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Contract Number SSL-01-B

Between: **The North Pacific Fishery Management Council (hereafter referred to as Council) and, THE NATIONAL ACADEMIES DIVISION ON EARTH AND LIFE STUDIES - OCEAN STUDIES BOARD (hereafter referred to as NAS).**

Subject: **The Alaska Groundfish Fishery and Steller Sea Lions**

Summary Scope of Work: This study will examine interactions between Alaska groundfish fisheries and Steller sea lions (Eumetopias jubatus, SSLs) and the role of these fisheries in the evolving status of the SSL population. The focus of the study will be: 1) the status of current knowledge about the decline of the SSL population in the Bering Sea and Gulf of Alaska ecosystems, 2) the relative importance of food competition and other possible causes of SSL population decline and impediments to SSL recovery, 3) the critical information gaps in understanding the interactions between SSLs and Alaska fisheries, 4) the type of research programs needed to identify and assess potential human and natural causes of SSL decline, and 5) the components of an effective SSL monitoring program, with yardsticks for evaluating the efficacy of various management approaches.

CONTEXT

Policy Context:

Steller sea lions are found throughout the North Pacific with about 70% living in Alaskan waters. The Alaskan populations have declined by roughly 80% from the mid-1970's to the present. In 1990, the Steller sea lion was listed as a threatened species and in 1997 reclassified as two distinct populations with the population west of 144 degrees W listed as an endangered species and the eastern population still listed as threatened. The causes of this decline are uncertain, although food quality and availability are often cited as likely contributing factors.

Under the Endangered Species Act (ESA), federal agencies are required to ensure that their actions, or actions authorized or funded by them, are not likely to jeopardize the survival or recovery of protected species or damage their critical habitat. Section 7 of the ESA requires that when an action may affect a marine listed species or its critical habitat, the federal agency conducting or authorizing that action must consult with the National Marine Fisheries Service (NMFS). As part of the authorization of the fishery management plans for the commercial groundfish fisheries in the Bering Sea and Aleutian Islands (BSAI) region and the Gulf of Alaska (GOA) region, NMFS summarized the consultation in a biological opinion as required under Section 7 of the ESA. The purpose of the biological opinion is to ascertain if the groundfish fisheries, as implemented under the fishery management plans, are likely to imperil the continued existence of Steller sea lions (and other listed species) or are likely to destroy or adversely modify critical habitat. In the opinion issued on December 22, 1998, NMFS concluded that the groundfish fisheries, excepting pollock, were unlikely to cause harm to listed species. In the case of the pollock fishery, there was a finding of jeopardy and restrictive measures to mitigate this jeopardy were implemented in 1999 and 2000. However, this

opinion was challenged in court and found to be arbitrary and capricious for failing to include a sufficiently comprehensive analysis of groundfish fisheries and their individual, combined, and cumulative effects. On this basis, the court found that NMFS was out of compliance with the ESA (GreenPeace v. National Marine Fisheries Service, 80 F. Supp. 2d 1137 WD. Wash. 2000). In the revised Biological Opinion issued on November 30, 2000, NMFS concluded that Steller sea lion populations are jeopardized by the Alaska groundfish fisheries including Atka mackerel, Pacific cod, and pollock, due to competition for prey and modification of prey distribution in critical habitat. This revised Biological Opinion found jeopardy with regard to pollock even with the restrictions imposed after the 1998 Biological Opinion.

At the heart of the recent Biological Opinion is the question of whether the groundfish fisheries compete with Steller sea lions for prey species. Answering this question requires evaluation of the dietary requirements, feeding behavior, and foraging success of the sea lions and analysis of commercial fishing practices at appropriate scales of time and space. Competition occurs if the fisheries reduce the availability of prey such that recovery of the population is compromised. Decreased sea lion condition, growth, reproduction, and survival are key indicators.

Technical Context:

It is critical to understand the cause of the population decline in order to develop policies that are most likely to benefit Steller sea lions. The Ocean Studies Board has been asked to review the scientific information and analyses being used in response to the endangered status of the western Steller sea lion population.

The November 2000 Biological Opinion on Steller sea lions (*Eumetopias jubatus*; SSLs) and Alaska groundfish fisheries was discussed at both the North Pacific Fishery Management Council's December 2000 and February 2001 meetings. The following questions are illustrative of issues of concern: 1) Does the evidence of the degree of overlap and potential adverse interaction of the Atka mackerel, pollock, and Pacific cod fisheries indicate that they impede SSL population recovery, given current and past levels of prey base? 2) Have natural environmental phenomena (eg. climate regime shifts) affected the diet of SSLs? 3) What is the relationship between the quality and quantity of prey fish in the diet of SSLs, and does the evidence support the nutritional stress hypothesis? 4) What is the extent of the area that is critical for SSL foraging based on updated foraging and migration observations? 5) Do the extrapolated rates of SSL decline represent the best available science? 6) What is the impact of shark and killer whale predation on SSL populations? 7) What are the enduring effects of past intentional kills and current subsistence takes? 8) What are other potential causes of the decline in SSLs or impediments to their recovery? and 9) What is the marginal benefit of the various reasonable and prudent alternatives (RPAs) implemented or proposed in response to the 1998 and 2000 Biological Opinions based on existing data?

