NOAA Technical Report NMFS 4

Management of Northern Fur Seals on the Pribilof Islands, Alaska, 1786-1981

Alton Y. Roppel

April 1984

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

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Management of Northern Fur Seals on the Pribilof Islands, Alaska, 1786-1981

ALTON Y. ROPPEL[1]

ABSTRACT

This paper includes information about the Pribilof Islands since their discovery by Russia in 1786 and the population of northern fur seals, *Callorhinus ursinus*, that return there each summer to bear young and to breed. Russia exterminated the native population of sea otters, *Enhydra lutris*, here and nearly subjected the northern fur seal to the same fate before providing proper protection. The northern fur seal was twice more exposed to extinction following the purchase of Alaska and the Pribilof Islands by the United States in 1867. Excessive harvesting was stopped as a result of strict management by the United States of the animals while on land and a treaty between Japan, Russia, Great Britain (for Canada), and the United States that provided needed protection at sea. In 1941, Japan abrogated this treaty which was replaced by a provisional agreement between Canada and the United States that protected the fur seals in the eastern North Pacific Ocean. Japan, the U.S.S.R., Canada, and the United States again insured the survival of these animals with ratification in 1957 of the "Interim Convention on the Conservation of North Pacific Fur Seals," which is still in force. Under the auspices of this Convention, the United States launched an unprecedented manipulation of the resource through controlled removal during 1956-68 of over 300,000 females considered surplus. The biological rationale for the reduction was that production of fewer pups would result in a higher pregnancy rate and increased survival, which would, in turn, produce a sustained annual harvest of 55,000-60,000 males and 10,000-30,000 females.

Predicted results did not occur. The herd reduction program instead coincided with the beginning of a decline in the number of males available for harvest. Suspected but unproven causes were changes in the toll normally accounted for by predation, disease, adverse weather, and hookworms. Depletion of the animals' food supply by foreign fishing fleets and the entanglement of fur seals in trawl webbing and other debris discarded at sea became a prime suspect in altering the average annual harvest of males on the Pribilof Islands from 71,500 (1940-56) to 40,000 (1957-59) to 36,000 (1960) to 82,000 (1961) and to 27,347 (1972-81). Thus was born the concept of a research control area for fur seals, which was agreed upon by members of the Convention in 1973 and instituted by the United States on St. George Island beginning in 1974. All commercial harvesting of fur seals was stopped on St. George Island and intensive behavioral studies were begun on the now unharvested population as it responds to the moratorium and attempts to reach its natural ceiling. The results of these and other studies here and on St. Paul Island are expected to eventually permit a comparison between the dynamics of unharvested and harvested populations, which should in turn permit more precise management of fur seals as nations continue to exploit the marine resources of the North Pacific Ocean and Bering Sea.

INTRODUCTION

The northern fur seal, *Callorhinus ursinus*, is well known internationally for its luxurious fur and historically as a resource steeped in controversy. The species is largely pelagic, spending much of its life at sea in subarctic waters of the North Pacific Ocean. It resorts to land only to bear and nurse its young and to breed. In this latter respect, the Pribilof Islands in Alaska's Bering Sea are host to 80% of the total estimated population of 1,800,000, with territories belonging to the U.S.S.R. accounting for the remainder. Included in the latter are Robben, or Tyuleni, Island in the Sea of Okhotsk, the Commander Islands in the western Bering Sea, and several of the Kuril Islands just north of Japan. Two additional colonies containing a few thousand breed off the coast of southern California, one on San Miguel Island and the other on nearby Castle Rock; both belong to the United States (Fig. 1).

There are five Pribilof Islands, of which only three, St. Paul (Fig. 2), St. George (Fig. 3), and Sea Lion Rock (Fig. 2—Sivutch), have rookeries and hauling grounds. Between 25,000 and 30,000 males (mostly of ages 3 and 4 yr) are currently harvested commercially on St. Paul Island, and 350 males are taken annually for local use as food on St. George Island.

The Pribilof Islands are located approximately 200 mi (322 km) north of Unalaska in the Aleutian Islands (Fig. 1). St. Paul Island (Fig. 2) is the largest, with a total land mass of 44 mi² (114 km²). Next in size, St. George Island (Fig. 3) with 35.5 mi² (92 km²) lies 40 mi (64 km) to the southeast. Five mi (8 km) south of St. Paul Island lies Otter Island with an area of 0.77 mi² (2 km²) and Walrus Island 10 mi (16 km) off St. Paul Island's northeastern cape with an area of 0.02 mi² (0.05 km²). Sea Lion Rock (Fig. 2—Sivutch) lies 300 yd (274 m) off the southern tip of St. Paul Island and is the smallest with 0.003 mi² (0.008 km²) (Barth 1956).

St. Paul Island once had five other rookeries in addition to the current 14 (Fig. 2) and St. George Island had seven instead of six (Fig. 3). According to Elliott (1884), Nah Speel Rookery behind the village of St. Paul contained 8,000 fur seals in 1874, Lagoon Rookery (on the dike separating Village Cove from the Salt Lagoon) had 37,000 animals (extinct after 1941), and Suthetunga (Kursoolah) Rookery between Antone Lake and Ridge Wall was "unworthy of survey." Little Eastern Rookery on St. George Island contained 13,000 fur seals (extinct after 1914) and was located just west of East Reef Rookery. During the Russian occupation, apparently in 1836, "Two small rookeries were then on the north shore of St. Paul, near a place called 'Maroonitch' " (Elliott 1884:49). The

[1]National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

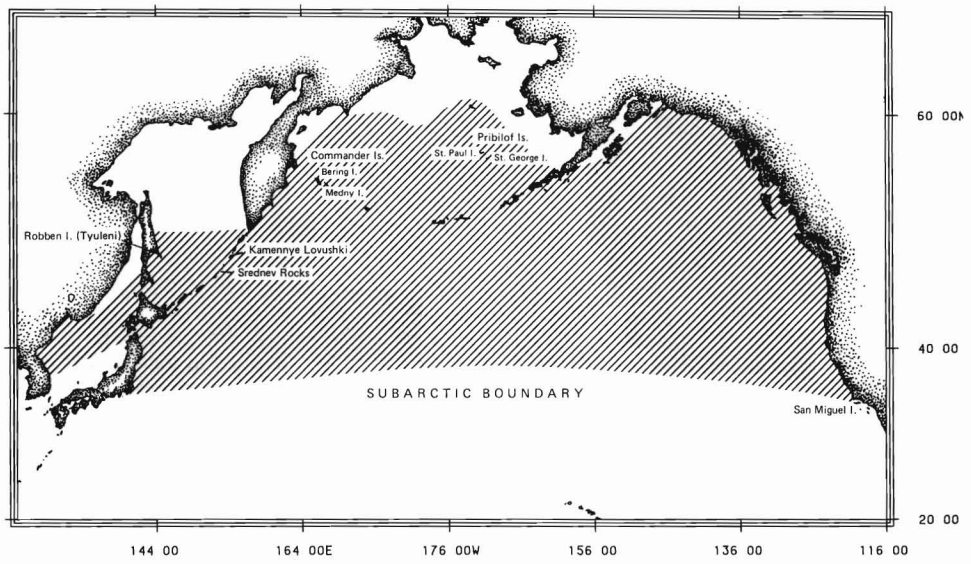

Figure 1.—Breeding grounds and range of the northern fur seal.

other four rookeries became extinct before 1912 but the year is not known.

In addition to the fur seal, the northern sea lion, *Eumetopias jubatus*, breeds on Walrus Island and hauls out on the other four; Otter and St. George Islands each hosts a small breeding colony of hair seals, *Phoca* sp. A few hair seals, apparently from Otter Island, haul out on some of the exposed rocks off St. Paul Island. An occasional walrus, *Odobenus rosmarus divergens*, is seen on St. Paul and St. George Islands.

The islands of St. Paul and St. George and, to a lesser extent, Otter, support what may be the largest marine bird colonies in the world. On these three islands are also more than 100 species of flowering plants, together with numerous grasses, sedges, rushes, lichens, and mosses. Walrus Island and Sea Lion Rock are essentially barren in this respect.

The arctic blue fox, *Alopex lagopus*, is on all five of the Pribilof Islands. The shrew, *Sorex* sp., is on St. Paul Island; the lemming, *Lemmus* sp., is on St. George Island; and both islands have reindeer (*Rangifer* sp.) and possibly the sea otter, *Enhydra lutris*, from a transplant in the 1960's.

Much has been written about fur seals of the Pribilof Islands since 1867, the year in which the United States purchased Alaska from Russia. This information has appeared in countless scientific journals, task force reports, popular magazines, and reports by various agencies of the U.S. Federal Government, including the U.S. Congress. Information about the Pribilof Islands before 1867 appeared in accounts by Bancroft (1886), Dall (1870), and Elliott (1884), and publication of the book "Russian America" in 1979 by the Soviet Union provided new information about pre-1867 Alaska, including the Pribilof Islands. Descriptions of life and conditions in these islands were given; data on the human populations as well as their utilization of fur seals and other marine mammals, plants, and sea birds were obtained from the unpublished notes of Khlebnikov (1979) for some of the years between 1786 and 1829.

This paper presents information from the Russian era with further details on the management of fur seals on the Pribilof Islands, as reported by Roppel and Davey (1965), and how the modern and much less isolated communities of St. Paul and St. George might now influence the fur seal resources there. Some research results are given; however, the primary objective of the paper is to document information accumulated by the author during 26 yr (1956-81) of involvement with management of the resource and to list appropriate references to which other scientists can turn for additional details.

RUSSIAN REGIME

According to Bancroft (1886), the Pribilof Islands were discovered by Stoorman[2] Gerassim Pribylov late in the 18th century: St. George in 1786 and St. Paul in 1787 or possibly 1786. During the next few years, the islands underwent a succession of name changes (Khlebnikov 1979). Called the "New Islands" at the time of discovery, they were later renamed after the company's discovery ship "Lebedenski." The names "Zybovyi," "Northern," and, occasionally, "Fur Seal Islands" followed. Finally, they were given the name "Pribylov Islands" in honor of their discoverer.

Human Population

The islands were uninhabited when discovered, and a labor force was required to harvest the fur seals,[3] sea otters, and arctic blue foxes found in abundance there. This need was satisfied during the early years by importing Aleuts from the village of Unalaska on the Aleutian Island of the same name (Khlebnikov 1979). These people at first "took turns" working on the Pribilof Islands, but some eventually relocated there permanently and no longer exercised an option to return home to Unalaska every 3 or 4 yr as they once did. There were apparently considerable fluctuations in the number of Aleuts on the Pribilof Islands as a result of this interisland movement. For example, in 1825 the total population of 226 humans on the Pribilof Islands contained 189 Aleuts from Unalaska, yet 4 yr later in 1829 only 30 of 248 persons were of this race (Khlebnikov 1979). In either case, the remainder were Russians, Indians, and Creoles (the latter were offspring of Russian men/Aleut women [Dmytryshyn and Crownhart-Vaughn 1979]).

[2]Russian for ship's mate.

[3]According to Khlebnikov (1979:32) "there were at least no fewer than a half million of these animals there."

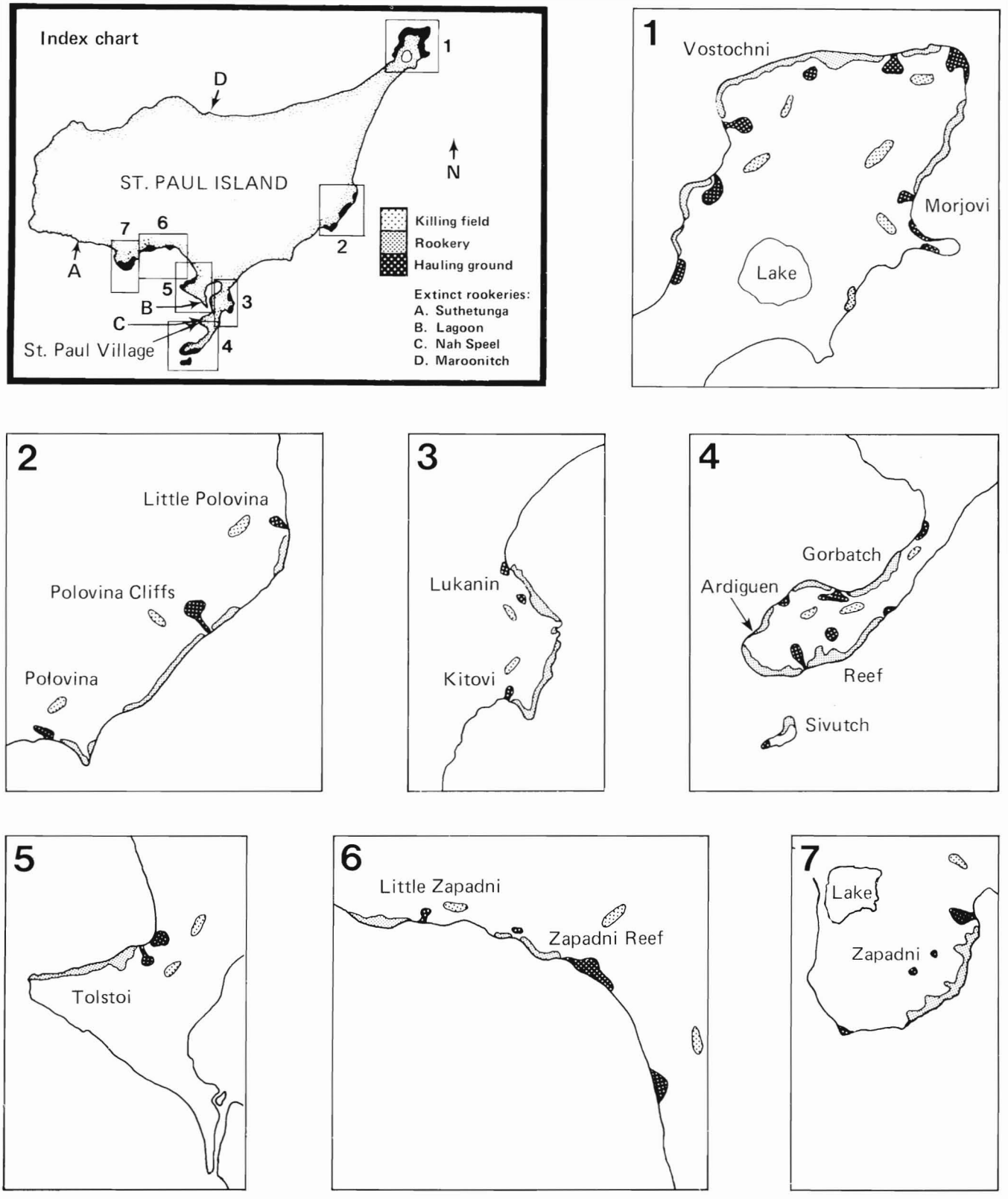

Figure 2.—St. Paul Island, Alaska, and the rookeries and hauling grounds of the northern fur seal. Sivutch is Russian for sea lion.

