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Living Marine Resources of the Chukchi Sea:

A Resource Report for the Chukchi Sea Oil and Gas Lease Sale Number 85

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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by

Byron F. Morris

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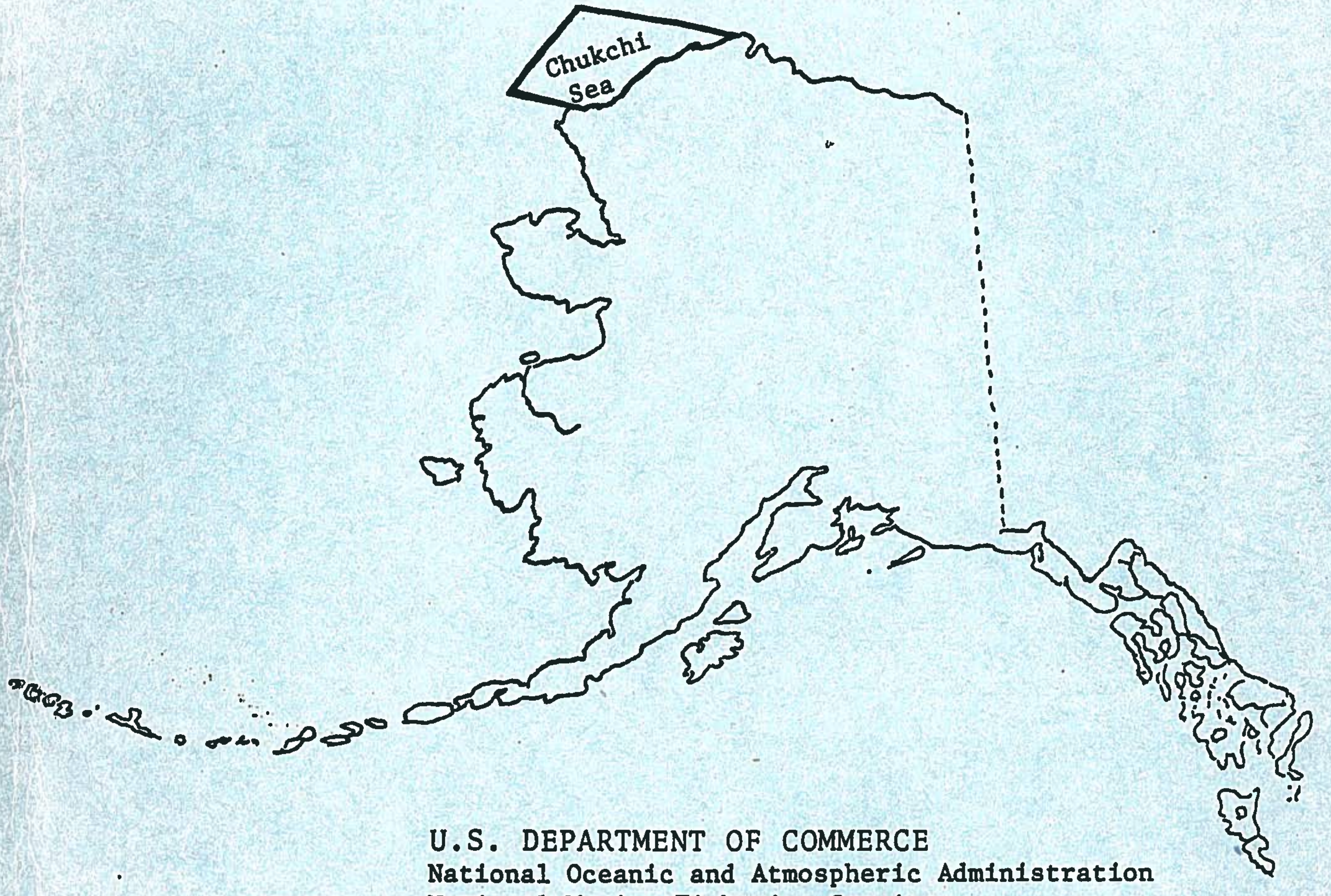

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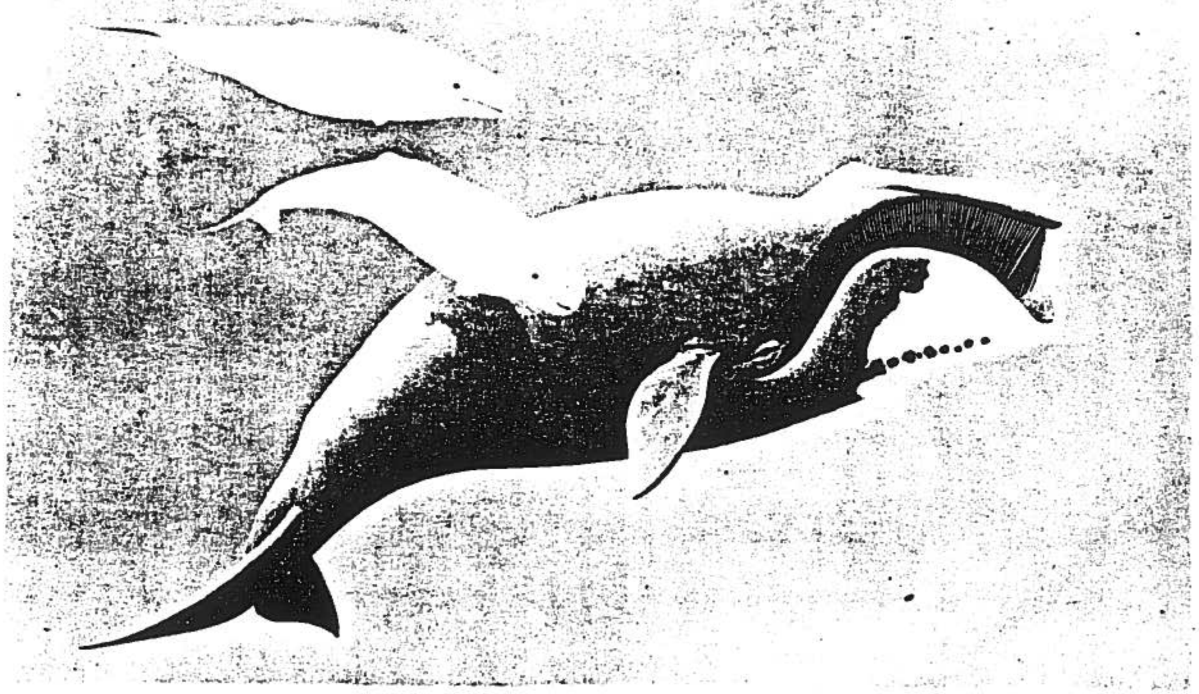

Beluga or White whale (*delphinapterus leucas*) Bowhead or Greenland Right whale (*Balaena mysticetus*)

Prepared By

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Anchorage, Alaska

April, 1981

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ADDENDUM

In the final days of completing this report, the Department of the Interior announced a proposed new 5-year OCS leasing schedule. There are only a few proposed changes in the new schedule that affect the contents of this report: the name of the sale area has been changed to Barrow Arch Sale No. 85, and the date of the sale has been moved ahead one month to January, 1985. The boundary of this area is now defined as "North of 69° N. lat. and south and west of a line that starts at a point where 71° N. lat. intersects the coastline west of Barrow, Alaska, thence west to 162° W. long., thence north."

This new description of the planning area moves the southern boundary 1/2° to the north (to north of Cape Lisburne) and extends the northern boundary an undefined distance toward the North Pole. The western boundary is not defined, but is illustrated at about 169° W. at the U.S.-U.S.S.R. 1867 Convention Line. This area is said to encompass 28 million acres including the area out to the continental slope.

SUMMARY

1. An area of the outer continental shelf of the northeastern Chukchi Sea is currently proposed by the Department of the Interior's Bureau of Land Management for oil and gas leasing in February 1985. The proposed area is located between latitude 68° 30'N. and 71° 0'N., and is bounded on the east by the Federal/State 3-mile boundary, and on the west by the U.S.-U.S.S.R. 1867 Convention Line.

2. This report assesses the biological resources of the northeastern Chukchi Sea that may be at risk from petroleum exploration and development, and proposes research needs to minimize and avoid potential biological impacts.

3. In the area under consideration the Chukchi Sea shelf is relatively shallow (4 - 60 meters), and is ice-covered for most of the year (October through June). The zone of stable shorefast ice is relatively narrow along most of the coast, and nearshore incursions of the moving pack ice occur regularly.

4. The Chukchi Sea supports large populations of marine mammals and seabirds, which depend on the fish and invertebrate populations of the region. The marine mammals of major importance in this region are the bowhead whale, gray whale, beluga whale, walrus, ringed seal, bearded seal, spotted seal, and polar bear. Less frequent but regular visitors to this area are the fin, minke, humpback, and killer whales, the harbor porpoise, and ribbon seals.

   * Bowhead whales, the entire population of the western Arctic stock, regularly follow the narrow nearshore lead systems through the northeast Chukchi Sea on their northward spring migration, generally between April to June. Fall return migrations are poorly known, but appear to be more dispersed, farther offshore, and along the Siberian coast.

* Beluga whales migrate north through both nearshore and offshore leads with some of the population summering along the Chukchi coast in certain bays, lagoons, and river mouths, where feeding and calving occur. Their fall movements are poorly known.

* Walrus follow the seasonal retreat of the pack ice northward through the area, generally staying offshore of the fast-ice zone. They often gather in herds of several hundred animals and may move nearshore with pack ice incursions.

* Ringed seals overwinter and pup in the fast-ice zone of the Chukchi Sea. The highest densities of ringed seal in Alaska occur along this coast. In summer they move northward to inhabit the polar pack ice.

* Bearded seals overwinter in the broken pack ice zone, mainly south of the Chukchi Sea. In spring they migrate through the Chukchi Sea with the northward drift of the pack ice, and summer along the pack ice edge.

* Spotted seals inhabit the Chukchi Sea during the ice-free season and are particularly common nearshore in summer. They are the only Arctic seal to commonly haul out on land.

* Polar bears range over the area during the ice-covered season. They commonly occupy the pack ice and flaw zone, enter the fast ice zone and even come ashore on feeding excursions. A few den along the coast of the Chukchi Sea in low numbers. During summer, the polar bear retreats north with the pack ice.

* Other whales and seals are seasonal migrants that irregularly enter the Chukchi Sea depending on annual sea ice and hydrographic conditions. Knowledge of the distribution and habitat usage by these marine mammals is scant and is based mainly on scattered sightings.

5. Marine mammals form a major portion of the diet of Chukchi Sea villages. The bowhead whales are hunted at Wainwright and Barrow during their spring migration. Beluga whales, seals, and walrus are also important subsistence resources. The take of these marine mammals varies by season and village. Beluga whales are especially important to Point Lay villagers.

6. Fish and invertebrate populations do not support any viable commercial fishing operations. Biomass is low compared to the Bering Sea for the commercially important species also known to inhabit the Bering Sea.

7. Subsistence fishing is an important supplement to the largely meat diet (marine mammals, caribou) of the coastal residents. Marine species of subsistence importance include shrimp, Tanner crab, clams, flounder, and herring. Anadromous species taken nearshore or in fresh waters are primarily pink and chum salmon, smelt, Arctic char, and whitefish.

8. The biological and physical processes that control the oceanic productivity and marine populations of the Chukchi Sea are poorly known. Delineation of ecosystems, interactions between organisms and their environment, and food-web dependencies are largely conjectural. The identification of sensitive organisms, critical habitats, and the responses of ecosystems to environmentral perturbations has not been accomplished. Seasonal changes in the environment in response to winter ice cover and summer open water conditions need better understanding to address OCS impacts.

9. Potential biological impacts of major concern are:

   * The effects of oil spills, especially in the shear zone and moving pack-ice zone, and in nearshore areas during the open-water season.

   * The impacts of noise and other human disturbances, associated with all phases of OCS activity, on marine mammals especially during the spring migration.

* Sensitivity and vulnerability of habitats to alteration and destruction from construction, emplacement, and operation of OCS facilities.

10. Our primary recommendations are the following:

* The initial lease sale should be limited to the stable shorefast ice zone. Subsequent leasing beyond the zone should require test structures to demonstrate a capability of dealing with the forces of moving ice.

* Seasonal habitats of marine mammals and fish need to be better defined for most species.

* Studies on the effects of noise and industry activity on marine mammal behavior and migration must be continued.

* The use of the nearshore region, lagoons, and bays by anadromous fish needs study.

* Coastal circulation needs better understanding to develop oilspill risk models and to assess shoreline vulnerability.

1. INTRODUCTION

1.1 Request for Resource Report

The Bureau of Land Management of the Department of the Interior is proposing oil and gas lease sale 85 in the northeastern Chukchi Sea. This sale is currently scheduled for February 1985. The area from which tracts will be identified for leasing is located between 68°30' N. and 71° N. latitude and is bounded on the east by the Federal/State 3-mile geographical boundary and on the west by the U.S. - U.S.S.R. 1867 convention line (Figure 1.1). The Bureau of Land Management has requested a report from the National Marine Fisheries Service that describes the resources within the general area of evaluation and identifies the potential effects of oil and gas operations upon these resources and their environment. This document is prepared in response to that request.

The area under consideration extends from 55 to more than 200 nautical miles offshore over water depths ranging from 2 to 29 fathoms. The area is ice covered for most of the year. Sea ice conditions can be hazardous and unpredictable. The climate is severe. During the brief summer period the Chukchi Sea supports significant populations of sea birds and marine mammals associated with both open water and with pack ice. During winter it is the home of several ice-dependent marine mammals.

There is a lack of detailed environmental information for the Chukchi Sea. Present knowledge of this region is mainly of the survey type, descriptive, and has primarily been focused on the nearshore zones in the summer season only. Mapping of the shorefast ice regime has been conducted, but relatively little is known about the moving pack ice conditions, the extent of ice gouging and ice-override, and the subsea permafrost conditions. If the sale area extends beyond the narrow nearshore area of stable shorefast ice, pack ice hazards will be an overriding concern.

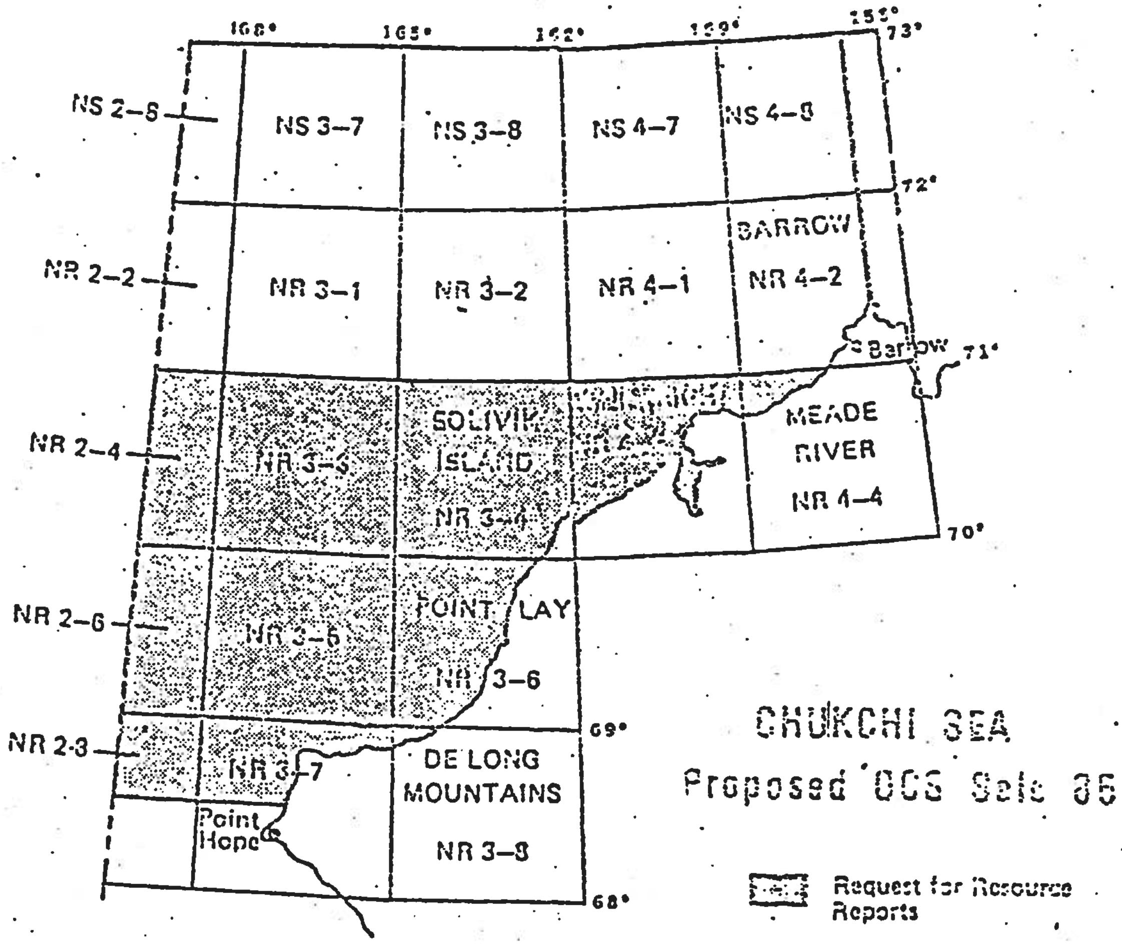


Figure 1.1. Location of the area of Call for Nominations for tracts to be leased in proposed OCS Sale 85, the Chukchi Sea. Based on nomination patterns weighing industry interest against environmental concerns, tracts will be identified for environmental assessment prior to a final selection of tracts to be offered for lease. Individual tracts offered are typically 4.8 km sided squares (5700 acres) and generally number between 200-500. Locations of these tracts will first be known in February, 1982 following Tentative Tract Selection.

Our knowledge of the oceanographic circulation is sketchy. Neither the wind regimes nor the variability of nearshore currents are well known. No adequate oilspill trajectory analysis can be conducted from existing information.

Knowledge on the seasonal distribution and abundance of invertebrates, fish, and marine mammals lacks any detail, especially for the winter ice-covered season. The area is sparsely inhabited by Inupiat Eskimos who are dependent on these resources for their subsistence life-style.

Studies will be needed to address the concerns of sea ice hazards, oilspill risks, critical habitats, ecosystem composition and functioning, and vulnerability of marine mammals and other biological resources to potential OCS oil and gas activity.

1.2 Hydrocarbon Resource Potential

The occurrence of petroleum deposits at any location depends on the simultaneous existence of three key factors:

* Suitable hydrocarbon source materials, i.e. organic rich rocks.
* Reservoir rocks with sufficient permeability and porosity to allow hydrocarbon migration and accumulation.
* A trapping mechanism, either stratigraphic or structural in nature, to retain the petroleum in the geologic reservoir.

Suitable conditions for oil and gas deposits are believed to exist in several areas of arctic Alaska, including the Chukchi Sea Shelf. The northeastern Chukchi Shelf is an area with promising oil or gas potential. This shelf is underlain by some of the same geological units found in the large oil and gas fields of the Prudhoe Bay region and in the smaller fields of the National Petroleum Reserve - Alaska (NPR-A). There are three significant geologic features of the Chukchi Sea Shelf that may be conducive to petroleum deposits. These are the Barrow Arch to the north, the Herald Arch to the south and west, and the Colville geosyncline in the area between these arches (Figure 1.2).

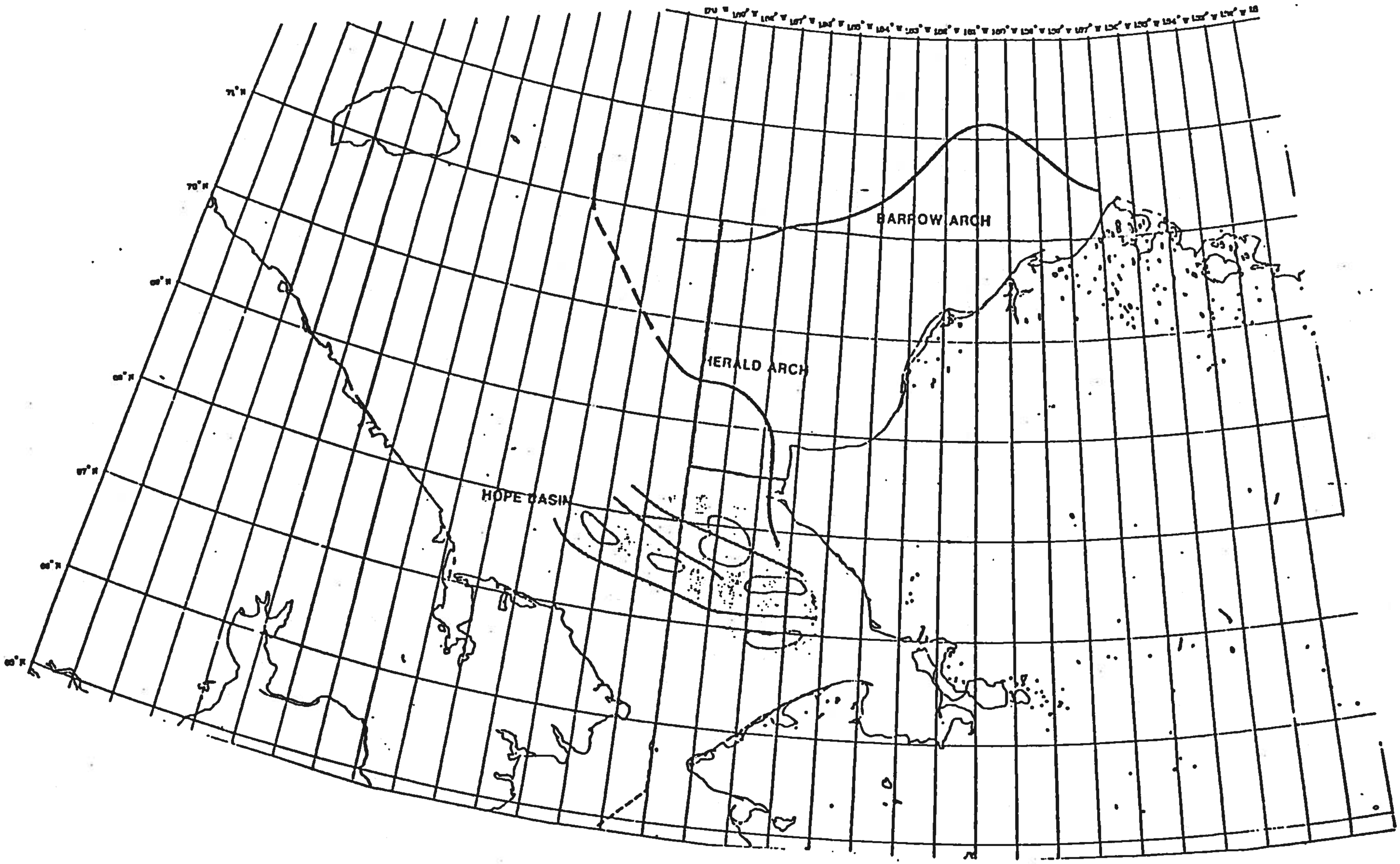
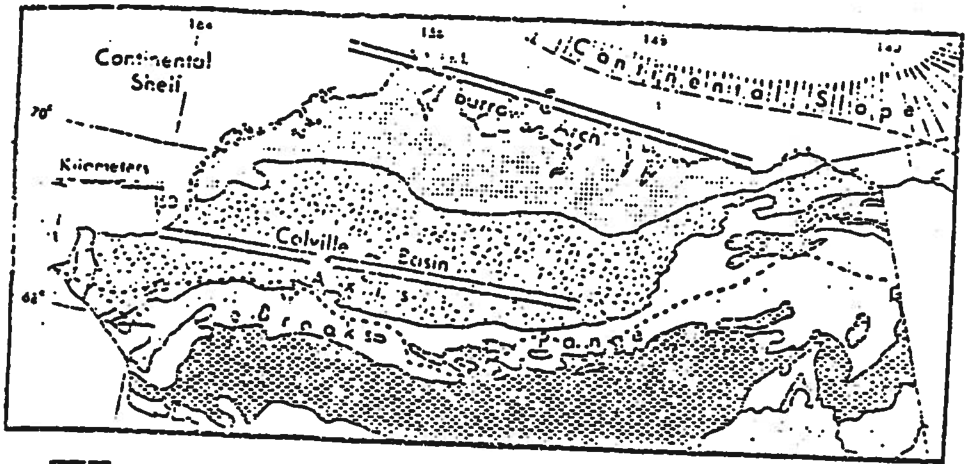


Figure 1.2. Geologic structures of northwest Alaska and the Chukchi Sea. The Chukchi Sea Shelf is a geologic extension of the western North Slope of Alaska and contains the same geologic units found in Prudhoe Bay and NPR-A. A) The offshore extension of the Chukchi Shelf is bordered by the Barrow Arch and the Herald Arch. B and C) The Colville Basin contains numerous faults and anticlines that may provide suitable trapping mechanism for petroleum hydrocarbons. The Colville geosyncline continues offshore (not shown). (B, C after Walker, 1973).



Quaternary Deposits on Mesozoic Basement

Successor Basin Deposits Late Mesozoic Sedimentary Rocks

Geosynclinal Deposits Mid-Paleozoic to Mid-Mesozoic Mainly Sedimentary Rocks

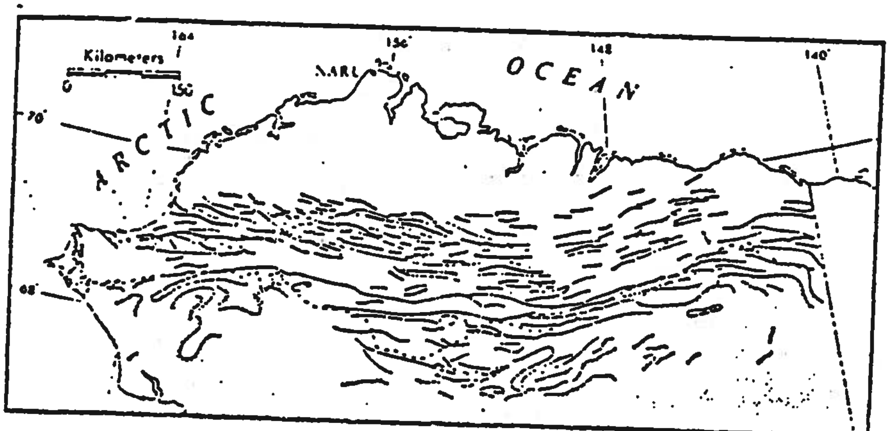
Drainage Divide

Older Geosynclinal Deposits Sedimentary and Metamorphic Rocks

Plutonic Rocks Paleozoic and Mesozoic

Thick Sedimentary Deposits Tertiary an Quaternary

Figure 1.2B (see previous page for legend)



Structure Symbols

Anticlines

Synclines

Drainage Divide

Thrust Faults (Ticks on Upthrown Side)

Normal Faults (Ticks on Downthrown Side)

Figure 1.2C (see previous page for legend)

Sedimentary deposits north of the Barrow Arch have thickness that may be 20,000 feet or more. These deposits may represent a late Cretaceous or Tertiary sediment delta, and if of the appropriate structure and history, could contain petroleum resources.

In the vicinity of Cape Lisburne and extending offshore to the northwest is the Herald Arch. This structure is accompanied by many smaller folds and faults that may offer good potential structural traps for hydrocarbons.

The northeast Chukchi Sea Shelf is itself a geologic extension of the Western North Slope of Alaska. The coastal shelf between Cape Lisburne and Port Franklin contains the Colville Geosyncline, with thick sequences of Cretaceous and possibly pre-Cretaceous shales to serve as the source rocks and thick sequences of Cretaceous and pre-Cretaceous sandstones to serve as reservoir rocks. Geophysical surveys have shown that major structural and stratigraphic trapping features also exist in this portion of the offshore shelf.

