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Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1977

Volume I. Receptors — Mammals

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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Outer Continental Shelf Environmental Assessment Program

Boulder, Colorado

March 1977

U.S. DEPARTMENT OF COMMERCE
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VOLUME I

RECEPTORS -- MAMMALS

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walrus only

ANNUAL REPORT

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Marine mammals of the Bering and southern Chukchi Seas

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I. Abstract

In Bristol Bay in April 1976, bearded seals were somewhat uniformly dispersed yet more frequent than larga seals west of 163° W. Longitude. Ringed seals were more numerous in the northwest part of the Bay. Walruses were clumped in the southeast, northeast and west ends of the Bay. Bearded seals were more frequent north of St. Lawrence Island than ringed seals, but ringed seals were more frequent southwest of St. Lawrence Island. More bearded seals and fewer ringed seals were seen than expected (X^2: $P < 0.01$). Bearded seals were less solitary than ringed seals ($P < 0.05$) in both the northern and southern Bering Sea. Larga seals were less solitary than either ($P < 0.01$); they appear to be pupping and pairing sooner in pack ice than near the ice front. Bearded seals appear to be pupping and pairing sooner in the northern Bering Sea than the southern Bering Sea.

The population of northern sea lions in the eastern Aleutian Islands appears to have declined by 50% since the 1950's. About 80% of the sea lion population in the study area occurs on islands of the Fox Islands group (eastern Aleutian Islands). Nine (9) new hauling areas were identified in 1976, but no new rookeries. Ugamak Island, Bogoslof Island and Cape Morgan (Akutan Island) are the major breeding areas for the species. The highest numbers of all counts in the eastern Aleutian Islands (i.e., 45-50%) came from these three islands. The Fox Islands were found to be a very important area for animals to haul out onto during the fall months.

Approximately 80% of all harbor seals sighted were found at eight hauling areas; of these, three were considered major. An unknown proportion of the winter population hauls out on ice, perhaps as a result of landfast ice invading the coastal bays.

Most large cetaceans appear to enter the southern Bering Sea in greatest numbers in June via the eastern Aleutian Islands. The species most sighted in the northern Bering Sea were the gray, humpback and sperm (off shelf) whales; in the southern Bering Sea, Dall porpoises and minke whales were most sighted. Gray whales have been found to migrate close to shore throughout Alaska while moving north. Part of their northern migration route north of Unimak Pass has been determined (quantified for the first time) to occur all along the coast of Bristol Bay. The species enters the Bering Sea <u>at least</u> by early April.

All data summarized in this report are preliminary, and are still undergoing final checking, editing and correcting. No data or conclusions should be quoted without the authors' approval.

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II. Introduction

The objective of Research Unit 67 is to summarize existing knowledge on the seasonal distribution and relative abundance of cetaceans and pinnipeds in the Bering Sea, and to the extent possible, in the southern Chukchi Sea. To accomplish this objective, we have supplemented the information found in published and unpublished accounts with data from our own aerial and vessel surveys.

Field research was divided into three sub-tasks: 1) ice seals; 2) sea lions and harbor seals; and 3) cetaceans. The reason for the division was that temporally and spatially the logistics, as well as the timing of the animals, dictated separate surveys. Surveys of ice seals are conducted during the late winter and early spring months, requiring a long-range survey aircraft. Harbor seal and sea lion studies must be conducted in the summer with a smaller, more maneuverable aircraft. Cetaceans, we have found, are generally best surveyed from sea-going vessels or from land stations, except where animals migrate near shore or through leads in the ice (e.g., bowheads and belugas). Specific studies on walruses and sea otters are under separate OCSEAP contract (RU 14 and 241, respectively), and are not covered in detail under RU 67. A detailed discussion of northern fur seal distribution will be made in the final report. Research in RU 67 overlaps with studies of bowhead and beluga whales (RU 69) and ringed and bearded seals (RU 230) in the Chukchi Sea, hence these topics received less treatment here.

The objectives of the ice seal study are to quantify discrete populations, and to assess their distribution with respect to the distribution of ice. This can best be accomplished while the animals are hauled out onto the ice just before, during, and after the breeding season (March through June). An assessment of their distribution at sea during the summer and fall months comes from incidental sightings, from the published literature, and from knowledgeable individuals. Unfortunately, it is almost impossible to adequately survey for these species during ice-free periods because of the animals' pelagic dispersal.

The objectives of the sea lion/harbor seal study are to quantify population sizes to determine seasonal movements and to assess the importance of areas of high density. Specifically, identification of important breeding sites and hauling grounds is paramount to this study. Since a major objective is to determine the maximum number of animals in the population, the breeding season (June-August) was chosen because this is the time most animals haul out onto land.

The primary objectives of the cetacean study are to delineate seasonal migration and local movements, but also to assess population sizes where possible. This latter measurement is extremely difficult to quantify because of the lack of adequate survey methodology, as pointed out by Anderson, et al. (1976). The cetaceans presently considered most vulnerable to energy related activities in the Bering and Chukchi Seas (i.e., gray whale, harbor porpoise and bowhead whale) are also the most easily surveyed (except perhaps for the harbor porpoise). Other species, which may be less vulnerable (e.g., the balaenopterids, killer whales, humpback whales and belugas) are much more difficult to study. (Note: gray, bowhead and humpback whales are endangered species.)

An adequate assessment of species effect cannot be made without some understanding of past and present population status. For some species, such as the walrus and northern fur seal, a considerable amount of information has been published. Little reliable information is available on harbor seals and sea lions, especially in the study area. Information on the ice seals (bearded, ringed, larga and ribbon) is limited, yet that which has been published clearly summarizes our present understanding (Burns, 1970; Fay, 1974). Important publications on cetaceans in the Bering Sea are few. A comprehensive list of published and unpublished materials located to date is available in "An Annotated Bibliography on Marine Mammals of Alaska" (Severinghaus and Nerini, 1977). This document was part of the RU 67 OCSEAP contract.

Two important factors relevant to assessing the interaction of energy development and marine mammal populations are sensitivity-resilience and vulnerability. In order for a species population to be viable (i.e., sustained at a definable level), three things must be present: 1) production, at least at the replacement level; 2) resource acquisition; and 3) temporal and spatial accessibility to the first two. Under the present scheme of research activities, the only realistic kinds of inputs from our research will relate to vulnerability (both species and habitat). (Note: the term "critical" is avoided here because no precise ecological definition is known to exist.) Vulnerability is defined here as any net adverse affect from a negative externality which has the potential of temporarily or permanently decreasing the biological productivity (including production) of a population or sub-population.

Alaska's marine mammals are protected by U. S. law and international agreement (e.g., 1946 International Convention for the Regulation of Whaling; 1957 Interim Convention on Conservation of North Pacific Fur Seals; Marine Mammal Protection Act of 1972; and Endangered Species Act of 1973). Fortunately for marine mammals, then, the concept of Pareto Optimality[1/] seems to have been mandated by congressional statute. As such, proper safeguards related to energy development activities must be implemented based upon an evaluation of the information provided by OCSEAP contractees.

This report covers the first full year's work (1976) and includes data on harbor seals and sea lions collected in June and August 1975. Each appropriate chapter (i.e., Current State of Knowledge, Methods, Results and Discussion, etc.) is subdivided according to the three sub-tasks. A synthesis of our thoughts will be made in the Conclusions section, especially with regard to oil and gas exploitation; keep in mind, however, that our capability of interrelating effects to these species is extremely limited. Detailed information concerning energy development activities is not at our disposal, and an integration of our work with the exploratory and transportation disciplines is necessary before understanding is achieved. These topics are beyond the scope of this report.

1/ "...an allocation of resources is optimal if no reallocation could make some members of society [or an ecosystem] better off without making others worse off". (Meyers and Tarlock, 1971:3) (our brackets)

III. Current State of Knowledge

Ice seals

Bearded seal. The bearded seal (Erignathus barbatus) is usually found singly or in pairs, though during molting periods (summer months), as many as 30 may be grouped together. The species occurs throughout the area of seasonal ice cover migrating north with the retreating ice. Bearded seals are generally found north of the other phocid seals, preferring heavier pack ice (Burns, 1970). They rarely come ashore and are not known to use areas of unbroken landfast ice (Burns, 1973). Their greatest abundance is north of the ice edge zone and south of the Bering Strait (Burns, 1970). Large concentrations have been seen near St. Lawrence Island, southeast of St. Matthew Island, south of Nunivak, and near Anadyr Bay (Kosygin, 1966). Localized distributions are probably related to food availability (Tikhomirov, 1964).

Bearded seals are believed to dive no deeper than 200 m during feeding (Popov, 1976), usually occurring in waters 100-150 m deep (Tikhomirov, 1966). Their spring and summer diet consists mostly of crustaceans -- especially anuran crabs and shrimp (Gragonidae) -- and mollusks (gastropods), octopuses, polychaetes, and a variety of fishes (Johnson, et al., 1966; Kosygin, 1971; Burns, 1973; Popov, 1976). Burns and Lowry (1976) have recently found that bearded seals prey mostly on decapod crestaceans near St. Lawrence Island, while in Norton Sound, near Nome, bivalves and shrimp seem to be preferred.

The Bering Sea population has been estimated at 90,000 (Shustov, 1972), 250,000 (Popov, 1976), 300,000 by Alaska Dept. Fish and Game (Burns, 1973), and 450,000 for a Soviet estimate (Burns, 1973). Approximately 8,000-10,000 are harvested annually by U.S. Eskimos and the U.S.S.R. (Burns, 1973).

Larga seal. Phoca largha, the ice-inhabiting relative of the harbor seal (Phoca vitulina), is usually found singly or in pairs near the edge of the pack ice. Concentrations of 50-100 may occur on large floes during molting periods (May-July). Generally associated with the southern edge of the seasonal pack ice, larga seals move north and towards the Siberian and Alaskan coasts as the ice pack recedes. Large concentrations extend from the Pribilof Islands east to Bristol Bay and off Nunivak Island during winter and spring, generally 20-40 km offshore (Tikhomirov, 1966). The distance from shore varies with the extent of pack ice.

Larga seals haul out on land during ice-free periods from the northern Bering to the Beaufort Seas (Burns, 1973). Although intermingling may occur between P. largha and P. vitulina during the winter, when the ice front is near the Alaska Peninsula, these species are considered to be reproductive isolates (Burns, 1970). Blood protein comparisons show similarities between them, suggesting recent stock separation or chance genetic interchange (Shaughnessy, 1975).

Fedoseev and Shmakova (1976) recognized three local populations of P. largha in the Bering Sea: in Karaginsky, Anadyr, and the eastern Bering Sea. The species is apparently more populus on the east side of the Bering Sea (Tikhomirov, 1966). In Alaska, larga seals are the dominant near-shore seal during the ice-free season (Burns, 1973), and during periods of ice cover it is the dominant species south of St. Lawrence Island (Tikhomirov, 1964).

Phoca largha adults eat pelagic fish, octopuses, crustaceans, and in summer, salmonoids. Young prefer amphipods, shrimp and shoaling fish (Popov, 1976).

Population estimates are 135,000 (Shustov, 1972; Popov, 1976), 200,000-250,000 by Alaska Dept. Fish and Game (Burns, 1973), and 450,000, a Soviet estimate (Burns, 1973). Approximately 7,000 are harvested annually by U.S. Eskimos and the U.S.S.R. (Burns, 1973).

Ribbon seal. Ribbon seals (Phoca fasciata) are usually solitary animals though pairing occurs during the breeding (April) and molting (May-June) periods (Fay, 1974); even then they stay 10-30 m apart. Their distribution is not related to water depths or associated feeding grounds but to ice conditions (Shustov, 1965). During the winter and early spring the entire population can be found along the southern edge of the pack ice up to 150 km north of the front (Fay, 1974). During periods of parturition and lactation, ribbon seals usually keep to the seaward edge of floes or in the center of large ice masses 50-250 km offshore. While molting, the seals move closer to shore with the melting of the ice pack, usually coming to within 20-100 km (Tikhomirov, 1966). Fedoseev and Shmakova (1976) defined two reproductive groups in the eastern and western Bering Sea.

As the ice retreats northward in the summer, ribbon seals abandon the ice and become pelagic until ice reappears in the autumn (Burns, 1973). Their distribution extends into the southern Chukchi Sea after ice breakup (Burns, 1970). A major concentration of ribbon seals has been reported to occur between Anadyr Bay and St. Lawrence Island, with a gradual drop in abundance south of St. Lawrence (Tikhomirov, 1966). Burns (1973) describes the center of abundance in the mid-Bering Sea area.

The Bering Sea population has been estimated to be 60,000 (Shustov, 1972; Fedoseev, 1973; Popov, 1976); 80,000-90,000, a Soviet estimate (Burns, 1973) and 100,000 by Alaska Dept. Fish and Game (Burns, 1973). The numbers of ribbon seals have been declining through the past decade, a decline believed due to heavy commercial harvesting by the U.S.S.R. (Burns, 1973).

Ribbon seals usually feed in water depths of 60-100 m on the nektobenthos, diving up to 200 m on occasion (Shustov, 1965; Popov, 1976). Their scarcity south of St. Matthews and Nunivak Islands is probably related to decreased feeding resources (Shustov, 1965). Shrimp, crabs and mysids are preferred; less so are fishes and cephalopods (Shustov, 1965). This diet is intermediate to those of bearded and ringed seals.

Ringed seal. The ringed seal (Phoca hispida) is the smallest of the ice inhabiting pinnipeds and is the most dependent upon the ice. Individuals are solitary, though during periods of molting group sizes can increase dramatically. They range throughout the seasonal ice cover of the Bering and Chukchi Seas and north into the permanent pack ice of the Arctic Basin (Burns, 1973). Ringed seals have been reported to occur as far south as the Pribilof Islands during the winter and spring (Kenyon, 1960; Thomas and Scheffer, 1962), but are considered rare in the Bering Sea during non-ice conditions (Tikhomirov, 1964). Fedoseev (1975) suggests that there are two stocks of ringed seals in the study area, those of the drift ice (in the Okhotsk and Chukchi Seas) and those of the fast ice, in bays and gulfs. He describes several morphological differences.

Burns (1970) found that adult, and especially male, ringed seals prefer areas of extensive landfast ice. Breeding activities usually occur within 5-40 km offshore unless the ice is blown to sea (Tikhomirov, 1966). The highly territorial breeding pairs (primarily the female) maintain a small breathing hole in the ice. The more dominant individuals maintain breathing holes and pupping dens in the fast ice, with juveniles and sub-adults more likely occurring farther offshore (Tikhomirov, 1966; Burns, 1973; Fay, 1974).

Ringed seals are the dominant seal species in near-shore area during periods of ice cover with densities of 3.70-5.36 seals/mi^2 along the coast in the Chukchi Sea between Pt. Lay and Wainwright (Burns and Harbo, 1972). A minimum population estimate of 11,612 animals was made by Burns and Harbo (1972) for the north coast of Alaska. The total population has been estimated at 50,000 (Shustov, 1972), 70,000-80,000 (Popov, 1976), and 250,000 (Burns, 1973). Some 12,000-16,000 are harvested annually, mostly by shore-based Eskimo hunters (Burns, 1973).

The ringed seal's diet is variable according to sea depth and location of food resource (Burns, 1973), and according to season (Johnson, et al., 1966; Popov, 1976). The dominant food item is shrimp, with preferences also shown for gamariid amphipods, mysids, euphausiids, saffron cod, polar cod, and sculpin (Pikharev, 1946; Kenyon, 1962; Burns, 1973; Popov, 1976). Burns and Lowry (1976) found that invertebrates (mysids and shrimp) were the predominate food item near St. Lawrence Island, but fish predominated (>85%) in stomachs from seals taken near Nome (Norton Sound).

Sea lions and harbor seals

Northern sea lion. The northern sea lion (Eumetopias jubatus) is found along the North Pacific coast from San Miguel Island (34°N) California, to the Pribilof Islands (57°N) in Alaska and west along the Aleutian Islands to Japan. In Alaska, breeding activity begins in late May when mature bulls begin to set up and defend territories. Pupping occurs throughout the month of June. Most females breed within a week to ten days after parturition (Sandegrin, 1970). Although females are capable of giving birth yearly (Gentry, 1970), it has been suggested that many animals give birth every other year (Sandegrin, 1970). Fiscus (pers. comm.), though, believes that they do give birth yearly. Male territorial behavior begins to decrease the first week of July, and by mid-July, most breeding activity has ended. Non-mating bachelor males often congregate on hauling grounds adjacent to rookeries.

From 1956 to 1958, Mathisen and Lopp (1963) conducted intermittent aerial surveys along the eastern Aleutian Islands. They found seasonal variations in the number of animals hauled out during the year. Generally, their counts were low in early spring, maximum in late summer, and declined toward the end of the year. They suggested two explanations for the apparent variation in the seasonal counts: 1) many animals may migrate from the area; and (more likely) 2) while foraging at sea, sea lions may spend increasing amounts of time away from the rookeries and hauling grounds.

Mathisen and Lopp (op. cit.) estimated the eastern Aleutian Island population to be 52,540 animals. Kenyon and Spencer surveyed the western Aleutian Islands in May 1959, and estimated the population to be 44,630 animals (Kenyon and Rice, 1961). They stated that the Aleutian Islands appear to be the center of abundance for the species. Unlike Mathisen and Lopp (op. cit.), Kenyon and Rice (op. cit.) believed that some sea lions migrate to the northern Bering Sea in the summer.

Wilke and Kenyon, on 4 April 1955, when the pack ice surrounded the Pribilof Islands, saw approximately 1,000 sea lions hauled out on Otter Island and several others resting on ice floes (Kenyon and Rice, 1961). Of the few animals which could be identified as to sex, all were males. It would appear that sea lions may haul out on ice floes during the early spring when the pack ice extends as far south as the Pribilof Islands.

Several aspects of the life history of the northern sea lion are unknown. For example, we do not know whether sea lions migrate to and from the study area. The feeding ground(s) for the species is also unknown. Fiscus (pers. comm.), during the summer of 1962, saw groups of 1,000 sea lions feeding in the Unimak Island bight area while commercial salmon gill netters and purse seiners fished there. It is not known whether these sea lions were from our study area or from the Kodiak archipelago. Although sea lions are believed to be an important predator on some commercially important fishes (e.g., salmon, halibut, ground fish), there is very little evidence to support this (Mathisen, et al., 1962; Fiscus and Baines, 1966).

Harbor seals. Land breeding harbor seals (<u>Phoca vitulina richardsi</u>) are abundant throughout the Alaska Peninsula and eastern Aleutian Island survey area (Alaska Dept. Fish and Game, 1973). The animals are primarily inhabitants of coastal waters, although occasional occurrences are known up to 50 mi offshore (Calkins, et al., 1975). These animals haul out on offshore rocks (swept at high tide), beaches, and sandbars exposed at low tide. The largest concentrations haul out on sandbars and islets at the mouths of rivers, such as the Cinder River, or in bays, such as Port Moller and Port Heiden. Stage of the tide and weather conditions are important factors determining timing and duration of haul out (Bishop, 1967).

During winter, some harbor seals are known to use the ice edge as a hauling area (Burns, pers. comm.). The harbor seal's versatility in habitat utilization is demonstrated by its wide range over varying bottom types, water clarity and salinity (Calkins, et al., 1975) and food resources (Spalding, 1964).

Little is known of the biology of <u>P. vitulina</u> in our study area. Bishop (1967) studied animals in the Kodiak area and determined sexual maturity for females at three to five years and males at five to six years. In the Gulf of Alaska, pupping begins in late May and lasts until early July (Calkins, et al., 1975).

Since regional variation is known to occur for reproductive timing in females (Bigg, 1973) a more exact determination of pupping activity in our survey area cannot yet be made.

Parturition takes place on land, and pups are almost immediately able to follow their mothers into the water (Klinkhart, 1967). Weaning occurs in 3-4 weeks and ovulation about 2 weeks later (Bishop, 1967). Breeding is dependent on the female being in estrus (Bishop, 1967). Breeding competition between males occurs, perhaps resulting in pods of only bachelors.

Food habit studies on harbor seals in our study area are lacking. Work in the Gulf of Alaska has revealed a wide variety of food items taken including herring, flounder, smelt, gadids, rockfish, sculpins, salmon, greenling, halibut, octopus, squid and shrimp (Imler and Sarber, 1947; Spalding, 1964; Calkins, et al., 1975).

Census of harbor seals in this study area are few and incomplete. Opportunistic recordings were made by Mathisen and Lopp (1963) in Port Heiden, Port Moller, and Izembek Bay during their sea lion survey, but no full counts were attempted. Harbor seal populations in the Gulf of Alaska have been determined by analysis of harvest data (Calkins, et al., 1975). This method is not known to have been applied to seals in our study area.

Cetaceans

The literature records the Bering and Chukchi Seas as within the range of 18 species of cetaceans (Nasu, 1960; Sleptsov, 1961; Berzin and Rovnin, 1966; Moore, 1966; Nishiwaki, 1967, 1974). From 1958 to the present, 17 of these species have been seen in our study area (Table 1). As one would expect, there is some seasonality to distribution and relative abundance. The peak number of animals in the southern Bering Sea seems to occur in June, and later in the summer and fall (July-November) in the northern Bering and southern Chukchi Seas.

The four most commonly observed species of cetaceans in the Bering Sea are the Dall porpoise (*Phocoenoides dallii*), harbor porpoise (*Phocoena phocoena*), beluga (*Delphinapterus leucas*) and minke whale (*Balaenoptera acutorostrata*) (Mizue and Yoshida, 1965; Klinkhart, 1966; Nishiwaki, 1967). Harbor porpoises and belugas probably occur in the study area year round. Presumably, Dall porpoises and minke whales migrate from southern waters into the Bering and Chukchi Seas, like gray, humpback, fin and killer whales, to forage for food over the productive eastern shelf region.

Few data exist on the distribution of all cetaceans north of the North Pacific, and abundance estimates are essentially non-existent. Population estimates by species for the North Pacific are summarized by Fiscus, et al. (1976), and presumably at least part of the population in the North Pacific migrates into the Bering Sea. There is no quantitative information to suggest that the North Pacific and Bering Sea cetaceans are from different populations although seasonal separation does exist (Nemoto, 1957, 1959; Nasu, 1963, 1966; Nishiwaki, 1967; Shurunov, 1970).

One of the most carefully studied cetaceans, the gray whale (*Eschrichtius robustus*), spends approximately eight months in the Bering and southern

Table 1. Species of cetaceans observed (or claimed to have been*) in the Bering and/or southern Chukchi Sea since 1958. Information collected from many references (see Severinghaus and Nerini, 1977, for a bibliographic listing).

Order: Mysticeti

- *Balaena glacialis* (right whale)
- *Balaena mysticetus* (bowhead whale)
- *Balaenoptera acutorostrata* (minke whale)
- *Balaenoptera borealis* (sei whale)
- *Balaenoptera musculus* (blue whale)
- *Balaenoptera physalus* (fin whale)
- *Eschrichtius robustus* (gray whale)
- *Megaptera novaengliae* (humpback whale)

Order: Odontoceti

- *Delphinapterus leucas* (beluga or white whale)
- **Globicephala macrorhynchus* (short-finned pilot whale)
- **Lagenorhynchus obliquidens* (Pacific white-sided dolphin)
- *Mesoplodon stejnegeri* (sabertooth whale)
- *Orcinus orca* (killer whale)
- *Phocoena phocoena* (harbor porpoise)
- *Phocoenoides dallii* (Dall porpoise)
- *Physeter macrocephalus* (sperm whale)
- *Ziphius cavirostris* (goosebeak whale)

Chukchi Seas (April-November), with peak abundance months from June through October. Gray whales migrate from their breeding grounds in lagoons of Baja California, Mexico, to arctic and sub-arctic feeding grounds in the summer. Their migration path has been shown to be coastal from California to southeast Alaska (Gilmore, 1959; Pike, 1962; Rice and Wolman, 1971; Hatler and Darling, 1974), however, almost no documented evidence exists for their migration route north of British Columbia (Wilke and Fiscus, 1961). It is generally agreed that the passage into the Bering Sea is through Unimak Pass or Isonatski Straits (Ichihara, 1958; Pike, 1962) but the route followed further north is surrounded by controversy. Areas of gray whale concentration are north of St. Lawrence Island to the Bering Strait (Ichihara, 1958; Nasu, 1960; Fay, pers. comm.). In the southern Chukchi Sea, most *E. robustus* are seen along the Siberian coast (Fedoseev and Golt'sev, pers. comm.) and in outer Kotzebue Sound (Wilke and Fiscus, 1961; Shurunov, 1970), although Maher (1960) reports sightings as far east as Barter Island (Beaufort Sea near U.S.-Canadian border).

IV. Study Area

The generalized RU 67 study area includes all of the Bering Sea over the continental shelf east of the US-USSR 1867 Convention line and north into the Chukchi Sea to approximately 68°20' N. Latitude (Figure 1). Some areas cannot be covered by aerial survey (e.g., west and north of the Pribilof Islands). Data from these areas come from shipboard observations. Cetacean research covers the entire general study area as does the ice seal research, at least to the extent of maximum ice cover. Four geographic areas have been delineated for reporting cetacean sightings. Sector *one* roughly approximates the outer Bristol Bay oil lease area ("3" on Figure 1); sector *two*, the St. George Basin ("2") north to St. Matthew Island and south to the Aleutian Island oil lease area ("1"); sector *three*, north to the Bering Strait — including the Norton Basin ("4"), and sector *four*, north of the Bering Strait in the Kotzebue Basin lease area ("5" on Figure 1). The sea lion/harbor seal studies are conducted along the north coast of Bristol Bay and the Alaska Peninsula,& all of the islands in the eastern Aleutian Islands east from Samalga Island (52°45' N. Lat., 169°15' W. Long.)(Figure 2). Pelagic islands such as St. Matthew and Hall Islands (60°20' N. Lat., 173°00' W. Long.) and Amak Island (55°20' N. Lat., 163°10' W. Long.) are periodically surveyed.

V. Methods and Materials

Ice Seals

The pack ice in the Bering Sea was aerially surveyed and the numbers of ice seals encountered scored as to perpendicular distance from the aircraft trackline. Two survey periods were completed: 6-23 April and 8-14 June. Surveys for ice seals in the southern Bering Sea were based out of King Salmon, Alaska, 6-13 and 17-19 April. Surveys in the northern Bering Sea were based out of Nome, Alaska, from 13-15 and 19-23 April and 8-14 June 1976. There were no surveys in May because of other research commitments. March 1976 data are included in our analysis of the 1 April 1976 to 30 March 1977 data.

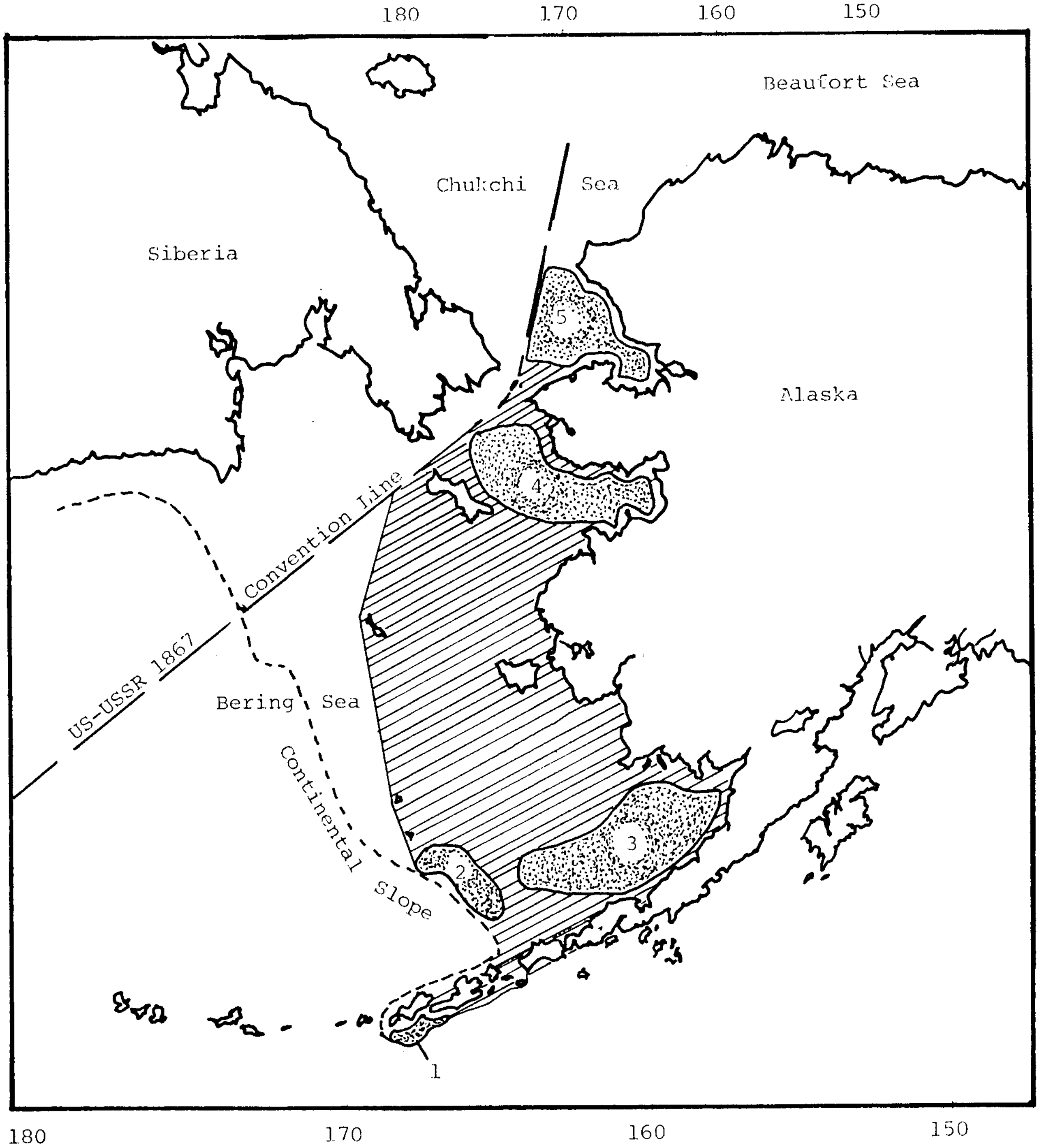

Figure 1. Study area for OCSEAP Research Unit 67 (hatching). OCS oil lease areas are noted (stippling) by number: 1 - Aleutian Basin; 2 - St. George Basin; 3 - outer Bristol Bay; 4 - Norton Basin, and 5 - Kotzebue Basin.

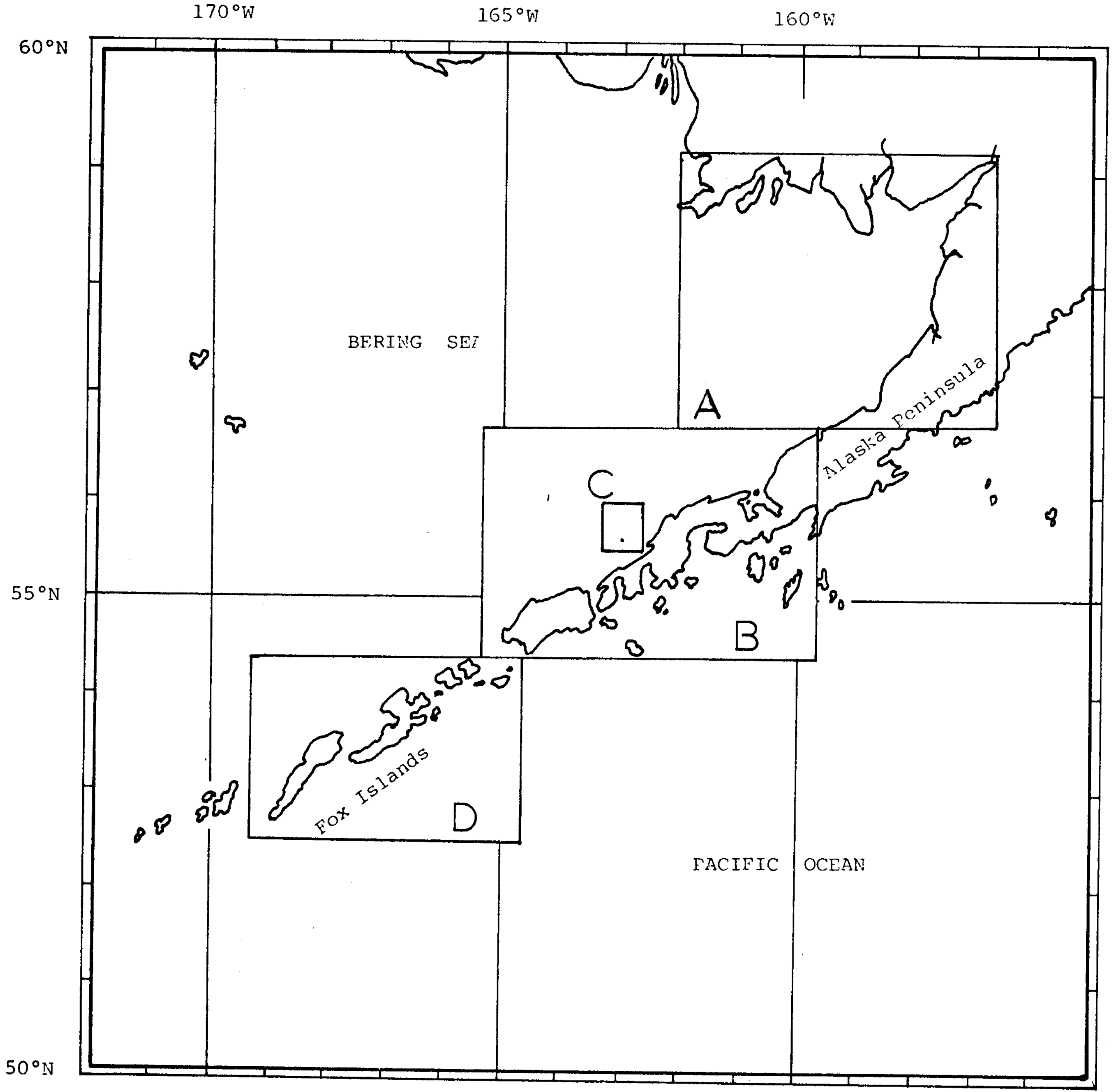

Figure 2. Overview of Alaska Peninsula and eastern Aleutian Islands northern sea lion - harbor seal study area. Boxed-in areas on this figure (A-D) are enlarged on succeeding figures.

Random and systematic strip census transects were flown in areas of stratified and unstratified sample areas. For example, we knew from previous flights (March flights and preliminary flights in April) that walruses would be found north of St. Lawrence Island; thus, the area was stratified (geographic areas predetermined) and flown in a systematic manner. In Bristol Bay, however, lines of latitude were randomized; these lines were then chosen at random and flown.

Each survey was divided into several flight periods (distances) called LEGS. Some legs were systematic or random transects, others were deadheads. It was during these systematic or random LEG flights that data were scored. Figures 3-6 represent the tracklines flown throughout the Bering Sea in April and June. More random transects were flown in April than in June because the pack ice was much more extensive in April, with animals dispersed over a larger area.

Two aircraft were used during our surveys: a turbo jet powered amphibian Grumman Goose (N780) and a Neptune P2V. The P2V was used only on 13-15 April. Both aircraft were chartered from the Office of Aircraft Services, U.S. Fish and Wildlife Service, Anchorage, Alaska. Air speed was generally 120 kts and survey altitudes were between 200-1,000 ft. Most transect surveys were flown at 500 ft, a compromise between maximum visibility and minimum disturbance to animals.

Data were scored by one recorder and two observers. Observers sat behind the pilot and co-pilot of the "Super Goose". As the plane flew along the trackline, animals directly below the aircraft could not be seen. Approximately 70% from the vertical out to 1/2 mile represented the area surveyed (area = 1 nmi^2) on either side of the aircraft. This represented a strip census method (Hayne, 1949; Robinette, et al., 1974; see Gilbert, 1975, for a general review). Data collection procedures were as follows: when animals were observed, the quantity and species identification were reported to the recorder who sat between the two observers. The right angle to the horizon was fixed to each sighting using an optical reading clinometer (model PM-5/360 PC; made by Suunto Oy of Finland). This procedure allowed us to precisely determine the right angle distance of the animal from the aircraft. This procedure has been shown to be a reliable method for establishing population density estimators (Burnham and Anderson, 1976). During data analysis, using this angular method, we will be able to determine our effectiveness in observing certain species as the distance away from the plane increases. Also, this method will allow us statistical reliability of the survey strip with respect to the number of animals seen.

Time, weather and ice conditions were systematically recorded approximately every five minutes and where a sighting took place. Photographs were taken of large pods of animals (e.g., walrus) using a single lens reflex 35 mm F2 Nikon camera with automatic aperature and motor drive assemblies. Most aerial photographs were taken with 105 and 135 mm lenses, using high speed Ektachrome film (ASA 160) which proved to be the best compromise between high resolution and film speed. These photographs were used to count high density concentrations of animals. Counts of animals were made in the laboratory from slides projected onto a large piece of white paper. Precise geographic locations were fixed (to within 1 nmi^2) using an electronic

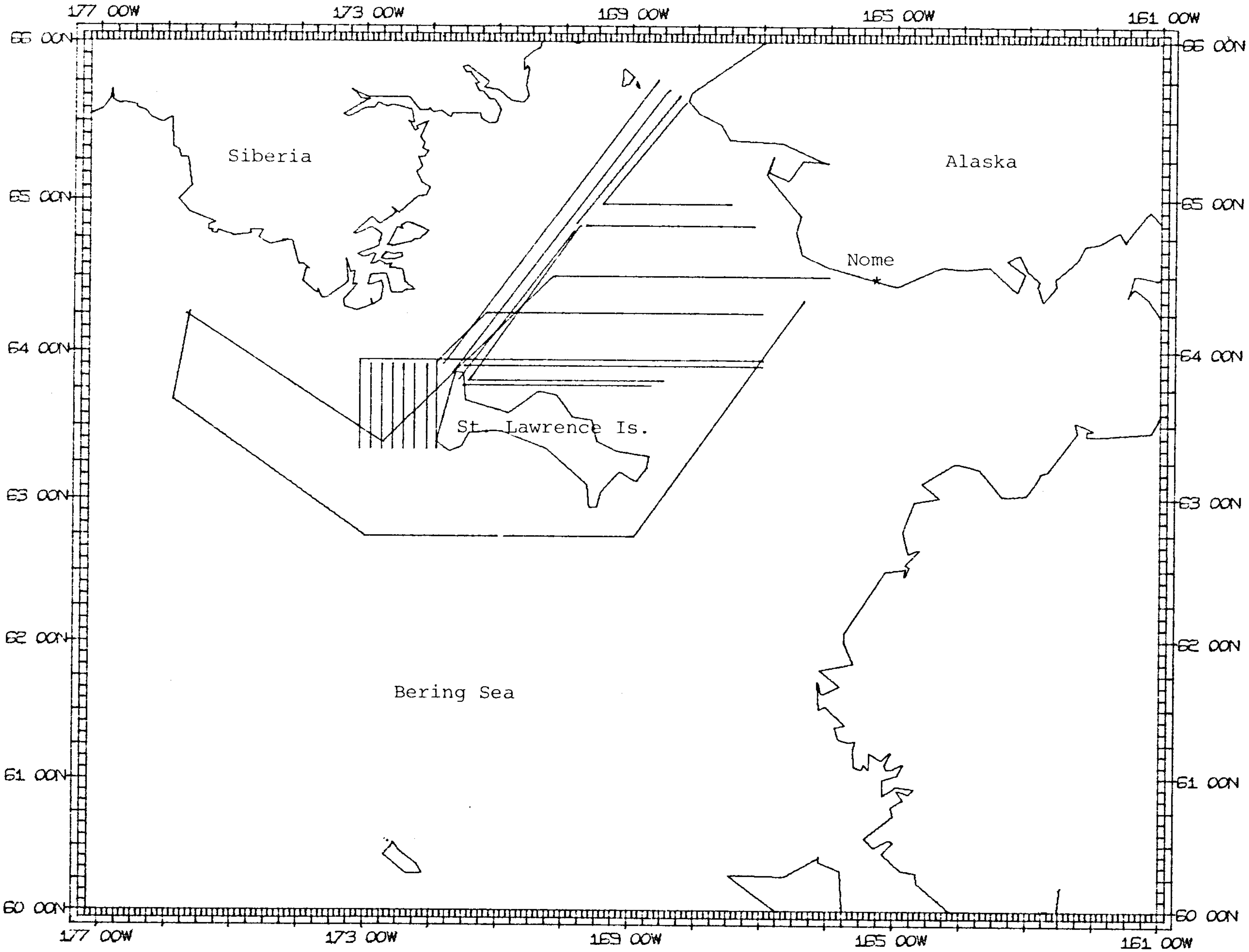

Figure 3. Aerial survey transect legs flown in the northern Bering Sea, 15-21 March 1976.

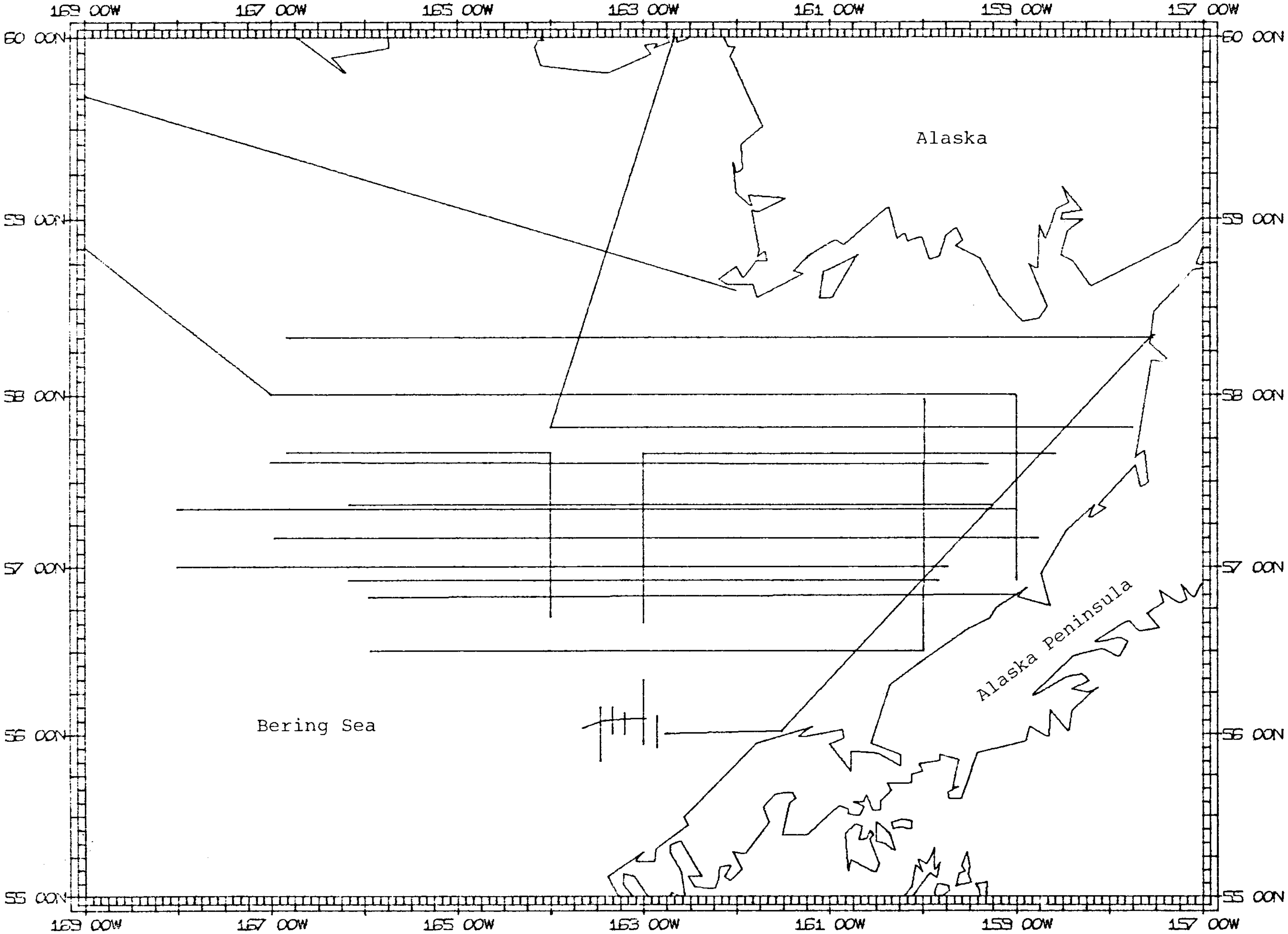

Figure 4. Aerial survey transect legs flown in southeastern Bering Sea, 6-13 and 15-19 April 1976.

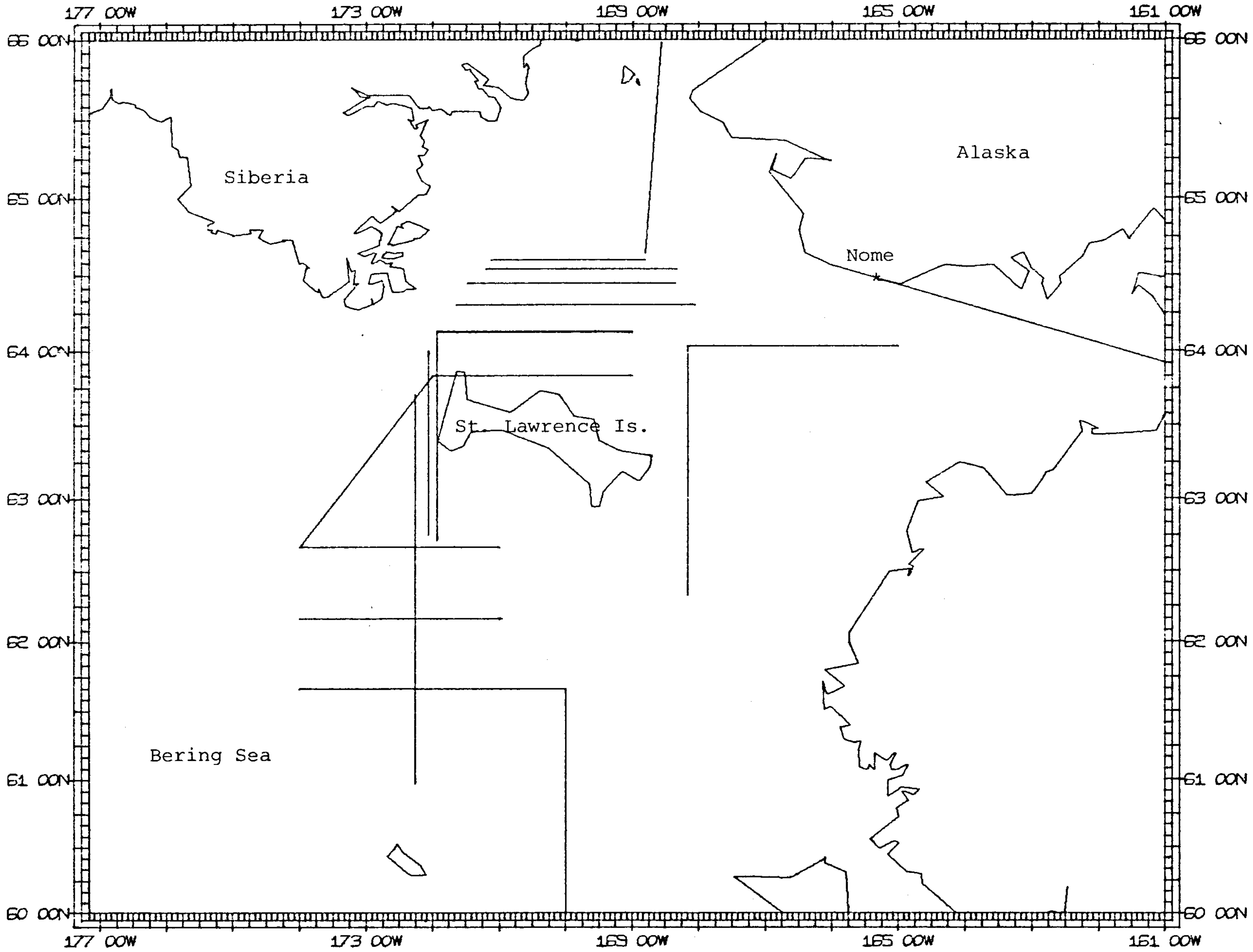

Figure 5. Aerial survey transect legs flown in the northern Bering Sea, 13-15 & 19-23 April 1976.

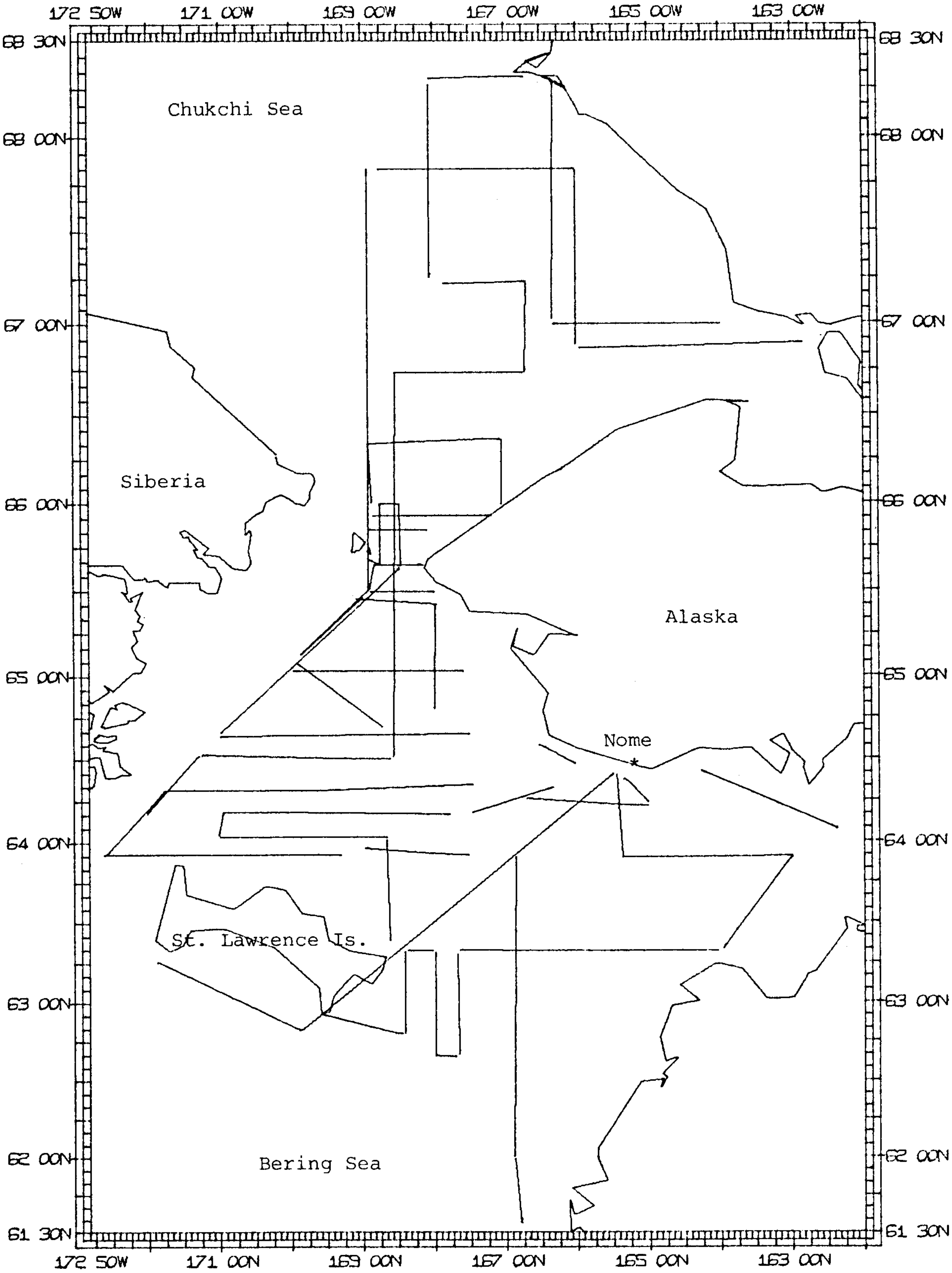

Figure 6. Aerial survey transect legs flown in the northern Bering and southern Chukchi Seas, 8-14 June 1976.

Global Navigation System (model GNS 500).

The recorder, front and aft observers rotated every hour to reduce fatique and to test for 1) variability in observer effectiveness, 2) bias due to right versus left side of aircraft, and 3) time of day. These and other aerial survey biases have been addressed by Erickson and Siniff (1963), Pennycuik and Western (1972), Caughley (1974), Wild and Ames (1974), and Caughley, et al. (1976).

In the laboratory, data were carefully transferred from field log sheets to computer abstracts, and computer cards were made. Several quality control steps were performed, including writing programs to check, verify and edit the data.

Sea lions and harbor seals

Three aerial surveys were flown over the Alaska Peninsula and eastern Aleutian Islands in 1976: 14-20 June, 19-21 August and 21-25 October. The June and August surveys were made using a Grumman Widgeon aircraft (twin engine, amphibious) chartered from Peninsula Airways, King Salmon, Alaska (pilot: Orin Siebert, President of Peninsula Airways). The October survey was made with a Bell 206B helicopter (pilot: Lt. William Harrigan, NOAA Corps) launched from the NOAA ship Surveyor during cruise RP-4-SU-76B, 18-29 October 1976 of the eastern Aleutian Islands.

During June and August systematic flights were made along the coast of the Alaska Peninsula and each island of the Fox Island group (eastern Aleutian Islands) as weather permitted. Sightings of marine mammals were made from altitudes of 200-500 feet. Immediate visual estimates of the number of animals present were made of all sightings. Photographs were taken where appropriate to improve species identification and, for large pods, to verify counts. In the laboratory, the photographs were counted as described earlier. These counts replaced the estimated counts in the field logs.

Northern sea lion and harbor seal rookeries and hauling grounds were flown over at varying altitudes and distances to minimize disturbance to pinnipeds and birds while still getting close enough for accurate counts. Altitudes of 1,000-1,500 feet were flown near harbor seal hauling out areas in order to make overview maps of the many sites in Port Moller and Port Heiden where Phoca were observed.

In the Widgeon, two to four observers were used. One sat in the co-pilot's seat and acted as the primary photographer. The second (or more) observer(s) sat behind the forward observer. They made visual estimates of the number of animals and recorded the exact position of each sighting using detailed charts of the respective area. Because we were flying island surveys, only one side of the aircraft was used for observing. The pilot proved to be an important observer when animals occurred on the pilot's side of the aircraft. During the August survey, a communication system was installed between the pilot and observers to increase efficiency in observer interaction and to reduce fatigue due to noise. The system we used was a battery operated Miniamp intercom device (Mark 2-D, 9v; Genie Electronics Co., Inc., Red Lion, PA) supplied with aircraft headsets (suggested by Don Calkins, Alaska Dept.

Fish and Game, RU 243).

Flights from the Surveyor in October were made on an opportunistic basis; thus, not all of the Fox Islands were surveyed. During the October cruise the helicopter surveys covered approximately 570 aerial track miles totalling 41 flight hours. Rookeries and hauling areas were surveyed from an altitude of about 700 ft. A continuous shipboard watch was maintained by one or more of five observers while the ship was underway. Total time on watch was 150 man/hours covering 828 nm. Land-based counts of sea lions and harbor seals were made on Bogoslof, Adugak (rocks on the northeast side), Ogchul, and the north side of Amak Island. Aerial and land party photographs were taken to be used in ground truthing studies. Discrete hauling areas were identified for site by site comparisons. A total of 72 man/hours were spent on land.

Cetaceans

Sighting data on whales and porpoises came essentially from two sources: 1) during pinniped surveys, and 2) from Marine Mammal Division or other NOAA personnel aboard OCSEAP chartered NOAA ships in the Bering and Chukchi Seas.

Gray whales were surveyed in the southern Bering Sea in June (with the Widgeon aircraft) and in the northern Bering Sea (above 60° N. Lat.) in June (with the Goose) in conjunction with the sea lion/harbor seal and ice seal surveys. Altitudes of 500-1,000 feet are generally flown over open water, and speeds of 100-120 kts were maintained. This altitude range and aircraft speed have proven to be effective for most cetacean surveys.

Other cetaceans, especially minke and killer whales and Dall and harbor porpoises, were recorded as they were encountered. No specific sampling design was attempted. All sightings of cetaceans (except gray whales) during aerial surveys, therefore, were opportunistic.

Several NOAA ship and charter vessel cruises during 1976 provided important cetacean distribution sighting data. Table 2 summarizes the cruises whose data are reported in the Results and Discussion section of this report. Data recording procedures during the ship cruises are included in the annual report for RU 68.

Table 2. Ship cruises into the Bering and Chukchi Seas during 1976 from which cetacean sighting data were submitted to date. MMD = Marine Mammal Division personnel aboard; POP-NOAA Corps officer from Platforms of Opportunity Program aboard; * - OCSEAP charters.

Ship	Dates		Location	Observer
Surveyor*	3-13/4-2	1976	ice edge (SE Bering Sea)	MMD
Oregon	4-4/11-18	"	Bering Sea	POP
Surveyor*	4-13/4-30	"	ice edge (SE Bering Sea)	MMD
Miller-Freeman*	4-24/5-13	"	SE Bering Sea	POP
Surveyor*	6-5/6-25	"	S Bering Sea	MMD
Anne Marie	6-12/6-19	"	SE Bering Sea	POP

Table 2. cont.

Ship	Dates		Location	Observer
Tordenskjold	6-19-8-4	1976	Bering Sea	POP
Moana Wave*	8-3/8-27	"	SE Bering Sea	MMD
Burton Island	8-12/8-19	"	Bering Sea	POP
Discoverer*	8-18/9-24	"	N Bering Sea S Chukchi Sea	MMD
Surveyor*	10-18/10-29	"	E Aleutian Is. (S Bering Sea)	MMD

VI. Results and Discussion

Ice seals

Aerial survey data on ice seals have been summarized for the southern Bering Sea in Table 3, and for the northern Bering/southern Chukchi Seas in Table 4. This apparent separation in collected data occurred because 1) few sightings of seals were made in the central Bering Sea (60°N to 63°N), and 2) the central Bering Sea is difficult to fly because of the limited range of the aircraft--and thus the distance from our bases of operation, Nome and King Salmon.

The spatial and temporal distribution of bearded, larga, ribbon and ringed seals, and the walrus, in the Bering Sea is highly dependent upon the location and extent of the pack ice. Hence, an overview of the March-June 1976 ice conditions is provided in Figure 7. A better understanding of species distribution with respect to ice can be gained if this figure is used in conjunction with our sighting plots.

Sightings (not total number of animals) of each species of phocid seal have been plotted in Figures 8-20. These data points can be compared to the tracklines by month provided, in Figures 3-6, to gain better insight into location of sightings versus location of aerial survey. These data, for each species, have also been summarized as density plots for each species by month by location in Figures 21-31. Tabulation of the density estimates for each species by location by month are reported in Table 5. Figures 8-31 are generally self-explanatory, thus a minimum amount of discussion about the plots follows.

Bearded seals in March in the northern Bering Sea were most abundant just north of St. Lawrence Island (Figures 8 and 21) as were walruses (Figures 17 and 28). In the southern Bering Sea (Bristol Bay) in April, bearded seals were found to be somewhat uniformly distributed except in the northeast portion of the bay where they were conspicuously absent (Figures 9 and 22). More sightings of bearded seals occurred west of 163° W. Long. than larga seals (Figures 12,22, and 25). Ringed seals were more numerous northwest of either bearded or larga seals (Figures 14 and 26). Sightings of walruses in Bristol Bay occurred most commonly in the southeast, northeast and west ends of this study area (Figure 18).

More sightings of bearded seals in northern Bering Sea occurred farther north and south of St. Lawrence Island in April than in March (Figure 10).

Table 3. Ice seal observations in the southern Bering Sea (south of 60°N), Spring 1976.

Date	*E. barbatus*	*P. largha*	*P. hispida*	*P. fasciata*	Unidentified Pinniped
6 April	29	591[a]	0	0	5
8 "	64	53	1	0	0
9 "	51	158	0	9	17
12 "	42	44	6	1	10
13 "	89	1	35	0	4
15 "	3	77	1	2	30
17 "	15	64	23	0	12
18 "	12	60	2	0	7
19 "	8	14	6	0	4
Sum	313	471[c]	74	12	89
Mean[b]	1.17	1.56[c]	1.03	1.09	-
S. D.	0.47	0.68	0.13	0.32	-
n	268	292	71	11	-

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[a] This figure may include a large portion of *Phoca vitulina*

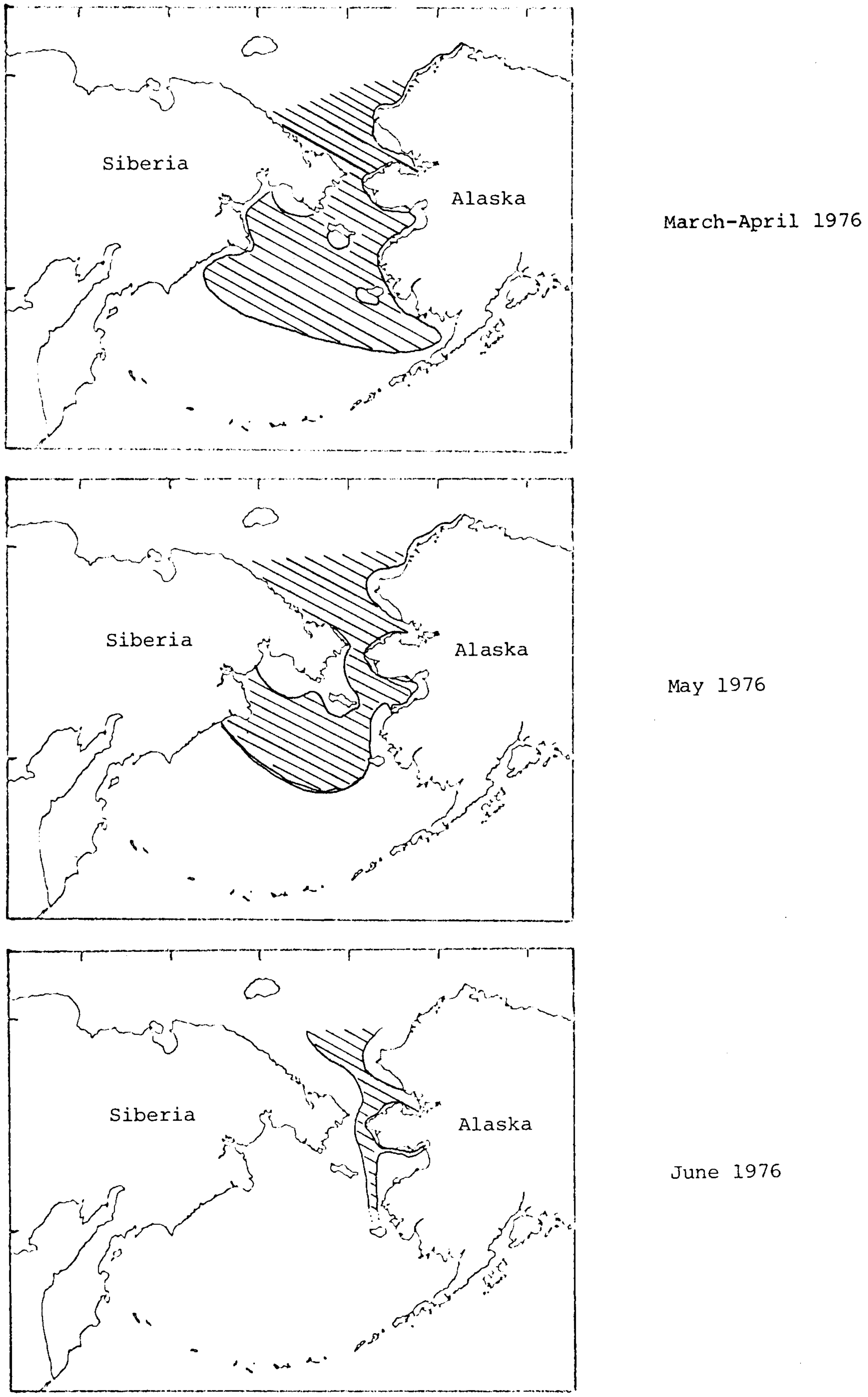
[b] Average group (pod) size -- number of animals per sighting

[c] Does not include data from 6 April

Table 4. Ice seal observations in the northern Bering and southern Chukchi Seas (north of 60°N), Spring 1976.

Date	*E. barbatus*	*P. largha*	*P. hispida*	Unidentified Pinniped
15 March				1
18 "	2			
19 "	1			
21 "	56			4
13 April	22	22	35	9
15 "	10			2
19 "				
20 "	148		2	2
21 "	29			1
22 "	7			1
23 "	9		7	
8 June	6		3	1
9 "	53	1	13	13
10 "	128	2	43	6
11 "	233		68	12
12 "	246		155	10
Sum	950	24	326	62
Mean	1.35*	-	1.12	-
S. D.	0.73	-	0.68	-
n	638	-	290	-

*not including 20 April with a mean of 4.23 ± 16.85 (S.D.), n=35, N=148



March-April 1976

May 1976

June 1976

Figure 7. General chart of the 1976 spring ice conditions. Schematic summarized from NOAA-4 VHRR satellite photographs and from our field notes. (Photos from Environmental Products Group, NOAA-NESS, Washington, D. C.)

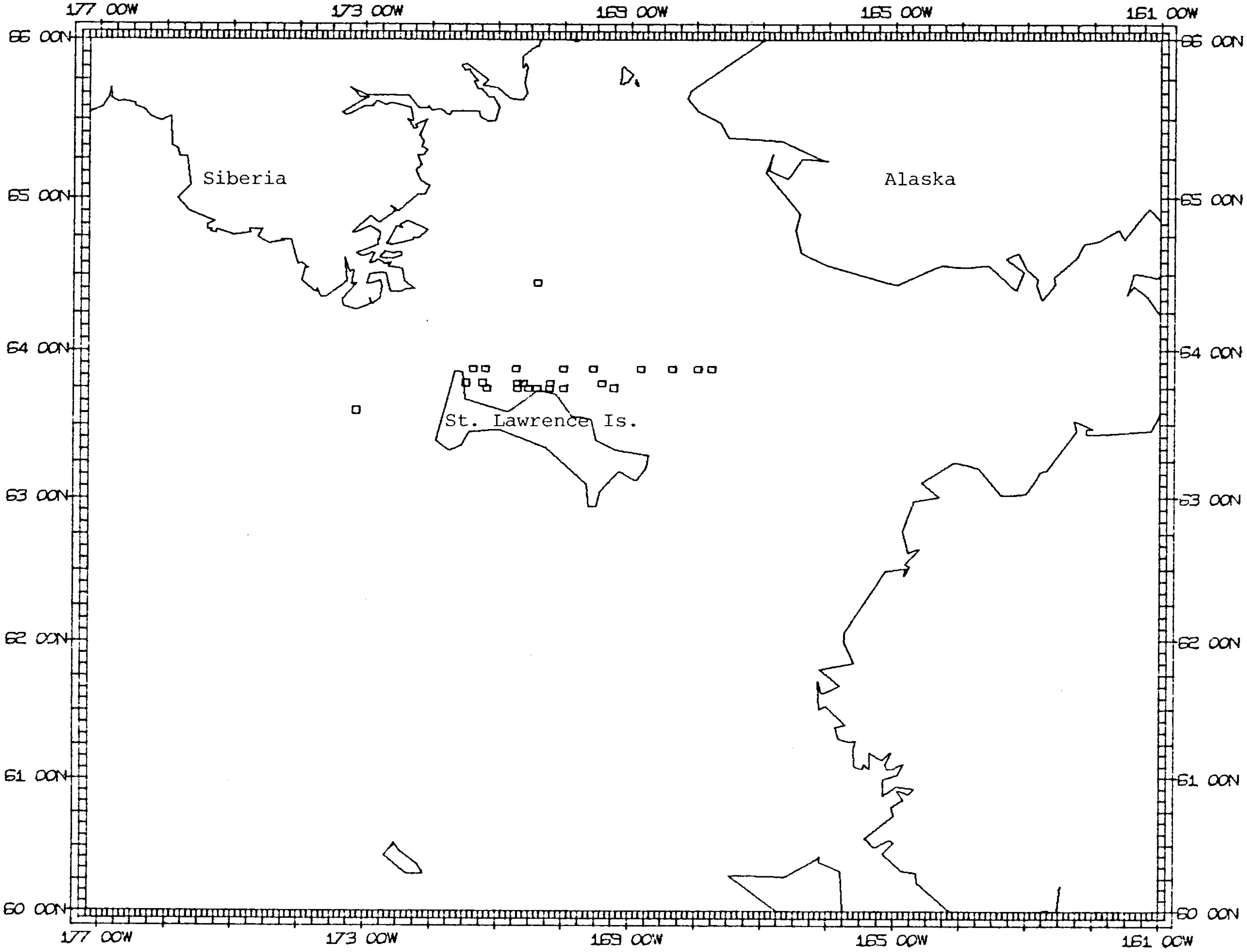


Figure 8. Sightings of Erignathus barbatus (bearded seal) in northern Bering Sea during March 1976 aerial surveys.

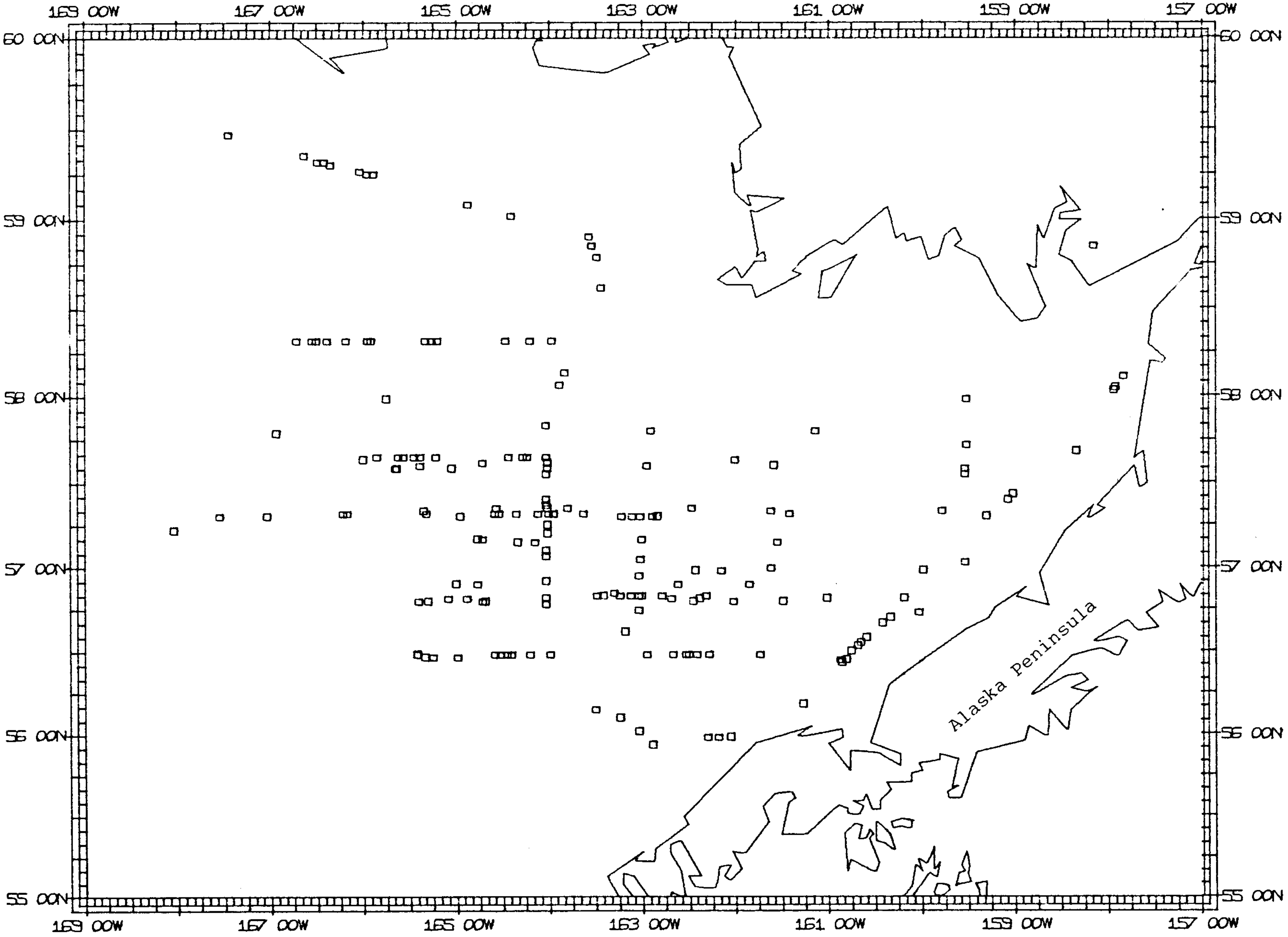


Figure 9. Sightings of Erignathus barbatus (bearded seal) in Bristol Bay during April 1976 aerial surveys.

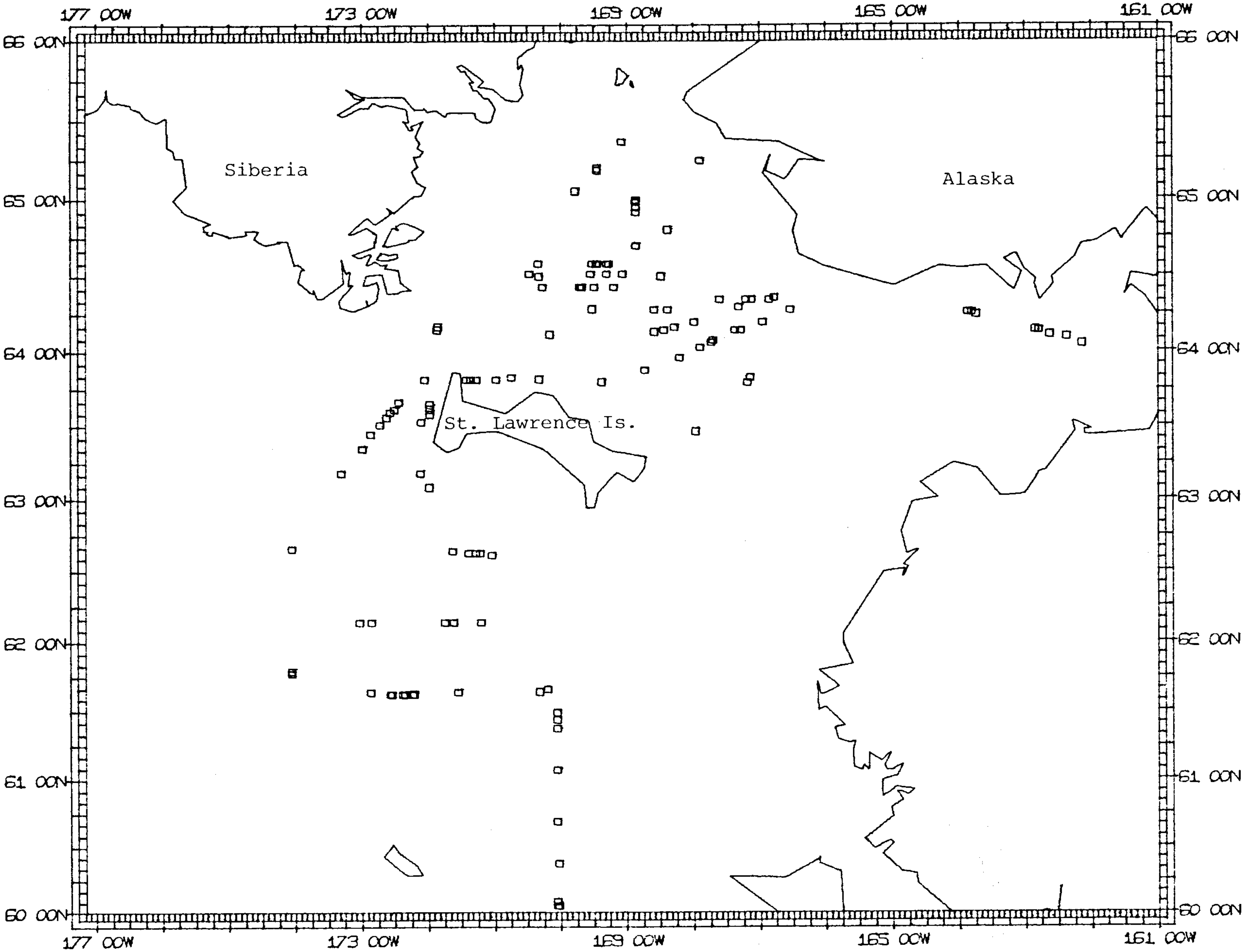


Figure 10. Sightings of Erignathus barbatus (bearded seal) in northern Bering Sea during April 1976 aerial surveys.

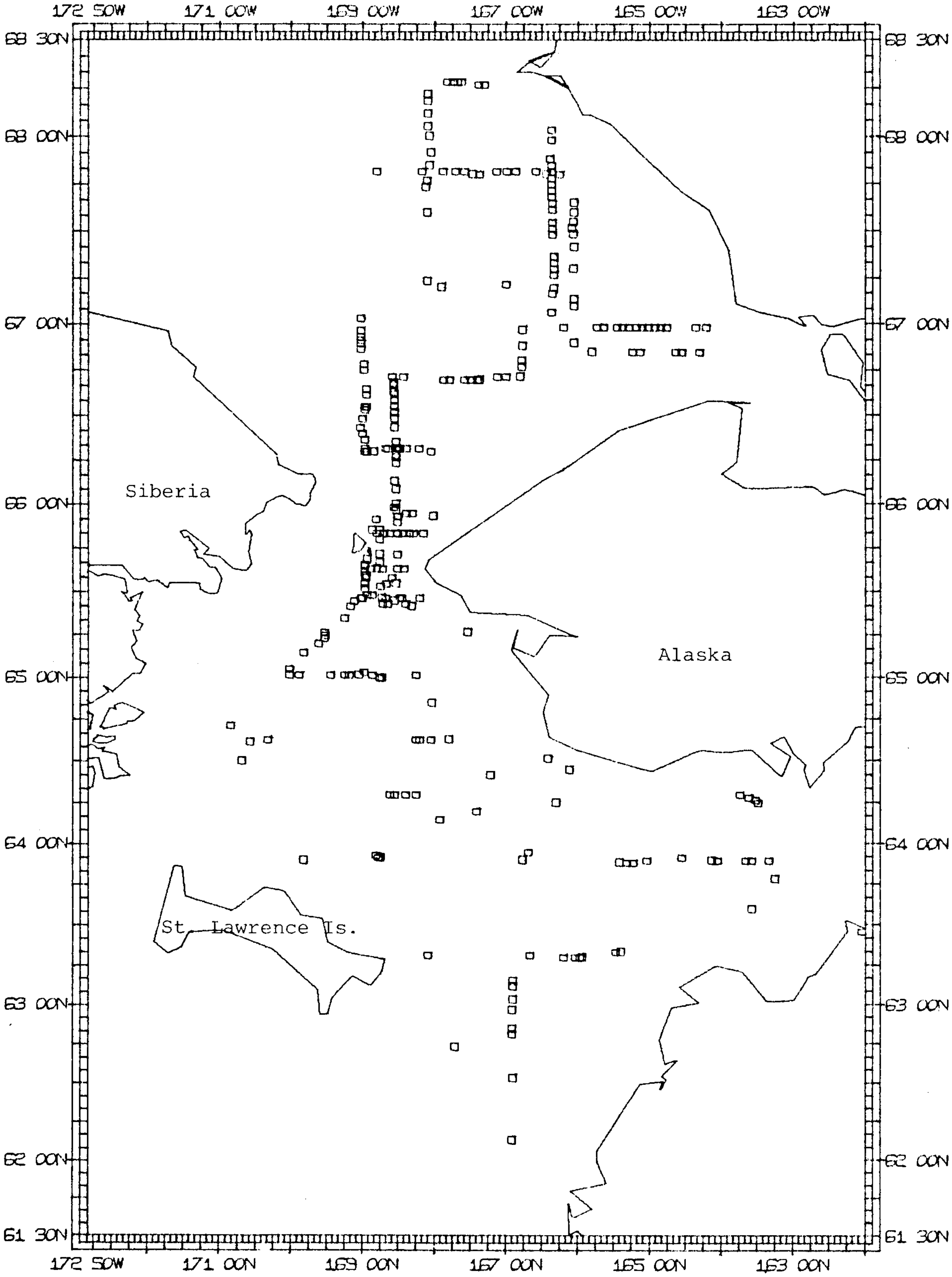


Figure 11. Sightings of Erignathus barbatus (bearded seal) in northern Bering and southern Chukchi Seas during June 1976 aerial surveys.

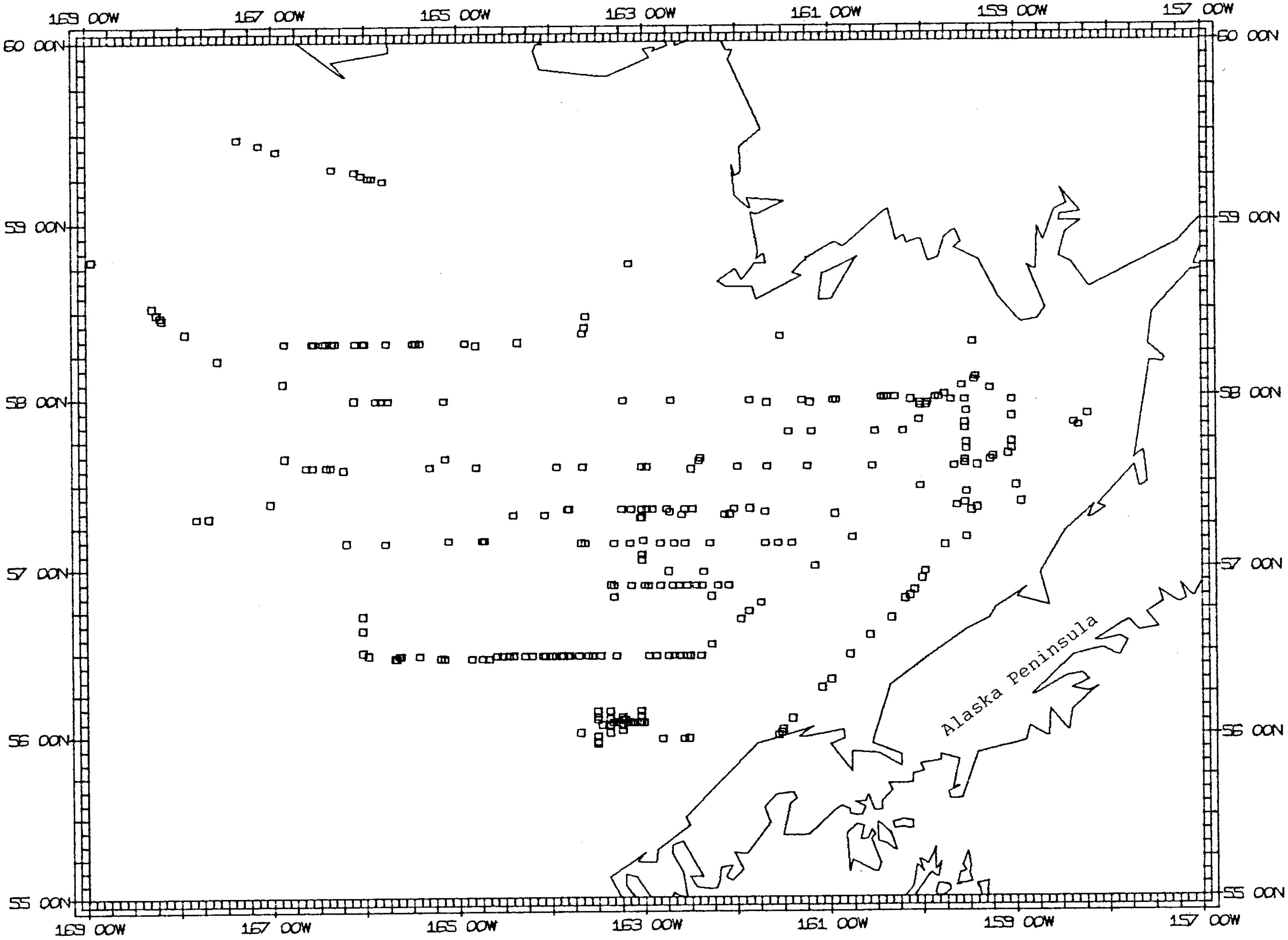


Figure 12 Sightings of Phoca largha (larga seal) in Bristol Bay during April 1976 aerial surveys.

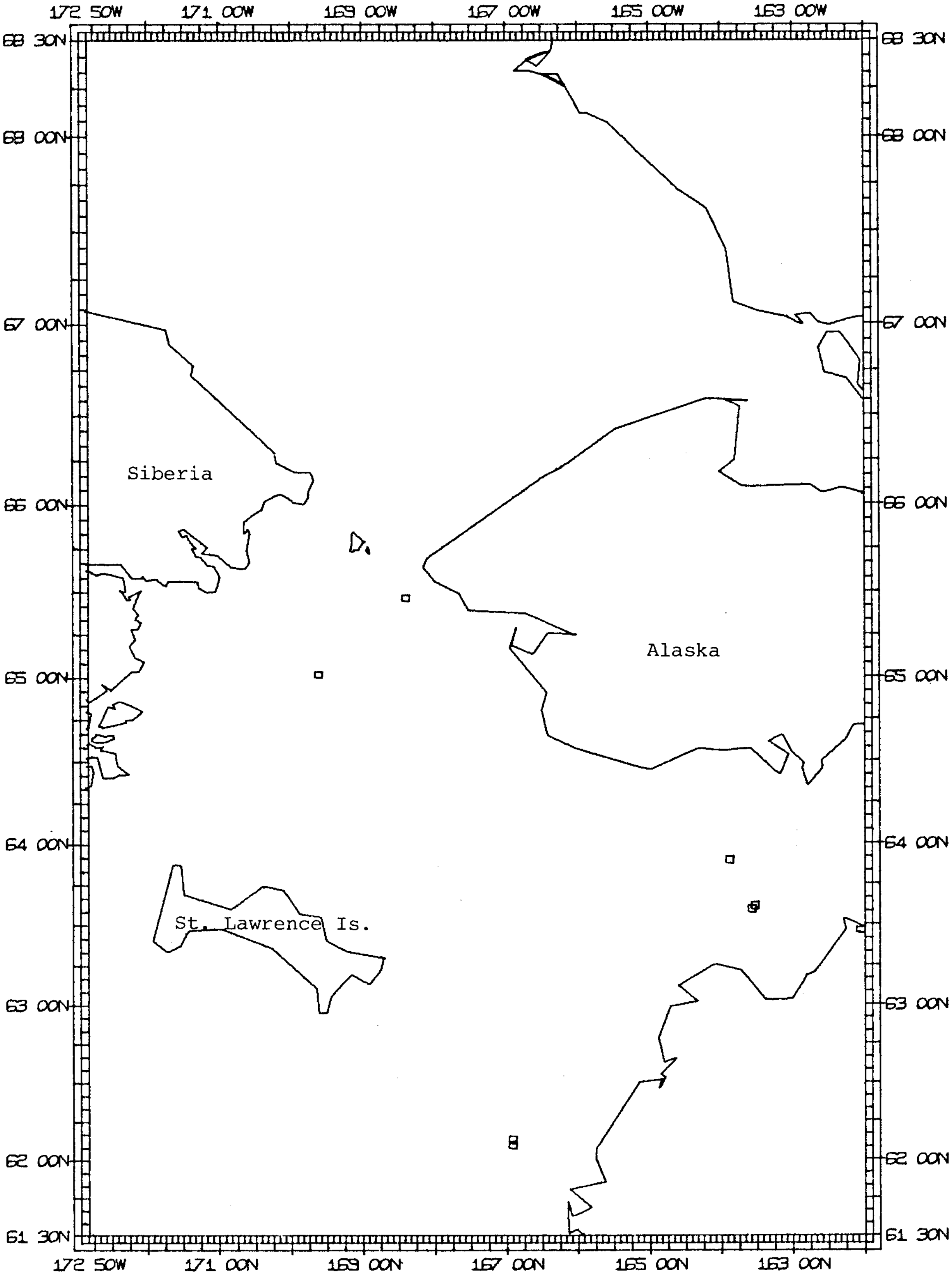


Figure13. Sightings of Phoca largha (larga seal) in the northern Bering Sea during June 1976 aerial surveys.

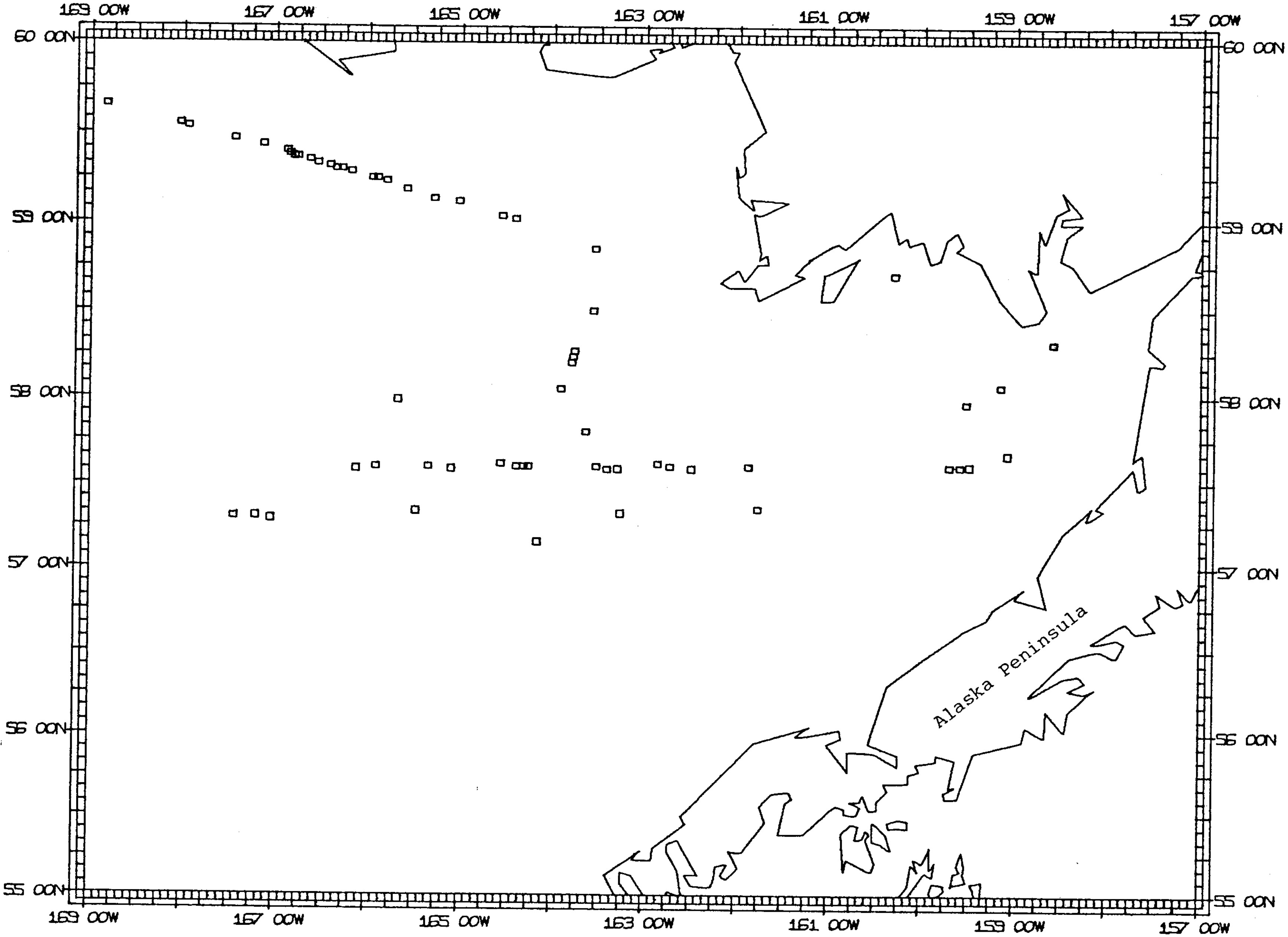


Figure 14. Sightings of Phoca hispida (ringed seal) in Bristol Bay during April 1976 aerial surveys.

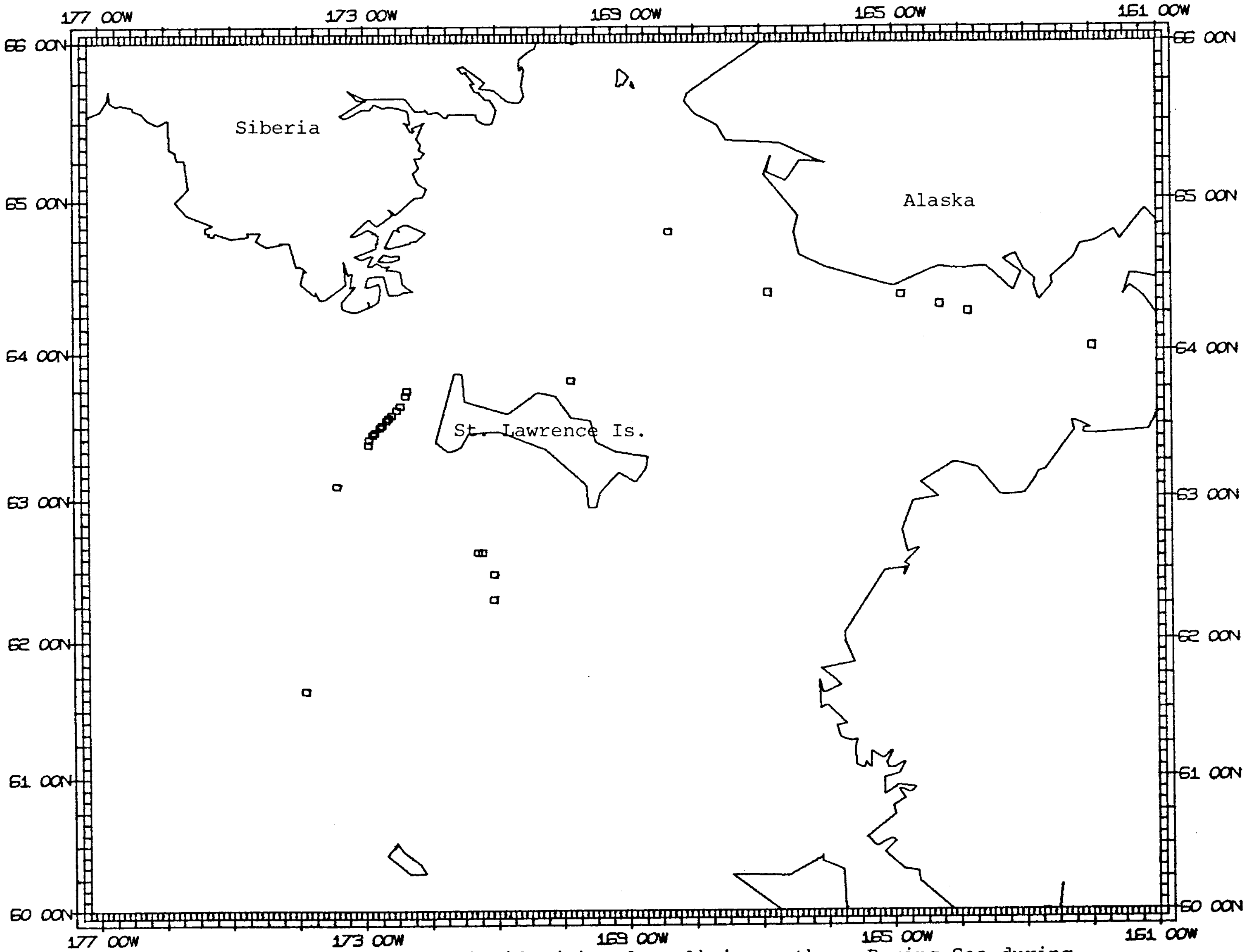


Figure15. Sightings of Phoca hispida (ringed seal) in northern Bering Sea during April 1976 aerial surveys.

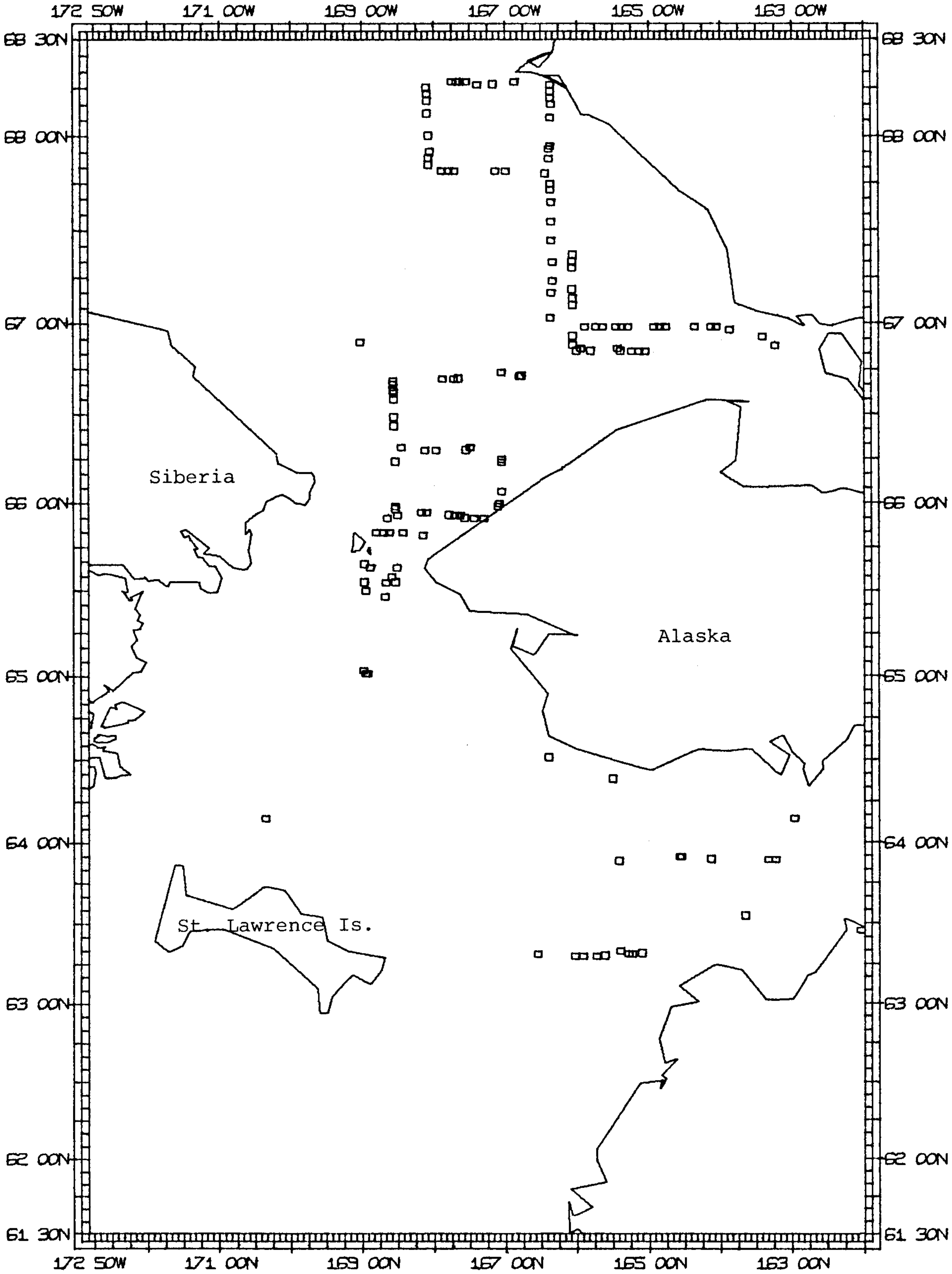


Figure 16. Sightings of Phoca hispida (ringed seal) in northern Bering and southern Chukchi Seas during June 1976 aerial surveys.

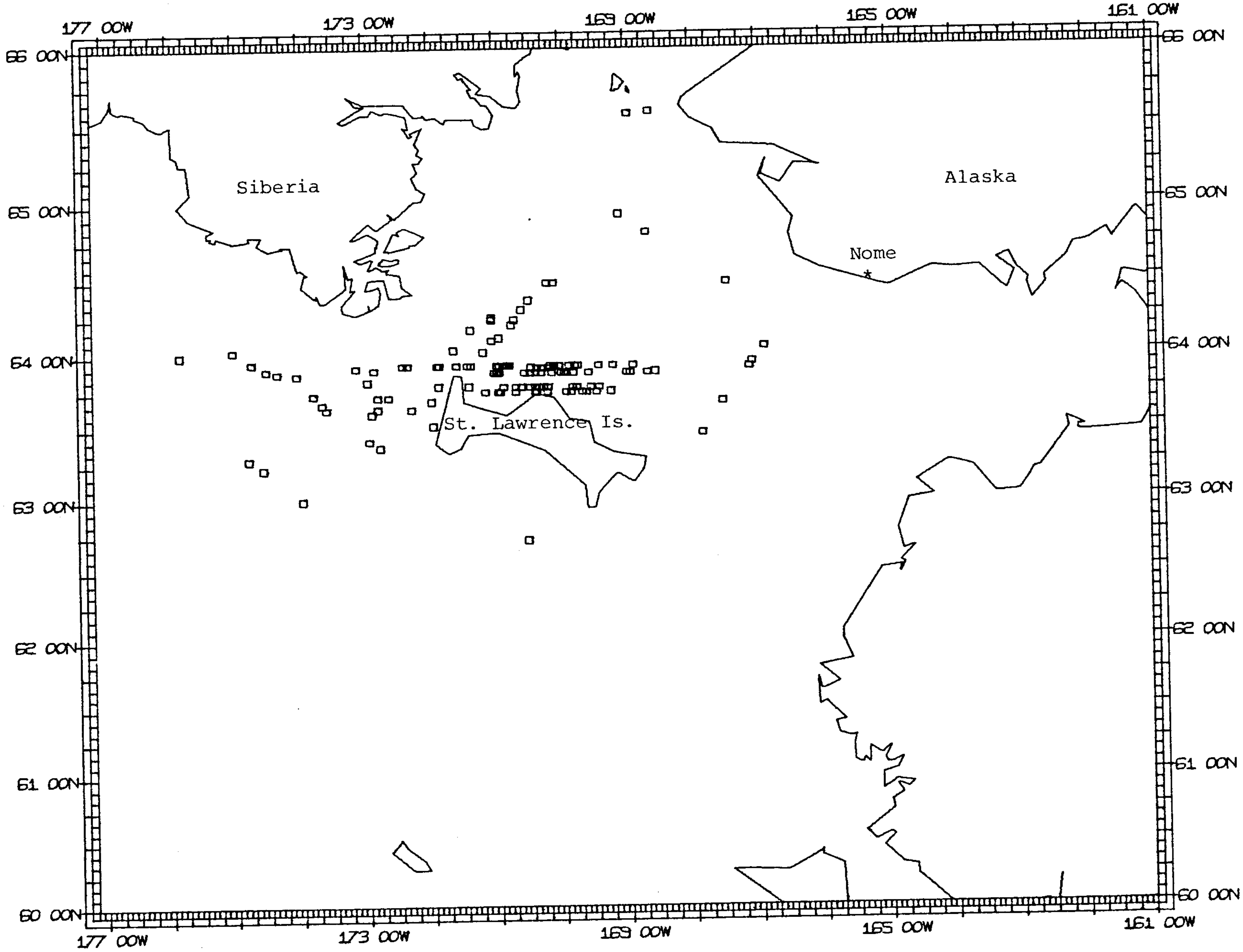


Figure17. Sightings of Odobenus rosmarus (walrus) in the northern Bering Sea during March 1976 aerial surveys.

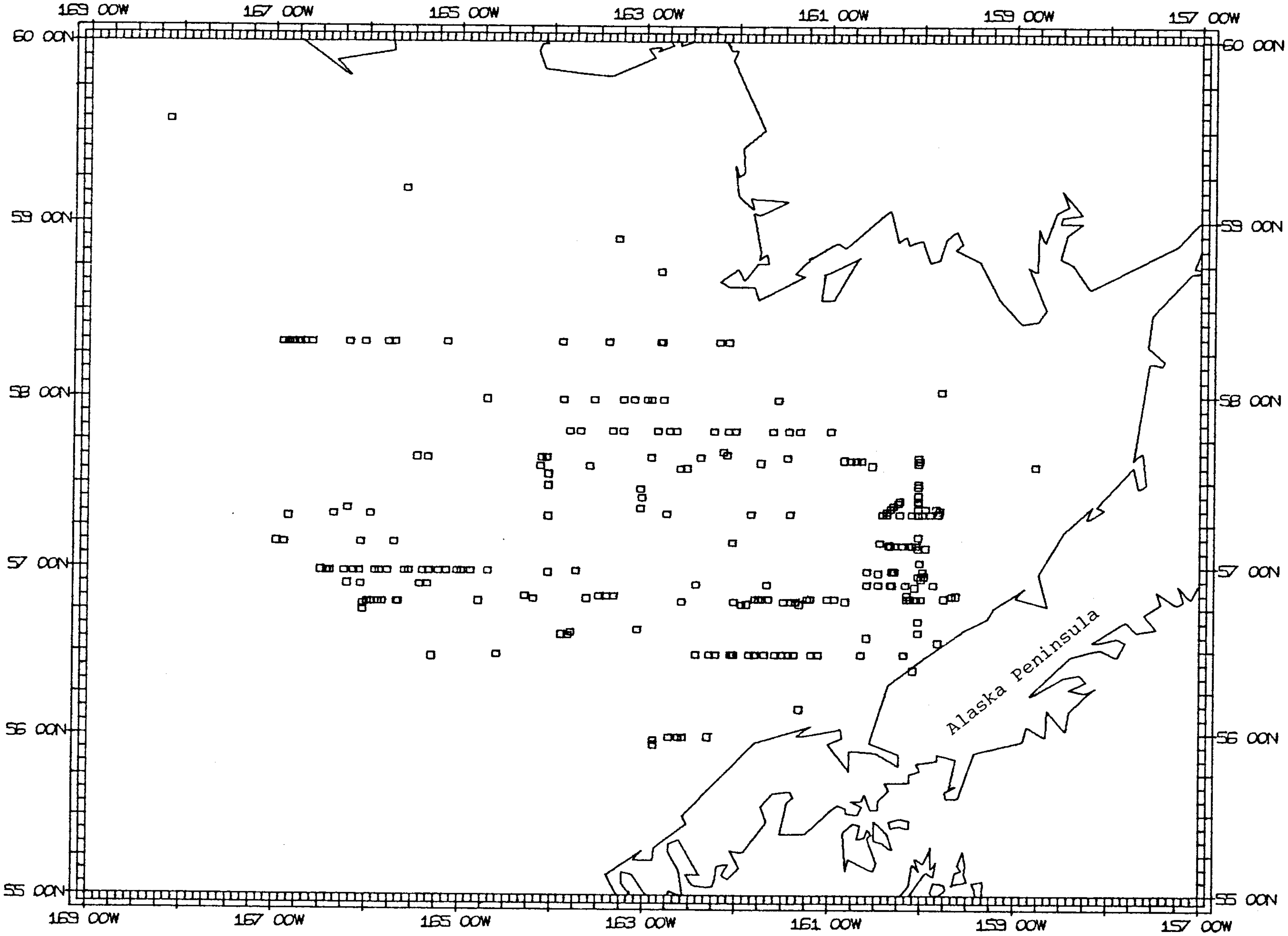


Figure 18. Sightings of Odobenus rosmarus (walrus) in Bristol Bay during April 1976 aerial surveys.

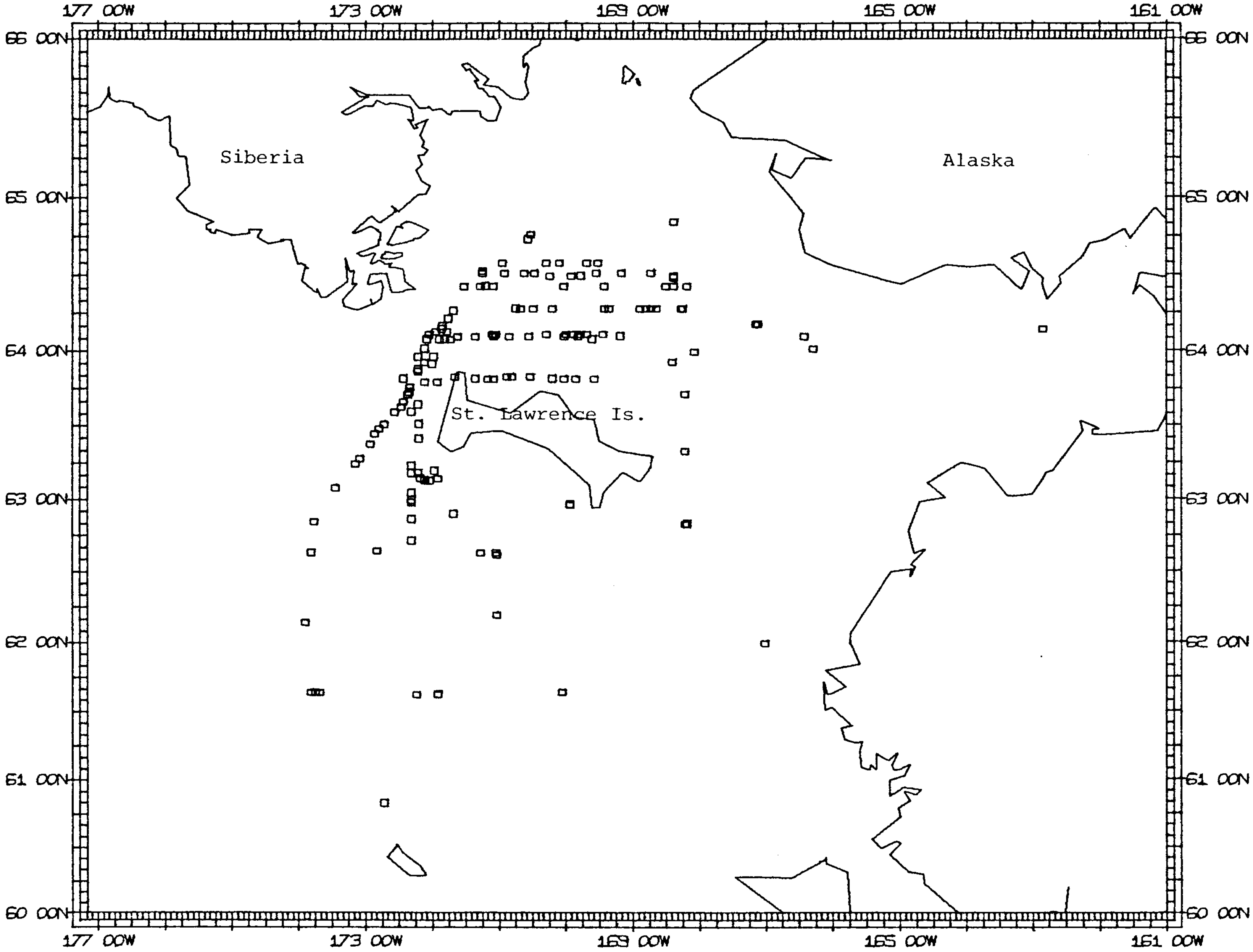


Figure 19. Sightings of Odobenus rosmarus (walrus) in northern Bering Sea during April 1976 aerial surveys.

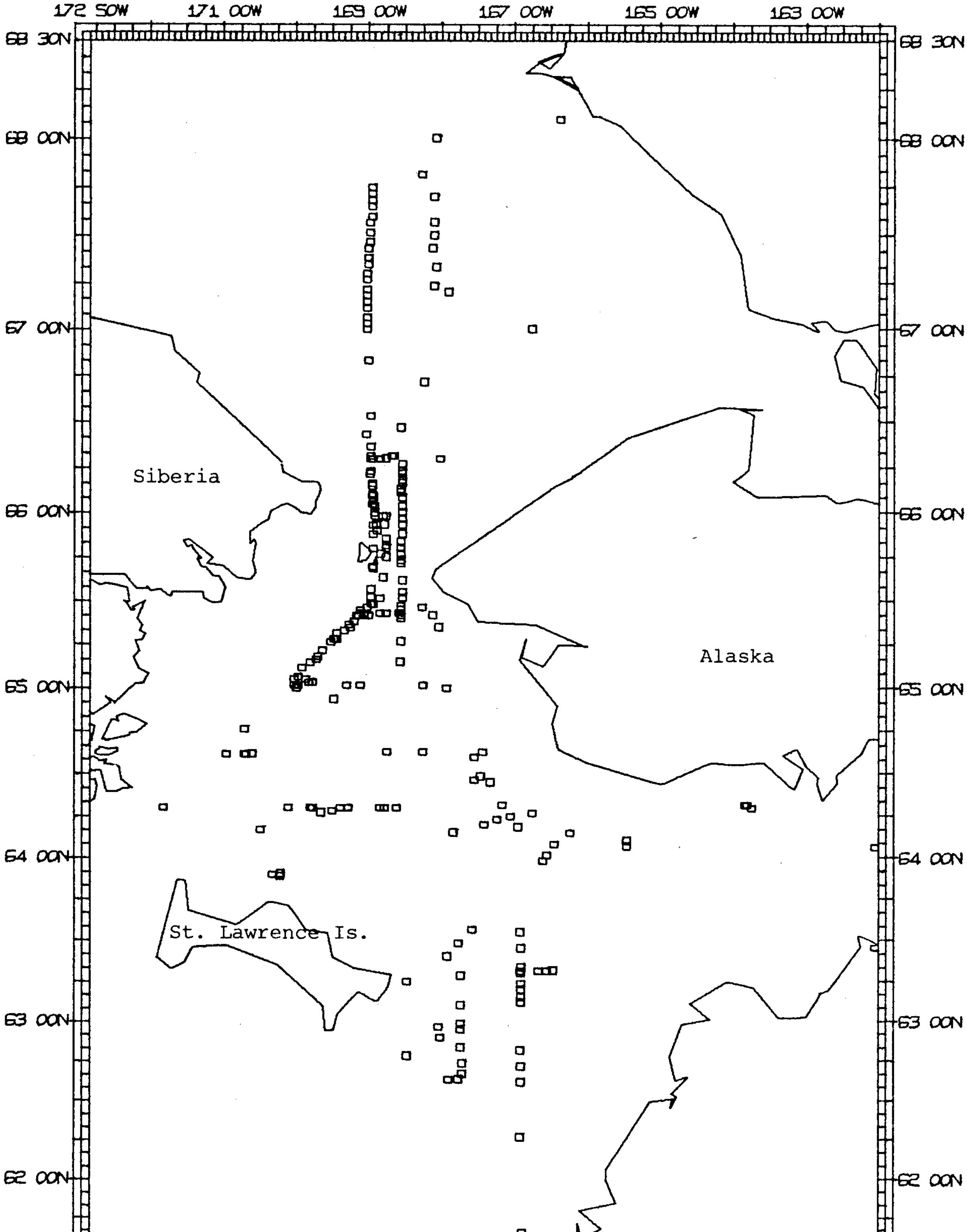


Figure 20. Sightings of <u>Odobenus rosmarus</u> (walrus) in the northern Bering and southern Chukchi Seas during June 1976 aerial surveys.

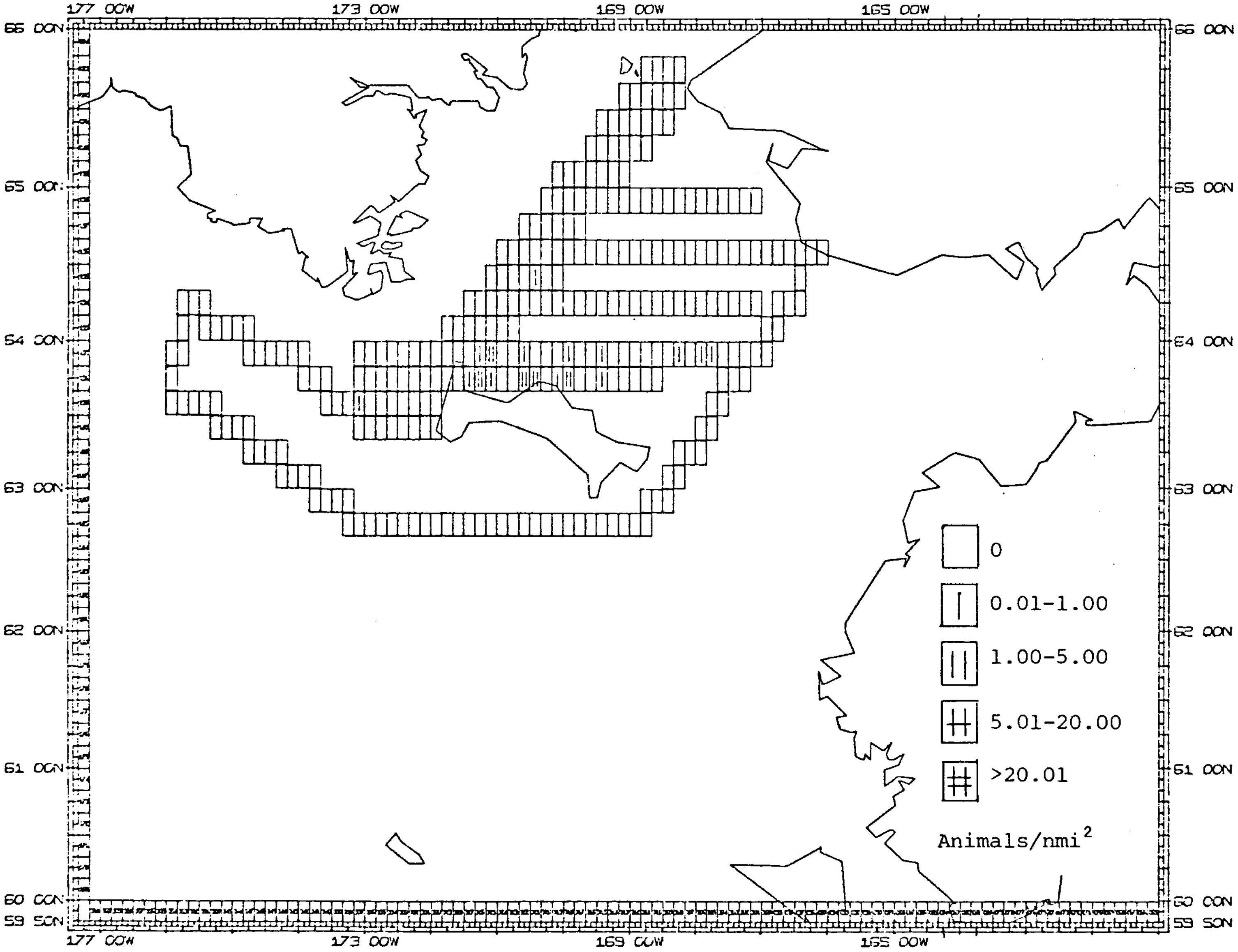


Figure 21. Density plot of bearded seals in northern Bering Sea, March 1976. The density estimates for all remaing charts are as follows:

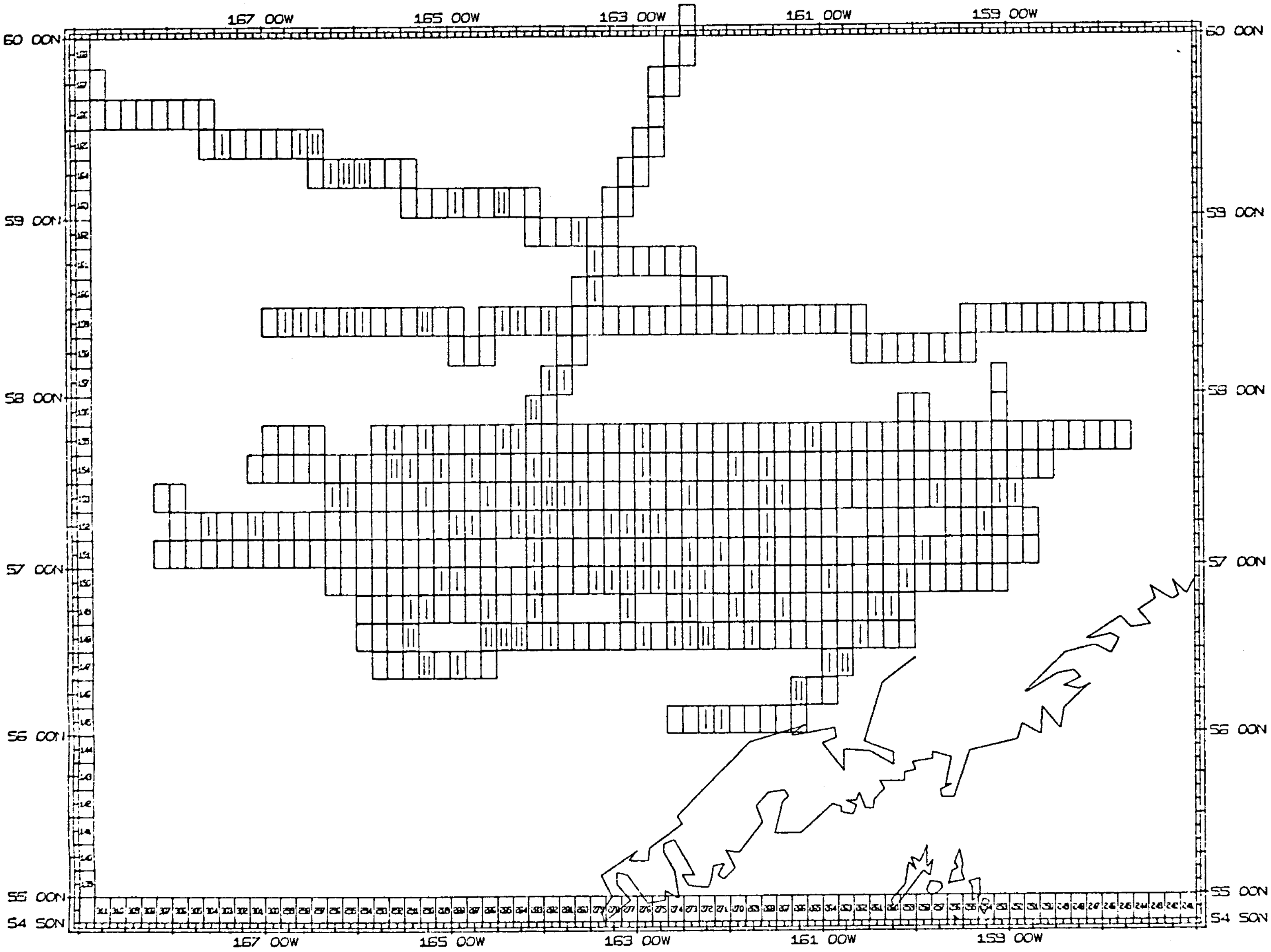


Figure 22. Density plot of bearded seals in Bristol Bay, April 1976.

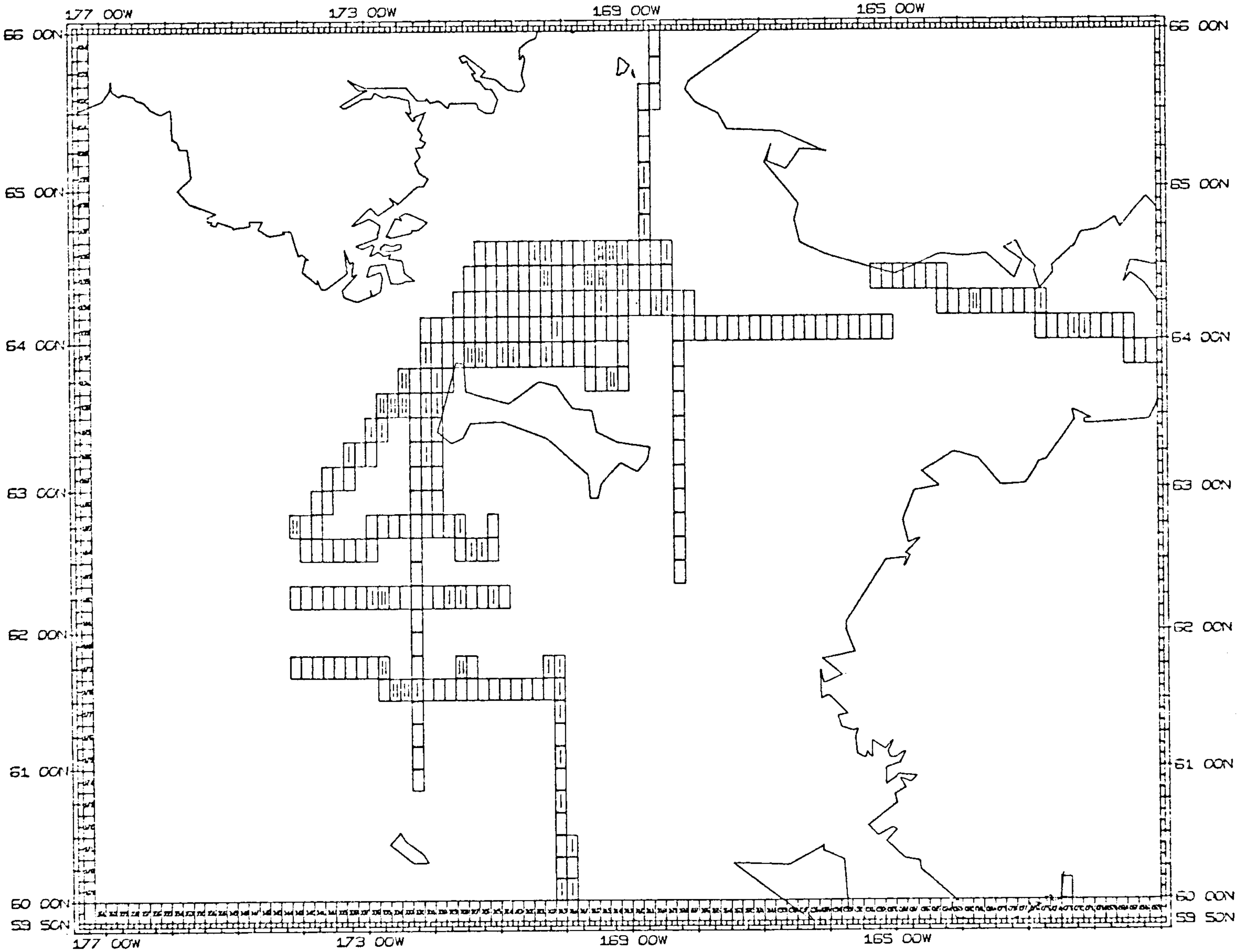


Figure 23. Density plot of bearded seals in northern Bering Sea, April 1976.

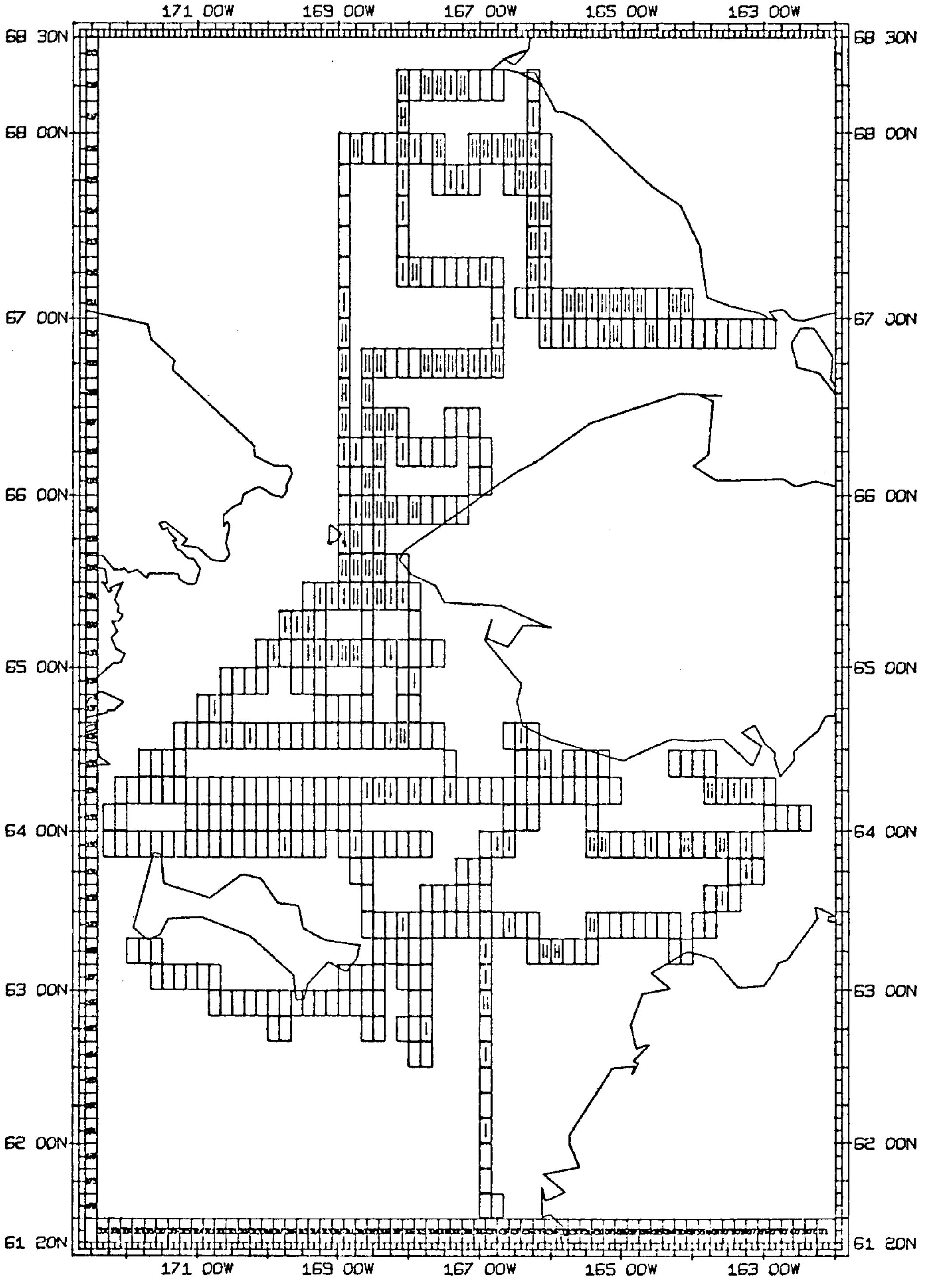


Figure 24. Density plot of bearded seals in northern Bering and southern Chukchi Seas, June 1976.

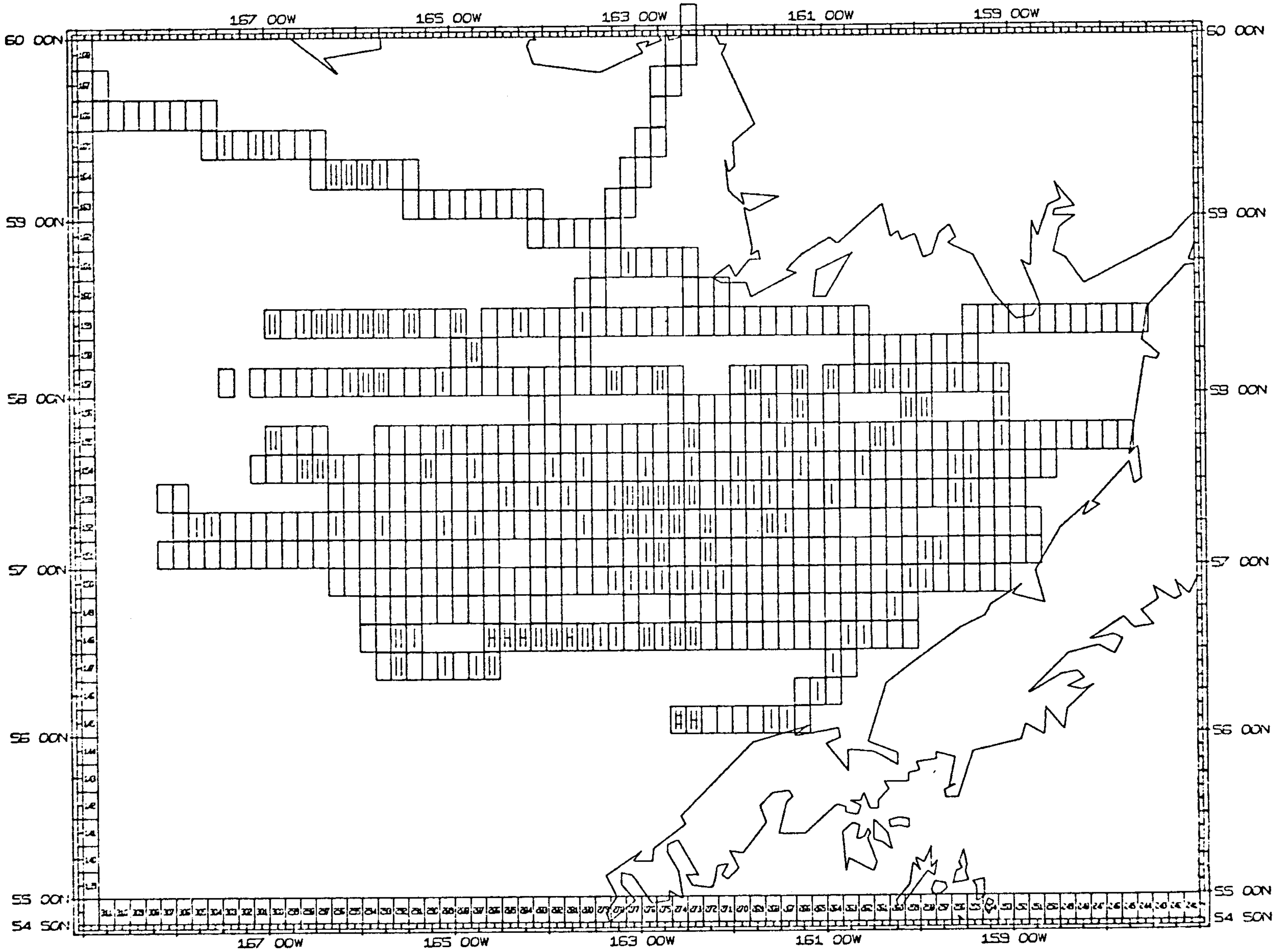


Figure 25. Density plot of larga seals in Bristol Bay, April 1976.

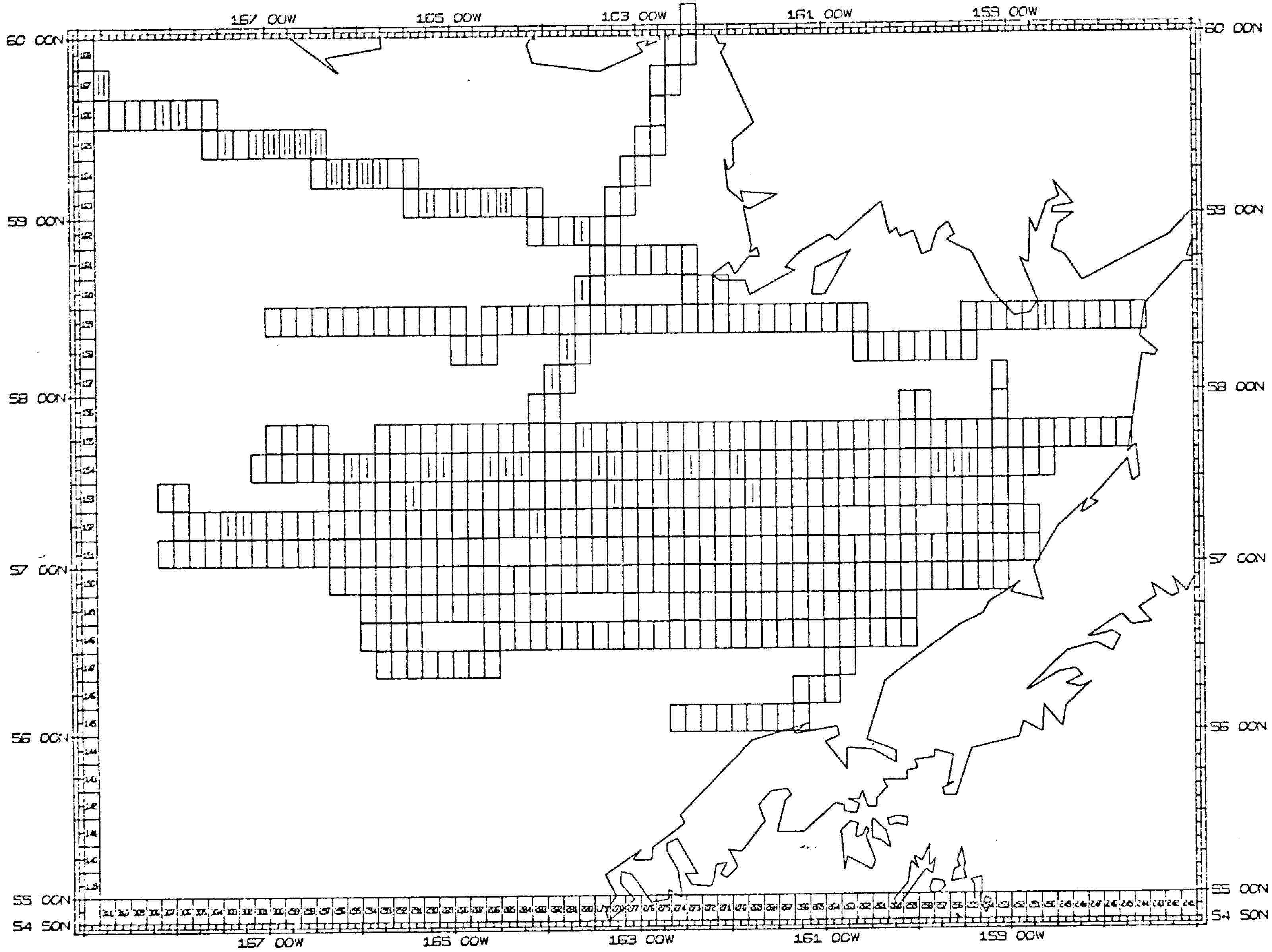


Figure 26. Density plot of ringed seals in Bristol Bay, April 1976.

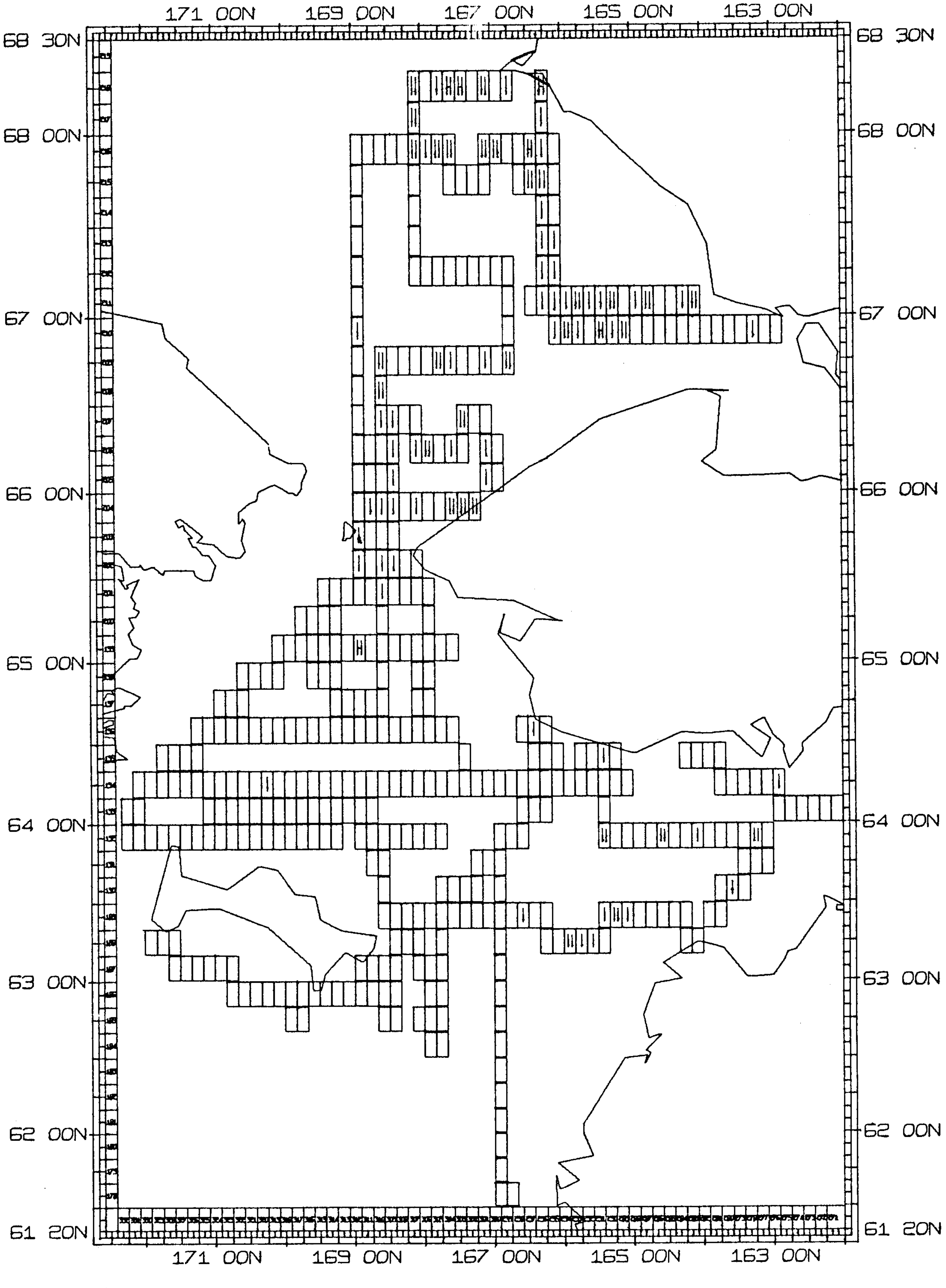


Figure 27. Density plots of ringed seals in the northern Bering Sea in June, 1976.

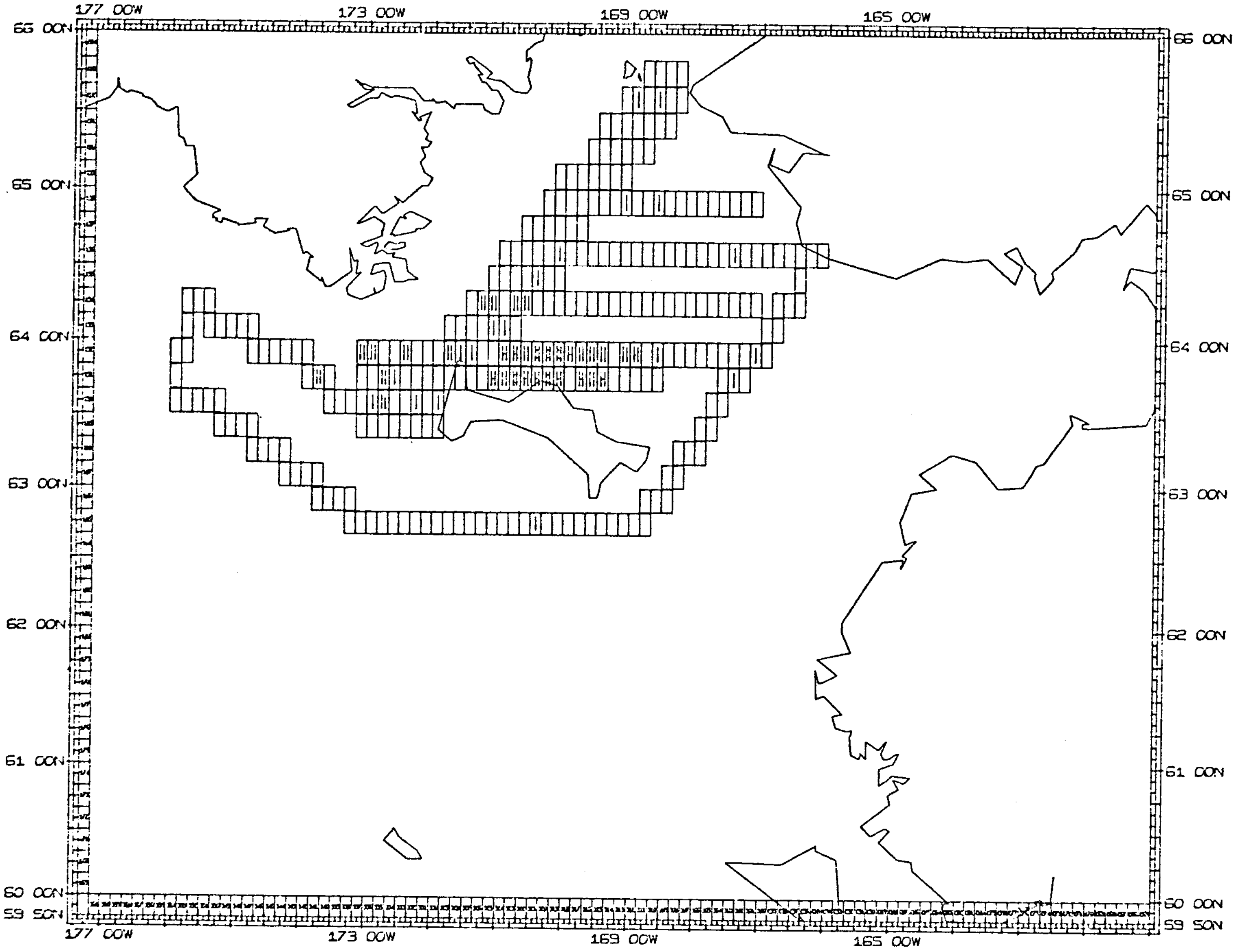


Figure 28. Density plot of walruses in the northern Bering Sea, March 1976.

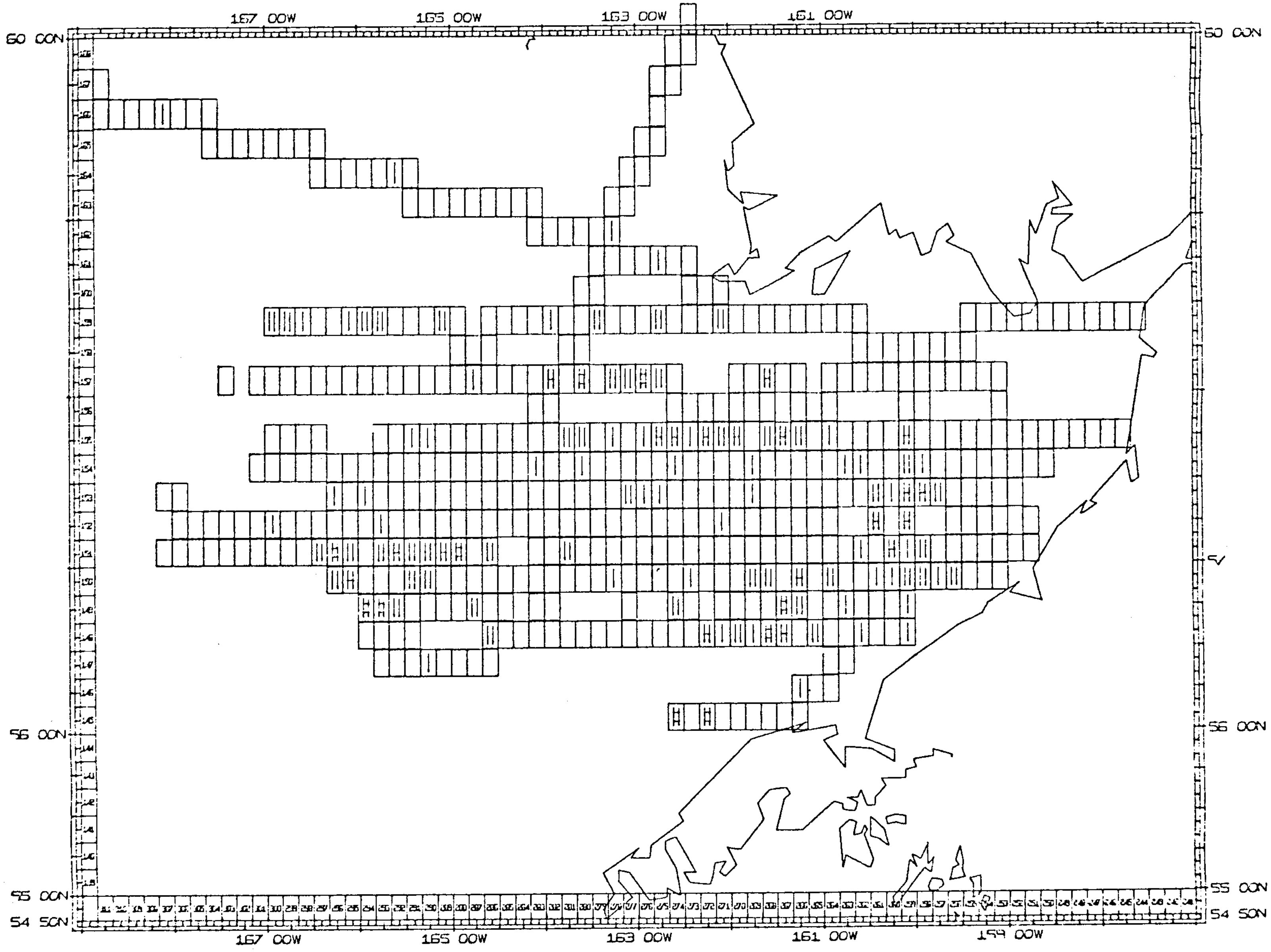


Figure 29. Density plot of walrus in Bristol Bay, April 1976.

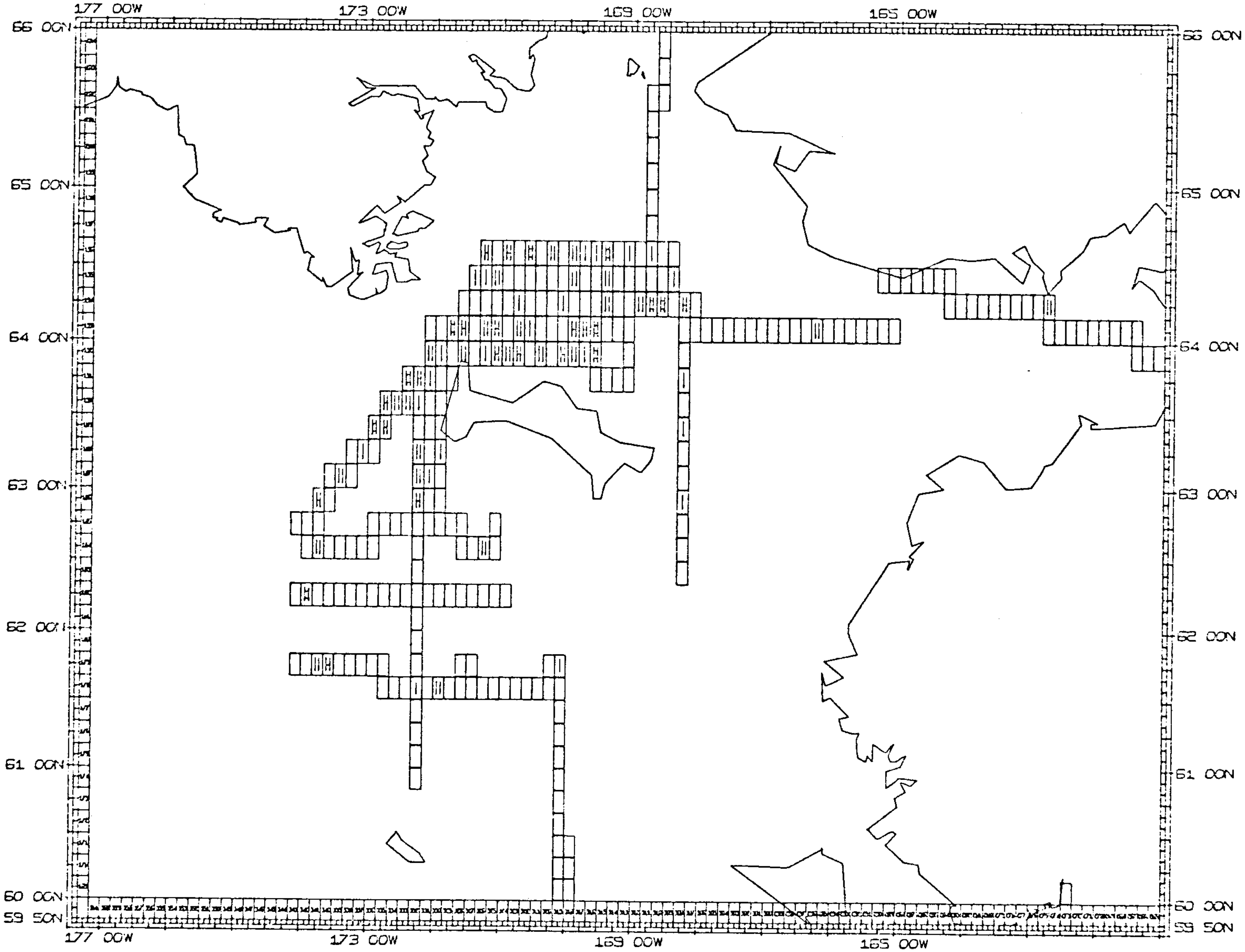


Figure 30. Density plot of walruses in northern Bering Sea, April 1976.

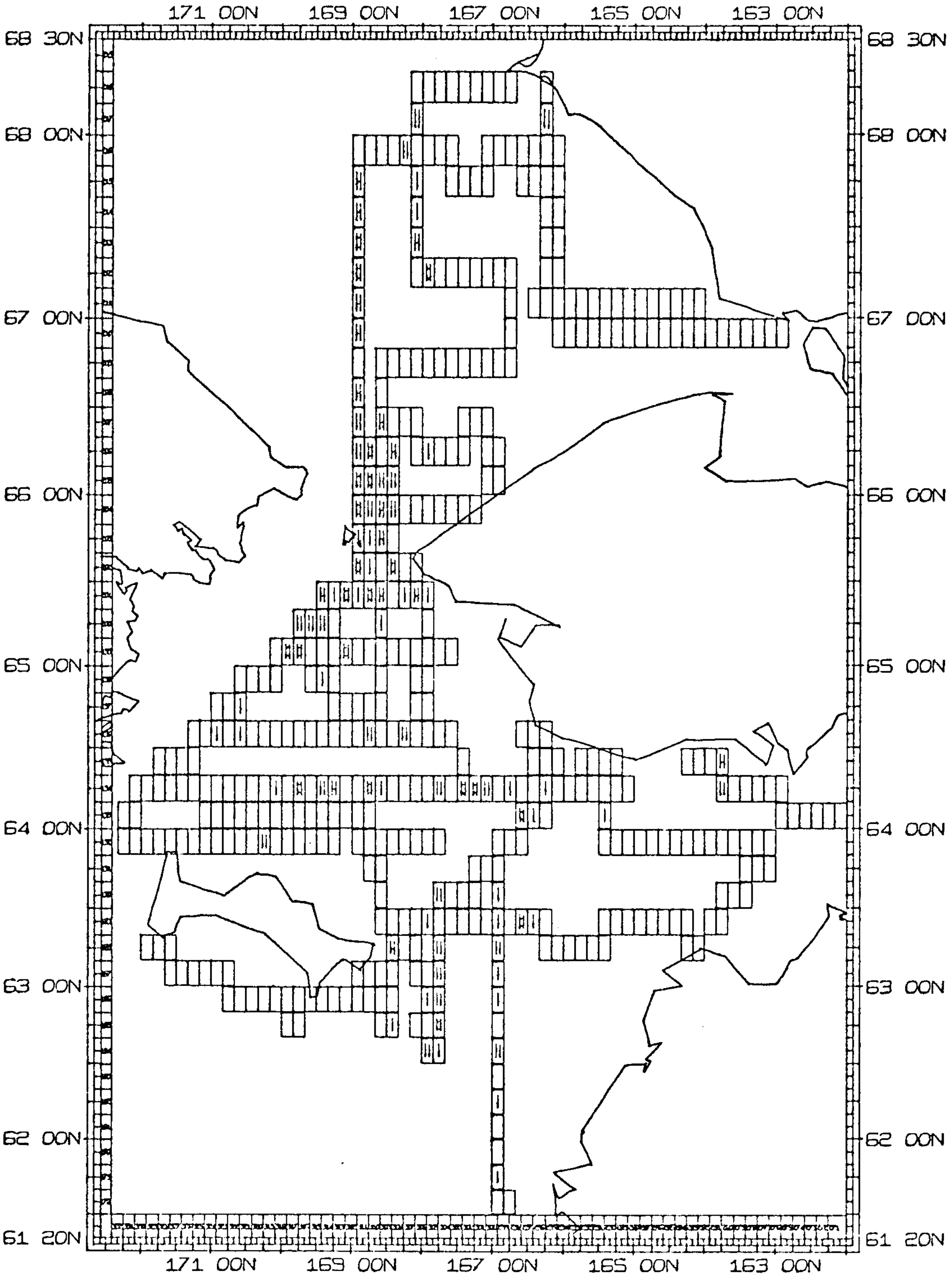


Figure 31. Density plot of walruses in northern Bering and southern Chukchi Seas, June 1976.

Table 5. Summary of the number of phocid seals and walruses per nmi^2 (density ± 95% confidence interval) for March and April in the northern Bering-southern Chukchi Sea (NBS) and southern Bering Sea (Bristol Bay) (SBS). These data are preliminary; they have not, as of yet, been corrected for time of day, daily variations, etc. April and June NBS density estimates are pending.

	Bearded Seal	Larga Seal	Ringed Seal	Walrus
March				
NBS	.052± .146	-----	-----	.224± .017
April				
SBS	.083± .036	.371± .365	.017± .014	.707± .165

Their distribution was more diffuse as evidenced by the density estimate (Table 5 and Figure 23). Ringed seal sightings were sparse, except southwest of St. Lawrence Island (Figure 15). Ringed seals normally occur near landfast ice. The animals depicted in Figure 15 were probably juveniles or immatures; or because of the heavy ice year, some may have moved further south. This past year (1976) was also a "good" polar bear year; with animals moving farther south perhaps in persuit of ringed seals (C.Grauvogel, ADF&G; J. Lentfer, USFWS, pers. comm.). Walrus sightings in April in the northern Bering Sea were more numerous than in March (Figure 19), perhaps as a result of an influx of animals from southwest or west of St. Lawrence Island.

In June in the northern Bering Sea, all three species (bearded and ringed seals and walruses) were found in greatest numbers near the Bering Strait (Figures 11,16 and 20). Ringed seals were more numerous in the Kotzebue oil lease site than bearded seals or walruses, probably because bearded seals prefer the heavier drift ice (Fay, 1974) found farther offshore. Walruses were concentrated along a line approximating the US-USSR 1867 Convention line (Figure 20) because thick ice occurred to the east and open water to the west--as evidenced in Figure 7. Details of walrus distribution and abundance are covered in the Final Report of Research Unit 14, "Distribution and Relative Abundance of the Pacific Walrus", to be submitted in April 1977.

Larga seals were the most numerous phocid seal seen in April in Bristol Bay, followed by bearded, ringed and ribbon seals (Table 3). Bearded seals were the most commonly seen in the northern Bering Sea, followed by ringed seals (Table 4). The number of sightings followed the same sequence; however, a test for goodness-of-fit between the numbers of bearded and ringed seals seen versus the number of sightings in the northern Bering Sea (chi-square 2 x 2 contingency table) indicates that fewer ringed seals were seen and more bearded seals were seen than expected by chance (X^2: $P < 0.01$). This would seem to indicate that either 1) ringed seals were more abundant (than we scored), 2) the data were biased because bearded seals were easier to see than ringed seals, or 3) ringed seals are less likely to group than bearded seals.

The numbers of bearded seals per sighting (a distribution indicator, i.e., are animals more likely to group together or remain solitary?) was greater ($\bar{x} = 1.35 \pm .06$, 95% C.I.) than that for ringed seals ($\bar{x} = 1.12 \pm .08$, 95% C.I.). The same relationship held true for bearded ($\bar{x} = 1.17 \pm .06$, 95% C.I.) and ringed seals ($\bar{x} = 1.03 \pm .04$, 95% C.I.) in Bristol Bay. Larga seals were less solitary than bearded or ringed seals (X^2: $P < 0.01$), which was not unexpected considering the species is believed to congregate near the ice front for purposes of reproduction (Burns, 1970; Fay, 1974).

Plots of larga seal sightings indicate that many animals were found north of the ice front (Figures 12 and 25). It would seem that larga seals are more solitary near the ice front than in the pack ice (Figure 32). Using John Burns' data, RU 231, collected between 8-23 April 1976 near the ice front in Bristol Bay, we find that the mean number of larga seals is greater in the pack ice ($\bar{x} = 1.56 \pm .10$, 99% C.I.) than at the ice front ($\bar{x} = 1.37 \pm .07$, 99% C.I.). The difference is statistically significant. This may

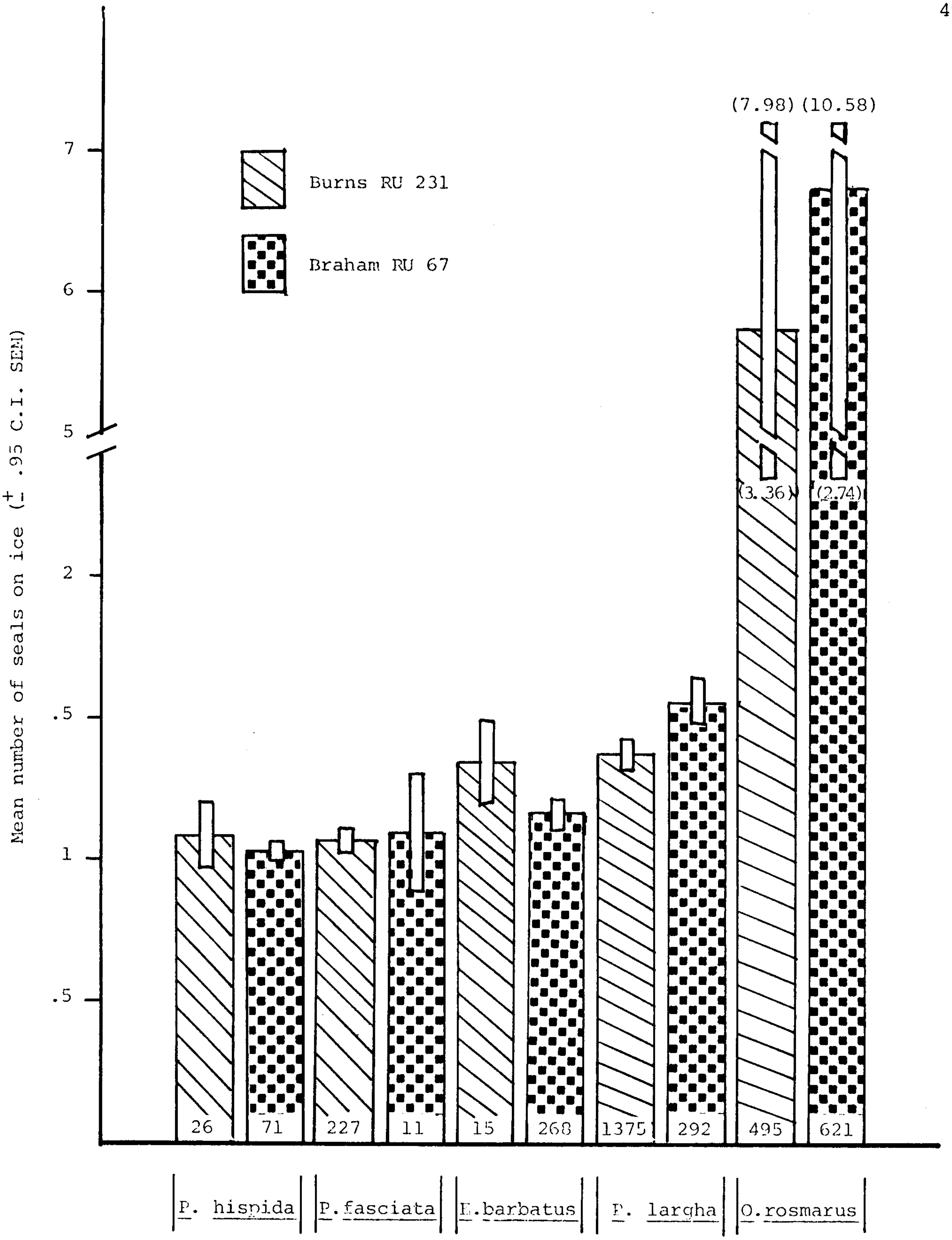


Figure 32. Species group sizes ($\bar{x} \pm .95$ confidence interval) of pagophilic seals from the ice front (Burns) and pack ice (Braham) in the southeast Bering Sea, 8-23 April 1976. The number at the bottom of each bar represents n number of sightings not N number of animals observed.

mean that 1) pairing and pupping occurs earlier or with greater relative frequency in the pack ice zone than near the ice front (i.e., there may be more juveniles or immatures at the front), or that 2) some bias existed between the way we scored data and that of Burns. The first explanation is probably the most likely. The numbers of animals per sighting for larga seals increased from about 1.3 to 1.7 from 8 April to 18 April, perhaps indicating that greater pairing and pupping was occurring as the breeding season progressed (Figure 33).

Many more ringed seals were seen in the northern Bering Sea than in the southern Bering Sea in April (Tables 3 and 4). This was not surprising, as the species is noted as being primarily a shore-fast ice animal (Burns, 1970). Apparently, P. hispida does not migrate with the drift ice during the winter and early spring to the extent that bearded and larga seals do.

During April, bearded seals were more numerous (per sighting) in the northern Bering Sea than in Bristol Bay than would be expected (X^2: $P < 0.01$). This suggests that pairing and/or pupping was more common to the north. Again, greater numbers of non-breeding animals might migrate farther to the south than mature adults, thus inflating our figures. This relationship needs testing. Burns' April 1976 data compared to ours (Figure 32) indicates that more bearded seals per sighting occurred at the ice front ($\bar{x} = 1.27 \pm .60$, 95% C.I.) than farther back in the Bristol Bay pack ice ($\bar{x} = 1.17 \pm .06$, 95% C.I.). Although the difference is not statistically significant (it is at the 0.10 level), if young bearded seals are grouped at the front, then the northern extent of the pack ice represents a more important breeding area for the species than the southern extent.

Sea lions and harbor seals

Over 2400 nm of aerial survey were conducted during 1975 and 1976 along Alaska Peninsula-Bristol Bay (from Cape Newenham to Unimak Island) and in the eastern Aleutian Islands (Table 6). The first three surveys (A1,A2,A6) covered the entire study area, except where fog or weather prevented flying. Survey A8 covered all areas except the Bristol Bay coast, and survey B1 (flown with the Bell 206B helicopter) covered the Krenitzen Islands, south end of Umnak Island, the northeast side of Unalaska Island, and the Amak Island group.

Table 6. Northern sea lion and harbor seal aerial survey dates.

Survey	Date	Data recordings*	Survey track miles**
A1	17-20 June 1975	1810	540
A2	9-13 August 1975	1760	527
A6	14-20 June 1976	1840	587
A8	19-21 August 1976	1350	510
B1	21-25 October 1976	861	277
		7621	2441

* A "data recording" is a single logged entry at a specific time and location, and represents one or more animals.

** In nautical miles (1 nm = 0.87 statute miles)

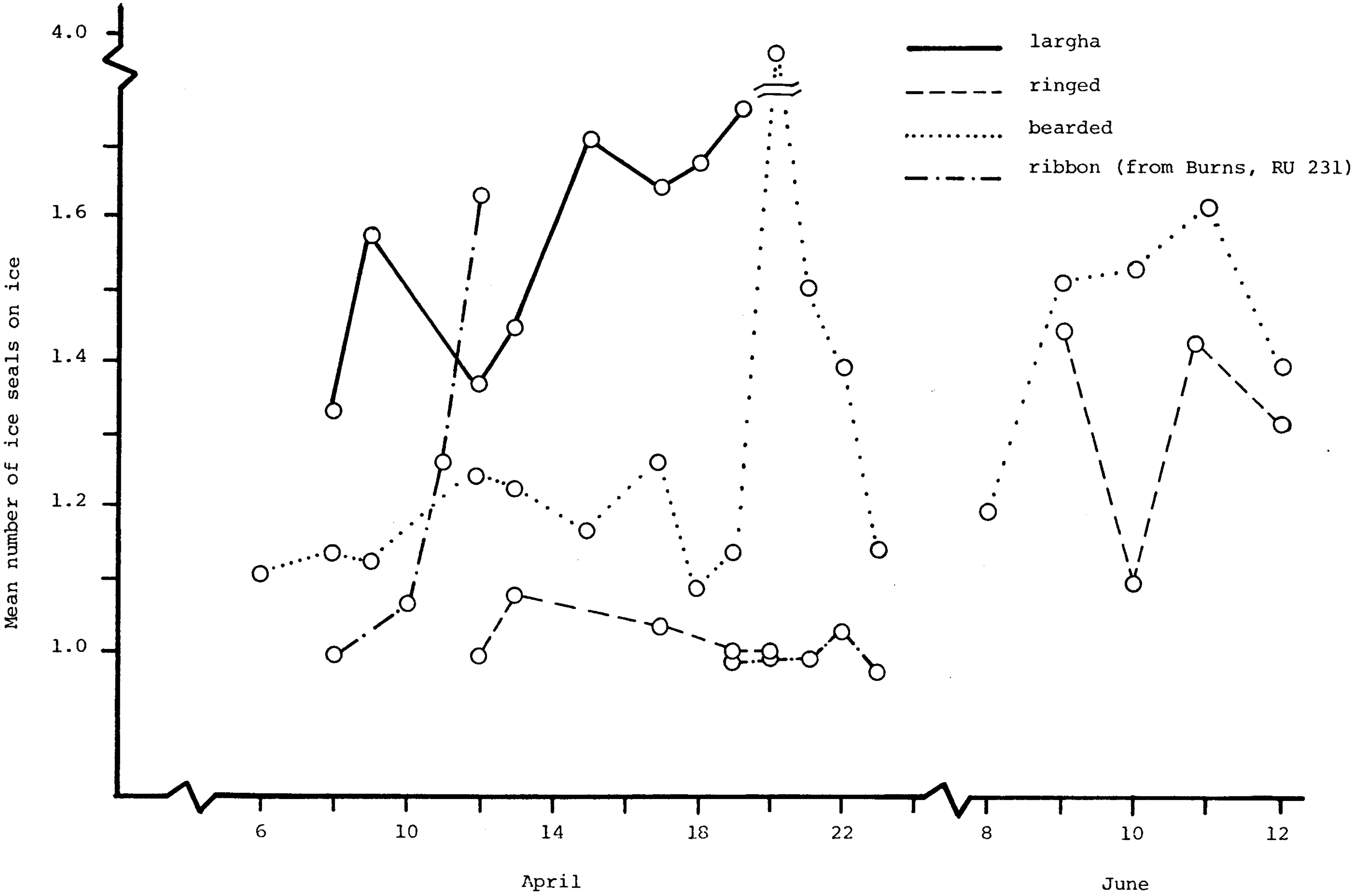


Figure 33 Mean number of ice seals (total number per sighting) with respect to the breeding season (April) and molting period (June-July) scored during aerial surveys of the Bering and Chukchi Seas, 1976. Larga and ribbon seal data from Bristol Bay; ringed seal data from the northern Bering Sea, and bearded seal data from both survey areas.

Northern Sea Lions

Sea lion rookery (R) and hauling areas (H) were identified during our surveys to precise location (Figures 34 and 35). The number of animals seen by location is covered in Table 7. Rookeries were identified by the presence of pups. All other areas were deemed hauling grounds. Whenever possible, photographs were taken and the numbers on each slide later scored. In a few instances (due to poor survey conditions) photographs were not taken and the visual estimate was used. Preliminary analysis (chi-square and students t-statistic) revealed that for model data (Table 8) no significant difference existed for a population estimate (taken from several locations) when comparing visual estimates and photographic counts ($P > 0.05$). Differences between certain individual location estimates (e.g., Ugamak Island aerial versus photos) were, however, significant (see Σx^2 for each cell in Table 8). The reason for no difference between the two population estimate methods was because of the large sample variances. It is clear that a greater statistical bias exists between location samples (e.g., A vs. B; Table 8) than the overall effect on the total population estimate (i.e.,locations summed). These tests suggest that ground truth counts are needed to satisfactorily evaluate population abundance estimates.

