Conservation Plan

For The

Northern Fur Seal

Callorhinus ursinus

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

National Marine Fisheries Service
Office of Protected Resources

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CONSERVATION PLAN

FOR THE

NORTHERN FUR SEAL

CALLORHINUS URSINUS

Prepared by the

NATIONAL MARINE MAMMAL LABORATORY
ALASKA FISHERIES SCIENCE CENTER
NATIONAL MARINE FISHERIES SERVICE
SEATTLE, WASHINGTON

and

OFFICE OF PROTECTED RESOURCES
NATIONAL MARINE FISHERIES SERVICE
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Approved: N Foster

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PREFACE

A Conservation Plan delineates reasonable actions to protect a depleted species under the Marine Mammal Protection Act (MMPA). Plans are prepared by the National Marine Fisheries Service (NMFS), sometimes with the assistance of planning groups, contractors, state agencies, and others. The Pribilof Islands Northern Fur Seal Conservation Plan (hereafter referred to as the Conservation Plan) was prepared by NMFS. This Conservation Plan represents the official position of NMFS after it has been approved and signed by the Assistant Administrator for Fisheries. Approved plans are subject to modification as dictated by new findings, changes in species status and completion of implementation tasks. Goals and objectives will be attained and funds expended contingent upon agency appropriations and priorities.

This final plan is intended to serve as a guide that delineates and schedules those actions believed necessary to restore the northern fur seal to pre-depleted levels of abundance. These actions are outlined in the Implementation Schedule of the plan. It is recognized that many of the tasks described in the plan are already underway. Inclusion of these ongoing tasks represents an awareness of their importance and offers support for their continuation.

The goal of this Conservation Plan will be met when the population of northern fur seals has increased to the level where it can be removed as depleted under MMPA listings.

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EXECUTIVE SUMMARY

On June 17, 1988, the National Marine Fisheries Service (NMFS) declared the Pribilof Islands, Alaska (St. Paul and St. George Islands), stock of northern fur seals (Callorhinus ursinus) depleted under the Marine Mammal Protection Act (MMPA) of 1972. Amendments to the MMPA passed into law on November 23, 1988 (Public Law 100-711), direct the Secretary of Commerce to develop a conservation plan on northern fur seals for "conserving and restoring the species or stock to its optimum sustainable population." The amendments further specify that the plan include information on the status of fur seals on the Pribilof Islands, causes of declines, threats to the species, critical information gaps, and recommended research and management actions for meeting the objectives of the plan.

The MMPA defines a species, population, or stock as depleted if it falls below its optimum sustainable population (OSP). The lower bound of OSP for northern fur seals is thought to be at least 60 percent of the carrying capacity (K) level. The Pribilof Islands population was designated depleted because it declined to less than 50 percent of levels observed in the late 1950s, and there was no compelling evidence that carrying capacity has changed substantially since the late 1950s. If the fur seal stock on the Pribilof Islands recovers to its OSP, then the depletion designation under the MMPA should be lifted. Monitoring population growth is therefore an essential long-term activity for determining population recovery.

The largest known cause of the decline of fur seal abundance from 1956 to 1968 was the commercial harvest of adult females. Since 1976 there has been lowered survival of juveniles from natural or human-induced causes. However, the factor(s) responsible for producing these changes are not well known. The incidence of entanglement in marine debris increased following the mid 1960s when fishing effort in the North Pacific Ocean and Bering Sea increased and when plastic materials began to be used extensively in trawl nets and packing bands to a level at least two orders of magnitude greater than that observed in the 1940s. The survival of 2- to 5-year-old male seals between 1970 and 1982 was negatively correlated with increased rates of entanglement. The significant correlation between entanglement rate and rate of change of pup numbers suggested that mortality of fur seals due to entanglement in marine debris may have contributed significantly to declining trends of the population on the Pribilof Islands during the late 1970s.

Changes in the quantity and/or quality of available prey may also influence the health and fitness of individual fur seals. Evidence that major shifts have occurred in the abundance of fish in the Gulf of Alaska and eastern Bering Sea over the past several decades is well documented. In the 1950s and early 1960s, the biomass of Pacific herring exceeded 3-5 million metric tons. Rapid increases in the estimated size of walleye pollock stocks in both the Bering Sea and Gulf of Alaska occurred between the 1960s and 1980s. In the early 1980s, walleye pollock biomass in the two regions increased significantly to a peak of approximately 18.5 million tons while sea herring biomass initially increased, then decreased. Recent estimates indicate that the walleye pollock biomass has accounted for nearly 85 percent of the pelagic and semi-demersal fish population in that region. Walleye pollock have been shown to be an important prey of fur seals in the eastern Bering Sea and the Gulf of Alaska in the summer. The development and expansion of commercial fisheries throughout the species' range, including the North Pacific Ocean, may have directly or indirectly changed the fur seal's food supply. Thus, although there is evidence suggestive of changes in the abundance of major fish species and the environment, the causes of these changes and their influence on northern fur seal population trends are largely unknown. The complexity of ecosystem interactions, and limitations of data and models make it difficult to determine how fishery removals may have influenced, or continue to have an influence on, the population.

The overall goal of this Conservation Plan is to promote recovery of the fur seal population on the Pribilof Islands to a level appropriate to justify removal from MMPA listings, and towards this end, take actions to promote the recovery of northern fur seals. The present abundance estimate is below OSP based on a population level of 1,800,000 during the 1940s and early 1950s (Kenyon et al., 1954 thought this population level to be at, or near, K; therefore this estimate was used in the proposed rule to list the northern fur seal as depleted under the MMPA, at 51 FR 47156, Dec. 30, 1986). However, more recent population estimates of fur seals on the Pribilof Islands during this time period indicate that annual pup production was up to 530,000, and the total stock size was 2,100,000 (Briggs and Fowler, 1984). The population level at which maximum productivity would occur, and the level at which NMFS would reconsider the depleted classification, would occur at a sustained population level (total abundance estimate) and/or a sustained level of annual pup production which are 60 percent of the peak historical estimates.

Management designed to provide for the continued protection and recovery of the fur seal population should be based on biological principles and ecological understanding. It is not completely clear what factors contributed to the population decline of the fur seal, and a great deal of current information vital to the effective management of the species remains lacking. Despite these information needs, efforts to reduce human-caused mortality to the lowest level practicable, to protect important habitats, and to enhance population productivity by ensuring that there is an ample food supply available should be undertaken. Immediate objectives are to identify factors that might be limiting the population, and to propose a set of actions that will minimize any human-induced activities that may be detrimental to the population. Conservation and management measures have addressed some of these needs. Additional management actions are described in this Conservation Plan. It is understood that the research and management actions recommended herein will require a considerable amount of time, effort and funding to produce the information needed to effect rational conservation and management measures considered under this plan.

PART I

1. INTRODUCTION

Amendments to the MMPA passed into law on November 23, 1988 (Public Law 100-711), direct the Secretary of Commerce to develop a conservation plan for the northern fur seal (Callorhinus ursinus). A Conservation Plan identifies specific management actions that must be taken to ensure that the species of concern recovers to the point that it can be removed from MMPA listing. The amendments further state that the conservation plan include the following essential elements:

(1) an assessment of the status of the stock;

(2) a description of the causes of any population declines or loss of essential habitat;

(3) an assessment of existing and possible threats to the species or its habitat;

(4) a discussion of critical information gaps;

(5) a description of research and management to be undertaken to meet the objectives of the plan; and

(6) an implementation schedule of the proposed action to promote recovery activities.

Some of the decline in the northern fur seal population can be explained as a direct result of harvesting practices. However, recent trends in the abundance of fur seals cannot be explained, solely, as a result of the commercial harvest. Like the situation that has resulted in the continued decline in abundance of the Steller sea lion, Eumetopias jubatus, throughout the Gulf of Alaska and Bering Sea (NMFS, 1992a), many of the problems that have inhibited the growth of the northern fur seal herd on the Pribilof Islands, and the necessary remedial actions, cannot be easily identified due to the ecological complexity of the problem. Unlike the observed, precipitous decline in abundance of Steller sea lions, it appears that the northern fur seal herd on St. Paul Island has stabilized (no significant trend is evident) during the past decade while the herd on St. George Island continues to decline.

This Conservation Plan recommends continuation of ongoing research and development of new programs designed to improve our understanding of fur seal management and conservation needs. It may still be a considerable length of time before we understand the role of all factors that influence the population. Specific management actions designed to help understand the fur seal population have been recommended in this Conservation Plan. A NMFS monitoring program has been conducted on St. Paul and St. George Islands (Pribilof Islands) to allow a near-continuous evaluation of the population trend and status of the fur seals. Continuing results from these monitoring programs, and subsequent research activities, will be considered in subsequent revisions and modifications to this Conservation Plan.

2. BACKGROUND

A. Species Description

Fur seals belong to the Order Carnivora, Suborder Pinnipedia, Family Otariidae, and Subfamily Otariinae. The family contains the extant genera Arctocephalus, Callorhinus, Eumetopias, Neophoca, Otaria, Phocarctos, and Zalophus. The genus Callorhinus contains one species, the northern fur seal, C. ursinus. Unless noted otherwise, all references to fur seals in this document are to northern fur seals.

B. Determination of Depleted Status Under the MMPA

The Pribilof Islands population was designated depleted on 17 June 1988 because it declined to less than 50 percent of levels observed in the late 1950s and there was no compelling evidence that carrying capacity (K) had changed substantially since the late 1950s. The MMPA defines the term "depletion" or "depleted" (16 U.S.C.1362 (1)) as meaning any case in which "(A) the Secretary of Commerce, after consultation with the Marine Mammal Commission (MMC) and the Committee of Scientific Advisors on Marine Mammals established under title II of this Act, determines that a species or population stock is below its optimum sustainable population; (B) a State, to which authority for the conservation and management of a species or population stock is transferred under U.S.C. 1379, determines that such species or stock is below its optimum sustainable population; or (C) a species or population stock is listed as an endangered species or a threatened species under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.)."

The MMPA further defines optimum sustainable population (OSP) as "...with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element (1362(8))."

NMFS regulations at 50 Code of Federal Regulations (CFR) 216.3 define OSP as "...a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem (K), to the population level that results in maximum net productivity (MNPL). MNPL is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth losses due to natural mortality."

Section (1361(2)) of the MMPA states that marine mammal species, populations and/or stocks should not be permitted to fall below their OSP level. The MNPL is the lower end of OSP. Therefore, to be within OSP, the ratio of current to historic levels should be at or above the maximum rate of pup production (or MNPL). Historically, MNPL has been expressed as a range of values (generally 50-70 percent of K) determined theoretically by estimating what stock size in relation to the original stock size will produce the maximum net increase in population (42 Federal Register (FR) 12010, March 1, 1977). MNPL for marine mammals is at least 50 percent of carrying capacity (Eberhardt and Siniff, 1977), and may be as high as 80 percent (Fowler 1981, 1988). In 1977, the mid-range value of 60 percent was used to determine if a stock of dolphins was depleted (42 FR 64548, Dec. 27, 1977). The 60 percent value was supported by NMFS in the final rule governing the taking of marine mammals incidental to commercial fishing operations (45 FR 72178, Oct. 31, 1980). The lower bound of OSP for northern fur seals is also considered to be at 60 percent of K (Fowler, 1981).

Both OSP and K are difficult to measure; K is especially hard if the ecosystem has changed significantly since historic high population levels. The most difficult aspect is determining what influence human activities may have on the natural regulation of the ecosystem. The following discusses how OSP and carrying capacity for fur seals are estimated to determine a depleted status under the MMPA.

Optimum Sustainable Population. OSP is estimated using one of three methods. The first method assumes that over time, a large-mammal population will grow towards, and fluctuate at or near, its carrying capacity (the upper bound of OSP) and thus reach a stable population size with a stable age distribution. Population changes are measured directly while the population is at K.

A second method of estimating OSP compares the current estimate of population size with an estimate of the maximum historical population size (i.e., presumed K). Maximum historical levels may be estimated by back-calculation, using exploitation levels and an estimate of present population levels, or from empirical data on past abundance.

A third method, called dynamic response analysis (Goodman, 1988), assumes that below MNPL the population increases at a rate of growth faster than when the population is above MNPL (DeMaster et al., 1982). Dynamic response analysis is difficult to use for many species because 10-15 year time-series of population indices are usually needed to determine whether the rate of population change is increasing. The method is also sensitive to precision in estimating population indices, and works best in the absence of a harvest, and cannot be used on a population declining from levels below carrying capacity unless there is a constant known harvest (Boveng et al., 1988; Goodman, 1988; Gerrodette, 1988). Determining whether the population is increasing or decreasing is difficult, and if the rate itself is changing an even longer time-series is needed. One apparently robust method of estimating population change for northern fur seals has been to use pup production as an indicator of population size (Lander, 1981; York, 1987a, 1987b; York and Kozloff, 1987), although the rate of population change may be biased using pup counts depending upon which life-history parameters are density dependent (Berkson and DeMaster, 1985; Boveng et al., 1988).

Carrying Capacity. Few efforts have been made to assess whether the fur seal carrying capacity of the Bering Sea and eastern North Pacific ecosystem has changed. However, significant changes have taken place in the abundance and size/age-structure of fish, shellfish, seabird, and marine mammal populations (cf., Bailey et al., 1986; Bakkala et al., 1986, 1987; Springer et al., 1986; Merrick et al., 1987; Nunnallee and Williamson, 1988; Bakkala, 1989; Loughlin and Merrick, 1989; Lowry et al., 1989; Pitcher, 1990). Swartzman and Haar (1983) reviewed fisheries data for the Bering Sea (primarily on walleye pollock, Theragra chalcogramma) as it relates to carrying capacity. While their work suggests that the data are more consistent with the hypothesis that the carrying capacity has increased since the early 1970s, they "did not reject the hypothesis that the fur seal carrying capacity was reduced by fisheries." Therefore, data concerning the effects of removing fish from the Bering Sea and Gulf of Alaska on marine mammals is equivocal. The impact of commercial fishing on the ecology of fur seals and community competition is poorly understood.

Changes in environmental and oceanographic features may also influence mortality rates of fur seals and other pinnipeds, and thus influence carrying capacity. In 1950, severe storms and low temperatures were possibly responsible for an estimated 700 deaths of fur seals that were stranded in Oregon and Washington (Scheffer, 1950a). York (1991) found a significant positive correlation between sea surface temperatures (SST) off British Columbia and early survival of male fur seals 4 months to 2 years old. She hypothesized that SST may influence Pacific herring, Clupea pallasi (a common fur seal prey in winter and spring), abundance and availability, thus affecting early survival of fur seals. Studies in Alaska suggest that a 1982-1983 El Niño event probably did not have an important affect on fur seals (Gentry, 1991) or some seabirds (Hatch, 1987) in that region. The same El Niño event had a significant impact (i.e., pup production declined significantly) on the 1983 breeding season of fur seals on San Miguel Island, California (the southern extent of their North Pacific range) (DeLong and Antonelis, 1991), emphasizing the potential influence of environmental or oceanographic changes on fur seal abundance and pup production.

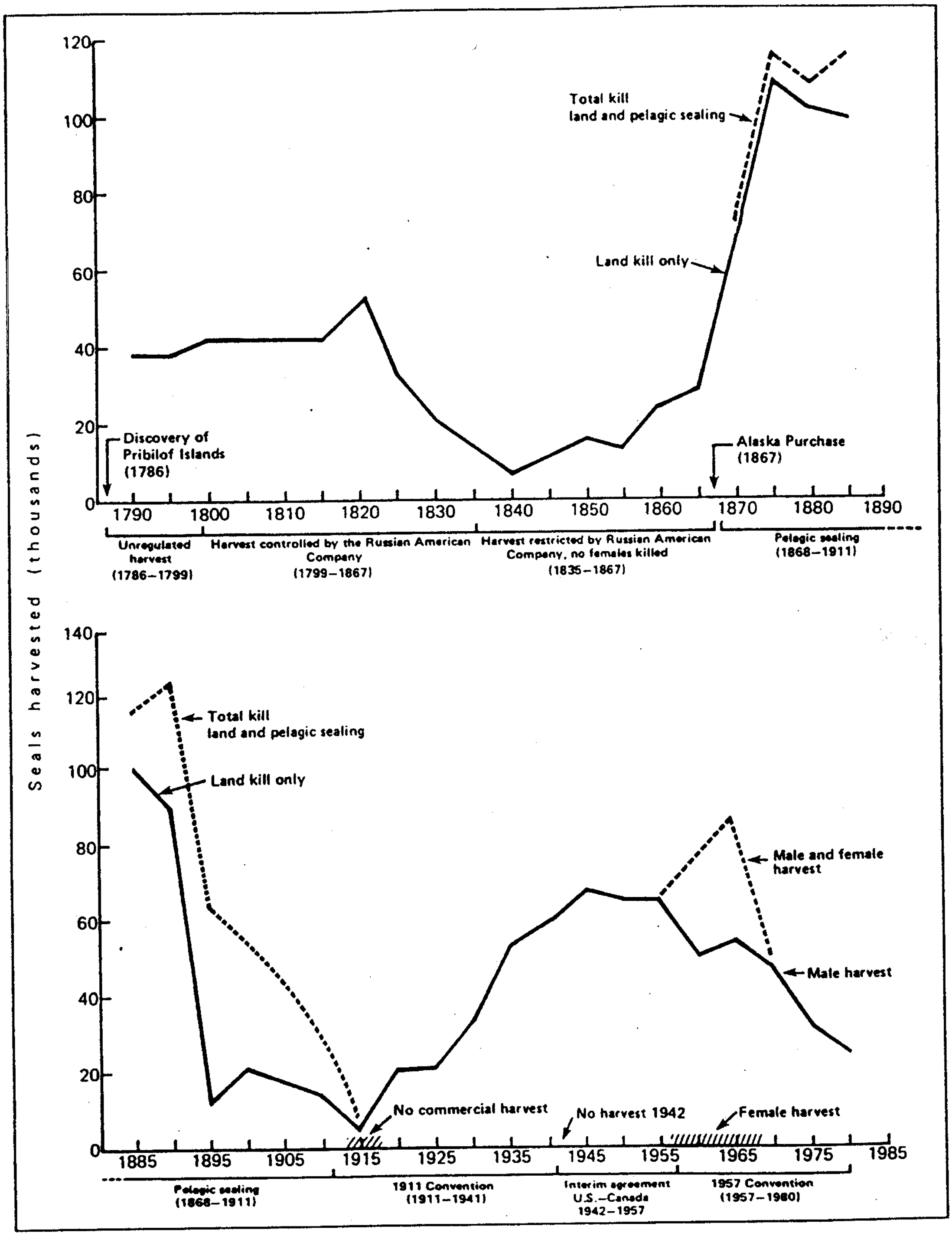
Therefore, a reliable measurement of the current carrying capacity for fur seals is not available, based on existing ecosystem conditions. Fowler (1986) stated that "given the available data and analyses, it is not possible to clearly determine whether the Pribilof fur seal population is currently at, above, or below carrying capacity levels; whether carrying capacity has changed significantly in the last two or three decades; or whether the observed population decline is due to declining carrying capacity, increased mortality, or some combination of both."

C. History of Exploitation

Commercial Harvest. The Pribilof Islands and its fur seal population were first discovered by Russian explorers in June 1786 (Fig. 1). From 1786 to 1828 the Russians, with Aleut labor, harvested an average 100,000 fur seals per year, primarily pups (Roppel, 1984). It was not until 1822 that bulls were protected and restrictions placed on the number of pups killed (Scheffer et al., 1984). From 1835 to 1839 an average of 70,000 seals were harvested annually. Beginning in 1847, the number of males taken was controlled and the harvest of females was stopped. About 30,000 to 35,000 fur seals were killed annually during the last 10 years of Russian occupation. The population was reportedly thriving and was sustaining an annual harvest of several thousand males when the United States purchased Alaska in 1867 (York and Hartley, 1981). During the first 2 years following the purchase of Alaska by the United States, the fur seal harvest ensued without regulations. For example, approximately 240,000 were taken in 1868 alone. Meanwhile, many fur seals were also harvested at sea (pelagic sealing).

The history of pelagic sealing (1875-1909), its impact on the fur seal population, and a subsequent treaty banning pelagic sealing is found in Roppel and Davey (1965). At the peak of pelagic sealing (1891-1900), more than 42,000 fur seals (mostly lactating females) were taken annually in the Bering Sea (Scheffer et al., 1984). In addition, pelagic sealing was removing a large but unknown number of fur seals from waters off British Columbia (Scheffer et al., 1984). Because the takes were greatly reducing the fur seal stock, Great Britain (for Canada), Japan,

Figure 1. History of northern fur seal exploitation on the Pribilof Islands, Alaska, 1786-1979 [1]



[1] from Lander (1980), reported in York (1987a)

Russia, and the United States ratified the Treaty for the Preservation and Protection of Fur Seals and Sea Otters in 1911. The treaty prohibited pelagic sealing and required a reduction in the taking of seals on the land. The population grew rapidly after the cessation of pelagic sealing until the mid 1940s. There was no commercial harvest from 1912-1917. From 1918 to about 1941, the Pribilof Island fur seal stock grew at 8 percent per year under a harvest which ranged from 15,862 in 1923 to 95,016 in 1941 (NMML, unpublished data). In 1941, Japan abrogated the 1911 Convention on the grounds that fur seals were too numerous and were damaging her fisheries; after World War II, a similar concern on the part of Japan was important in negotiating the 1957 fur seal Convention (Scheffer, 1980). No commercial harvest took place in 1942. The take from 1943 to 1955 averaged about 70,000 per year.

In 1957, the signatories of the 1911 Treaty ratified a new agreement, the Interim Convention on the Conservation of North Pacific Fur Seals, for the conservation, research, and harvesting of fur seals. During those negotiations, calculations presented by the United States suggested that maximum sustained productivity would occur at lower female population levels than those of the early 1950s. These projections postulated higher pregnancy and survival rates from a smaller herd (Anonymous, 1955). Consistent with that analysis, from 1956 to 1968, a total of about 300,000 female fur seals were killed on the Pribilof Islands (York and Hartley, 1981). Concurrently, 30,000 to 96,000 juvenile males were harvested each year (Lander and Kajimura, 1982; Fig. 1), and a pelagic collection of about 16,000 females was taken for research purposes by the United States and Canada during 1958-1974 (York and Hartley, 1981).