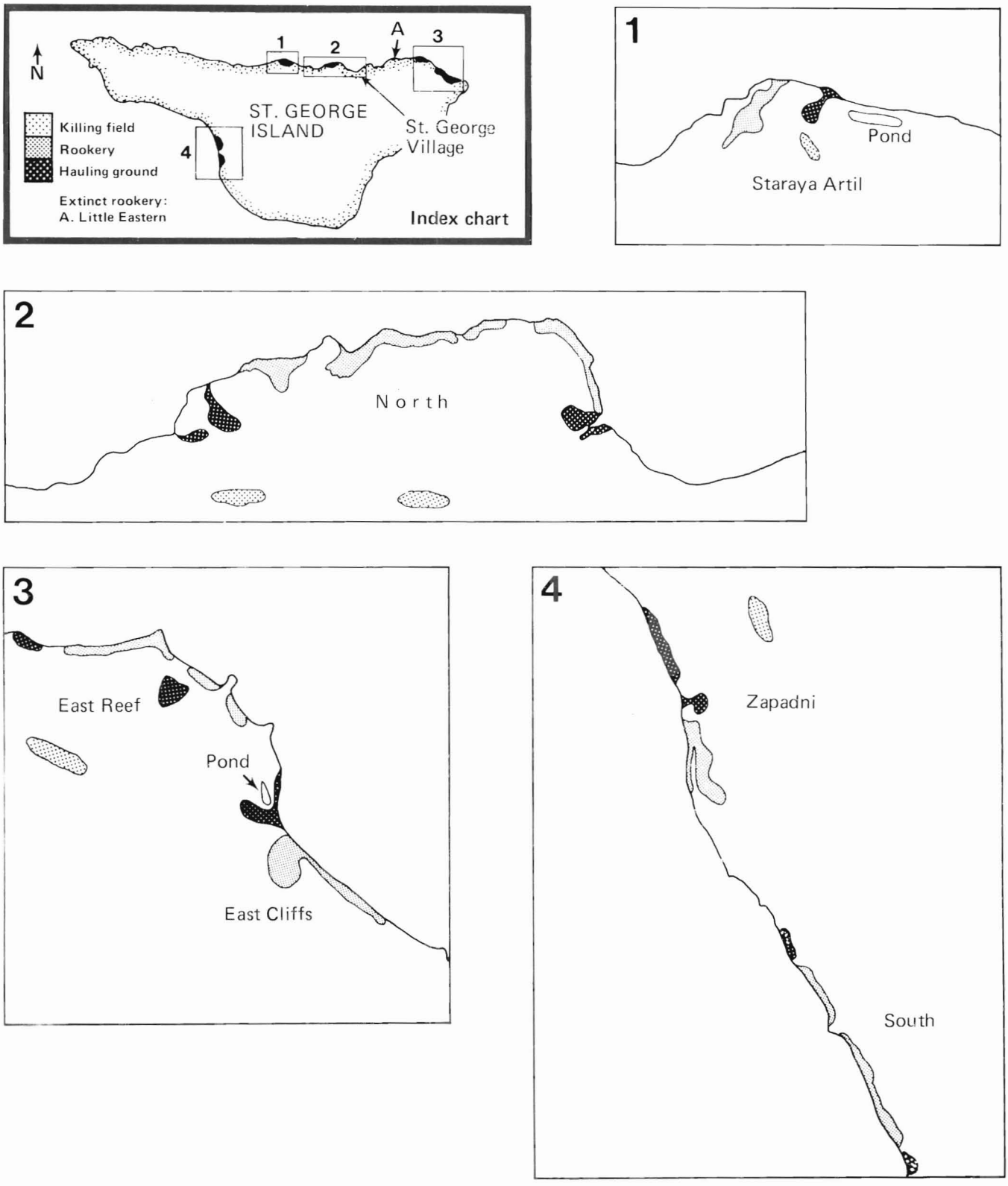

Figure 3.—St. George Island, Alaska, and the rookeries and hauling grounds of the northern fur seal.

Up to 1818, the Pribilof Islands were a part of the Unalaska District, but after that year administrative supervision was received directly from New Arkhangel (now Sitka). The primary settlement on St. Paul Island was constructed at the southeastern end where the present village is located. There were two other but smaller settlements, one at the eastern cape and the other in the western region. All three villages were placed near concentrations of fur seals for convenience in harvesting and processing the skins of these animals. The only village on St. George Island was established in the northern region. However, a small but permanent camp was located in an outlying area west of the present village. Taking its name from this camp, a nearby rookery was called Staraya Artil, literally "old Artel" or small collective (commercial) enterprise. The Russian Chief of the Pribilof Islands section resided on St. Paul but annually made a trip to St. George in the summer "to affirm business expenses there and to census the (human) population" (Khlebnikov 1979:23). Not without considerable danger, this 40-mi crossing in these early years was made in a large "baidara" or "skin boat" under sail, a trip that took 7 h. There were casualties and, in at least one instance, the island was bypassed altogether and the travelers eventually landed on one of the Aleutian Islands. Later, use of a sailing ship from Unalaska made the journey much safer.

Marine Mammals

Four species of marine mammals were associated with the Pribilof Islands at the time of discovery: The northern fur seal, sea otter, northern sea lion, and walrus. Scarcely a half century passed before the sea otter was exterminated. Khlebnikov (1979:6) wrote "Upon discovery of the island [St. Paul]... many sea otters were found; now they never appear" (reference is apparently to the 1820's). He also mentioned (1979:9) that walruses appeared on Walrus Island from time to time and that in 1821 they "... crowded the sea lions [on St. George Island], and this (crowded) the fur seals on occupied places, however, the next year and thereafter, they appeared nowhere at all." Early fur traders said that the Steller's sea cow, *Hydrodamalis gigas*, was found on the Pribilof Islands in extremely high numbers, but was later removed. According to Khlebnikov (1979:6) "... this information resembles a fable. This animal had sanctuaries somewhere if it existed, but... [they are] not seen anywhere at all at the present time" (as of the 1820's).[4]

At the very beginning, the sea otter had the highest value and was therefore the most valuable product shipped from the Pribilof Islands. The fur seal, estimated to number "no fewer than a half million" as previously mentioned, was at that time secondary in importance to the sea otter, and although harvested, it was apparently taken only in those places where it was most convenient (Khlebnikov 1979). The early harvests at least were apparently of pups, for according to Khlebnikov (1979:14) "When the young fur seals, having been born this year, arrive at the proper age and approach the time for their departure from the islands, then, that is, in the latter part of September or first of October, the drives are begun.... Having driven the whole herd to a flatland, they separate the sea lions, bachelors,[5] and females and accompany their return to the sea. Young designated for killing are driven closer to the village."

The practice of harvesting pups of both sexes during the 1700's and early 1800's in autumn compares with the current practice of taking primarily 3- and 4-yr-old males in late June and July and sparing the females. At first, i.e., late 1700's and early 1800's, there were available from St. Paul Island 50,000 to 60,000 and from St. George Island 20,000 to 25,000 fur seals (as indicated above, the kills were apparently of pups). The size of the annual harvest eventually dwindled to 20,000-25,000 on St. Paul Island and 5,000-8,000 on St. George Island, a situation that led to cessation of the kill on both islands for 3 yr (1805-7) and prompted the statement that "The first rule is to not kill the females and bachelors, and above all, the adult males" (Khlebnikov 1979:15). However, the kill was resumed in 1808, and from 1786 to 1828, a total of 3,080,655 fur seal skins had been shipped from the island (Khlebnikov 1979).[6] Just when the transition from taking pups of the year to harvesting older seals occurred is unknown. In 1822, Chief Administrator Muravev ordered a moratorium on one rookery each October as an emergency measure. But it was not until 1835 that the females were spared and the kill of males was regulated (Osgood et al. 1915).

In a land far removed from the amenities of civilization, preservation of the skins of thousands of fur seals, even the relatively small ones taken from pups, must have been a monumental task. The Russians accomplished the nearly impossible by stretching the skins onto wooden frames in pairs with fur against fur and flesh sides out, then placing the "stretched" skins in a specially built drying plant warmed with rocks under which a fire of driftwood was scantily fed four times every 24 h to maintain slight heat. Up to 2,000 skins were dried in 24 h on St. Paul Island (Khlebnikov 1979). This method of preserving the skins gave way, at least under American involvement (1867) with the Pribilof Islands and the resource, to kenching (burying in beds of salt); the actual year the method started is unknown. An entry in the St. Paul Island logbook for 1871 showed that skins were salted in that year. The current practice of brining in a saturated solution of salt began about 1951.

There was also a small industry utilizing sea lions on the Pribilof Islands, primarily on St. George where a thousand or more were harvested annually. The much smaller population of sea lions on St. Paul Island yielded 300-400 animals each year.[7] Primary products from sea lions included intestines for making waterproof shirts, throat linings for straps, bladders (use not mentioned), skin of the flippers for shoe soles, whiskers for decorating caps and hats, and hides for covering the baidars or "skin boats." The hides were stacked into piles and left there for as long as a month to rot the hair, then cleaned and stretched on stakes during the winter for drying. The fat was saved for use in oil lamps and in the cooking fire during shortages of driftwood, and as a medium in which to store eggs and prevent spoilage. Young sea lions were taken in addition to the older animals to augment the supply of food. Most of the products from sea lions were consumed locally; however, some were shipped to New Arkhangel.

According to Khlebnikov (1979:16), walruses were also taken but "Only the tusks are cut out; the meat and skin is left. However, for

[4]Steller's sea cow, discovered in 1741 in association with the Commander Islands, was exterminated by 1768 (Chelnikov 1969; Scheffer 1972, 1973).

[5]During this period, the Russians classified males of ages 2-4 yr as subadults and those estimated to be age 5 yr and older as adults. During their annual counts of breeding males, U.S. scientists classify males of estimated age 7 yr and older as adults.

[6]According to Khlebnikov, who mentioned difficulties in obtaining accurate data, an additional 700,000 skins were destroyed on the islands, which may or may not have included 312,324 skins from the old Merculief Company rejected at Unalaska. Thus, 4,193,000 fur seals (annual average 100,000) may have been taken during the 42-yr period from 1786 to 1828. It seems unlikely that an annual harvest of 100,000 pups would have depleted a herd even as small as a half million, unless half were females and the effects of what must have been a considerable disturbance to the rookeries were factors.

[7]Sea lion pups were last born on St. Paul Island (at Northeast Point) in 1957 (author's personal observation). Kenyon (1962) documented the history of the sea lion population on the Pribilof Islands.

some time in the past there has been no significant industry on these islands for the walrus." Baleen was collected from beached whales.

Fox

The number of arctic blue foxes taken on the Pribilof Islands each year ranged between 1,400 and 1,800, with 1,200-1,500 coming from the more heavily populated St. George and the remainder from St. Paul. Most were of the "blue" color, as opposed to the fairly rare white phase (Khlebnikov 1979).

Marine Birds

Murres, *Uria* sp., and the horned, *Fratercula corniculata*, and tufted, *Lunda cirrhata*, puffins contributed 6,000-9,000 skins annually for use in making parkas. The flesh of these and other birds was dried for consumption during the winter and the eggs of many were collected for food (Khlebnikov 1979).

Marine Fishes

The Pacific halibut, *Hippoglossus stenolepis*, was much sought for food then as now and the Pacific cod, *Gadus macrocephalus*, was also taken (Khlebnikov 1979).

MANAGEMENT BY THE UNITED STATES

Following the purchase of Alaska from Russia by the United States in 1867, the years 1868 and 1869 were "... characterized by a ruthless slaughter exceeding even that during early Russian ownership of the islands" (Roppel and Davey 1965:451). This practice was stopped with the setting aside of the Pribilof Islands in 1869 as a special reservation for the protection of the fur seals upon their return to land in summer to bear their young and to breed.

From 1870 through 1909, two consecutive 20-yr leases for harvesting fur seals were awarded to private firms operating out of San Francisco; the first lease was awarded to the Alaska Commercial Company and the second to the Northern Commercial Company (Roppel and Davey 1965). Each was mandated by contract to take only males. Following expiration of the second 20-yr lease in 1909, the U.S. Government assumed total responsibility for the harvest of fur seals and the welfare of the Aleut communities of the Pribilof Islands. The 40-yr-old policy of sparing the females over the next 45 yr was also continued. Additionally, extensive pelagic sealing had nearly exterminated the herd. The treaty of 1911, ratified by the governments of Great Britain (for Canada), Japan, Russia, and the United States protected fur seals at sea during most of this period. Japan exercised a right as stated in the Convention and caused its termination in October 1941. From then until 1957, the United States and Canada maintained a provisional agreement for the protection of fur seals in the eastern North Pacific Ocean (Roppel and Davey 1965).

In 1957, a new treaty was ratified by Canada, Japan, the U.S.S.R., and the United States and entered into force on 14 October of that year. A primary objective of this treaty, "Interim Convention on the Conservation of North Pacific Fur Seals," was to determine "what measures may be necessary to make possible the maximum sustainable productivity of the fur seal resources so that the fur seal populations can be brought to and maintained at the levels which will provide the greatest harvest year after year" (U.S. Congress, Senate 1970:74). In this connection, the United States collected 13,845 fur seals in the eastern North Pacific Ocean and Bering Sea during 1958-74 and is now cooperating with Canada in an extensive joint analysis of data on distribution and migration of these animals, age and growth, feeding habits, and reproduction. These pelagic data, (Kajimura et al. 1979,[8] 1980;[9] Lander 1980b)[10] together with those collected on the Pribilof Islands (Lander 1980a) with respect to physiology and medicine, behavior, and population assessment, make up the United States' contribution to the overall data base of the North American component of the species. The results of research carried out by the United States are periodically published in scientific journals and are formally reported to the Convention's North Pacific Fur Seal Commission (NPFSC) during its annual meetings. In addition, the United States uses the information as a basis for managing the fur seal resource of the Pribilof Islands. In addition to the above documents, Lander and Kajimura (1980) have summarized the data on northern fur seals collected by the U.S.S.R. and Japan in the western North Pacific Ocean.

Herd Reduction

The first intentional harvests of females on land after 1869 were initiated in 1954 and 1955 with the taking of all females appearing in the drives of seals from the hauling grounds that were within the body length limits for harvesting males. These animals were used primarily for studies of reproduction but also to provide information on the commercial value of skins from females. According to Kenyon (1954:31),[11] "... if the cow[12] skins prove to have commercial value it will be practical and not detrimental to the fur seal herd to continue in future sealing operations to take all cows of commercial size which appear on the killing fields." The management decision based on the answer to this question was especially important because a forthcoming reduction in the size of the herd through the harvesting of females had as its ultimate objective the limiting of pup production to 400,000 annually. The biological rationale for this reduction was that at a lower level, survival of the young would be enhanced and perhaps the overall pregnancy rate would increase as the population strived to reach its natural ceiling in terms of total number (Chapman 1961).

In return for this unprecedented manipulation of the number of fur seals, research scientists expected an increase in the total harvest with stabilization of year-class survival and an estimated sustained annual yield to the harvest of 55,000 to 60,000 males and 10,000 to 30,000 females.

[8]Kajimura, H., R. H. Lander, M. A. Perez, A. E. York, and M. A. Bigg. 1979. Preliminary analysis of pelagic fur seal data collected by the United States and Canada during 1958-1974. Unpubl. rep., 247 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[9]Kajimura, H., R. H. Lander, M. A. Perez, A. E. York, and M. A. Bigg. 1980. Further analysis of pelagic fur seal data collected by the United States and Canada during 1958-1974. Unpubl. rep., Part 1, 94 p. and Part 2, 172 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115. (Submitted April 1980 during the 23rd Annual Meeting in Moscow, USSR, of the Standing Sci. Comm., North Pac. Fur Seal Comm.)

[10]These data are also presented in various annual reports of fur seal investigations and proceedings of the North Pacific Fur Seal Commission meetings filed at the National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, NMFS, NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[11]Kenyon, K. W. 1954. Alaska fur seal investigations, Pribilof Islands, summer of 1954. Unpubl. rep., 48 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Branch Wildl. Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[12]Females older than pups are also referred to as "cows," males of ages 1-6 yr are called "bachelors," and the term "bull" is used when referring to the adult male (estimated age 7 yr and older).

Not having harvested females in large numbers before, federal administrators or managers of the islands and the harvest had no guidelines to follow nor was there any information available to suggest how, when, or where the females should or could be taken. As a result, the early harvests of females were largely experimental.

It was already known that few females appear on the hauling grounds before late July because most of the animals driven from these areas in the past had been males. This and the fact that the onset of molt or "staginess" of the skins of fur seals (sometime during the summer) adversely affects their value in terms of a DDM & F[13] product by interfering with traditional fur processing methods[14] prompted managers to ask "When would be the best time to harvest females and would it be possible to take males concurrently?"

Considering all factors known at the time, managers decided to take all females found on the hauling grounds during the normal harvest of males in 1956, which, in that year, was extended to 15 August. They also made plans to carry out an experimental harvest of females in September and October of 1956 to measure the availability of these animals on the hauling grounds; furthermore the onset of staginess would be more precisely pinpointed and thus the time of season when it would no longer be profitable to take fur seals because of it. Additional information about the development of staginess among females was obtained between the two major harvesting periods by taking 20 of these animals at 5-d intervals and examining their underfur; others were removed from the sand beach portion of Polovina Rookery in July of 1956 and 1957 (Abegglan et al. 1956,[15] 1957[16]) to test the availability of animals from this source. These "harem raids" netted 2,983 females from eight "drives" and exterminated that part of Polovina Rookery, which has not recovered to this date. Additional females were also taken directly from portions of Reef and Northeast Point Rookeries in 1957, but the numbers were too few to have any observable effect.