The Department of the Interior (1979) estimates that the oil and gas potential of the Chukchi Sea is immense. The "risked"[1/] estimates are 1.28 billion barrels of oil and 3.96 trillion cubic feet of gas. The mean "unrisked" estimates are 3.15 billion barrels of oil and 8.34 trillion cubic feet of gas. The "unrisked" high find (5% possibility) estimate is 14.5 billion barrels of oil and 38.8 trillion cubic feet of gas. These estimates will undoubtedly change as additional geophysical data for the area are gathered. The U.S. Geological Survey presently ranks the Chukchi Sea second after the Beaufort Sea in hydrocarbon resource potential. The petroleum industry nation-wide has ranked the Chukchi Sea 10th of the 22 OCS areas for resource potential and 17th in interest for exploration.

1/ A "risked" estimate is the mean amount of petroleum estimated to be present after a calculated probability of no oil being present is included. The mean (50% probability) and high find (5% probability) are "unrisked" estimates that do not incorporate a no-find risk factor into their calculation.

1.3 Potential Development Scenarios

The presence of sea ice for nine months of the year and the absence of existing shore-base facilities and transportation systems for any discovered oil, place severe limitations on the oil industry's development options in the Chukchi Sea. To be economically feasible to produce, discovered oil fields will have to be very large to warrant the capital outlays that would be required. Nevertheless, the oil companies have outlined the development options that are viewed as most feasible at present.

Industry representatives anticipate that the exploration phase would operate from man-made gravel islands, ice-resistant mobile rigs, or from floating drilling rigs during the ice-free season (Table 1.1).

Department of the Interior estimates (1979, 1980), based on resource probabilities of 1.28 to 3.15 billion barrels of oil, have defined the potential magnitude of OCS activity for the Chukchi Sea. Their scenarios call for four to six exploration wells to be drilled followed by 208 to 400 development/producing wells from six to ten platforms (Table 1.2). These development/production platforms would be either man-made gravel islands or conical gravity platforms capable of allowing operations in water depths to 60 feet. Oil or gas transportation is envisioned to be by pipeline to Kotzebue Sound where a marine terminal, LNG facilities and support bases would be located. Oil or gas would then be loaded onto ice-breaking tankers for shipment to the continental United States.

1.4 Oil Spills

The Department of the Interior (1979) estimates that for their mean resource estimate of 3.15 billion barrels of oil from 10 platforms and 400 wells, the statistically probable number of oil spills greater than 1,000 barrels in size is 18.08 over the life of the field. For their risked estimates of 1.28 billion barrels of oil from 6 platforms and 208 producing wells, the estimated number of spills decreases proportionately to 7.35. These numbers include spills from both production and transportation and are based on statistical calculations of the volume of oil handled, age of tankers, number of tanker port calls, and miles of pipeline. Although there is a large uncertainty in these estimates, they provide some perspective of the degree of oilspill risk contained in the proposed OCS activity.

Table 1.1. Exploration Time-Period Estimates for the Chukchi Sea (in months) (R. Herrera, personal communication, 1979)

	Exploratory Drilling Method	
	Gravel Island (with dredged gravel)	Mobile Rig (ice resistant cone structure)
Preferred Month for Sale	March-May	Jan-March
Permitting Time	8-12	8-12
Equipment Mobilization Time	12-15	36
Site Preparation Time	2-3	0
Elapsed Time to Spud	20-27	42
Preferred Month for Start of Exploratory Drilling	December 1 or August 1	August 15
Estimated Open Water Season	August 1 to October 1 (2 months)	July 15 to October 1 (2½ months)
Exploration Drilling Season	Dec-April and/or August-October	All Year
Comments	Helicopter access to island Dredged gravel necessary for construction	Rig construction concurrent with permit application

Table 1.2. Estimated Resource and Activity Scenarios for the Chukchi Sea (DOI 1979, 1980)

	Mean	Risked
Total Oil (billion barrels)	3.15	1.28
Peak Oil Production-yr (million bbl/day)	not stated	.449-1994
Total Gas (trillion cubic feet)	8.34	3.96
Peak Gas Production-yr (billion cu.ft./day)	not stated	.98-1994
Million Acres Offered/# Sales	0.6/1	0.6/1
Exploratory Wells	4	6
Development/Producing Wells	400	208
Platforms	10	6
Statistically Probable # Oil Spills > 1000 bbl.	18.08	7.35
Oil Transportation[1]	P to T (to lower 48)	same
Gas Transportation[1]	P (to LNG facility) to T (to lower 48)	same
Possible Onshore Locations	Kotzebue Sound (marine terminal, LNG, support)	same

1. P=pipeline
T=tanker
LNG=Liquid natural gas

2. THE CHUKCHI SEA ENVIRONMENT

The Chukchi Sea is a region of numerous natural hazards. Sea ice, the most severe environmental hazard in the area, is present at least nine months of the year. Other natural hazards include subsea permafrost, gas-charged sediments, bottom sediment movement and instability, extreme cold, severe storms and storm surging. However, the Chukchi Sea is virtually aseismic and has no volcanic hazards. The nature of the Chukchi Sea environment and the hazards it presents is discussed in the following subsections.

2.1 The Chukchi Sea Coast

The coastal area of the northeastern Chukchi Sea that is bounded by the Area of Call for proposed OCS Sale 85 extends from 68° 30'N. to 71° 0'N. This area extends from slightly north of Point Hope on the Lisburne Peninsula to the locality of Sinaru to the south of Point Barrow. The coast along this area varies from mountainous to flat and is, in the main, uninhabited and desolate. Major geographic features are shown in Figure 2.1. Information on this coast is contained in the United States Coast Pilot 9 (USDOC,1974).

In the southern area near Cape Lisburne the land is mountainous. Because of their bedrock formation, these coastal mountains slope down to the water in a series of steep bluffs and rugged shore cliffs with loose talus material at their base. Cape Lisburne, itself, is a barren brown mountain of sedimentary rock 849 feet in elevation, whose steep cliffs are summer rookeries for vast numbers of sea birds. Catabatic winds often rush down the mountains in gusts of great speed and varying direction. Mt. Hamlet, lying behind Cape Lisburne, is the highest promontory of the area, reaching in elevation of 2034 ft.

From Cape Lisburne, the coast turns abruptly eastward. The land is lower and the hills, which are composed of softer sedimentary rocks such as shales and sandstones, become rounded and rolling and slope to the sea. This is the Arctic Foothills physiographic province (Figure 2.2), with elevations of about 600 feet. Cape Sabine, 35 miles east of Cape Lisburne, is a series of east-

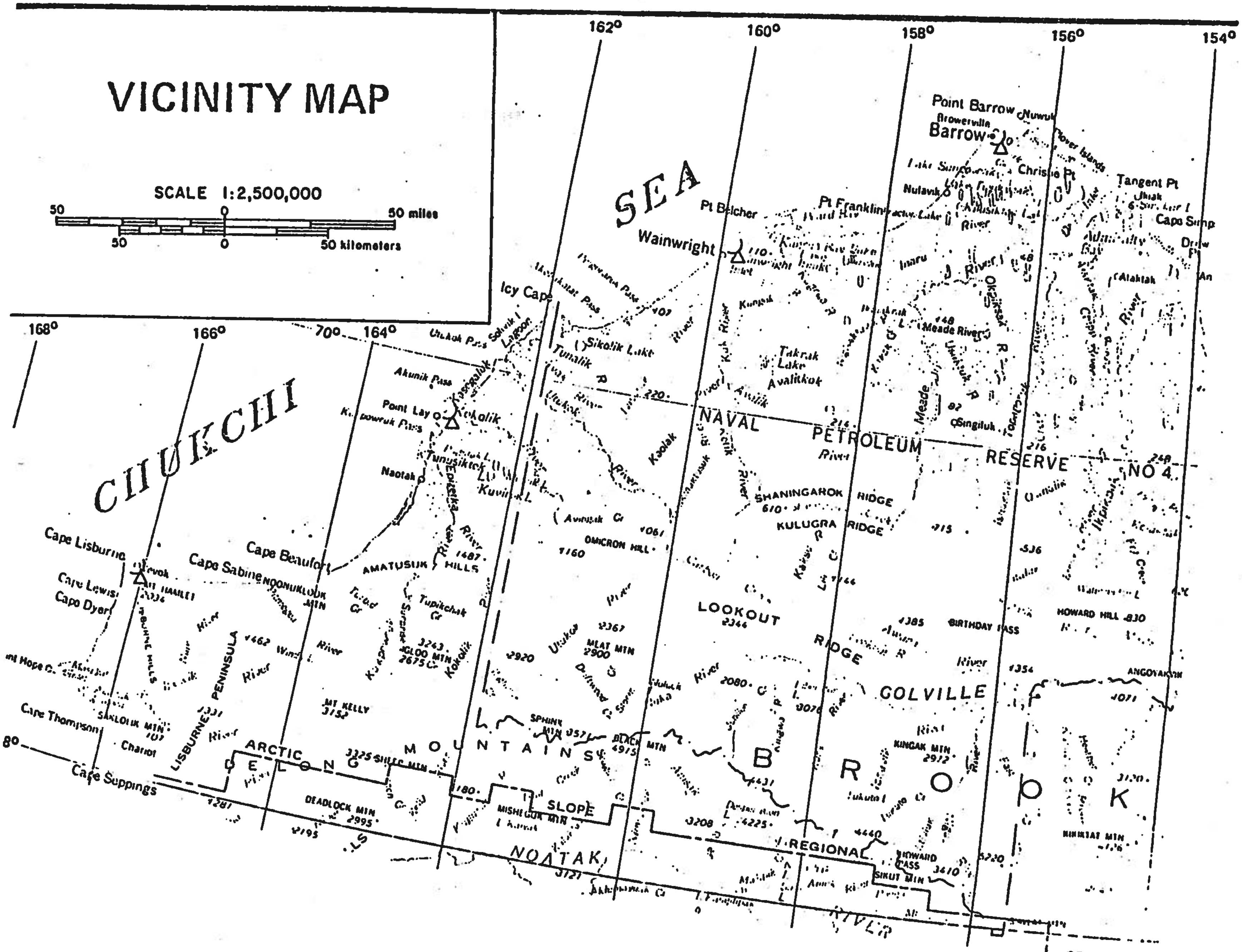


Figure 2.1. Map showing the coast line and geographic features of northwest Alaska bordering the Chukchi Sea (from AEIDC, 1978).

west trending ridges of the Amatusuk Hills that terminate at the coast in bluffs. Cape Sabine is the outer end of one of these ridges that projects only slightly from the general plane of the coast.

From Cape Sabine, the land continues in a rolling fashion until Cape Beaufort, a dark mountain on the coast 52 miles northeast of Cape Lisburne. Beyond this point the mountains recede inland and the coast continues northeastward in low relief. The entire remainder of the coast is the Arctic Coastal Plain, a region where the shoreline is actively retreating. This shoreline retreat can be up to 6 meters/yr., even where sheltered from direct wave action. Despite this rapid retreat, actual coastal features remain much the same because the mainland surface is nearly level. The net effect of this coastal retreat has been to form generally smooth coastlines with the eroded sediments deposited as beaches, spits, and barrier islands.

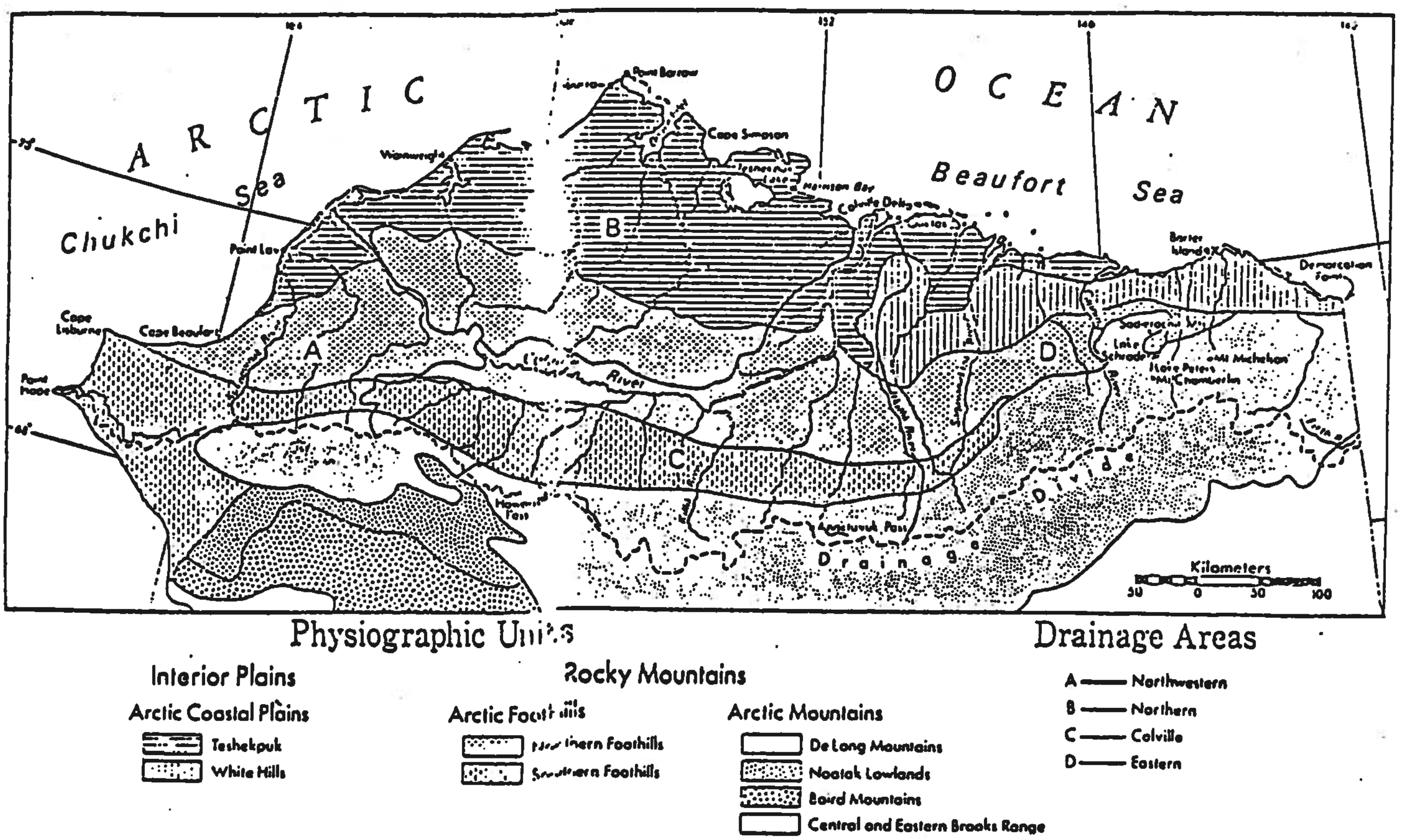


Figure 2.2. Map of the North Slope of Alaska showing the principal physiographic units and drainage areas of the region. The Chukchi Sea coast grades northward from the mountainous to rolling Arctic Foothills to the flat and poorly drained Arctic Coastal Plains (from Walter, 1974).

About 18 miles northward of Cape Beaufort is the southern extremity of Kasegaluk Lagoon, which extends for nearly 150 miles northward along the coast toward the settlement of Wainwright. Separating the lagoon from the ocean is a narrow sand barrier elevated only a few feet above sea level. The lagoon itself is occupied by extensive marshes, and south of Icy Cape it is reportedly unnavigable, even by native skin boats. The land behind the lagoon is low, with occasional small bluffs and low rolling terrain behind them. Four rivers (the Kukpowruk, the Epizetka, the Kokolik, and the Utokok) and several streams flow into the lagoon waters south of Icy Cape. The Utokok River is the largest drainage basin directly entering the Chukchi Sea. Its length is about 212 miles, and has a drainage area of 2700 square miles.

Point Lay is a slight bend in the barrier beach 49 miles from Cape Beaufort. The village of Point Lay (estimated population of 57 in 1977) is located on the beach 3 miles south of the point. There is no deep channel through Kasegaluk Lagoon to Point Lay, and vessel anchorage is restricted to 1.5 miles off the village in 6 fathoms of water.

Icy Cape, 40 miles northeast of Point Lay and 125 miles from Cape Lisburne, is a sharp turning point in the low, flat barrier beach that separates Kasegaluk Lagoon from the mainland. Blossom Shoals, which extend 6 to 8 miles off Icy Cape, are a number of seafloor ridges that parallel the coast. These sandy shoals show evidence of ice scour and probably shift from year to year.

North of Icy Cape the mainland sediments are mostly of marine origin and consist of lenses of silt, sand, and gravel with some clay. The upper 1 to 30 feet of soil is mostly permafrost-bonded silt with ice lenses and layers of peat. All of the sediments are frozen and the fine-grained materials contain much ice. This frozen ground also contains many masses of relatively pure ice usually within 1 to 5 feet of the surface.

The waters of Kasegaluk Lagoon north of Icy Cape are somewhat deeper than those to the south. Mid-channel depths are 9 to 11 feet. This part of the lagoon is normally ice-covered from mid-September to mid-July. There are two narrow channels through the barrier islands in the lagoon. Akoliakatat Pass, 12 miles north of Icy Cape has an entrance depth of about 7 feet, while Pingorarok Pass, 22 miles east of Icy Cape, has a depth of 5 feet.

Wainwright Inlet, 39 miles east-northeast of Icy Cape is the entrance to Wainwright Lagoon. The entrance is shallow, about 6 feet at normal water level, and the channel is narrow and winding. Waters inside the lagoon are generally 1 to 2 fathoms deep. The Kuk River empties into the head of Wainwright Lagoon. The river bottom is smooth with depths from about 10 feet at the lagoon entrance to 4 feet some 30 miles up river. The village of Wainwright (population 398 in 1977) is located on the beach about 2.5 miles northeast of the entrance to Wainwright Lagoon.

Point Franklin, 70 miles east-northeast of Icy Cape, is at the eastern end of a barrier sand beach that extends 8 miles along the northeastern side of Peard Bay. A mile east of Point Franklin is the northern extremity of the narrow barrier Seahorse Islands. The largest of these islands has an elevation of 20 feet, the highest of the coastal barrier beaches and islands.

Peard Bay, behind the barrier beaches of Point Franklin and the Seahorse Islands, is a semi-enclosed water body about 10 miles wide and 20 miles long with uniform depths of about 20 feet over most of its area. Bottom sediments in the sheltered bay are mud and clay. At the innermost (southwest) end of Peard Bay is Kugrua Bay, into which empties the Kugrua River. This bay has depths of 4 to 12 feet.

From Peard Bay north and east toward the northern end of the Chukchi Sea coast at Point Barrow, the coastline is rimmed with steep mud bluffs 25 to 90 feet high, which are furrowed by numerous small streams. These bluffs are formed by direct wave action on the perennially frozen shoreline sediments, causing slumping of large blocks of frozen coastal material. The highest of these bluffs is Skull Cliff, 20 miles east of Peard Bay. From there to the northern boundary of the Sale 85 Call Area, the coast has no projecting points or shoals and the water is fairly deep. The 5-fathom curve lies 0.5 to 1.0 mile from shore; however, depths may vary as much as a fathom from year to year because of ice gouging.

2.2 The Chukchi Sea Shelf

The Chukchi Sea Shelf is thought to be a submerged extension of the Arctic Foothills and Arctic Coastal Plain geomorphic structures that formed a dry intercontinental land connection of low mountains that existed until about one million years ago (Ostenso, 1968). This low mountain barrier was subsequently reduced by erosion to a peneplain-type feature that has been further modified by subsequent periodic rises and falls in sea level. Relief features have been substantially obscured by scouring and sediment deposition to the present time.

2.2.1 Bathymetry

The seafloor of the northeast Chukchi Sea is monotonously flat and relatively featureless (Figure 2.3). Water depths are shallow throughout (mostly less than 30 fathoms), and the contours are gentle. Depths within 30 miles of shore are usually less than 10 fathoms and remain less than 20 fathoms within 100 miles of shore except in the northernmost region where the 20-fathom depth approaches to within 10 miles of shore near Point Franklin. Nearshore depths are partially maintained by currents and altered by seasonal ice gouging. Storm actions shift sand spits and shoals considerably but there is little evidence of storm waves affecting deeper areas. Little else in the way of bathymetric features are present in this area. Detailed bathymetry can be found in NOS Chart 16005 (6th edition, 1976).

2.2.2 Seafloor Sediments

The sediments laying beyond the depth of wave action along the Chukchi Coast appear to be mainly relict and residual deposits of silt and sand (Figure 2.4). These sediments generally lack any depositional structure. The rich benthic fauna mixes the sediments and destroys any annual layering that might form (McManus, 1969).

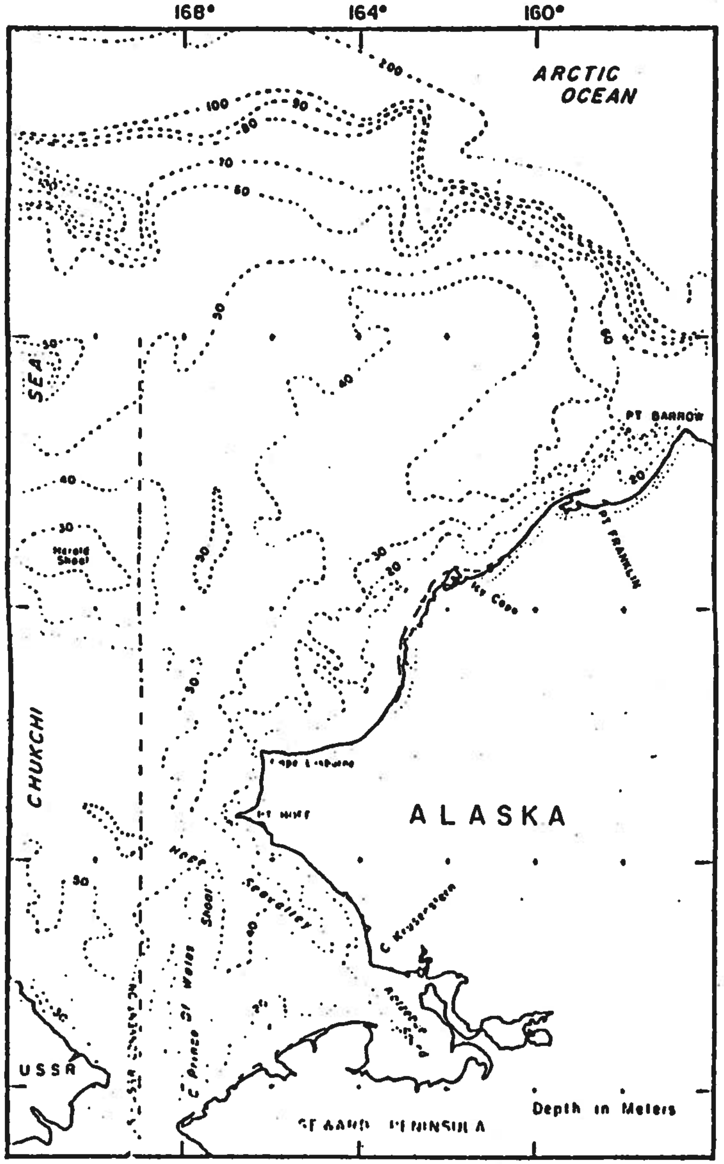


Figure 2.3. General bathymetry of the Chukchi Sea showing the shallow, relatively featureless condition of the sea floor. North of Icy Cape the 20 fathom (40m) contour approaches to within 10 miles of shore. The deepest water in this area is 32 fathoms (60m) located about 20 miles west of Point Franklin (from Sharma, 1979).

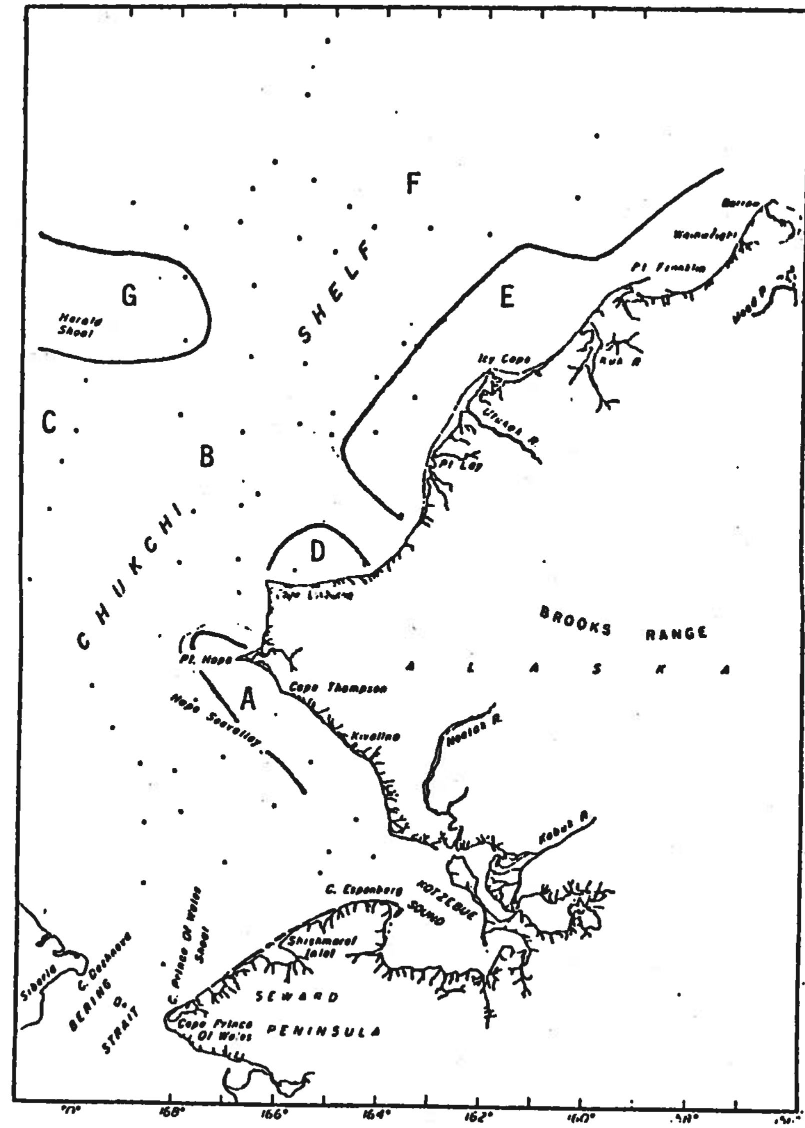


Figure 2.4. Sediment origin and composition on the Chukchi Sea Shelf. A=modern current-transported and current-deposited sand; B=modern silt; C=modern clayey silt; D=relict sand with gravel; E=relict and residual sediment; F=mixes sediment of ice-covered shelf; G=relict and residual sediment of Herald Shoal and Wrangel Island.

The seafloor sediments of the Chukchi Shelf are composed mostly of silt, sand, and gravel (Figure 2.5). Gravel deposits exist mainly as long narrow belts along the shore, as more expansive deposits at the base of the Cape Lisburne sea cliffs, and as isolated offshore patches. Sands predominate over most of the northeastern area to depths of 20 fathoms (60-80% of sediment composition) while silts are most common farthest offshore (40-60%). Clays form a relatively minor component of the seafloor sediments on the northeast Chukchi Shelf (less than 5% nearshore, to 35% offshore).

The sediment cover is often thin and patchy. In some areas its depth is reported to rarely exceed 10m and is frequently only 3-5m thick (Moore, 1964). In water depths greater than 25 fathoms, bedrock is frequently exposed with only local patches of sediment filling depressions.