PLAN OF ACTION

Statement of Task:

This study will examine interactions between Alaska groundfish fisheries and Steller sea lions (Eumetopias jubatus, SSLs) and the role of these fisheries in the evolving status of the SSL population. The focus of the study will be: 1) the status of current knowledge about the decline of the SSL population in the Bering Sea and Gulf of Alaska ecosystems, 2) the relative importance of food competition and other possible causes of SSL population decline and impediments to SSL

recovery, 3) the critical information gaps in understanding the interactions between SSLs and Alaska fisheries, 4) the type of research programs needed to identify and assess potential human and natural causes of SSL decline, and 5) the components of an effective SSL monitoring program, with yardsticks for evaluating the efficacy of various management approaches.

Preliminary Work Plan:

A committee of 10 experts will be appointed. The committee will meet four times, including two public sessions, one in Alaska and one in the Washington State. The report will address the five concerns listed in the Statement of Task. The committee will base its findings on an examination of the scientific literature, information contained in the Biological Opinion and supporting materials, input from the public meetings, and other written materials submitted to the committee. A full, in depth pre-publication will be delivered 15 months after receipt of funding (expected to be June 2002). The latter 4 months in the performance period will allow for final editing, layout, and production of the printed report, mailing to committee members and other interested parties, and briefings on the report by staff and committee.

FEDERAL ADVISORY COMMITTEE ACT

The Academy has developed interim policies and procedures to implement Section 15 of the Federal Advisory Committee Act, 5 U.S.C. App. § 15. Section 15 includes certain requirements regarding public access and conflicts of interest that are applicable to agreements under which the Academy, using a committee, provides advice or recommendations to a Federal agency. In accordance with Section 15 of FACA, the Academy shall submit to the government sponsor(s) following delivery of each applicable report a certification that the policies and procedures of the Academy that implement Section 15 of FACA have been substantially complied with in the performance of the grant with respect to the applicable report.

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Product and Dissemination Plan

A report will be prepared subject to the standard NRC review procedures. It will be disseminated to the NPFMC, agency administrators, program managers, congressional staff, scientists and interested local communities. The project staff will coordinate with the NRC Office of News and Public Information to produce materials appropriate for dissemination to the popular press and television and radio media. The report will be made available to the public without restriction and will be posted on the NAS World Wide Web site.

Pre-publication copy

This pre-publication version of the executive summary has been provided to the public to facilitate timely access to the committee's findings. Although the substance of the executive summary is final, editorial changes may be made prior to publication. The final report will be available through the National Academies Press later this month.

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Ocean Studies Board
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Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This study was supported by Contract/Grant No. SSL-01-B between the National Academy of Sciences and the North Pacific Fishery Management Council. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

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THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

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REPORT REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC)'s Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in their review of this report:

D. Lee Alverson, National Resource Consultants, Inc., Seattle
David R. Cline, retired, formerly with World Wildlife Fund, Anchorage
Richard B. Deriso, Inter-American Tropical Tuna Commission, La Jolla, California
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Andrew A. Rosenberg, University of New Hampshire, Durham
Douglas Wartzok, Florida International University, Miami

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Dr. May R. Berenbaum, University of Illinois, Urbana, Illinois, and by Dr. Kenneth Brink, Woods Hole Oceanographic Institution, Woods Hole, Massasschuettes. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

THE DECLINE OF THE STELLER SEA LION IN ALASKAN WATERS

UNTANGLING FOOD WEBS AND FISHING NETS

EXECUTIVE SUMMARY

Executive Summary

Theory helps us bear our ignorance of fact
—George Santayana, *The Sense of Beauty*, 1896

Steller sea lions are found along the North Pacific rim from California to Japan with about 70% of the population living in Alaskan waters. The Alaskan population declined precipitously during the 1970s and 1980s and continued to decline at a slower rate during the 1990s. Overall, the Alaskan population has declined by more than 80% over the past 30 years. In 1990, the Steller sea lion was listed as a threatened species and in 1997 the population west of Cape Suckling (144° W longitude) was listed as endangered under the Endangered Species Act (ESA). The eastern population (Southeast Alaska to California) increased gradually throughout most of its range since the 1970s, but this stock remains listed as threatened. The causes of the decline of the western stock have been the subject of much speculation and debate despite numerous analyses and many detailed reports. There is no widely accepted answer to the question: Why is the Steller sea lion population declining? What might otherwise be an obscure ecological mystery has become an issue of great regional and even national interest because of the regulatory implications for management of the large commercial fisheries in the North Pacific. These fisheries target many of the fish species that comprise the prey base for Steller sea lions.

In November 2000, the ESA consultation prepared by the National Marine Fisheries Service concluded that the Alaska groundfish fishery posed a threat to the recovery of the Steller sea lion and imposed more restrictive measures on the management of the fishery. Concern that the new regulations would bring significant social and economic disruption prompted Congress to direct the North Pacific Fishery Management Council to sponsor an independent scientific review by the National Academy of Sciences on the causes of Steller sea lion decline and the potential efficacy of the new management measures (Box ES.1). This report represents the results of that review.