The Pribilof Islands fur seal population did not react as expected to the herd reduction program. Kajimura et al. (1979) showed neither a substantial decrease in age at first pregnancy nor an increase in pregnancy rates as the population was reduced. Also, increased survival rates did not overcome losses to the population resulting from intentional herd reduction. These changes generated speculation that some natural factor or combination of factors had prohibited the expected recovery of the herd. Clearly, one or more factors, whether natural or man-made, adversely affected the recovery of the herd and caused extreme fluctuations in year class survival and a much reduced production of young males (Roppel, 1984). The United States believed it necessary to establish a research control area because of the failure of the Pribilof Islands population to respond as anticipated to changes in the management scheme started in 1956. Therefore, in 1973, a moratorium on the commercial harvest of male fur seals was established at St. George Island (Roppel, 1984), while the commercial harvest on St. Paul Island continued. Thus, the first long-term study of behavior in the history of fur seals on the Pribilof Islands was launched beginning in 1973 (Roppel, 1984). Meanwhile, on St. Paul Island, management regulations changed very little between 1973-1979, and harvests ranged from 24,000 to 27,000 animals per year (Harry and Hartley, 1981).

The authority of the 1957 Convention was extended in 1963, 1969, 1976 and 1980. Under the terms of the 1980 extension, the Convention expired on 14 October 1984. In consultation with the U.S. Departments of State and Justice, and the Marine Mammal Commission, the United States declined to sign an extension. It was determined that no commercial harvest could be conducted under existing domestic law and, therefore, the commercial harvest on St. Paul Island was terminated. Management of the fur seal then reverted to the MMPA. Accordingly, on July 8, 1985, NMFS issued an emergency interim rule to govern the subsistence taking of fur seals for the 1985 season under the authority of section 105(a) of the Fur Seal Act. A final rule was published on July 9, 1985.

Subsistence Harvest. The subsistence harvest of northern fur seals on the Pribilof Islands, Alaska, is governed by regulations found in 50 CFR part 215 subpart D--Taking for Subsistence Purposes. These regulations were published under the authority of the Fur Seal Act, 15 U.S.C. 1151 et seq., and the MMPA, 16 U.S.C. 1361 et seq. (see 51 FR 24828, July 9, 1986). The purpose of these regulations was to limit the take of fur seals to a level providing for the subsistence needs of the Pribilof Aleuts using humane harvesting methods, and to restrict taking by sex, age, and season for herd management purposes.

Each year NMFS publishes a proposed subsistence harvest estimate. The purpose of the annual notice is to provide an estimate for the current year's subsistence need for St. Paul and St. George Islands (Table 1). To minimize negative effects on the population, the subsistence harvest has been limited to a 47-day harvest season (June 23-August 8) during which only subadult male seals may be taken. In early August, immature female seals begin arriving at the rookeries in large numbers, and the immature females and males, which are not easily distinguished, become intermixed. The August 8 deadline was chosen to avoid an unacceptable taking of female fur seals.

Table 1. Subsistence harvest levels for northern fur seals on the Pribilof Islands, 1985-1992.

	Year							
	1985	1986	1987	1988	1989	1990	1991	1992
St. Paul	3,384	1,299	1,710	1,145	1,340	1,077	1,645	1,482
St. George	329	124	92	113	181	164	281	194
Total	3,713	1,423	1,802	1,258	1,521	1,241	1,926	1,676

The Assistant Administrator for Fisheries (Assistant Administrator) is required to terminate the harvest when it is determined that the subsistence needs of the Pribilof Aleuts have been met or on August 8 of each year, whichever comes first. From 1985 to 1992, the regulations allowed for extending the harvest period if the subsistence need of the Pribilof Aleuts have not been met. Section 215.32(f)(2) authorized the Assistant Administrator to extend the harvest period until September 30 if, by August 8, the subsistence needs of the Pribilof Aleuts were not met, and the number of female seals taken during the harvest was low. Extensions to the harvest season were requested and granted in 1986 and 1987. Extension of the harvest beyond the first week of August had resulted in a number of female fur seals taken. In response, NMFS announced its intent to amend 50 CFR 215.32(f) to eliminate the extension option for 1989 and subsequent years (53 FR 28887, Aug. 1, 1988), although no further action was taken by NMFS at that time.

Following the August 1, 1988, notice by NMFS, the Aleut Community of St. Paul Island requested a change in the Fur Seal Act regulations to allow the subsistence harvest to begin June 23, 1 week earlier than the June 30 start date dictated by 50 CRF 215.32(c)(1). They cited a desire for seal meat by community members before June 30, a lack of meat remaining from the previous year's take, and the possible inability to harvest their quota of seals in the absence of the harvest extension option. On June 3, 1991, NMFS published a proposed rule to eliminate the extension option and to begin the harvest 1 week earlier (56 FR 25066). The final rule was published on July 31, 1992 (57 FR 33900).

3. NATURAL HISTORY

A. Distribution

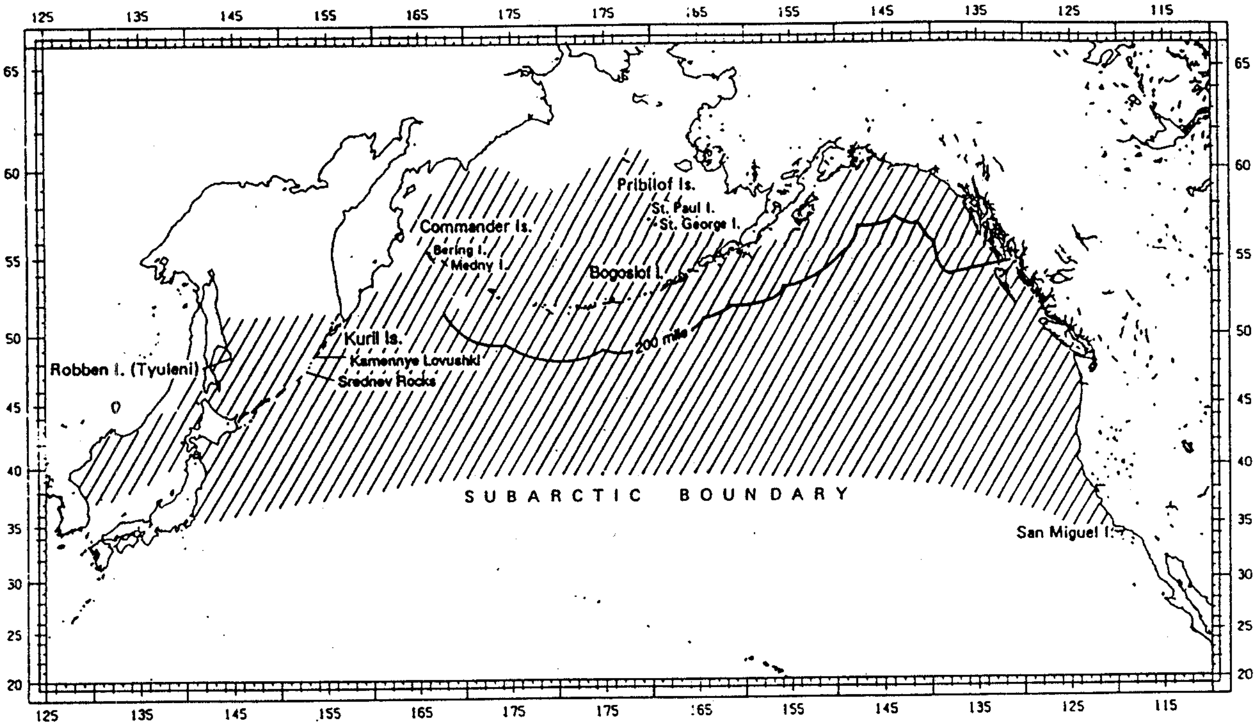
Northern fur seals are endemic to the North Pacific Ocean. They occur from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan (Fig. 2). In the eastern North Pacific Ocean, fur seals range from the Pribilof and Bogoslof Islands in the Bering Sea to the Channel Islands in southern California. During the breeding season approximately 72 percent of all fur seals are found on the Pribilof Islands in the southern Bering Sea, 15 percent are on the Commander Islands in the western Bering Sea (Russia), 9 percent are on Robben Island in the Okhotsk Sea (Russia), <2 percent are on the Kuril Islands in the western North Pacific Ocean (Russia) and <1 percent are on San Miguel Island off southern California (Lander and Kajimura, 1982). A small colony of fur seals also occurs on Bogoslof Island in the southern Bering Sea.

After pupping, mating and weaning of pups, adult females from the Pribilof Islands migrate south through passes in the Aleutian Islands into the North Pacific Ocean. Adult males are believed to migrate only as far south as the Gulf of Alaska (Kajimura, 1984). The timing and location of feeding by fur seals from Bogoslof Island are unknown, but are presumed to be the same as fur seals from the Pribilof Islands. Most pups travel through Aleutian Islands passes after leaving their birth islands and remain at sea in the North Pacific Ocean for about 22 months before returning to their islands of origin as 2 year-olds. Fur seals from San Miguel Island also spend their winter months feeding at sea in the eastern North Pacific Ocean.

Northern fur seal rookeries were discovered in 1786 on the Pribilof Islands and in 1968 on San Miguel Island. Historical records indicate that San Miguel Island was colonized in the late 1950s or early 1960s (Peterson et al., 1968). An adult male fur seal was discovered on Bogoslof Island (53°56'N, 168°02'W) in 1976 (Fiscus, 1983) and pups were first observed on the island in 1980 (Lloyd et al., 1981). The rookery contained 11-13 pups and 18 adult females (78 total animals) in August 1983, and by July 1989 the rookery had increased to 99 pups and 132 adult females (719 total animals) (Loughlin and Miller, 1989). On July 24, 1990, Baker and Kiyota (1992) counted 44 territorial males, 295 females, 181 pups and 951 non-territorial males.

The timing of reproduction on San Miguel Island is basically the same as on the Pribilof and Bogoslof Islands. Northern fur seals occasionally haul-out onto land for brief periods at other sites in Alaska, British Columbia, Canada, and on islets along the coast of the continental United States.

Figure 2. Range of the northern fur seal with breeding islands indicated



B. Status of Stock

At least five stocks (populations) of northern fur seals breed on at least six island groups: the Commander Islands stock (Russia), the Kuril Islands (Russia), Robben Island (Russia), Pribilof Islands and Bogoslof Island in the eastern Bering Sea (U.S.) and San Miguel Island (western U.S.). There is considerable interchange of individuals between rookeries and, therefore, they are considered one biological species. Stock designation is based principally on geographic separation during the breeding season. NMFS recommends that two stocks be recognized in U.S. waters for management purposes, the San Miguel Island stock and the Pribilof Island stock (Loughlin et al., in press). About 72 percent of the estimated world population occurs in the Pribilof Island stock, and rookeries occur primarily on two islands, St. Paul Island (Fig. 3) and St. George Island (Fig. 4).

Although at least five populations are recognized in the North Pacific Ocean, the depletion designation and the focus of this plan is on the Pribilof Islands population because it represents about 99 percent of all fur seals inside U.S. waters. However, a substantial portion of the Commander Island fur seal population may migrate through U.S. waters, and tagging studies indicate some interchange between fur seals from the Pribilof Islands with fur seals on the rookeries of the Commander Islands. Therefore, the Conservation Plan recommends cooperative international research and management actions.

Figure 3. Location of northern fur seal rookeries (present and extinct), hauling grounds and harvesting areas, St. Paul Island, Alaska.

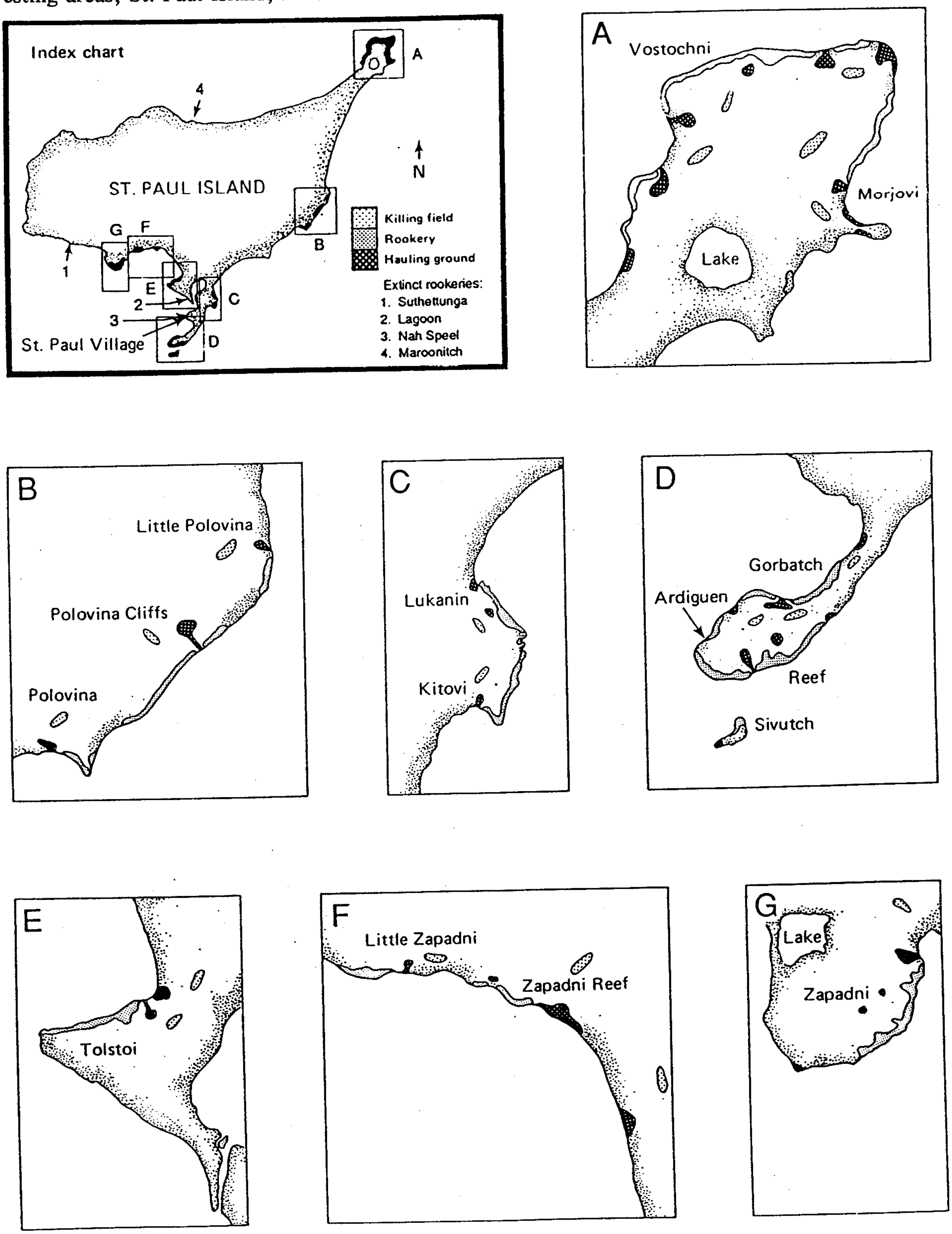
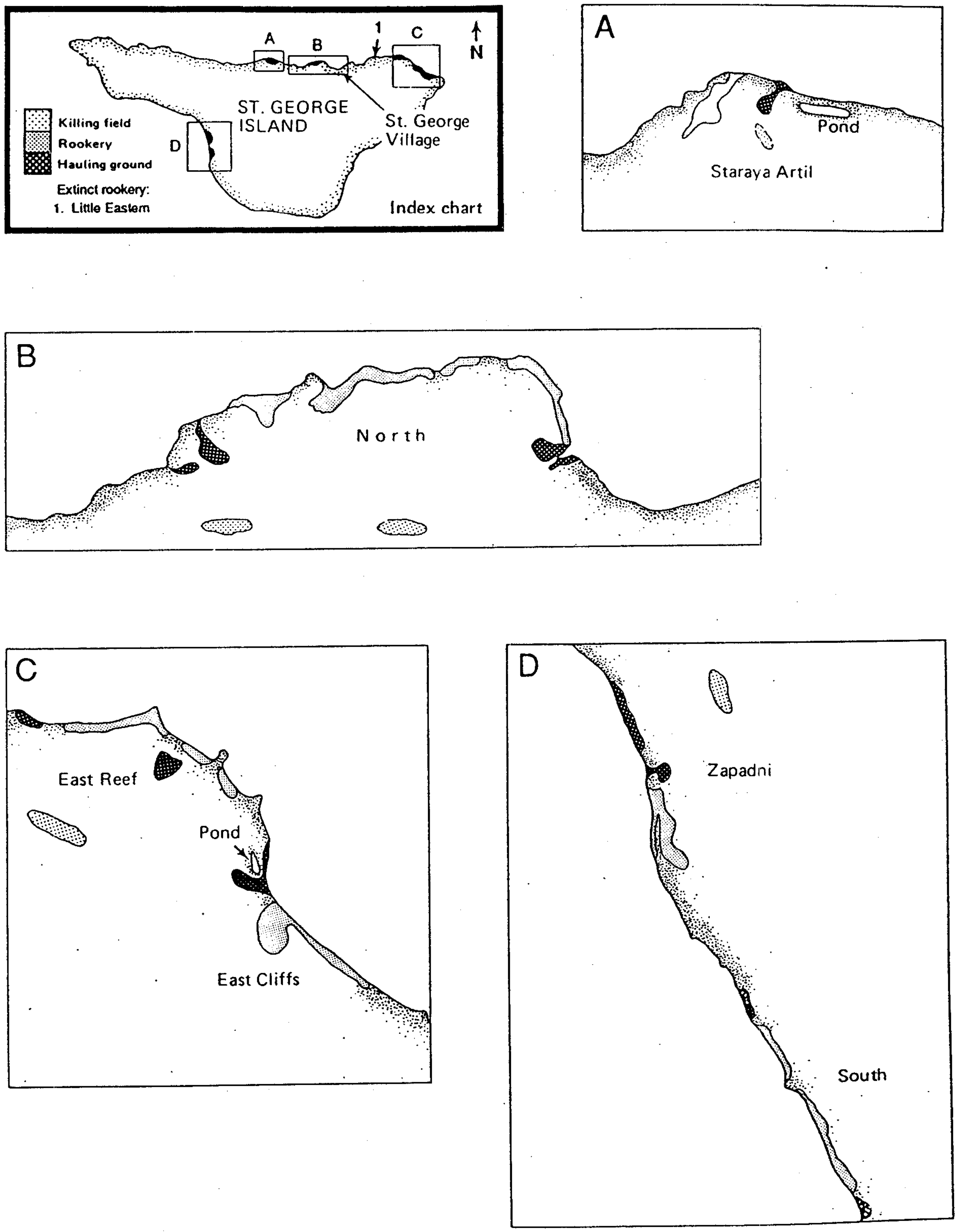


Figure 4. Location of northern fur seal rookeries (present and extinct), hauling grounds and harvesting areas, St. George Island, Alaska.



C. Habitat Requirements

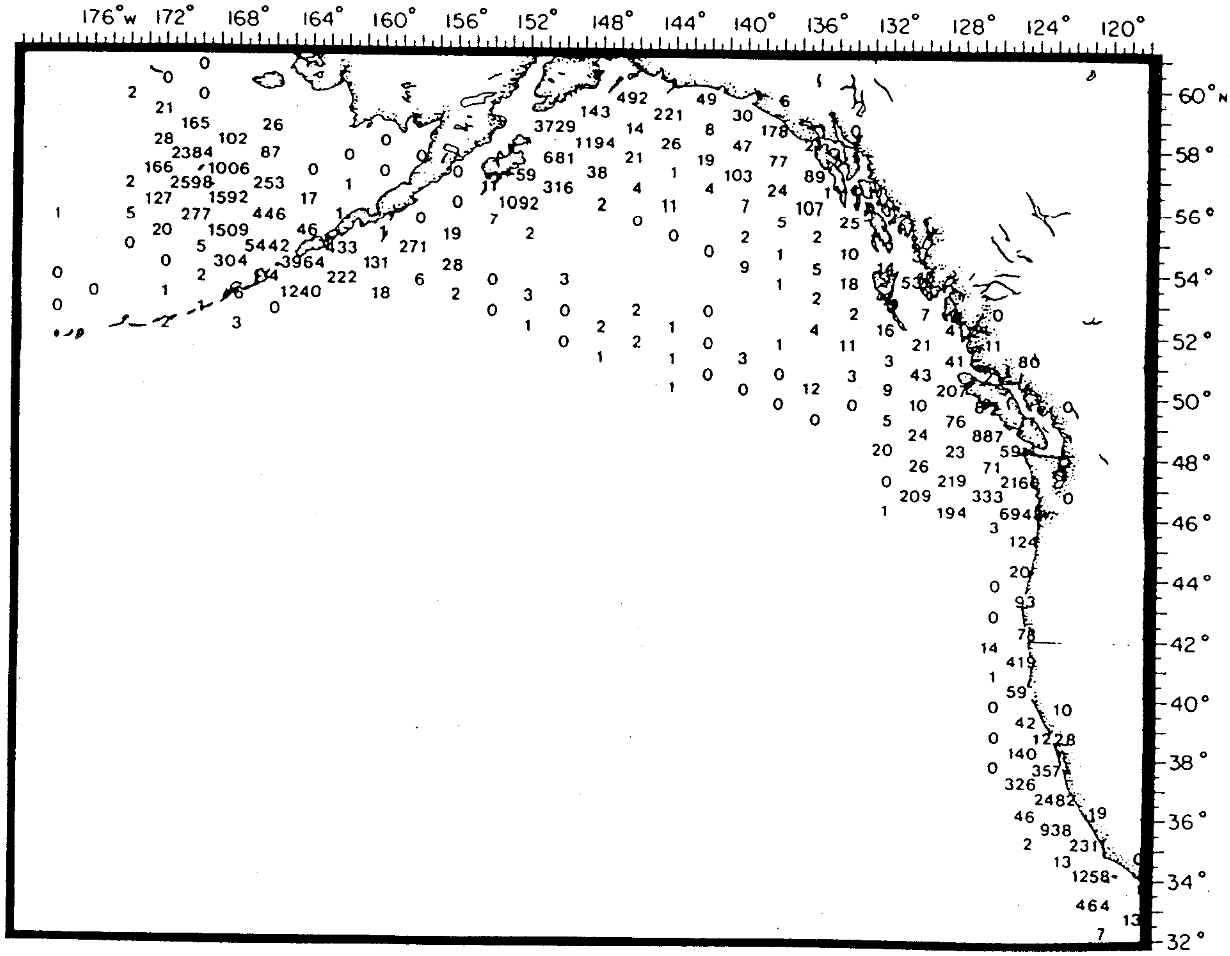
The Pribilof Islands are essential for pupping, mating and rearing of pups, and the surrounding feeding grounds out to at least 200-300 km from the islands are especially important for lactating females (Loughlin et al., 1987; Goebel et al., 1991). Passageways between the Aleutian Islands also appear important for their annual migration between the Bering Sea and North Pacific Ocean (Bigg, 1990).

