Steller Sea Lion Recovery Investigations in Alaska, 1995-1996

Contributors

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Alaska Department of Fish and Game Division of Wildlife Conservation NOAA Contract Report Contract NA57FX0256 August 1997 Steller Sea Lion Recovery Investigations in Alaska, 1995-1996

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ABSTRACT

The worldwide population of Steller sea lions (SSLs) has been divided into two stocks based on several biological factors, including differences in mitochondrial DNA. These include a eastern and western stock with a division at Cape Suckling, Alaska (144° west longitude). The western stock was recently (May 1997) reclassified as "endangered" under the U.S. Endangered Species Act while the eastern stock retained a "threatened" classification. Since 1992, the Alaska Department of Fish & Game (ADF&G) and National Marine Fisheries Service (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 high density 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.

We used models that controlled for the effects of the environmental covariates date, time and tide at the time of the survey to analyze trends in numbers of Steller sea lions counted in Southeast Alaska between 1979 and 1996. Sea lions numbers increased by an average of 6.2% per year between 1979 and 1996 based on counts of pups on rookeries. However, numbers appeared stable between 1989 and 1996 based on counts of both pup and nonpup numbers. We estimated the Southeast Alaska breeding population of Steller sea lions at 16,700 (including pups), a level that is probably near the highest in recorded history.

A total of 813 SSL pups were marked at the Forrester Island rookery in Southeast Alaska in 1994 and 1995. Resightings of 188 individual animals have been made at sites ranging from Seattle, WA to Jude Island in the western Gulf of Alaska. As marked females become sexually mature it will be important to search rookeries in the western stock to determine rates of immigration.

Reproductive behaviors of SSLs were studied at the Forrester Island rookery in the eastern stock and the Sugarloaf Island rookery in the western stock during 1994 and 1995 in order to compare behaviors that might be affected by nutritional status. Both perinatal periods and trips to sea were shorter at Sugarloaf Island in the area of decline. There were differences between years at both sites in length of perinatal period, trips to sea and visits ashore.

Data describing haulout patterns and activity budgets were collected on adult and immature (1-3 yrs.) sea lions during winter (January to April) 1996 at Timbered Island, Alaska. Behaviors 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: 30 minute interval instantaneous scan sampling and 15 minute interval focal animal sampling. Activity budgets showed immature animals spend the majority of on-shore time resting (57%), followed by suckling (14%). Male pups spend more time involved in play than female pups, while females are more likely to rest. Male pups suckle significantly longer per bout than females. No diurnal haulout pattern was observed. There was 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 behaviourally or physiologically weaned 3-5 months prior to breeding.

Nutritional stress is a leading hypothesis behind the decline in numbers of Steller sea lions in the Gulf of Alaska, Aleutian Islands and Bering Sea. To evaluate this hypothesis, we compared body growth of female Steller sea lions 1.0-13.9 yrs of age collected in the Gulf of Alaska during two time periods, 1975-1978 just prior to or early in the decline and 1985-1986 when the decline was well established. We found that growth, as measured by standard length, axillary girth, and mass, was reduced during the 1980s supporting the undernutrition hypothesis. We also found a suggestion of reduced growth in our 1970s and 1980s samples when compared to a collection of Steller sea lions obtained from the Gulf of Alaska in 1958. However, no direct link has been demonstrated between undernutrition and the actual decline in numbers.

Blubber samples from 24 adult female SSLs from Southeast Alaska were analyzed for chlorinated hydrocarbons and DDTs. Total PCB and DDT concentrations ranged from 630-9800 and 400-820 ng/g wet weight, respectively. Both PCB and DDT levels were higher for animals sampled in 1994 than those sampled in 1993.

In and under-water behavioral observations and capture technique development activities were conducted. A large, floating capture net was tested and did not prove effective as designed. It appears feasible, based on underwater observation, to directly capture younger animals using small nets or lines.

Foraging behavior of juvenile SSLs was studied using satellite linked time-depth recorders. Movements, duration of foraging trips and diving behavior of young SSLs varied considerably and was probably related to physical and behavioral maturity (age) and especially nursing status. Larger samples will be required to detect differences, if they occur, in foraging behavior between juveniles in Southeast Alaska and the Gulf of Alaska.

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females show a considerable degree of breeding fidelity to their site of birth or to near-by areas (Calkins and Pitcher 1982, Loughlin in press).

A recent analysis of mitochondrial DNA indicated that the worldwide population of SSLs is comprised of at least two 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, population dynamics and morphology studies support this idea (Loughlin in press).

In Alaska, the western population of SSLs 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 documented 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 overall decline has continued since 1989 but numbers may have stabilized in the eastern Aleutian Islands and western Gulf of Alaska (NMFS 1995, NMFS unpublished data). In contrast, the Alaskan portion of the eastern Steller sea lion stock (Southeast Alaska) is probably near its highest level of this century.

In 1990 the 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 1997, because of the continuing decline, the western stock was classified as endangered (U. S. Federal Register 62:24345-24355) while the eastern stock retained a threatened classification.

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. In 1992 NMFS approved a recovery plan prepared by the recovery team 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 to be designated as critical habitat.

Since 1992, ADF&G has been the recipient of Congressional appropriations, dedicated to investigating the decline with the goals of understanding the cause(s) of the decline and recommending management actions to promote population recovery. Congressional funding has continued through FY 97 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 whether abundance and composition of prey have changed and how this may have affected population dynamics.

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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. The Southeast Alaska 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. This approach proposes to compare a number of population characteristics and to identify those that may be different between 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, from this project. 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, the University of California-Santa Cruz and Colorado State University.

In this report we present findings of research conducted by ADF&G, and by major cooperators, during contract year 1995-96. In some instances more recent data are included when they fits logically with the analyses of earlier work. This report is organized into chapters based on research categories (Table 1). 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	Dispersal and Rookery Fidelity
Three	Behavioral Comparisons
Four	Growth and Condition
Five	Contaminants and Diseases
Six	Capture Technique Development
Seven	Movements, Habitat Use and At Sea Behavior

Seven 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.

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

- Lee, J. S., S. Tanabe, H. Umino, R. Tatsukawa, T. R. Loughlin and D. G. Calkins. 1996. Persistent organochlorines in Steller sea lions (*Eumetopias jubatus*) from the Gulf of Alaska and the Bering Sea, 1976-1981. Marine Pollution Bulletin 32:535-544.
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Steller Sea Lion Distribution and Abundance

STELLER SEA LION STATUS AND TREND IN SOUTHEAST ALASKA

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ABSTRACT

Steller sea lion numbers in the United States declined by about 75% over the past 30 years and are now classified, under the U.S. Endangered Species Act, as "threatened" in the eastern portion of their range and as "endangered" in the western portion. We used models that controlled for the effects of date, time and tide at the time of the survey to analyze trends in numbers of Steller sea lions counted in Southeast Alaska between 1979 and 1996. Sea lions numbers increased by an average of 6.2% per year between 1979 and 1996 based on counts of pups on rookeries. However, numbers appeared stable between 1989 and 1996 based on counts of both pup and nonpups. We estimated the Southeast Alaska breeding population of Steller sea lions of all ages at 16,700, a level that is probably near the highest in recorded history.

Key words: Steller sea lion, <u>Eumetopias</u> jubatus, Southeast Alaska, surveys, trends, abundance, population, environmental covariate models.

The United States population of Steller sea lions (<u>Eumetopias jubatus</u>) (SSLs) has declined to less than 50,000 nonpups over the past 30+ years, a reduction of about 75%. In response to this decline SSLs were classified under the U.S. Endangered Species Act as endangered in the western portion of their range and threatened in the eastern portion (U.S. Federal Register 62:24345-24355). In Alaska, which at one time contained about 74% of the worldwide population (Loughlin et al. 1992), numbers have declined by over 75%.

The National Marine Fisheries Service has recently divided the worldwide population of SSLs into two stocks with an east-west division near Cape Suckling in Alaska (144° west longitude) (U. S. Federal Register 62:24345-24355). This action was based on genetic information (Bickham et al. 1996) as well as population dynamics, the results of marked animal studies, and morphological comparisons (Loughlin in press). This division separates SSLs in Southeast Alaska (SEA) from the declining western stock.

Knowledge of population status and trend information from SEA is meaningful in the context of determination of appropriate classifications under the Endangered Species Act. This information is also useful, 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.

n an attempt to increase the accuracy of our trend analyses we examined and, when appropriate, controlled for the effects of date, time of day and tide on the number of sea lions counted during surveys. In this paper we report on recent trends in numbers of SSLs in SEA, present a new approach in the analysis of SSL populations trends and discuss options for future surveys.

METHODS

Beginning in 1979, systematic counts of SSLs were periodically made 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; dates of pup counts ranged from 23 June - 21 July. Pups were counted by herding nonpups (animals 1-year old and older) into the water and then walking through the rookery and counting the pups. Nonpups were counted on rookeries and haulouts from 35mm color transparencies taken during aerial surveys during the breeding period; survey dates ranged from 10 June - 19 July.

Counts of SSLs on rookeries and haulouts, dating back to the early 1900s, were obtained from the literature. These counts were of variable quality as they were not made with standardized techniques in regard to date and method of counting.

The standardized counts of pups on rookeries (1979-1996) and nonpups on rookeries and haulouts (1989-1996) during the breeding season were used for trend analyses. Counts of nonpups made prior to 1989 (1979, 1982) were excluded from these analyses because they were conducted substantially later than the more recent counts confounding the effects of population change over time and visibility change due to late counts which could not be adequately addressed by the covariate models. Ten summer haulout sites and the three SEA rookeries were selected as trend index sites for nonpups (Figure 1). Haulout sites were included as trend index sites if they were used consistently by sea lions during the

breeding season and had been surveyed a minimum of five times. In June 1996, 83% of the total number of SSLs counted in SEA were found at the trend index rookery and haulout sites. Up to eight replicate counts were made at some sites during some years. Because an exploratory analysis of the count data suggested the possibility of reduced population growth after 1989, we also conducted trend analyses of pup numbers from 1989-1996.

Variation in the counts of SSLs used for estimating population trends result from both changes in abundance and from factors that affect the proportion of the population visible during surveys. Rather than assume that a constant proportion of the sea lions were seen on every survey, we modeled the counting process as a function of environmental covariates. We estimated trends using overdispersed multinomial models (Link and Sauer 1997). With this method, the counts (Yii , i indicates site and j indicates replicate) are assumed to be overdispersed Poisson random variables (i.e. negative binomial) with expected values (μ_i) that have the relationship $\ln(\mu_i) = h(i) * g_i(x) * f_i(t)$. In this equation h(i), site effects, are treated as a multiplicative nuisance parameter, $g_i(x)$ is a loglinear function of the environmental covariables (x) that are unrelated to population change and $f_i(t)$ is the population trajectory with t indicating year. Conditioning on the total counts for each site yields a Dirichlet compound multinomial. A quasi-likelihood approximation to the Dirichlet compound multinomial likelihood, produced with an iteratively reweighted Newton-Raphson optimization algorithm, was used to estimate model parameters on which the trend estimate is based (Link and Sauer 1997, W. A. Link, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD, personal Standard errors were based on an approximated information matrix. Population communication). trajectory can be thought of as a smoothed and scaled version of the actual population sizes across years. Because trajectories were not always linear (i.e., the rate of change varies through time) on the log scale, we defined trend as the geometric mean rate of change over the interval of interest. Trend is therefore a single-number summary of the average change in the trajectory. The advantages of this approach are that counts are adjusted for the effects of the environmental covariates (i.e., overdispersion) simultaneously with the estimation of the population trajectory and trend, and that variability not accounted for by the covariates can differ among sites.

Covariables used in the analyses of nonpup numbers included date, time of day, tide height at the time of the survey and time relative to low tide. Quadratic terms (date and time) and two-way interactions (date-tide, time-tide height and time-time relative to low tide) were also included. Because of sample size constraints, especially for sites without within-year replicate counts, quadratic covariates and interactions were not included for sites with fewer than 10 survey counts. In the analyses of pup numbers, only date and date² were used as covariates. SSL pups are constrained to the rookery during the period when counts were made, therefore, neither time of day nor stage or height of tide should affect their countability. Models with both linear and quadratic population trajectories (log scale) were tested. The combination of covariates and degree of polynomial used in the models to produce the trajectory and trend estimates for each site were determined by starting with a model containing all covariates and a quadratic trajectory. Unnecessary covariates or the quadratic time parameter were then eliminated one at a time based on likelihood ratio tests (P>0.05). Final models, on which trend estimates were based, included only significant (P<0.05) covariates and the quadratic time parameter (if necessary). The linear time parameter was retained in all models.

We estimated trends separately for each site because we suspected that trends might differ among sites. The trend for each site was estimated using either linear or quadratic models with differing combinations of covariates for each site. This is plausible because both physical structure of sites and

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sea lion sex and age class utilization of sites varied which could result in some covariates affecting use at some sites more than at others. Site trend estimates were combined into composite estimates by first using empirical Bayes methods (Morris 1983) to reduce the influence of imprecise site trend estimates and then producing a weighted average of the empirical Bayes adjusted estimates. Weights were based on the average count for each site under the premise that the trends from sites with many animals should have a larger influence on the trend estimate for the entire population than should trend estimates from sites with fewer sea lions.

Adjusted indices of population size were based on the residual method of Sauer and Geissler (1990). For each survey site, residuals were computed for each count (observed count - predicted count). The average residuals for each year were summed across sites. These combined residuals were then added to the projected trend lines as an indication of the residual variation in the counts after the model had been fit.

We used pair-wise t-tests to determine if trends differed among sites and between pups and nonpups; overall tests of differences were based on comparing the P-values from the pairwise tests with a Bonferoni adjusted alpha-level (Milliken and Johnson 1984).

RESULTS

For counts of pups on rookeries, date entered into the covariate analysis only for the Hazy Islands rookery (Tables 1 and 2). For counts of nonpups on the 13 index sites, date was significant at 11 sites, time of day at 9 sites and tide at 12 sites (Table 3). The use of environmental covariates in trend models of changes in SSL population numbers reduced the negative bias associated with non-covariate trend estimates (Table 4), assuming the covariates were modeled correctly. Unexplained variation in the data was reduced greatly for most sites (Table 5).

SSL numbers increased in SEA between 1979 and 1996 as measured by counts of pups on the three rookeries combined (+6.2%/yr, P=0.0001) (Table 1, Fig. 2). While pup numbers increased at each individual rookery, Forrester Island had a lower rate of increase (+2.0%) than either Hazy Islands (+23.9%, P=0.0059) or White Sisters (+22.5%, P=0.0007) (Table 1).

For the period 1989-1996, pup numbers on the three rookeries combined were stable (+1.9%/yr, P=0.0894) (Table 2, Fig. 3). Pup numbers were stable on both Forrester Island (-1.0%/yr, P=0.4125), and Hazy Islands (+10.7%/yr, P=0.1561) and increased at White Sisters (+21.0%, P=0.0354).

For the period 1989-1996, nonpup numbers on all index sites combined were stable (+0.5%/yr, P=0.5685) although trends at individual sites varied substantially (Table 3, Fig. 4). Nonpup numbers were also stable on the combined rookery sites (+0.8%/yr, P=0.4861) and on the combined haulouts sites (-0.4%/yr, P=0.7514) (Table 3).

DISCUSSION

Covariate Analysis

Survey counts can be represented as $C = N^*P$, where C is the count, N is the actual population size and P is the probability of including an animal that is part of N in C (sighting probability). In trend analyses, we want to determine if and how N changes through time i.e., the population trajectory. With count data alone, we cannot estimate P directly but can model it as a function of environmental covariates. The objective of modeling is to produce a model complex enough to mimic the underlying phenomenon, in this case sighting probability, using as few parameters as possible. Models that are too simple (e.g., trend models without covariates when the covariates actually have an effect on counts) can produce biased estimates of other parameters, and hence biased estimates of trend (Burnham and Anderson 1992). Models that are too complex (e.g., contain unnecessary parameters) reduce precision (i.e., have larger estimated variances).

Another factor that complicates trend estimation is the potential confounding of population trends with the effects of environmental covariates on numbers of animals counted. Covariates that have a systematic pattern over the duration of surveys used to produce trends are confounded with time, making distinction between the effects of the covariate and true population changes over time (e.g., trend) difficult to separate. For example, if counts in early years are conducted late in the survey period and those in later years are conducted earlier in the survey period, changes in counts could not be unambiguously attributed to population change or to seasonal changes in visibility. The covariates used in our analyses (date, time of survey, tide) change over a short time interval. This, along with replicate within-year counts, reduces the problems of confounding. Not all survey sites had replicate counts and the number of replicates differed among sites, so the potential effects of this problem varied among sites. The true functional relationship of these continuous covariates with number of sea lions counted is unknown, and changes in the functions can result in large changes in estimates. Because there was no obvious "correct" functional form for the covariates, we modeled covariates in a similar manner to that used to model time change (linear on the natural log scale). However, we also allowed quadratic terms for some covariates and interactions for some combinations. This allowed a "wider array of choices" of covariate forms for the model selection procedure to "choose" from. However, this did not guarantee that the range of functional forms includes one that mimics the true relationship.

Lurking variables are factors that cause changes in counts that are not associated with changes in populations (Barker and Sauer 1992). The covariates we used, if not included in the model but actually influencing counts, would be lurking variables and their effect could be mistaken for population change. Similarly, lurking variables can still be a problem because measurements of all potential covariates are not available and sample sizes would preclude inclusion of extremely large pools of covariates. One common symptom of lurking variables is selection of very complex models, especially those involving interactions. The model building and selection procedures account for important variables not included by using complex functions of the variables that are included. One potential lurking variable in our pup count data set could be summer storms which could have washed pups off of rookeries prior to our counts.

These factors necessitate caution in interpreting the effects of covariates on counts. The covariates selected by the likelihood ratio tests are highly dependent on which covariates are available and the choices of functional forms. Also, the effects of covariates likely differ among survey sites, making generalization difficult.

Pup Counts

Pups are generally constrained to the rookery during the survey period, therefore time of day and tide would not be expected to influence the numbers counted and were not used in our analyses. Only

11-11linear and quadratic effects of date were used as covariates. Neither of the date covariates were included in the best models for the Forrester Island or White Sisters rookeries indicating that past counts were made during a range of dates when pup numbers were relatively stable. Date and date² were included in the best models for Hazy Islands. We have no explanation for why date covariates improved the model fit at Hazy Island but not at the other rookeries as counts were made on similar dates.

Counts of pups on rookeries may generally be a better measure of population trends than counts of nonpups (Calkins and Pitcher 1982, Berkson and DeMaster 1985). Nonpups spend variable portions of time at sea while pups are limited to the rookeries during the census period allowing total counts. Environmental covariates do not appear to influence numbers of pups counted to the degree they affect the numbers of nonpups counted, therefore trend analysis is more straightforward. Consequently, the detection probability (the probability that an animal belonging to a site "population" will be counted during a single survey) is a less complex function of fewer covariables. Trend analysis is simpler because fewer assumptions about the relationships between covariates and detection are required. In addition, trend estimates based on pup counts are less variable than those based on nonpups. The 1989-96 trend **CV** for pups was 53% versus 174% for nonpups.

