A REVIEW OF PROPOSED FISHERY MANAGEMENT ACTIONS AND THE DECLINE OF STELLER SEA LIONS *Eumetopias jubatus* IN ALASKA: A REPORT BY THE ALASKA STELLER SEA LION RESTORATION TEAM

by

Gordon H. Kruse, Morgen Crow, Earl E. Krygier, Denby S. Lloyd, Kenneth W. Pitcher, Lorrie D. Rea, Michelle Ridgway, Robert J. Small, Jay Stinson, and Kate M. Wynne

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ACRONYMS USED IN THIS REPORT

ADF&G – Alaska Department of Fish and Game

ASSLRT – Alaska Steller Sea Lion Recovery Team

BiOp1 – The Biological Opinion (NMFS 1998a), issued December 3, 1998, regarding threatened and endangered species potentially affected by federally managed fisheries for Atka mackerel and walleye pollock in the Gulf of Alaska and the Bering Sea/Aleutian Islands between 1999-2002.

BiOp2 – The Biological Opinion (NMFS 1998b), issued December 22, 1998, regarding threatened and endangered species potentially affected by federally managed groundfish fisheries in the Gulf of Alaska and the Bering Sea/Aleutian Islands for 1999.

BiOp3 – The Biological Opinion (NMFS 2000), issued November 30, 2000, regarding threatened and endangered species potentially affected by federally managed groundfish fisheries in the Gulf of Alaska and the Bering Sea/Aleutian Islands.

ESA – Endangered Species Act of 1973

$F_{40\%}$ – Instantaneous rate of fishing mortality that theoretically reduces spawning stock biomass to 40% of unfished levels.

FMP – Fishery Management Plan

IUCN – International Union for the Conservation of Nature and Natural Resources

NMFS – National Marine Fisheries Service

NPFMC – North Pacific Fishery Management Council

USFWS – United States Fish and Wildlife Service

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EXECUTIVE SUMMARY

On September 11, 2000, Alaska Governor Tony Knowles formed a State of Alaska Steller Sea Lion Restoration Team (ASSLRT or Restoration Team). The overall goal of ASSLRT is to promote the recovery of Steller sea lion populations while sustaining viable commercial fisheries in Alaska. Specific objectives are to: (1) review the justification of fishery restrictions to protect and restore Steller sea lions, and (2) recommend research priorities and adaptive management strategies designed to identify those factors inhibiting the recovery of the endangered western stock of Steller sea lions and provide increased understanding of fishery and sea lion interactions. Toward these ends, in this report we: (1) provide a concise synopsis of Steller sea lion declines and potential causes of those declines; (2) review the Steller sea lion listing status under the Endangered Species Act (ESA); (3) examine sea lion critical habitat definitions and related considerations; (4) provide an independent scientific review of the NMFS biological opinion (BiOp3) issued November 30, 2000; (5) offer management advice with regard to protection of Steller sea lions for consideration by federal and state regulatory bodies and management agencies; (6) summarize recent and ongoing research on sea lion biology, ecology, and fisheries and other human interactions; and (7) recommend scientific research needed to resolve uncertainties about the causes of Steller sea lion declines.

Contrary to the eastern stock of Steller sea lions, which appears to be at the highest levels of recorded abundance, the western stock has experienced a severe decline in abundance since the first assessment surveys in the late 1950s. The ultimate cause of the steepest segment of the decline (1970s and 1980s) is widely thought to have been low survival and low birth rates, and the proximate cause is thought to have been nutritional stress. During the 1990s, the overall rate of decline of juveniles and adults on index sites for the western stock moderated. The preponderance of evidence from research conducted in the 1990s on pups and females with pups during summer indicates that the declining western stock was not nutritionally limited relative to the increasing eastern stock and, by some measures, the animals in the western stock were actually healthier. However, comparable contemporary data are lacking on pups during the non-breeding period, on post-weaning juveniles, and on adult females without pups year-round. Of these other life stages, the Restoration Team is most concerned about juveniles because of their high caloric need per unit body weight and their relative inexperience in capturing prey, and about adult females because of their needs to obtain sufficient resources to maintain pregnancy. The team reviewed various hypotheses that have been proposed to explain both the historical and recent declines.

Regarding ESA listing status, the population trend and abundance data for the eastern stock of Steller sea lions does not support the definition of threatened, and it is highly unlikely that this stock will become endangered in the foreseeable future. Based on a cursory analysis, it appears that this stock should be de-listed from the ESA, although a more thorough analysis of the eastern stock should be conducted. For the western stock, continued declines in nearly all areas within its range are disconcerting, but a reassessment of its listing status is appropriate in light of recent population trend data, new alternative population viability models, and proposed new quantitative methods for ESA classifications. The specific question is whether new information influences the determination that the western stock of Steller sea lions is in danger of extinction.

In 1993 Steller sea lion critical habitat was designated including aquatic zones 20 nm around rookeries and important haulouts west of 144^{o} W. This designation was not adequately justified. ASSLRT supports a complete analysis of the telemetry data that integrates both location and dive behavior data from individual at-sea trips to directly estimate the spatial and temporal foraging patterns of sea lions. Once completed, these critical habitat designations should be revisited.

BiOp3 is a comprehensive document with good information on the history of regulations, current fishery management plans, stock trends and commercial catch histories, descriptions of the fisheries, and Steller sea lion biology and ecology. Yet, it has major deficiencies. Leading among these are a lack of a fair and thorough treatment of alternative hypotheses for the population decline, a failure to distinguish different sea lion population trends and potential causative factors in the 1970s and 1980s from the 1990s, and a lack of full treatment of recent and ongoing studies that suggest that nutritional limitation did not occur in the 1990s, at least with respect to the studied life stages, pups up to age 5 months and females with pups. For the other life stages, including juveniles, no information either supporting or contradicting current nutritional limitation exists.

Regarding management advice, the team identified two important biological activities of sea lions needing protection: (1) breeding and resting on land, and (2) foraging at sea. Management measures should be designed with particular goals in mind. Corresponding to these two sets of sea lion activities, the team developed two management goals against which the merits of alternative management measures were judged: *goal 1 is to prevent human disturbance of land-based sea lion activities including breeding, nursing, resting, and social structure and behavior; and goal 2 is to preclude diminution of prey of appropriate species, in adequate densities, of sufficient spatial distributions, and in the sizes preferred by Steller sea lions to meet their nutritional needs.*

The team considered a suite of management measures for their ability to meet these two goals. For goal 1, the best management tools to protect animals while out of the water are no-approach zones for persons on land, and no-transit zones around rookeries and haulouts for vessels at sea, during the seasons (i.e., summer, winter, or year-round) that these sites are occupied. The team feels that the appropriate size of the no-transit zones around haulouts to prevent disturbance is in the range of hundreds to thousands of feet. The team realizes that larger zones may be more effective if the intent is to limit direct mortality from illegal shooting. Also, the size of the no-transit zones may need to be larger for rookeries than for haulouts owing to the greater risk of adverse effects on pups. Information does not exist to quantify the merits of particular alternatives. Therefore, the size of no-transit zones should include public consultation so that sizes chosen for particular locations can reflect the best available scientific data, anecdotal information, local knowledge of the site, and considerations of required human activity such as access to harbors or routes needed for safe navigation.

The team struggled with the formulation of management advice to meet goal 2. Fishing restrictions would achieve this goal only if Steller sea lions are stressed due to an inability to meet nutritional needs and if fisheries contribute to the nutritional limitation. Data are limited, but there is no direct evidence that either contingency is true. A precautionary approach would hypothesize that juveniles experience nutritional stress at present because of their high nutritional demands, their inexperience in capturing prey, and a lack of contemporary data to indicate otherwise. However, among a suite of possible management measures, the Restoration Team was unable to determine any one measure or set of measures that is well suited to meet this goal. No-fishing zones could be useful tools to prevent diminution of prey availability to juvenile sea lions if the zones indeed correspond to juvenile foraging areas. The designation of effective no-fishing zones requires information yet to be realized from a full analysis of telemetry data that integrates both location and dive behavior data to directly estimate the spatial and temporal foraging patterns of sea lions. In the interim, it may be meritorious to include no-fishing zones in an experimental management approach to evaluate positive and negative effects of alternative designs on Steller sea lion trends on adjacent rookeries and haulouts.

The Restoration Team offered a list of research recommendations to help resolve many uncertainties regarding the causes of sea lion declines and potential remedial measures to foster recovery. Above all, research should emphasize adult females and subadults, especially pre-weaning and during the first 1-2 years post-weaning, to improve our knowledge of these life stages including whether there is any evidence for nutritional stress.

Did commercial fishing cause declines of the western stock of Steller sea lions? In the opinion of ASSLRT, a combination of natural (e.g., environmental change, predation, disease) and anthropogenic factors likely contributed to the historical decline of Steller sea lions through the 1980s, although the relative contributions remain uncertain. Regarding the anthropogenic factors, humans likely contributed significantly to the historical decline primarily through the following causes:

1. Mortality from intentional shootings of animals by government eradication programs, by fishermen in defense of fishing gear or catches formerly under federal permit, and illegally by fishermen and others without permits;

2. Bycatch mortality of sea lions in fisheries, particularly in roe-stripping trawl fisheries prosecuted by foreign and joint-venture operations in the 1970s and 1980s;

3. Experimental harvests of adults in 1959 and pups during 1963-1972; and

4. Nutritional stress of Steller sea lions associated with major changes in sea lion prey species composition and abundance in the 1970s and 1980s. Shifts in prey occurred as a result of a well-documented climate-forced regime shift in the mid 1970s perhaps in combination with cascading changes in the marine ecosystem originating from human overexploitation of whales and some fish stocks in earlier decades.

On the other hand, ASSLRT is not convinced that humans contributed significantly to the sea lion decline in the 1990s. While acknowledging the possibility that adverse fishery effects cannot be fully ruled out, ASSLRT concludes that the potential impact of current fisheries is considerably less than during the historical decline for the following reasons:

1. The annual rate of decline for the western stock moderated to 5.1% during the 1990s, with population stability in the eastern Aleutian Islands;

2. Sea lion prey are not limiting in a global sense based on analyses of sea lion consumption needs and survey biomass of groundfish (e.g., Appendix 3 in BiOp3), even without considering the biomass of non-surveyed prey species;

3. Pups and adult females with pups were not nutritionally stressed in the summer breeding period during the 1990s, and these two life history stages are most vulnerable to localized depletion of prey in close proximity of rookeries; and

4. Many precautionary conservation measures have been added to fishery regulations since the 1970s and 1980s. These include more conservative harvest control rules, no-trawl zones around rookeries and haulouts, and seasonal apportionments that collectively reduced the rate of harvest and dispersed the removal of sea lion prey both temporally and spatially to diminish the likelihood of localized depletion.

For these reasons, ASSLRT feels that it is unlikely that present fisheries currently put the western stock of Steller sea lions at risk of extinction, but the precise extinction probability should be reexamined with new population viability analyses informed with the best scientific data and methods currently available.

INTRODUCTION

On September 11, 2000, Alaska Governor Tony Knowles formed a State of Alaska Steller Sea Lion Restoration Team (ASSLRT or Restoration Team) comprised of "scientists and stakeholders to develop an alternative management strategy for protecting the Steller sea lions that allows sustainable fishing to continue." He outlined three elements of the ASSLRT mission: "First, work to restore healthy, sustainable populations of Steller sea lions so they can be removed from the federal threatened [endangered] species list; second, promote scientific research into the cause of sea lion population declines; and third, employ the principle of adaptive management."

ASSLRT was formed to address anticipated issues surrounding the biological opinion, BiOp3[1] (NMFS 2000), released November 30, 2000 by the National Marine Fisheries Service (NMFS), regarding threatened and endangered species potentially affected by federally managed groundfish fisheries in the Gulf of Alaska and the Bering Sea/Aleutian Islands. In particular, the focus of concern is the depressed western stock of Steller sea lions that is currently classified as an endangered species. Under the Endangered Species Act (ESA), a multifaceted Reasonable and Prudent Alternative within BiOp3 was intended to define the terms under which groundfish fisheries could proceed without causing jeopardy to the continued existence of the western Steller sea lion stock.

Pursuant to the Governor's guidance on these Steller sea lion issues, ASSLRT crafted the following mission statement: "The purpose of the Alaska Steller Sea Lion Restoration Team is to promote the recovery of Steller sea lion populations while sustaining viable commercial fisheries in Alaska. Specifically, we will (1) review the justification of fishery restrictions to protect and restore Steller sea lions, and (2) recommend research priorities and adaptive management strategies designed to identify those factors inhibiting the recovery of the endangered western stock of Steller sea lions and provide increased understanding of fishery and sea lion interactions." To achieve this goal and objectives, the team identified the following major tasks:

- Prepare a concise synopsis of Steller sea lion declines, including a chronology of potential causes during the earlier and most recent phases of the declines;
- Review the Steller sea lion endangered and threatened species determinations within the context of the ESA;
- Review current definitions of Steller sea lion critical habitat including the history of development, data used for the determinations, and what is considered "critical" to sea lions;
- Conduct a review of BiOp3;
- Develop management recommendations, primarily experimental and adaptive, for consideration by federal and state regulatory bodies and management agencies;

[1] By current convention, we distinguish BiOp3 (NMFS 2000) issued November 30, 2000 from BiOp1 (NMFS 1998a) issued December 3, 1998 and BiOp2 (NMFS 1998b) issued December 22, 1998.

- Prepare an overview of recent and ongoing sea lion-related research, including imminent unpublished findings from new research activities that may not have been considered by NMFS in preparing BiOp3; and

- Provide recommendations about scientific research needed to resolve uncertainties about the causes of sea lion declines and potential associations with natural and human-related factors.

Pursuant to this work plan, the state's Restoration Team met five times between November 20, 2000 and June 29, 2001. The team distributed meeting minutes by email distribution lists to members of the public, non-governmental organizations, and state and federal agencies. Also, the team distributed its findings and recommendations through letters and memoranda in anticipation of impending actions by NMFS and by the North Pacific Fishery Management Council. In addition to email distribution, all written products were posted at http://www.state.ak.us/adfg/geninfo/special/ssl/ssl_com.htm, an Alaska Department of Fish and Game (ADF&G) website. The email and Internet delivery of ASSLRT findings and advice was intended to meet urgent deadlines for decision making in the immediate aftermath of the release of BiOp3.

The purpose of this current report is two-fold. First, it is intended to serve as a vehicle to disseminate ASSLRT research and management advice to policy and decision makers as research plans and fishery management actions continue to unfold in association with the Steller sea lion issue in the coming months. Second, the report is intended to serve as a permanent compilation of work products developed by the state's Restoration Team. In preparing this report and all other written products, ASSLRT operated on the basis of consensus; differences of opinion, where they existed, are identified in the text. Unless otherwise noted, the entire team supports recommendations and conclusions outlined in this report.

The following chapters reflect the major work tasks that we identified in our first meeting. In particular, we (1) give a concise synopsis of Steller sea lion declines and potential causes of those declines; (2) review the Steller sea lion listing status under the ESA; (3) examine sea lion Critical Habitat definitions and related considerations; (4) provide an independent scientific review of BiOp3; (5) offer management advice with regard to protection of Steller sea lions for consideration by federal and state regulatory bodies and management agencies; (6) summarize recent and ongoing research on sea lion biology, ecology, and fisheries and other human interactions; and (7) recommend scientific research needed to resolve uncertainties about the causes of Steller sea lion declines.

SYNOPSIS OF STELLER SEA LION DECLINES

Population Status

Steller sea lions in Alaska belong to two biological stocks as distinguished by genetic evidence (mitochondrial DNA) (Bickham et al. 1996) and observations of marked animals (ADF&G and NMFS unpublished data) that showed extremely low rates of interchange of breeding females between stocks. Rookeries in the eastern stock occur in Southeast Alaska while those in the western stock range from Prince William Sound westward through the Aleutian Islands. The two stocks have shown disparate populations trends. The number of pups produced in the eastern stock has nearly doubled since 1978 with an annual rate of increase of 5.9% during 1979 – 1997. The annual rate of increase declined between 1989 – 1997 to 1.7% (Calkins et al. 1999). In the Southeast Alaska portion of the eastern stock, where non-pup counts on trend sites increased a total of 29.3% since 1990 (Sease et al. 2001), there are probably more sea lions at present than at any time in recorded history (Calkins et al. 1999). Over a similar time span numbers of sea lions in the western stock have declined precipitously (90% at some sites), and the stock is classified as "endangered" under the ESA (Sease and Loughlin 1999). The extent of the decline in the western stock has varied regionally and temporally with the decline first noted in the eastern Aleutian Islands and then spreading west and east. During the 1990s the greatest total declines occurred in the eastern (64%) and central (55%) Gulf of Alaska and the western Aleutian Islands (54%) in contrast to the eastern Aleutian Islands where counts increased 1% during the same time period (Sease et al. 2001). Recent surveys (1998 – 2000) of non-pups on rookery and haulout trend sites indicate a continuation of these trends, counts in Southeast Alaska increased 6.7% annually whereas those in the western stock decreased 5.2% annually (Sease et al. 2001).

Potential Causes of Population Declines

The primary causes of the original decline (1970s and 1980s) are thought to have been low survival and low birth rates due to nutritional stress. Evidence of undernutrition included reduced growth rates (Perez and Loughlin 1991, Castellini and Calkins 1993, Calkins et al. 1998) and high rates of reproductive failure (Pitcher et al. 1998). Modeling efforts by York (1994) suggested that low rates of juvenile survival were probably the driving force behind the original decline although there were likely episodes of high adult mortality, as well. An unpublished ADF&G analysis of survival rates, based on mark/resight models of 1987 and 1988 cohorts of branded animals from Marmot Island in the Central Gulf of Alaska, suggested that survival of all ages was low and that a linear model with survival increasing with age provided the best fit.

Three basic explanations have been proposed to explain the cause(s) of nutritional stress: (1) competition for prey with large-scale commercial fisheries, particularly those on walleye pollock and Atka mackerel; (2) changes in prey abundance, composition, and distribution resulting from changing climatic conditions (regime shift); and (3) the "cascade effect" in which a pollock-dominated ecosystem resulted from large-scale human harvests of predators such as whales and certain fishes (NRC 1996). These explanations are not mutually exclusive and they may act concurrently and possibly synergistically. The relative contributions of each of these factors are unknown; yet there is growing appreciation for the profound influence of climatic variability (regime shifts) on biological communities of the North Pacific Ocean (Anderson and Piatt 1999, Hollowed and Wooster 1992, Francis et al. 1998, Springer 1998).

Research was conducted during the mid 1990s to evaluate the nutritional limitation hypothesis. The approach was a comparative study of various biological parameters thought to reflect nutritional status, primarily of adult females and neonatal pups on rookeries, between the declining western stock and the increasing eastern stock. Following is a summary of the findings of that research:

- While pup masses (weights) at birth were similar between populations, pup growth rates were higher in the west (Brandon and Davis, unpublished).

- Pup masses at one month of age were greater in the west (Merrick et al. 1995, Rea et al. 1998).

- Foraging effort, as defined by foraging trip length and time spent ashore, for females with pups on rookeries was less in the west (Brandon et al., unpublished).

- Milk energy content was not significantly different between east and west (Adams and Davis, unpublished).

- No evidence was found that pups <1 month of age from the west were nutritionally compromised based on blood chemistry and hematology (Rea et al. 1998).

- Adult females had greater masses (Adams and Davis, unpublished) and were perhaps fatter in the west (Castellini, unpublished).

- Behavioral observations of maternal attendance patterns and activity budgets were not consistent with the hypothesis that animals from the western stock were having greater difficulty obtaining prey compared to those from the eastern stock (Milette 1999).

- The blubber layer appeared thinner, heat flow greater, and insulation of poorer quality for adult females from the west when compared to the east (Williams, unpublished).

All but the last of these findings suggest no difference or in some cases superior nutritional status for adult females and pups <1 month of age from the western stock in comparison to those of the eastern stock. The significance of these findings follows:

- Adult females and pups <1 month of age from the western stock are not currently nutritionally limited. The original decline may have been precipitated by nutritional stress, but as the environment changed and relative densities between sea lions and their prey populations changed, the western stock is no longer food limited. The recent (current) decline is caused by non-nutritional factors.

- The findings cannot be extended beyond the sex and age classes studied (adult females and young pups), the season when the research was conducted (summer), nor the sites where the research was conducted (only a few of many rookeries).

- Nutritional stress may still be limiting the population through decreased survival of juveniles and low reproductive rates, or during the non-summer period, or at other sites.

- Much of the research lacked "power" because of small sample sizes, limited number of study sites, low sensitivity, and lack of replication. Some comparisons between genetically distinct populations may be invalid.

Currently there are three general hypotheses (or variations thereof) put forth to explain the continued decline of the western stock. Again, these hypotheses are not mutually exclusive and may act concurrently and possibly synergistically. The hypotheses are:

- Nutritional limitation, due to localized depletion of prey, results in low survival and perhaps low reproductive rates. This hypothesis assumes that commercial fishing near rookeries and haulouts causes a localized depletion of the sea lion prey field. Newly weaned juveniles are likely most severely impacted because of their inexperience and limited foraging ability. Though there is currently no scientific evidence for this, this hypothesis provides the basis for fishery management recommendations limiting fishing effort near rookeries and haulouts.

- The "junk food hypothesis" maintains that nutritional limitation occurs because of a diet dominated by pollock, cod, flatfish and other low energy (low fat) prey. This premise, first developed by Alverson (1992), correlates the decline of sea lions in the western stock with a decline in fatty forage fishes and increases in pollock, cod, and flatfishes following a regime shift in the late 1970s (Anderson and Piatt 1999, Mueter and Norcross 1999). Supporting this concept was an analysis by Merrick et al. (1997) that found a strong correlation between diet diversity and population decline. Those populations whose diets were dominated by a single, low fat prey such as pollock or Atka mackerel showed the highest rates of decline. A study where captive Steller sea lions lost body mass when fed ad-libitum amounts of pollock in contrast to gaining mass when fed herring (Rosen and Trites 2000) also supports this hypothesis.

- One predation hypothesis, termed the "predator pit" hypothesis, postulates that the western stock is not currently nutritionally limited, but instead it is constrained by depensatory mortality. Depensatory mortality occurs when mortality rate is proportionately higher (i.e., survival rate is lower) at low population sizes, and fertility rate is too low to counteract these mortality factors (Clark 1974). These mortality factors may include predation by killer whales and sharks, illegal shooting, entanglement in marine debris, incidental mortality associated with fisheries, intraspecific aggression, pup abandonment, diseases, and subsistence harvests. Predation may not decline with reduced sea lion abundance because predators, such as killer whales, probably learn the locations of the traditional rookeries and haulouts and may consume considerable numbers of sea lions even at low abundance. The prospect that sharks may contribute to predation mortality of Steller sea lions is intriguing. Surveys by the International Pacific Halibut Commission and bycatch data from the halibut fishery suggest that Pacific sleeper shark abundance increased significantly in the northern Gulf of Alaska in the 1990s (L.B Hulbert and B. Wright, unpublished). Based on a small sample size (N=30), 17% of sampled Pacific sleeper sharks had recently fed on marine mammals, including harbor seals and porpoise (L.B Hulbert and B. Wright, unpublished). However, whether sharks eat Steller sea lions, and the rate of such predation, remains unknown at present.

Current Research

Current research is focused on various aspects of juvenile life history. Studies are being conducted to determine when young animals are capable of independent foraging, locations of foraging habitats, and at what age weaning occurs. Growth and condition (body composition) of pups and juveniles are being compared between the eastern and western stocks to evaluate the nutritional limitation hypothesis. Complementary research on diseases, pathology, health indicators, immune function, contaminants, and population dynamics is also being conducted.

REVIEW OF LISTING STATUS UNDER THE ENDANGERED SPECIES ACT

Overview of the Endangered Species Act

The federal Endangered Species Act (ESA) of 1973 provides for the conservation of all species (not just marine mammals) that are at risk of extinction throughout all or a significant portion of their range and the conservation of the ecosystems on which they depend. The term "species," as defined by the Act, includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Generally, the U.S. Fish and Wildlife Service (USFWS) is responsible for ESA considerations of terrestrial and freshwater species, whereas NMFS handles marine and anadromous species.

The responsible agency is required to make a listing decision based solely on the best scientific and other data available. The ESA prohibits economic impacts from being considered in making species listing decisions. A species is required to be listed if it is threatened or endangered from any of the following five factors:

- present or threatened destruction, modification, or curtailment of its habitat or range;
- overutilization for commercial, recreational, scientific, or educational purposes;
- disease or predation;
- inadequacy of existing regulatory mechanisms; and
- other natural or manmade factors affecting its continued existence.

Under the ESA, the term "endangered species" means "any species which is in danger of extinction throughout all or a significant portion of its range" and the term "threatened species" means "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

In association with ESA listing, critical habitat, necessary for the continued survival of the species, must be designated. Unlike the listing determination itself, economic impacts must be considered in the determination of critical habitat. Once a species is listed, the responsible agency is required to prepare a recovery plan if it is determined that such a plan will promote recovery of the listed species. Moreover, Section 7 of the ESA requires all federal agencies to consult with either USFWS or NMFS to ensure that their actions are not likely to jeopardize the continued existence of any listed species or result in the adverse modification of critical habitat.

History of ESA Listings for the Steller Sea Lion

In April 1990 NMFS listed the Steller sea lion as threatened under the ESA owing to a decline of this species in most areas of its range since the 1970s. Subsequently, Steller sea lions were separated into two stocks. An eastern stock extends east of Cape Suckling at 144^o W to California at the southern end of the range, and a western stock extends west of 144^o W to Japan at the westernmost extent of the range. The strongest evidence for two stocks comes from genetic studies (Bickham et al. 1996), but the separation is supported by divergent population trends and low rates of movement of tagged animals between the two regions. Consistent with the advice of the federal Steller Sea Lion Recovery Team in November 1994, in a proposed rule published in October 1995 NMFS proposed that the western stock should be listed as endangered while the eastern stock should remain listed as threatened (NOAA 1995). These determinations were finalized in a final rule in May 1997 (NOAA 1997). The endangered determination was based largely on a NMFS projection that, if the declining population trend during 1985-1994 continued, there was a high probability that the western stock will be extinct within 100 years. A chronology of critical habitat designations, associated with these ESA determinations, is described in the next chapter of this report, *Considerations of Steller Sea Lion Critical Habitat.*

Review of the Basis for ESA Listing Determinations

Threatened Status of Steller Sea Lions in 1990

The threatened ESA listing of Steller sea lions in 1990 was largely based on the long-term average decline of this species since the 1970s. Indeed, trend counts[2] of adult and juvenile Steller sea lions declined at least 67% from 140,000 or more animals in the Gulf of Alaska and Aleutian Islands during the first surveys in 1956-1960 to a count of 46,040 animals for all areas including the Bering Sea in 1992 (Ferrero et al. 2000).

Current Endangered Status of the Western Stock of Steller Sea Lions

A population viability analysis by York et al. (1996) formed the primary basis of the endangered listing of the western stock in 1997. A population viability analysis is an approach that estimates the likelihood that a population will persist for a specified period of time. The analysis requires an estimate of minimum viable population size, which is the number of animals needed for the population to exist and which is estimated independently of the model.

York et al.'s analysis involved three alternative versions of a population model corresponding to three spatial scales of the western stock of Steller sea lions in the region between the Kenai Peninsula in the northern Gulf of Alaska and Kiska Island in the western Aleutian Islands. The first was a rookery model (local scale), the second involved a cluster of rookeries (metapopulation scale), and the third was a Kenai to Kiska aggregate (geographic scale). Their analysis used population trend data from 1976 through 1994 with an emphasis on data during

[2] Trend or index counts are the numbers of animals actually observed on trend sites, a subset of all monitored sites with a relatively long history of observation thereby permitting analysis of long-term trend. These index counts are often confused with estimates of total population size. Total population size must be estimated by expanding these counts by the number of animals that were unobserved at the time the survey was conducted.

1985-1994. Results of the individual rookery model indicated that sea lions would totally disappear from 80% of the rookeries within 100 years, if the historical trends continued. Despite the projected loss of most rookeries, there was a relatively high probability of overall population persistence owing to positive growth rates at five small rookeries. Under the metapopulation model, five clusters of rookeries were modeled. Results indicated that the female population would be reduced to a few dozen animals with only one cluster remaining after 100 years. Again, a relatively high probability of overall population persistence was attributed to positive growth rates in the western Gulf of Alaska cluster. Under the geographic model, the probability of extinction (no females at *any* rookeries) was 50% after 106 years and 75% after 110 years. In summary, these results were interpreted by NMFS to indicate that there was a high probability that the western stock of Steller sea lions would become extinct within 100 years.

There are at least four reasons to revisit the current endangered ESA listing of the western stock of Steller sea lions. The first reason is that no clear, biologically sound criteria were used for the listing decisions. Without such criteria, listing decisions appear arbitrary. Toward more consistent decision making, Gerber (1998) suggested that global criteria, such as those developed by the International Union for the Conservation of Nature and Natural Resources (IUCN), should be developed for ESA listing determinations. Gerber and DeMaster (1999) proposed a quantitative approach for determining ESA classifications that explicitly ties uncertainty into the decision-making process.

The second reason to reevaluate the listing status of the western stock of Steller sea lions relates to population abundance. The minimum population estimate of pups and non-pups in the western stock was 39,031 in 1998 (Ferrero et al. 2000). A minimum population estimate is not corrected for unobserved animals at sea during the surveys, so total population size is larger than 39,031 animals. Among species for which abundance estimates exist, Steller sea lions are by far the most abundant species of marine mammals to be listed as endangered under the ESA (Gerber and VanBlaricom, *in press*). This statement is not intended to render a judgment of the merits of the endangered determination of Steller sea lions or any other species. Rather, it indicates an inconsistency, with respect to considerations of population abundance, in the ESA status of Steller sea lions relative to other listed marine mammals. Not surprisingly, subjective decisions about listing status result from vagueness in ESA listing criteria.

Third, an update of the population viability analysis conducted by York et al. (1996) is needed to include recent data on population trends. In conducting their analysis, York et al. noted different trends in population change among groups of rookeries corresponding to the periods 1959-1975, 1976-1985, 1985-1989, and 1989-1994. In particular, they noted that 1989-1994 was a period of modest population change in which trends among groups of rookeries ranged from moderate declines to increases. However, historically, periods of moderate decline were interspersed with periods of sharp decline, and the authors had no way to predict whether the moderation experienced during 1989-1994 would soon reverse to a renewed period of sharp declines or whether a protracted period of moderation would persist. Now, we know that the period of moderate population change has persisted from 1989 through at least 2000. Counts of adults and juveniles on rookery and haulout trend sites showed an average annual decline of 5.1% during 1990 to 2000 (Sease et al. 2001). During the 1990s, annual trends ranged from a 9.6% decline in the eastern Gulf of Alaska to no change in the eastern Aleutian Islands.

Fourth, recent alternative analyses should be considered. For instance, using data through 1996 Gerber and VanBlaricom (*in press*) developed two distinct population viability models and compared their results with those from the three alternative model forms of York et al. (1996). Median times to extinction for the two models of Gerber and VanBlaricom were similar to the metapopulation version of York et al.'s (1996) model. However, the range of extinction times was narrower for any given model than the range of extinction times between models. This suggests that more than one population viability model should be considered when estimating extinction risk and when determining ESA listing status. All three models met one IUCN criterion for endangered, based on a population decline of at least 50% over the last three generations.[3] Considering estimates of extinction risk, all three models meet the IUCN classification criterion of vulnerable, which may be considered as comparable to the ESA category of threatened (Gerber 1998). Interestingly, an ESA classification of threatened resulted when the approach of Gerber and DeMaster (1999) was applied to the western stock of Steller sea lions. Gerber and VanBlaricom (*in press*) made no formal recommendation about reclassifying the western stock of Steller sea lions as threatened based on their analysis. Rather, they advised that model uncertainty should be incorporated into a single measure of extinction risk prior to such a formal recommendation.