Many fur seals (presumably juveniles) have been seen far out to sea, as indicated by the sighting data collected from 1958 to 1974 (Fig. 5) and the bycatch data on fur seals collected from June through September 1990 (Fig. 6), even during the breeding season (Zeusler, 1936; NMML, unpublished data). The subpolar continental shelf and shelf break from the Bering Sea to California are essential feeding grounds while fur seals are at sea. Highest fur seal densities in the open ocean occur in association with major oceanographic frontal features such as sea mounts, valleys, canyons and along the continental shelf break (Lander and Kajimura, 1982; Kajimura, 1984). It should be noted that principal prey of fur seals may be concentrated or most accessible in such areas, and the association may be due to a combination of biological and physical factors. The pelagic distribution of fur seals in the North Pacific Ocean may be bounded on the south by the transition zone between subarctic and subtropic water masses, possibly because these fronts serve as physical barriers to fur seal prey. Given the known pelagic distribution of juvenile and subadult fur seals based on sighting data, and the high loss of juveniles as a factor in the population decline, these areas should be considered essential to the northern fur seal population for their survival.

D. Abundance and Population Trends

The number and the trend in abundance of fur seals have been determined in a variety of ways since the United States assumed direct management of the population in 1910. The history of fur seal population estimation during 1912-1947 and analyses of the reliability of methods then proposed for estimating numbers of pups are presented in Kenyon et al. (1954). From 1950-1954, Kenyon estimated the number of pups from direct counts at rookeries (Kenyon et al., 1954). However, the marking, then sampling of animals for mark/unmarked ratios, has been the best method used to determine a population estimate. Since 1962, the estimate of the size of the pup population has been obtained using the "shearing-sampling" method (Chapman, 1964; Chapman and Johnson, 1968). During August, a large number of pups (approximately 10 percent) are marked by shearing a small patch of hair from the top of their heads, producing an easily identifiable mark. The marking effort is allocated throughout the rookery so that each pup has an approximately equal chance of being marked. A few days later, each rookery is sampled to estimate the proportion of marked animals on the rookery. Thus, estimates of the population size and its variance can be calculated for each rookery (for mathematical details see York and Kozloff, 1987). York and Kozloff (1987) demonstrated the feasibility of obtaining accurate estimates of the total pup population on St. Paul Island from "shearing-sampling" estimates on a few sample rookeries. A principal advantage of obtaining estimates of the population from a subsample of rookeries was less disturbance to the total fur seal population.

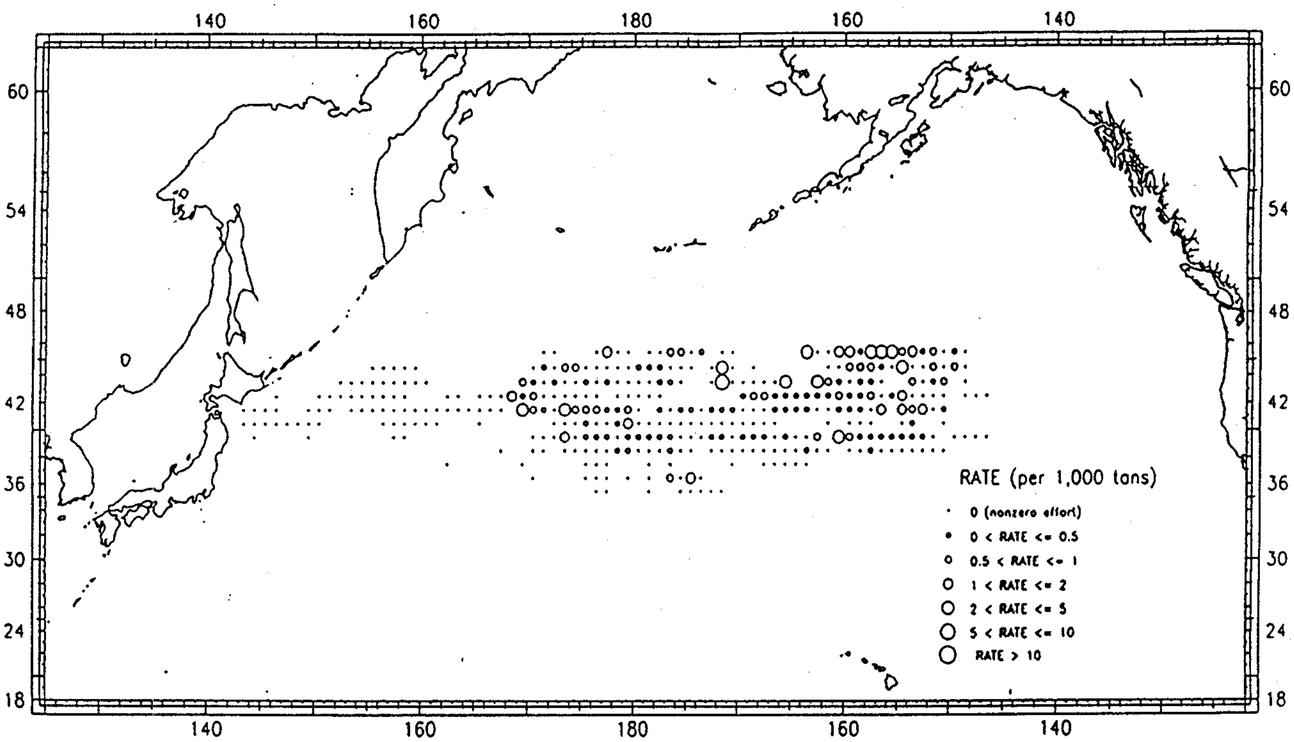
Figure 5. Distribution of 68,500 fur seal sightings by the United States and Canada during the years 1958-1974. Each unit measures 1 degree of latitude by 2 degrees of longitude. [1]



[1] from Harry and Hartley (1981)

Since their discovery in 1786, the abundance of fur seals on the Pribilof Islands has fluctuated dramatically (Roppel, 1984). The stock is thought to have been at peak abundance of perhaps 2-3 million in the early to mid-1800s, and at its lowest in the first decade of the 20th century. The greatest decline occurred in the last half of the 1800s and early 1900s because of the commercial harvest which included pregnant females. Female seals were not taken from 1917 to 1955 and the population had its greatest recovery during those years, principally between 1912 and 1940. During this period, the stock increased from perhaps 300,000 (Lander, 1980) to a peak this century of just under 2 million. In the decades after 1912, the number of pups born on St. Paul Island also

Figure 6. Bycatch rate (number per 1000 standardized tans) of northern fur seals during the summer months (June through September 1990), all three squid fisheries and Taiwanese large-mesh fishery combined. [1]



[1] from Hobbs and Jones (in press)

increased rapidly (York and Kozloff, 1987, data from Lander, 1980) with approximately 67,000 pups born in 1912 compared with about 469,000 in 1940 (York, 1985). York and Kozloff (1987) reported consistent and rather uniform rates of use of rookeries by breeding males and females. That is, if a rookery accounts for 10 percent of breeding males within a year, it will account for approximately 10 percent of the total pup production within the same year.

By the early 1940s, the rate of population growth of about 8 percent per year slowed and leveled off until 1956. The size of the fur seal stock in the early 1950s was estimated by Kenyon et al. (1954) to be 1.8 million and may have been at or close to carrying capacity under a limited commercial harvest for juvenile males. However, a more recent estimate of the total stock size indicated that it may have been closer to 2.1 million during this time period (Briggs and Fowler, 1984). Subsequent analyses by Chapman (1964), Lander (1981), and York (1987b) estimated that, between the early 1940s and 1956, about 450,000-470,000 pups were born annually.

The number of pups born was at a high level during the 1950-1958 year classes and lower during the 1959-1970 year classes (Lander 1979). From 1956 to 1968 the Pribilof stock was reduced when approximately 23,000 females were killed annually in the pelagic fur seal harvest (Table 2). The female harvest was terminated in 1968 and the stock again increased between 1970 and 1976. The population then declined again until 1980. York and Hartley (1981) estimated the total number of female pups that would have been born had the harvest not taken place and a particular survival schedule been operative (Fig. 7). The number of female pups born declined sharply from 1957 to 1962 following the initiation of the female harvest in 1956. Female pup production averaged about 224,000 from 1950 to 1956 but fell to a level of about 135,000 by 1962 (York and Hartley, 1981). Approximately 70 percent of the difference in pup production between 1950-1955 and 1962-1979 was due to the harvest of females (York and Hartley, 1981). The cause of the remaining discrepancy (about 30 percent) was not explained by their analyses. However, the authors suggested that a bias in the "shearing" technique may result in a marked-unmarked ratio being too high, thereby producing a downward bias in the estimation process. If the bias in technique was as much as 10 to 15 percent of the total number of pups born, then the decline in pup production may be attributed solely to the removal of females during the herd reduction (York and Hartley, 1981).

Table 2. Numbers and ages of female northern fur seals in the commercial harvest (St. Paul Island, Alaska) for 1956-1968 [1]

	Number Taken By Year												
Age	56	57	58	59	60	61	62	63	64	65	66	67	68
2	132	0	477	215	19	360	318	499	266	147	-	18	32
3	2018	953	9762	1769	258	3624	3421	2077	2239	966	-	558	620
4	5470	4551	6736	6379	466	5447	6401	5910	2387	1719	-	1083	2143
5	3497	9373	2719	3098	763	3547	4926	6950	2462	603	-	1176	1457
6	2149	4747	2387	2414	478	3868	2675	3150	1446	200	-	933	1211
7	1599	3201	649	2847	296	2315	2304	1406	432	148	-	-	765
>7	-	-	-	-	-	-	-	-	-	-	-	3559	494
8	1248	2880	293	1495	271	2183	2255	-	-	-	-	-	567
>8	-	-	-	-	-	-	-	14833	1519	108	-	-	464
9	738	2599	292	913	222	2408	1840	-	-	-	-	-	431
10	482	1389	430	849	135	1605	1321	-	-	-	-	-	288
>10	3555	7816	213	4230	394	9729	9364	-	-	-	-	-	314

[1] Data from York and Hartley (1981)

In 1974, the stock was estimated to be 1.25 million with about 326,000 pups born on both Pribilof islands (Lander, 1981). The number of pups born on St. Paul Island showed a decrease of about 7.5 percent per year from 1975 to 1981 (York and Kozloff, 1987; Fig. 8). No significant trend in the number of pups born on St. Paul Island can be detected after 1981 (York and Kozloff, 1987), although the number born in 1982 was significantly higher than the number born in 1981, 1983-1986, suggesting that the stock size has not changed much in recent years (York and Fowler, 1992). However, annual pup production on St. Paul Island has declined from an estimated 469,000 in 1940 and 461,000 in 1955, to a low of 166,000 in 1983 and 168,000 in 1986 (Fig. 8). Pup production estimates on St. Paul Island up to 1990 are summarized in Table 3.

Table 3. Northern fur seal population abundance and pup production estimates on the Pribilof Islands since the late 1940s[1]

Year	Stock Size	Number Of Pups Born	References
1949-1951[1]	2,100,000[2]	531,000[3]	Kenyon et al. (1954) Briggs and Fowler (1984)
1970	1,200,000	306,000	Johnson (1975)
1974	1,250,000	326,000	Lander (1981)
1983	877,000	198,000	Briggs and Fowler (1984) York and Kozloff (1987)
1990	1,012,000[4]	268,000[5]	NMML unpublished
1992	982,000[4]	253,000[5]	Loughlin et al. (in press)

[1] Numbers rounded to thousands

[2] Estimate for 1951 only

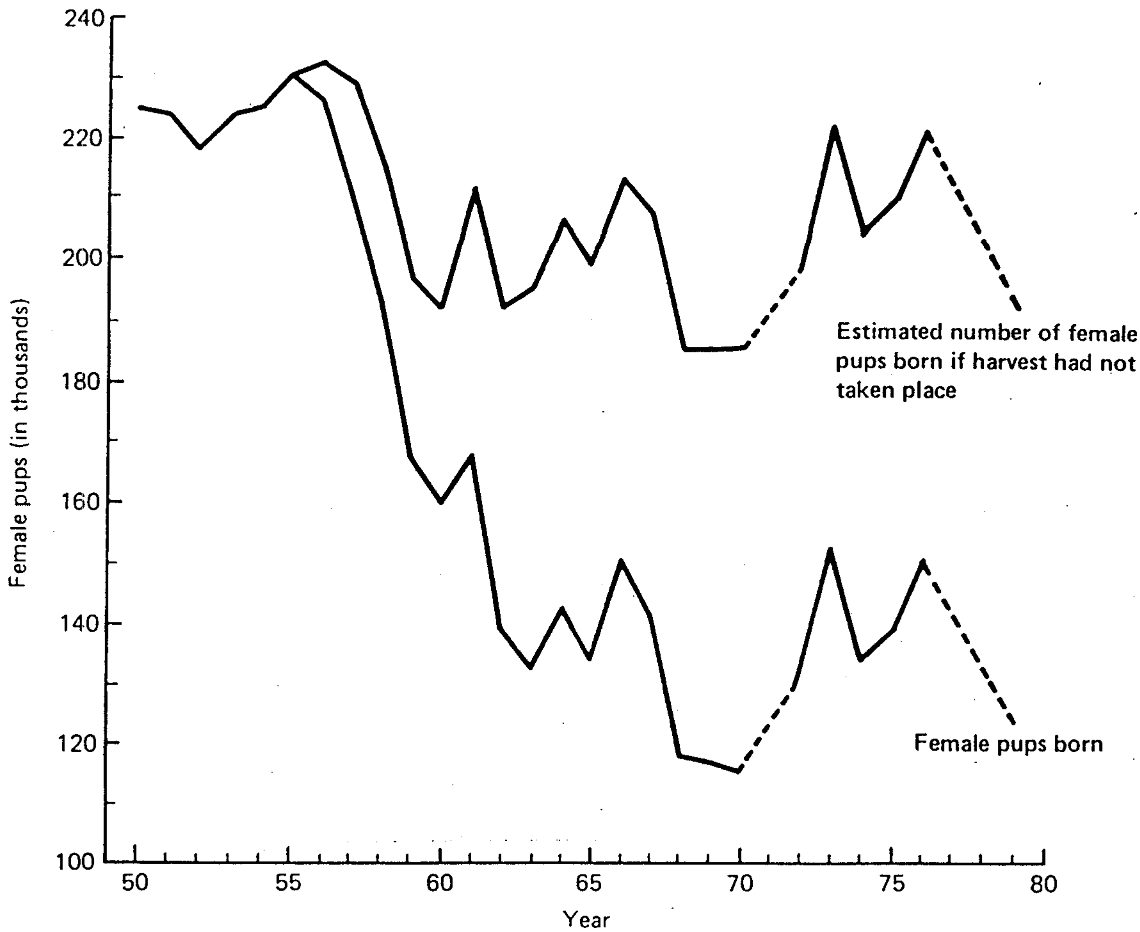
[3] Average value for pup production for 1949, 1950 and 1951

[4] Population size is due in part to increased numbers of male fur seals following the cessation of the commercial harvest in 1984

[5] Includes an estimated 10,000 pups born on Sea Lion Rock, St. Paul, Island, Alaska

Although there has been no significant trend in pup production on St. Paul Island since 1981, the number of pups born on St. George Island continued to decline during the 1980s (Fig. 8). However, as the number of pups born on St. George Island accounts for only about 10-15 percent of the total pup production on the Pribilof Islands, the entire stock appears to remain

Figure 7. Numbers of female northern fur seal pups born and estimated numbers of female pups born had the female harvest not taken place (St. Paul Island, Alaska). [1]

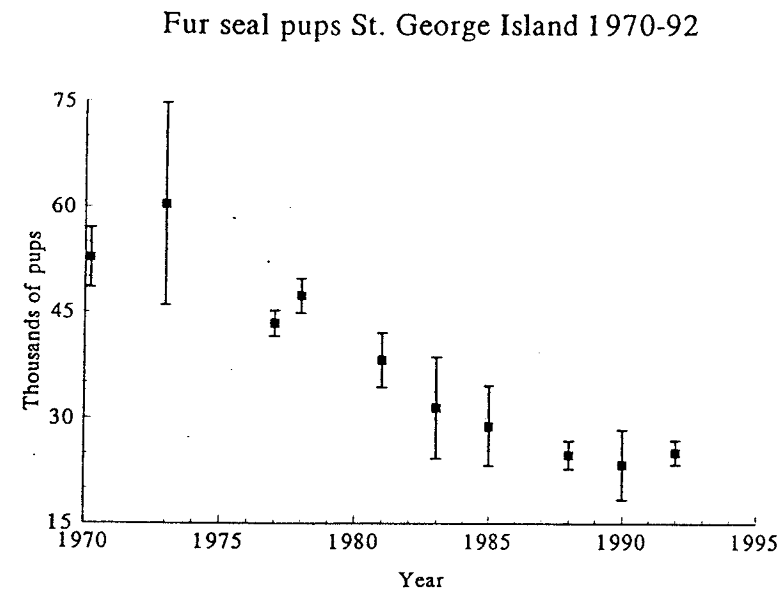


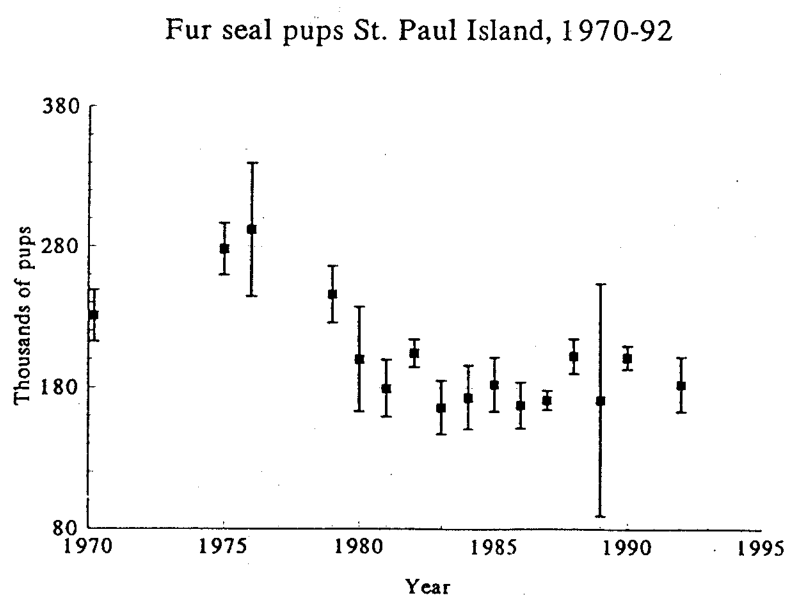
[1] from York and Hartley (1981)

relatively stable. Nonetheless, the recent decline on St. George may indicate localized factors (e.g., anthropogenic, environmental, or both) influencing the ability of the population to grow.

Other population parameters also demonstrate that the stock has declined significantly since the 1950s (Table 4). Mean harvest levels from 1976 (when the population began its latest decline) to 1984 (at the termination of the commercial harvest on St. Paul Island) were about 47 percent of the mean harvest levels for the period 1940 and 1956 (Kozloff and York, 1988). The amount of rookery space used by seals on St. Paul Island in 1985 was less than one third the area estimated in 1948 (NMML unpublished data and see Scheffer and Kenyon, 1989). The number of adult males holding territories is only 41 percent of the levels observed in the 1950s to mid-1960s (NMML unpublished data). The Pribilof Islands stock of fur seals is estimated to be 40-55 percent of the size of the stock in the 1940s and 1950s.

Figure 8. Estimated numbers of northern fur seal pups born on St. George Island (upper) and St. Paul Island (lower), Alaska, from 1970-1990 with 95 percent confidence intervals [1]





[1] from Antonelis et al., in review

Table 4. Parameter estimates used to illustrate the reduction of northern fur seals on St. Paul Island (rounded to the nearest hundred) since the 1940s and 1950s when the population was thought to be at or near maximum levels (presumed carrying capacity) [1]

Parameters Measured	Abundance Estimates		Percent Decline
	Previous Peak	Recent Peak	
Pups	469,000 (1955)	175,000 (1981-1988)[2]	- 63
Commercial Harvest[3]	52,000 (1947-1953)	24,700 (1976-1984)	- 53
Rookery Space[4]	109,100 (1967)	41,400 (1985)	- 62
Territorial Males[5]	10,300 (1958-1962)	4,200 (1984-1988)	- 59
Total Adult Males[6]	20,800 (1958-1962)	7,100 (1984-1988)	- 66

[1] Data from Kenyon et al. (1954); Briggs and Fowler (1984); Fowler (1985a, 1987b, 1988); York (1987a, 1987b); Swartzman et al. (1987); Kozloff and York (1988) and NMML (unpublished data).