In all cases it was difficult to identify pups from slides or when in the field. Many were obscured on the photos, hidden by other animals, in rocks or crevasses, etc.; therefore, no reliable pup data has been collected. Those pups that were counted are included in the total rookery count in our data.

In the survey area sea lions are concentrated in the eastern Aleutian Islands (Ugamak Island to Adugak Island), accounting for approximately 80% of all animals observed. The Amak Island group (Figure 34) accounted for the remaining 20%, with a small number (300-400) hauled out on Round Island (Walrus Island group) in northern Bristol Bay.

Several new hauling areas were identified from our surveys that had not been reported by Kenyon and Rice (1961) and Mathisen and Lopp (1963). These areas include: Polivnoi Rock, Bishop Point, Old Man Rock, Cape Sedanka, Sedanka Island, Outer Signal, Battery Point, Rootok Island (rocks north) and Cape Chagak (Table 7, Figure 35). Except at Bishop Point, Old Man Rocks, and Rootok Island, the remaining locations were found to have animals on them only once during our four surveys. Kenyon and Rice (1961) and Mathisen and Lopp (1963) recorded animals in many areas that we did not. This would indicate that sea lions are less selective of hauling grounds than of the more traditional rookery areas.

Our studies have shown a substantial decline in the numbers of northern sea lions in the eastern Aleutian Islands, when compared with earlier surveys (Figure 36). Population levels appear to be less than half of the estimated numbers in the late 1950's. The numbers of animals observed for seven of the most populous rookery/hauling grounds are shown in Figure 37. Bogoslof Island has a large number of animals present in June during the breeding and pupping period, with the numbers in August being smaller. In contrast, on Adugak Island, Cape Morgan, and Billings Head, more numbers of animals occur in August than in June. This suggests that these areas are more

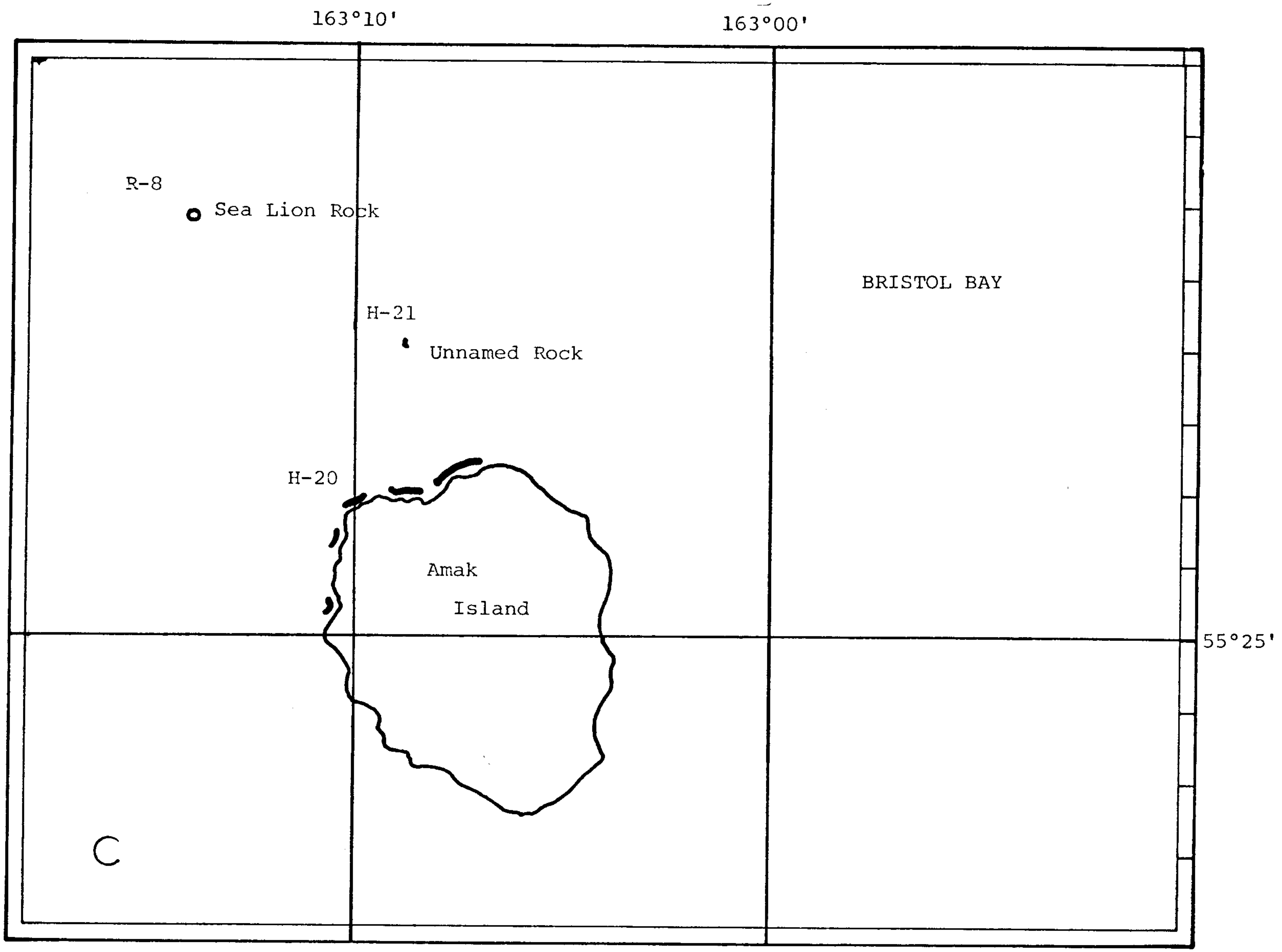


Figure 34. *Eumetopias jubatus* rookery (R) and hauling grounds on and near Amak Island, located northwest of Izembeck Lagoon, on the Alaska Peninsula.

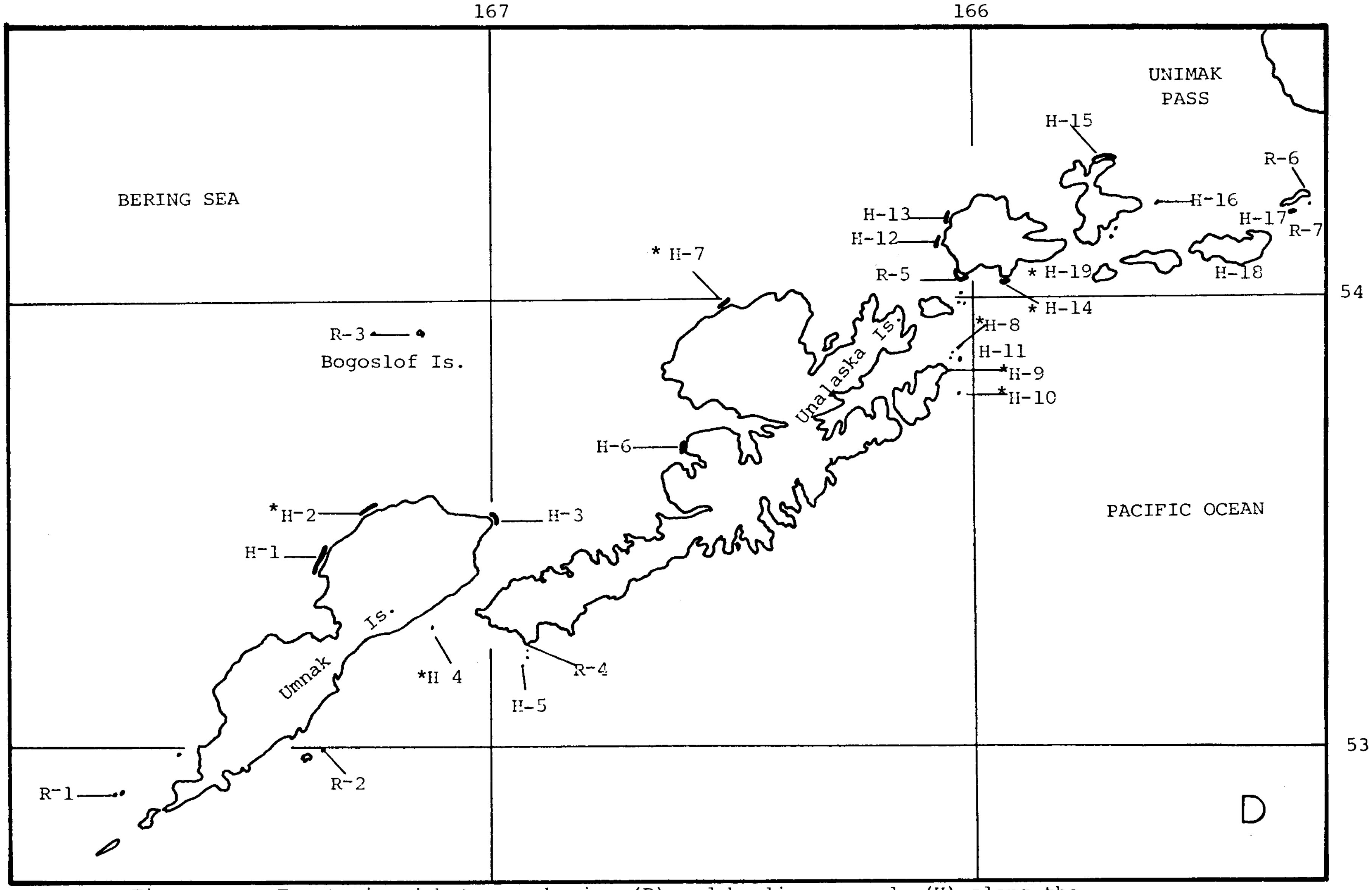


Figure 35 . *Eumetopias jubatus* rookeries (R) and hauling grounds (H) along the eastern Aleutian Islands (Fox Island group). See Table 7 for a listing of each R and H. Those with asterisks (*) are new locations identified during our June and/or August surveys in 1975 and 1976.

Table 7. Observations of northern sea lions (*Eumetopias jubatus*) from aerial surveys along the Alaska Peninsula, eastern Aleutian Islands, and Bristol Bay. Numbers are based on visual estimates or on counts taken from photographs (*). Dashed spaces indicate areas not surveyed; blank spaces mean no animals were observed.

General Location	Map Reference Number	Survey Date				
		June 1975	August 1975	June 1976	August 1976	October 1976
Adugak Is.	R 1	-	1,845*	1,177*	2,125	1,400*
Cape Aslik	H 1	285		221*	8	-
Cape Chagak	H 2	20		-		-
Cape Idak	H 3	-		223*		-
Polivnoi Rock	H 4	-	131*	-		-
Ogchul Is.	R 2	-	947*	-	1,138*	2,441*
Bogoslof Is.	R 3	-	1,872*	3,599*	2,127*	490*
South Rock	H 5	-	30	61*	8	-
Cape Izigan	R 4	-	600	724*	1,102*	-
Cape Starichkof	H 6	100		78*		-
Bishop Pt.	H 7	172*	13	555*		136*
Old Man Rocks	H 8	180*	300	829*		-
Cape Sedanka	H 9	-	200			-
Outer Signal	H 10	-		68*		-
Sedanka Is.	H 11	-		364*		-
Cape Morgan	R 5	2,894*	3,118*	3,441*	5,924*	2,637*
Reef Bight	H 12	100	182*	874*		58*
Lava Bight	H 13	115	178*		300	208*
Battery Pt.	H 14	30				

Table 7 (cont.)

General Location	Map Reference Number	Survey Date				
		June 1975	August 1975	June 1976	August 1976	October 1976
Billings Head	H 15	748*	2,641*	613*	2,032*	1,130*
Tanginak Is.	H 16	470*	3	358*		60*
Rocks, n.e. of Tigalda Is.	H 17	80		274*	22	30*
Tigalda Is.	H 18			314*		
Ugamak Is.	R 6	3,940*	4,630*	4,673*	2,939*[1]	3,765*
Round Is.	R 7	-	175*	246*	213*	158*
Rock, north of Rootok Is.	H 19	118*	46*			66*
Amak Is.	H 20	1,095*	2,316*	1,777*	1,356*	905*
Sea Lion Rock	R 8	2,006*	2,126*	1,944*	2,331*	1,836*
Unnamed Rock (near Amak Is.)	H 21	108*	234*	132*	355*	110*
The Twins, (Walrus Islands)	H 22	50	30		-	-
Round Is.	H 23	325*	244*	296*	-	-

[1] partial survey

Table 8. Northern sea lion (*Eumetopias jubatus*) population estimates comparing aerial versus photographic counts of animals observed on selected rookery and hauling grounds in the eastern Aleutian Islands, 18-28 October 1976.

Day	Location	Aerial Estimate (A)	Photo Count (B)	Estimate Difference	Σ Chi-Square[4] within cell. (A vs. B)
21	Ugamak Is.	2,985	3,765	-	19.16
21	Tigalda Is.	40	30	+	3.37
21	Tanginak Is.	105	60	+	19.93
21	Billings Head[1]	1,097	1,103	-	12.46
22	Ogchul Is.	1,235	2,441	-	98.65[5]
22	Adugak Is.	975	1,400	-	23.26
23	Bishop Pt.[2]	100	136	-	1.26
23	Bogoslof Is.	350	490	-	6.34
24	Amak Is.	825	905	-	1.80
24	Sea Lion Rock	1,860	1,836	+	26.30
25	Billings Head[1]	1,025	913	+	35.35
25	Rootok Is.	100	66	+	13.05
25	Cape Morgan[3]	2,317	2,437	-	13.34
25	Reef Bight[3]	63	58	+	1.71
25	Lava Bight[3]	195	208	-	0.85
		N = 13,329	16,605		Σx^2 = 361.07
		t = 1.83			$x^2_{.001(14)} \geq 32$
		$t_{105(14)}$ = 2.15			

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[1] Akun Is.

[2] Unalaska Is.

[3] Akutan Is.

[4] A+B x^2 within cells pooled.

[5] removing this estimate and recalculating does not change t or x^2 test results.

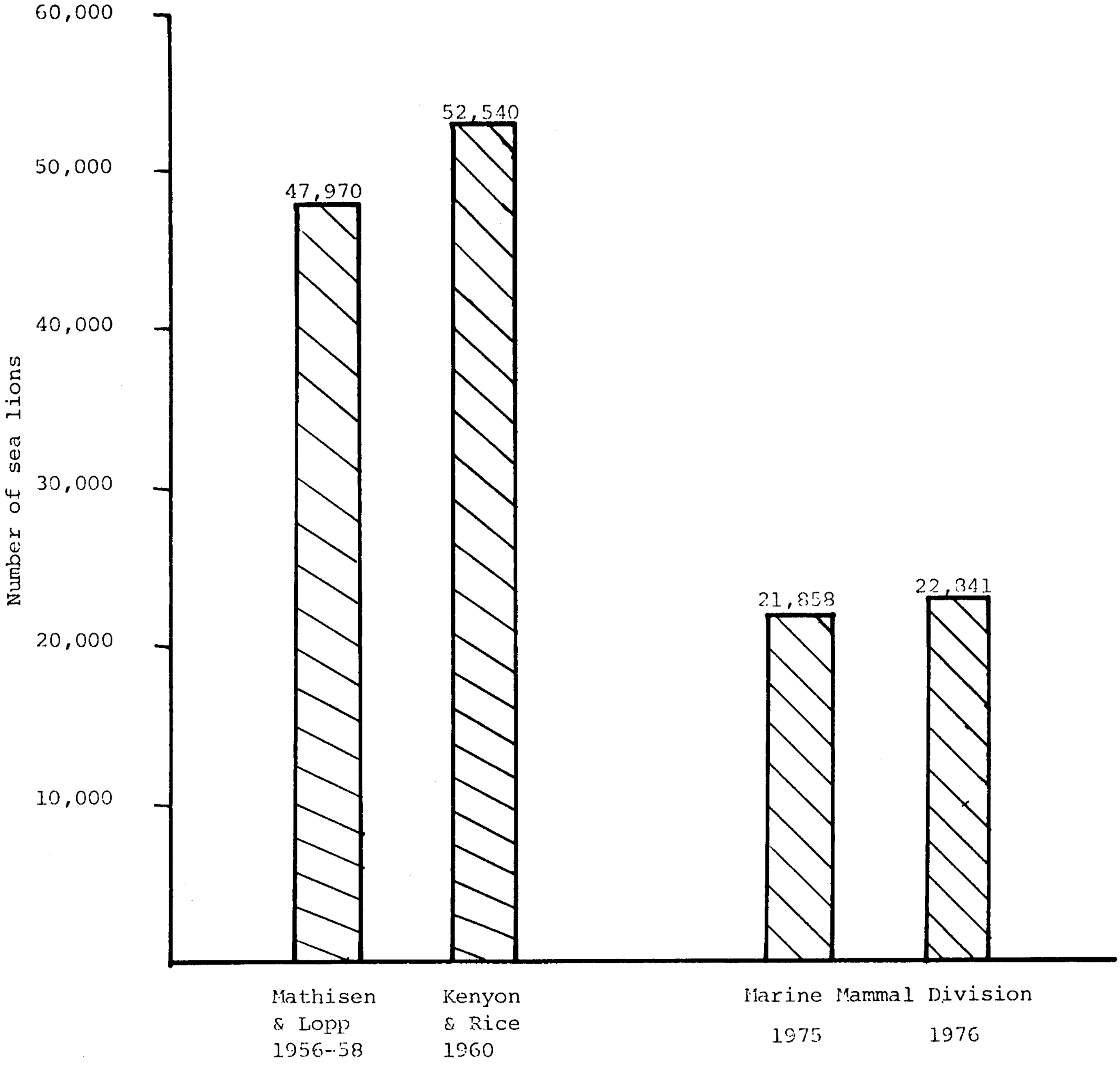

Figure 36. Comparison between the numbers of northern sea lions, Eumetopias jubatus, seen in the late 1950's-early 1960's, and during RU 67 OCSEAP studies along the eastern Aleutian Islands in Alaska. See Kenyon and Rice (1962) and Mathisen and Lopp (1963) for details of survey location.

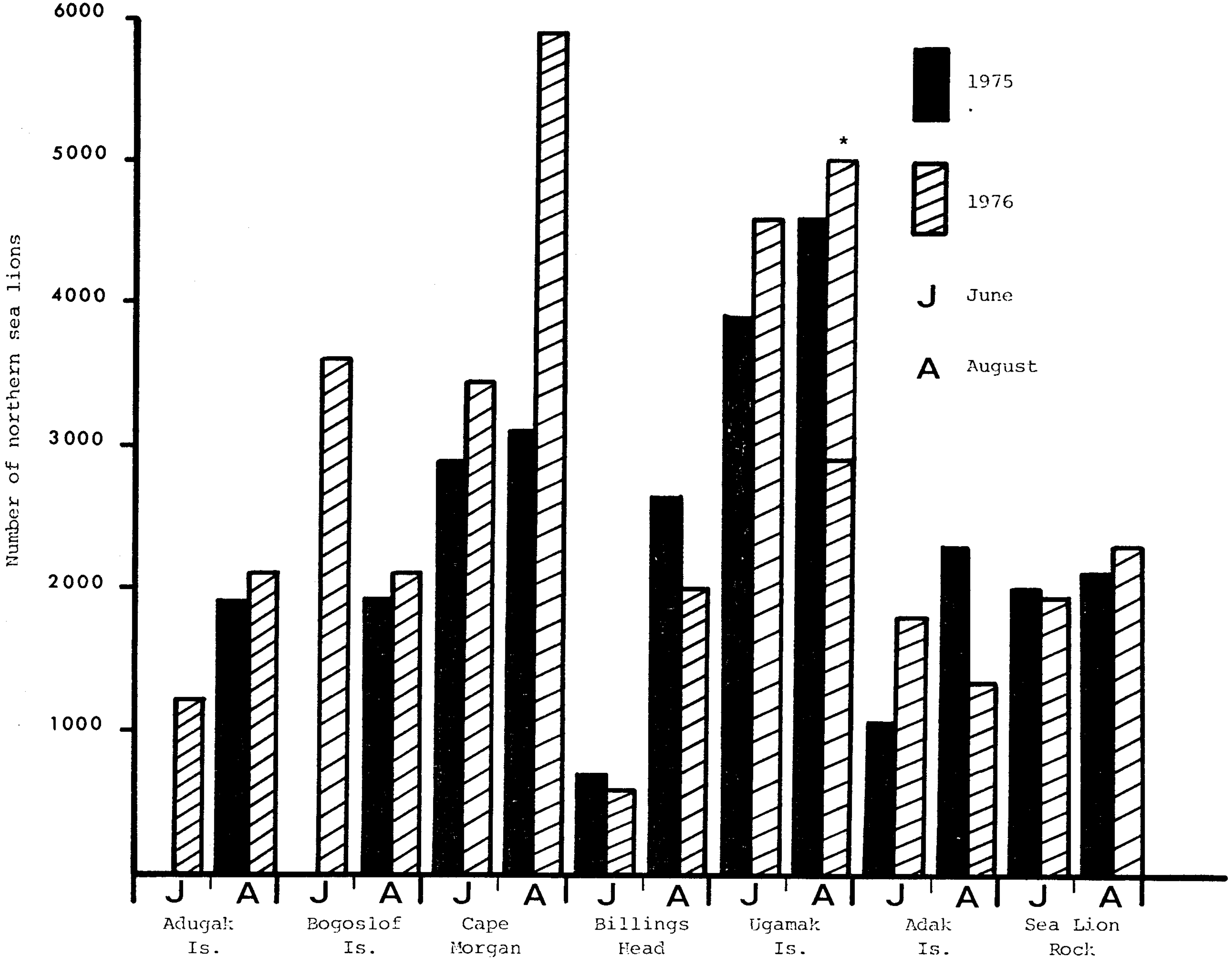

Figure 37. Northern sea lion population estimates from photographs taken of hauling grounds/rookeries of the eastern Aleutian Islands and Alaska Peninsula for June and August of 1975 and 1976. (*Data incomplete; estimate considered extremely reliable.)

important as hauling grounds than as breeding rookeries. Sea lion numbers on Ugamak Island, Amak Island and Sea Lion Rock appear to be similar during both June and August.

Data summarized in Figures 38 and 39 were done to answer two questions: 1) what are the relative differences in the numbers of animals between locations as a function of time (a spatial question) and 2) what effect does month have on the number of animals at any one location (a temporal question). In 1), the highest monthly estimate is used to determine the relative percent of the population for a month at each location. In 2), the highest estimate by location is used to predict relative percent between months.

When these seven hauling ground/rookeries are compared, on a percent basis, to the maximum population estimate for the eastern Aleutian Islands in 1976 (about 23,000 animals), the overall contribution of each location to the total population becomes more clear (Figure 40). The largest percentage of the population of northern sea lions for all months survey (June, August and October) can be found at Ugamak Island and Cape Morgan (Akutan Island). Cape Morgan and Ugamak Island also accounted for the major concentrations during the non-breeding month of August (Figures 38 and 39). The decrease in numbers on Bogoslof Island in August are matched by an increase in numbers at Billings Head. We are not suggesting, however, that the same animals are moving to Billings Head from Bogoslof Island. It must be pointed out that haulout areas also exist next to areas we have designated as rookeries. The extent of haulout behavior and group composition of non-breeding and breeding animals has not been characterized for these areas.

The numbers of sea lions observed during the October 1976 survey of the eastern Aleutian Islands are summarized in Table 8. Although northern sea lions were not as abundant during October as in either June or August 1976, we have established that the islands represent important haulout areas for the species during the fall months. Comparing similarly sampled islands for all three months (n = 10), we found that 68% (N = 17,876) and 63% (N = 19,424) of the numbers of animals seen in June and August respectively were present in October (N = 12,234). Comparing just August (N = 20,862) and October (N = 14,883) for twelve (n = 12) surveyed islands, only 29% fewer animals were counted. These results indicate that more sea lions remain on these islands during the fall than was expected.

Shipboard counts of pinnipeds from the Surveyor during October 1976 were: 134 *E. jubatus*; 25 *P. vitulina*; 18 *C. ursinus*; and 3 unidentified. Besides the total of 16,605 sea lions counted from the helicopter, 1,217 harbor seals and 146 sea otters (*Enhydra lutris*) were observed. See the 1 September - 31 December 1976 quarterly report for more details of the October survey (e.g., counts of dead animals, tissue samples collected, etc.)

Harbor Seals

Harbor seals are present throughout the survey area, though the majority of animals (80%) were observed in a few major hauling areas along the north side of the Alaska Peninsula (Table 9). Harbor seal distribution in the survey area is illustrated in Figures 41-43. The most important hauling

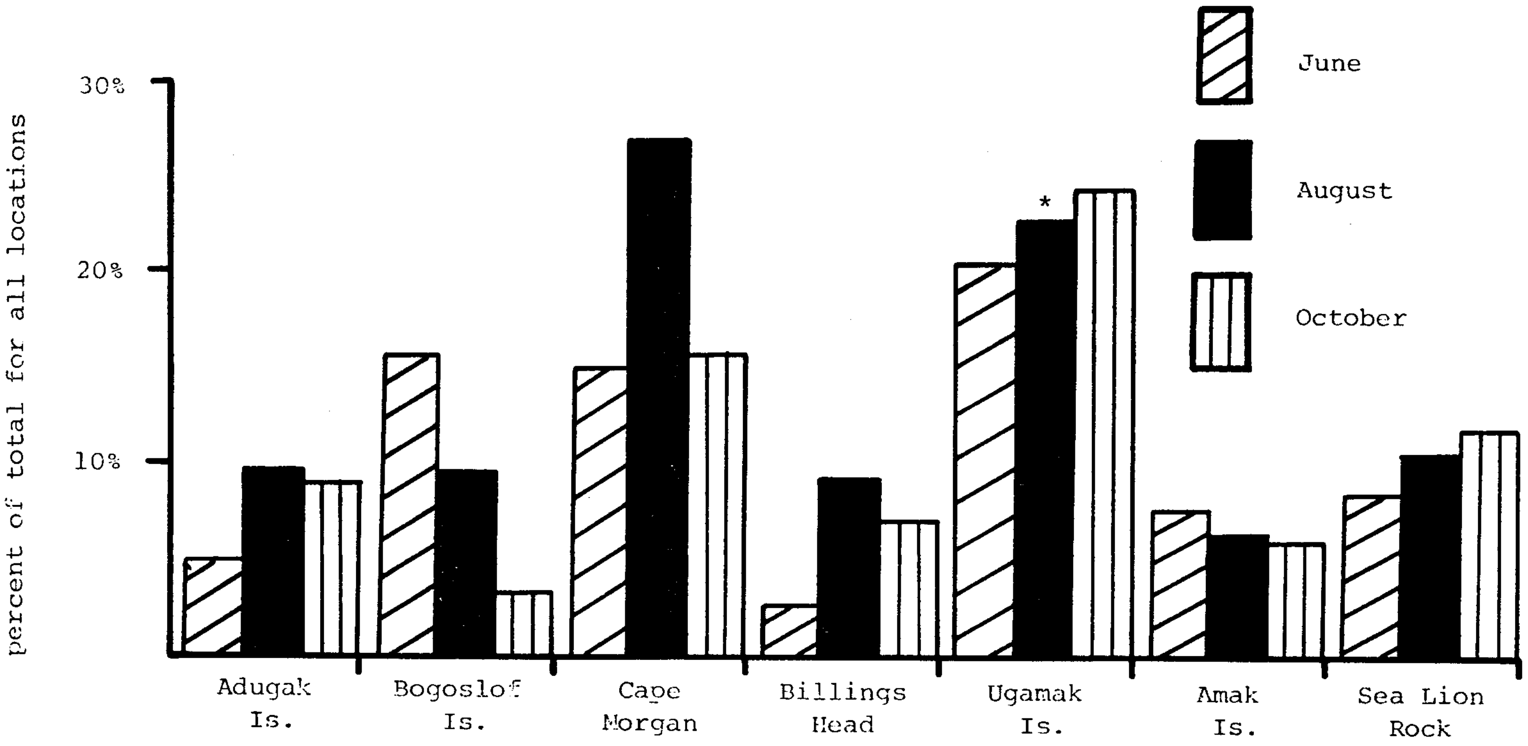

Figure 38. Relative percentage of the total 1976 northern sea lion population comparing locations by separate months. For example, Ugamak Is. had the largest percent of the population in June (20%) and October (23%), and Cape Morgan in August (27%). (*Data incomplete, estimate considered extremely reliable.)

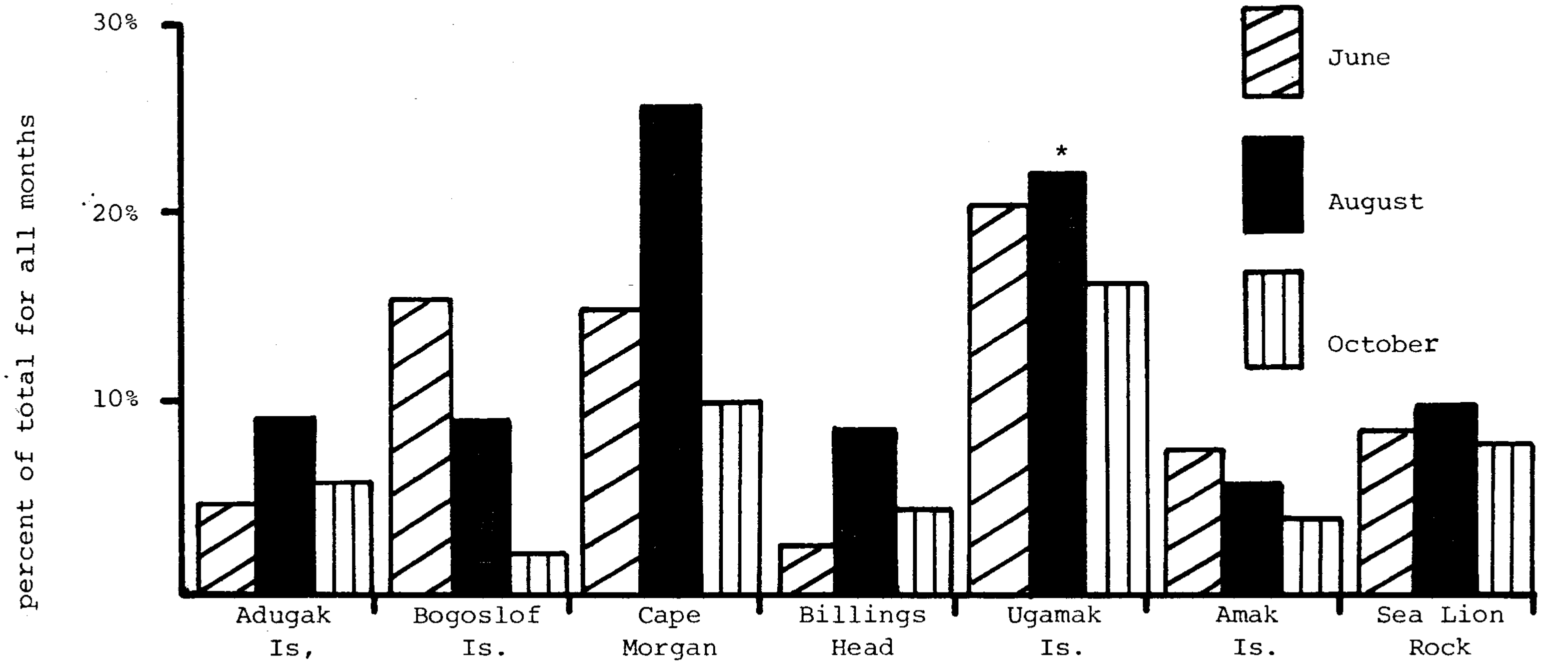

Figure 39. Relative percentage of the total 1976 northern sea lion population comparing the three months at each location separately. For example, the largest percentage of the animals found at Adugak Is. was in August (9%), then October (5%), then June (4%). (*Data incomplete, estimate considered extremely reliable.)

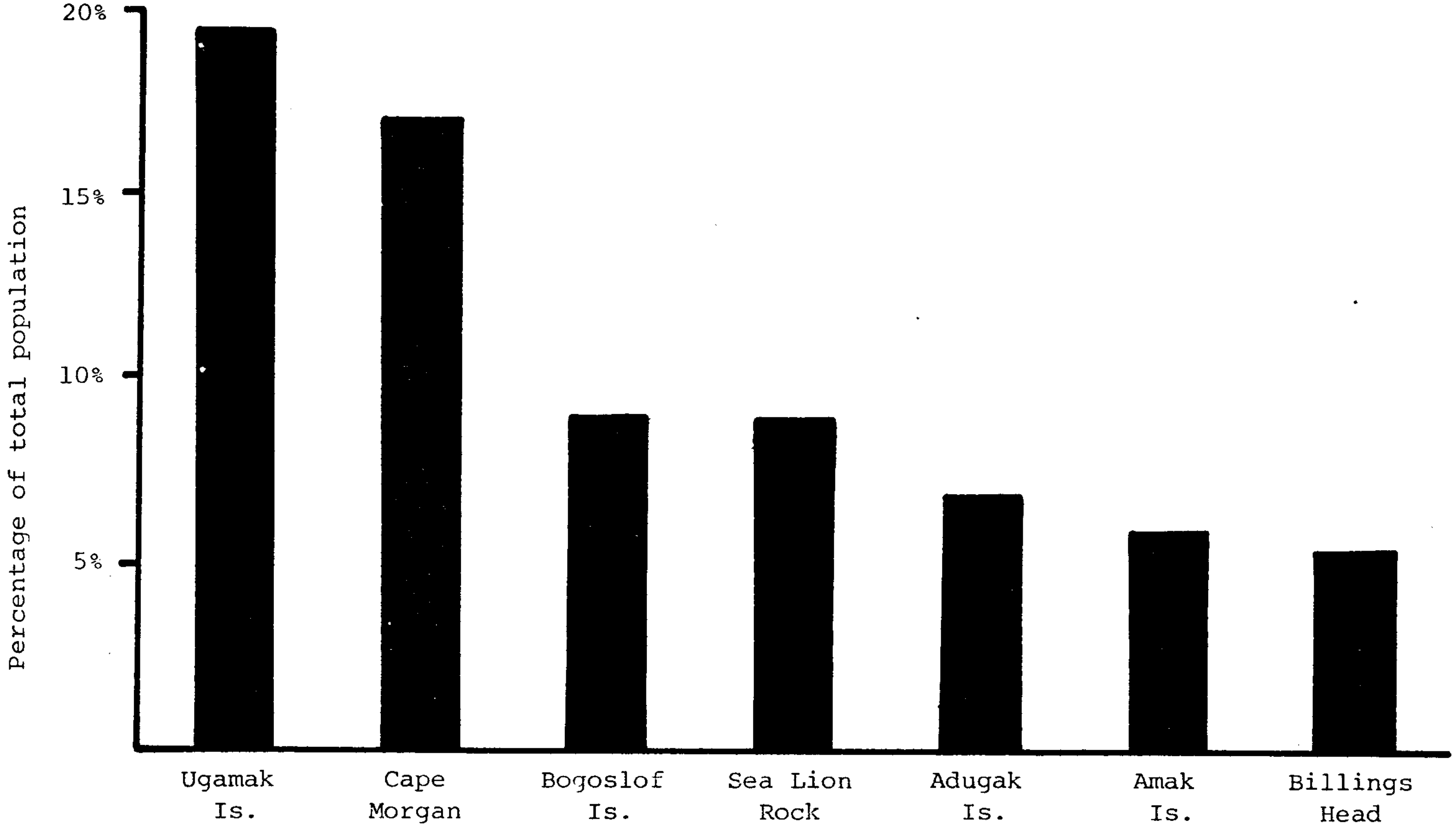

Figure 40. Percent of the total eastern Aleutian Island-Alaska Peninsula northern sea lion population seen at seven hauling ground/ rookeries during three aerial surveys in 1976. The number of animals counted at the above locations represented 75% of the total population count in June, 90% in August, and 52% in October.

Table 9. Observations of harbor seals (Phoca vitulina richardsi) from aerial surveys at major hauling areas along the Alaska Peninsula. Numbers are based on visual estimates or on counts taken from photographs (*). Dashed spaces indicate areas not surveyed; blank spaces mean no animals were observed.

General Location	Map Reference Number	Survey Date								
		June 1975		August 1975[3]		June 1976			August 1976[4]	
		18	20	11	13	15	18	20	19	21
Eggegik R.	1		50*					70		
Ugashik Bay	2	150	196*		2		65*	163*	438*	-
Cinder R.	3	925*	2,867*	3	113*	3,062*	800	4,503*	966*	-
Port Heiden	4	4,774*	5,273*	2,605*	3,453*	4,776*	2,486*	10,548*	4,770*	-
Seal Is.	5	1,137*	155*		75	246*	30	786*	241*	35*
Port Moller[1]	6	4,563*	6,078*	885*	1,053*	5,177*	671*	7,968*	1,088*	1,701*
Izembeck Lagoon[2]	7	-	2,034*			-	2	548*	-	1,204*
Izonotski Is.	8	-	258*	-	414*	-	98*	-	-	171*

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[1] includes Nelson Lagoon

[2] includes Moffet Pt.

[3] surveyed during high tide

[4] heavy fog north side of Alaska Peninsula

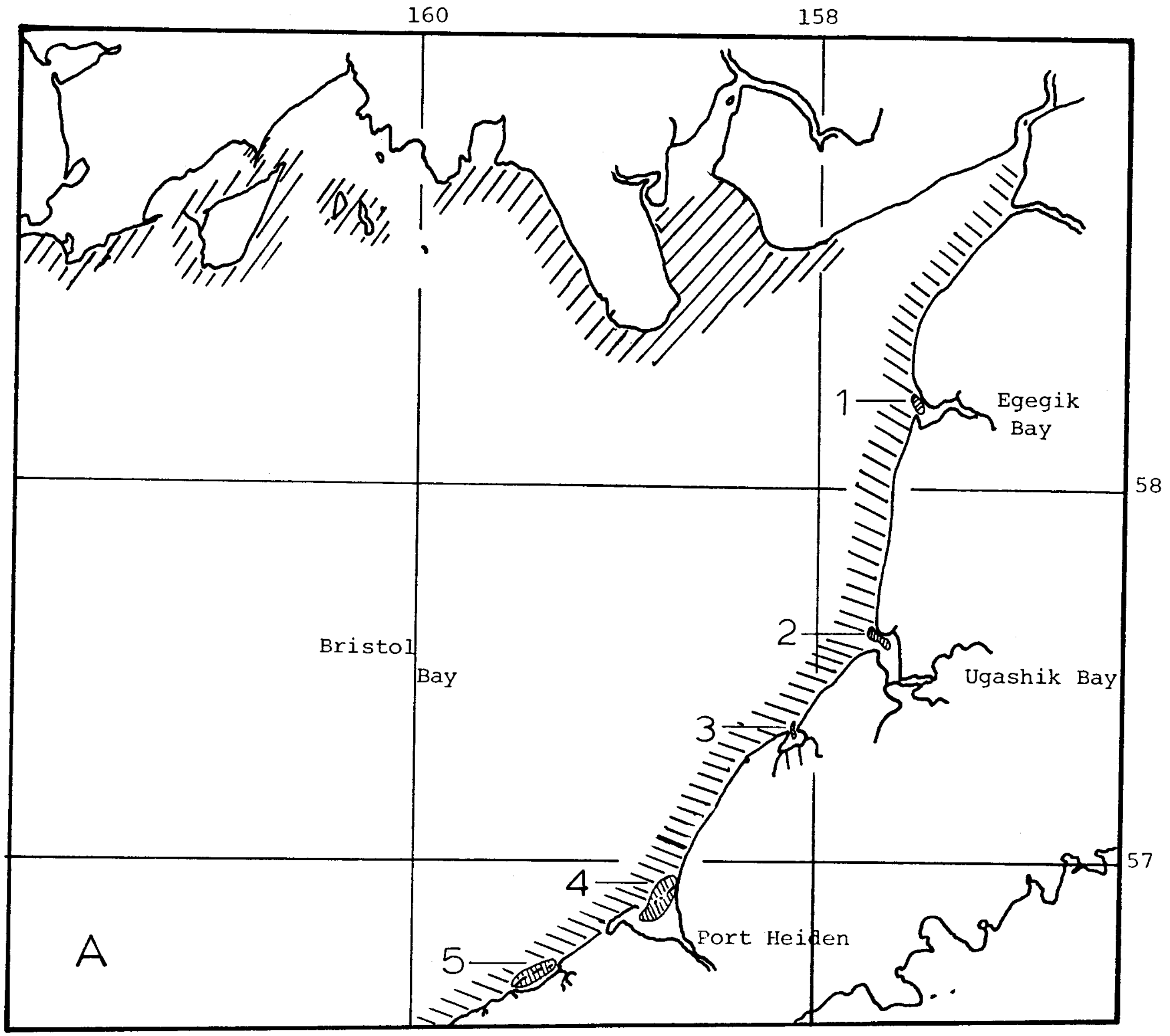

Figure 41. Major hauling areas and breeding grounds for *Phoca vitulina* along the north coast of the Alaska Peninsula: 1 - Egegik Bay; 2 - Ugashik Bay; 3 - Cinder River; 4 - Port Heiden; 5 - Seal Islands. Hatched coastal areas are where animals have been observed during June and August aerial surveys in 1975 and 1976. See Figure for key to adjacent areas.

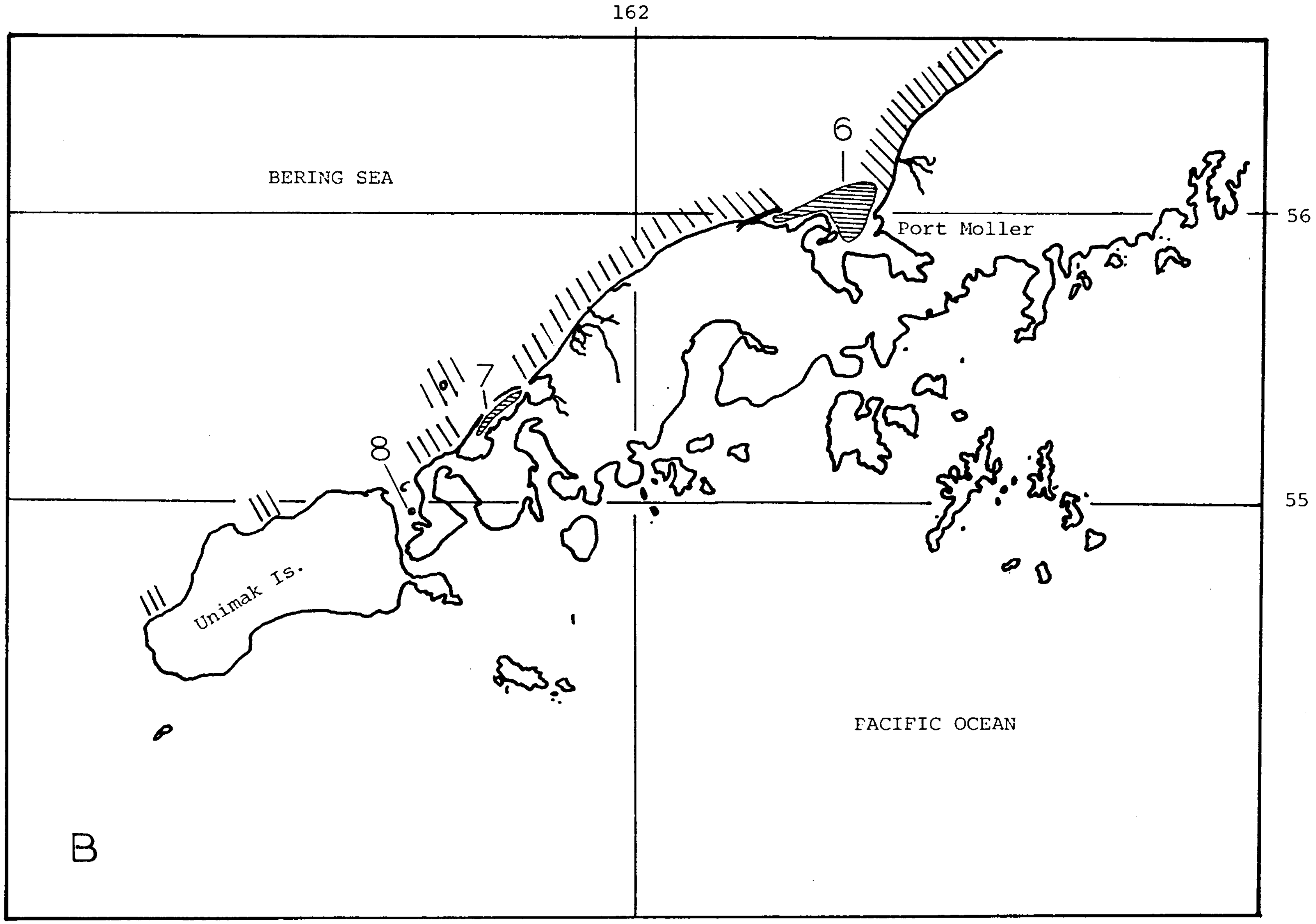

Figure 42. Major hauling areas and breeding grounds for <u>Phoca vitulina</u> along the north coast of the Alaska Peninsula: 6 - Port Moller; 7 - Izembek Lagoon; 8 - Bechevin Bay.

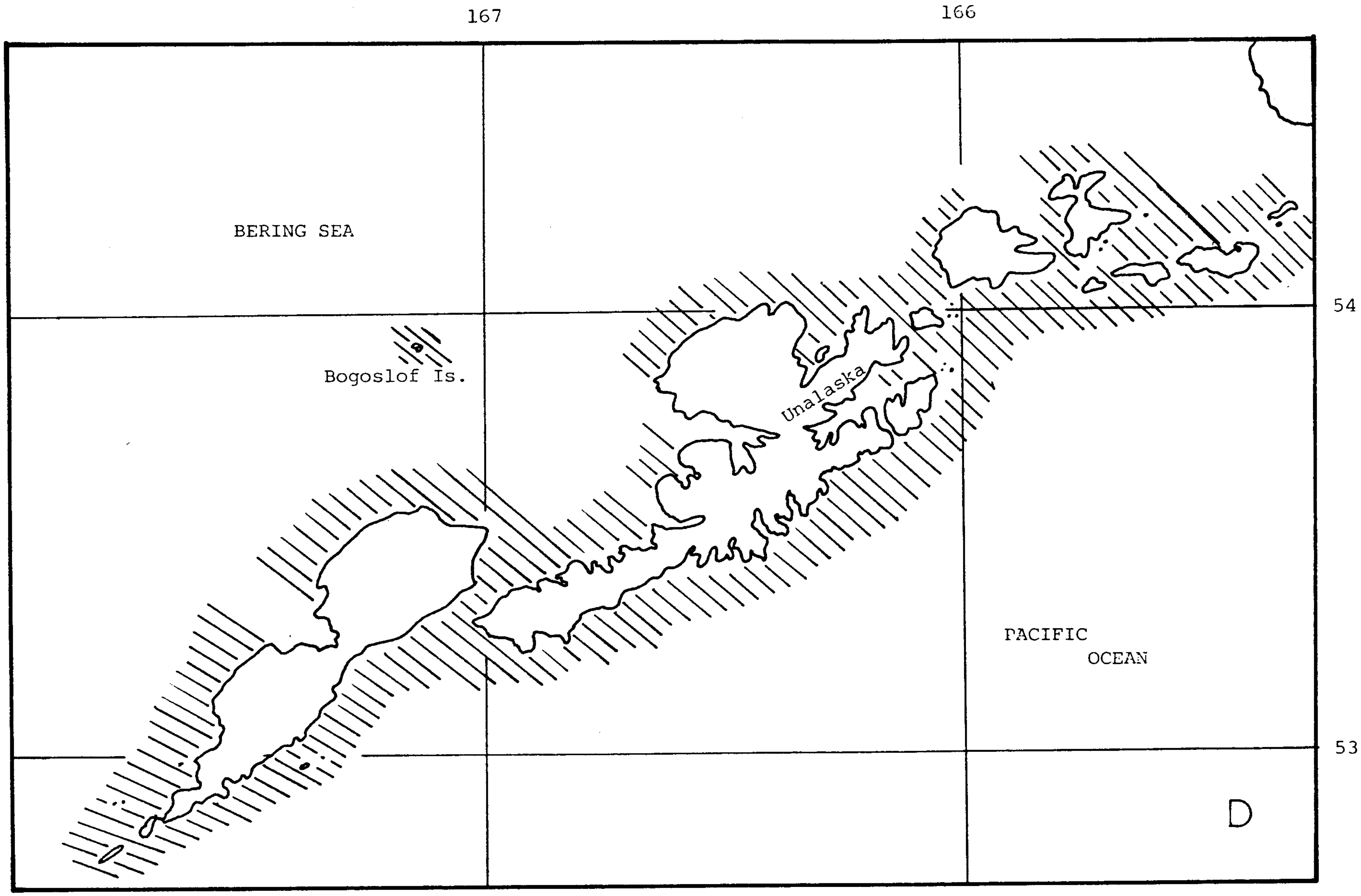

Figure 43. Hauling and breeding areas for <u>Phoca vitulina</u> on the eastern Aleutian Islands (Fox Islands group).

areas in terms of numbers of animals were Cinder River (#3), Port Heiden and Port Moller (Table 9, Figures 41 and 42). Coastal areas not surveyed are depicted in Figure 43 as having no seals present, and include Inanudak Bay, Kashega Bay, Skan Bay, Makushin Bay, and Beaver Inlet (not labelled in figure). Togiak Bay and the north end of Nugashik Bay (Bristol Bay area) were not surveyed (Figure 41); however, harbor seals have been recorded in all of these areas in the past (Alaska Dept. Fish and Game, 1973).

Harbor seals are difficult to see and thus count when they are in the water. The majority of our estimates are from animals hauled out. Haulout areas are typically offshore rocks and rocky beaches in isolated areas of the eastern Aleutian Islands. Sandbars in bays exposed at low tide are especially favored by P. vitulina along the north side of the Alaska Peninsula. Seals were also observed in the water along the Peninsula and occasionally a small pod would be observed on a beach (e.g., Cape Krenitzen, 20 June 1975, 110 animals) or by a river mouth (e.g., Bear River, 11 August 1975, 53 animals).

Ideally, surveys for harbor seals are conducted during favorable weather conditions (to optimize visibility) and during low tides when sandbars are exposed, creating hauling areas. Practically, however, budgetary and time restrictions prevented some surveys from being conducted during optimum periods.

The importance of tidal influence on hauling behavior is evident from differences in numbers of animals observed at the major hauling areas. On 20 June 1975, 16,911 animals were observed at the major areas versus 4,696 on 13 August 1975. Tidal differences were great: 3-4 feet rising, range 10-12 feet on 20 June 1975, and 10-11 feet rising, range 10-12 feet on 13 August 1975. This disparity was observed again in June and August 1976 (24,586 animals on 20 June versus 4,452 on 18 June and 7,503 on 19 August). The tides averaged much lower on 20 June (3-4 feet rising, range 9-10 feet) than 18 June (7-8 feet falling, range 9-10 feet) and 19 August (8-10 feet rising, range 10-11 feet). Figure 44 dramatically illustrates these differences.

It is obvious that the high tides, which covered sandbars and reduced the haulout area, account for the lower number of animals observed. The observation of fewer animals (N) and fewer sightings (n) in both June and August 1976 at plus tides support this (Figure 44). However, since no minus tide surveys were made, movement of animals at the end of the breeding season and seasonal distribution ranges (Calkins, et al., 1975) cannot be discounted as explanations for disparities in numbers of seals observed. Since harbor seals molt from late July to late September (Bishop, 1967) one might expect to see more animals hauled out during August than June. We will attempt to arrange a minus tide survey for August 1977 to examine this.

Movements of harbor seals are poorly understood. In April 1976 we surveyed the Port Heiden-Port Moller area. This was a heavy ice year, and both bays were frozen over; consequently no animals were observed. In less severe years animals have been observed to haul out in these areas during the late winter and early spring (Mathisen and Lopp, 1963), though in numbers greatly reduced from those of June and August. Burns (pers. comm.) has collected

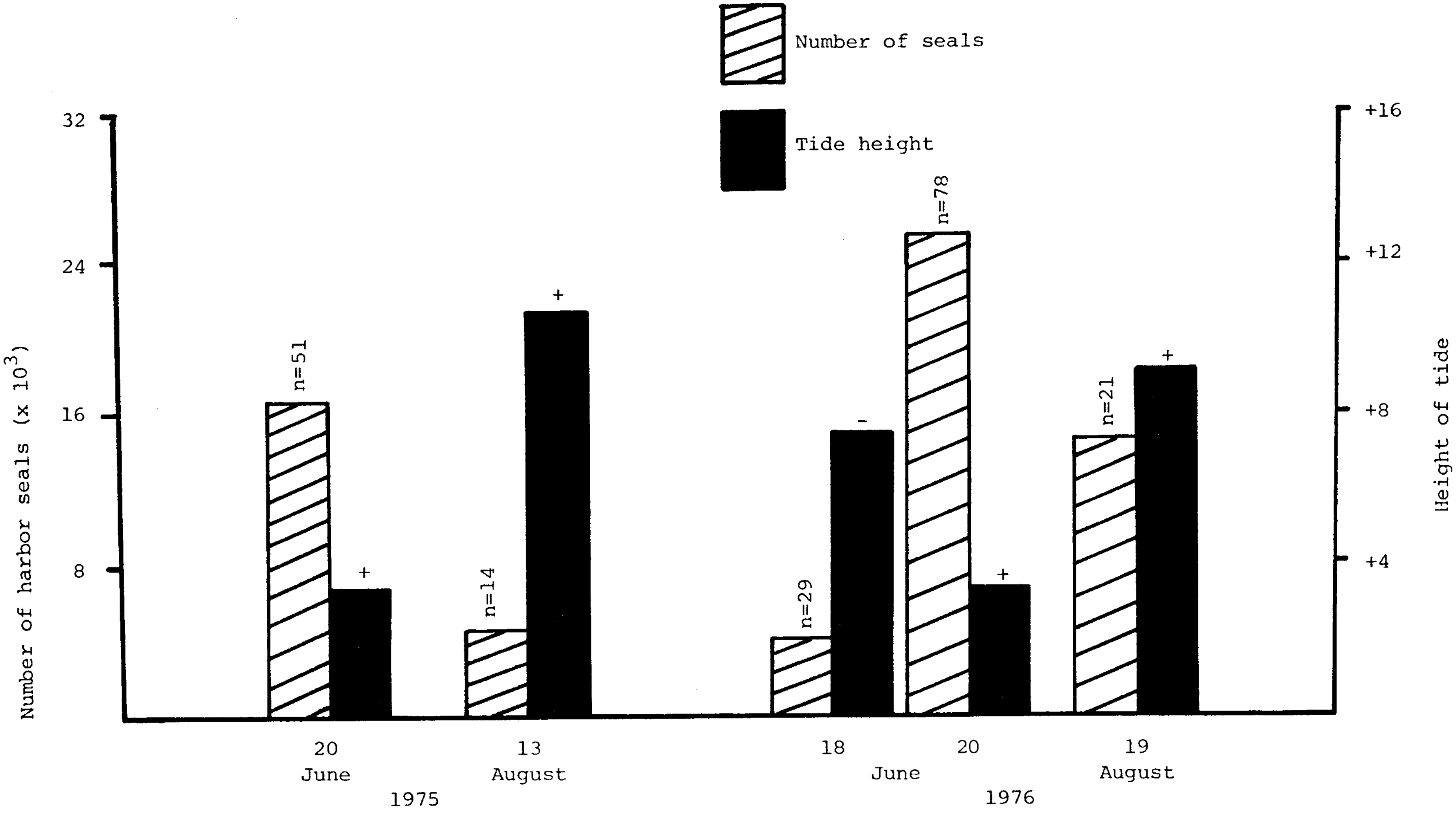

Figure 44. Numbers of harbor seals (Phoca vitulina) hauled out along the north coast of the Alaska Peninsula with respect to tidal conditions. n = the number of sightings, and ± whether the tide was rising or falling. Tide height was averaged for each survey day.

a few land-breeding Phoca vitulina from the ice edge in March and April 1976. Apparently some animals disperse to the pack ice in winter. This might be especially true if the pack ice extended far into the southern Bering Sea as it did in 1976. What proportion of the population doing this is inknown, and whether this is a yearly behavior or something that occurs only when landfast ice is extensive is as yet unclear. It is also possible that an unknown proportion of the population shifts to the ice-free Aleutian Islands in winter. A survey of these areas would be useful.

Surveys for harbor seals on the north coast of Bristol Bay did not reveal any major hauling areas, although pods were observed on Hagemeister Island (20-200 animals) during the June and August 1975 surveys. Small groups (1-5) were observed in the water throughout the coastal area.

Harbor seals were present throughout the eastern Aleutian Islands. Heavy concentrations were regularly observed on the Baby Islands and rocks off the northwest end of Tigalda Island. In all other areas, animals were observed in small groups hauled out on rocks and beaches. Tidal influence is important in this area too, as many of the offshore rocks used by seals are awash at high tide.

The survey in June 1976 gave us our largest count of harbor seals, throughout the study area. The total number of animals observed during this survey was 25,802. Heavy fog on the south side of Umnak and Unalaska Islands prevented a survey there. A total of 912 animals were observed in the Aleutian Islands during this survey. Obviously many more would have been counted had weather permitted.

In August 1976, favorable weather (plus lower tides) allowed for a total survey of the eastern Aleutian Islands; 4,023 harbor seals were observed. Using this total with the June figures for the north side of the Peninsula and Bristol Bay, an estimate of at least 28,000-30,000 animals were present in the study area.

Pups were observed in all areas surveyed. Since pups are considerably smaller and darker than adults and thus easily missed, few observations were made and no reliable estimate can be made at this time from our data. Assuming that 32% of the female population was parturient (Bishop, 1967), we expect at least 8,900-9,600 pups were produced in 1976.

Cetaceans

Data on cetacean distribution and relative agundance throughout Alaska come primarily from NOAA ships chartered under OCSEAP, and from those ships participating in the Platform of Opportunity Program. Sighting records came from observers onboard vessels from 1958 to the present.

The number of whales and porpoises sighted during the 1976 field season (other than bowhead and beluga whales) are summarized chronologically in Table 10. Cruise periods from which data were collected are listed in Table 2. Most large cetaceans appeared in the Bering Sea from May to October, with the peak abundance occurring in June (Figure 45). The total number of species by sector and total number of sightings for all cetaceans

Table 10. Sighting records of cetaceans during vessel and aerial surveys in the study area in 1976.

Survey Dates	General Location	Species[1/]	Number of Animals	Type of Survey[2/]
2 April	off S. Unimak Is.	BA	1	V
9 "	Unimak Pass	OO	10	V
13 "	E. Aleutian Is.	OO	3	V
16 "	20 mi. S. of St. George	BA	1	V
21 "	central Aleutian Is.	PP	5	V
24 "	S.W. Bristol Bay	BA	2	V
25 "	S.W. Bristol Bay	BA	1	V
26 "	S.W. Bristol Bay	BA	1	V
26 "	100 mi. W. of St. Paul Is.	BA	1	V
27 "	100 mi. W. of St. Paul Is.	BA	4	V
27 "	E. Aleutian Is.	OO	3	V
30 "	off St. Paul Is.	OO	1	V
April	S. central Bering Sea	PD	51	V
11 May	W. St. Paul Is.	PP	5	V
25 "	N. of Unimak Is.	ZC	1	V
27 "	N. of Pribilof Is.	OO	3	V
May	central Aleutian Is.	PD	10	V
May	S. of Pribilof Is.	PD	23	V
7 June	off tip of Alaska Peninsula	BA	1	V
12 "	N. of Unalaska Is.	BA	3	V
12 "	240 mi. E. of Pribilof Is.	BP	4	V
13 "	S. E. Bering Sea	BB	1	V
13 "	240 mi. E. of Pribilof Is.	BP	2	V
18 "	E. Aleutian Is.	PP	5	V
18 "	N. of Unalaska Is.	BA	1	V
20 "	N. of Unalaska Is.	BA	1	V
30 "	central Bristol Bay	PP	2	V
30 "	western Bristol Bay	BA	1	V
June	E. Aleutian Is.	PD	2	V
22 July	60 mi. S. of St. George	BA	1	V
July	S. E. Bering Sea	PD	3	V

Table 10. cont.

Survey Dates	General Location	Species[1/]	Number of Animals	Type of Survey[2/]
18 August	Unimak Pass	BA	7	A
19 "	Unimak Pass	BA	8	A
20 "	Unimak Pass	OO	13	A
21 "	Unimak Pass	BA	2	A
24 "	N. of St. Lawrence Is.	MN	10	A
24 "	N. of St. Lawrence Is.	OO	3	A
25 "	W. Bering Strait	MN	4	A
21 October	Unimak Pass	BA	1	V
October	Unimak Pass	PD	5	V

1/ BA - minke whale
BB - sei whale
PD - Dall porpoise
OO - killer whale
PP - harbor porpoise
BP - fin whale
ZC - goosebeaked whale
MN - humpback whale

2/ A - aerial
V - vessel

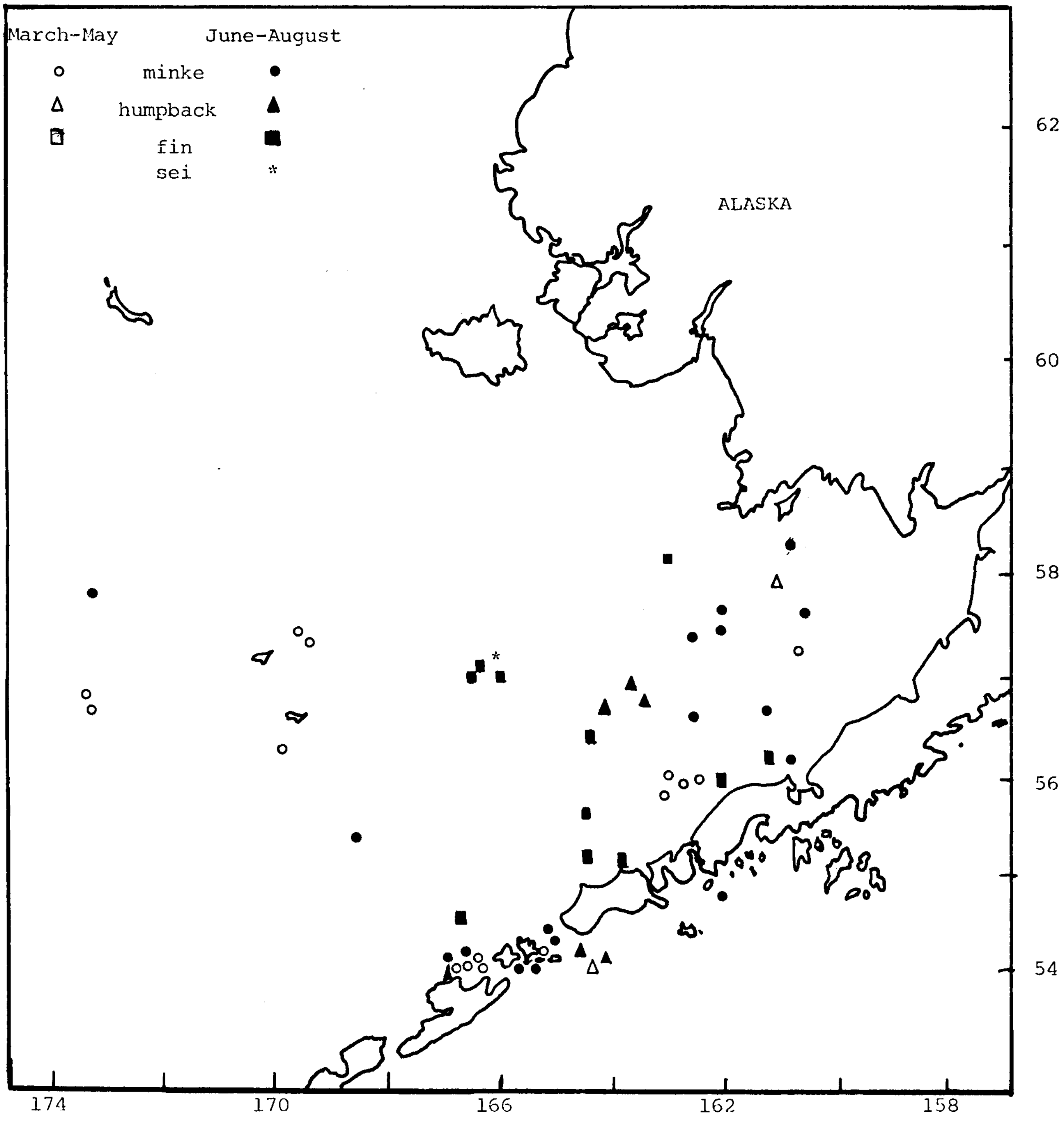

Figure 45. Seasonal sightings of large cetaceans in the S.E. Bering Sea from 1952 to 1976.

from vessel data are listed in Table 11. Again, the month with the greatest relative percent of all sightings was June. We have not been able to quantify sightings per unit effort, thus the interpretation of peak abundance in June is biased because more ships were in the Bering Sea during the summer than during other months. This interpretation is, however, consistent with the general movements of some whales reported by Nasu (1963, 1966) and Ivashin and Rovnin (1967).

The two most common species sighted in the southern Bering Sea were the Dall porpoise and the minke whale. A plot of Dall porpoise sightings is in Figure 46. North of 59° N. Lat., gray, humpback and sperm whales were the most frequently sighted. Harbor and Dall porpoise and minke and fin whales appear more frequently south of 61° N. Lat. (Figures 45 and 46). Killer whale sightings in the southern Bering Sea are plotted in Figure 47.

Some species are not commonly found in the Bering Sea. Since 1958, a few sightings have been made south of 61° N. Lat.: goosebeaked whale (1); pilot whale (3); false killer whale (1); Pacific white-sided dolphin (1); blue whale (1); and right whale (1). We can only speculate at this time as to the reliability of some of these sightings.

During our October 1976 cruise along the Fox Islands in the eastern Aleutian Islands, 45 cetaceans were observed: 30 Dall porpoises; 4 killer whales; 2 minke whales; 2 sei whales; 1 fin whale; 2 humpback whales; and 4 unidentified whales. High winds reduced sighting ability. The objective of this cruise was to ascertain if the gray whale migrates south through Unimak Pass in the fall; however, no gray whales were seen.

During surveys of the Bering Sea in 1976, gray whales were the most common cetacean sighted. A chronological summary of all reported 1976 sightings is reported in Table 12. The earliest known sightings of gray whales in the Bering Sea were recorded during 1976 on 10, 18 and 24 April by independent observers (Table 12). The 18 April sightings were made within a few kilometers of the north side of the Alaska Peninsula. It was along this same stretch of coast that many sightings were made in June during the sea lion-harbor seal survey. The consistency of the numbers of grays migrating along this part of the coast suggests that the species remains as close to shore as it does in California.

The literature would suggest a direct northerly migration across the Bering Sea to the west side of St. Lawrence Island (for a complete summary, see Rice and Wolman, 1971). If this were the case, one would expect more sightings near the Pribilof Islands than are known to exist (Gilmore, 1959; Fay, pers. comm.; our data). We believe that gray whales remain near the coast throughout their migration north, moving along the Alaska Peninsula, north coast of Bristol Bay, and then to the east end of St. Lawrence Island. Aerial surveys from 1976 support this hypothesis (Figure 48).

Several hundred gray whale sightings were made north, west and east of St. Lawrence Island in June 1976 (Table 12, Figure 49). The chief behavior observed was feeding. Although it has been well established that gray whales feed near St. Lawrence Island and in the northern Bering Sea and southern Chukchi Seas (Ichihara, 1958; Nasu, 1960; Wilke and Fiscus, 1961;

Table 11. Numbers of cetaceans and sightings in four geographic areas of the Bering and Chukchi Seas studied under RU 67. Maximum sightings have been converted to a percent value for the month with the greatest number of sightings. The most common species seen is also reported by sector. See text for a description of the sectors with respect to Figure 1.

Sector	Total Sighting	Total Species	Max. Sightings Percent-Month	Most Common Species Seen
1	629	12	49.3% June	Dall Porpoise Minke Whale
2	1029	12	24.2% June	Dall Porpoise Minke Whale
3	27	2	48.1% June	Dall Porpoise Killer Whale
4	115	5	84.3% June	Gray Whale Sperm Whale

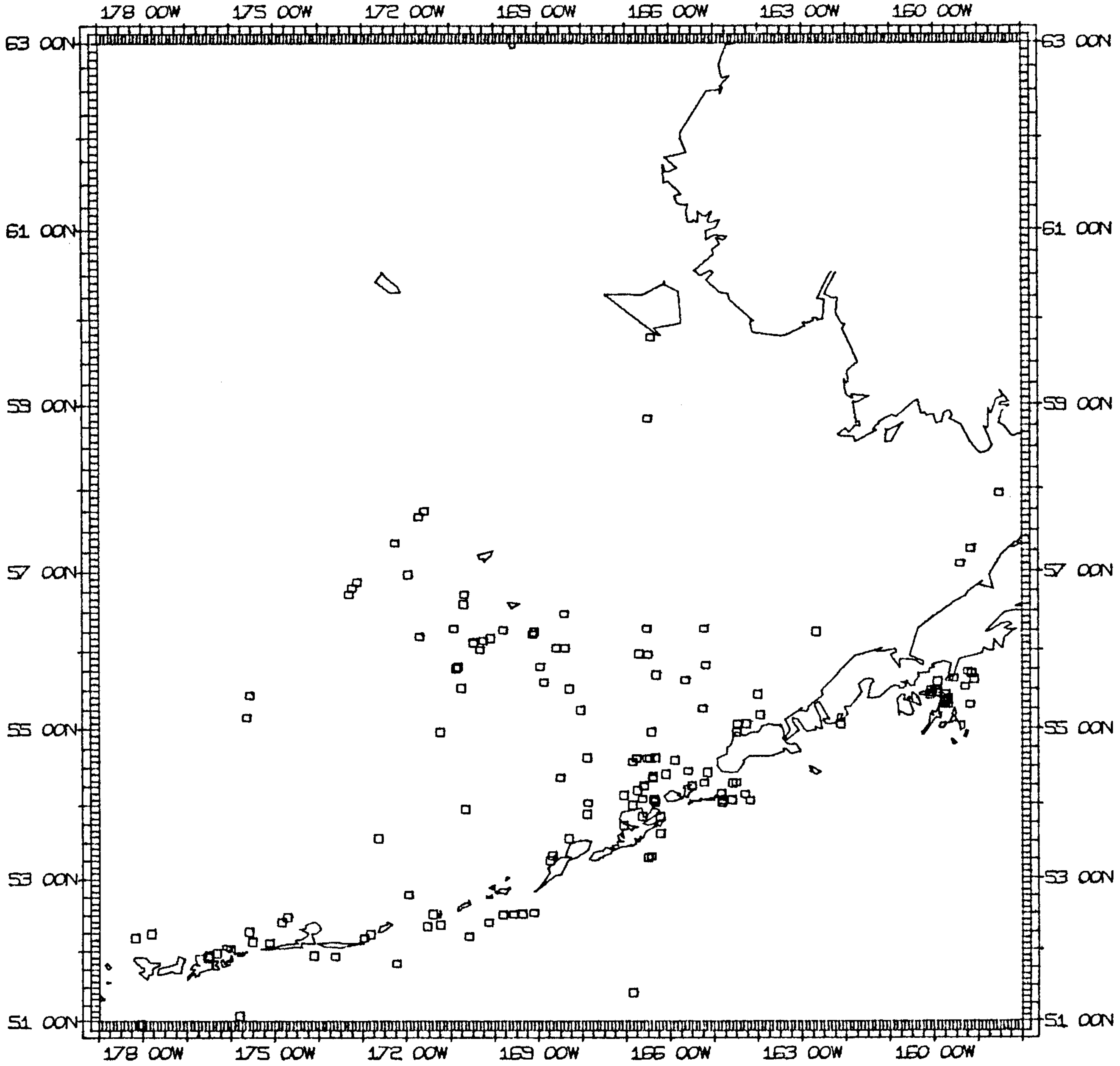

Figure 46. Dall porpoise (<u>Phocoenoides</u> <u>dallii</u>) sightings in the southern Bering Sea and North Pacific, collected since 1958. Most sightings occurred in the summer months.

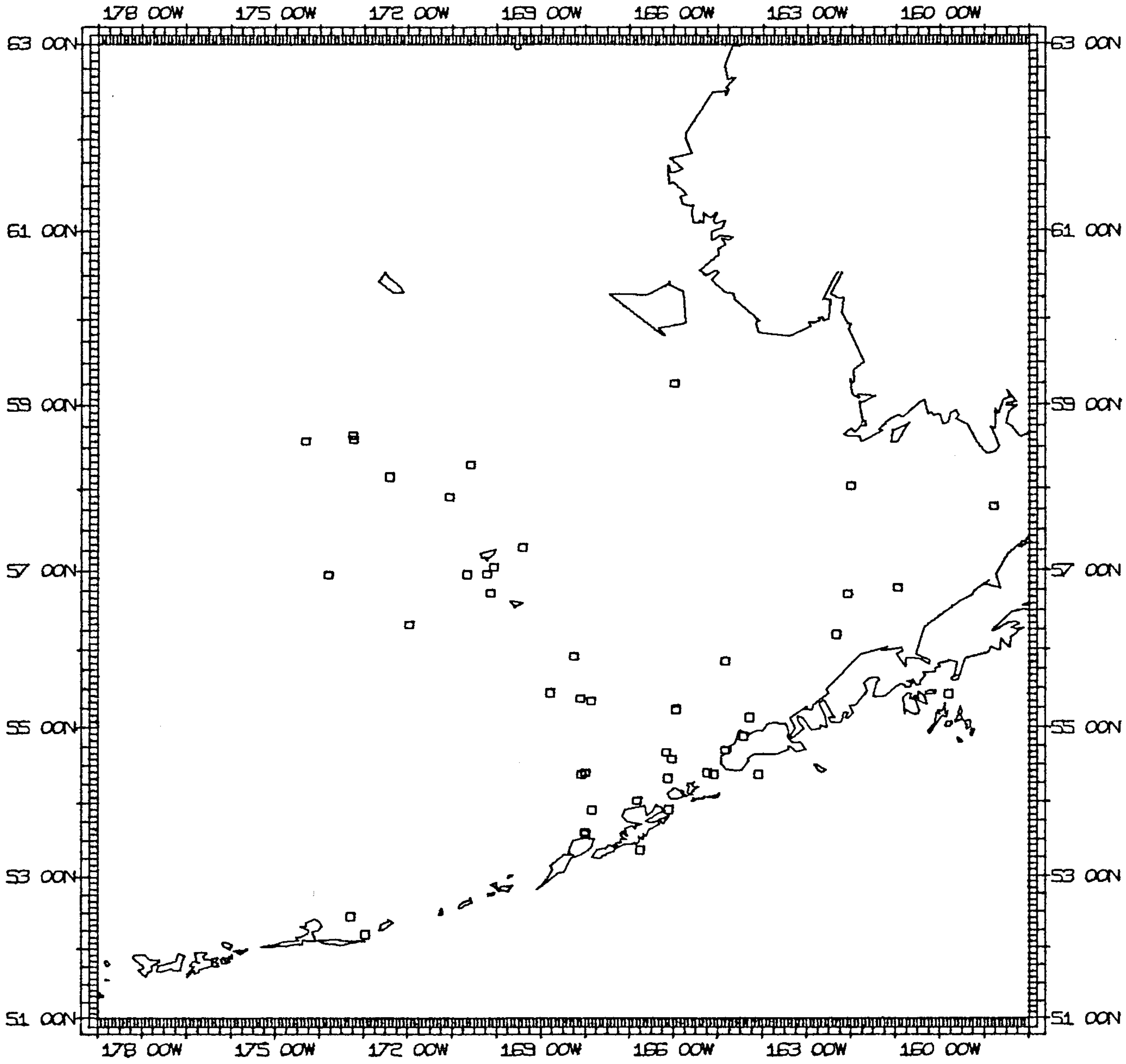

Figure 47. Killer whale (Orcinus orca) sightings in the southern Bering Sea from data collected since 1958. Most sightings occurred in the summer months.

Table 12. Sighting records of gray whales (Eschrichtius robustus) during vessel and aerial surveys in the study area in 1976. Numbers may include replicate sightings on succeeding days (e.g., 11 & 12 June: St. Lawrence Is.) or replicates on the same day (e.g., 15 June: 55 one way, 51 return trip).

Survey Dates	General Location	Number of Animals	Type of Survey 1/
10 April	E. of Pribilof Islands (ice edge)	1	FF
18 "	S. E. Bristol Bay, along coast	5	A
24 "	S. Bristol Bay	3	V
3 May	near Pribilof Islands (west side)	4	V
7 "	between St. Lawrence Is. & Cape Romanoff	2	F
12 "	just south of St. George	1	V
26 "	S. W. Bristol Bay	1	V
30 "	along Alaska Pen.; Pt. Heiden - Pt. Moller	35	FF
8 June	Unimak Pass	5	V
9 "	120 mi. S. of St. George	2	V
9 "	N. of St. Lawrence Is.	73	A
10 "	N. of St. Lawrence Is.	21	A
11 "	N. of St. Lawrence Is.	145	A
12 "	N. of St. Lawrence Is., and E. & W. coasts	281	A
12 "	W. side of St. Paul	3	V
14 "	20 mi. S. of St. George	1	V
15 "	King Salmon to Pt. Moller	106	A
18 "	Alaska Peninsula	54	A
20 "	Alaska Peninsula	76	A
19 August	off Pt. Moller	1	A
20 "	W. along coast of Pt. Barrow	1	A
21 "	N. mouth of Kotzebue Sound	4	A
23 "	mid-Chukchi Sea	6	A
24 "	30 mi. off N.E. coast of St. Lawrence Is.	8	A
25 "	just S. of Bering Strait	24	A
25 "	S. coast of St. Lawrence Is.	5	A
25 "	midway, St. Lawrence Is. & Seward Pen.	33	A
16 September	W. of Barrow, along coast	1	A

1/ F = G. Fedoseev, TINRO, Magaden, USSR
FF = F. Fay, Univ. Alaska, Fairbanks
A = OCSEAP aerial survey
V = OCSEAP vessel survey

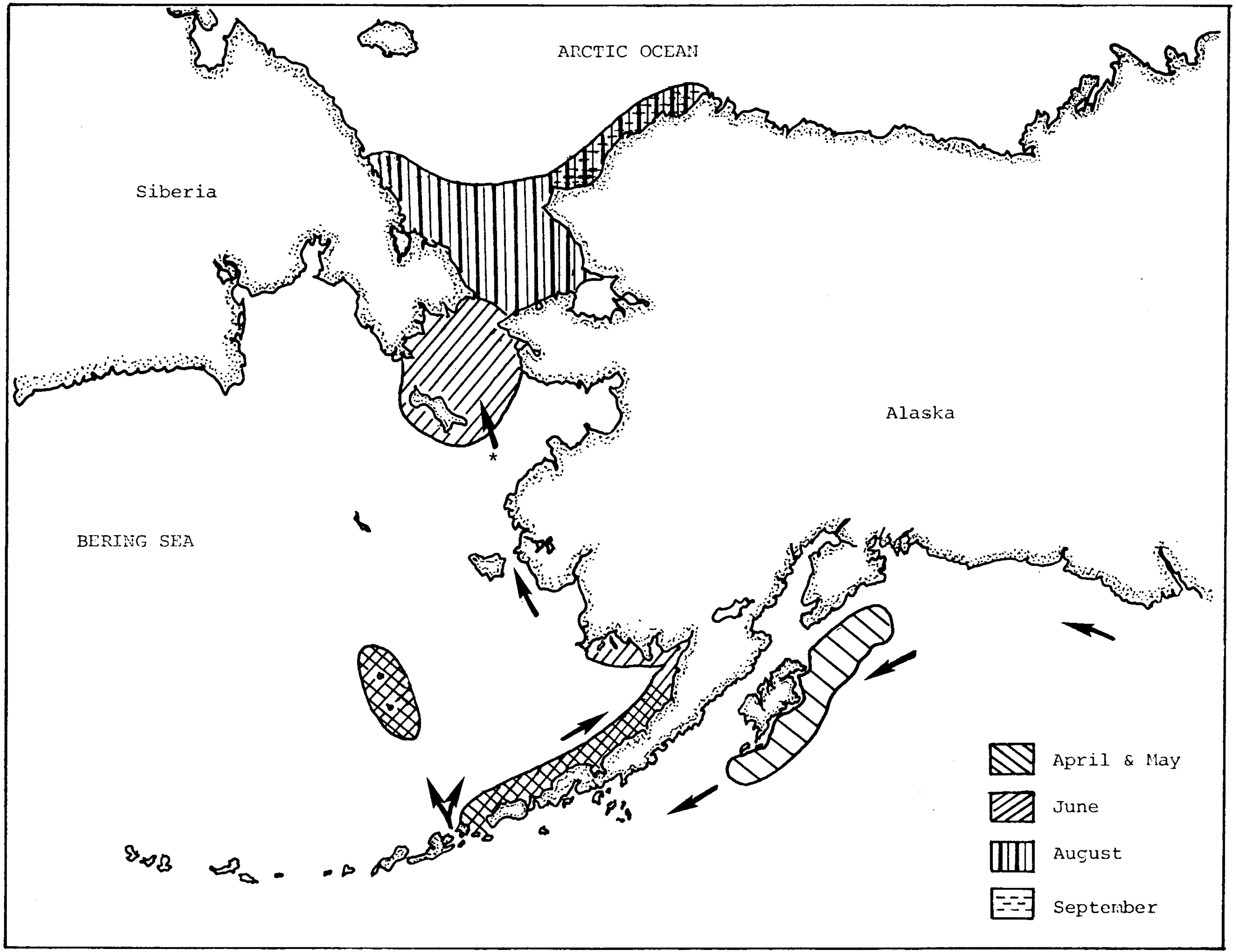

Figure 48. Monthly *Eschrichtius robustus* distribution projections based on RU 67 and RU 68 OCSEAP data and historical records. Arrows depict the projected migration route. The asterisk (*) depicts May 1976 sighting from G. Fedoseev (pers. comm.). See text for explanation of fall migration route.

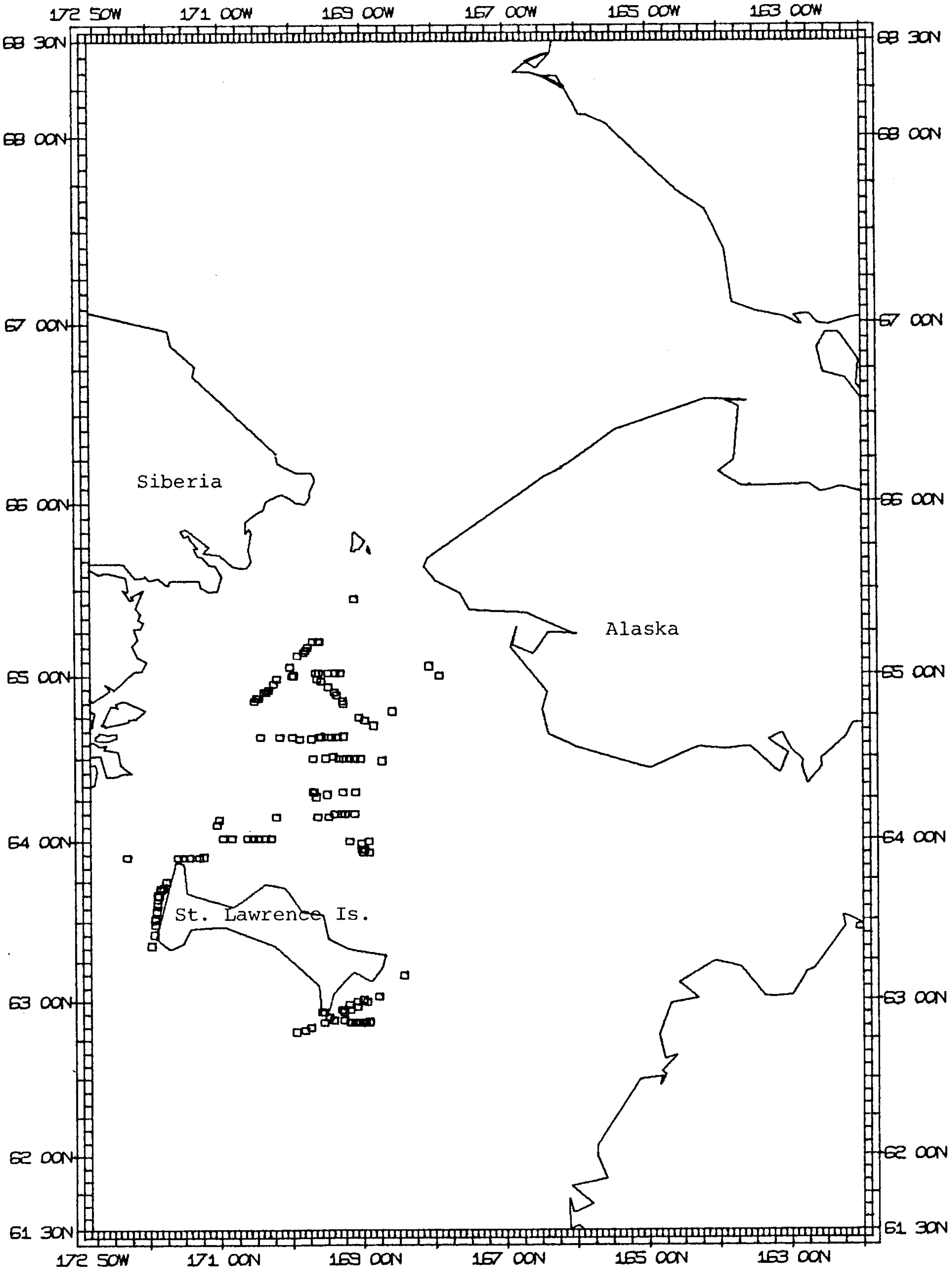

Figure 49. Gray whale (Eschrichtius robustus) sightings in the northern Bering Sea in June 1976.

Rice, 1965; Fedoseev, 1966; Shurunov, 1970), our sightings strongly suggest that the lagoons and near-shore coastal areas southeast and west of St. Lawrence Island are very important feeding grounds for this species.

VII. Conclusions and Recommendations

Through analysis of the sighting information from the literature, from unprocessed data in our files, and from our records in the field over the past two years, several important patterns are beginning to emerge. The most important of these is that, for the Bering and Chukchi Seas, we generally have good quantitative and qualitative information on pinnipeds, but for most cetaceans very little is known. This is especially true for the lesser known species, and for those not generally harvested in the North Pacific. The second most striking problem is that temporally and spatially the range of information about most species varies dramatically. For instance, in outer Bristol Bay, assuming a heavy ice year, a good amount of sighting information exists (more for pinnipeds than for cetaceans) during the spring and early summer, yet very little is known about marine mammals' distribution in the fall and winter. The reverse is generally true for the northern Bering Sea-Chukchi Sea, especially for cetaceans in the fall (some good information) and spring (very little information). It is also apparent that for certain times of the year, with respect to certain species, the various oil lease sites change in importance (Table 13). For example, if a heavy ice year occurs, breeding ice seals are likely to haul out on ice which has formed in the St. George and Bristol Bay oil lease basins. Unfortunately, many data gaps still exist.

To illustrate the discrepencies in the amount of information that is known (+) or not known (-) -- data that tell us if a species is or is not expected to occur in a particular oil lease area and/or if the animal exhibits any seasonal behavior -- a simple rank test of + versus - information can be made (from Table 13). By scoring the number of species for each oil lease area as to 1) animal not known to occur in area (+A) [blanks in Table 13], 2) animal may exhibit migration, feeding or breeding behavior but specific information is lacking (-B) [dashes and * in Table 13], and 3) some details of habitat use are known (+C) [W,Sp,Su,F in Table 13], a better fix on our state of knowledge can be gained.

	Number of Animals of 24 spp.		
	(+A)	(-B)	(+C)
Aleutian Shelf	7	11	6
St. George Basin	2	12	10
Bristol Bay	7	8	9
Norton Basin	3	12	9
Kotzebue Basin	2	13	9
Total (÷5)	4.2	11.2	8.6

Of the 24 species of marine mammals that are believed to occur in the Bering Sea, we have little or no reliable information on 11 (an average for all lease sites). Approximately nine species are reasonably well understood (i.e., natural history and distribution/abundance information has been quantified in at least a general way), and on the average, four species are absent from each lease area. Accordingly, we have information on about 50% of the species of marine mammals in the oil lease areas, which means

Table 13. Summary of proposed marine mammal habitat use by season in the Bering Sea and Chukchi Sea OCS oil lease areas (or important adjacent area*). Three major use factors were selected for comparison: mig = migration; rep = reproductive behavior (breeding and calving/pupping); fed = feeding. The seasons are: winter (W) = January-March; spring (Sp) = April-June; summer (Su) = July-September; fall (F) = October-December; Yr = year round. Blanks represent data gaps; dashes (-) mean that species is not known to occur or behavior is not noted for this lease area; asterisk (*) means that behavior or occurrence exists but no specific details are known; Bn = basin.

	OCS Oil-Gas Lease Areas														
Species	E.Aleutian*			St.George			Bristol Bay			Norton Bn.			Kotzebue Bn.		
	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed
Carnivores															
bearded seal	-	-	-	WSp	Sp	WSp	WSp	Sp	WSp	WSu	Sp	Yr	W	Sp	Yr
harbor seal		Sp	Yr		Sp	Yr	FW	Sp	Yr	-	-	-	-	-	-
larga seal	-	-	-	W	Sp	WSp	W	Sp	WSp	WSp	-	SuF	F	-	SuF
no. fur seal	FSp		F	FSp	SpSu	Su	-	-	-	-	-	-	-	-	-
no. sea lion		SpSu	Yr	SpSu	SpSu	Yr	Sp	SpSu	Yr	-	-	-	-	-	-
ribbon seal	-	-	-	WSp	Sp	WSp	WSp	Sp	WSp	Su	-	SuF	Su	-	
ringed seal	-	-	-	WSp	Sp	WSp	WSp	Sp	WSp	W	Sp	Yr	W	Sp	Yr
sea otter		SuYr	Yr	-	-	-	-	SuYr	Yr	-	-	-	-	-	-
walrus	-	-	-	WSp	-	WSp	WSp		WSp	WSp	Sp	WSp	WSp	Sp	Yr
Baleen whales															
blue	*	*	*				-	-	-	-	-	-	-	-	-
bowhead	-	-	-	*			*			Sp			Sp		
fin	Sp		Su	Su		Su				SuF		Su	SuF		Su
gray	F?	-		Sp	-	Su	Sp	-	Sp	SpF	-	SpSu	SuF	-	SpSu
humpback		-			-		SpSu	-		Su	-	Su	Su	-	Su
minke	Sp		SpSu							-	-	-	-	-	-
right	*	*	*							-	-	-	-	-	-
sei	*	*	*	*						-	-	-	-	-	-

Table 13. cont.

Species	OCS Oil-Gas Lease Areas														
	E.Aleutian*			St.George			Bristol Bay			Norton Bn.			Kotzebue Bn.		
	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed	Mig	Rep	Fed
Toothed whales															
beluga	-	-	-	-	-	-			Yr			Yr		Su	Yr
Dall porpoise	*	*	*	*	*	*	*	*	*	-	-	-	-	-	-
goosebeaked															
harbor porpoise	*		*	*		*	*		Yr	*		*	*		*
killer	*		*	*		*	*		*	SuF		Su	SuF		Su
sabertooth													-	-	-
sperm						Su									

a 50% data gap for the RU 67 study area!

From the 1976 data, the following recommendations are presently considered the most important:

1. The gray whale migration route should be completely delineated, and the importance of specific feeding areas in the Norton and Hope Basin oil lease sites should be determined. No energy development activity should begin until we can predict (with better certainty) how vulnerable the species might be to coastal and offshore perturbations.

2. Two problems with respect to cetacean sightings must be resolved -- one, reliability of sightings is presently only good to poor, owing to lack of training for non-scientific personnel; and two, much data exist on cetaceans in the Bering Sea but no resources are available to extract the records. Support for the Platforms of Opportunity Program and/or more trained observers aboard more vessels is essential.

3. Ground truth methodology must be determined and a reliable means of assessing population abundance estimates made <u>before</u> any adequate sampling can be done for a monitoring program once energy development activities commence. For pinnipeds, sea lions are the best choice, and for coastal cetaceans, gray whales are best.

4. An assessment of harbor seal (especially) and northern sea lion movement onto and off of rookeries and ice during the winter and early spring months should be made. Harbor seals' apparent dependency upon protected tidal bays make them vulnerable to direct impact. Sea otters probably pose the same kind of habitat vulnerability problem (e.g., in Bechevin Bay).

5. A true "synthesis" of data means that comparable data are pooled and treated (tested) together. A summary or compilation of statistically measurable variables does no juctice to the overall enhancement of sample size when tested together. We recommend that funding be made available to one group or a team of investigators who can, first, identify the data overlaps and synthesize all comparable marine mammal data collected under OCSEAP, and then expand this to include other ecosystem-related parameters.

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VIII. Summary of 4th quarter operations - RU 67

A. Ship or laboratory activities.

1. Ship or field trip schedule.

   NOAA ship Miller Freeman, So. Bering Sea (ice front), 14-25 March 1977.

2. Scientific party.

   Patrick McGuire, Marine Mammal Division, Seattle, Washington.

3. Methods: field sampling or laboratory analysis.

   At the time of this writing, the Miller Freeman has not returned. Discussion of methods deferred.

   The major accomplishments of this project during the past quarter involved the finalization of logging, formatting and transforming of data collected during the summer and fall of 1976. Laboratory activities consisted principally of reducing the data to a form which could be easily accessed and thus plotted and synthesized. Computer programming (approximately 10 programs were written by our group) played a major part in making the data available for analysis.

   Field format finalization was accomplished. This was necessary to reduce the time it takes to record data in the field, yet provide the maximum amount of information needed for proper reporting. Although we cannot report on the precision of reporting data in this report, after the 1977 spring field season an analysis of data collection procedures will be made. We expect that the results from this analysis of methodology could prove to be one of the most important scientific accomplishments concerning aerial survey techniques.

   Other procedures and laboratory activities were completed, including:

   a. An aerial survey training package including slides of species encountered, ice conditions and types, etc. The objectives of this project were to minimize internal errors associated with human observational differences by standardizing all aspects of the data collection procedure. This package was a refinement of the one developed prior to the 1976 field season.

   b. Completed cataloguing of all photographic slides by species and area by research unit. Some 9,000 photographs were processed.

   c. Development of a computer accessing report and complete format procedures for logging data and processing the data. These manual-type reports will be included with the final report.

d. Submission in January of "An Annotated Bibliography on Marine Mammals of Alaska".

4. Sample localities/ship or aircraft tracklines.

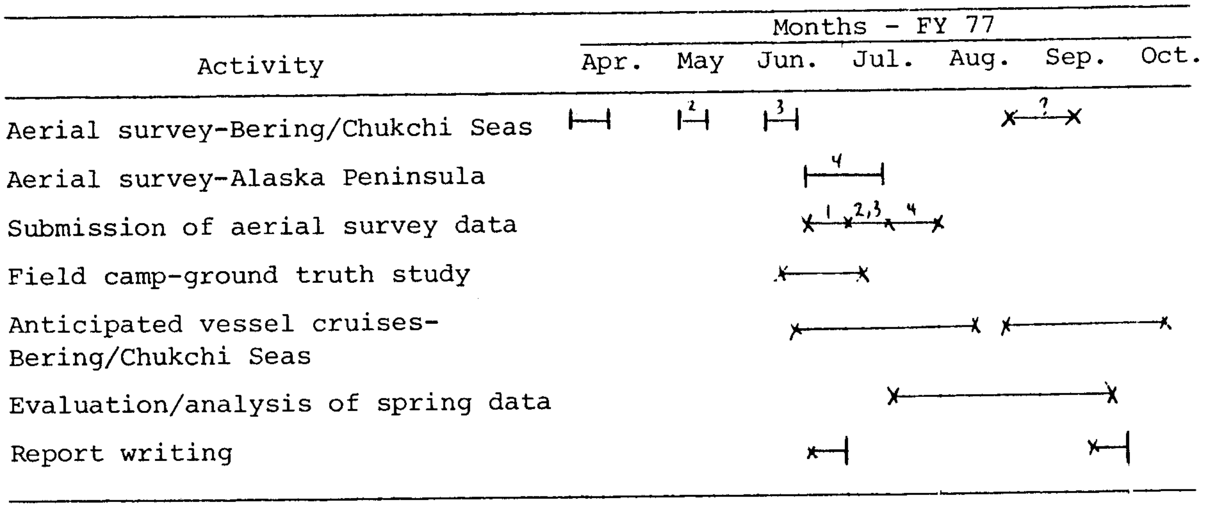
N/A

5. Data collected or analyzed.

Untold numbers of analyses were performed on the 1976 data. Most dealt with verification of computerized formatting, as well as plotting, density and abundance estimates, tracklines vs. sighting data verification, and incorporation of RU 230 spring data into our storage bank. Some 21,000 nautical miles of trackline flown during 1976 were reviewed during the fourth quarter. Accuracy was verified with respect to location of trackline legs and sighting data.

6. Milestone chart and data submission schedule.

a. Milestone chart for 1977.



b. Data submission schedules.

The following survey dates have been sent to the Juneau project office in accompaniment with this report. Some (*) were sent in September and November 1976, but an updated format change necessitated resubmission.

15 March
18 March
19 March
21 March
6 April
8 April
9 April
12 April
13 April
15 April
17-22 April
8-15 June
18-20 June

The following survey dates have either not been processed or not passed our quality control inspection. These surveys will be completed as time permits, but in no case later than the next reporting quarter.

17-20 June 1975
9-13 August 1975
9-14 October 1975
9-10 June 1976
17-27 August 1976
21-25 October 1976

The only remaining survey data in the RU 67 contract area are those from vessels and NOAA ships. Some cruises (5) include data collected by our own personnel, but because of limitations of money and people, we have not completed the computerization (most of the data were analyzed by hand and are included in the Annual Report). Approximately 40 cruises with sighting data have been or are expected to be sent, from OCSEAP and non-OCSEAP ships. Most of these data are incomplete. At this time, we do not have the resources to process them.

B. Problems encountered/recommended changes

It has taken us approximately one quarter longer to finalize data management and processing. The reasons are varied (and mostly of our own doing); but formatting, computer delays (e.g., card punchers were on strike for 2 months) and severe self-imposed quality control measures were pivotal.

We suggest (a reitteration) that a list of PI's and their addresses and telephone numbers be sent to each PI.

C. Estimate of funds expended

Salaries (plus overtime, benefits, etc.)	$12,709.00
Travel	204.00
Per Diem	319.00
Equipment/supplies	572.90
Miscellaneous (computer, etc.) (approx.)	1,200.00
	$14,704.90

D. Other activities

1. Conference

Howard Braham, U. S. delegate to the US-USSR Marine Mammal Agreement on Environmental Protection. Summarized OCSEAP research, planned cooperative research with Soviets in the Bering and Chukchi Seas. January 1977, Southwest Fisheries Center, NMFS, NOAA, La Jolla, California.

2. Training

David Rugh, David Withrow and Bruce Krogman attended a course at the University of Washington on marine mammals, in preparation for the forthcoming field season.

ANNUAL REPORT

Contract No. R7120806
Research Unit 68
Period: 1 April 1976-
31 March 1977
31 pages

Seasonal Distribution and Relative Abundance Of Marine Mammals in the Gulf of Alaska

Principal Investigators:

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Research Assistants:

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Patrick McGuire
Carl Peterson
Ronald Sonntag

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Northwest & Alaska Fisheries Center
National Marine Fisheries Service
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Seattle, Washington 98115

March 25, 1977

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I. Summary of Objectives, Conclusions and OCS Implications

The baseline objectives of this year's project (FY 77) are to provide a better understanding of the relative seasonal distribution and abundance of marine mammal species in the western Gulf of Alaska extending to the eastern Aleutian Islands. These objectives are being accomplished by integrating 1) sighting records taken aboard NOAA, US Coast Guard ships and chartered vessels working in and crossing through the western Gulf; 2) data from aircraft surveys collected by supporting OCSEAP projects (e.g., Alaska Department of Fish and Game, U. S. Fish and Wildlife Service); and 3) data from historical whaling, sealing and research records.

The eastern Aleutian Islands and western Gulf of Alaska are expected to be important areas for oil-gas research and tanker traffic. Two major oil lease areas occur in the study area: Kodiak region and Aleutian Basin. These areas also represent resident as well as seasonal habitats for at least 20 marine mammal species, some of which are seasonally engaged in breeding (e.g., northern sea lions) and migrating (e.g., gray whales).

Our understanding of marine mammal temporal trends in the western Gulf are meager, especially with respect to cetaceans (i.e., whales and dolphins). An understanding of seasonal distribution and vulnerability of marine mammals to various aspects of petroleum development is needed before exploritory activities begin.

II. Introduction

Research Unit 68 has evolved from a general Gulf of Alaska project in 1975 to a very specific geographic project in 1977. This year we will investigate only the approximate area from Prince William Sound to the eastern Aleutian Islands because research funds were specifically earmarked for this region only. Formerly, a contract was let out to the Alaska Department of Fish and Game concerning marine mammals in the near-shore areas of the Gulf. A final report of their findings was submitted in September 1975 (Calkins, et al., 1975). In November 1976, Fiscus, Braham and Mercer (1976) submitted an unsolicited final report covering pelagic marine mammals in the Gulf, specifically addressing the NEGOA (Kodiak Island to Yakatat Bay). These documents are the forerunners of research to be carried out in the western reaches of the Gulf.

A. General nature and scope of study. Research Unit 68 consists of a general review of the existing literature and of an on-going Platforms of Opportunity marine mammal reporting program. The emphasis of the RU 68 program is on collecting opportunistic data and relating these to historical information on distribution.

B. Specific objectives.

1. To develop a comprehensive annotated bibliography of the marine mammal literature for work already accomplished throughout Alaska.

2. To provide computer card summarization of five season's (FY 72-76) worth

of "Marine Mammal Platforms of Opportunity" data presently in our files, and data which will be collected during the remainder of FY 77.

3. To evaluate catch statistics from the literature and historical data on seasonal distribution of marine mammals in the western Gulf of Alaska, and to integrate these findings with our own research.

III. Current State of Knowledge

There are approximately 20 species of marine mammals that are known to occur in the western Gulf of Alaska study area (Prince William Sound to Umnak Island) either as residents or infrequent visitors. A list of the most frequently sighted species is given in Table 1, along with a brief account of "habitat" types these animals are normally found in; a general usage of the area; and a statement of possible vulnerability. Other species may occasionally be found in the study area, but less commonly. These species are: Risso's dolphin (grampus), north Pacific white-sided dolphin, giant bottlenose dolphin, goosebeaked whale and "other" beaked whales. Sea otters are present but are covered under RU 240. Since we know little about the frequency of occurrence for most marine mammals in the Gulf, information provided by RU 68 should fill an important gap in our understanding. The most comprehensive source of information on the distribution and abundance of pelagic species of marine mammals is by Fiscus, Braham and Mercer (1976). This document serves as the most up to date "current state of knowledge" for the western Gulf as well as the eastern Gulf.

IV. Study Area

The study area consists of the western Gulf of Alaska from approximately 148° W. Longitude to Umnak Island (Lat. 52°30' N, Long. 169°00' W). The approximate southern boundary of the survey area is 50° N. Latitude. Figure 1 depicts the study area and outlines four sub-areas or sectors used during data analysis in this report.

V. Methods and Materials

Marine mammal observers aboard Platforms of Opportunity and OCSEAP contract vessels have little input into trackline selection; hence, there is no systematic sampling method behind data collection efforts. A certain amount of specific watch effort is quantified when Marine Mammal Division personnel are on-board OCSEAP vessels. For the most part, however, distribution data are the result, requiring fewer precise sampling procedures (e.g., an elaborate experimental design). Watch effort and sightings are recorded in a record book or in the Marine Operations and Station Abstract (MOSA) when no MMD observer is aboard.

Sightings are coded and carded for species, number seen, location, behavior, direction of travel, visibility, surface temperature, and related information. These field data are then punched onto computer cards for computer processing of the raw data. All data transcribed to computer format are verified on a record for record basis prior to keypunching, and a 10% random verification check is made after data have been keypunched. Any batch

Table 1. Commonly occurring and endangered (*) cetaceans and pinnipeds (those likely to be seen out to the continental slope) in the western Gulf of Alaska study area. F = feeding; C = calving; P = pupping; M = migration.

Species	Habitat Type	Peak Occurrence		Area Usage	Special Vulnerability to Petroleum Development
		Area	Time		
Cetaceans					
Balaenopterids					
Minke	coastal waters/ photic zone	Prince Wm. Sound	May-Sep.	F	toxicity to large schools of small fish locally
Sei* Fin*	photic zone pelagic	So. of Montague Is.	summer	F	important areas of high productivity & surface pollution
Blue*	photic zone pelagic	So. of Montague Is.	June-July?	F	important areas of high productivity
Humpback*	photic zone, continental shelf	Portlock/Albatross Banks;Pr.Wm.Sound	Apr.-Sep.	F,M	interference with movement into feeding areas
Gray*	coastal waters	Kodiak Is.	Apr.-May? Dec.-Jan.?	M,F?	may have restricted spring migration corridors
Right whale*	surface	?	summer	F	oil fouling baleen plates during surface skimming?
Killer	bays, harbors, coastal	Pr.Wm.Sound & entrance to	Mar.-Oct., year round?	F,C?	local movements in Pr. Wm. Sound; oiled prey (seals?)
Sperm*	deep waters	?	summer	F	
Beluga	bays, rivers, estuaries	Lower Cook Inlet	year round?	F,C?	development may alter local movements, behavior, feeding
Dall porpoise	deeper bays/ shelf/slope	Portlock/Albatross Banks,So.Montague Is., Pr.Wm.Sound	spring-summer year round?	F,M? C?	local calving areas may be disrupted by heavy activity
Harbor porpoise	shallow bays, rivers,estuaries	Kodiak Is.; Pr.Wm.Sound	year round	F,C	dependent upon shallow water spawning fish; especially vulnerable to human activities, pollution

Table 1. cont.

Species	Habitat Type	Peak Occurrence		Area Usage	Special Vulnerability to Petroleum Development
		Area	Time		
Pinnipeds					
No. fur seal	continental shelf & slope area	offshore so. of Montague Is. & Kodiak Is.	Apr.-June	M,F	oil fouling pelage
No. sea lion	haulout islands, photic zone, continental slope	Portlock/Albatross Banks to Kenai; so. Montague Is.	Apr.,May; Sep.	P	fouling during pupping period: June-July

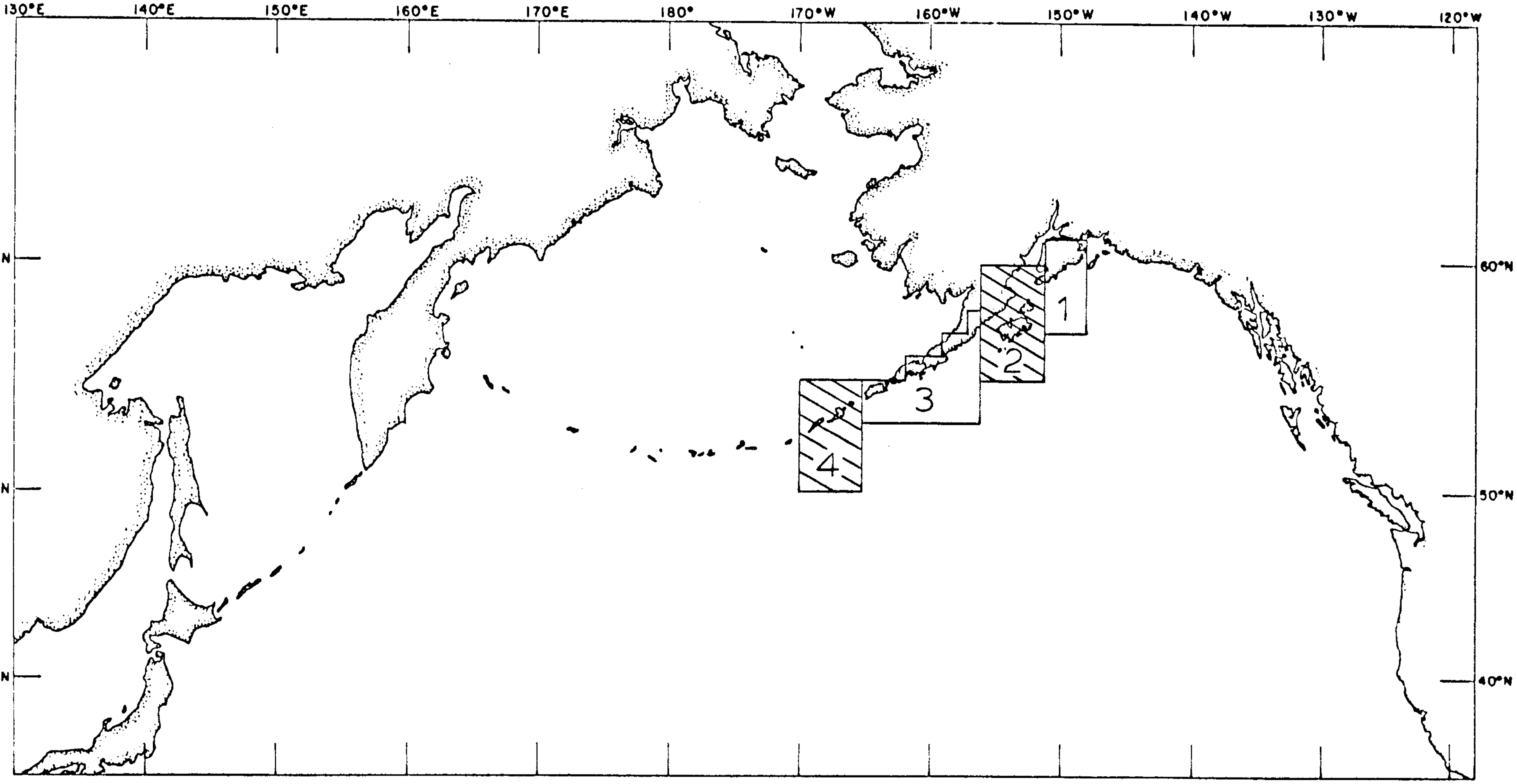

Figure 1. Boxed in areas indicate sectors utilized in analysis of data from SW Gulf of Alaska.

of data for which greater than 10% errors are found after keypunching are completely rechecked against the raw field data.

Distribution data are examined by computer by month, sector, and season. After data have been computerized, they are plotted. Data are then sectored into selected areas for crosstabulation and statistical breakdown. All valid watch effort data and corresponding sighting data are analyzed for sighting per unit of effort breakdown. If sufficient resources are available, the data will be examined by the post-stratified random sample method (Cochran, 1963) to develop population indices. Since most research conducted in this area was from spring through early fall (March-October) the amount of information on winter distribution is minimal.

VI and VII. Results and Discussion

The annotated bibliography was completed during FY 76 and stands as a NWAFC processed report (Severinghaus and Nerini, 1977). The second of three final reports on the Gulf of Alaska under RU 68 was submitted during the past year (Fiscus, Braham and Mercer, 1976).

Data from pelagic fur seal research and incidental sightings from 1958-73, from the Platforms of Opportunity Program files, and from NOAA OCSEAP ships from 1971 to the present have been logged and smoothed sufficiently for limited computer plot reproduction and crosstabulation of species by season per sector. These data are reported in this annual report only for the Kodiak-Prince William Sound area, sectors 1 and 2 (Figures 1-16). An analysis of data in sectors 3 and 4 were not completed in time for this report. Figure 2 is a summary of sightings of all species by season per one degree square latitude-longitude in sectors 1 and 2. Only a few sightings exist for large cetaceans in the fall and winter months (October to March). These sightings (n=7) were not included in the plots.

Species account. The greatest number of sightings for all species occurs in the spring south of Montague Island, in the western sector of Portlock Bank, and along the southwestern areas of Albatross Bank (Figure 2). The general spatial trend in sightings as the season progresses (spring to summer) tends to be from southwest of Kodiak Island to the entrance,and into Prince William Sound. Whether this is an artifact of greater sampling effort in these areas during the spring and summer cannot be evaluated as yet. We suspect that some bias does prejudice our data; however, when inspecting Figures 3-17, a similar trend emerges by species by time/location.

Although not presented here, we do have information which leads us to believe that, for the Kodiak region, sighting trends in Figures 3-17 are real. Many vessels have travelled the Kodiak to Prince William Sound area in the spring and summer; thus, there is undoubtedly some degree of equivalence spatially. If we make the assumption that watch effort (sightings per unit effort) is at least within an order of magnitude (and we make with some misgivings), then some interesting trends emerge.

Humpback whale sightings are frequent on Portlock and Albatross Banks in the spring, but shift to Prince William Sound during the summer (Figures 3 and 4).

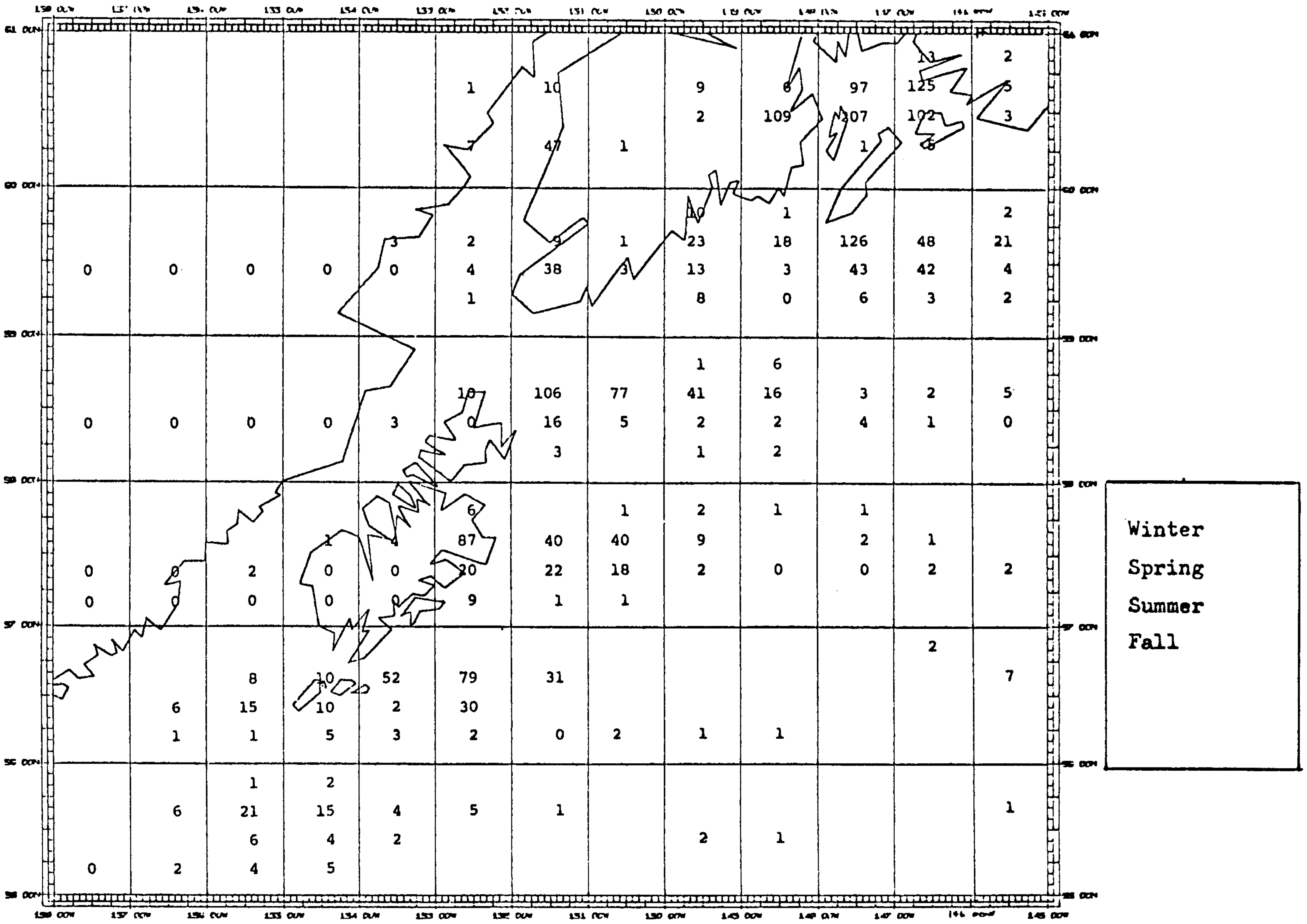

Figure 2. Total number of sightings of all species per season (Winter=Jan.-Mar., Spring=April-June, Summer=July-Sept., Fall=Oct.-Dec.) per sector (1°X1°).

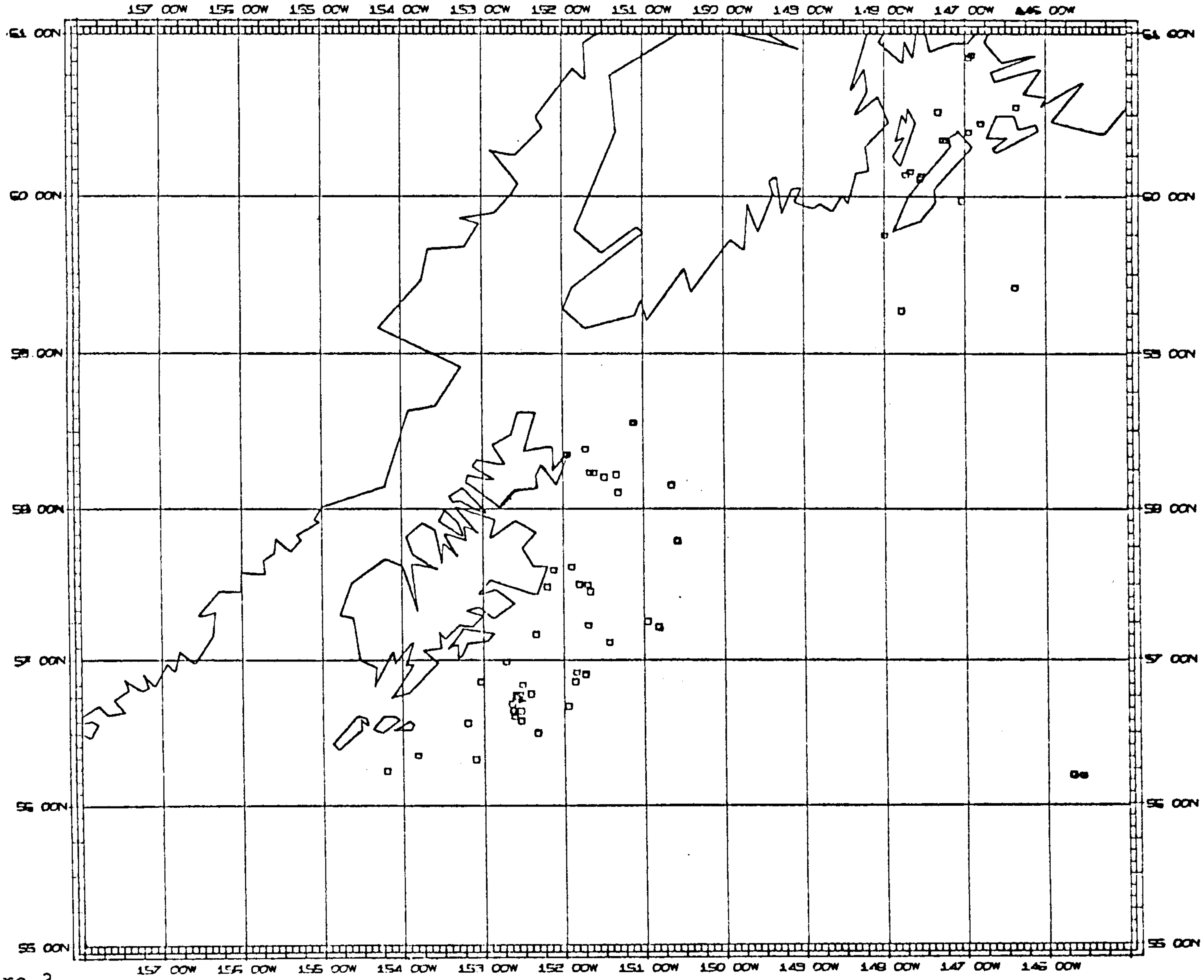

Figure 3. MEGAPTERA NOVAENGLIAE APRIL-JUNE ALL YEARS

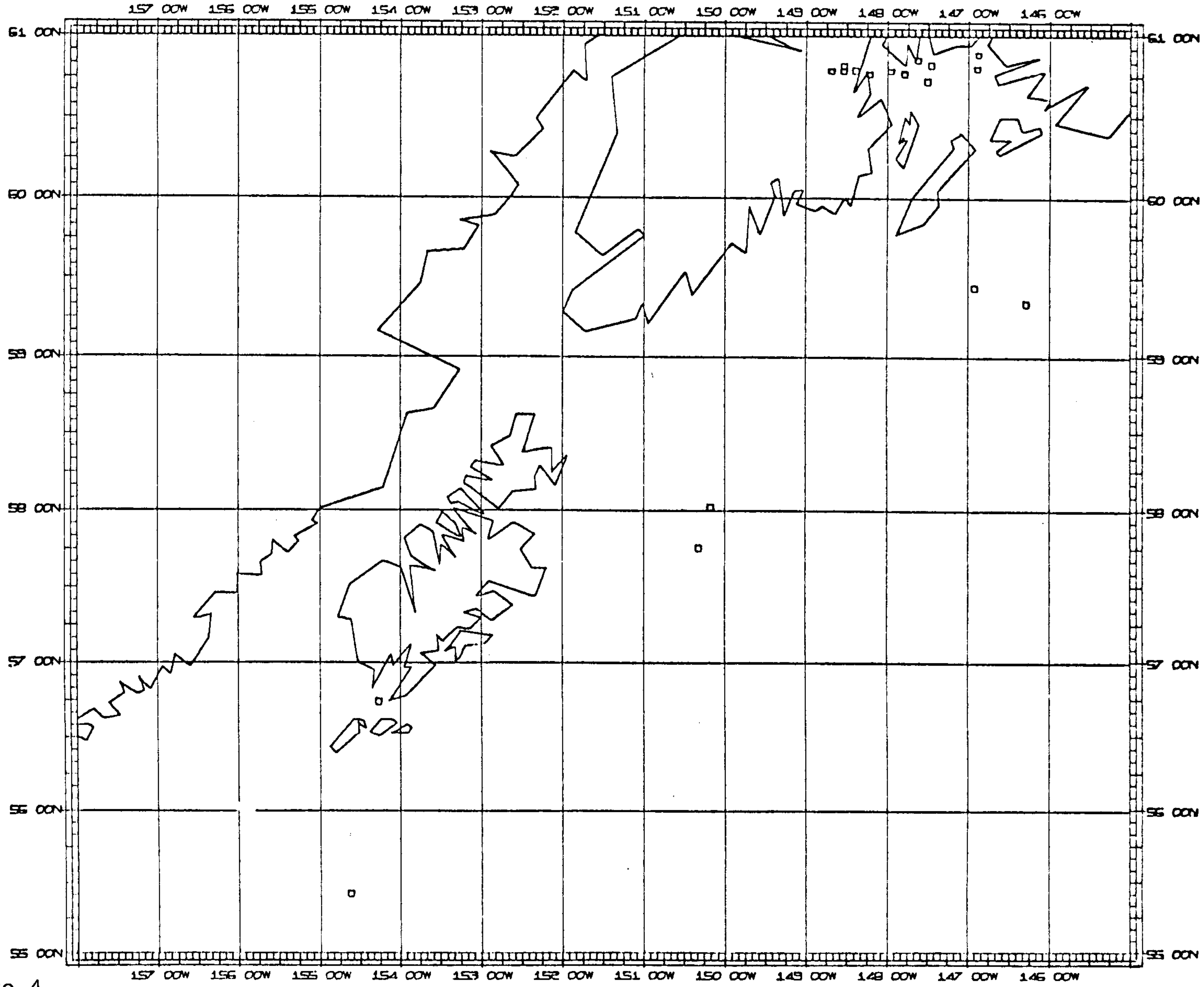

Figure 4. MEGAPTERA NOVAENGLIAE JULY-AUGUST ALL YEARS

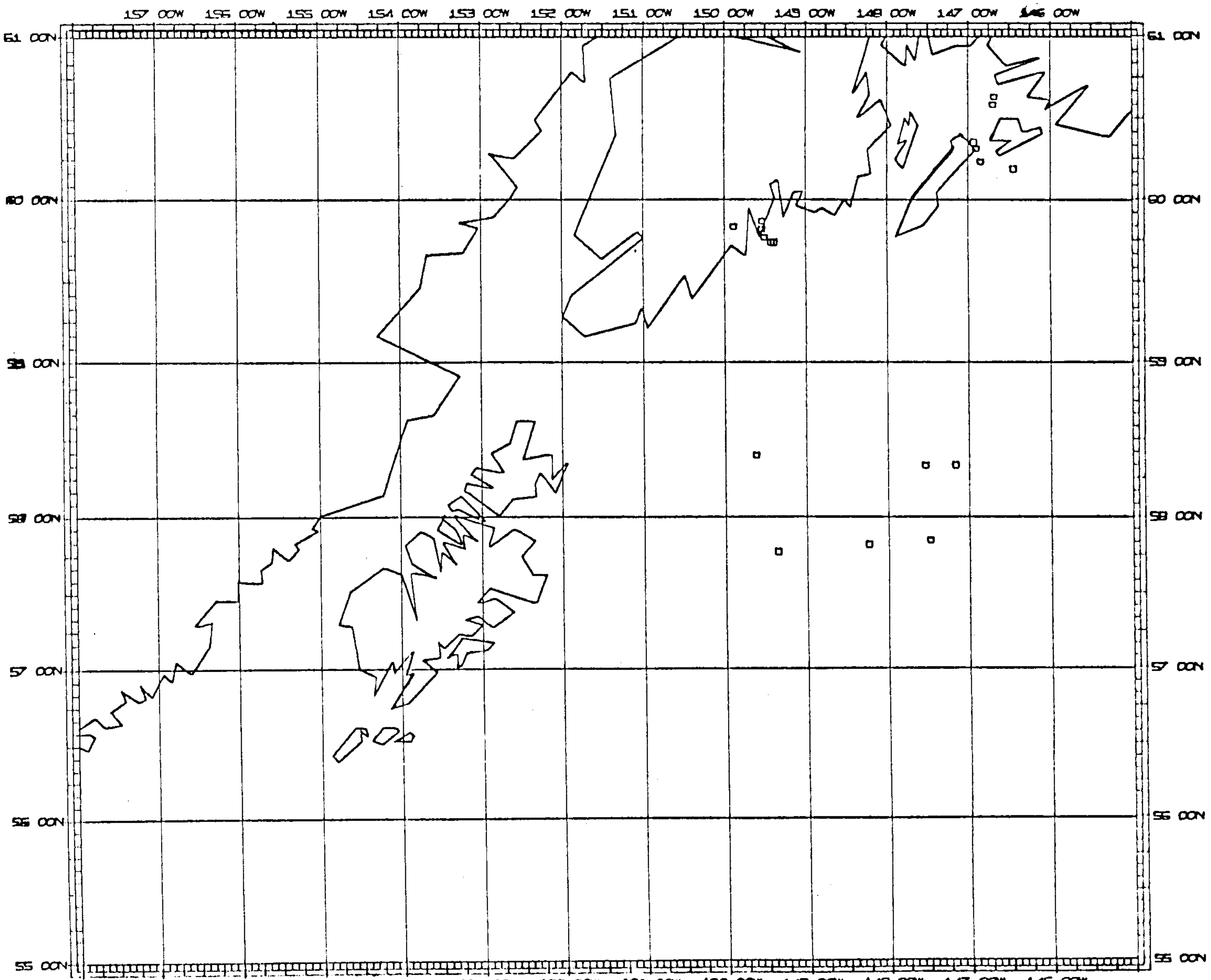

Figure 5. PHOCOENOIDES DALLI JANUARY-MARCH ALL YEARS

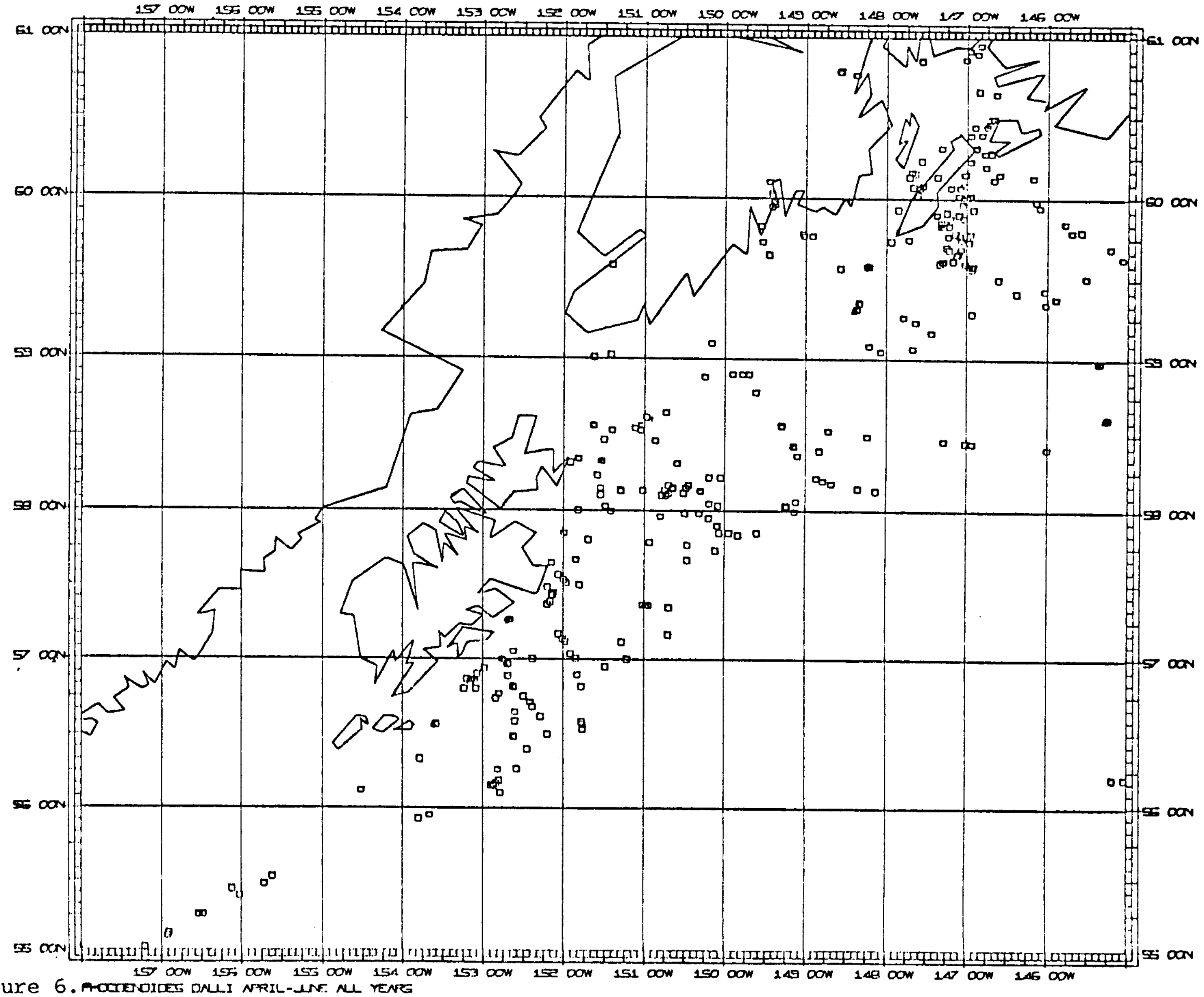

Figure 6. PHOCOENOIDES DALLI APRIL-JUNE ALL YEARS

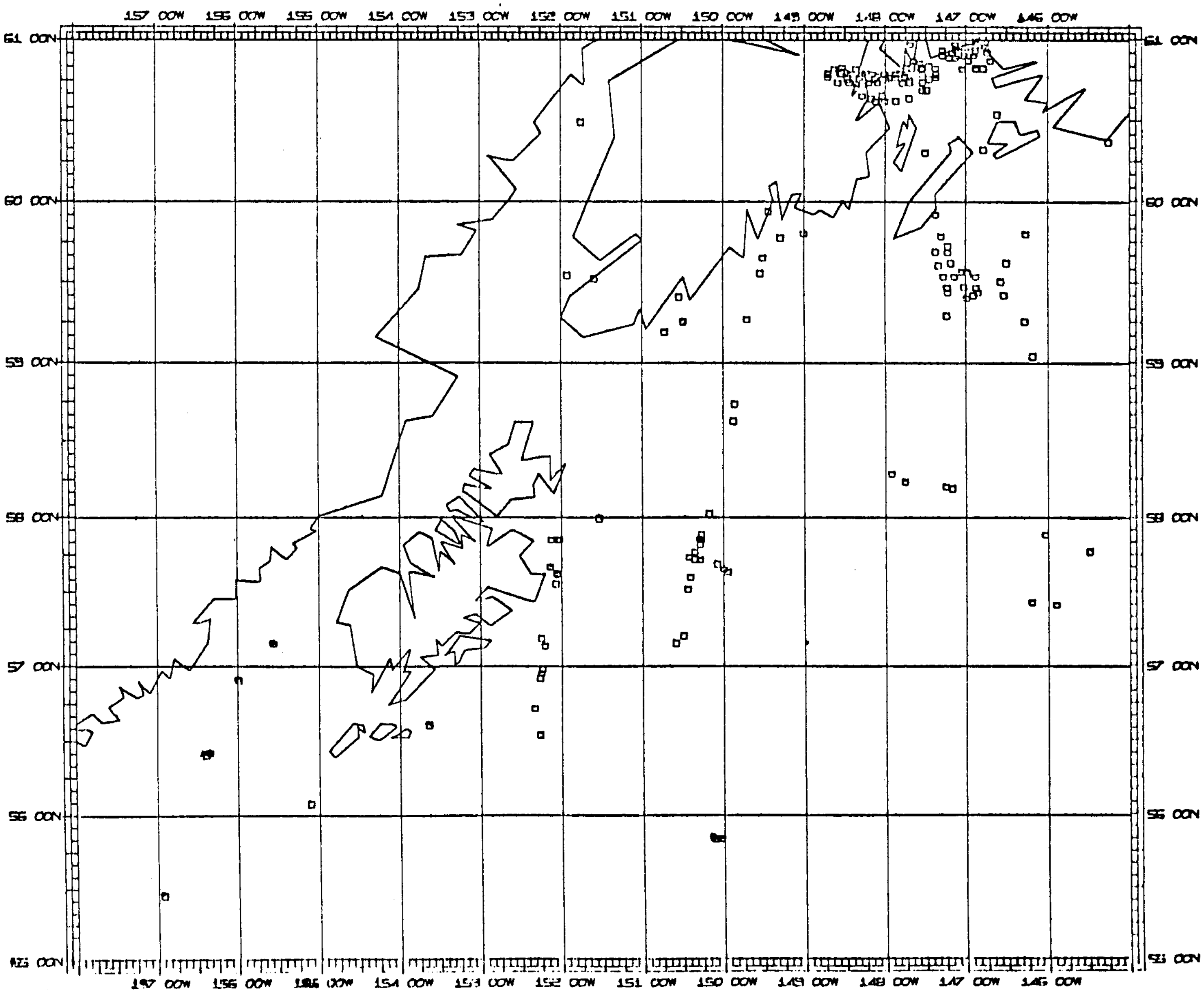

Figure 7. PHOCOENOIDES DALLI JULY-SEPTEMBER ALL YEARS

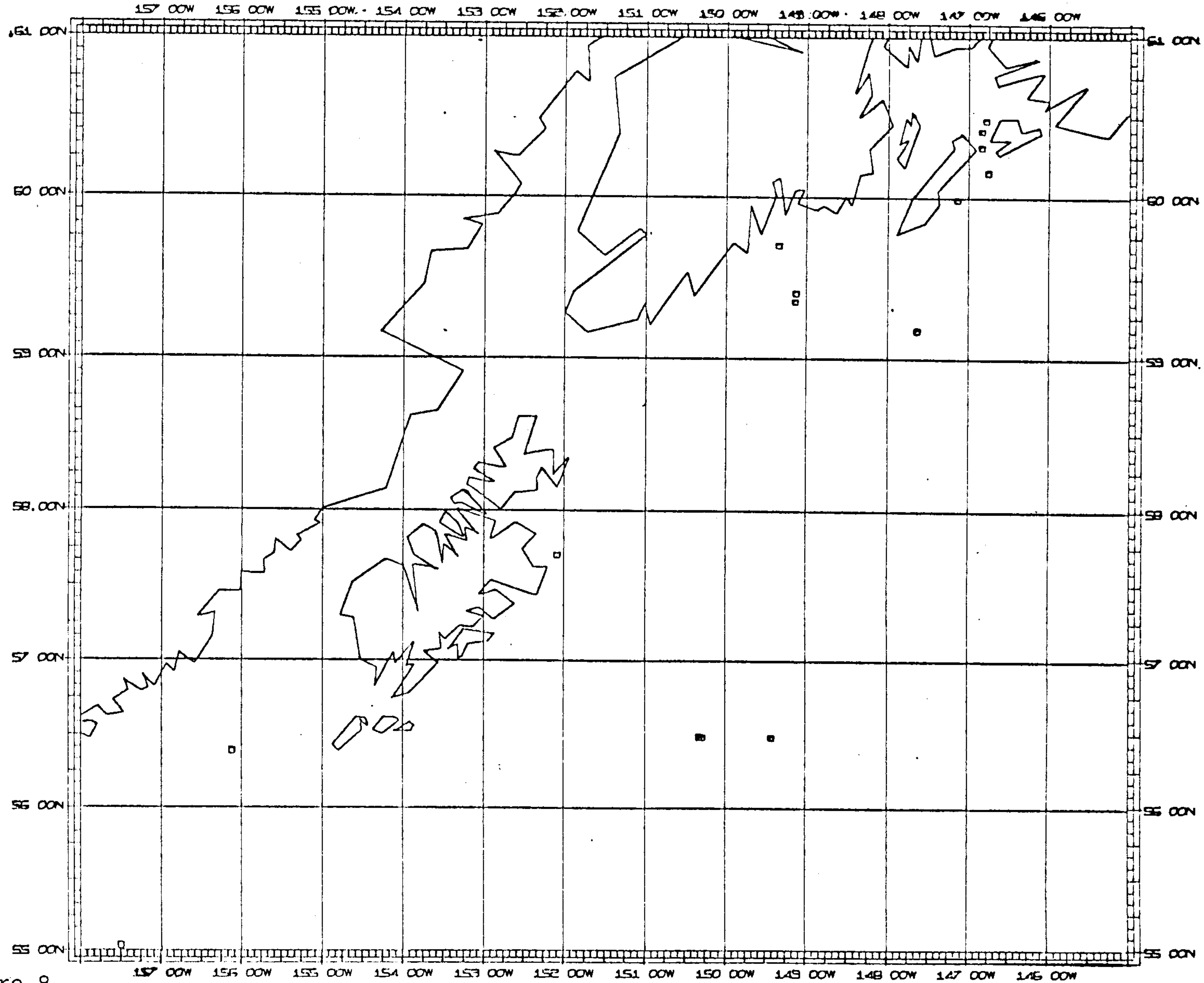

Figure 8. PHOCOENOIDES DALLI OCTOBER-DECEMBER ALL YEARS

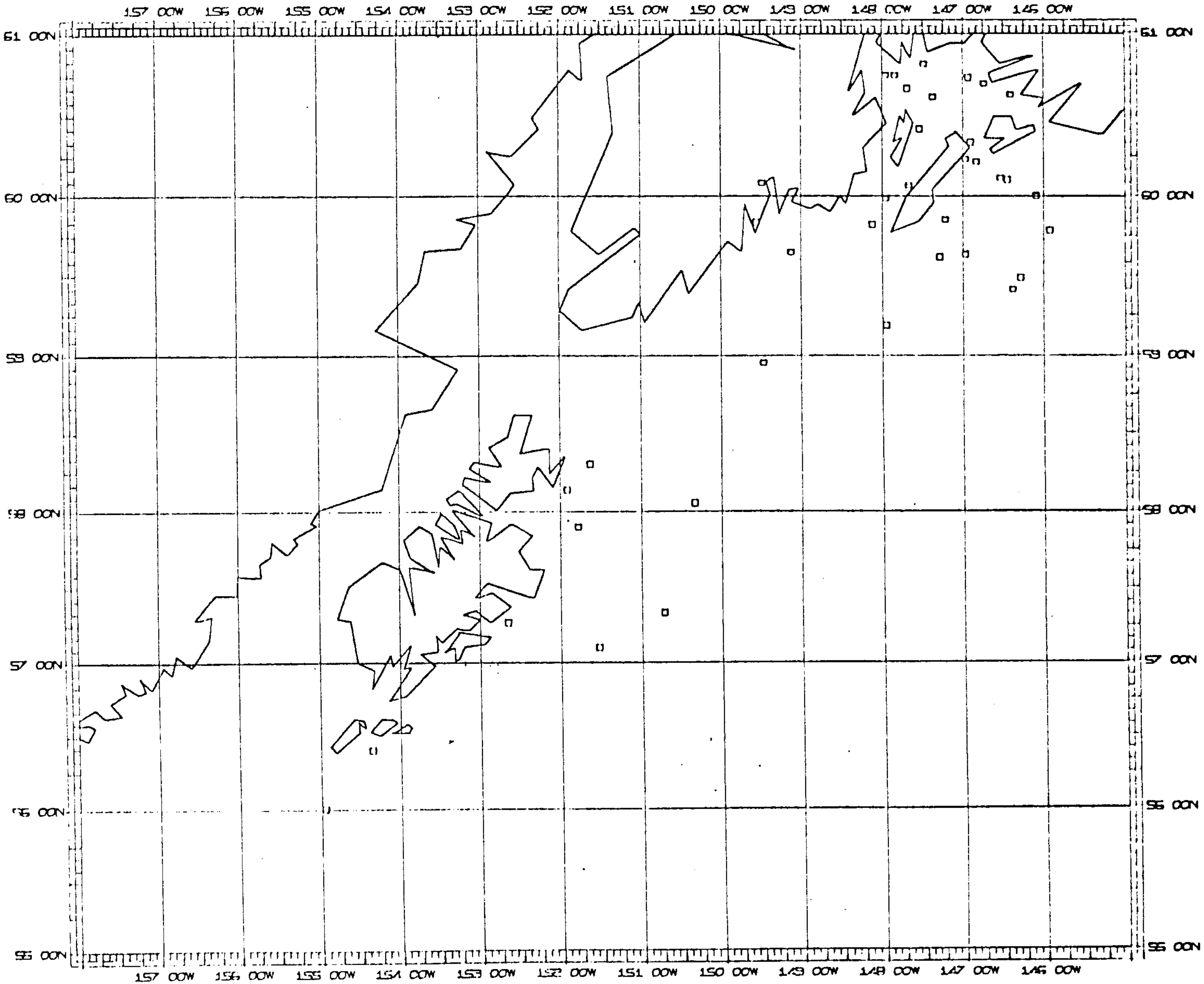

Figure 9. ORCINUS ORCA APRIL-JUNE ALL YEARS

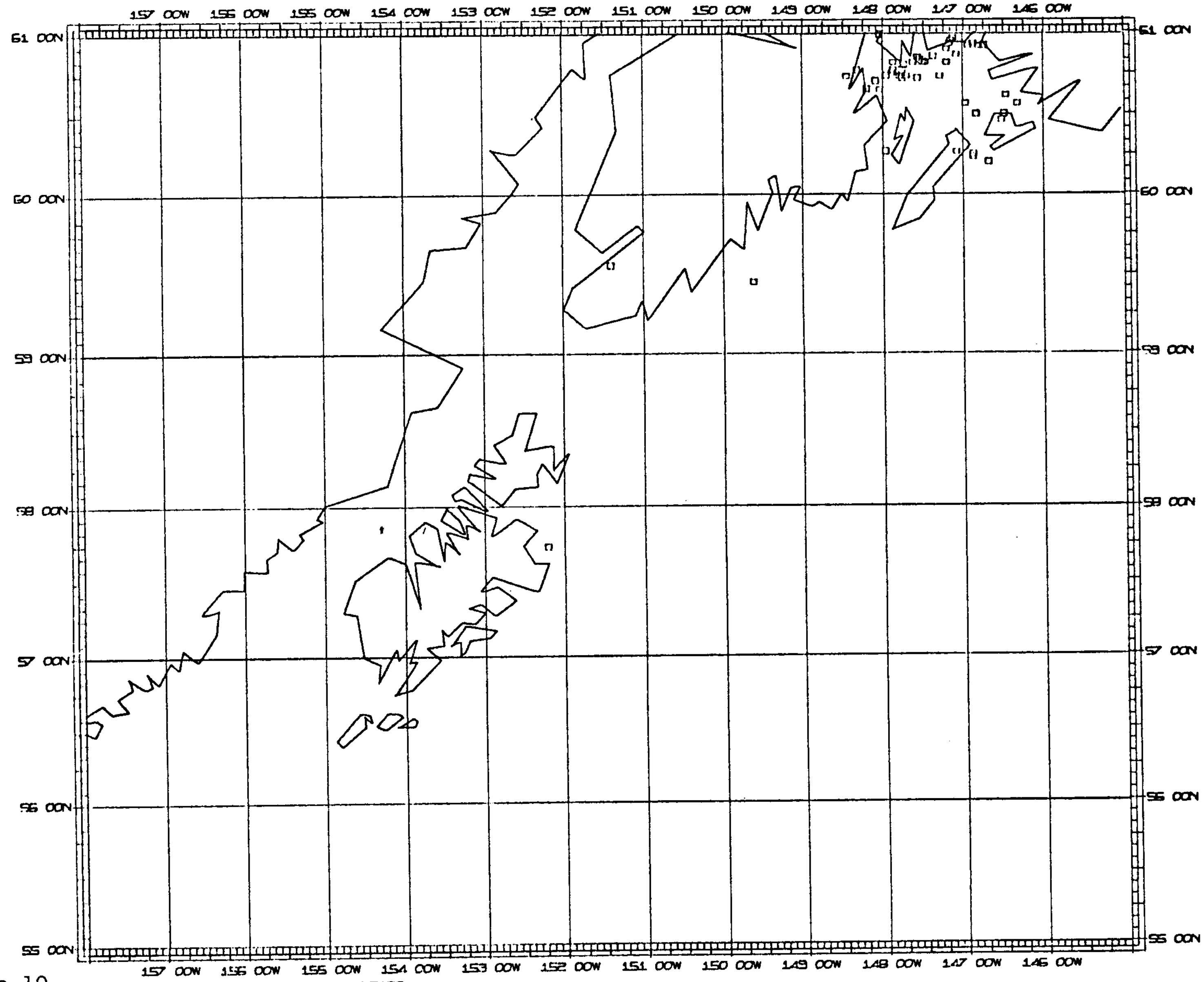

Figure 10. ORCINUS ORCA JULY-SEPTEMBER ALL YEARS

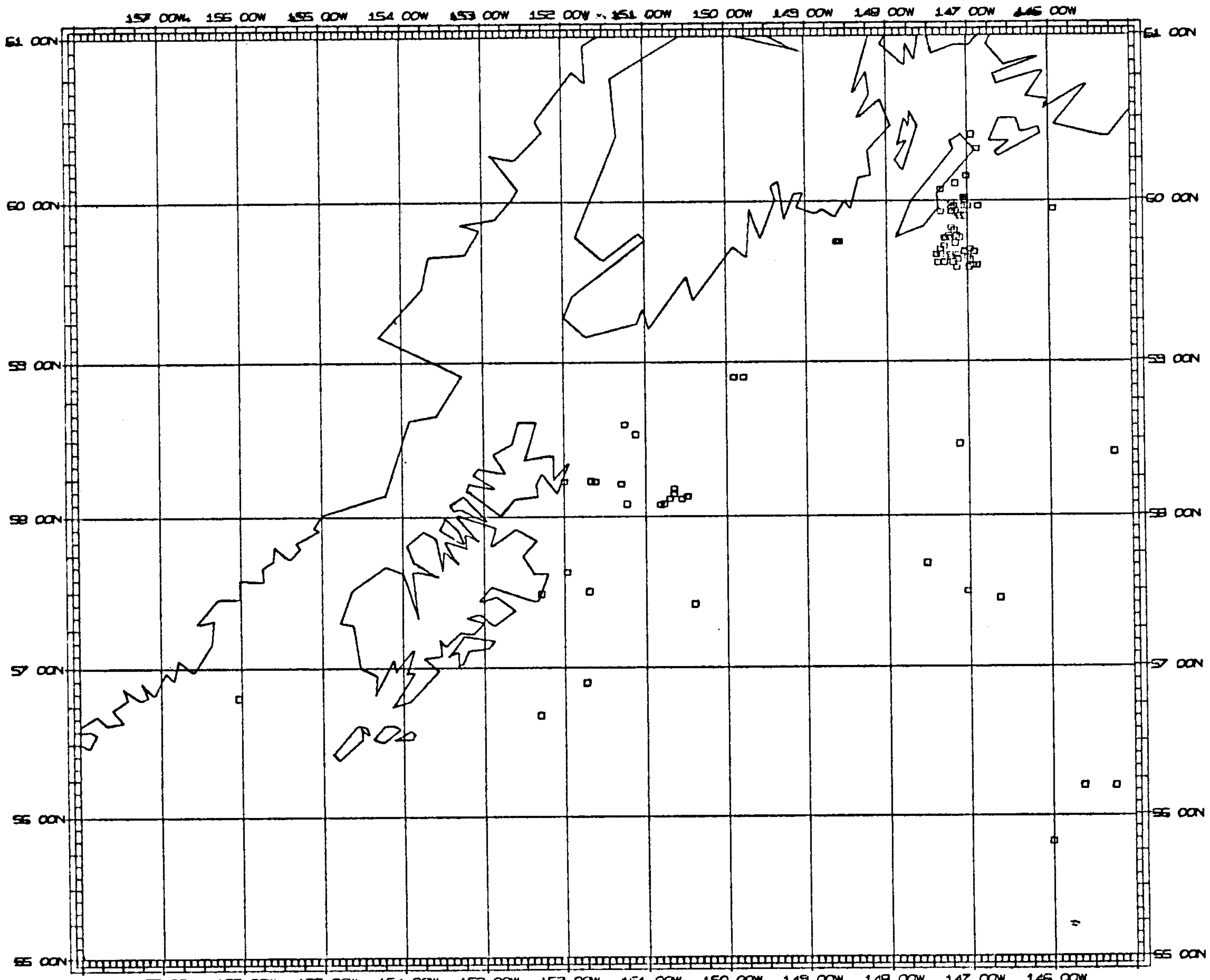

Figure 11. BALAENOPTERA MUSCULUS,PHYSALUS AND BOREALIS MAY-JUNE ALL YEARS

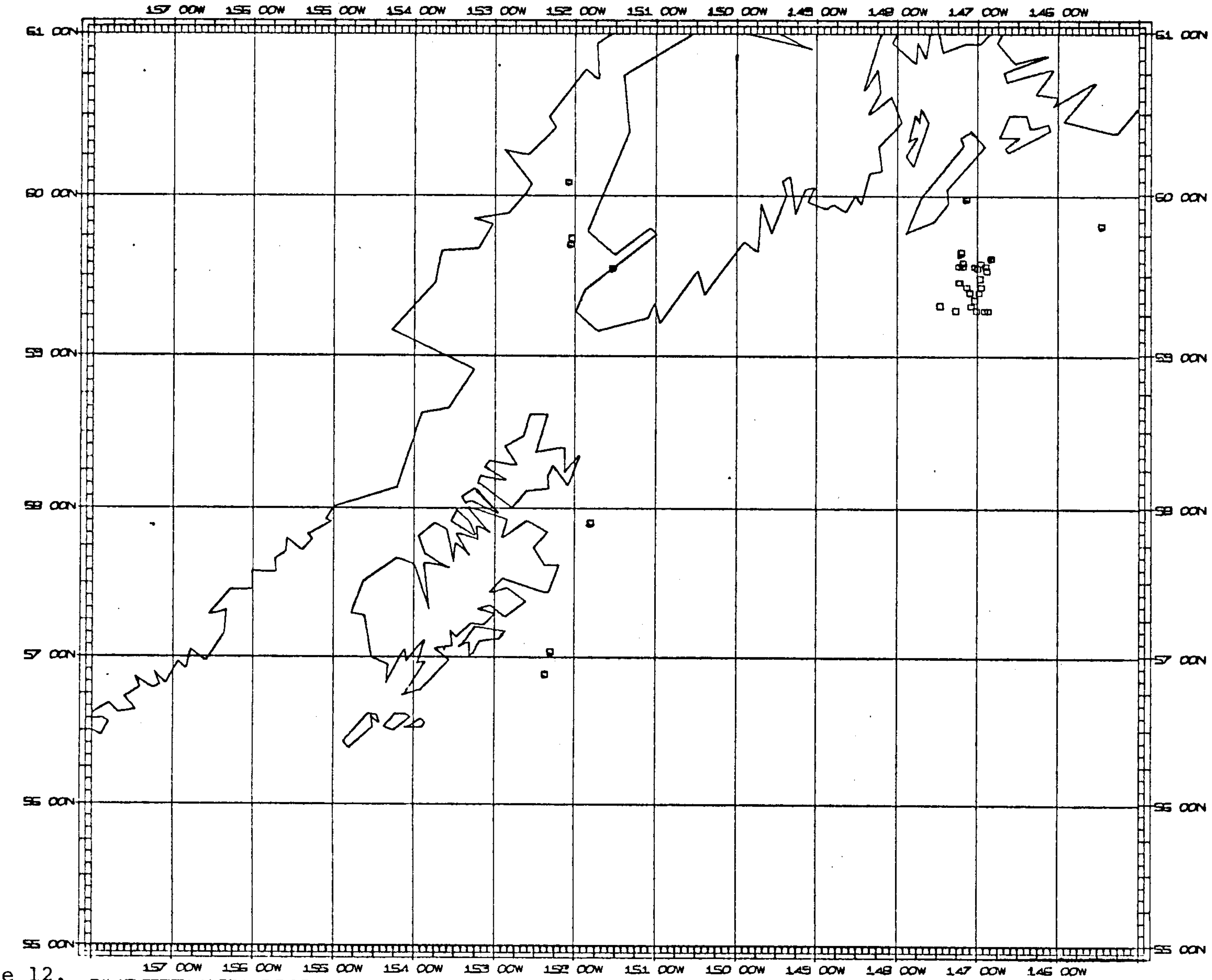

Figure 12. BALAENOPTERA MUSCULUS,PHYSALUS AND BOREALIS JULY-SEPTEMBER ALL YEARS

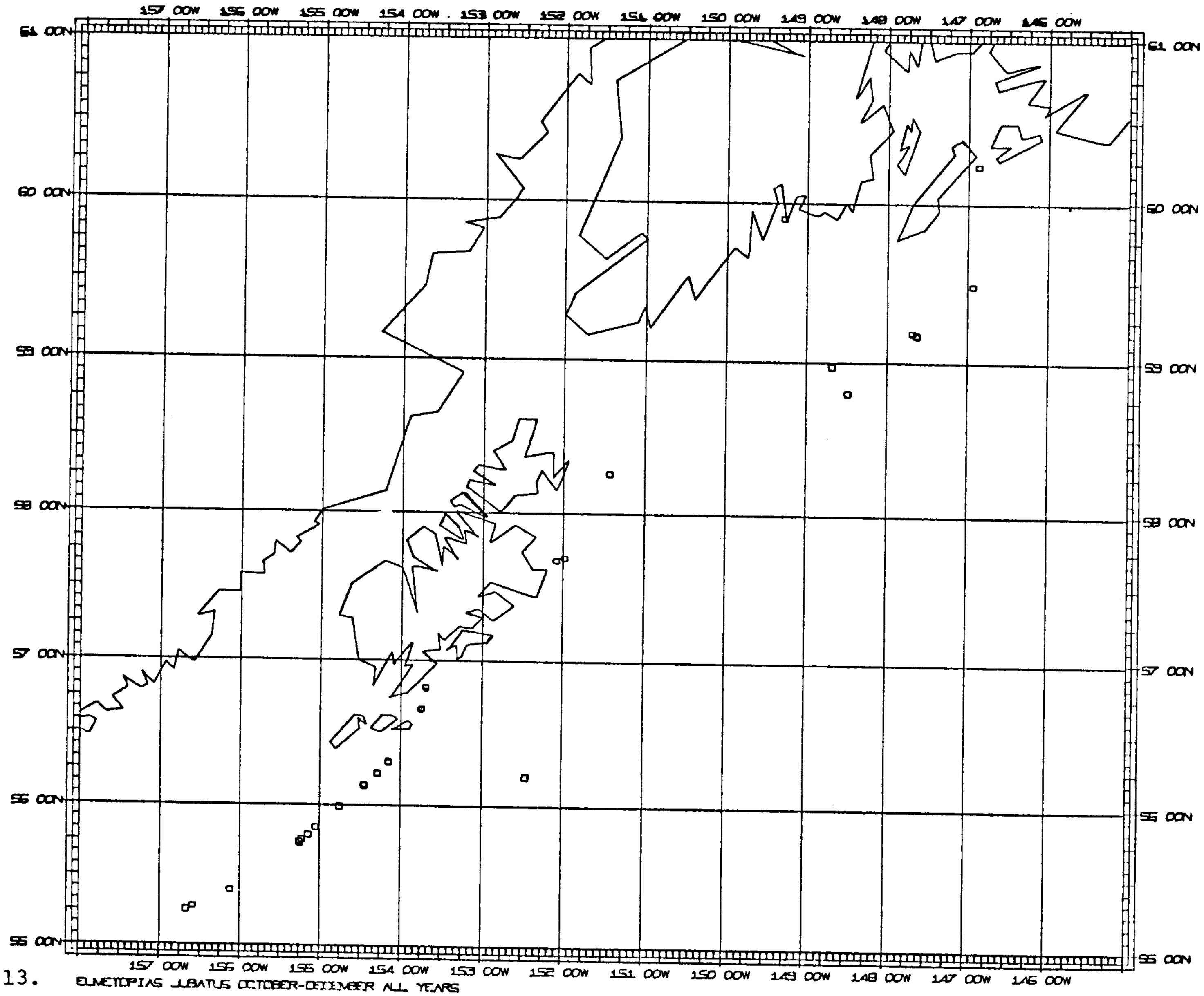

Figure 13. EUMETOPIAS JUBATUS OCTOBER-DECEMBER ALL YEARS

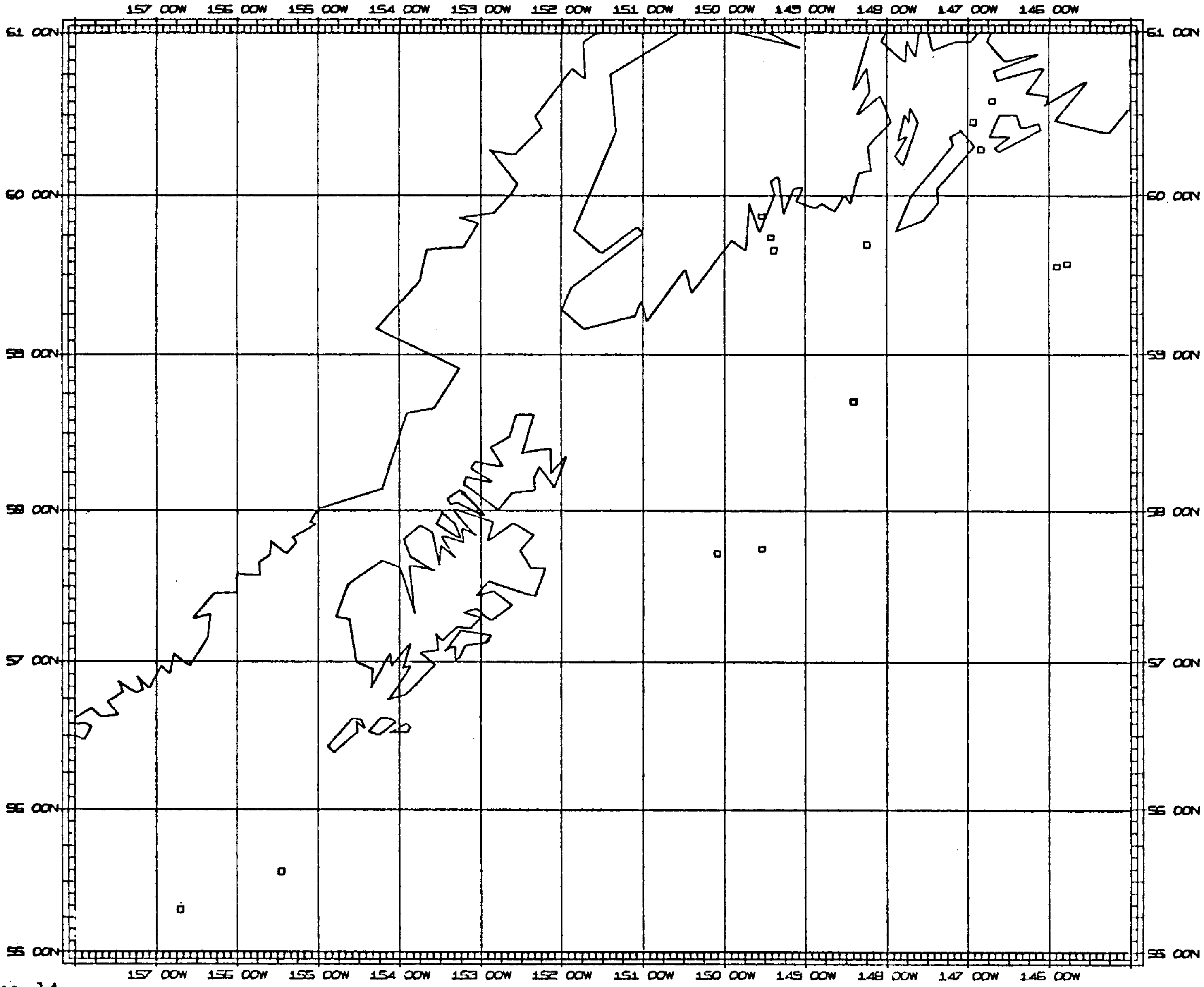

Figure 14. EUMETOPIAS JUBATUS JANUARY-MARCH ALL YEARS

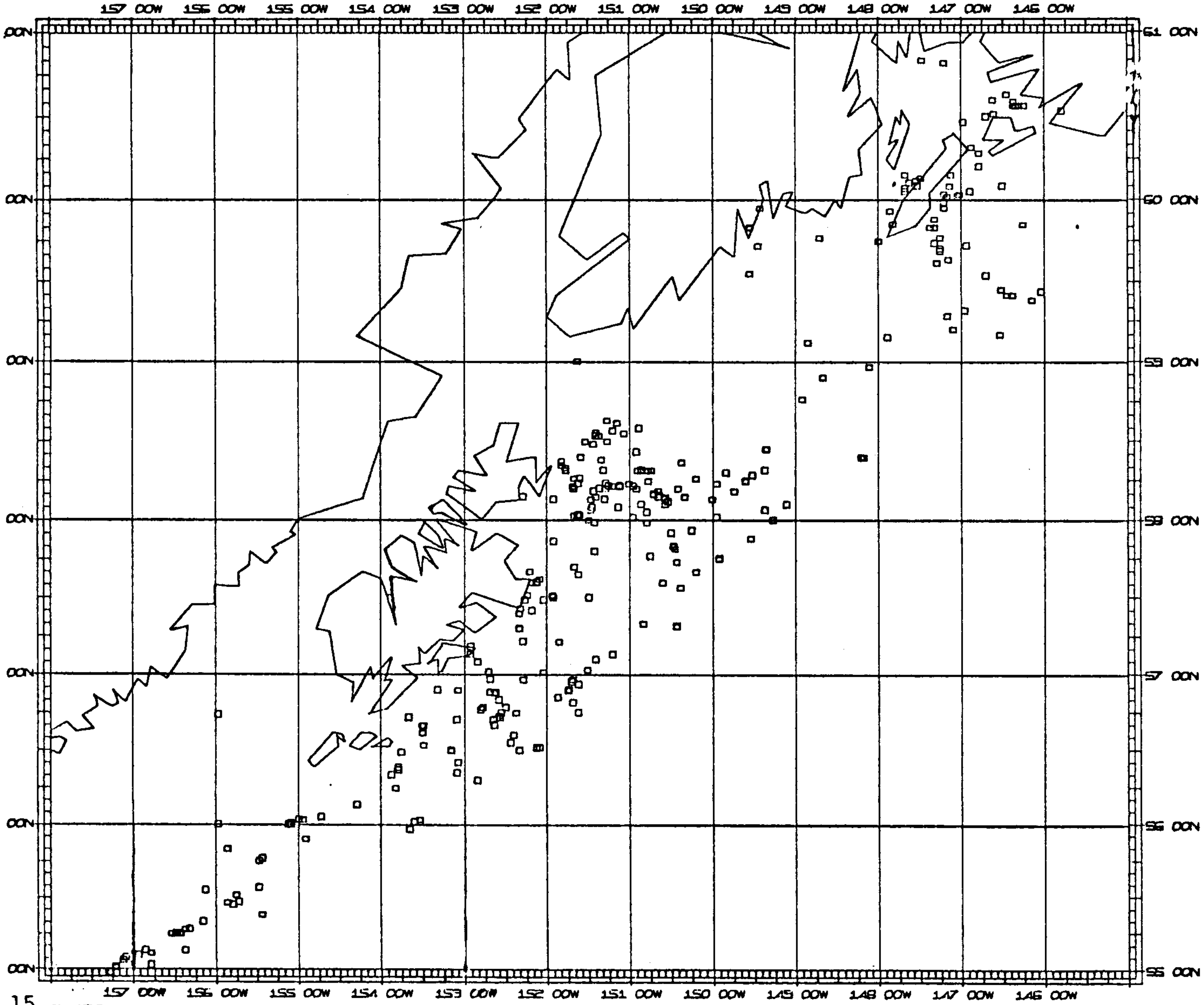

Figure 15. EUMETOPIAS JUBATUS APRIL-JUNE ALL YEARS

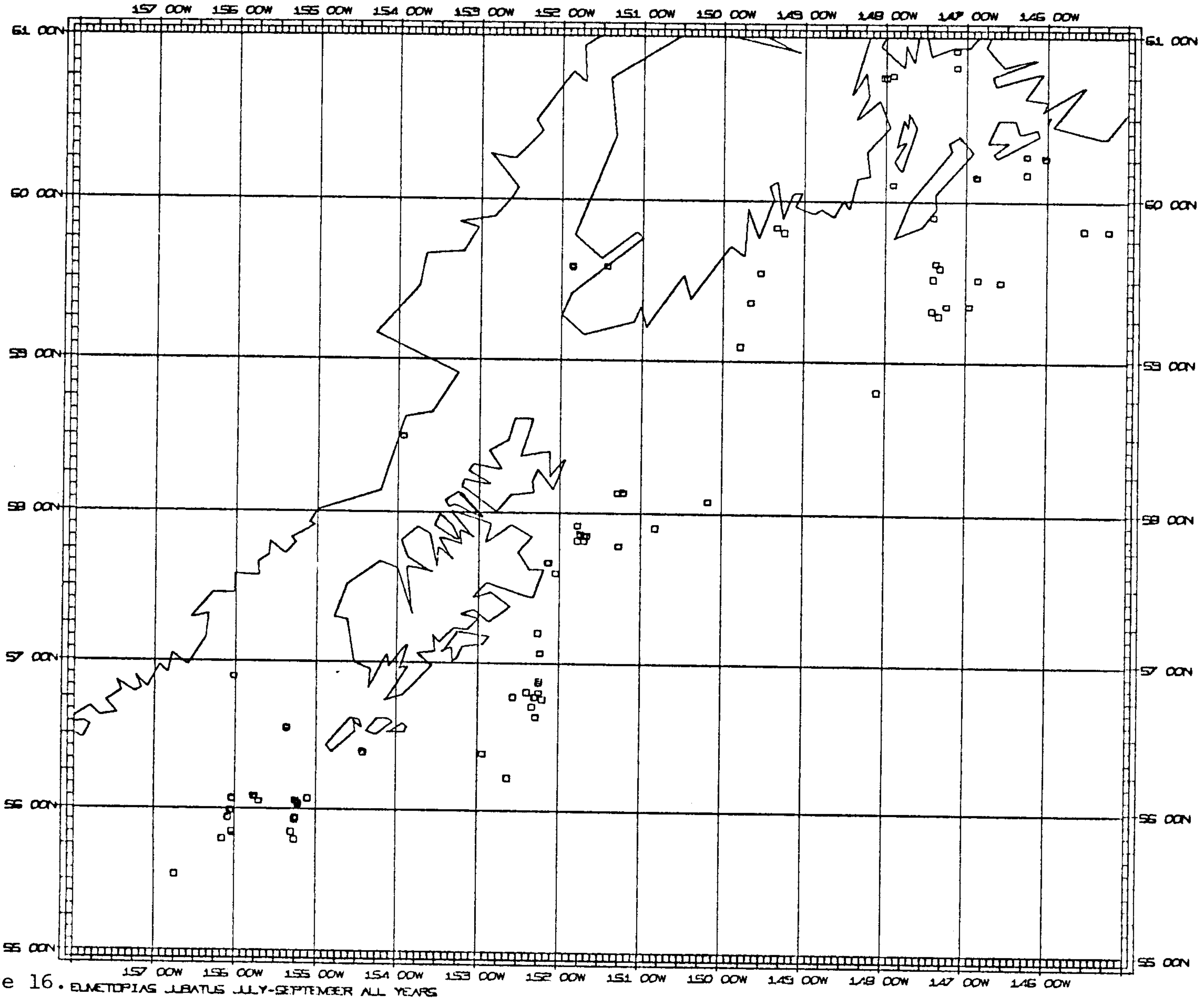

Figure 16. EUMETOPIAS JUBATUS JULY-SEPTEMBER ALL YEARS

Dall porpoise sighting records tend to show a similar trend (Figures 6 and 7), except that this species is much more abundant, being spread out over a larger area of Portlock and Albatross Banks up into the entrance of Prince William Sound in the spring. In the summer, however, P. dallii congregate heavily along shallow inlet waters. When sightings of Dall porpoises are plotted for all sectors (1-4; Figure 1) we find that the smallest percent of sightings occurs in July (Figure 17) -- a period presumed to be a time when the species are most abundant (Figures 6 and 7). We have no explanation for this, except that an influx of feeding whales into this area at this time may act to depress the proportion of P. dallii reported.

Data on Orcinus orca (killer whale) indicate that this species moves into Prince William Sound earlier than most other cetaceans (Figures 9 and 10); whether they migrate here from Kodiak is open to conjecture. Sighting records for the large baleen whales, Balaenoptera musculus (blue), B. physalus (fin) and B. borealis (sei) indicate a strong preference for the productive waters between Montague and Middleton Islands (Figures 11 & 12), with no appreciable spring-summer change in distribution.

Fall and winter sighting data on Eumetopias jubatus (northern sea lion) are meager (Figures 13 and 14). The spring and summer data may suggest that 1) the animals are on the move between winter feeding areas and pupping or hauling grounds, or 2) more animals have moved offshore during the breeding season to feed along Portlock and Albatross Banks out to the productive shelf/slope area (Figures 15 and 16). It is curious that our sighting records end abruptly at the continental slope. We suspect that this is a real effect and that E. jubatus does not feed off the shelf near Kodiak Is.