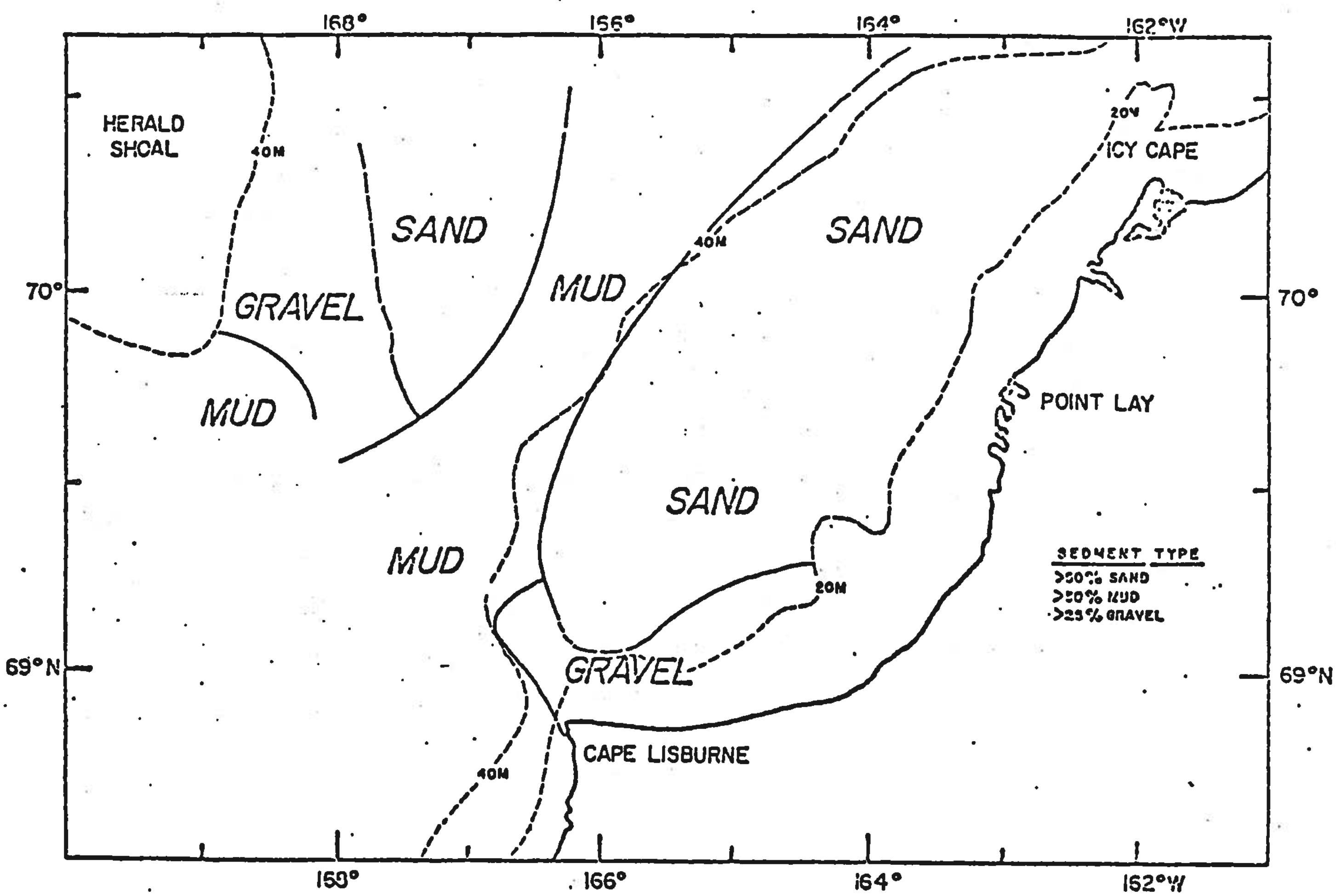


Figure 2.5. Bottom sediment composition of the Chukchi Sea Shelf from Cape Lisburne to Icy Cape. Sediment size classes are gravel = 2 mm+, sand = 0.6-2 mm, silt and clay (mud) = 0-0.6 mm. (From AINA, 1974).

2.3 Climate and Weather

Detailed information on the climate and meteorology of the Chukchi Sea coast can be found in Brower et al. (1977) and AEIDC (1975). The following summarizes this information.

The climate of the Chukchi Sea coast is cool in the summer and cold in the winter. The short summers are under the influence of maritime winds with much cloudiness, fog, frequent light precipitation, and continuous daylight. In winter, cloudiness decreases and cold northeasterly winds prevail along the coast. Average climatic conditions measured at the few recording locations in the northeast Chukchi Sea coast are given in Table 2.1.

Temperatures average -20°F to -10°F in the winter and +40°F to +50°F in the summer. The low winter temperatures are often worsened by wind chill factors equivalent to -60° to -100°F.

Year-round precipitation is light, averaging just over 5 inches annually, mostly as rain in July and August. The average annual snowfall on the coast is only 12 inches. A snow-cover is usually established by mid-September and persists until the following late June or early July.

Figure 2.6 shows the monthly variation in temperature, precipitation and snowfall at three Chukchi Sea locations (AEIDC, 1978).

Surface winds along the coast are fairly constant throughout the year. Winds are predominantly from east to northeast except for the stronger south winds associated with storms from the Bering Sea. A general yearly average is 10-15 mph, or 15-20 mph at more exposed locations. Wind speeds greater than 25 mph occur usually less than 20% of the time except during the windiest months of October and November. Maximum steady winds of 35 mph can occur any month and gusts occasionally attain much greater speeds. The predicted maximum sustained wind speed in the arctic region is 80 knots (90 mph). An extreme steady wind of 58 mph was reported from Barrow in March 1960.

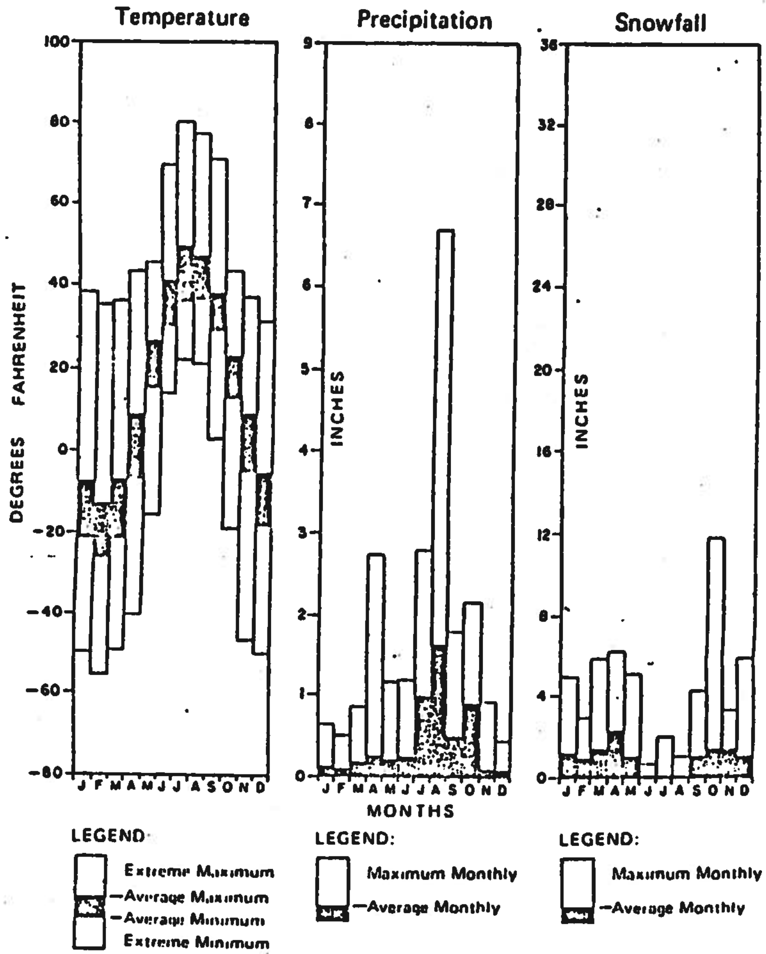
Cloudiness is most prevalent in summer and autumn, with low stratus overcasts and cloud ceilings less than 1500 feet. These overcasts result from low clouds and fog formed over the open water and moved onshore by the prevailing winds. These overcasts and low ceilings can persist for weeks. Cloudiness decreases in the winter when the surrounding water is frozen and fewer clouds form.

Fog is the most important visibility-limiting factor during the summer, while blowing snow reduces winter visibility. Fog occurs at least 90 days each year along the coast, primarily during the summer. Advection fog, caused by warm, moist air moving over the cold water or ice, occurs along the Chukchi Sea coast about 15-20 days per month during June-September. At Cape Lisburne, minimum horizontal visibility of less than one mile occurs 20-24 days/month during the summer, and 10 to 20 days/month during the winter.

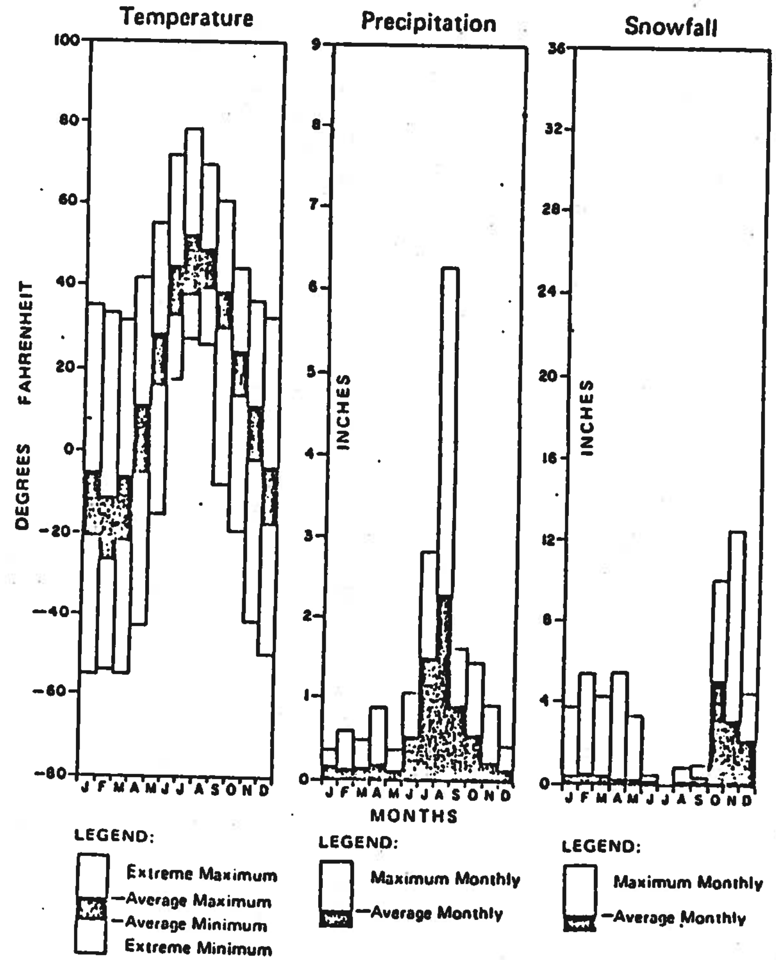
Table 2.1. Selected Climate Data for Chukchi Sea Locations.

	Cape Lisburne	Pt. Lay	Wainwright	Barrow
Temperature, °F				
Mean Monthly High	+50/July	+53/July	+48/July	+45/July
Record High	+73	+79	+80	+78
Mean Monthly Low	-15/Feb	-26/Feb	-26/Feb	-24/Feb
Record Low	-47	-56	-56	-56
Precipitation, inches				
Mean Monthly High	2.7/Aug	2.3/Aug	1.6/Aug	1.1/Aug
Mean Monthly Low	0.3/Apr	0.1/May	0.1/Feb	0.3/Mar
Mean Annual	11.3	7.0	5.1	4.9
Mean Annual Snowfall	49.8	20.6	11.8	28.9
Surface Winds				
Mean Direction/Speed (kts)	E/12	NE/?	E/?	E/12
Max. Direction/Speed	SE/70	?	?	?/58

? = unrecorded



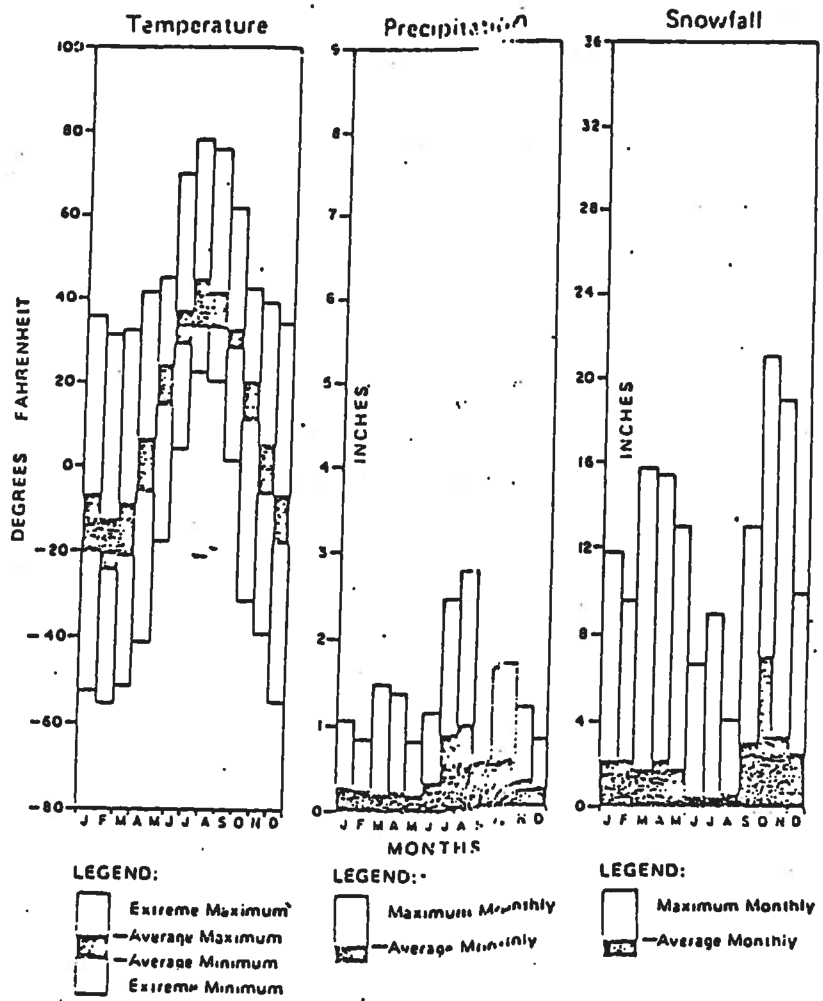
A. Point Lay



B. Wainwright

Figure 2.6. Monthly mean and extreme values of temperature, precipitation and snowfall at three Chukchi coast villages. A. Point Lay, B. Wainwright, C. Barrow (from AEIDC, 1978).

The Chukchi coast receives continuous daylight from May through August. At Barrow, the sun never sets for 84 days between May 10 and August 2. During the winter there are 67 days, from November 18 to January 23, when the sun does not rise above the horizon. In spring and fall the ratio of daylight to darkness is continuously changing. Twilight hours are important for light during the intervening seasons. Twilight lasts for to 6 to 7 hours in late November and early February, but is reduced to 3 hours by December 21, the shortest day of the year. Annually, the Arctic receives about an equal amount of daylight as lower latitudes. However, because the sun's rays reach the Arctic at a low angle, the amount of incident radiation received is much less.



C. Barrow

Figure 2.6. (Continued)

2.4 Physical Oceanography

The waters of the eastern Chukchi Sea originate from a northward flow of Bering Sea waters through the Bering Strait. These waters are derived from three sources: Alaskan Coastal Water, the Bering Shelf Water, and the Anadyr Shelf Water. As they flow northward across the 700 km expanse of the Chukchi Sea, these water masses undergo considerable modification before eventually entering the Arctic Ocean as a subsurface water layer.

The circulation patterns of the Chukchi Sea are only generally understood. There is a northward flowing coastal current composed of Alaskan Coastal Waters, which flows along the northeastern side of the Chukchi Sea, paralleling the bottom contours. In the summer, near the coast, this water is identified as a warm, low salinity water which generally occupies the entire water column of nearshore areas. Farther from shore, the Alaskan Coastal Water often forms a warm surface water layer up to 25 m in depth. The low salinity of this water mass results from the large freshwater discharge of Alaskan rivers into the Bering Sea and Kotzebue Sound. This warm coastal current has been traced as far north as the Colville River delta in the Beaufort Sea (Paquette and Bourke, 1974).

Bering Shelf and Anadyr Shelf Waters lose their separate identity by mixing within short distance of passing the Bering Strait and enter the Chukchi Sea as a water mass termed the Bering Sea Water by Coachman et al. (1975). This water (Figure 2.7) covers the central portions of the Chukchi Sea and is characterized by a temperature of at least 2°C and a salinity of greater than 32°/oo. Near the coast, Bering Sea water may occur as a subsurface water layer beneath Alaska Coastal Water.

An amount of high density residual water from the previous winter remains in the Chukchi Sea throughout the summer. This water is characteristically colder and more saline than either Bering Sea Water or Alaskan Coastal Water, and tends to occupy the bottom layer of the deeper shelf areas.

Since practically all information available on water circulation is for the summer period, the above circulation and water mass description may be valid only for that season. Classification of currents and water masses during the winter is lacking.

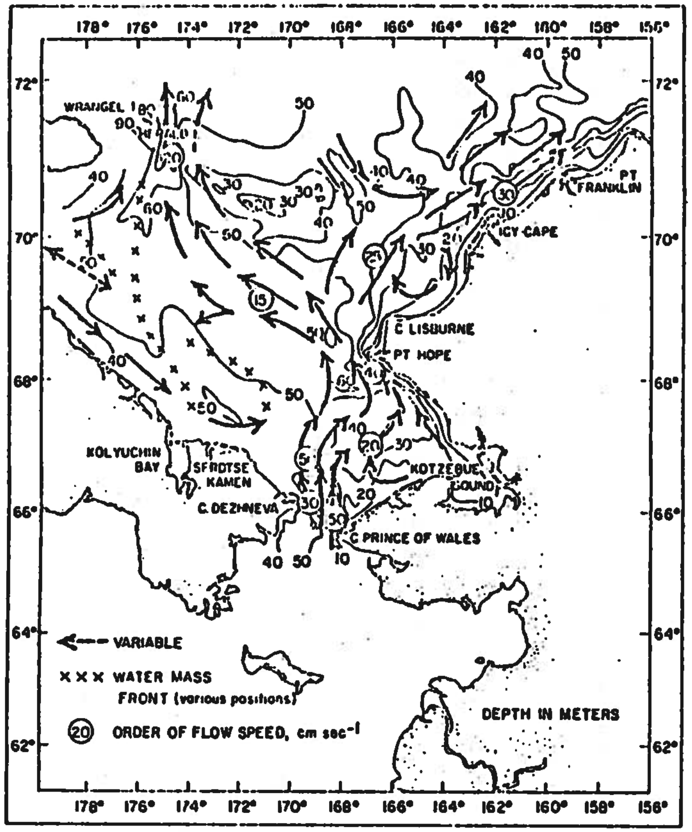
Nearshore currents in the Chukchi Sea are greatly influenced by wind, coastal configuration, and bottom topography. Persistent northerly winds may stop or reverse their normally northward flow. Local currents and their response to storms are not known. This information is essential for oilspill trajectory modeling.

The average volume of water flow through the Bering Strait into the Chukchi Sea is 1.7 X 10^6 m^3/sec. Current speeds are highest in the eastern channel of the Bering Strait, where speeds in excess of 150 cm/sec (0.9 knot) are common. Nearshore along the Point Hope - Cape Lisburne Peninsula, the current averages about 40 cm/sec but can reach 150 cm/sec. Past Cape Lisburne, the flow remains high and relatively constant, but the current separates with the Alaska Coastal current continuing along the coast toward Pt. Barrow and Bering Sea water flowing predominantly north-northwest (Figure 2.7). The northward flow of Alaskan Coastal and Bering Sea Water combine with the westward drift along the arctic pack ice margin to establish a broad counterclockwise circulation pattern in the Chukchi Sea (Figure 2.8).

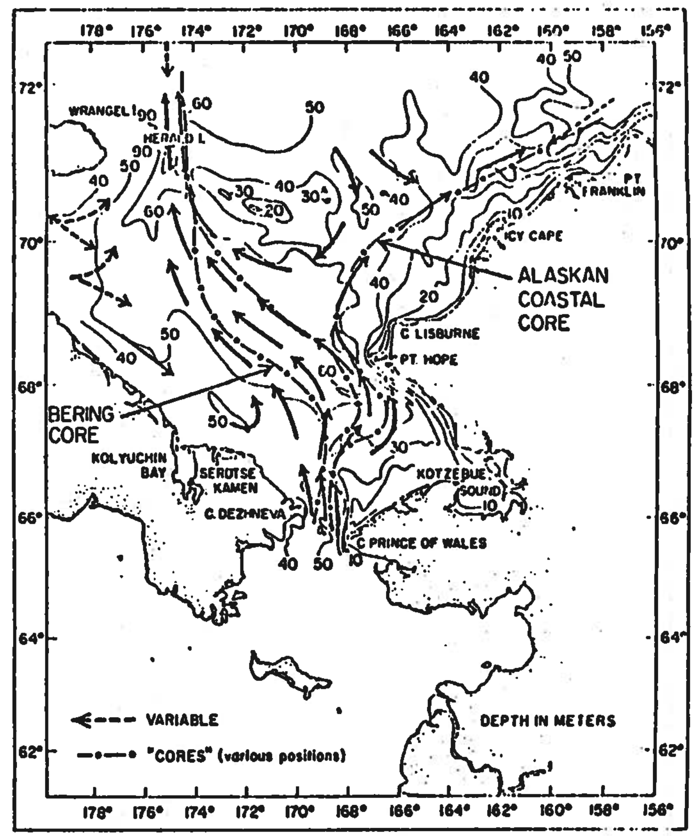
Along the northeast Chukchi Sea coast, surface currents average 20 to 30 cm/sec. A weak but apparently persistent anticyclonic gyre, at least through the summer, occurs northeast of Cape Lisburne. This gyre causes some local upwelling and an increase in biological productivity in this area. Another anticyclonic eddy reportedly occurs near Point Franklin.

A few current measurements that were taken in the winter through the ice southwest of Cape Lisburne (Coachman and Tripp, 1970) showed a northward transport, as in the summer, but the flow was decreased to between a fourth to a third of the summer transport values.

Tides are semidiurnal in the Chukchi Sea, but the tidal range is small. At Kotzebue the maximum range is 1.5 m. Normal tides at Point Barrow are 0.5 feet. Tidal action has a minor influence on beach scour by sea ice.



Upper Layer Flow



Lower Layer Flow

Figure 2.7. Schematic of flow in the Chukchi Sea in the summer. Dotted arrows indicate variable currents. Various positions of water mass fronts are indicated. Circled numbers are estimated current speeds in cm/sec. (from Coachman et al., 1975).

2.5 Storm Surges

Much of the Chukchi Sea coast north of Cape Sabine is susceptible to storm surges, i.e., increases in sea level over that of normal tides, that are usually caused by intense storms and low pressure systems. Along the Chukchi coast storm surges are possible from mid-June through November, when the sea ice cover is minimal. Most severe storm surges have been found to occur from storms moving northward through the Bering Strait toward the Arctic (Wise and Searby, 1977). October is the month for most frequent storms of this type. Storm surges are a recurrent hazard to shore-based and shallow-elevation nearshore facilities that may be sited along the coast of the Chukchi Sea.

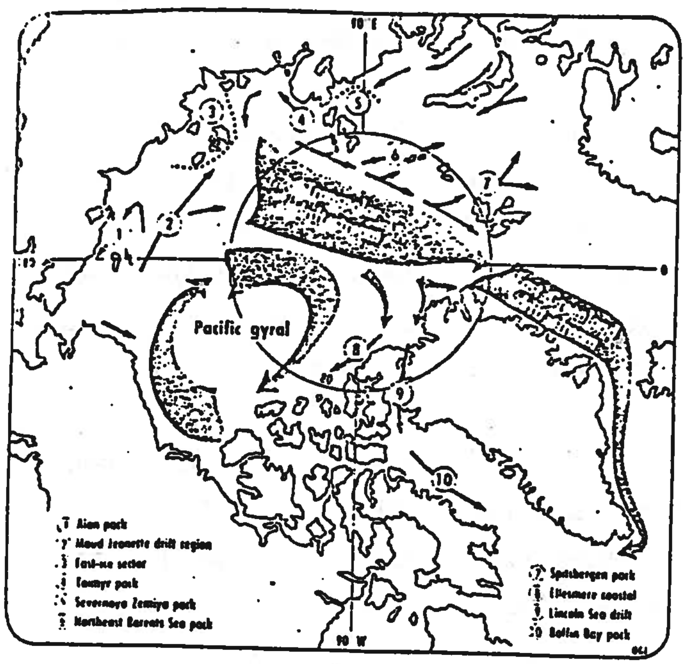


Figure 2.8. Major flows and polar drift patterns of the Arctic Ocean (from Kovacs and Mellon, 1974).

The most severe storm recorded along the Chukchi Sea coast (October 3-5, 1963) caused extensive storm-surge damage at Barrow. Winds, during this storm, were westerly with sustained speeds of 42 knots and gusts to 65 knots. A storm surge estimated at 3 meters with 3 m high waves resulted. Coastal areas were inundated for distances up to 1200 meters from shore and up to a mile inland where the shore was backed by lakes. At Wainwright and Pt. Lay the storm surge height was 2.7 to 3 meters.

2.6 Sea Ice

The Chukchi Sea is ice-covered for most of the year. Total ice coverage in the Chukchi Sea averages 98-99% during January - May. Ice coverage is least in the late summer months of August to October, but still averages 40% of the sea surface south of Icy Cape and 80% north of Icy Cape. First-year ice (fast ice and seasonal pack ice) forms 42 to 60% of the winter ice cover. Multiyear ice (i.e., polar pack ice) is most abundant in the area north of Icy Cape. Between 25-27% of the winter ice cover is deformed ridged ice. General ice conditions in the northeast Chukchi Sea are summarized in Table 2.2.

Freeze-up generally begins by late September or early October and breakup occurs late the following June or in July (Table 2.3). The first continuous fast-ice sheet is usually formed nearshore by mid to late October. This fast-ice sheet continues to extend and thicken throughout the winter. In general, stable land-fast ice out to the 15 m isobath is formed by December, and out to the 30 m isobath by March-April.

North of Icy Cape, the fast ice freezes to thicknesses of 1.8 to 2.4 m. South of Icy Cape, the normal winter thickness is 0.6 to 1.2 m. The fast ice zone is generally most extensive between Cape Lisburne and Point Lay where shallow waters are extensive, and narrowest north of Icy Cape where bottom depths increase more rapidly and the shelf is vulnerable to pack-ice incursion. The pack ice usually lies about 10 miles offshore from Icy Cape north toward Point Barrow. Beyond this point the edge of the pack ice swings northwestward toward Wrangel Island. Pack ice incursion is frequent along the coast as far south as Icy Cape.

The pack ice lasts all year. Normally, polar pack ice is 3 to 4 m thick at the end of winter and decreases to 1.8 to 3 m thick during the summer. In years of maximum ice retreat, the polar ice pack lies well north and west of the Chukchi Sea coast. The heavy pack ice begins to close in on the coast by October with new ice forming along its margin and in open water areas between the pack ice and the shorefast ice. In heavy ice years, the pack ice lays close to the Chukchi coast and can unexpectedly be blown inshore even in midsummer (Figure 2.9). When it is blown ashore, the deep (up to 20m) ice keels on the bottom of the ice sometimes gouge deeply (5m) into the sea floor.