BOX ES.1

Statement of Task

This study will examine interactions between Alaska groundfish fisheries and Steller sea lions (Eumetopias jubatus, SSLs) and the role of these fisheries in the evolving status of the SSL population. The focus of the study will be: (1) the status of current knowledge about the decline of the SSL population in the Bering Sea and Gulf of Alaska ecosystems, (2) the relative importance of food competition and other possible causes of SSL population decline and impediments to SSL recovery, (3) The critical information gaps in understanding the interactions between SSLs and Alaska fisheries, (4) the type of research programs needed to identify and assess potential human and natural causes of SSL decline, and (5) the components of an effective SSL monitoring program, with yardsticks for evaluating te efficacy of various management approaches.

CAUSES OF DECLINE

Over the past 200 years, many populations of terrestrial and marine mammals have declined precipitously, some to the point of extinction. Most declines of marine mammals have been attributed to human activities, typically as a result of commercial harvest for fur, meat, and oil or because of fishery interactions, through incidental catch in fishing nets, disturbance from fishing activities, or predator control programs. Suspension of these activities reduces the risk of extinction, but for some long-lived species recovery may take decades.

The case of the dramatic decline in the Steller sea lion population has been less straightforward. Steller sea lions have not been subject to large commercial harvests since 1972 and the take of sea lions by fisheries has been estimated to be small relative to the size of the population. During the period of rapid population decrease during the late 1970s through the 1980s, there were also major shifts in abundance of many marine species in the North Pacific attributed to both climatologic events and commercial harvests of fishes. Analysis of these trends has been complicated by the scarcity of baseline population data on the robust sea lion population that existed before 1975 which is needed for comparison with data on the current, depleted population. Since there are few avenues for augmenting this historical database (e.g., reanalysis of existing data, testing of archived tissue samples for contaminants and disease agents, reconstruction of environmental events based on isotope anomalies or annual growth patterns), the cause, or causes, of the early phase of the sea lion population decline will likely remain a source of speculation and debate. However, existing information can be used to identify scenarios that could explain the historical decline and will be valuable in understanding the prospects for recovery of the remaining population.

Under the ESA, federal agencies must ensure that their actions, or actions they authorize, are not likely to jeopardize the survival or recovery of protected species or damage the protected species' critical habitat. Therefore, if a federally regulated activity may affect Steller sea lions, the responsible agency must take actions to ensure that negative impacts are avoided. This requirement has made it imperative to identify human activities that may contribute to the decline of Steller sea lions so that regulatory actions can be adjusted to address threats to the western population's survival. Unlike the biological opinions required by the ESA listing, this report does not assess the statutory basis for regulating the groundfish fisheries.

At least eight plausible hypotheses have been proposed to explain the decline of the sea lion population. These include threats as the result of human activities and naturally occurring events that affect sea lion survival. Human activities that may threaten sea lion recovery include direct takes such as illegal shooting and subsistence harvest, and incidental takes through capture or entanglement in fishing gear. Indirectly, commercial fisheries may disrupt feeding patterns, breeding, and other aspects of sea lion behavior. Also, fishing may decrease the carrying capacity of sea lion habitat through removal of prey species or by shifting the distribution of species such that less nutritious fish dominate the prey base, the so-called "junk food hypothesis." Pollution may pose another indirect effect by impairing the health of sea lions and increasing their susceptibility to disease.

But increased mortality of sea lions may not be just a consequence of human activities. There are natural cycles of abundance and decline in marine ecosystems that are driven by climate variability, predator-prey interactions, and invasions by infectious diseases or toxic algal blooms. It is difficult, and often impossible, to resolve the relative contributions of human and

natural sources of change, especially since complex interactions among species may cause the combined effects to be significantly different from the effects of any single factor.

In part because of the absence of definitive data confirming or excluding any particular hypothesized cause of decline, the regulatory measures taken in response to the protected status of the western population under the ESA have been particularly contentious. **Resolution of this conflict requires management that not only improves chances for the recovery of Steller sea lions, but also facilitates scientific study of the efficacy of these protective measures.**

MAKING THE MOST OF EXISTING INFORMATION

The hypotheses proposed to explain the decline of the western stock fall into two categories. The first category, the bottom-up hypotheses, includes potential causes that would affect the physical condition of sea lions such as:

1) Large scale fishery removals have reduced the availability or quality of prey species,
2) A climate/regime shift in the late 1970s has changed the abundance or distribution of prey species,
3) Non-lethal disease has reduced the foraging efficiency of sea lions, and
4) Pollutants concentrated through the food web has contaminated fish eaten by sea lions, possibly reducing their fecundity or increasing mortality.

The second category, the top-down hypotheses, encompasses factors that kill sea lions independently of the capacity of the environment to support the sea lion population. These include:

1) Predators such as killer whales (or possibly sharks) have switched their prey preference to sea lions,
2) Incidental take of sea lions through capture or entanglement in fishing gear has increased as a result of the expansion of commercial fisheries,
3) Takes of sea lions in the subsistence harvest have been higher than estimated,
4) Shooting of sea lions has been underestimated in the past and present, and
5) Pollution or disease has increased mortality independently of effects on nutrition. For example, introduction of a contagious pathogen could decimate a population and give the same appearance as an efficient predator.

