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# SYNTHESIS OF INFORMATION ON THE EFFECTS OF NOISE AND DISTURBANCE ON MAJOR HAULOUT CONCENTRATIONS OF BERING SEA PINNIPEDS

by

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**ABSTRACT**

This study investigated the use of terrestrial haulout sites in the eastern Bering Sea by four species of pinnipeds, northern fur seal, northern sea lion, harbor seal and Pacific walrus. Historical information on the use of each site was summarized. For a few sites there was little or no information about the number of animals present and consistency of use of the site, so we were unable to properly evaluate these.

Available information on the effects of airborne and waterborne noise, and human disturbance (from stationary and moving sources) was reviewed. We also conducted a detailed analysis of the acoustic environment of eight haulout sites. These eight sites were representative of others used by each of the four species studied. The analyses included investigations of (1) characteristics of airborne and underwater ambient noise, (2) characteristics of industrial noise sources, including aircraft, small boats, fishing trawlers and commercial cargo traffic, and (3) sound transmission loss in air, water and through the air-water surface.

Inter-site Population Sensitivity Index (IPSI)

As a means to evaluate the potential vulnerability of each haulout site to noise and disturbance, we developed a quantitative rating system (IPSI) whereby an index of sensitivity was assigned to each site. IPSI values were computed from rank scores assigned to eight categories associated with each site occupied by each of the four pinniped species. The eight categories were (1) the peak count of a particular species of pinniped recorded at a site since 1980, (2) the mean maximum number of animals recorded at a site during the past three decades and during the most recent count at the site, (3) the proportion of the current total estimated Bering Sea population present at a particular site, (4) the age and sex composition, and the kinds of behavioral activities that have been recorded at a site, (5) the duration of use of a haulout site, (6) consistency of use of a haulout site, (7) various physical characteristics of the site, including substrate type, local relief, water depth and proximity to airports, shipping lanes, human settlements, and (8) species characteristics, i.e. susceptibility of animals of this species to noise and disturbance and the potential for mortality. Sites that rated high had high IPSI scores and were considered most sensitive.

Norton Basin Planning Area

There are 14 haulout sites in this planning area; they are used by two of the four species of pinnipeds studied. No northern fur seals or harbor seals haul out in significant numbers here. Twelve of the 14 sites are used by Pacific walrus. Two haulout sites, the one on North Punuk Island, and the one on King Island ranked high in our IPSI evaluation scheme. Northern sea lions have occasionally hauled out at Southwest Cape on St. Lawrence Island and on nearby South Punuk Island. However, there is no current information concerning the use of these sites by sea lions.

St. Matthew-Hall Planning Area

In this planning area 24 haulout sites are used by three of the four pinnipeds studied; there are no northern fur seal haulout sites in this area. Most of the sites (11) are used by northern sea lions, however none ranked high in the overall IPSI evaluation scheme. Pacific walrus sites were second in abundance (8) and four of these, all on St. Matthew or Hall islands, ranked high. Harbor seal sites were least abundant (5) in this planning area, but the site(s) in Kuskokwim Bay ranked relatively high. This area, and the areas to the east near Avinof Point, may be the most northerly major harbor seal pupping areas in the eastern Bering Sea.

North Aleutian Basin Planning Area

This planning area contains 44 haulout sites used by three of the four species studied; no northern fur seals haul out in this planning area. Harbor seals used 22 of the sites including 9 (20%) that rated high in our IPSI evaluation scheme. Twelve sites were occupied by northern sea lions, and at least six (14%) of these were ranked high. Ten sites are occupied by Pacific walrus, and five (11%) of these were ranked very high.

## St. George Basin Planning Area

This planning area has 54 haulout sites used by three species; this is the largest number of haulout sites in any of the four planning areas in the eastern Bering Sea. There are no consistently used Pacific walrus haulout sites, but all 22 northern fur seal haulout sites in the eastern Bering Sea are found here (Pribilof Islands and Bogoslof Island). Seventeen sites are occupied by northern sea lions, and 6 (11%) of these were ranked very high in our IPSI evaluation scheme. At least 15 sites are used by harbor seals, and three (6%) of these (two in the Fox Islands and one on Otter Island) were ranked very high.

Overall, we evaluated 120 of 136 terrestrial haulout sites in four different OCS Planning Areas in the eastern Bering Sea. Of the 44 sites in the North Aleutian Basin Planning Area, almost half (20 sites; 45%) ranked high in our IPSI evaluation scheme. This number represents almost half of the total 41 most highly rated sites in the study area. Of the 54 sites in the St. George Basin Planning Area, 19 (35%) were rated high; this number was strongly influenced by 10 highly ranked northern fur seal sites on the Pribilof Islands. Of the 24 sites in the St. Matthew-Hall Planning Area, 5 (21%) rated high in our IPSI evaluation, and most (4 of 5; 80%) were sites occupied by Pacific walrus. Of the 14 sites in the Norton Basin Planning Area, only 2 rated high in our IPSI evaluation; both of these sites were occupied by Pacific walrus.

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Many people helped us complete this study. In particular, we thank the biologists, and resource and information specialists with state and federal agencies in Alaska, Washington State, and Canada. Those at the National Marine Mammal Laboratory (NMML), National Marine Fisheries Service (NMFS), Seattle, who helped are Bud Antonellis, Chuck Fowler, Roger Gentry, Hiro Kajimura, Tom Loughlin, Rick Merrick and Ann Yorke. We especially thank Sherry Pearson, information specialist at the NMML library for allowing us free access to files and publications. Hiro Kajimura gave us updated maps of northern fur seal rookeries and haulout sites on the Pribilof Islands. Peter Boveng, NMFS Southwest Fisheries Center, Ja Jolla, provided recent reports on the status of the harbor seal and fur seals.

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Steve Treacy, Minerals Management Service (MMS), Anchorage, Alaska, helped set the geographical limits to the study area, and arranged for us to get official protraction diagrams of the coast and islands of the eastern Bering Sea. We thank Steve for his patience and cooperation throughout this study.

# INTRODUCTION

## Background

In Alaska four species of pinnipeds congregate, often by the thousands or tens of thousands, at specific terrestrial haulout sites along island and mainland coasts of the eastern Bering Sea. These species are the northern fur seal (*Callorhinus ursinus*), northern or Steller sea lion (*Eumatopias jubatus*), harbor seal (*Phoca vitulina richardsi*) and Pacific walrus (*Odobenus rosmarus divergens*). Except for the walrus, these species may occupy terrestrial haulout sites during pupping, nursing, mating and molting, which are all potentially times of elevated stress. (Mating, pupping and nursing by Pacific walruses occurs during January through June in the pack-ice rather than at terrestrial sites.) Consequently, acoustic and/or visual disturbance of animals at terrestrial haulout sites could adversely affect these and other functions, or could further decrease resistance to parasitic infection, thermoregulatory impairment, disease and other stress factors.

In recent years, the northern fur seal, northern sea lion and harbor seal populations in the North Pacific region including Bering Sea have experienced significant declines. These declines have been attributed to a variety of causes, e.g., entanglement in abandoned or discarded fishing gear, disease and parasitic infections, and reductions (principally through overfishing) in the abundance of principal prey species. However, there have been few studies of the potential sensitivity of these pinniped species to industrial disturbance near haulout sites. Additionally, although the Bering Sea population of the Pacific walrus has increased markedly in the past decades, mass mortality has occurred at some locations, and it has been suggested that this species may be sensitive to certain vessel and aircraft traffic.

Literature exists which identifies Bering Sea haulout locations for the four pinniped species. However, site-specific population information has not been combined with known behavioral and acoustic information to describe the potential for disturbance of these four pinniped species by oil and gas development activities in the Bering Sea. The present study was conducted on behalf of the U. S. Department of Interior, Minerals Management Service, in anticipation of eventual oil and gas exploration and development on the Outer Continental Shelf of the eastern Bering Sea. The purpose of this study was to provide an up-to-date and comprehensive synthesis of available information of the known and expected effects of (1) underwater noise, (2) nearby vessel traffic, (3) low-flying aircraft and (4) other associated human disturbances on major concentrations of northern fur seals, northern sea lions, harbor seals and walruses at rookeries and haulouts in the eastern Bering Sea.

## Objectives

The principal objectives of this investigation were as follows:

1. Summarize the literature and compare the year-round utilization of major Bering Sea haulout sites by northern fur seals, northern sea lions, harbor seals and Pacific walruses. This objective included (a) a review of available literature on the distribution of the four pinniped species in the Bering Sea adjacent to Alaska, (b) the identification of the major haulout sites for these species, (c) an analysis of the use of major haulout sites by different age and sex cohorts, and (d) a summarization and estimation of the year-round use and relative biological value of each major haulout site to each species.

2. Summarize and quantify available information on the effects of industrial disturbances on the four major species being studied. This objective included (a) a summary and comparison of available information on the immediate and long-term effects of acoustic and visual disturbance on individuals and on concentrations (haulout sites) of the four species of pinnipeds, (b) a discussion of the applicability of information available for other pinniped species, and (c) a review of responses of marine mammals to various acoustic stimuli.

3. Based on data obtained in 1 and 2 above, estimate the relative vulnerability of the major haulout sites to industrial disturbances.

4. Assess whether disturbance to specific haulouts may have population-level effects on the above mentioned four species.

5. Conduct an analysis of the acoustic environment of representative pinniped haulout sites.

## Study Area

The study area for this project is the Bering Sea adjacent to Alaska (Fig. 1) including the mainland coast from Cape Prince of Wales in the north to Cape Krenitzin at the tip of the Alaska Peninsula, in the south. It also includes all of the islands in the Bering Sea from Little Diomede Island in the north (in Bering Strait) to Unimak Island and the Fox Islands in the eastern Aleutian chain. Umnak Island is the most westerly island considered in detail in this review.

Some information from haulout sites on the Pacific Ocean sides of some of the Fox Islands (i.e., Ugamak I., Aiktak I.) are also considered. In general, however, we have restricted our investigations to haulout sites on the Bering Sea sides of the eastern Aleutian Islands.

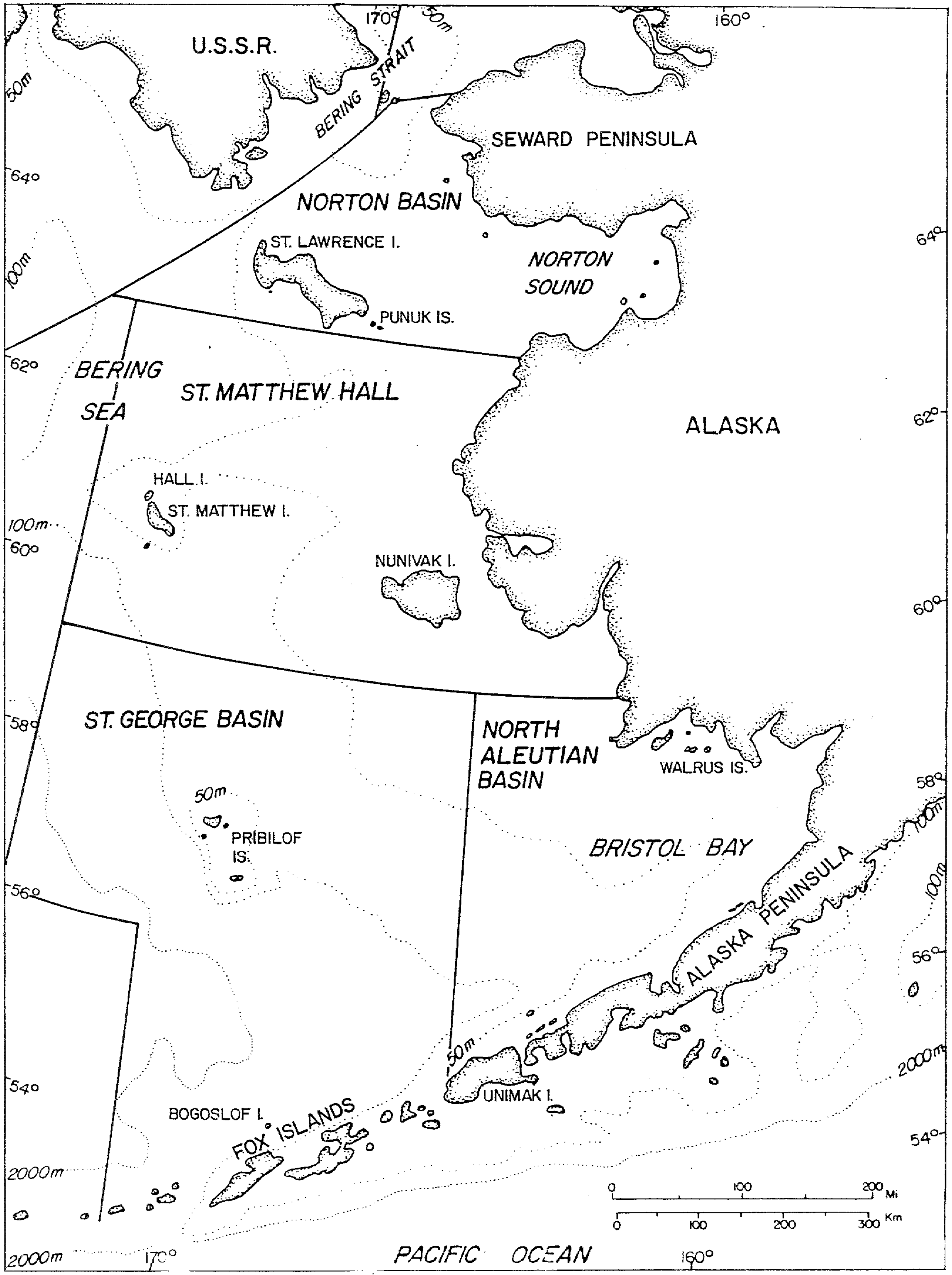



Figure 1. Map of Bering Sea, Alaska study area showing OCS planning areas.

# METHODS

## Terminology

Throughout this report we use the terms 'haulout site', 'rookery', and 'hauling ground' or 'haulout'. These terms refer to any site where pinnipeds traditionally haul themselves out of the water; however, the terms are not used synonymously. Haulout sites are composed of 'rookeries' and 'hauling grounds' (or 'haulouts'), which serve different biological functions for northern fur seals, northern sea lions, and other eared seals.

For northern fur seals, rookeries are areas generally near the water where females have their pups, where males and females congregate to breed, and where pups are raised. Hauling grounds are generally located near the rookeries but are more inland, and are occupied by non-breeding individuals during the breeding season. Some adult males may move to hauling grounds after the breeding season.

Similar to northern fur seals, northern sea lions give birth, nurture their pups, and breed at traditional, well established rookeries. Hauling grounds are often adjacent to the rookeries and are occupied by non-breeding or "bachelor" males (3+ years of age), and later by harem bulls. Bachelor bull northern sea lions aggregate at hauling grounds and spend much of their time mock-fighting or making occasional trips into the rookeries where they are chased by resident males. Unlike fur seals, northern sea lions haul out throughout the year, rather than only during the breeding season. In the present report we make a distinction between northern sea lion rookeries (breeding/pupping areas) and haulouts.

Harbor seals often congregate to feed and give birth at traditional sites, but these sites do not fit the definition of a rookery as described above, i.e., where males have well established territories in which females are defended and bred, and pups are born.

Walrus (mainly males in the present study) haul out at traditional terrestrial sites in the study area, but these sites are not rookeries; few females are present at terrestrial sites in the Bering Sea except in the far north during late fall. During this period, males may fight over females, but virtually all breeding and pupping occurs in the pack-ice during late winter through spring. The 'Glossary' provided in Appendix 9 gives more details and documentation of terminology used in this report.

## Review and Summary of Information on Pinniped Populations and Disturbance

Initially we conducted a search of data bases such as ASFA (Aquatic Sciences and Fisheries Abstracts), ASTIS (Arctic Science and Technology Information Service), BIOSIS Previews (Biological Abstracts) and NTIS (National Technical Information Service). We also conducted thorough searches for relevant information in libraries at (1) the U. S. National Marine Mammal Laboratory (Nat. Mar. Fish. Serv., NOAA, Seattle, WA), (2) the Pacific Biological Station (Dept. Fish. and Oceans, Nanaimo, B.C.), (3) the University of British Columbia, Vancouver, B.C., (4) the various offices of LGL Limited (King City, Ontario; Sidney, B.C.) and LGL Alaska Research Associates (Anchorage and Fairbanks, Alaska), (5) office and staff libraries of the U. S. Fish and Wildlife Service in Alaska (Anchorage, Fairbanks, King Salmon, Cold Bay, Dillingham) and (6) office and staff libraries of the Alaska Dept. of Fish and Game (Anchorage, Fairbanks, King Salmon, Dillingham, Nome). Important sources of valuable information for this study have been personal communications from people who are currently working or have in the past worked extensively with pinnipeds in the Bering Sea and elsewhere.

We summarized pinniped population information for each major haulout site, i.e. with a few exceptions, a site where at least 1% of the total population had been recorded since 1950. Since populations of some species have fluctuated greatly in the past 2-3 decades, and no doubt will continue to do so in future years, we decided that it was not justifiable to exclude a haulout site because it had not been used in the past 10 years.

Counts at haulout sites may be influenced by a large number of factors, e.g., time of year, time of day, weather conditions, visibility, type of observation platform (aircraft, ship, boat, land), count procedure, observer ability, disturbance levels at sites, and nature of survey (opportunistic or otherwise). Counts at some sites on the same day may fluctuate from several thousands (or tens of thousands) of individuals to virtually none. As noted in most summary tables in this report, counts of northern sea lions, harbor seals and Pacific walruses are from many different sources, and many data have not been collected in a systematic or consistent manner (data for the northern fur seal are an exception). For this reason, in our main summary tables we present peak counts at each site for each of the four decades since the 1950's (Frost et al. 1983 used a similar approach), as well as the most current count and year of most current count for each site; details of all other individual counts are given in Appendices 6 through 8. In many cases, the most current count is often significantly lower than the peak count for the 1980's (because of recent regional population declines). When available, we give a breakdown by age and sex.

## Inter-site Population Sensitivity Index (IPSI)

The importance and vulnerability to disturbance, i.e. the sensitivity of each haulout site used by each of the four species, was computed and an Inter-site Population Sensitivity Index (IPSI) was generated for each site using a series of variables or factors related to (1) the location and major physical characteristics of the haulout site being considered, (2) the status, composition and trend in numbers of the population being considered, and (3) the species being considered and its general response to disturbance (based on the literature). These variable factors and the way they fit into the Inter-site Population Sensitivity Index (IPSI) are described in more detail below.

The eight variables associated with each species and each site were ranked on an integer scale (1 through n) according to the total number of sites (n) considered for the species in question. Where variables (or factors) at two or more sites were of equal importance, they were treated as ties (ranked equally). In instances where two factors were highly interdependent, they were pooled into a single complex factor in order to reduce bias. It should be pointed-out, however, that most of the variables considered in this analysis were to some degree dependent on one or more of the other variables; it was not possible to eliminate all redundancy and/or bias in this ranking procedure. Thus, because of inherent unavoidable biases, the evaluation procedures that we used should not be considered a rigorous statistical treatment.

A mean rank was computed from the rank scores for each site. These means were then ranked again to determine the overall Inter-site Population Sensitivity Index (IPSI) for each site considered. For example, if there were 25 haulout sites described for a particular species of pinniped, then the site with the lowest overall mean rank (based on currently available information) had the highest IPSI score--i.e., was considered a site where severe disturbance could cause population-level effects.

Important variables or factors considered in evaluating each site were as follows:

1. The peak count of a particular species of pinniped recorded at a site since 1980. This peak emphasizes the most current counts (1980's count and the most current count) at a particular site. Peak count data for northern fur seal, northern sea lion, harbor seal and Pacific walrus are from Tables 3, 5, 6 and 7, respectively.

2. The mean maximum number of animals recorded at a site during the past three decades and during the most recent count at the site. This provides an indication (but only an indication) of the degree of use of the site over the past 30 years. The values given in Tables 8 through 11 are based on the average of peak counts for each of the 1960's, 1970's, 1980's, and the most current count at the sites given in Tables 3, 5, 6 and 7. Data from the 1950's, although presented in many of the review tables in order to provide historical perspective, have not been included in the evaluation scheme.

3. The proportion of the current total estimated Bering Sea population present at a particular site. A site that supports a large percentage of the population is considered more important than a site that supports only a small percentage. The values given in Tables 8 through 11 are the proportions based on current counts, i.e., the most current count recorded since 1980 and the most recent population estimate given in Tables 3, 5, 6 and 7, respectively.

4. Age and sex composition, and the kinds and amount of behavioral activities that have been recorded at a site. A large and complex site that is used for pupping and nursing, and for breeding was considered to be more important to a species and potentially more sensitive than a small site or a site used only for resting, or only by subadults. This factor therefore actually includes several important variables--(1) age/sex composition and complexity of the site, and (2) behavior--and both are highly interdependent. Information on the age/sex composition (and thus behavior), and complexity (number of subdivisions and areal extent) of the site are given in Tables 3, 5, 6 and 7, and in Figures 13, 14, 15 and 16, respectively.

5. Duration of use of a haulout site. A site that is used for a large part of the year is considered to be more important and more vulnerable than a site used only intermittently (e.g., only during migration). Since sites that are used for a large part of the year often are the rookeries, where various age and sex classes and a variety of different behaviors are exhibited, this variable is obviously related to several of the other variables. Duration of use was computed for each species using information given in the literature; e.g., Table 2 for northern fur seal where virtually all sites have rookeries and are occupied for about seven months (0.583 yr). Only some northern sea lion sites are rookeries or are near rookeries, which are occupied for an extensive period (0.500 yr, Table 3). Other southern Bering Sea sites may be used for about 0.250 yr and more northerly sites are used for only 0.167 yr (see Table 9). Harbor seal sites are also occupied for various durations depending on their geographic location and the average position of the ice front during winter. Southern sites are occupied by seals all year while the northerly sites are occupied for only about six months (0.500 yr, Table 10). Similarly, Pacific walrus occupy sites for various periods depending on the sex and age composition of the animals and the location of the site (Table 11). Southern sites are used almost exclusively by males for periods ranging from 2 to 7 months (0.167 to 0.580 yr). Northerly sites may be used by all ages and sexes for periods ranging from 2 to 4 months (0.167 to 0.333 yr).

6. Consistency of use of a haulout site. A site that is used every year is considered to be more important and more vulnerable than a site that is used only sporadically. Rookeries are used most consistently from one year to the next; thus, there is a strong relationship between consistency of use of a site and the age/sex classes, behaviors and duration of use of a site. Consistency of use of a site is determined by the frequency with which animals are recorded at sites during different surveys over a period of years.

7. Site characteristics, i.e., the physiography and associated susceptibility of the site to disturbance. This factor is based on the major physical characteristics of the site, e.g., the substrate, vertical relief, bathymetry, etc., in the immediate vicinity of the site, and its proximity to sources of disturbance. Any site located within 5 km of a source of noise or disturbance (shipping lanes, airports and/or air traffic lanes, settlements, etc.) was ranked high

in our evaluation scheme. Other sites not located close to noise or disturbance sources were ranked in accordance with the physical characteristics of the site.

8. Species characteristics, i.e., susceptibility of a species to disturbance. This factor is based on how the species responds to disturbances of different types (based largely on the literature presented in this report). It is dependent to a degree on the composition (age/sex, behavior) of the animals present at the site, how that segment of the population is affected by disturbances, and whether or not there is a high, medium or low probability of mortality as a direct or indirect result of noise/disturbance. Species that are known to have suffered mortality as a result of noise/disturbance (e.g., Pacific walrus, northern sea lion, harbor seal) were ranked high, and others (e.g., northern fur seal) were ranked lower (Tables 8 through 11).

## Analysis of the Acoustic Environment

We also conducted a separate analysis of the acoustic environment of eight haulout sites (see Appendix 1). These sites were considered to be representative of those used by each of the four pinniped species considered in the present study. The physical conditions (location in the study area, proximity to noise sources, site substrate, slope of beach and sea bottom, bottom type), and pinniped use of these eight sites were included in our selection criteria. The analyses included investigations of the following topics:

1. Characteristics of airborne and underwater ambient noise.
2. Characteristics of industrial noise sources, including aircraft, small boats, fishing trawlers and commercial cargo traffic.
3. Sound transmission loss in air, water and through the air-water surface.

The ambient noise characteristics of the sites were estimated using data obtained from studies of similar areas. The noise source characteristics were obtained from data reported in the literature and data in the archives of BBN Systems and Technologies Corporation. Transmission loss characteristics for airborne and underwater sound were estimated using standard analytical procedures and computer models (see Appendix 1). An analytical procedure was developed for prediction of transmission of sound from aircraft into shallow water, since an existing procedure was not available. Procedures are described for using the information obtained in this study to predict noise exposure levels and to develop 'zone-of-influence' estimates for the various species of concern. All of these procedures are described and discussed in detail in Appendix 1.

# RESULTS

The following results are presented in several sections, in accordance with the general objectives of the study. The first sections give descriptions of important background life-history information about each of the four species, information about patterns of occupancy and history of use of key haulout sites, and information about the location and status of haulout sites for each of the four species in the eastern Bering Sea. Later sections (1) review information on the effects of disturbance and noise on pinnipeds, and (2) review information on acoustic processes that may be relevant to OCS development near pinniped haulout sites in the eastern Bering Sea (Appendix 1). Specific descriptions of the physical characteristics and maps of each major haulout site are given in Appendices 2 through 5.

## Northern Fur Seal (Callorhinus ursinus L.)

### Background

The northern fur seal belongs to the family of eared seals (Otariidae); it is a medium-sized pinniped with adult bulls in prime condition on their breeding territories measuring about 2-3 m in length and weighing between 135 and 280 kg. Northern fur seals remain at sea for most of the year, often far from shore along the continental shelf and slope. The distribution of northern fur seals in the Pacific is from the Bering Sea to Southern California and Japan (Fowler 1985, In press). Figure 2 shows the general distribution of this species in the eastern Bering Sea.

No individual fur seal older than a neonate spends longer than 60-70 days of the year on shore (Gentry 1981). Males reach sexual maturity by about 6 years of age and females by 4-5 years of age; they give birth to a single pup (very rarely twins) weighing 4.5-5.5 kg each year. Adults may live to be almost 25 years of age (Fowler 1985, In press).

Northern fur seals are the most abundant marine mammal in the Bering Sea, but recent declines have occurred throughout its range. The current worldwide population of 1,173,000 is significantly less than the 1,765,000 individuals

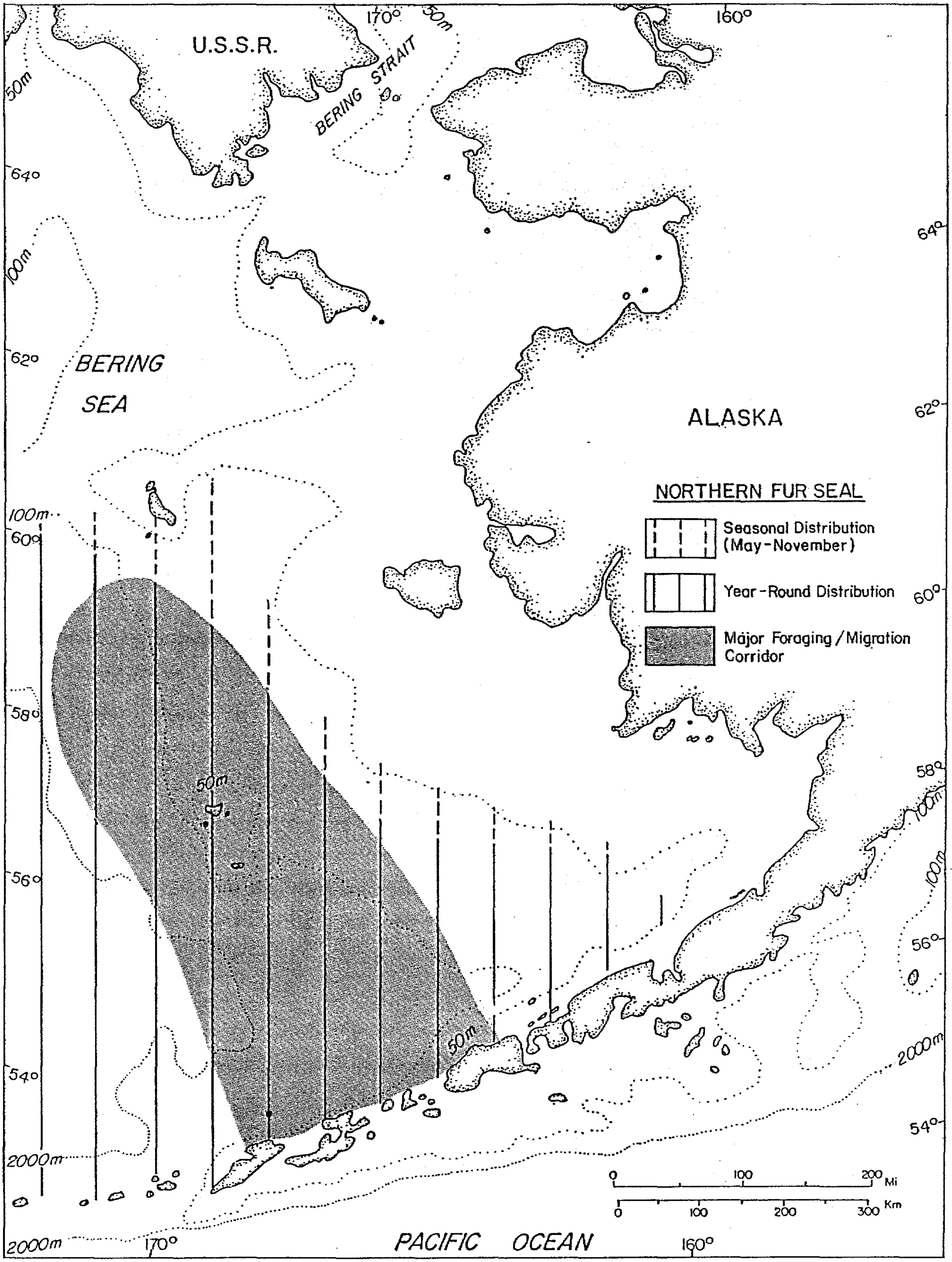



Figure 2. General distribution of the northern fur seal in the Bering Sea, Alaska.

reported in the mid 1970's by Lander and Kajimura (1982). Similarly, the number of fur seals estimated on the Pribilof Islands has declined from 1.3 million in the mid-1970's (Lander and Kajimura 1982), to 0.9 million in the mid-1980's (North Pacific Fur Seal Commission 1984, cited in Bigg 1986:383), to the current estimate of about 0.8 million individuals. This represents a decline since the mid- to late 1970's of about 4-8% per year (average = 6.1%; Fowler 1985). Recent studies indicate that the decline may in part be the result of increased mortality of younger age classes through entanglement in abandoned and lost fishing gear and other debris (Fowler 1984, 1985, 1987, In press; Yoshida and Baba 1985). Because of the decline, the National Marine Fisheries Service recently (May 1988) listed the Pribilof Islands population of northern fur seals as a 'depleted species' under terms of the Marine Mammal Protection Act of 1972 (MMPA).

Fur seals come ashore at several important locations in the North Pacific, Bering Sea and Sea of Okhotsk, though mainly during and after the breeding season (May-November). The distribution of northern fur seal haulout sites (rookeries and hauling grounds) in the eastern Bering Sea is limited to the Pribilof Islands including Sivutch (also known as Sea Lion Rock) and Bogoslof Island (Fig. 3 and Appendix 2) which are used by about 70-74% of the world population of this species. This relatively restricted distribution of haulout sites is thought to be related to nearby oceanographic features. Lloyd et al. (1981) speculated that the feeding habitats of all fur seals, not just those in the Bering Sea (Perez 1979, Perez and Bigg 1980), consist of the outer continental shelf and oceanic domains, and that "only islands in or immediately adjacent to the [very productive and food-rich] outer shelf domains are suitable for fur seal rookeries."

## Patterns of Occupancy at Haulout Sites

Bigg (1986) conducted a detailed investigation of the rather complex patterns of arrival and departure of northern fur seals at haulout sites on St. Paul Island in the Pribilofs (see discussion above). Arrival and departure patterns on St. Paul probably are also representative of arrival and departure patterns on St. George Island, also in the Pribilofs (M. Bigg, pers. comm. 1987). Northern fur seals occupy haulout sites at different times depending on

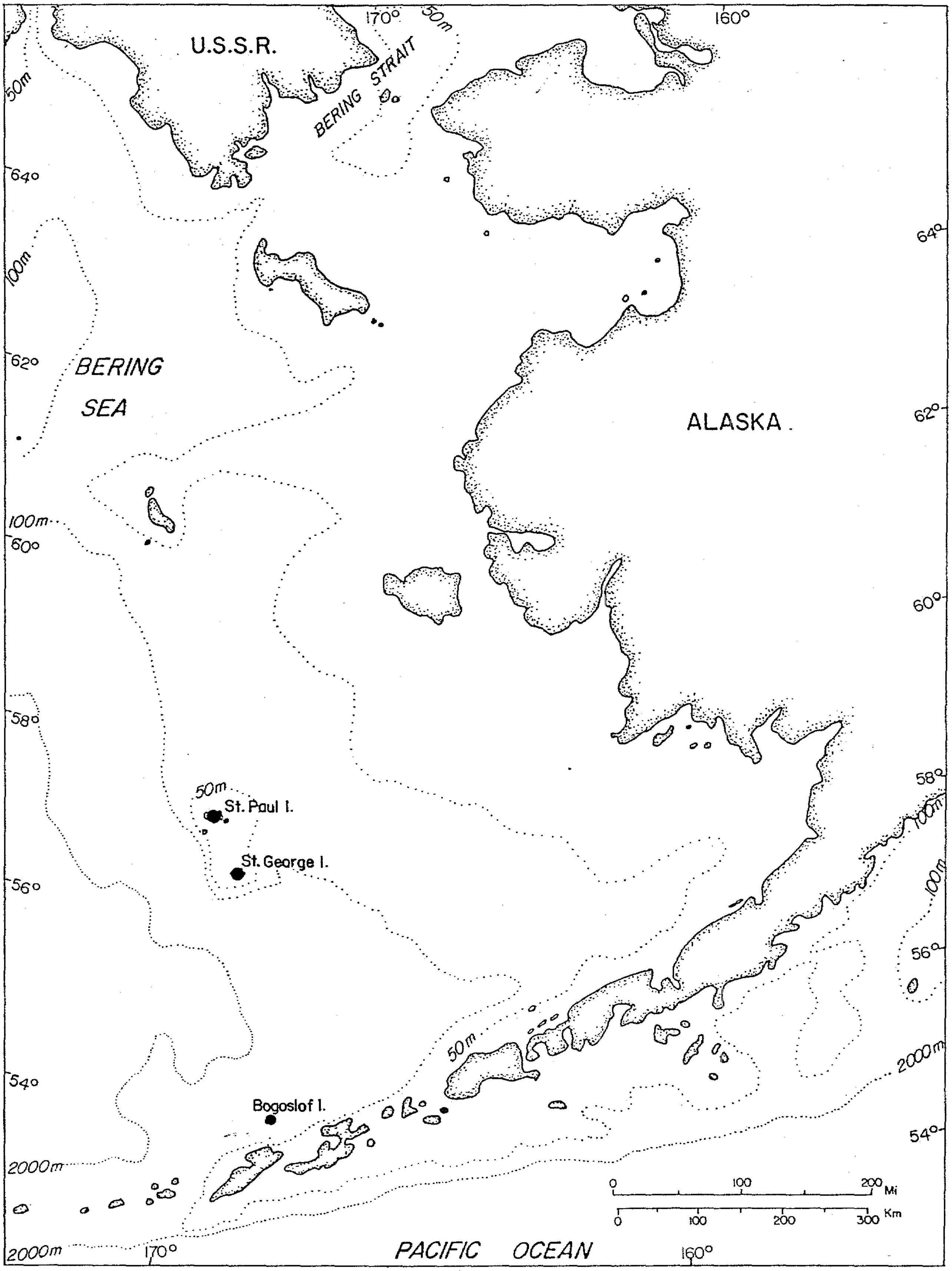



Figure 3. Locations of northern fur seal haulout sites in the Bering Sea, Alaska.

their sex and age. In general, the oldest and strongest bulls return first, followed by younger bulls and adult females, followed by even younger bulls and females (Table 1). The first bulls begin arriving at Pribilof Island rookeries in early to mid-May and usually abandon their territories by mid-August. Pregnant females begin arriving in mid-June. Females usually give birth within a day of arriving at the rookery, but it is not unusual for some females to give birth up to three days after arriving. The peak of pupping is in early July (Fiscus 1986). Pups are nursed until the female breeds 5-6 days after giving birth (Gentry and Holt 1986). Females then return to sea to feed for several days (mean 3.5 days, Loughlin et al. 1987). This is the first period of feeding by females after their arrival at the rookery. The female continues to come and go to and from the rookery for about 120 days (Gentry and Holt 1986). She travels to sea for periods averaging 5.7 days in July and 7.3 days in August; each feeding period is followed by two days of nursing (mean 1.9-2.2 days according to Loughlin et al. 1987 and Gentry and Holt 1986,

Table 1. Summary of the timing of arrival of hauling grounds and rookeries by northern fur seals of different ages and sexes, St. Paul Island, Bering Sea, Alaska (from Bigg 1986).

| Sex | Site* | State** | Age | Date of Last Arrival*** | Abundance |
|---|---|---|---|---|---|
| Male | R | - | 1 | Late Sep to early Oct | Few |
| | HG | - | 2 | Mid-to late Aug | 2 yr >1 yr |
| | HG | - | 3 | Late Jul | 3 yr >2 yr |
| | HG | - | 4 | Mid-Jul | all |
| | HG | - | 5 | Late Jun to early Jul | all |
| | HG | - | 6 | Late Jun | all |
| | R | - | >7 | Late Jun | all |
| Female | R | NP | 1 | Oct to early Nov | Few |
| | HG,R | NP | 2 | Mid-to late Sep | 2 yr >1 yr |
| | HG | NP | >3 | Mid-Aug | 3 yr >2 yr |
| | HG | P | >4 | Mid-Aug | all |
| | R | P | >4 | Mid-Jul | all |

* R = rookery; HG = hauling ground.
** NP = not pregnant; P = pregnant.
*** Date when essentially all seals have arrived.

respectively). This process continues until the pups are weaned. Adult females start to leave the rookeries in early October (Gentry 1981) and departure continues into November (Table 2). Pups first enter the sea at about 4-6 weeks of age, but may remain at the rookery until early November (Fiscus 1986).

Table 2. A summary of the occupancy of haulout sites on the Pribilof Islands, Bering Sea, Alaska, by different age and sex classes of northern fur seals.

| | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|
| Breeding Bulls | 1* | | | 2 | | 3 | | |
| Adult Females | | 1 | | | | 3 | | |
| Subadult Males | | 1 | | | | 3 | | |
| Subadult Females | | | 1 | | | 3 | | |
| Pups | | 1 | | | | 3 | | |

* '1' in the time line indicates the approximate earliest dates of arrival, '2' indicates the approximate date of abandonment of territories by adult bulls and breakdown of the social structure of the rookery, and '3' indicates the beginning of the departure of fur seals from the islands and the start of the southbound migration.

The 3 to 5-year-old males begin to haul out on the hauling grounds in late June, and younger animals continue to arrive well into September. The latest arrivals include many 2-year-olds. Although most yearlings remain at sea and do not return to haulout sites, a few yearling females may make brief visits to the periphery of rookeries or hauling grounds as late as early November.

## Location and Status of Northern Fur Seal Haulout Sites

### Pribilof Islands

**St. Paul Island.** There are 14 distinct haulout sites (rookeries with associated hauling grounds) on St. Paul Island (Table 3; Appendix 2; Kozloff 1985). The history of use of these haulout sites (Table 3) shows a general decline in the number of breeding bulls and pups since the 1950's. The most

Table 3. Peak numbers of northern fur seals at major haulout sites (all are rookeries) in the Bering Sea, Alaska.#

| Haulout Site (Rookery) | 19 50's* | | 19 60's* | | 19 70's* | | 19 80's** | | Cur rent | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Breed. Bulls | Pups Born | Breed. Bulls | Live Pups | Breed. Bulls | Live Pups | Breed. Bulls | Pups (Est.)† | Breed. Bulls | Pups (Est.)† |
| **St. George Island** | 1958* | | 1961* | 1966* | 1979* | 1973* | 1984** | 1984** | 1986** | 1986** |
| Zapadni | 370 | | 363 | 8970 | 182 | 6821 | 157 | 5393 | 140 | 4809 |
| South | 276 | | 335 | 7574 | 210 | 11164 | 247 | 8484 | 200 | 6870 |
| North | 985 | No | 1235 | 26507 | 674 | 19987 | 593 | 20370 | 599 | 20576 |
| East Reef | 212 | Data | 169 | 2645 | 132 | 2922 | 96 | 3298 | 92 | 3160 |
| East Cliffs | 350 | | 366 | 10208 | 282 | 10290 | 279 | 9584 | 282 | 9687 |
| Staraya-Artil | 426 | | 375 | 8854 | 236 | 6540 | 101 | 3469 | 81 | 2782 |
| SUBTOTAL | 2619 | | 2843 | 64758 | 1716 | 57724 | 1473 | 50598 | 1394 | 47884 |
| **St. Paul Island** | 1959* | 1955* | 1961* | 1961* | 1978* | 1975* | 1984** | 1984** | 1987** | 1987** |
| Lukanin | 219 | | 231 | w/Kitovi | 120 | 5704 | 119 | 4088 | 76 | 2611 |
| Kitovi | 600 | | 609 | 24005 | 282 | 12965 | 236 | 8107 | 219 | 7523 |
| Gorbatch | 856 | | 842 | 17103 | 810 | 17038 | 358 | 12297 | 280 | 9618 |
| Ardiguen | 119 | No | 153 | w/Reef | 93 | 2774 | 55 | 1889 | 57 | 1958 |
| Reef | 1663 | | 1825 | 69246 | 455 | 27561 | 526 | 18068 | 427 | 14667 |
| Morjovi | 791 | | 878 | 27628 | 518 | 21284 | 361 | 12400 | 245 | 8416 |
| Vostochni | 1568 | Specific | 1898 | 19899 | 1093 | 41356 | 811 | 27858 | 570 | 19579 |
| Little Polovina | 331 | | 341 | 8794 | 107 | 3415 | 46 | 1580 | 19 | 653 |
| Polovina Cliffs | 740 | | 870 | w/Polovina | 569 | 24870 | 404 | 13877 | 318 | 10923 |
| Polovina | 291 | Data | 356 | 21663 | 126 | 4355 | 70 | 2405 | 56 | 1924 |
| Tolstoi | 973 | | 1149 | 34885 | 719 | 31108 | 614 | 21091 | 483 | 16591 |
| Zapadni Reef | 258 | | 277 | 5850 | 203 | 7223 | 210 | 7213 | 145 | 4981 |
| Little Zapadni | 583 | | 666 | 13294 | 519 | 21168 | 367 | 12606 | 280 | 9618 |
| Zapadni | 1011 | | 1068 | 42102 | 882 | 36815 | 626 | 21503 | 443 | 15561 |
| SUBTOTAL | 10003 | 461000 | 11163 | 284469 | 6496 | 257636 | 4803 | 164982 | 3618 | 124623 |
| **Sivutch** | | | 1968* | 1966* | 1979* | 1970's†† | 1980's• | 1980's†† | 1980's• | 1980's†† |
| | | | 166 | 17922 | 470 | 20000 | 582 | 20000 | 582 | 20000 |
| **Bogoslov Island** | No Data | No Data | No Data | No Data | No Data | No Data | 1980** | 1980** | 1984** | 1984** |
| | | | | | | | 1 | 2 | 7 | 14 |
| GRAND TOTAL | 12622 | 461000 | 14172 | 367149 | 8682 | 335360 | 6859 | 235582 | 5601 | 192521 |

# Note: data in this table are from many different years and may not have been collected in a systematic manner.
* 1950's, 1960's and 1970's data are from Lander (1980).
** 1980's and 'Current' data are from Lloyd et al. (1981), Kozloff (1986) and NMFS files.
† Estimates of pup production are based on the ratio--Breeding Bulls : Pups = 1 : 34.35 (Kozloff 1986:11).
†† Recent annual pup production on Sivutch (Lander and Kajimura 1982:322).
• Est. of recent annual Breeding Bulls on Sivutch are based on the ratio - Breeding Bulls:Pups =1:34.35 (Kozloff 1986:11).

current estimates indicate that about 124,500 pups (plus at least the same number of adult females) and about 3600 harem bulls used these 14 haulout sites during 1987 (NMFS file data).

**Sivutch.** This haulout site is located on a small island about 0.5 km S of St. Paul Island (S of the rookery at Reef; Appendix 2). Jordan and Clark (1898) reported about 6000 fur seals during investigations there late in the last century, and Lander and Kajimura (1982) indicated that the rookery at this haulout site produces about 20,000 pups each year.

**St. George Island.** There are six distinct haulout sites on St. George Island (Appendix 2; Kozloff 1985). A decline in the number of breeding bulls and pups similar to that recorded on St. Paul Island is also evident on St. George Island (Table 3). The most current estimates indicate that about 48,000 pups (plus at least the same number of adult females) and about 1400 harem bulls used these 6 haulout sites during 1986 (NMFS file data).

## Bogoslof Island

Bogoslof Island is volcanic in origin; it rose from the sea about 65 km north of Umnak Island in the eastern Aleutians on 18 May 1796 (Orth 1967, Byrd et al. 1980; see Appendix 2). Today it is about 1.5 km long, and supports a very small number of reproductively active northern fur seals (Table 3). Nevertheless, the number of fur seals using this haulout site has grown since 1980 (Lloyd et al. 1981). The most current estimates indicate that 14 northern fur seal pups (plus the same number of adult females) and 7 harem bulls used this site during 1984 (NMFS file data) .

# Northern Sea Lion (Eumatopias jubatus Schreber)

## Background

The northern or Steller sea lion belongs to the family of eared seals (Otariidae). The northern sea lion is the largest of the eared seals, with some bulls exceeding 3 m in length and 1000 kg in weight. This species breeds along the west coast of North America from the southeastern Bering Sea and the

Aleutian Islands to southern California. It also breeds in Asia on the Kurile Islands, in the Sea of Okhotsk and on the Kamchatka Peninsula (Gentry and Withrow 1986, Loughlin et al. 1987; Hoover 1988a). Major breeding concentrations of this species in North America occur mainly in the northwest Gulf of Alaska and the Aleutian Islands; Forrester Island, off SE Alaska, is also a major rookery. Figure 4 shows the general distribution of this species in the eastern Bering Sea.

Similar to fur seals, the birth and the nurturing of pups and breeding by northern sea lions occurs on traditional, well established rookeries. As mentioned earlier, however, northern sea lions may haul out throughout the year (at different sites), rather than only during the breeding season. Nevertheless, there are definite seasonal peaks in haulout activity.

The annual distribution of northern sea lions is such that more males are seen along the north coast of North America during winter than during summer; individuals from California migrate northward during winter and return south in summer. Similarly, juvenile males from haulout sites in the Aleutian and Pribilof islands migrate north into the central and northern Bering Sea in late summer, then return south as ice begins to form.

The maximum size of the northern sea lion population for the 1974-1980 period was estimated to be about 290,000 individuals (some pups included); more than 196,000 (67.6%) of this total were counted in Alaska (Loughlin et al. 1984). The numbers of northern sea lions counted in Alaska during 1974-1980 apparently was unchanged since surveys in 1956-1960 by Kenyon and Rice (1961) and Mathisen and Lopp (1963). However, there had been a significant shift in their distribution. Fewer sea lions were using haulout sites in the eastern Aleutians (Braham et al. 1980), and more were using haulout sites in the central and western Aleutians (Fiscus et al. 1981). Since 1980 there have been further significant declines in the number of northern sea lions at most sites in Alaska.

The area from the central Aleutian Islands (Kiska Island eastward) to the central Gulf of Alaska (Sugarloaf and Marmot islands, north of Afognak Island) has been studied more systematically than most other areas of Alaska (see

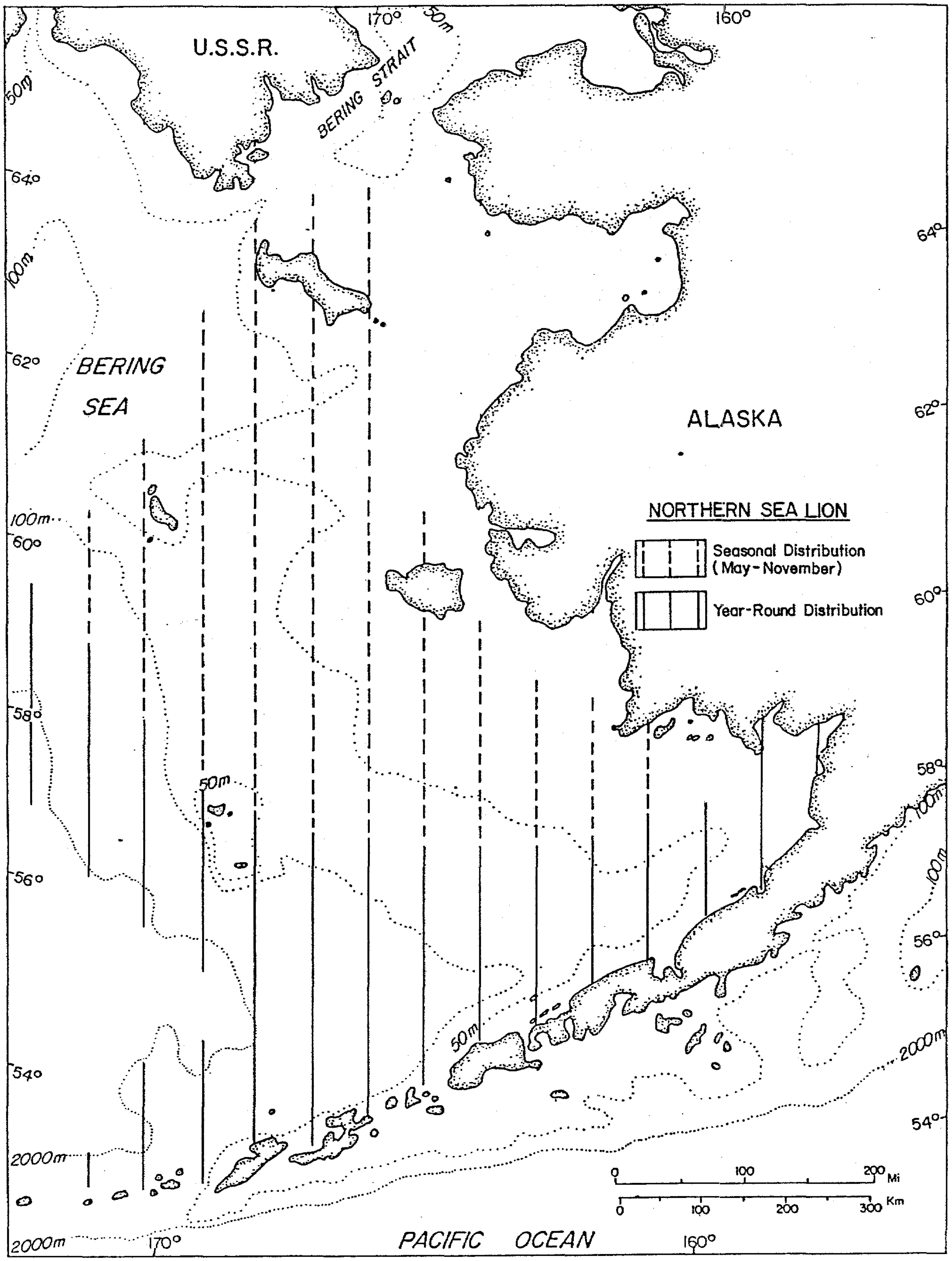



Figure 4. General distribution of the northern sea lion in the Bering Sea, Alaska.

Merrick et al. 1987), and best shows the recent declines in numbers. About 140,000 northern sea lions were counted in this area in 1958. Several different indicators confirmed that by 1985 the number had declined to less than 68,000; this represents a reduction of about 52% in 27 years or about -2.7% per yr (Merrick et al. 1987).

It is suspected that these declines may have occurred in two phases. The first decline probably was confined to the eastern Aleutian Islands and western Gulf of Alaska, and likely began in the early 1970s; it has not been possible to determine rates of decline earlier than 1969. Nevertheless, counts in the Central Aleutians to the Central Gulf of Alaska region as a whole declined by about 25% (-1.6% per yr) between 1958 and 1977 (Merrick et al. 1987). The second phase of the decline has occurred since 1977; all areas were apparently affected and the overall reduction in numbers was about 36% (-5.2% per yr) during this 8-yr period (Merrick et al. 1987). Results of counts at major haulout sites indicate that reductions may still be occurring in the southeastern Bering Sea as well as in the eastern Aleutian Islands and Gulf of Alaska.

Compared to the information available for northern sea lions in the Aleutian Islands and Gulf of Alaska, records for Bering Sea rookeries and haulout sites are less comprehensive. However, data given in Frost et al. (1983) indicate that significant declines in the numbers of northern sea lions also have occurred at Walrus Island and Dalnoi Pt. in the Pribilofs, and at Sea Lion Rock near Amak Island (North Aleutian Shelf).

The ultimate causes of the decline in the northern sea lion population in Alaska are unknown (Merrick et al. 1987). However, it has been postulated that disease (possibly Leptospira), changes in prey resources, mortality through shooting, and possible entanglement in nets and other debris may all be contributing factors. Some evidence suggests that changes in the quantity and size of walleye pollock (Theragra chalcogramma), the principal prey of northern sea lions, may be a significant factor in the decline (Frost and Lowry 1986, Loughlin 1987, Bakkala et al. 1987).

## Patterns of Occupancy at Haulout Sites

Northern sea lions occupy haulout sites at different times depending on their sex and age. In general, the oldest and strongest bulls return to rookeries first, followed by adult females. The first bulls begin arriving at Aleutian Island rookeries in mid-May. They usually begin to abandon their territories in mid-July and move to nearby hauling grounds by mid-August (Table 4). Some pregnant females also begin arriving at rookeries in mid-May; pupping usually occurs within 2-3 days of arrival. Although pups are born at Alaskan rookeries from mid-May through mid-July, the peak of pupping is during the 10-20 June period (Calkins 1985).

Table 4. A summary of the occupancy of haulout sites on the Eastern Aleutian Islands and SE Bering Sea, Alaska, by different age and sex classes of northern sea lions.

| | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|
| Breeding Bulls | 1* — | — | — | 2 — | — | 3 — | — | —.. |
| Adult Females | | 1 — | — | — | — | 3 — | —.. | |
| Subadult Males | 1 — | — | — | — | — | 3 — | — | —.. |
| Subadult Females | | | 1 — | — | — | 3 — | —.. | |
| Pups | | 1 — | — | — | — | 3 — | —.. | |

* '1' in the time line indicates the approximate dates of arrival at rookeries, '2' indicates the approximate date of abandoment of territories by adult bulls and breakdown of the social structure of the rookery, and '3' indicates the beginning of the departure of sea lions from their haulout sites in the study area.

Pups begin nursing almost immediately after birth, and are nursed until the female breeds again, usually within two weeks of pupping. Females stay ashore with their pups for an average of 6.7 days (± 2 days) before making their first feeding trip to the sea (Higgins et al. 1988). This is the first period of feeding by females after they arrive at the rookery. They assume a schedule of feeding at night and suckling their young during the day. At about 14 days of age pups first enter the sea; for about two weeks they restrict their swimming activity to littoral zone pools (Sandegren 1970). Each day they spend more time in the water, and eventually join their mothers on 'tours' of deeper waters adjacent to the rookery. Pups are usually able to swim and dive quite well after about 28 days in pelagic waters with their mothers.

The number of sea lions at rookeries during the breeding season show diel fluctuations, with early morning lows and late afternoon highs resulting from the movement of females to and from the sea to feed (mostly nocturnally). The numbers of sea lions in some locations are also affected by tide and weather (Sandegren 1970; Withrow 1982). Calkins (1985) indicated that the areas over which sea lions forage are very broad, extending from the intertidal zone to the continental shelf break.

Males leave the rookeries immediately after the breeding aggregation breaks down in mid-July to August. Most adult females and young have left their rookeries by mid October. However, in the eastern Aleutian Islands the majority of the breeding population is still present at haulout sites through the end of October. As mentioned above, there is a general northward movement of sea lions (primarily immature bulls) into the central and northern Bering Sea. They usually occur in largest numbers on St. Lawrence Island (63°30'N) during September. In the central Bering Sea region, sea lions also may haul out on sea ice when it is present during winter and spring.

Location and Status of Northern Sea Lion Haulout Sites

There are approximately 15 rookeries and associated hauling grounds used by large numbers of northern sea lions in the eastern Bering Sea, and there are about 30 additional sites where smaller numbers have hauled out (Table 5; Fig. 5; Appendix 3). Only six of the total number of haulout sites are rookeries where more than one or two pups are born, and all but one of these sites are in the eastern Aleutian Islands or extreme southwestern part of Bristol Bay. The exception is Walrus Island, in the Pribilof Islands group (Table 5). Similar to the situation described for the northern fur seal (Lloyd et al. 1981), the locations of key northern sea lion haulout sites, especially the rookeries, may in part be determined by important oceanographic features

Table 5. Peak counts of northern sea lions at major haulout sites in the Bering Sea, Alaska.†

| Haulout Sites | 1950's | 1960's | 1970's | 1980's | Current Estimate | Year of Curr. Est. |
|---|---|---|---|---|---|---|
| Bogoslof Island* | | | | | | |
| Adults/Subads. | 3707 | 2566 | 3300 | 1379 | 1287 | 1985 |
| Pups | 3106 | 2385 | 2328 | – | | 1985 |
| Fire Island | – | 100 | 4 | – | – | – |
| Unalaska Island | | | | | | |
| Spray Cape | – | 200 | 2 | 161 | 20 | 1985 |
| Cape Starichkof | – | 100 | 244 | – | – | – |
| Bishop Point | – | 300 | 501 | 549 | 549 | 1985 |
| Cape Tebenkof | – | 200 | 8 | – | – | – |
| Akutan Island* | | | | | | |
| Cape Morgan* | | | | | | |
| Adults/Subads. | – | 9000 | 5925 | 2840 | 1338 | 1986 |
| Pups | 1735 | – | – | – | 1130 | 1985 |
| Akun Island* | | | | | | |
| Billings Head* | | | | | | |
| Adults/Subads. | – | – | 2641 | 760 | 435 | 1985 |
| Pups | – | – | – | – | 60 | 1985 |
| Akun Head | – | 2000 | 10 | – | – | – |
| Tanginak Island | – | 600 | 470 | – | 61 | 1985 |
| Tigalda Island | 103 | 650 | 314 | – | – | – |
| Rocks NE of Tigalda I. | – | 750 | 190 | 225 | 82 | 1985 |
| Ugamak Island Group* | | | | | | |
| Adults/Subads. | 14536 | 19400 | 5408 | 2033 | 1684 | 1986 |
| Pups | 1466 | – | – | 1635 | 1386 | 1986 |
| Aiktak Island | – | 600 | 1 | 0 | 0 | 1985 |
| Unimak Island | | | | | | |
| Cape Sarichef | – | 200 | 4 | 40 | 128 | 1985 |
| Cape Mordvinof Area | 500 | 4000 | 2 | – | – | – |
| Amak Island | 3016 | 2000 | 2316 | 2400 | 599 | 1986 |
| Unnamed Rocks | -- | – | 355 | 250 | 218 | 1986 |
| Sea Lion Rock* | | | | | | |
| Adults/Subads. | 4694 | 4100 | 2530 | 1298 | 527 | 1986 |
| Pups | 424 | – | – | – | – | – |
| Right Hand Point | – | – | – | 50 | 50 | 1981 |
| Hagemeister Island | – | – | 150 | – | 0 | 1985 |
| Twin Islands | | | | | | |
| S. Twin Island | 45 | – | 300 | – | – | – |
| N. Twin Island | – | – | 150 | – | – | – |
| N. & S. Twin Islands | 300 | 400 | – | – | – | – |
| Round Island | – | 0 | 500 | 1000 | 1000 | 1987 |
| Cape Peirce | – | – | present | 450 | 450 | 1981 |
| Cape Newenham | 250 | – | 800 | 1500 | 950 | 1987 |
| Nunivak Island | | | | | | |
| Binajoaksmiut Bay | – | – | 49 | – | – | – |
| Nabangoyak Rock | – | – | 35 | – | – | – |
| Cape Mendenhall | – | – | – | 50 | 50 | 1981 |
| St. Matthew Island | | | | | | |
| Sugarloaf Mtn. | – | – | – | 50 | 50 | 1982 |
| Cape Upright | – | 100 | – | 90 | 90 | 1982 |
| Rocks at Lunda Pt. | – | – | – | 52 | 600 | 1983 |
| Hall Island | | | | | | |
| Arre Rock | – | – | – | 150 | 150 | 1982 |
| North Cove | – | – | – | 75 | 4000 | 1983 |
| S. Elephant Rock | 350 | – | – | – | – | – |
| Pinnacle Island | – | – | 100 | 257 | 257 | 1985 |
| Gull Islands | – | – | 159 | 550 | 550 | 1986 |
| St. George Island | – | 1200 | 138 | 86 | 86 | 1980 |
| St. Paul Island | | | | | | |
| Northeast Point | 490 | 71 | 50 | – | – | – |
| Sivutch | 500 | 500 | 100 | – | – | – |
| Otter Island | 1000 | 160 | 800 | 29 | 11 | 1984 |
| Walrus Island* | | | | | | |
| Adults/Subads. | 3000 | 5000 | 1529 | 868 | 459 | 1987 |
| Pups | 3000 | 3000 | – | 304 | 114 | 1987 |
| Otter Island | – | – | 200 | – | – | – |
| St. Lawrence Island | | | | | | |
| Southwest Cape | – | 1000 | – | – | – | – |
| South Punuk I. | – | 200 | – | – | – | – |
| GRAND TOTAL | 42222 | 60782 | 31613 | 19131 | 18371 | |

† Note: data in this table are from many different sources and years; they have not been collected systematically or consistently. Peak counts at different sites on the same island may be from different censuses; only counts of adults/subadults and pups at a rookery may be from the same census and may be summed. Unless otherwise indicated, counts are of adults/subadults.

Peak count data were taken from Kenyon and Rice (1961), Kenyon (1962;1965), Mathisen and Lopp (1963), Braham et al. (1980), Frost et al. (1983), Loughlin et al. (1984), Calkins (1985), Merrick et al. (1987), O'Neil and Haggblom (1987), Sherburne and Lipchak (1987), Envirosphere Co. file data, NMFS file data, USFWS file data, ADFG file data.

* Signifies that this haulout site is (or has been) a major rookery (breeding area) where a significant number of pups are (were) born. The Ugamak I. group includes Round I.

"–" signifies that no data are available.

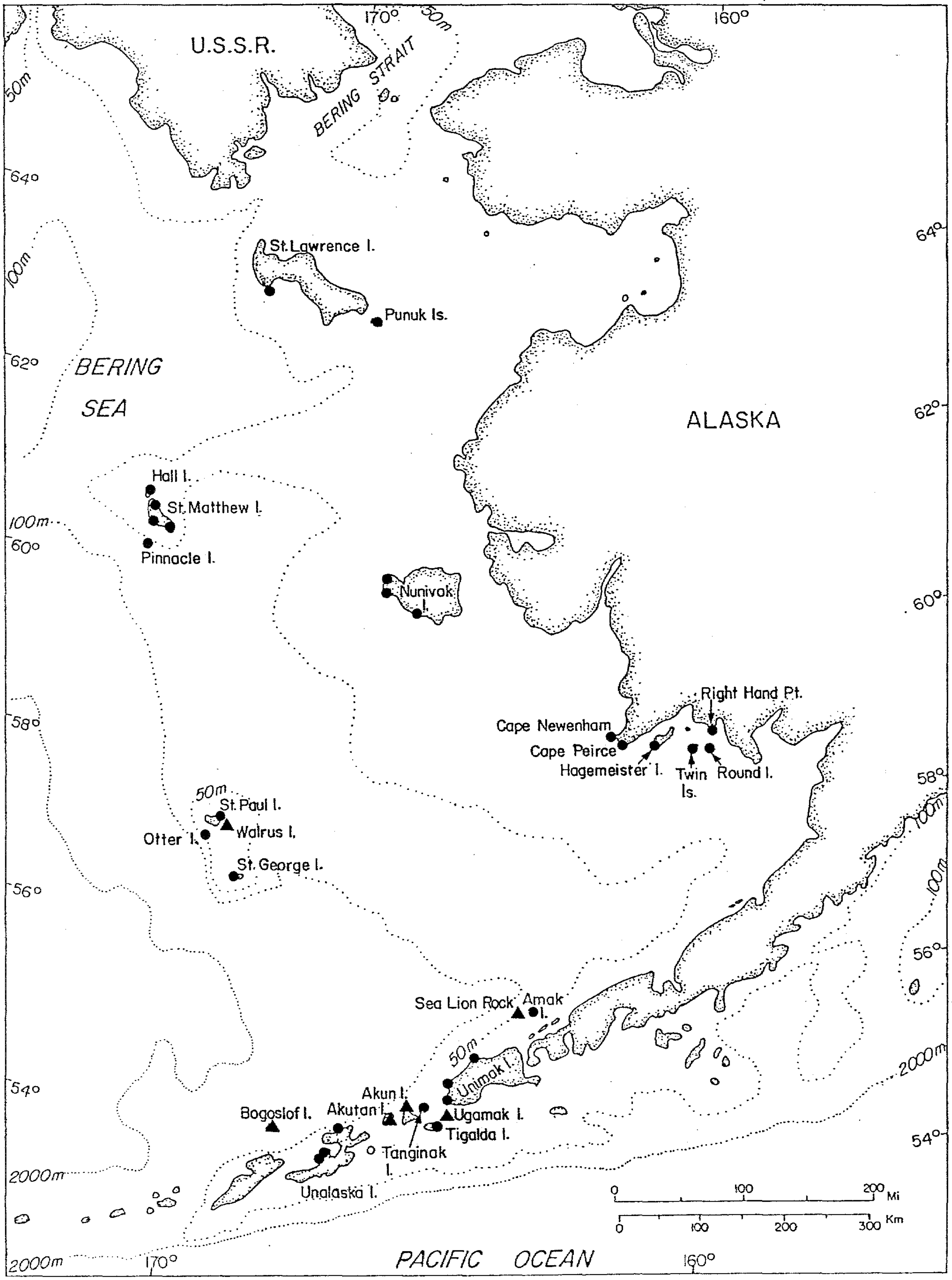



Figure 5. Locations of important haulout sites used by northern sea lions in the Bering Sea, Alaska. Sites designated by (▲) are rookeries.

which effect the distribution and abundance of principal prey (see earlier discussion of northern fur seal).

Sea lions occur irregularly and in small numbers (usually as singles) along the mainland coast of Alaska north of Cape Newenham; there are no known rookeries or haulouts used on a regular basis in this area. General comments of long-time residents indicate that single animals are known to have occurred on Besboro Island, Cape Denbigh, Cape Darby, Rocky Point, Cape Nome, Sledge Island and Cape Prince of Wales. During summer and autumn Nunivak Island is also regularly visited by relatively small numbers of northern sea lions, most of which are presumed to be juvenile males. The largest number that has been reported at any of these sites was 50 (Frost et al. 1983; Table 6.9). Lantis (in Kenyon and Rice 1961) indicated that sea lions were familiar to all of the Nunivak Island hunters, though they were not considered by them to be numerous. The sites near Cape Mendenhall and Cape Mohican are used most frequently (E. Shavings, pers. comm.).

At St. Lawrence Island, sea lions usually occur in small numbers (1-6 animals) in the autumn (Kenyon and Rice 1961). Reportedly sea lions are molting when they haul out on St. Lawrence Island. The two main haulout locations are at Southwest Cape and on South Punuk Island (F.H. Fay *in* Kenyon and Rice 1961). In one exceptional case, on 25 September 1953, Fay recorded about 1000 northern sea lions hauled out on the rocks and beach at Southwest Cape; three or four days later there were about 200 animals hauled out on South Punuk Island. Aside from this report, there have been no other sightings of more than 100 animals at haulouts in the St. Lawrence Island area. Farther north, at King and Little Diomede islands, sea lions occur irregularly, mostly as single animals during late summer and autumn.

## Harbor Seal (Phoca vitulina L.)

### Background

The harbor seal belongs to the family of true or earless seals (Phocidae). The distribution of the Pacific form (*Phoca vitulina richardsi*) extends as far south as the coast of Baja California and north to the Gulf of

Alaska, along the entire Aleutian Islands, and into the Bering Sea (Jeffries and Newby 1986; Hoover 1988b). Harbor seals are regularly found as far north in the Bering Sea as the Kuskokwim River mouth and Nunivak Island, and as far offshore as the Pribilof Islands where they are year-round residents (Frost et al. 1983). On the other hand, large-scale seasonal movements apparently occur in Kuskokwim Bay and northern Bristol Bay where many harbor seals are found in summer but few are found in winter when the area is largely covered with ice (Pitcher 1980; J.J. Burns, pers. comm. 1988). In general, the harbor seal is replaced north of Nunivak Island by the ice-breeding spotted seal (Phoca largha), whose pups are born much earlier and with white coats. Figure 6 shows the general distribution of the harbor seal in the eastern Beaufort Sea.

An interesting situation exists in the Pribilof Islands area where harbor seals occur in small numbers in all areas (especially when compared with the northern fur seals) except on Otter Island. Johnson (1974) estimated that about 1300 harbor seals were hauled out on Otter Island in 1974; Fiscus (cited in Johnson 1974) estimated that there were about 1500 harbor seals throughout the Pribilof Islands area. It should also be noted that the ice-associated spotted seal (Phoca largha) is abundant on the pack ice in heavy ice years when it extends as far south as the Pribilof Islands; a few of these seals, mainly pups, occasionally come ashore.

Harbor seals are more-or-less restricted to the coastal zone. Although they do not undertake regular seasonal migrations on a large scale, they are known to move considerable distances. One radio-tagged individual crossed a 75 km stretch of open water between two islands in the Gulf of Alaska. Other individuals have been seen up to 80 km from shore. Tagging studies have shown that young harbor seals move up to 250 km from their place of birth (Pitcher 1980). During the 1960's when the seals (primarily pups) were killed for the fur trade, hunters active at haulout sites on the Alaska Peninsula recognized that seals harassed and displaced from one site would move to another (e.g., from Port Heiden to the Seal Islands). Also, some harbor seals move northward along the Alaska mainland during summer and early autumn.

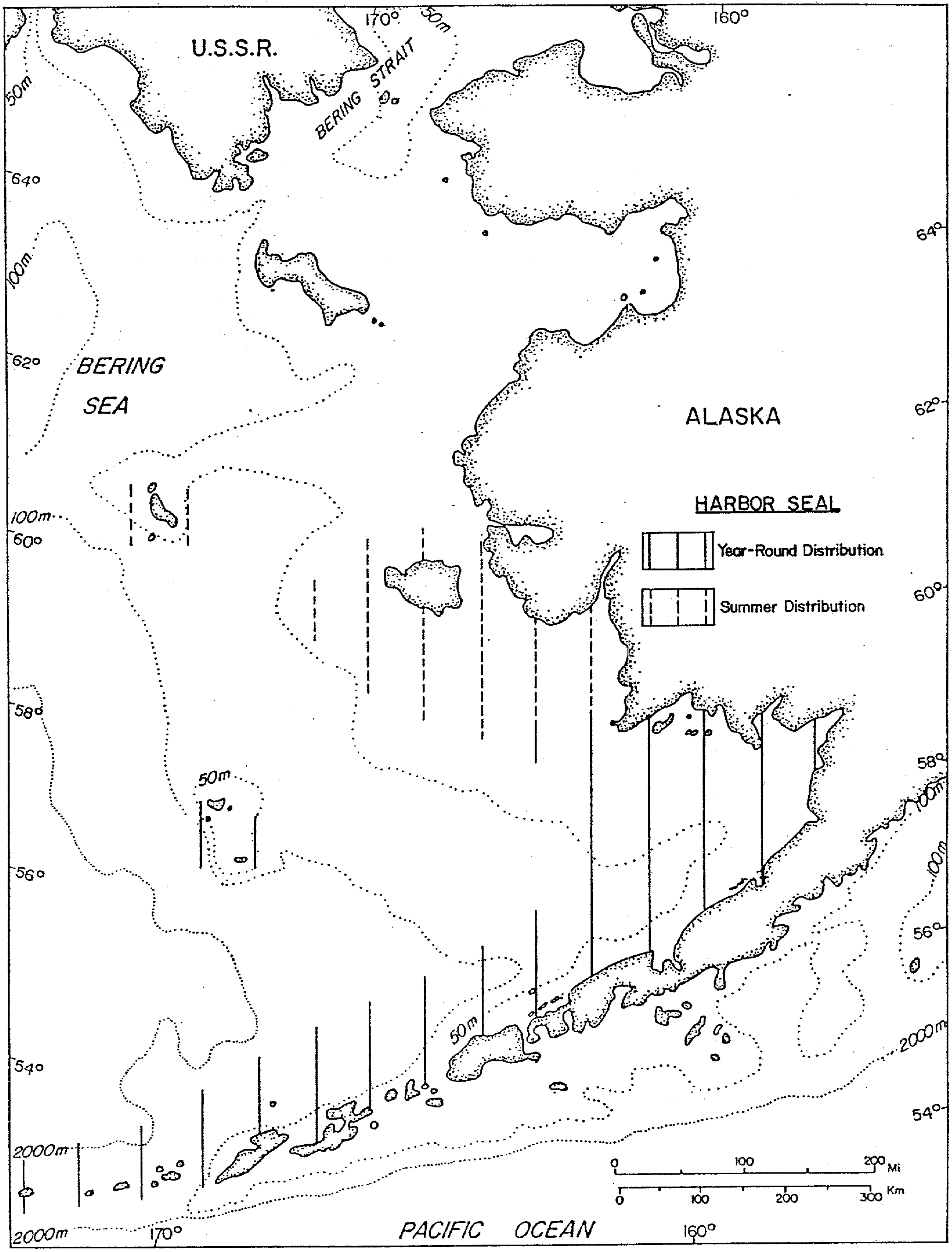



Figure 6. General distribution of the harbor seal in the Bering Sea, Alaska.

In general, most harbor seals haul out of the water to rest, give birth, and suckle their pups. However, it is not necessary for them to be hauled out to give birth; occasionally a pup is born and suckled in the water (J.J. Burns, pers. comm. 1988). Sand and gravel beaches, sand and mud bars, reefs, low lying rocks and ledges and pieces of ice are used as haulout areas. It is probably important for harbor seals to haul out during the molt period. The peak of the adult molt period on Otter Island (in the Pribilof Islands) was in late August (Johnson 1974); this period is probably the same throughout most of the Bering Sea. Access to food, freedom from disturbance, ready access to water, and protection from wind and wave action are among important criteria for haulout site selection by harbor seals.

Harbor seals reach sexual maturity at about 6 years of age, and may live for 30 years (Jeffries and Newby 1986; Hoover 1988b). In the Bering Sea mating takes place (in the water) mainly from mid-July to early August. As with other phocids, there is a period of arrested embryonic growth and delayed implantation, with implantation occurring in late October to early November (Burns and Gol'tsev 1984). Most pups are born during the early June to mid-July period. As a rule, pups are born on land. They enter the water shortly after birth, as most preferred haulout sites in the study area are awash during the twice-daily high tides. According to Lawson and Renouf (1987), prior to weaning, pups spend as much time in the water as out of it. They also found that the highly defensive behavior of mothers, together with the maternal bonding immediately after birth (especially during the first five minutes after birth), was responsible for maintaining early mother-pup contact. After that short time, pups followed their mothers. Mother-pup pairs went into the water about 50 minutes after birth. Some pups apparently remain with their mothers after weaning. In areas such as estuaries, where haulout habitat is limited, they may segregate into nursery groups composed almost exclusively of females with pups.

The population of harbor seals along the Pacific coast of North America is composed of about 330,000 individuals, of which almost 80%, or 260,000 individuals are found in Alaska (Jeffries and Newby 1986). The size of the eastern Bering Sea population was conservatively estimated to be about 30,000 in 1973. However, it was estimated that about 29,000 were present on sand and mud bars in the large estuaries on the north side of the Alaska Peninsula (Izembek Lagoon, Port Moller, Seal Islands, Cinder River, Port Heiden and Ugashik Bay) during the period 1975-1977 (Everitt and Braham 1980). Thus the overall estimate for the Bering Sea may have been in excess of 30,000. Harbor seals are difficult to census since the only time when they can be counted with any degree of accuracy is when they are hauled out. Although they haul out by the thousands in some locations, the proportion of the total population that may be hauled out at any one time is unknown, thus repeated counts usually represent trends in abundance rather than precise censuses.

Harbor seals and spotted seals reach the greatest degree of sympatry in the coastal zone from northern Bristol Bay (Nanvak Bay) to Kuskokwim Bay. Spotted seals occur in greatest numbers when the seasonal sea ice is present. Thus they move farthest south in greatest numbers during late winter and spring, although some occur in the coastal zone during summer and autumn; their abundance in this area increases from south to north. Arvey (1973) initiated a field study of sympatry in these seals and found that in summer, a small proportion of the seals hauled out in Nanvak Bay were spotted seals; the majority were harbor seals. Based on seals killed by subsistence hunters in Kuskokwim Bay during May and July, Arvey also found that one species replaced the other as the season progressed. All of the seals he examined in May were spotted seals, whereas those taken in July were harbor seals. The relative abundance of seals also showed a seasonal trend; seals were very abundant in May through early June and were much less abundant by July. These finding suggest that in the northern part of their range harbor seals are probably migratory; they occupy northern coastal areas in summer that are vacated by spotted seals in late spring after the ice disappears.

Harbor and spotted seals are also sympatric on coastal areas of the mainland from northern Bristol Bay northward, and around the central and northern Bering Sea islands. The actual number of harbor seals in this area is small and there are no known major haulout sites (i.e., where more than 100 have been reported to haul out). Nunivak Island seems to support the greatest number, and they may occur there year-round; the largest numbers of harbor seals recorded on Nunivak Island are at Ikookstakswak Cove, 5 km NE of Cape Mohican, at the west end of the island (<45 seals), in the bays around Ikook

Point at the extreme western end of the island (up to 70), and in the vicinity of Cape Mendenhall on the southern tip of the island (up to 80). They are present on islands of the St. Matthew group, though in small numbers, and they probably occur infrequently in the St. Lawrence Island area.

Burns (J.J. Burns and F. H. Fay, unpubl. data) was able to confirm the presence of harbor seals on St. Matthew Island based on definitive photographs taken by R. Johnson (Univ. of Alaska) on 20 August 1986. However, spotted seals are more abundant and they haul out in relatively large numbers (more than 100 in a herd) at several locations in this island group, as suggested in Frost et al. (1983). According to L.F. Lowry (ADFG, Fairbanks, AK) only the spotted seal was seen during observations on St. Matthew Island in mid-June 1986 when sea ice was still present. Few harbor seal pups are born on St. Matthew Island and St. Lawrence Island, and the few that biologists and native hunters have reported there are probably only seasonal residents during late summer through early autumn.

Records of harbor seals north of Kuskokwim Bay are particularly poor, although they are known to coastal residents as far north as St. Michael, on the southern shore of Norton Sound. They are usually referred to as "summer" seals or freshwater seals.

Patterns of Occupancy at Haulout Sites

Pitcher (1980) mentioned that studies in Washington State and San Francisco Bay have shown that harbor seals may adapt the timing of haulout to avoid human disturbance in some situations. Autumn haulout patterns by harbor seals on San Miguel Island, California, indicated that the largest proportion of individuals under observation hauled out between 13:00 and 15:00 h (Yochem et al. 1987). Most seals remained hauled out less than 12 h, and most seals were hauled out on fewer than 51% of the days sampled. Only about 40% of a sample of tagged seals hauled out each day; only 19% of tagged seals were hauled out during peak afternoon hours.

Renouf et al. (1981) found no recognizable diurnal pattern to harbor seal movements where harbor seals hauled out in a shallow bay on the French island of Michelon, in the Gulf of Saint Lawrence, Canada. They also found no relationship between the direction and intensity of seal traffic and various weather factors.

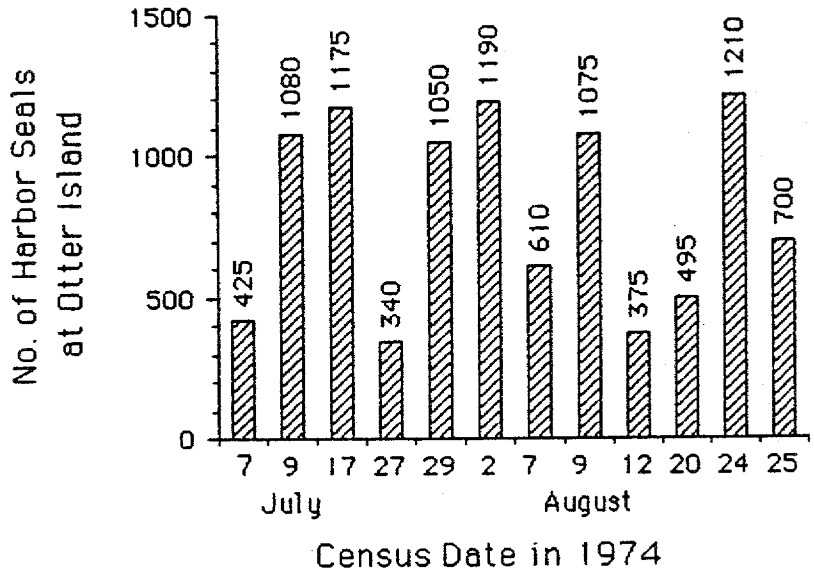
Johnson (1974, 1977) found more harbor seals hauled out on Otter Island, Alaska during his morning census (09:00 h) than during his evening census (21:00 h). In the southeastern Bering Sea, on the other hand, Everitt and Braham (1980:285) found a strong inverse correlation between the number of harbor seals hauled out and tide level. Significantly more seals were seen at lower tides than higher tides, regardless of whether the tides were rising or falling. This relationship has also been reported elsewhere (Scheffer and Slipp 1944, Fisher 1952, Bishop 1967, Newby 1971; all seen in Everitt and Braham 1980).

Repeat counts of harbor seals hauled out at Port Heiden in 1971 (data from Pitcher, in Frost et al. 1983; and Pitcher 1986) and on Otter Island in 1974 (data from Johnson 1974) illustrate the magnitude of day-to-day and week-to-week fluctuations in the number of individuals recorded at haulout sites (Fig. 7).

## Location and Status of Harbor Seal Haulout Sites

Unlike the situation described for the northern fur seal and northern sea lion, births of harbor seal pups apparently are not restricted to a select few rookeries. As indicated by their broad distribution and occupation of habitats with many different physical characteristics, harbor seals are quite adaptable. It is thought that areas with adequate prey, especially in large expanses of shallow water, are necessary to support large harbor seal populations.

The number of harbor seals recorded at haulout sites in the Bering Sea, especially at some sites in the southeastern Bering Sea, has apparently declined dramatically during the recent decade (Pitcher 1986). Numbers of harbor seals may have been below carrying capacity during the early to mid



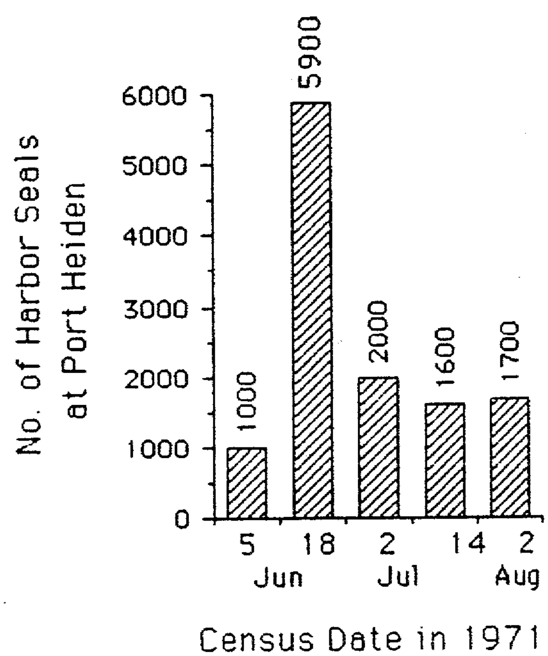




Figure 7. Variability in counts of harbor seals at two haulout sites in the Bering Sea, Alaska. Otter Island data are from Johnson (1974); Port Heiden data are from Pitcher (1986, in Frost et al. 1983).

1960's when as many as 50,000 individuals were harvested in Alaska in 1965 (Pitcher 1980). The harvest declined until the early 1970's when the Marine Mammal Protection Act of 1972 (MMPA) was passed. Currently, most of the harvest is taken by Alaskan Natives under the Native Exemption to the MMPA. Although several reasons have been given for the apparent recent decline of harbor seals (e.g., disease, over-exploitation in earlier years, increased predation, increased fouling in fishing gear, supposed reductions in principal prey [walleye pollock]), none of these suggestions have been clearly documented.

We have identified about 33 haulout sites that are or have been important for harbor seals in the Bering Sea and 9 other sites for which there is less complete information (Table 6; Fig. 8; Appendix 4). Except for the recent counts at several major haulout sites along the north side of the Alaska Peninsula, there is little current published information for several sites that were last censused and considered to be important in the 1970's. In general, the largest proportion of harbor seals in the Bering Sea occur along the north side of the Alaska Peninsula and in Bristol Bay (25,000-29,000), in Nanvak Bay (3,000), and at Otter Island (1,300; see Table 6). Smaller numbers are scattered along the coast of the Bering Sea, but no other major concentration areas have been recorded.