Some information regarding gray whale migration indicates that this species may be moving past Kodiak Island in mid-March (P. McGuire, MMD aboard Miller Freeman, March 1977). For a more detailed theoretical account of E. robustus movement across the northern Gulf of Alaska, see Fiscus, Braham and Mercer (1976). Humpback whales, which were subjected to intense whaling pressures from 1962-64, seem to be occurring with greater frequency. Then, too, more vessels are surveying in the Gulf with an expected increase in sighting frequency.

Data processing. We have revised our formats and logging procedures since January 1977, and, as a result, have made considerable logging progress. All data from OCSEAP contract vessels (except the Moana Wave -- no MOSAs received) have been applied to computer cards and checked with the original MOSAs for final verification. In addition to OCSEAP vessels, approximately 4,000 marine mammal sighting records from other Marine Mammal Platforms of Opportunity have been logged and verified. At present, approximately 3,000 of these records are from sightings made in the NWGOA; 2,000 from the Bering and Chukchi Seas; and 2,500 from the NEGOA. Over 30% of these records from the NEGOA were not included in the NEGOA Final Report, and approximately 35% more records are now in computer files than were used for the Kodiak synthesis meetings.

No time has been available for an in depth analysis of the data on a sectorized watch effort basis. This will be necessary before relative abundance

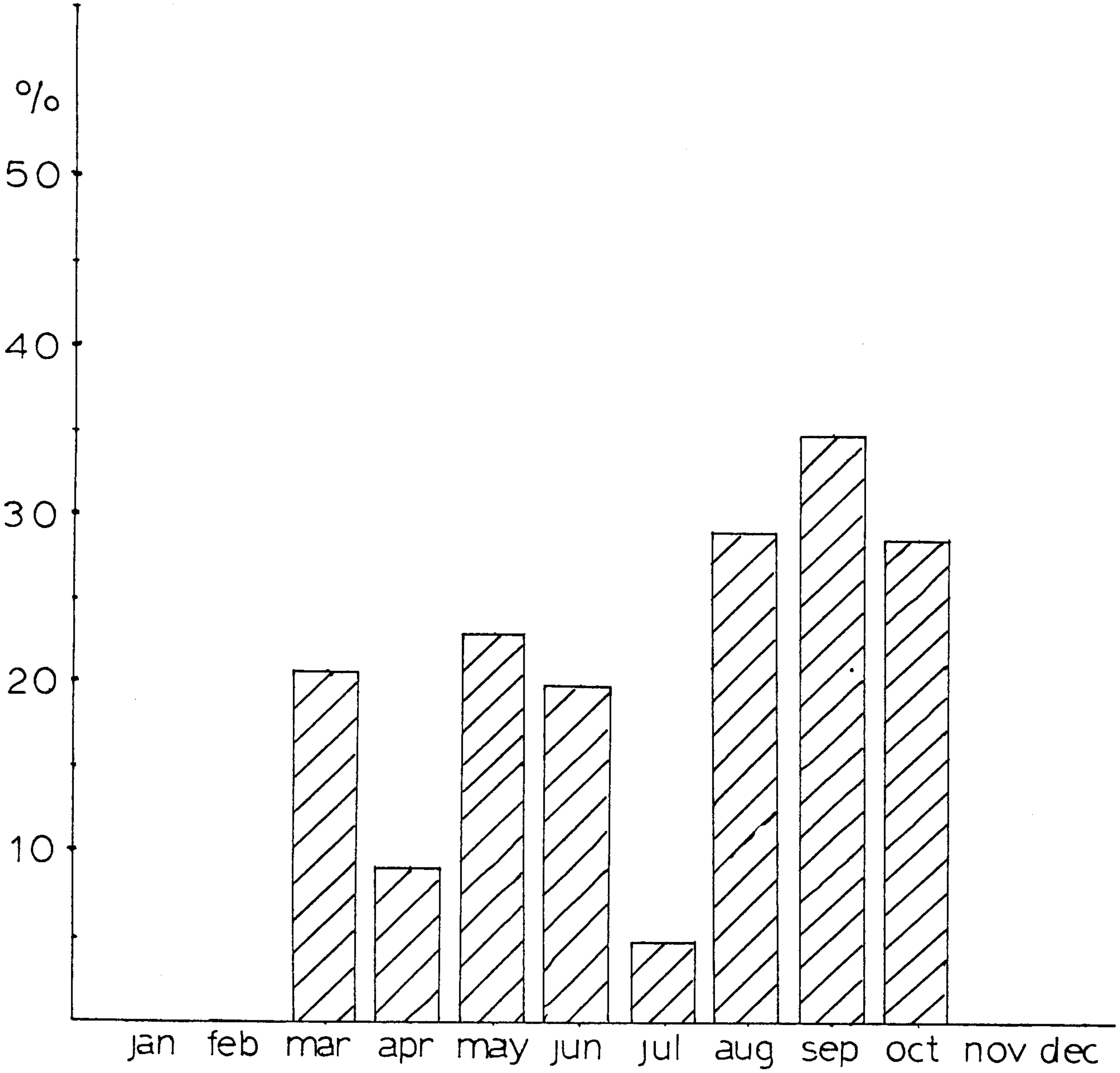

Figure 17. Percentage of Dall porpoise(*Phocoenoides dallii*) sightings of all reported sightings for each month from Kodiak to Unimak Pass.

estimates can be made. At present plans are being made for a complete sectoring of the data by species by month. Some apparent patterns are already beginning to emerge from the data but further testing of currently held hypotheses will be necessary before any definitive conclusions can be made.

VIII. Conclusions and Recommendations

The most glaring deficiency in the research now conducted in the western Gulf of Alaska is the paucity of information, and of vessel cruises, into the area from Unimak Pass to the Aleutian Oil lease area.

A second concluding remark deals with establishment of data gaps. During the January 1977 NEGOA synthesis meeting in Anchorage, Alaska, one of us (Braham) developed a table which depicted areas of the NEGOA where no information existed (Table 2). A similar kind of analysis of the western GOA will be made soon. The important point here is that for the NEGOA data, gaps existed in the areas considered most productive for marine mammals, and during that time of the year (June-September) when sightings should be at their peak. Although we are not now actively researching the NEGOA, it is apparent that much more information on cetaceans is needed. Such information is vital if we are to gain a better understanding of pre-development conditions.

IX. Needs for Further Study

1. Some additional funding for computer processing and analysis of non-OCSEAP data now held by RU 68 may be necessary.

2. Watch effort data need to be extracted from the data base and used to make density estimates.

3. More data are needed from the proposed lease areas south of Unalaska and Umnak Islands. Aerial surveys of this area for the near-shore environs, and vessel cruises offshore, might prove to be the most expeditious method of sampling this area for marine mammals. Correlation of shipboard sighting data with aerial data from the same areas and time frames should be attempted in an effort to ground truth.

4. Information is needed to help resolve gray whale migration routes during their fall southward migration. In November such information might be collected from the Unimak Pass area by a vessel with helicopter.

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X. Summary of 4th quarter operations.

A. Ship or laboratory activities.

1. Ship schedules.

NOAA ship DISCOVERER | MMD Observer
Leg I: 21-26 February, Homer/Kodiak | None
Leg II: 1-10 March, WGOA | None
Leg III: 13 March-1 April, NEGOA | None
Marine mammal officier: Ensign Susan Ludwig

NOAA ship MILLER FREEMAN
Legs I-III: 18 January-25 March, NWGOA and Bering Sea,
Marine mammal officier: Ensign Patrick Rutten
Marine Mammal Division: Patrick McGuire (Leg III)
NOAA ship SURVEYOR
Leg I: 25 February-11 March, NEGOA/Kodiak
Leg II: 15 March-8 April
Marine mammal officier: Ensign Lewis Consiglieri

Ships which have no Marine Mammal Division employees on board will provide a marine mammal officer who will oversee logging of marine mammal observations in the Marine Operations and Station Abstract.

Labratory activities.
All efforts in RU 68 have been directed toward computerization and verification of data from 1976 and 1971-1974. 1975 data were logged during 1976, but have been re-verified since January, 1977. Data from the following non-OCSEAP vessels have been logged during the fourth quarter:

AREA	VESSEL /GROUP	DATES
Bering, N. Pac.	Foreign Ves. Prog.	1972-1976
GOA, BERING	OREGON	10-24 October 1973
GOA	THOMAS G. THOMPSON	25 July-14 Sept.1973
GOA, BERING	RV TORDENSKJOLD	3 June-17 Aug. 1973
GOA	DAVIDSON	5 May-31 October 1974
GOA,LCI	MCARTHUR	18 March-9 Nov. 1974
GOA	RAINIER	15 May-29 Aug. 1974
GOA,PWS	DAVIDSON	18 May-2 Aug. 1976
NEGOA	RAINIER	23 June-21 Sept. 1976
GOA, BERING	FEDERAL ENFORCEMENT	1972-1976
SE AK, PW SND	US FOREST SERVICE	13 June-29 Aug. 1973
SE AK, PW SND	US FOREST SERVICE	21 June-23 Aug. 1974
GOA, LCI	FAIRWEATHER	20 April-21 Aug. 1975
PW SND, GOA	MACARTHUR	6 May-16 Aug. 1976
SE AK, PW SND	US FOREST SERVICE	15 June-13 Aug. 1971
SE AK, PW SND	US FOREST SERVICE	20 June-17 Aug. 1972
GOA, BERING	HALIBUT COMMISSION	7-23 June 1972
GOA	KELEZ	27 July-6 Sept. 1971

AREA	VESSEL	DATES
NWGOA, BERING	OREGON	14 April-14 July 1974
NWGOA	TORDENSKJOLD	19 June-4 Aug. 1976
GOA, BERING	FEDERAL ENFORCEMENT	10 Jan.-6 Oct. 1974
GOA	TORDENSKJOLD	28 May-16 Aug. 1974
E. ALEUTIANS	MV MARK I	24 Jan.-10 Mar. 1974
GOA, LCI	RV RESOLUTION	24 April-20 Oct. 1974
GOA, PW SND	MV MONTAGUE	12-19 Sept. 1974

Data collected from OCSEAP supported NOAA ships were tabulated and placed into computer files during the fourth quarter. The ships cruises and geographic area of research are summarized in table

2. Scientific party.

Patrick McGuire, Marine Mammal Division, Seattle, Wahington. Observed on the MILLER FREEMAN cruise, Leg III, 12-25 March, 1976.

3. Methods.

See annual report.

4. Sample localities/ship or aircraft tracklines.

OCSEAP vessels and areas of operations are listed in section A 1. Coast Guard vessels operating in the Kodiak to Unimak Pass area also record marine mammal sightings as a part of MMD's Platforms of Opportunity Program. The general location of the MILLER FREEMAN cruise, Leg III, 12-25 March, was in Bristol Bay near the ice front. Specific information on this cruise will be reported on in the next quarterly report.

5. Data collected or analyzed.

All data concering the Kodiak region, reported and discussed in the annual report, were examined during the fourth quarter. Computer listings have been prepared of all data from cruises listed in section A 1, and in table 3. These listings have been verified against the raw field logs and corrections made as appropriate. Approximately 8,000 sighting records are now computerized and ready for plotting and analysis.

6. Milestone chart and data submission schedules.

Plots showing species by season and areas of high seasonal abundance of most species will be completed by June 1, 1977. Correlation of sighting data with watch effort should be complete also by June 1. Conversion of data to OCSEAP File Type 027 format for submission to NODC will be accomplished by June 1. All RU 68 data collected up to April 30 is expected to be available for submission to NODC by June.

MILESTONE CHART

Activity	April	May	June	July
*DISCOVERER cruise, Bering Sea	X——	——	——X	
*SURVEYOR cruise, Bering Sea			X——	——X
Complete transformation of stored OCS data to EDS format	X——	——X		
Quarterly report			X——X	
Logging, processing and analyzing rough data from OCS and non-OCS vessels	X——	——	——	——X

* These vessels will be traversing our study area, from Kodiak to Unimak Pass. One to two observers aboard.

B. Problems encountered/recommended changes

Most problems encountered in the field of data processing have been solved. Work is progressing slowly on analysis of the data now in computer files due to insufficient funding. More and higher quality data could be obtained from OCSEAP vessels if funds were availabe to hire two additional observers and for continued laboratory data analysis.

C. Estimate of funds expended.

Salaries	$ 6,197.00
Equipment	39.84
Travel	469.15
Per Diem	450.00
Misc.	2.84
	$ 7,158.83

Table 3. OCSEAP contract vessels utilized in 1976.

1. NOAA ship Discoverer

LEG	Dates	Area
I	24-28 Feb.	PMC-Kodiak
I	2-12 Mar.	NGOA
II	16-30 Mar.	NGOA
III	6-13 Apr.	Lower Cook Inlet & Prince Wm. Sound MMDO: Marsha Caunt
IV	14-30 Apr.	NGOA
V	6-9 May	Cook Inlet
VI	12-20 May	NGOA
VII-VIIA	25 May-1 June	Lower Cook Inlet & Prince Wm. Sound to PMC
	15-19 July	PMC-Kodiak MMDO: David Withrow
I	19-31 July	NGOA, Prince Wm. Sound, Resurrection Bay
II	4-17 Aug.	Kodiak-WGOA-Bering-Norton Sound-Kotzebue Sound - Bering Strait-Chukchi Sea
III	19 Aug.-1 Sep.	Norton Sound-Chukchi Sea MMDO: Renee Engle
IV	8-24 Sep.	Norton Sound-Chukchi Sea MMDO: Renee Engle
V	27 Sep.-6 Oct.	Norton Sound
VI	14-24 Oct.	Shelikof Strait, NGOA-PMC

Assigned ship's officers: Ens. Christine Wencker
Ens. Susan Ludwig

2. NOAA ship Miller Freeman

LEG	Dates	Area
	24 Jan.-10 Feb.	GOA
I	2-15 Apr.	Eastern Bering Sea
II	24 Apr.-13 May	Eastern Bering Sea
III	18 May-4 June	Eastern Bering Sea

Table 3 (cont.)

IV	6-23 June	Eastern Bering Sea - PMC MMDO: Ken Raedeke
	25-29 Aug.	PMC - SEGOA
I	31 Aug.-24 Sep.	Norton Sound, Chukchi Sea
II	28 Sep.-14 Oct.	Norton Sound, Chukchi Sea
III	19-30 Oct.	Cook Inlet
IV	1-19 Nov.	NEGOA, Lower Cook Inlet, NWGOA

Assigned ship's officer: Ens. Patrick Rutten

3. NOAA ship Surveyor

LEG	Dates	Area
	8-12 Mar.	PMC-Kodiak MMDO's: Howard Braham, Bruce Krogman, Bob Everitt, Carl Brooks, Pat McGuire, Keith Parker
I	12 Mar.-2 Apr.	Kodiak, east Bering Sea MMDO: Bob Everitt
II	13-30 Apr.	Kodiak, east Bering Sea MMDO: Pat McGuire
IV	11 May-3 June	GOA
V	5-20 June	Kodiak, Pribilof Islands, Aleutian Islands MMDO: Carl Peterson
	20-25 June	Kodiak-PMC MMDO: Carl Peterson
	27-31 July	PMC-Kodiak
I	1-20 Aug.	Kodiak, Norton Sound
II	24 Aug.-3 Sep.	Cook Inlet & Prince William Sound
III	7-16 Sep.	NEGOA & Prince William Sound MMDO: Ron Sonntag
IV	20 Sep.-2 Oct.	Lower Cook Inlet & Kodiak area
V	5-14 Oct.	NWGOA (Kodiak area)
VI	18-29 Oct.	Kodiak, Aleutian Islands, Amak MMDO's: Roger Mercer, Carl Peterson, Bruce Krogman, Bob Everitt, David Rugh
VII	15 Nov.-14 Dec.	PMC-Mexico and return

Assigned ship's officer: Ens. Louis Consiglieri

ANNUAL REPORT

Contract No. R7120807
Research Unit 69
Period: 1 April 1976 to
31 March 1977
22 pages

Bowhead (Balaena mysticetus) and Beluga (Delphinapterus leucas) whales in the Bering, Chukchi and Beaufort Seas

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March 25, 1977

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I. Abstract

Spring survey findings indicate that significantly fewer belugas than bowheads are seen using the ice camp census method. Also, for the amount of time surveyed, more of both species were seen using aerial survey than ice camp. This latter finding may be an artifact of sampling. We predict that the ice camp method of censusing bowheads would be more cost productive than the aerial method, due to the extremely high costs of the latter. Aerial survey methods are better, however, for delineating distribution, whereas fewer abundance estimate biases occur using ice camp counting methods.

Reproductive activity in the bowhead whale was observed in early May near Pt. Barrow, Alaska, indicating that this species may calf and breed during the northward migration.

Bowheads congregate in an area near-shore during September, for reasons that are not yet clear. The region from Smith Bay to Pt. Barrow should be off limits to any exploration until the area can be further studied.

A hypothesis is proposed that an unknown segment of the bowhead whale population migrates north past Pt. Barrow in the spring and continues north to Banks Island, Canada, before entering the southeast Beaufort Sea, rather than migrating east in near-shore leads along the north coast of Alaska. Circumstantial evidence is offered which supports this hypothesis.

We have evidence to indicate that beluga whales may not be as ice limited as first thought, as sightings have placed animals deep in the spring and summer pack ice. Also, numerous hummocks in thin ice (made by belugas) have been observed, indicating that (directional) movement occurs under the ice.

II. Introduction

This report represents the culmination of the first year of research on the distribution and abundance of bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales in the Bering, Chukchi and Beaufort Seas, as part of the Outer Continental Shelf Environmental Assessment Program. The research reported on stems from contracts under Research Units 69 (FY 1976 and 1977) and 70 (FY 1975-76) administered by the Environmental Research Laboratory, National Oceanic and Atmospheric Administration in Juneau, Alaska, and Boulder, Colorado. Funds were provided by the Bureau of Land Management, U. S. Fish and Wildlife Service.

The purpose of this report is to provide a summary of the known information on bowhead and beluga whale distribution by integrating published and unpublished accounts with sighting data collected by us during 1976. The report serves as our first annual report of combined work effort for the Bering Sea and Arctic Ocean research on the two species. Our intent is to provide a document which can be rapidly transmitted to other scientists, managers and administrators who are in a decision or policy-making position.

Bowhead and beluga whales are thought to be particularly vulnerable to the activities of oil-gas development because they migrate within a small corridor of the Chukchi and western Beaufort Seas in near-shore leads (open water in the ice). The fact that they are seasonally harvested, and that any estimate of their population size is purely conjecture, it is not only prudent but essential that these animals be intensively studied. Since the bowhead is fully protected under the Marine Mammal Protection Act of 1972 (MMPA) and the Endangered Species Act of 1973, and the beluga under the MMPA, private and public energy development groups are obligated to determine which, if any, energy-related activities might be detrimental to both species, their habitats and trophic needs. To this end, we expect that during the next two to three years, habitat requirements will be delineated relative to local movements and migration.

Research on the bowhead whale began at the Marine Mammal Division in 1974 (Fiscus and Marquette, 1975). Biological data from animals harvested by Eskimos have been essentially the only kind of information collected under this program. To date, there are no quantitative data on the numbers of bowhead and beluga whales which migrate in shore-leads from the Bering Sea into the Chukchi and Beaufort Seas. It was principally because of this data gap that our research under OCSEAP was initiated.

The experimental plan to delineate distribution and relative abundance was to combine the data collected by a census team stationed on the shore-fast ice near the Eskimo hunters, with data collected by aerial survey observers. Independent estimates by each survey method are then compared to establish overlap and/or variability and reliability of the data.

For the 1977 field season (April-June) two census crews, instead of one as in 1976, will be stationed on the ice; one in the Chukchi Sea and one at the entrance to the Beaufort Sea. An unknown component of the bowhead and perhaps the beluga population may migrate north into the northern Chukchi Sea rather than east along the north coast of the Beaufort Sea. Hence, independent estimates of the numbers of animals which migrate past these two camps will provide a comparative data base for understanding the movements of these animals into the Arctic Ocean.

This report is divided into seven sections: Introduction, Current State of Knowledge, Study Area, Data Collection Procedures, Results and Discussion of the 1976 Field Season, and Conclusions and Recommendations. The Current State of Knowledge section will provide a brief historical account of the available information from published and unpublished literature. An update of distribution, and an estimate of how many bowhead and beluga whales were believed to pass through our census study area near Barrow in 1976 will be reviewed in the Discussion section. The Discussion section will also include heretofore unsummarized data collected on bowhead whales by other scientists during fall surveys in 1974 and 1975. In the Conclusions and Recommendations section projections are made from very limited data as to important areas of concern for each species.

III. Current State of Knowledge

Beluga whale

The beluga or belukha whale (Delphinapterus leucas) is usually found in shallow bays or estuaries north of 40° N. Latitude. In Alaskan waters there are at least two resident populations: one is localized around Cook Inlet and consists of 300-400 animals; the other is in the vicinity of Bristol Bay and numbers perhaps 1,000-1,500 individuals (Klinkhart, 1966). Belugas begin a northward migration to arctic waters in April, and tend to travel in large herds (Bailey and Hendee, 1926). Kleinenberg et al. (1964) have recorded a pod of 500-600 animals, and Johnson et al. (1966) report seeing groups of 100 animals in the southern Chukchi Sea.

Like the bowhead, this species follows leads in the pack ice which extend into the Bering Sea and Arctic Ocean. Once through the Bering Strait, it appears some animals move along the Siberian coast (Kleinenberg et al., 1964) while others move along the Alaskan coast. It remains to be determined how much of the entire population moves north in the late winter in the western Bering Sea, as opposed to the eastern Bering Sea. Depending on ice conditions, the first belugas appear off Pt. Hope sometime between the end of April to the middle of May (Fiscus and Marquette, 1975), although other records for the southern Chukchi Sea exist for February and March (Kleinenberg et al., 1964). Whales are believed to be still moving north in July as evidenced from hunting records at Pt. Hope (Foote and Williamson, 1966). In the Kotzebue Sound region, belugas have been reported at Sheshalik, across Hotham Inlet north of Kotzebue (Foote and Williamson, 1966). Belugas are believed to concentrate for purposes of breeding and calving in southeastern Kotzebue Sound (U.S. Department of the Interior, 1974, in AEIDC).

By May and June, some belugas have reached the eastern Beaufort Sea and the pack ice around Banks Island (Sergeant and Hoek, 1974), as well as along the eastern Siberian coast (Klinkhart, 1966). It is unclear what portion of the population arriving at Banks Island comes from Alaskan waters. During the summer and fall, belugas enter river estuaries as soon as the ice moves offshore (Klinkhart, 1966; Fraker, 1977). On 24 June 50 belugas were observed at the mouth of Pitmegea River just northeast of Cape Lisburne (Childs, 1969, in AEIDC). In a July aerial survey, Sergeant and Hoek (1974) reported up to 5,000 belugas near the Mackenzie River delta. Fraker (1977) reported between 5,000-6,000 animals during a July 1976 survey of the Mackenzie River delta.

The fall migration commences in September from the Mackenzie delta (Sergeant and Hoek, 1974) but the precise direction of travel is as yet unclear. Fraker (1977) supports the hypothesis that most belugas in the Mackenzie River delta area come from the east, the Canadian side, rather than from the Chukchi Sea. Since belugas are not able to maintain breathing holes in thick ice, and generally do not swim long underwater (Fraker, 1977), they probably precede the fall freeze-up (LeResche and Hinman, 1973). It is believed that the Bering Sea is the wintering ground for beluga from the Siberian, Canadian, and Alaskan arctic, although data are lacking.

Klinkhart (1966) records a seasonal shift in feeding habits. While offshore the beluga presumably feeds on a variety of fish, especially arctic cod, crustaceans and squid. It is believed that when they move inshore, they feed first on fingerlings moving down rivers, and later in the season they prey on adult salmon moving up river to spawn.

Bowhead whale

Bowhead whales (*Balaena mysticetus*) migrate from the Bering Sea into the Chukchi and Beaufort Seas from mid-April to early May (Berzin and Rovnin, 1966; Durham, 1972). They generally begin passing through the Bering Strait as early as late March and early April, as evidenced by sighting and harvest records at Wales (Bailey and Hendee, 1926) and at Cape Thompson (Johnson et al., 1966). Their arrival at Barrow, Alaska, can vary by two weeks (Maher and Wilimovsky, 1963; Foote, 1964; Fiscus and Marquette, 1975) and is probably dependent upon ice conditions. In the southeastern Chukchi Sea the migration is believed to occur in "waves": the first and second waves are comprised of young or smaller animals, and the third wave is made up of adults (Maher and Wilimovsky, 1966; Druham, 1975; Marquette, 1976). The end of the migration past the northwest coast of Alaska (Pt. Hope and Barrow) is unknown because ice conditions generally do not permit observers the opportunity to remain on the ice past mid-June.

Bowheads are reportedly at Banks Island in the Canadian Arctic by mid-May, where they can be found all summer (Sergeant and Hoek, 1974; Fraker, 1977). No information exists for the period from early June through August in the western Beaufort Sea, however. Fiscus and Marquette (1975) record the first catch of the fall Eskimo whaling season in September in the western Beaufort Sea. Early commercial whaling records indicate that the period of July-September was the favored time to hunt bowheads in the northern Bering-southern Chukchi Seas, and eastern Beaufort Sea. Fraker (1977) has recently completed a brief but good summary of our present knowledge with respect to bowhead commercial whaling records in the Beaufort Sea.

The population size of the bowhead whale appears to be open to conjecture. Rice (1974) estimated the population at 4,000-5,000 animals between 1868 and 1884. Since their decline brought on by the whaling industry in the early part of this century and last part of the nineteenth century, very few population estimates have been made. Sergeant and Hoek (1974) estimated the number in the Beaufort Sea to be "in the low hundreds". In August and September of 1976, Fraker (1977) reports that about 80 sightings were made (probably includes duplicate sightings) north and east of the Mackenzie delta area in the eastern Beaufort Sea.

Since there is very little evidence to suggest a precise migration route for the bowhead past Barrow, the question of timing and seasonal distribution remains open. Undoubtedly, some animals remain in the northeastern Chukchi Sea, just as some remain in the Banks Island area while others are found along the north coast of Canada. The number of animals which summer in the U.S. and Canada remains to be quantified.

Bowheads are believed to feed on copepods and euphausiids (*Calanus hyperboreus*, *Parathemisto libellula* and *Thyanoessa inermis* and *T. rauschi*). Because their numbers are so few, they are not believed to be food limited (Sergeant and Hoek, 1974).

IV. Study Area

The study area includes the northern Bering Sea from St. Lawrence Island essentially from the US-USSR 1867 Convention line east over the continental shelf, north into the Chukchi Sea to approximately 72°N. Latitude, and east into the Beaufort Sea to the U.S.-Canadian border at 141° W. Longitude.

Aerial surveys in the Beaufort Sea generally took place within 50 km of shore, because,we thought, open water leads do not normally occur far from land. In the Chukchi Sea, however, surveys were flown offshore in the spring to delineate offshore leads. The most heavily surveyed area of the Arctic Ocean was between 69° N. Latitude and 72° N. Latitude to within a few kilometers of shore.

The two census camps were located on the shore-fast ice approximately eight miles northwest of Pt. Barrow and eight miles west of the village of Barrow (Figure 1). The south ice camp was used primarily during the early part of the season (April-May) and the north camp later in the season (May-June). The two camps were only once simultaneously occupied. Working in concert, the ice-based camp and aerial surveys maximized our chances of providing the geographic coverage necessary to delineate bowhead and beluga movements along the northwest coast of Alaska.

V. Materials and Methods

Aerial survey

Aerial surveys over the pack ice and open leads were conducted at elevations of 200 to 1,000 feet depending upon cloud conditions. The aircraft used was a twin engine Grumman otter chartered from the Naval Arctic Research

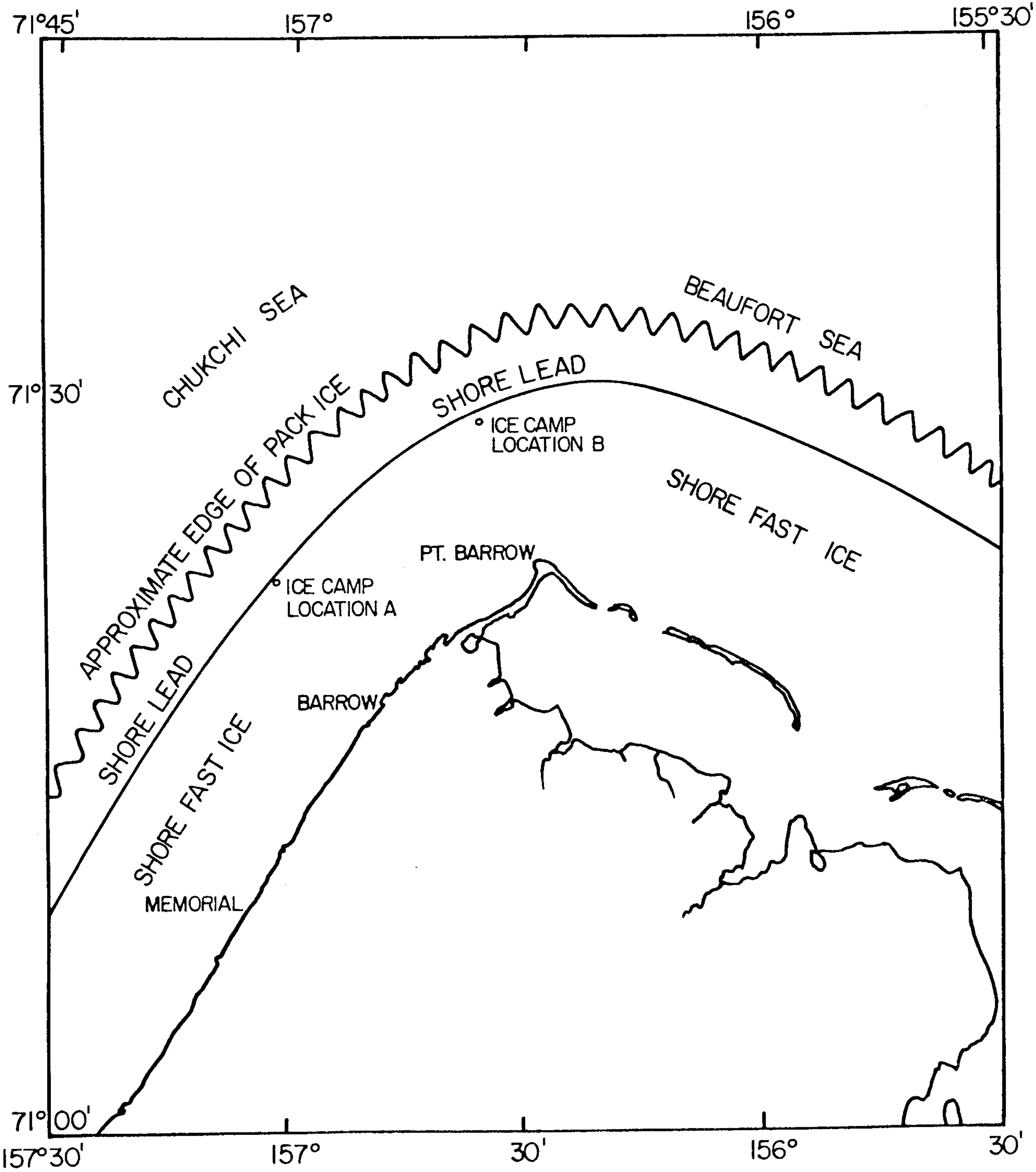

Figure 1. Study area map of bowhead and beluga whale census camps on the shore-fast ice northwest (Location A) and north (Location B) of Barrow, Alaska.

Laboratory. An on-track nagivational system was available on the Otter, providing a means of locating our position to within 1 nmi^2. This was important because we attempted to determine the width of the lead and its geographic position in relation to the shore (for later plotting).

Two to three observers (plus the pilot) were used, each acting as his own recorder and noting the details of each sighting plus environmental conditions. Communications between observers were poor, but will be improved in FY 77 with the addition of an intercom system (see RU 67 Annual Report). One observer sat in the co-pilot's seat, and acted as the "chief spotter" and photographer. A single lens reflex 35 mm F2 Nikon camera was used with the aid of 105 and 135 mm lenses using high speed Ektachrome film (ASA 160) to verify species identification (e.g., with some seals) and group sizes (e.g., beluga).

Data scored in the field were transferred to computer abstract forms in the laboratory.

Ice camp

Counts of bowhead and beluga whales were made by observers standing on the ice next to the shore-fast lead. As whales migrated within the lead, the number of animals, direction, behavior, and other factors such as weather conditions, time of day, etc., were recorded. Two observers stood watch together, and a 24-hour watch was maintained using six to eight hours rotating shifts. Photographs were taken using the same camera system as described above to verify species and note behavior and lead conditions.

Two camps were used during the season (Figure 1), and were simultaneously occupied only once. One camp was used when the ice conditions near the other were unsafe. The camping facilities were made approximately 1/4 to 1/2 mile back from the shore-fast lead. The pair of whale counters thus were some distance from the base camp. Radio communications and emergency gear were therefore a critical part of the program as ice and weather conditions can change abruptly.

Data were scored on a standardized field log sheet and maintained on a continuous basis as each watch period changed.

Laboratory

As with all marine mammal sighting data, a system of logging, checking, editing and final processing was developed. A description of the procedures and flow diagram of the four-phase program are described in our FY 76 quarterly report for July-September 1976.

VI and VII. Results and Discussion

Aerial survey and ice station census sighting data on bowhead and beluga have been summarized in Table 1 and Figures 2 and 3. The aerial survey tracklines are covered in detail in the April-June 1976 quarterly report, as are the details of each flight.

Bowhead whales. Of the 346 bowhead whales observed at Barrow during the spring 1976 survey, 248 were seen by the ice station crew and 98 by Eskimos near the census crew's camp (Table 1, Figure 2). Eskimo sightings were considered independent of ours, yet positive in their identification. (See the October-December 1976 RU 69/70 quarterly report for a discussion of the Eskimos' role in counting bowheads.) Some 108 bowhead whales were observed from the air during approximately 93 hours (maximum) of air time. About 360 hours (minimum) were spent by the census crew on the ice counting whales. Using non-parametric chi-square analysis, it was more efficient to observe bowheads from the air than from the ice station. That is, more bowheads were seen for the time spent in the air than would be expected by chance (x^2: $P < 0.01$). However, aerial survey data contain duplicate sightings. Thus, the above analysis is biased.

An important component of the bowhead whale sightings during the spring related to three or four "pulses" of increased sightings (Figure 2). On about 1, 6, 18 and 22 May, larger numbers of bowhead whales passed the census camp than during other days. Although it has been suggested that "waves" of migrating animals occur, our data tend to show that the "waves" or pulses are closely related to weather. Just prior to each major increase in the numbers of animals seen, the lead was essentially closed. On 10, 11 and 12 May, no bowheads were seen. On 20 May our crew was not on the ice because the lead was closed. These dates agree with those previous days when only a few animals were seen, and with later days when maximum numbers were seen (Figure 2). Animals appeared to group up in larger pods "waiting" for the lead to re-open. This behavior was witnessed several times during the aerial surveys. Also, we have found no relationship between the amount of time or the specific time of day to the number of animals counted, which suggests that movement of whales is probably dependent upon environmental conditions. So far, we see no pattern to the ways in which these animals are moving past Barrow, but it is important to note that our data are preliminary.

Aerial survey and ice census counts show that the majority of bowheads migrating past Barrow in 1976 did so during the first half of May. Fewer animals were seen during the last half of May and first few days of June than earlier in the season, primarily because of ice conditions. Whales were still moving by in June, however, as 26 animals were seen by the aerial survey team (17% of total) after the last census camp had reduced operations considerably (after 26 May).

Computer plotting of the spring 1976 data did not materialize for this report. Once these sighting data are plotted, we will have a better idea of the overall pattern of distribution during the spring.

Table 1. Number of bowhead and beluga whales sighted by the ice station census crew, by Eskimos, and by the aerial survey team. See text for an explanation of the Eskimos' role in the "census". Dashed spaces mean no surveys took place; blank spaces mean no animals were observed.

	Number of Bowheads			Number of Beluga	
Date	Ice Crew	Eskimos	Aerial Crew	Ice Crew	Aerial Crew
25 April	3	2	-		-
29 "	11	6	4		248
30 "	7	10	-		-
1 May	17	3	6		48
2 "	3	6	-		-
3 "	1	1	3		67
5 "	11	9	-		-
6 "	16	19	-		-
7 "	8	1	-		-
8 "	4	1	34		85
9 "	2		5		27
10 "		1	-		-
11 "			-		-
12 "			2		
13 "	10	7	-		-
14 "	5		-		-
15 "	11	3	18		134
16 "	18	11	-	2	-
17 "	26	9	-		-
18 "	52	9	-	100	-
19 "	1		3		8
20 "	-	-		-	20
21 "	4		-		-
22 "	19		4	207	129
23 "			-		-
24 "	9		3		1
25 "	1		-		-
26 "	6		-		-
28 "	-	-	1	-	
31 "	1		4		1
1 June	1		3		144
2 "	1		-		-
4 "	-	-	15	-	35
5 "	-	-	2	-	
18 "	-	-		-	12
19 "	-	-	1	-	61
20 "	-	-		-	

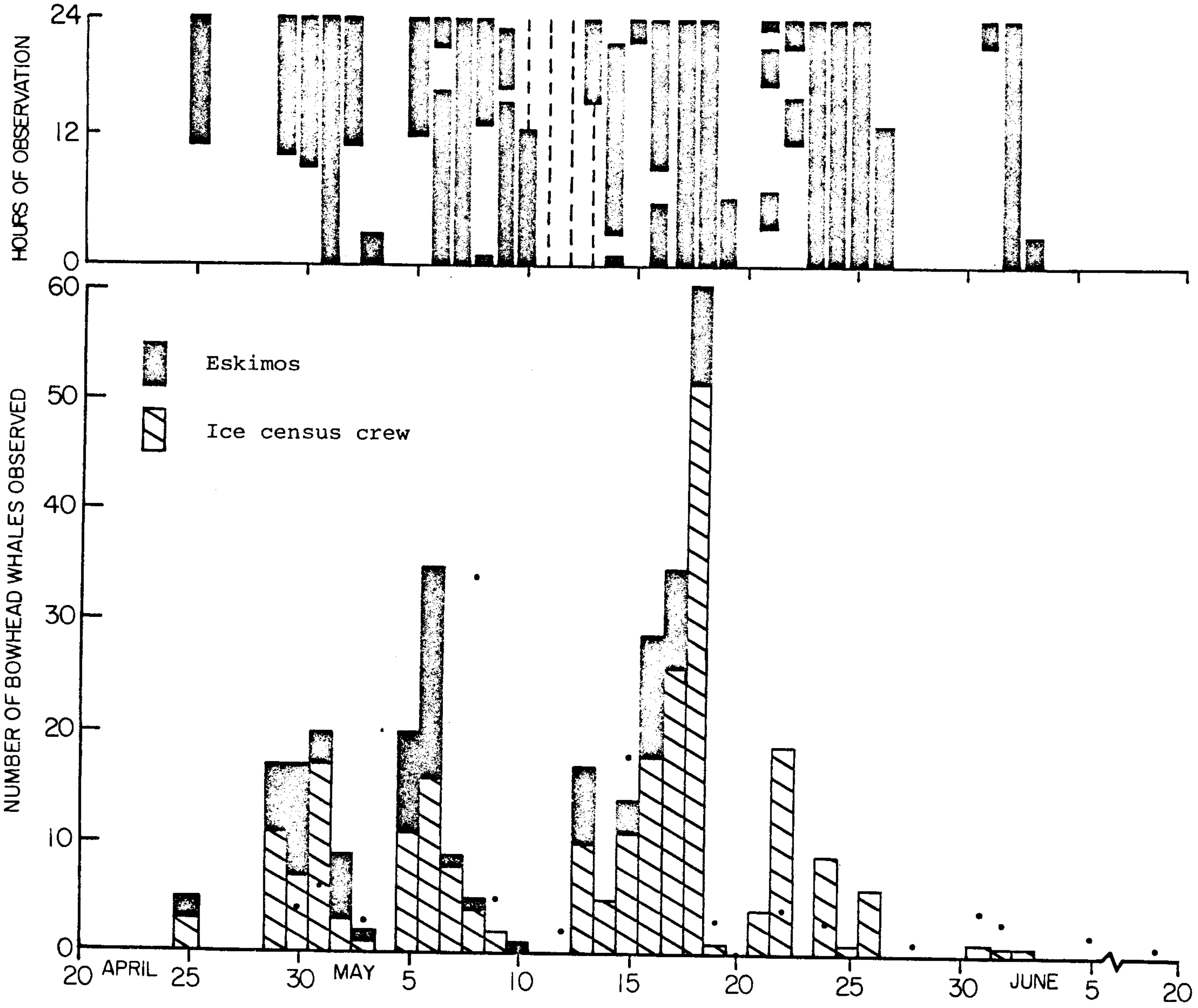

Figure 2. Histogram of the numbers of bowhead whales observed along the shore-fast ice lead at Barrow, Alaska, 1976. Sightings are related to the hours in the day when the census crew was observing. The dots (·) are the number of bowheads seen by the aerial survey team on that date.

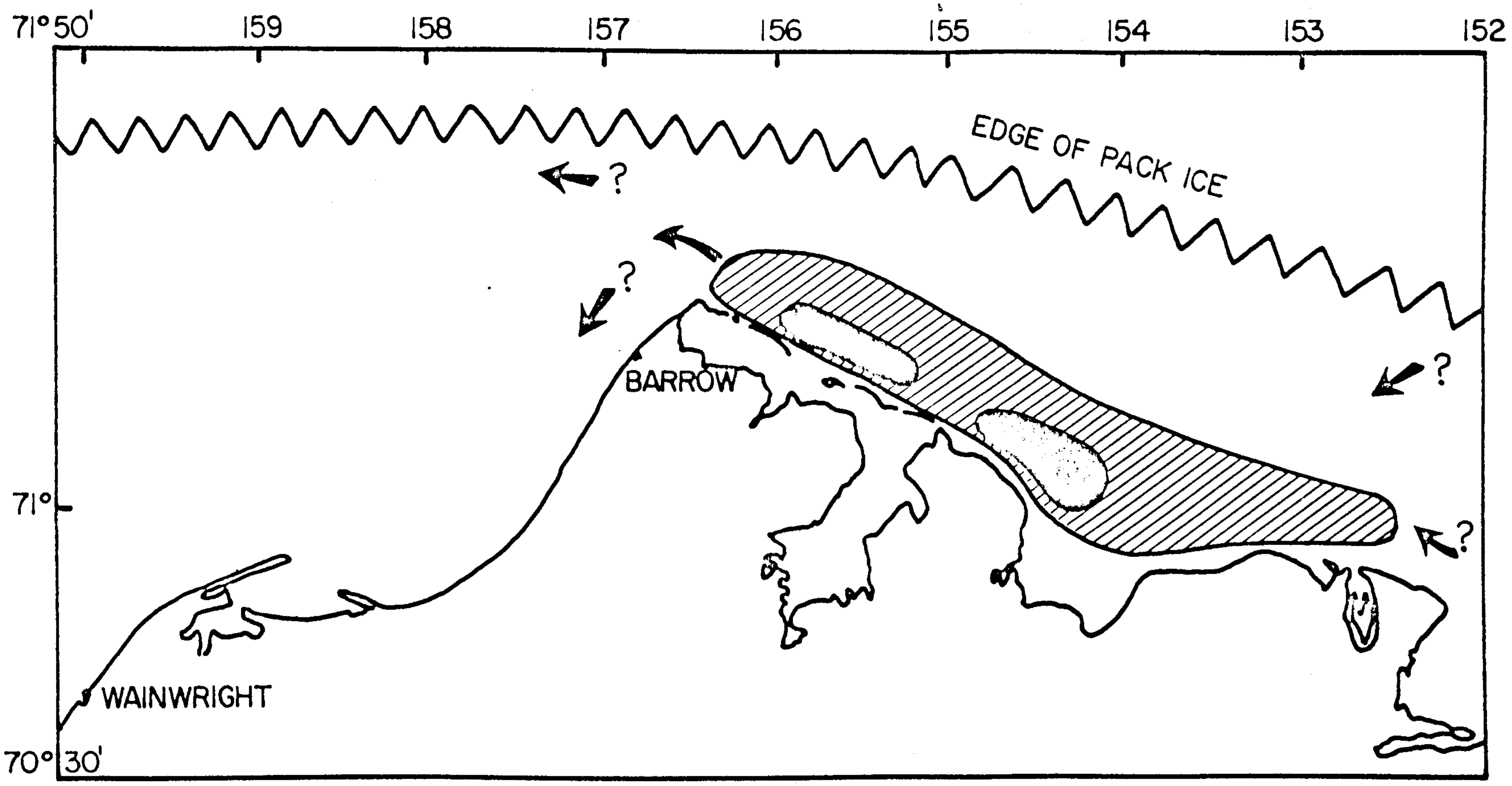

Figure 3. Area map of the northwest coast of Alaska depicting the region where bowhead whales are concentrated during the fall. Darkened areas are areas of highest density; hatched areas, where animals are less dense. Movement into and out of this region remains unclear.

Bowhead sighting data during the fall are minimal. Fiscus (unpublished) sighted bowheads near Cape Simpson between 12 and 22 September 1974. The highest number seen was 57 on 18 September. No sightings occurred during the fall of 1975 because of poor ice conditions. Between 16 and 26 September 1976, Robert Everitt sighted over 100 bowhead whales in the same general area as the 1974 sighting by Fiscus. The greatest single day's sighting was 47 on 21 September 1976. From these sightings it would appear that the Smith Bay to Pt. Barrow area represents a very important area of congregation for bowheads prior to their southern migration. This apparent "critical" area is outlined in Figure 3. The darkened areas are where the greatest numbers of animals were seen in both 1974 and 1976; hatching marks the areas where bowheads were less dense, yet numerous.

Sighting data exist from other OCSEAP contractees as well. In August 1975 C. Ray (pers. comm.; RU 34) sighted 74 bowheads northeast of Icy Cape (about 70°30' N. Latitude, 161°00' W. Longitude). He also observed large concentrations of bowhead between Smith Bay and Pt. Barrow, and, in October 1975, Ray (pers. comm.) saw six bowheads in the Chukchi Sea at about 70°30' N. Latitude, 163°-169°30' W. Longitude. Although the data are sparse, they suggest that bowheads move west and south from Pt. Barrow during the fall, probably in September. We have, as does Ray (pers. comm.), some sightings that put bowheads east along the north coast within 100 km of Pt. Barrow, south of Barrow along the coast to Peard Bay, and west into the Chukchi Sea by as far as 100 km -- all within a one-month period. Data collected by Ray in 1975 would suggest that because of the heavy ice year, bowheads moved farther south (Icy Bay) than usual, or that they began their southward movements earlier.

Eleven bowhead whale sightings were reported to us from the southern Chukchi Sea and the Bering Sea during 1976 (Table 2). Two sightings totalling three animals occurred in the western end of Bristol Bay and St. George Basin region. The remaining sightings occurred farther north. Townsend (1935) records bowheads being taken in the central Bering Sea but not generally as far east as the Pribilof Islands and the west end of Bristol Bay.

Berzin (pers. comm.) reports seeing the following bowhead whales on the Soviet side of the 1867 Convention line, 8-11 October 1974-75 (the conflict between these dates has not been resolved).

General location	Number seen
N. W. St. Lawrence Is.	3
S. Bering Strait	5
Bering Strait	2
N. W. Bering Strait	4
N. W. of Shishmaref	3
N. E. Chukotski Pen.	
Cape Serdzekamen	1
Cape Chautau	20
Kolyuchin Is.	60
Cape Vankarem	60
Cape Syeverni	23

Table 2. Summary of the number of bowhead and beluga whale sightings in the Bering and southern Chukchi Seas by date from aerial (A) or vessel (V) surveys during 1976. The general location of each sighting and the individual or survey group reporting the data are included. RU 67 or 69 denotes the OCSEAP research team conducting the survey.

Date	Species	Number of Animals	General Location	Survey Type	Survey Observer
15 March	Beluga	8	N. Bering Sea	A	RU 69
18 "	Beluga	18	N. Bering Sea	A	RU 69
19 "	Beluga	2	N. Bering Sea	A	RU 69
9 April	Beluga	33	E. Bristol Bay	A	RU 67
9 "	Bowhead	1	W. Bristol Bay	A	J. Hall[1]
14 "	Bowhead	1	W. Bering Sea	A	G. Fedoseev[1]
15 "	Bowhead	1	S.W. St. Matthew Is.	A	G. Fedoseev
18 "	Bowhead	1	W. St. Lawrence Is.	A	G. Fedoseev
19 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire[1]
19 "	Bowhead	1	E. St. Lawrence Is.	A	RU 67
19 "	Beluga	4	E. St. Lawrence Is.	A	RU 67
19 "	Beluga	79	N.W. St. Lawrence Is.	A	C. Ray[1]
20 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire
20 "	Bowhead	1	N.W. St. Lawrence Is.	A	RU 69
20 "	Beluga	4	N. Bering Sea	A	RU 69
21 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire
21 "	Bowhead	2	S. Bering Strait	A	RU 69
21 "	Beluga	118	S. Chukchi Sea, N. St. Lawrence Is.	A	RU 69
22 "	Beluga	25	N.W. St. Lawrence Is.	A	RU 69
23 "	Bowhead	1	W. Bristol Bay	A	J. Burns[1]
23 "	Beluga	1	N.E. Norton Sound	A	RU 69
6 May	Beluga	10	W. Bering Sea	A	G. Fedoseev
7 "	Beluga	2	W. Bering Sea	A	G. Fedoseev
12 June	Bowhead	2	S. Chukchi Sea	A	RU 69
13 "	Beluga	18	S.W. Norton Sound	A	RU 67
26 August	Beluga	4	W. Norton Sound	A	RU 67

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[1] John Burns, Alaska Dept. of Fish and Game, Fairbanks, AK
Genadi Fedoseev, TINRO, Magadan, USSR
John Hall, U. S. Fish and Wildlife Service, Anchorage, AK
Patrick McGuire, Marine Mammal Division, Seattle, WA
Carleton Ray, Johns Hopkins University, Baltimore, MD

[2] Probably the same animals.

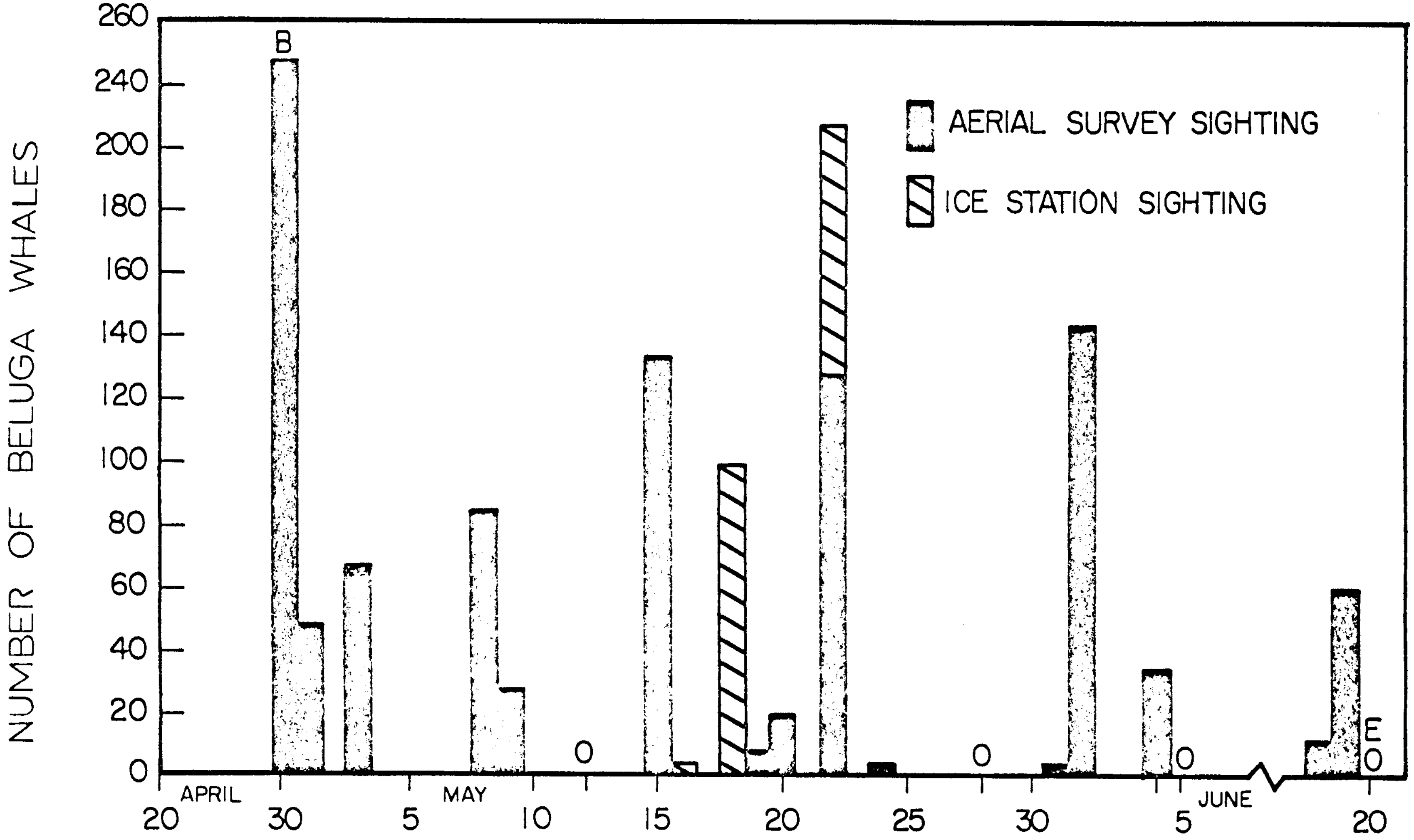

Figure 4. Numbers of beluga whales observed during aerial and ice-based surveys along the shore-fast ice lead between Barrow and Wainwright, Alaska, during the spring of 1976. B and E denote the dates of first and last aerial survey.

From these sightings it would appear that many animals migrate to the northern coast of Siberia before moving south through the Bering Strait. Since few bowhead whales are reported along the Siberian coast during the spring (Fedoseev, Golt'sev and Berzin, pers. comm.), it would appear that the majority of animals during the spring migration move north in the eastern Chukchi Sea, and during the fall (perhaps) move south in the western Chukchi Sea. Additional fall sighting data from the Chukchi Sea is necessary to clarify this point.

Beluga whales. Aerial survey and ice station data on beluga whale sightings during the spring of 1976 are reported in Table 1 and Figure 4. More belugas were seen during aerial surveys (1020) for the amount of time spent sampling (about 93 hours) than were observed by the ice crew (309 animals; about 300 hours) than could be expected by chance (x^2: $P < 0.001$). Hence, aerial surveys were considered a more "efficient" means of observing (counting and delineating) this species. A test for goodness-of-fit between the numbers of bowheads observed by aerial survey and ice camp censusing, compared to beluga observations, indicates that more bowheads were seen from the ice and more beluga from the air than expected (x^2: $P < 0.001$).

At this time, no extrapolation can be made on the number of beluga whales which passed Barrow. The variability in the numbers of animals seen by day (Figure 4) and the fact that some duplication in sightings probably occurred, make it difficult to quantify our sightings. Experiments are being developed for the spring 1977 season using aerial surveys which may prove to be useful for estimating abundance of beluga.

Beluga whale sightings in the Bering Sea and southern Chukchi Sea are reported in Table 2. Most observations occurred in the northern Bering Sea, probably because more surveys were conducted there. C. Ray (pers. comm.); RU 34) reports seeing over 300 beluga whales northwest of Port Moller in Bristol Bay on 13 April 1976. Whether this group, and perhaps the group observed on 9 April (Table 2), are part of the "resident" population in Bristol Bay remains to be explored. The 9 April group was observed in a small polynya within the pack ice. We do not know if the 13 April group was at the ice front or in the pack ice. Ray (pers. comm.) reports that approximately 47 beluga whales were observed northwest of St. Matthew Island during April 1975.

Fall sightings of belugas have been minimal during our 1975 and 1976 aerial surveys of the Chukchi and Beaufort Seas. Sightings from other researchers have been more frequent. In September 1974, Ray (pers. comm.; RU 34) sighted 23 beluga in the western Beaufort Sea northeast of Pt. Barrow. His most significant observation occurred in the pack ice in the area of 73°00' N. Latitude, 162°00' W. Longitude, where "a thousand or more" belugas were seen over the continental slope, where depths of 80-200 m occur. No other details are known. In October 1975 Ray (pers. comm.) reported seeing 175-180 beluga in the southern Chukchi Sea just east of the 1867 US-USSR Convention line.

These data clearly indicate that belugas have the potential to be spread throughout the Chukchi Sea in the fall and the Bering Sea during the spring.

It remains to be seen how much, if any, division occurs between groups of animals during the spring and summer migration north. Belugas are known to occur in rivers and estuaries in Bristol Bay, Norton Sound (Yukon River delta), Kotzebue Sound, and along the northwest coast of Alaska. However, what we need to determine is whether these local population divisions are just that - local - or whether they intermix during the winter months in the Bering Sea.

Sightings of other marine mammals were scored during RU 69 surveys (Table 3) but are not discussed in this report.

VIII. Conclusions and Recommendations

Although a limited amount of data exist from one year of field work, circumstantial evidence indicates that bowhead whales might not migrate in large numbers near shore along the north coast of Alaska into the eastern Beaufort Sea. Instead, we feel that some, at least, continue migrating north into the pack ice to Banks Island and then move south to the coast in the summer. This hypothesis is based on three clues: 1) NOAA satellite photographs indicate that leads form farther off shore than the scope of our surveys (Marko, 1975); 2) bowheads are believed to arrive farther north at Banks Island earlier in the year (May) than south by the Mackenzie River delta (Sergeant and Hoek, 1974; Fraker, 1977); and 3) very little positive sighting data exist for the near shore leads along the north coast of Alaska (although, admittedly, weather has prevented extensive surveys). Also, fall whaling occurs along the northeast coast of Alaska (although limited) in the fall, but not during the spring. This hypothesis needs testing, because, if true, then bowheads would be more vulnerable to oil and gas development activities in the fall than in the spring. This, of course, assumes that the fall migration is westerly through the Beaufort Sea basin, and that the spring migration is northerly, away from the Beaufort Sea basin.

On 8 May 1976, copulatory behavior was photographed by one of our research team (Krogman). To our knowledge, this is the first evidence of this type of reproductive activity in bowheads. This incident took place just northwest of Pt. Barrow, where, on the same day, an apparent female and calf (less than half the size of the cow) were photographed. While we do not know how important the northern Bering-southern Chukchi Seas and Beaufort Sea areas are for bowhead reproduction, the fact remains that these activities have now been observed in or adjacent to the oil lease areas.

Fewer bowhead whales are believed to occur in the Banks Island-Mackenzie River delta area than might be expected given a minimum population of "a few thousand animals" (Rice, 1974). The summer range of the remainder of the bowhead population is unknown.

The Cape Simpson area near Smith Bay, south and east of Pt. Barrow, should be considered, at least temporarily, a "critical" habitat for bowheads, until we can determine why these animals congregate there in the fall.

General survey type studies on beluga whales should probably shift to localized studies after the FY 77 field season. It would seem to be more

Table 3. Marine mammals, other than bowhead and beluga whales, observed in 1976 during aerial surveys of the northeastern Chukchi (C) and western Beaufort (B) Seas. The surveys were conducted out of the Naval Arctic Research Laboratory, Barrow, Alaska. Blanks represent no sightings. (Note: these data include replicate sightings, e.g., polar bears on 20 and 22 May.)

		Pinnipeds				Cetaceans		
Date	Survey Location	Bearded Seal	Ringed Seal	Walrus	Unid.	Gray Whale	Unid.	Polar Bear
30 April	C	60	6					
1 May	B	11						
3 "	B		6					
8 "	B	46						4
9 "	B	20	8					
12 "	B	1	15					
14 "	B				3			
15 "	C	4	2					2
19 "	C	2	13					2
20 "	B	2						34
22 "	B	5	10		2			35
24 "	C	1	1		2			7
28 "	C	7	78					1
31 "	C	5	81					10
1 June	C	1	63					
4 "	B	5	69					
5 "	C		245					
18 "	C		9	619				
19 "	C	4	77	2600	1	2		1
20 "	B		66					
20 August	B					1	2	
21 "	C					4		
23 "	C					6		
16 September	C					1		
20 "	C			2*	38	4		
21 "	B				10	1		
22 "	B			166	4			
23 "	B				1			
24 "	B			28				
26 "	B			1				

* 8 single sightings of dead animals on the beach were made.

cost productive in terms of specific abundance and distribution projections to study specific areas (e.g., Kotzebue Sound, Norton Sound, or Bristol Bay). An alternative would be to develop a tagging or radio tracking program to determine the extent of local movement, or to see if some animals do in fact migrate from the southern Bering Sea to the eastern Beaufort Sea. Another alternative (short-term) study would be fall sampling of the three oil lease areas mentioned above (Kotzebue and Norton Sounds and Bristol Bay) for breeding activities of beluga whales.

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X. Summary of quarterly activities ending 31 March 1977

A. Ship or laboratory activities

1. Ship or field trip schedule. (No activities.)

2. Scientific party. N/A

3. Methods

   a. Final logging, transformation and computerization of all data collected in 1976.

   b. Several complex programs were developed for transformational purposes, and for statistical snalysis on the data (in conjunction with research units 67 and 68).

   c. Inventory evaluation, and purchasing of new equipment for the spring 1977 field season.

   d. Development of experimental design for sampling from the ice station and by means of aerial survey.

   e. Arrangements made for logistic needs; equipment sent to Barrow; personnel hired for both camps (pending NMFS hiring freeze).

4. Sample localities/ship or aircraft tracklines. N/A

5. Data collected or analyzed.

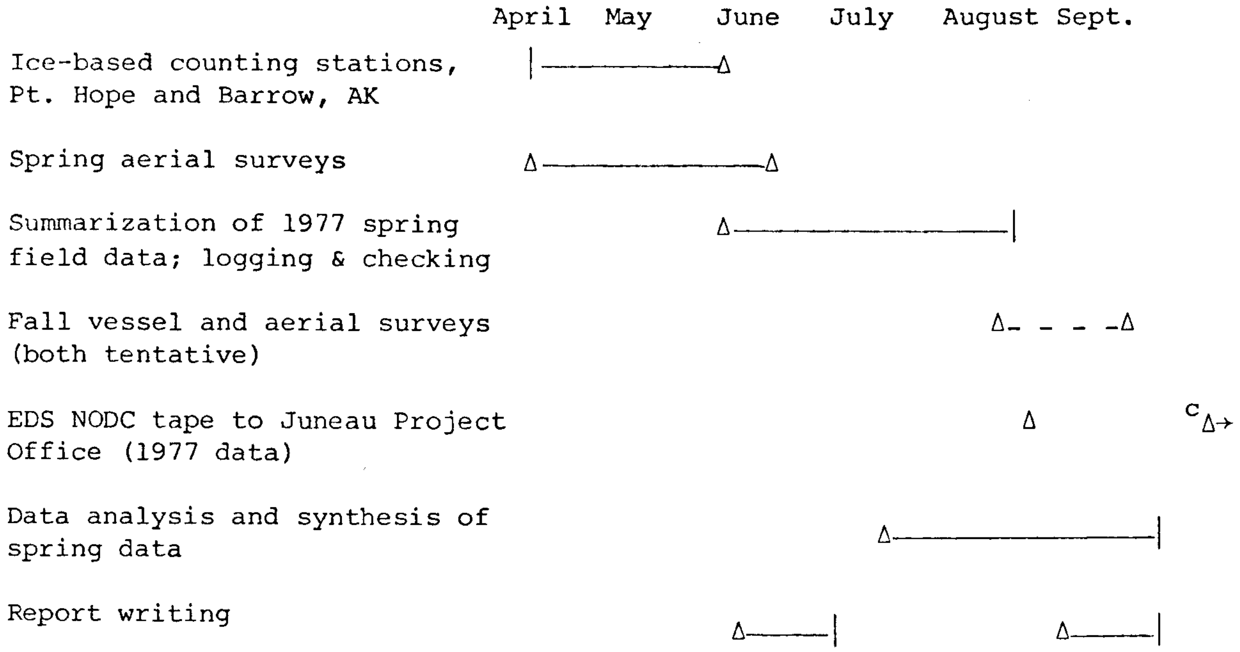
   a. All data collected under RU 69 and RU 70 in FY 76 were reviewed for accuracy -- a total of 5,895 marine mammals were seen (undoubtedly including some replicates) covering 102 separate survey days.

   b. Non-parametric tests on sighting data were performed to determine 1) if a cost-benefit ratio exists between ice station censusing and aerial surveys, and 2) appropriateness of the two survey methods with respect to collecting sighting data on bowhead and beluga whales. Plotting (by hand and computer) of sighting data was performed to delineate distribution, and to determine if specific areas of the Arctic Ocean are "more important" to these species than other areas.

   c. Trackline miles. N/A

6. Milestone chart and data submission schedules.

a. Activity milestones.



B. Data submission schedule. All data collected during 1976, with the following exceptions, are to follow this report. Exceptions -- fall 1975 aerial data (no important marine mammal sightings) and fall 1976 (not transformed with EDS code). These data plus fall 1974 (non-OCSEAP) aerial survey data will be transmitted to the Juneau Project Office on NODC format by the end of June. The reason for the delay was that these data are not of sufficient quality (except fall 1974) or in a form amenable to satisfactory interpretation (i.e., the data are poor). Any delays in data submission (FY 76 data) were a result of 1) difficulty on our part of formatting and processing the large volume of data; 2) holdups at our computer facilities (labor contracts for card punching were not renewed), and 3) some probelms in EDS-NODC-Marine Mammal (027) format finalization. All of these problems have, essentially, been resolved.

Data submission schedule for FY 77 field season:

Activity	Est. date of data submission
Ice camp census	1 September 1977
Aerial survey	
Spring data	1 September 1977
Fall data (tent.)	1 November 1977

B. Problems encountered/recommended changes. We recommend that a one page abstract be submitted with each quarterly and annual report. Each principal investigator can then receive a summary update (upon request) of each specific RU that he is interested in--long before the published accounts of the entire reports. This would increase the flow of important information between research units.

C. Estimate of funds expended.

Salaries	$ 8,569.00
Travel/per diem	279.98
Equipment	1,159.31
Computer/misc.	405.71
Total	$10,414.00

D. Other activities.

1. US-USSR Marine Mammal Agreement on Environmental Protection. Howard Braham, U. S. Delegate, representing OCSEAP research. San Diego, California, 18-23 January 1977.
2. Chukchi-Beaufort Sea, OCSEAP Synthesis Meeting. Bruce Krogman, Marine Mammal Division representative for RU 69. NARL, Barrow, Alaska, 7-10 February 1977.
3. David Rugh, David Withrow, Mary Nerini and Bruce Krogman received University of Washington training by taking an advanced course on marine mammals.

ANNUAL REPORT

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Research Unit #194
Task Order #8
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MORBIDITY AND MORTALITY OF MARINE MAMMALS - BERING SEA

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March 31, 1977

I. Summary

The objectives of this study are:

1. To determine the normal rate of occurrence (by species, sex, and age) of dead and moribund marine mammals along the eastern shore of the Bering Sea,
2. To determine the causes of death and morbidity of those animals, and
3. To determine the kinds and rates of occurrence of pathological conditions and their causes in the living populations of Bering Sea mammals.

Surveys in 1976 of about 1395 km of the Alaskan coast in the Bristol Bay and Bering Strait regions yielded counts of 107 relatively fresh carcasses of marine mammals. The majority of those necropsied had died from gunshot wounds (as in 1975). Other causes were: malnutrition (1 sea otter); umbillical hernia (1 walrus, 1 harbor porpoise); killer whale predation (1 gray whale); and trauma, possibly also related to killer whale predation (1 larga seal). Carcasses in this and the previous year occurred at the mean rate of about .05/km of beach, except in areas downstream from major hunting sites of the coastal Eskimos and from major hauling grounds of pinnipeds, where their rate of occurrence was about 10 times greater.

In the course of three research cruises in southeastern Bering Sea, 236 other marine mammals were examined. Data from 361 others, examined in connection with various investigations prior to the inception of this project, were summarized from the records of the former Arctic Health

Research Center (USPHS). Taken as a whole, these suggest that about six percent of the living populations of Bering Sea marine mammals have some kind of grossly evident pathological condition, the most common of which seem to be abcessed wounds, mycotic infections of the skin, various kinds of tumors, and liver disease. Serological analysis from the recent series, though still incomplete, suggests the presence of at least two important infectious agents (San Miguel Sea Lion Virus and *Leptospira* sp.), not otherwise detected in the necropsies. In addition, the helminth parasites of 43 specimens were determined, including discovery of two species new to science.

II. Introduction

A. General nature and scope of study

This study is designed to provide baseline information on the incidence and causes of pathological conditions in marine mammal populations of the Bering Sea that will be useful in evaluating future impacts of petroleum-related activities in that region. Emphasis is placed on surveys of distribution and numbers of beached carcasses of moribund and dead animals, and on necropsy of such specimens and of samples from the living populations for determination of causes of illness and death.

B. Specific objectives

1. to determine the number (by species, sex, and age) and location of stranded marine mammals on samples of the Alaskan Bering Sea coast,

2. to determine the pathological conditions and agents thereof that caused or contributed to the death of those mammals, and Alaskan Bering Sea coast,

3. to determine the causes and rates of occurrence of pathological conditions in living marine mammal populations of the Bering Sea through necropsy of individuals collected non-selectively as regards the purposes of this project.

C. Relevance to Problems of Petroleum Development

Marine mammals are the top level consumers in the Bering Sea trophic system. On that account, to monitor their health and welfare, including the incidence of diseases and other pathological conditions, is to monitor the "health" of the marine ecosystem itself, since they are the ultimate recipients of all changes that take place within the system, from perturbation and pollution to simple physical disturbance. Because they tend to be long-lived, they provide a cumulative historical record of past conditions, e.g., in their overall growth and the growth of certain body parts, such as the tusks of walruses and the vibrissae of seals and sea lions, and in their stores of certain pollutants, such as heavy metals, pesticides, and mineral hydrocarbons. But they are also responsive to short-term changes, in that their nutrition and the nurture and survival of their young are finely tuned to certain environmental requirements that are easily disrupted by man-made changes in the system itself.

III. Current state of knowledge

At the inception of this project, there was very little published information on either the rates of occurrence of moribund and dead marine mammals or the causes thereof in any part of the Alaskan O.C.S. area. Fragmentary reports of mass strandings of walruses (Odobenus rosmarus) on St. Lawrence Island (Schiller, 1954) and the nearby Punuk Islands (Murie, 1936) provided little reliable data on the nature or causes of those incidents. In the first case, from his examination in January 1952 of 17 of the 52 carcasses (mostly adult females) that washed up in October 1951, and from the reports of Eskimos who had examined some of the others, Schiller (1954:209) concluded that they probably had been killed by "a great and sudden external pressure," possibly "by concussion resulting from an (underwater) explosion." However, the reported signs (intestinal prolapse, free blood in the abdomen, and mutilated appendages) could just as easily have been due to putrefactive postmortem changes; none of the known diagnostic signs of implosive damage (as described by Rausch, 1973) was recognized in the animals examined. In the second case, Murie (1936), Collins (1940), and Cahalane (1947) reported that the flattened, hairless condition of the multitudes of walrus carcasses found on the Punuk Island was indicative of their having died from being crushed by the weight of other walruses, stampeded perhaps by the threat of preying killer whales (Orcinus orca). In this instance, also, the reported signs were by no means diagnostic, for the carcasses were not fresh and could easily have attained their condition through long-term putrefaction. Hanna (1920, 1923) reported on eight walrus carcasses examined by him on St. Matthew and the Pribilof islands, noting that "in each case death had been caused by crushing of the body cavity" (1923:213). Kenyon (1961) reported that two Cuvier's beaked whales (Ziphius cavirostris) which stranded on Amchitka Island in the Aleutians had been killed by rifle bullets. Jellison (1953) reported a Stejneger's beaked whale (Mesoplodon stejnegeri) stranded on the Pribilof Islands, and Moore (1963) reported two others from the Nushagak Peninsula and the Kasilof River, but no pathological information was provided for any of these. There are several other isolated records of occurrence of such unusual or rare specimens, but these provided no real basis for appreciation of the normal abundance of carcasses of the more common species.

In the summer of 1975, personnel of this and one related project surveyed some 2,014 km of the shores of the eastern Bering Sea and Bering Strait (Fay, 1976) and recorded 250 newly stranded marine mammals of nine species, weighing some 1,200 tons (Table 1). These occurred at the rate of from less than .01 to 14 carcasses per km of shoreline, the highest rates being in areas downstream from intensive hunting sites of the coastal Eskimos and in areas where large numbers of animals haul out to rest. As might be expected, the majority of carcasses in those high-rate hunting areas were determined to have died from gunshot wounds. The rate of occurrence in the lighly settled areas or areas with low hunting intensity averaged about .05 carcasses per km, with a range from .01 to .15/km. Most of these had died from natural causes. Some pathological conditions identified at necropsy as having contributed to the death of these animals were: hepatitis, peritonitis, and omphalitis (2 harbor seals), gastric ulcers, hemoendometritis, hepatitis, and interstitial pneumonia (2 sea otters), predation by killer whales (2 gray whales), dental abcess and acute pneumonitis (1 walrus), and dermatomycosis and streptococcal lymphadenitis (1 ringed seal). None of the carcasses were of species known to reside more than a few km from the location where they were found, implying that carcasses of animals that die in more distant areas do not persist at sea long enough to be transported

TABLE 1. Frequency of occurrence of stranded carcasses of marine mammals per kilometer of surveyed shoreline, Bering Sea to Kotzebue Sound, 1975 (Data from Fay, 1975)

		Numbers of stranded marine mammal carcasses*						
Area	Dist. (km)	Whales**	Sea lions	Walrus	Hair seals***	Sea otters	Total	No/km
BRISTOL BAY								
Southern	654.2	10	0	8	12	2	32	.05
Northern	238.1	0	0	15	0	0	15	.06
KUSKOKWIM BAY	113.7	0	1	0	0	0	1	.01
ST. LAWRENCE I.								
Southern	116.2	9	0	6	2	0	17	.15
Northern	151.3	0	0	45	24	0	69	.46
Punuk Is.	0.5	0	0	7	0	0	7	14.00
BERING STRAIT	235.2	7	0	91	13	0	111	.47
KOTZEBUE SOUND	505.2	0	0	1	4	0	5	.01

* Includes only those <four months *in situ*, i.e., stranded after breakup of the pack ice. All areas surveyed in July, except St. Lawrence Island (August).

** All gray whales (*Eschrichtius robustus*), except one minke whale (*Balaenoptera acutorostrata*) in southern Bristol Bay.

*** All harbor seals (*Phoca richardsi*) in Bristol Bay, and mainly ringed seals (*P. hispida*) elsewhere.

great distances, though surface air and water currents my be favorable for such passage.

Some of the best and most useful information on morbidity-mortality rates and the causes thereof in Bering Sea marine mammals have been obtained in connection with intensive studies of the northern fur seal (*Callorhinus ursinus*) populations on the Pribilof Islands and of sea otter (*Enhydra lutris*) populations at Amchitka Island. Of some 700,000 to 1,000,000 fur seal pups born each year on the Pribilofs, about 75 percent die by age five years, mainly from natural causes (Roppell, et al., 1963, 1965). While predation by killer whales and sharks is certainly an important factor in this mortality, its extent is unknown (Baker, et al., 1963). Other contributing factors are: intraspecific strife (Johnson, 1968), parasitism (Neiland, 1961; Keyes, 1965; Dunlap, et al., 1976), and toxins (Keyes, 1965). Still other conditions, e.g., renal fibrosarcoma (Brown, et al., 1975), and agents of disease, e.g., *Leptospira* sp. (Smith, et al., 1974), *Sarcocystis* (Brown, et al., 1974a), viruses of the psittacosis group (Eddie, et al., 1966), and vesicular exanthema viruses (Prato, et al., 1974; Smith, et al., 1975, 1976; Madin, et al., 1976) have been recognized and, especially the latter, are now believed to play an important role in die-offs at sea. The mortality of pups on the rookeries has been studied in greatest detail. Of the 40 to 120 thousand pups that die each year on the Pribilof rookeries (Roppell, et al., 1965), the most frequent primary cause of death is malnutrition (37.6%; Keyes, 1965), followed closely by trauma (17.4%: *Ibid*.), hookworm infections (12%: *Ibid*.; Lyons, 1963; Brown, et al., 1974b), bacterial invasion of open wounds (11%: Keyes, 1965), and gastrointestinal problems (4.6%: *Ibid*.; Jellison and Milner, 1958).

Kenyon (1969) has indicated that there is a substantial mortality of sea otters in the Aleutian Islands in winter and early spring and that this involves mainly the youngest age classes and more often the males than the females. The ultimate cause of death, in most cases, is malnutrition, which seems to be the result most often of dental problems coupled with severe weather as a deterrant to normal feeding. Gastro-intestinal conditions, associated with helminthic infestations (especially *Phocanema decipiens*) and bacterial agents (*Clostridium* spp.) seem to be common contributors. A liver disease of unknown etiology and various other conditions that occurred infrequently were judged to be relatively unimportant in the pristine wilderness environment but might become more important under more stressful circumstances of environmental pertrubation. One such condition is contamination of the fur by foreign matter, causing it to lose its water-repellency. When this occurs, according to Kenyon, "the insulating blanket of air among the dense fur fibers is lost, the animal is chilled, and soon dies."

The information on causes and rates of morbidity and mortality in other species of Bering Sea marine mammals is extremely spotty at this time. A thorough review of all sources, based mainly on a bibliography compiled by this project (Quart. Rep. 31 Dec 76), is in preparation for submittal at a later time.

IV. Study Area

The basic study area is the shelf of the eastern Bering Sea and Bering Strait, from Unimak Pass north to Kotzebue Sound. The shoreline of that area, including the islands, is more than 5,000 km, of which we have selected about 20 percent for annual stranding surveys, with other parts surveyed on an opportunistic basis. The regular survey areas are (1) the southern shore of Bristol Bay from Naknek to Bechevin Bay, (2) the coast of St. Lawrence Island, and (3) from Bering Strait to Point Hope. These were selected because of their accessibility and their juxtaposition to proposed lease areas and centers of abundance of major marine mammal populations. Necropsy of specimens taken in connection with other OCSEAP projects is undertaken on an opportunistic basis anywhere within the basic study area and in other areas to which the same migrant populations journey in the course of the year (e.g., eastern Chukchi and western Beaufort Seas).

V. Sources, Methods, and Rationale of Data Collection

Stranding data are collected about one month after the breakup of sea ice in the vicinity of the regular survey areas. Data from earlier and later surveys have indicated that this is the optimal timing for obtaining near-maximal counts and for access to the greatest number of specimens in relatively fresh condition. For the Alaska Peninsula, this means initiation by late May to mid-June; for St. Lawrence Island, by late June to mid-July; and for the Bering Strait area, by mid- to late July. With allowance for weather, about two to three weeks of work are required in each area.

Each survey is conducted by a 2-man team, including one senior scientist and one technician. In the Alaska Peninsula and Bering

Strait areas, the mode of transportation for the team is a Supercub aircraft with extra-large balloon tires for beach landings; on St. Lawrence Island, a combination of all-terrain vehicles and small boats is utilized. In the areas covered via aircraft, the survey is begun with a complete coverage of the sampling area (preferably, all in one day), noting the kinds of carcasses and moribund animals and marking the location of each on suitably large-scale aerial charts. Thereafter, the team works out from various camps along the way, landing near each carcass and examining it in accordance with the procedures outlined in the project manual for postmortem examination (See Annual Report, R.U. #194 31 March 76). At St. Lawrence Island, the modes of transportation necessitate that the survey of numbers and locations is conducted simultaneously with the examinations.

Necropsy of specimens taken in conjunction with other projects (i.e., OCSEAP, R.U. #230,232) is performed as soon as possible after death of the animal and in accordance with procedures outlined in the project manual. The primary objective of this is to obtain adequate samples of each species with which to describe the normal rates of occurrence of pathogens and pathological conditions in their populations, and to obtain materials for comparison with those from the stranded carcasses, whose condition is seldom satisfactory for isolation of pathogens or acquisition of high quality histopathological samples.

Histopathological and other materials collected during the necropsies are transported back to the home base (University of Alaska-Fairbanks) at the end of the field work period for processing, analysis and, as necessary, distribution to various specialists for further study. These comprise mainly of (1) samples for serological, heavy metals, and hydrocarbon analysis, (2) bones and teeth for identification and age determination, (3) preserved tissues for histopathological examination, (4) microbiological isolates, and (5) photographs for identification.

VI. Results

Stranding Surveys

The survey of beach dead animals in 1976 covered a total of 1,395 km of shoreline in three areas: southern Bristol Bay, Bering Strait, and Kotzebue Sound (Table 2). The St. Lawrence Island area was not surveyed, due to inability to obtain permission from the local Native corporations in a timely fashion for conduct of the work. In the areas covered, a total of 107 carcasses of 9 species were found, with a total estimated weight of about 218 tons. As in the previous year, these were about ten times more numerous in the area downstream from a major hunting "ground" of the Bering Strait Eskimos than in the rest of the areas surveyed. Again it seemed that the usual rate of occurrence outside those high-intensity hunting areas was about .05 carcasses per km of shoreline. Also, as in 1975, none of the carcasses were of species known to reside more than a few km from the locality in which they were found.

The necropsy results from 21 of the 44 carcasses examined are summarized in Table 3. The cause of death in the remainder was not determined with certainty.

TABLE 2. Frequency of occurrence of stranded carcasses of marine mammals per kilometer of surveyed shoreline, Bering Sea and Bering Strait, 1976.

		Numbers of carcases (<4 months since death)					
Area	Dist. (km)	Whales	Walrus	Hair seals	Sea otters	Total	No/km
BRISTOL BAY							
Southern part	654.2	4*	8	18	1	31	.05
BERING STRAIT	235.2	2**	47	15	0	64	.27
KOTZEBUE SOUND	505.2	1***	10	1	0	12	.02

* Includes 3 gray whales, 1 minke whale

** One gray whale and 1 harbor porpoise (*Phocoena phocoena*)

*** One belukha (*Delphinapterus leucas*)

TABLE 3. Major pathological findings in beach dead marine mammal carcasses necropsied in 1976.

Field No.	Species		Major findings	Diagnosis
CETACEA				
503-7	Eschrichtius	robustus	Throat, tongue, mandible torn away; remainder severely lacerated.	Killed and eaten by killer whales
503-3	Phocoena	phocoena	Blubber very thin, yellow; hernia of umbilicus with gut loop extruded and strangulated, both ends of loop intussuscepted.	Constrictive blockage of GI tract; malnutrition.
PINNIPEDIA				
102-3	Odobenus	rosmarus	Umbillical hernia with partial extrusion of uterus containing full-term foetus.	Trauma (?)
502-3	"	"	Skull fractured by bullet	Gunshot
502-8	"	"	Same	"
503-14	"	"	Same	"
503-1	"	"	Bullet hole associated with cerebral hemorrhage.	"
503-5	"	"	Same	"
502-9	"	"	Several bullet holes in neck, associated with severe hemorrhage.	"
502-7	"	"	Bullet hole in neck, associated with hemorrhage	"
503-4	"	"	Same	"
503-6	"	"	Same	"
503-8	"	"	Same	"
503-13	"	"	Severe hemorrhage in neck, with fractured vertebrae	"
502-2	Erignathus	barbatus	Skull fractured by bullet	"
101-8	Phoca	largha	Subpleural hemorrhage and lung congestion; microabcesses in liver (unrelated).	Trauma (possibly due to killer whales)

TABLE 3 Continued

Field No.	Species	Major findings	Diagnosis
503-9	*Phoca largha*	Massive hemorrhage of neck, with fractured cervical vertebrae	Gunshot
502-5	*Phoca hispida*	Skull fractured by bullet	"
502-6	" "	Same	"
503-12	" "	Same	"
SEA OTTER			
103-1	*Enhydra lutris*	Emaciated; gut empty; bladder full; rupture of right cornea	Malnutrition, possibly secondary to eye injury.

Necropsy of Specimens from Other Projects

In the course of three research cruises in the southeastern Bering Sea (ZRS *Zagoriany*, 15 March-4 May; OSS *Surveyor*, Legs I & II, 14 March-1 May), project personnel examined 236 marine mammals collected primarily for purposes other than those of this study. Each of these was taken non-selectively, as regards their health and general physical condition. The numbers examined per species were:

6 Steller sea lions (*Eumetopias jubatus*)
158 Walruses (*Odobenus rosmarus*)
3 Bearded seals (*Erignathus barbatus*)
39 Larga or spotted seals (*Phoca largha*)
2 Harbor seals (*Phoca richardsi*)
28 Ribbon seals (*Phoca fasciata*)

Blood serum samples from 110 of these were forwarded to the Naval Biomedical Research Laboratory (Oakland, California) for serum antibody screening, the results of which are not yet completely in hand. Preliminarily, it seems that the five sea lions sampled (but none of the other species) had antibodies for two of the five known serotypes of San Miguel Sea Lion Virus (SMSV) with titers to 1:160. It is probable that there will also be a high proportion of reactors to *Leptospira* antigen in several species. Each of these pathogens is suspected of having had a severe impact on marine mammal populations in the western United States (including the Alaska fur seal) in recent years, as well as being important agents of disease in domestic animals and, in the case of the latter, man.

Blubber samples from 71 specimens for hydrocarbon analysis and organ samples from 24 for heavy metals analysis also were collected and are being processed at this time in connection with other OCSEAP projects (R.U. #162/275).

Major pathological findings in these specimens are summarized in Table 4. In addition, the helmith parasites of 43 specimens were determined (including discovery of two species new to science); data from these were summarized in tabular form in a recent Quarterly Report (R.U. #194, 31 Dec 76).

A compilation of data relative to frequency of occurrence of pathological conditions in Bering Sea marine mammals was begun, drawing from the files of the former Arctic Health Research Center's Zoonotic Disease Section (with which the principal investigator was formerly connected). The results to date, combined with those from the work of this project, are shown in Table 5. These data, from 597 necropsies of 10 species, suggest that about six percent of animals taken non-selectively have some kind of grossly evident pathological condition. Of these, the most common seem to be abcessed wounds, mycotic infections of the skin, various kinds of tumors, and fibrosis of the bile ducts. Numerous other records of specimens of pathological interest that were drawn from samples of unknown size also are being reviewed and will be reported at a later time.

VII. Discussion

The marine mammals of the Bering Sea are mainly transient, some of them residing there in summer and spending the winter farther to the south,

TABLE 4. Major pathological findings in marine mammals collected in connection with other projects, 1976

Field No.	Species		Major findings
Z-102	*Odobenus*	*rosmarus*	Dermatomycotic lesions over most of the body, circular to oval, some raised and with sloughing of hair and cornified layer.
Z-103	"	"	Same, but restricted to ventral surface and flippers.
Z-115	"	"	Cystic ovary filled with caseous material; other normal.
Z-122	"	"	18 x 21 cm arterial aneurism in dorso-lateral aspect of spleen; contents mixed whole and necrotic blood.
Z-14	"	"	Abcessed puncture wound in neck; abcess 20 cm in diameter, 2 cm thick, subcutaneous, no drainage.
SUV-30	*Phoca*	*largha*	Splenomegaly (13 x 32 cm; 0.7 kg).
Z-211	"	"	Fibrosis of liver margins.
Z-175	"	"	Healing perforative gastric ulcers.
Z-221	"	"	Healing ulcerative skin lesions on belly.
SUV-23	*Phoca*	*fasciata*	Fibrosis of liver margins.
SUV-28	"	"	Splenomegaly (0.9 kg); dermatomycosis with extensive hair loss, epidermal hyperkeratosis.
Z-194	"	"	Dermatomycosis, patchy hair loss.
Z-226	"	"	Healing crescentic lacerations on back and flank, largest 25 cm long, 3 cm deep.
Z-228	"	"	Fistulated wound in left rear flipper; tarsal-metatarsal area edematous.

TABLE 5. Preliminary summary of available data on rates of occurrence of gross pathological conditions in Bering Sea marine mammals necropsied from 1950 to 1976.*

Species	Number examined		% path-	Types of conditions
	Total	Pathological	ological	
Eschrichtius robustus	2	0	-	-
Delphinapterus leucas	6	1	-	Middle ear inflammation (1)
Phocoena phocoena	2	0	-	-
Eumetopias jubatus	16	1	6	Focal necrosis of kidney (1)
Odobenus rosmarus	276	15	6	Subcutaneous abcess (2); acute dermatomycosis (2); dental pulpitis (1); malnutrition (1); biliary fibrosis (2); renal calculi (1); splenic aneurism (1); cystic ovaries (1); uterine tumor (2); epithelial fibropapilloma (2)
Erignathus barbatus	89	6	7	Biliary fibrosis (3); acute dermatomycosis (1); trauma (1 evidently wounded by bear or killer whale); old gunshot wound (1)
Phoca largha	102	7	7	Old bullet wound? (1); splenomegaly (2); ulcerative skin lesions (1); gastric ulcer (1); malnutrition (2)
Phoca richardsi	22	1	4.5	Lacerations and splenomegaly (1)
Phoca hispida	40	1	2.5	Consolidative pneumonia (1)
Phoca fasciata	42	3	7	Subcutaneous abcess (1); acute dermatomycosis (2)

* Data from the files of the former Arctic Health Research Center (USDHEW, Public Health Service), Fairbanks, and from work performed under this project. All specimens were taken non-selectively. Data from beach dead animals are *not* included.

while others reside there in winter and spend the summer farther to the north. As a whole, about 3 million individuals utilize this area on an approximately half-time basis. In their peregrinations, they are exposed to a wide variety of environmental conditions and contacts with other species and populations, some as far south as Baja California and Japan, or as far north as the Beaufort and East Siberian Seas. The results of our investigations thus far indicate that about six percent of those individuals at any given time shows grossly evident signs of having been affected by diseases or injuries, and it is becoming evident that many more had been exposed to other infectious agents. It is probable that some of those agents and the conditions that they cause would have led or contributed to the demise of the animals. Indeed, it is probable that at least 5 to 10 percent of the marine mammals utilizing the Bering Sea dies there each year, many of them from the same kinds of diseases and injuries as we have recognized.

Carcasses of some of those dead and dying animals come ashore on the beaches of the eastern Bering Sea throughout the ice-free period, June to October or November, evidently at a mean rate of about .05 to .1/km/yr. However, in a few localities where large numbers of animals are wounded by subsistence-hunting Eskimos or where large numbers haul out to rest, the rate of stranding tends to be about 10 times as great. Along the approximately 5,000 km of shoreline, then, it is reasonable to expect some 250 to 500 carcasses in any given year, with the greatest concentrations in the areas downstream from intensive hunting sites or major hauling grounds.

The findings thus far, in both the stranded and non-stranded specimens, suggest that, apart from bullet wounds, predator-induced trauma, malnutrition, and various infectious agents of disease are the main causes of morbidity and mortality in Bering Sea marine mammal populations, at present. The most common infectious conditions and agents seem to be (a) mycotic infections in the skin, (b) streptococcal infections leading to focal necrosis of the liver, (c) wound infections probably by strains of both Streptococcus and Staphylococcus, and (d) tentatively, leptospirosis and vesicular viral disease (SMSV). It is easily conceivable that the potential variety of additional stresses brought to bear by oil development in the Bering Sea could have a synergistic effect on many of these.

VIII. Conclusions (tentative)

1. Dead and moribund marine mammals are deposited on the shores of the eastern Bering Sea at the rate of about .05/km/yr, except in areas close to major hunting sites and major haulout sites, where the rate locally is about 10 times as great.
2. About 6 percent of individuals in the living populations of Bering Sea marine mammals have grossly evident signs of pathological conditions, many of which could eventually lead to or contribute to the death of the animal.
3. Many other individuals show clinical signs of exposure to infectious diseases, but the rates of occurrence of these are not yet certainly known.

IX. Needs for Further Study

1. Stranding Surveys:

The results thus far suggest that the rate of occurrence of stranded marine mammal carcasses is relatively constant and varies more with juxtaposition to major hunting sites and hauling grounds than with year-to-year differences in environmental conditions. Adequate confirmation of this is needed in areas other than those regularly surveyed, i.e., we feel that it would be particularly useful to undertake at least one greatly expanded survey of the eastern shore of the Bering Sea, from Unimak Pass to Bering Strait, covering at least half of that area, in order to compare predicted (on the basis of present findings) with observed stranding rates. This could also greatly enlarge our present sample of diagnosed causes of death. Ideally, the survey should be undertaken via helicopter capable of carrying a 2-man team of experienced observers/examiners. Alternatively, the present system of survey via Supercub aircraft could be utilized, but the number of carcasses available for necropsy would be much less, due to greater limitations for beach landings in some areas.

2. Necropsy of Non-Selective Samples:

As can be seen from Table 5, the samples from several species are still insignificantly small and need to be expanded. Present efforts (FY '77) will contribute to their expansion, but every effort should be made to expand them further, as long as specimens are available from other projects. Additional data, particularly from species of Phoca, from Eumetopias jubatus, and from the cetaceans, will be needed, inasmuch as these are large populations of major economic importance that regularly frequent the proposed lease areas.

X. Summary of 4th Quarter Operations

A. Ship or Laboratory Activities

1. Ship or field trip schedule

    a. 15 March - 8 April OSS Surveyor, Leg II - Bering Sea

    b. 11 April - 1 May OSS Surveyor, Leg III - Bering Sea

    c. 19 May - 12 June OSS Discoverer, Bering Sea

    d. 15-30 June Alaska Peninsula Stranding Survey

2. Scientific party

    a. Surveyor Leg II: Associate investigator R. A. Dieterich and biological technician L. M. Shults, Institutes of Arctic Biology and Marine Science, University of Alaska, Fairbanks.

    b. Surveyor Leg III: Principal investigator F. H. Fay and biological technician L. M. Shults, Institutes of Arctic Biology and Marine Science, University of Alaska, Fairbanks.

    c. Discoverer: Principal investigator F. H. Fay and biological technician L. M. Shults, Institutes of Arctic Biology and Marine Science, University of Alaska, Fairbanks.

d. Alaska Peninsula: Associate investigator R. A. Dieterich and field assistant (to be named), Institute of Arctic Biology, University of Alaska, Fairbanks.

3. Methods

a. Surveyor II, III; Discoverer: Necropsy of specimens taken non-selectively in conjunction with field work of other OCSEAP projects (R.U. #230,232, 248).

b. Alaska Peninsula: Aerial survey of numbers, kinds, and locations of stranded carcasses in southern Bristol Bay, with necropsy of as many as possible.

4. Sample localities

a. Surveyor II, III: Ice Front, from 165° to 174°W, and within 40 helocopter miles of 72-hr oceanographic stations in the Front at 165°, 170°, and 174°W.

b. Discoverer: In vicinity of the central "Ice Remnant" (approximately 174°W, 62°N).

c. Alaska Peninsula: Southern shore of Bristol Bay, from Naknek to Bechevin Bay.

5. Data to be collected or analyzed

a. Surveyor II, III and Discoverer: Tissue samples for histopathological study; helminthological, bacteriological, viral, and mycological isolates; serum and blubber samples.

b. Alaska Peninsula: As above, plus survey data on numbers, kinds, locations, and causes of death of stranded carcasses.

6. Milestone chart

All milestones were attained in a timely fashion, with the following exceptions:

a. Mass strandings or fall '75 survey: - There were no mass strandings other than those surveyed in the course of the regular surveys. A fall survey was not feasible because of early freezeup and foul weather.

b. Collections from icebreaker: - Not feasible as planned; icebreaker unavailable for winter work.

c. Delivery of final report: - Project was continued in FY '77, rather than terminated.

B. Problems encountered/recommended changes

None.

C. Estimate of funds expended

See attached.

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OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 8 R.U. NUMBER: 194

PRINCIPAL INVESTIGATOR: Dr. F. H. Fay

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1			
Alaska Peninsula	7/23/75	7/24/75	submitted			
Kotzebue Sound	7/17/75	7/20/75	submitted			
Kotzebue Sound	7/22/75	7/24/75	submitted			
St. Lawrence Is.	8/8/75	8/22/75	submitted			
Alaska Peninsula	Summer 1976		submitted			
Kotzebue Sound	Summer 1976		submitted			

All FY '76 data have been submitted

Note: 1 Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer.

ANNUAL REPORT

Contract #03-5-022-69

Research Unit #229

Reporting Period 1 April 1976-
31 March 1977

Number of Pages:

Biology of the harbor seal, *Phoca vitulina richardi*, in the Gulf of Alaska

Principal Investigators:

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SUMMARY

This project is an investigation of several phases of the biology and ecology of the harbor seal in the Gulf of Alaska. Specific objectives include: (1) investigation of food habits and identification of important prey species, (2) examination of growth and physical condition and (3) determination of population productivity. Other goals are the collection of data on abundance, distribution, use of critical habitats, effects of disturbance, population composition and collection of specimen materials for disease and environmental contaminant analyses.

There are a number of potential, adverse effects on harbor seal populations which may result from the exploration for and development and transport of crude oil and natural gas. These include (1) direct injury or death through contact or ingestion of oil, (2) disturbance, particularly during pupping and molting, (3) reduced productivity of the ecosystem, (4) direct mortality of prey species and (5) increased levels of environmental contaminants.

Principal prey species of the harbor seal in the Gulf of Alaska identified to date are *Theragra*, *Octopus*, *Gadus*, *Ammodytes* and *Mallotus*. The families Cottidae and Pleuronectidae were frequently utilized in some areas.

The reproductive cycle of harbor seals is summarized as follows: pupping, 15 May to 27 June; lactation period, 3 to 6 weeks, completed by mid-July; ovulation and breeding, within 2 weeks after weaning, late June to

late July; implantation, late September to late October. Females become sexually mature between 5 and 8 years of age. No females 4 years old or younger were pregnant. The pregnancy rate for females older than 4 years (5-30 years) was 86.8 percent. Of 45 females between the ages of 4 and 30 years, reproductive failure occurred in seven animals.

The data collected supported previous findings that male harbor seals were mature by 7 years. The period of seasonal potency was from about March to September.

Tugidak Island, 20 miles southwest of Kodiak Island, has the largest single concentration of harbor seals known. On 2 September 1976, an aerial survey indicated a minimum population of about 13,000 seals. True population size may be considerably larger. Observations of harbor seal behavior and the effects of disturbance indicated that during the pupping period disturbance had a high probability of increasing mortality rates of pups through interference in the formation of mother-pup bonds. The most disruptive sources of disturbance were helicopters involved in oil exploration activities. Preliminary observations indicate that the molt may be another period when harbor seals are sensitive to disturbance. We recommend that restrictions be placed on all O.C.S. activities which result in disturbance of major harbor seal hauling areas during the periods 15 May-15 July (pupping) and 15 August-15 October (molt). These restrictions should be applied to all exploratory activities as well as included as conditions of lease sales.

Recommendations for future research include a census of the Tugidak Island harbor seal population, continued collecting with emphasis on summer food habits and investigations of the life histories and vulnerability of major prey species including *Theragra, Gadus, Clupea, Mallotus, Thaleicthys, Ammodytes* and *Octopus*.

INTRODUCTION

This research unit is a basic ecological, life history study of the harbor seal in the Gulf of Alaska. Specific objectives include: (1) investigation of food habits and identification of important prey species, (2) examination of growth and physical condition and (3) determination of population productivity with emphasis on establishing age of sexual maturity and age specific pregnancy rates. Peripheral objectives include collection of data concerning distribution, use of critical habitats, effects of disturbance and population composition, and collection of specimen materials for disease and environmental pollutant analyses.

Exploration, development and transportation of petroleum reserves in the Gulf of Alaska have a number of potential harmful effects on harbor seal populations. Some of the more obvious include the following: 1) direct injury to animals through contact or ingestion of oil (this may result directly in death of the individuals involved or could result in lowered physical condition which in turn might alter long term survival and biological processes such as growth and reproduction) 2) disturbance, particularly during vulnerable stage of their life cycle such as pupping and molting activities, 3) reduction of productivity of the marine system by contamination, 4) direct mortality of important prey species by contact with oil and 5) increased levels of environmental contaminants.

This project was designed to collect information to aid in the decision making process for gas and oil development in the Gulf of Alaska. Data gathered will enable guidelines to be placed on all stages of the O.C.S. development program that will reduce harmful effects on harbor seal populations. Predevelopment data are being collected so changes which might occur can be detected.

PREVIOUS RESEARCH

Bishop (1967) conducted the first meaningful life history study of harbor seals in the Gulf of Alaska. Working both on Tugidak Island and on the coast of the Kenai Peninsula, he used a cementum annuli age determination technique combined with reproductive analyses to gather information on the reproductive cycle. He also collected data on growth and development. On Tugidak Island, he gathered some preliminary data on population composition and productivity. His work was a pioneer study and only touched the surface. From 1956 to 1958 Mathisen and Lopp (1963) photographed and counted concentrations of harbor seals in conjunction with a census of Steller sea lions. A particularly important observation was a maximum count of 16,776 seals on the Trinity Islands south of Kodiak Island. Imler and Sarber (1947) collected data on food habits on the Copper River Delta during the months of June and July. The Alaska

Department of Fish and Game conducted research on Tugidak Island between 1965-1972. This was mainly related to commercial harvests for pelts. Seasonal distribution studies were conducted in the Prince William Sound area by the Alaska Department of Fish and Game in 1973 and 1974 (Pitcher and Vania 1973 and Pitcher 1975). In 1975, Pitcher conducted research on population productivity, growth, condition and food habits of harbor seals in Prince William Sound (Pitcher 1977). This project, conducted under contract to the Marine Mammal Commission, provided the first sizable sample of life history data from any area in the Gulf of Alaska. A general discussion of harbor seal abundance and distribution in the Gulf is presented by Calkins et al. (1975).

STUDY AREA

The study area for this project includes the Gulf Coast from Yakutat Bay north to Cape St. Elias, the Copper River Delta, Prince William Sound, coastal Kenai Peninsula from Cape Puget to Dangerous Cape, the Barren Islands and the Kodiak Archipelago including Shuyak, Afognak and the Trinity Islands. Specific localities from which we have collected thus far include Yakutat Bay, Icy Bay, Kayak Island, Controller Bay, Middleton Island, Prince William Sound, the Kenai Coast, Afognak Island, Shuyak Island, Kodiak Island and the Trinity Islands.

METHODS

1. Harbor seals are being collected systematically from different areas and habitat types throughout the year. This is being done in order to detect variations in food habits with season, area and habitat type.

2. Weights and standard measurements are taken from each collected animal including: total weight, blubber weight, standard length, curvilinear length, axillary girth, maximal girth, hind flipper length and blubber thickness (Scheffer 1967). These data are being collected to establish growth rates, seasonal condition patterns and assist in making calculations of biomass.

3. Age determinations are being made. This is done by decalcifying a canine tooth from each animal, using a microtome to produce thin sections, staining the sections with hematoxylin and counting the annual growth rings with the aid of a microscope (Johnson and Lucier 1975). Age determinations are necessary for development of growth rates and to determine population structure and productivity.

4. The ovaries and uterus are taken from each female seal and preserved in formalin. Presence or absence of a conceptus in the uterus is determined using standard laboratory techniques for reproductive analysis and a partial reproductive history is reconstructed by examination of ovarian structures. These data are necessary for determination of ages of sexual maturity and age specific reproductive rates, basic parameters required for population productivity calculations.

5. Testes and epididymides from each male seal are collected and preserved. A microscopic examination is made of epididymal fluid to determine whether sperm are present or not. These data are used for determination of age of sexual maturity and periods of seasonal potency in males.

6. Stomach contents from each seal are preserved in formalin. Weights and volumes are determined for all contents. Identifications of prey species are made by examination of recognizable individuals and skeletal materials of diagnostic value. Frequency of occurrence and numbers of individual prey species are then determined.

7. Intestinal contents from each seal are strained through mesh sieves to recover fish otoliths. Otoliths, which are diagnostic to species, are compared to a reference collection and identified. All otoliths to date have been sent to John Fitch for verification of the identifications (Fitch and Brownell 1968).

8. Tissue samples are being collected and frozen so that baseline levels of heavy metals, pesticide residues and hydrocarbons can be determined.

9. Observations of harbor seals are recorded during collecting cruises and during aerial surveys conducted by personnel of other marine mammal projects in the Gulf of Alaska. These data are being compiled and will eventually be of value in delineating areas with high harbor seal concentrations, patterns of seasonal distribution and critical habitat.

10. A field camp was established on Tugidak Island. Periodic censuses were conducted on the island. Instances of disturbance, both man-related and natural, were recorded. The progression of life history events i.e. birth, lactation, weaning and molting were documented as animals may be particularly sensitive to disturbance during certain of these periods.

RESULTS AND DISCUSSION

Collecting Activities

Seven collecting trips were completed resulting in the collection of 154 harbor seals (Table 1). All laboratory procedures have been completed for these animals except for environmental contaminant analyses. Arrangements are being made to start hydrocarbon and trace metal analyses on a subsample of tissue specimens.

Table 1. Locations, numbers and composition of collected harbor seals.

Location	No. of females	No. of males	Total
Kodiak area	39	39	78
Kenai coast	8	18	26
Prince William Sound	10	15	25
Icy Bay	9	4	13
Yakutat Bay	4	1	5
Middleton Island	3	2	5
Kayak Island	--	2	2
Total	73	81	154

Age Determination

Canine teeth from each animal have been thin-sectioned, stained and mounted on microscope slides. Ages were determined by counting the annual cementum growth rings (Table 2).

Table 2. Sex and age structure of 153 harbor seals collected in the Gulf of Alaska.

Age	Males		Females	
	#	%	#	%
0-12 months	8	10.0%	7	9.6%
1 years	3	3.8%	4	5.5%
2	5	6.3%	2	2.7%
3	5	6.3%	6	8.2%
4	9	11.3%	7	9.6%
5	4	5.0%	3	4.1%
6	0	0.0%	5	6.8%
7	6	7.5%	5	6.8%
8	5	6.3%	3	4.1%
9	3	3.8%	4	5.5%
10	4	5.0%	8	11.0%
11	5	6.3%	3	4.1%
12	4	5.0%	3	4.1%
13	1	1.3%	0	0.0%
14	2	2.5%	4	5.5%
15	3	3.8%	1	1.4%
16	6	7.5%	1	1.4%
17	2	2.5%	0	0.0%
18	1	1.3%	3	4.1%
19	3	3.8%	0	0.0%
20	1	1.3%	0	0.0%
23	0	0.0%	2	2.7%
24	0	0.0%	1	1.4%
30	0	0.0%	1	1.4%
Total	80 *	100.6%	73	100.0%

* Plus one age unknown male.

Pupping

Field observations on Tugidak Island provided some data on timing and progression of pupping. The first pup (not accompanied by a female and still retaining fetal lanugo) was observed on 15 May 1976. The first attended pup was observed on 19 May. The maximum number of pups seen was on 22 June. After 27 June no evidence of recent births was noted. The peak of pupping or time of highest birth rate was determined to be about 14 June. Other data from the Gulf of Alaska include a pupping period of 4 May to 25 June on Tugidak Island (Bishop 1967). Bishop concluded that the early births (May) almost always resulted in the female deserting the pup with the pup soon dying. In Prince William Sound, Pitcher (1977) found that pupping began about 20 May, peaked in the first week of June and was completed by early July.

Lactation and Weaning

Published values for length of lactation range from 3-6 weeks (Bishop 1967, Bigg 1969, Knudtson 1974 and Pitcher 1977). Observations on Tugidak indicated that by mid-July nearly all pups were weaned.

Ovulation and Breeding

No data were collected on timing of ovulation and breeding. However, based on observed pupping and weaning dates on Tugidak and on published sources ovulation occurs within 2 weeks after weaning (Fisher 1954, Bishop 1967, Bigg 1969 and Pitcher 1977). It appears that ovulation and breeding probably occur from late June until late July.

Delay of Implantation

Although harbor seals breed shortly after weaning the blastocyst does not implant immediately. Various researchers have calculated a delay of implantation ranging from 2-3 months (Fisher 1954, Bishop 1967, Harrison 1960, Bigg 1969 and Pitcher 1977). Based on the size of embryos collected in October and November (Figure 1) it appears that implantation begins in late September and extends through October. Given the pupping, weaning and breeding information presented earlier an estimate of 2.5 months delay in implantation can be calculated.

Female Age of Sexual Maturity

Sexual maturity in the female is often defined as the age at which ovulation first occurs (Bigg 1969). The age at which a female first produces offspring or productive maturity is a more meaningful parameter when population dynamics are considered (McLaren 1958).

In our sample from the Gulf of Alaska (Table 3) all females 4-years-old and younger were nulliparous. The one 5-year-old female for which a reproductive history could be calculated was primiparous. Two of four, 6-year-old females were pregnant for the first time. One, 7-year-old and one, 8-year-old female were primiparous. All females collected 9 years and older were multiparous.

Table 3. Proportion of females attaining productive maturity by age class.

Age	Number of females	Number becoming sexually mature	Becoming sexually mature
0-4 years	19	0	0%
5	1	1	100%
6	4	2	50%
7	5	1	20%
8	3	1	33%
9	3	0	0%
10-30 years	23	0	0%

Pregnancy Rates

Age specific reproductive rates were calculated after examination of females collected between implantation and ovulation (Table 4). The overall pregnancy rate for collected females was 56 percent while that for all collected females 5-years-old and older was 84.6 percent.

Table 4. Age specific pregnancy rates for harbor seals in the Gulf of Alaska.

Age	Total Females	Number Pregnant	Pregnancy Rate
1-12 months	5	0	0%
1 year	3	0	0%
2 years	2	0	0%
3 years	5	0	0%
4 years	5	0	0%
5 years	2	1	50%
6 years	3	3	100%
7 years	6	5	83%
8 years	2	2	100%
9 Years	3	3	100%
10-19 years	20	17	85%
20-30 years	3	2	67%
All Ages	59	33	56%

Reproductive Failures

Reproductive failures may be classified in three categories: (1) a missed pregnancy where either fertilization did not occur or the blastocyst failed to implant, (2) resorption of an embryo and (3) abortion in which the fetus was expelled from the uterus (Craig 1964 and Bigg 1969).

Two 4-year-old females were collected on 7 November 1976. Neither had ever born a pup. Neither was pregnant and no evidence of an implantation site was found. Each had ovulated the previous summer as shown by copora luteau. The corpora luteau were smaller than normal and appeared to be degenerating. Apparently in both instances the animals ovulated but either fertilization did not occur or the blastocyst failed to implant.

A 7-year-old female collected on 21 March 1976 was not pregnant and there was no evidence of prior pregnancies. A small corpus luteum was present in one ovary indicating that ovulation had occurred that year. The cause of the unsuccessful pregnancy was not apparent.

A 30-year-old female was collected on 21 April 1976 which was not pregnant. One ovary contained a small corpus luteum which had nearly degenerated to the point where it would be classified as a corpus albicans. There was no follicular activity in either ovary which is unusual for a sexually mature animal. It is possible that old age may have affected reproductive performance in this animal.

Three, multiparous females ages 10, 10 and 12 years old were collected at Middleton Island on 26 May 1976. None of these animals were pregnant, lactating nor accompanied by pups. All had ovulated the previous summer and had apparently been pregnant. It appears that all three probably aborted or had premature pups. This is extremely unusual and no explanation is now available.

Sexual Maturity and Seasonal Activity in the Male

Because of the seasonal nature of the collecting activities (all collecting was done between 1 October and 10 June because of the emphasis on determining pregnancy rates) sufficient data have not been collected to precisely determine age of sexual maturity and seasonal potency in male harbor seals in the Gulf of Alaska. However, the limited data collected (Tables 5 and 6) agree closely with the information previously reported from Prince William Sound (Pitcher 1977). It was found that males become mature from 3 to 6 years of age. All were mature by 7 years. Mature males were in breeding condition from April until September.

Table 5. Age of sexual maturity in 8 male harbor seals based on the presence of abundant epididymal sperm during the period 26-31 May 1976.

(Years) Age	No. of Males	Epididymal Sperm Absent	Trace	Abundant	% Mature
2	1	1			0%
3	1	1			0%
5	1		1		0%
7	1			1	100%
8	2			2	100%
9	1			1	100%
10	1			1	100%
13	1			1	100%

Table 6. Seasonal potency in male harbor seals, 7 years and older.

Time Period	No. of Males	Epididymal Sperm None	Trace	Abundant	% Potent
7-11 Feb	2	2			0%
18-21 March	9	7	1	1	11%
15-24 April	14	2	2	10	71%
26-31 May	5			5	100%
9-12 Oct	3	3			0%
5-10 Nov	6	6			0%

Growth

Assuming a 1 October mean implantation date and a 14 June mean birth date the period of active fetal development is about 8.5 months. When this is combined with a 2.5 month delay of implantation the combined gestation period is approximately 11 months. Fetal weights and lengths are presented in Fig. 1. Of particular interest are the weights and measurements of the four near term fetuses collected around 1 June. These are comparable in size to fetuses taken in April. The June specimens were taken in Icy Bay and the April specimens were collected along the Kenai coast and around the Kodiak Archipelago. This limited sample indicates that fetal growth rates may differ in different locations of the Gulf of Alaska.

Birth weights and lengths collected during this study and those presented in the literature for the Gulf of Alaska are summarized in Table 7. When additional data are collected these should be compared on an area to area basis.

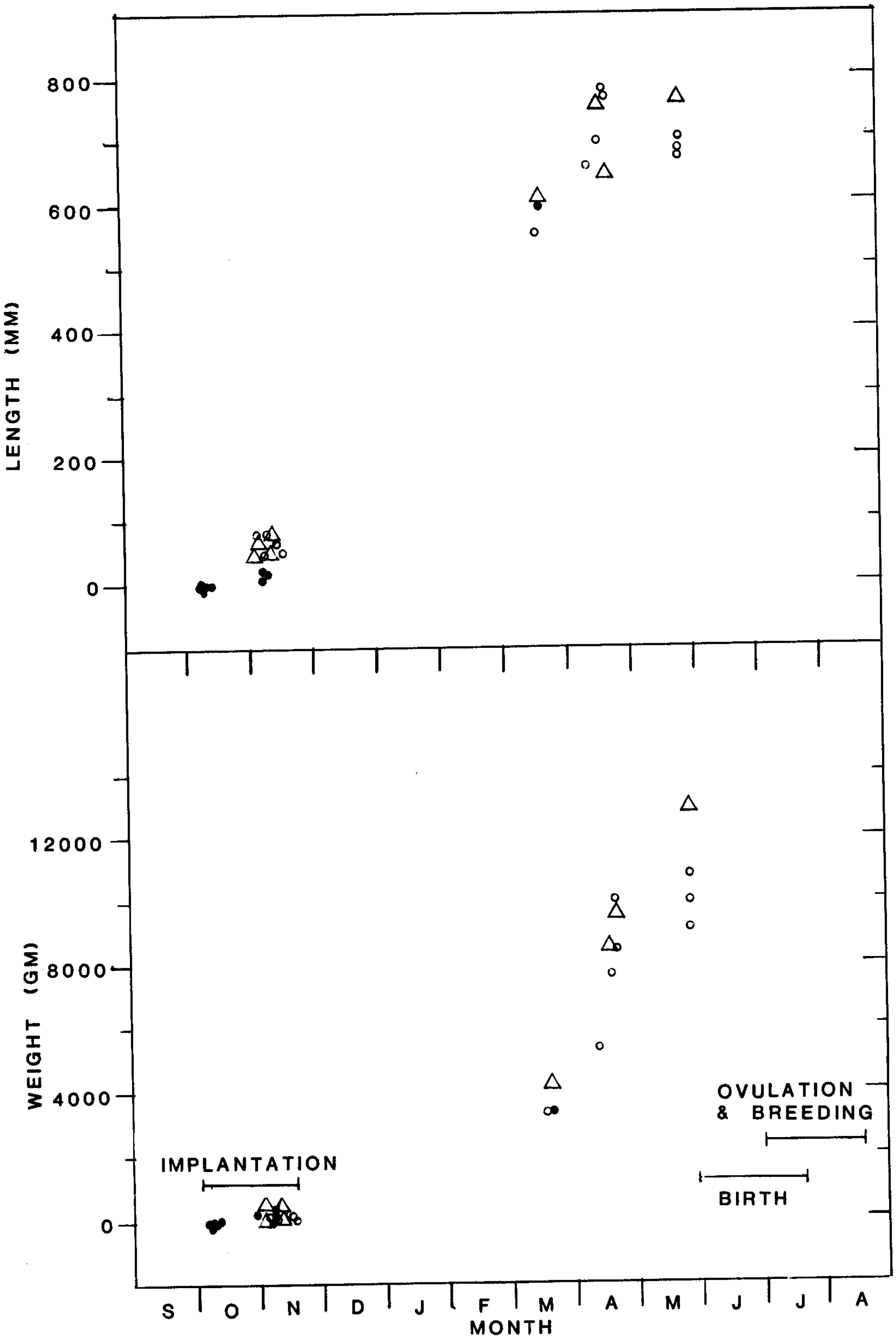

FIG. 1. PRENATAL GROWTH IN STANDARD LENGTH AND WEIGHT FOR 30 HARBOR SEALS. △, MALE; O, FEMALE; ●, SEX UNKNOWN.

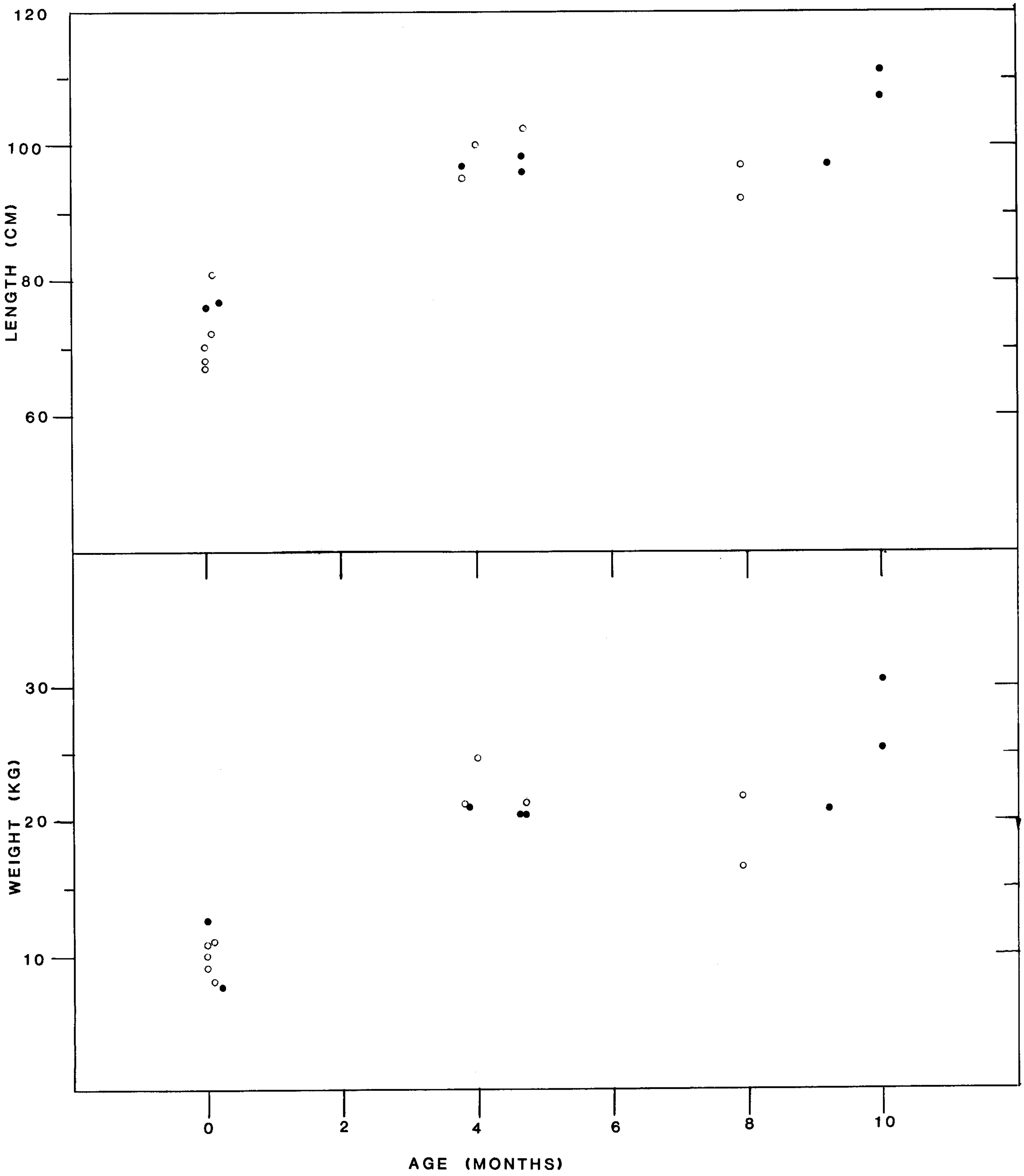

FIG. 2. FIRST YEAR BODY GROWTH IN STANDARD LENGTH AND WEIGHT FOR 18 HARBOR SEALS FROM THE GULF OF ALASKA. ●, MALE; O, FEMALE.

Data collected on weights and lengths during the first year of life are presented in Fig. 2. The data are not adequate to analyze the pattern of first year development, particularly if birth size differs by area in the Gulf of Alaska.

Table 7. Weights and standard lengths of new born pups of full term fetuses--harbor seals.

Area	Sex	Weight	Length	Source
Icy Bay	♀	10,000 g	680 mm	This study
"	♀	9,100 g	670 mm	"
"	♀	10,700 g	700 mm	"
"	♂	12,800 g	760 mm	"
"	♀	11,300 g	810 mm	"
"	♂	7,700 g	767 mm	"
Yakutat Bay	♀	8,200 g	720 mm	"
Copper River Delta	♀	13,000	823 mm	Pitcher (1977)
"	♀	10,900	810 mm	"
"	♂	10,900	875 mm*	Imler & Sarber (1947)
	♀	12,500	910 mm*	"
Tugidak Island	♀	11,800	765 mm	Bishop (1967)
	♂	11,600	845 mm	"

* No specified but probably curvilinear length rather than standard length.

Postnatal growth data are depicted in Figs. 3 and 4. There is considerable individual variation in both skeletal growth and weight. Growth (both weight and length) appears to be completed by 10 years and possibly as early as 7 years. Mean standard length for males 10-years-old and older was 157.2 ± 2.8 cm (95% confidence interval) compared to 147.4 ± 2.6 cm for females. Mean weights for males 10-years-old and older were 85.7 ± 3.9 kg compared to 80.1 ± 6.2 kg for females. When larger sample sizes are available it will be important to compare growth in different areas of the Gulf.

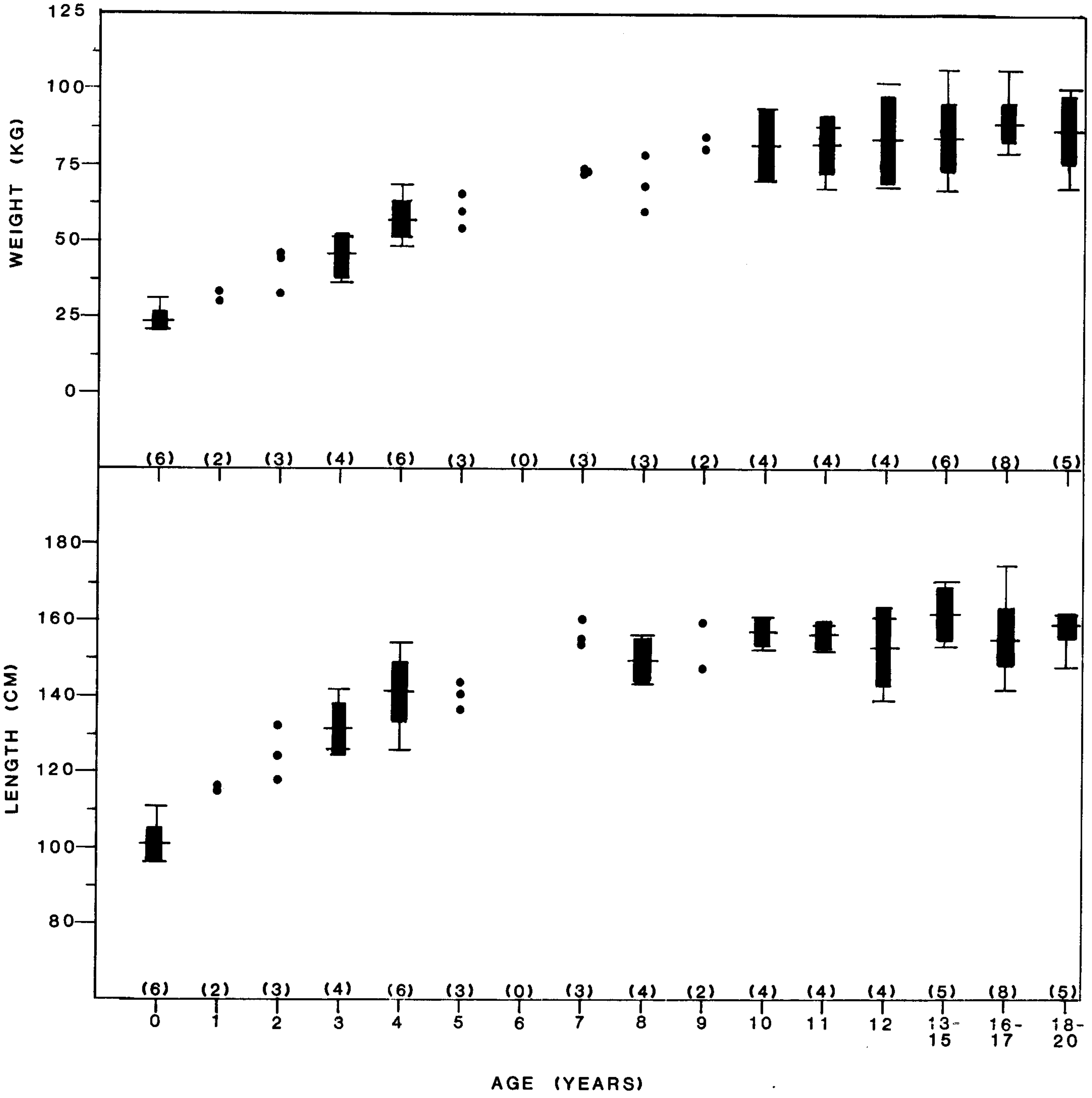

FIG. 3. STANDARD LENGTHS AND WEIGHTS OF MALE HARBOR SEALS FROM THE GULF OF ALASKA BY AGE CLASS. VERTICAL LINE, RANGE; BOX, MEAN WITH 95% CONFIDENCE LIMITS; HORIZONTAL LINE IN BOX, MEAN; NUMBER IN PARENTHESES, SAMPLE SIZE.

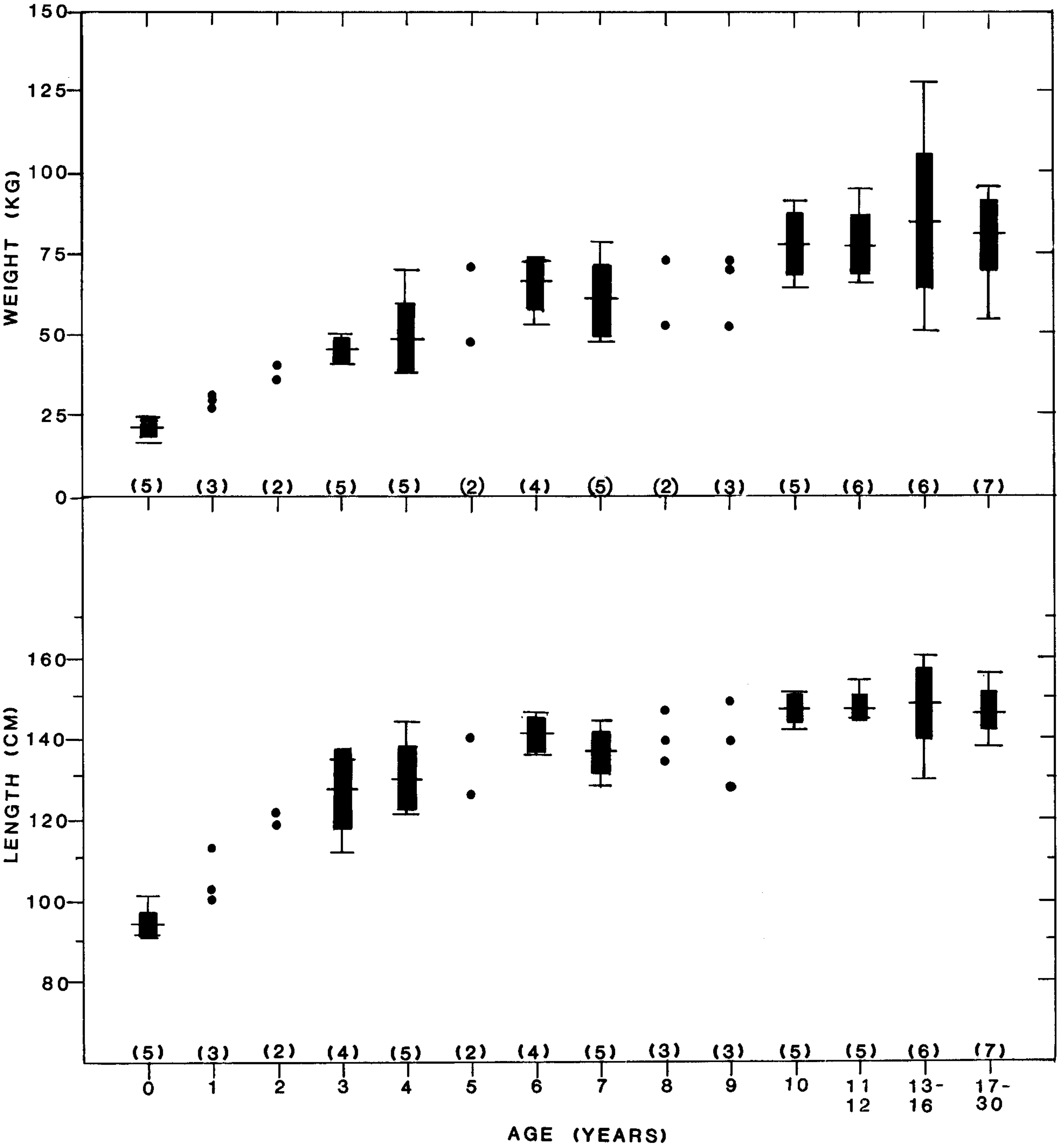

FIG. 4. STANDARD LENGTHS AND WEIGHTS OF FEMALE HARBOR SEALS FROM THE GULF OF ALASKA BY AGE CLASS. VERTICAL LINE, RANGE; BOX, MEAN WITH 95% CONFIDENCE LIMITS; HORIZONTAL LINE IN BOX, MEAN; NUMBER IN PARENTHESES, SAMPLE SIZE.

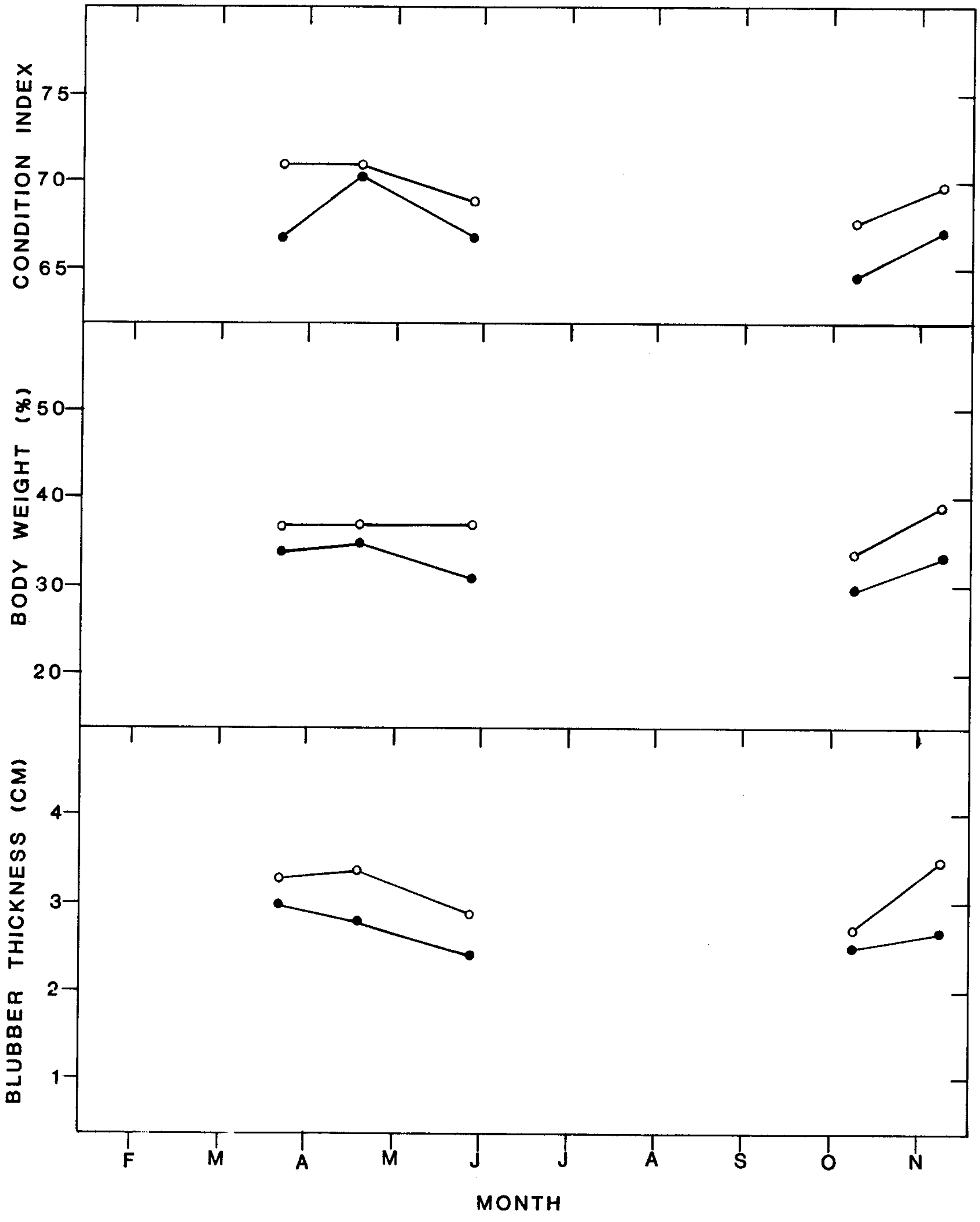

FIG. 5 HARBOR SEAL CONDITION INDICES, GULF OF ALASKA, BLUBBER THICKNESS; WEIGHT OF HIDE AND BLUBBER AS PERCENT OF TOTAL BODY WEIGHT; AND CONDITION INDEX (AXILLARY GIRTH X 100/STANDARD LENGTH). POINTS ARE MEANS FOR EACH COLLECTING PERIOD. O, FEMALE AND ●, MALE.

Condition

Measurements of body fat have been used by seal researchers as indices of body condition. These include blubber thickness, the ratio of blubber weight to total body weight and a condition index i.e. axillary girth x 100/ standard length (Pitcher 1977). Data collected to date are summarized in Table 8 and Fig. 5. In Prince William Sound, Pitcher (1977) found a pattern of good condition during winter, slowly increasing until early to midsummer. In July blubber reserves were reduced but were again increasing by early October.

Table 8. Harbor seal condition indices by collection period. Means with 95% confidence intervals.

Collection Period	Blubber Thickness		% Hide + BL.		Condition Index	
	♀	♂	♀	♂	♀	♂
18-21 March	3.3±.63	3.0±.33	36.9±3.1	33.8±2.5	70.9±3.5	67.7±1.8
13-24 April	3.4±.49	2.8±.29	37.2±2.5	34.9±1.8	70.9±3.3	70.3±2.8
26 May-1 June	2.9±.43	2.4±.26	36.9±2.6	30.7±1.6	68.9±2.9	66.7±3.0
6-12 October	2.7±.5	2.5±.24	33.5±2.4	29.6±2.1	67.6±3.7	64.5±2.3
4-10 November	3.5±.38	2.7±.21	38.8±2.6	33.5±1.6	69.6±2.4	67.0±2.2

Food Habits

Exclusive of the animals collected in Prince William Sound (data are presented in Pitcher 1977), stomachs and large intestines from 129 animals were examined for food items during this study. Food items were found in 104 of these animals.

Food habit analysis was based primarily on frequency of occurrence and secondarily on proportion of total individuals. Volumetric measurements were made of total stomach contents. When more than one species was present in a stomach, an attempt was made to determine volumes for each species. This was not possible in most cases as the flesh had been digested to the point where it could not be separated. Because of this either a volume or weight based analysis was not practical in most cases.

Based on frequency of occurrence, fishes composed 79.0 percent, cephalopods 14.2 percent and decapod crustaceans (shrimp and crabs) 6.2 percent of the harbor seal prey items (Table 9). Primary groups of prey species were gadids (33.6%), cephalopods (14.2%), pleuronectids (9.3%), Ammodytidae (7.5%), Osmeridae (7.1%) and cottids (6.2%). Principal species included *Theragra chalcogramma, Octopus sp., Gadus macrocephalus, Ammodytes hexapterus* and *Mallotus villosus*. The major differences in selection of prey species found in the Gulf when compared to Prince William Sound (Pitcher 1977) were reduced use of *Clupea harengus* from 16.0 percent down to 3.1 percent, reduced use of *T. chalcogramma* from 34.2 percent to 22.1 percent, reduced use of squid from 8.6 percent to 1.8 percent, increased use of pleuronectids from 2.1 percent to 9.3 percent and the appearance of cottids (6.2%) and *A. hexapterus* (7.5%) as important food items.

To evaluate the different methods of presentation of food habit data a comparison was made (Table 10). There are major differences depending on the method of data analysis. A volumetric or biomass evaluation is

Table 9. Frequency of occurrence and number of individual food items of harbor seals from the Gulf of Alaska.

Food Items	Number of Occurrences	Percent Occurrences	Number of Individuals	Percent Total Individuals
Cephalopoda (Total)	32	14.2%	73	4.8%
Decapoda (squids)	4	1.8%	4	0.3%
Octopoda (*Octopus sp.*)	27	11.9%	68	4.5%
Unid. cephalopods	1	0.4%	1	0.1%
Decapoda (crustaceans) Total	14	6.2%	256	16.8%
Crangon sp. (shrimp)	1	0.4%	1	0.1%
Eualus sp. (shrimp)	1	0.4%	10	0.7%
Pandalidae (shrimp)	5	2.2%	229	15.1%
Sclerocrangon sp. (shrimp)	1	0.4%	1	0.1%
Spirontocaris sp. (shrimp)	1	0.4%	1	0.1%
Hyas lyratus (spider crab)	2	0.9%	2	0.1%
Paguridae (hermit crab)	1	0.4%	1	0.1%
Brachyera (unid. crab)	2	0.9%	11	0.7%
Rajidae				
*Raja sp.** (skate)	1	0.4%	5	0.3%
Clupeidae				
Clupea harengus	7	3.1%	232	15.3%
Osmeridae (Total)	16	7.1%	118	7.8%
Mallotus villosus (capelin)	14	6.2%	115	7.6%
Thaleicthys pacificus (eulachon)	2	0.9%	3	0.2%
Gadidae (Total)	76	33.6%	589	38.7%
Eleginus gracilis (saffron cod)	2	0.9%	2	0.1%
Gadus macrocephalus (Pacific cod)	19	8.4%	68	4.5%
Microgadus proximus (tomcod)	5	2.2%	19	1.2%
Theragra chalcogramma (pollock)	50	22.1%	500	32.8%
Zoracidae				
Lycodes spp. (eelpouts)	4	1.8%	7	0.5%
Scorpaenidae				
Sebastes spp. (rockfish)	3	1.3%	7	0.5%
Hexagrammidae (Total)	6	2.7%	7	0.5%
Hexagrammos spp. (greenlings)	5	2.2%	5	0.3%
Ophidon elongatus (ling cod)	1	0.4%	2	0.1%
Cottidae (Total)	14	6.2%	23	1.5%
Dasycottus setiger (spinyhead sculpin)	1	0.4%	1	0.1%
Myoxocephalus spp. (sculpin)	3	1.3%	9	0.6%
Unid. cottids	10	4.4%	13	0.9%
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	7	3.1%	48	3.2%

Table 9. (cont.) Frequency of occurrence and number of individual food items of harbor seals from the Gulf of Alaska.

Food Items	Number of Occurrences	Percent Occurrences	Number of Individuals	Percent Total Individuals
Bathymasteridae				
Bathymaster sp. (ronquil)	1	0.4%	3	0.2%
Stichaeidae (pricklebacks)	1	0.4%	6	0.4%
Ammodytidae				
Ammodytes hexapterus (sandlance)	17	7.5%	87	5.7%
Pleuronectidae (Total)	21	9.3%	50	3.3%
Atheresthes stomias (arrowtooth flounder)	5	2.2%	6	0.4%
Hippoglossoides elassodon (flathead sole)	2	0.9%	15	1.0%
Hippoglossus stenolepis (Pacific halibut)	1	0.4%	1	0.1%
Isopsetta isolepis (butter sole)	1	0.4%	1	0.1%
Lepidopsetta bilineata (rock sole)	1	0.4%	4	0.3%
Limanda aspera (yellowfin sole)	2	0.9%	2	0.1%
Lyopsetta exilis (slender sole)	2	0.9%	2	0.1%
Parophrys vetulus (English sole)	4	1.8%	11	0.7%
Unid. pleuronectid	1	0.4%	4	0.3%
Unidentified fishes	6	2.7%	10	0.7%
TOTAL	226	99.4%	1,521	101.0%

* Possibly misidentified, checked by three experts, two identified it as *Raja* and one as cyclopteridae.

generally accepted as the best indicator of prey importance. In this study several problems were encountered which considerably reduced the value of this method. In many cases more than one prey species had been fed upon. Digestion was often well advanced and although identifications and number of individuals could be determined, it was not possible to determine volumes for each species. The collecting activities took place along the coast but it appears that much of the feeding takes place offshore. Identifications and often proportions of individual species could be determined from prior meals, however, volumes from these well digested remains were low. In contrast, near shore species such as *Octopus* and cottids were occasionally encountered in a fresh state and comparative volumes were exaggerated. Analysis of proportion of total individuals exaggerates the importance of small species and minimizes the significance of large prey. The major shortcoming of frequency of occurrence is a situation where a species occurs frequently but in small quantities. In this instance it was felt that frequency of occurrence presented the best overall portrayal of prey species importance.

Table 10. Comparison of frequency of occurrence, proportion of total individuals and percentage of volume analyses of food habit data for major species.

Prey Species	Frequency of Occurrence	Proportion of Individuals	Percentage of Volume
Octopus sp.	11.9%	4.5%	40.8%
Pandalid Shrimp	2.2%	15.1%	1.3%
Raja sp.	0.4%	0.3%	7.6%
Clupea harengus	3.1%	15.3%	8.3%
Mallotus villosus	6.2%	7.6%	1.8%

Table 10. (cont.) Comparison of frequency of occurrence, proportion of total individuals and percentage of volume analyses of food habit data for major species.

Prey Species	Frequency of Occurrence	Proportion of Individuals	Percentage of Volume
Gadus macrocephalus	8.4%	4.5%	7.6%
Theragra chalcogramma	22.1%	32.8%	5.1%
Cottidae	6.2%	1.5%	9.0%
Ammodytes hexapterus	7.5%	5.7%	3.4%
Pleuronectidae	9.3%	3.3%	0.4%

Harbor Seal Concentrations

All observations of harbor seals concentrations made during field activities were recorded (Table 11). Over time, these will provide information on patterns of seasonal distribution and critical habitat.

Table 11. Summary of harbor seal concentrations seen during field activities of RU-3, RU-229 and RU-243.

Date	Location	Number of Seals
5 Oct. 75	Cape Fairfield	55
5 Oct. 75	Day Harbor	29
4 Oct. 75	Aialik Bay	191
4 Oct. 75	Surok Pt.	25
3 Oct. 75	Nuka Bay	20
3 Oct. 75	East Chugach Island	18
3 Oct. 75	Elizabeth Island	35
2 Oct. 75	Sadie Cove - Tutka Bay	23
2 Oct. 75	Halibut Cove - China Poot Bay	15
6 Oct. 75	Marmot Island - east side	14
6 Oct. 75	Sea Lion Rocks	34
6 Oct. 75	Seal Bay	30
11 Feb. 76	Zachar Bay	18
20 Mar. 76	Nuka Island - west side	25
20 Apr. 76	Big Fort Bay - Shuyak	25
21 Apr. 76	Big Bay - Shuyak	25
22 Apr. 76	Blue Fox Bay - Afognak	25
24 Apr. 76	Raspberry Straits	35
8 May 76	Dry Bay	93
29 May 76	Disenchantment Bay	331
30 May 76	Pt. Manby	50+
29 May 76	Pt. Riou	100+
28 May 76	Icy Bay	500+
28 May 76	Kaliakh River	200
26 May 76	Middleton I.	138
13 Apr. 76	Harris Bay	75-125
15 Apr. 76	Aialik Bay	150
24 Aug. 76	Cape Fairfield	30
31 Aug. 76	Calisto Head	70
31 Aug. 76	Cheval I.	200
31 Aug. 76	Aialik Cape	40
31 Aug. 76	Home Cove	37
24 Jun. 76	Taylor Bay	24
24 Jun. 76	Rocky Bay	176
22 Jun. 76	Fox River	45
3 Oct. 76	Yukon I.	250
5 Jul. 76	Iniskin Bay	57
30 Sep. 76	Augustine I.	1,175
5 Nov. 76	Zachar Bay	30
5 Nov. 76	Spiridon Bay	50
25 Sep. 76	Tugidak I.	13,000
2 Sep. 76	Sitkinak I.	800
2 Sep. 76	Geese I.	800
2 Sep. 76	Aiaktalik I.	600
9 Oct. 76	Ayakulik River	100
8 Oct. 76	Nagai Rocks	40
10 Nov. 76	Ugak Bay	250
1 Mar. 76	Womens Bay	31
28 Feb. 76	Sitkalidak I.	35

Tugidak Island

Tugidak Island (Fig. 6) one of the Trinity Island group is located 20 miles southwest of Kodiak Island. The island is about 18 miles long and 4-7 miles wide and has the largest known single concentration of harbor seals in the world (minimum population size 13,000--possibly considerably higher). Because of its size and uniqueness and its proximity to proposed O.C.S. lease areas it was decided to gather detailed information on this population. Specific objectives were to determine seasonal use patterns, the progression of life history events (e.g. pupping, weaning, molting) and effects of disturbance (Appendix 1).

About two-thirds of the seals haul out on a 3-mile-long stretch of beach on the southwestern end of the island. There are high bluffs overlooking the beach and the seals can be easily counted and observed. The remainder of the animals haul out on the northeastern end of the island and due to the flat terrain can not be approached and counted effectively except by aircraft. Because of this nearly all of the data were collected from the southwest portion of the island. Periodic aerial surveys of the entire island were conducted to supplement this information.

Data collected on pupping, weaning and breeding have been presented in the section dealing with reproduction. Results of counts of the southwest sector are summarized in Fig. 7. These data show a small peak in June during pupping, followed by a decline in midsummer and a tremendous increase in late August and early September during the molt. Periodic observations made during winter months indicate relative low usage

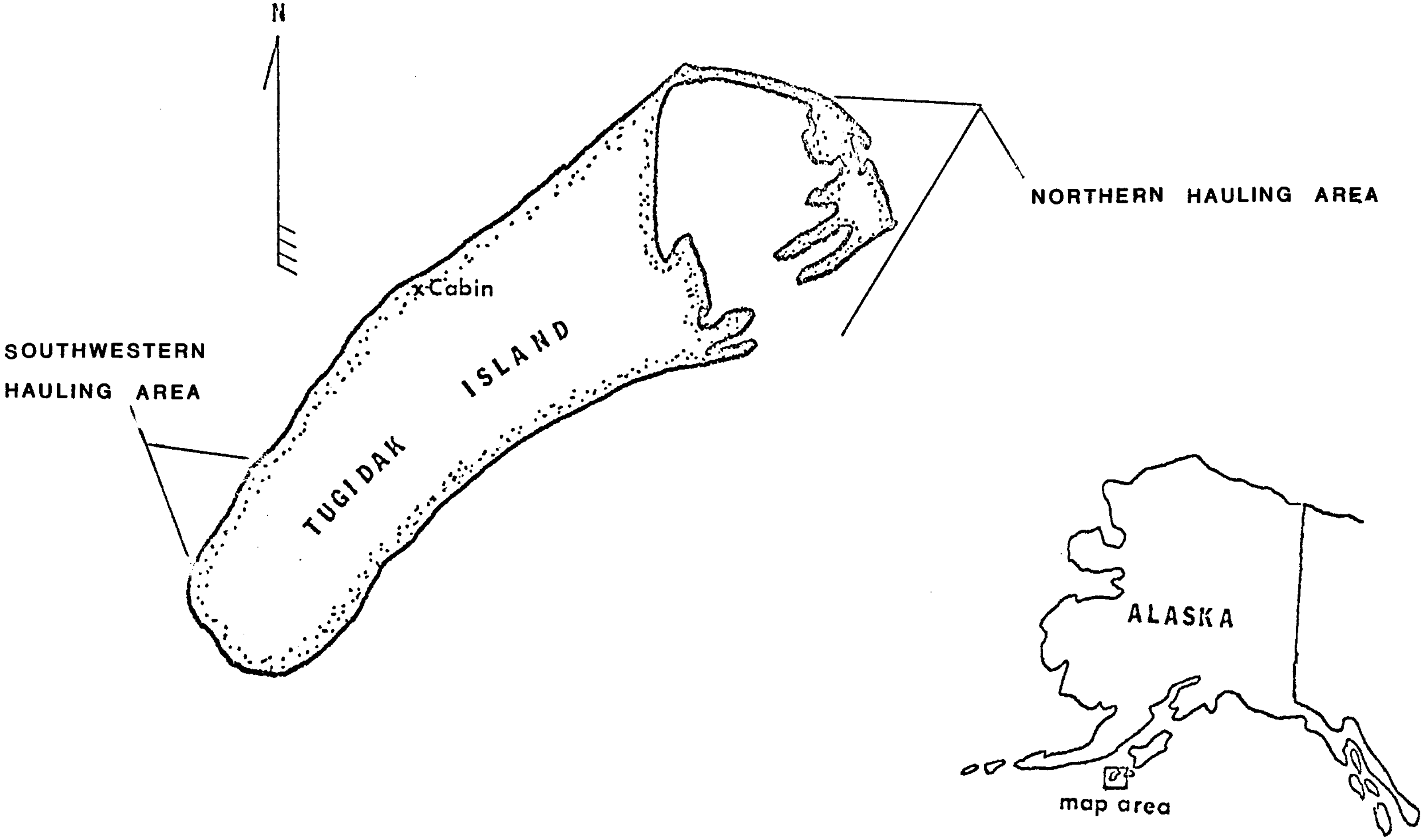

FIG. 6- TUGIDAK ISLAND
LOCATED SOUTHWEST OF KODIAK ISLAND

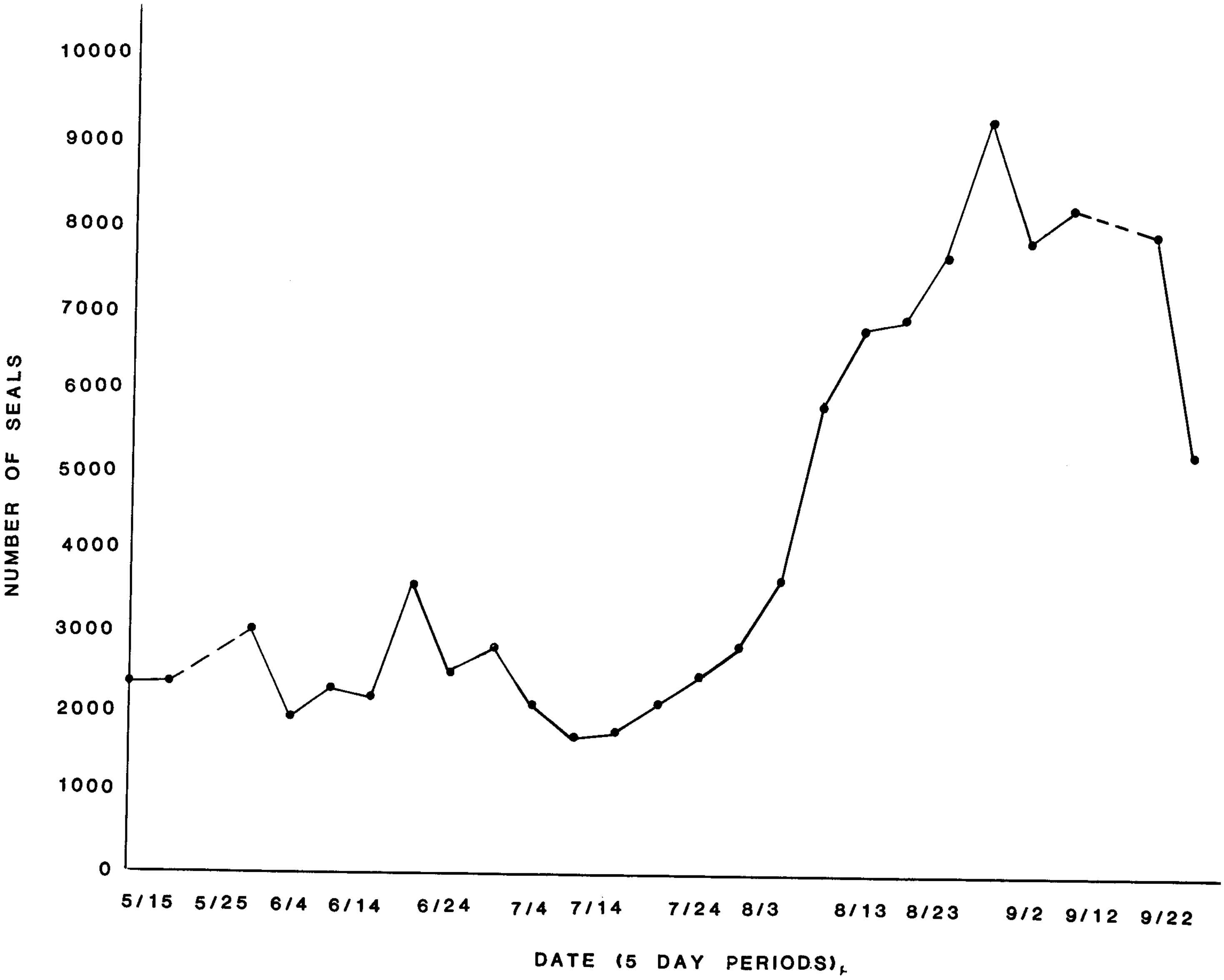

FIG. 7. NUMBER OF HARBOR SEALS ASHORE ON THE SOUTHWEST SHORE OF TUGIDAK ISLAND, MAY-SEPT. 1976.

(ADF&G unpublished data). On 2 September 1976 an aerial survey was flown to determine total numbers of seals using the entire island. On this survey 12,300 seals were counted. As the southwest area count was 2,500 animals lower than the high of 30 August it was likely that the 12,300 figure was low. Also animals were visible in the water (and could not be counted) during all counts indicating that the entire population was not hauling out. From these data we know that the minimum population for Tugidak exceeds 12,300 seals probably by several thousand. We have no information on what proportion of the animals are hauling out so it is possible that the total population is considerably larger than observed.

One of the more obvious and immediate effects of exploration and development of O.C.S. lease sites is disturbance of animal populations. A principal objective of the Tugidak project was to document effects of disturbance on harbor seals. We have included the field report of this investigation (Appendix 1). This is a preliminary report and many of the conclusions are speculative. However, the material is of sufficient importance to be presented in this form.

RECOMMENDATIONS AND NEEDS FOR FURTHER STUDY

1. Based on the results of Tugidak Island studies we recommend that all lease sales contain strong provisions preventing disturbance of harbor seal rookeries and hauling areas during pupping (15 May - 15 July) and during the molt (15 August - 15 October). These conditions should be aimed particularly at aircraft, helicopters being the most frequent violators. Both linear distance (perhaps 2 miles) and altitude (2500') should be considered. Land and boat based activities in the immediate area of the rookeries or haul out areas should be restricted during these time periods.

2. Not only should disturbance restrictions be a condition of lease sales, they should also be placed on exploratory activities. The majority of the disturbance on Tugidak during 1976 was related to O.C.S. exploration. Helicopters transporting geologists were the most severe disturbance factor. The helicopters usually followed the beach flying very low, often below 100 feet, causing all animals to scramble into the water. Total restriction would not be necessary if altitude and linear distance requirements were established and followed.

3. A series of harbor seals should be collected from lower Cook Inlet to provide information on principal prey species and to provide specimen materials for environmental pollutant analysis.

4. Intensive research should begin on Tugidak Island. Tugidak must be considered critical harbor seal habitat based on size of the population

(largest single concentration in the world). Several of the proposed lease areas are nearby and may be important feeding areas for Tugidak seals. The first major research effort should be directed at establishing size of the current population. This could be accomplished utilizing the combination of marked animals (radio transmitters), repetitive aerial photographic censuses and application of the Schnabel estimation formula.

5. Collecting should continue for at least one additional year to further clarify seasonal and area differences in prey species useage. As nearly all of the collecting has been during winter to facilitate determination of reproductive rates we have a void in summer food habit information.

6. Research should be directed at the life histories of important prey species including *Theragra, Gadus, Clupea, Mallotus, Thaleicthys, Ammodytes* and *Octopus* sp. The effects of oil on the various developmental stages should be determined.

ESTIMATE OF FUNDS EXPENDED

1 March 1977 - $10,000 - @ 17 percent.

SUMMARY OF FOURTH QUARTER ACTIVITIES

Ship Schedule - 19-27 March 1977 - Outer Kenai coast - ADF&G Research vessel "Pandalus"

Scientific Party - Ken Pitcher, Roger Aulabaugh, Fred Woelkers, Dave Hardy - ADF&G

Methods - See methods section annual report

Sample Localities - Kenai Peninsula - outside coast

Data Collected and Analyzed.

a. During the March cruise, 29 harbor seals were collected.

b. Reproductive tract analysis was completed for all animals taken during 1975 and 1976.

c. Food habit analysis was completed for all animals taken during 1975 and 1976.

d. Growth and condition data were analyzed for all animals taken during 1975 and 1976.

e. Considerable time was spent compiling and analyzing data and preparing the annual report.

f. Attendance and preparation for the Kodiak synthesis meeting.

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Annual Report

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Number of Pages: 57

The Natural History and Ecology of the Bearded Seal (*Erignathus barbatus*) and the Ringed Seal (*Phoca hispida*)

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April 1, 1977

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I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development

Ringed seals, Phoca hispida, and bearded seals, Erignathus barbatus, are major components of the marine mammal fauna of the Bering, Chukchi and Beaufort Seas. They have been chosen as target species for investigation based upon criteria including their significance in the ecosystem, importance to people residing along the coast and considerations of timeliness, feasibility and applicability to OCS requirements. This does not overlook the significance of other marine mammal species of the region, some of which are the subjects of other investigations (i.e. walrus, spotted seals, bowhead whales), and some which suggest a lower probability of successful achievement of important task objectives (i.e. ribbon seals or grey whales). All of the marine mammal species of the area will be included in certain kinds of analyses such as that of distribution.

The broad objectives of this project are to obtain baseline information about the natural history and ecology of ringed and bearded seals. These species occupy vastly different ecological niches within the ice dominated marine systems in question.

The ringed seal is a small, widely distributed and very abundant species which mainly occurs in areas of extensive, relatively thick and stable sea ice. It is the only species within our study area that occupies the land fast ice. It is the species taken in largest numbers by Eskimo seal hunters. Ringed seals feed mainly on zooplankton, the smaller shrimp and demersal fishes.

In marked contrast, bearded seals are the largest of our northern seals. They are also widely distributed, but occur in the drifting ice. They feed almost exclusively on benthic organisms. Annual harvests of bearded seals are much lower than those of ringed seals. However, due to the great difference in size, the amount of usable protein obtained is almost the same. Bearded seals are preferred by coastal residents.

Our intent in selecting these species for investigation was to examine simultaneously the biology of two species which are of significant importance to man, and which depend on vastly different habitats within the marine ecosystem.

The implications with respect to oil and gas development are basically that we will be able to recognize how, when, where and why certain activities may have proximal or ultimate effects on these two important species. As examples, how does seismic exploration in areas of land fast ice affect ringed seals which breed there? What food organisms are these seals utilizing? Are there differences in the susceptibility of prey species to oil pollution--or, which of the seals is most susceptible to significant indirect effects of oil development? How much disturbance will the seals tolerate? Will they avoid areas of intensive human activity? Are there critical migration routes, etc. Answers to almost all of the questions concerning the potential effects of oil and gas development on these seals depend on an understanding of their natural history and ecology.

II. Introduction

Bearded and ringed seals constitute two of the five pinniped species associated with the ice dominated habitat of the Bering, Chukchi and Beaufort Seas. By virtue of numbers and distribution they are of great significance to coastal residents of northern Alaska and Siberia; providing reliable sources of food and usable by products. Their importance as significant, functioning elements of the marine environment is not adequately known. Both species occur throughout the seasonally ice covered regions. However, differences in habitat requirements (including food habits) result in an ecological partitioning of the marine system in question. Proposed OCS lease areas in the Bering, Chukchi, and Beaufort Seas fall directly within the habitat of these two species.

The primary emphasis of our ecological studies responds to OCSEAP tasks A-1, A-2 and A-3. Information required for accomplishment of objectives A-6 and A-31 is being obtained. Our study (as well as many others) is required in order to eventually achieve objective E-1.

Information required to meet the task objectives include, but are not limited to, such things as natality, mortality, population size, population structure, trophic relationships, detailed understanding of factors determining density, distribution, seasonal movements, critical habitat requirements, relationship to ice habitats, behavior and other biological processes. Historical events indicate that marine mammals, as intelligent, irritable (in the physiological sense) and ecologically specialized organisms have almost always been adversely affected by the activities of man. The proposed exploitation of outer continental shelf resources poses the real threat of habitat alteration. Adverse impacts can be lessened if there is an adequate understanding of the ecosystem and its component parts and types of perturbation that can be anticipated.

Specific objectives of this project are as follows:

1. Summarization and evaluation of existing literature and available unpublished data on reproduction, distribution, abundance, food habits and human dependence on bearded and ringed seals in the Bering, Chukchi and Beaufort Seas.

2. Acquisition of large amounts of specimen material required for an understanding of food habits in these two species.

3. Acquisition of additional data on productivity and growth rates.

4. Acquisition of baseline data on mortality and morbidity (including parasitology, diseases, predation and human harvest) of ringed and bearded seals.

5. Determination of population structure of bearded and ringed seals as indicated by composition of harvest taken by Eskimo subsistence hunters.

6. Initial assessment of regional differences in density and distribution of ringed and bearded seals in relation to major habitat conditions.

7. Acquisition of additional information on seasonal migrations.

III. Current state of knowledge

A considerable amount of general background information concerning bearded and ringed seals is presently available and is being summarized under our task objective 1. Almost all of this information relates to general understanding of aspects such as reproduction, age and growth, gross physical characteristics, general seasonal movements, general distribution and food habits. However, the knowledge presently available remains inadequate for purposes of understanding the dynamic processes of these two species, their impact on and role in the northern marine environment and the probable effects of disturbance both to the species themselves and the environment on which they depend.

A. Ringed seal

Ringed seals have a circumpolar distribution in arctic and subarctic seas, and they are the most abundant seal found in the Arctic. Polar bears, arctic foxes and ringed seals are the only mammals that have been recorded north of 85°N latitude.

In Alaska, ringed seals inhabit the shorefast and moving pack ice of the northern Bering, Chukchi and Beaufort Seas. Stragglers have been collected at Unalaska Island in the Aleutian Islands and on the Pribilof Islands.

The general distribution of ringed seals is limited by the distribution and quality of sea ice; however, some ringed seals are seen during ice-free periods in the Bering and Chukchi Seas. Seals appear at various coastal locations with the formation of shorefast ice in the fall and then disappear in the spring with the ice breakup. Seals which winter in the Bering Sea may appear to move farther and are more widely distributed than adult ringed seals. The density of ringed seals varies greatly with the area and the season, but chiefly depends on the stability of shorefast ice for reproduction.

In addition to man, predators of ringed seals include polar bears (Ursus maritimus) (the chief predator), arctic (Alopex lagopus) and red foxes (Vulpes vulpes), dogs, wolves (Canis lupus) and ravens (Corvus corax).

Females give birth to a single, white-coated pup in ice dens (lairs) on both landfast and drifting pack ice during March and April. The female seals build the lairs on ice pressure ridges or under snow in refrozen leads for protection from predators and severe weather. Lairs are about 10 feet (305cm) long with an entrance from the water located at one end.

There is some evidence that females lacking maternal experience give birth in marginal habitat--drifting pack ice--and may be more subject to polar bear predation. The more experienced females give birth in better habitat, landfast ice, and may have higher reproductive success.

At birth the average weight of pups is 10 pounds (4.5kg) and the average length is about 24 inches (61cm). Females nurse pups for about 2 months during which the pup doubles its birth weight, to about 20 pounds (9.0kg). This gain is due to an increase in blubber thickness which provides the pup insulation to reduce heat loss to the cold water, air and ice, and provides an energy reserve. Weaning usually takes place at ice breakup.

Most females breed again within a month after the birth of the pup. Implantation of the new fetus is delayed 3-1/2 months and occurs in mid-July or early August. Pregnancy lasts about 11 months. Female ringed seals first ovulate at five or six years of age but successful conception does not appear to take place until the female is seven years old. Males become sexually mature at seven or eight years of age.

Ringed seals have been reported to live to an age of 36 to 40 years in the wild, however very few animals exceed 10 to 15 years of age.

Until recently the ringed seal has been considered a silent species unlike many of its relatives which produce very melodious and complex "songs." Recent studies have found that ringed seals do emit several types of vocalization under water and that these vocalizations are not readily audible above water or ice. Although these vocalizations are "heard" all year, if one uses a hydrophone (underwater microphone), the number of vocalizations increases during the breeding season. This may mean that the vocalizations are used to maintain social organization or to defend territories.

The behavior of ringed seals is poorly understood since both males and females spend the greater part of the year in lairs or in the water. From May and June until ice breakup, ringed seals "haul out" on the shorefast ice on sunny and warm days and undergo a molt (shedding and regrowth of the hairs). Apparently the warmth and rest are required for rapid regrowth of the hairs.

The primary food of ringed seals in the nearshore western Beaufort Sea during spring and summer is euphausiids. In the Chukchi Sea they appear to feed primarily on shrimps in the summer and fishes (largely polar cod) in the winter.

B. Bearded seals

Bearded seals are also a circumpolar arctic species. Although they can maintain breathing holes in ice, they appear to do so only rarely and are thus largely excluded from the winter fast ice zone. The winter density of bearded seals in the Beaufort Sea is low (about 0.1 animals/mile^2) with animals found in the flaw zone and nearshore pack ice.

Bearded seal pups are born on top of the ice from late March through May. Pups are capable of swimming shortly after birth and are weaned in 12 to 18 days. Subsequent to pupping, animals breed and molt.

As was the case with ringed seals, a seasonal concentration of animals occurs during summer. However, as they are primarily benthic feeders, few bearded seals remain with the summer pack ice when the southern edge is over deep water. They redistribute south with winter ice formation. The majority of animals winter in the Bering Sea and in the highly fractured ice north of the Bering Strait.

Bearded seals in the Chukchi and Bering Seas feed primarily on shrimps, crabs and bivalve molluscs. Foods of bearded seals in the Beaufort Sea are essentially unknown.

IV. Study area

The study area for this project includes the nearshore and offshore waters and ice of Bristol Bay, Bering Sea, Norton Sound, Bering Straits, Kotzebue Sound, Chukchi Sea, Beaufort Sea and Arctic Ocean. Specific collection localities from which we have attempted to sample during this contract period include Stebbins, Nome, Savoonga, Gambell, Shishmaref, Kotzebue, Point Hope, Cape Lisburne, Point Lay, Wainwright, Barrow, and Barter Island. With the aid of ships and helicopters we have sampled the offshore areas of Bristol Bay, Bering Sea, Norton Sound, Chukchi Sea, Kotzebue Sound, Beaufort Sea and Arctic Ocean. We have attempted to sample within and adjacent to areas outside the following proposed lease areas: Beaufort Basin, Hope Basin, Norton Basin, Bristol Bay, and Saint George Basin.

V. Sources, methods and rationale of data collection

A. Ringed and bearded seals are collected as systematically as possible from different geographic areas and habitat types throughout the year. The objective of our sampling program is to detect variations in sex and age distribution, growth rates, reproductive conditions, parasites and food habits in relation to season, geographic area and habitat type. Acquisition of the large amounts of specimen material required for an understanding of the natural history and ecology of these two species is continuing at major Eskimo hunting villages. In addition, selective collection by the Principal Investigators is utilized to collect animals under specific environmental, temporal or behavioral conditions. Selective collection provides additional data that cannot be obtained from the animals taken at the Eskimo hunting sites.

B. Weights and standard measurements are taken, when possible, from animals taken by Eskimo hunters, and from all animals selectively collected. The weights and measurements include: gross weight, hide and blubber weight, curvilinear length, standard length, axillary girth, maximum girth, front and hind flipper lengths and widths, navel to anus length, penis to anus length, tail length and blubber thickness at the sternum. These data are used to establish fetal, pup, subadult and adult growth rates, seasonal condition patterns and to assist in making biomass calculations. In addition to weights and standard measurements, we attempt to obtain: specific location, date and time of collection; habitat and ice type; behavior at time of collection; group size and composition; tidal stage; and water depth.

C. The sex of a specimen is determined by examination of the external genitalia, or reproductive organs in those cases where the intact animal is not presented.

D. The ages of all seals for which claws are available are initially estimated by claw examination. The claw provides a rapid and accurate means of age determination for seals up to six years of age, as growth rings or ridges are formed annually on the claw. After six years the claws are worn such that the initial ring ("constriction of birth") and usually subsequent rings are worn off. For these specimens, a canine tooth is sectioned and stained, using a modification of the Johnson and Lucier (1975) technique. The tooth sections are examined with the aid of a light microscope and the age of the seal is determined by enumerating the dentine or cementum annuli (Smith 1973, Benjaminsen 1973). Age determinations are necessary for development of growth rates, to determine population structure and productivity, and age specific food habits.

E. The analyses of food habits of bearded and ringed seals involves separation and identification of food items and determination of frequency of occurrence and volume of prey species. (See Annual Report for RU #232 for a detailed discussion.)

F. Species productivity is determined through laboratory examination of reproductive tracts and correlation of these data with the age of each specimen.

Testes are weighed to the nearest 0.1g with and without epididymides. Length and width at the middle of the testes are measured to the nearest millimeter. Testes volume (nearest cc) is determined by water displacement. Bacula are cleaned by boiling, air dried and then measured (nearest mm) and weighed (nearest 0.1g).

The presence of sperm in the epididymides is used to ascertain breeding condition. The epididymides are sliced and a drop of fluid is squeezed onto a slide and examined under 78x or 300x magnification. Sperm presence or absence in the epididymal fluid is quantified as: none found, trace or abundant.

Ovaries are weighed to the nearest 01.g and then cut into 2mm longitudinal sections. The sections are left joined at the base to preserve their relative position. The sections are examined macroscopically for corpora lutea, corpora albicantia, follicles and ovarian masses or abnormalities. The largest diameter of corpora lutea, corpora albicantia and largest follicle are measured to the nearest mm. Drawings are made of each ovary for later reference. The presence or absence of a fetus is noted at necropsy.

G. All specimens are examined macroscopically for gross pathological conditions. We attempt to conduct a complete necropsy on each seal selectively collected. Time and conditions do not allow complete necropsies of all the specimens obtained in the various villages but we endeavor to examine, at least partially, as many as possible. The necropsy procedure followed is that outline in Fay et al. 1976.

H. Samples (about 125cm^3) of heart, liver, kidney, skeletal muscle and skin and blubber are wrapped in aluminum foil, labeled and frozen. These tissue samples will be provided to other investigators for microbiological, hydrocarbon, pesticide and heavy metal analyses.