Based on these considerations, the state's Restoration Team recommends a reexamination of the current endangered listing of the western stock of Steller sea lions. Although continued declines in many areas remain of concern, the specific question here is whether new information influences the determination that the western stock of Steller sea lions is in danger of extinction. A reassessment is appropriate in light of recent population trend data, new alternative population viability models, and proposed new quantitative methods for ESA classification. Ideally, the vague listing criteria of the ESA requiring subjective interpretation should be replaced with an objective set of criteria that can be applied more evenly to all ESA candidate species, perhaps something similar to the IUCN classification criteria. ASSLRT recommends that NMFS work towards developing a more global set of less ambiguous listing criteria for application to ESA determinations. In making these recommendations, ASSLRT acknowledges that the comprehensive, in-depth analyses required to render an informed opinion on whether the western stock of Steller sea lions should be down-listed from endangered to threatened have not been conducted. Rather, the Restoration Team is recommending the conduct of such analyses.

Current Threatened Status of the Eastern Stock of Steller Sea Lions

In 1997 when Steller sea lions were split into two stocks and the western stock was listed as endangered, the eastern stock remained listed as threatened. In rendering the threatened status determination of the eastern stock, NMFS cited (1) declining pup counts in Southeast Alaska in the early to mid 1990s, (2) declining sea lion numbers in southern California and the possibility that the geographic range of the species is shrinking, (3) concern that the decline in the western stock represents a threat to the continued existence of the entire species including the eastern stock, and (4) concern that the unknown factors affecting the western stock could move eastward and begin to affect the eastern stock (NOAA 1995, 1997).

[3] Gerber and VanBlaricom (*in press*) assumed a mean generation length of 8.5 years, so three generations span 25.5 years. They noted that, during the 24 years spanning 1970-1994, the western stock declined by 77%.

The eastern stock includes animals from California to Southeast Alaska. Ferrero et al. (2000) reported recent population trends for this stock. In southern and central California, actual counts ranged between 5,000 to 7,000 non-pups during 1927-1947, but declined by over 50% to 1,500 to 2,000 animals during 1980-1998. Limited data suggest that counts in northern California are stable. Counts in Oregon increased an average of 7.6% per year from 1,486 in 1976 to 3,971 in 1998. A relatively large increase from 2,005 in 1990 to 2,696 animals in 1994 may have resulted, in part, from improved counting techniques (NOAA 1995), but this increase has continued and the Oregon count in 1998 is 1.5 times larger than in 1994. In British Columbia, counts of non-pups increased 2.8% annually during 1971-1998. In Southeast Alaska, counts of non-pups increased by a total of 28% from 1979 to 1996 (Ferrero et al. 2000), and increased another 20% from 1996 to 2000 (Sease et al. 2001). For all regions combined, non-expanded counts of non-pups in the eastern stock of Steller sea lions increased 44% from 15,214 in 1982 to 21,864 in 1998 (Ferrero et al. 2000). Overall, the eastern stock of Steller sea lions appears to be at its highest level of recorded abundance and is continuing to increase.

Notwithstanding concerns about the ambiguity in ESA listing criteria, the population trend and abundance data for the eastern stock of Steller sea lions do not support the definition of threatened which designates "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Although more thorough review of the eastern stock may be appropriate, it seems to ASSLRT that the eastern stock of Steller sea lions should be removed from the ESA threatened species list because it is highly unlikely to become endangered in the foreseeable future. There could be considerable controversy associated with a potential de-listing of the eastern stock because the public views Steller sea lions as a highly charismatic species. However, the threatened status promulgates misinformation about the overall healthy status of this stock; the listing status of this stock should be based on an objective analysis of the best available scientific data.

CONSIDERATIONS OF STELLER SEA LION CRITICAL HABITAT

Chronology of Critical Habitat Designations

Section 3(5)(A) of the ESA defines critical habitat for a threatened or endangered species as "(i) the specific areas within the geographic area occupied by the species, at the time it is listed …" with "… physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographic area occupied by the species at the time it is listed … essential for the conservation of the species." Conservation means recovery to the point where the species can be down-listed. Section 4(b)(2) states, "…the Secretary shall designate critical habitat, and make revisions thereto, … on the basis of the best scientific data available and after taking into consideration the economic impact, and any other relevant impact, of specifying any particular area as critical habitat." Since 1978, the Secretary of Commerce has been required to consider economics and non-biological information and has discretion to exclude any or all of the qualifying area (as defined) from designation as critical habitat. Section 4(b)(5) of the ESA says that "With respect to any regulation proposed by the Secretary to implement a determination, designation, or revision … the Secretary shall … (i) publish a general notice and the complete text of the proposed regulation in the Federal Register, and (ii) give actual notice of the proposed regulation … to the State agency in each State in which the species is believed to occur, and to each county or equivalent jurisdiction in which the species is believed to occur, and invite the comment of such agency, and each jurisdiction, thereon …" Section 4(b)(3)(D)(i) indicates that any person can petition the Secretary to revise the critical habitat designation.

In 1990 when Steller sea lions were first listed as threatened under the ESA (prior to critical habitat designation), three-mile buffer zones were created to prohibit vessel entry around all rookeries west of 150° W. Also, in 1990, the following modifications were made to the groundfish fishery management plans: (1) 10 nm no-trawl zones around rookeries year-round, (2) 20 nm no-trawl zones for six rookeries in the eastern Aleutian Islands for the pollock *A* season, and (3) the pollock total allowable catch was split in time and space.

In the federal register notice of final rule 50 CFR Part 226 (NOAA 1993), NMFS proposed to designate critical habitat as a zone that extends 3,000 feet (0.9 km) landward and vertical of all Steller sea lion rookeries and major haulouts and 3,000 feet seaward for sites east of 144° W and 20 nm seaward for sites west of 144° W. Also included were three critical foraging areas within the core of the sea lion's geographic range.

In their comments on the proposed designation, the State of Alaska Division of Governmental Coordination and ADF&G urged adoption of a seaward boundary of 3,000 feet throughout the sea lion's range in order to provide a buffer zone that could be used to prevent disturbance and other possible impacts, as proposed by the Steller Sea Lion Recovery Team (NOAA 1993). ADF&G recognized the need to designate certain important foraging areas as critical habitats, such as the three large marine areas proposed, in addition to the 3,000-feet buffer zone. ADF&G and the Alaska Division of Governmental Coordination suggested the 20-nm zones around rookeries and major haulouts were inappropriate because they were based on satellite telemetry data from few locations, and that NMFS did not supply sufficient documentation to justify the 20-nm designation. ADF&G recommended that foraging areas in coastal and offshore waters be defined as critical habitat where they contain the appropriate environmental and biological characteristics to provide important feeding habitats for sea lions.

In addition to ADF&G's recommendation for establishing critical aquatic habitats, the federal Sea Lion Recovery Team proposed that further recommendations should be developed as additional data became available. However, NMFS adopted the 20-nm buffers in their federal register notice of the final rule 50 CFR Part 226 (NOAA 1993). NMFS stated, "It is important to emphasize that in designating these extended aquatic zones, NMFS is not attempting to justify or prove that these areas, in fact, actually do need special management or special regulation, but rather that these areas may be in need of management." NMFS went on to say "This final rule does not include specific management measures … as a result of the designation of these extended aquatic zones as critical habitat. If and when specific management measures are proposed, it is anticipated that the proposed rule will explain the scientific basis and justification for the measures." Regarding the need for scientific justification, NMFS pointed out that new research was planned on sea lion foraging behavior including satellite telemetry studies and that "Modification of critical habitat designation or specific management measures may be considered based upon this research." In the rule, it was stated, "NMFS has determined that Alaskan groundfish fisheries are not likely to jeopardize the continued existence of Steller sea lions or essential habitat." Moreover, the rule declared that "If, at some future time, it is determined that further restrictions are necessary to protect Steller sea lions or critical habitat, NMFS will initiate the rulemaking process which provides opportunity for public review and comments."

In the revised final Reasonable and Prudent Alternatives defined in the December 1998 biological opinion (BiOp2), NMFS defined haulouts seasonally as winter-only, summer-only, or year-round. Sites were designated as critical if, at least once since 1979, an annual count exceeded either 75 animals in winter or 200 animals in summer. BiOp2 also established pollock trawl exclusion zones within 10 nm of critical haulouts in the Gulf of Alaska and 20 nm of critical haulouts in the Bering Sea and Aleutian Islands.

ASSLRT has discussed the merits of alternative classification rules for determining critical haulouts. The team discussed whether it might be more appropriate to use, for example: (1) the last 10 years of counts, rather than counts since 1979; (2) sites that met the criteria in more than one year, rather than just one year; and (3) other designation criteria for minimum counts. On the one hand, some concern was expressed that a site could be designated as critical even if no sea lions have been associated with it for decades. On the other hand, the team wants to be careful that measures do not solely reflect current sea lion distributions that could change once the population begins to recover. The team discussed the idea that all sites meeting the criteria should remain designated, but that protective measures should apply only to the occupied sites until the sea lion population trends are reversed. The team did not reach any conclusions on these issues, except that the criteria are extremely important and deserve further consideration.

The Restoration Team developed two recommendations. First, the team feels that criteria should be developed in addition to whether abundance exceeded a subjective threshold once in the history of observations since 1979. Second, annual count data, in addition to maximum counts since 1979, should be compiled and used to define these rookeries and important haulouts as critical habitats.

Beyond this, the team did not investigate specific alternatives that would better define rookeries and important haulouts as the basis for critical habitat designations. However, ASSLRT feels that the criteria selected are extremely important and that these designations deserve further careful consideration and analysis, and their justifications should be made public.

In BiOp3 issued November 2000, NMFS proposed major changes in management measures associated with sea lion critical habitat designations. The primary changes included: exclusion zones in the Gulf of Alaska were extended to 20 nm around rookeries and major haulouts; seasonal closures were extended to year-round; and a pattern of 13 open and closed management zones were proposed. It was also noted that the list of rookeries and major haulouts has been modified including the addition of 19 Reasonable and Prudent Alternative sites that were not ESA listed.

The team discussed these changes in management measures in light of previous NMFS statements (50 CFR Part 226) that future changes will be scientifically justified, that new foraging data including satellite telemetry studies will form the basis for modifications, and that a rulemaking process will be established for public comment. These conditions have not been satisfied.

The increase in radius of the Gulf of Alaska trawl exclusion zones from 10 to 20 nm is described in a single paragraph on page 234 of BiOp3. This change is based primarily on two considerations. The first is that the 1999 Revised Final Reasonable and Prudent Alternatives were to establish no trawling zones that encompassed important shelf waters adjacent to rookeries and haulouts. The second is a new GIS analysis of depth contours in an unpublished NMFS report that is cited to indicate the need to increase the radius from 10 to 20 nm to satisfy the original intent of the 1999 Revised Final Reasonable and Prudent Alternatives. Additional supporting evidence mentioned included descriptions of foraging behavior (no citations given), "what little satellite data is available … as presented in Section 4" on pages 87-88, and the broader consideration of the FMP process. The extension of closures from seasonal to year-round is described on pages 236-237 of BiOp3. In essence, NMFS recognizes that sensitivity of sea lions to competition from fisheries may vary seasonally, yet especially for adult females with pups and recently weaned pups NMFS stated, "… food availability is surely crucial year-round." In reviewing the biological opinion's justification for the increase in radius of trawl exclusion zones from 10 to 20 nm and their extension from seasonal to year-round, ASSLRT believes that all pertinent new information, especially on foraging behavior, should be reviewed and evaluated for major modifications in regulations pertaining to sea lion critical habitats as planned in the 1993 federal register notice of the final rule. Also, ADF&G's comments on critical habitat designations, made at the time of the 1993 Final Rule, should be revisited, particularly in light of recent data. Finally, in determining critical habitat, considerations of economic impacts should be clarified as required by the ESA.

Ecological Basis of Critical Habitats

ASSLRT discussed the biological and ecological basis of habitats needed by sea lions to perform specific activities because the team felt that management actions should be directly linked to the biological and ecological considerations of the species to be protected. The team identified two critical sets of sea lion activities: (1) breeding and resting on land, and (2) foraging at sea. The team considered spatial and temporal aspects in these activities.

Breeding and Resting on Land

Breeding and pup rearing occurs on rookeries during May through September. Resting and nursing occurs on winter haulouts during October through April, and resting occurs on summer haulouts during May through September. Disruption of these activities by approaching vessels at sea or people on land has been well documented. On rookeries, human disturbance may disrupt breeding and nursing activities, lead to pup abandonment or loss at sea, and increase the likelihood of killer whale predation of animals that are provoked into the sea. On haulouts, disturbance can lead to disruption of social structure and increased predation. Therefore, regulations are necessary to prevent disruption of these activities.

ASSLRT expressed no opinion on the extent to which disturbance of Steller sea lions on rookeries and haulouts might have contributed to the population decline, but the team concluded that it would be prudent to reduce the potential for such disturbances nonetheless. Further, the Restoration Team felt that the best management tools to protect animals while on land are no-approach zones for persons on land and no-transit zones for vessels at sea. No other management tools offer similar protections to those provided by these buffer zones.

The Restoration Team next considered the appropriate size of the buffer zones needed to prevent disturbance of animals. In 1993, in response to the proposed federal rule 50 CFR Part 226, the State of Alaska urged adoption of a 3,000-foot seaward boundary of rookeries and major haulouts throughout the sea lion's range in order to provide a buffer zone that could be used to prevent disturbance and other possible impacts. Previously (1991), the federal Steller Sea Lion Recovery Team recommended 3,000-foot buffer zones around rookeries and major haulouts, and also noted that larger buffer zones could be appropriate for rookeries that experienced major declines. Currently, standard federal marine mammal guidelines suggest that vessels remain at least 100 yards from whales, dolphins, and porpoises at sea and 100 yards from seals and sea lions on land, rock, or ice. For the endangered western stock of Steller sea lions, current federal regulations generally prohibit persons on land from approaching a sea lion rookery within 0.5 miles (or 0.8 km) and vessels at sea from transiting within 3 nm of listed rookeries.

In BiOp3, NMFS proposed continuation of the 3-nm no-transit zones around rookeries year-round, and additional 3-nm no-fishing zones around major haulouts for all federally permitted vessels. The team was uncertain about the basis for the NMFS proposal for the new 3-nm no-fishing zones, as well as whether a distinction between no-transit and no-fishing zones is needed around major haulouts. Current regulations of the State of Alaska include 3-nm no fishing zones, but do not include no-transit zones, around sea lion rookeries. The rookeries protected by state Emergency Order include the same rookeries protected by federal regulations except for recent federal changes that added and deleted two rookeries from the list. With the exception of no-trawling zones around several haulouts in Prince William Sound, state regulations generally do not include no-transit or no-fishing zones around haulouts at the present time.

ASSLRT is unaware of any studies that quantify the distance needed to protect Steller sea lions from disruption while on land. Anecdotal information suggests that animals may have different tolerances depending on location, activity, time of year, and degree of habituation. Examples include occupations of new haulouts in the presence of many human activities within Kodiak harbor, and haulouts where seiners set their nets directly adjacent to the rocks and where sea lions have learned to dive into those nets to catch fish. In its final rule concerning the change in ESA listing status (NOAA 1997), NMFS stated that one purpose of the buffer zones was "to restrict opportunities for individuals to shoot at sea lions and to facilitate enforcement of the restriction." Thus, the team recognizes that existing and proposed buffer zones may more reflect a distance intended to discourage illegal shooting of sea lions than the distance at which disruption occurs from approaching vessels.

The Restoration Team considered whether the size of no-transit zones around major haulouts should be 3,000 feet, whether the size of no-transit zones around rookeries should be 3 nm, or whether these distances are larger than needed to prevent disruption of land-based animals. In its final analysis, the team agreed that it does not have a basis to select particular buffer sizes for no-transit zones. In specifying no-transit zones around specific haulouts, the team recommends that some accommodation should be made, where needed, for local conditions, such as required human activity, areas where the radius includes harbors or routes needed for safe navigation, and traditional use. Habituation should be considered, but the team noted that habituation does not necessarily infer a lack of negative effects from human interactions.

Critical Foraging Areas

Three critical foraging areas have been defined: Shelikof Strait, Sequam Pass, and the Sea Lion Conservation Area in the vicinity of Bogoslof Island. ASSLRT focused most of its consideration on the Shelikof Strait area where it is prudent to distinguish important feeding areas for Steller sea lions from historical areas of high bycatch rates that were inflated by fishing practices no longer in use. Historically, the foreign joint-venture pollock fishery in Shelikof Strait in the 1980s was a roe-stripping fishery in which large numbers of pollock carcasses were discarded at sea. The team suspects that those discards may have attracted sea lions to the area and contributed to increased sea lion bycatch and other direct sea lion – human interactions. Because codends were towed at the surface to pack the contents of the net prior to transfer, this activity may have enhanced the bycatch of sea lions near the surface. The North Pacific Fishery Management Council banned the practice of roe stripping in 1989.

The current domestic fishery in Shelikof Strait occurs primarily at depths of 110-170 fathoms on spawning pollock, a range deeper than the mean dive depth of young of the year sea lions. However, the potential spatial overlap between pollock during their diurnal migration and foraging juvenile sea lions is uncertain.

Given these considerations, it is appropriate to reconsider the basis for designating these offshore critical foraging areas. Specifically, in addition to reviewing the initial justifications, ASSLRT recommends the following tasks: (1) analyze current pollock fishery observer data for depth of operation, bycatch of sea lions, and other attributes; (2) analyze the seasonal use of these foraging areas by sea lions; and (3) conduct foraging ecology studies using telemetry in these foraging areas, such as at Shelikof sites and adjacent sites in the Kodiak Island area.

Foraging Near Rookeries and Haulouts in Summer

The time period of May through September is critical for feeding in the vicinity of rookeries, and likely for summer haulouts, as well. Unfortunately, data available to determine the foraging areas, and analyses of existing data, are limited. The team noted that the 20-nm proposal in BiOp3 was based on the average of the maximum distances from rookeries for individual foraging trips in summer by only six females with pups. Whereas the team agreed that these are places and times of the year to be conservative, all available information needs to be more thoroughly analyzed to determine the spatial extent of important sea lion foraging areas.

The distribution of sea lion at-sea locations is one method to examine the spatial overlap of sea lions with fisheries. A preliminary report (ADF&G and NMFS[4]) estimated the distance (nm) for all sea lion at-sea locations recorded prior to 2001 to the nearest landmass. Overall, the large majority of at-sea locations occurred close to shore (<10 nm) across regions and seasons, with more distant locations observed for adult females in winter, and in some cases juveniles in summer. Several important caveats were noted relative to these data: (1) due to a larger proportion of time spent at the surface nearshore, the probability of obtaining at-sea locations near haulouts and rookeries is likely higher than when further offshore when sea lions are diving

[4] ADF&G (Alaska Department of Fish and Game) and NMFS (National Marine Fisheries Service). 2001. Satellite telemetry and Steller sea lion research. Alaska Department of Fish and Game and National Marine Fisheries Service. Unpublished manuscript, August 2001.

to depth in deeper waters; (2) at-sea locations do not directly indicate where sea lions are foraging; (3) the large majority of pups, and perhaps most juveniles, were likely still nursing and thus not foraging independently for prey; and (4) telemetry data are lacking for subadults and females without pups.

Additional foraging information has been obtained using stomach temperature probes to determine when sea lions ingest prey. Based on data from adult females in summer (1994 and 1997) in both the eastern and western stocks, nearly all prey ingestion occurred when animals repeatedly exhibited deep dives (>10 m). Prey was ingested during all at-sea trips during which such 'foraging dives' occurred. However, long periods of time often elapsed and large distances were covered between successful foraging events (SSLRT[5]). This preliminary study demonstrated that knowing where sea lions traveled and dove does not necessarily allow one to distinguish productive feeding areas from unproductive ones (SSLRT[5]).

The Team believes using the distances from at-sea locations to the nearest landmass to determine sea lion foraging areas is inappropriate due to the numerous biases associated with the caveats described. Rather, ASSLRT supports a complete analysis of the telemetry data that integrates both location and dive behavior data from individual at-sea trips to directly estimate the spatial and temporal foraging patterns of sea lions.

Foraging Near Haulouts in Winter

Winter haulouts are used seasonally, approximately from October through April. The Restoration Team noted that this also is an important time for pregnant females to support their pups, a developing fetus, and themselves. However, few winter data are available, and analyses of existing data are limited. Consideration should be given to initiating seasonal surveys of sea lion distribution and abundance and foraging studies so that critical habitat designations can be fine-tuned according to time of year. In this regard, there is a high priority for research on pregnant females supporting pups in winter and on juveniles (age 1-3 years) year-round.

Management Basis of Critical Habitats

Once integrated analyses of dive (foraging) and movement data have been completed and the ecological bases for designation of critical habitats have been established, the next question concerns whether particular areas should be considered for special management actions, such as no-fishing zones. We provide most of our advice on no-fishing zones and other management measures in a subsequent chapter of this report, *Review of Protective Measures*, but because ecologically based designations of critical habitat and the identification of areas in need of special management are intertwined, we offer our general perspectives on this topic here.

The goal is to provide adequate prey of appropriate species and sizes to sea lions while they are occupying the rookeries, haulouts, and offshore foraging areas. Two conditions would have to occur in order for fishery management restrictions to accomplish this goal successfully. First, Steller sea lions must be nutritionally stressed owing to an inability to meet nutritional needs.

[5] SSLRT (Steller Sea Lion Recovery Team). 1997. Steller sea lion research review: Telemetry workshop. Seattle, WA, December 8-10, 1997. Unpublished report.

Second, fishing, not environmental change, must be the primary cause of the nutritional limitation. Fisheries could be responsible if removals sufficiently deplete overall prey abundance to levels so low that sea lions cannot find adequate prey or if the fishery removals were spatially concentrated so as to cause localized depletion in areas critical to successful sea lion foraging.

As described in the chapter *Synopsis of Steller Sea Lion Declines*, evidence indicates that nutritional limitation was problematic in the 1970s and 1980s. However, data collected in the 1990s do not indicate that the western population of Steller sea lions has been nutritionally stressed with respect to the eastern population, at least not during summer for pups (up to approximately 5 weeks of age) nor for adult females with pups during early lactation. However, contemporary data are lacking on pups during the non-breeding period, on post-weaning juveniles, or on adult females without pups year-round.

If nutritional limitation exists for other life stages, then an important question is whether or not fisheries are contributing factors. In this regard, in an independent review of BiOp3, Bowen et al. (2001) stated, "There is, as far as we know, no direct evidence that prey depletion by fisheries has affected the demography of any seal population, whereas there are a number of cases in which seal populations have continued to increase exponentially following the complete collapse of an important prey stock as a result of overfishing." Likewise, the Scientific and Statistical Committee of the North Pacific Fishery Management Council (SSC 2001) in their review of BiOp3 stated, "There is no information supporting the conclusion that local depletion is now occurring in Alaska's fisheries." The Restoration Team acknowledges that the few studies conducted to date are insufficient to fully address the localized depletion issue. An unpublished manuscript on a NMFS study, prepared in July 1998, provided some evidence consistent with the occurrence of localized depletion in portions of the Atka mackerel fishery in the early 1990s. The principal evidence was a decline in catch per unit effort in some fishing areas, although the analysis was unable to discount declines from other potential causes such as dispersal of fish after spawning. Largely based on this analysis, in January 1999, subsequent to North Pacific Fishery Management Council action, NMFS issued a final rule to spatially and temporally distribute the Atka mackerel fishery in the Aleutian Islands in a precautionary approach to reduce the probability of localized depletions of Atka mackerel inside sea lion critical habitat.

Recent data are unavailable to determine whether nutritional stress is experienced by pups during the non-breeding period, post-weaning juveniles, and adult females. Among these, the Restoration Team is most concerned about juveniles owing to their caloric needs per unit body weight and their relative inexperience in capturing prey. So, a precautionary approach is to consider some fishery restrictions that focus on nutritional requirements of juvenile sea lions.

The team struggled with the development of potential special management measures in all or a portion of critical habitat in order to mitigate nutritional limitation by juvenile Steller sea lions owing to fishery-caused localized depletion; these are two potential problems for which limited data provide no direct evidence. Lacking a complete analysis of foraging data and the effect of fisheries on the prey field, the merits of particular areas in need of special management, such as no-fishing zones, cannot be evaluated. In a subsequent report chapter, *Protective, Adaptive, and Experimental Management Recommendations*, specific management measures (e.g., no-fishing zones, harvest rates, fishing seasons, gear allocations) are assessed for their potential to avert deviations in prey fields from levels required by foraging sea lions.

OVERVIEW OF ASSLRT COMMENTS ON BIOP3

This chapter provides an overview of the Restoration Team's comments on the Biological Opinion (BiOp3) issued by NMFS on November 30, 2000. For a complete ASSLRT review of BiOp3, see Appendix A.1.

The Restoration Team appreciates the effort that went into the preparation of BiOp3. It is a comprehensive document with good information on the history of regulations, current fishery management plans, stock trends and commercial catch histories, descriptions of the fisheries, and Steller sea lion biology and ecology. Yet, despite all the information contained in BiOp3, it has some major deficiencies, some of which are outlined here.

Although designated in 1993 (NOAA 1993), in the opinion of ASSLRT these critical habitat designations still have not been adequately justified. Now that BiOp3 proposes specific management measures associated with critical habitat, it is even more important to be sure that critical habitat is correctly specified. The Restoration Team recommends completion of the ongoing analyses of extensive telemetry data as soon as possible. Once completed, critical habitat designations should be reconsidered in light of the new findings about important sea lion foraging areas.

The Restoration Team feels that diet diversity may have played a larger role in sea lion health and historical population trends than acknowledged in BiOp3. The percent frequency of occurrence of gadids in stomach samples of the western stock of sea lions doubled from the 1950s-1970s to the 1980s (Figure 4.5 in BiOp3) consistent with an increase in groundfish abundance following the climate regime shift in the late 1970s. These coupled observations of prey abundance and predator stomach contents are not consistent with a hypothesis that sea lion nutrition is compromised by a recent lack of availability of walleye pollock, Pacific cod, and Atka mackerel. Recognition of these observations gave rise to the junk food hypothesis (Alverson 1992) that contends that sea lions eat too much pollock and not enough fatty, high-energy fishes. Because more than half of the top 14 species (e.g., squid, octopus, Pacific sand lance, smelt, Irish lord, Pacific sandfish, snailfishes, rock greenling) of sea lion prey by percent frequency of occurrence, as reported in BiOp3, are not subjected to directed fisheries, fluctuations in their availability to sea lions may be predominantly driven by environmental factors. The role of diet diversity in historical sea lion population trends seems plausible, given sea lion population trends, trends in diet, and evidence for nutritional limitation in the 1970s and 1980s. However, for this mechanism to operate presently, nutritional limitation must occur in sea lion age and sex classes other than pups and females with pups in summer.

Similarly, the topic of competition for prey among Steller sea lions and other natural predators is treated superficially without the reference to published diet and foraging studies. Pollock, squid, octopus, herring, and other forage fishes are heavily preyed upon, not only by Steller sea lions, but also by other marine mammals (e.g., harbor seals) and fish predators (e.g., Pacific cod and halibut). Abundant relevant diet data are available, but were not considered. Diet diversity and natural competitors are just two examples but, generally speaking, BiOp3 does not evaluate the Steller sea lion as an integrated member of a dynamic marine ecosystem influenced by a suite of climatic and anthropogenic factors.

BiOp3 generally lacks a fair and thorough treatment of alternative hypotheses (e.g., regime shift effects on prey, historical eradication programs, non-reported shootings, predation) for their potential roles in sea lion declines. The overall approach in BiOp3 is biased in that individual alternative mechanisms are subjectively discounted on a one-by-one basis for their inability to solely account for all of the observed population declines. Because the burden of proof is reversed for the fisheries competition hypothesis (localized depletion), the default assumption becomes BiOp3's conclusion. That is, the alternative hypotheses cannot be proven to individually explain all of the sea lion trends and thus are not accepted, whereas the hypothesis of localized depletion by groundfish fisheries cannot be disproved and thus it is not rejected. In addition, ASSLRT is confident that no single factor can account for historical Steller sea lion population trends. However, a fundamental flaw in the BiOp3 analysis is that the synergistic effects of different mechanisms, including fishing, to collectively account for population trends are not considered.

BiOp3 concludes that the groundfish fisheries jeopardize the continued existence of the western stock of Steller sea lions. Rather than the result of an objective scientific analysis, this conclusion primarily rests upon a series of speculative arguments. Indeed, some data (e.g., increase in gadid harvest from critical habitat during the early 1980s) were presented in support of this hypothesis. However, a thorough and objective analysis of the evidence for and against this hypothesis was not provided.

In BiOp3 some diet data were disaggregated into interesting contrasts between the eastern and western stock during two periods (e.g., Figure 4.5) and between summer and winter (e.g., Figure 4.6). However, generally, the analysis tends to lump data across large spatial and temporal scales potentially missing important underlying patterns at the scales relevant to sea lions that may be tied to causative mechanisms. For example, where existing data would support a site-by-site analysis of sea lion seasonal diet and annual population trends, key insights into the connection between prey and population status may be possible.

BiOp3 failed to recognize that there are statistically significant and biologically important differences in sea lion demographics and population trends in the 1970s and 1980s compared to the 1990s. The 1970s and 1980s was a period of steep population decline, whereas the 1990s was a period of overall modest decline. Unlike the earlier time period when reproductive failures were rather clearly tied to poor nutrition, substantial evidence of nutritional limitation is lacking for adult females with pups and pups up to age 5 months in the 1990s. Although dissimilar types of data collected during the two time periods hinder more direct comparisons, it seems plausible that a different suite of mechanisms are responsible for the steeper earlier decline as opposed to the more recent period of modest decline (some individual sites show an increase) and lack of recovery. For instance, the lack of evidence for nutritional limitation among adult female sea lions and their pups in the 1990s is more consistent with mortality-based hypotheses than with a food-driven hypothesis involving competition with fisheries. In the chapter of this report titled *Synopsis of Steller Sea Lion Declines*, the state's Restoration Team provided lists of mechanisms that may be relevant to the two different time periods.

Nutritional stress in the 1990s is an open possibility for juveniles, adult females without pups, and pups outside the breeding season, because comparable data on these life stages remain to be collected. Juveniles have high energetic demands and poorly developed foraging skills, so this is a critical stage to consider with respect to local and global prey availability. If nutritional limitation is a current problem for juveniles but not for other life stages, then the Reasonable and Prudent Alternatives can be focused accordingly. On the contrary, if nutritional stress is not present, then attention should focus on other demographic problems, such as accumulative mortality from various sources, and a different set of Reasonable and Prudent Alternatives should constitute the basis of a recovery plan.

With regard to the fishery-driven localized depletion hypothesis, BiOp3 does not fully present the state of knowledge, including analysis of existing data, on size distributions of sea lion prey and fishery removals. Additionally, the spatial and temporal distributions of state and federal fisheries were not thoroughly analyzed. For instance, a report on state fisheries (Kruse et al. 2000) presented a great deal of detailed information on the timing and locations of state-managed fisheries with respect to designated critical habitat. These data could have shed more light on the prospects for competition from particular fisheries in particular times and places. Detailed spatiotemporal fishing patterns will become even more useful, once improved knowledge of sea lion foraging behavior results from analyses of satellite location and dive data.

PROTECTIVE, ADAPTIVE, AND EXPERIMENTAL MANAGEMENT RECOMMENDATIONS

ASSLRT offers some comments and advice on current and proposed protective measures, and suggestions about alternative criteria for adaptive and experimental management of Steller sea lions and fisheries, particularly fisheries for groundfish. Some additional general advice on the management basis for critical habitat designation of rookeries and important haulouts was presented in a previous subsection of this report titled, *Management Basis of Critical Habitats*.

Review of Protective Measures

The team considered alternative approaches to reviewing and commenting on proposed state and federal sea lion protective measures. It was decided that it was best to take a science-based approach. First, as reported in another subsection of this report, *Ecological Basis of Critical Habitats*, the team identified the important biological activities of sea lions. In particular, two critical sets of Steller sea lion activities were recognized: (1) breeding and resting on land, and (2) foraging at sea. Next, the team discussed the merits of alternative management measures to protect those vital activities. Management measures should be designed with particular goals in mind. Corresponding to these two sets of sea lion activities, the team developed two management goals against which the merits of alternative management measures were judged. Regarding the activities of animals while on land, *a goal is to prevent human disturbance of land-based sea lion activities including breeding, nursing, resting, and social structure and behaviors.* Regarding foraging activities, *a goal of fishery management is to preclude diminution of prey of appropriate species, in adequate densities, of sufficient spatial distributions, and in the sizes preferred by Steller sea lions to meet their nutritional needs.* The team considered a suite of management measures for their ability to meet these two goals, which we subsequently refer to as goal 1 and goal 2.