During the winter and spring, the Chukchi Sea ice is more dynamic than Beaufort Sea ice. The Beaufort Sea has a large area of stable landfast ice, often with an even larger area of immobile pack ice attached to it. Along the Chukchi coast there is an extremely active flaw zone and lead system between the fast-ice and the moving pack ice (Figure 2.10, 2.11). This lead system often extends from Pt. Barrow to Cape Lisburne and new ice in this flaw zone is continually being formed, detached, piled-up, and transported southward. In some years, the flaw zone may exceed 50 km in width near its southern end (Burns et al., 1977). The pack ice is continually in motion (Figure 2.12). A major reason for this dynamic condition is the opportunity for ice in the Chukchi Sea to be transported southward and out through the Bering Strait.

Shear ridges are formed where blocks of sea ice are slid, broken, pushed, and packed together in the Chukchi Sea. This most frequently occurs at the boundary between the fast ice and the moving pack ice. These shear ridges generally have a sail height to keel depth ratio of 1:4.5, but this ratio can vary from 1:3 to as much as 1:9. Throughout the winter and early spring ice movements are creating large and massive shear ridge systems. These shear ridges are most prevalent along the shoals that extend seaward from capes and headlands. The ridging is particularly extensive in the nearshore area of the coast north of Icy Cape and in the offshore north of Cape Lisburne (Figure 2.13).

Table 2.2. Mean Sea Ice Conditions in the Northeastern Chukchi Sea in Selected Months of the Year (AEIDC, 1975)

	Feb	May	Aug	Nov
First Year Ice Thickness, inches	35	35	10	20
Multi-year Ice Thickness, inches	90	96	72	78
Ratio of First Year:Multi-year	0.9	0.8	0.5	0.7
Coverage, %	95	70	10	60
No. Pressure Ridges/Nautical mile	16	16	2	11
Ave. Pressure Ridge Thickness, feet	30	25	20	20

Table 2.3. Freezeup and Breakup Dates for Coastal Locations on the Chukchi Sea. (AEIDC, 1975).

	Freezeup			Breakup		
	Average	Earliest	Latest	Average	Earliest	Latest
Point Hope	Nov 11	Oct 6	Dec 19	June 20	May 30	July 8
Cape Lisburne	Oct 29	Oct 13	Nov 11	July 15	June 18	July 16
Point Lay	Nov 4	Oct 12	Nov 27	June 24	May 20	July 10
Wainwright	Oct 2	Sep 16	Oct 25	June 29	June 7	July 26
Barrow	Oct 3	Aug 31	Dec 19	July 22	June 15	Aug 22

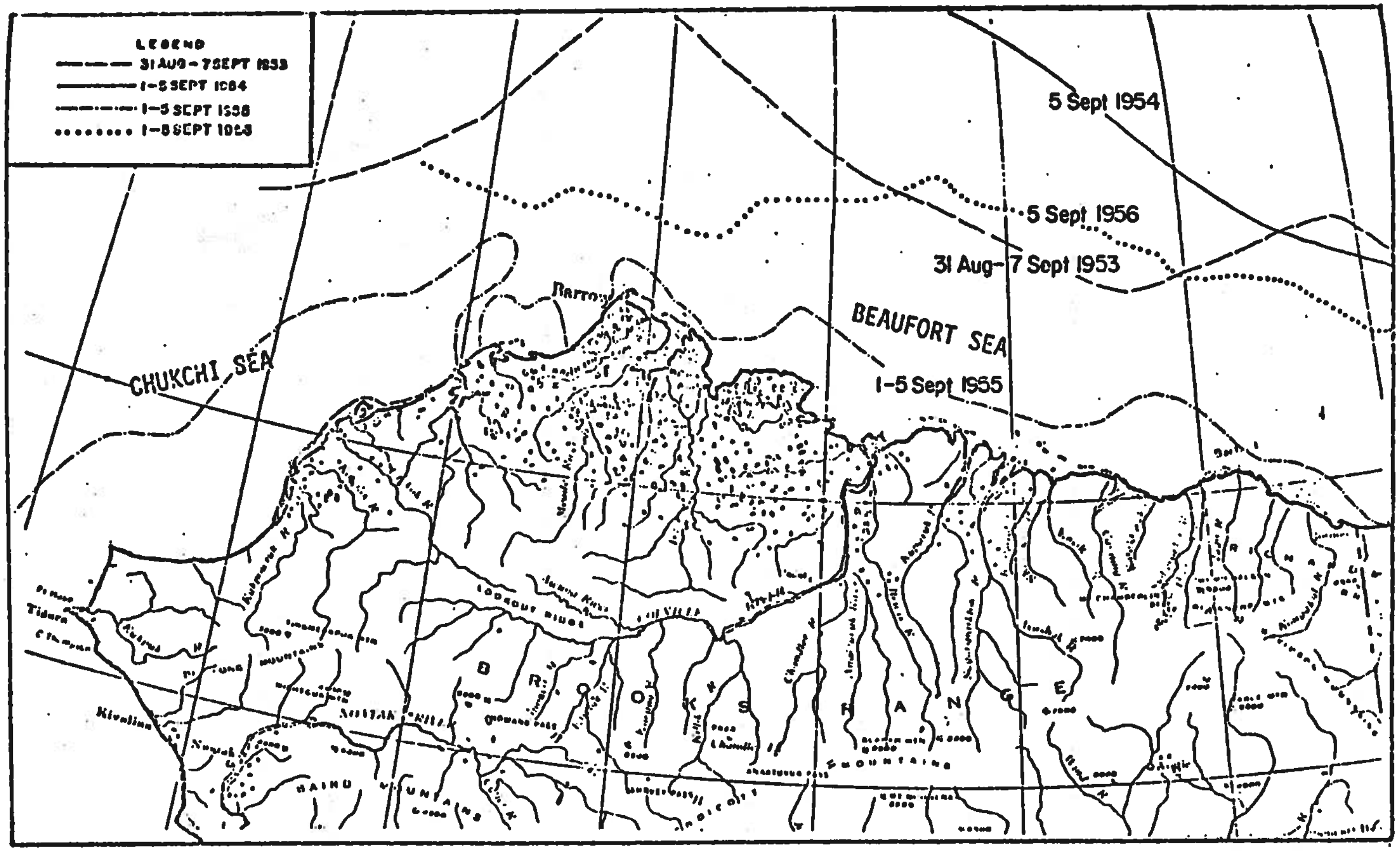


Figure 2.9. Comparison of polar pack boundaries in summer for selected years. In years of minimum ice retreat, the pack ice remains in the Chukchi Sea and may be blown ashore (i.e. 1955). In years of maximum ice retreat, the pack ice edge is well north and west of the area during the summer (from AINA, 1974).

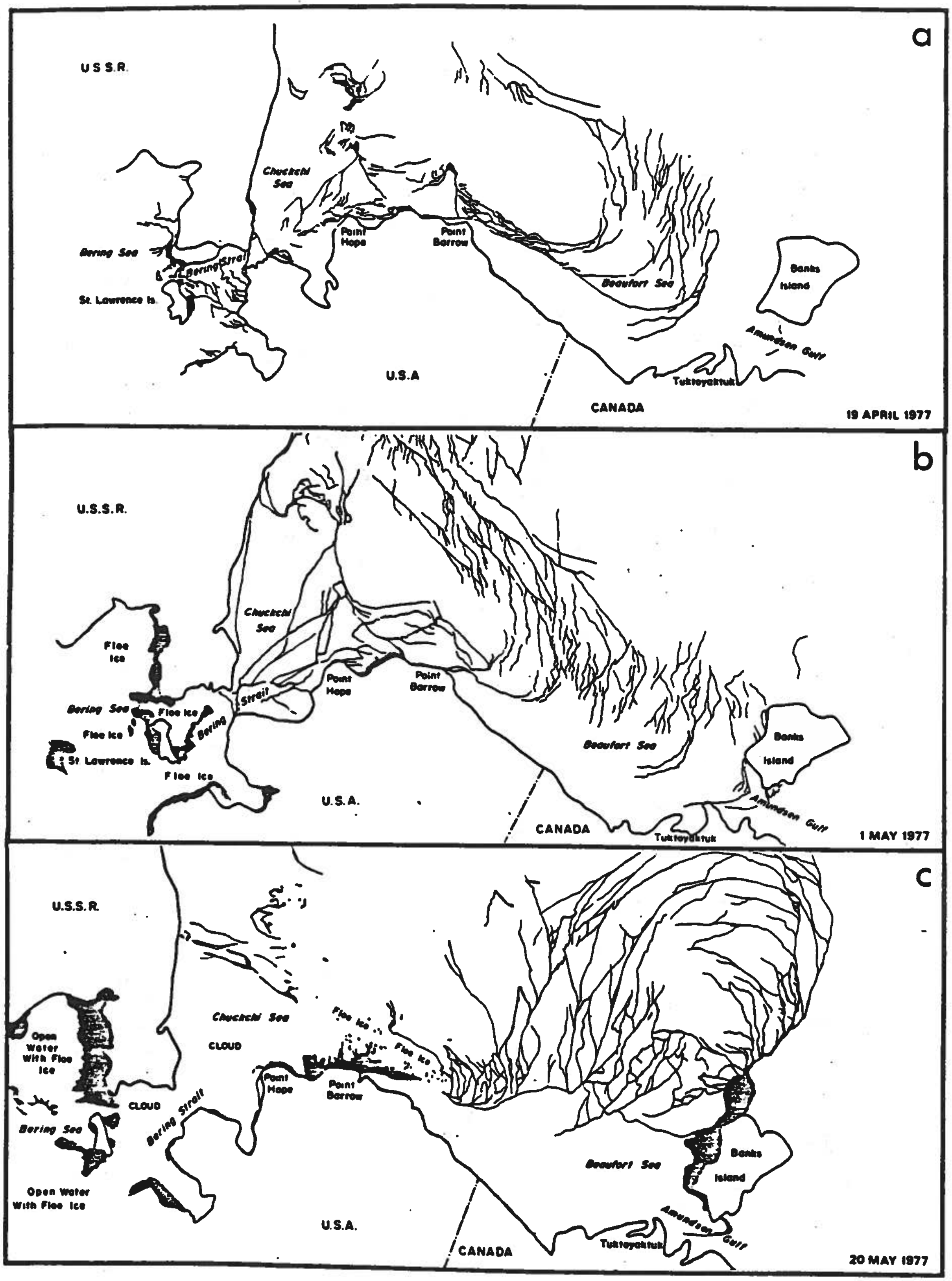
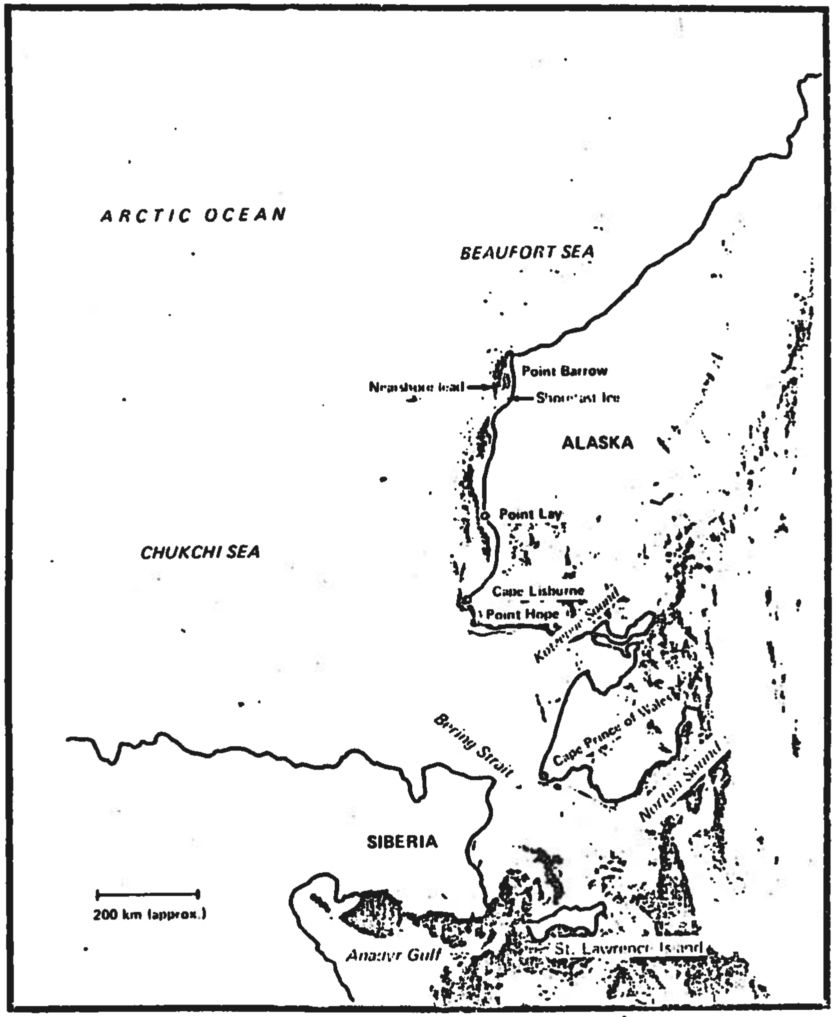


Figure 2.10. Pattern of lead development in the Bering, Chukchi, and Beaufort Seas, April and May 1977. Drawn from NOAA satellite imagery; differences in proportions between drawings are due to differences in satellite position (from Braham et al., 1980b).



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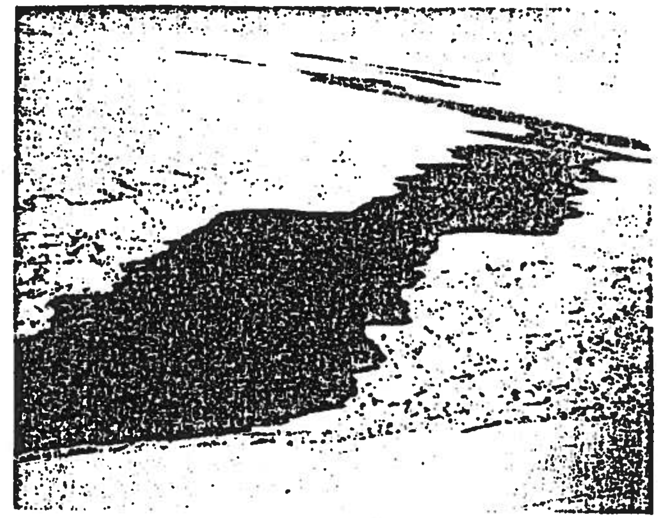


B

Figure 2.11. Ice leads in the Chukchi Sea. A) NOAA satellite image, 26 April 1978, of the spring lead system which forms from the Bering Strait to Point Barrow. Light areas are ice, dark areas are water or thin ice (newly refrozen lead) (from Braham et al., 1980b). B) Recurring winter lead off Point Barrow. Such leads are common along the Chukchi Sea coast when the seasonal pack ice drifts away from the edge of the fast ice. At times these leads may open 30 km or more wide (from Kovacs and Mellor, 1974).

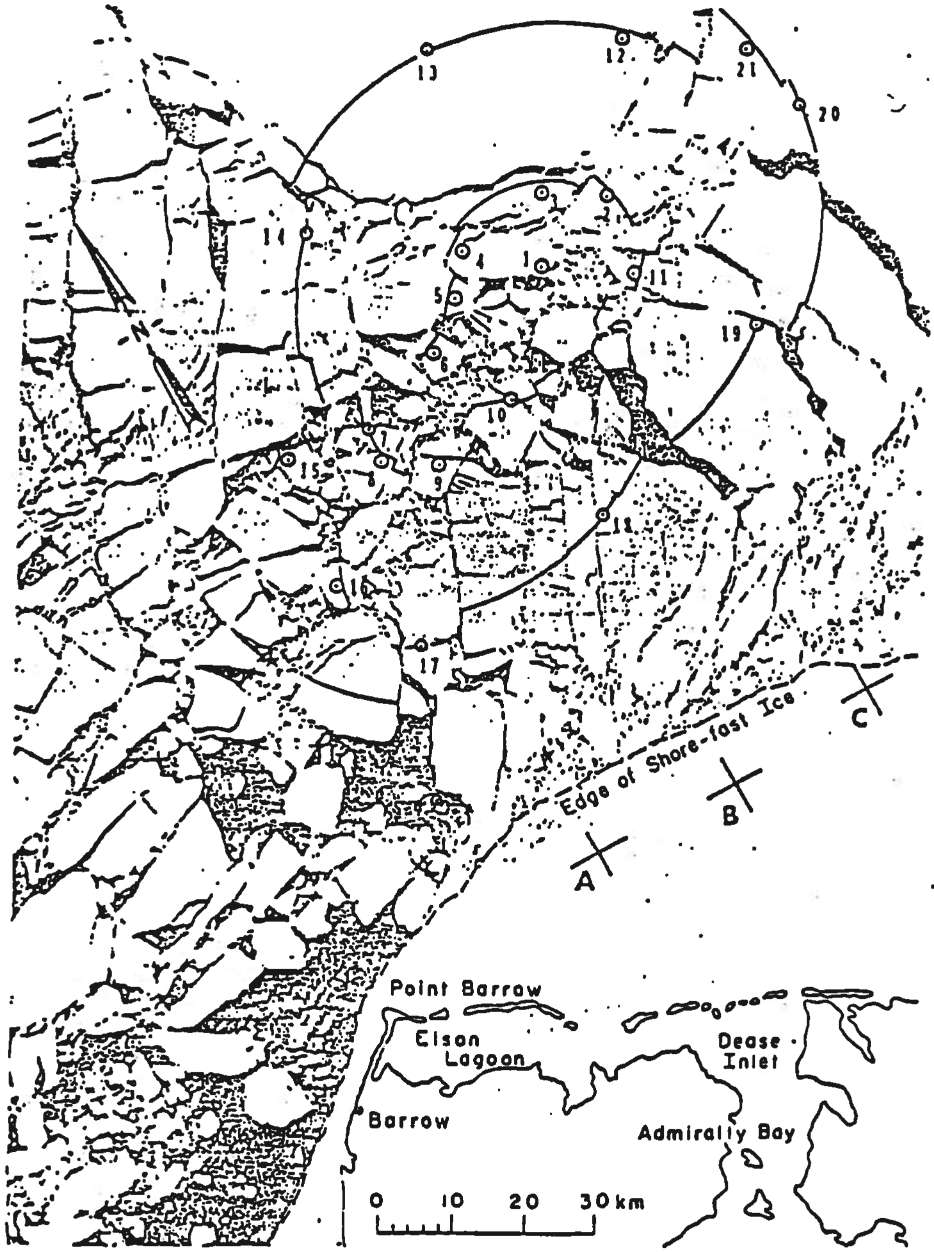


Figure 2.12. Satellite image showing pack ice along the shear zone northeast of Point Barrow in March. The circle grid indicates the movement and deformation of the pack ice after a 3 day period. The shorefast ice zone and an outline of the coast is shown in the lower right corner (from Hibler et al., 1974).

Pressure ridges differ from shear ridges in being formed by the compression of adjacent pack ice sheets with an accumulation of blocks of ice both above and below the abutting ice floes. These pressure ridges may be free-floating or grounded if in shallow water. Both types of pressure ridges are frequent in the Chukchi Sea, and sail heights of 18 to 20 feet are found. In the north-eastern Chukchi Sea, the frequency of pressure ridges is high, about 16 per nautical mile (Weeks and Kovacs, 1977). Average ridge thickness in February (including sail and keel) is 30 feet. The frequency of ridge sails during February 1976 surveys in the eastern Chukchi Sea is shown in Figure 2.14. Figure 2.15 illustrates the general features and stages of development of the fast ice and seasonal pack ice zones.

Breakup occurs in late June-July. Commencing in late May or early June, river breakup causes estuarine flooding of the shorefast ice. Continued warming and summer insolation leads to melt pond formation on the ice by early June. The ice continues to thin and weaken and looses its attachment to shore through June. Open water begins to form near river mouths and embayments and grows in extent. Eventually winds, storms, or water currents dislodge the fast ice, and breakup occurs usually in late June (see Table 2.3). This marks the beginning of the "open season". Scattered leads open along the coast and the pack ice recedes offshore and begins its gradual disintegration.

As the ice decreases in concentration it drifts northward towards the Arctic Ocean as it breaks up. By July there is generally a navigable lead opened from Cape Lisburne to Point Barrow. This lead increases in width through August. August and September are the months with least sea ice concentration in the Chukchi Sea and because the coastal area is generally free of fast ice to Point Barrow, these are the best months for navigation. The north-setting Alaska Coastal Current usually keeps the Chukchi Coast free of ice through September. After September, freeze-up and the incursion of the pack ice prevents further shipping, other than for ice breakers.

Ice conditions during the open season can vary considerably from year to year. Numerous pieces of floating ice and grounded ice blocks may persist year-round, and the annual and multiyear pack ice can be pushed back into nearshore waters by changing wind conditions. During August ice concentration in the northeastern Chukchi Sea south of Icy Cape averages 10% of the sea surface.

2.7 Permafrost Conditions

Although offshore permafrost is known to occur under the coastal waters of the Chukchi Sea, very little is known of its areal extent, thickness, or physical characteristics. Some investigators believe that onshore permafrost does not extend seaward more than a few hundred yards from shore (Lachenbruch et al., 1966). Offshore subsea permafrost has been found, however, in the Alaska Beaufort Sea (OCSEAP, 1978). Any subsea permafrost that may be present farther from shore is believed to be remnant permafrost originally formed in the subaerial environment during times of lower sea-level stands (AINA, 1974). The depths and thickness of this relict subsea permafrost would be determined by the equilibrium between thermal regimes, heat flow, bathymetry, geomorphology, and thermal and physical properties of the subject environment.

Except for some work performed in the Barrow area, there have been no reports of offshore drilling to evaluate permafrost in the region. Permafrost could pose problems to the laying of drilling casing, burial of pipelines, and placement of foundations, especially in the nearshore zone. The potential areas for subsea permafrost in the northeast Chukchi Sea and the Beaufort Sea are shown in Figure 2.16.

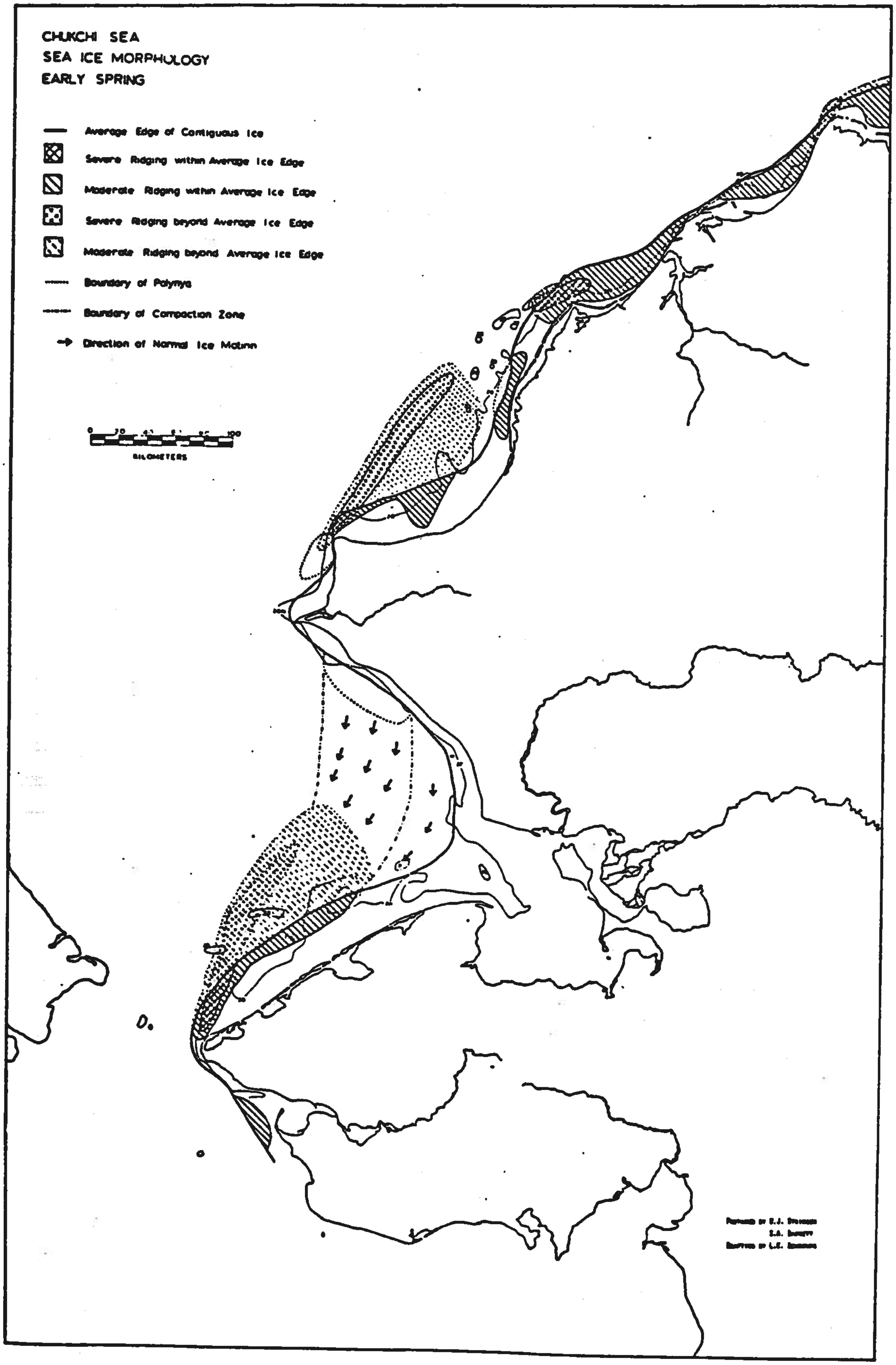


Figure 2.13. Legend Opposite

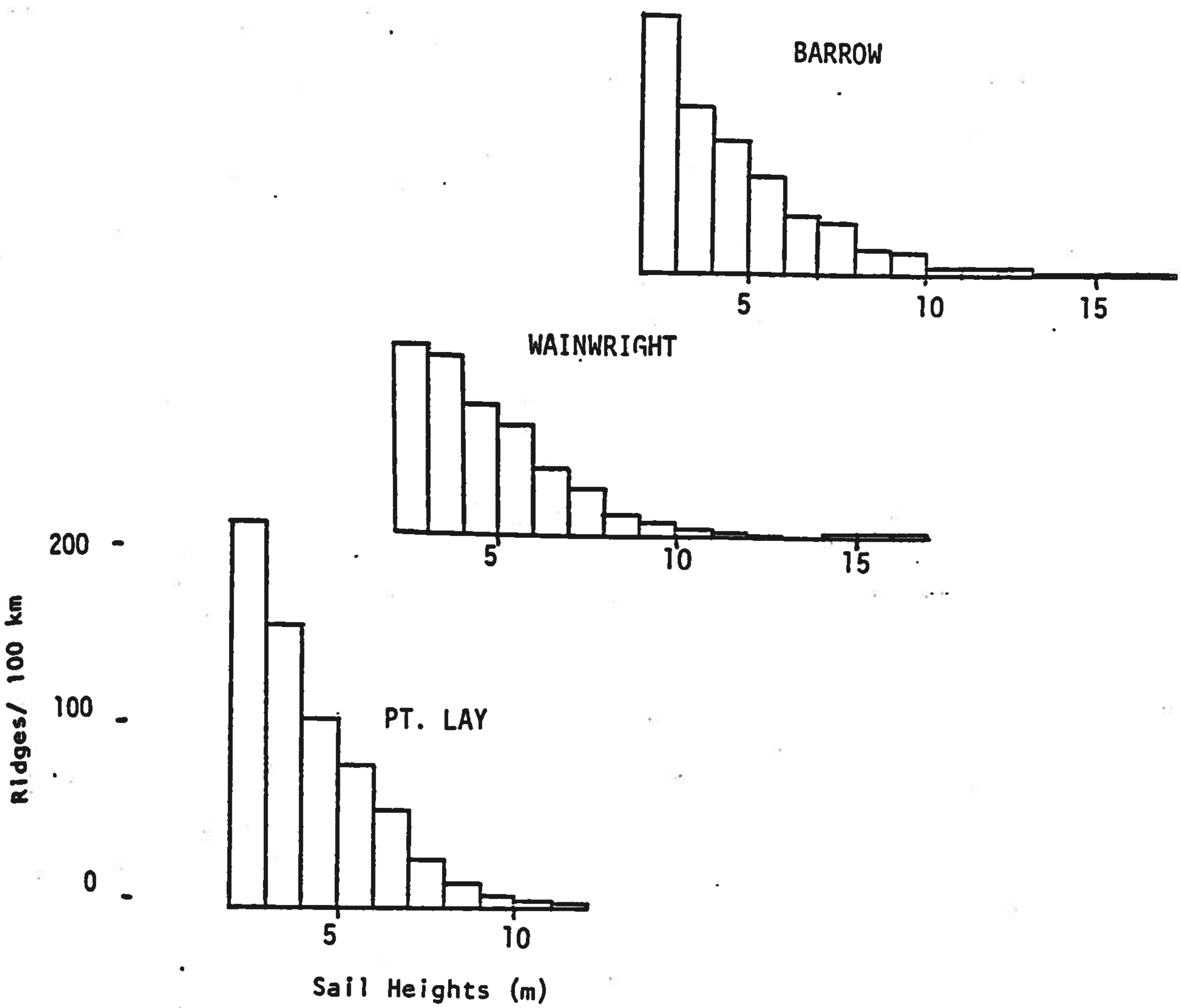


Figure 2.14. Histograms showing the frequency per 100 km of pressure ridge sails of varying heights, as determined by laser profilometer flights in February 1976 (from Weeks and Kovacs, 1977). Profiles were flown at right angles to the coast. Ridge sail heights greater than 15 m were found west of Wainwright. Pressure ridges often have ridge height: keel depth ratios of 1:4 or more.