Observed characteristics of sea lion biology and behavior should be different under these two categories. The bottom-up hypotheses predict increased mortality through reduction in physical condition, manifested by changes in physiology, reproductive success, and foraging behavior. Top-down hypotheses predict no loss of individual fitness, but require increased activity by predators, people, or pathogens. Hence, indicators of sea lion health and feeding behavior may be informative in distinguishing the likelihood of these two modes of sustained population decline. It is important to remember that some combination of both types of factors may have contributed to the population decline. For instance, evidence indicating a significant decrease in sea lion physical condition would not exclude the possibility that top down causes

also contributed to overall mortality. Also, geographic variation in environmental conditions across the range of the western population may mean that different factors are to varying degrees responsible for mortality in different parts of the range.

In the existing body of information about Steller sea lions, there is no conclusive evidence supporting either the bottom-up or the top-down hypotheses. Therefore, the available data must be carefully evaluated to ascertain the more plausible causes. First, the evidence can be categorized according to the time period during which it was collected. The rate of decline of the western population has changed since it began in the 1970s. From 1975-1985, the annual rate of decline averaged 5.9%. Over the next five years, the population dropped precipitously – about a 15.6% decrease per year. Since the early 1990s (through 2001), the population has continued to decrease but at the more gradual rate of 5.2% annually. The loss of such a large fraction of the population during a relatively short time span (1985-1990) indicates that sea lions were subject to a threat, or threats, that spurred the decline in the 1980s but by the 1990s these threats either had ended or had less impact.

Second, the evidence can be sorted geographically. In 1995, the National Oceanic and Atmospheric Administration (NOAA) determined that Steller sea lions west of 144° W constituted a distinct population unit based on dispersal patterns, population trends, and genetic differentiation. Because female Steller sea lions tend to return to their natal rookeries for breeding, the western stock may be considered a metapopulation. A metapopulation is a regional population comprised of semi-isolated local populations with limited exchange or interaction, which may fluctuate in response to regional as well as global impacts. Hence, variability in the geographic pattern of decline may point to causes that are specific to particular areas.

Temporal and spatial evaluation of the population data show that the 5-year period of rapid decline (1985-1989) was a range-wide phenomenon and hence was most likely caused by an ecosystem-wide change in the Steller sea lion's environment. Hypotheses that are consistent with this pattern include nutritional limitation through competition with fisheries and changes in prey abundance due to the environmental regime shift in the late 1970s, predators switching from a depleted prey population to sea lions, or introduction of a lethal, highly contagious disease agent such as a virus. Evidence for nutritional limitation includes observations that sea lion condition, growth, and reproductive performance were lower during this time period. However, ecosystem models based on data from the eastern Bering Sea indicate that changes in the relative abundance of prey cannot account for the full magnitude of the decline. Either increased predation or epidemic disease could account for the high mortality rate, but systematic observations of killer whale (or possibly shark) predation were not conducted at that time and serological tests to date have been negative for common pathogens associated with disease epidemics in marine mammals. The large increase in the rate of decline was unlikely to be caused primarily by subsistence harvest, toxic algal blooms, or illegal shooting because these threats tend to vary by geographic location and there is no evidence to suggest that they greatly intensified during this time period. **Multiple factors probably contributed to the widespread decline in the 1980s, including incidental and deliberate mortality associated with fishing activities, but elucidation of the complete spectrum of causes and consequences is unlikely because of gaps in the available data.**

The pattern of decline has changed since the early 1990s. Not only has the overall rate of decline decreased, but also individual rookeries show different population trends. Over the past decade, the majority have continued to decline, some have stayed at the same level, and a few even have shown modest increases. Based on the most recent census of trend sites, comparison

of adult and juvenile counts from 2000 to 2002 show a 13.6% increase in the Gulf of Alaska and less than a 1% decrease in the Aleutian Islands. However, it would be premature to conclude that the Gulf of Alaska population is recovering based on counts from a single year. The predominant cause of decline may have changed between the 1980s and 1990s. It is possible that minor factors during the 1980s have a larger relative impact now because the remaining population is much smaller. Observations made at one site may not apply to other areas or even to nearby rookeries. Research will be required at multiple sites to resolve whether survival is threatened by local, regional, or population-wide causes. **Finer scale spatial analysis of Steller sea lion populations and environmental conditions will be required to uncover potential region-specific determinants that are affecting sea lion survival.**

The more recent period of decline (1990-present) is the primary concern of this report because of the need to provide scientific advice for the design of management actions that do not jeopardize the continued survival of the western Steller sea lion population. Although limited in sample size, geographic range, and seasonality, recent measurements of sea lion condition and foraging activity indicate that the western stock is not nutritionally stressed and individuals are not spending a disproportionate amount of time or energy in locating prey. Analysis of scat components provides evidence that dietary diversity is lower in the western than in the eastern range, but this may represent opportunistic feeding patterns rather than a decrease in availability of preferred prey species. Additionally, the levels of groundfish biomass during the 1990s were large relative to the reduced numbers of sea lions, suggesting that there has been no overall decrease in prey available to sea lions, although it is still possible that localized depletion of some fish species may affect particular rookeries. **Existing data on the more recent period of decline (1990-present) with regard to the bottom-up and top-down hypotheses indicate that bottom-up hypotheses invoking nutritional stress are unlikely to represent the primary threat to recovery.**