<u>Goal 1:</u> **Prevent human disturbance of land-based sea lion activities including breeding, nursing, resting, and social structure and behaviors.**

No-transit Zones

In the subsection of this report titled, *Breeding and Resting on Land*, the Restoration Team described the biological and ecological reasons to prevent disruption of Steller sea lions on land. Those considerations form the basis for the management advice offered here.

The best management tools to protect animals while out of the water are no-approach zones for persons on land, and no-transit zones around rookeries and haulouts for vessels at sea, during the seasons (i.e., summer, winter, or year-round) that these sites are occupied. The team recognizes that seasonal sea lion use patterns are not well understood at all sites. The size of the zones should be based on sea lion ecology. The team feels that the appropriate size of the no-transit zones around haulouts to prevent disturbance is in the range of hundreds to thousands of feet. The team realizes that larger zones may be more effective in limiting direct mortality from illegal shooting. Also, the size of the no-transit zones may need to be larger for rookeries than around haulouts owing to the greater risks of adverse effects on pups. Information does not exist to quantify the merits of particular alternatives. Therefore, the size of no-transit zones should be a matter of public consultation so that sizes chosen for particular locations can reflect the best available scientific data, anecdotal information, local knowledge of the site, and considerations of required human activity such as access to harbors or routes needed for safe navigation. Habituation of sea lions to human interactions should also be considered, but the team noted that habituation does not necessarily infer a lack of negative effects due to human interactions.

In addition to this general advice, the Restoration Team developed additional specific advice to the State of Alaska concerning no-transit zones relative to goal 1:

1. The state should update its list of Steller sea lion rookeries to reflect the most recent changes in the federal list; two sites were added and two were dropped;

2. Assuming that the State of Alaska is vested with such authority, state regulations should consider including no-transit zones around currently utilized sea lion haulouts for the seasons they are occupied, with minimum size on the order of hundreds to thousands of feet. Such regulations should apply to vessels involved in fisheries that are currently prosecuted within close proximity of haulouts; and

3. If the state continues to allow the prosecution of any salmon or other fisheries within close proximity of occupied haulouts, then field programs should be implemented to monitor potential direct fishery-sea lion interactions for those fisheries.

<u>Goal 2:</u> **Preclude diminution of prey of appropriate species, in adequate densities, of sufficient spatial distributions, and in the sizes preferred by Steller sea lions to meet their nutritional needs.**

Preface to Considerations of Other Fishery Management Measures

The team struggled with the formulation of management advice to mitigate nutritional limitation of Steller sea lions owing to fishery-caused localized depletion, two potential problems for which there is no direct evidence albeit limited data. At the risk of redundancy, ASSLRT wishes to preface the following sections by restating our view that the preponderance of evidence indicates that nutritional limitation was likely problematic in the 1970s and 1980s, but data collected in the 1990s do not indicate that the western population of Steller sea lions has been nutritionally stressed with respect to the eastern population, at least during summer for pups and adult females with pups on which studies have focused to date. However, we cannot rule out the possibility of nutritional stress because contemporary data is lacking for other life stages. Of these other life stages, the Restoration Team is most concerned about juveniles because of their high caloric needs per unit body weight and their relative inexperience in capturing prey. The team is also concerned about adult females because of their need to obtain sufficient resources to maintain pregnancy. So, a precautionary approach would consider the possibility that juveniles and some adult females may experience nutritional stress, because data are unavailable to indicate otherwise. Moreover, there is insufficient evidence to determine whether fisheries cause localized depletions of prey over the time and spatial scales relevant to sea lion foraging. With these considerations in mind, the team considered the following suite of management measures primarily for their ability to protect prey availability for juvenile Steller sea lions to mitigate the possibility that they are nutritionally stressed: no-fishing zones, harvest rates, fishery thresholds, fishing seasons, rationalization programs, and gear allocations.

No-fishing Zones

No-fishing zones associated with sea lion critical habitat would be useful tools to maximize prey availability to juvenile sea lions if the zones indeed correspond to juvenile foraging areas and if prey abundance is reduced, as a result of a fishery, over the time scales associated with sea lion nutrition. The first question concerns the location of juvenile foraging areas for which there is no definitive answer. A preliminary examination of telemetry location data by distance from shore (summarized in the subsection *Ecological Basis of Critical Habitats*) indicate the preponderance of juvenile locations nearshore in winter but then further offshore in summer, likely after weaning (ADF&G and NMFS[4]). ASSLRT feels that it is inappropriate to characterize juvenile foraging areas by distance from shore, and new analyses integrating dive behavior with individual at-sea trips will provide a more direct measurement of sea lion foraging patterns.

Lacking a complete analysis of foraging data and the effects of fisheries on prey fields, the merits of alternative no-fishing zones cannot be evaluated, and ASSLRT could not determine meaningful no-fishing zones despite the team's desire to be precautionary. The team noted that, in BiOp3, NMFS found that the fisheries for Pacific cod, pollock and Atka mackerel, as currently prosecuted, jeopardize the continued existence of sea lions, and no-fishing zones were proposed as part of the Reasonable and Prudent Alternative to remove jeopardy. However, we have not seen compelling evidence on which to base such specific recommendations about no-fishing zones. It is possible that creation of nearshore no-fishing zones could actually prove to be deleterious to Steller sea lions if the offshore areas turn out to be more important sea lion foraging areas and if imposition of nearshore closure zones results in increased fishing effort offshore. Once a thorough analysis of existing data has been completed, specific no-fishing zones can be considered for their ability to foster goal 2.

Based on these considerations, ASSLRT offers the following advice about no-fishing zones relevant to goal 2:

1. The goal of no-fishing zones should be to prevent diminution of prey of appropriate species, in adequate densities, of sufficient spatial distributions, and in the sizes preferred by Steller sea lions. Therefore, no-fishing zones should be based upon sea lion foraging ecology and other biophysical factors that determine prey distributions and vulnerability to fishing gear. Sighting data (i.e., presence or absence observations at sea) alone are insufficient to design meaningful no-fishing zones. No-fishing zones are difficult to develop at this time because comprehensive analyses of sea lion foraging are not yet available and effects of fishing on sea lion prey fields remain uncertain. Accordingly, we cannot determine whether no-fishing zones, based on distances from shore, would be advantageous or deleterious to sea lion foraging success.

2. Given the current state of knowledge, it may be meritorious to include no-fishing zones in an experimental management approach to evaluate positive and negative effects on Steller sea lion trends on adjacent rookeries and haulouts. In this way, no-fishing zones could be part of a process-oriented investigation of the nutritional limitation and localized depletion hypotheses. Later in this report we discuss experimental design more fully.

3. The Restoration Team recommends that existing telemetry location and dive data be analyzed as quickly as possible to provide a more direct assessment of sea lion foraging, which is needed to help design precautionary management actions based on relative risk associated with different fishing activities.

4. When considering no-fishing zones, it may be useful to distinguish Steller sea lion critical habitat from special areas in need of extra protection. In 1993 when NMFS established 20-nm aquatic zones around rookeries and important haulouts as critical habitat, no specific management measures were associated with these areas. The team believes that delineation of no-fishing zones should include additional sea lion ecological parameters that were not available when Steller sea lion critical habitat was designated. Better yet, ASSLRT suggests revisiting the critical habitat designations (including the offshore foraging areas designations) themselves following our advice offered in the subsection of this report titled *Ecological Basis of Critical Habitats*.

5. If implemented, no-fishing zones should be specified for the seasons in which rookeries and haulouts are occupied rather than simply year-round if concern about localized depletion is the rationale for the closures. Such seasonal closure would need to safely buffer against prey depletion effects that may persist after the cessation of fishing.

6. The size and extent of potential no-fishing zones should depend largely on the spatial and temporal foraging use patterns of the segment of the population of concern; thus, for instance, the size determinations of closure areas should be specified primarily based on the foraging ecology of juvenile and adult female sea lions.

Harvest Rates

The Restoration Team considered the value of changes in fishery harvest rate to increase the abundance of Steller sea lion prey. The team believes that this topic is intimately tied to the code of conduct for responsible fisheries management. Harvested fish stocks should be enumerated with precise assessment programs, and a harvest rate strategy should be based on conservative target reference points set safely below limit reference points associated with overfishing. Of the commercially harvested species in sea lion diets, most stocks (e.g., walleye pollock, Pacific cod, Atka mackerel, rockfishes, arrowtooth flounder, rock sole, and other flatfishes) are enumerated by assessment programs, generally considered to be technically sound, and managed by harvest rates (e.g., $F_{40\%}$) thought to be conservative. Many flatfishes are harvested at rates markedly below $F_{40\%}$ owing to bycatch concerns and market demands. Nonetheless, the team recognizes that uncertainty in stock assessments and imprecision in estimates of reference points can lead to actual harvest rates that exceed intended rates in some years or areas.

Some species of Pacific salmon (e.g., sockeye and king salmon) are fully enumerated as they pass by weirs on some river systems, whereas other species (e.g., pink and chum salmon) are imprecisely assessed by stream or aerial surveys. However, all salmon runs are managed on an escapement goal policy that uses open and closed fishing periods in an attempt to allow an optimum escapement of spawners to return to natal streams so as to maximize future run sizes.

Several key herring stocks in the eastern Gulf of Alaska, such as Southeast Alaska and Prince William Sound, are assessed relatively precisely by spawn deposition or hydroacoustic surveys that are conducted routinely. Stocks with such data are managed by a harvest rate strategy. Harvest rate is zero if the stock is below threshold, and intermediate harvest rates are applied at intermediate levels of abundance up to a maximum harvest rate of 20% of spawning biomass. This harvest rate is thought to be conservative, and the rationale for the harvest rate is partly to provide for the role of herring as a forage species for upper trophic level predators, such as sea lions. However, to our knowledge, the optimum degree of harvest rate reduction associated with such ecological considerations has not been quantified. Around Kodiak Island, herring stocks have not been comprehensively assessed, and in lower Cook Inlet assessments are sporadic because of turbid water, harsh weather and the remote spawning locations. Associated with this lack of assessment, there is some risk that the harvest rate could exceed the acceptable harvest rate range in some years or areas.

The team had a long discussion about difficulties in estimating the increase in sea lion prey abundance to be expected from a given reduction in harvest rate. The team noted that harvest rate reductions do not translate directly into proportionate increases in abundance. For instance, ignoring all other complicating factors, if a harvest rate of 20% was reduced by half to 10%, the biomass of a species does not double. Instead, in simplistic terms, biomass would increase about 12.5% from 80% of unfished levels to 90% of unfished levels. Further, “biomass” is typically estimated as spawning biomass. If one considered total population biomass, including juveniles that may be available to Steller sea lions as prey but are not included in the spawning biomass estimates, then the harvest rate is actually lower and the marginal benefits of a harvest rate reduction are less. ASSLRT offers this example for illustrative purposes only; this rough calculation involves a number of unrealistic simplifying assumptions.

In the real world, intricacies of population dynamics and trophic dynamics make it much more difficult to predict the resultant increase in sea lion prey from a reduction in harvest rate. In fact, ASSLRT is not convinced that a reduction in harvest would, in fact, result in any increase in prey abundance of some species for a number of reasons. First, gadids generally have fairly strong density-dependent stock-recruit relationships. So, increases in standing stock above a midrange result in lower levels of recruitment on average. If juvenile sea lions generally eat juvenile fish, then an increase in standing stock may reduce prey availability to juvenile sea lions. Flatfish, on the other hand, tend to have stock-recruit relationships in which recruitment is independent of stock size over a broad range of spawning stocks, except when stocks fall to very depressed levels. So, reduced harvest rate would not increase the production of juvenile flatfish from the stock, but adult flatfish abundance would increase as abundance accrues from the harvest rate reduction. Better information on the sizes and ages of groundfish consumed by Steller sea lions would help to evaluate the tradeoffs between stock productivity (recruitment) and biomass (standing stock), including caloric value related to spawning, with respect to sea lion prey density.

Some fish species (e.g., pollock, cod, arrowtooth flounder) that are Steller sea lion prey at one life stage are sea lion competitors at later life stages. Pollock are cannibalized by larger pollock, particularly in the Bering Sea. Adult pollock consume other sea lion prey, including Pacific cod, herring, arrowtooth flounder and other flatfishes. Adult cod eat sea lion prey such as pollock, flatfish, squid, octopus, and sand lance. Likewise, the arrowtooth flounder diet includes pollock, squid, octopus, sand lance, smelts, herring, and flatfish. So, a reduction in harvest rate on some species that are sea lion prey at one life stage will increase the abundance of sea lion competitors at another life stage. The dynamics are too complex for us to evaluate whether reductions in harvest rates for these species will result in a net increase or net decrease in the abundance of prey available to juvenile Steller sea lions.

Aside from the sea lion prey that are targets of commercial fisheries, the team noted that about half of the primary species in the sea lion diet shown in Figure 4.6 in BiOp3 include those that are unfished or very lightly fished, such as squid, octopus, Pacific sand lance, Irish lord, Pacific sandfish, smelt, snailfishes, rock greenling, capelin, and some species of flatfishes. Although some of these species are subjected to bycatch mortality in some fisheries, factors other than fisheries are likely to regulate the abundance of these species. A reduction in harvest rate is not a viable management tool to affect an increase in the abundance of unfished sea lion prey.

Based on these considerations, ASSLRT offers the following advice about the use of harvest rate to achieve goal 2:

- Reduced fishery harvest rates may appear to be an effective management measure to promote an increase in sea lion prey abundance; fewer fish caught implies more fish available for fish predators. However, ASSLRT identified a number of prey taxa for which this may not necessarily be the case. First, many sea lion prey species are not targeted by directed fisheries, and changes in their abundance are mostly likely due to environmental factors rather than fishing. Second, some fish species that are sea lion prey as juveniles become sea lion competitors as adults. Reduced harvest rates of these species may increase the abundance of adults and therefore may lead to future reductions in juvenile abundance owing to density-dependent stock-recruit relationships. Reductions in the harvest rate of exploited species (e.g., herring) that remain sea lion prey throughout their life span are the most likely to result in net increases in sea lion prey abundance on average over the long term.

Fishery Thresholds

A fishery threshold is an abundance level below which no fishing is allowed, that is, harvest rate is set equal to zero. The use of thresholds for fishery management increased in the 1990s. However, thresholds are not applied to all exploited fish stocks. Typically, thresholds are set as a fraction (e.g., 20%) of estimated virgin spawning biomass. When current biomass levels fall below threshold, then no fishing is permitted. Threshold is intended as a safeguard against recruitment overfishing. However, if the exploited species is eaten by Steller sea lions, then the threshold will also help to maintain sea lion prey abundance above some density level. Of course, there are no guarantees that prey biomass will not continue to decline further below threshold in the absence of fishing. Also, prey densities required for sea lion nutritional requirements have not been explicitly considered in the establishment of current threshold levels. Nonetheless, ASSLRT feels that thresholds should be a routine component of conservative fishery management plans, especially when the target species is a sea lion prey species. For fish stocks lacking abundance estimates, assessments should be initiated to implement a threshold-based harvest policy.

ASSLRT offers the following advice with respect to fishery thresholds and management goal 2:

1. Fishery thresholds should be developed for fishery management plans in which they are not currently used. Aside from their merits as a precautionary approach to avert possible recruitment overfishing, ASSLRT feels that thresholds can help maintain minimum prey densities to benefit predators, such as Steller sea lions. Such ecological considerations could be incorporated into the threshold estimation process.

2. The State of Alaska should attempt to improve its herring stock assessments in several areas. First, attempts should be made to develop a viable method that overcomes technical and logistical hurdles that have prevented assessments of lower Cook Inlet herring to date. Second, a routine stock assessment program should be reinstated for herring in Prince William Sound, where assessment efforts have been sporadic in recent years. Finally, the state should implement assessment surveys for Kodiak herring stocks. This would allow the implementation of a fishery management strategy, comprised of a harvest rate and fishery threshold, like that used in Southeast Alaska. The assessments would provide important information about the abundance of this forage fish, and harvest rate and threshold strategies could be established to reduce the potential for adverse affects of the fishery on the availability of herring as prey to Steller sea lions.

Fishing Seasons

The Restoration Team considered the use of fishing seasons as a means to increase the density of prey available to Steller sea lions and briefly discussed the ability of this management tool to reduce the likelihood of localized depletion. Fishing seasons could be used to spread out the harvest over the year, but average annual abundance of fish would be unchanged, as the fishing mortality would remain the same. The team noted that the abundance of most fish species in a particular time and place is largely a function of seasonal migrations between spawning and feeding grounds. The team also noted that, as a management measure, fishing seasons are primarily used to meet socioeconomic objectives, such as spreading out seafood employment over the course of the year.

The team considered the possibility that fishing activity may disrupt fish spawning behavior. We are aware of an unpublished NMFS study in which pollock aggregations at depth appeared to react to the vessel noise from a factory trawler. Also, spawning aggregations of Atlantic cod show avoidance behavior in response to bottom trawls (Morgan et al. 1997). This avoidance behavior affected the shoal structure up to 200-400 m on either side of the trawl track for a time period on the order of the length of the study, 77 minutes. However, we do not know if fish school responses on the order of hundreds of meters and tens of minutes adversely affect the ability of Steller sea lions to forage successfully. Also, we do not know if Pacific cod display similar responses to trawling as Atlantic cod. Research is needed to examine fish responses to typical trawling effort in sea lion foraging areas in Alaska.

Finally, ASSLRT discussed the issue of which type of fishery causes less disruption of Steller sea lion foraging success: a short or a long fishery? A herring fishery may be prosecuted in the vicinity of many sea lions, but the fishery may be extremely fast, perhaps as short as an hour or less. On the other hand, a protracted fishery, which is spread out over the entire year, may involve fewer sea lion interactions per hour, but involves many more hours of fishing.

ASSLRT did not delve very deeply into the concept of localized depletion in the context of fishing seasons. On the one hand, fishing seasons may spread out harvest over the year, reducing the likelihood of localized depletion at any one time and place. On the other hand, fishing seasons could displace the harvest from seasons when fish are most abundant to times of the year when fish densities are low and most vulnerable to localized depletion as sea lion prey. Hence, the team struggled with the application of fishing seasons as a management tool to address this concern largely owing to the lack of data on fishing effects, sea lion foraging, and seasonal prey dynamics and availability. In the absence of such data, the team could not recommend a preferred structure of fishing seasons to meet goal 2, and our advice is summarized as follows:

- Fishing seasons may not be an effective mechanism to increase sea lion prey abundance. If annual fishing mortality rate is unchanged, then mean prey abundance is unchanged. Also, ASSLRT was unable to draw definitive conclusions about the efficacy of fishing seasons as a management tool to reduce the likelihood of localized depletion of sea lion prey. Their utility depends upon sea lion foraging behavior; harvest rates and distribution of fishery removals on the spatial and temporal scales relevant to sea lions; and the abundance, distribution, school structure, movements, and directional migrations of fish populations – nearly all of which are unknown and likely to be highly dynamic, especially over seasonal time scales. Likewise, it is not clear whether a protracted fishing season, with sea lion-fishery interactions spread throughout the year, results in less deleterious effects than a short, intense season with all sea lion-fishery interactions occurring at once.

Fishery Rationalization Programs

Following fishing seasons, the team briefly discussed rationalization programs that lead to overall reduction of capital and fishing effort. The team noted that smaller fishing fleets may have greater flexibility to harvest at alternative times of the year. Thus, there may be more potential to avoid seasons when sea lion interactions are more likely, but decisions on when to fish are usually based on economic decisions. Also, if effort is reduced, then there would be fewer vessels to interact with Steller sea lions. However, again, the team had difficulty in evaluating effects of fishery-sea lion interactions under a short fishery versus a protracted fishery, and no specific advice was offered on fishery rationalization programs with respect to management goal 2.

Gear Allocations

The team was unable to identify gear types as a means to increase the availability of prey to juvenile Steller sea lions. A switch to a more inefficient gear type was not viewed as a means to this end because, if the catch quota is unchanged, there is unlikely to be any net change in sea lion prey availability as a result of gear changes. Also, allocation of harvest to an inefficient gear type may lead to more effort causing more vessel-sea lion interactions. Therefore, no specific advice about gear allocations was offered with respect to management goal 2.

Adaptive Management and Experimental Design

The Restoration Team discussed the development of an experimental design independent of any potential closed areas that may be part of a management plan intended to remove jeopardy. The experimental component of the monitoring plan is a highly desirable feature of a Reasonable and Prudent Alternative. However, the Restoration Team feels very strongly that the experiment, as well as other research studies, must be well designed and coordinated to provide useful data. The experiment should not be implemented until a sound design has been developed. The team would much prefer the conduct of targeted, informative studies on fishing effects rather than the hasty implementation of a poorly designed large-scale experiment with low statistical power. The team feels that the red/green design of “open” and “closed” areas, proposed in BiOp3, does not meet these desired standards.

Any experiment runs some risk of failure owing to wide-scale movement of animals among treatments and difficulties of manipulating prey fields by fishing. The Restoration Team feels that inclusion of the following design features would enhance the likelihood of success of an experiment involving open and closed areas:

- The experiment should be designed to address explicitly stated hypotheses. In advance of the experiment, statistical tests should be defined to test the stated hypotheses, and statistical power of the tests should be estimated. The experiment should include an adequate number of replicates to assure that responses in individual areas are not due to chance.

- A multivariate statistical analysis, such as cluster analysis, of sea lion population trends by region and site may be useful to select areas as treatments. The analysis should account for any shifts in rates of decline over time. Areas that experienced similar rates of decline could be assigned to different treatments (i.e., open and closed areas) to determine whether trends diverge during the experiment.

- The choice of spatial scale is one of the most difficult considerations of this type of experiment. The size of the treatment areas should be large enough to embrace the extensive movement patterns of juvenile and adult sea lions. However, the overall experiment should not cover so vast an area that it necessitates an unattainable monitoring program of important diagnostic variables. The team feels that the experimental design in BiOp3, the 13 red/green areas encompassing the entire state, is much too large to monitor the relevant diagnostics. A smaller portion of the coastline should be considered for the experiment.

- The time scale of the experiment is also important. A commitment must be made to maintain the experiment until a specified time period by which the response is expected based on ecological principles and knowledge of sea lion population dynamics. Applying the treatments over one response time interval, then reversing the open and closed areas over a second response interval may increase the power of the experiment.

- The design should consider the fact that Steller sea lions do not respond to artificial open or closure designations but rather may respond to changes in prey density, distribution, and composition given their diet preferences. It must be recognized that prey include species consumed by sea lions regardless of whether they are fished or unfished and regardless of whether they are managed by federal or state agencies inside or outside 3 nm. If the experiment is to determine whether a particular fishery (e.g., walleye pollock or Pacific cod) causes an individual and/or population effect on a local group of Steller sea lions, then it is important that the experimental design considers abundance and all removals of that species, including any from state-managed fisheries. The issue then becomes whether the fishery was capable of causing localized depletion and, if so, whether the sea lions were able to switch to other species to obtain adequate prey to meet their needs. On the other hand, if the experiment is to determine whether broad open and closed areas encompassing all fishing affect sea lions, then it may be important to consider all prey species in the design. For reasons such as these, the hypotheses to be tested must be clearly articulated.

- The experiments must include fishing regimes of sufficient contrast to produce changes in the sea lion prey field beyond those related to natural variability. It appears to the team that the fishing regime associated with the experimental design in BiOp3 provides inadequate contrast to be ecologically meaningful to sea lions.

- A monitoring program must be conducted to confirm that fishing did, in fact, cause the desired directional changes in the Steller sea lion prey fields, that is, that the treatments exist.

- The experiment must be associated with a long-term commitment to a meaningful monitoring program of diagnostic variables (covariates). The team feels that it is insufficient to simply attempt to correlate commercial landings from selected federally managed fisheries with sea lion non-pup population trends among treatments. Not only is a monitoring program needed to verify that the manipulations resulted in the desired treatments (e.g., changes in prey fields), but a monitoring program should collect data on the operative mechanisms associated with sea lion population responses. Key elements of the monitoring program should include: (1) record-keeping of all fishing mortality of sea lion prey; (2) estimation of prey densities, schools, and distributions; and (3) metrics of sea lion population health including foraging trip duration, diet, blubber thickness, pregnancy rate, milk production, pup birth weight, pup counts, recruitment indices, and growth indices.

STELLER SEA LION RESEARCH RECOMMENDATIONS

Introduction

As evidenced by two recently published bibliographies (Harper 2001, Hunter and Trites 2001), a large body of scientific research has been conducted on Steller sea lions. Owing to the depressed status of the western stock, a great deal of additional research has been conducted in the last few years, with much research currently ongoing. The team wanted to become more familiar with this new research as it relates to ASSLRT's goals and objectives, particularly recent measures of sea lion health, potential causative mechanisms, and other issues related to BiOp3. Toward these ends, the team conducted a review of ongoing research on Steller sea lions (see Appendix A.2). Also, NMFS provided a summary of proposals for new research that were recommended for funding under a Steller sea lion research initiative in 2001, and they kindly allowed us to reproduce the list here (see Appendix A.3). The Restoration Team recommends that recent research findings should be brought to bear upon imminent considerations of new conservation and management measures.

To more thoroughly examine the potential causes of the current Steller sea lion population decline, increased knowledge is needed about important sea lion life history parameters, ecological relationships, and the effect of fishing on prey abundance and spatial distribution. The Restoration Team developed the following checklist as a guide to research needed to further identify the causes of Steller sea lion declines. In developing this list, the team considered ongoing (Appendix A.2) and impending research (Appendix A.3).

Research recommendations are focused on two overall objectives:

- Obtain a greater understanding of sea lion biological and ecological processes; and
- Determine the probability of competition for food between sea lions and fisheries.

The Restoration Team recognizes that limitations in technology, logistics, experienced personnel, and funding will make it difficult to pursue all of the following recommendations to the fullest extent. However, process-oriented, hypothesis-driven research should be pursued within an experimental and adaptive management approach to the greatest extent possible. The team recommends particular research emphasis on adult females and subadults of both sexes, especially pre-weaning and during the first 1-2 years post-weaning, to improve our knowledge of these life stages including whether there is evidence for nutritional stress.

Sea Lion Biology and Ecology

- Estimate current age-specific survival and reproduction rates.

- Estimate the potential impact of killer whale and shark predation on population growth rates.

- Continue to estimate the level of Steller sea lion mortality attributed to subsistence harvest, intentional shooting, and incidental takes.

- Continue to explore the potential impact of disease and contaminants on sea lion populations.

- Continue genetic analyses designed to further determine population structure.

- Determine the seasonal (breeding vs. non-breeding) use patterns of rookeries and haulouts.

- Determine Steller sea lion habitat requirements, and their ecological bases, by age, sex, season, and region.

- Estimate the spatial extent of habitat required for sea lion survival and recovery based on all ecological data, especially the relevant spatial and temporal scales used by foraging sea lions.

- Monitor the abundance and distribution of sea lion prey at finer spatial scales with more precision, including unexploited species not currently enumerated by annual assessment surveys.

- Determine the relationships among sea lion population trends, habitat attributes, predator populations, and prey fields on spatial scales of individual rookeries or small groups of rookeries with common trends.

- Continue to develop additional indices of the nutritional status of individual Steller sea lions.

- Determine the rate that sea lion body condition responds to changes in food availability (quantity and quality), and subsequent relationships with vital population parameters.

- Determine sea lion diet (species and size) by age, season, and region on both short-term (scats) and long-term (blubber fatty acids) time scales.

- Assess relationships among large-scale shifts in environmental conditions (e.g., regime shift), primary and secondary productivity, fish community composition, and Steller sea lion population trends.

- Develop techniques to identify when weaning occurs, which will allow an assessment of when sea lions may be more sensitive to changes in food availability.

- Estimate seasonal energy budgets, including nutritional requirements, of juvenile sea lions during pre-weaning and first two years post-weaning.

- Determine the rate at which blubber fatty acid signatures respond to changes in sea lion diet, including the switch from milk ingestion to prey consumption.

- Develop or test new technologies to determine the feasibility of:

    - Satellite-linked mortality tags
    - Photo-identification for detailed population dynamic studies
    - Permanent instrument attachment, including surgical implantation
    - Medium-format aerial photography to census pups and non-pups, and provide indices of juvenile recruitment and body size
    - Remotely monitoring body condition
    - Remotely monitoring foraging behavior (e.g., with stomach temperature sensors)

Potential Competition Between Sea Lions and Fisheries

- Determine the associations between seasonal changes in sea lion diet, body condition, movements, prey aggregations, and the timing and location of fisheries.

- Determine the effect of fishing on the abundance (biomass and size) and distribution of sea lion prey at spatial and temporal scales pertinent to foraging sea lions, that is, attempt to determine if fisheries cause localized prey depletion. Experiments are likely to be more informative if conducted when fish are concentrated in spawning aggregations and seasonally when sea lions may be more sensitive to food limitations. It is important that such studies distinguish reductions in prey density associated with fishery removals from seasonal declines in fish density resulting from dispersal following spawning activities.

- If localized prey depletion occurs, determine if Steller sea lions subsequently exhibit a response in their foraging behavior, body condition, and survival and reproductive rates.

- For fisheries prosecuted in close proximity to rookeries, haulouts, or at-sea feeding aggregations of Steller sea lions, determine the nature of interactions between sea lions and vessels (e.g., temporary or permanent displacement of sea lions, decreased foraging activity, and incidental take).

- Determine the effect of no-fishing zones by estimating sea lion population trends among rookeries and haulouts within treatment (no-fishing) and control (fishing) areas.

CONCLUSIONS

The Alaska Steller Sea Lion Restoration Team reviewed existing and proposed fishery management actions in light of the status of the Steller sea lions in Alaska. We offer the following major findings and recommendations.

Contrary to the eastern stock of Steller sea lions, which appears to be at its highest levels of recorded abundance, the western stock has experienced a severe decline in abundance since the first assessment surveys in the late 1950s. The ultimate cause of the steepest segment of the decline (1970s and 1980s) is widely thought to have been low survival and low birth rates, and the proximate cause is thought to be nutritional stress. The causes of this nutritional stress are unknown, but hypotheses include: competition for food between Steller sea lions and commercial fisheries; changes in prey abundance, composition, and distribution associated with climate-driven regime shifts; and a cascade effect of ecosystem changes, triggered by overharvests of whales and certain fish species, that led to the current pollock-dominated system.

In the opinion of ASSLRT, a combination of natural (e.g., environmental change, predation, disease) and anthropogenic factors likely contributed to the historical decline of Steller sea lions through the 1980s, although the relative contributions remain uncertain. Regarding the anthropogenic factors, humans likely contributed significantly to the historical decline primarily through the following causes:

1. Mortality from intentional shootings of animals by government eradication programs, by fishermen in defense of fishing gear or catches formerly under federal permit, and illegally by fishermen and others without permits;

2. Bycatch mortality of sea lions in fisheries, particularly in roe-stripping trawl fisheries prosecuted by foreign and joint-venture operations in the 1970s and 1980s;

3. Experimental harvests of adults in 1959 and pups during 1963-1972; and

4. Nutritional stress of Steller sea lions associated with major changes in sea lion prey species composition and abundance in the 1970s and 1980s. Shifts in prey occurred as a result of a well-documented climate-forced regime shift in the mid 1970s perhaps in combination with cascading changes in the marine ecosystem originating from human overexploitation of whales and some fish stocks in earlier decades.

During the 1990s, the overall rate of decline of juveniles and adults on index sites for the western stock moderated. During this period, counts were stable in the eastern Aleutians and counts in the eastern Gulf of Alaska declined most steeply. Research was conducted on pups and females with pups during summer in the 1990s to evaluate the nutritional limitation hypothesis by comparing animals among the declining western stock and the increasing eastern stock. The preponderance of evidence from these studies indicated that, for the seasons and classes of animals investigated, the declining western stock was not nutritionally limited relative to the increasing eastern stock, and by some measures, the animals in the western stock were actually healthier.

A range of hypotheses has been proposed for the most recent period of modest decline. A leading alternative to the nutritional limitation hypothesis may be a cumulative mortality hypothesis in which a number of mortality sources (e.g., entanglement, illegal shooting, predation by killer whales and sharks, incidental fishing mortality, disease, etc.) may fully account for recent population trends. Owing to a lack of data on sea lion nutrition on all life stages and a paucity of fishery studies on localized depletion, the possibility cannot be eliminated that nutritional limitation, caused by localized depletion from commercial fisheries, contributes to the current situation.