Managers extended the harvest of males in 1956 from a traditional termination date in late July to 15 August because of exceptional survival of the 1952 and 1953 year classes and recent but rapid increases in the numbers of idle males on the hauling grounds, which indicated a need to reduce recruitment into the breeding reserve. During this period, the available females taken from the hauling grounds numbered 22,681. A 5-d harvest of females during 4-8 September in that year yielded an additional 4,807 animals, but because 603 or 12% of these had by then become stagey and had to be rejected as unfit for processing, plans for additional kills as late as into October were abandoned. From the results of experimental harvests in 1956 and 1957 (portions of three rookeries were used as sources of females in 1957 also), and from subsequent developments in the processing and marketing of skins from females, managers learned that: 1) It is not only dangerous for the workers but impractical to conduct harem raids because of the aggressiveness of the territorial males, 2) females become increasingly available on the hauling grounds and on the rookery fringes as the season progresses beginning in late July when the organized breeding structure starts to break up, 3) it is necessary to harvest most females in August and September because it is not until then that they become available from sources other than harem raids, 4) staginess becomes a problem with the skins of animals taken from early September on if they are to be subjected to traditional DDM & F processing, 5) staginess begins at the nose and progresses to the animal's posterior, 6) males become stagey before females, and 7) the younger animals of both sexes become stagey before the older seals.

Backed by years of tradition in sparing the females and with little or no knowledge of biology or population dynamics, certain federal managers involved with the resource and members of the local Aleut communities were understandably quick to question the wisdom of harvesting these animals. It was emphatically noted that killing a female not only took her life and the newly fertilized ovum within her body, but left her pup to die from starvation on the rookery as well. This same argument had been raised by the United States late in the 19th century during the controversy over pelagic sealing. Objections of the 1950's, though just as valid, nevertheless triggered substantial resistance to the harvest of females and slowed development of new processing methods and a badly needed market for the skins of older females, which were "very different" from those of males in terms of traditional quality. The situation would have been much improved had steps been taken to correct such deficiencies in the herd reduction program before rather than after it commenced.

There was no particular problem with skins from the younger females, i.e., ages 3 and 4 yr, because they had not yet entered the formal breeding structure and were as unscarred and clean as the skins of males of the same ages. In fact, the skins of young females mistaken for males and taken accidentally had in the past been included in DDM & F processing with skins from males and sold at the same prices. However, the skins of the older females, scarred from life on the rookery, had little to offer to an industry based on soft luxurious furs coming from the DDM & F process. Other problems arose because the rather large kills of females, together with the harvest of males, severely taxed the labor force as well as processing and storage facilities both on the Pribilof Islands and in the Fouke Fur Company's[17] skin processing plant in St. Louis, Mo. It soon became economically impractical to care for and provide storage for thousands of skins that were unwanted for lack of a suitable processing method and a market for the finished fur. A new method of treating the skins of females by close shearing of fur and guard hair was eventually to be developed under the trade name "Lakoda."[18] This process overcame problems associated with staginess and scarring but not in time to prevent the destruction of over

[13]Dressed, dyed, machined, and finished. Each skin is subjected to a tanning process involving the use of oil from the fur seal itself, trimming and removal of the guard hairs. The skin is also dyed and machined and finished to a thickness thin enough to permit drawing it through a napkin ring.

[14]A pelt is said to be stagey when short, new guard hairs, called "peepers" by the trade, appear among the underfur fibers and the flesh side of the skin becomes bluish or grayish because of new melanin (dark pigment) in the area. These short, new guard hairs, which cannot be removed, interfere with the "lay" of the underfur in the finished product.

[15]Abegglen, C. E., A. Y. Roppel, and F. Wilke. 1956. Alaska fur seal investigations, Pribilof Islands, Alaska. Report of field activities June-September 1956. Unpubl. rep., 145 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Branch Wildl. Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[16]Abegglen, C. E., A. Y. Roppel, and F. Wilke. 1957. Alaska fur seal investigations, Pribilof Islands, Alaska. Report of field activities June-September 1957. Unpubl. rep., 162 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Branch Mar. Mammals. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[17]This firm, since renamed the "Fouke Company," has for many years been under contract to the Federal Government to finish the skins of fur seals taken on the Pribilof Islands.

[18]The "Lakoda process," one of closely shearing the hair and fur of the fur seal, was cooperatively developed in 1957 by the Federal Government (through its Marine Mammal Biological Laboratory, now the National Marine Mammal Laboratory) and the New Method Fur Dressing Company in San Francisco. Later, after one or more of the "Lakoda" skins had been sent to the Fouke Fur Company for evaluation, S. J. Pingree, assignor to the Fouke Fur Company, patented the shearing process (Scheffer et al. in press).

50,000 skins, losses which appeared in official records as "skins not utilized."

Managers formulated many courses of action during several years of the herd reduction program on both islands to eliminate as great a percentage as possible of the labor costs associated with "commercialization" of the unwanted skins from females while achieving the planned reduction (Table 1). The actual take of older, but the then commercially worthless, females in 1958 and 1959 was minimized to some extent by imposing an upper body length limit of 46 in (117 cm). Larger animals were to be taken in those years only if necessary to reach quotas established for taking females and reducing the size of the herd. In the summer of 1960, however, lack of males in expected numbers by mid-July prompted managers to seek and obtain permission to abandon their assigned quota of 17,500 females and in its place to take only a few for research, up to 250/d from the hauling grounds of St. Paul Island and 100/d on St. George Island. The total take of females in that year was restricted to 4,315 and concern over the welfare of the herd brought about a flurry of photographing the rookeries for comparison with past photographs in an attempt to learn if geographical boundaries of the breeding areas were actually shrinking in size. Satisfied that they were not, managers decided that during each of the next 3 yr, from 1961 through 1963, they would complete quotas established for taking females with harvests extended into September, if necessary. The managers received instructions from Washington, D.C., to take or keep only those skins in 1961 that were from females with dark whiskers, a decision that effectively prevented the processing of all animals age 6 yr and older (both females and males through age 4 yr have dark whiskers, age 5 yr a mixture of dark and white, and age 6 yr and older, white.

The policy of keeping only the dark whiskered females in 1961 led to the discarding of nearly 70% of the 43,849 skins taken that year as unfit for processing (though developed in the late 1950's, the "Lakoda" process was not yet totally accepted by the fur trade). Managers altered their plans for 1962 to selectively kill (on St. Paul Island only) young females in July and August and older females in September to demonstrate an ability to take these animals by age. This decision followed an attempt by the Japanese contingent to persuade the other members of the North Pacific Fur Seal Commission to permit pelagic sealing in conjunction with harvesting on land. According to Japan's fur seal scientists, selective killing of young females was possible at sea but not on land. The "experiment" was moderately successful in that during the early period 59% of the females taken were of ages 2-5 yr and in September 75% were age 6 yr and older. Most of the skins from the older females taken in 1962 were not processed, bringing the total "not utilized" in 1961 and 1962 to more than half the total of 87,609 females harvested during those 2 yr.

Table 1.—Number of fur seals harvested and skins rejected[1] because of staginess, St. Paul Island, Alaska, August-September 1956.

	Females (all ages)		Males (ages 1-4 yr)	
Date	Harvested	Rejected (%)	Harvested	Rejected (%)
August				
20	20	0	0	0
25	19	0	2	2 (100)
30	20	2 (10)	1	0 (0)
September				
4	519	101 (19)	18	Unknown
5	520	50 (10)	18	Unknown
6	399	36 (9)	33	28 (85)
7	479	97 (20)	76	66 (87)
8	426	85 (20)	86	76 (88)
13	21	6 (28)	1	1 (100)
18	20	8 (40)	1	1 (100)
23	12	3 (25)	10	9 (90)

[1]As unfit for further processing.

In 1963, the last of the herd reduction years, all except a few hundred of the skins taken were kept, regardless of age. By this time, reserves of skins held in storage on the Pribilof Islands and at the Fouke Fur Company's plant had been depleted sufficiently to accommodate additional skins. More importantly, the "Lakoda" process was now gaining in importance as a method of treating the skins of females, which were becoming increasingly valuable in a rapidly expanding market for the product. The attitudes of federal administrators on the islands and officials of the Fouke Fur Company were reversed almost overnight: later there was even concern about maintaining supplies of raw skins as average values of the "Lakodas" closely approached those of DDM & F skins.

In 1964, it was decided to terminate the herd reduction program but to try to maintain the population of females at the 1963 level. Thus, females harvested from 1964 through 1968 were considered surplus to maintaining herd size at the level achieved by 1963. During this period, an estimated 45,000 females were needed annually to replace breeding animals that died of natural causes. All above this number, usually between 9,000 and 18,000, were considered surplus.

Also, in 1964, most of the old females appearing in the drives were allowed to escape because the new and lower level of pup production had been achieved and the need to reduce the total number of females had ended. In general, only those females having black or a mixture of black and white whiskers were taken, which essentially restricted the kill of this sex in 1964 to those of ages 2-5 yr. The kill of females on St. Paul Island in 1965 was characterized by a harvest selective for those with black or a mixture of black and white whiskers; all females available on St. George Island, however, were taken regardless of their whisker color. In 1966, there was essentially no commercial harvest of females on either island because managers believed that all were needed to maintain the population at the estimated level in existence at that time. A few were taken for research and some were killed accidentally during the commercial harvest of males, bringing the total taken in that year to 481. In 1967 and 1968, females believed to be in excess of the number needed to maintain the population were again harvested. These animals were taken without regard for age or size, and the relative size of each rookery in terms of total population was used as a guide in killing most of the animals. Special efforts were made not to exceed quotas set for Reef and Polovina Rookeries on St. Paul Island and for Staraya Artil Rookery on St. George Island. Because of the extreme accessibility of females on these rookeries, they were considerably and disproportionately overharvested during the period of herd reduction.

Thus, the removal of 270,000 females from 1956 through 1963 and the taking of nearly 51,000 during the period of "population maintenance" from 1964 through 1968 brought the total harvest of this sex during the 13-yr period to well over 300,000 animals.

The impetus for reducing the number of females and, as a consequence, the number of pups born had as its primary basis historical data that showed a relationship between the size of the pup population and survival to age 3 yr. Chapman (1961, 1964) concluded that survival to age 3 yr would be maximized with a total pup population of about 400,000, as mentioned earlier. A level much lower than 400,000 would recruit too few pups into the system for

maintenance of the population, whereas density dependent factors would become operative at a higher level.

Unfortunately, the start of the herd reduction program coincided with the beginning of a decline in the number of males available for harvest. This development revived past objections to the removal of females, a harvest that was now viewed by some individuals as a direct cause of the decline in the number of young males.

There was no denying the reality of a lesser number of young males, but there was no real nor logical explanation for a sudden and distressing shortage of these animals beginning in the late 1950's.[19] Contrary to the opinions of federal administrators on the islands and many of the Aleut residents, it was immediately obvious that the offspring of females harvested in 1956 could not have entered the commercial harvest of males until 1959 at the earliest. Even so, only half the pups born of the 22,680 females taken in 1956 were males, of which 80% or more normally would be destined for death before reaching age 3 yr in 1959. Mathematically then, those females could not have contributed more than 2,000 young males to a harvest of 12,922 3-yr-old males ending 31 July in 1959, a number insufficient to account for a 63% drop from a take of 34,462 the year before or even the 39% decline from the harvest of 21,113 3-yr-old males by 31 July in 1957.

These sudden and substantial changes generated speculation within the scientific community that some natural factor or combination of factors had become fundamentally significant—such as predation, disease, or climatic circumstance. The hookworm, *Uncinaria lucasi* Stiles, identified in 1945 as a significant cause of mortality among fur seal pups (Scheffer et al. in press), was immediately suspect. There eventually arose additional conjecture that perhaps the invasion of foreign fishing fleets into Alaskan waters, beginning in the mid-1950's, influenced survival through a substantial reduction of the fur seal's supply of food around the Pribilof Islands during the nursing season and along its migration corridor between the breeding grounds and the Aleutian Islands.

Whatever may have been the cause, managers and scientists alike saw a 17-yr average harvest of 71,500 males from 1940 through 1956 slip to one of barely over 40,000 during the next 3 yr. The harvest in 1960 declined even further to 36,000. Additional evidence that the onset of the herd reduction program had no real relationship to the decline in the number of males available for harvesting became apparent with a dramatic rise in the harvest of 1961 to 82,197. The average annual harvest of 45,000 from 1962 through 1971, though somewhat higher than the average of 40,000 during 1957-59, was still considerably below the average of 71,500 during 1940-56.

Clearly, one or more factors, whether natural or man-made, were operating to adversely affect the herd and cause extreme fluctuations in year class survival and overall, a much reduced production of young males. As a result, the NPFSC had by 1972 recognized a need to develop a coordinated land-pelagic program and concentrate on new avenues of research. Accordingly, the NPFSC at its annual meeting that year discussed the desirability of collecting fur seals in the Bering Sea between the Pribilof Islands and Unimak Pass in the Aleutian Islands and of establishing one or more research control areas on the Pribilof Islands (North Pacific Fur Seal Commission 1973). The ultimate objective of the research at sea was to compare feeding habits in the 1970's with those of the 1950's and 1960's (Kajimura et al. footnotes 8, 9) to determine if there had been changes in species of food taken (North Pacific Fur Seal Commission 1973). In 1973, the United States submitted and the NPFSC adopted a proposal that was to provide for renewed emphasis on fur seal research in the Bering Sea and establish all of St. George Island as a research control area where fur seals would not be harvested for several years (Anonymous 1973; North Pacific Fur Seal Commission 1973). The only change made in the harvest moratorium on St. George Island since then occurred in 1976 when, beginning in that year, a limited annual take for local use as food was permitted. The research planned for 1973 and several subsequent years on St. George Island was to include the collection of data on:

1) Behavior and such activity patterns of adult males as time spent establishing and defending territories.
2) Length of nursing-feeding cycles of lactating females.
3) Distance traveled to feeding areas and time spent feeding by lactating females.
4) Activity of pups, such as time spent nursing and average number of nursing periods prior to leaving the island.
5) Activity patterns of adult females and young males on the hauling grounds.
6) Changes in activity patterns of fur seals when disrupted by research and management activities.
7) Interaction between fur seals and northern sea lions on fur seal rookery areas.
8) Causes of death among pups before and after the expected increase in number of males.

The United States believed it necessary to establish the research control area on St. George Island and a moratorium on the harvest of fur seals there because of failure of the Pribilof Islands herd to respond as anticipated to changes in the management scheme started in 1956. Instead of increasing, the average number of males harvested during 1957-60 declined to 40,000 and a similar situation with regard to the females began to develop in that by the early 1960's, fewer and fewer young females were appearing on the hauling grounds. In order to complete quotas established for taking females, especially during the relatively large kills of these animals during 1961-63, managers found it increasingly necessary to "raid" the rookeries by skimming parturient females off the inland fringes as soon as they became available following the breakup of organized breeding in August.

The decision to impose the harvest moratorium on St. George Island rather than on selected rookeries of St. Paul Island and to substantially increase the research effort there was based on several factors. First, an analysis of tag recovery data showed that the degree of homing to the island of birth is considerably higher than to the individual rookery units on each. Although fur seals returning to St. Paul Island exhibited greater homing tendencies in all areas than did fur seals born on St. George Island, the collective advantages of the latter as a research control area outweighed those of St. Paul Island in this regard. Second, St. George Island contained 20% of the total population of the Pribilof Islands or slightly less than that of the largest rookeries on St. Paul Island (but the harvest there had declined from 20% to 11% of the total), and had four physically discrete subpopulation units which would permit research to be carried out on separate units and allow replication of studies. Additionally, it would be possible to make direct counts of the

[19]Four-year old males normally peak in their arrival on the Pribilof Islands about mid-July and the 3-yr-olds do so approximately 2 wk later. Thus, an extension of the season into August in a given year increases the take of 3-yr-olds but reduces the kill of 4-yr-olds from that year class the following year. Regardless of such extensions and their effect on the harvest, the harvest of males since 1956 has been much depressed over what it had been previously. The decline is especially evident in the kill by year class; 5 yr averages are 43,793 (1957-61), 36,917 (1962-66), 31,691 (1967-71), and 25,311 (1972-76). Year classes 1977 and later have not yet been totally subjected to harvest and are therefore not included here.

relatively small pup populations of from 8,000 to 20,000 on St. George Island. Moreover, access to the rookeries and hauling grounds there was as good as or better than to those on St. Paul Island.