[2] Mean of means; the range of the 95 confidence intervals (CI) is 148,000 (low 1983) to 210,000 (high 1988).

[3] Highest annual harvest of juvenile (1-6 year old) males during peak abundance in 1940-58 (mean 52,643, sd 7,517, range 42,272 to 64,481), compared with the period beginning with the recent decline in 1976 through the last year of a commercial harvest in 1984 (mean 24,741, sd 1,813, range 22,034 to 28,396).

[4] Measured in m^2. Four major rookeries were compared (Tolstoi, Kitovi, Morjovi and Zapadni), which make up about 65 percent of space used by fur seals on St. Paul Island. A comparison of five rookeries (Kitovi, Polovina, Little Zapadni, Lucanin and Zapadni), where data are available for 1948 and 1985, suggests a decline greater than 70 percent.

[5] Five-year mean territorial bull count for peak abundance (1958-62)(95% CI range 9,910 to 10,776) and lowest mean count (95% CI range 3,701 to 4,699) for the period of no statistical trend in pup production (1984-1988). The greatest decline in territorial bull counts occurred between 1962-1968, from 10,000 to 6,000. Since 1968, the number of territorial males has ranged from 6,496 in 1978 to 3,585 in 1988. There has been no significant change at St. George Island this decade.

[6] Includes territorial and non-territorial adult males only: 1958-62 mean 20,803 (95% CI 19,482 to 22,124) and 1984-88 mean 7,058 (95% CI 5,944 to 8,172). There was no change at St. George Island.

E. Reproduction

Most adults occur on land between June and October defending territories, giving birth, mating, and rearing pups, and then spend the remaining months at sea feeding. Male fur seals become sexually mature at 5-7 years of age and begin competing for a territory after about age 7-9 (Johnson, 1968). Most females become sexually mature between 4 and 7 years of age (average about 5) (York, 1983). Females give birth to a single pup, usually each year, and are known to give birth up to at least 23 years of age (Lander, 1981). Within 2 days after adult females arrive on land, their pups are born. Within 3-8 days of parturition the females mate (Peterson, 1968; Gentry and Holt, 1986).

F. Mortality Rates

Neonatal mortality on land is density dependent, higher at high population levels than at lower population levels (Fowler, 1990), and neonatal mortality on St. George Island is lower than on St. Paul Island (York, 1985). Since the late 1970s, mortality rates of pups up to 4 months of age have been less than 10 percent on both islands, although historically they reached 20 percent.

Mortality at sea is highest during the first 2 years of a fur seal's life when it may reach 60-80 percent (Keyes 1965; Lander 1981; Fowler 1985a; York 1987a). Most of this mortality occurs during the first winter after weaning. Lander (1979) estimated that at-sea mortality of 0-2 year olds from 1950 to 1970 was 60-65 percent. Smith and Polacheck (1981) estimated that the mortality rate of 0-3 year olds in the 1970s was about 46 percent. York (1985, 1987a) reported that mortality rates of 0-2 year olds at sea increased from 1964 to 1976, and Fowler (1985a) and Trites (1989) suggest that the mortality rate of 2-5 year old seals may also have increased during the late 1960s and the 1970s. Adult female mortality at sea may also have increased after 1975, by about 2-5 percent (Trites and Larkin, 1989). Survival of adult females remains high (>80 percent) until age 14, after which it decreases to about 30 percent by age 19 (Smith and Polacheck, 1981). Males have a higher mortality rate than females after 2 years of age, particularly after 7 years of age when males begin defending territories (Lander and Kajimura, 1982).

G. Feeding and Energetics

All references to 'fur seal feeding habits' or to 'fur seal prey' in this text are based on studies conducted on adult female and juvenile fur seals. Little is known about the diet and feeding behavior of adult male northern fur seals. Sinclair (1988) analyzed the prey remains in the stomachs of adult female and juvenile northern fur seals collected in the Bering Sea in 1981, 1982 and 1985, and summarized the results of previous studies. Brief excerpts from her discussion are provided in this section.

Fur seals eat, primarily, schooling fishes and cephalopods. Walleye pollock, gonatid squid, and bathylagid smelt were the most frequently occurring prey in collections of fur seal stomachs from the eastern Bering Sea between 1892 and 1950 (Scheffer, 1950b). Most of the collections occurred on, and the samples were from, the Pribilof Islands. In more recent reviews of stomach samples from the 1958-1974 pelagic collections, walleye pollock was the predominant prey of fur seals in the eastern Bering Sea (Kajimura, 1985; Perez and Bigg, 1986). Kajimura (1984) included Pacific herring, capelin (Mallotus villosus), Atka mackerel (Pleurogrammus monopterygius) and gonatid squids (Gonatus sp., Berryteuthis magister and Gonatopsis borealis) as principal prey in the eastern Bering Sea. The relative importance of any prey type varied by sample area and year of collection. Perez and Bigg (1986) concluded that capelin was also a major food item in the southern portion of the eastern Bering Sea, with squids as the primary oceanic prey, but that walleye pollock was the most prevalent seal prey around the Pribilof Islands and inshore waters of the Bering Sea. Generally, walleye pollock have been consistently cited as major prey of fur seals in the Bering Sea, as have gonatid squids and bathylagid fish. Despite the wide variety of prey available to fur seals within their dive range (Hacker and Antonelis, 1986; Sinclair, 1988), these three prey items have shown up consistently in prey studies. Pacific herring and capeline were absent in the Sinclair (1988) study, despite collection areas and times similar to previous studies (Kajimura, 1984; Perez and Bigg, 1986). As in previous studies, Atka mackerel was identified as a primary prey item in Sinclair (1988), but only in the 1981 collections, despite similar collection areas in 1982 and 1985.

From collections in the Gulf of Alaska, primary prey species of fur seals included Pacific herring, Pacific sandlance (Ammodytes hexapterus), capelin and walleye pollock. Rockfish (Sebastes spp.), salmonids (Oncorhynchus spp.) and gonatid squids were important offshore (Kajimura, 1984). Myctophid fishes are a primary prey of fur seals in the western North Pacific (Wada, 1971) and possibly in the central North Pacific as well.

Fur seals preyed upon herring, salmonids, and Onychoteuthid squids in offshore waters of British Columbia. The market squid (Loligo opalescens) was important in inshore waters (Perez and Bigg, 1986).

Principal prey of fur seals taken off California from January-June was northern anchovy (Engraulis mordax), Pacific whiting (hake) (Merluccius productus), Pacific saury (Cololabis saira), market squid, and clubhook squid (Onychoteuthis spp.) (Antonelis and Perez, 1984). These were similar to the prey species found in fur seals taken off Oregon and Washington in December-June, except that rockfish and salmonids were also important (Antonelis and Perez, 1984).

Sinclair (1988) and Sinclair et al. (in press) found that walleye pollock represented 79 percent of the total number of prey taken from stomachs of fur seals collected in the eastern Bering Sea during 1981-1982 and in 1985. Of the stomach samples examined by Sinclair (1988), walleye pollock occurred in 100 percent of the stomachs containing food in 1981, 96 percent in 1982 and 72 percent in 1985. For all years combined in Sinclair (1988), juvenile walleye pollock (3-20 cm) were the most numerous and frequently occurring prey species. Sixty-five percent of prey walleye pollock were from the age-0 group, and 31 percent were from age-1 group. Only 4 percent of prey walleye pollock were from age-2 group and older. Cephalopods (5-12 cm dorsal mantle length) accounted for 11 percent of the total number of prey.

The modal size distribution of walleye pollock as fur seal prey in the 1980s study (Sinclair, 1988) reflected year-class strength projections of walleye pollock. Strong year classes (1982 and 1984) were highly represented in stomach samples as age-0 (98 percent of 1982 prey walleye pollock) and age-1 (60 percent of 1985 prey walleye pollock) fish. Walleye pollock year-class strength in 1981 was exceptionally weak (Bakkala et al., 1987), and the only collection year in which adult walleye pollock (3-4 year old fish from the strong 1978 year class) were well represented (38 percent of prey) in stomach contents (Sinclair, 1988). Interannual variation in the importance of walleye pollock in the diet on fur seals changed in relationship to the year-class strength of walleye pollock (Sinclair, 1988).

Northern fur seals may select prey on the basis of size and schooling behavior (Sinclair, 1988). Size range and schooling behavior of fur seal prey throughout their range are similar. The body size of prey was not consistently recorded in fur seal diet studies prior to 1981, but there are indications that the size of walleye pollock in the diet of northern fur seals may have decreased since the 1970s (Sinclair, 1988).

Differences in species of prey occurred between seal sample locations over the continental shelf and oceanic (deepwater) domain (greater than 200 m in depth). Fur seals collected over the deepwater regions at, or beyond, the continental slope contained primarily bathylagid smelt and gonatid squid (Gonatopsis borealis or Berryteuthis majister). Seals collected over the continental shelf preyed upon juvenile walleye pollock and a gonatid squid (Gonatus madokai or G. middendorfii).

Adult walleye pollock, overall, were uncommon in the samples examined by Sinclair (1988) but were found in greatest frequency in seals collected from the outer domain (100 to 200m in depth) of the continental shelf. Juvenile pollock were more widely distributed than adults in stomach samples collected over the outer and midshelf (waters less than 100 m in depth) domains of the shelf.

Preliminary analyses of 4 years of scat (feces) collections from St. Paul and St. George Islands indicate differences in prey consumption by fur seals (Antonelis et al., in prep) which is probably related to differences in the oceanography and shelf structure around each island. Further studies and analyses should assess these differences with respect to the recent decline on St. George Island.

Diving Patterns and Possible Prey Availability: Gentry et al. (1986a) used time-depth recorders to describe three general patterns of the diving behavior for breeding female fur seals: shallow, deep or mixed (i.e., shallow and deep dive behavior exhibited by an individual seal). However, they could not determine the feeding locations of individuals exhibiting different diving patterns. Loughlin et al. (1987) initiated studies using radio transmitters attached to female fur seals to determine where seals were foraging and what foraging areas in the Bering Sea were important for lactating females. Goebel et al. (1991) linked fur seal diving behavior with foraging locations using radio transmitters (to determine location) and time-depth recorders (to measure depth of dive), and examined diving behavior in relation to location and patterns of foraging, and possible prey species.

Sinclair (1988) suggested that foraging efficiency could be maximized if seals take advantage of the hydrographic-frontal characteristics of the Bering Sea continental shelf in that the abrupt changes in the horizontal temperature and salinity that occur on either side of frontal regions may form physical boundaries to prey. Diving depths of 175 m reported by Gentry et al. (1986b) coincide with boundary depths between the continental shelf and slope, and diving depths of 50-60 m coincide with the boundary between the midshelf and outer shelf frontal systems. Females feeding at or near the shelf break may exhibit both diving patterns. Females located on the continental shelf were more likely to exhibit the deep-diving pattern (greater than 75m in depth) throughout the day and night (Gentry et al., 1986b; Goebel et al., 1991).

The results of Goebel et al. (1991) showed that fur seal females diving in the Bering Sea in deep water beyond the continental shelf primarily exhibited the shallow-diving pattern (less than 75m) and dove predominately at night. Fur seals feeding beyond the continental shelf over deep water fed on juvenile gonatid squid or deep-sea, bathylagid smelt (Sinclair, 1988). Deep-sea smelts (Bathylagidae) exhibit diel vertical movements, and it is at night that they are most likely fed upon by fur seals (Gentry et al., 1986b; Goebel et al., 1991). Fur seals feeding over the continental shelf probably concentrate on juvenile walleye pollock and juvenile gonatid squid (Sinclair, 1988). The 50-60 m dive depths described by Gentry et al. (1986b) coincide with the depth distribution of juvenile walleye pollock over the continental shelf. Kajimura (1984) also suggested that fur seals foraging over the shelf were likely to feed on walleye pollock, Pacific herring and capelin. Each of these prey items is distributed throughout the water column over the shelf; but, adult walleye pollock are principally found near the bottom. Even when the prey are near the bottom over most of the shelf floor, they are shallower than the maximum diving depths observed for most fur seals and are accessible during all hours of the day (Goebel et al., 1991).

Feeding Energetics: Perez (1986) estimated that during foraging trips, juvenile and non-territorial male fur seals consumed approximately 312 x 10^3 metric tons of fish and cephalopods in the Bering Sea during July-October, of which 133 x 10^3 metric tons (43 percent) were walleye pollock. Lactating females consumed 202 x 10^3 metric tons of fish and squid, of which 87 x 10^3 metric tons were pollock (also 43 percent) (Perez and Mooney, 1986). Annual food consumption by northern fur seals was estimated at 51 x 10^3 metric tons off California and 35 x 10^3 metric tons off Oregon and Washington; 62 percent was consumed by pregnant females (Antonelis and Perez, 1984).

4. KNOWN AND POSSIBLE FACTORS INFLUENCING THE POPULATION

The number of pups born on St. Paul Island decreased about 7.5 percent per year from 1975-1981 (York and Kozloff, 1987). The causes of the decline beginning in 1976 are unknown, thus considerable attention has centered on potential causes of increased mortality of fur seals (Table 5). These include entanglement in debris, long-term effects of weather, and decreased food availability from competition with fisheries in the North Pacific and eastern Bering Sea. Entanglement (Fowler, 1985b, 1987a) and unidentified changes in the ecosystem (e.g., perhaps resulting in starvation of juveniles less than 2 yrs of age) (York and Kozloff, 1987; York, 1991), may have operated synergistically. York and Kozloff (1987) speculated that the pattern of decline and apparent stabilization in numbers of pups born resulted from disease which has subsequently been abated by an immune response of the population. There is no evidence that natality (birth) rates changed significantly from 1974 to 1983 (Goebel and Gentry, 1984).

Table 5. Possible causes for declines of northern fur seals on the Pribilof Islands

Causes	Evidence[1]	References
Emigration	-	Lander and Kajimura (1982)
Lower Reproductive Rates		
Age of First Reproduction	+	York (1983)
Fewer Adult Females	+	York and Hartley (1981)
Fewer Conceptions		
Behavioral		
Physiological/Genetic		
Parasites/Disease		
Pollutants	-	Fowler (1985a)
Fewer Births		
Nutrition of Female		
Abortion		
Lowered Survival		
Pups on Land	-	York (1985)
Parasites	-	Keyes (1965)
Disease	-	Keyes (1965); Fowler (1984)
Starvation	-	Kozloff and Briggs (1986)
Injury/Trauma	-	Fowler (1985b, 1987a)
Starvation		
Prey Availability		
Fisheries Competition		
Oceanographic	+	York (1991); Delong and Antonelis (1991)
Entanglement		
On-Land	+	Fowler (1985b, 1987a)
Bering Sea/GOA		
North Pacific		

Table 5 (continued). Possible causes for declines of northern fur seals on the Pribilof Islands

Causes	Evidence[1]	References
Incidental Take		
Salmon Gillnet Fishery	-	Jones (1980, 1981, 1982)
Squid Gillnet Fishery		
Trawl Fishery	-	Loughlin et al. (1983)
Diseases/Parasites		Fowler (1982, 1985a)
Leptospirosis		
Biotoxis		
Distemper/Viruses		
Parasites	-	Kim et al. (1980)
Pollutants/Contaminants		
Predation		
northern Sea Lions	-	Gentry and Johnson (1981)
Sharks		
Killer Whales		
Injury of Adults on Land	-	Kozloff and York (1988)
Harvests of Animals	+	Roppel and Davey (1965)
Female Harvest	+	York and Hartley (1981)
Juvenile Male Harvest	-	Swartzman (1984)

[1] Known evidence for a positive effect is indicated by a "+" and for a negative effect by a "-" symbol. A blank space indicates that data are not available to determine an effect.

The following describes several possible factors that might have contributed to the unexplained mortality, although it should be emphasized that we may never know the cause of the 1975-1981 decline in fur seal production. However, gaining an understanding of the decline may have long-term predictive value allowing researchers to anticipate similar events in the future. York and Kozloff (1987) showed that unless a population decline is sudden and dramatic, the estimates of population size are sufficiently variable that a statistically significant decline can not be observed until several years following its initiation. It may be only by comparing the population dynamics, food habits, incidence of diseases, and entanglement rates of fur seals with other pinniped species which share their habitat (i.e., Steller sea lions), that additional light may be shed on the following possible factors.

A. Commercial Harvest

Northern fur seals were possibly near their carrying capacity between 1940 and 1956 when peak numbers of animals were seen on the Pribilof Islands. The commercial harvest of approximately 300,000 females from 1956 to 1968 reduced the stock and resulted in a decrease in pup production from the late 1950s through the 1960s. The reduction in the numbers of females probably accounted for at least 70 percent of the subsequent reduction in pup production; the remaining 30 percent is unexplained but may be attributed to external or environmental factors (York and Hartley, 1981). With cessation of the commercial harvest of female seals, the population increased (based on pup production estimates) until 1976.

The commercial harvest from 1976 to 1984 (the year commercial harvesting ended) ranged from 21,000 to 28,000 per year. Because these harvests were on juvenile males only, and because the take was small relative to total pup production (about 10-15 percent), it is highly unlikely that this was a major factor in the decline since 1976 (Swartzman 1984). Under a similar harvest during the 1920s, the population increased approximately 8 percent per year. Furthermore, the herd on St. George Island has continued to decline continuously despite a cessation of commercial harvest since 1972 (York, 1989).

Since 1985, an annual subsistence harvest of 1,258 (1988) to 3,713 (1985) juvenile males has taken place on the Pribilof Islands (see Table 1). This is a small fraction of the previous commercial take, and also considered of little significance to the population trend.

B. Emigration

An estimated 12-21 percent of the tagged, young males harvested on the Commander Islands were tagged as pups on the Pribilof Islands in 1958-63, and only 0.1-1.0 percent were tagged on Robben Island. Less than 1 percent of northern fur seals harvested on the Pribilof Islands came from other islands in the North Pacific Ocean (Lander and Kajimura, 1982). Northern fur seals re-colonized San Miguel Island, California Channel Islands, in the 1950s or early 1960s and increased 46 percent annually from 1969 to 1978 (DeLong, 1982). Some of this high production was attributed to immigration of females from the Pribilof Islands, Robben Island, and the Commander Islands (DeLong, 1982; Antonelis and Delong, 1985). However, only 1,520 juvenile and adult seals (not pups) were on the Channel Islands in 1982 (Antonelis et al., 1988). Thus, emigration does occur between the Pribilof Island population and other populations in the North Pacific (including San Miguel Island), but not at a rate that could have influenced the decline observed on the Pribilof Islands during the 1960s and 1970s (York, 1987b; Loughlin et. al., in press).

C. Entanglement

Fur seals become entangled and die in marine debris, principally trawl webbing, packing bands and monofilament nets (Fowler, 1985b, 1986, 1987a). Fowler (1987a) stated that the incidence of such entanglement increased following the mid-1960s and 1970s when fishing effort in the North Pacific and Bering Sea increased and when plastic materials began to be used extensively in making trawl netting and packing bands. The observed rate of entanglement of juvenile male fur seals on St.

Paul Island in the commercial harvest increased from <0.2 percent in 1965 to >0.6 percent in 1974-75 (Table 6, Fig. 9), and remained stable at about 0.4 percent from 1976 to 1986 (Table 6). That rate was at least two orders of magnitude greater than was observed in the 1940s (Fowler, 1987a). The survival of 2- to 5-year-old male seals between 1970 and 1982 was negatively correlated with increased rates of entanglement, and there was a significant correlation between entanglement rate and rate of change of pup numbers (Fowler, 1985b). Based largely on the changes in the numbers of pups born and mortality in the first several years of life, Fowler (1987a) suggested that mortality of fur seals due to entanglement in marine debris contributed significantly to declining trends of the population on the Pribilof Islands during the late 1970s.

Table 6. Rates of entanglement of juvenile northern fur seals from St. Paul Island[1]

Years	Rate (Standard Deviation)
1967-1970	0.20 (0.059)
1971-1973	0.44 (0.036)
1974-1975	0.65 (0.092)
1976-1986	0.42 (0.037)
1987[2]	-
1988[3]	0.28
1989	0.29
1990	0.32
1991	0.21
1992	0.29

[1] Data from 1967-1986 in Fowler (1987a) and NMML (unpublished).

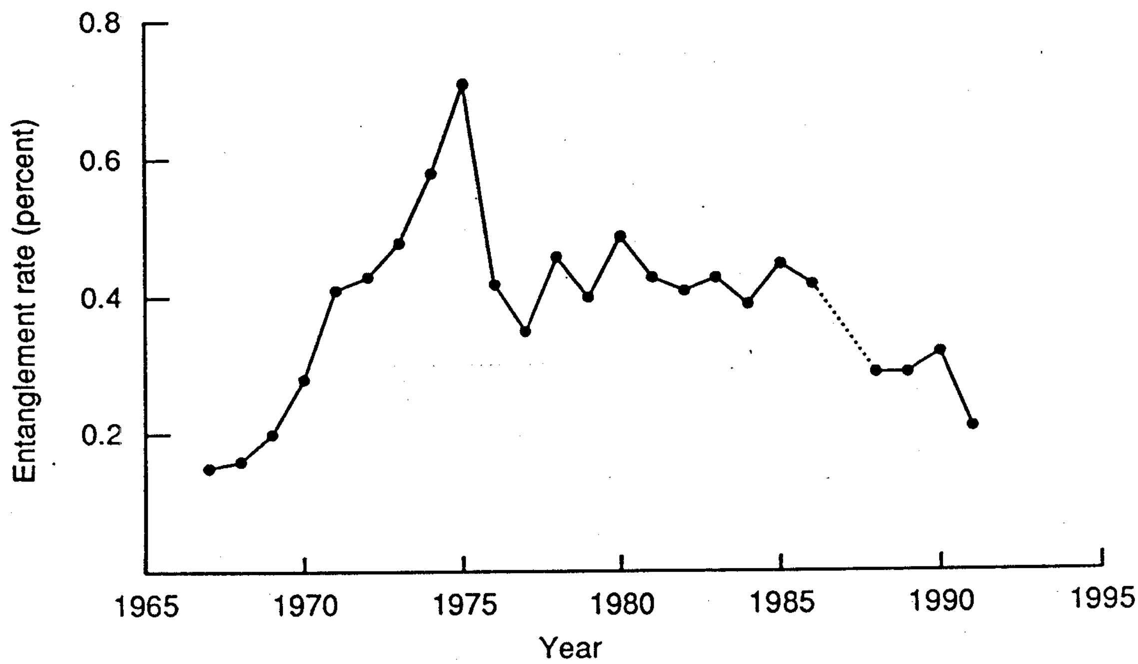
[2] No data were collected in 1987

[3] Data from 1988-1991 in Fowler et al. (1992)

Fowler (1985b, 1987a) further suggested that young seals (<2-3 years of age) appeared to be much more susceptible to entanglement than older seals. He also suggested that pups during their first few months at sea may be more susceptible to entanglement than juvenile males. However, Trites (1992), based on conclusions he reached using the data contained in Fowler (1985b), suggested that the sample size and age composition of entangled versus non-entangled males in the harvest used by Fowler in his determination were invalid to support an inference concerning differential mortality of young seals.