Changes in birth rates and population sex and age structure over time would complicate the tracking of populations with counts of pups (Berkson and DeMaster 1985). Another potential problem with using pup counts to track population trends is the possibility that storms may wash pups off rookeries before counts are made during some years. Fluctuating environmental conditions may affect birth rates and thus the number of pups counted during some years (Lunn and Boyd 1993) to a greater degree than for animals older than pups.

Nonpup Counts

The fact that nonpup SSLs spend substantial amounts of time at sea away from the rookeries and haulouts is reflected in the more complex model fits for the count data (Table 3.). Use of environmental covariate modeling for aerial survey data of nonpups appears particularly appropriate because in practice it is nearly impossible to survey each site during the optimum window in regard to date, time of day and stage of tide because of the large geographic area to be covered and the fact that the environmental covariates affect sites differently. In our analysis, covariate modeling controlled for a negative bias in trend estimates (Table 4) and substantially reduced unexplained variance at individual sites (Table 5).

Aerial surveys of nonpups have generally been designed according to the recommendations of Withrow (1982) in regard to date and time of survey (Merrick et al. 1987, Loughlin et al. 1992). Based on his study at Ugamak Island in the eastern Aleutian Islands, he found that date and time of day were significant factors affecting numbers of animals counted and recommended that surveys be conducted from 18 June to 16 July between 1000 and 1800 hours, regardless of tidal stage. These recommendations have been broadly applied under the assumption that the breeding season was synchronous throughout the SSL range (Pitcher and Calkins 1981, Loughlin et al. 1992, Merrick et al. 1995). In practice, actual survey dates and times have not always fallen within the recommended windows. It has since been found that pupping dates differ between geographic areas (Pitcher et al. 1996). Tide was not found to be a significant variable affecting numbers of SSLs counted at Ugamak Island (Withrow 1982), however at some other sites the haulout cycle is strongly influenced by tide (Kastelein and Weltz 1990). Tide was a significant covariate in our analysis of nonpups counts and entered into the preferred model at 12 of 13 sites in SEA. This difference may be explained by the fact that the mean tidal range in the area of Ugamak Island is small (100 cm) compared to many rookery and haulout sites in SEA (e.g., 265 cm at Forrester Island). Also at some sites, tide may be a significant covariate only at high sea lion densities when crowding becomes an issue. These factors indicate that a

survey window, considering only date and time of day, may not be appropriate throughout the SSL range and that tide should be considered at some sites. Our findings indicate that the accuracy and precision of trend estimates of nonpup SSLs, at least in SEA, were improved by controlling for date, time and tide (Tables 4 and 5). However, the importance of individual covariates differed by site.

Surveys of nonpups at rookeries, rather than rookeries and haulouts combined, may be adequate for monitoring population trends if resources are limited. Similar trends were derived from surveys of both rookeries and the 13 index sites combined (P=0.861) (Tables 2 and 3). Rookeries contain the breeding female population critical for population growth (York et al. 1996). Also rookeries contain the majority of nonpup sea lions counted during aerial surveys of SEA (63% of the total counted on the trend sites in 1996). Rookeries are probably more representative of the "local" SEA breeding population as young SSLs range widely (Calkins and Pitcher 1982, NMFS 1995, Calkins and Pitcher 1996), and at the time of the surveys, young animals from the south and west are present in SEA and are probably found more frequently on haulouts than rookeries.

Status of Steller Sea Lions in Southeast Alaska

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There was an increasing trend in pup numbers in SEA between 1979 and 1996 (Tables 1). Both Hazy Islands and White Sisters became established as rookeries during this period. However, it now appears that between 1989 and 1996 both pup and nonpup numbers stabilized (Tables 2 and 3), particularly at the large Forrester Island rookery. One explanation could be that the decline that occurred in the west has spread to the east. A plausible alternative hypothesis is a density dependent response. Numbers of pups on rookeries doubled between 1979 and 1989. Either food or space on rookeries may have become limiting with increased numbers, particularly on the large Forrester Island rookery. Numbers of pups continued to increase (Table 2) at White Sisters, the newest and smallest rookery in SEA.

Only sketchy data are available (Table 6) to evaluate earlier population trends. Observations made during the first half of the century are suggestive of a much smaller population (Rowley 1929, Imler and Sarber 1948). However, counts made in the 1950s and 1960s (Mathisen and Lopp 1962, Bigg 1985) indicated the presence of a substantial population although probably somewhat smaller than that of 1979-1996.

An estimate of the total SSL breeding population including pups in SEA can be made from the total number of pups counted on the three rookeries. Pitcher and Calkins (1982) calculated the total number of animals in the Gulf of Alaska was 4.5 x the number of pups born. This was based on estimates of the sex and age structure of the population and birth rates. This method likely produces a conservative estimate, as some pups are born after the counts are completed and some have died and been scavenged or washed off the rookery before the counts are made. We estimate, using the 1996 count of 3,714 pups, that the SEA breeding population is about 16,700 animals of all ages. This assumes that SSL populations in SEA and the Gulf of Alaska (at the time the estimates of population composition and birth rates were made) had similar sex and age structures and birth rates. It should be recognized that at any given time sea lions from this subpopulation (particularly young animals) are scattered from at least the Pacific Northwest to the Gulf of Alaska and Aleutian Islands, and that animals born in these other areas also spend time in SEA. We conclude, based on our data and historical records, the SEA SSL breeding population is probably near its highest level in recorded history.

Population trends of SSLs in SEA since 1979 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 stocks, including physical condition, juvenile mortality rates, physiology, prey use, behavior, foraging effort and diseases in an attempt to explain the decline. It will be important to continue monitoring population numbers in light of the severe decline that has occurred in the adjoining western subpopulation and because population growth in SEA appears to have stabilized over the past few years.

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Table 1. Trends	in numbers of pu	ips counted o	n Steller	sea lion	rookeries	in Southeast	Alaska,	1979-
1996.								
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Rookery Site	1996	n	Model	Trend	Approximate	P (Ho: trend = 0)
	Count	•		(%/yr)	95% CI	
Forrester Island	2764	.11	·L	+2.0	+0.2 - +3.8	0.0311
Hazy Islands	768	7	Q,1,2	+23.9	+3.3 - +44.5	0.0325
White Sisters ²	182	7	L	+22.5	+9.5 - +35.6	0.0068
Combined	3714		Weighted Average	+6.2	+3.5 - +9.0	0.0001
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¹Model: L=linear, Q=quadratic, 1=date, 2=date² ²1982-1996

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Rookery Site	1996	n	Model	Trend (%/yr)	Approximate	P (Ho: trend = 0)
5	Count		4 		95% CI	
Forrester Island	2764	6	L	-1.0	-4.0 - +2.0	0.4125
Hazy Islands	768	6	Q,1,2	+10.7	-23.2 - +44.6	0.1561
White Sisters ²	182	• 6	L	+21.0	+2.3 - +39.7	0.0354
Combined	3714		Weighted Average	+1.9	-0.4 - +4.1	0.0894

Table 2. Trends in numbers of pups counted on Steller sea lion rookeries in Southeast Alaska, 1989-1996.

¹=Model: L=linear, Q=quadratic, 1=date, 2=date² ²=1990-1996

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Site #	Site	1996	n	Model ²	Trend	Approximate	P(HO: trend = 0)
		Count			(%/yr)	95% CI	
1	Biali Rocks	342	15	Q,1,2,3,5,7	-16.1	-20.911.2	- 0.0001
2	Cape Addington	756	6	Q,1,3	-1.3	-34.3 - +31.6	0.7005
3	Cape Cross	67	6	Q,1,3	-15.1	-34.2 - +4.1	0.0776
4	Cape Ommaney	332	15	L,1,2,3,5,6,7,8	-9.4	-24.0 - +5.3	0.1676
5	Coronation Island	64	15	Q,1,2,3,5,8	-6.3	-22.9 - +10.3	0.3980
6	Forrester Complex ¹	3551	7	Q,2,3,4	-2.8	-17.7 - +12.2	0.2371
7	Gran Point	276	5	L,1,4	+39.4	-2.7 - +81.5	0.0534
8	Graves Rock	475	7	Q,1,2,3	+1.7	-1.4 - +4.8	0.1426
9	Harbor Point	243	6	Q,2,4	+28.1	-70.5 - +126.7	0.1716
10	Hazy Islands ¹	1759	14	Q,1,2,3,4,5,6,7,8	+8.7	-4.4 - +21.8	0.1244
11	Jacob Rock	52	15	L,1	+15.3	-14.7 - +45.4	0.2848
12	Timbered Island	210	9	Q,1,2,3	+15.9	+1.8 - +30.1	0.0373
13	White Sisters ¹	894	14	L,1,2,4,6	+4.6	+1.7 - +7.5	0.0063
	All Rookeries	6204		Weighted Average	+0.8	-1.5 - +3.1	0.4861
	All Haulouts	2817		Weighted Average	-0.4	-3.1 - +2.2	0.7513
	All Sites Combined	9021		Weighted Average	+0.5	-1.3 - +2.4	0.5685

Table 3. Steller sea lion nonpup population trends at rookeries and haulouts in Southeast Alaska, 1989-1996.

¹=Rookery

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²=Model: L=linear, Q=quadratic, 1=date, 2= time, 3= tide height, 4= time relative to low tide, 5= date², 6= time², 7=date*tide height, 8=time*tide height, 9=time*time relative to low tide Table 4. Effects of using environmental covariates when estimating Steller sea lion population trends. Note that all biases are negative if covariates are not used.

Age Class	Trend With Covariates (%/yr)	Standard Error	Trend Without Covariates (%/yr)	Standard Error	Bias If Covariates Not Used (%/yr)
Nonpups (1989-96)					
Rookeries	0.77	1.07	0.18	0.95	-0.59
Haulouts	-0.42	1.32	-4.17	1.98	-3.57
All Sites	0.52	0.91	-1.58	1.18	-0.66
Pups (1989-96)					
Hazy Island	10.67	2.67	7.83	3.49	-2.84
All Rookeries	1.87	0.98	1.36	1.06	-0.51

Table 5. Variation in Steller sea lion counts explained (r^2) by models with and without environmental covariates.

	Nonpups (1989-96)		Pups (1989-96)	
Site	With Covariates	Without Covariates	With Covariates	Without Covariates
Biali Rocks	0.951	0.622		
Cape Addington	0.923	0.409		
Cape Cross	0.935	0.483		
Cape Ommaney	0.870	0.046		
Coronation Island	0.056	0.031		•.
Forrester Complex ¹	0.959	0.205	0.194	0.194,
Gran Point	0.999	0.335		
Graves Rock	0.999	0.005		
Harbor Point	0.681	0.581		
Hazy Islands ¹	0.929	0.208	0.971	0.786
Jacob Rock	0.079	0.015		
Timbered Island	0.989	0.367		, 、
White Sisters ¹	0.886	0.004	0.812	0.8121

¹ Covariates did not improve model for pup counts at this site.

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Year	Site	Count	Source
pre-1929	Cape Addington	200-300	Rowley 1929
pre-1929	Forrester Island	50-100	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

Table 6. Historical counts of Steller sea lions in Southeast Alaska.

List of Figures

Figure 1. Locations of Steller sea lion index trend sites in Southeast Alaska. Site names and numbers are in Table 3. Star = rookery, Circle = haulout.

Figure 2. Trend in number of Steller sea lion pups counted on Southeast Alaska rookeries, 1979-1996. Observed and adjusted counts are included for those years when counts were obtained at all rookeries.

Figure 3. Trend in numbers of Steller sea lion pups counted on Southeast Alaska rookeries, 1989-1996. Observed and adjusted counts are included for those years when counts were obtained at all rookeries.

Figure 4. Trend in numbers of Steller sea lion nonpups counted on 13 index rookery and haulout sites in Southeast Alaska, 1989-1996.







Figure 2. Trend in numbers of Steller sea lion pups counted on Southeast Alaska rookeries, 1979-96. Observed and adjusted counts are included for those years when counts were



Figure 3. Trend in numbers of Steller sea lion pups counted on Southeast Alaska rookeries,

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Figure 4. Trend in numbers of Steller sea lion nonpups counted on 13 index rookeries and haulout sites in Southeast Alaska, 1989-1996.

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CHAPTER TWO

Steller Sea Lion Dispersal and Rookery Fidelity

Steller Sea Lion Movements, Emigration and Survival

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The worldwide population of Steller sea lions (SSLs) is currently recognized as being comprised of two stocks with an east-west division at Cape Suckling (144 degrees W longitude) in Alaska (Hill et al. 1996). This division was based on genetic information (Bickham et al. 1996) as well as on population dynamics, marked animal studies and morphological comparisons (Loughlin in press).

SSL numbers have declined precipitously over the past 30 years (Loughlin et al. 1992) in the western stock which is now classified as endangered under the U. S. Endangered Species Act. However in Southeast Alaska (SEA) SSL numbers are near the highest level in recorded history (see manuscript on SSL status and trend in SEA in this report). The eastern stock, which includes SEA, is classified as threatened.

A potential mechanism in aiding the rebuilding of the western stock is the emigration of animals from SEA. SSLs are highly mobile with movements of many hundreds and even thousands of kilometers documented (Calkins 1986, Calkins and Pitcher 1982, NMFS 1995). Most current information suggests 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 may occur from an area of high density (SEA) into an adjoining area where numbers have been severely reduced (western stock). Knowledge of the extent of emigration of SEA SSLs into the western stock is important for evaluating the division of the worldwide SSL population into two stocks. It also has important implications in evaluating stock classifications under the Endangered Species Act and in evaluating the potential rate of recovery of the western stock.

This study was designed to evaluate the extent of emigration of SEA SSLs into the western stock. Secondarily, data on range of movements and survivorship rates will be obtained.

Methods

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SSL pups were marked with individually recognizable hot iron brands at the Forrester Island rookery in SEA in late June 1994 and 1995. Allflex tags were also applied to the rear margins of the front flippers in 1995. 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, directed searches will be

made for the Forrester Island marked animals at all potential breeding rookeries, particularly those in the western stock, to estimate rates of emigration.

Survivorship rates will be estimated 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-year and between year resightings will be used in the "robust design" to help account for temporary emigration and nonconstant resighting probabilities (Pollock et. al. 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 188 individual marked animals have been made at sites ranging from Seattle, Washington to Jude Island (Shumagin Islands) in Alaska (Figure 1, Appendix 1).

Discussion

The observations made to date support earlier findings that young SSLs disperse widely (Calkins and Pitcher 1982, NMFS 1995). We hypothesize that SSLs from SEA will not play a significant role in the rebuilding of the western stock. This is based on earlier observations of substantial rookery fidelity by breeding females (Calkins and Pitcher 1982, Loughlin in press) as well as genetic findings. Bickham et al. (1996) found low levels of interchange of mitochondrial DNA between the eastern and western stocks. While they considered, from a genetics perspective, 9.5 female migrants per generation to be high; from a demographic viewpoint it would not be significant unless the western stock neared extinction.

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 estimated from these data.

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Figure 1. Resighting locations of Steller sea lions marked as pups at Forrester Island, Southeast Alaska during during 1994 and 1995.

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Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
201	f	1.8	1995	100	Beniamin I.	58.56	134.91
201	r F	2.6	1997	10	Beniamin I.	58.56	134.91
201	m.	13	1995	307	Sail I.	57.35	133.72
217	m	1.3	1995	307	Sail I.	57.35	133.72
217	m	1	1995	170	Lowrie I.	54.86	133.54
220	m	1 1	1995	198	Lowrie I.	54.86	133.54
220	m	1.1	1995	199	Lowrie I.	54.86	133.54
220	m	11	1995	204	Lowrie I.	54.86	133.54
220	f	. 1.2	1995	218	Gran Pt.	59.13	135.24
221	۰ f	1.2	1995	307	Sail I.	57.35	133.72
221	f	1.0	1996	33	Timbered I.	55.7	133.8
221	f	1.1	1995	218	Gran Pt.	59.13	135.24
221	f	2	1995	163	Gran Pt.	59.13	135.24
221	f	17	1996	33	Timbered I.	55.7	133.8
222	m	1.7	1996	218	Timbered I.	55.7	133.8
223	m	1.2	1996	89	Timbered I.	55.7	133.8
223	 m		1996	201	Timbered I.	55.7	133.8
225	f	∩⊿ [_]	1994	327	Lowrie I.	54.86	133.54
225	m	16	1996	14	Timbered I.	55.7	133.8
220.	m	1.8	1996	89	Timbered I.	55.7	133.8
220	m	1.0	1995	206	W Brother I	57.3	133.84
221	- 111 - F	1	1995	170	Lowrie I	54.86	133 54
230	' f	11	1995	199		54 86	133.54
230	۱ ۴	21	1996	183	Timbered I	55 7	133.8
230	۱ F	2.1 1 1	1996	214	Cape Addington	55 44	133 82
202	ı F	21	1006	209	Timbered I	55 7	133.8
232	т т	11	1005	198	Poundstone Rock	58.1	134.9
234 -	 m	0.4	1994	326		54 86	133 54
241	m	1	100-	152	Lowrie I	54.86	133 54
241		4 ·	1005	156	Lowrie I	54 86	133 54
241	- III 	1 1	1005	100	Lowrie 1	54 86	133 54
241	m	1.1	1006	120	Sunset Pt	57 5	133 5
241		1.9	1006	120	Timbered I	55.7	133.8
241		2	1990	160		54.86	133 54
242		27	1007	40	Marmot I	58 14	151 47
244	- III 	17	1006	- 	Benjamin I	58 56	134 91
240	- III 	1.7	1990	208		54.2	133 08
200	- III 	1.1	1995	188	Eich I	59 53	147.2
201	m	1.1	1005	180	Fish 1	50 53	147.2
201		1.1	1990	105	Gran Pt	50 13	135.24
201		1 1	1990	100	Gran Pt	50 12	135.24
201	(I) ~~	1.1	1000	100 56	Gran Pt	50 12	125.24
201	m	1.0	1990	151	Gran Pt.	59.15	130.24
201	m 2	2	1990	101		09.10 54 96	133.24
201	T	0.4	1004	322	Lowne I.	54.00	133.04
200	m 4	U.4 1 2	1994	322	LUWINE I.	57 25	122 72
209	T s	. I.J 4 0	1990	307 100	Sall I. Sail I	57.50	122.72
209	ا ء	1.0	1000	100	Gran Pt	50 12	125.72
209	T	2	1990	103	Gian PL	29.13	133.24