Thus, the first long-term study of behavior in the history of fur seals on the Pribilof Islands was launched beginning in 1973. Earlier but relatively short term studies were carried out by Bartholomew (1951,[20] 1953, 1959), Bartholomew and Hoel (1953), Bartholomew and Wilke (1956), and Peterson (1965). Although 10 breeding seasons have since passed, these studies are still somewhat in their infancy because of a need to examine the behavior and biology of the herd at its "natural level," which will not occur until about 1990 due to the relatively long life span of the species—17 yr for males (Johnson 1968) and 20 yr or more for females.[21]

Collection of Data

Information for studies of the population dynamics of the northern fur seal comes from several sources. Included are data on animals harvested commercially, counts of adult males, tagging and marking programs, estimates of the number of pups born, counts of dead pups, and other measurements of mortality. Notes on the development of and various features of these programs are presented in this section.

Harvest of males.—The commercial harvest of males is by necessity restricted mostly to the months of June and July and perhaps part of August because it is during this period that the males appear on land and have yet to start their molt. Before 1930, however, it was the practice to take seals in other months of the year as well. These "off season" and relatively small harvests were conducted to provide food for the people of the Pribilof Islands (Bower 1930). After 1929, the killings for food were discontinued (Bower 1931) and from 1930 through 1955 what is now considered a "traditional season" prevailed, i.e., from a starting date in late June to termination near the end of July. The need to take females under the herd reduction program started in 1956. However, attendant difficulties in identifying young males from females of the same ages plus seemingly excessive numbers of adult males on the hauling grounds and rookery fringes also led to the concurrent harvesting of many males in August as well as during the regular season in that and several subsequent years. This practice in turn led to increasing utilization of each year class at age 3 yr, with the result that with each passing year, progressively fewer and fewer animals remained alive to return at age 4 yr. Managers responsible for overseeing the harvest responded to the lack of males early in the season[22] by delaying the start of the kill to as late as 7 July (Marine Mammal Biological Laboratory 1969) and postponing termination several days beyond 31 July in some years from 1956 through 1968.

This seasonal shift in the period of the harvest prompted the question of whether it was economically preferable to take fur seals at age 3 yr before overwintering mortality reduced their numbers or to take them a year later at age 4 yr after this loss had occurred. But it was not until an analysis of average skin size and relative numerical abundance of animals at the two ages was carried out, that it was learned that there was little, if any, difference in economic return, at least up to the mid-1960's (Marine Mammal Biological Laboratory 1966[23]). The lesser value of the smaller 3-yr-olds was offset by their greater abundance.

Because the managers preferred an earlier season to take advantage of summer weather (for such outdoor activities as construction and maintenance), and because the change to a later season had made the results of scientific analysis of the harvest data less useful, they opted to return to the starting and ending dates of past years. The change back to June was made in 1967 with termination near the end of July starting in 1969.

To decrease operating costs and provide time off for laborers involved with the harvest, the work week on St. Paul Island was reduced from 7 to 6 d in 1967 and finally to 5 d beginning in 1977. On St. George Island, it had been the practice for the same laborers to not only harvest the seals each day but when finished with that work to also process the skins. This situation was eliminated beginning in 1963 when managers changed their regime to one of harvesting the animals on Mondays, Wednesdays, and Fridays and processing the skins on alternate days. Both of these changes were possible only because the number of animals available for harvesting had declined from the much higher levels of former years.

Other aspects of the harvesting regime have also changed through the years. First, it had long been the custom on the Pribilof Islands to drive the seals from the hauling grounds to suitable killing fields and start the harvest during the relatively cool air temperatures of early morning[24] when the grass is laden with dew to prevent overheating of the animals, undue stress, and even the deaths of some. Thus, starting times for the drives have ranged from about 0515 h for rookeries close to the village to 0600 h for the most distant hauling grounds. In years of exceptionally large harvests such as in 1956, the starting times were as much as 2 h earlier. The starting times on St. George Island were changed from 0515 h to 0830 h with the shift from a 6- to a 3-d harvest week mentioned earlier. The later hour was possible because of the relatively small kills on St. George Island, which seldom exceeded 20% of the number taken on St. Paul Island. Second, a "round" system has been followed on both islands when harvesting the seals. The round or kill sequence on St. Paul Island was[25] and still is of 5 d duration, meaning that each rookery/hauling ground complex is visited once during the period. Thus, the total period of the harvest in a given season consists of several rounds. On St. George Island, the round was only 4 d long, a number equal to the total number of rookery/hauling ground complexes on that island (there are six rookeries but essentially only four hauling grounds). The 4-d round on St. George Island was changed to one of 3 d beginning in 1963 when harvesting was restricted to Mondays, Wednesdays, and Fridays.

[20]Bartholomew, G. A., Jr. 1951. Summary of observations made on the social and reproductive behaviour of the Alaska fur seal during June, July, and August 1951. Unpubl. manuscr., 3 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[21]A 21-yr-old animal wearing tag USA-6218 applied to it on Zapadni Rookery of St. Paul Island in 1941 was taken there 16 August 1962. In 1981, a new known-age record was established when a 25-yr-old nursing female wearing tag I-7876 was seen in Reef Rookery, St. Paul Island. She had been tagged as a pup on North Rookery of St. George Island in 1956.

[22]As mentioned earlier, the 4-yr-olds peak in abundance on land about 2 wk ahead of the 3-yr-olds.

[23]Marine Mammal Biological Laboratory. 1966. Evaluation of fur seal skins by age, sex, and method of processing. Unpubl. manuscr., 29 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[24]Seal drives were occasionally made the day before the harvest on Reef Rookery and the animals held overnight in front of the village. The last such drive was made in 1950.

[25]Exceptions from 1967 through 1972 occurred on St. Paul Island when managers attempted to maximize the kills first by inspecting the hauling grounds then conducting the harvest the following day from those with the most seals.

A representative of the Washington office of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) noted, when visiting St. Paul Island in 1965, that a substantial number of males were being rejected from the harvest, many of which appeared to be just slightly over the upper body length limit established for harvesting in that year. This was during an era when field decisions concerning the harvest and even strictly biological questions were often made by members of the Washington, D.C., office staff. Because of the observation, an extra 854 males were added to the harvest in that year to test the commercial value of "oversize" skins, many of which were of ages 4-5 yr (Roppel, Johnson, and Chapman 1965) and of commercial quality. A non-biological problem associated with the taking of males over a certain body length at that stage was that their relatively large skins could not be accommodated within the drying hoops and other equipment used by the processing contractor. Many of these large skins were from seals of the same ages as those normally taken and were equal in quality and sold for higher prices (the contractor requested, but was not granted, permission to develop new processing equipment, but instead was permitted to trim large skins to fit).

It had once been the practice to harvest seals on Sea Lion Rock (Fig. 2—Sivutch) and such other inaccessible places as a gravel beach just east of East Cliffs Rookery on St. George Island (Fig. 3) and Ardiguen Rookery and an exposed reef off the western end of Zapadni Rookery on St. Paul Island (Fig. 2). It has been many years since seals were harvested on these areas. Firecrackers were used in 1967 and 1968 on St. Paul Island to frighten the animals off inaccessible reefs (Marine Mammal Biological Laboratory 1970a, b) and from under cliffs and presumably to some nearby hauling ground where they would then become available for the harvest.

According to Gentry (1981), males of harvestable ages are most abundant on land between 1300 and 1900 h, a fact to consider with respect to the time of day the harvest is carried out. In this connection, managers conducted three experimental harvests in 1981 on the Polovina Rookeries of St. Paul Island during the afternoons of 23 June and 10 and 17 July. The conclusion, however, was that it would probably never be feasible to implement a full-scale harvest in the afternoon as opposed to a starting time of 0500 h currently in effect because 1) the seals are much more alert and aggressive later in the day and can escape into the water with much greater ease and speed, 2) the animals would be subjected to higher ambient air temperatures and possibly death as a result of overheating, 3) the driving and handling of large numbers of animals over long distances and up steep slopes would not be possible because of 2), and 4) the sealing crew would be resistant to such a change (Scordino 1981[26]).

The use of right maxillary canine teeth in determining the ages of fur seals has been described by Scheffer (1950a) and Scheffer et al. (in press). Bauer et al. (1964) examined the potential of using weights of eye lenses to determine the ages of fur seals. The latter investigators found that although the lenses did in fact grow heavier with age, the overlapping of weights between ages precluded any useful application of the results. Thus, the best technique so far developed for determining the ages of fur seals is still one of collecting, cleaning, and "reading" maxillary canine teeth. Anas (1970) measured accuracies in assigning ages to fur seals and found them to be within acceptable limits. The NPFSC also conducted reader tests among member scientists, not only to measure accuracies but to standardize the methods and techniques used by scientists of different countries to determine the ages of fur seals from canine teeth (North Pacific Fur Seal Commission 1967, 1970, 1979, 1980). The Marine Mammal Biological Laboratory (1969) summarized the results of one reader test conducted by the NPFSC.

Abegglen (footnote 15), Roppel, Johnson, and Chapman (1965), and the Marine Mammal Biological Laboratory (1969) discussed sample sizes with respect to the collection of maxillary canine teeth. A beginning sample in the early 1950's of 5% of the males harvested was increased to 10% in 1956 to eliminate inaccuracies and variability found in the smaller sample. Kills of 100-300 males, mostly on St. George Island, were sampled at the 20% level and those of <100 at 30% or more to achieve representativeness. In 1966, the sample was increased from 10 to 20% of those taken to provide better representation of the relatively small numbers (10% or less of the total) of 2- and 5-yr-old animals harvested.

Thus, body size, age composition, and a prescribed season became primary considerations of the managers in controlling the harvest of males. Changes in the maximum limit of body length are imposed to modify the utilization rate of the year classes, whereas lengthening or shortening the season at the end of the kill in late July increases or decreases the harvest of 3-yr-olds in a given year and influences the size of the harvest of 4-yr-olds from the same year class the following year. The results of these manipulations are reflected most immediately in the age composition of harvested animals as determined from annual collections of canine teeth and several years later by changes in the number of adult males. A 20-yr practice of counting over- or undersized males "rejected" (permitted to escape) during the harvest was abandoned at the conclusion of the season in 1960 primarily because there was no way, short of marking the animals, to separate seals counted once from those counted two or more times.

As mentioned by Roppel and Davey (1965), limits of body length for taking males were established after 1912 and applied first in 1922 to restrict the kill to males of age 3 yr. From 1922 through 1958, these limits were a minimum of 41 in (104 cm) and a maximum of 45.75 in (116 cm), tip of nose to base of tail. At the end of the 1958 season, managers considered the number of idle males (as counted on the hauling grounds and rookery fringes during the breeding season) to be more than needed for recruitment into the breeding stock and raised the maximum limit for 1959 to 46.75 in (119 cm) to increase utilization of the year classes. The maximum in 1960 was lowered to 45.75 in (116 cm) but raised again in 1961, this time to 47.75 in (121 cm).

The old technique of classifying harvested males by body length to reveal age totally gave way to the new method of determining ages from maxillary canine teeth beginning in 1962, but use of body size as a guide in selecting males for harvesting was continued and occasional checks were made of the lengths of harvested animals to ensure that the workers took only those within prescribed limits. In 1962 (and all subsequent years when an actual numerical upper length limit was imposed), the approximately 1-in-long (2.5 cm) tail was included in the measurement. Thus the range of 42 to 48.75 in (107-124 cm) from tip of nose to tip of tail in effect that year was actually equal to the range used the previous year (1961) of 41 to 47.75 in (104-121 cm), tip of nose to base of tail. The 1963 season started with the same limits (42 to 48.75 in or 107 to 124 cm) as used in 1962, but the maximum was removed early in July and all males without a mane (long, silver-colored, guard hairs on the shoulders and on the back of the neck) were taken throughout the remainder of the season. This relaxation of control, which continued through 1968, essentially permitted the taking of all available 4-yr-olds and

[26]Scordino, J. 1981. Report on the experimental afternoon harvest of fur seals on St. Paul Island in 1981. Unpubl. manuscr., 11 p. (Available Pribilof Islands Program, Northwest Reg. Off., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.)

more than the normal number of 5- and 6-yr-olds. The minimum limit of 42 in (107 cm) was maintained throughout the 6-yr period to protect the 2-yr-olds.

This level of utilization continued during the next 3 yr (1969-71) and even increased slightly through removal of the lower limit altogether to permit the taking of all available 2-yr-olds in an effort to learn if the total number appearing on land would be useful as a guide in predicting the size of year class return at age 3 yr (earlier, the lower length limit had been removed for a limited number of days only for such studies—20 and 24 July in 1967 and 22-26 July during 1964-66 and 1968-71). Thus, all males found on the hauling grounds in 1969, 1970, and 1971 were taken regardless of size as long as they did not have a mane. A minimum length limit was never again imposed because the number of 2-yr-olds taken in uncontrolled situations was not considered excessive (the skin of the relatively small 2-yr-old is of less value than the larger skin of a 3- or 4-yr-old).

In 1972, managers replaced use of the mane with 49 in (124 cm) (tip of nose to tip of tail) as an upper limit of body length. From 1973 through 1975, the upper limit of 45.75 in (116 cm) (rounded to 46 in or 117 cm) used from 1922 through 1958 and in 1960 was again imposed to increase the escapement of young males into the breeding reserve. Managers later realized that because of the change in 1962 in measuring seals to the tip rather than to the base of the tail, they actually took animals of 45 in (114 cm) in length from 1973 through 1975 instead of 46 in (117 cm) as planned for these years. Therefore, the upper limit in 1976 was increased to 47 in (119 cm) to compensate for the approximately 1-in-long (2.5 cm) tail and presumably, provide for year class escapement similar to the proportion permitted from 1922 through 1958 and in 1960. An upper limit of 47 in (119 cm) was used again in 1977.

The 1978 season started with an upper limit of 47 in (119 cm), but was increased to 49 in (124 cm) effective 11 July to reduce escapement, which managers believed had been excessive in recent years, as indicated by growing numbers of adult males counted on the hauling grounds and fringes of the rookeries. Although managers wanted to use 49 in (124 cm) again in 1979, the limit of 47 in (119 cm) was imposed because Canada would not agree to the change without background material to justify it. This material was later developed and a limit of 49 in (124 cm) used during 1980-81. The effect of these changes will be evaluated in the future to determine how they influence productivity and to ascertain whether additional measures must be taken to produce the desired result, which is to maximize the harvest and control the escapement of young males into the breeding reserve.

Finally, it should be noted that the age-body length standards established between 1913 and 1918 (Roppel and Davey 1965), but first used in 1922 as minimum/maximum limits for harvesting seals, indicated the 3-yr-olds as ranging up to a length of 45.75 in (116 cm) and that males within the 46 to 51.75 in (117-131 cm) range were considered 4-yr-olds. Officials at the time recognized that there was an overlapping of lengths of any three consecutive age classes. Scheffer and Kenyon (1952[27]) and Wilke (1953,[28] 1955[29]) showed that there was some overlapping in the body lengths of 3- and 4-yr-old fur seals. Roppel, Johnson, and Chapman (1965) demonstrated considerable overlapping in 1963 by measuring 1,005 3-yr-old males tagged as pups in 1960. Twenty-nine percent of these animals would have been classified as 4-yr-olds according to the previously established age-length standards.

Limits of body length used to control the harvests of males from 1922 through 1981 are summarized in Table 2.

Table 2.—Limits of body length used to control the harvest of male seals, Pribilof Islands, Alaska, 1922-81.

	Body length (in-cm)	
Year	Minimum	Maximum
[1]1922-58	41-104	45.75-116
[1]1959	41-104	46.75-119
[1]1960	41-104	45.75-116
[1]1961	41-104	47.75-121
[2]1962	42-107	48.75-124
[2]1963-68	42-107	48.75-124 to early July in 1963, thereafter in that year and during 1964-68, all without manes (long silver-colored guard hairs on the shoulders and on the back of the neck).
1969-71	None	All without manes.
[2]1972	None	49-124 or less
[2]1973-75	None	46-117 or less
[3]1976-77	None	47-119 or less
[4]1978	None	47-119 or less through 10 July and 49-124 or less thereafter.
1979	None	47-119 or less
1980	None	49-124 or less
1981	None	49-124 or less

[1]Tip of nose to base of tail.

[2]Tip of nose to tip of tail. The addition of 1 in (2.5 cm) to the limit beginning in 1962 accounted for the change in measuring from base to tip of tail, which is approximately 1 in (2.5 cm) in length.

[3]The proportion of males permitted to escape the harvest during 1973-75 was intended to equal that during 1922-58 and in 1960, hence the return to an upper limit of 46 in (117 cm) in those 3 yr. Beginning in 1962, however, the tip of the tail, rather than the base, was used, therefore the limit during 1973-75 should have been 47 in (119 cm) to account for the approximately 1-in (2.5 cm) long tail.

