island. Merrick et al. (1995) reported that pup masses from Forrester Island were less than those from the Gulf of Alaska which also does not appear seem with the undernutrition hypothesis.

A basic assumption in the interpretation of these comparative studies, which were conducted between 1992 and 1995, was that SSL populations in the 2 areas (Gulf of Alaska and Southeast Alaska) were continuing to behave as they had during the late 1970s and 1980s and were being affected by the same environmental factors. The validity of this assumption is open to question. Density dependent relationships of SSL and their environments have changed substantially over the past 20 years. SSL numbers in SEA have about doubled since 1979, whereas, as numbers in the central Gulf of Alaska have declined by about 80% during a similar period. Per capita food availability in both populations has probably changed substantially resulting in increased competition in SEA and decreased competition in the Gulf.

It may also be, as suggested by Merrick (1995), that only certain age classes such as juveniles are having difficulty obtaining adequate food and are incurring high rates of mortality. There could also be seasonal bottlenecks in food availability. There has been a very clear geographic component to the timing of the decline in the western stock which complicates the interpretation of comparative studies. The decline began in the early 1970s in the eastern Aleutian Islands (Braham et al. 1980) but did not appear to start until 1989 in the eastern Gulf of Alaska (NMFS 1995)

While the results of the studies reported here are equivocal in regard to their support of the undernutrition hypothesis of the western stock decline, there is evidence indicating that reduced food availability or changes in prey species composition were likely involved in the initial declines. The findings of Calkins and Goodwin (1988) that growth of SSL in the central Gulf of Alaska was reduced during the mid-1980s when compared to the mid-1970s is highly indicative of undernutrition. An examination of their age specific growth data showing reduced skeletal growth indicates that reduced growth first appeared in animals born around 1976 and 1977. Our findings of late pupping at Sugarloaf Island from 1978-1980 may indicate that nutrition was not have been optimal during that period.

Based on counts of nonpups (unpublished data, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518) at the Sugarloaf and Marmot Island rookeries, the decline likely began in the mid-1970s. A corresponding decrease in pup numbers appeared to lag behind the decline in nonpup numbers by several years which is indicative of high mortality rates of juveniles rather than adults (Merrick 1995, York 1994). The timing of the start of the SSL decline in the central Gulf of Alaska appears very similar to that of harbor seals (*Phoca vitulina*) on nearby Tugidak Island (Pitcher 1990). There is also substantial evidence that a major shift in the marine ecosystem of the Gulf of Alaska,. marked by increased water temperatures, occurred at about the same time (Francis and Hare 1995, Kerr 1992, Trenberth and Hurrell 1995) and resulted in marked changes in finfish and shellfish composition and abundance (J. E. Blackburn, pers. commun., Alaska Department of Fish and Game, 211 Mission Road, Kodiak, AK 99615-6399).

Factors that caused the decline are probably complex, possibly interrelated and the relative contribution of each factor may have varied over time. Besides nutrition, other factors have been discussed including; incidental take, shooting, disease, predation, pollutants and entanglement (Merrick 1995).

While nutrition was probably a major factor in the initial decline it is uncertain if it is still significant. SSL populations in the Gulf of Alaska are now at low levels, and it is possible that other mortality sources, such as predation by killer whales (*Orcinus orca)*, (Barret-Lennard et al. 1995) and sharks, plus human-caused mortality, such as directed killing and incidental take in fisheries, are sufficient to prevent or slow recovery.

RECOMMENDATIONS

1. Based on marked animal studies and genetics work, that SSL may have very low rates of emigration. Therefore population recovery in the depressed western stock will probably result from internal growth of this stock rather than emigration from SEA or some other area. To enhance recovery, every possible effort should be made to reduce or eliminate human-caused mortality. The possibility exists that much of the western stock is in a "predator pit" and will have difficulty recovering even if environmental conditions are favorable.

2. The resight phase of the Forrester Island marked animal study should continue until the females have reached sexual maturity to determine if significant emigration to the western subpopulation does occur. The results of this study will have direct application to the designation of an appropriate classification under the U. S. Endangered Species Act for SEA SSL and to their management.

3. Consideration should be given as to whether the current classification of "threatened" is appropriate for SEA SSL in light of their current population status.

4. Population monitoring through counts of pups and nonpups should continue. Research should be conducted to develop a less invasive method for counting pups. It will probably be more difficult to detect positive growth than it was to detect the decline as rates of change will likely be much smaller and our population assessment techniques are not particularly sensitive.

5. Pupping chronology data should continue to be collected at Forrester and Sugarloaf Islands. When the opportunity is available these data should be collected at additional rookeries.

6. The feasibility of evaluating historical trends in SSL abundance by determining the relative abundance of hairs in sediment core samples taken near rookeries should be investigated. This has the potential to determine if similar declines have occurred in the past.

7. The potential of pollutants as a factor in the decline should be investigated by compiling all information and literature references associated with pollutant loads of Alaskan marine mammals and synthesizing this information. This is particularly pertinent because of findings of surprisingly high levels of DDT metabolites and PCBs in western Aleutian Island sea otters (Bacon et al. 1993). SSL may be particularly vulnerable to pollutants as they have extended lactation and pollutants could be concentrated and transferred from the female to offspring through milk.