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

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Appendix I continued

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Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
762	f	17	1006	34	Timbered I	55.7	133.8
202	.i F	1.7 2 1	1006	194	Timbered I	55.7	133.8
202	- F	04	1994	323	Lowrie I	54.86	133.54
207	ı F	13	1995	281	S Marble I.	58.6	136
200	ı f	1.0	1995	141	Lowrie L	54.86	133.54
203	m	1 1	1995	187	Fish I	59.53	147.2
271	- 111 - F	1.1	1006	00	Timbered I	55.7	133.8
212	, m	1.0	1006	84	Horn Cliffs	56 85	132 79
2/0	111 F	0.4	100/	322		54.86	133 54
292	ן. גר	0.4	1006	200	Timbered I	55 7	133.8
300	۱ ع	2.1	1006	179		50 53	147.2
301		· · · · ·	1990	170	Soottle Harbor	17 E	197.2
302		17	1990	10/	M Brothor I	573	133.84
303	m	1.7 4 Ê	1990	19	W.Diolilei I.	57.5	133.04
306	T	1.0	1995	304	VV.DIOLIIEIS I	57.5 EE 7	100.04
308	m _.	1.8	1990	30	M Brothoro I	55.7	122.0
313	Ţ	1.5	1995	304		57.3 EA D	100.04
326	Ţ	1.9	1996	120	Langara I., D.C.	54.Z	133.00
332	Ť	1	1995	185	VV. Drotner I.	57.3 50.12	133.04
341	T	1.1	1995	16/	Gran Pt.	50.13	135.24
341	T	1.7	1990	8Z	Gran Pt.	59.15	100.24
341	T	1.8	1996	109	Gran Pt.	59.13	135.24
346	T	1.7	1995	39	Benjamin I.	58.55	134.91
411	Ť	1.1	1995	205	W.Brotner I.	57.3	133.84
412	Ť	2	1996	1/8	FISH I.	59.53	147.2
413	m	1.1	1995	218	Kodiak Harbor	57.8	152.4
422	m	0.4	1994	322		54.85	133.54
427	t	1.9	1996	108	Gran Pt.	59.13	135.24
435	, †	1.1	1995	193	Poundstone Rock	58.1	134.9
441	m	1.7	1996	34	White Sisters	57.64	136.26
442	Ť	1	1995	157	Gran Pt.	59.13	135.24
442	f	1	1995	170	Gran Pt.	59.13	135.24
442	† f	1.7	1996	66	Pt. League	57.61	133.64
442	f	1.8	1996	66	Timbered I.	55.7	133.8
442	f	2.1	1996	164	Timbered I.	55.7	133.8
443	m	1.1	1995	205	W.Brother I.	57.3	133.84
443	m	1.3	1995	302	Sail I.	57.35	133.72
443	m	1.3	1995	307	Sail I	57.35	133.72
447	m	1.7	1996	39	Benjamin I.	58.56	134.91
447	m	1.7	1996	40	Benjamin I.	58.56	134.91
447	m	1.7	1996	49	Benjamin I.	58.56	134.91
447	m	1.8	1996	102	Benjamin I.	58.56	134.91
447	m	1.9	1996	108	Gran Pt.	59.13	135.24
447	m	2	1996	163	Gran Pt.	59.13	135.24
451	۳.	1.5	1995	363	Pt. League	57.61	133.64
451	m	1.5	1995	364	SW Brothers	57.27	133.87
451	М	1.9	1996	120	Sunset Pt.	57.5	133.5
451	m	1.9	1996	241	Pt. League	57.61	133.64
452	m	1.3	1995	281	S. Marble I.	58.6	136
452	m	2.8	1997	72	Marmot I.	58.14	151.47
463	f	18	1996	89	Timbered I	55 7	133.8

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Appendix I continued

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Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
		<u> </u>				e	
463	f	2.1	1996	.188	Timbered I.	55.7	133.8
468	- m	1.7	1996	34	Timbered I.	55.7	133.8
471	f	0.4	1994	323	Lowrie I.	54.86	133.54
474	f	1.6	1996	19	W.Brother I.	-57.3	133.84
474	f	1.1	1996	187	Gran Pt.	59.13	135.24
474	f	1.1	1996	188	Gran Pt.	59.13	135.24
475	f	1.7	1996	70 [•]	Turnabout I.	57.13	133.97
477	m	1.7	1996	149	Benjamin I.	58.56	134.91
482	m	2	1996	151	Gran Pt.	[°] 59.13	135,24
487	m	2.1	1996	194	Timbered I.	55.7	133.8
490	m	1.8	1996	90	Timbered I.	55.7	133.8
497	f	2	1996	151	Gran Pt.	59.13	. 135.24
501	f	1.3	1995	302	Sail Island	57.35	133.72
501	f	1.7	1996	71	W. Brother I.	57.3	133.84
501	m	2.2	1996	253	Cape Alava, WA	48.18	124.73
502	m	1.6	1996	19	W.Brother I.	57.3	133.84
502	m	. 2	1996	151	Gran Pt.	59.13	135.24
506	m	2	1996	167	Fish I.	59.53	147.2
514	f	1.8	1996	90	Timbered I.	55.7	133.8
514	f	2.1	1996	198	Timbered I.	55.7	133.8
517	f	0.9	1996	120	Sunset Point	57.5	133.5
521	m	1.3	1995	283	S. Marble I.	58.6	136
530	F	1.7	1996	34	Cape Cross	57.91	136.57
538	f	2.1	1996	212	Timbered I.	55.7	133.8
539	M	1.5	1996	349	Jude Landa and Ma	55:16	161.06
541	f	12	1995	242	Grindall I	55.44	132 11
542	m	2	1996	170	Timbered I	55 7	133.8
543	m	- 1	1995	157	l owrie I	54 86	133 54
543	m	1	1995	170	Lowrie I	54.86	133 54
545	f	04	1994	322	Lowrie I	54.86	133 54
551	∙.mi	1	1004	167	Henry I. Puget	48.5	123
551		•	1000		Sd	40.0	120
551	m	2.2	1996	253	Cape Alava, WA	48.18	124.73
555	f	0.4	1994	323	Lowrie I.	54.86	133.54
559	f	1.2	1995	203	Sugarloaf I.	58.88	152.03
559	f	1.2	1995	204	Sugarloaf I.	58.88	152.03
559	f	1.2	1995	207	Sugarloaf I.	58.88	152.03
559	f	12	1995	208	Sugarloaf I	58.88	152.03
559	f	12	1995	211	Sugarloaf I	58.88	152.03
559	f	12	1995	212	Sugarloaf I	58 88	152.03
569	f	1	1995	187	Gran Pt	59 13	135.24
569	f	11	1995	188	Gran Pt	59 13	135.24
569	f	17	1996	56	Gran Pt	50.10	135 24
569	f	· 1Q	1996	108	Gran Pt	50.13	135 24
560	f))	1006	151	Gran Pt	50.13	125.24
560	i f	2	1006	197	Timbered I	55.15	122.24
577	i F	<u>ک</u> ۸ ۸	100/	200		51 26	122 54
581	, m	1.5	1006	<u>्</u> र	Renjamin I	59 56	124.01
581	m	1.5	1006		Benjamin I	58 56	12/ 01
587	m	13	1995		Sail I	57 35	133 70
507	111	1.0	1000	,007	Jun I.	01.00	· 100.72

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Appendix I continued

Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
<u></u>		<u> </u>	1006	201	Timbered I	55 7	133.8
000		1.1	1006	16	Timbered I	55.7	133.8
609	m	0.0	1990	63	Timbered I	55 7	133.8
609	m	0.8	1006	83	Timbered I	55.7	133.8
011	111	0.0	1005	207	Sail I	57 35	133 72
614	m	0.3	1990	. 24	Gana Cross	57.00	136 57
614	m	0.7	1990	34	Timborod I	55.7	133.8
637	m	0.8	1995	90	Timbered I.	55.7	133.0
637	m	1.1	1995	193		55.7	100.0
640	Ť	0.5	1995	304	VV.Brother I.	57.3	133.04
644	m	0.7	1996	/1	vv. Brotner I.	57.3	133.04
647	f	1	1996	184	limbered I.	55.7	133.8
651	f	0.5	1995	364	W. Brother I.	57.3	133.84
655	f	0.5	1995	364	W. Brother I.	57.3	133.84
660	m	0.6	1996	14	Timbered I.	55.7	133.8
660	m	0.8	1996	90	Timbered I.	55.7	133.8
. 660	m	1.2	1996	218	Timbered I.	55.7	133.8
661	m	1 '	1996	168	Timbered I.	55.7	133.8
674	f	1.2	1996	216	Timbered I.	55.7	133.8
680	m	1.1	1996	183	Timbered I:	55.7	133.8
686	f	0.8	1996	90	Timbered I.	55.7	133.8
686	f	1.2	1996	218	Timbered I.	55.7	133.8
687	f	1.2	1996	216	Timbered I.	55.7	133.8
687	f	1.7	1997	32	W. Brother I.	57.3	133.84
689	m	0.7	1996	56	Gran Pt.	59.13	135.24
694	f	0.8	1996	· 90	Timbered I.	55.7	133.8
708	f	0.8	1996	83	Timbered I.	55.7	133.8
712	m	0.7	1996	33	Biali Rock.	56.71	135.34
713	m	1.7	1997	32	W. Brother I	57.3	133.84
721	f	1.2	1996	218	Timbered I.	55.7	133.8
728	f	0.3	1995	307	Sail I.	57.35	133.72
732	m	໌1	1996	174	Timbered I.	55.7	133.8
737	m	0.6	1996	19	W.Brother I.	57.3	133.84
737	m	1.7	1997	64	W.Brother I.	57.3	133.84
739	f	0.7	1996	42	Timbered I.	55.7	133.8
740	f	1.1	1996	190	Timbered I.	55.7	133.8
741	m	0.3	1995	307	Sail I.	57.35	133.72
741	m	0.7	1996	56	Gran Pt.	59,13	135.24
741	m	0.8	1996	81	Gran Pt.	59.13	135.24
744	f	0.8	1996	90	Timbered I.	55.7	133.8
744	f	1	1996	174	Timbered I.	55.7	133.8
747	m	0.7	1996	53	Timbered I.	55.7	133.8
751	f	1	1996	38	Timbered I.	55.7	133.8
752	· f	0.7	1994	34	Cape Cross	57.91	136.57
755	f	1	1996	184	White Sisters	57.64	136.26
761	f	0.6	1996	16	Timbered I	557	133.8
761	۱ ۴	1.8	1996	83	Timbered I	55.7	133.8
764	г т	1.0	1006	165	Fich I	50.7	147.2
765		07	1006	70	Turnahout I	53.55	122.07
765	i F	0,7 1 ·	1006	190	Mast Brothar I	57.13	122 94
767	l f	0.5	1005	365		57 12	133.04
101		0.0	1330	JUU	i un duout I.	J7.1J	100.07

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Appendix I continued

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Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
767	f	0,7	1996	70	Turnabout I.	57.13	133.97
768	m	0.7	1996	34	White Sisters	57.64	136.26
770	f	1	1996	177	Timbered I.	55.7	133.8
781	f	0.8	1996	90	Timbered I.	5 5.7	133.8
781	f	1	1996	169	Timbered I.	55.7	133.8
793	f	1.2	1996	218	Timbered I.	55.7	133.8
798	f ·	0.3	1995	. 307	Sail I.	57.35	133.72
800	m	0.7	1996	71	West Brother I.	57.3	133.84
803	f	1	1996	189	West Brother I.	57.3	133.84
805	m	0.6	1996	16	Timbered I.	55.7	133.8
805	m	0.8	1996	84	Timbered I.	55.7	133.8
805	m	1	1996	182	Timbered I.	55.7	133.8
807	f	0.8	1996	90	Timbered I.	55.7	133.8
807	f	1.	1996	173	Timbered I.	55.7	133.8
808	m .	0.9	1996	128	Cartwright SD, BC	53.2	132.5
811	f	0.5	1995	364	. W. Brother I.	57.3	133.84
811	f	1 /	1996	167	Timbered I.	55.7	133.8
812	m	1	1006	·184	White Sisters	57.64	136.26
813	m	0.7	1996	40	Benjamin I.	58.56	134.91
813	m	1.7	1997	32	W. Brother I.	57.3	133.84
813	m	1.8	1997	65	W. Brother I.	57.3	133.84
816	m	0.3	1995	307	Sail I.	57.35	133.72
819	F	0.7	1996	33	BIALI R.	56.71	135.34
823	m	0.7	1996	39	Benjamin I. 🚓 😘	58.56	134.91
824	m	1	1996	162	Fish I.	59.53	147.2
828	f	0.7	1996	- 39	Benjamin I.	58.56	134.91
828	f	0.9	1996	108	Gran Pt.	59.13	135.24
829	f	1 -	1996	?	Fish I.	59.53	147.2
831	m	0.7	1996	39	Benjamin I.	58.56	134.91
831	m	1	1996	151	Gran Pt.	59,13	135.24
833	f	0.6	1996	[`] 19	Timbered I.	55.7	133.8
833	f	1	1996	189	W.Brother I.	57.3	133.84
835	М	0.7	1996	34	White Sisters	57.64	136.26
836	f	1.2	1996	218	Timbered I.	55.7 [°]	133.8
838	f	0.8	1996	90	Timbered I.	55.7	133.8
838	f	1.1	1996	201	Timbered I.	55.7	133.8
841	m	0.7	1996	56	Gran Pt.	59.13	135.24
841	m	0.9	1996	108	Gran Pt.	59.13	135.24
843	f	0.3	1995	307	Sail I.	57.35	133.72
847	m	1	1996	184	White Sisters	57.64	136.26
851	f	0.3	1995	302	Sail I.	57.35	133.72
851	f	0.3	1995	307	Sail I.	57.35	133.72
851	f	0.9	1996	108	Gran Pt.	59.13	135.24
857	f	0.7	1996	70	Turnabout I.	57.13	133.97
859	, m	0.8	1996	90	Timbered I	55 7	133.8
860	f	0.7	1996	53	Timbered I	55.7	133.8
868	m	1.8	1997	88	Marmot I	58.14	151 47
871	 ∞ f	0.7	1996	49	Benjamin I	58 56	134 91
876	m	0.8	1996	64	Timbered L	55 7	133.8

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Appendix I continued

Brand#	Sex	Resight-Age	Year	Day	Location	Latitud	Longitude
885	f	1	1996	172	Timbered I.	55.7	133.8
886	f	1.2	1996	264	Sea Lion Rocks	56.25	134.82
889	f	0.8	1996	90	Timbered I.	55.7	133.8
889	f	1.2	1996	218	Timbered I.	55.7	133.8
894	. − f	0.7	1996	52	Timbered I.	55.7	133.8
896	m	0.7	1996	43	Timbered I.	55.7·	133.8
898	m	0.6	1996	19	W.Brother I.	57.3	133.84
901	m	1	1996	189	W.Brother I.	57.3	133.84
903	f	0.9	1996	125	League Pt.	57.61	133.64
910	f	1.1	1996	230	Forrester; SLR	54.86	133.54
913	m	0.6	1996	16	Timbered I.	55.7	133.8
927	f	1	1996	178	Timbered I.	55.7	133.8
928	m	0.8	1996	100	Benjamin I.	58.56	134.91
931	М	0.6	1996	16	Timbered I.	55.7	133.8
931	m	0.8	1996	90	Timbered I.	55.7	133.8
934	m	0.7	1996	52	Timbered 1.	55.7	133.8
936	f	0.6	1996	43	Timbered I.	55.7	133.8
947	F	0.7	1996	34	White Sisters	57.64	136.26
949	m	0.6	1996	16	Timbered I.	55.7	133.8
949	m	0.8	1996	90	Timbered I.	55.7	133.8
957	f	0.3	1995	307	Sail I.	57.35	133.72
967	f	1	1996	174	Fish I.	59. <u>5</u> 3	147.2
971	f	0.7	1996	45	Timbered I.	55.7	133.8
973	m	0.5	1995	365	Turnabout I.	57.13	133.97
973	m	0.7	1996	70	Turnabout I.	57.13	133.97
979	m	0.9	1996	126	Langara I., B.C.	54.2	133.08
983	f	0.5	1995	365	Turnabout I.	57.13	133.97
983	f	0.7	1996	67	W. Brother I.	57.3	133.84
983	f	1.7	1997	32	Turnabout I.	57.13	133.97
995	m	1	1996	188	Timbered I.	55.7	133.8
997	f	0.8	1996	90	Timbered I.	55.7	133.8
997	f	1	1996	179	Timbered I.	55.7	133.8
?44		0.3	1995	302	Sail I	57.35	133.72
34?		1.3	1995	307	SAIL I.	57.35	133.72
34?		1.3	1995	309	Benjamin I.	58.56	134.91
34?		⁻ 1	1995	170	Gran Pt.	59.13	135.24
34?(1)		1	1996	157	Gran Pt.	59.13	135.24
50?(1)		1.7	1996	70	Turnabout I.	57.13	133.97
8?6		0.7	1996	40	Benjamin I.	58.56	134.91
7??		0.7	1996	40	Benjamin I.	58.56	134.91
696?		1.3	1995	281	S. Marble I.	58.6	136
f6??		0.9	1996	120	SW Brother I.	57.27	133.87
887?		•	1996	126	Langara I., B.C.	54.2	133.08
F ?			1996	152	Fish I.	59.53	147.2
F72-?		1	1996	175	Fish I.	59.53	147.2
F2U?			1996	76	Mary I.	55.15	131.1
5351			1996	170	Timbered I	55.7	133.8

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CHAPTER THREE

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Steller Sea Lion Behavioral Comparisons

Steller Sea Lion Behaviour During the Breeding Season: A Comparison Between a Stable and Declining Population in Alaska

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The Steller sea lion (*Eumetopias jubatus*) was classified as *a threatened* species under the U.S. Endangered Species Act in 1990, after the world population dropped from about 300,000 in 1980 (Loughlin et al., 1992) to under 100,000. The last survey conducted by the National Marine Fisheries Service and the Alaska Department of Fish and Game (ADF&G) in 1996 confirmed that the world population is still declining.

One of the leading hypotheses to explain the overall decline is that Steller sea lions are nutritionally stressed. The greatest decline has occurred in the Aleutian Islands and Gulf of Alaska where sea lions have fallen from 225,000 in the late 1970s (Merrick et al., 1987; Loughlin et al., 1992) to under 85,000 in the late 1980s (Trites and Larkin, 1992). In contrast, Steller sea lion numbers in Southeast Alaska appear stable and the species in this part of their range, is not thought to be nutritionally stressed at this time.

The goal of my two year study was to document and compare the reproductive behaviour 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).

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My study 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). Gentry (1991) speculates that tenure duration among male otariids may decrease during periods of nutritional stress.

Controlled experiments using terrestrial mammals have also demonstrated behavioural, developmental and physical effects of nutritional deficiencies that can be quantified by observation (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 selected the following behavioural, developmental and physical indices to compare at my two sites:

- activity budgets
- maternal attendance patterns
- territoriality
- male copulatory behaviour
- delayed weaning
 - early pup development and maternal care postpartum
 - fungal patches

Although behavioural differences between the two study sites can 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) collected the data at Lowrie Island. Boyd and Dave 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) collected the data at Lowrie Island. Dave and Carolyn arrived on May 16 and left 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 following describes the data we collected at each site.