I. Aerial, ship and ground surveys are being used to determine the distribution and densities of ringed and bearded seals killed by polar bears and arctic foxes. These dead seals are being examined to determine cause of death, physical condition, and amount consumed by predator. Specimens are collected for laboratory analyses. In addition, the geographic location, specific habitat (breathing hole, lead, lair, etc.) and ice type are noted. Standard measurements are made on all seals.

Teeth and claws are collected to determine the age of the prey. Reproductive tracts are examined for sex and reproductive condition following standard techniques. Blubber, selected organs and tissues, stomach and digestive tract of prey species are examined for parasites, diseases or pathologic conditions and food habits, and will be provided to cooperators for analyses for pesticides, heavy metals and petro-chemicals.

Several ecological and behavioral parameters will be investigated to determine factors affecting prey availability and selection and hunting success of predators. For example, polar bears tend to take at breathing holes, seals hauled out on the ice, or in lairs, therefore, these factors influence hunting success of bears. The numbers and kinds of seals seen on the ice during surveys will be related to ice conditions, weather and seal biology data to obtain environmental and natural history correlates to hauling out behavior.

J. Population structure of ringed and bearded seals is assessed through sex and age determination of samples obtained at coastal hunting sites and during the course of selective collection. Eskimo collectors have been established in various villages, with hopes of obtaining jaws and claws and other specimen material from seals killed by the villagers. The collectors also maintain logs of dates, species and sexes of kills.

K. Seasonal migration patterns are determined through observations at coastal hunting sites, and from shipboard and aerial surveys.

L. Aerial, shipboard and ground surveys are used to determine the distribution and densities of pinnipeds in the ice-covered Bering, Chukchi and Beaufort Seas. These surveys are conducted chiefly in June during the post-reproductive and molting period of ringed and bearded seals but by the end of this research, surveys will have been conducted during every season and will have covered all ice types.

Aerial surveys are flown in both fixed-wing airplane and helicopters. Aircraft used thus far for surveys have been a Cessna 180, Cessna 185, DeHavilland Twin-Otter, and Lockeed P2V (all fixed-wing aircraft) and a Bell 206B helicopter. Survey transects were 0.8 km (0.5 miles) on each side of the aircraft. Transect width was maintained with fixed reference points on the windows and wing struts or floats. Surveys were flown at altitudes of 91.5 meters (300 feet). All seals (by species) and polar bears observed on these flights were enumerated on a prepared survey form.

Locations and distances traveled along flight tracts were determined by standard aerial navigation techniques, by radar fixes from various DEW-Line stations, or with the aid of GNS-500 system (very low frequency, Omega navigation system).

Ground surveys were conducted on shorefast ice near villages or base camps either on foot or on snow machines. Shipboard surveys were conducted from U.S. Coast Guard and N.O.A.A. ships working near the ice edge.

M. Natural history and behavioral observations are obtained from several sources: (1) field observations by the principal investigators, (2) unpublished field observations of other reliable investigators, (3) reports from Eskimos, and (4) observation of captive animals.

The bulk of the natural history and behavioral observations are recorded by the principal or other investigators while they are on the sea ice, or aboard ships, skin boats or aircraft. These observations are usually made with the aid of field glasses or spotting scopes and are recorded as field notes with appropriate ecological and behavioral conditions.

Because of the amount of time they spend on the ice pursuing marine mammals, Eskimo hunters can provide a wealth of information concerning behavior and natural history. However, this information is accepted with caution. Interview of several hunters may be required to separate facts from legends, or information given just to please the investigators. Rarely has information been given which is intended to mislead the investigators.

VI-VII. Results and Discussion

A. Field activities and specimen collection

Field activities during the reporting year were conducted extensively throughout our study area. These activities included both collections of specimens and surveys of ice habitats and seal densities and distribution. Specimens were obtained at hunting sites in Nome, Stebbins, Savoonga, Gambell, Shishmaref, Point Lay, Wainwright, Barrow, and Barter Island. Collections offshore, with the aid of ships, boats or helicopters, were made in Norton and Kotzebue Sounds and the Beaufort, Chukchi and Bering Seas. A complete listing of field activities for the reporting year are presented in Table 1.

During reporting year 1976-1977, specimens were obtained from 307 ringed seals and 133 bearded seals (Table 2). Measurements, jaws, claws, stomachs, reproductive tracts and parasitological material were obtained from most specimens. All specimen material is processed as rapidly as possible.

Of the 293 ringed seals obtained, 154 were males and 139 were females; a 1:1 sex ratio ($P > 0.05$). Similarly 128 bearded seal (54 males and 74 females) were found to have a 1:1 sex ratio (P 0.05).

B. Marine mammal harvests

One objective of this study is to determine the size and composition of the harvest of ice associated marine mammals obtained by coastal residents of Alaska. The area in which this was done extends from Cape Newenham to Barter Island and includes all coastal settlements of the northern Bering, Chukchi and Beaufort Seas. This aspect of the work for seals, belukha whales and walrus was accomplished by J. Matthews, ADF&G, Nome.

A record of annual seal harvests was obtained for four of the most dependably productive seal hunting locations; the villages of Hooper Bay, Gambell, Savoonga and Shishmaref. Hooper Bay is in

Table 1. Schedule of field activities, March 1976-March 1977.

Location	Date	Activity
Cape Lisburne	March-April 1976	Specimen collection and surveys of seals and ice habitats
OSS SURVEYOR (Bering Sea ice edge)	March-April 1976	Specimen collection and surveys of seals and ice habitats
P2V aerial surveys (Bering Sea ice edge)	April 1976	Aerial surveys of seals and ice habitats
Point Hope	April-June 1976	Specimen collection
Oliktok	May 1976	Specimen collection
St. Lawrence Island (Gambell and Savoonga)	May-June 1976	Specimen collection
Kotzebue Sound to Barter Island	June 1976	Aerial survey of seals and ice habitats
Barrow	June 1976	Specimen collection
Shishmaref	July 1976	Specimen collection
Wainwright	July-August 1976	Specimen collection
USCGS GLACIER (Beaufort Sea ice edge)	August 1976	Specimen collection and seal surveys
OSS DISCOVERER	August 1976	Specimen collection and seal surveys
R/V NATCHIK	September 1976	Specimen collection
Nome	November 1976	Specimen collection
Stebbins	November 1976	Specimen collection
Nome	January 1977	Specimen collection
Barrow	February 1977	Specimen collection
Wainwright	February 1977	Specimen collection

Table 1. (Continued).

Location	Date	Activity
Point Lay	February 1977	Specimen collection
Norton Sound	March 1977	Specimen collection
Kotzebue Sound	March 1977	Specimen collection

Table 2. Seal specimens obtained from March 1976 to March 1977.

Location	Males	Females	Unknown	Total
Barrow, 1976				
Ringed seal	10	4	2	16
Bearded seal	2	-	-	2
Barrow, 1977				
Ringed seal	2	-	-	2
Barter Island, 1976				
Ringed seal	-	2	1	3
Bearded seal	-	3	-	3
Cape Lisburne, 1976				
Ringed seal	12	-	7	19
Bearded seal	-	1	-	1
OSS DISCOVERER, 1976				
Ringed seal	-	2	-	2
Bearded seal	-	1	-	1
Gambell, 1976				
Ringed seal	2	3	-	5
Bearded seal	5	11	3	19
USCGC GLACIER				
Ringed seal	1	-	-	1
R/V MILLER-FREEMAN				
Bearded seal	1	-	-	1
Nome, 1976				
Ringed seal	3	6	-	9
Bearded seal	2	3	1	6
Nome, 1977				
Ringed seal	10	19	-	29
Bearded seal	5	-	-	5
Point Hope, 1976				
Ringed seal	37	7	3	47
Savoonga, 1976				
Ringed seal	11	7	-	18
Shishmaref, 1976				
Ringed seal	59	84	1	144
Bearded seal	31	42	-	73
Stebbins, 1976				
Ringed seal	2	1	-	3
OSS SURVEYOR, 1976				
Bearded seal	-	1	-	1
Wainwright, 1976				
Ringed seal	5	4	-	9
Bearded seal	8	12	1	21
Total Seals				
Ringed seals	154	139	14	307
Bearded seals	54	74	5	133

southeast Bering Sea, Gambell and Savoonga are on St. Lawrence Island, in northern Bering Sea and Shishmaref is in extreme southeast Chukchi Sea. These villages account for approximately 20 percent of the annual seal harvest and data obtained from them are used as a basis for estimating total harvest. Additional information, obtained from work in other villages, is utilized to augment and refine estimates.

In view of the geographical location of our four major sampling sites, and distribution of the seal species, composition of the harvest tends to overestimate the proportion of spotted seals in the harvest and to underestimate the proportions of ringed and bearded seals.

All factors considered, the estimated harvest of seals during calendar year 1976 was 7,000 to 8,500 animals with a species composition as follows:

59% ringed seals (4130 - 5015 individuals)
28% bearded seals (1960 - 2380 individuals)
13% spotted seals (910 - 1105 individuals)
1% ribbon seals (50 individuals)

With respect to comparative yield, it should be noted that each bearded seal is equivalent to between three and five ringed seals.

Estimates of the annual walrus harvest are much more precise than for seals. ADF&G personnel are stationed at all of the major walrus hunting sites during the period of productive walrus hunting. Other villages where walruses are taken are routinely visited and the take of walrus determined. The walrus harvest, composition, chronology and geographic distribution of the kill during 1976 was as follows:

1. Total harvest - 2,989 animals

   1,820 males older than one year (61%)
   867 females older than one year (29%)
   302 calves of either sex (10%)

2. Geographical distribution of harvest

   Bering Sea - 2,570 animals (86% of total)
   1,485 males (58%)
   789 females (31%)
   296 calves (11%)

   Chukchi Sea - 419 animals (14% of total)
   335 males (80%)
   78 females (19%)
   6 calves (1%)

3. Seasonal distribution of harvest

January-March, 50 animals (2%)
April-June, 2,444 animals (82%)
July-September, 436 animals (14%)
October-December, 59 animals (2%)

A fall survey of walruses in the Soviet sector of the Chukchi Sea, during September and October 1975, was conducted by V. N. Gol'tsev, Magadan Branch of the Pacific Research Institute of Fisheries and Oceanography (TINRO). An English version of this very important paper, translated by J. Burns, is attached as Appendix 1.

Other significant harvests of ice associated marine mammals obtained by residents of the west and north coasts of Alaska during 1976 include:

39 bowhead whales (data reported by NMFS);
79 polar bears (as indicated by ADF&G bear sealing records);
285 belukha whales (based on information from villages where belukhas were taken).

A majority of the belukhas were taken by residents of Buckland, a village in southeastern Kotzebue Sound. The remaining kill was taken at scattered locations between Kuskokwim Bay and Wainwright.

C. Bearded and ringed seal food habits

See Annual Report of "Trophic relationships among ice inhabiting phocid seals" (RU#232).

D. Bearded seals

During this report period investigation of the natural history and ecology of bearded seals has been secondary to that of the ringed seal. Because of the smaller number of these seals which are taken by coastal residents and other difficulties associated with working on this large mammal, our main objective has been to acquire an adequate sample of sufficient size to warrant detailed analyses. The number of bearded seals examined during the past year is not yet sufficient for meaningful, detailed assessment of the major aspects of their biology.

Emphasis of our work on bearded seals during the past year was directed at (1) determination of distribution and density within the ice front and shore ice areas surveyed (mainly for other species of seals), (2) the collection and examination of seals obtained in the vicinity of coastal hunting sites by subsistence hunters, (3) collection of seals by ADF&G personnel in areas not sampled by land-based subsistence hunters, (4) the partial analysis of some specimen material (mainly stomachs examined and reported on under project RU#232), and (5) the formating, keypunching and submission of those data about bearded seals which did not involve the laboratory examination of material collected (excepting stomachs).

1. Aerial surveys

Extensive surveys of marine mammals, by aircraft, were conducted in two separate areas; the ice front of southeastern Bering Sea and the landfast ice of the northeastern Chukchi Sea and Beaufort Sea east to Barter Island. These surveys were primarily for the purposes of determining density and distribution of other marine mammal species. However, they did provide additional information about bearded seals.

A survey of the ice front was undertaken between 27 March and 23 April. The principal objective of this survey was to determine distribution and density of spotted seals, Phoca vitulina largha, which concentrate in the front during the winter-spring period. Short survey flights were undertaken with a helicopter from the OSS SURVEYOR and extensive coverage of the front in southeastern Bering Sea was achieved with use of a long range P2V aircraft (refer to reports of project RU#231). The region within which surveys were conducted with the P2V aircraft is shown in Fig. 1. It was bounded to the south by the ice "edge" and to the north by the heavy pack ice.

Bearded seals were uncommon in the front, especially near the southern boundary. Most sightings were made near the northern limit of survey tracks, indicating the possibility that larger numbers were north of our survey area, associated with heavier pack ice. This has been the situation observed in the past. Surveys by H. Braham (RU#67), also conducted during April 1976, confirmed the occurrence of higher densities of bearded seals north of the front.

Fig. 2 indicates sightings of bearded seals in the area shown in Fig. 1. Fig. 3 shows sightings of ringed seals made during the same survey flights.

It can be concluded that both species are not commonly found in the front.

An extensive survey of ringed seals was undertaken during June 1976 and included mostly areas of landfast ice from Kotzebue Sound to Barter Island. Bearded seals do not occur on landfast ice of these regions until it begins to melt and break up during June. A total of 4,157 seals were counted on the landfast ice of which only 51 (1.2%) were bearded seals. The remainder were ringed seals. Part of this June survey included survey tracks over the drifting ice of northwestern Chukchi Sea. Composition of seals observed was markedly different. In the drifting ice bearded seals accounted for 33 percent of all seals observed and the proportion of ringed seals dropped to 66 percent.

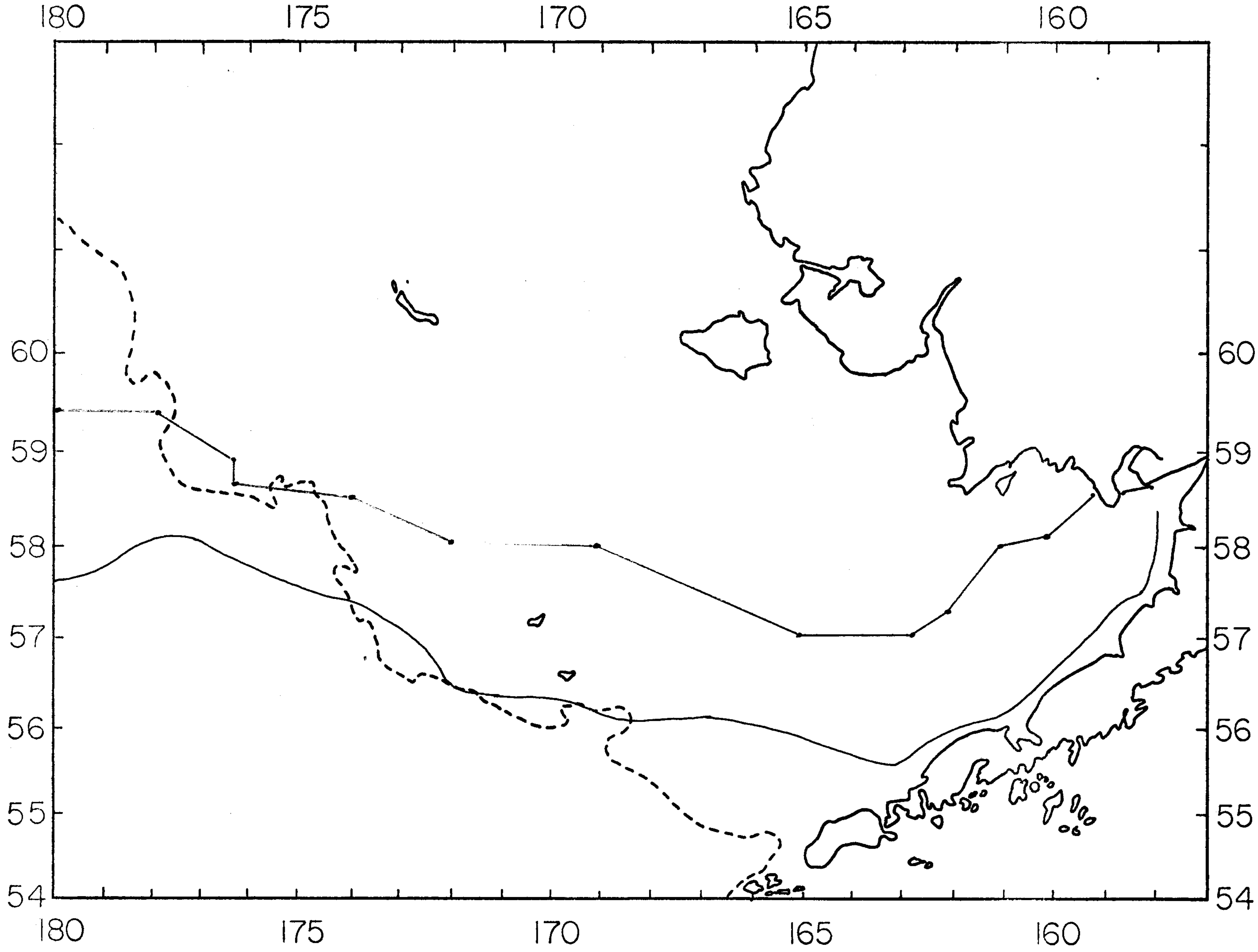

Fig. 1. Area within which shipboard and aerial surveys were conducted during March-April 1976. Southern limit of surveys was the ice edge. Northern limit approximated the inner margin of the front. The 200 meter depth contour is indicated by the light, dashed line.

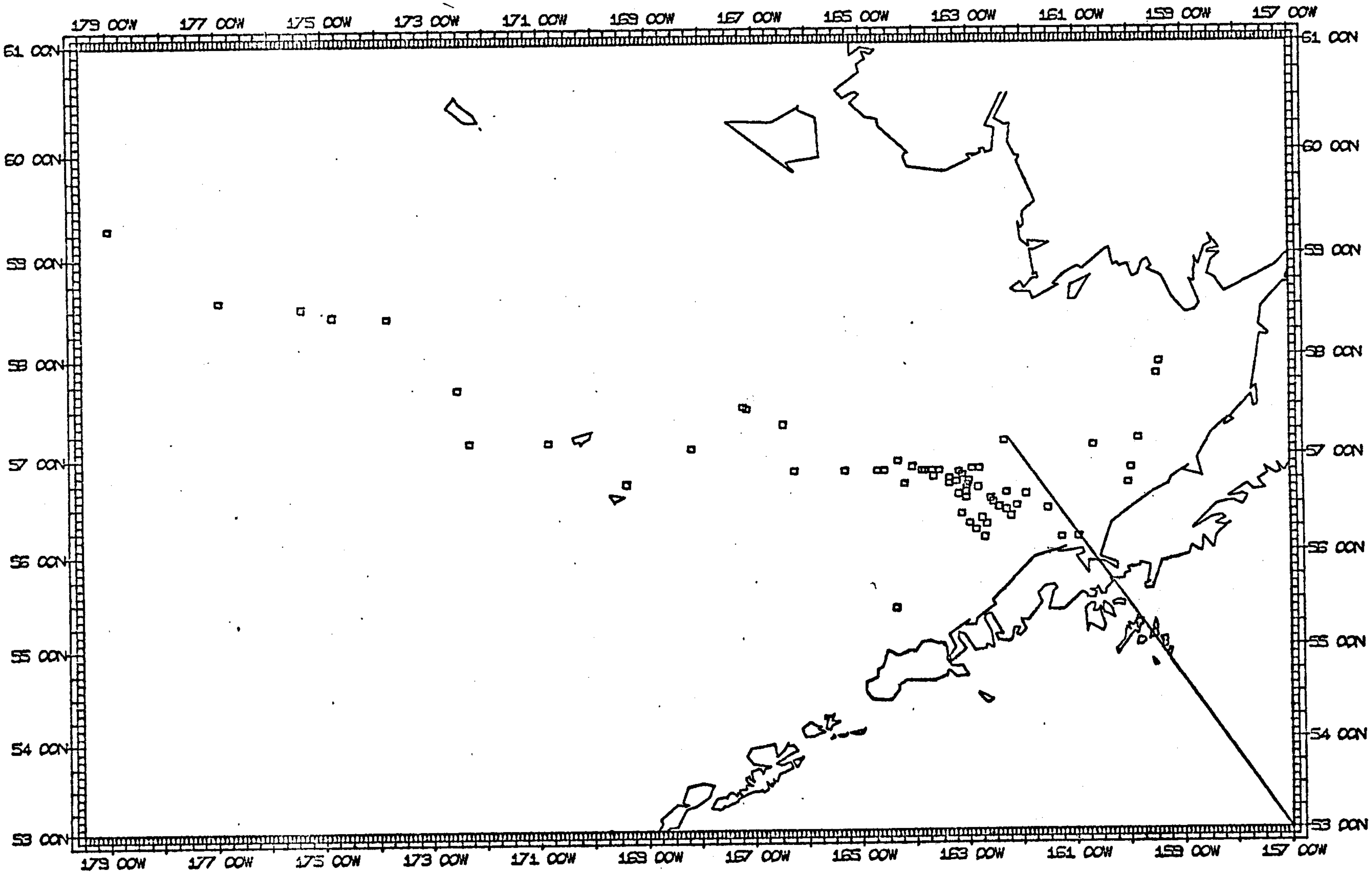

Fig. 2. Combined sightings of all bearded seals observed during surveys within the area shown in Fig. 1. Computer map courtesy of H. Braham and B. Krogman, NMFS, Seattle.

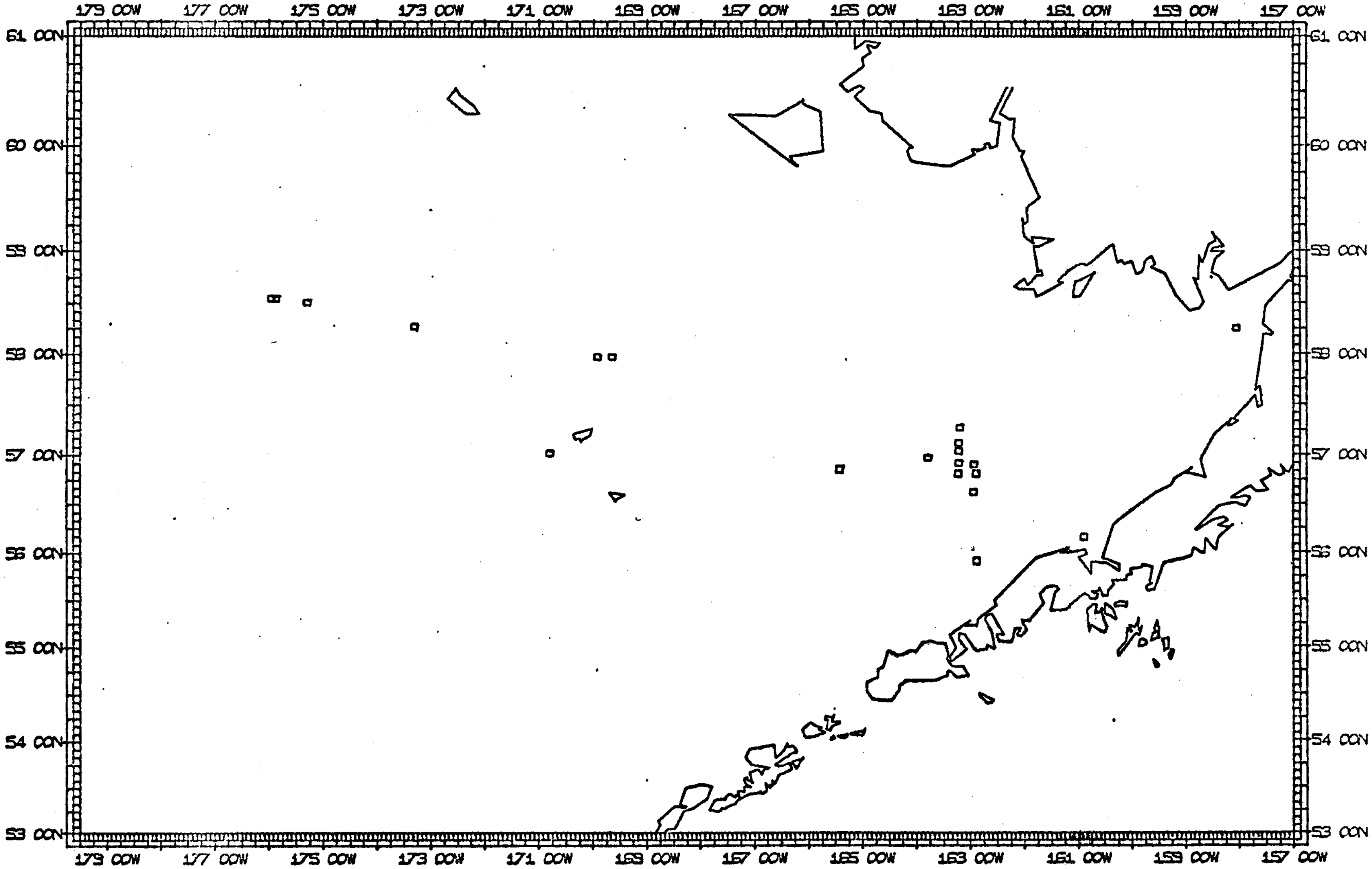

Fig. 3. Combined sightings of all ringed seals observed during surveys within the area shown in Fig. 2. Computer map courtesy of H. Braham and B. Krogman, NMFS, Seattle.

2. Specimen collections

A total of 114 bearded seals were examined during this report period. Eight were obtained between March and June, 99 between July and September, 2 between October and December and 5 between January and March. Examination of stomachs obtained prior to January and containing food has been completed and reported elsewhere (RU#232). Body measurements and other information recorded on field data forms have been coded and, except for seals collected since January, these data have been submitted to NODC. To date, no analyses have been made.

It was anticipated that the required laboratory analyses of reproductive tracts would be completed for inclusion in this report. However, due to other commitments, including the Beaufort Sea Synthesis Meeting and associated reports, this aspect of the work has not yet been accomplished.

Age determination of all bearded seals obtained during this report period has not been completed, but will be in the near future.

E. Ringed seals

1. Distribution and taxonomy

The ringed seal has a widespread northern, circumpolar distribution. Ringed seals have been recorded from the North Pole southward, in ice covered seas, to Finland, northern Iceland, southern Greenland, Labrador, Hudson Bay, southern Bering Sea, Sea of Okhotsk and northern Hokkaido. There are isolated ringed seal populations in the Gulfs of Bothnia and Finland, Lake Ladoga (USSR), Lake Saimaa (Finland) and in at least one lake on Baffin Island (Canada). Stragglers have been recorded in France, Scotland, southern Japan and at San Diego, California. In Alaska, ringed seals inhabit the Bering, Chukchi and Beaufort Seas, and have been found in the Pribilof and Aleutian Islands.

Seven subspecies have been proposed for the ringed seal (Table 3) (Scheffer 1958, Muller-Wille 1969). However, the ringed seal is a highly variable species and the subspecies are difficult to separate without examining a large number of specimens. Muller-Wille (1969) investigated the relationships of _P. h. botnica_, _P. h. ladogensis_, _P. h. saimensis_ and _P. h. pomororum_. These four subspecies were found to overlap in many traits but Muller-Wille concluded that they were significantly different enough to be classified as subspecies. The differences are attributed to the isolation of these populations for 8,000 to 12,000 years. The relationship between _P. h. pomororum_ and _P. h. hispida_ is unclear.

The populations and taxonomic relationships between _P. h. hispida_, _P. h. krascheninikovi_ and _P. h. ochotensis_ are presently

Table 3. Distribution of currently accepted subspecies of the ringed seal.

Subspecies	Distribution
Phoca hispida hispida	Arctic Ocean, northern Eurasia, Greenland, northern North America and southward to Hudson and James Bays and Labrador
Phoca hispida krascheninikovi	Bering Straits southward throughout the Bering Sea and Bristol Bay to the southern Kuril Islands
Phoca hispida ochotensis	Sea of Okhotsk, northern Kuril Islands and south to Hokkaido
Phoca hispida botnica	Baltic Sea, Gulf of Bothnia and Gulf of Finland
Phoca hispida ladogensis	Lake Ladoga
Phoca hispida saimensis	Lake Saimaa and its series of interconnected lakes
Phoca hispida pomororum	White Sea and the coasts of the Kola Peninsula and Novaya Zemlya

under investigation by Soviet and American biologists. P. h. ochotensis appears to be a valid subspecies. The status of P. h. kraschenìnikovi is unclear. Based on our observations, ringed seals move widely and Bering Strait is not a barrier. There is a net movement of ringed seals southward through the Strait in the fall with the formation of sea ice and conversely a net northward movement in the spring with breakup.

The Soviets have examined large numbers of ringed seal specimens from the Bering and Chukchi Seas and are finding that there are two morphos (which may be subspecies) of ringed seals. A larger morph is found in the shorefast ice and a smaller morph in the drifting ice. However, not enough is known about the ecology and behavior of ringed seals to ascertain the relationships between the drifting and shorefast ice seals. Based on specimen material and collecting programs, there appears to be age-specific, seasonal movements of seals between shorefast and drifting ice. In our future work we hope to delineate these movement patterns more clearly.

The Caspian seal (Phoca caspica) and the Baikal seal (Phoca sibirica), both found in landlocked water bodies (Caspian Sea and Lake Baikal), evolved from the ringed seal but are presently considered separate species.

2. Pelage

The color of ringed seals is quite variable, but the basic pattern is a gray back with black spots and a light belly. These black spots are ringed with light marks from which comes the seal's name. Several specimens have been examined which have the ringed pattern on back and belly and one adult specimen was observed to have the light coloration on both back and belly.

Pups are born with a white lanugo. The lanugo is shed when the pup is two to six weeks old. The first year pelage is quite variable but it is generally light in coloration with faint spots and rings.

Ringed seals molt annually. During the period of molt they haul out on the sea ice on "warm," sunny days. Hauling out during the molt appears to be an important adaptation to the arctic environment. Skin temperatures of ringed seals during immersion are generally within 30°C of water temperatures (which may be 2°C); upon hauling out the skin temperature may increase to 20°C or more. Epidermal cells of phocid seals in in vitro cultures were found to survive for six months at 4°C but required temperatures of at least 17° to 19°C for growth. The most rapid growth was at 37°C (Feltz and Fay 1966). Sleep or inactivity also may be a requirement for mitosis (Bullough 1962, Bullough and Rytomaa 1965). Therefore, growth and reparative functions of ringed seal skin may only be possible when the animal is hauled out and/or at rest.

The molt appears to begin in mid-May in the Bering Sea-Norton Sound and progressively later as one goes farther north; in Alaska the peak is in mid-June. Two adult ringed seals (BP-11-76, BP-12-76) collected at Barrow, Alaska in early August were just completing their molt.

3. Dentition

The dental formula of phocid seals varies according to the subfamily:

	<u>Incisors</u>	<u>Canines</u>	<u>Postcanines</u>	
Phocinae	$\frac{1-2-3}{0-2-3}$	$\frac{1}{1}$	$\frac{1-2-3-4-5-(6)-0}{1-2-3-4-5-0-0}$	= 34-36
Monachinae	$\frac{0-2-3}{0-2-3}$	$\frac{1}{1}$	$\frac{1-2-3-4-5-(6)-0}{1-2-3-4-5-0-0}$	= 32-34
Cystophorinae	$\frac{0-2-3}{0-0-3}$	$\frac{1}{1}$	$\frac{1-2-3-4-(5)-(6)-0}{1-2-3-4-(5)-(6)-0}$	= 26-34

The ringed seal follows the Phocinae pattern and typically has 34 teeth (lacks upper postcanine 6). Dental anomalies are not uncommon and those that we have found include:

a. Upper postcanine number 6 present
b. Upper postcanine numbers 4, 5 and/or 6 absent (never found)
c. Lower incisor number 1 present
d. Lower incisor number 3 absent
e. Supernumary lower incisor number 3
f. Supernumary lower canine

The incisors, canines and first postcanines are single rooted, while postcanines (upper and lower) 25 are double rooted. One postcanine number 5 had 3 roots. The relative size of postcanines in descending order is 3-4-2-5-1. The postcanines are reticulated and are offset such that when the jaws are closed a net-like structure is formed, which is presumably used to assist in the retention of smaller invertebrates from the seawaters.

Five early and mid-term fetuses (NP-14-76, STP-1-76, BS-11-70, BS-14-70, BS-15-70) had the deciduous dental formula:

$$i\,\frac{3}{2} \qquad c\,\frac{1}{1} \qquad pc\,\frac{3}{3} \qquad = \qquad 26$$

A mid-February fetus (N-2a-71) had a complete set of permanent teeth but they were not erupted. At birth, ringed seals have a complete set of fully erupted, permanent teeth.

Several cases of dental disease have been noted during examination of specimens. Two ringed seals were found to have caries in their second postcanines. The caries were situated in the pit of a tooth reticulation. One seal from Nome had grooves in the enamel of all teeth and the grooves resembled those of hypoplasia. Hypoplasia is a deficient formation of enamel due to injury or dysfunction of the ameloblasts (enamel-forming cells) during enamel formation.

Erosion of the teeth at the gingivolabial and buccal level has been noted in 30 ringed seals. The lesion is characterized by a smooth, highly polished notch in the tooth surface with no evidence of caries. Erosion appears to originate in the canine-postcanine 1 region and spreads anteriorly and posteriorly. The lesion appears to become progressively worse and ultimately the tooth erodes to a thin level and breaks. The etiologic factors responsible for this condition are unknown. In humans, erosion is caused by acid secretions from the labial or buccal glands and it is found in nervous individuals who are chronic worriers (Massler et al. 1958).

Another form of tooth wear, noted in several seals, appears to be a mechanical wearing away of the cusps. The cusps become flattened and the tooth takes on a peg shape. The abrasive action of invertebrate exoskeletons has been postulated as the etiologic factor.

4. Growth rates and productivity

Ringed seals are the smallest of all pinnipeds, with the largest adult female recorded for Alaska being 155 cm in length and the longest male 146 cm. The heaviest ringed seals examined thus far in this research were a 111.0 kg pregnant female, taken in March, and a 90.0 kg male, taken in January. However, the weight of an individual varies with age and season. Heaviest weights are achieved, by adults, in winter and early spring when the seal has a heavy layer of fat or blubber under the skin. This blubber is used for insulation and as an energy source during the breeding and pupping seasons. The weights of ringed seals decline with the decrease in feeding during the reproductive and molting season.

Fetal and pup development

The embryonic and fetal development of the ringed seals is one of the parameters that influences fertility. Embryological development is usually considered as a continuous process of growth and differentiation from the formation of the zygote to parturition. Growth and differentiation appear continuous, albeit slow during the 3-1/2 month delay before implantation, but the factors that affect the rate of growth and differentiation are unknown.

Female ringed seals appear to be impregnated in mid- to late April, soon after the birth of the pup. Impregnation is followed by a delay of up to 3-1/2 months before implantation, approximately in August. Additional seal specimens are required from August and

September to demonstrate the precise period of implantation and to determine early fetal growth rates.

Thus far, 50 ringed seal fetuses (27 males and 23 females) have been examined and measured, yielding a fetal sex ratio of 1:1 ($P > 0.01$). The fetal growth curve for length (Fig. 4) closely resembles that of ringed seals in Canada (McLaren 1958). The growth curve for weight (Fig. 5) is similar to those for most mammals. The relative growth of length and weight (L/M) (Fig. 6) is most rapid just after implantation, in August and September, with relative growth rates leveling off in late pregnancy. No differences between the growth rates of males and females were detected ($P > 0.05$).

Pup growth rates

Weights of 55 ringed seal pups (21 males, 33 females and 1 sex unknown) have been obtained thus far, yielding a pup sex ratio of 1:1 ($P > 0.05$). Ringed seal pups weigh about 4.0 kg at birth. A live pup two or three days old weighed 5.0 kg while the mean weight of eight full-term fetuses was 3.4 kg.

Pup weights increase steadily from birth until weaning in late May or early June (Fig. 7). In late June and early July the weights of pups decrease somewhat as the pups adjust to life on their own. In mid- and late July pups' weights increase steadily leveling off in August and September. The mean weights of male and female pups generally do not differ ($P > 0.05$), however, there is more variation in the weights of males than in the weights of females.

Blubber thickness over the sternum increases from 0.5 cm or less at birth to an average of 2.6 cm in May and early June. During mid- and late June and July, the blubber thickness decreases to a mean of 1.1 cm and this decrease in thickness is probably associated with the loss of weight immediately after weaning. By August mean blubber thickness has increased to 1.9 cm and then levels out at a mean of 3.0 cm from September to February. There appears to be no difference in blubber thickness between male and female pups ($P > 0.05$ cm).

The lengths of pups increased steadily from birth and appeared to begin leveling out in August and September (Fig. 8). A significant decrease in length immediately after weaning was not noted. The mean lengths of males and females did not differ ($P > 0.05$) and the variation in lengths was approximately equal in the two sexes.

Reproduction

The epididymides of 275 male ringed seals (representing all age classes and collected during all months) have been examined for the presence of sperm. Active spermatogenesis has been detected in essentially all males seven years old and older which were collected

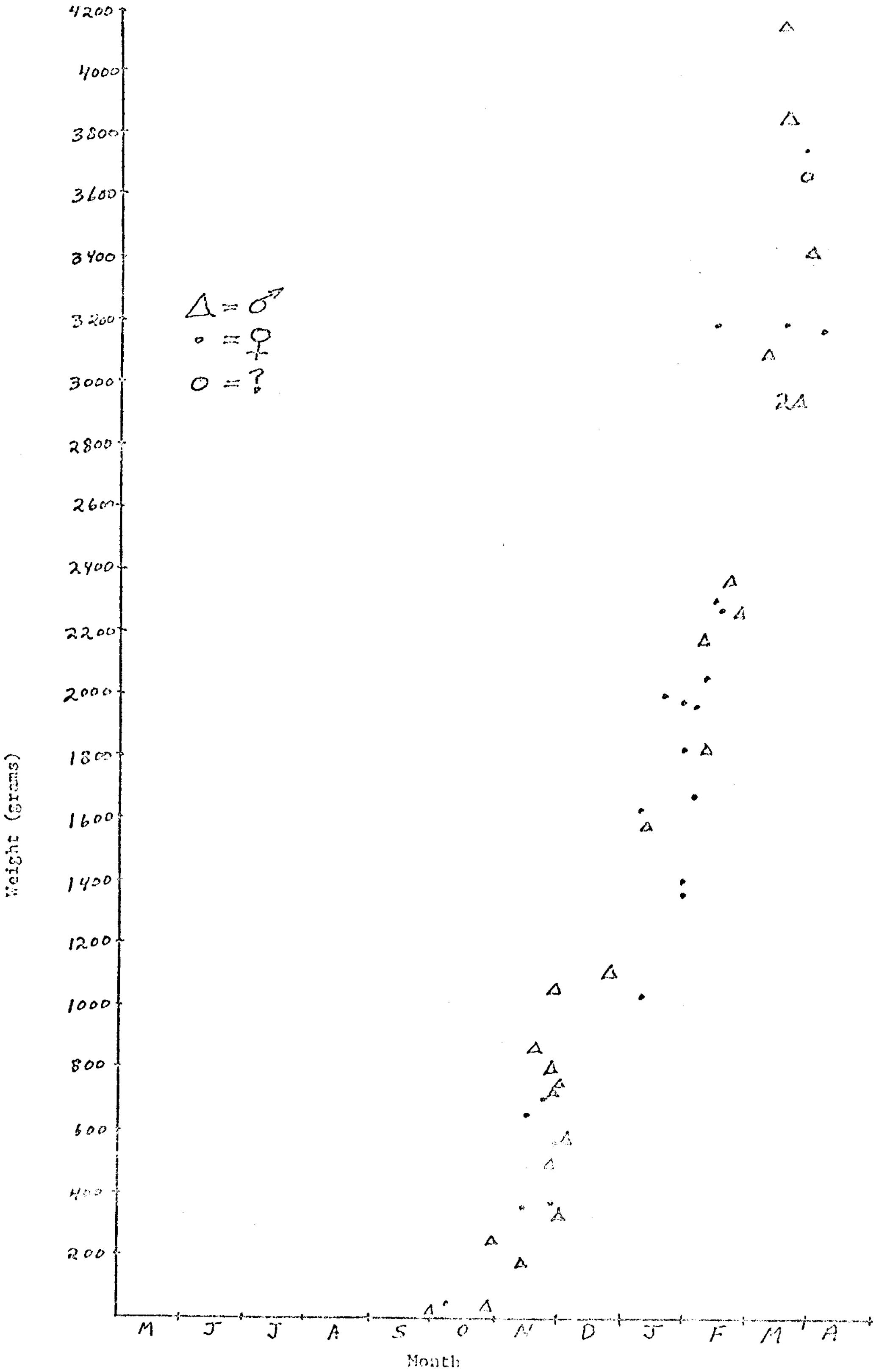

Figure 5. Fetal growth, weight in relation to month of collection.

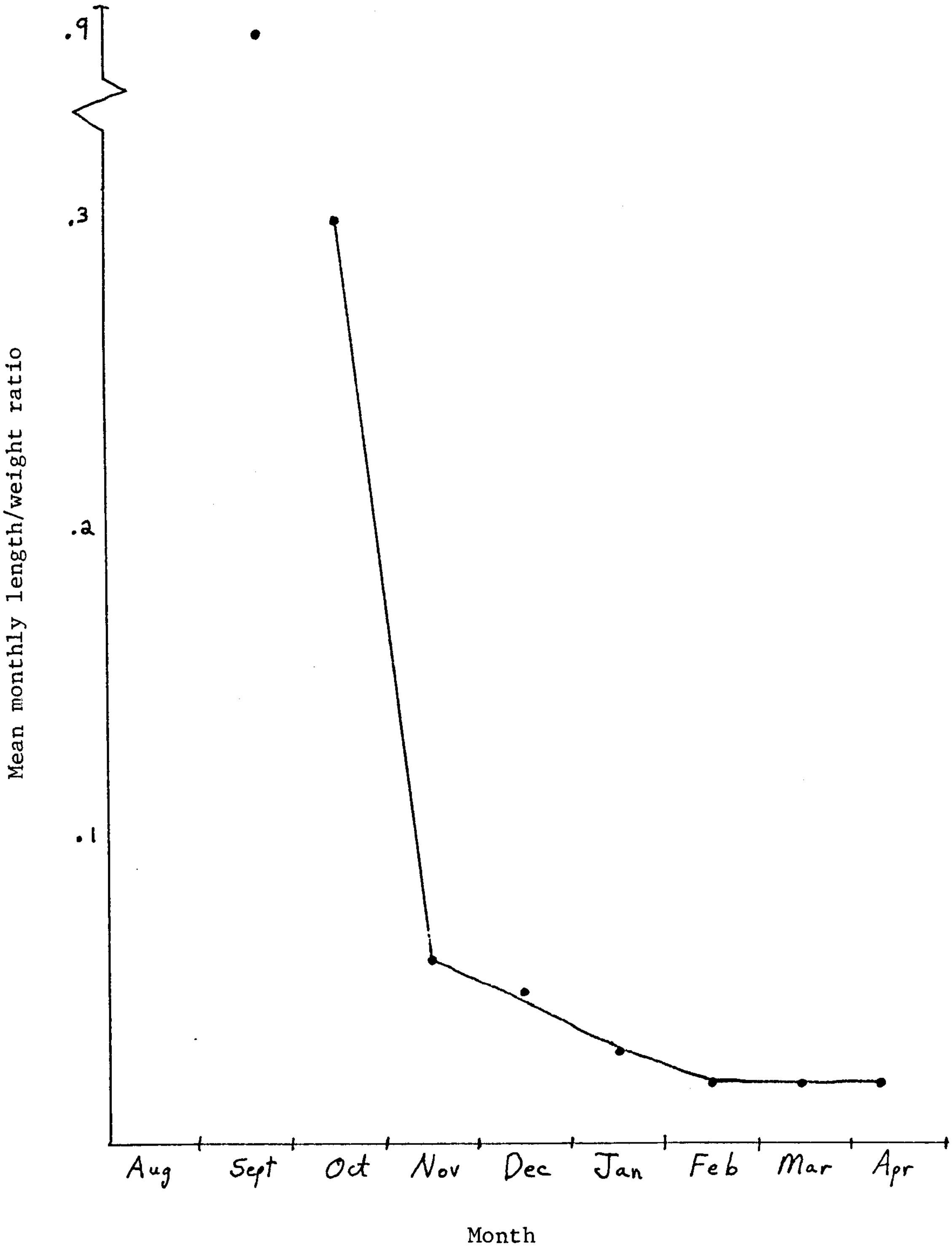

Figure 6. Fetal growth, length in relation to weight.

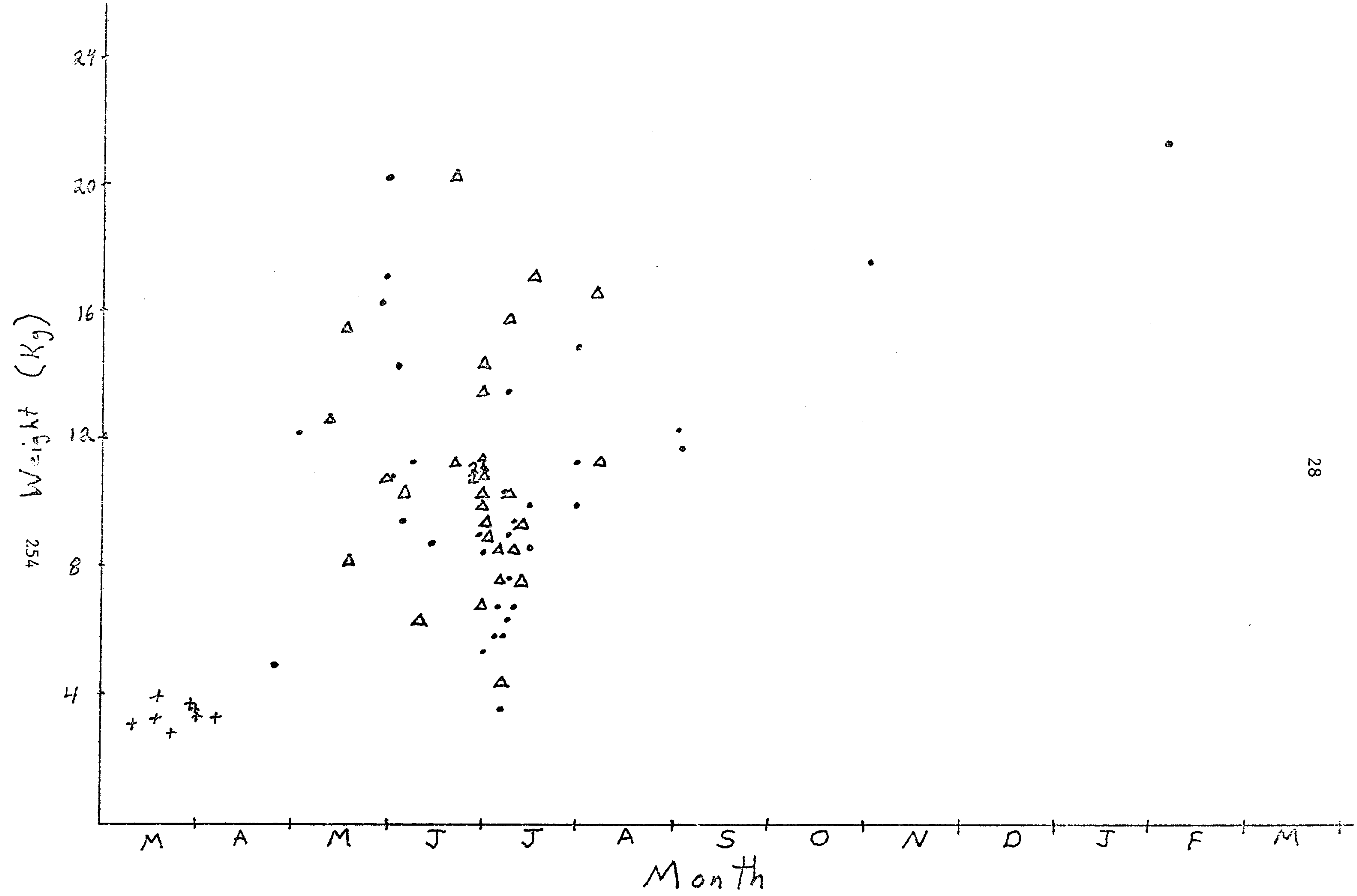

Figure 7. Pup growth, weight in relation to month of collection.

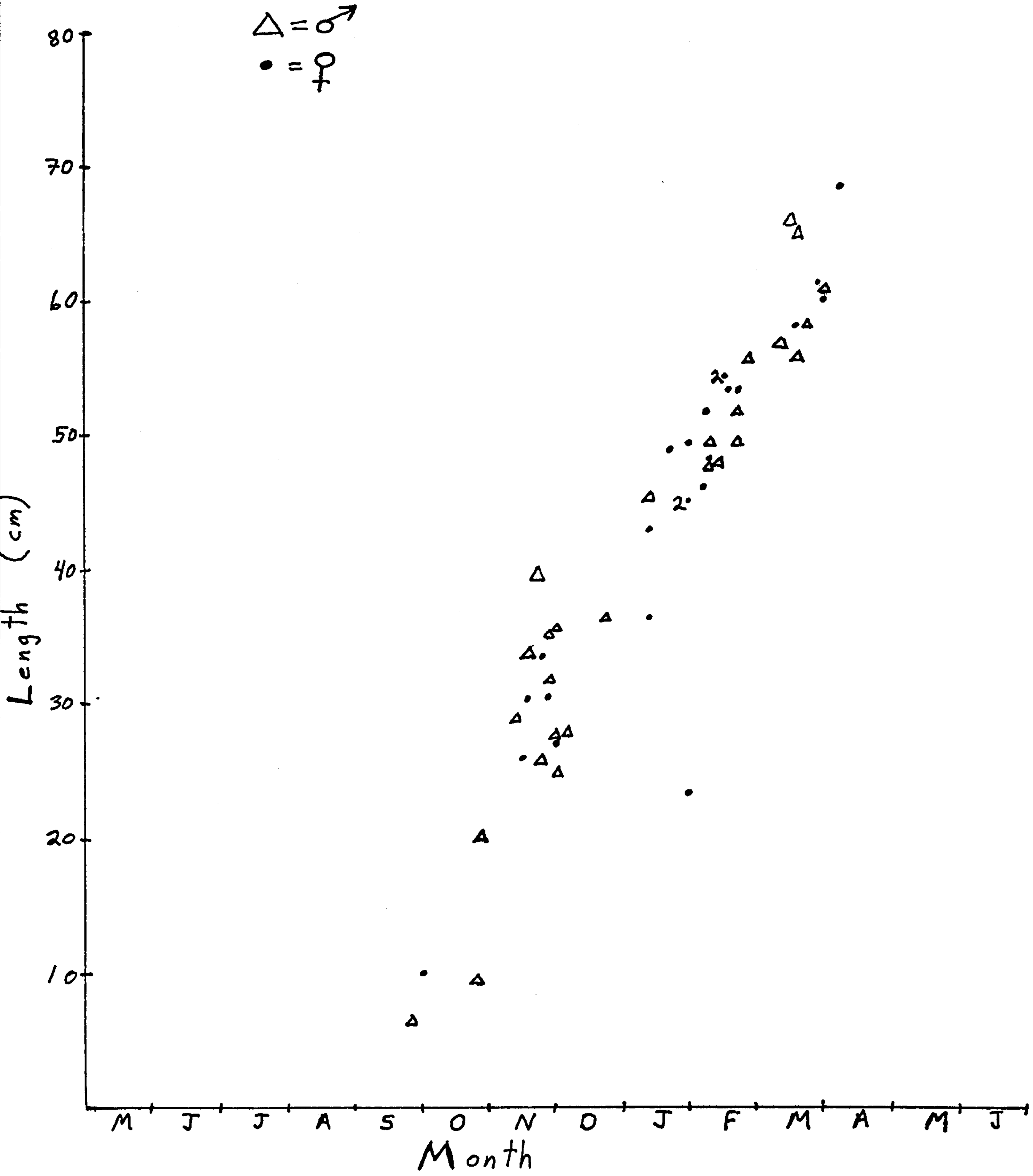

Figure 4. Fetal growth, length in relation to month of collection.

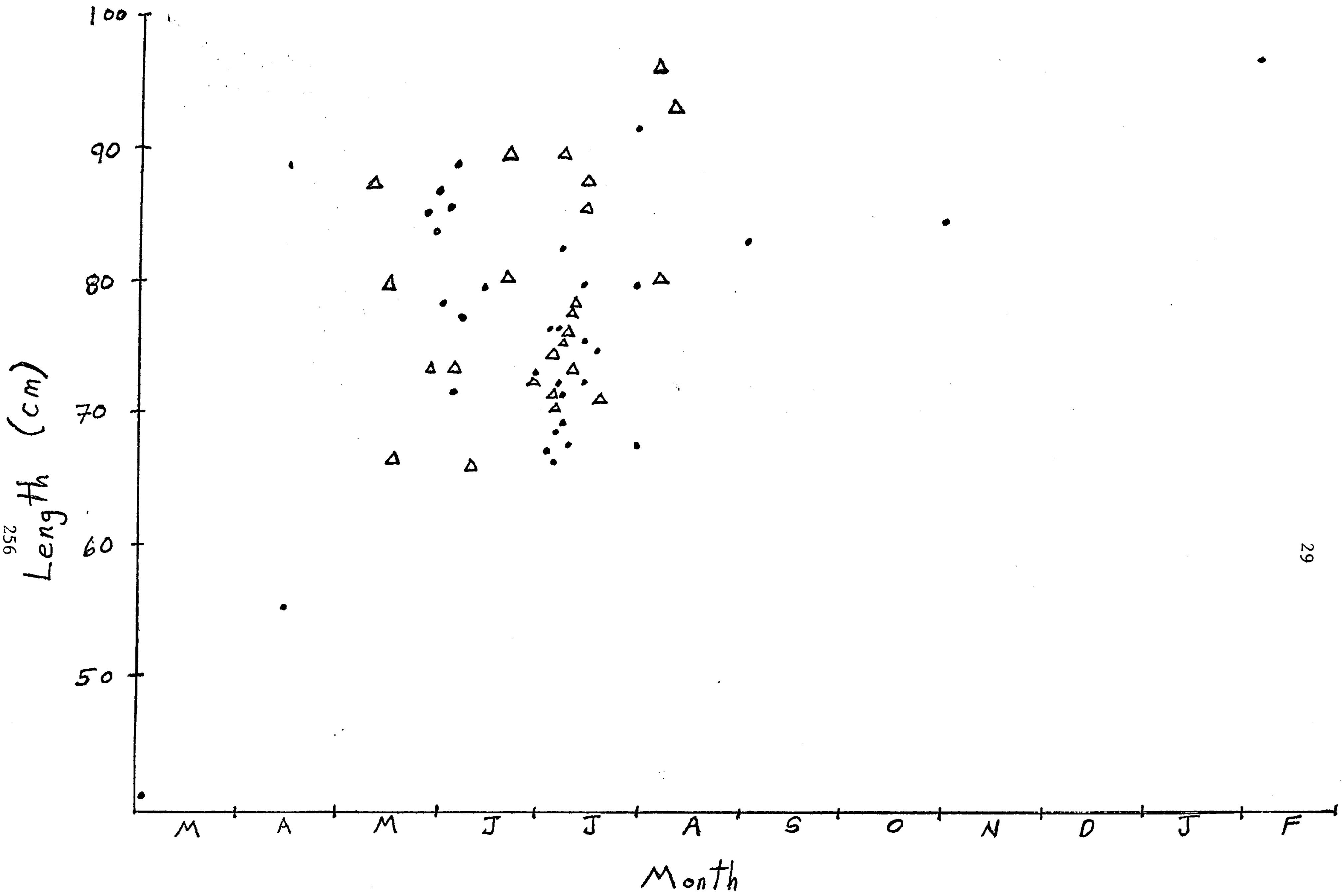

Figure 8. Pup growth, length in relation to month of collection.

during the months of March, April, May and June (Table 4). Two of five (40%) of seven-years-old plus males had abundant sperm during January, as did two of three (67%) males taken in February. Of 14 males examined during December, 1 nine-year-old had abundant sperm in his epididymides while 1 eleven-year-old had a trace of sperm. Eight of 15 (53%) six-year-old males collected between March and May had abundant sperm in their epididymides. One five-year-old male taken in May had a trace of sperm in its epididymides. No geographic variation in spermatogenic activity has been detected thus far, however our sample size from the Beaufort Sea is small.

The earliest date that sperm was found in male epididymides was mid-December and active spermatogenesis appears to continue until mid-June. Sperm remains in the epididymides of some males until mid-August. Most adult female ringed seals appear to ovulate in April and May, therefore the males are physiologically capable of breeding well before and long after most females. Similarly, a longer season of potential breeding capability has been found in male grey seal (Halichoerus gypus) (Ling 1969).

The ovaries of 143 female ringed seals have been examined thus far. Sexual maturity in the female is determined by the presence of a corpus luteum of ovulation and recent corpus albicans indicates an ovulation during the previous age-year. Older than previous age-year corpus albicans and corpus albicans of pregnancy also are discernible.

The examination of 53 females in the age classes pup to two years old failed to find any evidence of ovulations. Two (25%) three-year-old females, 1 (17%) four-year-old and 8 (57%) females had ovulated for the first time and apparently had not conceived. Twelve of 17 (71%) six-year-old females had ovulated during the age-year of collection but none had conceived. Seven of the 12 (58%) recently ovulated six-year-olds had ovulated the previous age-year, as evidenced by the presence of a corpus albicana. In addition, three of five (60%) of the non-recently ovulated six-year-old females supported corpus albican but no recent corpus luteum. One six-year-old female supported a corpora albicans and was pregnant. Of the 44 females seven-years-old and older, all 44 (100%) had apparently ovulated at least twice. A female 14 years old had cysts on both uterine horns. The cysts caused complete obstruction of the uterine horns and both ovaries had begun to atrophy. A 21-year-old female showed no follicular activity, whereas a 22-year-old female had ovulated but it could not be determined whether she had conceived. Three females (23, 25 and 29 years old) were pregnant and they appeared to have given birth during the previous year.

Recent pregnancies are determined either by the presence of a fetus in the uterus or by the presence of a corpus luteum or corpus albicans of pregnancy in an ovary. From 1964 to 1973, 33 adult female ringed seals were examined and 30 were or just had been

Table 4. Seasonal variation in sperm presence in the epididymides of male ringed seals seven years old and older.

Month	Number Examined	Sperm Presence		
		Abundant (Number)	Trace (Number)	None (Number)
January	5	2	-	3
February	3	2	-	1
March	17	17	-	-
April	15	15	-	-
May	24	23	-	1
June	36	21	5	10
July	21	1	1	19
August	5	-	2	3
September	1	-	-	1
October	2	-	-	2
November	1	-	-	11
December	14	1	1	12

pregnant, yielding a pregnancy rate of 91 percent. The reproductive tracts of 42 adult females, collected during 1975 to 1977, have been examined thus far and 26 (62%) were or just had been pregnant. Johnson et al. (1966) found 240 of 280 (86%) adult females (collected near Cape Thompson, Alaska during 1960 and 1961) pregnant. The decline in the pregnancy rates of our samples between 1964-1973 and 1975-1977 corresponds to the decline in the pregnancy rates reported by Stirling et al. (1975). However, the magnitude of the decline in pregnancy rates in Canadian ringed seals is significantly greater (Stirling et al. 1975); in 1972 a pregnancy rate of 59 percent was found and in 1974 and 1975 a 0 percent and 11 percent pregnancy rate was found, respectively. The reason for the decline of pregnancy rates of female ringed seals in Alaska waters is unknown and it is presently under investigation. It may be that ringed seal populations, due to decreased hunting pressure and possible immigration of seals from Canadian waters, are reaching carrying capacities and that there is a concomitant decrease in productivity as the seals reach this level as seen in other animal populations. The Canadians attribute their decrease in productivity to poor ice conditions for ringed seals and emigration of some seals. However, their data are still speculative and they are also trying to determine the causative factors.

5. Polar bear predation on seals

From March 1976 to March 1977, 25 seals killed by polar bears were examined (Table 5). Ringed seals comprised 96 percent (24) of the seals killed and one bearded seal made up the remaining 4 percent. Four cases of bears feeding in garbage dumps near human habitation were noted and numerous observations were made of bears feeding on carrion, particularly on whale carcasses north of Barrow and on the beaches of St. Lawrence Island.

Of the 24 ringed seals examined, 14 (58%) were male and 10 (42%) were of undetermined sex. Thirteen (54%) of the ringed seals were adults (greater than six years old; had achieved sexual maturity); 2 (8%) of the seals were subadults (older than pups yet less than 6 years old); and 9 (39%) of the seals were of undetermined age, although tenuous evidence from the kill sites indicated that these seals were probably adults or older subadults. The single bearded seal comprised the only pup and the only identified female in the sample.

At Cape Lisburne, polar bears were tracked for 3,105 bear-kilometers, along which 20 seal carcasses were found. Bears killed, on the average, one seal every 155.2 kilometers at Cape Lisburne during March and April.

After killing a seal, a polar bear feeds predominantly on the hide and blubber and the meat is generally abandoned. In all seal specimens examined, all hide and blubber was consumed, except for that on the head. However, Stirling (1974) found that a large part of the blubber was often not consumed. The hide and blubber of

Table 5. Seal examined during 1976 that were killed by polar bears.

Location	Specimen Number	Species	Sex	Age (Years)	Ice Type	Kill Site	Date
Cape Lisburne	CLP-1-76	Ringed Seal	Male	10+	Flaw Zone	Breathing Hole	3/24/76
Cape Lisburne	CLP-2-76	Ringed Seal	Male	9+	Flaw Zone	Breathing Hole	3/24/76
Cape Lisburne	CLP-3-76	Ringed Seal	Male	3	Flaw Zone	Breathing Hole	3/25/76
Cape Lisburne	CLP-4-76	Ringed Seal	Male	11+	Flaw Zone	Breathing Hole	3/25/76
Cape Lisburne	CLP-5-76	Ringed Seal	Male	11	Flaw Zone	Breathing Hole	3/27/76
Cape Lisburne	CLP-6-76	Ringed Seal	Male	8	Shorefast Ice	Breathing Hole	3/31/76
Cape Lisburne	CLP-7-76	Ringed Seal	Male	10+	Flaw Zone	Breathing Hole	4/1/76
Cape Lisburne	CLP-8-76	Ringed Seal	Male	8+	Flaw Zone	Breathing Hole	4/1/76
Cape Lisburne	CLP-9-76	Ringed Seal	Unknown	Unknown	Moving Pack	Breathing Hole	4/7/76
Cape Lisburne	CLP-10-76	Ringed Seal	Unknown	Unknown	Flaw Zone	Breathing Hole	4/10/76
Cape Lisburne	CLP-11-76	Ringed Seal	Male	9	Flaw Zone	Breathing Hole	4/10/76
Cape Lisburne	CLP-12-76	Ringed Seal	Unknown	Unknown	Moving Pack	Lair	4/15/76
Cape Lisburne	CLP-13-76	Ringed Seal	Male	10	Shorefast Ice	Lair	4/16/76
Cape Lisburne	CLE-14-76	Bearded Seal	Female	Pup	Flaw Zone	Breathing Hole	4/16/76
Cape Lisburne	CLP-15-76	Ringed Seal	Unknown	Unknown	Shorefast Ice	Breathing Hole	4/16/76
Cape Lisburne	CLP-16-76	Ringed Seal	Unknown	Unknown	Moving Pack	Breathing Hole	4/16/76
Cape Lisburne	CLP-17-76	Ringed Seal	Unknown	Unknown	Flaw Zone	Breathing Hole	4/17/76
Cape Lisburne	CLP-18-76	Ringed Seal	Unknown	Unknown	Shorefast Ice	Lair	4/17/76
Cape Lisburne	CLP-19-76	Ringed Seal	Male	6	Flaw Zone	Breathing Hole	4/17/76
Cape Lisburne	CLP-20-76	Ringed Seal	Male	7	Flaw Zone	Breathing Hole	4/17/76
Barrow	BP-8-76	Ringed Seal	Male	8+	Flaw Zone	Breathing Hole	3/23/76
Barrow	BP-9-76	Ringed Seal	Male	Unknown	Moving Pack	Breathing Hole	3/25/76
Barrow	BP-10-76	Ringed Seal	Unknown	4	Moving Pack	Breathing Hole	4/22/76
Barrow	BP-14-76	Ringed Seal	Unknown	Unknown	Moving Pack	Breathing Hole	4/22/76
Barter Island	BIP-6-76	Ringed Seal	Unknown	12	Shorefast Ice	Breathing Hole	7/27/76

seals have the highest caloric value of any part of the seal (Stirling and McEwan 1975). The abandoned seal meat is consumed by other bears or more often by arctic foxes which follow polar bears for long distances (100 km+) over the ice.

When two adult bears are at a kill, the larger bear consumes the hide and blubber while the smaller bear is left with the meat. The division of a seal between a sow and her cubs has not been ascertained at this time, but in five observations of a sow and cubs feeding on kills the entire kill was consumed. Two of 20 (10%) kills examined at Cape Lisburne during March and April were found cached by bears apparently for later use. The unconsumed seals were buried under about one meter of snow near the kill site and the bears (a male, and a sow and her two, one-year-old cubs) were found within 1-1.5 km of the cached seals. Stirling and McEwan (1975) found that polar bears in the eastern Canadian Arctic generally did not cache seals for later consumption.

Approximately 35 flight hours of surveys were conducted in each of the three major ice types (shorefast ice, flaw zone and pack ice). Fourteen (56%) of the seals were killed on flaw zone ice, six (24%) on heavy, moving pack ice, and five (20%) on shorefast ice.

Most seals (88%) were killed by bears waiting at seal breathing holes. Bears were relatively unsuccessful in obtaining ringed seals from lairs as only 3 seals were killed in 32 lairs (9%) excavated by bears. Eighteen lairs were excavated on shorefast ice and 14 lairs on moving pack ice. No excavated lairs were noted in the flaw zone. The densities of lairs in the various ice types were unknown, however, the preferred habitat of the ringed seal is the shorefast ice. No observations or evidence were noted of bears stalking seals hauled out on the ice.

6. Sex and age composition

The fetal, pup and older-than-pup sex ratio of ringed seals obtained in this study does not depart significantly from unity (1:1). A 1:1 sex ratio also has been found by other ringed seal investigators (McLaren 1958; Johnson et al. 1966; and Smith 1973).

The age composition of ringed seal specimens obtained during 1975 and 1976, for which ages could be determined, are presented in Table 6. This age composition generally conforms to that of Smith (1973) except that Smith has a far greater proportion of pups in his sample. The sample obtained by Smith was collected from July through October when pups may be more available or at least more vulnerable. Table 7 compares the age composition of our samples from Shishmaref, Wainwright and Barrow, taken during the period July through October. When analyzed on a comparable time frame we find no significant difference between the age composition of our sample and that of Smith (1973).

Table 6. Sex and age composition of ringed seal specimens obtained during 1975 and 1976.

Age (years)	Males	Females	Sex Unknown	Total
pup	19	19	-	38
1	10	11	-	21
2	4	6	-	10
3	11	9	-	20
4	16	10	-	26
5	13	14	2	29
6	24	11	-	35
7	14	10	1	35
8	19	15	-	34
9	10	6	1	17
10	15	3	-	18
11	16	7	-	23
12	3	2	1	6
13	5	2	-	7
14	4	3	-	7
15	4	4	-	8
16	3	1	-	4
17	1	6	-	7
18	1	2	-	3
19	1	3	-	3
20	-	1	-	1
21	-	1	1	2
22	1	1	-	2
23	2	1	-	3
24	-	-	-	-
25	1	1	-	2
26	-	-	-	-
27	-	-	-	-
28	-	-	-	-
29	1	1	-	2
unknown	2	2	10	14

Table 7. Age composition of ringed seals collected during the period July-October.

Age (years)	This Study		Smith 1973	
	Number	Percent	Number	Percent
pup	40	22	235	21
1	10	6	121	11
2	3	2	106	9
3	8	5	94	8
4	11	6	83	7
5	14	8	73	6
6	15	8	64	6
7	13	7	47	4
8	15	8	50	4
9+	52	29	271	24

7. Literature review

Approximately 635 literature citations concerning ringed seals have been recovered from our searches and those of OASIS and its updates. OASIS searches were not as effective in finding older references as were our own because OASIS searches did not extend back past 1972 for Biological Abstracts and 1964 for Oceanic Abstracts and Governmental Report Announcements. In addition, Zoological Record, the best leterature citation source for marine mammals, is not searched by OASIS. OASIS search updates have been timely in providing references to recent publications.

A summary of the literature as related to Alaskan ringed seals was presented in our Annual Report for 1976 and it is summarized as III. Current state of knowledge in this report. The more important references are listed as XI. References and literature cited. A more complete ringed seal bibliography will be presented in a future report.

8. Densities of ringed seals

Successful feeding and reproduction are tantamount to the survival of all species. Therefore the goal of seal management should be to protect these critical feeding and reproduction areas from unnecessary disturbance or disruption. These critical areas change temporally and spatially and, considering the dynamic state of the sea-ice ecosystem, there can be large spatial changes in the location of critical areas in a short period of time. Habitat selection by ice-inhabiting pinnipeds has been aptly discussed by Fay (1974) and Burns (1972), and the reader is referred to those papers for a fuller discussion. Breeding adult ringed seals are found primarily (but not entirely) associated with shorefast ice, while the bearded seal is associated with many ice types and overlaps with all ice associated pinnipeds in the study area.

Critical areas are ascertained first by determining seal densities in various locations and then by correlations of densities with observed or measured ice, behavioral, ecological or oceanographic conditions. In June 1970, 1975 and 1976, ringed seal surveys were conducted by airplane over the shorefast ice from Barter Island to Point Lay. In addition, the 1976 survey was expanded to cover the shorefast ice from Point Hope to Cape Krusenstern and Kotzebue Sound. The results of these surveys are presented in Table 8. The areas of highest mean densities (Cape Krusenstern-Point Hope; Cape Lisburne-Point Lay; Wainwright-Barrow; Barrow-Lonely) are normally areas of very stable shorefast ice during late winter and spring. Within these larger areas there are variations in the density of ringed seals which appear to be dependent on the quality of shorefast ice. For example, between Cape Krusenstern and Point Hope the mean density was 2.3 ringed seals per square mile yet within this larger area the densities varied from 0.2 seals per square mile near Kivalina (early breakup of shorefast ice) to 3.8 seals per square mile near Cape Thompson (stable shorefast ice).

Table 8. Ringed seal densities (observed seals/mi^2) calculated from 1970, 1975 and 1976 surveys.

Location	1970	1975	1976
Kotzebue Sound	-	-	0.7
Cape Krusenstern - Pt. Hope	-	-	2.3
Pt. Hope - Cape Lisburne	-	-	0.9
Cape Lisburne - Pt. Lay	-	-	4.9
Pt. Lay - Wainwright	5.4	2.9	1.9
Wainwright - Barrow	3.7	6.2	3.8
Barrow - Lonely	2.3	2.8	1.4
Lonely - Oliktok	1.0	1.4	1.1
Oliktok - Flaxman Island	1.4	1.0	1.4
Flaxman Island - Barter Island	2.4	1.8	0.4
Chukchi Sea - moving pack ice	-	-	0.2
Beaufort Sea - moving pack ice	-	-	0.1

The most stable shorefast ice is found either along complex coasts or along coasts where the 10 fathom line lies far offshore. The edge of the shorefast ice tends to coincide with the 10 fathom curve. The higher densities in the Chukchi Sea are probably reflective of the better ice condition together with higher overall biological productivity of the Chukchi as compared to the Beaufort Seas.

In June, 23 transects totaling 689 square miles and 3 transects totaling 29 square miles were flown, respectively, over Kotzebue Sound and Hotham Inlet (Fig. 9). In Kotzebue Sound 504 ringed seals were observed, yielding an ecological density of 0.73 ringed seals per square mile of available habitat. In addition, one bearded seal and two spotted seals (Phoca vitulina largha) were observed in Kotzebue Sound. No seals were seen in Hotham Inlet.

The ecological density of ringed seals varied from 0.92 seals per square mile at the mouth of the Sound to 0.26 seals per square mile in the eastern portion of the Sound. The higher density of seals at the mouth was due to more stable ice conditions in this area. In the eastern portion of the Sound and in Hotham Inlet the ice had begun to break up due to warm weather and the influx of warm water from the Noatak, Kugruk, Kiwalik, Buckland, Selawik and Kobuk Rivers.

The ice cover in Kotzebue Sound was estimated to be 2,715 square miles and from the transects an ecological density of 0.73 seals per square mile was determined. Therefore, the estimated molting population of ringed seals is about 2,000 animals.

The density of molting ringed seals in the moving pack ice is known to be less than the shorefast. This year transects were flown over the pack ice of Chuckhi and Beaufort Seas to provide comparative data for our shorefast ice surveys. The data from these pack ice transects are still under analyses but the tentative findings are summarized at the bottom of Table 8.

It is obvious that densities of molting ringed seals are considerably less in the moving pack ice than in the shorefast ice. As was found in the shorefast ice, densities of ringed seals in the Chukchi Sea are 2 to 2.5 times higher than in the Beaufort Sea.

The total areas of fast ice, flaw zone ice and moving pack ice present during the 1975 and 1976 surveys are being calculated at this time from ERTS imagery. The total area of each ice type in each sector and the mean seal density for each type in a sector will give a minimum estimate of the ringed seal population in each sector. However, this estimate will only reflect the seals on the ice. Not enough is known of ringed seal behavior to correct for animals in the water or otherwise not seen.

The data from the 1970, 1975 and 1976 survey will be combined with data for surveys flown during 1977 and a detailed "population" analysis will be presented in our September 1977 Quarterly Report.

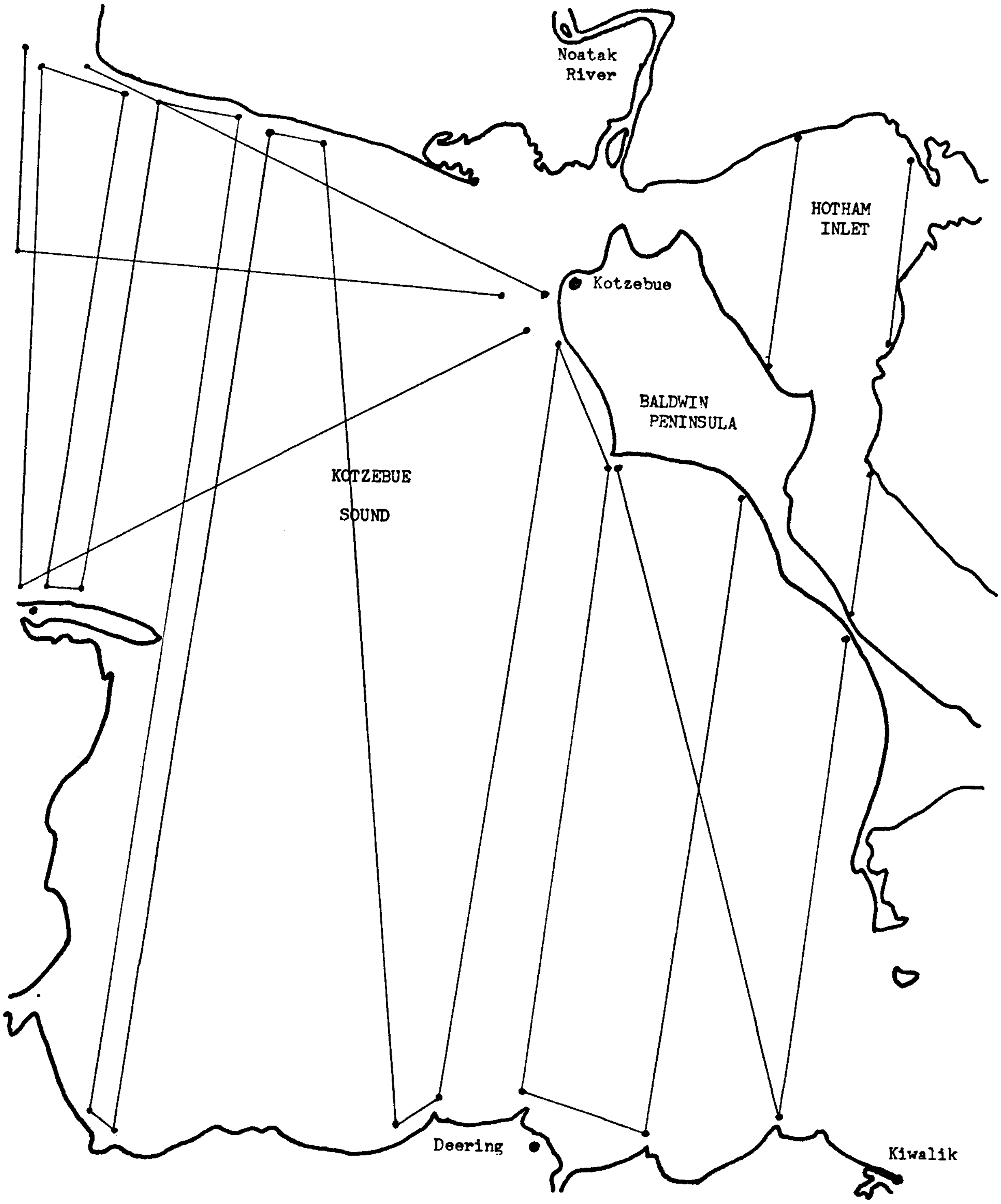

Figure 9. Seal survey tracks, Kotzebue Sound and Hotham Inlet, June, 1976.

F. Pathology and Parasitology

A considerable amount of material for pathological and parasitological examinations has been collected by this project. The bulk of this material has been provided to Dr. F. H. Fay and R. A. Dieterich and Mr. L. M. Shults (RU#194 - Morbidity and Mortality of Marine Mammals) for examinations and analyses. Within the limits of available time and funding, some material has been examined by ADF&G parasitologist Carol Nielsen. Her reports have been presented as Appendix IV to OCS Quarterly Report of RU#230, dated 30 September 1976.

Marine mammal hearts, either obtained from specimens collected by personnel working on RU#230 and 232 or those provided by RU#194, 229 and 243, are examined for marine mammal heartworms, _Dipetalonema_ _(Acanthocheilonema)_ _spirocauda_ (Leidy 1858) Anderson 1959. Examinations are still underway but findings thus far are presented in Table 9. The pathological and resultant physiological, behavioral and ecological effects of marine mammal heartworms is presently under investigation.

VIII. Conclusions - Ringed Seal

Ringed seals and associated data have been gathered by the Department of Fish and Game personnel since 1962. However, this annual report covers examinations and analyses conducted between 31 March 1976 and 31 March 1977. Most of our sampling and analyses are incomplete at this time and of an ongoing nature. Therefore the results and their preliminary interpretation are considered tentative and _are not_ to be quoted without permission of the Principal Investigators.

Adult ringed seals are mainly associated with the shorefast ice of the Bering, Chukchi and Beaufort Seas. By virtue of their nearshore habits and numbers, they are important to the coastal residents as a source of food and usable products. Proposed OCS lease areas in the Bering, Chukchi and Beaufort Seas are within the habitat of the ringed seal and pose a real threat to this species. The objectives of our studies are to develop a baseline of ecological and behavioral data in order to prevent or lessen adverse impacts of outer continental shelf development.

General conclusions are as follows:

1. Three subspecies of ringed seals (_P. h. hispida_, _P. h. ochotensis_, and _P. h. kraschenínikovi_) may be found in Alaskan waters; however, the taxonomic relationship between these subspecies is unclear.

2. The color of ringed seals is quite variable, but the basic pattern is a gray back with black spots ringed with light marks and a light belly.

Table 9. Examinations for marine mammal heartworms (Dipetalonema (Acanthocheilonema) spirocauda).

Species	Location	Number Examined	Number Positive	Number Positive
Phoca vitulina richardii	Kodiak Island	18	4	22.2
Phoca vitulina richardii	Nanvek Bay	2	0	0
Phoca vitulina richardii	Southern Bering Sea	2	0	0
Phoca vitulina largha	Southern Bering Sea	13	0	0
Phoca vitulina largha	Shishmaref	8	2	25.0
Phoca hispida	Bering Sea	142	2	1.4
Phoca hispida	Chukchi Sea	65	1	1.5
Phoca hispida	Beaufort Sea	6	0	0
Phoca fasciata	Bering Sea	9	1	11.1
Erignathus barbatus	Bering Sea	4	0	0
Erignathus barbatus	Chukchi Sea	4	1	25.0
Odobenus rosmarus	Bering Sea	27	0	0
Odobenus rosmarus	Chukchi Sea	8	0	0
Odobenus rosmarus	Beaufort Sea	1	0	0
Eumetopias jubatus	Gulf of Alaska	21	0	0
Eumetopias jubatus	Southern Bering Sea	4	0	0
Phocoena phocoena	Gulf of Alaska	1	0	0

3. Ringed seals typically have 34 teeth and follow the Phocinae pattern. Several forms of dental disease have been noted.

4. Heaviest weights are achieved in winter and early spring when the seal has a heavy, thick layer of blubber. The weights of ringed seals decline with the decrease in feeding during the reproductive and molting season.

5. Pregnancy lasts approximately 11 months with implantation delayed for about 3-1/2 months after conception. Females appear to be impregnated in mid- to late April, soon after the birth of the pup.

6. Pups weigh 4.0 to 5.0 kg at birth and grow rapidly doubling their weight by weaning, two months after birth.

7. Active spermatogensis is found in essentially all seven-year-old and older males collected from March through June. Some five and six-year-old males also undergo active spermatogensis.

8. Males are physiologically capable of breeding earlier in the year and long after most females.

9. All females seven years old and older appear to be capable of ovulation. Some three to seven-year-old females are also capable of ovulation. Pregnancy rates have decreased from 91 percent during the period of 1964-1973 to 62 percent for those collected from 1975 to 1977.

10. In Alaskan water, polar bears feed primarily on adult, male ringed seals and the bears kill one ringed seal about every 150 kilometers traveled during the spring. The hide and blubber are the preferred part of the seal by bears.

11. The fetal, pup and older-than-pup sex ratio is 1:1 and the age composition essentially follows that of other ringed seal populations.

12. A literature review is underway and about 635 citations pertaining to ringed seals has been recovered. Few citations pertain specifically to ringed seals in Alaskan waters.

IX. Needs for further study

There are many needs within the Outer Continental Shelf Environmental Assessment Program which will no doubt be elucidated by many other investigators. Our primary need for further work is the examination of additional specimens, especially from the winter, from far offshore and from the Beaufort Sea, so that we can fully address our task objectives. Collection of specimens should continue until a sample sufficiently large to determine seasonal, areal and habitat variation in food habitats and population distribution and structure is obtained. This same sample should provide enough reproductive material to calculate population productivity parameters.

The natural histories of important prey species of ringed and bearded seals should be investigated. The life histories and behaviors of prey species appear to have a direct effect on seal distribution, densities and behavior. Emphasis should be given to potential effects of oil and gas exploration and development on these prey species.

Consideration should be given to developing a radio tracking system for pinnipeds. Once developed the technique would rapidly provide badly needed information on movements, seasonal distribution, feeding areas, habitat utilization and behavior.

X. Summary of Fourth Quarter Operations

A. Field and Laboratory Activities

1. Schedule

Date	Location	Purpose
Jan.-Mar. 1977	Fairbanks	Routine laboratory and data analyses and management
January 1977	Anchorage	Met with other OCS marine mammal investigators
January 1977	Nome	Collection of specimens
February 1977	Barrow	Beaufort Sea Synthesis Meeting and collection of specimens
February 1977	Wainwright	Arranged for collection of specimens
February 1977	Point Lay	Arranged for collection of specimens
Feb.-Mar. 1977	Fairbanks	Preparation of Annual and Fourth Quarter Report
March 1977	Nome-Norton Sound	Collection of specimens and seal habitat surveys
March 1977	Kotzebue-Kotzebue Sound	Collection of specimens and seal habitat surveys
March 1977	Barrow	Collection of specimens and seal habitat surveys
March 1977	OSS SURVEYOR cruise	Collection of specimens and seal habitat surveys

2. Scientific Party

Name	Affiliation	Role
John J. Burns	ADF&G	Principal Investigator RU#230 and 232
Thomas J. Eley	ADF&G	Principal Investigator RU#230
Lloyd F. Lowry	ADF&G	Principal Investigator RU#232

Kathy J. Frost	ADF&G	Principal Investigator RU#232
Harry V. Reynolds	ADF&G	Game Biologist
Edward Muktoyuk	ADF&G	Marine Mammals Technician
Glenn Seaman	ADF&G	Marine Mammals Technician

3. Methods

From all specimens we endeavor to obtain weights, standard measurements, lower jaws, foreflipper claws, stomachs, reproductive tracts and intestines. We also obtained blubber, tissue, organ and blood samples as time and situation permitted.

The ages of seals are determined by examination of claw annuli (for animals six years and younger) and dentine or cementum annuli (for animals over six years of age). Growth rates are based on weight and standard measurements correlated with specimen age, sex and date and locality of collection. Species productivity and parasite burden are determined, respectively, through laboratory examinations of reproductive tracts and various organs and correlation of these data with age, sex, and date and locality of collection of each specimen.

Regional differences in seal density and distribution were assessed through aerial surveys following the methods of Burns and Harbo (1972).

Analytical methods are discussed in detail in our Annual Report.

4. Sample Localities

Bering (including Norton Sound), Chukchi and Beaufort Seas.

5. Data Collected

Specimens collected during January and February 1977 are as follows:

Specimen Number	Species	Date of Collection	Sex	Age	Stomach	Reproductive Tract	Parasitological Material
NP-1-77	P. hispida	27 Jan 1977	F	11+	X	X	X
NP-2-77	P. hispida	28 Jan 1977	F	10+	X	X	X
NP-3-77	P. hispida	28 Jan 1977	F	8+	X	X	X
NP-4-77	P. hispida	28 Jan 1977	M	8+	X	X	X
NP-5-77	P. hispida	27 Jan 1977	M	fetus	-	-	-
NP-6-77	P. hispida	28 Jan 1977	F	fetus	-	-	-
NP-7-77	P. hispida	28 Jan 1977	M	fetus	-	-	-
BP-1-77	P. hispida	1 Feb 1977	M	10+	X	X	X
BP-2-77	P. hispida	14 Feb 1977	M	11	X	X	X

As this report is being written during late February and early March, no specimens collected during March are reported. The next quarterly report will cover these animals.

6. Milestone Charts

All updated milestone charts are attached.

B. Problems Encountered/Recommended Changes

None

C. Estimate of Funds Expended

100. Salaries and Wages	$19,698.01
200. Travel	805.96
300. Contractual Services	3,912.15
400. Commodities	427.94
500. Equipment	00.00
	$24,844.06

Project: RU# 230

PI: Burns and Eley

REVISED MILESTONE CHART

MAJOR MILESTONES--OTHER PROJECT ACTIVITIES	1976-77											
	O	N	D	J	F	M	A	M	J	J	A	S
BEAUFORT SEA - Shipboard											✱	✱
CHUKCHI SEA												
Wainwright					✱		✱			✱	✱	
Point Lay					✱		✱					
Cape Lisburne							✱					
Point Hope							✱	✱				
Kotzebue						✱	✱					
Shishmaref						✱			✱	✱		
BERING SEA - NORTON SOUND												
St. Lawrence Island									✱	✱		
Nome						✱	✱	✱	✱			
Diomede									✱	✱		
Stebbin								✱				
Norton Sound - Helicopter operations						✱						

✱Sampling Period

Project: RU# 230
PI: Burns and Eley

REVISED MILESTONE CHART

MAJOR MILESTONES--OTHER PROJECT ACTIVITIES	1976-77											
	O	N	D	J	F	M	A	M	J	J	A	S
St. George Basin - Shipboard in ice front and ice remnant						*	*	*				
Bristol Bay - Shipboard						*	*					
*Sampling Period												

Project: RU# 230

PI: Burns and Eley

REVISED MILESTONE CHART

MAJOR MILESTONES--OTHER PROJECT ACTIVITIES	1976-77											
	O	N	D	J	F	M	A	M	J	J	A	S
Acquisition of specimen	△											△
Processing of specimens for age determination	△											△
Processing of reproductive tract specimens	△											△
Processing of parasitological material	△											△
Compilation and analysis of specimen data			▲		▲	△			△			△
Submission of data	▲			▲			△			△		
Preparation of reports			▲		▲				△			△
Preparation of FY 1978 proposal							△					

△ planned completion date ▲ actual completion date

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Aerial Surveys of Pacific Walrus in the Soviet Sector during Fall, 1975*

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1976

I. Introduction

From September 17 through October 16, 1975 following a five-year break, work has again been done to determine the abundance of Pacific walrus (Odobenus rosmarus divergens, 1811), based on counts from aircraft.

The hauling grounds of walrus were photographed and walrus groups on the ice were subjected to methods of visual counts from aircraft, and subsequent extrapolation.

During the period of surveys there were nine coastal hauling grounds, seven of which were in the Bering Sea and two in the Chukchi Sea. Two new hauling grounds were found, one on the island of Nuneangan and the other one on the island of John the Baptist (Ioanna Bogoslova) both in the Bering Sea. The ice hauling grounds of the walrus were situated in the western part of the Chukchi Sea from Point Billings to Koluchin Island in near proximity of shore.

The count of walrus in the Soviet sector of the Arctic was 128 to 130 thousand head. Of that number the shore rookeries yielded 96.9 thousand head as photographed from the air. The remaining numbers were observed on the ice and while swimming. In comparison to the count of 1970 (101 thousand walrus) we have observed the growth of the population and extension of summer distribution in a southward direction.

The history of harvest of Pacific walrus is very similar to that of the northern fur seal, the bowhead and gray whales. Only the most severe measures of the interested governments had to be undertaken to save the species from complete extinction.

The take of Pacific walrus started in the middle of the 17th century. Each year 5 to 6 thousand walrus were taken. However, in the middle of the 19th century, as established by F. Fay (13), the size of the (walrus) stock had to still constitute around 200 thousand head and by the end of the 19th century 150 thousand head. The annual harvest was 15 to 20 thousand animals. However, the continued harvest attained in the beginning of the 20th century was 8-12 thousand head, not including losses additional to this. By the mid 1950's the walrus population had decreased to 38-40 thousand head (7, 13). By the end of the 1950's, both the United States and the Soviet Union forbade national harvesting in general, permitting harvesting only to serve the needs of the local population of Alaska and Chukotka.

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*Translated by J. J. Burns, Alaska Department of Fish and Game, Fairbanks

The aerial count which was conducted in September 1958 by N. G. Nikulin was the first attempt by Soviet scientists to establish the absolute number of the walrus population. The second count was made in 1960 when aerial photo equipment was used to take pictures of the shore hauling grounds (9).

The total number in the population at that time was estimated at 50 thousand animals. On the basis of this figure recommendations for the conservation and regeneration of the stock were put forward (by the Soviet Government). Beginning in 1963, the ship harvesting of the walrus stopped and the size of the harvest was limited to serve the local needs of people inhabiting Chukotka. The annual take was set at 1000 animals. At this time also, American specialists began aerial surveys of the walrus (11) and they determined the population to be 70 thousand head or greater. At about that time F. Fay began studying the reestablishment of walrus in the southern portion of their range, as it showed an indication of an increase in their number (11). In 1965 J. Burns (12) estimated the population of the walrus to be 90 thousand animals. In 1968, on the basis of aerial surveys in walrus wintering areas, K. Kenyon (unpublished data) gave the figure 73 to 113 thousand.

Numerous facts obtained during the period 1966-1970, by Soviet investigators, have also indicated a southward shift of the southern border of distribution. In 1966 individual walruses were found in the Bay of Russia and Listvenichnia in Kamchatka. The appearance of smaller groups of walruses in Karaginski Bay was noted and the formation of a hauling ground on Verksoturova Island (10) was also observed. Individual walrus were observed near the Commander Islands (8) and on ice of the Okhotsk Sea (5). Several hauling grounds in the Bering Strait region (Island of Arakamchechen and near the abandoned village of Naukan) which up to this time were considered to be defunct and were not visited by walrus for many years, now started functioning regularly. The number of animals visiting these islands has grown each year.

Another count conducted in 1970 (3) supported the data provided by American scientists. The shore hauling grounds of the Chukotsk Peninsula and the ice formations of the Chukchi Sea (in the shared sector of the Arctic) yielded the count of 101 thousand animals.

New data have been obtained during the five year period following the last count. That data, in particular information of the new hauling ground in Peters Bay (personal observations by Captain A. V. Kiselev), supported the picture of walrus migrating farther south. In 1971 in Lavrov Bay (61°16' north) a female walrus with a calf were taken (5). In the fall of 1974 large groups of walruses were observed in Anastasii Bay (information provided by inspector of the Okhotsk Fisheries, N. Sokolov). All these facts suggest that the stock of Pacific walrus is increasing and is about to occupy its former range, which extends south along the coast of eastern Kamchatka to Cape Kronotski and, on the American coast, to the Alaska Peninsula (13).

To check the data obtained from the former survey and to monitor the abundance of the population, it was decided according to the agreements reached with American scientists to simultaneously conduct a count of walruses in the Soviet and American territories in the fall of 1975. Each side would conduct a count in its own territories and the boundary between them would be the "International Date Line."

II. Biological Considerations for Making Counts and the Methods Used In Carrying Out the Work

I(2). During the fall-winter period Pacific walruses inhabit ice in the northern part of the Bering Sea, occupying a broad aquatic territory from Nunivak Island in the south to the Chukchi Peninsula in the north. In the summer-fall period the basic mass (majority) of walrus move north to the Chukchi Sea when ice conditions permit. Only a small part of the herd stays in the Gulf of Anadyr forming one or two shore rookeries by Rudder Bay and on Meechkin Spit. According to observations made during the 1960's (2) this portion of the herd does not exceed 6 to 8 thousand head. During the June-August period, owing to the abundance of drifting or moving ice, the majority of the population disperses over the large water territory from Chaunskoi Inlet in the west, to Point Barrow in the east, and north to 72°.

At the time of greatest destruction of ice, which usually occurs in September, walrus concentrate in the region of Wrangell Island and also at one coastal hauling ground by Cape Inchoun. During years when the summers are warm and the edge of the pack ice is far north (to 73° or 74°) walrus abandon the ice and form coastal hauling grounds on Wrangell Island, Herald Island and a number of other places on the northern coast of the Chukchi Peninsula. The maximal hauling out of walrus on these rookeries takes place during the second half of September. These circumstances are particularly convenient for counting because by photographing the hauling grounds it is possible to obtain an absolute count of the larger portion of the population. In the case that summer ice remains close to shore, walruses do not abandon it. During the first 10 days of October, when the intense formation of ice begins in the region of Long Strait the walruses' ice rookeries are concentrated in a relatively small area near the ice edge, facilitating conduct of aerial surveys. At that same time migration of the walruses begins to the southeast, in the direction of Bering Strait. If no ice is present on their migration route, near shore, the walruses haul out on the shore, forming temporary hauling grounds. Knowing these peculiarities of this animal's distribution during the autumn period, we wanted to conduct two to three aerial surveys of the ice hauling grounds and to photograph the shore hauling grounds several times.

Taking into account what we have just said, the dates for conducting counts were in the period from September 15 to October 20.

2(2). Work was conducted from an airplane of the IL-14 type, from September 16 to October 16, 1975. The plane was equipped with two "blisters" with visors, which allowed the exact delineation of width of the survey track.

Subject to conditions of visibility and altitude of the flight, the observation angle was 45° or 63°; that is, the width of the strip in the first instance was equal to the altitude of the plane and in the second instance it was equal to two times the flight altitude. The plane speed, on the average, was 250 kilometers per hour.

The plane was equipped with two cameras: AFA TE-500 with a film format of 18 x 18; and AFA-42-20 with a film format of 30 x 30 cm. Focal length of the objective lens in the first camera was 500 mm. For the second camera it was 200 mm. Scale of the pictures depends on the relationship of focal distance of the objective lens to flight altitude. Pictures were usually taken from a height of 1000 m. In this case (from a height of 1000 m) the scale of pictures for the first camera was 1/2000, i.e. 1 cm on the photograph corresponded to 20 m of the place being photographed. For the second camera the ratio was 1/5000. On photos made with the first camera it is possible, using binocular magnifying lenses, to see the different parts of a walrus. The second camera was operated simultaneously with the first only when there were many walruses in the water near the rookeries and they could not be seen in the frames of the AFA-TE-500 camera.

3(2). Counts were accomplished in the following manner. First, the shoreline was inspected from Karaginski Bay (including Karaginski and Verkooturov islands) to Cape Schmidt with the aim of searching for occupied walrus hauling areas. Observation through the blisters and from the cockpit of the plane was constant throughout these search flights. The optimum altitude of these flights was 300-400 m. The shore was continually observed through binoculars.

After finding a rookery the plane assumed the required altitude and at the moment it flew directly over the rookery, pictures were taken. In order that nothing was missed, pictures with a linear overlap of 30-35 percent were made. The altitude from which pictures were taken was usually 1000 m. However, if there was a problem due to clouds, pictures were taken from a height of 700 m. In this case the speed of the airplane was reduced to a minimum in order not to obtain photos which were out of focus. With this same aim (obtaining pictures in focus) a minimum exposure time (1/140 sec.) was used. Regulation of light was done with the diaphragm. Counting of the animals appearing on the pictures was done by drawing contour lines around the hauling ground, and measuring its area with a planimeter. Several places in each frame, where the density of walrus varied, were pierced with needles marking the central points. Each of these areas was 1 cm^2. In these areas the number of walruses was counted with the aid of binocular magnifiers. After that, the average number of the animals per unit area was calculated and the results extrapolated to the entire area of the hauling ground. In areas with marked variation in density from the basic hauling ground all animals were counted individually under a binocular magnifying glass. The same procedure was used for counting walrus close to the rookery but in the water.

As a control for the area extrapolations of the hauling grounds we checked our data, obtained by this method, with the counts of individual walruses included in these same photographs. For instance, a picture of the Meechinsk rookery, taken on September 18, yields a difference between the area extrapolations and individual counts of only 198 animals or 2.46 percent (Table 1). As we can see this is not a large error.

Animals underwater at the moment pictures were taken could not be enumerated. However, as this is the period of greatest occupation of the hauling areas, the number of animals in the water was insignificant. Those that were diving were even fewer. Errors from this source can be ignored.

The process of aerial surveys of the ice rookeries was initially achieved with reconnaissance flights. During such flights a map would have ice conditions indicated on it. Those areas occupied by walruses were designated.

During the following day the areas in which walruses were discovered would be covered by uniform transects. The distance between adjacent transects varied between 10-20 kilometers. In the flight records, on board the aircraft, the time of sighting individual walruses or herds on the ice was noted. As we processed the resulting material these data were put on maps and regions with varying concentrations of walruses would be singled out. The extrapolation would only be done for those areas with similar densities of walruses. Simultaneously, from another airplane, a count of gray whales was also being conducted under the direction of a collaborator from the Magadan Branch of TINRO, V. V. Zimooshko. We used the data obtained by him concerning the distribution of the walruses in the open sea.

III. Distribution and Number of Walrus in September and October 1975

1(3). The reconnaissance flights that were carried out on September 17 and 19 and on October 25 allowed us to survey the coast from the Ossora Peninsula in eastern Kamchatka, to Koluchin Island in the Chukchi Sea and also the ice extending from the eastern ice edge to Point Billings in the west and Wrangell Island in the north. In September (1975) there were seven coastal hauling grounds in the Bering Sea. They were as follows:

1. on John the Baptist Island (o. Ioanna Bogoslova);
2. on the western extremity of Meechkin Spit (locally called Meechkinskoye);
3. on Red'kin Spit next to Rudder Bay (Rudderskoye);
4. on the coast of Nuneangan Island in Bering Strait (Nuneanganskoye);
5. the eastern end of Arakamchechen Island (Arakamchechenskoye);
6. the southern end of Ratmanova Island ((Big Diomede) Ratmanovskoye);
7. the former site of the village Naukan (Naukanskoye)

One hauling ground in the Chukchi Sea, the southeast part of Point Inchoun (Inchounskoye) was occupied by walruses. The Rudderskoye hauling ground stopped functioning in October. Walruses no longer appeared there but in the Chukchi Sea a large hauling ground at Cape Serdse-Kamen' was formed.

2(3). The greatest number of ice rookeries during September were concentrated mostly on the narrow strip of ice extending from Koluchin Island to the Bar of Two Pilots (Kosi Dvuk Pilotov) and extending 15 to 20 km eastward from Point Billings. The smaller hauling areas on the ice and in general the swimming walruses were noted all along the way from Point Billings to the eastern edge (of ice) (Fig. 1).

The ice conditions being formed in the region of Long Strait in September of that year (1975) were quite complex. Suffice it to say that the ice edge at the beginning of the last decade of September was 140-160 km farther to the east than it was at the same time in 1970 (3), and the ice density (coverage) was much higher. The basic ice hauling areas for walruses in 1970 were to the west and southwest of Wrangell Island, that is 300-350 km to the northwest of where they were in 1975. The new ice formations with densities reaching 5 to 9 tenths extended northward 15 to 20 km from the shoreline. The walruses occurred in this ice zone. Farther north the ice cover was complete (10 balls) consisting of grey and grey white ice among which were found occasional deposits of multiyear ice. There were no walruses observed on this ice.

The following day, September 20, the entire region from Point Billings to Koluchin Island was covered with transects. It turned out that in the region of Point Billings there are small polynia. Significant numbers of walrus were found in the water and on the adjacent ice. Amidst the thin ice along the coastline the walruses were in small groups of 3 to 5 animals as well as singly, and they were moving southeast. Quite frequently the groups included females and calves.

When the walrus would reach a field of grey ice or nilas, they would swim under the ice and, in order to breathe, they would break through it with their heads. Along the edge, where the water was clear enough to observe walrus, they were primarily moving to the southeast, although some animals moved in the opposite direction. In the area extending from Point Billings to 178° west longitude the density of walruses was .76 animals per square kilometer and here there were 6.5 thousand animals counted. The lowest density turned out to be near the eastern ice edge between 69° and 70° north. That is .03 walruses per square kilometer. The greatest density was in the near shore strip of ice extending from the estuary of the Amguema River to Point Onman - 16.4 animals per square kilometer. Altogether 23 thousand animals were counted in this region. It is difficult to judge how complete this count was because the majority of the walruses encountered were in the water. While the count was taken it was inevitable that not all walruses were seen because the plane files low. Some walruses, because of fear of the noise of the motors, would dive as the plane came within 500-800 meters of them. After 4 or 5 seconds it was impossible to identify them in the water. Moreover it is entirely possible that some walruses were west of Point Billings but it was not possible to survey this region. There was no ice along the Chukchi coast between Koluchinskoi Inlet and Cape Inchoun and walruses were not observed on the side of Bering Strait.

3(3). The photocensus conducted on September 18 and 21 showed that on those dates the number of walruses on the shore hauling grounds reached 82 thousand head (Table 1). In 1970, at the same time, there were about 20 thousand walruses on them. Apparently because of the unusual ice conditions which occurred in the region of Long Strait in September of 1975, the majority of the population that (usually) inhabits Wrangell Island waters in the summer moved to the Bering Sea somewhat earlier than usual.

4(3). We expected that the freezing weather which started in mid-September would speed up the formation of ice in the Chukchi Sea and, because of this, the walruses would leave the ice earlier than usual and occupy the shore hauling grounds. However, the deep cyclone which paused over the Chukchi Peninsula at the end of September reversed the situation; the ice was broken up and its eastern edge moved 100-200 km westward, reaching the meridian of the Point Schmidt (Fig. 2).

On October 5 and 6 the ice hauling groups of walrus were situated 10-15 km north of Point Schmidt, although the general picture of distribution was practically unchanged from that of September (Fig. 1). Twenty-six thousand and six hundred walruses were counted on the ice. The greater part of these walruses, 19.7 thousand, were concentrated in two relatively small areas with a total area of 475 square km. Walrus density in the remaining part of the territory was low, between .3 to .76 per square km.

5(3). During the first 10 days of October, as in previous years (3,9), there was a migration of walruses to the southeast. Approximately half way between the Island of Koluchin, where the ice ended, and the Meechkinskii hauling ground, the walruses formed one large hauling ground, in October, near Cape Serdse-Kamen'.

6(3). Of the nine hauling grounds that functioned in the fall of 1975, two of them on John the Baptist Island (Ioanna Bogoslov) and Nuneangan Island, were recorded for the first time. There are no earlier references in literature about them. On the Island of John the Baptist the walruses were apparently part of a small herd which has remained in this region for several years during the summer. As has already been mentioned, in 1971 hunters saw the walrus hauling ground in Peter Bay (containing up to 1000 animals). The Island of John the Baptist is situated in the inlet to that bay. A bit to the north, in Anastasii Bay, on June 25, 1971, a group of 500 walruses was observed (8). In Olutorski Bay on September 9, 1975, 50 walruses were seen from an airplane which was engaged in a survey of whales. A colleague from the Magadan Branch of TINRO, V. V. Zimooshko, who at the time was conducting this work, also indicated encountering walruses 12 to 15 km off the coast of Anastasii Bay on October 1 (12 animals), and 3 walruses by Point Vitgenshtein. He counted 5 animals in Olutorskii Bay. On October 2, in the Anadyrskii estuary, he counted 7 walruses and 60 miles to the east of Cape Navarin he counted 2 walruses. Because there are no hauling grounds in the region of coast between Cape Olutorskii and Cape Navarin we assumed that the groups of walruses encountered were performing a feeding migration and all of them belonged to the herd which spends the summer in the Koryakskii region of the coast.

The hauling ground on Nuneangan Island was occupied for the first time in 1975 and perhaps, in some measure, took over the function of the Akkaniiskii hauling ground. This hauling ground was situated at Point Kriguigan and functioned during three seasons - 1972, 1973 and 1974. Up to 12 thousand walruses would haul out there. However, this fall, for some reason, this hauling ground was empty.

7(3). The majority of hauling grounds were photographed many times which, to some degree, permits us to evaluate their dynamics. It has frequently been noted that the maximum occupation of the hauling grounds usually occurs after a storm and during the evening. On stormy days the walruses occupy only those areas that are protected from the wind and waves, while the majority of animals go into the open sea or float near the hauling ground.

During calm weather the walruses begin abandoning their hauling grounds after 9 or 10 o'clock in the morning and the groups leave to feed. The distance of feeding migrations apparently varies greatly and may be due to the fact that the animals do not have sufficient time to return to the hauling ground during that same day. The walruses off the Islands of Arakamchehen and Nuneangan go to feed in Mechigmenskii Bay and also to the east and southeast off the hauling ground. We observed groups of walruses in October, 70-80 km eastward of Arakamchechen Island and one was encountered 120 km away (Fig. 2).

The fluctuations in counts of walruses occupying the hauling grounds is, to a great extent, connected with the fall migration. For instance, we can see that the Naukanskoye hauling ground is constantly occupied because of the animals coming there from the Chukchi Sea and the hauling grounds in the Chukchi Sea would correspondingly have smaller numbers of walrus.

By comparison with the 1970 count, a significantly larger number of the walruses were seen in 1975 on the Arakamchechenskii hauling ground. On the Naunkanskii and Inchounskii hauling grounds the number did not reach half of that which occurred in 1970 at the same time of year. This again is connected with the displacement of the migration dates.

8(3). V. P. Krilov determined the average area occupied by one walrus on the shore hauling grounds to be 3.3 square meters. In 1970 (3) the average area occupied by a single walrus on the hauling grounds varied from 2.7 to 3.8 square meters. This year (1975) on the same hauling grounds it appeared to be reduced by 50 percent (Table 1) with a variation of from 1.3 to 2.82 square meters.

Thus, this indicator was not constant and use of it as a reliable measure could yield large errors.

9(3). In calculating the total count of walruses we used the data obtained for the Chukchi Sea on October 5 and 6 and for the Bering Sea on September 18 and 21. It was during these days that we could photograph the maximum occupation of the hauling grounds (Table 2). Moreover 3 to 5 thousand walruses had to be added, which were encountered on September 21 as they were approaching the Arakamchechen hauling ground. The minimum figure obtained was 128 to 130 thousand animals. These are minimum numbers because between September 21 and October 5, the migration of the walruses from the Chukchi Sea to the Bering Sea continued. However, to determine the number of the walruses that actually moved from one sea to the other is impossible because the September count of the Chukchi Sea ice cannot be considered complete and in October, because of bad weather, we were prevented from photographing the maximum occupation of hauling grounds in Bering Strait.

Thus, based on a comparison with the data from previous surveys we observed a good increase in the Pacific walrus population.

But, once again, as we have stated, the data which we have obtained characterizes the number of the walruses that are in the Soviet sector of the Arctic only.

Table 1. Numbers of walrus on coastal hauling grounds in September-October 1975.

Date and local time of counts	Weather	Number of walruses	Area occupied by one walrus(m^2)	Remarks
1	2	3	4	5
John the Baptist Island				
4-X-75, 1313	Overcast, calm	220	4	Individual count*
Meechkinskoye (Point Kungas)				
17-IX-75, 1007	Clear, calm	8,242	1.8	Number based on extrapolation
17-IX-75, 1007	Clear, calm	8,044	1.8	Individual count
21-IX-75, 1547	Clear, slight wind	500-600	-	Visual estimate
17-X-75, 1546	Clear, moderate wind	Walruses swimming near the rookery and on the ice in Kresta Bay		
Rudderckoye rookery				
21-IX-75, 1533	Clear, occasional light wind	445	-	Individual count
Nuneanganskoye rookery				
18-IX-75, 1153	Overcast, stormy	1,152	-	Individual count
19-IX-75, 0955	Overcast, windy	627	-	Individual count
21-IX-75, 1412	Clear, occasional light wind	19,977	1.54	Number based on extrapolation
9-X-75, 1033	Overcast, north wind	1,628	-	Individual count
Arakamchechenskoye rookery				
18-IX-75, 1215	Overcast, stormy	3,996	1.89	Extrapolation and individual count
19-IX-75, 1007	Overcast, windy	1,208	-	Individual count
21-IX-75, 1400	Clear, occasional light wind	41,882	1.56	Extrapolation and individual count
9-X-75, 1050	Overcast, north wind	Several thousand walruses sleeping in the water near the rookery.		
Ratmanovskoye rookery				
21-IX-75, 1142	Clear, occasional light wind	4,228	2.43	Individual count
21-IX-75, 1146 (second pass over rookery)	Clear, occasional light wind	3,516	-	Individual count
Naukanskoye rookery				
21-IX-75, 1132	Clear, occasional light wind	2,144	1.76	Extrapolation and individual count
5-X-75, 1233	Clear, calm	2,326	-	Walruses approaching from north
7-X-75, 1146	Clear, occasional light wind	2,417	1.32	Many walruses in the water

9-X-75, 1150	Overcast, south wind	3,357	1.88	Walruses approaching from north
Inchounskoye rookery				
21-IX-75, 1115	Clear, slight wind	5,029	1.70	Extrapolation and individual count
5-X-75, 1246	Clear, calm	7,742	1.67	Extrapolation and individual count
7-X-75, 1132	Clear, north wind	3,700	1.30	Extrapolation and individual count
9-X-75, 1202	Light clouds, calm	5,700	-	Individual count
Cape Serdse-Kamen' rookery				
5-X-75, 1320	Clear, calm	11,972	1.95	Extrapolation and individual count
9-X-75, 1245	Clear, calm	9,188	2.83	Extrapolation and individual count

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*Translators note - Individual count refers to animals counted from photographs. JB

Table 2. Number of walruses on coastal hauling grounds and on the ice, based on aerial surveys in 1975.

Number	Date of count	Name of Rookery	Local time of survey	Number of walruses
1.	4 October	Ioanna Bogoslov	1313	220
2.	18 September	Meechkin Spit	1007	8,242
3.	21 September	Rudderskoye	1533	445
4.	21 September	Nuneanganskoye	1412, 1422	19,977
5.	21 September	Arakamchechenskoye	1400	41,882
6.	21 September	RaTmanovskoye	1142	4,228
7.	21 September	Naunkanskoye	1132	2,144
8.	5 October	Inchounskoye	1245	7,742
9.	5 October	Serdse-Kamen'	1315	11,972
	Total on coastal rookeries:			96,852
10.	5-6 October	On ice floes in the region between Point Billings and Koluchin	-	26,600
11.	21 September	Swimming in Mechigmenskii Bay	1350	5,500
12.	5 October	Swimming in waters between Cape Des~~c~~hnev and Cape Serdse-Kamen'	1235, 1315	1,500
	Grand Total:			128-130 thousand

Legend to Figures 1 through 4

Fig. 1. Distribution of walruses on the ice and at shore rookeries, 17 to 21 September 1975. A = distribution on the ice; B = places of walrus concentration; C = groups of walruses in the water and the direction of their movement.

Fig. 2. Distribution of walruses on the ice and at shore rookeries, 4-9 October 1975. Symbols as in Fig. 1.

Fig. 3. The scheme of survey tracks flown on 20 September 1975. Dashed line indicates the ice edge.

Fig. 4. The scheme of survey tracks flown on 6 October 1975. Dashed line indicates the ice edge.

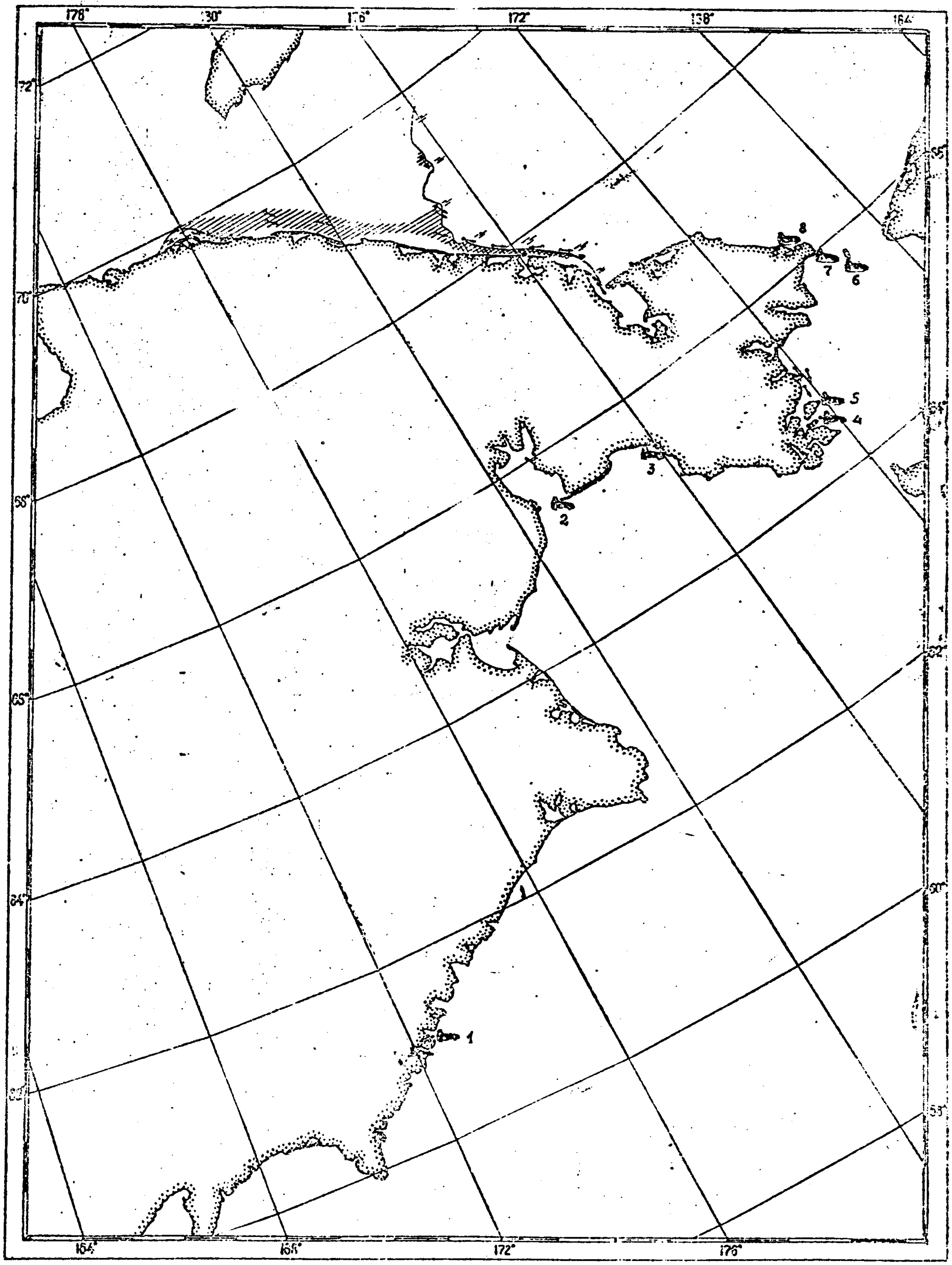

Рис. I. Распределение моржей на льдах и береговых лежбищах
Fig. I. 17 – 21 сентября 1975 г.

A. ☰ распределение на льдах; B. |||| места концентраций; C. ↗ ↗ группы моржей на плаву и направление их движения;

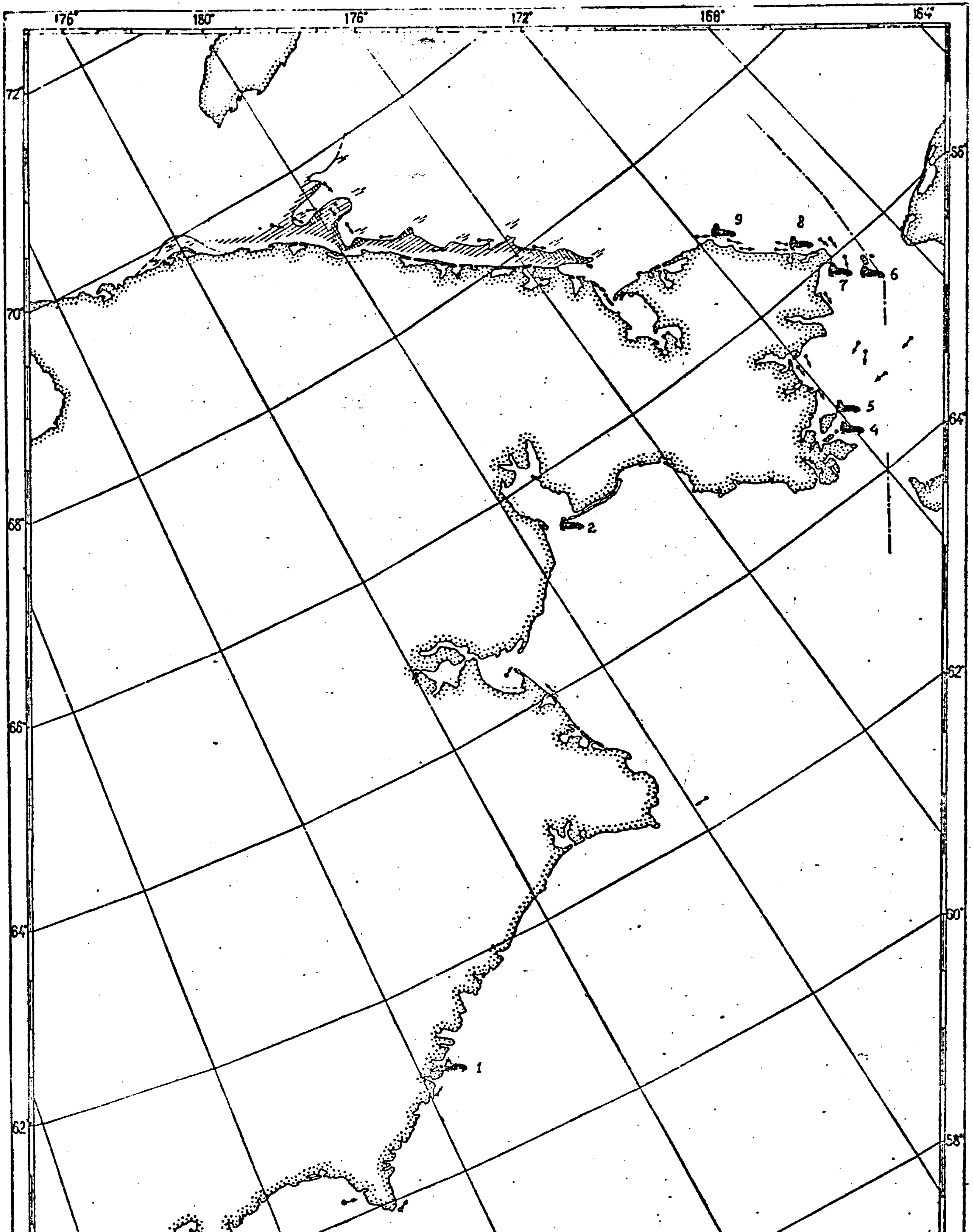

Fig. 2.

Рис. 2. Распределение моржей на льдах и береговых лежбищах 4–9 октября 1975 г.
(Условные обозначения на рис.I.)

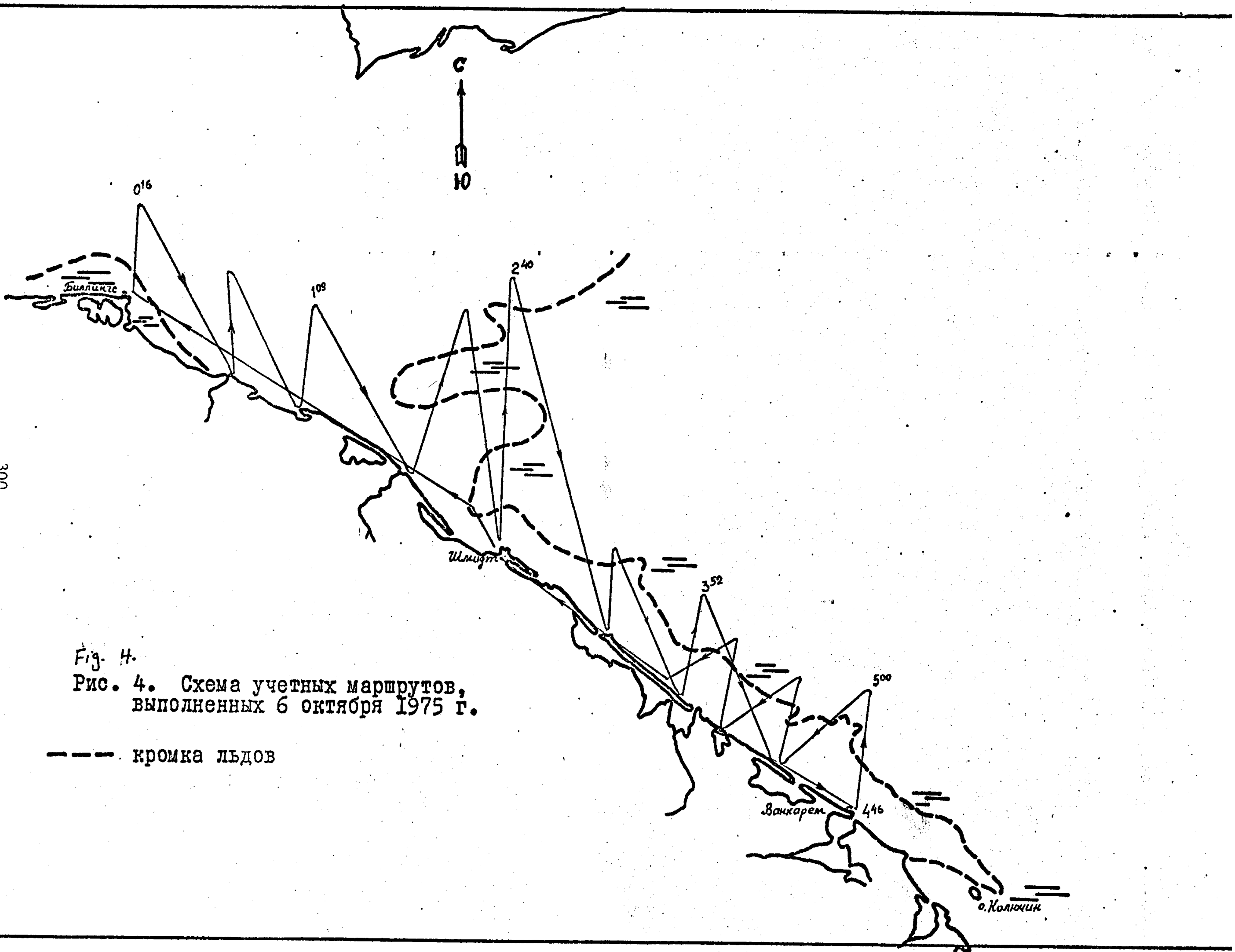

Fig. 4.

Рис. 4. Схема учетных маршрутов, выполненных 6 октября 1975 г.

— — — кромка льдов

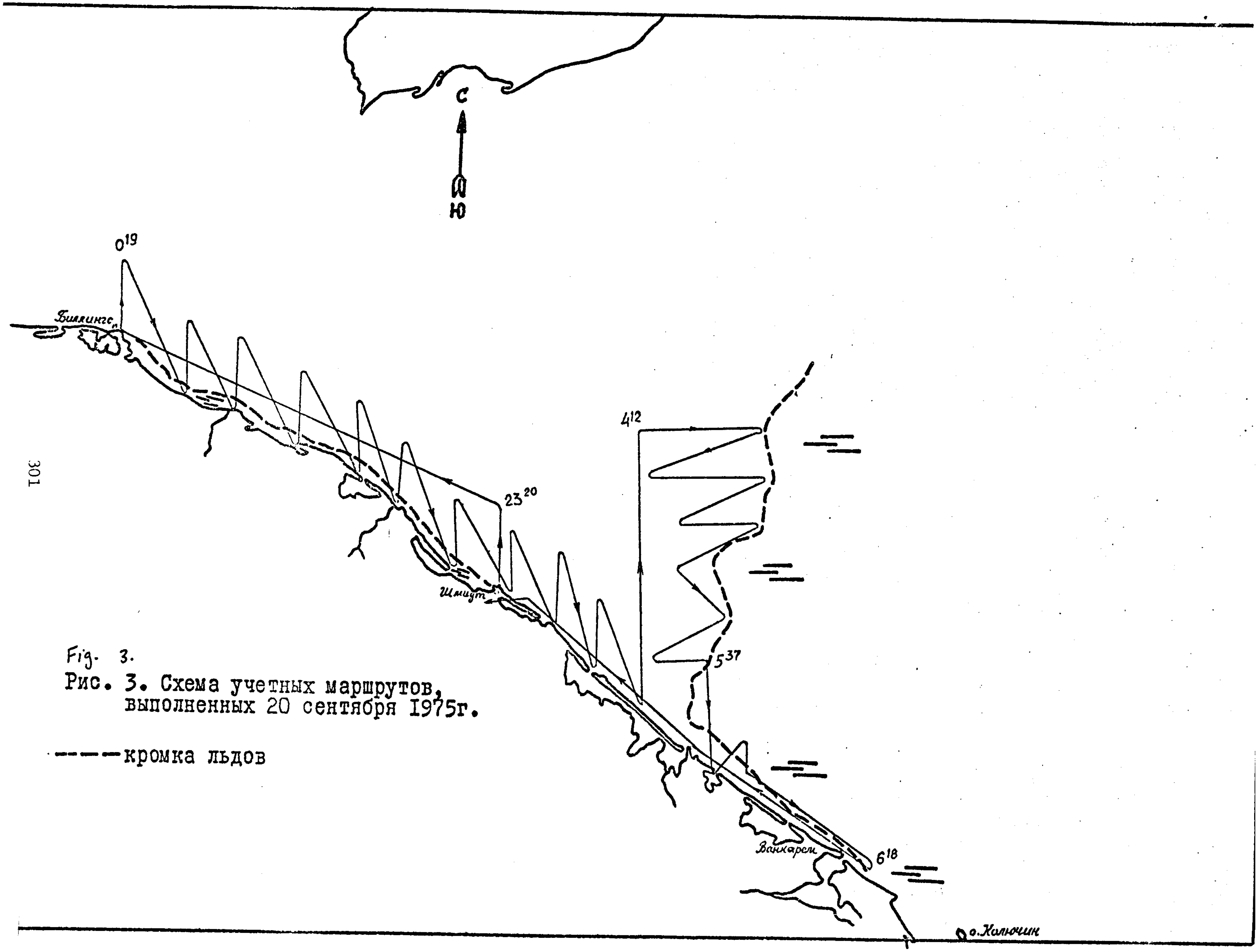

Fig. 3.

Рис. 3. Схема учетных маршрутов, выполненных 20 сентября 1975г.

- - - - кромка льдов

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Trophic relationships among ice inhabiting phocid seals

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CONTENTS

I. Summary

Ice inhabiting seals are highly visible, numerous, sociologically and economically important species in the Bering-Chukchi, and Beaufort marine ecosystems. A complete understanding of the role of these seals in the trophic structure of these ecosystems is crucial to the evaluation of potential impacts of OCS development. As a first step, the important items in the diet of each species in all areas at all times of year must be determined. Key areas and times of foraging must be determined and will have direct bearing on the suitability of various areas for leasing. When key prey species have been identified and data correlated with information on the distribution, abundance and natural history of these prey species (from other projects), an evaluation of effects of OCS development on the food base of the seals can be made. By understanding the trophic relationships among ice inhabiting seals and other consumers in the system, indirect effects of OCS development (e.g. those favoring population increase of potential food resource competitors) can be predicted.

Previous studies on food habits of ice inhabiting seals have all been geographically and temporally rather limited. From the literature surveyed it appears that ringed seals feed primarily on planktonic crustaceans and fishes, bearded seals eat a variety of benthic invertebrates and fishes, spotted seals eat pelagic and demersal fishes and crustaceans, and ribbon seals consume fishes (gadids and herring), cephalopods and shrimp.

Stomachs containing food from 218 ringed seals, 110 bearded seals, 26 spotted seals and 5 ribbon seals have been collected and examined. The majority of these samples were collected at coastal hunting sites in the Bering and Chukchi Seas during summer. These collections were supplemented by shipboard and helicopter collections made by ADF&G personnel in the Bering, Chukchi and Beaufort Seas.

Results are presented by locality and time of year within four major geographical areas; southeastern Bering Sea, northern Bering Sea, Chukchi Sea and Beaufort Sea. General feeding patterns are discussed for each species in each area. A brief evaluation of geographical, temporal and age and sex-related dietary differences is made. Results of our investigations of seal feeding habits are compared to those of previous investigators and to what is known of food availability. Key prey items for each species in each area are identified.

The determination of prey items is only an initial step in this project. In order to attain the goal of ability to predict effects of OCS development, much information will be needed on the functioning of other components of the ecosystem. It is hoped that other OCSEAP projects will provide this information.

II. Introduction

The waters off the coast of Alaska support a tremendous abundance and diversity of marine mammals. Some species occur only during ice free months while others are more or less dependent on sea ice as a habitat in which to whelp, breed, molt and feed. The relationship between northern marine mammals and sea ice has been well summarized by Burns (1970) and Fay (1974).

In this project, four closely related species of pinnipeds have been chosen for study: the ringed seal, *Phoca* (*Pusa*) *hispida*; the bearded seal, *Erignathus barbatus*; the spotted seal, *Phoca vitulina largha*; and the ribbon seal, *Phoca* (*Histriophoca*) *fasciata*. Ringed seals and bearded seals are associated with ice throughout the year, with breeding ringed seals more common on shorefast ice and bearded seals occupying the drifting ice (Burns 1967, 1970; Burns and Harbo 1972). Ribbon seals and spotted seals utilize the ice front of the Bering Sea for whelping and molting in late winter and early spring, then ribbon seals appear to become pelagic while spotted seals move to the coast or north with the retreating ice (Burns 1970, in press, personal observations). An estimate of the combined numbers of these four species in the Bering, Chukchi and Beaufort Seas would be 1.5 to 2 million animals.

Marine mammals have a long history of subsistence and commercial utilization (Scammon 1874, Johnson et al. 1966, Reiger 1975). There is great public concern today for their continued well being. Some indications of this concern and interest are the Marine Mammal Protection Act of 1972, the increased interest in research and management at the international level and the present awareness of the nonconsumptive recreational value of marine mammals (Reiger 1975). Subsistence utilization of certain species is still of considerable economic and cultural importance to coastal Eskimo communities (Johnson et al. 1966). These factors and others make it imperative that the potential effects of outer continental shelf development on ice inhabiting seals be anticipated and minimized to whatever degree possible. Such an evaluation requires a complete understanding of the biology of the species involved as well as how these species affect and are affected by their environment. This project will contribute to such an understanding by examining the trophic relationships of ice inhabiting phocid seals in the Bering, Chukchi and Beaufort Seas.

Specific objectives of this project are as follows:

1. Compilation of existing literature and unpublished data on food habits of ringed seals, bearded seals, spotted seals and ribbon seals. In addition, available information on distribution, abundance and natural history of potentially important prey species is being gathered.

2. Collection of sufficient specimen material (stomachs) for determination of the spectrum of prey items utilized by the species being studied throughout the geographic range involved and during all times of year that the species occurs in a particular area. The contents of these stomachs are sorted, identified and quantified. This information is analyzed for geographical and temporal variability in prey utilization patterns as well as for species, sex and age related dietary differences.

3. Analysis of feeding patterns in relation to distribution, abundance and other life history parameters of key prey species. This involves determination of the degree of selectivity demonstrated by each species of seal as well as the availability and suitability of primary and alternative food sources. To whatever extent possible the effect of seal foraging activities on populations of prey species will be examined in light of observed rates of food consumption and foraging behavior. The accomplishment of this objective is largely dependent on information gathered by other OCSEAP projects involving benthic and planktonic organisms.

4. Analysis of trophic interactions among these species and other potential competitors such as walruses, whales, marine birds, fishes and humans. Input from other OCSEAP studies is critical in this phase of the project.

5. With the understanding thus obtained of the trophic interrelationships of ice inhabiting phocids in the Bering-Chukchi and Beaufort marine systems, evaluate the probable kinds and magnitude of effects of OCS development on these species of seals. This will entail both direct effects such as disruption of habitat in critical feeding areas or alterations of populations of key prey species and indirect effects such as influences on populations of competitors for food resources.

III. Current state of knowledge

The search for information on distribution, abundance, and natural history of potential prey items is essentially complete. Our efforts have been to a large degree aided by the efforts of other projects (e.g. Carey 1977). However, although literature searches have turned up a great many references, it is evident that such information as is presently available (e.g. Stoker 1973, Crane 1974) is not sufficient to satisfy the needs of this study. This problem will be discussed in Section IX.

The earliest accounts of foods of marine mammals are to be found in the records of early polar expeditions. However, such reports usually involve small samples and are lacking in taxonomic refinement. The discovery that seals are better collectors of some faunal elements, for example swimming crustaceans, than more traditional collecting gear resulted in the analysis of a number of ringed and bearded seal stomachs (e.g. Rathbun 1919, VanWinkle and Schmitt 1936, Dunbar 1954). Most of these studies were concerned with the nature of the contents rather than the feeding biology of the seals, a notable exception being the study of Dunbar (1941). The recognition of seals as potential competitors for commercially important fishes spurred a surge of research on pinniped feeding habits (e.g. Scheffer and Sperry 1931, Spaulding 1964, Briggs and Davis 1972, Rae 1973). Although at least two species (ribbon seals and spotted seals) are known to feed somewhat extensively on commercially important pollock (Arseniev 1941, Burns in press, Wilke 1954), ice inhabiting seals have not been given systematic attention. Some limited information on the food of ice seals in Alaskan waters is available from the reports of interested persons who recorded the stomach contents of specimens they encountered (Kenyon 1962, Burns 1967, unpublished). The only systematic studies of feeding habits of ice inhabiting phocids were done by Johnson et al. (1966) as part of Project Chariot and the work of several Soviet investigators utilizing material made available by commercial sealing operations. Translations of some of these works have been obtained from various translation services. Several important papers for which translations were apparently not available have recently been translated for this project. These are included at the end of this report, for distribution purposes. A summary of the results of previous studies of food habits of each of the four species being considered in this project follows.

Ringed seals

By observations and discussions with native hunters in northwest Greenland, Vibe (1950) determined the principal foods of ringed seals in that area to be polar cod, amphipods, decapod crustaceans and occasionally sculpins. In the spring animals were taken mostly while basking on the ice and always had empty stomachs.

Dunbar (1941) reported on the stomach contents of 47 seals taken in Baffin Island waters during August and September. The pelagic amphipod Parathemisto (=Themisto) libellula was by far the most common food. Mysids were occasionally abundant in the stomachs. Other invertebrates and fishes were found in very small quantities.

McLaren (1958) examined stomachs of ringed seals taken at several localities in the eastern Canadian arctic. The feeding pattern observed in this area appeared to be largely determined by water depth. In shallow inshore areas the major food items were fishes (mostly polar cod and sculpins). mysids and shrimps. In deeper offshore waters the primary food was Parathemisto libellula. No seasonal or age related differences in food items were noted. A decreased percent of stomachs containing food was noted from late April to the end of June.

Barabash-Nikiforov (1936) reported that the contents of stomachs from two specimens from the Commander Islands contained fishes (Hexagrammidae), crabs and an octopus.

Pikharev (1946) examined the stomachs of 377 seals taken in the spring of 1939 in the Shantar Sea and the Sakhalin Gulf (western Sea of Okhotsk). Only 16 of the stomachs contained food remains, all of these being animals that were in the water or had only recently hauled out on the ice. From this Pikharev concluded that ringed seals do feed during the molt period, and digestion takes place quite rapidly. The most commonly encountered food items were the isopod Saduria (=Mesidotea) entomon and the euphausiid Thysanoessa raschii. Two species of gammarid amphipods and one species of hyperiid amphipod were found as well as shrimp (Pandalus goniurus), **pollock (Theragra chalcogramma), smallmouth smelt (Hypomesus olidus)** and herring (Clupea harengus pallasi), each found in one stomach.

Fedoseev (1965) analyzed the stomach contents of 159 ringed seals taken in the northern Sea of Okhotsk. Animals taken in spring (February-April) had fed almost entirely on euphausiids, amphipods, isopods and mysids. Shrimps were also eaten in small quantities. Food was found in 77 percent of the stomachs examined in this period. During the molting period (May-June), remains of food were found in only 21 percent of the animals examined. Shrimps, euphausiids and amphipods were all important in the diet. No stomachs were examined from animals taken in summer but, on the basis of food availability and distribution of the seals, euphausiids were inferred to be the primary food. In the late autumn and early winter (November and December), fishes (saffron cod, smelt, herring and others) were the main food, followed by shrimps, amphipods and euphausiids. Fedoseev noted that pups and yearlings fed largely on small crustaceans (euphausiids and amphipods). Fish and larger crustaceans were found more frequently in adults than in younger animals.

Fedoseev and Bukhtiyarov (1972) reported on the foods of 209 ringed seals taken during spring in the Tamsk and Shantur regions of the Sea of Okhotsk. Euphausiids were the primary food in both areas. Shrimps and fishes were eaten more often in the more southerly (Shantur) region than in the north.

Nikolaev and Skalkin (1975) reported on the stomach contents of 27 ringed seals taken during March and April on the drifting ice in Terpenie Bay (southern Sea of Okhotsk). The primary food was euphausiids followed by shrimps, fishes and crabs.

Kenyon (1962) reported on the stomach contents of 14 seals taken at Little Diomede Island, May 11-June 14, 1958. Shrimp of the genus Pandalus accounted for 96 percent of the food items encountered with mysids, amphipods and fishes present in small amounts.

The intensive study of Johnson et al. (1966) at Point Hope and Kivalina resulted in the examination of 1923 stomachs from seals taken over the period November 1960 to June 1961. During the months of November, December, January and February, fishes (mostly sculpins, arctic cod (Boreogadus saida) and saffron cod (Eleginus gracilus)) made up 90 percent or more of the contents. During March, April, May and June, invertebrates, mostly shrimp and amphipods, were the predominant food making up more than half and occasionally more than 80 percent of total stomach contents.

Bearded seals

Vibe (1950) in his report on investigations of the biology of marine mammals in northwest Greenland describes the feeding of the bearded seal as follows: "As regards its food the bearded seal is not particular, it is almost omnivorous; it will, however, mainly stick to the fauna in or just above the sea bottom, where it can get down at it, but if the depths are too great, it will be content with polar cod. It does not select its food elements but seems to feed indiscriminately on all kinds of food which accidentally is found within its habitat." The gastropod mollusc Buccinum and several species of shrimps were the food items most frequently found. Interestingly no clams of the genera Serripes or Clinocardium (listed as Cardium in Vibe) were found in bearded seal stomachs although they were the primary food of walruses in the area. This casts some doubt on the supposition that bearded seals are indiscriminant in their feeding. When taken in water more than 100 meters deep, bearded seals usually had only polar cod in their stomachs. Polar cod were also a major food in the heads of fiords in summer.

Dunbar (1941) examined the stomach contents of five bearded seals from the eastern Canadian arctic. These seals had eaten shrimps, a sculpin and a tube worm.

Inukai (1942) found shrimps (mostly crangonids), king crabs, sea cucumbers, snails, octopus and echuiroid worms in the stomachs of 11 bearded seals taken off southeast Sakhalin in May.

Kosygin (1966, 1971) reported on the foods of the bearded seal in the Bering Sea in spring and early summer (March to June) 1963 to 1965. Stomachs from 565 animals were examined, 152 of which contained food. The snow crab (Chionocetes opilio) was the species most commonly eaten making up from 53 to 76 percent of the food. Shrimp (particularly Argis (=Nectocrangon) lar) were the second most important food. Snails were also important. Octopus, priapulids and fishes (particularly pricklebacks and flatfishes) were eaten quite regularly. Kosygin noted considerable constancy in the diet from year to year which he explained by the fact that the animals tend to be found in the same areas each year. Some annular changes were noted (e.g. polychaetes were commonly eaten in 1963 but not in 1964 or 1965) which Kosygin thought were mostly due to heavy ice fields excluding the animals from certain feeding areas. No age or sex related feeding differences were noted with the exception that it appeared that young bearded seals foraged mostly in the morning while mature animals ate more in the afternoon. The average amount of food in the stomachs decreased from April to June.

Fedoseev and Bukhtiyarov (1972) examined 72 stomachs of bearded seals taken in the Sea of Okhotsk in spring. In the northern

(Tamsk) region decapod crustaceans made up 87 percent of the food. Molluscs accounted for less than 6 percent and fishes 3.7 percent. In the Sakhalin Bay (eastcentral) area, clams and snails (found in 40 and 27 percent of the stomachs respectively) were the main food. Worms of an unspecified type were also commonly eaten.

Nikolaev and Skalkin (1975) reported on the foods of 31 bearded seals taken in the southern Sea of Okhotsk (Terpenie Bay) in March and April. Crabs (Chionocetes and Hyas), molluscs (particularly octopus) and shrimps were the primary foods. Several types of benthic fishes (poachers, flatfishes and sand lance) were also eaten. Twenty-nine of the bearded seals taken were molting, 22 of these had food in their stomachs.

Kenyon (1962) reported on the stomach contents of 17 specimens taken at Little Diomede Island, May 11-June 6, 1958. Shrimps (Pandalus sp. and Sclerocrangon sp.), crabs (Hyas coarctatus alutaceus and Pagurus sp.) and clams (Serripes groenlandicus) comprised the bulk of the contents. Other benthic invertebrates (sponges, annelids and snails) and several species of fish were present in small amounts.

Johnson et al. (1966) examined the stomach contents of 164 bearded seals taken at Point Hope and Kivalina from November 1960 through June 1961. The only month in which a large sample (129) was obtained was June. Shrimp, crabs and clams were the most common food items with other benthic invertebrates found in small quantities and fishes (sculpins and arctic cod) usually comprising less than 10 percent of the total volume.

In his summary of the biology of the bearded seal, Burns (1967) reported on his examination of stomachs from seals collected at Nome, Gambell and Wainwright. In May he found that crabs (Hyas coarctatus alutaceus and Pagurus sp.) accounted for 57 percent of the contents with shrimp, fishes (saffron cod, arctic cod and sculpins) and sponges comprising most of the remainder. In July and August, clams (Serripes groenlandicus, Spisula sp. and Clinocardium sp.) were the most abundant food item, with shrimp, crabs and isopods also quite commonly found.

Spotted seals

Many studies have been done on the food of Phoca vitulina, however most of these have been on the land-breeding subspecies (P. v. richardi). Only five reports have been found dealing with the feeding habits of the ice-breeding form (P. v. largha).

Barabash-Nikiforov (1936) reported on the stomach contents of animals taken on the Commander Islands. He found that during the winter and early spring the principal foods were small octopus, crabs and sipunculids (Phascolosoma sp.). Amphipods (Gammarus sp.), algae and fishes were present but in small quantities. Later in the year benthic fishes (sculpins and greenlings) became important in the diet.

Wilke (1954) examined the stomach contents of 21 spotted seals killed on the pack ice of the southern Okhotsk Sea during April of 1949. In the 19 stomachs containing food, pollock made up 83 percent of the total volume, herring 10 percent and traces of octopus, squid and other fishes the remainder.

Fedoseev and Bukhtiyarov (1972) examined the stomachs of 23 spotted seals taken in spring in the northern and eastern Okhotsk Sea. Pollock was the main food, being found in 65 percent of the stomachs examined. Saffron cod, sand lance, euphausiids and decapod crustaceans were also eaten.

Nikolaev and Skalkin (1975) found food in three of the seven spotted seal stomachs they examined from Terpenie Bay. Most of the contents were fragments of fishes. Shrimp, crabs and octopus had been eaten in lesser amounts.

Gol'tsev (1971) examined 319 stomachs from seals collected primarily in the northwest Bering Sea during the 1966-68 hunting seasons (April-June). From his collections he concluded that spotted seals feed in the morning and in the evening and digest their food quite rapidly. The food of newly weaned young (five weeks old) was entirely amphipods (Nototropis sp. and Anonyx nugax) and some algae. At seven to eight weeks old they begin to feed on shrimps (Spirontocaris macarovi, Eualus fabricii and E. gaimardii) and sand lance. When 12 weeks old, larger fish (flatfish and saffron cod) begin to be eaten. Juveniles (age one to four years) fed mostly on fish (arctic cod, sand lance, saffron cod) and shrimp (Pandalus sp.). Adults appear to feed more on benthic forms with octopus, crabs, flounders, sculpins and other bottom fishes prevalent.

Ribbon seals

Arseniev (1941) examined stomachs of 398 ribbon seals taken in the spring off the eastern coast of Sakhalin. The incidence of empty stomachs was very high and increased from 71 percent empty in April to 100 percent empty in July. Pollock was the primary food throughout the sampling period. Cephalopods were eaten commonly from April 30 to May 20 but much less frequently from May 25 to the end of the sample. Shrimp (Pandalus goniurus) occurred only occasionally in the stomachs.

The results of Arseniev were confirmed by Wilke (1954) who found 60 percent pollock and 40 percent squid in two stomachs he examined from animals taken in the Okhotsk Sea in April.

Fedoseev and Bukhtiyarov (1972) examined the stomach contents of 48 ribbon seals taken in the Sea of Okhotsk in spring. Forty-two of these animals had eaten pollock. Saffron cod were found in two animals, octopus in eight and shrimps in one.

Shustov (1965) examined 1207 stomachs from seals taken at the ice front of the Bering Sea from March through July. Only 32 of these stomachs contained recognizable food. Shrimps (*Pandalopsis* sp., *Argis lar*, *Pandalus borealis*, *Eualus gaimardii* and others), amphipods (*Parathemisto* sp.), mysids and cephalopods were frequently found. Many types of fishes, especially arctic cod, saffron cod and herring were encountered but were not very common. In interesting contrast to the findings in the Sea of Okhotsk (Arseniev 1941, Wilke 1954, Fedoseev and Bukhtiyarov 1972), no pollock were found in the Bering Sea sample. This can perhaps be explained by the fact that the seals examined by Shustov were taken in the northern Bering Sea, somewhat north of the main concentrations of pollock.

Burns (in press) reports on the food remains found in the stomachs of six specimens collected in the Bering Sea. Four animals were taken in April and May; one contained fish (*Pholis* sp.), two contained shrimp (*Pandalus* and *Sclerocrangon* sp.) and one contained only milk. The stomachs of two specimens collected in February contained large volumes of pollock and arctic cod.

IV. Study area

The area involved in this study includes the Beaufort, Chukchi and Bering Seas. Since some of the species being studied show extensive seasonal movement in relation to changes in ice conditions, the geographic focus of the study will also vary seasonally. For convenience and to facilitate application of our results to specific OCS lease areas, we have broken down the study area into four sub-areas. We will present and discuss our results for these sub-areas separately. However, it should be remembered that the species involved are highly mobile and animals could occupy any and all areas at different times of the year. A map of the entire study area showing proposed lease sale areas is shown in Fig. 1.

V. Sources, methods and rationale of data collection

Literature

Compilation of existing literature and unpublished data on the food habits and trophic interactions of ice inhabiting seals is essentially complete. Much of the literature examined this year was from Soviet publications. Translations were done by personnel associated with or contracted by this project. Available information on the distribution, abundance and natural history of potentially important prey species has also been compiled through an OASIS literature search for information about food habits of seals, discussion and consultation with personnel from the University of Alaska Marine Museum Sorting Center, use of various translation services (Israel Program for Scientific Translations and Fisheries Research Board of Canada) for access to Russian literature, search of Alaska Department of Fish and Game reprint files, library and other literature collections, use of University of Alaska library facilities and inter-library loan services.

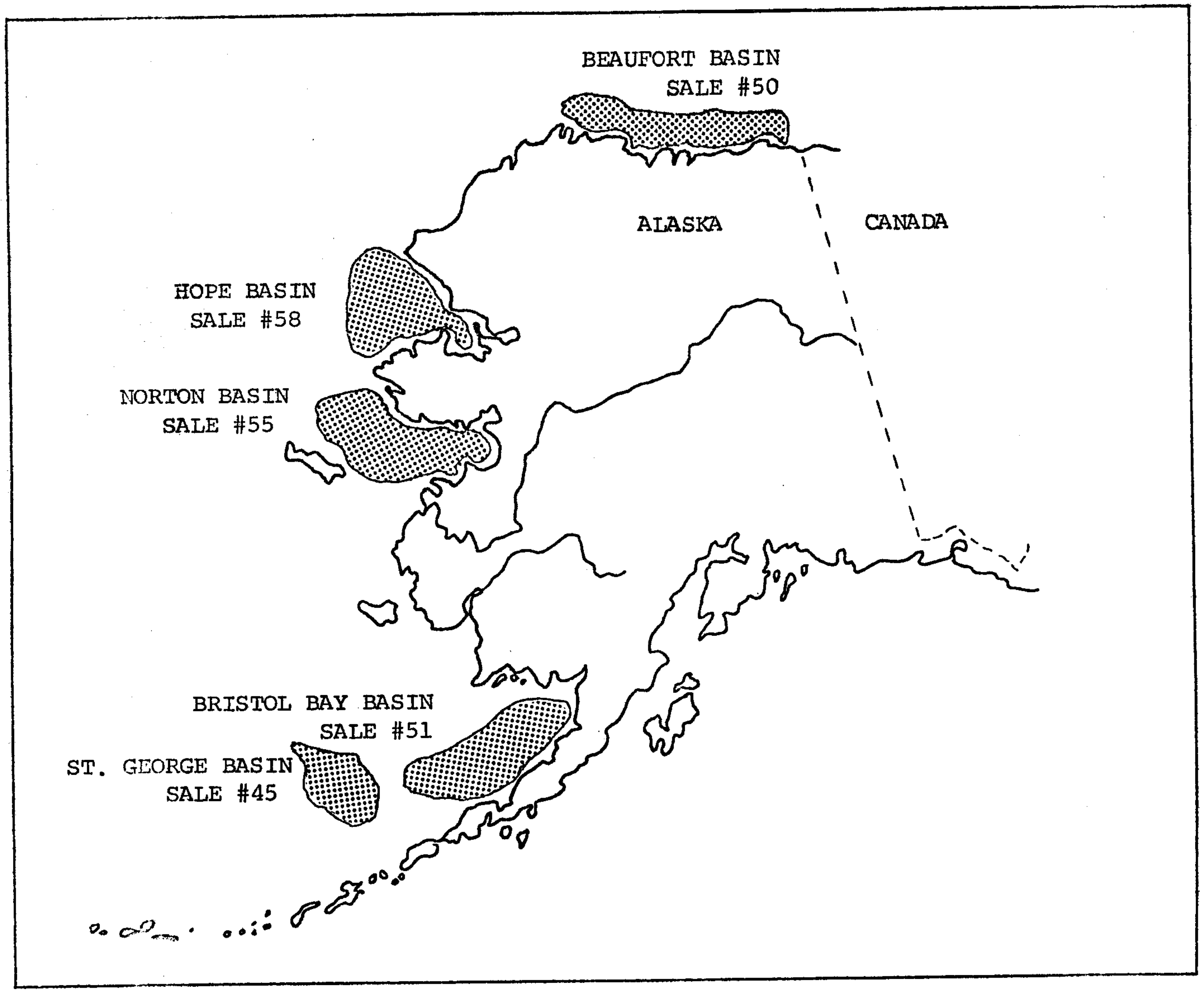

Figure 1. Map of Alaska showing proposed OCS lease sale areas which are included in the study area of this project.

Field collection of specimen material

Collectors were sent to coastal hunting villages on the Bering, Chukchi and Beaufort seas during predictably good hunting periods. Specimen material, including jaws and claws for age determination, reproductive tracts, and stomachs were purchased directly from hunters. Sampling was done by Lloyd Lowry, Kathy Frost, Glenn Seaman, Tom Eley, John Burns and other ADF&G employees. Some specimens from Point Barrow were provided by Harry Reynolds, ADF&G Area Biologist, who had access to intact seals purchased from local hunters by the Naval Arctic Research Lab, as food for the animal colony. Other specimens from Barrow were provided by Bob Everitt, National Marine Fisheries Service, and by Jack Lentfer, U. S. Fish and Wildlife Service.

Shipboard collections of seals were made by project personnel in areas inaccessible to coastal hunters. Collection in the Bering Sea ice front, where the ice was often impenetrable by small boats, was aided by a Bell 206 helicopter. Other shipboard collection efforts were conducted from small boats. Animals were shot either on the ice or in the water, taken to the ship and processed as described below.

Seals from which specimen material was taken were weighed, sex was obtained, and, whenever possible, a series of standard measurements were made for use in this and other ongoing studies on ice inhabiting seals. Tissue and blood samples were collected in some cases and made available to other investigators for heavy metal, hydrocarbon, PCB and pathogen analysis. (See methods section in RU #230, annual report, for detailed description of standard measurements and collection of additional specimen material.)

Only stomachs containing food were collected. Stomachs were tied at the cardiac and pyloric sphincters and severed from the remainder of the alimentary canal near these ties. They were then either injected with 10 percent formalin, labeled, and placed intact in plastic bags containing 10 percent formalin, or placed in bags and frozen. All stomachs were shipped to the ADF&G Fairbanks office. In addition, in some of the animals collected by project personnel, the contents of the small intestine were retained and examined for food remains. In cases where the stomach was empty this often provided some information on recent diet. Some of the stomachs not collected by us were opened in the field and the contents preserved or frozen.

In addition to collection of stomach specimen material, bottom sampling for fishes and invertebrates was conducted with a 19 foot Marinovich otter trawl (3/4 inch stretch mesh body, 1/4 inch mesh cod end liner). Trawls were of 10-20 minutes duration at a ship speed of 2-4 knots. Contents of each trawl were identified, enumerated and representative specimens of organisms retained. Fishes were measured and weighed and the otoliths removed and measured to determine the correlation of otolith size to fish size. Stomach contents of some fishes were examined. Examples of selected invertebrate species were measured and weighed to provide an index of length/weight ratios that could be applied to partially digested food items found in seal stomachs.

Laboratory procedures and identification

Laboratory analysis of stomach contents began October 15, 1975 and has continued intermittently to date. Procedures for processing the stomachs, determining volumes of stomach contents, rough sorting, fine sorting and identification of species have been developed and refined. Necessary taxonomic keys and references have been accumulated, a voucher specimen collection established, and personnel trained for sorting activities. Data sheets have been designed and modified to be compatible with NODC data formats.

Stomachs examined early in the project were trimmed of excess esophageal and small intestinal tissue and weighed full and intact. This process has been discontinued, as has the weighing of empty stomachs. Stomachs were then cut open and the contents transferred onto a standard 100 mm Tyler screen where they were thoroughly washed. Empty stomachs were reweighed, returned to 10 percent formalin and stored for future pathological examination. The volume of the total stomach contents of each seal was then determined by water displacement. Those contents that had been removed from the stomachs in the field were simply washed and a total volume determined as above.

The washed contents were either transferred to finger bowls and petri dishes for immediate rough sorting, or placed in jars and stored in 10 percent formalin until sorting could be done. If the latter took place, otoliths were first sorted out and stored separately in 70 percent ethyl alcohol to avoid degradation by the formalin. Rough sorting entailed separation of parasites from food items, and separation of food items into major taxonomic groups. Parasites were examined by other ADF&G personnel as part of natural history studies on ringed and bearded seals.

Fine sorting and identification consisted of further refinement of the initial sorting procedure. Sorted fractions were broken down to the lowest possible taxonomic levels permitted by the condition of the material. All sorting and identification required recognition of small bits and pieces of organisms. Seldom were intact organisms present. Shrimp, crabs and amphipods were frequently identified only by the presence of claws, carapaces, or abdomens. Clams were recognized by feet, gastropods by operculae, fish by individual bones or otoliths, etc. Individuals of a group or species were counted, size range was measured (mm) and the volume of the fraction determined by water displacement (ml). Some fractions were also weighed (g) to obtain volume to weight ratios for different groups or species.

Virtually all identifications were done by project personnel. Necessary taxonomic keys and references have been accumulated through library facilities, contact with personnel at the University of Alaska Marine Museum Sorting Center, and correspondence with people presently working in related fields. Much use was made of the Marine Museum Sorting Center reference collection and of the expertise of sorting center personnel. A reference and voucher specimen collection including bits and pieces of individuals from stomachs, as well as intact specimens from trawls, has been established at ADF&G for use in future identifications and in training of personnel.

In addition, an otolith reference collection has also been compiled. Otoliths were taken from fish recovered by otter trawls, as well as from existing ADF&G fish collections. Considerable interchange of specimen material and ideas occurred between personnel of this project and J. Morrow, RU #285.

Data

Design of formats to handle data and design of compatible data sheets to facilitate keypunching was completed. Data are keypunched, recorded on magnetic tape and submitted to NODC to meet data archiving requirements. To date, data have been manually compiled for all reports. There have been repeated efforts to initiate computer manipulation of data. At present a basic program to tabularize and analyze data is nearing completion. Further effort will be devoted to obtaining more sophisticated programming and computer analyses.

VI and VII. Results and Discussion

The search for background literature and unpublished data is nearly complete. Much information about the feeding of pinnipeds has been accumulated. However, little of this is pertinent to the species and areas presently being investigated. The most relevant articles are summarized under section III of this report. Most of the unpublished data on feeding of ice inhabiting phocids has been gathered by one of the Principal Investigators in this project (John J. Burns) and will be incorporated into this study as appropriate. As pointed out in section III, information on distribution, abundance and life history of potential prey items is not commonly available. Such information as is considered relevant will be included in the discussion.

As mentioned in section IV, our presentation and discussion of results will be broken down into several sub-areas. Detailed presentation of results has been presented in quarterly reports, the annual report for 1976 and the summary of fourth quarter activities accompanying this report. In the following presentation and discussion, we will deal with results in more general terms in order to elucidate patterns and to increase the potential use of our findings. All specimens collected since the beginning of this project are included.

Southeastern Bering Sea

A map of the southeastern Bering Sea area is shown in Fig. 2. Included in this region are the Bristol Bay, St. George and Navarin Basin lease sale areas. The southern edge of seasonal pack ice in the Bering Sea occurs in this region. In the late winter and spring, large numbers of spotted and ribbon seals are found along the ice edge. Bearded seals are found mainly farther north in the pack ice and ringed seals most numerous near the coast and in areas of shorefast ice. Ringed seals, bearded seals and spotted seals are taken by coastal hunters mostly during spring migration.

Table 1 gives a schedule of field activities conducted in the southeastern Bering Sea. Locations are shown in Fig. 2. Specimens obtained are shown in Table 2. Results of the analysis of stomach contents are given in Tables 3, 4, 5 and 6.

Table 1. Schedule of Field Activities: Southeastern Bering Sea

LOCATION/PLATFORM	DATES	PERSONNEL
Mekoryuk - village collection	22 May - 12 June 1975	ADF&G Personnel
OSS SURVEYOR cruise	14 March - 2 April 1976	L. Lowry, J. Burns, E. Muktoyuk
	12 April - 1 May 1976	L. Lowry, K. Frost

Spotted seals taken from the OSS SURVEYOR had all fed entirely on capelin (Mallotus villosus). No capelin were caught in several otter trawls taken in the vicinity of where spotted seals were collected. Apparently the capelin were not on or very near the bottom. Capelin must have been abundant in the area as they were the only food item found in the stomachs and the mean volume of contents was large. Four of the 11 spotted seals collected had empty stomachs.

Spotted seals taken during May at Mekoryuk fed primarily on fishes and lesser amounts of shrimps. Greenling (Hexagrammos sp.) were the species constituting most of the stomach contents. However, this resulted from one seal which contained several freshly eaten greenling in its stomach.

Five ribbon seals were collected from the SURVEYOR. All animals were collected while basking on the ice and the stomachs were essentially empty (mean volume of stomach contents 11 ml). An estimate of foods recently consumed was made by examination of otoliths from the stomach and small intestine. Pollock (Theragra chalcogramma) was by far the fish most commonly eaten, followed by eelpout (Lycodes sp.). Four otter trawls taken in the area indicated pollock to be the most abundant fish. Flatfishes, pricklebacks and sculpins were more common in the trawls than were eelpout. This indicates some selectivity by either the seals or the trawl.

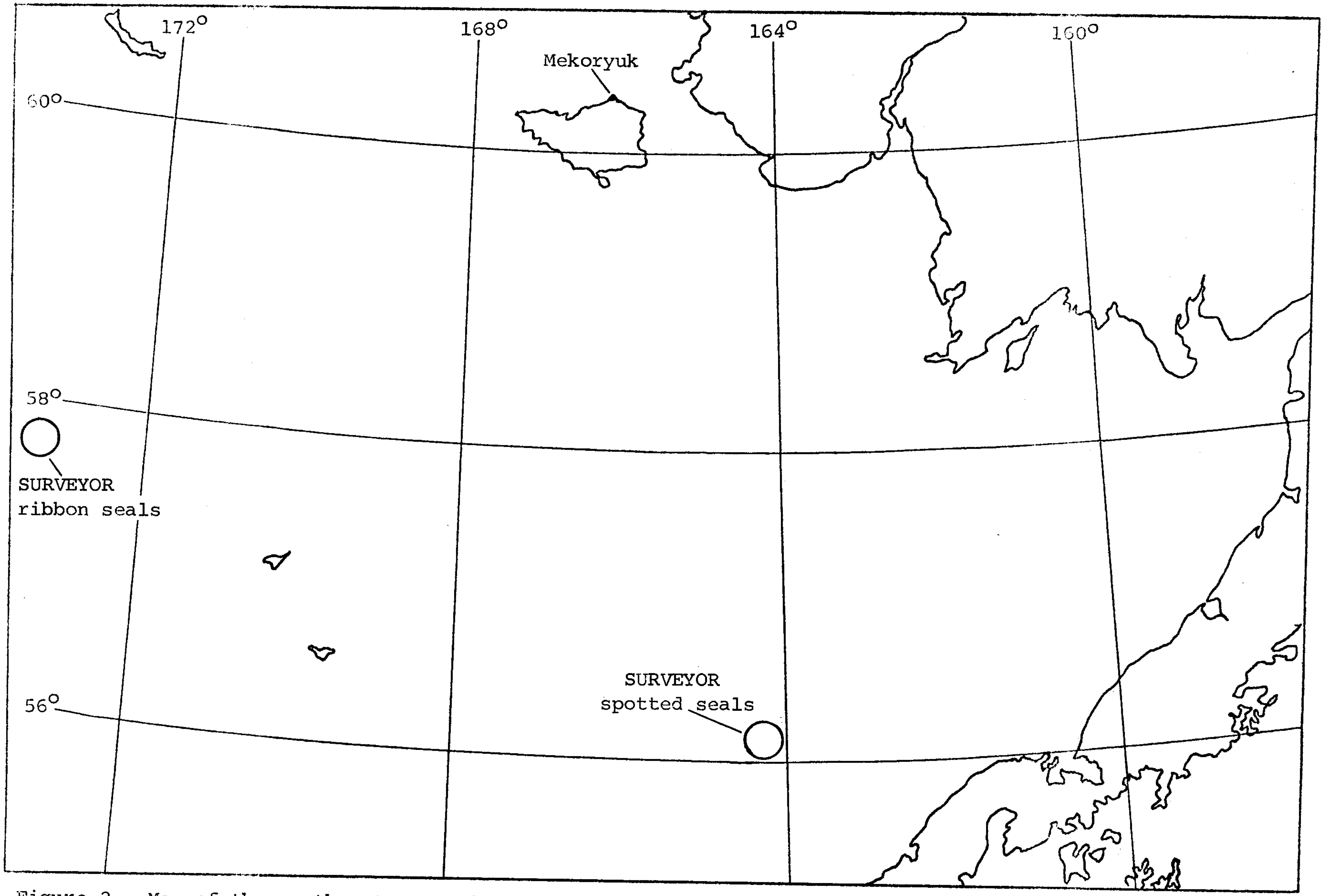

Figure 2. Map of the southeastern Bering Sea showing locations of specimen collections.

Table 2. Stomach specimens collected at various locations in the southeastern Bering Sea. (Only stomachs containing food and collected after 1 April 1975 are listed.)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RINGED SEALS Mekoryuk				1	4	1						
BEARDED SEALS Mekoryuk				12								
SPOTTED SEALS Mekoryuk					8							
SURVEYOR			7									
RIBBON SEALS SURVEYOR				5								

Table 3. Prey items of spotted seals taken at several localities in the southeastern Bering Sea. Major taxa (generally those accounting for mor than 5% of the total volume of contents) are listed in order of decreasing importance. For major taxa and individual species of invertebrates, numbers indicate mean percent of total volume made up of that taxon or species. For the individual species (or groups of species) of fishes, numbers indicate percent of the total number of identified fishes made up by that species. The number of specimens in the sample and the mean volume of stomach contents for that sample are also given.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
SURVEYOR	1) Fish 100 capelin 100 n = 7 506.3 ml			
Mekoryuk		1) Fish 86 greenling 62 2) Shrimps 14 *Crangon dalli* 10 n = 8 97.7 ml		

Table 4. Prey items of ribbon seals taken in the southeastern Bering Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
SURVEYOR		1) Fish 100 Pollock 89 Eelpout 9 n = 5 11.0 ml		

Table 5. Prey items of bearded seals taken at Mekoryuk. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Mekoryuk		1) Shrimp 39 *Sclerocrangon boreas* 23 2) Fish 19 Sculpins 82 Pollock 7 3) Crabs 18 *Hyas lyratus* 15 4) Isopods 10 *Saduria entomon* n = 12 137.9 ml		

Table 6. Prey items of ringed seals taken at Mekoryuk. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Mekoryuk		1) Fish 58 Pollock 65 Sculpins 32 2) Mysids 18 *Neomysis rayii* 18 3) Amphipods 14 *Parathemisto libellula* 13 n = 6 67.0 ml		

Twelve bearded seal stomachs containing food were collected at Mekoryuk. Shrimp (Sclerocrangon boreas) made up the majority of the stomach contents followed by fishes (sculpins and pollock), crabs and isopods.

Six ringed seal stomachs containing food were collected at Mekoryuk. Fishes (pollock and sculpins) were the most common prey item followed by mysids (Neomysis rayii) and pelagic amphipods (Parathemisto libellula).

Fishes and shrimps are consistently important food items of seals in the southeastern Bering Sea. Pollock are the most abundant fish in this area. This was the species most commonly eaten by ribbon seals west of the Pribilof Islands, and ringed seals at Mekoryuk. They are also presently the target of one of the largest single species fisheries in the northern hemisphere. Total harvest of pollock in 1974 was over 1.5 million metric tons. There are several indications that this harvest level is well above maximum sustainable yield (NMFS 1977). Benthic fishes (sculpins and eelpout) supplemented the diet of ribbon and ringed seals. Sculpins were the fish most commonly eaten by bearded seals. However, benthic invertebrates made up the bulk of the stomach contents in this species. Small zooplankters made up over 30 percent of the stomach contents of ringed seals in our sample. Greenling were the fish most commonly eaten by spotted seals at Mekoryuk. This group of fishes occurs mainly in nearshore, rocky areas and would likely be of importance to spotted seals only in certain areas. The importance of capelin in the diet of spotted seals collected from the SURVEYOR is very interesting and merits further attention. The area in which these seals were collected had a very large concentration of spotted seals, perhaps in response to a combination of abundant food and proper ice type. Capelin are widely distributed in northern waters. They spawn in the surf zone of sandy beaches during summer. Their distribution in the Bering Sea during the pre- and post-spawning periods is not well known.

Northern Bering Sea

A map of the northern Bering Sea is shown in Fig. 3. Included in this region is the Norton Basin lease sale area. Seasonal sea ice is present here from late fall until late spring, providing ringed and bearded seal wintering habitat. Ringed, bearded and spotted seals pass through this area on their spring and fall migrations. Spotted seals, and occasional ringed and bearded seals (primarily juvenile and subadult animals) summer in some areas in Norton Sound and around St. Lawrence Island. Residents of the villages of Gambell, Savoonga, Diomede, Nome and Stebbins actively engage in seal hunting. The peak of hunting activity occurs in the spring, with fall and winter hunting occurring sporadically at some localities.

Table 7 indicates the schedule of field activities conducted in the northern Bering Sea. Localities are shown in Fig. 3. Specimens obtained are listed in Table 8. Results of stomach contents analyses are given in Tables 9, 10 and 11.

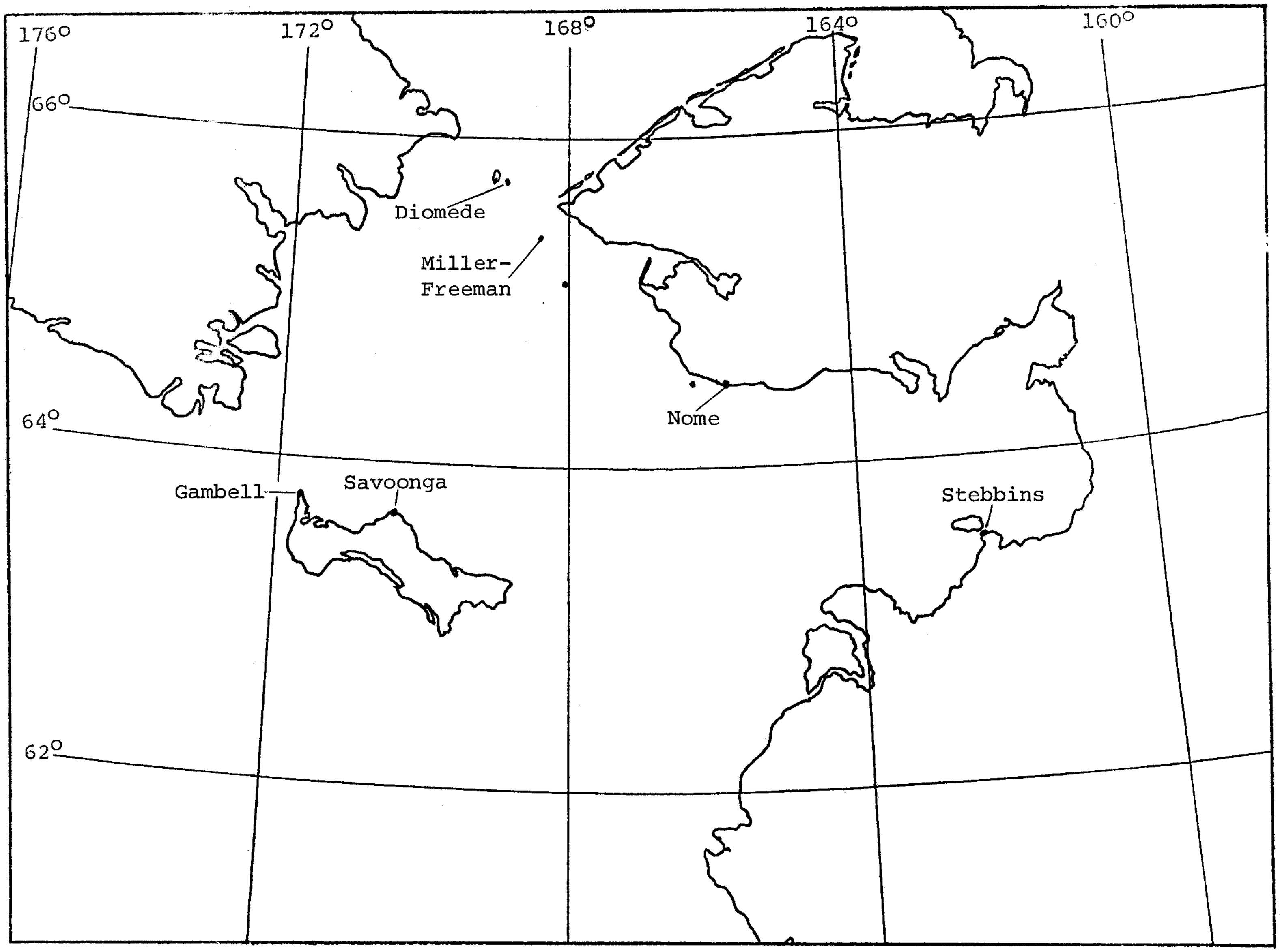

Figure 3. Map of the northern Bering Sea showing locations of specimen collections.