Because the preponderance of evidence gathered during the current phase of the decline runs counter to expectations based on bottom-up hypotheses, the committee gave serious consideration to each of the top-down (direct mortality) hypotheses. All four hypotheses in the top-down category identify sources of mortality applicable to both the earlier and current phases of the decline. What has changed since the 1980s is the potential impact of this mortality on the remaining, much smaller population. Although killer whale predation may have had a significant impact on the historical population, continued predation, as well as illegal shooting, incidental take by fishing gears, and subsistence harvests may have a proportionately larger impact on the current depleted sea lion population. In the absence of other significant changes in the ecosystem, the intensity of bottom-up threats is expected to decrease as the sea lion population decreases, but top-down threats are often less dependent on population size. Sea lions remain easy targets for humans and marine predators because they congregate at rookeries and haulouts at certain times of the year. Similarly, sea lions may continue to get ensnared by fishing gear because of the ample banquet of food available around fishing operations. Attraction of killer whales to these same fishing vessels could increase the vulnerability of sea lions to predation. Identifying the most likely top-down hypothesis may depend on matching the different threats to the spatial patterns of sea lion population decline. Different hypotheses may apply to some but not all parts of the large geographic range of the western population. **Although no hypothesis can be excluded based on existing data, top-down sources of mortality appear to pose the greatest threat to the current population. Investigations of**

top-down sources of Steller sea lion mortality should be increased to evaluate the proportionate impact of these factors on the population decline.

MONITORING TO EVALUATE MANAGEMENT EFFICACY

Although most evidence indicates that groundfish fisheries are not causing a range-wide depletion of food resources necessary to sustain the current western population of sea lions, there is insufficient evidence to fully exclude fisheries as a contributing factor to the continuing decline. In some areas, fisheries may compete with sea lions for localized fish stocks, increase incidental mortality due to gear entanglement and associated injuries, disturb animals on haulouts, increase exposure to natural predators through attraction to fish catches, and provide motivation for continued illegal shooting of animals to mitigate lost catches and damaged fishing gear. Moreover, fisheries are one of the few human influences on the Steller sea lion's environment, and hence are subject to regulation under the Endangered Species Act. Therefore, restriction of fishing operations in sea lion habitat remains a reasonable response to the continuing decline of the endangered western population.

The committee identified 5 general management options that might be taken to address the potential impacts of the groundfish fisheries on sea lions and recommended priorities for monitoring to assess the efficacy of each option. These options are evaluated with regard to their scientific potential for discerning the role of the groundfish fishery in the Steller sea lion decline. Each of these options would require continuation of the existing monitoring program (i.e., continued census of trend sites and collection of demographic data based on pup branding and resighting). The committee made the assumption that it is possible to craft each of these options so as to satisfy the requirements of the ESA. The five options are presented below.

1. Wait and see, maintaining current closures indefinitely. Recent management actions, including area closures, may be sufficient to reverse or reduce the rate of population decline. **Under this option the most valuable monitoring information would be derived from annual reference rookery and haulout counts and new demographic data from branded pups.**

2. Eliminate direct fishery impacts with greatly expanded closures. This would require closing the Atka mackerel fishery in the Aleutians and reducing the main pollock fishing areas in the southern half of the eastern Bering Sea. **Under this option, monitoring of fish population dynamics, both locally and at the stock level would be required to determine the effects of the fisheries on stock distribution and fish community composition.**

3. Establish spatial management units consisting of two sets of closed and open areas where each treatment area is centered on a rookery. The western population would be divided into management regions with at least two closed and two open rookeries per region. Because most monitoring activities are conducted at rookeries (pup counts, measurement of vital rates, juvenile tagging, etc.) it makes the most sense to use rookeries (rather than rookeries and haulouts) as the experimental units. Also, sea lions are thought to be more

vulnerable near rookeries because of the age composition (presence of pups and juveniles) and because females must forage near the rookeries so they can return to nurse their pups. The "closed" treatment units would be subject to fishery closures and the "open" units would have sea lion-related fishery restrictions removed. **Under this option, the most critical monitoring needs would be detailed local Steller sea lion censuses and spatial analyses of fish population change for each experimental unit in the overall design.**

4. Implement a "titration experiment" where restrictions on fisheries (such as area closures) are increased progressively over time until a positive response is achieved. This option is a variation on the strategy used during the 1990s. Fishery regulations continue to become more restrictive as long as the sea lion population continues to decline. **This approach requires monitoring of sea lion population trends, but results could be confounded by the lack of baseline data and natural environmental variability.**

5. Micro-monitor and manage localized interactions between sea lions and fisheries to reduce mortality where and when it occurs in the future. **This option would require expansion of all basic monitoring activities (abundance, prey fields, mortality agent distribution) around key rookeries to pinpoint times and places of increased mortality so that appropriate management measures could be taken.** The expense of this program would be high because of a requirement for year-round, continuous monitoring to allow detection of mortality events in all seasons and locations.

