



NOAA Technical Memorandum NMFS-AFSC-129

Steller Sea Lion Research and Coordination: A Brief History and Summary of Recent Progress

by
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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

June 2002

NOAA Technical Memorandum NMFS

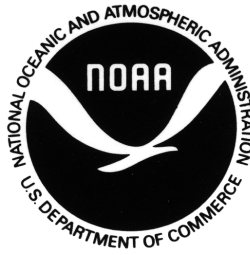
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This document should be cited as follows:

Ferrero, R. C., and L. W. Fritz. 2002. Steller sea lion research coordination: a brief history and summary of recent progress. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-129, 34 p.

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Abstract

The Steller sea lion (*Eumetopias jubatus*), first listed under the Endangered Species Act (ESA) in 1990, has been the subject of intensive scientific research since a steep population decline was identified in the late 1980s. Research efforts during most of the 1990s were guided by recommendations contained in the Steller Sea Lion Recovery Plan. Research funding for federal agencies during this period was <\$1 million (M) annually, of which over half was required for population monitoring surveys. During the late 1990s, Steller sea lion research activities were intensified as recent scientific findings, litigation, and new legislation focused increasing attention on the ongoing decline and concern over possible impacts by commercial fisheries in Alaskan waters. This renewed attention was manifest in a seven-fold increase in funding between 2000 and 2001, with over 125 individual projects planned or implemented. A wide spectrum of research entities were engaged in these studies, including federal and state agencies, universities and non-governmental research organizations. In cooperation with the entities that received federal funding, the National Marine Fisheries Service developed a research coordination framework to clarify the context of individual research projects, to show their relationships to each other and to link them to the underlying hypotheses that might explain the continued decline of Steller sea lions. This paper summarizes the evolution of Steller sea lion research over the past two decades and describes the development of a comprehensive and coordinated program that responds to Congressional intent.

Contents

Abstract..... iii

Introduction 1

Steller Sea Lion Research in the 1970s, 1980s, and 1990s 2

Renewed Research Emphasis in the Late 1990s and Early 2002s 4

NMFS Response to the FY01 Congressional Appropriations Language 10

Coordination 13

Steller Sea Lion Research Framework 13

Comprehensiveness 19

Summary and Conclusions 19

Citations 21

Introduction

In 1990, the western stock of Steller sea lion (*Eumetopias jubatus*) was listed as threatened under the U.S. Endangered Species Act of 1973 (ESA) after a steep decline in the population (>15% per year) was observed in the late 1980s. After seven more years of continued decline, the western stock was re-listed as endangered in 1997. Despite research and management efforts to bring about recovery, the population has continued to decline (Fig. 1). The underlying causes of the steep decline in the 1980s are uncertain, while the factors underlying the protracted slide since then are equally enigmatic. The pace at which scientific information has become available to provide guidance to management has been slow, due largely to constraints on the resources available to fund research, but also due to the difficulties associated with designing and conducting studies of Steller sea lions in their natural habitat.

Compounding the research problem, several of the largest U.S. fisheries operate within the range of the Steller sea lion and their role, if any, in the decline or failure to recover remains both a topic of debate (National Research Council 1996, NMFS 1998a, NMFS 1999, NMFS 2000) and a significant issue for ongoing litigation (Greenpeace et al. v NMFS and At-Sea Processors et al., Civ. No. C98-0492-C). On the one hand, if fisheries play a significant part in the continued decline and lack of recovery, then actions should be taken to avoid those effects. On the other hand, if fisheries do not impede recovery, then the economic viability of those fisheries should not be unnecessarily compromised. In either case, scientific information is critical to the future of both the Steller sea lion population and U.S. fisheries in Alaska.

While frustrating, these circumstances do not imply that the past 20 years of research on Steller sea lions have been fruitless. On the contrary, this record underscores the reality and complexity of the problem facing resource managers: the Steller sea lion occupies expansive, remote, and rugged habitat across the North Pacific Ocean (Fig. 2); simple solutions explaining the decline do not exist, and our understanding of marine ecosystems and the factors that impact Steller sea lion population trends is rudimentary at best. The development and implementation of broad scale, comprehensive scientific investigations needed to address an issue of this magnitude and complexity are enormous and costly undertakings. Therefore, it should not be unreasonable to expect scientific progress to be tempered by both the availability of research funds and the intricacy of the studied ecosystem and research questions. However, unlike most of the period since the 1980s, the current level of research funding offers renewed opportunities to understand the Steller sea lion decline and to promote its recovery (Table 1).

The objectives of this paper are two-fold. First, we trace the progress of Steller sea lion research as it evolved from a modestly funded protected resource issue in the 1980s to its present form: one of the largest single-species research efforts in U.S. history. Second, we describe the research framework developed by the National Marine Fisheries Service (NMFS) as an organizational tool to guide the development of a comprehensive and coordinated program in keeping with Congressional intent. We explain how the framework can clarify the context of individual research projects as well as their relationships to each other and the underlying hypotheses that might explain the continued decline of the western stock of Steller sea lions.

Steller Sea Lion Research in the 1970s, 1980s, and 1990s

Despite being the most abundant sea lion in North America at the time, research on Steller sea lions prior to the 1970s principally involved studies of its population status and distribution (Kenyon and Rice 1961, Mathisen and Lopp 1963), or brief descriptions of their diet (Imler and Sarber 1947, Mathisen et al. 1962, Thorsteinson and Lensink 1962). In the 1970s and early 1980s, potential exploration of Alaska's continental shelf for oil and gas prompted baseline research on growth, reproduction, and other aspects of their life history, along with continued monitoring of the Steller sea lion population (Pitcher 1981, Pitcher and Calkins 1981, Calkins and Pitcher 1982, Loughlin et al. 1984, Calkins and Goodwin 1988). At this time, the decline in the Steller sea lion population in Alaska was first noted by Braham et al. (1980) after surveys conducted in the eastern Aleutian Islands in 1975-77. It was evident from these surveys and others that the population of Steller sea lions in the eastern Aleutians had begun to decline in the 1960s. By 1989, significant declines ranging from 33% to 87% had been observed in most segments of its range, including Russia, the Bering Sea, Aleutian Islands, western and central Gulf of Alaska, and Oregon/California. (Loughlin et al. 1990, 1992). These significant and steep (particularly in the late 1980s) decreases in the size of the Steller sea lion population resulted in NMFS being petitioned to list the species under the ESA, and which prompted NMFS to list it as threatened in 1990.

Section 4(f) of the ESA requires that recovery plans be developed for listed species unless the appropriate Secretary (of the Department of Commerce or Interior) finds that such a plan will not promote conservation of the species. NMFS appointed a Steller Sea Lion Recovery Team (SSLRT) in 1990 to draft a plan, which it completed in December 1992 (NMFS 1992). Recovery Plans must incorporate a) site-specific management actions that are considered necessary to achieve conservation goals and survival of the species, b) objective and measurable criteria to determine when a species will no longer need protection under the ESA, and c) estimates of the time and costs associated with plan recommendations. When the SSLRT drafted the plan, it was not able to make recommendations on site-specific management actions because the factors that caused the decline in Steller sea lion abundance were poorly known. Therefore, the plan focused primarily on recommendations for research essential to determine population (and recovery) status and immediate, tangible actions such as reducing direct mortality from shooting and incidental takes in fisheries that could help arrest the population decline. The plan also identified other research needs relating to both natural and human-related factors that could be affecting the population. This discussion of research needs provided most of the initial guidance for the development of subsequent plans and projects conducted from 1993 to 1998. Funding for research by federal agencies during this period was <\$1 million (M) annually, of which over half was required for population monitoring surveys (Table 1).

Baseline and monitoring studies included identification of management stocks or units through tagging/branding and genetic investigations, and monitoring the status and trend of sea lion populations through adult/juvenile surveys and pup counts. As a result, extensive branding

and brand resight efforts were re-initiated in the mid-1990s, and aerial survey protocols were standardized between the principal agencies conducting baseline studies: the Alaska Department of Fish and Game (ADF&G) and NMFS' National Marine Mammal Laboratory (NMML). Genetic studies of pup mtDNA (which reflect matrilineage or the distribution and movement of reproductive females) conducted in the early 1990s indicated that Steller sea lions have at least two distinct population segments (DPSs): the western DPS which breeds on rookeries in Russia and Alaska west of 144°W (Cape Suckling east of Prince William Sound), and the eastern DPS which breeds on rookeries in southeast Alaska, British Columbia, Oregon and California (Fig. 2; Bickham et al. 1996, Loughlin 1997). Genetic differences, along with differences in their population status and trend, led to separate listings under the ESA in 1997, with the western DPS reclassified as endangered and the eastern DPS remaining threatened (62 FR 30772).