Table 7. Schedule of Field Activities: Northern Bering Sea

LOCATION/PLATFORM	DATES	PERSONNEL
USCGC GLACIER cruise	April 1971	J. Burns, E. Muktoyuk
Savoonga - village collection	intermittent since 1966	ADF&G Personnel
	7 May - 13 June 1975	ADF&G Personnel
	1 May - 30 June 1976	ADF&G Personnel
Gambell - village collection	intermittent since 1966	ADF&G Personnel
	7 May - 13 June 1975	ADF&G Personnel
	1 May - 30 June 1976	ADF&G Personnel
Diomede - village collection	intermittent since 1970	ADF&G Personnel
	28 May - 10 June 1975	ADF&G Personnel
	1 May - 30 June 1976	ADF&G Personnel
Nome - village collection	intermittent since 1969	ADF&G Personnel
	22 - 25 January 1976	T. Eley
	11 - 21 June 1976	L. Lowry, K. Frost, E. Muktoyuk
	18 - 24 November 1976	L. Lowry, K. Frost, E. Muktoyuk
	25 - 29 January 1977	L. Lowry, E. Muktoyuk
Stebbins - village collection	19 - 21 November 1976	K. Frost
OSS MILLER-FREEMAN cruise	27 Sept - 13 Oct 1976	K. Frost

Table 8. Stomach specimens collected at various locations in the northern Bering Sea. (Only stomachs containing food and collected after 1 April 1975 are listed.)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RINGED SEALS Nome	1					2*					5	
Stebbins											2	
Savoonga		2	2			1						
Gambell					2							
Diomede					10	3						
BEARDED SEALS Nome					1	5						
Savoonga					5	1						
Gambell					6							
Diomede					6	4						
MILLER- FREEMAN									1			

* May or June

Table 8 (cont) Stomach specimens collected at various locations in the northern Bering Sea. (Only stomachs containing food and collected after 1 April 1975 are listed.)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SPOTTED SEALS												
Nome											1	
Savoonga					5							

Table 9. Prey items of spotted seals taken at several localities in the northern Bering Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Savoonga		1) Shrimp 90 *Pandalus goniurus* 87 2) Euphausiids 5 3) Amphipods 5 n = 5 104.5 ml		
Nome				1) Fish 100 Sand lance 100 n = 1 867.0 ml

Table 10. Prey items of bearded seals taken at several localities in the northern Bering Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Savoonga		1) Shrimp 56 *Argis lar* 22 2) Fish 15 Sculpins 63 Pollock 25 3) Clams 13 *Serripes* sp. 13 n = 6 228.7 ml		
Gambell		1) Crabs 29 *Hyas coarctatus* 28 2) Shrimp 29 *Sclerocrangon boreas* 11 *Argis lar* 9 *Argis crassa* 7 3) Fish 19 Sculpins 100 4) Clams 5 *Serripes* sp. 5 n = 6 253.3 ml		
Diomede		1) Crabs 46 *Hyas coarctatus* 38 *Chionocetes opilio* 7 2) Fish 23 Sculpins 91 3) Clams 6 *Serripes* sp. 6 4) Shrimp 6 *Argis lar* 2 n = 10 522.1 ml		

Table 10. Prey items of bearded seals taken at several localities in the northern Bering Sea. Data are expressed in the same manner as in Table 3 (continued).

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
MILLER-FREEMAN			1) Fish 66 Sculpins 65 Sea snails 29 Polar cod 5 2) Shrimp 26 *Argis lar* 22 3) Crabs 5 *Chionocetes opilio* 5 n = 1 524.3 ml	
Nome		1) Clams 87 *Serripes* sp. 86 2) Shrimp 10 *Sclerocrangon boreas* 7 n = 6 795.9 ml		

Table 11. Prey items of ringed seals taken at several localities in the northern Bering Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUN	JUL - AUG - SEP	OCT - NOV - DEC
Savoonga	1) Mysids 79 *Mysis litoralis* 79 2) Amphipods 13 *Parathemisto libellula* 11 3) Shrimp 8 *Lebbeus polaris* 7 n = 4 71.8ml	1) Shrimp 100 *Sclerocrangon boreas* 100 n = 1 35.8 ml		
Gambell		1) Amphipods 66 *Anonyx nugax* 52 2) Shrimp 30 *Eualus fabricii* 8 *Argis crassa* 7 n = 2 37.4 ml		
Diomede		1) Amphipods 56 *Anonyx nugax* 32 *Gammarus wilkitzkii* 23 2) Fish 18 Polar cod 50 Sculpins 50 3) Shrimp 17 *Pandalus goniurus* 6 n = 13 53.6 ml		
Nome	1) Fish 100 Saffron cod 50 Polar cod 50 n =1 15.0ml	1) Shrimp 38 *Pandalus hypsinotus* 36 2) Fish 60 Sticklebacks 90 Saffron cod 7 n = 4 81.7 ml		1) Fish 93 Saffron cod 79 Polar cod 8 Boreal smelt 4 2) Shrimp 7 *Pandalus hypsinotus* 6 n = 2 178.2 ml

Table 11. Prey items of ringed seals taken at several localities in the northern Bering Sea. Data are expressed in the same manner as in Table 3 (continued).

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Stebbins				1) Fish 100 Saffron cod 92 Boreal smelt 6 n = 2 416.5 ml

Spotted seals collected during the spring at Savoonga fed predominantly on pandalid shrimps. Small amounts of euphausiids and amphipods were also eaten. A single spotted seal taken at Nome in November contained only sand lance (Ammodytes hexapterus).

Bearded seals were collected almost exclusively during the spring months, April through June. Animals during this time are moving north on their spring migration and ice and weather conditions are favorable for hunting.

At Savoonga bearded seals ate mainly crangonid shrimps, in addition to smaller amounts of fish (sculpins and pollock) and clams. Seals taken at the nearby village of Gambell ate equal amounts of spider crabs and crangonid shrimps, and smaller amounts of fish (all sculpins) and clams.

Bearded seals from the Diomede area ate mainly spider crabs, followed by fish (sculpins), clams, and crangonid shrimps. Kenyon (1962) reported similar results for 17 bearded seals collected during May and June 1958. Spider crabs and clams were the major food items in his collection. In addition, shrimps (pandalids and crangonids), some fishes (sculpins and saffron cod) and sponges were eaten. A single bearded seal collected during late September in open water southeast of Diomede had eaten primarily fish (sculpins, sea snails and polar cod), along with shrimp (Argis) and a few spider crabs.

Unlike bearded seals at the previous four locations, those from the Nome area were found to eat predominantly clams during the spring months. A small fraction of their diet was shrimp, mostly Sclerocrangon. The only other records of food habits of bearded seals in the Nome area are those of Burns (1967) in which he reports combined results for seals from Nome, Gambell and Wainwright. He found the diet in May to consist of spider crabs, shrimps and fishes. In July and August, clams were the predominant food, supplemented by shrimp, crabs, and fishes.

Ringed seal stomach specimens were obtained during all times of the year except July to September, when they are not normally resident in the northern Bering Sea area. Unfortunately, however, no one locality has sufficiently large samples throughout the year to allow definitive seasonal comparisons.

Five ringed seal stomachs from Savoonga have been examined, four of which were collected in late February and March. Crustaceans, primarily mysids but also some hyperiid amphipods and hippolytid shrimps, made up the entire diet of those seals. The single stomach collected in June contained only one prey species, the shrimp Sclerocrangon boreas.

Only two ringed seal stomachs from Gambell were analyzed. These seals were collected in May, and like the Savoonga seals had eaten only crustaceans, primarily amphipods and a lesser amount of shrimps.

The Diomede April to June collection of 13 stomachs was our largest single sample of ringed seals in the northern Bering Sea area. As was the case at Gambell, amphipods were the main prey item. Pandalid shrimps were present in substantial amounts as were fish (polar cod (Boreogadus saida) and sculpins). Kenyon (1962) found Pandalus to be the major food item of ringed seals collected at Diomede in the spring of 1958.

In the vicinity of Nome, at least one ringed seal was collected during each of the three "seasons" when ice and seals are present. A single seal collected during January had fed entirely on fishes (saffron and polar cods). Cursory inspection of four other stomachs collected this January but not yet analyzed revealed that those seals also had fed entirely on cods. Seals taken in April-June ate a mixture of fish (sticklebacks and saffron cod) and pandalid shrimps. The high percentage of fish is due to two stomachs containing large amounts of nine-spined sticklebacks, a primarily brackish water fish often found in estuaries and near river mouths. The stomachs of seals taken in November contained almost entirely saffron cod (Eleginus gracilus) and polar cod and smaller amounts of pandalid shrimps.

At Stebbins, on the south side of Norton Sound, two ringed seals were collected in November. Both stomachs contained only fish, mostly saffron cod and a few boreal smelt.

Too few stomachs have been examined from the different times of year to draw any firm conclusions on temporal variability in feeding of ringed seals in the northern Bering Sea area. Perhaps, however, a trend is indicated. At both Nome and Stebbins where November samples were available, cods, specifically saffron cod, were the most abundant food item. At Nome, in January, cods were the sole food item. Savoonga is the exception to this trend, but those seals were collected later in the season (late February and March). During the spring months, crustaceans comprise most of the food at all locations. Where fish appear, cods are only sparsely represented. It would appear that fish, specifically cods, comprise most of the diet during the winter months of heavy ice cover, and crustaceans replace fishes as the primary food during spring and summer. This agrees with the findings of Johnson et al. (1967) farther north in the Point Hope area. Trawl data are not available for winter months and therefore distribution and abundance of invertebrates at that time is unknown. It is known that at the time of freeze-up, large numbers of saffron cod are close to shore at both Nome and Stebbins, and that arctic and saffron cod are present in large spawning aggregations under the fast ice in winter (personal observations and discussions with local residents; Andriyashev 1954).

Pandalus goniurus is probably one of the most abundant far northern shrimps. Little is known about its distribution. However, it was taken throughout the northern Bering Sea in trawls conducted in August and September. It was most abundant northeast of St. Lawrence Island, though never the most abundant shrimp in the trawl. Nothing is known about seasonal movements or concentrations in near or offshore waters, or vertically in the water column. Pandalus is a protandric hermaphrodite. Males mature the first summer and change to mature females by the second summer. Females are reported to be ovigerous from November to April (Butler 1964). In our collections ovigerous females were found in August and October. This shrimp is probably an omnivore. In addition to being eaten by spotted seals, it is also an important food source for ringed seals and is eaten by belukhas, birds and fishes.

Argis lar is widely distributed throughout the Bering Sea. Trawls conducted in the St. Lawrence Island area and in Norton Sound indicate that it is probably the most abundant large shrimp in that area. Large numbers of ovigerous females were retrieved in almost every trawl made in the month of October. Sclerocrangon boreas, another large crangonid reported to be the most abundant large shrimp in the Alaskan arctic, appears to be less abundant farther south in the Bering Sea. It occurred sporadically and in low numbers in otter trawls conducted in this area. About a third of the Sclerocrangon collected were ovigerous females. This may, however, be a function of bottom types sampled (all non-rocky) or of patchy and localized abundance. Substantial numbers of these shrimps were eaten by bearded seals at Gambell and Nome and by ringed seals at Savoonga.

Shrimps of the genera Argis and Sclerocrangon are tolerant of relatively wide temperature ranges, $-1.6^{o}C$ to $6^{o}C$, and in northern waters are found in depths of at least 0-150 meters. Crangonid shrimps are omnivorous, eating phytobenthos, polychaetes, crustaceans and diatoms.

Spider crabs, both Hyas and Chionocetes, were common in trawls throughout the northern Bering Sea. Both species occurred at the same stations, sometimes in about equal numbers. In bearded seal stomachs Hyas appeared to be the most numerous. In Norton Sound in October, trawls recovered very few spider crabs. No bearded seals were collected in Norton Sound at this time of the year, but those stomachs collected in April - June contained no crabs. King crabs were present, and in some places abundant, in Norton Sound. Not a single king crab was found in any seal stomach. These crabs are probably too large and their carapaces too hard and spiny to be palatable.

According to trawl results obtained in the Norton Sound area, Serripes groenlandicus is probably the most abundant large, non-burrowing clam in the northeastern Bering Sea. Although otter trawls are not adequate to sample bivalves, they do pick up some surface dwelling forms and provide a relative index of abundance. Serripes were trawled in very low numbers throughout the area north and west of St. Lawrence Island. In northern Norton Sound, considerably larger numbers of clams were caught. This perhaps explains the greater importance of clams in the diet of bearded seals from the Nome area. Perhaps a further indication of the abundance of clams in Norton Sound is the distribution of sea stars. In Norton Sound, very large numbers of sea stars, many of which were feeding on clams, were taken at almost every trawl station. In the area northeast of St. Lawrence Island, substantially fewer sea stars were caught.

Sand lance are often found in large schools near the bottom in 100 to 120 meters of water. They sometimes bury themselves in the sand. In summer they appear to move inshore. Spawning occurs from November to February on sandy bottoms in 50 to 75 meters of water (Andriyashev 1954). Sand lance feed primarily on small crustaceans, including copepods, euphausiids, amphipods and barnacle larvae. They are occasionally eaten in quantity by ringed, bearded and spotted seals and are also an important food of birds and other fishes.

Polar cod and saffron cod were discussed briefly with regard to results of ringed seal stomach analyses. These two fishes, at different times of the year, are probably dominate ichthyofauna of arctic waters. They are eaten by other species of fishes, by many species of birds, by ringed, bearded and spotted seals, by harbor porpoises and belukhas (and perhaps other species of cetaceans), and by people inhabiting coastal areas. Little is known of the biology of either species in the northern Bering Sea area. According to Andriyashev (1954) large schools of polar cod form in the fall and approach the coasts and warm water areas of river mouths. During winter months polar cod associate with ice. Spawning occurs under the ice in January and February. Saffron cod also come to the coast in the fall in large schools. Spawning probably occurs in the winter in Norton Sound. Summer distribution and abundance of both species is unknown, but neither polar nor saffron cod were taken in trawls off Nome and St. Lawrence Island in August. In October large numbers of saffron cod and some polar cod were caught off Nome and in northern Norton Sound. Relatively low numbers of both species occurred in the area between Nome and St. Lawrence Island.

Sculpins of several genera are consumed by both ringed and bearded seals, primarily during spring and summer months. Judging from trawls made throughout the northern Bering Sea in summer and fall, sculpins are a common and fairly evenly distributed group of fishes. They never occurred in large numbers in any one trawl, nor were they ever completely absent. Myoxocephalus, Gymnocanthus, and Enophrys were the most common genera.

Chukchi Sea

The Hope Basin lease sale area occupies a large portion of the southern Chukchi Sea. Many ringed, bearded and spotted seals pass through the Chukchi Sea as they follow the seasonal advance and retreat of the ice. Spotted seals summer along the coast in certain areas. In the winter and spring, ringed seals are abundant in the area with a high density of breeding adults occurring on the shorefast ice. Bearded seals winter throughout the flaw zone and pack ice regions. Seal hunting occurs with regularity at the villages of Shishmaref, Point Hope and Wainwright, especially in the spring and early summer as days grow longer and warmer and the sea ice breaks up and moves north. Hunters at Shishmaref harvest the largest number of seals, primarily ringed seals with fewer bearded seals and very few spotted seals.

Table 12 presents the schedule of field activities conducted in the Chukchi Sea. Localities are shown in Fig. 4. Specimens obtained are enumerated in Table 13 and the results of stomach contents analyses are presented in Tables 14, 15, 16 and 17.

Table 12. Schedule of Field Activities: Chukchi Sea

LOCATION/PLATFORM	DATES	PERSONNEL
R/V ALPHA HELIX cruise	September 1973	J. Burns, E. Muktoyuk
Shishmaref - village collection	22 June - 1 July 1976	G. Seaman
Point Hope - village collection	19 Apr. - 1 June 1976	G. Seaman
Cape Lisburne - helicopter collection of polar bear kills	10 Mar. - 20 Apr. 1976	T. Eley
Wainwright - village collection	24 July - 11 Aug. 1975	J. Burns, G. Seaman
	22 July - 1 Aug. 1976	J. Burns
OSS DISCOVERER cruise	17 Aug. - 3 Sept. 1976	K. Frost, D. James

Only a few spotted seal stomachs were examined, three from Shishmaref and two from Wainwright. All were collected during July and August. Spotted seals at Shishmaref ate almost entirely crangonid shrimps. Fishes, arctic flounder (Liopsetta glacialis) and saffron cod, made up the remainder. Spotted seals at Wainwright ate no shrimp and neither of the above mentioned species of fish. They fed entirely on sculpins.

Bearded seals were collected at the same two villages and during the same months as spotted seals, however the collections were much larger. At Shishmaref the primary food source was crangonid shrimps as was the case for spotted seals. Crabs and clams were eaten in lesser amounts. In Wainwright, clams were the most abundant food item. Shrimp and fishes (mostly sculpins with some sand lance and polar cod) were also eaten.

The only other data available for the foods of bearded seals in the Chukchi Sea are those of Johnson et al. (1966) from Point Hope and the combined data for Nome, Gambell and Wainwright of Burns (1967). Few seals were taken in the months of November to May at Point Hope. A large collection was obtained in June. In all months decapod crustaceans, shrimps and crabs were the major

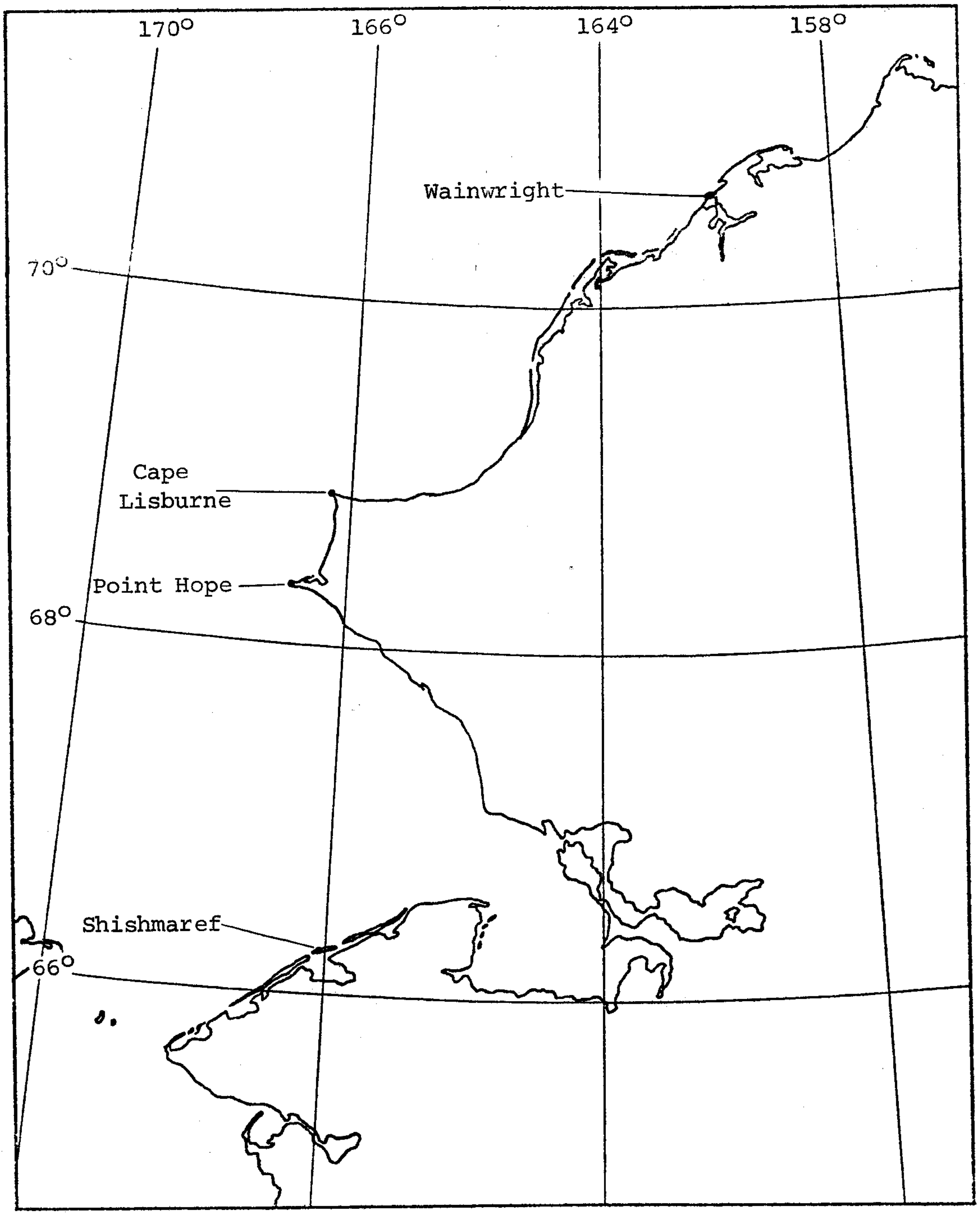

Figure 4. Map of the Chukchi Sea showing locations of specimen collections.

Table 13. Stomach specimens collected at various locations in the Chukchi Sea. (Only stomachs containing food and collected after 1 April 1975 are listed.)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RINGED SEALS												
Shishmaref						21	84					
Point Hope			1	12	20							
Cape Lisburne (Bear Kills)			2	1								
Wainwright							11	9				
BEARDED SEALS												
Shishmaref							40					
Wainwright							14	15				
SPOTTED SEALS												
Shishmaref							3					
Wainwright							1	1				

Table 14. Prey items of spotted seals taken at several localities in the Chukchi Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Shishmaref			1) Shrimp 86 *Crangon* *septemspinosa*86 2) Fish 13 Arctic flounder62 Saffron cod 38 n = 3 402.9 ml	
Wainwright			1) Fish 97 Sculpins 100 n = 2 91.2 ml	

Table 15. Prey items of bearded seals taken at several localities in the Chukchi Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUN	JUL - AUG - SEP	OCT - NOV - DEC
Shishmaref			1) Shrimp 51	
			Crangon septemspinosa 33	
			Argis lar 17	
			2) Crabs 19	
			Telmessus cheiragonus 16	
			3) Clams 16	
			Serripes sp. 10	
			Clinocardium sp. 6	
			n = 40 415.2 ml	
Wainwright			1) Clams 58	
			Serripes sp. 42	
			Clinocardium sp. 15	
			2) Shrimp 19	
			Sclerocrangon boreas 14	
			3) Fish 7	
			Sculpins 66	
			Sand lance 22	
			Polar cod 12	
			n = 29 607.7 ml	

Table 16. Comparison of food items identified from bearded seals taken at Wainwright in July and August 1975 and July 1976. Data are expressed in part A as the percent of the total volume of contents comprised by each species or group and frequency of occurrence.[1] Part B indicates the species composition of fishes expressed as the percentage of the total number of fishes identified and the frequency of occurrence.

		Wainwright 1975 n=22		Wainwright 1976 n=7	
		% Volume/#	% Frequency	% Volume/#	% Frequency
A.	Isopods Total	3.1	45	1.9	29
	Saduria entomon	2.6	32	1.9	29
	Other isopods	*	9		
	Brachyuran Crabs Total	4.2	82	4.9	57
	Hyas coarctatus	4.2	82	4.9	57
	Shrimps Total	15.9	95	25.0	86
	Sclerocrangon boreas	9.5	86	23.4	86
	Argis lar	1.1	11	1.0	43
	Other shrimps	5.3	77	*	29
	Gastropods Total	3.8	55	*	29
	Gastropod eggs	2.1	9		
	Other gastropods	1.7	23	*	29
	Bivalves Total	54.3	68	65.5	86
	Serripes sp.	37.5	64	49.6	86
	Clinocardium sp.	15.2	32	15.8	43
	Other bivalves	1.5	23	*	14
	Other Invertebrates	6.8	64	1.3	43
	Invertebrates Total	88.1	100	98.6	100
	Fishes Total	10.4	73	1.0	100
B.	*Boreogadus saida*			14.2	29
	Family Gadidae	3.7	5		
	Myoxocephalus sp.	59.2	9	3.7	14
	Gymocanthus sp.	14.8	13		
	Megalocottus platycephalus	3.7	5		
	Dasycottus setiger	3.7	5		
	Family Cottidae	14.8	5	56.0	86
	Ammodytes hexapterus			26.1	14
Total Number of Fishes Identified		27		134	
Mean Volume of Contents		531.1		848.3	

[1] Frequency of occurrence = $\frac{\text{number of times taxon found}}{\text{number of stomachs examined}} \text{ X } 100$

* Indicates food items which constituted less than 1 percent of the total volume

Table 17. Prey items of ringed seals taken at several localities in the Chukchi Sea. Data are expressed in the same manner as in Table 3.

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT	OCT - NOV - DEC
Shishmaref			1)*Shrimp 47 *Crangon septemspinosa* 41 2) Fish 42 Saffron cod 92 Arctic flounder 4 n = 105 97.5 ml	
Point Hope		** 1) Fish 56 Saffron cod 63 Polar cod 22 Sculpins 8 2) Amphipods 20 *Ampelisca* spp. 20 3) Shrimp 13 *Argis lar* 5 n = 33 57.7 ml		
Cape Lisburne	*** 1) Shrimp 48 *Pandalus goniurus* 14 *Argis lar* 11 *Sclerocrangon boreas* 7 2) Fish 31 Polar cod 96 3) Amphipods 20 *Anonyx nugax* 16 n = 3 36.7 ml			

Table 17. Continued

LOCATION	JAN - FEB - MAR	APR - MAY - JUNE	JULY - AUG - SEPT		OCT - NOV - DEC
Wainwright			1) Shrimp	45	
			Eualus gaimardii	24	
			Sclerocrangon boreas	11	
			2) Fish	25	
			Sculpins	43	
			Cod	43	
			3) Amphipods	10	
			Gammarus wilkitzkii	4	
			4) Isopods	5	
			Saduria entomon	5	
			n = 20	23.6 ml	

* Includes some specimens from late June.

** Includes one specimen from March.

*** Includes one specimen from April 1.

food. Only in June was another invertebrate group important in the diet, that being clams. From observations at various places, it appears that clams may be an important food item only in summer months (Burns 1967, personal observations). Additional winter samples are needed to further clarify this matter. Only in February were appreciable numbers of fishes (polar cod) eaten by bearded seals at Point Hope. Sand lance, pricklebacks and sculpins were occasional food items.

The sample size for our collection of bearded seals at Shishmaref was sufficiently large to permit some comparisons within the sample. Males and females were compared as were pups, yearlings and seals older than one year. No substantial differences in prey items were apparent between males and females. Males ate a slightly larger proportion of fish and had a slightly smaller volume of contents. Among age classes there were apparently some feeding differences. Pups ate almost entirely shrimps, while yearlings and older animals ate large amounts of clams and crabs in addition to shrimps. These differences were presented and discussed in more detail in the 31 December 1976 Quarterly Report of RU #232.

Bearded seals were collected at Wainwright during two successive summers, which enables a preliminary examination of year to year variation in diet (Table 16). No major differences were apparent in food types between the two summer's collections. Seals collected in 1975 had eaten about 10 percent more fish and as a result proportionately less crabs and clams. The sample size for 1976 was relatively small. One would expect bearded seals to evidence little year to year dietary variation as they eat sedentary benthos, epibenthic crustaceans and demersal fishes. Spotted, ringed and ribbon seals, on the other hand, eat many pelagic schooling species which may show less regularity in availability.

Food habits of ringed seals from four locations in the Chukchi coast were examined. No area was sampled at more than one time of year and no samples were obtained during winter months. In all cases except one, Point Hope, shrimps were the major food item followed by fishes, primarily cods. A large sample of ringed seals was collected at Shishmaref during July. As was the case with both spotted and bearded seals at Shishmaref, crangonid shrimps were the predominant food. Saffron cod made up almost the entire remainder of the contents with a few small arctic flounder also present.

At Point Hope, during April, May and June ringed seals ate primarily saffron and polar cod and lesser amounts of amphipods and shrimps. These results may be compared with those of Johnson et al. (1966) in which fish in general and cods in particular made up considerably less of the total food volume for those months. Amphipods, shrimps and mysids were instead the most abundant foods. However, a single stomach with a large volume of polar cod was responsible for the high percentage of fish in our sample. If that stomach were not included in the sample, our results would agree very closely with those of Johnson et al. (1966) for the months of April, May and June. They found a marked seasonal change in primary food. In over 700 stomachs examined from November to February, fishes (almost entirely polar cod) were by far the most important food.

Only three stomachs containing food were collected near Cape Lisburne. They were from the remains of seals killed by polar bears in late March and early April. Crustaceans (shrimps and amphipods) were eaten in the greatest quantity, followed by polar cod. These data fit the pattern suggested by data from the Point Hope area in which a change to primarily invertebrate foods occurs in March and April.

The remaining collection of seals from Wainwright also fits the above pattern. Shrimp and amphipods were the primary food. Fish (polar cod and sculpins) were eaten in smaller amounts.

Sex and age related comparisons of feeding habits were made on the sample of ringed seals from Shishmaref. The diets of male and female seals were generally similar. Shrimp and flatfishes were slightly more abundant in males and saffron cod were more abundant in females. If the diet of pups is compared to that of older seals of each sex, it appears that pups feed more like older females than like older males. They ate considerably more fish (essentially all saffron cod) than did older seals. These differences were presented and discussed in more detail in the 31 December 1976 Quarterly Report of RU #232.

Shrimps were important to all three kinds of seals in all areas. Species of the family Crangonidae, Argis lar, Sclerocrangon boreas, and Crangon septemspinosa, were the most widely utilized; they figured heavily in the diets of ringed, bearded and spotted seals. Two other families represented by Pandalus goniurus and Eualus gaimardii were important to ringed seals. Whereas some information is available on the distribution and abundance of these shrimps in the northern Bering Sea, very little if any exists for the Chukchi Sea.

Rathbun (1904) states that Crangon septemspinosa is found along the Alaskan coast from the Shumagin Islands to Eschscholtz Bay in Kotzebue Sound. All collection sites noted by Rathbun are in shallow water, most less than 15 meters deep. Squires (1965) notes that in the Canadian arctic this species is commonly found in shallow sandy areas where eelgrass is present. These shrimps probably move away from shore in winter. In June and July 1976 this was apparently the most common shrimp in the Shishmaref area. However, trawls taken about 25 kilometers off Shishmaref, in approximately 15 meters of water, in August, produced no individuals of this species.

As in the northern Bering Sea, Argis and Sclerocrangon are common species. Both are distributed throughout the Bering, Chukchi and Beaufort Seas (Rathbun 1919, Squires 1967). However, information on abundance is sparse. Several trawls conducted by us off Shishmaref and Point Hope in August brought up small numbers of both species.

The most numerous shrimp in those trawls were juvenile *Pandalus goniurus*. *Pandalus* constituted a major portion of ringed seal stomach contents only at Cape Lisburne. It is also eaten by birds and fishes in the Chukchi Sea. Sparks and Pereyra (1966) and Alverson and Wilimovsky (1966) conducted trawls from the Bering Straits to north of Cape Lisburne. They reported crangonids, pandalids and hippolytids all as present in almost all trawls, but never in large amounts.

Low numbers of fishes were recovered by us in trawls in the Chukchi Sea. Alverson and Wilimovsky (1966) also report low catches for the same area at the same time of year. We found pricklebacks, sculpins and polar cod to be the most abundant fishes. In Alverson and Wilimovsky's list of the 10 dominant marine fishes, polar cod, pricklebacks and 4 species of sculpins appear. Polar cod was the most abundant fish in the entire survey, whereas saffron cod was much less common. We recovered no saffron cod in any of our trawls off the southeast Chukchi coast. This was probably a function of distance offshore as saffron cod are known to congregate close to shore in warm waters during late summer and early fall.

Beaufort Sea

See attached Final Report of Beaufort Sea Activities.

VIII. Conclusions

Feeding habits of seals

To date we have examined the stomach contents of 218 ringed seals, 110 bearded seals, 26 spotted seals and 5 ribbon seals. These seals have been collected from a number of locations in the Bering, Chukchi and Beaufort Seas, largely during spring and summer months. The majority of specimens have come from a few coastal villages where the residents actively hunt seals. Our coverage of the area is therefore geographically and temporally rather spotty. However, within the limits of our collections, we can generally describe feeding habits of the seal species we are studying and identify some key prey items.

Ribbon seals are commonly found in the Bering Sea and Sea of Okhotsk in late winter and spring. Squids and pollock are the main foods in the Sea of Okhotsk. Pollock, shrimps, eelpout and squids are all important in the diet in the Bering Sea. Feeding habits in the late summer through winter period are totally unknown.

Spotted seals in the Bering Sea eat mostly pollock, capelin, arctic and saffron cod, sand lance and shrimps. Very few stomachs of spotted seals taken in the Chukchi Sea have been examined. Shrimps and several kinds of fishes were important foods. All samples were taken in the spring and summer months.

Ringed seals in the Bering Sea feed mostly on fishes (saffron and polar cod, pollock, and sculpins) in the fall and winter and crustaceans (shrimps, amphipods and mysids) in the spring. Although few data from the fall-winter period are available, the same pattern appears to hold true for the Chukchi Sea. In the Beaufort Sea in summer, euphausiids are by far the most important food. Polar cod and shrimps may be important in the diet in the winter and spring.

At most areas sampled in the Bering and Chukchi Seas, bearded seals ate mostly spider crabs, shrimps and benthic fishes. At two localities, Nome and Wainwright, bivalve molluscs were very important in the diet. Only two stomachs of bearded seals taken in the Beaufort Sea were examined. These animals had eaten a wide variety of invertebrates and fishes.

We have examined age and sex related feeding differences in bearded and ringed seals taken at Shishmaref. Some quantitative differences in feeding were noted. However, it would be desirable to repeat the sampling at this locality to increase the sample size, and to treat the data statistically. Year to year differences in feeding of bearded seals were examined in the 1975 and 1976 samples from Wainwright. Only very slight differences were noted.

Table 18 gives a listing of key prey species of seals in the various areas. The species indicated are definitely important food items. However, further studies could determine other species to be more important.

Potential effects of petroleum development

The potential effects of petroleum development on seal populations are multiple. This project is primarily concerned with effects which might be mediated through the trophic structure of the areas under consideration. The following general considerations are involved:

1. Incorporation and potential accumulation of petrochemicals in food webs and the direct effects of ingestion of the compounds by seals.

2. Effects of petrochemicals on the availability and suitability of various food items in light of observed importance in the diet.

3. Resultant effects of 1 and 2 above on the physiological conditions of animals and their ability to respond to normal and abnormal environmental stresses.

Pertinent results of some recent hydrocarbon studies are mentioned below. Other studies are mentioned in the September Quarterly Report of RU#232.

Table 18. Important prey species of ribbon, spotted, ringed and bearded seals in the Bering, Chukchi and Beaufort Seas.

	Southeastern Bering Sea	Northern Bering Sea	Chukchi Sea	Beaufort Sea
Ribbon Seals	*Pandalus borealis* *Theragra chalcogramma* *Lycodes* spp.	*Theragra chalcogramma* *Boreogadus saida*		
Spotted Seals	*Mallotus villosus* *Theragra chalcogramma* *Pandalus* spp.	*Eleginus gracilus* *Boreogadus saida* F. Cottidae *Pandalus goniurus*	*Crangon septemspinosa* *Eleginus gracilus* *Gymnocanthus tricuspis*	
Ringed Seals	*Theragra chalcogramma* *sample is too limited to determine important invertebrate prey species.	*Pandalus goniurus* *Anonyx nugax* *Eleginus gracilus* *Boreogadus saida*	*Crangon septemspinosa* *Argis lar* *Ampelisca* sp. *Eleginus gracilus* *Boreogadus saida*	*Thysanoessa raschii* *Thysanoessa inermis* *Eualus gaimardii* *Saduria entomon* *Boreogadus saida*
Bearded Seals	*Chionoecetes* spp. *Theragra chalcogramma* *Myoxocephalus* sp.	*Argis lar* *Hyas coarctatus* *Chionocetes opilio* *Serripes groenlandicus* *Myoxocephalus scorpius*	*Argis lar* *Crangon septemspinosa* *Sclerocrangon boreas* *Telmessus cheiragonus* *Serripes groenlandicus* *Clinocardium ciliatum* *Myoxocephalus* sp.	*Sclerocrangon boreas* *Saduria entomon* *Boreogadus saida* *Eleginus gracilus* *Myoxocephalus quadricornis*

Cods are an important part of the trophic structure of all study areas. Pollock are eaten by all species of seals in the southern Bering Sea. They are also consumed by sea lions, numerous species of birds and other fishes. They are the main target of a very large commercial fishery that exists in this area. Saffron cod and polar cod are seasonally important to spotted, ringed and bearded seals throughout the northern Bering, Chukchi and Beaufort Seas. The effects of hydrocarbon pollution on these three species is largely unknown. However, acute toxicity tests using water soluble fractions of Cook Inlet oil have been done on saffron cod from Norton Sound (DeVries 1976). He found that at lower temperatures (3°C) the water soluble fractions have much less effect than at higher temperatures (8°C). Concentrations of 1.83 ppm parafins at 3°C and 2.48 ppm at 8°C produced 50 percent mortality within 24 hours. Kuhnhold (1970), working with another cod species, Gadus morhua, found water extracts of crude oils to be highly toxic to eggs tested 5-30 hours after fertilization. Mortality was lower in older eggs, but many of the hatched larvae were abnormal and died within a few days. Mirinov (1967) also working on cod found that crude oil killed all eggs within two days at 100 ppm and within three days at 10 ppm. Herring, also a prey species of spotted and ringed seals, and plaice larvae were exposed to similar concentrations. Herring larvae appeared more sensitive and plaice less so at similar stages of development. In later experiments, Mirinov (1970) reported death of fish eggs at 10^{-3} and 10^{-4} ml/l, and survival reduced by 11-45 percent at 10^{-4} and 10^{-5} ml/l. Surviving eggs showed delayed hatching with many of the larvae inactive and abnormal. Once again, larvae appeared more resistant than eggs.

In light of the preceding information, potential exists for impact on the three cod species important to ice inhabiting seals. Pollock and polar cod both have pelagic eggs often found in the top few centimeters of the water column where contact with oil is most likely to occur. Eggs of saffron cod are demersal but are often deposited on sandy bottoms that are influenced by tides and surf (Andriyashev 1954). Such areas can be expected to be contaminated by oil.

Sculpins of several genera (Myoxocephalus, Gymnocanthus, Enophrys) are important food species to bearded and spotted seals and are also eaten by ringed seals. Virtually nothing is known of their sensitivity to petrochemicals. However, Percy and Mullin (1975) found fry of Myoxocephalus quadricornis, an important prey species in the Beaufort Sea, to be the most sensitive organism they tested. All fry died after 24 hours in a heavy dispersal of oil.

Spider crabs, Chionoecetes and Hyas, are major food items of bearded seals in all areas except the Beaufort Sea. Their susceptibility to petrochemicals is suggested by the work of Karinen and Rice (1974) and Parker and Menzel (1974). Karinen and Rice found that oil emulsions at 1 ml/l and less caused autonomizing of limbs in newly molted animals. They also found delay of molt with lower rates of molt success. Parker and Menzel working on crab larvae (hermit, spider and stone) found them sensitive to No. 2 fuel oil. High concentrations retarded growth and inhibited molting at concentrations of 0.5 ppm in hermit and spider crab larvae. Smith (1976) found that exposure to Gulf of Alaska crude oil caused alteration of gill ultrastructure in Alaska king crabs. Mirinov (1970) states that crabs which have highly resistant adult forms often have sensitive larvae.

Work on hydrocarbon sensitivity of crangonid shrimps, important seal foods in all areas, is entirely lacking. DeVries (1976) has begun to look at Eualus, a hippolytid genus important especially in far northern waters. Preliminary results indicate that water soluble fractions with high aromatic content are more toxic than those with lower aromatic content. Temperature does not seem to affect toxicity. Mecklenberg and Rice (1976) report that Pandalus hypsinotus was sensitive to Cook Inlet crude oil at 4-1000 ppm. These shrimp, in the second stage of molt, were the most sensitive. Concentrations of 4-8 ppm for over six hours caused death. According to Malins and Hodgins (1976) Pandalus platyceros demonstrates inhibited feeding and search response at high concentrations of water soluble fractions. Effects were less pronounced at low concentrations.

Percy and Mullin (1975) found the arctic amphipod Onisimus affinus was the most sensitive to oil of all invertebrates tested. They were killed by high concentrations (30-140ppm) in water, and also by oil in the sediment. Oil tainted food and sediment were avoided. Anonyx nugax and Ampelisca sp., also benthic arctic forms, are important food items in the northern Bering and Chukchi Seas. They, too, may be affected in the same manner.

Bivalve molluscs are major food items of bearded seals at a number of locations. In addition they are the major food of the Pacific walrus and an important food of Alaska king crabs and some fish. Scarratt and Zitko (1972) reported that scallops and clams (Mya) assimilate hydrocarbons. Renzoni (1975) found that water soluble fractions of crude oil cause reduction in gamete fertilization at 1 ml/1 Decreased survival of eggs, sperm and larvae, and abnormal embryos were caused in Mulinea and Crossostrea. Dow (1975) reported 20 percent reduction in clam populations and reduced growth on oil contaminated mudflats. Mirinov (1970) reported that molluscs in the Black Sea were sensitive to oil and oil products.

IX. Needs for further study

In general, in order to increase our ability to describe the main food items of seals in the various lease areas, the temporal extent of our samples must be increased. Coastal villages have provided us with much material for the summer months. However, seal hunting at other times of the year is so reduced as to make collections in villages either not productive or very expensive on a per specimen basis. We are attempting to improve our collection of winter-spring samples this year by land-based helicopter collections.

In addition few specimens have been collected in some areas (e.g. Bristol Bay, St. George Basin and Beaufort Sea) because of the near or complete absence of Native hunting. In these areas we must collect animals ourselves and are dependent on proper logistics (ice strengthened vessels with helicopters and small boats). Specimens collected in this manner are more difficult and expensive to obtain. However, each specimen can yield considerably more data as exact conditions (e.g. time of day and availability of food as indicated by otter trawls) at the collection site are known. To date, due to the nature and availability of vessels and the scheduling of multi-project cruises we have obtained only a very few specimens from these areas in the spring and summer months. Availability of proper logistics, such as an icebreaker in the Bering Sea in winter, would increase our information base considerably.

In order to predict, in a reasonable manner, the potential trophic effects of OCS development on ice inhabiting seals, a considerable amount of information must be available concerning other biological components of the system. Detailed information must be gathered on distribution, abundance, life history and hydrocarbon sensitivity of important prey species (Table 18). Food habits of potential competitors (sea birds, sea lions, dolphins, whales, walruses and people) must be known. Sources of energy and energy flow through lower trophic levels should be delineated and quantified.

Finally the quantities of contaminants expected to enter the system must be predicted and their composition, distribution and persistance estimated.

X. Summary of 4th quarter operations

A. Ship or Laboratory Activities

1. Ship or field trip schedule

A schedule of field and laboratory activities conducted during the fourth quarter is given in Table 19. As was expected, field operations were quite limited due to the very reduced seal hunting activity in coastal villages. Five ringed seal stomachs containing food were obtained, four from Nome and one from Barrow. Specimens collected during the previous quarter at Nome and Stebbins were examined and the data compiled. The results of these analyses and analysis of material collected at Diomede and on the OSS MILLER-FREEMAN during the previous quarters will be reported below.

All principal investigators involved with this project participated in the Beaufort/Chukchi Sea synthesis meetings in Barrow. A disciplinary session was chaired by L. Lowry and an interdisciplinary session by J. Burns.

Intensive field collection efforts involving a helicopter operating in the northern Bering and Chukchi Seas and the OSS SURVEYOR operating in the Bering Sea ice front commenced in March and will continue through April.

2. Scientific party

See Table 19.

3. Methods

Methods of field sampling and laboratory analysis were as described in section V of this annual report.

4. Sample localities

Sample localities are shown in Figure 5.

5. Data collected or analyzed

Results of our analysis of 8 ringed seal stomachs and 12 bearded seal stomachs are given in Tables 20 and 21.

The single ringed seal stomach we examined, taken from Diomede during May, contained almost entirely polar cod. Five ringed seals collected at Nome in November had eaten primarily saffron cod and lesser amounts of other fishes and shrimps. Two ringed seals collected at Stebbins in November had eaten entirely fishes, again mostly saffron cod.

A single bearded seal collected from the OSS MILLER-FREEMAN had eaten mostly fishes (sculpins and sea snails) and shrimps. Four bearded seals collected at Diomede in May and June had eaten mostly crabs and lesser amounts of shrimps and fishes. Seven bearded seals collected at Wainwright in July had eaten primarily bivalve molluscs and shrimps.

The stomach of a spotted seal collected at Nome in November was also analyzed. This animal had eaten 224 sand lance, 2 saffron cod and 1 sculpin.

Results presented above and in Tables 20 and 21 have been included in the presentation and discussion of results in sections VI, VII and VIII of this report.

6. Milestone charts and data submission schedules

Milestone charts are given on the following pages. The chart of specimen collection milestones has been revised to more accurately reflect anticipated activities. Several previously planned activities have been canceled due to impracticality, lack of logistic platforms and lack of available personnel. Helicopter-based collections in Norton Sound and the Chukchi Sea have been added to the schedule.

Table 19. Schedule of Field and Laboratory Activities during the Fourth Quarter.

ACTIVITY	DATES	PERSONNEL
Specimen collection - Nome	25 - 29 Jan 1977	L. Lowry, E. Muktoyuk
Specimen collection - Barrow	11 - 16 Feb 1977	T. Eley
Specimen collection - Norton Sound	commenced 5 Mar 1977	J. Burns, T. Eley, E. Muktoyuk
Specimen collection - OSS SURVEYOR	commenced 15 Mar 1977	K. Frost, L. Lowry
Analysis of specimen material	intermittent	L. Lowry, K. Frost, G. Seaman
Attend Beaufort Sea Synthesis Meeting	7 - 11 Feb 1977	L. Lowry, K. Frost, J. Burns
Preparation of Annual Report	22 Feb - 11 Mar 1977	L. Lowry, K. Frost, J. Burns

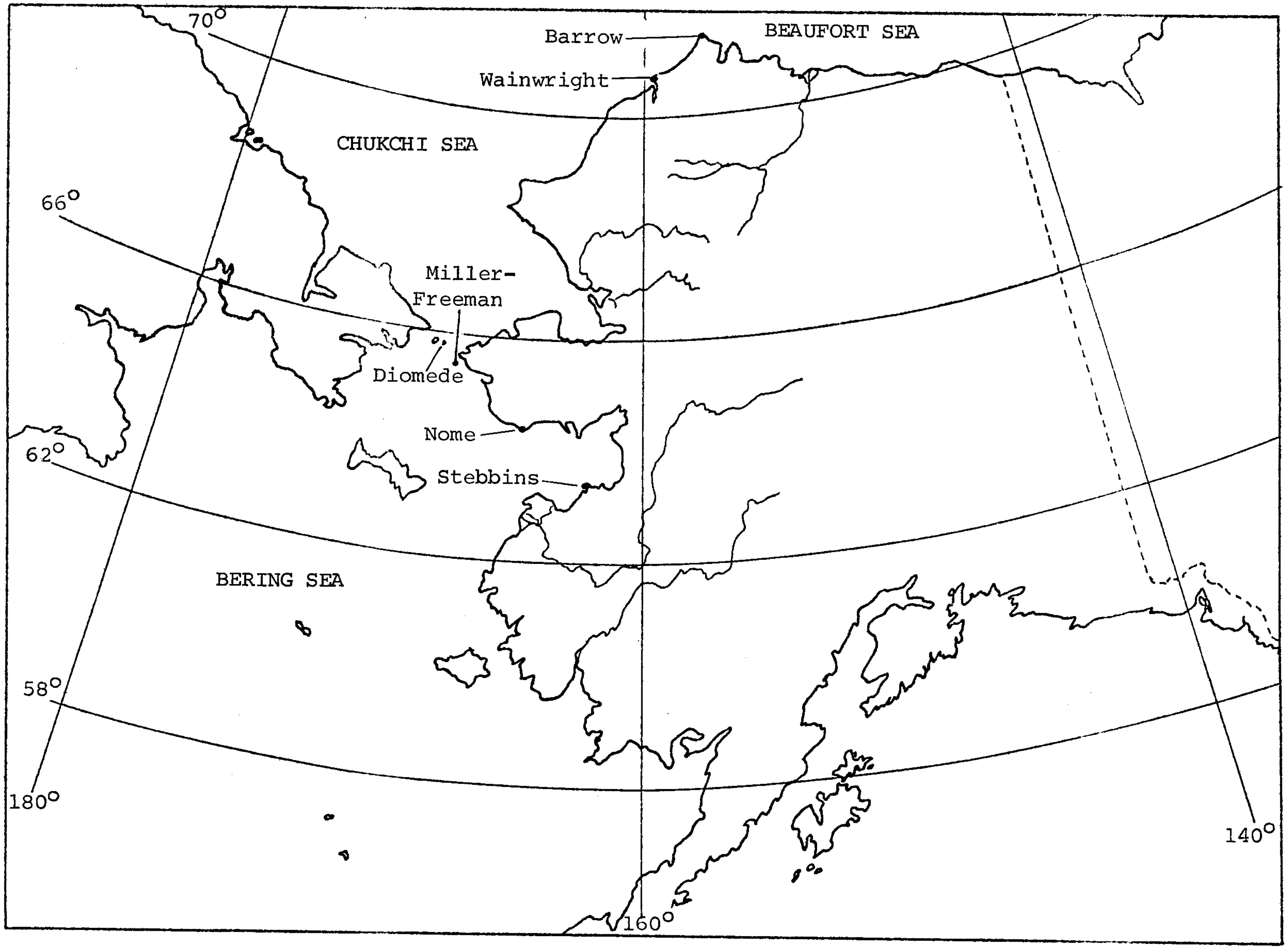

Figure 5. Sample localities for 4th quarter operations.

Table 20. Food items identified from 8 stomachs of ringed seals taken at Diomede, Nome and Stebbins. Data are expressed in part A as the percent of the total volume of contents comprised by each species or group. Part B indicates the species composition of fishes expressed as percent of the total number of fishes identified. Frequency of occurrence is not given due to the small sample sizes.

	DIOMEDE May 1976 N=1	NOME 18-23 Nov 1976 N=5	STEBBINS 18 Nov 1976 N=2
FOOD ITEM	% Volume/#	% Volume/#	% Volume/#
A. Shrimp Total	3.1	6.5	
<u>Eualus gaimardii</u>	3.1		
<u>Pandalus hypsinotus</u>		5.7	
Other shrimps		0.8	
Other Invertebrates	1.0	0.4	
Invertebrates Total	.4.1	6.9	
Fishes Total	95.9	93.1	100
B. <u>Boreogadus saida</u>	100	7.6	
<u>Eleginus gracilus</u>		79.0	92.2
<u>Osmerus dentax</u>		3.8	5.9
<u>Clupea harengus</u>			0.5
<u>Ammodytes hexapterus</u>		7.9	
<u>Myoxocephalus</u> sp.		1.0	
Family Cottidae		0.7	1.4
Total Number of Fishes Identified	1	291	219
Mean Volume of Contents (ml)	38.6	178.2	416.5

* Indicates food items which constituted less than 1 percent of the total volume

Table 21. Food items identified from 12 stomachs from bearded seals taken at Diomede, Wainwright, and aboard the OSS MILLER-FREEMAN (approximately 20 km SSE from Diomede). Data are expressed in the same manner as in Table 19.

FOOD ITEM	MILLER-FREEMAN 28 Sept 1976 N=1 % Volume/#	DIOMEDE 5 May-7Jun 1976 N=4 % Volume/#	WAINWRIGHT 28-29 July 1976 N=7 % Volume/#
A. Bivalves Total	*	1.5	65.5
Serripes sp.		1.3	46.9
Clinocardium sp.			15.8
Other bivalves	*	*	*
Anomuran Crabs Total	*	11.3	*
Pagurus sp.	*	2.5	*
Paralithodes sp.		8.9	
Brachyuran Crabs Total	5.0	71.1	4.9
Hyas coarctatus	*	48.2	4.9
Chionocetes opilio	4.8	22.8	
Shrimp Total	26.4	7.9	25.0
Sclerocrangon boreas		*	23.4
Argis lar	22.1	6.9	1.0
Other shrimps	4.2	*	0.6
Isopods Total			1.9
Saduria entomon			1.9
Amphipods Total	1.3		*
Other Invertebrates	1.1	*	1.2
Invertebrates Total	33.8	91.8	98.6
Rocks and Shells	*	2.4	*
Fishes Total	65.8	5.7	1.0
B. *Boreogadus saida*	4.6		14.2
Lycodes sp.		11.1	
Liparis sp.	29.2		
Ammodytes hexapterus	1.5		26.1
Gymnocanthus sp.	6.2		
Myoxocephalus sp.	4.6		3.7
Family Cottidae	53.8	88.9	56.0
Total Number of Fishes Identified	65	8	134
Mean Volume of Contents (ml)	524.3	410.2	848.3

* Indicates food items which constituted less than 1 percent of the total volume

Project: RU# 232

PI: Lowry, Frost and Burns

REVISED MILESTONE CHART

MAJOR MILESTONES--SPECIMEN COLLECTIONS	1976-77											
	O	N	D	J	F	M	A	M	J	J	A	S
BEAUFORT SEA--Shipboard											*	*
CHUKCHI SEA												
Wainwright										*	*	
Shishmaref									*	*		
Helicopter based							*					
ST. LAWRENCE ISLAND								*	*			
NORTON SOUND												
Nome						*	—	—	*			
Stebbins								*				
Helicopter based						*						
ST. GEORGE BASIN												
Shipboard in ice front						*	*					
Shipboard in ice remnant								*				
BRISTOL BAY--Shipboard						*	*					

* sampling period

Project: RU# 232

PI: Lowry, Frost and Burns

MILESTONE CHART

MAJOR MILESTONES--OTHER PROJECT ACTIVITIES	1976-77											
	O	N	D	J	F	M	A	M	J	J	A	S
Acquisition and archival of reference specimens	△											△
Processing of stomach contents	△											△
Compilation and analysis of stomach contents data			▲			△			△			△
Submission of data	▲			▲			△			△		
Preparation of reports			▲			△			△			△
Preparation of FY 1978 proposal							△					

△ planned completion date ▲ actual completion date

Our data submission schedule for upcoming collections is as follows:

Collection Period	Data Submission
1/77 - 3/77	4/77
4/77 - 6/77	7/77
7/77 - 9/77	10/77

B. Problems encountered/recommended changes

None.

C. Estimate of funds expended

As of February 28 we have expended approximately the following amounts during FY 77:

Salaries and Benefits	$36,000
Travel and Per Diem	5,000
Contractual Services	2,000
Commodities	2,000
Total expenditures	$45,000

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Feeding of the Ribbon Seal

V. A. Arsen'ev

From: Izv. TINRO 20:121-127 (1941)

Translated by John J. Burns, ADF&G

Up to the present time the biology of the ribbon seal has been very poorly studied. It follows to note that up to the moment of organization of the far eastern vessel hunting industry (in 1932) information about this animal was vague, as if the ribbon seal, as it is known, dwells year-round in the open sea. Studies of the biology of seals of the far east, to that time, were made only on the basis of data from shore based harvests in which the ribbon seal is almost not involved.

With the appearance in the sea of hunting ships, more rookeries of ribbon seals were discovered on the drifting ice, far from shore. Then, investigators were able to acquaint themselves more with these interesting animals. But the question about feeding of ribbon seals, to which this work is devoted, was until now not worked out because there was no one to collect the stomach contents.

In the literature, the feeding of ribbon seals is characterized only in generalizations. Thus, P. G. Nikulin (3) in this connection writes: "In 1933 and 1934 all dissected stomachs of molting ribbon seals were found to be empty. In 1934 we observed only one stomach of a molting animal that was filled with mysids." In the work of S. P. Naumov (2) he states: "Judging by the structure of its teeth, the ribbon seal feeds on a mixture of foods - fishes and invertebrates, for example crustaceans." S. U. Freeman (9) gives a more definite indication of what ribbon seals consume. He writes that, "During dissections of stomachs from ribbon seals obtained in the first half of May, from ice along eastern Sakalin, there were found considerable quantities of bones from large fish, mainly saffron cod."[1] The interesting data of G. A. Pikarev (5), who, in 1938, sailed on a hunting ship and dissected stomachs of ribbon seal, found that they were always completely empty. According to indications of the author, he succeeded in finding food remains in the intestines of only three animals.

Finally, in 1939, I first obtained some factual material about the nutrition of ribbon seals. After sailing on the hunting ship Captain Voronin, in April, May and June 1939, in ice of the Okhotsk Sea, I dissected 153 ribbon seal stomachs and gathered 27 samples of their contents. Furthermore, sailing on the hunting ship Nashim, G. A. Pikarev dissected 245 ribbon seal stomachs and also gathered 27 samples of their contents. G. A. Pikarev kindly gave me his material for processing and I consider myself indebted to express my thanks to him. The 1939 collection

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[1] I think in this case a mistake was made in the determination of fish remains apparently they were not saffron cod, but pollock.

of stomach contents was obtained only in the southwestern part of the Okhotsk Sea, along the eastern shores of Sakalin Island and in the region between Sakalin and Ioni Island. Data in this article pertains to seals inhabiting ice in these parts of the Okhotsk Sea. The material available to me is undoubtedly insufficient for a detailed characterization of nutrition of ribbon seals, but it gives us, more or less, the first representation of it.

In dissected stomachs of ribbon seals one can observe the same picture which is known from the work of S. K. Klumov, S. E. Kleinenberg and V. A. Arsen'ev for other marine mammals (belukha, dolphins), namely: the majority of stomachs appear to be completely empty. It is necessary to note that the dissected stomachs were obtained during all times of the day - in the morning, afternoon and evening, but we failed to notice any difference connected with time of day. Results of the study of ribbon seal stomachs in 1939 are shown in Table 1.

As can be seen from Table 1, the percent of empty stomachs is very great (82.9) and this value is constant in all seasons. This table also shows that there is no significant difference between males and females in the proportion of empty stomachs.

Thus, of 398 ribbon seal stomachs examined, only 68 contained food. Of this number we took 54 samples. Identification of the prey items was accomplished with the kind assistance of professors I. G. Zaks, D. N. Logvinobich (invertebrates), A. Ya. Tarantz and P. A. Moiseev (fishes). The following animals were found in stomachs and are arranged according to the frequency of occurrence:

1. Pollock (Theragra chalcogramma Pall.)
2. Cephalopods (Ommastrephes sp., Gonatus magister and others)
3. Cod (Gadus morhua macrocephalus)
4. Pandalid shrimp (Pandalus goniurus Stimpson)
5. Lumpsuckers (Aptocyclus ventricosus Pall.)
6. Capelin (Mallotus villosus)
7. Crangonid shrimp (Crangon dalli ?).

It is necessary to note that squid and octopus are poorly represented (strongly digested) so that they were not found in sufficient condition to identify them precisely. Only Gonatus magister is identified to species. However, I. G. Zaks doubts the correctness of this identification. Therefore, all of these animals will be consolidated in one group - cephalopods, without further subdivision. All of the other food items were identified to species.

The analyses of contents found in each stomach are presented in Table 2. Specimens are arranged in chronological order. Samples were taken in the following manner: either by taking the whole stomach, or by carefully collecting all of the stomach contents. Thus, all weights are of total stomach contents (not individual species of prey).

In the column "lower jaws of pollock" each pair of bones is included as, in most cases, both halves were found. This was the same with cephalopod beaks. If, for example, in stomach number 2, 112 beaks were counted and in stomach number 3 there were 29, these represent 56 cephalopods in the first case and 15 in the second.

Looking at Table 2 it is possible to see that of the entire list of prey items only one (complete) pollock was encountered in a ribbon seal stomach during the entire period of observation. The most consistent prey items during the first half of the period were cephalopods. Other food items occurred only rarely, apparently indicating that the seals ingest them occasionally. It is interesting to note that two stomachs (nos. 17 and 41) contained Pandalus goniurus, exclusively. One of these seals, as indicated by body length (128 cm), was young. It can be proposed that the young seals, in changing from a diet of milk to independent feeding eat crustaceans at first and later change to prey items characteristic of adult animals. This is known to occur in the belukha (Delphinapterus).

Among the other prey items several species of cephalopods are chosen. From Table 2 it can be seen that these animals were found in almost every seal stomach taken up to 20 May. In seal stomachs taken after that date cephalopods rarely occurred. During the first half of May the hunting ship took seals generally to the east of Cape Elizabeth (Sakhalin Island) and later went into the region north of Sakhalin Bay. During the latter period cephalopods were not encountered in ribbon seal stomachs. It appears that this may be the result of cephalopods leaving the region of hunting, diving to greater depths or finally that the seals change over to feed on other prey - this is not known. The presence of cephalopods in a majority of stomachs obtained in the first half of May allows me to think that they are one of the basic prey items of ribbon seals, but only in specific periods.

A very small number of cod remains were observed in the ribbon seal stomachs. In my opinion this does not indicate that cod are a secondary prey item but that few are observed in the region whereas pollock are found here in large numbers. The biology of these fishes is very similar. It is possible that in other regions of the Okhotsk Sea or in the Bering Sea, by dissections of ribbon seal stomachs, we can observe, in contrast, that the basic mass of stomach contents will consist of cod remains and pollock will be encountered very rarely.

Based on the preceding information it can be said that the basic food items of ribbon seals are pollock and cephalopods. These, as well as this seal's other food items, are necto-benthonic animals. Consequently, ribbon seals eat pelagic prey but obtain them from great depth. Sometimes the ribbon seal takes its food from the bottom (Pandalus). This is seldom the case with adult seals as sand is never observed in their stomachs. By comparison, sand is always present in the stomachs of bearded seals (Erignathus barbatus), which feed on benthic animals. The fact that the ribbon seal feeds at great depths is confirmed in that the majority of seals which had food in their stomachs were killed in places where water depths were 100 to 200 meters or more. Furthermore, the ribbon seal possesses a so-called air sac which increases its reserves of air before diving. Preparation and detailed study of the air sac was accomplished in 1939 by M. M. Sleptsov.

The present material permits the advancement of some ideas about quantitative characteristics of nutrition in ribbon seals. Of the bones of cod and pollock the easiest to separate from each other is the operculum. Therefore, I will base the summary of the number of these fishes eaten, on counts of these bones. It follows to say that apparently the operculum takes a longer time to digest than does other bones. In some stomachs we saw several well preserved opercula whereas other bones which were present were strongly digested and it was not possible to identify them. Consequently, because opercula are digested slowly, their number must always exceed the number of fish consumed at a single time because some of the opercula from earlier feedings apparently remain but the remainder of the fish are already digested. Two to 10 pollock opercula were counted in the large part (majority ?) of stomachs, representing the remains of 1 to 5 fish. Those opercula found in ribbon seal stomachs were always in several stages of digestion: some completely whole and others having the appearance of thin plastic. Consequently, these bones are the remains of fish eaten by seals at various times. The condition of opercula found indicate that ribbon seals usually eat three to four pollock at one feeding.

The greatest number of opercula found were from stomach number 52, taken on 9 June (22 opercula). Total contents of this stomach weighed 630g and were very strongly digested. The opercula were also partly digested. The number of opercula which were in a similar stage of digestion allow the assumption that in this case the seal consumed seven to eight pollock in one feeding.

Bones of codfish were found in only four stomachs and the largest number of opercula was six; that is no more than three cod were consumed.

It turns out to be more difficult to determine the number of cephalopods in ribbon seal stomachs. These animals are found in such a digested condition that it is impossible to count them. It was easy to count the number of halves of cephalopod beaks. In each of two stomachs there were more than 100, constituting 50 whole animals. In my opinion this number is more than the seals can consume in one feeding. Beaks accumulate in the stomachs as do opercula of pollock. Further attesting to this fact is that in stomachs 16, 19, 20 and some others, several cephalopod beaks were observed, but the bodies of these animals were fully digested. In one stomach I was fortunate to count the head parts of 11 cephalopds besides some which were already digested and could not be enumerated. This leads me to consider that at one feeding the ribbon seal will consume up to 20 cephalopods, or a few more.

It still remains to consider the relationship between molt and feeding in the ribbon seal. To obtain knowledge about this question we, in the course of examining stomachs, also noted condition of hair on all seals studied. The material collected shows (see Table 2), that of the 52 seals which were found to contain food in the stomachs, 37 (71.2%)

were not molting and 14 (26.9%) were in some stage of molt. In addition, there were two seals which had food in their stomachs, for which status of molt was not noted and one seal, killed on 8 June, which had completed molting. It is necessary to state that in large part non-molting animals were recorded during the first half of May, i.e. during the time when the molt is only beginning. In the latter period, of the seals which had food in their stomachs, the number of molting and non-molting animals was about the same. From these data it can be said that ribbon seals feed throughout the entire period of molt.

Table 2 shows that food remains can be observed in the stomachs of seals which are intensively molting. G. A. Pikarev, who studied the nutrition of bearded seals, observed the same picture. Apparently this condition prevails in all seals of the far east.

Based on the current work it is possible to say:

1. For the period 25 April to 19 June, I and G. A. Pikarev dissected the stomachs of 398 ribbon seals, of which 82.9 percent turned out to be empty. It can be assumed that in the period when seals haul out on the ice they do not feed. This is a characteristic biological trait of the seals. Apparently, during this time they feed only when concentrations of prey occur in the region of the seals' molting rookeries. If food is not present the seals do not search for it, and cease feeding.

2. The major prey item of ribbon seals in the southwestern part of the Okhotsk Sea is pollock. However, in the first half of May cephalopods were not of lesser importance. Several other species of fish and invertebrates were also encountered in ribbon seal stomachs but were encountered rarely.

3. A first attempt to determine the quantity of food eaten by a seal permits us to assume that at one time it will consume, on the average, 3-4 pollock, or 20 (or slightly more) cephalopods.

4. Of those seals which had food in their stomachs, about half were found to be in some stage of molt. Consequently, if conditions are favorable, seals feed. This is independent of the condition of their hair cover.

All of these conclusions are preliminary and have the goal of giving a rough outline for future detailed study of ribbon seal feeding habits.

Table 1. Results of investigation of seal stomachs

	April		May		June		July		Total for season	
	No.	%	No.	%	No.	%	No.	%	No.	%
					Males					
empty stomachs	6	66.7	113	82.5	95	81.2	1	100	215	81.4
stomachs with food	3	33.3	24	17.5	22	18.8	-	-	49	18.6
Total	9	100	137	100	117	100	1	100	264	100
					Females					
empty stomachs	4	80.0	40	83.3	69	87.3	2	100	115	85.8
stomachs with food	1	20.0	8	16.7	10	12.7	-	-	19	14.2
Total	5	100	48	100	79	100	2	100	134	100
					Males and Females					
empty stomachs	10	71.4	153	82.7	164	83.7	3	100	330	82.9
stomachs with food	4	28.6	32	17.3	32	16.3	-	-	68	17.1
Total	14	100	185	100	196	100	3	100	398	100

Table 2. Stomach contents of ribbon seals

number	date	body length (cm)	sex	stage of molt	weight of contents (gms)	pollock bones			cod operculae	cephalo-pods		Pandalus goniurus	notes
						operculum	cleithrum	lower jaws		beaks	bodies		
1	25/IV	169	♀	not molting	58	--	--	--	--	--	-	--	contents not analyzed
2	30/IV	161	♂	"	486	--	--	--	--	112	+	--	
3	6/V	172	♂	"	1260	17	10	13	1	29	+	--	
4	6/V	157	♂	"	865	6	4	4	--	80	+	--	
5	6/V	150	♂	"	75	--	--	--	--	--	-	--	contents not analyzed
6	6/V	180	♀	"	254	--	--	--	--	15	+	--	
7	6/V	169	♀	"	1015	4	13	10	6	43	+	--	
8	7/V	174	♀	"	737	2	8	10	--	14	+	--	*Aptociclus ventricosus* 1 individual
9	7/V	170	♀	"	436	5	7	3	3	45	+	--	
10	7/V	164	♂	"	81	5	1	5	--	33	+	--	
11	7/V	161	♂	"	140	12	10	10	--	28	+	--	
12	16/V	159	♂	"	267	13	--	6	--	114	+	--	
13	16/V	167	♂	"	888	2	relatively undigested pollock						
14	16/V	174	♂	"	51	6	2	2	--	39	+	--	
15	16/V	166	♂	"	191	5	6	4	--	34	+	--	
16	16/V	159	♂	"	8	4	--	--	--	10	-	--	
17	19/V	172	♂	"	268	--	--	--	--	--	-	246	
18	20/V	162	♂	"	253	6	--	--	--	133	+	--	
19	20/V	150	♂	"	17	4	--	--	--	10	-	--	
20	20/V	161	♀	"	2	--	--	--	3	--	-	--	
21	20/V	180	♂	not seen	25	10	--	2	--	--	-	--	
22	20/V	166	♂	molting	393	8	--	7	--	9	+	--	
23	25/V	158	♂	"	--	1	--	--	--	--	-	--	
24	26/V	154	♂	intensive molt	2	4	--	--	--	--	-	--	
25	26/V	166	♀	"	6	8	--	--	--	--	-	--	
26	26/V	158	♀	not seen	35	9	--	7	--	--	-	--	
27	29/V	166	♂	intensive molt	356	4	6	6	1	--	-	1	
28	31/V	158	♂	not molting	231	6	--	8	--	--	+	--	
29	31/V	166	♂	intensive molt	289	2	--	4	--	--	-	--	
30	31/V	144	♀	slight molt	208	1	relatively undigested pollock						
					86	1	cephalopods-1 whole and 1 head						
31	31/V	178	♂	"	283	14	--	13	--	--	-	--	
32	1/VI	180	♂	intensive molt	11	2	--	2	--	--	-	--	
33	2/VI	158	♂	not molting	7	9	--	--	--	--	-	--	
34	2/VI	181	♀	intensive molt	164	4	--	2	--	--	-	--	
35	2/VI	160	♂	molting	172	8	--	6	--	--	-	--	*Crangon dalli* ? 1 individual
36	2/VI	--	♂	not molting	3	6	--	--	--	--	-	--	
37	2/VI	162	♂	"	700	1	whole pollock						
					234	--	pieces of pollock						
					170	7	--	--	--	--	-	2	

Table 2 continued. Stomach contents of ribbon seals

number	date	body length (cm)	sex	stage of molt	weight of contents (gms)	pollock bones			cod operculae	cephalopods		Pandalus goniurus	notes
						operculum	cleithrum	lower jaws		beaks	bodies		
38	3/VI	172	♀	"	65	6	--	3	--	2	-	--	
39	5/VI	167	♂	"	297	6	--	6	--	--	-	--	
40	5/VI	165	♂	"	8	4	--	2	--	1	-	--	
41	5/VI	128	♀	"	29	--	--	--	--	--	-	17	
42	5/VI	178	♂	"	49	10	--	--	--	2	-	8	
43	5/VI	167	♀	intensive molt	7	15	--	--	--	2	-	--	
44	7/VI	143	♂	slight molt	5	2	--	--	--	--	-	--	
45	7/VI	158	♂	intensive molt	22	--	--	--	--	--	-	--	*Mallotus villosus* 1 individual entire
46	8/VI	163	♀	molt completed	--	3	--	1	--	--	-	--	
47	8/VI	166	♂	not molting	--	2	--	--	--	--	-	--	
48	8/VI	157	♂	"	19	16	--	--	--	--	-	--	
49	8/VI	168	♂	not molting	22	9	--	--	--	5	-	--	
50	9/VI	175	♂	"	28	12	--	--	--	--	-	--	
51	9/VI	157	♂	"	28	4	--	3	--	--	-	--	
52	9/VI	162	♀	"	630	22	15	15	--	1	-	--	
53	9/VI	140	♀	"	--	4	--	--	--	--	-	--	
54	19/VI	156	♂	"	41	2	--	2	--	--	-	--	

Food of the Ringed Seal

G. A. Fedoseev

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Translated by: Meg L. Poppino for ADF&G

In the literature, the food of the ringed seal is elucidated only for the Canadian sector of the Arctic (McLaren, 1958), the Barents' Sea and the Kara Sea (K. K. Chapskii, 1940; G. F. Kurcheva, 1948; M. P. Vinogradov, 1949). For the remaining areas - the Sea of Okhotsk, the Bering Sea, the Eastern-Siberian and Laptev Seas - information about feeding habits, like other biological information, is non-existent or extremely inadequate.

In this work the food of the Okhotsk ringed seal[1] (Pusa hispida ochotensis Pall.) is examined, and an attempt is made to compare it to the food of other subspecies.

A comparison of the food of the ringed seal in different regions provides some explanations for the peculiar distribution of its subspecies according to the season of the year, and a more complete idea of the ecology of this seal as a species on the whole.

Original material collected in the period 1960-1963 at the Sea of Okhotsk, and some data in the literature, are assumed as the basis of this work.

In connection with the study of feeding habits, the contents of 159 stomachs of Okhotsk ringed seals were analyzed (out of 550 examined). The larger part of the material was acquired from the area of the Tauiskoj Inlet, Babushkina, Kekuriovo, Shel'tinga and Ushki Bays. No noticeable specific difference in the composition of the contents of the stomachs of ringed seals from different regions and years was observed. Therefore, all of the original material concerning feeding habits of the ringed seal has been united.

The contents of the seal stomach were weighed on "cup"[2] scales (5 kg.). Individual components in a number of cases were weighed on pharmaceutical scales. Identifications of food components were carried out both under field conditions and through laboratory analysis. Under field conditions only easily diagnosed components were identified. The identification was made according to the 1960 method of our colleague J. I. Zhitle of the Magadanskij section of TINRO.[3]

In most cases in the literature about the feeding of the Okhotsk ringed seal, only an enumeration of the food components is made, without a quantitative analysis. Thus, P. G. Nikulin (1937) notes that the food of the ringed seal consists of small fish (navaga, smelt) and crustaceans. S. P. Naumov (1941), discussing the feeding of the ringed seal, notes that in June 1929 he found mainly shrimp (Sclerocrangon) in ringed seal stomachs; in several stomachs gammarus and the remains of navaga were found. In July at the western shores of Sakhalin, according to the opinion of S. P. Naumov, the ringed seal pursues smelt, and partly feeds on crustaceans, and in the second half of the summer and early autumn (until October) it eats gobys, herring, navaga and crustaceans. C. J. Freiman (1936) also points out the feeding of the ringed seal on fish, noting that the approach of this seal to the shores of the Gizhiginskaja Inlet is connected with the presence there of navaga. In June 1939 during the investigations of G. A. Pikharev (1946), out of 377 ringed seal stomachs, food was found in only 16. Such an insignificant quantity of stomachs with contents is explained by G. A. Pikharev as being due to the fact that the digestion of food takes place very quickly in seals. In characterizing the composition of the food, he indicates that crustaceans were found in 10 stomachs, the predominate ones being: Thysanoessa raschii, Themisto compresso f. bispinosa, Mesidothea, Gammarus schmidtii, Anonyx nugax.

In five stomachs only fish were found: pollock (Theragra chalcogramma), smelt (Hypomesus olidus Pall.) and herring (Clupea harengus Pall). The food in one stomach was mixed.

The observations of the feeding of ringed seals (Table 2, Fig. 1) show a rather large diversity of components of food and their noticeable shift in region according to the seasons of the year. The basic food of the ringed seal consists of higher crustaceans. Of these, one most often encounters Euphausiacea of the genus Thysanoessa, which were found in 137 stomachs out of 159 containing food (87%). In relation to the other food components in the ringed seal stomachs, one also comparatively often finds Amphipods and Decapods, which were found in 70 (44%) and 52 (32%) respectively. Other representatives of the crustaceans were encountered signficantly less often: Isopods in seven (4%) and Copepods in three (1%). Fish were found in 44 stomachs (28%).

In the spring the ringed seal feeds on Euphausiacea. Thus, of the 128 individuals examined in March-April 1961 and 1963, food was found in 98 (77%) and consisted almost entirely of Euphausiacea. The quantity of these crustaceans in the ringed seal stomachs often reached 700 g and more (Table 2, Fig. 1).

In the moulting period (May-June) feeding activity in the ringed seal noticeably drops, but does not cease, as may be seen at once on examination of the stomachs. The fact is that during the moulting period the animals lie for long periods of time on the ice floes and so food is quickly digested; thus in the majority of stomachs procured food was not found. For example, of 397 animals which we examined in May-June, food remains were found in the stomachs of only 47 individuals, and in the intestines of 39. In all, food remains were found in only 21% of the animals examined. It is noteworthy that in the moulting period the number of food components noticeably decreased (Fig. 1). This is due to the fact that in May and especially in June, when mass moulting takes place among the ringed seal, the animals spend the major part of the 24-hour period on drifting ice, and it becomes necessary to feed on whatever food is encountered on the way. In the moulting period (May-June) the animals grow very much thinner (Fig. 2). After the end of the moult (the end of June - first 10 days of July) the ringed seals begin to actively feed. In the period of increased feeding the ringed seal spread throughout the greater part of the area. The seals continually remain in the water. With the cease of captures of ringed seal in the summer and early fall the study of their feeding habits becomes difficult; at this time the feeding habits of the ringed seal may be judged only indirectly through observation of their distribution and behavior.

According to the information of a number of researchers and our observations in July-September, the greater number of ringed seals leave the shores, mainly gathering in the areas of growth of zooplankton, occurring in the zone of the continental shelf, singly and in small groups (20-60) annually encountered throughout nearly the whole northern part of the Sea of Okhotsk. Information about the gathering of ringed seal in the summer months is also to be found in the literature. For example, C. J. Freiman (1935) informs us that he encountered huge groups of this seal in the water from Cape Otlichitel'no to Aldoma in August 1929 and that, in his opinion, the animals were chasing a school of some fish, evidently capelin. P. G. Nikulin (1937) observed a large gathering of ringed seal in the area of Reinecke and Men'shikov Islands.[4]

Thus, the continual habitation of the ringed seal in the area of massive growth of zooplankton during the summer months allows us to assume that the seal feeds on planktonic crustacean forms at this time, as in the autumn, concentrating on fattening themselves in this region. We are inclined to consider that in the summer in the northern part of the Sea of Okhotsk, the ringed seal feeds mainly on Euphausiacea, since according to the data of L. A. Ponomareva (1963) the gathering of these crustaceans[5] in the surface layers reaches a maximum at that time. This assumption is corroborated by the fact that at the end of the winter and in the spring the number of Euphausiacea is noticeably smaller than in the summer, and the food of the ringed seal consists almost exclusively of these crustaceans, in spite of the concentration of spawning navaga and herring at the same time. This fact indicates that the Euphausiacea are evidently the preferred food of the ringed seal.

The period of intense feeding is not limited to the summer fattening, but also includes the autumn and part of the winter. In October and the beginning of November the ringed seal are concentrated in enormous numbers in inlets, bays and gulfs. In our opinion, the ringed seals' autumn approach to the shore zone shows a law-governed process of seasonal change of area, involving the seals' shift to regions with different feeding conditions. Judging by the stomachs' evidence, in the autumn-winter months the ringed seals' main food components are navaga, smelt, herring, sometimes gobys, sand lance and other fish. Of the crustaceans, mainly nektobenthic forms are found: hippolytid shrimp, pandalid shrimp and even molluscs (Gastropoda). Planktonic forms of crustaceans are found in stomachs more rarely at this time than at other periods, evidently due to their decrease in number in consequence of their being eaten by fish, whales, birds and seals, and also of the migration of plankton from the surface layers to the depths as a result of the autumn cooling of the surface water.

A sharp decrease in the fatness of the ringed seal in May-June (Fig. 2) is observed in connection with moulting. By out measurements, the thickness of the fatty layer from November to the end of April hardly changes, and varies from 5-8 cm.

The composition of food hardly changes with the age of the animal. The exceptions are young pups[6] and yearlings, whose food in large part consists of small crustaceans - Euphausiacea and Amphipods. Fish and larger crustaceans are encountered more seldom in the food of young ringed seals than in that of full-grown animals, even in the autumn.

In comparing the feeding of Okhotsk ringed seals to that of other subspecies of this seal (Table 2) one should pay attention to the large similarity between the food components within a certain species distinction, according, apparently, to the specific biotope of one or another sea. It follows to note as a general natural law that in many regions of the Arctic and the Far East the ringed seal feeds primarily on crustaceans for the greater part of the year. Only in the late autumn and winter does fish predominate in its ration. But the significance of crustaceans and fish in the feeding of the ringed seal is not identical in different regions.

The main object of fish-feeding of the ringed seal in most of the Arctic seas is the polar cod. This is one of the most accessible fish for seals. Another distinguishable particularity of the ringed seal in the Arctic seas is that of the crustaceans, the largest share consists of Mysis oculata. These crustaceans form concentrations in the freshening waters of inlets, bays and near the mouths of rivers. The mass gatherings of Mysis oculata in these areas is connected to the presence of the distinctive "polar front" at the juncture of river and sea waters near the mouths of large rivers.

In the northern part of the Sea of Okhotsk, due to the absence of large rivers, no noticeable freshening of sea water is observed and large concentrations of Mysis oculata do not form. The main crustacean food of the ringed seal is Euphausiacea. Concentrations of them in the northern part of the Sea of Okhotsk are found in the surface layer in connection with their mating seaon in March-April, and with the spawning 2 1/2 months later, for which these crustaceans ascend to the surface layer of water (L. A. Ponomareva, 1963).

The particular distribution of objects for feeding is connected to the particular distribution of the ringed seal in several regions of the Arctic and the Far East. This consists in the fact that in the northern part of the Sea of Okhotsk the ringed seal is less bound to the shore than in the areas of Canadian north, the Barents' Sea and the Kara Sea. This is especially clear when a comparison is made of the distribution of seals in the period of whelping and the feeding of young.

The Okhotsk seal's whelping place is largely far from the shore beyond the edge of the shore line ice shelf, amidst moving, hummocky ice fields, interspersed with open areas of water. In terms of feeding this location is much more advantageous for the pups, since in the spring the first concentrations of Euphausiacea appear here. The presence of accessible food is especially important for the young when the time comes for independent feeding.

A completely different picture is seen in the Arctic seas. Thus, in Canada by the shores of Baffin Land, and also in the seas of the European north, the ringed seal is shielded, for the most part, near the shore on immovable ice floes, in bays and inlets, undergoing moulting on the ice. Undoubtedly, in the choice of places there is a definite advantage for the pups in shelter from winds and frosts; however, the food factor is not less important in this question.

Reduction of the material concerning the ringed seal shows that a significant part is played in its ration by small crustaceans, sometimes not exceeding 10 mm in size. In this connection interest is aroused in the suitability of the ringed seal for the capture of such small food. MacLaren (1958) suggests that the ringed seal catches the small crustaceans in water, and then filters them. In our opinion this means of food capture is entirely realistic, as the structure of the dental system of the seals is suitable for this. When the jaws close, the teeth touch one another in such a way that orifices remain between them, through which the ringed seal evidently filters the water, leaving the crustaceans which were caught in it.

CONCLUSION

The ringed seal of the Sea of Okhotsk, like other subspecies of this seal, feeds on higher crustaceans and fish. Each plays an important part in the seals' feeding regimen, depending on the season of the year. In spring and summer the food of the ringed seal consists of crustaceans, in the fall and winter, fish.

Along with the similar features of feeding behavior of the various subspecies of ringed seal there is a definite difference, connected, possibly, with the specific biotope of the different seas in which these seals reside. In the Arctic seas the main objects for feeding, of the crustaceans, are Mysis oculata, Themisto lebelula, Gammaracanthus loricanthus, and, as in the Sea of Okhotsk, Thysanoessa raschii. The main fish food source in the Arctic seas is polar cod, but in the Sea of Okhotsk it is navaga, smelt and herring.

The peculiarities of distribution of food sources condition the distribution of ringed seals in a number of areas. This is concluded from the fact that the ringed seal of the Sea of Okhotsk is less bound to the shore than in a number of regions of the Arctic.

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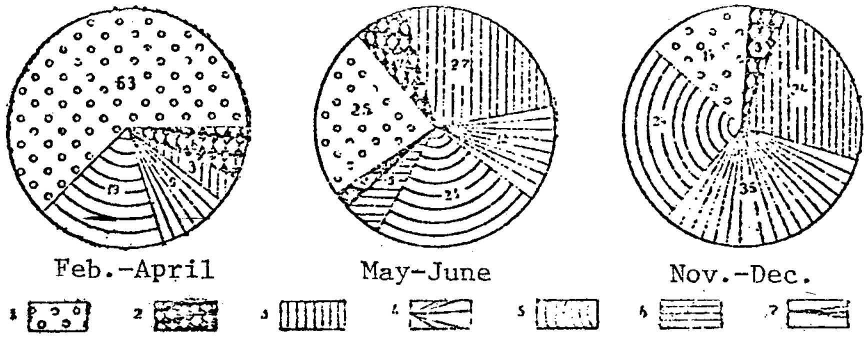

Figure 1. Relative weights (in %) of the food components of the Okhotsk ringed seal indifferent seasons of the year:
1. Euphausiids 2. Mysids 3. Decapods 4. Fish
5. Amphipods 6. Copepods 7. Isopods

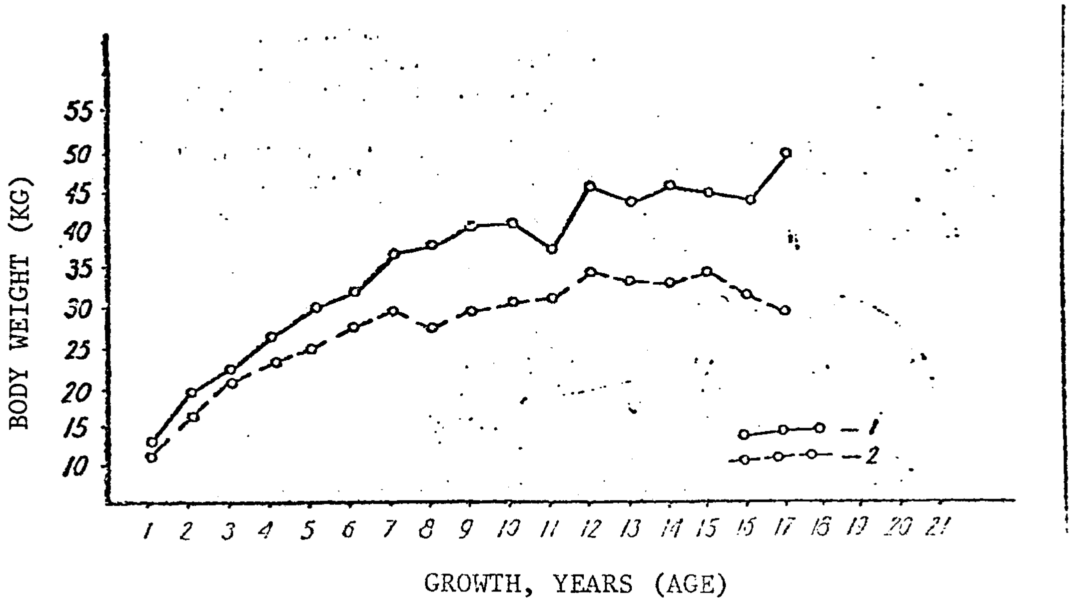

Figure 2. Conditions of fatness of ringed seals:
1 - March-April, 2 - May-June (by average data)

Table 1. Distribution of examined stomachs of ringed seals by time and degree of observation:

Time of year	No. of stomachs			Weight of stomach contents (5)	
		Tot. w/food		Limits of variation	Average
	All	#	%		
Feb-Apr	128	98	77	60-950	370
May-June	397	47	12	40-560	210
Nov-Dec	25	14	56	150-600	350
Total	550	159	29	40-950	320

Table 2. List of food items of the ringed seal.

FOOD ITEM	CANADIAN ARCTIC	EUROPEAN ARCTIC	SEA OF OKHOTSK
Веслоногие рачки — Copepoda	+	—	+
Calanus hyperboreus Kroyer	+	—	—
Pareuchaeta norvegica Boeck	+	—	—
Усоногие раки — Cirripedia	+	—	—
Balanidae	+	—	—
Разноногие раки — Amphipoda	+	+	+
Gammarus setosus Demet	+	—	—
Gammarus oceanicus Segerst	+	—	—
Gammarus wilkitzkii Birula	+	—	—
Gammarelbus homari Fabr	+	—	—
Gammaracanthus loricatus Sabine	+	+	—
Anonyx nugax Phipps	+	+	+
Socarnes bidenticulatus Bate	+	—	—
Stegocephalus inflatus Kröyer	+	—	—
Ampelisca eschrichti Kröyer	+	—	+
Acanthostepheia sp.	—	+	—
Atylus carinatus Fabr.	+	—	—
Rhachotropis aculeata Lepechin	+	—	—
Pontogeneia inermis Kröyer	+	—	—
Amphithopsis longicaudata Boeck	+	—	—
Ischyrocerus anguipes Kröyer	+	—	—
Hyperia galba Mantagu	+	—	—
Themisto libellula Mant.	+	+	+
Pleudalibrotus biulai (gurjanova)	—	+	—
Pseudlibrotus sp.	—	+	—
Десятиногие раки — Decapoda	+	+	+
Pasiphaea pacifica Rathbun	—	—	+
Pandalus sp.	—	—	+
Pandalus goniurus Stimpson	+	—	—
Pandalus montagui Leach.	—	—	+
Spirontocaris sp.	—	+	+
Spirontocaris murdochi Ratbun	—	—	+
Spirontocaris spinus Sawerby	+	—	—
Spirontocaris phippsi Kröyer	+	—	—
Eualus fabricii Kröyer	+	—	—
Eualus gaimardi Milne-Edwards	+	—	—
Lebbeus groenlandica Fabr.	+	—	—
Lebbeus polaris Sabine	+	—	—
Расщепленноногие раки — Mysidacea	+	+	+
Mysis oculata Fabr	+	+	—
Mysis mifta Lilljeborg	+	—	—
Черноглазки — Euphausiacea	+	+	+
Thysanöessa inermis Kröyer	+	—	—
Thysanöessa raschii Sars.	—	+	+
Равноногие раки — Isopoda	—	+	+
Mesidothea entomon	—	+	+
Idothea ochotensis Brandt	—	—	+
Брюхоногие моллюски — Gastropoda	+	—	+
Margarites helicina Phipps	+	—	+
Turritellidae	+	—	+
Двустворчатые моллюски — Bivalvia	+	—	+
Limacina helicina Phipps	+	—	+
Nucula tenuis Montagu	+	—	—
Головоногие моллюски — Cephalopoda	+	+	—
Многощетинковые черви — Polychaeta	+	+	—
Maldanidae	+	—	+

Table 2 (continued). List of food items of the ringed seal.

FOOD ITEM	CANADIAN ARCTIC	EUROPEAN ARCTIC	SEA OF OKHOTSK
Fishes			
Сайка Boreogadus saida	+	+	—
Гренландский палтус Reinhardtius hippoglossoides Walbaum	+	—	
Песчанка Ammodytes sp.	+	—	+
Морской петух Triglops sp.	+	—	—
Остроносый триглопс Triglops pingeli Reinhardt	+	—	—
Люмпенус Lumpenus sp	+	—	—
Люмпенус фабрициуса Lumpenus fabricii Reinhardt.	+	—	—
Ликоды Lycodes sp	+	—	—
Бычки Cottidae	+	+	+
Навага Eleginus navaga	—	+	+
Полярная камбала Liopsetta glacialis	—	+	—
Корюшка Osmerus sp.	—	+	+
Морские слизни Liparis liparis	+	—	—
Минтай Theragra chalcogramma	—	—	+
Сельдь Clupea harengus	+	+	+
Мойва Mallotus sp	—	+	+
Треска Gadus morhua Linne	—	+	—
Пикша Melanogrammus sp.	—	+	—
Омуль Coregonus autumnalis Pall.	—	+	—
Семга Salmo salar Linne	—	+	—
Голец Salvelinus sp.	—	+	—

Notes on the Translation:

1. The Russian common name for the ringed seal of the Sea of Okhotsk is "akiba," which apparently has no direct counterpart in English.

2. The scales referred to are called "chashechnyje vesy," from the word for cup; the technical dictionaries don't mention them.

3. TINRO: Pacific Ocean Fisheries Institute.

4. I assumed that the word is, in fact, "islands," from the abbreviation "O-vov."

5. The word used is "rachki," probably from "rak" meaning "crayfish."

6. The word used is "sevoletkii," meaning "of that year."

On the food of true seals of the eastern coast of Sakhalin

A. M. Nikolaev and V. A. Skalkin

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Translated by: Francis Fay, University of Alaska, Institute of Marine Science

The question of the food of true seals (Phocidae) of the Okhotsk Sea was considered in a succession of publications (Arsen'ev, 1941; Pikharev, 1941; Inukai, 1942; Fedoseev, 1965; Fedoseev and Bukhtiarov, 1972; and others), but only T. Inukai provided some brief information on the food of seals in Terpenie Bay, where fragmentary material was gathered in the present work. In as much as our data were gathered at a different time than in the Japanese investigation, they have definate value from the point of view of accumulation of material concerning the food of seals of the eastern coast of Sakhalin.

Materials and Methods

The materials concerning the food of seals were collected from 25 March to 9 April 1972 on the pack ice drifting in the southeastern part of Terpenie Bay, not far from Tiulenie Island (Robben Island), and at latitudes extending 130 to 140 km from the southern side of Cape Svobodnyi (Fig. 1). The investigation was conducted in the periods of pupping, lactation, and molt of the animals. Dissection of the stomachs and removal of the samples of food was done immediately after the animals were taken. A large part of the seals was killed while they were swimming; the remainder was taken on the ice.

Altogether, 66 stomachs were examined (27 ringed seals, 7 largas, 31 bearded seals, and 1 ribbon seal) from animals ranging in age from 8 months to 16 years old. Food was found in 51 of the stomachs (77.2%).

The easily recognized food items were identified in the field; the remainder was fixed in formalin and identified in the laboratory.

The samples of food were counted, information as to the time and place when the animals were killed was noted, and materials (teeth and claws) were collected for determination of their age. The pelage of the seals was examined for ectoparasites.

Food Spectrum and the Feeding of the Seals

Fragments or whole specimens of 24 representatives of the marine fauna were found in the stomachs of the seals (Table 1). This number was distributed as follows among the taxonomic groups: anenomes - 1, nemerteans - 1, crustaceans - 15, amphipods - 1, gastropods - 1, bivalves - 1, cephalopods - 1, and fishes - 4. Not all of the enumerated animals had the same importance in the diet of the seals. The ringed seal most often (Table 2) ate euphausiids, then shrimps, then fishes and crabs. A predominance of euphausiids in the diet of these seals in the northern part of the Okhotsk Sea was recorded by G. A. Fedoseev (1965).

In the stomachs of the largas, a considerable part of the food mass was made up of fragments of fishes, in lesser amounts shrimps, crabs, and small octopus. Approximately the same composition of basic foods was characteristic of largas inhabiting the Tartar Strait (Gol'tsev, 1971).

As seen in Table 1, in the area of investigation, the bearded seal consumed not less than 23 representatives of the marine fauna, but the basic objects of its feeding here, as in the Bering Sea (Kosygin, 1966, 1971), were Tanner crabs and spider crabs (Chionocetes and Hyas, respectively). Second in frequency of occurrence were molluscs, among which cephalopods were predominant. In the Bering Sea, gastropods were first among the molluscs (Kosygin, 1971). In the stomachs of the bearded seals taken in June 1973, in the area of Spafar'ev Island (northern part of the Okhotsk Sea), the most numerous items were the remains of gastropods; second, were cephalopods (Nikolaev, 1973, handwritten, scientific fund SakhTINRO).

The third place in the food of this seal was occupied by shrimps. They play a similar role in the food of the Bering Sea bearded seal (Kosygin, 1971). According to the data of A. M. Nikolaev (1973), shrimps appeared to be the basic food of this animal in June 1973, not far from Spafar'ev Island.

In the stomachs of bearded seals taken in the area of our investigation, we often found such bottom fishes as sea-poachers, flounders, and sand lances. The sand lance was discovered by A. M. Nikolaev (1973) also in the stomachs of these animals in the vicinity of Spafar'ev Island, therefore we share the point of view of G. M. Kosygin (1971), that fishes do not appear to be accidentally ingested by the bearded seal.

In the food items, we note coelenterates and nemerteans. Coelenterates were found in these animals in Sakhalin Strait by G. A. Pikharev (1946), and nemerteans were found by T. Inukai (1942) in Terpenie Bay and by A. M. Nikolaev (1973) near Spafar'ev Island.

In the bearded seal, crabs, octopus, shrimps, nemerteans, and fishes are eaten whole, whereas it is probable that only the foot is bitten off the bivalve molluscs, because whole shells never occur in the stomach, and small pieces of them are very rarely found. Judging by the observations on food organisms of the seals, and the contents of their stomachs, the bearded and ringed seals obtained food at 15 to 120 meter depths in the area of our investigations. The feeding places of the largas varied in depth from 85 to 100 meters. However, as rightly noted by V. N. Gol'tsev (1971), the distribution of the animals along a depth zone in this period does not depend on the distribution of food items but more on the presence of ice suitable for their reproduction.

In the period of investigation, the bearded seal was molting intensively, but the molt had just begun in the ringed and larga seals; however, all three species were actively obtaining food (Table 3). For example, in the stomach of a 12 year old molting female bearded seal there were 25 crabs, 32 shrimps, 15 octopus, and 40 feet of bivalve molluscs.

The data obtained corroborate the point of view of G. A. Fedoseev (1956) and G. M. Kosygin (1971) that these seals continue to feed during the molt. The short time for observations and the difficult ice conditions in the area prevented our collection of detailed information on the feeding and resting times of the animals. However, from the fullness of the stomachs at different times of the day (Tables 4 and 5), it is possible to conclude that the animals were feeding during the whole day, but most intensively in the evening.

Some investigators (Shustov, 1965; Kosygin, 1971) consider that seals obtain food not only during the day but at night as well. We share that point of view, because we repeatedly found food in the stomachs of animals taken at dawn.

Conclusions

1. In the spring of 1972, in the stomachs of seals obtained in Terpenie Bay and to the south of it, fragments or whole specimens from 24 representatives of the marine fauna were found.

The basic foods of the ringed seal comprised euphausiids and shrimps; fishes and crabs were consumed in smaller quantities.

The food of the larga was predominantly fishes, however an important role was played also by shrimps, crabs, and cephalopod molluscs.

The bearded seal consumed coelenterates, nemerteans, crustaceans, molluscs, and fishes, but the main items were crabs, molluscs, shrimps and fishes.

2. The bearded seal and ringed seal obtained food at depths of 15 to 120 meters, and the largas fed at depths ranging from 85 to 100 meters.

In the period of pupping, lactation, and molt, seals do not discontinue feeding. They obtain food throughout the day and night, but, most intensively, in the evening.

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Table 1. Food items from seals.

Food item	Bearded seal		Ringed seal		Larga	Condition of food items found
	♂	♀	♂	♀	♀	
Actinaria						
Actinis sp.	-	+	-	-	-	Part of body
Nemertini						
Enopla sp.	+	+	-	-	-	"
Crustacea						
Amphipoda sp.	-	+	-	-	-	"
Thysanoessa raschii	-	+	+	+	-	Whole specimens
Spirontocaris murdochi	-	+	-	-	-	"
Spirontocaris sp.	+	+	+	-	-	Fragments
Eulaus sp.	+	-	-	-	-	"
Lebbeus sp.	+	-	-	-	-	"
Heptacarpus sp.	+	-	-	-	-	"
Pandalus meridionalis	-	+	-	+	-	Whole specimens
P. goniurus	+	-	-	-	+	"
P. hypsinotus	-	+	-	-	-	"
P. sp.	-	-	-	-	+	Fragments
Crangon dalli	+	+	+	-	+	Whole specimens
C. sp.	-	+	-	-	-	Fragments
Chionoecetes opilio	+	+	-	+	+	Whole specimens
Hyas coarctatus alutaceus	+	+	-	-	-	"
Mollusca						
Gastropoda sp.	-	+	-	-	-	Fragments
Bivalvia sp.	+	+	-	-	-	"
Octopodidae sp.	+	+	-	-	+	"
Pisces						
Podothecus sp.	-	+	-	-	-	"
Hippoglossoides ellassodon	-	+	-	-	-	Whole specimens
Ammodytes hexapterus marinus	-	+	-	-	-	"
Pisces sp.	+	+	+	+	+	Fragments

Table 2. Frequency of occurrence of food items in the stomachs of seals (%).

Food item	Ringed seal	Larga	Bearded seal
Actinaria	---	---	9.6
Nemertini	---	---	12.9
Crustacea			
Amphipods	---	---	3.2
Euphausiids	74.1	---	3.2
Shrimps	33.3	14.2	48.4
Crabs	3.7	14.2	61.2
Mollusca			
Gastropods	---	---	9.6
Bivalves	---	---	16.1
Cephalopods	---	14.2	32.2
Pisces	7.4	28.5	38.7

Table 3. Degree of fullness of stomachs of seals in relation to condition of the pelage.

Species	Fullness of stomach	Condition of Pelage			
		Molting		Non-molting	
		No. of occurrences	%	No. of occurrences	%
Ringed seal	Empty	---	---	1	5.6
	With food	9	100.0	17	94.4
Larga	Empty	1	100.0	3	50.0
	With food	---	---	3	50.0
Bearded seal	Empty	7	24.1	2	100.0
	with food	22	75.9	---	---
Ribbon seal	Empty	---	---	1	100.0
	With food	---	---	---	---

Table 4. Relation of empty and full stomachs of seals.

Species	Time of day (hrs)					
	8 - 12		12 - 16		16 - 20	
	Empty	w/food	Empty	w/food	Empty	w/food
Ringed seal	1	7	---	8	---	11
Larga	3	1	1	2	---	---
Bearded seal	3	7	3	5	3	10

Table 5. Degree of fullness of stomachs of seals.

Species	Time of day (hrs)																	
	8 - 12						12 - 16						16 - 20					
	Stomach fullness						Stomach fullness						Stomach fullness					
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
Ringed seal	1	4	2	-	1	-	-	1	-	1	6	-	-	1	-	4	4	2
Larga	3	-	1	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-
Bearded seal	3	3	1	1	2	-	3	-	-	1	4	-	-	-	1	2	4	3

The diet of seals of the Okhotsk Sea

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Translated by: Francis Fay, University of Alaska, Institute of Marine Science

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This is a status report on the results of analysis of the contents of 352 seal stomachs (ringed - 209, bearded - 72, ribbon - 48, larga - 23) obtained in the spring of 1970 and of 1971, together with a few data from the literature.

The diet of the ringed seal was studied in the Tamsk region and the Shantur Islands. In both areas, the basic food was euphausiids, which were found in 70 to 90 percent of the stomachs. The weight of these little crustaceans ranged from 50 to 900 grams per stomach.

In the stomachs of ringed seals from the Shantur region, decapod crustaceans (in 10% of the stomachs) and fishes (in 52% of the stomachs) were found considerably more often than in the north. In one stomach, up to 300 shrimp (497 gm) and 145 sand lance (500 gm) were counted.

Generalizing from materials in the literature (Vinogradov, 1949; Naumov, 1941; Pikharev, 1946; Fedoseev, 1965; and others), it is possible to conclude that the principal foods of the ringed seal are small planktonic crustaceans, i.e. euphausiids. In certain areas or in certain seasons, a substantial role is played by decapod and amphipod crustaceans, as well as by schooling fishes such as the sand lance, herring, capelin, navaga, and smelt.

The diet of the Okhotsk bearded seal was found to include 41 species of benthic and nektonic invertebrates. In the Tamsk area, the basic diet was made up of decapod crustaceans (22 species), which, on the average, amounted to 87% of the food. The proportion of bivalve, gastropod, and cephalopod molluscs in the total amounted to not more than 6%, and of fishes 3.7%. In Sakhalin Bay, on the contrary, the basic diet of the bearded seal was made up of bivalves (in 40% of the stomachs) and gastropods (in 12%), as well as worms (23%).

The recorded differences in diets of bearded seals essentially confirm the ecological distinction of the northern Okhotsk and Sakhalin populations (Fedoseev, 1972).

From 48 stomachs of ribbon seals, 42 (88%) contained pollack numbering from 1 to 57 individuals and weighing from 100 to 3000 grams. Navagas were found in 2 animals, octopus in 8, shrimps in 1. Supplementing our materials with the data of V. A. Arsen'ev (1940), one can conclude that the basic diet of the Okhotsk Sea ribbon seal is made up of pollack; in some areas a substantial role is played by cephalopod molluscs.

Analysis of the contents of stomachs of the larga shows that, in its diet as in the ribbon seal's, pollack predominate (in 65% of the stomachs), generally comprising 100 to 4000 grams per stomach. However, as a whole, the nutritive spectrum of the larga is considerably broader than that of the ribbon seal. Of the fishes, after the pollack, comes that navaga (in 5%), the sand lance (in 5%), and other unidentified fishes (in 10%). Of the crustacea, euphausiids (in 16%) and decapods were found.

The simultaneous occurrence of many individuals of the same kind in the stomachs of seals attests to their acquiring food from dense aggregations of organisms. In that connection, these seals obviously spend more energy searching for such aggregations than they expend in catching the organisms from those schools. This is important to consider when analyzing the morphophysiological indeces of the rate of energy expenditure of these animals.

The narrowest specialization is evident in the diet of the seals of the central Okhotsk Sea, where, obviously, the ribbon seal is the main consideration.

The different trophic relations explain to a considerable degree the unequal numbers of Okhotsk Sea seals. As is to be expected, the species feeding on the lower trophic levels (ringed and bearded seals) surpass in number, as well as in bionass, the species feeding on the higher trophic levels (ribbon and larga seals).

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navaga = *Eleginus navaga*

moiva = *Mallotus villosus* = capelin

koryushka = *Osmerus* sp. = smelt

peschanka = *Ammodytes tobianus* = sand lance

sel'd = *Clupea* sp. = herring

mintai = *Theragra chalcogramma* = pollack

FINAL REPORT OF BEAUFORT SEA ACTIVITIES

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Trophic Relationships Among Ice Inhabiting Phocid Seals

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INTRODUCTION

An extensive area of the Beaufort Sea outer continental shelf is scheduled to be leased for oil development in October 1977. Included within the lease sale area are three major ice dominated marine mammal habitats: the shorefast ice, the transition zone of drifting seasonal ice and the polar pack ice. The nearshore area experiences two "seasons," an ice free period and an ice covered period. Both the geographical and temporal extent of the ice is variable, as is the "quality" of ice dominated habitats. In some years the ice moves offshore more than 200 kilometers and the nearshore areas remain ice free for perhaps two months. In other years the sea ice barely leaves the shore. The polar pack is a persistent feature which usually shows much less annual variation. Needless to say, sea ice exerts a profound effect on the marine fauna and flora.

Several species of marine mammals normally occur within the ice habitats of the Beaufort Sea. From April to June, bowhead whales (Balaena mysticetus) pass Point Barrow on their way from an unknown wintering area in the Bering Sea to their summer feeding grounds in the Beaufort Sea. These whales retreat from the Beaufort Sea when ice reforms in September and October. The smaller belukha or white whales (Delphinapterus leucas) accompany the bowheads north. These small whales often bear their young in coastal lagoons and estuarine systems. They too retreat in autumn as the ice forms. Belukhas are occasionally trapped in polyni where they overwinter or perish as the ice cover becomes complete.

As the pack ice disintegrates and recedes north in the spring, most of the Pacific walrus (Odobenus rosmarus divergens) population also moves north. The majority of these animals summer in the northern Chukchi Sea and off the coast of northeast Siberia. Few walrus penetrate the central and eastern Beaufort Sea. They too move south in the early fall, passing through Bering Strait mainly in the months of October, November and December.

In summer, spotted seals (Phoca vitulina largha) are found along the Beaufort Sea coast, however this species is no more suited to a winter existence in this area than are those mentioned above.

Only three species of marine mammals can be considered year-round residents, these being the ringed seal (Phoca (Pusa) hispida), the bearded seal (Erignathus barbatus) and the polar bear (Ursus maritimus). The hardy arctic fox (Alopex lagopus) ranges widely over all types of sea ice in the Beaufort Sea. However, it is debatable whether it can be considered a truly marine species. All of the above mentioned species are of considerable cultural and economic importance to Alaskan Eskimos and non-native residents of this region. National interest in these animals and the habitats they utilize is also high.

This study has focused on the trophic interrelationships of ice inhabiting phocid seals. The species of particular interest in the Beaufort Sea are the ringed and bearded seals. As it is well understood that all animals act as part of a system in which radiant energy from the sun is captured by plants, passed on to animals and ultimately recycled in the form of organic compounds, an attempt will be made to deal with these two species as part of such a system. However, the intricacy of biological systems is such that even gross simplifications are difficult to render, graphically and/or verbally.

Considerable information is presently available on the distribution and ecology of ringed and bearded seals and more is being generated by current OCS projects. Relatively little work has been done in the specific area under consideration. Pertinent information will be incorporated in the discussion as appropriate.

METHODS AND MATERIALS

Field Collections

Field collections of specimens were made in several ways. The primary method used was the acquisition of specimens from hunters in Native villages. In the Beaufort Sea there are only three coastal settlements, none of which depend on seals as a primary source of food or income. We did manage to obtain several sets of specimens taken by residents of Barrow and Kaktovik (Barter Island). Whenever possible a complete series of standard measurements of each animal was obtained. Jaws, claws, stomachs, reproductive tracts and tissue samples were collected. A listing of measurements made and a description of the procedures followed in measuring seals and in the examination of specimen material are discussed in the 1976 Annual Report for Research Unit #230. For each seal obtained an attempt was made to determine the location, date and time of capture. Determination of the exact location and time of capture was not always possible.

In May 1976, an attempt was made to collect seals during the period when extensive shore fast ice was present. Four ADF&G personnel utilizing a Beaver aircraft equipped with wheel skis were stationed at the Oliktok Point DEW line site with the intention of flying to offshore leads and collecting seals. Inclement weather rendered this attempt futile.

Two ADF&G personnel were aboard the USCGC GLACIER during its Beaufort Sea operations. Seal collection attempts were made from a small boat whenever weather and ice conditions permitted.

A final attempt was made to collect seals in the Beaufort Sea by two ADF&G personnel aboard the NARL R/V NATCHIK. No animals were collected due to poor weather and lack of seals in the area.

Some specimen material was provided by Mr. Jack W. Lentfer, U. S. Fish and Wildlife Service. These specimens were obtained in conjunction with Mr. Lentfer's polar bear research. The material consisted of the remains of seals killed by bears, and sometimes included stomachs containing food.

Specimen material from a bearded seal collected at Barrow 11/15/76 was provided by Dr. A. Blix, University of Alaska, Institute of Arctic Biology.

Laboratory Activities

Stomachs of seals were opened, the contents washed onto a 1 millimeter mesh screen, then preserved in 10 percent formalin. Contents were later sorted and identified to the lowest taxonomic level permitted by their condition, using appropriate taxonomic keys and reference specimens. In the majority of cases identifications entailed the sorting and recognition of small bits and pieces of organisms. Crustaceans were frequently identified by claws, carapaces or abdomens. Fishes were identified on the basis of otoliths and bone fragments. The volume and number of each type of prey item was determined by water displacement and counts of individuals. Size ranges of various prey items were determined when possible.

RESULTS

Field Collections

The results of field collection attempts are shown in Table 1. Locations of these collections are shown in Fig. 1. A total of 21 ringed seal and 3 bearded seal stomachs containing food were collected. Of the ringed seals, 15 were males, 5 were females, and 1 (a polar bear kill) was of unknown sex. Two bearded seals were males, the other a female. With the exception of one ringed seal and one bearded seal taken at Barter Island, all animals were taken in the western Beaufort Sea. Collections were made during the period 4/29/74 through 11/15/76 with the majority of specimens taken during the months of May through August.

Analysis of Stomach Contents - Ringed Seals

Results of our analysis of the stomach contents of 21 ringed seals are shown in Fig. 2. Data are presented for five spatial or temporal subsamples as well as for all subsamples combined. Those prey species which constituted more than two percent of the total volume in one or more of the subsamples are shown. A complete lising of all prey items identified is given in Appendix I.

Fishes accounted for between 0 and 13 percent of the food material found in the various subsamples. With the exception of otoliths from two capelin (*Mallotus villosus*) and one saffron cod (*Eleginus gracilus*), all remains of fish (73 individuals) were from polar cod (*Boreogadus saida*).

Invertebrates constituted the bulk of the food material found. A single seal from Barter Island and three seals killed by polar bears had eaten small numbers of amphipods and shrimps. The samples collected at or near Barrow all contained substantial amounts of euphausiids.

Table 1. Schedule of field work in the Beaufort Sea and summary of specimens obtained.

Location	Dates	Specimens Obtained[1] Ringed Seals	Bearded Seals
Northeast of Pt. Barrow[2]	4/29-5/1/74 and 4/26/75	3	0
Barrow	spring-summer 1975[3]	10	0
Oliktok Point	5/10-5/19/76	0	0
Barrow[4]	5/11-5/25/76	3	0
Barrow	6/13/76	1	0
Barter Island	7/20-8/3/76	1	1
Barrow	8/2-8/10/76	2	1
USCGC GLACIER	8/17-9/3/76	1	0
R/V NATCHIK	9/27-9/30/76	0	0
Barrow[5]	11/15/76	0	1
TOTAL		21	3

[1] only stomachs which contained food are listed

[2] specimens provided by Mr. Jack W. Lentfer, U. S. Fish and Wildlife Service

[3] nine of the ten specimens were obtained from seals purchased by the Naval Arctic Research Lab for polar bear food--time of collection was estimated from physical and reproductive condition of the animals

[4] specimens provided by Mr. Robert Everitt, National Marine Fisheries Service

[5] specimen provided by Dr. A. Blix, University of Alaska, Institute of Arctic Biology

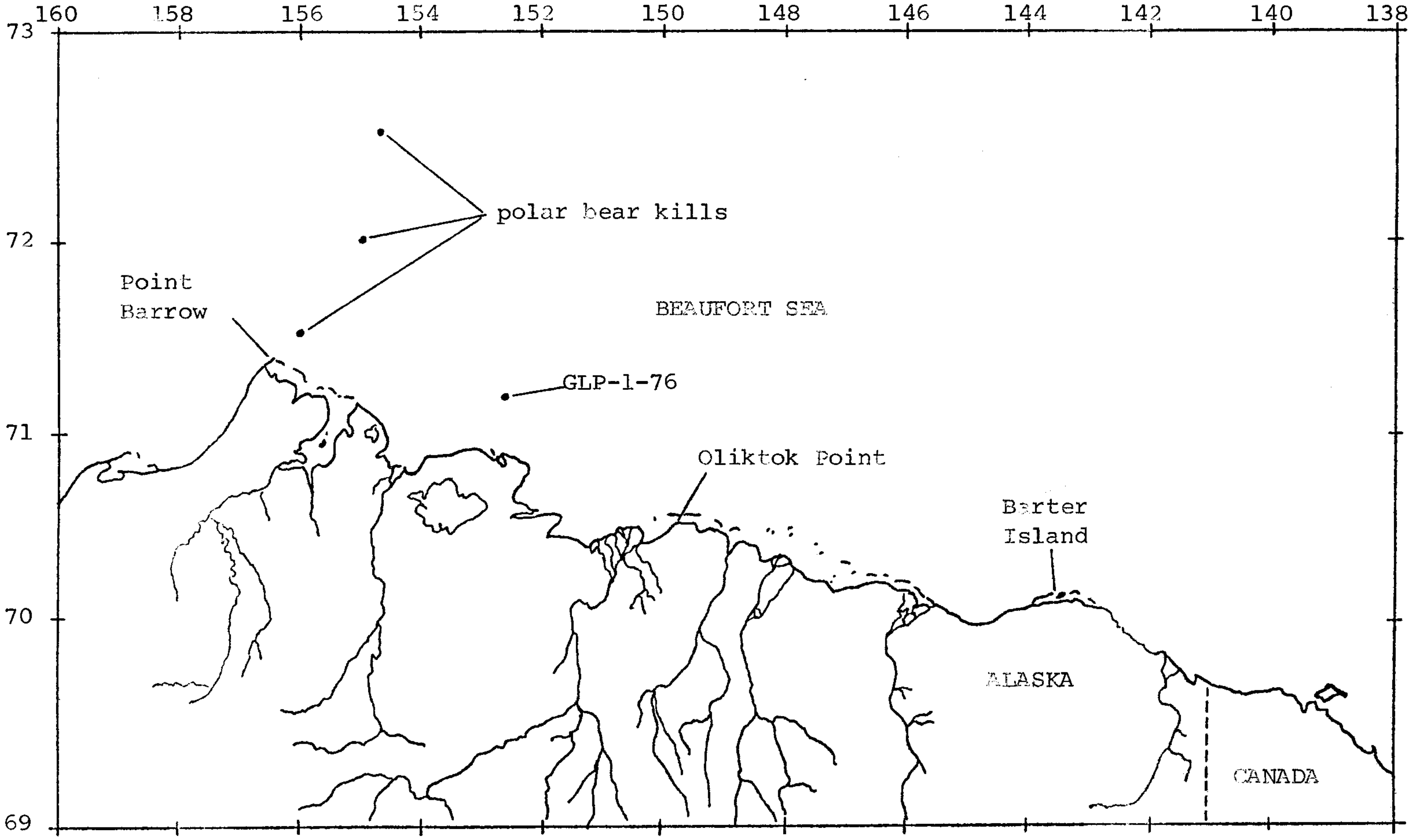

Figure 1. Map of the Beaufort Sea and Alaskan coast showing collection localities

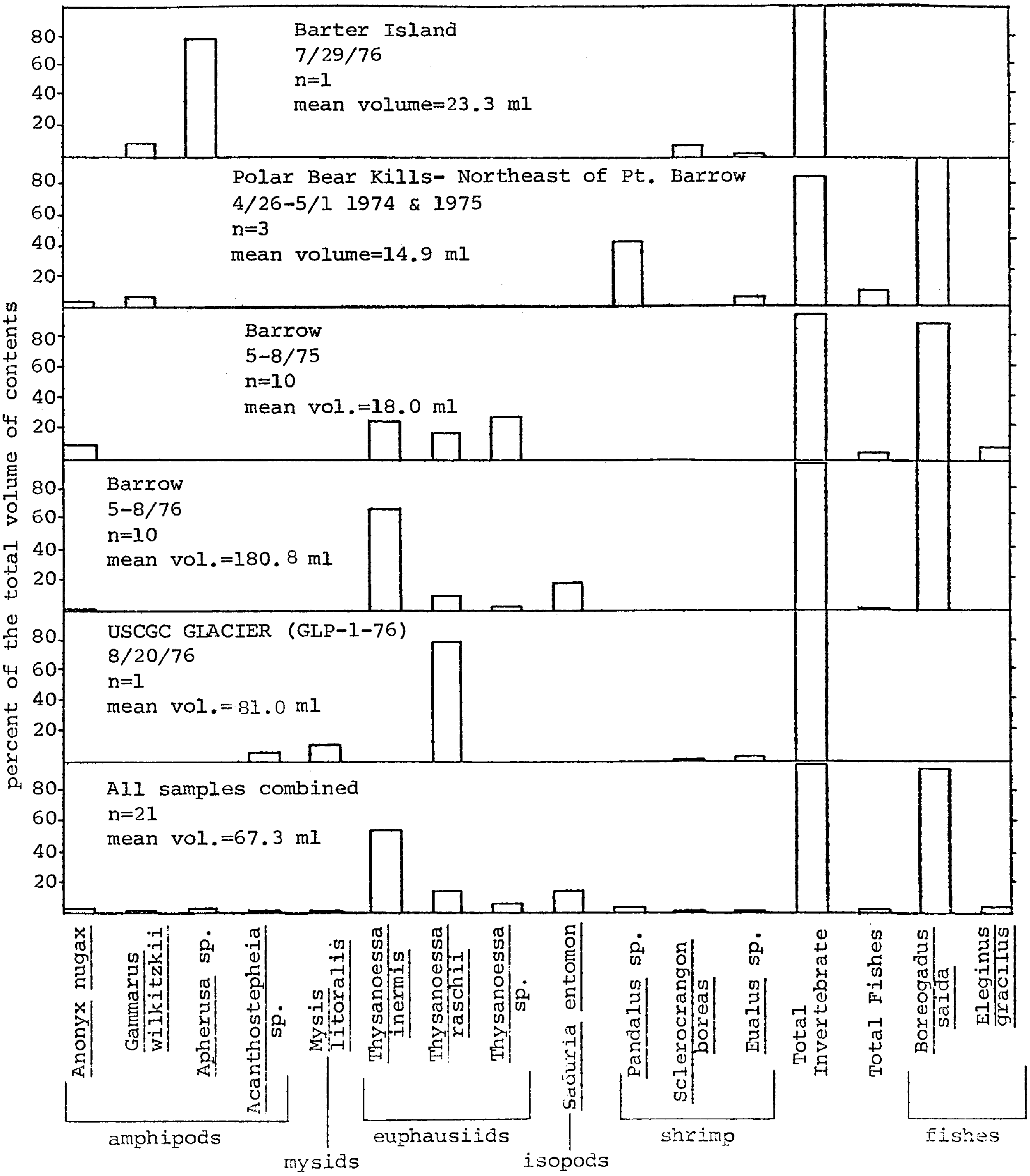

Figure 2. Prey items found in stomachs of ringed seals taken in the Beaufort Sea. Data are expressed as percent of the total volume of contents for total invertebrate material, total fish material and individual species of invertebrates. For the individual species of fishes, data represent the percent of the total number of identified fish represented by that particular species.

Amphipods were frequently found in small volumes in the Barrow samples. The stomach of one animal (BP-6-76) taken on 6/13/76 contained 200 milliliters (ml) of the isopod *Saduria entomon*. This single stomach is responsible for the apparent importance of *Saduria*. The two stomachs with the largest total contents encountered (497 and 234 ml) were both taken on 8/7/76 off Tapkaluk Island. In these two seals food consisted almost entirely of the euphausiid *Thysanoessa inermis*. The single seal collected from the USCGC *GLACIER*, at a point 75 miles west of Barrow, contained mostly *Thysanoessa raschii* and smaller amounts of mysids, shrimps and amphipods. Overall, on a volume basis, euphausiids were the most common food item followed in decreasing order by isopods, amphipods, shrimp, fish and mysids. On the basis of frequency of occurrence, the items most commonly eaten were amphipods followed in decreasing order by euphausiids, shrimps, fishes, mysids and isopods.

Bearded Seals

Only three bearded seal stomachs were collected. The entire contents of one stomach collected at Barter Island on 7/27/76 consisted of a portion of a single shrimp *Eualus gaimardii*. Results of the analysis of the other two stomachs are shown in Fig. 3. In the stomach of the animal collected in August, invertebrates, almost entirely the isopods *Saduria entomon* and *S. sabini*, made up 83 percent of the contents. Otoliths and other recognizable pieces of 39 fishes were found, of these 56 percent were polar cod, 38 percent were sculpins (family Cottidae) and 5 percent were sea snails (*Liparis* spp.). Invertebrates made up 64 percent of the stomach contents of the seal collected in November. This material was mostly amphipods (*Acanthostepheia behringiensis* and *Gammarus wilkitzkii*) and shrimps (*Sclerocrangon boreas*). Fishes made up 34 percent of the food volume. Fish remains were mostly of saffron cod. Sculpins, polar cod, sea snails and eelpout (*Lycodes* spp.) had been eaten in lesser numbers.

DISCUSSION

Specimen Collections

The results of our specimen collections are far from adequate. The two main reasons for this are 1) the lack of intensive seal hunting activities along the Beaufort Sea coast proper and 2) the chronic inclement weather experienced in the area. On several occasions we attempted to make collections utilizing our own personnel. However, since these people were also responsible for collecting material in the Bering and Chukchi Seas, doing the necessary and time consuming laboratory analyses, and preparing reports and proposals, it was not possible to station field teams at several localities for long periods, as would have been desirable. Also, less than optimum logistic platforms and the low priority given to marine mammal collections during multi-project endeavors, hampered our efforts. Given sufficient time and funds, an adequate collection of material could almost certainly be made. Unfortunately, neither the time nor the funds made available to this project were adequate. In spite of our limited sample we will consider the material we have examined together with a knowledge of both the prey species

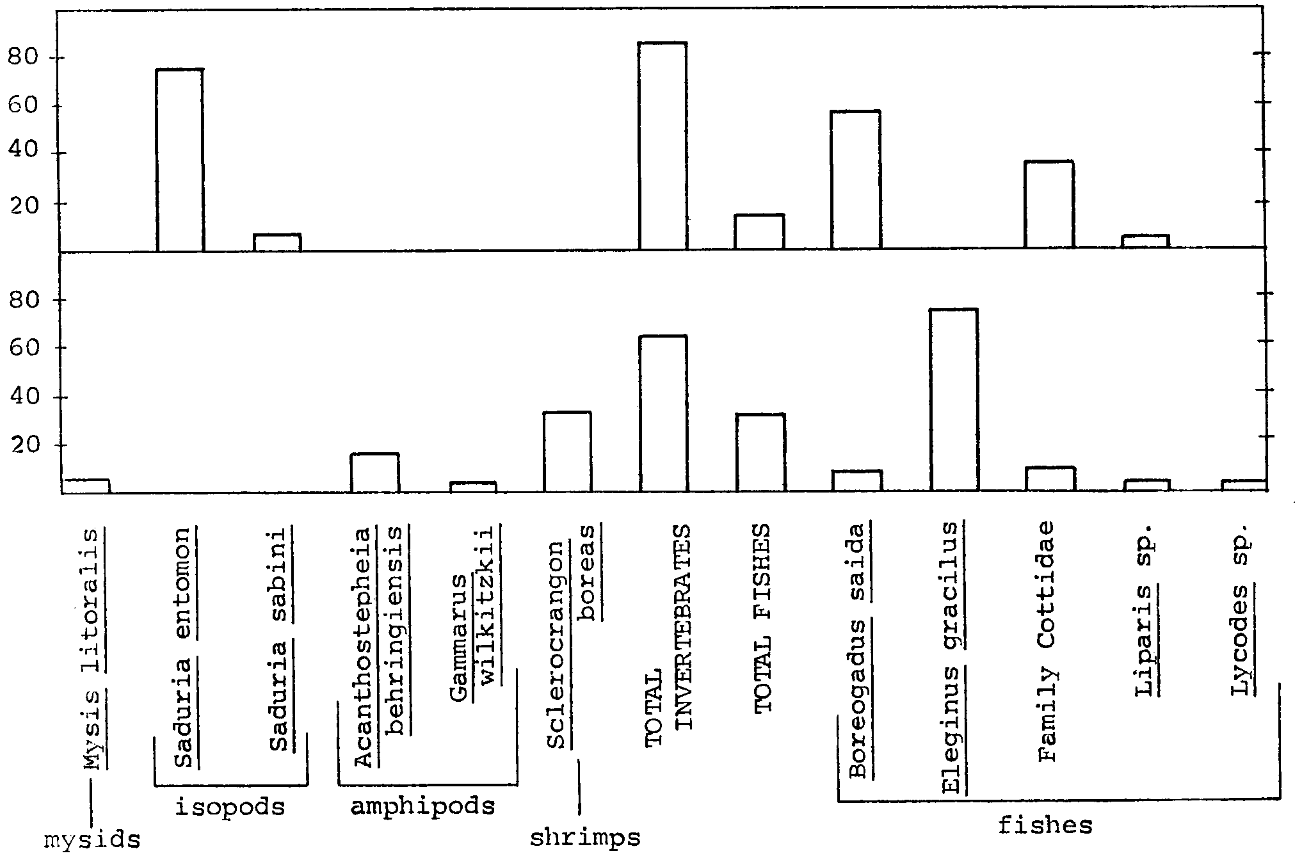

Figure 3. Food remains occuring in the stomachs of bearded seals from the vicinity of Barrow, Alaska. Data are expressed in the same manner as in Figure 2.

available in the Beaufort Sea and the feeding modes and preferences observed elsewhere (see Annual and Quarterly Reports of this research unit) and will attempt in this report to make a realistic evaluation of the trophic relationships of ice inhabiting phocid seals in the Beaufort Sea.

Ringed Seal Foods

Our investigations to date as well as results of previous work (Dunbar 1941, Pikharev 1946, McLaren 1958, Johnson et al. 1966) have shown that ringed seals eat primarily nektonic crustaceans (euphausiids, mysids, and hyperiid amphipods), small benthic crustaceans (shrimps, isopods and gammarid amphipods), and small to medium size, schooling pelagic fishes (polar cod, smelt, capelin and herring). Benthic fishes (sculpins and flatfishes) play a relatively minor role in the diet.

The two most abundant species of euphausiids in the near shore area of the Beaufort Sea are Thysanoessa raschii and T. inermis (Geiger et al. 1968). Redburn (1974), in a sampling of the plankton in the Chukchi Sea off Barrow, found a maximum concentration of 93 T. raschii (mostly juveniles) /100 cubic meters of water on June 22, during the ice covered period. This species had largely disappeared from his samples by the end of August. Thysanoessa raschii was less common in our stomach samples than was T. inermis. According to Nemoto (1966), T. inermis is believed to spawn in shallow waters along the continental shelf. The finding of several thousand individuals of this species in stomachs of ringed seals taken in August indicates presence of high concentrations which might perhaps be associated with spawning. MacDonald (1928) working in the Firth of Clyde (Scotland) found two spawning periods for T. raschii, the first from February to mid Mav and a second from mid August to mid September.

Thysanoessa raschii was the most abundant food item in the stomachs of two ringed seals taken at Barrow in May 1976 and the seal taken from the USCGC GLACIER in late August. The frequency and period of spawning of Thysanoessa spp. in the Beaufort Sea are unknown. However, considering the cold temperatures and short "summer" season in the arctic waters, a single spawning in summer seems most likely (see Dunbar 1957). Redburn noted two periods during which larvae of euphausiids were abundant; the first from the middle until the end of June and the second in late July and early August. Perhaps these two peaks correspond to the spawning periods of the two species. Nemoto (1966) states that the main stocks of T. raschii winter in ice covered waters. Mohr and Geiger (1968) found the abundance of Thysanoessa spp. to be considerably lower under the central polar ice pack than nearshore. It seems likely that euphausiids are eaten to some extent by ringed seals in the Beaufort Sea throughout the year. However, they are probably most important in the diet of seals nearshore in the summer. Thyanoessa spp. feed largely on algae and microcrustaceans (Berkes 1976).

Mysids (Mysis litoralis and Neomysis rayii) occurred only infrequently in our samples from the Beaufort Sea. However, they were found in substantial quantities in samples from other localities (e.g. Mekoryuk and Savoonga). Redburn (1974) encountered mysids only rarely in his collections from the Chukchi Sea near Pt. Barrow. MacGinitie (1955) noted that *Mysis relicta* was at times found washed up in rows on the beaches of Elson lagoon (Barrow area). Crane (1974) encountered high concentrations of *Mysis oculata* in samples from the Beaufort Sea off Simpson lagoon. He estimated a standing stock of 28 milligrams carbon/square meter. It seems likely that at certain locations in the Beaufort Sea, mysids figure significantly in ringed seal diets. The food habits of mysids have been little studied. It seems likely that they consume both animal and plant material.

The hyperiid amphipod (*Parathemisto libellula*) occurred frequently in our samples, but always in low numbers, especially when compared to euphausiids. Dunbar (1941) found *Parathemisto* to be the most important food item in the diet of ringed seals from the Baffin Island area of the eastern Canadian arctic. He later stated (Dunbar 1957) that *P. libellula* "forms the most important link in the food chain between the copepods and other smaller planktonic forms on the one hand, and the vertebrates on the other, and in fact it takes the place, in cold water, of the euphausiids in this respect." While this may be the case in the eastern Canadian arctic, our samples indicate that it is definitely not so in nearshore waters of the western Beaufort Sea. This emphasizes the need for information specific to the locality under consideration. MacGinitie (1955) noted that *P. libellula* was extremely abundant at Barrow, while Redburn (1974) found them to be less common than gammarid amphipods, reaching maximum concentrations under the ice in spring and early summer. Mohr and Geiger (1968) consider *Parathemisto* an important food source for whales in waters north of Alaska. Undoubtedly *Parathemisto* is a potentially important food item for ringed seals.

Although ringed seals from the Beaufort Sea which we have examined had eaten almost entirely nektonic crustaceans, samples from other areas indicate that they readily eat a variety of more benthic forms.

As mentioned in the results section of this report, one ringed seal taken at Barrow had eaten a large quantity of the isopod *Saduria entomon*. This is the most common species of isopod in the area (MacGinitie 1955) especially in shallow waters seaward of the barrier islands. In these areas Crane (1974) found a standing stock of 9.24 milligrams carbon/square meter. Crane postulated that the biomass of *Saduria* in this zone might be greater during the ice covered season because they may migrate out of lagoons due to the high salinity of water beneath the ice. McCrimmon and Bray (1961) working in the Canadian region of the Beaufort Sea found biomass to be highest on muddy bottoms (0.46-0.93 grams/square meter). They caught no animals of this species in waters deeper than 24 fathoms (44 meters). *Saduria entomon* and its two less abundant congeners *S. sibirica* and *S. sabini* are probably important ringed seal foods particularly near shore during the ice covered period. In summer the ice edge will frequently occur over water too deep for *Saduria* spp. and if the ice is close to shore, euphausiids may be the preferred food. *Saduria entomon* is known to be both a scavenger and a predator on benthic and near bottom organisms (McCrimmon and Bray 1961, Green 1957).

Gammarid amphipods are a conspicuous and diverse element of the Beaufort Sea fauna (MacGinitie 1955, Shoemaker 1955). Although primarily benthic, several species make use of the inverted substrate provided by the undersides of ice floes in arctic waters (Barnard 1959, George and Paul 1970, Tencati and Leung 1970). In most of the ringed seal stomachs we examined, gammarids were found in very small quantities and were likely ingested incidentally in the process of foraging near the bottom. The stomach of our single specimen from Barter Island contained almost entirely gammarid amphipods. Interestingly, the two species eaten, Gammarus wilkitzkii and Apherusa sp. are very common near the under surface of ice (Barnard 1959, Tencati and Leung 1970). Redburn (1974) found gammarids in his plankton samples to be most common during the early summer, with the population density decreasing during the seasonal transition to open water. Gammarid amphipods are typically considered scavengers and predators on small benthic organisms. Animals collected from the undersides of ice floes had no recognizable animal material in their guts (Barnard 1959).

Shrimps of several species are commonly encountered in the stomachs of ringed seals at all locations we have sampled to date. Squires (1969) found Sabinea septemcarinata and Eualus gaimardii to be the two most common species occurring in the Canadian Beaufort Sea. MacGinitie (1955) notes that Eualus gaimardii was the shrimp he collected in greatest numbers, while Sclerocrangon boreas was "the largest and most abundant of the larger shrimps taken at Point Barrow." An analysis of two otter trawls made by us in late August, east of Point Barrow, in 123 and 40 meters of water showed Eualus macilenta, E. gaimardii and Sabinea septemcarinata to be the most common species. Shrimp undoubtedly enter into the diet of ringed seals in the Beaufort Sea. The finding of a relatively large volume of Pandalus sp. in stomachs of seals killed well offshore by polar bears during April and May is interesting and perhaps significant. Shrimp are known to feed on a variety of benthic plants and animals (Squires 1969).

The polar cod (Boreogadus saida) is probably the most common fish in the Beaufort Sea (MacGinitie 1955, McAllister 1962, Milne and Smiley 1976). In spite of this, the basic biology of this species is only imperfectly known. The distribution of polar cod is closely related to the presence of ice, with the majority of the population believed to stay under or near the edge of compact ice (Svetovidov 1948, Andriyashev 1954, Ponomarenko 1968). Andriyashev (1954) indicates that in fall large schools are found near shore, especiallv in warm relatively fresh water near river mouths. Our general observations indicate that the selection may, in fact, be for ice, which forms considerably earlier in fall and at higher water temperatures in brackish and fresh water areas. Not surprisingly, polar cod were the fish most commonly eaten by the ringed seals we examined from the Beaufort Sea. Usually only otoliths were found. In cod these are relatively very large. When portions of the fish were found, it was usually the remains of one or two individuals in stomachs which contained mostly euphausiids. When ringed seals encounter concentrations of polar cod, they probably eat them in large quantities. Polar cod feed mostly on zooplankton and amphipods and to a lesser extent on benthic crustaceans (Svetovidov 1948, Barnard 1959, and personal observations).

Otoliths representing two capelin (*Mallotus villosus*) were found in one of the 21 ringed seal stomachs from the Beaufort Sea which we examined. Otoliths of capelin are much smaller than those of polar cod and probably do not persist as long. The significance of capelin as a prey item is therefore probably underestimated. Capelin are a benthopelagic species of the continental shelf (Andriyashev 1954). In the Beaufort Sea, capelin come to shore to spawn in late July, at which time they are extremely abundant. At Pauline Cove in the Canadian Beaufort Sea, about 1500 pounds were caught on July 29, 1960 with 8 hauls of a 60 foot beach seine (McAllister 1962). Polar cod are sometimes found in association with, and feeding on, juvenile capelin (Gjosaeter 1973). At certain times and places capelin may be an important ringed seal food. These small fish are known to eat copepods, hyperiid amphipods, euphausiids and other microzooplankton (Jangaard 1974). Two capelin stomachs examined by Kendal et al. (1975) contained mysids.

Otoliths of saffron cod (*Eleginus gracilus*) were found in one of the seal stomachs examined. Although this species of gadid is capable of surviving and reproducing in arctic waters, saffron cod are much less abundant then polar cod in the Beaufort Sea. None were caught in our trawls, nor were any found in the extensive work of McAllister (1962) in the Canadian Beaufort Sea.

Several other species of fish are potential ringed seal foods in the Beaufort Sea. These include the rainbow smelt (*Osmerus esperlanus mordax*) and the Pacific herring (*Clupea harengus pallasii*) both of which spawn in coastal bays and rivermouths shortly after ice breakup, the sand lance (*Ammodytes hexapterus*) which forms schools near the bottom in water about 100 meters deep, and two nearshore benthic fishes, the arctic flounder (*Liopsetta glacialis*) and the fourhorn sculpin (*Myoxocephalus quadricornis*). In light of the material we have examined, it appears that these species are of slight importance to ringed seals, especially in comparison to the other species mentioned above.

Ringed seals are found almost throughout ice covered seas of the northern hemisphere. However, their density in any given area is closely related to ice conditions. In late March and early April, ringed seal pups are born in lairs excavated in snow covered ice (McLaren 1958, Burns 1970, Smith and Stirling 1975). Although stable landfast ice is the preferred area for pupping, and the greatest density of seals occurs there, pups are also born on heavy drifting ice. Ringed seals of the drifting ice probably constitute the largest proportion of the total population because of the vast areas of drifting ice habitat. There are some indications that older, more experienced females may occupy the preferred breeding habitat (McLaren 1958, Burns 1970). Subadult animals are often found congregated along transient lead systems (Stirling et al. 1975; Burns, unpubl.).

Subsequent to pupping and breeding, ringed seals undergo a period of molting during which they spend a large amount of time hauled out on the ice and are relatively easy to observe and count. During this period it seems that feeding intensity is quite low (McLaren 1958, Johnson et al. 1966). The overwintering population of ringed seals in the western Beaufort Sea is and may have for many years been relatively low. Burns and Harbo (1972) estimated the minimum population on the shorefast ice in June 1970 to be 8,717 animals. There are strong indications that the size of the population has decreased since then, perhaps in response to heavy ice conditions (Burns, unpubl. data). In summer, the population size increases with the seasonal influx of animals from the south. During the summer season ringed seals are found throughout the restricted ice covered waters. With the onset of winter and expansion of the ice cover, the area occupied by ringed seals expands accordingly. Specific details of these movements are largely unknown.

A schematic representation of the food web of ringed seals in the Beaufort Sea is presented in Fig. 4. For the sake of simplicity, only known or portentially important food items are indicated. It is obvious that nektonic crustaceans, especially euphausiids, are the most important organisms in this region, not only supporting ringed seals directly, but also functioning as a primary food source for polar cod and capelin. The abundance of euphausiids probably fluctuates throughout the year, reaching a maximum after the summer spawning period, then decreasing as consumers take their toll. The importance of euphausiids is probably roughly proportional to their abundance. The coincidence of maximum euphausiid abundance with the end of the molt associated period of reduced feeding by ringed seals, and the influx of seals from southern waters may accentuate their importance as a forage item. These speculations are reinforced by the findings reported here.

Polar cod are probably taken by ringed seals throughout the year since they, as well as the seals, are feeding on euphausiids. The importance of polar cod in the diet may be highest in offshore areas and in the winter months.

Capelin are only available in large concentrations in early summer. However, such a food source could be heavily exploited by animals having recently fasted during the molt.

Shrimps, amphipods and isopods are available and abundant. However, our observations indicate that they are of minor importance in the western Beaufort Sea in the summer. At some locations in the Chukchi Sea, shrimps and isopods form the bulk of the ringed seal's diet. It is likely that at some times and localities they would be eaten in quantity by ringed seals in the Beaufort Sea.

The underside of sea ice is known to support a relatively dense growth of algae during late spring and summer. It appears that a community consisting of copepods, amphipods and polar cod is associated with this under ice flora. Barnard (1959) found no recognizable animal material in guts of amphipods collected from ice island T-3. Two polar cod examined had fed exclusively on the amphipod Apherusa glacialis. The source of energy in this system during lightless months is unknown.

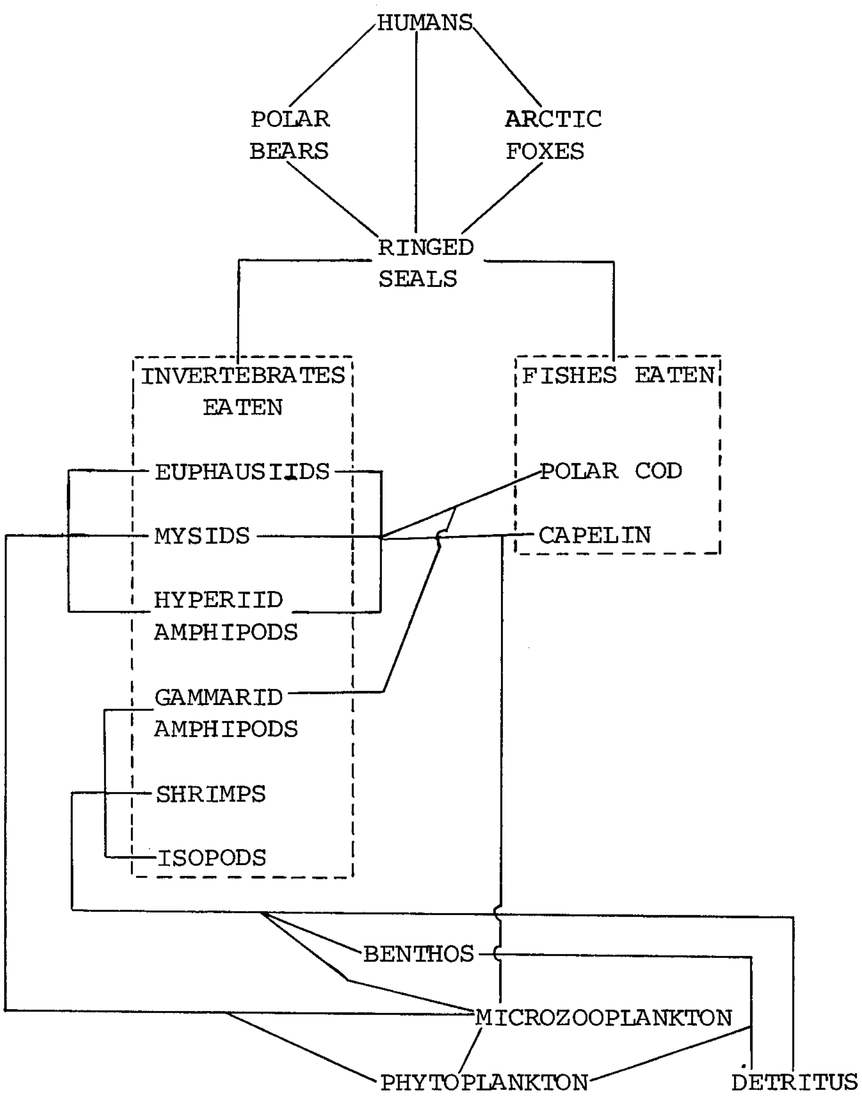

Figure 4. Schematic food web of ringed seals in the Beaufort Sea

Heterotrophy has often been suggested. However, at least for diatoms this does not appear to be a major source (Horner and Alexander 1972). A considerable portion of the productivity associated with the sea ice community occurs in enclosed brine pockets (Meguro et al. 1966) and is unavailable to herbivores except at the time of spring melt. The interactions in this system obviously deserve more investigation as the organisms in it may be a very important food source for ringed seals, especially in the winter.

Bearded Seal Foods

Bearded seals are known to feed on a wide variety of benthic organisms (Kenyon 1962, Kosygin 1966, Johnson et al. 1966, Burns 1967). In our examinations of bearded seal stomachs taken at several locations in Alaska, we have found animals representing at least 9 phyla of invertebrates and 8 families of fishes. In spite of such a diverse diet relatively few types of organisms comprise the bulk of the food; these are bivalve molluscs, crabs, shrimps and sculpins.

The bivalve molluscs *Serripes groenlandicus* and *Clinocardium ciliatum* are eaten in large quantities when and where they are available (see Quarterly Report RU#232, September 30, 1976). These species do not appear to be common in the Beaufort Sea as none were reported by Hulsemann (1962) or Crane (1974) and they were found at only a few stations by Carey (1976). Other bivalves (e.g. *Yoldia*, *Macoma*, *Mya*) are common, but we have not encountered them in bearded seal stomachs. Indeed it seems as if some behavioral or morphological pecularity of *Serripes* and *Clinocardium* makes them particularly suitable for consumption by bearded seals, as only the foot portions of these clams are eaten.

Isopods (*Saduria* spp.) made up the bulk of food contents in one of the bearded seal stomachs from Barrow. When ice conditions are such that bearded seals can forage nearshore, *Saduria* probably forms a major portion of the diet. Some aspects of the biology of *S. entomon* were discussed in the previous section.

Shrimps are important food items of bearded seals. They were found in appreciable quantity in almost all net samples and from all localities we have examined. In the previous section, a brief discussion was given of the abundance of various species of shrimp in the Beaufort Sea. Although our data have not yet been quantitatively analyzed, information from other localities seems to indicate a greater importance of the more heavily armored, perhaps slower moving, crangonid shrimps in bearded seal diets.

Two species of brachyuran crabs which are commonly found in bearded seal stomachs from other localities were also found in the Beaufort Sea. These are *Chionocetes opilio* and *Hyas coarctatus*. MacGinitie (1955) noted that *Hyas* was the most abundant of the true crabs and was found in nearly every haul took. Carey (1976) reported *Hyas* from 10 stations. We encountered numerous individuals in both of our trawl samples from the Beaufort Sea. Chionocetes was not reported by Carey (1976) and was found at only five stations by MacGinitie (1955). This crab occurred in one of our trawl samples. Hyas was about 100 times more abundant than Chionocetes in the Canadian Beaufort Sea samples of Squires (1969). The ratio of Hyas to Chionocetes was about 6 to 1 in our trawls. Both species feed on benthic organisms, particularly crustaceans (Squires 1969).

A variety of other invertebrates which are potential bearded seal prey items occur in the Beaufort Sea. These include gastropod molluscs, octopus, echiuroids, sea cucumbers, priapulids, amphipods and annelids. Without additional samples it is impossible to evaluate their importance.

Our data from various locations in Alaska indicate that sculpins (family Cottidae) are the fishes most commonly eaten by bearded seals. This is very understandable as they are benthic forms which would likely be encountered while foraging along the bottom. Comprehensive fish surveys of the offshore Beaufort Sea are nonexistent. Our trawl samples indicate the most common benthic fishes to be sculpins (Gymnocanthus, Triglops, Icelus and Artediellus), eelpout (Lycodes and Gymnelis), poachers (Aspidophoroides), sea snails (Liparis) and pricklebacks (Lumpenus and Eumesogrammus). All of these are probably consumed at some time by bearded seals. The two most common nearshore benthic fishes are the fourhorn sculpin and the arctic flounder (Percy 1975, Kendel et al. 1975). These species may be of considerable importance in bearded seal diets when the seals are feeding nearshore. In general, these fishes feed on benthic and near bottom crustaceans, pelecypods and polychaetes.

The majority of fish remains in the bearded seal stomachs we examined from Barrow were those of polar and saffron cod. Although polar and saffron cod have been found in samples from other localities, benthic fishes were always much more common. The apparent importance of polar cod in the Beaufort Sea may be artifactual or perhaps an indication of the great abundance of this species in this area. The finding of several saffron cod in the stomach of the bearded seal collected in November may indicate that this species is common at that time of year. No adequate sampling of marine fishes has ever been done in the Beaufort Sea during the ice covered period.

Unlike ringed seals, bearded seals are seldom found on landfast ice. Rather they are most common in the transition zone and offshore pack ice (Burns 1967, Burns and Harbo 1972, Stirling et al. 1975). The western Beaufort Sea unlike the Chukchi Sea and northern Bering Sea has a relatively narrow continental shelf with the hundred meter contour occurring mostly within 40 km of shore. As 100 meters is probably close to the maximum effective feeding depth for bearded seals, the western Beaufort Sea does not offer a very large foraging area. This is especially true in the winter when landfast ice extends 20 to 40 km offshore resulting in a relatively narrow band of proper ice type and water depth. It is perhaps possible for bearded seals to forage on polar cod when both occur over deep water. However, such pelagic foraging does not appear to be the usual case. The suggestion of MacGinitie (1955) that bearded seals use their whiskers to sweep amphipods from undersides of ice floes is intriguing but finds no support in our investigations. In summer the potential feeding area for bearded seals would be somewhat larger and they may find the large isopod concentration of the near shore zone attractive. As was the case with ringed seals, the bearded seal population shifts northward in the summer. The majority of animals appear to stay over the shallow Chukchi platform rather than moving into the Beaufort Sea (personal observations).

Figure 5 is a schematic representation of the food web of bearded seals in the Beaufort Sea. Again only potentially important food items are shown. Unfortunately, having looked at such a limited amount of material, we can do little more than suggest what items might be important. Hopefully future studies may eliminate or reinforce some of the possibilities.

Interaction with other Marine Mammals

As mentioned in the introduction, several species of marine mammals in addition to ringed and bearded seals are found in the Beaufort Sea in summer. A general summary of the major food items of all species is given in Table 2.

To the best of our knowledge no data about food habits of spotted seals or belukha whales taken in the western Beaufort Sea occur in the literature. Therefore the food items indicated are surmised from our observations and those of other investigators (Sergeant and Hoek 1974, Mansfield et al. 1975, Goltsev 1971) from specimens taken at other localities. Both species feed largely on fish, shrimp and cephalopods. Belukha may tend to feed more on pelagic forms (e.g. squid and polar cod) while spotted seals probably consume more of the benthic forms (e.g. octopus and sculpins) in their diet. As is obvious from Table 2, the foods of both of these species broadly overlap those of ringed seals. Off the north coast of Alaska both spotted seals and belukhas are present only in the late spring-fall and tend to stay nearshore, often at or in the mouths of rivers. It seems therefore that the foraging of belukhas and spotted seals is largely geographically and temporally separated from that of ringed seals, although many of the prey species may be similar.

Perhaps a more significant trophic competitor of ringed seals is the bowhead whale. MacGinitie (1955) mentioned that bowhead whales eat euphausiids, mysids, pteropods and copepods. Mitchell (1975) states that bowheads eat amphipods and various small to medium size zooplankton. We have had an opportunity to examine subsamples of two stomachs of bowheads taken at Barrow during September 1976. These samples were remarkably similar to samples of ringed seals from the same locality. They contained mostly euphausiids and lesser amounts of gammarid and hyperiid amphipods and mysids. Although the present population of bowhead whales is fairly small, probably numbering between fifteen hundred and three thousand animals, the size of the animals is so great that the daily consumption of a single medium sized whale would exceed that of 150 ringed seals. One wonders what effect the decimation of the

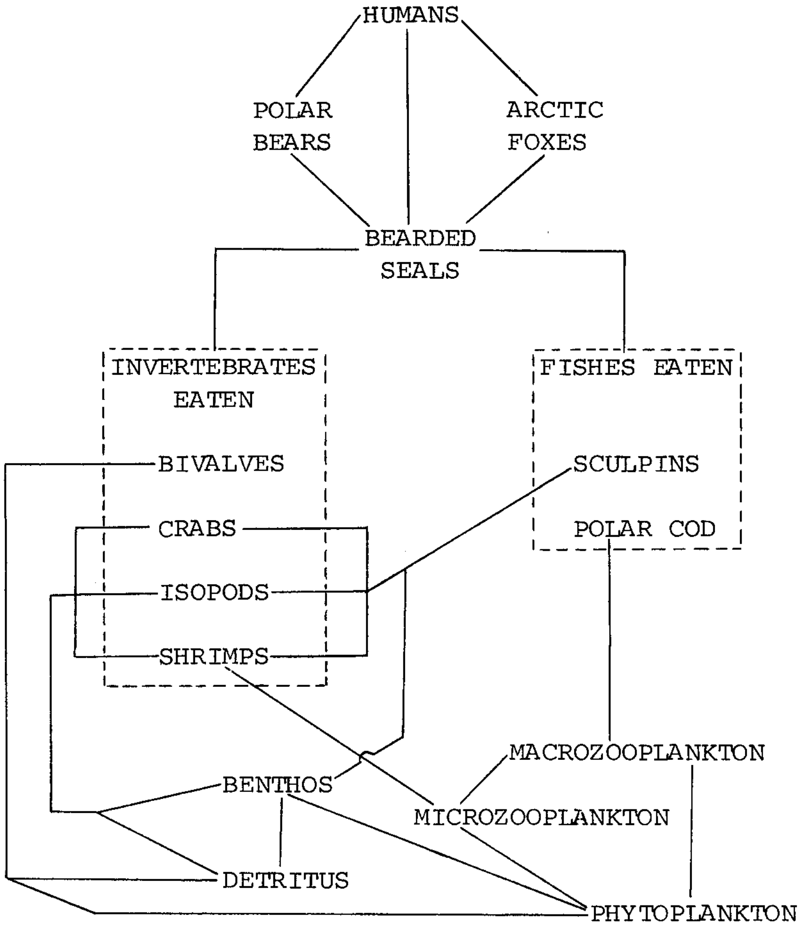

Figure 5. Schematic food web of bearded seals in the Beaufort Sea

Table 2. Summary of major food items of marine mammals in the Beaufort Sea - *** indicates items of major importance; ** indicates items of moderate importance; * indicates items of slight importance.

Food item	Bowhead Whale	Ringed Seal	Spotted Seal	Belukha Whale	Bearded Seal	Walrus
Euphausiids	***	***				
Mysids	**	**				
Hyperiid Amphipods	**	**				
Gammarid Amphipods	**	**			*	
Shrimps		**	**	**	***	
Crabs					***	*
Isopods		**			**	
Bivalve Molluscs					**	**
Gastropod Molluscs					*	**
Cephalopods			*	**	*	*
Other Benthos					*	***
Polar Cod		***	**	**	*	
Capelin		**	**	**		
Other Pelagic & Anadromous Fishes		*	***	***	*	
Demersal Fishes		*	**	*	***	

bowhead whale population has had on the trophic structure of the Beaufort Sea. It is perhaps significant that so far in our investigations the Beaufort Sea is the only area where euphausiids figure prominently in the diet of ringed seals.

As discussed earlier, the Beaufort Sea does not support a large number of bearded seals probably because of the limited habitat. The same is probably the case for walruses. Historically, the number of walruses found east of Pt. Barrow has been quite low. The majority of animals summer in the northern Chukchi Sea and north of Siberia near Wrangell Island. In the Bering Sea in spring, walruses feed largely on bivalve molluscs (L. Schults, pers. comm.). A casual examination of the stomach of a walrus taken northeast of Pt. Barrow revealed mostly sea cucumbers and lesser amounts of priapulids, gastropods and bivalves. This very limited sample further substantiates the speculation that the bivalve fauna of the Beaufort Sea is relatively sparse and extremely patchy, at least as regards those species suitable for consumption by walruses and bearded seals. Trophic interaction of these two species in the Beaufort Sea is probably very limited.

Shrimps and a variety of fishes are utilized by ringed, spotted and bearded seals and belukha whales. Our data are too limited at present to give a meaningful detailed analysis of potential interactions with regard to these food sources. Bearded seals tend to eat more sedentary benthic forms, while ringed seals, spotted seals and belukha whales eat more nektonic species.

The trophic interactions between polar bears and seals are quite simple. Where they both occur, polar bears kill and eat seals. The seal most available to polar bears is the ringed seal (Lentfer 1972). Bearded seals are taken much less frequently. There are several reported instances of polar bears attacking and eating belukha whales (Freeman 1973, Heyland and Hay 1976). This apparently happens most frequently when belukha have become trapped in small polynyi by the formation of new ice. Bears frequently scavenge on carcasses of bowhead whales and walruses. It is possible for them to occasionally kill a walrus. It is unlikely that bears often encounter spotted seals as their distributions hardly overlap.

Arctic foxes frequently scavenge the remains of polar bear kills, as well as any other carcasses of marine mammals. They also kill and eat ringed seal pups which are restricted to subnivian lairs (Smith and Stirling 1975, Smith 1976). Because of their small size, it is unlikely that arctic foxes ever kill healthy, weaned seals.

Productivity and Food Chains

Differences among seasonal conditions in the Beaufort Sea ecosystem are extreme. In the winter the sun does not shine. The sea surface is covered by ice from October through June or July. As a result of these two factors alone, primary productivity is essentially zero throughout the winter. As the daylight increases and especially in May and June, an algal flora develops on and in the undersurface of the ice. This bloom of epontic algae is followed by a planktonic bloom in August, when the open water period occurs (Alexander 1974). Total annual primary production is probably on the order of 15-20 grams carbon/square meter. Although relatively low, this production supports a crop of primary consumers which is evidently adequate to feed a variety of fishes, marine mammals and seabirds. The tremendous numbers of birds breeding and feeding along the Beaufort Sea coast are undoubtedly a most important factor in the trophic structure of the area. An evaluation of their role and importance is beyond the scope of this report and will hopefully be dealt with by other projects.

Figures 6a and 6b illustrate some pathways by which epontic and planktonic algae may contribute to the support of marine mammals. The under ice community is likely exploited mostly by ringed seals. As the ice melts, a major pulse of food may reach the benthos from released epontic algae. The planktonic algal bloom is used by a larger number of species through more diverse pathways. With such an apparent abundance of euphausiids in the system it is perhaps possible that the algae are quite efficiently grazed resulting in a rather small input to benthic filter feeders. Indeed it appears that the populations of sponges and tunicates in the Beaufort Sea are quite low (personal observations) although this may be a substrate related phenomenon. It is interesting to note that the two species for which the Beaufort Sea appears to be a very important foraging ground, ringed seals and bowhead whales, can both feed directly on euphausiids thereby resulting in a very short food chain.

Two other potential sources of nutrient input to the Beaufort Sea ecosystem are production by benthic algae and detritus from terrestrial and marine sources. To the best of our knowledge, production by benthic algae has not been studied, but because of the lack of marine macroalgae it would likely be quite limited (Mohr and Tibbs 1963). The numerous large rivers emptying into the Beaufort Sea undoubtedly contribute a tremendous pulse of terrestrial detritus at spring breakup. A significant amount of material may enter the system from marine sources such as carcasses and feces of marine mammals and birds. However, the magnitude of this source would be very difficult to estimate.

Some of the potential pathways for utilization of energy in the benthic communities are shown in Fig. 6c. Omnivores such as shrimp, crabs, isopods and amphipods are very important in benthic food webs.

Potential Effects of Oil Development

The main concerns of this project are to understand the trophic relationships among marine mammals and to assess the potential effects, on seals, of changes in the trophic structure of the Beaufort Sea caused by OCS exploration and development. If the magnitude and kinds of changes to be expected were known, our task would be relatively easy. However, such work as has been done on the fate and effects of hydrocarbons in marine systems merely emphasizes the complexity of the problem and, as yet, has yielded little of predictive value.

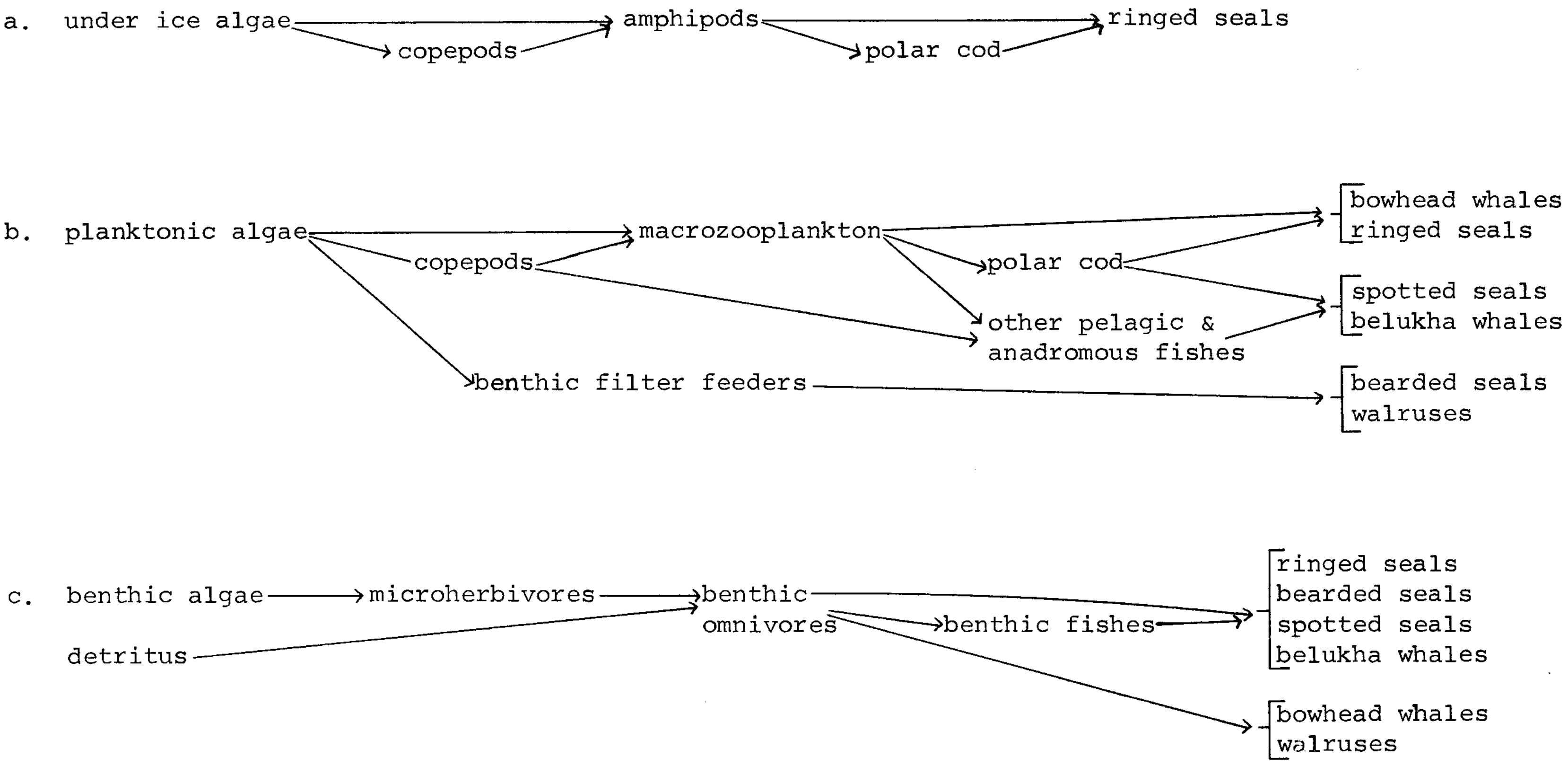

Figure 6. Trophic webs for energy inputs resulting from a) under ice algae, b) planktonic algae, and c) benthic algae and detritus

In order to assess the impact of oil in the environment in a quantitative sense, two sorts of information must be available. First, the quantities and kinds of petrochemicals expected to be released into the environment must be estimated. In addition, the probable vertical and horizontal distribution and persistance of these compounds must be known. From this, the duration and concentration of the various chemicals in various habitats (e.g. under ice, water column, sediments) must be predicted.

The second kind of information required is an evaluation of the effects of expected levels of petrochemical pollution on representative organisms. Consideration must be given to effects on all life history stages as well as to sublethal effects which may significantly alter long-term population levels. This information coupled with knowledge of the concentrations of pollutants which might occur and an understanding of basic biological parameters (e.g. seasonal movements, reproductive rates, growth rates) of the species under consideration might allow a prediction of the expected effects on population levels of the species tested. If the species tested were well chosen and a sufficient knowledge of ecological interactions such as food dependencies and competition existed, an evaluation of effects at the ecosystem level might be attempted.

It appears that an estimate of the potential quantity and expected resultant distribution of petrochemicals resulting from OCS development has yet to be made. Milne and Smiley (1976) estimate the barrels of oil per day expected to be released by a blowout, but do not consider the concentration of various hydrocarbons that might result in different habitats or their specific aerial and temporal distribution. To the best of our knowledge, this problem is not being dealt with in the Alaskan OCS program.

Numerous ongoing projects presently deal with lethal levels and sub-lethal effects of petrochemicals on marine organisms. Unfortunately, few of the organisms being tested appear important in the food webs of marine mammals in the Beaufort Sea. Therefore our discussion of potential effects of OCS development on food webs of seals will, of necessity, be inconclusive and brief.

The majority of oil released into the Beaufort Sea would be expected to rise to the sea surface. During winter, this oil would accumulate under and, to some extent, be incorporated into sea ice (NORCOR Engineering and Research Ltd., 1975). The immediate and perhaps most significant effect of this oil under ice would be a decrease in light penetration and productivity in the area. In an area where low primary productivity supports a high biomass of consumers, such an effect would be quite significant if the aerial extent were large. Percy and Mullin (1975) found that the amphipod Onisimus affinus, closely related to Onisimus nanseni which is common under ice floes (Barnard 1959), was killed by high concentrations of oil in water or sediments and tended to avoid oil contaminated foods and sediments. Thus the presence of oil under ice could directly effect a potentially important food source of ringed seals. An overall reduction of primary production would undoubtedly decrease the production of euphausiids. This, in turn might dramatically effect bowhead whales and ringed seals. The direct effects of oil on larval and adult euphasuiids have evidently not been investigated. In fact, oil near the surface would potentially effect reproductive success of many forms having planktonic larvae, although the general tendency toward suppression of larval stages in arctic forms (Chia 1970, Marshall 1953) may tend to reduce this effect.

A certain amount of oil would undoubtedly become mixed in the sediment. Saduria spp. have proven to be very resistant to oil pollution while fry of Myoxocephalus quadricornis are extremely sensitive (Percy and Mullin 1975). Juvenile stages of gadids are also extremely sensitive to petrochemicals. As discussed earlier, the Beaufort Sea is probably not a prime feeding area for bearded seals or walruses, and the benthos is of secondary importance as a food source to the other species of marine mammals.

Needs for Further Study

In our opinion, an investigation of the distribution, productivity and tolerance to petrochemical pollution of euphausiids, Thyasanoessa inermis and T. raschii, and of polar cod is absolutely essential. These species form important links in the food chains of marine mammals and seabirds in the Beaufort Sea, and any severe detrimental effects on them would likely have catastrophic effects on higher trophic levels. Bowhead whales which are apparently highly dependent on euphausiids for food are presently greatly reduced in numbers.

Further work is required to evaluate the relative importance of under ice fauna, macrozooplankton, and benthos in the diet of ringed seals. Samples obtained during the months when ice is present and throughout the year in offshore areas are particularly needed, however they will be difficult to obtain.

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APPENDIX I. Taxonomic listing of species found in ringed seal (RS) bearded seal (BS) stomachs from the Beaufort Sea.

- Phylum Arthropoda
  - Class Crustacea
    - Subclass Copepoda
      - Order Calanoida RS
    - Subclass Malacostraca
      - Superorder Peracarida
        - Order Mysidacea
          - *Mysis litoralis* RS, BS
          - *Neomysis rayii* RS
        - Order Isopoda
          - *Saduria* (= *Mesidotea*) *entomon* RS, BS
          - *S. sabini* BS
        - Order Amphipoda
          - Suborder Gammaridea
            - *Apherusa* sp. RS
            - *Acanthostepheia* sp. RS, BS
            - *Atylus* sp. RS
            - *Anonyx nugax* RS
            - *Gammarus wilkitzkii* RS, BS
            - *Gammaracanthus loricatus* RS, BS
            - *Onisimus* (= *Pseudalibrotus*) sp. RS
            - *Weyprechtia* sp. RS, BS
          - Suborder Hyperiidea
            - *Parathemisto libellula* RS
            - *P. abyssorum* RS
      - Superorder Eucarida
        - Order Euphausiacea
          - *Thysanoessa inermis* RS
          - *T. raschii* RS, BS
          - *T. longipes* RS
        - Order Decapoda
          - Suborder Natantia
            - *Eualus gaimardii* RS, BS
            - *E. macilenta* BS
            - *Lebbeus polaris* RS
            - *Pandalus* sp. RS
            - *Sclerocrangon boreas* RS, BS
          - Suborder Reptantia
            - *Hyas coarctatus* BS

- Phylum Mollusca
  - Class Pelecypoda
    - *Musculus* sp.
  - Class Cephalopoda
    - Unidentified squid RS

- Phylum Annelida
  - Class Polychaeta RS, BS

APPENDIX I. (continued)

- Phylum Chordata
  - Subphylum Vertebrata
    - Class Osteichthyes
      - Family Gadidae
        - *Boreogadus saida* RS, BS
        - *Eleginus gracilus* RS, BS
      - Family Osmeridae
        - *Mallotus villosus* RS
      - Family Liparidae BS
      - Family Cottidae BS
        - *Myoxocephalus quadricornis* BS
      - Family Zoarcidae
        - *Lycodes* sp. BS

APPENDIX I

THE EFFECTS OF HUMAN DISTURBANCE ON A POPULATION OF HARBOR SEALS

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Tugidak Island (56°30'N. 154°40'W), one of the Trinity Islands, is located in the Gulf of Alaska 20 miles southwest of Kodiak Island. About 18 miles long and four to seven miles wide, its sand and pebble beaches are used by large concentrations of harbor seals (*Phoca vitulina richardi*) throughout the year.