To resolve questions about the impact of the fisheries on Steller sea lion survival, the preferred option is #3 because it is the only approach that directly tests the role of fishing in the decline. Option #3 provides the benefits of an adaptive management experiment, reducing the possibility that regulation of the fishing industry is perpetuated without demonstrable benefit to the Steller sea lion population. Not only does the removal of all sea lion-related fishing restrictions in the open areas create opportunities for the industry, it provides a contrasting management treatment necessary for a valid experimental comparison with closed areas. A careful evaluation of past fishing effort in the proposed experimental areas will be required to assess the amount of displaced fishing effort. Placement of open areas where fishing effort has historically been high would decrease the potential for negative impacts arising from shifting effort from the closed to open areas.

Option #3 provides the setting necessary to carry out research studies on Steller sea lion behavior and performance in contrasting environments while controlling for common effects such as large-scale change in oceanographic regimes. This approach acknowledges that there is no best or precautionary policy because the origin of the decline is unknown. Hence, every segment of the population has an uncertain future with or without new restrictions on the fisheries. Multiple sites in various locations must be included in the experiment to control for site-specific variation in threats to the population. If there are multiple causal factors such as food, predation, or fishing-related mortality, then replication is critical to guard against incorrectly applying the results from any single treatment/control comparison to areas where the results would not apply.

Experimental treatment is a policy option that improves management as well as increases understanding of interactions between fisheries and sea lions. Open areas restore opportunities

for fisheries by removing restrictions; closed areas remove any potentially negative local impacts of fisheries on sea lions.

Although the incremental approach may be easier to implement, it contains two serious shortcomings. First, it cannot account for ecosystem change due to factors such as oceanographic regime changes. Hence, the efficacy of new management restrictions would not be distinguishable from environmental change that occurs on decadal time scales, confounding either positive or negative outcomes. Second, a false positive outcome would commit managers to prolong additional fishery restrictions without realizing significant improvement in the survival of Steller sea lions.

Listed below are several guidelines for implementing the spatial management units described under option #3:

- **Fished area (under normal management plans).** Design closures to minimize displacement of fisheries to more distant, and less safe areas. The groundfish fisheries have been the focus of restrictions to protect sea lions based in part on the large amount of biomass removed by this fishery, but the potential effects of other fisheries have not been as thoroughly examined. Hence, there are two basic "experimental treatment" options for area closures: (1) closure to groundfish fisheries only, or (2) closure to all fishing. A positive response to treatment (1) would measure the impact of the groundfish fisheries separately from the effects of other fisheries. A positive response to treatment (2) would implicate fishing activities, but there would be uncertainty as to whether the response was due to exclusion of the groundfish fisheries or exclusion of another fishery, for example herring or salmon. Closure of these areas to all fishing activity would provide the greatest contrast with the open areas for assessment of fishery-related effects on Steller sea lions. If only the groundfish fisheries are excluded from the closed areas, logbook data and as much observer coverage as possible should be obtained for other fisheries. Strict enforcement would be essential for the correct interpretation of effects of the closures.

- **Size and number of treatment areas.** The size of the closed areas depends on both fish movements and sea lion movements. The radius of the closure might range between 20 to 50 nautical miles (centered on a rookery). Replicates of each open/closed area comparison site will be required to assess the effects of environmental variability.

- **Timescale.** Some data gaps can be filled in less than 5 years (evidence of disease, localized fish depletion, improved estimates of direct mortality sources), but long-term monitoring (5-10 years) will be required to assess recruitment and mortality rates. If substantial numbers of Steller sea lions are taken as bycatch, open areas should be closed or fishing gears modified to prevent further decline of the population. This should apply to all fisheries that take sea lions as bycatch.

RECOMMENDATIONS FOR RESEARCH AND MONITORING

Research and monitoring should be directed towards measuring the vital rates and response variables most indicative of the status of the Steller sea lion population. This should include:

- **Population trends.** The current program for monitoring the juvenile and adult population by aerial survey should be continued along with the direct pup counts at selected rookeries.

- **Vital rates.** Vital rates have not been measured since the mid-1980s and urgently require updating. This should include measurements of fecundity, age at first reproduction, age distribution, juvenile survival, adult survival, and growth rates. Cooperative programs with subsistence hunters could provide reproductive data without additional mortality. Other parameters may be measured through increased effort in branding and resighting programs, requiring a commitment of resources for a long enough period of time to cover the lifespan of a Steller sea lion.

- **Critical habitat.** Although the rookeries and haulouts of sea lions have been catalogued and described, the at-sea distribution of sea lions and related foraging activity are less well documented. Mostly, this reflects the difficulty in collecting such data. The most valuable information comes from telemetry data, but analysis is constrained by the relatively small number of animals tagged, biases inherent in the recovery of data, and inaccuracies from inferring foraging activity based on swimming and diving behavior. Stomach telemetry tags that monitor temperature shifts associated with ingestion of prey should improve correlations of at sea distribution with feeding. In conjunction with the analysis of Steller sea lion's at sea activities, the activity and impacts of fisheries should be documented. Studies should be undertaken to determine if fisheries cause localized depletion of the various groundfish stocks through monitoring of fish distribution and density during the course of the fishing season with consideration of the need to distinguish these effects from natural changes in abundance. Designation of critical habitat should be revisited based on the results of the research proposed above.