Natural factors discussed in the recovery plan that could have contributed to the population decline were parasitism and disease, environmental changes, and predation (Table 2). The SSLRT recognized that the effects of disease agents and environmental changes on Steller sea lions were largely unknown. As such, compilation and examination of tissue samples for diseases were identified as research needs in the plan, but little progress was made throughout the 1990s in determining the role that diseases or parasites had played in the continuing decline (NMFS 2000). Furthermore, while the SSLRT did not include studies of environmental change on their list of recommended research, numerous reports were written in the 1990s on the "regime shift" of 1976-77 and its effect on climate, oceanographic conditions, and the fish community structure in the North Pacific Ocean (Hollowed and Wooster 1992, Beamish 1993, Francis and Hare 1994, Hollowed and Wooster 1995, Francis et al. 1998, Anderson and Piatt 1999, Shima et al. 2000). How such changes relate to the decline in abundance of Steller sea lions is still largely uncertain. The SSLRT dismissed increased predator activity as a significant factor in the decline, but recommended research to evaluate the current magnitude of killer whale or shark predation. The potential for killer whale predation having an impact on Steller sea lion populations was later underscored by the discovery of 14 flipper tags (which had been applied to sea lion pups in 1987-88) in the stomach of a beached killer whale in 1992. This observation, along with the results of a killer whale-sea lion predation model (Barrett-Lennard et al. 1995), has led to renewed interest in predation as a factor in at least the sea lion population's lack of recovery, if not the continued decline observed since 1990.

Human-related factors discussed in the recovery plan that may have contributed to the population decline of sea lions were residual effects of the commercial harvest of pups and adult males from 1959 to 1972, the ongoing subsistence harvest by Alaska natives, incidental take by fisheries, intentional killing, entanglement in debris, toxic substances (contaminants), disturbance, and competition for food (with fisheries; Table 2). Each of these factors were considered by the SSLRT, and for each except for entanglement and effects of commercial harvests, the SSLRT concluded that there was insufficient information to determine its role in the decline. The plan contains recommendations to estimate and reduce rates of mortality due to incidental take, intentional killing, and struck and loss rate by subsistence hunters, as well as the development of non-harmful methods of deterrence for fishers and programs to minimize marine debris. Much

of this work was begun or was continued in the 1990s by ADF&G and NMFS through increased monitoring of subsistence hunts, partnerships with native organizations, or through fishery observer programs (Wolfe and Mishler 1993, Angliss et al. 2001). In part due to inadequate funding, little progress has been made on assessing the impact of contaminants despite the recommendations in the plan, and the effects of disturbance have largely been ignored. While considerable attention has been focused on competition with fisheries for food in scientific reviews (National Research Council 1996), litigation (Greenpeace et al. v NMFS and At-Sea Processors et al., Civ. No. C98-0492-C) and official government documents (NMFS 1998a, NMFS 1999, NMFS 2000), there has been little progress on the scientific front in assessing the mechanisms or magnitude of such interactions until recently (i.e., 2001).

Renewed Research Emphasis in the Late 1990s and Early 2000s

By the late 1990s, interest in Steller sea lion research was renewed due to a combination of several factors, including recent scientific findings, litigation, and legislation. NMFS reinitiated formal ESA consultations on specific groundfish fisheries (Atka mackerel (*Pleurogrammus monopterygius*) and walleye pollock (*Theragra chalcogramma*) based on information and analyses that showed the potential for competitive overlap between them and sea lions. This new information consisted primarily of

- Steller sea lion food habits.
- Depths, locations, and size ranges of fish targeted by groundfish fisheries.
- Disproportionate rates of harvest in sea lion foraging habitats.
- Potential localized depletions of prey.

The food habits information revealed strong prevalences of Atka mackerel, walleye pollock, and Pacific cod (*Gadus macrocephalus*), all of which are targeted by groundfish fisheries, in the diet of Steller sea lions. The size ranges of fish consumed by sea lions and those targeted by fisheries overlapped considerably, as did the depths and geographic locations used by both fisheries and sea lions. While these data in and of themselves suggested the potential for competitive overlap, further analyses of the distribution of the Atka mackerel and walleye pollock fisheries indicated that there was likelihood they could affect survival and recovery of Steller sea lions. Survey and fishery data suggest that harvest rates in some of the areas utilized by the Atka mackerel and walleye pollock fisheries are greater than the target rate on the stock as a whole (Fritz 1995, NMFS 1998b, NMFS 1999, Fritz 2002). This could reduce the availability of prey in areas used by the fishery, many of which are within areas designated as Steller sea lion critical habitat.

Because of these concerns, NMFS and the NPFMC took actions in 1998 which spatially and temporally dispersed the Atka mackerel fishery and reduced effort in Steller sea lion critical habitat in the Aleutian Islands. Efforts to restructure the pollock fisheries in the North Pacific to address Steller sea lion concerns have been more protracted. The conclusions of a NMFS

biological opinion on the effects of the proposed 1999 walleye pollock fishery on Steller sea lions (NMFS 1998a) were that it was likely to jeopardize their continued existence and adversely modify Steller sea lion critical habitat. This was based on an analysis of the information described above which suggested that fisheries could reduce the prey availability for Steller sea lions in important foraging habitats. Consequently, NMFS and the NPFMC modified the fishery (in a reasonable and prudent alternative, or RPA, to the fishery as originally proposed) to spatially and temporally disperse effort as well as reduce catches within critical habitat. However, considerable scientific uncertainty existed regarding the effects of fisheries on Steller sea lions as well as the efficacy of the management measures proposed to mitigate them. While NMFS gave the “benefit of the doubt” to the sea lion in its conclusions regarding the effects of the walleye pollock fishery, NMFS could not convince the U.S. Western District Court and the Honorable Thomas S. Zilly how the RPA avoided jeopardy to the continued existence of Steller sea lions and avoided adversely modifying their critical habitat. As a result, the RPA was remanded back to NMFS, which produced a revised final RPA under which the walleye pollock fishery operated through 2000.

The U.S. Western District Court also required NMFS to write a biological opinion analyzing the combined and cumulative effects of all the groundfish fisheries as managed under the fishery management plans. This document (NMFS 2000), finalized in November 2000, concluded that the BSAI and GOA groundfish fisheries were likely to jeopardize Steller sea lions and adversely modify their critical habitat because effects would likely occur at three scales: local, regional, and global. Much of the evidence for the local and regional fishery effects came from analyses of Steller sea lion food habits and fishery data as described above. However, new information on the potential impacts at the global, or ecosystem, scale of the overall target fishing rates supported, according to NMFS, the conclusion of jeopardy and adverse modification. The RPA developed in the November 2000 Biological Opinion, however, was controversial because of the magnitude of perceived impacts to the fishing industry. Again, this stemmed largely from the lack of firm evidence and considerable scientific uncertainty on the magnitude of fishery effects on Steller sea lions and the efficacy of the proposed measures in mitigating these effects.

The growing concern over the Steller sea lion decline and the possibility that the decline may be related to uncertain but adverse interactions with the Alaskan groundfish fisheries surfaced on the national scene during Congressional appropriations hearings in summer 2000. While the House Report on appropriations for the Departments of Commerce, Justice, and State (CJS)(H.R. 106-680) did not mention the Steller sea lion issue, the Senate Report on CJS appropriations (S. Rept 106-404) addressed the issue in detail. The differing responses were likely due, at least in part, to the composition of the two Appropriations Committees, with the Senate side being chaired by Senator Ted Stevens of Alaska. The subsection outlining the NMFS budget contained the following paragraph:

“The Committee is greatly concerned by the administration’s proposed reduction of funding for Steller sea lion recovery off Alaska. The cause of the Steller sea lion decline is still unknown, and the costly limitations which could seriously impede the Nation’s most

productive fisheries are being implemented. Lawsuits are being filed which challenge the agency's data on the Steller sea lion, and more resources are needed to enable the agency to produce the science and data to keep these fisheries open while protecting the sea lion population. The Committee, therefore, has provided a total of \$12,300,000 including \$7,000,000 for the National Marine Fisheries Service; \$2,500,000 for the State of Alaska; \$1,000,000 for the Alaska SeaLife Center; \$1,000,000 for the Gulf Apex Predator study at the University of Alaska; and, \$800,000 for the North Pacific Marine Mammal Consortium, to address this pressing concern."