Figure 2.13 Chukchi Sea ice morphology in the early spring (Stringer, 1978). The average edge of the shore fast ice generally follows the 20 m bathymetric contour. This ice is widest and most stable in the Cape Lisburne region, and narrowest and more subject to pressure ridging north of Icy Cape. The Chukchi Sea is much more dynamic than the Beaufort Sea ice. Severe ridging occurs in the fast ice zone near Icy Cape and in the pack ice north of Cape Lisburne.

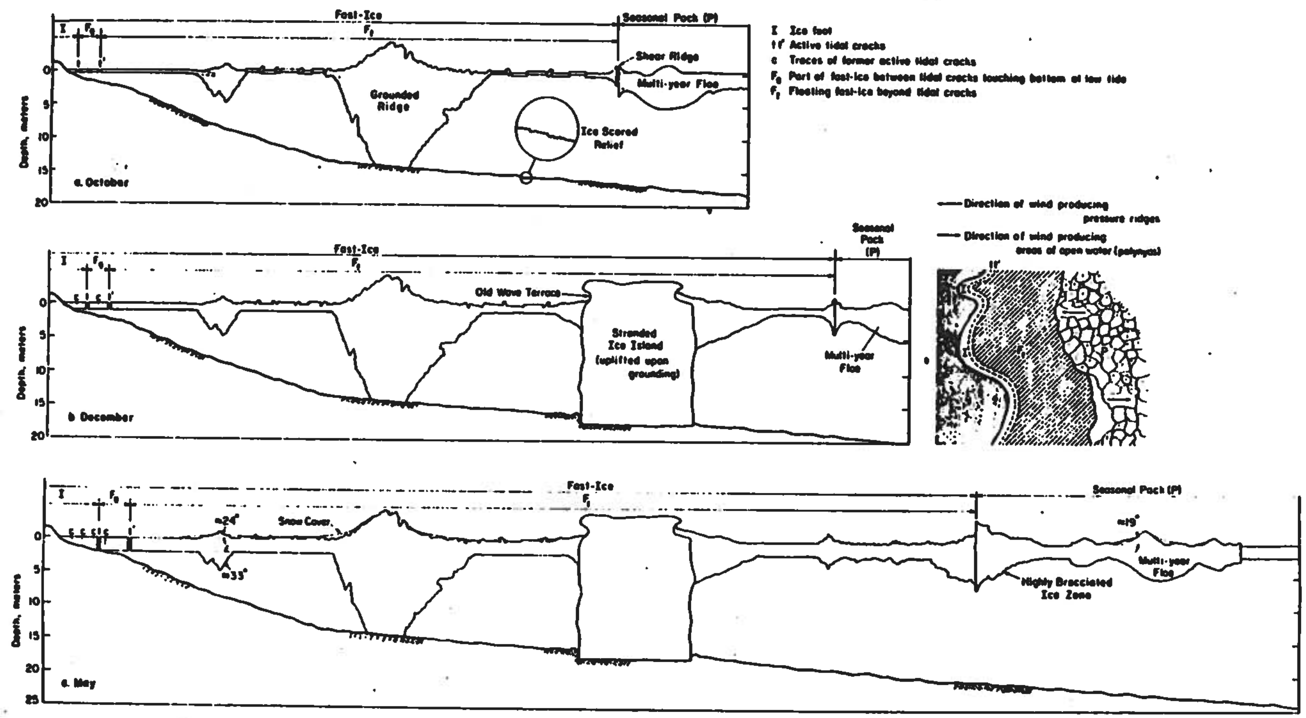


Figure 2.15. Illustrations showing several stages related to the development of the fast ice and seasonal pack ice zones as they occur in the Beaufort and Chukchi Seas (from Kovacs and Mellor, 1974). Others often consider the fast ice zone as extending only to the grounded ridges which mark the innermost incursion of the pack ice zone. Beyond the shear zone is drifting pack ice consisting of first year and multi-year pack ice.

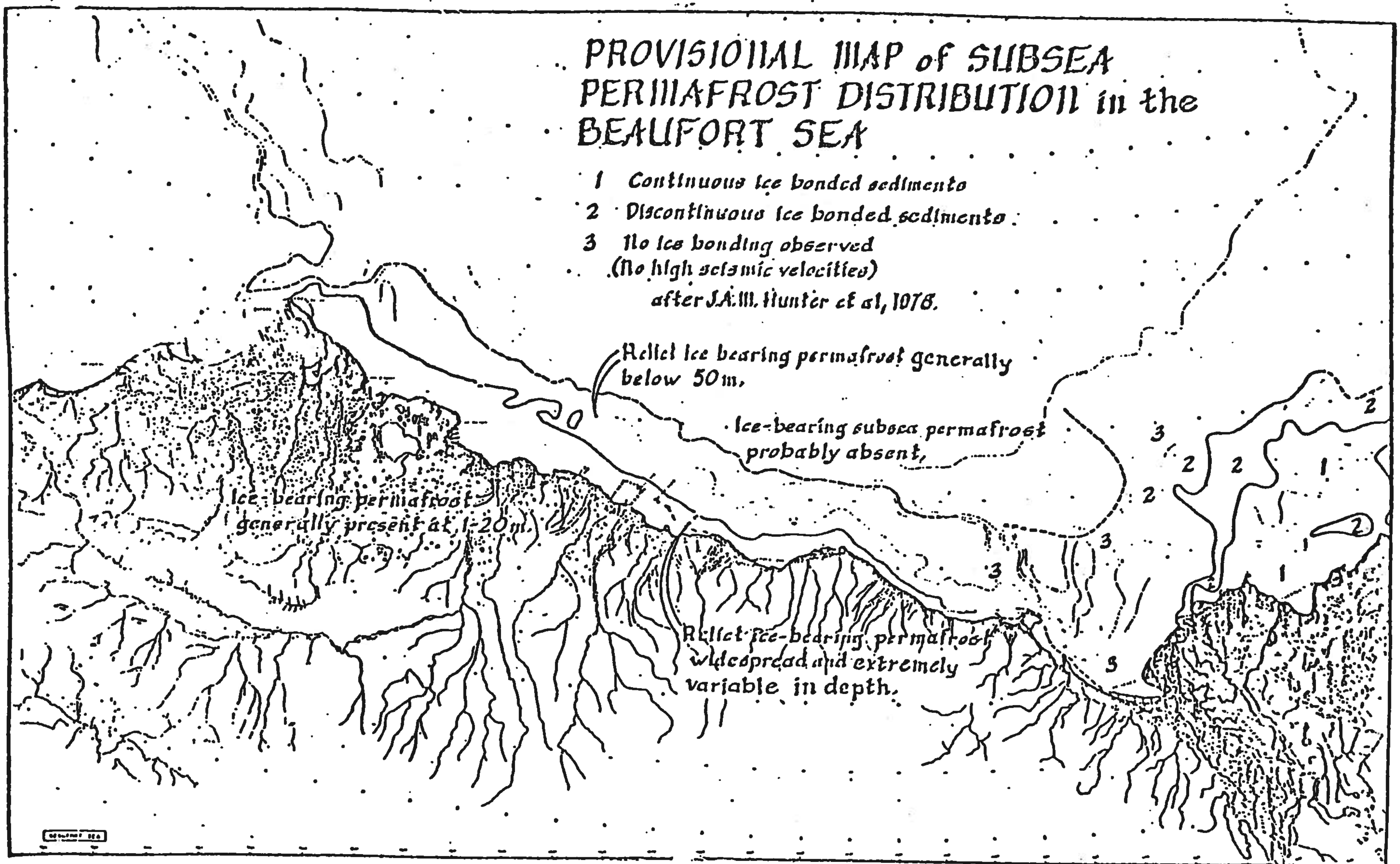


Figure 2.16. Provisional Map of Subsea Permafrost Distribution in the Beaufort Sea and northeast sector of Chukchi Sea coast (Hunter _et al._, 1976 in OCSEAP, 1978).

3. THE BIOLOGICAL ENVIRONMENT

The seasonal ice cover is the dominant influence in determining the kinds and abundance of marine life of the Chukchi Sea. Sea ice, combined with seasonal changes in available sunlight, govern the ability of phytoplankton to produce food for the zooplankton and subsequently higher organisms of the trophic system.

The Chukchi Sea is relatively fertile, particularly in the deeper layers and in areas of upwelling. When day length is increasing in the spring, the phytoplankton flourish at the ice edge, in ice leads and open waters, and even at the underlayer of the sea ice. The contribution of the under-ice algae, mainly diatoms, to the productivity in these waters is uncertain but probably significant (Goering and McRoy, 1974; Horner and Alexander, 1972). Phytoplankton production in the leads begins by late March, as much as two months before it peaks in the open water. Because of the low angle of incident sunlight, the zone of highest phytoplankton productivity is limited to relatively near the sea surface. Since the waters are vertically stratified in the summer by ice melt and surface warming, little additional nutrient is replenished from the underlying waters. This concentration of plant cells depletes the available nutrients in the surface waters relatively quickly, limiting the most productive period to about 5 weeks of the summer. River runoff provides added nutrients to the coastal waters during the summer season when sunlight is also available. Compared to the Bering Sea, the level of total seasonal and annual productivity is low and does not support as large zooplankton populations.

The lower total productivity of the Chukchi Sea results in lower abundances of plankton, benthos, and fish than are found in the Bering Sea. However, their abundance is not poor. Zooplankton transported in from the Bering Sea are added to local population stocks to enhance the productivity of the Chukchi Sea. In many cases biomass and density are comparable to those found in many temperate regions.

The invertebrate benthos of the offshore region is substantial, and is an important food source of marine mammals, especially the gray whale, bearded seal, and walrus. This fauna is dominated by deposit feeders, while suspension feeders, scavengers, and predators are more abundant in nearshore waters. Overall, echinoderms (basket stars, brittle stars, sea cucumbers, sea urchins) are the dominant animals of the benthic fauna. A variety of crustaceans are also common, including amphipods, shrimps, and crabs. Other common invertebrates are tunicates, molluscs, annelids, and coelenterates. A list of the most common invertebrates of the southeastern Chukchi Sea is given in Table 3.1.

Tanner crabs (Chionoecetes opilio) and spider crabs (Hyas coarctatus) are frequently abundant offshore. Blue king crabs (Paralithodes platypus) occasionally occur. Some trawl catches are dominated by jellyfish.

Nearshore areas contain a wide variety of organisms, but not in as large numbers. Seasonal shorefast ice has a major effect in forming the nearshore benthic fauna. Mysids, cumaceans, sponges, soft corals, and decapods usually dominate these areas. Sizeable concentrations of crangonid shrimp can occur in certain nearshore areas.

Although commercially exploitable quantities of benthic invertebrates have not been located in the Chukchi Sea, the quantities of Tanner crab, shrimp, scallops, and clams (Macoma calcarea) are sufficient for some seasonal utilization by natives.

The coastal lagoons behind the barrier islands do not provide stable environments and do not support large benthic populations. A limited number of mysids, some mussels, and numerous nemertine worms (Lepidurus) are the most commom organisms found there. Other marine forms are occasionally washed in during storms and can form temporary populations during the ice-free season. Nevertheless, these lagoons provide unique habitats for anadromous fish, waterfowl, and some marine mammals. R.H. Fleming (unpublished, 1959; quoted in Johnson, 1966) summarized the character of these coastal lagoons as follows:

Table 3.1 --Rank order by frequency of occurrence and relative abundance of the 20 most common invertebrate taxa in the southeastern Chukchi Sea (AEC survey, 1959). (Adapted from Sparks and Pereyra, 1966).

Rank	Taxon	Percent frequency of occurrence1/	Relative abundance index2/
1	Decapod crustaceans	98.6	5882.5
2	Starfish	77.0	2253.4
3	Gastropod molluscs	70.3	1064.5
4	Amphipod crustaceans	67.6	1039.0
5	Pelecypod molluscs	63.5	1422.5
6	Omphiuroidean echinoderms	62.2	2797.5
7	Annelid worms	56.8	2048.0
8	Anthozoan collenterates	56.8	1267.1
9	Ascidians	55.4	2715.0
10	Holothuroidean echinoderms	41.9	1354.0
11	Echinoidean echinoderms	32.4	922.5
12	Cirripedia crustaceans	32.4	625.0
13	Scyphozoa coelenterates	29.7	485.0
14	Bryzoans	27.0	377.7
15	Sponges	23.0	664.0
16	Hydrazoan coelentrates	21.6	286.4
17	Sipunculoidea (coelomate worms)	20.3	59.1
18	Nemertian worms	18.9	47.5
19	Isopod crustaceans	13.5	25.0
20	Amphineura molluscs	10.8	51.4

1/ Number of sampling stations (trawls or trawls and dredge): 74.

2/ Total number of animals present in all samples adapted from rank key presented by Sparks and Pereyra (1966).

"The geological and oceanographic processes that have led to development and life history of these features are of major scientific interest. Because each of them may represent a variable but unique micro-environment, the biology of these lagoons is also of unusual interest because they represent a transitional series of marine to freshwater environments. At one extreme these lagoons are, in effect, the complex estuaries of rivers that flow only during the summer. At the other extreme the older lagoons, now permanently isolated from the sea and clogged with sediment and vegetation, are only distinguishable from aerial photographs. Between these two extremes are bodies of water, varying greatly in size, that must from time to time be flooded with sea water and then are closed off again and slowly diluted by the accumulation of precipitation and runoff."

Johnson (1966) studied nine lagoons in the Cape Thompson area and found dissimilar zooplankton populations in each, supporting Fleming's hypothesis that they represent unique micro-environments. At present, very little else is known concerning the ecology of these lagoons.

4. THE FISH RESOURCE

The fish populations of the Chukchi Sea can be categorized as marine (including pelagic, demersal, coastal, and estuarine), anadromous, and freshwater. There are no commercial fisheries in this region, and subsistence fisheries focus primarily on the anadromous species. The marine fish are important primarily as a food resource for marine mammal populations of the region.

Although marine fish have been the subject of only a few studies (see Section 4.1), anadromous fish (Section 4.2) are even more poorly known. The importance of lagoons, bays, and river mouths to the habits of coastal fish needs to be determined.

4.1 Marine Fish

The marine fishes of the northeastern Chukchi Sea have received little attention in the past. The limited trawl surveys that have been conducted (Pruter and Alverson, 1962; Alverson and Wilimovsky, 1966; Quast, 1972; Wolotira et al., 1977), were mainly in the Hope Basin region south of Cape Lisburne. Frost et al. (1978) reported on trawl samples taken in the northern Chukchi and Beaufort Sea. From this limited sampling, the number of marine fishes reported for the Chukchi Sea is 41 species representing 11 families (Table 4.1). Very little is known about the life history, population dynamics, or ecological relationships of most of these species.

Compared to the northern Bering Sea, the fish fauna of the Chukchi Sea is sparse, both in species diversity and in abundance. Nevertheless, it is apparently greater than the fish fauna found in the Beaufort Sea. The distribution of the species in the Chukchi Sea appears to be governed by temperature and salinity. Yellowfin sole and saffron cod occupy the shallower and seasonally warmer waters, while Arctic cod and Bering flounder are usually found in the deeper and colder water areas. Arctic flounder, starry flounder, and fourhorn sculpin are most frequent in low-salinity waters in estuaries and

Table 4. 1. A list of Marine Fishes Reported from the Chukchi Sea (from Alverson and Wilimovsky, 1966; Wolotira et al., 1977; Frost et al., 1978)

Scientific Name	Common Name 1/
Family Clupeidae - herrings	
Clupea harengus pallasi	Pacific herring
Family Osmeridae - smelts	
Mallotus villosus	capelin
Family Gadidae - codfishes	
Boreogadus saida	Arctic cod
Eleginus gracilis	saffron cod
Gadus macrocephalus	Pacific cod
Theragra chalcogramma	walleye pollock
Family zoarcidae - eelpouts	
Gymnelis viridis	fish doctor
Lycodes palearis	wattled eelpout
Lycodes raridens	eelpout
Lycodes polaris	Canadian eelpout
Family Stichaeidae - pricklebacks	
Eumesogrammos praecisus	fourline snakeblenny
Lumpenus fabricii	slender eelblenny
Lumpenus maculatus	daubed shanny
Lumpenus medius	stout eelblenny
Stichaeus punctatus	Arctic shanny
Family Ammodytidae - sand lances	
Ammodytes hexapterus	Pacific sand lance
Family Hexagrammidae - greenlings	
Hexagrammos stelleri	whitespotted greenling
Family Cottidae - sculpins	
Artediellus scaber	hamecon
Hemilepidotus sp.	Irish lord
Icelus spatula	spatulate sculpin
Triglops pingeli	ribbed sculpin
Megalocottus platycephalus	belligerent sculpin
Myoxocephalus scorpius	shorthorn sculpin
Myoxocephalus axillaris	?
Myoxocephalus jaok	plain sculpin
Myoxocephalus stelleri	?

Table 4.1 Continued

Myoxocephalus quadricornis	fourhorn sculpin
Microcottus sellaris	brightbelly sculpin
Gymnocanthus tricuspis	Arctic staghorn sculpin
Enophrys lucasi	leister sculpin
Nautichthyes pribilovius	eyeshade sculpin
Family Agonidae - poachers	
Aspidophoroides olriki	Arctic alligator fish
Agonus acipenserinus	sturgeon poacher
Family Cyclopteridae - snailfishes	
Liparis herschelinus	bartail snailfish
Family Pleuronectidae - righteye flounders	
Atheresthes stomias	arrowtooth flounder
Hippoglossoides robustus	Bering flounder
Hippoglossus stenolepis	Pacific halibut
Limanda aspera	yellowfin sole
Pleuronectes quadrituberculatus	Alaska plaice
Liopsetta glacialis	Arctic flounder
Platichthyes stellatus	starry flounder

1 - Common names according to Robins *et al*., 1980 - American Fisheries Society, Special Publication No. 12

at river mouths. Most of the other marine species prefer higher salinity water and probably occur throughout the broad marine coastal shelf. Very few fish overwinter in the coastal lagoons; the saffron cod is the major exception.

The majority of the marine fish of the Chukchi Sea are demersal as adults. Only a few species are pelagic, i.e., Arctic cod, Pacific herring, smelt, capelin, and sand lance. The Arctic cod may be classified as semi-pelagic since adults usually occur close to the bottom when in shallow water.

Many of the marine fish in the Chukchi Sea are believed to maintain their populations by recruitment of eggs and larvae transported north from the Bering Sea (Pruter and Alverson, 1962). This is indicated by the generally small size, young age, and slow growth of individuals of many species in the Chukchi Sea relative to their Bering Sea populations. Bering flounder, yellowfin sole, Alaska plaice, and walleye pollock are some of the species present in low densities, and whose individuals exhibit slow growth rates (Burns and Morrow, 1972), most likely related to the short growing season and low temperatures.

Fish that probably maintain their populations by resident breeding stocks include the Arctic cod, saffron cod, sand lance, capelin, and some of the flounders (Walters, 1955). These resident spawners tend to lay large, yolky eggs in shallow waters. Their larvae hatch and become planktonic during the summer, eventually sinking to deeper waters to mature (Stonehouse, 1971).

The relative abundance of marine fish in the Chukchi Sea by number and frequency of occurrence is given in Table 4.2. These data are mainly from the Chukchi Sea south of Point Hope. The area north has received only limited attention - six stations only in the vicinity of Cape Lisburne (Alverson and Wilimovsky, 1966). Four fish contributed to over half the total fish biomass catch in the 1976 BLM/OCS trawl surveys (Wolotira et al., 1977) also in the southeastern Chukchi Sea (Hope Basin area). These were: starry flounder - 20.5%, Pacific halibut - 11.8%, saffron cod - 11.4%, and Pacific herring - 9.6%. Arctic cod, while being the most frequent and abundant fish caught, ranked fifth in biomass at 7.6% because of its smaller individual size.

Arctic cod is however, the dominant marine fish in both numerical and frequency of occurrence.

Arctic cod especially juveniles, are extremely abundant during the ice-free season. First year juveniles are always found near the sea surface (Hognestad, 1968). Quast (1974) estimated that over 21,000 mt (46 million lb.) of juvenile Arctic cod were present from Cape Lisburne to Icy Cape during a 1970 survey. This species is heavily fed upon by the large populations of cliff-nesting seabirds (primarily thickbilled murres, common murres, and kittiwakes) of the Lisburne Peninsula. Schwartz (1966) estimated that as many as 250 million Arctic cod are consumed annually by the nearby Cape Thompson sea bird populations. Arctic cod also is an important prey species for other fish, seals, walrus, and beluga whales. Arctic cod composed 39% of all fish caught by Frost et al. (1978), occuring in 28 of 33 trawls (85%). Arctic cod spawn in the winter, but their spawning areas are unknown.

Other marine fish that are important prey of marine mammals and seabirds include the Pacific sand lance, capelin, and Pacific herring. Herring are found primarily in the Bering Sea, but also occur along the Arctic coast as far as the MacKenzie River. It is not known how far north of Pt. Hope herring spawn.

The abundance of the Pacific sand lance is unknown. According to Schwartz (1966) and Springer et al. (1979), the sand lance is the second most important prey species for the Cape Lisburne seabird colonies. Large schools of this fish are known to occur north of Cape Lisburne in the summer.

Capelin is another important pelagic prey species of seabirds, seals, and belugas. Little is known about this fish resource along the Chukchi coast.

4.2 Anadromous Fish

Knowledge of the anadromous fish resource in the Chukchi Sea is limited. Thirteen of the 23 species of fish reported from freshwaters of the Arctic coast are anadromous, and can also be found in the open sea or in estuarine

Table 4.2 --Rank order by catch rate (numbers/trawl) and frequency of occurrence (percent) of the 20 most common fish taxa in the southeastern Chukchi Sea (AEC survey, 1959) (adapted from Alverson and Wilimovsky, 1966).

Rank	Taxon	CPUE[1/] (No./trawl)	Proportion of total CPUE[2/]	Percent frequency of occurrence
1	Arctic cod	58.98	0.586	71.9
2	Arctic staghorn sculpin	10.58	0.105	68.4
3	Bering flounder	4.30	0.043	61.4
4	Capelin	4.04	0.040	22.8
5	*Artediellus* sp.	3.68	0.037	43.9
6	Ribbed sculpin	2.11	0.021	45.6
7	Toothed smelt	1.96	0.019	22.8
8	*Myoxocephalus* sp.	1.35	0.013	33.3
9	Saffron cod	1.32	0.013	24.6
10	Unidentified eelpouts	1.18	0.012	43.9
11	Unidentified snailfish	1.05	0.010	31.6
12	Sturgeon poacher	0.89	0.009	24.6
13	Leister sculpin	0.63	0.006	22.8
14	Slender eelblenny	0.60	0.006	24.6
15	Stout eelblenny	0.58	0.006	22.8
16	Yellowfin sole	0.54	0.005	14.0
17	*Triglops* sp.	0.53	0.005	14.0
18	Pacific herring	0.49	0.005	14.0
19	Unidentified sea poachers	0.46	0.005	28.1
20	Eyeshade sculpin	0.19	0.002	14.0

1/ Overall catch per unit effort, no./trawl. Total effort = 57 trawls.

2/ Proportion of total catch per unit effort, fish only. Total CPUE = 100.63 fish/1 hr. trawl haul.

areas during part of their life cycle (Table 4.3). Some of these species undertake extensive migrations from freshwater as juveniles, mature at sea and return to freshwaters as adults to spawn. Among this group are Arctic lamprey, pink salmon, chum salmon, and rainbow smelt. The remainder of the species seasonally enter the brackish or marine environment in the summer and spend most of their life in freshwater lakes and rivers. Three marine species also occasionally enter brackish or freshwater: fourhorn sculpin, Arctic flounder, and starry flounder.

The distribution and abundance of these anadromous fish species is markedly affected by the seasonal sea ice. During the summer open-water season, anadromous species range throughout the region, in offshore coastal waters,in brackish estuaries and river mouths, as well as in the freshwater rivers, streams, lakes, and ponds.

Most of the anadromous species spawn in the fall in lakes or streams (Table 4.4). There are 12 rivers along the northeastern Chukchi Sea coast (Figure 4.1) that have been catalogued as important for the spawning and migration of anadromous fish (ADF&G, 1975), but the extent of their use is not known.

Arctic Char

The most widely-occurring of the anadromous fish is the Arctic char, being found in most streams, lagoons, and coastal waters of the region. Although the majority of the species is anadromous, some individuals remain year-round in freshwater. The coastal distribution and abundance of Arctic char between Cape Lisburne and Point Barrow is largely undefined.

Arctic char overwinter primarily at rivermouth deltas and inshore lagoons that are fed with freshwater and remain partially unfrozen throughout the winter. Some overwinter in the deeper portions of spring-fed streams. The species avoids the subzero winter water temperatures of the marine environment. Migration to the nearshore marine waters immediately follows spring breakup. While in coastal marine waters, they feed extensively on small fish and plankton as they travel along the shore. Arctic char migrations along the

Table 4.3 List of Anadromous Fishes Reported from the Chukchi Sea.

Scientific Name	Common Name
Family Petromyzontidae - lampreys	
Lampetra japonica	Arctic lamprey
Family Salmonidae - trouts	
Coregonus autumnalis	Arctic cisco
Coregonus laurettae	Bering cisco
Coregonus nasus	broad whitefish
Coregonus pidschian	humpback whitefish
Coregonus sardinella	least cisco
Oncorhynchus gorbuscha	pink salmon
Oncorhynchus keta	chum salmon
Salvelinus alpinus	Arctic char
Family Osmeridae - smelts	
Hypomesus olidus	pond smelt
Osmerus mordax	rainbow smelt
Family Gadidae - cods	
Lota lota	burbot
Family Gasterosteidae	
Pungitius pungitius	ninespine stickleback

coast are limited to within 100 miles from their home streams. They begin re-entering freshwater rivers in August, with the spawners entering first. Arctic char spawn every other year in September and October; the eggs hatch in April; and the juveniles remain in freshwater for 3 or 4 years before migrating to the sea.