8. SSL data collected in the 1970s and 1980s should be reexamined in light of emerging evidence of a major ecosystem shift, concurrent with the beginning of the decline, in the Gulf of Alaska.

9. Managers should consider, based on the movements of SSL females with pups on rookeries, the prohibition of commercial fishing within 20 nautical miles of rookeries in SEA during summer months. An area north of the Forrester Island complex was heavily used and should be considered for protective status. This would be particularly relevant if the SEA subpopulation begins showing indications of food stress.

10. Development of improved techniques for immobilizing sea lions continues to be a high priority. Testing and development of new drugs for immobilizing SSL should continue.

11. Much of the the work has focused on adult females and pups. Little is known about juvenile sea lions even though there is reason to believe this segment of the population has a high mortality rate. Juveniles are difficult to capture. Capture technique development for juveniles should continue.

12. If it is decided to pursue research into the use of foraging behavior as a measure of changes in prey availability, it should be determined which aspects of behavior are the most sensitive and quantifiable indicators. The summary nature of the dive data, as collected by SDRs, limits its utility. Conventional TDRs, perhaps in the form of reconfigured SDRs, may be more useful.

13. The concept of using recent or current comparative studies of SSL from SEA and the western stock to test hypotheses pertaining to the cause(s) of the decline

should be reevaluated. There is a high probability the relative contributions of the factors involved in the original decline have changed due to either/or density dependent changes in both populations and environmental changes.

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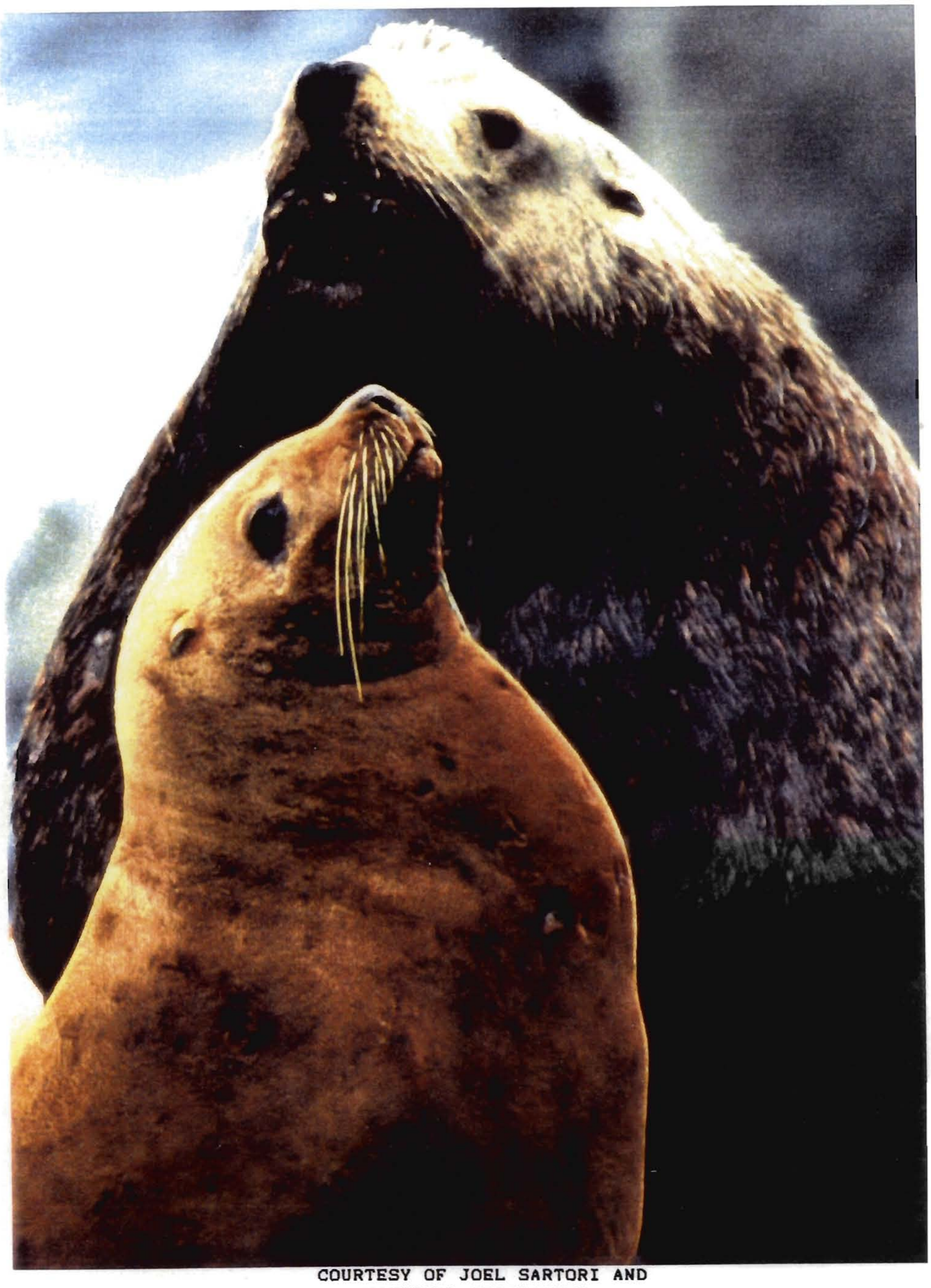

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