Clearly the need for better scientific data was recognized both as a means of clarifying the relationship between Steller sea lions and commercial fisheries to promote recovery, and as a stimulus for a more thorough investigation of factors besides fisheries that might actually be driving the decline. It is also worth noting that the initial Senate plan gave the majority of the funds to the NMFS as the agency mandated with management authority for Steller sea lions under ESA and the Marine Mammal Protection Act (MMPA) , and the remainder to the State of Alaska and other non-governmental research organizations that were already involved with Steller sea lion research. At this point, the proposed changes in funding were almost \$7.6 M more than the total research funds appropriated in FY00.

The existence of disparate versions of the CJS appropriations bills on the House and Senate side followed a typical pattern in the Congressional Budget process and a Conference Committee was established to draft a final, compromise version of the bill. The Conference Committee met in the fall, and their report (H. Rept. 106-1005) was issued on 25 October 2000. The proposed funding for Steller sea lions specified in the Senate Report (106-404):

"The conference agreement includes \$12,300,000 for Steller sea lion recovery, to be allocated according to the direction of the Senate report. Senate language regarding the Administration's reduction of funding for Steller sea lion recovery is included by reference."

In addition to the \$12.3 M, the conference language contained an additional allocation under the heading of Fisheries Management Programs:

"...to provide increases for data collection on fishery management programs, including..., and \$10,000,000 for research regarding the Alaska Steller sea lion and pollock lawsuit".

Whereas the appropriations contained in a conference report are normally the same as those that appear in the final bill, the process by which the Department of Commerce (and so the National Marine Fisheries Service) funding was determined for FY01 took a different route. Up to this point, the process was on track with all three committee reports tiering off of the original CJS appropriations bill (H.R. 4690). That bill was replaced in December by a version that referenced a conference report containing additional, even more specific language regarding Steller sea lions and the disposition of the Alaskan groundfish fisheries. To understand these events, it is important to remember that NMFS was in the process of redrafting the

SSL/groundfish fishery Biological Opinion (hereafter referred to as the November 2000 Biological Opinion), and when its contents were made public on 30 November 2000, a suite of restrictive measures to promote Steller sea lion protection were included.

In a speech on the Senate floor on 14 December, Senator Ted Stevens (Alaska), Senate Appropriations Committee Chairman, reacted to the November 2000 Biological Opinion and the course of action NMFS was recommending. He stated, "I have made the statement that I will not sign this conference report if it does not adequately restore this fishery"(i.e. the conference report on the bill that would ultimately contain the Commerce Department's appropriations). The final package of FY01 appropriations passed after language was added to conference report H.R.106-1033 (on H.R. 4577) (also referred to as the "Steven's Rider"). Of that language, Sections 206 and 209 are relevant to Steller sea lion research funding.

SEC. 206. The Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriations Act, 2001, as enacted by section 1(a)(2) of the Act entitled "An Act making appropriations for the government of the District of Columbia and other activities chargeable in whole or in part against revenues of said District for the fiscal year ending September 30, 2001, and for other purposes" is amended by inserting before the period at the end of the paragraph under the heading "National Oceanic and Atmospheric Administration, Operations, Research, and Facilities" the following new proviso: "": Provided further, That, of the amounts made available for the National Marine Fisheries Service under this heading, \$10,000,000 shall be available only for research regarding litigation concerning the Alaska Steller sea lion and Bering Sea/Aleutian Islands and Gulf of Alaska groundfish fisheries, of which \$6,000,000 shall be available only for the Office of Oceanic and Atmospheric Research to study the impact of ocean climate shifts on the North Pacific and Bering Sea fish and marine mammal species composition, of which \$2,000,000 shall be available only for the National Ocean Service to study predator/prey relationships as they relate to the decline of the western population of Steller sea lions, and of which \$2,000,000 shall be available only for the North Pacific Fishery Management Council for an independent analysis of Steller sea lion science and other work related to such litigation.

In essence, the new proviso contained in Section 206 reallocated the \$10 M "for research regarding the Alaska Steller sea lion and pollock lawsuit" in the NMFS budget as specified by the 25 October CJS conference report to non-NMFS entities. Given the ire that the November 2000 Biological Opinion had caused because of its focus on avoiding potential adverse impacts by the Alaskan groundfish fisheries, it appears that this change in language represented Congressional intent to investigate a broader range of possible factors explaining the decline (i.e., climate change and increased predation by killer whales and sharks). Further, the appropriation of \$2 M to the NPFMC to review the science underlying the November 2000 Biological Opinion also signaled discomfort with the NMFS position to further restrict certain fisheries based on the scientific information available at the time. However, independent of the funding distribution, this \$10 M, over and above the \$12.3 M already identified, substantially increased the potential breadth of future Steller sea lion research.

Section 209 provided further guidance, with language that superseded the RPAs contained in the November 2000 Biological Opinion (*sub-section c*), the appropriation of still more funds for Steller sea lion research (*sub-section d*) and a directive for a National Academy of Science review of the basis for the NMFS conclusions in the November 2000 Biological Opinion (*sub-section b*):

SEC. 209. IMPLEMENTATION OF STELLER SEA LION PROTECTIVE MEASURES.--

(a) FINDINGS.--The Congress finds that--

(1) the western population of Steller sea lions has substantially declined over the last twenty-five years.

(2) scientists should closely research and analyze all possible factors relating to such decline, including the possible interactions between commercial fishing and Steller sea lions and the localized depletion hypothesis;

(3) the authority to manage commercial fishing in federal waters lies with the regional councils and the Secretary of Commerce (hereafter in this section ``Secretary'') pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (hereafter in this section ``Magnuson-Stevens Act''); and

(4) the Secretary of Commerce shall comply with the Magnuson-Stevens Act when using fishery management plans and regulations to implement the decisions made pursuant to findings under the Endangered Species Act, and shall utilize the processes and procedures of the regional fishery management councils as required by the Magnuson-Stevens Act.

(b) INDEPENDENT SCIENTIFIC REVIEW.--The North Pacific Fishery Management Council (hereafter in this section ``North Pacific Council') shall utilize the expertise of the National Academy of Sciences to conduct an independent scientific review of the November 30, 2000 Biological Opinion for the Bering Sea/Aleutian Islands and Gulf of Alaska groundfish fisheries (hereafter in this section ``Biological Opinion'), its underlying hypothesis, and the Reasonable and Prudent Alternatives (hereafter in this section ``Alternatives') contained therein. The Secretary shall cooperate with the independent scientific review, and the National Academy of Sciences is requested to give its highest priority to this review.

(c) PREPARATION OF FISHERY MANAGEMENT PLANS AND REGULATIONS TO IMPLEMENT PROTECTIVE MEASURES IN THE NOVEMBER 30, 2000 BIOLOGICAL OPINION.--

(1) The Secretary of Commerce shall submit to the North Pacific Council proposed conservation and management measures to implement the Alternatives contained in the November 30, 2000 Biological Opinion for the Bering Sea/Aleutian Islands and Gulf of Alaska

groundfish fisheries. The North Pacific Council shall prepare and transmit to the Secretary a fishery management plan amendment or amendments to implement such Alternatives that are consistent with the Magnuson-Stevens Act (including requirements in such Act relating to best available science, bycatch reduction, impacting on fishing communities, the safety of life at sea, and public comment and hearings.)

(2) The Bering Sea/Aleutian Islands and Gulf of Alaska groundfish fisheries shall be managed in a manner consistent with the Alternatives contained in the Biological Opinion, except as otherwise provided in this section. The Alternatives shall become fully effective no later than January 1, 2002, as revised if necessary and appropriate based on the independent scientific review referred to in subsection (b) and other new information, and shall be phased in in 2001 as described in paragraph (3).