ASSLRT is not convinced that humans contributed significantly to the sea lion decline in the 1990s. While acknowledging the possibility that adverse fishery effects cannot be fully ruled out, ASSLRT concludes that the potential impact of current fisheries is considerably less than during the historical decline for the following reasons:

1. The annual rate of decline for the western stock moderated to 5.1% during the 1990s, with population stability in the eastern Aleutian Islands;

2. Sea lion prey are not limiting in a global sense based on analyses of sea lion consumption needs and survey biomass of groundfish (e.g., Appendix 3 in BiOp3), even without considering the biomass of non-surveyed prey species;

3. Pups and adult females with pups were not nutritionally stressed in the summer breeding period during the 1990s, and these two life history stages are most vulnerable to localized depletion of prey in close proximity of rookeries; and

4. Many conservation measures have been added to fishery regulations since the 1970s and 1980s. These include more precautionary harvest control rules, no-trawl zones around rookeries and haulouts, and seasonal apportionments that collectively reduced the rate of harvest and dispersed the removal of sea lion prey both temporally and spatially to diminish the likelihood of localized depletion.

For these reasons, ASSLRT feels that it is unlikely that present fisheries currently put the western stock of Steller sea lions at risk of extinction, but the precise extinction probability should be reexamined with new population viability analyses informed with the best scientific data and methods currently available.

The current endangered listing of the western stock of Steller sea lions should be reviewed. Although the continued declines in most areas remain of concern, the specific question is whether new information influences the determination that the western stock of Steller sea lions is in danger of extinction. A reassessment is appropriate in light of recent population trend data, new alternative population viability models, and proposed new quantitative methods for ESA classifications.

The population trend and abundance data for the eastern stock of Steller sea lions does not support the definition of threatened, and it is highly unlikely that this stock will become endangered in the foreseeable future. Based on a cursory analysis, it appears that this stock should be removed from the ESA threatened species. A more thorough analysis of the eastern stock should be conducted and more objective scientific criteria for listing and de-listing determinations should be developed.

Sea lion critical habitat, designated in 1993 as circles with a 20-nm radius around rookeries and important haulouts west of 144^{o} W, has not been adequately justified. The Team believes using the distances from at-sea locations to the nearest landmass to determine sea lion foraging areas is inappropriate due to the numerous biases. Rather, ASSLRT supports a complete analysis of the telemetry data that integrates both location and dive behavior data from individual at-sea trips to directly estimate the spatial and temporal foraging patterns of sea lions.

BiOp3 is a comprehensive document with good information on the history of regulations, current fishery management plans, stock trends and commercial catch histories, descriptions of the fisheries, and Steller sea lion biology and ecology. Yet, it has major deficiencies. Leading among these are a lack of a fair and thorough treatment of alternative hypotheses, failure to distinguish different sea lion population trends and potential causative factors in the 1970s and 1980s from the 1990s, and a lack of full treatment of recent and ongoing studies that suggest that nutritional limitation did not occur in the 1990s, at least with respect to the studied life stages, pups up to age 5 months and females with pups.

Precaution is warranted in the face of uncertainty. Protection measures should focus on two critical sea lion activities: breeding and resting on land, and foraging at sea. The best management tools to protect animals while out of the water are no-approach zones for persons on land and no-transit zones around rookeries and haulouts for vessels at sea, during the seasons (i.e., summer, winter, or year-round) during which these sites are occupied. The size of the zones should be based on sea lion ecology, although the team recognizes that buffer zones may also need to reflect a distance that discourages illegal shooting of sea lions. The team feels that the appropriate size of the no-transit zones around haulouts to prevent disturbance is in the range of hundreds to thousands of feet, and that the size of the no-transit zone for rookeries may need to be larger owing to greater risk of adverse effects on pups. Information does not exist to quantify the merits of particular alternatives. Therefore, the size of no-transit zones should be a matter of public consultation so that sizes chosen for particular locations can reflect best available scientific data, anecdotal information, local knowledge, and considerations of required human activity such as access to harbors or routes needed for safe navigation.

The team struggled with the formulation of management advice to mitigate nutritional limitation of Steller sea lions from fishery-caused localized depletion; these are two potential problems for which there are limited data and currently no direct evidence. A precautionary approach might consider the possibility that juveniles experience nutritional stress at present because of their high nutritional demands, their inexperience in capturing prey, and a lack of contemporary data to indicate otherwise. The goal should be to preclude diminution of prey of appropriate species, densities, spatiotemporal distributions, and sizes important to Steller sea lions. Among the suite of management measures, the Restoration Team was unable to determine any one measure or set of measures that is well suited to meet this goal.

Fishery thresholds should be developed for fishery management plans in which they are not currently used. Aside from their merits as a precautionary approach to avert possible recruitment overfishing, thresholds can help maintain minimum prey densities to benefit predators, such as

Steller sea lions. Such ecological considerations could be incorporated into the threshold estimation process.

Harvest rate reductions may have some merit for species, such as herring, that are sea lion prey throughout much of their life. However, for most species, the efficacy of harvest rate reductions to increase the availability of prey to sea lions is uncertain. Some species (e.g., cod, pollock, arrowtooth flounder, etc.) are sea lion prey at one life stage and sea lion competitors at other life stages. Owing to complex population dynamics (stock-recruitment) and trophic relationships, it is unclear whether harvest rate reductions for these species would be manifested as a net increase or net decrease in prey availability. Moreover, many sea lion prey species (e.g., squid, octopus, sculpins, capelin, sand lance, sandfish, some flatfishes) are unfished or lightly fished and changes in their abundance and availability are likely driven by environmental factors.

No-fishing zones have been proposed as part of the Reasonable and Prudent Alternative to remove jeopardy, but compelling evidence on which to base such specific recommendations about no-fishing zones is absent. As with designation of critical habitat, potential use of no-fishing zones in a precautionary management approach requires information yet to be realized from a full analysis of telemetry data that integrates both location and dive behavior data from individual at-sea trips to directly estimate the spatial and temporal foraging patterns of sea lions.

Given the current state of uncertainty, it may be meritorious to include no-fishing zones in an experimental management approach to evaluate positive and negative effects of alternative designs on Steller sea lion trends on adjacent rookeries and haulouts. In this way, no-fishing zones could be part of a process-oriented investigation of the nutritional limitation and localized depletion hypotheses. Design considerations for such experiments include: a priori hypotheses, statistical tests, and statistical power analysis; spatial scales large enough to account for sea lion movements and small enough to permit a feasible monitoring program; temporal scales that are long enough to span realistic expectations of ecological responses; application of treatments over one response period and then reversal of treatments over a second response period to improve statistical power and reduce risk of responses due to chance; and a commitment to a monitoring program of diagnostic covariates to substantiate the ecological processes causing the responses.

A list of research recommendations are offered to help identify critical information needs. In particular, a research emphasis is needed on adult females and subadults, especially pre-weaning and during the first 1-2 years post-weaning, to improve our knowledge of these life stages including whether there is evidence for nutritional stress.

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APPENDIX

Appendix A.1. ASSLRT review of BiOp3.

Foreword

On November 30, 2000, NMFS issued BiOp3 (NMFS 2000) on the authorization of fisheries in the Gulf of Alaska and Bering Sea and Aleutian Islands under the auspices of groundfish fishery management plans (FMPs). BiOp3, in compliance with Section 7 of the ESA, determines whether the Gulf of Alaska and Bering Sea and Aleutian Islands groundfish fisheries jeopardize the continued existence of listed species and critical habitat. Of particular interest is the NMFS consultation regarding the western stock of the Steller sea lion, which is currently listed as endangered.

This chapter summarizes the review of BiOp3 by the Alaska Steller Sea Lion Restoration Team (ASSLRT). Minutes of the team's first four meetings, especially the second meeting (December 15, 2000), contain comments by the Restoration Team on BiOp3. In the interest of efficiency, we have limited our review to a summary of our primary comments. The team noted that several reviews of BiOp3 have already been conducted and that there is significant commonality among their conclusions (Anonymous 2001, Bowen et al. 2001, SSC 2001).

Executive Summary

This executive summary was presented verbatim in a section of this report titled, *Overview of ASSLRT Comments on Biop3*. It is reprinted here for completeness. Readers who read that section can skip to the next subsection of this Appendix, titled *Description of Fishery Management Process*.

The Restoration Team appreciates the effort that went into the preparation of BiOp3. It is a comprehensive document with good information on the history of regulations, current fishery management plans, stock trends and commercial catch histories, descriptions of the fisheries, and Steller sea lion biology and ecology. Yet, despite all the information contained in BiOp3, it has some major deficiencies, some of which are outlined here.

Although designated in 1993 (NOAA 1993), in the opinion of ASSLRT these critical habitat designations still have not been adequately justified. Now that BiOp3 proposes specific management measures associated with critical habitat, it is even more important to be sure that critical habitat is correctly specified. The Restoration Team recommends completion of the ongoing analyses of extensive telemetry data as soon as possible. Once completed, critical habitat designations should be reconsidered in light of the new findings about important sea lion foraging areas.

The Restoration Team feels that diet diversity may have played a larger role in sea lion health and historical population trends than acknowledged in BiOp3. The percent frequency of occurrence of gadids in stomach samples of the western stock of sea lions doubled from the 1950s-1970s to the 1980s (Figure 4.5 in BiOp3) consistent with an increase in groundfish

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abundance following the climate regime shift in the late 1970s. These coupled observations of prey abundance and predator stomach contents are not consistent with a hypothesis that sea lion nutrition is compromised by a recent lack of availability of walleye pollock, Pacific cod, and Atka mackerel. Recognition of these observations gave rise to the junk food hypothesis (Alverson 1992) that contends that sea lions eat too much pollock and not enough fatty, high-energy fishes. Because more than half of the top 14 species (e.g., squid, octopus, Pacific sand lance, smelt, Irish lord, Pacific sandfish, snailfishes, rock greenling) of sea lion prey by percent frequency of occurrence, as reported in BiOp3, are not subjected to directed fisheries, fluctuations in their availability to sea lions may be predominantly driven by environmental factors. The role of diet diversity in historical sea lion population trends seems plausible, given sea lion population trends, trends in diet, and evidence for nutritional limitation in the 1970s and 1980s. However, for this mechanism to operate presently, nutritional limitation must occur in sea lion age and sex classes other than pups and females with pups in summer.

Similarly, the topic of competition for prey among Steller sea lions and other natural predators is treated superficially without the reference to published diet and foraging studies. Pollock, squid, octopus, herring, and other forage fishes are heavily preyed upon, not only by Steller sea lions, but also by other marine mammals (e.g., harbor seals) and fish predators (e.g., Pacific cod and halibut). Abundant relevant diet data are available, but were not considered. Diet diversity and natural competitors are just two examples but, generally speaking, BiOp3 does not evaluate the Steller sea lion as an integrated member of a dynamic marine ecosystem influenced by a suite of climatic and anthropogenic factors.

BiOp3 generally lacks a fair and thorough treatment of alternative hypotheses (e.g., regime shift effects on prey, historical eradication programs, non-reported shootings, predation) for their potential roles in sea lion declines. The overall approach in BiOp3 is biased in that individual alternative mechanisms are subjectively discounted on a one-by-one basis for their inability to solely account for all of the observed population declines. Because the burden of proof is reversed for the fisheries competition hypothesis (localized depletion), the default assumption becomes BiOp3's conclusion. That is, the alternative hypotheses cannot be proven to individually explain all of the sea lion trends and thus are not accepted, whereas the hypothesis of localized depletion by groundfish fisheries cannot be disproved and thus it is not rejected. In addition, ASSLRT is confident that no single factor can account for historical Steller sea lion population trends. However, a fundamental flaw in the BiOp3 analysis is that the synergistic effects of different mechanisms, including fishing, to collectively account for population trends are not considered.

BiOp3 concludes that the groundfish fisheries jeopardize the continued existence of the western stock of Steller sea lions. Rather than the result of an objective scientific analysis, this conclusion primarily rests upon a series of speculative arguments. Indeed, some data (e.g., increase in gadid harvest from critical habitat during the early 1980s) were presented in support of this hypothesis. However, a thorough and objective analysis of the evidence for and against this hypothesis was not provided.

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In BiOp3 some diet data were disaggregated into interesting contrasts between the eastern and western stock during two periods (e.g., Figure 4.5) and between summer and winter (e.g., Figure 4.6). However, generally, the analysis tends to lump data across large spatial and temporal scales potentially missing important underlying patterns at the scales relevant to sea lions that may be tied to causative mechanisms. For example, where existing data would support a site-by-site analysis of sea lion seasonal diet and annual population trends, key insights into the connection between prey and population status may be possible.

BiOp3 failed to recognize that there are statistically significant and biologically important differences in sea lion demographics and population trends in the 1970s and 1980s compared to the 1990s. The 1970s and 1980s was a period of steep population decline, whereas the 1990s was a period of overall modest decline. Unlike the earlier time period when reproductive failures were rather clearly tied to poor nutrition, substantial evidence of nutritional limitation is lacking for adult females with pups and pups up to age 5 months in the 1990s. Although dissimilar types of data collected during the two time periods hinder more direct comparisons, it seems plausible that a different suite of mechanisms are responsible for the steeper earlier decline as opposed to the more recent period of modest decline (some individual sites show an increase) and lack of recovery. For instance, the lack of evidence for nutritional limitation among adult female sea lions and their pups in the 1990s is more consistent with mortality-based hypotheses than with a food-driven hypothesis involving competition with fisheries. In the report chapter titled *Synopsis of Steller Sea Lion Declines*, the state's Restoration Team provided lists of mechanisms that may be relevant to the two different time periods.

Nutritional stress in the 1990s is an open possibility for juveniles, adult females without pups, and pups outside the breeding season, because comparable data on these life stages remain to be collected. Juveniles have high energetic demands and poorly developed foraging skills, so this is a critical stage to consider with respect to local and global prey availability. If nutritional limitation is a current problem for juveniles but not for other life stages, then the Reasonable and Prudent Alternatives can be focused accordingly. On the contrary, if nutritional stress is not present, then attention should focus on other demographic problems, such as accumulative mortality from various sources, and a different set of Reasonable and Prudent Alternatives should constitute the basis of a recovery plan.

With regard to the fishery-driven localized depletion hypothesis, BiOp3 does not fully present the state of knowledge, including analysis of existing data, on size distributions of sea lion prey and fishery removals. Additionally, the spatial and temporal distributions of state and federal fisheries were not thoroughly analyzed. For instance, a report on state fisheries (Kruse et al. 2000) presented a great deal of detailed information on the timing and locations of state-managed fisheries with respect to designated critical habitat. These data could have shed more light on the prospects for competition from particular fisheries in particular times and places. Detailed spatiotemporal fishing patterns will become even more useful, once improved knowledge of sea lion foraging areas result from analyses of satellite location and dive data.

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Description of Fishery Management Process

BiOp3 provides a concise overview of the fishery management process including the setting of annual total allowable catches and prohibited species catch limits. Also, new details (tables, figures, and maps) on important fisheries are presented, particularly for the walleye pollock, Pacific cod, and Atka mackerel fisheries.

The section describing the consultation history under the ESA is useful in understanding the chronology of jeopardy and no-jeopardy findings for groundfish fisheries in the context of Steller sea lions. This section would have benefited greatly by including a more complete description of the sea lion protective measures already instituted and the bases for changes in jeopardy findings over time. For example, some management measures were specifically instituted to afford protection to Steller sea lions, and previous findings of jeopardy were reversed, presumably as a result of the implementation of remedial regulations. It would have been helpful if BiOp3 had clearly described the linkages between historical regulatory actions and the reasons for changes in findings of jeopardy from previous biological opinions.

Sections on fishery management would have benefited from some additional descriptions of existing conservation measures for groundfish fisheries in the Gulf of Alaska and Bering Sea and Aleutian Islands areas. Such measures include gear restrictions, license limitations, rationalization programs, seasonal fishery allocations (particularly in the pollock roe fishery), closure of pollock fishing in the Bogoslof District, full retention and utilization of pollock and cod, prohibition of forage fish fisheries, and areas closed to fishing in state and federal waters. Some of these measures are discussed on pages 213-221 of BiOp3. Whereas such measures may not foreclose the need for additional protections for sea lions, the groundfish FMPs conform to responsible fishing standards, especially when compared to fisheries in other locations around the world including areas where seal and sea lion populations are healthy despite weak fishery management controls. More importantly, most groundfish stocks in the Gulf of Alaska and Bering Sea and Aleutian Islands are healthy. Exceptions include Greenland turbot, which continues to undergo a long-term decline in the Bering Sea, and Pacific ocean perch, which is still recovering from foreign overfishing in the Gulf of Alaska and Bering Sea and Aleutian Islands in the 1960s and 1970s.

Steller Sea Lion Biology and Ecology

BiOp3 provides a useful, albeit somewhat abbreviated, summary of Steller sea lion biology and ecology. A few of the most critical ecological considerations with regard to potential fisheries interactions include sea lion foraging and prey consumption, critical habitat, and competition. Accordingly, the Restoration Team focused comments on these areas.

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Historical Diet Data

BiOp3 includes some useful information on sea lion diet. Comparisons between the eastern and western stock were helpful, and interesting contrasts in temporal diet patterns from stomach contents were presented between the 1950s-1970s and the 1980s. Likewise, analysis of scat data revealed interesting seasonal shifts in diet in winter and summer.

Beyond these contrasts, BiOp3 generally fails to identify the specific location and month during which diet samples were collected. By considering location and season, additional seasonal and spatial patterns in prey consumption may have emerged. Merrick et al. (1997) found, and more recent studies by other scientists confirmed, that statistically significant and biologically meaningful differences in sea lion diet exist on spatial scales smaller than the broad regions occupied by the eastern stock or western stock. Likewise, analysis of stomach and scat data on time scales finer than winter and summer, when possible, may be necessary to understand possible connections between diet, prey availability, and fisheries removals. Also, if data are available, an analysis of population trends and diet patterns on an index site-by-site basis may be an invaluable addition to future biological opinions. Multivariate data analysis (e.g., cluster analysis) of index site data may also reveal groupings of sites with common features that could serve as a basis for meaningful experimental management designs. On the contrary, failure to disaggregate the data on the temporal and spatial scales relevant to sea lions can cause misleading results, as discussed in the chapter titled *Synopsis of Steller Sea Lion Declines.*

As noted in BiOp3 on page 91, each diet data collection method has its own bias. For instance, scat data may be biased for certain prey that have relatively indigestible hard parts and which may represent the accumulation of multiple meals in the stomach at any one time. On the other hand, animals composed mostly of soft tissue, such as cephalopods, may be underrepresented in scats as opposed to stomach samples. Both stomachs and scats may predominantly reflect the contents of the last meal as opposed to fatty acids that may integrate prey over a longer time period. Stomachs and scats also may be biased in favor of the prey base in close proximity to the haulout rather than prey consumed in at-sea foraging areas. Large bias associated with data collection methods has been demonstrated in a number of other species. Because there are substantial differences in diet data collection methods over time for Steller sea lions (i.e., stomach contents through the 1980s and scat analysis since the 1990s), it would have been helpful if the frequency of occurrence data were interpreted in the context of these biases. Finally, it should be stressed that the use of the statistic “frequency of occurrence” may overemphasize the importance of numerically abundant small prey to sea lion diets and underestimate the energetic contribution of large prey that are consumed less frequently.

Size Distribution of Prey

The analysis and description of size of prey consumed by sea lions in BiOp3 is inadequate. This topic is treated in one paragraph on page 93 and two paragraphs on pages 184-185. No data are presented and no published reports or publications are cited. If the goal is to ensure that

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adequate prey of appropriate size and species are available to sea lions when and where they forage, then it is important to know the size of prey consumed. Sea lion prey size data have been presented in some NMFS reports and should have been presented in chapter 4 of BiOp3 where sea lion ecology is described. If for some reason these data are suspect, then the problem of estimating prey size distributions should be discussed in future biological opinions.

These size data have several important ramifications. The size of consumed prey is highly relevant to calculations of biomass of prey available to sea lions. If the fishery stock assessment models do not estimate the abundance of juvenile fish of sizes consumed by sea lions, then estimates of sea lion prey densities may be underestimated. Conversely, if the assessment models include older fish of sizes not consumed by sea lions, then prey biomass may be overestimated.

The spatial distribution of sea lion prey may depend heavily upon their life stage. For instance, immature fish may have very different spatial distributions than adults. Also, diet differences may exist between juvenile and adult sea lions. The size distribution of sea lion prey and their spatial distributions are critical to considerations of prey availability to sea lions in critical foraging areas.

Finally, considerations of prey size directly bear upon the degree of competition between foraging sea lions and fisheries. The treatment of prey-size competition on pages 184-185 of BiOp3 is largely speculative. This should be replaced with commercial-catch size distributions of species important to Steller sea lions for which there are abundant data. For species and years in which sufficient data exist, the size composition of fishery removals and sea lion prey size should be compared quantitatively. In part, potential benefits of fishery regulatory actions hinge upon whether sea lions and fisheries are competing for prey of the same sizes. If year classes of fish prey pass through the size window corresponding to sea lion foraging before entering the commercial fishery, then the basis for competition is weak provided that recruitment overfishing does not occur. In summary, ASSLRT recommends that sea lion prey size distributions and catch-size compositions should be presented in detail in future biological opinions.

Role of Diet Diversity

A stronger case for the role of diet diversity in sea lion population trends may exist than presented on page 95. Results from Merrick et al. (1995) suggest that at least two prey taxa need to be commonly available in sea lion diets for population success. Rookeries at which consumption by sea lions was dominated by gadids tended to have a greater rate of population decline than rookeries at which sea lions had a more diverse diet. BiOp3 dismisses this evidence by stating “to the extent that pollock or Atka mackerel currently dominate the prey field, sea lions survive on those prey.” Some recent work lends support to the proposed importance of diet diversity. Rosen and Trites (2000), not cited in BiOp3, found that sea lions experienced progressive metabolic depression while feeding on an unlimited pollock-only diet under

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laboratory conditions. Although extrapolations from laboratory studies to field populations must be done cautiously, ASSLRT feels that possible connections between diet diversity, Steller sea lion health, and population success deserve further consideration.

Decadal changes in sea lion diet appear to have occurred. For instance, Pitcher (1981) found capelin in 61% of sampled sea lion stomachs in the Kodiak area in 1975-1978. Subsequent studies failed to find capelin in any significant amounts in sea lion stomachs. Octopus ranked second in 1985-1986 in Kodiak. Sand lance occurred in 26% of sea lion stomachs in the Gulf of Alaska in the 1960s. Although changes in diet must be evaluated in the context of changes in sampling methods, decadal shifts in forage fish abundance are also likely to be manifested in changes in the diversity of sea lion diets.

In general, BiOp3 tends to downplay the contributions of non-exploited species to sea lion diets. About half of the species in the diet listed in Figure 4.6 of BiOp3 include species that are unfished or lightly fished, such as squid, octopus, Pacific sand lance, Irish lord, Pacific sandfish, smelt, snailfishes, rock greenling, capelin, and some species of flatfishes (see Figure 4.6 in BiOp3). Some of these species are caught in sufficient numbers to be enumerated during annual stock assessment surveys. Also, some species are subjected to bycatch mortality in some fisheries, and onboard observer data could be used to quantify the discards of these non-commercial species. We anticipate that there is little fishery impact on these non-targeted species, and factors other than fisheries are likely to regulate the abundance of these prey.

In summary, the Restoration Team does not feel that BiOp3 presents a complete and objective analysis of the potential importance of diet diversity to Steller sea lions. Future biological opinions would benefit from a more complete treatment of the importance of gadids and non-gadid prey on sea lion diets and population health, including recent publications on this topic.

Designation of Critical Habitat

Steller sea lion critical habitat is discussed in sections 3.1, 4.13, and 6.6.2 of BiOp3. BiOp3 presents the location of rookeries, haulouts and three designated aquatic foraging areas. Three critical foraging areas were defined as Shelikof Strait, Sequam Pass, and the Sea Lion Conservation Area. The locations and boundaries of these critical habitats were defined, and considerations leading to the designation of the foraging areas were listed. Here, we provide a brief review of the treatment of critical habitat in BiOp3. In another chapter of this report *(Considerations of Steller Sea Lion Critical Habitat)*, we discuss this topic in much greater depth.

Definitions of Steller sea lion critical habitat have changed significantly over time. When first specified in 1993, NMFS designated critical habitat including a zone that extends 3,000 feet landward and vertical of all Steller sea lion rookeries and major haulouts and 3,000 feet seaward for sites east of 144^{o} W and 20 nm for sites west of 144^{o} W (50 CFR Part 226). The three critical foraging areas were also included at that time. When adopting the 20-nm buffers, NMFS stated, "it is important to emphasize that in designating these extended aquatic zones, NMFS is not attempting to justify or prove that these areas, in fact, actually do need special management or special regulation, but rather that these areas may be in need of management." No management actions were involved and NMFS stated, "if and when specific management measures are proposed, it is anticipated that the proposed rule will explain the scientific basis and justification for the measures." At that time new research was initiated on sea lion foraging behavior including satellite telemetry studies and NMFS stated that "modification of critical habitat designation or specific management measures may be considered based upon this research."

In BiOp2 (released in 1998), modifications to critical habitat were made. Haulouts were defined seasonally as winter-only, summer-only, or year-round. Sites were designated as critical if, at least once since 1979, an annual count exceeded either 75 animals in winter or 200 animals in summer. Also, BiOp2 established pollock trawl exclusion zones within 10 nm of critical haulouts in the Gulf of Alaska and within 20 nm of critical haulouts in the Bering Sea and Aleutian Islands.

In BiOp3, NMFS proposed major changes in management measures associated with sea lion critical habitat designations. The primary changes included: extension of fishery exclusion zones in the Gulf of Alaska to 20 nm around rookeries and major haulouts, seasonal closures were extended to year-round, and the list of rookeries and major haulouts was modified. Unfortunately, the scientific justification for these changes, promised in 1993 (50 CFR Part 226), was not provided.

Back in 1993, in their written comments on this proposed action, the State of Alaska suggested that the 20-nm zones around rookeries and major haulouts were inappropriate because they were inadequately justified with little supportive data. ADF&G recommended that the foraging areas in coastal and offshore waters should be defined as critical habitat where they contain the appropriate environmental and biological characteristics to provide important feeding habitats for Steller sea lions.

In the opinion of ASSLRT, current critical habitat designations lack adequate justification. The ecological bases for sea lion critical habitats should be described so that mitigation of potential fishing and other (e.g., vessel transit) effects can be tailored to functional requirements of sea lions. A full analysis of satellite location and dive data should be brought to bear on sea lion critical habitat designations.

Seasonality should be considered in future evaluations of sea lion habitat requirements and considerations of needed management measures. Winter and summer haulouts should be distinguished, and it should be noted that some haulouts are used for a few months per year only. Also, the relative historical and current importance of haulouts should be documented, as some haulouts currently support very few animals. Relevant movement, telemetry, diet, and ecological data should be brought to bear on revised definitions of critical habitat, rather than the 20 nm distances around rookeries and haulouts, as currently designated. Finally, the three critical

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foraging areas should be reevaluated with historical and recent data. For instance, the foreign pollock fishery in Shelikof Strait in the 1980s was a roe-stripping fishery in which large amounts of pollock carcasses were discarded at sea. The possibility exists that those discards attracted sea lions to the area and contributed to increased sea lion bycatch and other physical interactions between fisheries and sea lions. Analyses should be undertaken in an attempt to determine the ecological bases for this critical foraging area to ensure that it is not merely an artifact of past fishing practices.

Natural Competitors

The potential for competition between sea lions and other species could have been presented more thoroughly. There is more potential for competition among Steller sea lions and other mammalian and fish predators than indicated in BiOp3. Sea lion prey such as herring, sand lance, smelt, squid, and other forage fish are heavily preyed upon by many fish and marine mammal species. For instance, Steller sea lions and harbor seals (see Hoover 1988 and papers cited therein) consume some of the same prey, and the potential for competition, particularly in coastal areas, should be considered. The Restoration Team suspects that Steller sea lions may occupy similar trophic levels as Pacific cod, Pacific halibut, and arrowtooth flounder.

Considerations of competition between Steller sea lions and other marine species should have considered diet data on other marine mammal and fish species in the Gulf of Alaska and Bering Sea and Aleutian Islands. For instance, NMFS has a large database on prey consumption by commercially important groundfish species in the Bering Sea, and there are a number of fish predation studies in the Gulf of Alaska. Rather than speculative arguments such as "to some extent, these potential competitors may partition the prey resources so that little direct competition exists" (page 100 in BiOp3), relevant diet data should be brought to bear on this subject. Although diet overlap alone does not prove competition, diet similarity provides insights into the potential for competition and prey partitioning that can be further scrutinized with additional analysis and new research.

Trends in Population Status and Health

In the section on reproduction (pages 80-82), BiOp3 summarizes information from the 1970s and 1980s that support the hypothesis that Steller sea lions had inadequate forage to support vital activities such as reproduction. This summary, though brief, is presented objectively. In fact, data from the 1970s and 1980s support the nutritional limitation hypothesis, not only through effects on reproductive success, but also through effects on mortality of juveniles and/or older animals.

However, BiOp3 fails to fairly present evidence that does not support the nutritional limitation hypothesis in the 1990s. For instance, BiOp3 mentions (page 81) one study in which pups in the declining western population of sea lions were actually larger than pups in the increasing eastern population, contrary to expectations for the endangered western stock. This result is dismissed

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with the contention that pups in the western population may be born earlier and that older age could account for the greater pup sizes in the western population. On the contrary, the state's Restoration Team noted the pups in the western population are actually born later; so western pups are truly heavier than eastern pups.

A number of comparisons were conducted in the 1990s between the declining western population and the stable and/or increasing eastern population with very interesting and important results. These studies are not "control and treatment" experiments, but rather these are comparisons of health attributes of sea lions living in different areas under different conditions. From these studies, evidence that reproduction in the western population was not compromised in the 1990s include: (1) pup birth weights are higher in the western population; (2) pup growth rates are greater in the western population; (3) pup size at 1 month old is higher in the west than east; and (4) blood chemistry studies do not indicate that pups in western population are nutritionally stressed.

Aside from considerations of reproduction, the following findings from comparative studies of the eastern and western stocks suggest that adult females from the western stock did not exhibit nutritional stress in the 1990s (see chapter titled *Synopsis of Steller Sea Lion Declines* for more details): (1) foraging effort was higher in the east compared to the west; (2) females from eastern and western populations had similar milk energy content; (3) adult females from the western population weigh more than those from the eastern population; (4) western females appeared to have more fat than eastern females, although the evidence for this is somewhat incomplete; and (5) maternal attendance and energy budgets are normal for females in the western population. Evidence that females from the western population exhibited nutritional stress in the 1990s comes from a study that indicated that the blubber layer was thinner in western females than eastern females, but this finding is somewhat preliminary. In conclusion, there is little evidence for nutritional stress for adult females and pups in the western stock during the 1990s. However, it is important to note that data are lacking for pups older than 5 weeks old, juveniles, and adult females without pups. Thus, possibility of nutritional limitation has not been fully addressed.

Given this, it is crucial to distinguish the population during the 1990s from the 1970s and 1980s in order to understand potential causes and effects of Steller sea lion abundance trends. The rate of population decline shows a marked reduction in the 1990s versus the 1970s and 1980s (Figure 4.8 in BiOp3), and it may be unlikely that one factor, or even one set of factors, is responsible for both the historical sharp decline in abundance as well as the continued lack of recovery.

Analysis of Alternative Hypotheses

Potential explanations of the causes of Steller sea lion population declines are covered in chapters 5 and 6 of BiOp3. In general, BiOp3 lacks a fair treatment of alternative hypotheses for the decline of sea lions. It would be helpful if the alternative hypotheses and mechanisms were

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clearly outlined and described. ASSLRT has attempted to draft alternative mechanisms as follows. Owing to significant changes in the 1990s compared to the 1970s and 1980s, alternative suites of potential cause and effect mechanisms can be distinguished for these two time periods, as described in the chapter of this report titled *Synopsis of Steller Sea Lion Declines.*

In analyzing alternative mechanisms, with one exception, BiOp3 appears to take an approach in which individual alternatives are considered on a one-by-one basis for their ability to solely account for all of the observed population declines. The single exception is the mechanism of localized depletion by fishing. A problem with the univariate approach is that it is probable that several factors are involved and these factors likely have changed over time. The ability of synergistic effects of different mechanisms to collectively account for population trends is not considered in BiOp3.