1) Activity Budgets

The proportion of time sea lions spend 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 differ 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.

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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 estimate the perinatal period (the period after birth that a female stays onshore with her pup before leaving on her first trip to sea), the length of time females are away from the rookery and with their pup while on the rookery. Changes in trip or visit lengths over time can also be estimated. 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 for every hour for 14 hours. There were five days on Lowrie Island where no data were recorded. On Sugarloaf Island, there were also several days where 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 hours. No days were missed at either site in 1995.

3) Territoriality

Like the perinatal period, tenure duration and territory size may reflect the amount of energy reserves that bulls have when they come ashore. It seemed prudent to document any differences that may have occurred 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. Territory 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 of territory 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 hours. 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 to estimate territory size.

4) Male Copulatory Behaviour

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

5) Delayed Weaning

The proportion of juveniles nursing on a rookery may indicate prolonged maternal investment to ensure the 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 (Areas 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 it's head, take a first step, search for a teat and suckle. 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

Fungal patches which are caused by a fungus (T. Spraker, pers.comm) appear to be more numerous in the area of decline. Why sea lions would have more fungal patches in the declining area is unclear. Given these circumstances, it seemed prudent to quantify the number of adults and sub-adult males that had these patches. In 1994 and 1995, both study teams recorded the number of adult females, adult males and sub-adult males that had 1) at least one fungal patch 2) more than two fungal patches. A count was done once per week at both sites.

Stage of Study

Maternal attendance patterns have been statistically analyzed for both years. Results show that the length of perinatal periods and trips to sea are shorter in the area of decline. However, differences in trip length should be interpreted with caution since they may simply reflect the distance to feeding areas at each of the study sites. In 1994, the length of perinatal periods, trips to sea and visits ashore were shorter than in 1995. Further analysis of maternal attendance shows that females at both sites, exhibit a diurnal pattern where most of the arrivals and departures occur overnight (between 20:00 - 6:00 hrs) However, fewer departures occurred overnight in 1994 than in 1995. Why both sites were affected in similar ways between years is not yet clear.

Preliminary results also suggest that attendance patterns change over time. For both sites and years combined visit lengths ashore become shorter. However, one final analysis needs to be done on this data set to verify these trends.

Presently, I am statistically comparing the data to determine whether postpartum female activity budgets differ between the two study sites. Preliminary results from 1995 suggest that females in the area of decline may spend more time nursing their pups but whether this has any biological significance is not yet clear. Total time at sea has not yet been calculated but will be useful to interpret my results.

Final results for mother-pup associations, delayed weaning and fungal patches are still pending for both years. I have not yet looked at the bull behavioural data for 1994 and 1995.

The early pup development and maternal care study will be excluded from the final report due to poor experimental design. Better criteria to identify behaviours is needed before sound data can be collected.

A final report is expected in December 1997. Please find enclosed the proposed contents of my dissertation. (Appendix I)

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I - Milette Thesis Outline

Steller Sea Lion Behaviour During the Breeding Season: A Comparison Between a Stable and Declining Population in Alaska

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WINTER ECOLOGY OF IMMATURE STELLER SEA LIONS

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Abstract

The world population of Steller sea lions (*Eumetopias jubatus*) has been declining since the late 1970s. One hypotheses explaining this decline is that young Steller sea lions are nutritionally stressed and are experiencing high mortality during winter. Understanding the winter ecology of immature sea lions 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 (1-3yrs.) sea lions during winter (January to April) 1996 at Timbered Island, 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 (14%). Male pups spend more time involved in play than female pups, while females are more likely to rest. Male pups suckle significantly longer per bout than females. No diurnal haulout pattern was observed. There was significant correlation (r =.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 behaviourally or physiologically weaned 3-5 months prior to breeding.

Introduction

Little is known at present about the biology of juvenile Steller sea lions (*Eumetopias jubatus*), 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 measures 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 spent more time alone.

Haulout Behaviour

Steller sea lions are essentially coastal, shelf-zone pinnipeds that make frequent use of coastal haulout sites. Although they present specific practical problems for researchers, their characteristic of hauling out regularly is one feature of their behaviour which makes them a tractable research subject. Not only is hauling out an important part of their life cycle, most fundamentally for energetic reasons and secondarily for social reasons, it also provides a window through which specific indices of population status may be developed (Boyd 1995).

Seasonal variation in numbers of sea lions at rookeries is similar wherever they breed (Bigg 1985). Approximately 60% of the total sea lion population are accounted for at the rookery sites during the summer breeding season (Loughlin et al. 1992). Typically, the number at rookeries is lowest in December and highest after pupping in July before the majority of animals disperse (Aumiller and Orth 1980, Smith 1988). The seasonal changes of animals at haulout, or non breeding sites is less well documented. Few animals remain at the rookery sites during the winter months, but they do not undertake extensive seasonal migrations like some pinnipeds. There are 39 major rookeries and 250 known haulouts found throughout Alaska (Loughlin et al. 1992), most of which are on remote and exposed rocks and islands.

While studies on phocids have investigated haulout patterns of non-breeding individuals (Yochem et al. 1987) similar studies on otariids are lacking. Little information is available on the historical use of most winter haulout sites throughout the range of the Steller sea lion. The purpose of this study was to document daily and seasonal haulout patterns during the winter period Jan.-Apr. and to look for relationships between environmental conditions and total numbers of animals on land. Understanding these patterns will help researchers predict when the highest numbers of animals are likely to

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be on shore for population monitoring and for capture work which will provide important physiological information.

Changes in sex and age composition of the haulout population were noted over the winter months (Jan.-Apr.) at one hour intervals during the entire study period to determine daily and seasonal changes. Information recorded at hourly intervals to test for proximate factors influencing haulout patterns included: date, time, weather (wind direction and speed, cloud cover, temperature), sea conditions (swell and wave conditions, tide). Counts included: total animals hauled out by sex and age, and total numbers of animals in the water. The final result will provide researchers with a best estimate of when the most animals are likely to be on shore for population estimates and capture work.

Attempts to show a fit with the commonly used linear model failed because it violated critical assumptions about the distribution of the data. Instead, to derive an accurate model for conditions that would predict when the highest numbers of animals would likely be on land, I am instead using a Poisson equation. Preliminary results indicate the numbers of animals on shore are influenced by several weather and tide conditions. Many low counts can be explained by severe storm conditions, followed by high numbers of animals hauled out after extended time in the water.

Suckling

Suckling information on Steller sea lion pups (<1 y) and yearlings (>1 y) were noted during 340 hours of behavioural observations from (Jan - Apr) 1996 at a non breeding haulout site on Timbered Island, Alaska.

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Parents are usually expected to invest more heavily in offspring of one sex where additional investment has greater fitness returns. In some mammals, body size and early growth affect the fitness of males more than females, and mothers would be expected to invest more heavily in sons (Clutton Brock 1991).

In theory, male pups should consume more milk than females and require mothers to invest more energy in male offspring to support the greater growth rates and higher total metabolic costs associated with the larger male body size (Kerley 1985; Costa and Gentry 1986). Male California (Oftedal et al. 1987a) and Steller (Higgins et al. 1988), sea lion pups have been shown to consume more milk than female pups, but there is no significant sex affect when milk or energy intake is calculated per unit body weight. Investment theory predicts that differences in suckling behaviour are probably due to selective pressures associated with adult sexual dimorphism. The proximate mechanism is probably the behaviour of larger male immatures rather than any conscious effort on the part of the mother (Clutton-Brock et al. 1985). Other strategies such as sneak suckling are used by immature animals to obtain additional nutrition.

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The objective of this portion of the study was to test for differences in suckling frequency and duration in Steller sea lion pups as a measure of differential investment. Two hypotheses were tested. First, do mothers spend more time nursing male offspring than female offspring; and second, do pups, or young of the year, suckle for shorter periods than the larger yearling offspring. Both strategies, if true, would offset the cost of rearing a larger and more energetically demanding immature animal. I also looked for signs that animals were actively being weaned, or for lack of contact by a mature female indicating they were already independent.

Results indicate that male pups do suckle significantly longer during each bout than female pups. They suckle similar proportions during the time mom is present. Suckling as a proportion of total time observed (instead of only the time the mother was available) was higher for female pups (13.6% SE 5.8) compared to males (13.0% SE 4.1), but the difference was also not significant. There was no seasonal change in the daily proportion of time spent suckling during the winter. This was surprising since the majority of these immature animals would soon be weaned.

Completion Target Dates

Data analysis is 95% complete. Two of four chapters are complete; the remaining two are in progress. Each chapter is written as a publishable paper to be submitted to various scientific journals. An overall introduction and summary will be included to meet University thesis requirements. The completion of the thesis and defense is projected for September 3, 1997.

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CHAPTER FOUR

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Steller Sea Lion Growth and Condition

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REDUCED BODY SIZE OF FEMALE STELLER SEA LIONS

FROM A DECLINING POPULATION IN THE GULF OF ALASKA

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Abstract

Nutritional stress is a leading hypothesis behind the decline in numbers of Steller sea lions in the Gulf of Alaska, Aleutian Islands and Bering Sea. To evaluate this hypothesis, we compared body growth of female Steller sea lions 1.0-13.9 yrs of age collected in the Gulf of Alaska during two time periods, 1975-1978 just prior to or early in the decline and 1985-1986 when the decline was well established. We found that growth, as measured by standard length, axillary girth, and mass, was reduced during the 1980s supporting the undernutrition hypothesis. We also found a suggestion of reduced growth in our 1970s and 1980s samples when compared to a collection of Steller sea lions obtained from the Gulf of Alaska in 1958. However, no direct link has been demonstrated between undernutrition and the actual decline in numbers.

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Key words: Steller sea lion, <u>Eumetopias jubatus</u>, Gulf of Alaska, growth, undernutrition, population decline.

Steller sea lion (SSL) (Eumetopias jubatus) numbers have declined precipitously throughout the western portion of their range in Alaska (west of 144° west longitude) (NMFS 1995). This decline, which is in the general magnitude of 80-90%, started in the eastern Aleutian Islands and spread throughout the Aleutian Islands, Bering Sea and Gulf of Alaska (GOA) (Braham et al. 1980, Merrick et al. 1987, Loughlin et al. 1992, NMFS 1995). In 1990, SSLs were classified as threatened under the U.S. Endangered Species Act because of this decline. In 1997 SSLs in the western portion of their range were reclassified as endangered because of a continuing decline and concern about the long-term viability of the species (U. S. Federal Register 62:24345-24355).

While a cause-effect mechanism for the decline has not been identified, nutritional stress is a leading hypothesis (Calkins and Goodwin 1988, Merrick 1995, NMFS 1995). To evaluate this hypothesis, we compared body measurements and masses of female SSLs collected in the GOA during three time periods, 1958, 1975-1978 just prior to or early in the decline and 1985-1986 when the decline was well established. Our findings of reduced growth of SSLs in the GOA during the 1980s support the nutritional stress hypothesis.

Methods

Data Collection-Female SSLs were collected by shooting on rookeries, haulouts and in coastal waters of the GOA from the Kenai Peninsula to Unimak Island (Fig. 1) between 1975 and 1978 (n=80) and again between 1985 and 1986 (n=102). These animals were taken from within the range of the genetically differentiated western stock (Bickham <u>et al.</u> 1996) and were from areas with similar declining trends in numbers. Observations of marked animals indicated substantial movement and mixing of animals from this area (Calkins and Pitcher 1982, NMFS 1995), particularly during winter months when most of the collections occurred. In most cases the animals were placed aboard a vessel where they were weighed (MASS)(kg) and measured for standard length (mm), axillary girth (AG) (mm) and blubber and skin thickness (BL) (mm) over the posterior end of the sternum. Standard length was measured with the dorsal surface up rather than with the ventral surface up as described by the American Society of Mammalogists (1967). Collection and measurement techniques were consistent between periods; several of the investigators were involved with the data collections during both periods. Body size data are summarized in Tables 1-4.

Second upper premolar teeth were taken from each animal and sectioned and stained using methods described by Calkins and Pitcher (1982). Ages were estimated from counts of cementum annuli utilizing a reference collection of known-age teeth. Ages were estimated by one of us (D. G. Calkins) for both collections ensuring consistency. The assumed \overline{x} date of birth was 15 June. Ages were entered to the nearest 0.00 year to accommodate for differences in the timing of collections.

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<u>Data analysis</u>-Our analyses were limited to those female sea lions ages 1.00-13.99 yrs of age because few animals were in other age classes and some of these data points were highly influential as measured by leverage values. Based on examination of scatterplots, we determined that body size of animals 0-0.99 yrs was highly variable.

We used multiple regression analysis to determine if differences in SL, AG, MASS and BL existed between the 1970s and 1980s samples. The primary objective of our analyses was to determine if body size differed between periods rather than to provide the most biologically realistic description of growth possible. In order to obtain a good model fit to the four response variables, we used the following transformations: natural log, inverse, and an inverse of the natural log. For each transformed response variable, we used a stepwise regression procedure (Myers 1990), with an entry/exit level of 0.05, to obtain the best model. For non-inverse transformed response variables, potential explanatory variables included: age, age², age³; indicator variables for period and pregnancy status; and interaction terms for age by period, age² by period and age⁻¹, age⁻², age⁻³; indicator variables for period. During exploratory analyses we entered a seasonal category to determine if seasonal life history events such as the molt were associated with body size. However season never entered the models.

To determine the best fitting model for each response variable we compared, on an untransformed scale, PRESS and s(natural) statistics (Myers 1990). The adequacy of the model fit was assessed through examination of residual plots, Q-Q plots, and a test of homogeneity of variance based on a Spearman rank correlation between the absolute value of the residuals and the predicted values (Carrol and Ruppert 1988).

We used a stratified Wilcoxon-Mann-Whitney exact test (Mehta et al. 1992) to evaluate differences in SL and AG between a sample of SSLs collected at Chernabura Island in 1958 (Fiscus 1961, Mathisen et al. 1962) and our data from the 1970s and 1980s. The 1958 sample was comprised nearly exclusively of older aged females (9-22 years) therefore we used comparable subsets of our 1970s and 1980s samples. We used a nonparametric approach due to our inability to meet the normality assumption using a two-way ANOVA. For each variable, two one-sided tests were performed, the first tested whether 1958 sea lions were bigger than those from the 1970s and the second tested whether the 1958 animals were bigger than those collected in the 1980s. Differences in age composition between the data sets were controlled by stratifying the analysis on age class.

Results

For all four response variables, a transformation to the natural log scale produced the best model fit. The best model for both mass and AG contained a second order polynomial involving age, indicator variables for period and pregnancy, and an age by period interaction (Table 5). The standard length model included a 3 rd order polynomial involving age, and a period effect (Table 5).

We found that 1970s animals were significantly larger than 1980s animals (period effect) for AG, MASS and SL, after controlling for age and pregnancy (Table 5, Figs. 2-6) and that for AG and Mass this difference diminished with age (age and age by period interaction). The model (partial regression coefficients) (Table 5) indicated that at age 1, AG was reduced by 10.4% and mass by 26.9% in the 1980s. These differences narrowed to 6.2% for AG and 12.3% for MASS by age 7 and were down to 1.7% for AG and 3.0% for mass by age 14. This is demonstrated by the converging growth curves (Figs 2-5). None of the dependent variables entered into the BL model; therefore there were no differences in BL between periods, ages or pregnancy status.

Adult female SSLs collected in 1958 were longer (SL) than those from both the 1970s (P=0.0001) and the 1980s (P=0.0004) (Table 6, Fig. 7). There was a significant difference (P=0.0024) in AG between 1958 and the 1980s but not between 1958 and the 1970s (P=0.2658) (Table 6, Fig. 8).

Discussion

Our data show that in the 1980s female SSLs in the GOA were shorter, thinner and had lower masses than a comparable sample of animals from the 1970s. Regardless of model choice we found significant period effects for mass, axillary girth and standard length although not for blubber thickness; resulting in similar biological conclusions. Perez and Loughlin (1991) found that SSLs caught in a GOA trawl fishery for walleye pollock (Theragra chalcogramma) during 1982-84 were shorter than females in our 1970s collection. Castellini and Calkins (1993) concluded that masses were smaller for female SSLs collected from the GOA in the 1980s than in the 1970s based on body volume estimates calculated from length and girth measurements.

Food limitation, resulting from an absolute reduction of food, a reduction in per capita food availability because of an increase in the consumer population, or a reduction in quality of food, can result in reduced body size in marine mammals (Scheffer 1955, Laws 1956, Read and Gaskin 1990, Trites and Bigg 1992) as well as terrestrial mammals (Klein 1964, Skogland 1990). Eberhardt and Siniff (1977) suggested that growth rates may be a useful indicator for evaluating marine mammal population status relative to carrying capacity. Baker and Fowler (1990) provided an example of using body growth, as reflected by tooth weights, in evaluating population status of northern fur seals (Callorhinus ursinus) in relation to carrying capacity. Fowler and Siniff (1992) suggested that characteristics of populations and the individuals within, such as growth, give a better measure of ecosystems conditions and relationships than do direct measurements.

Undernutrition generally causes larger reductions in mass than in length (Mellor 1983), as we found in our analyses. Body length best reflects nutritional conditions through the first 8 or 9

yrs of life (Calkins and Pitcher 1982) while mass and AG reflect recent nutritional status as well as lifetime nutrition. The period effects for both mass and AG are not the result of reduced fatness as period was not a significant dependent variable for BL. Also female SSLs are relatively lean with lipids comprising <10% of body mass (Davis <u>et al.</u> 1996), thus reduced fatness could not solely account for mass differences (26.9% at age 2).

The findings of reduced body size between samples of SSLs collected in the mid-1970s and the mid-1980s seemingly indicate a reduced carrying capacity because of either an absolute reduction in the abundance or availability of prey and/or a change in prey composition to less nutritious species. In this case it would seem to indicate that carrying capacity declined even more rapidly than the population (Fowler and Siniff 1992). There is some degree of support for several somewhat related hypotheses regarding changes in the GOA marine environment that may have affected SSL prey resources and thereby nutritional status. (1) A major oceanic regime shift, characterized by increased water temperatures, began about 1975-76 and may have affected both biomass and composition of SSL prey (Kerr 1992, Francis and Hare 1994, Trenberth and Hurrell 1995, J. Blackburn, Alaska Department of Fish and Game, Kodiak, personal communication). (2) The development of fisheries targeting walleye pollock, a major SSL prey in the GOA (Pitcher 1981, Calkins and Goodwin 1988), occurred during this period (Alton et al. 1987) and could have resulted in competition for pollock with SSLs. (3) SSL prey availability and composition may have been affected by a major restructuring of the North Pacific Ocean marine ecosystem characterized by greatly reduced abundance of certain species such as large whales, northern fur seals and Pacific Ocean perch (Sebastes alutus), an increased biomass of walleye pollock and reduced biomass of small forage fishes such as capelin (Mallotus villosus) (Merrick 1995, National Research Council 1996). (4) There may have been a reduction in the biomass of fatty fishes available to SSLs such as capelin, herring (Clupea harengus) sand lance (Ammodytes hexapterus) and Atka mackerel (Pleurogrammus monoptervgius) and an increase of leaner prey such as walleye pollock, Pacific cod (Gadus macrocephalus) and flatfishes in the SSL diet because of changing ocean conditions and fisheries (Alverson 1992, Merrick and Calkins in press).