(3) The 2001 Bering Sea/Aleutian Islands and Gulf of Alaska groundfish fisheries shall be managed in accordance with the fishery management plan and federal regulations in effect for such fisheries prior to July 15, 2000, including--

(A) conservative total allowable catch levels;
(B) no entry zones within three miles of rookeries;
(C) restricted harvest levels near rookeries and haul-outs;
(D) federally-trained observers;
(E) spatial and temporal harvest restrictions;
(F) federally-mandated bycatch reduction programs; and
(G) additional conservation benefits provided through cooperative fishing arrangements, and said regulations are hereby restored to full force and effect.

(4) The Secretary shall amend these regulations by January 20, 2001, after consultation with the North Pacific Council and in a manner consistent with all law, including the Magnuson-Stevens Act, and consistent with the Alternatives to the maximum extent practicable, subject to the other provisions of this subsection.

(5) The harvest reduction requirement ("Global Control Rule") shall take effect immediately in any 2001 groundfish fishery in which it applies, but shall not cause a reduction in the total allowable catch of any fishery of more than ten percent.

(6) In enforcing regulations for the 2001 fisheries, the Secretary, upon recommendation of the North Pacific Council, may open critical habitat where needed, adjust seasonal catch levels, and take other measures as needed to ensure that harvest levels are sufficient to provide income from these fisheries for small boats and Alaskan on-shore processors that is no less than in 1999.

(7) The regulations that are promulgated pursuant to paragraph (4) shall not be modified in any way other than upon recommendation of the North Pacific Council, before March 15, 2001.

(d) SEA LION PROTECTION MEASURES.--\$20,000,000 is hereby appropriated to the Secretary of Commerce to remain available until expended to develop and implement a coordinated, comprehensive research and recovery program for the Steller sea lion, which shall be designed to study--

- (1) available prey species;*
- (2) predator/prey relationships;*
- (3) predation by other marine mammals;*
- (4) interactions between fisheries and Steller sea lions, including the localized depletion theory;*
- (5) regime shift, climate change, and other impacts associated with changing environmental conditions in the North Pacific and Bering Sea;*
- (6) disease;*
- (7) juvenile and pup survival rates;*
- (8) population counts;*
- (9) nutritional stress;*
- (10) foreign commercial harvest of sealions outside the exclusive economic zone;*
- (11) the residual impacts of former government-authorized Steller sea lion eradication bounty programs; and*
- (12) the residual impacts of intentional lethal takes of Steller sea lions.*

Within available funds the Secretary shall implement on a pilot basis innovative non-lethal measures to protect Steller sea lions from marine mammal predators including killer whales,...

Focusing on Section 209(d), the most specific expression of Congressional intent for the Steller sea lion research objectives is readily apparent. Not only would an additional \$20 M be made available, but it was to be spent on investigations or activities related to a list of 13 topics representing the full range of possible factors underlying the Steller sea lion decline and failure to recover. Of the \$20 M, \$5 M was earmarked for the Alaska Sea Life Center elsewhere in the Congressional Record. Subsequent clarification of Congressional intent for the use of the remaining \$15 M indicated that the funds were to be used by non-federal parties. This further suggests another expression of Congressional interest in widening the range of Steller sea lion related research, inclusion of participants from diverse academic backgrounds, and enhanced attention to non-fishery related factors.

NMFS Response to the FY2001 Congressional Appropriations Language

Recapping the Congressional actions during 2000, the FY01 appropriations language identified a total of \$43.15 M in the NOAA budget for the implementation of Steller sea lion protective measures. Congress directed that a broad research program be conducted to examine all possible factors relating to the Steller sea lion decline, including interactions with commercial fishing and further investigation of alternative hypotheses. The FY01 appropriations represented an increase of \$38.43 M in research funding over the previous year. Further, the funds were directed to several organizations, both federal and non-federal, that are involved in Steller sea lion research. This group of FY01 directly funded entities included:

- NOAA-Fisheries (National Marine Fisheries Service: NMFS)
- NOAA-Office of Oceanic and Atmospheric Research (OAR)
- NOAA-National Ocean Service (NOS)
- North Pacific Fishery Management Council (NPFMC)
- Alaska Department of Fish and Game (ADF&G)
- University of Alaska (UAF)
- Alaska Sea Life Center (ASLC)
- North Pacific Universities Marine Mammal Research Consortium (NPUMMRC).

The intended scope of this research effort was far broader and more robust than previously available resources could have allowed. Thus, the challenge in January 2001 was to marshal the collective resources and expertise of the entities that had received funding and to develop a coherent and calculated approach to the expanded investigations. Two issues were immediately apparent; first, many Steller sea lion research projects begin in winter so there was little time to waste in getting new or expanded projects up and running. Second, Congress succeeded in spreading out the research funding and involving many new parties, but ultimately, management responsibility for Steller sea lions still rested with NMFS. Thus, the subsequent actions by NMFS represented an effort to encourage and support the efforts of all involved while maintaining its management role and providing guidance during the process of program development.

With large-scale increases in funding, a broadened base of participating parties and the consequent proliferation of individual investigations, the appropriations language references to *coordination and comprehensiveness* were interpreted by NMFS' Alaska Fisheries Science Center (AFSC) as the fundamental requirements of the Steller sea lion research program as a whole.

The following discussion summarizes NMFS activities in support of the Steller sea lion research program development during FY01 and assesses the level of *coordination and comprehensiveness* achieved thus far. For brevity, actions of parties other than the AFSC are not fully discussed. We note, however, that their contributions to the overall program are substantial. Additional details can be found at the web-sites of the Cooperative Institute for Arctic Science

(CIFAR) (www.cifar.uaf.edu), PMEL (www.pmel.noaa.gov), ADF&G (www.state.ak.us/adfg), ASLC (www.alaskasealife.org), NPUMMRC (www.marinemammal.org), and UAF (www.sfos.uaf.edu/npmr/projects/mammals).

Although all of the \$43.15 M FY01 Steller sea lion appropriations were included in the NMFS budget, the total available to support NMFS-sponsored activities totaled \$22.85 M; the remainder was earmarked for non-NMFS parties (Table 1; Fig. 4 showing how FY01 funds were distributed). The NMFS funds appeared in three allocations: \$0.85 M for Steller sea lion recovery, \$7.0 M for expanded Steller sea lion research and \$15.0 M initially assigned to the Secretary of Commerce for unspecified Steller sea lion research.

The first two allocations, totaling \$7.85 M, were used by AFSC to support and expand ongoing Steller sea lion and related Alaska groundfish/fishery investigations. Changes in the program were based on guidance in the appropriations language. Of note, new programs were designed to investigate fisheries effects and the efficacy of management measures (e.g., no-trawl zones), expand sea lion branding, tagging, and scat collection efforts, study shark and killer whale predation, survey groundfish and forage fish populations in sea lion habitats, and examine the effects of diseases and contaminants on Steller sea lions. An approximate breakdown of AFSC funding allocation included:

- Fisheries effects \$1.0M
- Sea lion biology and ecology \$5.0M
- Shark and killer whale predation \$0.6M
- Groundfish and forage fish surveys \$1.0M
- Diseases and contaminants \$0.2M

The \$15 M allocation was used to fund a competitive grants process (the Steller Sea Lion Research Initiative (SSLRI)), administered through the NMFS' Alaska Regional Office with technical support from the AFSC. This program was designed to draw upon non-NMFS expertise by soliciting proposals that addressed any of the 13 areas of research emphasis listed in the appropriations language (Sec 209(d) above). While federal entities could not compete directly for these funds, they could be identified as collaborative partners where their support was critical to the study.

The research areas named in Sec 209(d) included both general hypotheses as well as specific lines of investigation relevant to many hypotheses which complicated project organization. Therefore, the list was distilled into six principal hypotheses or factors contributing to, or causing, the decline that more closely tracked the logic and terminology familiar to the Steller sea lion research community:

- Fisheries effects.
- Environmental change.
- Other anthropogenic effects.

- Predation.
- Disease.
- Contaminants.

A total of 31 research proposals were funded under the SSLRI. Selected projects addressed five of the six research hypotheses (no disease studies were proposed) and all but two of the research areas from the appropriations language (i.e., disease and the non-lethal deterrence of killer whales). The SSRLI-funded research project themes included baseline collection of sea lion vital rates (population counts and assessment of reproductive rates), development of new tools and techniques to understand sea lion foraging ecology, improved and expanded collection of data on prey distribution and abundance, and construction of new mathematical bioenergetic models that will attempt to synthesize a multitude of physical and biological interactions.