## Walrus (Odobenus rosmarus (L.))

### Background

The Walrus shares some characteristics with both the otariid or eared seals (fur seals and sea lions) and the phocids or earless seals (harbor seal, spotted seal, ringed seal and relatives). However, because of several distinct characteristics, such as its skin, method of sleeping at sea and feeding, and its distinctive tusks, it is placed in a separate taxonomic family--Odobenidae (Kenyon 1986). The walrus is among the largest of pinnipeds, with some males weighing almost 1600 kg; only the elephant seal (*Mirounga angustirostris*) is larger. The species has a discontinuous holarctic distribution; the widest gap is between the eastern Chukchi Sea and the central Canadian Arctic (Fay 1985). The range of the Pacific Walrus (*Odobenus rosmarus divergens*) is generally

Table 6. Peak counts of harbor seals at major haulout sites in the Bering Sea, Alaska†.

| Haulout Site | 1950's | 1960's | 1970's | 1980's | Current Estimate | Year of Curr. Est. |
|---|---|---|---|---|---|---|
| Umnak Island | -- | -- | 415 | -- | -- | -- |
| Bogoslof Island | -- | -- | 56 | -- | -- | -- |
| Unalaska Island | -- | 40 | 612 | -- | - | -- |
| Akutan Island | -- | 0 | 99 | 6 | 6 | 1980 |
| Akun Island (incl. Tangik I) | -- | -- | 179 | 23 | 23 | 1980 |
| Tanginak Island | -- | -- | -- | -- | -- | -- |
| Avatanak Island | -- | 0 | 135 | -- | -- | -- |
| Tigalda Island | 8 | -- | -- | -- | -- | -- |
| Kaligagan & islets NE of Tigalda I. | -- | 60 | 437 | 245 | 245 | 1980 |
| Ugamak Island | -- | 50 | 30 | -- | -- | -- |
| Aiktak Island | -- | 150 | 149 | 94 | 94 | 1980 |
| Unalga, Babies & rocks/islets | -- | 200 | 430 | 125 | 125 | 1980 |
| Cape Lapin (Unimak I.) | -- | 200 | 40 | -- | -- | -- |
| North Creek (Unimak I.) | -- | 70 | -- | -- | -- | -- |
| Unimak I. (all of N side) | -- | 550 | 125 | -- | -- | -- |
| Bechevin Bay | -- | 1500 | -- | -- | -- | -- |
| Cape Krenitzin | -- | 1500 | -- | -- | -- | -- |
| Isanotski Islands | -- | -- | 511 | -- | -- | -- |
| Izembek/Moffet Lagoons | 1142 | 1000 | 5000 | 1974 | 325 | 1987 |
| Amak Island | -- | 13 | 61 | 2 | 2 | 1981 |
| Cape Lieskof | -- | 100 | 199 | -- | -- | -- |
| Cape Seniavin | -- | -- | 71 | -- | -- | -- |
| Port Moller | 431 | 8000 | 7968 | 4010 | 4010 | 1985 |
| Seal Islands (incl. Ilnik) | -- | 3200 | 1600 | 1521 | 75 | 1988 |
| Port Heiden | 1295 | 10000 | 10548 | 6196 | 800 | 1986 |
| Cinder River | -- | 3000 | 4503 | 350 | 300 | 1988 |
| Ugashik Bay | -- | -- | 438 | -- | 1000 | 1988 |
| Egigik R. Flats | -- | -- | 300 | -- | -- | -- |
| Deadman Sands | -- | -- | 150 | 150 | 150 | 1988 |
| Cape Constantine | -- | -- | -- | 100 | 100 | 1981 |
| Tvativak Bay | -- | -- | -- | 77 | 77 | 1981 |
| Hagemeister Island | -- | -- | 200 | 100 | 100 | 1980 |
| Black Rock | -- | -- | -- | 300 | 300 | 1981 |
| Nanvak Bay* | -- | -- | 3000 | 3100 | 221 | 1987 |
| Cape Newenham | -- | -- | 50 | -- | -- | -- |
| Chagvan Bay (Mouth) | -- | -- | 150 | -- | -- | -- |
| Quinhagak (Middle Bar) | -- | -- | 3000 | -- | -- | -- |
| Kongiganak (South Bar) | -- | -- | 50 | -- | -- | -- |
| Kuskokwim Bay** | -- | -- | 2000 | -- | -- | -- |
| Nunivak I. (Cape Mendenhall) | -- | -- | -- | 80 | 80 | 1981 |
| St. George I. (Dalnoi Pt. area) | -- | -- | 289 | 50 | 50 | 1982 |
| Otter Island | -- | -- | 1210 | 119 | 119 | 1981 |
| TOTAL | 2876 | 29633 | 44005 | 18622 | 8202 | |

† Note: data in this table are from many different sources and years and have not been collected in a systematic or consistent fashion. Sources of peak count data are Kenyon (1960, 1965; Mathisen and Lopp (1963); Johnson (1977); Everitt and Braham (1979, 1980); Frost et al. (1983); Pitcher (1986); NMFS file data; USFWS file data; J. J. Burns field notes.

* The Nanvak Bay haulout site is reported to be the most northerly pupping colony of harbor seals in the Bering Sea (Clarence Rhode Nat. Wildl. Refuge Rep. 1981, in Frost et al.1983).

** Adult harbor seals, many with pups, were seen on sandbars at the mouth of the Kuskokwim River on 4 July 1972 (R. Baxter pers. comm., in Frost et al. 1983). Hence, haulout sites in Kuskokwim Bay, rather than Nanvak Bay, actually may be the most northerly pupping colony of harbor seals in the Bering Sea.

"--" signifies that no data are available.

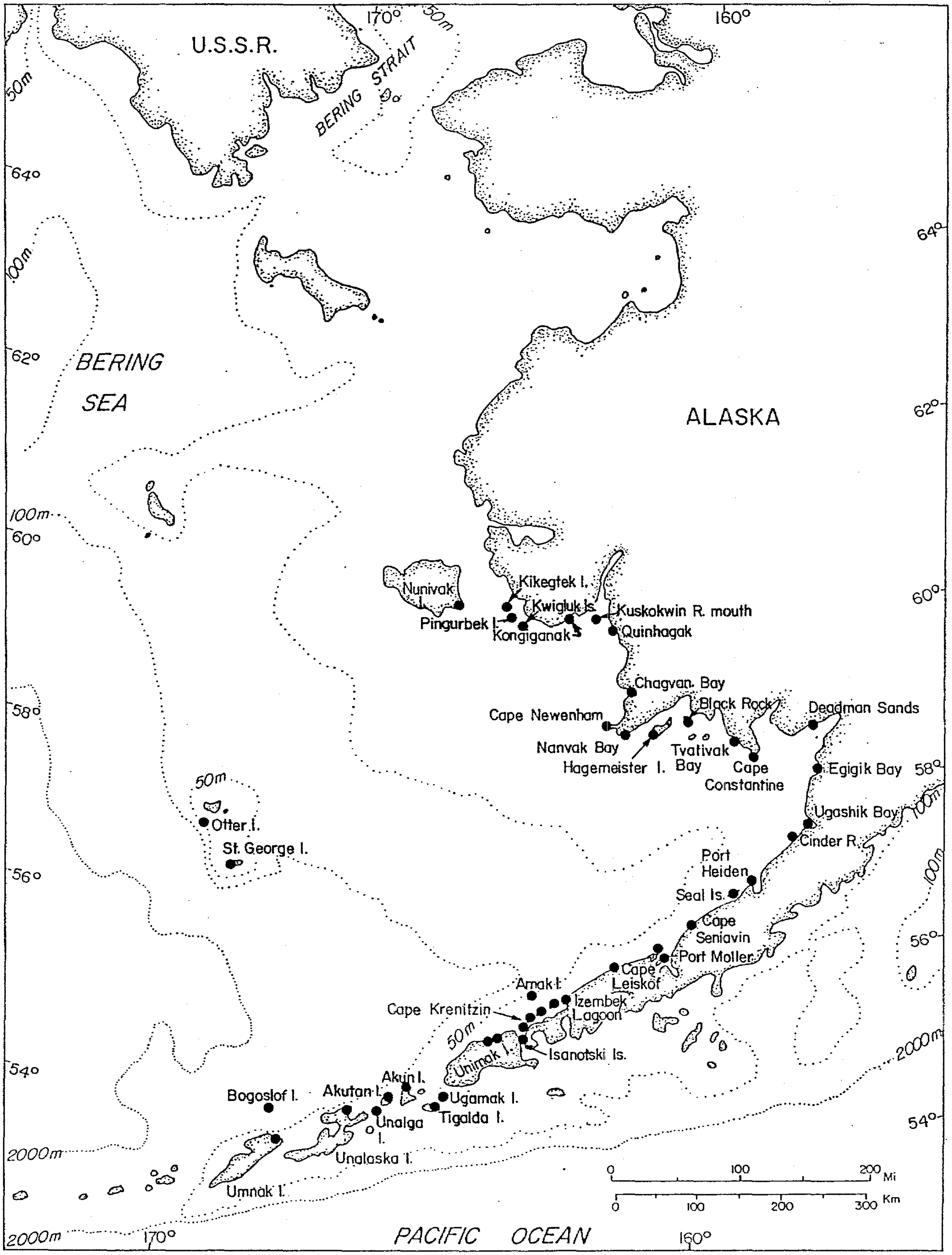



Figure 8. Locations of important haulout sites used by harbor seals in the Bering Sea, Alaska.

confined to the Bering and Chukchi seas. Aerial surveys conducted during 1960-1972 showed that when the Bering Sea ice pack is at its maximum, walruses though widely distributed were concentrated in two principal locations in the Bering Sea: north and south of St. Lawrence Island, and in southeastern Bristol Bay (Kenyon 1986; Sease and Chapman 1988). Figure 9 shows the general annual distribution of the species in the eastern Bering Sea.

Male walruses reach sexual maturity at 8-10 years but do not reach physical maturity (i.e. are not able to successfully compete for mates) until about 15 years of age. Females reach sexual maturity at about 6-8 years of age and may give birth to a single calf about every 2 years. Calves are born on the ice in April or May after a gestation period of 14-15 months. Walruses may live to be 35-40 years of age (Fay 1985).

Walruses feed primarily on bivalve molluscs which they obtain from bottom sediments in the shallow continental shelf waters of the Bering and Chukchi seas (Fay 1985, Nelson and Johnson 1987). The distribution and abundance of the walrus is thought to be closely tied to the availability of large volumes of molluscan crustaceans; captive walruses consume up to almost 30 kg of bivalves daily (Kenyon 1986).

The size of the Pacific walrus population was greatly reduced during the last half of the 19th century and again during the 1950's. The first of those major reductions resulted in the virtual extirpation of walruses from haulout sites in southeastern Bering Sea and the Pribilof Islands. Elliot (1882) indicated that walruses had formerly hauled out on the Pribilofs in large numbers, and he referred to the acquisition of considerable amounts of ivory from there (by early Russian hunters and traders) as proof of the former abundance. Jordon and Clark (1898) considered that walruses were practically extinct on the Pribilofs and True (1899) said that they had been exterminated there.

Pacific walruses have increased greatly since the 1950's; the population was estimated to be 250,000 animals in 1980 (Fay et al. 1984; Sease and Chapman 1988) and many experts believed that the walrus population had reached or exceeded the long-term carrying capacity of the habitat. The increase

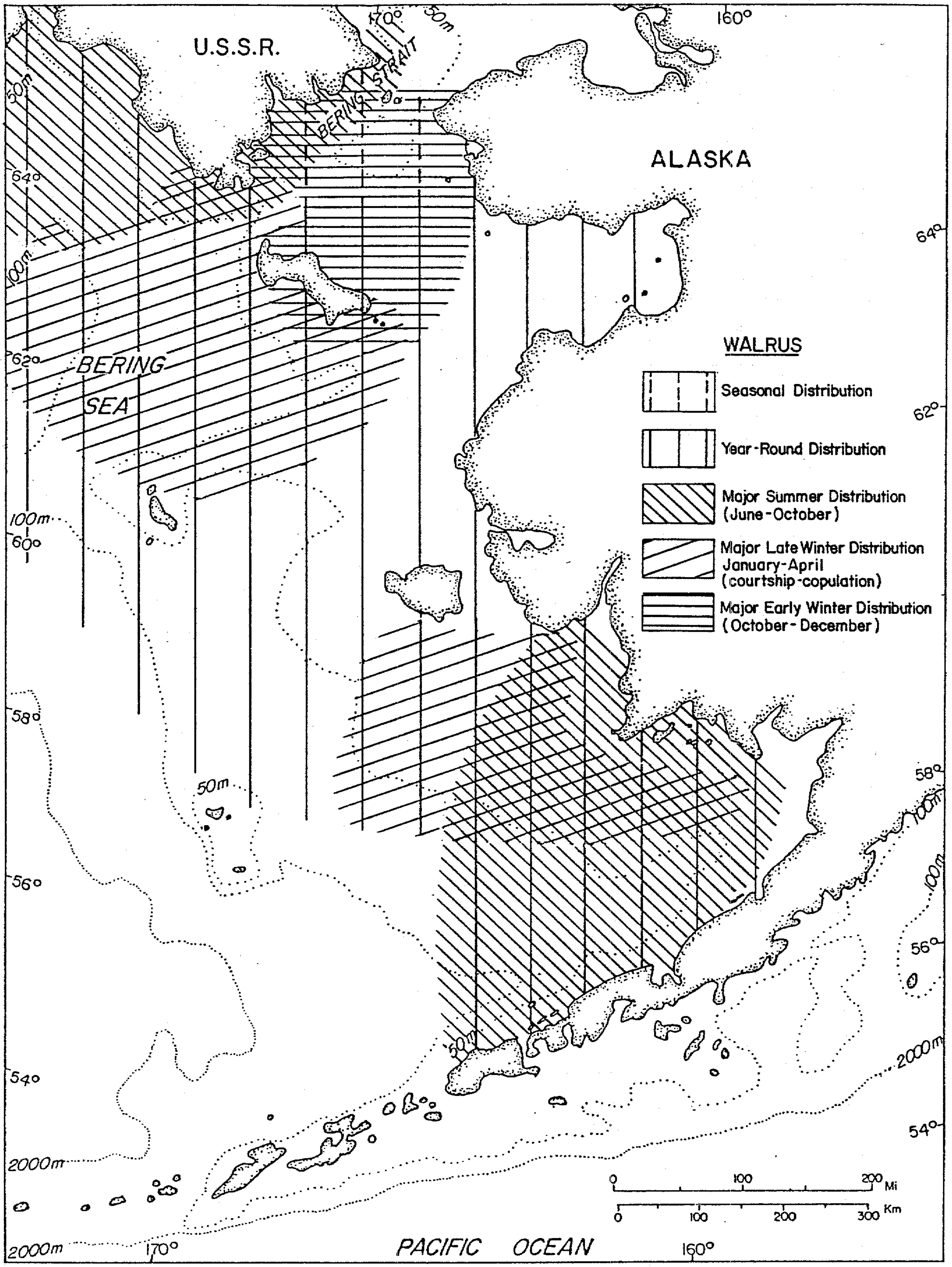



Figure 9. General distribution of the Pacific Walrus in the Bering Sea, Alaska.

resulted in the reoccupation of many former hauling grounds; so far, however, the Pribilof Islands remain a notable exception.

Patterns of Occupancy at Haulout Sites

The distribution of Pacific walruses varies considerably throughout the year. Males and females aggregate together in the pack ice as far north as St. Lawrence Island during late winter and early spring, which is when mating occurs; during some mild winters, many walrus may remain in the northern Bering Sea throughout the winter. As the ice pack breaks up and begins to move north (May-July), the population of walruses segregates; females with young stay with the ice and drift north through the Bering Strait into the Chukchi Sea. Virtually all males move toward the coast and south into Bristol Bay where they aggregate in large numbers at traditional haulout locations, principally along the north coast of Bristol Bay (Kenyon 1986; Sease and Chapman 1988). The largest and most regularly used summer haulout sites for these bull walruses are on the Walrus Islands (Round Island, N. Twin Island, High Island) and at nearby Cape Peirce (Fig. 10).

Bulls remain at these coastal haulout locations throughout the summer-early fall period, after which they begin moving west and north to rendezvous with the females and young that have drifted south with the advancing pack ice. Large numbers of walruses sometimes aggregate on St. Lawrence Island and regularly on the nearby Punuk Islands during October through December.

Walruses are known to be synchronous in their arrival at and departure from haulout sites on land and ice (Mazzone 1987; O'Neil and Haggblom 1987). To date that phenomenon, although important to the issue of protecting haulout sites, has not been adequately studied. All observations at haulout sites on land show generally alternate peaks of high and low numbers. At Cape Peirce, Mazzone (1987) reported that during the summer of 1985 and 1986 walruses were ashore for an average of 2.54 days and were away (presumably at sea) for an average of 8.5 days. O'Neil and Haggblom (1987) found that the mean duration of time ashore at Cape Peirce was 2.97 days and the time away from the haulout sites was 7.87 days. Counts of walruses hauled out at Cape Seniavin in 1987 and 1988 (data from S. Hills, USFWS pers. comm. 1988) illustrate the magnitude

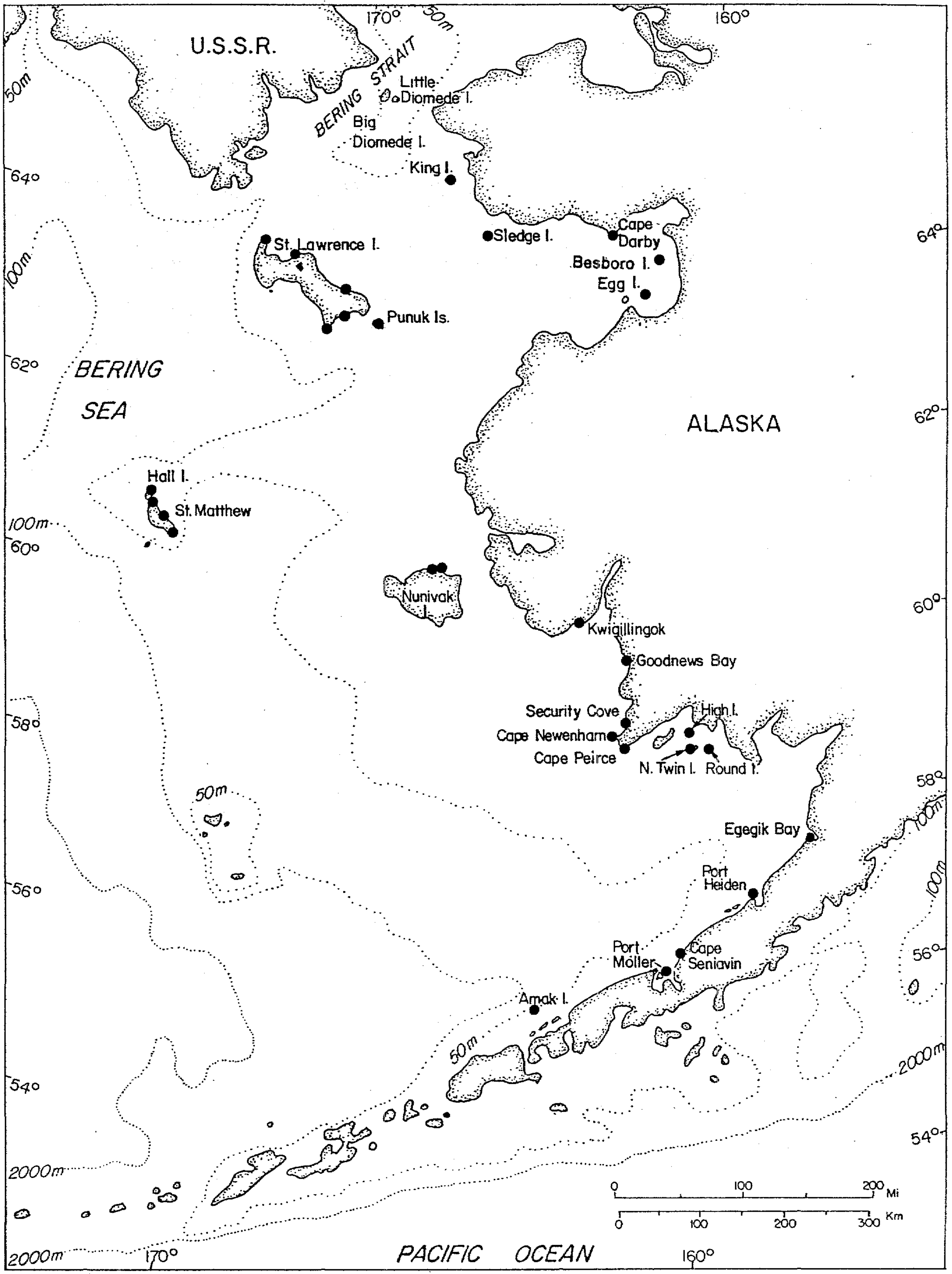



Figure 10. Locations of important haulout sites used by Pacific walruses in the Bering Sea, Alaska.

of day-to-day and week-to-week fluctuations in occupancy at haulout sites (Fig. 11).

Freedom from disturbance, particularly that associated with hunting and other types of harassment of hauled out walruses is required before reoccupancy of abandoned haulout sites is possible. Although walruses have been attempting to use former haulout sites and have been reported at many locations, relatively few places are protected from undue disturbance by man. An interesting comparison of successful vs. unsuccessful reoccupancy has occurred on the Diomede Islands. Big and Little Diomede islands are very similar to each other and are only 4 km apart. Walrus haulout sites were re-established on Big Diomede Island starting in about 1968. That island is now regularly used every year by several thousand walruses. In contrast, small numbers of animals have repeatedly attempted to haul out on Little Diomede Island, but are usually hunted and frightened away when discovered. As yet, there is no regularly used haulout site on that island.

## Location and Status of Pacific Walrus Haulout Sites

Data from Frost et al. (1983) indicated that only 12 of 39 specific locations where walrus had been reported to haul out in the eastern Bering Sea were regularly used by substantial numbers of animals. Six of these major locations were in the North Aleutian Basin (Amak Island, Port Moller, Cape Seniavin, Big Twin Island, Round Island, Cape Newenham), one was in the St. Matthew Island-Hall Island area, and five were in Norton Basin (Besboro Island, St. Lawrence Island, Punuk Islands, King Island and Big Diomede Island (USSR)). Except for the addition of Cape Peirce, which is currently used by a large proportion of the walrus that historically have hauled out in the Walrus Islands area, we found the general trend given in Frost et al. (1983) to be generally consistent with our current review (Table 7; Fig. 10; Appendix 5); we evaluated about 30 different haulout sites for Pacific walrus.

It is noteworthy that the reoccupancy by significant numbers of walruses of haulout sites in the southern Bristol Bay area, and some sites in northern Bristol Bay (e.g., Cape Peirce), is a relatively recent event. It is thought that these sites were abandoned earlier in the century when walrus numbers

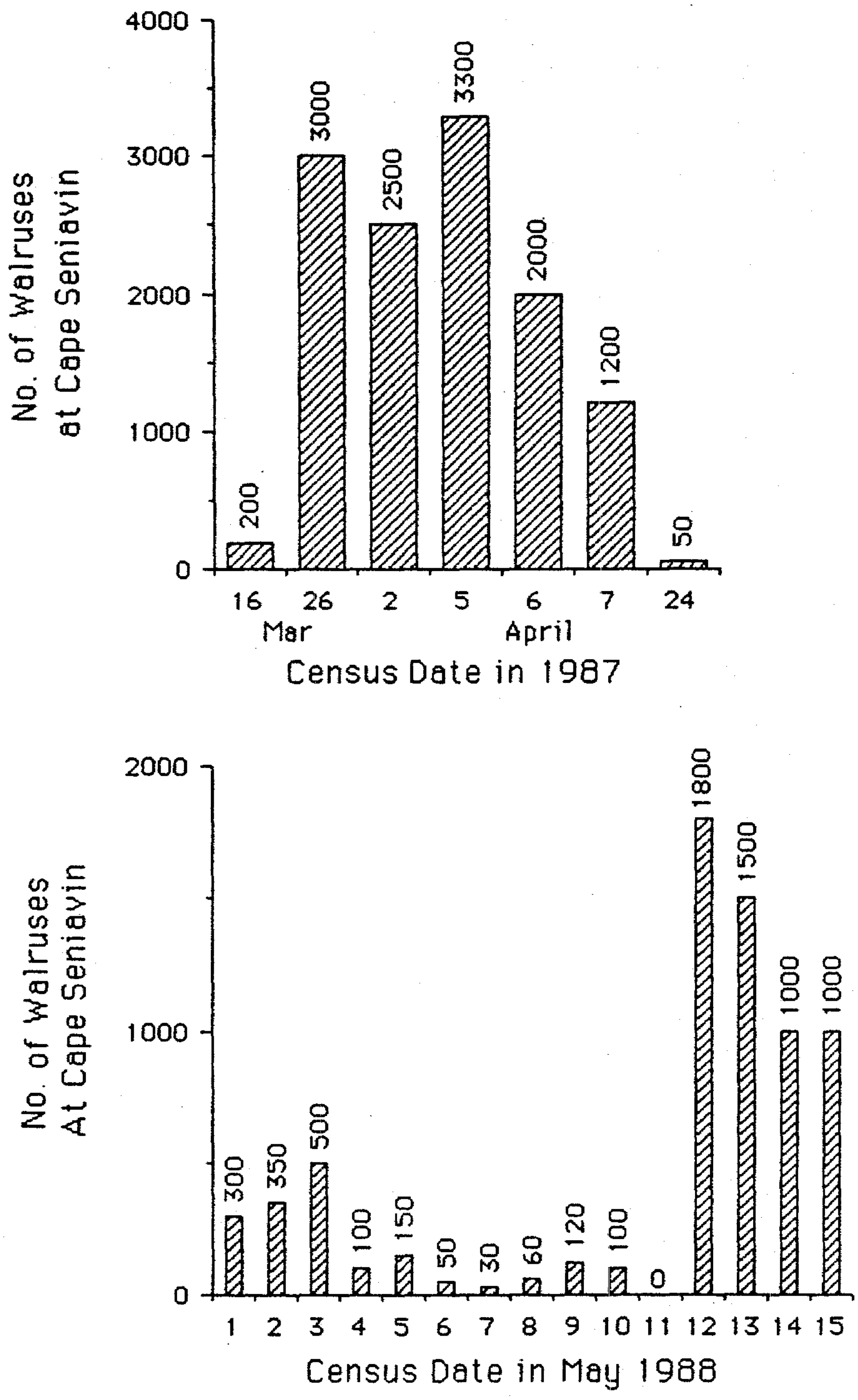



Figure 11. Variability in counts of Pacific walruses at Cape Seniavin, Alaska. Data are from S. Hills, USFWS (pers. comm. 1988).

Table 7. Peak counts of Pacific walruses at major terrestrial haulout sites in the Bering Sea, Alaska.† (This table does not include walruses that do not haul out in terrestrial habitats, i.e., many females and young.)

| Haulout Site | 1950's | 1960's | 1970's | 1980's | Current Estimate | Date of Curr. Est. |
|---|---|---|---|---|---|---|
| Amak Island* | -- | 120 | 500 | 0 | 0 | 1982 |
| Port Moller* | -- | 1000 | 4000 | 3250 | 3250 | 1983 |
| Cape Seniavin* | -- | -- | 140 | 3500 | 1800 | 1988 |
| Port Heiden* | -- | -- | 60 | -- | -- | -- |
| Egegik Bay* | -- | -- | -- | 1000 | 1000 | 1983 |
| High Island* | 250 | -- | -- | -- | -- | -- |
| North Twin Island* | 1000 | -- | 1000 | -- | -- | -- |
| Round Island* | 3076 | 2000 | 10000 | 12400 | 5300 | 1987 |
| Cape Peirce* | -- | -- | -- | 12500 | 6300 | 1987 |
| Cape Newenham* | -- | -- | 500 | 700 | 70 | 1987 |
| Security Cove* | -- | -- | 30 | 10000 | 10000 | 1983 |
| Goodnews Bay* | -- | -- | 250 | -- | -- | -- |
| Kwigillingok* | -- | 500 | -- | -- | -- | -- |
| Nunivak Island* | | | | | | |
| Cape Etolin* | -- | -- | 200 | -- | -- | -- |
| Mekoryuk* | -- | -- | 200 | -- | -- | -- |
| St. Matthew Island* | | | | | | |
| Cape Upright* | -- | -- | -- | 160 | 160 | 1982 |
| Cape Glory of Russia* | -- | -- | -- | 80 | 80 | 1980 |
| Lunda Bay* | -- | -- | -- | 180 | 180 | 1982 |
| Hall Island* | -- | -- | -- | 550 | 130 | 1986 |
| Egg Island* | -- | -- | 300 | -- | -- | |
| Besboro Island* | -- | 400 | -- | 100 | 100 | 1981 |
| Cape Darby* | -- | -- | 7 | 50 | 50 | 1981 |
| Sledge Island | -- | -- | 1050 | 3 | 3 | 1981 |
| King Island | -- | -- | 1000 | 5000 | 1000 | 1985 |
| Punuk Islands | | | | | | |
| North Island | 100 | 1500 | 32000 | 15000 | 15000 | 1981 |
| Middle Island | -- | -- | 14000 | -- | -- | -- |
| South Island | -- | -- | 11000 | -- | -- | -- |
| St. Lawrence Island | | | | | | |
| Chibukak Pt. | 5 | 100 | 100 | 100 | 100 | 1988 |
| Salghat | -- | -- | 19000 | -- | -- | -- |
| Maknik | -- | -- | 35000 | -- | -- | -- |
| Kialegak Pt. Area | -- | -- | 37000 | -- | -- | -- |
| TOTAL | 4431 | 5620 | 167337 | 64573 | 44523 | |

† Note: data in this table are from many different sources and have not been collected in a consistent or systematic manner. Peak counts were taken from the following sources: Kenyon (1960); Fay and Kelly (1980); Kelly (1980); Fay (1982); Frost et al. (1983); Mazzone (1986); O'Neil and Haggblom (1987); Sherburne and Lipchak (1987); S. Hills (USFWS, pers. comm. 1988); ADFG files; Izembek NWR files; NMFS files; USFWS files.

* An asterisk indicates that this haulout site is occupied mostly by adult males. All other haulout sites (those without asterisks) are occupied mostly by male and female adults, subadults and calves.

"--" signifies that no data are available.

were considerably reduced. Some of the first relatively recent sightings in the southern Bristol Bay region were on Amak Island in spring 1962 (J.J. Burns files), near Ugashik Bay in spring 1962 and 1963 (Fay and Lowry 1981), and on ice in Herendeen Bay (Port Moller area) in late winter-early spring 1968 (Frost et al. 1983). Cape Seniavin apparently was reoccupied in the late 1970's. The largest number of walruses recorded along the north coast of the Alaska Peninsula was 6,750 individuals on 26 April 1983. About 3,500 of these were hauled out at Cape Seniavin and 3,250 were in the Port Moller area, including Herendeen Bay (USFWS file data).

## Reactions of Pinnipeds to Disturbance

The following section of the report describes documented reactions of northern fur seal, northern sea lion, harbor seal and Pacific walrus to various types of noises and disturbances similar to those that may result from OCS development in the eastern Bering Sea. As mentioned in the 'Methods' Section, we have used published information as much as possible, but also have relied on relevant personal communications from experienced and knowledgeable biologists. We have also used relevant published and unpublished information concerning species or subspecies closely related to the four pinnipeds considered in this study, e.g., Guadalupe and Cape fur seals (*Arctocephalus townsendi* and *A. pusillus*), respectively, California sea lion (*Zalophus californianus*), spotted seal (*Phoca largha*), ringed seal (*P. hispida*), bearded seal (*Erignathus barbatus*), harp seal (*P. groenlandica*), and Atlantic walrus (*Odobenus rosmarus rosmarus*).

Our discussion of the effects of noise and disturbance is organized by the four species, but is further broken down into three additional categories, namely: airborne noise and disturbance (mainly aircraft), underwater noise and disturbance (mainly ships and boats), and human presence and disturbance. Airborne and underwater noises and disturbances are further subdivided into stationary sources and moving sources. Several recent observations suggest that animals are more likely to accommodate to stationary noise sources than moving sources (see Richardson et al. 1983 for review).

## Northern Fur Seal

### Airborne Noise and Disturbance

**Moving Sources.** A well documented example of aircraft disturbance to northern fur seals occurred at the Gorbatch hauling grounds on St. Paul Island (Pribilof Islands) in September 1981 (S. Swibold, pers. comm. 1988). Swibold was photographing from a blind near thousands of resting bachelor bull fur seals. As a large twin-engine aircraft passed overhead (at 300-500 feet altitude), the seals panicked and stampeded toward the water. Her film apparently shows the seals looking up (toward the low-flying aircraft) as they stampeded. No mortality was recorded as a result of this disturbance.

In contrast to the above observation, was an observation during July of a group of sleeping subadult male northern fur seals at a hauling ground adjacent to East Rookery, on St. George Island in the Pribilofs. As a twin-engine cargo plane flew directly overhead at low altitude (S. Zimmerman, NMFS, pers. comm. 1988), the seals responded by awakening and lifting their heads, but there was no mass movement, no milling behavior, nor any other obvious overt reaction to the aircraft.

In the opinion of C. Fowler (NMFS, pers. comm. 1988), the Little Polovina rookery/hauling ground may be the next fur seal haulout site to be abandoned in the Pribilof Islands--possibly within the next several years. This haulout site is within 5 km of the airport runway on St. Paul Island, and one fur seal biologist (A. York, NMFS, pers. comm. 1988) speculated that the decline in numbers of fur seals at the Polovina Complex (Polovina, Little Polovina and Polovina Cliffs; see Fig. 15, Appendix 2) of rookeries may be related to their close proximity to the St. Paul airport.

York tried to document the number of commercial aircraft using the St. Paul airport each year since its construction during WW II (1941-1943) in relation to the steady decline in the number of fur seals using the Polovina Complex of rookeries. Although the airport records showed a general increase over the years in the number of commercial flights to and from St. Paul, there were many more unrecorded military and charter flights that she was unable to document. Although her investigation was inconclusive, York felt there was no basis to completely discount the possible relationship between the level of aircraft overflights and the decline in use of the Polovina complex of rookeries/hauling grounds, especially at Polovina and Little Polovina.

York said that on several occasions during the past few years she has observed large helicopters flying over her study area at the Kitovi rookery on St. Paul Island. However, she has never noticed a stampede as a result of these overflights.

In the opinion of A. Antonelis (NMFS, pers. comm. 1988), fur seals respond differently to different types of aircraft. When he conducted photo-censuses using a single-engine, fixed-wing aircraft flying at 100-175 m over the fur seals, he saw no overt reaction by the seals to his aircraft. However, he was aware of severe disturbances caused by larger multi-engine aircraft flying low over rookeries/hauling grounds. Antonelis has seen the film by Swibold and noted that it is a clear example of severe aircraft disturbance to northern fur seals. He further pointed out that fur seals seem to be more easily disturbed (i.e., are more inclined to stampede) on hot rather than cool days. Antonelis reiterated that he was not aware of any instance where mortality has resulted from a low-level aircraft overflight.

**Stationary Sources.** A. Antonelis (NMFS, pers. comm. 1988) is currently conducting research and synthesizing information on the effects of sonic booms on fur seals at San Miguel Island, California. His research is primarily related to possible hearing impairment in the seals caused by sonic booms associated with activities at the nearby Pacific Missile Range (Vandenberg Air Force Base) in California. He has found no example in a fur seal of hearing impairment caused by a sonic boom. Based on his observations, fur seals usually respond to sonic booms by assuming an upright posture (they appear startled), and they sometimes stampede from the beach into the water. Antonelis has never seen a case where mortality has resulted from such disturbance.

Underwater Noise and Disturbance

**Moving Sources.** During his pelagic studies of northern fur seals, H. Kajimura (NMFS, pers. comm. 1988), has found them to be quite tame when first encountered at sea; they are curious and often approach the research vessel. However, after one or two days of collecting (hunting) northern fur seals in one area, it is often very difficult to maneuver the ship close to the seals. In some instances, sleeping fur seals were seen to respond to the approaching ship at distances up to about a mile; the seals apparently were awakened by the noise of the ship, and then rapidly swam away. Kajimura said that he thought the seals were responding to the sounds of the ships propellers and engine. He thought they could hear the prop and engine sounds, and that they associated those sounds with earlier collecting activities, and fled away from the source of the ship sounds. However, such a response could also, in part, be an artifact of removing (hunting) the least wary seals from an area.

**Stationary Sources.** Shaughnessy et al. (1981) reported on attempts to scare cape fur seals away from fishing nets in waters off southern Africa. The seals disturb shoals of fish and pursue fish into nets, causing damage to the nets. Fur seals remained in an area where they were subjected to 'firecrackers', killer whale playbacks, rifle shots and an arc-discharge transducer. The arc-discharge transducer produced pulses at 10-second intervals with a peak source level of 132 dB//1 μPa at 1 m. Fur seals did not appear to be deterred by any of the devices used in this study.

Human Presence and Disturbance

According to C. Fowler (NMFS, pers. comm. 1988), the abandonment of the 'Lagoon' rookery on St. Paul Island in the late 1940's may have been due to increased activities at the village of St. Paul, which is situated directly across the bay from the 'Lagoon' rookery. Fowler speculated that increased hunting, as well as increased general activity at the village of St. Paul, including the operation of the fur seal by-products processing plant, may have been responsible for the abandonment of this rookery.

A. York (NMFS, pers. comm. 1988) said that people (including biologists) walking near or through fur seal rookeries/hauling grounds also may cause major disturbances. In some cases, such disturbances may be as severe as aircraft overflights. According to York, one reason why there is so little documentation of mortal effects of aircraft overflights or other disturbances and consequent stampedes in breeding rookeries, is because observers are often too far away from the rookeries to be able to see dead or dying pups that may have been crushed during stampedes. Most of the observation blinds at the rookeries on the Pribilof Islands are far enough away to greatly reduce the possibility of human disturbance. Blinds near the hauling grounds may be closer to concentrations of seals, so there is a greater risk to the non-breeding animals concentrated at those locations.

## Northern Sea Lion

### Airborne Noise and Disturbance

**Moving Sources.** Calkins (1983) indicated that different types of aircraft appear to have substantially different effects on marine mammals. Reactions of northern sea lions to aircraft is varied and depends on several factors. At haulout sites where sea lions are not breeding and not pupping, approaching aircraft will usually cause some disturbance, frightening at least some animals into the water. On some occasions at haulouts (not rookeries), approaching aircraft can cause complete panic and stampede all sea lions to the water. The variability in reaction at haulouts (as opposed to rookeries) appears to depend on environmental conditions (weather, tide, etc.) as well as the type, speed and altitude of the approaching aircraft.

When sea lions are at rookeries during the breeding and pupping season, their reaction to aircraft is altered and appears to depend more upon the sex, age and reproductive status of the individual (R. Merrick, NMFS, pers. comm. 1988). Immatures and pregnant females may enter the water when aircraft approach, but territorial males and females with small pups generally remain hauled out, but may vocalize during the disturbance. In general, aircraft disturbance to sea lions appears to cause at least some panic stampedes into the water on most occasions. Merrick knew of very few examples of serious disturbance to northern sea lions in the Bering Sea by aircraft flying within several hundred meters.

**Stationary Sources.** Stewart (1981) reported that breeding California sea lions and elephant seals exposed to intense impulsive airborne noise from a carbide pest control cannon apparently were not greatly affected, although the details of this study are not available. Apparently 'Habitat use, population growth, and pup survival of both species were unaffected by periodic exposure to carbide cannon impulse noise' (Stewart 1981).

Underwater Noise and Disturbance

**Moving Sources.** Northern and California sea lions have been hauling out since 1978 on the Steveston jetty, adjacent to the middle arm of the Fraser River where it flows into Georgia Strait, in southwestern British Columbia (M. Bigg, DFO, pers. comm. 1987). They aggregate in this area in April and May to feed on smelt which move into the Fraser River. The haulout site is immediately adjacent (≤500 m) to the main shipping channel leading from Georgia Strait to New Westminister, British Columbia. Bigg said there is no evidence that these seal lions have been affected by nearby heavy ship traffic or by tour boats that approach close to the hauled out sea lions.

Similarly, at Race Rocks, in Jaun de Fuca Strait, British Columbia, up to 800 California and northern sea lions haul out near a busy shipping lane leading to ports in Puget Sound, Washington, and Georgia Strait, British Columbia (M. Bigg, DFO, pers. comm 1987). This haulout site has been heavily used by sea lions in spite of increasingly heavy ship traffic over the past two decades. Bigg knows of no major disturbance to sea lions at the Race Rocks haulout site.

Bigg mentioned that northern and California sea lions aggregate (major "rafting area") in Active Pass, British Columbia, a narrow and heavily used shipping lane through the southern Gulf Islands of British Columbia. He is not aware of any disturbance to sea lions in this area, even though such shipping has been going on near "rafting" sea lions for many decades. J.J. Burns has observed northern sea lions actively congregating around and following vessels engaged in fishing and processing of fish in the Gulf of Alaska and the Bering Sea.

## Human Presence and Disturbance

Lewis (1987) studied the effects of human disturbance on sea lions at rookeries in the northeast Gulf of Alaska. Here census procedures (by biologists) involved purposely flushing all animals except pups from the rookeries. Results indicated that there was little pup mortality as a result of this procedure, but that aggressive behavior and territorial behavior by breeding females increased significantly, and the rookery was much more easily disturbed (more stampedes) by natural events after such a disturbance. There was some abandonment of the rookery by non-pup sea lions immediately after the disturbance. The significant finding, however, was that there was markedly lower maintenance of female-pup contact (49% vs. 71%) in the year of disturbance compared to a year of no such disturbance. The female-pup bond during the early stages of pup development is critical to the survival of the pup; if this bond is broken, the pup is likely to die. It should be noted that natural mortality of pups during the first year of life may reach 50% (ADF&G 1973). The variety of natural mortality factors is not clearly understood, but young pups washed to sea during storms are presumed to drown.

Northern sea lions are generally less easily disturbed at rookeries early in the breeding season (June) during mating and pupping, and generally more sensitive later, after the breeding season (August), when most of the adult males and non-breeding females are hauled out at locations away from rookeries (R. Merrick, NMFS, pers. comm. 1988). During August, only the pups and productive females would still be present near rookeries; Merrick said that this is the period when sea lions are most reactive to disturbance.

According to Merrick (NMFS, pers. comm. 1988), the shooting of northern sea lions has caused severe disturbance in the Unimak Pass area of the Bering Sea. In the past, sea lion meat apparently was used as bait in certain commercial fishing operations (e.g., crab fishery, long-line halibut fishery); sea lion rookeries near fishing grounds traditionally were hardest hit by such activities. Although this practice is no longer common, the large rookery on Ugamak Island recently was affected by such a shooting. Similarly, Kenyon (1962) suggested that the large northern sea lion rookery near Northeast Point on St. Paul Island was abandoned because of excessive harvesting. Formerly, this was the largest sea lion rookery in the Pribilof Islands; no pups have been recorded there since 1957.

## Harbor Seal

### Airborne Noise and Disturbance

**Moving Sources.** Pinnipeds that haul out for molting or pupping probably are the most susceptible to adverse effects resulting from disturbance by aircraft. Johnson (1977) gave evidence that harbor seals may temporarily leave pupping beaches when aircraft fly over. Since harbor seals may not always haul out at the same site when returning to the beach, pups left behind at one site may be permanently separated from their mothers and may die. Low-flying aircraft may have been responsible for the deaths of more than 10% of the approximately 2000 pups born on Tugidak Island, Alaska, in 1976 (Johnson 1977). All types of aircraft flying below 400 ft (122 m) nearly always caused seals to vacate the beaches, sometimes for 2 h or more, with helicopters being particularly disturbing. Responses of harbor seals to overflights at altitudes between 400 and 1000 ft varied with weather, frequency of disturbance, altitude and aircraft type. Aircraft were more disturbing on calm days, after recent disturbance, and at lower altitudes. According to Johnson (1977), helicopters and large planes were more disturbing to harbor seals than small airplanes.

Pitcher and Calkins (1979) reported that harbor seals are susceptible to disturbance from low-flying aircraft and are noted for their mass exodus (stampedes) from hauling areas in the event of such disturbance. As mentioned earlier, Johnson (1977) has warned that one of the major negative consequences of such stampedes is the separation of mother-pup pairs, and the consequent reduction in pup survival.

Several thousand harbor seals haul out during May through October on the sand and mud bars at the entrance to Nanvak Bay, near Cape Peirce, Alaska (Johnson 1975; USFWS file data; LGL file data). Single-engine float planes and less frequently small amphibious aircraft land and take off near the beach about 2-3 times each month during this same period. During these aircraft activities, the seals appear to leave the beach as soon as the aircraft either land or take off.

M. Bigg (DFO, pers. comm. 1988) said that there are two major haulout sites for harbor seals on the sand bars and shoals near the entrance to the Sea Island Arm of the Fraser River, in British Columbia. One of these haulout sites (the northernmost) is fairly close to the main E-W runway at Vancouver International Airport. Aircraft frequently fly low over this haulout site with little or no reaction by the harbor seals, which Bigg thinks have habituated to the noise/disturbance. Hovercraft, on the other hand, do frighten these seals into the water. Bigg speculated that the noise from a hovercraft was "probably 10 times greater than the aircraft flying overhead". Since the hovercraft operates on the water, it is possible that the seals perceive it as more of a 'threat' than the more numerous aircraft overhead.

Spotted seals are closely related to harbor seals, and also haul out on beaches along the Bering Sea coast (Burns 1970). Burns and Harbo (1977, in Cowles et al. 1981) reported that spotted seals react to aircraft at rather great distances by 'erratically racing across [ice] floes and eventually diving off'. This type of 'panic' reaction also may be common during summer when spotted seals are hauled out on beaches. However, disturbance by aircraft at terrestrial haulout sites is unlikely to cause pup mortality because spotted seal pups are usually independent by summer when they might be hauled out at terrestrial sites. Nevertheless, Eley and Lowry (1978) speculated that spotted seals may abandon summer haulout sites if disturbed frequently.

Burns and Harbo (1977) found that reactions by ringed seals on fast ice to an aerial survey aircraft were variable depending on proximity to high headlands, position of the aircraft in relation to seals, and weather conditions. When transects were within 2 miles of a rock cliff, most seals hauled out adjacent to the cliffs dived through nearby holes and ice cracks as the aircraft came abreast or over them. Seals under the aircraft dived even when those to the side did not. Reactions on nice days were less severe than on marginal days for surveying, and seals overflown during optimal haulout conditions often shifted positions and looked upward at the aircraft but did not dive.

Burns and Frost (1983) reported that "Bearded seals usually react mildly to an airplane even at close range. They almost always raise their heads, frequently look up at the plane and usually remain on the ice unless the plane passes directly over them." "On a warm calm spring day when they are basking, they often show little concern for a low-flying aircraft." "Low-flying aircraft, especially helicopters frighten seals resting on the ice. This kind of disturbance can be minimized by requiring normal flight altitudes higher than 2,000 feet, by short climbs and descents from installations in bearded seal habitat and by use of the shortest, most direct flight routes." In general, bearded seals appear to be only mildly affected by aircraft overflights, usually showing some reaction only at very low altitudes.

**Stationary Sources.** A small population of harbor seals resides in upper Kachemak Bay, Alaska, near where the Bradley Lake Hydroelectric Project is under construction. During 22 May to 17 June 1987, before construction activity had begun at the site, as many as 150-200 seals have been seen hauled out in groups of 50-75 on bars in the upper bay near the construction site (Roseneau 1988). The seals typically haul out at a location about 1.6 km from the project powerhouse site and permanent construction facilities. During construction activities in the area (late June through October) the seals appeared to ignore most project activities, and no marked changes in overall numbers or patterns of use were noted during construction activities or after project activities ceased during 1987 (D. Trugden, pers. comm., in Roseneau 1988).

Underwater Noise and Disturbance

**Moving Sources.** Ugashik Bay in upper Bristol Bay, Alaska, supports a relatively large population of harbor seals (about 400-500). The seals occupy the bay along with many diesel-powered commercial fishing boats and noises emanate from the processor, including noises from large compressors. Small outboard-powered skiffs from Pilot Point, Alaska, also operate throughout the bay. Harbor seals remain in Ugashik Bay despite these activities (R. Gill, USFWS, pers. comm. 1987).

J.J. Burns (pers. obs. 1988) observed two groups of harbor seals (200 to 400 seals in each group), many of which were pups hauled out during daytime low tides on 9, 11, 13 and 14 July 1988 in Ugashik Bay. This was during the peak of fishing operations in the area and numerous fishing boats continuously passed relatively close to the animals. Fishing activity had been going on since about mid-June. It was noted that the seals paid little attention to moving boats that were at least 200 m away. The seals became alert and agitated when boats stopped at that same distance and some animals slowly (not in a stampede) entered the water when boats approached closer than 150 to 200 m. All seals vacated the haulout site when boats approached closer than about 60 m. The haulouts were submerged at high tide and the seals became broadly scattered through the fishing fleet, occasionally feeding on salmon hanging in gill nets.

Thousands of harbor seals haul out near Port Moller (Pitcher 1986), on the north side of the Alaska Peninsula. In this area, a large fish-processing vessel is stationed for most of the summer fishing season; many fishing boats deliver catches to the processor vessel each day (R. Gill, USFWS, pers. comm. 1987). During these deliveries, the fishing boats, including outboard-powered skiffs and tenders, motor through a channel close to the hauled out seals, apparently causing little if any disturbance to the resting animals.

M. Bigg (DFO, pers. comm. 1988) said that there are two major haulout sites for harbor seals on the sand bars and shoals near the entrance to the Steveston Arm of the Fraser River, in British Columbia. According to Bigg, harbor seals at these sites have become habituated (do not respond) to nearby fishing boats that pass quite close to the haulout sites.

Few authors have described responses of seals to ships or boats. Kapel (1975) noted that hunters in one part of Greenland are opposed to the use of outboard motors because they think that they frighten seals away. In fact, pinnipeds may associate the boat noise with being hunted (H. Kajimura, NMFS, pers. comm. 1988), and thus they may be reacting to the threat of being hunted rather than the noise of the ship or boat.

Murphy and Hoover (1981) noted that "Disturbance may have considerable impact where haulout space is limited, since seals frightened from haulouts tend to search for new sites rather than use those they abandoned...".

In Bonner's (1982) review of human-related impacts on seals, he states that "Drescher (1978) has drawn attention to the need of harbor seals for an undisturbed nursing period. Disturbance by passing sailboats or power craft can seriously reduce the survival of pups".

Terhune et al. (1979) obtained qualitative information about the amount of harp seal vocalization before and after a 36.5 m stern trawler approached within 2 km of a pupping area in the offshore pack ice. There was little evidence of a decrease in vocalizations the first night after the ship arrived, but many fewer vocalizations were recorded after that. It was not known whether some seals moved away from the pupping area, or whether all remained but vocalized less often. The results were ambiguous because of temporal variation in vocalizations and varying levels of other disturbance, such as seal hunting. Ship sounds often were so intense that harp seal vocalizations (if any) were totally masked.

Brodie (1981a, 1981b) has pointed out that harp and hooded seals continue to return to traditional breeding and molting areas in the moving pack ice off Newfoundland each year despite centuries of disturbance by vessels and seal hunting. It should be pointed out that the seals have few options short of changing their habitat. Also, there are never any hunters present when the seals coalesce into the breeding herds on the ice in early March. The hunters wait until the herds have formed and pupping has begun before travelling to the floes for the hunt.

**Stationary Sources.** Anderson and Hawkins (1978) conducted a series of trials to study the effects of sound as a deterrent to predatory seals at an Atlantic salmon netting station. A feasibility trial and follow-up experiment were conducted on a captive harbor seal. A variety of sounds were used in the trials; pure tones, killer whale calls, and loud noises were transmitted and responses were recorded on videotape. Although one sound appeared to cause an alarm reaction, the seal appeared to accommodate rapidly. Further field trials were conducted where grey seals were eating salmon at a river netting station. Although a broad range of sounds were played, none was consistently effective in scaring seals from the nets. The results of this study led to the conclusion that an acoustic deterrent for feeding seals is not effective. Thus, it is probable that harbor seals and some other phocids are quite tolerant to underwater sounds, especially when they are feeding in areas where prey are abundant. This conclusion is supported by a variety of recent studies that are summarized in the proceedings of a symposium on acoustical deterrents in marine mammal (almost solely pinniped) conflicts with fisheries (Mate and Harvey 1987).

Cummings et al. (1986) broadcast man-made noises associated with on-ice seismic (Vibroseis) activity to ringed seals on two occasions during haulout periods in March and April. On two occasions early in the season, sound production by seals before and after the broadcasts were not significantly different. During two broadcasts later in the season, sound production by seals was higher than recorded earlier. However, this increase was thought to be related to the timing of the breeding cycle in ringed seals rather than the sound broadcasts. In general, sound production by ringed seals was probably not affected by seismic activity noise.

Human Presence and Disturbance

Allen et al. (1984) studied the effects of various types of disturbance on harbor seal haulout behavior in Bolinas Lagoon, California. Their results indicated that harbor seals were disturbed on 71% of days monitored; people in canoes were the principle source of disturbance. Human activities closer than 100 m caused seals to leave haulout sites more than activities at greater distances. On average, it took harbor seals 28 $\pm$ 21 minutes to haulout again after they were disturbed. After disturbances, the number of seals that hauled out again was lower than the original number. Based on results of other studies on the effects of human disturbance on harbor and monk seals, the authors speculated that disturbances near Marin County haulout sites could cause harbor seals to switch to nocturnal haulout behavior, increase pup mortality, and/or cause the haulout site to be abandoned.

Osborne (1985) studied the effects of disturbance on a local population of harbor seals that haul out in Elkhorn Slough, California. She found that recreational boating, primarily canoes and power boats, were the single largest source of disturbance to hauled-out seals. Boating caused two-thirds of the seal flight reactions; most of the disturbance was in summer when recreational activity was greatest. All flight reactions occurred when the boats were within 100 m of the haulout site; 74% were when the boats were less than 30 m.

Laursen (1982) reported that coastal areas of the Dutch Wadden Sea where harbor seals haul out were receiving increasing recreational pressures. As numbers of people using beach and water areas increased, more harbor seals were being displaced from loafing areas. Analysis of data on the distribution of humans and seals showed that the first disturbing event of the day determined where seals were or were not found. Loafing harbor seals were present only in areas where they had not been disturbed earlier in the day, indicating it may take only one such disturbance to keep seals away from otherwise adequate loafing habitat for that day. This indicates that the timing and frequency of disturbance may be an important aspect of short-term displacement.

Reijnders (1984) reported that "Direct effects of disturbance on reproductive success of pinnipeds are unlikely to occur, as only very dramatic events--such as collisions or injuries--will cause intrauterine mortality or abortion. This is concluded from reports on heavily-hunted seal populations in which any differences between the rate of ovulating and pregnant females, and the differences between numbers of half-term-pregnant and parturient animals, were neglectable [sic] (Bigg, 1969; Smith, 1973; Boulva, 1974). " Reijnders (1984) goes on to state that "This is not unexpected, because hunting of seals mainly takes place between birth and weaning, and stress involved with those activities is of short duration. It is assumed, however, that more frequent disturbance throughout the whole year might act indirectly to depress reproductive success through impairing reproductive performance."

During the daylight hours from 14-27 June 1980, Renouf et al. (1981) watched movements of harbor seals (and grey seals) through a narrow channel connecting their haulout sites with the sea. Seals used this channel to come and go from the sea after being forced from their haulout sites on nearby sand flats exposed at low tide. Before the study it was presumed that the seals returned to the sea to feed and/or to avoid disturbance. There was only a slight increase in seaward travel by seals after they were disturbed by humans at their haulout sites (automobile and boat traffic; tourists walking nearby and touching pups), and the seals did not always go to sea when the sand flats where they hauled out were flooded by the high tide.

It has been reported that hunting in the Shetland Islands (Scotland) has, in at least one place retarded the onset of the pupping season (Tickell 1970). However, even those stocks which were heavily hunted continued to pup on their traditional hauling grounds rather than move to a new area (Bonner et al. 1973).

Terhune (1985) noted that "The seals readily enter the water in response to a wide variety of disturbances. They react in essentially the same manner when shot at, approached by humans or dogs walking along a beach, or approached by boats or light aircraft."

## Walrus

### Airborne Noise and Disturbance

**Moving Sources.** Walruses at terrestrial haulout sites may show responses to aircraft disturbance that vary with distance, aircraft type, flight pattern and age-sex class of the animals. Brooks (1954) noted that walruses onshore were disturbed by an aircraft passing overhead at 300 m. In a more extensive study, Salter (1979) found that, at horizontal distances beyond 2.5 km, the only response elicited by aircraft was raising of the head by some of the hauled out animals. A Bell 206 helicopter 1.3 km from a haulout site and flying at an altitude of less than 150 m prompted orientation toward the water by 31 of 47 animals. When the helicopter veered suddenly causing an abrupt change in the pitch of the noise, 26 of 47 walruses rushed into the water (Salter 1979). Another flight by a Bell 206 helicopter at the same altitude but at a range less than 1 km elicited head raising and orientation toward the water by some animals but no escape reactions--presumably because there were no sudden changes in the flight pattern or noise. DeHavilland Otter aircraft, which have a piston-driven single engine, caused escape reactions by walruses at horizontal distances less than 1 km during overflights at altitudes of 1000 and 1500 m (Salter 1979). Disturbance observed by Salter never caused escape reactions in all the walruses at the haulout site. Adult females, calves and immatures were more likely than adult males to enter the water during disturbance. However, severe disturbance may cause stampedes into the water by all the walruses at a haulout site.

Loughrey (1959) reported that walruses started to scramble towards the water when an aircraft was still more than 400 m away, and had all reached the water by the time the aircraft passed overhead. The walruses were most disturbed by the noise of the aircraft when it flew overhead at low rather than high altitudes; he noted that some calves were crushed to death by walruses stampeding from low-flying aircraft. Tomilin and Kibal'chich (1975 in Fay 1981) reported that an overflight at 150 m by an IL-14 twin piston engine aircraft caused a stampede by walruses that resulted in 21 calves being crushed to death and two aborted fetuses.

Burns and Harbo (1977) found that walruses hauled out on ice floes at the Bering Sea ice front responded in a variable manner to aircraft overflights, depending on weather. Apparently the walrus were most sensitive to aircraft disturbance on cold, overcast days. They speculated that in general, aircraft disturbance was not anticipated to affect pup survival in the eastern Bering Sea, except under specific conditions at terrestrial sites on the Punuk Islands (J.J. Burns).

Salter (1979) observed no detectable response to six approaches by outboard-powered inflatable boats at distances of 1.8-7.7 km from walruses hauled out at a terrestrial site. Similarly, Brooks (cited in Fay 1981) said that walruses hauled out on ice floes appeared not to be disturbed by the sound of outboard engines on small boats at distances of 400 m.

Frost et al. (1986) reported that "Fay observed instances when walruses at Cape Seniavin were stampeded into the water by low-flying aircraft. When animals flee from the hauling areas some mortality of animals...will occur through injury or abandonment and subsequent starvation... . Regular human disturbance has prevented the long-term use of haulouts at Cape Newenham, Sledge Island, and to some extent King Island (ADF&G, unpub. data)". The 'regular human disturbance' at Cape Newenham was not specified in Frost et al (1986), nor were any data presented. However, we presume they were referring to disturbance associated with regular activities at the U.S. Air Force Radar Station at Cape Newenham. Disturbances at King and Sledge islands were probably associated with boat and aircraft traffic from nearby Nome, Alaska.

Fay et al. (1986) reported on a series of disturbances to a herd of about 1,000 male walruses that had been under observation at a terrestrial haulout site at Cape Seniavin, in southern Bristol Bay. In one day (8 April 1981), over the course of 8 hours, three fixed-wing aircraft and one helicopter passed the haulout site at altitudes of 60-80 m and flushed all of the animals into the water. The number of animals remaining at the site after each of these overflights was not mentioned. However, by early morning of the following day (9 April) about 100 animals had returned to the haulout site, but about half of them left when another fixed-wing aircraft passed them at less than 100 m. About 100 walrus were present when observations started on the following day (10 April), but those were stampeded into the water about an hour later by another passing aircraft.

Fay et al. (1986) reported on another aircraft disturbance to walruses hauled out on a beach on the Punuk Islands (near St. Lawrence Island) on 8 November 1981. During that episode a twin-engine aircraft (type unspecified) made three passes at an altitude of about 60 m over about 4,500 walruses. About 1,000 of the animals raised their heads when the aircraft passed, but fewer than 100 of them went into the water. Two other aircraft passed within hearing range of the Punuk Islands that same day, but caused no apparent response among the walruses.

Similarly, Roseneau (1988) reported that walruses hauled out along rocky beaches near the Air Force Station at Cape Lisburne often ignored low-flying aircraft. In one case, a group of about 50 sleeping walruses were not disturbed (did not respond) when a 4-engine Hercules C-130 cargo aircraft took off from the Air Force station and flew within 0.8 km of the resting animals. According to Roseneau (1988), "Noise from the climbing, departing aircraft flushed many seabirds, but the walruses did not respond to the disturbance." Roseneau also notes that "Some aircraft-related disturbances of walruses have almost certainly occurred at Cape Lisburne over the years. Site personnel have related several incidents...of groups flushing from landing aircraft when animals have been hauled out near the western end of the runway.... However, the arrival of varying numbers of summering and migrating walruses remains an annual event."

The consequences of aircraft disturbances to walruses is discussed by Fay et al. (1986), but most of their discussion relates to disturbances of females and calves hauled out on ice, or of disturbances to wintering or breeding animals. They do not discuss the consequences of disturbance to walruses hauled out at terrestrial sites. However, Fay and Kelly (1980) recorded a case of mass natural mortality apparently caused through injury during a stampede of several thousand walruses during late autumn 1978 at terrestrial haulout sites on eastern St. Lawrence Island and on the Punuk Islands (located southeast of St. Lawrence Island). Fay and Kelly (1980) estimated that about 148,000 walruses had hauled out at six major sites on St. Lawrence Island and the Punuk Islands during autumn 1978. They estimated the following spring (June 1979) that about 411-1134 walrus carcasses (range; based on aerial survey results) were present on the coast of St. Lawrence Island; most of the carcasses had apparently drifted away from the haulout sites and had washed up at 'non haulouts'.

The details of the above incident are best quoted from Fay and Kelly (1980:227-228). "...At the time when these events occurred, the weather was very stormy, with high winds and heavy seas from the south. The walruses, mainly adult females and young, were arriving from the northwest, presumably having swum from the edge of the pack ice which was then just north of Bering Strait, some 300 km away. The Eskimos remarked that the animals coming ashore appeared weak and physically exhausted, sleeping so soundly that it was possible to walk up and touch them without waking them. Observers on the Punuk Islands in early November estimated that there were at least 6000 walruses on the beach at one time. Hunters camped at Kialegak Point [about 40 km W of the Punuk Islands; on St. Lawrence Island] stated that the animals covered about 2.5 km of beach and, in some places, extended inland onto the tundra.

According to the reports from Eskimos camped on Punuk, a few adult bulls were present among the females. These bulls were extremely belligerent, rushing through the resting herd to engage other bulls in battle. On one occasion, two bulls fought with such vigour that one appeared to have mortally wounded the other. In their rushes through the herd, the bulls trampled and struck at other animals with their tusks, and some calves (about 6 months old) were believed to have been killed by them. One night, an entire herd stampeded off the beach into the sea, leaving behind about 25 dead and disabled animals at the water's edge, below a wave-cut terrace. ..."

According to biologists working at the Cape Peirce haulout sites since 1983 (D. Fisher, USFWS, pers. comm. 1988) low-flying (<500 ft ASL) single engined aircraft have disturbed walrus hauled out on the beach near the entrance to Nanvak Bay on several occasions. During one incident in summer 1986, an aircraft flew low (<500 ft ASL) over 4000-5000 hauled out animals several times and caused a stampede into the water that resulted in 2-3 animals being trampled and killed.

## Human Presence and Disturbance

Frost et al. (1983) mentioned that "We have noted that ... walruses almost invariably flee into the water when approached by humans... ." Similarly, Kelly (1980) reported that walruses will leave haulout areas in response to the presence of man, and speculated that continued harassment may prevent recolonization.

Shooting of walrus at Cape Peirce by passing boaters and aircraft has been a chronic problem at this site (D. Fisher, USFWS, pers. comm. 1988). During summer 1983 at least 20-23 walruses were shot and killed on the beach near the entrance to Nanvak Bay by a passing boater or a low-flying aircraft (D. Fisher, USFWS, pers. comm. 1988).

# DISCUSSION

We have evaluated haulout sites used by fur seals, sea lions, harbor seals and walruses in the eastern Bering Sea in an objective and quantitative manner in an attempt to determine which sites appear to be most sensitive to disturbance. Our IPSI evaluations were based on eight different (but sometimes related) criteria (see 'Methods') for each haulout site, and are presented and discussed here on a species-by-species basis.

## Northern Fur Seal

This species differs from the other three pinnipeds considered because virtually all animals haulout in the study area at sites on the Pribilof Islands, although there is a relatively new and small haulout site on Bogoslof Island, in the eastern Aleutians. Lloyd et al. (1981) speculated that the feeding habitat of fur seals consists of outer continental shelf and oceanic domains, and that "only islands in or immediately adjacent to the [very productive] outer shelf domains are suitable for fur seal rookeries."

In addition, virtually all haulout sites are used by all age and sex classes of northern fur seals that haul out on an annual basis, even though these classes may be segregated in different sections of the site (see Appendix 2 for maps of haulout sites on the Pribilof Islands). The northern fur seal is also unique because it does not haul out except during the breeding and post breeding season; it is pelagic throughout most of the year.

There is considerable evidence that northern fur seals respond to various forms of disturbance in different ways (see 'RESULTS'). However, there is no direct evidence that significant mortality has resulted from any of the recent disturbances that have occurred at haulout sites. Most of the recent disturbances are similar to those that may accompany OCS development (e.g., aircraft overflights at altitudes <500 m, nearby ship traffic, human presence). It should be noted, however, that this subject has not been thoroughly investigated through field experiments (R. Gentry, NMFS, pers. comm. 1987).

There is circumstantial evidence that some formerly used historic sites were abandoned because of proximity to man. Overharvesting-overshooting and other chronic disturbances may have been significant factors in the abandonment of the Lagoon rookery on St. Paul Island and the Little Eastern rookery on St. George Island. Both of these haulouts were close to village sites (Jordan and Clark 1898). Also, some workers are concerned that there may be a relationship between low-level (<500 m) aircraft flights on St. Paul Island and the declining numbers of northern fur seals at the Polovina complex of rookeries which are located near the airport (A. Yorke, NMFS, pers. comm. 1988).

Based on all criteria considered in this study, including the general sensitivity of this species, and the susceptibility of the 22 haulout sites to disturbance, North Rookery on St. George Island, Vostochni, Zapadni, Tolstoi, Reef, Polovina Cliffs and Gorbatch rookeries on St. Paul Island, and Sivutch Rookery south of St. Paul Island rated highest in our IPSI evaluation scheme (Table 8). In particular, the Polovina Cliffs rookery is thought by some workers (C. Fowler, NMFS, pers. comm. 1988) to be a likely candidate for abandonment in the near future.

As mentioned earlier, there is some evidence that mortality of younger age classes at sea, through entanglement in abandoned fishing nets and other debris, is an important cause of the recent severe declines in numbers of northern fur seals (Fowler In press; 1985). Because of this decline, the National Marine Fisheries Service recently (May 1988) listed the Pribilof Islands population of northern fur seal as 'depleted' under terms of the Marine Mammal Protection Act of 1972.

## Northern Sea Lion

Unlike northern fur seals, northern sea lions may haul out at terrestrial sites throughout the year. Nevertheless, there are definite seasonal peaks in haulout activity in the Bering Sea, especially at the breeding sites, or rookeries. Virtually all of the important rookeries in the study area, with the exception of Walrus Island in the Pribilofs, are in the eastern Aleutian Islands or southeastern Bristol Bay. Similar to northern fur seals (Lloyd et

**Table 8. Inter-site Population Sensitivity Index (IPSI) for northern fur seal haulout sites in the Bering Sea, Alaska.**

| Haulout Site | Max. Count | Rank | Mean Max. Count | Rank | Propor. Pop. | Rank | Age/Sex Comp. x Activity | Rank | Duration of Use | Rank | Consist. of Use | Rank | Site Char. | Rank | Species Char. | Rank | Mean Rank (n=8) | IPSI Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **St. George I.** | | | | | | | | | | | | | | | | | | |
| Zapadni | 157 | 15 | 211 | 14 | 0.025 | 15 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 14.6 | 18 |
| South | 247 | 12 | 248 | 13 | 0.036 | 13 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 13.6 | 15 |
| North | 593 | 4 | 775 | 3 | 0.107 | 1 | 2 | 4.5 | 0.583 | 11.5 | 1 | 11 | 1 | 3 | 2 | 11.5 | 4.4 | 1 |
| East Reef | 96 | 18 | 122 | 20 | 0.016 | 16 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 16.3 | 21 |
| East Cliffs | 282 | 11 | 302 | 12 | 0.050 | 9 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 3 | 11.5 | 2 | 11.5 | 11.5 | 11 |
| Staraya-Artil | 101 | 17 | 198 | 15 | 0.014 | 17.5 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 1 | 3 | 2 | 11.5 | 13.0 | 14 |
| **St. Paul I.** | | | | | | | | | | | | | | | | | | |
| Lukanin | 119 | 16 | 137 | 18 | 0.014 | 17.5 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 2 | 7.5 | 2 | 11.5 | 14.1 | 17 |
| Kitovi | 236 | 13 | 337 | 11 | 0.039 | 12 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 3 | 11.5 | 2 | 11.5 | 12.2 | 12 |
| Gorbatch | 358 | 10 | 573 | 6 | 0.050 | 9 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 2 | 7.5 | 2 | 11.5 | 9.7 | 8 |
| Ardiguen | 57 | 20 | 90 | 21 | 0.010 | 19.5 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 2 | 7.5 | 2 | 11.5 | 15.6 | 20 |
| Reef | 526 | 6 | 808 | 2 | 0.076 | 6 | 2 | 4.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 7.9 | 5 |
| Morjovi | 361 | 9 | 501 | 8 | 0.044 | 11 | 2 | 4.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 10.3 | 9 |
| Vostochni | 811 | 1 | 1093 | 1 | 0.102 | 3 | 1 | 1.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 5.9 | 2 |
| Little Polovina | 46 | 21 | 128 | 19 | 0.003 | 21 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 1 | 3 | 2 | 11.5 | 14.9 | 19 |
| Polovina Cliffs | 404 | 7 | 540 | 7 | 0.057 | 7 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 1 | 3 | 2 | 11.5 | 8.3 | 6 |
| Polovina | 70 | 19 | 152 | 17 | 0.010 | 19.5 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 1 | 3 | 2 | 11.5 | 14.0 | 16 |
| Tolstoi | 614 | 3 | 741 | 5 | 0.086 | 4 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 2 | 7.5 | 2 | 11.5 | 7.5 | 4 |
| Zapadni Reef | 210 | 14 | 209 | 15 | 0.026 | 14 | 2 | 4.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 12.8 | 13 |
| Little Zapadni | 367 | 8 | 458 | 9 | 0.050 | 9 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 3 | 11.5 | 2 | 11.5 | 10.5 | 10 |
| Zapadni | 626 | 2 | 755 | 4 | 0.079 | 5 | 1 | 1.5 | 0.583 | 11.5 | 1 | 11 | 4 | 18 | 2 | 11.5 | 6.9 | 3 |
| **Sivutch** | 582 | 5 | 450 | 10 | 0.104 | 2 | 3 | 14.5 | 0.583 | 11.5 | 1 | 11 | 3 | 11.5 | 2 | 11.5 | 9.0 | 7 |
| **Bogoslof I.** | 7 | 22 | 2 | 22 | 0.001 | 22 | 3 | 14.5 | 0.583 | 11.5 | 2 | 22 | 4 | 18 | 2 | 11.5 | 20.1 | 22 |

Max. Counts are Breed. Bulls only from either "1980's" or "Curr. Est." columns in Table 3.
Mean Max. Counts are Breed. Bulls only from "1960's", "1970's", "1980's" and "Curr. Est." columns in Table 3.
Proportion of Population is calculated from "Curr. Est." column in Table 3.
Age/Sex Composition x Activity values are based on whether all age/sex classes are present and whether breeding occurs regularly at the site (all=1, ad.=2, subad.=3), and the number of different locations at the site where fur seals haul out (1=many, 2=several, 3=few).
Duration of Use of site is the approximate proporition of the year that the site is occupied.
Consistency of Use categories are as follows :1 = annual and consistent, and 2 = inconsistent.
Site Characteristic values were based on topography and proximity to noise/disturb. near the haulout site (1=any site near noise/disturbance, 2=cliffs, 3=bluffs/slopes, 4=low or no relief).
Species Characteristics values were assigned based on the degree of sensitivity of the species and potential for mortality as a result of noise/disturbance (1=high, 2= medium, 3=low).

al. 1981), it may be possible that the locations of northern sea lion rookeries in part are determined by the distribution and abundance of their principal prey, walleye pollock (Frost and Lowry 1986; Loughlin 1987; Bakkala et al. 1987), which in turn may be affected by overfishing and/or oceanographic characteristics.

Consistently used haulout sites are generally located in the southern half of the Bering Sea, south of Cape Newenham and the Pribilof Islands. Haulout sites farther north are generally used for shorter durations and less consistently from one year to the next (J.J. Burns, pers. obs. 1988).

Northern sea lions respond to noise and human disturbance in a variety of ways. There have been instances where human disturbance at northern sea lion rookeries has caused mortality (Lewis 1987; R. Merrick, NMFS, pers. comm. 1988). Thus, human disturbance has the potential to significantly affect the health of the Bering Sea population. Our evaluation of the sensitivity of northern sea lions at their 26 terrestrial haulout sites in the study area has been influenced by the fact that mortality associated with disturbance is known to occur. Based on all criteria considered in this study (IPSI evaluation), including the general susceptibility of this species, and the susceptibility of the 26 haulout sites to disturbance, we determined that the rookeries and associated hauling grounds on Ugamak Island and nearby rocks and islets (incl. Round I.), at Cape Morgan on Akutan Island, on Sea Lion Rock near Amak Island, on Walrus Island in the Pribilofs, on Bogoslof Island, and at Billings Head on Akun Island rated the highest in our IPSI evaluation scheme (Table 9). Recent severe disturbances at the Ugamak Island rookery, and increased chronic disturbances from aircraft and ship traffic near Sea Lion Rock (close to the airport at Cold Bay, AK) and Bogoslof Island (increased fishing activity nearby) are of particular concern.

The history of use and disuse of haulout sites in the Pribilof Islands is of particular interest, considering that these islands are likely to be the focus of activity during possible OCS development in the St. George Basin. Of the eight historically used sea lion haulout sites in the Pribilofs (4 on St. George, 1 on St. Paul, and 3 on smaller surrounding islets), there is current information (1980's) for only 3 sites (Walrus I., Otter I. and Dalnoi Pt.

Table 9. Inter-site Population Sensitivity Index (IPSI) for northern sea lion haulout sites in the Bering Sea, Alaska.

| Haulout Site | Max. Count | Rank | Mean Max. Count | Rank | Propor. Pop. | Rank | Age/Sex Comp. x Activity | Rank | Duration of Use | Rank | Consist. of Use | Rank | Site Char. | Rank | Species Char. | Rank | Mean Rank (n=8) | IPSI Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bogoslof Island* | 1379 | 5 | 2133 | 4 | 0.083 | 4 | 6 | 3.5 | 0.500 | 5 | 1 | 4.5 | 4 | 26 | 1 | 3.5 | 6.9 | 5 |
| Unalaska Island | | | | | | | | | | | | | | | | | | |
| Spray Cape | 161 | 17 | 96 | 22 | 0.001 | 25.5 | 4 | 12 | 0.250 | 14.5 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 16.9 | 18 |
| Bishop Point | 549 | 12 | 475 | 11 | 0.035 | 9.5 | 4 | 12 | 0.250 | 14.5 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 12.9 | 11 |
| Akutan Island* | | | | | | | | | | | | | | | | | | |
| Cape Morgan* | 2840 | 2 | 5996 | 2 | 0.110 | 2 | 1 | 3.5 | 0.500 | 5 | 1 | 4.5 | 2 | 14 | 1 | 3.5 | 4.6 | 2 |
| Akun Island* | | | | | | | | | | | | | | | | | | |
| Billings Head* | 760 | 9 | 1459 | 7 | 0.028 | 13 | 1 | 3.5 | 0.500 | 5 | 1 | 4.5 | 2 | 14 | 1 | 3.5 | 7.4 | 6 |
| Tanginak Island | 61 | 22 | 377 | 14 | 0.004 | 21 | 4 | 12 | 0.250 | 14.5 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 15.9 | 16 |
| Rocks NE of Tigalda I. | 225 | 15.5 | 312 | 16 | 0.005 | 20 | 4 | 12 | 0.250 | 14.5 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 15.3 | 15 |
| Ugamak Island Group* | 2033 | 3 | 7131 | 1 | 0.109 | 3 | 1 | 3.5 | 0.500 | 5 | 1 | 4.5 | 1 | 4 | 1 | 3.5 | 3.4 | 1 |
| Unimak Island | | | | | | | | | | | | | | | | | | |
| Cape Sarichef | 128 | 19 | 115 | 21 | 0.008 | 17 | 4 | 12 | 0.250 | 14.5 | 2 | 13.5 | 1 | 4 | 2 | 16.5 | 14.7 | 14 |
| Amak Island | 599 | 11 | 1379 | 8 | 0.039 | 7.5 | 4 | 12 | 0.500 | 5 | 1 | 4.5 | 1 | 4 | 2 | 16.5 | 8.6 | 7 |
| Unnamed Rocks | 225 | 15.5 | 266 | 17 | 0.014 | 15 | 4 | 12 | 0.500 | 5 | 1 | 4.5 | 1 | 4 | 2 | 16.5 | 11.2 | 9 |
| Sea Lion Rock* | 1298 | 6 | 1967 | 6 | 0.035 | 9.5 | 1 | 3.5 | 0.500 | 5 | 1 | 4.5 | 1 | 4 | 1 | 3.5 | 5.3 | 3 |
| Right Hand Point | 50 | 24 | 50 | 25 | 0.003 | 23 | 4 | 12 | 0.167 | 23 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 18.9 | 21 |
| Round Island | 1000 | 7 | 833 | 10 | 0.064 | 5 | 4 | 12 | 0.167 | 23 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 12.6 | 10 |
| Cape Peirce | 450 | 13 | 450 | 12 | 0.029 | 12 | 4 | 12 | 0.167 | 23 | 2 | 13.5 | 1 | 4 | 2 | 16.5 | 13.3 | 12.5 |
| Cape Newenham | 1500 | 4 | 1083 | 9 | 0.061 | 6 | 4 | 12 | 0.167 | 23 | 2 | 13.5 | 1 | 4 | 2 | 16.5 | 11.0 | 8 |
| Nunivak Island | | | | | | | | | | | | | | | | | | |
| Cape Mendenhall | 50 | 24 | 50 | 25 | 0.003 | 23 | 6 | 23 | 0.167 | 23 | 3 | 22.5 | 3 | 23 | 2 | 16.5 | 22.5 | 26 |
| St. Matthew Island | | | | | | | | | | | | | | | | | | |
| Sugarloaf Mtn. | 50 | 24 | 50 | 25 | 0.003 | 23 | 6 | 23 | 0.250 | 14.5 | 3 | 22.5 | 2 | 14 | 2 | 16.5 | 20.3 | 25 |
| Cape Upright | 90 | 20 | 93 | 23 | 0.006 | 18.5 | 6 | 23 | 0.250 | 14.5 | 3 | 22.5 | 2 | 14 | 2 | 16.5 | 19.0 | 22 |
| East of Lunda Pt. | 600 | 10 | 326 | 15 | 0.039 | 7.5 | 6 | 23 | 0.250 | 14.5 | 3 | 22.5 | 3 | 23 | 2 | 16.5 | 16.5 | 17 |
| Hall Island | | | | | | | | | | | | | | | | 16.5 | | |
| Arre Rock | 150 | 18 | 150 | 20 | 0.010 | 16 | 6 | 23 | 0.250 | 14.5 | 3 | 22.5 | 3 | 23 | 2 | 16.5 | 19.2 | 23 |
| North Cove | 4000 | 1 | 2038 | 5 | 0.258 | 1 | 6 | 23 | 0.250 | 14.5 | 3 | 22.5 | 3 | 23 | 2 | 16.5 | 13.3 | 12.5 |
| Pinnacle Island | 257 | 14 | 205 | 18 | 0.017 | 14 | 6 | 23 | 0.167 | 23 | 3 | 22.5 | 2 | 14 | 2 | 16.5 | 18.1 | 20 |
| St. George Island | 86 | 21 | 378 | 13 | 0.006 | 18.5 | 6 | 23 | 0.167 | 23 | 3 | 22.5 | 3 | 23 | 2 | 16.5 | 20.1 | 24 |
| Walrus Island* | 868 | 8 | 2392 | 3 | 0.031 | 11 | 1 | 3.5 | 0.500 | 5 | 1 | 4.5 | 2 | 14 | 1 | 3.5 | 6.6 | 4 |
| Otter Island | – | 26 | 200 | 19 | 0.000 | 25.5 | 6 | 23 | 0.500 | 5 | 2 | 13.5 | 2 | 14 | 2 | 16.5 | 17.8 | 19 |

Max. Counts are Ads./Subads. only from either "1980's" or "Curr. Est." (whichever is larger) in Table 5.
Mean Max. Counts are Ads./Subads. only from "1960's", "1970's", "1980's" and "Curr. Est." columns in Table 5.
Proportion of Population is calculated from "Curr. Est." column in Table 5.
Age/Sex Composition x Activity values are based on whether all age/sex classes are present and whether breeding took place at the site (all=1, adults and subad.=2), and the number of different locations at the site where sea lions haul out (1=many, 2=several, 3= 1 or 2).
Duration of Use is the approximate proportion of the year the site is occupied.
Consistency of Use categories are as follows: 1=annual and continuous, 2=annual but discontinuous, and 3=inconsistent.
Site Characteristic values were based on topography and proximity to noise/disturb. near the haulout site (1=any site near noise/disturbance, 2=cliffs, 3=bluffs/slopes, 4=low or no relief).
Species Characteristics values were assigned based on the degree of sensitivity of the species and potential for mortality as a result of noise/disturbance (high=1, medium=2, low=3).

* Asterisks indicate that the haulout site is a rookery.

area). Formerly there were four rookeries on the Pribilofs: Walrus Island; near Northeast Point; near East Rookery; and near Tolstoi Point. Currently only the site on Walrus Island is an active rookery. Kenyon (1962) noted that the haulout site near Northeast Point on St. Paul Island was formerly the largest rookery in the Pribilof Islands, however, no pups have been seen there since 1957, which is about when major declines in the numbers of northern sea lions apparently began.

The ultimate causes of the decline in the northern sea lion population in Alaska are unknown (Merrick et al. 1987). However, it has been postulated that disease (possibly Leptospira), changes in prey resources, increased mortality through shooting, and possible entanglement in nets and other debris may all be contributing factors.

Some evidence suggests that changes in the quantity and size of walleye pollock (Theragra chalcogramma), the principal prey of northern sea lions, may be a factor in their decline (Bakkala et al. 1987; Fowler In press; Loughlin 1987; Frost and Lowry 1986). It is also possible that increased mortality of pups that become separated from their mothers during some types of censuses at rookeries (Lewis 1987) may be a factor contributing to the decline. Away from the haulout sites, there is little evidence that noise from either airborne or underwater sources has serious detrimental effects on northern sea lions. In fact, some studies show that sea lions habituate well to some severe forms of noise (Shaughnessy et al. 1981, Mate and Harvey 1987).

## Harbor Seal

Harbor seals are distributed throughout the portion of the study area south of Nunivak and the Pribilof islands. Harbor seals do not necessarily aggregate at large rookeries to breed, pup and suckle their young. Aside from the resident population on Otter Island in the Pribilofs, most harbor seals in the northern part of the study area probably move south (away from advancing ice) during winter. Of the 41 terrestrial haulout sites considered in detail in our study area, only about 6-8 appear to have consistently supported large fractions of the total eastern Bering Sea population of this species--most of these important sites are on the Alaska Peninsula.

Harbor seals respond to noise and human disturbance in a variety of ways. In some situations it is not possible to disperse them even using severe forms of disturbance; i.e., they appear to accommodate to noise and disturbance in some instances when they are actively feeding. However, there have been instances where human disturbance at harbor seal haulout sites have caused the sites to be abandoned and pups to be separated from their mothers, thereby causing mortality (Johnson 1977; see 'Results' section for details). Thus, our evaluation of the importance and vulnerability of harbor seals at 41 terrestrial haulout sites has been influenced by the fact that abandonment of sites and consequent mortality of pups has been shown to be associated with some kinds of noise and disturbance near such sites. Based on all criteria considered in this study, including the general susceptibility of this species, and the susceptibility of the 41 haulout sites to disturbance, we determined that the sites in Izembek/Moffet Lagoon, Port Heiden, Port Moller, Cinder River, Seal Islands and Ilnik (all on the Alaska Peninsula), and in Nanvak Bay near Cape Peirce, Ugashik Bay, and on Otter Island in the Pribilofs to be the most important and potentially most vulnerable to noise and disturbance associated with OCS development (Table 10).

The number of harbor seals recorded at haulout sites in the Bering Sea, especially at some sites in the southeastern Bering Sea, has apparently declined dramatically during the recent decade (Pitcher 1986). Although several reasons have been given for the apparent recent decline of harbor seals (e.g., disease, over-exploitation in earlier years, increased predation, increased fouling in fishing gear, reductions in principal prey [walleye pollock]), none of these suggestions have been clearly documented. At present, the sites that appear to have been most significantly reduced in size (fewer seals counted recently) are the Seal Islands, Cinder River, and Izembek/Moffet Lagoon, on the Alaska Peninsula. However, as noted in the 'Results', counts at any one of these sites may be greatly influenced by such factors as the time of day, time of year, tide, weather, availability of prey, etc. Recommended programs designed to more carefully monitor the number of harbor seals at haulout sites in Bristol Bay could provide more of the data needed to determine the status of this species in the study area, prior to OCS development (Hoover 1988b).