There is uncertainty as to just when nutrition became suboptimal for GOA SSLs. While not conclusive, consideration must be given to the possibility that food limitation began prior to our 1970s collection because of the findings of greater SL measurements from a sample of sea lions taken at Chernabura Island in 1958. Assuming that sampling protocols were similar among samples and recognizing that the range of geographic sampling was different between periods, this could indicate a progressive decline in body growth (and nutritional status) from 1958 to the mid-1970s and then to the mid-1980s. Examination of the individual data points in Figs. 2-6 suggest that the largest reductions in body size occurred for ages 1-8 years in the 1980s collection. Backdating eight yrs from 1985-86 would indicate that the breakpoint for nutritional differences between the 1970s and 1980s began about 1977 or 1978. For at least some portions of the GOA it appears that recent population declines began in the mid-to late 1970s (Merrick et al. 1987, unpublished data, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518). A sympatric species, the harbor seal (Phoca vitulina), which feeds on similar prey (Pitcher 1981), declined rapidly at a major rookery in the GOA during the late-1970s (Pitcher 1990). If the decline in SSL numbers was related to

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nutritional status, the level of nutrition may not have declined enough to impact population trajectory until the mid-to late 1970s although growth may have already been affected to some degree. An analysis of growth layers of teeth (Boyd and Roberts 1993) from SSLs in our 1970s collection might provide additional insight into temporal variations in nutritional status. While it appears that SSL body growth declined from the 1950s to the 1970s and 1980s, likely the result of declining nutrition, there is no solid evidence linking undernutrition to the population decline. No observations have been made of large numbers of emaciated or dead SSLs. Most recent studies showed no direct indications of disease problems or malnutrition in GOA adult female or pup SSLs (Merrick et al. 1995, Davis et al. 1996, Brandon et al. 1996, Adams et al. 1996, Spraker and Bradley 1996). Although, Zenteno-Savin et al. (1997) reported elevated levels of the acute phase protein haptoglobin in GOA SSLs in comparison to SSLs from Southeast Alaska and healthy humans. Chronically elevated haptoglobin levels are indicators of infection and disease in humans and have been associated with physical, psychological and environmental stresses leaving the question open as to whether factors other than undernutrition may be involved in the decline.

Acknowledgments

Funding for this work was provided by Bureau of Land Management through the Outer Continental Shelf Environmental Assessment Program, the National Marine Fisheries Service and direct appropriations from the U.S. Congress. The Alaska Department of Fish and Game provide Many coworkers and colleagues participated in field studies. Earlier drafts of this manuscript were reviewed and improved by Thomas Loughlin, Lloyd Lowry, Richard Merrick, Rod Towell and Andrew Trites. Marine Mammal Science reviewers Peter Perkins and Ian Boyd provided meaningful critiques and suggestions. All research was conducted under the auspices of Marine Mammal Protection Act permits issued by the National Marine Fisheries Service Office of Protected Resources.

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Age	1970s <u>x</u>	<u>SD</u>	n	1980s <u>x</u>	<u>SD</u>	n
1	1825	13.4	6	1687	165.0	4
2	1980	50.1	9	1892	86.0	7
3	2077	33.1	12	1953	3.5	2
4	2197	32.9	12	2027	100.2	3
5	2278	46.8	4	2149	47.8	6
6	2295	62.3	5	2206	64.8	7
7	2270	60.7	8	2238	61.0	6
8	2289	30.5	5	2290	60.1	7
9	2279	104.1	4	2246	90.0	7
10	2237	143.5	2	2303	69.2	9
11	2300	2.12	2	2346	96.9	5
12	2311	68.3	6	2313	89.7	8
13	2443	18.9	3	2287	59.3	5

Table 1. Mean standard lengths in mm for female Steller sea lions ages 1.00-13.99 yrs from the Gulf of Alaska during the 1970s and 1980s.

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Age	1970s <u>x</u>	<u>SD</u>	n	1980s <u>x</u>	<u>SD</u>	n
		12.4				
1	133	13.4	5	97	24.6	4
2	158	50.1	8	125	0.01	9
3	178	33.1	10	140	21.8	2
4	223	32.9	10	160	8.1	4
5	236	26.2	4	191	25.5	6
6	243	18.2	5	218	27.6	9
7	243	26.8	8	223	28.8	11
8	259	23.3	5	253	9.3	. 10
9	253	36.7	4	233	38.0	8
10	283	77.8	2	266	45.7	11
11	268		1	297	29.1	6
12	265	19.5	3	254	36.8	9
13	296	48.8	2	249	32.8	6

<u>Table</u> 2. 1	Mean mass in	kg:for femal	e Steller sea	lions ages	
1.00-13.99	yrs from the G	ulf of Alask	a during the	1970s and	1980s.

Age	1970s <u>x</u>	<u>SD</u>	'n	1980s <u>x</u>	SD	n	•
					ſ		
1	1177	72.5	6	1015	97.0	4	
2	1231	88.7	9	1110	53.9	8	
3	1308	107.4	11	1187	119.3	3	
4	1387	78.2	12	1248	59.5	6	ž
5	1417	78.3	6	1328	58.0	6	
6	1414	28.8	5	1339	86.9	11	•
7	1464	63.2	8	1393	50.1	12	
8	1482	45.7	5	1461	53.0	13	:
9	1489	115.4	4	1435	132.4	8	ħ
10	1578	145.0	2	1451	73.8	10 .:1	•
11	1537	4.2	2	1499	108.2	6	r'
12	1517	59.3	5	1471	89.7	9	••
13	1557	60.1	3	1445	87.4	6	

Table 3. Mean axillary girths in mm for female Steller sea lions ages 1.00-13.99 yrs from the Gulf of Alaska during the 1970s and 1980s.

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Age	1970s <u>x</u>	<u>SD</u>	n	1980s <u>x</u>	<u>SD</u>	n
1	26.3	4.4	6	25.8	2.9	4
2	26.3	7.7	9	25.8	6.2	8
3	24.2	6.5	12	21.0	6.6	3
4	22.8	7.1	12	23.0	3.1	5
5	24.3	3.7	6	25.5	5.1	6
6	21.8	5.4	5	26.6	7.6	12
7	25.9	6.7	8	23.4	5.9	12
8	24.4	4.8	5	31.4	6.4	13
9	23.0	3.4	4	26.6	7.4	8
10	26.0	5.7	2	24.6	5.2	10
11	20.0	0.0	2	22.7	5.1	6
12	27.3	9.7	6	23.7	6.5	9
13	21.7	3.8	3	26.8	9.1	6

<u>Table</u> 4. Mean blubber thickness in mm for female Steller sea lions ages 1.00-13.99 yrs from the Gulf of Alaska during the 1970s and 1980s.

<u>Table</u> 5. Multiple regression models for ventral standard length (SL), axillary girth (AG) and MASS for female Steller sea lions ages 1.00-13.99 yrs in the Gulf of Alaska from the 1970s and 1980s.

Response	Explanatory	Partial	Standard	Р Р
Variable	Variable	Regression	Error	
-		Coefficient		
LN(AG) ₁	Y-Intercept	6.9835	0.0209	0.0000
ADJ. R ² =0.7222	Age ₂	0.0685	0.0056	0.0000
P=0.0000	Age ²	-0.0033	0.0004	0.0000
	Pregnancy ₃	-0.0156	0.0051	0.0024
	Period ₄	-0.1105	0.0200	0.0000
· · ·	Age*Period	0.0067	0.0026	0.0107
		a ganga sa	·	
LN(MASS) ₅	Y-Intercept	4.6680	0.0524	0.0000
ADJ. R ² =0.7836	Age	0.1912	0.0138	0.0000
P=0.0000	Age ²	-0.0094	0.0009	0.0000
	Pregnancy	-0.0398	0.0122	0.0012
	Period	-0.2919	0.0505	0.0000
	Age*Period	0.0229	0.0505	0.0000
LN(SL) ₆	Y-Intercept	7.3443	0.0276	0.0000
ADJ. $R^2 = 0.7654$	Age	0.1126	0.0144	0.0000
P=0.0000	Age ²	-0.0110	0.0021	0.0000

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Age ³	0.0004	0.0001	0.0000
Period	-0.0233	0.0070	0.0012

1LN(AG (mm))

 $_{2}$ Age (0.0 yrs)

₃Pregnancy (0=Pregnant, 1=Nonpregnant)

₄Period (0=1970s, 1=1980s)

5LN(MASS (kg))

₆ LN(SL (mm))

Period	$\overline{\underline{x}}$ SL (mm)	SD	n	<u>x</u> AG (mm)	SD	n
1958	2444	105.0	21	1571	87.3	20
1970s	2320	81.8	25	1525	77.6	24
1980s	2312	84.9	41	1470	94.8	46

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<u>Table</u> 6. Summary statistics for ventral standard length and axillary girth for adult (9+ yrs) female Steller sea lions from the Gulf of Alaska during 1958, 1975-78 and 1985-86.

Figure Titles

Figure 1. Steller sea lion study area, showing subareas, where sea lions were collected for growth study.

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Figure 2. Predicted axillary girths for pregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnAG, age, age², period, age*period and pregnancy status.

Figure 3. Predicted axillary girths for nonpregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnAG, age, age², period, age*period and pregnancy status.

Figure 4. Predicted masses for pregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnMASS, age, age², period, age*period and pregnancy status.

Figure 5. Predicted masses for nonpregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnMASS, age, age², period, age*period and pregnancy status.

Figure 6. Predicted standard lengths for female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnSL, age, age^{2} , age^{3} and period.

Figure 7. Scatterplot of standard lengths of female Steller sea lions ages 9-23 yrs from the 1950s, 1970s and 1980s.

Figure 8. Scatterplot of axillary girths of female Steller sea lions ages 9-23 yrs from the 1950s, 1970s and 1980s.



Figure 1. Steller sea lion study area, showing subareas, where sea lions were collected for growth study.

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AXILLARY GIRTH (MM) axillary girths of pregnant females 1970s axillary girths of pregnant females 1980s predicted axillary girths of pregnant females for the 1970s predicted axillary girths of pregnant females for the 1980s

AGE (YEARS)

Figure 2. Predicted axillary girths for pregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnAG, age, age², period, age*period and pregnancy status.

Chart1

Chart5 **AXILLARLY GIRTH F(MM)** axillary girths of nonpregnant females 1980s axillary girths of nonpregnant females 1970s predicted axillary girth of nonpregnant females for the 1980s predicted axillary girths of nonpregnant females for the 1970s ſ AGE (YEARS) . .

Figure 3. Predicted axillary girths for nonpregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnAG, age, age², period, age*period and pregnancy status.

Chart10



Figure 4. Predicted masses for pregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnMASS, age, age², period, age*period and pregnancy status.



Figure 5. Predicted masses for nonpregnant female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnMASS, age, age², period, age*period and pregnancy status.

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Figure 6. Predicted standard lengths for female Steller sea lions ages 1-14 yrs from the 1970s and 1980s based on multiple regression model with lnSL, age, age², age³ and period.



Figure 7. Scatterplot of standard lengths of female Steller sea lions ages 9-23 yrs from the 1950s, 1970s and 1980s.

Chart3



AGE (YEARS)

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Figure 8. Scatterplot of axillary girths of female Steller sea lions ages 9-23 yrs from the 1950s, 1970s and 1980s.

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Chart8

Environmental Contaminants and Diseases

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UNITED STATES DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration NATIONAL MARINE FISHERIES SERVICE

Northwest Fisheries Science Center Environmental Conservation Division 2725 Montlake Boulevard East Seattle, Washington 98112

May 21, 1997

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

Dear Don:

As part of the NMFS' Marine Mammal Health and Stranding Response Program (MMHSRP), we have recently completed the analyses of blubber samples (n = 24) from Steller sea lion (*Eumetopias jubatus*) that were collected from Southeast Alaska in 1992-1994 by your colleagues. We analyzed the samples for chlorinated hydrocarbons (CHs), including polychlorinated biphenyls (PCBs) and DDTs, using a high-performance liquid chromatography method coupled with photodiode array detection (HPLC/PDA). This method also provides data on concentrations of the more toxic "dioxin-like" PCBs (i.e., those congeners that exhibit 2,3,7,8-tetrachlorodibenzo[*p*]dioxin (TCDD)-like toxicity). Previously, we had sent a letter to Dr. Terry Spraker (4/5/96) reporting the results from preliminary analyses of a few of these samples (n = 12).

The Steller sea lion data are summarized in the attached Table 1. I have also enclosed a manuscript published in *Chemosphere* that contains CH concentration data in blubber of four seal species from Alaska. The analyses reported in this paper were conducted using the same quality assurance procedures used in analyzing the samples reported herein. As such, the concentrations can be compared with confidence to the data reported in Table 1. The total PCB and DDT concentrations in the blubber of the Steller sea lions ranged from 630-9800 and 400-8200 ng/g wet wt, respectively (Table 1). These concentrations are somewhat higher than those in previously-analyzed blubber of Steller sea lions (from our database) and northern fur seals (*Callorhinus urisinus*) from the Pribilof Islands, AK (*Chemosphere* manuscript). For example, total PCB concentrations in blubber of Steller sea lions ranged from 39-2000 ng/g wet wt and in blubber of northern fur seals ranged from 550-2100 ng/g wet wt. Furthermore, CH concentrations in the sea lions are much higher than those found in blubber of ringed seals (*Phoca hispada*) (range 89-360 ng/g wet wt) and bearded seals (*Erignathus barbatus*) (range 45-360 ng/g wet wt) from the Bering Sea, Alaska. However, without more biological data for



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these sea lions, we cannot interpret the data any further with respect to comparisons with other species. We also determined TCDD equivalents of dioxin-like chlorobiphenyls (CBs) for these blubber samples and found the concentrations ranged from 2.6-70 pg/g wet wt. These TCDD-equivalent concentrations are comparable to those we have previously found in blubber of northern fur seals from the Pribilof Islands, AK.

Statistical analyses of the PCB, DDT and TCDD toxic equivalents data were conducted by analysis of variance (ANOVA) to determine if differences in the concentrations of CHs existed between collection years. Without additional biological data, this analysis must be considered preliminary. The ANOVA showed significantly higher total PCB concentrations in blubber of sea lions captured in 1994 compared to PCB levels in animals sampled in 1993. No statistical differences were observed for CH concentrations in blubber of sea lions collected in 1993. In addition, no significant interannual differences in percent lipid were observed. Similar to the total PCB data, we also found that the concentrations of DDTs and TCDD equivalent concentrations were significantly higher for blubber of sea lions collected in 1994 compared to those captured in 1993; however no significant differences were determined in sea lion blubber samples from 1992 and 1993.

If you have any questions regarding the enclosed data, please call me at (206) 860-3326. I also hope that we can continue collaborating in assessing contaminant bioaccumulation in Steller sea lions.

Sincerely,

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Peggy Kroka

Margaret M. Krahn, PhD Manager, Environmental Chemistry Branch

Enclosure

cc: Gina Ylitalo, NMFS (F/NWC2) John Stein, NMFS (F/NWC2) Tom Loughlin, NMFS (F/AKC3) Teri Rowles, NMFS (F/PR2)

Site	Fl oid Numb o r	Extract Numb or	Tissue Type	Sample Wt. (g)	TriCDD Rec. (%)	~ %	Lipid	Total CB (ng/g, wet wt.)	Total TCDD Eq. (pg/g, wet wt.)	Total DDTs (ng/g, wet wt.)
1992		,			• • • • • • • • • • • • • • • • • • • •		· · · · · ·			1.
	92SSL2	SP466	Blubber	0.29	. 97		63	6530	59.1	4260
	92SSL3	SP465	Blubber	0.34	96		68	9760	69.5	8240
	92SSL4	SP493	Blubber	0.25	95		15	820	4.5	540
	92SSL5	SP492	Blubber	0.23	87		20	2840	20.4	1980
	92SSL6	SP491	Blubber	0.26	. 92	•	35	1720	12.8	1050
	92SSL7	SP488	Blubber	0.26	90		66	1920	11.4	1470
	92SSL8	SP490	Blubber	0.23	. 96		46	1680	11.1	910
	92SSLM1	SP489	Blubber	0.39	90		52 .	2120	12.6	1470
	· · · ·			r.		Average	46	3420	25.2	2490
4000					· · ·	SD	19	2890	23.1	2420
1993	93551 Tao #22	SP469	Blubber	0.34	95		63	1340	10.6	910
	93SSL Tag #38	SP497	Blubber	0.30	90		57	1360	7.9	830
	93SSL Tag #40	SP498	Blubber	0.27	98		23	630	2.6	400
	93SSL Teg #41	SP494	Blubber	0.27	91		46	1440	8.1	820
	93SSL23	SP470	Blubber	0.32	93		57	5400	41.6	4000
	93SSL61	SP495	Blubber	0.26	95		38	1600	9.3	890
	93SSL62	SP467	Blubber	0.24	111		36 1	1600	12.2	940
	93SSLJ	SP468	Blubber	0.34	92		54	1080	5.9	630
		<u> </u>	·····			Average	47	1810	12.3	1180
	,					SD	13	1390	11.4	1080
1994								•		
	94EJ64	SP503	Blubber	0.37	86		43	3260	27.5	2830
	94EJ65	SP463	Blubber	0.38	97		34	3260	18.8	2550
	94EJ71	SP464	Blubber	0.36	99		63	1500	9.3	1110
	94EJ72	SP462	Blubber	0.38	97		48	1420	_ 10.5	950
	94EJ73	SP461	Blubber	0.24	98		38	5820	34.4	5280
	94EJ74	SP499	Blubber	0.25	96		29	7690	56.9	5500
	94EJM-1	SP501	Blubber	0.36	. 83		49	6180	52.9	5130
	94SSL69	SP460	Blubber	0.28	99		59	5370	42.1	4530
	_					Average	45	4310	31.5	3490
						SD	11	2140	17 1	1750

Table 1-p1: Concentrations of PCBs (total CBs) and DDTs (total DDTs) and TCDD equivalents for dioxin-like PCBs.

TriCDD = 1,7,8-trichlorodibenzo-p-dioxin

TCDD equivalents refer to the toxicity of the dioxin-like PCBs calculated in equivalents of the most toxic of the dioxins, tetrachlorodibenzo-p-dioxin (TCDD).