From 1965 to 1971 Alaska Department of Fish and Game (ADF&G) personnel conducted investigations of the Tugidak harbor seal population, including the tagging of over 4,300 pups, in conjunction with monitoring the intensive seal hunting operations on the island. With the passage of the Marine Mammal Protection Act of 1972, hunting operations ceased, and ADF&G discontinued the study. The present project was undertaken in 1976 by ADF&G in order to assess the population during a relatively undisturbed period to provide data to compare with past and future studies. This paper reports the effect of human disturbance on seals from May through September, 1976.

The study consisted of daily field observations of a 3-mile stretch of beach at the southwest end of the island, where about two-thirds of the population regularly hauled out. Occasional observations were also made on the other haul out area regularly used by the seals, a 10-mile stretch of beach at the northeast end of the island, to aid extrapolations

During the pupping season (May 15 to July 4) about 4,000 seals regularly hauled out on the island. This number increased dramatically during August to a peak of about 13,000 in early September. Over 1,000 pups were born in the primary study area, and the total estimated production for the island was 2,000 pups, though the actual number may have been somewhat higher.

The following is a brief summary of our findings on disturbances. Sections 1 and 2 provide background information and Section 3 offers preliminary conclusions concerning the effects of disturbance on the population.

1. Behavior of Mother-Pup Pairs

Harbor seal pups are generally born on land, although there is one reported case of a captive harbor seal successfully giving birth in the water (Johnson 1969), and there is circumstantial evidence that this may occasionally occur in the wild (Venables and Venables 1955). Prior to birth, the pregnant female hauls out in or near a group of seals and after an average of one-half hour of visible labor, gives birth. The first two hours after birth are the most critical for the pup's ultimate survival. Initially, the pup is disoriented and lacks coordination. During this period the mother frequently initiates "nose-to-nose" contacts and the resulting exchange of sensory information provides the basis for future mutual recognition. Generally, within one hour of birth the pup moves with its mother into the water, where, after an initial 15-30 minutes of disorientation, it rapidly becomes a proficient swimmer. On the average, the first nursing takes place two hours after birth (on land or in the water), further establishing the mother-pup bond.

Under normal circumstances the mother and pup remain together constantly for about three weeks. During the next week or two, periodic separations may be normal, and weaning occurs about the fifth week after which the pup leaves the area. A permanent separation of mother and pup during the first week of the pup's life usually leads to the death of the pup within two weeks. Permanent separations, occurring in the second or third week of life greatly reduce the pup's chance of survival, but early death is not inevitable. Upon separation from its mother a pup will approach and attempt to nurse off virtually any lactating female. Adult females are more discriminating than the pups, however, and will seldom allow any pup but their own to suckle, thus the chances of stolen meals or adoption are rare.

2. Mortality

As only a portion of a seal's life is spent ashore, harbor seal mortality is difficult to assess. The situation on Tugidak is further complicated because high tides frequently cover the entire beach, so carcasses seldom remain in the same place for over a day. With the exception of one tagged seal collected as part of the study, only three dead adults were seen during the study period. This adult mortality seems low for a population which numbered over 13,000.

The observed pup mortality was also undoubtedly a low figure. Fifty-three fresh pup carcasses were found at the southwest end of the island, representing 5 percent of the known pup production. Pup mortality in the first three months of life has been reported at 13 to 21 percent (Boulva 1975, Johnson 1969). As further evidence that beach dead carcasses represented only part of the actual pup mortality, 66 starveling pup were counted during one census in late June, more than the total accountable pup mortality (starvelings are unattended pups of such emaciated condition that there is virtually no chance of their survival). Even though the actual pup mortality is an elusive figure, the number of dead and starveling pups seen in 1976 can be used as an indicator of pup mortality, and can be compared with future work on Tugidak.

Causes of pup mortality on Tugidak were similar to those reported in other studies (Boulva 1975). Although stillbirths, premature births, injuries and illness could account for some deaths, most pups died from starvation, directly resulting from a permanent separation of the mother and the pup. A large number of these separations occurred within the first hour and a half of the pups' lives, either because of outright abandonment by the female, or more frequently because of a major disturbance.

3. "Natural" Disturbances

Harbor seals are a vigilant animal, spending much of their time ashore alert and orienting around the environment. Haul out locations are generally characterized by easy access to water, and are located in areas which are difficult to approach unseen.

Any loud or sudden noise, or the appearance of an unfamiliar object can lead to the desertion of a haul-out area by a seal herd. "Natural" disturbances (not man-related) were of two intensities. If the disturbance was minor, sending just a portion of the group into the water, seals returned rapidly to the haul-out sites. However, a major disturbance, which sent all the seals into the water, was often followed by a long period with seals milling about offshore, and when the animals did return to shore the previous haul out area was usually avoided.

The tendency to leave haul-out areas at the slightest provocation frequently resulted in separation of mothers and pups. This was especially true of mothers with very young pups. Although some reunions took place, often these separations were permanent.

Minor disturbances to the seals of Tugidak Island generally involved localized bird activity, small clay slides, or aggressive interactions; all affecting only a section of one group. Major disturbances resulted either from an eagle landing near or in a group, or from a massive rock slide; both of which caused great panic among the seals with all the seals in the area becoming alert, then rushing into the water.

During the pupping period seals hauled out in small discrete groups along the 3-mile study area. Minor disturbances to the groups were frequent. Occasionally a birth sent surrounding lone seals to the water, more often gulls arriving at a birth site to clean up the detritus of parturition caused small flights. Females pass the placental membranes an average of 30 minutes after the birth of their pup, and most females attempted to defend both the membranes and their pup from the persistent birds. These activities frequently sent many nearby seals into the water, including other mother-pup pairs, but the small number of seals involved created a minimum amount of confusion, and the seals generally hauled-out again within minutes. On occasion, the passage of the placental membranes would attract one or more eagles to the birth area, resulting in a massive exodus of all the surrounding seals to the water, often including the new mother. Any recently born pups were left ashore during this rush, lacking the locomotory ability as well as the practice to follow their mother to the water. Although cases of a female returning ashore to her newborn pup were observed, many separations of the mother and the pup were permanent. Older pups were frequently separated from their mothers during the move to and through the surf. Both females and pups approached other seals in the surf, but the chances of reunions were inversely proportional to the degree of the disturbance and the number of seals affected--the more seals in the water and the longer before hauling out began, the less the liklihood that a female would locate her pup.

4. Effects of Low Flying Aircraft

Planes of various types were frequent at Tugidak throughout the summer. Table 1 lists the dates and sizes of low flying aircraft, and includes only those high altitude planes which were observed to have an effect on the hauled out seals. Although planes flying at altitudes over 1,000 feet often caused seals to leave the haul out areas, they were seldom

Table 1. A list of aircraft over the beaches of Tugidak with date, time and altitude from mid-May through September, 1976.

Date	Time	Aircraft	Altitude
5-16	1400	large plane	250'
5-18	1200	helicopter	75'
5-20	1200	small plane	400'
5-24	1715	small plane	
5-25	1500	small plane	700'
5-31	1500	small plane	
6-02	1300	helicopter	75'
6-07	1115	small plane	50'
	1300	helicopter	50'
	1630	small plane	300'
6-10	0900	large plane	
	1430	helicopter	100'
6-18	1130	helicopter	
6-19	1400	helicopter	30'
	1515	helicopter	30'
6-20	1310	small plane	800'
6-21	0900	helicopter	30'
6-23	1600	small plane	
6-25	1700	helicopter	
	1730	small plane	
6-26	1830	helicopter	50'
6-27	0830	helicopter	50'
7-07	1500	small plane	400'
7-10	0930	helicopter	40'
	1145	helicopter	90'
7-14	0830	helicopter	
7-15	1200	small plane	1000'
7-17	1045	helicopter	30'
7-20	0900	helicopter	
7-31	1700	jet over island	
	1900	jet over island	
8-5	1500	helicopter	
8-12	1400	small plane	250'
8-16	1300	small plane	750'
8-19	1700	helicopter	100'
8-20	1400	jet over island	
8-22	1300	helicopter	20'
9-02	1400	small plane	700'
9-08	1710	small plane	800'
9-09	1510	large plane	1000'
9-10	1150	large plane	1000'
9-21	1430	small plane	700'

responsible for a total desertion of the beach. Aircraft flying at 400 to 1,000 feet had varied effects, depending on four factors; the weather, the frequency of recent disturbances, the type of aircraft, and the altitude. All other things being equal the effect of low flying aircraft on a group of seals is likely to be greater on a calm day than on a "noisy" day, with strong winds, rough seas or rain. Frequent disturbances in an area increase the wariness and disturbability of the seals, helicopters and large planes are more disturbing than small planes, and the lower the altitude the greater the reaction of the seals.

Aircraft flying at altitudes under 400 feet, particularly less than 100 feet, nearly always resulted in most or the seals in each herd entering the water. If all the seals in a group left the haul out beach, they rarely hauled out again at the same spot, instead, they cruised the shoreline looking for any seals which remained hauled-out, or waited for an "adventuresome" animal to choose a new location. If all the seals entered the water (e.g. when a helicopter flew over at 25 feet) at least two hours passed before the seals began to reuse the beach. The effects of low flying aircraft were therefore similar to the effects of major natural disturbances, except that natural disturbances were confined to one locality, while aircraft frequently circled the island causing the entire population to abandon all haul out areas.

Although low flying aircraft over seal haul-out areas are definitely disruptive to the normal daily activity patterns of the seals and thus may have a long term effect on the mortality rate of the population, the only direct evidence of resulting increased mortality was obtained during the pupping season. During the height of the pupping season, 10 June to 20 June, we saw an average of 1.5 births per hour of observation in the study area (2/3 of island population). Since two observers were able to watch slightly less than 1/2 of the seals in this area, we estimated that there were a total of approximately 5 births per hour on Tugidak during this period. Because of their particular vulnerability, pups born within two hours before a major disturbance, or one-half hour after, were likely to become permanently separtated from their mothers in the resulting confusion, especially if there had been a large number of seals onshore. Thus, any aircraft flying at less than 100 feet, circling the beaches of Tugidak during the peak pupping period can be considered responsible for the separation and ultimate death of about twelve newborn seal pups, plus an unknown number of older pups. Based on the number of births per hour throughout the pupping season and frequency of flights around Tugidak, we estimate that aircraft alone were directly responsible for the deaths of over 150 newborn pups, and up to twice that many slightly older pups. Therefore, the moderate number of low flying aircraft visiting Tugidak during 1976 may have accounted for the deaths of more than 10 percent of the pups born on Tugidak. In addition to aircraft, other human disturbances on Tugidak included all-terrain vehicles and hikers, each having effects similar to aricraft; thus the total human related pup mortality would be even higher.

Although the above calculations are speculative, it is clear that low flying aircraft have a deleterious effect on harhor seal populations. We therefore recommend that the number of aircraft flying over Tugidak (and other concentrations of harbor seals) be reduced, particularly during the pupping season--from 1 June to 15 July on Tugidak, and also during the molt from 15 August to 15 October on Tugidak, when seals are again particularly vulnerable the molt is a period of physiological stress for seals, when they must remain onshore to attain skin temperatures sufficient to promote growth of the new hair.

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Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska

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SUMMARY

This investigation is directed towards the life history and biology of the Steller sea lion (*Eumetopias jubatus*) in the Gulf of Alaska and is designed to provide basic information about population status, distribution, movement patterns, segregation, use of critical habitat population composition and dynamics, growth, pathology, food habits and trophic relationships. Achievement of these goals is being accomplished through concurrent subprojects involving: (1) aerial photographic census and distribution surveys; (2) autecological investigations; and (3) a study of food habits and trophic relationships.

Breeding rookeries and hauling areas throughout the Gulf of Alaska are defined and located. The most important breeding rookeries in the Gulf are Sugarloaf Island and Marmot Island. These two rookeries produce nearly one-half of all pups born each year in the Gulf of Alaska.

A total of 7,046 sea lion pups have been branded in the Gulf at six rookeries. The branding has shown a movement of sea lions across the Gulf to the east and to the south from Marmot and Sugarloaf Island. This movement takes place in the late fall, away from the rookeries. They probably return in the spring. Pupping and breeding does not appear to be substantially different from that reported elsewhere. Lactation probably takes place throughout much of the female's adult life. Delay of implantation appears to last about 3 months. Females become sexually mature at 3 to 5 years of age. Ninety percent of all females 5 years or older were pregnant.

Fishes were the most important component of the diet, followed by cephalopods and decapod crustaceans. The primary food item was *Theragra chalcogramma* and others of importance were *Trichodon trichodon, Gadus macrocephalus*, and *Mallotus villosus.*

Sea lions are particularly vulnerable to OCS oil and gas development through direct and indirect contamination and disturbance. In order to avoid substantial effects on sea lion populations, it is imperative that activities on or near major breeding and pupping rookeries such as Marmot Island and Sugarloaf Island be kept to an absolute minimum during the months of May, June and July. Oil contamination of habitat and food sources must be avoided.

INTRODUCTION

This project is a broadly based investigation of the population status and biology of the Steller sea lion in the Gulf of Alaska. Basic objectives are to provide information on population status, seasonal distribution, movement patterns, population composition and segregation and use of critical habitats. We are also examining food habits and basic trophic relationships. Reproductive biology is being examined in order to provide the parameters necessary for population productivity calculations. Other objectives include collection of data on growth, pathology and environmental contaminant levels.

The project is designed to closely examine the potential impact of development associated with exploration for, development of and transport of crude oil and natural gas reserves in the Gulf of Alaska. Delineation of rookeries, hauling grounds, feeding areas and their seasonal use patterns is very necessary as it has been shown that disturbance can modify use and even cause abandonment (Thorsteinson and Lensink 1962, Pike and Maxwell 1958). Population level and productivity should be determined before development in order to evaluate possible effects. Knowledge of the degree of segregation is important so that localized kills or disturbances can be evaluated in terms of importance to the total population. The importance of establishing trophic relations in the Gulf is evident. Activities which reduce basic productivity would eventually reduce the carrying capacity for high level consumers such as sea lions.

Basic objectives of the project are as follows:

To determine numbers and biomass of Steller sea lions in the Gulf of Alaska. To establish sex and age composition of groups of sea lions utilizing the various rookeries and hauling grounds. To determine patterns of animal movement, population identity and population discreteness of sea lions in the Gulf. To determine changes in seasonal distribution.

To investigate population productivity and growth rates of Steller sea lions in the Gulf of Alaska with emphasis on determining age of sexual maturity, overall reproductive rates, age specific birth rates and duration of reproductive activity.

To determine food habits of Steller sea lions in the Gulf of Alaska with emphasis on variation with season, area and habitat type. An effort will be made to relate food habits with prey abundance and distribution. To collect information on pathology, environmental contaminant loads and use of critical habitat.

Current State of Knowledge

A reservoir of general knowledge exists on pinnipeds but specific information on sea lions in the Gulf of Alaska is lacking. With the exception of the Prince William Sound area, population assessment studies have not been carried out in the Gulf since 1956-1958 (Mathisen and Lopp 1963). Changes in seasonal distribution are only partially understood. In general, it appears there is considerable movement from summer rookeries to wintering areas. There is no information about the proportions or composition of animals involved in such movements, nor the direction, rate or extent of movement. Large scale movements of Steller sea lions in Oregon have been noted by Mate (1973). Bartholomew and Boolootian (1960) suggested that seasonal migratory movements were correlated with age and sex in California. Seasonal movements are known to occur in British Columbia although they are not fully understood (Spalding 1964 and Smith 1972).

Composition of animals using the various rookeries and hauling grounds in the Gulf of Alaska is unknown although some degree of sex and age segregation obviously takes place. Data collected from various sea lion rookeries in Prince William Sound suggested they were not a discrete population but that there might be a considerable interchange with other areas, possibly from the large rookeries of the Kenai Peninsula and Kodiak area (Pitcher and Vania 1973).

Our knowledge of reproduction and growth in the Steller sea lion is supported by inadequate information. Data from other species of marine mammals (Sergeant 1966, 1973) suggest that population productivity may be a good indicator of relationship to carrying capacity. Laws (1959) showed that seals with plentiful food supplies grew faster and became sexually mature earlier, thus increasing population productivity. There are some indications that reproductive rates of sea lions in Alaska are lower than in other portions of their range (Brooks 1957, Pike and Maxwell 1958 and Thorsteinson and Lensink 1962).

Previous studies of food habits have been incidental in nature and all were done during summer months. Fiscus and Baines (1966) reported on the stomach contents of four animals taken in the Gulf. Species encountered included: *Ammodytes*, *Mallotus*, *Sebastes*, cottids and cyclopteridae. Imler and Sarber (1947) found *Theragra*, *Oncorhynchus*, *Platichthys*, *Microgadus*, *Hippoglossus Atheresthes*, *Raja* and *Octopus* in seven sea lions collected from the Barren Islands, Chiswell Island and Kodiak. Thorsteinson and Lensink (1962) reported on nine animals which contained food items from Marmot Island. They identified rockfishes, greenlings, sandlances and cephalopods.

Study Area

Population assessment activities are being conducted at rookeries and hauling grounds in the Gulf of Alaska from Cape Spencer to Scotch Cap on Unimak Island. Specific sampling areas from which we have collected or plan to collect sea lions include Kayak Island, Middleton Island, Prince William Sound, the Kenai Coast, Barren Islands, Marmot Island, Kodiak Island and Chirikof Island.

Sources, Methods and Rationale of Data Collection

Sea lion population data have been collected by three major methods. The first was aerial surveys of sea lion rookeries and hauling areas along the coast of the Gulf of Alaska. Recent procedures for aerial surveys of sea lions have proven quite effective because of the considerable body of information available about sea lion behavior and seasonal and diurnal activities (Orr and Poulter 1967, Sandegren 1970, Mate 1973, Bigg 1973, Fiscus 1969 and Fiscus and Baines 1966). Aerial surveys of hauling areas consisted of flying by in either fixed-wing aircraft or helicopters and photographing all hauled out animals with hand held, motor driven 35 mm cameras. The rookeries were approached to within 50 meters at an altitude of approximately 200 meters and overlapping photos were taken. From the developed photos a mosaic was constructed and numbers of animals were counted.

The second method of data collection on sea lion populations consisted of visiting selected rookeries for sex and age composition counts and marking pups. The marking system used is that of highly visible hot brands (Smith et al. 1973, Rand 1950, Scheffer 1950, Chittleborough and Ealey 1951). These brands were standard cattle type brands applied to the front shoulder of the sea lion pup. The iron, heated by propane gas, measured approximately 4 cm by 8 cm. Six rookeries were selected for branding on the basis of numbers of pups produced and location. Rookeries where pups have been branded are Marmot Island which is off the east side of Afognak Island, Sugarloaf Island in the Barren Islands, Outer Island one of the Pye Islands off the eastern Kenai coast, Fish Island in the Wooded Islands off Montague Island in Prince William Sound, Seal Rocks between Montague Island and Hinchinbrook Island in the entrance to Prince William Sound and Cape St. Elias.

Branding took place in late June and early July shortly after the pups were born. Gothic style letters were used and coded to the specific rookeries. Through the use of letter brands applied to different portions of the animal, it is possible to mark pups for several years and still distinguish between age classes and location of birth. Recovery of branded animals was through the collection of individuals and direct observation during sex and age composition counts on specific rookeries and hauling areas.

The third method of collecting information on sea lion populations has been through observations made while aboard vessels engaged in collecting sea lions and harbor seals. Crews of these vessels generally have contributed local knowledge about sea lion populations.

Data on growth, development, condition, reproduction, food habits, pathology and environmental contaminant loads are being obtained from the analysis of specimen materials from collected sea lions. These animals have been collected systematically from different areas throughout the year. This was done to detect variations in food habits and body condition with season, area and habitat type.

Weights and standard measurements were taken from each collected animal including total weight, blubber weight, standard length, curvilinear length, axillary girth, and blubber thickness (Scheffer 1967). These data were collected to establish growth rates and assist in making calculations of biomass.

The ovaries and uterus were taken from each female and preserved in formalin. Standard laboratory techniques for reproductive analysis were used through which the presence or absence of a conceptus in the uterus was determined and a partial reproductive history was reconstructed by examination of ovarian structures. These data were necessary for determination of ages of sexual maturity and age specific birth rates which are basic parameters required for population productivity calculations.

Testes and epididymides from each male sea lion were collected and preserved. A microscopic examination was made of epididymal fluid to determine whether sperm were present or not. This is necessary for determination of age of sexual maturity and periods of seasonal potency in males.

Age determinations were made for each animal. This was done by decalcifying a tooth from each animal, using a freeze microtome to produce thin sections, staining the thin sections with hematoxylin and counting the annual growth rings with the aid of a microscope (Johnson and Lucier 1975). Age determinations are necessary for assessment of growth rates and to determine population structure and productivity.

Stomach contents from each animal were preserved in formalin, weights and volumes were determined for all contents. Identifications of prey species were made by examination of recognizable individuals and skeletal materials of diagnostic value. Frequency of occurrence of prey species was then determined. Intestinal contents from each sea lion were strained through mesh sieves to recover fish otoliths. Otoliths, which are diagnostic to species, were compared to a reference collection and identified (Fitch and Brownell 1968). Tissue samples were collected and frozen so baseline levels of heavy metals, pesticide residues and hydrocarbons eventually can be determined.

RESULTS AND DISCUSSION

Breeding Rookeries and Hauling Areas

Two complete surveys of all of the known sea lion breeding areas and haul outs were accomplished during the year, as well as several partial surveys. Most haul outs were surveyed in March and June 1976. The Kenai Peninsula and northern Kodiak were surveyed in October 1975, and several areas around Kodiak, Chirikof and the Semidi Islands were surveyed in October 1976. The south side of the Alaska Peninsula was surveyed in March 1977. Only preliminary information is available from the March 1977 survey.

It is apparent from our surveys that a number of the previously identified haul out areas are not used on a regular basis. Often in the past, any area where one or more sea lions has been observed has been classified as a hauling area and any hauling area or portion of a hauling area where breeding and pupping activity occurred was considered a rookery. These definitions imply the existance of only two types of areas and have lead to considerable confusion.

In fact, there is a great deal of variability in the use of various areas by sea lions. Some are used continuously by many sea lions, some are used regularly but seasonally and many are used only sporadically by small numbers. Similarly, although most sea lions breed and pup on areas that are clearly major rookeries, some breeding and pupping activity occurs on areas that function primarily as hauling areas.

The broad definitions of rookeries and hauling areas used in the past have tended to over-rate the importance of some areas of minor significance to sea lions. We feel it is more appropriate to redefine these areas in a manner that reflects their primary use and importance to the populations. The following definitions will be used for this project:

Rookery - Any area where a large percentage of the sea lions present from the period of late May to early July are taking part in breeding and pupping. A rookery may become a hauling area during the rest of the year.

Hauling Area - Any area where sea lions haul out on a regular, predictable basis.

Stopover Area -All areas where sea lions have been sighted on land but only on an irregular basis and in low numbers.

Table 1 lists those "stopover" areas where sea lions have been sighted in the past but which do not appear to warrant classification as hauling areas. No sea lions were sighted at most of them during our surveys. Some of them had sea lions only once and generally, in this case only very few. Some of these areas are intertidal rocks which are exposed only at the lowest tides. Others are steep rock faces where sea lions are unlikely to haul out.

Table 1. Locations in the Gulf of Alaska where sea lions have been sighted but which are not considered true hauling areas.

Name	Latitude/ Longitude
Porpoise Rocks	60°19'10"N, 146°41'30"W
Fox Point	60°34'20"N, 146°00'00"W
Knowles Head	60°41'10"N, 146"38'10"W
Pleiades Is.	60°13'42"N, 148°00'50"W
Latouche I.	59°56'25"N, 148°02'25"W
Danger I.	59°55'30"N, 148°04'45"W
Fountain Rocks	59°32'15"N, 146°20'00"W
Wessels Reef	59°47'00"N, 146°10'00"W
Cape Junken	59°55'04"N, 148°38'25"W
Barwell I.	59°51'45"N, 149°16'40"W
Hive I.	59°53'12"N, 149°22'00"W
Aialik Cape	59°42'00"N, 149°32'00"W
Nuka Point	59°17'30"N, 149°32'00"W
Flat Island	59°19'40"N, 151°59'20"W
Sud I.	58°53'29"N, 152°12'49"W
Tonki Cape	58°20'45"N, 151°59'00"W
Ugak Island	57°22'15"N, 152°16'15"W
Sundstrom Island	56°41'30"N, 154°08'15"W
Bert Point	56°58'00"N, 153°53'00"W
Cape Hepburn	56°57'25"N, 153°57'50"W
Cape Alitak	55°50'45"N, 154°18'00"W
Sturgeon Head	57°30'30"N, 154°37'50"W
Noisy Islands	57°55'30"N, 153°33'00"W
Malina Point	58°02'30"N, 153°22'00"W
Steep Cape	58°12'00"N, 153°12'30"W
Cape Paramanof	58°18'15"N, 153°02'45"W
Augustine Rocks	59°13'30"N, 153°22'00"W
Cape Nukshak	58°23'30"N, 153°52'50"W
Cape Ugyak	58°16'35"N, 154°06'10"W
Cape Kuliak	58°08'00"N, 154°13'00"W
Foggy Cape	56°32'35"N, 156°58'45"W
Kumlik Island	56°36"45"N, 157°37'15"W
Atkulik Island	56°16'50"N, 157°44'05"W
Seal Cape	55°59'20"N, 158°25'50"W
Mitrofania I.	55°50'15"N, 158°41'45"W
Kupreanof Point	55°33'55"N, 159°35'45"W
Whaleback I.	55°16'50"N, 160°05'05"W
Haystacks	55°16'30"N, 160°03'10"W
Unga Cape	55°07'55"N, 160°31'25"W
Simeonof I.	54°51'50"N, 159°18'00"W
The Twins	54°57'35"N, 159°52'00"W
Wosnesenski I.	55°09'40"N, 161°20'20"W
Cherni I.	54°37'20"N, 162°22'30"W
Cape Lazaref	54°28'40"N, 163°35'07"W

Many of the areas listed as haul outs are also breeding and pupping rookeries. Small numbers of pups, usually less than 50, are born and some breeding activity occurs at several other hauling areas. While these are in fact small rookeries, their importance to the overall reproductive effort of the population appears minimal. These areas are more appropriately classified as regular hauling areas. Table 2 presents a list of the major breeding and pupping rookeries within the study area. A total of 17,950 pups are estimated to be produced in the Gulf of Alaska study area. The most important single rookery is Marmot Island with a breeding period population of 9,862 sea lions and an estimated annual pup production of 5,000 pups. Sugarloaf Island in the Barren Islands closely follows Marmot in importance. These two rookeries make up the geographic center of the sea lion population in the northern Gulf of Alaska.

Table 2. Sea lion breeding and pupping rookeries found in the Gulf of Alaska, June 1976.

Location	Lat./Long.	No. of sea lions counted June 1976	Estimated annual pup production	Notes
Seal Rocks		1,709	500	
Outer Island		3,847	750	
Sugarloaf Island		5,226	3,500	
Marmot Island		9,862	5,000	
Twoheaded Island		1,615	800	
Chirikof Island		2,391	1,000	
Chowiet Island		4,679	2,000	Surveyed only in Oct. 1976
Puale Bay		3,166	1,500	
Atkins Island		2,726	1,500	
Churnabura Island		1,437	700	
Lighthouse Rocks		1,315	700	Surveyed only in Oct. 1976
Total		37,973	17,950	

The following is an account of all known areas where sea lions haul out on a regular basis. Each of these areas has been photographed at least twice in the last year. Figures 1 through 6 show the locations of these haulouts in the Gulf.

Venisa Point and Sugarloaf Island 58°39'20"N, 137°39'10"W

Located on the north side of Graves Harbor, Greg Strevelar (U.S. Park Service, pers. comm.) reported sighting 11 sea lions hauled out on the south side of Sugarloaf Island in July 1974 and 3 at Venisa Point in June 1974. No sea lions were sighted here on the surveys of March and June 1976. This area is probably of minor importance and used only during periods of local abundance of sea lion prey species.

Harbor Point 58°39'20"N, 137°39'10"W

On the south entrance of Lituya Bay, Strevelar (pers. comm.) reported 40 sea lions in July 1970. A total of 5 sea lions were sighted here in March 1976 and none in June 1976. This hauling area is made up of a small number of large rocks which may be awash at high tide. It is probably used only during periods of peak local abundance of prey or when moving from one feeding area to another or to or from breeding areas.

Cape Fairweather 58°50'15"N, 137°56'30"W

Located 54 miles north of Cape Spencer, Strevelar (pers. comm.) reported about 200 sea lions here in April 1970. Our survey showed a total of 258 sea lions in March 1976 and none in June 1976. This is probably used as a winter and early spring hauling area by animals moving along the coast or feeding offshore on the Fairweather grounds.

Sitkagi Bluff 59°17'45"N, 140°45'50"W

Formally was an ice cliff north of Yakutat but now has the appearance of low glacial moraine. It was thought to have been used by as many as 1,000 sea lions (Alaska Department of Fish and Game 1973) although we counted only 199 animals here in March 1976 and 20 in June 1976. The haul out area is within a group of very large boulders on the open beach. This rocky beach is flanked on both sides by several miles of sand beach. Use is probably highest in winter and early spring.

Cape St. Elias 59°47'48"N, 144°36'05"W

Located on the south end of Kayak Island this area has been surveyed several times in recent years. Mathisen and Lopp (1963) photosurveyed this area October 2, 1957 and counted 1,343 animals. Alaska Department of Fish and Game personnel (Calkins, Pitcher and Schneider, 1975) found 1,548 adults and 18 pups in June 1973 and 505 sea lions in March 1974. Our photo surveys showed 435 animals in March 1976 and 1,628 in June 1976. Twenty-three pups were branded here on June 26, 1976 from a total of 25 pups in the area. This haul out is used all year although an interesting seasonal shift takes place. During the winter (all March surveys) the haul out area is located at the base of the southwest face of Pinnacle Rock on a boulder beach. Shortly before breeding and pupping the sea lions shift around to an elevated conglomerate of semi-flat rocks on the southeast side of Pinnacle Rock. No sea lions have been seen using the southwest haul out in the summer and none used the southeast area in winter. This shift probably is in response to a desire of the cows for a more suitable pupping area in the summer and a movement away from exposure to the worst storms in the winter.

Middleton Island 59°29'15"N, 146°18'30"W

Located about 50 miles south of the entrance to Prince William Sound, the sea lions haul out on a small sand spit which arcs off the north end of the island. Surveys in February 1975, (Calkins et al. 1975) showed 175 sea lions. We surveyed this area in March 1976 when we counted 92 sea lions and late May 1976 when we counted 2,901 animals. The tremendous increase in sea lions here in late May does not mean this area is used as a pupping or breeding area. Because the entire area is a sand bar which is completely exposed to storms and high storm driven tides it is unlikely many pups could survive if born here. It is more likely that this haul out is used as a rest stop by many sea lions moving westward across the Gulf to the larger breeding rookeries on the Kenai coast and the eastern Kodiak, Afognak and Barren Islands areas.

Wooded Islands 59°50'50"N, 147°20'43"W

Located off the southeast end of Montague Island, sea lion use of this area has been well documented. The sea lions haul out on the outermost island in this group. The island has been called either Fish Island or Lewis Island (Pitcher 1975). Mathisen and Lopp (1963) counted 2,500 sea lions here in summer 1956 and 3,762 in October 1957. Alaska Department of Fish and Game surveys in June 1973 showed 1,261 and in March 1974, 1,114. On our surveys we counted 861 sea lions in March 1976 and 878 in June 1976.

Sandegren (1970) described extensive topographic changes which took place here as a result of the 1964 earthquake. Pitcher (1975) speculated that these changes may have caused a reduction in the population here. It is entirely possible that a reduction in the available breeding and pupping area may have caused a segment of the population to shift to the nearby Seal Rocks rookery. A total of 29 sea lion pups were branded with the letter E on the right shoulder at the Wooded Islands on June 26, 1976. Thirty-five pups were counted just prior to branding.

Seal Rocks (Prince William Sound) 60°09'58"N, 146°50'30"W

Located 6 to 7 miles southwest of Cape Hinchinbrook, this is the largest breeding rookery in the Prince William Sound area. Pitcher (1975) pointed out a substantial increase in the sea lion population here subsequent to the 1964 earthquake. Mathisen and Lopp (1963) surveyed this area in 1956 and 1957, counting a maximum of 183 sea lions. Alaska

Department of Fish and Game surveys in June 1973 showed a total of 1,733 animals, including at least 200 pups, and in March 1974, 1,750 animals were sighted.

Our surveys provided a visual estimate of 2,500 in March 1976 and a photo count of 1,709 in June 1976. A visual estimate of pups from the helicopter prior to branding was made but was known to be inaccurate at the time. A total of 300 pups were estimated present. Branding was accomplished on 316 pups here on June 27, 1976. These pups were branded on the right front shoulder with the letter J.

This rookery presents an interesting case as it constitutes a rookery with limited space for pupping and breeding with an apparent rapidly increasing population. It appears as though there is an unusually high pup mortality rate here. The area is made up of a small gravel beach which is flanked by two large rock masses, only one of which is used by a small contingent of the breeding population. This leaves the majority of the breeding and pupping animals, and consequently the pups, pressed into an area which is small for the numbers using it under normal conditions but which must be drastically reduced during storms or extreme high tides. During the branding in June 1976 a total of 85 dead pups were counted on the gravel beach area. This means that more than 20 percent of the pups were killed due to crowding. If an accurate count of all pups killed had been possible it is likely this figure would exceed 50 percent.

Glacier Island 60°51'03"N, 147°10'57"W

On the north side of Prince William Sound, west of the entrance to Valdez Arm, the sea lions haul out on the southernmost point of the island. This area is used only as a winter hauling location. No sea lions have been seen here on summer surveys.

The Alaska Department of Fish and Game survey of March 1974 showed a total of 55 sea lions here (Pitcher 1975). We counted 197 sea lions in March 1976.

Perry Island 60°41'15N, 147°51'05"W

In the northwest corner of Prince William Sound, the sea lions haul out on the northeast side of the island. This also is strictly a winter hauling area. Mathisen and Lopp (1963) sighted 80 sea lions here in March 1957, Pitcher (1975) reported 153 in March 1974 and we counted 308 in March 1976.

Pt. Eleanor 60°35'N, 157°33'45"W

The northernmost point of Eleanor Island in Prince William Sound, this area is only used in the winter. Pitcher (1975) reported 91 sea lions seen here on an Alaska Department of Fish and Game survey in March 1974 and we sighted 222 in March 1976.

The Needle 60°06'45"N, 147°36'40"W

In Montague Strait 3.8 miles from the nearest point on Montague Island and 5.5 miles southeast from Point Helen, the southern extremity of Knight Island in Prince William Sound, this hauling area is used throughout the year. Peak use probably occurs in the winter, and it probably is used primarily by males during the winter. Mathisen and Lopp (1963) saw 179 sea lions here in March 1957 and 130 in June 1957. Pitcher (1975) counted 236 sea lions here in June 1974 and 568 in June 1973. We photographed 666 sea lions here in March 1976 and 537 in June 1976.

Pt. Elrington 59°55'58"N, 148°13'20"W

Located on the southwest end of Elrington Island, this area appears to be more important than formerly recognized. It is a hauling area which is used year-round but probably more animals are there in the winter than the summer. Mathisen and Lopp (1963) counted 200 sea lions here in March 1957 and 250 in June 1957. Pitcher (1975) counted 236 in June 1973 and 568 in March 1974. Our surveys showed 2,014 in March 1976 and 725 in June 1976.

Cape Puget 59°56'40"N, 148°27'W

The first prominent headland west of Prince William Sound, it forms the southwest side of the sound. Alaska Department of Fish and Game (1973) listed 20 sea lions here and Mathisen and Lopp (1963) saw 20 here in July 1956. We saw no sea lions hauled out here in March 1976 but counted

80 in June. At that time the sea lions were hauled out on a small group of intertidal rocks during the low tide period.

Rugged Island 59°30'12"N, 149°22'53"W

On the eastern side of the entrance to Resurrection Bay, the sea lions haul out on the southernmost point of the island. Probably used year-round although no sea lions were seen here in June 1976. Alaska Department of Fish and Game (1973) reported 100 sea lions. We surveyed this haul out in October 1975 when we saw no sea lions, March 1976, 215 sea lions and April when we estimated 150 sea lions. In April the animals using this haul out were primarily bulls, many of which were mature adults.

Chiswell Islands 59°35'57"N, 149°33'59"W

This is a group of islands on the west side of the approach to Resurrection Bay which was surveyed by Mathisen and Lopp (1963) in March 1957 with a count of 4,705 and June 1957 with 2,012 sea lions. Alaska Department of Fish and Game (1973) showed 4,715. We surveyed this area in October 1975 and counted 3,158 sea lions, March 1976 - 2,076 sea lions, April 1976 - estimated greater than 4,000 sea lions, and June 1976 we counted 1,106 sea lions. This area is used by both sexes and all age classes throughout the year but probably receives maximum use in the winter. Although a very small number of pups may be born here each year this is probably not a true breeding rookery.

Seal Rocks (Kenai Peninsula) 59°31'15"N, 149°37'W

The southernmost land feature in the western approach to Resurrection Bay. Mathisen and Lopp (1963) gave a count of 100 sea lions here in March 1957 and 250 in June 1957. Alaska Department of Fish and Game (1973) showed 500 animals. We counted 154 sea lions here in October 1975, 630 in March 1976 and 320 in June 1976. Like the Chiswell Islands this area is used by more animals in winter.

Outer Island 59°20'50"N, 150°24'07"W

The outermost and smallest of the Pye Islands on the east side of Nuka Bay of the Kenai Peninsula. Mathisen and Lopp (1963) counted 1,050 sea lions here in March 1957 and 2,989 in June 1957. Alaska Department of Fish and Game (1973) showed 6,000 sea lions here. This is the largest breeding rookery north of the Barren Islands. On our surveys we counted 2,904 sea lions here in October 1975, 1,528 in March 1976 and 3,847 in June 1976. On June 24, 1976 the pups were counted by helicopter and branded. Visual estimate of pups was in excess of 500 and a total of 249 were branded with the letter V on the right front shoulder.

Gore Point 59°10'47"N, 150°57'50"W

The southeastern end of a prominent headland on the east side of the entrance to Port Dick. Mathisen and Lopp (1963) saw no sea lions here in March 1957 and 200 in June 1957. We saw 2 sea lions here in October 1975, estimated 200 in March 1976 and counted 535 in June 1976.

Perl Island, Elizabeth Island and Nagahut Rocks 59°105'58"N, 151°39'31"W

All in the Chugach Island group located on the coast of the Kenai Peninsula near the entrance to Cook Inlet. One small hauling area exists on each of these islands and more may be found at other locations in this island group. Alaska Department of Fish and Game (1973) or Mathisen and Lopp give the following counts: East Chugach Island - 20; Perl Island - 737; Nagahut Rocks - 90 and Cape Elizabeth on Elizabeth Island - 129. On our surveys we saw the following, East Chugach Island - 0; Perl Island - March - 8, June - 33; Nagahut Rocks - March - 68; June - 344; Cape Elizabeth - March - 68, June - 124.

Sugarloaf Island 58°53'29"N, 152°12'49"W

One and one-tenth miles south of East Amatuli Island in the Barren Islands, Sugarloaf Island has one of the largest sea lion rookeries in the northern Gulf of Alaska. Alaska Department of Fish and Game (1973) showed a population of 10,000 here and Mathisen and Lopp (1963) counted 585 in March 1957 and 11,963 in June 1957. We counted 7,547 here in October 1975, 301 in March 1976 and 5,226 in June 1976. Vania (Alaska Department of Fish and Game, pers. comm.) felt that there is a significant amount of interchange of the breeding population between here and the large rookery on Marmot Island, off Afognak Island.

Sugarloaf Island has traditionally been a rookery with very high pup production. For instance, Vania (unpub. data) estimated 5,200 pups in

1967 and 3,000 in 1968. In 1975 and 1976, while branding here, we estimated in excess of 3,500 pups here each year. A total of 722 pups were branded here in 1975 with an X on the left front shoulder and 1,443 in 1976 with X on right front shoulder.

Rocks Southwest of Sud Island 58°52'50"N, 152°18'43"W

Small group of unnamed rocks located one mile southwest of Sud Island not previously identified as a sea lion hauling area. We sighted 87 sea lions here in March 1976 and 670 in June 1976.

Rocks Southwest of Ushagat 58°57'31", 152°20'42"W

Small group of rocks on the southwestern tip of Ushagat Island. Probably surveyed by Mathisen and Lopp and called Ushagat Island. Mathisen and Lopp (1963) saw no sea lions here in March 1957 and 834 in June. We saw 819 in March and 902 in June.

Rocks Northwest of Ushagat 58°57'31", 152°20'42"W

Another small rocky area off the northwest tip of Ushagat Island. Probably not previously identified as a sea lion haul out. We counted no sea lions here in March 1976 and 106 in June. This area appeared to be used primarily by non-breeding males in the summer.

Rocks Between W. Amatuli and E. Amatuli 58°55'20"N, 152°W

This small group of rocks is probably used by non-breeding bulls in the summer. We counted 57 animals here in June 1976.

Latax Rocks 58°41'25"N, 152°29'W

The northernmost feature of the Kodiak-Shuyak-Afognak group, 3,334 sea lions were counted here by Mathisen and Lopp (1963) in June 1957. We counted 466 here in October 1975, 322 in March 1976 and 1,164 in June 1976 and none in October 1976. This haul out is used at all times of the year by both sexes and all age classes. It is not known to be a pupping area.

Sea Otter Island 58°31'16"N, 152°12'35"W

Located 2 miles east of Shuyak straight off Afognak Island, this location has not previously been identified as a sea lion hauling area. We surveyed this area in October 1975 and saw 398 sea lions, again in March 1976 and saw 51 sea lions and in June 1976 we saw 541 sea lions. This area is used by both sexes and all age classes throughout the year.

Sea Lion Rocks 58°20'50"N, 151°47'50"W

Five and five-tenths miles eastward from Tonki Cape and four miles northward from Marmot Island, 500 sea lions were listed for here by Alaska Department of Fish and Game (1973). Mathisen and Lopp (1963) counted 1,600 here in May 1957 and 302 in June 1957. On our surveys we saw 121 in October 1975, 127 in March 1976 and 432 in June 1976.

Marmot Island 58°12'10"N, 151°47'50"W

Parallels the eastern side of Afognak Island. This, along with Sugarloaf Island in the Barren Islands, is one of the largest sea lion rookeries in the northern Gulf of Alaska. Unlike Sugarloaf Island, which is nearly vacated in the winter, this area is used extensively throughout the year as a hauling area. Alaska Department of Fish and Game (1973) showed a total of 10,000 sea lions here. Mathisen and Lopp (1963) counted 1,425 here in March 1957 and 4,157 in June 1957 with a high count of 6,790 in September 1957. On our surveys we counted 8,256 in October 1975, 3,655 in March 1976 and 9,862 in June 1976.

Clearly this is an area of major pup production, Vania (unpub. data) reported 5,900 pups in 1967 and over 5,000 in 1968. In 1976 while branding we estimated a total of 4,900 pups here. In 1975 a total of 598 pups were branded with an O on the left front shoulder. In 1976, 3,669 pups were branded on Marmot Island with a T on the right front shoulder.

Marmot Island rookery and haul out area is substantially different from the majority of the other rookeries and haul outs in the Gulf of Alaska. Most areas on Marmot where sea lions are found are narrow sand beaches on the southeast side. Sea lions rarely haul out on sand beaches anywhere else in the northern Gulf.

Long Island 57°45'N, 152°18'07"W

The easternmost island in northern Chiniak Bay. Mathisen and Lopp(1963) and Alaska Department of Fish and Game (1973) reported 50 to 75 sea lions here. We surveyed this area in October 1975 and saw no sea lions, March 1976 and saw 62 sea lions and saw no sea lions again in June 1976.

Cape Chiniak 57°37'10"N, 152°09'10"W

The southeast point of Chiniak Bay, Mathisen and Lopp (1963) saw 645 sea lions in March 1957 and 772 in June 1957. Alaska Department of Fish and Game (1973) showed 600 sea lions. We saw 883 in March 1976, 365 in June 1976 and 122 in October 1976. The haul out is comprised of three locations in the rocks off Cape Chiniak. This area is used throughout the year by both sexes and all age classes. Probably no breeding or pupping takes place here.

Gull Point 57°22'58"N, 152°35'55"W

The southeast point of Ugak Bay on Kodiak Island, this was not previously identified as a sea lion hauling area. We sighted 28 sea lions here in March 1976 and 145 in June 1976. The sea lions haul out on a small group of rocks just off Gull Point.

Cape Barnabas 57°08'20"N, 152°53'03"W

The eastern end of Sitkalidak Island, Mathisen and Lopp (1963) counted 540 sea lions here in March 1957 and 1,598 in June 1957 and a high of 2,487 in September 1956. Alaska Department of Fish and Game (1973) reported 1,000 sea lions here. We sighted 120 sea lions in March 1976, 364 in June 1976 and 28 in October 1976. There appears to be a substantial reduction in use of this area by sea lions.

Twoheaded Island 56°53'55"N, 153°33'30"W

Laying off the southern extremity of the western shore of Sitkalidak Strait, Mathisen and Lopp (1963) counted 2,740 here in March 1957 and 2,810 in June 1957 and a high of 4,261 in September 1956. Our surveys showed 1,636 sea lions in March 1976, 1,615 in June 1976 and 1,469 in October 1976. This rookery is the largest producer of pups on the south end of the Kodiak Archipelago with the exception of Chirikof Island. The sea lions haul out, pup and breed on the east side of the island.

Cape Sitkinak 56°33'10"N, 153°41'45"W

The easternmost point of Sitkinak Island, the northernmost of the Trinity Islands off the south end of Kodiak Island, had 470 sea lions in March 1957 and 343 in June 1957 (Mathisen and Lopp 1963) and reported by Alaska Department of Fish and Game (1973) as having a population of 470. We photographed 257 sea lions here in March 1976, 120 in June 1976 and 302 in October 1976. The sea lions haul out on a small group of rocks just off the Cape.

Chirikof Island 55°49'25"N, 155°44'20"W

Sixty miles south-southwest of the Trinity Islands, Alaska Department of Fish and Game (1973) reported 500 sea lions here and Mathisen and Lopp (1963) counted 1,742 in June 1957 and 2,450 in September 1957. Our counts show 3,870 in March 1976, 2,391 in June 1976 and 5,332 in October 1976. This area is used throughout the year by both sexes and all age classes and in excess of 1,000 pups are born here. The sea lions haul out, breed, and pup on the south side of the Island.

Nagai Rocks 55°49'50"W, 155°46'50"W

Off the westernmost point of Chirikof Island, this has not been previously identified as a separate hauling area. We sighted 1,401 sea lions here in March 1976, 657 in June 1976 and 554 in October 1976.

Cape Ikolik 57°21'40"N, 154°46'50"W

Four miles south of Middle Cape which is the westernmost promontory of Kodiak Island, this location and several other points and rocks in the same area including Middle Cape, Inner Seal Rocks, Outer Seal Rocks, and Tombstone Rocks all make up the same general hauling area which we call Cape Ikolik. We sighted 1,913 sea lions here in March 1976, none in June 1976, and 1,213 in October 1976. The largest concentrations are found at the base of Cape Ikolik and the animals are probably most numerous in winter.

Cape Ugat 57°52'20"N, 153°50'45"W

On the eastern shore of Shelikof Strait, 12 miles southwest of Cape Uganik, Alaska Department of Fish and Game showed 50 sea lions at this location, our counts show 222 in March 1976 and none in June 1976. The haul out is located on Ugat Island on the northeast side, just off the Cape. This area is used primarily by males.

Cape Gull 58°12'40"N, 154°08'45"W

Five miles south of Cape Ugyak on the Alaska Peninsula, the sea lions haul out on the rocks to the east of the point. We saw no sea lions here in March 1976 and 207 in June 1976 and none again in March 1977.

Takli Island Rock 58°03'40"N, 154°27'35"W

Between Cape Atushavik and Cape Iktugitak, north of Katmai Bay on the south side of the Alaska Peninsula, we counted 1,014 sea lions here in March 1976, 1,877 in June 1976 and estimated 700 in March 1977. The sea lions use the rocks due south of Takli Island.

Puale Bay 57°40'55"N, 155°24'05"W

Between Cape Kekurnoi and Cape Aklek on the south side of the Alaska Peninsula in the southern part of Shelikof Strait, Alaska Department of Fish and Game (1973) reported 2,800 sea lions here. We counted 1,014 in March 1976, 1,877 in June 1976 and estimated over 10,000 sea lions here in March 1977. This is an area that is used year-round by both sexes and all age classes. Several hundred pups are born here each year. The sea lions haul out in the group of large rocks on the north side of the bay.

Ugaiushak Island 56°47'25"N, 156°51'35"W

Six miles south of Cape Kuyuyukak on the south side of the Alaska Peninsula, Mathisen and Lopp (1963) reported 643 sea lions here in August 1956 and 213 in May 1957. Alaska Department of Fish and Game (1973) showed 600 sea lions here. We counted 125 sea lions here in June 1976 and none in March 1976 or March 1977. The sea lions haul out on a small group of rocks to the southeast of Ugaiushak Island. These rocks may be awash at high tide.

Sutwik Island (West End) 56°32'10"N, 157°20'05"W

Alaska Department of Fish and Game (1973) reported the haul out here. We counted 40 sea lions here in March 1976, 6 in June 1976 and estimated 20 in March 1977. The sea lions haul out in a small group of rocks on the southwest end of the island.

Chowiet Island 56°00'40"N, 156°41'W

The large southern island of the Semidi Islands, Alaska Department of Fish and Game (1973) showed 5,000 sea lions here and Mathisen and Lopp (1963) saw 6,323 sea lions in June 1957. On our surveys we counted

4,679 in October 1976 and were unable to completely survey the area in March or June 1976. In March 1977 we estimated 2,000 sea lions. The sea lions haul out on the southwestern end of Chowiet Island, on Aliksemit Island and the small islands and rocks in the area. This is a breeding and pupping rookery where several thousand pups could be produced.

Kak Island 56°17'15"N, 157°50'W

One and three-tenths miles south of Nakchamik Island (in the mid-entrance to Chignik Bay), Alaska Department of Fish and Game (1973) showed 100 sea lions here. We saw no sea lions here in March 1976 and June 1976 but estimated 25 here in March 1977. The sea lions haul out on the steep slope on the southwest side of the island.

Spitz Island 55°47'20"N, 158°53'40"W

One and two-tenths miles southward of the south tangent of Mitrofania Island, Alaska Department of Fish and Game (1973) estimated 700 sea lions here. We counted 25 here in June 1976 but none in March 1976 or 1977.

Lighthouse Rocks 55°47'N, 157°25'W

Twenty-seven miles southward of Chowiet Island and 56 miles westward of Chifikof, this area has not previously been identified as a sea lion haulout. We surveyed it only in October 1976 when we counted 1,315 sea lions with many pups. This is probably a breeding and pupping rookery.

Castle Rock 55°15'45"N, 159°29'45"W

Located about 1.5 miles north of Cape Thompson, the north point of Big Koniuji Island, Alaska Department of Fish and Game (1973) reported 400 sea lions here. We counted 189 sea lions in March 1976, and 401 in June 1976. The sea lions haul out on the northeast side of the rock.

Atkins Island 55°03'05"N, 159°17'50"W

Off the northeast headland of Little Koniuji Island (connected by shoals) in the Shumagin Islands, Alaska Department of Fish and Game (1973) showed 3,100 sea lions here. We photographed 1,211 sea lions in March 1976 and 2,726 in June. The sea lions haul out, pup and breed on the east side of the island. This is the largest breeding rookery in the Shumagin Islands.

Churnabuna Island 54°45'15"N, 159°33'W

The most southerly of the Shumagins, Alaska Department of Fish and Game reported 2,000 sea lions here. We counted 1,667 in March 1976 and 1,437 in June 1976. The sea lions haul out on the southeast side of the island.

Nagai Island 54°56'N, 160°15'10"W

In the center of the Shumagin Group, 15 sea lions were listed by Alaska Department of Fish and Game (1973). We saw 233 sea lions here in March

1973 and 405 in June 1973. The sea lions utilize a small group of rocks on the southwest side of the island, near the westernmost point.

Sea Lion Rock (Shumagins) 55°04'50"N, 160°30'45"W

One mile southeast of Unga Cape, Alaska Department of Fish and Game (1973) showed 400 sea lions haul out here. In March 1976 we photographed 187 sea lions here and 243 in June 1976.

Jude Island 55°15'50"N, 161°06'20"W

Thirteen miles northwest of Acheredin Point on the southwest end of Unga Island, a population of 3,000 sea lions shown by Alaska Department of Fish and Game (1973). Our counts show 302 in June 1976 and none in March 1976 or March 1977.

Pinnacle Rock 54°46'15"N, 161°45'45"W

The easternmost named point of the Sandman Reefs, 980 sea lions reported by Alaska Department of Fish and Game (1973). We counted 141 in March 1976 and 1,745 in June 1976.

Clubbing Rocks 54°42'50"N, 162°26'45"W

On the northwestern edge of the Sandman Reefs, Alaska Department of Fish and Game (1973) reported 5,600. Kenyon and Rice (1961) estimated 200 sea lions here. We photographed 1,217 in June 1976 but saw none here in

March 1976 or 1977. This haul out consists of three low rocks, each with an area of less than one acre.

South Rock 54°17'45"N, 162°42'30"W

The southernmost named point southeast of Sanak Island, used by 3,200 sea lions according to Alaska Department of Fish and Game (1973). Kenyon and Rice (1961) estimated 1,000 sea lions here. Our surveys showed 972 sea lions here in March 1976 and 1,004 in June 1976. The sea lions utilize either of the larger rocky islands which make up south rock.

Bird Island 54°40'10"N, 163°16'15"W

The most prominent land mark between Cape Pankof and Cape Aksit, in the mouth of Otter Cove on the northeast side of Unimak Island. Alaska Department of Fish and Game (1973) showed 260 sea lions here. We saw 112 sea lions here in June 1976, none in March 1976 or 1977.

Rock Island 54°36'30"N, 163°36'30"W

Located 1.5 miles west of Cape Lazaref on Unimak Island, 25 sea lions were sighted here on the June 1975 survey and 54 in June 1976.

Cape Lutke 54°29'25"N, 164°19'10"W

The southwest headland of Unimak Bight, we counted 22 sea lions hauled out on a small group of rocks here in June 1975.

Distribution and Movements

As can be seen from the previous section on sea lion hauling areas, sea lions are distributed throughout the coastal areas of the northern Gulf of Alaska with the major breeding population center in the northern Kodiak - Barren Islands area. A large portion of the breeding population disperses from these areas in the late fall, to winter at other locations, and returns in the late spring for pupping and breeding.

In order to study this seasonal shift in distribution a total of 7,046 sea lion pups were branded at six rookeries in the northern Gulf area. Table 3 shows the results of the branding in both 1975 and 1976.

Table 3. Results of sea lion branding in the Gulf of Alaska for 1975 and 1976.

	Number of Pups Branded		Location of Brand on Pup		Dates of Branding		Brand	
Location	1975	1976	1975	1976	1975	1976	1975	1976
Marmot Island	598	3669	left fr. shoulder	right fr. shoulder	July15-17	June22-26	O	T
Sugarloaf Island	719	1443	left fr. shoulder	right fr. shoulder	July10-12	June27-21	X	X
Outer Island		249		right fr. shoulder		June24		V
Wooded Islands		29		right fr. shoulder		June26		E
Seal Rocks		316		right fr. shoulder		June27		J
Cape St. Elias		23		right fr.		June26		L

These rookeries were selected on the bases of numbers of pups born and our expectations of where we would see sea lions which were branded at other locations. Thus, although pup production is low at Cape St. Elias and Wooded Islands, we branded pups there in order to distinguish them from pups born elsewhere. Table 4 lists the branded sea lions which were sighted at hauling areas other than where they were born. Numerous resightings have been made of pups at the rookeries of their birth.

Table 4. Branded sea lions sighted in the Gulf of Alaska at hauling areas other than where they were born.

Location Sighted	Date Sighted	Location Branded	Year Branded
Cape St. Elias	May 27, 1976	Sugarloaf Is.	1975
Cape St. Elias	June 26, 1976	Marmot Is.	1975
Point Eleanor	Feb. 17, 1977	Sugarloaf Is.	1975
Aialik Bay	Apr. 15, 1976	Sugarloaf Is.	1975
Chiswell Islands	Apr. 13, 1976	Sugarloaf Is.	1975
Outer Is.	Mar. 22, 1977	Marmot Is.	1976
Marmot Is.	Oct. 12, 1976	Sugarloaf Is.	1975
Cape Chiniak	Oct. 4, 1976	Sugarloaf Is.	1975
Cape Chiniak	Oct. 5, 1976	Marmot Is.	1975
Nagai Rocks (Chirikof)	Oct. 8, 1976	Sugarloaf Is.	1975

There is an apparent winter shift in sea lion distribution from the Marmot Island-Sugarloaf Island areas across the northern Gulf to the east and possibly to the south. This can be shown by the reduction of numbers of sea lions at Marmot Island and Sugarloaf Island in the winter and an increase in numbers of sea lions seen along the Kenai Peninsula, Prince William Sound, Middleton Island and Chirikof Island. The sighting of branded sea lions in those areas also supports this movement theory. Figure 7 shows this movement pattern.

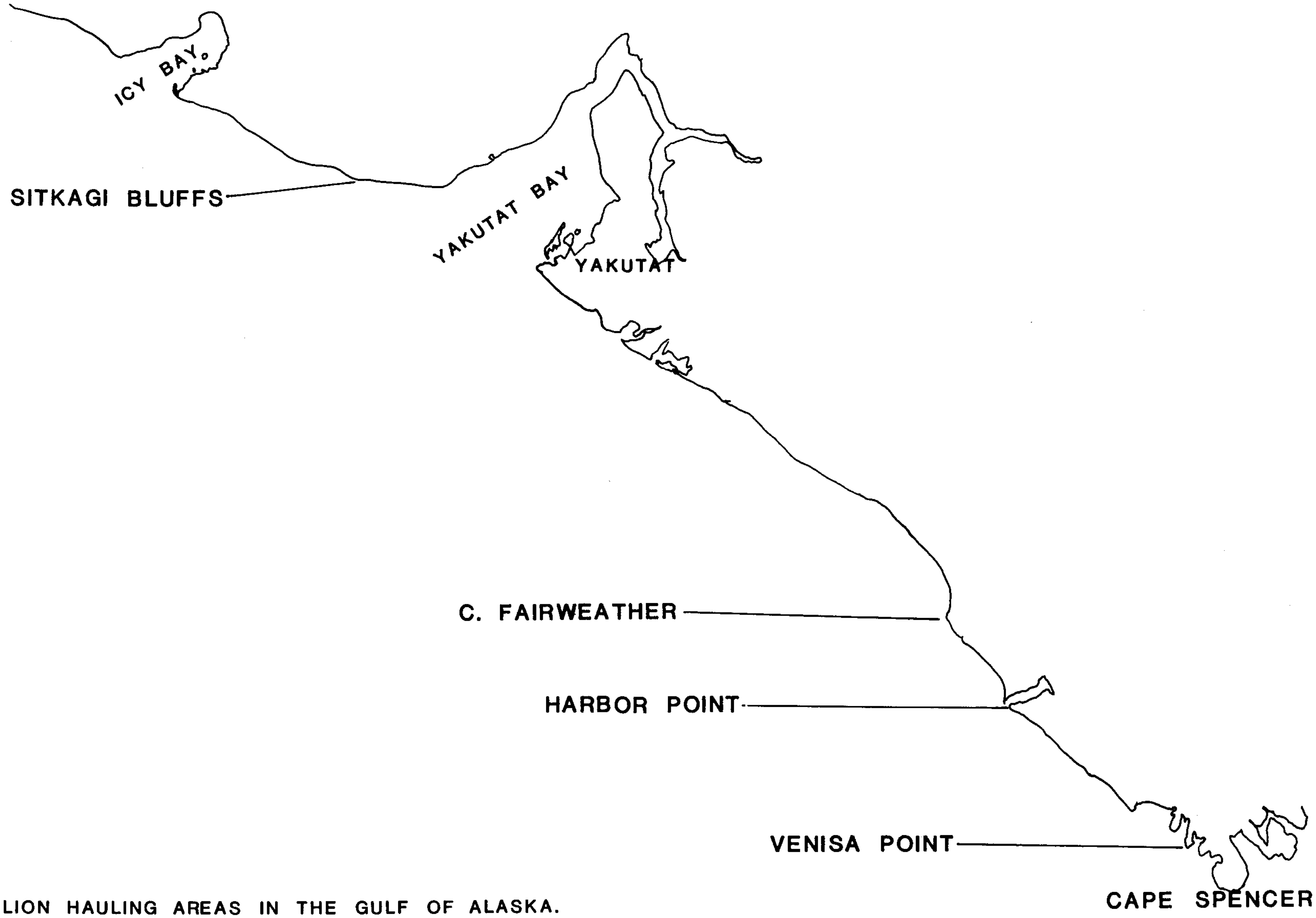

FIG. 1. SEALION HAULING AREAS IN THE GULF OF ALASKA.

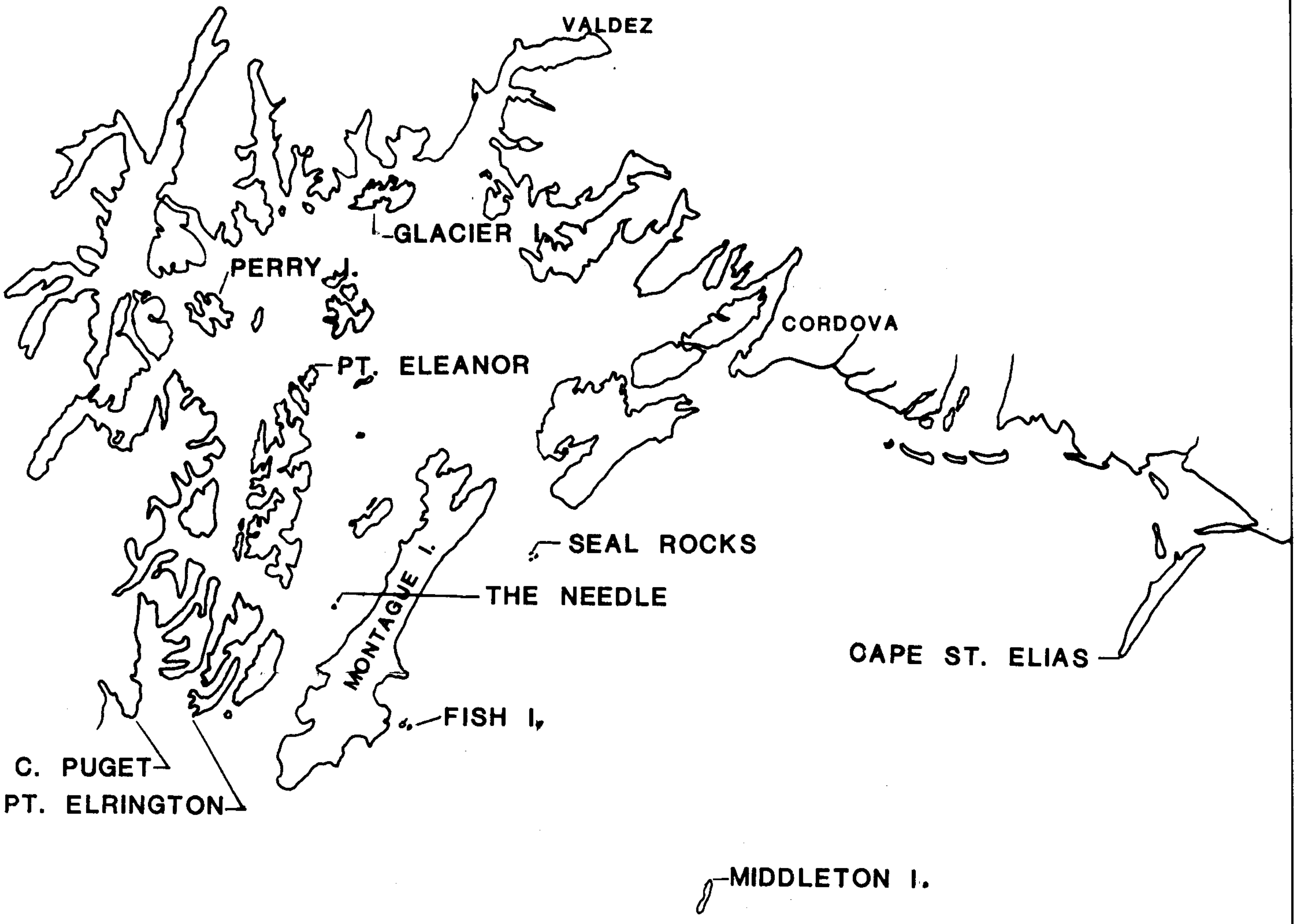

FIG. 2. HAULING AREAS (CONT.)

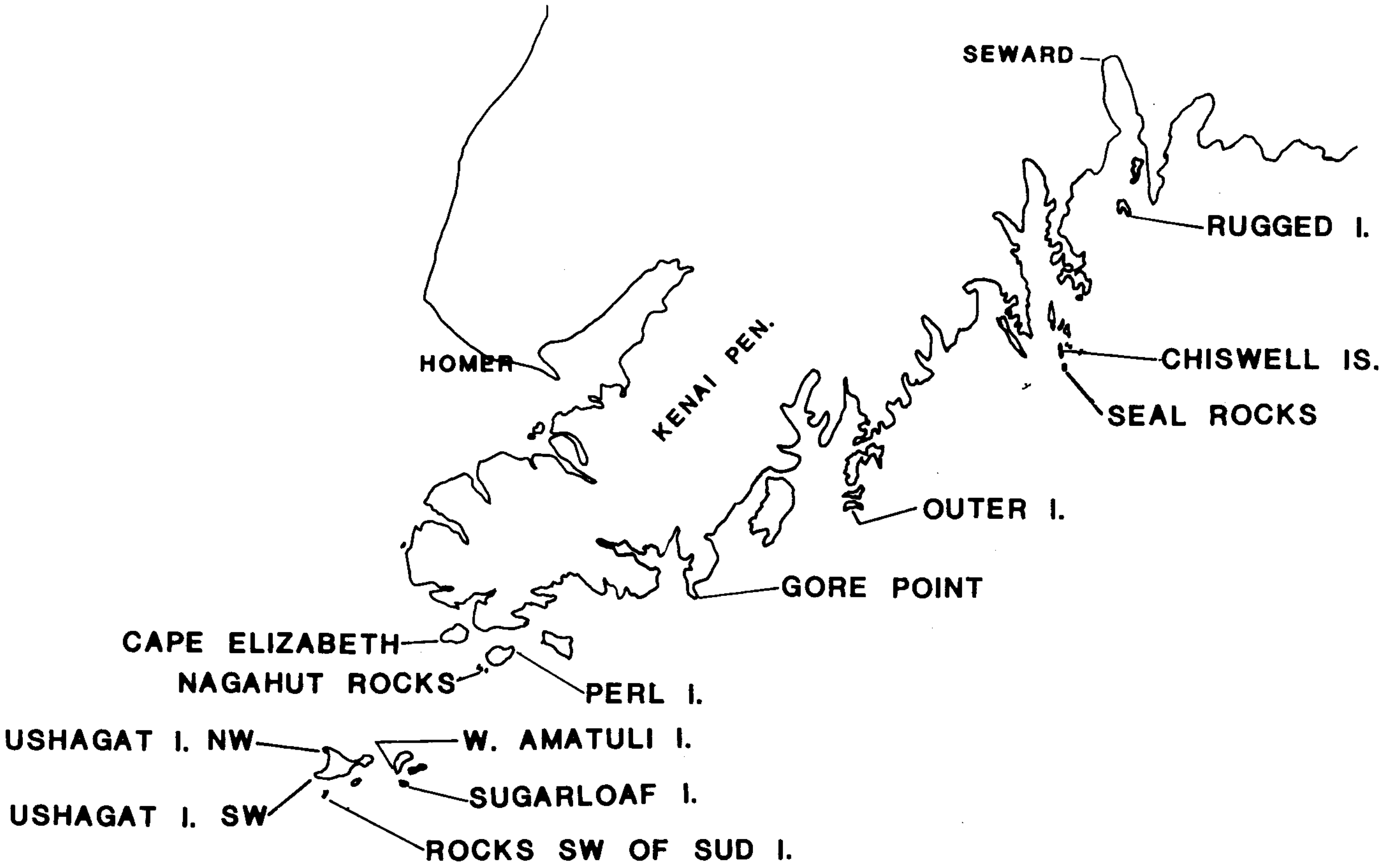

FIG. 3. HAULING AREAS (CONT.)

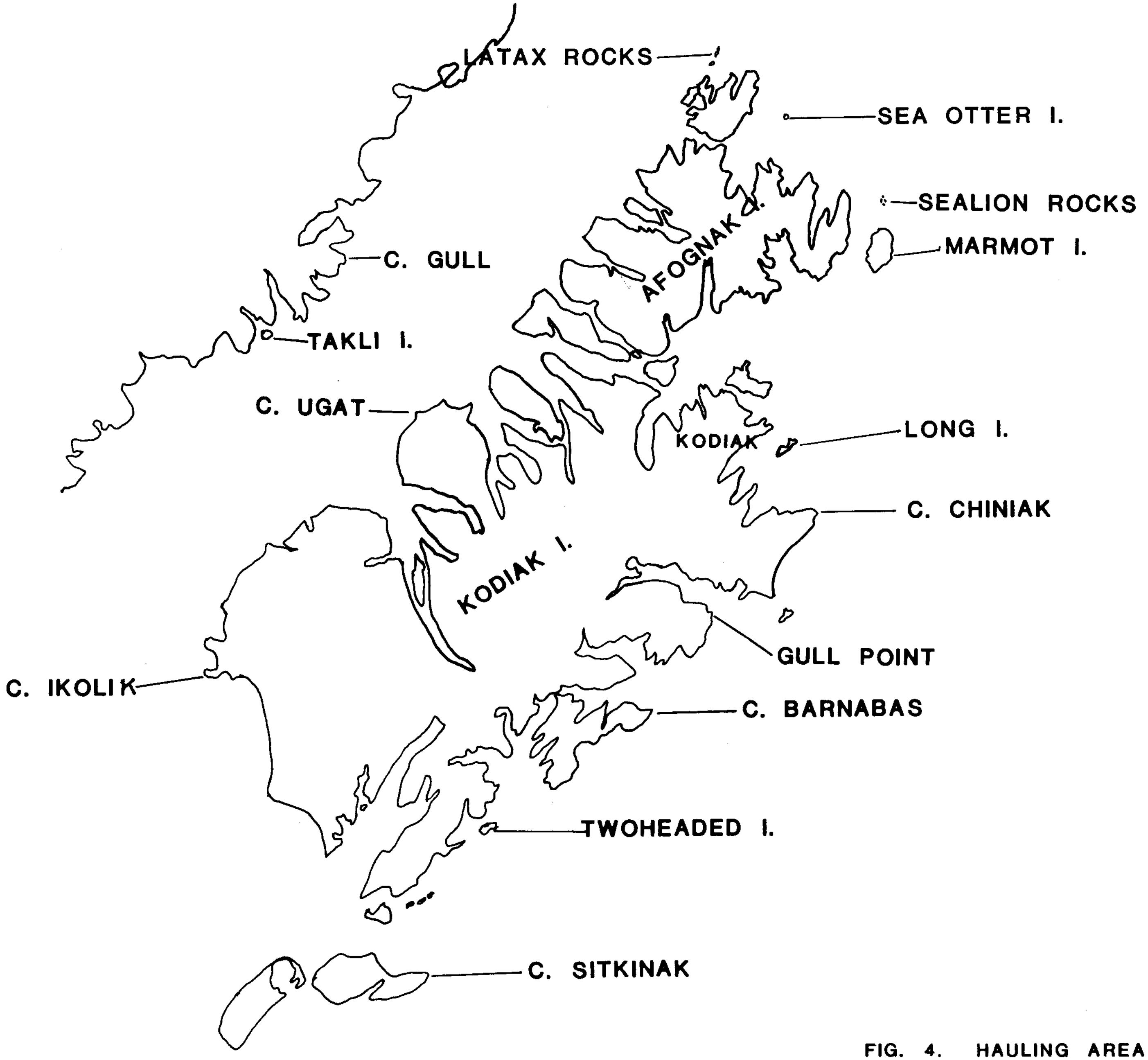

FIG. 4. HAULING AREAS (CONT.)

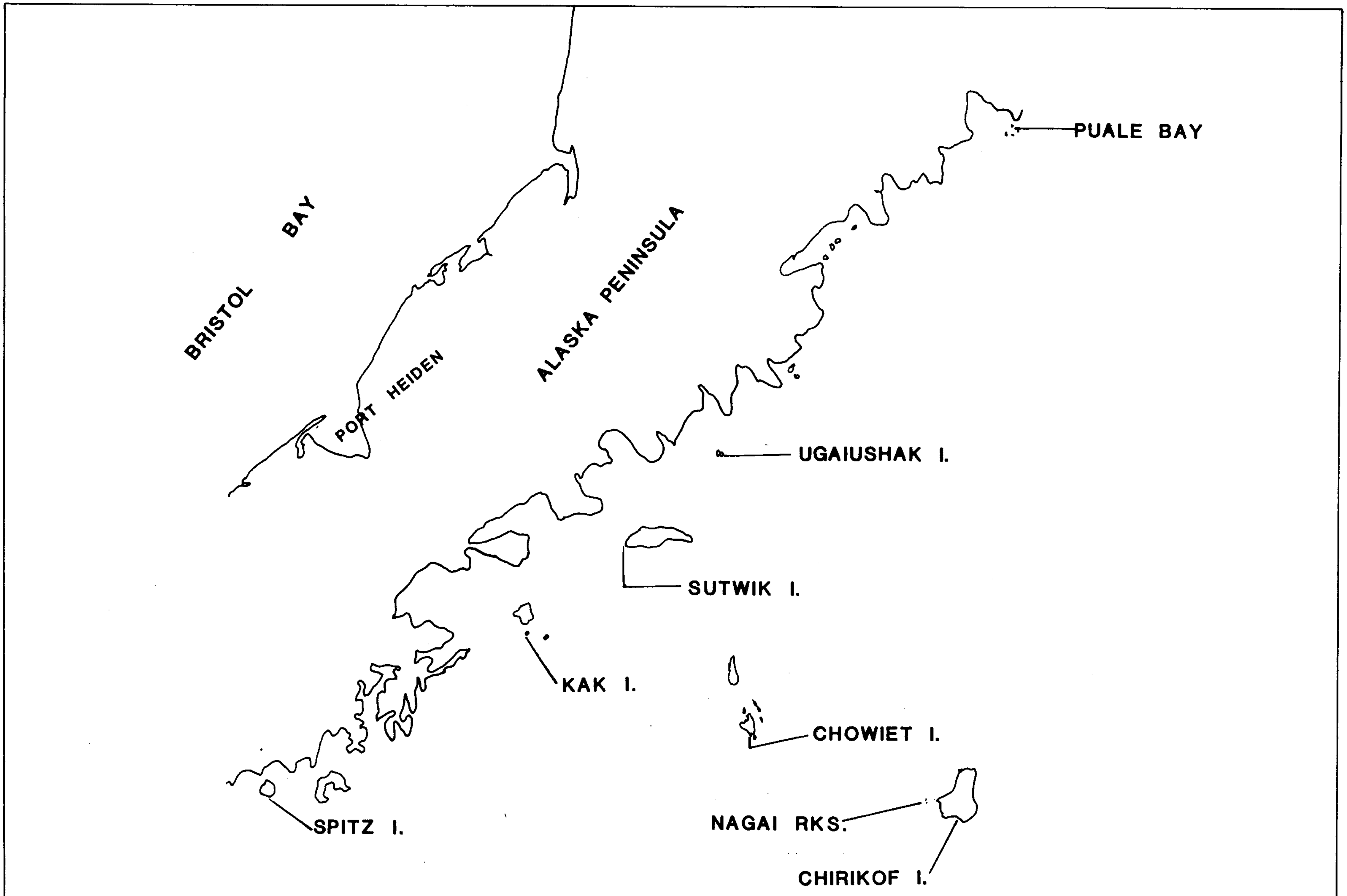

FIG. 5. HAULING AREAS (CONT.)

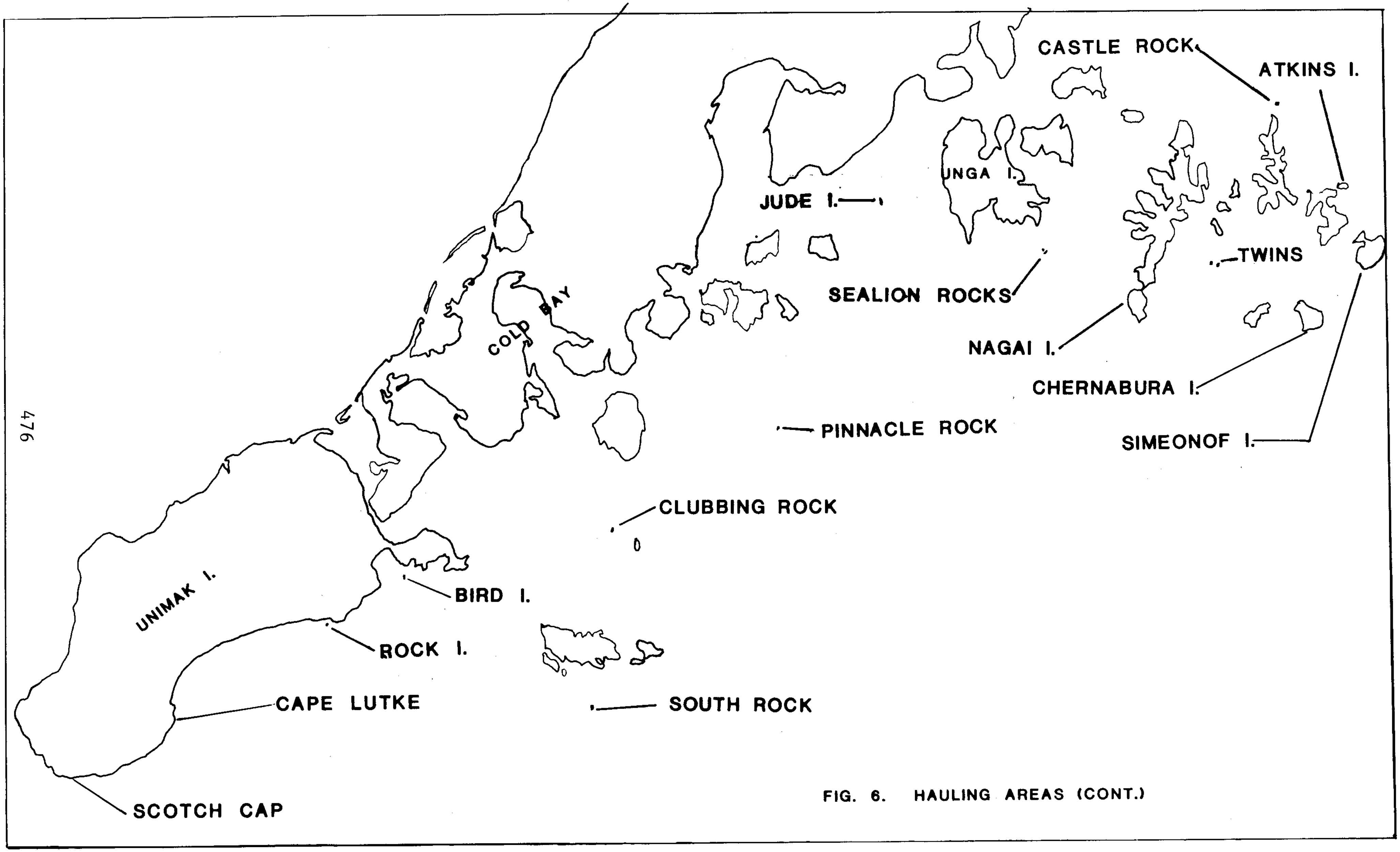

FIG. 6. HAULING AREAS (CONT.)

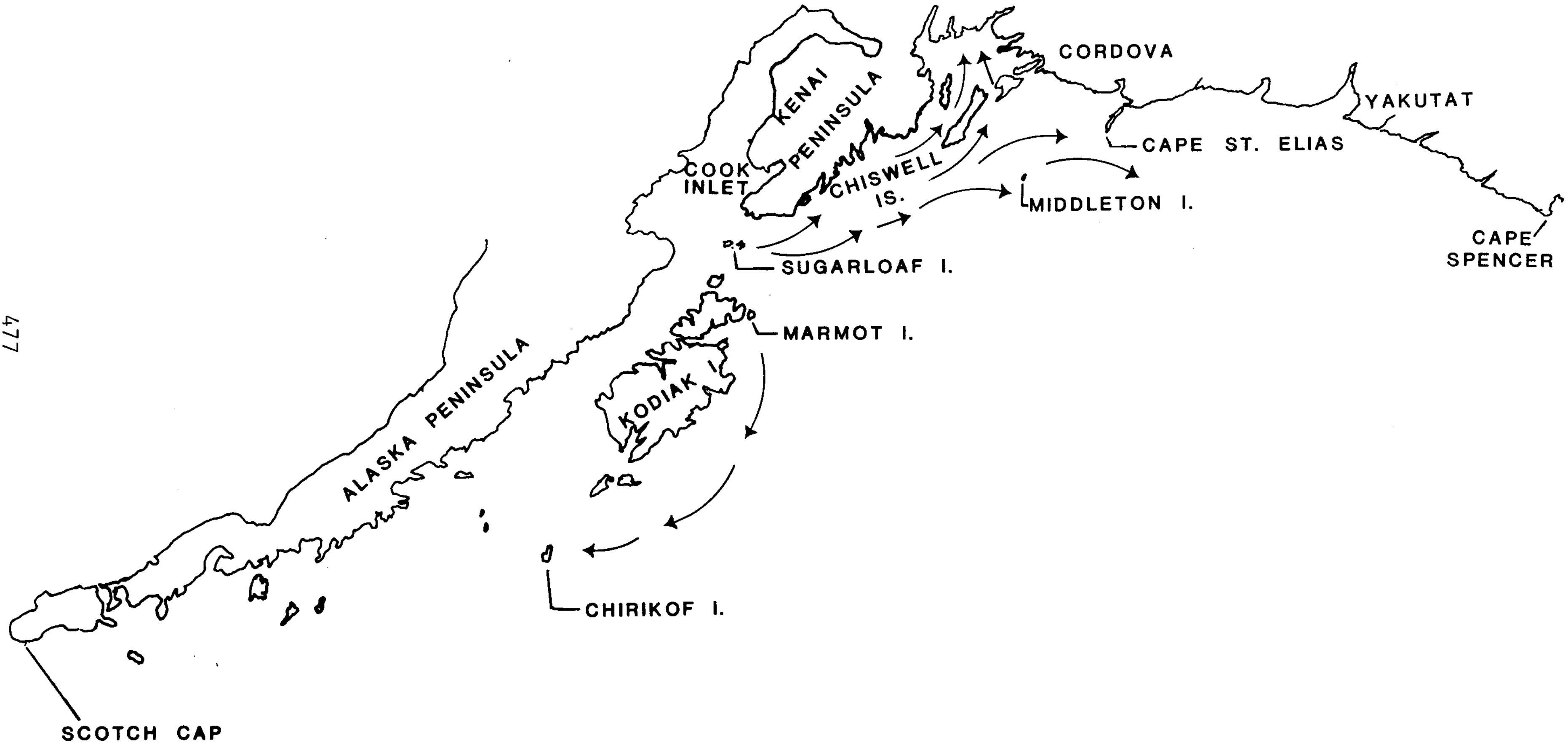

FIG. 7. LATE FALL/EARLY WINTER MOVEMENTS OF SEA LIONS IN THE GULF OF ALASKA.

Pupping

During a two-year study of sea lions on the Wooded Islands, in the Gulf of Alaska, Sandegren (1970) observed pupping periods of 32 and 33 days. The first births were noted on 28 and 30 May. The highest frequency of births was from 10-12 June. In California, Orr and Poulter (1967) reported that normally births do not begin until early June and continue into early July. Scheffer (1946) reported that on the Pribilof Islands pupping occurred between 23 May and 20 June with peak activity about 6 June. We saw fresh placental material on Sugarloaf Island on July 11, 1975, indicating birth within the last 24 hours.

Breeding

The best information on timing of breeding was reported by Sandegren (1970) who was able to recognize individual females and determine the interval between pupping and breeding. He found that copulation occurred from 10-14 days (mean of 11.8 days) after birth. The first copulations he observed were on 29 and 30 May. Peak breeding activity was about 10 June. Mathisen et al. (1962), who studied sea lions in the Shumagin Islands, observed the first copulation on 31 May. No matings were seen after 10 July. In California, Orr and Poulter (1967) stated copulations were commonly observed during the last half of June and the first two weeks of July. We observed copulations during the first two weeks of July at Marmot Island and Sugarloaf Island although they were not common.

Lactation and Weaning

The period of lactation and timing of weaning in the Steller sea lion have not been well documented and are apparently quite variable. In California, a female was observed nursing an 18-month old yearling (Orr and Poulter 1967). On the same date, two other females were seen discouraging yearlings from nursing. Mathisen et al. (1962) found that 25 percent of yearlings had milk in their stomachs. Sandegren (1970) reported that the majority of cows he observed were accompanied by nursing subadults of at least two age classes. He observed nursing subadults nearly as large as their mothers. Sandegren (1970) listed four ways in which the mother-offspring bond lasted more than a single year: (1) females didn't give birth every year and retained the bond with their young into the second year, (2) females renewed the bond with their last young after loss of a pup, (3) females rejected the newborn pup and kept the older offspring, and (4) the female kept both pup and yearlings.

On October 6, 1975 we observed a pup and a yearling nursing from a single female. We also saw a number of instances of either pups or yearlings nursing. On October 12, 1976 on Marmot Island we saw many instances of pups nursing and frequent nursing yearlings. On October 13, 1976 we collected a three-yearold female from Sea Otter Island. Her stomach contained what has been tentatively identified as milk along with unidentified fish bones.

It appears that female sea lions lactate much of their adult lives (Table 5). From the data we have collected and those reported in the literature we now have some insight into lactation and weaning patterns. Frequently nursing will continue into the second year if another pup is not produced or if the pup is lost or rejected in favor of the yearling. It appears that occasionally some animals may continue suckling after their second and even their third birthdays.

Table 5. Summary of lactation and reproductive status of 20 multiparous female Steller sea lions collected in the Gulf of Alaska.

Condition	Number	Percent
Lactating and pregnant	14	70
Lactating and not pregnant	2	10
Not lactating and pregnant	3	15
Not lactating and not pregnant	1	5
Total	20	100

Delay of Implantation

Although the Steller sea lion breeds within about two weeks after giving birth, the blastocyst apparently does not implant until about three months later. We collected 11 mature females from 7-14 October 1976. Ten of these had very small implanted fetuses. The other had a corpus luteum but no evidence of a fetus or implantation site. We were not able to determine if the animal was still in the delay of implantation or if it was not pregnant. These data tend to support the findings of Vania and Klinkhart (1967) that there is a three month delay of implantation, i.e. breeding in mid-late June and implanting in mid-late September.

Female Age of Sexual Maturity

Sexual maturity or productive maturity is the age at which a female first produces offspring. During this study we have collected three primipunous (pregnant for the first time) females. One was 3 years old and the other two were 4 years old. All animals collected that were 5 years old and older were sexually mature.

Pregnancy Rates

Age specific pregnancy rates were calculated by two methods. The current year's pregnancy was used, where the reproductive tract was examined for presence of a fetus (Table 6). Using this method we calculated the following rates: 0-2 years = 0%, 3-4 years = 20% and 5-30 years = 90.5%.

Table 6. Age specific pregnancy rate for Steller sea lions based on current years reproductive status.

Age	Number of Females in Sample	Number of Females Pregnant	Percent Pregnant
0-12 months	5	0	0
1 year	5	0	0
2	5	0	0
3	5	1	20
4	5	1	20
5	1	1	100
6	0		
7	3	3	100
8	2	2	100
9	1	0	0
10	1	1	100
11	1	1	100
12	4	4	100
13	2	2	100
14	2	2	100
15	1	1	100
16	1	1	100
20	1	1	100
30	1	0	0
Total	46	21	45.7

The other method for calculating pregnancy rates was to use ovarian structures, primarily copora lutea and albicantia in combination with placental scars to reconstruct an additional year of reproductive history (Table 7). Although this technique doubles the sample size, some interpretation is required and the resulting rates must be considered in this light. Reproductive rates calculated using those data were as follows: 0-2 years = 0%, 3-4 years = 25% and 5-30 years = 80.6%.

Table 7. Age specific pregnancy rates based on past two years reproductive performance for each animal.

Age	Number of Reproductive Years	Number of Pregnancys	Pregnancy Rate
0-12 months	10	0	0
1 year	10	0	0
2 years	10	0	0
3	10	2	20
4	6	2	33
5	1	1	100
6	1	1	100
7	4	3	75
8	2	2	100
9	1	0	0
10	2	1	50
11	3	3	100
12	5	5	100
13	3	3	100
14	4	3	75
15	1	1	100
16	1	1	100
19	1	0	0
20	1	1	100
30	1	0	0
Total	77	29	37.7

Male Reproduction

Our collecting was designed to maximize collections of data for use in calculating pregnancy rates. Therefore most of the collecting was done in winter months and selected against older males. Only limited data on male reproduction have been collected (Table 8). Three males were found to be sexually potent; a 4-year-old on May 26, 1976, a 5-year-old collected on April 20, 1976 and a 7-year-old taken on April 20, 1976.

Table 8. Male Steller sea lion reproductive analysis.

Number	Collection Date	Age	Testis Volume	Sperm* Presence
SL-21-76	13 March 76	10 mos.	5.0cc	none found
SL-16-76	13 April 76	10 mos.	6.9cc	none found
SL-14-76	13 April 76	10 mos.	5.2cc	none found
SL-52-76	8 Oct. 76	1 yr.	12.5cc	none found
SL-56-76	12 Oct. 76	1 yr.	5.0cc	none found
SL-65-76	14 Oct. 76	1 yr.	9.0cc	none found
SL-4-75	3 Nov. 75	1 yr.	13.0cc	none found
SL-38-76	23 Apr. 76	1 yr.	7.0cc	none found
SL-31-76	20 Apr. 76	1 yr.	7.0cc	none found
SL-7-75	3 Nov. 75	2 yrs.	17.0cc	none found
SL-13-75	4 Nov. 75	2 yrs.	36.0cc	none found
SL-14-75	4 Nov. 75	2 yrs.	22.0cc	none found
SL-4-76	10 Feb. 76	2 yrs.	10.5cc	none found
SL-24-76	14 Apr. 76	2 yrs.	6.0cc	none found
SL-26-76	16 Apr. 76	2 yrs.	6.0cc	none found
SL-29-76	20 Apr. 76	2 yrs.	9.2cc	none found
SL-6-75	3 Nov. 75	3 yrs.	40.0cc	none found
SL-5-75	3 Nov. 75	3 yrs.	18.0cc	none found
SL-8-75	3 Nov. 75	3 yrs.	28.0cc	none found
SL-12-75	4 Nov. 75	3 yrs.	21.0cc	none found
SL-8-76	21 Mar. 76	3 yrs.	30.0cc	none found
SL-25-76	16 Apr. 76	3 yrs.	24.0cc	none found
SL-27-76	18 Apr. 76	3 yrs.	17.0cc	none found
SL-44-76	27 May 76	3 yrs.	28.0cc	none found

SL-10-75	3 Nov. 75	4 yrs.	26.0cc	none found
SL-11-75	3 Nov. 75	4 yrs.	25.0cc	none found
SL-7-76	21 Mar. 76	4 yrs.	27.0cc	none found
SL-43-76	26 May 76	4 yrs.	60.0cc	abundant
SL-58-76	12 Oct. 76	5 yrs.	29.0cc	none found
SL-9-75	3 Nov. 75	5 yrs.	41.0cc	none found
SL-15-75	20 Apr. 76	5 yrs.	78.0cc	abundant
SL-28-76	20 Apr. 76	7 yrs.	121.0cc	abundant
SL-67-76	5 Nov. 76	12 yrs.	54.0cc	none found

Food Habits

During 1975 and 1976, the contents of stomachs and large intestines from 83 sea lions were examined for food items. Identifications of prey items were made from 68 animals (Table 9).

Food habit analysis was based primarily on frequency of occurrence and secondarily on proportion of total individuals. Volumetric measurements were made of total stomach contents. When more than one species was present in a stomach, an attempt was made to determine volumes for each species. This was not possible in most cases as the flesh had been digested to the point where it could not be separated. Because of this either a volume or weight based analysis was not practiced in most cases.

Based on frequency of occurrence, fishes composed 74.2 percent, cephalopods - 17.2 percent and decapod crustaceans - 8.6 percent of the sea lion prey items. Analysis based on percentage of total individuals provided a somewhat different picture. Fishes completely dominated at 97.6 percent, followed by cephalopods at 2.0 percent and decapod crustaceans at 0.6 percent.

Table 9. Frequency of occurrence and number of individual food items of Steller sea lions from the Gulf of Alaska.

Food Items	Number of Occurrences	Percent Occurrences	Number of Individuals	Percent Total Individuals
Cephalopoda (Total)	20	17.2%	26	2.08%
Decapoda (squids)	8	6.9%	7	0.6%
Octopoda (*Octopus* sp.)	9	7.8%	15	1.2%
Unid. cephalopods	3	2.6%	4	0.3%
Decapoda (crustaceans) Total	10	8.6%	7	0.6%
Pandalus spp. (shrimp)	3	2.6%	2	0.2%
Crangon spp. (shrimp)	3	2.6%	2	0.2%
Unidentified shrimp	1	0.9%	1	0.1%
Hyas lyratus (spider crab)	1	0.9%	1	0.1%
Chionoectes sp. (tanner crab)	2	1.7%	1	0.1%
Rajidae				
Raja sp.* (skates)	1	0.9%	5	0.4%
Clupeidae				
Clupea harengus (herring)	3	2.6%	7	0.6%
Osmeridae				
Mallotus villosus (capelin)	5	4.3%	50	3.9%
Gadidae (Total)	57	49.1%	1135	89.2%
Eleginus gracilis (saffron cod)	2	1.7%	13	1.0%
Gadus macrocephalus (Pacific cod)	6	5.2%	33	2.6%
Microgadus proximus (tomcod)	1	0.9%	16	1.3%
Theragra chalcogramma (pollock)	47	40.5%	1072	84.3%
Unid. gadid	1	0.9%	1	0.1%
Zoracidae				
Lycodes sp. (eelpouts)	1	0.9%	1	0.1%
Scorpaenidae				
Sebastes spp. (rockfishes)	2	1.7%	6	0.5%
Cottidae (Total)	3	2.6%	4	0.3%
Dasycottus setigen (spinyhead sculpin)	1	0.9%	1	0.1%
Enophrys bison (buffalo sculpin)	1	0.9%	2	0.2%
Malacocottus kincaidi (blackfin sculpin)	1	0.9%	1	0.1%
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	5	4.3%	16	1.3%
Pleuronectidae (Total)	8	6.9%	14	1.1%

Table 9. (cont.)

Eopsetta jordani (petrale sole)	2	1.7%	3	0.2%
Hippoglossoides elassodon (flathead sole)	2	1.7%	2	0.2%
Lepidopsetta bilineta (rock sole)	1	0.9%	4	0.3%
Limanda aspera	1	0.9%	1	0.1%
Platicthys stellatus (starry flounder)	1	0.9%	2	0.2%
Unid. pleuronectid	1	0.9%	2	0.2%
Unidentified fishes	1	0.9%	1	0.2%
Total	116	100.5%	1272	100.7%

* This identification may be in error. Three experts examined the material, two identified it as *Raja* sp. while another placed in in the family cyclopteridae.

It appears that percentage of individuals analysis is the most accurate in this case. With the exception of *Octopus* sp. the other invertebrate prey species were small and were found in small numbers, usually a single individual. This type of utilization exaggerates their importance in a frequency of occurrence analysis.

The primary food item regardless of method of calculations was *Theragra chalcogramma* (84.3% of individuals and 40.5% frequency of occurrence). Three other species were utilized on a regular basis; *Trichodon trichodon*, *Gadus macrocephalus* and *Mallotus villosus*. Although no single species occurred frequently the family Pleuronectidae was utilized to some extent.

Growth and Condition

Steller sea lion growth information is shown in Figures 8 through 10; sample sizes are small in most cases. Conclusions based on this information are tenuous at best. Usable data on sea lion growth and body condition will not be available until after field work is completed in July 1977.

Female sea lions appear to reach their maximum length and girth between the 6th to the 8th year. Weight apparently continues to increase through the 14th year. The male sample is too small to generalize at present.

Standard measurements (Scheffer 1967) of sea lion body condition have been taken throughout this study (Table 10). The hide plus blubber weight is depicted as a percentage of total body weight, condition index is shown (girth x 100 divided by standard length) (Pitcher 1977) and blubber thickness is shown. All are presented with calculated standard deviations. Little can be said about sea lion condition at this point. No trends are evident.

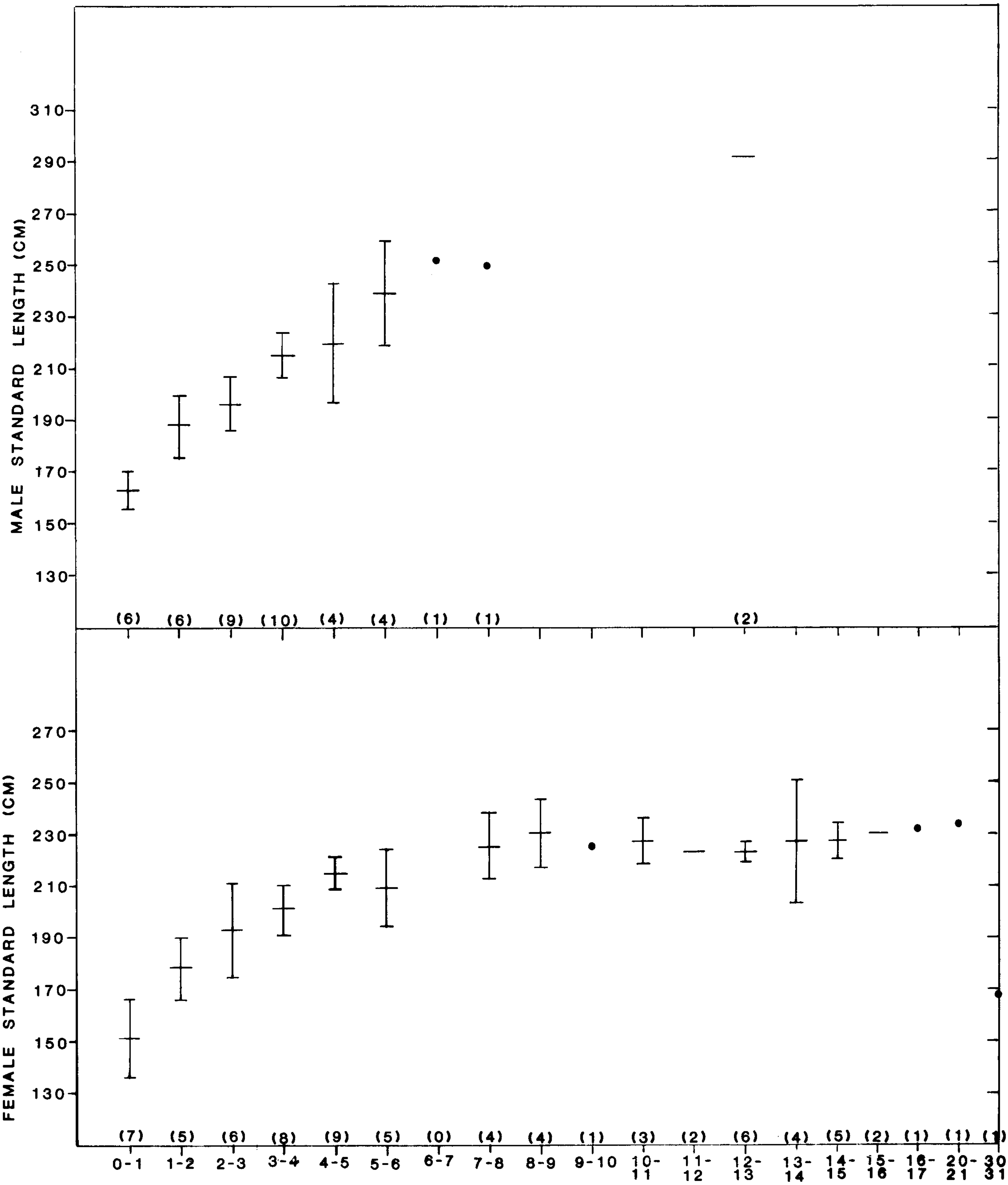

FIG. 8. MEAN STANDARD LENGTH (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEALIONS TAKEN IN THE GULF OF ALASKA, (N).

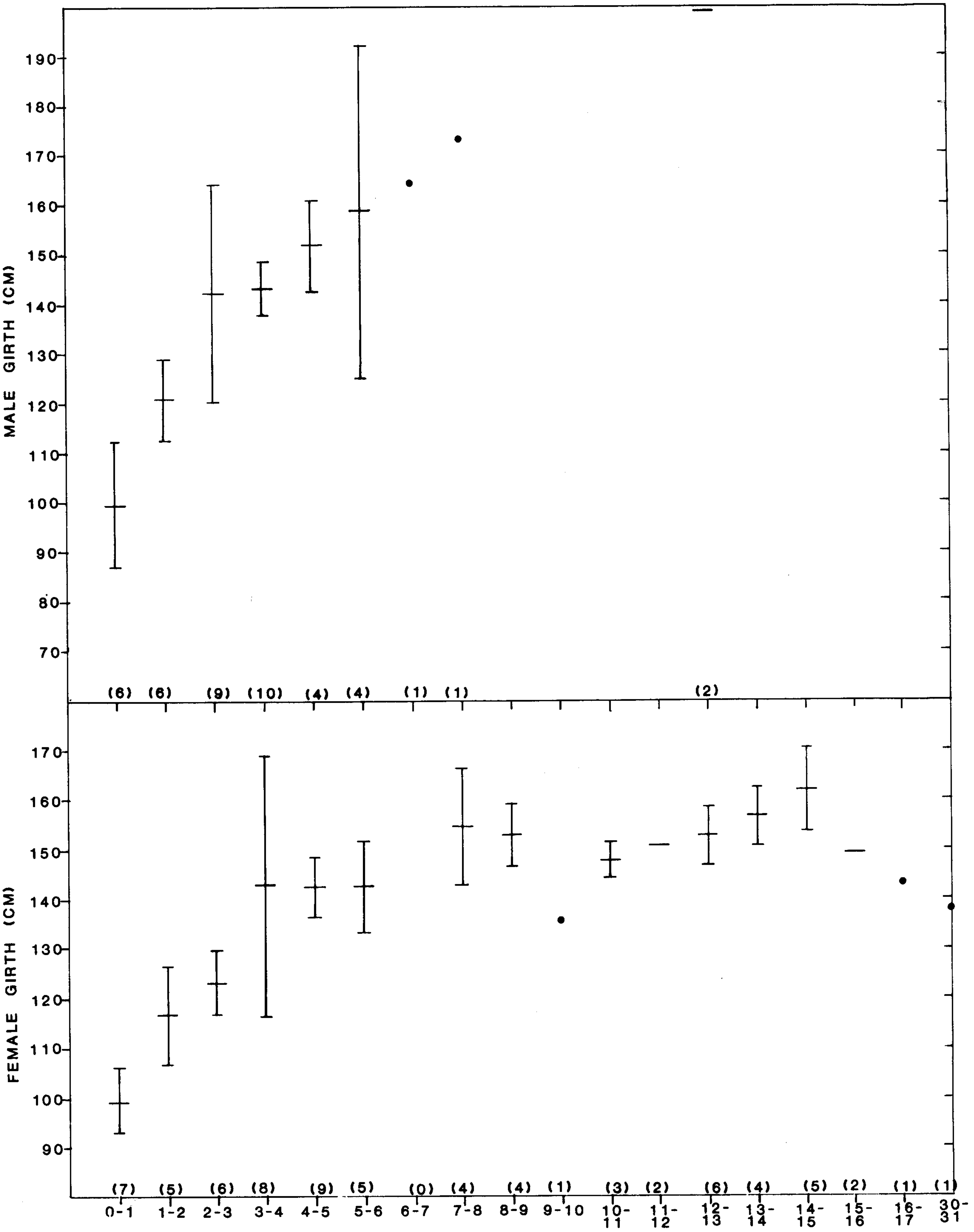

FIG. 9. MEAN GIRTHS (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEALIONS TAKEN IN THE GULF OF ALASKA, (N).

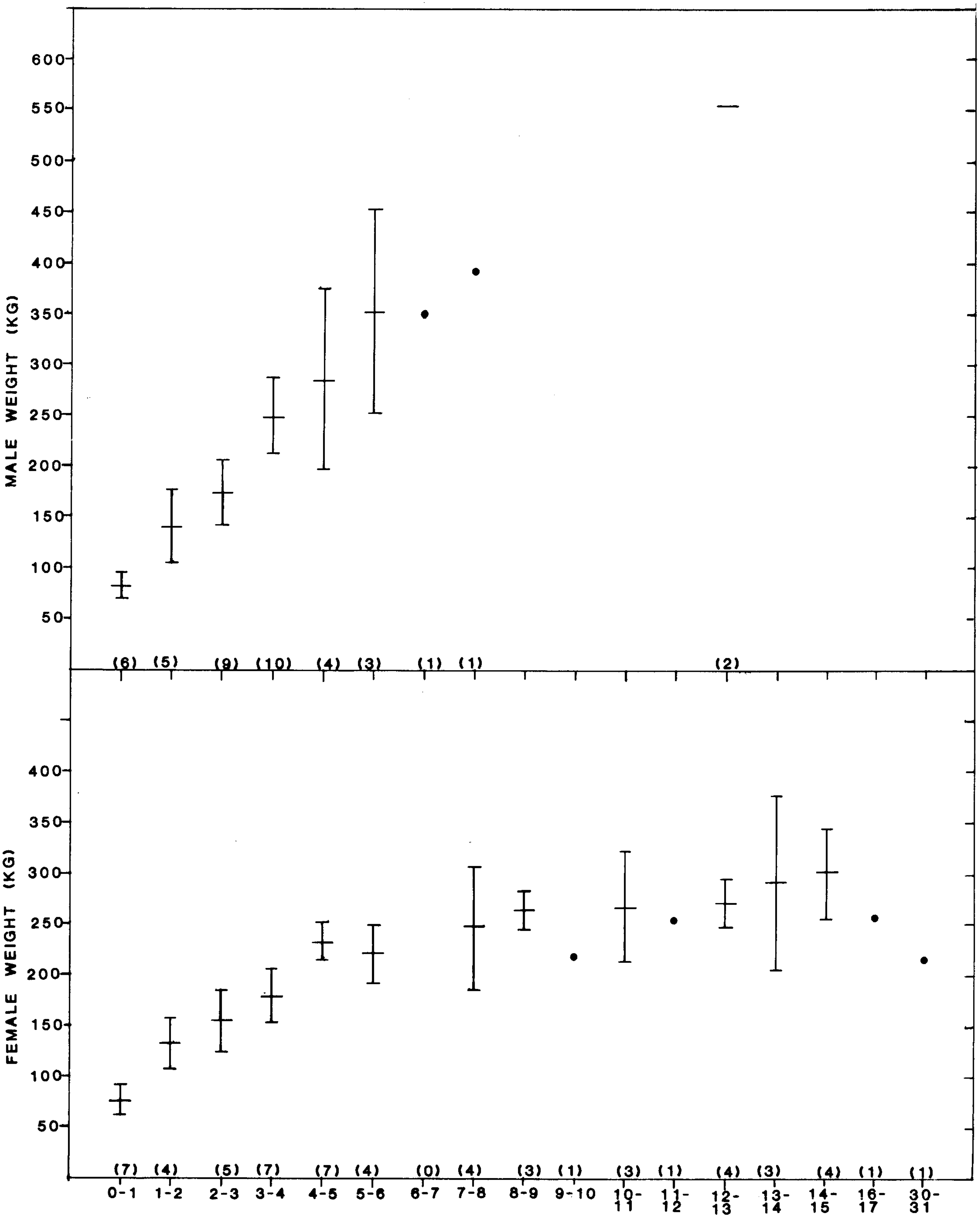

FIG. 10. MEAN WEIGHTS (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEALIONS TAKEN IN THE GULF OF ALASKA, (N).

Table 10. Mean hide plus blubber weights expressed as percent of total body weight, condition index and blubber thickness, averaged by collecting period. Standard deviations are shown in parenthesis. n = sample size.

Collecting	% Hide Plus Blubber		Condition Index		Blubber Thickness	
Period	♀	o	♀	o	♀	o
Feb. 10-16	21(7) N=30	22(4) n=10	67.53(4.5) n=30	62.28(6.8) n=10	3.0(0.86) n=60	2.9(1.2) n=18
Mar. 20-25	20(2.) n=11	--	67.10(3.6) n=6	--	3.25(0.43) n=12	--
Apr. 13-23	22(7.0) n=14	26(5.7) n=13	64.13(3.8) n=14	67.58(3.6) n=13	2.89(0.47) n=28	3.28(0.59) n=25
May 26-27	20(5.0) n=4	--	71.31(7.8) n=4	--	2.28(0.57) n=8	--
Oct. 8-27	20(4.0) n=4	24(2.7) n=3	66.49(4.2) n=18	64.16(3.2) n=6	2.30(0.66) n=36	2.64(0.82) n=12
Nov. 3-5	--	18(3.0) n=12	--	70.07(2.5) n=12	--	3.51(0.83) n=24

CONCLUSIONS

The Steller sea lion population in the Gulf of Alaska uses 60 different locations as haul outs on a regular, predictable basis. Eleven of these haul outs are also used as breeding and pupping rookeries in late May, June and early July. The most important area of sea lion haul outs and rookeries is the Barren Islands, northern Kodiak area. A total of 44 locations have been identified where sea lions have hauled out but which are not used on a regular basis. These areas are probably used during peak local abundances of sea lions, either foraging for local food species or migrating through the area.

Although sea lion haul outs have been well documented, it is important to remember that these are not the only critical areas. Sea lions probably utilize offshore feeding areas extensively. Our knowledge of the degree of use and exact locations of these areas is limited. We do know that areas such as Portlock Bank, Albatross Bank and possibly the Fairweather Grounds are important. Little is known about the extent of use of these areas.

Sea lion movement studies are beginning to show patterns of movements. Dispersion away from summer breeding areas in the late fall is evident. Impacts of OCS development in one area could affect sea lion abundance over large areas. It is important to determine the exact dispersal patterns and whether the animals return in the same manner in the spring.

It is also important to determine fidelity to rookery as this could influence rate of recovery of population should major but temporary disturbance at one occur.

Needs For Further Study

1. The investigation of sea lion movements and distribution should be continued. Branded animals in the Gulf are just beginning to yield valuable information and this work should be intensified in the future.

2. Counts of animals at any location at any time are useful only if we can determine what they mean to the total population. A site specific study should be initiated to determine what percent of the population can be expected to haul out at what time. This would involve a long-term study at one or more haul outs, and could contribute valuable life history information as well.

3. The search for branded animals should be extended to some of the larger hauling areas outside the Gulf of Alaska, both in the Aleutian Islands and Southeastern Alaska. This is essential if we are to determine the extent of sea lion movements and how important the Gulf of Alaska is to the sea lion population as a whole in Alaskan waters.

4. It is important to determine overall pup production and the location and size of the major pupping rookeries in the Gulf. An effort should be made in late June and early July to survey all known pupping rookeries by helicopter to make ground counts of pups.

5. Food habits data for sea lions during summer months, June–September, have not been collected. It is not known if specific selection of food items or increased availability of certain prey species occurs during this time period. Animals should be collected during these months in order to provide this information.

6. Although all sea lion collections has taken place in coastal waters (within 5 miles of land) sea lions are known to feed considerable distances offshore. It is not known if different patterns of prey utilization occur during pelagic feeding. In order to have a complete picture of sea lion feeding ecology these data should be collected. However, pelagic collecting is a very expensive and time consuming activity.

7. Research should be directed at the life histories of important prey species, particularly *Theragra*, *Gadus* and *Mallotus*. Specific information on the effects of oil on the developmental stages of these species should be collected.

Summary of 4th Quarter Operations

A. Ship and Aircraft Activities

1. Ship and Aircraft Schedule
    a. M.V. Yankee Clipper, Private Charter Feb. 8-Feb.18.
    b. Grumman Widgeon Aircraft, Private Charter Mar. 16-Mar.18.

2. Scientific Party
    a. Feb. 8, 1977 through Feb. 18, 1977.
        1. Donald Calkins, Alaska Department of Fish and Game, co-principal investigator.
        2. Kenneth Pitcher, Alaska Department of Fish and Game, co-principal investigator.
        3. Karl Schneider, Alaska Department of Fish and Game, collecting crew.
        4. Julius Reynolds, Alaska Department of Fish and Game, collecting crew.
        5. Albert Franzmann, Alaska Department of Fish and Game, collecting crew.
    b. March 16 through March 18, 1977.
        1. Donald Calkins, Alaska Department of Fish and Game, principal investigator.
        2. Karl Schneider, Alaska Department of Fish and Game, observer and recorder.
        3. Paul Arneson, Alaska Department of Fish and Game, sea bird observer.

3. Methods
    a. See annual report.

4. Sample Localities
    a. Feb. 8-18.
        1. Prince William Sound.
    b. March 16 through 18.
        1. South Side of the Alaska Peninsula.

5. Data Collected.
    a. Feb. 8-18.
        1. Thirty-five sea lions collected.
    b. March 16-18.
        1. All known sea lion haul outs on the south side of the Alaska Peninsula photosurveyed.

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ANNUAL REPORT

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THE RELATIONSHIPS OF MARINE MAMMAL DISTRIBUTIONS, DENSITIES AND ACTIVITIES TO SEA ICE CONDITIONS

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I. SUMMARY

The pack ice of the Bering, Chukchi, and Beaufort Seas is not stationary but perpetually in motion. As a result of this, a wide variety of ice-dominated habitats of importance to marine mammals is created by the interaction of major ice masses with each other, with the mainland coast and islands, and with the open seas to the south. The goal of this project is to gain understanding of (a) the dynamics of that ice, (b) the basis for selective use by marine mammals of specific habitats within it, and (c) the importance of those habitats to the populations in question relative to offshore oil exploration and development. Our work in the past year has centered on solution of four problems: (1) the location and persistence of major polynyi and flaw zones, (2) the nature of the ice "front" and its mammalian fauna, (3) the development and duration of persistent rafted "remnants" of the pack, after break-up and, (4) compilation of adequate data sets on marine mammal distribution for correlation with the seasonal ice features.

Data for the first were obtained mainly from NOAA 2/3 satellite imagery from 1974 to 1976. Ice conditions were classified on a 7-point scale in twenty areas selected on the basis of a preliminary analysis of major features of the pack in 1973-74. These data have confirmed that (a) a broad flaw zone exists along the northwestern coast of Alaska throughout the winter, (b) large polynyi are present for most of the winter south of Point Hope, western Seward Peninsula, eastern Chukotka, and St. Lawrence Island, (c) these polynyi tend to close in the presence of storms with southerly winds, and (d) ice conditions in the Bering, Anadyr, and Yukon Straits are highly variable. Final statistical analysis of the data is in progress.

Information on the ice front and its mammalian fauna was obtained from a combination of surface (ship), aerial and satellite surveys in March-April 1976. The front is definable from those data as a distinctive transition zone between open water and persistent cover of 8 oktas in the southern margin of the pack. In this zone, which is up to 130 km wide, floe size tends to be not more than about 20 m in diameter, usually with open water, brash, or slush ice between the floes. This is the zone of greatest concentration of ribbon and spotted seals and is the area in which they give birth and nurture to their young. A trend of increasing thickness and deformity of floes from east to west was recognized and correlated with probable areas of origin of the ice. Wave action, in the form of high amplitude, long frequency swells from the open sea, was identified as a major factor in the development and maintenance of this zone as a marine mammal habitat.

Data on the development and persistence of the rafted ice remnants were obtained from NOAA satellite imagery for May and June, 1974 to 1976. Three major remnants, each covering several thousand km^2 were identified in each year on the northeastern, central, and northwestern parts of the Bering Sea shelf. The central remnant has been recognized for many years as the site of a major concentration of molting seals, and it is probable that the others are also utilized in that manner. These remnants remain *in situ* for about one month after breakup and disintegration of the rest of the Bering Sea pack, and it is presumed that their persistence is due in part to their being made up of the largest, heaviest floes.

Data on seasonal distribution of marine mammals are still being acquired and coded for computer plotting. A preliminary plot of the set for walruses confirms that their occurrence and migrations are closely linked with the advance and retreat of the Bering-Chukchi pack ice and suggests that their distribution is severly restricted by ice conditions only in winter. At that time, they seem to be constrained to areas[1] of loose-pack heavy ice southwest of St. Lawrence Island and within the inner part of the front. Because they are the areas in which most of their reproductive activities take place and where food is in relatively short supply, they are identified as critical habitats in which perturbation will probably have a significant negative impact on the population.

II. INTRODUCTION

A. General Nature and Scope of Study

The relationships of ice-inhabiting marine mammals to the variety of ice-dominated habitats that exist in the Bering, Chukchi and Beaufort Seas are not well understood. It is generally known (a) that the distribution and activities of mammals in these areas are broadly synchronous with the seasonal dynamics of the pack ice; (b) that each species occupies a different ecological niche within the ice-dominated system; (c) that a variety of ice 'habitats' are present; and (d) that the various species 'utilize' sea ice in different ways (Burns, 1970; Fay, 1974).

As pointed out by Fay (1974), ice of these and other sub-polar and polar seas is important to marine mammals from several aspects. It serves as a substrate on which some pinniped species haul out to sleep, to bear their young and to undergo their annual molt. As such, it serves the same function as land. It also forms a rigid barrier through which pinnipeds and cetaceans alike must find or make holes in order to have access to the air that they breathe and the sea that holds their food. For some species of marine mammals, the nature of the ice may be as important in habitat selection as are terrain, soil type and vegetation to terrestrial mammals. For other species, the presence of ice may be disadvantageous, requiring them to carry on extensive southward migrations in order to avoid it.

Almost all investigations to date of the relationships of marine mammals to sea ice have focused on the species and its adaptations to the ice. This approach is understandable because more was known about the form, function and distribution of the animals than about the dynamic processes of ice formation, movement and deformation. The latter have been difficult to study in broad perspective from land, ships, or aircraft, but the recent introduction of repetitive high-resolution satellite imagery has provided that greater perspective. Broad views of sea ice distribution are now available from which these processes can be observed, so that the chronological and spatial distribution of marine mammals may now be related to sea ice characteristics, conceivably to the degree that a predictive model can be developed.

Our general objectives are to determine the distribution and aerial extent of the different ice habitats utilized by marine mammals of the Bering, Chukchi and Beaufort Seas, to investigate the relationships of the various marine mammals to those habitats, and to determine how the seasonal changes in sea ice cover regulate the distribution and activities of marine mammals. A continuing program for obtaining various kinds of 'ground truth' is an integral part of this project. Of necessity, this project requires, and is designed around, the involvement of both physical and biological scientists.

In the last annual report of this project, a preliminary discussion was given of the relationship between marine mammal distribution and ice conditions in the Bering and Chukchi Seas during March and April. The data on ice conditions were derived by examination of imagery acquired by the DAPP system during March and April of 1973, the NOAA 2/3 satellite system for the same months of 1974, and LANDSAT imagery for both years. Mammal distribution data were taken from Burns (1970). The correspondence between the two data sets was good in the sense that certain species appeared to be restricted in their distribution by recognizeable features of the ice cover, during the time covered by the study. Thus, this approach gave promise of producing useful results. For this reason, the study of ice conditions was continued during the past year in a form designed to provide information in greater detail than was available for the preliminary study described above.

B. Specific Objectives

The specific project objectives are:

(1) To determine the extent and distribution of regularly occurring ice-dominated marine mammal habitats in the Bering, Chukchi and Beaufort Seas;

(2) to describe and delineate those habitats;

(3) to determine the physical environmental factors that produce those habitats;

(4) to determine the distribution and densities of the various marine mammal species in the different ice habitats; and

(5) to determine how the dynamic changes in quality, quantity and distribution of sea ice relates to major biological events in the lives of marine mammals (e.g., birth, nurture of young, mating, molt and migrations).

C. Relevance to Problems of Petroleum Development

Petroleum development in the Bering, Chukchi and Beaufort Seas will, without exception, take place in regions covered by seasonal sea ice in which ice-associated marine mammals occur abundantly and are involved in major annual biological events. As examples, proposed lease areas in Bristol Bay, St. George Basin and Navarin Basin are in areas seasonally covered by the ice front in which spotted and ribbon seals concentrate in winter to give birth and nurture their pups. The Hope Basin is within the migration route of all ice-associated marine mammasl that winter in the Bering Sea. The Beaufort Sea lease area is occupied by ringed seals and polar bears almost all year.

The different regions are subjected to different ice conditions. In turn, the variety of ice conditions support different marine mammal species in varying numbers.

The relevance of this project to problems of petroleum development is that we are attempting to determine (1) what major recognizable marine mammal habitats exist, (2) how these habitats are spatially and temporally distributed, (3) to what extent the various mammal species depend on them and, (4) how the more important aspects of the biology of marine mammals are related to physical changes in their ice-dominated environment.

The answers to these questions are necessary in order to determine which species are likely to be affected by oil development, in what numbers, and how they are likely to be affected.

III. CURRENT STATE OF KNOWLEDGE

Ice-associated mammals of the Bering, Chukchi and Beaufort Seas include polar bears (*Ursus maritimus*), walrus (*Odobenus rosmarus*), spotted seals (*Phoca largha*), ringed selas (*Phoca hispida*), ribbon seals (*Phoca fasciata*), bearded seals (*Erignathus barbatus*), belukha (*Delphinapterus leucas*), and bowhead whales (*Balaena mysticetus*). The biology of some of these species has been intensively studied (i.e., Burns, 1965, 1967; Burns et al., 1972; Gol'tsev, 1968; Kleinenberg et al., 1964; McLaren, 1958; Tikhomirov, 1961). However, the ecology of some species such as the bowhead whale and ribbon seal is poorly understood.

Recent studies (Burns, 1970; Fay, 1974) have focused attention on the role of sea ice in providing a variety of habitats, each of which supports a different faunal association. However, the characteristics of these habitats (and others which have since been recognized) and the physical and biological processes which produce them are only beginning to be investigated.

Recent studies of ice distribution and dynamics in the study area, using both LANDSAT and NOAA 2/3 satellite data, have been reported by Shapiro and Burns (1975 a, b), Muench and Ahlnas (1976), Crowder et al. (1974), and Hibler et al. (1974). These illustrate the utility of satellite imagery for investigations of this type. However, the problem of using satellite data to define and identify those characteristics of the ice which determine its quality as habitat for particular species has not as yet been addressed. This constitutes an important part of this project.

IV. STUDY AREA

The study area includes all of the eastern Bering and Chukchi Seas and the shelf of the Beaufort Sea.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Data about mammals are derived from several sources including the published literature and unpublished reports from shipboard and aerial surveys, commercial aircraft flights to and from coastal villages, observations at coastal hunting sites, catch records of marine mammals harvested at Eskimo villages, ecological studies of various species of marine mammals, and occasional reports from interested individuals such as pilots and village residents.

Local ice conditions are monitored during the appropriate activities listed above. Additional data are available from aerial photographs and the results of other remote sensing flights in the study area. Finally, imagery from both LANDSAT and NOAA weather satellites is received at the remote sensing data library of the Geophysical Institute, University of Alaska. NOAA satellite data are available within one week of acquisition. Unfortunately, there is about a six-month delay in receipt of the LANDSAT data, plus time required for printing and preparation of special products.

The satellite data are especially useful for providing broad overviews that coincide with ground truth observations, permitting us to learn how to recognize on that imagery the kinds of ice conditions that are apparent at surface level. These overviews also make it possible to define "average" ice conditions in any area and to compare these seasonally and from year to year. Utilizing this approach, our work in the past year has centered on solution of four major problems:

A. Determination of the frequency of occurrence, duration, and interrelationships of major features of the winter pack ice that are of known importance to marine mammals of the Bering, Chukchi, and Beaufort Seas. These include such characteristics as persistent areas of dispersal and convergence, and major polynyi and flaw zones.

The annual ice cover in the Bering and Chukchi Seas was divided into twenty areas of interest based on our previous work. Ice conditions in those areas were classified into seven categories which could be readily recognized on the photographic products of the NOAA satellite imagery used for the study. The categories, and the basis for their identification were:

1. Continuous pack ice cover - continuous ice cover shown in uniform gray tones on the imagery.

2. Flaw zone - A narrow zone of relatively dark gray to black tones on the image, often mixed with small areas of lighter gray, which separates landfast ice from the moving pack ice. Note that the scale of the imagery requires that a flaw zone be at least several kilometers wide to be identified.

3. Pack ice with leads - Pack ice crossed by leads of a single set; that is, parallel or sub-parallel leads, or leads radiating into the pack ice from a promontory.

4. Broken pack ice - Pack ice broken by two or more sets of leads or by a network of leads. Floes between the leads are predominamtly angular, and heavy ice cover exceeds 85%.

5. Open pack ice - Areas of 50 to 80% heavy ice cover in which the floes are predominantly rounded as opposed to the angular form of category 3. Note that this classification is applied even when the ice cover is almost continuous, provided that discrete, rounded floes are dominant in the area. Finally, the classification does not distinguish between cases where the area between floes is occupied by thin ice or open water, because this is a function of the air temperature rather than the ice motion.

6. Open with scattered floes - Less than 50% heavy ice cover in scattered floes.

7. Open - No heavy ice present in the area although, as noted above, a continuous cover of new ice may be present. Polynyi along coastlines or on the lee sides of islands are included in this category, and the orientation of the open coastline forms a part of the classification.

This classification represents a gradation from continuous, heavy pack ice to absence of ice. However, this should not be considered to be a continuous spectrum, such that conditions in any one area must pass through all the intervening stages in changing, say, from a low to a high numbered category. As an example, along some coastline, the conditions could change from category 1, to category 2, to category 6 without passing through categores 3 through 5. This would occur if little or no recognizeable, disruption of the pack occurred during the movement. Examples of progressive changes through categories 1, 3, 4 and 5 also have been observed, so these do appear to have some significance in indicating gradations of deformation.

It should be noted that the categories of ice conditions given above were defined to be applied to the photographic imagery produced by the NOAA weather satellites. The resolution of these products is approximately .6 km, with a scale of about 1 mm = 9 km. Thus, the classification may not apply to larger scale imagery in all cases. However, preliminary work indicates that with some modification it might apply to LANDSAT imagery, as well.

During the winter months imagery in the visible band is not acquired by the satellites; instead, data are obtained only on the IR band. Based on comparison of data from both bands acquired at the same time, there is an apparent decrease in the detail visible on the ice surface, but the effect of this on the classification described above does not seem to be important. However, the possibility of errors being introduced does exist and needs to be investigated further.

To date, all of the imagery acquired by the NOAA weather satellite between March 1974, when the first of the satellites was orbited, through June of 1976, has been examined, and the ice conditions categorized for each of the areas listed. At present those data are being reduced to a form suitable for computer manipulation from which the final analysis will be done. However, for purposes of this report, some of the data were organized and plotted by hand for preliminary study. This set includes only the categorization of ice conditions for the periods March 3, 1974 - June 30, 1974; December 1, 1974 - May 28, 1975; and January 1, 1976 - May 12, 1976. The data for each area were plotted as a time series, with the ice conditions for each day represented by a point on a scale from 1 to 7 corresponding to the categories above. In this manner, the general, or average, conditions were readily recognized, and a description of these follows, below.

B. Location and physical description of the spring ice front, in relation to distribution of certain pinnipeds. The "front" is that zone of transition between the open, ice-free sea and the consolidated pack (i.e. between 0 and 8 oktas of persistent ice coverage). It is one of the most labile segments of the pack, being strongly affected by both surface weather and sea state and changing daily in character. It is also a zone of major importance to marine mammals, in that it harbors the main breeding populations of two species (spotted and ribbon seals) during the period of birth and nurture of the young.

Position of the southern limit of sea ice in 1976 was determined from very high resolution radiometric (VHRR) images obtained via the NOAA 2 and 3 satellites. More detailed information about the ice edge and the front was based on the Multispectral Scanner (MSS) imagery of the LANDSAT 1 and 2 satellite systems. Studies conducted from the OSS SURVEYOR and the ZRS ZAGORIANY, as well as from aircraft working within the front zone have provided detailed descriptions of weather conditions and characteristics of sea ice and mammal distribution during March and April.

While the OSS SURVEYOR was in the ice front in March - April, survey flights on seals and ice conditions were undertaken with a Bell 206 helicopter on 27 March and on 20, 23, 24 and 25 April. All flights were conducted within 40 nautical miles of the ship.

An extensive aerial survey of marine mammals in the ice front, also was conducted during April, utilizing a P2V aircraft. Flights were made on April 8, 9, 11, 17, 19, 20, 21 and 23. During the course of these flights, the front and adjacent ice to the north were covered in an area extending from Southern Bristol Bay to 178°58'E (Fig. 1).

C. <u>Description of the development and duration of the spring ice "remnants" of the Bering Sea</u>. As mentioned earlier (Ann. Rept. 1 Mar. 76), the remnant of primary interest is a large mass of rafted floes, several thousand km^2 in extent, that tends to remain to the south of St. Lawrence Island, well after the main pack has broken up and melted, i.e. well into late-June. This is known to be a feature of major importance to the Bering Sea ribbon seal population, which utilizes it annually as its molting site.

The distribution and movements of the Bering Sea pack ice in 1974-76 were studied on very high resolution radiometric (VHRR) images obtained via the NOAA 2 and 3 satellites and provided by the Gilmore Creek Tracking Station, NOAA/National Environmental Satellite Service, Fairbanks, Alaska, to the Geophysical Institute, University of Alaska. Supplementary information was derived from Multispectral Scanner (MSS) imagery of the LANDSAT 1 and 2 satellite systems. Since mapping of ice distribution and movements in March-June 1974 has already been accomplished by Muench and Ahlnas (1976), our attention was directed mainly at acquisition of data for the same seasonal period in 1975 and 1976. Preliminarily, ice distribution patterns and general qualities were traced directly from the VHRR imagery, and qualitative aspects confirmed or modified on the basis of the MSS imagery. Final plots will be made on standard charts, with compensation for distortion of the VHRR views, based on positions relative to known landmarks. Additional ground truth and confirmation of the use of these remnants by marine mammals will be made via ships and aircraft.

D. Compilation of distributional data on ice-inhabiting marine mammals of the Bering, Chukchi, and Beaufort Seas. All available reports of sightings are being compiled for eventual computer plotting on a monthly basis. A preliminary plot for one species (walrus) in relation to synoptic pack ice distribution is presented.

Finally, we undertook also an aerial survey of ringed seals in relation to fast ice quality and distribution in the eastern Chukchi and Beaufort Seas, but the data from this are not yet adequately prepared for presentation at this time.

VI. RESULTS

A. Occurrence, duration, and interrelationships of ice conditions in 20 areas of the winter pack.

It is convenient to discuss the areas individually in the order considered:

Area 1 - Point Hope to Point Barrow.

Ice conditions in this area were almost invariably of category 2 or 3, with the former predominating. The width of the flaw zone was variable in both time and space along the coast, reaching widths in excess of 50 km near the southern end of the area. At times, the condition graded from category 2 to category 3, as leads radiated out from various promontories along the coast. In general, these did not extend far offshore but were confined to the width of the flaw zone itself. Most commonly they tended to form arcs concave to the south, suggesting southward movement of the ice in the flaw zone.

It is of interest that changes in weather seemed to have no effect on the state of the ice in this area, as defined by the classification above. This probably was due to the fact that any movement of the ice other than in a southeasterly direction (which appears to occur rarely) would have tended either to move the ice offshore (thus opening a narrow flaw lead all along the coast), or to drive it with a component of motion parallel to shore. In this case, the interaction of the drifting pack with the coastline (as modified by landfast ice) tended to cause fracturing out to distances of several tens of kilometers. Thus, the existence of the flaw zone tended to be maintained irrespective of variations in the sense of motion of the ice.

Area 2 - Point Hope to Kotzebue Sound.

The data indicate that the ice conditions in this area were particularly sensitive to local winds. This is to be expected, because the coastline is oriented almost at a right angle to the prevailaing northeasterly winds of winter and spring which tend to keep the heavy ice offshore and maintain a persistent polynya in the area. However, it is likely that heavy ice cover (category 0) is virtually continuous during stormy periods (cloudy weather), when the winds are predominantly from the south. In almost every instance, on the first day following a period of cloudy weather, or when the ice was visible through the clouds, ice conditions were of category 1. By the second clear day after a storm, the polyna had re-formed, and it persisted then until the next cloudy period.

During the spring break-up, the ice tended to remain tight against the coast.

Area 3 - Kotzebue Sound

Continuous ice cover from freeze-up to break-up. The data on movement and distribution patterns following break-up are not yet available.

Area 4 - Chukchi sea north of Bering Strait.

Ice conditions in this area tended to be variable, both in the sense of rapid change within periods of a few days and when considered from year to year. In 1974 the ice conditions were classified as 3 to 5 for most of the year, with only a few days of continuous heavy cover. In contrast, in 1975 heavy ice dominated the area from mid-March to early May. The area was obscured by clouds during most of January, February and early-March, and the few observation from this period suggest that conditions may have been more variable at those times. In 1976, the conditions varied from continuous cover to catagory 5, with no one condition dominating.

Area 5 - Wrangell Island

In 1974 and 1975 the area was cloudy during most of the period covered by this report. The data that were available often indicated the presence of a polynya to one side of the island, but no side predominated. More data are available for 1976 and these show that ice conditions remained as broken pack through January and February. In the remainder of the year the area was either covered by continuous, heavy ice, or a polynya was present on one or another side of the island.

Area 6 - North Coast of the Chukchi Peninsula

The data are consistent for this area for all three years. The ice tended to remain tight against the coast, so the classification of continuous heavy ice (catagory 1) applied most commonly. There may have been a tendency for the ice occassionally to move offshore, opening a wide flaw lead in coincidence with closing of the ice against the coast southeast of Point Hope. However, once formed, the flaw lead closed within a day.

Area 7 - Bering Strait

Ice conditions in this area were variable, ranging from category 1 to category 5 each year. Broken pack was the most common description in 1976, when conditions were more stable than in 1974 or 1975.

Area 8 - Seward Peninsula between Bering Strait and Nome.

The ice along this coast, as might be expected, followed virtually the same pattern as that of Area 2.

Area 9 - Norton Sound

In contrast to Kotzebue Sound, the ice cover in Norton Sound tended to be in motion during most of the winter. In general, cover was continuous along the southern shore of the Sound and open along the northern side, even when the ice was against the shore in areas 2 and 8.

Area 10 - Coast of Chukotka from Bering Strait to Cape Chaplin.

Conditions in this area were variable, ranging from continuous pack to open. In 1976, the former was the most common condition.

Area 11 - Bering Sea South of Bering Strait.

Because area 10 and 11 are contiguous, a similarity in conditions was anticipated. In general, this was true with a respect to times of change between various ice states, but typically, the ice in area 11 tended to be somewhat heavier than that in area 10.

Areas 12, 13 - North and south sides of St. Lawrence Island.

These two areas are described together, because the ice conditions in them tended to complementary. That is, there was continuous ice cover on the north side when the south side was open, and vice versa. On a few occasions, the entire island was surrounded by ice classified as broken pack or open pack (categories 4, 5) but these conditions did not persist. The pattern of opening of the southern side of St. Lawrence Island was similar to that of areas 2 and 8, but appeared not be closely in phase with them.

Area 14, 15 - West and east sides of St. Lawrence Island.

Conditions in these areas tended to be similar, ranging from broken pack to open with scattered floes. In general, the cover was heavier to the east of the island than to the west, where occasionaly only a thin ice cover was present. Thus, the southerly drift of ice around the island seemed to be greater around the eastern than the western side.

Area 16 - Gulf of Anadyr

The northern Gulf of Anadyr is dominated by a polynya which persists through most of the ice year. Heavy ice tends to accumulate in the southern Gulf.

Area 17 - Nunivak Island

Cloud cover in the area limited the number of observations. When visible, a polynya was almost always present on the southern side of the island.

Area 18 - St. Matthew Island

Very few data are available for this area because of cloud cover. Ice conditions observed were variable, with open water or thin ice to the south the most common condition.

Area 19 - Pribilof Islands

Cloud cover was virtually continuous over the area in 1974 and 1975. When visible, the area was usually ice-free or scattered floes were present. More observations were possible in 1976 and conditions varied from continuous ice cover to open.

Area 20 - Bristol Bay

Observations in 1975 were limited by cloud cover, with only 14 clear days from January through April. Conditions on these days were variable from continuous cover to open pack ice. There was little heavy ice in the area in 1974, while continuous heavy ice appears to have been the dominant condition through early April of 1976.

B. Location and structure of the spring ice front

The southern limit of seasonal ice in east-central Bering Sea (from 168°W to 178°W) usually approximates the edge of the continental shelf. East of 168°W longitude, the late winter-spring ice edge is always considerably north of the shelf break. Since there is great annual variation in extent of ice cover in Bering Sea, there are major annual differences also in location of the ice edge and front zone. During March and April the southern margin of ice may be as far south as 55°10'N or as far north as 61° or 62°. Winter - spring 1976 was a period of prolonged north winds, lower than normal temperatures (especially in April) and extensive ice coverage, hence the southern limit of ice was relatively far south. Its position in March-April, in which period it did not change greatly, is shown in Fig. 2, relative to that on 22 March 1977, when it was approximately 220 km farther north. The difference between years is attributed to strikingly different climatic regimes, the winter of 1975-76 in eastern Bering Sea having been appreciably colder and with more frequent and stronger northerly winds than that of 1976-77.

The front zone in March-April 1976 was extremely wide (in excess of 130 km in the vicinity of the Pribilof Islands), and the southern limit approached the maximum reported by Wittmann and MacDowell (1964). It was made up mainly of small floes, up to 20 m in diameter, separated by water, slush ice, and brash for most of that period, with occasional re-freezing into a consolidated unit during brief periods of calm. In stormy periods, it was subjected to compaction or dispersal, depending on wind direction and velocity, and the re-frozen units were repeatedly broken up by heavy swells moving in from the open sea. Floe size seemed to be a function mainly of the frequency and amplitude of such waves. Indeed, it was our conclusion that the width of the front *per se* was a function of the depth of penetration into the pack by such waves with sufficient force to break the larger floes into units of 20 m or less.

East of 160°W longitude, in inner Bristol Bay, the cover was made up predominantly of rafted new ice in comparatively large floes (mostly greater than 100 m in diameter) with rough surfaces. Ice ridges were of very low profile, apparently resulting from re-freezing of rafted pancake ice, rather than from pressure of convergence. All visible surfaces were covered with silt, which also appeared to be incorporated into the ice. The latter probably was derived from the turbid waters of this part of the Bay and from windblown sediments off the land. Ice-associated marine mammals were conspicuously absent over most this area, though a few walruses and spotted seals occurred just inside the western edge of it.

The ice of the front from 160°W to approximately 169°W was quite uniform. The normal gradation in coverage from open water to approaching 8 octas occurred there over an average distance of 25 km in the eastern part, 40 km in the central part and 60 km in the western part. Maximal width of the front was 84 km in the vicinity of 166°W. There was a clear trend of increasing thickness of floes from east to west, those in the east being mainly of thin, gray ice, and those in the west of much thicker (about 0.5 m), snow-covered ice. The degree of deformation (pressure ridging) followed the same trends as thickness. In comparison to general observations of previous years, the overall extent of general deformation was not great and averaged less than 10 percent of the total ice cover. This also probably resulted from the continually dispersed nature of the front during 1976. Highest densities of walruses and spotted seals occurred in this area. Walruses were most numerous between 160°W and 162°W and spotted seals between 162°W and 165°W. However, both species occurred in lower numbers throughout the area.

Ice conditions in the front west of 169°W were markedly different from those in the foregoing areas. The majority of floes were about 20 m in diameter but made up of thicker (0.5-0.7 m) ice, even to the southern limit. Snow cover appeared to be much thicker, the degree of deformation was usually between 15 and 30 percent, and there was a strikingly higher proportion of clear, blue ice in the pressure ridges than was seen farther to the east. The front zone was widest in this area but more consolidated, reaching a width in excess of 160 km between 169°W and 172°W. Within the front the wind rafted areas of ice were considerably larger than those farther east. The ice edge extended south of the shelf margin in the region west of 174°W. Our surveys did not extend beyond 178°58'E. Spotted and ribbon seals were the two most abundant species in this area and the observed density of ribbon seals was higher than in the other areas of the front we surveyed.

Excellent LANDSAT images of the front during March - April 1976 are available. Some of these are illustrated in Figs. 4 through 8. A location map indicating areas included in these images is presented in Fig. 3.

C. Development and duration of spring ice remnants

The Bering Sea remnant ice is roughly divisible into eastern, central, and western units (Figs. 9-11), each of which tends to be several thousand km^2 in area but varies somewhat from year to year in extent and location. These extensive rafts of predominantly heavy, pressure-ridged ice are often interconnected early in the spring (May) but usually separate during the final month (June) of their existence.

The eastern unit, between St. Lawrence Island and the Alaskan mainland, consisted in 1975 and 1976 of an elongate strip of unconsolidated open pack, extending from southern Norton Sound southward through Yukon Strait to just west of the western end of Nunivak Island. Its development was evident in the last ten days of May, and it persisted as a recognizable unit throughout the month of June. In 1974, this unit was not apparent in late May and never did develop fully thereafter. It was represented only during the first three weeks of June by a few small unconsolidated rafts in Yukon Strait.

The central unit, between St. Lawrence Island and St. Matthew Island, was well developed by late May of 1974 and persisted throughout the month of June in that year. In 1976, it developed in connection with both the eastern and the western units and remained connected to the latter until its disappearance in the third week of June. In 1975, the satellite imagery in May and June was poor, due to persistent cloud cover in the areas of interest. An ice remnant developed in the central area in May but was not detectable after mid-June.

The western unit, in the Gulf of Anadyr, was well developed and persisted, until late June in all three years.

D. Seasonal distribution of marine mammals in relation to ice

We are still in the process of acquiring and plotting distributional data on ice-associated marine mammals and have, at present only one set that is sufficiently complete to permit adequate correlation with ice conditions. These are the data on the Pacific walrus populations, which has been under surveillance to a greater extent than any other for more than twenty years (Brooks, 1953; Fay, 1957; Kenyon, 1960, 1972; Fedoseev, 1962, 1966; Gol'tsev, 1968, 1972; Estes and Gol'tsev, in prep.). Because of their large size, distinctive appearance, and tendency to spend about half of their time out of the water in all seasons, walruses are among the most visible and easily recognized marine mammals in existence, and reports of their presence, even by unskilled observers, are more easily obtained and dependably accurate than of any other species. On that account, the quantity of sightings available for walruses is the greatest.

A preliminary manual plot of some of these data is presented by month in the accompanying charts (Figs. 12-13). As can be seen from these, the greatest quantity of observations is available for February to September; as might be expected, very few data are on hand for the period October to January. In the latter period, in the area of concern, daylength is short, there is little shipping, and inclement weather greatly restricts the visibility from aircraft. The principal findings are: (1) The population in winter (December to March) is distributed mainly from the vicinity of St. Lawrence Island, southward to the ice front, and from the vicinity of Nunivak Island, southeastward into northern Bristol Bay. Population estimates based on aerial surveys in February-March and in April have indicated that about two-thirds to three-fourths of the animals (100-115 thousand) occupy the first area, and the remainder (35-50 thousand), the Nunivak-Bristol Bay area. Few animals have been sighted in this period in the Gulf of Anadyr, Chirikov Basin or Norton Sound, or off the Alaskan coast north of Nunivak Island.

(2) In spring (April to June), the population is very much in motion, moving northward and tending to clump in the vicinity of St. Lawrence Island to Bering Strait before moving on into the eastern Chukchi Sea. Small groups of a few thousand animals lag behind in northern Bristol Bay and northern Gulf of Anadyr, where they remain throughout the summer.

(3) During summer (July to September), the animals are widely distributed along the ice front in the Chukchi Sea, from northwestern Alaska to Wrangell Island and the northern coast of the Chukchi Peninsual. Apart from the groups that regularly remain in Bristol Bay and the Gulf of Anadyr, a few stragglers are sighted in Bering Sea; a few groups also penetrate eastward into the Beaufort Sea and westward to the East Siberian Sea. In summers when the ice recedes far north, some tens of thousands haul out on Wrangell Island.

(4) In autumn (October to December) the population is again in motion, this time southward, the vanguard reaching the vicinity of St. Lawrence Island as early as late-October and the whole population presumably reaching that latitude by late-December. Along the way, in October-November, the animals congregate in prodigeous numbers on certain beaches in the Bering Strait region. More than 40 thousand were counted in one such group in 1975.

The relations of this dynamic distributional scheme to ice conditions are already apparent in a general way but will bear closer scrutiny. In winter, the apparent avoidance by the animals of the Chukchi Sea, the Gulf of Anadyr, and the Chirikov Basin-Norton Sound area, as well as the offshore zone south to Nunivak Island, seems clearly related to the fact that the first three are areas of dependably heavy, close-packed ice, in which pressure-ridging is extensive and extreme, and leads are scarce and short-lived. Their avoidance of the fourth may also be, in part, a result of ice conditions but, perhaps more importantly, a result of scarcity of food. Only a few small localities in the Chirikov Basin-Bering Strait region tend to have persistent leads and polynyas, where the ice is perpetually in motion and open water exists throughout the winter off the leaward sides of small islands (e.g. Fairway Rock, King and Sledge Islands, and the Stolbi Rocks near St. Lawrence Island). Occasionally, 1 to 5 animals have been known to inhabit those sites during the winter.

On fourteen low level flights and one icebreaker track between St. Lawrence Island the Seward Peninsula, over the winter ice of the Chirikov Basin-Norton Sound region, walruses or evidence of their rpesence were sighted on only six occasions, and on four of these only within 5 miles of the northeastern or northwestern ends of the island (24 January - Northeast Cape; 1 February, 12 and 21 March - Gambell). On only two occasions, a few animals were sighted about 50 miles north of the island (6 and 20 March).

There were no signs of their presence anywhere along the remaining nine flight and cruise tracks (2, 3, 7, 10, 17 January; 15 February; 23, 28, and 26-30 March). Thus, it appears that, even though the available food supplies for walruses are several times greater in this area than they are farther to the south (Stoker, Fay, and Shults, in prep), ice conditions tend to render the area uninhabitable in winter.

By mid- to late-April, walruses begin to appear with increasing frequency in the eastern Gulf of Anadyr, Chirikov Basin, Bering Strait, and the area north of Nunivak Island. While satellite imagery does not show any marked change from winter ice conditions in that period, the data from our aerial surveys over the Chirikov Basin, at least, do indicate a reduction in deformation pressure and more frequent occurrence of leads and polynyas there (18, 28, 30 April), along with a wider distribution of walruses. By May, the entire Bering Sea pack is rapidly degraded, allowing the animals free passage to the north, where the better food supplies exist. At that time, also, there tends to be open passage northward through Bering Strait to the eastern Chukchi Sea. In most years this is open as far as Point Hope and in some years as far as Barrow. With the exception of those summering in Bristol Bay and the Gulf of Anadyr, virtually all of the animals exit through Bering Strait by mid- to late June and penetrate the degrading Chukchi pack to the greatest extent feasible.

Throughout the summer, the distribution tends to be along the southern edge of the pack ice of the Chukchi Sea, which varies widely from year to year in its extent. With the formation of new ice over vast areas in October-November, the animals again move southward toward Bering Strait, tending to favor the western side and tending to stay ahead of the advancing ice front. They evidently continue this flight, ahead of the ice, until they reach the latitude of St. Lawrence Island, whereupon the majority settles in for the winter, the remainder continuing on toward Bristol Bay.

VII. DISCUSSION

A. Major features of the winter pack

The data presented above tend to reinforce some of the conclusions in the last annual report of this project regarding the distribution of ice conditions in the Bering and Chukchi Seas. However, some modifications need to be made. As an example, ice conditions in area 4 north of Bering Strait may be somewhat more severe than indicated in that report. In addition, the polynya along the coast southeast of Point Hope is now known to close during cloudy weather, and is therefore not as persistent as previously believed.

Further, several interesting and potentially important problems are indicated; in particular, the fact that the ice cover of the north coast of the Chukchi Peninsula and Norton Sound is generally not in phase with that of the coast near Point Hope and the south side of Seward Peninsula suggests the presence of zones of large-scale shear motion separating those areas.

Finally, at present is appears that sufficient data will be available for statistical analyses of ice conditions in each area and of conditions between areas. This will permit more accurate definition of "average" conditions than has been possible in the past.

B. Structure of the front

In his synoptic description of the dynamics of the Bering Sea pack ice, Fay (1974) predicted that the prevailing direction of movement was from northeast to southwest throughout the winter and that this was a result mainly of persistently strong northerly winds. He observed also that:

> "At its southern edge, the pack is intermittently affected throughout the winter also by southerly winds associated with the continuous progression of North Pacific storms. These winds seem

> to have two major effects: temporary compaction of ice north of the edge, due to opposition to the southwesterly drift, and destruction of the edge itself, due to the heavy swells produced in the open sea. Strictly speaking, there is no actual "edge" for a 15- to 65- km wide zone at the southern periphery of the pack is alternately dispersed and compressed."

That zone is distinguished as the "front", a term borrowed from North Atlantic sealers, who have long recognized the relationship of ice conditions in a similar zone there with the occurrence of certain kinds of pinnipeds.

Spotted and ribbon seals utilize the Bering Sea front intensively throughout the winter-spring period and the majority of these two species occur within this ice habitat during that time. These seals give birth on ice floes of the front, care for their young and also haul out to rest and molt. Walrus, bearded seals and ringed seals also occur in the front, although highest densities occur farther north, in heavier ice. Some sea lions also haul out along the southern edge, but their population centers are in ice-free areas farther south. Evidently some bowheads and belukhas also winter in this zone and, in spring, some gray whales, as well.

The characteristics of thickness and deformation of the ice floes that make up the front seem to us to be clearly relatable to their place of origin and their trajectory therefrom. Much of the ice west of 169^{o}W is of the thick, pressure ridged, heavily snow-covered type typical of the central pack, north to Bering Strait. In view of this and the general north-south drift pattern of the central pack (Shapiro and Burns, 1975a; Muench and Ahlnas, 1976), it is probable that most of this ice was formed much farther to the north, some of it perhaps as far as the Chukchi Sea (Shapiro and Burns, 1975b). Conversely, the ice in the area between 160^{o} and 169^{o}W is in the "shadow" of the Alaskan mainland, as regards that drift pattern, and this is reflected in the quality of ice there. Heavy, pressure ridged floes are much less numerous in the front, most of the ice being thinner and less deformed, probably having been generated not far to the north, in or near Kuskokwim Bay and the northern parts of outer Bristol Bay. Most of the ridging in this ice is around the periphery of the floes and of low relief, such as occurs in connection with their bumping and grinding against one-another under the influence of incoming swells from the open sea. Farther east, in inner Bristol Bay, the contrast is still greater, most of the ice there having been newly formed in place and never subjected to intensive pressures.

Based on characteristics of ice in the front and the motion frequently resulting from wave action, it appears that an oil spill in this zone could have serious consequences. Results of ongoing studies by S. Martin (RU #87), have graphically shown some of the interactions of oil with sea ice under laboratory conditions. During a recently concluded synthesis meeting held at Barrow, Alaska, Martin demonstrated what happens to an oil slick which occurs in ice under controlled conditions and subjected to wave action. The oil moves toward and accumulates in the openings between floes that are in motion and is "pumped" up onto the ice. We have observed such pumping action often in the front during periods of intensive swells when the algal-filled brash between the floes was thrown up onto the ice as the floes came together with each successive wave. It appears that an actual field experiment with oil in this zone can and should be undertaken.

Spotted and ribbon seal pups are born and nurtured during the first four weeks of their lives on floes of the front. Insulation value of the white coat (lanugo) of new born pups is critical to the maintenance of body heat and its thermoregulatory value is sharply reduced when it becomes wet (Davydov and Makarova, 1965; Ray and Smith, 1968). Young, white-coated pups less than three weeks of age and exposed to oil on the ice floes would almost certainly die of exposure. Older seals undergoing the annual molt in the same region would also be vulnerable to skin damage.

C. Ice remnants

As noted above, the winter pack ice of the Bering Sea is not stationary but is perpetually in motion, the general trend of movement being from northeast to southwest. The average rate of that movement in March-April 1974 was determined by Meunch and Ahlnas (1976) to be about 15.5 km/day, which could mean that ice formed in the vicinity of St. Lawrence Island would tend to reach the front in a period of about one month. The principal centers of ice formation that contribute to this moving mass are (a) the southern Chukchi Sea (from which ice moves southward through Bering Strait), (b) the large, persistent polynyas to the south of the major islands and peninsulas, and (c) the coastal flaw zone extending from near the mouth of the Yukon River southward to northern Bristol Bay (Shapiro and Burns, 1975a, 1975b; Meunch and Ahlnas, 1976). Throughout the winter, degradation of this ice takes place mainly at the southern edge of the pack, which (in central Bering Sea) lies for most of that time at or near the shelf break itself. Along the way, a substantial amount of deformation and consolidation takes place through formation of pressure ridges, mainly in areas of convergence in Bering, Anadyr, and Yukon Straits, and along the northern coasts of the major islands and peninsulas. Some amount of production of new ice takes place also in the multitude of irregular, temporary leads and polynyas that develop in the areas of divergence (e.g. south of the three Straits). The motion of this ice appears to be largely the result of prevailing, strong, northerly winds, with a lesser westerly set as a consequence of Coriolis force (Fay, 1954; Shapiro and Burns, 1975a, b; Muench and Ahlnas, 1976).

By May and continuing throughout the summer, surface winds over this area become weaker and more variable (U.S. Navy, 1956), with frequent southerly and easterly vectors. Also by May, with the increased solar radiation and consequent warming of the sea and surface air, the whole Bering Sea pack begins to break up and melt. Most of this degredation takes place in situ, i.e. the general north-south movement ceases, local movements are irregular, and the ice simply breaks up and melts in the same area that it had reached by the end of April. In the straits (especially Anadyr and Bering Strait), where sea surface currents are strongest, the ice tends to move northward with the currents (Muench and Ahlnas, 1976; Burns and Fay, unpublished). Ice coverage on the shelf is reduced to a 50% or less by late May, but some patches persist annually, well into late-June. These rafts of persistent or "remnant" ice have been recognized by us for many years as being of singular importance to several species of pinnipeds that utilize them annually in prodigious numbers during the period of their molt (Fay and Burns, unpublished).

The ice from which these remnants are derived is some of the heaviest, most deformed ice in the Bering Sea, which is, apparently, one of the principal reasons for its persistence. Preliminarily, pending completion of tracings of actual trajectories, it seems probable that its origin is the Chukchi Sea and northern Bering Sea, north of St. Lawrence Island, where the thickest ice is formed and the greatest amount of deformation pressure is applied to it while in transit southward.

Each of the major remnants, as well as a number of smaller, more irregularly developed ones, is utilized intensively by bearded, larga, and especially ribbon seals, which haul out there in May and June to rest in the warmth of the spring sun and undergo their annual shedding and replacement of hair. On that account, these remnants of the pack ice harbor some of the greatest concentrations of seals ever formed during the year. The seals, themselves, because of the delicate nature of their skin during the molting process, are at that time most vulnerable to skin damage by chemical irritants and to infection by dermatological pathogens.

These remnants, then, appear to us to be some of the most critically important habitats of Bering Sea pinnipeds, and it seems essential that this should be taken into account in planning for petroleum development.

D. Marine mammal distribution

It is evident from the foregoing that the annual distribution pattern of walruses in the Bering and Chukchi Seas is closely linked with the distribution of ice. Presumably, their occurrence is closely related also to the distribution of food organisms, i.e. benthic invertebrates, on which they are dependent at all times. It is becoming apparent, however, that the most abundant food supplies are situated in areas well to the north of their area of residence during the long winter season (Stoker, Fay and Shults, in prep.), which implies that the animals themselves are constrained at that time by some other factor, probably ice conditions. Indeed, they appear to be excluded almost entirely from access to the rich benthic resources of the Southern Gulf of Anadyr, Chirikov Basin, and Chukchi Sea in the wintertime, evidently because these areas are covered by some of the heaviest, most compacted ice in the entire Bering-Chukchi system and because such leads and polynyas as do develop are rapidly refrozen to a thickness that is impenetrable by these animals (i.e. 20 cm). While our observations indicate that they show a clear preference for thick, pressure-ridged floes as haulout areas, they appear to be restricted in winter to occupation of areas where near maximal divergence of such ice takes place, i.e. to the southwest of St. Lawrence Island and in the inner part of the front west of 160^{o}W. Wherever they occur in such areas, they tend always to favor the heaviest, most deformed floes, possibly because such floes move at a slightly different rate than the surrounding pack and usually have some open water adjacent to them.

Inasmuch as the vital reproductive functions of the walrus population take place mainly in the wintering areas, and since the food supplies in those areas appear to be among the leanest available over any part of their range (Stoker, Fay, and Shults, in prep.), it seems probable at this time that these are the areas in which any impact through pollution or perturbation will have the most significant negative effect on the population.

VIII. CONCLUSIONS (tentative)

A. Study of ice conditions in the 20 areas of the winter pack that were identified earlier as being of particular interest has tended to confirm most of our speculation, e.g. that the large polynyi south of the major islands and peninsulas tend to be open for most of the winter, and when they close, the ice on the northern coasts of those land masses opens up. However, the synchrony among them seems to be less regular than was predicted and, in some cases, entirely out of phase. The reasons for this are not yet clear.

B. The "front" appears to be a well defined zone that is the product of several factors at work on the southern part of the pack, namely winds, surface currents, air and water temperatures, and, especially, wave action. The depth of penetration into the pack by swells generated in the open sea seems to be the major factor that determines the width of the front as a marine mammal habitat of greatest importance to those species that cannot or do not maintain breathing holes in the ice.

C. Remnants of rafted ice persist each spring in the northern Bering Sea for about a month after the main pack has disintegrated. These are grossly divisible into eastern, central, and western units.

D. Ice conditions appear to be the principal constraint on the distribution of the walrus population in winter, restricting these animals to areas of low ice pressure, though the food supplies there are among the leanest in any part of their annual range.

IX. NEEDS FOR FURTHER STUDY

A. Ice trajectories and speeds

For the sake of better understanding of the forces at work in the pack and of the points of origin and routes traversed by floes that make up such major features as the front and the ice remnants, much more painstaking work needs to be done on tracing the trajectories and rates of movement of the floes. It is conceivable, for example, that a large part of the heavy ice making up the central and northern portions of the pack is derived from the Chukchi Sea, and that most of the remainder is generated in the large polynyi south of the major peninsulas and St. Lawrence Island. The important implications of this extend far beyond the objectives of this study, but have relevance to it as well. This "endless belt" of moving ice could be a major transporter of nutrients and pollutants, and its potential in that regard needs to be understood in much greater detail.

B. Ground truth

Much more surface observation, for correlation with satellite imagery and aerial surveys, will be needed by this project before completion. We are particularly lacking in information from within the winter pack as regards such matters as actual dimensions of floes (diameter and thickness), snow depths, rates of re-freezing of leads, and the kinds of animals present under different circumstances, and their activities. It would be particularly instructive to be able to observe and measure directly the conditions in some of the apparently critical areas, such as the major polynyi and flaw zones. For the most part, this would require the services of a Coast Guard icebreaker in winter, which vehicle could accommodate personnel of several other OCSEAP projects whose needs also include winter observations and measurements within the pack.

C. Marine mammal distribution data

In the course of our compilations of marine mammal distributional data in relation to ice, we have recognized an extreme scarcity of reliable information from the autumn-winter period, October to February, even for the more visible species, such as the walrus. While it may not be feasible to obtain a large amount of data from the area in question in that period, at least a superficial overall view is needed. Conceivably, this could be accomplished with a few strategically timed survey flights in November and January by personnel of this or another OCSEAP project.

D. Oil experiments

Some field experiments with small, simulated oil spills in the front zone are needed, in order to gather further information on the movements of oil in this area of unusual ice dynamics and to evaluate its effects on the biota, particularly (in the case of this project) on the newborn seals.

X. ACTIVITIES SCHEDULED FOR NEXT QUARTER

A. Ship or laboratory activities

1. Ship or field trip schedule

   11 April - 1 May: OSS Surveyor, Leg III

   19 May - 12 June: OSS Discoverer

2. Scientific party

   Surveyor: J. J. Burns, Alaska Department of Fish & Game
   F. H. Fay, Institute of Marine Science, Univ. Alaska

   Discoverer: (Same)

3. Methods

Surveyor: Ground truth observations of ice conditions in relation to marine mammal distributions and weather, from shipboard, small boat, and helicopter.

Discoverer: (Same)

4. Sample localities

Surveyor: Ice front from 165° to 174°W and within 40 air miles of ship.

Discoverer: Central ice remnant.

5. Data collected

Ice coverage, floe dimensions, degree of deformation; mammal abundance by species, floe type, activity; meteorological data and sea state. Approximately 550 km ship track, 900 km aircraft track.

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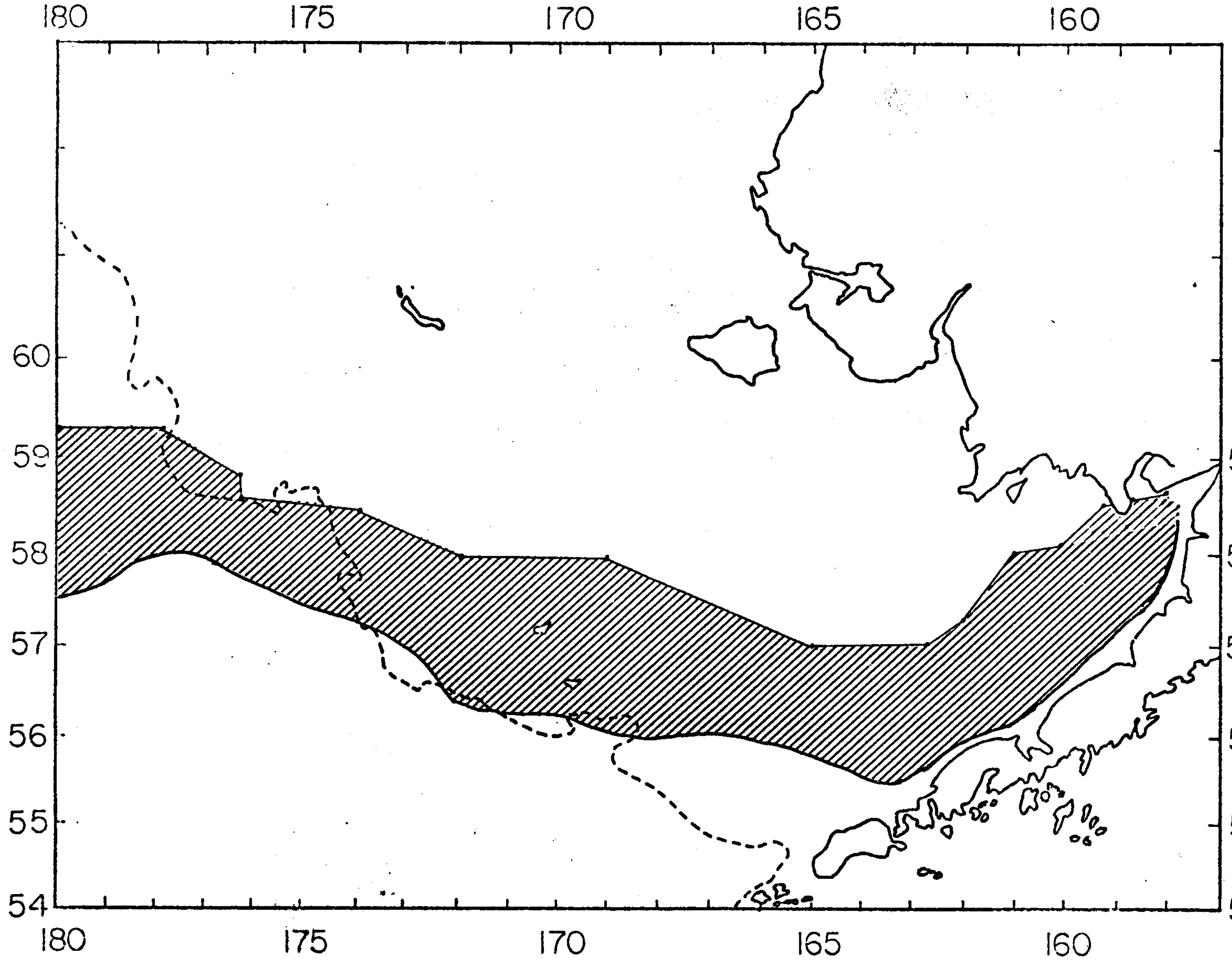


Fig. 1 Area within which shipboard and aerial surveys were conducted during March - April 1976 (crosshatched). Southern limit of surveys was the ice edge. Northern limit approximated the inner margin of the front. The 200 meter depth contour is indicated by the light, dashed line.

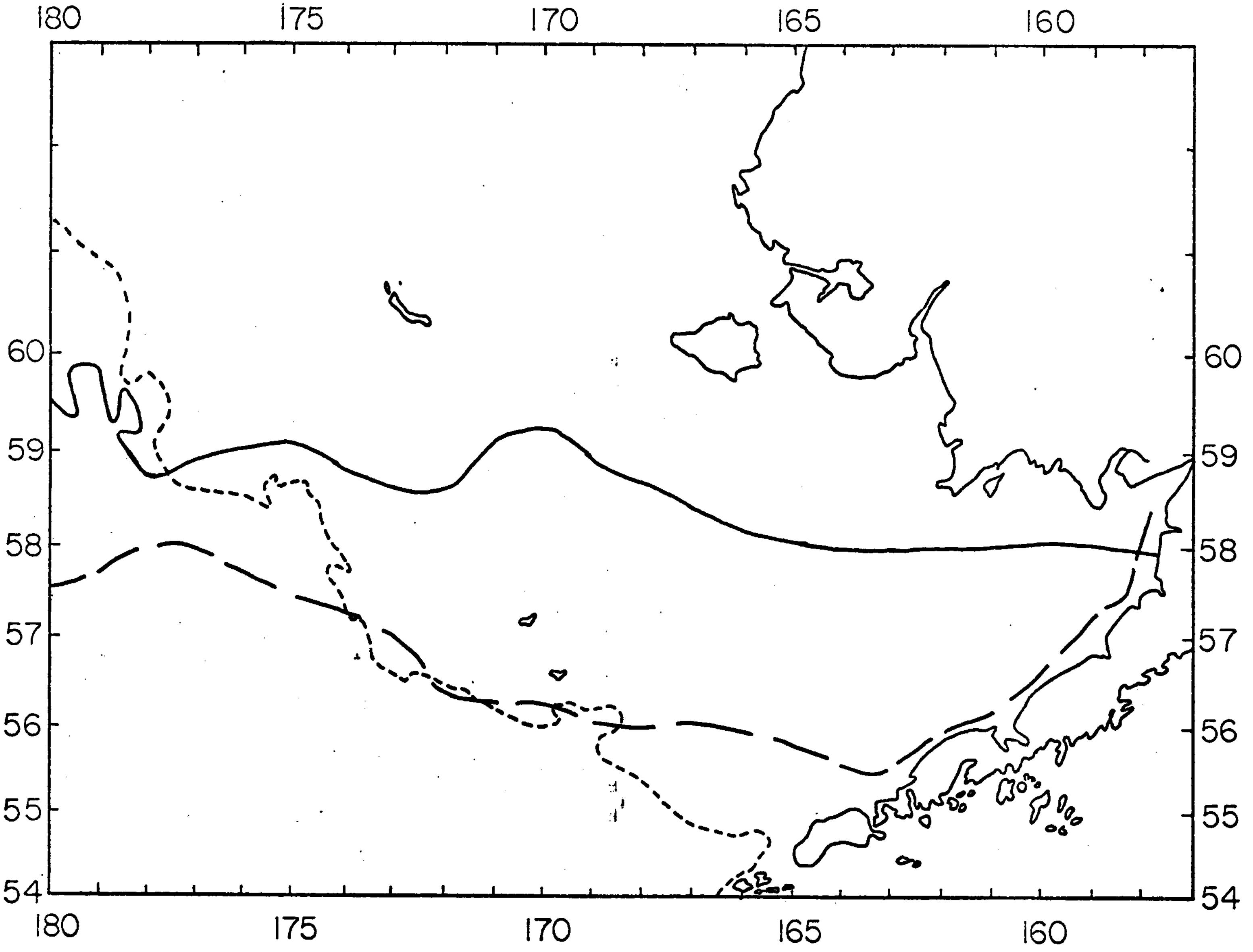


Fig. 2 Location of ice edge during March - April 1976 (----) and on 23 March 1977 (——).

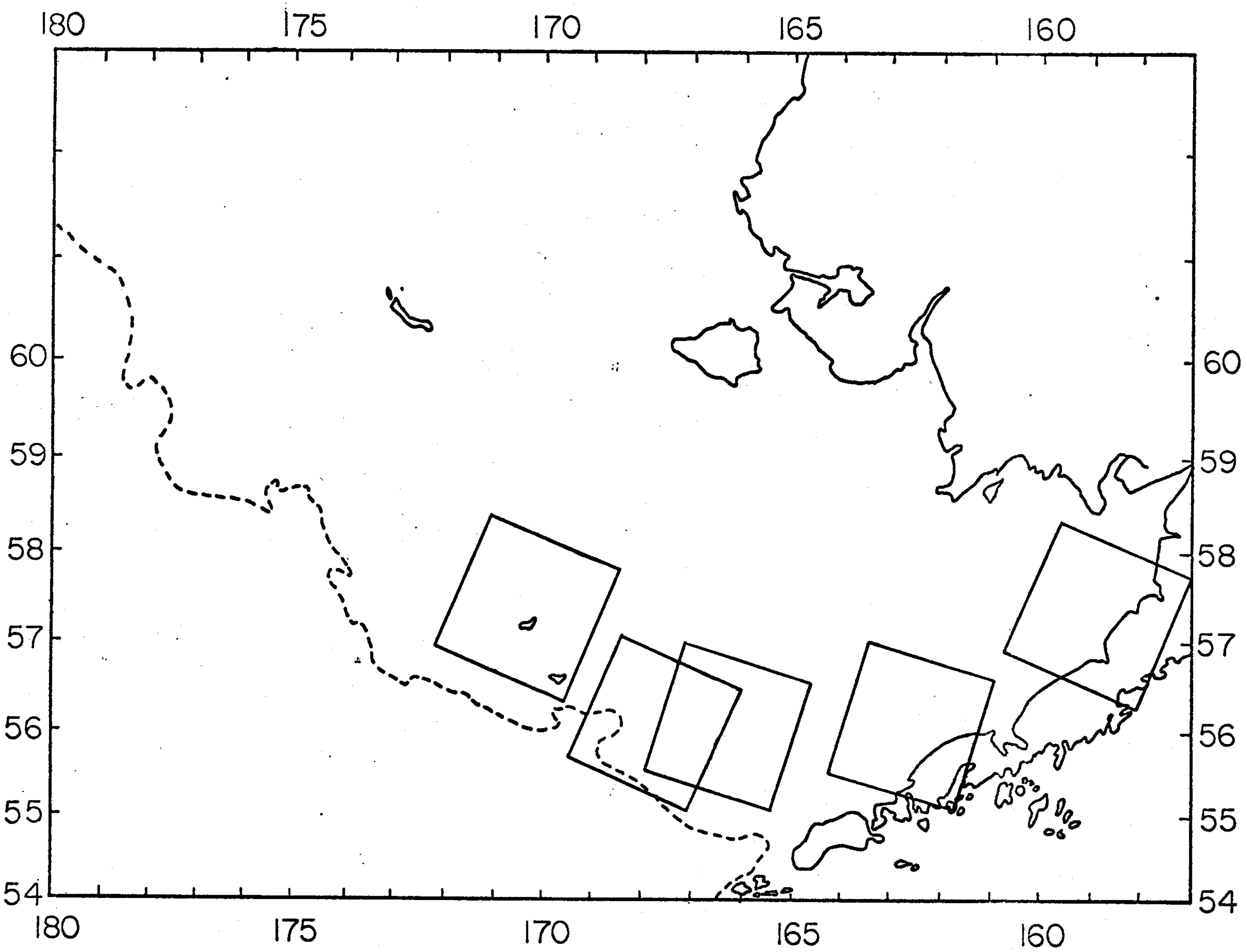


Fig. 3 Location map of LANDSAT images of the ice edge and front during March and April 1976.