In BiOp3, implications of well-documented ecosystem shifts in species abundance tend to be downplayed. ASSLRT feels that scientists and others often attribute too much to the effects of the regime shift of the late 1970s, and we agree with BiOp3 that evidence for changes in carrying capacity are equivocal. Also, for the most part, we concur with BiOp3 that "the cause of continued decline of Steller sea lions is not solely a function of the regime shift" (BiOp3, page 137), but this is the answer to the wrong question: can the regime shift solely explain the decline of Steller sea lions? We strongly believe the correct question is: "is it likely that the regime shift contributed to the decline?" To this we answer: "yes."

Ecological changes, some of which were related to the regime shift, and their likely effects on Steller sea lions, are incompletely described and not evenly interpreted. As a result of strong year classes, the abundance of salmon and many groundfish stocks increased in the early 1980s. Those with sharp increases in abundance included pollock, cod, Atka mackerel, arrowtooth flounders, and other flatfish. Shrimps and some crab stocks declined. Anecdotal evidence and auxiliary data from shrimp surveys indicate that capelin and other forage fish abundances declined or shifted in geographical distribution. Changes in some species, such as herring and capelin, could have directly affected sea lion nutrition, whereas changes in others, such as cod and arrowtooth flounder, could have had indirect effects through competition. There is a richer body of literature on climate-forced ecosystem changes than those cited in BiOp3. Just a few examples of important omissions covering a spectrum of species include Brodeur et al. 1999, Francis et al. 1998, Hollowed and Wooster 1992, 1995, Mantua et al. 1997, Springer 1998, and Zheng and Kruse 2000.

BiOp3 does not consider the potential downstream impacts of these changes on sea lions through natural competition for limited prey. Given that competition exists between sea lions and other natural predators, what are the implications of climate and fishing-induced fluctuations in the abundance of those predators? For example, strong year classes of important groundfish predators appear to be highly influenced by climate-forced regime shifts. We believe it is possible, or even likely, that the abundance and availability of herring, capelin and sand lance could be regulated in part by piscivores, such as Pacific cod, arrowtooth flounder, Pacific halibut, and others whose abundance changed dramatically after the mid 1970s.

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A section beginning on page 147 is titled "aggregate mortality," but all sources of mortality are not considered in aggregate. Later in BiOp3 other mortality sources (e.g., entanglement and intentional takes) are considered individually. Approaches, such as that taken by Alverson (1992) and Loughlin and York[1], may provide a better accounting of all cumulative sources of mortality. In either case, BiOp3 should attempt to aggregate all sources of mortality and compare those deaths with the current rate of sea lion population decline. Is it possible that a combination of mortality sources could account for recent annual declines in sea lion abundance? Deaths from all mortality sources must be considered in aggregate to answer this question.

The treatment of sea lion predation by killer whales misses the fact that both analyses presented on predation rate are based on a minimum estimate of transient killer whale population size (125) and that predation rate would be higher if more killer whales do, in fact, exist. The derivation of N=125 is not presented, and it is likely that abundance of transient killer whales is substantially higher than this estimate. In any event, ASSLRT feels that more killer whale predation research is needed, including better information from the western Gulf of Alaska and Aleutian Islands. Moreover, research is needed into the prospects of Pacific sleeper and salmon shark predation on sea lions, especially on young sea lions. An apparent increase in shark abundance in Alaska in the past decade, coupled with the documentation of shark predation on harbor seals (L.B Hulbert and B. Wright, unpublished), suggests that potential shark predation studies on sea lions may be worthy of study in the context of sea lion population declines. A recent analysis of Lucas and Stobo (2000) indicates that shark predation may limit the population growth of harbor seals on Sable Island, Nova Scotia. While predation may not fully account for recent sea lion population trends, the Restoration Team feels that this source of mortality must be considered in concert with other mortality sources (e.g., entanglements, bycatch, shooting, disease) for their combined ability to explain the lack of sea lion recovery in the 1990s.

Regarding fishing, BiOp3 documents some historical cases of overfishing, such as foreign fisheries for pollock in the Aleutian Basin, Pacific ocean perch, yellowfin sole, and Pacific halibut. Although BiOp3 is fairly thorough in describing these cases, this section does not analyze what role, if any, these may have played in the historical sea lion declines. In particular, could overfishing of pollock in Aleutian Basin in the 1970s and 1980s have depleted pollock as forage for sea lions in Western Aleutians? Could overfishing of herring in the mid-20th century have caused nutritional limitation in sea lions in the 1970s and 1980s? These are instances of historical failure to apply global control rules on large-scale fisheries. Historical cases of overfishing versus the more responsible conduct of current fisheries, and their potential differential implications on sea lions, are not distinguished in BiOp3.

BiOp3 has a very short section on effects of fishing on benthic habitat on pages 242-243. Given that the majority of sea lion prey species have benthic life stages, we would have anticipated a more complete review of the effects of fishing on the seafloor in sea lion critical habitats. There

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[1] Loughlin, T.R., and A.E. York. 2001. An accounting of the sources of Steller sea lion mortality. National Marine Mammal Laboratory. Unpublished manuscript, May 2001.

have been many reviews of this topic in addition to the one cited. Worldwide, there have been many directed studies on this topic, just a few of the review papers include Auster and Langton (1999), Collie et al. (2000), Dorsey and Pederson (1998), ICES (1999), Jones (1992), and Messieh et al. (1991).

BiOp3 concludes that the groundfish fisheries in the Gulf of Alaska and Bering Sea and Aleutian Islands areas are likely to jeopardize the continued existence of the western population of Steller sea lions. The Restoration Team acknowledges that fishing could have some adverse effects on sea lions and that it is simply impossible to prove otherwise. Therefore, precaution is warranted on behalf of the Steller sea lion. However, BiOp3's conclusions are not the result of an objective scientific analysis, but rationalized by a series of speculative arguments. Unlike the other alternative mechanisms, fishing is not examined for its ability to solely explain the declines of Steller sea lions. BiOp3 could have provided a more comprehensive and objective analysis of the evidence both for and against the localized depletion hypothesis.

Some evidence presented is consistent with a hypothesis that fisheries compete with sea lions for prey through a mechanism of localized depletion. The strongest evidence is the portion of the decline that is consistent with a large increase in the catch of walleye pollock, Pacific cod, and Atka mackerel in critical habitat in the early 1980s. The predominance of these three species in the diet of Steller sea lions is also consistent with this hypothesis. In a previous environmental assessment, NMFS presented some evidence of localized depletion in the Atka mackerel fishery in the late 1990s, however this information was not presented in BiOp3. This evidence should be discussed, along with the limitations of that study.

BiOp3 fails, however, to present evidence that is inconsistent with the localized depletion hypothesis. A large increase in biomass of cod, pollock, and Atka mackerel in the late 1970s and early 1980s failed to reverse a chronic decline in sea lion abundance. The gadid increase resulted from strong year classes. These strong year classes should have greatly increased in the availability of juvenile gadids to Steller sea lions by increasing the number and density of fish schools. Moreover, the frequency of occurrence of gadids in the diet of the western population sea lions doubled from the 1950s-1970s to the 1980s according to Figure 4.5 in BiOp3. This increase in consumption of gadids by sea lions is not consistent with a hypothesis that sea lions had difficulty finding gadid prey owing to localized depletion.

Analysis of a localized depletion hypothesis should consider the sizes of fish consumed by sea lions and the sizes of fish removed by fishing. Steller sea lions generally consume smaller fish than those caught by commercial fisheries. For instance, as reported by NMFS elsewhere, in 1981 the mean size of pollock in the Bering Sea fishery was 33.7 cm, and the mean size of pollock consumed by Steller sea lions was 27.1 cm. Most pollock consumed by juvenile sea lions are smaller than 30 cm (Merrick and Calkins 1996).

Some preliminary findings from some recent and ongoing studies are not consistent with a localized depletion hypothesis. For instance, one study of prey availability near a large, stable

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rookery in Southeast Alaska and a declining rookery in the Aleutian Islands found that juvenile groundfish prey abundance was 11 times greater in the Aleutian Islands than in Southeast Alaska (Andrews et al.[2]). Sea lions from the western stock spent less time foraging at sea for prey, consistent with the greater localized abundance of groundfish prey, but inconsistent with a hypothesis that the western stock was experiencing nutritional limitation.

A counter hypothesis to the localized depletion hypothesis, consistent with the notion that fish form schools for protection against predation, would posit that holes in the prey field are beneficial to predators. Some predators forage at the edges of prey aggregations, so mechanisms leading to more edges may lead to greater opportunity for predation.

Cumulative Effects

BiOp3 includes a cumulative effects section that analyzes other direct and indirect effects, including effects of fisheries managed by the State of Alaska. The treatment of state-managed fisheries is cursory. Parts of this section, including some figures, were plagiarized verbatim from a state report (Kruse et al. 2000) without citation. This text is occasionally interjected with unsubstantiated conclusions by NMFS about the effects of state-managed fisheries without supportive documentation and analysis. As an example, in chapter 10 of BiOp3 it is stated that state salmon fisheries "are likely to affect Steller sea lions." However, the incomplete analysis of state fisheries in section 7.2.1 does not analyze nor discuss salmon fisheries. Unfortunately, many of BiOp3's conclusions, such as this, are not the result of an objective analysis of available information. Substantial analysis of existing data on the spatial and temporal distributions of all state fisheries was prepared by Kruse et al. (2000) and could have been brought to bear on the analysis of cumulative effects of fishing in BiOp3. Similar levels of spatiotemporal detail would have been useful for the federally managed fisheries, as well.

Reasonable and Prudent Alternative

The Restoration Team offered substantial comments on fishery management measures, experimental designs, and other actions associated with the Reasonable and Prudent Alternative. These comments were presented in ASSLRT meeting minutes and elsewhere in this report such as in the chapter titled *Protective, Adaptive, And Experimental Management Recommendations.*

[2] Andrews, R., D. Calkins, R. Davis, T., Loughlin, B. Norcross, K. Peijnenberg, and A. Trites. 1999. A comparison of the foraging ecology of Steller sea lions from declining and stable populations. Thirteenth Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii, November 28 – December 3, 1999. Abstract, unpublished.

Appendix A.2. Overview of recent and ongoing research on Steller sea lions.

Foreword

The following excerpts have been condensed from graduate theses, manuscripts in various stages of publication, abstracts from conference presentations and project overviews or proposals that have been made available to ASSLRT. The intended purpose of this document is to provide a synopsis of recent, and predominantly unpublished research that would not have been previously available for inclusion in the NMFS November 2000 Biological Opinion. Much of this work is still in progress, and undoubtedly others have been overlooked. Nevertheless, this summary should provide a useful overview of recent areas of sea lion research.

Population Dynamics

1. COUNTING STELLER SEA LION PUPS IN ALASKA: AN EVALUATION OF MEDIUM-FORMAT, COLOR AERIAL PHOTOGRAPHY. 2001. Gary Snyder, Kenneth Pitcher, Wayne Perryman, and Morgan Lynn. Marine Mammal Science 17:136-146.

Abstract: Estimates of Steller sea lion (*Eumetopias jubatus*) pup production are valuable for estimating population trend and size. Currently in Alaska, pups are counted by visiting rookeries, driving older animals into the water, then walking through the rookeries and counting the pups, a highly disruptive procedure. At smaller rookeries, with good vantage points, pups are occasionally counted from the periphery of rookeries without disturbing the sea lions. We evaluated counts made from medium-format, color, aerial photographs as an alternative to drive counts and peripheral counts. Neither the peripheral counts nor the aerial photographic counts disturbed animals on the rookeries. There were strong 1:1 linear relationships between photographic counts and drive counts ($r^2 = 0.966$, $P < 0.001$) and between photographic counts and peripheral counts ($r^2 = 0.999$, $P < 0.001$). Precision was similar for all three methods of counting. We suggest medium-format, color, aerial photography is appropriate for routine surveys of Steller sea lion pups in Alaska because it is not disruptive to the hauled-out sea lions and provides comparable estimates with similar precision to drive and peripheral counts. Large areas can be rapidly surveyed during periods of good weather with a minimum of manpower.

2. SPATIAL AND TEMPORAL VARIATION IN THE TIMING OF BIRTHS OF STELLER SEA LIONS. In press. Kenneth Pitcher, Vladimir Burkanov, Donald Calkins, Burney Le Boeuf, Evgeny Mamaev, Richard Merrick, and Grey Pendleton. Journal of Mammalogy. 82(4): 000-000.

Abstract: Throughout the range of the Steller sea lion (*Eumetopias jubatus*), nearly all births of full-term pups observed from 1968 to 1998 occurred between 15 May and 15 July. We found significant differences in timing of births between rookeries with the earliest mean date of birth (4 June) at Forrester Island, Alaska and the latest (21 June) at Año Nuevo Island, California. Mean date of birth becomes progressively later both north and south of Forrester Island. Births

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at individual rookeries were synchronous, with 90% of pups born within a 25-day period. We hypothesize that the timing of births at rookeries is determined through selection for time periods when weather conditions are generally favorable for pup survival and when adequate prey items are predictably available near rookeries for lactating females. Temporal differences also were found in mean date of birth at four rookeries with a maximum difference between earliest and latest mean dates of birth of 10.2 days at Año Nuevo Island. The most likely explanation for temporal variability at individual rookeries is variable nutritional status of reproductive females.

3. INSIGHTS INTO DISPERSAL, ROOKERY FIDELITY, AND METAPOPULATION STRUCTURE OF STELLER SEA LIONS (*EUMETOPIAS JUBATUS*) IN AN INCREASING AND DECREASING POPULATION IN ALASKA. Kim Raum-Suryan, Kenneth Pitcher, John Sease, Thomas Loughlin, and Donald Calkins. Manuscript accepted for publication (with minor revisions pending) by Marine Mammal Science.

Abstract: Over the past 24 years, 8595 Steller sea lion (*Eumetopias jubatus*) pups were branded on their natal rookeries throughout Alaska with the objectives of determining survival rates, recruitment, movements, and site fidelity. Our objectives here were to examine the extent of dispersal of Steller sea lions away from their natal rookeries, movements within metapopulations and between stocks, and degree of natal rookery fidelity. Results indicated that branded juveniles were resighted at distances up to 1784 km from their natal rookeries, although as they approached adulthood, they generally remained within 500 km of their natal rookeries. No interchange of breeding animals between the eastern stock (ES) and western stock (WS) was observed. Steller sea lions generally conformed to the metapopulation concept of individuals dispersing among habitat patches *(i.e.* rookeries) within their respective stocks. Although natal rookery fidelity was prevalent, 33% of females branded in the WS during 1987-1988 and 19% of females branded in the ES during 1994-1995 were observed with newly born pups at sites other than their natal rookeries. Females in the WS may select new breeding sites for different reasons than females in the ES. Future marking studies will focus on estimation of vital parameters.

4. ESTIMATING THE FREQUENCY OF CATASTROPIC EVENTS: EXAMPLES FROM POPULATIONS OF OTARIIDS. 1999. Leah Gerber and Ray Hilborn. Abstract. 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii, Nov. 28 – Dec. 3, 1999. P. 66.

Abstract: One key factor influencing a population's risk of extinction is the frequency of catastrophic events. To formally incorporate data on catastrophes into analyses of species persistence we must specify how frequently they occur and how much of the population declines as a result. These numbers can be estimated based on the historical record for related species. We examined the literature on population dynamics of otariids to determine how frequently populations are subjected to catastrophic population declines, and to what extent depleted populations recovered from low population size. Using abundance data for 22 populations of otariids, we used a simple logistic model to compute the likelihood profile for frequency and

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intensity of catastrophes. Three general types of data were considered; (1) continuous counts; (2) discontinuous counts, (3) no counts, but reports. We found 8 examples of events leading to a population decline of 50% or greater among otariids and estimated that the frequency of such events is approximately 1 in 100 years. We show how these estimates of frequency and intensity of catastrophe may be used in analyses of extinction risk of the Hooker's sea lion.

5. RISK ANALYSIS AND USE OF STOCHASTIC POPULATION MODELS FOR DETERMINING ENDANGERED SPECIES ACT STATUS OF NORTH PACIFIC MARINE MAMMALS. 1998. Leah Gerber. Ph.D. thesis. University of Washington, Seattle, WA.

Thesis excerpts: The Endangered Species Act (ESA) mandates that Recovery Plans include specific criteria to determine when a species should be removed from the List of Endangered and Threatened Wildlife. To meet this mandate, I develop several approaches to determine listing and recovery criteria for marine mammals. First, I review the history of marine mammal extinctions, introduce the current approach and associated problems for ESA listing and recovery decisions, describe the existing tools for using biological information for such decisions, and review the currently existing Recovery Plans for marine mammals. This sets the stage for three case studies (Steller sea lions, humpback whales, gray whales) in which I provide quantitatively robust and practical tools to classify marine mammals under the ESA. In my first case study, the World Conservation Union (IUCN) classification scheme is applied to the western population of Steller sea lions to classify the population pursuant to the ESA. Three distinct Population Viability Analysis (PVA) models are developed and results of all models meet the classification criteria for vulnerable. These models were compared to a third, a metapopulation model, which encompassed three different geographic scales (York et al. 1996). Models varied in spatial structure, in whether density dependence was incorporated, and in the type and method of stochasticity incorporated (see Table 7). If assumptions were standardized to the maximum extent possible, estimates of median time to extinction did not differ significantly. Median times to extinction were 86, 85, 83, and 99 years, respectively, for the demographic, ALEX and York et al. (1996) aggregate and cluster models. If the first and third quartile times to extinction were considered, however, results were not so similar, particularly when comparing the York et al. (1996) models with the demographic and ALEX models. In general, the probabilities of extinction for the York et al. (1996) models were smaller initially but increased more rapidly than the other models. Clearly, the primary shortcoming of all approaches is the lack of data on density dependent mechanisms for Steller sea lions, and the lack of data on both the rate at which catastrophic events might occur and the consequences of such events. Results of all three models meet the classification criteria for vulnerable as defined by the IUCN. Under no circumstances did the probability of extinction within 20 years exceed 20%, and all models indicated that within 100 years the species had at least a 10% probability of extinction. This represents a case study where the results of different models were surprisingly consistent. If one accepts the results of these models and the classification criteria suggested by the IUCN, PVA is a reliable tool for risk classification of Steller sea lions.

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6. IMPLICATIONS OF THREE VIABILITY MODELS FOR THE CONSERVATION STATUS OF THE WESTERN POPULATION OF STELLER SEA LIONS (*EUMETOPIAS JUBATUS*). In press. Leah Gerber and Glenn VanBlaricom. Biological Conservation.

Abstract: Two distinct viability models are developed for Steller sea lions *(Eumetopias jubatus)* to evaluate the sensitivity of extinction risk to various levels of stochasticity, spatial scale and density dependence. These models include a metapopulation model, Analysis of the Likelihood of Extinction (ALEX; Possingham et al., 1992; Possingham, H., Davies, I.A., Noble, I. 1992. ALEX 2.2 Operation Manual. Department of Applied Mathematics, University of Adelaide, Adelaide, SA 5005; Australia.),and a model that incorporates both sampling and process error in estimating population parameters from time series data (Gerber and DeMaster, 1999; Gerber, L.R., DeMaster, D.P. 1999. An approach to endangered species act classification of long-lived vertebrates: a case study of north Pacific humpback whales. Conservation Biology 13 (5):1203 – 1214.). Results are compared with a third model that encompasses three different geographic scales (York et al., 1996; York, A.E., Merrick, R.L., Loughlin, T.R. 1996. An analysis of the Steller Sea lion metapopulation in Alaska. In: McCullough, D.R. (Ed.), Metapopulations and Wildlife Conservation. Island Press, Covelo, CA, pp. 259 –292). The combination of modeling approaches provides a basis for considering how model parameterization and the selection of classification criteria affect both model results and potential status determinations. Results from the models generally agree with regard to central tendency, 25th and 75th percentile times to extinction. For Steller sea lions, the distributions of time to extinction for each model were narrower than the range of extinction distributions between models. If this finding applies generally to listed species, it would suggest that more than one viability model should be considered when listing decisions are made. On a more applied basis, the results of our analysis provide a quantitative assessment of extinction risk of Steller sea lions in the context of its status pursuant to the US Endangered Species Act.

7. COMPARISON OF THE REPRODUCTIVE BEHAVIOR OF STELLER SEA LIONS AT THREE SITES. 1998. Kathryn Ono, Tom Loughlin, and Richard Merrick. Abstract. The World Marine Mammal Science Conference. Monaco, Jan. 20-24, 1998. P. 99.

Abstract: Steller sea lions have recently been classified as “endangered” in a large portion of their range due to the continuing precipitous decline in the overall population. The comparative method was used to study Steller sea lions (*Eumetopias jubatus*) for three consecutive breeding seasons (1993 – 1995 and 1996 on Lowrie Island only) at two areas of population decline (Marmot Island, AK (MAR) and AZo Nuevo Island, CA (ANI)) and at one site where the population is relatively stable (Lowrie Island, AK (LOW)). The multi-year study allowed us to look at variation between years as well as between sites. An initial analysis compared the daily presence or absence of individually recognizable females between the declining and stable sites. Using an ANOVA with site and year as the independent variables, we found that there was a significant effect of study site on the mean period of absence for females with pups. Females at ANI had longer periods of absence than those at LOW. We found no differences in the periods of

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absence for females between the two Alaska sites. The overall ANOVA for periods of presence on the study areas was also significant. However, this was driven by strong interactions between sites and years; there were no consistent differences between sites. Seventeen percent of the females at LOW and MAR took very short feeding trips of less than one day throughout the period of observations (i.e., they were seen part of every day of the study), indicating that feeding sites relatively close to the breeding sites may have been used.

8. INFLUENCES OF THE THERMAL ENVIRONMENT ON STELLER SEA LION (*Eumetopias jubatus*) BEHAVIOR. 1999. Kathryn Ono, Tom Loughlin, Ruth Bolster, and Richard Merrick. Abstract. 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii, Nov. 28 – Dec. 3, 1999. P. 140.

Abstract Excerpt: This analysis concerned the proximal effects of temperature and weather on terrestrial behavior during the breeding season. We observed Steller sea lions between the years 1993 and 1998 concurrently on three different islands (Lowrie Island (LOW), Marmot Island (MAR) and AЗo Nuevo Island (ANI)). Air temperature was significantly different between islands and years with ANI having the highest, and MAR having the lowest temperatures. Substrate temperature was highest on ANI and lowest on LOW. There were also significant differences between sites and years in wind speed and weather. Behavior related to heat conservation (tucking flippers under the body, lying in contact with others) and heat dissipation (foreflipper waving, entering the water) also varied significantly between islands and years. Adult females, pups of the year, and territorial males spent more time with their flippers tucked in cooler weather and on MAR compared to other islands. The number of females in contact with one another was negatively correlated with substrate temperature. Foreflipper waving and entering the water were positively correlated with air and substrate temperatures in all three age/sex classes, and more frequent on ANI. In conclusion, although thermal constraints are not likely the major cause of decline in this species, the increased energy demand of thermoregulatory behaviors could certainly be a contributing factor to declines in already stressed populations.

9. ATTENDANCE PATTERNS OF STELLER SEA LIONS *(EUMETOPIAS JUBATU*S) AND THEIR YOUNG DURING WINTER. In press. Andrew Trites and Boyd Porter. Journal of Zoology, London 0:000-000.

Abstract: Winter attendance patterns of lactating Steller sea lions *(Eumetopias jubatu*s) and their offspring were recorded during the late stages of nursing when the young were expected to move from milk to independent foraging. Trip duration and nursing visits to shore by 24 mothers with pups (7-9 months old) and 6 mothers with yearlings (19-21 months old) were noted during 600 hours of behavioral observations (from January 22 to April 1, 1996) at a non-breeding haulout site in southeastern Alaska. Pups and yearlings tended to stay on or near the haulout while their mothers were away and showed no signs of weaning during winter. Their average trips to sea were 43% shorter in duration than those of lactating females, suggesting that pups and yearlings

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make independent trips away from the haulout while their mothers forage. The winter attendance cycle of lactating females (consisting of one trip to sea and one visit on land) averaged about 3 days, with the mothers of pups spending an average of 15 hours of this time onshore with their offspring. The winter attendance cycle of pups and yearlings averaged just over 2 days, with the immature sea lions spending an average of 22 hours on shore. Foraging trips by mothers of yearlings were significantly longer than those by mothers of pups. However, there was no significant difference in the foraging times of mothers of male and female pups. Lactating females spent more time at sea during winter than during summer. The probability of sighting an individual on the winter haulout during daylight hours was 15% for lactating females and 40% for immature animals.

10. LONG-TERM MONITORING OF THE STELLER SEA LION ROOKERY ON CHISWELL ISLAND USING REMOTE CONTROLLED CAMERAS. Unpublished report for 1998-99. Vladimir Burkanov and Donald Calkins. Project in progress.

Project Outline - Video cameras have been placed at a Steller sea lion haulout near the entrance to Resurrection Bay. The video signal is continuously transmitted through a microwave transmitter to the receiver station at the Alaska SeaLife Center. Two cameras are available for the researchers, providing real-time alternate views of wild Steller sea lions when they are on land at this location. The signal is available to several researchers on video monitors and on the local area network. The incoming signal is continuously recorded on VHS format videotape. The total numbers of animals using this haulout will be monitored on a daily basis. Behavioral studies will be conducted throughout the year by observing individually recognizable animals. Monitoring will occur continuously to help understand the bond between mother and pup pairs, use of haulouts, and movements of animals.

11. DETERMINING SURVIVAL & LONG-TERM FORAGING BEHAVIOR IN JUVENILE STELLER SEA LIONS THROUGH IMPLANTED, SATELLITE-LINKED MORTALITY TRANSMITTERS. Markus Horning, Don Calkins, Ken Pitcher, and Tom Loughlin. In progress.

Proposal Abstract Excerpt: Despite years of productive research, little is known about the extent to which a hypothesized reduction in juvenile survival--in turn possibly related to reduced prey abundance--contributes to the present population trends. We will accurately measure survival rates in juvenile Steller sea lions at two locations of a declining population, along the Aleutian Islands and in the Gulf of Alaska. For the first time, our approach will also deliver longitudinal dive effort data spanning several years, as well as detailed dive behavior data from non-surviving sea lions, and thus from the very animals that presumably contribute most to the population decline. Survival rates and long-term dive effort data will be determined through the use of satellite-linked mortality transmitters, implanted into 60 free-ranging young-of-the-year Steller sea lions. As a central part of our project, we will directly test the hypothesized reduction in juvenile Steller sea lion survival. Our experimental design utilizes a previously impossible direct

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comparison between survivors and non-survivors. We will analyze the relationship between early body mass and condition, health, as well as pollution indicators, near-weaning dive behavior and performance, continued long-term foraging effort and the survival of individual juvenile Steller sea lions. The analysis of seasonal, interannual and ontogenetic changes and variability in dive effort and mortality, as well as of detailed dive effort prior to death, will allow us to assess the relative effects of reduced foraging efficiency, nutritional stress, and possibly predation on survival. Furthermore, we will assess the extent to which juvenile survival can be predicted by parameters that can be measured in young Steller sea lions prior to weaning. Such a predictive analysis might become a powerful tool in the assessment of future population trends before they become obvious at the population level. Our cooperative project--which integrates interdisciplinary research on population dynamics, foraging ecology, physiology, health, and contaminants – directly addresses key issues and implements specific recommendations of the Bering Sea Ecosystem Research Plan Draft, the Steller Sea Lion Recovery Plan, several workshops on Steller sea lion issues, as well as NPMR. These diverse plans identify needs on Steller sea lion research, highlighting long-term longitudinal monitoring and juvenile survival as two of the most central and pressing issues.

Ecosystem Interactions, Fisheries Effects, and Predator-prey Relationships

12. UNIVERSITY OF ALASKA'S GULF APEX PREDATOR STUDY (GAP) - Kate Wynne, Robert Foy, Loren Buck, Brenda Norcross, and Susan Hills. In progress.

Overview Excerpts: The primary goal of the program is to assess the degree of dietary overlap among Kodiak's sympatric apex predators while exploring processes that drive populations of their prey within a dynamic marine environment. Integration of distinct, but related, hypothesis-driven research projects overlap spatially and temporally allowing synchronous collection of predator and prey data and synoptic assessment of their seasonal interactions. The backbone of the GAP studies is an annual series of seasonal surveys of fish presence and distribution within sea lion critical habitat, initially centered within a 20 nm radius of the Steller sea lion haulout on Long Island, AK. These seasonal fish surveys are designed to (1) assess species available as prey to piscivorous predators within the area, (2) monitor oceanographic conditions associated with species presence (temperature, salinity, zooplankton), (3) assess the condition and nutritional content of fish species, and (4) collect samples for analysis of predatory fish diets. Associated GAP studies will address seasonal diets and distribution of apex predators that share this prey base. Due to the critical and immediate need for such data, the focus originated on documenting the seasonal distribution and diet of Steller sea lions in Kodiak waters, including the Long Island critical habitat area. GAP will attempt to assess the roles of apex predators that inhabit Kodiak waters, and incorporate results into a model of upper trophic-level consumption and energy budgets that will ultimately include humans (commercial, sport and subsistence fisheries). Results will help elucidate the role and relative significance of human predation (harvests) in the system and identify seasonal and inter-annual patterns and changes in prey use.

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13. A BIOENERGETICS MODEL FOR ESTIMATING THE FOOD REQUIREMENTS OF STELLER SEA LIONS *(EUMETOPIAS JUBATU*S) IN ALASKA. In press. Arliss Winship, Andrew Trites, and David Rosen. Marine Ecology Progress Series 0:000-000.

Abstract: A generalized bioenergetic model was used to estimate the food requirements of Steller sea lions *(Eumetopias jubatu*s) in Alaska. Inputs included age-and sex-specific energy requirements by date, population size and composition, and diet composition and energy content. Error in model predictions was calculated using uncertainty in parameter values and Monte Carlo simulation methods. Our model suggests that energy requirements of individuals were generally lowest in the summer breeding season (June – August) and highest in the winter (December – February) and spring (March – May) mainly due to changes in activity budgets. Predicted relative daily food requirements were highest for young animals (12 ± 3% S.D. and 13 ± 3% of body mass for 1 year old males and females respectively) and decreased with age (5 ± 1% and 6 ± 1% of body mass for 14 year old males and 22 year old females respectively). The mean daily food requirement of pregnant females predicted by the model was only marginally greater than the predicted mean daily food requirement of non-pregnant females of the same age. However, the model suggested that the mean daily food requirement of females nursing pups was about 70% greater than females of the same age without pups. Of the 3 sets of model parameters (diet, population, and bioenergetic), uncertainty in diet and bioenergetic parameters resulted in the largest variation in model predictions. The model provides both a quantitative estimate of the Steller sea lion population's food requirements and direction for future research.

14. COD POT BEFORE/AFTER STUDY. Peter Munro and Elizabeth Conners. Draft study proposal. Since the proposal was drafted, NMFS implemented a pilot study. Contact NMFS for details on the study that has been implemented, and future research plans.

Project Description: The purpose of this study is to provide a quantitative test of the localized depletion theory – i.e., do removals of prey by commercial fisheries reduce the abundance/availability of prey at local scales? This study specifically addresses the need to construct studies associated with commercial fishing that characterize the prey field before, during, and after fishing. The plan is to select a small group of study sites, including sites, where heavy fishing pressure is expected, and similar sites where commercial harvest is prohibited. Possible locations include "cod alley" north of Unimak Pass, the eastside of Kodiak, the western GOA around the Shumagin Islands, or among the eastern Aleutian Islands. Fishing/no fishing sites do not need to be paired, but do need to represent areas of similar depth, habitat, current, etc. For example, sites could be selected in similar habitat on either side of an RPA boundary. Each site will be surveyed using pot gear like that used commercially for Pacific cod. The average CPUE (weight/pot) will be estimated over a number of pot sets at each site. Pot gear is proposed because its catch variability is less than trawl samples and it is known to be effective for Pacific cod. Each site will be surveyed immediately before the opening of the season and after 2-3 weeks of commercial fishing. For each site, a difference in mean CPUE between the "before" and "after" surveys will be calculated. Changes in catch at unfished sites will be used

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as controls against changes due to climate, seasonality, etc. Since Pacific cod are most important in the Steller sea lion diet during the winter season, the experiment is planned for winter 2003, with feasibility and design work to be carried out in summer/fall 2001 and a pilot study in winter 2002. The winter pilot study will be used to check on the actual variability of catch under target conditions and determine necessary sample size for the full experiment.