Whitefish and Ciscoes

Fish of the genus *Coregonus*, which includes the whitefish and the ciscoes are common in arctic Alaska waters. Humpback whitefish (*Coregonus pidschian*) are the most widely distributed, and have both anadromous and freshwater forms.

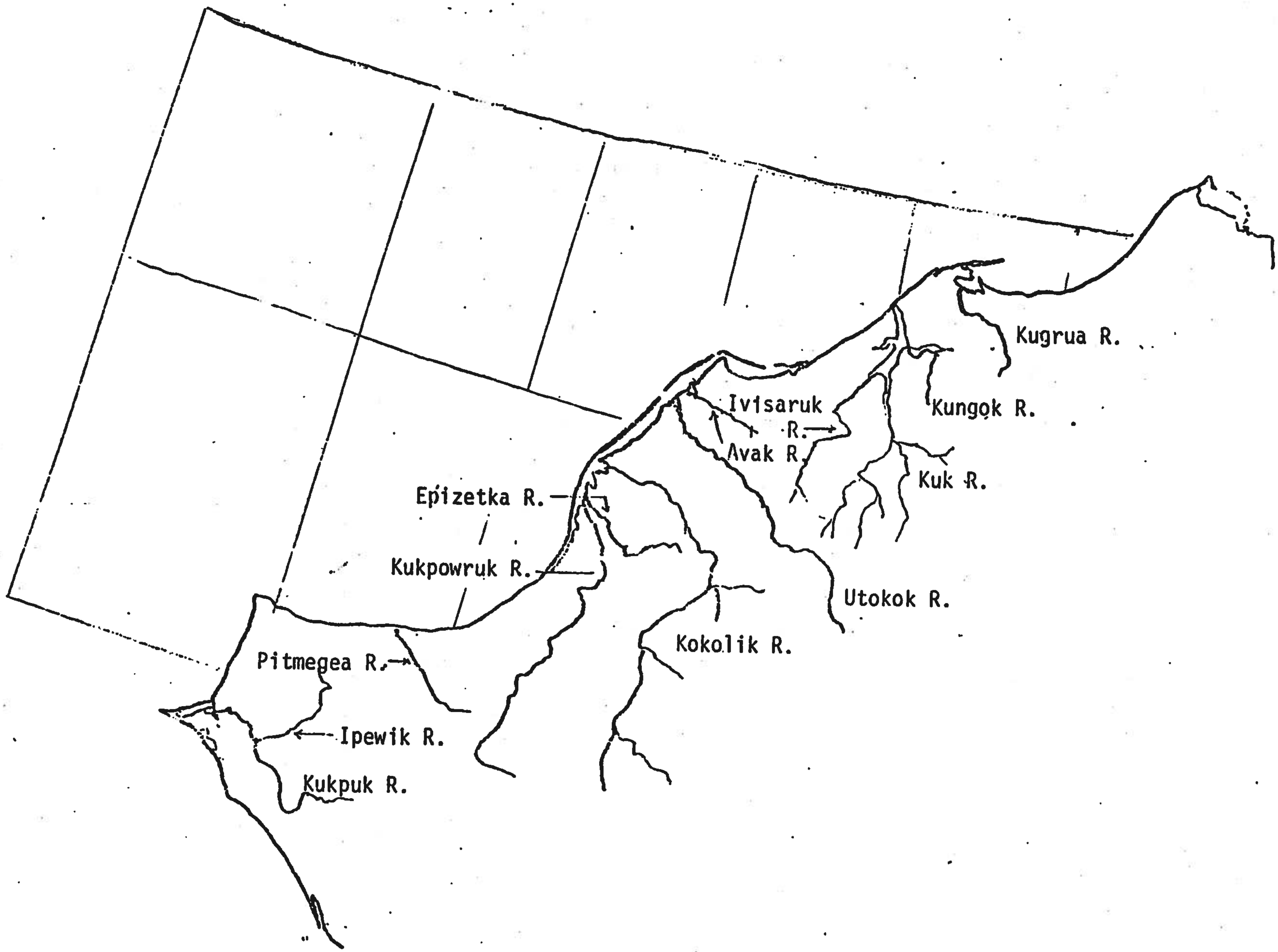


Figure 4.1. Freshwater rivers of the northeast Chukchi Sea known or suspected to support anadromous fish populations (ADF&G, 1975).

Table 4.4. Spawning Season and Habitat of Anadromous Fish in the Chukchi Sea

Season	Species	Spawning Habitat
Late Winter	burbot	lakes
Late Spring	ninespine stickleback	lakes and ponds, in vegetation
Summer	fourhorned sculpin	shallow inshore
Fall	Arctic char	lakes, streams, spring areas
	broad whitefish	river deltas
	humpback whitefish	rivers and lakes
	Arctic cisco	streams, on gravel
	Bering cisco	streams, on sand and/or gravel
	least cisco	streams, on sand and gravel
	chum salmon	rivers, streams, spring areas
	pink salmon	coastal streams

The anadromous forms primarily inhabit the lower reaches of rivers, brackish deltas, and estuaries. They overwinter in freshwater before out-migrating at breakup to their estuarine summer feeding grounds. Broad whitefish (Coregonus nasus) also occupy estuaries, but are most common in the slower moving waters of larger rivers and in interconnected lakes and slough systems.

The ciscoes are more estuarine and coastal than the whitefish. The Arctic cisco (Coregonus autumnalis) is primarily a nearshore and estuarine species that migrates upstream to spawn. They spawn over gravel in flowing waters in early autumn. After spawning, adults return downstream in distinct migrations. Bering ciscoes (Coregonus laurettae) are most common near the mouths of rivers and in brackish lagoons. Little is known of their life history, but it is presumed to be quite similar to that of coastal Arctic and least ciscoes. Least ciscoes (Coregonus sardinella) have both anadromous and freshwater races. Anadromous least ciscoes overwinter in freshwater, move downstream in the summer to riverflats and rivermouths, and return to freshwater streams to spawn in the autumn. The distribution and abundance of whitefish and ciscoes along the Chukchi Sea coast is not well known.

Salmon

Of the five species of Pacific salmon common along the Alaskan coast, only pink salmon and chum salmon are known to spawn in freshwater of the northeast Chukchi Sea Coast. Sockeye and chinook salmon may be caught in the coastal waters, but they reach their known northern spawning limit at Cape Lisburne. Both pink salmon and chum salmon spawn during the summer to autumn in the gravel of clear streams entering the Chukchi Sea. The eggs develop in the gravel during winter, and the young emerge the next spring. The newly hatched young of both species migrate directly to the sea. Little is known of the location of the spawning areas of these two species along the Chukchi Sea coast.

The runs of pink salmon and chum salmon in Chukchi Sea tributaries north of Cape Lisburne are small. Aerial surveys in 1961 (Smith et al., 1966) did not reveal any salmon in the Pitmegea, Kukpowruk, or Kokolik Rivers north of Cape Lisburne, but ADF&G (1978) has identified the Kukpowruk River as a pink salmon spawning stream and NPR-A (1979) report pinks and chums in the Kokolik and Utokok Rivers. Large runs occur more to the south, especially in Kotzebue tributaries (Noatak and Kobuk Rivers). There are no commercial fisheries for salmon north of Kotzebue Sound. Point Hope natives take an average catch of 3000 pink and chum annually (Raleigh, 1957), mainly by beach seine. The salmon are mainly caught incidentally to Arctic char, which the natives reportedly prefer (Smith et al., 1966).

It is hypothesized that the small salmon stocks of the Chukchi Sea coast are due to the intolerably long period of low winter temperatures in the spawning stream beds of this region. Although the streams appear accessible and suitable, low air temperatures, sparse snow cover, and the permafrost base probably combine to produce unfavorable temperature conditions for spawning and rearing.

Smelts

The anadromous pond smelt (*Hypomesus olidus*) is frequently found offshore in the eastern Chukchi Sea, but it does not appear to spawn in any of the freshwaters of this region (Scott and Crossman, 1973). Large runs of the rainbow smelt (*Osmerus mordax*) occur in the Kuk River during winter. The life history of this species is unknown.

5. THE MARINE MAMMAL RESOURCE

The Chukchi Sea is an important habitat for many marine mammals (Table 5.1) of the Arctic. Although the relative number of common species is low, their population abundance is high.

The distribution and abundance of these marine mammals in the Chukchi Sea (Table 5.2) is strongly correlated with the seasonal cycles of sea-ice coverage of the region (Burns et al., 1980). Certain of the mammals are closely ice-associated and are present in the area only with the presence of sea ice. Year-round residents generally move north with the retreating sea ice in summer to reside along the edge of the pack-ice. Other species are open water inhabitants, and reside in the Chukchi Sea only during the summer season when ice is absent, and migrate south with or before the advancing sea ice in the fall and winter.

The association with the sea ice varies among the species and can change seasonally (Figures 5.1 and 5.2). The main populations of the polar bear, bowhead whale, walrus, bearded seal, and ringed seal, remain near the sea-ice year round. The beluga whale, spotted seal, and ribbon seal occupy the ice zone during the winter but inhabit primarily the coastal or open sea waters during the ice-free season. Other whales winter south of the seasonal sea-ice, although they may have some association with it during their northward migrations (i.e., humpback whales, gray whales, and killer whales).

The Arctic fox (Alopex lagopus) is another common inhabitant of the shorefast ice in the winter. Although it is not discussed further in the report, it is one of the most common mammals of the fast ice environment. It preys chiefly on ringed seal pups during this season.

The Chukchi Sea is an important area for feeding and reproduction of most of these marine mammals. Table 5.3 summarizes the seasonal aspects of the feeding relationships of the more common marine mammals of this region. Fish and invertebrates are key foods that directly support the seal and whale

Table 5.1 A list of marine mammals of the northeastern Chukchi Sea and the frequency of their occurrence.

Scientific Name	Common Name	Occurrence
Order Carnivora		
Family Ursidae		
Ursus maritimus	polar bear	common
Order Cetacea		
Family Monodontidae		
Delphinapterus leucas	beluga	common
Monodon monoceros	narwhal	rare
Family Delphinidae		
Orcinus orca	killer whale	common
Phocoena phocoena	harbor porpoise	uncommon
Family Eschrichtidae		
Eschrichtius robustus	gray whale	common
Family Balaenopteridae		
Balaenoptera physalus	fin whale	uncommon
Balaenoptera borealis	sei whale	rare
Balaenoptera acutorostrata	minke whale	uncommon
Balaenoptera musculus	blue whale	rare
Megaptera novaeangliae	humpback whale	uncommon
Family Balaenidae		
Balaena mysticetus	bowhead whale	common
Balaena glacialis	Pacific right whale	rare
Order Pinnipedia		
Family Otariidae		
Callorhinus ursinus	northern fur seal	rare
Eumetopius jubatus	northern sea lion	rare
Family Odobenidae		
Odobenus rosmarus	Pacific walrus	common
Family Phocidae		
Phoca vitulina richardii	harbor seal	uncommon
Phoca vitulina largha	spotted seal	common
Phoca fasciata	ribbon seal	uncommon
Phoca hispida	ringed seal	common
Erignathus barbatus	bearded seal	common

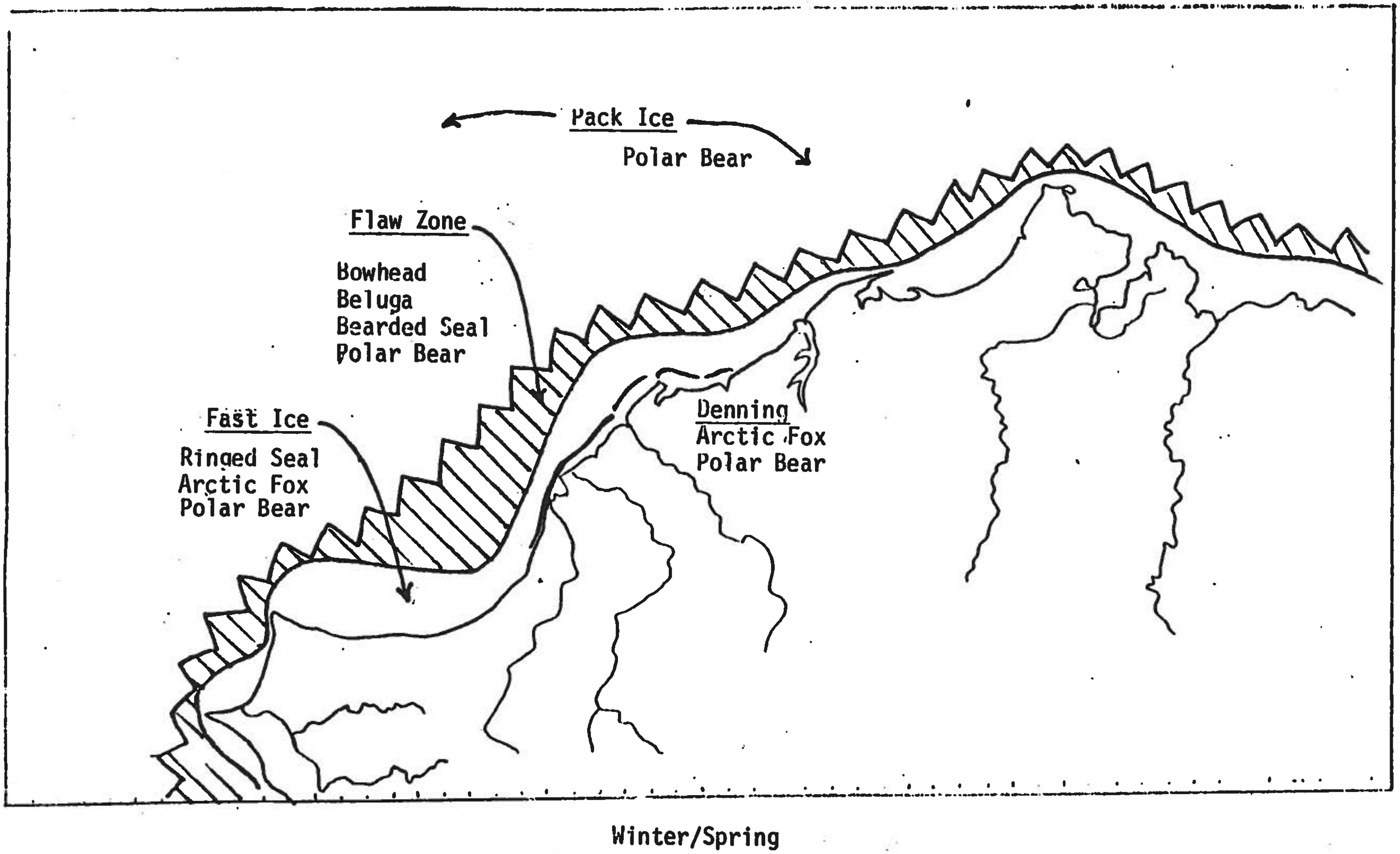


Figure 5.1. Winter/spring distribution of marine mammals of the northeast Chukchi Sea

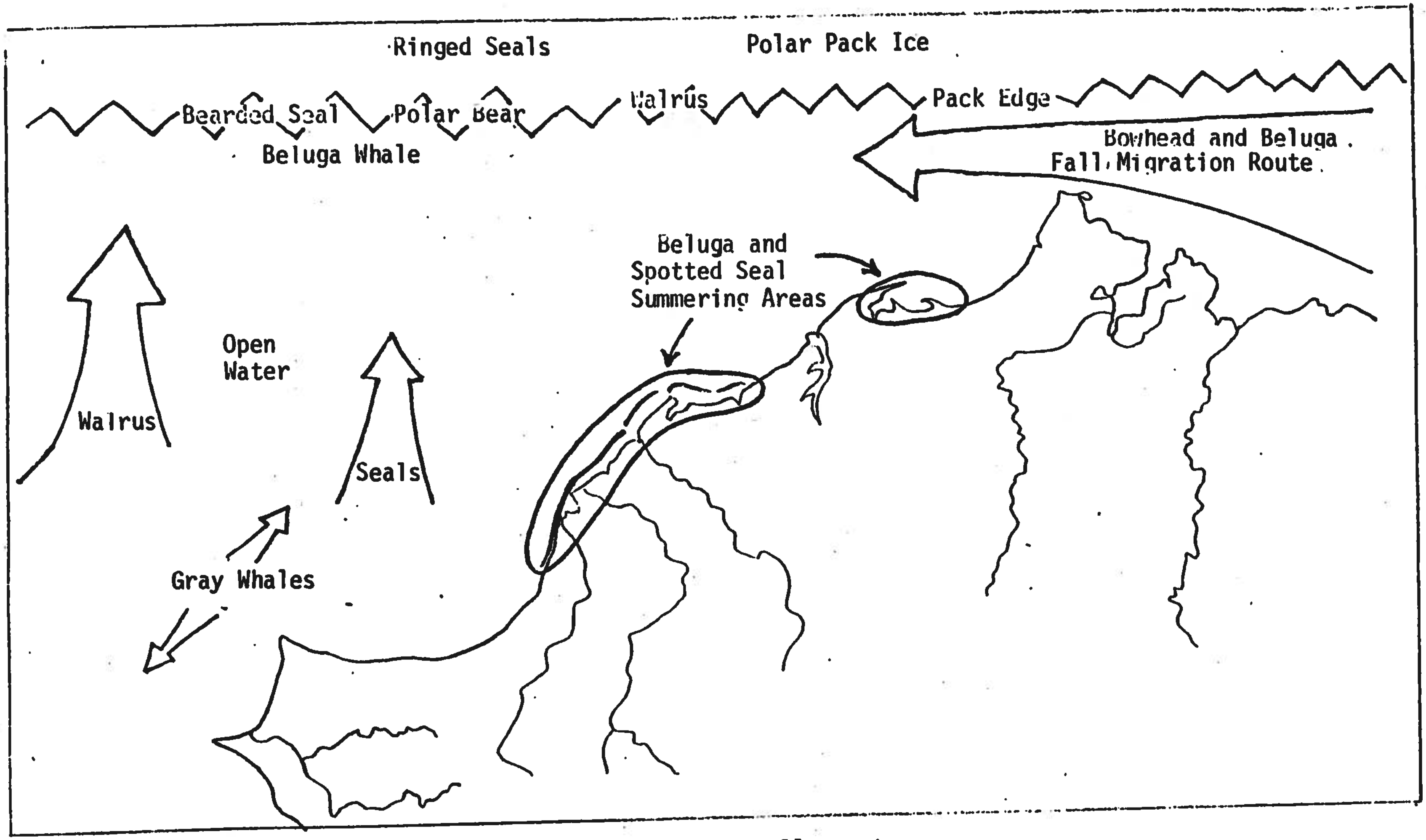


Figure 5.2. Summer/fall distribution of marine mammals of the northeast Chukchi Sea

Table 5.2. Relative Abundance and Activities of Ice-Associated Marine Mammals of the Chukchi Sea (after Burns *et al*., 1980)

Species	Ice type	
ARCTIC FOX	Consol. pack & fast	Abundant - winter, spring Feeding Travelling Mating
POLAR BEAR	Consol. pack & fast	Abundant-all yr Mating Birth Nurture Feeding Molt
BELUKHA	Open pack, flaw, & fringe	Absent-winter Abundant-spring, summer, fall Migrating Mating Birth Nurture Feeding
BOWHEAD	Open pack, flaw & fringe	Absent-winter Abundant-spring Migrating Birth Nurture Feeding Rare-summer Abundant-fall Migrating Feeding
WALRUS	Open pack & front (winter); Flaw & remnants (spring); Fringe (summer-fall)	Rare-winter Abundant-spring, summer, fall Migrating Nurture Feeding Molt
BEARDED SEAL	Open pack, flaw & front (winter, spring) & remnants (spring); Fringe (summer-fall)	Common-winter Feeding Abundant-spring, summer, fall Migrating Feeding Birth Nurture Mating Molting
RINGED SEAL	Consol. pack & fast (all yr); open pack, fringe, & remnants (spring, summer)	Abundant-all yr Feeding Birth Nurture Mating Molting
SPOTTED SEAL	Front, fringe, & remnants (winter, spring)	Abundant-spring, summer, fall Migrating Feeding Molting
RIBBON SEAL	Front & remnants (winter, spring)	Uncommon-spring, summer, fall

Table 5.3 Important Prey Organisms of the Common Marine Mammals of the Chukchi Sea

	Bowhead	Gray	Beluga	Ringed Seal	Bearded Seal	Spotted Seal	Walrus	Polar Bear
WINTER	absent	absent	absent	Arctic cod Saffron cod Sculpins Amphipods Sand Lance	Shrimp Crab Other benthos (Arctic cod) (Sculpins) (Other bottomfish)	absent	absent	Ringed seal Bearded seal (Carrion)
SPRING	minor feeding Plankton (Benthos)	absent	Arctic cod Flounders Capelin Smelt Shrimp Squid	mixed winter-summer	same as above Clams	absent	Clams Other invertebrates	Ringed seal Bearded seal
SUMMER	absent	Amphipods Other benthos	above plus Salmonids Herring	Shrimp Amphipods Crabs Euphausiids Mysids	same as above	Shrimp Salmonids Herring Capelin Smelts	same as above	above plus Walrus calves
FALL	Plankton (Benthos)	Amphipods Other benthos	Same as spring	Sculpins Arctic cod Saffron cod Shrimp	same as above	same as above	same as above	same as above

populations and indirectly support the polar bear populations, which prey chiefly on the bearded and ringed seals. The area is also an important breeding and/or rearing area for these marine mammals (Table 5.4).

5.1 The Bowhead Whale

Virtually the entire population of bowhead whales (*Balaena mysticetus* - estimated at about 2300 + 450, Braham *et al.*, 1980a) inhabits the waters of the Chukchi Sea during the spring and fall while performing their annual migration pattern. In character with their close association with the sea ice, the bowhead whales leave their wintering grounds in the Bering Sea, and follow opening leads and the retreat of the pack ice northward during the spring. Between March and June, the bowhead whale transits about 3000 km amid the ice on its way to the Canadian Arctic (Figure 5.3). Braham *et al.*, (1980a) provide a comprehensive review of current knowledge of this whale.

On their journey through the Chukchi Sea in the spring, the bowheads move from southwest to northeast through the newly opened lead systems in the shear zone between the moving pack ice and shorefast ice. They often pass close to shore during April and May, where they are hunted by spring whalers of the coastal villages of Point Hope, Wainwright, and Barrow. Braham *et al.*, (1980a) described their spring movements:

> "The northward spring migration of the bowhead whale from the Bering Sea is timed with the breakup of the pack ice. This generally occurs in April or earlier in a mild ice year (as in 1979). At that time, most whales travel north through the Strait of Anadyr, between St. Lawrence Island and the Chukchi Peninsula, continuing north by northeast through the Bering Strait on the Soviet side, west of Big Diomede Island. During an average ice-year, apparently few animals migrate through the eastern half of the northern Bering Sea, heavier ice usually occurs there than to the west. Even so, Eskimo whalers at Wales periodically take bowheads along the Alaska coast near the Bering Strait. Most of the migrating animals have passed through this corridor between St. Lawrence Island and the Bering Strait by early May.

Table 5.4. The birth period, characteristics of birth sites, duration of dependency and mobility of the young of seven species of ice-associated mammals inhabiting the Chukchi Sea (from Burns et al., 1980)

Species	Birth Period	Characteristics of Birth Site	Duration of Dependency	Mobility of Dependent Young
Arctic Fox	May-June	Subsurface den on land	3-5 mos.	Restricted to densite untill independent.
Polar Bear	Nov-Dec	Subnivian den mainly on land	24-28 mos.	2-3 mos. restricted to densite; then travel with mother
Belukha	June-Aug	Near shore-open water	24 mos.	Mobile - travel with mother
Bowhead	March-May	Leads in pack	24 mos.?	Mobile - travel with mother
Walrus	April-June	On pack	18-24 mos.	Mobile - travel with mother
Bearded Seal	March-May	On pack	2-3 weeks	Mobile - travel with mother
Ringed Seal	March-April	Subnivian liar on fast ice and heavy pack	4-6 weeks	Restricted to lair until weaned

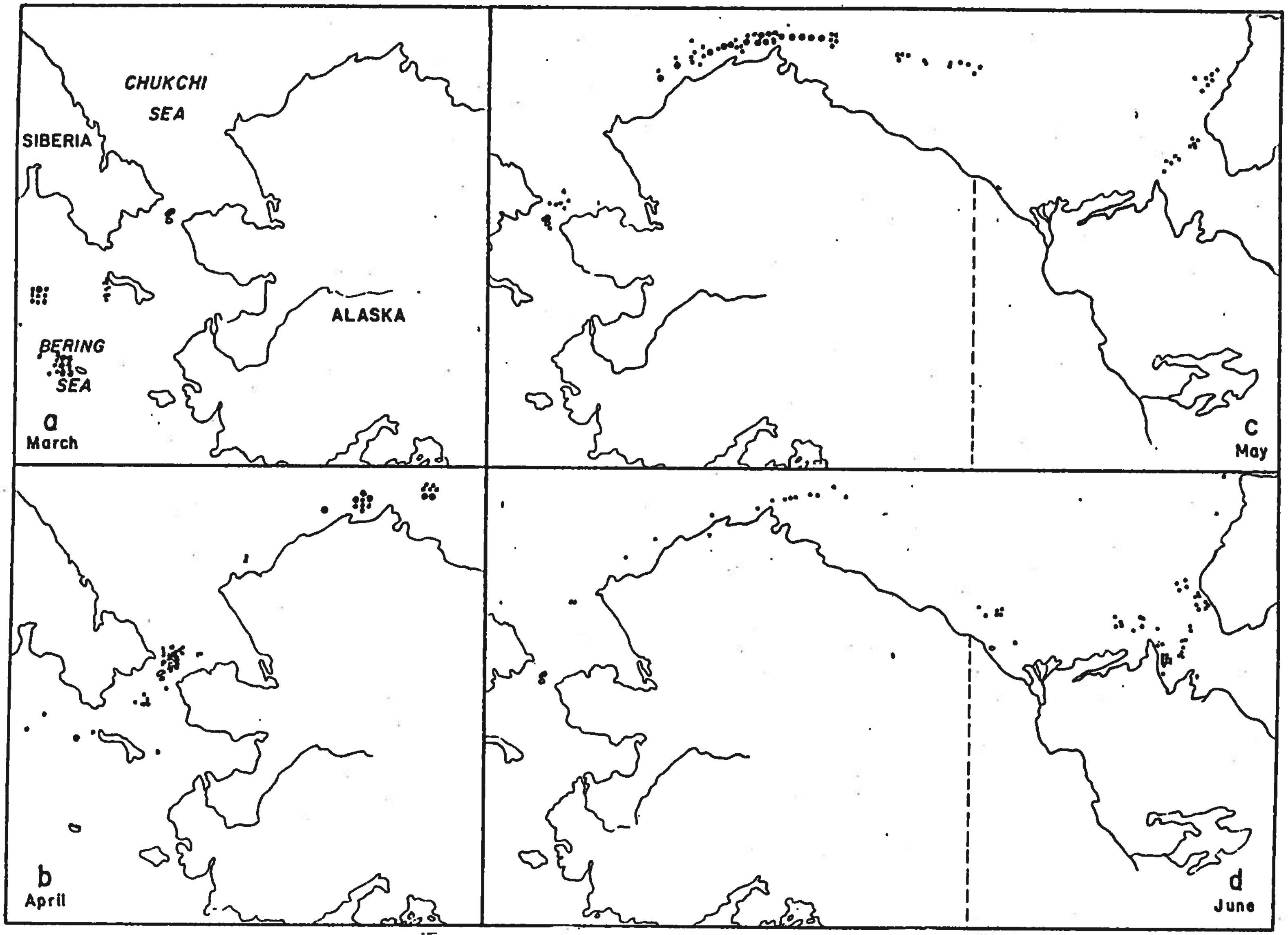


Figure 5.3. The location of observations of bowhead whales, 1974-79. Small dot = 10 whales (from Braham et al., 1980a)

Upon entering the Chukchi Sea the migration cuts northeastwardly across outer Kotzebue Sound in leads occurring in the flaw zone. A few whales move into a polynya that characteristically forms between Kivalina and Point Hope, while other whales move past Point Hope offshore to at least 45 km. Some whales are thought to move west into the western Chukchi Sea in the spring. However, this seems unlikely as pack ice is extensive with few leads north of the Chukchi Peninsula. Apparently, Siberian Eskimos living along the north side of the Chukchi Peninsula did not hunt for bowheads in the spring as did their counterparts along the east side of the Peninsula. Proceeding northward on a heading of 10-20° magnetic bowheads follow open leads north past Cape Thompson and Point Hope and then northeastward to Cape Lisburne and Point Barrow. The migration past Cape Lisburne seems to follow two or more corridors, depending on the number of leads, which range from 2-10 km offshore; sightings have been to 15 km offshore. No bowheads have been observed in offshore leads between Point Barrow during four years of aerial surveys, even though aerial survey time has been split equally between offshore (to 100 km) and nearshore coverage. The majority of bowheads usually pass Point Hope by mid-May arriving at Point Barrow shortly thereafter."