[4]Effective 11 July, the upper limit was raised from 47 in (119 cm) to 49 in (124 cm) to increase the utilization rate.

Harvest of females.—As mentioned earlier, few females are available for harvesting on land until beginning in late July when the young animals of ages 3 and 4 yr come onto the hauling grounds, the so-called harem structure breaks up, and some of the breeding females move to these areas from the rookeries. It has been speculated that the latter, most of which were parturient that same summer, had lost their pups through death and therefore had no particular allegiance to the rookery during the remainder of that breeding season.

Nearly 73,000 females were sampled from the commercial harvests during 1956-68 and classified by age, reproductive condition, body length, and vibrissal color. From this research it was learned that some, but not all, of the females first give birth to pups when 4-yr-old rather than at ages 2 and 3 yr as once believed (Abegglen and Roppel 1959), that females on the rookeries are concentrated within the age range of 5 through 9 yr, and that most females through age 4 yr have black vibrissae, the 5-yr-olds generally have a mixture

[27]Scheffer, V. B., and K. W. Kenyon. 1952. Alaska fur seal investigations: Report of studies on the Pribilof Islands in 1952. Unpubl. rep., 25 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[28]Wilke, F. 1953. Alaska fur-seal investigations, Pribilof Islands, Alaska. Summer of 1953. Unpubl. rep., 34 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Branch Wildl. Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[29]Wilke, F. 1955. Alaska fur seal investigations, Pribilof Islands, Alaska, 1955. Unpubl. rep., 46 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Branch Wildl. Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

of black and white, and those age 6 yr and older have white whiskers. In addition, high proportions, e.g., 64% of those taken on St. Paul Island in 1956, of the harvested females age 11 yr and older had not produced pups in the year examined. Either their reproductive lives were completed or not all females of these ages were producing pups each year.

Females taken on the Pribilof Islands from 1956 through 1968 were primarily from two sources—the hauling grounds[30] and rookery fringes. Animals within these groups differ considerably with respect to their pregnancy rates. According to Abegglen et al. (1959),[31] 100% of 950 rookery females had borne pups the summer they were taken whereas only 68% of 1,414 known to have been taken solely from hauling grounds were recently parturient. Thus, there is no known way to determine a proper mix of females from the various sources on land that would yield a satisfactory and usable estimate of the true pregnancy rate.[32] The figure of 60% used over the years has been derived from fur seals collected at sea where the intermixing of females of various ages and reproductive conditions is assumed to at least be more complete. Table 3 is a summary of information on annual quotas and actual numbers of females taken on the Pribilof Islands from 1954 through 1968 and on the source of females killed on St. Paul Island (females were taken from the same sources on St. George Island but this information was never documented).

In 1957 and 1958, the presence or absence of milk in the mammary glands was recorded for most females taken but found unreliable as an index of reproductive condition. Milk or milk-like fluid was found within the mammae of nulliparous and nonpregnant parous animals and in some instances the entire glandular tissue was stripped from the carcass during skinning, making it impossible to collect conclusive data one way or the other (Abegglen et al. footnote 16, 1958[33]).

Skins from 1,153 males and 1,609 females were collected and marked during 1958-65 to permit identification through processing into finished furs. Several biological attributes, particularly age and sex, were then related to the finished grade and size of each skin (Abegglen et al. footnotes 31 and 33, 1961;[34] Roppel et al. 1963; Roppel, Johnson, and Chapman 1965; Roppel, Johnson, Anas, and Chapman 1965). These kinds of data were later analyzed in detail by the Marine Mammal Biological Laboratory (footnote 23) and Scheffer and Johnson.[35,36]

J. T. Fouke of the Fouke Fur Company in a letter dated 26 March 1962 had this to say about 117 skins from females of ages 2-5 yr collected by Scheffer and Johnson (footnote 35, p. 13) for research on quality: "The results of processing this group seem to be quite satisfactory.... It is our feeling that if the females could be kept within the limits of these 117, there would be no great processing difficulties.... Although they graded well, with a substantial number of regulars, we believe that these skins still fall below male grades. In other words, proportions of Fines, I's and II's (all regular grades) run toward the II's, or the low end... whereas males tend in the other direction. In large quantities these differences in size and grade become important considerations." The fur processor (Fouke Fur Company) also offered several reasons why the skins of females were generally lower in value than those from males: 1) Smaller size, 2) narrower distance between flipper holes, giving a reduced area of fur, 3) thinner and silkier fur, and 4) more loss of fur from trimming during the manufacturing process because of the mammae (Roppel, Johnson, and Chapman 1965).

Scheffer (1962) published extensively on characteristics of northern fur seal fur and Scheffer and Johnson (1963) discussed the molting process and compared differences between males and females in this respect.

Counts of adult males.—The counts of adult males began in 1911 and have been continued since to measure recruitment of young males into the breeding stock. They are not, however, made completely without risk to the census taker who in places must expose himself to the extremely aggressive behavior of the territorial harem males. Conditions with respect to safety are now much improved over what they were in 1911 when elevated structures presently referred to as tripods and catwalks did not exist. In 1918, the census taker experimented with a hand-held ladder perched sufficiently high on the crest of the beach to permit a view of the water's edge for the count (Bower 1919). This method of elevation, however, exposed the census taker to the possibility of falls to the rocks below, especially during windy conditions which made it difficult to hold the ladder. As a result, plans were considered for "platform walkways" in 1918, but it was not until 1921 that the first was built—on Reef Rookery of St. Paul Island (Bower 1922). Walkways were erected on Little Zapadni, Zapadni, and Vostochni Rookeries of St. Paul Island, and Staraya Artil Rookery of St. George Island the following year (Bower 1923). Construction continued through the next several years until a reasonably full measure of safety to the census taker was achieved in relation to the size of the fur seal population at that time. This situation, however, changed with time and increases in herd size so that by mid-century there had developed a need for additional tripod/catwalk construction, most of which was accomplished in the 1960's. These structures not only provided safety for the census taker but improved the accuracy of the counts by eliminating an almost constant need to ward off aggressive males.

[30]Areas adjacent to the rookeries where nonbreeding fur seals congregate or where breeding females may assemble following the deaths of their pups.

[31]Abegglen, C. E., A. Y. Roppel, and F. Wilke. 1959. Fur seal investigations, Pribilof Islands, Alaska. Report of field activities, June-September 1959. Unpubl. rep., 132 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Mar. Mammal Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[32]True estimates of pregnancy rates from land-based samples can be calculated if pregnancy rates such as those developed by Abegglen et al. (footnote 31) were again obtained and combined with estimates of the number of parturient females (the equivalent of the number of pups born) and estimates of females using the hauling grounds, the latter to be developed from mark/recapture experiments conducted late in the season when most nonparturient females are on the hauling grounds (R. DeLong, Wildlife Research Biologist, National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115, pers. commun. March 1982).

[33]Abegglen, C. E., A. Y. Roppel, and F. Wilke. 1958. Fur seal investigations, Pribilof Islands, Alaska. Report of field activities, June-September 1958. Unpubl. rep., 187 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Section Mar. Mammal Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[34]Abegglen, C. E., A. Y. Roppel, A. M. Johnson, and F. Wilke. 1961. Fur seal investigations, Pribilof Islands, Alaska. Report of field activities, June-November 1961. Unpubl. rep., 148 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[35]Scheffer, V. B., and A. M. Johnson. 1962. Report on a sample of female sealskins taken on St. Paul Island, Alaska in 1961. Unpubl. manuscr., 13 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[36]Scheffer, V. B., and A. M. Johnson. 1963. Report on a sample of sealskins taken on St. Paul Island, Alaska in 1962. Unpubl. manuscr., 8 p (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

Table 3.—Annual quotas and numbers[1] of females killed, Pribilof Islands, Alaska, 1954-68.

Year	Source (St. Paul Island only)	Quota	Actual harvest	Remarks
1954	Hauling ground	All available during the kill of males	540	For research (all taken on St. Paul Island)
1955	Hauling ground	All available during the kill of males	641	For research (all taken on St. Paul Island)
1956	Hauling ground Rookery ("harem raids")	30,000	27,599	Took all 41 in (104 cm) or longer in body length
1957	Hauling ground Rookery ("harem raids")	50,000	47,414	Took all 41 in (104 cm) or longer in body length
1958	Hauling ground	30,000	31,102	Took all 46 in (117 cm) or less in body length
1959	Hauling ground	50,000	28,064	Took all 46 in (117 cm) or less in body length
1960	Hauling ground	17,500	4,315	Commercial harvest discontinued mid-July; research kills only thereafter
1961	Hauling ground Rookery fringe	43,750	43,849	Kept skins from young, dark whiskered females only
1962	Hauling ground Rookery fringe	43,750	43,760	Selective for young females July and August—most from hauling grounds; took older females in autumn from rookery fringes and hauling grounds; kept female skins with dark whiskers only
1963	Hauling ground Rookery fringe	43,750	43,860	Kept all skins except 976
1964	Hauling ground Rookery fringe	9,000-18,000	16,452	Kept all skins—Lakoda process becoming valuable
1965	Hauling ground	9,000-18,000	10,432	Kept all skins except a few
1966	Hauling ground	None	391	Took 330 for research and killed 61 accidentally
1967	Hauling ground	10,000	10,094	Kept most skins
1968	Hauling ground	13,000	13,335	Kept most skins

[1]Preseason statements or figures established for the harvesting of fur seals.

The counts have traditionally been made near mid-July when most of the females have arrived and given birth to their pups. Adult males were not counted on either of the Pribilof Islands in 1942 because of the threat of World War II and evacuation of the people on 16 June of that year to the safety of abandoned cannery (St. Paul residents) and mine (St. George residents) buildings on Funter Bay in southeastern Alaska, nor on St. George Island in 1956 because of a lack of interisland transportation.

Two classes of males, harem and idle, have been recorded each year since 1911. By definition, a harem male is one that is defending a territory containing one or more females (or pups).[37] The idle males are estimated to be age 7 yr and older and may or may not have territories.

From 1911 through 1958, the counts were made by a succession of managers associated with what is now called the Pribilof Islands Program. This responsibility was transferred in 1959 to what is now the National Marine Mammal Laboratory.

[37]A territorial male with only one or two females may be misclassified if those females are at sea. However, the presence of pups within a territory identifies the adult male there as one with females. Although the term "harem" has been used over the years to describe what to the casual observer appears to be individual breeding units within each rookery, the harem concept cannot be applied to the behavior of fur seals in the true sense of the word. In reality, the territorial male does not "collect" females, but rather the groups "... result more from the gregariousness of the females than from the efforts of the 'harem master' " (Peterson 1968:36).

Beginning in 1966 and continuing through 1974, the classifications of adults were expanded to include four kinds of idle males and one corresponding to harem males as follows:

Idle Males.—Class 1 Shoreline—Full-grown males without females but apparently with established territories at the high tide mark. Most of these animals are of estimated age 10 yr and older. Class 2 Territorial without females—Full-grown males without females (or pups) but with established territories on the rookery. Most of these animals are also approximately age 10 yr and older. Class 4 Back fringe—Males with neither females nor territories that are found along the inland fringe of the rookery. Most of these animals are partly grown at estimated ages 7, 8, and 9 yr (Johnson 1968). Class 5 Hauling ground—Males with neither females nor territories that are found on traditional hauling grounds. Most of these males are partly grown at estimated ages 7, 8, and 9 yr.

Harem Male.—Class 3 Territorial with females—Full-grown males with one or more females (or pups) and established territories on the rookery. Most of these animals are age 10 yr and older (Johnson 1968).

Since 1975, classes 1 and 4 have been combined with class 5 into a single count because it was found that although there was no problem in identifying the animals belonging to classes 1 and 4, there was no useful application of the results. Classes 2 and 3 were continued as is, so that there are now classes 2, 3, and 5.

The following summarizes the classifications of adult males used from 1911 to the present:

1911-65—2 classifications, harem and idle
1) Harem = territorial with one or more females (or pups)
2) Idle = territorial with neither females nor pups and all nonterritorial estimated to be age 7 yr and older.

1966-74—5 classifications as listed above (1, 2, 3, 4, and 5)
1) Class 3 = harem male classification used from 1911 to 1965
2) Classes 1, 2, 4, and 5 = idle male classification used from 1911 to 1965

1975 to present—3 classifications (2, 3, and 5)
1) Class 3 = harem male classification used from 1911 to 1965
2) Classes 2 and 5 = idle male classification used from 1911 to 1965.

In 1966, each rookery (except Ardiguen on St. Paul Island and East Reef on St. George Island) was divided into numbered sections containing approximately 100 harem (Class 3) males (more or less than 100 in certain places where prominent natural boundaries existed). Sectioning the rookeries has since made the counts easier and possibly more accurate.

From 1967 through 1980, the adult males were also counted in late June when most of the females had yet to arrive and disturbance to the rookery is much less. Preliminary comparisons of the counts in June and July indicate a strong correlation between the two, but a decision has not been made as to the possibility of changing to the early count without sacrificing comparability of data collected since 1911.

The only detailed counts available by rookery from 1911 through 1965 are those that might exist in the form of field records. Beginning in 1966, the counts by rookery section have been recorded in the annual reports of fur seal investigations on file at the National Marine Mammal Laboratory.

Marks.—Fur seals of both sexes have been marked by various methods and for different reasons on the Pribilof Islands since 1870 (Scheffer 1950b; Roppel and Davey 1965). However, the most ambitious marking program ever carried out there was one involving 863,584 pups over a span of 36 yr from 1940 through 1975, with about 80% of the marks applied to animals on St. Paul Island and 20% to those on St. George Island. There were only five seasons during this period when pups were not marked on a large scale. Information obtained from returns of these animals to the commercial harvest at ages 2-5 yr since 1940 was intended primarily for use in studies of growth and migration patterns as well as making estimates of the number of pups born from marked to unmarked ratios. An additional benefit came from the marking program through the accumulation of information on the degree to which fur seals tend to return to their island and rookery of birth (Marine Mammal Biological Laboratory 1969).

The use of tags to mark pups was largely experimental up to about 1950 with respect to size, type, and metal content (Kenyon 1949;[38] Scheffer 1950b). Tags of Monel Metal manufactured according to certain specifications (Abegglen et al. 1960[39]) were eventually found to be most suitable and were used to mark the pups beginning in 1949, each of which was also given a checkmark for use in identifying the animal at an older age should its tag become lost. Checkmarks were made by removing part of a flipper.

Tagging was not without its disadvantages, many of which surfaced early in the program. Scientists working with fur seals of the Pribilof Islands eventually realized that tag-caused mortality, tag loss as well as overlooked tags and checkmarks potentially could all combine to produce inflated estimates of the number of pups born (Abegglen et al. footnote 31; Roppel et al. 1963).

In his studies of the problem on St. Paul Island, Keyes (1962,[40] 1966[41]) pointed to overexertion and stress as possible causes of mortality among pups driven to suitable tagging sites, as well as infection from attachment of the tags themselves and impairment of limb function as a result of improper placement. Abegglen et al. (footnote 39) reexamined the carcasses of several hundred harvested seals on St. Paul Island and found that 6% of the available 1,691 tags and checkmarks (a notch, slit, hole, or other mark made on a seal flipper to ensure recognition of an animal that had lost its tag—such marks were used without tags during 1969-75) had been overlooked during the recovery process. Improperly applied checkmarks, which were difficult or impossible to identify at the ages of harvest, appeared most frequently among those overlooked. Because of uncertainties about the recovery of all available checkmarks from seals that had lost their tags, the NPFSC proposed that the United States double tag some of its pups in 1958 to determine rates of tag loss. Thus, 5,000 were so treated in that year (Abegglen et al. footnote 33).

[38]Kenyon, K. W. 1949. Report on the tagging of fur seal pups, St. Paul Island, Alaska, season of 1949. Unpubl. manuscr., 14 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Branch Wildl. Res. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[39]Abegglen, C. E., A. Y. Roppel, and F. Wilke. 1960. Alaska fur seal investigations, Pribilof Islands, Alaska. Report of field activities, June-October 1960. Unpubl. rep., 165 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[40]Keyes, M. C. 1962. Mortality among fur seal pups, St. Paul Island, Alaska, 15 August to 10 September 1962. Unpubl. rep., 24 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[41]Keyes, M. C. 1966. Research in fur seal mortality, St. Paul Island, Alaska, 19 July to 3 September 1965. Unpubl. rep., 97 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

Marking effort and size of the labor force used to carry out the program was reduced beginning in 1963 with the belief that devotion of more time to each pup would result in gentler handling and better placement of the tags with attendant lower mortality among the animals involved (Roppel, Johnson, and Chapman 1965). Even so, information obtained from the recoveries of these animals and from the double tagging experiment of 1958 led to additional doubt as to the validity of data based on returns. Thus, beginning in 1969, scientists were prompted to abandon the application of tags altogether in favor of physical marks only (Marine Mammal Division 1976[42]). This program, in turn, was abolished in 1975, partly because of known disadvantages, but primarily because the United States adopted the view that the recoveries of marked animals were too few for solving questions with respect to the intermixture of seals of different origins on land and at sea and, also, because a new and improved method of estimating the number of pups born had by then been developed.