Coordination

Progress toward achieving a coordinated approach for committing research resources to the various appropriations language directives is most evident in the chronology of meetings and production of planning documents between January and September 2001. It is important to recognize, however, that although the Steller sea lion research program was greatly enlarged and much attention given to naming areas of study in the appropriations language, the coordination aspect was addressed by Congress in only the most generic of terms. Further, the purposeful dispersion of funding to more fully involve non-NMFS participants initially confounded efforts to guide overall program design and development. Not surprisingly, given fiscal timing and logistical constraints, attention to coordination largely took a back seat to each party's need to rapidly enhance or establish projects in the face of field season startups only 2 months away. Nonetheless, by September, significant progress had been made, highlighted by three research planning meetings held in January, July, and September 2001. One of the principal goals of the planning meetings was to jointly develop a research framework.

Steller Sea Lion Research Framework

Representatives from each of the 2001 funded entities reviewed and finalized a Steller sea lion research framework based on a NMFS-AFSC concept. This framework (Fig. 3) was developed to

- Facilitate the exchange of information, ideas, and support among individual investigators doing similar or related research in the same geographic area (identify linkages).
- Assist in the research planning process to identify major research areas that are lacking in effort or are saturated (identify gaps).
- Ensure that each project is addressing one or more of the hypotheses related to one or more factors causing or contributing to the decline or lack of recovery of Steller sea lions.

Ultimately, there are only three reasons why a population of animals declines: decreased survival of one or more age classes, decreased numbers of births, or increased emigration from the area. In the case of the western stock of Steller sea lions, both of the first two reasons are likely operating, but increased emigration is probably not likely (NMFS 1992). While these may be the reasons that the population is declining, NMFS identified at least 6 factors that could be

causing or contributing to decreased survival or numbers of births (see above). Each of these factors could affect sea lions through one or more mechanisms:

- Nutritional stress, including cumulative impacts resulting from increasing exposure to other factors.
- Direct mortality.
- Reduction in individual fitness, which increases exposure to other factors.

In addition, each factor can have more than one type of effect on sea lions or their environment, each of which forms the basis for a specific hypothesis or question (Table 3).

The research framework developed by the coordination group organizes projects from two perspectives. The first is termed “top-down” since the main criterion is the factor causing the decline that the project is studying. In this approach, the results of each study will be used to address one or more hypotheses for the decline (Table 3). The other organizational perspective may be more functional for the individual researcher since it is based on the type of research being conducted, or research theme. This is termed the “bottom-up” perspective since similar tools or disciplines of study are grouped.

“Top-Down” Perspective: Factors Causing or Contributing to the Decline

Indirect effects of fisheries - Three categories of indirect fishery effects were identified: removal of prey, disturbance, and changes to fish community structure (Fig. 4). Effects of prey removals could be manifested at either large scales (on the order of ecosystems or fishery management units such as the Gulf of Alaska) or local scales (such as the eastside of Kodiak Island or the Unimak Pass area). Included at the local scale is the impact of prey removals as a function of fishing patterns (e.g., timing and location).

Fisheries disturb the marine environment in at least three ways that could affect sea lions. Two involve changes in prey and prey patch distribution, while the third addresses simple competitive spatial disturbance, or interference competition. Disturbances of prey could change patch structure in at least two ways: by reducing the density of individual patches (dispersion) or by changing the distribution, size, or number of patches in space (e.g., deeper, more dispersed, smaller, fewer). These are complex research questions which involve sea lion foraging behavior and how fish respond to fishing gear.

Changes in the composition of the fish community can result from fisheries targeting particular species, which could affect sea lions:

- By reducing the amount, availability, or quality of prey available to sea lions. These effects would flow from changes in the composition of the fish community as a result of the history of fishing on one or more species in the North Pacific Ocean, including whales (e.g. “trophic cascade hypothesis”).
- By increasing the rates of predation on sea lions due to prey switching by sea lion predators. This could occur if the population size of a preferred prey of a sea lion predator (e.g., shark) were depleted as a result of fisheries and the predator switched to eating more sea lions.
- By increasing the level of competition between sea lions and other groundfish consumers for a preferred sea lion prey.

This research hypothesis is well-covered by projects administered principally by NMFS-AFSC, UA, NPUMMRC, and ADF&G. Research runs the gamut from field examination of small-scale effects of fisheries on prey distribution and abundance to retrospective studies of data collected by fisheries observers and during fishery-independent groundfish surveys. The AFSC used a portion of its additional funds to conduct expanded surveys of the fish community in Steller sea lion critical habitat. Given the large number of projects that will directly or indirectly contribute to our understanding of fisheries effects (including baseline studies of Steller sea lion biology) and the high cost of ship time for fish surveys, this area (i.e., indirect effect of fisheries) has the largest funding total (\$20-25 M).

Environmental changes - As with indirect fisheries effects, three types of effects from changes in the environment were identified: decreased production, altered prey patch distribution, and changes to the structure or distribution of biological communities (Fig. 5). Each could reduce the environmental carrying capacity for sea lions, resulting in decreased survival or births through nutritional stress or direct mortality. Decreased production (primary and secondary) from environmental change would reduce the amount of prey available on either large or local scales. Similar to question F2, the local scale production hypothesis (E2) also addresses the issue of changes in the timing of local production as a result of changes in the environment and how this could affect sea lions. Environmental changes can alter the distribution of prey patches (i.e., with depth) making fish less available to sea lions. Structural and distributional responses of biological communities to environmental changes also include reductions in the amount, availability or quality of sea lion prey, or increased predation on or competition with sea lions.

Research into the possible effects of environmental change on Steller sea lions was initiated primarily by OAR and NOS through the CIFAR’s proposal solicitation process and by OAR’s Pacific Marine Environmental Laboratory (PMEL). However, several cross-cutting projects (funded by CIFAR, SSLRI, NPUMMRC, and AFSC) will attempt to produce models

that synthesize results from new oceanographic projects and a broad range of biological and physical data to examine relative impacts on Steller sea lion bioenergetics and survival. New funds allocated to NOS and OAR in FY01 totaled \$8M, while similar projects conducted by others (particularly modeling efforts) boosted the funding in this area to \$10-12M.

Direct anthropogenic effects - Subsistence hunting, intentional shooting, incidental take in fisheries, and residual effects of legal harvests or bounties are all examples of direct anthropogenic effects that could decrease survival or births of sea lions through direct mortality (Table 3).

Projects funded under this category will examine a wide variety of human-related activities that lead to sea lion mortality, including subsistence hunting, illegal shooting, incidental take in fisheries, and killing of sea lions outside of U.S. waters. Other effects, such as those resulting from discontinued pups harvests and bounty programs, are also considered here, primarily in modeling projects. Prior to FY01, ADF&G, AFSC and AKR conducted all of these research and monitoring activities, while modeling work was done at these institutions and at NPUMMRC. New funds allocated in FY01 permitted expansion of these existing programs and initiation of community-based research and monitoring of local sea lion rookeries and haulouts by native organizations in Alaska (funded through SSLRI). Some of these new community-based efforts are in collaboration with scientists at UA and environmental consulting firms. Approximately \$1M was spent in FY01 on these research activities.

Predation - Predation by both killer whales and sharks could be a factor in both the original decline and the lack of recovery of Steller sea lion populations in Alaska. Predation effects could be manifested in one of two ways (Table 3):

- The number of sea lions killed by predators has increased due to increases in killer whale or shark populations or their per capita rate of predation (prey switching).
- The number of sea lions killed by predators has remained relatively constant but it has an increased impact on the population because of low sea lion population size.

While killer whale and shark research and monitoring activities were already underway (primarily at AFSC and NPUMMRC), expanded funding in FY01 permitted the initiation of programs at UA and ASLC, as well as with the aforementioned groups. Shark biology investigations (e.g., tagging, food habits and movement), along with expanded killer whale monitoring, characterization (e.g., transient vs. resident), and population assessment were among the projects funded. In addition, mathematical models that incorporate the effects of predation along with other factors on the Steller sea lion population will be developed. Funding for these research activities totaled \$2-3 M.

Disease - The effects of diseases (either novel epidemic or increased incidence of endemic diseases) could decrease survival or births of sea lions through direct mortality of individuals or

through a reduction in individual fitness, which would increase their vulnerability to other factors (Table 3).

While routine monitoring for known diseases had been part of ongoing biological work at AFSC and ADF&G, new funding allowed for considerable expansion of these efforts. New, more comprehensive disease and parasite assessments will also begin at the ASLC. Funding totaled approximately \$1 M.