The migration along the northwest coast (Bering Strait to Point Barrow) essentially covers the period mid-April to early June. Thereafter only a few whales migrate by this coast. Figures 5.4 to 5.6 show locations of bowhead observations from aerial surveys taken between April-June, 1976, along the Chukchi Sea coast.

In other years, the variable location and structure of the lead system may allow the whales to pass farther offshore. Also, those animals migrating late in the spring will usually find more open waters and may move farther offshore. By June, most bowheads have passed through the Chukchi Sea and entered the Beaufort Sea.

Several observers have described the whale migration as occurring in pulses. According to NARL (1972) there are four waves: small males pass first, large males second, and the largest males third; adult females, some with calves pass last. Marquette (1976) observed three waves of migration, the first and

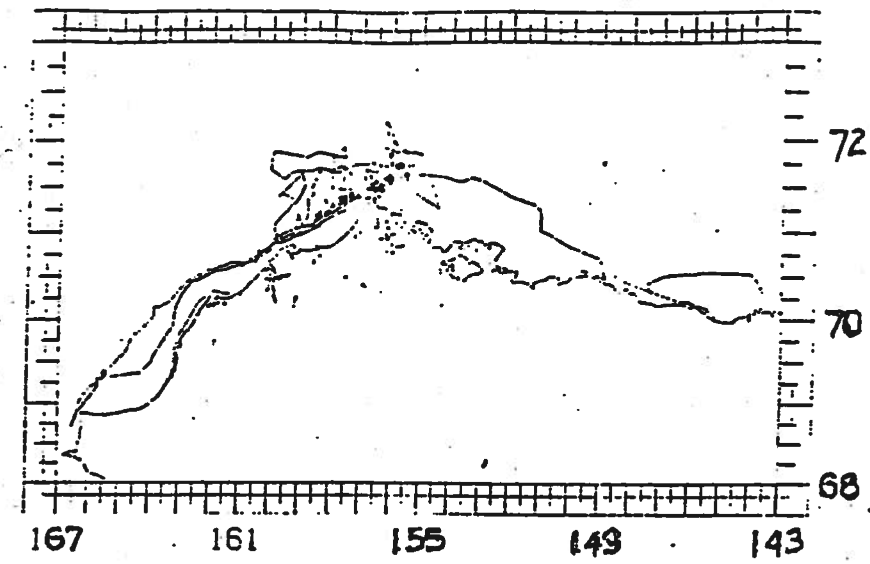


Figure 5.4a. Aerial survey tracklines flown in the eastern Chukchi and Beaufort Seas on 30 April and 1,3,8,9,12 and 14 May 1976. Dots represent presence of bowhead whales: a total of 68 whales were counted with a mean group size of 1.3 (S.D. 0.86). Whales were observed in the nearshore lead only in the Chukchi Sea (from Braham et al., 1980a).

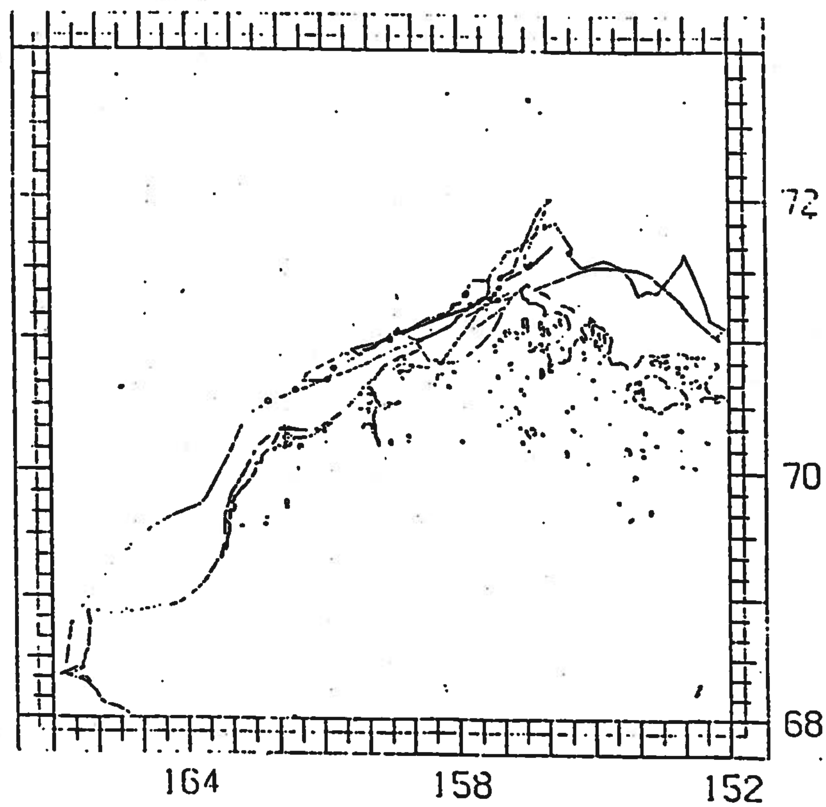


Figure 5.4b Aerial survey tracklines flown on 15, 19, 20, 22, 24, 28, and 31 May 1976. Dots represent presence of bowhead whales: a total of 30 whales were counted with a mean group size equal 1.2 (S.D. 0.82). Whales were observed in the nearshore lead only.

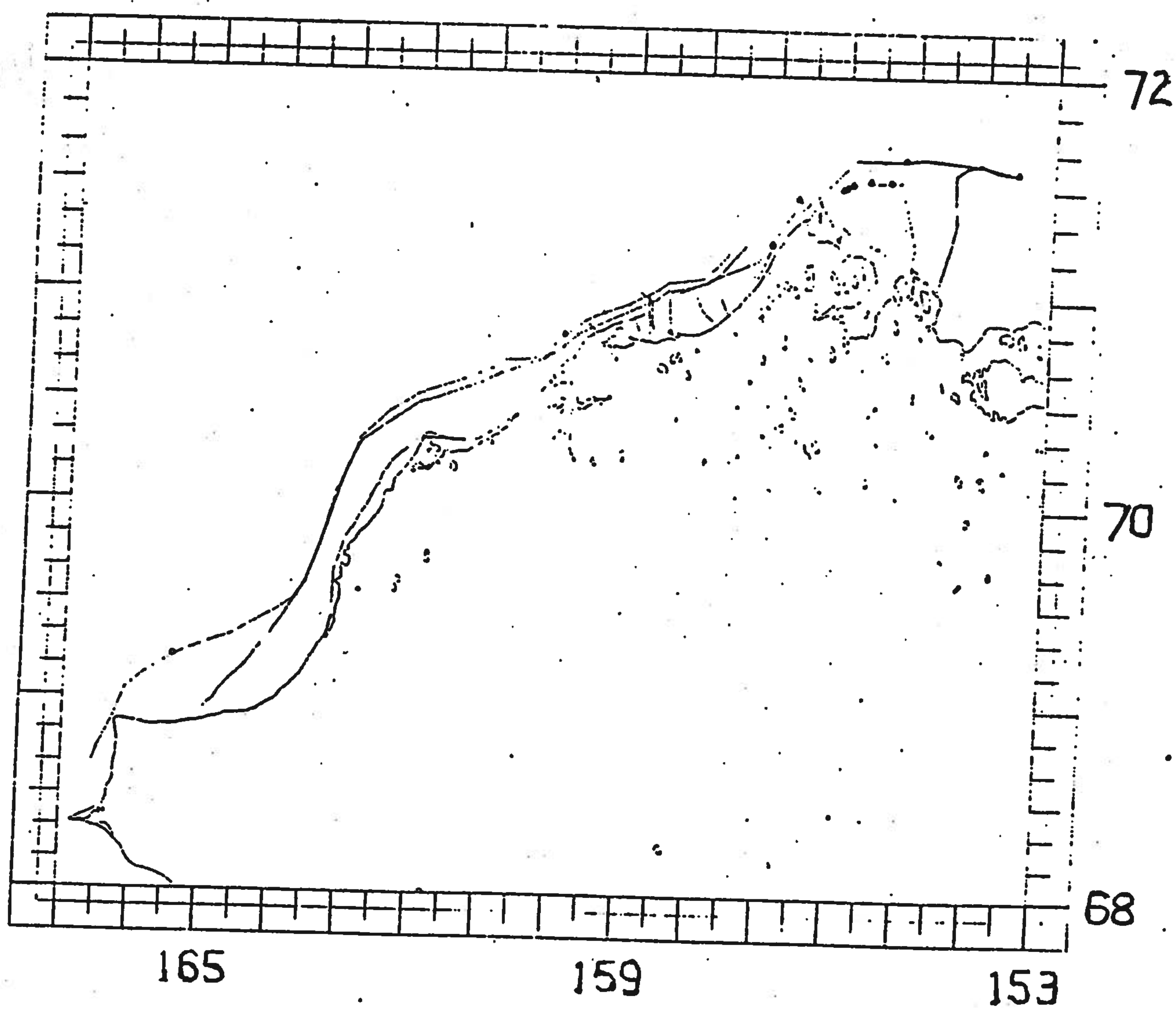


Figure 5.5 Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 1, 4, 5 June 1976. Dots represent presence of bowhead whales: a total of 20 whales were counted with a mean group size of 1.8 (S.D. 1.1).

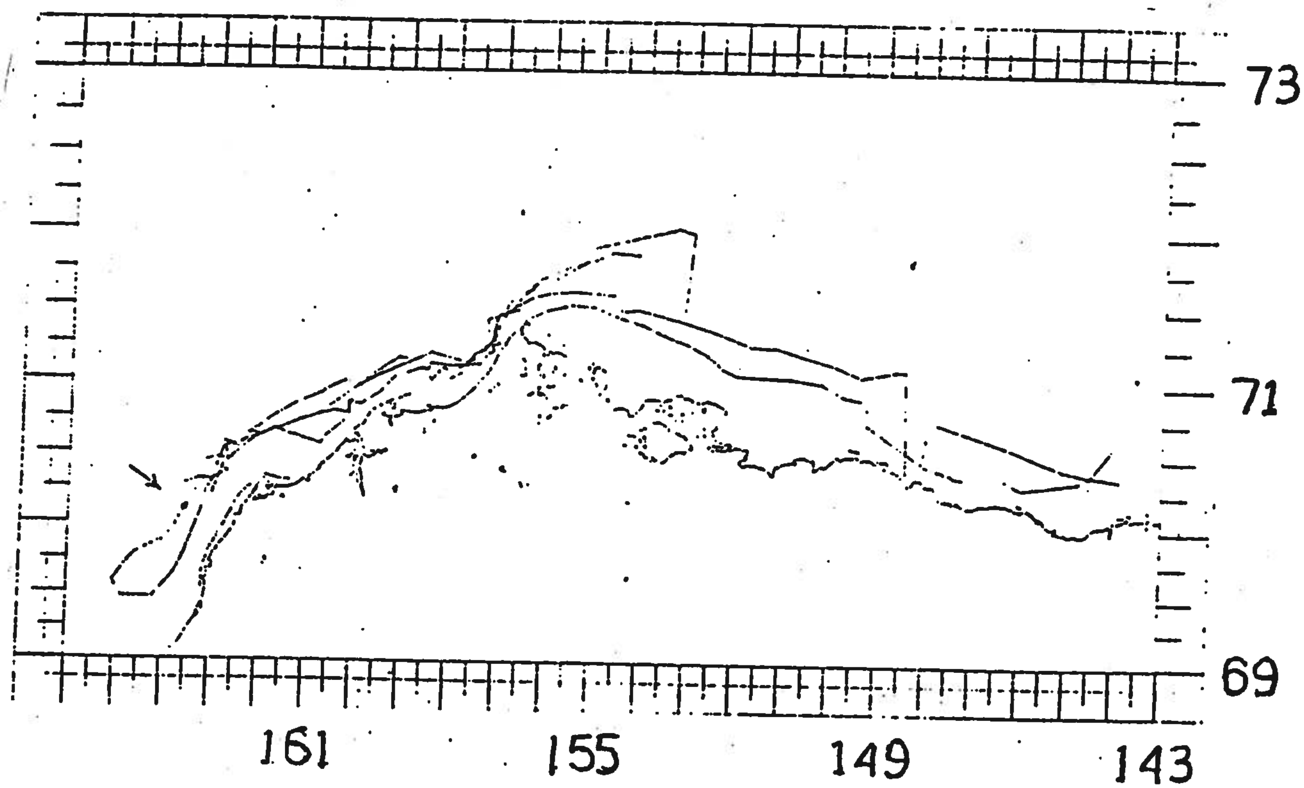


Figure 5.6. Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas 18-20 June 1976. The dot (highlighted by an arrow) represents one bowhead whale seen.

second being usually smaller animals of both sexes, and the third wave being made up of large males and females with calves. Braham and Krogman (1977) postulated that these waves are governed by ice conditions and result from the closing and reopening of leads. The first arrival of bowheads at Barrow annually varies by about 2 weeks, probably due to differences in ice conditions.

Field watches of bowhead whales at Cape Lisburne (Rugh and Cubbage, 1980) in April-June, 1978, observed that the spring migration of bowheads past Cape Lisburne commences during the latter half of April, the whales generally following a northeasterly course. It is estimated that the time needed for these whales to transit from Cape Lisburne to Point Barrow, a distance of about 300 nm, is 3-5 days. Swimming speeds necessary to traverse this distance would have to average 2.5 to 4.2 knots, well within their capability (Braham et al., 1980b).

The timing of the tail end of the spring migration through the Chukchi Sea and past Point Barrow is uncertain because ice conditions generally have not allowed observers to remain on the ice past mid-June. However, it is believed that very few whales pass Point Barrow beyond June 1 (Braham et al., 1980a), even in heavy ice years. Even during 1980, when heavy ice blocked the Bering Strait, and the first bowhead sighting off Barrow was not until May 21, the last sightings were recorded on June 2 (Johnson et al., 1981).

Most of the bowheads passing through the Chukchi Sea summer in the high Canadian Arctic in the vicinity of Banks Island and Amundsen Gulf. Although commercial whalers historically took bowheads in the Chukchi Sea, and even south of the Bering Strait in the summer, bowheads are no longer observed in these waters during this season. Braham et al., (1979) did not observe any bowheads during summer shipboard and aerial surveys of the Bering and Chukchi Seas. They speculate that whalers eliminated this southern portion of an earlier abundant bowhead population that was either resident in the Chukchi Sea or was a late migrating segment of the population. During extremely heavy ice years, some bowheads could still be kept south in the Chukchi Sea by the summer pack ice.

In the fall, generally in September, the bowheads begin leaving their summer feeding grounds and start a general westward movement along the Canadian Beaufort Sea coast. By October they have moved westward to along the Alaskan Beaufort Sea coast between the shore and the polar ice pack. Their further movement into and through the Chukchi Sea is not well known. Sergeant and Hoek (1974) and Marquette (1976) believe that the bowheads continue moving westward along the pack ice edge to the vicinity of Wrangel Island before turning southward along the Soviet coast on their return to the Bering Sea (Figure 5.7 and 5.8). Braham, et al., (1980a), describes these movements as follows (references omitted):

> "From Point Barrow the animals appear to move westward to Herald Shoal and Herald and Wrangel Islands, then south through the Chukchi Sea into the Bering Sea. There is speculation by Soviet scientists that bowheads pass to the Bering Sea by traveling the western Chukchi Sea. Some animals appear to move southwest along the northwest coast of Alaska past Point Barrow to the Bering Strait, but this probably varies with weather and ice conditions. Others in the population seem to migrate to the north side of the Chukchi Peninsula before entering the Bering Sea. (Certain researchers) believe that the fall migration through the Chukchi Sea followed an offshore passage, since bowheads were not seen at Wainwright, Cape Thompson, Point Hope, or Kivalina in the autumn during their studies. Bowheads generally enter the northern Bering Sea in November and December, arriving in central Bering Sea wintering areas in December - February, thus completing their annual migration cycle."

These contentions are supported by evidence gathered by a joint U.S.S.R.-U.S. marine mammal cruise in October, 1979. Johnson et al., (1981), observed bowheads near Wrangel and Herald Islands of the northwest Chukchi Sea, and the coast of Siberia, especially nearshore between Tenkergin and Cape Onman (Figure 5.9). What part of the population migrates along the northeast coast of the Chukchi Sea is not known. Because of the open water available in October-November, their return may be widely distributed in the area beyond the fast ice zone.

The life history, food habits, and behavior of bowhead whales are reviewed by

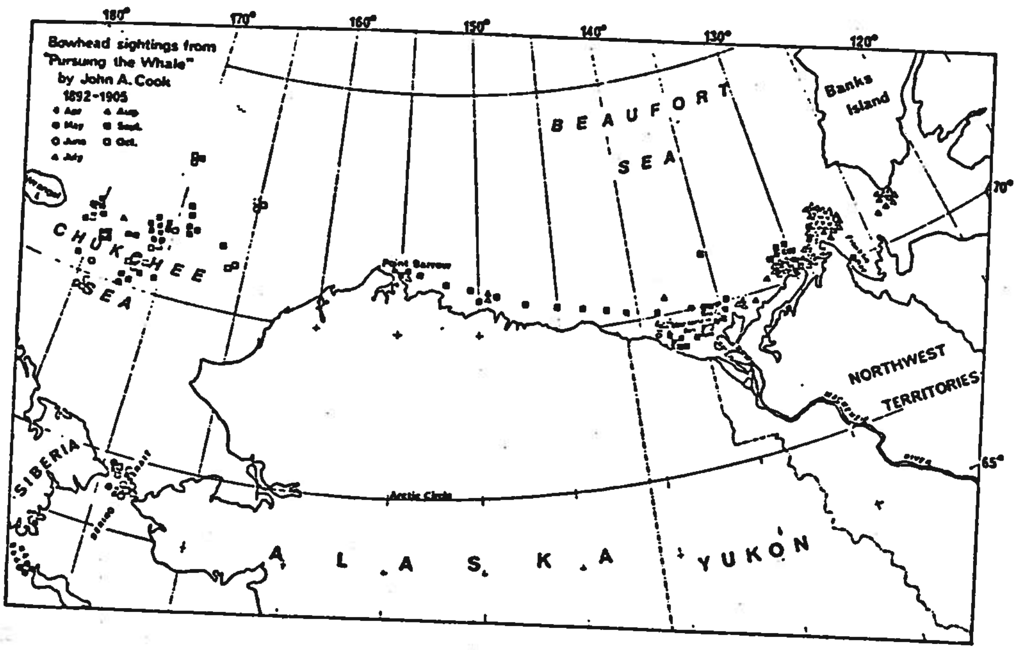


Figure 5.7. Bowhead whale sightings by month from whaling records compiled by Cook (1926) (from Sergeant and Hoek, 1974). Sea ice prevented spring sightings north of the Bering Straits. Fall sightings indicate a westward migration of bowheads along the edge of the polar pack ice toward the Soviet sector before turning south toward the Bering Straits. However, the lack of fall sightings along the northeast Chukchi Sea coast may be due to a bias in the location of the observations, and not entirely due to a absence of whales from this area.

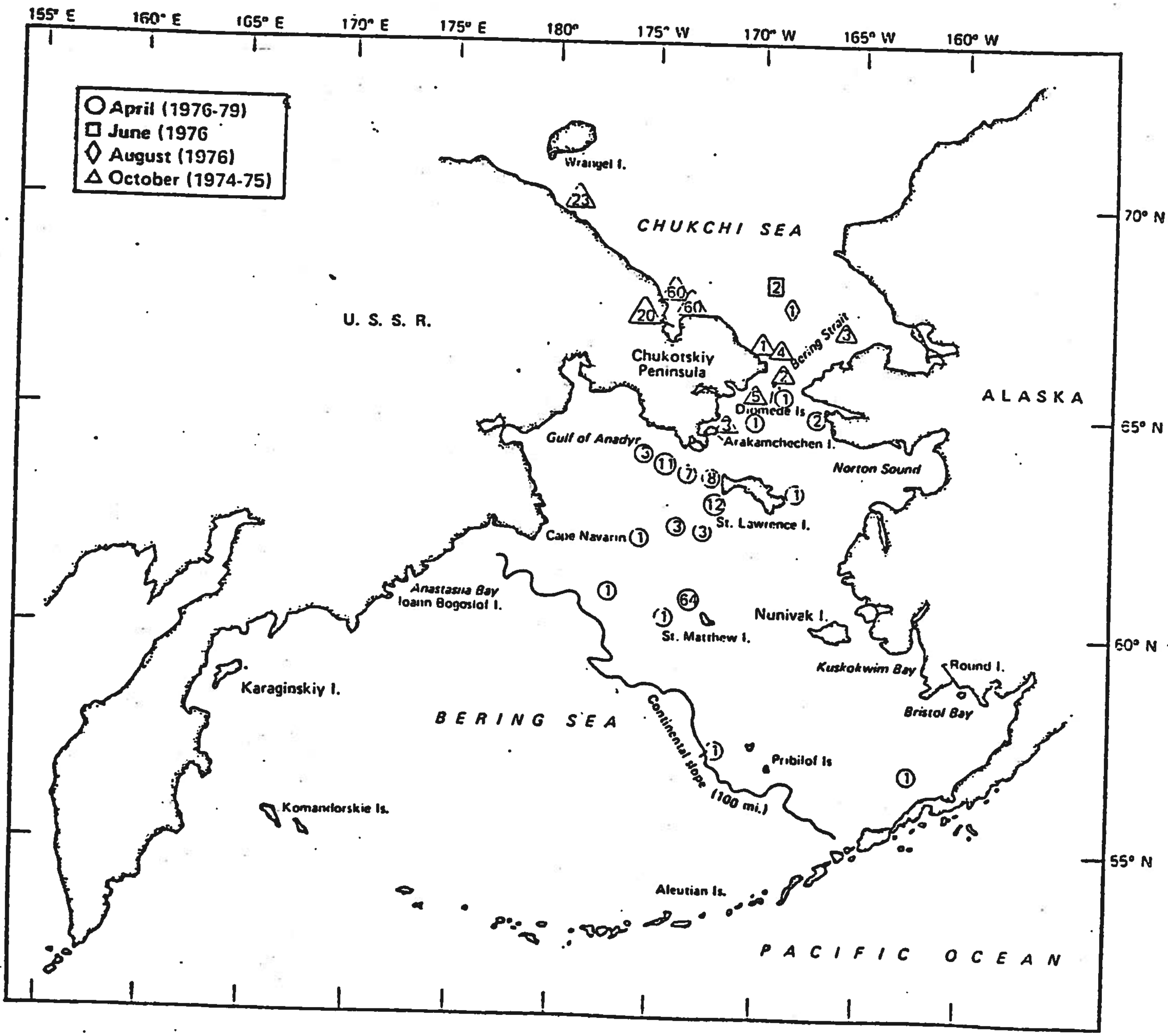


Figure 5.8, Bowhead whale sightings from other than NMFS aerial or ice based methods in the Bering and southern Chukchi Seas, 1974-78. October sightings (Δ) (provided by A. Berzin, pers. commun.) indicate fall migration along the Soviet Coast of the western Chukchi Sea (from Braham et al. 1980a).

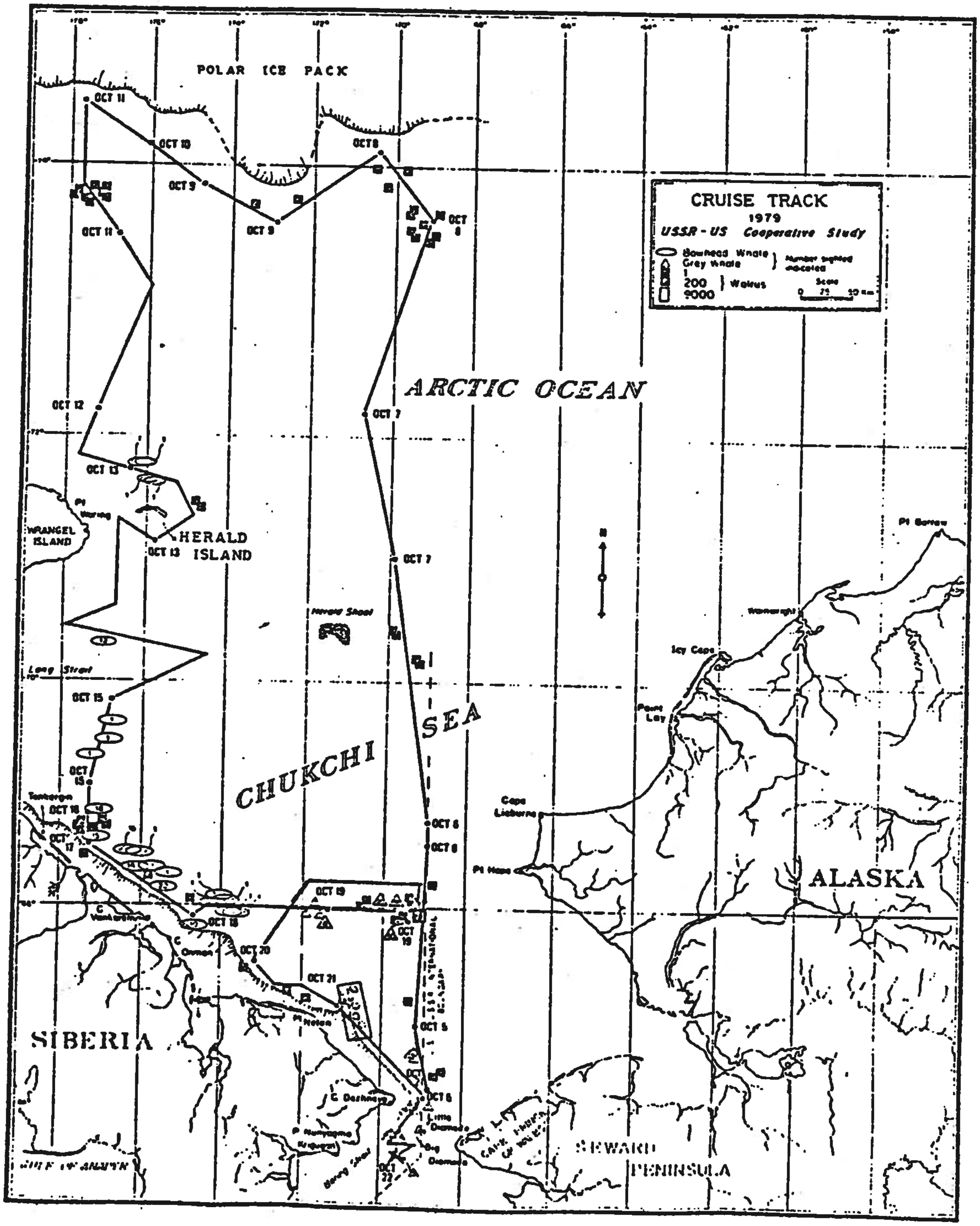


Figure 5.9. Cruise track of the joint U.S.S.R.-U.S. marine mammal cooperative study in the Chukchi Sea in October 5-22, 1979, on the M/V Avangard - a 64 m whale-catcher boat (from Johnson et al., 1981). Gray whales were common in the vicinity of the Bering Straits and to the northwest. Walrus occurred throughout the survey area. Bowhead whales were first observed in October 13 near Herald Island, and on subsequent days in Long Strait and along the Siberian Coast.