Table 10. Inter-site Population Sensitivity Index (IPSI) for harbor seal haulout sites in the Bering Sea, Alaska.

| Haulout Site | Max. Count | Rank | Mean Max. Count | Rank | Propor. Pop. | Rank | Age/Sex Comp. x Activity | Rank | Duration of Use | Rank | Consist. of Use | Rank | Site Char. | Rank | Species Char. | Rank | Mean Rank | IPSI Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Umnak Island | – | 31 | 415 | 14 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 22.2 | 24 |
| Bogoslof Island | – | 31 | 56 | 34 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 3 | 41 | 4 | 35 | 3 | 33 | 29.2 | 41 |
| Unalaska Island | – | 31 | 326 | 15 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 22.4 | 26 |
| Akutan Island | 6 | 20 | 28 | 38 | 0.001 | 20 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 21.1 | 23 |
| Akun Island (incl. Tangik I.) | 23 | 19 | 75 | 30 | 0.003 | 19 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 19.9 | 20.5 |
| Tanginak Island | – | 31 | – | 41 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 26.1 | 37 |
| Avatanak Island | – | 31 | 68 | 33 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 24.9 | 34 |
| Tigalda Island | – | 31 | 8 | 40 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 25.9 | 36 |
| Kaligagan & islets NE of Tigalda I. | 245 | 9 | 247 | 18 | 0.030 | 7 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 17.2 | 12 |
| Ugamak Island | – | 31 | 40 | 37 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 1 | 5 | 3 | 33 | 23.7 | 29 |
| Aiktak Island | 94 | 15 | 122 | 25 | 0.012 | 12 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 1 | 5 | 3 | 33 | 17.3 | 13.5 |
| Unalga, Babies, rocks & islets | 125 | 11 | 220 | 19 | 0.015 | 10.5 | 1 | 15 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 17.6 | 15 |
| Cape Lapin (Unimak I.) | – | 31 | 120 | 26 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 2 | 29.5 | 1 | 5 | 3 | 33 | 24.5 | 31 |
| North Creek (Unimak I.) | – | 31 | 70 | 32 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 2 | 29.5 | 1 | 5 | 3 | 33 | 25.4 | 35 |
| Bechevin Bay | – | 31 | 1500 | 9.5 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 1 | 9.5 | 1 | 5 | 2 | 16.5 | 16.9 | 10.5 |
| Cape Krenitzin | – | 31 | 1500 | 9.5 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 1 | 9.5 | 1 | 5 | 2 | 16.5 | 16.9 | 10.5 |
| Isanotski Islands | – | 31 | 511 | 12 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 1 | 9.5 | 1 | 5 | 2 | 16.5 | 17.3 | 13.5 |
| Izembek/Moffet Lagoon | 1974 | 4 | 1888 | 7 | 0.040 | 4 | 0.5 | 3.5 | 1.000 | 15.5 | 1 | 9.5 | 1 | 5 | 1 | 4.5 | 6.1 | 1 |
| Amak Island | 2 | 21 | 20 | 39 | 0.000 | 21 | 1.5 | 31.5 | 1.000 | 15.5 | 2 | 29.5 | 1 | 5 | 2 | 16.5 | 19.8 | 19 |
| Cape Leiskof | 0 | 31 | 150 | 21 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 2 | 29.5 | 3 | 27 | 2 | 16.5 | 24.6 | 32.5 |
| Cape Seniavin | – | 31 | 71 | 31 | – | 31.5 | 1.5 | 31.5 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 2 | 16.5 | 24.6 | 32.6 |
| Port Moller | – | 2 | 4884 | 2 | 0.488 | 1 | 0.5 | 3.5 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 9.1 | 3 |
| Seal Islands (incl. Ilnik) | 1521 | 5 | 1599 | 8 | 0.009 | 16.5 | 0.5 | 3.5 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 10.1 | 5 |
| Port Heiden | 6196 | 1 | 5768 | 1 | 0.098 | 3 | 0.5 | 3.5 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 8.8 | 2 |
| Cinder River | 350 | 7 | 2038 | 5 | 0.037 | 5.5 | 0.5 | 3.5 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 10.0 | 4 |
| Ugashik Bay | 1000 | 6 | 719 | 11 | 0.121 | 2 | 1 | 15 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 2 | 16.5 | 13.6 | 6.5 |
| Egigik R. Flats | 0 | 31 | 300 | 16.5 | – | 31.5 | 1 | 15 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 2 | 16.5 | 19.9 | 20.5 |
| Deadman Sands | – | 10 | 150 | 21 | 0.018 | 9 | 1 | 15 | 1.000 | 15.5 | 1 | 9.5 | 4 | 35 | 2 | 16.5 | 15.3 | 9 |
| Cape Constantine | 100 | 14 | 100 | 27 | 0.012 | 13 | 1.5 | 31.5 | 0.075 | 31.5 | 2 | 29.5 | 2 | 17.5 | 2 | 16.5 | 20.9 | 22 |
| Tvativak Bay | 77 | 17 | 77 | 29 | 0.009 | 16.5 | 1.5 | 31.5 | 0.075 | 31.5 | 2 | 29.5 | 3 | 27 | 2 | 16.5 | 22.8 | 27 |
| Hagemeister Island | 100 | 14 | 133 | 23 | 0.012 | 13 | 1.5 | 31.5 | 0.580 | 33.5 | 1 | 9.5 | 2 | 17.5 | 2 | 16.5 | 18.1 | 16 |
| Black Rock | 300 | 8 | 300 | 16.5 | 0.037 | 5.5 | 1.5 | 31.5 | 0.580 | 33.5 | 2 | 29.5 | 2 | 17.5 | 2 | 16.5 | 19.1 | 18 |
| Nanvak Bay (Mouth) | 3100 | 3 | 2107 | 4 | 0.027 | 8 | 1 | 15 | 0.500 | 38 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 13.6 | 6.5 |
| Cape Newenham | 0 | 31 | 50 | 35.5 | – | 31.5 | 1.5 | 31.5 | 0.500 | 38 | 2 | 29.5 | 2 | 17.5 | 2 | 16.5 | 28.5 | 40 |
| Chagvan Bay (Mouth) | – | 31 | 150 | 21 | – | 31.5 | 1.5 | 31.5 | 0.500 | 38 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 24.4 | 30 |
| Quinhagak (Middle Bar) | – | 31 | 3000 | 3 | – | 31.5 | 1.5 | 31.5 | 0.500 | 38 | 1 | 9.5 | 4 | 35 | 2 | 16.5 | 23.5 | 28 |
| Kongiganak (South Bar) | – | 31 | 50 | 35.5 | – | 31.5 | 1.5 | 31.5 | 0.500 | 38 | 1 | 9.5 | 4 | 35 | 2 | 16.5 | 28.1 | 39 |
| Kuskokwim Bay | – | 31 | 2000 | 6 | – | 31.5 | 0.5 | 3.5 | 0.500 | 38 | 1 | 9.5 | 4 | 35 | 1 | 4.5 | 18.2 | 17 |
| Nunivak I. (Cape Mendenhall) | – | 16 | 80 | 28 | 0.010 | 15 | 2 | 40.5 | 0.500 | 38 | 2 | 29.5 | 3 | 27 | 3 | 33 | 26.5 | 38 |
| St. George I. (Dalnoi Pt. area) | 50 | 18 | 130 | 24 | 0.006 | 18 | 2 | 40.5 | 1.000 | 15.5 | 2 | 29.5 | 2 | 17.5 | 3 | 33 | 22.3 | 25 |
| Otter Island | 119 | 12 | 483 | 13 | 0.015 | 10.5 | 1 | 15 | 1.000 | 15.5 | 1 | 9.5 | 2 | 17.5 | 3 | 33 | 14.4 | 8 |

Max. Count is from either "1980's" or "Curr. Est." columns (whichever is greater) in Table 6.
Mean Max. Count is from "1960's", "1970's", "1980's" and "Curr. Est." columns in Table 6.
Proportion of Population is calculated from "Curr. Est." column in Table 6.
Age/Sex Composition x Activity values are based on whether all age/sex classes are present and whether pupping occurs regularly at or near the site (all=0.5, Ad. only=1), and the number of different locations where harbor seals haul out (1=many, 2=several, 3=few) associated with the site.
Duration of Use is based on the approximate proportion of the year that the site is used.
Consistency of Use categories are as follows: 1=annual and relatively consistent, and 2=inconsistent.
Site Characteristics values were based on topography and proximity to noise/disturb. source near the haulout site (1=any site near noise/disturb., 2=cliffs, 3=bluffs/slopes, 4=low or no relief).
Species Characteristics values were assigned based on the sensitivity of the species and associated potential for mortality as a result of disturbance (1=high, 2=medium, 3=low).

## Pacific Walrus

Only male Pacific walruses haul out at terrestrial sites in the southern part of the study area, i.e., at island and mainland sites south of the St. Matthew-Hall Islands area (south of about 60°N). During fall, as the pack-ice advances south through Bering Strait, females with calves return to the northern part of the study area, where they are joined by males that have moved northward from southern sites. Haulout sites on St. Lawrence Island and on the nearby Punuk Islands are particularly important at this time of year (autumn); all age and sex classes may be found hauled out at these terrestrial sites in some years. Breeding occurs on the pack-ice in late winter-early spring and calves are born on the ice in spring. Females and newborn calves remain with the pack-ice as it retreats north out of the study area in early summer, whereas many males remain south and utilize haulout sites in Bristol Bay.

There is only a relatively small body of information concerning the effects on walruses of various kinds of noise and disturbance, however, some of this information is particularly relevant to this study. In general, walruses respond to noise and human disturbance by temporarily leaving the haulout site; if the disturbance persists, the site may be abandoned (Fay et al. 1986; for more details see 'RESULTS'). Natural mass mortality of walruses has occurred at a Punuk Island haulout site in at least one year, 1978 (Fay and Kelly 1980). Although it is unclear how mortality of this type has occurred, it does indicate the magnitude of such mortality (many hundreds of animals died) that can occur when large numbers of animals (tens of thousands) are hauled out at one site. At other sites (Cape Peirce), shooting and other types of harassment such as by aircraft and boats have caused severe disturbances.

Based on all criteria considered in this study, including the general susceptibility of this species, and the susceptibility of the 31 haulout sites to disturbance, we determined that the sites at (1) Port Moller and Cape Seniavin in southern Bristol Bay, (2) at Round Island, Cape Peirce and Cape Newenham in northern Bristol Bay, and (3) at St. Matthew and Hall islands, King Island, eastern St. Lawrence Island and North Punuk Island in the central and northern Bering Sea rate high in our IPSI evaluation scheme (Table 11).

Both the Amak Island and Cape Seniavin haulout sites have been disturbed in recent years by fishing boats and low-flying aircraft and beachcombers landing at the site; poachers have also frequently disturbed the Cape Seniavin site (J.J. Burns, pers. comm. 1988). It is probable that many of the walruses recorded in the Port Moller area have been displaced (through disturbance) from nearby Cape Seniavin (details given earlier in 'Results'). Further, there is evidence that walruses using the Cape Seniavin site are also associated with the Round Island site in northern Bristol Bay. At least one male walrus tagged at Round Island was recovered (dead) on the beach at Cape Seniavin.

The Cape Peirce haulout site has been reoccupied since the early 1980's. Significant numbers hauled out at this site in 1983, but shooting and other disturbances prevented a sustained reoccupancy that year (D. Fisher, USFWS, pers. comm. 1988). Large numbers of walrus (about 4,000-6,000 males) again reoccupied this site in 1984. Very large numbers of walrus (12,000 males) have been recorded at Cape Peirce in recent years, even though shooting of some animals has occurred at this site every year since 1986 (D. Fisher, USFWS, pers. comm. 1988). Daily surveillance at Cape Peirce during the summer haulout period began in 1984 and currently there is careful documentation of hunting and other disturbances.

**Table 11. Inter-site Population Sensitivity Index (IPSI) for Pacific walrus haulout sites in the Bering Sea, Alaska.**

| Haulout Site | Max. Count | Rank | Mean Max. Count | Rank | Propor. Pop. | Rank | Age/Sex Comp. x Activity | Rank | Duration of Use | Rank | Consist. of Use | Rank | Site Char. | Rank | Species Char. | Rank | Mean Rank (n=8) | IPSI Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amak Island* | 0 | 18 | 155 | 26 | 0.000 | 14.5 | 3 | 25.5 | 0.580 | 1 | 2 | 22 | 1 | 4 | 2 | 16 | 15.9 | 18 |
| Port Moller* | 3250 | 7 | 2875 | 10 | 0.073 | 5 | 2 | 19.5 | 0.417 | 4.5 | 2 | 22 | 1 | 4 | 2 | 16 | 11.0 | 5 |
| Cape Seniavin* | 3500 | 6 | 1813 | 12 | 0.040 | 9.5 | 3 | 25.5 | 0.417 | 4.5 | 1 | 6.5 | 1 | 4 | 2 | 16 | 10.5 | 4 |
| Port Heiden* | – | 25 | 60 | 29 | – | 25 | 3 | 25.5 | 0.333 | 12.5 | 2 | 22 | 1 | 4 | 2 | 16 | 19.9 | 26 |
| Egegik Bay* | 1000 | 8 | 1000 | 14 | 0.022 | 8 | 3 | 26 | 0.333 | 12.5 | 2 | 22 | 1 | 4 | 3 | 27 | 15.2 | 13.5 |
| High Island* | – | 25 | 0 | 31 | – | 25 | 3 | 25.5 | 0.333 | 12.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 20.8 | 28 |
| North Twin Island* | – | 25 | 1000 | 13 | – | 25 | 3 | 25.5 | 0.333 | 12.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 18.5 | 23 |
| Round Island* | 12400 | 3 | 7425 | 8 | 0.119 | 4 | 1 | 9 | 0.333 | 12.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 10.4 | 3 |
| Cape Peirce* | 12500 | 2 | 9400 | 7 | 0.141 | 3 | 1 | 9 | 0.333 | 12.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 10.1 | 2 |
| Cape Newenham* | 700 | 9 | 423 | 16 | 0.002 | 13.5 | 2 | 19.5 | 0.333 | 12.5 | 1 | 6.5 | 2 | 13.5 | 2 | 16 | 13.3 | 8 |
| Security Cove* | 10000 | 4 | 6677 | 9 | 0.225 | 2 | 3 | 25.5 | 0.167 | 24.5 | 2 | 22 | 3 | 23 | 2 | 16 | 15.8 | 17 |
| Goodnews Bay* | – | 25 | 250 | 20 | – | 25 | 3 | 25.5 | 0.167 | 24.5 | 2 | 22 | 3 | 23 | 2 | 16 | 22.6 | 31 |
| Kwigillingok* | – | 25 | 500 | 15 | – | 25 | 3 | 25.5 | 0.167 | 24.5 | 2 | 22 | 3 | 23 | 2 | 16 | 22.0 | 30 |
| Nunivak Island* | | | | | | | | | | | | | | | | | | |
| Cape Etolin* | – | 25 | 200 | 22 | – | 25 | 3 | 25.5 | 0.167 | 24.5 | 2 | 22 | 1 | 3.5 | 2 | 16 | 20.4 | 27 |
| Mekoryuk* | – | 25 | 200 | 22 | – | 25 | 3 | 25.5 | 0.167 | 24.5 | 2 | 22 | 1 | 3.5 | 2 | 16 | 19.4 | 25 |
| St. Matthew Island* | | | | | | | | | | | | | | | | | | |
| Cape Upright* | 160 | 12 | 160 | 25 | 0.004 | 9.5 | 1 | 9 | 0.417 | 4.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 13.4 | 9 |
| Cape Glory of Russia* | 80 | 15 | 80 | 28 | 0.002 | 13.5 | 1 | 9 | 0.417 | 4.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 14.6 | 12 |
| Lunda Bay* | 180 | 11 | 180 | 24 | 0.004 | 9.5 | 1 | 9 | 0.417 | 4.5 | 1 | 6.5 | 3 | 23 | 3 | 27 | 14.3 | 10 |
| Hall Island* | 550 | 10 | 340 | 18 | 0.003 | 11 | 1 | 9 | 0.417 | 4.5 | 1 | 6.5 | 2 | 13.5 | 3 | 27 | 12.4 | 6 |
| Egg Island* | – | 25 | 300 | 19 | – | 25 | 1.5 | 16 | 0.167 | 24.5 | 2 | 22 | 3 | 23 | 2 | 16 | 21.3 | 29 |
| Besboro Island* | 100 | 14 | 200 | 22 | 0.002 | 13.5 | 1.5 | 16 | 0.167 | 24.5 | 2 | 22 | 2 | 13.5 | 2 | 16 | 17.7 | 20 |
| Cape Darby* | 50 | 16 | 36 | 30 | 0.001 | 16 | 1.5 | 16 | 0.167 | 24.5 | 2 | 22 | 2 | 13.5 | 2 | 16 | 19.3 | 24 |
| Sledge Island | 3 | 17 | 352 | 17 | 0.000 | 17.5 | 1.5 | 16 | 0.167 | 24.5 | 2 | 22 | 2 | 13.5 | 1 | 5 | 16.6 | 19 |
| King Island | 5000 | 5 | 2333 | 11 | 0.022 | 7.5 | 1.5 | 16 | 0.167 | 24.5 | 2 | 22 | 2 | 13.5 | 1 | 5 | 13.1 | 7 |
| Punuk Islands | | | | | | | | | | | | | | | | | | |
| North Island | 15000 | 1 | 15875 | 4 | 0.337 | 1 | 0.5 | 2.5 | 0.167 | 24.5 | 1 | 6.5 | 4 | 29 | 1 | 5 | 9.2 | 1 |
| Middle Island | – | 25 | 14000 | 5 | – | 25 | 1 | 9 | 0.167 | 24.5 | 2 | 22 | 4 | 29 | 1 | 5 | 18.1 | 21 |
| South Island | – | 25 | 11000 | 6 | – | 25 | 1 | 9 | 0.167 | 24.5 | 2 | 22 | 4 | 29 | 1 | 5 | 18.2 | 22 |
| St. Lawrence Island | | | | | | | | | | | | | | | | | | |
| Chibukak Pt. | 100 | 13 | 100 | 27 | 0.002 | 13.5 | 1 | 9 | 0.167 | 24.5 | 1 | 6.5 | 3 | 23 | 1 | 5 | 15.2 | 13.5 |
| Salghat | – | 25 | 19000 | 3 | – | 25 | 0.5 | 2.5 | 0.333 | 12.5 | 2 | 22 | 4 | 29 | 1 | 5 | 15.5 | 16 |
| Maknik | – | 25 | 35000 | 2 | – | 25 | 0.5 | 2.5 | 0.333 | 12.5 | 2 | 22 | 4 | 29 | 1 | 5 | 15.4 | 15 |
| Kialegak Pt. | – | 25 | 37000 | 1 | – | 25 | 0.5 | 2.5 | 0.333 | 12.5 | 2 | 22 | 3 | 23 | 1 | 5 | 14.5 | 11 |

Max. Count is from either "1980's" or "Curr. Est." columns (whichever is greater) in Table 7
Mean Max. Count is from "1960's", "1970's", "1980's" and "Curr. Est." columns in Table 7.
Proportion of Population is calculated from "Curr. Est." column in Table 7.
Age/Sex Composition x Activity values are based on whether all age/sex classes are present at the site (all=0.5, ad. males only=1), and the number of different locations at the site where walruses haul out (1=many, 2=several, 3= few).
Duration of Use is the approximate proportion of the year that the site is occupied.
Consistency of Use categories are as follows: 1 = annual and consistent, and 2 = inconsistent.
Site Characteristic values were based on topography and proximity to noise/disturb. near the haulout site (1 = any site near noise/disturb., 2 = cliffs, 3 = bluffs/slopes, 4 = low or no relief).
Species Characteristics values were assigned based on the degree of sensitivity of the species and associated potential for mortality as a result of noise/disturbance (high=1, medium=2, low=3).

* An asterisk indicates that this haulout site is occupied mostly by adult males. All other haulout sites (those without asterisks) are occupied by male and female adults, subadults and calves.

# SUMMARY AND CONCLUSIONS

The following summary and concluding remarks are presented in relation to the four broadly defined OCS Planning Areas (Norton Basin, St. Matthew-Hall, North Aleutian Basin, and St. George Basin) in our study area (see Fig. 1). Each of these four planning areas contain haulout sites that are important to more than one of the pinniped species considered in this report. Many of these sites ranked high in our Inter-site Population Sensitivity Index (IPSI) evaluations.

## Norton Basin Planning Area

There are 14 haulout sites in the Norton Basin Planning Area used by two of the four species of pinnipeds considered in this study; no northern fur seals or harbor seals haul out in significant numbers in this planning area. However, 86% (12) of the 14 sites in this planning area are used by one species, the Pacific walrus (Fig. 12). Two (14%) of these haulout sites, the one on North Punuk Island, and the one on King Island had high IPSI ratings (see Table 11). Northern sea lions have occasionally hauled out at Southwest Cape on St. Lawrence Island and on South Punuk Island; however, there is no current information concerning the use of these sites by this species, consequently, there was insufficient information to assign an IPSI value (compare Table 5 with Table 9).

## St. Matthew-Hall Planning Area

In the St. Matthew-Hall OCS Planning Area 24 haulout sites have been used by three of the four pinniped species considered in this study; there are no northern fur seal haulout sites. The majority of the sites are used by northern sea lions (11 sites, 46%); however none of these 11 sites ranked high in the overall evaluation of importance or potential vulnerability (Table 9). Pacific walrus sites were second in abundance (8 sites; 33%) and four of these, all on St. Matthew or Hall islands, ranked high in our IPSI rating system (Table 11). Harbor seal sites were least abundant (5 sites; 21%) in this planning area. Nevertheless, the site(s) in Kuskokwim Bay had relatively high IPSI values (Table 10); this area , and the areas to the east near Avinof

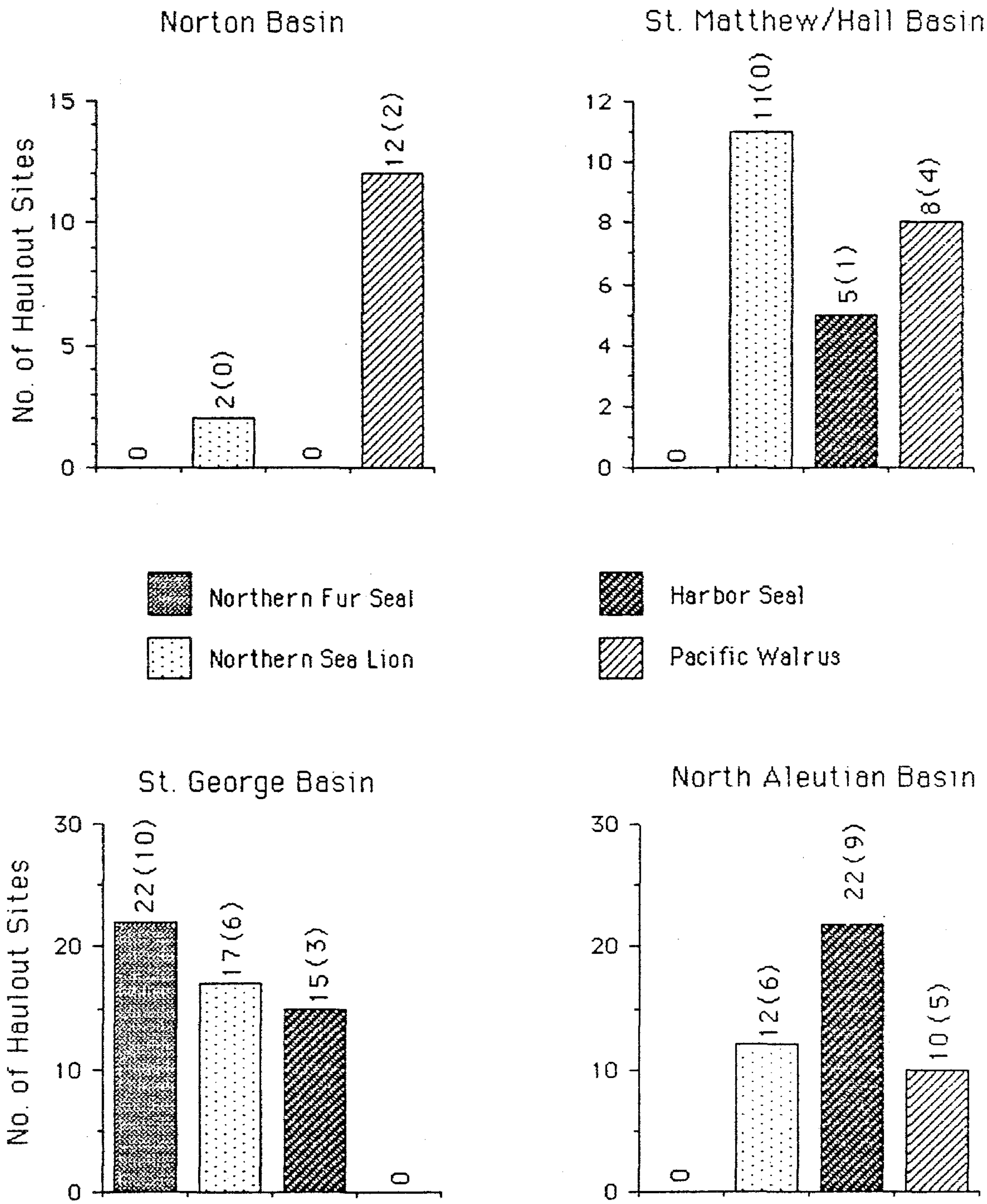



Figure 12. Summary of haulout sites in various OCS Planning Areas in the Bering Sea, Alaska. The number of sites that rated high in our IPSI evaluations are shown in parentheses.

Pt., may be the most northerly major harbor seal pupping areas in the eastern Bering Sea, and probably this is the least studied harbor seal habitat in the study area.

## North Aleutian Basin Planning Area

The North Aleutian Basin Planning Area contains 44 haulout sites used by three of the four pinniped species considered in this study (Fig. 12). Harbor seals use 22 (50%) of these sites including 9 of the 13 sites that had the highest IPSI ratings for harbor seals in this study (see Table 10). Twelve (27%) sites were occupied by northern sea lions, and at least six (14%) of these sites had high IPSI ratings. Ten sites (23%) in the North Aleutian Planning Area are occupied by Pacific walrus; five (11%) of these sites had very high IPSI values (Table 11).

## St. George Basin Planning Area

The St. George Basin Planning Area supports the largest number of haulout sites for the species considered in this study--a total of at least 54 sites for three species. There are no consistently used Pacific walrus haulout sites in the St. George Basin Planning Area. On the other hand, all 22 (100%) of the northern fur seal haulout sites in the eastern Bering Sea are in this planning area (Pribilof Islands and Bogoslof Island); these 22 sites represent about 40% of the total 54 sites used by the four species studied in this planning area (Table 10). Seventeen sites (32%) in this planning area are occupied by northern sea lions, and 6 (11%) of these had high IPSI ratings (Table 9). It was not possible for some sites to be evaluated (compare Table 5 with Table 9) because there was insufficient information on their current use. At least 15 sites (28%) in the St. George Basin Planning Area are used by harbor seals, and three (6%) of these sites (two in the Fox Islands and Otter Island) had very high IPSI ratings.

It should be remembered that we have not discussed rookeries/haulouts used by very small numbers of pinnipeds. With the exception of northern fur seals (which use only the Pribilofs and Bogoslof Island), hundreds of such sites are used by small groups (1-10 individuals) of Pacific walruses, northern sea lions, and especially harbor seals. The degree of fidelity to specific haulout sites (from greatest to least) by the four species we studied are: northern fur seal, walrus, northern sea lion and harbor seal. The last two species are most likely to haul out at sites not considered significant (far less than 1% of the study area population) and not considered in this study. This is especially true for harbor seals which are ubiquitous in most of the study area and haul out at hundreds of sites not considered here.

In summary, we evaluated 120 of 136 major terrestrial haulout sites in four different OCS Planning Areas to determine their overall importance and potential vulnerability, i.e. their sensitivity to possible OCS activities. It was not possible to evaluate some sites mentioned in the text and tables because of insufficient information on the number of animals currently using the sites and uncertainly about the consistency of use of the sites. Of the 44 sites in the North Aleutian Basin Planning Area, almost half (20 sites; 45%) were ranked high in our IPSI evaluations; this number represents almost half of the total 41 most highly rated sites for all four species in the study area. Of the 54 sites in the St. George Basin Planning Area, 19 (35%) were rated high; this number is strongly influenced by the 10 most highly rated northern fur seal sites on the Pribilof Islands. Of the 24 sites in the St. Matthew-Hall Planning Area, 5 (21%) were ranked high in our IPSI evaluations, and most (4 of 5; 80%) were sites occupied by Pacific walrus. Similarly, of the 14 sites in the Norton Basin Planning Area, only 2 were rated high in our IPSI evaluations; both of these sites were occupied by Pacific walrus.

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# APPENDICES

Appendix 1 gives details of an investigation of the acoustic environment at eight representative pinniped haulout sites in the eastern Bering Sea. Two sites were selected for each of the four pinniped species; sites were selected on the basis of their importance and vulnerability and the extent to which they represent different characteristics.

Appendices 2 through 5 give detailed descriptions and show locations of each major haulout site for the four species of pinnipeds considered in this study. Most descriptions are based (1) on information provided in the literature (e.g., Jordan and Clark 1898), (2) from available topographic maps, (3) from resource agency habitat maps (e.g., Sowls et al. 1978; ADFG 1973), (4) from NOAA hydrographic charts. Bathymetric and topographic information in the text and on the maps are approximate and should by no means be used for navigational purposes.

Appendices 6 through 8 provide detailed tabulations of all available information concerning the number of northern sea lions, harbor seals and Pacific walrus hauled out at different times at various sites in the study area. Most of the detailed information in Appendices 6-8 is not provided elsewhere in the report, but it has been used to produce the summary tables given in the 'Results' section of this report. We have not tabulated the masses of northern fur seal data collected over the last century in the Pribilof Islands area; virtually all of this information is available in the form of technical reports from the National Marine Mammal Laboratory, Seattle, WA.

# APPENDIX 1. ANALYSIS OF ACOUSTIC ENVIRONMENT OF SELECTED PINNIPED HAULOUT SITES IN THE ALASKAN BERING SEA

## INTRODUCTION

This investigation examines aspects of the acoustic environment at eight major pinniped haulout sites in the Alaskan Bering Sea. These sites are:

1. Sivutch on the south coast of St. Paul Island; northern fur seal.
2. Polovina on the east coast of St. Paul Island; northern fur seal.
3. Zapadni on the southwest coast of St. George Island; northern sea lion.
4. Ugamak Island (SE end) south of Unimak Pass; northern sea lion.
5. Port Moller on the north shore of the Alaska Peninsula; harbor seal.
6. Otter Island south of St. Paul Island; harbor seal.
7. Cape Peirce in northern Bristol Bay; Pacific walrus.
8. Cape Seniavin NE of Port Moller; Pacific walrus.

The aspects of the acoustic environment that were studied are:

Ambient Noise - Both airborne and underwater noise characteristics

Industrial Noise Source Characteristics - Aircraft, small-craft, fishing trawlers and commercial cargo traffic

Sound Transmission Loss - Airborne, underwater, and transmission through the water surface

The ambient noise characteristics for the sites were estimated using data obtained from studies of similar areas. The noise source characteristics were obtained from data reported in the literature and from BBN archives. Transmission loss characteristics for airborne and underwater sound were estimated using standard analytical procedures and computer models. An analytical procedure was developed for prediction of transmission of sound from aircraft into shallow water, since an existing procedure was not available. Procedures are described for using the information obtained in this study to predict noise exposure levels and develop zone-of-influence determinations for the various species of concern in this project.

## RESULTS AND DISCUSSION

### Ambient Noise Characteristics

Pinniped haulout sites are influenced by both underwater and airborne ambient noise. In the area near the beach, surf noise is the dominant contributor. The overall airborne noise level and spectrum shape are related not only to the local wind speed but also to the height of the swell which may be influenced by distant storms at sea. Beyond 100 to 200 m offshore the airborne noise level is influenced primarily by local breaking wave crests and may become quite low during calm sea conditions. Some surf noise data reported for moderate wind speed conditions (about 10 kts) are shown in Fig. 1[1]. The surf noise spectra reported for two different areas can be seen to be similar except at 50 Hz where the BBN data show a considerably higher level. This may be the result of higher swell conditions (swell height was not reported). The spectrum labeled "offshore" was measured for the same sea conditions as the surf noise spectrum but at a point about 200 m from the beach. The sea state was given as "choppy with some breaking crests". The band levels shown for the offshore spectrum correspond to those measured on land in rural areas and thus represent relatively quiet airborne noise conditions.

Several sources of data are available for ambient noise in shallow water. Wenz (1962) has compiled data from several shallow water regions. An example spectrum is shown in Fig. 2 for water depths less than 40 m and a wind speed of about 10 kt. The area had some contribution at low frequencies from distant shipping, producing a spectrum peak at 100 Hz. Data reported by Malme et al. (1986) for measurements near St. Lawrence Island in water depths of 12 m are also shown in Fig. 2. The wind speed during these measurements was about 10

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[1] It is customary to use 20 μPa as the reference for airborne sound levels since this results in a 0 dB sound pressure level for the normal human minimum threshold of hearing. We will use the underwater sound reference level of 1 μPa in this report for both airborne and underwater sound to avoid confusion and simplify spectrum comparisons.

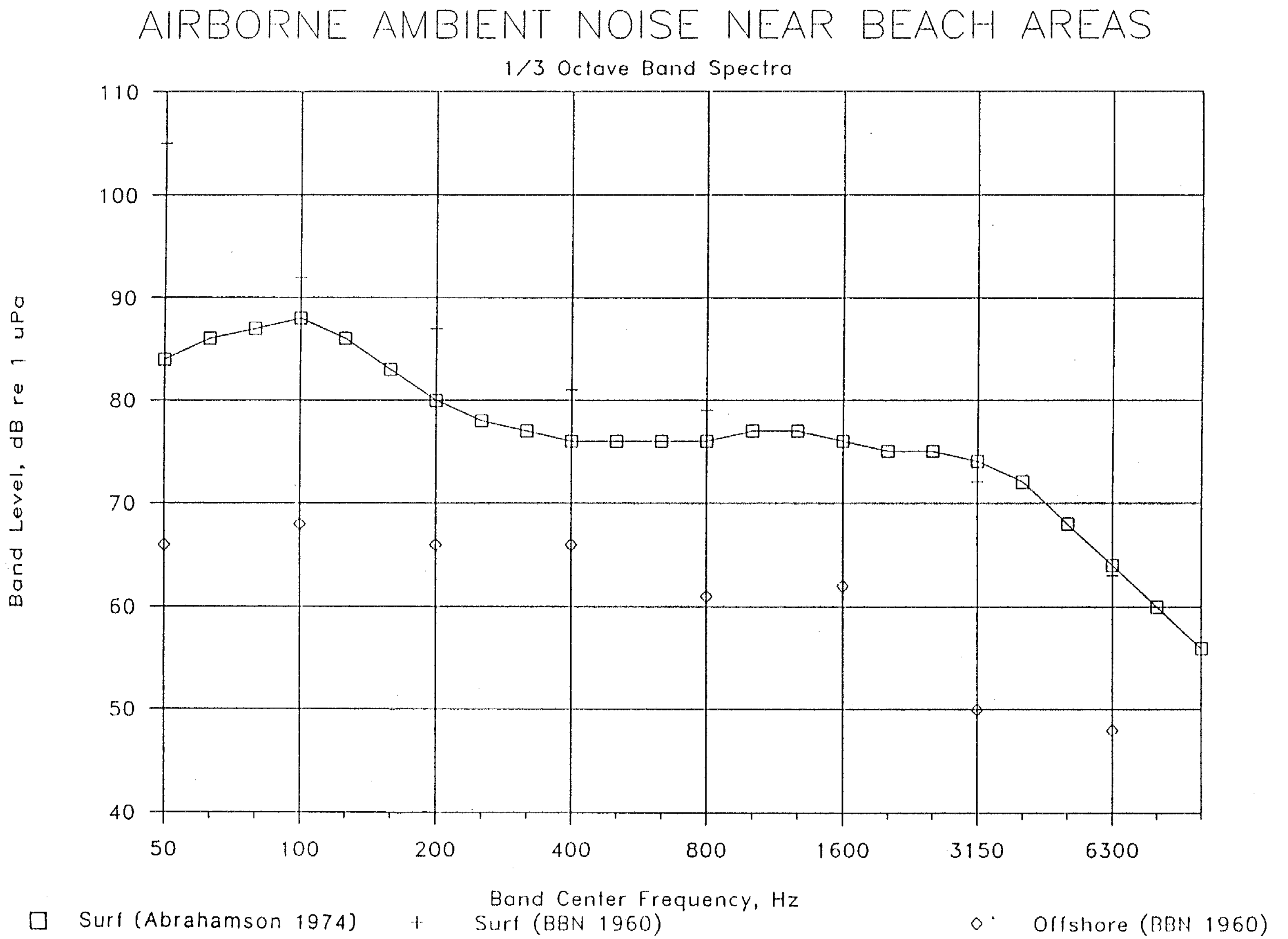



Figure 1. Airborne ambient noise near beach areas.

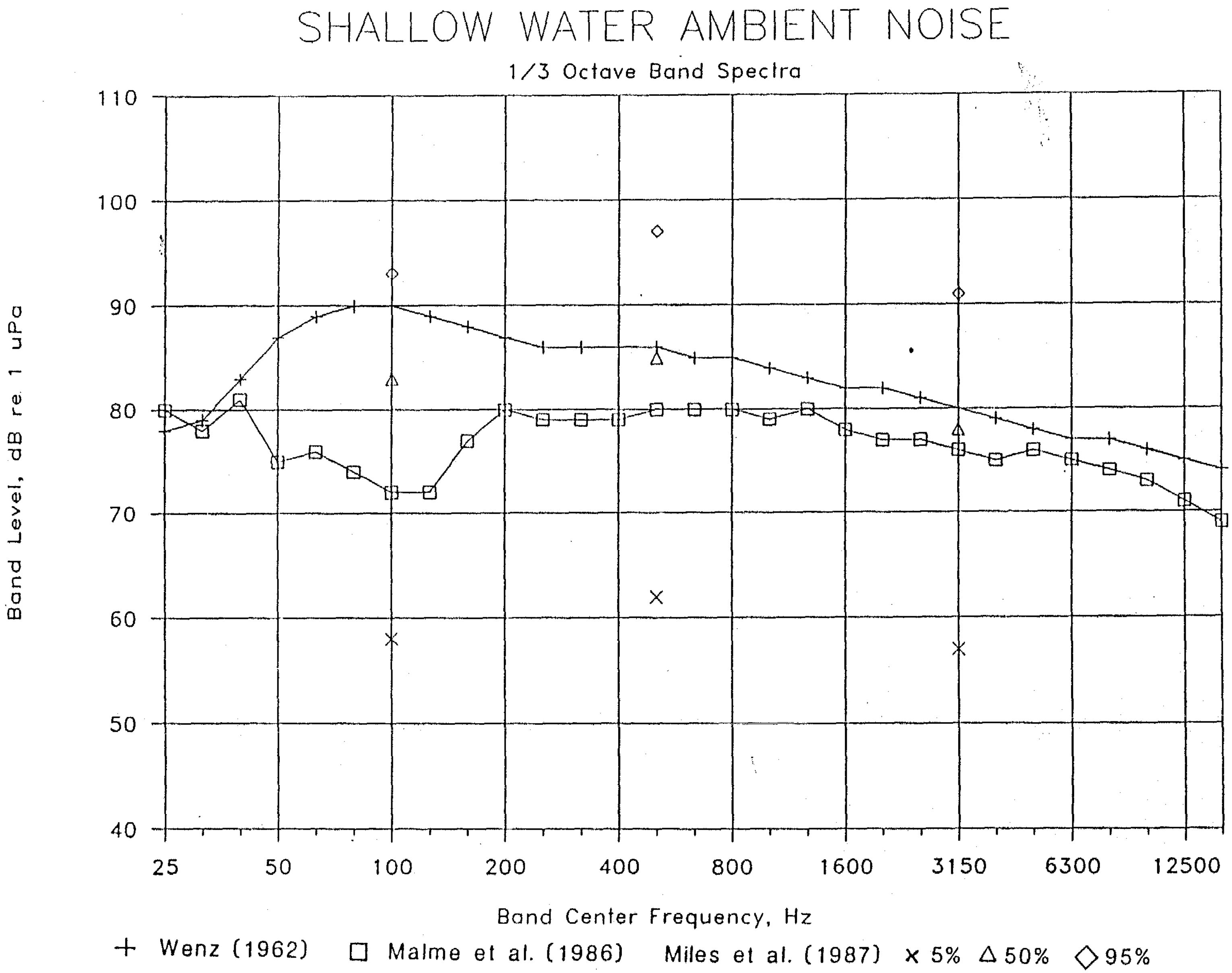



Figure 2. Shallow water ambient noise.

kt. Distant shipping did not evidently influence the ambient spectrum during this measurement since the levels at low frequencies do not show any increase over those at mid-band. No data were found for underwater ambient noise levels near the surf zone; however, at low frequencies in very shallow water the levels underwater are expected to be similar to those in air. This will be shown by an analysis presented in the section on Transmission Loss (p. 103).

The range of underwater ambient noise levels expected in shallow water where shipping noise is not an important factor is indicated in the figure by the percentile spectra. These spectra are based on data and estimates obtained for shallow (15 m) Beaufort Sea regions by Miles et al. (1987). The percentile levels shown would be expected to be relevant also for Bering Sea regions where shipping noise is not significant. However, for the Ugamak Island site near Unimak Pass shipping would be expected to contribute a moderate peak near 100 Hz similar to that shown in the Wenz spectrum.

## Industrial Noise Source Characteristics

At the study sites selected, single-engine and twin-engine aircraft, helicopters, small-craft, fishing vessels and commercial cargo vessels are expected to be the dominant types of industrial noise sources. These sources are all mobile and contribute noise to a pinniped haulout site over a time interval related to their speed and distance from the site. A small aircraft travelling at a low altitude will produce high levels for a relatively short period of time at a point on the ground under its flight path, whereas a large aircraft travelling at a high altitude may produce comparable levels for a longer period of time. The rate of increase in noise level on the ground is less abrupt for the large aircraft but the noise remains at high level for a longer period of time. Thus both startle and avoidance types of reactions may occur for aircraft overflights near haulout areas. Similar reactions may occur when high speed boats and larger cargo vessels pass near areas where animals are engaged in underwater activity. Most of the time the majority of the animals at a haulout site are out of the water so aircraft noise is potentially more likely to cause disturbance than boat traffic.

Information on the acoustic output of aircraft and vessels that may pass by the study sites is presented in the form of standardized 1/3 octave spectra to facilitate comparison of the noise levels produced by the various sources and provide source level spectra needed for estimating the noise exposure at various ranges. It is customary to present aircraft noise spectra as measured for an overflight at a reference altitude of 1000 ft (300 m) rather than a reference distance of 1 m as is usual for underwater sources. This is done because of the strong dependence of atmospheric absorption at high frequencies on temperature and humidity conditions. If aircraft radiated noise spectra were required to be corrected to a reference distance of 1 m it would be necessary to have very accurate measurements of temperature and humidity as a function of altitude in order to minimize errors in the corrected source level spectrum. Since most applications of radiated noise data are for predictions of levels at slant ranges of 300 m or greater, it is not necessary to correct measured levels to a reference distance of 1 m. Instead, flyover data are generally corrected to represent the received noise level on the ground for an overflight at 300 m altitude for "Standard Day" conditions of 15°C and 70% relative humidity.

## Aircraft Noise Spectra

Figure 3 shows 1/3 Octave radiated noise data for representative 1-engine and 2-engine propeller and turboprop aircraft. These data were obtained from overflights of Cessna 172, Piper Archer, Piper Navaho, Beech Baron, and Gulf stream Commander types of aircraft. Figure 3A presents data for a take-off power setting and Fig. 3B presents data for an approach power setting. (Note the 10 dB difference in band level between the two figures.) The 2-engine turboprop aircraft can be seen to be noisier than the two types of piston engine aircraft, however it is also the largest of the types represented in these data.

Radiated noise data for helicopters are presented in Fig. 4. Data are presented for those craft which might be expected to fly near the study sites such as the Bell 206B, 205, and 222 and the Sikorsky 61 (similar to the Hughes 369D). Figure 4A presents spectra for cruise and takeoff conditions. Spectra for loaded and approach power settings are shown in Fig. 4B. The Bell 205 can

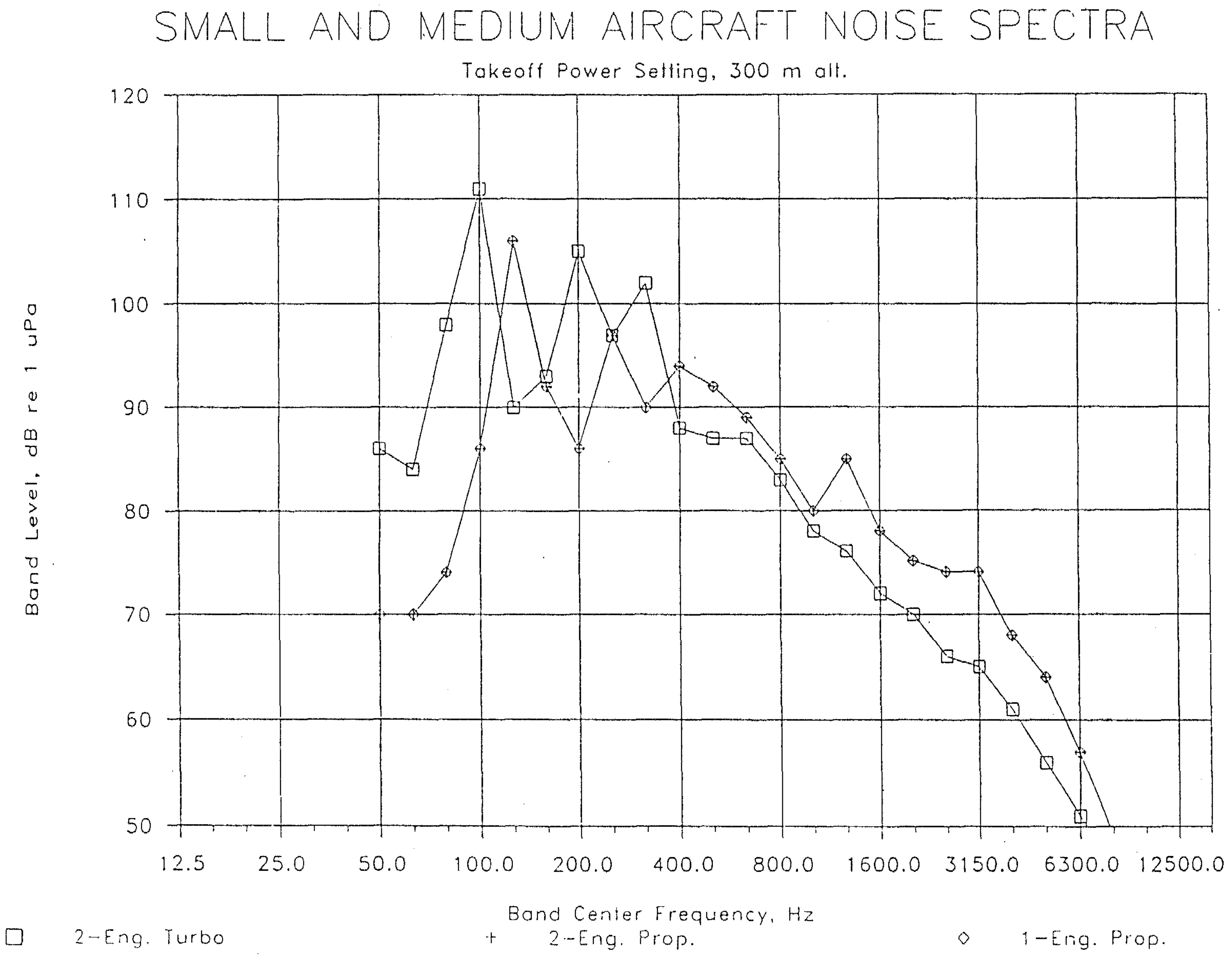



Figure 3. Small and medium aircraft noise spectra
A. Takeoff power setting, 300 m altitude
B. Approach power setting, 300 m altitude.

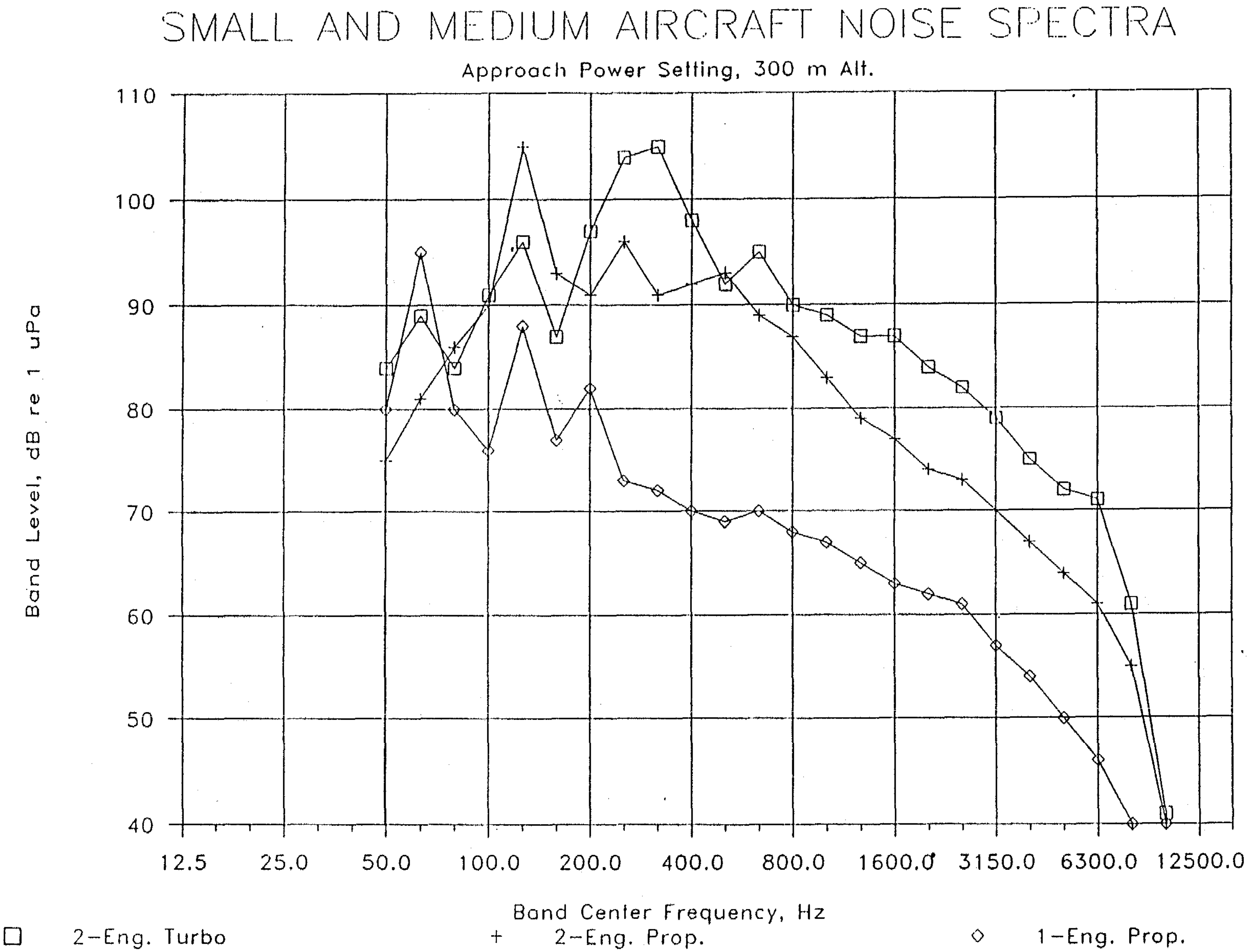

SMALL AND MEDIUM AIRCRAFT NOISE SPECTRA
Approach Power Setting, 300 m Alt.
Band Level, dB re 1 uPa
110
100
90
80
70
60
50
40
12.5
25.0
50.0
100.0
200.0
400.0
800.0
1600.0
3150.0
6300.0
12500.0
Band Center Frequency, Hz
2-Eng. Turbo
2-Eng. Prop.
1-Eng. Prop.

Figure 3B.

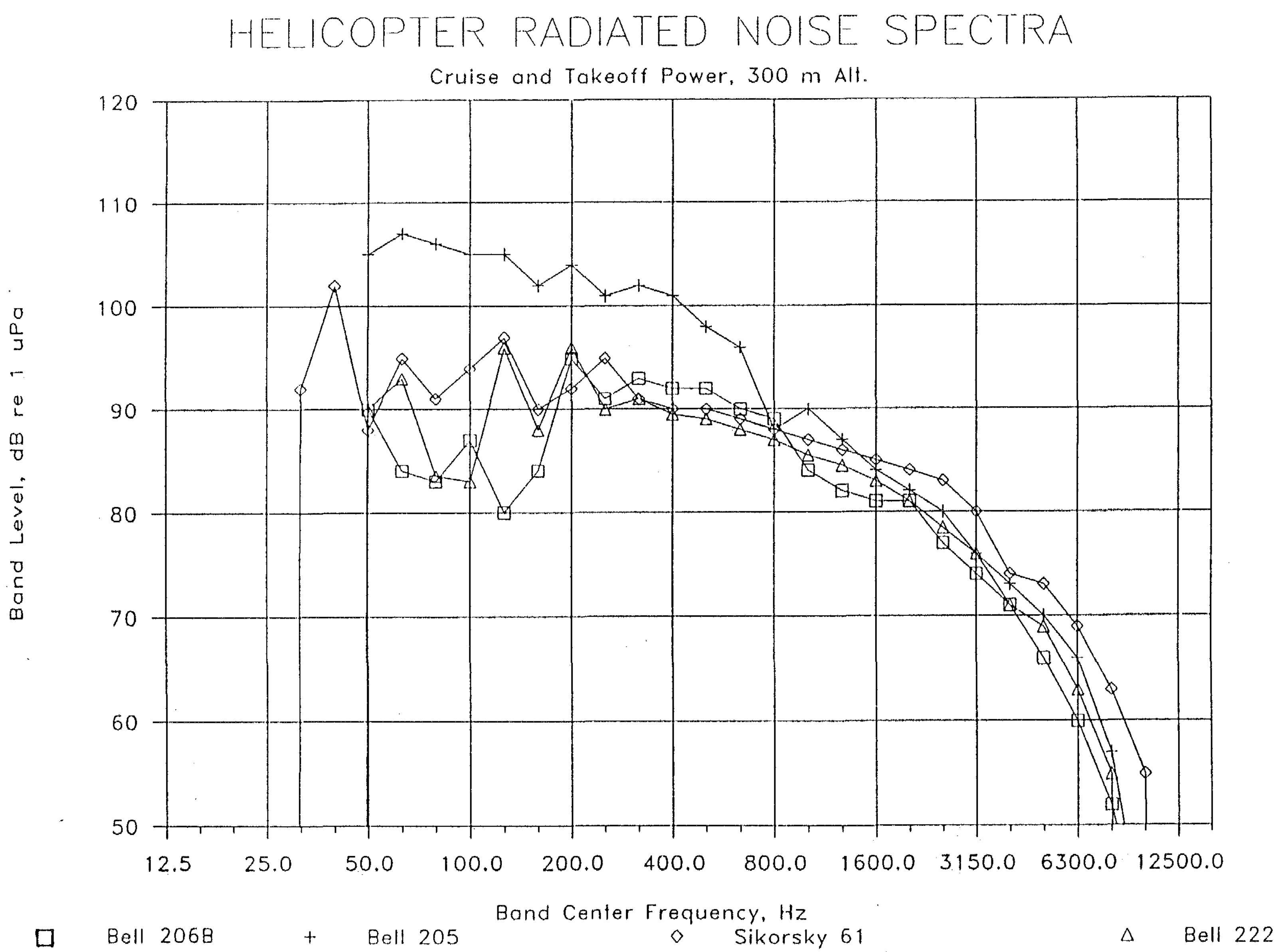



Figure 4. Helicopter radiated noise spectra
A. Cruise and takeoff power, 300 m altitude
B. Loaded and approach power, 300 m altitude.

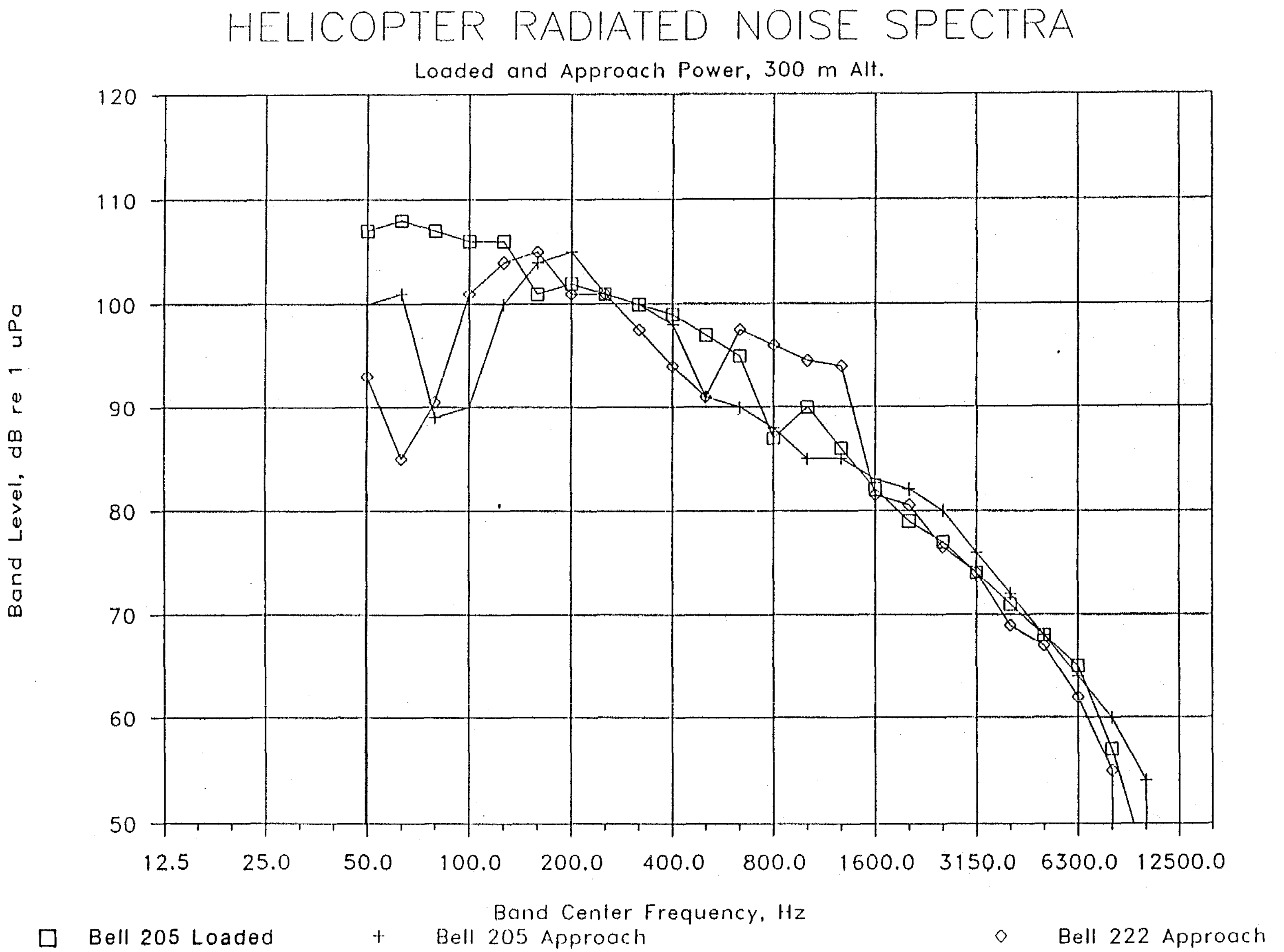

HELICOPTER RADIATED NOISE SPECTRA
Loaded and Approach Power, 300 m Alt.
Band Level, dB re 1 uPa
120
110
100
90
80
70
60
50
12.5
25.0
50.0
100.0
200.0
400.0
800.0
1600.0
3150.0
6300.0
12500.0
Band Center Frequency, Hz
Bell 205 Loaded
Bell 205 Approach
Bell 222 Approach

Figure 4B.

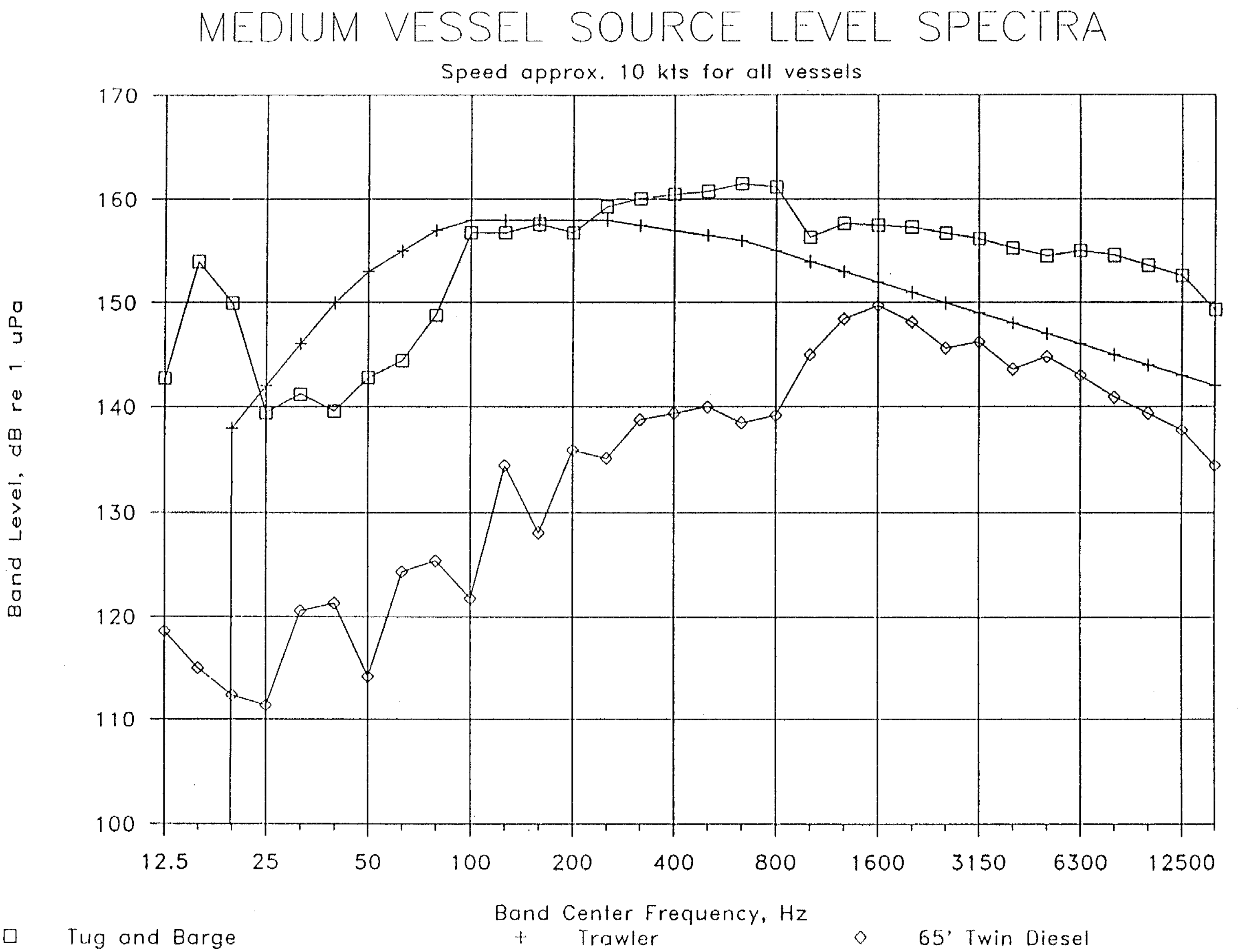

MEDIUM VESSEL SOURCE LEVEL SPECTRA
Speed approx. 10 kts for all vessels
Band Level, dB re 1 uPa
170
160
150
140
130
120
110
100
12.5
25
50
100
200
400
800
1600
3150
6300
12500
Band Center Frequency, Hz
Tug and Barge
Trawler
65' Twin Diesel

Figure 5B.

## Transmission Loss

A discussion of the transmission of airborne sound is presented first since aircraft are the most probable source of industrial noise near haulout areas. This is followed by a discussion of underwater sound transmission and transmission of sound through the water surface.

### Sound Transmission in the Atmosphere

Sound transmission from a source in an unbounded atmosphere is attenuated only by geometrical spreading of the sound energy and by absorption of sound energy by air molecules. Sound transmission from a source near a non-rigid or permeable boundary is also influenced by reflection and refraction losses and by wave transmission along the boundary surface. Fortunately the most significant sound transmission from an aircraft to a point on the ground involves a direct path from the source to receiver which is elevated well above the refracting and scattering effects of near-surface transmission. Because of this, it is necessary to consider only spherical spreading, atmospheric absorption, and ground reflection effects in the transmission loss (TL) equation for estimating the received level on the ground from an aircraft passing nearby. The relationship can be stated as:

$$Lr = Ls - 20\,\mathrm{Log}(R) - a\,R + Rg \quad \text{dB re } 1\ \mu\text{Pa} \qquad (1)$$

where:
- Lr = Received level spectrum near the ground
- Ls = Source Level spectrum at 1 m from the source
- R = Slant range in m
- a = Atmospheric absorption spectrum in dB/m
- Rg = Ground reflection spectrum, dB

Since for most aircraft noise transmission calculations, a reference sound level at 300 m is used rather than a 1 m source level, Eqn (1) can be rewritten as:

$$Lr = Lref - 20\,\mathrm{Log}\,(R/Rref) - a\,R + a(SD)\,Rref \qquad (2)$$

where:
- Lref = Reference source spectrum at 300 m for standard day conditions
- Rref = 300 m
- a(SD) = Atmospheric absorption spectrum for standard day conditions

The procedure for measuring Lref utilizes microphones near the ground so the ground reflection effect is included in the measured level. Equation (2) is to be applied successively to each spectrum band in calculation of the Lr spectrum; i.e., the 50 Hz band level of the Lref spectrum would be used with the 50 Hz band levels of the absorption spectra to determine the 50 Hz band level of Lr, etc. Since the spreading loss term is not frequency dependent, it is calculated once and used repeatedly.

Atmospheric absorption at low frequencies below 30 kHz is produced by molecular absorption by oxygen and nitrogen molecules. The amount of absorption is dependent on frequency, temperature, relative humidity, and to a small degree on atmospheric pressure. The physical relationship between these parameters is not easily expressed in mathematical relationships, but an empirical computer algorithm has been developed for closed-form calculation of absorption coefficients from input of the four atmospheric parameters (ANSI S1.26-1978). Examination of the climatic atlas data showing temperature and humidity values for the Bering Sea region of interest to this study during the pinniped haulout season disclosed that the expected range of variation was not large. A table of absorption coefficients was prepared using excerpts from the ANSI Standard. The results are shown in Table 1 which presents atmospheric absorption coefficients estimated for spring and summer conditions in the study areas. Values are presented showing attenuation per 100 m. Attenuation values at 150 m (500 ft) are also given to facilitate correction of reference spectra to 150 m and 450 m altitudes. For flyovers at 300 m the corrections to the standard day conditions can be used to estimate aircraft noise spectra at the Bering Sea sites.

## Underwater Sound Transmission

In unbounded deep water sound transmission characteristics are determined by geometric spreading loss and molecular absorption of the sound energy in the same manner as in atmospheric transmission. Molecular absorption losses are much less underwater, however, and are not significant for frequencies less than 5 kHz and ranges less than 5 km. Sound transmission in shallow water is influenced by reflection losses from the bottom and surface, refraction from sound speed gradients, refraction from sub-bottom layers, and scattering

Table 1. Atmospheric Attenuation for Representative Southern Bering Sea Conditions (Estimated using ANSI S1.26-1978, Method for the Calculation of the Absorption of Sound by the Atmosphere)

| Temp./Hum. | Freq.(Hz) Attenuation | 50 | 63 | 80 | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 | 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 | 4000 | 5000 | 6300 | 8000 | 10000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0°C, | a, dB/100 m | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.20 | 0.27 | 0.38 | 0.54 | 0.83 | 1.24 | 1.87 | 2.87 | 4.43 | 6.58 | 9.72 | 14.10 | 19.26 |
| 80% R.H. | a @ 150 m (dB) | 0.02 | 0.02 | 0.03 | 0.05 | 0.06 | 0.08 | 0.09 | 0.12 | 0.15 | 0.18 | 0.23 | 0.30 | 0.41 | 0.58 | 0.82 | 1.26 | 1.88 | 2.84 | 4.36 | 6.73 | 10.00 | 14.77 | 21.43 | 29.28 |
| 5°C, | a, dB/100 m | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.05 | 0.07 | 0.09 | 0.11 | 0.14 | 0.17 | 0.21 | 0.27 | 0.34 | 0.46 | 0.67 | 0.97 | 1.44 | 2.18 | 3.39 | 5.12 | 7.82 | 11.97 | 17.48 |
| 80% R.H. | a @ 150 m (dB) | 0.02 | 0.02 | 0.03 | 0.03 | 0.06 | 0.08 | 0.11 | 0.14 | 0.17 | 0.21 | 0.26 | 0.32 | 0.41 | 0.52 | 0.70 | 1.02 | 1.47 | 2.19 | 3.31 | 5.15 | 7.78 | 11.89 | 18.19 | 26.57 |
| 10°C, | a, dB/100 m | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.06 | 0.09 | 0.12 | 0.17 | 0.21 | 0.26 | 0.32 | 0.38 | 0.46 | 0.61 | 0.81 | 1.13 | 1.63 | 2.45 | 3.66 | 5.60 | 8.73 | 13.19 |
| 90% R.H. | a @ 150 m (dB) | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.06 | 0.09 | 0.14 | 0.18 | 0.26 | 0.32 | 0.40 | 0.49 | 0.58 | 0.70 | 0.93 | 1.23 | 1.72 | 2.48 | 3.72 | 5.56 | 8.51 | 13.27 | 20.05 |
| "Standard Day" | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15°C | a, dB/100 m | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.05 | 0.07 | 0.10 | 0.14 | 0.19 | 0.24 | 0.30 | 0.37 | 0.44 | 0.53 | 0.68 | 0.88 | 1.19 | 1.69 | 2.51 | 3.71 | 5.64 | 8.77 | 13.27 |
| 70% R.H. | a @ 150 m (dB) | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.08 | 0.11 | 0.15 | 0.21 | 0.29 | 0.36 | 0.45 | 0.56 | 0.66 | 0.80 | 1.02 | 1.32 | 1.79 | 2.54 | 3.76 | 5.57 | 8.46 | 13.16 | 19.91 |
| Corrections for Bering Sea Conditions<br>Add to data reported for "Standard Day" conditions | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0°C, | c, dB/100 m | 0.00 | 0.00 | -0.01 | -0.01 | -0.01 | 0.00 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.10 | 0.10 | 0.06 | -0.01 | -0.15 | -0.36 | -0.68 | -1.18 | -1.92 | -2.87 | -4.08 | -5.33 | -5.99 |
| 80% R.H. | c @ 150 m (dB) | -0.00 | -0.00 | -0.02 | -0.02 | -0.02 | -0.00 | 0.01 | 0.03 | 0.06 | 0.10 | 0.13 | 0.15 | 0.14 | 0.08 | -0.03 | -0.24 | -0.56 | -1.06 | -1.83 | -2.97 | -4.44 | -6.31 | -8.28 | -9.37 |
| 5°C, | c, dB/100 m | 0.00 | 0.00 | -0.01 | 0.00 | -0.01 | 0.00 | 0.00 | 0.01 | 0.03 | 0.05 | 0.07 | 0.09 | 0.10 | 0.10 | 0.07 | 0.01 | -0.09 | -0.25 | -0.49 | -0.88 | -1.41 | -2.18 | -3.20 | -4.21 |
| 80% R.H. | c @ 150 m (dB) | -0.00 | -0.00 | -0.02 | -0.00 | -0.02 | -0.00 | -0.00 | 0.01 | 0.04 | 0.07 | 0.10 | 0.13 | 0.14 | 0.14 | 0.10 | 0.00 | -0.15 | -0.40 | -0.78 | -1.39 | -2.22 | -3.43 | -5.04 | -6.66 |
| 10°C, | c, dB/100 m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.05 | 0.04 | 0.04 | 0.08 |
| 90% R.H. | c @ 15 0m (dB) | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 | 0.04 | 0.05 | 0.07 | 0.08 | 0.10 | 0.09 | 0.09 | 0.07 | 0.06 | 0.04 | 0.00 | -0.05 | -0.11 | -0.14 |

from rough surfaces. All these effects must be considered along with geometric spreading loss to obtain estimates of the received level at some distance from a source. In the present study, sound transmission is further modified by the bottom slope present in most beach areas. When sound is transmitted upslope, as is the case for a source passing near a haulout area, two effects occur. If the bottom reflection loss is low, sound levels tend to be higher than those predicted by geometric spreading because the sound energy becomes concentrated in a smaller water volume as it travels upslope. However, if bottom loss is high, sound levels are reduced at a greater rate than expected from geometric spreading since sound undergoes more bottom contact than would occur for transmission over a constant depth bottom. These effects are further complicated by sound transmission and refraction in bottom material which often is an important means of sound transmission in very shallow water.

For a rigid, impermeable bottom theory predicts that sound transmission is not possible at frequencies for which the depth of water is less than 1/4 wavelength. Thus for sound transmission upslope from a broadband source, the low frequencies will be cut off or attenuated heavily at shorter ranges than the high frequencies. However, since most bottom material is not rigid and impermeable, this frequency-selective cutoff characteristic is not always observed. The presence of water-saturated sediments often permits significant sound transmission to occur up into the surf zone.

The haulout sites selected for this study have several types of bottom material as well as differences in bottom slopes. After examining the charted depths near these sites and reviewing information about bottom conditions we were able to divide the 8 sites into two general categories based on bottom composition and beach slope as follows:

| Site | Slope | Bottom Composition |
|---|---|---|
| Port Moller | -0.003 | silt and sand |
| Cape Seniavin | -0.0045 | silt and sand |
| Cape Peirce | -0.0036 | sand and rock |
| Ugamak Island | -0.09 | sand and rock |
| Sivutch (St. Paul) | -0.01 | rocky |
| Polovina (St. Paul) | -0.009 | rocky |
| Zapadni (St. George) | -0.01 | rocky |
| Otter Island | -0.012 | rocky |

Ugamak Island was considered as a special case since it has a steeper beach than the other sites.

## Sound Propagation Modeling

The most appropriate type of sound propagation model to use for prediction of transmission characteristics at these sites is a model based on a solution of the parabolic wave equation for acoustic waves in a range-dependent medium. This type of model can accommodate changes in transmission properties with range such as sloping bottoms and variations in sound speed profiles and bottom layer materials. It also develops a solution for the sound field as a function of depth and is appropriate for sound transmission from a shallow source to a shallow receiver - as required by this study. The depth-averaged type of transmission models such as the Weston/Smith model (Miles et al. 1987) are not appropriate for shallow source - shallow receiver transmission and do not provide for sound transmission in bottom layers (unless special modifications are made to the input parameters). Fortunately a model based on an implicit finite difference solution of the parabolic wave equation has become available. This "IFD Model" was developed by Lee and Botseas (1982) at the U.S. Naval Underwater Systems Center, New London. It has been adapted to run on IBM AT compatible computers and was used for the modeling required by this study.

The geometry used for the model in this study is shown in Fig. 6. This geometry features a beach profile which has a constant slope connecting a flat region offshore with a small flat region near shore. There are also two sloping bottom layers which have range-dependent thickness. To represent transmission from smaller vessels to pinnipeds swimming in the surf zone, a source depth of 1 m and an average receiver depth of 2 m was used. In shallow water with a sloping bottom the transmission characteristics from the source become range-dependent because the water depth changes with source position along the transmission path. To model this dependence, two source locations were used as shown in Fig. 6.

Table 2. Parameter Values for IFD Beach Model.

| Type | Slope | Source Pos. 1 (10 km) Water | Layer 1 | Layer 2 | Source Pos. 2 (3.3 km) Water | Layer 2 | Layer 2 | Beach (20 m) Water | Layer 1 | Layer 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| **A. Bottom Layer Thickness, m (see Fig. 6)** | | | | | | | | | | |
| 1 | -0.004 | 37 | 25 | >200 | 13 | 11.7 | >200 | 1 | 5 | >200 |
| 2 | -0.01 | 91 | 2 | >200 | 31 | 0.8 | >200 | 1 | 0.2 | >200 |
| 3 | -0.01 | 91 | 2 | >200 | 31 | 0.73 | >200 | 1 | 0.1 | >200 |

B. Bottom Material Parameters

| | Bottom Type 1 | | | Bottom Type 2 | | | Bottom Type 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Water | Layer 1 | Layer 2 | Water | Layer 1 | Layer 2 | Water | Layer 1 | Layer 2 |
| Sound Speed (m/sec)* | 1470.5 | 1700 | 1900 | 1471 | 1620 | 4000 | 1471 | 1700 | 4000 |
| Density (kg/cu.m) | 1000 | 1800 | 2200 | 1000 | 1870 | 2800 | 1000 | 1800 | 2800 |
| Attn. (dB/wavelength | 0 | 0.13 | 0.13 | 0 | 0.97 | 0.04 | 0 | 0.13 | 0.04 |
| Layer 1 material | silt/fine sand | | | silt/black sand | | | silt/fine sand | | |
| Layer 2 material | sand/gravel | | | basalt | | | basalt | | |

* Sound speed at surface 1470 m/sec, sound speed at 90 m, 1472 m/sec, linear gradient

only one frequency for each set of calculations. As a result, the calculated values shown in Fig. 7A for 100 Hz incorporate considerable fluctuations in level caused by multipath interference patterns. The results have been smoothed somewhat by averaging the model-calculated TL over a depth range from 1 to 3 m to derive the solid curves shown in the figure. The dashed lines are the estimated rms-averaged TL characteristics which would be obtained by averaging several model calculations using closely-spaced tones to smooth out the interference pattern.

Figure 7A shows that for a source located 10 km from the beach, the TL becomes greater than 100 dB at range of 6 km from the source or 4 km from the beach. This is essentially the acoustic cutoff for sound at this frequency. For a source located 3.3 km from the beach the cutoff is reached within a few hundred meters of the beach. Note the TL at very short ranges from the source position is about 60 dB. This high value at short ranges is the result of the shallow source (1 m) and shallow receiver depths (2 m) selected for use in the study. This geometry was selected to represent the operating depth of the propellers of small and medium-sized vessels and the swimming depth of pinnipeds near the haul-out sites.

Figure 7B presents the TL characteristics of the Type 1 bottom for 315 Hz. At this frequency the bottom losses are not as severe and transmission from a source at 10 km is not cut off until it gets very near the beach. For a source range of 3.3 km, transmission up to the beach region can be seen to occur. While attenuation rates near the source can be seen to be high as a result of the shallow geometry, a TL plateau is reached wherein a constant level is maintained or the level decreases slowly with increasing distance from the source. This is probably the result of sound transmission within the bottom layers and reflection and refraction out of the layers to reinforce sound in the water column. The TL characteristics shown in Fig 7C for 1 kHz are similar to those obtained at 315 Hz with somewhat lower values of loss being observed.

The TL characteristics obtained from the model calculations for the Type 1 Bottom were interpolated to obtain a set of curves for predicting the TL from a shallow source to a shallow receiver near the beach as a function of

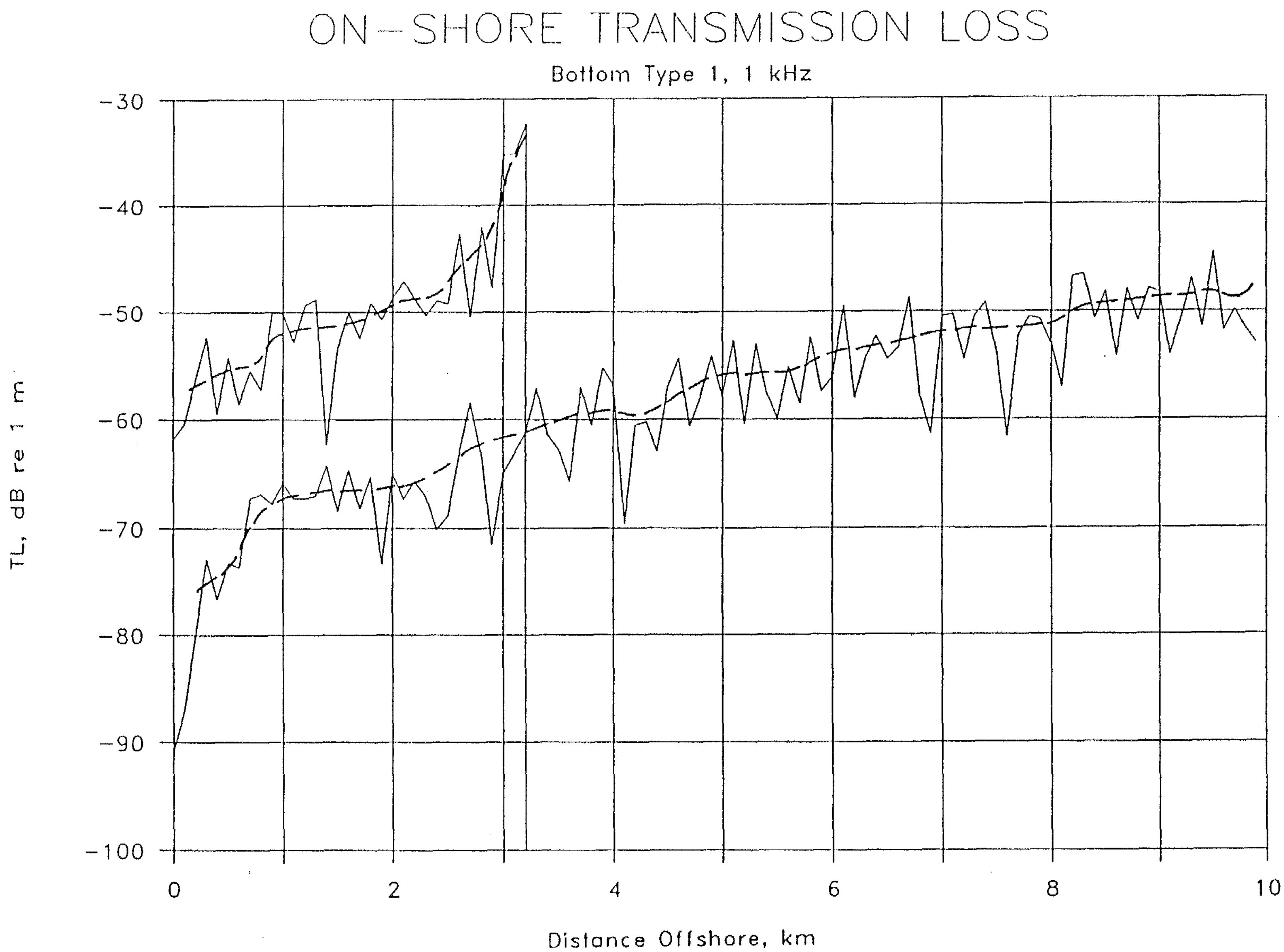

ON-SHORE TRANSMISSION LOSS
Bottom Type 1, 1 kHz
-30
-40
-50
-60
-70
-80
-90
-100
TL, dB re 1 m
0
2
4
6
8
10
Distance Offshore, km

Figure 7C.

the distance of the source from the shoreline. The results, shown in Fig. 7D, are presented to facilitate the estimation of received level near shore for a vessel operating directly offshore. The received level may be estimated as:

$$Lr = Ls - TL \quad \text{dB re 1 } \mu\text{Pa} \qquad (3)$$

where: Lr = Received level in a selected 1/3 octave band

Ls = Source level at 1 m in the selected 1/3 octave band for a specific source (from source level tables)

TL = The transmission loss from Fig. 7D for the 1/3 octave band at the range of interest (this may have to be interpolated)

The transmission loss characteristics calculated using the model with the Bottom Type 2 parameters are shown in Figs. 8A through 8C. Very few differences were found when comparing these characteristics with those for Bottom Type 3 shown in Figs. 9A through 9D. The difference between these two bottom types is a thinner sand layer with less internal damping for Bottom Type 3. The influence of the change in this layer is evident only in some minor details of the transmission characteristics at 1kHz. Therefore the basalt sub-bottom layer is apparently the controlling acoustic influence in determining the TL characteristics for Bottom Types 2 and 3. As a result, the discussion is focussed on the information shown in Figs. 9A through 9D for the Type 3 bottom.

When the TL characteristics at 100 Hz for the rocky bottom (Fig. 9A) are compared with those for the sandy bottom (Fig 7A), the propagation from the source at 10 km offshore can be seen to fall off more rapidly for the rocky bottom than for the sandy bottom. Normally sound transmission over a rocky bottom would be expected to be better than that over a sandy bottom. However in this case, because of the shallow source and receiver positions, most of the sound energy travels between the source and receiver by downward directed ray paths which incur a large number of bottom reflections in the case of the rocky bottom. For the sandy bottom much more sound energy is able to penetrate the bottom and eventually reflect and refract back out into the water layer to reinforce sound transmission at the longer ranges. The TL characteristics at 315 Hz (Fig. 9B) and at 1 kHz (Fig 9C) are similar to those at 100 Hz in that they all show a cutoff at a range offshore of 5 to 6 km for the 10 km source position. For the 3.3 km source position, the differences in TL

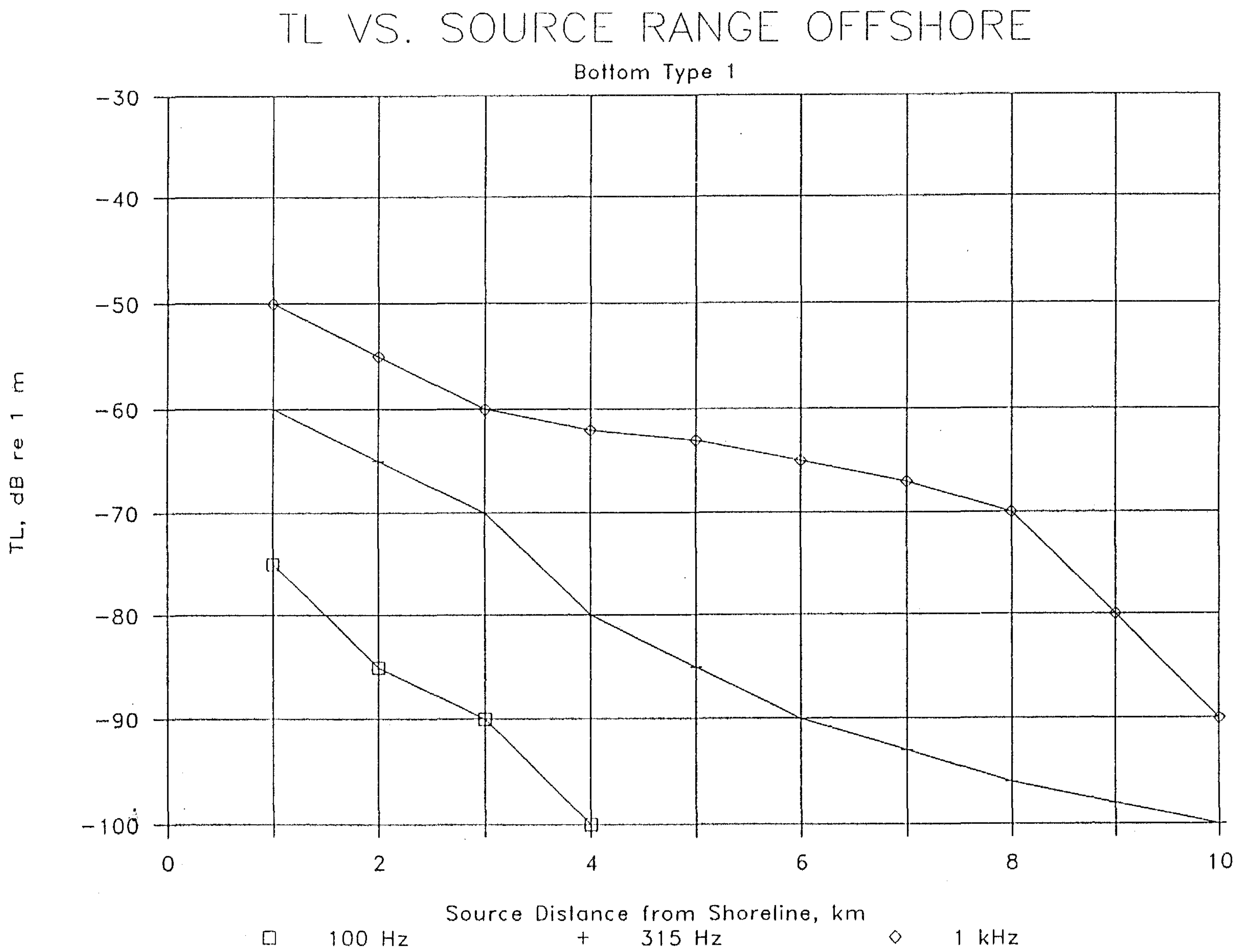

TL VS. SOURCE RANGE OFFSHORE
Bottom Type 1
TL, dB re 1 m
-30
-40
-50
-60
-70
-80
-90
-100
0
2
4
6
8
10
Source Distance from Shoreline, km
□ 100 Hz
+ 315 Hz
◇ 1 kHz

Figure 7D.