15. EFFICACY OF TRAWL FISHERY EXCLUSION ZONES IN MAINTAINING PREY AVAILABILITY FOR STELLER SEA LIONS: DESCRIPTION OF ATKA MACKEREL TAGGING PROJECT IN SEGUAM PASS, ALEUTIAN ISLANDS, AK, IN 1999 AND 2000. Lowell W. Fritz, Susanne F. McDermott, and Sandra A. Lowe. Unpublished draft report. Contact NMFS for details on the current status of the report.

Abstract: Atka mackerel is the principal prey species for the endangered Steller sea lion and the target species for commercial fisheries in the Aleutian Islands. The objective of this project is to determine the impact of fishing on localized abundances and distributions of Atka mackerel inside and outside of trawl exclusion zones around Steller sea lion terrestrial habitats (haulouts or rookeries). A pilot tagging project was conducted in August 1999, during which 2,340 Atka mackerel were tagged with spaghetti tags and released in the Seguam Pass area of the Aleutian Islands. Another tagging cruise was conducted in July-August 2000 during which 8,773 Atka mackerel were tagged and released in a more systematic manner in the same area. Through December 2000, 78 tagged fish released in 1999 and 104 tagged fish released in 2000 were recovered. Recovery effort in both years was supplied by the fishery in the open area outside the trawl exclusion zone, but supplemented by a chartered recovery cruise in the closed area in 2000. Preliminary results suggest that there was little or no movement of Atka mackerel between areas inside and outside the trawl exclusion zone within 40 days after release in late July-mid August. By 64 days after release, however, a small proportion of fish moved between areas, particularly from outside to inside the trawl exclusion zone.

16. THE EFFECT OF COMMERCIAL FISHING ON WALLEYE POLLOCK DISTRIBUTION AND ABUNDANCE. Anne B. Hollowed, Chris Wilson, Michiyo Shima, and Paul Walline. Unpublished report. Contact NMFS for details on the current status of the report.

Summary: NMFS plans a multi-year research program to examine the spatiotemporal characteristics of prey aggregations of pollock before, during, and after a commercial fishing season. This effort was initiated in 2000 with a feasibility study described here. The main focus of the 2000 feasibility study was to monitor potential changes in average depth and spatial distributions of the fish aggregations, as well as changes in biomass and abundance. The experimental design called for two adjacent sites with similar topographical features that could be assigned as treatment (where commercial fishing activities are allowed) and control (where commercial fishing is prohibited) areas. The feasibility study was conducted during 9-19 August 2000 off the east side of Kodiak Island in the absence of a fishery. Barnabas gully was selected as the treatment site and Chiniak gully the control site. An EIT survey of the control and

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treatment sites was conducted during daylight hours (about 15 hours/day in August) along a series of uniformly spaced (3 nm) parallel transects to describe patterns in the distribution and abundance of the dominant fish scatterers. Trawls were conducted during all EIT surveys to identify the species composition of selected echo sign and collect biological samples needed to estimate abundance and distribution patterns. A total of 1,113 nm of track line was surveyed in Barnabas (average 313 nm/pass) and Chiniak (average 244 nm/pass) during the two passes. One important difference between the two gullies is the apparent absence of age-1 fish in Barnabas gully. Age-1 pollock were present in Chiniak in numbers comparable to adult pollock. Juvenile pollock in Chiniak were shallower and distributed over a wider range (20-120 m) than were the adults. Adult pollock were about twice as abundant in Barnabas gully compared to Chiniak. Adult pollock vertical distribution differed only slightly between the 2 passes in Barnabas and Chiniak gullies. Neither gully exhibited significant change in adult pollock biomass estimates during the study. In summary, our feasibility study results suggest that the similarities between the two gullies make them appropriate as treatment and control sites. The study can therefore be focused on the effects of commercial fishing activity on adult pollock distribution. The experimental design based on treatment and control sites will increase the ability to distinguish between differences in abundance and distribution patterns of pollock due to commercial fishing activity and natural variability.

17. CONSIDERATIONS IN THE ANALYSIS OF ACOUSTIC-BUOY DATA TO INVESTIGATE FISH AVOIDANCE. Chris Wilson. In progress. Contact NMFS for current status.

Abstract: Acoustic data were collected with a free-drifting acoustic buoy containing an echosounder operating at 38 kHz to investigate fish avoidance reactions to vessel noise. Field experiments with the buoy were conducted on walleye pollock *(Theragra chalcogramma)* in the Gulf of Alaska during March 1998 and in the Bering Sea during August 1999. Work with the buoy was also conducted on Pacific hake (*Merluccius productus)* off the west coast of the United States during July-August 1998. The purpose of the fieldwork was to investigate whether these species exhibited behavioral responses to the research survey vessel, *R/V Miller Freeman,* when it was free running at the standard survey vessel speed of 11-12 knots. The vessel made repeated passes by the buoy during each buoy deployment. Each pass began (and ended) about 2 km away from the buoy and passed within about 5-10 m of the buoy (i.e., CPA; closest point of approach). The analysis of the data is currently in progress. Preliminary results suggest that neither walleye pollock nor Pacific hake exhibited strong, consistent avoidance responses to the vessel noise.

The work with the buoy in the Bering Sea included efforts to determine whether walleye pollock exhibited a consistent avoidance reaction during free-running passes by the buoy with a large, relatively “noisy” factory-trawler vessel. These results facilitated interpretation of the earlier results for the *R/V Miller Freeman*. An analytical procedure called superposed epoch analysis (Prager and Hoenig 1989, Trans. Amer. Fish. Soc: 118: 608-618; Prager and Hoening 1992,

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Trans. Amer. Fish. Soc: 121:123-131) was used to determine whether significant trends occurred in the buoy nautical area scattering coefficient (s_A) estimates. Superposed epoch analysis (SEA) is a nonparametric technique for conducting significance tests of association in autocorrelated time series. Time-series of the buoy data were created by appending all buoy passes together within a given deployment. The SEA tests were performed to determine whether significant associations occurred between particularly low s_A estimates, and the CPA times between the buoy and vessel during a deployment. Results of the epoch analysis tests were highly dependent on the width of the window that was used to define the CPA portion (and non-CPA portion) of the buoy time series.

18. SPECIES COMPOSITION AND ABUNDANCE OF JUVENILE GROUNDFISHES AROUND STELLER SEA LION *EUMETOPIAS JUBATUS* ROOKERIES IN THE GULF OF ALASKA. 2000. Franz Mueter and Brenda Norcross. Alaska Fishery Research Bulletin 7: 32–43. Copies available from: http://www.state.ak.us/adfg/adfghome.htm .

Abstract: We conducted bottom trawl surveys to determine species composition and abundance of juvenile groundfish communities around 6 Steller sea lion rookeries in the western Gulf of Alaska from 1994 to 1996. Overall, the most abundant species in our collections were rock sole *Pleuronectes bilineatus*, walleye pollock *Theragra chalcogramma*, Pacific halibut *Hippoglossus stenolepis*, northern sculpin *Icelinus borealis*, *Triglops* spp., *Gymnocanthus* spp., Pacific cod *Gadus macrocephalus*, slim sculpin *Radulinus asprellus*, and arrowtooth flounder *Atheresthes stomias*. Our results showed significant differences in species composition among rookeries within each of 3 depth strata and a greater abundance of juvenile groundfishes in the western part of the study area. Gadid and flatfish species were more abundant and had a higher probability of occurrence in the vicinity of sea lion rookeries on Akun, Ugamak, Atkins, and Chowiet Islands, compared to rookeries on Marmot and Sugarloaf Islands. The observed differences in species composition coincided with differences in topography, substrate composition, temperature, and salinity. A potential relationship between the abundance of juvenile groundfishes and sea lion survival is discussed.

19. EFFECTS OF CLIMATE VARIABILITY AND FISH SIZE ON STELLER SEA LION DECLINE IN THE BERING SEA. Michael Palmer and Brenda Norcoss. In progress.

Abstract: We propose to test the hypothesis that climate variability has contributed to the decline of the western stock of Steller sea lions (SSLs) in the Bering Sea through a retrospective analysis. Testing this hypothesis requires several intermediate steps examining physical and biological oceanography. Variations in climate control two physical variables, sea ice extent and temperature at the time of the spring bloom. We hypothesize that the extent of sea ice-coverage determines the area of the Bering Sea shelf receiving phytodetrital input of both the under-ice ice-algae bloom as well as the ice-edge bloom. The amount of phytodetrital material reaching the benthos from the traditional spring bloom is a function of the zooplankton-grazing rate. As zooplankton grazing is metabolically limited by temperature, we expect the sea surface

temperature at the time of the spring bloom to provide an accurate proxy for comparing interannual variability of benthic phytodetrital material delivery from the spring bloom. We further hypothesize that variations in sea ice extent and temperature at the time of the spring bloom affect benthic-pelagic coupling in the eastern Bering Sea, and thus regulate growth rates of fish species on which Steller sea lions feed.

We expect fish response to depend upon their feeding behavior. Those that feed in the water column should respond negatively to tight benthic-pelagic coupling. While do bottom-feeding demersal fish should respond positively. Therefore we further hypothesize that these differences will result in different amounts and types of food available to SSLs. Though SSLs are known to feed on fish that feed both in the water column (herring, pollock, capelin) and on the bottom (flatfishes), a greater proportion of their diet comes from water-column feeding species. We expect that the years of weak benthic-pelagic coupling and tight phytoplankton-zooplankton coupling will produce more fishes on which SSLs prefer to feed. Our empirical comparisons of fish and SSLs will serve as proxy estimates of the effect of climate variability on SSLs, and thus of the potential of climate variability as one cause of the decline of the western stock of Steller sea lions.

Foraging Ecology and Diving Behavior

20. CLASSIFYING PREY HARD PART STRUCTURES RECOVERED FROM FECAL REMAINS OF CAPTIVE STELLER SEA LIONS *(EUMETOPIAS JUBATU*S). In press. Paul Cottrell and Andrew Trites. Marine Mammal Science 0:000-000.

Abstract: Feces were collected from six Steller sea lions *(Eumetopias jubatu*s) that consumed known amounts of Atka mackerel *(Pleurogrammus monopteryiu*s), Pacific herring *(Clupea harengu*s), pink salmon *(Oncorhynchus gorbusch*a), walleye pollock *(Theragra chalcogramm*a) and squid *(Loligo opalacen*s). The goal was to determine the numbers and types of taxon-specific hard parts that pass through the digestive tract and to develop correction factors for certain abundantly occurring structures. Over 20,000 fish and squid were consumed during 267 days of fecal collection. During this period, over 119,000 taxon-specific hard parts representing 56 different structures were recovered. Skeletal structures and non-skeletal structures accounted for 72% and 28% of all hard parts, respectively. The branchiocranium, axial skeleton and dermocranium regions of the skeletal system accounted for the greatest number of hard parts recovered. Over 70% of all recovered hard parts were represented by 1-6 taxa specific structures for each prey type. The average number of hard parts (3.1-31.2) and structure types (2.0-17.7) recovered per individual prey varied across taxa. Identifying all taxon-specific prey hard parts increases the likelihood of identifying and estimating the number of prey consumed. Correction factors (to reconstruct original prey numbers) were derived for certain abundantly occurring prey hard parts.

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21. SIMULATING FORAGING OF DIVING MAMMALS IN CAPTIVITY: A FEASIBILITY STUDY WITH STELLER SEA LIONS (*EUMETOPIAS JUBATUS*). 2000. Leslie Cornick and Markus Horning. Abstract: Experimental Biology 2000 at San Diego, CA, USA. (Ph.D. thesis in preparation.)

Project Overview Excerpt: This study is testing the feasibility of simulating different prey density and distribution scenarios during feeding dives of captive juvenile Steller sea lions held at the Alaska SeaLife Center at Seward, AK. The goal of our study is to find out whether we can learn from captive animals how changes in relative prey accessibility are reflected in behavioral parameters that we can later observe via telemetry on free-ranging Steller sea lions. In the large Steller sea lion habitat tank at the SeaLife Center, several PVC pipes with remotely operated trapdoors for fish release are used as feeder tubes. The sea lions have to swim between these feeder tubes during their simulated dives. From a console in front of a large viewing window into the Steller sea lion habitat, light targets used for training and fish release from the feeder tubes are controlled. The sea lions have to swim between the feeders to obtain food. Fish is released at various times. Leslie is testing how long the sea lions will remain submerged for different fish encounter rates, how fast they swim, and what distances they cover.

22. PREY OF STELLER'S SEA LIONS, *EUMETOPIAS JUBASTUS*, IN WASHINGTON STATE. 1999. Patrick Gearin, Steven Jefferies, Susan Riemer, Lawrence Lehman, Kirt Hughes, and Lawrence Cooke. Abstract. 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii, Nov. 28 – Dec. 3, 1999. P. 65.

Abstract Excerpt: The prey consumed and dietary components of Steller sea lions were examined by the collection and analysis of sea lion fecal samples (scats) and from stomach contents of beach cast animals on the northern Washington coast from 1993-1998. Scat samples (n=850) were collected primarily during the summer months from late June to early September. The stomach contents of 20 Steller sea lions were examined from animals found stranded from March through September. Prey were identified from the scat or stomach contents using both fish otoliths and other bony and skeletal parts and from the beaks or statoliths of cephalopods. The frequency of occurrence (FO) of prey was determined by season and for the total samples. The dominant prey of Steller sea lions from the scat samples for each year and for all years combined was Pacific whiting, *Merluccius productus* (FO ranged from 89% to 98%). Other numerically dominant prey in order of FO values were; Pacific herring, *Clupea pallasi* (23%), Spiny dogfish, *Squalus acanthias* (19%), and skates in the Family Rajidae (11%). Salmon, though important in certain locations and months, overall was found in less than 10% of the total scat samples. The stomach contents contained similar prey as found in scat samples but contained higher percentages of smelts (Family Osmeridae) reflecting the seasonal bias when most were collected. Pacific whiting appears to be the dominant and most important prey of Steller sea lions on the northern Washington coast during the summer months. We conclude that the migration and abundance of Steller sea lions on the northern Washington coast appears to be strongly correlated with the availability of Pacific whiting.

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23. PRELIMINARY PROGRESS REPORT OF STELLER SEA LION (SSL) FORAGING ECOLOGY STUDIES. 1999. Russ Andrews. Appendix B.9 in the final report from the Steller Sea Lion Foraging Ecology Workshop, Seattle, WA, Feb 11-12, 1999.

Report Excerpt: Captive juvenile Steller sea lions (SSLs) at the Vancouver Aquarium were used to develop and validate the use of stomach temperature telemeters (STTs) in order to determine the timing and quantity of prey ingestion (indicated by precipitous drops in stomach temperature). Estimation of the quantity of ingested prey was complicated by many factors (e.g. body temperature and stomach heat flux changes, movement of the STT within the stomach, diverse prey size and shape, potentially concomitant water ingestion, and insulation of the STT by previously swallowed prey) and suffered a large margin of error. Determination of the timing of ingestion, however, was much more accurate, at least for the first few ingestion events in a bout of feeding. In 1993 we developed and successfully field-tested a portable data logger for attachment to free-living SSL to monitor location, dive depth, swim speed, and changes in stomach temperature. A remote-release device was developed in 1994 to recover the backpack instruments without having to recapture sea lions. This method not only increased instrument recoveries but also reduced the amount of disturbance to the sea lions, both for the individual subjects and for the entire rookery. In the summer of 1994, 7 adult female SSLs carried data loggers, satellite transmitters and ingested STTs. Although three of the backpacks broke off the sea lions prematurely, those on the other four were successfully retrieved using the remote-release device. The sea lions made from 1 to 3 foraging trips before the devices were recovered, with individual trips varying in length from 8 to 50 hr. Prey were consumed on all trips. However, long periods of time often elapsed and large distances were covered between successful foraging events. This preliminary study demonstrated that knowing where sea lions traveled and dove does not necessarily allow one to distinguish productive feeding areas from unproductive ones.

In June 1997, SSLs were studied at two of the central Aleutian Islands, Seguam and Yunaska, and at the Forrester Is. rookery complex in southeast Alaska. During the research cruise near Forrester Is., real-time satellite tracking data on the at-sea locations of sea lions were relayed to a vessel conducting a fish assessment around Forrester Is., and a similar fish assessment occurred around Seguam Is. that summer (by B. Norcross, UAF). The following factors restrict our ability to make inferences concerning either the past or current SSL population decline from this limited comparison of the foraging ecology of SSLs from the declining and stable populations: extremely small sample sizes, the possibility of adverse effects of the instruments on foraging behavior and energetics, the difference between the current rate of decline compared to the larger rate from 1979 to 1990, density dependent effects on individual foraging success (reduced population size implies reduced intra-specific competition) and the potential interannual variations in many environmental parameters (e.g. the 1997 El Niño and the anomalous conditions in the Bering Sea that year). However, the direct comparison between two similarly handled groups should allow some general conclusions about SSL foraging behavior to be drawn.

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24. A COMPARISON OF THE FORAGING ECOLOGY OF STELLER SEA LIONS FROM DECLINING AND STABLE POPULATIONS – Russ Andrews, Don Calkins, Randy Davis, Tom Loughlin, Brenda Norcross, K. Peijnenberg, and Andrew Trites. Abstract. 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui, Hawaii, Nov. 28 – Dec. 3, 1999. P. 6.

Abstract: Recent population declines of Steller sea lions (SSLs) may be related to reduced prey availability. We examined this hypothesis by comparing SSLs breeding at two sites: a large and stable rookery in Southeast Alaska (SEA), and a declining rookery in the central Aleutian Islands (CAI). In June 1997 we monitored the movements, dive behavior, prey ingestion (*via* stomach temperature telemetry), and energetics of lactating SSLs. Simultaneously, bottom and mid-water trawls were conducted to assess demersal fish abundance, and scats were collected to determine diet. Data loggers were recovered from 5 SSLs from SEA, and 3 from CAI. Contrary to predictions that reduced prey availability would lead to longer foraging trips in CAI, SSLs there made much shorter trips than SEA SSLs. SSLs from CAI spent only 22% of their time at sea, while SSLs from SEA spent 48% at sea. Field metabolic rate (FMR) of SEA SSLs was 26% greater than FMR of CAI SSLs. Percent time submerged and other indices of foraging effort were similar between groups, but CAI SSLs made shorter, shallower dives than SEA SSLs. In both areas, SSLs began searching for prey soon after entering the water, but the mean time from departure until the first prey ingestion event was 5 times longer for SEA SSLs. Prey intake rate for CAI SSLs was roughly 2 times greater than for SEA SSLs. The abundance of juvenile groundfishes was 11 times greater around CAI than around SEA, possibly explaining why CAI SSLs found prey much quicker and ingested it at a higher rate, but the diet of SEA SSLs was much more diverse. The lack of a single highly abundant prey species and the larger SSL population at SEA may result in longer search times for SEA SSLs, but the mixture of prey they ingest may ultimately be healthier.

25. A THREE-DIMENSIONAL DIVE RECORDER WITH GPS FOR MONITORING THE MULTI-DIMENSIONAL MOVEMENTS AND FORAGING BEHAVIOR OF STELLER SEA LIONS. Randall Davis and Shane Collier. In progress.

Project overview: This task will develop and test a 3 dimensional depth recorder that will record the position of the animal when it is at the surface utilizing the Global Positioning System (GPS), and the depth and duration of dives the animal makes while carrying the instrument. The instrument will also measure and store the swim speed, compass bearing, stomach temperature and water temperature. Software will be developed to analyze the graphical data to display an animated three-dimensional dive path in a fully interactive virtual environment. The point where fish are consumed along the dive path will be indicated through the use of a stomach temperature transmitter. A remote release device will also be developed and tested to allow recovery of the instrument and thus recovery of the data. The instruments will be tested on the ASLC sea lions to validate the underwater and GPS tracking capability; test the stomach temperature sensor during controlled feeding; and test the remote release system. Most of the work at the ASLC will be done in September 1999.

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Condition Indices

26. THREE DIMENSIONAL PHOTOGRAMMETRY AS A TOOL FOR ASSESSING MORPHOMETRICS AND ESTIMATING BODY MASS OF STELLER SEA LIONS. 2000. Jason Waite. M.Sc. thesis, Texas A&M University, Galveston, TX.

Abstract: A technique was developed to indirectly assess morphometrics and to estimate body mass of Steller sea lions (*Eumetopias jubatus*) using three-dimensional (3D) photogrammetry. 3D computer wire frames of thirty-five Steller sea lions of various age classes were generated from multiple time-synchronous digital photos. Overall average estimate of standard length and axillary girth were within ± 2.8% and ± 4.2% of physically measured dimensions, respectively. Average estimates of standard length and axillary girth from wire frames based on ideal body postures were within ± 1.7% and ± 3.1% of physically measured dimensions, respectively. These measurements were used to estimate body mass by applying previously existing regression equations. Regressions of physically measured mass on photogrammetrically estimated body volume yielded a predictive model. Body mass estimates using this model were on average within 10.5% (with a 95% confidence interval of ± 2.35%) of the physically measured mass. The use of 3D photogrammetry decreases many of the problems associated with camera and body position encountered with two-dimensional photogrammetric techniques. This technique can be used to estimate the body mass of free-ranging, active sea lions, eliminating the need for sedation, heavy weighting equipment, and animal disturbance.

27. GROWTH IN BODY SIZE OF THE STELLER SEA LION *(EUMETOPIAS JUBATU*S). 2001. Arliss Winship, Andrew Trites, and Donald Calkins. Journal of Mammalogy, 82(2): 500–519.

Abstract: Growth models (mass and length) were constructed for male (1 year old), female (1year old), and pregnant female Steller sea lions *(Eumetopias jubatu*s) shot on rookeries or haulouts, or in coastal waters of southeastern Alaska, the Gulf of Alaska, or the Bering Sea ice edge between 1976 and 1989. The Richards model best-described growth in body length and mass. Females with fetuses were 3 cm longer and 28 kg heavier on average than females of the same age without fetuses. Males grew in length over a longer period than did females and exhibited a growth spurt in mass that coincided with sexual maturity between 5 and 7 years of age. Average predicted standard lengths of males and females 12 years of age were 3.04 and 2.32 m, respectively, and average predicted masses were 681 and 273 kg, respectively. Maximum-recorded mass was 910 kg for an adult male. Males achieved 90% of their asymptotic length and mass by 8 and 9 years of age, respectively, compared with 4 and 13 years, respectively, for females. Residuals of the size-at-age models indicated seasonal changes in growth rates. Young animals (6 years old) and adult males grew little during the breeding season (May–July), and adult males did not resume growth until sometime after November.

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28. PLASMA ANGIOTENSIN II, ARNININE VASOPRESSIN AND ATRIAL NATRIURETIC PEPTIDE IN FREE RANGING AND CAPTIVE SEALS AND SEA LIONS. 1998. Tania Zenteno-Savin and Mike Castellini. Comparative Biochemistry and Physiology. 119C: 1-6.

Project Overview: focused on three vasoactive hormones - AVP, ANP and ANG II - found in blood plasma. Humans suffering from eating disorders (anorexia, bulimia) have elevated levels of these hormones. It was therefore speculated that Steller sea lions might exhibit similar changes in their blood hormone levels if they are suffering from nutritional stress. To test this hypothesis, blood samples were collected and analyzed from nearly 200 Steller sea lions in Southeast and Northwest Alaska. A concurrent experiment was also run with the captive Steller sea lions at the Vancouver Aquarium to determine how fasting or food restriction affected blood hormone levels. In the controlled study, ANG II rose in response to food restrictions. AVP was unaffected, while ANP seemed to decline. These feeding experiments seem to indicate that blood hormones do provide some gauge of how well a Steller has been eating. However, in the wild Steller sea lions, ANG II levels were higher in the thriving southeast population compared to the declining Aleutian population. This is not consistent with the hypothesis that Steller sea lions in the western population are nutritionally stressed.

29. CHANGES IN SERUM LEPTIN LEVELS DURING FASTING AND FOOD LIMITATION IN STELLER SEA LIONS (*Eumetopias jubatus*). 2000. Lorrie Rea and Tim Nagy. Abstract. Third Biennial Symposium of the Comparative Nutrition Society, Pacific Grove, California. August 4-9, 2000. P. 171-175.

Abstract Excerpt: Leptin (*ob* protein), is a peptide hormone secreted by adipocytes that has been shown to have a role in control of energy metabolism and food intake in rodents and man. It is thought that leptin acts as a negative feedback signal to satiety centers in the hypothalmus to regulate body energy stores. The purpose of this study is to investigate how serum leptin concentrations change in response to food deprivation in an animal, which is known to undergo periods of voluntary natural fasting in the wild. Also, if a close correlation between leptin and body fat content is established in Steller sea lions, this hormone could provide an index of body condition that would be more easily monitored in free-ranging animals. Presently the best method for determining body fat content in these animals involves holding captured individuals under anesthesia during the two-hour equilibration period necessary for the dilution of deuterium oxide. To address the related, but individual effects of fasting and decrease in body reserves on leptin production we held 5 sea lions on a low plane of nutrition (food limitation) for 28 d such that body mass loss was similar to that experienced during 14 d fasting experiments. The three male sea lions showed a consistent decrease in serum leptin levels during the 9 to 14 d fasting period, while the two female sea lions showed progressive increase in serum leptin concentrations over the same period of fasting. Serum leptin patterns were less distinct during food limitation studies. Serum leptin concentrations were not significantly correlated with total body fat mass as measured by the dilution of deuterium oxide (p=0.627) but were significantly

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correlated with plasma water content (p<0.001, r^2=0.49). At present, we conclude that young animals produce significantly lower levels of leptin than do older, larger sea lions, however it is unclear the role that body fat content plays in this difference in leptin concentration. There are also clearly differences in how serum leptin levels change in response to fasting in males and females of this species, although the factors influencing leptin production in Steller sea lions require further study.

30. THYROID HORMONES AND PLASMA LEPTIN CONCENTRATIONS DURING FOOD DEPRIVATION AND SATIETY: USE AS AN INDEX OF METABOLIC CONDITION IN FREE-RANGING STELLER SEA LIONS. Shannon Atkinson, Lorrie Rea and Matt Myers. In progress.

Proposal Abstract Excerpt: The primary goal of this study will be to develop an index or tool for the assessment of metabolic condition in free-ranging Steller sea lions based upon circulating hormone levels. We believe that we can develop such a tool through the measurement of a combination of hormones that are involved in the regulation of metabolism and food intake in mammals – thyroid hormones, cortisol and leptin. The value of this approach is that hormones represent an integrated response to a number of environmental and physiological factors that influence metabolism. Previous studies have used thyroxine and cortisol, along with several morphometric measurements to assess the well being of yearling Hawaiian monk seals that appeared to be malnourished. Their results suggest that a suite of measurements, including these hormones, provides a good indication of the physiology of a seal and its ability to adapt to suboptimal environments. Recent studies on terrestrial mammals have shown a close correlation between serum leptin levels and total body fat that could provide an index of body condition more easily monitored in free-ranging animals than the presently used deuterium dilution technique. This study will build upon a preliminary study on the effect of food deprivation on serum leptin concentrations and utilize blood samples collected during previous studies to investigate the interrelationships between hormone levels, body fat content and nutritional state. Other environmental effects, such as circadian changes in hormone production and seasonal change in hormone levels will also be addressed. On-going studies on free-ranging Steller sea lions will provide additional samples to test the application of our indices on wild populations.

31. BIOCHEMICAL AND PHYSIOLOGICAL PROFILES OF NUTRITIONAL STATUS AND BODY CONDITION. 1999. Mike Castellini. Appendix B.8 of the Final Report of the Steller Sea Lion Physiology Workshop February 8-10, 1999. P. 27.

Abstract: This study attempted to apply models of mammalian fasting and starvation to compare Steller sea lions from declining (Western) and stable (Eastern) populations using morphometrics and blood chemistry. By these measures, animals from the declining population were expected to be both distinct and compromised. Test animals were adult female Steller sea lions selected on rookeries between 1993 and 1997 during the course of other studies. All animals had pups and were approximately 3 days postpartum. Measurements of body girth and length were taken, and

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body mass was projected using the volumetric methods of Castellini and Calkins (1993). Hematocrit, percent body water, and a variety of blood chemistry parameters did not match expectations. Animals from the Western population were generally rounder, longer and heavier. Body water percentages were significantly lower for the Western group in 1997, implying the presence of more body fat. Hematocrit values were not significantly different. Similarly, blood chemistry values did not provide evidence of nutritional stress, especially when compared with the captive animals. Copper levels were significantly higher in the Western population, but were only one-third of those observed in the captives. However, globulin levels were significantly higher (implying greater stress) in the Eastern population.

32. CAPTIVE FEEDING REGIME STUDY. Don Calkins, Mike Castellini, and Vladimir Burkanov. In progress (Year 3 of a 3 year study).

Project Outline: The three captive Steller sea lions at the SeaLife Center will be fed sets of mixed species diets for four-month periods for two years. The first feeding regime will closely follow the diet found in the wild population in the Gulf of Alaska prior to the beginning of the decline in that area. In the second regime during the second four months of the study the sea lions will be fed a mixed species diet that will closely follow the diet seen in the Gulf of Alaska after the decline began. During the third regime in the last four months of the first year the sea lions will be fed a mixed species diet that will closely follow the diet found in southeastern Alaska where no decline has been seen in the last three decades. The animals will be monitored daily for condition, weight gain and loss and general health. Following each of the four-month intervals, the animals will undergo a battery of tests including body condition and composition using ultrasound blubber measurements, and bioelectrical impedance and deuterium dilution. Health status will also be evaluated monthly using standard clinical biochemical evaluations of the blood. In the second year the animals will be fed the same three diet regimes but during different time periods so as to eliminate seasonal biases. The experiment may continue into the third year if it is determined that each diet regime should be fed for an entire year to reduce biases.

Metabolism and Nutritional Physiology

33. CHANGES IN METABOLISM IN RESPONSE TO VARYING ENERGY INTAKE IN A MARINE MAMMAL, THE STELLER SEA LION. 1998. Dave Rosen and Andrew Trites. Abstract. Proceedings of the Comparative Nutrition Society Symposium, Number 2 . Banff, Alberta, Canada. August 14-19, 1998. Pg. 182- 185. Similar title in review for Functional Ecology. 0:000-000.

Abstract Excerpt: The most common response to experimental undernutrition or fasting in homeotherms is metabolic depression. Invoking such physiologic responses that limit energy expenditures limits tissue loss and delays death by starvation. Some species of marine mammals have exhibited metabolic depression, although its occurrence, scope and triggers are still unclear.

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This study was designed to document the extent of metabolic depression in Steller sea lions. It investigated the role of energy and food intake on metabolic depression, and the relationship between changes in body mass and the scope of metabolic depression. The experimental conditions were: a) a 9 to 14-day period of complete fasting, b) food restriction: approximately 50% of their normal herring intake for 27 to 28 days, c) ad libitum diet of pollock for 12 to 14 days, d) ad libitum diet of squid for 12 to 14 days. Resting metabolic rate (RMR) was measured weekly, starting prior to the diet manipulation (control period of ad libitum herring diet) through the experimental period, and continuing 2 weeks after the switch back to herring (recovery period). Mass loss varied with gross energy intake (GEI): pollock diet = 0.55 kg/d, squid diet = 1.09 kg/d, food restriction = 0.35 kg/d, and fasting trials = 2.32 kg/d. Metabolic depression was observed during the fasting trials, as well as the two GEI limitation trials. RMR was 30.7 ± 4.2% (mean ± SE) lower by the end of the experimental fasting period compared to control levels. During the squid trials, RMR was 24.2 ± 3.4 % lower by the end of the second week, and 14.7 ± 1.6% lower by the end of the second week of the pollock trials. In contrast, RMR remained unchanged during the experimental food restriction trials, except for week 2 when there was a significant increase. We found a strong relationship between the proportion of initial body mass loss and the degree of metabolic depression in Steller sea lions.