Contaminants - Similar to the effects of disease, the effects of organic and inorganic contaminants could decrease survival or births of sea lions through direct mortality of individuals or through a reduction in individual fitness, which would increase their vulnerability to other factors (Table 3).

Prior to FY01, sea lion blubber and tissue samples were collected and analyzed for metals and organic pollutants by both the AFSC and ADF&G. However, no research program existed with the sole purpose of examining the role of contaminants in the decline of Steller sea lions. New research programs funded under SSLRI (at Yale University) and initiated at ASLC, along with continued funding of the work at AFSC and ADF&G, will develop tools to assess the threat posed by pollutants and provide for field data collection. FY01 funds spent on contaminant research totaled approximately \$1M.

Synergies - A frequent topic of discussion among the funded entities when the framework was being developed was that each factor was considered in isolation, when in reality, more than one of them could be in effect now or in the past. Several of the projects, particularly those that have a modeling component, specifically address how fisheries and environmental effects could combine in an unpredictable manner to reduce prey availability, abundance, or quality to sea lions. All possible combinations of effects were addressed in a single question, S1 (Table 3).

“Bottom-Up” Perspective: Research Themes

The bottom-up perspective for organizing research projects is the one that is probably most familiar to both researchers and the public. This is because it reflects the type of research being conducted. Just as it is possible for research conducted under a single theme to address several questions, it is also possible for a series of projects that each attempt to answer a single question to use different tools or techniques, or be responsive to different themes. The 11 themes identified were as follows:

Life History - Investigations of the life history of Steller sea lions, including all aspects of ontogenetic development (e.g., weaning process, molt), growth, and reproduction. Behavioral studies are included as a sub-theme since the age and sex of the studied individuals are central to their behavior.

Foraging - Studies of the foraging ecology of Steller sea lion juveniles and adults. This includes all aspects of foraging, including what is eaten (food habits and diet), the costs incurred in locating and obtaining prey (bioenergetics), and differences in habitat use by juveniles and adults (habitat use).

Vital Rates - All studies related to population assessment (both counting of animals and assessment of their condition), reproductive rates, and survival/mortality rates (e.g. branding studies). Modeling studies, such as the creation of a new life table, would also fall under this theme. Many of these studies supply baseline information necessary to address all of the hypotheses/questions.

Fish Assessment and Fisheries - Prey or fish surveys, along with any studies of the impacts of fisheries on either large or small spatial/temporal scales.

Ecosystems - Any study dealing with bottom-up processes in the ocean and how changes in them might affect the prey field for Steller sea lions. As with the Fish Assessment and Fisheries theme, there are two sub-themes (local/regional and global) depending on the scale of the ecosystem study.

Other Anthropogenic Effects - Any studies of the effects or quantification of subsistence hunting, intentional shooting, incidental take, or the residual effect of harvests and bounties on the Steller sea lion population. This theme, along with the following three, directly corresponds with one of factors causing or contributing to the decline.

Predation - Killer whale and shark predation are sub-themes under this general research theme, which would include all studies whose primary focus is addressing questions P1-P4.

Disease - Studies of sea lion diseases (including parasites) are included in one of two sub-themes: 1) assessment of the effects of diseases on the health of individuals, and 2) assessment of the population-level impact of diseases.

Contaminants - Similar to sea lion disease studies, contaminant studies were also placed into one of two sub-themes depending on the scale at which contaminant effects were analyzed: 1) assessment of the effects of contaminants on the health of individuals, and 2) assessment of the effects of contaminants on sea lion habitats (environmental-level effects), and how this could reduce sea lion survival or births.

Management - Projects under this theme involve funding for meetings to implement regulations (e.g., NPFMC), for independent reviews of the scientific and legal basis for actions, and for analysis of impacts of actions (particularly economic). Reviews address the information available and required to answer some or all of the questions posed, while other projects inform decisions made by managers.

Communications - Communication of ideas and information both among researchers (coordination) and between researchers and the interested public (outreach) are the principal goals of projects under this theme. Forms of communication considered include symposia, publishing of scientific literature, and web-based content.

Comprehensiveness

Major strides have been made in achieving a comprehensive research program to investigate the factors responsible for the Steller sea lion decline. Most of the research areas identified in the Stevens Rider have projects oriented to them and over 150 individual research projects are underway. The expansion not only addresses a broader series of plausible hypotheses for the Steller sea lion decline, but also enables a much more thorough, integrated investigation of each. However, whether the current mix of projects constitutes a fully responsive, comprehensive program is yet to be determined. Gaps, overlaps, efficiencies, and potential synergies will be monitored as the program unfolds. AFSC intends to provide oversight and coordination for the ongoing program. As results accumulate and concepts arise from the work now underway, our sense of the degree to which the program is responding will evolve. Through its coordination and leadership efforts, the AFSC will place a high priority on assuring that this diverse research program stays integrated and on track. A key component of this effort will be the timely reporting of results to all constituent groups that express interest.

The efforts to expand the Steller sea lion research capabilities both inside NMFS and among our new partners have largely met the initial objectives noted above, especially in light of practical expectations for a program of this magnitude and complexity. While results from the majority of studies were not available prior to the completion of FY02 field studies and analyses (many of which are multi-year projects with starting dates in FY02), much of the planning and organizing apparatus necessary to provide direction for them has seen significant progress. In essence, aside from ongoing Steller sea lion studies, FY01, and to a certain degree, FY02, served as periods of preparation during which new projects were designed, funds were distributed, and communications links among key participants receiving earmarks were solidified. With respect to responsiveness to the 13 areas of research emphasis, all but one is addressed and in most cases by a variety of complementary studies. With a core group of contacts representing each of the endowed parties now established, we are also in position to monitor progress and identify both opportunities for coordination and gaps in need of attention. Whether the current suite of studies constitutes a comprehensive and coordinated program depends on the success of individual projects, but with the aid of a research framework, we now have a means of evaluation that has been jointly developed and accepted by the participating parties.

Summary and Conclusion

The current outlook for Steller sea lion research suggests promise for future science-based management efforts. The complexity and scope of research, and the communication and coordination among the participants are considerably enhanced relative to the program capabilities of the past two decades. However, expectations for meaningful progress toward identification of key factors for the recovery of Steller sea lions should be tempered by two realities.

First, few, if any of the ongoing studies are likely to yield conclusive results regarding the underlying constraints on Steller sea lion recovery in the short term. That is, most efforts involve multi-year studies, ranging from 2 to 10 years, designed to provide insights and inferences on various facets of the issue. A realistic expectation is for new information to coalesce over time and provide the basis for more refined or targeted questions centered on those aspects that have shown particular promise. Likewise, progress will be evident as the new information points out the factors less likely to play important roles and so are de-emphasized in future work. The underlying assumption for the entire research effort, however, is that sufficient funding levels persist long enough for the ongoing suite of studies to produce meaningful results, and to allow those results to form the basis for more refined investigations.

Second, our understanding of ecosystem processes is limited and marine science is more likely to produce glimpses of the underlying mechanics rather than an overall picture of its dynamics for many years to come. As such, while the Steller sea lion research efforts are very likely to greatly enhance our knowledge base, they should not be expected to either prove causal relationships or produce tools for predicting ecosystem function. Rather, we should consider the real value of the new information as ever improving the scientific foundations for management decisions, which in turn, must still rely on the application of conservation principles in the face of uncertainty.

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Table 1. -- Federal funding (\$1,000s) for Steller sea lion research in fiscal years (FY) 1982 - 2000 available to NMFS and other federal agencies¹, and to other research organizations².

FY	Federal Agencies	Non-Federal Research Organizations	Total
1982	50		50
1983	50		50
1984	50		50
1985	200		200
1986	100		100
1987	300		300
1988	200		200
1989	200		200
1990	600		600
1991	559		559
1992	676	750	1,426
1993	517	728	1,245
1994	584	708	1,292
1995	645	708	1,353
1996	831	1,005	1,836
1997	867	1,022	1,889
1998	978	2,043	3,021
1999	1,653	1,863	3,516
2000	2,110	2,610	4,720
2001	15,850	27,300 ³	43,150
2002	25,650	14,495	40,145

¹NOAA Office of Oceanic and Atmospheric Research and National Ocean Service

²Alaska SeaLife Center, Alaska Department of Fish and Game, North Pacific Universities Marine Mammal Research Consortium, North Pacific Fishery Management Council, University of Alaska, and Alaska Fisheries Development Foundation

³Includes funds for the Steller Sea Lion Research Initiative (SSLRI)

Table 2. -- Summary of the potential factors contributing to the decline of Steller sea lions identified by the Steller Sea Lion Recovery Team's (SSLRT) recovery plan (NMFS 1992), their research recommendations, and progress made in the 1990s in evaluating the contribution of each factor in the continued decline.