Data from the Environmental Conservation Division, Northwest Fisheries Science Center; for personnel use, not to be distributed.

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SUMMARIES OF SEROLOGIC DATA COLLECTED FROM STELLER SEA LIONS IN THE BERING SEA AND GULF OF ALASKA, 1978-1996

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July 1997

Introduction

During 1978-1996, the Alaska Department of Fish and Game (ADF&G) obtained sera from Steller sea lions (*Eumetopias jubatus*) collected from the Bering Sea, the Kodiak and Prince William Sound (PWS) regions of the Gulf of Alaska, and southeast Alaska. These sera were collected to determine the antibody prevalence of selected microbial disease agents. Samples were provided by a number of investigators who collected blood while conducting a variety of scientific studies. Specimens from 304 sea lions were analyzed at several laboratories that specialized in specific disease agents (Table 1). This report provides a summary of test results and archived sera.

Methods

Data were transferred electronically from previously archived computer files or were entered manually into a computerized database (Foxpro 2.5b).

Threshold titers were selected for each disease agent (Table 2). Sera which met or exceeded these titers were considered indicative of previous natural exposure to the agent in question. Such sera were referred to as "positive". Sera with titers below the threshold were interpreted as coming from animals which had not been exposed to the agent. These sera were referred to as "negative". Only sea lion records that contained positive or negative test results were tabulated. Summaries of the number of sea lions tested, by year, are given in Tables 3-4. Summary statistics of test results were calculated by year and age class (Tables 5-11).

Results

Canine distemper virus

Eighty-seven samples, collected between 1978 and 1993, were tested for evidence of exposure to canine distemper virus (CDV) using a serum neutralization test (60 TCID_{50}). Sixty-two percent of the samples were from the Kodiak region, 24% from southeast Alaska, 8% from PWS, and 6% from the Bering Sea (Table 3). Only samples from 1986 showed any positive test results (Table 5).

Phocine distemper virus

One hundred and seventy-four samples, collected between 1978 and 1996, were tested for evidence of exposure to phocine distemper virus (PDV) using a serum neutralization test (60 $TCID_{50}$). Forty-nine percent of the samples were from the Kodiak region, 44% from southeast Alaska, 4% from PWS, and 3% from the Bering Sea (Table 3). One sample had no location information. Over 60% of all PDV samples were collected between 1989 and 1996, and only two of those showed evidence of exposure (Table 6). However, of 46 samples collected in 1986, 14 (30%) were positive.

Phocid herpesvirus 1

One hundred and eighty-six samples, collected between 1978 and 1996, were tested for evidence of exposure to phocid herpesvirus 1 (PhHV) using a serum neutralization test (60 TCID₅₀). Forty-six percent of the samples were from the Kodiak region, 41% from southeast Alaska, 9% from the Bering Sea, and 4% from PWS (Table 3). Twenty-nine percent of all samples collected between 1978 and 1986 had evidence of exposure. Between 1989 and 1996, however, only 4% of the samples were positive (Table 7).

Toxoplasma gondii

Twenty-five samples, collected between 1978 and 1994, were tested for evidence of exposure to *Toxoplasma gondii* (TOXO) using a modified agglutination test. Forty percent of the samples were from the Kodiak region, 32% from southeast Alaska, 16% from PWS, and 12% from the Bering Sea (Table 4). Thirty-six percent of the samples tested showed evidence of exposure (Table 8).

Influenza and Brucella spp.

Twenty-seven samples, collected from 1978 to 1994, were tested for both influenza A virus using a double agar immunodiffusion assay, and *Brucella* spp. bacteria using an indirect enzyme linked immunosorbent assay (Table 4). None of these samples had evidence of exposure to either agent (Tables 9-10).

Chlamydia

Seventy-six animals were tested for evidence of exposure to *Chlamydia psittaci* (CHLAM) using a complement fixation method in 1985 (Table 11). Over 50% of the samples were positive.

Available sera

Frozen serum samples from 129 animals remain archived at the ADF&G office in Fairbanks. Future testing of archived sera is anticipated.

Synopsis

These summaries provide a basis for future serologic studies of Steller sea lions. The database provides access to serologic data and the specimen's sex, age, and collection date. Additionally, the database provides information regarding the current availability of archived sera. The serologic database does not represent the total number of sea lions collected or captured during the 1978-1996 period as animals were incorporated in these summaries only if tests were available for their sera. Furthermore, the serologic database will be updated as additional historical data or future test results become available.

Acknowledgments

Sera were provided by a number of people, especially John Burns, Don Calkins, Francis Fay, Lorrie Rea, John Sease, and Terry Spraker. Many other biologists helped to collect the animals and blood samples used this report and their efforts are greatly appreciated. Test results for *Chlamydia psittaci* were provided by Enid Goodwin. Analysis of data and preparation of this report were supported by the Alaska Department of Fish and Game.

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Table 1. Laboratories which conducted serologic tests for evidence of exposure to selected microbial disease agents.

Disease agent (acronym)	Laboratory
Canine distemper virus (CDV)	Dept. of Virology, Erasmus Universiteit Rotterdam, Netherlands
Phocine distemper virus (PDV)	Dept. of Virology, Erasmus Universiteit Rotterdam, Netherlands
Phocid herpesvirus 1 (PhHV)	Dept. of Virology, Erasmus Universiteit Rotterdam, Netherlands
Toxoplasma gondii (TOXO)	Parasite Biology and Epidemiology Lab., Beltsville, Maryland
Influenza A virus (FLU)	School of Vet. Medicine, U. of Wisconsin, Madison, Wisconsin
Brucella spp. bacteria (BS4)	CVL, Bacteriology Dept., Surrey KT, United Kingdom
Chlamydia psittaci (CHLAM)	National Veterinary Services Laboratory, Ames, Iowa

Table 2. Threshold titers for selected microbial disease agents.

Disease agent (acrony	Threshold titer	
Canine distemper viru	100	
Phocine distemper vir	100	
Phocid herpesvirus 1	(PhHV)	20
Toxoplasma gondii	(TOXO)	25
Chlamydia psittaci	(CHLAM)	20

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Table 3. Samples sizes of Steller sea lions tested for canine distemper, phocine distemper, and phocid herpes viruses between 1978 and 1996, by year.

										<u>.</u>
Canine distemper virus	1978	1979	1985	1986	1989	1992	1993	1994	1995	1996
Bering Sea	1	4								
Kodiak	16			27	6	3	2			
Prince William Sound					7					
Southeast				21	s					
Phocine distemper virus	1978	1979	1985	1986	1989	1992	1993	1994	1995	1996
Bering Sea	1	4								
Kodiak	16			26	5	3	23	9		3
Prince William Sound					7					
Southeast				20			28	19	9	
Phocid herpesvirus 1	1978	1979	1985	1986	1989	1992	1993	1994	1995	1996
Bering Sea	1	4	12							
Kodiak	16			24	5	3	24	11		3
Prince William Sound					7					
Southeast				20			28	19	9	

Toxoplasma gondii	1978	1979	1985	1986	1989	1992	1993	1994
Bering Sea		3						
Kodiak	2				3		5 ·	
Prince William Sound					4			
Southeast							3	5
Influenza A	1978	1979	1985	1986	1989	1992	1993	1994
Bering Sea		3						
Kodiak	2				3		5	
Prince William Sound					4			
Southeast				• • • •	is		3	7
Brucella spp.	1978	1979	1985	1986	1989	1992	1993	1994
Bering Sea	1							<u> </u>
Kodiak	4				3		7	
Prince William Sound					4		-	
Southeast							1 .	7

Table 4. Sample sizes of Steller sea lions tested for *Toxoplasma gondii*, Influenza A, and *Brucella* spp. between 1978 and 1994, by year.

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CDV	age	n	% positive
1978	•		
Kodiak	*	14	. 0
	adults	2	0
Bering Sea	*	1	0
1979			
Bering Sea	*	4	0
1986			
Kodiak	pups	2	0
	yearlings	11	0
	2-5 yr.	8	25
	adults	5	20
	*	1	0
Southeast	pups	· 1	0
	adults	20	15
1989			
Kodiak	2-5 yr.	2	0
	adults	4	0
PWS	2-5 yr.	6	0
	adults	1	0
1992			
Kodiak	adults	3	0
1993			
Kodiak	2-5 yr.	1	0
	adults	1	0
Test method: serum neutralization			

Table 5. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1993 for evidence of exposure to canine distemper virus (CDV).

Test method: serum neutralization Threshold titer: 100

* unknown age

PDV	age	n	% positive
1978 Bering Sea Kodiak	* * adults	1 14 2	0 0 0
1979 Bering Sea	*	4	25
1986 Kodiak	pup yearlings 2-5 yr. adults	1 10 8 6	100 40 63 17
Southeast	pup adults	1 19	0 11
1989 Kodiak PWS	2-5 yr. adults 2-5 yr.	1 4 6	100 0 0
1992	adults	1	0
Kodiak	adults	3	33
1993 Kodiak	pup 2-5 yr. adults	13 1 9	0 0 0
Southeast	pup adults	11 17	0 0 0
1994 Kodiak Southeast	pup pup adults	9 1 18	0 0 0
1995 Southeast	pup	9	0
1996 Kodiak	_pup	3	0
Test method: serum neutralization Threshold titer: 100			

Table 6. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1996 for evidence of exposure to phocine distemper virus (PDV).

* unknown age

Table 7. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1996 for evidence of exposure to phocid herpesvirus 1 (PhHV).

PhHV	age	n	% positive
1978	* ~	1	0
Bering Sea	*	· I 1/I	50
Koulak	adults	24	50
	aduns	2	50
1979			
Bering Sea	*	4	75
1005	•		
1985 Doring Soc	*	10	0
Dering Sea		12	U
1986			
Kodiak	yearlings	10	10
	2-5 yr.	8	38
	adults	6	50
Southeast	pup	1	100
	adults	19	16
1000			
1909 Kodiak	2-5 vr	1	0
RUUIAK	2-5 yr.	1	0
PWS	2-5 yr	6	17
1 44 0	2-5 yr. adults	. 1	0
	aduits	· 1	0
1992			
Kodiak	adults	3	67
4000			
1993 Kadiala		10	0
Kodiak	pup	13	0
	2-5 yr.	10	0
Southoast	aduns	10	10
Soumeast	pup adults	17	0
	auuns	17	U
1994			
Kodiak	pup	11	0
Southeast	pup	1	0
	adults	18	0
1005			
1995		0	0
Southeast	pups	9	0
1996			
Kodiak	pups	3	0
Test method	serum neutr	alizatio	<u></u> n
Threshold tit	er: 20		 ,
* unknown 2			
and will a	57		

ΤΟΧΟ	age	n	% positive
1978			,
Kodiak	*	2	0
			•
1979			
Bering Sea	*	3	67
1989			
Kodiak	adults	3	0
PWS	2-5 yr.	3	0
	adults	1	0
1993			
Kodiak	pup	1	0
	adults	4	50
Southeast	pup	2	0
	adults	1	100
1994			
Southeast	adults	5	80
Test method: modified agglutination test			

Table 8. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1994 for evidence of exposure to *Toxoplasma gondii* (TOXO).

Test method: modified agglutination test Threshold titer: 25

* unknown age

FLU	age	n	% positive
1978			
Kodiak	*	2	0
40.00			
1979			
Bering Sea	*	3	0
1989			
Kodiak	adults	3	` 0
PWS	2-5 yr.	3	0
	adults	1	0
1993			
Kodiak	pup	1	0
	adults	4	0
Southeast	pup	1	0
	adults	2	0
			-
1994			
Southeast	adults	7	0

Table 9. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1994 for evidence of exposure to influenza A virus (FLU).

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Test method: double agar immunodiffusion assay

* unknown age

Steller Sea Lion Capture Technique Development

BS4	age	n	% positive
1978		*	
Bering	*	1	0
Kodiak	* ,-	4	0
1989			
Kodiak	2-5 yr.	2	0
	adults	1	0
PWS	2-5 yr.	3	`О
1993 -			÷
Kodiak	pup	1	0
	adults	6	0
Southeast	pup	1	0

Table 10. Results of serologic tests conducted on Steller sea lion samples from the Bering Sea, the Kodiak and Prince William Sound regions of the Gulf of Alaska, and southeast Alaska between 1978 and 1994 for evidence of exposure to *Brucella* spp. bacteria (BS4).

1994

Southeast adults 7 0

Test method: indirect enzyme linked immunosorbent assay

* unknown age

Table 11. Results of serologic tests conducted on Steller sea lion samples from the Kodiak region of the Gulf of Alaska during 1985 for evidence of exposure to *Chlamydia psittaci* (CHLAM).

CHLAM	age	n	% positive
1985			······································
Kodiak	fetuses	30	0
	2-5 yr.	14	71
×	adults	32	94

Test method: complement fixation Threshold titer: 20

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Steller Sea Lion Capture Techniques Development

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It is important for the Alaska Department of Fish and Game Steller sea lion (*Eumetopias jubatus*) research project to have the ability to live-capture sea lions for biological sampling and instrument deployment. Captures of adult females during the summer pupping period are now routine using standard animal darting procedures (Loughlin and Spraker 1989, Heath et al. 1996). These techniques, however, have not proven suitable for other sex and age classes, nor for use at other times of the year. Repeated, very costly, attempts to capture juveniles during the winter over the past four years have failed to yield an acceptable sample size for the intended research.

A number of alternative capture methods have been considered, but most have been dismissed as impractical. One approach, however, seemed to be feasible. It has been noted that some sea lions are attracted to divers and that they will interact very closely with them. It followed that this behavior might be exploited to facilitate capture.

Methods

Early in 1994, a project was begun to test this concept. A Department dive team was trained and equipment was acquired. Five vessel trips and three skiff supported trips were undertaken, all in Southeast Alaska. We made 48 dives over two winters making in-the-water sea lion behavioral observations and testing a variety of attractants and capture devices. The objective was to find a capture method that would provide sufficient numbers of animals for research purposes, be safe for both research personnel and the animals, be usable over a wide geographic range under varying conditions and cause minimal disturbance to the targeted groups of sea lions.

Results and Discussion

Observations confirmed that Steller sea lions were indeed curious about oddities within their environment, including divers. They gradually approached and interacted with divers very closely. In general, they first inspected the divers visually by rapidly swimming past at about the limit of their visual range. Usually they would eventually swim closer for a better look and hang motionless in the water only a few feet, sometimes inches, away. Occasionally they would approach from the side or from behind if the diver was moving forward. Sometimes they would touch the diver very

tentatively with their extended vibrissae and perhaps push gently with their noses. They would then test with their lips, sometimes, but not always, opening their mouths slightly. Some nipped with their front teeth and tugged lightly on swim fins, suits, hoods, gloves and other equipment. At times they opened their mouths fully and bit very gently. At such times, their mouths easily spanned a diver's hand, arm or leg, however their behavior was not aggressive. They did not appear inclined to touch a diver with their flippers or other parts of their bodies. If they bumped a diver while swimming, it appeared inadvertent.

Animal response to divers was variable and some did not interact and left the immediate vicinity. The animals' response seemed to depend upon at least six factors; the number of animals in the group, their age, the amount of time spent near the divers, the activity of the divers, the bottom topography and the presence of other attractants.

The most important variable seemed to be group size. One or two animals seldom did more than briefly examine the dive team from a distance. Often they darted past a couple of times then vanished. In small groups they usually appeared quite timid. As the number of sea lions in the group increased, they ventured closer and remained in the vicinity longer. Some tentative physical contact usually began to occur. They sometimes swam away, but generally returned repeatedly. As the group size approached a dozen or more animals, they usually stayed with the divers for lengthy periods of time and established physical contact very quickly. Some animals surfaced for air as others descended. The larger the group of sea lions, the bolder they appeared to become.

The age of the animals also appeared to be important in determining their behavior. Younger animals seemed more curious and bold. Pups were generally the first to approach the divers and the first to establish physical contact. Yearlings and other juveniles often followed. Older animals appeared much more timid, almost always remaining some distance away, and seldom making contact. They occasionally circled but generally retreated to near the limit of their visual range and disappeared after a few minutes.

As the amount of time a group of sea lions interacted with the divers increased, the animals appeared to become less wary. They often resumed interacting with each other or engaged in other activities. Occasionally, they remained very close to the divers even when their attention was focused elsewhere.

The divers' activity also affected sea lion behavior. The sea lions seemed to need to be in control of early interactions. Rapid movements would almost always prevent them from approaching and would often cause them to flee. As they became accustomed to the divers, the animals would tolerate more movement. After a time, the divers could move about freely without causing alarm and the activity appeared to be viewed as an invitation to play.

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Proximity to a haulout or in-the-water congregation point and the nature of the bottom topography also seemed to influence how readily the animals would approach and the degree to which they would interact with the divers. Near any gathering place they appeared willing to interact. If the bottom topography at these locations was steep and broken, the animals remained longer and

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engaged the divers more closely. Further from these gathering areas and over flatter, more uniform bottoms, the sea lions seemed much less interested in divers.

Certain artificial attractants also seemed to influence the animals behavior. Air bubblers, troll flashers, mirrors and brightly colored plastic strips were of little interest. The sea lions would slowly examine them, but then mostly ignore them. Near life-sized painted plywood sea lion cutouts, caused great excitement. When the divers moved the cut-outs about the sea lions approached closely, swam rapidly about and followed the divers for several hundred feet even across a featureless bottom.

In conjunction with behavioral observations, the initial focus of this work was for the divers to attempt to lead sea lions into a capture net. The net was a large, triangular enclosure floating horizontally in the water. Overall, it measured 120 feet in length along two radiating cork lines with a six foot opening at the apex and a mouth that spanned 76 feet in width by 38 feet in depth. It was constructed of commercial seine web of 3 1/2 inch stretched mesh in order not to entangle the animals and of sufficiently heavy twine to prevent breakouts.

This net has not yet proven effective although progress is being made. Due to its size and susceptibility to current, the net had to be set in somewhat protected waters which are often several hundred feet from haulouts or congregation points. Initially, sea lions could not be led far enough, especially over featureless bottoms, to reach the net. With the use of the painted cut-outs, they could be led to the net mouth, but would not enter the net far enough or remain within long enough for the net to be pursed behind them. They were very aware of and wary of the net despite its large size. Occasionally an animal or two would venture a few feet into the opening, but would quickly exit.

Additional net panels to be used as leads and a smaller trap capable of being stealthily deployed underwater have been fabricated and partially tested. They function well in the water, but have not vet been deployed in the presence of sea lions. These may have value in confining animals nearer their congregation points or in restricting their movements when approaching the large capture net.

The underwater behavior of sea lion pups, five to ten months of age, and some older animals suggested that more direct means of capture might be possible. These animals interact very closely with divers, become preoccupied, and can be grasped and held for several seconds. This mimics their grasping of each other between their foreflippers in what seems to be play behavior. It appears feasible to safely and humanely restrain individual pups and perhaps juveniles using small hoop nets, lines or other devices.