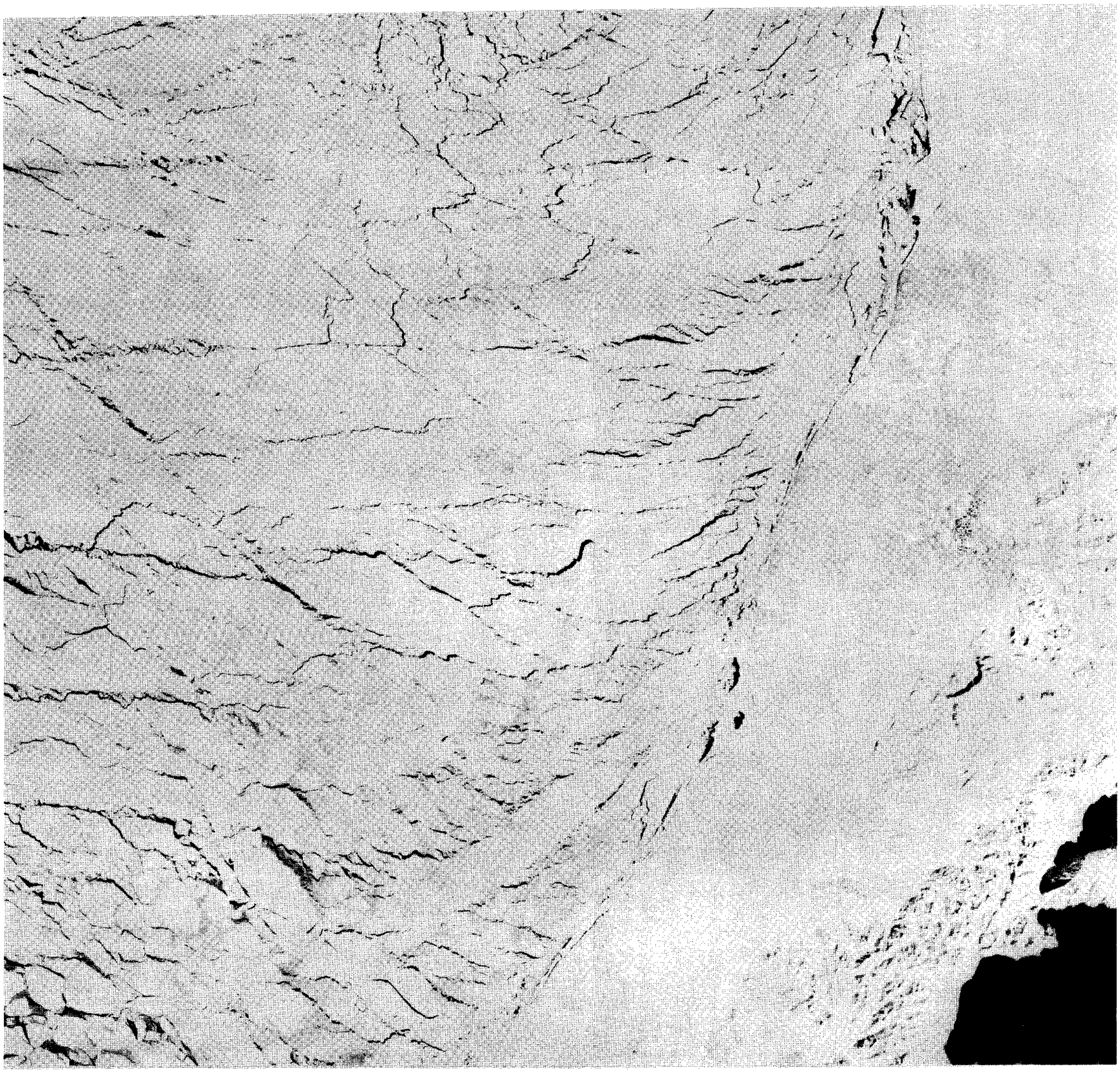


Fig. 4 LANDSAT imagery2427-20595; southeastern Bristol Bay, 24 March 1976.

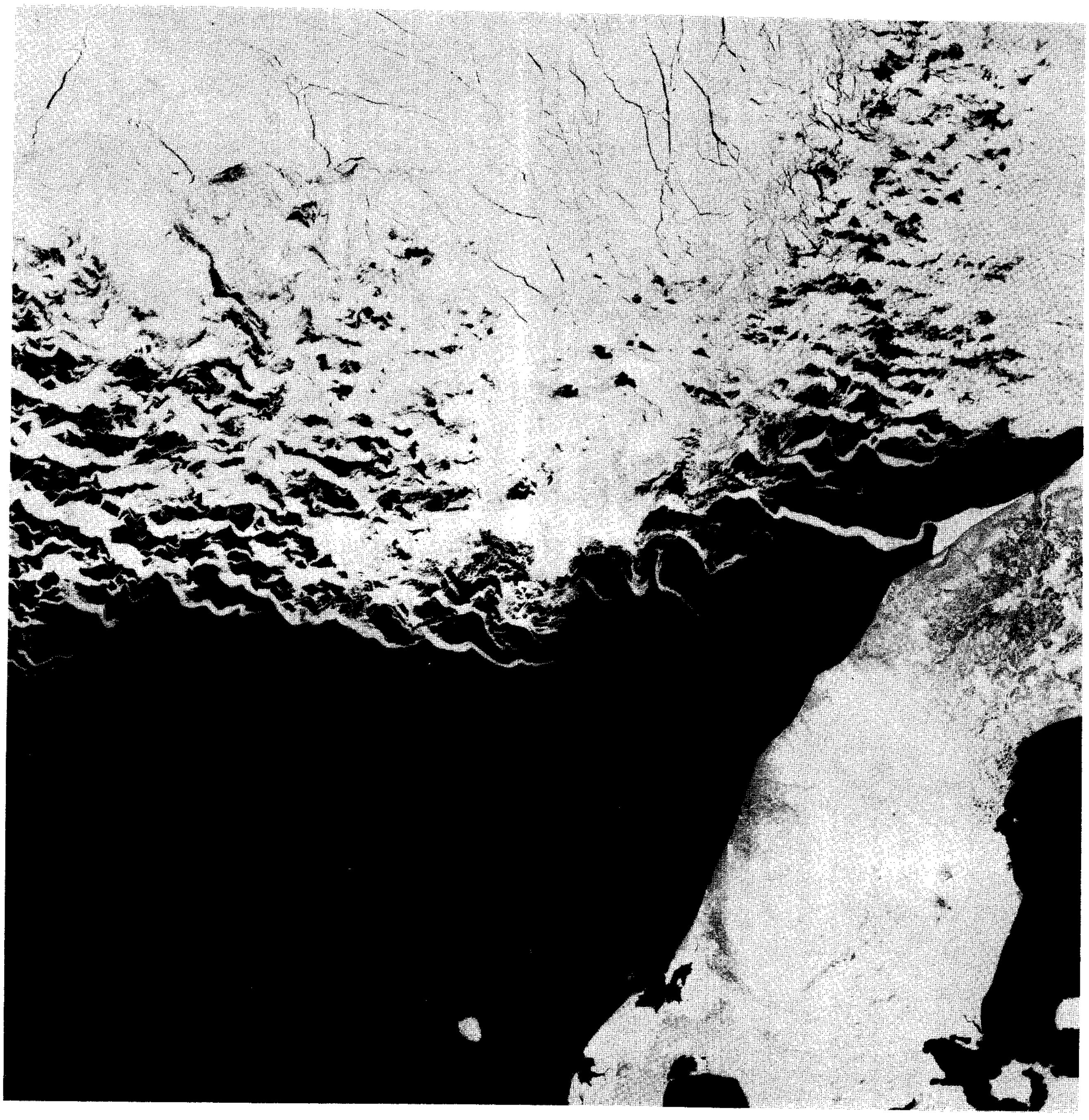


Fig. 5 LANDSAT image 2447-21110; ice edge and front zone in the area north of Cold Bay and Amak Island, 13 April 1976.

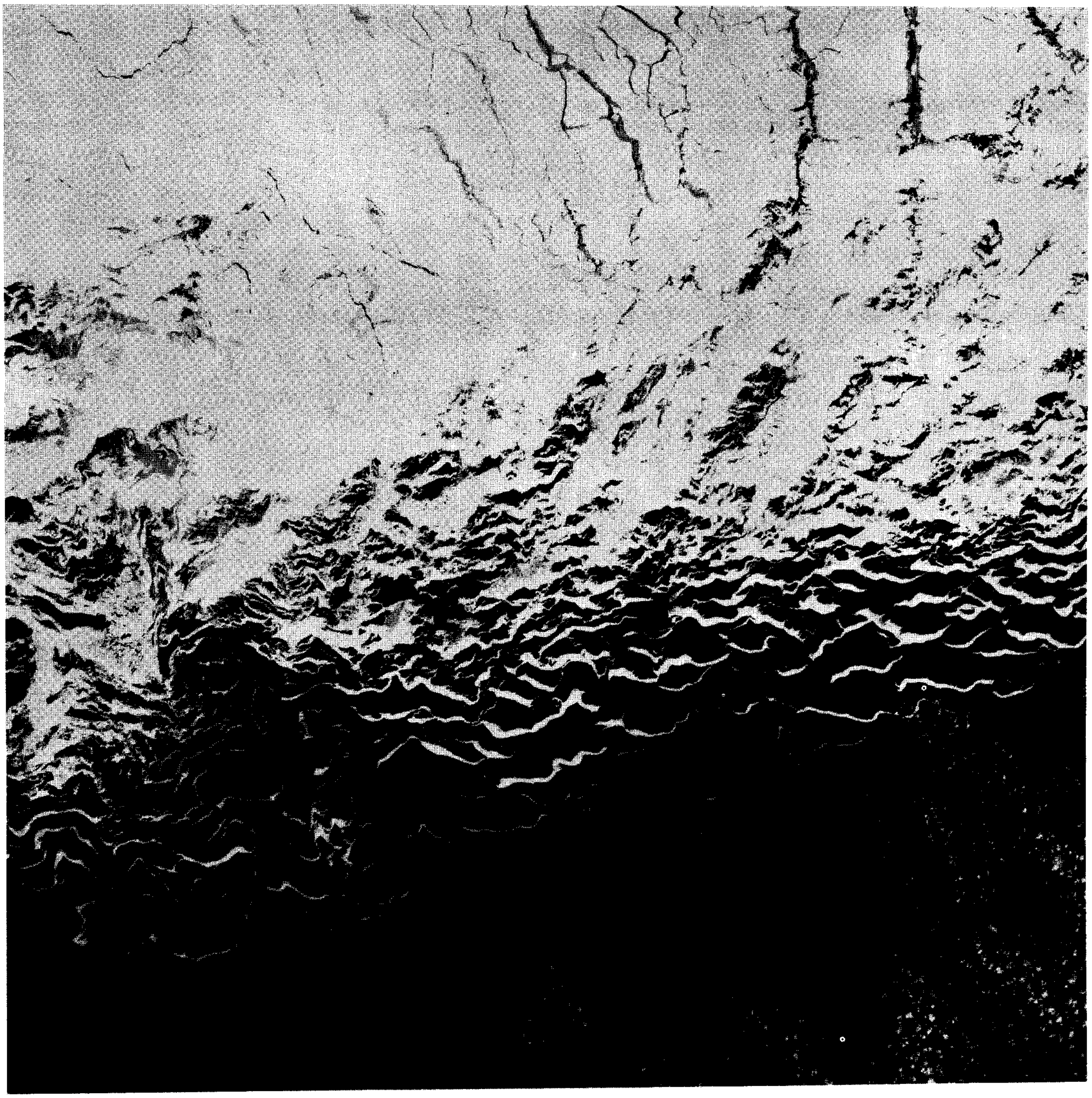


Fig. 6 LANDSAT image 2431-21230; ice edge and front zone in area between 165°W and 167°W, 28 March 1976.

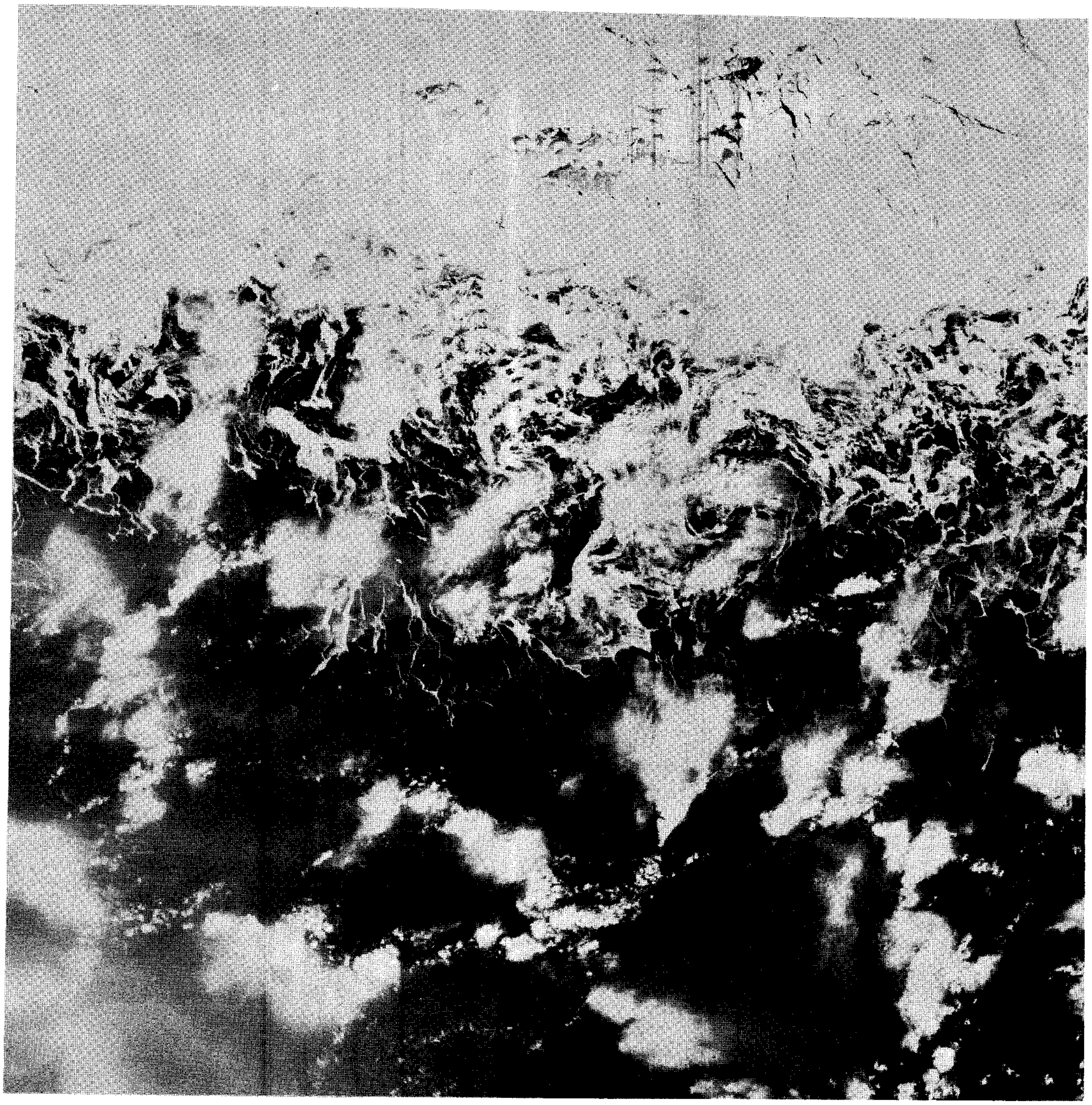


Fig. 7 LANDSAT image 2432-21284; ice edge and front zone in area between 166°W, and 168°30'W, 29 March 1976.

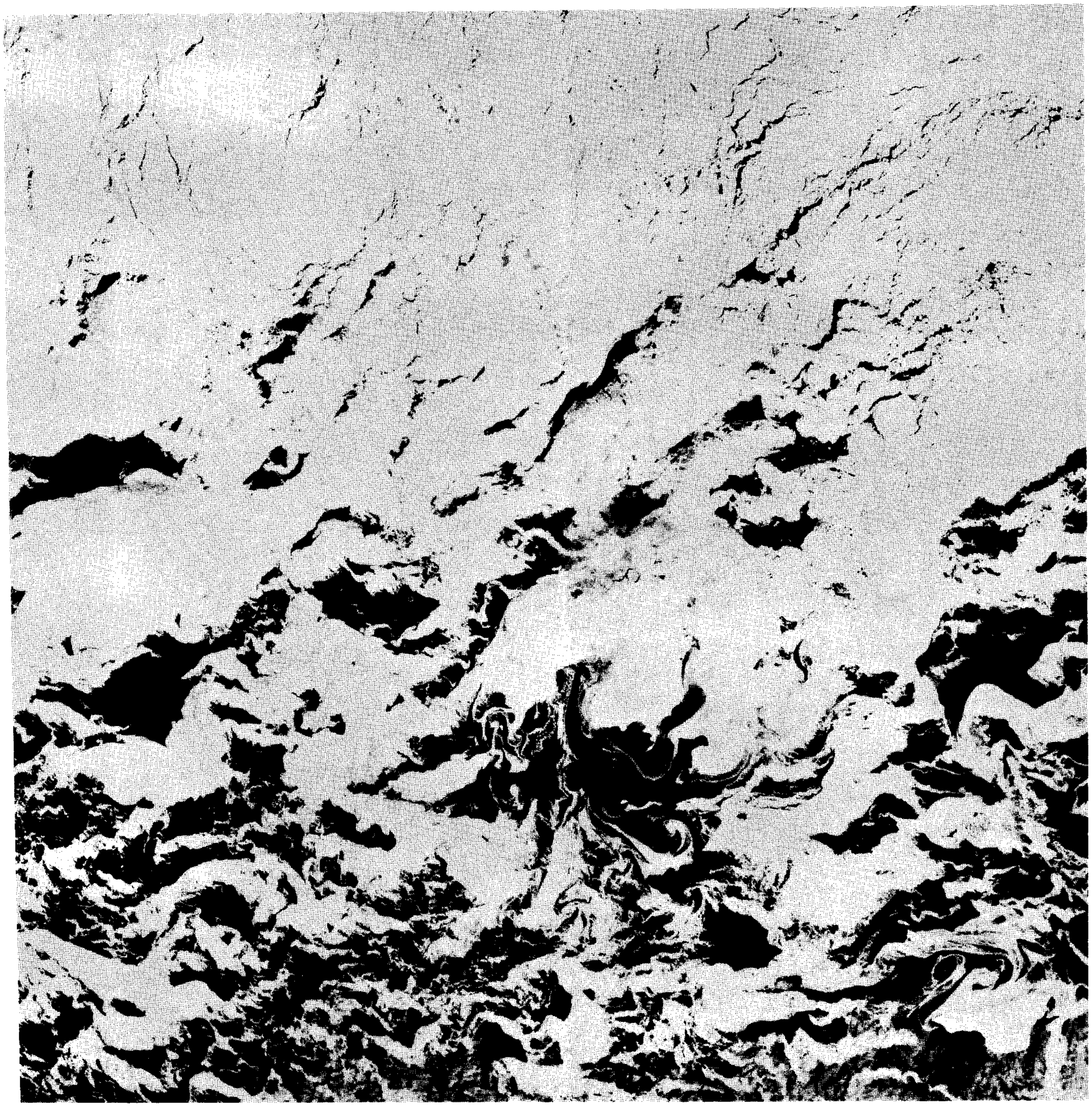
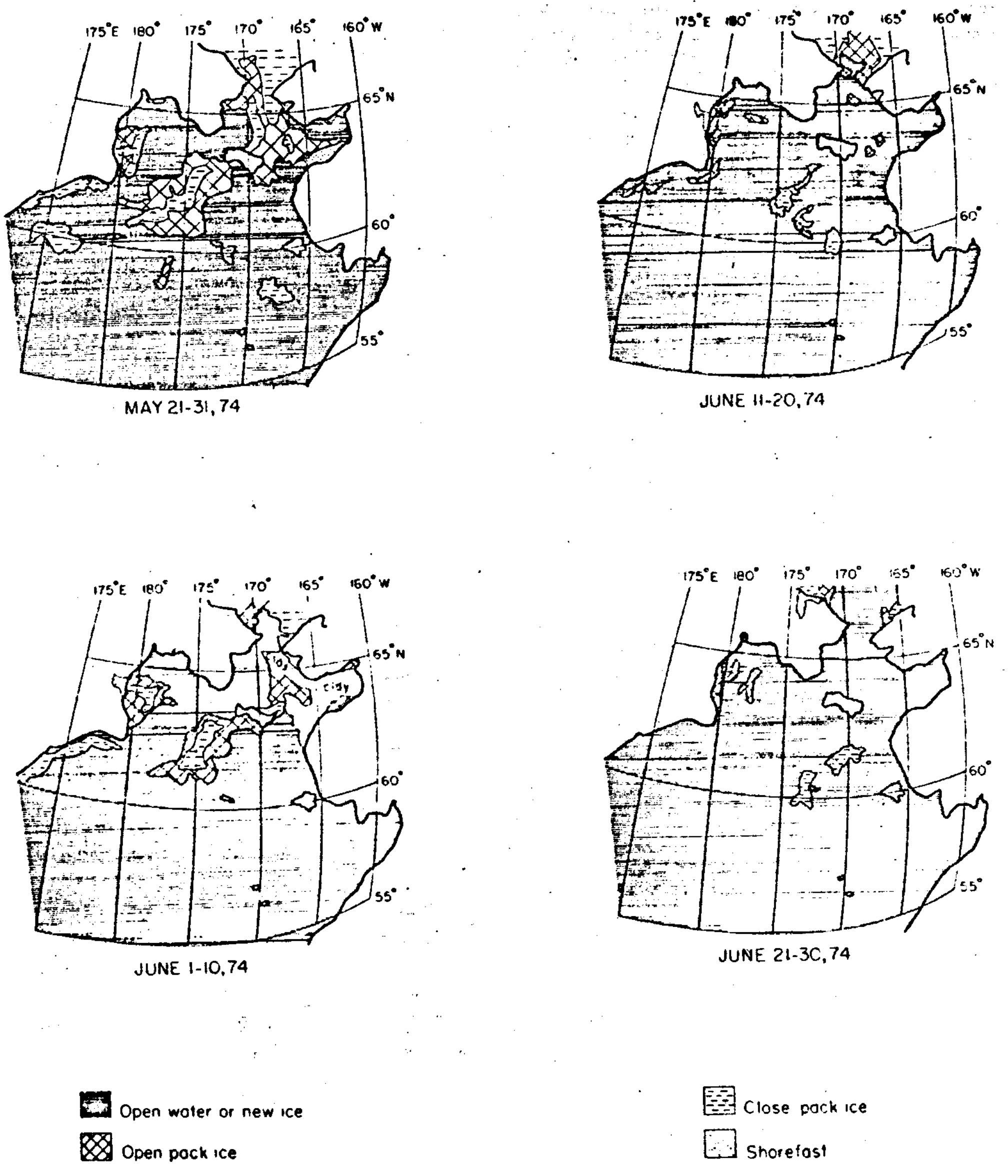


Fig. 8 LANDSAT image 2453-21445; ice edge and front zone in area between 169°30'W and 172°30'W, 19 April 1976.



MAY 21-31, 74

JUNE 11-20, 74

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Fig. 9. Ice conditions in late-May and June, 1974, as determined from VHRR imagery. (After Muench and Ahlnas, 1976)

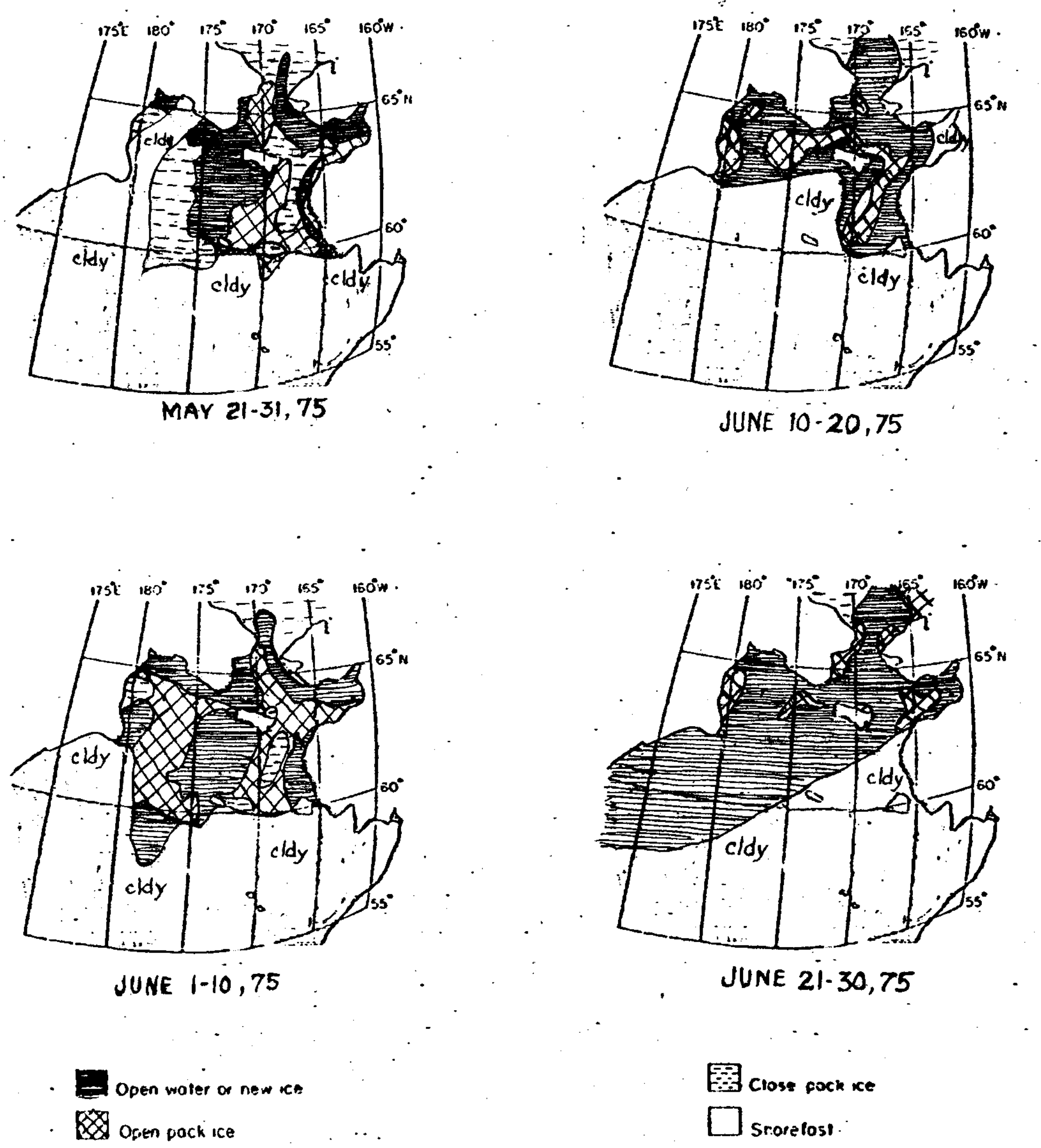

Fig. 10. Ice conditions in late-May and June, 1975, as determined from VHRR imagery.

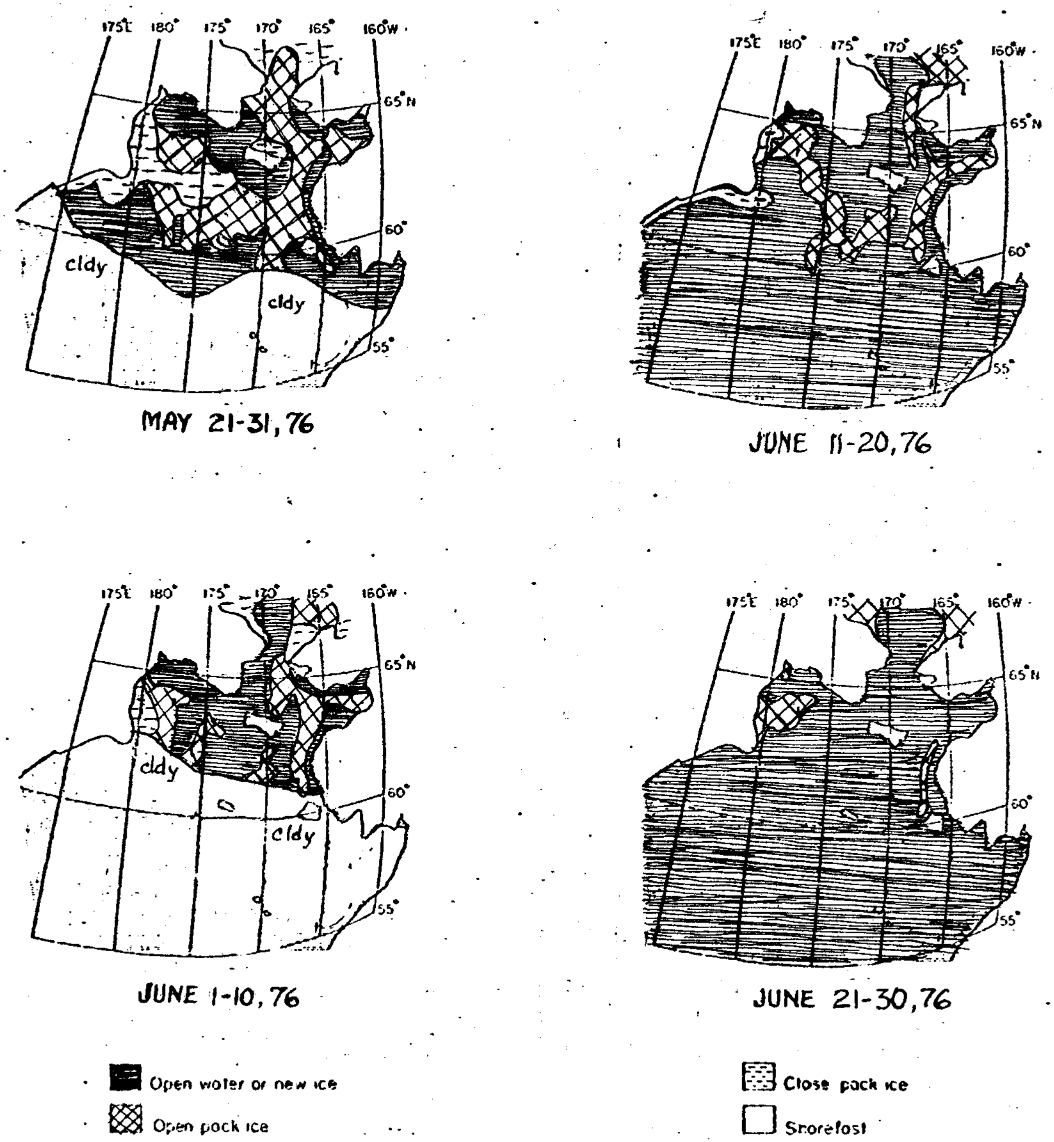

Fig. 11. Ice conditions in late-May and June, 1976, as determined from VHRR imagery.

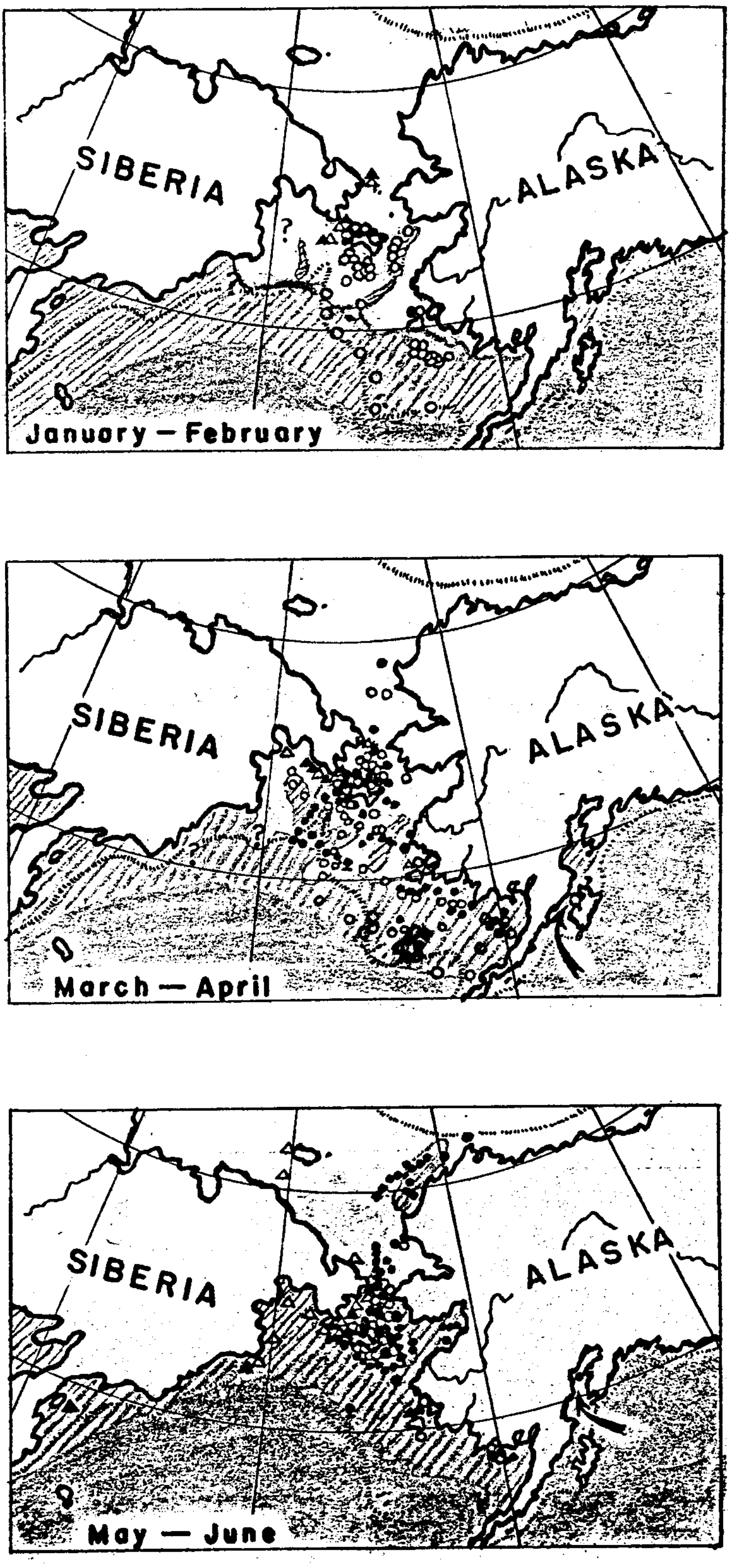

Fig. 12. Distribution of walruses in the Bering and Chukchi seas, in relation to approximate mean ice conditions. Each symbol represents the position of one or more animals, as reported in a published (▲△) or unpublished (● ○) account. Solid symbols are for the first month of each 2-month set; open symbols are for the second month. The minimal extent of heavy ice navigable only by icebreakers is shown by the unshaded area; the maximal extent of lighter or broken ice is cross-hatched; open water is shaded. Dotted lines show the approximate position of the 100-meter isobath.

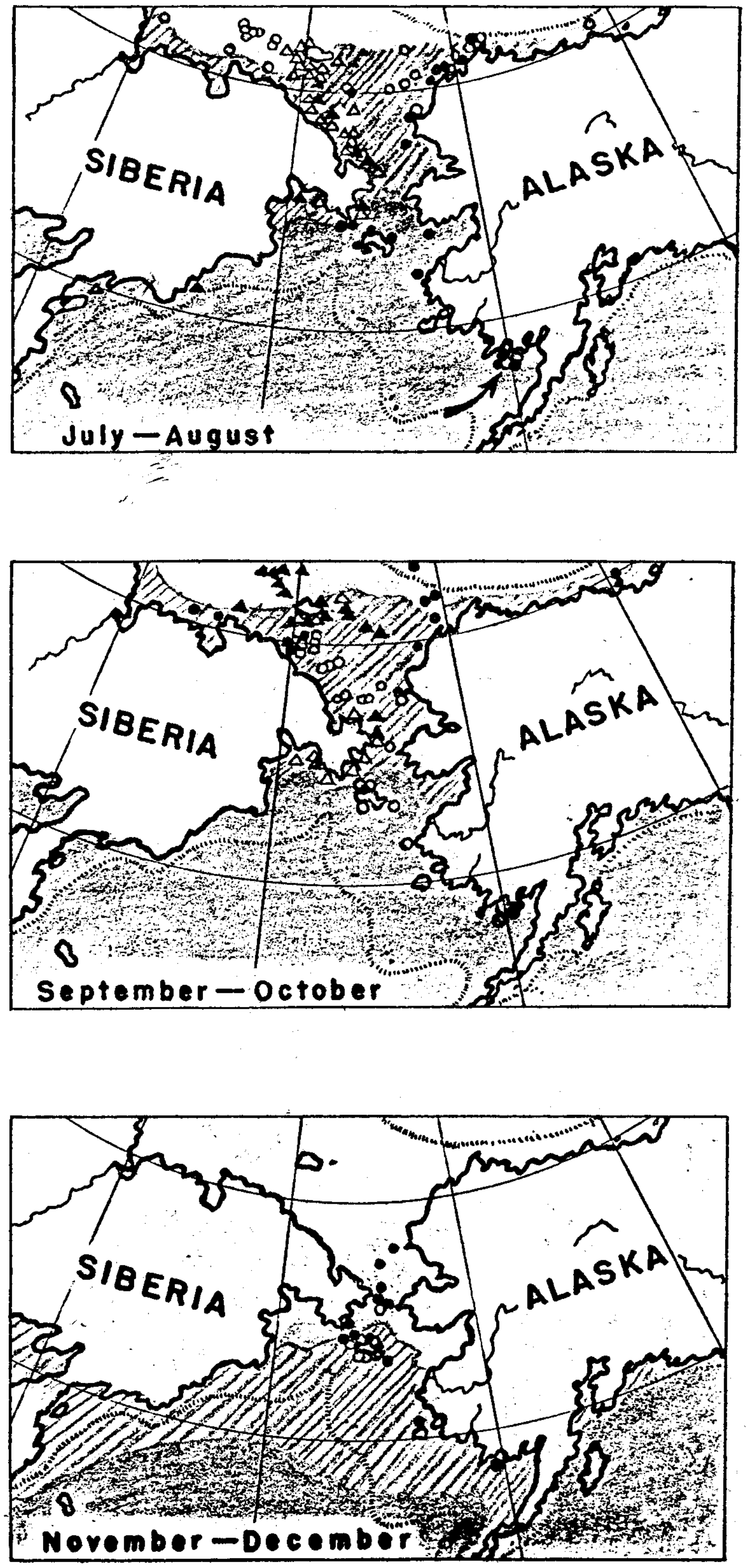

Fig. 13. Distribution of walruses in the Bering and Chukchi seas, in relation to approximate mean ice conditions. (For explanation of symbols, see Fig. 12.

AN UPDATED ASSESSMENT OF BIOLOGICAL RESOURCES AND THEIR COMMERCIAL IMPORTANCE IN THE ST. GEORGE BASIN OF THE EASTERN BERING SEA

(OCSEAP Research Unit #437)

Prepared for
Department of Commerce
National Oceanic and Atmospheric Administration
Environment Research Laboratories

by

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March, 1977

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EXECUTIVE SUMMARY

The St. George Basin of the eastern Bering Sea, which is generally that area between Unimak and St. George Islands (Fig. 1), is under consideration by the U.S. Bureau of Land Management as an oil and gas lease area.

The Bering Sea, in general, is one of the richest fish producers in the world, second only to the North Sea in terms of demersal fish yields. Since 1970, the total annual harvest of demersal fish and shellfish from the eastern Bering Sea has ranged between 1.7 and 2.4 million metric tons (mt). A large proportion of the harvest comes from the St. George Basin. In 1974, the Japanese fishery harvested about 499,900 mt of fish and shellfish in the area of the St. George Basin (Fig. 2).

The present target species of fish in the eastern Bering Sea fishery is Pacific pollock (Theragra chalcogramma). Pollock ranked first in order of abundance among the 20 most abundant fish taxa in the St. George Basin area of the 1975 OCSEAP demersal resource surveys.

Pollock undergo temperature-related seasonal migrations (Fig. 3), concentrating in shallower waters of the shelf in warm seasons, but moving to deeper waters of the shelf and slope in cold seasons. Spawning by pollock occurs northwest of Unimak Island in May. Eggs are pelagic and are concentrated along the continental shelf in the upper water layers (Fig. 4).

All-nation catches of pollock in the eastern Bering Sea have been as big as about 1,900,000 mt. The 1974 Japanese catch in the St. George Basin area was about 1,200,000 mt. Large yields came from west of Unimak Island (Fig. 5).

Red and blue king crabs (*Paralithodes camtschatica* and *P. platypus*, respectively) occur north of Unimak Island and around the Pribilof Islands (Fig. 6). Concentrations of Tanner crabs (*Chionoecetes bairdi*, *C. opilio*, and their hybrids) occur throughout the continental shelf, but *C. bairdi* is more abundant near Unimak Island, whereas *C. opilio* is more abundant near the Pribilofs (Fig. 7). Foreign and U.S. crab fisheries concentrate in the areas of crab distribution (Fig. 8).

Halibut are found throughout the continental shelf, but commercial concentrations occur in the St. George Basin. During winter months, halibut concentrate in deeper waters of the continental slope (Fig. 9), but migrate onto the shelf during spring and summer months. Traditional halibut fishing grounds are located along the 100-f contour (Fig. 10) between Unimak Island and the Pribilof Islands.

The St. George Basin is an important pupping and rearing area for many seasonal and resident marine mammal species. The largest northern fur seal herd in the world reproduces on the Pribilof Islands.

Considering the importance of the southeastern Bering Sea, including the St. George Basin area, as a protein producer, the primary recommendation of the National Marine Fisheries Service is:

Establishment of a marine sanctuary in the southeastern Bering Sea, including Bristol Bay and the St. George Basin area, bounded on the west generally by the 100-fm contour, under provisions of Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 (P.L. 92-532).

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INTRODUCTION

The St. George Basin is being considered by the Bureau of Land Management and the oil industry as an oil and gas lease area. In particular, four lease areas are being considered in the Basin between longitudes 165°W and 168°W and latitudes 55°N to 56°30'N (Fig. 1). The purpose of this paper is to summarize and evaluate biological resources and their commercial uses in the St. George Basin area for which the National Marine Fisheries Service has a responsibility and with which oil and gas development may be in conflict.

The St. George Basin generally falls between Unimak Island and St. Paul Island (Fig. 1). For purposes of limiting discussion, this evaluation will mainly focus on an area of the eastern Bering Sea between longitudes 164°W and 171°W and latitudes 54°30'N and 57°30'N.

The eastern Bering Sea, in general, is one of the most important ecosystems in the world. Its continental shelf is very expansive, being greater than the combined shelf areas of the Gulf of Alaska and the entire west coast from Washington to California. Waters of the Pacific Ocean extend through the Aleutian Passes and up the continental slope, which in some outer parts has a gradient steeper than 25 degrees. Transported in this water flow are nutrients such as phosphorous, which enriches the subsurface and intermediate water layers. This process partly creates conditions leading to the high bioproductivity manifested primarily in the great abundance of plankton and forage benthos, which directly or indirectly favors the concentration of many fish species. There are seasonal extremes in climate with a buildup of nutrients in shelf waters during the winter months followed by high plant production in the spring and summer with increased insolation. The St. George Basin area is ice-free throughout the year, the southern boundary of the ice pack being generally 59°N latitude (USN 1955) between longitudes 164°W and 170°W. Lack of ice also contributes to the high production of

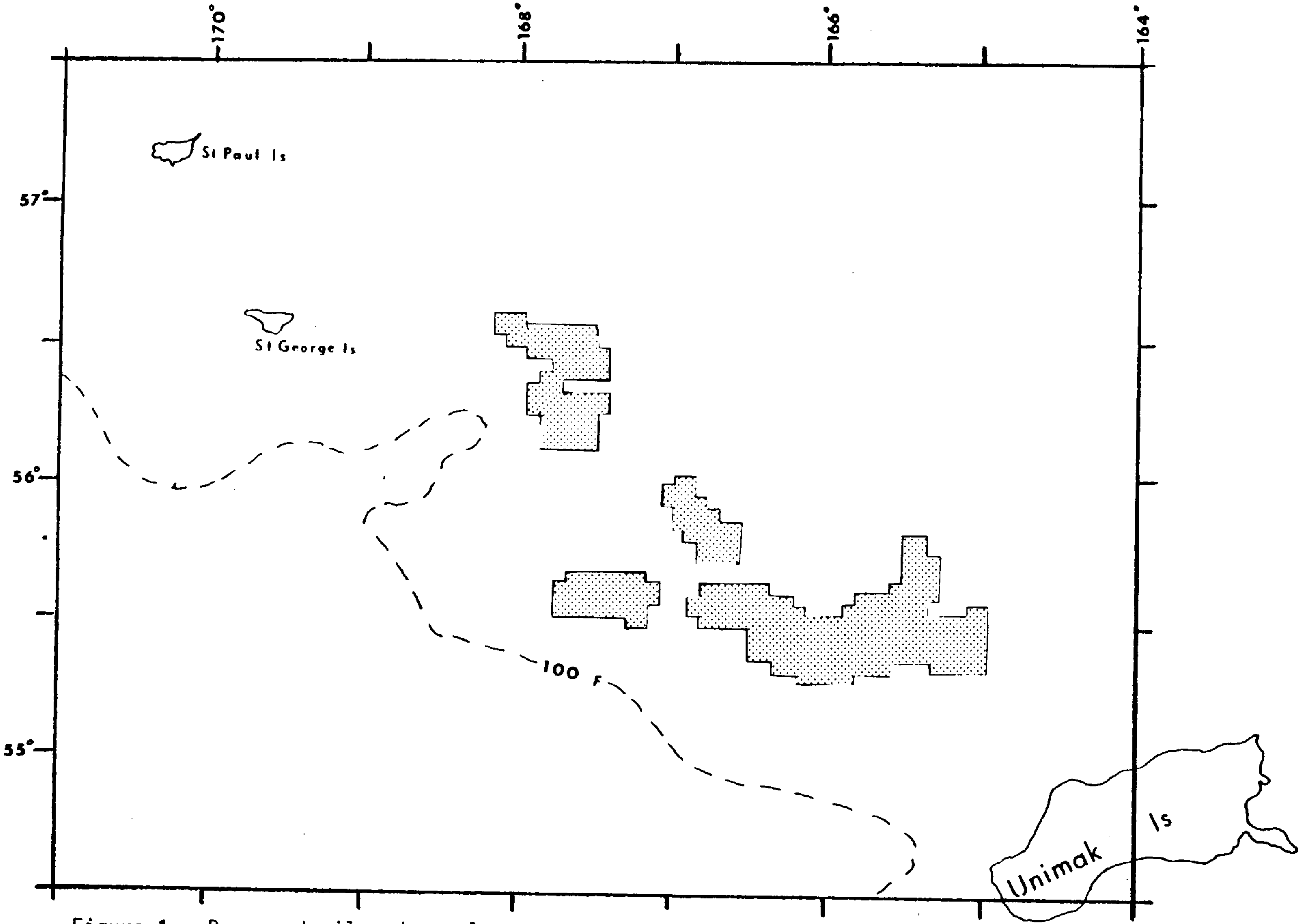

Figure 1 Proposed oil and gas lease areas in the St. George Basin area.

phytoplankton compared to more northern latitudes where the permanent pack ice reduces light transmission considerably during most of the year (Redburn 1976). Food organisms such as zooplankton (euphausiids, copepods, etc.), squid, and planktivorous fish (capelin, smelt, herring, and lanternfish) are abundant here throughout the year (Gershanovich et al. 1974).

In terms of harvest yields of demersal fish throughout major fishing areas of the northern hemisphere, the Bering Sea is second only to the North Sea (Table 1).

Table 1. Average annual yields of demersal fish in metric tons per square kilometer from major fishing areas in the northern hemisphere (adapted from Bakkala et al. 1976).

	Bering Sea	NE Pacific	NW Atlantic	NE Atlantic	North Sea
Yield	2.9	1.6	1.7	1.2	3.3

The Bering Sea also supports huge salmon populations consisting of all five Pacific species, chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), chum (*O. keta*), and pink salmon (*O. gorbuscha*). A high seas fishery for salmon is currently conducted only by Japan, which operates a mothership gillnet fishery and a land-based driftnet fishery in the western Bering Sea. This paper will not address salmon in any great detail, since there is no fishery for them in the St. George Basin and their spawning occurs further to the east in Bristol Bay and northwestern Alaska, as discussed in another paper (NMFS 1977a). However, it should be noted that their spawning migrations pass through St. George Basin. The time spent by sockeye salmon in the St. George Basin area is relatively short, considering that the duration of spawning migrations by adults through the Bering Sea from their North Pacific Ocean feeding grounds is about 40 to 50 days. Seaward migration by sockeye salmon juveniles, however, probably lasts longer than six months

(Straty 1974). Hence, early marine growth and survival will be greatly influenced by environmental conditions prevailing in the Bering Sea during this period of migration (Straty 1974).

The region on the outer continental shelf between Unimak Island and the Pribilofs, i.e., the St. George Basin area, is probably the most important on a year-round basis in terms of demersal fish biomass and is known to provide substantial proportions of the total catch (mainly pollock) of foreign fisheries (Pereyra et al. 1976).

Some population densities for fishes used in this report have been obtained from the Japan Fishery Agency and from results of the 1975 OCSEAP baseline survey of demersal resources. It should be noted that these data are representative of single year sampling or fishing efforts and do not necessarily represent continuous population densities. Nonetheless, these data empirically demonstrate the biomass which can be produced in the St. George Basin.

POTENTIAL RESOURCE USE CONFLICTS

The present major use of the St. George Basin is commercial fishing. With the advent of oil and gas development in this traditional fishing area, conflicts between fishing and oil-related developments may arise. Physical conflicts may involve time/space competition resulting from two resource users exploiting the same area at the same time. This may involve physical obstacles to fishing efforts as in the case of exploratory vessels or fixed platforms impeding the movements of fishing vessels. Well heads on the ocean bottom would certainly be an obstacle to bottom trawl efforts. Surface structures could be hazardous to navigation. Spilled oil may foul fishing gear that comes in contact with it. On the other hand, physical conflicts may involve the impediment or restriction of movements of oil industry-related vessels due to fixed fishing gear sets, e.g. crab pot sets, including their attached buoys and lines.

International conflicts may arise if foreign fishing within the 200-mile zone is adversely impacted. Determining liability between the involved oil-related company and the U.S. government, involved because it issued the international fishing agreement to a foreign interest whose fishing success was affected, is a possible future conflict.

Biological conflicts may result from oil pollution during oil and gas development, which could cause habitat degradation and associated damage to living marine resources, both commercial and non-commercial. Most ecosystems can tolerate some pollution and will likely recover after pollution occurs, the rate and extent of recovery being dependent on the magnitude of pollution, its constituents, environmental conditions, and the elements in the ecosystem including seasonal species composition and life phases that are present. During recovery, however, a year class of a commercially important species of fish or shellfish may be reduced in numbers, and any fishery dependent on it will be reduced. Chronic or long-term pollution, however, may eliminate a species from an area entirely, and once eliminated, that species may not repopulate the area because of continuing chronic pollution or because its niche has been filled by a more tolerant, possibly less desirable, species (Evans and Rice 1974).

The fate of spilled oil varies in the natural environment. It can be partially ingested by zooplankton (Conover 1971), removed from the water column by absorption within organisms and accumulation within the food chain, or carried to the sea floor with flocculated suspended particles (Kolpack 1971). It can be diluted by wind action, waves and currents that increase spreading and vertical mixing. Some is dissipated by evaporation. The impact of oil pollution on intertidal life is difficult to predict, especially in the unstudied Alaskan environment (Zimmerman and Merrell 1976a).

As cited by Evans and Rice (1974), Blumer (1970) summarizes the potential damage to living marine resources by crude oil and oil fractions as follows:

1. Direct kill of organisms through coating and asphyxiation.

2. Direct kill through contact poisoning of organisms.

3. Direct kill through exposure to the water-soluble toxic components of oil at some distance in space and time from the accident.

4. Destruction of the generally more sensitive juvenile forms of organisms.

5. Destruction of the food sources of higher species.

6. Incorporation of sublethal amounts of oil and oil products into organisms (resulting in reduced resistance to infection and other stresses--the principal cause of death in birds surviving immediate exposure to oil).

7. Incorporation of carcinogenic and potentially mutagenic chemicals into marine organisms.

8. Low-level effects that may interrupt any of numerous events (such as prey location, predator avoidance, mate location or other sexual stimuli, and homing behavior) necessary for the propagation of marine species and for the survival of those species higher in the marine food web.

Some of the potential effects listed by Blumer may be obvious, such as the direct deaths from acute exposures. Less obvious indirect deaths may occur from effects at either the individual or population level.

Individual organisms subjected to sublethal exposures may undergo "ecological death" if they are less capable of adjusting to and responding to natural changes in their physical and biological environments. For example, postmolt Tanner crabs were observed to lose their legs during short exposures to crude oil (Karinen and Rice 1974). Even though Tanner crabs lived through the exposure, they would not be able to survive in the natural environment.

Some organisms, e.g., zooplankters (Mironov 1968), have the ability to concentrate hydrocarbons in their tissues, which are then passed on to higher organisms. Hydrocarbons reach relatively high levels in tissues of some fishes. Adult herring concentrate benzene in tissues of their ovarian eggs and gall bladder. Concentrations in these tissues may increase 14 and 30 times initial concentration, respectively (Korn et al. 1976). Hydrocarbons may not reach acutely toxic levels in higher organisms, however, due to depuration. It has been demonstrated (Rice et al. 1976) that, although pink salmon fry rapidly accumulate napthalenes in tissues of their gut, gills, and muscles, the napthalenes were rapidly lost after peak uptake (at 10 hours exposure) while fry remained in the WSF exposure. In all tissues, the naphthalenes were near control levels after 96 hours of exposure. Some animals of commercial importance may not be fit for human consumption due to an unsavory flavor caused by oil contamination. Even if still edible, some sea foods may not be safe to eat because of their contamination with possible carcinogenic oil fractions. Battelle Memorial Institute (1967) noted that live oysters contained 3,4-benzpyrene, a known carcinogen, in their bodies. Such contamination of Alaska species could void their being sold commercially, thereby reducing the monetary return to a fisherman.

Even though concentrations of oil may be sufficiently diluted to not be physically damaging to marine organisms or their consumers, it still may be detected by them, and alter certain of their behavior patterns. For instance, some animals may alter their migration routes as an avoidance response. Laboratory studies (Rice 1973) indicate that pink salmon juveniles are able to detect low sublethal oil concentrations. Migration of pink salmon juveniles through the St. George Basin from Bristol Bay or, for that matter, their migration in Bristol Bay itself, if oil spilled in St. George Basin reached that area, could be altered. In their attempts to avoid oil-contaminated water, pink salmon juveniles could move into less productive waters, reducing their chances for survival. This may be true for other salmon species as well.

Year-class success of many animals largely depends on events occurring during their first year of life. Egg and/or larval stages could be severely threatened by a surface oil spill. Stage I larvae of scooter shrimp (*Eualus fabricii*), kelp shrimp (*Eualus suckleyi*), humpy shrimp (*Pandalus goniurus*), coonstripe shrimp (*P. hypsinotus*), Tanner crab and king crab are all more sensitive to the water soluble fraction of Alaska crude oil (Cook Inlet) than their adult stages. Ninety-six-hour LC50's for moribundity (failure to react) ranged from 0.95 to 1.8 ppm among larvae of these species. Within each species, larvae were more sensitive than the older animals by factors of from 1.2 for humpy shrimp to 4.9 for king crab (Brodersen et al. 1977).

Effects of oil on fishes have been studied. The median tolerance levels of pink salmon alevins exposed to Prudhoe Bay crude oil were drastically reduced during migrations from fresh to salt water (Rice et al. 1975). Struhsaker (1977) studied the effects of benzene, a large constituent of the water-soluble fraction of crude oil, on spawning Pacific herring. Stress behavior in the form of gasping at the surface and disequilibrium occurred when exposed to a concentration of 800 ppb. Struhsaker also suggests that survival of eggs and larvae was reduced when exposed to a concentration of 800 ppb of benzene. Most of the commercially important fishes in the St. George Basin and elsewhere have egg and/or larval stages which are pelagic (Table 2). One exception is the Pacific cod, which have demersal eggs and larvae. The eggs of crab and shrimp can be

Table 2. Major fauna in the St. George Basin which have pelagic (P) and/or demersal (D) stages during early life histories.

Fauna	Eggs	Larvae
Salmon	P*	P(Juveniles)
Herring	D	P
Pollock	P	P
Cod	D	D
Pacific ocean perch	D**	P
Sablefish	P	P
Yellowfin sole	P	P
Rock sole	D	P
Greenland halibut	P	P
Arrowtooth flounder	P	P
Pacific halibut	P	P
Alaska plaice	P	P
Flathead sole	P	P
King crab	D	P
Tanner crab	D	P
Shrimp	D	P
Snails	D	D

* In females migrating through St. George Basin

** Larvae released directly (ovoviparous) in deep water considered demersal in that they are attached to their bottom-living progenitors. However, crab and shrimp larvae are pelagic. Eggs and larvae of snails are demersal. If a surface oil spill occurs coincident with the presence of fish and shellfish larvae, the year-class success of several species may be threatened. Certain water-soluble fractions of oil could descend to deeper waters, thereby perhaps harming demersal life, including egg, larval, juvenile, and adult forms.

A characteristic feature in the dynamics of Bering Sea waters is the marked current gyres observed in certain regions of the sea. One example is the anticyclonic gyre occupying a large shelf area of the shelf east of the Pribilof Islands (Natarov 1963). Hence, even if an oil and gas lease area is miles distant from important biological areas, such as those in Bristol Bay, surface currents in the St. George Basin area could transport spilled oil to concentrations of pelagic eggs and larvae elsewhere, including shore life, miles away in Bristol Bay. Hence, there is no guarantee that establishing oil and gas lease areas outside of spawning and rearing areas will provide protection to living marine resources in the St. George Basin or elsewhere in the Bering Sea, including Bristol Bay.

At present, Dutch Harbor, southwest of the St. George Basin, is the primary choice of the oil industry for a staging area. However, if current lease areas change, the Pribilof Islands may be considered for a staging area for crude oil storage and transport, although there are no plans for this at present. Increased airplane and vehicle traffic could prove harassing to breeding populations of fur seals on the Pribilof Islands. Incidents of fur seal mothers abandoning their pups as a response to harassment may increase. Exposure to oil reduces the water repellant properties of fur seal pelts. Kooyman et al. (1976) suggest that oiled seals probably could not sustain themselves long in cold water. In due course they would probably experience exhaustion, hypothermia and death. Oil spills in the vicinity of the Pribilofs could impact the marine organisms on which the fur seals are dependent. The culture and economic status of Pribilof Island residents would be affected, at least for the duration of the development activities.

RECOMMENDATIONS

This report summarizes some of the biological information and commercial importance of marine organisms in the St. George Basin area of the eastern Bering Sea. Various researchers have referred to this area as being the most biologically productive area in the eastern Bering Sea in terms of demersal fish biomass. Its importance to the ecology of the eastern Bering Sea and its importance as a major protein source for mankind is an inviolable fact, which further investigations will not refute. To best protect this area and assure its viability as a protein source for future generations, no oil and gas development should occur in the southeastern Bering Sea, including St. George and Outer Bristol Basins.

Our primary recommendation is:

1. Establish a marine sanctuary in the southeastern Bering Sea, including Bristol Bay and the St. George Basin area, bounded on the west generally by the 100-fm contour, under provisions of Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 (P.L. 92-532). An important feature of this recommendation is that sanctuary status does not necessarily exclude oil and gas development. However, oil and gas development would require certification by the Secretary of Commerce that impacts of development would be consistent with the purposes of the marine sanctuary.

If creation of a marine sanctuary is inconsistent with national goals and the nation's demand for energy overrides the extremely high values associated with the living marine resources of the St. George Basin area, we offer the following secondary recommendations:

2. Studies should be conducted to compare the long-term economic benefits of protecting the renewable fishery resources with the short-term benefits of developing the nonrenewable oil and gas reserves in the St. George Basin.

3. Defer oil and gas development in the St. George Basin until such a time as alternative oil reserves and alternative energy sources are inadequate and it is determined that the St. George Basin reserves are critically needed.

4. The fate and effects of postulated oil spills at selected locations in the area under consideration should be determined through development and testing of models and completion of necessary field experiments prior to reaching decisions concerning final tract selection.

5. Limit oil and gas development activities to the winter months of October through February to best protect egg and larval stages that are characteristically present during seasonally warmer months in the eastern Bering Sea, including the St. George Basin and Bristol Bay. (This recommendation assumes that the success of a fish or shellfish population is dependent on the success of its egg and larval stages that are present in the seasonally warmer months. It further assumes that impacts from surface oil spills would be more adverse in the upper portions of the water column than on the ocean floor. Hence, animals overwintering in the deeper waters of the continental shelf and upper slope presumably would be removed from the direct effects of surface oil pollution in case of oil spills occurring during October through February.)

6. Continue research to further define spawning and rearing times and areas, including migration routes, of marine mammals and commercially important species of fish and shellfish in the eastern Bering Sea.

7. Emphasize and expand field research that addresses acute and chronic effects of oil pollution on marine life, including uptake through the food chain, to better put potential problems in perspective.

8. Studies be done to determine allowable levels of toxic discharges from platforms.

COMMERCIAL FISHERIES

Commercial fisheries in the Bering Sea, including the St. George Basin area, include Japanese, Soviet, and South Korean fisheries for bottomfish; Soviet fisheries for herring; Japanese, Soviet, and U.S. fisheries for crabs; Canadian and U.S. fisheries for halibut; and Japanese fisheries for snails. In the early 1960's, a significant Japanese fishery for shrimp existed and this resource may again become of commercial importance with suitable environmental conditions. No salmon fishery exists in the St. George Basin. The Japanese high seas salmon fishery operates west of longitude 175°W.

Since 1970, the total annual harvest of demersal fish and shellfish from the eastern Bering Sea has ranged between 1.7 and 2.4 million metric tons (mt). The average annual catch of 2.1 million mt for the period 1970-1973 approximately equaled demersal fish catches in the Northwest Atlantic and North Sea. It exceeds the catch in the northeast Pacific by a factor of five, and is only exceeded by catches in the northeast Atlantic, where annual catches were 3.2 million mt for a similar period (Bakkala et al. 1976). In 1974, the catch of all demersal fish and shellfish in the eastern Bering Sea was approximately 2.0 million mt, valued at over $400 million. About 499,900 mt of demersal fish and shellfish, or about 25% of the total 1974 eastern Bering Sea catch, were caught by the Japanese in the St. George Basin area, the largest catch densities being mostly along the continental slope (Fig. 2).

Fishes

The major species in the bottom fishery was yellowfin sole until 1963; thereafter pollock has since predominated (Table 3). Pollock has been

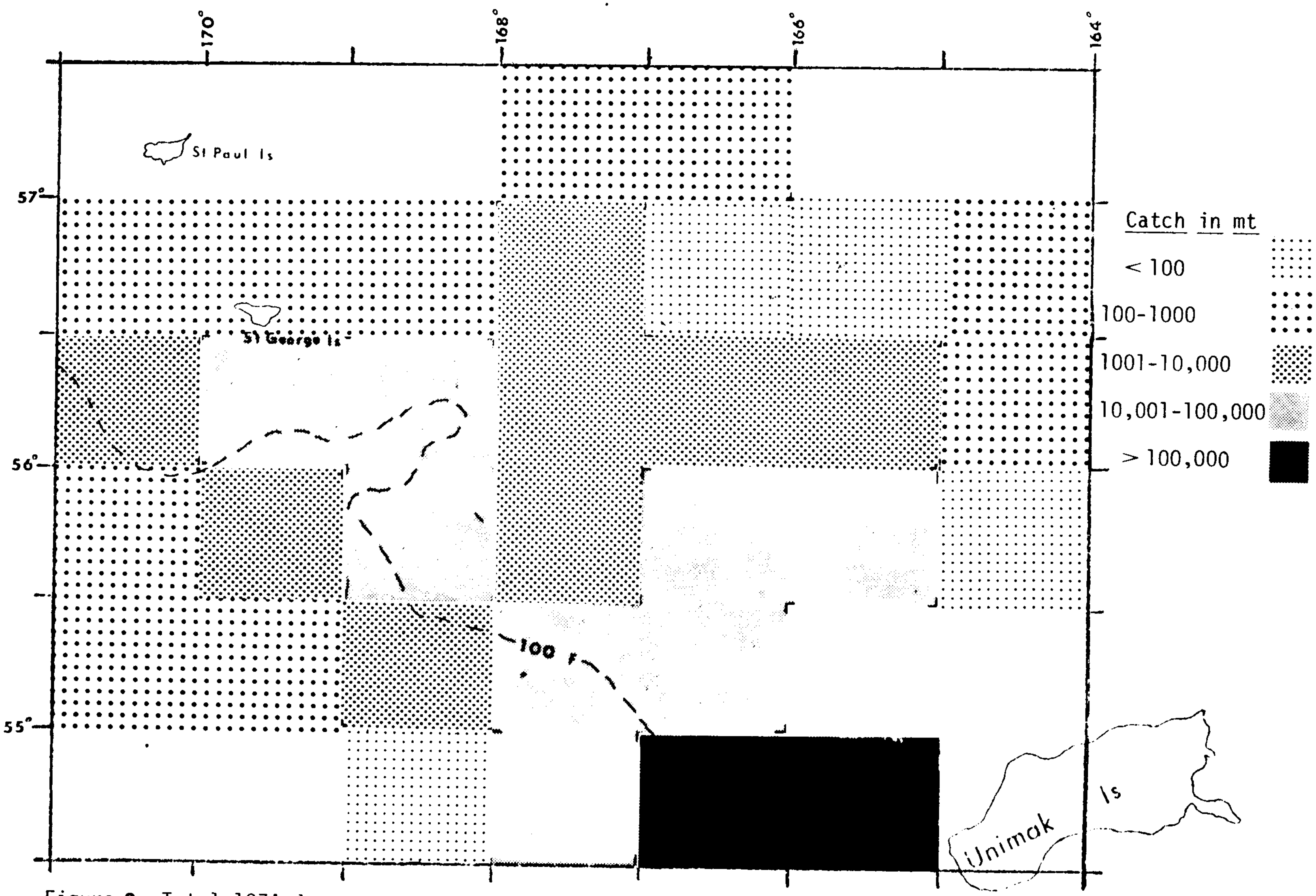

Figure **2** Total 1974 Japanese catch of fish and shellfish in the St. George Basin area (adapted from data of the Japan Fishery Agency).

the mainstay of the foreign trawl fisheries during the years 1971-1974. Annual landings have averaged 1.7 million mt, which represents 83% of the total average annual yield of all demersal animals (Alton 1976). Other species, including Pacific ocean perch, "turbot," Pacific cod, rock sole, flathead sole, and sablefish, have significantly contributed to the catch but have generally declined in the most recent years of the fishery. Additional information on the commercial aspects of these demersal fishes is discussed for each species in the section on Major Fishes.

There are three principal fisheries for the Pacific herring in the eastern Bering Sea: a Japanese trawl fishery, a Soviet trawl fishery, and a Japanese gillnet fishery. The Japanese herring fishery in the eastern Bering Sea increased to a production of 44,000 mt in 1968 and then fell to 15,000 mt by 1970 (Pruter 1973). There is a small subsistence fishery for herring by Alaska natives at scattered places along the coast (NMFS 1974). Most of the herring fishery in the St. George Basin is located in the Polaris, Misty Moore and Clipper fishery grounds (Fig. 3).

The halibut fishery, regulated by the International Pacific Halibut Commission, has been conducted on the same fishing grounds as the herring fishery. Japan, Canada and the U.S. participated in the fishery until 1964 when Japan withdrew. The all-nation catch of halibut in the Bering Sea (not including incidental catches by trawlers) peaked at about 15,000 mt in 1962-1963. Catches since that time have ranged from about 4,000 to 8,000 mt (Bakkala et al. 1976). The incidental catch of halibut in the Bering Sea by foreign trawlers is highly significant. It increased to over 11,000 mt in 1971 and then declined to about 6,000 mt in 1974 (Hoag and French 1976).

Crabs

King crab, Tanner crab, shrimp, and snails have been the principal shellfish harvested in the eastern Bering Sea. Japan fished for king

Table 3. Total all-nation catch (in thousands of metric tons) of groundfish in the eastern Bering Sea and Aleutian Island waters, 1954-74. Catches for 1954-63 as reported by Forrester et al. (1974) with the addition of U.S.S.R. catches of yellowfin sole for 1958-63 (Fadeev 1970) and Pacific ocean perch for 1960-63 (Chikuni 1975). Catches for 1964-74 from data provided the United States by Japan since 1964 and by the U.S.S.R. since 1967. + = small catch.

Year	Pollock	Yellowfin sole 1/2/	Flathead sole 2/	Rock sole 2/	Turbot 2/	Halibut	Pacific cod	Sablefish	Pacific Ocean perch	Other fish	Total
1954	---	13	---	---	---	+	---	---	---	---	13
1955	---	15	---	---	---	+	---	---	---	---	15
1956	---	25	---	---	---	+	---	---	---	---	25
1957	---	24	---	---	---	+	---	---	---	---	24
1958	7	44	---	---	---	3	+	+	+	+	54
1959	33	185	---	---	---	5	4	+	+	+	227
1960	26	493	---	---	---	10	6	2	6	10	553
1961	24	610	---	---	---	14	7	26	47	1	729
1962	60	393	---	---	58	15	10	30	20	43	629
1963	112	114	7	3	29	15	14	18	46	6	364
1964	175	93	22	4	62	5	19	6	118	3	507
1965	231	52	6	4	15	4	17	8	127	4	468
1966	263	94	11	8	21	4	19	14	110	7	551
1967	553	153	29	5	24	7	34	16	80	22	923
1968	707	66	27	6	33	6	64	19	84	42	1,054
1969	871	162	19	10	31	6	53	20	56	37	1,265
1970	1,282	119	42	21	18	7	75	14	79	61	1,718
1971	1,761	157	49	42	36	8	50	19	34	56	2,212
1972	1,876	48	14	62	81	5	47	18	41	147	2,339
1973	1,770	79	18	26	51	4	59	10	17	73	2,107
1974	3/ 1,554	43	14	20	70	4	65	7	63	87	1,927

1/ Includes catches of some other flounders up to 1963.

2/ Soviet catches of flounders were prorated by species based on Japanese catches

3/ Preliminary figures.

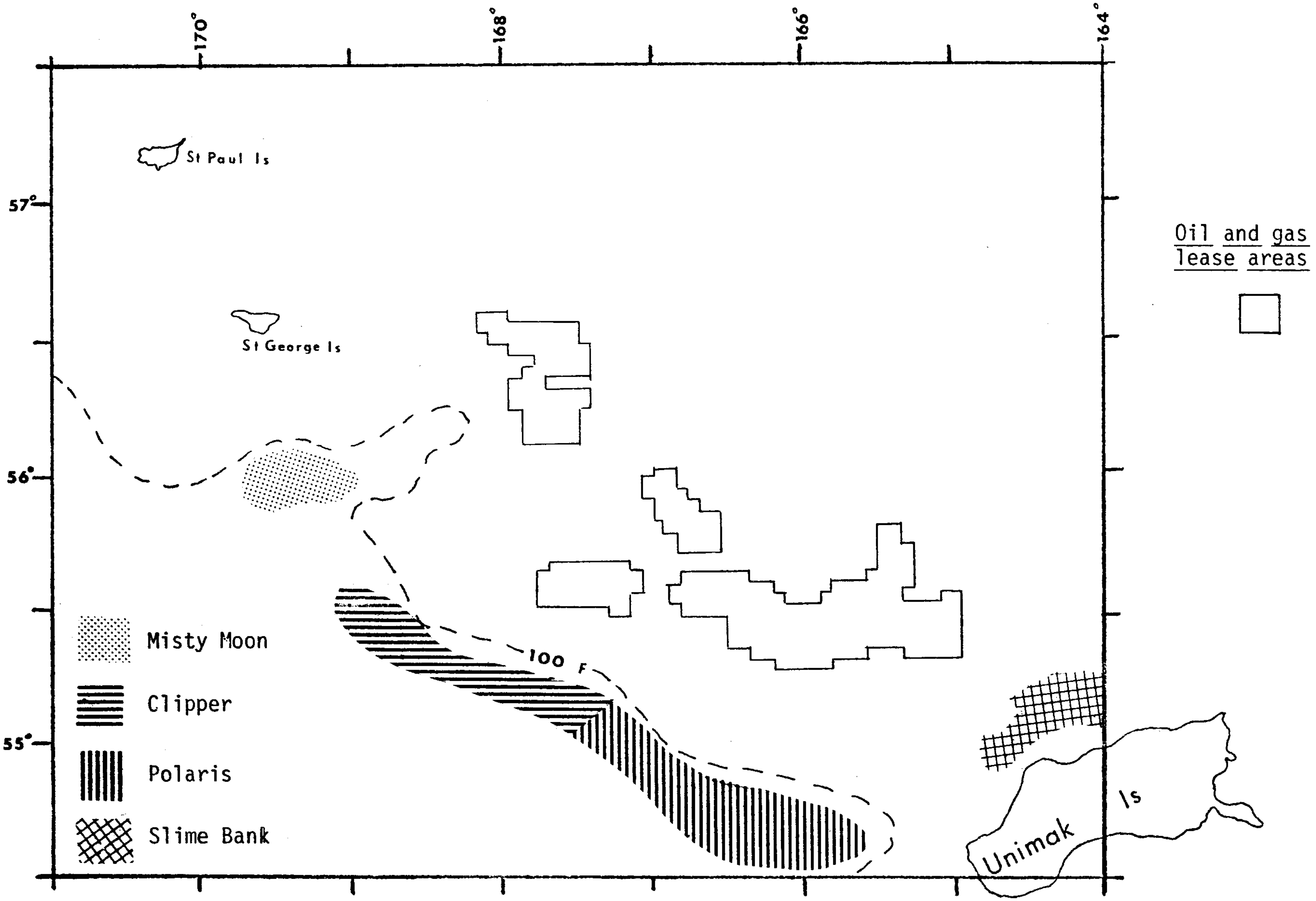

Figure 3. Major halibut and herring fishing grounds in the St. George Basin area.

crab in the eastern Bering Sea from 1930 to 1940, except for 1931. Reentering the fishery in 1953, Japan harvested nearly a million king crabs annually (Table 4) until 1960 when the Soviet Union entered the fishery. Catches of these two nations grew rapidly to 8.8 million crabs in 1964. Then, combined agreements between the U.S., Japan, and the Soviet Union led to reduction in foreign catches of king crab.

The U.S. fishery for king crabs in the eastern Bering Sea (Fig. 4) was small before 1968, but has since grown to be a major fishery, increasing from 1.3 million crabs in 1968 to an all-time record catch of 9.1 million crabs in 1975. The 1975 harvest was taken entirely by the U.S. fleet (Bakkala et al. 1976). About 17 percent of the 1975 catch was harvested in the St. George Basin area (from Alaska Department of Fish and Game statistics).

Foreign catch of Tanner crabs was emphasized after 1964. The combined Japanese-Soviet Tanner crab catch increased rapidly to about 24 million crabs in 1969 and 1970 (Table 5). The Soviet Tanner crab fishery ended in 1971 (Bakkala et al. 1976). Beginning in 1968, the U.S. entered the Tanner crab fishery in the Bering Sea. Prior to 1974, the U.S. Tanner crab catch was incidental to the king crab harvest but has since grown to a purposeful fishery. Landings increased from 14 mt (6 thousand crabs) in 1968 to 680 mt (482 thousand crabs) in 1970, dropped to 52 mt (43 thousand crabs) in 1972 and increased sharply again to 2,530 mt (2,532 thousand crabs) by 1974. In 1975, the U.S. harvested 3 thousand mt of Tanner crabs in the eastern Bering Sea.

Shrimp

Shrimp were initially exploited by Japan in 1960 and shortly thereafter by the Soviet Union. The only commercially important species was the pink shrimp (*Pandalus borealis*), which was fished for northwest of the Pribilof Islands.

Table 4. Catches (thousands of crabs) of king crab in the eastern Bering Sea 1953-1975 (adapted from Bakkala et al. 1976).

Year	Japan	U.S.A.	U.S.S.R.	Total
1953	1,276	361	-	1,637
1954	1,061	328	-	1,389
1955	1,129	313	-	1,442
1956	1,079	294	-	1,373
1957	1,171	107	-	1,278
1958	1,130	1	-	1,131
1959	1,292	-	620	1,912
1960	1,949	88	1,995	4,032
1961	3,031	62	3,441	6,534
1962	4,951	10	3,019	7,980
1963	5,476	101	3,019	8,596
1964	5,895	123	2,800	8,818
1965	4,216	223	2,226	6,665
1966	4,206	140	2,560	6,906
1967	3,764	397	1,592	5,753
1968	3,853	1,278	549	5,680
1969	2,073	1,749	369	4,191
1970	2,080	1,683	320	4,083
1971	886	2,405	265	3,556
1972	874	3,994	0	4,868
1973	228	5,000	0	5,228
1974	476	8,618	0	9,094
1975	0	9,060 1/	0	9,060

1/ Includes 8,745,294 red king crab and 314,931 blue king crab.

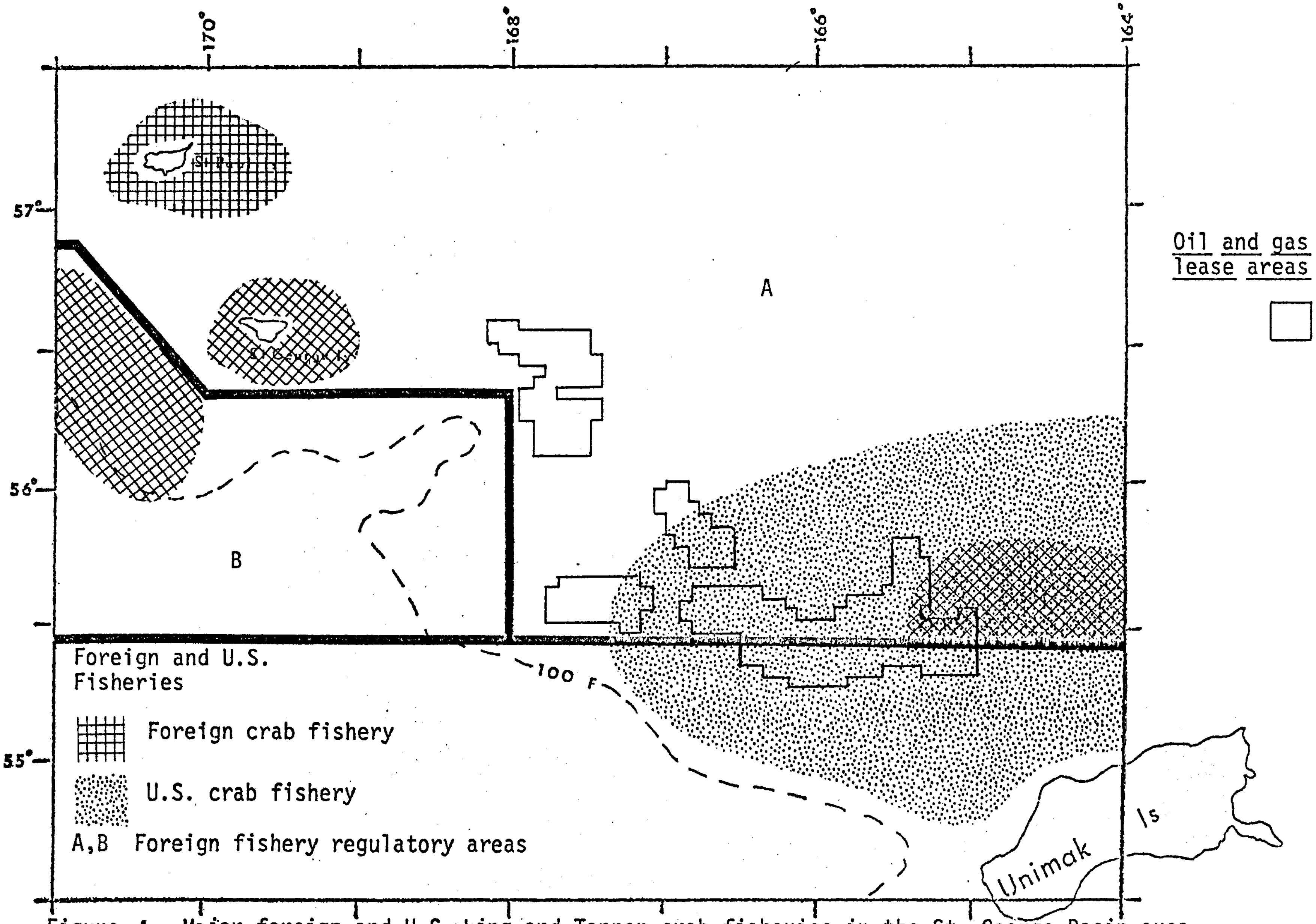

Figure 4. Major foreign and U.S. king and Tanner crab fisheries in the St. George Basin area.

Table 5. Catches (thousands of crabs) of Tanner crabs in the eastern Bering Sea, 1965-1976 (adapted from Bakkala et al. 1976)

Year	Japan	U.S.S.R.	U.S.A.	Total
1965	1,030	665	-	1,695
1966	1,490	665	-	2,155
1967	8,610	3,390	-	12,000
1968	11,980	3,490	6	15,476
1969	17,591	6,243	353	24,187
1970	18,190	5,724	482	24,396
1971	15,739	4,204	61	20,004
1972	15,593	-	43	15,635
1973	13,943	-	133	14,076
1974	13,986	-	2,532	16,518
1975	9,228	-	2,760	11,988
1976	9,228	-	8,931	18,159

The total Japanese catch in 1961 was about 14 thousand mt and quickly reached a peak of 27,127 thousand mt in 1963. After 1963, catches dropped rapidly and by 1966, amounted to only about 3 thousand mt but increased to about 13 thousand mt in 1968. (Table 6).

The Soviet shrimp fishery lasted two seasons, 1963 and 1964. In late 1974 they shifted their efforts to areas in the North Pacific Ocean due to declining stocks in the Bering Sea. Since the termination of the Japanese fishery in 1968 (NMFS 1976a), shrimp in the Bering Sea have not been directly harvested with the exception of some renewed interest by Japan in July, 1976. Small catches are made incidentally to other trawl fisheries (NMFS 1976a). Shrimp stocks of the Pribilof Island area have not been restored and are currently in a depressed state (Bartlett 1976).

Snails

At present, Japan is the only country harvesting snails in the eastern Bering sea. Their fishery, which began in 1971, is located along the continental shelf adjacent to and northwest of the Pribilof Islands. During the years 1972-1975, the Japanese respectively harvested 3,218; 3,319; 3,574; and 3,000 (estimated) metric tons of edible meat. The average annual dockside value of the snail fishery is estimated at $3.9 million (Bakkala et al. 1976).

MAJOR FISHES

Of about 300 species of fish in the Bering Sea (Quast and Hall 1972), 235 species occur in the eastern Bering Sea (Wilimovsky 1974). Trawl catches of demersal species in the Bering Sea south of 60°N latitude are dominated by four families in terms of weight: cods (Gadidae), flatfishes (Pleuronectidae) eelpouts (Zoarcidae), and sculpins (Cottidae) (Dunn and Kaimmer 1976).

Table 6. Japanese catch of pink shrimp from the eastern Bering Sea (1960-74) (from Forrester et al. 1974; Japan Fishery Agency, 1975).

Year and Catch (mt)							
1960	1961	1962	1963	1964	1965	1966	1967
680	14,117	18,387	27,127	20,527	8,839	2,984	3,302
1968	1969	1970	1971	1972	1973	1974	
12,690	9,484	6,150	2,765	222	155	103	

There are five species of cods in the eastern Bering Sea (Quast and Hall 1972), but the walleye pollock (*Theragra chalcogramma*) and the Pacific cod (*Gadus morhua macrocephalus*) dominate in terms of numbers. Other species include the Arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), and longfin cod (*Antinora rostrata*).

The yellowfin sole (*Limanda aspera*) is the dominant flatfish in the eastern Bering Sea, as determined by trawl catches. Other important species are Greenland halibut (*Reinhardtius hippoglossoides*, rock sole (*Lepidopsetta bilineata*), flathead sole (*Hippoglossoides elassodon* and *H. robustus*), arrowtooth flounder (*Atheresthes evermanni* and *A. stomias*), and Alaska plaice (*Pleuronectes quadrituberculatus*).

Of lesser importance, as determined by trawl catches, are the rex sole (*Glyptocephalus zachirus*), Pacific halibut (*Hippoglossus stenolepis*), longhead dab (*Limanda proboscidea*), Dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), and lefteye flounder (*Citharichthys sordidus* - family Bothidae).

Cottid species predominating in demersal trawl catches of the eastern Bering Sea are the great sculpin, *Myoxocephalus polycanthocephalus*, other *Myoxocephalus* spp., and sculpins of the genus *Gymnocanthus*. Dominant eelpouts are the shortfin eelpout, *Lycodes brevipes*; wattled eelpout, *L. palearis*; and other *Lycodes* spp. and *Lycodapsus* spp.

A description of the biology and commercial importance of the major fish species follows.

Walleye Pollock (*Theragra chalcogramma*)

Pollock occur throughout the northern arc of the Pacific Ocean from California waters through the Gulf of Alaska and Aleutian Island chain to waters off Japan and Korea (Salveson and Alton 1976). In the Bering

Sea, pollock are widely distributed, on the continental shelf and in the surface and intermediate layers of offshore waters, far away from the shelf during some periods of the year.

The biomass of pollock, as estimated from the 1975 OCSEAP baseline surveys, is 2.4 million mt, or 41 percent of the total demersal animal biomass available to the trawl gear. This figure of 2.4 million mt is definitely an underestimate; since pollock is a semi-demersal species, an unknown proportion of the pollock population was not sampled. Chang (1974) has estimated the standing stock of pollock older than ages 2-3 to be at least 2.4 million mt or about 8.4 billion fish. Although this species may live as long as 12 years, few fish older than 6 years have been taken throughout the history of the fishery. Dominant age classes are 3 to 6 year olds. Users of this resource are the USSR, Republic of Korea, and Japan, the latter being responsible for 87 percent of the annual catch during 1964-1972. The 1972 pollock harvest was 1.9 million metric tons (Table 7), a tenfold increase since 1964 (Alton and Fredin 1974). By 1974, the all-nation catch of pollock fell to about 1.6 million metric tons due principally to a decline in the Japanese catch to about 1.2 million metric tons.

Table 7. Annual catch (metric tons) of pollock in the eastern Bering Sea, 1964-74 (adapted from Bakkala et al. 1976).

Year		Nation		Total
	Japan	USSR	ROK	
1964	174,792			174,792
1965	230,551			230,551
1966	261,678			261,678
1967	550,362			550,362
1968	700,891		1,200	702,181
1969	830,494	27,295	5,000	862,789
1970	1,231,145	20,420	5,000	1,256,565
1971	1,513,923	219,840	10,000	1,743,763
1972	1,651,438	213,896	9,200	1,874,534
1973	1,412,239	280,005	3,100	1,695,344
1974	1,193,073	309,613	26,000	1,528,686

Pollock ranked first in order of abundance among the 20 most abundant fish taxa in the St. George Basin area, subarea 2, of the 1975 OCSEAP demersal survey area (Kaimmer et al. 1976).

The total Japanese pollock harvest for the years 1964-1974 for INPFC halibut conservation area A, which includes the St. George Basin area, is listed in Table 8. For the years 1964-73, this area contributed 29 percent of the total Japanese catch.

Major catch areas of the 1974 Japanese fishery are shown in Figure 5. Heavy fishing effort has resulted in a serious deterioration in the condition of the pollock resource in recent years (Low 1976).

Table 8. Total Japanese pollock catch (metric tons) in INPFC halibut conservation area A, which includes the St. George Basin. (adapted from Bakkala et al. 1975).

Year	Total Catch by All Gear Types
1964	25,528
1965	14,411
1966	49,129
1967	201,887
1968	194,546
1969	372,335
1970	351,782
1971	643,313
1972	589,166
1973	270,053
1974	388,004

Pollock undergo temperature-related seasonal migrations. In the warm season, pollock concentrate on the shallow part of the shelf (Fig. 6), but move to deeper parts of the shelf and to the upper slope in winter over bottom depths of approximately 160 to 300 m (Serobaba 1970). The principal winter concentration of pollock in March occupies great depths

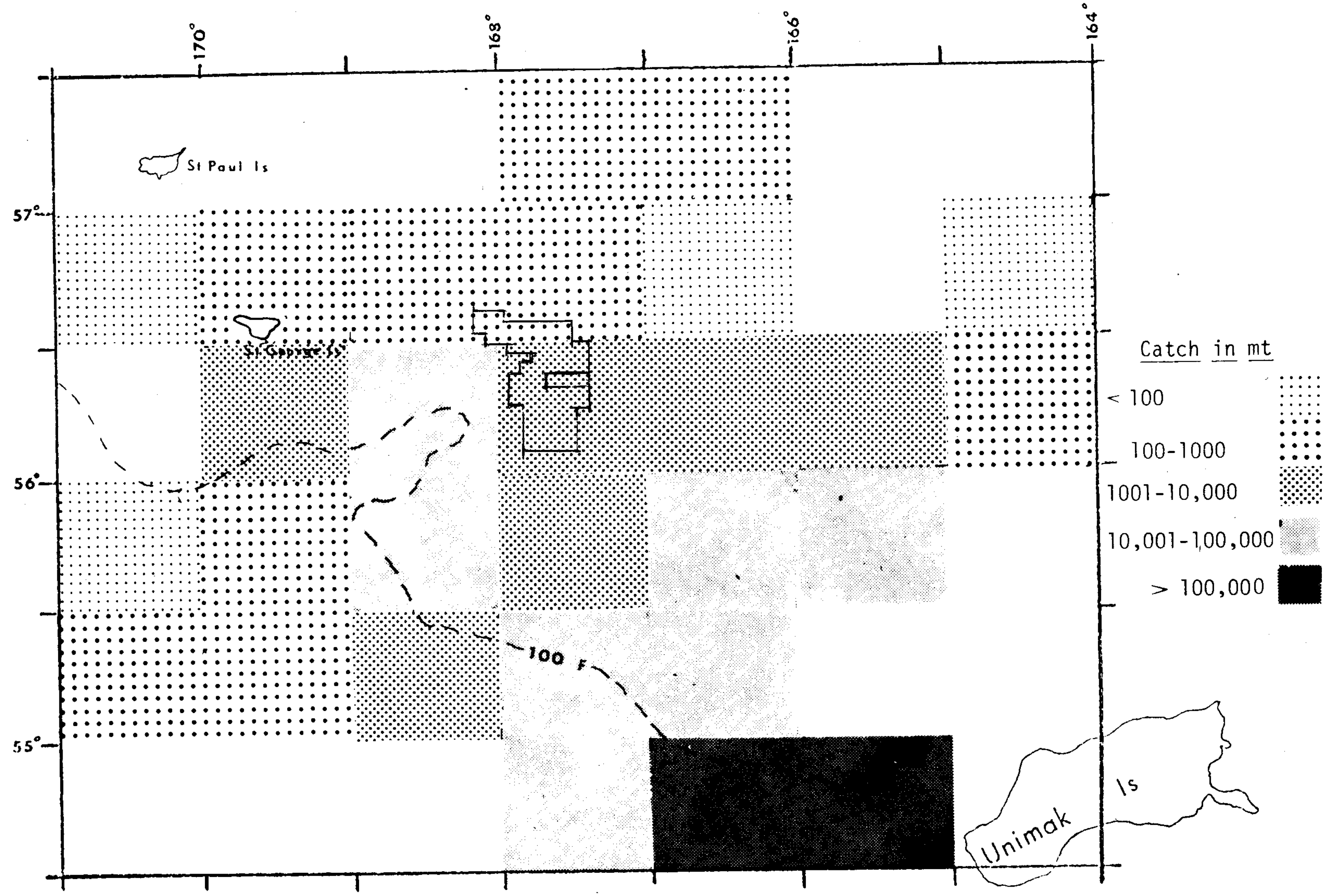

Figure **5** 1974 Japanese catch of Pacific pollock (*Theragra chalcogramma*) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

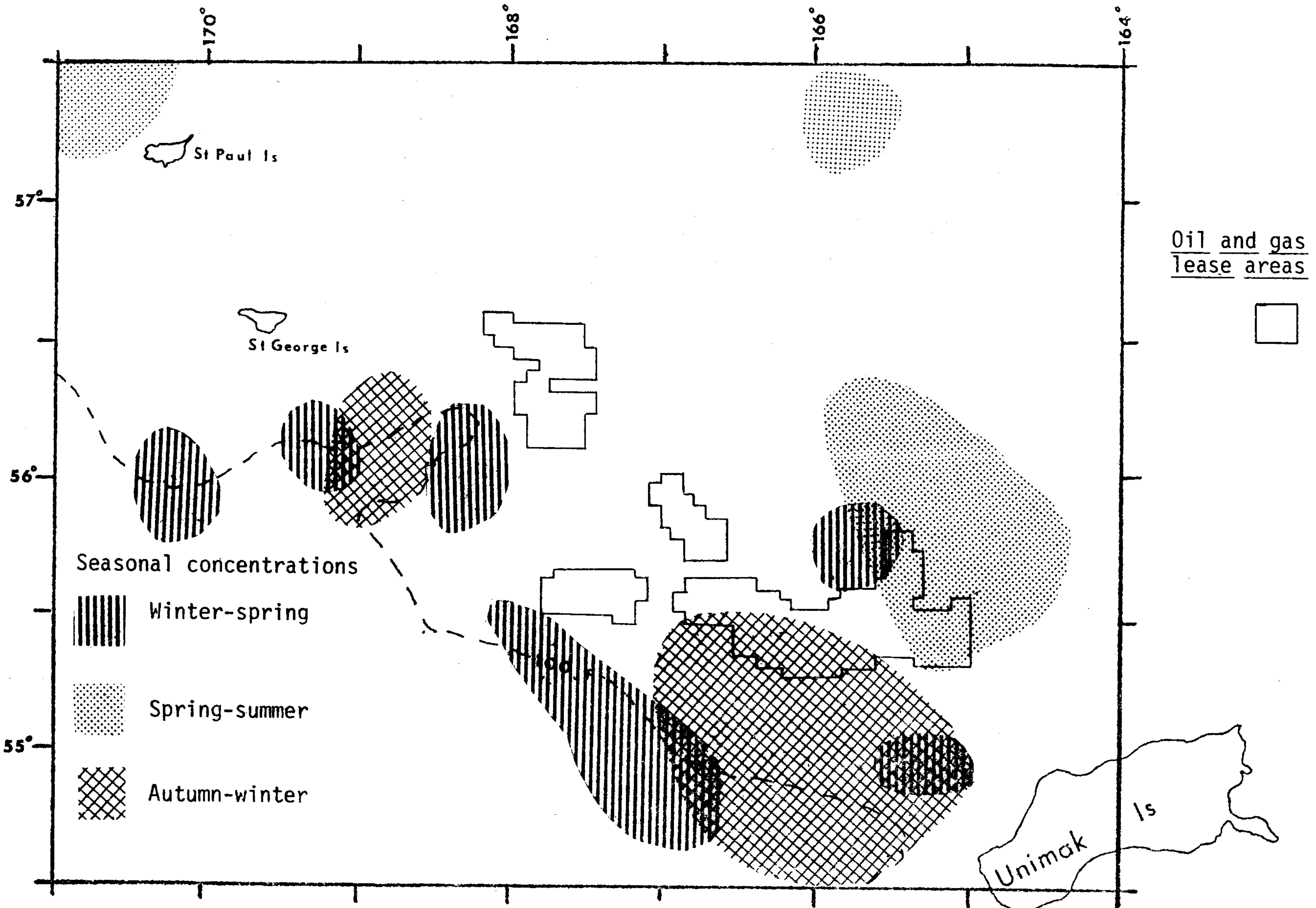

Figure 6. Seasonal concentrations of pollock in the St. George Basin area. General distribution occurs throughout the area north of the 100-fathom isobath (adapted from Serobaba 1970).

between the Pribilof and Unimak Islands. Since pollock are a relatively cold-water species, concentrating in areas of 0 to 5°C or colder, the availability of food to adult fish, and not changing temperatures, may be the controlling factor responsible for their seasonal migrations (Gershanovich et al. 1974). Pollock also migrate upwards during night in relation to movements of their prey (Alton and Nicholl 1973).

According to Serobaba (1970), a spawning concentration, occupying an area of 8,200 km^2, forms northwest of Unimak Island in May. Spawning begins in March, peaks in May, and ends in the middle of July. During spawning, part of the population, constituting the prespawning concentration in the Unimak area, rises to depths of 80-140 m. The spawning grounds of pollock in the Bering Sea are bounded by the ice front and the continental shelf. Ripe females occasionally are found among clearings in the ice.

During the spawning period, eggs occur at depths of 50 to 300 m (Serobaba 1974). Eggs sometimes occur at depths exceeding 1,000 m, but maximum concentrations are associated with the shelf zone (Fig. 7), mainly in the upper 100-meter layer where they develop. Eggs may occur to 300 m, but rarely at greater depths (Serobaba 1967). Eggs are pelagic and hatch in the upper 10 m of the water column as they drift with the currents. Waldron and Favorite (1976) report major concentrations of pollock eggs in surface layers (neuston samples) along the edge of the continental shelf, generally over depths greater than 100 m.

Juvenile pollock exhibit a distinct vertical movement, rising to the surface at night to feed and descending to mid or bottom depths during the day (Kobayashi 1963). As juveniles develop, they become progressively more demersal. Pollock mature in 3 to 4 years and may live as long as 12 or 15 years (Alton and Nicholl 1973).

Pollock feed on a variety of organisms, but predominant food items include pelagic or semi-pelagic crustaceans, particularly euphausiids,

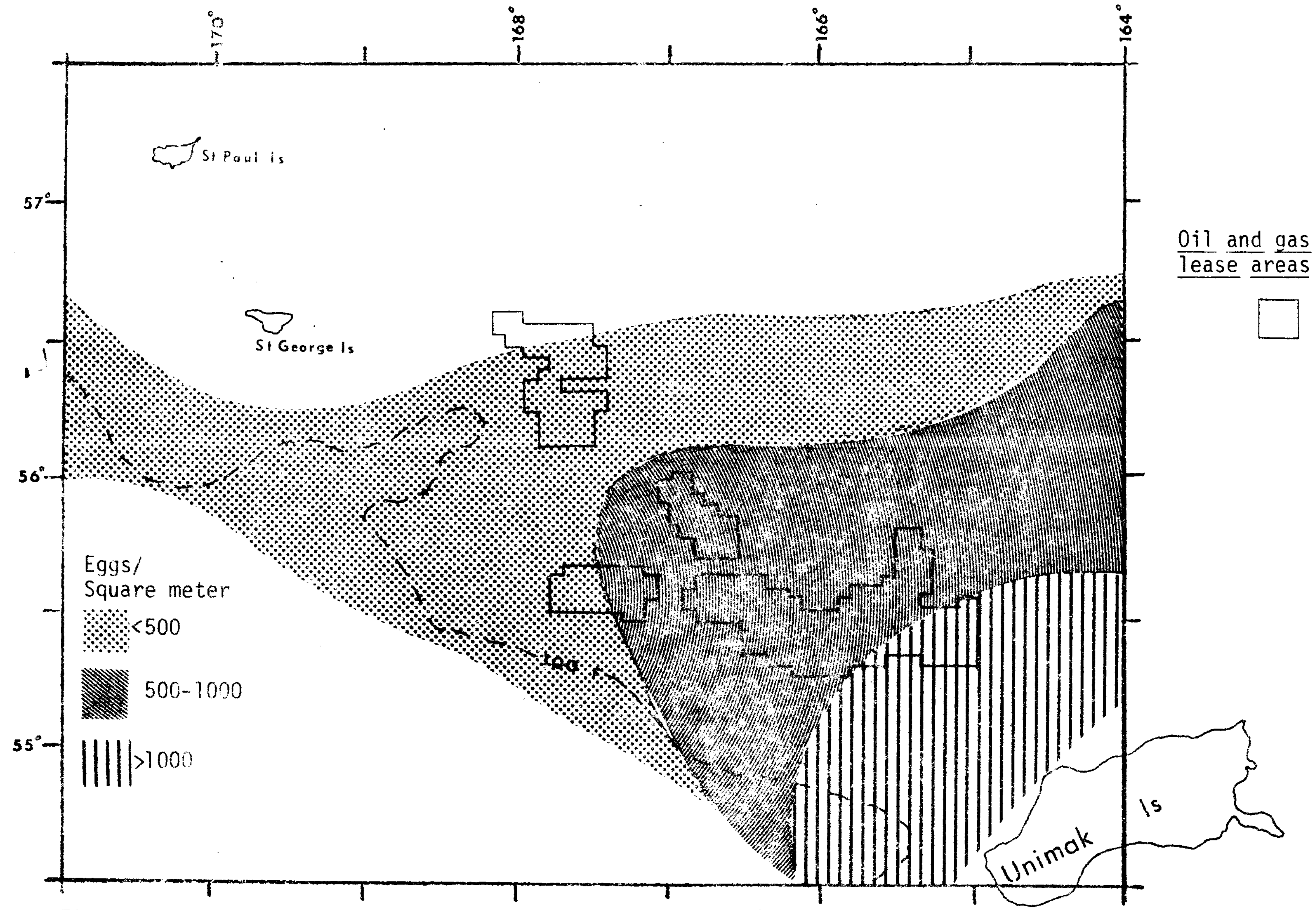

Figure 7. Distribution of pollock (*Theragra chalcogramma*) eggs in the St. George Basin area in March-May, 1965 (adapted from Serobaba 1967).

copepods, and amphipods. Pollock are cannabalistic. Takashashi and Yamaguchi (1972) observed that young pollock (0-1 year old) may constitute over 50 percent of the stomach contents of pollock over 50 cm long.

Pollock are preyed upon by fur seals (Moiseev 1952) and possibly by beluga and killer whales (Tomilin 1957). Moiseev (1952) stated that the fur seals of the Pribilof Island population alone consume nearly 1.5 million mt annually.

Pacific Cod (*Gadus macrocephalus*)

Pacific cod in the eastern Bering Sea range north to St. Lawrence Island and south to the Alaska Peninsula. Its distribution pattern is quite similar to that of pollock.

This species ranked seventh in order of abundance among the 20 most abundant fish taxa in the St. George Basin area-subarea 2 of the 1975 OCSEAP survey area (Kaimmer et al. 1976).

The United States entered the Pacific cod fishery in the Bering Sea in 1857 with the use of handline gear by one American brig. Reported catches led to the development of the Okhotsk Sea fishery in 1863 by schooners, which delivered their catches to San Francisco. Peak years of the U.S. Pacific cod fishery in the eastern Bering Sea were 1915 to 1919,. when catches amounted to about 12,000 to 14,000 mt per year. Following this period, catches and number of vessels declined until the U.S. fishery was terminated in 1950. In contrast, the intensive Japanese and Soviet trawl fisheries in the eastern Bering Sea took from 47,000 to 75,000 mt annually between 1968 and 1974 (Bakkala et al. 1976).

The Japanese catch of both Pacific cod and pollock is taken from grounds between 165°W and 175°W. Some cod must be taken as incidental catches in the fisheries by USSR and South Korea, but quantities are small compared with Japan's harvest (Pruter 1973). Annual catches of Pacific cod by Japan occur primarily along the çontinental slope during late autumn, winter, and early spring. They have risen from 19 thousand mt in 1964 to a peak of 74 thousand mt in 1970 (Low 1976a). During the period 1964-1973, the total catch of Pacific cod by the Japanese in INPFC halibut conservation area A, which includes the St. George Basin, was 124,277 mt (Wolotira 1974). This catch was 36 percent of the total Japanese Pacific cod catch from all conservation areas during this period. The total 1974 Japanese catch of Pacific cod by all gear types in the St. George Basin was 19,590 mt (Japan Fishery Agency data). Catch densities were largest along the continental slope (Fig. 8).

Pacific cod are mostly benthic, occurring occasionally in quite shallow water and to depths of 550 m. Small fish, less than 20 cm, occur in the shallower regions, whereas large fish primarily occur in deeper waters of the shelf (Salveson and Dunn 1976). The distribution of Pacific cod is affected by periods of cold weather. During the exceptionally cold winters of 1971-1975 (McLain and Favorite 1976) in the southeastern Bering Sea, Pacific cod concentrated in the warmer, deeper waters of the St. George Basin even during summer months (Fig. 9). During the warmer years of 1965-1970, Pacific cod were more concentrated northeastward in the warmer, shallower waters of Bristol Bay (see also NMFS 1977).

Pollock also apparently undertake an inter-seasonal, temperature-controlled, bathymetric movement. In the winter, the species migrates to relatively deep water, and in the spring or early summer (following spawning), migrates to shallower water (Forrester 1969). However, pollock do not undertake extensive geographical migrations, but instead form local populations in various areas of their distribution, undertaking only relatively short seasonal migrations of 300-500 km (Moiseev 1956). East-west movements are reported by Low (1974) as the fish migrate back and forth between the continental slope and the continental shelf.

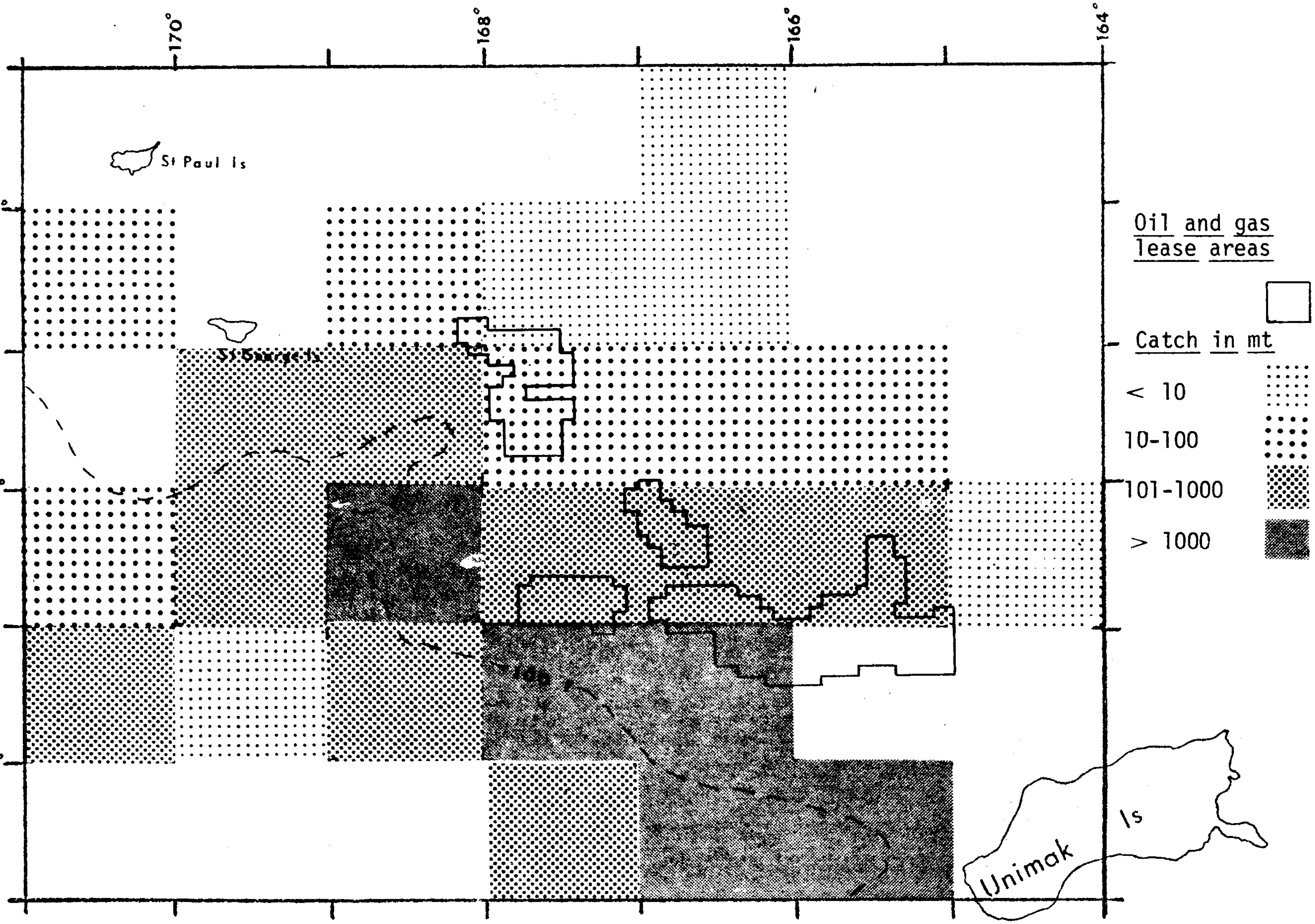

Figure 8. 1974 Japanese catch of Pacific cod (Gadus macrocephalus) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

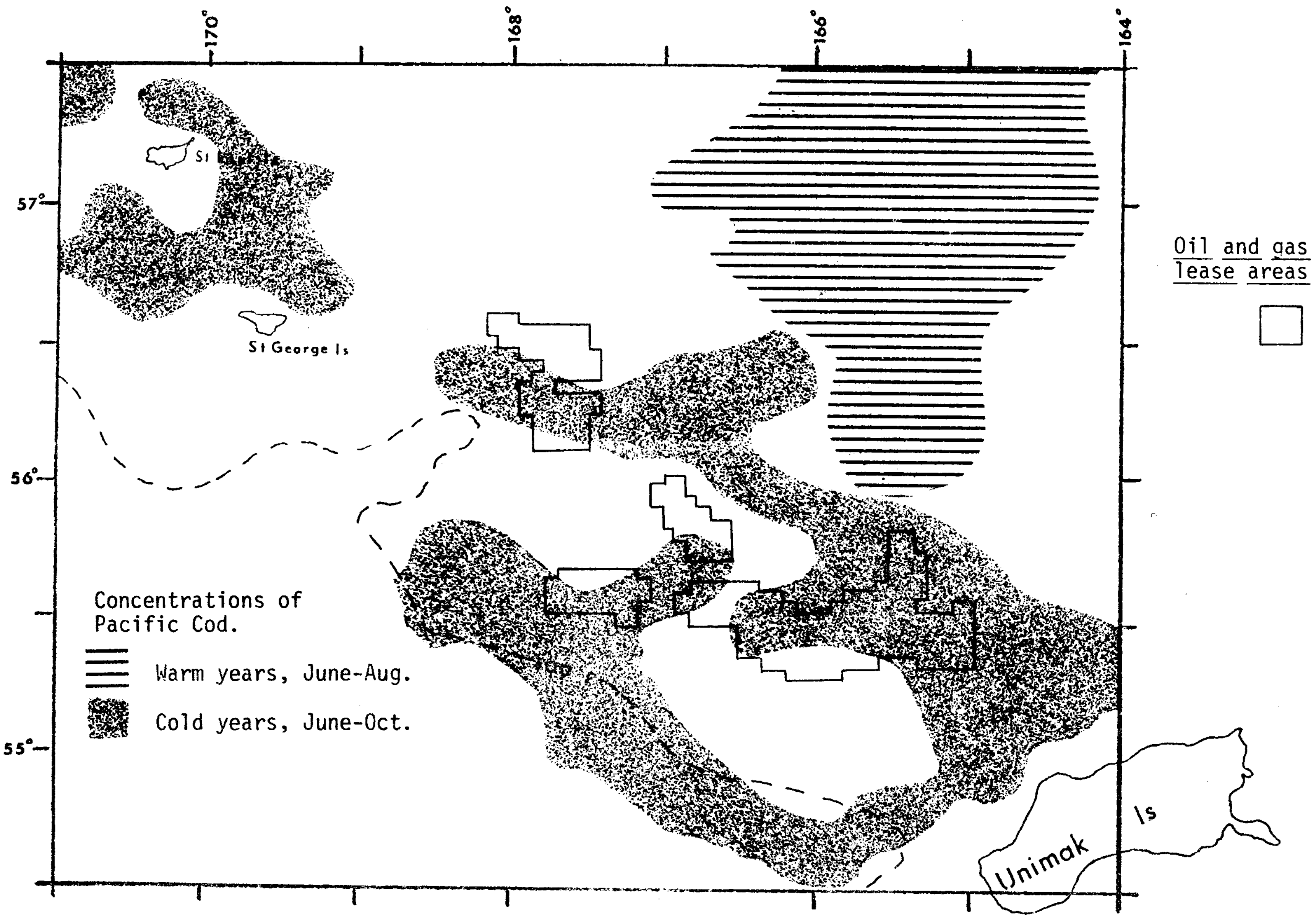

Figure 9. Concentrations (10 to 40 kg/km) of Pacific cod in the St. George Basin area during warm years (1965-1970) and cold years (1971-1975). (adapted from Smith et al. 1976 and Kaimmer et al. 1976)

Spawning periods and areas have not been delineated for the eastern Bering Sea (Salveson and Dunn 1976). In the northern Bering Sea spawning takes place from January to February or March (Svetevidov 1948). In general, Pacific cod spawn at temperatures of 0-5°C in Asian waters. Eggs are demersal and, initially, slightly adhesive. Besides being cold stenothermal and euryhaline, cod are tolerant of wide ranges of dissolved oxygen concentrations in terms of total and viable hatching success.

Pacific cod are relatively fast-growing fish with a relatively short life span. Age 2, 5, and 9 fish may be 30, 54, and 84 cm in length, respectively (Salveson and Dunn 1976). The maximum age for Pacific cod in the Bering Sea is reported to be about 12 years (Moiseev 1953). Cod feed upon pollock, herring, smelt, capelin, flatfish, eelpout, crab, shrimp, octopus, mollusks and other food (Krivobok and Tarkovskaya 1964). In turn, Pacific cod are fed upon by fur seals (North Pacific Fur Seal Commission 1975), beluga whales (Kleinberg et al. 1964), sperm whales (Berzin 1971), and other whales (Tomlin 1957).

Pacific Ocean Perch (*Sebastus alutus*)

Pacific ocean perch range from southern California to the Bering Sea (Hart 1973). It is the most important species of rockfish harvested in the northeastern Pacific, accounting for 77 to 98 percent of the total rockfish catches on the outer continental shelf and upper continental slope in regions between Oregon and Unimak Pass (Alverson 1967).

In the eastern Bering Sea, the largest concentrations of ocean perch are located in the vicinity of the Pribilof Islands and in the southeastern portions of the continental slope (Pautov 1972). Most of Japan's harvest of this species is by independent factory trawlers around the Aleutians and in the southeastern and central Bering Sea. The Soviet fishery is comparable to Japan's, both in areas fished and size of harvest (Pruter 1973).

Catches of ocean perch in the eastern Bering Sea have ranged between 3 and 47 thousand mt (INPFC 1975). During the period 1964-1973, the total ocean perch catch by the Japanese in INPFC conservation area A, which includes the St. George Basin, was 44,279 mt (Wolotira 1974). This catch was 43 percent of the total Japanese catch of ocean perch from all conservation areas for this period. Total 1974 Japanese catch of ocean perch by all gear types in the St. George Basin area was 1,018 mt (Japan Fishery Agency data). In 1974, largest catches were taken just west of Unimak Island and southeast of St. George Island (Fig. 10).

This species is common in and along gullies, canyons, and submarine depressions of the upper continental slope (Fig. 11). Adults occur in abundance over a variety of substrates including clay and jagged rock, but their occurrence may be determined more by food and hydrographic factors than substrates (Quast 1972). (Lestev (1961) observed that schools of ocean perch during May and June were usually 9 to 15 m off the bottom, but occasionally they ascended to within about 50 m of the surface in waters 140 to 465 m deep.) Ocean perch is a long-lived, slow-growing species with sexual maturity not occurring until age 9 (Pautov 1972) and a life span of 26 years (Low 1976).

Little is known about migrations of ocean perch in the eastern Bering Sea. Moiseev and Paraketsov (1961), however, reported daily vertical migrations of ocean perch in the Bering Sea during the pre-spawning period (January-April). The fish were on the bottom during the day and as much as 40 m off the bottom during the night. However, Lestev (1961) did not find this to be true during the summer, and he speculated that the reason was the seasonal lack of complete darkness in the Bering Sea. Daily vertical movement was attributed to feeding (Lyubimova 1965; Skalkin 1964). Pautov (1972) reported findings similar to those of Moiseev and Paraketsov (1961), and agreed with Lestev (1961) that vertical migrations vary seasonally. Pautov (1972) also believed that food and light caused the seasonal and diurnal vertical migrations of ocean perch in the Bering Sea.

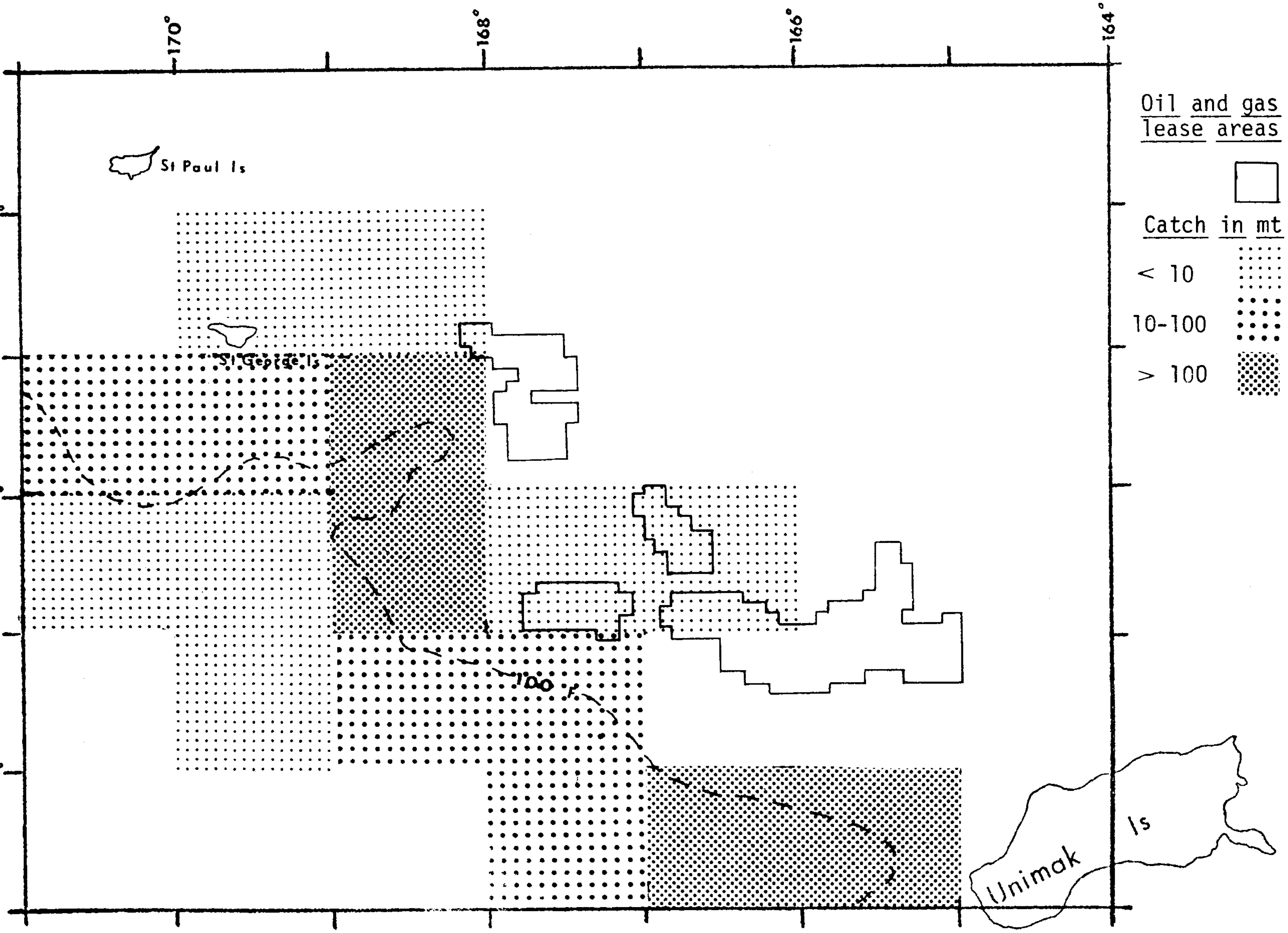

Figure 10. 1974 Japanese catch of Pacific Ocean perch (*Sebastes alutus*) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

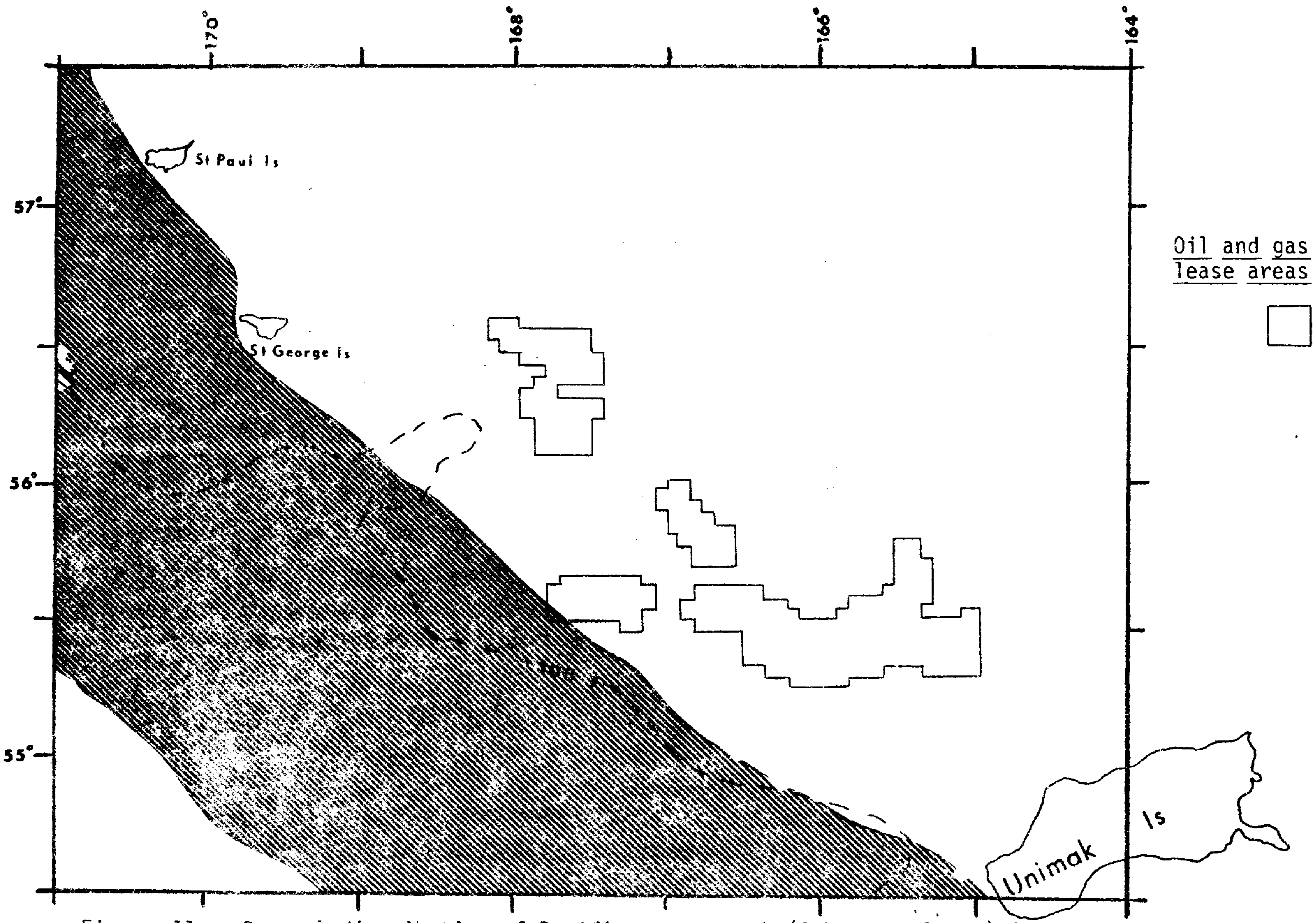

Figure 11. General distribution of Pacific ocean perch (Sebastes alutus) in the St. George Basin area (adapted from Major and Shippen 1970).

Ocean perch, an ovoviparous (Major and Shippen 1970) species, spawn once a year during March through May in the Bering Sea (Paraketsov 1963) at depths of 360-370 m (Moiseev and Paraketsov 1961). Fertilization is internal and eggs are retained in the ovary during incubation. Juveniles are planktonic during their first year. Those from the Pribilof Islands area are spawned in spring and are swept by currents toward the shores of the Aleutian Islands and the Alaska mainland. According to Paraketsov (1963), juveniles become demersal during their second year of life. However, Carlson and Haight (1976) believe they become demersal during their first year of life; their conclusion is based on data showing catches of age 1 perch in bottom trawls.

Paraketsov (1963) reported that planktonic crustaceans are the basic food of perch for the first 2 years of life after which they feed on increasingly larger euphausiids and pandalid shrimp. During March, April, and May, ocean perch seem to feed very little (Skalkin 1964; Carlson and Haight 1976).

Sablefish (*Anoplopoma fimbria*)

Also called black cod, sablefish range from northern Mexico northward in the eastern Pacific to Alaska, along the Aleutians, and in the Bering Sea to the coast of Siberia (Low 1976). Its relative biomass is distributed approximately 67 percent in the Gulf of Alaska, 13 percent in the Bering Sea, 13 percent in the Vancouver-California region, and the remaining 7 percent in the Aleutian region (Low et al. 1976).

Sablefish have been utilized by the U.S. and Canada for nearly a century. Presently, the resource is fished directly and indirectly by nine countries along the continental shelf and slope of the Bering Sea and northeastern Pacific Ocean. Most of the sablefish have been caught by the Japanese stern trawl and longline fisheries. In recent years, Japan accounted for about 85 percent of the all-nation sablefish catch in the

Bering Sea. The rest were taken by the USSR and the very limited ROK longline fishery initiated in 1975. The Japanese fishery increased from 32 mt in 1958 to a peak of 29,000 mt in 1974. Soviet landings from 1967 to 1974 declined from 4,256 mt in 1968 to 71 mt in 1974 (Low 1976). The 1974 Japanese catch of sablefish by all gear types in the St. George Basin area was 1,014 mt (Japan Fishery Agency data). Most of the catch was concentrated along the 100-fathom contour (Fig. 12).

The occurrence of sablefish along the continental edge of the eastern Bering Sea is known from commercial exploration (Fig. 13). Sablefish are less numerous in the inner shelf waters (Alverson 1967); in the eastern Bering Sea, trawl surveys have encountered sablefish as deep as 910 m. The bulk of the adult population, however, appears to reside at bottom depths of 200-700 m, and depths of 500-700 m are considered optimum. The presence of sablefish in the slope zone of the Bering Sea is due mainly to the stable and comparatively high temperatures of 3-5°C (Kulikov 1965).

Sablefish become sexually mature at about 5 to 7 years of age. Spawning in the eastern Bering Sea occurs in February (Shubnikov 1963) in water 250 m to 750 m deep (Thompson 1941). Fecundity of sablefish is high. Large females may produce as many as 1 million or more eggs each season (Phillips 1964). Spawned eggs are pelagic and rise to the surface where development occurs. Post-larvae have been encountered at the surface far from shore over bottom depths from several hundred to approximately 2,000 m, which supports the belief that adults spawn well off shore. Juveniles have a pelagic or semi-pelagic existence until about age 1.5 years when they make the transition to a demersal life. Larval and juvenile sablefish have been encountered east of the St. George Basin area north of Unimak Island in the Outer Bristol Basin area (Kodolov 1968). Sablefish conduct extensive migrations between the Bering Sea, the Gulf of Alaska, and off the Pacific Northwest. However, the exchange is slow; the majority of these fish are localized and do not migrate

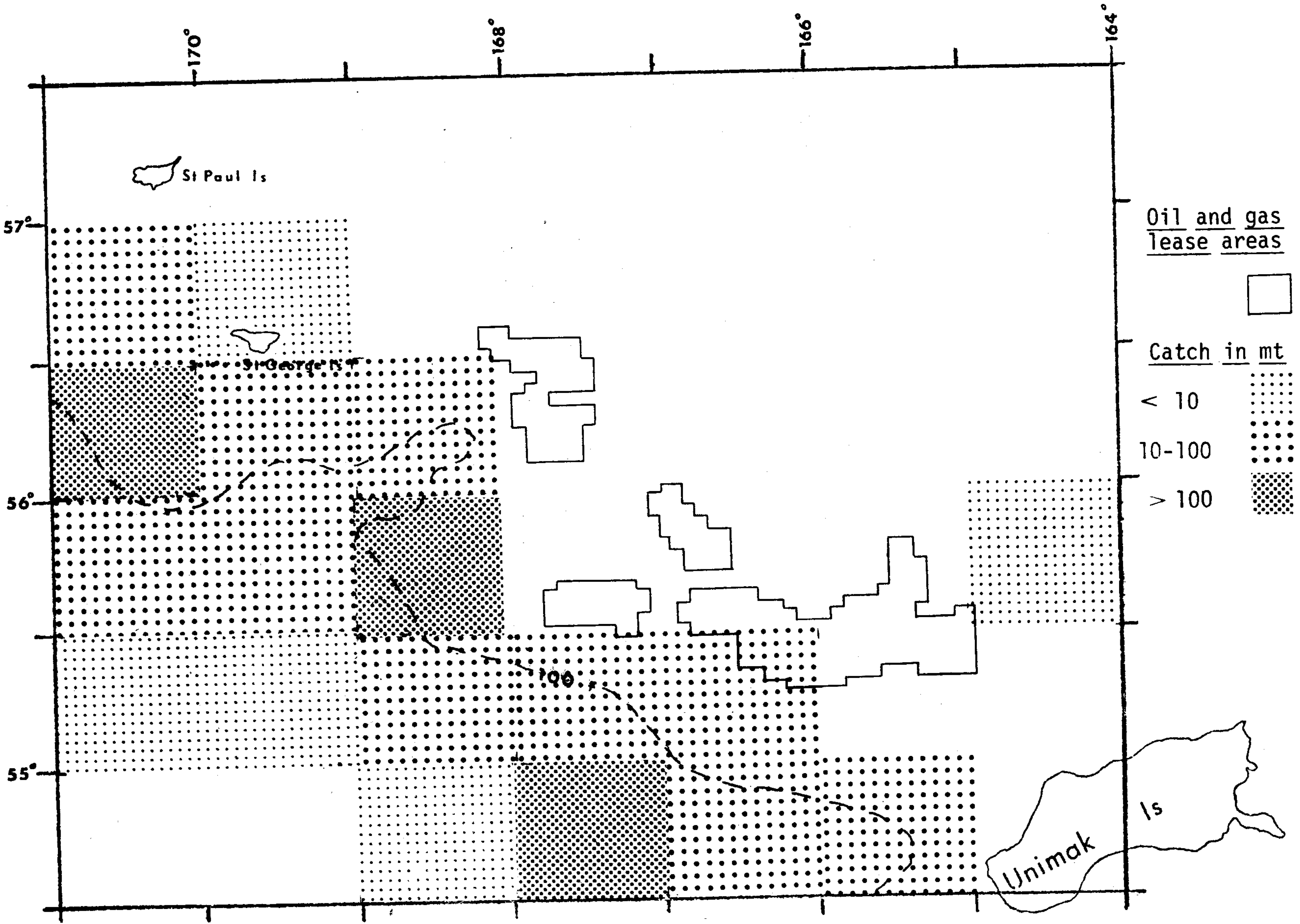

Figure 12, 1974 Japanese catch of sablefish (Anoplopoma fimbria) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

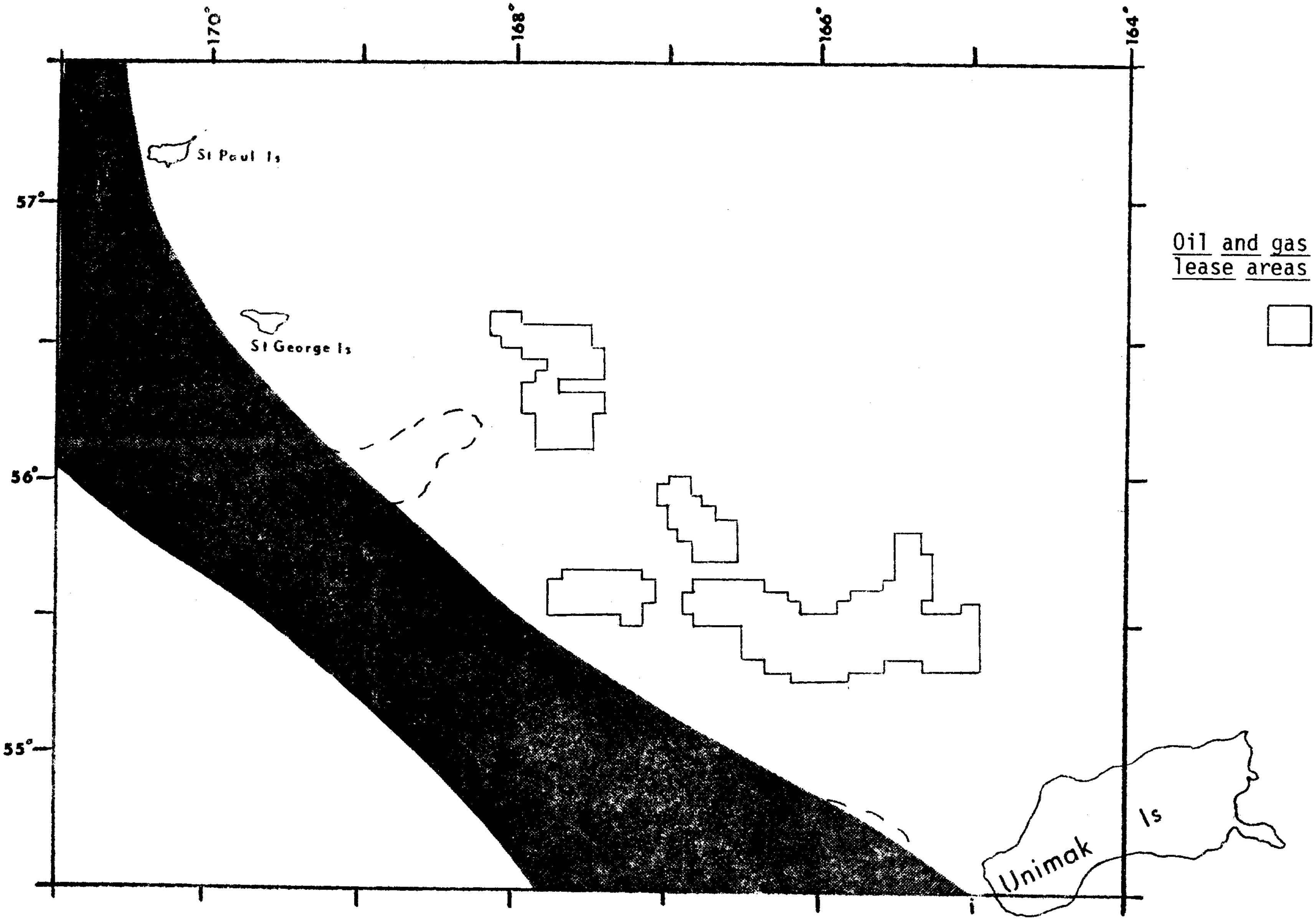

Figure 13. General distribution of the sablefish (Anoploma fimbria) in the St. George Basin area (adapted from Low et al. 1976)

over long distances (Low et al. 1976). According to Kulikov (1965), this species undertakes daily vertical movements in the eastern Bering Sea that are associated with changing light conditions and food habits.

Kulikov (1965) observed that there was a daily vertical movement of sablefish associated with changing light conditions and food habits. During the day, sablefish are in the upper water layers, feeding on such pelagic and off-bottom species as walleye pollock, herring, and capelin. At night they are near the bottom where they prey on deep sea fish including grenadiers, (family Macrouridae), viperfish (family Chauliodontidae), and bottom dwelling vertebrates and invertebrates. Thus, their vertical movements appear to be opposite to that of other species.

Other fish in the diet of Bering Sea sablefish include saffron cod, Pacific cod, sculpins, small flounders (Shubnikov 1963), rockfish, and small sablefish (Sasaki et al. 1975). Shubnikov (1963) reported that fish form the major part of the sablefish diet in early spring and autumn, whereas during the summer sablefish switch to a diet consisting of shrimp, ctenophores, and some benthic organisms.

Intensity of feeding is highest at the beginning of summer; it decreases towards autumn, is lowest in winter, and rises again during early spring. Sablefish are preyed upon by Pacific halibut (Bell and St. Pierre 1970), sea lions (Phillips 1969), and ling cod, *Ophiodon elongatus* (Shippen 1974).

Pacific Halibut (*Hippoglossus stenolepis*)

The halibut fishery, one of the more valuable fisheries on the North American continent, is controlled by the International Pacific Halibut Commission, which sets the start and duration of the season and regulates catch quotas and areas.

Halibut are found on the continental shelf in boreal waters at temperatures from about 3° to 8°C. It is the largest of the flatfish, averaging 30 to 35 pounds but reaching a recorded maximum size of 495 pounds (Bell 1968). Adult halibut (65 cm or larger) are found in sub-commercial concentrations through the southeastern Bering Sea but commercial concentrations are located in the St. George Basin (see Fig. 3) and adjacent areas.

Halibut are captured by longlines, and the fishing season is generally from late April or early May to September or October. The peak halibut catch in IPHC Regulatory Area 4A, which includes the St. George Basin area, was 7,005,000 lbs in 1963 (R. J. Myhre, IPHC, written communication). This catch had a value of approximately $1,471,000. Catches in recent years (Table 9) are relatively low and not indicative of the long-term production potential of the resource. In part this is due to resource depletion caused by excessive fishing in the area.

Table 9. 1967-1975 halibut catch (pounds x 1,000) in area of St. George Basin (Regulatory area 4A) by Canadian and U.S. fishermen. [1]

1967	1,297
1968	508
1969	238
1970	278
1971	488
1972	80
1973	7
1974	2
1975	3

[1] Data from Myhre, written communication.

In the early 1960's, foreign (Japan and USSR) and domestic fleets expanded their trawling effort for bottom fish. It was during this period that the catch per unit effort of adult halibut began to decline (Myhre 1971). Young halibut are also vulnerable to capture by the trawl fishery, and the number of young halibut has declined drastically on some grounds. Estimates of incidentally caught halibut by Japan and the USSR during the years 1954-1976 range between 42 mt and 11,519 mt. The majority of the catch was by Japan, although the proportion taken by the USSR has increased in recent years (Hoag and French 1976).

Halibut spend most of the winter on the continental slope, then begin temperature-related migrations (Natarov and Novikov 1970) in spring northward and eastward toward shallower waters of the shelf (Fig. 14) where they spend the summer (Best 1969; Takahashi 1969). There is some speculation (Novikov 1964) that halibut travel between 320-350 km during seasonal migrations.

Spawning takes place from November to March along the edge of the continental shelf at depths from about 230 to 450 meters (Bell and St. Pierre 1970). A large female may produce 2 to 3 million eggs annually. The specific gravity of the eggs enables them to remain suspended at midwater depths as they drift with ocean currents. Larvae, too, are free-floating and may be transported many hundreds of miles by ocean currents. Thus, the eggs and larvae may be dispersed far from the point where they were produced. Eggs produced on the shelf edge in the eastern Gulf of Alaska and even from more distant grounds could, under some conditions, be the source of the young found in the Bering Sea (Bell and St. Pierre 1970). Halibut larvae have been taken southwest of the Pribilof Islands and northwest of Unimak Island along the 100-fathom isobath (Favorite and Waldron 1976). As development proceeds, larvae rise closer to the surface. Inshore surface currents carry many larvae into coastal shallows favorable for growth. The free-floating stage may last up to 6 months. Then juvenile halibut settle to shallow bottoms. The area of the Outer Bristol Basin north and east of Unimak Island is an important halibut rearing area.

Although some females may mature as young as about 8 years of age, others may be immature until as late as 16 years of age. The average

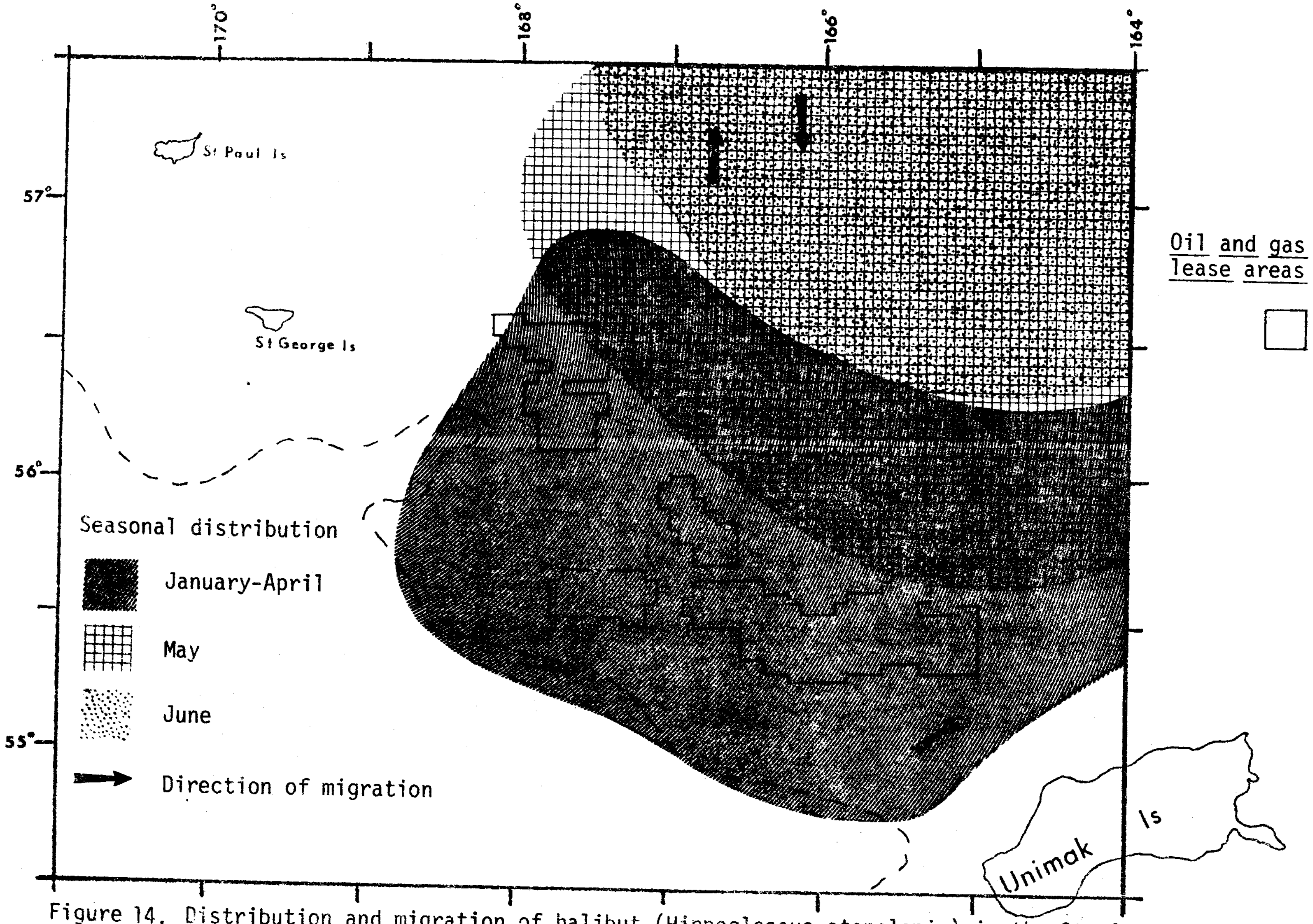

Figure 14. Distribution and migration of halibut (<u>Hippoglossus</u> <u>stenolepis</u>) in the St. George Basin area (adapted from Natarov and Novikov 1970).

age of first maturity for females is considered to be 12 years. Males, on the other hand, mature much younger and the average age of first maturity of males is about 7 to 8 years of age (Bell and St. Pierre 1970). Halibut feed primarily upon benthic fauna, e.g., yellowfin sole and pollock.

Arrowtooth Flounder (Atheresthes stomias)

Arrowtooth flounder mainly inhabit the northwestern Pacific Ocean from California north into the Bering Sea in waters as warm as 9°C. In the eastern Bering Sea, arrowtooth flounder occur along the continental slope and in smaller concentrations on the shelf.

Both this species and another flatfish species, Greenland halibut (Reinhardtius hippoglossoides), are sometimes referred to as "turbot" in catch statistics (Low 1976a). Turbot are used solely for fish meal by Japan. Early Japanese fishing in the eastern Bering Sea harvested about 30-50 thousand mt of turbot per year during 1960-1964. Because of the depletion of yellowfin sole stocks and the conversion of many vessels to minced pollock production, turbot became an incidentally caught species. During 1964-1973, the total Japanese catch of turbot from INPFC halibut conservation area A, which includes the St. George Basin, was 64,663 mt (Wolotira 1974) or 53 percent of the total catch from all conservation areas. The total 1974 Japanese catch of turbot by all gear types in the St. George Basin area was 1,947 mt (Japan Fishery Agency data). Largest catches were taken in areas south and southwest of the Pribilof Islands (Fig. 15)

The arrowtooth flounder ranked eighth in order of abundance among the 20 most abundant fish taxa in the St. George Basin area, subarea 2, of the 1975 OCSEAP demersal resource survey (Kaimmer et al. 1976). Subarea 2 had the largest concentration of arrowtooth flounders of all areas surveyed (Fig. 16). However, major concentrations of arrowtooth flounder

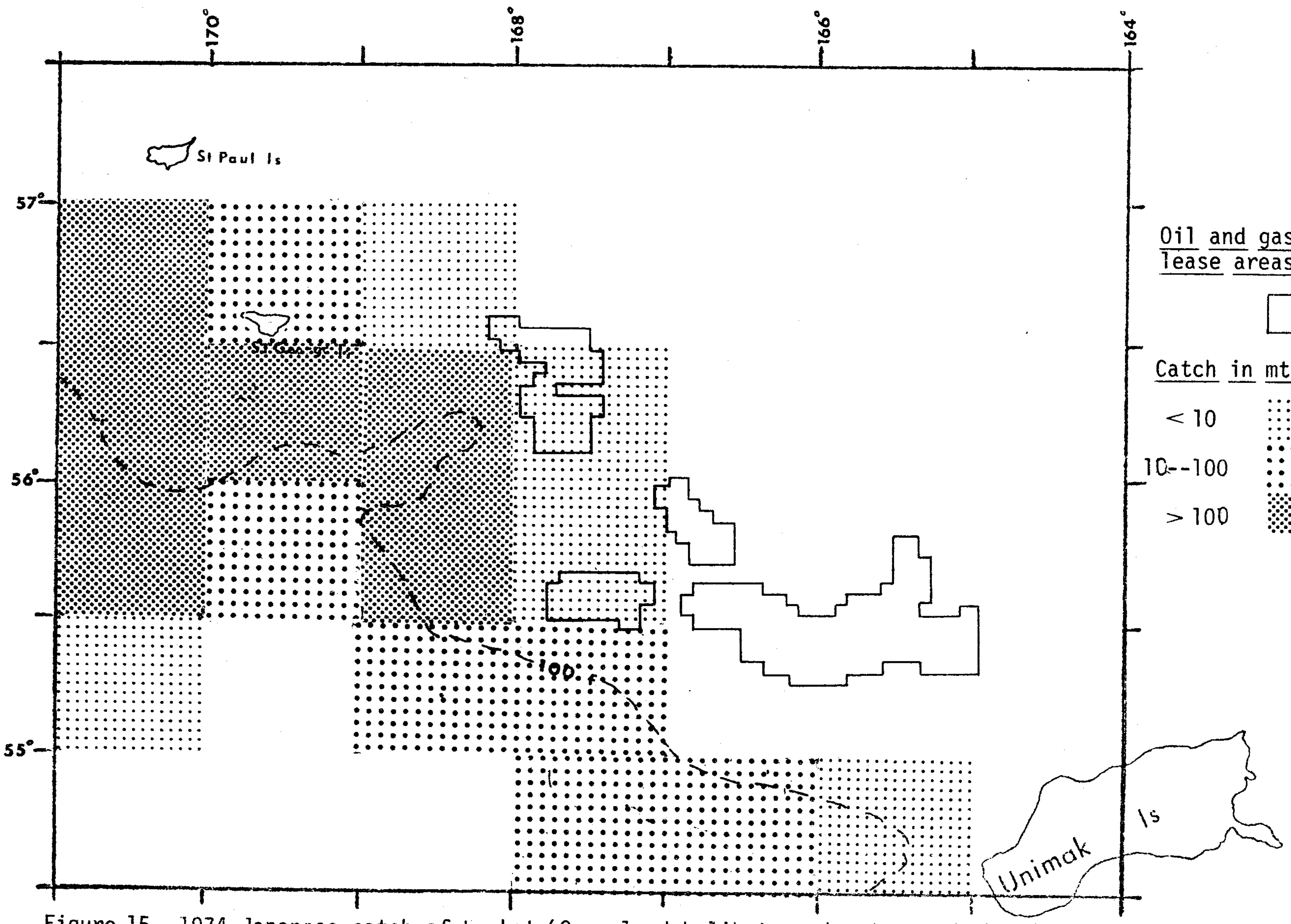

Figure 15. 1974 Japanese catch of turbot (Greenland halibut, and arrowtooth flounder) by all gear types in the St. George Basin (adapted from data of the Japan Fishery Agency).

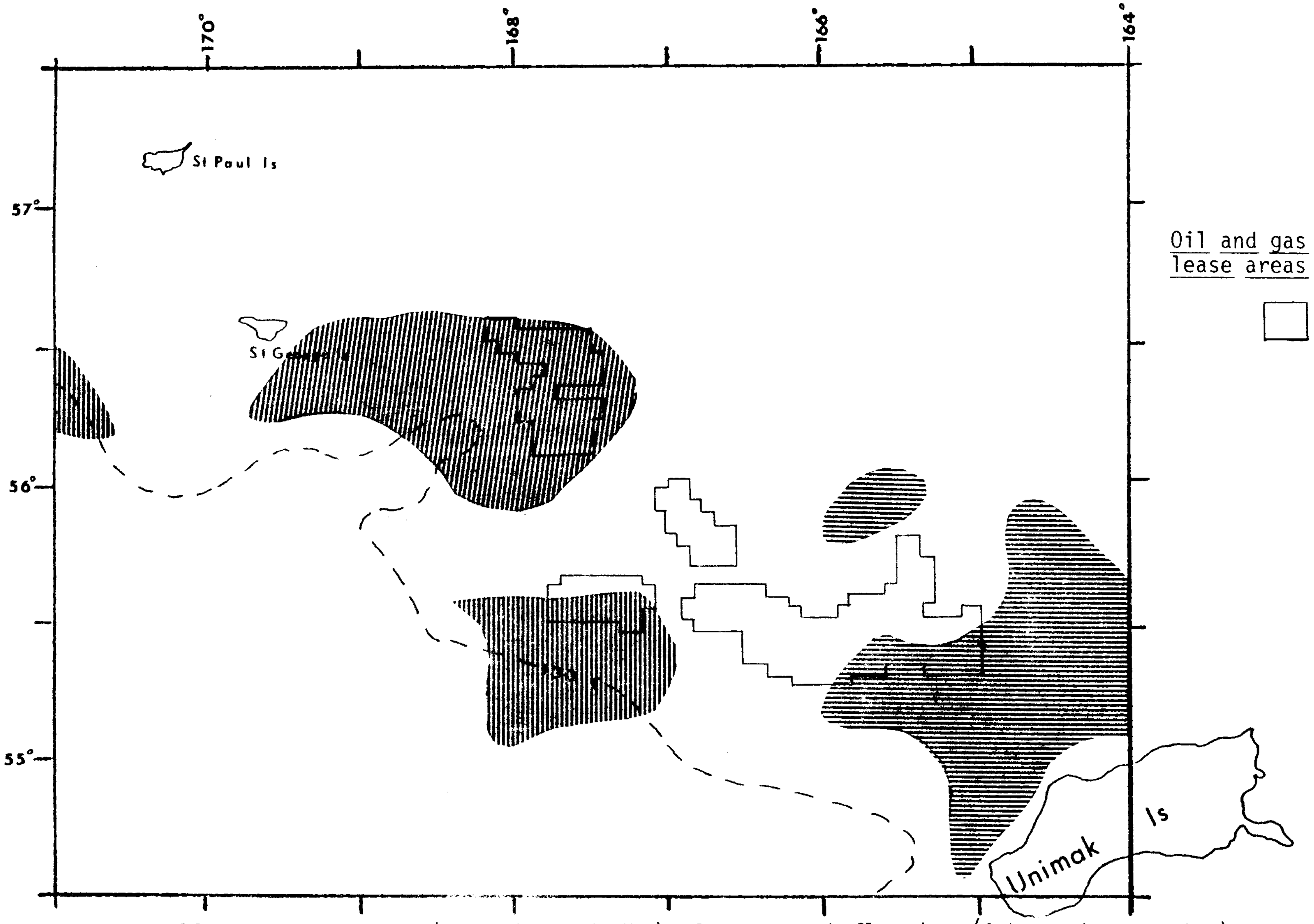

Figure 16. Concentrations (50 to > 200 kg/km) of arrowtooth flounder (*Atheresthes stomias*) in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

occurring at depths greater than 200 m were not adequately sampled (Kaimmer et al. 1976). Future sampling may lead to different results.

Young arrowtooth flounder are eurythermal and occur at lower temperatures than adults, mainly in waters with temperatures of 1-5°C. Adults are most often encountered at demersal water temperatures of 3-4°C. During winter, young arrowtooth flounder migrate to the deepest part of the continental shelf and the upper parts of the slope. The water temperature of the Bering Sea continental slope does not vary appreciably during the year. However, adult arrowtooth flounder concentrate in winter at depths of 300-500 m. Since temperature variations there are small, seasonal migrations of arrowtooth flounder are probably related to changes in feeding conditions and times of spawning (Shuntov 1970). When water temperatures increase with the advent of spring, feeding migrations to shallower waters commence. The migration becomes intensive in May when the northern boundary of distribution shifts appreciably northward. The distribution of the comparatively warm-water loving young arrowtooth flounder is bounded on the north by the 0°C isotherm, i.e., the edge of the sub-zero "cold spot" remaining from the previous winter. Young arrowtooth flounder migrate more rapidly in water adjacent to these cold spots than through them.

During summer, concentrations of arrowtooth flounder are found in waters 200-400 m deep, although a certain number of large individuals are found at depths of 50-200 m. On the continental slope, arrowtooth flounder gradually shift to deeper water in October.

Information on spawning times is lacking but, like the closely related A. evermanni, may occur in winter. That female arrowtooth flounder with unripe eggs have been encountered in the Bering Sea in October and November, but only spent females in March (Shuntov 1970), implies that spawning occurs during December through February.

Greenland Halibut (Reinhardtius hippoglossoides)

Greenland halibut occur in deep waters of the Pacific Ocean from Baja California to Honshu Island, Japan, through the Bering and Okhotsk Seas (Hart 1973). The greatest abundance occurs in the northern portion of its range. In the eastern Bering Sea, Greenland halibut are primarily concentrated in waters over the continental shelf and slope (Dunn and Sample 1976).

In the area of the St. George Basin, subarea 2 of the 1975 OCSEAP demersal baseline survey area, this species ranked tenth in order of abundance among the 20 most abundant fish taxa (Kaimmer et al. 1976). Surveys by NMFS, 1973-75, and the 1975 OCSEAP demersal baseline survey indicate that Greenland halibut accounted for 30-65 percent of the combined catch of Greenland halibut and arrowtooth flounder (Smith et al. 1976). In the area of the St. George Basin, however, arrowtooth flounder are more abundant (Figures 15 and 17).

Catch statistics for this species are confusing, since they are often included with catch statistics for arrowtooth flounder, the two species being lumped together as "turbot." Catch statistics of turbot are discussed in the preceeding section (see arrowtooth flounder). The turbot fishery is operated mainly by the Japanese northwest of the Pribilof Islands where Greenland halibut are much more abundant than arrowtooth flounders.

Greenland halibut prefer colder water than do arrowtooth flounder young and a considerable number overwinter in water with below zero temperatures. During February through April, they partly descend the slope. In spring and summer they remain in cold spots, discussed in the previous section, at depths of 50-100 m where they actively feed. In the southeastern Bering Sea, adult Greenland halibut concentrate at depths of 600-900 m in winter and at depths of 400-700 m in summer (Shuntov 1970).

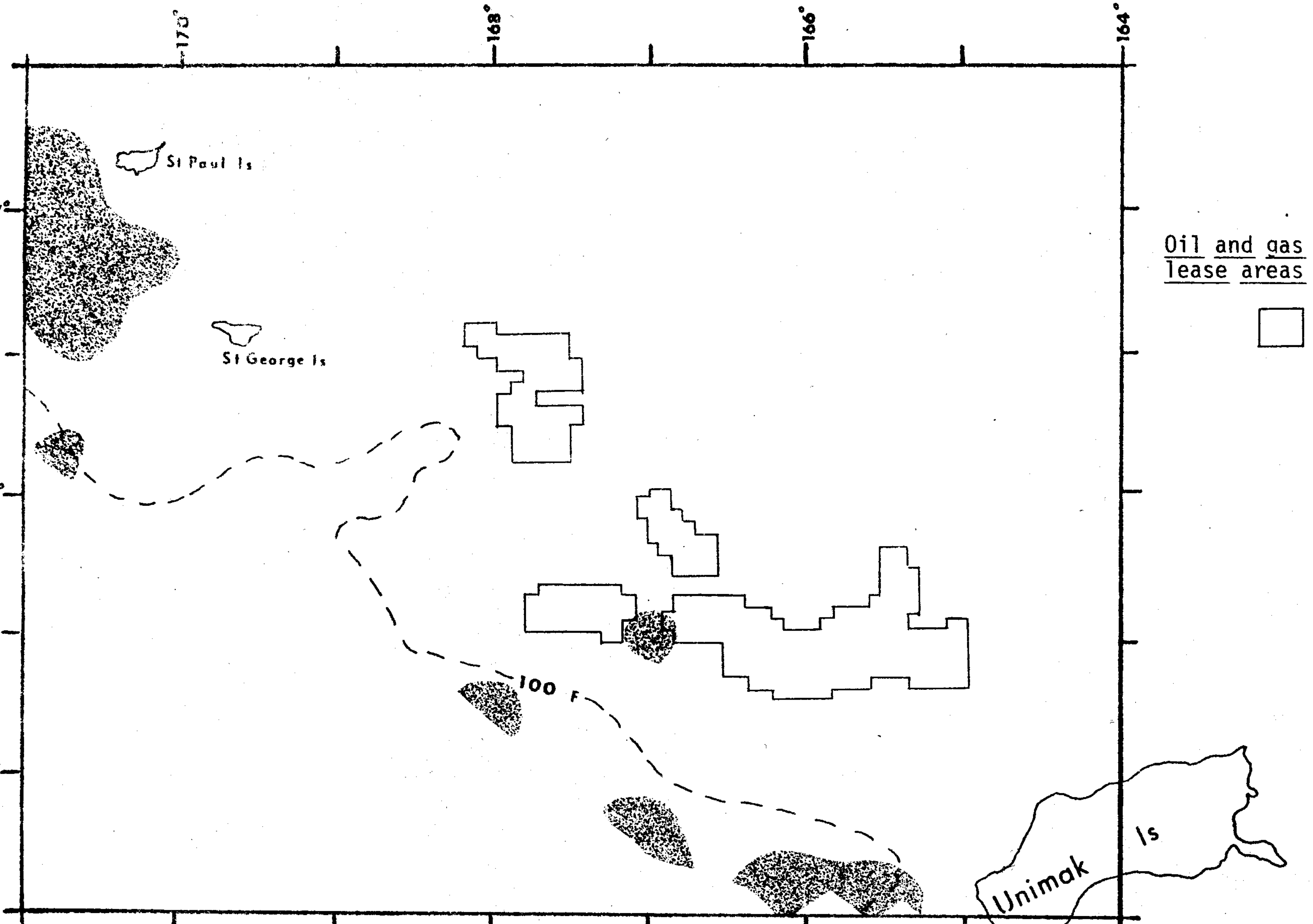

Figure 17. Concentrations (10 to > 30 kg/km) of Greenland halibut (*Reinhardtius hippoglossoides*) in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

Little is known concerning Greenland halibut spawning times or areas in the eastern Bering Sea. Soviet investigators have encountered nearly ripe fish in the western Bering Sea in September, and spent females were found in December-January. Hence, spawning in this region occurs in the fall and winter, most likely during October-December (Musienko 1970).

Spawning apparently takes place at depths greater than 100 m, most likely on the continental shelf, at temperatures of 1-3°C. Little is known about the life history of juvenile Greenland halibut in the Bering Sea, but larvae occur in the southeastern Bering Sea in May and June, according to Dunn and Naplin (1973).

According to Shuntov (1965), three conditions must be met for successful reproduction of the Greenland halibut and other halibuts: (1) permanent currents must be directed from the deepsea zone to the shallows, otherwise eggs and larvae would not reach the shallows; (2) shallows must have predominantly gyral currents to prevent the escape of eggs and larvae to deep waters; and (3) the shallows must occupy a sufficient area and have waters whose physicochemical properties are suitable for young fish. These requirements become all the more important in view of the fact that the eggs and larvae are at the mercy of currents for several months.

Stomach analyses by Mikawa (1963) demonstrate that Greenland halibut feed on a variety of organisms, including zooplankton, pelagic, midwater and demersal fishes, as well as squids. Mikawa (1963) also determined the seasonality of feeding of Greenland halibut. Feeding was most intense in June-September and then less so in fall and winter, with the lowest incidence of feeding occurring in January-May.

Greenland halibut are preyed upon by Pacific halibut, fur seals, beluga whales, and other marine mammals (North Pacific Fur Sea Commission 1971; Bergen 1971; Tomilin 1957).

Yellowfin Sole (Limanda aspera)

Yellowfin sole range widely in the northern Pacific Ocean and in the northern seas, as far north as the Chukchi Sea. The eastern Bering Sea supports the largest biomass of yellowfin sole of any area (Fadeev 1970). The exploitable portion of yellowfin sole was estimated to be about 2.0 million mt before its fishery became intensified in the 1950's.

The Japanese harvested demersal fishes in the eastern Bering Sea in the 1930's and 1940's but greatly expanded their efforts and catch in the 1950's and early 1960's, targeting on the yellowfin sole. From 1958 to 1963, the Russians also entered this fishery, operating in winter, whereas the Japanese operated during April to September. Catches of yellowfin sole rose from 44,000 mt in 1958, peaking at 610,00 mt in 1961, and dropping rapidly to 86,000 mt in 1963 (Bakkala and Hirschhorn 1974). Fishing activities targeting on this species have continued; thus, the fishery has never recovered from the heavy exploitation of the 1960's. Beginning in 1969-70, the Japanese yellowfin sole fishery shifted from spring and summer months to winter months. Japanese vessels directed toward flatfishes in winter operate mainly on yellowfin sole in the Unimak Island area, and then move to west of St. Paul Island (Wakabayashi 1974).

Yellowfin sole rank second in order of abundance among the 20 most abundant fish taxa in the St. George Basin area-subarea 2 of the 1975 OCSEAP survey area (Kaimmer et al. 1976). The total 1974 Japanese catch of yellowfin sole by all gear types in the St. George Basin area was 13,526 m (Japan Fishery Agency data). Largest catches were taken in the area north of Unimak Island and southeast of St. George Island (Fig. 18).

Fadeev (1970) has indicated that groups of yellowfin sole overwinter: (1) north of Unimak Island, (2) west of St. Paul Island, (3) south of St. George Island and (4) in Bristol Bay. The group south of St. George

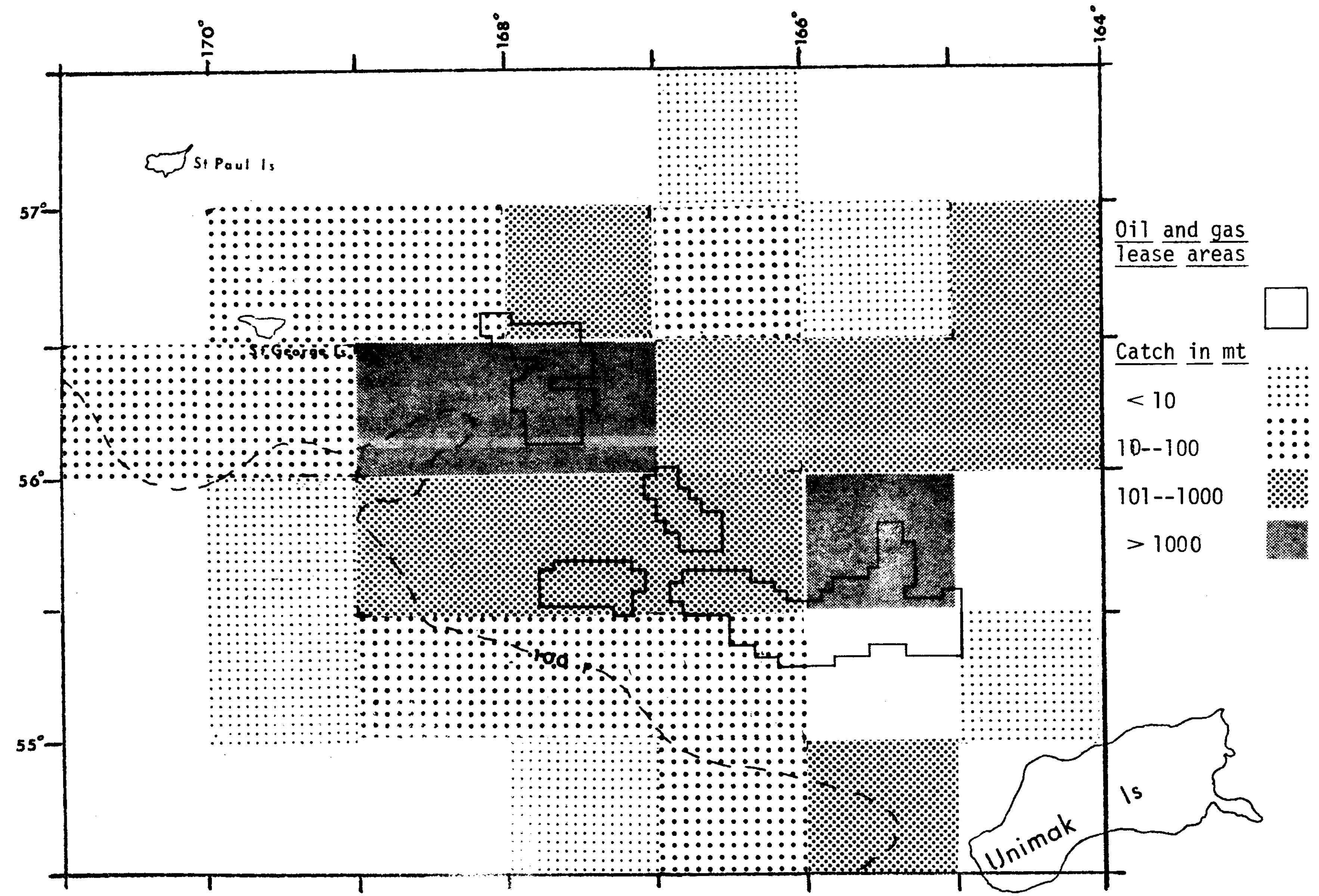

Figure 18. 1974 Japanese catch of yellowfin sole (Limanda aspera) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

Island is not stable and has not been seen in some years (Wakabayashi 1974).

As early as April and May yellowfin sole apparently move out of the St. George Basin. In summer they are found on the inner shelf (Fig. 19). During their migration, yellowfin sole move not only on the bottom but also well off the bottom. They feed vigorously during migration even in areas with below-zero bottom temperatures. The direction of migration is essentially northeastward with the Unimak Island group locating in Bristol Bay and the group west of the Pribilofs locating off Nunivak Island. By summer, the main body of yellowfin sole is found on the inner shelf at bottom depths of 100 m or less (Salveson and Alton 1976).

Spawning takes place in Bristol Bay and southeast of Nunivak Island during summer in waters shallower than 50 m (Kashkina 1965). Further discussion of spawning areas and egg distribution is contained in a separate report on Outer Bristol Basin (NMFS 1977).

Rock Sole (*Lepidopsetta bilineata*)

The rock sole is the single representative of the endemic Pacific genus *Lepidopsetta*. It has a wide range, being distributed in the North Pacific from the Bering Strait to Monterey, California (Shubnikov and Lisovenko 1964). Within the St. George Basin area, subarea 2 of the 1975 OCSEAP demersal survey area, it ranked fourth in order of abundance among the 20 most abundant fish taxa (Kaimmer et al. 1976). Rock sole was a relatively abundant species in the St. George Basin during the period 1963-1975, with catch rates approximately an order of magnitude greater than Pacific halibut, and 20-100 percent those for yellowfin sole (Smith et al. 1976). However, it cannot by itself support an economical fishery (Low 1976). Annual all-nation catches of rock sole did not exceed 20 thousand mt until 1970. In the following two years (1971 and 1972), it increased substantially to 50 and 68 thousand mt.