Regardless of how the pups are marked, mid-September or later seems to be the best time of the season for doing so, apparently because the animals are larger and older and better able to withstand fright and the stress of handling. Because of a growing suspicion that perhaps the survival of these animals would be improved if tagged later in the season (as they had at various times since 1945), half of the pups marked on St. Paul Island in 1963 and 1964 were tagged in August and half in mid-September. As predicted, the recovery rate in the harvest 3 and 4 yr later for tags applied to pups in September was significantly higher than for those applied in August (Marine Mammal Biological Laboratory 1970a).

Evidence that marking and even handling of the pups actually affects growth rates first appeared in 1962 when a weighing program started in 1957 with a different objective was modified to include three weighings a month apart, the first about 1 wk after tagging. The results showed that tagging causes an immediate loss of weight among tagged pups but that this loss is at least partially overcome 2 mo later (Roppel et al. 1963). Additional data followed when it was learned that tagged and checkmarked pups weighed less than untagged and unmarked pups each year from 1957 through 1965. In 1965, untagged pups marked by removal of part of the hind flipper also weighed less than pups given no marks at all. These discoveries were carried further in 1966 by means of an experiment that involved shearing patches of fur from the rumps of 800 pups (small groups of pups were driven as short a distance as possible and held in three-sided barricades for shearing) then weighing samples of sheared (handled) and unsheared (unhandled) animals 13 d after marking. Again, pups driven a few yards and sheared, while held on the ground, weighed less than did those that were not handled in any way (Marine Mammal Biological Laboratory 1969).

In addition to the pups, several hundred yearling fur seals and males of ages 2-4 yr were marked during 1961-71 on St. Paul Island because of the potential of these programs in producing information on mortality at sea (Abegglen et al. footnote 34; Roppel et al. 1963). Tagging of yearlings was begun in 1961 by Peterson[43] and continued by the staff of the Marine Mammal Biological Laboratory in following years mostly because of the reason just given but also because the only previous comprehensive study of this element of the herd was conducted by Wilke and Banner (1941).[44] Over 5,000 fur seals presumed to be yearlings were double tagged during the 7-yr period ending with 1967 and nearly 3,000 males of ages 2-4 yr were so treated in 1966 and 1967. Relative size of the animals, color of the pelage, and behavior and appearance were used in combination to identify yearlings from older seals in 1961. Beginning in 1962, body length was found superior as a guide in selecting yearlings and was used thereafter. Only those females 95 cm or less and males 100 cm or less were considered yearlings (Roppel et al. 1963). In all cases true ages of the yearlings (and males of ages 2-4 yr) were determined after the fact from maxillary canine teeth collected from survivors subsequently taken in the harvest (Marine Mammal Biological Laboratory 1970a).

Gentry (1979,[45] 1981) marked and branded juvenile males for studies of land-sea movements as did Griben (1979) to obtain information on interisland (St.Paul - St.George) movements of these animals.

Estimates of Population Size.— Until 1896, estimates of population size were based on density and areal measurements. According to Jordan (1898, footnote 46), Captain Charles Bryant, a Government agent detailed to the Pribilof Islands in 1869 to investigate the condition of the herd, made the first attempt at enumerating the seals on the basis of space occupied by animals, not including pups. Smithsonian artist/naturalist Henry Wood Elliott arrived in 1872, as an agent of the Treasury Department, to study the herd. His estimate of pup production and of the numerical size of other elements of the total herd was based on an average of 2 ft^2 (0.2 m^2) of rookery space occupied by every seal whether adult male, female, or pup (Elliott 1884). When applied to total rookery area as computed by himself and added to an estimate of the number of nonbreeding animals, Elliott was convinced that all classes of animals totaled no less than 4,500,000 in each of the years 1872-74. It was generally believed at the time that conservation measures as practiced by the Russians following their near annihilation of the herd by the early 1800's had by 1867 returned the population to its pre-discovery level. Even so, a total population of 4,500,000 (breeding and nonbreeding seals included) was discounted by Jordan (1898) as not necessarily based on sound scientific facts and measurements. In this connection, I once had the opportunity to view one of Elliott's original water colors depicting seal life on Lukanin Rookery of St. Paul Island in which he had virtually covered the entire slope and top of the hill behind this breeding ground with fur seals. Had this been true historically, the exposed rocks most assuredly would have been worn smooth by the overland movement of thousands of seals throughout the centuries. This was not so. Those rocks were and still are as rough as the day they were formed, a fact that lends credence to the contentions of Jordan that Elliott's estimates were grossly exaggerated. In 1886, George R. Tingle, then Treasury Agent on St. Paul Island, also disagreed with Elliott's estimate in

[42]Marine Mammal Division. 1976. Fur seal investigations, 1975. Unpubl. rep., 115 p. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Cent., Mar. Mammal Div. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[43]Peterson, R. S. 1962. Report and analysis of yearling recoveries and tagging, St. Paul Island, 1961. Unpubl. manuscr., 19 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[44]Wilke, F., and A. H. Banner. 1941. Recovery of branded yearlings. Unpubl. manuscr., 5 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.).

[45]Gentry, R. L. 1979. Land-sea movements of juvenile males. *In* Fur Seal Investigations, 1978. Unpubl. rep., 84 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[46]David Starr Jordan, President of Stanford University, headed a special commission authorized and funded by the U.S. Congress to document the depleted condition of the herd and the cause of its threatened destruction with studies undertaken in 1896 and 1897.

that he considered the space assigned by the latter to the individual animal as too small. He therefore reduced his own estimate of breeding seals and young by one-fourth to 4,768,430, a figure which nevertheless exceeded Elliott's estimate of 3,193,420 for the same group by 1,575,010 animals (nonbreeding seals were not included in either estimate).

Other investigators of herd size followed with equally questionable results, including Elliott again in 1890. In its day, the estimate that most likely represented the best numerical level of breeding seals and young was that offered by Jordan (1898). His method was to count all of the harems on all of the rookeries at the peak of the breeding season and then to multiply that figure by the average harem size counted on some typical rookery space.[47] In doing so, Jordan (1898, vol. 1, p. 98) suggested that there were "... a total of 262,850 'breeding seals and young' at one time or another on the rookeries of the Pribilof Islands during the past season [1897]." Because the nonbreeding animals were not necessarily available for counting, he was forced to theorize their numerical strength, which, when added to the above figure, brought his estimate of total herd size to 402,850 in that year.

In 1914, Wilfred H. Osgood of the Field Museum of Natural History in Chicago, Ill., Edward A. Preble, Bureau of Biological Survey in the Department of Agriculture, and George H. Parker, Harvard University, were engaged by the Department of Commerce and detailed to the Pribilof Islands for the purpose of investigating the Alaskan fur seals and related questions. Prior to their investigation, Osgood et al. (1915:27) "... found that unpublished charts showing the number and approximate position of the harems on each rookery had been made in 1912 and again in 1913 by Special Investigator G. A. Clark. These charts showed the contours of the topography as surveyed by the United States Coast and Geodetic Survey and also indicated the position of the rocks on which conspicuous numbers were painted at the time of the survey." In their historical account of the scientific study of the Alaskan fur seal, Scheffer et al. (in press) mentioned that these numbers were painted on the rocks in 1897 and that they "have been renewed at intervals down to the present [year]." They also stated that there were numbered (and lettered) camera stations, although those of the 1890's were not "exactly those in use today." The rookeries (on St. Paul Island) were last photographed (by Ford Wilke and Alton Roppel) from some of these "stations" in 1960.

Total counts of pups were made on all rookeries from 1912 through 1916 and in 1922, and additionally on a few rookeries during 1917-21 and in 1924 (Lander 1980a). By inference and in conjunction with such other actual counts as those of the adult males (described later), estimates were made of all classes of fur seals.

The counts of pups were abandoned after 1922 because their number had by then become too large for an accurate census on all but four relatively small rookeries. Instead, an annual increase of 8%, the rate observed between 1912 and 1922, was used up to about 1940. Several years later, however, it was learned that use of this method was in error because the actual rate had diminished to $< 8\%$ per year after 1930.

A new technique for estimating year-class size was developed beginning in 1941 with the use of metal tags to mark 12,000 pups in that year on St. Paul Island. This relatively large-scale marking program, interrupted by World War II and resumed in 1947, was used into the 1960's to determine the number of pups born from tagged to untagged ratios among harvested males. Tagged and untagged ratios were also used to estimate the total size of the herd and develop a life table for males and females (Kenyon footnote 11).

The first attempt at enumerating fur seals on the Pribilof Islands through the use of aerial photography came in 1938 when Administrative Superintendent Harry J. Christoffers took motion and still pictures of a few of the rookeries from a U.S. Coast Guard aircraft. Scheffer followed in 1945 with additional photographs from a U.S. Navy PBY airplane. According to Kenyon (1951),[48] neither experiment produced useful results. The year 1948 saw the first complete coverage of all fur seal rookeries with photographs from a U.S. Fish and Wildlife Service twin-engine aircraft (Kenyon 1948[49]). During 1947-49, Scheffer and Kenyon (1948,[50] 1950[51]) suspended a camera from a tethered balloon over Northeast Point Rookery of St. Paul Island, also for the purpose of obtaining photographs for counting seals. Wilke and Kenyon (1951)[52] reported on the use of a U.S. Navy helicopter in 1951 from which to take a few photographs. From the results, Kenyon (footnote 52) concluded that as a photographic platform the helicopter showed promise. Complete coverage of all rookeries occurred again in 1967 when the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) contracted with the Bureau of Land Management to take photographs, with Alton Roppel aboard as adviser and observer (unpublished material on file, Northwest and Alaska Fisheries Center, National Marine Mammal Laboratory). The results of this latter venture were generally superior to the foregoing experiments in that they were useful in delineating boundaries of the rookeries; however, they were, for the most part, equally unsatisfactory for determining numerical abundance of the animals.

In 1950, Kenyon began preliminary trials with what he called "rapid field estimates of living pups" and in 1951 produced an estimate of total year-class strength based on this method (Kenyon et al. 1954). From a suitable vantage point, observers simply estimate the number of pups on the rookery before them. The method has the advantage of speed: 5,000-10,000 pups can be estimated per hour. In using this technique a second and final time in 1954, however, Kenyon (footnote 11, p. 17) stated that "Their value is questionable because of their highly subjective nature."

The most satisfactory of all the methods so far developed for estimating the number of pups, regardless of numbers, has been one involving marking then sampling living animals for marked/unmarked ratios (Chapman and Johnson 1968), to which must be added the count of dead pups to arrive at the total number born. This type of program superceded a mark/recapture technique used on the

[47]The herd had by this time been considerably reduced in size through pelagic sealing and was correspondingly much easier to work with in terms of determining numerical levels of the various components.

[48]Kenyon, K. W. 1951. Aerial photography of fur seals from a Navy helicopter. Unpubl. manuscr., 4 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[49]Kenyon, K. W. 1948. Preliminary report of aerial photography of fur seal breeding areas on the Pribilof Islands, July 14-15, 1948. Unpubl. manuscr., 6 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[50]Scheffer, V. B., and K. W. Kenyon. 1948. Research on the Alaska fur seal herd, 1948. Unpubl. rep., 49 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[51]Scheffer, V. B., and K. W. Kenyon. 1950. Research on the Alaska fur seal herd in 1949. Unpubl. rep., 24 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[52]Wilke, F., and K. W. Kenyon. 1951. Alaska fur seal investigations, Pribilof Islands, Summer of 1951. Unpubl. rep., 25 p. U.S. Dep. Inter., U.S. Fish Wildl. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

Pribilof Islands for several years. It is superior in that it permits an estimate of year-class strength during the summer of birth rather than 4-5 yr later when the animals are harvested and eliminates most or perhaps all of the problems associated with the latter. The mark/recapture program was a key element used by Kenyon et al. (1954) in producing an estimate of the total population.

The marking/sampling program, which was developed on St. Paul Island, first used pups that had been given tags as usual in 1960 and 1961. The objective of the small-scale study in 1960 was to test the feasibility of the technique in producing satisfactory estimates of year-class size. As followed in that year, the procedure was first to complete the total tagging program, wait a few days for tagged and untagged animals to intermix, then count approximately 25 pups at each of 14 stations on Zapadni Reef Rookery and 17 stations on Little Polovina Rookery and record the number tagged within each sample (Abegglen et al. footnote 39). This technique was repeated on three rookeries in 1961 and expanded in that year to include a modified version that was carried out on all rookeries of St. Paul Island. The latter technique also employed the use of tagged pups, but with this difference: Successive groups of pups were rounded up along the length of each rookery, then 100 in each were driven between two observers who recorded the number tagged (Abegglen et al. footnote 34).

There were three known disadvantages associated with either version of the tagging/sampling program. First, large-scale tagging of pups was necessarily carried out on certain areas of the rookeries where the animals were most abundant, which produced "lumping effects" within the population and consequently within the samples. Thus, samples of counted pups were heavily saturated with marked animals in and around the areas of tagging but were without marked individuals elsewhere. Second, pups with tags attached to their flippers were difficult to identify because the tags were next to the ground and the animals tended to crowd closely together, behavior that obscured this type of mark from view by the observer. Finally, loss of unclinched tags or the deaths of some of the marked animals produced inflated estimates.

The most promising of the two methods tried in 1960 and 1961 was the counting of groups of 25 pups along transect lines systematically distributed throughout each rookery (Roppel et al. 1963). These transects were permanently marked with steel stakes in 1966 (Marine Mammal Biological Laboratory 1969). The primary advantage of this method was that about 500 pups/man-hour could be sampled compared with only 200/man-hour using sample sizes of 100. For this reason, the smaller sample size was used throughout the rookeries on St. Paul Island in 1962. Still, it had all of the disadvantages as outlined above.

In 1963, known disadvantages of the program were eliminated by marking the pups through shearing guard hair from the heads to expose the light-colored underfur and by randomizing the marking and sampling efforts (Chapman and Johnson 1968; Roppel et al. 1963). The new mark not only was not susceptible to loss as were the tags but was also highly visible during the counts. The latter advantage, however, was not totally satisfactory at first because the observers tended to begin their counts with pups marked in this fashion, which renders them extremely conspicuous. To eliminate selection for marked and perhaps unmarked pups, persons making the census were instructed to begin each count at a fixed object such as a log, rock, or dead animal and then count the nearest 25 pups and record the number marked within the group.

The only known and proven way to check the accuracy of estimates of pup production based on shearing/sampling is to make total counts of the living animals, which in terms of current herd size is possible only on the smallest rookeries. The first check was made in 1964 with counts on three small rookeries and an isolated section of a fourth. Estimates based on shearing/sampling varied from −4% to +17% of the counts on the three rookeries and +26% of the number counted on the isolated section (Roppel, Johnson, Anas, and Chapman 1965), with a mean of +5% for all four. The estimate was 91% of the count on these same rookeries in 1965 (Roppel et al. 1966) and 105% in 1966 (Marine Mammal Biological Laboratory 1969). Total counts of pups were made on some, but not all, of these small rookeries in following years as well.

The shearing/sampling program and other methods used to estimate the number of pups born on the Pribilof Islands have been fully analyzed by York and Kozloff (1979),[53] who suggested that the shearing/sampling program may be selective for younger pups, i.e., they are still totally on land and available for marking whereas some of the older pups are venturing into the water at the time of shearing (Kozloff 1981[54]). York and Hartley (1981) concluded from their study that 62,300 or 70% of the 89,000 decline in the number of female pups born on St. Paul Island (224,000 during 1950-56 to 135,000 by 1962) can be traced directly to the herd reduction program for females in effect on that island beginning in 1956. Their analysis does not explain the remaining 30% decline. In another analysis, however, Eberhardt (1981) discussed density dependence combined with the effect of harvesting females. Lander (1980a) gave estimates of pup production from 1912 through 1979 for the Pribilof Islands.