Source	Factor in Steller Sea Lion Decline	SSLRT Research Recommendation	Progress in the 1990s in Evaluating Contribution of Factor in Recent Decline
Natural	Parasitism and disease	Increase monitoring	Little
	Environmental change	None	Re-emergence as factor
	Predation	Evaluate	Re-emergence as factor
Human	Commercial harvest	None	Much; not considered a factor
	Subsistence harvest	Monitor	Much; better estimates and mortality rate reduced
	Incidental take	Monitor	Much; not considered a factor
	Intentional killing	Evaluate and educate	Little
	Entanglement	Evaluate and educate	Much; not considered a factor
	Toxic substances	Increase monitoring	Little
	Disturbance	None	Little
Competition for food	Determine effects of fisheries on prey	Little	

Table 3.-- Structure of specific hypotheses for each factor causing or contributing to the decline of Steller sea lions.

A. Indirect Fisheries Effects. Read each hypothesis (F1-F8) as:

Has [General Effect][Specific Effect] resulting in [Reason for the Decline] through [Mechanism]

Code	General Effect	Specific Effect	Reason for the Decline	Mechanism		
F1	Prey removal by fisheries	Reduced ecosystem-wide prey abundance or availability	Decreased survival or births of sea lions	Nutritional stress		
F2		Reduced local prey abundance or availability				
F3	Prey disturbance by fisheries	Reduced density of individual prey patches				
F4		Changed distribution and reduced size or number of prey patches				
F5	Competitive interaction with fisheries	Reduced prey availability				
F6	Fish community changes from fishing	Reduced abundance, availability, or quality of prey				
F7		Increased predation on sea lions			Decreased survival of sea lions	Direct mortality
F8		Increased competition for prey with sea lions			Decreased survival or births of sea lions	Nutritional stress

B. Environmental Changes: Read each hypothesis (E1-E6) as:

Has [General Effect][Specific Effect] resulting in [Reason for the Decline] through [Mechanism]

Code	General Effect	Specific Effect	Reason for the Decline	Mechanism
E1	Decreased production from environmental change	Reduced ecosystem-wide prey abundance or availability	Decreased survival or births of sea lions	Nutritional stress
E2		Reduced local prey abundance or availability		
E3	Environmental change	Altered distribution and availability of prey patches		
E4	Environmental change altered composition of biological communities	Reducing abundance, availability, or quality of prey	Decreased survival of sea lions	Direct mortality
E5		Increasing predation on sea lions		
E6		Increasing competition for prey with sea lions	Decreased survival or births of sea lions	Nutritional stress

C. Direct Anthropogenic Effects: Read each hypothesis (A1-A4) as:

Has [Specific Effect] resulted in [Reason for the Decline] through [Mechanism]

Code	Specific Effect	Reason for the Decline	Mechanism
A1	Subsistence hunting	Decreased survival of sea lions	Direct mortality
A2	Intentional shooting		
A3	Incidental take in fisheries		
A4	Residual effect of legal harvests		

D. Predation: Read hypotheses (P1-P4) as:

Have [Specific Effect] of [Predator] resulted in [Reason for the Decline] through [Mechanism]

Code	Specific Effect	Predator	Reason for the Decline	Mechanism
P1	Increases in the population	Killer whales	Decreased survival of sea lions	Direct mortality
P2	Increases in per capita predation rates			
P3	Increases in the population	Sharks		
P4	Increases in per capita predation rates			

E. Diseases: Read hypotheses (D1-D2) as:

Have [Specific Effect] resulted in [Reason for the Decline] through [Mechanism]

Code	Specific Effect	Reason for the Decline	Mechanism
D1	A single or combination of endemic or new diseases	Decreased survival or births of sea lions	Direct mortality
D2			Reduction in individual fitness

F. Contaminants: Read hypotheses (C1-C2) as:

Have [Specific Effect] resulted in [Reason for the Decline] through [Mechanism]

Code	Specific Effect	Reason for the Decline	Mechanism
C1	A single or suite of organic or inorganic contaminants, either persistent or acute	Decreased survival or births of sea lions	Direct mortality
C2			Reduction in individual fitness

G. Synergisms (S1): Have two or more of the above factors combined to decrease survival or births of sea lions through nutritional stress, direct mortality, or a reduction in individual fitness?

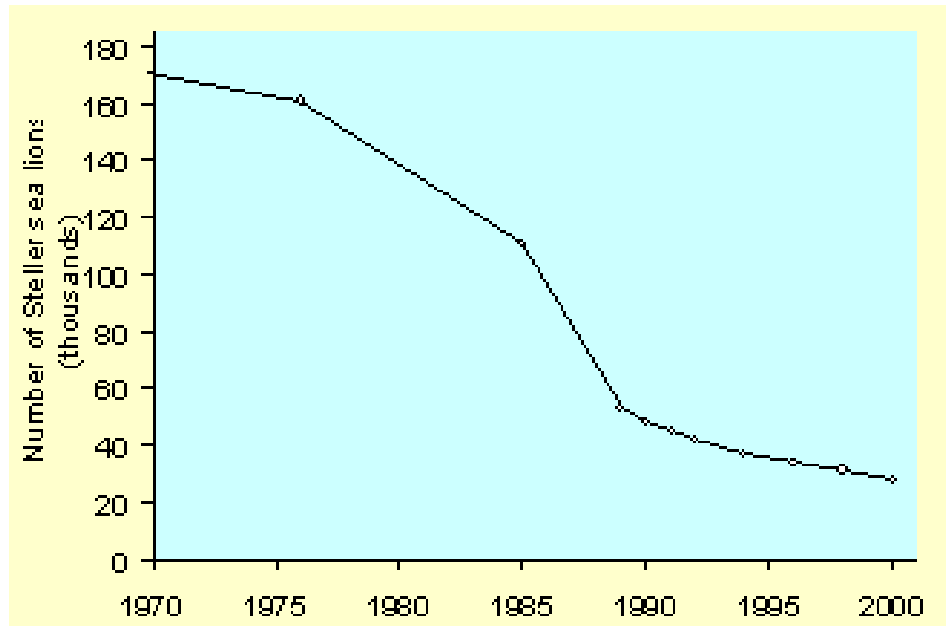


Figure 1. -- Estimated number of Steller sea lions in the western population in Alaska, 1970-2000.