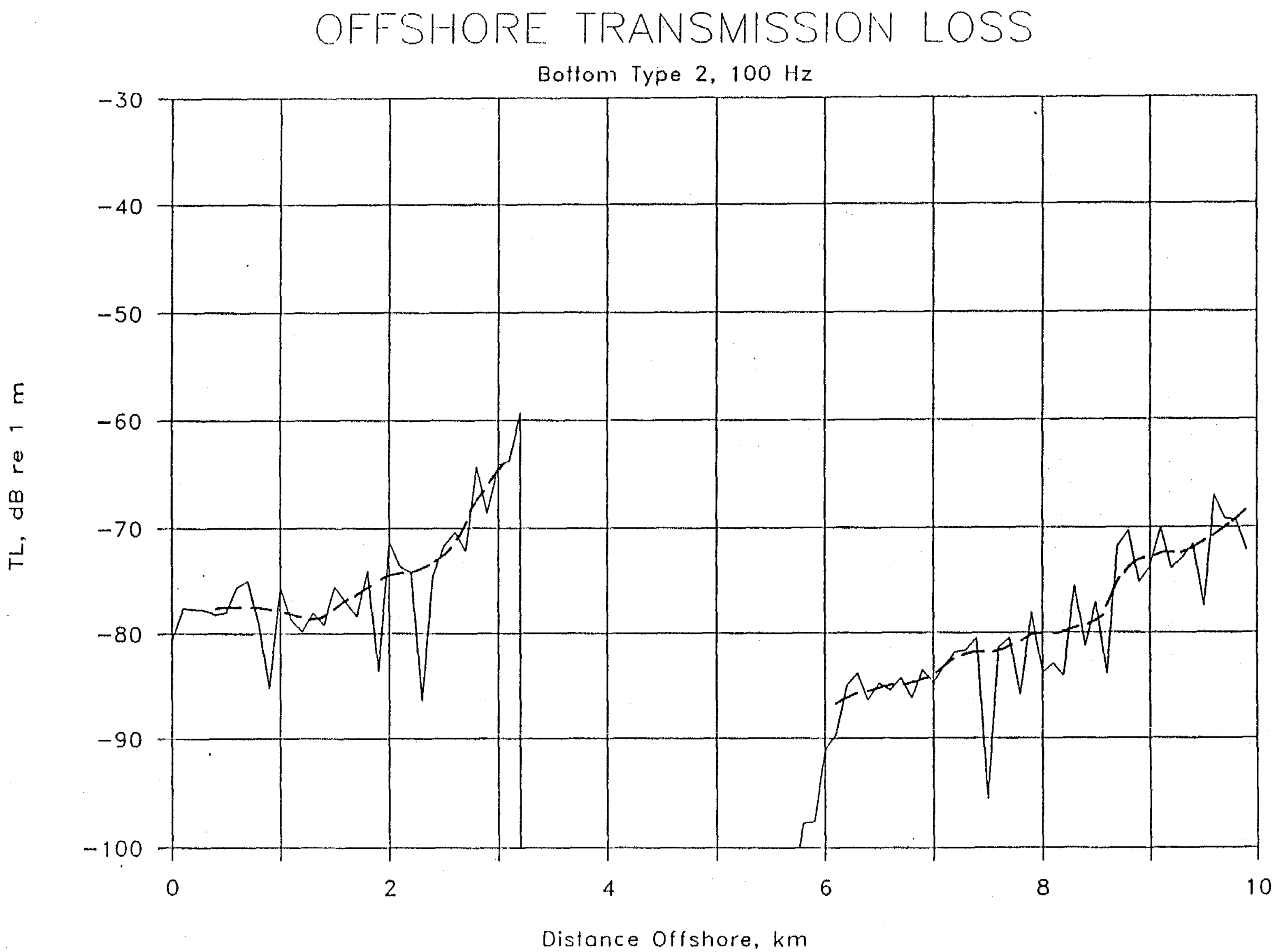



Figure 8. Offshore transmission loss
A. Bottom type 2, 100 Hz
B. Bottom type 2, 315 Hz
C. Bottom type 2, 1 kHz.

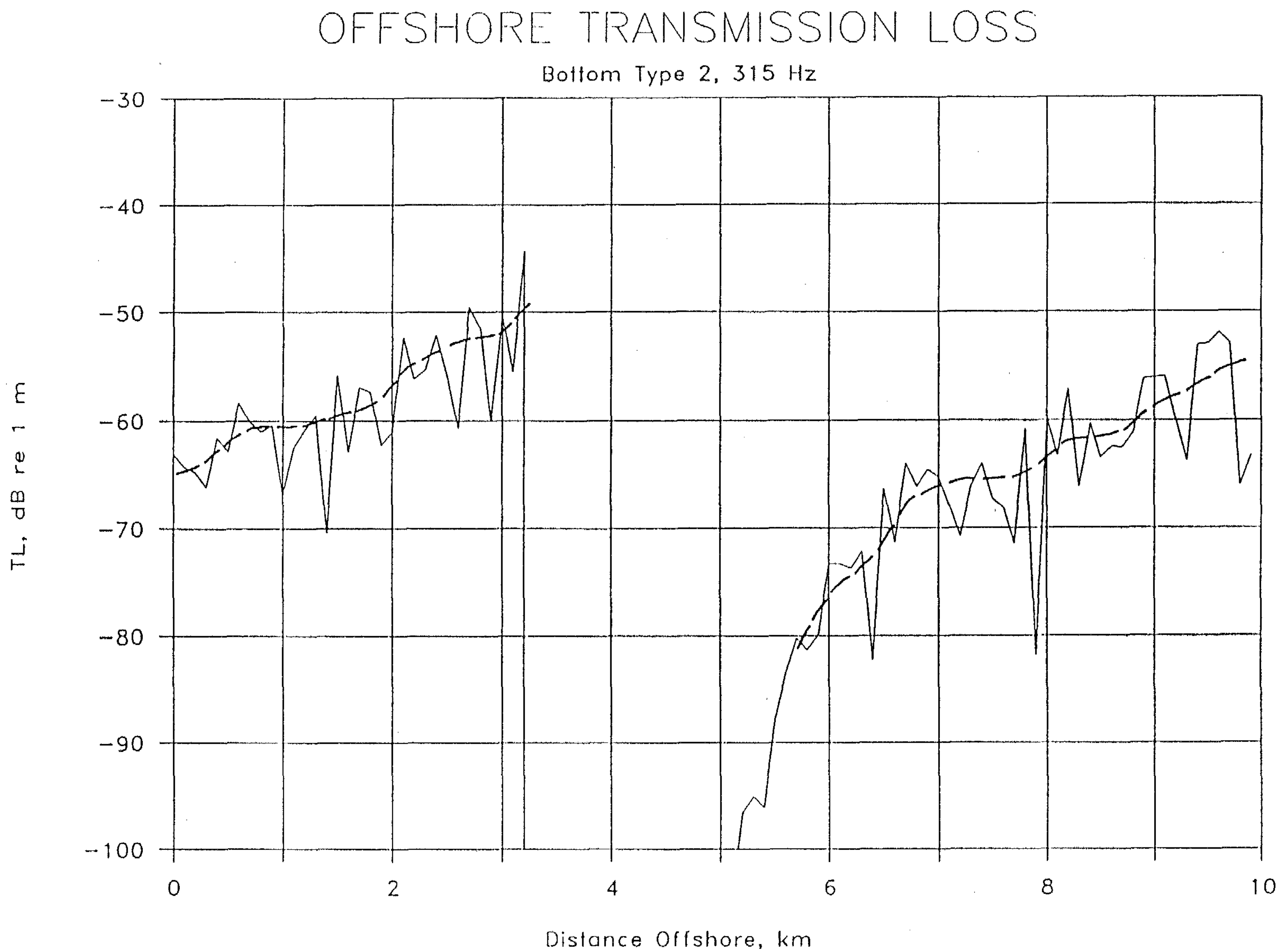

OFFSHORE TRANSMISSION LOSS
Bottom Type 2, 315 Hz
TL, dB re 1 m
-30
-40
-50
-60
-70
-80
-90
-100
0
2
4
6
8
10
Distance Offshore, km

Figure 8B.

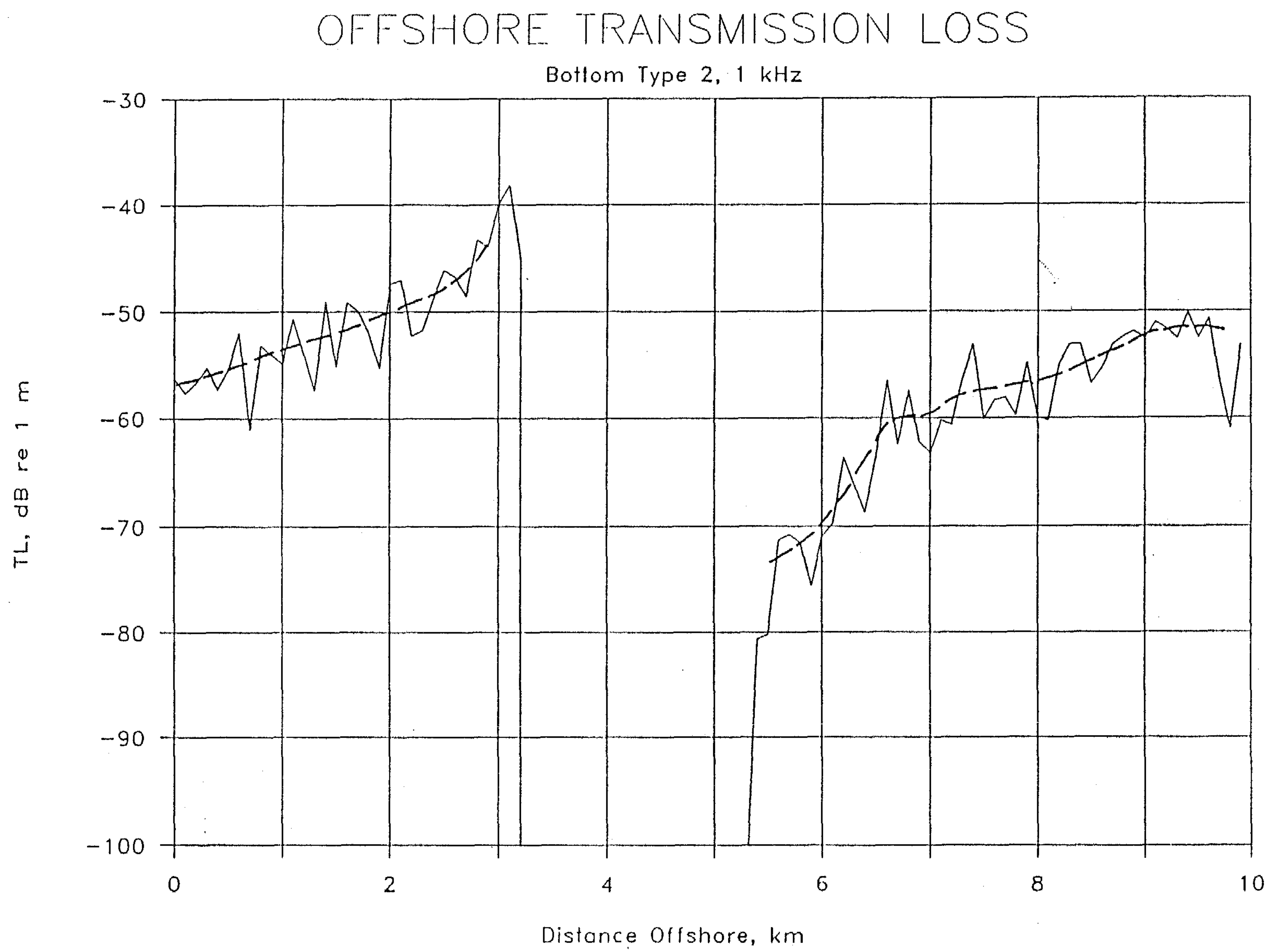

OFFSHORE TRANSMISSION LOSS
Bottom Type 2, 1 kHz
-30
-40
-50
-60
-70
-80
-90
-100
TL, dB re 1 m
0
2
4
6
8
10
Distance Offshore, km

Figure 8C.

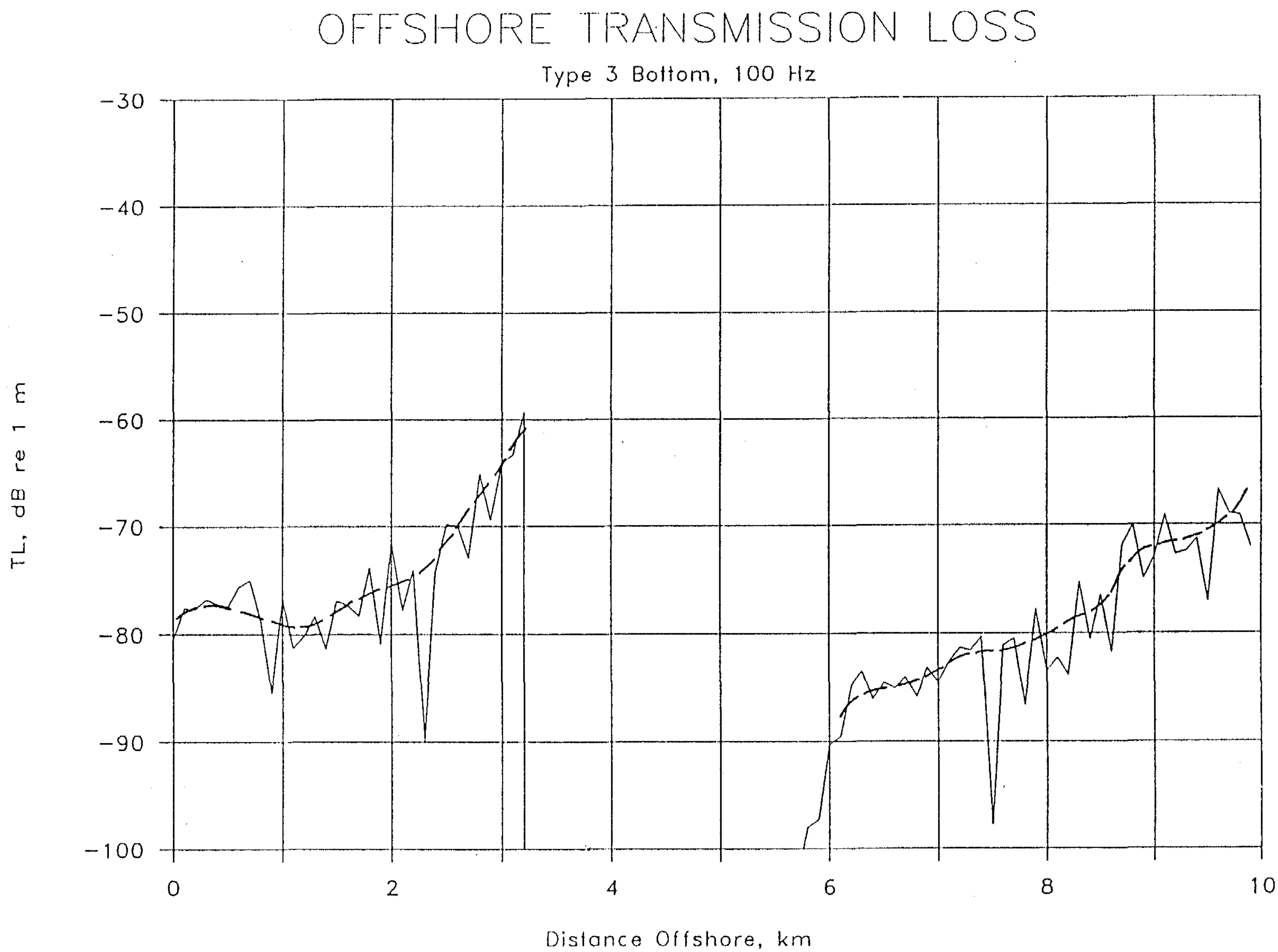



Figure 9. Offshore transmission loss
A. Bottom type 3, 100 Hz
B. Bottom type 3, 315 Hz
C. Bottom type 3, 1 kHz
D. Bottom type 3, TL vs. source range offshore.

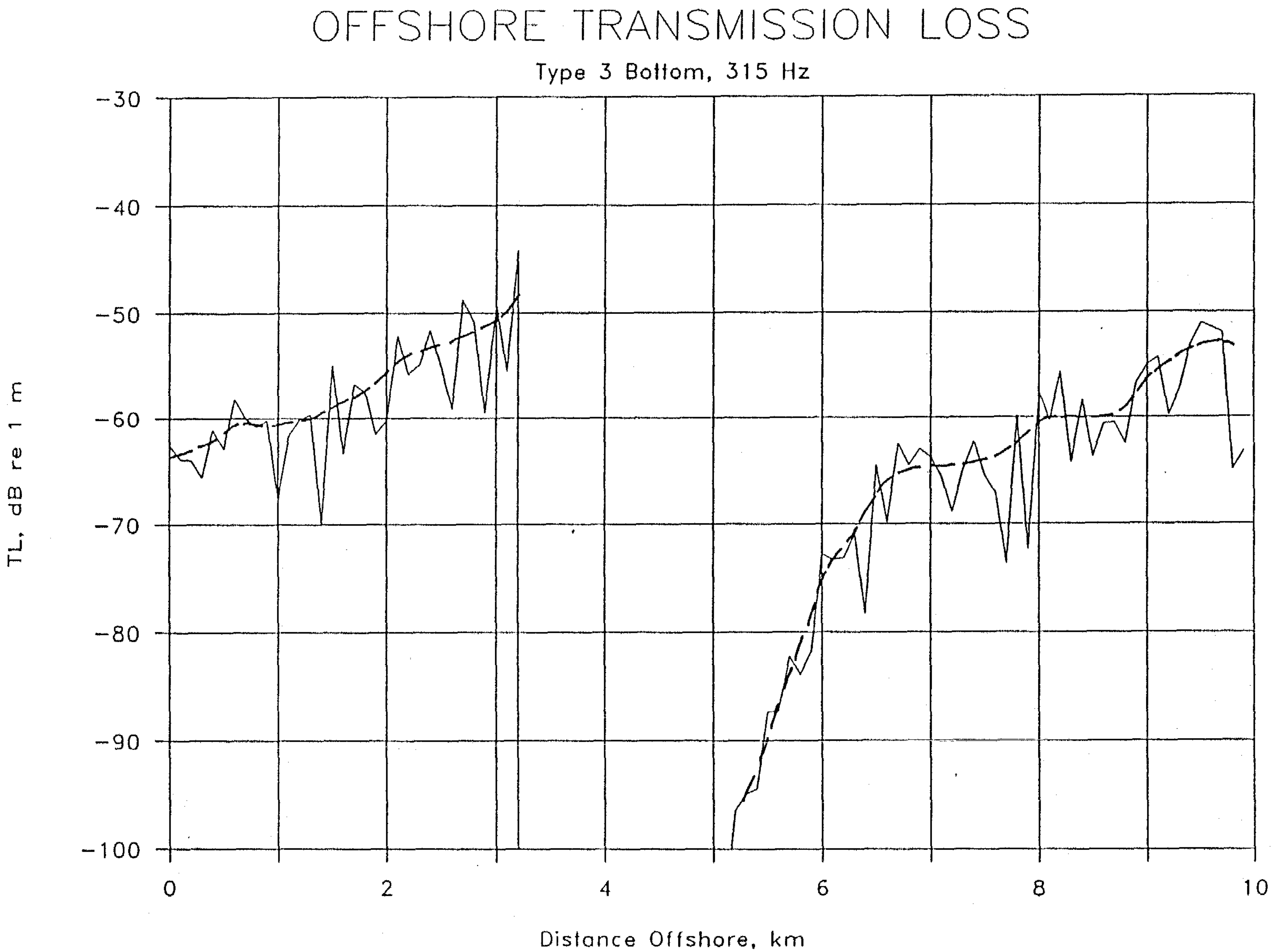

OFFSHORE TRANSMISSION LOSS
Type 3 Bottom, 315 Hz
-30
-40
-50
-60
-70
-80
-90
-100
TL, dB re 1 m
0
2
4
6
8
10
Distance Offshore, km

Figure 9B.

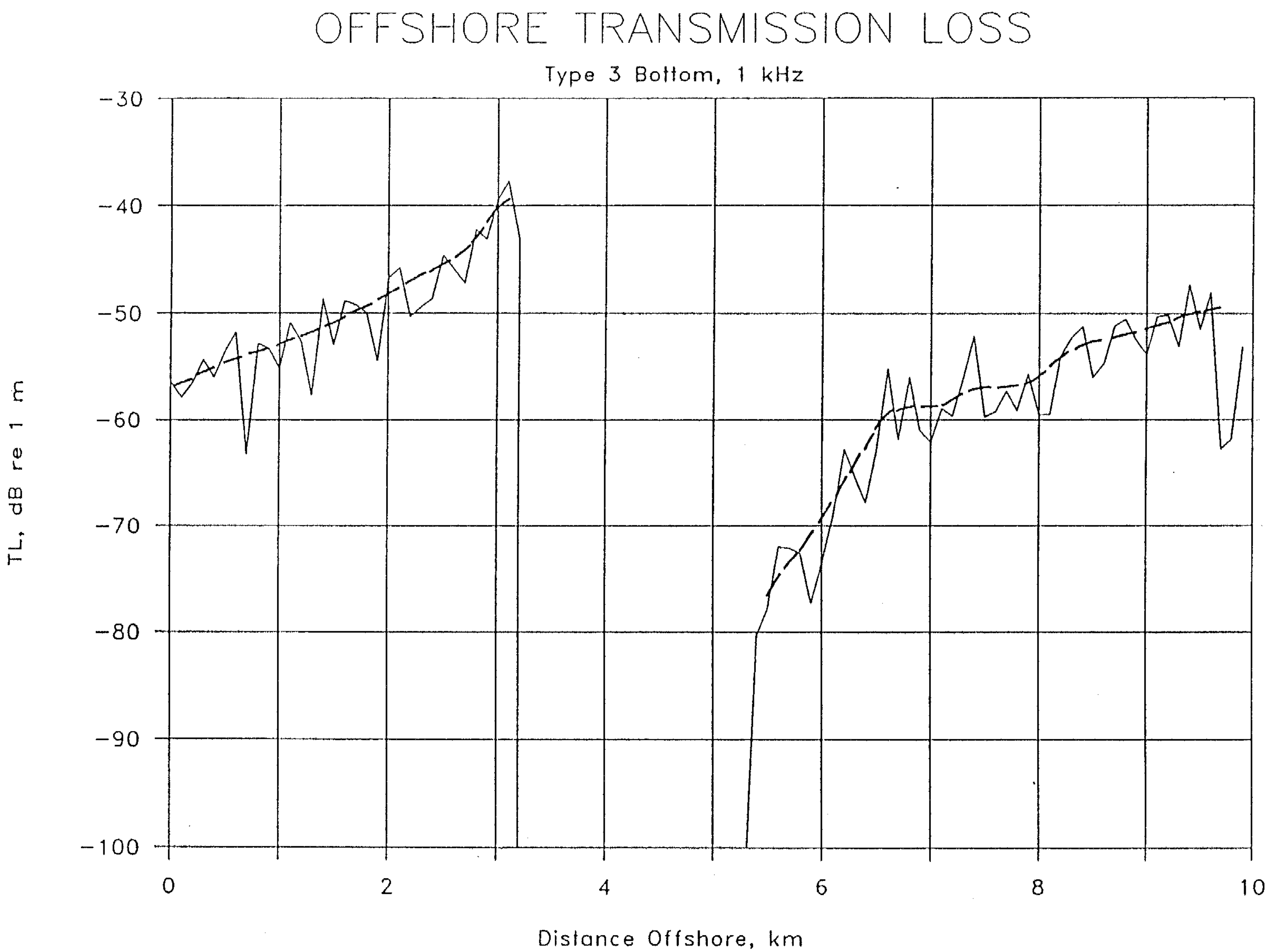

OFFSHORE TRANSMISSION LOSS
Type 3 Bottom, 1 kHz
TL, dB re 1 m
-30
-40
-50
-60
-70
-80
-90
-100
0
2
4
6
8
10
Distance Offshore, km

Figure 9C.

characteristics between the Type 1 bottom and the Type 3 bottom are small. The TL near the beach is somewhat less for the rocky bottom than for the sandy bottom.

Figure 9D was developed by interpolation of the model results to obtain curves of TL versus source distance directly offshore for the Type 3 bottom. Comparison of the results for a rocky bottom (Fig. 9D) with those for a sandy bottom (Fig. 7D) shows that, while the TL is high at 100 Hz for both types of bottom, it is somewhat lower for the rocky bottom. At 315 Hz the TL for the rocky bottom is less than that for the sandy bottom for source distances less than 7 km offshore. For 1 kHz the TL values are similar for source distances less than 4 km, beyond which the TL for the sandy bottom condition is smaller. Thus the model results indicate that for the bottom geometries and parameter values used in the study, a rocky beach has less TL for nearby offshore sources than a sandy beach. While the transmission properties of a sandy beach provide less TL for the more distant offshore sources (>5 km) than a rocky beach, the relatively high losses for both types of beaches at these ranges probably makes the difference academic for most of the sources of concern.

The TL characteristics shown in Figs. 10A and 10B were obtained using the IFD Model with a Type 1 Bottom and the layer geometry shown in Table 2 for the 10 km source position. A uniform water depth of 70 m was used. These results were originally obtained to represent conditions near Unimak Island and are believed to also be appropriate for conditions offshore from the haulout site on Ugamak Island, which is directly south of Unimak. Figure 10A shows the TL detail for ranges out to 10 km from a source position with Fig. 10B giving the TL characteristics out to a range of 50 km. While the TL characteristics shown in Fig. 10A for 315 Hz and 1 kHz at ranges greater than 5 km appear to be nearly flat, with little additional TL for increase in range, the longer range characteristics of Fig. 10B show that this is part of a broad peak produced by a multipath transmission pattern in the TL characteristic. The general trend of the TL characteristics over the entire range out to 50 km follows the general 15 Log (Range) slope expected for shallow water propagation. The characteristic for 100 Hz transmission is somewhat lower because of the increased bottom loss at this frequency.

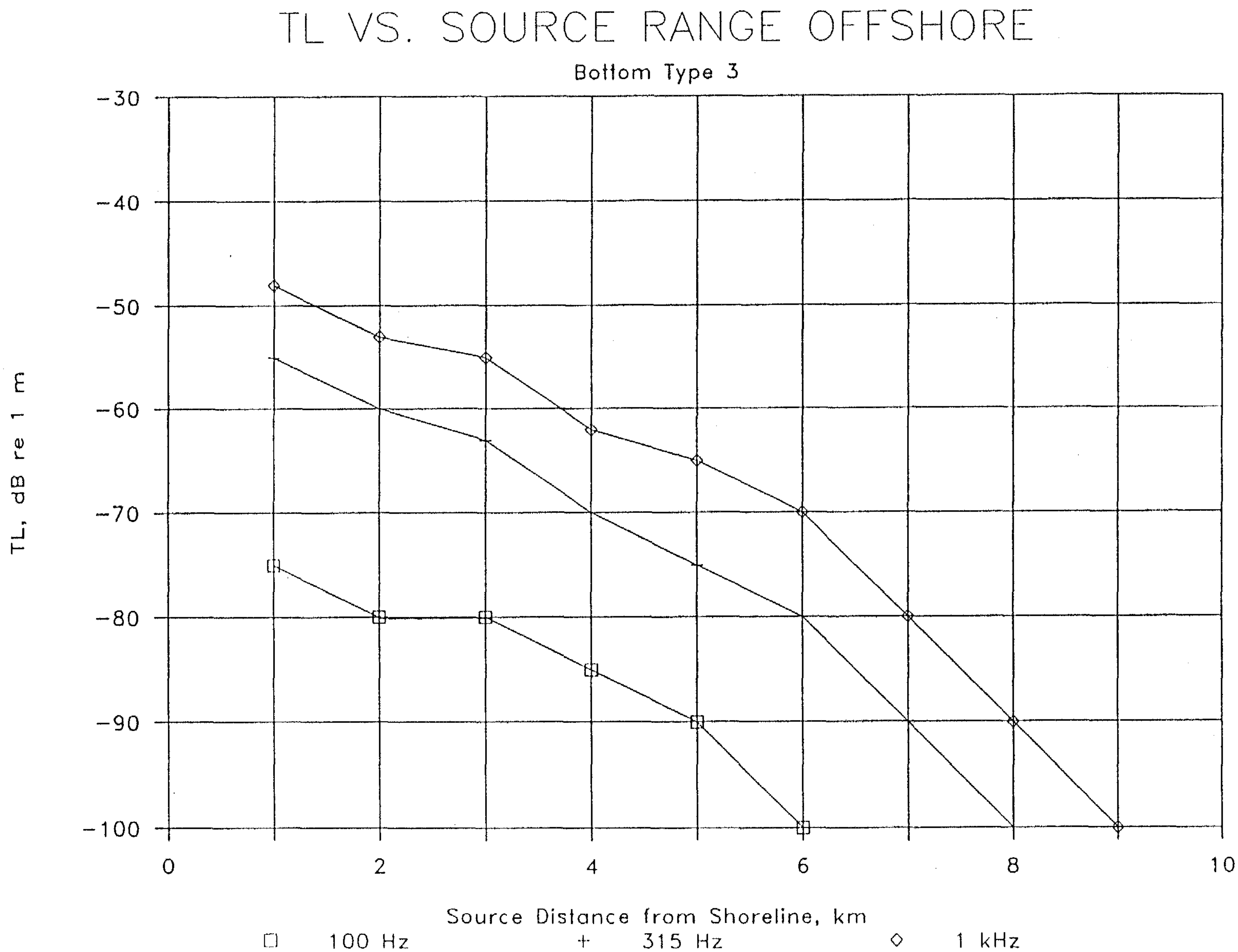

TL VS. SOURCE RANGE OFFSHORE
Bottom Type 3
TL, dB re 1 m
-30
-40
-50
-60
-70
-80
-90
-100
0
2
4
6
8
10
Source Distance from Shoreline, km
□ 100 Hz
+ 315 Hz
◇ 1 kHz

Figure 9D.

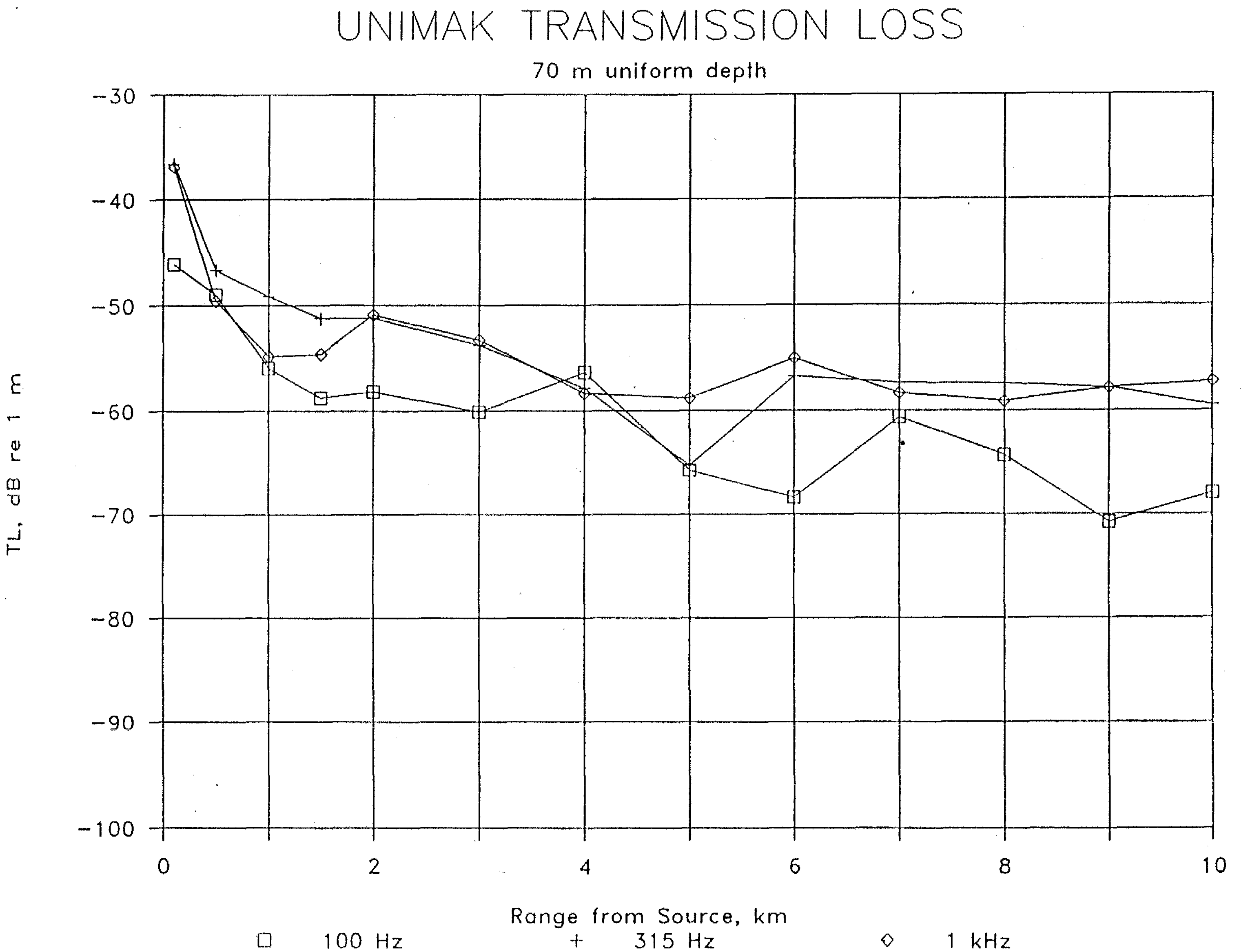
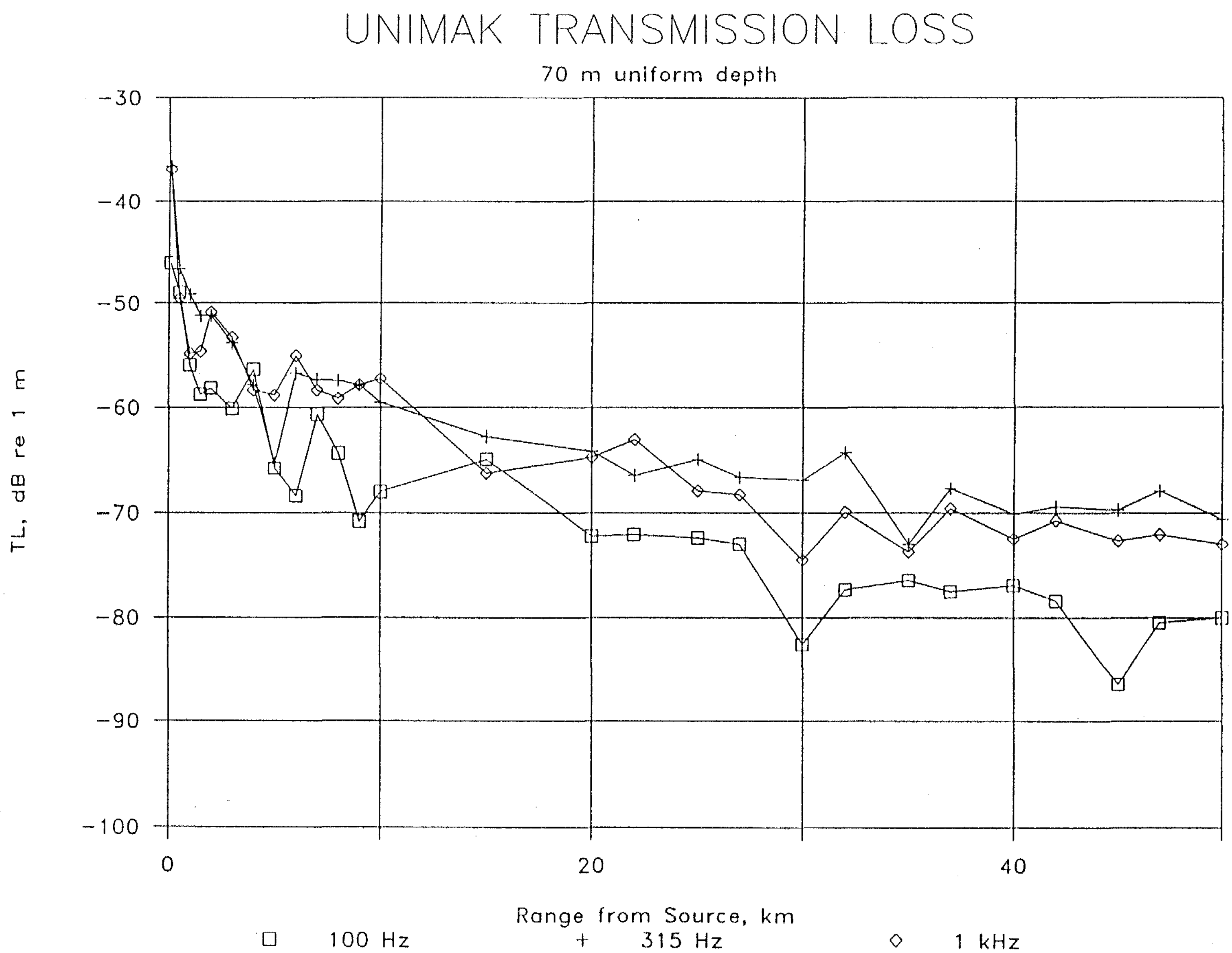



Figure 10. Transmission loss near Unimak Island, depth = 70 m
A. Short range detail
B. Long range characteristics.



UNIMAK TRANSMISSION LOSS
70 m uniform depth
TL, dB re 1 m
-30
-40
-50
-60
-70
-80
-90
-100
0
20
40
Range from Source, km
□ 100 Hz
+ 315 Hz
◇ 1 kHz


Figure 10B.

Air-To-Water Transmission

Of the several papers available in the literature concerning transmission of sound from air into water, most do not consider the effect of shallow water conditions. Urick (1972) presents a discussion of the effect and reports data showing the difference in the underwater signature of an aircraft overflight for deep and shallow conditions. No analysis is presented which would permit estimation of the effective TL underwater for shallow water multipath transmission conditions. Young (1973) presents an analysis which, while directed at deep water applications, derives an equivalent underwater source for an aircraft overflight which can be used for direct path underwater received level estimates. Unfortunately, for the aircraft - pinniped encounter geometry relevant to this study, the usual source - receiver geometry involves transmission by both direct and bottom reflected paths. Because of this, it was necessary to develop an analytical model to help predict the total acoustic exposure level for pinnipeds in shallow water near the path of an aircraft overflight.

The model which was developed provides for calculation of the acoustic energy at an underwater receiver contributed by both the direct sound field and a depth-averaged reverberant sound field. The direct sound field is produced by sound transmitted into the water along a direct refracted path from the airborne source to the underwater receiver. The reverberant sound field is produced by sound reflecting from the bottom and surface as it travels outward from the region directly under the aircraft. An analysis developed by P.W. Smith, Jr. based on an earlier study of shallow water sound propagation (Smith 1974) is used to predict the horizontally propagating sound field produced by the reflected sound energy.

Figure 11 shows the geometry and parameters used in developing the air-water transmission model. The details of the analysis are included in Appendix A with a summary of the general results and an explanation of the use of the model presented in the following discussion. As depicted in the figure, sound from an elevated source in air is refracted upon transmission into water because of the difference in sound speeds in the two media. A virtual source location is formed which is the apparent location of the source for the sound

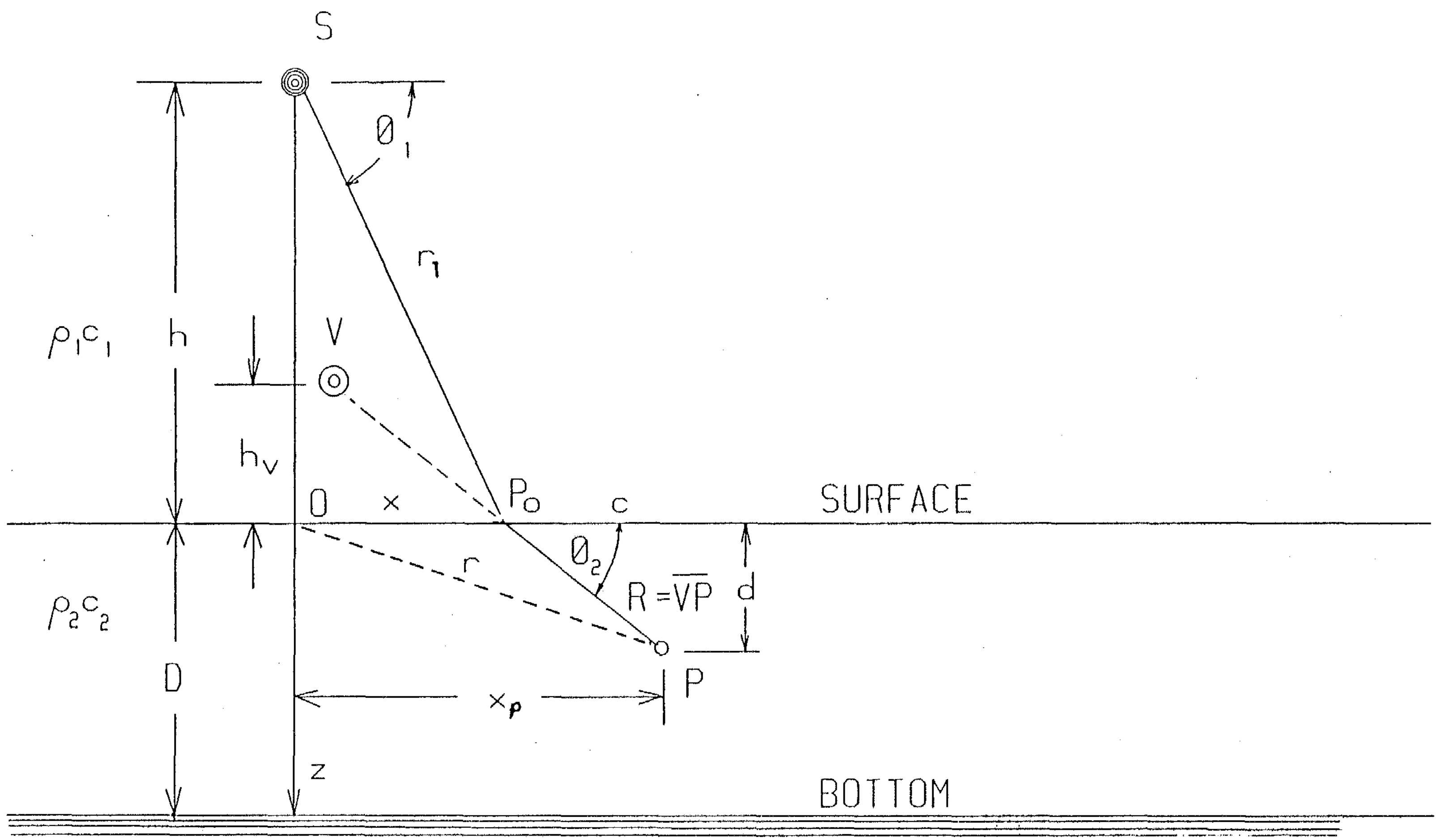



Figure 11. Geometry for air to water sound transmission.

path in water. Because of the large difference in sound speeds between air and water (a ratio of about 0.23) the direct sound path is totally reflected for grazing angles less than 77 degrees. For smaller grazing angles sound reaches an underwater observation point only by scattering from wave crests on the surface, by non-acoustic (hydrostatic)[2] pressure transmission from the surface and from bottom reflections in shallow water. As a result, most of the acoustic energy transmitted into the water from a source in air arrives through a cone with a 26 degree apex angle which intersects the surface and traces a "footprint" directly beneath the path of the source.

For underwater observation points in shallow water within this cone the directly transmitted sound energy is generally greater than the energy contribution from bottom reflected paths. At horizontal distances greater than 1 water depth from the boundary of the acoustic intercept cone on the surface, the energy transmitted by reflected paths becomes dominant and is an important feature of air-to-water transmission in shallow water. Thus two terms become necessary in the air-water transmission model to predict underwater received levels for the full range of expected source-receiver geometries. The theoretical analysis used to develop these terms is presented in Appendix A. The results of this analysis are presented in a normalized, logarithmic form.

Let $A = (h_v+d)/D$ where $hv = nh$ and $n = c_1/c_2$, the normalized effective source altitude.

$X = x/D$, the normalized horizontal range.

$L_r$ = the underwater sound level, dB re 1 μPa.

$L_{inc}$ = the sound level in free air at a distance h from the source (excluding boundary effects), re 1 μPa.

Then

$$L_r = L_{inc} + 20\text{Log}(h/D) - 7 + 10\text{Log}[T_d(A,X) + kT_a(b,X)] \qquad (4)$$

where $T_d(A,X) = [A/(A^2+X^2]^2$ (the direct field transmission factor) (5)

$T_a(b,X) = I/X$ for Beta < 5 (6A)

$T_a(b,X) = (pi/2b^3X^5)^{1/2}$ for Beta => 5 (the channel transmission factor) (6B)

Beta = bX/2, a depth-averaged sound field parameter (See Appendix A) (7)

$k = 1/(A^2/X^2+1)$, a weighting factor for $T_a$

---

[2] This has been called "evanescent wave" transmission by Urick and others. It is important for transmission at low frequencies to receiver locations near the surface.

b = bottom loss factor (see Appendix A)
I = Reverberant energy summation factor (see Appendix A)

The relationship shown in (4) suggests that there is a 7 dB drop in level which occurs as sound passes through the water surface, in addition to the spreading loss. This is correct for the radiated pressure component at some distance from the surface, however close to the surface near field effects occur which cause the underwater pressure to become equal to the pressure in air just above the surface (Urick 1972). This pressure is double that in the free field at the same range from the source because of the high acoustic impedance of water relative to that of air.

To facilitate computation of TL, the field transmission factors Td and Ta have been calculated for the normal range of values for A, X, and b as shown in Figs. 12A and 12B. The procedure for calculation of TL using Eqn (4) would proceed as follows:

Given the aircraft altitude (h), receiver depth (d), water depth (D), horizontal distance between the aircraft CPA and the receiver ($x_p$), and the bottom loss factor (b);

Calculate the normalized height (A), normalized horizontal distance (X), the weighting factor k, and the parameter Beta;

Enter Fig. 12A with values of A and X to determine the direct field component, Td;
If k < 0.1 the direct field is dominant, the $T_a$ component can be ignored, and only the last step of this procedure is needed.
If Beta < 5 enter Fig. 12B with values of b and X to determine the depth-averaged field component, Ta; If Beta >= 5, calculate Ta using Eqn (6B);
Then enter Eqn (4) with Td, Ta, A, and X and calculate either the transmission loss between the incident sound level and the sound level in water or the sound level in water if the incident level is known.

The procedure for estimating the received level underwater using the calculated TL value requires either measured aircraft signature information or published data from standard flyover tests. If standard flyover data, referred to a sound pressure of 20 μPa and a height of 300 m, are used it is necessary to correct these data to 1 μPa (add 26 dB). If the temperature and relative

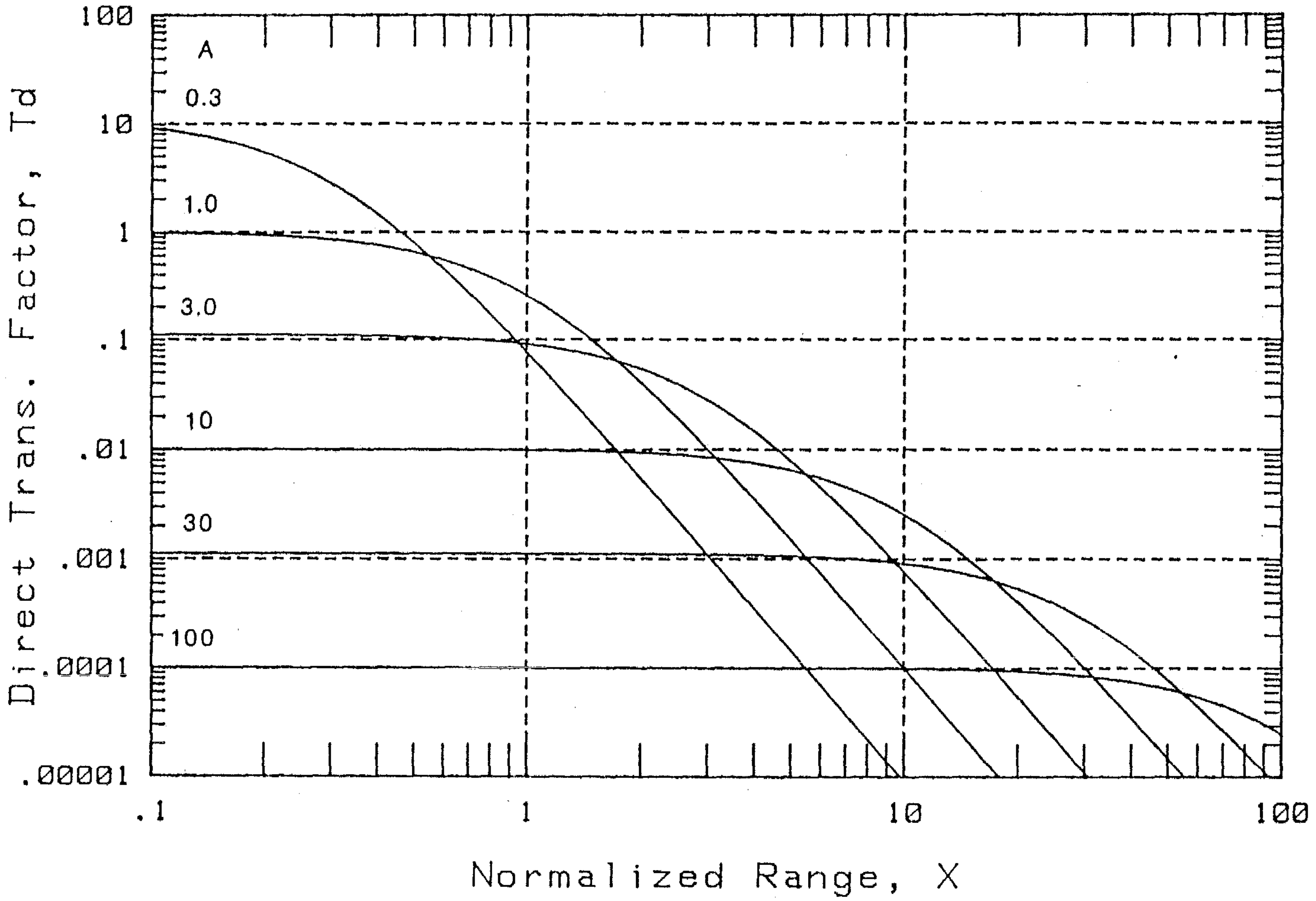
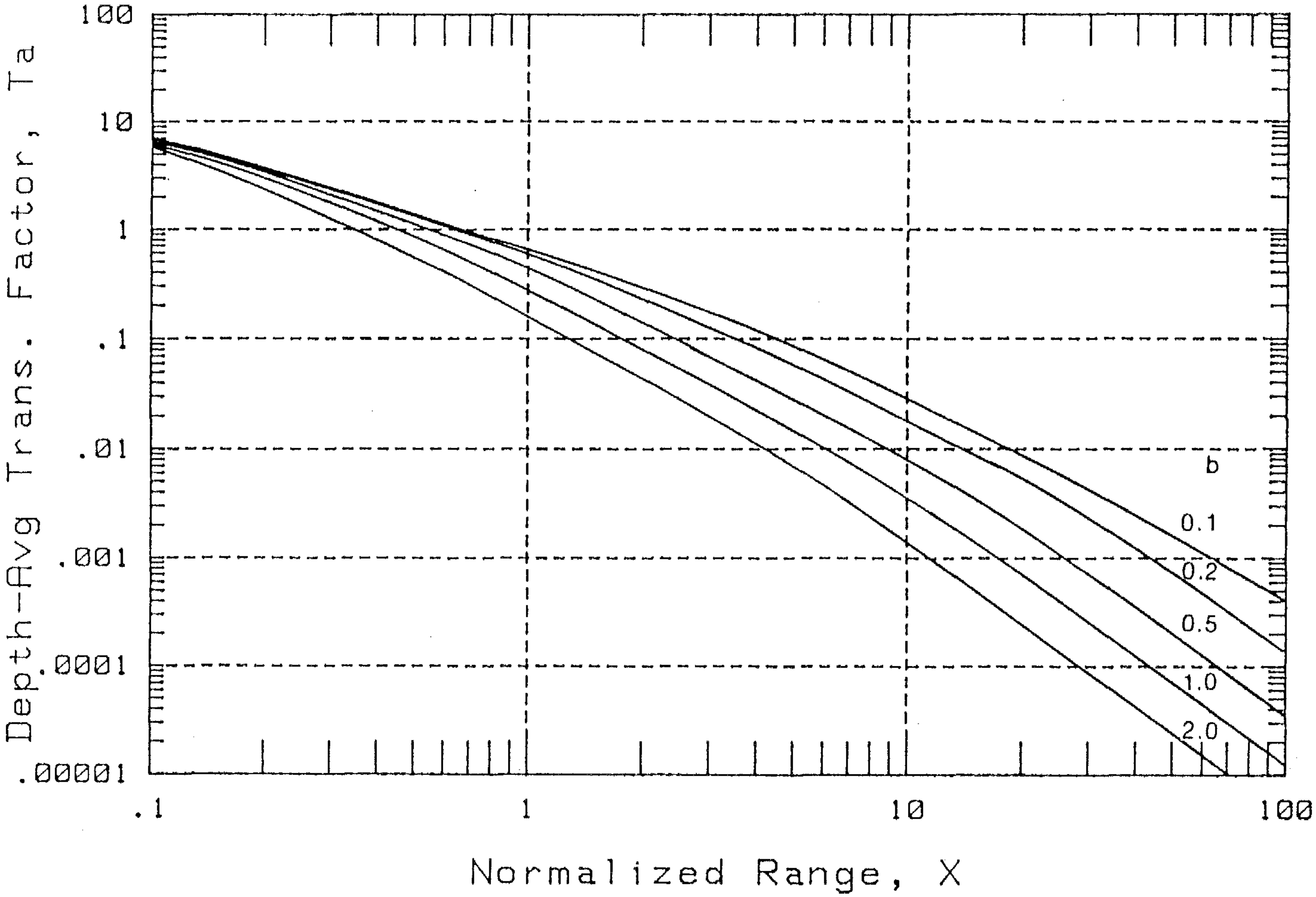



Figure 12. Factors for air - shallow water sound transmission
A. Direct path transmission factor
B. Depth-averaged path transmission factor.



100
10
1
.1
.01
.001
.0001
.00001
Depth-Avg Trans. Factor, Ta
.1
1
10
100
Normalized Range, X
b
0.1
0.2
0.5
1.0
2.0


Figure 12B.

humidity for the calculation conditions are greatly different from Standard Day conditions, the corrections given in Table 1 can be applied to the aircraft flyover spectrum to obtain better received level estimates at high frequency. These corrections are applied to obtain the correct sound level value for the high frequency bands at the water surface if the actual flyover altitude is greatly different from the standard test height. The additional absorption loss incurred in the underwater path is generally negligible for the short range transmission considered in this application.

## Comparison of Airborne and Underwater Aircraft Noise Spectra

Very few data are available from measurements of aircraft noise in shallow water. Radiated noise spectra obtained from overflights of a Cessna 185 float plane are shown in Fig. 13 (Malme et al. 1982). Of special interest here is the comparison of the airborne and underwater spectra for the overflight at an altitude of 150 m. The water depth at the measurement location was about 40 m. For these measurements the air microphone was mounted on a boat mast about 5 m above the water with the hydrophone located nearby at a depth of 10 m below the surface. The airborne spectra are somewhat higher in level than the underwater spectra at low frequencies, but at high frequencies, the underwater sound levels are significantly higher - possibly as a result of underwater reverberation. The underwater spectrum for a takeoff of this aircraft is also shown for a CPA at a horizontal range of about 100 m with an altitude of about 10 m. The low frequency levels of this spectrum agree well with the takeoff power setting spectrum shown in Fig. 3A for propeller type aircraft. The high frequency spectrum levels for the Cessna 185 underwater data are much higher than those shown in Fig. 3A because of its low altitude, and possibly also as a result of underwater bottom reflection effects.

Underwater radiated noise data reported by Greene (1982) are shown in Fig. 14. These data were measured using a hydrophone depth of 9 m for overflights at an altitude of 150 m of a Twin Otter, an Islander and a Bell 222 helicopter. The data for the two twin engine aircraft may be compared to the reference spectra shown in Fig. 3B. The helicopter data may be compared to the reference data for the Bell 222 presented in Fig. 4A. The results for all

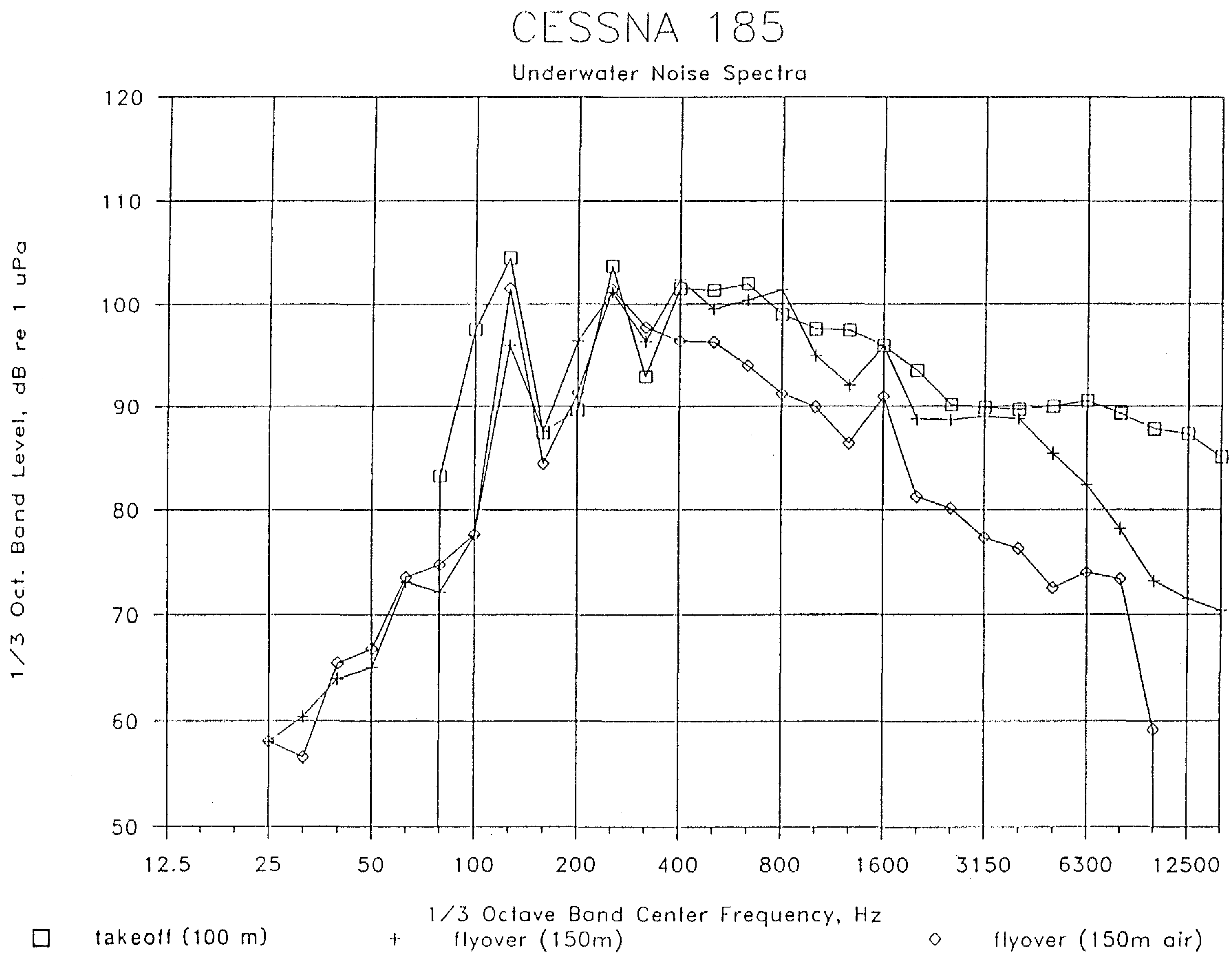



Figure 13. Cessna 185 underwater noise spectra (Malme et al. 1982).

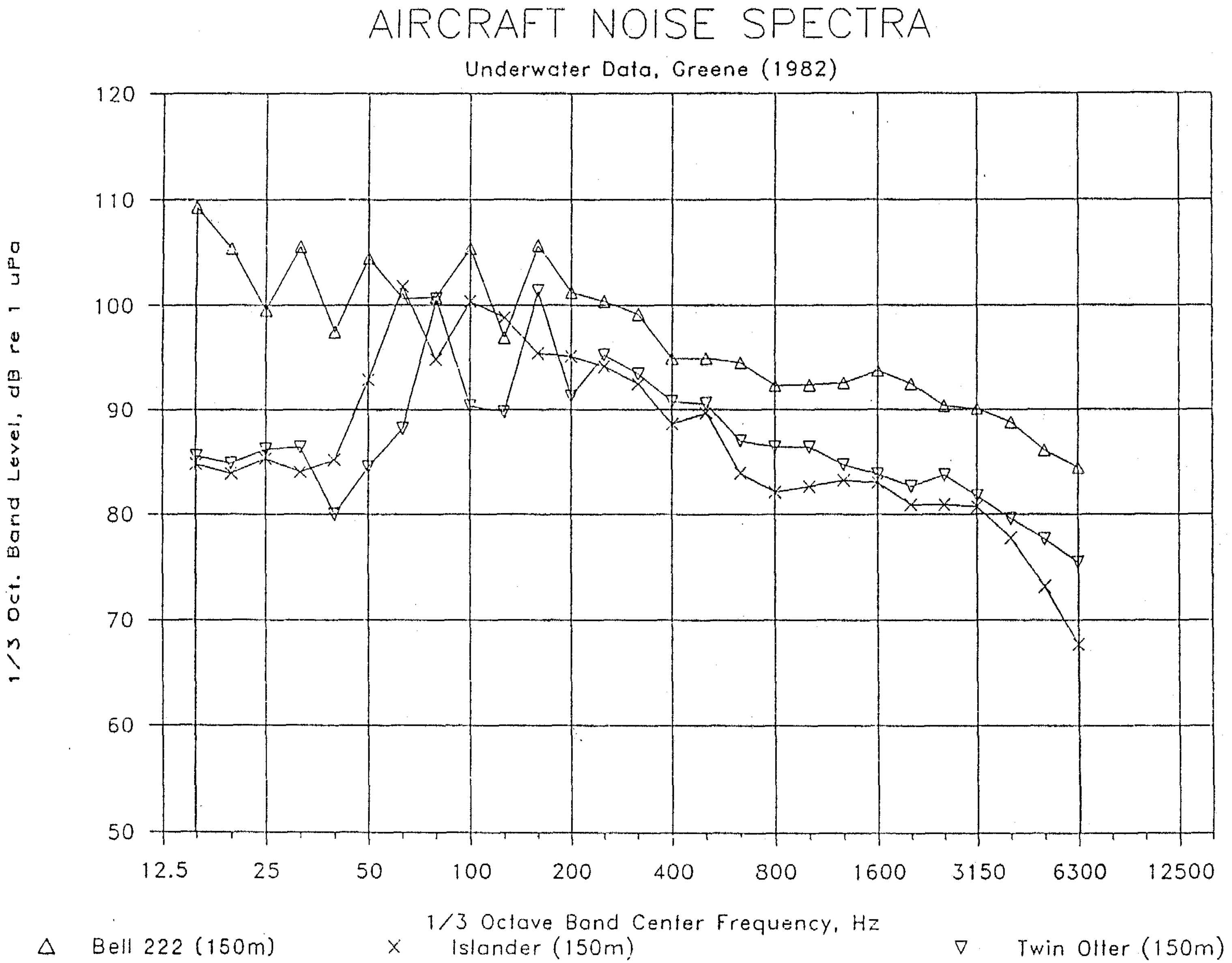



Figure 14. Aircraft noise spectra, underwater data (Greene 1982).

aircraft show good agreement when a 6 dB correction is made for the difference in altitude between the measured data and the reference data.

## CONCLUSIONS

The usual location of pinniped rookeries on beaches and rocky shorelines results in this habitat having levels of ambient noise that are closely related to the sea state. Both airborne and underwater ambient noise spectrum levels are expected to be similar because the airborne surf noise is transmitted directly into the water.

The noise sources which may affect pinniped behavior in rookeries are 1-engine and 2-engine aircraft, helicopters, small boats, fishing vessels and cargo vessels. The sound source levels produced by these types of aircraft and vessels have a maximum of about 160 dB at 1 m in a 1/3 octave band. All of these sources present a transient, rise and fall type of noise signature to the rookery area, the rate of which may be an important factor in determining the level of disturbance.

The underwater acoustic transmission properties of the sloping beach found at most rookery sites provide high attenuation of sound arriving from seaward. Rocky sites provide somewhat greater attenuation for distant (>6 km) noise sources than do sandy beaches. Noise sources operating close to shore (<3 km) over a rocky beach are attenuated less than over a sandy beach at the same distance. Frequencies less than 200 Hz are attenuated more rapidly than high frequencies.

The underwater sound levels produced by direct aircraft overflight of shallow water areas are comparable to the levels produced in air near the water surface. There appears to be some enhancement of high frequency sound energy which may be produced by bottom reflection effects. A significant amount of underwater sound energy is transmitted away from the region below the direct path of an aircraft by bottom and surface reflections. Sound transmission characteristics for this propagation have been shown by analysis to follow a 25 Log Range slope which is appropriate for transmission in shallow water from a source located near the surface.

Using several propagation models we determined the characteristics of sound transmission from different potential industrial noise sources in air and water under conditions similar to those at pinniped haulout sites. Sound transmission loss curves, i.e., sound attenuation with increasing distance from the source, were computed for situations prevalent at various pinniped haulout sites (e.g., various bottom types, water depths, source types and distances from sources; Figs. 7-10). Given the appropriate source sound levels, actual received sound levels at different distances from the source (i.e. at the haulout site) may be computed directly from the transmission loss curves. For example, considering sound near 100 Hz, at an offshore location with a specific bottom type, a 160 dB source sound level, which is the maximum expected from most individual sources, attenuates by 90 dB at a distance of 2 km from the source (Fig. 7D).

One may compute actual received sound levels at pinniped haulout sites based on our transmission loss curves. By taking into account typical ambient noise levels (p. 91-93), one can also calculate the distance at which a received level drops below ambient and become inaudible. Unfortunately, however, there is no quantitative information describing threshold sound levels which cause disturbance in pinnipeds. This limitation prevents a quantitative determination of the actual zones-of-influence of different sounds produced near haulout sites. Attempts to compute zones-of-influence based on qualitative or anecdotal information would be misleading. Carefully designed studied that simultaneously measure sounds (noise) and behavior at active pinniped haulout sites are needed to provide the kind of quantitative data necessary to make zone-of-influence computations. Such studies have been conducted or are in progress for some cetaceans, but to our knowledge none have been conducted for pinnipeds.

Thus, without more information, we are unable to take the final step in predicting disturbance responses in pinnipeds from received noise levels at haulout sites. It is surprising that this type of information is not available for pinnipeds; however, once it is available, it would be relatively straightforward to apply the information presented in this report to estimate the actual zones-of-influence near pinniped haulout sites.

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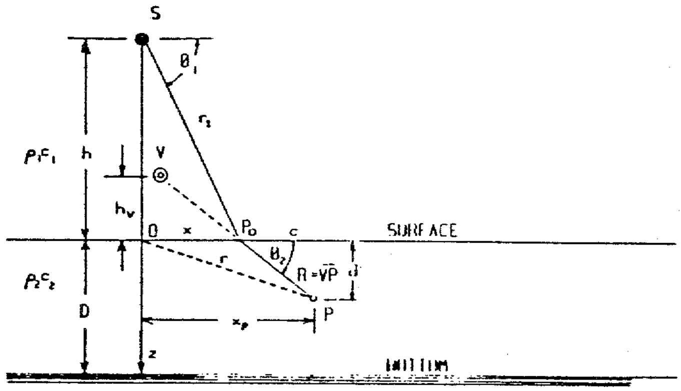
# APPENDIX 1-A. TRANSMISSION OF SOUND FROM A SOURCE IN AIR INTO SHALLOW WATER

## A.1 Source Strength in Water of an Air Source and Subsequent Response of an Isospeed Channel*

O: origin
S: source
V: virtual source (vertical plane)
P: observation point
$P_o$: surface-breaking point




Snell's law:

$$\frac{\cos\theta_2}{c_2} = \frac{\cos\theta_1}{c_1} \tag{1a}$$

$$\frac{d\theta_1}{d\theta_2} = \frac{c_1}{c_2}\frac{\sin\theta_2}{\sin\theta_1} \tag{1b}$$

geometrical relations:

$$r_1 = h/\sin\theta_1 \tag{2}$$

$$x = h\cot\theta_1 \tag{3}$$

$$\frac{dx}{d\theta_1} = -\frac{h}{\sin^2\theta_1}\ , \tag{4}$$

Assuming pressure doubling at surface, continuity of pressure across surface:

$$@P_o:\ \ p_2(z=0) = 2p_{inc}(r_1,\theta_1) \quad (\rho_1 c_1 << \rho_2 c_2) \tag{5}$$

differential area on surface associated with annulus, $d\theta_1$; using (3) (4):

$$dA = 2\pi x\, dx = 2\pi h^2 \frac{\cos\theta_1}{\sin^3\theta_1} d\theta_1\ . \tag{6}$$

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*By P.W. Smith, Jr.

differential of power into water, associated with dA:

$$dP = \frac{p_2^2(z{=}0)}{\rho_2 c_2} \sin\theta_2 dA \tag{7a}$$

$$= \frac{p_2^2(z{=}0)}{\rho_2 c_2} \sin\theta_2 \; 2\pi h^2 \frac{\cos\theta_1}{\sin^3\theta_1} d\theta \; . \tag{7b}$$

Same dP evaluated as $r/R \rightarrow 1$, $r \sim \infty$:

$$dP = \frac{p_2^2(r,\theta_2)}{\rho_2 c_2} \times 2\pi r^2 \cos\theta_2 \; d\theta_2 \tag{7c}$$

or, using (1b):

$$dP = \frac{p_2^2(r,\theta_2)}{\rho_2 c_2} \times 2\pi r^2 \cos\theta_2 \frac{c_2 \sin\theta_1}{c_1 \sin\theta_2} d\theta_1 \tag{7d}$$

Equating (7b) and (7c), using (5):

$$r^2 p_2^2(r,\theta_2) = 4h^2 p_{inc}{}^2(r_1,\theta_1) \frac{\sin\theta_2 \cos\theta_1}{\sin^3\theta_1} \frac{c_1 \sin\theta_2}{c_2 \sin\theta_1 \cos\theta_2}$$

and, using (1a):

$$r^2 p_2^2(r,\theta_2) = 4h^2 p_{inc}{}^2(r_1,\theta_1) \; n^2 \frac{\sin^2\theta_2}{\sin^4\theta_1} \tag{8}$$

where $n = c_1/c_2$

Now, using (2) to eliminate h:

$$r^2 p_2^2(r,\theta_2) = 4r_1^2 p_{inc}{}^2(r_1,\theta_1) \; n^2 \frac{\sin^2\theta_2}{\sin^2\theta_1}$$

or taking the square root, we get far-field pressure in water:

$$r p_2(r,\theta_2) = 2 \; r_1 p_{inc}(r_1,\theta_1) \; n \; \frac{\sin\theta_2}{\sin\theta_1} \; . \tag{9}$$

Since (air/water) $\sin\theta_1 \gtrsim 0.97$, it may be neglected.

Range-Averaged Response in Isospeed, Range-Independent Channel

We adapt the analysis of Smith (1974) by (i) making the source strength $\Psi$ (m.s. pressure at a unit range) vary with D/E angle [Smith (1974), Eq. (2)]; (ii) specializing to a range independent medium; (iii) specializing to an isospeed channel.

Making changes (i) and (ii), Eq. (4) of Smith (1974) for the response pressure at horizontal range x becomes

$$p^2(x) = \frac{1}{x} \int_{-\pi/2}^{\pi/2} \frac{2\Psi(\theta)e^{-S(x,\theta)}}{X(\theta)\tan|\theta|} d\theta \ , \qquad (10)$$

where $\theta$ = depression angle (radians)

$\Psi(\theta)$ = source strength = $\lim_{r\to 0} \left[r^2 p^2(r,\theta)\right]$, r being slant range from source

$X(\theta)$ = bounce distance

$S(x,\theta)$ = integrated attenuation factor due to boundary reflection loss and volumetric attenuation [Smith (1974), Eq. (7)].

For an isospeed channel, where the rays are straight, we have a bounce distance

$$X(\theta) = 2D/\tan|\theta| \qquad (11)$$

where D is the water depth. The value of S, calculated from number of bounces in range x times a loss per bounce in the form

$$\text{dB loss per bounce} = 4.343\ b\ \sin|\theta|\ \text{dB}\ , \qquad (12)$$

is

$$S(\theta) = (bx/2D)\ \sin|\theta|\tan|\theta|\ . \qquad (13)$$

For a source in air injecting sound into the channel, the directional source strength has been found to be [Eq. (9)]

$$\Psi(\theta) = 4\,\Psi_{inc}(\theta_{air})\, n^2 \sin^2\theta,\ \theta > 0;\ 0,\ \theta < 0\ , \tag{14}$$

where $\Psi_{inc}$ is the source strength (m.s. pressure at unit range) of the sound in air incident upon the surface at a depression angle given by Snell's law:

$$\cos\theta_{air} = n \cos\theta\ . \tag{15}$$

Hereafter we assume an omnidirectional source in air:

$$\Psi_{inc}(\theta_{air}) = \Psi_{air}\ ,\ \text{a constant}\ . \tag{16}$$

Finally we note that, for $x \gtrsim 5D$, S is so large at large $\theta$ that it is a reasonable approximation to take $\sin\theta \approx \tan\theta \approx \theta$ and also to extend the upper limit of integration in (1) to infinity. With these approximations, Eqs. (10) through (16) combine to

$$p^2(x) = \frac{4\,\Psi_{air} n^2}{xD} \int_0^{\infty} \theta^2\, e^{-\frac{bx\theta^2}{2D}}\, d\theta\ . \tag{17}$$

The integral is found in standard tables. The final result has the form

$$p^2(x) = \frac{\Psi_{air}}{x^2}\, n^2 \left(\frac{8\pi D}{b^3 x}\right)^{1/2}\ . \tag{18}$$

Note that the first factor is the squared-pressure in air at the same range x, assuming spherical spreading. The remaining factors are typically less than unity.

## A.2 Combining Direct Path Transmission and Channel Response to Obtain a General Model of Air to Shallow Water Transmission

For underwater receiving points near the source, the far field pressure relationship given previously by Eq. (9) must be modified. The exact solution for the sound field in water near a source in air is a complicated relationship which has been discussed by Urick (1972), Young (1973) and others. For our purposes, a sufficiently accurate form can be derived by rewriting Eq. (9) as

$$p_2^2(r,\theta_2) = 4n^2 \frac{\psi_{air}}{r^2} \sin^2\theta_2 \qquad (19)$$

where $\psi_{air} = r_1^2 \, p_{inc}^2$, source strength in air. Let

$$r^2 \approx (h_v+d)^2 + x_p^2 \qquad (20)$$

$$\sin^2\theta_2 \approx \frac{(h_v+d)^2}{r^2} \qquad (21)$$

Combining (19), (20), and (21), the direct pressure field is

$$p_d^2 = 4n^2\psi_{air} \left(\frac{h_v + d}{(h_v+d)^2 + x_p^2}\right)^2 \qquad (22)$$

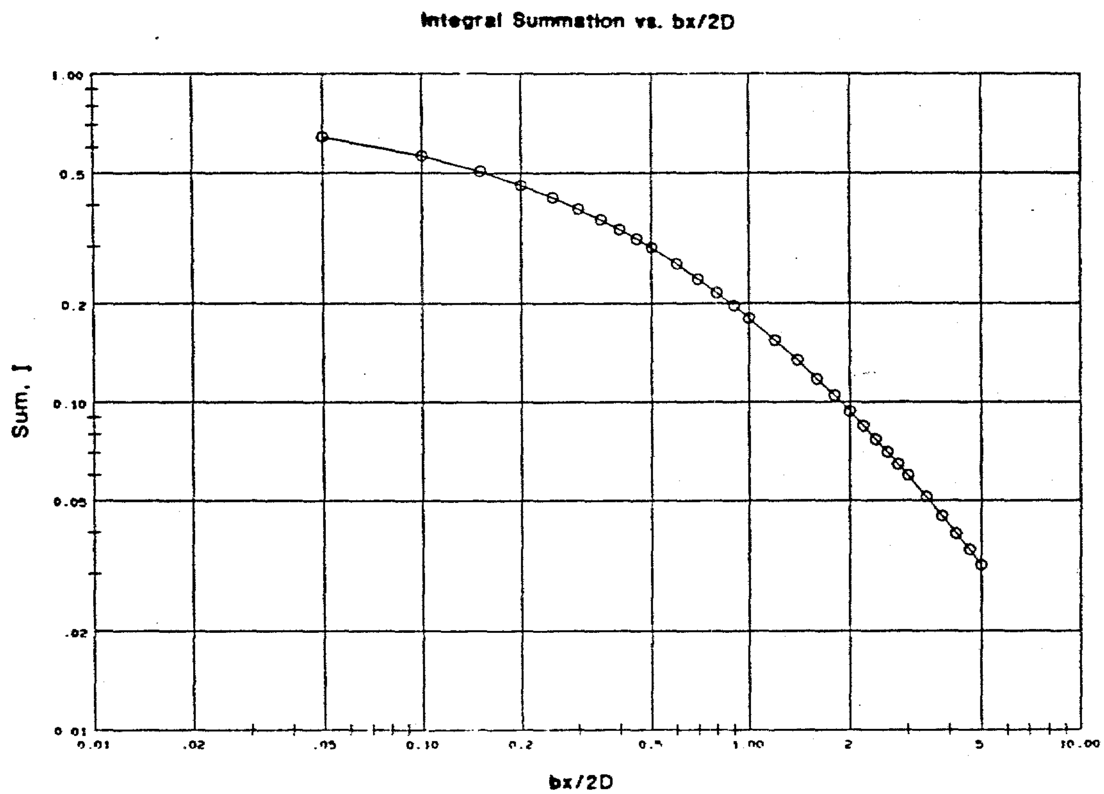
The direct field intensity and the depth-averaged sound channel intensity are combined to obtain a general model for air to shallow water transmission. The depth-averaged transmission given by Eq. (18) was obtained for far-field conditions. To adapt this relationship for conditions closer to the source, it is necessary to solve the integral of Eq. (10) at ranges closer than $x \gtrsim 5D$. The exact integral becomes

$$p^2(x) = 4n^2 \frac{\psi_{air}}{xD} \int_0^{\pi/2} \sin^2\theta \varepsilon^{-\beta\sin\theta\tan\theta} \, d\theta \qquad (23)$$

where $\beta = \frac{bx}{2D}$ or

$$p^2(x) = 4n^2 \frac{\psi_{air}}{xD} I(\beta) \qquad (24)$$

The integral $I(\beta)$ was integrated by computer summation with results as shown below. The integral solution for the depth-averaged path (24) should be used for $\beta \geq 5$. For the region near the source, $x \leq (h_v+d)$, inclusion of the depth-average channel response is not appropriate and the contribution from the direct path should be considered to represent the total acoustic field.




Using the above considerations, it is possible to obtain the power sum of the shallow water pressure field by combining Eqs. (22) and (24) or (22) and (18). For $\beta < 5$, we have

$$p_w^2 = 4n^2\psi_{air}\{[\frac{h_v+d}{(h_v+d)^2 + x^2}]^2 + k\frac{I}{xD}\} . \quad (25)$$

For $\beta \geq 5$, we have

$$p_w^2 = 4n^2\psi_{air}\{[\frac{h_v+d}{(h_v+d)^2 + x^2}]^2 + k(\frac{\pi D}{2b^3x^5})^{1/2}\} , \quad (26)$$

where

$$k = \frac{1}{(h_v+d)^2/x^2+1} , \quad (27)$$

a weighting factor to automatically reduce the depth-averaged channel component in the region where it is not valid.

Equations (25) and (26) were normalized by the water depth, D and converted to logarithmic form to facilitate plotting. The resulting combined air to shallow water transmission model is:

Let $A = (h_v+d)/D$ where $h_v \approx nh$

$X = x/D$

$$L_r = L_{inc}+20\log(h/D)-7 + 10\log[T_d(A,X) + \frac{T_a(b,X)}{(A^2/X^2+1)}] \text{ dB re } 1\mu\text{Pa} \quad (28)$$

where $T_d(A,X) = [A/(A^2+X^2)]^2$ (the direct field transmission factor)

$T_a(b,X) = I/X$ for $\beta < 5$

$T_a(b,X) = (\pi/2b^3X^5)^{1/2}$ for $\beta \geq 5$ (the channel transmission factor)

$L_r$ = The underwater sound level re 1 μPa

$L_{inc}$ = The sound level in free air at a distance h from the source (excluding boundary effects), re 1 μPa.

Plotted values of $T_d(A,X)$ and $T_a(b,X)$ have been presented previously in Fig. 12.

**APPENDIX 2. DESCRIPTIONS AND MAPS OF NORTHERN FUR SEAL HAULOUT SITES IN THE EASTERN BERING SEA (taken from Jordon and Clark 1898, Byrd et al. 1980, Kosloff 1985, NMML files).**

Table 2.1. Descriptions of northern fur seal haulout sites in the eastern Bering Sea.

| Rookery | Physical Characteristics |
|---|---|
| St. Paul Island | |
| Vostochni | Situated on a coarse boulder beach with occasional harems on flat ground above. Intermittent sand beaches are not used as rookeries, but as runways by the bachelor bulls to reach the hauling grounds. |
| Morjovi | This site is almost continuous with the Vostochni rookery. It is situated mostly on a boulder beach and rocky point extending back from the sea. Bachelor runways are on the intermittent sand beaches. |
| Polovina | This complex includes Polovina, Little Polovina and Polovina Cliffs rookeries. It is situated partly along a boulder beach and partly on the flats above a series of low cliffs; some scattered harems are along a narrow gravel beach. The Little Polovina portion of this rookery is on a rocky slope. |
| Lukanin | This site is situated on a rocky slope and at the foot of a series of cliffs. |
| Kitovi | This site is situated on a rocky beach below columnar basaltic cliffs and on slopes of cinder and lava. |
| Reef | This site is situated on an irregular beach. The central portion of the rookery extends back from the beach (in a wedge shape) for a considerable distance over a gentle slope strewn with large boulders. |
| Ardiguen | This site is situated on a rocky beach and rock-slide; the rookery extends to the flat area above and along a narrow beach at the foot of cliffs. |
| Gorbatch | This site is situated on a boulder beach and at the foot of a slope that extends along a narrow beach at the base of cliffs. |

Continued...

Table 2.1. Concluded.

| Rookery | Physical Characteristics |
|---|---|
| Tolstoi | Tolstoi rookery is situated on a narrow beach at the foot of cliffs that merge with a long slope strewn with angular boulders; it extends onto a broad, flat sandy beach. This is the most diverse of the St. Paul Island rookeries. |
| Zapadni | Zapadni rookery is situated on a boulder beach and on a gently sloping upland. |
| Little Zapadni | This site is situated on an extremely rugged and broken boulder beach and slope. |
| Zapadni Reef | This site is situated on a narrow, rocky reef and on a beach of boulders. |
| Sivutch | Sivutch (also known as Sea Lion Rock) is situated on a small crescent shaped islet less than 1 km S of the southern tip of St. Paul Island. It has an abrupt cliff on its southern side that gradually slopes to the north, toward the water. The rookery is on a rocky slope on the north side of the island. |
| St. George Island | |
| Staraya-Artil | This site is situated along a narrow belt against steep cliffs. The rookery extends up-slope as far as the seals can climb. |
| North | This site is situated primarily on a narrow beach at the foot of perpendicular cliffs; some seals move up-slope onto the intermittent rock-slides. |
| East | This area includes East Reef and East Cliff rookeries. To the west (East Reef) the rookery is situated on a rocky beach, and to the east (East Cliffs) it extends up a rocky slope. |
| Zapadni | This area includes both Zapadni and South rookeries. They are both situated on a rocky beach that extends up-slope on a long hill. |
| Bogoslof Island | The rookery at this site is situated on a gravel-boulder beach immediately south of Kenyon Dome (about 10 m high) on the NW side of the island. |

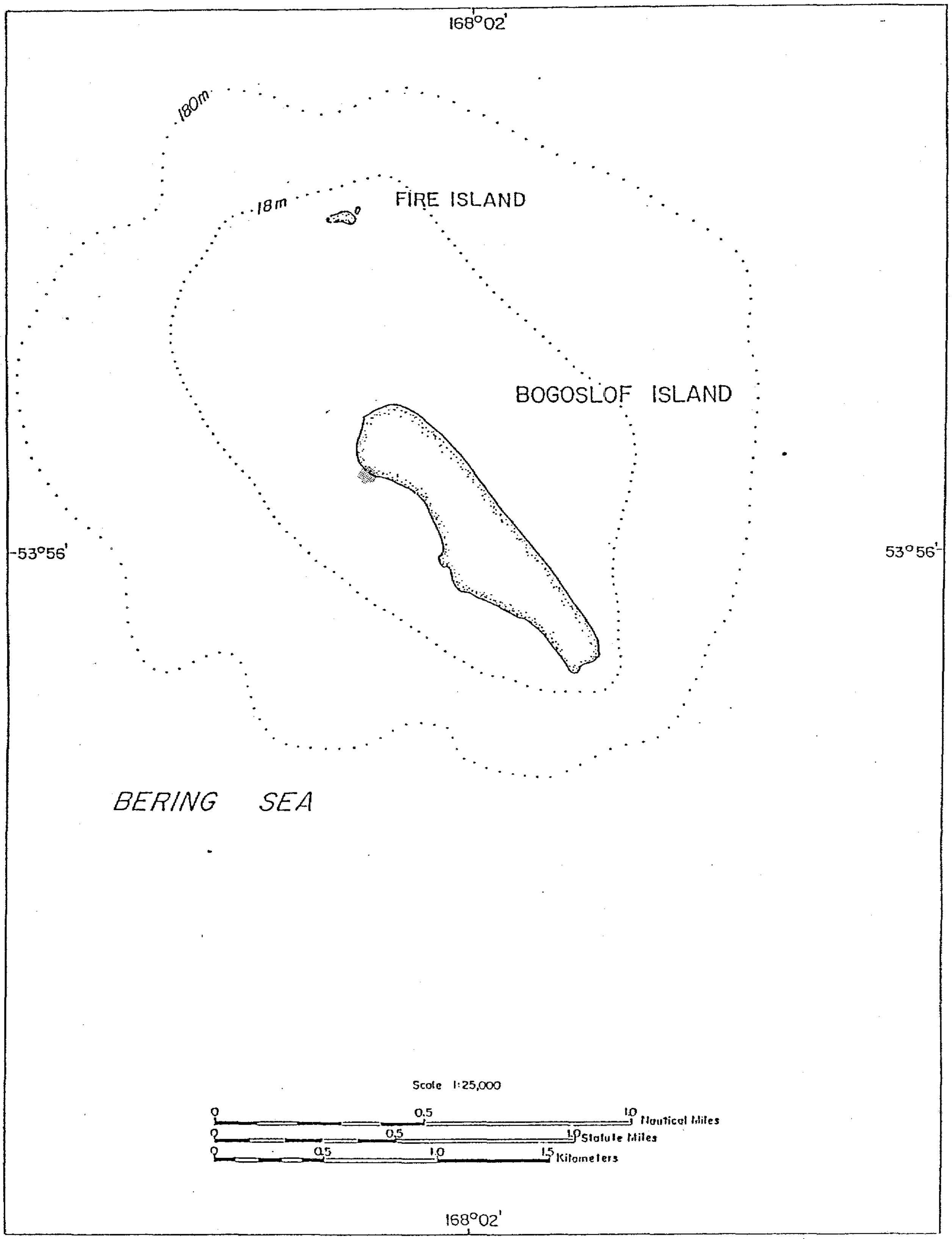
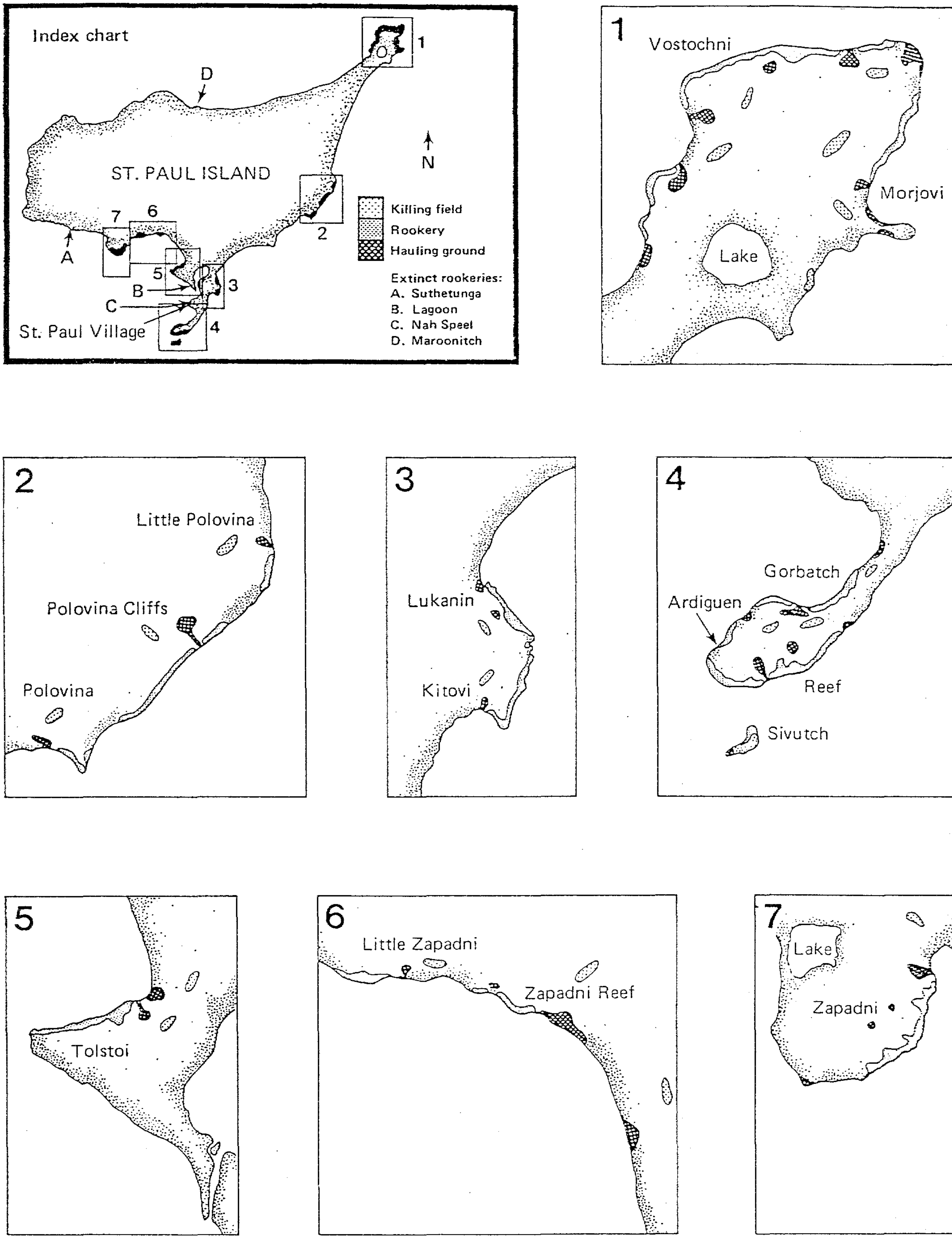



Figure 15. Maps of northern fur seal haulout sites on Bogoslof Island, and on St. George and St. Paul islands and Sivutch in the Pribilof Islands. Scale is 1:250,000 for the index map of the Pribilofs; larger scale maps of Pribilof sites are about 1:34,000. (Maps of the Pribilof Islands are courtesy of the National Marine Mammal Lab., National Marine Fisheries Service, Seattle, WA.)