In 1985, 0.06 percent to 0.23 percent of the adult females on several rookeries on St. Paul Island were entangled in fishing gear (DeLong et al., 1988). Pups of these entangled females had a significantly higher mortality rate and lower body weight than pups of unentangled females. Entangled females either did not return to the rookeries from feeding trips, or remained at sea significantly longer than did unentangled females. In 1988 and 1989, the rate of entanglement declined to about 0.3 percent (Fowler et al., 1989; Fowler and Ragen, 1990). In 1991, the rate further declined to approximately 0.2 percent (Fowler et al., 1992). The change seemed to be associated with a reduction in entanglement in trawl webbing, possibly a reflection of reduced occurrence of trawl webbing among pelagic debris as reported in 1988 by Japanese scientists (Fowler et al., 1989, Fowler and Ragen, 1990).

Figure 9. The percentage of juvenile male seals found entangled in the commercial harvest from 1967-1984, and in research roundups from 1985 to 1988, on St. Paul Island, Alaska.[1]



[1] from Fowler et al. (1992)

D. Incidental Take

Foreign Fisheries: The incidental take of fur seals in commercial fisheries in the North Pacific Ocean was not considered large enough in the late 1970s to have been a significant factor in the decline of the Pribilof Islands stock of fur seals. Only eight fur seals were observed caught in foreign trawl fisheries in the eastern North Pacific Ocean between 1978 and 1981 (Loughlin et al., 1983). Perez and Loughlin (1991) reported that 48 northern fur seals were observed killed incidentally in foreign and joint-venture trawl fishing operations in U.S. waters between 1973 to 1987, based on observations of 30 percent of the fleet. Their estimate of the total kill was 246 (95 percent CI, 68 to 567) in both the foreign and joint U.S.-foreign commercial groundfish trawl fisheries from 1978 to 1988. Similar numbers of fur seals were probably killed between 1966 to 1977 (Perez and Loughlin, 1991).

The rapid expansion of high seas gillnet fisheries in the 1980s raised the concern that large numbers of marine mammals were being incidentally killed at levels which might be reducing their abundance. Each year, beginning around 1978, an unknown but potentially large number of fur seals were killed incidentally in the high seas squid driftnet fishery. This multi-nation fishery operated in the North Pacific Ocean from about 20° N to 46° N and 145° W to 170° E. More than 700 commercial driftnet vessels fished about 10 months a year, and set about 40-60 km of gillnet per boat per night. This represented more than 35,000 linear km of gillnet per night (each net is usually set below the surface and hangs down about 10 m).

Early estimates of total marine mammal mortality were based on little information (Hobbs and Jones, in press). Scientific monitoring of high-seas squid fisheries in the North Pacific was initiated in 1988. Joint monitoring programs were initiated in 1989 on high seas driftnet vessels (Hobbs and Jones, in press). In 1990, observer programs were expanded to include five high seas driftnet fisheries . Data collected by these observer programs provided the basis for estimating the total bycatch of marine mammals in the high seas driftnet fisheries. One of the most commonly caught bycatch species was the northern fur seal (Hobbs and Jones, in press), mainly 1- and 2-yr old fur seals (Baba and Kiyota, in press). The estimated total incidental catch of northern fur seals by the Japanese squid driftnet fishery in 1989 and 1990 was 4,960 (95 percent CI 4,362-5,557) (Hobbs and Jones, in press; see Fig. 5 for location of takes in 1990). The estimated incidental catch of fur seals in 1990 in the Korean and Taiwanese large-mesh fisheries was 147 and 206 individuals, respectively. This represented approximately 2 percent of the estimated population of 1- and 2-year old fur seals in the North Pacific (based on calculations by Buckland et al., in press).

The number of northern fur seals caught in Japanese high-seas salmon gillnet fisheries was estimated to be between 250 and 2,000 per year between 1975 and 1978 (Jones, 1980), 739 in 1980 and 94 in 1981 (Jones, 1981, 1982).

An unknown number of incidental catches have occurred in the Japanese land-based fishery. This fishery probably played little or no role in the fur seal decline in the late 1970s because few vessels were involved in the fishery, and effort was low at the beginning of the fishery. Therefore, it is likely that only a few fur seals were caught in this fishery.

Domestic Fisheries: The incidental take of fur seals in U.S. domestic fisheries was largely unknown prior to 1989 because domestic fishery observer programs were limited until that date. The

1988 amendments to the MMPA now allow for the monitoring of incidental take within selected domestic fisheries through an observer program, and an incidental take of about 50 fur seals per year in commercial fishing operations through 1993. It is unlikely that the effect of incidental take in domestic fisheries during the period of the greatest decline was significant (Fowler, 1982). The number of animals taken in domestic observer programs since observer monitoring was initiated has also been relatively low (< 10 per year).

E. On-land Mortality

Based on the limited data available, there is no evidence that on-land natural mortality has increased for any year-class, and the levels of mortality reported are too low to have made a significant contribution to the decline in the population since the mid 1970s. In part, this reflects the fact that pup mortality on land is density dependent (York, 1985; Fowler, 1987b). At high population levels pup mortality is high, and at low population levels pup mortality is low (Fowler, 1985a). In the 1940s and 1950s when the population was high, pup mortality on land was 10 to 22 percent. Between 1976 and 1986, annual pup mortality on land decreased from 6-10 percent to 3.7 percent, concurrent with the decline in the total population (based on an analysis of raw data in York and Kozloff, 1987). This density-dependent relationship between pup survival and pup abundance has remained relatively unchanged since the 1940s (Fowler, 1984).

The most common cause of mortality among pups on the Pribilof Islands during the first 2 months of life is emaciation syndrome (Keyes et al., 1979). However, the frequency of this and other causes of mortality, such as hookworm disease, tend to be cyclic (Keyes et al., 1979). Of 109 dead pups examined in 1964, 37.6 percent had died from starvation, 17.4 percent from trauma, 12.0 percent from hookworm disease, 4.6 percent from gastrointestinal infection, and 11.0 percent from miscellaneous infections (Keyes, 1965). Between 1974 and 1977, the primary causes of pup deaths in 725 pups were hookworm (45 percent), starvation (34 percent), microbial infections (14 percent), trauma (3 percent), and miscellaneous (4 percent) (Gentry, 1981). The causes of death for approximately 1,025 fur seal pups from 1986 to 1991 were emaciation (40 percent), trauma-blunt (18 percent)/trauma-sharp (4 percent), stillborn (8 percent), pneumonia (5 percent), fetal anomalies (1 percent), miscellaneous (18 percent), and undetermined/no gross lesions (6 percent) (Spraker et al., 1991).

Pup weight is also an important component of mortality because larger body size may be advantageous to individuals facing their first winter. Baker and Fowler (1992) reviewed studies where juvenile weight was shown to be positively correlated with survival for several mammalian species. With regards to fur seals, these authors found that seal pups who weighed more than their cohort's mean weight had a significantly greater chance of surviving to at least age 2. They concluded that pup weight significantly influences post-weaning survival at sea. Calambokidis and Gentry (1985) also found that pups weighing less than the average pup at birth, or those born to young mothers (<7 years old), had a greater probability of dying within the first 4 weeks of life when compared to pups of average birth weight from older females.

The weight of pups as an index to their general health and survival may also be of value in assessing the physical condition of the pup's mother.

F. Diseases and Parasites

The effects of diseases and parasites on fur seals between the late 1970s and the late 1980s are unknown. Necropsies of juvenile seals taken in the St. Paul Island subsistence harvest during the 1980s suggest that the population is relatively disease free compared to the period from the 1950s to early 1970s (NMML unpublished data). For example, mortality from ascarid (nematode worm) infection may have been important during the 1950s and 1960s (Neiland, 1961; Keyes, 1965), and while Leptospirosis was not identified until the 1970s (Smith et al., 1977). Thus, fur seals do succumb to diseases, as do all mammals. However, the relative importance of this form of natural mortality in the decline of the Pribilof Islands stock is unknown. Although natural conditions in the environment such as disease (and predation) have not been a significant threat to the fur seals in the past, disease should be considered a constant threat given the densities of fur seals (and their potential vulnerability to a disease) during the breeding season.

G. Predation

Captain Charles Bryant, first special agent of the Treasury Department, arrived on the Pribilofs in 1869 and stated that he took, respectively, 18 and 24 seal pups from the stomachs of two killer whales (original account chronicled by Lucas (1899) and reported in Scheffer et al. 1984). However, it has been since suggested that the record may have been incorrectly reported as being from the Pribilof area (Scheffer et al., 1984). The only authenticated stomach examination of a killer whale on the Pribilofs occurred in 1868 when a killer whale was seen "swimming with such force that he ran aground and was unable to get off. When the tides went out the whale was cut open and three seals were found in its stomach" (original record reported in Scheffer et al. 1984).

Preble and McAtee (1923) (as reported in Scheffer et al. 1984) gave numerous records of killer whales seen from 1875 to 1917. One killer whale seen off Reef rookery on December 2, 1902, "was playing havoc with a band of seals." At Northeast Point on November 6, 1904, "fragments of both cows and pups, the work of killer whales, were found strewn along the beach."

Killer whales (Orcinus orca) have also been observed to attack fur seals near Robben Island (Bychkov 1967), but no information is available for the Pribilof Islands in recent years. The account by Scheffer et al. (1984) concluded by stating that "evidence of predation by killer whales upon seals has not, we believe, been reported since 1917. We [Scheffer et al. 1984] conclude that killer whales have not changed their habits, but that Pribilof residents now spend less time watching the beaches than they used to." It is not known to what extent killer whales prey upon fur seals in waters adjacent to the Pribilof Islands.

Other sources of mortality to pups is predation by foxes and northern sea lions. On three occasions, foxes have been seen attacking living pups (reported in Roppel, 1984). Northern sea lions have also been reported to kill weaned fur seal pups close to shore on St. George Island (Gentry and Johnson, 1981) but, generally, at rates considered too low (3.4-6.8 percent of neonates) to be considered significant to the decline of the Pribilof Island stock of fur seals. Mortality of fur seal pups by sea lions was also observed in 1992. However, in general, the effects of predation on the decline and recovery of fur seals are not considered to have had, nor are they considered to have presently, a major impact on the stock (Fowler, 1985a).

H. Environmental Change

Fur seal behavior and survival could be influenced by changes in environmental conditions. York (1992) examined the relationship between sea surface temperature and early survival of fur seals. While a significant positive correlation was found, cause and effect relationships could not be identified. A model constructed by Trites (1990) has shown that thermal conditions on land could affect early survival of fur seal pups, but that the animals generally are able to tolerate the range of conditions to which they are normally exposed. Fur seals inhabit an area encompassing approximately 30 degrees of latitude, and they therefore must be able to tolerate a relatively wide range of environmental conditions.

If environmental changes affected the abundance or availability of a necessary food resource, the survival and productivity of fur seals could be reduced. A study of foraging patterns and energetics of Antarctic fur seals (Arctocephalus gazella) showed a dramatic effect of changes in prey (krill) availability on the nutrition and growth of pups (Costa et al., 1989). Lactating females provided their pups with the same amount of milk each time they came ashore regardless of whether food was abundant or scarce. However, in a year when krill were less abundant and more dispersed, feeding trips were almost twice as long (8.4 days versus 4.5 days). This resulted in the pups receiving about one-half as much milk per day, and correspondingly low pup growth rates. In the year of low food availability, 32 percent of the pups died, 68 percent due to starvation. These values were approximately double the normal rates.

Responses to environmental changes by northern fur seal populations have occurred as a result of El Niño events (DeLong and Antonelis, 1991; Trillmich and Ono, 1991). The 1982-1983 El Niño event had a significant impact on the 1983 breeding season of fur seals on San Miguel Island, California (at the southern limit of the range of northern fur seals). Pup production declined significantly largely because of a reduction in the numbers of adult females. Births occurred later in the season, feeding trips of lactating females were longer, weights of 3-month old pups were significantly below the average weights during years not influenced by an El Niño event, and pup survival of cohorts born during the 1976 and 1983 El Niño events was lower than all other cohorts from 1976 through 1984 (DeLong and Antonelis, 1991). However, Gentry (1991) found little change in the following behaviors for adult female fur seals on St. George Island before and after the 1983 El Niño event: duration of first visit to shore, mean duration of trips to sea; mean duration of subsequent visits to shore; natality rate, number of foraging dives; or mean or maximum diving depths. The only change in any parameter measured was that territorial tenure of some adult males was longer in the year after the 1983 El Niño event than during or before it, possibly as a result of some prey enhancement effect of the El Niño event in the eastern Bering Sea ecosystem, although Gentry (1991) suggests that this is problematic.

The number of walleye pollock consumed by fur seals in the Bering Sea is directly related to year-class strength of the walleye pollock (Sinclair, 1988). If environmental conditions strongly influence year-class success of walleye pollock, fur seals could be directly impacted. Such factors may also influence the foraging success of fur seals as the prey on other species (e.g., Pacific herring, Pacific whiting (hake), and anchovy) during their migration south into the North Pacific (Antonelis and Perez, 1984).

Evidence that major shifts have occurred in the abundance of fish and shellfish in the Bering Sea over the past several decades is well documented. Naumenko et al. (1990), for example, note that "in the last four decades the community of pelagic fishes in the western Bering Sea has shown considerable structural change." In the 1950s and early 1960s, the most abundant pelagic species was Pacific herring, whose biomass exceeded 3-5 million metric tons. In the late 1970s, walleye pollock biomass increased significantly (from an estimated 0.8 million metric tons to over 3.5 million) as the herring biomass initially increased, then sharply decreased. The relationship, if any, between the fluctuation in walleye pollock and Pacific herring numbers and the population decline in northern fur seals may never be fully understood. Recent estimates indicate that the walleye pollock biomass has accounted for nearly 85 percent of the pelagic fish population in that region. Also, the abundance of fish and shellfish stocks in the eastern Bering Sea has been characterized by rapid growth of the salmon, gadid (codfish) and flatfish (Pleuronectidae) populations in the early 1980s, with corresponding declines in shrimp and crab populations. Rapid increases in the estimated size of walleye pollock stocks in both the Bering Sea and Gulf of Alaska occurred between the 1960s and 1980s (Natural Resources Consultants, 1983; Larkin et al., 1990; Quinn and Collie, 1990).

The Bering Sea ecosystem appears to have shifted over the last 20 years from a community dominated by pelagic species (Pacific herring and possibly capelin, Mallotus villosus, and eulachon, Thaleichthys pacificus) and a semi-demersal species complex (rockfishes) to a community composed of fewer pelagic species and larger biomasses of semi-demersal (particularly walleye pollock and Atka mackerel) and demersal (all flatfishes) species. Natural phenomena, possibly responsible for producing these changes, are not well known. A number of authors note that there has been a general warming in the Bering and Okhotsk seas over the past three decades and theorize that shifts in temperature and wind patterns may have influenced recruitment and fish and shellfish population trends, but the relationship with oceanographic data are poorly understood (Swan and Ingraham, 1984; Khen and Glebova, 1990; Rodinov and Krounin, 1990). Furthermore, many of the population changes in both fish and shellfish have occurred during and following periods of intense fishing activity on same or other species. Thus, although there is evidence suggestive of changes in the abundance of major fish species and the environment, the causes of these changes and their influence on the fur seal population trend are largely unknown. Further studies to examine these relationships would be useful as an aid to evaluating natural versus human factors that may have influenced, and may continue to influence, fur seal population changes. Our ability to appropriately manage the northern fur seal population depends on our ability to interpret the synergistic effects of shifts in the Bering Sea and North Pacific ecosystems (climate, oceanography, distribution and abundance of prey).

I. Prey and Prey Availability

Several important fur seal prey species are the target of commercial fisheries on the continental shelf in the Bering Sea. In combination, these fisheries remove millions of metric tons of fish (Guttormsen et al., 1992), some of which may influence the availability and abundance of food to northern fur seals. For the most part, the commercial fishery is not directly targeting on the same size of prey eaten by juvenile and adult female fur seals. Walleye pollock are targeted by the fishery at age-4, >30 cm fork length (Wespestad and Dawson, 1992). Young fur seals and adult females eat primarily age-0 and age-1 fish, 3-20 cm fork length (Sinclair, 1988). Larger walleye pollock are eaten to a lesser extent by juveniles and adult females. The degree to which adult male fur seals depend upon walleye pollock and the size of walleye pollock they target is unknown. The influence of the fishery on the fur seal population cannot be examined independent of the remaining ecosystem. In addition to larger scale changes in abundance of food, fisheries could affect nutrition of marine mammal predators by causing localized prey depletion. Such changes could result in fur seals expending more energy to obtain prey. Removing large numbers of adult walleye pollock may allow for niche expansion of other fish species that consume juvenile and larval walleye pollock (e.g., arrowtooth flounder, Atheresthes stomias), thus competing directly with northern fur seals. Changes in the quantity or quality of available prey may influence the health of individual fur seals, resulting in reduced reproductive potential or fitness. However, the complexity of ecosystem interactions and limitations of data and models make it difficult to determine how fishery removals have influenced fur seals, or any other marine mammal species (Lowry et al., 1982; Harwood and Croxall, 1988; Loughlin and Merrick, 1989).

Age-structured population models indicate that walleye pollock biomass in the Bering Sea fluctuated from approximately 7.0 million tons in 1979 to 14.0 million tons in 1985, then back to about 7.0 million tons in 1992 (Wespestad and Dawson, 1992). In the Gulf of Alaska, abundance estimates ranged from about 1.0 million tons in 1972 to 4.5 million tons in 1982, and 1.2 million tons in 1992 (Hollowed et al., 1992). Peaks in biomass occurred in the early 1970s and the mid-1980s due to strong year classes in 1965-1968, and 1978, 1982, and 1984 (Bakkala et al., 1987). While the overall biomass of pollock has remained relatively high, low abundance of certain age groups in some years could have resulted in fewer fish available in the size range usually consumed by fur seals. Availability of certain sized prey may be particularly important for juvenile fur seals. Sinclair (1988) suggested that while a shift in the importance of walleye pollock as a prey species is not evident, the size of walleye pollock prey consumed by fur seals may have decreased since the 1960s. Sinclair (1988) found that juvenile walleye pollock were the most highly represented in her samples and adult walleye pollock ($>$4 years of age) were uncommon. Swartzman and Haar (1983) suggested that intensive commercial fishing on adult walleye pollock since 1964 may have resulted in increased numbers of juvenile walleye pollock. Sinclair (1988) suggested that the combined effect of naturally occurring interannual variability in prey resources other than walleye pollock, and the decreased availability of these potential alternate prey, may have forced seals to switch to the "newly abundant" juvenile walleye pollock as primary prey in the 1970s, and that seals may be food limited in years of low walleye pollock recruitment if other sources of nutrition are no longer available.

Foraging Trip Duration and Possible Prey Availability: If seals have switched from large to small walleye pollock in their diet, then Sinclair (1988) suggested that the duration of feeding trips could be expected to decrease, both because of the "increased" availability of juvenile walleye pollock, and because juvenile walleye pollock are available on the midshelf closer to the Pribilof Island rookeries. It has been suggested that a correlation exists between feeding trip duration and distance to feeding areas (Gentry et al., 1986a).

Foraging trip duration studies have yielded variable conclusions regarding a decrease vs. an increase in trip time for females, partly because the data is based on animals both from St. Paul and St. George Islands. Loughlin et al. (1987) reported that female fur seals on St. Paul rookeries were spending less time foraging at sea during the mid 1980s relative to the 1960s and 1970s, supporting the hypothesis that a switch in prey in terms of the size of pollock consumed by seals may have occurred and that prey were closer to shore, or that there was reduced competition for food. Baker (1991) found that trip duration decreased as females were removed from the population during the 1956-1968 harvests and concluded that trip duration was inversely related to prey availability. However, Gentry and Holt (1986) reported no consistent change in female feeding trip duration from St. George Island. Gentry et al. (1986b) suggested that transit time on St. George Island may largely determine trip duration for the species, and noticed a large variation in transit times and trip duration of some individual animals. In another study, Goebel et al. (1991) found no significant difference between individual seals in the time from shore to the first dive bout in their study. Goebel et al. (1991) also suggested that transit time from shore to the first diving bout and from the last diving bout to shore is a subset of actual time spent in transit, but cautioned that this may not represent an actual measure of total transit time.

Both studies by Loughlin et al. (1987) and Goebel et al. (1991) show that female fur seals feed while in transit to primary foraging areas. Also, although the studies by Loughlin et al. (1987), Gentry et al. (1986b) and Goebel et al. (1991) indicate differing results on whether time spent foraging by female fur seals has decreased or not in recent years, all of the studies suggest that prey availability to fur seals has not declined in recent years (i.e., time spent foraging did not increase in any of the studies). Further studies should examine recent trends in foraging trip duration for St. Paul and St. George Islands.