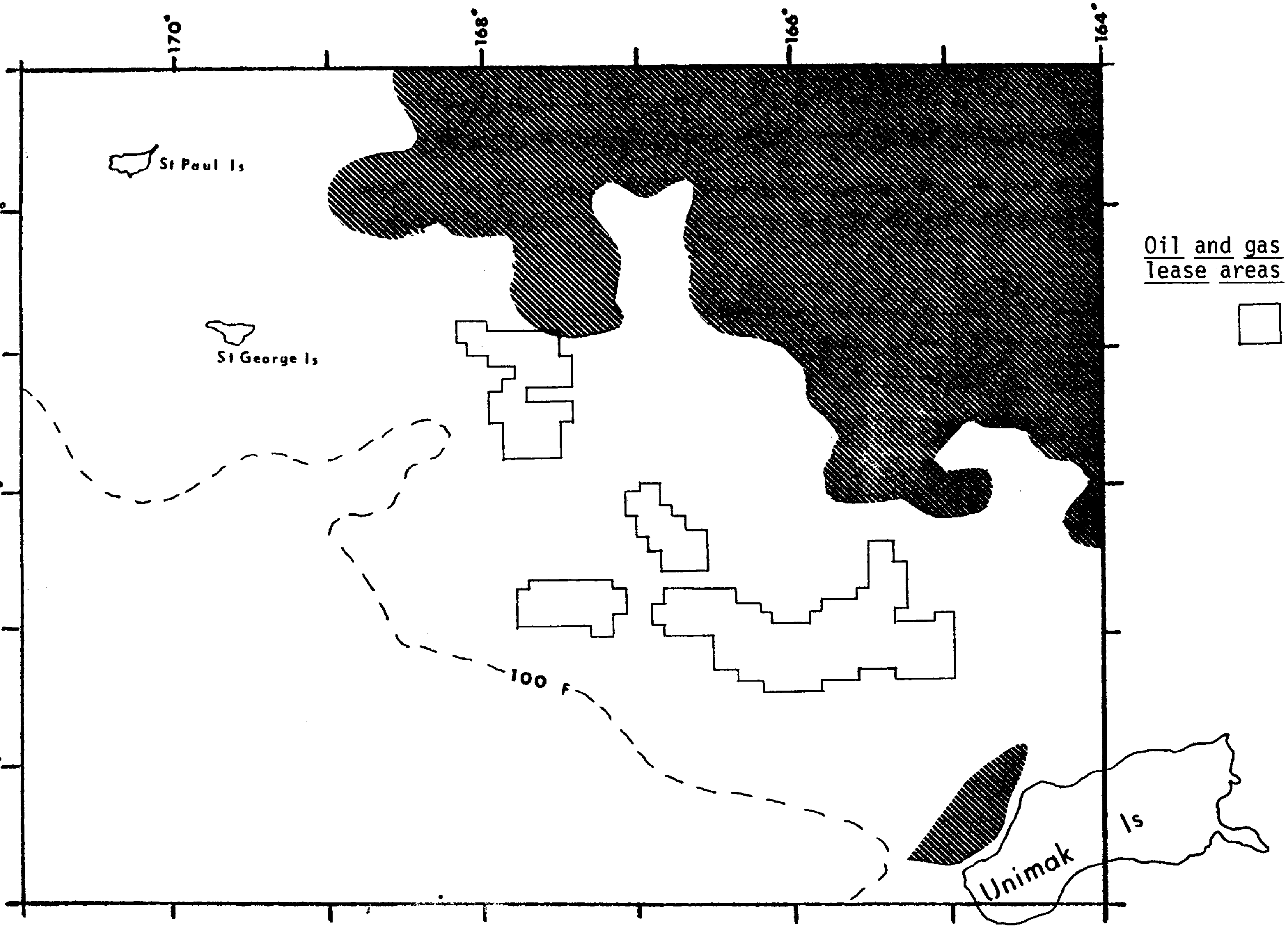

Figure 19. Concentrations (25 to > 250 kg/km) of yellowfin sole (*Limanda aspera*) in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

This increase was immediately followed by a rapid decline to 34 thousand mt in 1973.

During the period 1964-1973 the total catch of rock sole by the Japanese in INPFC conservation area A, which includes the St. George Basin, was 53,586 mt (Wolotira 1974). This catch was 48 percent of the total Japanese catch of rock sole from all conservation areas.

The 1974 Japanese catch of rock sole by all gear types in the St. George Basin area was 10,920 mt (Japan Fishery Agency data). Greatest catch densities were along the 100-fm contour between Unimak and St. George Islands (Fig. 20).

Rock soles inhabit hard bottoms with coarse sediments including gravel. Such areas are mostly found in the littoral region (Fadeev 1970). However, Shubnikov and Lisovenko (1964) encountered rock sole almost everywhere in the southeastern part of the Bering Sea at depths of 27-250 m. During the 1975 OCSEAP surveys, rock sole were found to be concentrated north of Unimak Island and in the region of the Pribilof Islands (Fig. 21).

Shubnikov and Lisovenko (1964) describe seasonal movements of rock sole which appear to be similar to those of the yellowfin sole. According to Fadeev (1965), rock sole winter at the same depths as yellowfin sole. Concentrations of rock sole north of Unimak Island have been reported at depths of 100-110 m during winter months (Shubnikov and Lisovenko 1964; Fadeev 1965). Commercial concentrations of this species are usually found near those of yellowfin sole, particularly on the Unimak bank and on the slope southeast of St. George Island. Some rock sole remain on the slope in summer without forming large concentrations. The rock sole migrating to the shallows are mostly dispersed and rarely form compact concentrations. Part of the young rock sole population winters on the

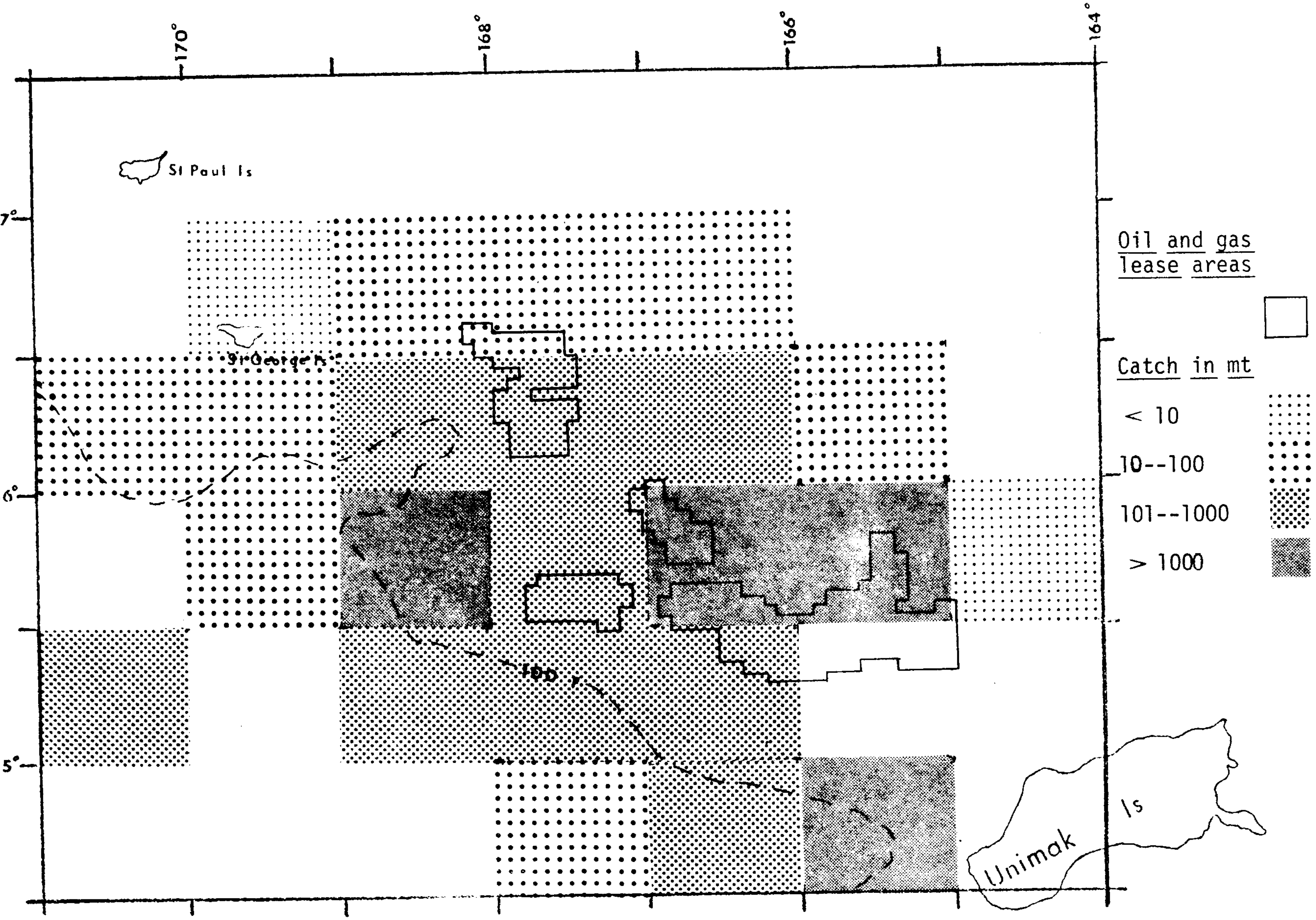

Figure 20. 1974 Japanese catch of rock sole (Lepidopsetta bilineata) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

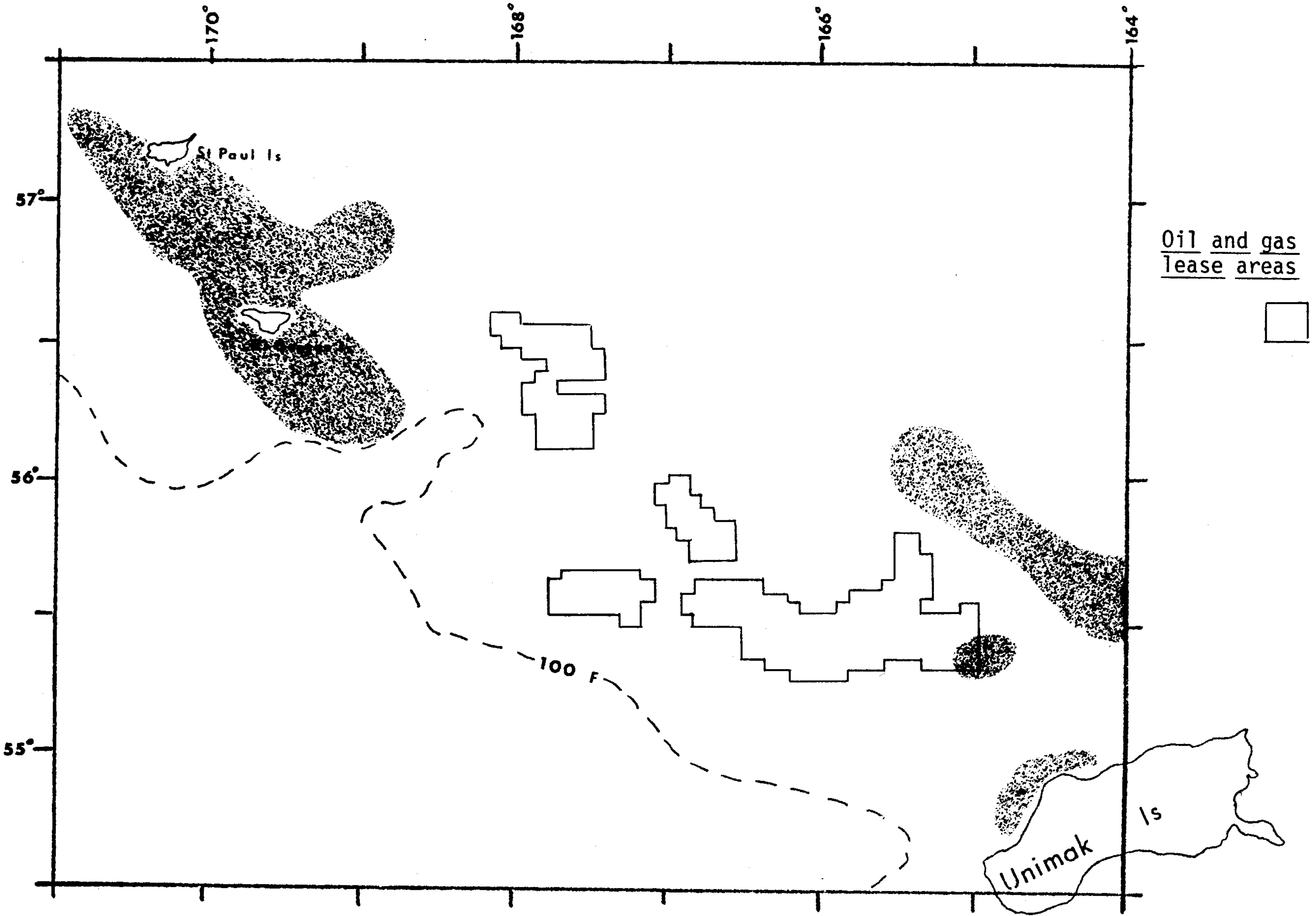

Figure 21. Concentrations (20 to >40 kg/km) of rock sole (*Lepidopsetta bilineata*) in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

Pribilof shelf. In summer, rock sole occur in slightly greater concentrations in the northern part of the central shallows at a depth of 20-40 m. In contrast to yellowfin sole, some rock sole remain on the slope during the warm season.

Rock sole spawn in their winter grounds, where they form dense concentrations. However, some rock soles spawn while dispersed all over the range occupied during the winter spawning period (Fadeev 1965). Rock sole in the southeastern Bering Sea reach sexual maturity at 5 to 7 years of age. Large rock sole may exceed 55 cm in length and 13 years of age.

The rock sole is a typical benthophage. Basic items of its diet are polychaetes, mollusks, and crustaceans (mostly shrimps). Polychaetes are the preferred food of rock sole in the southeastern Bering Sea. Fishes (sand lances) and echinoderms are occasionally found in rock sole stomachs. In winter and the beginning of spring, rock sole hardly eat. The most intensive feeding is observed in June and July in shallow water at depths of less than 50 m (Skalkin 1963).

Alaska Plaice (Pleuronectes quadrituberculatus)

Alaska plaice, a species of small commercial importance, is found throughout the Bering Sea except in the Commander Islands area at depths of 30-100 m over sandy bottoms. It ranked twelfth in order of abundance among the 20 most abundant fish taxa in the St. George Basin area, subarea 2, of the 1975 OCSEAP survey area (Kaimmer et al. 1976).

The total 1974 Japanese catch of Alaska plaice in the St. George Basin by all gear types was 1,566 mt (Japan Fishery Agency data). Catch densities are indicated in Figure 22. Alaska plaice lives year-round on the shelf (Fadeev 1965), but, like yellowfin sole, rock sole, and flathead sole, this species performs seasonal migrations. It moves south to

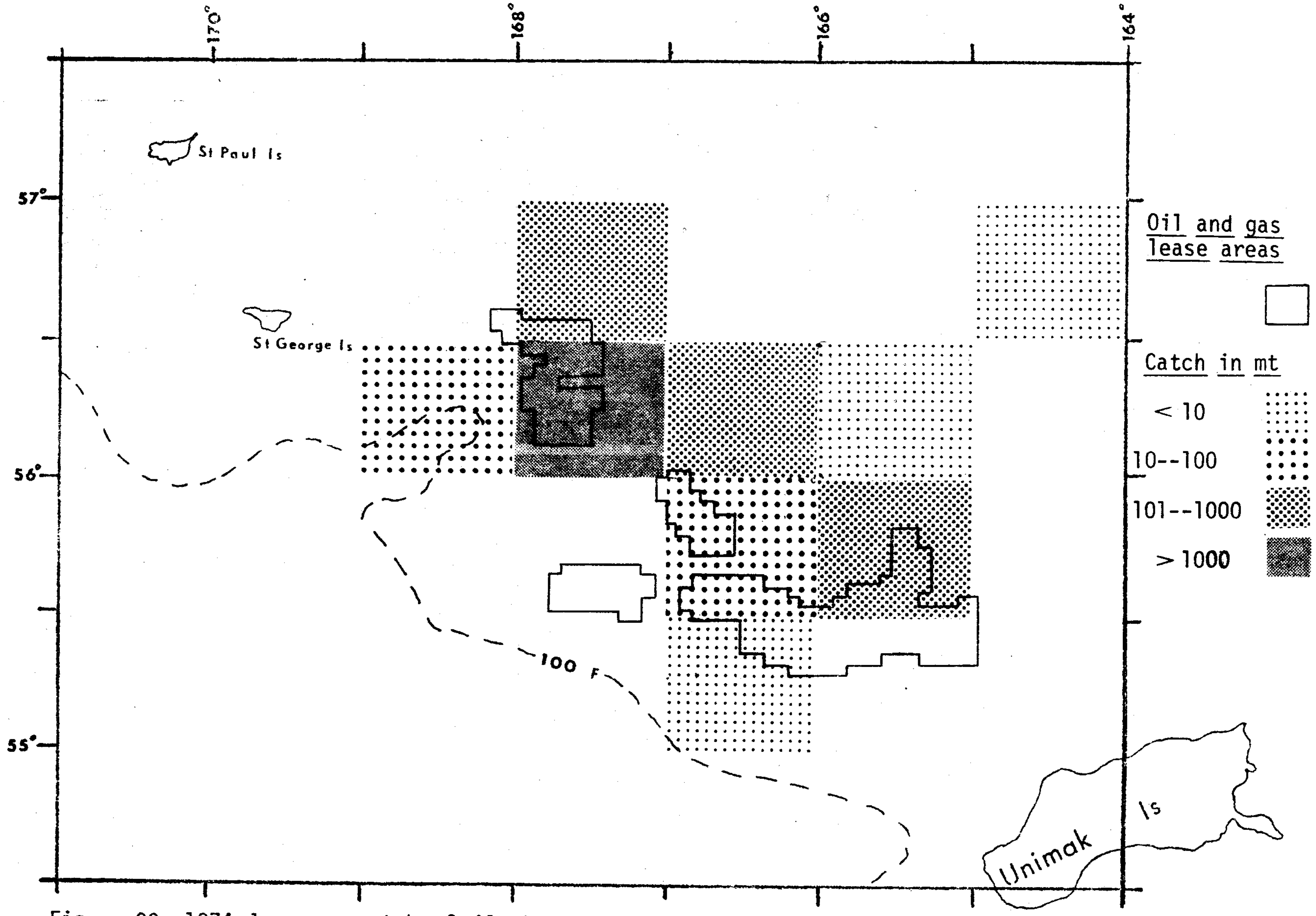

Figure 22. 1974 Japanese catch of Alaska plaice (*Pleuronectes quadrituberculatus*) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

overwinter in the lower part of the shelf at depths of 90-130 m where bottom temperatures are from 1 to 4.8°C (Mineva 1964). In summer, it is found in shoaler waters (Fig. 23). Alaska plaice is always dispersed and does not form separate commercial concentrations, even during the spawning period.

This species spawns from late April to mid-June (Pertseva-Ostroumova 1960), immediately after the ice melts. Spawning grounds of Alaska plaice are situated on the shelf mainly around the 100-m isobath and over depths of 75-150 m on hard sandy bottoms. As a rule, spawning begins when temperatures are around zero and ends when temperatures are about 3-4°C. Developing eggs are partly carried to greater depths in the open sea, although some are transported closer to the shore. Small larvae mostly occur in the surface layer, although they are occasionally caught in deeper waters down to 50-120 m (Musienko 1970).

Alaska plaice does not feed in winter (Mineva 1964). During other months, it feeds on benthic organisms such as polychaetes, molluscs, and crustaceans. When molluscs form a considerable proportion of the diet, one species dominates: Serripes groelandicus in the southern part of the shallows, Yoldia hyperborea and Y. johanni at a depth of about 50 m, Gomphina fluctosa in shallower waters. The lowest feeding rate is in May (Skalkin 1963).

Flathead Sole (Hippoglossoides elassodon)

Flathead sole are common in the Bering Sea, including the St. George Basin. This species ranked third in order of abundance among the 20 most abundant fish taxa in the St. George Basin area, subarea 2, of the 1975 OCSEAP survey area (Kaimmer et al. 1976).

During 1964-1973, the total catch of flathead sole by the Japanese in INPFC conservation area A, which includes the St. George Basin, was

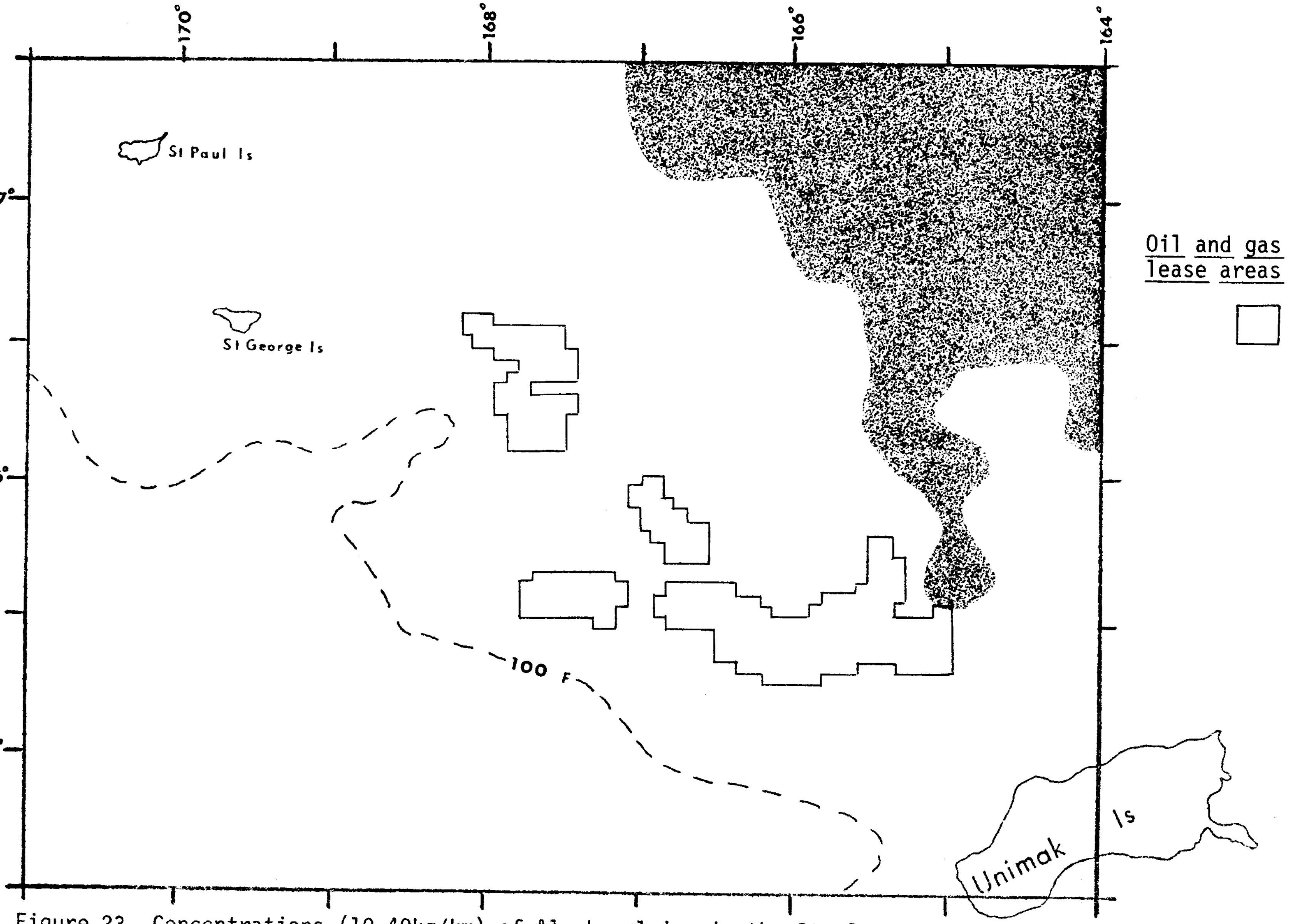

Figure 23. Concentrations (10-40kg/km) of Alaska plaice in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

28,555 mt (Wolotira 1974). This catch was 24 percent of the total Japanese catch of flathead sole from all conservation areas for that period. The 1974 Japanese catch of flathead sole by all gear types was 7,587 mt (Japan Fishery Agency data). Catch densities are indicated in Figure 24.

The flathead sole is a basically demersal species, occurring over muddy-sandy bottoms. It makes only limited vertical migrations (Cooney 1967). During winter, flathead sole form separate, large concentrations over all of the slope and the lower parts of the shelf. In spring, this species migrates to depths mainly less than 200 m, as determined by the 1975 OCSEAP survey (Fig. 25). Larger specimens are generally distributed over the entire shelf. Small concentrations have been noted between the Pribilof and St. Matthew Islands (Salveson 1976). Russian researchers in summer have caught flathead sole alone at depths of 100-140 m but with yellowfin sole, Alaska plaice, and rock sole at depths of 50-100 m (Mineva 1964).

Flathead sole do not form stable, localized spawning concentrations. Ovaries of the sexually mature flathead sole contain both ripe and unripe eggs of different sizes and colors. Together with the prolonged period of spawning, this suggests that these species spawn intermittently (Fadeev 1965). Eggs, larvae, and fry were found in outer Bristol Bay between Cape Newenham and Cape Sarichef (Musienko 1963).

When in deeper water, the flathead sole feeds on benthic crustaceans and echinoderms. Their most common food species are the brittle star, Ophiura sarsi, which is widely distributed (Neiman 1960), and pink shrimp, Pandalus borealis. As flathead sole migrate from the southern half of the region to shallower waters, O. sarsi decreases in numbers and vanishes altogether from their diet; pink shrimp are replaced by planktonic crustacea (Hyperids and euphausiids) and chaetognaths (Sagitta). Flathead sole feed in winter, unlike allied species, but only scantily, most stomachs being empty or nearly so (Mineva 1964). Qualitative

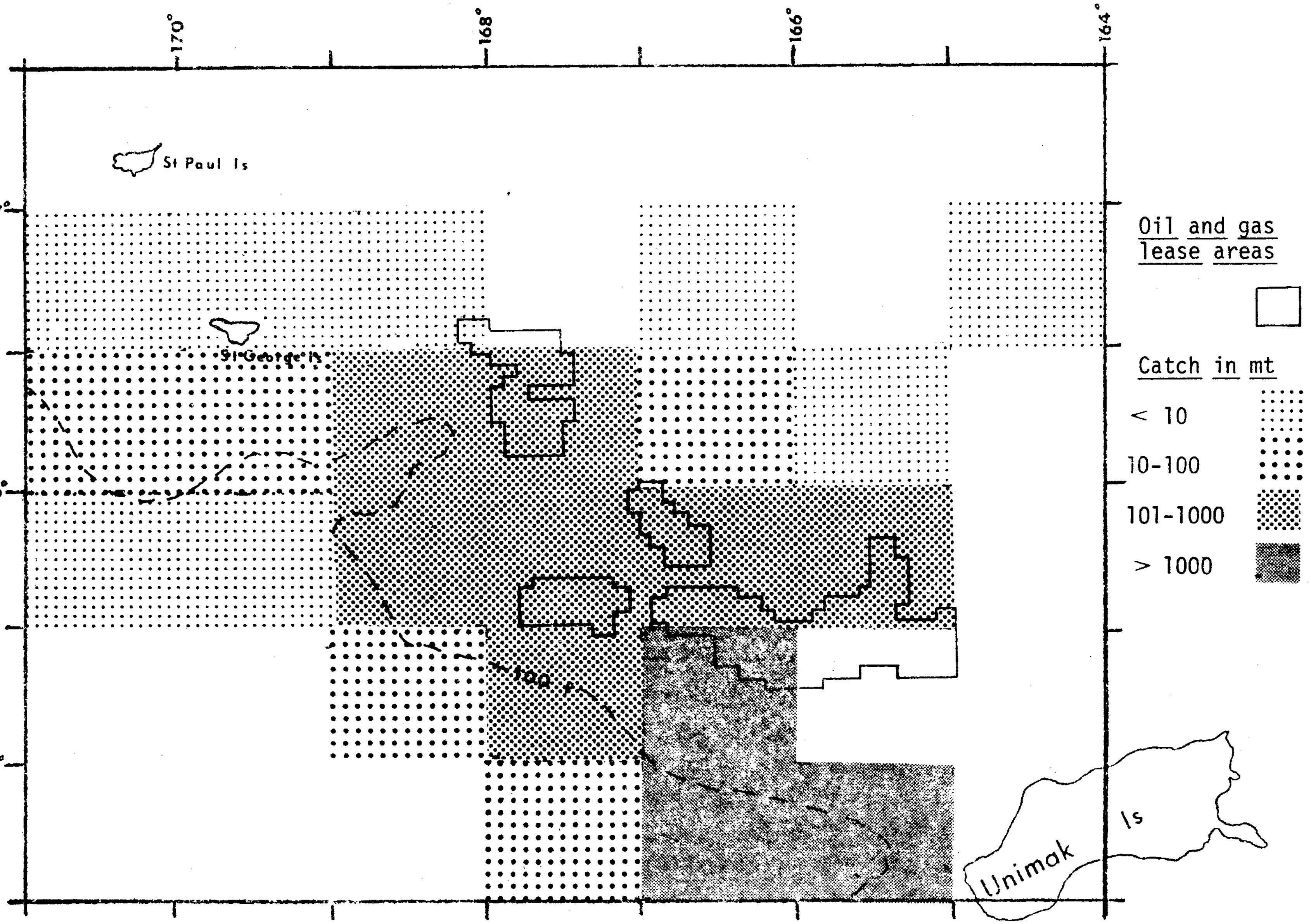

Figure 24. 1974 Japanese catch of flathead sole (Hippoglossoides elassodon) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

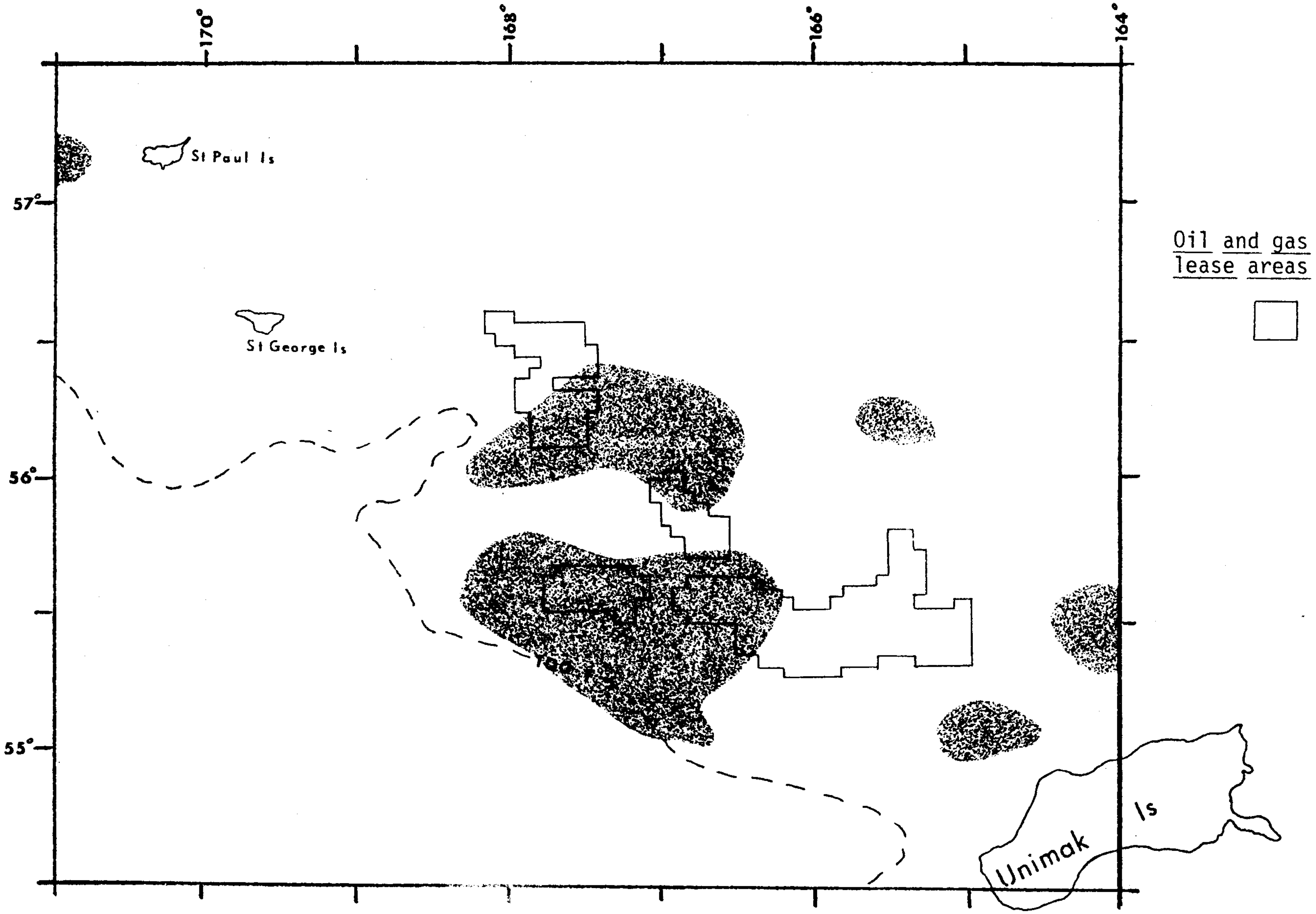

Figure 25. Concentrations (20 to>40 kg/km) of flathead sole in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

visual observations indicate a low food similarity between flathead sole and the other species; thus, no marked food competition would be expected among them (Skalkin 1963).

Pacific Herring (Clupea harengus pallasi)

Pacific herring is a widely distributed species that ranges along the coasts of the Gulf of Alaska, Bering Sea, and Arctic Ocean. Commercial concentrations occur near northern Japan, the Okhotsk Sea, and northeast coast of Kamchatka. In Alaska, the largest commercial quantities occur around Kodiak Island in Prince William Sound, and in much of southeastern Alaska (Reid 1972).

Herring is a species exhibiting strong schooling and migratory characteristics that make them vulnerable to fishing operations. During winter months, they are fished for along the continental slope in the eastern Bering Sea. Catch densities in the 1974 Japanese fishery are indicated in Figure 26. Rumzantsev and Darda (1970) noted periodic large concentrations of herring near Unimak Island and the Pribilofs during winter that move toward the Alaska coast and into bays during summer. Adult herring remain in inshore waters and bays throughout the summer, then form wintering schools northwest of the Pribilof Islands and along the southern margin of the ice pack. Dense wintering schools of herring occur near the bottom in waters deeper than 100 m (Dudnik and Usol'Tsev 1964). Summer and fall distributions in the St. George Basin area are indicated in Figure 27.

Herring spawning takes place from late April to early June in bays along the north shore of the Alaska Peninsula and Unimak Island (University of Alaska 1974). Herring eggs are adhesive and are deposited on solid surfaces rather than being loosely broadcast in the water. The generally preferred surface is living plants such as eelgrass (Zostera marina),

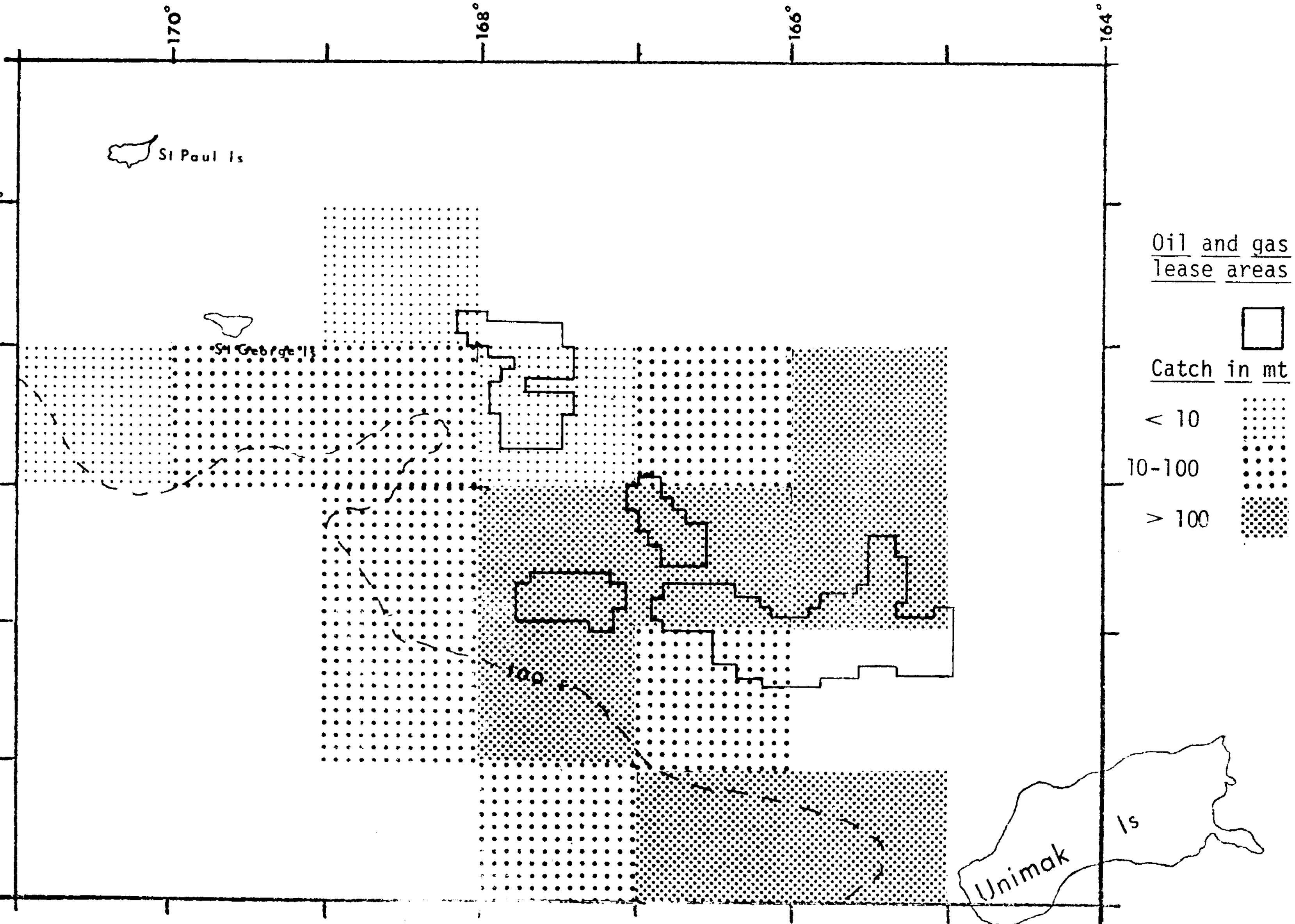

Figure 26. 1974 Japanese catch of herring (Clupea harengus pallasi) by all gear types in the St. George Basin area (adapted from data of the Japan Fishery Agency).

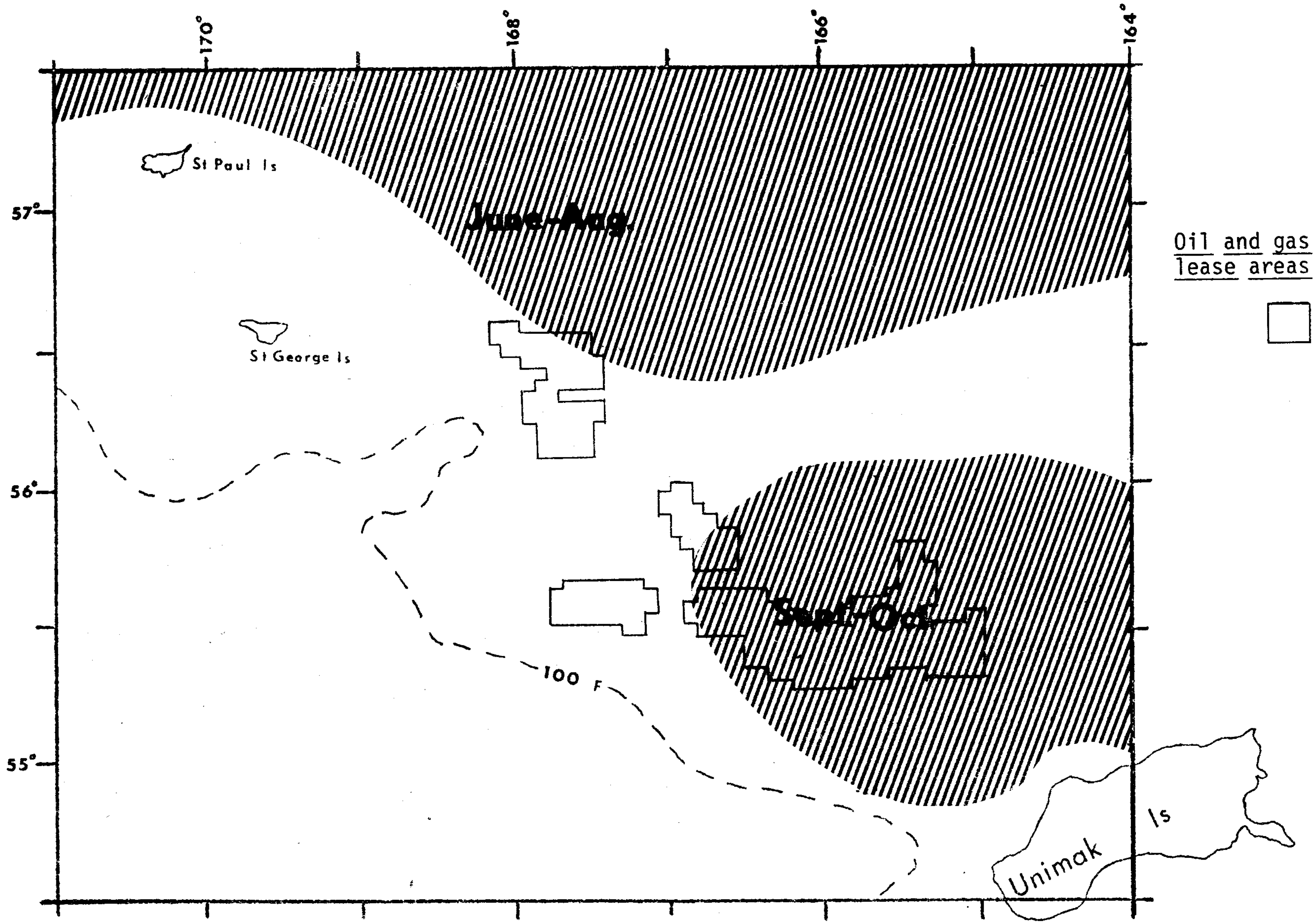

Figure 27. Distribution of herring in the St. George Basin area (adapted from Dudnik and Usol'Tsev, 1964).

rockweed (Fucus), and other vegetation (Reid 1972). Much of the beach area along the Alaska Peninsula is inadequate for herring spawning due to the predominance of sand with little rock and vegetation. Eggs develop for 23 days at 6 to 8°C before hatching into planktonic larvae. Metamorphosis into a scaled juvenile takes 6 to 8 weeks. The young form small schools and gradually move seaward toward the mouths of bays and inlets in which they were hatched. By early fall, individuals about 4 inches long form schools of perhaps 1 million or more fish. Most of the schools move into deep or offshore waters by late fall. They stay at sea for about 2-1/2 years, then return to shallows to spawn for the first time.

Herring feed upon plankton, primarily euphausiids, and migrate vertically toward the surface at night in pursuit of these crustaceans. In turn, herring are food for many species of fish, sea mammals, and birds.

MAJOR SHELLFISHES

Two genera of crabs, king crabs (Paralithodes) and Tanner (or snow) crabs (Chionoecetes), are of commercial importance in the eastern Bering Sea. There are four species of king crabs: red (P. camtschatica), blue (P. platypus), brown (P. brevipes), and golden (Lithodes aequispina). Only the red and blue king crabs are of significant commercial importance. There are two species of Tanner crabs, C. bairdi and C. opilio, both of which are important commercially. The foreign crab fishery is located north of Unimak Island and around the Pribilof Islands (see Fig. 4, COMMERCIAL FISHERIES section).

Abundance estimates for 1975 of the major crab species in the eastern Bering Sea are listed in Table 10.

In the St. George Basin area, red king crabs occur north of Unimak Island and near the Pribilof Islands. Blue king crabs occur mainly near the Pribilofs (Fig. 28.).

Table 10. 1975 estimates of abundance (in millions) of commercially important crabs in the eastern Bering Sea. Data from NOAA ship *Oregon* surveys.

Red king crab, *P. camtschatica*	267.3
Blue king crab, *P. platypus*	28.4
Tanner crab, *C. bairdi*	756.4
Tanner crab, *C. opilio*	5,598.9
C. hybrid	301.0

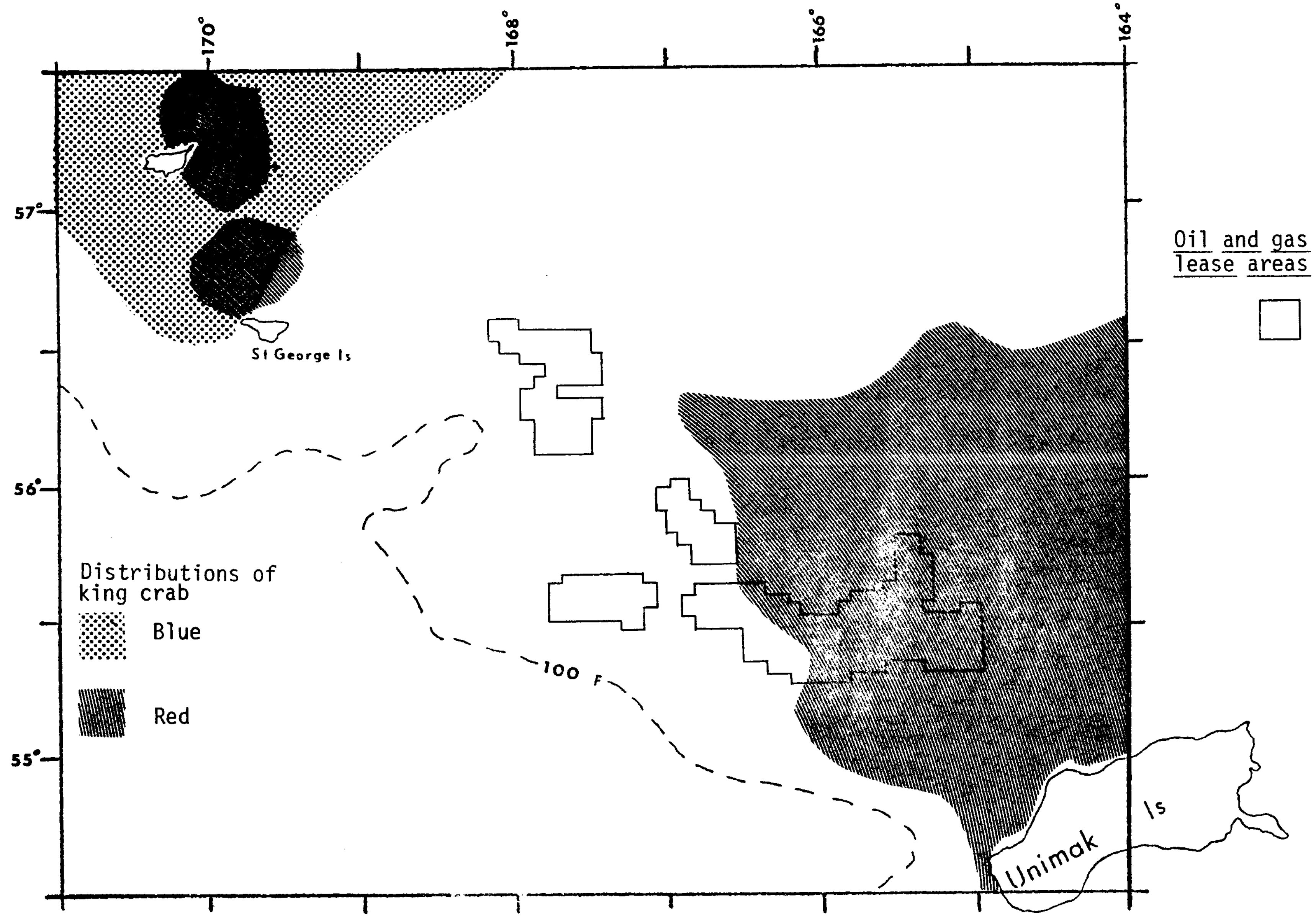

Figure 28. Distributions of red king crab (*Paralithodes camtschatica*) and blue king crab (*P. platypus*) in the area of the St. George Basin (adapted from Kaimmer et al. 1976).

Red King Crab (P. camtschatica)

Red king crabs inhabit cold North Pacific waters at temperatures of generally 0 to 10°C. Data compiled by Stinson (1975) indicate that adult male red kings inhabit 0 to 5.5°C waters and are most abundant at 1.5°C during summer months. Adult females inhabit the same temperature range, and are most abundant at temperatures of 3 to 5°C.

The annual life cycle of red king crabs is dominated by two migrations: a molting and mating/spawning migration in the spring, and a feeding migration in the summer and fall. The spring migration draws crabs to the inshore spawning areas north of Unimak Island (Fig. 28) and off Port Moller in Bristol Bay (see NMFS 1977). The offshore migration returns the crab to deeper waters to feed.

Weber (1967) indicates that sexual maturity of red crabs is attained at an age of five years for males and 5-1/2 years for females. During spring spawning, king crabs exhibit the behavioral characteristics of grasping, whereby the male holds fast the female in a pre-copulatory embrace that may last as long as seven days. After the female molts, the male inverts the female such that their abdomens are in close contact. After breeding, the pair separates. Developing eggs are carried by the female until they hatch the following spring. The general location of mating and larval release is the same.

The time of peak hatching varies with location; for example, early May in Bristol Bay and mid-April off Unalaska Island (Weber 1967). Larvae actively swim to the water surface after hatching and then sink lower in the water column as they proceed through several molts. The first juvenile stage is about 2 mm long. At about 15 mm, they inhabit the littoral zone of open exposed coastal areas where they seek protection from currents and predators among the rocks and algae. Larger juveniles form large aggregations called pods, which may number several thousand individuals and be in shallow water to 30 m.

Red king crabs are estimated to attain great age. Hoopes and Karinen (1971) estimated a Bering Sea male to be at least 17 years old. However, most crabs caught in the commercial fishery are 8 or 9 years old.

King crabs are bottom foragers, feeding on a wide range of food items, including dead organisms. Crab larvae feed on sponges, hydroids, and algae during the transition to their demersal mode of life (Korolev 1964). Brittle stars (Ophiuroidea) are an important food item for newly molted king crabs. King crabs also feed on molluscs, reported to be a major food item in the Bering Sea (McLaughlin and Hebard 1959), polychaetes, isopods, young Tanner crabs, and algae (Chebanov 1965). Bright (1967) reports that king crabs consume entire sea urchins (Strongylocentrotus drobachinesis) and the rays of 20-rayed starfish (Pycnopodia helianthoides).

King crabs are preyed upon by a number of animals. Juveniles may be especially susceptible to predation by crabs (Powell and Nickerson 1965) and sculpins (Powell 1974) because of their small size (Bartlett 1976). Adult crabs are preyed upon by halibut (Gray 1964), sculpins (Wallace et al. 1949), and river otters (Carl 1971).

Blue King Crab (P. platypus)

Blue king crabs are generally found in colder waters near the Pribilof Islands (Fig. 28). It is the second most abundant species of king crabs in the eastern Bering Sea. Other concentrations occur southwest of St. Matthew Island and from King Island (south of Bering Strait) to Herendeen Bay (off Bristol Bay). Female blue king crabs have been observed in the process of molting and hatching eggs in late July near the Pribilof Islands (Karinen 1974). Reproduction and growth characteristics are similar to those of red king crabs.

Tanner Crabs (Chionoecetes)

Distribution of Tanner crabs in the St. George Basin area extends from Unimak Island to the Pribilofs (Fig. 29). Scattered concentrations of

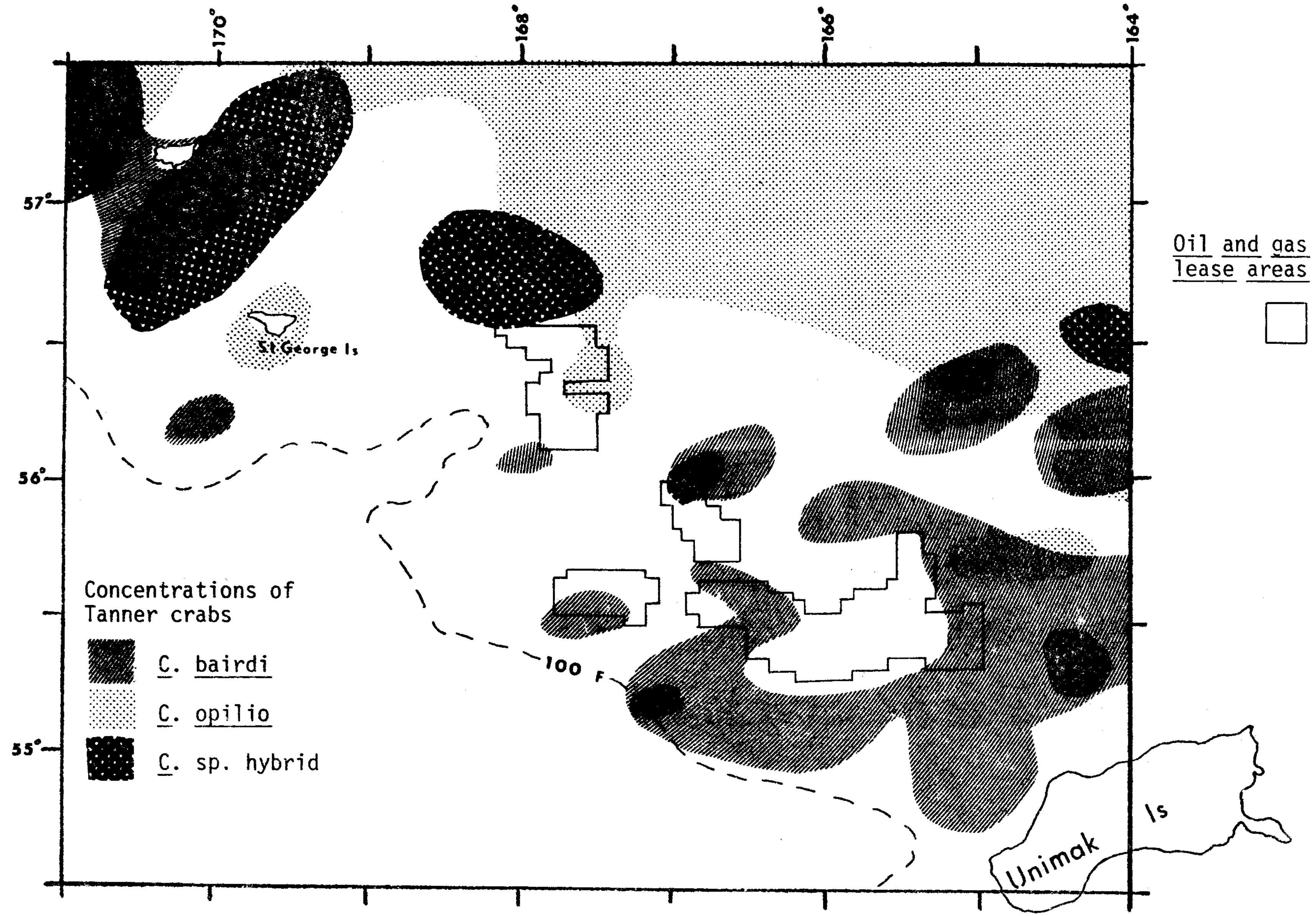

Figure 29. Concentrations (10 to 50 kg/km) of Tanner crabs (Chionoecetes) in the St. George Basin area (adapted from Kaimmer et al. 1976).

females occur northwest of the Pribilof Islands along the edge of the continental shelf, the largest concentration being just south of St. George Island. Concentrations of large males occur north of Unimak Island and near the Pribilof Islands (Kaimmer et al. 1976).

Stocks of *C. opilio* are found more to the north and west of *C. bairdi*, although there is a broad area of overlap between the two species (Fig.29). The two species are known to hybridize freely; all Bering Sea Tanner crabs are managed by the Alaska Department of Fish and Game as if they were one species. Female *C. opilio* occupy areas throughout the distribution of the total population; however, large specimens are more predominant north of the Pribilof Islands. Concentrations of large males occur between the Pribilofs and St. Matthew Island and northwest of Unimak Island (Kaimmer et al. 1976).

Hybrids of the two species occupy a wide band parallel to the continental shelf. 1975 survey estimates indicate that hybrid Tanner crabs constitute about 8 percent of the total Tanner crab population in the St. George Basin area (Kaimmer et al. 1976). Concentrations of female hybrids are scattered throughout the northwestern portion of the population near the Pribilof Islands and north of Unimak Island. Males are concentrated north of Unimak Island and north of St. Paul Island.

The distribution of Tanner crabs appears to be temperature-related (Karinen 1974). *C. bairdi* may be limited to water generally warmer than 2°C. *C. opilio* and the hybrid form are abundant within the cold water mass in the central portion of the Bering Sea (Hayes and Reid 1975).

Tanner crabs of all sizes are most abundant at depths where king crabs are infrequently encountered; i.e., generally at depths of 50 m to 90 m (Haynes and Lehman 1969). Eldridge (1972) suggests that Tanner and king crabs may compete for either food or space and that king crabs may prey on soft-shelled Tanner crabs.

The mating season of Tanner crabs is from early January to mid-May (Brown and Powell 1972). Mating activities take place at depths of less than 25 m (Watson 1970). After mating, the crabs carry the fertilized eggs for almost twelve months. The planktonic larvae drift for about two months. They then settle to the bottom and the young crabs begin to feed on debris. Spawning, larval release, and nursery areas are believed to coincide with the fishing areas, as shown in Fig. 3, COMMERCERIAL FISHERIES section. Life history information on Tanner crabs in this area is generally lacking (Bartlett 1976) and research is required.

Shrimp

The only commercially important family of shrimp in the Bering Sea, the Pandalidae, is represented in the Bering Sea by five species: pink (Pandalus borealis), humpy (P. goniurus), coonstripe (P. hypsinotus), spot (P. platyceros), and side-stripe (Pandalopsis dispar). Pink and side-stripe shrimp generally inhabit waters of 90 m or deeper above soft mud bottoms. Humpy and coonstripe shrimp tend to inhabit depths of 20 to 30 m during their first two years of life and then move to deeper waters, usually over rough bottoms, for the remainder of their lives. Spot shrimp inhabit depths of 30 to 55 m and prefer rough bottoms. Humpy shrimp are present in areas of the Bering Sea when residual winter cooling affects the bottom. This area is generally over muddy bottoms of the Bering Sea shelf east of the Pribilof Islands and extending into Bristol Bay. Scattered populations of sidestripe shrimp are found in water deeper than about 366 m along the continental slope (Bartlett 1976). Commercial concentrations are not known to exist.

All five species may be found in small numbers off the extreme northwest corner of Unimak Island (Univ. of Alaska 1974). Concentrations of pink and humpy shrimp have been noted in the St. George Basin area (Fig. 30). The only fishery occurs in an area northwest of the Pribilof Islands.

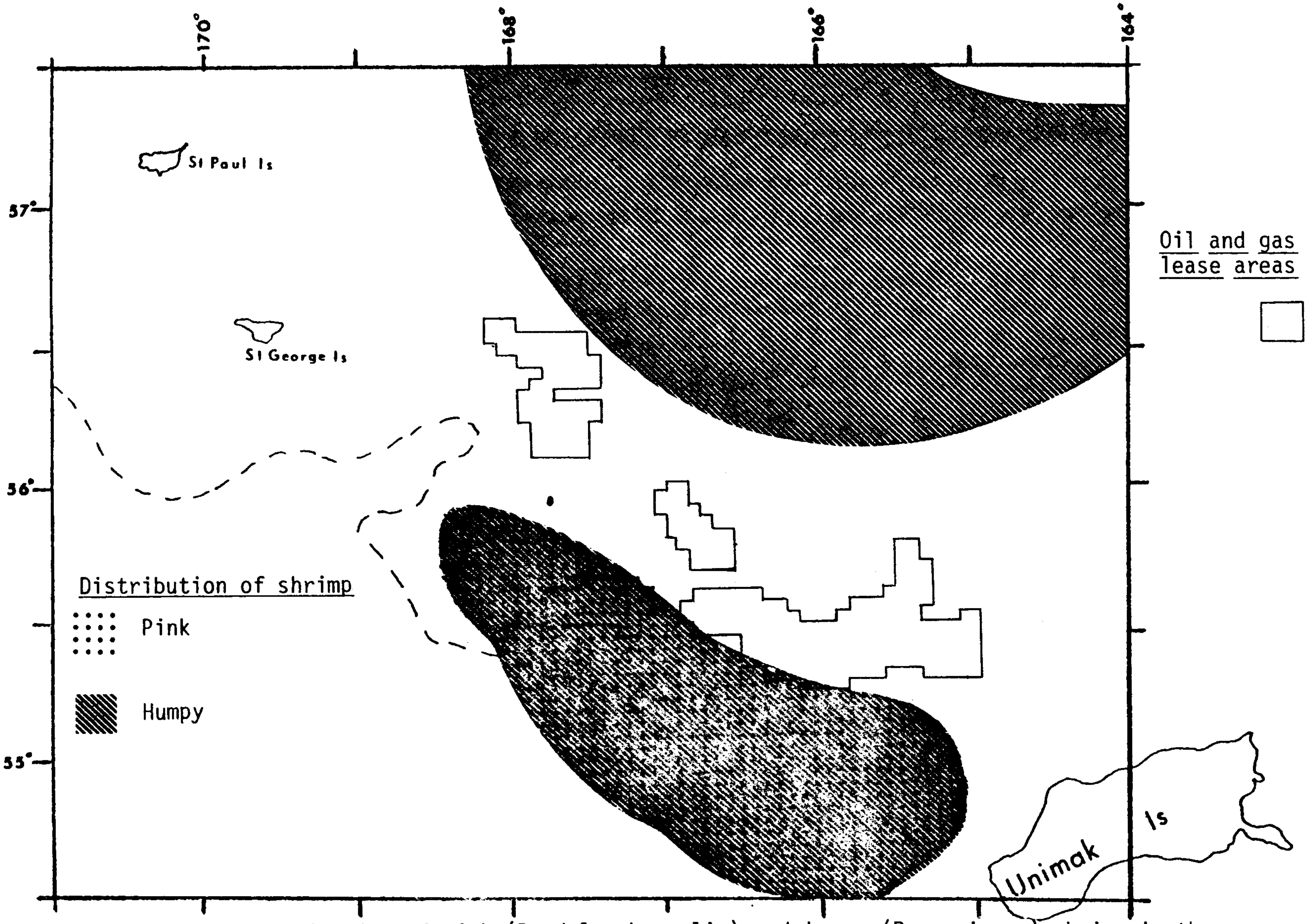

Figure 30. Distribution of pink (*Pandalus borealis*) and humpy (*P. goniurus*) shrimp in the St. George Basin area (adapted from NMFS 1976a).

This fishery exploits pink shrimp, the major commercially important species in Alaska. Pink shrimp in the Pribilof fishery occur over sandy-mud bottoms at depths of 70 to 100 m along the zone where deep water of the continental slope intrudes into the colder waters of the continental shelf. Distribution of the Pribilof population is determined by three factors: a favorite temperature regime as the result of warm deepwater intrusions; the presence of suitable bottom substrate; and a closed water circulation that insures the retention of larvae in favorable areas for development (Ivanov 1969).

According to Barr (1970a), pink shrimp in Kachemak Bay, Cook Inlet, undergo diel vertical migrations during all seasons in pursuit of food. Smaller individuals exhibited a greater tendency for vertical migration than larger ones. Research by Soviet investigators (Ivanov 1974) suggests that in the Bering Sea pink shrimp do not undergo vertical migrations. This research was done in August and may be inconclusive, as no mention was made of size groups or correlation with plankton abundance (Bartlett 1976).

The generalized life histories of the five shrimp species are nearly the same. Growth patterns, age at sexual maturity, and transition to functional females may vary with the species and by geographical location within the species. All species of pandalid shrimp are bisexual (Fox 1972). Ivanov (1969) observed pink shrimp to be sexually mature as males at ages of 2.5 years, when they participate for the first time in autumn breeding. At the age of 3.5 years, nearly all shrimp observed were males; a small number had changed into females. Most individuals at 4.5 years were still observed to function as males, but in the fifth year most were breeding females. Individuals called primary females are believed to exist in every shrimp population. These individuals never function as males, and their early maturation as females serves as a survival mechanism beneficial to the population (Butler 1964). Most shrimp live about 6.5 years; the few observed to have lived longer are usually sterile females (Ivanov 1969).

In August and September, eggs begin to ripen in the ovaries of the female. All species migrate to waters about 20 m deep to breed (Univ. of Alaska 1974). The female molts into a breeding carapace, and within 36 hours copulation occurs (Needler 1931). The eggs are extruded and attach to the pleopods and abdominal segments where they are carried for 5 to 7 months. The number of eggs extruded increases with the size of the shrimp. Most pandalid shrimp carry eggs in masses of 500 to 4,000 (Hynes 1929). In winter shrimp return to deeper waters (Univ. of Alaska 1974). Hatching usually occurs from February to May. Larvae are planktonic for about the first 2 or 3 months after hatching. By early summer, the larvae change through successive molts to the adult form, taking up life stations on or slightly above the bottom.

Although shrimp feed mostly on worms, mollusks, and small crustaceans, including other shrimp, they are also known to scavenge on almost any newly dead animal matter. In turn, they are fed upon by harbor seals, octopuses, and many fishes, including salmon and halibut (Barr 1970b). Shrimp of all life stages are an important part of the food web, being utilized by many marine organisms from the lowest filter feeders to large marine mammals and birds.

Snails

About 46 species of snails occur in the eastern Bering Sea, as determined by the 1975 OCSEAP baseline survey (Kaimmer et al. 1976). The fifteen most abundant species are listed in Table 11. About 95 percent of the snails collected in the approximately 800 trawl hauls belonged to these species (MacIntosh 1976). Concentrated populations of snails in the St. George Basin are indicated in Figure 31.

By far the most common species is Neptunea pribiloffensis, which also accounts for the greatest biomass of the eastern Bering Sea gastropods. It occurs in a band along the edge of the continental shelf from the

Table 11. A list and depth distribution of fifteen of the most abundant large eastern Bering Sea snails, in approximate order of decreasing abundance (from Kaimmer et al. 1976).

Species	Major Depth Distribution (m)
Neptunea pribiloffensis	>92
N. heros	26-104
N. lyrata	31-200
N. ventricosa	<92
Fusitriton oregonensis	>92
Buccinum angulossum	92-146
B. scalariforme	>100
B. plectrum	100-163
Beringius beringii	53-163
Volutopsius middendorffii	86-163
Clinopegma magna	80-146
Plicifusus kroeyeri	92-137
Volutopsius fragilis	55-92
B. polare	48-106
Pyrulofusus deformis	66-201

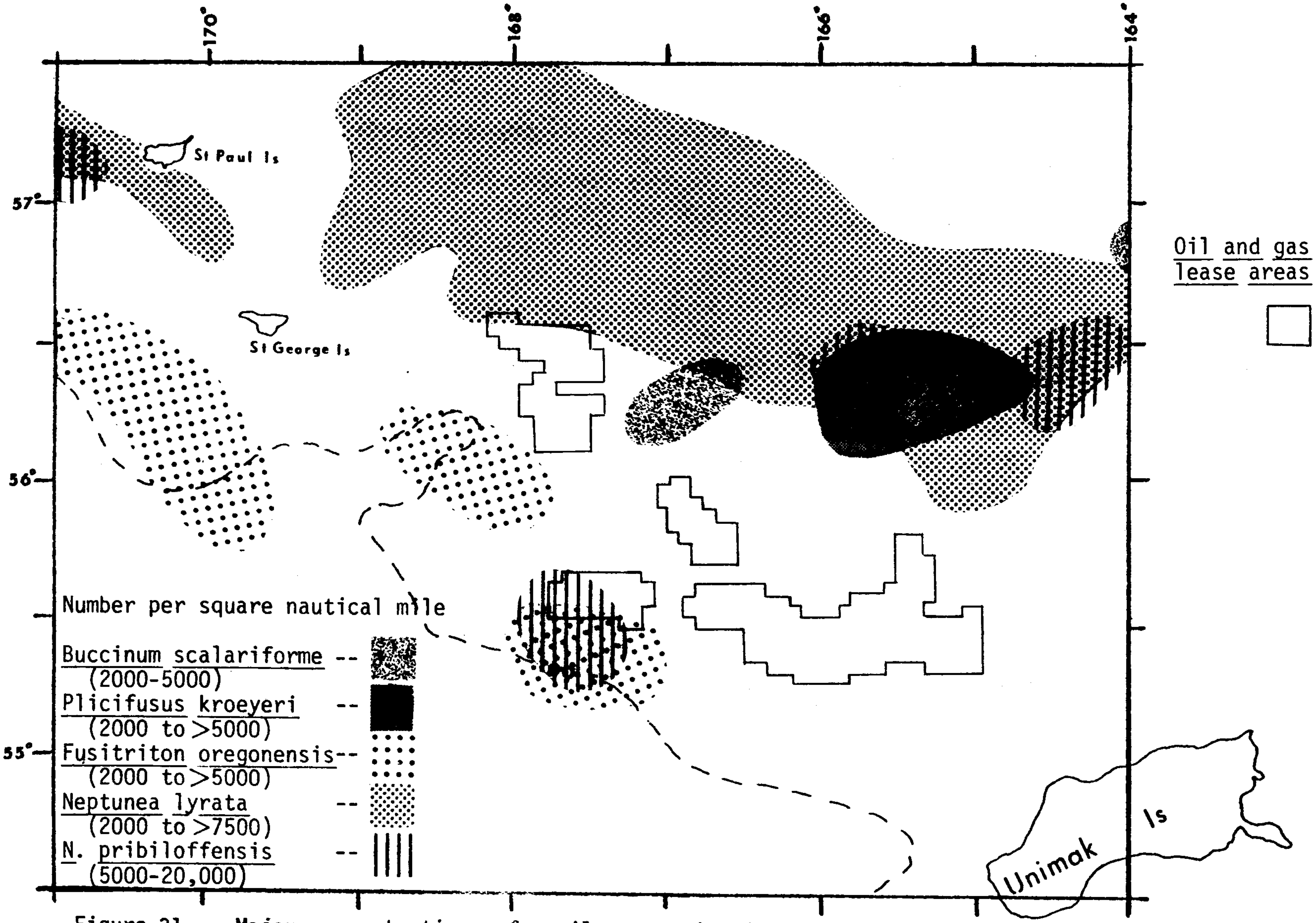

Figure 31. Major concentrations of snails occurring in the St. George Basin area, Aug.-Oct. 1975 (adapted from Kaimmer et al. 1976).

vicinity of Unimak Pass to and probably beyond 62°N latitude, but is most concentrated northwest of the Pribilof Islands. In the 1973 Japanese fishery, this species contributed 50 percent of the catch and 70 percent of the weight. Two other species, *Buccinum angulossum* and *B. scalariforme*, accounted for an additional 20 percent of the weight (Nagai 1974). The latter two species are also more abundant nearer the edge of the continental shelf northwest of the Pribilof Islands. The worldwide distributions of the 15 most abundant species in the eastern Bering Sea vary widely. Some are restricted to arctic and subarctic zones where they may range into temperate waters. Nothing is known of the migrations or behavior of these snails (MacIntosh 1976b).

A common feature of the life histories of all fifteen species of snails is the production of egg clusters from which crawling young are hatched. No pelagic larval stage exists. Egg clusters are usually laid on the shells of large snails, both living and dead; no correlation apparently exists between the species of snail depositing its eggs and the species on which the eggs are deposited. Freshly laid *Neptunea* egg clusters are present in large numbers in the eastern Bering Sea in July. Also present at this time are large numbers of capsules ready to hatch.

Literature on larval development is sparse (MacIntosh 1976b). Golikov (1961) reports that *Neptunea lyrata* hatches within three months in Soviet waters. A European species, *Neptunea antiqua*, takes up a benthic existence immediately after hatching (Pearce and Thorson 1967). Large specimens of *Neptunea* in the eastern Bering Sea may be as old as 10-12 years (MacIntosh 1976b).

Little is known concerning the natural prey of snails. The genus *Neptunea* has been artificially fed freshly killed specimens of mussels (*Mytilus californicus*), worms (*Nereis brandti*), crabs (*Cancer gracilis*), fishes (*Xiphister atropurpurens*; *Gobieosox meandricus*), and shrimp (*Upogebia pugettensis*) (Avery 1961). *Neptunea* has also been known to accept live worms of the genera Ophilia, Lumbriconereis, Stylaroides, and Amphitrite (Pearce and Thorson 1967). In nature, snail populations are preyed upon by crabs, which are probably their major predators in the eastern Bering Sea.

Bivalves

There is little information on bivalve molluscs in the eastern Bering Sea. Although there are at least 77 species, none is commercially important. Zimmerman and Merrell (1976a, 1976b), Abbott (1974), and Neiman (1963) list those that specifically range into the eastern Bering Sea (Table 12). Some species occurring on the beaches in the Unimak Island area are utilized by local residents. There are apparently no extensive scallop beds in the Bering Sea (Hennick 1970).

The life history of bivalve mollusks is basically the same for all species. Spawning takes place in summer. Clams reproduce by shedding eggs and sperm into the water; their fertilization is external. However, in some species fertilization takes place in the mantle cavity.

Developing larvae are free swimming for several weeks. They are quite small when they settle onto the bottom. Some species burrow into the sediments where they spend the remainder of their life cycle (Nosho 1972). Others attach to suitable solid substrate by means of byssus threads. Some scallops lie on the bottom and are able to swim about by rapidly contracting the two halves of their shells.

Most bivalve mollusks are filter feeders, utilizing incurrent and excurrent siphons to transport food, mainly suspended phytoplankton. However, some are deposit feeders and have extensions of the labial palps or lips that collect organic deposits from the soft substratum in which the animals live.

Table 12. A partial list of bivalve molluscs occurring in the eastern Bering Sea.

Acila castrensis
Astarte alaskensis
A. borealis
A. montagui
A. rollandi
A. vernicosa
Axinopsida viridis
Cardiomya beringensis
C. planetica
Cardium ciliatum
Chlamys lioicus
Clinocardium nuttallii
Crenella columbiana
C. dessucata
Cuspidaria crebricostata
C. crassidens
Dacrydium pacificum
Delectopecten randolphi
D. tillamookensis
D. vancouverensis
Hiatella (Saxicava) arctica
Leda pernula
Limatula attenuata
Limopsis skenea
L. vaginatus
Liocyma viridis
Lyonsia striata
Macoma balthica
M. brota
M. calcarea
M. carlottensis
M. inconspicua
M. inquinata
M. lama
M. loveni
M. middendorffi
M. obliqua
Malletia talama
Modiolus modiolus
Musculus discors
M. impressus
M. olivaceus
M. phenax
M. protractus
M. seminudus
Mya arenaria
M. elegans
M. priapus
M. truncata
Mytilus edulis
Nuculana minuta
N. mirablis
N. radiata
N. tenuisulcata
Pandora grandis
Panomya ampla
P. arctica
Parvilucina tenuisculpta
Penitella penita
P. alaskense
Pododesmus macroschisma
Propeamussium davidsoni
Rhomboinella grisea
Serripes groenlandicus
Siliqua alta
Spisula polynyma
Tellina lutea alternidentata
Thracia beringi
Thyasira flexuosa
Tindarea brunnea
Venericardea crebricostata
Yoldia amygdaiea
Y. beringiana
Y. hyperborea
Y. seminuda
Y. thraciaeformis
Zirfaea pilsbryi

MARINE MAMMALS

Marine mammals of the Bering Sea, including the St. George Basin area, include 7 species of Pinnipedia and 16 species of Cetacea (Table 13). Pinnipeds are represented by four regular inhabitants (northern sea lion, Pacific walrus, Pacific harbor seal, northern fur seal) and four occasional inhabitants (ice-breeding harbor seal, ringed seal, ribbon seal, and bearded seal). The cetaceans are represented by two major groups, the toothed whales (Odontoceti) and the baleen whales (Mysticeti). Four species of toothed whales (beluga whale, Pacific killer whale, harbor porpoise, and Dall porpoise) are regular inhabitants. Other toothed whales such as the narwhal, sperm, goose-beaked, Stejneger's beaked, and giant bottlenose whales occur sporadically. The baleen whales that may be regularly found in the St. George Basin include gray and minke whales. Other baleen cetaceans that occur infrequently are black right, bowhead, humpback, blue, sei, and fin whales.

Marine mammals abound along the edge of the ice pack and where the continental shelf drops off to the Bering abyssal plain. In these places, high concentrations of plankton provide seasonally abundant food for baleen whales, while the larger marine invertebrates and fish are consumed by toothed whales, walrus, seals, and sea lions. It has been estimated that the annual consumption of fish by marine mammals greatly exceeds the combined annual catches of all the world's fishing fleets in the eastern Bering Sea (Laevastu et al. 1976, McAlister and Perez 1976).

Distribution and abundance of marine mammals are closely correlated with ice and climatic conditions, ocean current patterns, and bottom type. Some species are regularly associated with sea ice, whereas others are associated with ice only partially or not at all (Burns and Morrow 1973). Many species occur in the area only during the ice-free season in summer and migrate south with or before the advancing sea ice in fall and winter. Year-round residents move farther north in summer and

Table 13. A partial list of marine mammals that may occur in the St. George Basin area (from Fay 1974, Johnson et al. 1966, NMFS 1976b).

Taxon
Order CARNIVORA
Suborder FISSIPEDIA
Sea otter, *Enhydra lutris*
Suborder PINNIPEDIA
Northern (Steller) sea lion, *Eumetopias jubatus*
Northern fur seal, *Callorhinus ursinus*
Pacific walrus, *Odobenus rosmarus*
Pacific harbor seal, *Phoca vitulina richardii*
Spotted seal, *Phoca vitulina largha*
Ringed seal, *Pusa (=Phoca) hispida*
Ribbon seal, *Histriophoca fasciata*
Bearded seal, *Erignathus barbatus*
Order CETACEA
Suborder ODONTOCETI
Pacific killer whale, *Orcinus orca*
Harbor porpoise, *Phocoena phocoena*
Dall porpoise, *Phocoenoides dalli*
Sperm whale, *Physeter catodon*
Goose-beaked whale, *Ziphius carvrostris*
Stejneger's beaked whale, *Mesoplodon stejnegeri*
Giant bottlenose whale, *Berardius bairdii*
Narwhal, *Monodon monocerus*
Suborder MYSTICETI
Black right whale, *Balaena glacialis*
Bowhead whale, *Balaena mysticetus*
Gray whale, *Eschrichtius robustus*
Minke whale, *Balaenoptera acutorostrata*
Sei whale, *Balaenoptera borealis*
Fin whale, *Balaenoptera physalus*
Blue whale, *Balaenoptera musculus*
Humpback whale, *Megaptera novaengliae*

reside along the edge of the pack ice. Suitable water depth and bottom type are important factors, as feeding generally takes place in shallow waters.

Eight species (northern fur seal, three species of beaked whales, sperm whale, Dall porpoise, and blue and sei whales) have virtually no contact with ice, for they occur only in the southern ice-free part of the sea or enter the northern part only in summer when it also is ice-free. Ten other species (sea otter; northern sea lion; harbor seal; harbor porpoise; and killer, right, gray, humpback, fin, and minke whales) have some contact with ice when it occasionally impinges on their range in the southern Bering Sea or when they advance into the northern area while some ice is still present. Some of the latter group may live in the ice front for a short time each year, but they are not usually regarded as "ice-inhabiting marine mammals," since they do not reside there for long and reproduce in open seas to the south. The remaining nine species (walrus, spotted, ringed, ribbon, and bearded seals, and narwhal, beluga, and bowhead whales) are the true ice-inhabitants, spending all or most of their lives in the seasonal ice pack.

Except for subsistence use by certain Alaskan natives and for display and scientific collections, the Marine Mammal Protection Act of 1972 prohibits the harvest of marine mammals by United States' vessels or foreign vessels using U.S. ports. An exception is made for the fur seal, which is regulated by international treaty, and their harvest is shared between four countries. A waiver of the moratorium on the taking of nine species of marine mammals and the return of management of these species to the State of Alaska is presently under active consideration.

Most of the marine mammal species that occur in the St. George Basin area seasonally migrate through or inhabit international waters. Their harvest is shared by the United States, Soviet Union, Japan, and Canada, and is therefore of concern and potential value to these and other nations.

Several whales (bowhead, fin, humpback, sei, blue, and gray) that regularly or occasionally inhabit the Bering Sea are considered endangered species and, as such, are afforded protection as endangered species under the Endangered Species Act of 1973.

The Marine Mammal Protection Act of 1972 divided jurisdiction over species of marine mammals between the Secretary of Commerce for whales, porpoises, seals, and sea lions and the Secretary of the Interior for all others, including polar bears, sea otters, and walruses. Authority and responsibility for the functions prescribed by the Act were delegated to the National Marine Fisheries Service.

Marine Mammals could be affected directly or indirectly by oil pollution and human disturbances. Exposure to oil could cause hypothermia due to reduction in water repellancy by the pelts of pinnipeds. Prolonged exposure to oil could result in ingestion of oil or eye irritation, which could cause subsequent sublethal physiological effects leading to disability or death owing to sickness, inability to find food or avoid predators. Those species which breed in the St. George Basin area might be most vulnerable to major oil spills and human disturbances. Survival of pups and reproductive success could be impaired. In addition, a major oil pollution incident could adversely affect marine mammals indirectly by contaminating or killing fish and invertebrates upon which they feed. Again, these effects might be most detrimental during the spring and summer--a critical period for mammals and their food organisms for feeding and reproducing in the Bering Sea.

The following discussion is limited to those species over which NMFS presently has jurisdiction and emphasizes those species that occur regularly in the St. George basin area.

PINNIPEDS

Northern (Steller) Sea Lion

In the Bering Sea, the sea lion is a common inhabitant of the littoral zone above the continental shelf. According to ADF&G (1973), sea lions generally forage near shore in waters less that 90 m deep. Kenyon and Rice (1961) observed sea lions 70 to 85 nautical miles offshore in the Bering Sea.

Northern sea lions are not believed to undertake regular migrations as does the northern fur seal; however, within their range of year-round abundance, seasonal (both latitudinal and longitudinal) movements do occur (Kenyon and Rice 1961) and cyclical population fluctuations may indicate movements of animals (Scheffer 1972).

Sea lions remain in the Bering Sea throughout the winter, frequently hauling out on floes in the southern part of the ice front. During February to April, sea lions are abundant along the front, at least from Bristol Bay to the International Date line, but they do not penetrate far into the pack where there is little open water. During the winter, both male and female sea lions seek shelter in bays and river mouths, using rocky outcrops exposed to all tidal stages as hauling grounds. In the spring, sea lions may move into herring spawning areas, and in the summer they also occur in the Pribilof Islands (ADF&G 1973).

The most pronounced characteristic of the sea lion that distinguishes it from other marine mammals, except fur seals, is its affinity for specific, well-defined locations used as breeding and pupping rookeries and hauling areas. Northern sea lions favor isolated locations with some shelter, free access to the sea, and freedom from human harassment. Colonies may become established on rock outcrops and boulder, cobblestone, and coarse sand beaches. Alaska has 202 (NMFS 1976b) known sea lion rookeries and hauling grounds. Of these, Cape Sarichef and Oksenof Point on Unimak Island and the Pribilof Islands (Fig. 32) are in the vicinity of the proposed oil and gas lease area. Others occur to the east along the shores of Bristol Bay. As many as 4,000 sea lions have been estimated

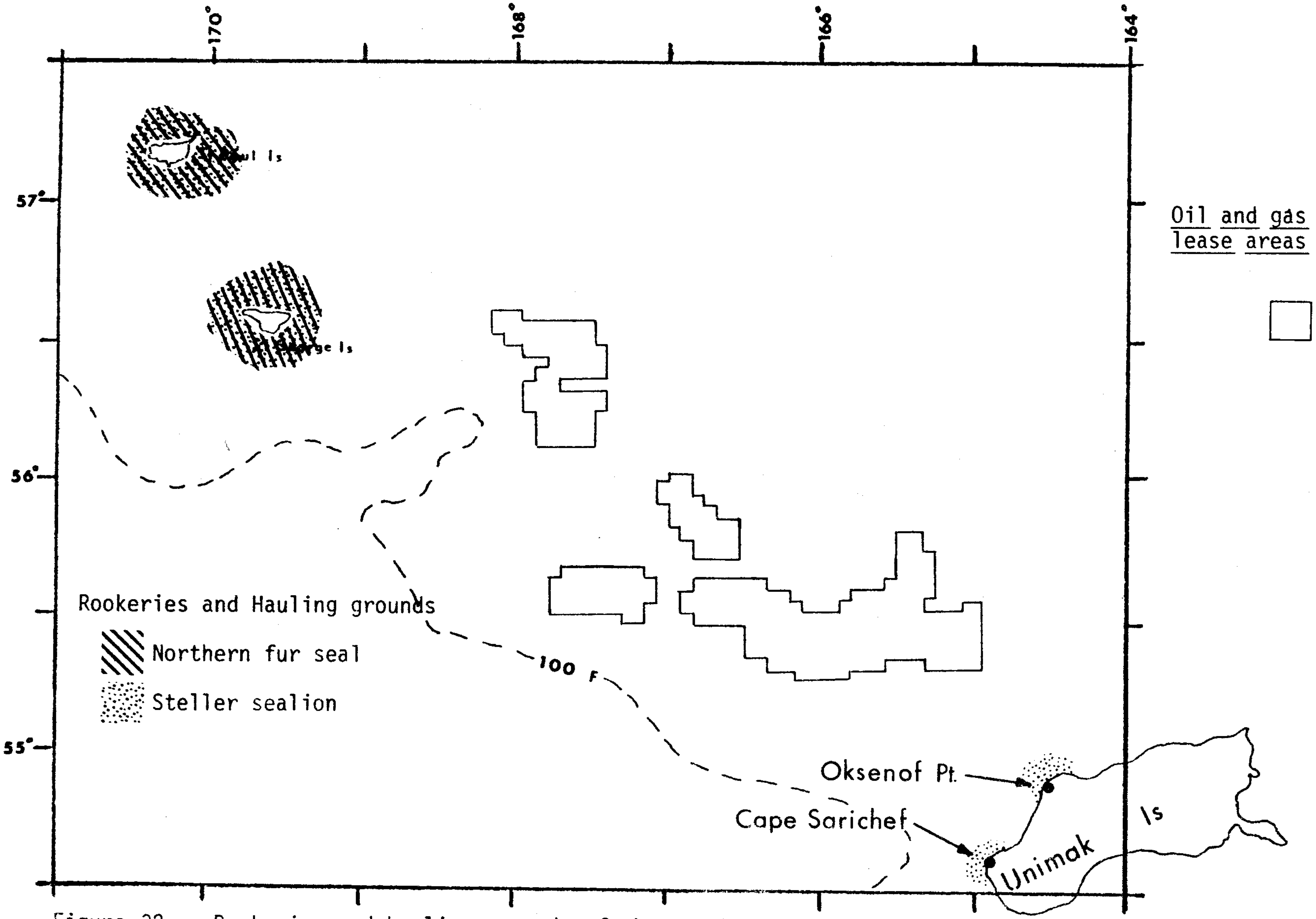

Figure 32. Rookeries and hauling grounds of the northern fur seal and Steller sea lion in the St. George Basin area (from ADF&G 1973).

at Oksenof Point, which is one of the largest rookeries in the eastern Bering Sea.

Estimates of the numbers of sea lions in Alaska suggest a population s ize of 200,000-225,000 animals (ADF&G 1973; McAlister and Perez 1976). About 50,000 (winter)-100,000 (summer) sea lions inhabit the eastern Bering Sea shelf (McAlister and Perez 1976). Survey information on northern sea lions in the St. George Basin area is minimal but population estimates approach 8,000 to 9,000 on the Pribilof Islands. Fiscus and Braham (1976) reported that the number of sea lions in the Alaska Peninsula-Bering Sea survey area appears to have been decreasing over the last 20 years; however, this preliminary interpretation of the data must be verified by further analysis.

In May, mature bulls begin to defend territories against other males, but will usually tolerate the presence of females. Pupping occurs in June, and most females will breed within a week to 10 days after giving birth. Although sea lion pups are able to swim at birth, they seldom leave the land during their first month, during which time the females continue to care for them. After this critical time, the females and their pups leave these defended areas, and the bulls cease to guard their territories (ADF&G 1973).

Pollock constitute about 80 percent of the diet of sea lions (McAllister and Perez 1976), which also consume rock fish, sculpin, greenling, sand lance, smelt, halibut, flounder, octopus, shrimp, lumpfish, and crabs (Thorsteinson and Lensink 1962). Stomach contents of sea lions have included seal parts (Tikhomirov 1964). Sea lions may be principal consumers of adult salmon (Laevastu et al. 1976; Mathisen 1959).

Northern Fur Seal

The northern fur seal, as discussed by Baker et al. (1963), ranges from the Pribilof Islands in the Bering Sea to the Channel Islands off Santa

Barbara, California in its migrations. In the Bering Sea, they breed on the Pribilof Islands and also on the Commander Islands, Robbin Islands, and some of the Kurile Islands in the western Bering Sea.

The fur seal population on the Pribilof Islands, including St. Paul and St. George, is about 1.2 million individuals and accounts for about 80 percent of all the northern fur seals. Economically, the northern fur seal is the most important pinniped occurring in the Bering Sea. The annual harvest of about 40,000 to 50,000 fur seals on the Pribilof Islands yields over $3 million.

Fur seals in the Pribilof Islands are administered by the National Marine Fisheries Service, Department of Commerce, under a bilateral agreement, whereby Japan and Canada each receive 15 percent of the seal skins from the Pribilof Islands and 15 percent of those from the Commander Islands. Canada, Russia, and the United States each receive 10 percent of the pelts from the Robbin Islands.

Fur seals are pelagic except when they come inshore to breed. The only known exception is Samalga Island 180 nautical miles southwest of Unimak Island where seals, apparently males, have been observed hauled out on a reef. Fur seals are most abundant 30 to 70 miles offshore (Baker et al. 1963). However, fur seals off California from mid-February to mid-April were reported by Taylor et al (1955) to be most abundant 10 to 30 miles offshore.

Bull seals begin arriving on the Pribilof Islands in late April and appear in increasing numbers until the middle of June. They establish territories and await the arrival of the females which arrive in late June and early July. The females, which were impregnated the previous year, give birth to a pup usually a day after first coming ashore at the rookery. Five days later they mate again. A large proportion of the pups are born in the first three weeks of July. Females nurse their offspring for a period of about 3 or 4 months. The pups are ready to leave the rookery in November and begin finding their own food in the form of fish and squids. Most of the animals have left the rookeries by December.

Fur seals feed particularly on pollock of about 15 cm long which constitute about 77 percent (Laevastu et al. 1976) of their diet. They also feed on other small schooling fish such as anchovy, capelin, and herring, but will feed on whatever species are are available, including squid. Feeding generally occurs before sunrise (JFA 1959). During feeding, fur seals may descend over 100 meters (Ichihara and Yoshida 1972). The deepest recorded dive reported for this species is 190 m, which lasted 5.4 minutes (Kooyman et al. 1976).

Fur seal pups die from many natural causes, including parasitism, being crushed by rolling stones, falling into pits where they drown or starve, and exposure to prolonged storms. Cumulative natural mortality is estimated at 72 percent up to the beginning of the second year of life (Kenyon et al. 1954). Killer whales, great white sharks, and of course man, are predators of fur seals. During the summer harvest, many of the Pribilof Island residents eat the livers and hearts from the freshly killed carcasses.

Harbor Seal

Land-breeding harbor seals (*Phoca vitulina richardii*) occur along the entire coastline of Alaska from Dixon Entrance to Kuskokwim Bay, including all of the Aleutian Islands and the Pribilof Islands. They are sympatric with the ice-breeding spotted seal (*P. v. largha*) in a broad area from Bristol Bay to Kuskokwim Bay and in the vicinity of the Pribilof Islands. These seals are common in the nearshore marine environment, frequently ascending rivers during the spawning runs of anadromous fishes.

Harbor seals are less adapted to a land environment than sea lions and fur seals, and they need gentle slopes to haul out. Consequently, these seals will usually be found on sand bars, beaches, and low rocks, especially along the southern coast of Bristol Bay. Harbor seals are gregarious but do not usually congregate in huge colonies as do fur seals and sea lions; they generally remain in groups of 100 or less.

About 65,000 harbor seals are estimated to inhabit the eastern Bering Sea shelf (McAlister and Perez 1976). Perhaps 30,000 harbor seals live along the north side of the Alaska Peninsula, in Bristol Bay, and on the Pribilof Islands.

Females give birth to one or occasionally two dark-coated pups between late May and early July. These pups are able to swim at birth, but may be abandoned if their mothers are disturbed during the first months of nursing. Ovulation and breeding take place about one month after birth of the pup.

The southern, coastal harbor seals have little contact with the ice pack, and their behavior in its presence is unknown. They are believed to be non-migratory and reproductively isolated from the ice-breeding spotted seals of the ice front, though there may be some possibility of their interbreeding with the latter in the Bristol Bay-Kuskokwim Delta area. Some Alaskan populations of *P. v. richardii* regularly utilize icebergs from coastal glaciers as a place to rest and bear their young in apparent preference to available islets and sand bars (Bishop 1967, and Fay 1974). Harbor seals south of the ice pack are most commonly found near shore in water less than 55m deep (ADF&G 1973). Unlike sea lions, which prefer relatively clear water, harbor seals occupy both turbid and clean waters.

Harbor seals feed on fish and invertebrates, including herring, salmon, flounders, cod, sculpins, octopus, squid, and small crabs (ADF&G 1973).

Pollock constitute about 30 percent of the diet of harbor seals (McAlister and Perez 1976). Predators include walrus, killer whales, sharks, including the great white shark (Scheffer 1958). Golden eagles have been known to prey upon newborn pups resting on sand bars. In Alaska, the bald eagle occasionally kills young harbor seals (Scheffer 1958).

Harbor seals tolerate moderate boat traffic through their marine habitat and some disturbance of their hauling-out areas. Pupping areas probably are the most critical and least able to withstand disturbance. Although seals may be able to tolerate low levels of pollution, large amounts of oil or other toxic substances in the water could be detrimental to the seals or their food supply.

Harbor seals in most areas require certain traditional beaches and offshore rocks for resting areas and places where they can give birth to their young. Land areas where pups are born are particularly important to seals; disturbance of these areas should be avoided, especially during June.

Other Seals

Depending on the extent and character of the seasonal ice pack in the eastern Bering Sea, four species of ice-breeding hair seals (Phocidae) may be found in the Bering Sea at the southern part of the ice front: ringed, bearded, ribbon, and spotted seals.

CETACEANS, Toothed Whales

Killer Whale

In the Bering Sea, killer whales occur throughout the ice-free waters. They migrate into the northern part of the Bering Sea in spring, before the last ice has disintegrated, and some go on into the Chukchi Sea in summer. They return southward in autumn, usually before the first ice is formed. Killer whales travel in packs of 10 to 100 or more individuals led by a "pod bull." Breeding appears to occur year-round, although it may peak in May to July. Gestation lasts 13-16 months. Births usually occur in autumn. Killer whales feed on fish, invertebrates, other marine mammals, and seabirds.

Sperm Whales

The sperm whale, the largest toothed whale, is currently the most important species to the world whaling industry. In general, sperm whales in the Bering Sea are considered to migrate as far north as 60°N latitude (Nasu 1963); however, most are taken by whalers in temperate waters. Male sperm whales are probably only seasonal visitors to the St. George Basin area.

Sperm whales have been captured in the region centered at 56°N, 170°W, just south of the Pribilof Islands (Nasu 1963).

Sperm whales feed mainly on large squid (Kodolov 1970), taking these, octopus, and mesopelagic and demersal fishes at depths as deep as 1,000 m.

Beaked Whale

Three beaked whales may occur in the Bering Sea: Stejneger's beaked whale; goose-beaked (or Cuvier's beaked) whale; and giant bottlenose (or Baird's beaked) whale. All three beaked whales are endemic to the North Pacific. They range from California north to about St. Matthew Island in the eastern Bering Sea. Seasonal movements and abundances of beaked whales are unknown. Beaked whales feed mostly on deepwater fishes and squid.

Narwhal

The narwhal is the most northern cetacean, occurring primarily in north polar seas, including the entire Arctic Ocean. The species is infrequently observed in the Bering Sea. Food of the narwhal consists mainly of cephalopods and demersal fish.

CETACEANS, Baleen Whales

Baleen whales generally (except for gray whales) feed on plankton, especially euphausiids, pteropods, and calanoid copepods (Matthews 1968). In the eastern Bering Sea, these zooplankters ("krill") are generally concentrated between Unimak Island and the Pribilofs, although some are carried eastward into Bristol Bay on the currents that sweep around Unimak Island (Meshcheryakova 1964).

Gray Whale

Gray whales overwinter in warm California waters where they bear their calves, then migrate north along the coast to the northern Bering, Chukchi and Beaufort Seas where they spend the summer feeding on the rich plankton stocks. They enter the Bering Sea through passes of the Aleutian chain. Observations of five gray whales in mid-April (Fiscus and Braham 1976) apparently represents the earliest known sightings for this species in the spring in the Bering Sea. A few gray whales were seen near Unimak Pass in June indicating that migrating animals were still moving into the Bering Sea at that time. Most observations indicate that gray whales remain close to shore, migrating around Bristol Bay and then north. Several gray whales were observed in English Bay, St. Paul Island during June, 1976 (Zimmerman and Merrell 1976b). To reach St. Paul Island, these whales probably pass on through the St. George Basin.

The feeding habits of the gray whale are unlike those of other baleen whales. Gray whales feed on bottom organisms by plowing through the sands and sediments with their snouts. The small invertebrates that are stirred up are filtered out of the turbid water. Amphipods are the main food item. Gray whales fast during migrations and on wintering grounds. The distribution of gray whales within their summer range is primarily dependent upon the availability of their food. The fall migration southward begins in September-October and ends in southern California waters in December.

Other Baleen Whales

Other members of the baleen whale group, humpback, fin, sei, blue, and black right whales, make seasonal migrations between high-latitude summer feeding grounds and low-latitude winter breeding grounds.

Blue whales are seldom seen in the Bering Sea, but occur mainly south of the Aleutian Islands. They seem to be found mainly near 50°N, 170°W (Nasu 1963).

Bowhead whales, on the contrary, frequent the ice front of the central and southwestern Bering Sea in winter, migrating to the Arctic Ocean in summer. They move northward from the Bering Sea in late March or early April as leads begin to open (Fiscus et al. 1976). Bowhead whales are plankton feeders, being too slow to catch fish. Those fish accidentally taken into the mouth can escape between the baleen plates which do not meet in front of the mouth (Durham 1972). Bowhead whales also consume benthic invertebrates.

Fin whales range from the North Pacific Ocean to the Bering and Chukchi Seas (Nasu 1963), migrating into the Siberian waters of the Chukchi Sea at least from early summer to October (Nasu 1960). Fin whales have been found in relatively dense numbers along the continental slope northwest of Unimak Island where they were probably feeding on Alaska pollock and euphausiids (Nemoto 1963).

Humpback whales are most prevalent south of the Aleutian Islands (especially east of 170°W), but are also found in the Bering Sea north of Unalaska Island (Nasu 1963). Humpback whales like shallow waters, and may use similar habitats as gray and minke whales. Other baleen whales migrating through Unimak Pass and the other passes in the Aleutian Chain tend to occur in the open ocean rather than close to shore.

These whales feed primarily on copepods and euphausiids. Humpback, fin, and sei whales eat fish when concentrated and available. Humpback, gray, blue, and fin whales are known to be seasonal feeders; they fast and live off their body fat during the breeding season in southern waters. Thus, these whales depend on a plentiful and uncontaminated food supply being available each summer in the Bering, Chukchi, and Beaufort Seas. Any natural or man-induced perturbation that affects these whales' food supply could adversely affect their survival and reproductive success. Starvation has been cited as being one of the chief causes of infertility in the bowhead whale (Durham 1972).

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ANNUAL REPORT

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A Survey Of Cetaceans Of Prince William Sound And Adjacent Vicinity - Their Numbers And Seasonal Movements

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I. Summary of Objectives, Conclusions, and Implications with Respect to OCS Oil and Gas Development

Basic objectives of this first year of a planned three-year project are to document the relative numbers and seasonal distribution of cetaceans in Prince William Sound, Alaska; to determine major foraging and accumulation areas for principal species; and to determine the food habits of the most numerous small cetacean in the area, the Dall porpoise, _Phocoenoides dalli_.

During this first year of field work, it has become clear that greater numbers of cetaceans inhabit Prince William Sound, at least seasonally, than was originally suspected. While field operations were limited by the lack of a formal funding agreement prior to 2 January 1977, our efforts, nonetheless, indicate that Prince William Sound is an area of significant cetacean concentration. Though demonstrated deleterious effects of oil and gas development upon cetaceans are lacking, the presence of petroleum development equipment and support activity in the nearby Northeast and Northwest Gulf of Alaska may possibly be considered harassment under the terms of the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. How the passage of tankers carrying Prudhoe Bay oil through known marine mammal habitat in Prince William Sound will be construed in light of the above two acts is beyond the scope of this report.

II. INTRODUCTION

Between mid-May 1976 and 15 March 1977, periodic field surveys were conducted in Prince William Sound and the adjacent northern Gulf of Alaska. These surveys were designed to identify and enumerate the various whales and porpoise found in these areas. The preliminary results presented here represent part of the effort by the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Alaska Department of Fish and Game to obtain baseline resource data from outer continental shelf areas in Alaska. These data will be used by the Bureau of Land Management (BLM) to evaluate the probable impacts on natural resources from development of petroleum reserves in Alaskan waters.

The objectives of this study are to:

1. Determine relative numbers and seasonal distribution.
2. Determine major foraging and accumulation areas.
3. Determine the food habits of the Dall porpoise, _P. dalli_.

While marine scientists feel confident that an oil spill in an area inhabited by sea otters, _Enhydra lutris_, will be extremely damaging to those otters actually oiled by the spill, there is much less concurrence about the effects of oil spills on cetaceans. Kooyman, _et_. _al_. (1975)

found that gray whales, Eschrichtius robustus, actively take surface water into the upper sacs of the respiratory system. Should these findings apply to most, or all cetaceans, it would indicate a much higher vulnerability to oil spills by these animals than originally suspected. Of more general importance than the effect of oil spills on cetaceans is the likelihood of disturbance to cetacean populations by exploratory and development activity in the lease areas and from or by marine petroleum transport corridors, such as Hinchinbrook Entrance and the area between Hinchinbrook Entrance and the port of Valdez. The Marine Mammal Protection Act states that it is illegal to harass marine mammals without a permit, and the House report (supra note 22, at 4155) defines harass to include "the operation of motor vessels in waters in which these animals are found" (Coggins, 1975).

III. CURRENT STATE OF KNOWLEDGE

We have been unable to find published evidence of previous cetacean survey work in Prince William Sound. The U.S. Fish and Wildife Service (FWS), the Alaska Department of Fish and Game (ADFG), the National Park Service (NPS), the U.S. Forest Service (FS), and personnel of the National Marine Fisheries Service (NMFS), as well as numerous commercial fishermen have reported incidental sightings of cetaceans in Prince William Sound during the course of other activities. These sightings have been included in the quarterly distribution maps (Figures 1-4). A list of cetaceans known to occur in the Sound is included in Table 1.

We know, from conversations with people and organizations familiar with Prince William Sound, that certain species of large whales occur on a semi-regular seasonal basis, and that at least two species of porpoise occur in the Sound year-round. However, until now, we have had no knowledge of numbers of animals in this area. Brochures produced by the FS and the NPS provided information on cetaceans those groups had seen; and Karl Schneider, Ken Pitcher, and Don Caulkins of ADFG provided us with records of their previous and current cetacean sightings. Jim Johnson of the NMFS mentioned sighting numerous Humpback whales, Megaptera novaeangliae, in Prince William Sound during the early 1950's; while Jim King of the FWS mentioned that he saw no Humpbacks in the Sound in the late 1950's. Pete Isleib of Cordova saw very few Humpbacks in the mid to late 1960's in the Sound, but noted that they were becoming more numerous in the early 1970's. Fin whales, Balenoptera physalus, have been reported in the Sound by the FS and NPS, but we considered this species a highly variable visitor until over 50 fin whales were sighted during a FWS aerial survey over Prince William Sound in 1975. All sources reported minke whales, Balaenoptera acutorostrata, to be common visitors, perhaps residents of the Sound. Both commonly sighted species of small cetaceans, Dall porpoise, Phocoenoides dalli, and the harbor porpoise, Phocoena phocoena, were reported to occur in varying numbers throughout the year by several sources, including BLM, FWS, NMFS, NPS, and local fishermen. Gray whales have been sighted passing through the northern Gulf of Alaska on their annual migration by Richard MacIntosh of the Kodiak laboratory of the NMFS. Gray whales have also been sighted

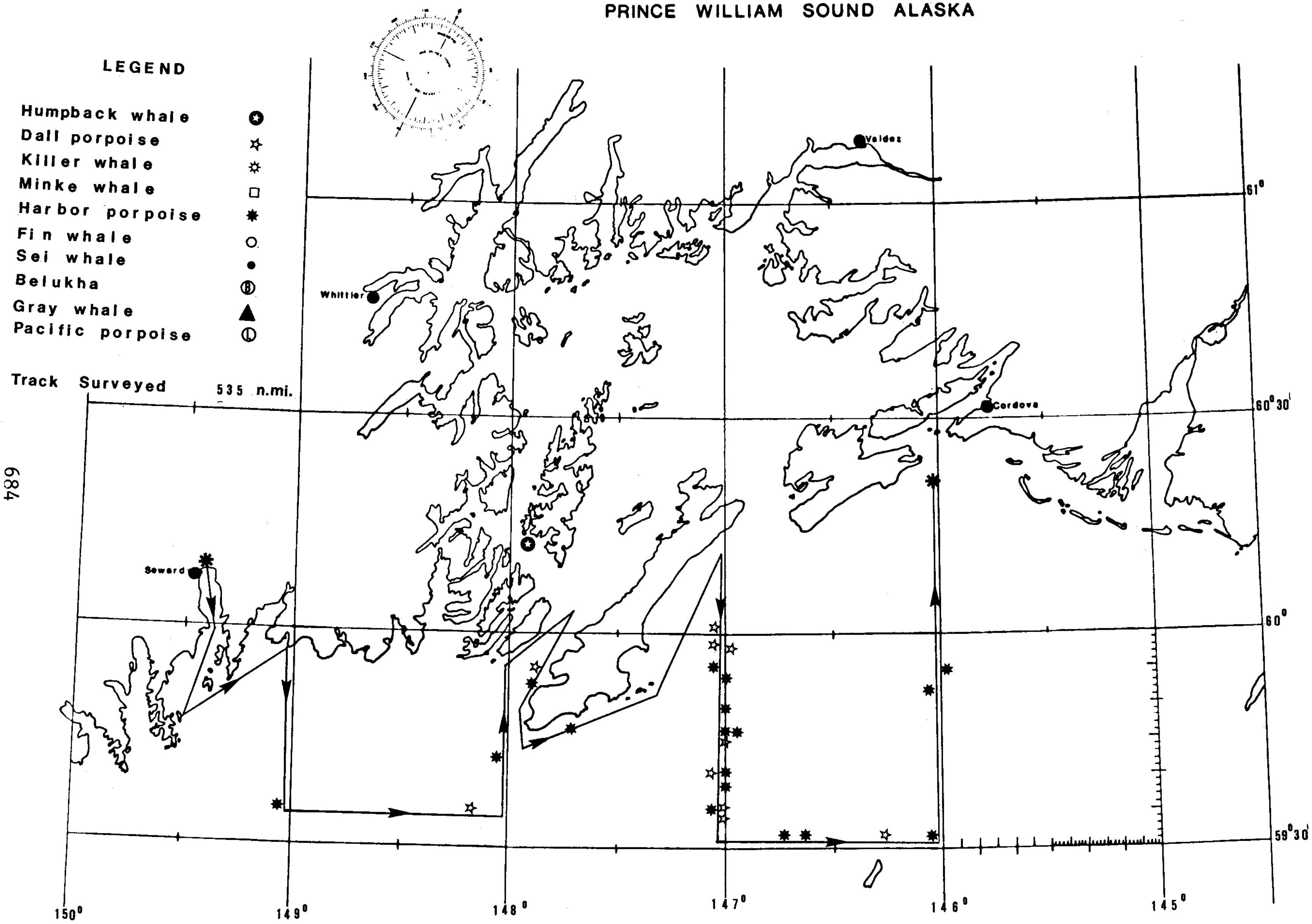

Figure 1. Winter Quarter Survey Tracks and Sightings

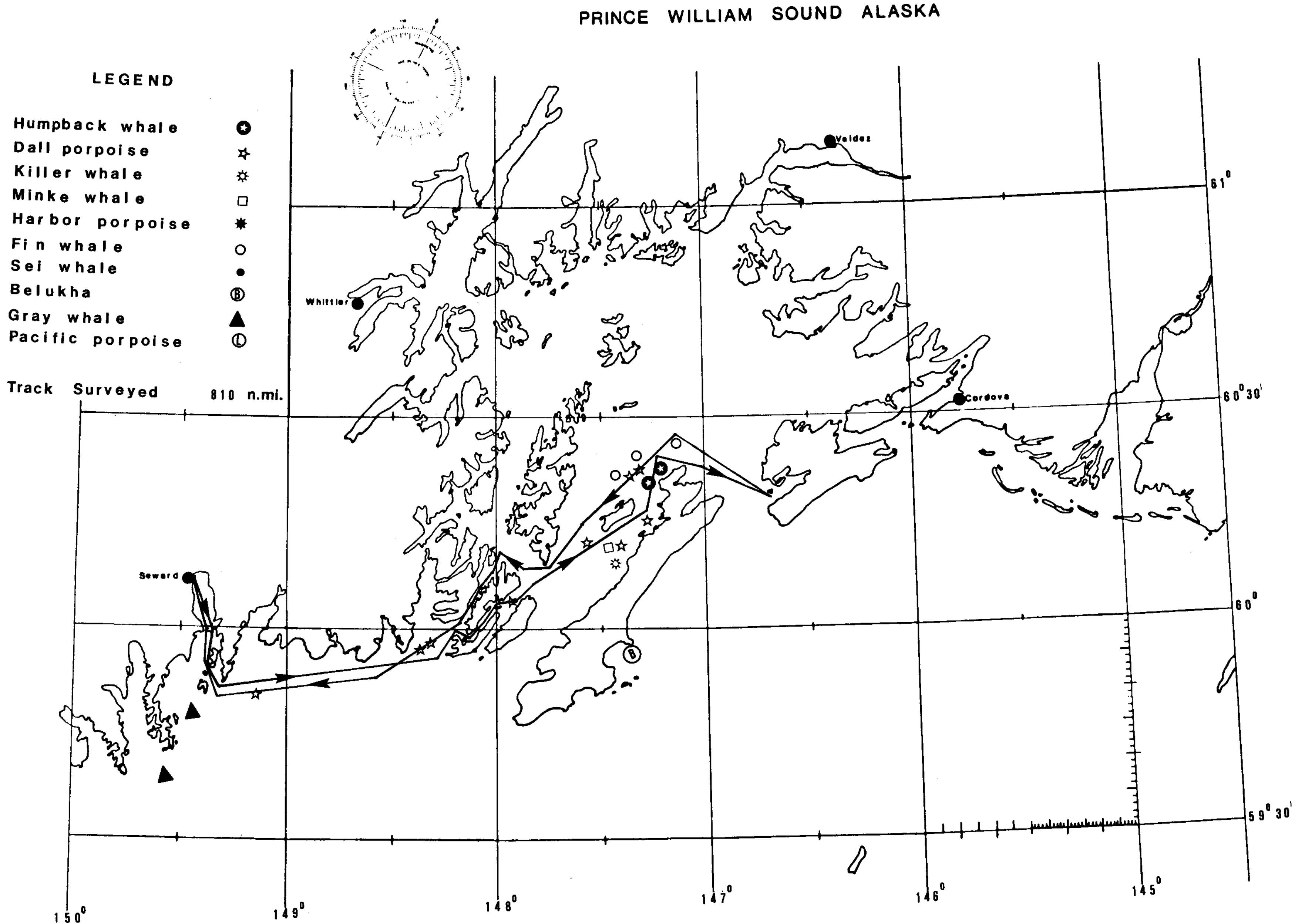

Figure 2. Spring Quarter Survey Tracks and Sightings

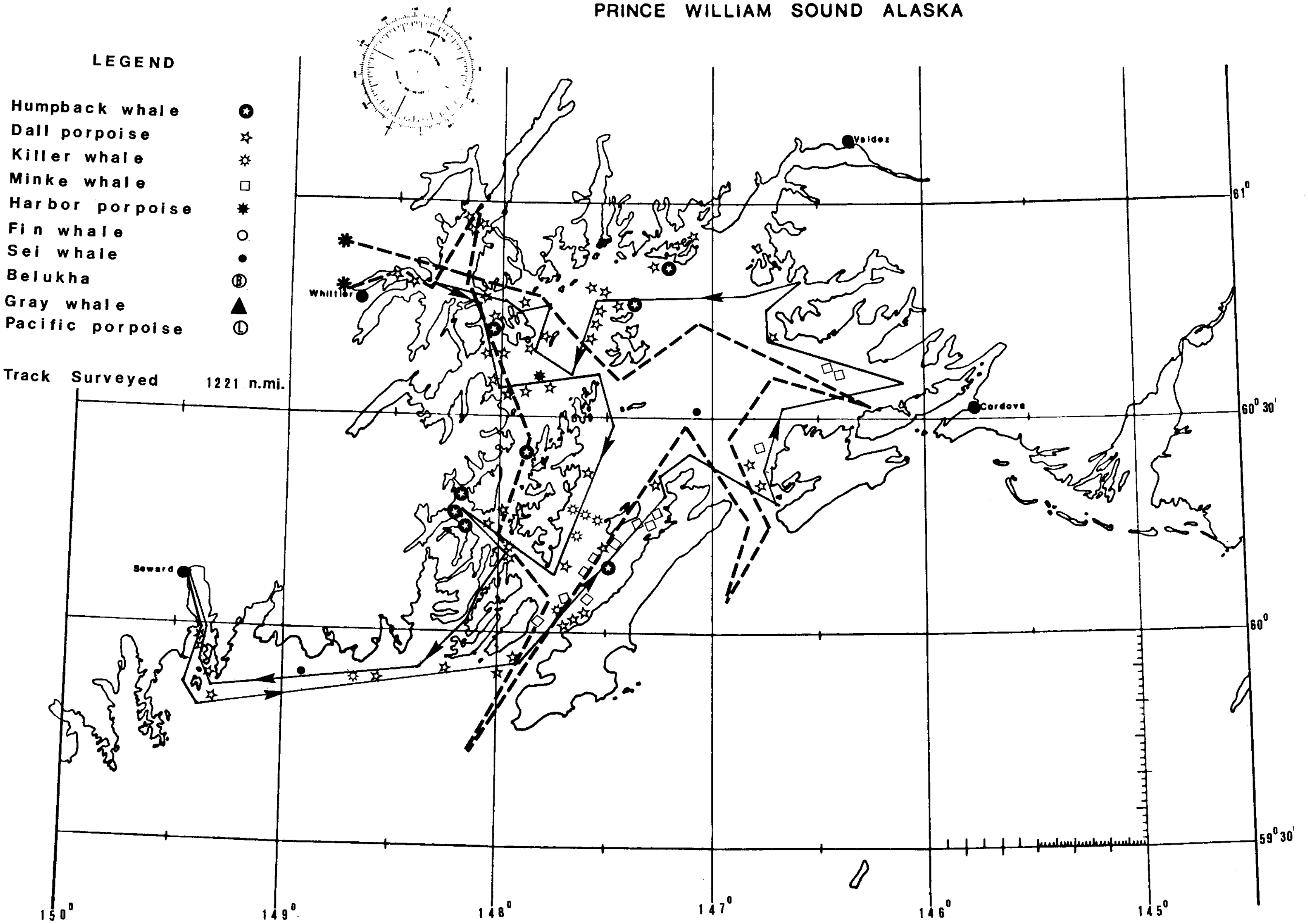

Figure 3. Summer Quarter Survey Tracks and Sightings (Surface——, Aerial – – –)

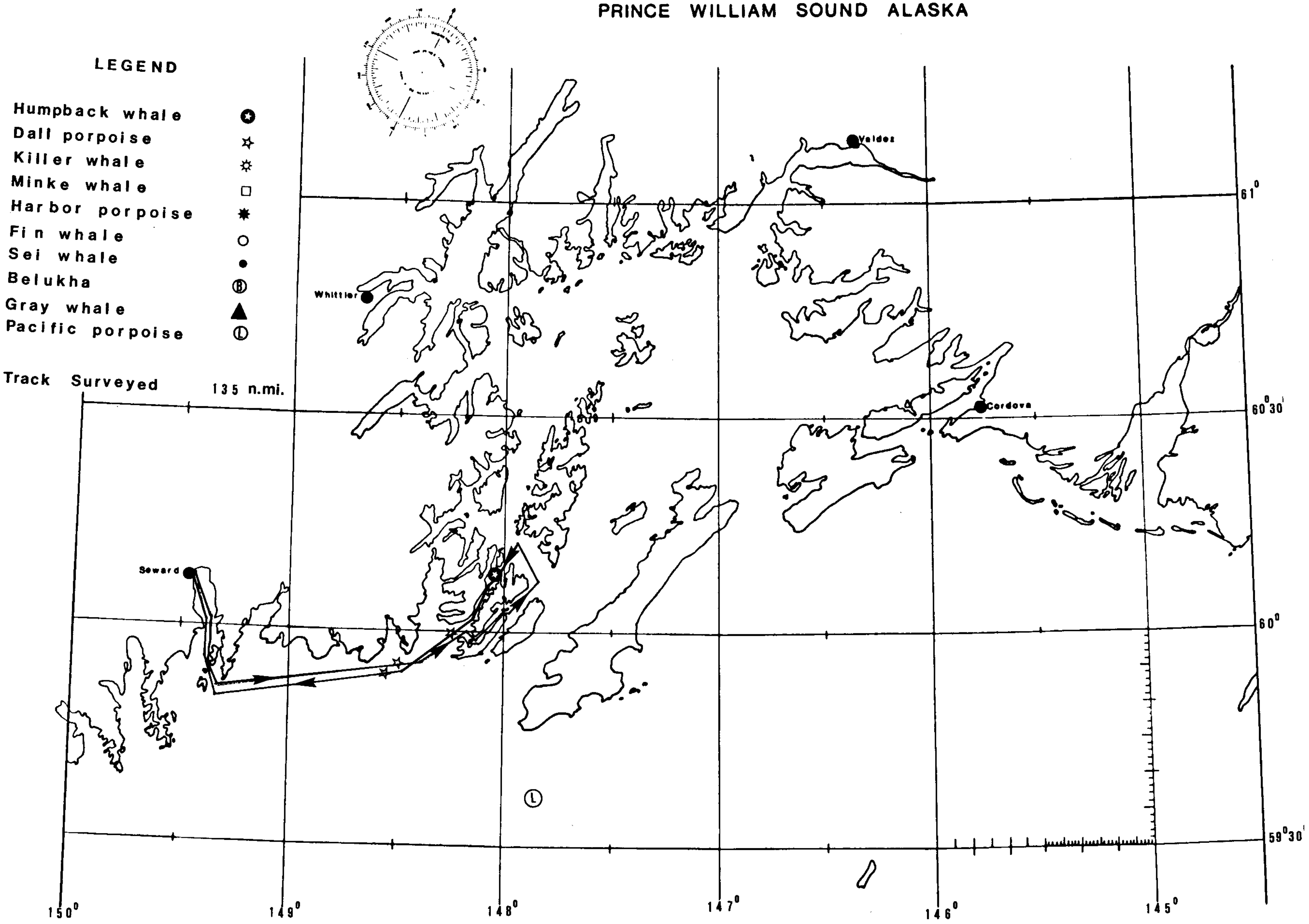

Figure 4. Fall Quarter Survey Tracks and Sightings

Table 1. Cetaceans Reported From Prince William Sound

- Order Cetacea
  - Suborder Mysticeti
    - Family Eschrichtiidae
      - *Eschrichtius robustus*- gray whale
    - Family Balaenopteridae
      - *Balaenoptera physalus*- fin whale
      - *Balaenoptera borealis*- sei whale
      - *Balaenoptera acutorostrata*- minke whale
      - *Megaptera novaeangliae*- humpback whale
    - Family Monodontidae
      - *Delphinapterus leucas*- belukha
    - Family Ziphiidae
      - *Ziphius cavirostris*- Cuvier's beaked whale
    - Family Delphinidae
      - *Orcinus orca*- killer whale
      - *Lagenorhynchus obliquidens*- Pacific white-sided porpoise
    - Family Phocoenidae
      - *Phocoena phocoena*- harbor porpoise
      - *Phocoenoides dalli*- Dall's porpoise

in the Kodiak area by other NMFS personnel (Rice and Wolman, 1971), and by FWS observers aboard OCSEAP vessels near Montague Strait in Prince William Sound.

Thus it was clear, before this project started, that people from various agencies had seen whales and porpoise in and near Prince William Sound. It was also clear that no systematic effort had been made to quantify the numbers and distribution of cetaceans in the Sound, even though sizeable populations of whales and porpoises were thought to inhabit the area.

IV. STUDY AREA

Prince William Sound is located in southcentral Alaska at the northernmost point of the Gulf of Alaska (Figure 5). Central latitude and longitude of the area is approximately 60°30'N, 147°00'W, though the study includes an area of over 10,000 km^2. The Sound is characterized by a series of deep glacier-fed fjords around the perimeter while several large barrier islands form the southern boundary. Because of its protected nature and oceanic accessability through two major entrances, Hinchinbrook Entrance to the east and Montague Strait to the west, the Sound has recently been described as a potential petroleum cesspool due to the wind and current patterns in the Gulf of Alaska (NEGOA Synthesis Meeting, December 1976, Anchorage, AK). While it has the potential of becoming a cesspool in the future, at present Prince William Sound is a relatively untouched marine gem with extensive natural resources. Marine mammals, birds, fish, invertebrates, and macrophytes abound, and at present undergo relatively light utilization by man, with the exception of salmon, herring, king, and tanner crabs and certain macrophytes.

The climate in Prince William Sound is decidedly northern maritime with rain and clouds common in spring, summer, and fall, and snow and rain common in winter. Temperatures are mild with highs in the summer generally less than 18°C and lows in the winter normally above 5°C. Wind is a common feature with two general patterns visible. Winds tend to be light and variable in the summer, but change to heavy SW to SE blows in fall, winter, and spring when associated with the passage of frontal lows. Thoughout the year, but especially during high pressure periods in the winter, the winds change more to N to NE and blow down canyons and fjords with velocities of 70 knots or greater.

During the passage of occluded lows, the entire area may be blanketed by fog and low clouds for several days, but during periods of high pressure, visibility may exceed 100 km. Marine water temperatures (surface) range from 11° to 13°C in the summer to 3° to 6°C in the late winter.

Because of the abundance of forage fish in Prince William Sound, high trophic level consumers, such as marine mammals and birds, find this area a nearly ideal niche, especially in spring, summer and fall. Commonly utilized forage fish include herring (*Clupea harengus pallasi*), capelin (*Mallotus villosus*), pollock (*Theragra chalcogramma*), and sand lance (*Ammodytes hexapterus*).

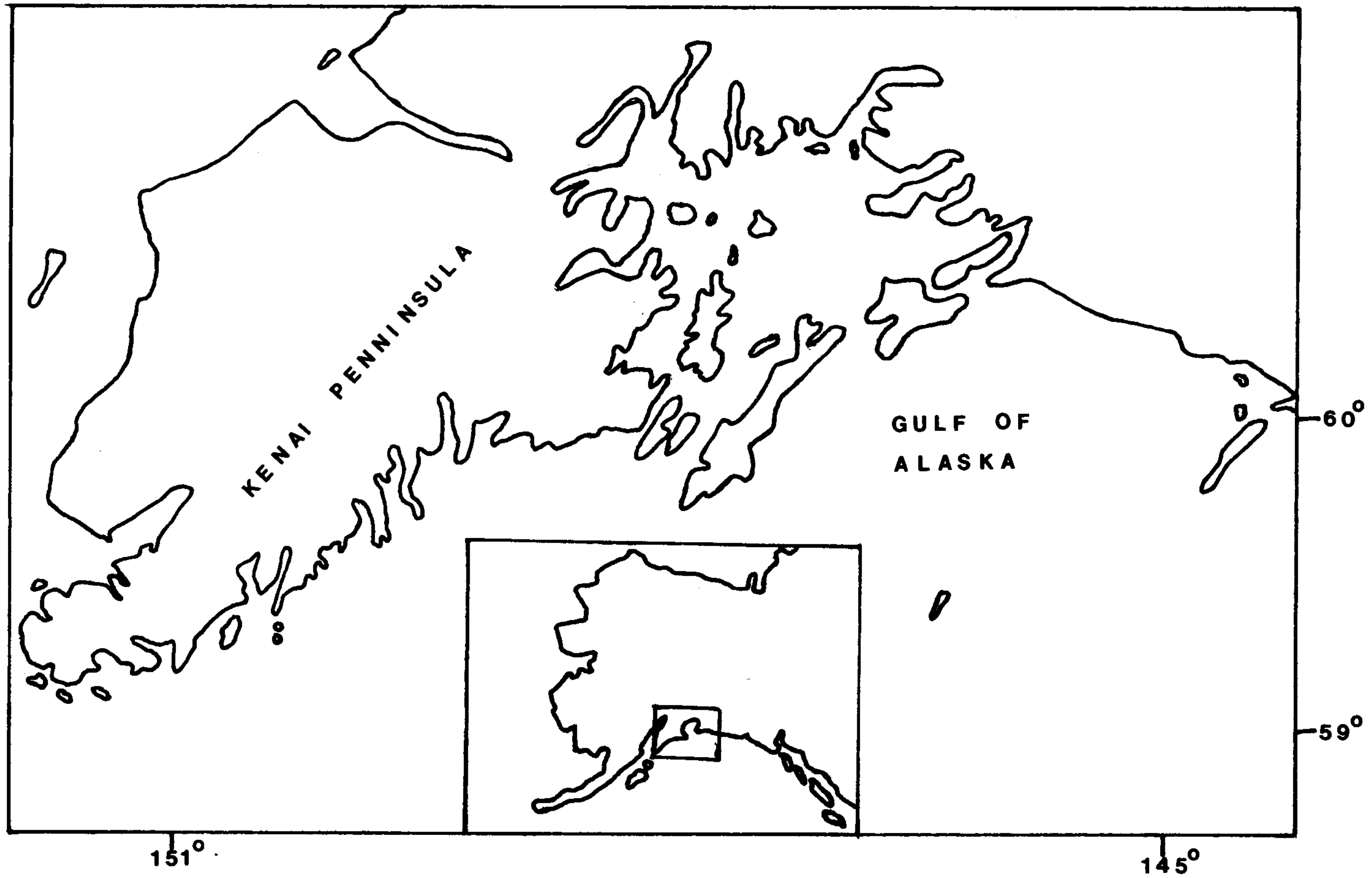

Figure 5. RU-481 Study Area

V. METHODS

To date, the study has attempted to utilize semi-standardized marine mammal survey techniques (Leatherwood and Platten, 1975). These have included strip census techniques from fixed-wing aircraft and surface vessels, streamer tag development for mark-recapture studies, and natural mark cataloging for unique individuals. (Figure 7.)

Strip census techniques as utilized in marine mammal studies vary considerably from one study to the next because of the different characteristics of various orders of marine mammals. For the aerial survey portion of our study, we have flown predetermined fixed transects, at fixed altitudes and speeds, and have attempted to actually measure the distance from the aircraft to the marine mammal target using a standardized commercial inclinometer to measure the vertical angle from the aircraft to the target (Figure 6). Using the computation, $b = a/\tan B$ or $b = a \cot A$, the horizontal distance between the survey aircraft and the target may be determined. This distance clearly varies as a function of observer experience, weather and sea condition, and platform speed and altitude (Caulley, 1974). In order to minimize the effects of the above variable parameters, we have utilized a standard platform, the Office of Aircraft Service's McKinnon Turbo-Goose, N-780, which has been redesigned especially for over-water aerial surveys. The aircraft is equiped with a Global Navigation Inc. GNS-500 VLF Navigator. This instrument provides a continuous digital output of the plane's position in longitude and latitude measured to 1/10 arc minute. All sightings are voice recorded on magnetic tape by the starboard or port observer for later analysis. Information collected on each sighting includes, but is not limited to; species identification, time, position, platform altitude and speed, number of targets sighted, inclinometer angle, and comments on specific animal behavior observed. On return to Anchorage, the tapes are manually stripped of information and resulting data is coded on EDS approved marine mammal sighting records and batch submitted for processing.

Vessel surveys differ significantly from aircraft surveys in that several activities in addition to marine mammal observations are conducted. These include remote tagging of both large and small cetaceans; capture of Dall porpoise (P. dalli) for freeze branding, stomach pumping, and telemetry attachment prior to release; and the collection of certain environmental data such as surface water temperature, water depth, weather pattern, wind speed and direction, sea state, air temperature, and barometric pressure. These data, along with the sighting data, are recorded on EDS approved records. Submission of data records to the keypuncher occurs on a regular basis as described in the Milestone/Activity Chart. During vessel surveys, a marine mammal watch is posted continuously during daylight hours and will continue on a 24-hour/day basis during radio tracking efforts.

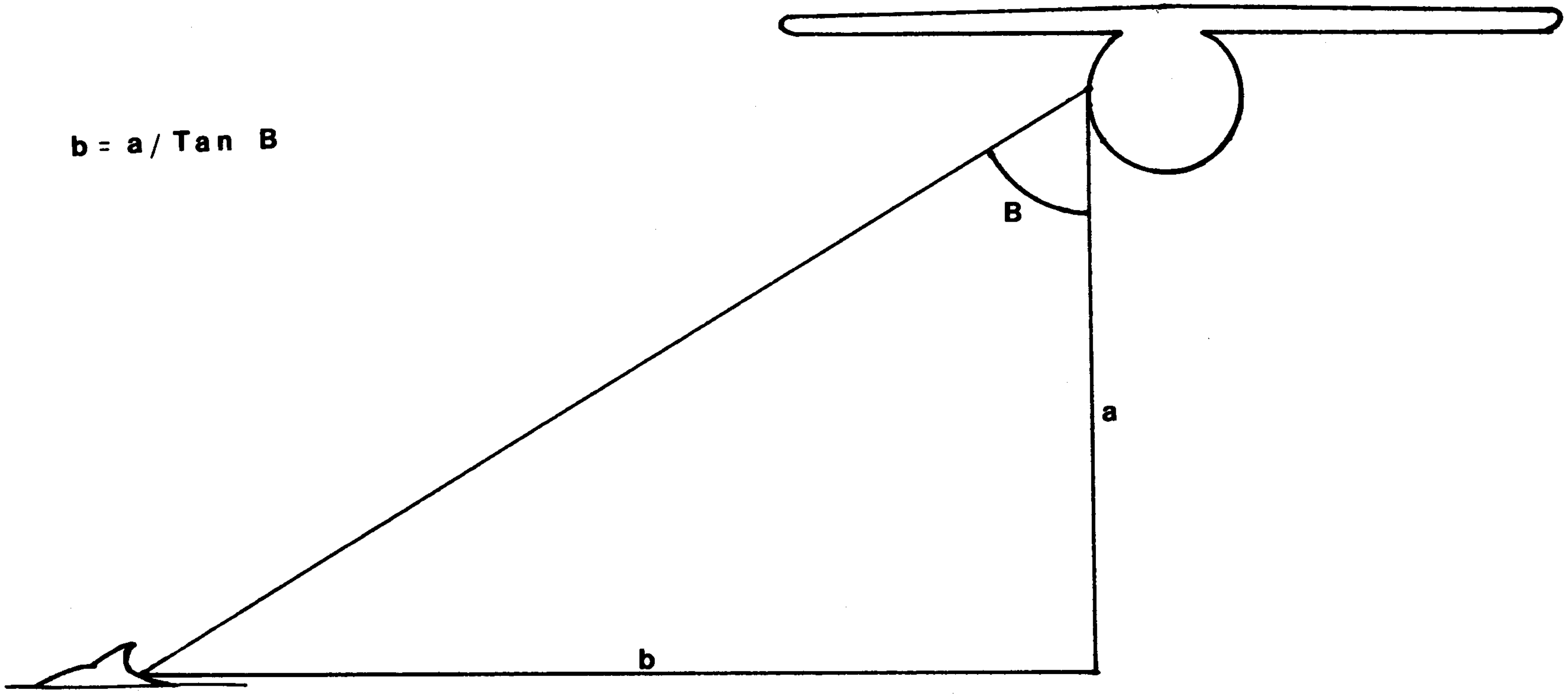

Figure 6. Measurement of Target Distance from Survey Aircraft

HUMPBACK WHALE

KILLER WHALE

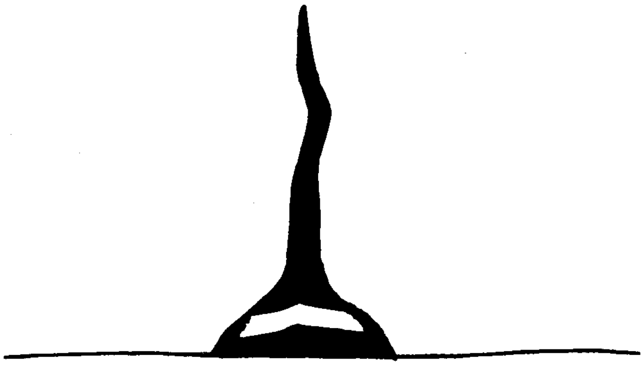

Figure 7. Examples of repeatedly sighted cetaceans bearing unique natural marks. Prince William Sound, 1976.

The track design of the vessel surveys is quite different from those described above for the aircraft. Because we are interested in describing areas of extensive utilization, we attempt to transverse areas that have been reported as whale "hot spots" in the past. In addition to covering these "hot spots", we survey as much of the rest of Prince William Sound as possible. As we begin utilizing radio telemetry, we will be able to locate areas of cetacean accumulation much more rapidly than at present (Evans, 1971).

VI. RESULTS

The data presented in this section are those accumulated during the past twelve months, plus additional historical data supplied by cooperating agencies, and should therefore be looked upon as preliminary in nature. Hopefully, an additional season of sampling will allow us to begin to draw the data together in a more realistic picture of cetacean use of Prince William Sound. The present review should be looked on as only an overview especially in light of the warm and mild summer, fall, and winter of 1976.

Annotated Species Accounts

Dall porpoise - Phocoenoides dalli. This animal appears to be the most numerous cetacean in Prince William Sound. In 1976, a total of 974 Dalls was sighted in or near the Sound. It is a year-round resident, but appears to increase in numbers during the summer (Figure 8). Though in other areas, the Dall porpoise appears to be an offshore resident (Norris and Prescott, 1961), in the Sound these animals have been observed feeding in less than 20 fathoms of water and less than 1/2 mile from land. Though abundant in the southwest corner of the Sound, especially in Montague Strait, Knight Passage, Knight Island Passage, and Hinchinbrook Entrance, a group of over 100 P. dalli was sighted 16 February 1977 near Glacier Island in northern Prince William Sound (Ken Pitcher, ADFG, personal communication). Paired animals, presumed to be mother and calf, have been sighted from March through June.

Harbor porpoise Phocoena phocoena. This small and shy cetacean is a year-round resident of Prince William Sound. Aerial surveys and previous observations indicate that these porpoise are more numerous in the winter months (Ancel Johnson, FWS, personal communication). A total of 185 harbor porpoise was reported sighted in the study area in 1976 (Figure 9). Occasionally a harbor porpoise is taken in a salmon purse seine, however these animals generally avoid vessels or human marine activity.

Pacific white-sided porpoise - Lagenorhynchus obliquidens. These gregarious animals are rarely sighted inside Prince William Sound. They appear to be common, in certain years, in late summer or early fall over the continental shelf between the Sound and Middleton Island. In October 1976, a school of over 500 of these animals was

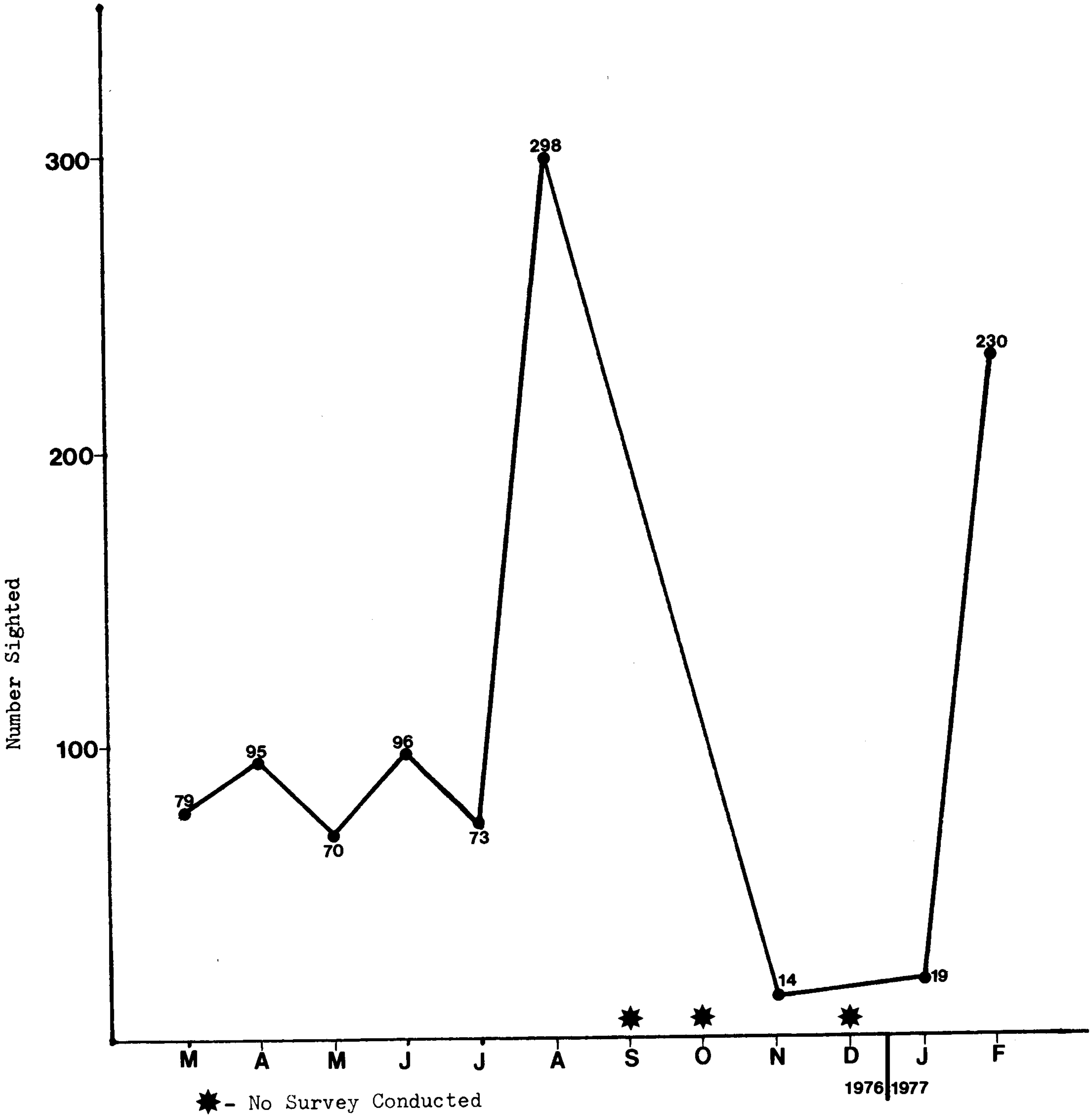

Figure 8. Dall Porpoise Sightings in Prince William Sound

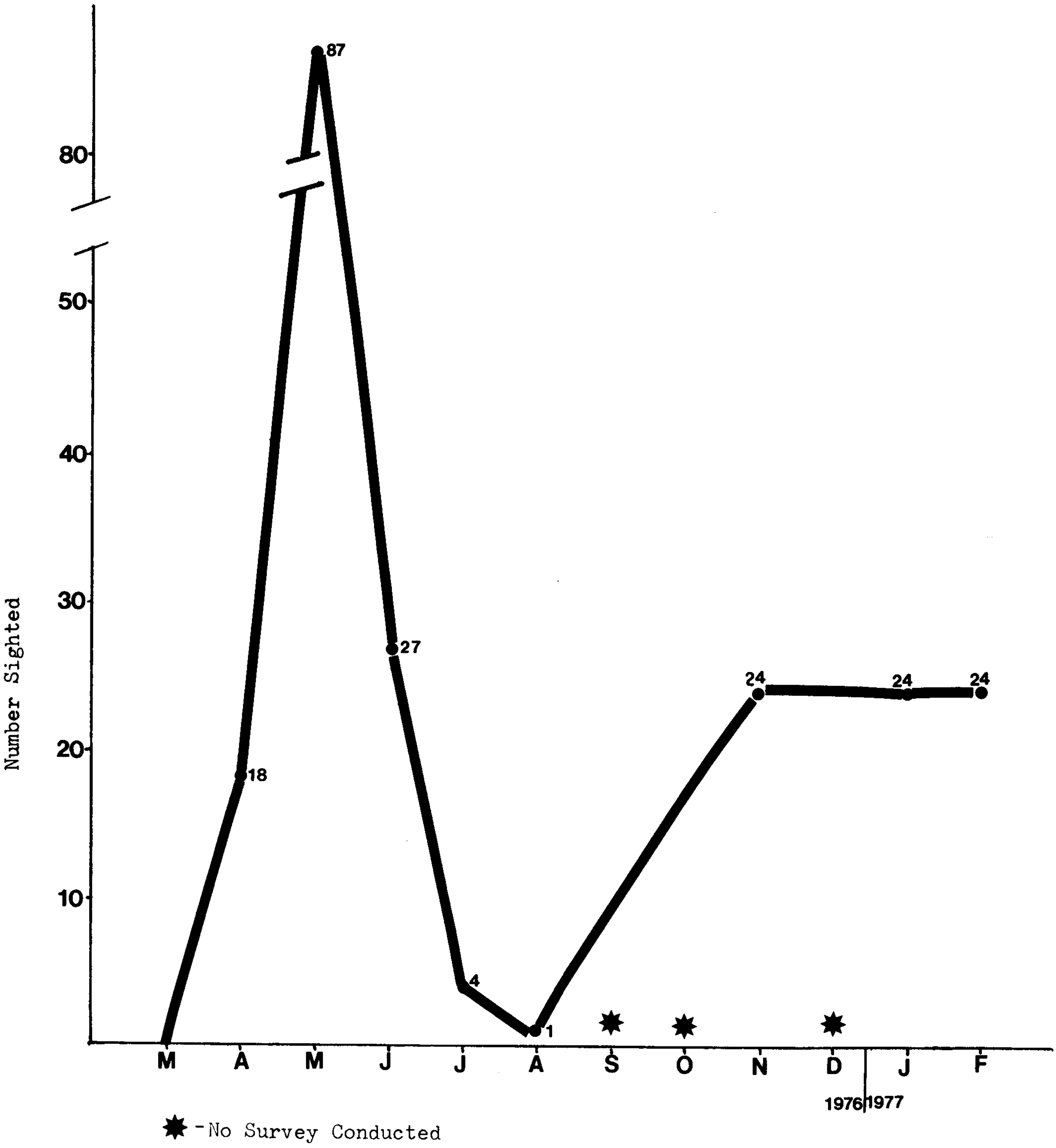

Figure 9. Harbor Porpoise Sighted in Prince William Sound

sighted from the R/V Surveyor just outside Montague Strait. It appears that the presence of L. obliquidens in the Gulf of Alaska is positively correlated with warm surface waters.

Killer Whale - Orcinus orca. These large and boldly marked porpoise are found in Prince William Sound throughout the year in relatively small groups. In 1976 the largest group we observed numbered over 30 animals, though a more usual number would be four to eight animals per group. One hundred and sixty-seven (167) killer whales were seen in the Sound in 1976 (Figure 10). Because of their bold markings, killer whales may occasionally be distinctly marked, or disfigured, so that future individual recognition is possible. Throughout the summer of 1976 we sighted and later recognized a large male killer whale because of a deformity in the dorsal fin (Figure 7). By resighting this animal again in the future, we may be able to document a seasonal movement pattern of killer whale groups in the Sound.

Gray whale - Eschrichtius robustus. Although this species passes through the study area only twice a year on its annual migrations, it does so in such numbers that it is included in the present account. Perhaps in both the spring and fall, but certainly during the former, essentially the entire population of gray whales (11,000 +) passes by Prince William Sound on its way to the Bering Sea (Rice and Wolman, 1972). These animals have been observed at the entrance to Montague Strait in April by FWS observers, and probably stray into Hinchinbrook Entrance as well. A total of 23 gray whales was sighted in the study area in 1976. Because gray whales are coastal (almost littoral) in nature, and because they appear to spend some time at openings in the coast, these animals, more than other whales, may be subject to accidents invloving vessels. Gray whales bearing scars resulting from collisions with boat propellers are commonly sighted in the calving lagoons of Baja, California (J. D. Hall, personal observation).

Humpback whale - Megaptera novaeangliae. This species of baleen whale has been recorded in Prince William Sound, or the adjacent vicinity, for at least 25 years (Jim Johnson, NMFS, personal communication). During the mid-1950's, the Japanese whaling fleet took 145 humpbacks from the area just south of the Alaska Peninsula, and an additional 15 humpbacks in 1962 from the Kodiak-North Gulf of Alaska area (Nishiwaki, 1966). This may account for the absence of humpback sightings in the Sound by Jim King of the FWS during the summers of 1956-57. Since at least the mid-1960's, humpbacks have been sighted again in the Sound but only in small numbers. It was not until 1975 that Pete Isleib of Cordova saw more than a few, and that year he saw one group of 16. In 1976, we sighted a single group of at least 35 humpbacks in the Sound, and the summer population probably numbers between 40-60 at this time (Figure 11). During the 1976 season, a total of 106 humpbacks was sighted in the Sound. Until this winter, it was felt that humpbacks probably left the Sound by late November or early December, and returned in April or May; however, on 16 February 1977 Karl Schneider of ADFG sighted a lone

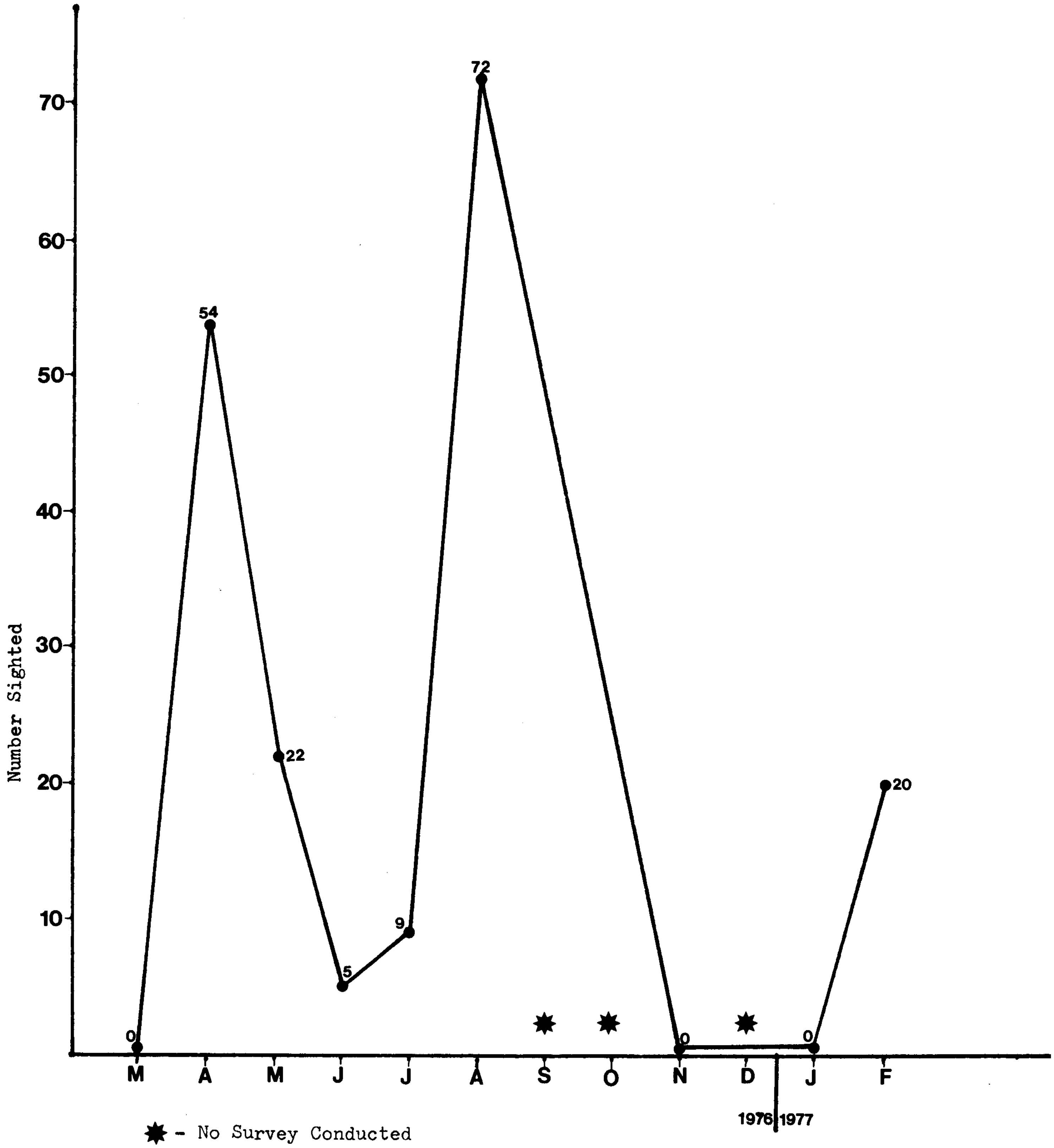

Figure 10. Killer Whales Sighted in Prince William Sound

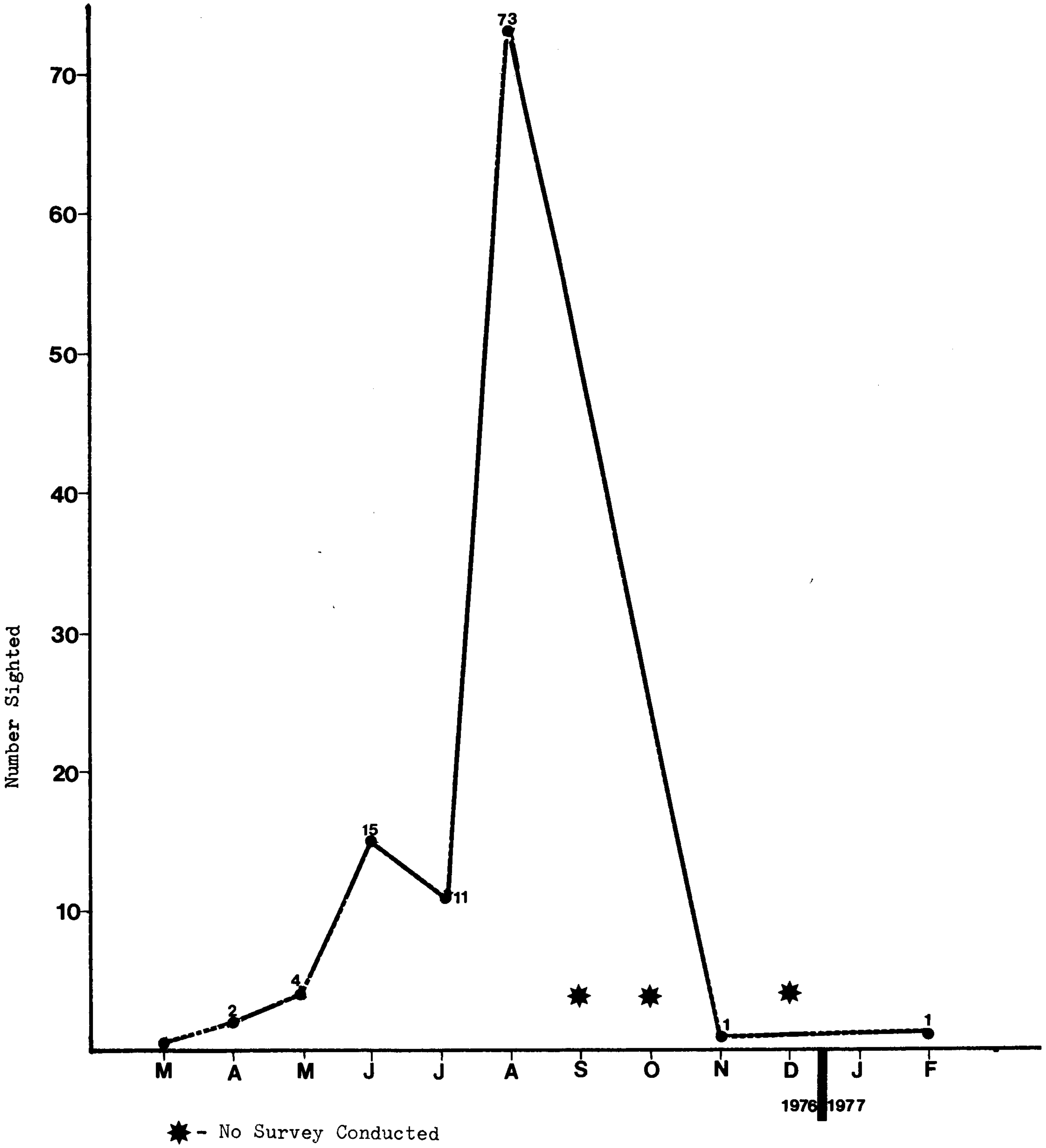

Figure 11. Humpback Whales Sighted in Prince William Sound

humpback in Knight Passage. It seems unlikely that this animal would have traveled from the Sound to the tropics, either near Hawaii or Okinawa, and returned in only 2 and 1/2 months. A more reasonable explanation is that the mild winter of 1976-77 made it possible for the animal to winter over in Prince William Sound. We have no idea whether or not this is the beginning of a trend or just an anomolous individual.

From Figures 1-2, it would appear that humpbacks utilize both entry corridors to the Sound and tend to accumulate in the southwest region, though they are frequently sighted further north in the Sound, especially near Passage Canal, Glacier Island, and Naked Island.

Finback whale - Balaenoptera physalus. We have only sighted fin whales in Prince William Sound during the spring. They appear to arrive in May and may stay until July, when they probably continue north to the Bering Sea and Gulf of Navarin. Although a FWS aerial survey in April 1975 sighted over 50 fin whales in the Sound, we more normally see them in groups of two to eight, and sighted a total of 23 in 1976 (Figure 12). They appear to be quite calm when in the Sound, and we have been able to approach very close to them for identification purposes.

Minke whale - Balaenoptera acutorostrata. This species, the smallest of Northern Hemisphere baleen whales, is ubiquitous in Prince William Sound. We find them in small groups throughout the Sound year-round, but they are more numerous in the summer and fall (Table 2), and appear to concentrate in the southwestern region of the Sound, especially between Green Island and the Needle in Montague Strait (Figure 2). In 1976, we sighted a total of 52 minke whales in or near the Sound. These little whales are curious and will frequently approach a boat that is dead in the water and spend some time apparently investigating the vessel.

Other Cetaceans in Prince William Sound. Sei whales and belukhas are reported from the Sound occasionally. In 1976 we sighted one belukha and five sei whales. They are almost certainly casual visitors and probably should not be considered regular members of the cetacean faunal assemblege in the Sound. Whales of the genera Mesoplodon, Ziphius, and Berardius may occasionally appear in the Sound. A few strandings of these pelagic animals have been reported from Alaskan waters (Jellison, 1953), and a single Cuvier's beaked whale, Ziphius cavirostris, stranded on Wooded Island outside Prince William Sound in July 1976 (Pete Mickelson, University of Alaska, personal communication). Unfortunately, the surf removed the animal before it could be properly examined.

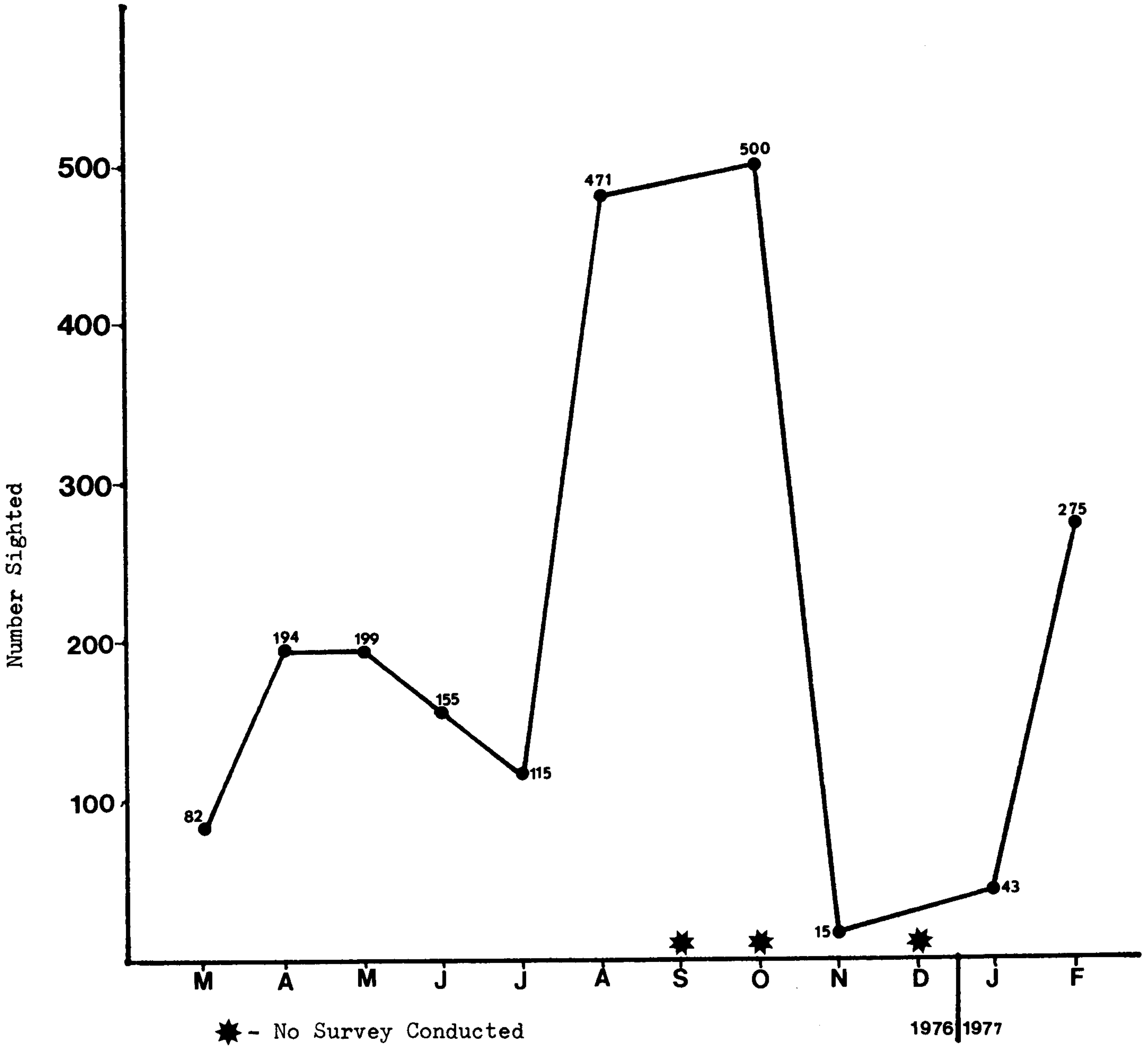

Figure 12. Cetacean Counts From Prince William Sound

Table 2. Monthly Counts of Cetaceans Sighted in Prince William Sound

Species	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Yr. Total**
Dall porpoise	79	95	70	96	73	298			14		19	230	
Harbor porpoise		18	87	27	4	1			24		24	24	
Minke whale		2	6	5	12	27							
Humpback whale		2	4	15	11	73			1			1	
Killer whale		54	22	5	9	72						20	
Fin whale			10	7	6								
Sei whale				5									
Gray whale		23											
Pacific white-side porpoise	2							500					
Belukha	1												
Mo. Totals	82	194	199	155	115	471	0	500	15	0	43	275	2049

VII. DISCUSSION AND CONCLUSIONS

A total of 2,049 cetaceans was reported seen in or near Prince William Sound between March 1976 and February 1977. Because of the lack of a consistent survey effort prior to FY 77, the figure of 2,049 is probably not representative of the total cetacean population, although we did sight distinctly marked cetaceans repeatedly during our surveys, indicating that certain individuals remain in the Sound for varying lengths of time. (Figure 13)

It appears that at least one group of 25-35 killer whales spends several months in the Sound, though perhaps not constantly. We sighted a male killer whale with a deformed dorsal fin on three occasions, and he, along with his herd, was also sighted by researchers on the Wooded Islands, and by FWS observers on Hinchinbrook Island (Figure 7).

A uniformly gray Dall porpoise was sighted in a group of 50 normally pigmented Dall porpoise on 2 August 1976, and again on 6 August 1976. On the latter occasion, the gray animal was accompanied by two other normally pigmented Dalls. The resighting occurred 13 miles from the point of initial sighting.

A humpback whale with a distinctly marked fluke underside (Figure 7) was sighted twice in August near Knight Island and again in late November in Prince of Wales Passage. The November sighting was 14 miles from the August sighting position. We do not know if the whale had remained in that general vicinity for four months, but when sighted in November, it was headed toward the area of the August sighting at high speed and refused to alter course except to elude the survey vessel.

We feel it unwise to draw even tentative conclusions as to numbers and areas of concentration at this time since we have less than one complete field season of consistent data collection. Even so, it seems clear that the apparent seasonal variations in population numbers (Figure 14) is real, with maximum cetacean biomass occurring in spring, summer, and fall. Whether winter is a time of real, or merely apparent, low density is difficult to access due to the uniformly stormy weather experienced this past winter. For instance, we scheduled the Turbo-Goose for an aerial survey on 7 January 1977, but bad weather forced us to delay the survey until 26 January, when we flew under marginal conditions. Delays of this type, but not magnitude, were anticipated and are reflected in the modified Milestone/Activity Chart submitted to the Juneau Project Office in February 1977.

Because of the apparent seasonal nature of cetacean useage in Prince William Sound, it is clear that the animals must enter and leave by Hinchinbrook Entrance or Montague Strait, thus forcing the animals to be concentrated in these areas at least during times of immigration and emmigration. In addition, the southwestern area of the Sound appears, on the basis of our cursory surveys, to be an area of marine mammal concentration.

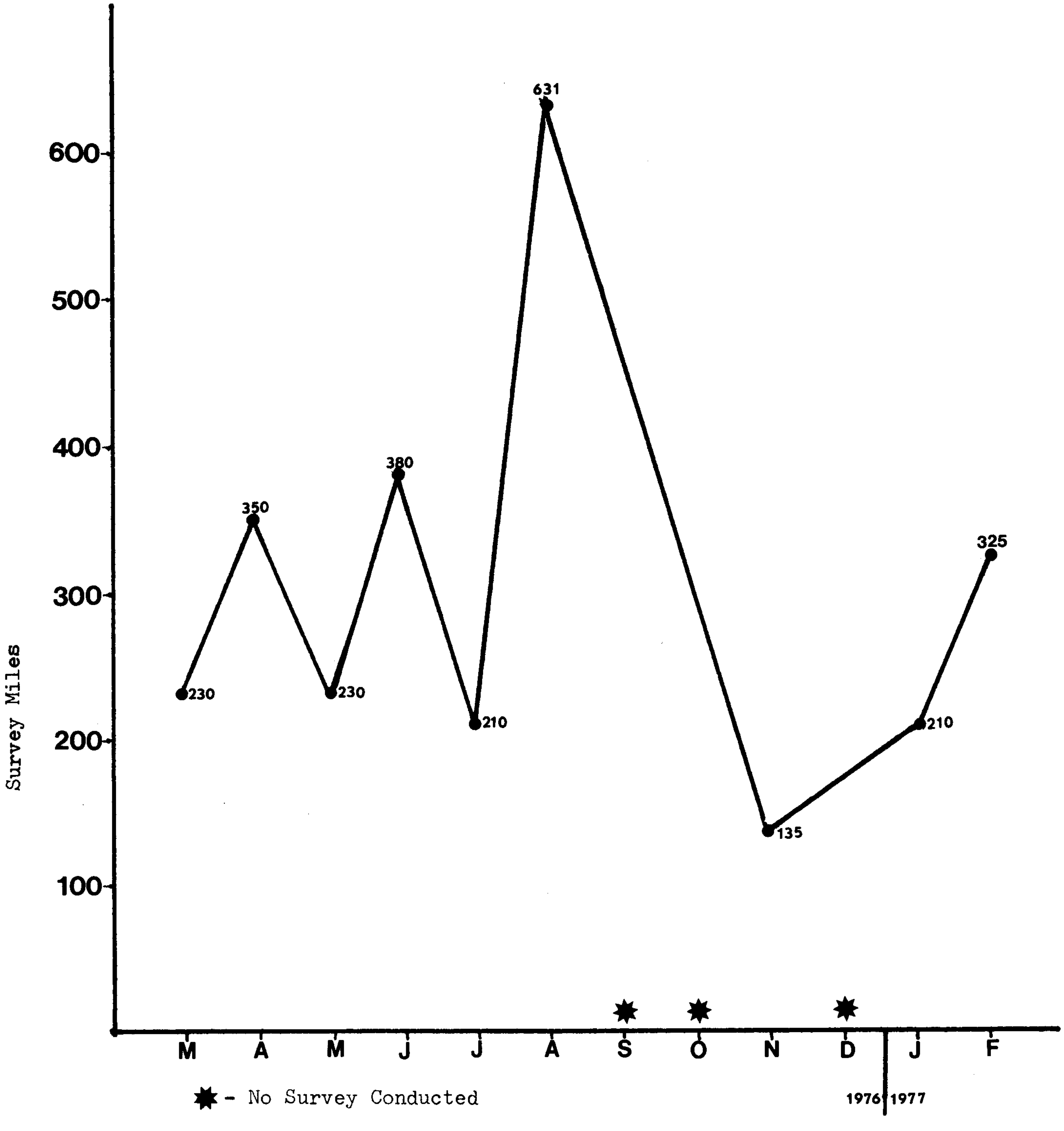

Figure 13. Sighting Effort

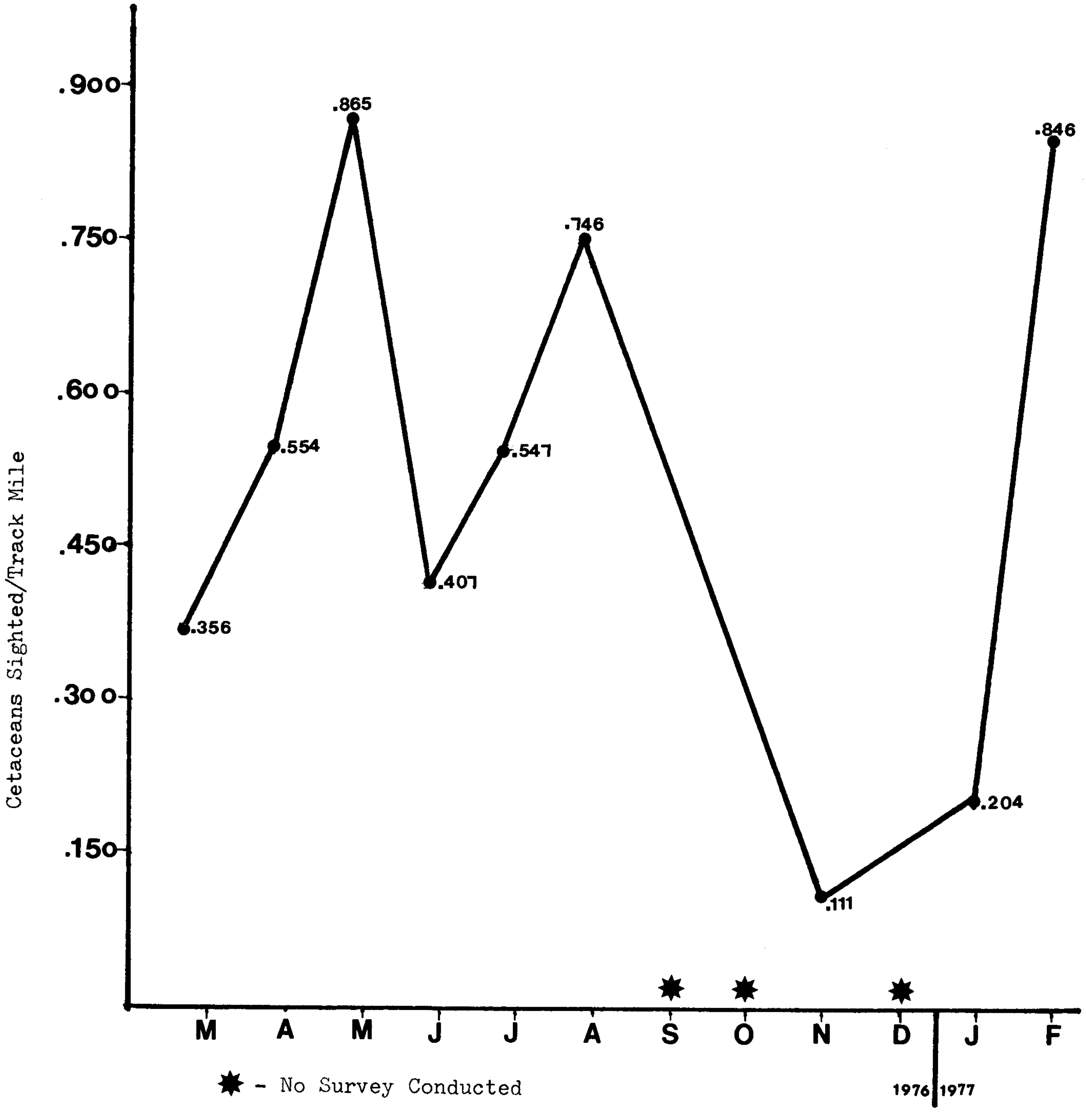

Figure 14. Relative Cetacean Abundance

IX. NEEDS FOR FURTHER STUDY

As specified in our June 1976 proposal, this project, if it is to provide useful data to OCS decision-makers, needs to continue for an additional fiscal year. If our tagging and telemetry program is to yield any information on long and short term cetacean movements, it must continue long enough for us to collect statistically valid resight and track data.

We need to replicate the aerial and surface surveys over at least a two-year period, so we will know whether or not the numbers and distributions of cetaceans in Prince William Sound represents a stable or dynamic community. If, as the bits and pieces of information now available indicate, the humpback whale population is increasing in number and the length of time spent in the northern Gulf of Alaska and the Sound, then these endangered marine mammals may be expected to interact with man and his petroleum transport and development activities on an increasing basis. While increasing cetacean/human interaction is not necessarily bad, we need to be able to document the probability of increasing interaction in order to minimize the potentially negative aspects of that interaction.

We believe the basic design of the project is sound, but in the interest of cost efficiency, we plan on eliminating surface surveys in November, December, January, and February. Experience gained this year indicates that the short photo period during these months precludes effective vessel surveys. We suggest that utilization of the survey aircarft during this period will greatly increase the cost effectiveness of the project, and yet not sacrifice data flow.

X. SUMMARY OF FOURTH-QUARTER ACTIVITIES

Two aerial surveys were scheduled from the Turbo-Goose this quarter. One took place on 26 January 1977 and required 4.0 hours of aircraft time to complete. Observers on the January flight were: John D. Hall, Craig S. Harrison, David Nysewander, and Margaret Petersen.

The second aerial survey was completed 12 March 1977. Annual report submission deadline precludes inclusion of results of this effort. John D. Hall and Craig S. Harrison were observers on this second flight. As described in this report, aerial surveys this quarter will utilize the strip-census technique (Figure 1). Analysis of the survey data will be conducted upon return to Anchorage.

A. Aerial survey tracks will follow those detailed on Figure 4 of this report. The trackline includes 450 nautical miles of planned track. The 26 January 1977 survey covered 210 nautical miles due to heavy fog conditions encountered inside Prince William Sound.

During the 26 January 1977 survey, we sighted 24 groups of cetaceans representing 43 individuals. In addition, the Alaska Dept. of Fish and Game sighted 15 groups of cetaceans representing 275 individuals. Thus, during the fourth quarter (Jan-Mar 1977), a total of 318 whales and porpoise were sighted by OCSEAP observers in the Sound.

A modified Mileston/Activity Chart and justification was submitted to the Juneau Project Office in February. This document will cover activities and data submissions for the remainder of FY 77.

B. No significant problems have been encountered to date. Delivery of the telemetry equipment is taking longer than expected due to additional informational requirements of the FWS purchase office in Portland, Oregon, but this delay is not expected to alter our radio tracking capability as noted on the modified Milestone/Activity Chart. The only real change will be that we will eliminate surface surveys in November, December, January, and February due to insufficient daylight.

C. Estimate of Funds Encumbered to Date.

Salaries and Benefits	$11,070
Supplies and Equipment	9,100
Travel	1,300
Word Processing	518
Logistic Support	9,092
	$31,080
Funds remaining in FY 77	$90,125

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