A preliminary study of the weights of sheared and unsheared pups in 1980 supports the results of previous experiments that showed that male pups are significantly heavier than female pups and that there are major differences in pup weights between rookeries. In addition, sheared pups weighed less than unsheared pups (Kozloff footnote 54). The effect of these weight differences, if any, on estimates of pup production need further study.

Pup Weights.—Fur seal pups were weighed annually on St. Paul Island from 1957 through 1971 in an effort to learn whether average body weights in autumn vary from one year class to another and, if so, what influence these differences might have on survival at sea. The animals were weighed on about the same dates each year, i.e., late August-early September, and on the same rookeries—Northeast Point, Polovina, Reef, and Zapadni Reef. Subsequent correlations of pup weights with numerical returns of the year classes to the harvests (Marine Mammal Biological Laboratory 1972[55]) and with body weights and lengths of harvested animals (Abegglen et al. footnote 39) were of little or no value in predicting survival based on average body conditions of pups in autumn.

As with large-scale marking of pups, the weighing of these animals was expedited when carried out in parts of the rookeries with relatively large concentrations of pups. As a result, and because weighing each year followed tagging, many of the pups so handled were also tagged. This fact was recorded as well. As

[53] York, A. E., and P. Kozloff. 1979. Estimation of numbers of fur seal pups born on St. Paul Island. Unpubl. manuscr., 27 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[54] Kozloff, P. (editor). 1981. Fur seal investigations, 1980. NWAFC Processed Rep. 81-2, 96 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[55] Marine Mammal Biological Laboratory. 1972. Fur seal investigations, 1971. Unpubl. rep., 132 p. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Cent., Mar. Mammal Div. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

previously discussed, it was later discovered that the tagged pups of both sexes weighed significantly less than the untagged animals.

Mortality.—Fur seals die of many causes but at different rates at various stages of their life cycle. Most losses, some of which have been documented by Scheffer (1950c), occur at sea; Lander (1975, 1979) described a method of determining natural mortality in northern fur seals and analyzed its influence on the size of the commercial harvest.

Mortality following birth of the pups begins on the breeding grounds, where multiple hemorrhage-perinatal complex (hemorrhage of internal organs "around birth," especially of the liver) emaciation syndrome (malnutrition from varied causes), hookworm disease, microbial infections, and trauma account for most of the deaths (Doyle 1957;[56] Engle et al. 1980;[57] Keyes 1964,[58] 1965, footnote 59, 1966 (footnote 41), 1971, footnote 60, 1972,[61] 1973;[62] Anonymous 1969, 1970a, b; Lander 1980a; Lyons 1963). In past years, 20% (< 10% in most years since 1963) or more of the newborn pups died from various causes during the summer of birth (Baker et al. 1970).

Little information has been collected on causes of death at sea; however, sharks and killer whales are presumed to account for some mortality with disease and starvation of pups playing a prominent but unmeasured role. Bychkov (1967) summarized the views of several scientists with respect to the relationship of the killer whale to mortality of fur seals together with his own observations and concluded that "...it may be assumed that the fur seals do not constitute a substantial portion of the killer whales' diet; while procuring their food, the killer whales do not hunt them regularly, and attack them very seldom, even though such opportunities are present." There is little or no direct information available on the impact of sharks on the fur seal.

Another source of mortality among the pups is predation by foxes and northern sea lions. On three occasions, foxes were observed to attack living pups, severely injuring them (Marine Mammal Division footnote 42); studies of predation by sea lions on St. George Island suggest that mortality from this cause may be significant (Marine Mammal Division footnotes 42, 63).

The advent of extensive foreign fisheries in the Bering Sea and North Pacific Ocean in the 1950's provided additional causes of death among the fur seals. Direct losses as a result of these fisheries come from an incidental take of fur seals. Fukuhara (1974)[64] estimated this catch of fur seals by the Japanese salmon mothership fishery (which uses gill nets) to range between 3,500 and 3,750 annually. Nishiwaki[65] estimated the total incidental take of fur seals to be 7,000 annually. In her extensive analysis of the problem, Jones (1980)[66] estimated incidental takes of from 500 to nearly 8,000 fur seals each year during 1975-79, depending upon the amount of gear fished. An even greater cause of death attributable to high-seas fisheries, however, may be the entanglement of fur seals in scrap trawl webbing and other synthetic material discarded by mariners at sea. The incidence of animals so entangled increased annually from 75 or 0.15% of 50,229 fur seals harvested on St. Paul Island in 1967 to 211 or 0.72% of 29,148 taken in 1975 (Lander 1980a; Kozloff footnote 54). If extrapolated to the total Pribilof Islands population of fur seals (estimated by Johnson (1975) at 1.2 million and by Lander (1981) at 1.25 million), the minimum annual number of animals entangled ranged from about 1,800 to 9,000 annually during the 9-yr period. This estimate is probably conservative because an unknown but additional number of fur seals may have succumbed at sea due to the effects of discarded material around their necks (Fowler 1982).[67]

Fur seals apparently have a penchant for investigating floating debris and putting their heads through circular objects. In the late 1940's and in the 1950's, a few males of harvestable size occasionally appeared on the hauling grounds of the Pribilof Islands wearing rubber rings around their necks. The origin of these rings, which apparently caused little or no immediate damage to the animal because of their elasticity, was never determined, although it was surmised that perhaps each had originally served to reinforce the mouth of a waterproof rubber bag. Scheffer and Kenyon (footnote 50) learned of the possibility that the bags were used by the Japanese for aerial delivery of food and water during the latter years of World War II.

Of much more serious concern has been the aforementioned incidence of entanglement in scrap trawl webbing and uncut plastic bands used on fishing boats and other marine vessels to strap bundles of new netting, crates, etc. In a study of plastic litter on the beachs of Amchitka Island in Alaska, Merrell (1980:175) accumulated evidence during a 3-yr survey to indicate that "Under conditions of large fisheries and attendent accidental loss and deliberate dumping of discarded plastic fishing gear, marine litter accumulates at a rate that exceeds theoretical estimates." Trawl webbing headed

[56]Doyle, L. P. 1957. Investigation of death losses in fur seal pups on St. Paul Island, Alaska, June 28 to August 15, 1957. Unpubl. rep., 10 p. U.S. Fish Wildl. Serv., Bur. Sport Fish. Wildl., Mar. Mammal Biol. Lab., Seattle, Wash. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[57]Engel, R. M., R. H. Lander, A. Y. Roppel, P. Kozloff, J. R. Hartley, and M. C. Keyes. 1980. Population data, collection procedures, and management of the northern fur seal, *Callorhinus ursinus*, of the Pribilof Islands, Alaska. NWAFC Processed Rep. 80-11, 212 p. Natl. Mar. Mammal. Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[58]Keyes, M. C. 1964. Research in fur seal mortality, St. Paul Island, Alaska, 8 July to 24 September 1963. Unpubl. rep., 140 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.)

[59]Keyes, M. C. 1965. Research in fur seal mortality, St. Paul Island, Alaska, 6 July to 24 August 1964. Unpubl. rep., 48 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115.)

[60]Keyes, M. C. 1971. Pathology (of fur seals). *In* Fur seal investigations, 1970. Unpubl. rep., 155 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[61]Keyes, M. C. 1972. Pathology (of fur seals). *In* Fur seal investigations, 1971. Unpubl. rep., 132 p. U.S. Dep. Inter., Bur. Commer. Fish., Mar. Mammal Biol. Lab. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA.)

[62]Keyes, M. C. 1973. Pathology (of fur seals). *In* Fur seal investigations, 1972. Unpubl. rep., 93 p. Northwest Fish. Cent., Mar. Mammal Div. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[63]Marine Mammal Division. 1975. Fur seal investigations, 1974. Unpubl. rep., 125 p. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Fish. Cent., Mar. Mammal Div. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[64]Fukuhara, F. 1974. Estimated mortality of seabirds, fur seals, and porpoise in Japanese salmon drift net fisheries and sea lions in the Eastern Bering Sea trawl fishery. Unpubl. manuscr., 10 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[65]M. Nishiwaki, University of the Ryukyus, Shuri, Naha City, Okinawa 903 Japan, pers. commun. to Lander and Kajimura in 1976.

[66]Jones, L. L. 1980. Estimates of the incidental take of northern fur seals in Japanese salmon gill nets, 1975-1976. Unpubl. manuscr., 15 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[67]Fowler, Charles W. 1982. Interactions of northern fur seals and commercial fisheries. Unpubl. manuscr., 30 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

his list in terms of weight, and strapping material was third numerically.

Once encircled about the neck of a fur seal, these nonelastic and extremely durable materials are prone to remain there indefinitely or until death of the animal. If anything, they tend to work their way over the posteriorly sloping guard hair and become even further entrenched with no possibility of removal except by the hand of man. With time and growth of the animal, the material deeply girdles the neck into the flesh. Death may come to the wearer very early, not from infection and perhaps choking as certainly would be the case later, but from impairing the animal's ability to swim and to catch food. Some of the fur seals appearing on the breeding grounds have massive amounts of trawl webbing about their necks.

Convinced that entanglement (principally in polypropylene trawl webbing) was definitely a factor of considerable importance in the survival of fur seals at sea, the NPFSC carefully reviewed the subject at several of its annual meetings (North Pacific Fur Seal Commission 1971, 1974, 1976-80) and instructed its members to develop posters and written material for distribution to their respective fishing industries in an attempt to explain this dilemma and persuade fishermen to delay disposal of their waste until they reach port. Whether the distribution of posters was wholly or even partly the cause of a decline beginning in 1976 in the number of entangled fur seals harvested on St. Paul Island will probably never be known. In that year, however, the proportion dropped to 0.44% from a high of 0.72% in 1975. The following year saw an even further decline to 0.35% and from 1978 through 1980 the average was 0.45%. Enactment of the U.S. Magnuson Fishery Conservation and Management Act of 1976, which established a 200-mi (322 km) fishery conservation zone in which foreign fishing vessels are controlled may also have been a factor in the decline.

Although polypropylene trawl webbing has no national markings, it is assumed to be of Japanese or Soviet origin because trawl fishing in the North Pacific Ocean and Bering Sea has been primarily by vessels of these two nations (Merrell 1980). Another aspect of the trawl web story is that the U.S.S.R. has used polyethylene netting, which sinks. This fact gives rise to the question of whether fur seals also become entangled in debris on the bottom. Problems associated with entanglement have been described and the data summarized by Fiscus and Kozloff (1972),[68] Sanger (1974),[69] Bigg (1979),[70] Kozloff (1979),[71] and Fowler (footnote 67).

The only direct measure of the mortality of fur seals is through counts of dead animals when they are on the breeding grounds. The most important[72] of these has been the partial and total counts of dead pups on the Pribilof Islands in various years following acquisition of these lands by the United States in 1867. Counts during the early 1900's, which were usually made in conjunction with censuses of the living pups in late July and early August, tended to produce underestimates of mortality. This was not learned until 1951 when it was demonstrated that it is not until 15-20 August that the death rate on land declines to insignificance. These dates have since been reconfirmed.[73]

In an effort to reduce the amount of time needed to make total counts of dead pups and to eliminate much of the disturbance associated with this activity, sample areas were established on all except the four smallest rookeries on St. Paul Island in 1956 (Abegglen et al., footnote 15). Each of these areas contained approximately 30% of the total number of dead pups on a given rookery. Although records were kept for several years of the number of dead pups counted within the study areas for comparison with total counts made during those same years, the study areas were never used alone as a basis for estimating the total number of dead pups.

In 1966, the rookeries on the Pribilof Islands were subdivided into numbered sections containing approximately 100 harem males each to facilitate the counting of adult male fur seals and the distribution of marking effort during surveys to estimate the number of live pups. Since that year, the dead pups have also been counted by section to determine if there are relationships between pup mortality and such factors as density of harem males.

An unknown number of dead pups are not "seen" during the count each year due to removal by foxes, gulls, the heavy surf generated by storms, and through advanced decomposition of those born early in the season which makes identification difficult or impossible, and simply because the counters inadvertently overlook some of the dead pups as they work their way through each rookery.

An attempt has been made to account for dead pups overlooked during the counts by increasing the actual number counted by 5% in the various reports. Abegglen et al. (footnote 39, p. 49) checked the validity of the 5% addition by reexamining Morjovi Rookery immediately after the count and found that 5.9% had been overlooked. According to their report, "This agrees closely with the standard 5 percent addition, though the number of dead pups missed would probably vary from none on sand or [cobblestone] beaches to many on boulder beaches. For example, during the 'clearing off' of dead pups on Zapadni Reef Rookery, [boulders and cobblestone] 10 percent were overlooked. On Little Polovina Rookery, [sand and cobblestone] a negligible number were missed during the [removal of dead pups]. . . . The surface of Morjovi Rookery varies from sand to [cobblestone]."

Other possible causes of mortality among fur seals at sea, besides starvation, are the increasing amounts and kinds of pollutants added to the marine food chain by man. According to Klein and Goldberg (1970), 4,000-5,000 tons of mercury are contributed annually by man to the environment in addition to the 5,000 tons of this element transferred to the oceans by continental weathering. In their research on fur seals, Anas (1974), Anas and Wilson (1970a, b), and Anas and Worlund (1975) analyzed samples of liver, muscle, brain, and kidney tissue not only for mercury but for other heavy metals such as lead, cadmium, and arsenic as well as organochlorine pesticides. General results were that the levels of mercury were much higher in liver than in other tissues, that this element was significantly correlated with age, and that pesticides were found in every sample examined. The relationship of these pollutants to mortality of fur seals, however, has not yet been identified.

[68]Fiscus, C. H., and P. Kozloff. 1972. Fur seals and fish netting. *In* Marine Mammal Biological Laboratory, Fur seal investigations, 1971, Appendix E, p. 124-132. Unpubl. rep. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[69]Sanger, G. A. 1974. On the effect of fish net scraps and other oceanic debris on northern fur seals. Unpubl. manuscr., 4 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[70]Bigg, M. 1979. Incidence of adult northern fur seals entangled in debris on St. Paul Island, 1978. Unpubl. manuscr., 5 p. Dep. Fish Environ., Fish Mar. Serv., Resour. Serv. Br., Pac. Biol. Stn., Nanaimo, B.C., Canada.

[71]Kozloff, P. 1979. Fur seals entangled in fishing debris and other materials. Unpubl. manuscr., 5 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[72]Dead fur seals of both sexes that are older than pups are also counted each year and their canine teeth collected for studies of age at death. These numbers are relatively small.

[73]R. Gentry, Wildlife Research Biologist, National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115, pers. commun. November 1981.

Forecasts.—It should be mentioned at the outset that forecasts of the size of the commercial harvest of male fur seals on the Pribilof Islands were never intended to be anything more than that. Nevertheless, many persons, including some closely involved with fur seals, have come to look upon the forecasts as quotas, such as those that were in effect from 1870 through 1909 and again from 1918 through 1923. Quotas have not been established since 1923, except for females during 1956-68 (Roppel and Davey 1965).

Forecasts of the returns of male seals started in 1960 when D. G. Chapman, through a contract between the Marine Mammal Biological Laboratory (now the National Marine Mammal Laboratory) of the Bureau of Commercial Fisheries and the University of Washington, was asked to predict the size of the commercial harvest in 1961. These forecasts have essentially been attempts to estimate the survival of the year classes to ages 3 and 4 yr so as to better enable managers to plan for materials, equipment, and the off-island labor force needed to take and process the skins. Success in forecasting requires reasonably accurate information on: 1) Number of pups born, and 2) mortality of pups on land, and annual mortality between the time they leave the rookeries in November of the summer of birth and their return at ages 3 and 4 yr.

Major obstacles to success in predicting year-class returns have been variability in mortality and lack of adequate data for estimating losses at sea, which have a much greater influence on the magnitude of returns than do those that occur on land. Forecasts of the kill have been reasonably accurate and useful when based on year classes with average survival, but of no practical value for those with extreme variations in numerical levels. Such predictions, therefore, are of little or no use unless these extremes can be estimated with accuracy.

Forecasts of the return of 4-yr-olds have been based on the kill of 3-yr-olds the previous year, mean air temperature on St. Paul Island for 12 mo preceding birth of the year class,[74] weights of pups in autumn, number of pups born, counts of dead pups and harem males, and estimates of yearling males. Most of these factors have also been examined with respect to forecasting the return of 3-yr-olds.

The kill of 3-yr-olds should be a good basis for estimating the return of the year class a year later at age 4 yr. However, this indicator has suffered certain inaccuracies as a result of changes in termination dates of the kill and variations in the time of arrival on land of the 3-yr-olds.