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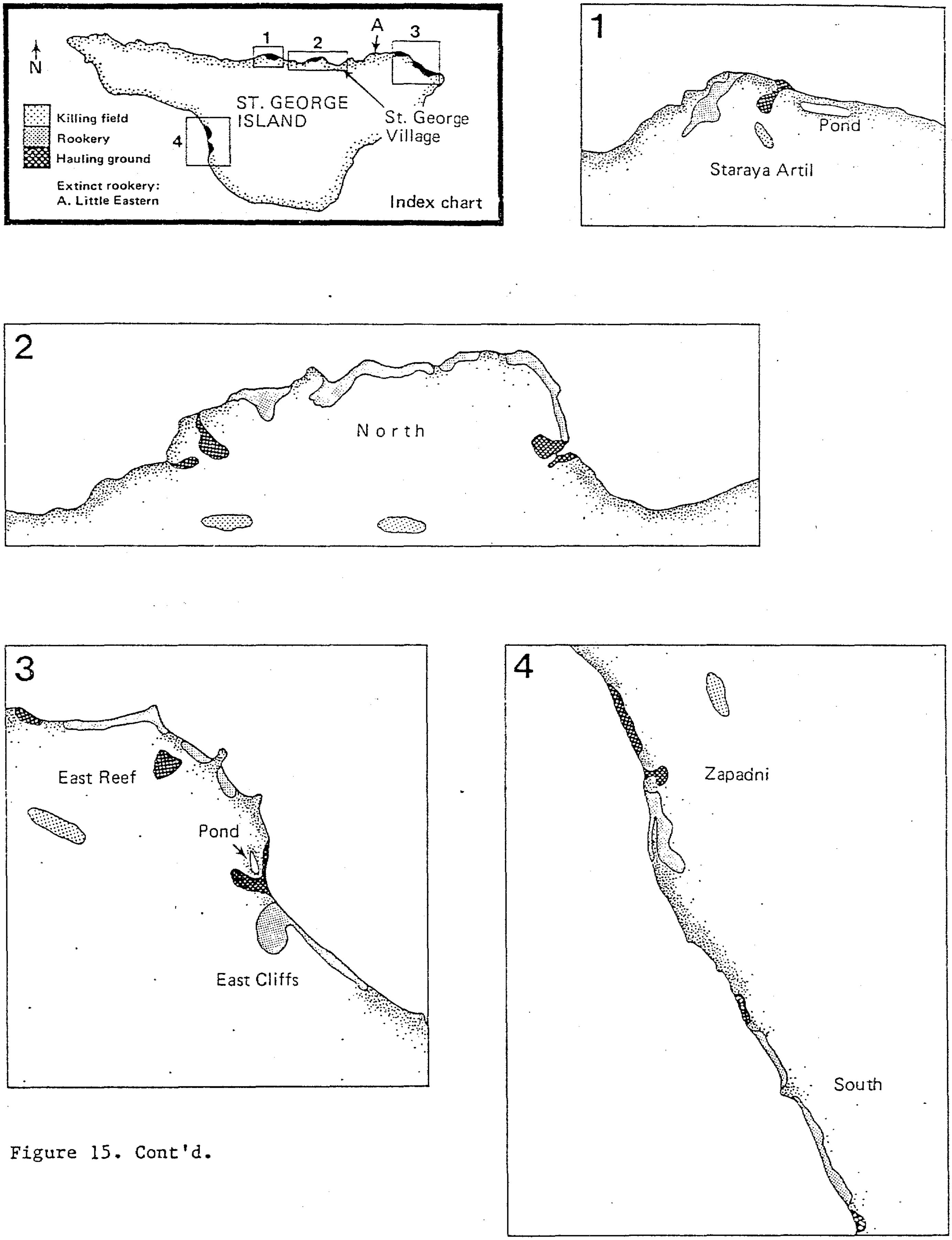



Figure 15. Cont'd.

**APPENDIX 3. DESCRIPTIONS AND MAPS OF NORTHERN SEA LION HAULOUT SITES IN THE EASTERN BERING SEA (Sources are many; see APPENDIX 6 for details).**

Table 3.1. Descriptions of northern sea lion haulout sites in the eastern Bering Sea.

| Rookery | Physical Characteristics |
|---|---|
| Bogoslof Island | This haulout site is a rookery situated on sand/gravel beaches on the NW end of the island near Kenyon Dome; extensive gravel beaches on the SE side of the island and nearby Fire Island (about 1 km NW of Bogoslof I.) also may be used. Vertical relief is no greater than 12 m at Kenyon Dome or at Castle Rock. Waters are very deep near Bogoslof I. The 18 m isobath is about 500 m from the haulout site, the 180 m isobath is about 1 km from the site, and the 1800 m isobath is only about 10 km NE of the site. |
| Unalaska Island | |
| Spray Cape | This site is on a point of land along the W side of Unalaska I., just W of Skan Bay. Vertical relief behind the haulout site rises steeply to over 300 m. The 18 m isobath is about 400 m offshore from the site. |
| Cape Starichkof | This site is located about 10 km NE of Spray Cape. Haulout sites are on rocks and ledges with steep cliffs rising to over 500 m immediately to the SE of the site. The 18 m isobath is within 400 m of shore; the 90 m isobath is about 1-2 km from shore. |
| Bishop Point/ Cape Tebenkof | These two haulout sites are located several km apart along the N side of the island. Sea lions haul out on rocks and ledges backed by 70 m cliffs at Bishop Pt. and 200 m cliffs at Pt. Tebenkof. The 18 m isobath is within 400 m of shore and the 90 and 180 m isobaths are within about 1.5 and 5 km from shore, respectively. |
| Akutan Island | |
| Cape Morgan | This haulout site is a rookery situated on a point at the SW end of the island. The W side of the point is composed of a 10 m wide cobble beach backed by 200-300 m high cliffs. The east side of the point |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | (separated from the W side by Triple Rock) is composed of rocky ledges and islets backed by 200-300 m high cliffs. The 18 m isobath is within 1 km from shore; most of the area near the site is shallower than 100 m deep. |
| Reef Bight/ Lava Bight | This complex of sites is located about 10-15 km NW of Cape Morgan in an area of recent lava flow; there are no beaches. Sea lions haul out on rocky basalt ledges that are backed by 20-30 m high bluffs. The 18 m isobath is within 400-800 m from shore; the 90 m isobath is about 8 km offshore. |
| North Head | This site is situated on the north side of Akutan Island about 12-15 km NE of the site at Lava Bight. Sea lions haul out on the islets, rocky ledges, and boulder beaches at this exposed site; it is backed by high bluffs and cliffs. The 18 m isobath is about 1 km from shore and the 90 m isobath is about 5 km from shore. |
| Akun Island | |
| Billings Head | This haulout site is a rookery; it is situated at the NE end of Akun I. Sea lions haul out mostly at the E end of a 10 m wide and 5 km long cobble/gravel beach, and on boulders and rock ledges backed by 300-350 m high cliffs. The 18 m isobath is within about 200 m from shore; the 100 m isobath is about 1.5-2.0 km to the E. Most of the surrounding area is less than 90 m deep. |
| Akun Head | The haulout site is situated at the NW end of the island, about 8 km W of Billings Head. Sea lions haul out along a 1 km section of coast on rock ledges and boulders backed by 100-150 m high cliffs. The 18 m isobath is within 100 m from shore; the 90 m isobath is 6-7 km to the N. |
| Tanginak Island | Tanginak is a small island located about 5 km E of Akun I. Sea lions haul out at N end of the island on boulders and rock ledges backed by 50 m high cliffs. The island is situated within 400 m of the 90 m depth contour. |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
| --- | --- |
| Tigalda Island | Tigalda I. is about 15 km SE of Tanginak I. Sea lions haul out on rocks, boulders and ledges on the W end of the island (adjacent to Derbin Strait). Vertical relief at the W end is about 30-100 m. The 18 m isobath is within 200 m of shore. |
| Kaligagan I. and rocks NE of Tigalda I. | Sea lions haul out on rocky ledges primarily on the 2 most northwesterly rocks in this group; vertical relief is no greater than 20 m. The 18 m isobath extends to 200-400 m from most rocks and islets in this group. |
| Ugamak Island Group | |
| Ugamak Island | This haulout site is an important rookery; it is currently the largest sea lion rookery in the Alaskan Bering Sea. It is situated on the SE end of the island along a gravel/sand beach about 10 m wide and 10 km long. Vertical relief behind the rookery is about 100 m. The 18 m isobath is within 200 m of shore; most of the area is less than 90 m deep. Sites on rocky beaches and boulder/cobble beaches farther E and N on the island are also used, especially by subadult animals and adults later in the season, after breeding territories at the rookery disintegrate. |
| Round Island | Considered part of the Ugamak I. rookery. This small island is situated about 1 km S of Ugamak Island. Sea lions haul out on rocks and ledges mostly on the S side of the island. This island is situated in waters 18-30 m deep. |
| Aiktak Island | This island is about 1 km S of Ugamak Island; it is about 3.5 km long and 1 km wide, with grassy slopes on N side rising to 100-150 m cliffs on S side. Sea lions haul out on rocks, ledges and beaches, mostly on the N side of island. |
| Unimak Island | |
| Cape Sarichef | Sea lions haul out on rocks, boulders, inshore islets and cobble beaches that are backed by 20-30 |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | m high cliffs and bluffs. The 18 m isobath is about 1.5 km from shore. |
| Oksenof Point/ Cape Mordvinof | These two points of land are located about 8-10 km apart along the N side of the island, about half way between Cape Sarichef and Bechevan Bay. Sea lions haul out on rocks, boulders and inshore islets that are backed by 20-50 m high bluffs that rise to a steep headland over 500 m high. The 18 m isobath is about 1.5 km from shore, and the 90 m isobath is more than 20 km to the NW. |
| Amak Island | Sea lions haul out on the rocks and ledges on the north and east sides of the island. Approximate vertical relief is 10-25 m, rising steeply to 250-300 m. Boulder beaches adjacent to this area also are used occasionally. The 18 m isobath is within 500 m of the island; the 90 m isobath is about 50 km farther offshore to the NW. |
| Sea Lion Rock | This site is an important rookery. The rock is large--approximately 150 m long, 50 m wide and 15 m high, with sloping access on E, W and S sides. Sea lions mainly haul out on the lower one-third (smooth portion) of the S side of the rock; on some occasions higher levels are occupied. The 18 m isobath is within 500 m of the rock; the 90 m isobath is about 50 km to the NW. |
| Unnamed Rocks SE of Sea Lion Rock | This haulout site is situated on a cluster of islets and rocks SE of Sea Lion Rock and north of Amak Island. Relief varies from 3-10 m. Bathymetry is similar to Sea Lion Rock. |
| Right Hand Point | This haulout site is located in northern Bristol Bay. Sea lions haul out on rock ledges and boulder beaches at the point of land, which is backed by steep cliffs rising to 80 m. Waters are shallow in the vicinity of the site; the 5.5 m isobath is 1.5-2.0 km from shore. |
| Twin Islands | These are the southernmost in the Walrus Islands group, which are located E of Hagemeister Island |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | and S of Togiak Bay. Sea lions most consistently haul out on rocky ledges and boulders on South Twin Island. Vertical relief is about 75 m and water depth is over 30 m <2 km offshore from the site. Sea lions also occasionally haul out on the southern ends of nearby Crooked Island and High Island. Both of these sites are also adjacent to steep cliffs (>150 m) and deep water (>30 m). |
| Round Island | Sea lions haul out on the southern tip of Round Island, which is also one of the islands in the Walrus Islands group. Vertical relief on Round Island is near 500 m, and waters are 30 m deep immediately offshore from the site. Although sea lions also haul out on High Island and on the Crooked Islands, the exact locations are unknown to us and therefore are not indicated on the map. |
| Hagemeister Island | Sea lions haul out on rocks, boulders and ledges at the south end of the island, near Clam Point. Vertical relief behind the site is over 500 m, and the water is deep (over 30 m) immediately offshore (within 200 m) from the site. |
| Cape Peirce | Sea lions haul out along 2-4 km of rocky shoreline both N and S of Cape Peirce, and on several rocks about 3 km offshore the entrance to Nanvak Bay. Vertical relief behind most of these sites is from 20-100 m and the 18 m isobath is about 5 km from shore. |
| Cape Newenham | Sea lions haul out on the rocks, boulders and ledges on the Cape Newenham peninsula, and at the cape itself and on nearby islets. Vertical relief near the site on the south side of the peninsula is about 200 m, and at the cape is about 20 m (low bluffs) . The 18 m isobath is about 3-5 km from shore at these sites. |
| Nunivak Island | |
| Cape Mendenhall | A small number of sea lions haul out on the rocks and islets located about 6 km W of Cape Mendenhall. Vertical relief is less than 10-15 m, and the 18 m isobath is located about 3 km to the south. |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
| --- | --- |
| Binajoaksmiut Bay | A few sea lions haul out on several small rocky islets (<10 m high) at the mouth of Binajoaksmiut Bay, which is about 25 km NW of Cape Mendenhall, along the S coast of Nunivak Island. The site is about 100 m from shore and water depth within 1 km of the site is less than 10 m; the 18 m isobath is about 8 km offshore to the S. |
| Nabangoyak Rock | A few sea lions haul out on a rocky islet (<10 m high) about 10 km SE of Cape Mohican, near the W end of Nunivak Island. The 18 m isobath is located about 3.5 km W of the site. |
| Cape Mohican | This haulout site is located at the extreme west end of Nunivak Island; sea lions haul out on the ledges, rocky islets and boulder beaches. Vertical relief at the cape is about *** m. The 18 m isobath is about 2 km S of this site. |
| Cape Manning, Cape Corwin, Datheekook Point | Cape Corwin is the SE tip of Nunivak Island; Cape Manning is the NE tip (not shown on maps). However, the exact locations and numbers of animals is unknown, so no maps have been prepared. According to local residents, sea lions also haul out at these sites and at Datheekook Point. |
| St. George Island | |
| Dalnoi Pt. Area | This haulout site is composed of rock ledges, boulders and gravel beaches. Vertical relief immediately behind the site is less than 20 m, and nearshore waters at the site are less than 18 m within 2 km from shore. |
| St. Paul Island | |
| Northeast Point | This haulout site is situated on a relatively low, rocky, gravel and boulder strewn point of land on the extreme NE end of St. Paul Island. Vertical relief is less than 5 m and water depth adjacent to the site is very shallow; the 40 m isobath is over 10 km from shore and waters 2 km N of the site are less than 2 m deep. |

Continued...

Table 3.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| Sivutch | This haulout site (also known as Sea Lion Rock) is situated on a small crescent shaped islet several hundred meters S of the southern tip of St. Paul Island. The islet has an abrupt cliff on its south side that gradually slopes to the north, toward the water. The sea lions haul out on a rocky slope on the north side. Water depth within 500 m off the haulout site on Sivutch is generally less than 5 m. |
| Otter Island | This small island is located about 8 km SW of St. Paul Island. Vertical relief on the island is over 80 m at its W end, and water depth within 2 km of the site is less than 40 m. |
| Walrus Island | This small island is an important rookery for northern sea lions. It is located about 12 km E of St. Paul Island; vertical relief behind the site is almost 90 m and water depth within 500 m of shore is generally less than 30 m. The 40 m isobath is located about 1 km E of the site. |
| St. Matthew Island | |
| Sugarloaf Mtn. | This haulout site is situated on rocky ledges and boulders at the foot of 300-400 m cliffs and slopes on the southern end of St. Matthew Island. Water depth is less than 18 m along a reef that extends SW of the site as far as Pinnacle I. (about 15 km). Off this reef, water depth increases to 30+ m within a few hundred meters. |
| Cape Upright | This site is located at the extreme SE end of St. Matthew Island, on rocks, boulders and on ledges at the base of 500 m high cliffs. The 18 m isobath is within 200 m from shore at this haulout site. |
| Near Lunda Point | Sea lions haul out on a series of low rocks and islets situated 150-200 m offshore from Lunda Point. The 18 m isobath extends about 8-10 km from shore to the NE. |
| Pinnacle Island/ Gull Islands | This haulout site is located on a series of inshore rocks along the southern shore of |

Continued...

Table 3.1. Concluded.

| Rookery | Physical Characteristics |
|---|---|
| | Pinnacle Island, which is about 30 km SW of Sugarloaf Mt., and on an island cluster (Gull Rocks) about 0.75 km W of the south end of Pinnacle Island. Vertical relief is great on Pinnacle I. (about 380 m) and the 18 m isobath extends W about 1 km. Vertical relief on Gull Rocks varies from 3-15 m, and the 18 m isobath is within 200 m from shore at this site. |
| Hall Island | |
| Arre Rock | This site is composed of several clusters of small rocky islets about 1.5 km offshore from the SW side of Hall Island. Rocks vary in size; vertical relief is from 3-15 m. The 18 m isobath is about 2 km from shore (to the W). |
| North Cove | The haulout site is located on a medium-sized rock located inshore about 2 km SSE of Cape Hall, at the N end of North Cove; vertical relief about 10-15 m. The 18 m isobath is close (about 1 km) to shore in this area, and the 60 m isobath is within about 5 km from shore. |
| Elephant Rocks | Sea lions haul out on mainly on a small islet (S. Elephant Rock) in a cluster of inshore islands north of Cape Hall; vertical relief of the rocks is about 3-15 m. The 18 m isobath is less than 1 km from shore from the site; the 60 m isobath is within about 5 km from shore. |
| St. Lawrence Island | |
| Southwest Cape | This haulout site is characterized by gravel and boulder beaches backed by low bluffs up to 15-20 m high. Numerous rocky inshore islets up to 5-10 m high are most consistently used by sea lions. Water depth within 400 m of this site is generally less than 18 m. |
| Punuk Islands | Sea lions haul out on the rocky, boulder beaches along the SE sides of the Punuk Islands, but most regularly only on South Punuk Island. Vertical relief near the haulout site is no greater than 5-10 m, and the 18 m depth contour is about 5 km from shore to the S and extends uninterrupted 20 km N to St. Lawrence Island. |

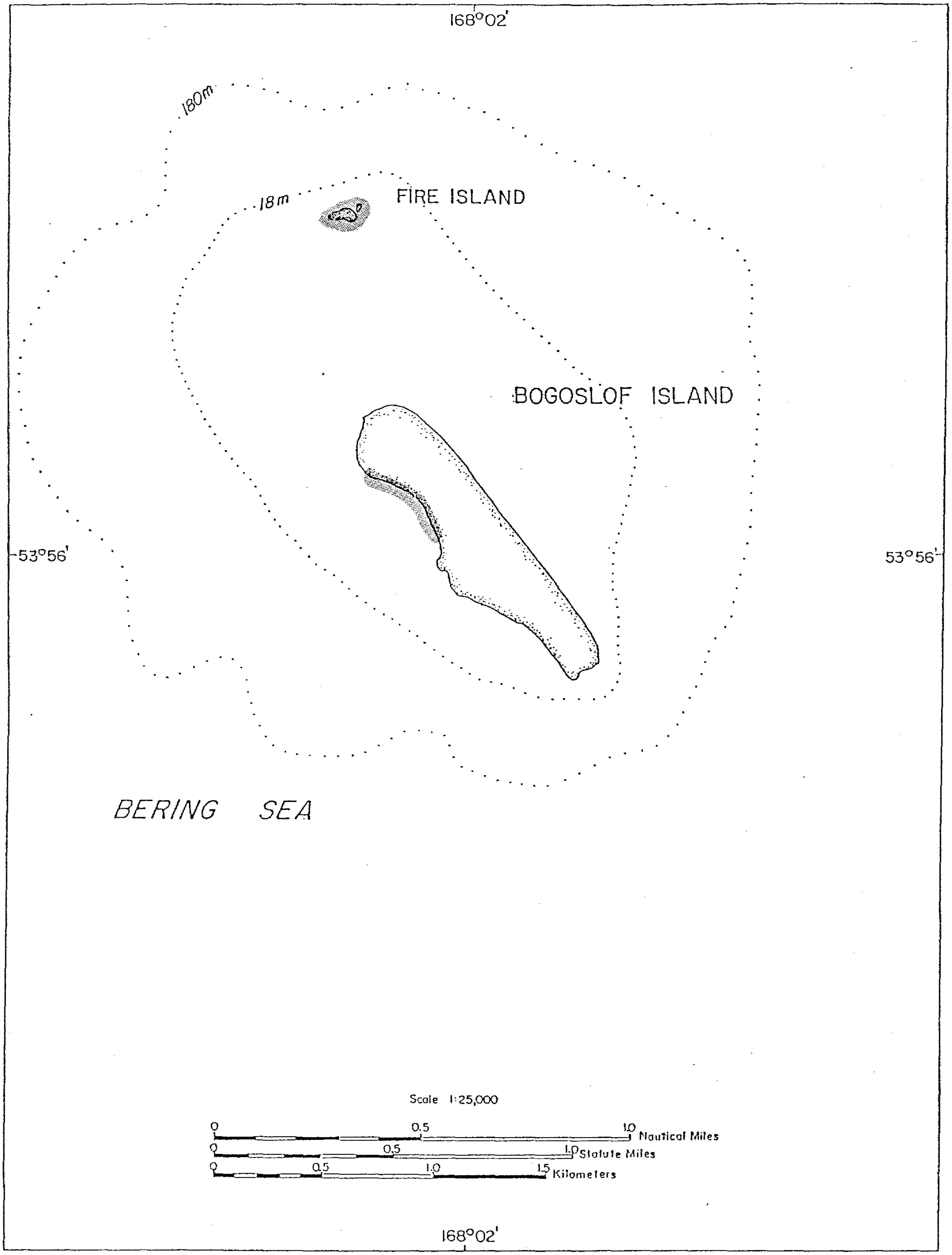
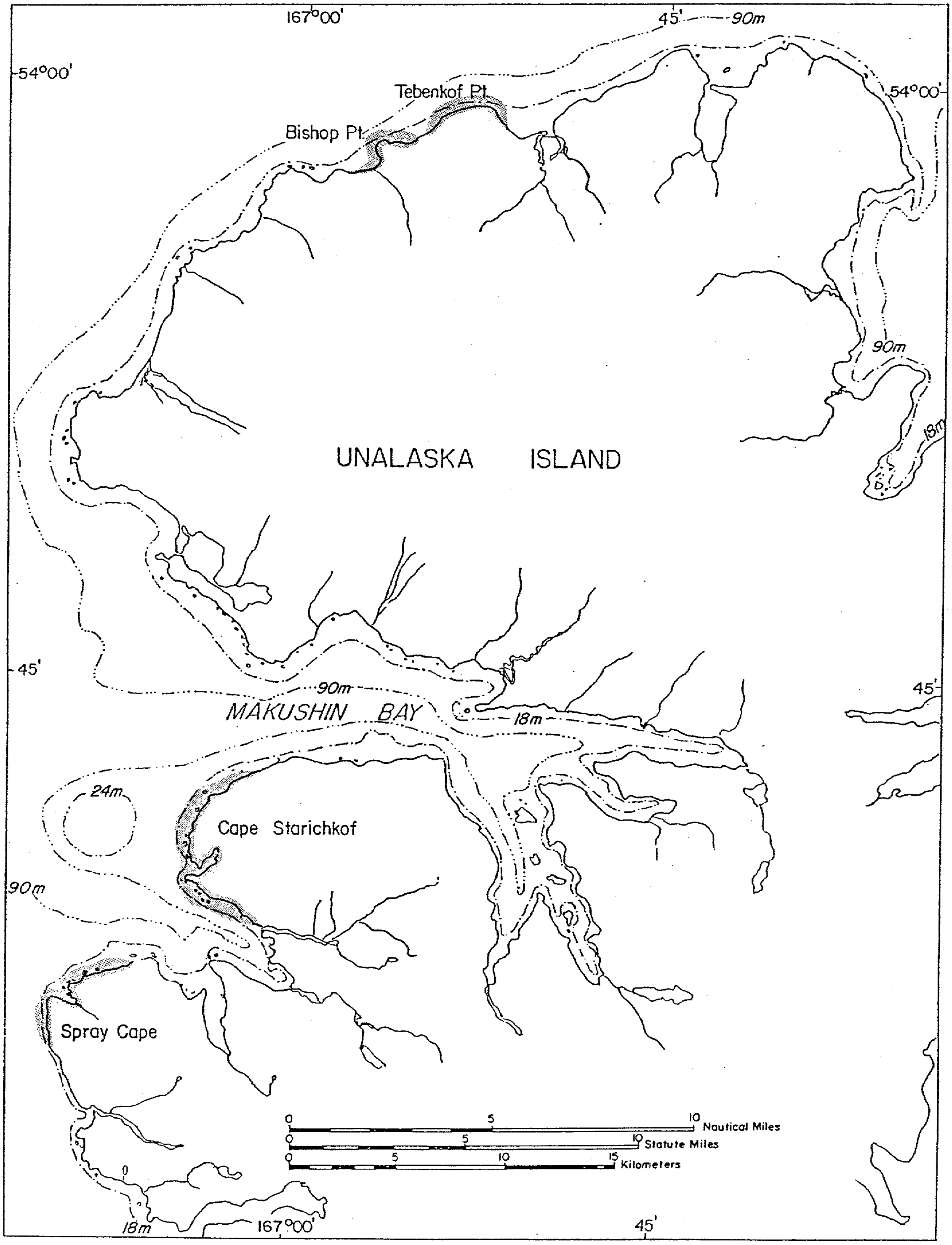



Figure 16. Maps of important northern sea lion haulout sites in the eastern Bering Sea. Bogoslof and Fire islands are shown at a scale of 1:25,000. All other maps are at scales of 1:250,000.

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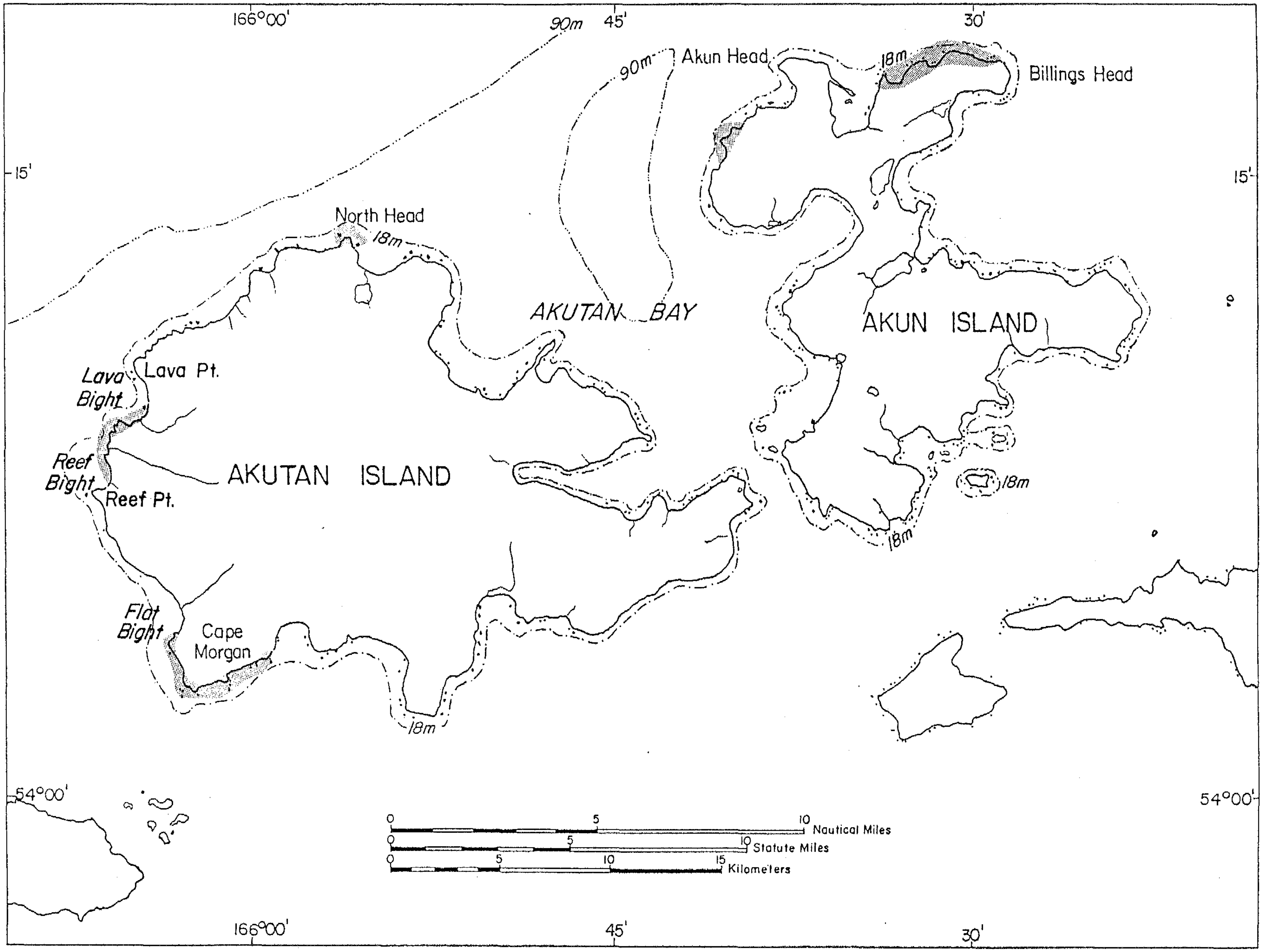


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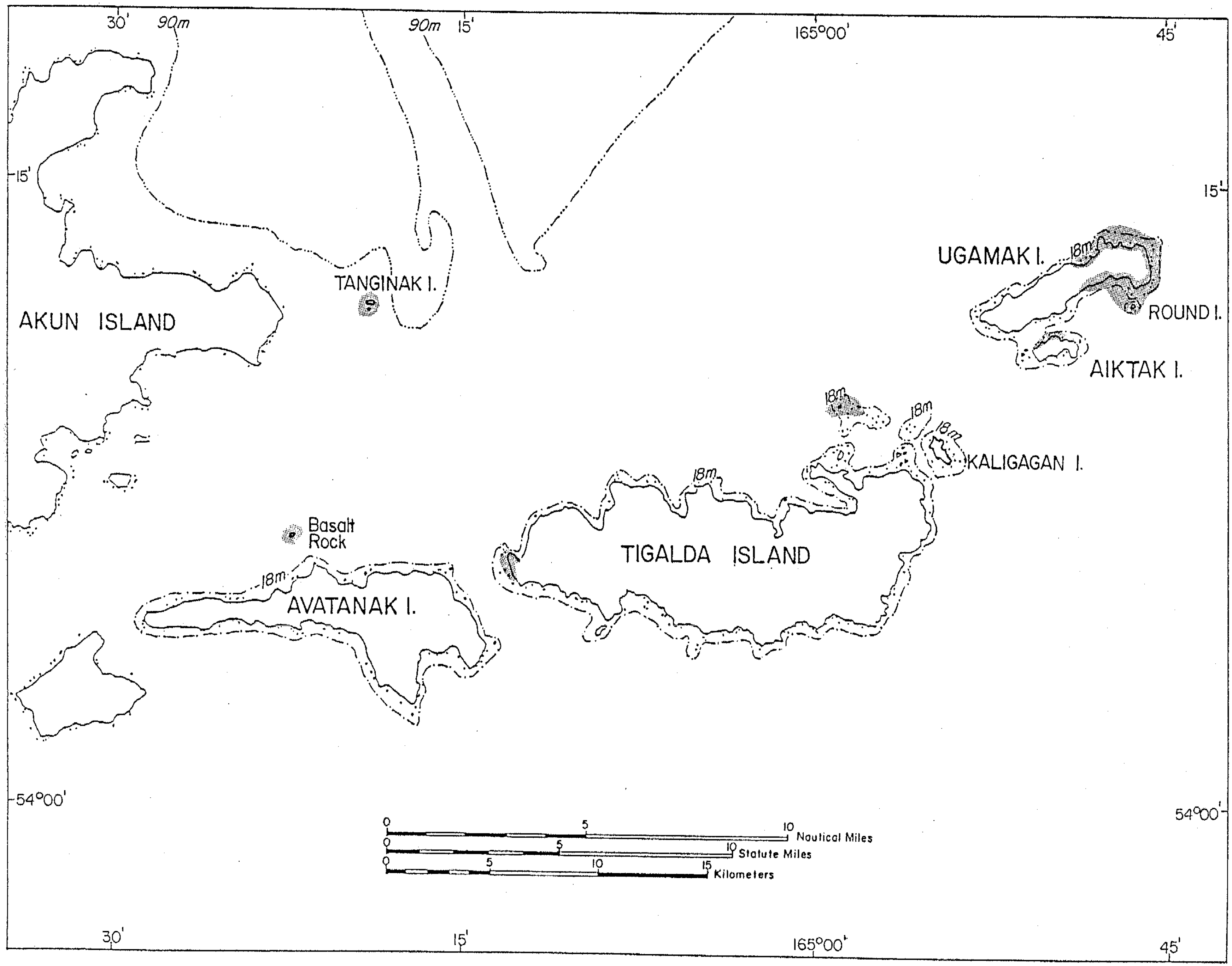


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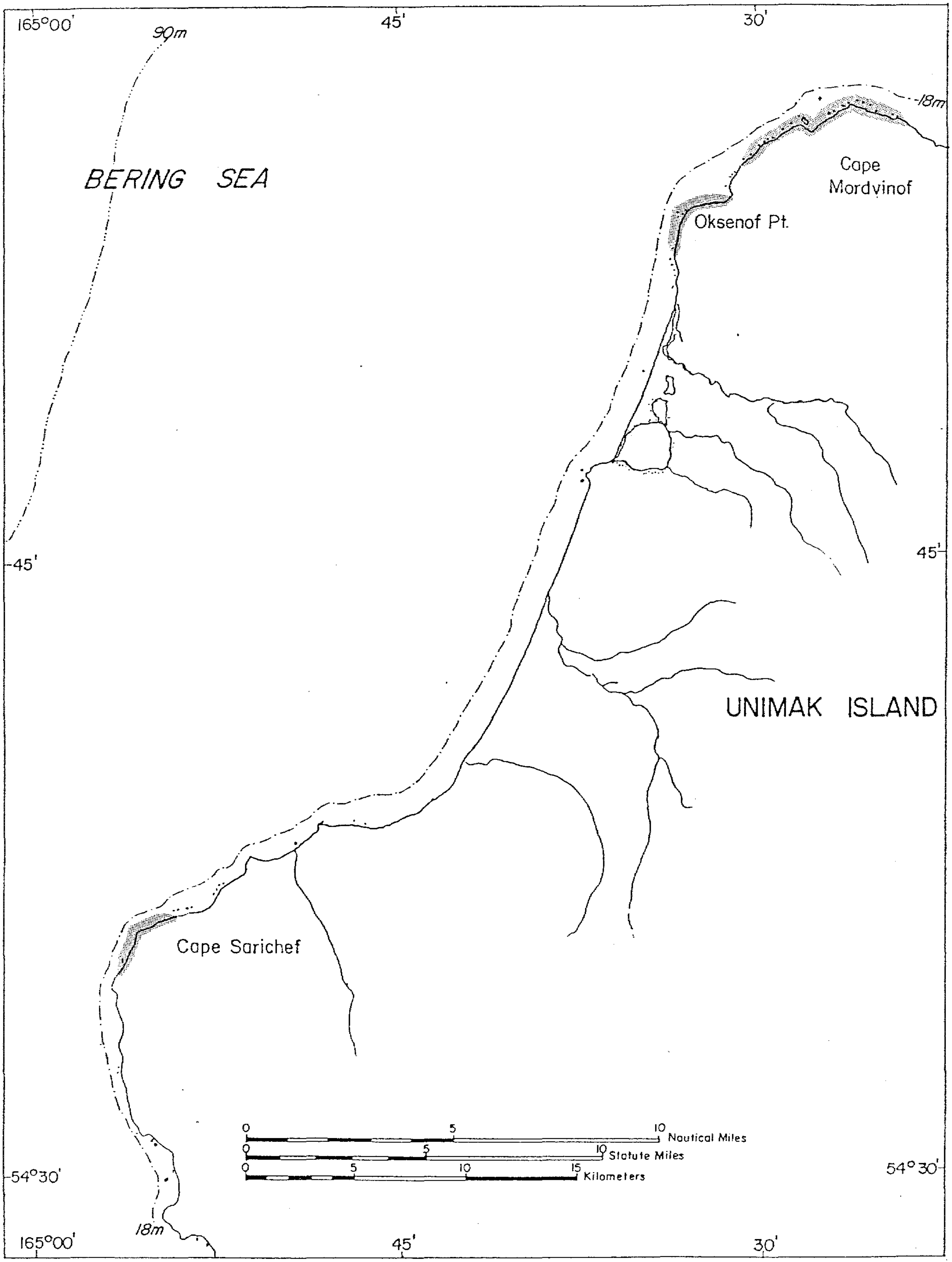


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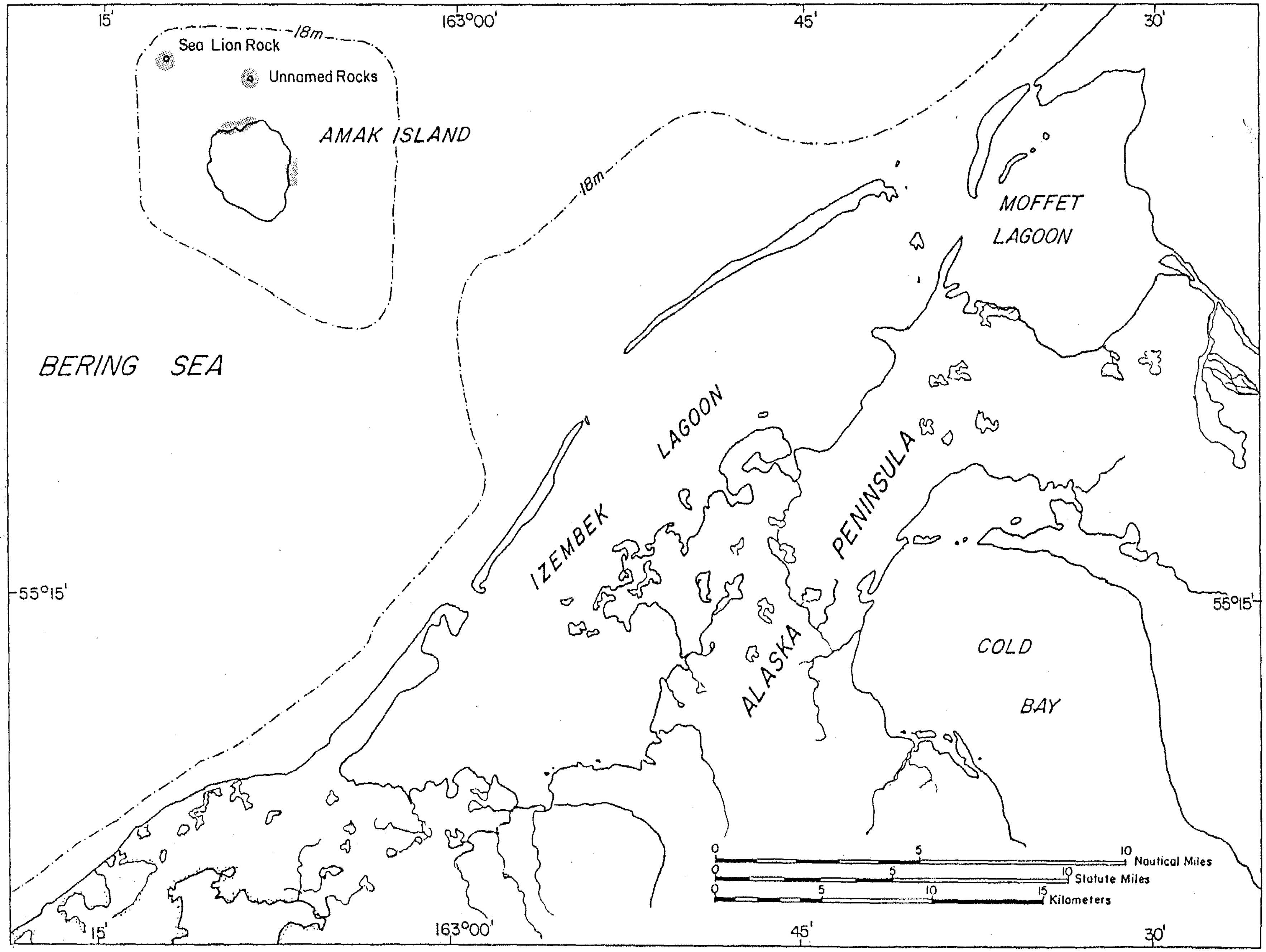


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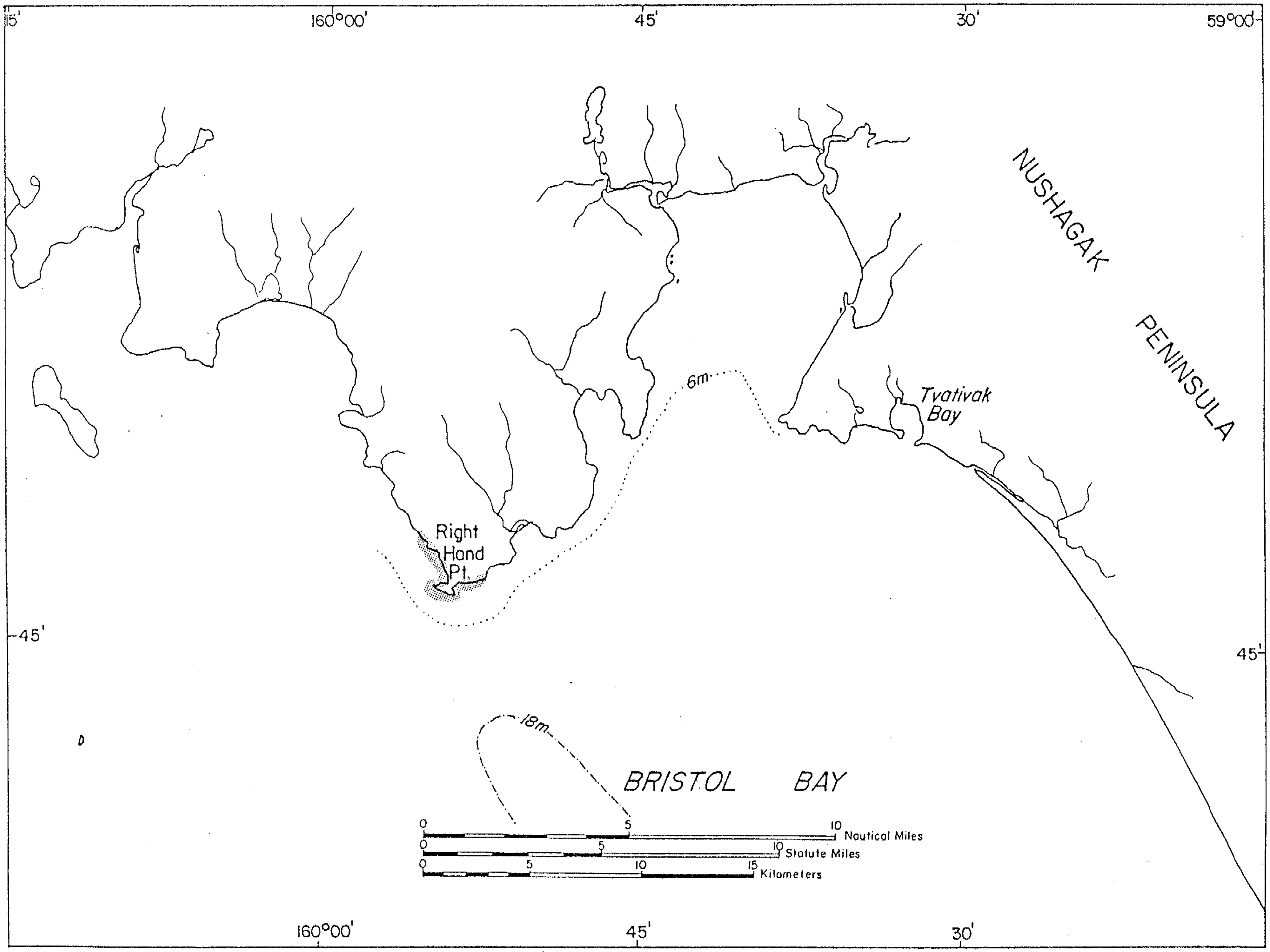
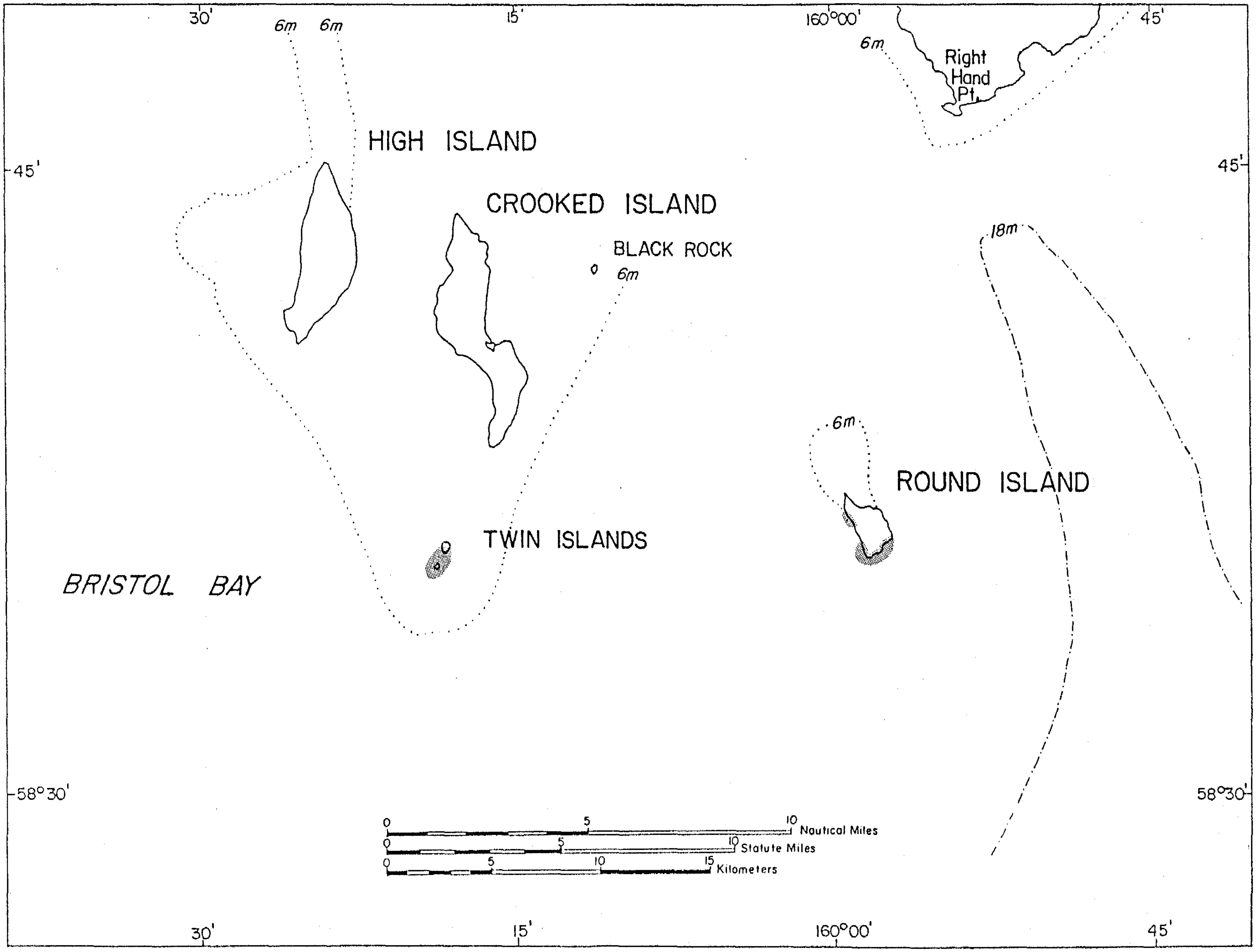


15'
160°00'
45'
30'
59°00'
NUSHAGAK
PENINSULA
Tvativak Bay
6m
Right Hand Pt.
45'
18m
BRISTOL BAY
0
5
10
Nautical Miles
Statute Miles
15
Kilometers


F[illegible]e 1[illegible]ont[illegible]

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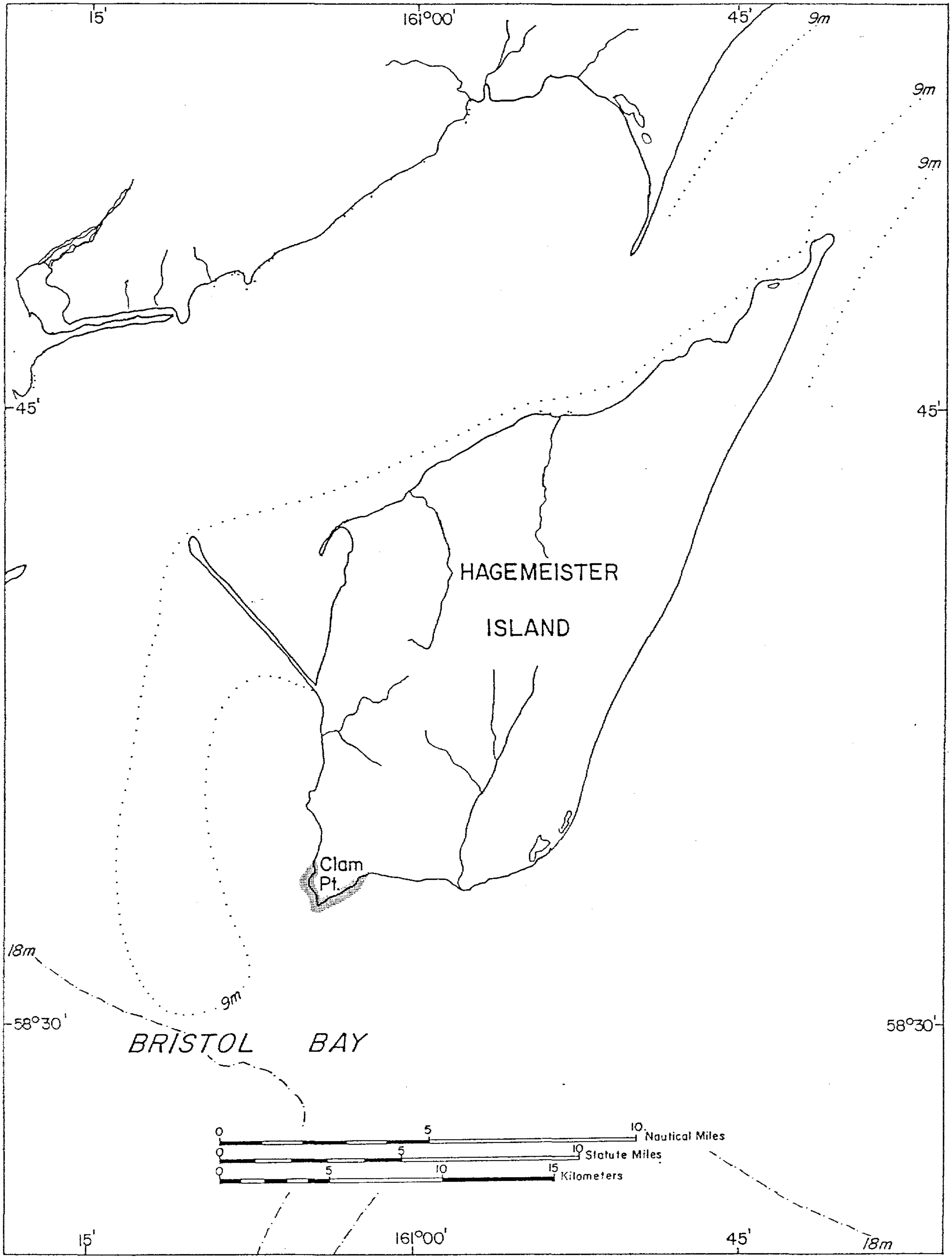


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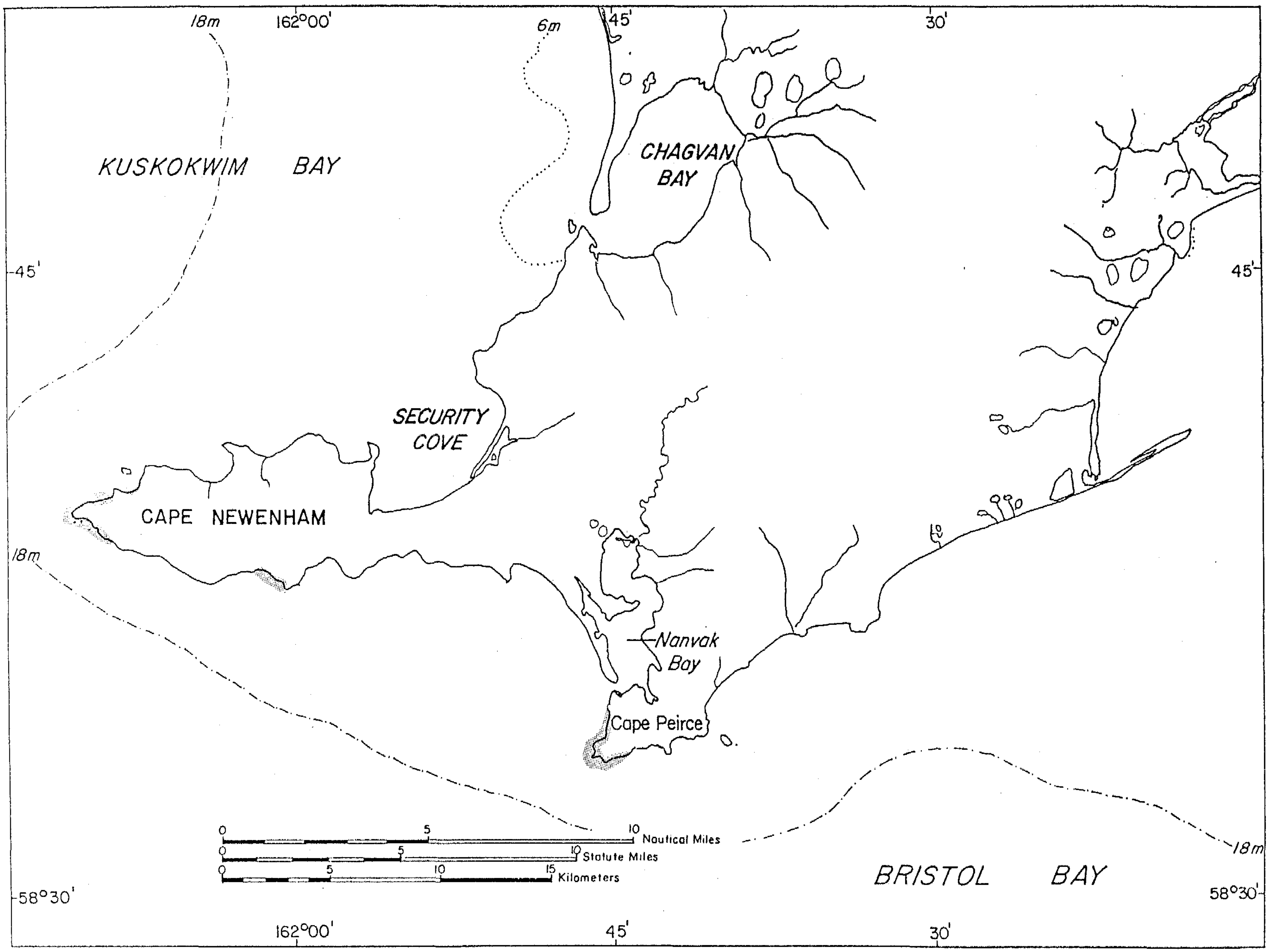


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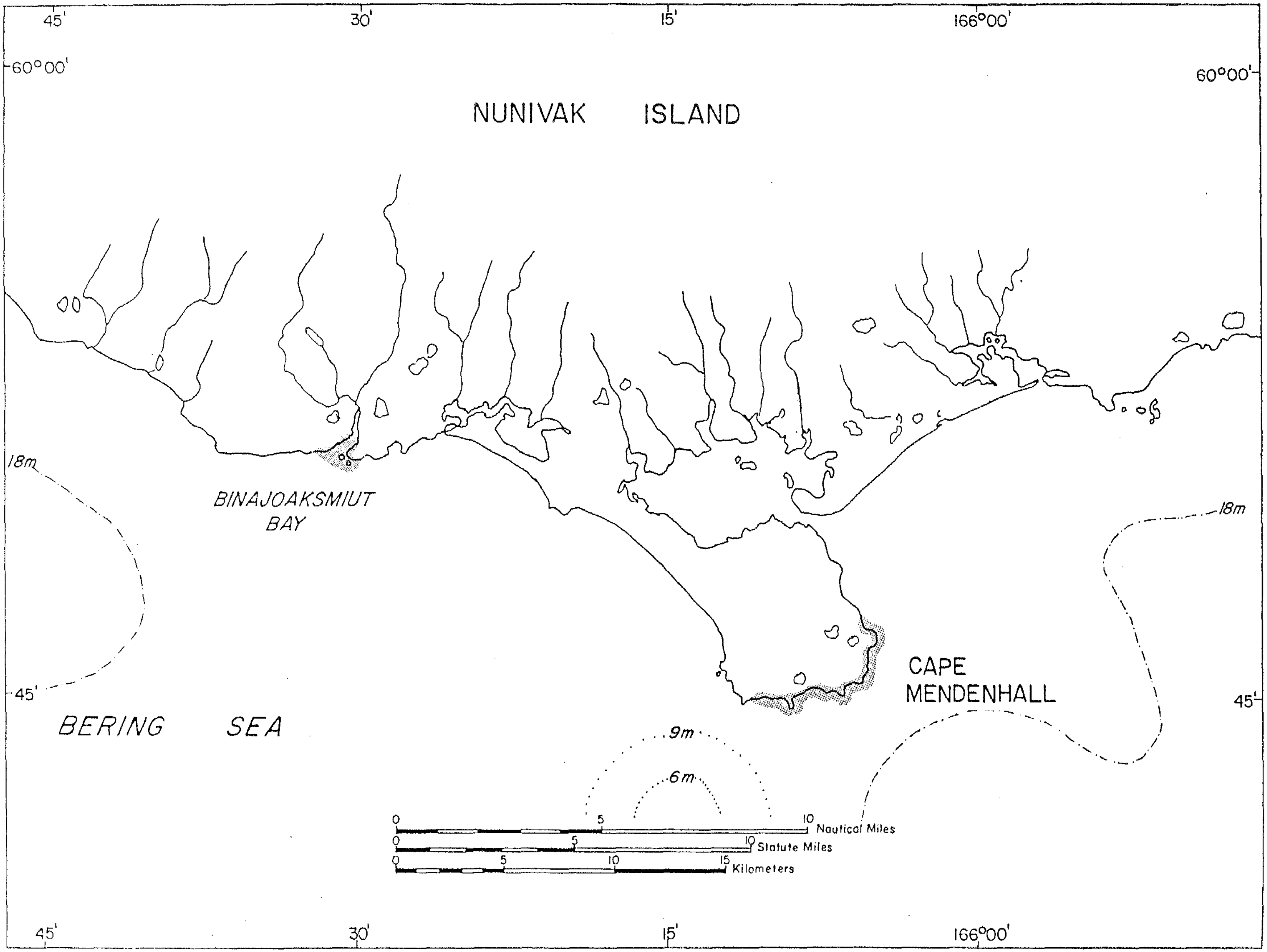


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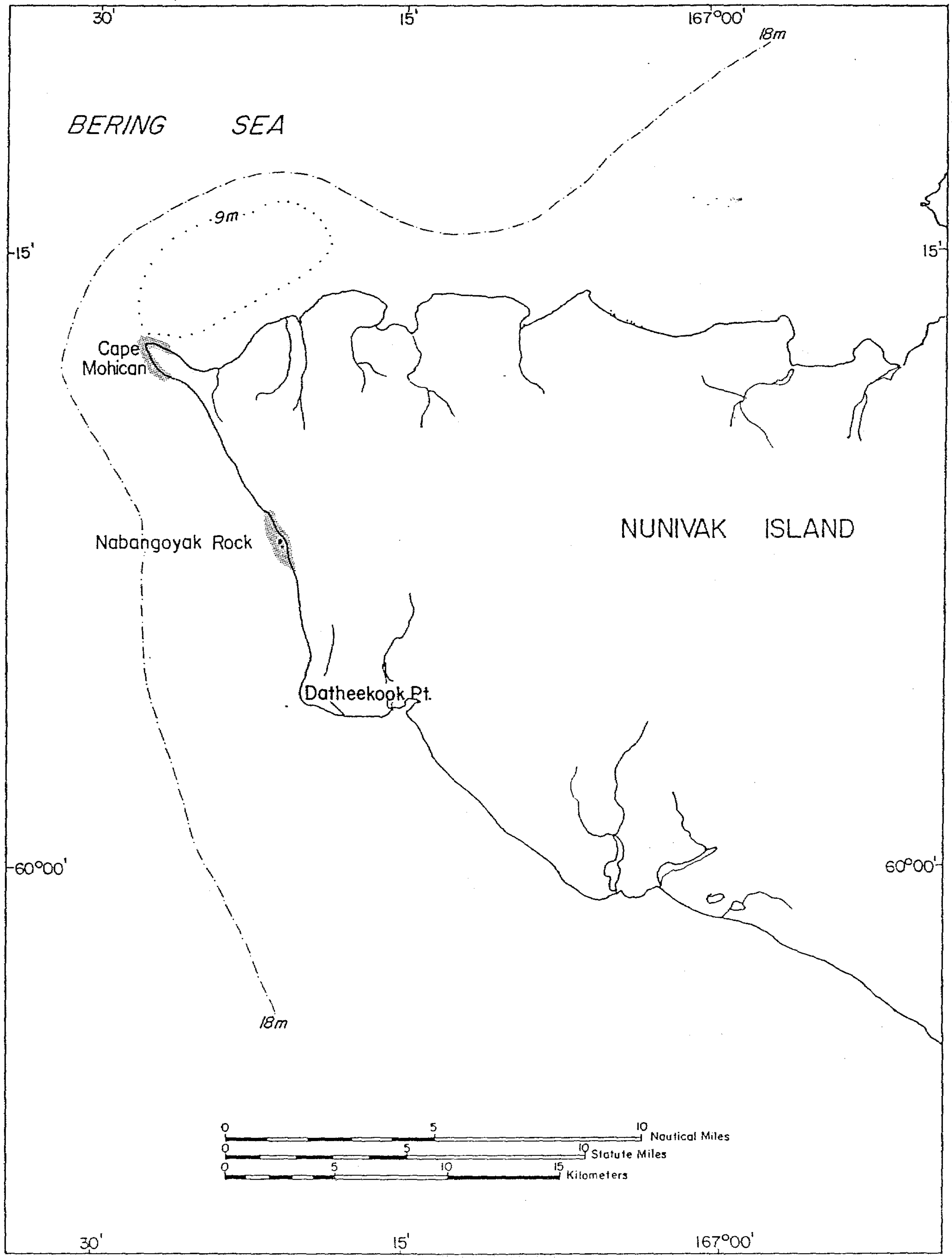


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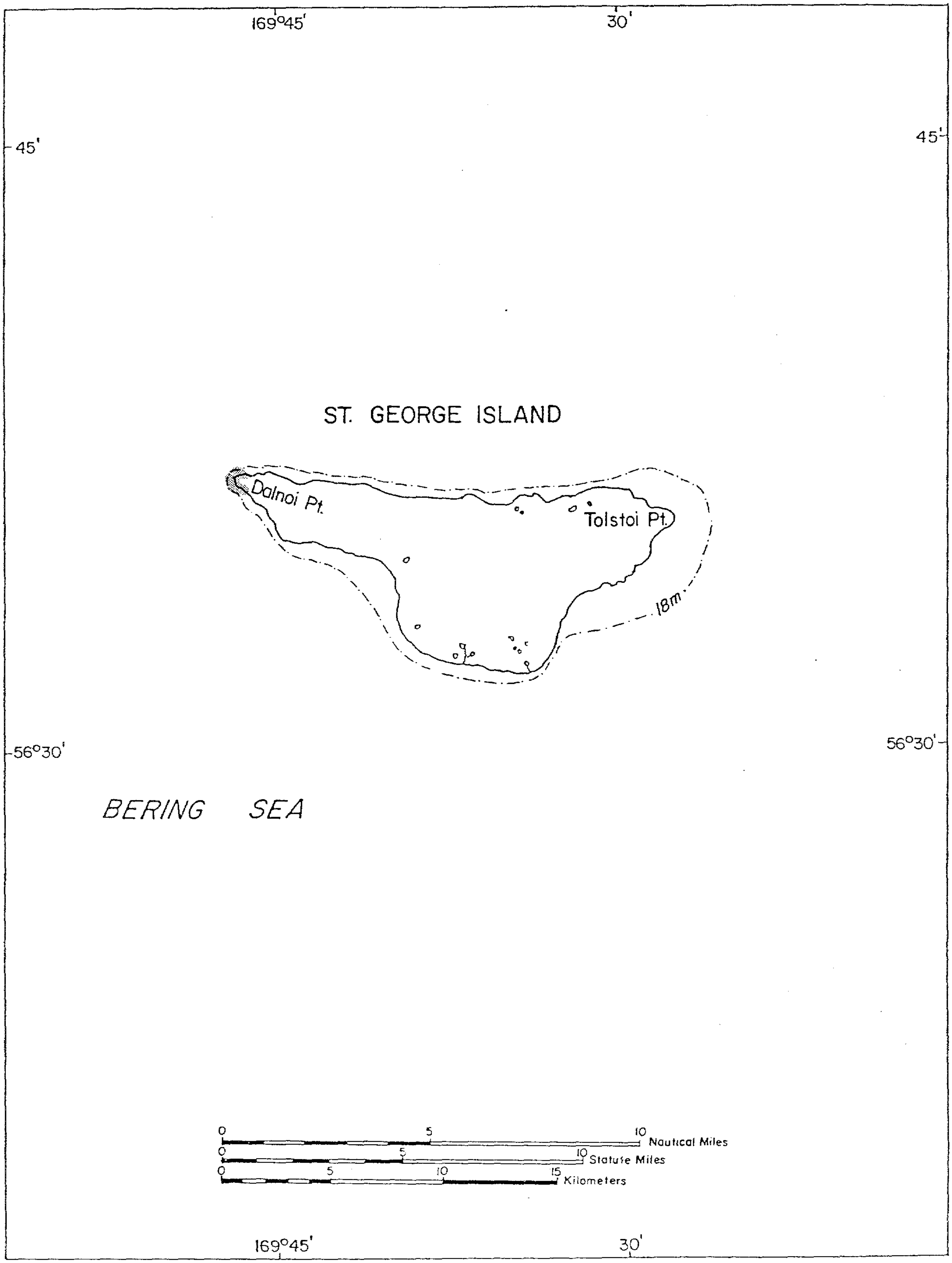


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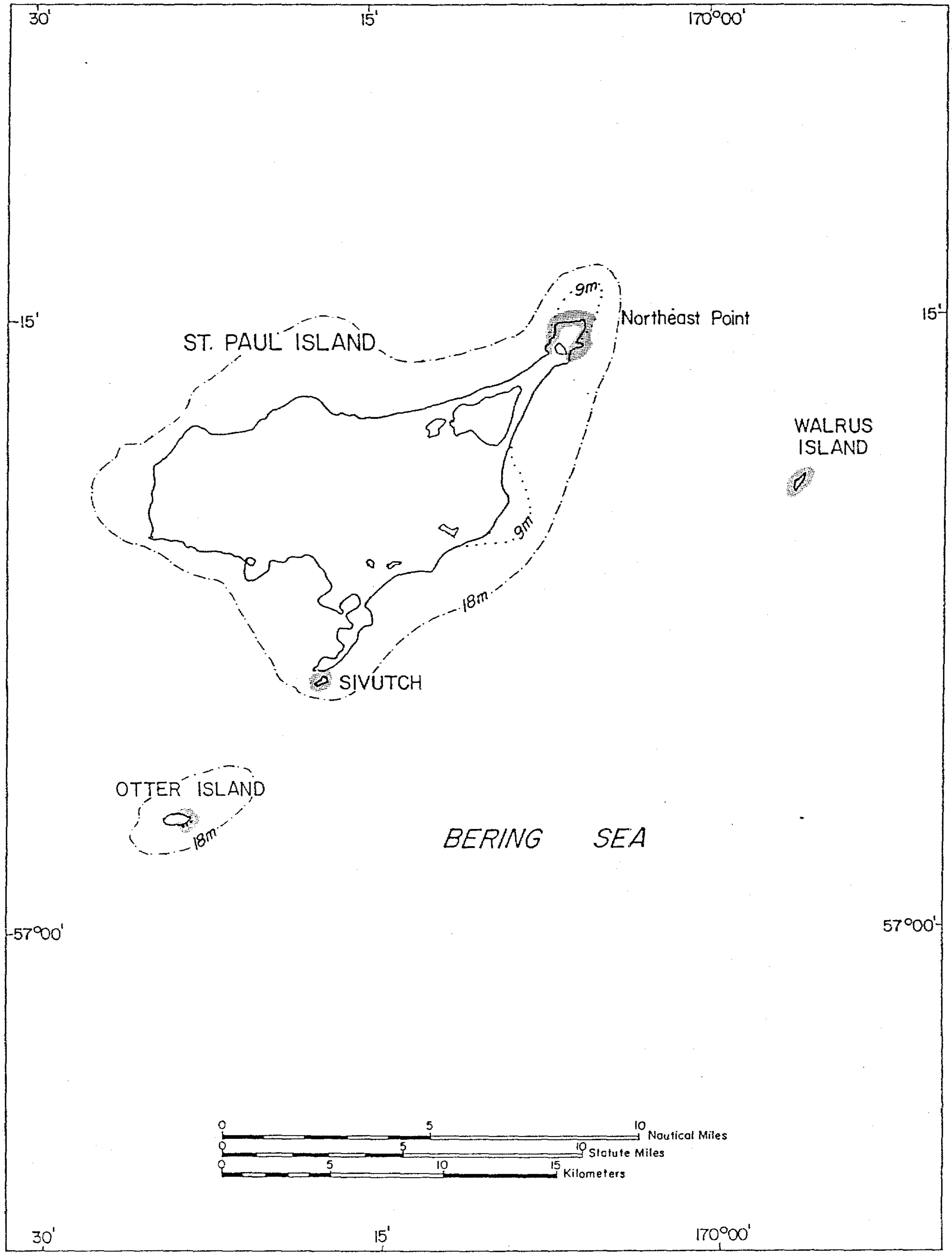
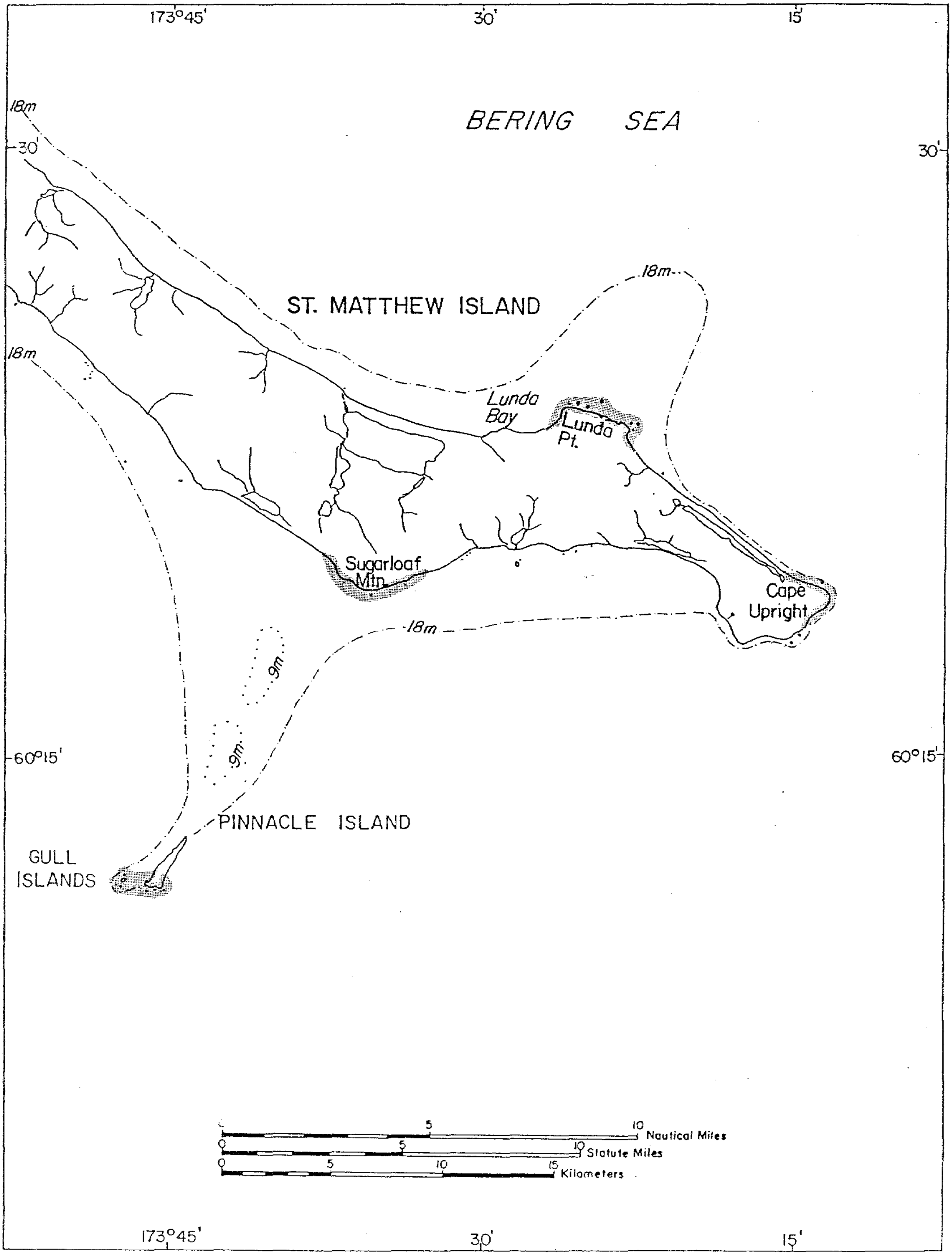



Figure 16. Cont'd.

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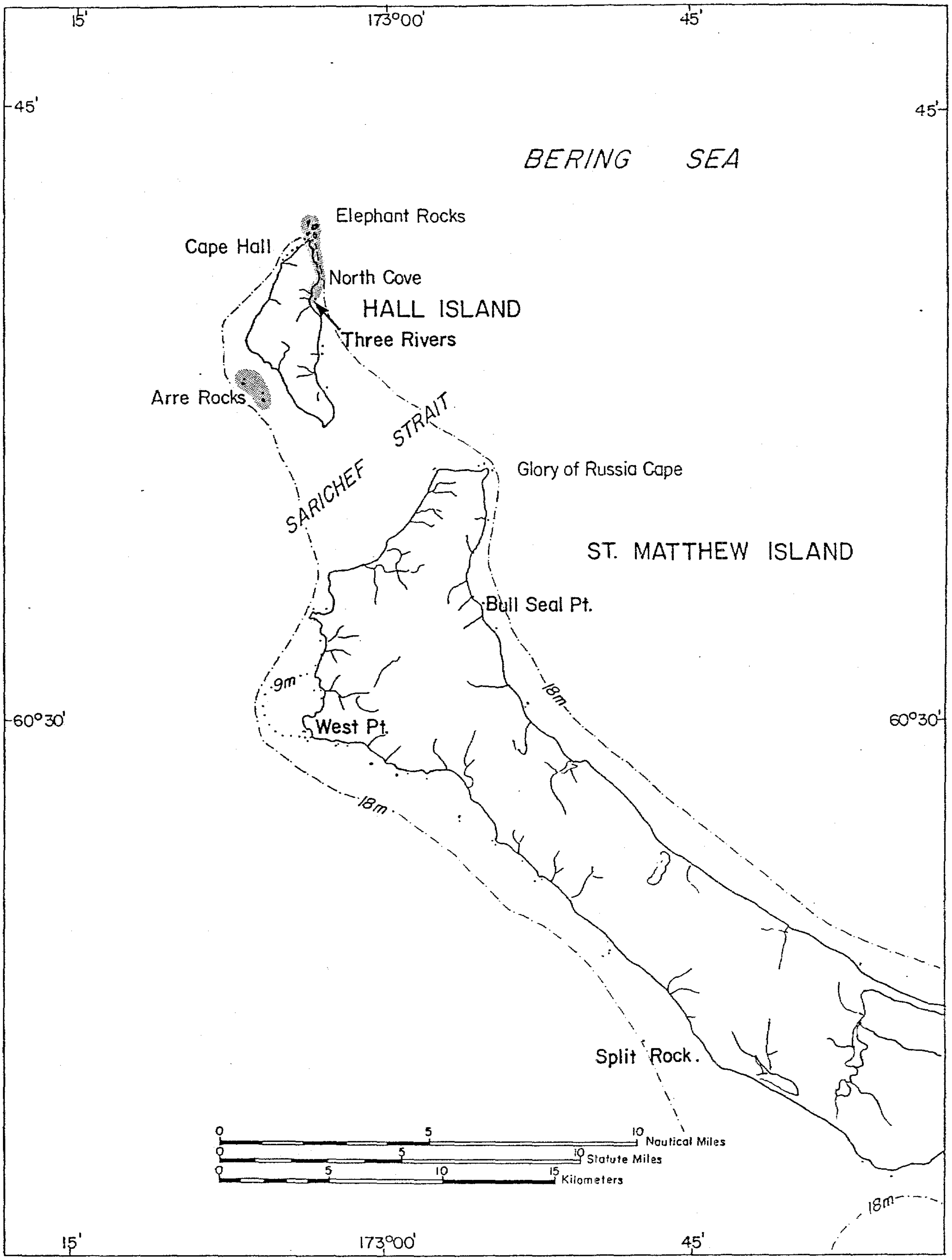


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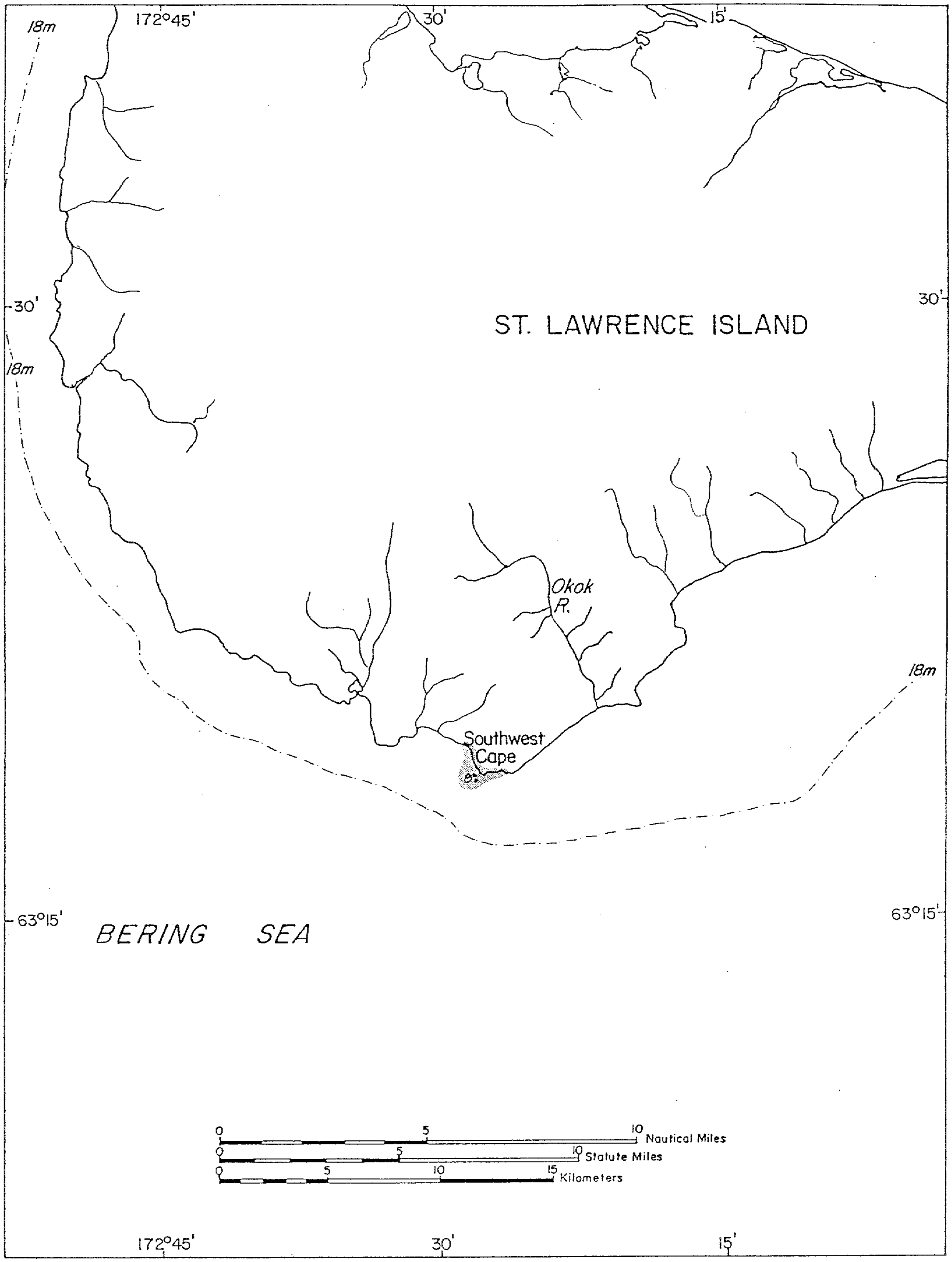


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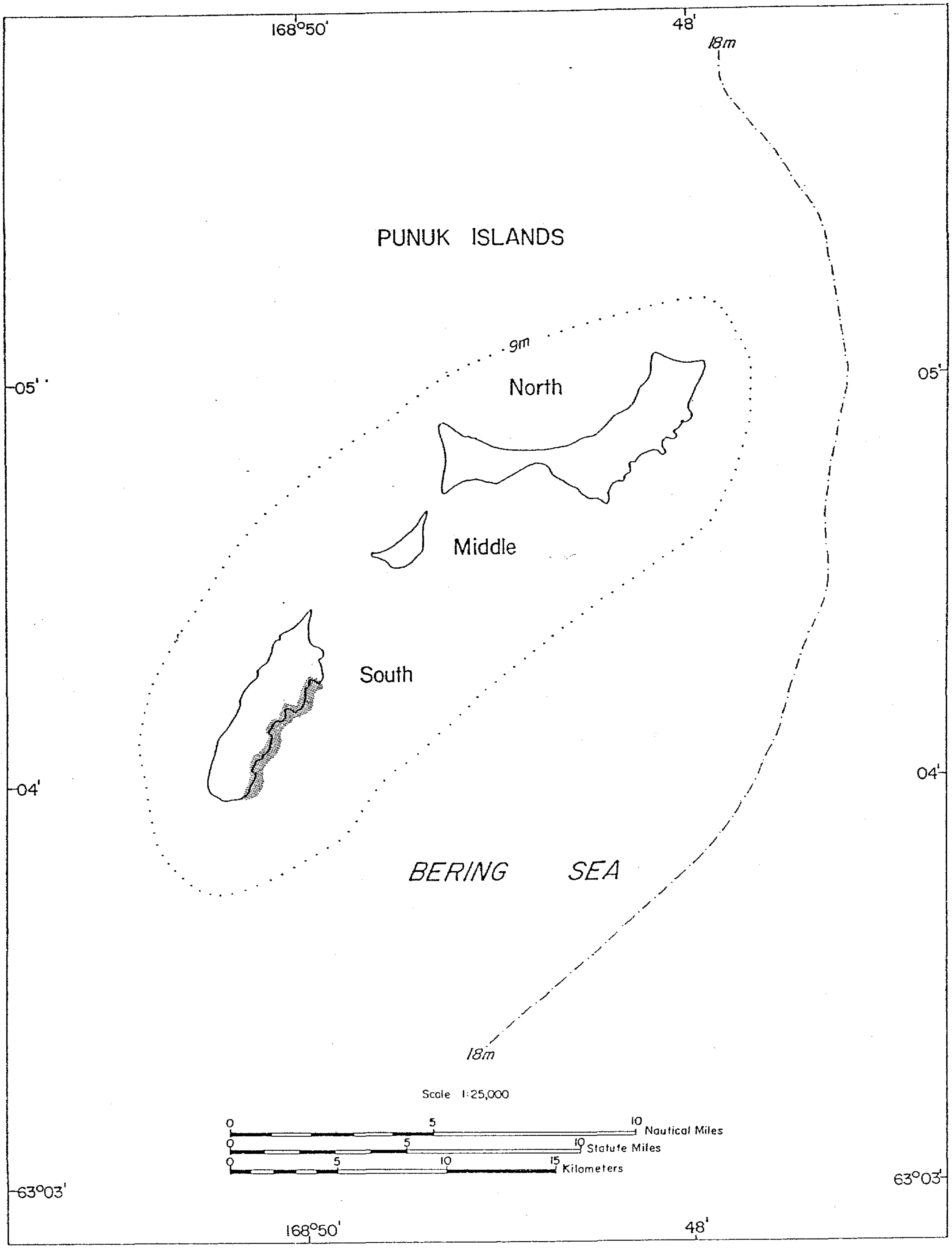



Figure 16. Cont'd.