Pup and female weights have increased, consistent with good rearing success, and perhaps indicate a better food supply around the Pribilof Islands or a reduction in competition within the ecosystem (cf., Kozloff and Briggs, 1986). Baker (1991) found a correlation between the mean weight of pups and the number of foraging trips by females. Also, the number of walleye pollock in the fur seals diet has likely increased compared to the years before and after the onset of the walleye pollock fishery (Swartzman and Haar, 1983). Directed studies on the effects of prey availability and fur seal feeding have been reported by Sinclair (1988) and Sinclair et al. (in prep.). The authors concluded that fur seals are size-selective midwater feeders.

Starvation and Possible Prey Availability: The effect of prey availability on starvation of fur seals is unknown. Starvation at sea is one hypothesis for the observed decline since 1976, and may be one of several important factors in the natural regulation of the stock. Young fur seal pups frequently wash ashore along the Pacific northwest coast in winter, and many of those animals examined have been emaciated (cf., Scheffer, 1950a). York (1989) hypothesized that survival of young seals at sea may be correlated with sea state conditions. If adverse storm and ocean conditions and poor prey availability operate together at times, then starvation within a cohort may be significant. Trites (1992) suggested that the decline of the fur seal population may be from starvation due to reduced food resources south of the Aleutian Chain. Ragan and Antonelis (in prep.) indicate that newly weaned pups use many Aleutian Island passes during November and December as they migrate from the Bering Sea to the North Pacific. Trites (1992) suggested that food availability near the Aleutians may be insufficient during the fall migration to cause large numbers of young fur seals to starve after passing into the Gulf of Alaska, thereby creating a "bottleneck" for the entire Pribilof population.

The possibility of limited food availability during the non-breeding season in the North Pacific should be further examined. This would include investigations of food availability throughout the fur seal's range and an assessment of the factors which influence its variability.

J. Reproduction

Trends in reproductive rates are equivocal. York (1983) has shown that age at first reproduction is usually inversely related to juvenile survival. However, contrary to the usual density dependent model, age at first reproduction actually increased slightly during and after the female harvests of 1956 to 1968 (York and Hartley, 1981). From 1962 to 1970, there may have been a slight decrease in pregnancy rates for females 3 to 5 years-of-age; however, these observations were possibly due to sampling variability and other biases (Smith and Polachek, 1981). York (1987a) reported that pregnancy rates of females greater than 7 years old did not change significantly between 1958 and 1974. Goebel and Gentry (1984) reported that natality (birth) rates of tagged females on St. George Island had not changed significantly from 1974 to 1983.

5. POTENTIAL MAN-INDUCED THREATS TO THE FUR SEAL POPULATION

The following human-related activities may impede the recovery of Pribilof Island fur seals: commercial fisheries, onshore disturbance and coastal development, and, to a lesser extent, aircraft and vessel traffic and oil-related mortality.

A. Commercial Fisheries

Although the number of fur seals taken incidental to commercial fisheries has declined with a decline in overall fishery effort, the potential impacts of commercial fisheries through changes in the availability of prey directly or indirectly, and entanglement in fishing gear such as nets and ropes, are still considered threats to the fur seal population on the Pribilof Islands.

Prey Availability: The effect of removing potential fur seal prey by commercial fisheries in the North Pacific Ocean and eastern Bering Sea is unknown. Cephalopods and groundfish are important prey for fur seals, and both of these prey groups are heavily exploited, both directly and indirectly as bycatch, by commercial fisheries. Also, the potential of natural environmental variability on the distribution, density, abundance and quality of prey cannot be overlooked. If fisheries and natural fluctuations work in parallel at times to reduce the availability of prey, then fur seals may be at risk and their survival threatened. However, mytophid fish are probably the prey base that sustains many of the fur seals during their southern migration into the North Pacific during the nonbreeding season (Wada, 1971; Hobbs and Jones, in press). No directed fishery for this abundant and widespread resource exists.

Debris Entanglement: It is clear that entanglement has contributed to overall mortality, at some level, and possibly to the decline of fur seals. The amount of trawl webbing in the Bering Sea may be diminishing (Fowler et al., 1989). Following the leveling off of pup production on St. Paul Island, the rate of entanglement of juvenile males has also declined. There has been a declining trend in entanglement rates of juvenile males observed on land over the last 10 years.

B. Disturbance and Coastal Development (including Vessel Traffic)

Information is lacking on the long-term effects of disturbance on fur seals. Some rookeries on St. Paul Island have shown a greater decline than other rookeries. The Island of St. Paul once had five other rookeries in addition to those still present on the island (Roppel, 1984) (see Fig. 3). A rookery behind the village of St. Paul had over 8,000 fur seals in 1874, Lagoon rookery (near the present village cove) had over 37,000 animals but was extinct by 1941 (reported in Roppel, 1984). The similar "extinction" of rookeries has occurred on St. George Island. Although they are located close to present human occupation, it is not known whether disturbance or some other unknown factor led to the abandonment of these rookeries. This is a potentially serious problem that should be monitored. Disturbance from repeated human intervention onto the rookeries, increasing vessel traffic close to shore (something expected with the expansion of fisheries activities at St. Paul Island), and low flying aircraft are all potential disturbances that might affect the long-term use of a rookery area.

There is little data on the effects of human activities on fur seals, such as construction operations. Gentry et al. (1990) reported that fur seals occasionally looked toward the source of air-borne sounds or ground vibrations caused by heavy equipment in a rock quarry. From an experiment in which territorial males were scattered off a rookery before females had arrived (Gentry and Johnson, 1975) the authors concluded there was "little effect on territorial structure." These somewhat isolated, short-term studies suggest little or no effect from disturbance. However, the effect of chronic, long-term disturbance is unknown.

C. Toxic Substances

Contaminants have the potential to affect the immune system which could make fur seals more susceptible to disease (P. Reijnders, personal communication). Organochloride pollutant residues have been associated with reproductive failure in California sea lions (Zalophus californianus) (DeLong et al., 1973; Gilmartin et al., 1976) and have been shown to cause reproductive failure in harbor seals (Phoca vitulina) in the Dutch Wadden Sea (Reijnders, 1987). The level of chlorinated hydrocarbons in northern fur seals in 1980 indicated that these chemicals had no measurable effect on the northern fur seal population, and the DDE concentrations had increased but not significantly since 1969 (Calambokidis and Peard, 1985).

Estimates of northern fur seal abundance off the coastline of California to Washington during February-April indicate that many fur seals of the Pribilof population seasonally migrate into these waters to forage (Antonelis and Perez, 1984). The potential for contaminants which have affected California sea lions to move through the food chain into fur seal tissues is very real.

D. Petroleum Industry

Fur seals are vulnerable to the physiological effects brought on by oiling and subsequent loss of control of thermal conductance (e.g., Wolfe, 1980; Kooyman et al., 1976). Fur seals have a high metabolic rate and have no clear thermal neutral zone in water less than 25 C., indicating that the Bering Sea environment is energetically costly to these animals (Harry and Hartley, 1987). Crude-oil fouling of fur seals increases the conductance of the pelage and thereby facilitates heat loss. Any spill occurring in areas where fur seals concentrate could cause significant mortality (cf., Reed et al., 1987). The time and area most crucial for vessel and fur seal interactions is during the seals' migration into (spring) and out of (late fall-early winter) the Bering Sea. Fur seal densities increase as they move through the passes of the eastern Aleutian Islands, and one of the most common routes is through Unimak Pass. Unimak Pass is also the route taken by virtually all large vessels steaming into and out of the Bering Sea from the eastern North Pacific. An oil spill in or near Unimak Pass at critical times of the year could pose a great threat to seals from the Pribilof Islands (especially pregnant females in the spring and newly weaned pups in late autumn and winter) and thousands of other marine mammals and birds that use the pass seasonally. Fur seals would also be vulnerable to oil spills during their southern migration in the winter and spring while off the coasts of Washington, Oregon and California.

Numerous fishing vessels have run aground on St. Paul Island in the past decade (most when fur seals were generally absent). This further illustrates the potential vulnerability of the islands and the fur seal herd to oil spills and oil-related fur seal mortality. Any oil-exploration or oil-related commercial activity in or on the eastern Bering Sea shelf in the future should be required to have an oil-contingency plan that includes the Pribilof Islands and the adjacent Alaskan Peninsula and Aleutian Islands.

PART II

1. CONSERVATION ACTIONS AND IMPLEMENTATION

A. Goal and Objectives

The goal of this Conservation Plan will be met when the population of northern fur seals has increased to the level where it is no longer considered depleted under the MMPA. The present abundance estimate of 982,000 (Table 3) is approximately 47 percent of its carrying capacity, and therefore below OSP, based on a population level of 2.1 million during the late 1940s and early 1950s (Kenyon et al., 1954; Briggs and Fowler, 1984). The 1992 estimate of the number of pups born (253,000, Table 3) is approximately 48 percent of the peak in estimated pup production in the late 1940s and early 1950s. The population level at which maximum productivity would occur, and the level at which NMFS would reconsider the depleted classification, would occur at a sustained population level (total abundance estimate) and/or a sustained level of pup production which are 60 percent of the peak historical estimates.

Two objectives are proposed which are aimed at restoring and maintaining the Pribilof Islands fur seal population at its OSP level as mandated by the 1988 amendments to the MMPA. Research and management actions are included in these objectives as follows:

Objective I. Continue and, as necessary, expand research or management programs to monitor population trends and detect natural or human-related causes of changes in the Pribilof Islands northern fur seal population and habitats essential to its survival and recovery.

Objective II. Assess and avoid or mitigate possible adverse effects of human-related activities on or near the Pribilof Islands and other habitat essential to northern fur seals throughout their range.

B. Stepdown Outline

Items in this outline are not in order of priority. Priorities are identified in Section 2.A.

1.0. Monitor status and trend of northern fur seals

1.1. Continue annual counts of adult males and regular shearing/sampling of pups on both St. Paul and St. George Islands

1.11. Censuses of adult males
1.12. Estimates of pup production rates

1.2. Complete St. George Island studies

1.21. Complete analyses of fur seal investigations on St. George Island begun in 1973 following the cessation of the commercial harvest

2.0. Monitor health, condition and vital parameters

2.1. Develop indices of condition of individuals

2.2. Examine Reproduction and Survival

2.21. Expand tag-resighting program

2.211. Monitor reproduction and survival of tagged animals

2.22. Analysis of fur seal teeth

2.3. Conduct Observational and Behavioral Studies on Rookeries

3.0. Assess and evaluate causes of mortality

3.1. Investigate sources of natural mortality

3.11. Examine dead animals from rookeries, incidental take, and subsistence harvest
3.12. Determine causes and rates of pup mortality

3.2. Monitor incidental take in commercial fisheries

3.21. Observer programs
3.22. Develop and implement methods to reduce incidental take

3.3. Monitor entanglement rates

3.31. Evaluate entanglement and survival of sub-adult males
3.32. Evaluate entanglement at-sea
3.33. Conduct beach surveys
3.34. Improve and continue programs to minimize marine debris

3.4. Assess the effect of diseases

3.41. Conduct studies of diseases and parasites, contaminant levels, and nutritional status
3.42. Compile a catalog of all tissues and other samples

3.5. Assess the Effect of Environmental Pollutants

3.51. Monitor pollutant levels

4.0. Assess and minimize the effect of disturbance on northern fur seals

4.1. Document effects of disturbance caused by human activities

4.2. Prepare guidelines and regulations to control potentially disruptive activities

4.3. Evaluate causes and extent of intentional mortality to seals other than subsistence harvest

4.4. Review recommendations for maximum allowable levels of lethal take

5.0. Investigate feeding ecology and factors affecting energetic requirements

5.1. Describe foods eaten by fur seals

5.11. Collect and analyze stomach contents
5.12. Collect and analyze scats

5.2. Investigate northern fur seal feeding ecology

5.21. Identify feeding areas, habitat requirements and foraging strategies
5.22. Investigate diving behavior and trends in female feeding cycles
5.23. Characterize geographic and seasonal patterns of prey availability and utilization by fur seals

5.24. Behavioral/physiological studies

6.0. Investigate relationships between fur seals, fisheries and fish resources

6.1. Relationship between population growth and prey availability

6.2. Determine effects of fisheries on northern fur seal prey

6.21. Model effects of fishing on prey composition, distribution, abundance, and behavior

6.3. Ensure adequate food availability in feeding areas

6.31. Regulate fishing areas, seasons, and types of operations
6.32. Regulate fishery catches

7.0. Identify natural ecosystem changes

7.1. Determine how abiotic and biotic factors affect long-term trends in fur seals either directly or indirectly through their prey

8.0. Coordinate conservation efforts with other agencies and countries

8.1. Monitor Federal actions for potential impacts to northern fur seals

8.2. Develop mechanisms for international conservation efforts

8.21. Continue comparative studies on other populations

8.211. Distribute conservation plan to other involved nations
8.212. Develop bilateral or multilateral conservation agreements

8.3. Establish Conservation Plan Coordinator position

8.31. Coordinate information and education programs

8.4. Enforce existing regulations

C. Narrative

Data collected through any research outlined in this plan should be analyzed and reported in a timely manner. Reports should be thoroughly referenced and follow standards of organization to facilitate comparison with existing reports. As much as possible, data should be presented in peer-reviewed periodicals and other open publications to ensure that research programs benefit from regular peer commentary.

To the maximum extent possible, research efforts should collect data that can be compared with historical data. Studies may need to be conducted to calibrate results from newly developed techniques with those obtained by previous methods. Data analyses should examine trends over time and attempt to correlate observed changes with physical, biological, or human- induced changes in the environment.

Analyses should emphasize correlations between regional differences in fur seal population trends with factors such as physical oceanography, food resources, and human activities (e.g., fishing or tourist activities). Such correlations can indicate causes of declines which may lead to more effective management.

1.0. Monitor status and trend of northern fur seals

Monitoring population growth remains one of the most important aspects of fur seal research. Information on the number of adult males and pups, number, ages, and sexes of fur seals found dead on the rookeries, and pup mortality and survival rates of sub-adult males contribute to long-term data sets which began in the early 20th century. Most studies in this section represent ongoing research designed to detect changes or trends in the growth of the Pribilof population of northern fur seals.

1.1. Continue regular counts of adult males and shearing/sampling of pups on St. Paul and St. George Islands

Currently, fur seal abundance is monitored using annual counts of adult males and biennial pups censuses at rookeries on St. Paul and St. George Islands. These surveys are compared over time to evaluate population trends (Antonelis 1992).

Counts of adult males and estimates of pup production are recommended as the best indices of population trends. These data should be collected to maintain a long-term database for evaluating recovery of the stock. Continuation of the regular post breeding season beach surveys to determine the number of pups that die before leaving the islands is required to both determine the total number of pups born and to monitor the annual level of pup mortality rates. These data should be compared to other rookery islands (e.g., San Miguel and Commander Islands) for evaluation of differential survival rates.

1.11. Censuses of adult males: Counts of adult males began on the Pribilof Islands in 1911 and have continued annually since that time. Adult males constitute the only component of the fur seal population for which a total count can be obtained. Adult male counts are an important method of monitoring the population and assessing changes due to the cessation of the commercial harvest. Adult males are counted on all St. Paul and St. George Island rookeries as close to July 10th as possible. Two classes of males, territorial and idle, have been recorded each year since 1911. A territorial male is one who defends a territory containing one or more females. Idle males are estimated to be age 7 years and older and do not have territories with females. Counts for each rookery are made from the same locations each year.

1.12. Estimates of pup production rates: When the fur seal population of the Pribilof islands was small (e.g., during 1912-1924), it was possible to directly count the number of fur seal pups on the rookeries. However, as the population grew, this became impossible. Presently, the numbers of fur seal pups are estimated using the shearing-sampling method (see Part I, section D, Abundance and Population Trends). Pup estimates are an index of productivity because they reflect the number of parturient females. However, caution must be exercised when generalizing about population trends based solely on pup counts. Declining pup production could be indicative of a declining total population, a decline in fecundity, a decline in the number of reproductively active females, or a combination of these and other factors.

Estimates or counts of pups born are the most sensitive index to identify changes in the eastern North Pacific population. This activity is conducted biennially and will result in some disturbance and temporary displacement of adults.

1.2. Complete St. George Island studies

In 1973, NMFS began a long-term study of the effect of the cessation of the commercial harvest on the behavior and population composition of fur seals on St. George Island. The United States established a research control area on St. George Island and a moratorium on the harvest of fur seals there because the Pribilof Islands herd failed to respond as expected to changes in the management scheme started in 1956. The research included: (1) behavior and activity patterns of adult males; (2) length of nursing-feeding cycles for lactating females; (3) distance traveled and time spent feeding by females; (4) activity of pups; (5) activity patterns of adult females and young males on hauling grounds; (6) changes in activity patterns of seals when disrupted by research and management activities; (7) interaction between fur seals and northern sea lions on fur seal rookery areas; and (8) causes of death among pups before and after the expected increase in the number of males (for more details see Roppel 1984).

1.21. Complete analyses of fur seal investigations on St. George Island begun in 1973 following the cessation of the commercial harvest: A 15-year database from this study has been collected, and a full analysis and final report of this work will be completed to help determine why the fur seal herd on St. George Island has continued to decline (about 6 percent per year) since the early 1970s. This research effort will be published as a separate book.

2.0. Monitor health, condition, and vital parameters

The health and condition of individual fur seals are important to monitor in relation to the population recovery. Condition of individuals affects their survival and reproductive output (i.e., vital parameters) which in turn influences population trends. Assessment of the factors contributing to population trends requires reliable life-table data to provide quantitative measures of the dynamics of age- and sex-specific rates of productivity and mortality within the population. Likewise, the success of management efforts is ultimately assessed by subsequent mortality and productivity measurements.

2.1. Develop indices of condition of individuals

Various measurements may be used independently and in combination to evaluate the physical condition of individual fur seals. Methods currently in use for Steller sea lions include body weight (compared to age or length), length/girth ratios and blubber thickness (Calkins and Goodwin, 1988). Other techniques can provide measures of certain aspects of condition not reflected by body size and subcutaneous fat stores (e.g., Huntley et al., 1987). These include, but are not limited to, morphometric measurements, isotopic tracer techniques for assessing body composition and metabolism, ultrasound and electrical conductivity measures of body fat, measures of lactation energy exchange, and blood chemistry measures (e.g., anemia, immune response, ketone bodies, humoral enzyme levels). Expert advice on this field should be solicited and a complete plan for condition assessment should be developed based on multiple indices of condition.

2.2. Examine reproduction and survival

A systematic study of the reproductive and survival rates of female fur seals has not been done in sufficient detail to be used to monitor trends in vital rates. This information is central to understanding mechanisms of population change and to assess future reproductive potential of the population. Historically, females were killed for age-specific reproductive information. The number that would need to be killed to obtain a statistically representative sample from all age classes would be prohibitive in view of the current population status. Alternative methods must be developed to address this question.

The recovery of the Pribilof fur seal stock is largely dependent on the recruitment of young females into the reproductive population. Information on recruitment is lacking, however. This information can be obtained by marking female pups and assessing survival to at least age 3-5 when females generally reach sexual maturity and give birth for the first time. Alternative methods of assessing age composition of females on the rookery by using vibrissae and pelage characteristics may be used in the future, but at present these techniques need to be validated. Currently, there are no tags available that can be applied to pups and then successfully used for a mark-recapture study of adult females for determining reproductive rates.

2.21. Expand tag-resighting programs: Approximately 8,000 female pups have been tagged on St. Paul Island from 1987 to 1990 for long-term analysis of survival and recruitment. To assess female survival and reproductive rates, follow up on these animals and an expanded tagging and resighting program is necessary. The tags presently used (round post monel tags), however, are not easily read from greater than 5 meters. A new tag needs to be tested for durability and readability. The time and cost to develop such a tag may not represent the most efficient use of available resources, and alternative methods to tagging need to be investigated.

2.211. Monitor reproduction and survival of tagged animals: During August, 1987-1990, samples of male pups were tagged with modified round post monel tags, one on each flipper. In 1989, the first of these were resighted in the research roundups as 2 year-olds. Data on returns of tagged males will be used to estimate survival of males during their first 2-5 years of life for the 1987-1990 year classes. Weights of tagged males are also gathered. Information on the presence, absence and condition of tags applied is also collected to assess tagging techniques.

2.22. Analysis of fur seal teeth: The analysis of male and female teeth collected over the past 50 years provides a means of evaluating long-term density-dependent changes in the population (Fowler, 1990; Baker and Fowler, 1990). A study of growth layers of the canine teeth of females is recommended to evaluate changes in the age composition of the population, feeding cycles and, possibly, reproductive rates of females. Teeth from males collected in the subsistence harvest can also be used to evaluate the availability of food to their mothers based on nursing lines when they were pups (Baker, 1991).

2.3. Conduct observational and behavioral studies on rookeries

Focused observational studies of fur seals on land should be conducted at selected sites. These should include: population monitoring efforts (specified in Section 1.0), monitoring of mortality specified in Section 3.0, and sampling from dead animals described in Section 3.11. In addition, observations of certain behaviors on the rookery can also serve as indices of health, condition, and vital parameters. These include: copulation rates of males (e.g., Gisiner 1985), average tenures of territorial males and female attendance patterns. Female attendance patterns in closely related otariids have been shown to be correlated with female condition and food availability. For example, during the 1983 El Niño climatic disturbances, female attendance patterns and pup condition in California sea lions, Galapagos fur seals (Arctocephalus galapagoensis) and northern fur seals were altered by climatically induced food shortages (i.e., female's stayed at-sea longer to forage for food) (Trillmich et al., 1986; Ono et al., 1987). Data on attendance patterns may also be obtained from telemetry packages placed on post-parturient females (see Section 5.22).

Data on mother-pup attendance patterns should be combined with lactation energetics data (Section 5.2) to provide a more complete picture of the foraging ecology of reproductive females. These data are important for data compilations and models of foraging ecology in Sections 5.22 and 5.24.