It appears that disturbance on the haulouts using underwater capture techniques will be minimal compared to the darting technique. It has not been necessary to physically enter the haulouts or rapidly spook the animals. Some animals have been driven into the water to provide sufficient numbers to interact with the divers, but this has been done slowly by personnel in skiffs. Most often only a few animals were disturbed leaving many still hauled out. Approaching the haulouts with small skiffs has also been done slowly and in view of the sea lions in order that they have time 1 二百姓的神圣 10.00

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to become accustomed to the activity. Boat drivers monitored the animals for signs of unintended disturbance and did not accelerate or maneuver rapidly.

In the water, the divers did not seem to cause stress to the sea lions. Older animals slowly swim away. Pups and juveniles usually remained and interacted with the divers. Often, the more the divers moved about or played with these animals, the more the young sea lions seem to want to interact and the more forceful their physical contact became. At no time have the divers thought the animals' behavior indicated stress. Behavior by young sea lions is best described as exuberant and playful.

Future capture method development work is likely to focus on restraining individuals at aquatic congregation points, often some distance from haulouts. This should further reduce disturbance caused by these efforts.

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CHAPTER SEVEN

Steller Sea Lion Foraging Behavior, Movements and Habitat Use
Foraging Behavior of Juvenile Steller Sea Lions in the Northeastern Gulf Of Alaska: Diving and Foraging Trip Duration

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Steller sea lion (SSL) (*Eumetopias jubatus*) numbers are declining throughout most of their range in Alaska and Russia (Loughlin et al. 1992). In Alaska, the western stock declined by about 81% between the 1960s and 1994; from 177,000 to 33,600 nonpups (NMFS 1995). Numbers continued to decline through 1996 (National Marine Fisheries Service unpublished data). However in Southeast Alaska (SEA), SSL numbers appear to have increased during the same period and are now stable (ADF&G 1996). Genetic evidence has identified a western and eastern stock in Alaska, corresponding to these differences in population dynamics (Bickham et al. 1996).

Causes of the decline in the western subpopulation are not well understood. A decrease in prey availability, which could be caused by environmental changes and/or commercial fishing activities, is postulated to be a cause of the recent declines in abundance (Loughlin and Merrick 1989, Lowry et al. 1989, Merrick 1995). Juveniles sea lions are more likely to be affected by changes in prey resources, because of lesser foraging abilities. A leading hypothesis of the proximate mechanism behind the decline is reduced juvenile survival (Merrick 1995, NMFS 1995). Support for this hypothesis comes from observations of reduced proportions of juveniles on the Ugamak Island and Marmot Island rookeries (Merrick 1995).

Past research suggests diving behavior and foraging patterns 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, Boyd et al. 1994). Few data about the foraging behavior of juveniles are available, indeed very little is known about the biology of juvenile SSLs. The aim of this study was to enhance our understanding of the foraging ecology of SSLs and, in particular, to investigate the foraging behavior of juvenile sea lions in the eastern Gulf of Alaska where the population is continuing to decline. The study examined the foraging behavior of juvenile SSLs during the winter and summer by using satellite linked time-depth recorders to collect information on at-sea behavior. The main objectives of the research were to (1) describe the diving behavior; and (2) investigate behavioral indices of foraging effort. Data from this study will be used in the future to determine whether differences in foraging behavior could indicate differences in prey availability for the two subpopulations.

Methods

SSLs were captured and satellite linked time-depth recorders (SDRs) were attached at the Cape St. Elias haulout (CSE) and the Fish Island rookery (FSH) in the eastern Gulf of Alaska. Sea lions using

the haulout at CSE are considered to be at the eastern edge of the western subpopulation where numbers have declined sharply since 1989 (NMFS 1995). Although FSH, on the southeast side of Montague Island, is in the area of population decline, numbers of pups born here may have increased during the early 1990s. FSH is also unique for its high proportion of juveniles. One male and one female juvenile were captured at CSE in January 1995. The male was believed to be two years old, and the female was either one or two years old. One male, considered to be a yearling, was captured at the FSH rookery in June 1995. All three juveniles were observed suckling, although the juvenile male at CSE was only observed to suckle once in three months of observation.

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 (Heath et al. 1996). 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 behavior, and habitat use, as has been done for several other pinnipeds (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 hair 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 are lost when the sea lions molt or the hair becomes brittle. 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 micro-processors 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 two 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 10 hours.

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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 four of these periods (2100-0300, 0300-0900, 0900-1500, 1500-2100 local sun time). Dive depths and durations were summarized separately within the same four periods and stored in a "transmit buffer" that contained the previous four histogram periods (24 hours). Each histogram recorded dive information into six separate bins which were set prior to deployment. The minimum depth for a dive was 4 m based on earlier studies in Alaska (Merrick et al. 1994). The dive-depth bins for all three of the 1995 SDRs were 4-10 m, 10-20 m, 20-50 m, 50-100 m, 100-150 m, and > 150 m. Corresponding dive-duration

bins were 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.

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 time 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 SSLs using VHF radio transmitters (Davis et al. 1996) interpreted a foraging trip to be a minimum of three 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 a minimum between two and three hours. To be consistent and to take into account behavioral 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 mid-point 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 bins which were open-ended, the minimum depth or duration was used to calculate the average (e.g. 150 m for a > 150 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 one 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:

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

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 inter-dive 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 four periods were available. Mean daily time submerged was also used to determine percent time spent 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 to be on land during the entire period.

Analyses

Records from all three instruments were used for the analyses, although only 11 days of data were available for the summer yearling male. Data analyses in part followed that of Merrick (1995), as well as our previous analyses (Swain 1996), to allow for preliminary comparisons of foraging behavior with other SSLs. Differences in dive frequencies by time of day for individual sea lions were tested using a one-way ANOVA and Tukey's multiple comparisons.

Results

The two SDRs on the CSE juveniles studied during January-June yielded data during an average deployment of 129 days. The SDRS for the CSE animals were lost in May and June. Data were obtained for only 11 days from the FSH juvenile during June and then the SDR was lost. The foraging behavior was described for all individual sea lions, and results for these sea lions are presented. Comparisons between sea lions were not undertaken because of limited sample sizes. Data from a yearling female studied in SEA during summer 1993 are also presented in the tables. Results from this sea lion were previously reported (Swain 1996).

Duration of time at sea and on land

The two CSE juveniles spent a mean of 31.3 hr (sd = 15.0) at sea during 134 trips and a mean of 12.1 hr (sd = 3.0) on land during 163 haulouts (Table 1). The FSH juvenile had a mean of 8.3 hr (sd = 2.9) for nine trips to sea and a mean of 11.8 hr (sd = 9.6) for 11 haulouts. Data were available for an additional 34 trips to sea, 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. Mean trip duration varied considerably for individual juveniles and ranged from 8.3 hr to 41.9 hr. The longest trip to sea (180.4 hr) was recorded for the two year old male at CSE which was considerably longer than the longest trips made by the juvenile CSE female (64.6 hr) and the FSH juvenile (13.8 hr). Mean time on land ranged from 10.0 hr to 14.2 hr. The proportion of time at sea averaged 57% (sd = 27%) for the CSE juveniles, 58% for the FSH juvenile, and ranged from 38% to 76% for individuals.

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	•		· <u> </u>]	Haulout		Trip	Percent time
SDR	Sex	Age	Deployment	n	mean (hr)	n	mean (hr)	_at sea
Juvenil	les in w	vinter, Cape S	st. Elias (EGOA)					
2321	Μ	2 years	1/10-6/4 '95	83	10.0	60	41.9	75.5
2324	F .	1-2 years	1/22-5/15 '95	80	. 14.2	74	20.7	37.6
			Both	163	12.1	134	31.3	56.6
Juvenile in summer, Fish Island (EGOA)								i
2323	Μ	yearling	6/11-6/22	11	11.8	9	8.3	57.6
Juvenile in summer, Forrester Island (SE)								
2094	F	yearling	6/22-9/14 '93	69	11.1	61	19.3	61.1

Table 1. Duration of deployments, haulouts, and at-sea trips of juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and in Southeast Alaska during 1993.

Dive depth

Depth histograms summarized data from 31,731 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 the CSE juveniles for all dives greater than 4 m was 17.4 m (sd = 9.6) and 74% (sd = 16.1) of all dives were less than 10 m. Dive depths varied considerably for these two individuals. The maximum dive depth recorded was 252 m for the male juvenile at CSE. In contrast, the mean dive depth was only 7 m (sd = 0.5, max = 12 m) for the yearling male at FSH.

		Depth		Percenta	ige of Div	ves			
SDR	No. of	Mean	Max	4-10	10-20	20-50	50-100	100-150	>150 m
	Dives	(m)	(m)	(m) ·	(m)	(m)	(m)	(m)	
Juveniles	s in winter	/spring, C	ape St. Eli	as (EGOA	A)				
2321	15,552	24.2	.252	62.6	17.5	5.4	7.1	4.1	3.3
2324	15,362	10.5	164	85.4	9.2	3.2	1.6	0.6	0.1
Both	30,914	17.4		74.0	13.4	4.3	4.4	2.4	1.7
Yearling male in summer, Fish Island (EGOA)									
2323	817	7.0	12	99.6	0.4				
Yearling	female in	summer, 3	Forrester Is	sland (SE)			· ·	
2094	25,338	18.0	220	57.7	21.5	16.3	2.9	1.6 ª	· · ·
^a Denth b	<u>vin is 100-</u>	250 m							

Table 2. Dive depths for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and in Southeast Alaska during 1993.

The proportion of dives in the 4-10 m depth strata ranged from 63% to nearly 100% for all juveniles (Fig. 1). Twenty percent of the dives by the CSE male juvenile were greater than 20 m compared to 6% for the CSE yearling female, while the male yearling at FSH dove no deeper than 12 m. Overall dive depths changed during the deployment period for both the CSE juveniles (Jan - May/June). The percentage of deeper dives (> 50 m) decreased in the spring and early summer (17-23% during Jan-March vs. 0-3% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the male juvenile; 6% during Jan-March vs. 0% during April-June for the veget for

Dive duration

Duration histogram data were collected on 33,574 dives (Table 3). Mean dive duration for all dives by the CSE juveniles was 1.4 min (sd = 0.3). Most dives were short: 57% were less than 1 min and 24% were 1-2 min. The FSH yearling male made short dives (mean = 1.1 min) and had the highest percentage of dives between 0 - 1 min (78%), however, the proportion of dives exceeding 8 min was greater than that of the CSE juveniles (3.3% vs. 0.2%) (Fig.1). Unlike dive depth, the SDR software did not allow determination of a precise duration as a maximum, so maximum dive duration was considered equal to that of the longest bin which contained dives. The maximum dive duration was greater than 8 min for all three juveniles. **DIVE DEPTH**



DIVE DURATION



Figure 1. Proportion of dives in depth and duration categories (bins) for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and from a juvenile in SEA (SE) during 1993.

Overall, dive depths were shallow, dive durations were short, and depth and duration showed similar proportions of dives in the various depth and duration bins. Generally, a high proportion of shallow dives resulted in a high proportion of short dives. As with dive depths, dive durations changed during the deployment period for both the CSE juveniles. The proportion of short dives increased in spring and early summer.

Table 3. Dive durations for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and a juvenile in SEA during 1993. The number of dives in the longest duration category (bin) is given in parentheses.

		Duratio	n .			Percentag	ge of Dives		
SDR	No. of	Mean	Max	0-1 min	1-2 min	2-4 min	4-6 min	6-8 min	> 8 min
	Dives	(min)	(min)						
Juveniles	s in winter	/spring, (Cape St. I	Elias (EGC	DA)		, (
2321	16,834	1.6	> 8	46.3	28.8	16.1	8.0	0.7	0.1 (14)
2324	15,933	1.2	> 8	67.5	19.5	11.7	1.0	0.1	0.2 (28)
	32,767	1.4		56.9	24.2	13.9	4.5	0.4	0.15
Juvenile in summer, Fish Island (EGOA)									
2323	807	1.1	> 8	78.4	9.7	4.8	2.4	1.4	3.3 (27)
Yearling	iemale in	summer,	Forreste	r Island (S	E)				ĩ
2094	26,148	1.06	> 16	66.3	21.7 ·	10.8	1.2 %	of dives >	4 min

Dive frequency

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Data were obtained on 16,834 dives from the CSE juvenile male, 15,933 dives from the CSE juvenile female, and 807 dives from the FSH yearling male (Table 4). Mean dive frequencies for the CSE juveniles were 9.5 and 8.3 dives per hr. The highest dive frequency was recorded for the CSE juvenile female (42.8 dives per hr), although a high dive frequency was also observed for the CSE juvenile male (max = 36.3 dives per hr).

Significant diurnal patterns in dive frequency were evident for both the CSE juvenile male (F = 12.42, P < 0.0001) and female (F = 5.55, P < 0.001) (Table 5). The CSE juvenile male dove most frequently at night (2100-0300) with a mean frequency of 13.6 dives per hr (Fig. 2). The juvenile female dove most frequently (mean = 11 dives per hr) in the early morning (0300-0900), however, this frequency was only significantly different from the dive frequency observed during the late afternoon (1500-2100). No significant diurnal differences in dive frequency were observed for the FSH yearling male.

Table 4. Dive frequencies for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and a juvenile in Southeast Alaska during 1993.

SDR	No. of dives	No. of 6-hr periods [*]	Dive frequency (mean no.
			per hr)
Juveniles in w	inter/spring, Cape St.	Elias (EGOA)	
2321	16,834	295	9.5
2324	15,933	314	8.3
Both	32,767	609	8.9
Dom			
Yearling male	in summer, Fish Isla	nd (EGOA)	
Yearling male 2091	in summer, Fish Islar 807	nd (EGOA) 30	4.5
Yearling male 2091 Yearling fema	in summer, Fish Islan 807 le in summer, Forrest	nd (EGOA) 30 er Island (SE)	4.5

Table 5. Dives per hour by time of day for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and a juvenile in Southeast Alaska during 1993.

	Mear	n dive frequency by	y by time of day (dives/hr)				
SDR ····	2100-0300	0300-0900	0900-1500	1500-2100			
Juveniles in winter/spring, Cape St. Elias (EGOA)							
2321	13.6ª	8.7 ^b	6.4 ^b	8.8 ^b			
2324	8.1 ^{ab}	11.0°	8.2 ^{ab}	5.6 ^{ab}			
Yearling male in summer, Fish Island (EGOA)							
2323	3.6ª	4.0 ^a	7.5°	2.7 °			
Yearling female in summer, Forrester Island (SE)							
2094	33.5ª	14.1 ^b	9.9°	6.1 °			

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





Figure 2. Dive frequency by time of day for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and a juvenile in Southeast Alaska during 1993.

A seasonal effect on the frequency of dives was observed for the CSE juveniles. Both dove more frequently in the spring and early summer (Figs. 3 and 4). As dive depths decreased during the spring, a trend of increasing dive frequency was observed; dive frequency was considerably higher in April (12.5 and 10.3 dives per hr for the juvenile male and female) and May (12.8 and 10.6 dives per hr) than in January (4.4 and 5.2 dives per hr) and February (6.5 dives per hr for both). The juvenile male showed a large increase in diving at night (2100-0300) during April and May as did the juvenile female, although diving during the morning (0300-0900) also increased considerably during March - May.



Figure 3. Monthly dive frequency by time of day for a juvenile male SDR-tagged Steller sea lion in the Eastern Gulf of Alaska during winter and spring 1995.



Figure 4. Monthly dive frequency by time of day for a juvenile female SDR-tagged Steller sea lion in the Eastern Gulf of Alaska during winter and spring 1995.

Foraging effort and time submerged

Foraging effort for the CSE juvenile male was very high (5.8 hrs per day) compared to 1.5 hrs per day for the CSE juvenile female and 1.1 hrs per day for the FSH yearling male (Table 6).

Data were obtained for all juvenile sea lions on 153 days in which all four periods (times of day) were represented. The mean number of hours per day spent submerged or diving ranged from 1.7 hrs to 4.2 hrs (Table 6). The CSE juvenile male spent considerably more time submerged (18% of the day) than the two other juveniles. The maximum daily time this juvenile spent submerged was 13.2 hours.

Table 6. Time submerged and foraging effort for three juvenile SDR-tagged Steller sea lions in the eastern Gulf of Alaska (EGOA) during 1995 and a juvenile in Southeast Alaska during 1993 are also presented.

SDR	No. of 24-hr periods ^a	Time submerged (hrs/day)	Percent time submerged	Foraging effort ^b (hrs/day)	►		
Juveniles i	n winter/spring, C	ape St. Elias (EGOA)		······································			
2321	58	4.2	17.5	5.8			
2324	86	2.6	10.8	1.5	, Martin -		
Both	144	3.4	14.2	3.7			
Yearling m	ale in summer, Fi	sh Island (EGOA)	the standard		v		
2323	9	1.7	7.8	1.1 ···· · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·		
Yearling fe	male in summer, l	Forrester Island (SE)		··· ··· ·. ,	•••••		
2094	70	5.7	23.8	4.4	•		
^a No. of co	^a No. of complete days for which data is available from all 4 periods (2100-0300, 0300-0900, 0900-						
1500, 1500	-2100), i.e., an pe	-	n me 24-m perio	·u.			
^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							
1		T_{D} = Mean dive durat	ion in minutes				
	- <u>-</u> , · · ·	P_T = Proportion of tim	ie at sea	· · · · · ·	اله ودیو مراجع ا ب		
	:			· · ·	· ·		

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', then the mean proportion of time at sea for the CSE juvenile male was 51% which is considerably lower than the proportion estimated from the 'land/sea' sensor data (76%). By using the same criteria for time submerged, the proportions of time at sea for the CSE juvenile female and for the FSH yearling male were estimated as 31% and 35% compared to 38% and 58% respectively.

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Discussion

Limited conclusions on the foraging behavior of juvenile Steller sea lions can be drawn from the three juvenile sea lions studied in 1995, because of the small sample size and the differences in age and sex class and foraging season.

Interpretation of results (foraging trip duration and proportion of time at sea) is complicated by the limitations of the 'land/sea' sensor data and the assumptions inherent in the calculations. Information on whether a sea lion is on land or at sea is obtained only when the satellite passes overhead. The information is 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 and histogram data, varied considerably for the CSE juvenile male and the FSH yearling male. The reason for the higher 'land/sea' estimate is unclear, as time at sea was most likely underestimated using the 'land/sea' method and overestimated using the histogram data.