**APPENDIX 4. DESCRIPTIONS AND MAPS OF HARBOR SEAL HAULOUT SITES IN THE EASTERN BERING SEA (Sources are many; see APPENDIX 7 for details).**

Table 4.1. Descriptions of harbor seal haulout sites in the eastern Bering Sea.

| Rookery | Physical Characteristics |
|---|---|
| Fox Islands | Harbor seals haul out at low to moderate densities at a number of locations in the Fox Islands, especially at low tide when more available haulout habitat is exposed. Small numbers of harbor seals may be seen hauled out at virtually any location in the Fox Islands and on Bogoslof Island, therefore, maps showing specific haulout sites have not been prepared. Recent reports include seals hauled out on rocks and ledges at the E end of Umnak I., on Bogoslof I., Unalaska I., Unalga I. (including The Babies), Akutan I., Akun I. (incl. Tangik I.), Tanginak I., Avatanak I., Tigalda I., Kaligagan I. and other rocks NE of Tigalda I., and on Ugamak and adjacent Round and Aiktak islands. Vertical relief at these sites varies considerably, but generally most sites on the larger islands are backed by bluffs and cliffs rising from 60 to over 500 m in height. Other sites on rocks and smaller islets are considerably lower in relief (1-10 m). Waters are very deep throughout the Fox Islands. The 200 m isobath is only 2-3 km N of Umnak, Unalaska and Akutan islands. Bogoslof I. lies within 10 km of the 2000 m isobath. The only relatively shallow areas (<18 m deep) in the Fox Islands are very nearshore (<1-2 km) on the N side of Umnak I., N of Avatanak I, around the rocks NE of Tigalda I., and S of Ugamak and Aiktak island. Most other areas are in waters much deeper than 60 m. |
| Unimak Island | |
| Cape Lapin | Harbor seals haul out on the rocks, ledges and islets (especially at low tide) at the Cape and immediately offshore from there. Vertical relief at the sites varies from 1-30 m, and the 18 m isobath is about 3 km from shore to the N. |
| North Creek | Seals haul out on rocks and ledges, especially at low tide. Vertical relief immediately behind this site varies from 3-30 m and waters are relatively shallow (<18 m) out to at least 5-7 km offshore. |

Continued...

Table 4.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| Cape Krenitzin | Harbor seals haul out on the extensive beaches and sandbars at Cape Krenitzin and nearby islands at the entrance to Bechevin Bay. Vertical relief in this area generally does not exceed 1-5 m and the waters within 6 km are generally less than 10 m; the 18 m isobath is about 7 km offshore (N) from this site. |
| Isanotski Islands | This site is situated on several very small islands located deep within Bechevin Bay, immediately E of Unimak Island. Vertical relief at the site is generally less than 1 m, depending on the condition of the tide. Water depth also varies with the tide, but is generally less than 1-3 m near the islands, also depending on the proximity to drainage channels. |
| Izembek Lagoon and Moffett Lagoon | This is an important haulout area for harbor seals in the Alaskan Bering Sea. Haulout sites in Izembek Lagoon (and contiguous Moffett Lagoon) are composed of a variety of mud and sand bars scattered throughout the area. One of the most heavily used areas is in the Moffett Point-Newmann Island area, at the NE entrance to Izembek Lagoon. Vertical relief at this location varies from 1-3 m and water depth varies (1-4 m) with tide conditions. |
| Amak Island and Sea Lion Rock | Harbor seals haul out primarily on a broad flat area of boulders and rocks on the S and E sides of the island, which are exposed at low tide. Nearby boulder beaches with intermittent gravel and sand also are used. Vertical relief varies from 1-3 m on the S side and up to 20-30 m on the E side. Water depth varies with tide condition (1-10 m). Harbor seals also haulout on nearby Sea Lion Rock, at the periphery of the rookery when northern sea lions are present and more widespread when sea lions are absent. |
| Cape Leiskof | This site is located about 55 km NE of Moffet Pt. Harbor seals haul out on rocks and ledges and sand and gravel bars exposed at low tide. Vertical relief behind this site is generally less than 5-10 m, and the 18 m isobath is relatively close to shore immediately offshore from this site (about 1-2 km). |
| Port Moller | This is a major haulout site for harbor seals in the Alaskan Bering Sea. They haul out on sand, mud and gravel bars primarily south and west of the entrance to |

Continued...

Table 4.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | this embayment. Broad expanses of mud and sand flats exposed at low tide around the (1) Kudobin Islands, (2) at the entrance to nearby Nelson Lagoon, and (3) on the exposed tide flats around Deer Island (adjacent to Hagus Channel) are used extensively by harbor seals. Very little vertical relief is present at these sites (1-2 m) except near Deer Island (5-10 M), and water depth varies greatly with tide conditions and proximity to major drainage channels (1-10 m). |
| Cape Seniavin | This site is composed of rocks and boulders, many of which are exposed at low tide, and are backed by 30 m high cliffs. Narrow gravel and sand beaches on both sides of the Cape, backed by 30 m high cliffs, also are used as haulout sites by harbor seals. The 18 m isobath is located about 7 km from shore at this location. |
| Seal Islands (Ilnik) | This is a major haulout site for harbor seals in the Alaskan Bering Sea. The site is composed of a long stretch (over 25 km) of low sand and gravel barrier islands, and sand, gravel and mud flats and bars exposed at low tide. There is very little vertical relief in the general area (1-5 m). The 18 m isobath is quite close to shore on the seaward side of the islands (<1.5 km). Water depth varies greatly inshore (about 1-5 m), depending on tide conditions and proximity to drainage channels. |
| Port Heiden | This is a major haulout site for harbor seals in the Alaskan Bering Sea. They haul out on the sand bars and spits and exposed mud and sand flats from Strogonof Pt. to Chistiakof I. and adjacent areas. Vertical relief is very low in this area--generally less than 1-3 m, and water depth varies from less than 1 m to over 3 m, depending on tide condition and proximity to drainage channels. The 18 m isobath is 5-6 km offshore from the entrance to the Port Heiden estuary. |
| Cinder River | This had been a major haulout site for harbor seals in the eastern Bering Sea. The most extensively used areas were the tidal flats offshore from the mouth of the river. Vertical relief in the area is generally less than 2 m, and water is shallow (<18 m) out to about 20 km from shore. |

Continued...

Table 4.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| Ugashik Bay | This is an important haulout area for harbor seals. The shallow sand and mud bars in the estuary south of South Spit and Smokey Pt., as well as the shallow bars and spits offshore from the estuary that are exposed at low tide are used extensively by harbor seals. Vertical relief in the area is generally less than 1-3 m, and the 18 m isobath is about 20 km offshore. |
| Egegik Bay | This series of sites is situated on the sand, mud and gravel bars, spits and flats in and immediately offshore from the Egegik River estuary at the mouth of the King Salmon and Egegik rivers. Vertical relief near most sites generally varies from 1-3 m and water depth is generally less than 10 m throughout the area. The 18 m isobath is at least 20 km from shore in this area. |
| Deadman Sands | This site is located midway along the north coast of Kvichak Bay, in NE Bristol Bay near the mouth of the Kvichak River. Harbor seals haul out on the sand, mud and gravel bars and beaches, especially at low tide when extensive areas are exposed. Vertical relief in the area is generally less than 1-3 m, and water depth varies generally between 1-3 m depending on tidal conditions and proximity to drainage channels. |
| Cape Constantine | Harbor seals haul out on sand, mud and gravel flats and beaches generally W and N of Cape Constantine. Vertical relief in the area is generally less than 10 m immediately along the coast and much less (<1-2 m) farther from shore, depending on tidal conditions. Waters are generally less than 1-3 m deep for several km away from shore; the 18 m isobath is about 10 km offshore all along this section of coast. |
| Tvativak Bay | Harbor seals haul out on the sand and mud flats in the bay and on the sand and mud flats SE of the bay along the coastline. Vertical relief near the entrance to the bay varies from 3-15 m with a high point (300 m) about 1 km inland E of the bay; along the coastline SE of the bay, vertical relief is around 3-5 m. The 6 m depth contour is probably no more than 2-3 km from shore and the 18 m contour is 25 km SW of this site. |
| Black Rock | Harbor seals haul out on the gravel beaches and rocks around the perimeter of this small island. Vertical relief is about 40 m at this site and the 6 m depth |

Continued...

Table 4.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | contour is about 1-2 km from shore. Small numbers of harbor seals (2-38) also haul out on nearby High Island, Round Island, Crooked Island, The Twins and Summit Island. However, the exact locations and numbers at each site are unknown, therefore no maps were prepared for these sites (see p. 167 for locations of these islands). |
| Hagemeister Island | Harbor seals haul out on the gravel beaches and rocks in the Clam Point area at the south end of the island. Vertical relief behind the site is over 500 m, and the water is deep (over 30 m) immediately offshore (within 200 m) from the site. |
| Nanvak Bay | This is an important haulout area for harbor seals in the Alaskan Bering Sea, and is one of the northernmost pupping areas for this species in the Bering Sea. They haul out on a series of low sand and mud bars exposed during low tide in the main channel leading from Nanvak Bay. Vertical relief is normally less than 1 m and water depth varies (1-3 m) depending on tide conditions. Early in the season spotted seals also haul out at this site; a small proportion of seals at this site during summer also are spotted seals. |
| Cape Newenham | Harbor seals haul out on the rocks, ledges and beaches at Cape Newenham and on nearby islets. Vertical relief at the Cape is about 20 m (low bluffs) and water depth is over 30 m about 3 km from shore. |
| Chagvan Bay | Harbor seals (and spotted seals in spring) haul out on sand, mud and gravel bars at the entrance to Chagvan Bay, and along tidal channels in the bay itself. Vertical relief in the area is generally less than 2 m and water depth in the bay and nearshore is very shallow (1-3 m), depending on tidal conditions and proximity to drainage channels. The 18 m isobath is about 16-18 km (W) from shore. Harbor seals have also been reported to haul out off the mouth of Goodnews bay. However, the exact proportion of harbor vs. spotted seals is unknown. No map of Goodnews Bay has been prepared. |
| Quinhagak | Harbor seals haul out on beaches and sand and mud flats exposed at low tide at the mouth of the Kanektok River. Vertical relief in this area is generally less than |

Continued...

Table 4.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | 1-10 m, depending on distance from shore and tidal conditions. Water depth near shore is generally less than 3 m; the 18 m isobath is over 40 km from shore at this site. |
| Kuskokwim Bay | This is an important haulout area for harbor seals in the Alaskan Bering Sea. The seals haulout on a series of sand/mud bars at the mouth of the Kuskokwim R., especially at low tide. During spring, virtually all seals at this site at spotted seals; during July through freeze-up harbor seals are at this site. Vertical relief is normally less than 1 m and water depth varies with the tide (1-3 m). This is thought to be the most northerly haulout site in the eastern Bering Sea where harbor seal pups are born. |
| Islands off Cape Avinof | The low sand and gravel islands and associated bars and mudflats off Cape Avinof (about 60 km W of Kwigillingok) are used by both spotted seals (spring) and harbor seals (summer). In particular, the Kwigluk Islands, Pingurbek Island, Kikegtek Island and Krekatok Island are used by harbor seals from July to freeze-up. However, the exact numbers of animals using these sites and sites farther north off Baird Inlet are unknown. |
| Kongiganik/ Kwigillingok | Theses haulout sites are located midway along the north coast of Kuskokwim Bay. Seals haul out on sand, mud and gravel beaches and flats exposed at low tide. Vertical relief in the area is generally less than 10 m along the coast. Water depth is variable depending on tidal conditions (1-5 m nearshore); the 18 m isobath is over 40 km (S) from shore. |
| Nunivak Island | |
| Cape Mendenhall | This haulout site is located on the rocks, islets and protected beaches in the vicinity of Cape Mendenhall. Vertical relief at the Cape is about 75 m; adjacent to this area relief is generally less than about 20-30 m. The 18 m isobath is located about 2-5 km from shore to the S and W, |

Continued...

Table 4.1. Concluded.

| Rookery | Physical Characteristics |
|---|---|
| | but the area to the E is considerably shallower (<18 m throughout). |
| St. George Island | |
| Near Dalnoi Pt. | Harbor seals haul out on rocks, ledges and beaches all around the Pribilof Islands, however, the site near Dalnoi Pt., at the extreme W end of St. George Island, often supports more than just a few animals. Vertical relief in this area is generally less than 10 m and waters are generally deep; the 18 m isobath is less than 100 m from shore at Dalnoi Pt. |
| Otter Island | Virtually all of the perimeter of this small rocky island (0.08 $km^2$) is used by harbor seals for hauling out. Boulder beaches, reefs and offshore rocks are dominant substrates. The E end of the islet is generally of low relief (<3-5 m), with the exception of a pinnacle rising to about 45 m. The W end of the islet rises to about 80 m and water depth within 2 km of the island is less than 40 m. |

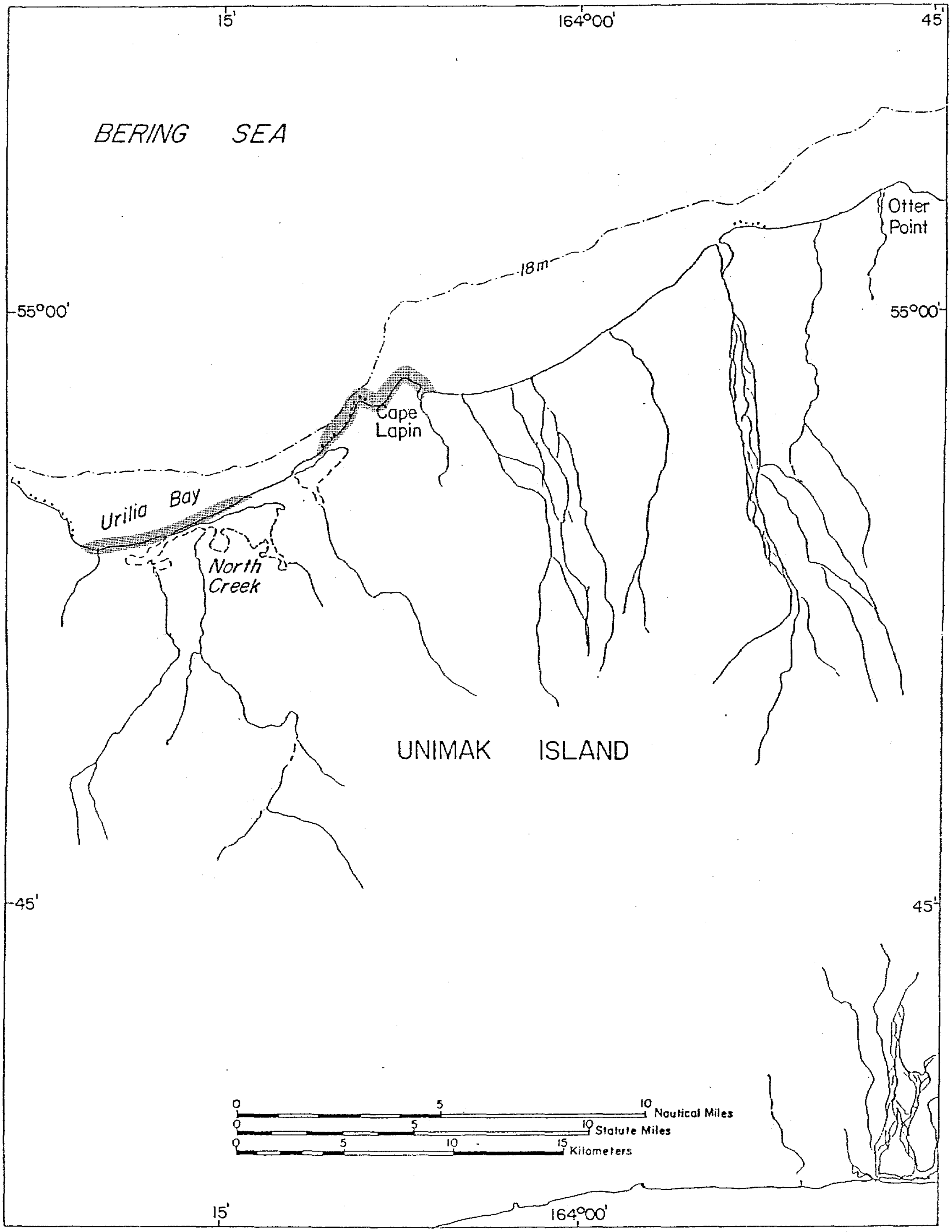
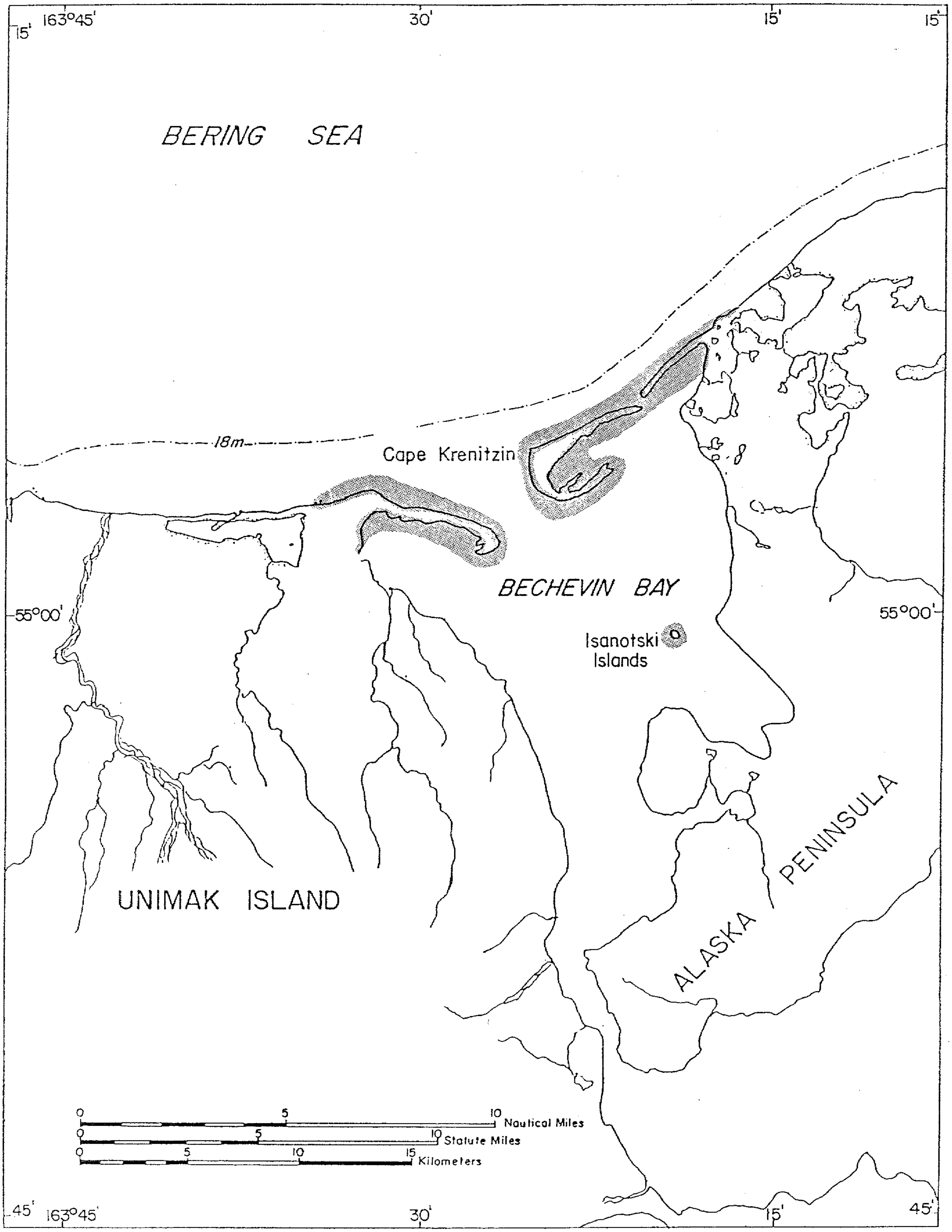



Figure 17. Maps of important harbor seal haulout sites in the Bering Sea, Alaska. Maps are at a scale of 1:250,000.

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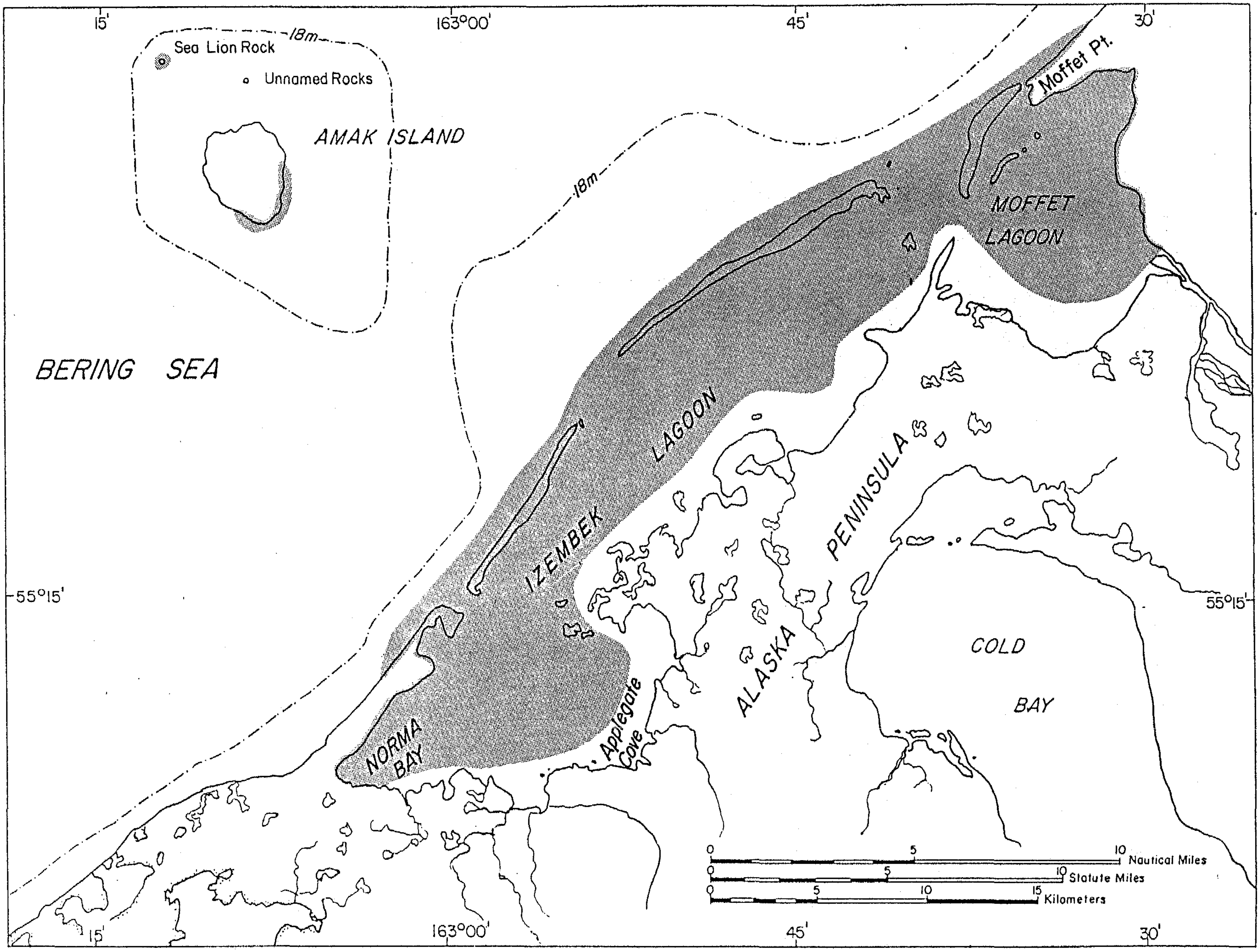


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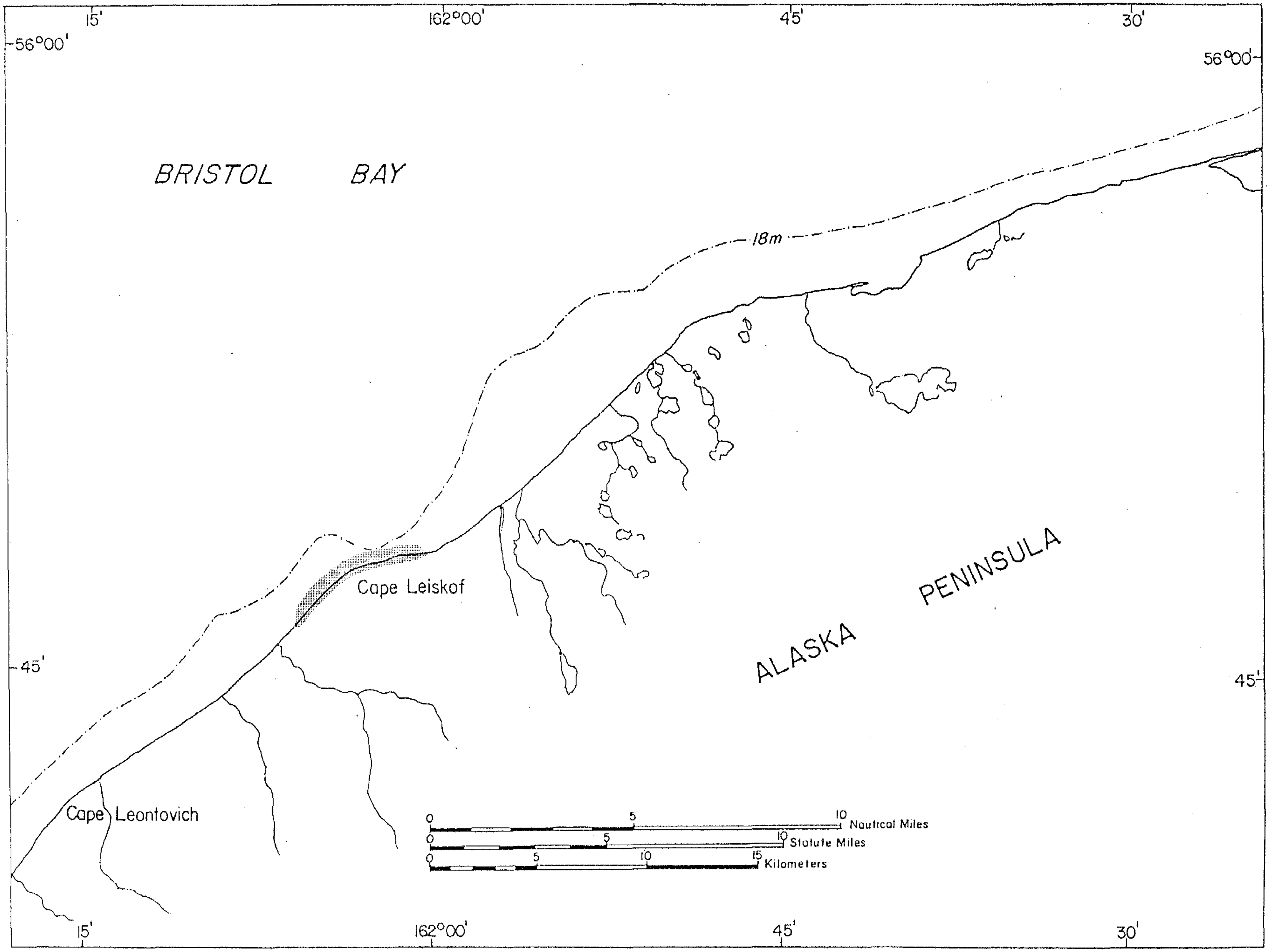


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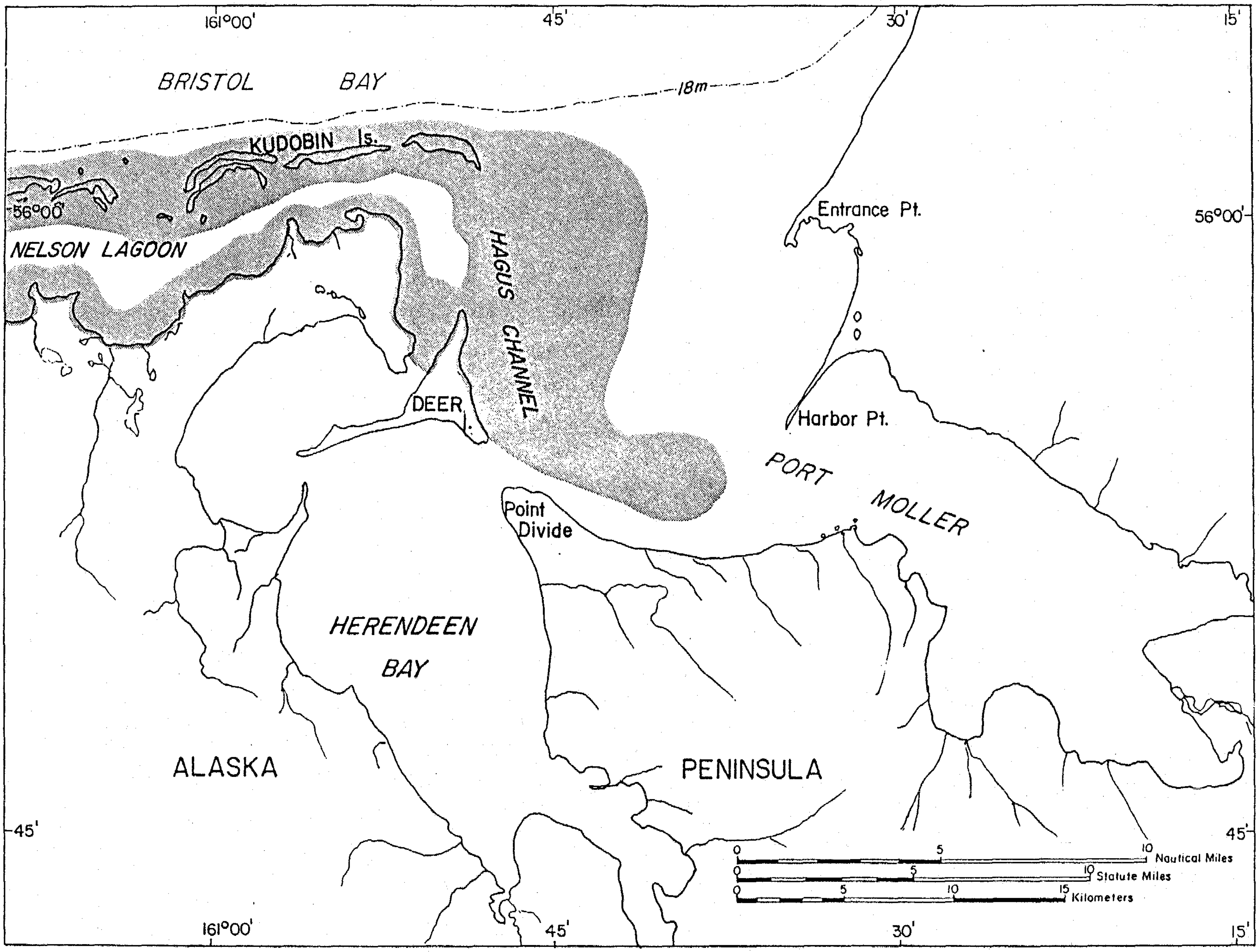


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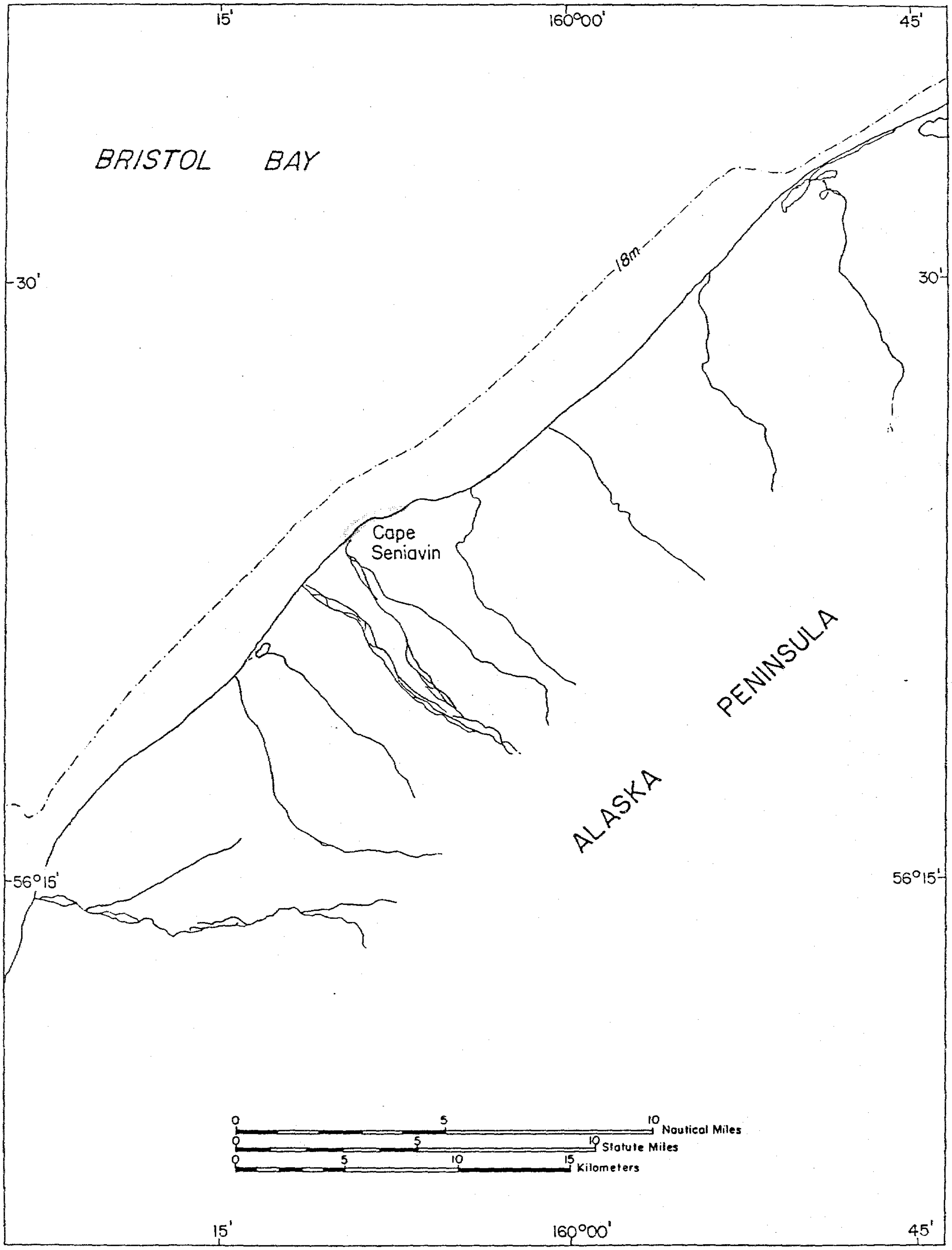


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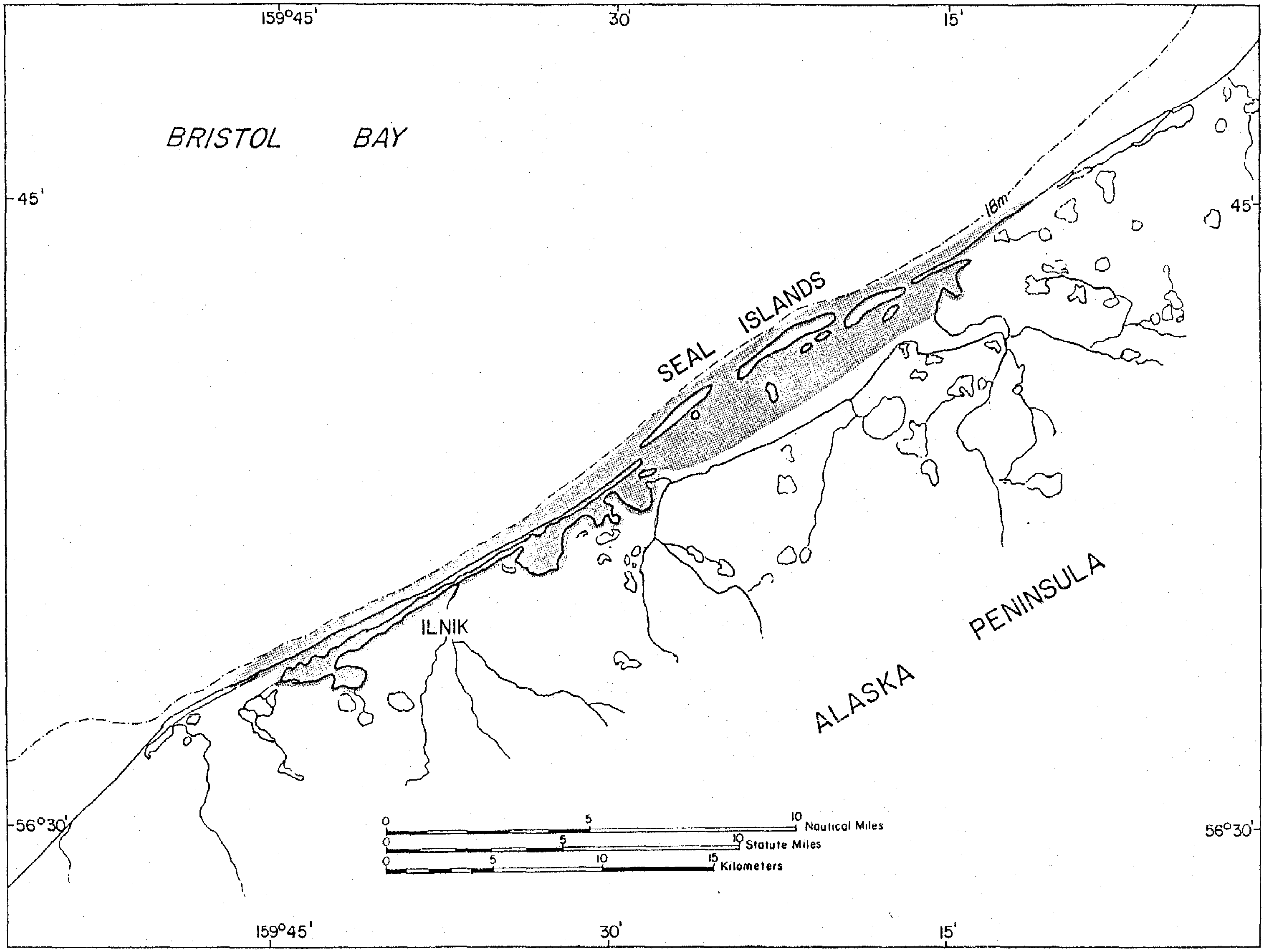


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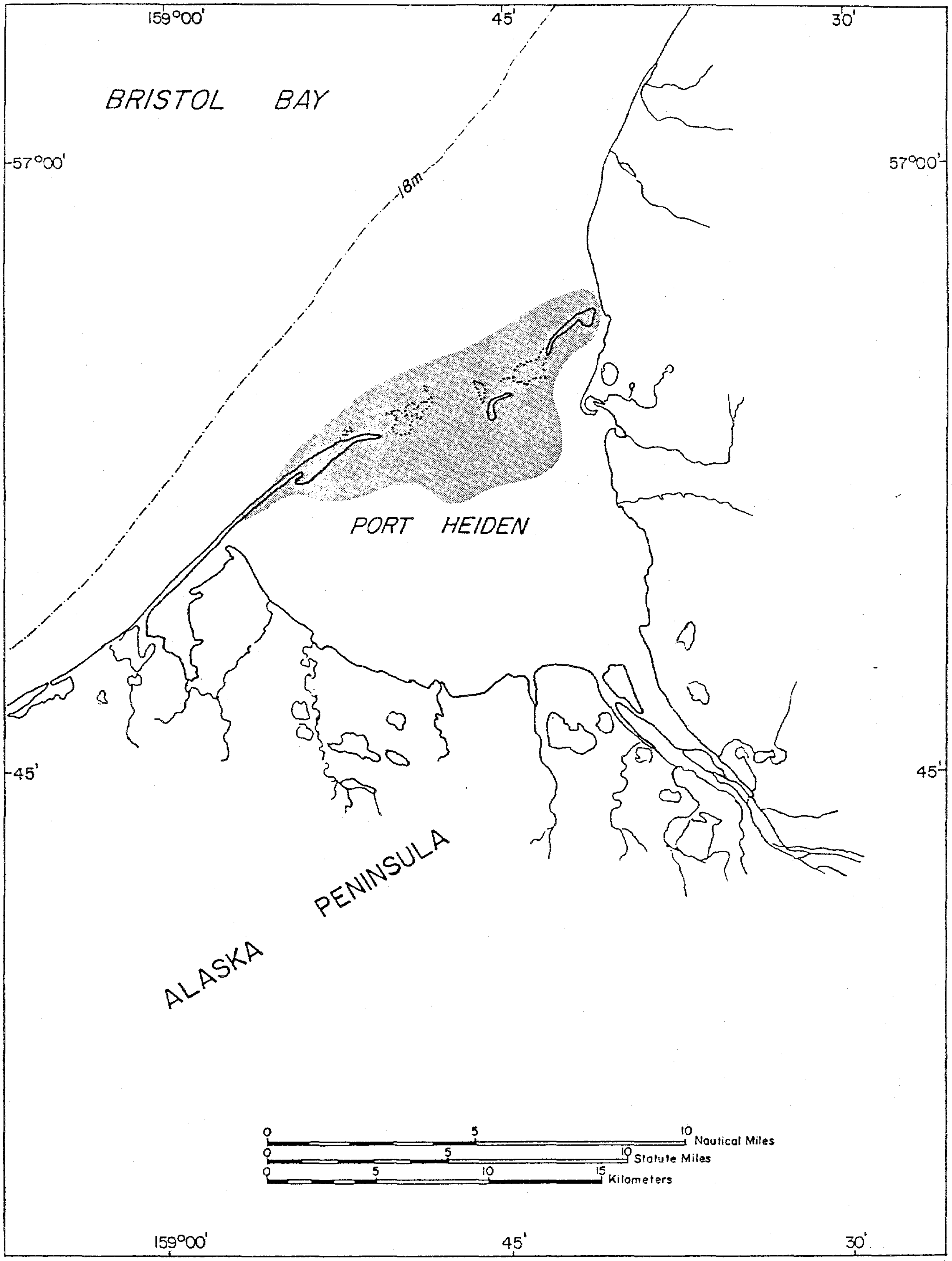


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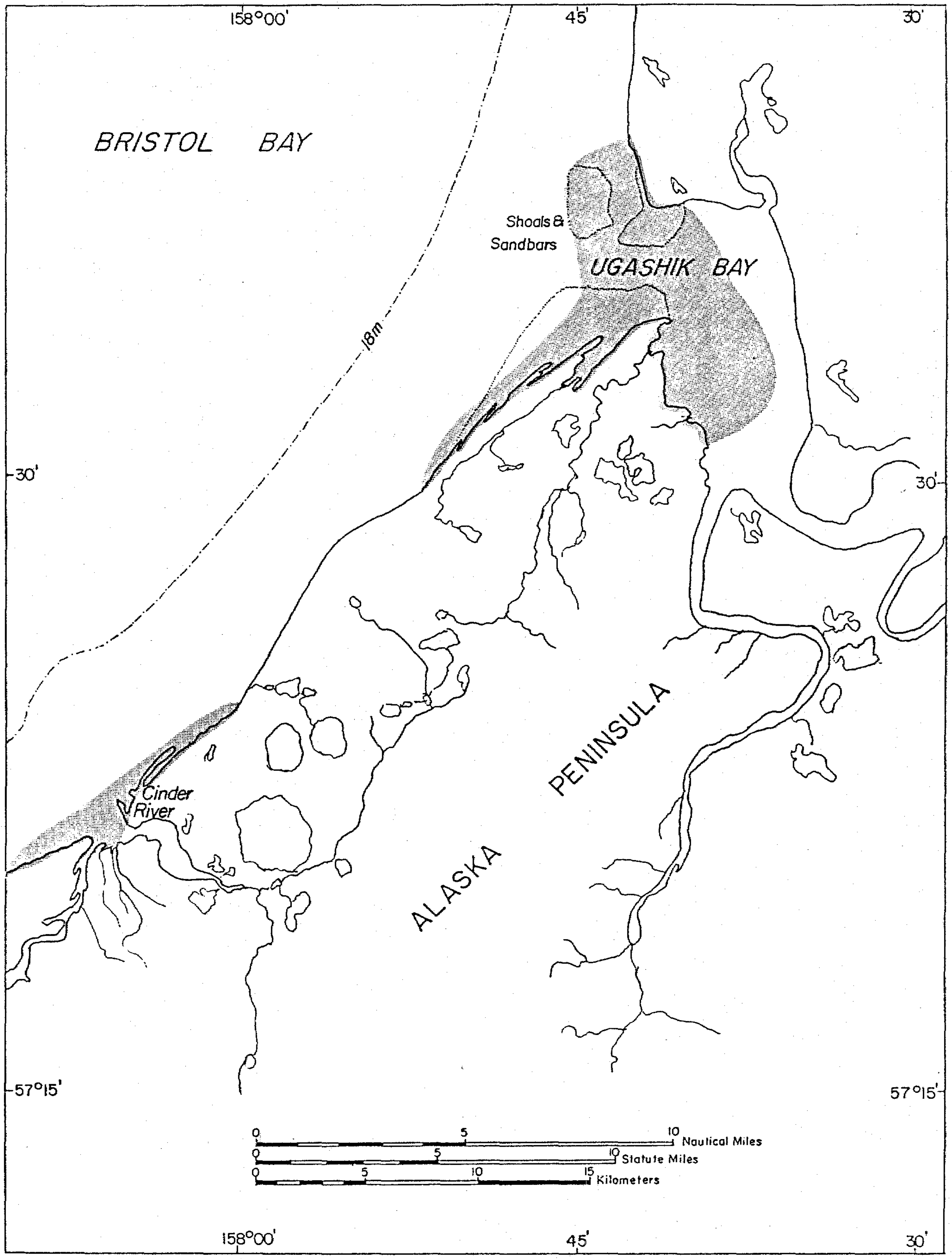


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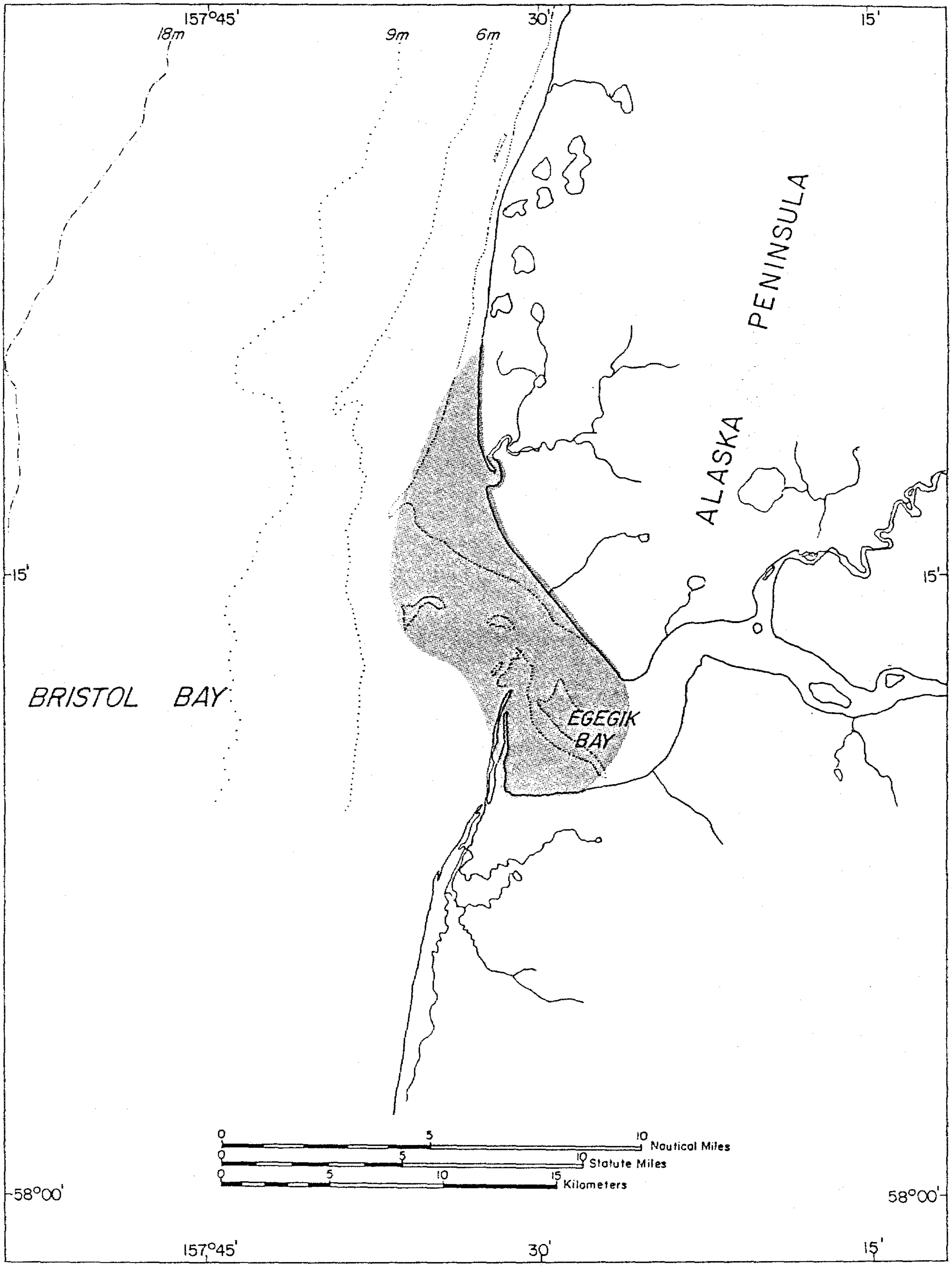


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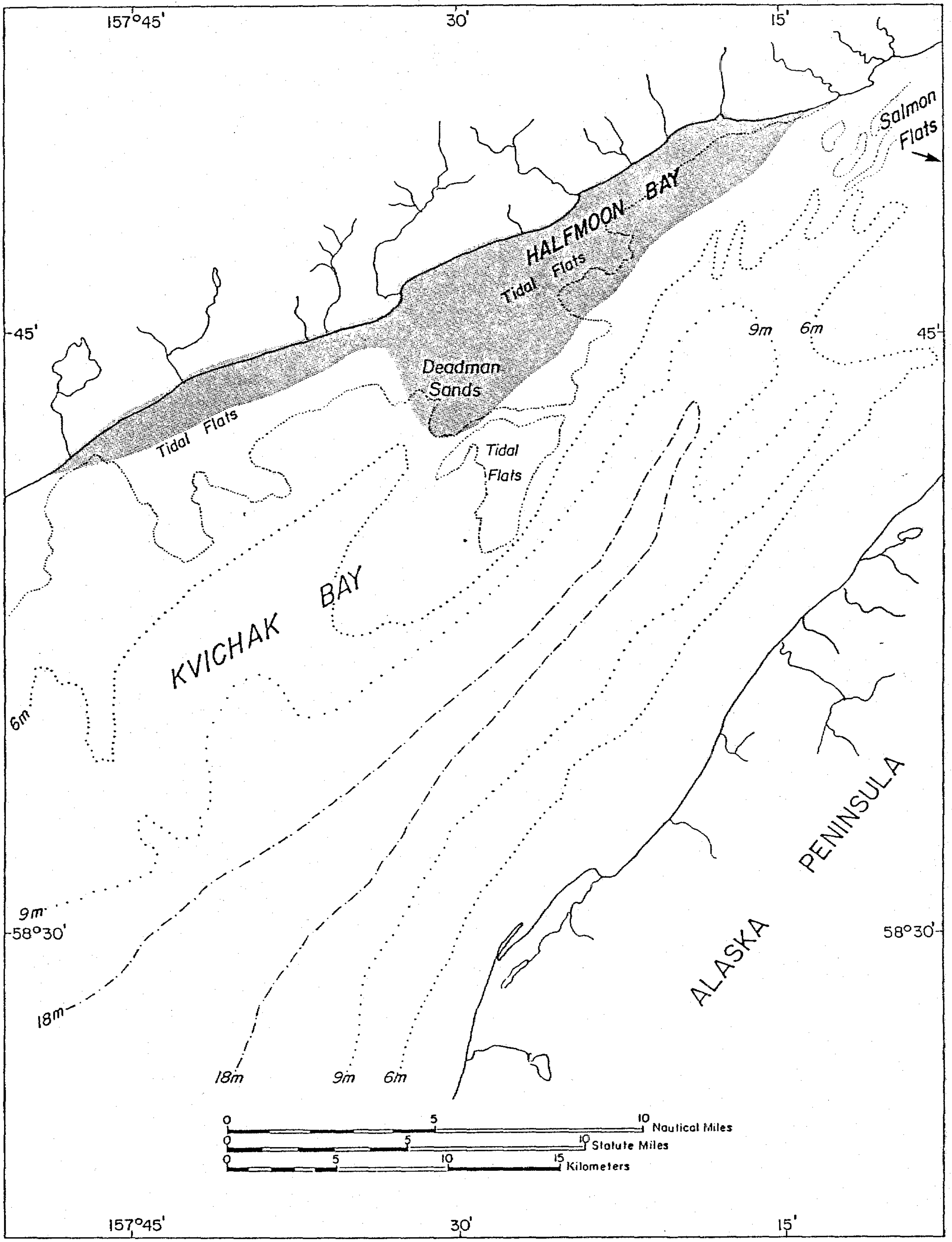


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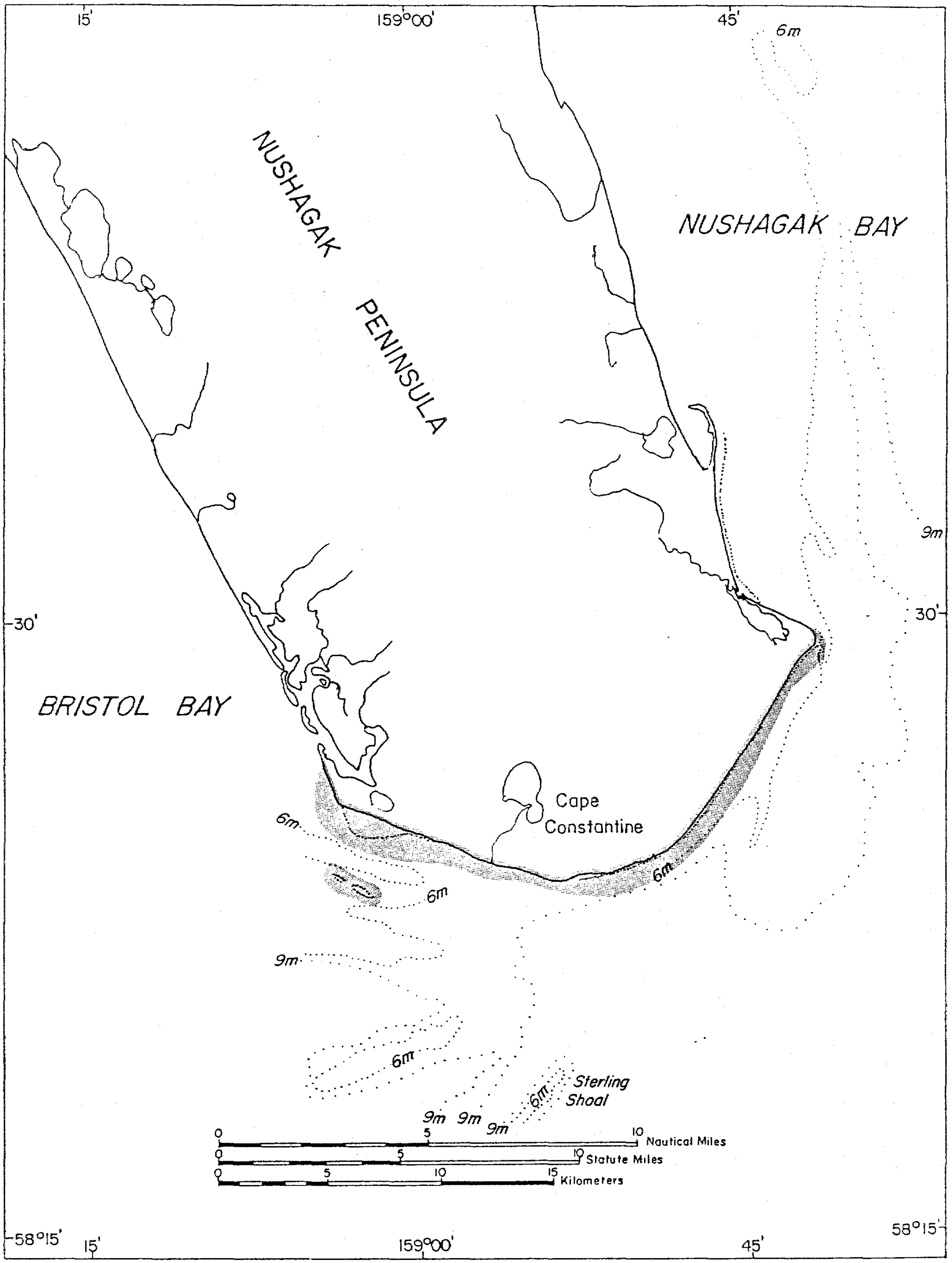


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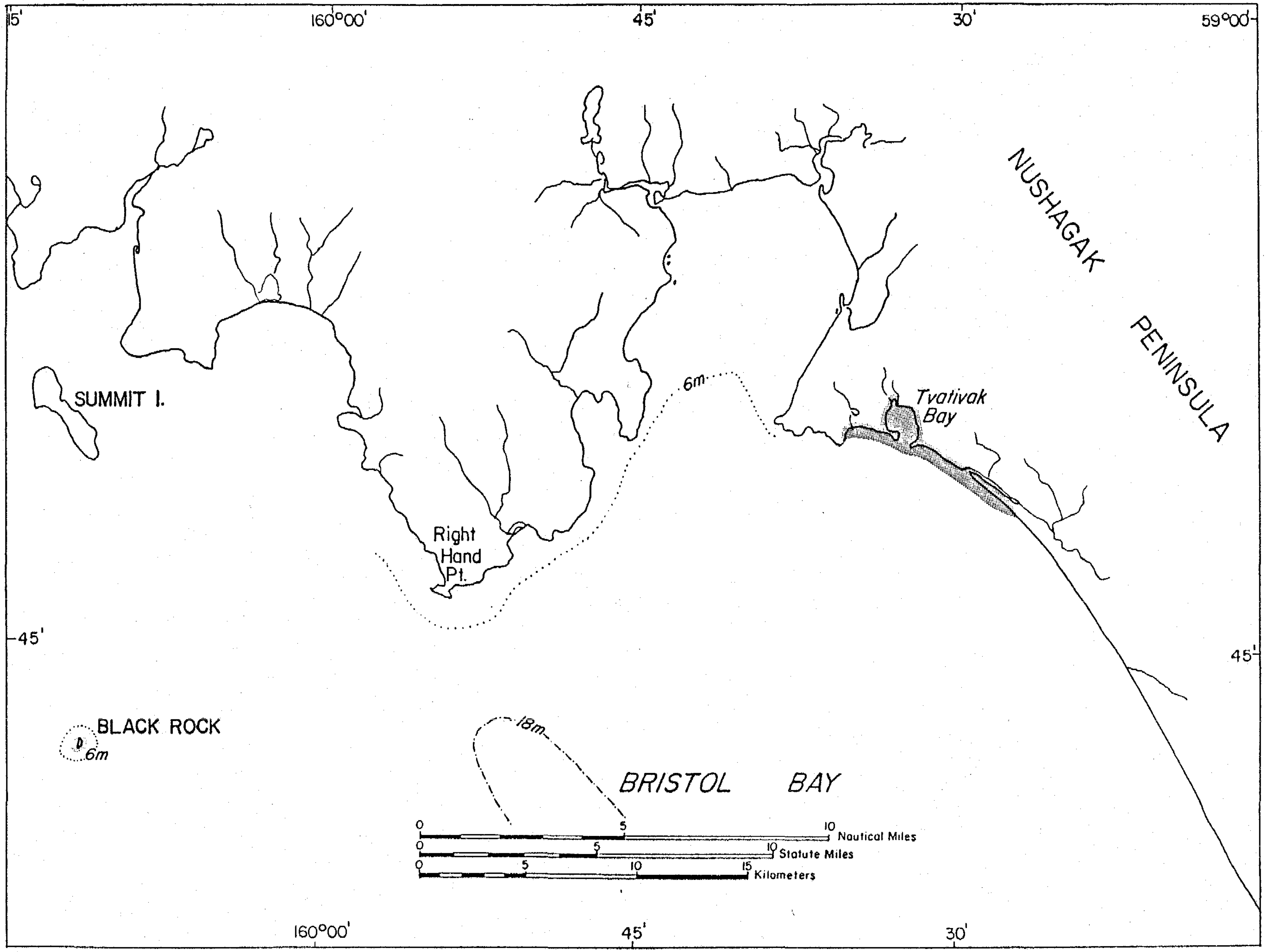


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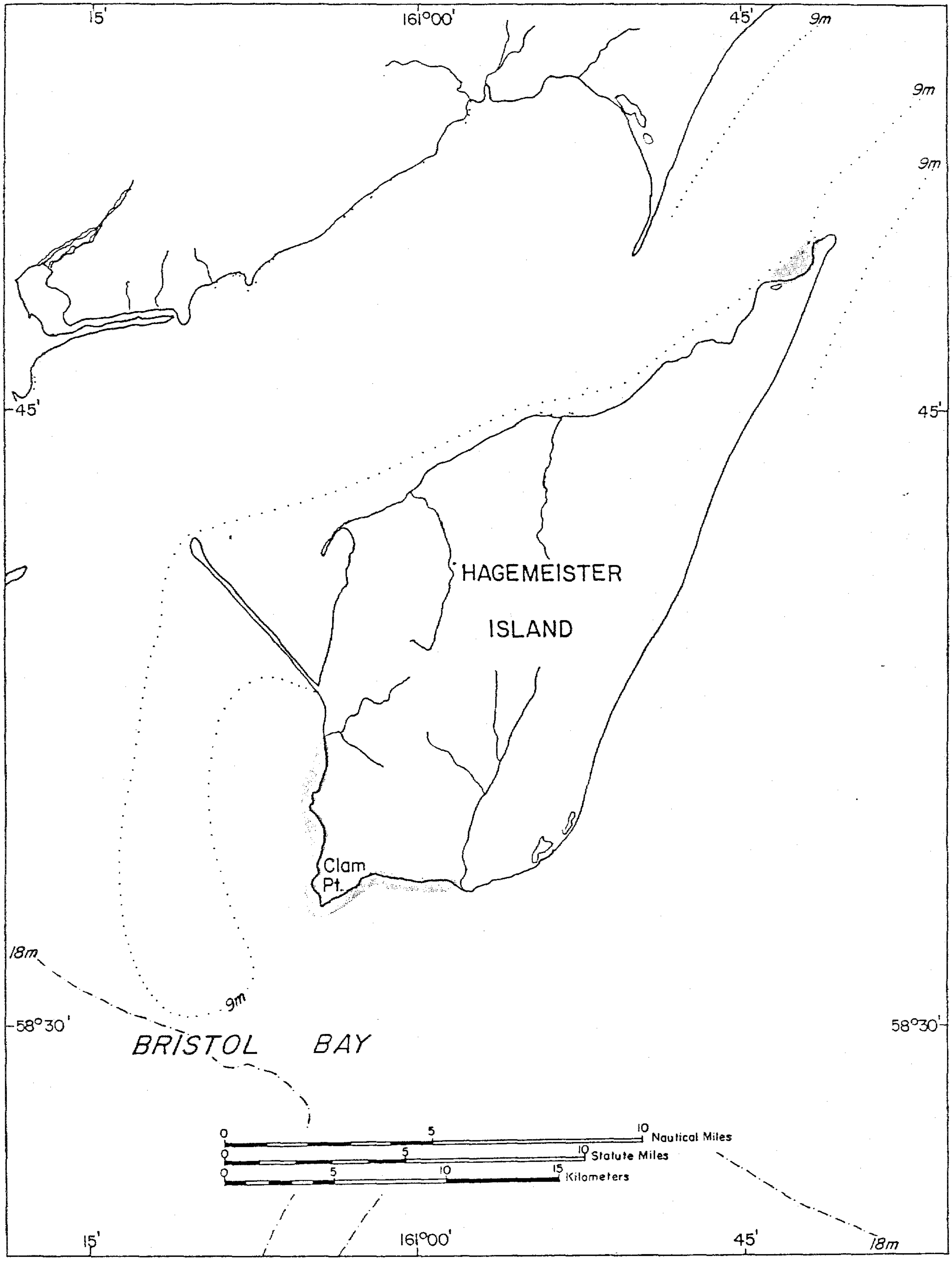


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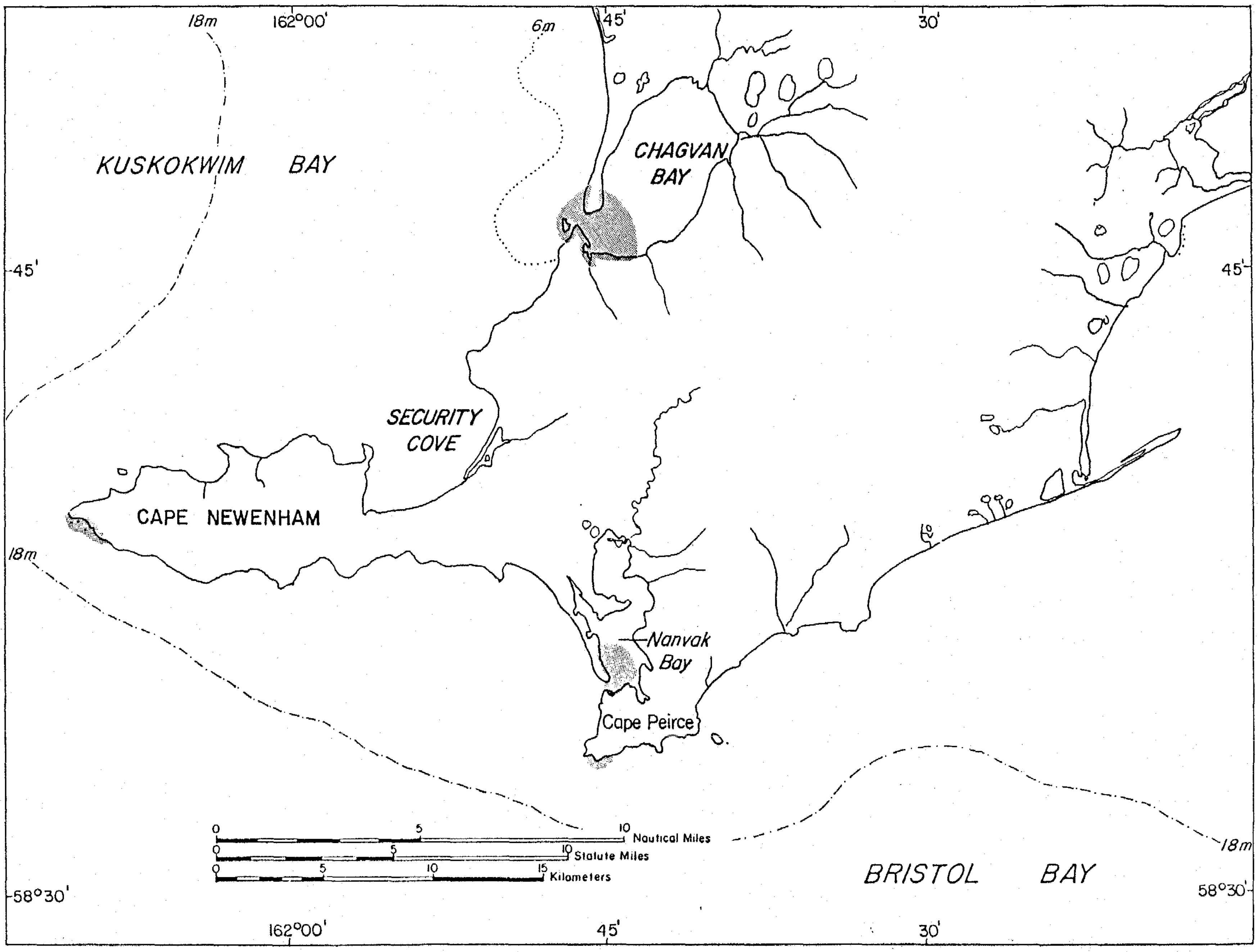


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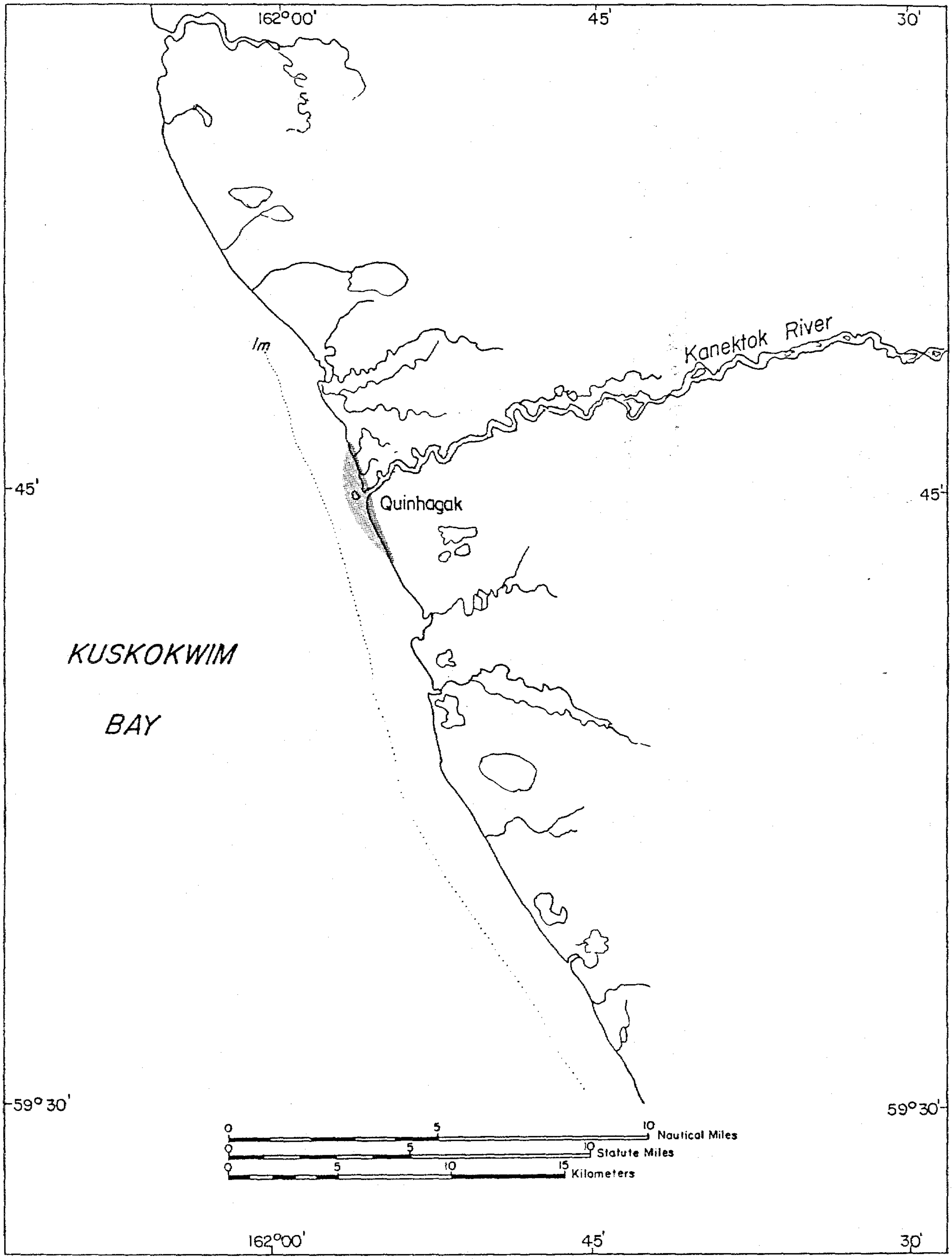


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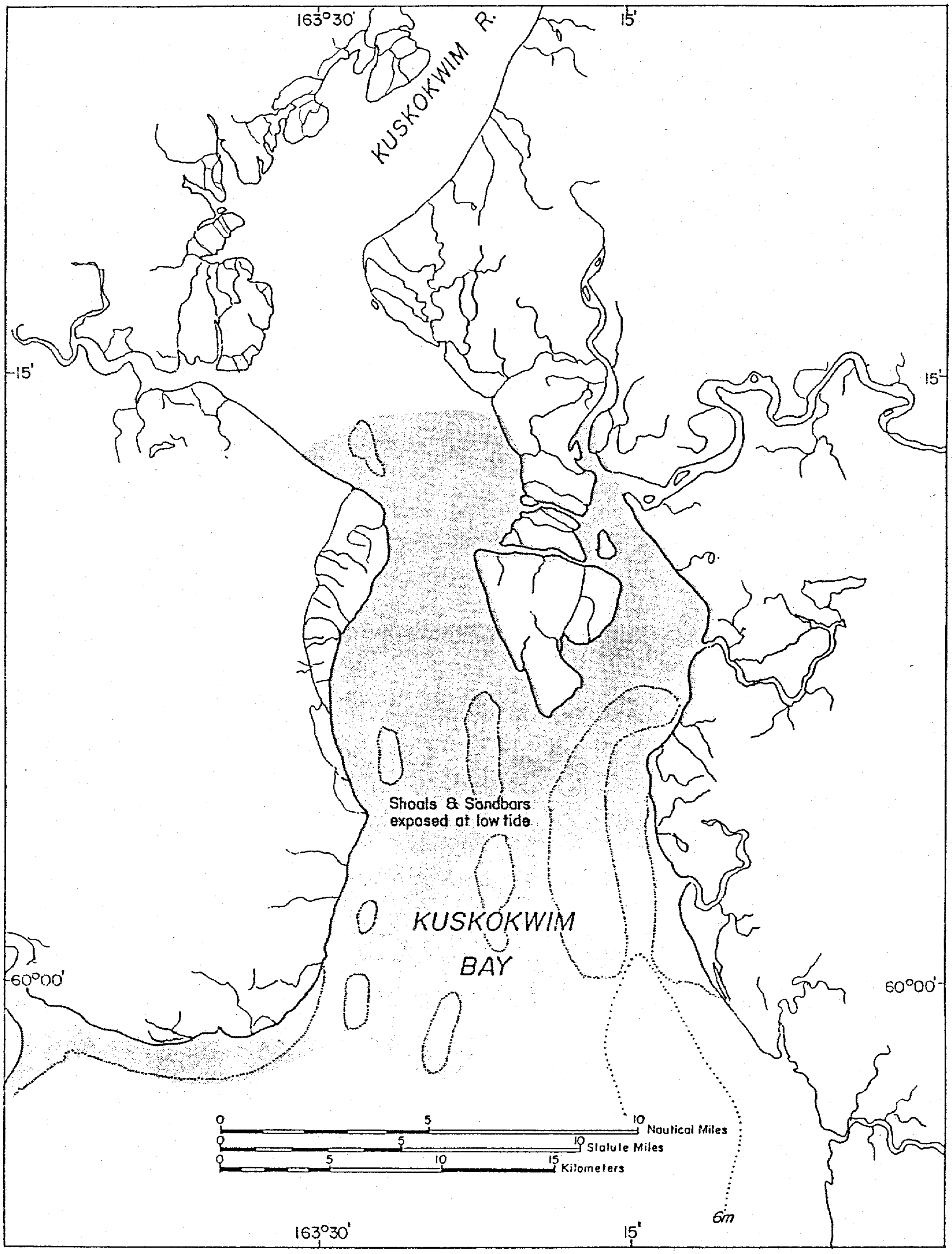


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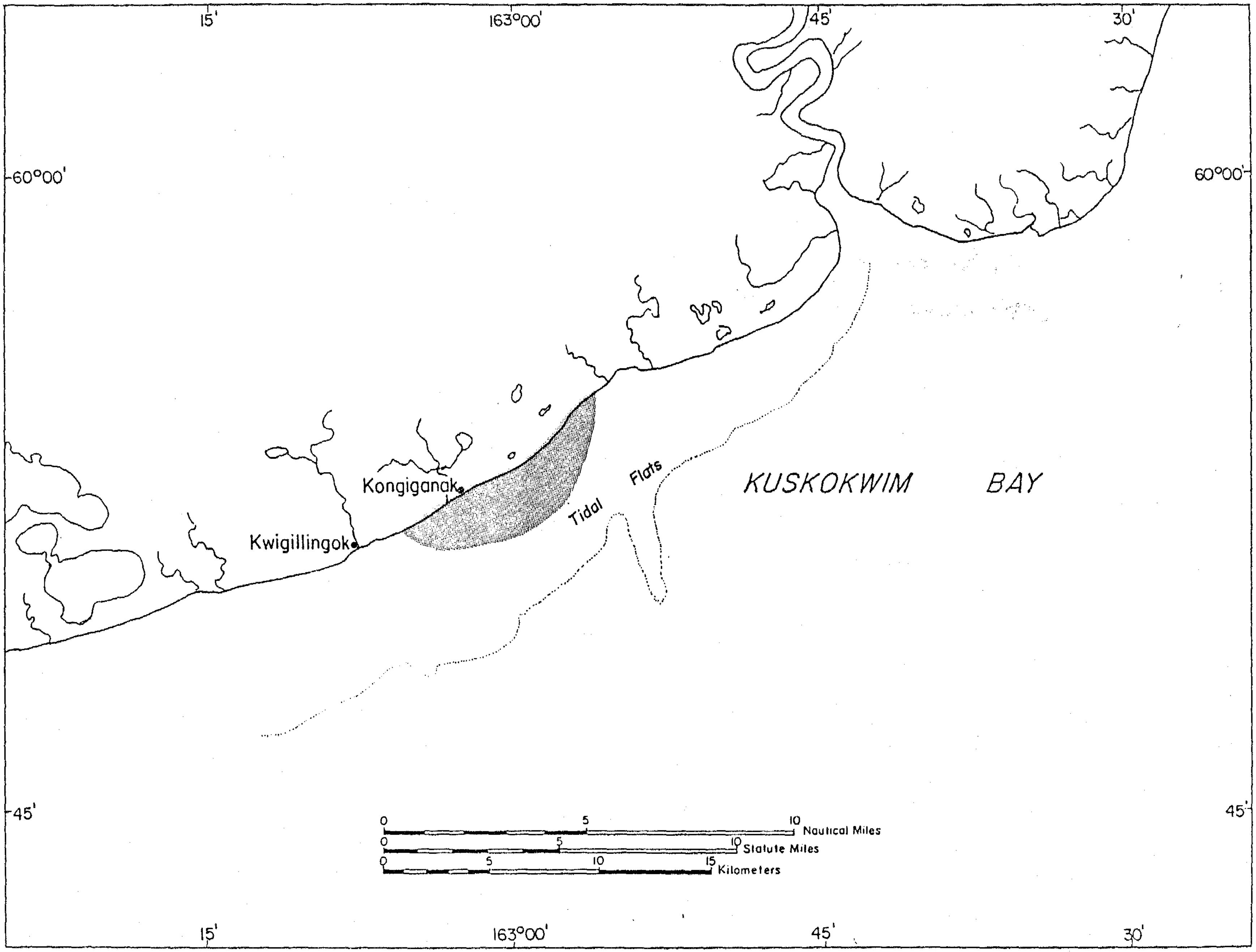


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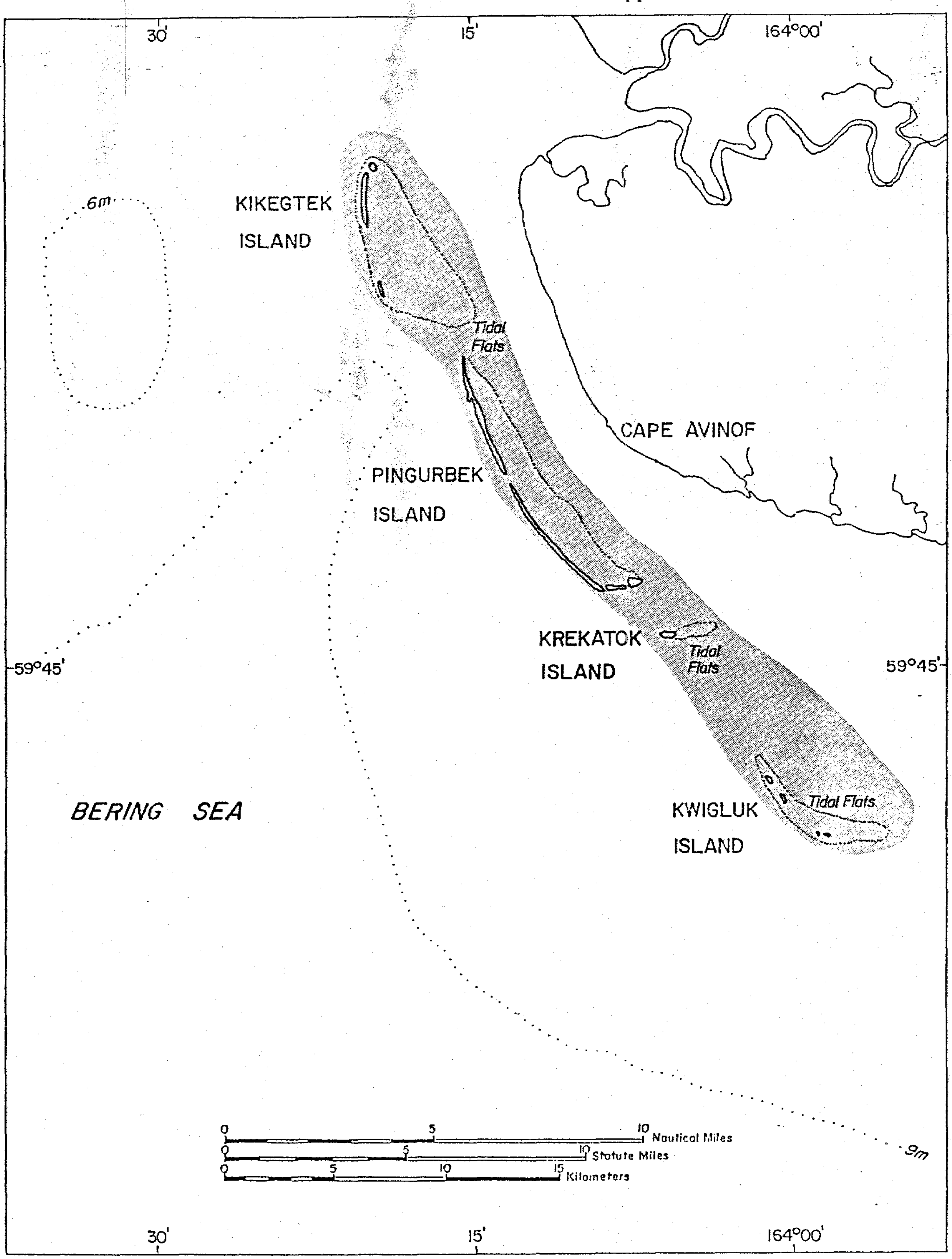


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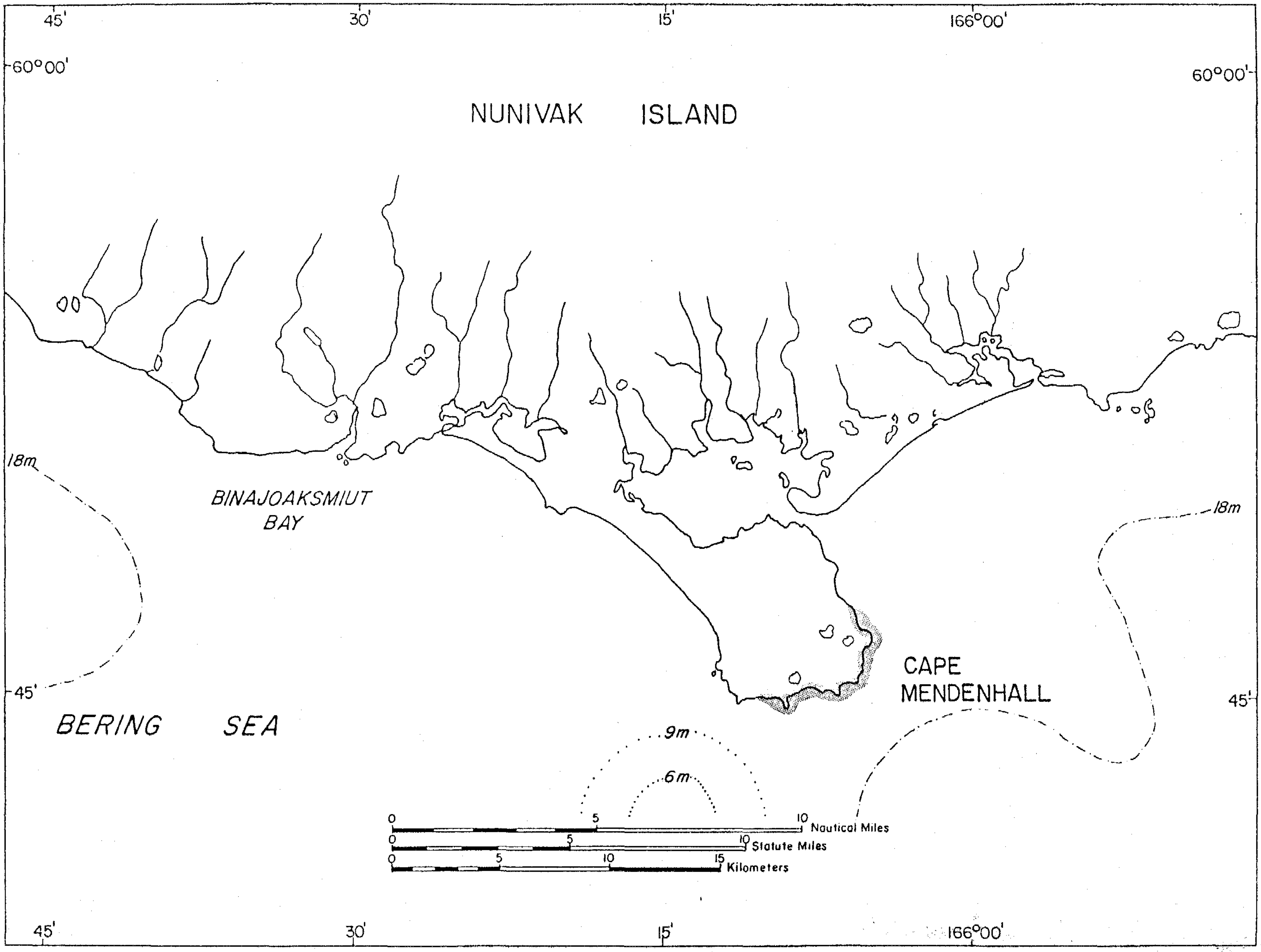


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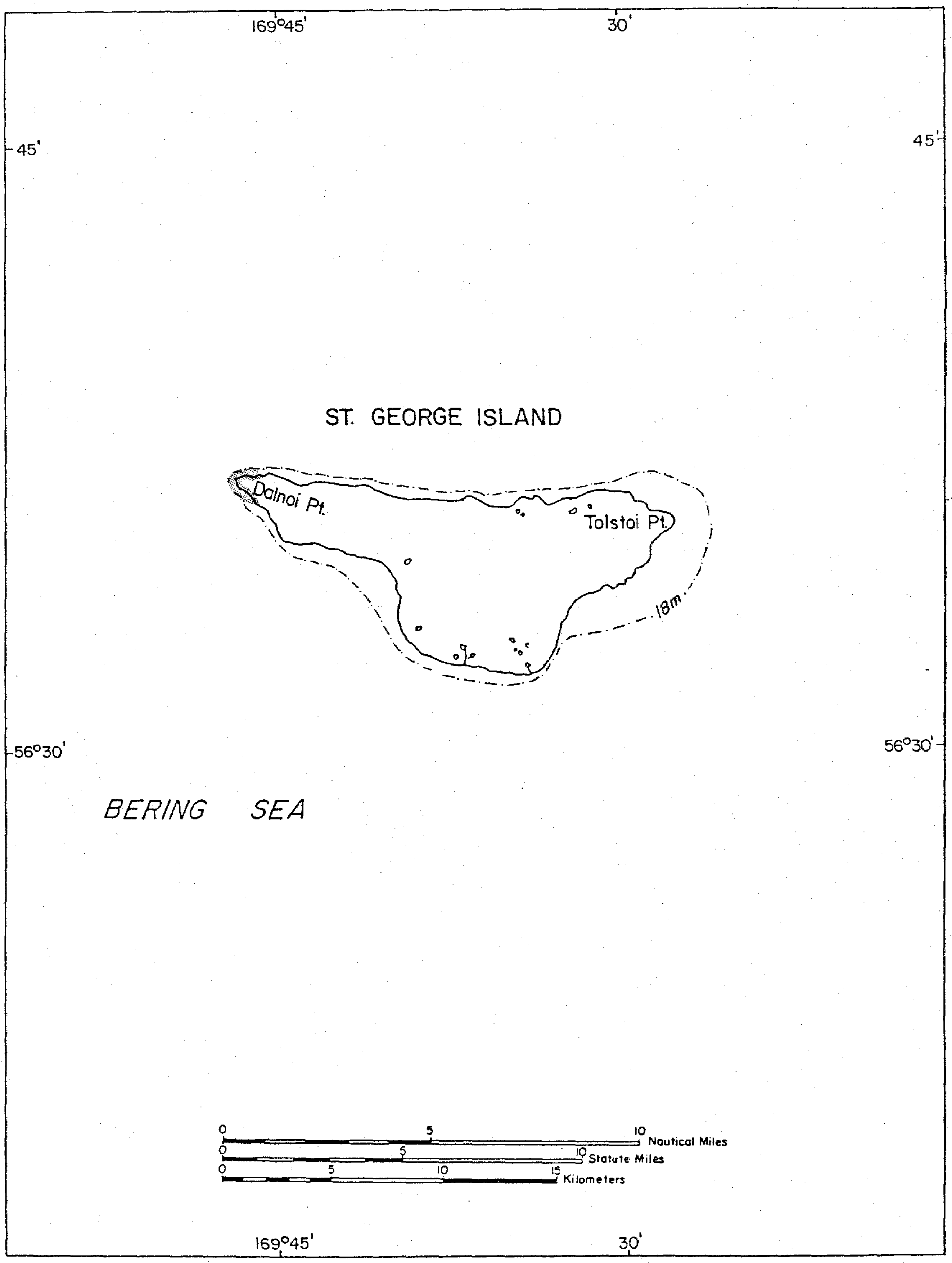


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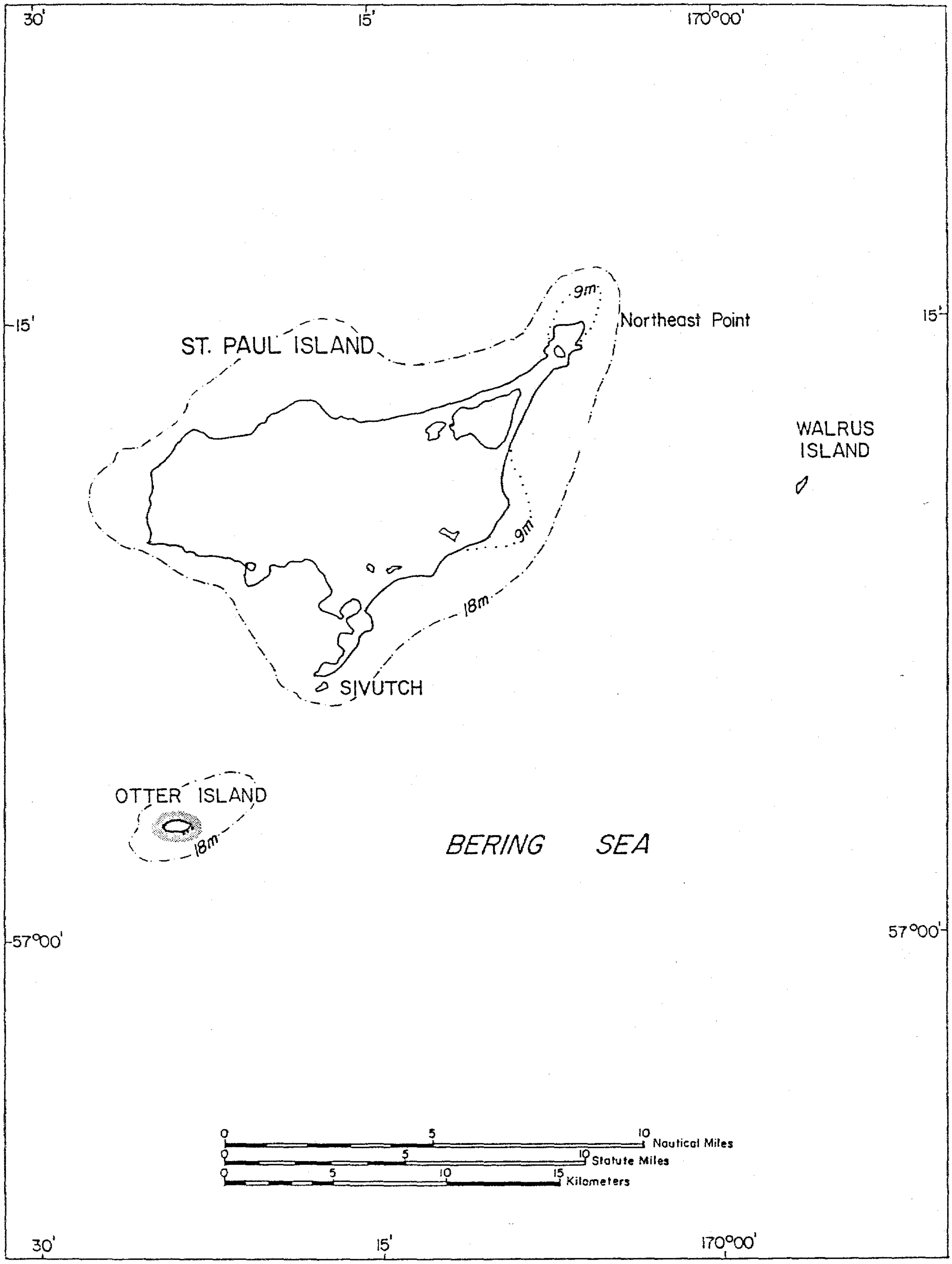


Figure 17. Cont'd.