34. GROWTH RATES OF VIBRISSAE OF HARBOR SEALS (*PHOCA VITULINA*) AND STELLER SEA LIONS (*EUMETOPIAS JUBATUS*). 2001. Amy Hirons, Donald Schell and David St. Aubin. Canadian Journal of Zoology 79: 1053-1061.

Abstract: Growth rates of vibrissae (whiskers), which act as a temporal record of feeding in harbor *seals (Phoca vitulina*) and Steller sea lions (*Eumetopias jubatus*), were estimated using ^{13}C- and ^{15}N-labeled glycine followed by stable isotope analysis. The labeled glycine was incorporated into the keratin and served as a temporal marker for growth rate calculation. One captive seal received two doses 147 days apart while a second seal received only one dose; vibrissae were analyzed after 86 and 154 days. The peak positions indicated that growth began in the fall, continued into spring, but ceased in June, with active growth rates of 0.33 mm/day. Two captive Steller sea lions each received two labeled doses during a 308-day period. After 427 days vibrissae in both sea lions showed two peaks corresponding to the markers; growth rates were calculated as 0.05 – 0.07 mm/day. Growth rates in captive juvenile and wild adult sea lions 0.1-0.17 mm/day, supported the assumption that the major isotopic oscillations in vibrissae of wild sea lions were annual. The multi-year records imply that Steller sea lions retain their vibrissae; harbor seal vibrissae, in contrast, have periods of rapid growth and appear to be shed, at least in part, annually.

35. THERMOREGULATION IN STELLER SEA LIONS: A MODELLING APPROACH. – Emma Roscow and Markus Horning. M.S. thesis in preparation, Texas A&M University, Galveston, TX.

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Project Abstract Excerpt: The development of a predictive energetics-based model, to help identify sensitive parameters for otariid energetics, will greatly help in the further understanding of this family of pinnipeds. Energetic demands include a variety of obligatory costs such as maintenance metabolism, locomotion & foraging, and maintenance of thermal homeostasis, as well as facultative costs related to social activities, reproduction, parental investment, molt, and anabolism during ontogeny. Among the obligatory costs, thermal costs can be offset by skeletal muscle thermogenesis from locomotion and feeding i.e. thermoregulatory demands can be met by maintenance, locomotion and foraging costs. Since otariids forage in waters that range in temperature from a summer high of 35°C in the Galapagos, to a winter low near freezing (below 0°C for sea water) in the Bering Sea they are subject to a variety of environmental conditions, which in turn affects the partitioning of resources for these energetic needs. Utilizing metabolic rate and other relevant published data a descriptive model will be constructed incorporating the environmental factors commonly experienced by otariids in the wild. Within the model all the components will be constructed using Matlab and Simulink modeling software. This will make it possible to predict under what conditions, be it physical or environmental, the animals may be utilizing additional energy for thermoregulation. The model will account for both the physiology and behavior of the animals based on passive mechanisms and decision-making processes. Energetic based models provide researchers with the ability to identify key factors that will predict an energetic imbalance in foraging marine mammals and perhaps help to explain why for certain species such as the Steller sea lion nutritional stress may occur when energetic demands are not met by the energy input. This technique will ultimately permit predictions of survival likelihood's based on energetic balances for otariids.

36. COST OF TRANSPORT IN STELLER SEA LIONS, *EUMETOPIAS JUBATU*S. In press. David Rosen and Andrew Trites. Marine Mammal Science 0:000-000.

Abstract: The cost of swimming is a key component in the energy budgets of marine mammals. Unfortunately, data to derive predictive allometric equations is limited, and estimates exist for only one other species of otariid. Our study measured the oxygen consumption of three juvenile Steller sea lions *(Eumetopias jubatu*s) swimming in a flume tank at velocities up to 2.2 m s^{-1}. Minimum measured cost of transport ranged from 3.5-5.3 J kg -1 m^{-1}, and was reached at swimming speeds of 1.7-2.1 m s^{-1}. These cost of transport values are higher than those reported for other marine mammals. However, once differences in stationary metabolic rate were accounted for, the locomotor costs (LC) for the Steller sea lions were commensurate with those of other marine mammals. Locomotor costs (LC in J m^{-1}) appeared to be directly proportional to body mass (M in kg) such that LC = 1.651M 1.0. These estimates for the cost of locomotion can be incorporated into bioenergetic models and used to determine the energetic consequences of observed swimming behavior in wild marine mammals.

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37. THERMOREGULATION IN ADULT FEMALE STELLER SEA LIONS AND PUPS. 1999. Terrie Williams. Appendix B.13 of the Final Report of the Steller Sea Lion Physiology Workshop February 8-10, 1999. P. 34.

Abstract: Steller sea lions are highly specialized mammals that spend much of their lives at sea. One of the greatest physiological challenges for these marine endotherms is thermoregulation. To counterbalance the high thermal conductivity of water, Steller sea lions like many marine mammals have developed a thick insulating blubber layer that encases the body. Maintenance of this insulating layer depends on an appropriate diet for the deposition of lipids that compromise the blubber. This study compared the thermal profiles and quality of insulation for Steller sea lions from declining (Chirikof Island, Aleutian Islands, Marmot Island) and stable (Lowrie Island) populations in Alaska. Heat flow and skin temperature were measured with a hand-held probe placed on six anatomical sites for adult females (n=53) and pups (n=83). Blubber thickness for nine sites was determined by ultrasound for adults and skinfold thickness for pups. Insulation quality was calculated from the ratio of heat flow to the temperature differential and blubber thickness. Preliminary assessment of the results demonstrates that blubber thickness in adult females is comparatively lower for animals in the declining areas. For example, blubber thickness for the dorsal mid-truck region was approximately 10.0 mm for adult females from Lowrie Island and over 17.0 mm for females from Chirikof Island and the Aleutians. The level of heat flow in air and the quality of insulation were correlated to the differences in blubber thickness. Heat flow was comparatively more variable (range 74.1 – 350.0 W/m2) for females from the area of decline. The quality of insulation was relatively poorer for these animals. Pups showed similar trends for blubber thickness as indicated by skinfold measurements. However, differences in heat flow and insulation quality between the areas of decline and stability were not as distinct as observed for the adults. These results indicate subtle differences in insulation between Steller populations. Interestingly, these differences were not apparent with courser morphological measurements such as length-girth relationships and body mass. Future research directions should focus on the correlation between insulation and fatty acid composition of the blubber. In this way, the link between prey availability, insulation quality, and vulnerability to thermal stress can be assessed.

38. BLOOD CHEMISTRY AND BODY MASS CHANGES DURING FASTING IN JUVENILE STELLER SEA LIONS (*Eumetopias jubatus*). 1998. Lorrie Rea, Dave Rosen, and Andrew Trites. Abstract. Proceedings of the Comparative Nutrition Society Symposium, Number 2. Banff, Alberta, Canada. August 14-19, 1998. P. 174-178.

Abstract Excerpt: Five juvenile Steller sea lions were fasted in captivity for 9 to 14 days to test the hypothesis that juvenile Steller sea lions exhibit changes in key plasma metabolites indicative of biochemical adaptation to fasting. Blood samples and body mass measurements were collected from each sea lion at the onset of the study following an overnight fast (control sample). Body mass was documented daily and blood samples were collected every 3 to 4 days. Plasma concentrations of blood urea nitrogen (BUN) and beta-hydroxybutyrate (b-HBA)

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were measured by spectrophotometric assay techniques. Total mass loss ranged from 20.4 to 35.1 kg, which equated to a mean daily percent mass loss of 1.0 to 2.0% for the five animals studied. Two animals fasted during the breeding months exhibited a mean daily mass loss of 1.6 ± 0.1 kg d^{-1} which was significantly lower than the mean rate of 2.8 ± 0.1 kg d^{-1} seen in the 3 remaining sea lions fasted outside of the normal breeding season. Within the first 3 days of fasting all animals studied showed evidence of protein sparing, a primary biochemical adaptation to fasting. However, when forced to fast outside of the natural breeding season of this species, three juvenile Steller sea lions showed increases in the utilization of protein stores after only 7 days, reflected in increases in BUN concentrations. When two juveniles were fasted during the natural breeding season, there was continued evidence of protein sparing typical of long-term fasting in phocids. Unexpectedly, fasting juvenile Steller sea lions did not show the progressive increase in b-HBA concentrations documented in fasting phocid seal pups. These data suggest that there may be an age related difference in how body reserves are utilized during fasting or in how these resulting metabolites are circulated during fasting.

39. THE EFFECT OF FOOD DEPRIVATION ON SERUM LIPID CONCENTRATION AND CONTENT IN STELLER SEA LIONS. 2000. Michelle Berman and Lorrie Rea. Abstract. Proceedings of the Comparative Nutrition Society Symposium, Number 3. Pacific Grove, CA. August 4-9, 2000. P. 13-16.

Abstract Excerpt: Nine Steller sea lions, 4 juveniles and 5 sub-adults, were used in 13 different fasting experiments lasting from 7 to 14 days. Eight of the fasts were conducted during the natural breeding season (May-July) and five were conducted throughout the rest of the year (non-breeding season). Blood samples were collected after an overnight fast and every 2 to 4 days thereafter. Non-esterified fatty acid (NEFA) concentration was quantified using a spectrophotometric assay. Fatty acid composition of fatty acid methyl esters was determined by gas chromatography (GC). The 28 fatty acids that contributed >0.2 wt % of the total were analyzed using principal components analysis to determine if the scores (axis) developed in the PCA significantly explained the trends. The results of this study suggest difference in lipid metabolism between seasons in some age classes. Although no difference of NEFA concentration was found between the breeding and non-breeding season, NEFA concentration did significantly increase during the breeding season fasting in juveniles and not during the non-breeding season fast. In sub-adults, NEFA concentrations did not differ between seasons and did not significantly change over the fast. In assessing the seasonal trends of serum fatty acid changes during fasting, the juveniles again experienced differences between seasons. The variables that had the most influence on this separation were three saturated fatty acids, 14:0, 15:0, and 16:0. The sub-adults showed no change in fatty acid composition between seasons but did change throughout the fasts.

40. THE EFFECT OF SEASONAL FOOD LIMITATION ON ADAPTATION TO FASTING IN CAPTIVE STELLER SEA LIONS. 2001. Lorrie Rea, David Rosen and Andrew Trites. Abstract. 34th International Congress of Physiological Sciences. Christchurch, New Zealand. August 26 – 31, 2001.

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Abstract: In order to assess whether continued declines in the endangered population of Steller sea lions (*Eumetopias jubatus*) are related to food availability, we must understand the physiological effects of fasting in this species and how these are manifested in rates of body mass loss, changes in body condition (relative fatness), and the catabolism of stored body reserves during periods of limited food availability. We must also understand if there is a seasonal component to how well Steller sea lions can adapt to limited food resources, given that they naturally fast during their summer breeding season.

This study included 16 complete fasting experiments (7 to 14 days in duration) to test if Steller sea lions have a greater capacity to adapt to periods of food deprivation during the breeding season (BS; n=8) than when fasting during other times of the year (non-breeding season or NBS; n=8). To ensure the good health of the study animal, fasting trials were discontinued if body mass loss exceeded a total mass loss of 15% of initial body mass. Blood samples and body mass measurements were collected following an overnight fast to provide a control sample for each individual prior to prolonged fasting. Body mass was measured daily and blood samples were collected every 3-4 days. Body fat content was measured on the first and last day of the study using the deuterium dilution technique. Plasma metabolite concentrations were measured by spectrophotometric assay. Two-way analysis of variance adjusted for repeated measures design (ANOVA) and Tukey multiple range tests were used to determine significant changes ($p = 0.05$) in blood chemistry during the fast and to determine significant differences in how these patterns change related to the season of study. Paired t-tests were used to test for significant difference in rates of total mass loss between the fasts conducted during the BS and those undertaken in the NBS.

Rates of mass loss ranged from 1.4 to 3.5 kg/d that equated to 1.0 to 2.0 % of original body mass lost per day. Percent body fat ranged from 11 to 28% of total body mass at the initiation of fasting trials and decreased during all completed studies. There were no consistent differences in rate of mass loss to suggest that fasting during the NBS had any more impact on overall mass loss than when animals are fasted during the natural BS.

Blood urea nitrogen (BUN) concentrations in the plasma decreased significantly during the first 2-4 days of fasting in all animals ($p<0.01$) suggesting that sea lions are able to enter a fasting adapted metabolism to spare protein at all times of the year. Animals fasted in the NBS showed increasing BUN levels after 7 days of fasting suggesting that the ability to maintain this conservative state may be limited during the NBS, and may be limited even during the BS in smaller animals. During the BS, higher lipid mobilization, as suggested by the higher (although transient) levels of ketone bodies and higher NEFA concentrations late in fasting may allow sea lions to minimize the reliance on protein reserves for energy. This suggests that sea lions could adapt easily to reduced food resources during summer months, but may be more severely impacted by low food availability during the rest of the year.

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Reproduction, Pup Growth, and Maternal Investment

41. DETERMINATION OF REPRODUCTIVE MATURITY AND STATUS OF STELLER SEA LIONS (EUMETOPIAS JUBATUS) FROM STEROID CONCENTRATIONS IN FECAL MATERIAL. Patience Brown and Thomas Loughlin. In progress.

Project Overview: This study will attempt to profile concentrations of reproduction related steroids in feces throughout the entire reproductive cycle for one year. It requires collection of scat material from all three sea lions opportunistically and blood samples one or two times a month. The scat material will be tested to identify steroids related to reproduction and develop standards that can then be used for testing scat collected from the wild population. Standard genetic techniques will be used to identify gender of scats from the wild population.

42. DETERMINING REPRODUCTIVE ACTIVITY IN STELLER SEA LIONS USING SALIVARY HORMONE ANALYSIS, VAGINAL CYTOLOGY AND TESTICULAR SIZE FLUCTUATIONS. 2000. Heather Harmon, Michael Castellini, Janice Rowell and Shannon Atkinson. Abstract. Society for the Study of Fertility. Edinburgh, Scotland, GB. July 29-August 3, 2000.

Abstract: The goal of this ongoing project is to describe the reproductive endocrinology and physiology of Steller sea lions (SSLs). Some Alaskan populations are declining for unknown reasons and recently there has been interest in determining if hormone balance or changes in reproductive rates are related to this decline. The objectives are to validate alternative methods for determining peripheral hormone concentrations using saliva, provide anatomical verification of reproductive status and to describe the annual cycles of reproductive hormones. Three adult captive SSLs housed at the ASLC are being used for this project. Plasma was collected monthly and frozen. Saliva samples were collected twice weekly and frozen. Progesterone (P_4), estrone (E_1) and testosterone (T) concentrations in plasma and saliva were measured by RIA and were compared. Vaginal swabs were taken twice weekly to determine percent cornification of epithelial cells, which may indicate the state of estrus. Testicle lengths and girths were measured monthly. The correlation coefficient between plasma and saliva for both P_4 and T was 0.94. These results indicate that saliva is a valid alternative to plasma for determining P_4 and T concentrations for SSLs. However, the correlation coefficient between plasma and saliva for E_1 was only 0.34. Therefore, salivary E_1 cannot be reliably used for the determination of reproductive status for SSLs. Vaginal cytology was found to be useful in determining reproductive status. Both T and testicle size increased with the onset of the breeding season.

43. THE USE OF PLASMA AND SALIVA PROGESTERONE, TESTOSTERONE AND OESTRONE TO DETERMINE REPRODUCTIVE ACTIVITY IN CAPTIVE STELLER SEA LIONS. Heather Harmon, Mike Castellini, Janice Rowell and Shannon Atkinson. Manuscript in preparation.

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Summary - The objectives were to validate alternative methods for determining peripheral hormone concentrations using saliva and to describe the annual cycles of reproductive steroid hormones for Steller sea lions (SSLs). Samples were collected from captive adult research trained SSLs. Voluntary saliva samples were collected from September 1998 until July 2000. Blood samples were collected either under physical restraint or gas anesthesia from June 1998 until July 2000. Progesterone (P_4), oestrone (E_1) and testosterone (T) concentrations in plasma and saliva were measured by RIA and paired samples were statistically compared by linear regression analysis. Plasma and salivary P4 and T are highly correlated (r= 0.96, P< 0.001 and r= 0.87, P< 0.001, respectively). These results indicate that saliva is a valid alternative to plasma for determining P_4 and T concentrations for SSLs. However, the correlation coefficient between plasma and salivary E_1 changed significantly when data sets including and excluding samples taken during a fasting experiment were analyzed. The correlation coefficient when all samples were analyzed is very low (r= 0.07, P= 0.83), but when samples taken during fasting periods are excluded the correlation is high (r= 0.85, P< 0.001). At this time, salivary E_1 can't be reliably used for the determination of reproductive status for SSLs. P4 and T were found to be at baseline levels year-round, except during discreet periods of increased concentrations.

44. CRANIAL MORPHOMETRICS OF FUR SEALS AND SEA LIONS (FAMILY: OTARIIDAE) – SYSTEMATICS, GEOGRAPHIC VARIATION AND GROWTH. 2000. Sylvia Brunner and Mike Bryden. PhD. dissertation, University of Sydney, Sydney, Australia. (Manuscript of similar title submitted to Marine Mammal Science).

Dissertation Abstract: The standard anatomical descriptions given to identify species of the family Otariidae (fur seals and sea lions), particularly those for the genus Arctocephalus, have been largely inconclusive. Specimens of some species have conformed more to the description of others, have overlapped in many identifying characteristics. Recent re-examination of the genetic basis of taxonomic diversity within the Otariidae required matching by comprehensive new studies of skull morphometry based on large sample sizes, in order to provide a sound basis for re-appraisal of species limits in the family. In this study, sub-family separation of otariid seals was not supported. Instead, a separation of genus, species and subspecies is proposed for the Otariidae, with some re-arrangement of taxonomy at the level of genus. *Arctocephalus australis, A. forsteri* and *A. galapagoensis* appeared to be congeneric, with only subspecific differences in morphology. *Arctocephalus townsendi* and *A. philippii* also appeared congeneric, yet were morphologically divergent from the remaining *Arctocephalus*. Skulls *of Zalophus californianus japonicus* were significantly different from those of *Z. c. californianus* and *Z. c. wollebaeki*, and should be considered a separate species of *Zalophus*. Geographic variation was observed in skulls of most otariids, with a general change in size corresponding in a gradient with latitude. Several specimens were morphologically divergent from the typical otariid representatives, indicating outliers or hybrids among species, genera and/or subfamilies. An adult male *O. byronia x Z. californianus* was identified, along with the appearance of *A. galapagoensis* at Macquarie Island and New Zealand. Because cranial measurements are used as taxonomic characters in pinnipeds, it is important to understand how the appearance of the skull

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changes at different stages of growth for each species and for each sex. Little interspecific differences in patterns of growth and development of skulls were observed, with only minor differences in rates of growth. Sexual dimorphism was significant in all otariids but was more apparent in larger species. Female otariids of each species showed monophasic development in all characteristics, while males expressed monophasic growth for some characters and biphasic growth for others. Biphasic growth in skulls of male otariids occurred well after physical maturity had been reached, usually at a suture index of 27. The rate of development varied between skull characters in otariids; components relating to the nervous system and its adnexa completed growth well before the rest of the skull, while those relating to feeding, breathing and sound-producing developed in synchrony with the overall growth of total skull length.

45. FORAGING DIFFERENCES AND EARLY MATERNAL INVESTMENT IN ADULT FEMALE ALASKAN STELLER SEA LIONS (*Eumetopias jubatus*). 2000. Tammy Adams. PhD. Dissertation. Texas A&M University Galveston, TX.

Dissertation Abstract: For lactating Steller sea lions (SSLs), access to sufficient food within close proximity to the rookery is essential for milk production and successful pup rearing. Food limitation has been suggested as a cause of the SSL decline, which has been ongoing since the 1970s. The severity of the decline has resulted in SSLs being listed as threatened in the eastern portion of their range and endangered in the western region. This study compared the proximate composition of milk, and milk and energy intake rates of pups during the first month postpartum between regions of stable and declining population. Feeding preferences of adult females were also examined using fatty acid profiles of their milk and blubber. The proximate composition of milk did not differ significantly among regions, except for total protein. Milk averaged 61.8 ± 7.13% water, 21.6 ± 5.70% lipid, 9.3 ± 1.89% protein, and 2.2 ± 0.73% ash. The difference in total protein did not significantly affect energy content, which averaged 10.2 ± 2.31 kJ A ml^{-1}. Energy intake rates of pups did not differ among regions, averaging 733.2 ± 117.37 kJ A kg^{-1} A d^{-1}. However, estimated maintenance requirements for milk energy of pups in the region of stable population were over twice that of pups in the region of population decline. Daily growth rates of pups in the region of stable population were slower than those of pups in the region of population decline. Fatty acid profile analyses indicated both spatial and temporal differences in the diets of lactating SSLs that may reflect the abundance and diversity of prey in various geographic regions. The results also indicated that winter and summer foraging ranges or prey preferences of adult female SSLs are sufficiently distinct between metapopulations to allow determination of geographic region from either milk or blubber fatty acids. While analyses of prey fatty acids are needed to determine species composition of diet, it appears that females in the region of stable population are consuming different prey compared with those in the area of population decline, and that this has had a significant effect on maternal investment during the first month postpartum.

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Immunology, Toxicology, Pathology, and Anesthesia

46. RETROSPECTIVE AND PROSPECTIVE SEROLOGY STUDY. Kathy Burek, Francis Gulland, Terry Spraker, D. Kapan and Andrew Trites. In progress.

Abstract: A collaborative is testing the hypothesis that disease is causing the decline of Steller sea lions. The study has two parts: a modeling exercise to explore whether the patterns of decline of Steller sea lions are consistent with the transmission of an infectious agent, and a serological survey to determine exposure of declining and control populations of Steller sea lions to various pathogens. The serological survey has analyzed archived and current samples for caliciviruses, *Brucella species*, influenza A, morbilliviruses, phocine herpesvirus, *Leptospira interrogans*, canine parvovirus, and *Chlamydia psittaci*. Results to date suggest that it is unlikely that these diseases are a primary cause of the decline because they are either not present, or are present in both declining and thriving populations. It may be that endemic agents are more pathogenic in stressed animals, or that agents that have not been tested for are the cause of extensive though undetected disease. Further research is necessary to examine these possibilities and to determine possible differences between populations in immune response to the pathogens that are present.

47. STUDIES OF IMMUNE FUNCTION IN STELLER SEA LIONS. Kimberlee Beckmen, Jeff Stott, Kathy Burek, Kenneth Pitcher. In progress.

Project Objectives: Investigate immune function in Steller sea lions as a potential factor in the population decline. Use multiple immune functional assays to quantitatively and qualitatively define each of the components of the immune system. Our approach is to include lymphocyte function including specific T-cell function, B lymphocyte function; perturbations in leukocyte subpopulations and inflammatory/stress responses utilizing peripheral blood of Steller sea lions at the Alaska SeaLife Center and Vancouver Aquarium. We will document the normal individual, seasonal and stress-induced variation in responses in immune function in captive, growing animals over time and thereby validate this use of these assays to assess the health of free-ranging Steller sea lions. The results obtained from this study will allow further studies to investigate the possible connection between organochlorine exposure and impaired immune function in free ranging Steller sea lions. If significant immunosuppression is occurring in the declining population, it may be possible to document that fact and enhance the chances of identifying the causal factors whether they are toxic or infectious in origin.

Preliminary Findings: In 5 Steller sea lions differential cell counts were obtained during both the first and second anesthetic episodes the following were found: There was no significant change (paired *t* test) between 1st and 2nd total WBC. One animal had a leukopenia on both draws. All others were within the apparent normal range for free-ranging pups and juveniles. The change seen in individuals ranged from an increase TWBC of 2225 to a decrease TWBC of 1800 However, there was a significant increase in the N:L ratio, from a mean of 2.8 to 4.2 with a mean increase of 1.4. This is due to the PMN increase in 4 of 5 and lymphocytes decrease in 4 of 5.

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This is consistent with a stress-induced leukogram. Therefore, a stress-induce leukogram can be induced quickly in Steller sea lions and observed within just a few hours of capture or due to multiple anesthetic episodes. Testing of captive individuals trained to accept blood sampling under behavioral restraint will best differentiate the factors contributing to the stress leukogram. It is therefore important to be aware (and be consistent) of when the blood is drawn for the CBC. It is recommended that blood be drawn as early as possible during the initial anesthetic episode.

48. POPULATION SURVEY OF ORGANOCHLORINE CONTAMINANTS IN ALASKAN STELLER SEA LIONS. Margaret Krahn, Kimberlee Beckmen, Ken Pitcher, Kathy Burek. In progress.

Project Objectives: Evaluate organochlorine contaminant levels in composite samples of feces from 17 Steller sea lion (SSL) rookeries from Southeast Alaska, the Gulf of Alaska, and the Aleutian Island relative to population status and trend, and relative to reported levels associated with adverse impacts. Additionally, analyze samples of blubber, blood, and feces from captive SSLs at the Alaska SeaLife Center to determine the relationships of contaminant levels and congener composition between these sampling mediums. This is an important component of the proposed research as it provides a mechanism for interpreting the concentrations of contaminants in the fecal samples in relation to blubber and blood levels reported to result in adverse impacts. We also analyzed fecal porphyrin levels in the composite samples from the rookeries and from the individual samples from the captive SSLs to evaluate the relationship of contaminant levels, porphyrin levels, and population status. This research was designed as an avenue for determining whether additional research on the potential impacts of these contaminants on SSLs is warranted.

49. EVALUATION OF IMMUNE HEALTH OF STELLER SEA LIONS: DEVELOPMENT OF REAGENTS AND ASSAYS FOR QUANTITATION OF THE MAJOR IMMUNOGLOBULIN CLASSES AS AN EVALUATION MEASURE OF HUMORAL IMMUNITY AND DEVELOPMENT OF IMMUNOPROLIFERATIVE ASSAYS FOR IN-VITRO EVALUATION OF CELLULAR IMMUNITY. 2000. Bobby Middlebrooks. Unpublished programmatic report.

Project Overview - This project proposes the development of medical tests to assess the health status of immune systems of Steller sea lions. In order to do this, antisera will be developed specific for the heavy chains of the major immunoglobulin classes IgC, IgM, and IgA of the Steller sea lion. These antisera will permit the quantification and partial immunochemical characterization of these immunoglobulin classes. Use of antisera against IgC, IgM, and IgA will allow establishment of baseline data concerning levels of all of these immunoglobulin classes in serum and of IgA in saliva samples over at least a one-year period in the sea lions at ASLC. Baseline data will be established for cellular immunocompetence of the Steller sea lion by performance of monthly B cell and T cell immunoproliferative assays using peripheral blood lymphocytes from the ASLC sea lions.

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50. PURIFICATION OF IMMUNOGLOBULIN ISOTYPES G,A AND M FROM THE SERUM OF THE STELLER SEA LION (*Eumetopias jubatus*). 2000. Jennifer Colvocoresses, Rhonda Patterson and Bobby Middlebrooks. Proceedings of the AAZV and IAAAM Joint Conference. P. 477-478.

Abstract Excerpt: The status of the humoral immune system is one indicator that can be evaluated through immunoassays used to determine the concentrations of specific immunoglobulin isotypes within a sample. This approach has led to efforts in this lab to develop an ELISA to assess baseline immunoglobulin levels in Steller sea lions; however, it was first necessary to isolate the immunoglobulin isotypes (IgG, IgA, and IgM) of interest and to develop Steller sea lion specific reagents for the ELISA. Purification of the immunoglobulins involved an initial purification step to remove non-immunoglobulin proteins from serum (leaving all immunoglobulins present). The next step involved separating proteins in the filtrate based on molecular weights. Since the immunoglobulin isotypes being studied have molecular weights greater than 100,000 Dalton, the serum was further processed in a centrifugal filter device with a molecular weight cutoff of 100,000 Dalton to remove the non-immunoglobulin proteins still present. In order to produce antisera containing antibodies against all Steller sea lion isotypes normally present (for use in evaluating the immunoglobulin purification techniques) serum processed through this initial partial purification step was used to immunize a rabbit. The resulting serum fraction containing immunoglobulins was applied to selected affinity columns and gel filtration columns in order to separate individual isotopes based on binding affinities of each isotype or molecular weight differences respectively. Protein peaks obtained were analyzed by immunoelectrophoresis and SDS-PAGE.

51. COMPARISON OF SEVOFLURANE TO ISOFLURANE IN STELLER SEA *LIONS (EUMETOPIAS JUBATUS*). 2000. Bruce Heath, Kenneth Pitcher, William Taylor and M. Read. Proceedings 7th World Congress of Veterinary Anaesthesia, September 20-23. Berne, Switzerland.

Abstract: The effect of isoflurane and sevoflurane on Steller sea lions was evaluated during body condition, disease and toxicity studies. Thirty-five Steller sea lion juveniles were captured by noose in the water by divers. They were pulled out of the water, restrained in funnel shaped boxes and brought aboard a research vessel. Eighteen animals (80.7 ± 22.2 kg) were subjected to ISO, and 17 (69.9 ± 14.4 kg) to SEVO anesthesia. This work was performed in Southeast Alaska under permit from US National Marine Fisheries Service dealing with this threatened species in that area. During the study an Argos satellite tag was applied for data acquisition and tracking after release. The sea lions were returned directly to the sea in a familiar area from the boat after recovery from anesthesia. Water temperature was 4^{o} C, the surgery suite was 18^{o} C, and air temperature varied from –6 to 6^{o} C. The sea lions were mask induced with either ISO (4% vaporizer setting and then maintained at 1.0 – 1.5%) or SEVO (7% vaporizer setting then maintained at 2.3 –3.0%). All patients were intubated. Duration of induction and anesthesia time to extubation and recovery were determined. HR, RR, BT, SpO2 (pulse oxymeter) and ETCO2

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(capnograph) were determined. Statistical analysis: unpaired test for significance between the isoflurane and sevoflurane groups was performed (Mann Whitney U test). A $p < 0.05$ was considered significant. All variables are expressed as mean ± SD.

ISO patients: Masking time from mask application to intubation was 14 ± 5 min. Time of anesthesia was 86 ± 2.3 min. Time from vaporizer off to extubation was 5 ± 5 min. Time from extubation to walk was 10 ± 5 min. Time from extubation to swim safely away from the boat was 18 ± 5 min. HR ranged from 80 to 130 bpm. RR ranged from 2 to 18 brpm. SpO2 ranged from 94 to 100%. ETCO2 ranged from 33 to 53 mm Hg.

SEVO patients: Masking time 10 ± 4 min. Time of anesthesia was 60 ± 15 min. Anesthesia off to extubation was 4 ± 1 min. Extubation to walk was 7 ± 2 min. Extubation to swim away was 11 ± 3 min. HR ranged from 72 to 132 bpm. RR ranged from 1 to 14 brpm. SpO2 ranged from 92 to 100%. ETCO2 ranged from 27 to 55 mm Hg. Time from anesthesia off to extubation and to safely swimming away was significant (p<0.0005 and p<0.0006, respectively). Rest was important to allow the animals to stabilize from their capture (p<0.05). In those animals taken directly from capture to anesthesia, BT dropped precipitously to 32.9 ± 0.9^{o} C (n=9), and vigorous temperature correction with artificial heat sources was necessary. Those allowed 45 to 60 min (n=24) of rest before anesthesia maintained BT throughout subsequent anesthesia with no external heat measure necessary. During their rest period they were not monitored nor disturbed in any way. Their average BT during anesthesia was 35.7 ± 1.0^{o} C. Other times or physiologic readings were not greatly different. Sevoflurane recoveries were subjectively characterized by the authors as producing a more alert and stronger animals at extubation. They awoke and returned to the water 7.0 min on mean time quicker than isoflurane patients. Even through the time benefit is significant it is outweighed by the greater cost of sevoflurane. (Abbreviations: ISO isoflurane, SEVO sevoflurane, BT body temperature, HR heart rate in beats per min, RR respiratory rate in breaths per min)

Miscellaneous

52. Overview of collected North Pacific Universities Marine Mammal Research Consortium (NPUMMRC) projects. The NPUMMRC is a consortium of scientists associated with various universities along the west coast of North America including Alaska. The following text was excerpted from the NPUMMRC website at www.marinemammal.org. Only those sections that have referenced specific projects are included.