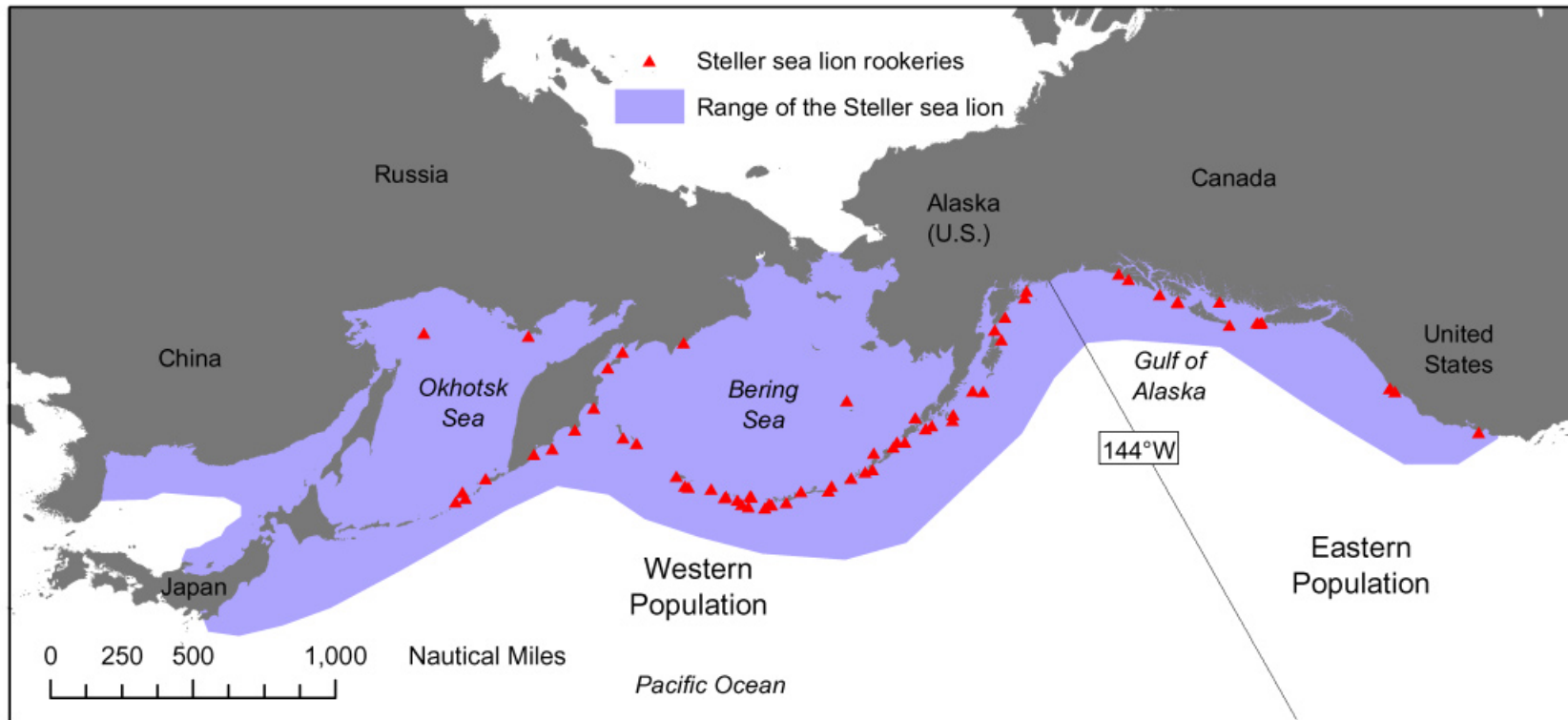


Figure 2 -- Range of the Steller sea lion (*Eumetopias jubatus*) in the North Pacific Ocean. Rookeries are terrestrial breeding locations.

Framework structure

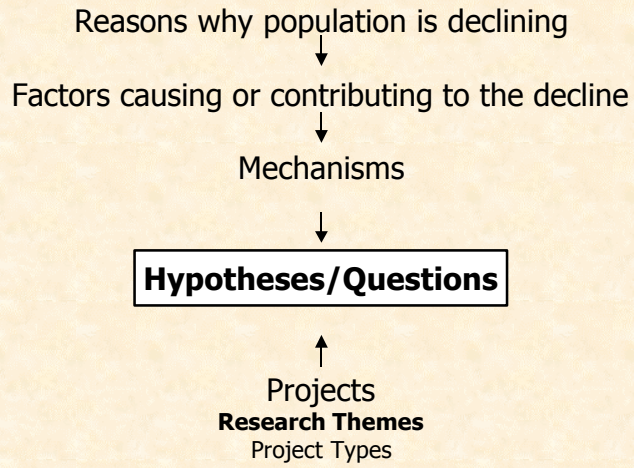


Figure 3. -- Generalized structure of Steller sea lion research framework.

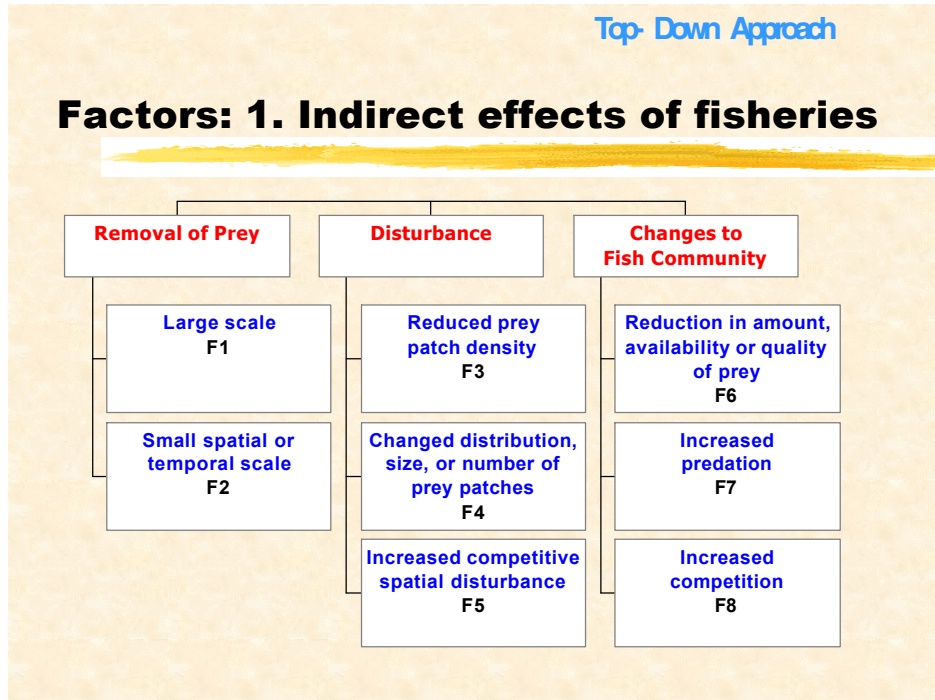


Figure 4.-- Organization of hypotheses and questions related to the possible indirect effects of fisheries on the decline of Steller sea lions. F1 through F8 refer to the hypotheses listed in Table 3.

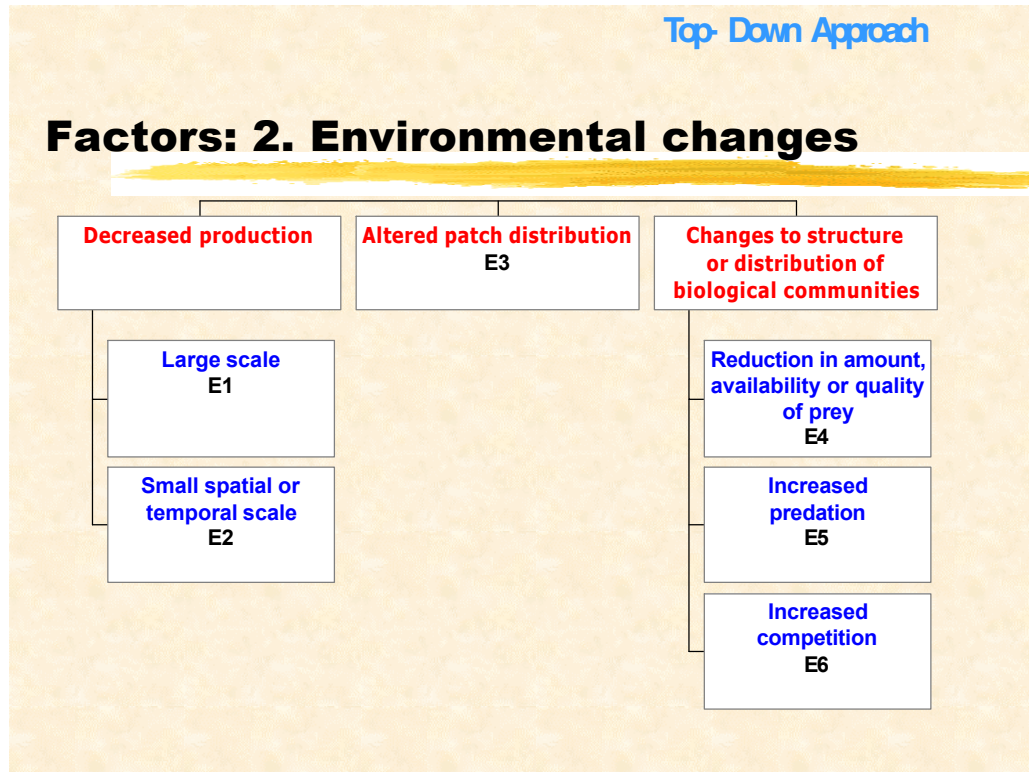


Figure 5.-- Organization of hypotheses and questions related to the possible effects of environmental changes on the decline of Steller sea lions. E1 through E6 refer to the hypotheses listed in Table 3.

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