**APPENDIX 5. DESCRIPTIONS AND MAPS OF PACIFIC WALRUS HAULOUT SITES IN THE EASTERN BERING SEA (Sources are many; see APPENDIX 8 for details).**

Table 5.1. Descriptions of Pacific walrus haulout sites in the eastern Bering Sea.

| Rookery | Physical Characteristics |
|---|---|
| Amak Island | Walruses haul out on the coarse gravel and rocky beaches on the NE side of this island. The beaches are relatively narrow (3-10 m), the vertical relief behind the site is over 500 m and the 18 m isobath is about 7.5 km offshore from the site. |
| Port Moller | In the past walruses have consistently hauled out on the beach near Wolf Pt. on Walrus Island, at Entrance Pt., Bear River (about 15 km up the coast from Entrance Pt.), Harbor Pt., on Deer Island and Point Divide. Vertical relief is these areas varies from 1-5 m except in major channels, depending on tide conditions, and water depth is generally less than 5 m; the 18 m isobath is over 7 km N of Walrus I. and over 25 km N of Harbor Pt. |
| Cape Seniavin | Walruses haul out on the gravel and sand beaches at this site. Vertical relief behind the 3 to 10-m-wide beaches varies from 5-20 m, and the 18 m isobath is about 4 km offshore. |
| Port Heiden | Walruses occasionally haul out on the beach near Strogonof Pt., at the western entrance to the Port Heiden estuary. Vertical relief in this area is about 1-3 m, and water depth offshore is generally less than 6 m out to about 1.5 km; the 18 m isobath is about 5 km offshore. |
| Egegik Bay | Walruses have hauled out in recent years on the sand and gravel spits and bars at the entrance to Egegik Bay. Vertical relief near these sites generally varies from 1-3 m and water depth is generally less than 10 m throughout the area. The 18 m isobath is at least 20 km from shore in this area. |
| High Island | Walruses haul out on the rocky boulder strewn beaches on this relatively large island in the Walrus Island group. Vertical relief immediately behind the haulout sites is generally 10-50 m, however maximum relief is over 300 m at some sites on the island. Waters are shallow around this island (1-5 m out to 2 km from |

Continued...

Table 5.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | shore); the 18 m isobath is almost 40 km to the S of this site. |
| North Twin Island | North Twin Island is the northernmost of the Twin Islands, the southernmost of the Walrus Islands group in northern Bristol Bay. Walruses haul out on the gravel beaches and rocky slopes all around these islands. Vertical relief is 145 m. The 18 m isobath is <1 km north of the island and the 30 m isobath is <3 km from the island. |
| Round Island | This is a major terrestrial haulout site for walruses in the Alaskan Bering Sea. They haul out on the rocky beaches around the island. Vertical relief at most sites rises to about 300 m; the highest point on the island is about 400 m. Round Island is the farthest E of the Walrus Island group, which is generally situated in fairly shallow water (generally less than 10 m); the 18 m isobath is about 7 km E of the island. |
| Cape Peirce | In recent years, this site has regained prominence as a very important terrestrial haulout site for walruses. They haul out in two distinctly different habitats in the Cape Peirce area: along 2-4 km of extensive gravel and rocky beaches both N and S of Cape Peirce, and on the beaches and in the dunes near the entrance to Nanvak Bay. The rocky beaches vary in width from 3-20 m; vertical relief behind most of these sites is from 20-100 m and the 18 m isobath is about 5 km from shore. Vertical relief on the beaches and in the dunes near the entrance to Nanvak Bay varies from 2-10 m and waters are generally very shallow adjacent to the site, i.e., <2 m except in the main channel that drains the Bay. |
| Cape Newenham | Walruses haul out on the rocky gravel beaches on the south side of the Cape Newenham peninsula, and at the cape itself. Vertical relief at the site generally varies from 10 to 50 m with maximum relief in this area being over 200 m. Water depth is less than 18 m out to about 4-5 km from shore around the Cape. |
| Security Cove | Walruses haul out on the wide gravel and sand beaches in Security Cove. Vertical relief behind the site is generally less than 5 m near the shoreline; waters are |

Continued...

Table 5.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | less than 5 m in the Cove and the 18 m isobath is about 18 km offshore to the NW. |
| Goodnews Bay | Walruses haul out on the gravel and sand beaches on the spits at the entrance to Goodnews Bay. Vertical relief at these sites is generally less than 3 m and waters are very shallow (<5 m) out to 2-3 km from shore; the 18 m isobath is about 35 km offshore to the W. |
| Kwigillingok | Walruses haul out on the gravel and sand beaches at this site. Vertical relief behind the site is generally less than 10 m and water depth is variable, depending on tidal conditions. In general, waters are only 1-5 m deep within 10-15 km from shore; the 18 m isobath is over 40 km (S) from shore. |
| Nunivak Island | |
| Mekoryuk | Walruses occasionally haul out on the beaches and shoals adjacent to the village of Mekoryuk on the N side of Nunivak I. Vertical relief in the area varies from 1-10 m and the 18 m isobath is over 15 km to the NW. |
| Cape Etolin | This haulout site is located about 6 km N of the village of Mekoryuk, on the far N side of Nunivak I. Walrus haul out on the gravel and sand beaches and rocky shores on and adjacent to the Cape itself. Vertical relief in the area varies from 1-10 m, depending on the exact location where the animals are hauled out. Waters are relatively shallow throughout the area N of Nunivak I. The 18 m isobath is over 10 km to the W and about 4 km to the E of this site. |
| St. Matthew Island | |
| Cape Upright | This site is located at the extreme SE end of St. Matthew Island, along gravel and rocky beaches at the base of 500 m high cliffs. The 18 m isobath is within 200 m from shore at this haulout site. |
| Lunda Bay | Walruses haul out along the narrow gravel beaches and rocky slopes at this series of sites. Vertical relief varies considerably (30-250 m) depending on the exact location along this section of coast where the |

Continued...

Table 5.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| | walruses have hauled out. Nearshore water depth is generally deep at this site; the 18 m isobath is about 1-2 km from shore to the N. However, the area to the E of Lunda, near Lunda Pt., is relatively shallow; the 18 m isobath in this area is about 6 km offshore. Some walruses occasionally haul out 10 km W of Lunda Bay, along a section of beach that separates a large freshwater lake from the sea; relief in this area is less than 5 m, and the 18 m isobath is only about 1 km offshore at this location. |
| Cape Glory of Russia | Walruses haul out on gravel and rough rocky beaches at this site. Vertical relief behind the site is generally less than 50 m but rises to over 400 m about 8 km S of the Cape along the E side of island. Waters are relatively shallow NW of the Cape, between St. Matthew I. and Hall I., but the 18 m isobath is only about 1 km NE of the Cape and waters deepen rapidly to over 40 m less than 3 km NE from the site. |
| Hall Island | Walruses haul out on the gravel and rocky beaches primarily on the N and E side of Hall Island, which lies immediately N of St. Matthew Island. Vertical relief behind these sites is generally 200-250 m and the 18 m isobath is about 1 km offshore to the E. |
| Egg Island | Walruses haul out on the rocky ledges and the few stretch of narrow gravel beach on this small islet in SE Norton Sound. Vertical relief on the islet is about *** m. The 9 m isobath is about 500 m from shore, and the 18 m isobath is over 60 km to the NW. Waters throughout Norton Sound are generally less than 18 m. |
| Besboro Island | Walruses haul out on the rocky ledges and gravel and rock beaches around this small island in E Norton Sound. Vertical relief varies from 75 m to more than 300 m on the island, and the 9 m isobath is about 2-5 km from shore. The 18 m isobath is about 15 km W of this island. |

Continued...

Table 5.1. Continued.

| Rookery | Physical Characteristics |
|---|---|
| Cape Darby | Cape Darby is at the tip of a sharp peninsula that extends into northern Norton Sound. Walruses haul out along on gravel and rocky beaches on both sides and at the tip of the Cape. Bluffs and cliffs rising to over 300 m back most of the sites in this area. Waters are relatively deep (>18 m) within 1.5 km from shore. |
| St. Lawrence Island | |
| Chibukak Pt. | This site is used by several hundred walruses, primarily in the autumn. It is located about 3 km E of the village of Gambell (Northwest Cape). Walruses haul out on the rocks and boulders along a steep beach backed by a slope leading uphill to 300 m-high Sevuokuk Mtn. The 18 m isobath is only about 3 km offshore (to the north) at this site. |
| Kialegak Pt. | This site is used by large numbers of walruses, primarily in the autumn. It is located NE of Southeast Cape. Walruses haul out on the gravel and rocky beaches that are backed by tundra flats and low bluffs (2-5 m high). The 18 m isobath is only 1-3 km offshore. Walruses also haul out on the spit adjacent to Sekinak Lagoon, which is situated about 15 km NW of SE Cape. |
| Maknik | This site is situated along a stretch of sand and gravel beach on a spit adjacent to Maknik Lagoon, at the E end of St. Lawrence I Vertical relief is low, generally less than 2-3 m, and the 18 m isobath is about 2-3 km (S) offshore. |
| Salghat | This haulout site is located on a stretch of gravel and sand beach at the NE end of St. Lawrence I. Vertical relief behind the site is generally low (2-5 m), and the 18 m isobath is about 2-3 km (N) offshore. |
| Punuk Islands | Walruses haul out on gravel, sand and rocky beaches on all three of the Punuk Islands, but North Punuk I. is used most regularly. An exceptionally large number of walruses hauled out in autumn 1978 all along the N, NW and W sides of North Punuk I, all of Middle Punuk I., and over most of the north end of South Punuk I (Fay and Kelly 1980). On such occasions walruses no doubt haul out far back from the beach, on lowland tundra habitats. Vertical relief is generally less than 2-8 m |

Continued...

Table 5.1. Concluded.

| Rookery | Physical Characteristics |
|---|---|
| | on all three islands. One hill at the extreme W end of North Punuk I. is about 70 m high; this is the highest point on the islands. Water depth around all three of the Punuk Islands is generally less than 18 m 2-3 km to the E and W and 5-6 km to the S; waters are very shallow, generally less than 10 m, along a shelf 6-8 km wide that extends N all the way to St. Lawrence I. |
| Sledge Island | This site is located about 50 km W of Nome, in relatively shallow waters (<18 m deep) about 10 km offshore from the mainland. Vertical relief of this island is about 230 m. Walruses haulout on the narrow gravel and rocky beach on the NE side of the island. |
| King Island | Walruses haul out on gravel and rocky beaches at this site. Vertical relief is over 350 m at some locations and the 18 m isobath is about 25 km to the NW. |

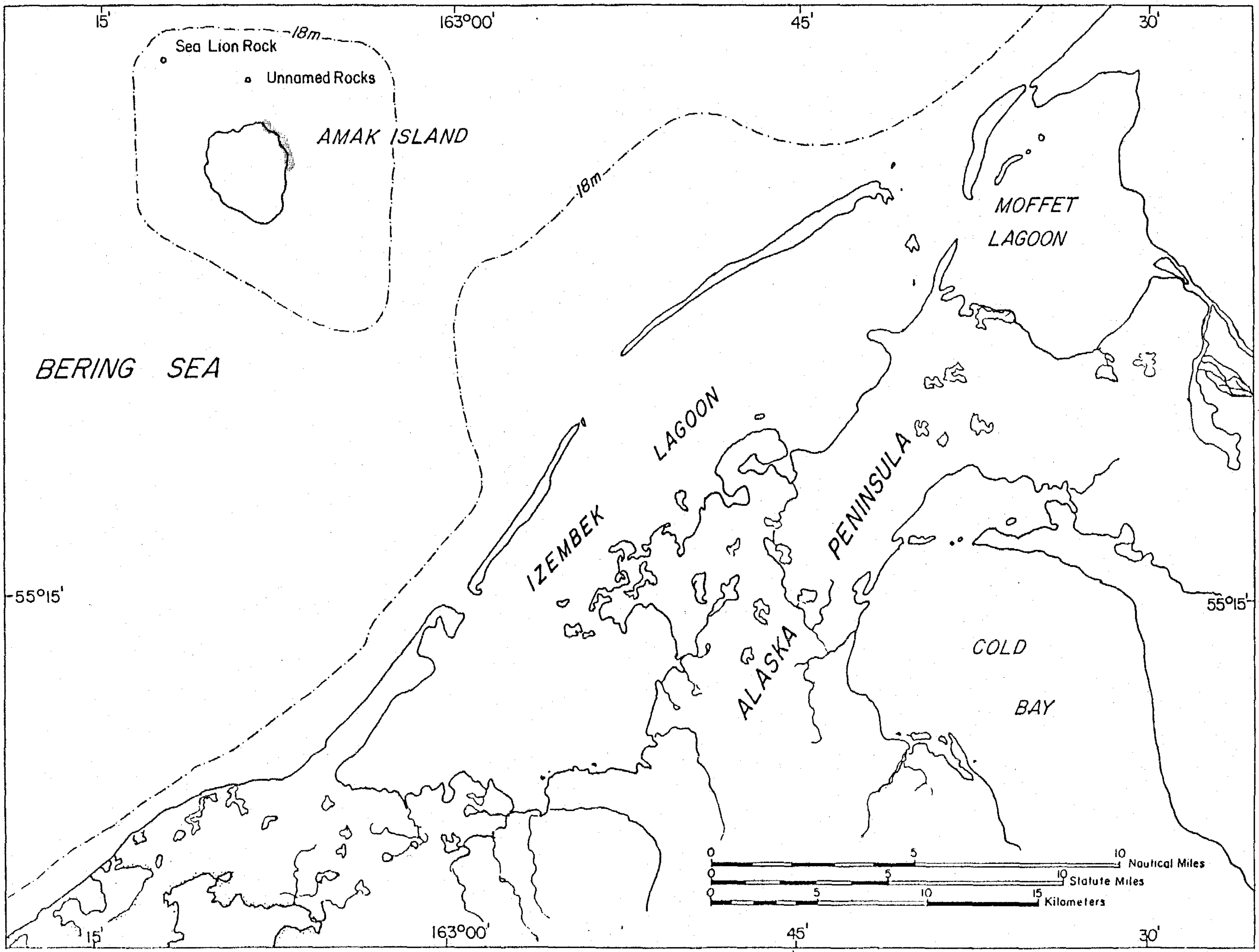


Figure 18. Maps of important Pacific walrus haulout sites in the Bering Sea, Alaska. Maps are at a scale of 1:250,000.

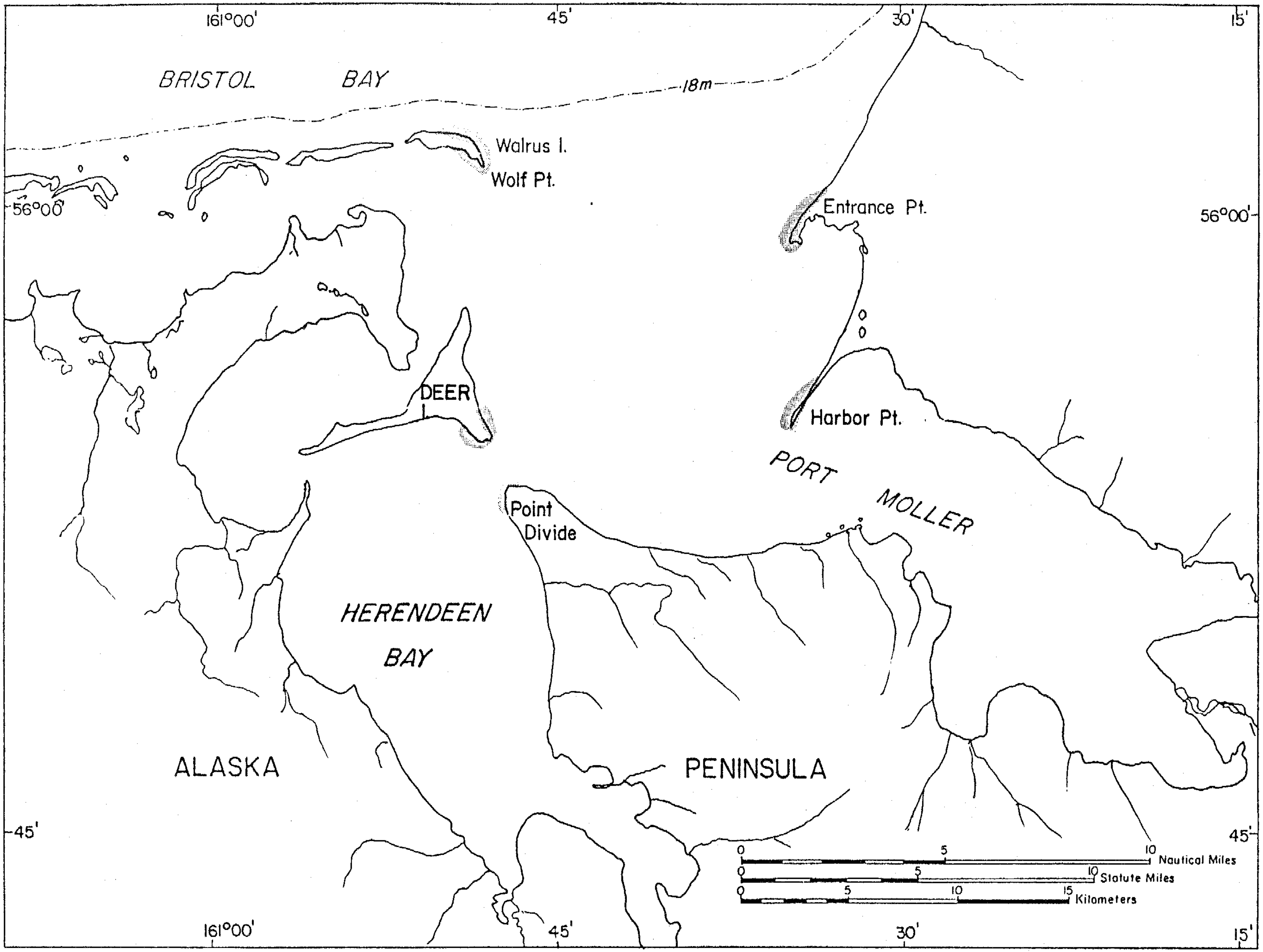


Figure 18. Cont'd.

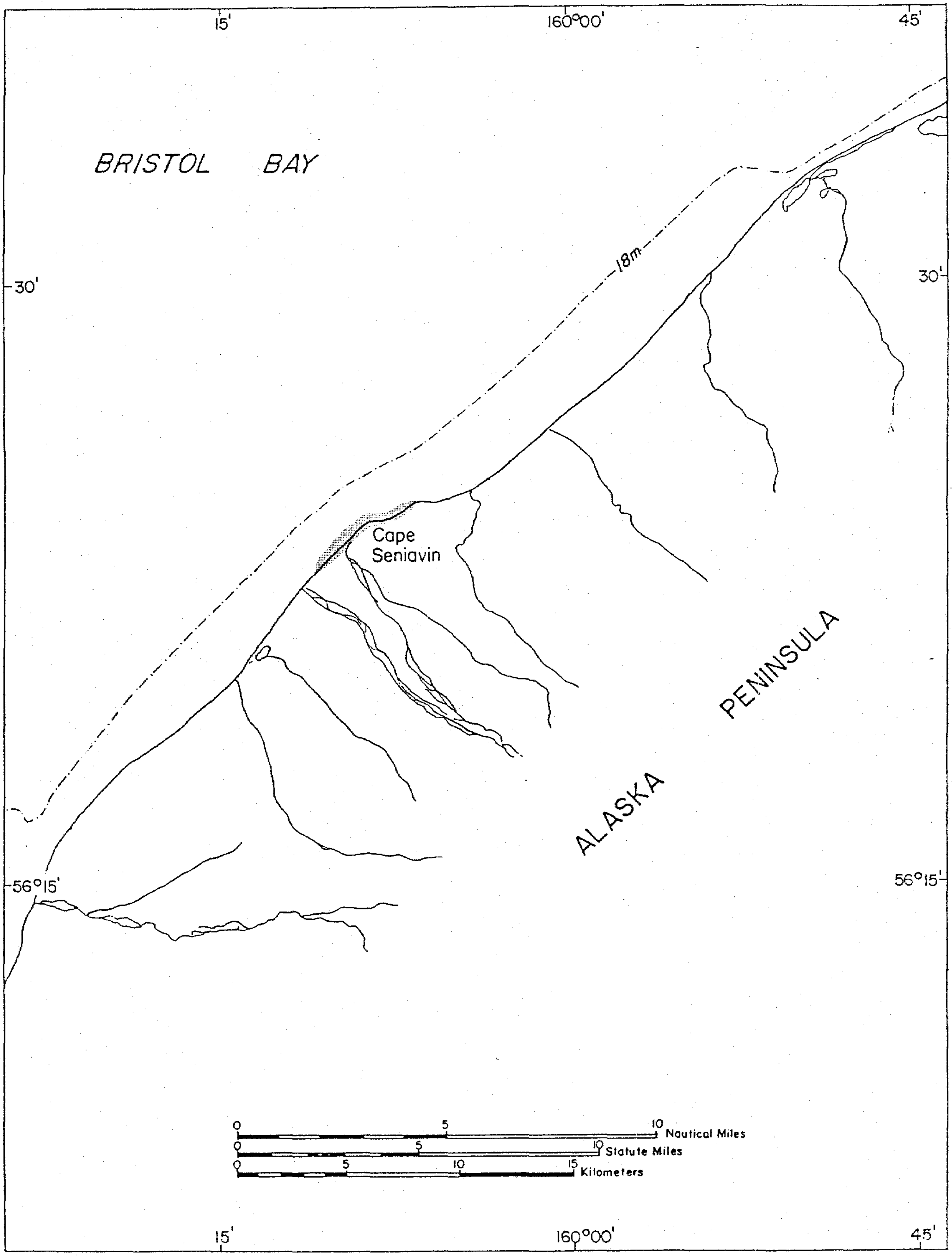


Figure 18. Cont'd.

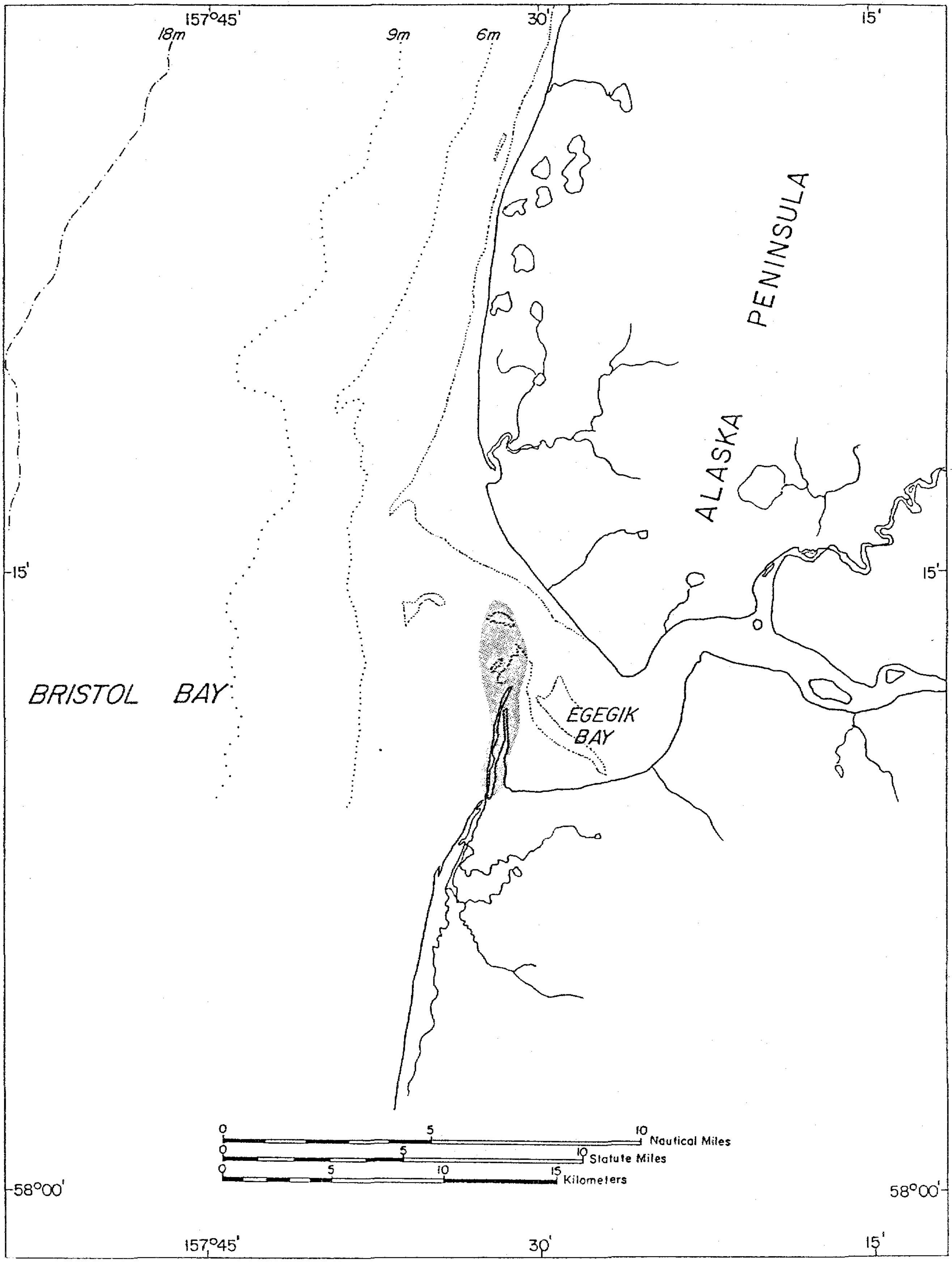


Figure 18. Cont'd.

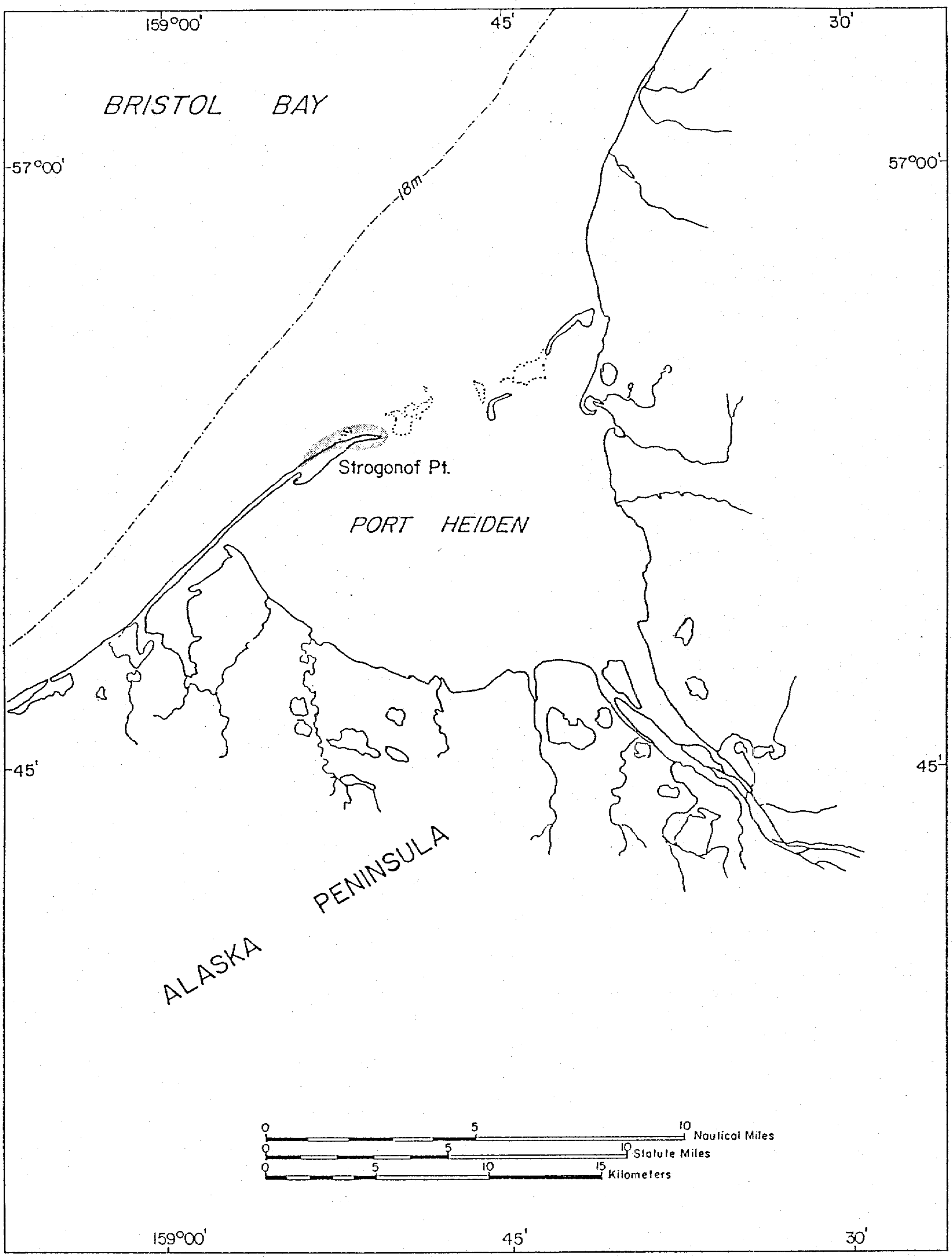


Figure 18. Cont'd.

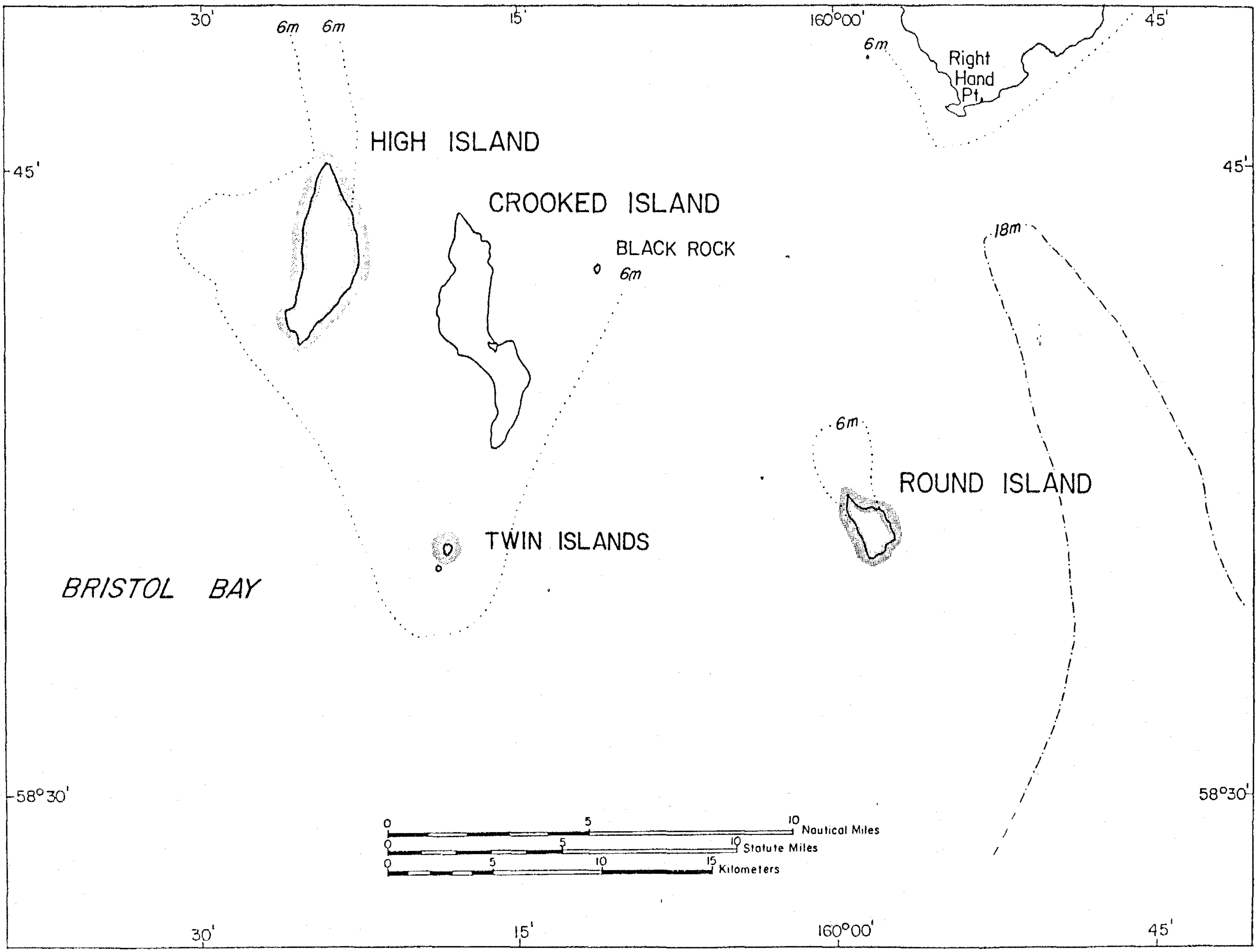


Figure 18. Cont'd.

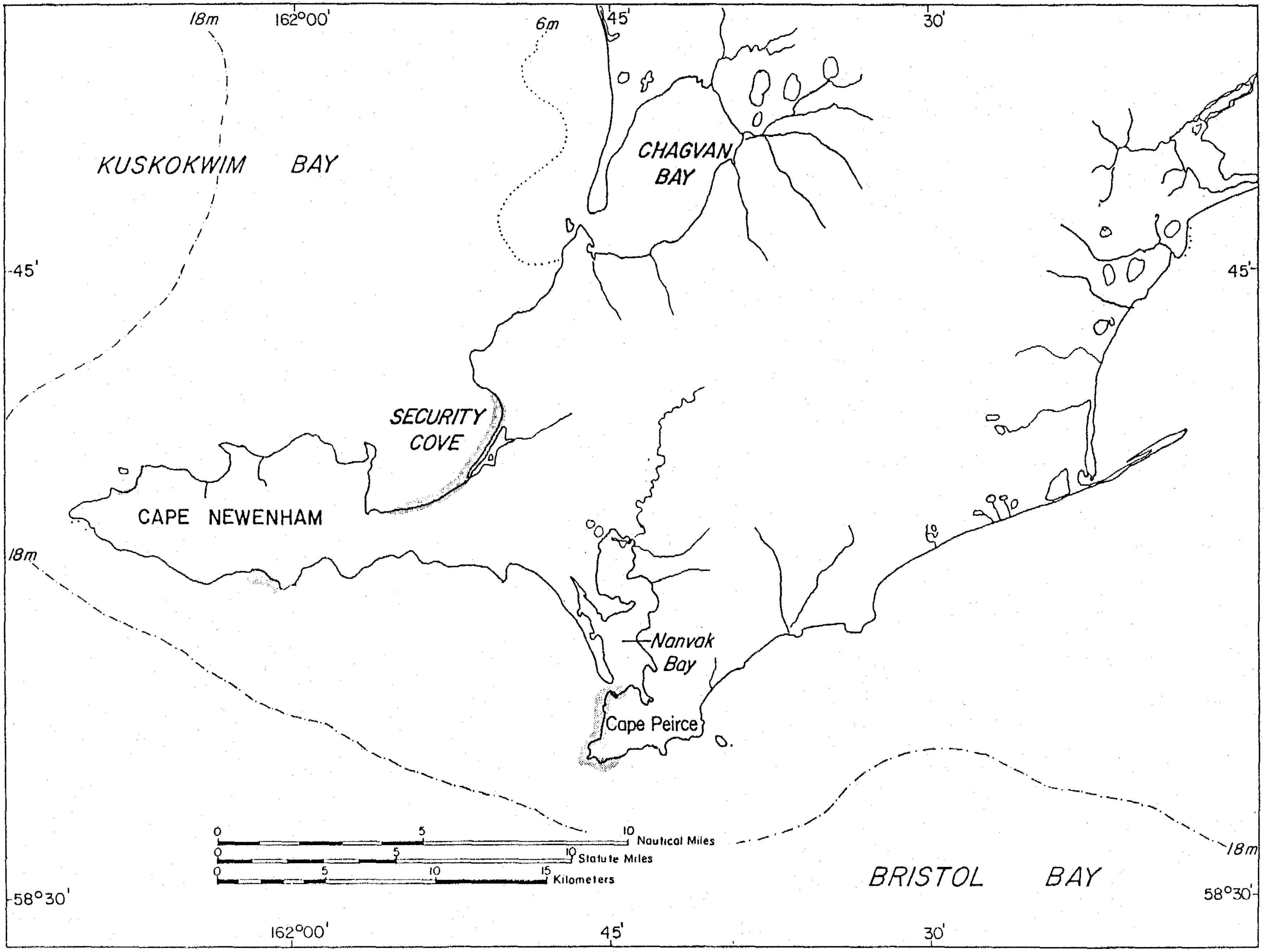


Figure 18. Cont'd.

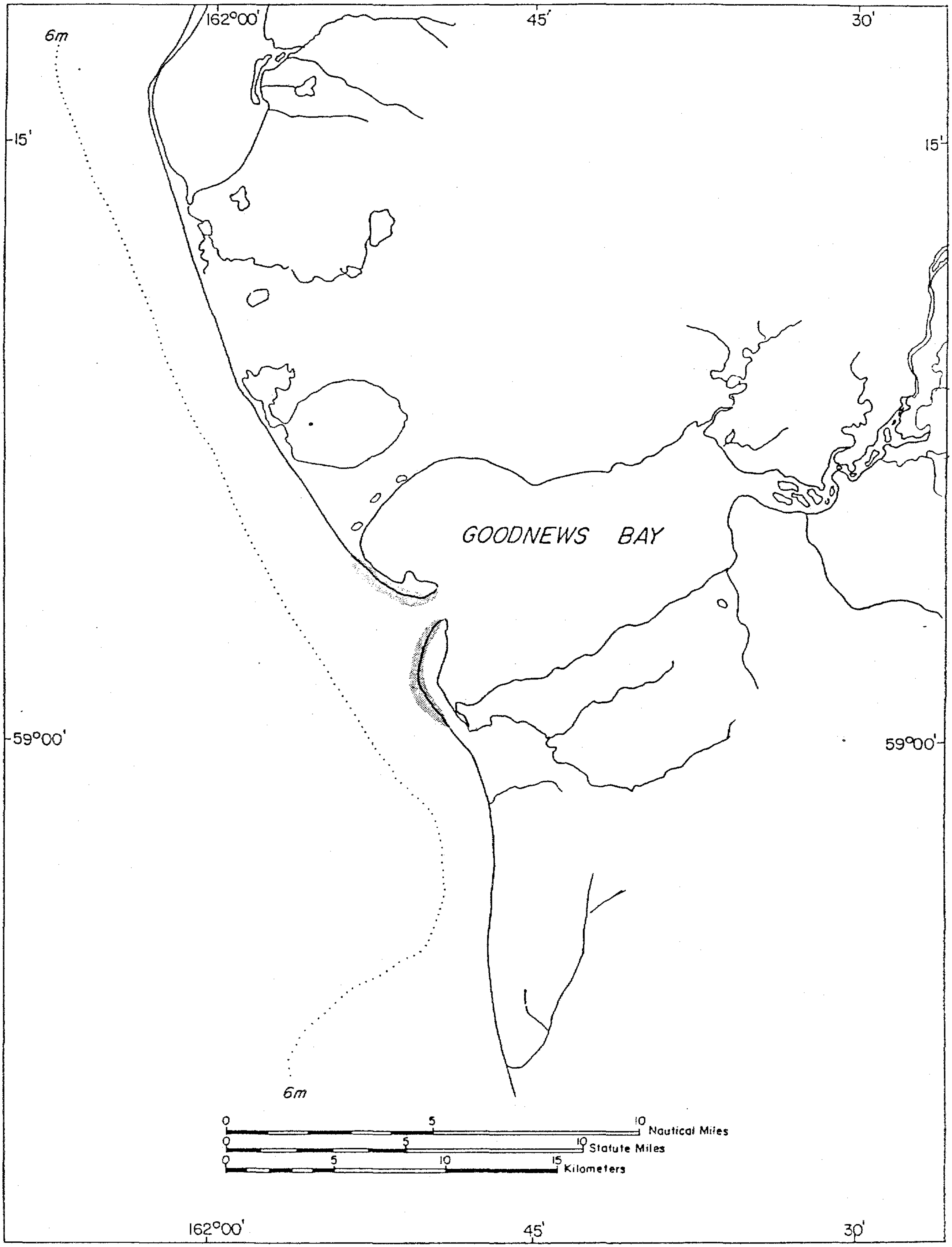


Figure 18. Cont'd.

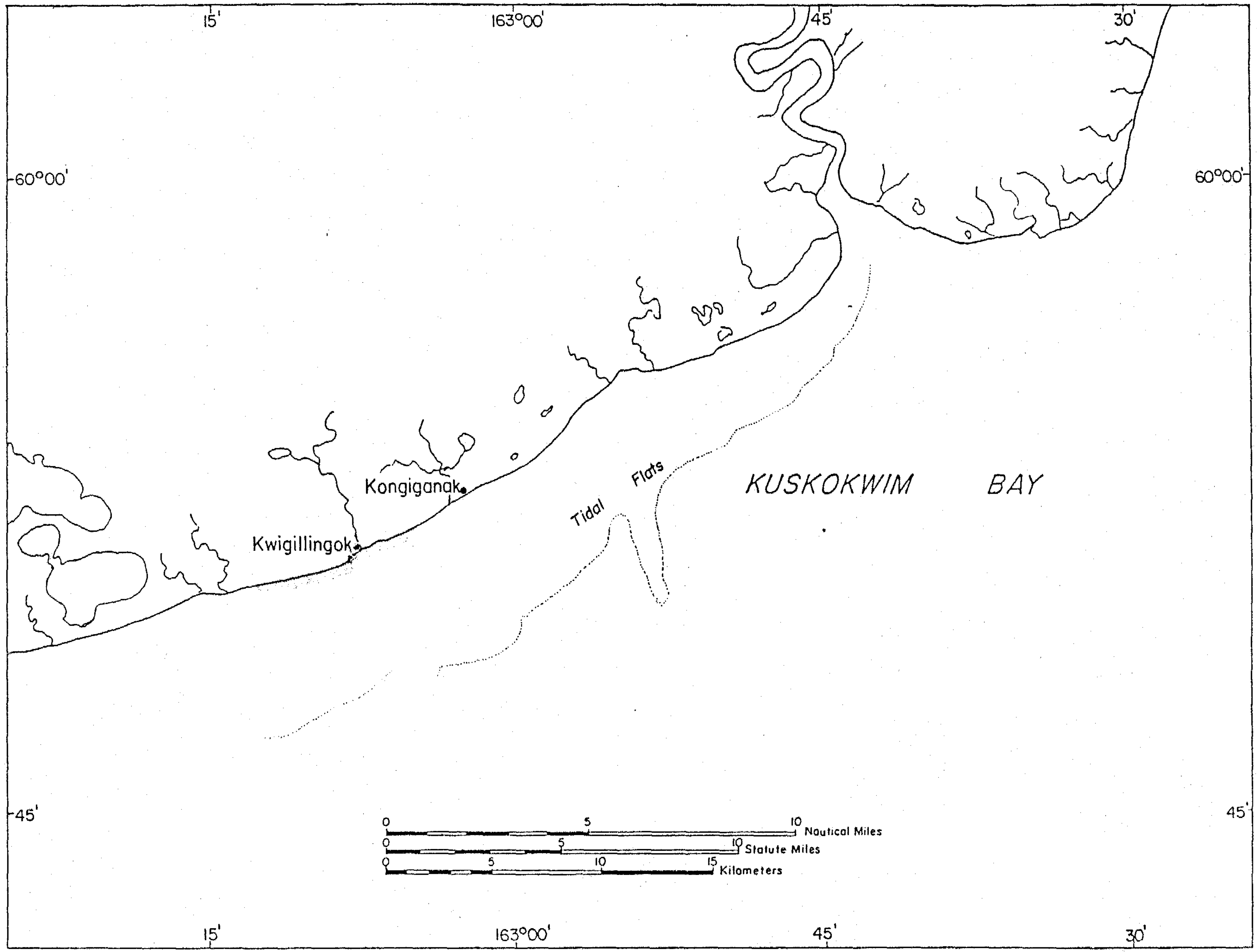


Figure 13. Cont'd.

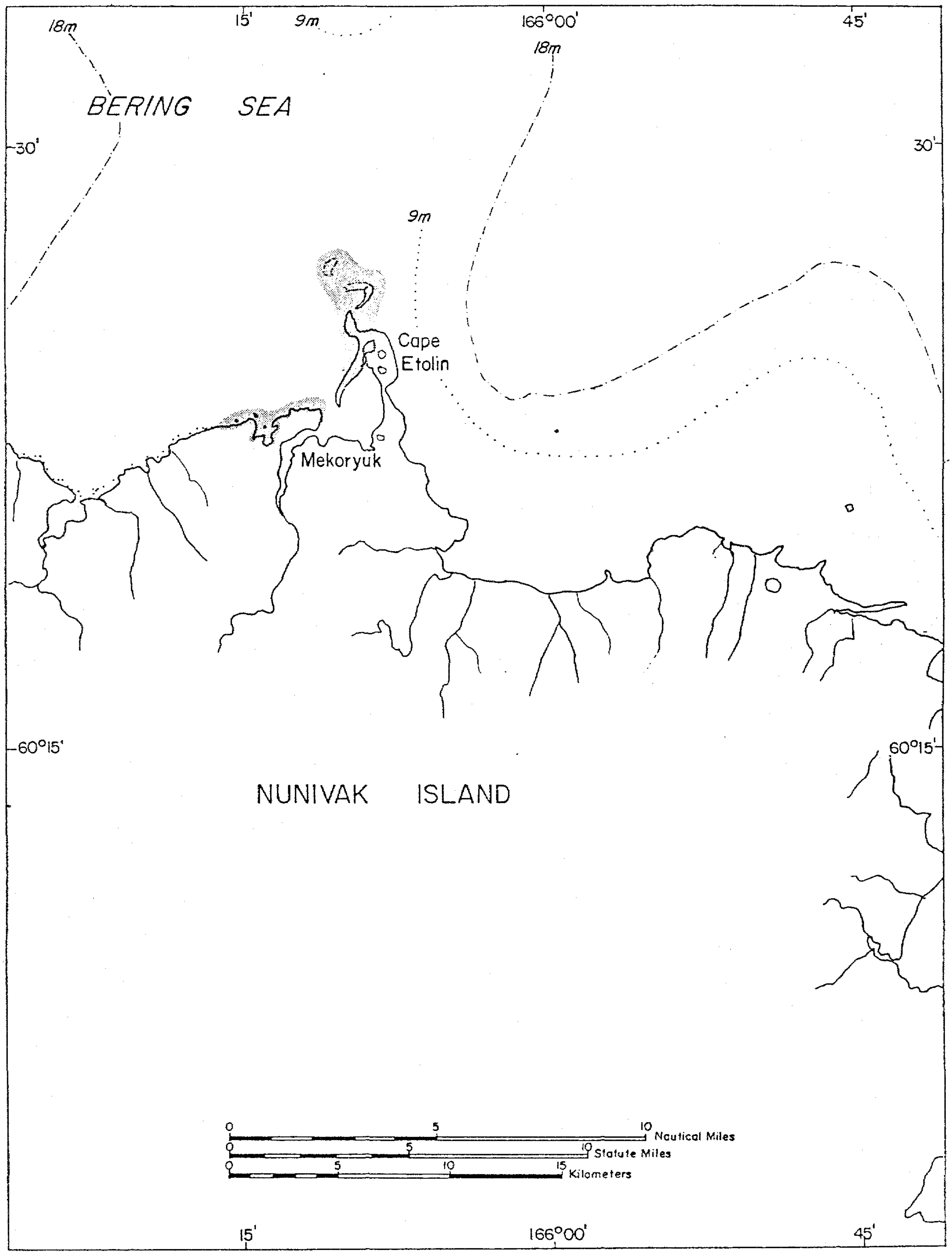


Figure 18. Cont'd.

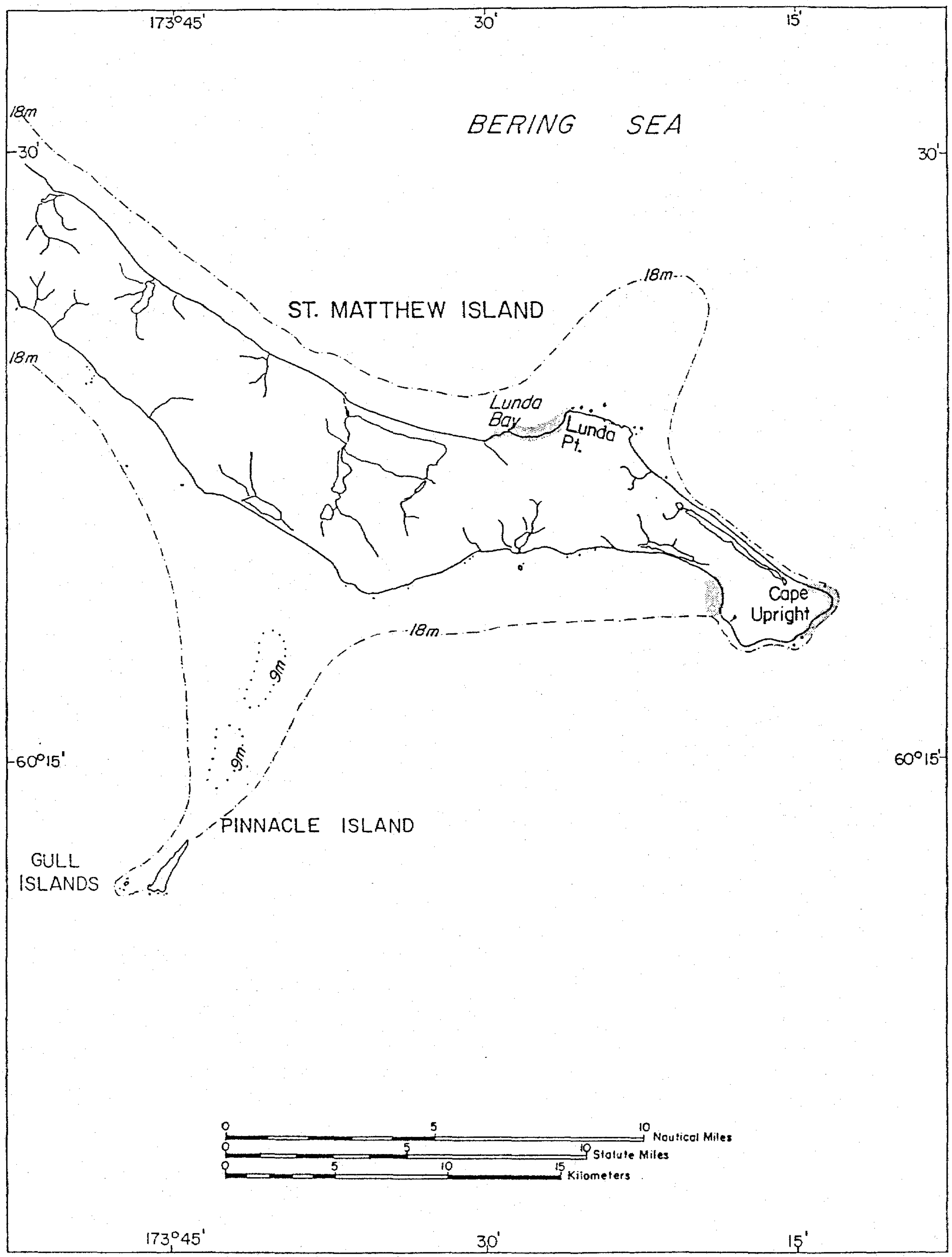


Figure 18. Cont'd.

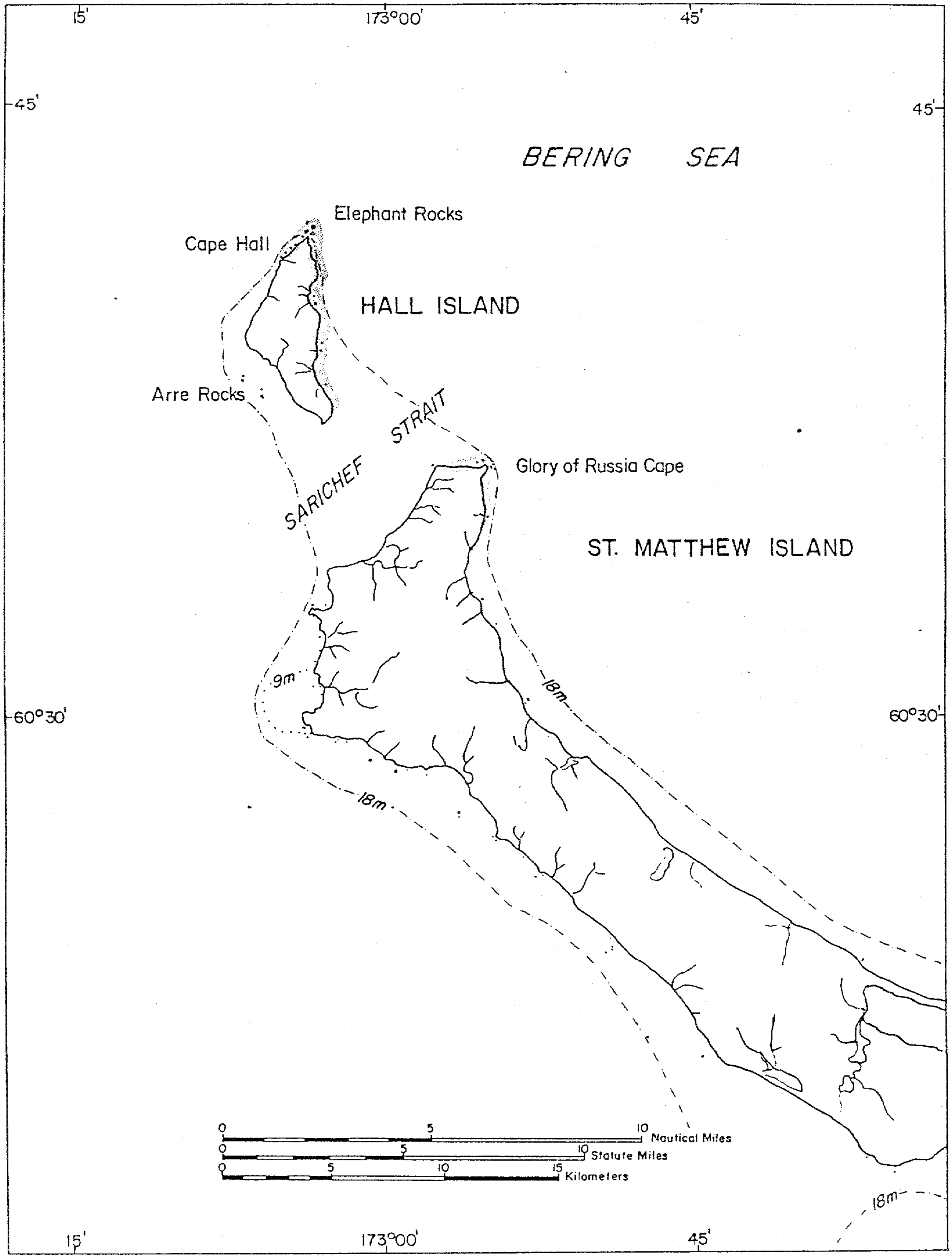


Figure 18. Cont'd.

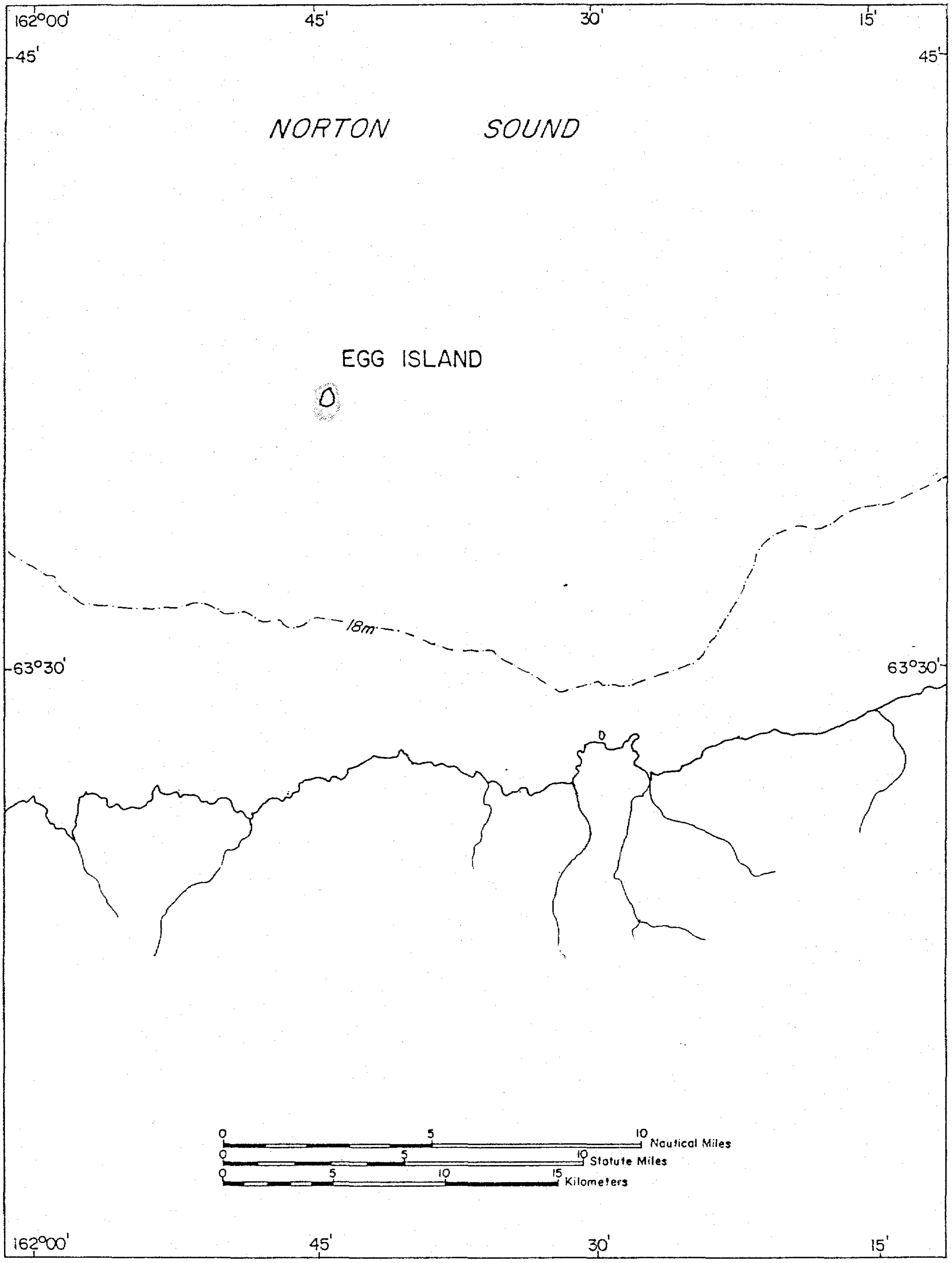


Figure 18. Cont'd.

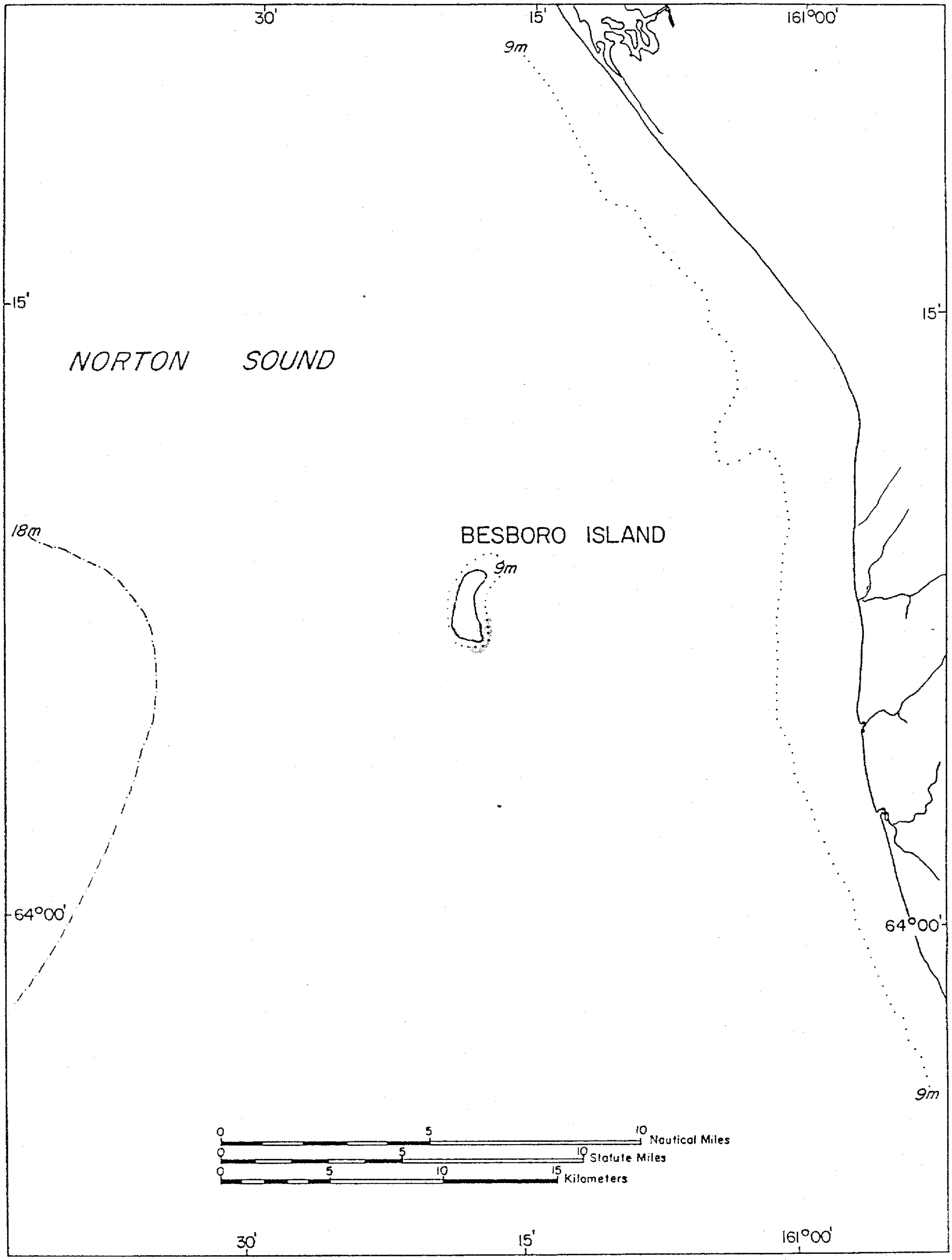


Figure 18. Cont'd.

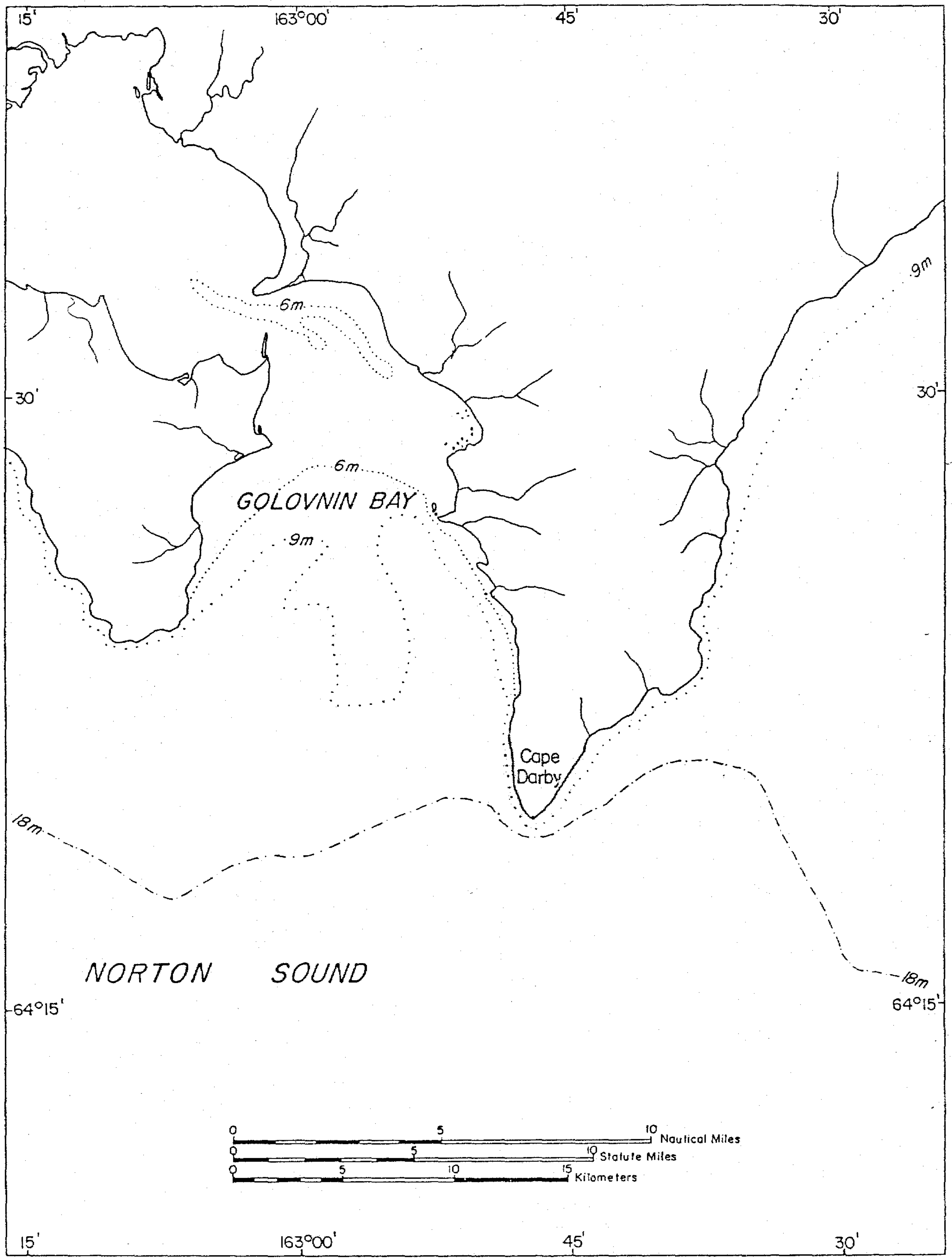


Figure 18. Cont'd.

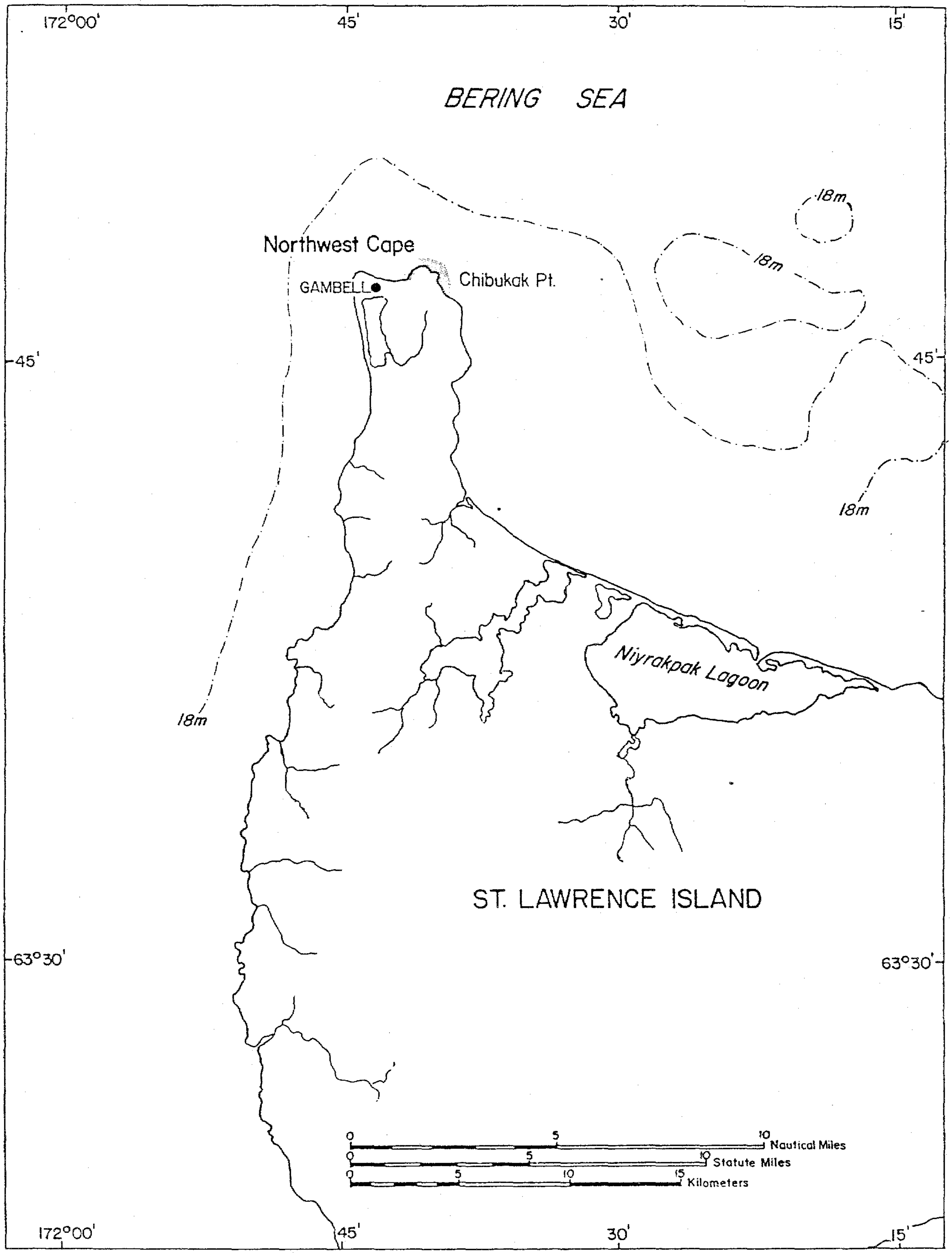


Figure 18. Cont'd.

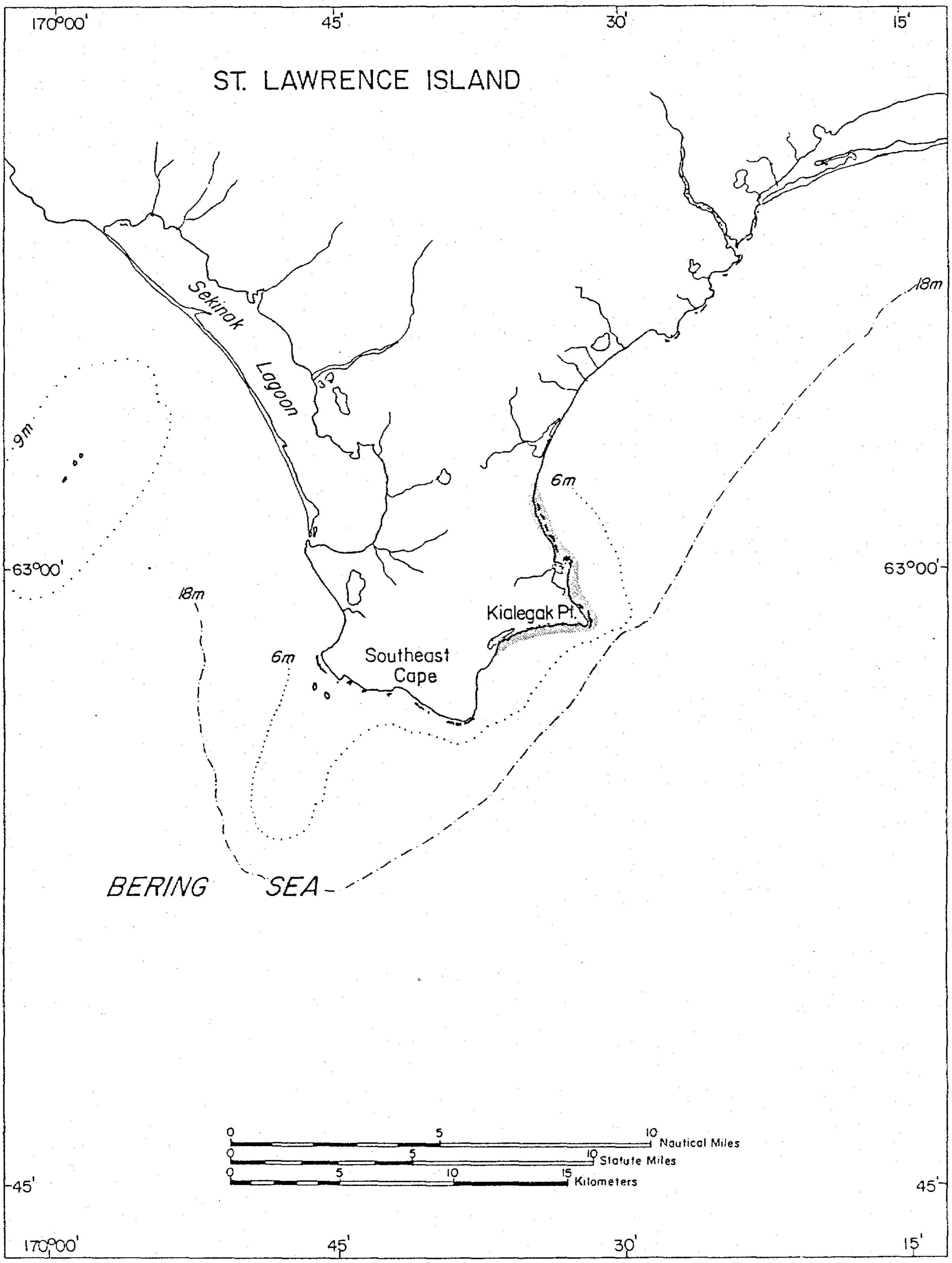


Figure 18. Cont'd.

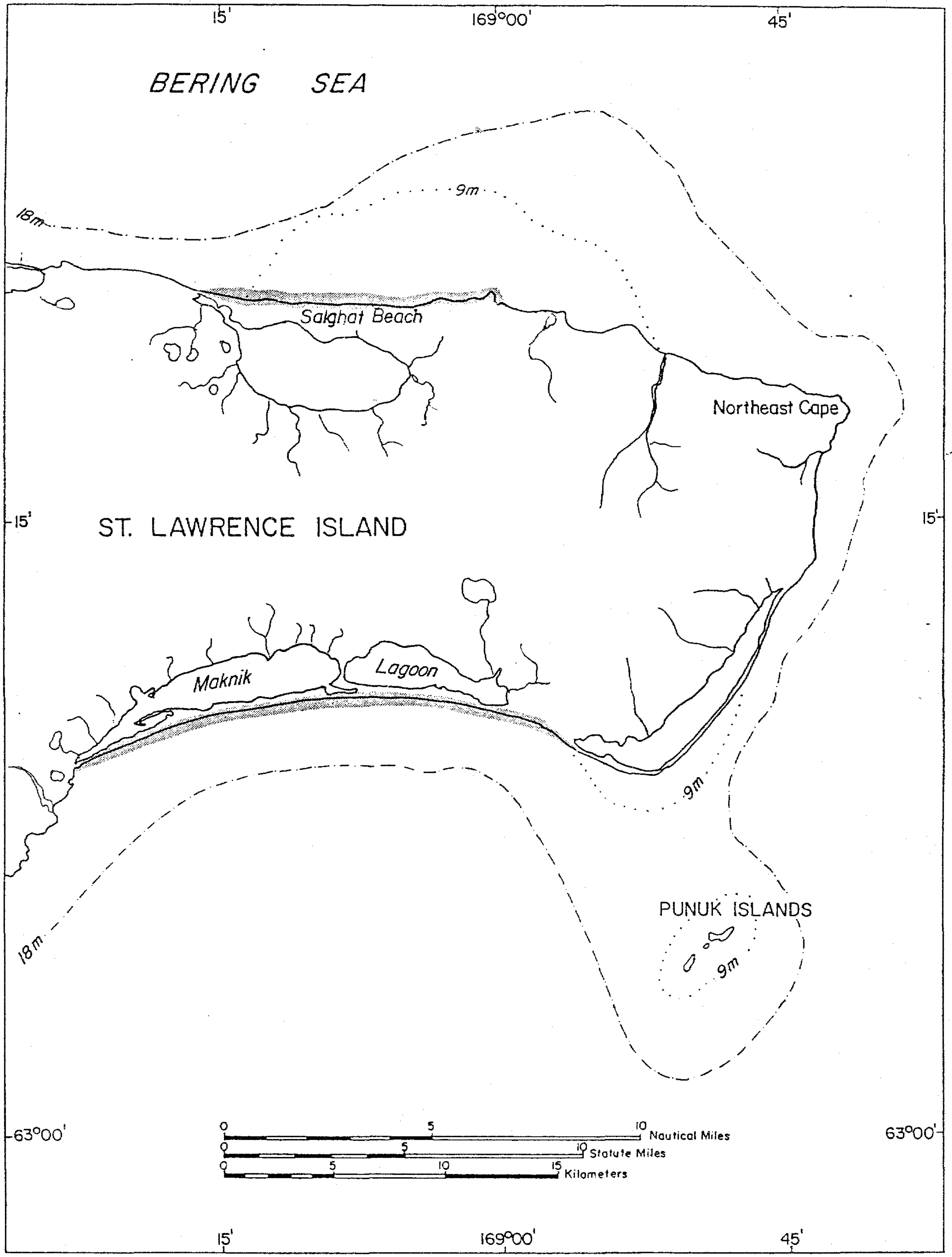


Figure 18. Cont'd.