Body condition

We are attempting to collect additional data from sea lions taken in the native Alaska subsistence harvest in a project coordinated by Dr. Alan Springer (UAF). Subsistence hunters are providing increasing numbers of samples and morphometric measurements to researchers.

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Teeth

The teeth of sea lions have annual growth annuli (rings much like in trees), which scientist have been using to age individuals. However, Dr. David Sampson (OSU) thinks that the chemical composition of the teeth can yield even more information. His idea is that changes in the physical or chemical structure of the teeth can be used to date specific life-history events, such as weaning, the onset of maturity, or age at first lactation. Dr. Roger Nielson (OSU) has been using an electron microprobe to measure the elemental micro-composition of teeth obtained from dead Steller sea lions and from the National Marine Mammal Laboratory (NMFS). This initial study will determine whether archived teeth can be used to reconstruct changes in life history parameters that may provide insight into what happened to Steller sea lions.

Haulout Behavior

A second behavioral study was initiated in June 1996 at a non-breeding (haulout) site at Timbered Island in Southeast Alaska to quantify the activities and behaviors of these animals. Roughly 45% of Steller sea lions use haulouts during the summer, yet relatively little is known about this group of animals. Our pilot study was designed to monitor the juvenile age class and document summer behavior, noting the incidence of copulation and the processes of weaning. With financial assistance from the National Fish and Wildlife Foundation, a team of biologists returned to Timbered Island in May 1997, and a second team was sent to Sea Otter Island, another nonbreeding site in the area of decline.

Thermoregulation

Steller sea lions are well adapted to a life spent in the waters of the North Pacific. However, it still takes energy to maintain a constant deep body temperature. This is known as the cost of thermoregulation. It is unclear whether a Steller sea lion (particularly a young one) has to expend more energy to stay warm when water temperatures approach the freezing point. The Consortium has installed a water-chilling unit, so that water temperatures in the testing tanks can be lowered to mimic those found in the natural environment. Dr. Rosen (UBC) has been measuring the energy use (oxygen consumption) of the sea lions at different water temperatures and during different seasons. Additionally, the effect of exercise on thermoregulation can also be measured in the swim mill.

Predation

Killer whales have been observed to attack sea lions. The stomach of a dead killer whale that washed ashore in Prince William Sound in the summer of 1992 contained flipper tags from 14 Steller sea lions. A study led by Lance Barrett-Lennard (UBC) sought to determine whether killer whale predation could significantly affect sea lion numbers. Using a number of techniques, they developed a mathematical computer simulation that concluded that predation by 'transient' killer whales may account for a significant portion of the total annual mortality of sea

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lions in Alaska and British Columbia. The effects of predation on a robust sea lion population (consisting of over 100,000 animals) are minimal, but with smaller populations (<50,000) the effects are more significant, and may even be sufficient to drive a population decline. The authors conclude that killer whales did not cause the sea lion decline, but may now be a significant contributing factor. The model suggests that as many as 18% of the sea lions that die each year in Alaska are taken by killer whales. What is killing the other 82% of the missing Steller sea lions remains unanswered.

Ecosystem Change

Another possible explanation for the decline of Steller sea lions is that an ecosystem shift changed the food base in the North Pacific in the mid 1970s. Dr. Springer (UA) is examining the hypothesis that mass removals of whales from the North Pacific contributed to ecosystem change and declines in the abundance of pinnipeds and seabirds. Removals of whales, plus the collapse of Pacific Ocean perch, herring, and yellowfin sole stocks during the same interval in the eastern Bering Sea and Gulf of Alaska (1950s-1960s), resulted in the rapid loss of several million tons of biomass from this region. Such an abrupt change in biological constraints could have altered energy flow through food webs and could have caused the recent declines of sea lions, harbor seals, fur seals, and certain seabirds.

Another hypothesis under consideration is that ecosystem change resulted primarily from variability in patterns of weather and climate, particularly as related to the Aleutian Low pressure system. According to a recent forecast, the NE Pacific climate will cool through the coming decade and enter a "cold" regime by about the year 2005, characterized by conditions that prevailed in the 1950s-1970s. Biological correlates of atmospheric regime shifts continue to be discovered over a wide part of the North Pacific and Bering Sea. These include broad scale changes in primary and secondary ocean production, numbers of salmon and forage fishes, and the abundance of certain species of seabirds and marine mammals. Thus, the structure and functioning of the ecosystem may respond to changes in atmospheric forcing. A team of researchers headed by Dr. Trites has been constructing a mathematical model of the Eastern Bering Sea ecosystem. With financial support from the David and Lucille Packard Foundation, the model is being used to test the hypothesized cascading effects on Steller sea lions of commercial whaling, overfishing, and climate change.

Appendix A.3. Summary of proposals recommended by NMFS for funding under the Steller Sea Lion Research Initiative (SSLRI).

Foreword

This summary of research proposals recommended for funding under the Steller Sea Lion Research Initiative (SSLRI) was kindly provided by NMFS. Please note that recommendations are subject to final approval by the NOAA Grants Officer who ensures compliance with all Federal laws, policies, and procedures (e.g., name checks, permit requirements, NEPA, etc.). Projects should not be initiated in expectation of Federal funding until notice of award document is received. Further information about the Steller Sea Lion Research Initiative can be found at the NMFS website http://www.fakr.noaa.gov/omi/grants/sslri/default.htm.

List of Proposals

Proposal #:01-SSL-041
Name of Proposal: Nutritional Significance of Ephemeral High-quality Foraging Opportunities for Steller Sea Lions.
Applicant: University of Washington
Principal Investigator: Glenn B. VanBlaricom
Number of years: 3
Proposed Funding Amount: $573,712
Brief Project Description: An evaluation of the hypothesis that ephemeral high-quality foraging opportunities on certain forage fish species may be more readily available to the eastern population of Steller sea lions than to the declining and endangered western population. They will examine the hypothesis by characterizing within and between region variation in the characteristic dietary fatty acid profiles of forage fish species; conduct studies of captive sea lions to determine the strength and persistence of fatty acid signatures, in sea lion blubber, that result from the feeding on forage fish; and conduct blubber sampling of free ranging sea lions to assess the frequency of occurrence of fatty acid signatures from forage fish in wild sea lion populations. Sampling of blubber from free ranging sea lions will be done in collaboration with scientists from the National Marine Mammal Laboratory.

Proposal #: 01-SSL-018
Name of Proposal: High Resolution Foraging Behavior and Movement Patterns of Steller Sea Lion Juveniles in Regions of Increase and Decline
Applicant: University of Alaska Anchorage
Principal Investigator: Jennifer M. Burns PhD.
Number of years: 3
Proposed Funding Amount: $478,981
Brief Project Description: This project will determine the foraging range and behavior of 20 juvenile Steller sea lions in the Kodiak region (decline) and 20 in the Dutch Harbor/Unimak region (increase) using purpose designed high-resolution satellite relay date loggers (Sea Mammal Research

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Unit, St. Andrews, Scotland). From this, we will be able to construct fine-scale 3D habitat use maps, map juvenile movement patterns with respect to habitat characteristics (both physical and biological), assess movements relative to critical habitat, and examine differences in foraging effort and diving patterns (diel, seasonal, and regional patterns depth, duration, bout lengths), and characterize the relationship between foraging effort and physiological status. Cooperative activities with ADF&G and NMFS include coordinating tagging effort and design, sharing data on juvenile condition, placing project personnel on cruises within the study areas, and identifying a subset of juveniles captured by NMFS and ADF&G to be outfitted with our SRDLs.

Proposal #: 01-SSL-001
Name of Proposal: Implications of Varying Food Distribution For Fitness in Steller Sea Lions
Applicant: University of St. Andrews, UK
Principal Investigator: Ian Boyd, PhD
Number of years: 2
Proposed Funding Amount: $658,443
Brief Project Description: This proposal addresses the issue of what prey distributions are required to sustain Steller sea lions. It is based upon the application principles concerning the way in which body size interacts with energy expenditure and about how these animals are likely to maximize fitness by optimizing their time-energy budgets under differing environmental conditions. To describe and understand the functional response of Steller sea lions to variation in prey distribution and abundance. This will be done by linking models of sea lion behavior at different scales to examine how changes in prey encounter rates during individual dives is likely to scale up to influence fitness and, in turn, how this influences population dynamics. The study will integrate across most data sources for Steller sea lions and it will develop a new state-based approach to examining population dynamics. Thereby, it will create a tool for the synthesis of past, current and future empirical studies populations and also of the potential consequences of management actions for the recovery of these populations. It will also provide a framework within which to understand how changes in prey distribution and abundance, caused by climate change or by fisheries, are likely to effect sea lion populations. Cooperative activities with NMFS will be required only in as much as access is requested to selected aerial photographs of Steller sea lion haul-outs and data will be required form historical hydroacoustic surveys to develop statistical descriptions of the prey field.

Proposal #: 01-SSL-010
Name of Proposal: Investigations of Steller Sea Lion Predation by Killer Whales in Southeastern Alaska
Applicant: University of Alaska Southeast
Principal Investigator: Janice M. Straley
Number of years: 3
Proposed Funding Amount: $210,774
Brief Project Description: Studies of killer whale predation on declining Steller sea lion populations have suggested that killer whales may have contributed to the decline and that predation

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is preventing recovery. However, a lack of information on killer whales exists for many areas of Alaska. Killer whale population numbers and the proportion of that population that eat marine mammals are needed to fully assess this situation. We propose to study killer whale predation rates in Southeast Alaska, where Steller sea lion numbers are increasing. The population dynamics of Steller sea lions that live in Southeast Alaska may be similar to what existed historically in western Alaska, where Steller sea lion numbers have declined dramatically since the 1970s. The project goals will be to: (1) provide observational data on killer whale predation upon increasing Steller sea lion population; and (2) collect acoustic recordings to determine the structure and composition of killer whale calls at the time of kills. The primary objective will be to compare data collected during this study with data from concurrent studies in the Gulf of Alaska and Aleutian Islands conducted by the North Pacific Universities Marine Mammal Research Consortium (NPUMMRC). NPUMMRC will use these data in mathematical models of killer whale predation by region in Alaska to better understand the role of predation in the decline and recovery of Steller sea lions.

Proposal #: 01-SSL-007
Applicant: North Pacific Marine Science Foundation
Subproject #1: Bioenergetics Studies of Captive Steller Sea Lions
Principal Investigator: Dr. Andrew Trites, Dr. David Rosen
Number of years: 3
Brief Project Description: A series of bioenergetic and nutritional experiments will be conducted with captive Steller sea lions to determine how changes in the biotic and physical environment effect the energy needs, health and survival of sea lions. Feeding manipulations will document the biological value of different key prey species. Also to be consider will be the consequences for Steller sea lions of changes in the type, abundance, or distribution of prey. Determinations of key bioenergetic parameters, in association with a computer model, will clarify the relationship between (individual and population level) sea lion energy budgets, food availability, energetic demands, and survival. Open-water experiments with captive animals will be initiated for the first time to provide bioenergetic data across a wider range of conditions than can be obtained from inside an Aquarium. Our research program will also permit the testing and development of tools and techniques to evaluate sea lions in the wild.
Subproject #3: Steller Sea Lion Diet Quantification Studies
Principal Investigator: Domonic Tollit PhD, Dr. Andrew Trites
Number of years: 3
Brief Project Description: Controlled feeding studies of captive Steller sea lions and statistical modeling will be used to derive an integrated set of keys, correction factors, relationship, and validations to estimate the composition and size of prey consumed by Steller sea lions (with error terms). Captive feeding studies will focus on the remains of prey found in scat. A concurrent study will validate the use of blubber fatty acid signatures to determine diet composition. A biostatistician will derive appropriate statistical techniques for estimating the size and composition of prey consumed from bones found in scats, as well as address questions concerning the numbers of samples required to accurately quantify diet. Together, these studies aim to improve the accuracy of methods used to determine Steller sea lion diets.

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Subproject #8: Killer Whale Predation on Steller Sea Lions in Western Alaska
Principal Investigator: Lance G. Barrett-Lennard, PhD.
Number of years: 3
Brief Project Description: Predator studies will investigate the role that killer whales and sharks have played in the decline and lack of recovery of Steller sea lions.
Subproject # 9: Remote Passive Acoustic Monitoring of Killer Whales
Principal Investigator: John Ford, PhD
Number of years: 3
Brief Project Description: This proposal is to develop an innovative new system for passive acoustic monitoring of the movements of killer whale pods in coastal waters of Alaska. This system will take advantage of the unique vocal dialects used by killer whales, which allow acoustic identification of population and, in many cases, social group affiliation of vocalizing individuals. An instrumentation package will be developed which continually monitors the underwater acoustic environment and, upon detection of killer whale signals by an advanced voice recognition algorithm, automatically samples and digitally stores the vocalizations. A network of such acoustic monitoring devices deployed at strategic locations would provide important data on the year-round frequency of occurrence of specific killer whales groups and ecotypes, and an indication of the extent of predatory activities involving marine mammals at key locations.
Proposed Funding Amount (Total all subprojects): $2,807,000

Proposal #: 01-SSL-069
Name of Proposal: A Study to Evaluate Transmitter Implant Methodology
Applicant: Colorado State University
Principal Investigator: Albert Wendell Nelson, DVM
Number of years: 2
Proposed Funding Amount: $331,444
Brief Project Description: Study in sheep will develop a protocol to be used in sea lions for long term tracking of activities. After this study is complete the technology will be tested in non-endangered seals of sea lions before sea lion study is initiated.

Proposal #: 01-SSL-046
Name of Proposal: Installation of a Remote Census and Photogrammetry Network: Validation and Assessment of Seasonal and Individual Steller Sea Lion Body Condition and Population Trends
Applicant: Texas A&M Research Foundation
Principal Investigator: Dr. Markus Horning
Number of years: 3
Proposed Funding Amount: $1,056,139
Brief Project Description: Develop and validate the photogrammetric, remote estimation of body mass and condition of Steller sea lions, using animals held at the Alaska Sea Life Center. Build and install two remote, Satellite Linked Data Acquisition and Photogrammetry systems (SLIDAP systems), currently under development, at locations in the Aleutian Islands. The two new SLIDAP

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systems will be used in conjunction with two more systems to collect detailed, year-round census data. We will estimate by three-dimensional photogrammetry, body mass and condition trends at monitoring locations, both cross-sectional and longitudinal, and throughout the year. Assistance is requested from the NMFS for the installation of two SLIDAAP systems in the Aleutian Islands, as well as for periodic servicing, via helicopter flights.

Proposal #: 01-SSL-062
Name of Proposal: Early and Late Pregnancy Rates of Alaskan Steller Sea Lions and Examination of the Role of Maternal Condition
Applicant: The Regents of the University of California
Principal Investigator: Bill L. Lasley
Number of years: 3
Proposed Funding Amount: $774,564
Brief Project Description: This project will examine pregnancy status of Steller sea lion in an increasing (Kodiak Island) and decreasing (Unimak Pass) subpopulation during early and late gestation using reproductive hormone concentrations excreted in fecal material. The effects of maternal condition on reproductive status will also be examined using a surrogate otariid species (northern fur seals). Female fur seals will be captured, blood samples collected, and a non-invasive method of determining lactation status of Steller sea lions (from fecal material) will be generated. All field sampling will be conducted cooperatively between UC Davis and NMML to reduce research cost and greatly expand information obtained from these data. There is a paucity of information available during our sampling periods and they are life-history stages critical for reproductive female and juvenile Steller sea lions.

Proposal #: 01-SSL-073
Name of Proposal: Improving Access to ADF&G's Lower Cook Inlet Pacific Herring Stock Assessment and Commercial Fishery Database, Including Observations of Steller Sea Lions
Applicant: State of Alaska
Principal Investigator: Edward Otis
Number of years: 1
Proposed Funding Amount: $66,499
Brief Project Description: Aerial surveys to assess the distribution, abundance, and spawning timing of herring stocks in Lower Cook Inlet (LCI) since 1978. Aerial surveyors also frequently noted the number and location of Steller sea lions and other marine mammals as indications that herring were in the area. Much of this geo-referenced information is available only as notations drawn onto paper maps surveyors used to document their observations during surveys. This project will synthesize ADF&G's LCI herring stock assessment and commercial herring fishery information into an ArcView GIS database that will be made available to other researchers via CD-ROM copies and map layouts. The resulting database is expected to have utility to other researchers attempting to better understand the relationship between sea lions, fisheries, and a shared prey species.

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Proposal #: 01-SSL-050
Name of Proposal: Foraging Ecology and Hunting Behavior of Adult and Juvenile Steller Sea Lions
Applicant: Texas A&M Research Foundation
Principal Investigator: Randall Davis
Number of years: 3
Proposed Funding Amount: $711,112
Brief Project Description: Much of our knowledge about Steller sea lion diving and foraging behavior is based on dive depth and duration data, but information on actual foraging behavior and effort is circumstantial. We propose to study the hunting behavior and three-dimensional movements of SSL by attaching a small video system/data recorder to adults and juveniles. This system will record 80 hr of video and audio as well as depth, swim speed, compass bearing, ambient water temperature, dissolved oxygen, and ambient light level at one-second intervals. In addition, it will record swimming effort by monitoring fore flipper movement with a digital accelerometer. These data will provide fundamental information on foraging ecology of SSL and the foraging behaviors they use to locate and capture prey. We will examine the question of whether juvenile SSL are excluded from food resources available to deeper diving adults.

Proposal #: 01-SSL-025
Name of Proposal: Fish Assemblages Associated with Steller Sea Lion haul-outs
Applicant: UAF, School of Fisheries & Ocean Sciences
Principal Investigator: Brenda Konar
Number of years: 2
Proposed Funding Amount: $175,559
Brief Project Description: The proposal is to use SCUBA-based surveys to quantify juvenile and adult fish species present in nearshore waters adjacent to two sea lion haul-outs. Seasonal prey availability and biological and physical parameters recorded at these sites will be used to describe nearshore habitat used by young sea lions for shelter, prey, and training. This will be compared to results of similar surveys we will conduct at two nearby sites not used by Steller sea lions as haul-outs as a means of assessing key components of traditionally used haul-out habitat. Our SCUBA surveys will be coordinated and scheduled to coincide with and augment ongoing research on Steller sea lions diets, foraging patterns, and offshore prey availability.

Proposal #: 01-SSL-065
Name of Proposal: Coastal Bathymetry within the Range of Steller Sea Lions in Alaska
Applicant: State of Alaska
Principal Investigator: Thomas S. Gelatt
Number of years: 1
Proposed Funding Amount: $44,101
Brief Project Description: High-quality digital bathymetry of the continental shelf, bays and fjords are sparse. Alternative digital bathymetry layers, which cover the entire range of Steller sea lions in Alaska, are of low resolution. The low resolution has made the extant data difficult to work with,

especially in bays, fjords, and areas close to shore. This award is for the purchase of an existing digital bathymetric map of the Gulf of Alaska, Aleutian Islands, and Bering Sea. In addition, to hire a professional contractor to digitize those areas not included in the existing map, and for the equipment required to store and process these data. Once processed into a surface model of the seafloor, we will use these bathymetry to enhance the presentation and analysis of Steller sea lion movement and diving behavior.

Proposal #: 01-SSL-047
Name of Proposal: Satellite-Linked Mortality Transmitters in Steller Sea Lions: Assessing the Effects of Health Status, Foraging Ability, and Environmental Variability on Juvenile Survival and Population Trends
Applicant: Texas A&M Research Foundation
Principal Investigator: Dr. Markus Horning
Number of years: 3
Proposed Funding Amount: $1,689,406
Brief Project Description: This project is to implant satellite-linked mortality transmitters (SMX tags) into 60 free-ranging juvenile Steller sea lions, and an additional 12 animals temporarily held at the Alaska Sea Life Center. We will perform comprehensive assessments of the status of body condition, health and immune system, and pollutant levels. From the SMX tags we will determine the time and date of death and weekly cumulative foraging effort from implantation until death. In a new experimental paradigm, we will analyze differences between survivors and non-survivors in conditional and health status at time of release, as well as seasonal, interannual and ontogenetic dive effort. We will test the predictive power of health, condition and behavioral parameters measurable after weaning, on future survival and thus population trends. Assistance is requested from the NMFS for coordinating and conducting ship-based juvenile sea lion capture trips since NMFS is the organization most qualified to conduct this task. At the discretion of NMFS, this task can be subcontracted partially or entirely to ADF&G. In addition, NMFS will be tasked with deploying and monitoring external SRDs on SMX implanted sea lions.

Proposal #: 01-SSL-021
Name of Proposal: Seasonal Forage Patterns of Steller Sea Lions
Applicant: UAF, School of Fisheries & Ocean Sciences
Principal Investigator: Kate M. Wynne
Number of years: 2
Proposed Funding Amount: $111,464
Brief Project Description: Collection of potential prey species will be augmented by fish surveys conducted by NMFS during the course of this study.

Proposal #: 01-SSL-055
Name of Proposal: Metal Toxicity in Steller Sea Lion (Eumetopias jubatus) Tissues and Cell Lines
Applicant: Yale University, School of Medicine
Principal Investigator: John P. Wise, PhD.
Number of years: 3
Proposed Funding Amount: $1,096,715
Brief Project Description: This proposal investigates the role of contaminants as environmental factors in the decline of the western population of the Steller sea lion. It focuses on metals, particularly widespread and toxic class of environmental contaminants and measures of their accumulation in the tissues of the sea lions. Further, it investigates the toxicity of these metals in the major organ systems of the sea lions by establishing cell lines from these organ systems and determining the potencies of metals in these lines, so that a priority list can be developed for intervention measures.

Proposal #: 01-SSL-002
Name of Proposal: Investigation of retinol (Vit. A) and tocopherol (Vit. E) status in Steller Sea Lion: Contribution to Nutritional Stress in Declining Populations
Applicant: Sea Research Foundation, Mystic Aquarium
Principal Investigator: Dr. Lisa Mazzaro
Number of years: 2
Proposed Funding Amount: $421,690
Brief Project Description: Significant evidence supports the hypothesis that Steller sea lions are declining because of an altered diet that does not meet their nutritional needs. Low lipid content has been identified as an important difference. This study will investigate a related aspect of diet quality, fat-soluble vitamins. Vitamins A and E are required for normal growth, development and reproduction, yet there is little information on the vitamin content of the current diet of the Steller sea lion in areas of decline, the vitamin status of wild animals, and the specific dietary requirements of the sea lions. The study will analyze samples collected by and/or archived by NMFS.

Proposal #: 01-SSL-049
Name of Proposal: Linking Animal-borne Data Records to Autonomous remote Imaging Systems: Implementing the RAT-Link
Applicant: Texas A&M Research Foundation
Principal Investigator: Dr. Markus Horning
Number of years: 2
Proposed Funding Amount: $281,446
Brief Project Description: This proposal is to develop the hardware and software specifications for a short-range, bi-directional radio data link between animal-borne data records, and satellite-linked remote, automated data collection and relay stations. This Roving Archival Tag Link (RAT-Link) will be adapted for use on and tested with a miniaturized Timed-Data Recorder (TDR), in cooperation with the leading manufacturer of TDRs, Wildlife Computers. The purpose of the RAT-

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Link is to facilitate the recovery of high-density data from implanted or external archival tags for use on Steller sea lions under typical conditions where recovery of high-density data is very difficult. The development of the RAT-Link concept has just been initiated by Texas A&M's Applied Biotelemetry Lab in conjunction with Wildlife Computers, under sponsorship by the National Science Foundation, Division of Polar Programs. This same NSF program is also sponsoring the development and application of the SLIDAP system, a satellite-linked remote autonomous imaging and data collection system suitable for integration for the RAT-Link.

Proposal #: 01-SSL-022
Name of Proposal: Comparison of Prey Availability and Ecology in Steller Sea Lion Foraging Regions: A Coordinated Aerial Remote Sensing Study
Applicant: UAF, School of Fisheries & Ocean Sciences
Principal Investigator: Evelyn Brown
Number of years: 2
Funding Amount: $1,003,147
Brief Project Description: This proposal is coordinated with ongoing shipboard sea lion research programs in the three areas in Alaska (Kodiak, Lower Cook Inlet, and Southeast Alaska) during two time periods (late spring, late summer). The overall objective is to compare synoptic marine ecological information between two sea lion foraging regions over large spatial regions at three temporal scales (diurnal, seasonal, interannual), supplementing data from the existing surveys. One region (Southeast Alaska) has a healthy population and the other (Kodiak) has a population in decline. The secondary objective is to cover regions not accessible by ship in the extreme nearshore and upper surface (<5 m) and to extend coverage beyond ship transects. Using airborne remote sensing instrumentation (including lidar, IR radiometer, ocean color video, high resolution digital video, and IR video) we will map ocean fronts, chlorophyll, zooplankton, fish prey resources, fish and marine mammal predators, predator/prey interactions (foraging bouts), and human activity in the upper 50 m of the water column during the day and night. We will use shipboard results for signal validation, interpretation, and to estimate detection probabilities (sub-attenuation correction factors). We will produce 3-D visualizations of the results, link aerial to satellite data, and perform geostatistical analysis for interpretation. We require collaboration from the NOAA ETL lab in Boulder to provide instrumentation and personnel for airborne surveys and signal processing.

Proposal #: 01-SSL-052
Name of Proposal: Acoustic Characterization of Steller Sea Lion Forage Species
Applicant: University of Washington
Principal Investigator: John K. Horne, PhD.
Number of years: 2
Proposed Funding Amount: $196,436
Brief Project Description: This proposal has four components: (1) acoustic characterization of Steller sea lion prey species; (2) quantify variance of acoustic backscatter within and among species; (3) comparison of forage and other fish species in the Bering Sea and Gulf of Alaska; and (4) comparison of acoustic model results to acoustic survey data.

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Proposal #: 01-SSL-013
Name of Proposal: Traditional Knowledge of Steller Sea Lions and Community-Based Monitoring of Local Seasonal Haul-outs.
Applicant: The Alaska Sea Otter and Steller Sea Lion Commission
Principal Investigator: Lianna Jack
Number of years: 3
Proposed Funding Amount: $475,855
Brief Project Description: The Commission, in partnership with 10 Alaska coastal communities, will develop and implement a traditional knowledge of Steller sea lion health and abundance survey. From the survey, local seasonal haul-outs will be identified, protocols will be developed for community based monitoring of local seasonal haul-outs, and the testing of the protocols will ensure reporting of survey results.

Proposal #: 01-SSL-016
Name of Proposal: Subsistence Harvest Monitoring of Steller Sea Lions on St. Paul Island, Alaska
Applicant: Aleut Community of St. Paul Island
Principal Investigator: Michael T. Williams, Jesse A. Coltrane
Number of years: 3
Proposed Funding Amount: $210,957
Brief Project Description: This project objectives are: (1) to design and implement a monitoring program for the subsistence harvest of Steller sea lions on St. Paul Island, Alaska; (2) to train samplers from other rural Alaska communities in tissue sampling techniques; and (3) to devise and implement a marine mammal tissue collection and distribution center for samples collected from marine mammals during subsistence harvests.

Proposal #: 01-SSL-053
Name of Proposal: Assessing Population Trends and Dietary Intake of Steller Sea Lion Populations Along the Western Alaska Peninsula and Eastern Aleutians.
Applicant: Aleutians East Borough
Principal Investigator: Kate Wynne
Number of years: 3
Proposed Funding Amount: $547,907
Brief Project Description: This proposal seeks to improve the accuracy and precision of the population indices through expanded aerial and vessel surveys in one portion of the endangered western stock of Steller sea lions. Also to provide additional information on seasonal prey consumption by Steller sea lions through scat collection at rookeries and haul-outs along the Alaska Peninsula and Eastern Aleutians. Provide additional platforms of opportunity to observe Steller sea lion behavior at haul-outs and rookeries, observe possible killer whale predation on Steller sea lions, and resight animals branded under National Marine Fisheries Service research programs. This proposal will require the issuance of marine mammal permits from NMFS.

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Proposal #: 01-SSL-006
Name of Proposal: Identify Steller Sea Lion Rookeries; Gathering Traditional Ecological Information on Steller Sea Lions from Perryville, Alaska
Applicant: Bristol Bay Native Association
Principal Investigator: Helen Chythlook
Number of years: 1
Proposed Funding Amount: $80,844
Brief Project Description: Due to decline in Steller sea lion populations around Perryville, traditional subsistence hunting activities in some areas of the Alaska Peninsula has stopped. This proposal will fill the need for Steller sea lion research associated in identifying rookeries and gathering important traditional ecological information to build local research capacity of Alaska Natives in the Peninsula communities to enhance their subsistence way of life.

Proposal #: 01-SSL-042
Name of Proposal: Assessment of Fine-Scaled Interactions Between Steller Sea Lion Abundance and Trends of Local Fisheries
Applicant: University of Washington, School of Aquatic and Fishery Sciences
Principal Investigator: John R. Skalski
Number of years: 2
Proposed Funding Amount: $268,238
Brief Project Description: This project will examine the fine-scaled spatial-temporal trends in multispecies fisheries abundance and localized declines in sea lion abundance. Experimental trawl and NOAA survey data, along with NOAA fisheries stock assessment models, will be used in assessing localized trends in Steller sea lion abundance. NMFS will provide access to survey data and stock assessment models.

Proposal #: 01-SSL-031
Name of Proposal: Geographical Ecology of Steller Sea Lions and Ephemeral, High-quality Prey Species in Southeast Alaska
Applicant: University of Alaska Fairbanks
Principal Investigator: Mary F. Wilson
Number of years: 2
Proposed Funding Amount: $136,575
Brief Project Description: This proposal will examine the geographical relationship of spring-spawning forage fish runs to Steller sea lion haul-out and foraging distribution in Southeast Alaska. This goes toward an ultimate goal of determining the fitness consequences of high-quality spring prey for sea lions. We will provide prey samples for caloric and fatty acid analyses with NMFS biologists and share information.

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Proposal #: 01-SSL-068
Title: Interaction of Steller Sea Lions and Fisheries Managed by the State of Alaska.
Applicant: Alaska Department of Fish and Game
Principal Investigator: Douglas Eggers
Number of years: 1
Funding Amount: $250,478
Brief Project Description: This project proposes to evaluate competitive interaction of state managed fisheries and Steller sea lions based on a framework procedure to determine candidate areas (Western, Central and East Gulf of Alaska) and prey species (pollock, salmon, Pacific cod, and small forage fishes included Herring) where a potential competitive interaction between fisheries and SSL exist. Candidate areas are areas where SSL declines cannot be explained from documented takes; candidate prey species are prey species where there is a significant overlap in the size consumed and exploited. If a decline in the abundance of a candidate prey species or an expansion of fisheries targeted on the candidate prey species has occurred in the candidate area, coincide with decline in SSL, then competitive interaction cannot be ruled out. For these situations, management measures to mitigate competitive interaction will be implemented.

Proposal #: 01-SSL-066
Title: The Subsistence Harvest of Steller Sea Lions and Harbor Seals by Alaska Natives. Harvest Assessment Program, 2001
Applicant: Alaska Department of Fish and Game
Principal Investigator: James Fall
Number of years: 1
Funding Amount: $250,000
Brief Project Description: This project proposes to document the annual subsistence takes of sea lions and harbor seals by Alaska Natives in 62 communities in 2001. The project will be conducted by the State in partnership with the Alaska Native Harbor Seal Commission. The project goal is to estimate the total annual direct takes of sea lions and harbor seals by geographic area. Information collected will include harvest, struck and lost, total take, month of take, sex of animals, age class of animals, number of hunters, harvest success rates. Qualitative information will be statistically analyzed and presented in a published annual report and an updated computer accessible database.

Proposal #: 01-SSL-071
Title: Estimates of changes in the foraging behavior of Steller sea lions in response to precipitous declines of the herring population in Prince William Sound
Applicant: Prince William Sound Science and Technology Institute
Principal Investigator: Richard Thorne
Number of years: 1
Funding Amount: $220,000
Brief Project Description: The Pacific herring population in Prince William Sound has declined 50-fold over the past decade, and recently dropped below estimates of average annual marine

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mammal predation from the mid-1990s. Changes in the foraging behavior of Steller sea lions are apparent in the past year. The anticipated continued herring decline will force major changes in sea lion foraging behavior, distribution, and possibly abundance. This study proposes to investigate these changes using techniques developed by the Prince William Sound Science Center over the past several years.