- **Environmental monitoring.** Assessment of various ecological features of the sea lion environment will provide a broader context for evaluating sea lion population trends. These should include assessments of oceanographic conditions, plankton composition, forage fish abundance and distribution, seasonal migrations by groundfish, cephalopod abundance and distribution, and arrowtooth flounder interactions with groundfish (competition and predation). Also, monitoring for harmful algal bloom frequency and distribution through sampling of coastal waters will be valuable for assessing sudden mortality events. Biological sampling of sea lions should include testing for known marine mammal disease agents.

- **Predator feeding habits and population size.** Much more information is necessary to evaluate the impact of predation by killer whales and sharks on the continuing decline of the western population. Current evidence suggests that sharks are unlikely to be a major source of mortality based on distribution, limited diet data, and the relatively infrequent observations of shark wounds on sea lions. Better estimates of killer whale diet, population size and distribution (including patterns of movement and habitat use) throughout Alaska are required to estimate potential predation mortality. In addition, observer programs should be instituted to record killer whale feeding behavior that may be different in different regions. Salmon shark and sleeper shark bycatch data from longline fisheries should be collected to assess shark abundance, and shark stomach contents should be examined to determine whether sea lions are a significant component of the sharks' diets.

Most studies on Steller sea lions have been conducted in the summer when sea conditions are favorable and it is relatively easy to work with females and pups on rookeries. However, this introduces a strong bias into the results because this season may not be the time when Steller sea lions are subject to increased mortality. The fate of juveniles remains a potentially pivotal question justifying the recent emphasis on their capture and tagging. In addition to increasing efforts directed towards year-round research at selected, more accessible sites, remote observation methods such as satellite telemetry and video monitoring at rookeries and haulouts will be necessary to assess seasonal activity patterns. Although some research programs will yield data in a relatively short time (1-5 years), many of the variables most critical to assessing the efficacy of the various management regimes will take a minimum of 5-10 years before conclusive results are available. This is a consequence of the biology of sea lions; their long generation time means a slow population response and increased time required for assessing vital rates. Hence it is even more urgent to develop and implement a prioritized, cohesive research plan to address these information needs. Under an adaptive management scheme, the requirement to reduce jeopardy can be effectively coupled with a rigorous research program to reduce the uncertainty about the causes of the ongoing decline of the Steller sea lion population.

In Summary...

The Decline of the Steller Sea Lion in Alaskan Waters

Untangling Food Webs and Fishing Nets

Photo by Rolf Ream, courtesy NOAA/NMFS/NMML

Steller sea lions live in the North Pacific with about 70% living in Alaskan waters. The number of Steller sea lions in Alaskan waters has dropped by more than 80% in the past three decades. The decline resulted in their protection under the Endangered Species Act (ESA) since 1997 for the population west of Cape Suckling. A precipitous population decline from 1985-1990 – about a 15.6% decrease per year - indicated that Steller sea lions were subject to a threat that spurred the decline but had ended or abated by the 1990s. Since the early 1990s (through 2001), the population has continued to decrease but at a more gradual rate of 5.2% annually and individual rookeries show different population trends.

BACKGROUND

Under the ESA, federal agencies must ensure that actions they authorize are not likely to jeopardize the survival or recovery of protected species or damage the protected species' critical habitat. This requirement has made it imperative to identify human activities that may contribute to the decline of Steller sea lions so that regulatory actions can be adjusted to address threats to the western population's survival. In response to a request from Congress, the North Pacific Fishery Management Council asked the National Academies to examine possible causes of Steller sea lion decline and the potential efficacy of new management measures.

HYPOTHESIZING CAUSES OF DECLINE

The several hypotheses that attempt to explain the decline of the sea lions can be divided into two categories. The "bottom-up" hypotheses include potential causes that would limit the amount or quality of food available to the sea lions such as: 1) Large scale fishery removals reducing the availability or quality of prey species 2) A climate/regime shift changing the abundance or distribution of prey 3) Non-lethal disease and 4) Pollutants contaminating fish eaten by sea lions.

"Top-down" hypotheses encompass factors that kill sea lions independently of the capacity of the environment to support the sea lion population. These include: 1) Predator switching by killer whales (or sharks) to target sea lions, 2) Increasing incidental take (or disturbance) through capture or entanglement in fishing gear, 3) Subsistence harvesting of sea lions taking more than estimated, 4) Underestimation of sea lion shooting, and 5) Increasing mortality from pollution and disease, independent of nutrition.

Existing data on the current phase of decline indicate that bottom-up hypotheses resulting in food limitation are unlikely to represent the primary threat to Steller sea lion recovery. Although no hypotheses can be excluded based on existing data, top-down sources of mortality appear to pose the greatest threat to the current population. It is important to remember that a combination of both types of factors may contribute to the decline. Also, geographic variation may mean that different factors are responsible for mortality in different parts of the sea lions' range.