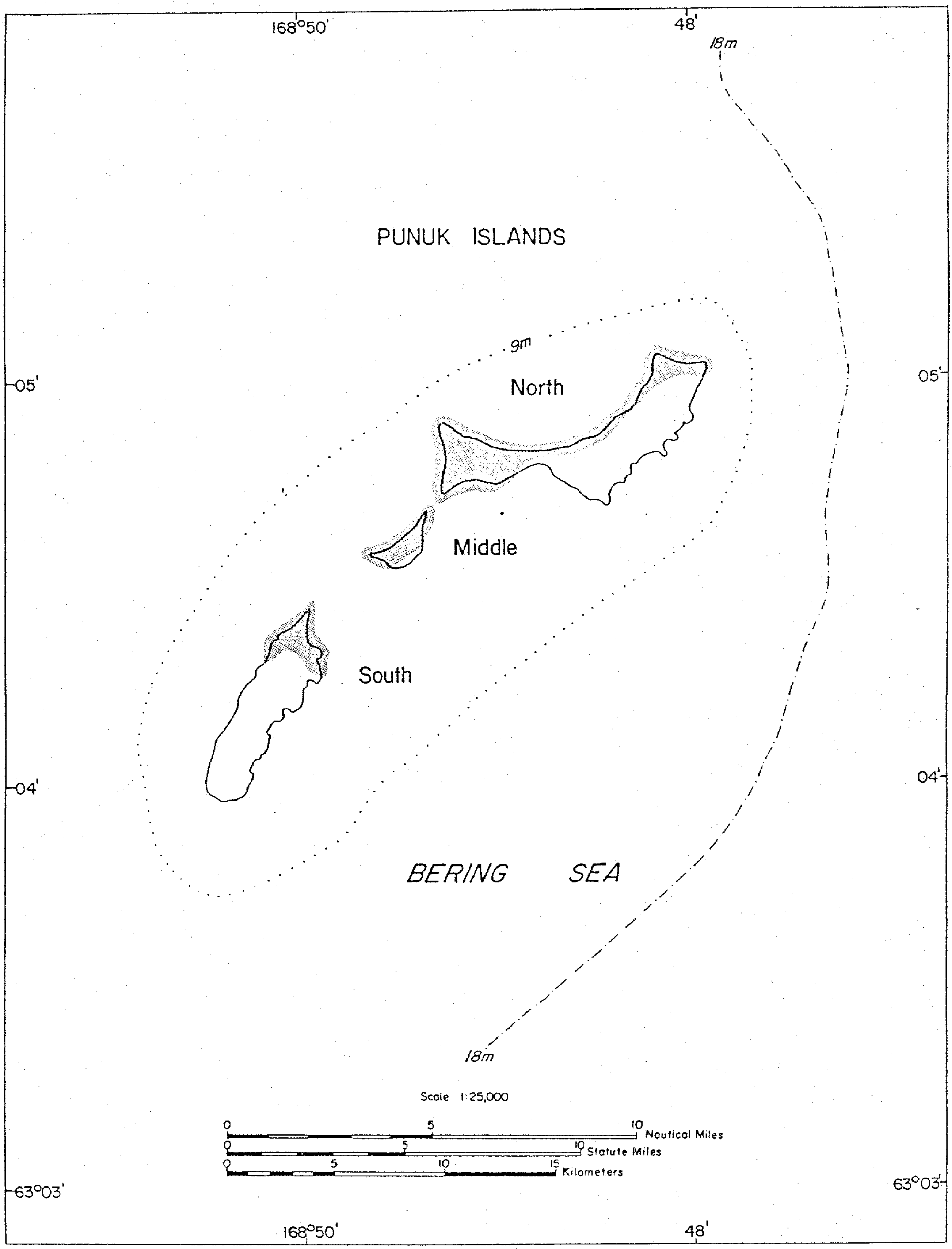


Figure 18. Cont'd.

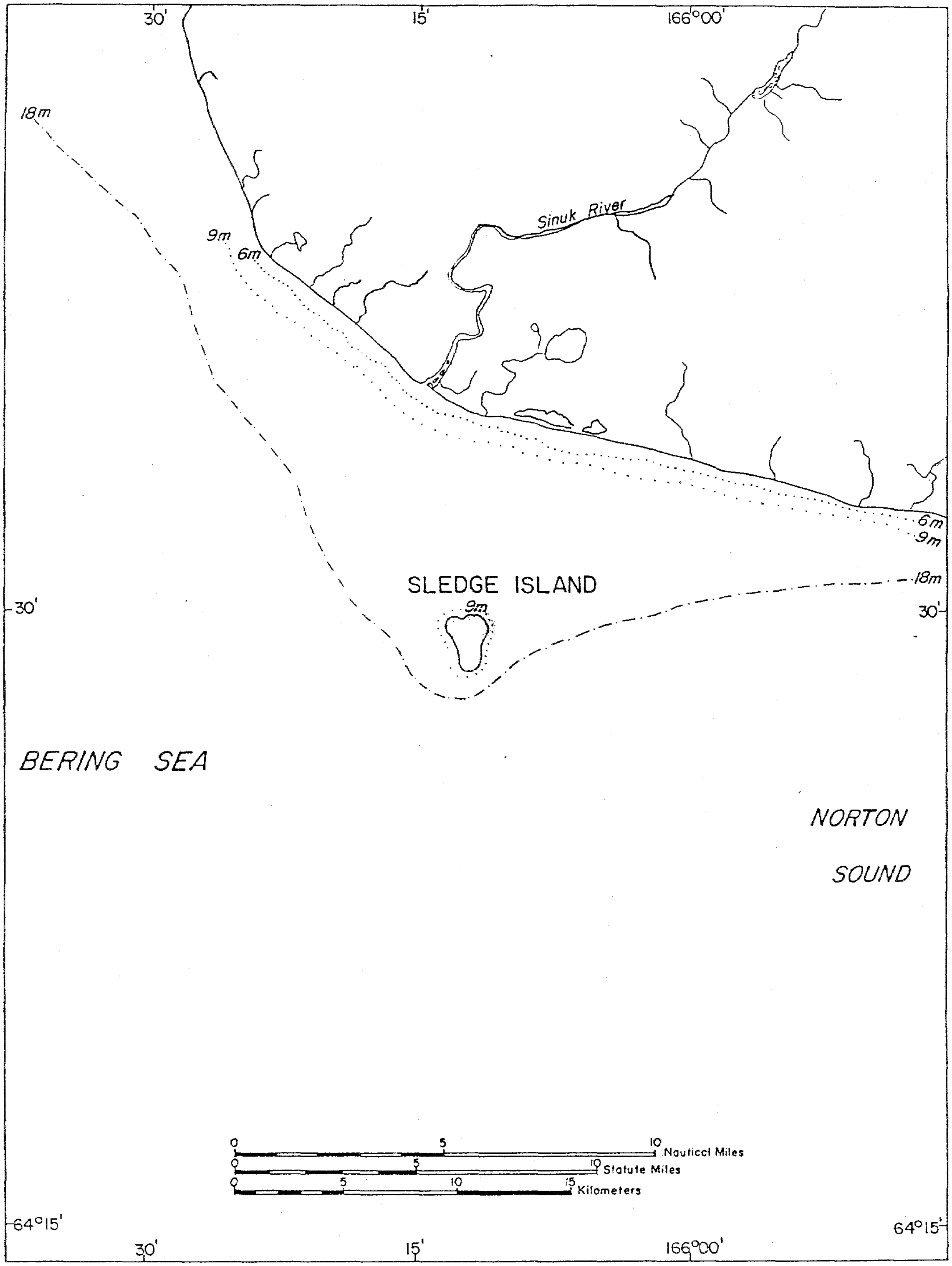


Figure 18. Cont'd.

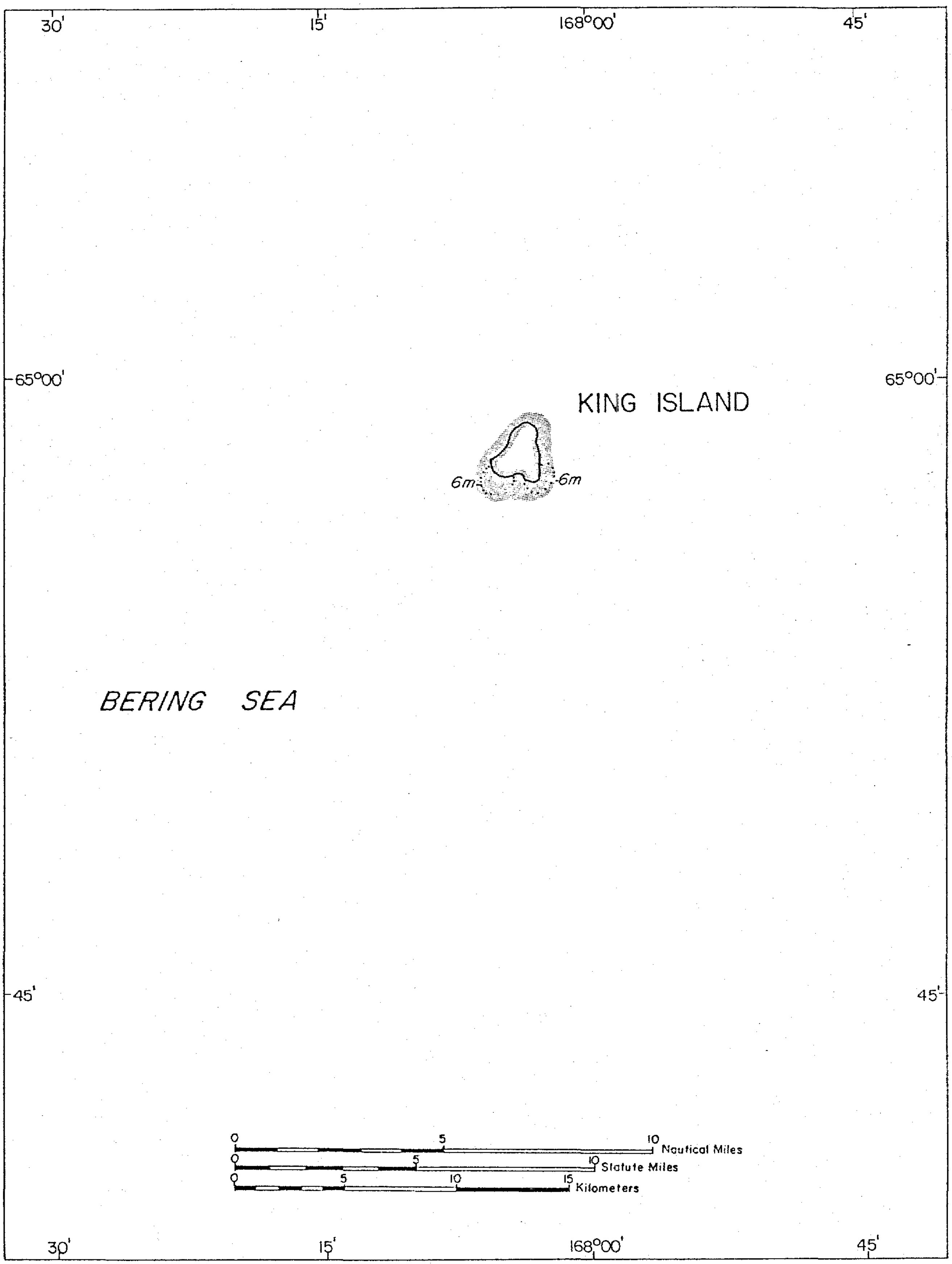


Figure 18. Cont'd.

**APPENDIX 6. DETAILED COUNTS OF NORTHERN SEA LIONS AT TERRESTRIAL HAULOUT SITES IN THE EASTERN BERING SEA.**

Table 6.1. Selected counts of northern sea lions at the Walrus Island rookery (Pribilof Islands group), 1872–1981.

| Year | No. Pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1872 | – | – | A few | Summer | Elliot (1875) in Kenyon (1962) |
| 1913 | 0 | 100 | 100 | Summer | Lembkey (1914) in Kenyon (1962) |
| 1922 | 0 | 0 | 0 | Summer | Hanna (MS 1923) in Kenyon (1962) |
| 1940 | – | – | 1500 | Summer | Scheffer (MS 1940) in Kenyon (1962) |
| 1948 | – | – | 1258 | Summer | Kenyon (1962) |
| 1953 | – | 1340 | – | Summer | Wilke (MS 1953) in Kenyon (1962) |
| 1954 | 3000 | 3000 | 6-7000 | Summer | Kenyon (1962) |
| 1958 | 2500 | – | – | Summer | Wilke and Pike (notes) in Kenyon (1962) |
| 1960 | 3000 | 4-5000 | 7-8000 | Summer | Kenyon (1962) |
| 1975 | – | 1529 | – | 9 Aug | Loughlin et al. (1984) |
| 1977 | – | – | 2000 | 22 Apr | Frost et al. (1983) |
| 1979 | – | – | 1996 | 13 Apr | Calkins (Pers. Comm.) in Loughlin et al. (1984) |
| 1981 | 304 | 868 | 1172 | 4 Aug | Antonelis (notes) in Loughlin et al. (1984) |
| 1982 | – | 600 | – | Summer | Merrick et al. (1987) |
| 1987 | 114 | 459 | 573 | Summer | NMFS files |

Table 6.2. Selected counts of northern sea lions at Akutan Island (Cape Morgan rookery only), 1957–1985.

| Year | No. Pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1957 | 994* | – | – | 13-14 Aug | Mathisen and Lopp (1963) |
| | 1735* | – | – | 30 Sep-1 Oct | " |
| 1960 | – | – | 7000 | 3-4 Mar | Kenyon and Rice (1961) |
| 1965 | – | – | 9000 | May | Braham et al. (1980) |
| 1968 | – | – | 6700 | Jun | " |
| 1975 | – | – | 3200 | Jun | " |
| | – | – | 3585 | Aug | " |
| 1976 | – | – | 3145 | Jun | " |
| | – | – | 5925 | Aug | " |
| 1977 | – | – | 2967 | Jun | " |
| 1984 | – | 2533 | – | 7-12 Jul | Merrick et al. (1987) |
| 1985 | 1130* | 1710 | 2840 | Jun | " |
| 1986 | – | – | 1288-1338 | 10 Jul | Envirosphere Co., files |

* Based on the assumption that all (or most) of the pups recorded by Mathisen and Lopp (1963) and Merrick et al. (1987) were at the Cape Morgan rookery.

Table 6.3. Selected counts of northern sea lions at Akutan Island (all sites, including the Cape Morgan rookery), 1957-1977.

| Year | No. pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1957 | 994 | 7675 | 8669 | 13-14 Aug | Mathisen and Lopp (1963) |
| | 1735 | 9275 | 11,010 | 30 Sep-1 Oct | " |
| 1957* | - | - | 719 | 30 Sep-1 Oct | " |
| 1960 | - | - | 15,720 | 3-4 Mar | Kenyon and Rice (1961) |
| 1968 | - | - | 10,316 | Jun-Jul | Fiscus and Johnson (1968) <u>in</u> Merrick et al. (1987) |
| 1975 | - | - | 3958 | Aug | Braham et al. (1980) |
| 1976 | - | - | 6227 | Aug | " |
| 1977 | - | - | 3272 | Jun | " |

* Mathisen and Lopp (1963) reported this count for North Head separately from that of Akutan Island, on which North Head is located.

Table 6.4. Selected counts of northern sea lions at the Sea Lion Rock rookery (Amak Island group), 1956-1985.

| Year | No. Pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1956 | 1035 | 3780 | 4815 | 28 Jul-9 Aug | Mathisen and Lopp (1963) |
| 1957 | 424 | 4694 | 5118 | 28 Aug-2 Oct | " |
| 1960 | - | - | 2000 | 3-4 Mar | Kenyon and Rice (1961) |
| 1962 | - | - | 3500 | 8 Apr | J.J Burns, field notes |
| 1965 | - | - | 4100 | 8 May | Kenyon (1965) |
| 1975 | - | - | 2126 | Aug | Braham et al. (1980) |
| 1976 | - | - | 2530 | Aug | " |
| 1977 | - | - | 2130 | Jun | " |
| 1980 | - | - | 1300 | 2 Jul | Frost et al. (1983) |
| 1981 | - | - | 1500-1600 | 11 Oct | J. Burns, Notes |
| | | | 1100 | 16 Oct | K. Frost, Notes |
| 1982 | - | - | 1350 | 13 Jul | Frost et al. (1983) |
| 1984 | - | 1298 | - | 7-12 Jul | Merrick et al. (1987) |
| 1985 | - | 538 | - | 23 Jun-15 Jul | " |
| 1986 | - | - | 466-527 | 29 Jun | Envirosphere Co., files |

Table 6.5. Selected counts of northern sea lions at the Ugamak Island rookery (all sites), 1957–1986.

| Year | No. pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1957 | 1466 | 14,536 | 16,002 | 30 Sep–1 Oct | Mathisen and Lopp (1963) |
| 1960 | – | – | 13,400 | 3–4 Mar | Kenyon and Rice (1961) |
| 1965 | – | – | 10,975 | May | Braham et al. (1980) |
| 1968 | – | – | 13,553 | Jun–Jul | Fiscus and Johnson (1968) in Merrick et al. (1987) |
| 1969 | – | 10,295 | – | Jun | Fiscus (1970) in Merrick et al. (1987) |
| 1975 | – | – | 2500 | Jun | Braham et al. (1980) |
| | – | – | 4569 | Aug | " |
| 1976 | – | – | 4760 | Jun | " |
| 1977 | – | – | 5106 | Jun | " |
| | – | 3577 | – | 19–28 Jun | Merrick et al. (1987) |
| 1985 | 1635 | 2033 | 3668 | 20 Jun | " |
| 1986 | 1386 | 1684 | 3070 | 20 Jun | " |

Table 6.6. Selected counts of northern sea lions at the Bogoslof Island rookery, 1938–1985.

| Year | No. pups | No. Non-pups | Total Number | Time of Survey | Information Source |
|---|---|---|---|---|---|
| 1938 | – | – | 800 | ? | Murie (1959) |
| 1957 | 3106 | 3707 | 6813 | 13–14 Aug | Mathisen and Lopp (1963) |
| 1960 | – | – | 1000 | 3 Mar | Kenyon and Rice (1961) |
| 1962 | – | – | 3000 | 7 Apr | Kenyon (1962) in Fiscus et al. (1981) |
| 1962 | 2385 | 2566 | 4951 | 26 Aug | Fiscus et al. (1981) |
| 1973 | 2328 | 3300 | 5628 | 29 Jun | Byrd et al. (1980) in Fiscus et al. (1981) |
| 1976 | 291 | – | 3599 | 14–20 Jun | Fiscus et al. (1981) |
| 1977 | – | – | 2328 | 29 Jun | Braham et al. (1980) |
| 1978 | – | – | 1000 | 31 May | Day et al. (1979) in Fiscus et al. (1981) |
| 1979 | 914 | 1463 | 2377 | 15 Jul | Fiscus et al. (1981) |
| 1985 | 1109 | 1287 | 2396 | 25 Jun–15 Jul | Merrick et al. (1987) |

Table 6.7. Reported counts of northern sea lions at haulout sites facing the Bering Sea in the eastern Aleutian Islands. Sites where <100 animals have been recorded are not included.1

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Fire Island | (All Sites) | 1960 | 100 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1978 | 0 | 31 May | Day et al. (1979) in Fiscus et al. (1981) |
| | | 1979 | 4 | 15 Jul | Fiscus et al. (1981) |
| Unalaska Island | Spray Cape | 1960 | 200 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1975 | 0 | Aug | Braham et al. (1980) |
| | | 1976 | 0 | Aug | " |
| | | 1977 | 2 | Jun | " |
| | Cape Starichkof | 1960 | 100 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1975 | 101 | Jun | Braham et al. (1980) |
| | | 1976 | 78 | Jun | " |
| | | 1977 | 244 | Jun | " |
| | Bishop Point | 1975 | 172 | Jun | " |
| | | | 13 | Aug | " |
| | | 1976 | 304 | Jun | " |
| | | | 0 | Aug | " |
| | | | 136 | Oct | " |
| | | 1977 | 501 | Jun | " |
| | Point Tebenkof | 1960 | 200 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1975 | 0 | Jun/Aug | Braham et al. (1980) |
| | | 1976 | 0 | Jun | " |
| | | | 8 | Aug | " |
| | | 1977 | 0 | Jun | " |
| Akutan Island | (All Sites) | 1957 | 8699 | 13-14 Aug | Mathisen and Lopp (1963) |
| | | | 11,729 | 30 Sep-1 Oct | " |
| | | 1960 | 15,720 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1968 | 10,316 | Jun-Jul | Fiscus and Johnson (1968) in Merrick et al. (1987) |
| | | 1975 | 3958 | Aug | Braham et al. (1980) |
| | | 1976 | 6227 | Aug | " |
| | | 1977 | 3272 | Jun | " |
| | | 1984 | 2533 + pups | 7-12 Jul | Merrick et al. (1987) |
| | | 1985 | 2840 | 9-13 Jun | " |
| | Flat Bight | 1960 | 2000 | 3-4 Mar | Kenyon and Rice (1961) |
| | Reef Point to Lava Point (incl. Reef and Lava bights) | | 6720 | 3-4 Mar | " |
| | | 1975 | 365 | Jun | Braham et al. (1980) |
| | | | 366 | Aug | " |
| | | 1976 | 874 | Jun | " |
| | | | 300 | Aug | " |
| | | | 278 | Oct | " |
| | | 1977 | 302 | Jun | " |
| | | 1980 | 360 | 6 Jun | USFWS Catalog of Seabird Colonies |

Continued...

Table 6.7. Continued.

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Akutan (Cont.) | North Head | 1957 | 719 | 30 Sep-1 Oct | Mathisen and Lopp (1963) |
| | | 1975 | 0 | Jun/Aug | Braham et al. (1980) |
| | | 1976 | 0 | Jun | " |
| | | | 1 | Oct | " |
| | | 1977 | 3 | Jun | " |
| Akun Island | South Side | 1965 | 9000 | 8 May | Kenyon (1965) |
| | (All Sites) | 1957 | 1361 | 13-14 Aug | Mathisen and Lopp (1963) |
| | | 1960 | 2100 | 3 Mar | Kenyon and Rice (1961) |
| | Akun Head | 1960 | 2000 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 0 | Jun | Braham et al. (1980) |
| | | | 3 | Aug | " |
| | | 1976 | 0 | Jun | " |
| | | | 2 | Oct | " |
| | | 1977 | 0 | Jun | " |
| | Billings Head/Bight | 1960 | 100 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 748 | Jun | Braham et al. (1980) |
| | | | 2641 | Aug | " |
| | | 1976 | 1050 | Jun | " |
| | | | 2032 | Aug | " |
| | | | 1133 | Oct | " |
| | | 1977 | 1166 | Jun | " |
| | | 1984 | 760 + pups | 7-12 Jun | Merrick et al. (1987) |
| | | 1985 | 435 + 60 pups | Jun | " |
| Tanginak Island | (All Sites) | 1960 | 600 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 470 | Jun | Braham et al. (1980) |
| | | | 4 | Aug | " |
| | | 1976 | 358 | Jun | " |
| | | | 20 | Aug | " |
| | | | 60 | Oct | " |
| | | 1977 | 79 | Jun | " |
| | | 1985 | 61 | Summer | NMFS files |
| Tigalda Island | (All Sites) | 1957 | 103 | 30 Sep-1 Oct | Mathisen and Lopp (1963) |
| | | 1965 | 650 | 8 May | Kenyon (1965) |
| | | 1975 | 2 | Aug | Braham et al. (1980) |
| | | 1976 | 314 | Jun | " |
| | | | 19 | Aug | " |
| | | | 65 | Oct | " |

Continued

Table 6.7. Concluded.

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Unnamed rock off NE end | | 1960 | 750 | 3 Mar | Kenyon and Rice (1961) |
| of Tigalda Island | | 1975 | 80 | Jun | Braham et al. (1980) |
| | | | 6 | Aug | " |
| | | 1976 | 190 | Jun | " |
| | | | 6 | Aug | " |
| | | | 75 | Oct | " |
| | | 1977 | 84 | Jun | " |
| | | 1985 | 82 | Summer | NMFS files |
| Aiktak Island | All Sites | 1960 | 600 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 1 | Jun | Braham et al. (1980) |
| | | | 0 | Aug | " |
| | | 1976 | 0 | Jun | " |
| | | | 0 | Aug | " |
| | | | 0 | Oct | " |
| | | 1977 | 1 | Jun | " |
| | | 1985 | 0 | Summer | NMFS files |
| | North Side | 1965 | 100 | 8 May | Kenyon (1965) |
| Round Island[2] | | 1960 | 6000 | 3 Mar | Kenyon and Rice (1961) |
| (Unimak Pass) | | 1975 | 175 | Aug | Braham et al. (1980) |
| | | 1976 | 246 | Jun | " |
| | | | 134 | Aug | " |
| | | | 158 | Oct | " |
| | | 1977 | 302 | Jun | " |
| | | 1980 | 119 | 28 Jun | USFWS Catalog of Seabird Colonies |
| Unimak Island | Cape Sarichef | 1960 | 200 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 0 | Jun | Braham et al. (1980) |
| | | | 0 | Aug | " |
| | | 1976 | 0 | Jun | " |
| | | | 3 | Aug | " |
| | | 1977 | 4 | Jun | " |
| | | 1981 | 40 | 26 May | Izembek NWR, files |
| | Oksenof Point | 1960 | 4000 | 3 Mar | Kenyon and Rice (1961) |
| | | 1975 | 0 | Jun | Braham et al. (1980) |
| | | | 0 | Aug | " |
| | | 1976 | 2 | Jun | " |
| | | | 0 | Oct | " |
| | | 1977 | 0 | Jun | " |
| | Cape Mordvinof | 1958 | 500 | Mar | Aleutian Isl. NWR Rep. (1958) in Frost et al. (1983) |

1 Counts reported in the literature were sometimes for an entire island and sometimes for specific sites on an island, as indicated.
2 Braham et al. (1980) suggest that a minor rookery exists on Round Island; they pooled counts from Round Island with those from the large rookery on Ugamak Island.

Table 6.8. Reported counts of northern sea lions at haulout sites in the southern Bristol Bay region. Haulout sites at which <100 animals have been recorded are not included.

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Amak | (All Sites) | 1956 | 253 | 28 Jul-9 Aug | Mathisen and Lopp (1963) |
| | | 1957 | 3016 | 28-30 Jun | " |
| | | | 570 | 6-14 Aug | " |
| | | | 683 | 28 Aug-2 Oct | " |
| | | | 1401 | 4 Dec | " |
| | | 1960 | 350 | 3-4 Mar | Kenyon and Rice (1961) |
| | | 1962 | 2000 | 8 Apr | J.J. Burns, field notes |
| | | 1965 | 4100 | Summer | NMML, files |
| | | 1967 | 500 ± | 14 Mar | Izembek NWR files in Frost et al. (1982) |
| | | 1973 | 418 | Jul | USFWS Catalog of Seabird Colonies |
| | | 1975 | 927 | Jun | Braham et al. (1980) |
| | | | 2316 | Aug | " |
| | | 1976 | 1777 | Jun | " |
| | | | 1381 | Aug | " |
| | | | 905 | Oct | " |
| | | 1977 | 1315 | Jun | " |
| | | 1978 | 688 | Summer | NMML, files |
| | | 1980 | 1350 | 7 May | Izembek NWR, files |
| | | | 2400 | 6 Jun | " |
| | | | 1045 | 2 Jul | " |
| | | 1981 | 475 | 9 Mar | " |
| | | | 300 | 11 Oct | Frost et al. (1982) |
| | | | 300 | 16 Oct | " |
| | | 1982 | 700 ± | 13 Jul | " |
| | | 1984 | 353 | Summer | NMML, files |
| | | 1985 | 302 | Summer | " |
| | | 1986 | 486-599 ± 20% | 29 Jun | Envirosphere Co., file data |
| Unnamed rock (Approx. 2 km N of Amak I.) | | 1975 | 108 | Jun | Braham et al. (1980) |
| | | | 234 | Aug | " |
| | | 1976 | 132 | Jun | " |
| | | | 355 | Aug | " |
| | | | 110 | Oct | " |
| | | 1977 | 97 | Jun | " |
| | | 1980 | 250 | 6 Jun | Izembek NWR, files |
| | | | 15 | 2 Jul | " |
| | | 1982 | 225 ± | 13 Jul | Frost et al. (1982) |
| | | 1986 | 218 | 29 Jun | Envirosphere Co., file data |

Table 6.9. Reported counts of northern sea lions at haulout sites in the northern Bristol Bay region. Most haulout sites where <100 animals have been recorded are not included.

| Island | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|
| Round Island | 1960 | 0 | Feb-Mar | Kenyon and Rice (1961) |
| | | 0 | Late Apr | " |
| | 1970 | 50 | 11 Nov | J. Faro *in* Frost et al. (1983) |
| | 1973 | 400-500 | 12 Jul | K. Pitcher *in* Frost et al. (1983) |
| | 1975 | 325 | Jun | Braham et al. (1977) *in* Frost et al. (1983) |
| | | 244 | Aug | " |
| | 1976 | 296 | Jun | " |
| | 1980 | 400-500 | Summer | K. Taylor *in* Frost et al. (1983) |
| | 1981 | 200 ± | 14 Apr | F. Fay *in* Frost et al. (1983) |
| | | 200-250 | Summer | K. Taylor *in* Frost et al. (1983) |
| | | 200-300 | 7 Oct | J. Burns, notes; Frost et al. (1983) |
| | 1982 | | | |
| | 1983 | Info for missing dates supposedly coming from ADF&G, Dillingham | | |
| | 1984 | | | |
| | 1985 | 1000+ | Summer | Sherburne (1985) |
| | 1986 | 560 | Jun | Sherburne (1986) |
| | 1987 | 1000 ± | May | Sherburne and Lipchak (1987) |
| | | 100-200 | Aug | " |
| The Twins (two islands, u = unspecified, N = North and S = South) | 1956 (u) | 300 | 26 Jul-4 Aug | Mathisen and Lopp (1963) |
| | 1957 (u) | 147 | 10 Sep | " |
| | 1958 (S) | 45 | 20 Jun | Kenyon (1958) |
| | 1958 (u) | 66 | Late Jun | Kenyon and Rice (1961) |
| | 1960 (u) | 400 | 27 Apr | " |
| | 1973 (N) | 100-150 | 12 Jul | K. Pitcher *in* Frost et al. (1983) |
| | 1973 (S) | 200-300 | 12 Jul | " |
| | 1975 (u) | 30-50 | Summer | Braham et al. (1977) *in* Frost et al. (1983) |
| | 1975 (S) | 1 | 7-14 Jun | R. Baxter *in* Frost et al. (1983) |
| | 1977 (S) | 9 | 26 Jun | USFWS Catalog of Seabird Colonies (1978) |
| High Island | Unspecified | 50 | Summer | ADF&G (1973) |
| | 1960 | 0 | Late Feb-Early May | Kenyon and Rice (1961) |
| | 1977 | 1 | 10 Jul | USFWS Catalog of Seabird Colonies (1978) |
| Crooked Island | Unspecified | 50 | Summer | ADF&G (1973) |
| | 1960 | 0 | Late Feb-Early May | Kenyon and Rice (1960) |

Continued...

Table 6.9. Concluded.

| Island | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|
| Hagemeister Island | Unspecified | 150 | Summer | ADF&G (1973) |
| Clam Point | 1985 | 0 | 24 Jan | AK. Maritime NWR (files) |
| | | 0 | 6 Feb | " |
| Cape Peirce | 1976 | Present | Summer | USFWS Catalog of Seabird Colonies (1978) |
| | 1981 | 450 | 26 Jun | D. Calkins *in* Frost et al. (1982) |
| | 1985 | Few[2] | Summer | Mazzone (1987) |
| | 1986 | Few[2] | Summer | " |
| | 1987 | Few[2] | May-Jun | O'Neil and Haggblom (1987) |
| Cape Newenham[3] | 1956 | 250 | 26 Jul-4 Aug | Mathisen and Lopp (1963) |
| | 1957 | 30 | 10 Sep | " |
| | 1971 | 250 ± | 24-28 Sep | Togiak NWR (file) |
| | 1975 | 75 | 30 May | R. Baxter *in* Frost et al. (1982) |
| | 1977 | 80 | 20 May | L. Barton *in* Frost et al. (1982) |
| | | 100+ | 27 May | " |
| | 1978 | 800 | 17 May | D. Jonrowe *in* Frost et al. (1982) |
| | | 500 ± | 20 May | " |
| | 1979 | 600 | 8 May | L. Barton *in* Frost et al. (1982) |
| | 1981 | 150 | 8 May | L. Lowry *in* Frost et al. (1982) |
| | 1982 | 135 | 4 Aug | L. Hotchkiss *in* Frost et al. (1982) |
| | 1987 | 950 | May | O'Neil and Haggblom (1987) |
| | | 130 | Dec | " |
| Nunivak Island | | | | |
| Binajoaksmiut Bay | 1979 | 49 | 5 Jun | USFWS *in* Frost et al. (1983) |
| Nabangoyak Rock | 1978 | 35 | 11 Jul | Ritchie (1978) *in* Frost et al. (1983) |
| Cape Mendenhall (32 km W) | 1981 | 50 | 4-5 Oct | Frost et al. (1983) |

1 Sea lions are abundant in waters of N. Bristol Bay during May/June, and are found in association with the huge schools of herring that spawn at that time. Apparently only a small fraction of these sea lions haul out.

2 These sightings (Cape Peirce 1985-1987) were mostly of animals in the water that were swimming north.

3 L. Hotchkiss (*in* Frost et al. 1982) reported sea lions hauled out at Cape Newenham during the summers of 1980, 1981 and 1982, with numbers ranging from 100-1500.

Table 6.10. Reported counts of northern sea lions at haulout sites (not rookeries) on the Pribilof Islands.

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Otter Island[1] | | 1872 | Present | Summer(?) | Elliot (1882) |
| | | 1955 | 1000 | 9 Apr | Kenyon and Rice (1961) |
| | | 1960 | 160 | Summer | " |
| | | 1974 | 200 | Jun | Johnson (1974) |
| | | 1977 | 200 | 22 Apr | Frost et al. (1983) |
| | | 1978 | 800 | 2 May | " |
| | | | 34 | 10 Jul | Kelly (1978) |
| | | 1979 | 400 | 13 Apr | Frost et al. (1983) |
| | | 1981 | 29 | 26 Jun | NMFS in Frost et al. (1983) |
| | | 1984 | 11 | 3 Jul | USFWS Catalog of Seabird Colonies |
| St. Paul | Near Northeast Point[2] | 1872 | 10,000 | Summer | Elliot (1884) in Kenyon (1962) |
| | | 1904 | 230 | Summer | Osgood et al. (1915) in Kenyon (1962) |
| | | 1914 | 120 | Summer | " |
| | | 1916 | 400 | Summer | Hanna (1923) in Kenyon (1962) |
| | | 1922 | 1000 | Summer | " |
| | | 1940 | 1100-1400 | Summer | Scheffer (1940) in Kenyon (1962) |
| | | 1944 | 300-500 (pups) | Summer | Scheffer (notes) in Kenyon (1962) |
| | | 1947 | 100-200 (pups) | Summer | Kenyon (1962) |
| | | 1949 | 252 (pups) | Summer | " |
| | | 1950 | 490+ | Summer | " |
| | | 1951 | 485 | Summer | " |
| | | 1954 | 65 | Summer | " |
| | | 1956 | ? (0 pups) | Summer | " |
| | | 1957 | 15 (pups) | Summer | " |
| | | 1960 | 71 (0 pups) | Summer | " |
| Sivutch | | 1872 | 1000's | Summer(?) | Elliot (1882) |
| | | 1940's & 1950's | 200-500 | Summers | Kenyon (1962) |
| | | 1960 | 300 | Summer | Kenyon and Rice (1961) |
| St. George | Near East Rookery | 1913 | 75 | Summer | Kenyon (1962) |
| | Near Garden Cove | 1872 | 4000-5000 | Summer | Elliot (1882) |
| | Near Tolstoi Point | 1872 | 4000-5000 | Summer | Elliot (1885) in Kenyon (1962) |
| | | 1960's | 100 | Summer | ADF&G (1973) |
| | Near South Rookery | 1960's | 500 | Summer | " |
| | Near Dalnoi Point[3] | 1960's | ~1200 | Summer | " |
| | | 1980 | 86 | Summer | NMFS files |

1 Otter Island is mainly used in winter (Kenyon 1962). This is reflected in the reported counts (above) that indicate higher numbers in spring than in summer.

2 According to Kenyon (1962) the last pups born near Northeast Point were in 1957. There are no indications in the literature of pups having been born there in recent years, though it is possible that some have been.

3 A report of 2500-3000 sea lions near Dalnoi Point in the 1960's is not in agreement with the statement in Kenyon (1962) that "In the summer of 1960, Riley estimated that about 1200 sea lions hauled out on St. George Island" (Kenyon and Rice 1961).

Table 6.11. Reported counts of northern sea lions at haulout sites in the St. Matthew Island area.

| Island | Haulout Site | Year | Number of Sea Lions | Time of Survey | Information Source |
|---|---|---|---|---|---|
| St. Matthew | All | 1916 | 0 | 8-14 Jul | Hanna (1920) |
| | Cape Upright | 1960 | 100 | 2 Aug | Kenyon and Rice (1961) |
| | | 1982 | 90 ± | 8 Jun | USFWS Catalog of Seabird Colonies (1978), and Frost et al. (1983) |
| | Lunda Point | 1982 | 52 | 23 Jul | " |
| | | 1983 | 600 | Summer | USFWS files |
| | Split Rock | 1982 | 20 | 28 Jul | USFWS Catalog of Seabird Colonies (1978), and Frost et al. (1983) |
| | Rock off West Point | 1982 | 13 | 28 Jul | " |
| | Gull Islands | 1986 | 500+ | 10 Jun | L. Lowry, field notes |
| Hall Island | All | 1916 | 0 | 8-14 Jul | Hanna (1920) |
| | S. of Elephant Rock | 1957 | 350 | 9 Aug | Klein (1959) _in_ Kenyon and Rice (1961) |
| | Three Rivers | 1977 | 3 | 9 Jul | Frost et al. (1983) |
| | Arre Rocks | 1982 | 150 | 16 Jul | " |
| | North Cove (rocks) | 1981 | 75 | 2 Aug | " |
| | | 1983 | 4000 | - | USFWS files |
| Pinnacle Island | | 1976 | 0 | 26 Jul | Frost et al. (1983) |
| | | 1979 | 100 | 16 Mar | B. Kelly _in_ Frost et al. (1983) |
| | | 1980 | 150-200 | 22-23 Sep | USFWS walrus survey and Frost et al. (1983) |
| | | 1985 | 257 | 11 Jul | USFWS Catalog of Seabird Colonies |

## APPENDIX 7. DETAILED COUNTS OF HARBOR SEALS AT TERRESTRIAL HAULOUT SITES IN THE EASTERN BERING SEA.

Table 7.1. Locations of reported harbor seal haulout sites in the eastern Aleutian Islands.[1]

| Island[2] | Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|---|
| Bogoslof | | 1890's | Present | Unspecified | Merriam (1901) |
| | | 1968 | Present | 3 Jun | J.J. Burns, field notes |
| | | 1970's | Present | Unspecified | Everitt and Braham (1980) |
| | | 1979 | Present | 15 Jul | Fiscus et al. (1981) |
| Unalaska | | 1965 | Present | 8 May | Kenyon (1965) |
| | | 1968 | Present (all Locs.) | 4 Mar | J.J. Burns, field notes |
| | | 1975 | 612 | Jun | Everitt and Braham (1980) |
| | | | 483 | Aug | " |
| | | 1976 | 156 | Jun | " |
| | | | 173 | Aug | " |
| | | 1977 | 262 | Jun | " |
| | Cape Kalekta | 1968 | 35-40 | 4 Mar | J.J Burns, field notes |
| Akutan | | 1965 | 0 | 8 May | Kenyon (1965) |
| | | 1975 | 0 | Jun | Everitt and Braham (1980) |
| | | | 24 | Aug | " |
| | | 1976 | 57 | Jun | " |
| | | | 99 | Aug | " |
| | | 1977 | 13 | Jun | " |
| | Cape Morgan | 1980 | 6 | 6 Jun | USFWS Catalog of Seabird Colonies (1978) |
| Akun | | 1975 | 20 | Jun | Everitt and Braham (1980) |
| | | | 146 | Aug | " |
| | | 1976 | 71 | Jun | " |
| | | | 179 | Aug | " |
| | | 1977 | 35 | Jun | " |
| Tangik | | 1980 | 23 | 13 Jun | USFWS Catalog of Seabird Colonies (1978) |
| Avatanak | | 1965 | 0 | 8 May | Kenyon (1965) |
| | | 1975 | 44 | Jun | Everitt and Braham (1980) |
| | | | 135 | Aug | " |
| | | 1976 | 78 | Jun | Everitt and Braham (1980) |
| | | | 107 | Aug | " |
| | | 1977 | 6 | Jun | " |

Continued...

Table 7.1. Concluded.

| Island[2] | Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|---|
| Tigalda & Adjacent Rocks | | 1957 | 8 | Sep/Oct | Mathisen and Lopp (1963) |
| | | 1965 | 60 | 8 May | Kenyon (1965) |
| | | 1975 | 1 | Jun | Everitt and Braham (1980) |
| | | | 116 | Aug | " |
| | | 1976 | 103 | Jun | " |
| | | | 437 | Aug | " |
| | | 1977 | 130 | Jun | " |
| Kaligagan & Adjacent Rocks | | 1975 | 75 | Jun | Everitt and Braham (1980) |
| | | | 50 | Aug | " |
| | | 1976 | 308 | Aug | " |
| | | 1977 | 94 | Jun | " |
| | | 1980 | 245 | 20 Jun | USFWS Catalog of Seabird Colonies (1978) |
| | Adjacent Rocks | 1980 | 109 + 13 + 3 | 22 Jun-2 Jul | " |
| Aiktak | | 1965 | 150 | 8 May | Kenyon (1965) |
| | | 1975 | 50 | Jun | Everitt and Braham (1980) |
| | | | 62 | Aug | " |
| | | 1976 | 100 | Aug | " |
| | | 1977 | 149 | Jun | " |
| | | 1980 | 94 | 25 Jun | USFWS Catalog of Seabird Colonies (1978) |
| Ugamak | | 1965 | 50 | 8 May | Kenyon (1965) |
| | | 1975 | 30 | Aug | Everitt and Braham (1980) |
| | | 1977 | 0 | Jun | " |

1 Harbor seals are ubiquitous around all islands, though in relatively low numbers. They can be expected to haul out at innumerable locations not included in this table. This region has never been intensively sampled throughout the year.
2 Reported locations are those facing the Bering Sea or Unimak Pass.

Table 7.2. Harbor seal haulout sites, Unimak Island to Kvichak Bay.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Unimak I.-Mainly N. side | 1960 | 550 | 3-4 Mar | Kenyon (1960) in Frost et al. (1983) |
| | 1965 | 0 | 8 May | Kenyon (1965) |
| | 1975 | 125 | Jun | Everitt and Braham (1980) |
| | | 0 | Aug | " |
| | 1976 | 5 | Jun | " |
| | | 0 | Aug | " |
| | 1977 | 0 | Jun | " |
| Sea Lion Pt. | 1977 | Present | 13 May | Frost et al. (1983) |
| Cape Lapin area | 1967 | 200 | 23 Jun | Izembek NWR files in Frost et al. (1983) |
| | 1976 | 40 | 26 May | Frost et al. (1983) |
| Bechevin Bay-Mouth | 1965 | 1500 | 21 Apr | Kenyon (1965) |
| | | 1500 | 8 May | " |
| Cape Krenitzin | 1967 | 500-1000 | 3 May | Izembek NWR files in Frost et al. (1983) |
| | | 1500 | 19 Jul | " |
| | | 500 | 17 Aug | " |
| Isanotski Is. | 1975 | 368 | Jun | Everitt and Braham (1980) |
| | | 414 | Aug | " |
| | 1976 | 99 | Jun | " |
| | | 511 | Aug | " |
| | 1977 | 422 | Jun | " |
| Amak Island | 1960 | 13 | 3-4 Mar | Kenyon (1960) in Frost et al. (1983) |
| | 1965 | 0 | 8 May | Kenyon (1965) |
| | 1975 | 14 | Jun | Everitt and Braham (1980) |
| | | 61 | Aug | " |
| | 1976 | 46 | Jun | " |
| | | 14 | Aug | " |
| | 1977 | 12 | Jun | " |
| | 1981 | 2 | 16 Oct | Frost et al. (1983) |
| Sea Lion Rock | 1965 | 0 | 8 May | Kenyon (1965) |
| Cape Leontovich area | 1965 | 20 | 4 Jul | Izembek NWR files in Frost et al. (1983) |
| Cape Lieskof area | 1965 | 100 | 29 Oct | Izembek NWR, files in Frost et al. (1983) |
| | 1975 | 125 | Jun | Everitt and Braham (1980) |
| | | 89 | Aug | " |
| | 1976 | 199 | Jun | " |
| | | 1 | Aug | " |
| | 1977 | 1 | Jun | " |

Continued...

Table 7.2. Concluded.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Bear River | 1965 | 6 | 18 Jul | Izembek NWR files in Frost et al. (1983) |
| Cape Seniavin area | 1973 | 40 | 11 Jul | K. Pitcher in Frost et al. (1983) |
| | 1975 | 10 | Jun | Everitt and Braham (1980) |
| | | 0 | Aug | " |
| | 1976 | 71 | Jun | " |
| | | 0 | Aug | " |
| | 1977 | 2 | Jun | " |
| Ugashik Bay area | 1973 | 40 | 11 Jul | K. Pitcher in Frost et al. (1983) |
| | 1975 | 196 | Jun | Everitt and Braham (1980) |
| | | 2 | Aug | " |
| | 1976 | 163 | Jun | " |
| | | 438 | Aug | " |
| | 1977 | 215 | Jun | " |
| | 1988 | 1000+ | 13 Jul | J.J. Burns, field notes |
| Cape Greig area | 1975 | 0 | Jun | Everitt and Braham (1980) |
| | | 0 | Aug | " |
| | 1976 | 1 | Jun | " |
| | | 0 | Aug | " |
| | 1977 | 2 | Jun | " |
| Egegik Bay area | 1973 | 300 | 11 Jul | K. Pitcher in Frost et al. (1983) |
| | 1975 | 50 | Jun | Everitt and Braham (1980) |
| | | 0 | Aug | " |
| | 1976 | 70 | Jun | " |
| | | 0 | Aug | " |
| Naknek River area | | Present | | Burns |
| Kvichak Bay | | Present | | Burns |
| Alaska Peninsula (general) | | | | |
| Bechevin Bay to Ugashik Bay | 1984 | 5294 | 28 Apr-4 May | Izembek NWR Rep. (1984) |
| | 1985 | 1595 | 12-16 May | Izembek NWR Rep. (1985) |
| Bechevin Bay to Port Moller | 1965 | 1860 | 8 May | Kenyon (1965) |

Table 7.3. Harbor seal numbers at the five major haulout sites in the southern Bristol Bay area.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Izembek/Moffet Lagoons (All Areas) | 1956 | 620 | May | Mathisen and Lopp (1963) |
| | 1957 | 1142 | Aug | " |
| | 1975 | 4000-5000 | Summer | Izembek NWR files (1982) |
| | | 2034 | Jun | Everitt and Braham (1980) |
| | | 208 | Aug | " |
| | 1976 | 559 | Jun | " |
| | | 1204 | Aug | " |
| | 1977 | 874 | Jun | " |
| | 1981 | 150 | 27 Apr | Izembek NWR _in_ Frost et al. (1983) |
| | 1982 | 1971 | 7 Jul | Izembek NWR files (1982) |
| | 1983 | 995 | 10 Jun | Izembek NWR files (1983) |
| | | 1974 | 11 Jul | " |
| Norma Bay | 1967 | 20 | 23 Jun | Izembek NWR _in_ Frost et al. (1983) |
| | | 85 | 9 Jul | " |
| | | 200 | 26 Jul | " |
| Applegate Cove | 1968 | 100 | 13 Jul | Izembek NWR _in_ Frost et al. (1983) |
| Moffet Point | 1966 | 250 | 21 Oct | Izembek NWR _in_ Frost et al. (1983) |
| | 1967 | 800-1000 | 18 Oct | " |
| | 1982 | 400+ | 13 Jul | Frost et al. (1983) |
| Barrier Islands | 1965 | 350 | 19 Apr | Kenyon (1965) |
| | | 350 | 8 May | " |
| | 1981 | 150 | 27 Apr | Izembek NWR files, Goose surveys |
| | 1982 | 190 | 4 May | " |
| | 1983 | 125 | 28 Apr | " |
| | 1984 | 649 | 30 Apr | " |
| | 1985 | 105 | 15 May | " |
| | 1986 | 40 | 5 May | " |
| | 1987 | 325 | 3 May | " |
| Port Moller area (incl. Nelson Lagoon) | 1957 | 431 | 8 Dec | Mathisen and Lopp (1963) |
| | 1965 | 1400 | 18 Jul | Frost et al. (1983) |
| | 1965 | 1500 | 9 Oct | " |
| | 1966 | 8000 | 6 Jul | Pitcher (1986) |
| | 1968 | 1250 | 10 Jul | " |
| | 1969 | 3300 | 14 Jul | " |
| | 1970 | 2500 | 2 Jul | " |
| | 1971 | 4100 | 18 Jun | " |
| | 1973 | 1675 | 11 Jul | " |
| | 1975 | 6078 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 1740 | Aug | Everitt and Braham (1980) |

Continued...

Table 7.3. Continued.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Port Moller area (Cont.) | 1976 | 7968 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 1701 | Aug | Everitt and Braham (1980) |
| | 1977 | 4335 | 28 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | 1981 | 500-600 | 10 Oct | Frost et al. (1983) |
| | 1985 | 4010 | 17 Jun | Pitcher (1986) |
| Seal Islands/Ilnik | 1966 | 3200 | 6 Jul | Pitcher (1986) |
| | | 250 | 2 Aug | K. Pitcher in Frost et al. (1983) |
| | 1967 | 200 | 5 May | K. Pitcher, ADF&G file |
| | | 330 | 1 Jun | " |
| | | 500 | 18 Jul | " |
| | 1968 | 300 | 2 Jul | " |
| | | 350 | 10 Jul | Pitcher (1986) |
| | | 300 | 17 Jul | K. Pitcher, ADF&G file |
| | | 400 | 23 Jul | K. Pitcher in Frost et al. (1983) |
| | | 400 | 31 Jul | K. Pitcher, ADF&G file |
| | | 450 | 4 Aug | K. Pitcher in Frost et al. (1983) |
| | 1969 | 900 | 30 Jun | Pitcher (1986) |
| | | 1000 | 17 Jul | K. Pitcher in Frost et al. (1983) |
| | 1970 | 1000 | 21 Jun | Pitcher (1986) |
| | | 1600 | 25 Jul | K. Pitcher in Frost et al. (1983) |
| | 1971 | 400 | 5 Jun | K. Pitcher, ADF&G file |
| | | 1000 | 18 Jun | " |
| | | 860 | 6 Jul | " |
| | | 1550 | 14 Jul | Pitcher (1986) |
| | | 1350 | 2 Aug | K. Pitcher, ADF&G file |
| | 1973 | 374 | 11 Jul | K. Pitcher in Frost et al. (1983) |
| | 1975 | 1137 | 18 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 75 | Aug | Everitt and Braham (1980) |
| | 1976 | 786 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 241 | Aug | Everitt and Braham (1980) |
| | 1977 | 497 | 28 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | 1984 | 600 | 29 Apr | Izembek NWR file, Goose surveys |
| | 1985 | 1521 | 14 Jun | Pitcher (1986) |
| | 1986 | 650 | 5 May | Izembek NWR file, Goose surveys |
| | 1988 | 75 ± | 30 Apr | S. Hills, USFWS (Pers. Comm.) |
| Ilnik Only | 1971 | 3200 | 5 Jun | K. Pitcher in Frost et al. (1983) |
| Port Heiden | 1965 | 2500-3000 | 19 May | K. Pitcher in Frost et al. (1983) |
| | | 8000-10,000 | 1 Jul | " |
| | | 2500-3000 | 1 Aug | " |
| | 1966 | 800 | 7 Jun | " |
| | | 1500 | 24 Jun | Pitcher (1986) |
| | | 2500 | 30 Jun | " |
| | | 1500 | 4 Jul | " |
| | | 2500 | 6 Jul | " |
| | | 750 | 2 Aug | K. Pitcher in Frost et al. (1983) |

Continued...

Table 7.3. Continued.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Port Heiden (Cont.) | 1967 | 800 | 5 May | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 350 | 1 Jun | " |
| | | 2300 | 18 Jul | " |
| | 1968 | 1200 | 2 Jul | Pitcher (1986) |
| | | 2500 | 10 Jul | " |
| | | 3000 | 17 Jul | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 800 | 4 Aug | " |
| | 1969 | 1400 | 27 Jun | Pitcher (1986) |
| | | 2100 | 29 Jun | " |
| | | 2100 | 4 Jul | " |
| | | 1300 | 8 Jul | " |
| | | 2050 | 17 Jul | K. Pitcher <u>in</u> Frost et al. (1983) |
| | 1970 | 4000 | 20 Jun | Pitcher (1986) |
| | | 3100 | 21 Jun | " |
| | | 2400 | 27 Jun | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 6500 | 2 Jul | Pitcher (1986) |
| | | 2100 | 18 Jul | " |
| | 1971 | 1000 | 5 Jun | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 5900 | 18 Jun | Pitcher (1986) |
| | | 2000 | 2 Jul | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 1600 | 14 Jul | Pitcher (1986) |
| | | 1700 | 2 Aug | K. Pitcher <u>in</u> Frost et al. (1983) |
| | 1973 | 4298 | 11 Jul | Pitcher (1986) |
| | 1975 | 4774 | 18 Jun | " |
| | | 5273 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 4776 | 15 Jun | Pitcher (1986) |
| | 1975 | 3453 | Aug | Everitt and Braham (1980) |
| | 1976 | 10,548 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 4782 | Aug | Everiit and Braham (1980) |
| | 1977 | 6222 | 28 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | 1981 | 1100 | 9 Oct | Frost et al. (1983) |
| | 1984 | 1000 | 10 May | ADF&G, King Salmon |
| | 1985 | 4700 | 17 Jun | Pitcher (1986) |
| | | 6196 | 18 Jun | " |
| | | 4405 | 19 Jun | " |
| | | 6035 | 20 Jun | " |
| | | 5782 | 21 Jun | " |
| | 1986 | 800 | 5 May | Izembek NWR files, Goose survey |
| Strogonof Point | 1956 | 100 | Jul/Aug | Mathisen and Lopp (1963) |
| | 1957 | 1295 | Dec | " |
| Cinder River | 1965 | 1000 | 19 May | K. Pitcher <u>in</u> Frost et al. (1983) |
| | 1966 | 1500 | 13 Jun | Pitcher (1986) |
| | | 1000 | 24 Jun | " |
| | | 950 | 6 Jul | " |
| | | 2000 | 2 Aug | K. Pitcher <u>in</u> Frost et al. (1983) |
| | | 2000 | 5 Aug | " |

Continued...

Table 7.3. Concluded.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Cinder River (Cont.) | 1967 | 3000 | 18 Jul | K. Pitcher in Frost et al. (1983) |
| | 1968 | 600 | 2 Jul | Pitcher (1986) |
| | | 800 | 10 Jul | " |
| | | 700 | 17 Jul | K. Pitcher in Frost et al. (1983) |
| | | 800 | 23 Jul | " |
| | | 200 | 31 Jul | " |
| | | 200 | 2 Aug | " |
| | 1969 | 500 | 27 Jun | Pitcher (1986) |
| | 1970 | 3400 | 2 Jul | " |
| | | 1500 | 5 Jun | K. Pitcher in Frost et al. (1983) |
| | | 350 | 14 Jul | Pitcher (1986) |
| | 1973 | 875 | 11 Jul | " |
| | 1975 | 925 | 18 Jun | Pitcher (1986) |
| | | 2867 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 113 | Aug | Everitt and Braham (1980) |
| | 1976 | 3062 | 15 Jun | Pitcher (1986) |
| | | 4503 | 20 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | | 1008 | Aug | Everitt and Braham (1980) |
| | 1977 | 1530 | 28 Jun | Everitt and Braham (1980); Pitcher (1986) |
| | 1981 | 350 | 8 Oct | Frost et al. (1983) |
| | 1985 | 1 | 14 Jun | Pitcher (1986) |
| | | 0 | 15-21 Jun | Pitcher (1986) |
| | 1988 | 300 ± | 30 Apr | S. Hills, USFWS (Pers. Comm.) |

Table 7.4. Harbor seal haulout sites, northern Bristol Bay to Yukon River.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Kvichak Bay (incl. | | | | |
| Salmon Flats, Halfmoon Bay | 1973 | 150 | 11 Jun | K. Pitcher in Frost et al. (1983) |
| and Deadman Sands | 1988 | 150+ | 5 Jul | J. Burns, notes |
| Nushagak Peninsula | | | | |
| East Side | 1974 | Present | Aug | Frost et al. (1983) |
| | 1975 | Present | 30 May-15 Jun | " |
| Cape Constantine | 1981 | 75-100 | 29 Jul | D. Calkins in Frost et al. (1983) |
| Tvakivak Bay area | 1981 | 77 | 8 May | L. Lowry in Frost et al. (1983) |
| Summit Island | 1977 | 5 | 11 Jul | Frost et al. (1983) |
| | 1980 | 30 | 23 Sep | " |
| Hagemeister Island | 1974 | Present | Aug | Frost et al. (1983) |
| | 1975 | 150 ± | 30 May | " |
| | | Present | 30 May-15 Jun | " |
| | | 20-200 | Jun & Aug | Everitt and Braham (1980) |
| | 1977 | 70 ± | 9-10 Jul | Frost et al. (1983) |
| | 1980 | 100 | 23 Sep | " |
| High Island | Various | Present | Various | J. Brooks (Pers. Comm.) |
| East Side | Unspecified | 12+ | 5 & 10 Jul | Frost et al. (1983) |
| West Side | Unspecified | 25+ | 5 & 10 Jul | " |
| North End | 1973 | 20 | 12 Jul | K. Pitcher in Frost et al. (1983) |
| South End | | 2 | 12 Jul | " |
| | 1977 | 38 + pups | Jul | ADF&G files, Fairbanks |
| Crooked Island | 1973 | 30 | 12 Jul | K. Pitcher in Frost et al. (1983) |
| | 1977 | 10's + pups | 16 Jun-17 Jul | Frost et al. (1983) |
| Round Island | 1981 | 2 | 7 Oct | Frost et al. (1983) |
| Black Rock | 1973 | 20-30 | 12 Jul | K. Pitcher in Frost et al. (1983) |
| | 1981 | 300 | 7 Oct | Frost et al. (1983) |
| The Twins | Various | Present | Various | Burns (Pers. Comm.) |
| Cape Peirce | 1981 | 30 ± | 6 Oct | Frost et al. (1983) |
| | Various | Present | Various | Burns (Pers. Comm.) |

Continued...

Table 7.4. Continued.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Nanvak Bay* | 1966 | 1000-2000 | Various | ADF&G files, Fairbanks |
| | 1970 | 1000 ± | 25 Jul | Frost et al. (1983) |
| | 1971 | 458 | 24 Sep | " |
| | | 900 + | 28 Sep | " |
| | 1973 | 250-300 | Late Jun-early Jul | " |
| | 1975 | 2918 | 31 Aug (max. count) | Johnson (1975) |
| | 1979 | 2000 | 13-25 Sep | Frost et al. (1983) |
| | 1980 | 200 | 5 May | " |
| | | 500 | 6 Oct | " |
| | 1981 | 200 | Apr/May | " |
| | | 3100 | 31 Aug | " |
| | | 3000 | end Sep | " |
| | 1983 | 2500 | 26 Sep | K. Taylor, ADF&G files |
| | | 450 | 12 Oct | " |
| | 1986 | 70 ± | May (monthly max.) | Mazzone (1987) |
| | | 250 | Jun " | " |
| | | 540 ± | Jul " | " |
| | | 460 | Aug " | " |
| | | 500 | Sep " | " |
| | 1987 | 180 ± | May " | O'Neil and Haggblom (1987) |
| | | 100 ± | Jun " | " |
| | | 150 ± | Jul " | " |
| | | 205 ± | Aug " | " |
| | | 221 | Sep " | " |
| Cape Newenham area | Various years and dates. Present in low numbers. Maximum reported count was 50 on 30 May 1975, as reported in Frost et al. (1983). | | | |
| Security Cove | Various years and dates. Present in low numbers. Frost et al. (1983). | | | |
| Chagvan Bay | Various years and dates. Present. Maximum reported count 150 (% harbor seals unknown) on 17 June 1977, as reported by Frost et al. (1983). | | | |
| Goodnews Bay | Various years and dates. Present. Maximum reported count 25 (% harbor seals unknown) on 17 June 1977, as reported by Frost et al. (1983). | | | |

Continued...

Table 7.4. Concluded.

| Location | Year | Number of Seals | Date | Information Source |
|---|---|---|---|---|
| Kuskokwim Bay | | | | |
| Numerous bars and flats | (Note: Spotted seals in late spring, early summer, replaced by harbor seals in summer to autumn. Seasonal proportions not well known). Sampling in May showed 100% spotted seals and sampling in July showed mainly harbor seals (ADF&G files) - selected counts are: | | | |
| | 1972 | 2000 + | 4 Jul | Frost et al. (1983) |
| | 1977 | 2000 + | 17 Jun | " |
| | 1978 | 5650 ± | 17 May | " |
| | | 6000 ± | 20 May | " |
| Islands off Cape Avinof area and North, including: | | | | |
| Kwigluk Islands | Various | Numerous | Summer | Burns (Pers. Comm.) |
| Pingurbek Island | (probably spotted seals in late spring-early summer and harbor seals during July freeze-up. Proportions unknown. Numbers unknown but reported by locals as numerous). | | | |
| Kikegtek Island | | | | |
| Krekatok Island | | | | |
| Nunivak Island | | | | |
| Cape Mendenhall | 1981 | 80 | 4 Oct | Burns (Pers. Comm.) |
| | | 20 | 5 Oct | " |

* Arvey (1973) recognized the presence of both harbor and spotted seals in Nanvak Bay. Johnson (1975) found that on 31 August 1975, the date of his highest summer count, 90% of 2918 seals hauled out were harbor seals and 10% were spotted seals.

Table 7.5. Harbor seal haulout sites on the Pribilof Islands.

| Island | Rookery/ Haulout Site | Year | Number of Seals | Time of Survey | Information Source |
|---|---|---|---|---|---|
| St. Paul | All | 1870's | Present | Year round | Elliot (1882) |
| | | 1895 | Present | Summer | True (1899) |
| | | Currently | Present | Year round | This study |
| | Gorbatch | 1870's | Present | Year round | Elliot (1882) |
| | | 1895 | Few | Summer | True (1899) |
| | Southwest Bay | 1895 | Present | Summer | True (1899) |
| | North Shore | 1895 | Present | Summer | True (1899) |
| St. George | All | 1870's | Present | Year round | Elliot (1882) |
| | | Currently | Present | Year round | This study |
| | near Dalnoi Pt. | 1982 | 40-50 | Summer | Frost et al. (1983) |
| Walrus Island | All | Currently | Few | Year round | This study |
| Sivutch or Sea Lion Rock | All | Currently | Few | Year round | This study |
| Otter Island | All | 1870's | Present | Year round | Elliot (1882) |
| | | 1953 | Present | 14 Jul | Scheffer (1977) |
| | | 1973 | 500 ± | 12 Aug | Frost et al. (1983) |
| | | 1974 | 425 ± | 7 Jul | Johnson (1974) |
| | | | 1080 ± | 9 Jul | " |
| | | | 1175 ± | 17 Jul | " |
| | | | 340 ± | 27 Jul | " |
| | | | 1050 ± | 29 Jul | " |
| | | | 1190 ± | 2 Aug | " |
| | | | 610 ± | 7 Aug | " |
| | | | 1075 ± | 9 Aug | " |
| | | | 375 ± | 12 Aug | " |
| | | | 495 ± | 20 Aug | " |
| | | | 1210 | 24 Aug | " |
| | | | 700 ± | 25 Aug | " |
| | | 1975 | 200 ± | 16 Jul | Frost et al. (1983) |
| | | 1978 | 300 | 2 May | " |
| | | | 707 | 16 May | Kelly (1978) |
| | | 1979 | 250 ± | 13 Apr | Frost et al. (1983) |
| | | 1981 | 119 | 26 Jun | Prib. Isl. Ann. Rep. (1981) <u>in</u> Frost et al. (1983) |

**APPENDIX 8. DETAILED COUNTS OF PACIFIC WALRUSES AT TERRESTRIAL HAULOUT SITES IN THE EASTERN BERING SEA.**

Table 8.1. Reported counts of Pacific walruses at haulout sites in the southern Bristol Bay region.

| Location | Haulout Site | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Unimak Island | Otter Point | 1967 | Present | 11 May | Izembek NWR files |
| Amak Island | Amak Island | 1962 | 100-120 | 8 Apr | J. Burns, field notes |
| | | 1969 | 100 | 15 Apr | Frost et al. (1983) |
| | | 1979 | 500 | 28 Jun | " |
| | | | 400 | 15 Jul | " |
| | | | 50 | 28 Jul | " |
| | | | 0 | 26 Aug | " |
| | | | 20 | 29 Aug | " |
| | | | 4-5 | 1 Sep | " |
| | | | 5 | 5 Sep | Izembek NWR files |
| | | | 9 | 6 Sep | Frost et al. (1983) |
| | | | 0 | 11 Oct | " |
| | | | Many | Autumn-1 Nov | " |
| | | 1980 | 0 | 7 May | " |
| | | | 0 | 6 Jun | " |
| | | | 0 | 23 Jun | " |
| | | | 0 | 2 Jul | " |
| | | 1981 | 0 | 9 Mar | " |
| | | | 0 | 7 Apr | " |
| | | | 0 | 11 Oct | " |
| | | | 0 | 16 Oct | " |
| | | 1982 | 0 | 13 Jul | " |
| Port Moller areal | Herendeen Bay | 1968 | up to 1000 | 20 Apr | Frost et al. (1983) |
| | Port Moller (incl. Harbor Pt.) | 1969 | 200 ± | Jan/Feb | Fay and Lowry (1981) |
| | | 1976 | 1000's (offshore) | Summer | Frost et al. (1983) |
| | | | Present | Summer | Fay and Lowry (1981) |
| | | 1979 | 2000-4000 | Apr/May | Frost et al. (1983) |
| | | | 400 | Mid May | " |
| | | 1980 | 750-1000 | 6 May | " |
| | | | 800 ± | 27 May | Izembek NWR files |
| | | | up to 1000 | Late May | " |
| | Pt. Divide | 1982 | 4 | 21 Apr | Izembek NWR files |
| | | | 0 | 27 Apr | " |
| | Bear River | 1978 | 140 | 23 Apr | Izembek NWR files |
| | | 1979 | 100 | 17 Apr | ADF&G, Fairbanks |
| | Port Moller to Herendeen Bay | 1983 | 3250 | 26 Apr | Izembek NWR files |

Continued...

Table 8.1. Continued.

| Location | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|
| Cape Seniavin | 1978 | 140 | 23 Apr | J. Sarvis, Aleutian Islands NWR |
| | | Many | Apr | Fay and Lowry (1981) |
| | 1979 | Many | Apr/May | " |
| | 1980 | Many | Late Mar | " |
| | | 600 | 5 Apr | " |
| | | 500-600 | 7 Apr | " |
| | | 50 | 10 Apr | " |
| | | 0 | 13 Apr | " |
| | | 0 | 14 Apr | " |
| | | 1000-1500 | 16 Apr | " |
| | | 1000 | 17 Apr | ADF&G, King Solomon |
| | | 383 | 18 Apr | Fay and Lowry (1981) |
| | | 200 | 15 May | " |
| | | 1 | 20 May | " |
| | | 2 | 21 May | " |
| | | 100 | 22 May | " |
| | | 130 | 23 May | " |
| | | Departed | 25 May | Izembek NWR files |
| | 1981 | 1500-2000 | 7 Apr | Fay and Lowry (1981) |
| | | 250 ± | 8 Apr | Izembek NWR files |
| | | 60-100 | 9 Apr | Fay and Lowry (1981) |
| | | 100 | 10 Apr | " |
| | | 40 | 11 Apr | " |
| | | 34 | 12 Apr | " |
| | | 0 | 23 Apr | " |
| | | 0 | 7 May | " |
| | 1982 | Few, if any | Apr/May | Izembek, NWR files |
| | 1983 | 2500 | 31 Mar | " |
| | | 1000 ± | 9 Apr | " |
| | | 3500 | 26 Apr | " |
| | | 75 | 7 May | " |
| | | 250 | 19 Jun | " |
| | | 1000 ± | 13 Apr | Izembek NWR files |
| | | 150-200 | 28 May | ADF&G, King Solomon |
| | | 400 ± | 14 Jun | " |
| | 1984 | 40-50 | 24 Apr | R. Wilk, USFWS King Salmon |
| | | 625 | 29 Apr | Izembek NWR files |
| | | 150-170 | 9-18 May | R. Wilk, USFWS King Salmon |
| | 1985 | 0 | 3 Apr | Izembek NWR files |
| | | 0 | 12-16 May | " |
| | 1986 | 132 | 25 Apr | R. Wilk, USFSW King Salmon |
| | 1987 | 200 | 16 Mar | S. Hills, USFWS (Pers. Comm.) |
| | | 3000 | 26 Mar | " |
| | | 2500 | 2 Apr | " |
| | | 3300 | 5 Apr | " |

Continued...

Table 8.1. Concluded.

| Location | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|
| Cape Seniavin (Cont.) | 1987 | 2000 | 6 Apr | S. Hills, USFWS (Pers. Comm.) |
| | | 1200 | 7 Apr | " |
| | | 50 | 24 Apr | " |
| | | 200 | 9 Jun | " |
| | | 25 | 13 Jun | " |
| | | 5 | 14 Nov | " |
| | 1988 | 50-60 | 23 Apr | " |
| | | 200 | 27 Apr | " |
| | | 100 | 28 Apr | " |
| | | 300 | 1 May | " |
| | | 350 | 2 May | " |
| | | 500 | 3 May | " |
| | | 100 | 4 May | " |
| | | 200 ± | 4 May | Izembek NWR files |
| | | 150 | 5 May | S. Hills, USFWS (Pers. Comm.) |
| | | 50 | 6 May | " |
| | | 30 | 7 May | " |
| | | 60 | 8 May | " |
| | | 120 | 9 May | " |
| | | 100 | 10 May | " |
| | | 0 | 11 May | " |
| | | 1800 | 12 May | " |
| | | 1500 | 13 May | " |
| | | 1000 | 14 May | " |
| | | 1000 | 15 May | " |
| Port Heiden | 1979 | Present | Jun/Jul | Fay and Lowry (1981) |
| | | 40 | 30 Jun | Frost et al. (1983) |
| | | 50-60 | 15 Jul | " |
| | | 1 | 2 Oct | " |
| Cinder River | 1962 | Present | May | Fay and Lowry (1981) |
| | | A few | - | Frost and Lowry (1983) |
| | 1963 | Present | May | Fay and Lowry (1981) |
| | 1971 | 1 | Early Oct | Frost et al. (1983) |
| | 1973 | 1 | Late May | " |
| Egegik Bay | 1983 | 1000 ± | 1 Apr | ADF&G, King Solomon |
| | | 200-250 | 2 Apr | " |

[1] An unknown number of walruses are reported to haul out on Deer Island, which is in the narrows between Port Moller and Herendeen Bay.

Table 8.2. Pacific walrus haulout sites, northern Bristol Bay to Bering Strait.

| Location | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|
| High Island | 1953 | 0 | 29 May | F. Fay, notes |
| | | 250 ± | 22 Jul | J. Brooks *in* Frost et al. (1983) |
| | 1958 | 0 | 12 May | F. Fay, notes |
| North Twin Island | 1953 | 600 ± | 29 May | Frost et al. (1983) |
| | | 850 ± | 22 Jul | " |
| | 1957 | 899-1000 | Jun | " |
| | 1958 | 300 | 12 May | " |
| | | 2 | 25 Jun | " |
| | 1959 | 10 | Aug | " |
| | 1974 | Present | Aug | " |
| | 1975 | Present | 30 May-15 Jun | " |
| | 1976 | 1000 ± | 12 Jun | " |
| Crooked Island | 1957 | ~20 | Jun | F. Fay, notes |
| Round Island | 1953 | 400 ± | May | Frost et al. (1983) |
| | 1954 | 500 ± | May | " |
| | 1955 | Some | May | " |
| | 1957 | 500 | Aug | " |
| | 1958 | 2-3000 | May/Jun | " |
| | 1959 | 3076 | Jun | " |
| | 1960 | 1-2000 | Aug | " |
| | 1966 | 200 | Jul | Lowry et al. (unpubl.) |
| | 1968 | 1000 | Apr | Frost et al. (1983) |
| | 1970 | 500 ± | Nov | " |
| | 1972 | 3000 | Summer | ADF&G files |
| | 1973 | 1000 | Jul | " |
| | 1974 | 3000 ± | Jul | " |
| | 1975 | 10,000 ± | Summer | " |
| | 1976 | 8-10,000 | 23 Aug | " |
| | | 5210 | Sep | Taggart and Zabel *in* Frost et al. (1983) |
| | 1977 | 10,000 + | Jun/Jul | Taggart and Zabel (1975) |
| | 1980 | 1500 ± | Late Mar | ADF&G, Dillingham |
| | | 4000 ± | 17 Apr | ADF&G, King Solomon |
| | | 11,600 | Jun | Taggart and Zabel *in* Frost et al. (1983) |
| | 1981 | 5000 | Apr/May | Frost et al. (1983) |
| | | 10-12,000 | Summer | ADF&G files |
| | 1982 | 10-12,000 | Summer | " |
| | 1983 | 2000 | Aug | " |
| | 1984 | 80-100 | 16 Jan | ADF&G, Dillingham |
| | | 6000 ± | Jul | ADF&G files |
| | 1985 | 6112 + | 29 Jun | " |
| | 1986 | 12,400 | Summer | Sherburne and Lipchak (1987) |

Continued...

Table 8.2. Continued.

| Location | Haulout Site | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Hagemeister Island | | 1935 | 8 | Jun | Frost et al. (1983) |
| | | 1953 | 0 | 29 May | " |
| | | | 0 | 22 Jul | " |
| | | 1958 | 0 | 12 May | " |
| | | 1974 | Present | Aug | " |
| | | 1975 | Present | 30 May-15 Jun | " |
| Cape Peirce area[1] | | 1981 | 2800 | Sep | Frost et al. (1983) |
| | | 1983 | 150 | 8 Apr | K. Taylor, ADF&G, Dillingham |
| | | | 4 | 21 Apr | " |
| | | | 0 | 1 Jun | " |
| | | | 3800 | 9 Aug | " |
| | | | 6000-7000 | 17 Aig | " |
| | | | 7000 | 23 Aug | Taggart and Zabel (1985) in ADF&G files |
| | | | 5000 | 22 Sep | K. Taylor, ADF&G, Dillingham |
| | | | 0 | 26 Sep | " |
| | | | 900 | 12 Oct | " |
| | | 1984 | 650 | 18 Jan | K. Taylor, ADF&G, Dillingham |
| | | | 125 + | 19 Jan | " |
| | | | 8600 | Summer | O'Neil and Haggblom (1987) |
| | | 1985 | 150 ± | 1 Jun | ADF&G, Fairbanks |
| | | | 12,500 | Jul | Mazzone (1986) |
| | | 1986 | 11,600 | Summer | O'Neil and Haggblom (1987) |
| | | 1987 | 6300 | Summer | " |
| Cape Newenham area | | 1978 | 500 ± | Jun | Frost et al. (1983) |
| | | 1979 | up to 400 | Spring/Summer | " |
| | | 1980 | up to 400 | Spring | " |
| | | 1981 | up to 400 | Spring | " |
| | | 1986 | 700 | Summer | O'Neil and Haggblom (1987) |
| | | 1987 | 70 | Summer | " |
| Security Cove area | | 1978 | 25-30 | May | Frost et al. (1983) |
| | | 1983 | 10,000 | 1-4 May | ADF&G files, Bethel |
| Goodnews Bay area | | 1978 | 1 | 17 May | Frost et al. (1983) |
| | | | 200-250 | Nov | " |
| Kwigillingok area | | 1968 | 500 ± | Jun | " |
| Nunivak Island | | | | | |
| | North Side | 1978 | 200+ | Oct-Nov | Frost et al. (1983) |
| | Near Cape Etolin | 1978 | 200+ | Nov-Dec | " |
| | Cape Mohican | Various | Present | Summer-Autumn | Local Informants |

Continued...

Table 8.2. Continued.

| Location | Haulout Site | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Cape Vancouver (W tip of Nelson Island) | | 1978 | Present | Oct | Frost et al. (1983) |
| Egg Island | | 1971 | 200-300 | Jun | " |
| Besboro Island | | 1961 | 200 | 15 Aug | Frost et al. (1983) |
| | | 1963 | 200-400 | Jun/Jul | " |
| | | 1964 | 0 | 7 Jul | " |
| | | 1971 | A few | Jun/Jul | " |
| | | 1980 | 100+ | Summer | " |
| | | 1981 | 100+ | Summer | " |
| Cape Darby area | | 1979 | 7 | 22 Jun | " |
| | | 1981 | 50 | 2 Jun | " |
| | | | 1 | 4 Jun | " |
| | | | 1 | 5 Jun | " |
| Sledge Island | | 1971 | 1000 ± | 16 Jul | " |
| | | 1976 | A few | Summer | " |
| | | 1980 | 2-3 | Summer | " |
| | | 1981 | 2-3 | Summer | " |
| Pribilof Islands | | 1899 | "Exterminated" | - | True (1899) |
| | St. Paul | 1898 | Abandoned | - | Jordan and Clark (1898) |
| | St. George | 1898 | Abandoned | - | " |
| | Walrus Island | 1870's | A few | Summer | Elliot (1882) |
| | | 1874 | Present | Summer | " |
| | | 1898 | Abandoned | - | Jordan and Clark (1898) |
| | | 1979 | 1 | 13 Apr | Frost et al. (1983) |
| | Otter Island | 1898 | Abandoned | - | Jordan and Clark (1898) |
| | | 1979 | 1 | 13 Apr | Frost et al. (1983) |
| St. Matthew Island | | 1874 | 0 | 5-13 Aug | Elliot (1882) |
| | | 1916 | 500 | 8-12 Jul | Hanna (1920) |
| | | 1957 | 0 | Jul-Aug | Klein (1959) |
| | | 1986 | 0 | 10-19 Jun | L. Lowry, notes |
| | North Side | 1978 | 2 | 27 May | Frost et al. (1983) |
| | near Glory or Russia Cape | 1980 | 80 | 22-23 Sep | Frost et al. (1983) |
| | near Cape Upright | 1981 | 110 | Autumn | " |
| | | 1982 | 160 | Summer | " |
| | Lunda Bay | 1982 | 180 | Summer | " |

Continued...

Table 8.2. Continued.

| Location | Haulout Site | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|---|
| Hall Island | | Circn. 1916 | Present | Summer | Hanna (1920) |
| | | 1980 | 550 + | 22-23 Sep | Frost et al. (1983) |
| | | 1982 | 80 | Jul-Aug | " |
| | | 1986 | 130 | 15 Jun | L. Lowry, notes |
| St. Lawrence Island and Group[2] | | | | | |
| Regularly used haulout sites[3] | | | | | |
| St. Lawrence Island | Chibukak Pt. | 1956 | 5 | Oct | Frost et al. (1983) |
| | | 1962 | Few (First reported reoccurrance) | Autumn | Fay and Kelly (1980) |
| | | | 100's | Nov | Frost et al. (1983) |
| | | 1963-1980 | Up to several 100's | Autumn | Fay and Kelly (1980) |
| | | 1981-Present | Variable | Autumn | R. Silook (Pers. Comm.) |
| Punuk Islands | North Punuk Island | 1900-1950's | Up to several 100's | Autumn | General Accounts of locals |
| | | 1930-1932 | Large numbers | Autumn | Fay and Kelly (1980) |
| | | 1959 | 100's | Autumn | Burns (1965) |
| | | 1960 | 100's | Autumn | " |
| | | 1961 | 100's | Autumn | " |
| | | 1962 | 1500 (estimate) | Oct | " |
| | | 1963 | 20-25 | Late Oct-Nov | " |
| | | 1965 | 60+ | 24 Oct | Frost et al. (1983) |
| | | 1966 | Many | 6 Dec | " |
| | | 1975 | 6000 | 18 Oct | Ray in Fay (1978) |
| | | 1978 | 32,000 ± | Oct/Nov | Fay and Kelly (1980) |
| | | 1981 | 15,000 ± | 16 Nov | Kelly in Frost et al. (1983) |
| | Middle Punuk Island | 1978 | 14,000 ± | Autumn | Fay and Kelly (1980) |
| | South Punuk Island | 1978 | 11,000 ± | Autumn | " |
| Irregularly used haulout sites | | | | | |
| St. Lawrence Island | Salghat | 1978 | 19,000 ± | Autumn | Fay and Kelly (1980) |
| | Maknik | 1978 | 35,000 ± | Autumn | " |
| | Kialegak | 1970 | Few ("for first time") | Dec | Frost et al. (1983) |
| | | 1978 | 37,000 ± | Autumn | Fay and Kelly (1980) |

Continued...

Table 8.2. Concluded.

| Location | Haulout Site | Year | Number of Walruses | Time of Survey | Information Source |
|---|---|---|---|---|---|
| King Island | | 1979 | 1000 ± | 19 Jul | Frost et al. (1983) |
| | | 1980 | 5000 ± | Jun-Sep | " |
| | | 1981 | 1000 ± | Jun-Sep | " |
| | | 1982 | 800 ± | Jul | " |
| | | 1983 | 2000 ± | Summer | R. Koezuna (Pers. Comm.) |
| | | 1984 | 2000 ± | Jul-Aug | " |
| | | 1985 | 1000 + | Jul-Aug | " |
| Little Diomede Isl.[4] | | 1974 | Numerous | Summer-Autumn | Frost et al. (1983) |
| | | 1980 | Numerous | Summer-Autumn | " |

1 According to O'Neil and Haggblom, significant reoccupation of hauling grounds in the Cape Peirce area did not occur prior to 1983. However, Frost et al. reported significant use starting in 1981.

2 We have distinguished, arbitrarily, between haulout sites that are regularly used (A) and those used irregularly (B). Walruses of both sexes and all ages use haulout sites in the St. Lawrence Island as they are migrating southward, primarily during autumn, ahead of the seasonally advancing sea ice. Dead and dying animals are commonly found.

3 Murie (1936) in Geist and Rainey (1936) discusses the presence of a former haulout site at East Cape, and stated ... " It is a well known fact that in older days walruses hauled up in great numbers at both of these places [Punuk Island and East Cape]...". He further indicated that walruses frequented East Cape annually, "though in small numbers". The site referred to as East Cape is unknown to us; it might be Northeast Cape or Southeast Cape (= Kialegak).

4 Walruses, coming from the large, established haulout sites on Big Diomede Island, 2.7 miles from Little Diomede Island, have repeatedly tried to again establish haulout sites on Little Diomede. To date, those pioneering efforts have been unsuccessful due to hunting and other sources of disturbance by people and dogs.

## APPENDIX 9. GLOSSARY OF SCIENTIFIC TERMS

Definitions of the following terms are based on standard usage in the scientific literature. In the case of pinnipeds, terminology is not consistent in the scientific literature; as noted in Hoover (1988a:161),"...Criteria used to distinguish rookeries and haulouts are unclear and different between regions...". In this report, we have used terminology that is appropriate and most relevant to the four species of pinnipeds considered in this study.

### 1. Pinniped Terminology

**Haulout Site** — A specific location on land or ice where pinnipeds (and sea otters) climb from the water (i.e. haul out) to rest, breed, give birth, care for their young, molt, and/or thermoregulate (Bigg 1985; Hoover 1988a, 1988b; Sease and Chapman 1988).

**Rookery** — A term used to define specific terrestrial haulout sites where adult male sea lions and fur seals rest, defend territories around females, and where breeding, pupping and nursing of young by females occurs (Fiscus 1986; Hoover 1988a). These sites are usually along beaches or rocky slopes near the water (Calkins and Pitcher 1983; Bigg 1985; Loughlin et al. 1984, 1986, 1987). In general, rookeries are located far from continental land masses (Bigg 1985).

**Hauling Ground** — A term used to define sites where subadult male and some subadult female northern sea lions and northern fur seals congregate during the mating season (Gentry and Kooyman 1986; Merrick 1987). These sites are associated with rookeries but, especially in the case of northern fur seals, are usually inland and farther from the shoreline than rookeries (Kozloff 1986).

**Haulouts** — A term used to define sites where northern sea lions haul out, generally to rest, during the non-breeding season (Hoover 1988a). This term is also used in a more general sense to designate any pinniped haulout site that is not a rookery (Bigg 1985; Hoover 1988a, 1988b; Sease and Chapman 1988).

## 2. ACOUSTIC TERMINOLOGY

Sound Level or Received Level, $L_r$

The sound pressure at an observation position expressed in logarithmic terms

$$L_R = 20 \log_{10} p/P_r \text{ (dB)}$$

where the reference pressure, $P_r$ = 1 microPascal (μPa)

Source Level, $L_s$

The sound pressure at an observation position 1 m from an acoustic source (dB re 1μPa at 1 m)

Transmission Loss, TL

The reduction in sound level with distance along a given acoustic path caused by spreading loss and absorption loss components

$$TL = L_s - L_r \quad \text{dB re 1 m}$$

Source Directivity, D

The change in acoustic output of a source as a function of aspect angle in both the horizontal and vertical plane. Generally expressed as a logarithmic ratio

$$D = 20 \log_{10} p/P_m \quad \text{dB}$$

where p is the pressure in a given direction and $P_m$ is the maximum source pressure in a reference direction.

Sound Wavelength, λ (m)

λ = c/f, where c is the speed of sound (m/sec) and f is the frequency (Hz).

Spreading Loss

The reduction in sound level caused by geometric spreading of sound energy, generally expressed as cylindrical spreading (10 $\log_{10}$ range) or spherical spreading (20 $\log_{10}$ range).

Absorption Loss, $A_v$

The reduction in sound level caused by volumetric absorption of sound energy by the transmission medium.

Reflection Loss (RL)
The reduction in sound level after reflection from an absorptive surface, expressed in logarithmic terms

$$RL = L_{ref} - L_{inc} \quad (dB)$$

where $L_{ref}$ and $L_{inc}$ are the reflected and incident sound levels at 1 m from the reflection point.

Sound Speed Profile
The variation of the speed of sound as a function of water depth.

Grazing Angle
The angle between the sound propagation direction and a reflecting surface.

Critical Angle
The reflection loss is 0 for grazing angles less than the critical angle.

Shear Wave
A method of wave propagation in solid media wherein the particle motion is transverse to the direction of propagation. (In an acoustic wave the particle motion is aligned with the direction of propagation.)

Acoustic Ray Theory
A solution to the acoustic wave equation which considers sound propagating as uniform phase wavefronts along a path (ray) determined by the initial radiation direction from the source and the refractive properties of the medium; (similar to optical theory for light) useful for deep water and high frequencies.

Acoustic Normal Mode Theory
A solution to the acoustic wave equation which considers sound propagation as a series of acoustic standing waves (normal modes) which match the boundary and source conditions specified. The pressure contributions from a series of modes are added to give the total acoustic pressure at a selected observation point (similar to room acoustic theory); useful for shallow water and low frequencies.