3.0. Assess and evaluate causes of mortality

The cause(s) of the decline of the Pribilof Islands fur seal population have not been determined. Existing data do suggest, however, that the following may have killed or compromised substantial numbers of fur seals: entanglement in lost and discarded fishing gear and other marine debris, incidental take during fishing operations, fishing for walleye pollock or other important species in the fur seals' diet, past harvest practices, disease, environmental pollution in one or more parts of the population's range, or natural variation and long-term changes in the marine ecosystem of which fur seals are a part.

The goal of population recovery requires an understanding of current causes of mortality and their relative contributions to total mortality so that mortality can be decreased wherever possible. This work is also essential to mitigate future declines, and to determine which activities might encourage recovery of the population.

3.1. Investigate sources of natural mortality

At present, the causes and extent of natural mortality are poorly understood for those age classes other than pups, especially mortality at sea. Planned research may reveal causes of natural mortality (e.g., disease) that could be controlled to facilitate population recovery. Currently, however, no programs for reducing natural mortality are planned.

3.11. Examine dead animals from rookeries, incidental take, and the subsistence harvest: Examination and sampling of dead fur seals can indicate causes of mortality. Dead fur seals should be collected whenever possible without disturbance to normal rookery activities. Carcasses should be examined and sampled to the maximum extent possible to determine cause of death, presence of disease, etc.. Animals taken incidentally to commercial fisheries, and in the subsistence harvest, can be sampled when very fresh. People collecting specimens should be trained and provided with necessary protocols. About 1,500 juvenile male fur seals are harvested each year for subsistence on St. Paul and St. George Islands. Collection of data in future harvests should provide information for monitoring the condition of each harvested cohort of the seal population. Whole body weights, blood samples and upper canine teeth have been collected on St. Paul Island, and ages determined for a selected subsample of seals. This allowed monitoring of the age distribution of seals taken in the harvest. When considered together, the weight and age data may provide an index of animal/cohort health (see section 2.1). The collection of these data should be continued on St. Paul Island. Given the declining trend in the St. George population, this data should also be collected on that island.

3.12. <u>Determine causes and rates of pup mortality</u>: Studies of mortality and causes of death of pups on the Pribilof Islands assess elements that affect cohort survival.
The objectives of this work are to determine the frequency and causes of pup mortality at selected rookery sites on St. Paul and St. George Islands, and any differences in causes or rates of pup mortality over-time between the islands. Dead pups have been collected daily from catwalks overlooking sections of the Reef and Vostochni rookeries on St. Paul Island (see Figure 3 for rookery location) and from portable observation blinds on Staraya Artil and Zapadni rookeries on St. George Island (see Figure 4). Viral and bacterial analysis of the pathogens will be performed if funding for such work is available.

3.2. <u>Monitor incidental take in commercial fisheries</u>

Continued monitoring of domestic fisheries is recommended to identify and eliminate sources of mortality of fur seals. Mechanisms for reporting incidental takes and ensuring compliance are provided in the MMPA and NMFS regulations. Emphasis should be placed on the collection of biological data for marine mammal population assessments, as well as for determining the impact of incidental take. Specific methods for assuring maximum compliance in reporting and for proper sampling of animals and storage of specimens should be developed. To increase their cooperation and compliance, fishermen should be encouraged to participate in developing strategies for reporting takes. Educational programs aimed at fishing organizations and communities (see Section 8.213) would be particularly useful for developing better monitoring procedures.

3.21. <u>Observer programs</u>: Observers placed on fishing vessels should record fishing effort (e.g., number of sets, size of nets, time and location of sets) and document the number, sex, and age of all fur seals caught. Measurements, samples of teeth, stomach contents, blubber thickness, reproductive tracts, blood, and tissues from incidentally caught fur seals would help in assessing physiological condition, composition of the take compared to the population, and possibly allow for an analysis of stock structure by area. Properly collected samples from fisheries can be of great use in evaluating the role of disease, starvation, and other factors in the pelagic survival of fur seals.

3.22. <u>Develop and implement methods to reduce incidental take</u>: Gear modification programs should be considered for fisheries where fur seals are incidentally taken. Particular attention should be paid to the timing and location of fisheries where fur seal mortality is known to occur. For example, current data indicate that Steller sea lion mortality in fishing gear is more a function of area and feeding activity than of the gear (i.e., incidental take is higher when fishing is conducted at night) (Loughlin and Nelson, 1986).

Data should be reviewed annually to determine where the likelihood of incidental take is greatest and to identify alternative areas or times where those fisheries could operate. If necessary, new regulations or modifications to existing regulations should be developed and implemented. Educational programs should involve fishermen in developing techniques to reduce and eliminate incidental takes.

3.3. Monitor entanglement rates

Trends in northern fur seals may have been related to mortality caused by entanglement in free-floating marine debris. This mortality may have its greatest adverse impact on juvenile seals, which may be more vulnerable because of their behavior and relatively small size. Efforts to address the problem of entanglement have involved cooperative U.S.-Japan studies during roundups. Additional data collected from examination of debris entanglement on fur seals include rate of entanglement, type and size of debris, and degree of injury due to entanglement.

In 1985, 1986, and 1988, entangled and control seals were tagged and released. Returns in later years have been used to estimate the relative return rates of entangled and unentangled seals and to estimate mortality caused by entanglement. During 1989, 1990, 1991 and 1992, entangled seals were freed of their debris and tagged, as were controls. Returns from these releases in 1990, 1991, and 1992 served as the basis for assessing the changes in survival caused by debris removal.

3.31. Evaluate entanglement and survival of sub-adult males: Monitoring the rate of entanglement of juvenile seals on St. Paul Island is recommended to determine trends in the rate of entanglement. This is also the only way to evaluate whether existing mitigating measures may be working (e.g., laws to eliminate dumping debris overboard). This study of sub-adult males will produce information on entanglement rates, survival of entangled and disentangled seals, and trends of on-land entanglement rates which provide an index of the amounts of small debris encountered by seals while at sea, and test the following three hypotheses: (1) the mortality rate for entangled juvenile male fur seals is the same as for unentangled juvenile males; (2) the current rate of observed on-land entanglement is unchanged in recent years; and (3) removing debris has no effect on survival.

It is important to continue monitoring juvenile males to assess the effects of any mitigating measures (i.e., disentanglement, efforts to slow inputs of marine debris) or changes that might otherwise occur (i.e., changes in fishing effort due to changing fishery management). The rates of juvenile male entanglement in small debris should decrease as mitigating measures are applied. The portion of juvenile males entangled decreased by 30 percent from 1988 through 1991, then increased slightly in 1992.

Assessing the incidence of entanglement includes a description of the debris on each entangled seal, descriptions of wounds caused by the debris, total and age-specific rates of entanglement, and estimates of survival rates.

3.32. Evaluate entanglement at-sea: The amount of debris on beaches and at sea is only partially known. The rate of entanglement at sea and subsequent death of females is unknown. Presumably, most entanglements occur in the Bering Sea and near the subarctic boundary (about 40°-46°N) where fur seals and oceanic debris tend to concentrate (cf., Shomura and Yoshida, 1985; Ribic and Swartzman, 1989).

The role of entanglement in mortality on the fur seals cannot be fully evaluated without information on the amount of debris in the marine environment and the rates and effects of debris entanglement on fur seals at sea. There should be a dedicated effort to estimate the number of entangled animals seen during vessel surveys. The objective is to test whether most entanglement of juveniles occurs near the Pribilof Islands and whether the rates of entanglement are sufficient to effect the population growth rate. When possible, the entangling material should be identified to provide clues about the circumstances under which fur seals become entangled.

Literature surveys should be conducted to update information on related marine mammal and bird entanglement incidents, and surveys of occurrence of entangling materials (e.g., packing bands, net fragments) at sea. Improved education, enforcement and other efforts to mitigate mortality, are needed to minimize the impact of debris on fur seal survival (see Section 3.34).

3.33. Conduct beach surveys: A study to examine the distribution and abundance of debris on shore relative to fur seals could be carried out at the beginning of the reproductive season (May-June), during the peak of lactation (July-September), and when most females depart the islands (October-November).

3.34. Improve and continue programs to minimize marine debris: An educational program within the fishing industry, including all support units, in order to eliminate the at-sea discard of materials that may cause marine mammal entanglement, should be continued. Entanglement of fur seals in net fragments have decreased (Fowler and Ragen, 1990; Fowler and Baba, 1992), but efforts to further reduce or eliminate this problem should be continued. Foreign fishing and support vessels may be major sources of packing bands and scraps of netting. Efforts should involve the international level through the International Convention for the Prevention of Pollution from Ships (MARPOL) and related organizations, the NMFS Marine Entanglement Research Program. Educational programs (Section 8.31) should stress the harmful effects of marine debris.

3.4. Assess the effect of diseases

Some pathogens have a history of impacting seal and sea lion populations. Leptospirosis killed approximately 15 percent of the California sea lions passing through Oregon in 1984-85 (Hodder et al., in press). The San Miguel sea lion virus may also have been important in an increase in miscarriages in California sea lions off California (DeLong et al., 1973). A canine distemper-like virus killed approximately 50 percent of the harbor seals in the North Sea in 1987-1989 (Osterhaus et al., 1988a, 1988b). With the exception of a high pup mortality caused by hookworm disease in the 1950s, no such known major events have been documented in Pribilof fur seals, but there has been no full evaluation of disease conditions over the past two decades.

3.41. Conduct studies of diseases and parasites, contaminant levels, and nutritional status: Although many dead pups are collected annually on St. Paul Island to assess the presence of disease, body condition and cause of death, there have been no routine necropsies of dead adult fur seals for more than 10 years. Future studies of all age groups should be done throughout the breeding season to identify pathogens in the population and their potential effect on population recovery. Samples should come from juvenile males killed during the subsistence harvest, animals found dead on the beach, from those taken incidentally in fisheries. Arrangements should be made with laboratories that can provide reliable, timely, and cost-effective analyses of samples. In many cases, the data collection and analyses may be carried out by a single agency or contractor. Criteria should be established for prioritizing samples for analyses. Blood, oral and anal samples should be collected from adult females and their pups regularly to assess disease and contaminant transfer between mother and pup.

3.42. Compile a catalog of all tissues and other samples: Previous research has resulted in the collection of a considerable number of tissues and other samples from northern fur seals. Most of this material is currently held by NMML. Not all of this material has been analyzed. All existing samples should be centrally cataloged and preserved for completion of ongoing analyses or for future analyses. The catalog should include the location of samples, their condition, whether they have been analyzed, and the protocols under which they were collected. Samples should be properly archived.

3.5. Assess the effect of environmental pollutants

In the eastern North Pacific Ocean, pollutants from many sources have been identified in marine mammals since the 1960s. These primarily include heavy metals and organochlorine compounds. Recent Federal legislation and enforcement programs have substantially changed the practices of commercial fishermen and others regarding their responsibilities to reduce and dispose of hazardous contaminants and marine debris. Education programs, enforcement, and regulations are necessary to continue to further reduce the amount of marine debris and disposition of hazardous materials.

3.51. Monitor pollutant levels: The effect of pollutants on the health and status of individual fur seals is unknown. Since high concentrations of some contaminants may be associated with reproductive failures, periodic biopsies of adult females may be warranted as a long-term tool to assess changes in environmental input.

The highest rate of mortality in fur seals occurs during the first year of life, probably in large part because of malnutrition. Some studies have shown that organochlorine and PCB levels are highest in juvenile animals. Periodic comparisons of certain tissues of presumably "healthy" fur seals collected in fisheries and the subsistence harvest with dead animals found on the beach may be of some value.

Although Calambokidis and Peard (1985) indicated that in 1980 the level of organochlorines in northern fur seals had not changed significantly over the previous 20 years, routine monitoring of Aleuts who subsist on fur seals should be considered.

4.0. Assess and minimize the effect of disturbance on northern fur seals

Information is lacking on the long-term effects of disturbance on fur seals. This is a potentially serious problem that should be investigated. Disturbance from repeated human presence on the rookeries, increasing vessel traffic close to shore (something expected with the expansion of fisheries activities at St. Paul and St. George Islands), and low flying aircraft, are all sources of disturbance that might affect the long-term use of a rookery area, survival of pups, and social behavior of fur seals.

4.1. Document effects of disturbance caused by human activities

The importance of disturbance on the survival of pups needs to be studied at various rookeries on the Pribilof Islands. This can be done by comparing the rates and types of disturbance to changes in pup production, territoriality, pup mortality and condition, and changes in number of animals on various rookeries. Causes and impacts on fur seals of disturbance caused by human activities (e.g., noise from aircraft, boats, or other vehicles; presence of humans on rookeries, noise, habitat alterations) should be summarized. The response of fur seals in disturbed areas can be readily observed.

Little is known about disturbance of fur seals in feeding areas other than incidental take associated with commercial fishing operations. Instances of disturbance should be recorded by observers who are now in place on commercial fishing vessels.

4.2. Prepare guidelines and regulations to control potentially disruptive activities

The continued seasonal/restricted access to rookeries may be the best way to limit disturbance around rookeries. Current regulations limit access to fur seal rookeries between June 1 and October 15. However, many female fur seals nurse their pups into November. The appearance of a single person on a rookery can cause the mothers and pups to move into the water, thus disrupting nursing activity. If it is determined that current disturbance levels negatively effect the growth of a rookery, then it may be necessary to institute more restrictive measures regarding human activities, especially during the latter part of the pup rearing period. Existing regulations protecting fur seals from disturbance may also require stronger regulations enforcement.

Specific guidelines or regulations should address disturbance that may be caused by vessels (commercial and sport fishing, tourist, research, and recreational), aircraft (private, commercial and military), and activity on the ground (tourists, researchers, motorized vehicles, and industrial activities).

4.3. Evaluate causes and extent of intentional mortality to seals other than subsistence harvests

Enforcement and education programs should yield information about specific instances of deliberate killing not associated with the subsistence harvest. Follow-up on reports of deliberate killing are needed to determine the circumstances of such cases and how prevalent they are. Programs to eliminate deliberate killing should be developed.

4.4. Review recommendations for maximum allowable levels of lethal take

The NMFS is currently working on a plan for setting allowable levels of incidental take that will apply to all marine mammal species. A draft regime has been proposed (NMFS, 1991) and has been submitted to Congress for consideration during the 1993 reauthorization of the MMPA. Takes in fisheries should be divided by region, season, and gear type to prevent high takes in one fishery or region from overburdening or closing other fisheries.

5.0. Investigate feeding ecology and factors affecting energetic requirements

Pelagic collections of northern fur seals were conducted to investigate the food habits of northern fur seals between 1958 and 1974. This work was conducted under the auspices of the Fur Seal Act of 1911 and its subsequent Convention of 1957. This research has been summarized by Kajimura (1984) and Perez and Bigg (1986). No comparative data has been collected since the mid 1980s (Sinclair, 1988). These studies indicated that fur seal diets change depending on their location and the availability of food resources. Information on the food and foraging habitat needs of weaned pups, adult, and juvenile seals will be a key element in identifying habitat essential for successful foraging. Such information is also needed to determine where commercial fishing activities and foraging fur seals overlap.

Many of the prey species eaten by fur seals are taken in commercial fisheries. Although the fur seal diet as a whole is diverse, in particular areas a single species may comprise more than 50 percent of their food for certain periods. Such species are usually locally concentrated in particular areas and times. Examples include walleye pollock and squid. It is unclear at present whether or how particular fisheries may affect the ability of fur seals to obtain an adequate supply of food. Comparisons of the condition of sea lions collected in the Gulf of Alaska in the mid-1970s and the mid-1980s suggested that animals collected in the latter period were nutritionally stressed (Calkins and Goodwin, 1988), but the data did not identify specific problems. Fluctuations in abundance of fish stocks in Alaska have been well documented in recent years (e.g., Naumenko et. al., 1990; Megrey and Wespestad, 1990). However, the influences of predators, commercial harvests, and environmental factors on fish stock abundance are poorly understood. Additional information will be needed to design properly focused and effective management measures that ensure food supplies, especially in critical areas and times, are adequate to support the fur seal population in the Bering Sea and the North Pacific Ocean. Actions that must be taken to obtain the necessary information and to implement appropriate measures are described below.

Three fundamentally important questions need to be answered: (1) what are the primary prey species and how do they vary between location, year, and season; (2) where do fur seals go during their time at sea; and (3) how does prey distribution and foraging behavior relate to location and oceanographic conditions? These questions cannot be answered using pelagic fur seal distribution data collected from 1958 to 1974 (Kajimura et al. 1979). Those data entailed non-random sampling biases. Moreover, significant changes in the eastern Bering Sea and Gulf of Alaska prey-base have occurred during the past several decades. More recent studies were limited because of small sample sizes and restricted study areas (Antonelis et al., 1990; Bengtson et al., 1989; Loughlin et al., 1987; Gentry and Kooyman, 1986).

5.1. <u>Describe foods eaten by fur seals</u>

The diet of northern fur seals must be monitored in order to assess possible causes of changes in population growth. This was best illustrated during the 1983 El Niño when a change in the diet of northern fur seals on San Miguel Island was correlated with a decline in the number of pups born and in the weight of pups examined in September 1983 (DeLong and Antonelis, 1991). Monitoring diet is also necessary in order to understand dynamic connections between fur seal foraging, prey availability and potential influences of commercial fisheries.

The ultimate goal of food habits studies should be to identify prey species and the size (or age) classes of prey for all age/sex classes of fur seals in all areas and seasons. Prey utilization among regions, and changes from year to year within regions, should be analyzed. Analyses should determine the relative importance of prey items (by number, weight, and/or volume). Diagnostic hard parts should be used for identification of prey where necessary. Sizes of prey consumed should be estimated using relationships between size of intact organisms and hard parts such as otoliths.

5.11. Collect and analyze stomach contents: Stomach contents should be collected from dead fur seals whenever possible. Animals taken in commercial fisheries are of particular interest since it is likely that their stomachs will contain fresh food remains, and the location where they were feeding will be known. The entire stomach contents should be collected from every animal incidentally taken in commercial fisheries as part of observer programs. Intestinal contents should also be collected and examined for prey remains. Samples collected from these sources may not reflect the exact diversity or relative proportions of prey species eaten by the fur seal population, and small sample sizes may preclude statistical treatment of the data. They may nonetheless be useful for comparisons among areas and over time. While other methods may produce larger sample sizes, analysis of stomach contents will give data that are the most comparable with data collected in previous years and eliminate the need to kill animals for stomach samples.

5.12. Collect and analyze scats: An alternative to killing fur seals for food habit information has been the analysis of scats (e.g., Antonelis et al., 1990; Bigg and Olesiuk, 1990; Olesiuk et al., 1990; DeLong and Antonelis, 1991). Beginning in 1987, the diet of fur seals on the Pribilof Islands has been monitored through the analysis of scats. This nonlethal method of collecting dietary information is especially desirable, given the depleted status of the fur seal population. Scats are collected from rookery and haul-out areas after the fur seals have been displaced during other research activities outlined in this conservation plan (thus this activity represents no additional harassment to the northern fur seals). Although there are biases associated with differential digestion and passage, and it is usually not known which individual produced a particular scat, valuable information on diet composition can be obtained from scat analysis (DeLong and Antonelis, 1991; Antonelis et al., in prep.). By comparing scats from rookeries and male haulouts, it will be possible to investigate possible differences in prey consumption between adult females and sub-adult males. Similar comparisons between islands may provide insight to the recent discrepancy between the growth rates of the fur seal populations on St. Paul and St. George Islands.

5.2. Investigate northern fur seal feeding ecology

A principal reason for investigating fur seal feeding ecology is to understand the interaction between food availability and the fur seal population. Understanding interactions between fur seals and their food resources requires additional information beyond a description of prey. Telemetry and other methods should be used to describe diving behavior and characteristics of feeding cycles and to identify feeding areas. Foraging/energetics models need to be developed to integrate those factors that may influence predator/prey relationships. Such models can be used to identify areas of significant interaction and to evaluate the possible effectiveness of potential management actions.

Declines in the fur seal population may be related to changes in aquatic habitat quality. Information is needed on the pelagic behavior of northern fur seals in order to identify and subsequently protect those oceanographic resources and regions essential to their survival.

Much is already known regarding areas used by fur seals. Nevertheless, more detailed information is needed to determine how best to minimize potentially disturbing activities and to document changes in habitat characteristics and use patterns. It is likely that the various parts of the fur seal's overall range are of different biological significance to age-specific components of this population by season. To the extent possible, the importance of these various habitats should be evaluated.

5.21. Identify feeding areas, habitat requirements, and foraging strategies: Feeding areas throughout the range should be mapped and described as specifically as possible. The significance of feeding areas should be evaluated based on the number/age/sex of the fur seals using them and their location relative to rookeries. Although some of this information may be obtained in conjunction with other activities, specific research projects may be required at certain areas.

With existing data it is possible to identify only general areas that are used for feeding. Observers on fishing vessels may provide additional anecdotal information about at-sea distribution of fur seals. However, satellite telemetry holds the greatest promise for delineation of major feeding areas and the degree to which they change. Radio or satellite tracking of individual seals is recommended to determine essential foraging habitat and to understand the behavior and at-sea distribution of fur seals in relation to commercial fisheries. Radio telemetry was used successfully in 1985 and 1986 to determine rates and distances fur seals traveled to feeding areas off the Pribilof Islands during the breeding season (Loughlin et al., 1987; Goebel et al., 1991). Time-depth recorders have also proven effective in studying diving and foraging strategies (Gentry and Kooyman, 1986; DeLong et al., 1989). Satellite telemetry may be the best way of describing in detail the seasonal habitat-use patterns of individuals at sea. These studies have been made possible by recent developments in the technology of microprocessors and the Satellite Linked Time-Depth Recorders (SLTDR). The use of SLTDRs allows the remote recording of location, temperature, and dive behavior of free-ranging marine mammals.

SLTDRs should be applied to an adequate sample of animals at selected locations throughout their range. Because of the limited duration of tag function, it will be necessary to apply them at different times of the year in order to obtain coverage for all seasons. While these instruments are expensive, they provide the most accurate and detailed information about feeding areas and migrations.