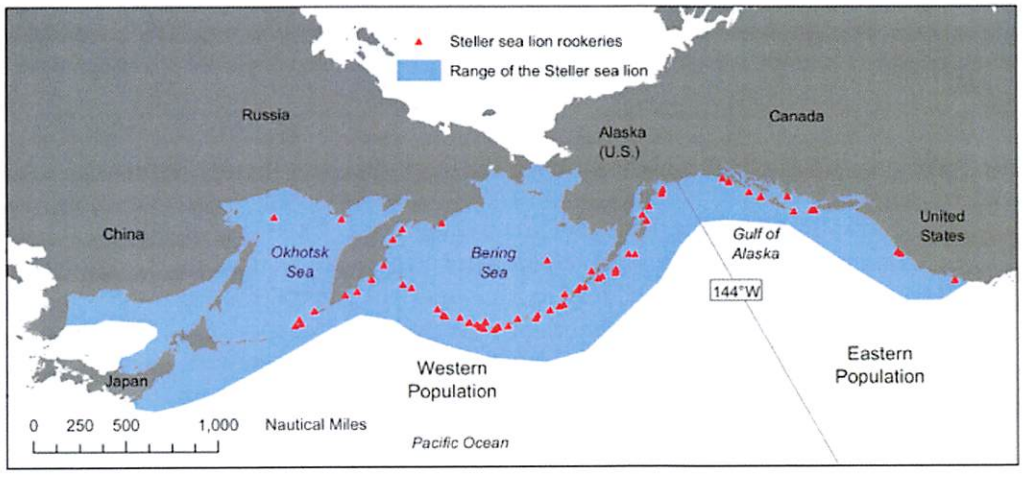

Figure 1. The range (in blue) and rookeries (in red) of Steller sea lions. 144° W defines the boundary between the eastern and western populations. Source: National Marine Fisheries Service, Alaska Fisheries Science Center.

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THE NEED FOR EVIDENCE

Although most evidence indicates that groundfish fisheries are not depleting the food resources necessary to sustain the current western population of sea lions, there is insufficient evidence to fully exclude fisheries as a contributing factor to the decline. Sea lions may get ensnared in fishing gear because of the ample food available around fishing operations. Attraction of killer whales to these same vessels could increase the vulnerability of sea lions to predation. **Investigations of top-down sources of Steller sea lion mortality should be increased to evaluate the proportionate impact of these factors on population decline.**

MONITORING AND MANAGEMENT

The report recommends using adaptive management to uncover the effect of the fisheries on Steller sea lion survival. Because of potential interference of the Alaska groundfish fisheries with the recovery of endangered Steller sea lions, the fisheries have been increasingly restricted as the sea lion population has continued to decline. In an adaptive management experiment, the western population could be divided into several treatment units, with "closed" and "open" areas centered on rookeries. The "closed" areas would be subject to local closures and the "open" areas would have all fishery restrictions related to Steller sea lions removed.

The approach is germane to the problem because it directly tests the involvement of the fishery in the decline and reduces the possibility that regulation of the fishing industry is perpetuated without demonstrable benefit to the Steller sea lion population. The removal of all sea lion-related fishing restrictions in the open areas creates opportunities for the industry and provides a contrasting management treatment necessary for comparison with closed areas. The approach controls for changes that are unrelated to fishing, such as ecological effects related to climate variability.

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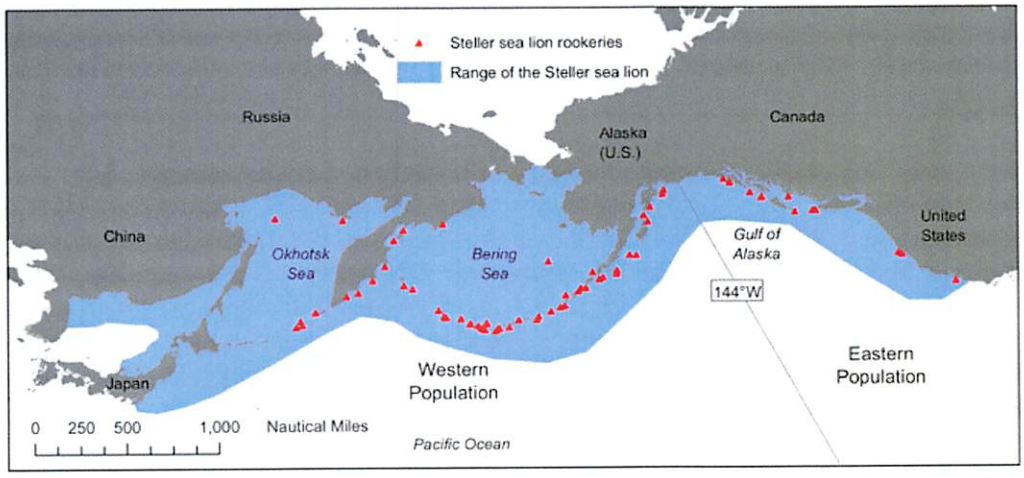

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