The foraging behavior of the two CSE juveniles differed substantially and was most likely due to the differences in ages. The older old male spent considerably more time at sea on relatively long foraging trips, dove deeper as well as longer, and dove significantly more often at night. These characteristics are similar to those described for adult females in winter in the Gulf of Alaska and the eastern Aleutians (Merrick 1995, Swain 1996). Overall dive characteristics were also similar and did not indicate the size-based physiological constraints evident in the younger juvenile female. Data from of the CSE juvenile female seemed to confirm her age as a yearling. The foraging behavior of the yearling female was characterized by relatively brief trips to sea that represented about a third of its time and by fairly frequent, short and shallow dives. Less than 6% of her dives exceeded 20 m, and her mean maximum daily dive depth was 24 m, compared to 113 m for the juvenile male. The diving abilities of the yearling female were similar in most respects to young-of-year animals studied in the eastern Aleutians and the central Gulf of Alaska (Merrick 1995), except that the CSE juvenile showed some diurnal patterns in dive frequency in March - April.

The frequency of diving for both CSE juveniles increased significantly in the spring as did the percentage of shallow dives. For the juvenile male, less than 3% of dives were greater than 50 m in April and May compared to 33% in January-March, and in June there were no dives exceeding 20 m. The yearling female did not dive deeper than 50 m during April and May. There was also a marked increase in diving at night by the juvenile male during April-June. The yearling female showed a considerable increase in diving in the early morning in March and April, although dive frequencies were highest at night during May. The increased frequency of shorter and shallower dives in late spring suggest the CSE juveniles may have been foraging on spawning fish such as herring (*Clupea harengus*).

The diving behavior of the yearling male at FSH was only described for 11 days, since the SDR was lost after this time. The behavior was characterized by very short trips to sea that nevertheless represented about half of his time and by very shallow and short dives. The yearling never dove deeper than 12 m. The FSH yearling male had much shorter trips to sea and shallower, shorter and less frequent dives than the CSE juveniles. This was likely due to its younger age and close association with its mother. It had

not been weaned and was rarely observed without its mother on FSH (pers. observation). Dive characteristics were similar in many respects to young-of-year sea lions (Merrick 1995), however, dive frequency was considerably lower.

Less developed foraging skills would require more dives to successfully obtain prey, yet the juvenile sea lions appeared to behave similarly in many respects to the adult females studied at the same time of year (Merrick 1995, Swain 1996). The small number of very shallow dives characterizing the diving behavior of the FSH yearling male reflected that he was actively nursing and obtaining a significant amount of nutrition from the mother. The CSE juveniles had mean dive frequencies similar to young-of-year and adult female sea lions in winter (Merrick 1995, Swain 1996), however, dive frequency increased significantly in the spring and early summer. There appears to have been a pronounced seasonal effect on dive frequency. The very high dive frequency of the yearling female studied in SEA during summer likely had a seasonal component, yet the yearling dove significantly more often than lactating females and the yearling male studied at FSH. The SE yearling was unlikely to still be nursing, and the higher dive frequency may have reflected a greater foraging effort.

Young-of-year sea lions from the declining population were reported to expend less energy in foraging than adult females (Merrick 1995), however, these animals may still have been nursing. The low foraging efforts portrayed by the CSE yearling female and the FSH yearling male seemed to reflect their nursing status, as did times spent submerged. The CSE juvenile male, believed to be mostly independent, appeared to have fairly high indices of foraging effort compared to both young and adult female sea lions. 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).

Diving patterns varied widely among the individual juvenile sea lions and appeared to be strongly influenced by nursing status. Seasonal and diurnal variations in diving patterns suggest 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 behavior between individuals also suggest that individuals can adjust their foraging strategies and that behavioral indices of foraging effort may be able to discern differences in prey availability. The predictive value of foraging behavior 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). Greater sample sizes, especially for juveniles, are necessary to discern potential differences in foraging behavior between the western and eastern Steller sea lion subpopulations.

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Foraging Behavior of Steller Sea Lions in the Northeastern Gulf of Alaska: Movements and Tracklines

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Steller sea lions (SSLs) (*Eumetopias jubatus*) are found across the North Pacific Rim from Northern California to northern Japan. The worldwide population was recently classified as two stocks with an east-west division near Cape Suckling in Alaska (144° west longitude) (U. S. Federal Register 62:24345-24355). The western stock has declined so severely in the last two decades that it was recently listed as endangered under the U.S. Endangered Species Act. The eastern stock retained threatened status. The exact cause(s) of this decline is unknow although some of the best evidence suggests it may be related to nutritional stress (Calkins and Goodwin 1988; Calkins et al. in press, Merrick 1995). There are indications that high mortality of juveniles has driven the decline (York 1994, Merrick 1995). This research was directed toward the feeding ecology of juvenile SSLs through the use of satellite-linked time depth recorders (SDRs). Here we report on location information generated from SDRs that were attached to juvenile sea lions during 1995.

METHODS

Three juvenile SSLs were captured in 1995. Two were captured and fitted with SDRs at Cape St. Elias on the southern tip of Kayak Island in January 1995 and one was fitted with a SDR on Fish Island, off the southeastern end of Montague Island, in June, 1995. The first juvenile (SDR 2321) was captured at Cape St. Elias on January 10. This animal was a male and, judging from its body size and tooth eruption pattern, was approximately 32 months old at the time of capture. Through repeated observations of this animal on the haulout we determined that this sea lion was weaned from its mother, although it was observed to attempt to suckle on one occasion. The second animal, a female, was captured and fitted with SDR 2324 on January 11, 1995 at Cape St. Elias. Size and tooth eruption pattern suggested this animal was approximately 20 months old. We observed this animal suckling during January, February and March 1995. The third juvenile was captured at Fish Island on June 11, 1995 and fitted with SDR 2321. This was a male that was estimated to be 12 months old and was observed suckling during June and July.

Sea lions were captured by darting with a tranquilizer and placed on gas anesthesia (Heath et al. 1996). 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. The SDRs were manufactured by Wildlife Computers (Redmond, WA), and produced 0.5 watts of power. Physical measurements of the units were 14.8 x 10.0 x 3.8 cm. They weighed about 750 g and were powered by four lithium C cells.

SDRs were equipped with conductivity and pressure sensors and built-in programmable microprocessors that collected and summarized data on diving and haulout patterns over six hour period and stored it for later transmission, as has been done for spotted seals (*Phoca largha*), crabeater seals (*Lobodon carcinophagus*), and SSLs in other studies (Lowry et al. 1994 *a,b*; Hill et al. 1987; Bengtson et al. 1993; Merrick et al. 1994). Data were collected and stored in six hour blocks (0300-0900 hrs, 0900-1500 hrs, 1500-2100 hrs, and 2100-0300 hrs local time) and transmitted to a satellite once the six 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 the sea lion was hauled out, or when the antenna broke the surface of the water, and the satellite was positioned such that it could 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. The units were programmed to allow a maximum of 400 transmissions per day while above the surface. Transmissions ceased after 24 hours hauled out and until the sea lion re-entered the water. Therefore signals should have been transmitted from each SDR for up to 250 days.

Satellite Tag Data Analysis

Data from satellite tagged sea lions were obtained from Service ARGOS. The ARGOS system recorded date and time of each signal uplink and calculated a location for the SDR based on the 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 descriptions and analyses 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 10 hours. The minus 10 hour correction adjusts for the actual position of the sun with mid-day occurring at approximately 1200 hours.

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The accuracy of locationa vary depending partly on the number of uplinks that occur during a satellite pass. Service ARGOS assigns a quality ranking to each location. Locations resulting from standard data processing were ranked as 0, 1, 2, or 3, with quality 3 providing the highest accuracy.

An error index value (KEI) was calculated for each record according to the equation described by 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 20 were removed. The next step in screening records was to locate and remove erroneous locations based on the apparent movement speeds of the sea lions. 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 greater than 10 km/hr for a period of greater than 5 minutes; 2) apparent speeds greater than 100 km/hr for a period of greater than 1 minute; and 3) apparent speeds 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 (Williams and Kooyman 1985), while the latter two 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 20 were deleted. Numbers of location records referred to in this report include only those records that remained after the complete screening process.

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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 whether sensors indicated 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 datafiles were used to produce geographic information system coverages in ARCINFO, and datasets 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 or haulout where the sea lion was tagged to the furthest location point in a trip. Only those trips were used that had two or more at-sea locations within the same trip.

RESULTS

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All locations for SDRs 2321, 2323 and 2324 are shown in Figures 1 through 3. The juvenile sea lion carrying SDR 2321 used three different haulouts in the vicinity of CSE. In addition to hauling out at CSE, where he was tagged, he also hauled out on a rock off the northeast side of Kayak Island and on Wingham Island (Table 1).

Sea lion 2323 remained in the vicinity of Fish Island where he was tagged and only hauled out on Fish Island. The maximum distance from Fish Island this animal was located was 52 km around the south end of Montague Island.

Sea lion 2324 hauled out on Cape St. Elias, Wingham Island and Kanak Island. Table 2 shows the dates and locations when sea lion 2324 was hauled out. Most at-sea locations for sea lion 2324 were within 10 km of one of these haulouts. The maximum distance from a haulout was 43 km to the east of Cape St. Elias in the Gulf of Alaska.

Sea lion 2321 made several discreet "foraging" trips during the monitoring period. Figures 4 through 6 show three typical trips. These trips ranged in length from 4-6 days. They were all in the same general area to the north and west of Cape St. Elias. Maximum distance from Cape St. Elias ranged from 74 to 89 km and minimum distances traveled during a foraging trip ranged from 39 to 211 km.

SDR NUMBER	TIME PERIOD	LOCATION
2321	10 January - 22 April	Cape St. Elias
2321	23 April - 3 May	Wingham Island
2321	5 May - 9 May	Cape St. Elias
2321	10 May - 11 May	Rock NE of Kayak Island
2321	12 May	Wingham Island
2321	13 May - 2 June	Cápe St. Elias

S. C. Starley

Table 1. Time periods and locations SDR 2321 was hauled out during winter 1995.

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Figure 1. All locations of Steller sea lion 2321, January 10-June 3, 1995. The first and last locations received and the first and last locations received each month, are labelled with the date.



Figure 2. All locations of Steller sea lion 2323, June 12-22, 1995. The first and last locations received are labelled with the date.

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Figure 3. All locations of Steller sea lion 2324, January 10-May 15, 1995. The first and last locations received, and the first location received each month, are labelled with the date.

SDR NUMBER	TIME PERIOD	LOCATION
2324	23 Jan 6 Feb.	Cape St. Elias
2324	7 Feb.	Wingham Island
2324	8 Feb 15 Mar.	Cape St. Elias
2324	16 Mar.	Kanak Island
2324	17 - 21 Mar.	Cape St. Elias
2324	22 Mar.	Wingham Island
2324	23 - 30 Mar.	Cape St. Elias
2324	31 Mar.	Kanak Island
2324	1 - 3 Apr.	Wingham Island
2324	4 Apr.	Cape St. Elias
2324	5 - 6 Apr.	Wingham Island
2324	7 - 9 Apr.	Cape St. Elias
2324	10 Apr 15 Apr.	Wingham Island
- 2324	16 Apr.	Kanak Island
2324	17 Apr 14 May	Cape St. Elias

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Table 2. Time periods and locations SDR 2324 was hauled out during winter 1995.

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Figure 4. Track line and all locations of one foraging trip for Steller sea lion 2321, Jan. 12 through Jan. 18. Each location is labelled with the month /day and time.



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Figure 6. Track line and all All locations of one foraging trip for Steller sea lion 2321, Feb. 4 through Feb. 8. Each location is labelled with the month /day and time.

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DISCUSSION

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Little can be concluded about the foraging strategy of juvenile sea lions from only three animals. Some general comparisons between these three animals may be useful. The three animals showed quite different patterns of movements while they were monitored. The primary reason for this was likely the result of differences in weaning status and ages of the three juvenile SSLs and perhaps foraging season. The first animal, sea lion 2321 was approximately 32 months old when tagged and had been weaned. This animal showed the most extensive foraging movements of the three. He made the longest trips and he was at sea for the longest periods of time (see Foraging Behavior of Juvenile Sea Lions in the Northeastern Gulf of Alaska: Dive Behavior and Trip Duration, this report). Sea lion 2321 was the only one of the three that made what appeared to be exploratory foraging trips over relatively long periods and long distances.

Sea lion 2323 was a 12 month old male captured at Fish Island. During the time the SDR was attached to this animal, it was observed to repeatedly suckle from an adult female. This animal had not been weaned and remained at least partially dependent on its mother for food. According to the location data this animal usually remained in the vicinity of Fish Island (Fig. 2) but may have made some exploratory movements in the general area. It was located as far as 51.8 km from Fish Island. However, as this relocation was near the coast of Montague Island, the sea lion may have followed the shoreline. Location data for this animal suggests that it did not make detailed foraging trips to sea as seen for sea lion 2321. It is not known whether this juvenile was accompanied by its mother (Swain pers. Communication). The usual pattern for juvenile sea lions before weaning is to remain within the vicinity of the haulout where the female left them, then join her when she returns from a foraging trip for suckling. At some point the offspring probably begins to accompany the adult on some of the foraging trips. This may be depicted in some of the relocations more distant from Fish Island.

Sea lion 2324 was an 20 month old female that was observed to suckle often enough to consider her dependent upon her mother. Her movement patterns reflected this (Figure 3) and were similar in many respects to sea lion 2323. She remained in the vicinity of the haulouts, probably waiting for her mother to return to feed her. Some of the at-sea relocations of sea lion 2324 could have been while accompanying her mother on foraging trips but we had no way of determining that. One such relocation point was 43 km to the east of Cape St. Elias recorded on May 15. This was the longest movement to sea and time away from a haulout by this animal. She may have been on an exploratory or practice foraging trip, possibly accompanied by her mother.

Both of the sea lions tagged at Cape St. Elias also hauled out at Wingham Island occasionally during the winter (Figures 1 and 3). Each of them also utilized another haulout (Tables 1 and 2). We are only beginning to understand haulout behavior. However, it is apparent that while a juvenile, either suckling or independent, may remain in the same general area, it is not necessary for them to return to the same location each time. Again, it is not certain if the dependent female (2324) accompanied her mother to these locations, although it seems likely that this was the case.

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GENERAL DISCUSSION

SSL numbers in the Alaska portion of the western stock continued to decline based on surveys conducted during 1996 (NMFS unpublished data). Numbers of animals counted in the Kenai to Kiska trend area declined by 4.6% between 1994 and 1996. Relatively stable numbers in the eastern Aleutian Island and central Gulf of Alaska suggested moderation or cessation of the decline in those areas. In Southeast Alaska, numbers are probably near their highest level in recorded history and appear to have been stable since 1989. There is still a marked contrast in relative population levels and population trends between the eastern and western SSL stocks in Alaska, even though changes appear to be occurring in both areas.

SSLs, that were branded as pups at the Forrester Island rookery in Southeast Alaska have been resighted at sites ranging from Washington state to Jude Island in the western Gulf of Alaska. Many, but not all, of the long-range dispersers were males. Based on the results of genetics studies (Bickham et al. 1996), we hypothesize that the marked females will return to Southeast Alaska to breed and that immigration of females SSLs into the western stock is unlikely to play a significant role in the recovery of that population. We will evaluate this hypothesis over the next several years as branded females from Forrester Island reach sexual maturity and we determine the locations where they give birth to pups.

Data from behavioral studies in Southeast Alaska and the Gulf of Alaska are still being analyzed but there is a suggestion of nutritional stress in SSLs from the Gulf as evidenced by a shorter perinatal period. There were interannual differences in perinatal periods, trips to sea, visits ashore, and timing of feeding trip departures between 1994 and 1995 in both areas.

Findings of reduced growth (standard length, axillary girth and mass) of SSLs from the Gulf of Alaska between the 1970s and 1980s supports the hypothesis that nutritional stress was a factor in the decline. There was also a suggestion that body size declined from the 1950s to the 1970s and 1980s. Examination of growth layers of teeth from animals (Boyd and Roberts 1993) collected during the 1970s and 1980s could provide additional information on temporal variations in growth and nutrition.

Blubber samples from 24 adult female SSLs from Southeast Alaska were analyzed for chlorinated hydrocarbons and DDTs by the Environmental Conservation Division of NMFS, Northwest Fisheries Science Center. There were significant concentrations of both PCBs and DDTs in the samples. This is of particular interest because levels of these contaminant have been found to be lower for sea otters (*Enhydra lutris*) from Southeast Alaska than for sea otters from the Aleutian Islands (Estes et al. in press) and because the samples were from adult females that eliminate much of their chlorinated hydrocarbon loads through lactation. These pollutants have been associated with reproductive failures (Platonow and Karstad 1973, Aulerich and Ringer 1977, Mason 1989, Coburn et al. 1993) and impaired immune systems (Coburn et al. 1993, de Swart et al. 1996) in mammals. Additional research into contaminant levels and effects on SSLs is warranted. It would be of particular interest to examine contaminant levels in milk samples and blubber from nursing juveniles.

It appears feasible to capture pup, and perhaps juvenile, SSLs during winter using SCUBA equipment. This will allow for comparisons of growth, condition, the prevalence of diseases and levels of contaminants from young sea lions in the eastern and western stocks. This should aid in the evaluation of the hypothesis that the decline is associated with low juvenile survival in the western stock (York 1994, NMFS 1995, Merrick 1995).

Diving behavior and movements of young SSLs varied considerably and was probably related to physical and behavioral maturity (age) and nursing status. Our knowledge of juvenile sea lion biology is limited. We need to better understand the development of nutritional independence in young sea lions and how it is affected when prey resources are limited. Extended lactation has been frequently observed; however its importance as a source of nutrition to young animals is not known. If food becomes limiting, is lactation extended at the cost of future offspring or does premature weaning occur which could reduce juvenile survival (Merrick and Loughlin 1997)?

RECOMMENDATIONS

- 1. Based on the findings of marked animal studies and genetics work, it appears that female SSLs may have very low rates of emigration. Therefore, population recovery in the western stock will probably result from internal growth rather than emigration of animals from the eastern stock. To enhance recovery, every possible effort should be made to reduce or eliminate human-related mortality of sea lions. Non-density dependent sources of mortality may slow or prevent recovery even if adequate food resources are available.
- 2. Over the next several years, as the marked female SSLs from Forrester Island become sexually mature, searches of rookeries from the Pacific Northwest to the Aleutian Islands should be made to determine the extent of emigration of Southeast Alaska animals into other areas in order to evaluate the hypothesis of low rates of emigration.
- 3. Population monitoring through counts of pups and nonpups should continue. Development of alternative methods of counting pups which are less invasive should proceed.
- 4. Research should be conducted to evaluate the utility of measurements of growth layers in tooth fine structure to examine relative nutritional status over time.
- 5. The feasibility of evaluating trends in historical abundance of SSLs 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.
- 6. Research on the biology of young (0-3 years) SSLs should be conducted. These animals, which are undergoing the process of becoming nutritionally independent, are likely to have high rates of mortality during periods when food resources are suboptimal. Research should be continued to develop efficient capture techniques for SSLs, particularly young animals.
- 7. A plan should be developed to evaluate the importance of environmental contaminants, particularly chlorinated hydrocarbons and DDTs, in SSLs in Alaska. Young animals could be accumulating high levels as they often nurse for several years and these contaminants are transferred from the female to the offspring in milk.

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