Information obtained using satellite and radio telemetry will be compared in real-time to oceanographic data (e.g., bathymetry, temperature, and salinity) to provide more complete understanding of the fur seals' habitat requirements. Primary objectives of these studies are to: (1) identify age and sex related differences in the movement and foraging patterns of adult females and sub-adult males; (2) characterize movement and foraging patterns of weaned pups at sea; and (3) evaluate the foraging energetics and requirements of fur seal populations.

Studies to determine the locations, time of day, and depths at which fur seals feed should be coupled with simultaneous studies of prey distribution and abundance. This will enhance efforts to assess and monitor prey resources. It will also help characterize the relationship between fur seals and commercial fisheries and to identify which areas and depths constitute essential foraging habitat. Continued monitoring will reveal variability in feeding area use and may indicate the limits of the seals' ability to change location or depth in response to changing prey availability.

5.22. Investigate diving behavior and trends in female feeding cycles: Characteristics of dives can be determined by using devices that record time and depth. In situations where animals may easily be captured and handled, time-depth recorders (TDR) and radio tags can be deployed and recovered.

Radio tags allow very precise monitoring of feeding cycles because the likelihood of overlooking animals when they are ashore is minimal. Because lactating females return to land frequently to nurse their pups, their attendance patterns on the rookeries can be relatively easily monitored using these techniques. These observations should provide an indirect measure of prey availability around the Pribilof Islands during the summer and fall. Additional deployments of these instruments on juvenile males will provide information needed to make comparisons with lactating females. Combined with SLTDR information, such comparisons will be used to evaluate the degree to which the increasing juvenile male population is competing with lactating females for food on both St. Paul and St. George Islands.

Measurement of time on shore and at sea should be compared among areas and years. Because foraging effort may vary in addition to the amount of time at sea, energetics studies should be conducted concurrently with studies of feeding cycle patterns. Changes in feeding cycle patterns should be analyzed for correlations with commercial fisheries catches and with rates of growth and mortality of pups.

Feeding cycles can also be monitored using teeth from juvenile males taken in the subsistence harvest (see Section 2.22). The analysis of teeth may be a more cost-effective method of monitoring the number of feeding cycles from birth to weaning.

5.23. Characterize geographic and seasonal patterns of prey availability and utilization by fur seals: Prey availability should be estimated in areas where animals are known to be feeding by using hydroacoustics, net sampling, underwater cameras, or other appropriate techniques for evaluating oceanographic characteristics. Sampling should be designed to estimate prey availability in actual feeding areas, as opposed to broad geographic regions. Surveys should include non commercial species in the Bering Sea and North Pacific (i.e., Osmerids, Myctophids, Cephalopods) important to northern fur seals. Annual patterns of prey availability should be determined using these data. In addition, measurements of parameters such as density and depth of prey, and distance from the rookery or haulout, are necessary to evaluate foraging costs. Prey sampling in areas adjacent to identified feeding areas would help determine why animals feed in certain locations and not in others.

While some of the information described in Section 6.0 may be obtained during standard NMFS resource assessment cruises, adjustments will have to be made to techniques and the distribution of effort to satisfy fur seal data requirements.

5.24. Behavioral/physiological studies: Behavioral and physiological studies (3 years minimum) are recommended to assess the current foraging effort (energetics) of post-parturient females and their ability to transfer energy to their offspring. Telemetry and radio isotopic techniques would be employed to estimate food requirements of the fur seal population during the breeding season. This work would be done in conjunction with studies of foraging location and feeding cycles.

The number of male fur seals has been increasing on St. Paul and St. George Islands since the cessation of the commercial harvest in 1985 and 1973, respectively. It is possible that their increased numbers have decreased the overall per capita availability of food to fur seals. To assess the ramifications of this increase, similar foraging behavior and physiological studies of the male population are required.

6.0. Investigate relationships between fur seals, fisheries, and fish resources

The relationship between fur seal growth and survival and the removal of prey by commercial fisheries is not well understood. The distribution and abundance of fish resources vary by area, season, and year. Removals by commercial fisheries need to be studied to understand the complex relationship between fur seal feeding behavior, growth, and survival.

6.1. Relationship between population growth and prey availability

While the dynamics of the fur seal population may be affected by a variety of factors, growth of individuals and productivity of the population may be limited by food availability at some point. Field studies have demonstrated the role of food in regulating population productivity in many terrestrial ecosystems (e.g., McCullough, 1979; Skogland, 1985). However, marine mammals foraging in complex marine ecosystems make such studies difficult. El Niño events have provided some insight into the role of food in limiting pinniped productivity (Ono et al., 1987; Trillmich and Ono, 1991).

Existing data should be examined for information on local prey abundance. Future data collection efforts and analyses may need to be designed specifically to address questions of relevance to northern fur seal feeding ecology. Growth and productivity of fur seals breeding and foraging in different areas should be investigated in relation to food availability in those areas.

6.2. Determine effects of fisheries on northern fur seal prey

Traditional fishery assessments usually attempt to gather broad scale information on stock abundance. Data are gathered at the times and areas when sampling can be conducted most efficiently. Results of such assessments may be used to track overall changes in stock sizes, but they are of limited value for assessing changes in prey availability in fur seal feeding areas.

The abundance of commercially harvested fish stocks is known to fluctuate, sometimes declining drastically. It is clear that some stock fluctuations have been due to overfishing (Pruter, 1976; Megrey and Wespestad, 1990). In addition to large changes in long-term overall abundance, fisheries may affect fur seal food availability by changing small scale distribution, abundance, and behavior of prey. Intensive pulse fisheries could reduce the density of fish in specific areas. The activities of boats and gear may alter prey aggregations. Subtle ecosystem changes may accompany large human-induced removals of major species. The influence of fisheries on prey in the actual areas used by fur seals for feeding can be addressed in two manners: (1) detailed assessments of short- and long-term effects can be conducted in feeding areas before, during, and after fishing activities occur (feeding areas will be identified by studies described in Section 5.21). Hydroacoustics may be very useful for identifying localized concentrations of fish that can serve as fur seal prey; (2) alternatively, comparisons can be made of prey stocks in similar areas that are and are not fished. However, additional sampling (e.g., time series that span the course of fishing activity) will be necessary to assess changes in prey stocks that may be specifically attributable to fishery removals. Special attention should be given to the depth distribution of the species and size classes of prey needed by sensitive age/sex classes of fur seals (e.g., juveniles).

6.21. Model effects of fishing on prey composition, distribution, abundance, and behavior: Models may prove useful for evaluating the possible effects of fishing on prey availability. Current models used for stock assessment should be applied to specific areas to examine how removals affect abundance of various age groups of prey. Field studies will be needed for the development and testing of models that describe effects on prey distribution, abundance, and behavior. Models should be designed so that they can be used to predict how various levels and types of fishing may influence availability of prey for fur seals.

6.3. Ensure adequate food availability in feeding areas

Measures may be needed to ensure that food availability is not limiting to northern fur seal population growth (i.e., recovery). Fish stocks must be assessed and monitored on a local basis along with certain parameters of the fur seal population. Where fur seals show signs of nutritional stress and prey abundance is low, it may be necessary to take actions which might increase or enhance the availability of prey to northern fur seals.

6.31. Regulate fishing areas, seasons, and types of operations: In some instances, it may be possible to reduce competition between commercial fisheries and fur seals by changing fishing areas, seasons, time of day, and types of operations. Studies should be initiated on the amount and species of fish, including bycatch, taken by fisheries under various conditions. These results should be compared to studies of fur seal feeding ecology (Sections 5.1 and 5.2) to determine the extent of overlap, especially for any age/sex classes that are likely to be food limited (e.g., weaned pups or lactating females). Where alterations in operations can reduce competition, appropriate changes should be initiated and the fur seals monitored for responses.

6.32. Regulate fishery catches: Development of fishery management policies and plans must take into account the types and amounts of food needed to support a recovering fur seal population. The mechanism by which fur seal food requirements are accounted for in the calculation of acceptable commercial harvest levels should be described. Where appropriate, a specific portion of the acceptable biological catch should be set aside for fur seal consumption. Alternatively, natural mortality estimates used in models should be modified to ensure that predator consumption is adequately provided for. If there are signs that prey availability is being reduced by a fishery such that it is a limiting factor in the recovery of the fur seal population, then restrictions should be placed upon the commercial fisheries' allowable catches to the extent necessary to ensure adequate prey. Quotas for catches should be set on a regional and seasonal basis for each stock of each prey species identified as important (Section 8.11). If certain year/sex classes of fur seals are found to be especially food-limited, then special efforts should be made to regulate total allowable catches in their feeding areas.

7.0. Identify natural ecosystem changes

In addition to fisheries interactions with fur seals, it is necessary to study environmental conditions including climate, oceanographic changes and community dynamics.

7.1. Determine how abiotic and biotic factors affect long-term trends in fur seals either directly or indirectly through their prey

Climate data (sea and air temperature, precipitation, wind velocity) should be compared with data on pre-weaning pup mortality recorded in the extensive pup necropsy database. Climate data should also be compared with historical natural fluctuations in abundance of fur seal prey. Also, NMFS should determine whether climate effects other measures relating to fur seals (mean parturition date, time until weaning and weaning weight of pups, post-weaning migration and survival, and female foraging trip/visit duration).

Research should attempt to continue establishing links between fur seals (and other top predators) and dynamics of prey species.

8.0. Coordinate conservation efforts with other agencies and countries

Responsibility for implementation of the Northern Fur Seal Conservation Plan lies with the NMFS Office of Protected Resources, the NMFS Alaska Regional Office and NMFS Alaska Fisheries Science Center. Recovery actions will need to be coordinated among these NMFS offices, the Aleut communities on St. Paul and St. George Islands, and other resource management agencies and user groups. Changes and updates to the Conservation Plan should be made upon periodic review. International coordination will be necessary in order to implement an effective conservation program. Education and enforcement are critical components of the overall recovery effort.

8.1. Monitor Federal actions for potential impacts to northern fur seals

Under the National Environmental Policy Act (NEPA), Federal agencies must consider major activities and prepare, if necessary, an environmental impact statement detailing every significant aspect of the environmental consequences of the proposed action. NEPA requires that the views of local, state, and Federal agencies having expertise or jurisdiction, and any interested citizens, be obtained and documented as part of the NEPA process.

Various agencies and industries have responsibility for oversight, issuance of permits, etc., regarding activities that may affect fur seals. These groups should consult with NMFS to determine whether proposed, planned, or contemplated actions could jeopardize fur seals or damage habitats essential to their survival and, if so, steps that could be taken to avoid or minimize possible adverse effects. Both the population and habitats essential to its survival and recovery must be monitored to determine the effectiveness of conservation measures which are instituted and to detect natural variation and the possible unforeseen effects of human activities.

Activities such as offshore oil and gas development and harbor development have probably not contributed to the Pribilof Islands fur seal population decline, but could further jeopardize or hamper recovery of the population. Fur seals are not likely to survive being oiled in an oil spill. Efforts should be made to solicit and review all proposed Outer Continental Shelf (OCS) exploration and developmental plans, fishery management plans, or any other plans as needed to determine and recommend measures necessary to avoid or minimize possible adverse effects on fur seals or their habitat.

Strict management controls may be necessary as oil and gas development moves from lease sale to exploration to extraction and transportation. Transportation of oil needs to be closely regulated and monitored to prevent accidents and to quickly respond to spills. Areas of present concern are the Gulf of Alaska, the west coast of Canada and continental United States. Future areas of concern if oil is to be extracted from the OCS are all Aleutian Island passes and the St. George Basin.

8.2. Develop mechanisms for international conservation efforts

The United States and Russia have a particular interest in conservation of northern fur seals since all rookeries occur within their territorial waters. Because fur seals move freely across the boundaries separating these nations, conservation efforts and research activities put in place by each nation should be closely coordinated. Where appropriate (e.g., during range-wide surveys), close coordination of research activities is also desirable.

8.21. Continue comparative studies on other populations: Comparisons of population growth rates of fur seals on different islands are valuable for identifying factors which influence population change. Prior to the expiration of Interim Convention on the Conservation of North Pacific Fur Seals in 1984, population assessments of the fur seal colonies in U.S. and Russian waters were compared annually. In the absence of this international agreement, it has been difficult to assess the current status of the world fur seal population and examine the factors that influence population growth rates. A workshop of U.S. and Russian scientists was held in March 31- April 2, 1992, to redefine and standardize the techniques used to assess population change (NMFS, 1992b).

This workshop prioritized monitoring programs to evaluate and compare factors thought to have the greatest influence on population growth. Such programs (detailed in other portions of this document) included population assessment (pup production estimates and counts of adult males), dietary studies based on scat analysis, estimates of age-specific natality, age composition of females, and evaluations of early pup growth and survival. Stock identification and intermixture using DNA studies was also recommended (NMFS, 1992b).

8.211. Distribute Conservation Plan to other involved nations: The approved Conservation Plan and implementation schedule, should be sent to appropriate agencies and organizations in Canada, Russia and Japan.

8.212. Develop bilateral or multilateral research and conservation agreements: NMFS should develop (through the Departments of Commerce and State) and implement agreements to coordinate conservation and research efforts for northern fur seals with Canada, Russia and Japan . Management issues that should be considered include adequacy of protective regulations and mechanisms for allocating allowable take of fur seals between jurisdictions. Joint research programs to look at interchange of animals between areas and to compare biological characteristics and population parameters among regions are needed.

8.3. Establish Conservation Plan Coordinator position

NMFS should support a full-time person to coordinate conservation efforts outlined in this plan. The Conservation Plan Coordinator would be based in the Alaska Regional Office or the Alaska Fisheries Science Center, act as the principal agency personnel on St. Paul and St. George Islands, and represent the agency during all harvest activities. The Coordinator could also provide information to regional Fishery Management Councils, enforcement agencies, appropriate agencies within the State of Alaska, researchers and other interested parties on activities affecting northern fur seals. The Coordinator would be responsible for determining whether issues addressed in Section 7 consultations on Steller sea lions under the Endangered Species Act might also have relevance to northern fur seals, and notify appropriate agencies if northern fur seal issues need be similarly addressed.

8.31. Coordinate information and educational programs: Many regulations to protect northern fur seals apply to members of the public, especially at or near the rookeries on St. Paul and St. George Islands. Public affairs personnel in responsible agencies should coordinate with the Conservation Plan Coordinator (see Section above) to plan and implement public awareness programs that describe the status of fur seals and protective regulations. Types of coverage that might be effective include news releases, mail-outs, signs, public service announcements, interpretive programs, films, and environmental education lesson plans featuring fur seals and the Pribilof Islands.

Because fishermen in many areas may interact with fur seals on a regular basis, it is particularly important that they be made aware of and kept informed about fur seal conservation efforts. Information can be distributed as part of ongoing regulatory/information programs (e.g., in logbooks and regulation books), as well as through media directed specifically at the fishing industry (e.g., trade magazines). Mail-outs to permit holders and signs posted in boat harbors may also be effective. Materials and trained personnel should be made available to assist industry in developing its own educational programs. Fishermen and their representatives should be encouraged to become involved in the development, evaluation, and implementation of fur seal conservation measures.

8.4. Enforce existing regulations

In addition to its role in directly protecting animals, enforcement of regulations is important as an educational tool. However, the successful enforcement of regulations around the rookeries requires extensive field work and is expensive. If information is gathered that is likely to result in successful conviction of violators of fur seal protective regulations, such cases should be given high priority by NMFS enforcement. It is essential that violators are prosecuted in a timely fashion so that the seriousness of regulations and the effectiveness of enforcement are made evident.

PART III

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2. APPENDICES

A. Implementation Schedule

As conservation and recovery plans are developed for each species, specific tasks are identified and prioritized. As new information warrants, these plans, including tasks and priorities, will be reviewed and revised. In addition, funding and implementation of the tasks identified in conservation and recovery plans are tracked in order to aid in effective management of specific recovery programs. NMFS believes that periodic review and updating of plans and tracking of conservation efforts are important elements of a successful conservation program. Information from tracking and implementing recovery actions and other sources will be used to review plans and revise them as necessary.

Tasks specified within the Northern Fur Seal Conservation Plan are prioritized 1-3. A Priority 1 ranking is assigned to the highest priority tasks within this plan, and is given to those actions necessary to monitor the decline of, or to prevent the northern fur seal from further decline following guidelines specified at 55 FR 24296, June 15, 1990.

NORTHERN FUR SEAL IMPLEMENTATION SCHEDULE

PLAN TASK	Task Number	Priority	Task Duration	Fiscal Year Costs (thousands of $) FY 1	FY 2	FY 3	FY 4	FY 5	Comments
1.0. MONITOR STATUS AND TRENDS									
1.1 Continue Counts									
Census of Adult Males	1.11	1	Annual	6	6	6	6	6	
Estimates of Pup Production Rates	1.12	1	Biennial		40		40		
1.2 St. George Island Studies									
St. George Island fur seal population analyses	1.21	2	2 yrs	10	5				
2.0. MONITOR HEALTH, CONDITION AND VITAL PARAMETERS									
2.1 Develop Indices of Condition		2	Annual	5	15	5	15	5	
2.2 Examine Reproductivity and Survival									
Expand Tag-resighting Program	2.21	2	5 yrs	100	30	30	30	100	
Monitor status of tagged animals	2.211	2	Annual	10	10	10	10	10	
Analyze Fur Seal Teeth	2.22	2	Annual	20	15	15	15	15	
2.3 Conduct Observational Rookery Studies		2	5 yrs	10	15	10	10	15	
3.0. ASSESS CAUSES OF TOTAL MORTALITY									
3.1 Monitor Natural Mortality									
Examine Dead Animals	3.11	2	Annual	20	20	20	20	20	
Determine Pup Mortality Rates	3.12	1	Annual	5	5	5	5	5	Part of 3.11

PLAN TASK	Task Number	Priority	Task Duration	Estimated Fiscal Year Costs (thousands of $)					Comments
				FY1	FY2	FY3	FY4	FY5	
3.2 Monitor Incidental Take									
Observer Programs	3.21	2	Annual	5	5	5	5	5	
Reduce Incidental Take	3.22	2	Annual	50	50	50	50	50	
3.3 Monitor Entanglement Rates									
Evaluate Sub-adult Male Entanglement	3.31	2	Periodic	25	25		25		
Evaluate Entanglement at-Sea	3.32	3	2 yrs	120			120		Costs Due to Vessel Charter
Conduct Beach Surveys	3.33	2	2 yrs	10			10		
Improve Programs to Minimize Debris	3.34	2	Annual	10	10	10	10	10	
3.4 Assess Effects of Disease									
Conduct Studies of Disease and Health	3.41	2	Annual	20	20	20	20	20	
Catalogue Tissues and Samples	3.42	2	Annual	10	10	10	10	10	
3.5 Assess Environmental Pollutants									
Monitoring Pollutant Levels	3.51	2	Annual	50	50	10	10	10	
4.0 ASSESS EFFECTS OF DISTURBANCE									
4.1 Document Effect of Disturbance by Humans		1	5 yrs	30	20	20	20	30	
4.2 Prepare Guidelines		2	2 yrs			2	1		
4.3 Evaluate Intentional Mortality		2	Annual	5	5	5	5	5	
4.4 Review Allowable Take Levels		2	Annual						

PLAN TASK	Task Number	Priority	Task Duration	Estimated Fiscal Year Costs (thousands of $) FY1	FY2	FY3	FY4	FY5	Comments
5.0 **INVESTIGATE FEEDING ECOLOGY**									
5.1 Describe Prey									
Analyze Stomach Contents	5.11	2	Annual	5	5	5	5	5	
Analyze Scats	5.12	2	Annual	35	35	35	35	35	
5.2 Investigate Fur Seal Foraging Ecology									
Identify Feeding Areas and Foraging Strategies	5.21	1	5 yrs	150	150	150	150	150	
Investigate Diving Behavior	5.22	2	5 yrs	100	100	100	100	100	
Characterize Prey Availability	5.23	1	3 yrs	200	200	200			Costs due to Vessel Charter
Behavioral/Physiological Studies	5.24	2	Periodic	50	50		30	30	
6.0 **INVESTIGATE FUR SEAL/FISHERIES INTERACTIONS**									
6.1 Relationship Between Population Growth and Prey Availability		2	annual	25	25	25	25	25	Part of 5.23
6.2 Determine Effects of Fisheries on Prey									Part of 5.23
Model Fishing Effects	6.21	2	3 yrs			50	30	30	
6.3 Ensure Adequate Food for Fur Seals									
Regulate Fishing	6.31	2							No Additional Funding Required
Regulate Catches	6.32	2							No Additional Funding Required

PLAN TASK	Task Number	Priority	Task Duration	Estimated Fiscal Year Costs (thousands of $)					Comments
				FY1	FY2	FY3	FY4	FY5	
7.0 IDENTIFY ECOSYSTEM CHANGES									
7.1 Determine Effects of Abiotic and Biological Changes on Fur Seals and Prey		1		60	60	60	60	60	Contracted
8.0 COORDINATE CONSERVATION PLAN EFFORTS WITH OTHER COUNTRIES AND AGENCIES									
8.1 Monitor Agencies Actions		2							No Additional Funding Required
8.2 Develop International Conservation Efforts									No Additional Funding Required
Continue Comparative Population Studies	8.21	2	Annual	50	50	50	50	50	
Distribute Conservation Plan	8.211	1							No Additional Funding Required
Develop Conservation Agreements	8.212	1	2 yrs	10	10				
8.3 Establish Conservation Plan Coordinator		1	Annual	80	80	80	80	80	In Alaska
Coordinate Education and Information	8.31	2	Annual	35	35	35	35	35	
8.4 Enforce Existing Regulations			Annual						No Additional Funding Required
SALARIES FOR NORTHERN FUR SEAL RESEARCH STAFF		2	Annual	350	350	350	350	350	
TOTAL (MILLIONS)				1.671	1.506	1.373	1.387	1.266	