Forecasts of the kill at age 3 yr have been even more difficult and uncertain because the number available on land at age 2 yr as a basis for making predictions is relatively small, at least during the traditional period of the harvest in July.

A potential indicator of the number of males surviving their first winter at sea is the number of yearling seals that come ashore in autumn. Problems encountered in the use of this measurement include: 1) Difficulty in marking an adequate number of yearling male seals, 2) relatively small kills the following year of 2-yr-old males that had been tagged as yearlings, and 3) bias should tagged animals be killed more frequently than those without tags.

Mean air temperature in the year preceding birth of a year class, weights of pups in autumn, number of pups born, and counts of dead pups are all collected before the year class suffers a substantial part of its losses. Therefore, if the factors that influence survival at sea cannot be measured, data collected on land have little value for forecasting.

Erratic management of the seal kill on land has at various times in the past also contributed to the difficulty in making useful forecasts. There have been few good reasons for varying the termination date of the kill. The onset of molt is not known to cause problems through any extensive variations from year to year (Scheffer and Johnson footnote 36) and unless future studies indicate otherwise, there is no real financial advantage in emphasizing utilization of the year classes at age 3 rather than age 4 yr (Marine Mammal Biological Laboratory footnote 23). The only known reasons for varying the termination date of the harvest are: 1) The possibility of an exceptionally large survival of a year class, making it necessary to take more at age 3 yr, 2) significant variation in timing of the returns of 3-yr-olds, 3) a rather dubious need to take additional 2-yr-olds, even if available, as a way to improve the forecast of the kill the following year at age 3 yr, and 4) to increase (or decrease) recruitment of males into the breeding reserve.

The actual and forecasted returns of male seals during 1961-81 are presented in Table 4, and methodologies used in making these predictions are on file in various annual reports of fur seal investigations and other documents at the National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center. Also on file is a summary of estimation procedures developed by Chapman (1975)[75] as a background paper for the 19th meeting of the NPFSC in 1976.

Socioeconomic Factors

Fur seals of the Pribilof Islands are subject to disturbance from various groups of people, including tourists, Coast Guard personnel, research scientists, photographers, and the Aleuts. Officially, the rookeries, hauling grounds, and certain parts of adjacent beaches are closed to all but authorized persons each summer from 1 June through 15 October. Regardless, several changes have in the past and undoubtedly will in the future contribute to some disruption of these animals on their breeding grounds.

Located in an extremely remote part of the world, the Pribilof Islands were once seldom viewed by anyone other than federal officials and the people who lived there or landed to work with the fur seals.[76] Construction of a runway and the beginning of air service to the islands in the 1950's, however, opened the way to tourism, an industry that in its infancy brought only 5-6 sightseers weekly and perhaps as many as 100 to St. Paul Island during an entire summer. Now promoted commercially as part of their overall tourist package, Alaska Tour and Marketing Services, Inc., annually brings in up to 1,000 people interested in marine birds and fur seals. St. George Island may be added to Alaska Tour and Marketing Services' list of tourist attractions; however, the existing runway on St. George Island is suitable only for small twin-engine aircraft. Two studies were started on St. George Island in 1981, one on the feasibility of extending the runway to accommodate four-engine

[74]Hookworm larvae were once thought to overwinter in rookery soil and infect the following year class of pups through their flippers and that perhaps weather had some influence over the number of these larvae, the degree to which the pups were infected, and death rates (Abegglen et al. footnotes 31, 33). It has since been learned that free-living hookworm larvae do in fact penetrate the flippers. This occurs predominantly in August by larvae produced by the pups themselves. Mortality of pups from hookworm disease, however, is actually caused from 3rd stage larvae passed from mother to pup through the milk, and overwintering of larvae is unimportant (Lyons 1963).

[75]Chapman, D. G. 1975. Methods of forecasting the kill of males on the Pribilof Islands. Unpubl. manuscr., 10 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[76]All other visitors to the islands were required to have permits issued under the authority of a succession of federal agencies beginning with the Treasury Department in 1869. The permit system was in effect from that year to about 1964, at which time it was abolished.

Table 4.—Actual and forecasted kills of 3- and 4-yr-old male seals and relative error [error = (forecast - actual)/forecast] of the forecast, St. Paul Island, Alaska, 1961-81.

	Age (yr)					
	3		4		Total	
	Number	Error (%)	Number	Error (%)	Number	Error (%)
1961						
Actual	29,523		12,488		42,011	
Forecast	34,500	14	13,500	7	48,000	12
1962						
Actual	25,098		13,422		38,520	
Forecast	36,000	30	11,000	−22	47,000	18
1963						
Actual	11,596		12,283		23,879	
Forecast	30,000	61	15,000	18	45,000	47
1964						
Actual	22,203		10,509		32,712	
Forecast	24,000	7	13,000	19	37,000	12
1965						
Actual	12,126		9,838		21,964	
Forecast	26,000	53	13,000	24	39,000	44
1966						
Actual	25,535		12,156		37,691	
Forecast	26,000	2	14,000	13	40,000	6
1967						
Actual	26,991		11,785		38,776	
Forecast	27,500	2	14,300	18	41,800	7
1968						
Actual	18,706		13,279		31,985	
Forecast	22,000	15	13,000	−22	35,000	9
1969						
Actual	17,826		10,565		28,391	
Forecast	23,600	24	18,300	42	41,900	32
1970						
Actual	22,176		11,548		33,724	
Forecast	27,800	20	11,600	0	39,400	14
1971						
Actual	12,888		12,503		25,391	
Forecast	18,000	28	13,000	4	31,000	18
1972						
Actual	15,024		14,932		29,956	
Forecast	19,600	23	16,000	7	35,600	16
1973						
Actual	16,337		10,800		27,137	
Forecast	16,700	2	13,200	18	29,900	9
1974						
Actual	14,652		15,533		30,185	
Forecast	13,000	−13	9,600	−62	22,600	−34
1975						
Actual	15,186		10,768		25,954	
Forecast	16,000	5	16,000	33	32,000	19
1976						
Actual	13,397		8,050		21,447	
Forecast	17,100	22	11,000	27	28,100	24
1977						
Actual	16,476		9,421		25,897	
Forecast	15,700	− 5	11,000	14	26,700	3
1978						
Actual	13,752		8,955		22,707	
Forecast	15,100	9	10,200	12	25,300	10
1979						
Actual	15,245		7,918		23,163	
Forecast	15,500	2	10,600	25	26,100	11
1980						
Actual	13,157		8,183		21,340	
Forecast	17,700	26	8,400	3	26,100	18
1981						
Actual	14,224		6,714		20,938	
Forecast	16,700	15	9,300	28	26,000	19
All years						
Actual	372,118		231,650		603,768	
Forecast	458,500	19	265,000	13	723,500	17

aircraft and another on the impact of these aircraft and tourism on the fur seals there.

Early tourists to St. Paul were largely on their own with respect to moving about the island. The servicing airline provided occasional transportation and a few visitors rented vehicles from local residents, but most walked everywhere they went. Later, federal managers assumed some responsibility for the tourists in the form of transportation and a driver/guide to supply information. At the same time, the servicing airline asked each of its passengers to complete a questionnaire designed to produce information that would assist it and the Federal Government in a bid to help the tourists realize the most from dollars spent. Finally, Alaska Tour and Marketing Services put a bus on St. Paul Island for transporting its customers to places of interest, and federal managers constructed one "blind" on Little Zapadni Rookery and another on Gorbatch Rookery in 1976 from which tourists and others could observe fur seals in safety without disturbing the animals. From 1963 through 1975, people wishing to view fur seals at close range were taken to an observation hut on Kitovi Rookery (Amphitheater) where they caused some disruption among the animals when they wandered away from the hut.

Construction of a Coast Guard loran station on St. Paul in the late 1950's brought an additional 20 people to this island on a year-round basis. Many of them "beachcomb" as a recreational outlet, and in some instances have run seals into the sea from areas closed to the public. In an effort to eliminate or at least minimize this problem, managers have erected appropriately worded signs along access roads and at various points on the beaches and now patrol all of the rookeries and hauling grounds one to four times daily from about mid-June to mid-August each summer.

Before 1962, the people of the Pribilof Islands were paid a token wage supplemented by furnished housing and utilities and such dole as surplus military clothing and footwear. In that year, however, the workers began receiving a full day's pay for a full day's work comparable with that paid others in similar occupations elsewhere in Alaska. Among other material possessions, their new-found wealth translated into various kinds of vehicles which in turn gave the people mobility about the island never before enjoyed. The effect has been one of access to all parts of the islands, including the fur seal rookeries. Visible as a result of this access has been a certain amount of destruction to the landscape, particularly from four-wheel drive units and motorbikes. Not so visible has been disturbance to the fur seals, indicated indirectly by the occasional appearance of fresh tire tread marks on or along certain rookeries and hauling grounds during the closed period mentioned earlier. Increased mobility, especially among those too young to drive, and additional potential for disturbance of the fur seals has come with development of a local motorbike rental business. Installation of gates across roads leading to the rookeries in the 1960's proved to be an unworkable and a locally unpopular solution to the problem, mostly because large areas without fur seals beyond or near concentrations of these animals were also closed to use in summer.

A large number of independent scientists have carried out research on various aspects of fur seal biology in recent years. University professors, postgraduate students, and members of the Scientific Committee of the NPFSC have participated. Some disruption of rookery life has been necessary because of a need to capture fur seals for use as subjects of research and because of construction and use of long catwalks to enhance certain kinds of research.

Another possible source of disturbance to the fur seals is professional photographers. Fortunately, most or all of these people in the past have been interested in filming the animals under completely

natural conditions. It is not inconceivable, however, that some photographers in the future will want or attempt to take "action" shots, which in most situations must be created through disturbance. The adult males are normally given to boundary displays rather than actual fighting unless excited by the presence of humans.

During the summer of 1980, a two-man team from Seattle experimentally fished for Korean horse hair crab, *Erimacrus izenbeckii*, off St. Paul Island; in 1981, the Tanadgusix Corporation (a local subsidiary of the Alaskan Aleut Corporation) began fishing halibut commercially. Both operations would benefit from construction of a small boat harbor on St. Paul Island, a subject that has been given considerable thought for several years and for which a draft environmental impact statement has been developed (U.S. Army Corps of Engineers 1981[77]). So far as is known, the fur seals will not in any way be affected should a harbor be developed at the site now contemplated. However, the protection afforded boats by it may cause a local increase in vessel traffic with unknown consequences to these animals.

Objections to the Harvest

Periodically since the late 1960's, the fur seal of the Pribilof Islands received considerable attention from animal protection groups because of their attempts to stop the harvest on the grounds that it is an inhumane[78] use of the resource. Organizations actively opposed to the harvest were the Humane Society of the United States, Fund for Animals, Friends of Animals, and Greenpeace. The International Society for the Protection of Animals, and World Federation for the Protection of Animals were primarily interested in the humaneness of the kill. The activities of the first four groups have been especially intense each time the Convention has come up for renewal. In this connection, for example, a dozen people, including one U.S. Congressman and two national television network crews, observed the harvest on St. Paul Island in 1979.

Federal managers responded to pressure and publicity brought to bear by these groups with studies of the effectiveness of traditional and alternate methods of stunning and killing the animals, and for several seasons since 1972 have utilized the services of a succession of volunteer veterinarians to observe the harvest to ensure that it was as humane and stress-free for the animals as possible.

The first of the studies was by a veterinary pathologist from the University of Cambridge, England, who was also a representative of the World Federation for the Protection of Animals. Simpson (1968) observed the rounding up of the seals and the harvest, and conducted postmortem examinations of animals on the killing fields and at the byproducts plant where the carcasses were ground and frozen for mink food. Of 1,121 carcasses examined, 21 (1.9%) did not have fractured crania and those without punctured hearts totaled 38 (3.4%).[79] However, the thorax of every seal had been opened, a condition that would lead very rapidly to death from collapse of the lungs and respiratory failure. The conclusions were that none of the seals had been skinned while still alive, that the mechanics of the harvest were reasonably humane, and that the traditional method of stunning by club followed by myocardial puncture is probably the best method of euthanasia considering all of the factors.

In 1968, the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) organized a five-man team of mixed biological professions and one member of the Humane Society of the United States to experiment with alternative methods of killing fur seals and to review the entire seal harvesting operation (U.S. Department of the Interior 1968[80]). The team employed several forms of euthanasia including carbon dioxide, electricity, shooting, stunning, and concussion bolts as well as drugs and tranquilizers. They concluded that none of the methods tested were adaptable to harvesting fur seals at that time. However, the members did recommend several changes that would improve conditions for driving the animals from the hauling grounds to the killing fields and reduce stress on the animals. The panel suggested that the length of the drives be shortened,[81] that the drive paths be improved by removing surface rocks and filling depressions to prevent crowding and pileups of the animals, that seals unsuitable for harvesting be rejected as soon as possible along the drive path, that where possible the animals be driven around rather than over obstacles, and that at least two relief stunners be available to provide rest periods, which in turn should result in greater accuracy in stunning the animals and eliminate the need for multiple blows.

Because the Humane Society of the United States suggested further investigations involving carbon dioxide and nitrogen asphyxiation, the Federal Government contracted with the Virginia Mason Research Center, Seattle, Wash., to carry out experiments on surgically instrumented seals. The objective was to compare the effectiveness of hypoxic atmospheres of CO_2 and N_2, the drug succinylcholine chloride, and the traditional method. Spencer et al. (1971) concluded that the two experimental methods took five to eight times longer to kill than did manual stunning and exsanguination.

In 1971, the National Oceanic and Atmospheric Administration invited six veterinary medical doctors, members of the American Veterinary Medical Association's panel on euthanasia, to evaluate the humaneness of harvesting fur seals and make recommendations for the future. Specific objectives were to: 1) Observe current methods of slaughter from roundup until death occurred and skinning was completed and to assess for humaneness, and 2) suggest research which might lead to more humane methods of euthanasia or methods which might be equally humane but more aesthetically acceptable. With respect to the roundups and drives, the group observed that although obstructions existed in the drive paths in the form of rocks, the seals were accustomed to traveling over this type of terrain on the rookeries. The members also agreed that distances over which the animals were driven were reasonable and did not constitute inhumane treatment. The current method of slaughter, i.e., manual stunning followed by exsanguination, was considered painless, humane euthanasia, a fact that has been overwhelmingly supported by tourists who viewed the kills and reported their feelings in questionnaires routinely handed out by the servicing airline. The panel did, however, suggest that the aesthetics of the operation could be improved by: 1) Shifting the collection of genital organs (a byproduct in demand as an aphrodisiac) from the killing field to the

[77]U.S. Army Corps of Engineers, Alaska District. 1981. Harbor feasibility report, St. Paul Island, Alaska. Unpubl. manuscr., 244 p. U.S. Army Corps Eng., Alaska Dist., P.O. Box 7002, Anchorage, AK 99510.

[78]First objections into the early 1970's were primarily of questioning the humaneness of the killing techniques. After the studies listed were carried out the major emphasis for stopping the harvest changed to one of questioning the moral issue of killing wild animals for profit and luxury skins.

[79]The procedure then and now is to first stun the animal with a blow to the head, then open the chest with a knife and puncture the heart to reduce blood pressure to zero.

[80]U.S. Department of the Interior, Bureau of Commerical Fisheries. 1968. Report of the task force to study alternate methods of harvesting fur seals. St. Paul Island, Alaska. Unpubl. rep., 41 p. (Available Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.)

[81]New access roads and extensions of old ones to shorten the drives were constructed during 1970-71.

byproducts plant, 2) speeding removal of carcasses and skins from the places of harvest, and 3) constructing panels on both sides of the outside portion of the "turkey line" on which the carcasses were suspended at the byproducts plant for processing (Veterinary Panel 1971[82]). The intent of the panel was to shield from public view these three parts of the harvesting operation.

Finally, Battelle Columbus Laboratories were contracted by the National Marine Fisheries Service in 1972 to carry out research on "Concept scrutiny, prototype development, and field evaluation of improved fur seal slaughtering techniques." In a final analysis, their report stated, "the [seal] club emerges as the best technique for stunning fur seals on a mass harvest basis." However, the scientists conducting these studies saw two objections to the club: Aesthetics and inaccurate blows; they felt that a reduction in the number of inaccurate blows should help to improve the aesthetics. Accordingly, the group "recommended that a serious analysis of the clubbing approach be undertaken to determine desirable qualities for fabrication of a 'super club' " (Williams et al. 1973[83]).

Keys (1980)[84] summarized the activities of these various groups in a background paper submitted to the NPFSC at its 23rd meeting.

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