Braham et al., (1980a), and will not be discussed at length here. They are also summarized in the resource assessment for the Navarin Basin (Morris, 1981). Some aspects of these subjects pertinent to the Chukchi Sea do deserve further mention.

Breeding and Calving: Breeding times for the bowhead are not well known. Durham (1972) believed that breeding occurs in early April before the whales reach Point Hope. However, possible copulatory behavior has been observed at Point Hope in May (Foote, 1964) and north of Point Barrow (Everitt and Krogman, 1979), also in May. Mating may occur throughout their spring migration path, including in the lead system along the Chukchi coast.

Calving is reported to occur just prior to the time of breeding, that is, from early spring to early summer. Cows with calves are seen passing Point Hope and Point Barrow from mid-April to early June. Braham et al., (1980a), believe that most calving occurs in the spring during the April-June migration period. Thus calving also, may occur along the Chukchi Sea lead system.

Feeding: Feeding does not appear to be an important activity during the spring migration. Stomach contents of bowheads taken during the spring whale hunts are empty, or relatively so, compared to those of whales taken in the fall. Although this may reflect the lack of food availability (i.e., plankton) in the water column during the spring, bowheads are also known to be bottom skimmers (Nemoto, 1976) and could presumably utilize the benthic food resource if desired. Johnson et al., (1966) found two of three spring-taken bowheads had empty stomachs, while the third contained fragmentary remains of benthic animals (polychaetes, shrimp, snails, echinoids, sand and gravel). The extent of spring feeding in the Chukchi Sea is essentially undetermined.

Behavior: The spring migration through open nearshore leads between Cape Lisburne and Point Barrow is a steady northeast movement when unobstructed by sea ice. A little time may be spent resting, feeding, courting and mating, or breaching. According to Braham et al., (1980b) most whales travel singly (75.4%), or in pairs (19.5%), and rarely in groups of 4 or more (0.7%). In obstructed leads the whales behavior changes and their progress is altered. They may be seen milling in polynyas, and apparently dive to search for adjacent leads or polynyas. If unsuccessful, they return to their original hole. They also push up underneath the ice to breath and form hummocks. They may even find air pockets underneath the ice in which to breath. Occasionally they have known to be trapped under the ice and perish when not able to find suitable space to breath.

The reaction of the bowhead whale to any man-caused factor that obstructs their migration is unknown. They react negatively to small boats, and normally avoid or vacate the area and flee pursuit. The reaction to aircraft disturbance is variable. Most bowhead whales react to aircraft overflights less than 405m (LGL, 1981) but some do not exhibit visible disturbance even down to 65m (Braham et al., 1980a). It appears that their reaction to aircraft varies in unknown ways with the source, time of year, environmental conditions, and activity of the animals.

Their reaction to industrial noises such as dredges, ships, seismic operations, drilling rigs, is beginning to be learned (LGL, 1981), at least during the summer period in the open waters of the MacKenzie Delta area. Reactions are variable and their patterns still remain to be determined. It is not clear, however, whether any behavior toward a source of disturbance in open waters would be the same as they would exhibit during the spring migration when confined to lead systems.

5.2 The Gray Whale

Most of the 15,000 - 17,000 California gray whales (Eschrichtius robustus) migrate annually between summer feeding grounds in the Bering and Chukchi Seas and their winter breeding grounds along Baja California. Their northward migration reaches the Bering Sea by April and continues through July. The whales generally travel close to the shoreline (within 3 miles) until they reach the vicinity of Nunivak Island in the Bering Sea. From there they apparently divert offshore towards St. Lawrence Island. Gray whales occur mainly in shallow (50m) shelf waters from St. Lawrence Island northward, where they remain to feed during the summer. Part of the population remains in the Bering Sea; others pass north through the Bering Strait and disperse over the wide Chukchi Sea shelf area in late June or early July. Data from sightings in Soviet waters and from the literature suggests that gray whales are most common in the central Chukchi Sea and relatively more common to the south and west than to the east and north of the central shelf area. They are most frequently sighted in the eastern Chukchi Sea in August and September (Braham et al., 1977 and 1980c).

In the northeastern Chukchi Sea, gray whales are commonly encountered nearshore just north of Cape Lisburne to as far north as Barrow, and occasionally eastward along the Arctic coast to the Canadian Beaufort (Figure 5.10). They may be regularly encountered in low numbers along the coast between Wainwright and Barrow from July to September. These animals remain in the Chukchi Sea to feed in areas rich in benthic amphipods until about October when they make their exit. Gray whales are dependent on these summer feeding areas, as they fast while on their wintering grounds. By November or December, they have departed the Bering Sea on their return south.

Gray whales are taken only rarely by villages along the Chukchi Sea coast (Marquette and Braham, 1981). They are not known to have been taken at either Point Hope or Point Lay. Wainwright whalers last took a gray whale in 1957 and only nine are known to have been taken since 1925. Barrow whalers last took a gray whale in 1965. Out of 11 grays landed at Barrow since 1925, eight were taken in 1958 and 1959, six of these in 1959 alone. Because the village whalers failed to capture a single bowhead during these years, it seems probable that the gray whales were taken as a substitute for the lack of bowheads.

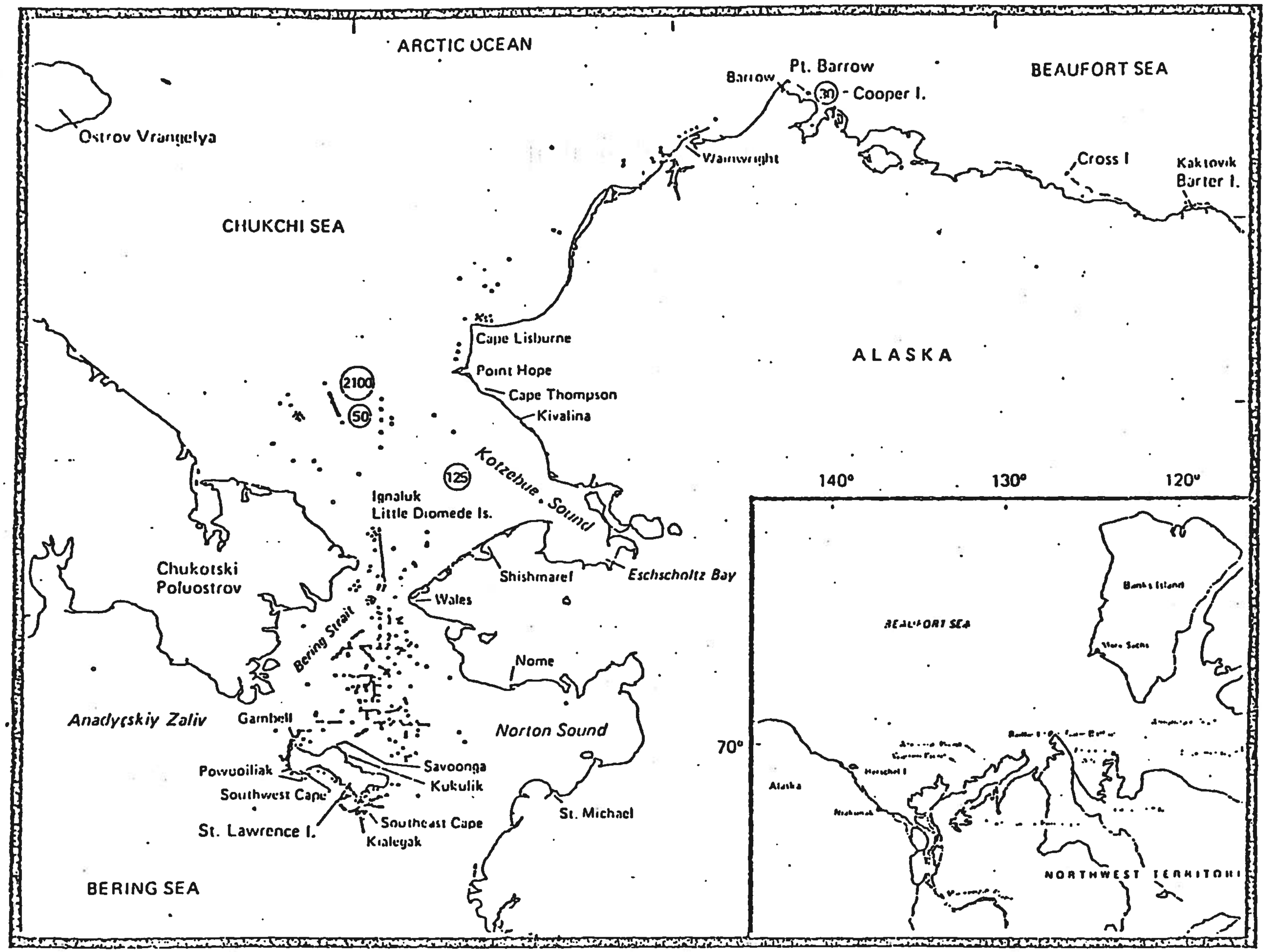


Figure 5.10. Gray whale sightings in the northern Bering, Chukchi, and Beaufort Seas since 1961. Data compiled from records of the NMFS Platforms of Opportunity Program 1974-1979, scientists, Eskimos, and from the literature.

5.3 Beluga Whale

The beluga (belukha) or white whale (Delphinapterus leucas) is primarily an inhabitant of Alaska coastal waters. Most belugas are highly migratory and move regularly from wintering areas in the Bering Sea through the Chukchi Sea to summer as far north as the Canadian Beaufort (Figure 5.11). Overwintering in the Chukchi Sea would probably only occur during mild ice years with substantial open water. The pattern of their migrations, other than the general north-south seasonal movement, appears to be complex and varies from year to year or even from week to week with changing ice conditions. The size of this migrating population is uncertain.

Spring migration occurs from March to early July, beginning in close association with the bowhead whale migration. However, belugas are more widely distributed in the Chukchi Sea than the bowheads. The belugas follow both nearshore and offshore leads in April to June through the Chukchi Sea and into the Beaufort Sea (Figure 5.12 A-D). Aerial surveys (Braham et al., 1980a) have commonly observed them in the leads farther offshore (approximately to 60-150 km) and penetrating farther north into the pack ice than the bowheads.

Belugas begin their travel in large herds of up to 100 or more, but as the pack ice begins to disintegrate, these congregations split into smaller groups of two to four animals until they reach their summering grounds. Depending upon ice conditions, the first animals pass Point Hope between late April and mid-May and continue to move north through July. By May and June, some belugas have passed Point Barrow and have entered the eastern Beaufort Sea (Braham et al., 1980a).

A segment of the beluga population summers in Kotzebue Sound and may breed and calve there also. The Chukchi Sea coast north of Cape Lisburne is apparently used by the majority of the Arctic population for their spring and fall migrations, but many do summer along this coast. Belugas have been observed in the summer at the mouth of the Pitmegea River just east of Cape Lisburne during June (Childs, 1969), and in Kasegaluk Lagoon and Peard Bay (OCSEAP,

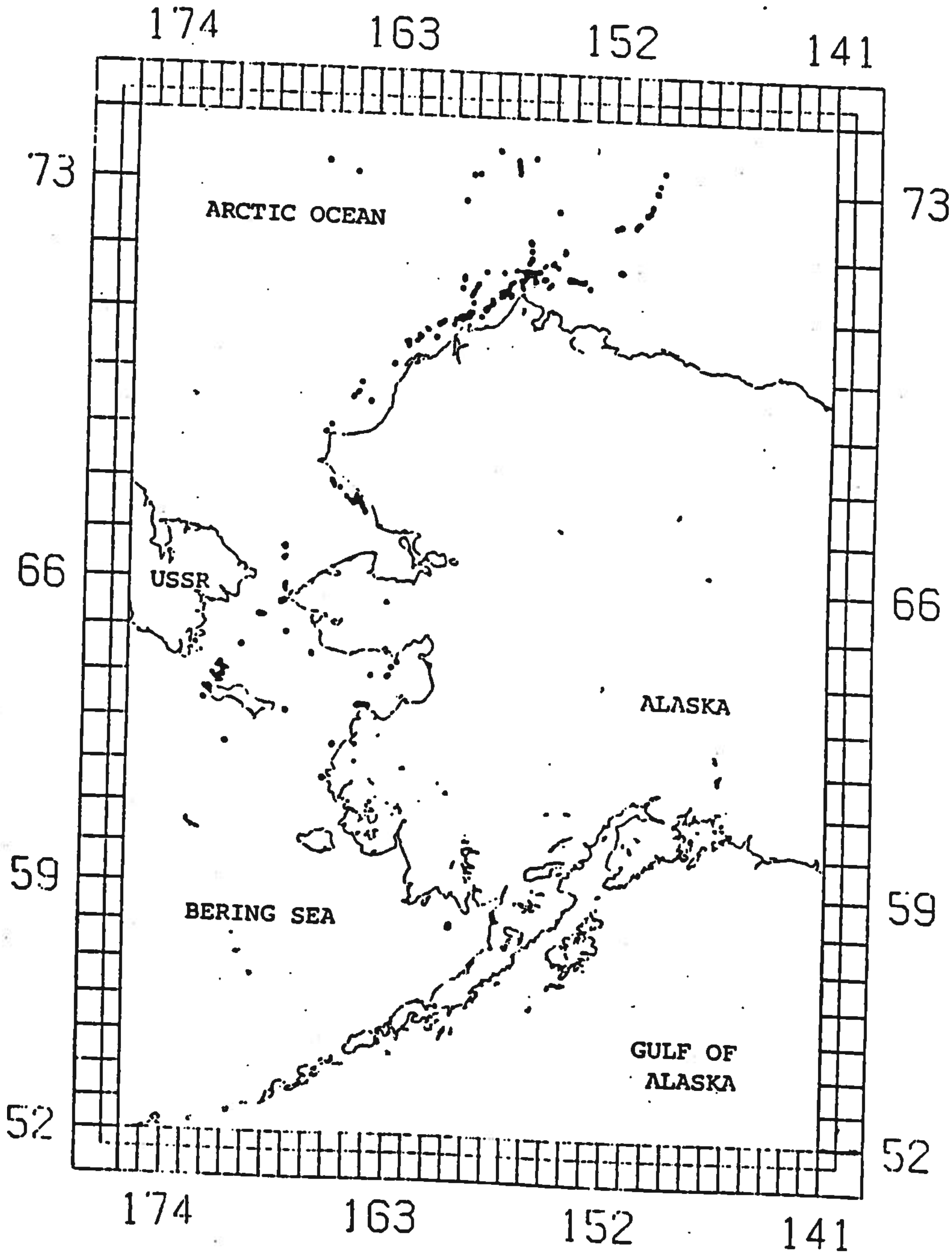


Figure 5.11. Sightings of white whales during aerial surveys conducted between the months of March and September, 1975-1977. The total number of sightings (419) corresponds to 2,002 whales observed.

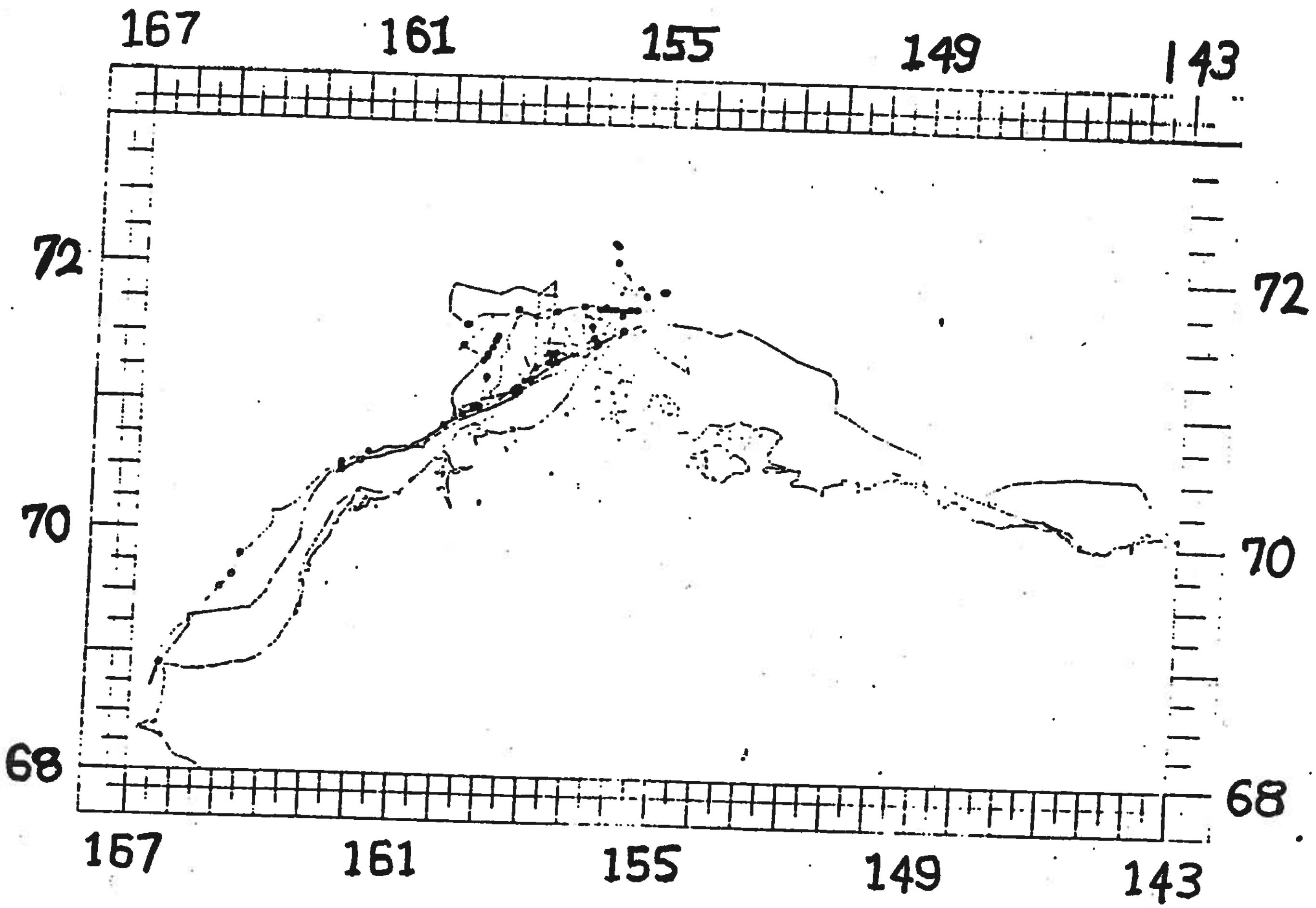


Figure 5.12. Sightings of beluga whales from aerial surveys flown in the eastern Chukchi and Beaufort Seas. Dots represent presence of white whales (from Braham et al., 1980a).

Figure 5.12A. A) April 30-May 14, 1976, a total of 485 whales were counted with a mean group size of 3.7.

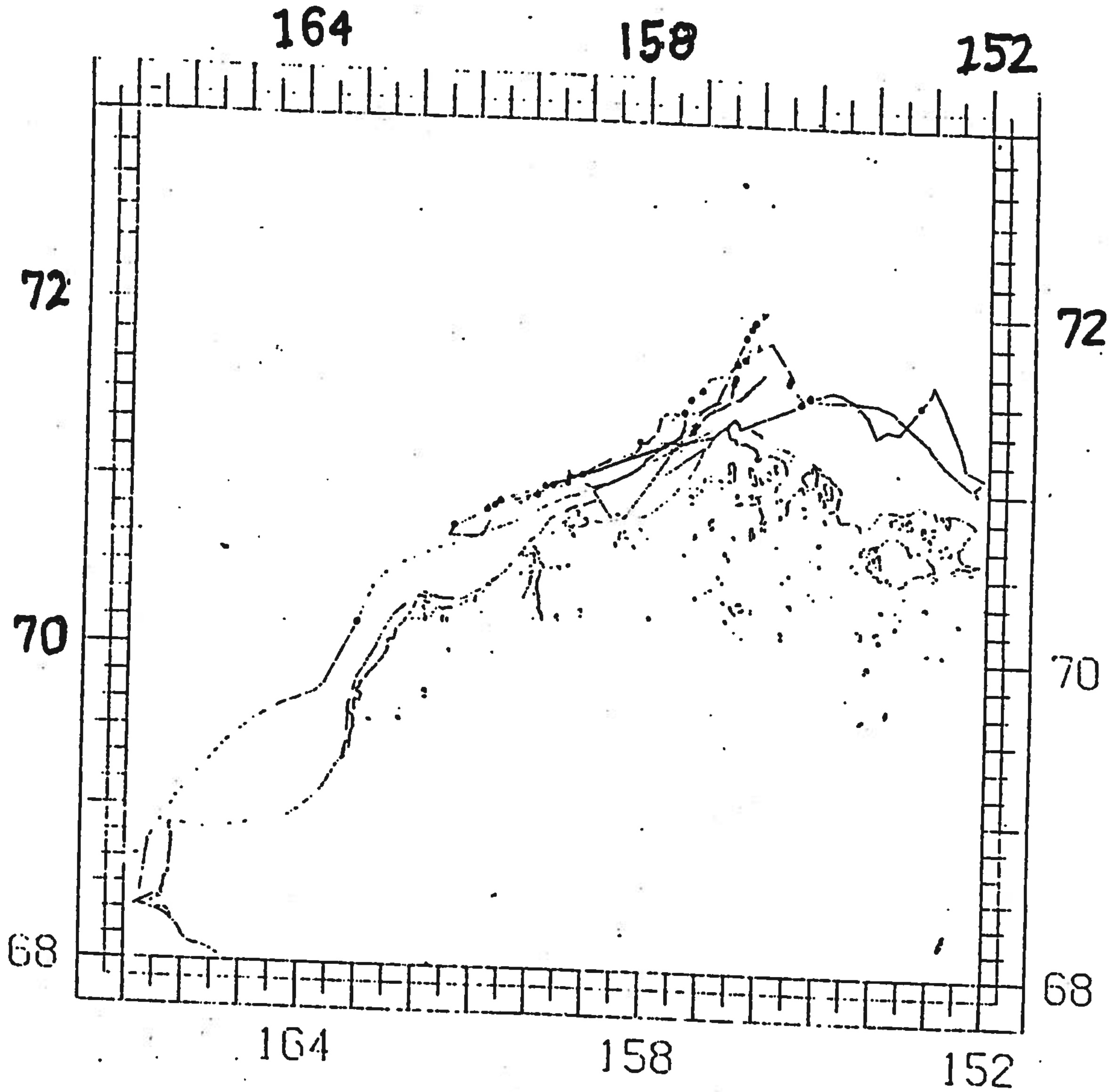


Figure 5.12B. May 15-31, 1976. A total of 289 whales were counted with a mean group size of 6.0.

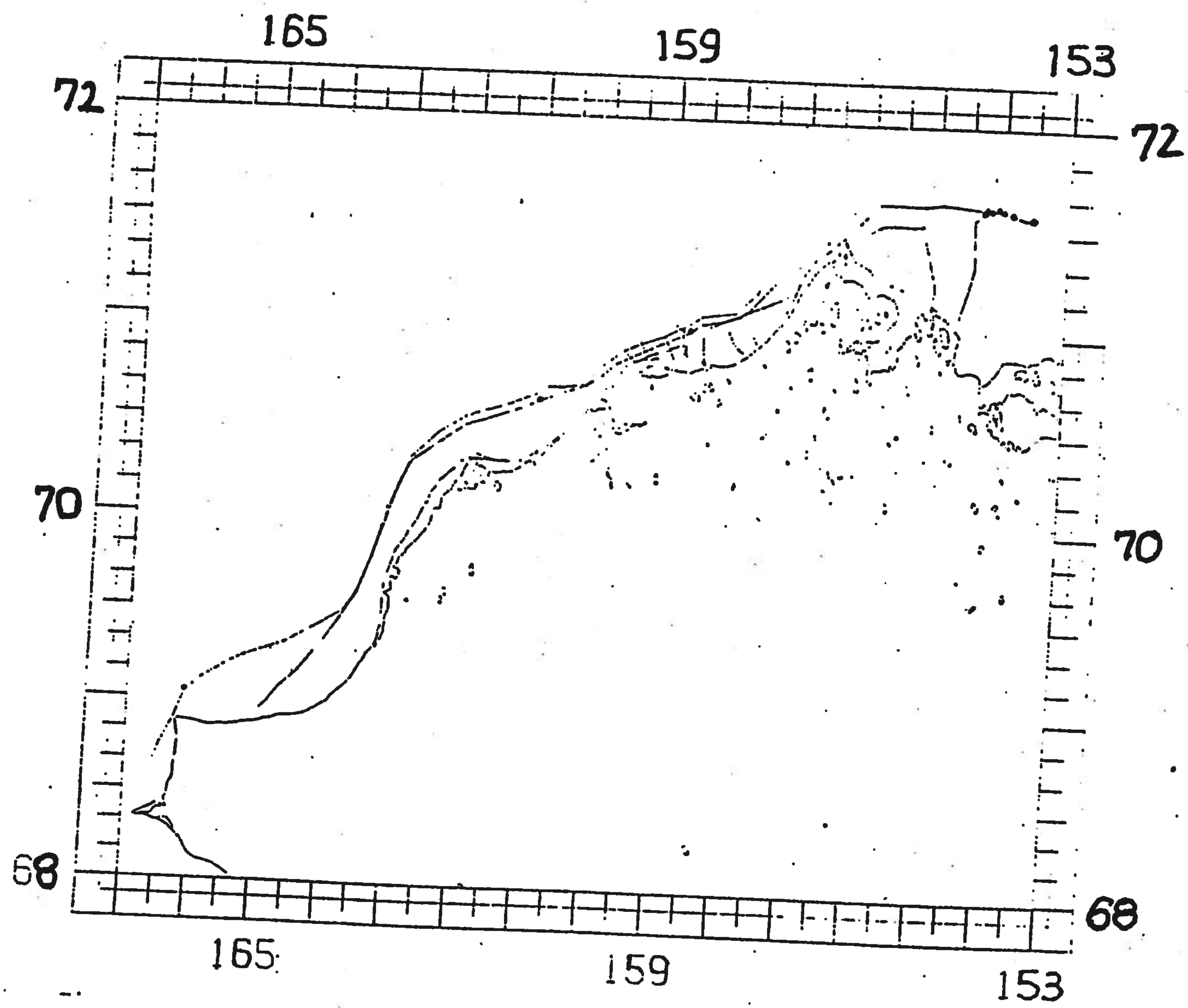


Figure 5.12C. June 1-5, 1976. A total of 177 were counted with a mean group size of 11.1.

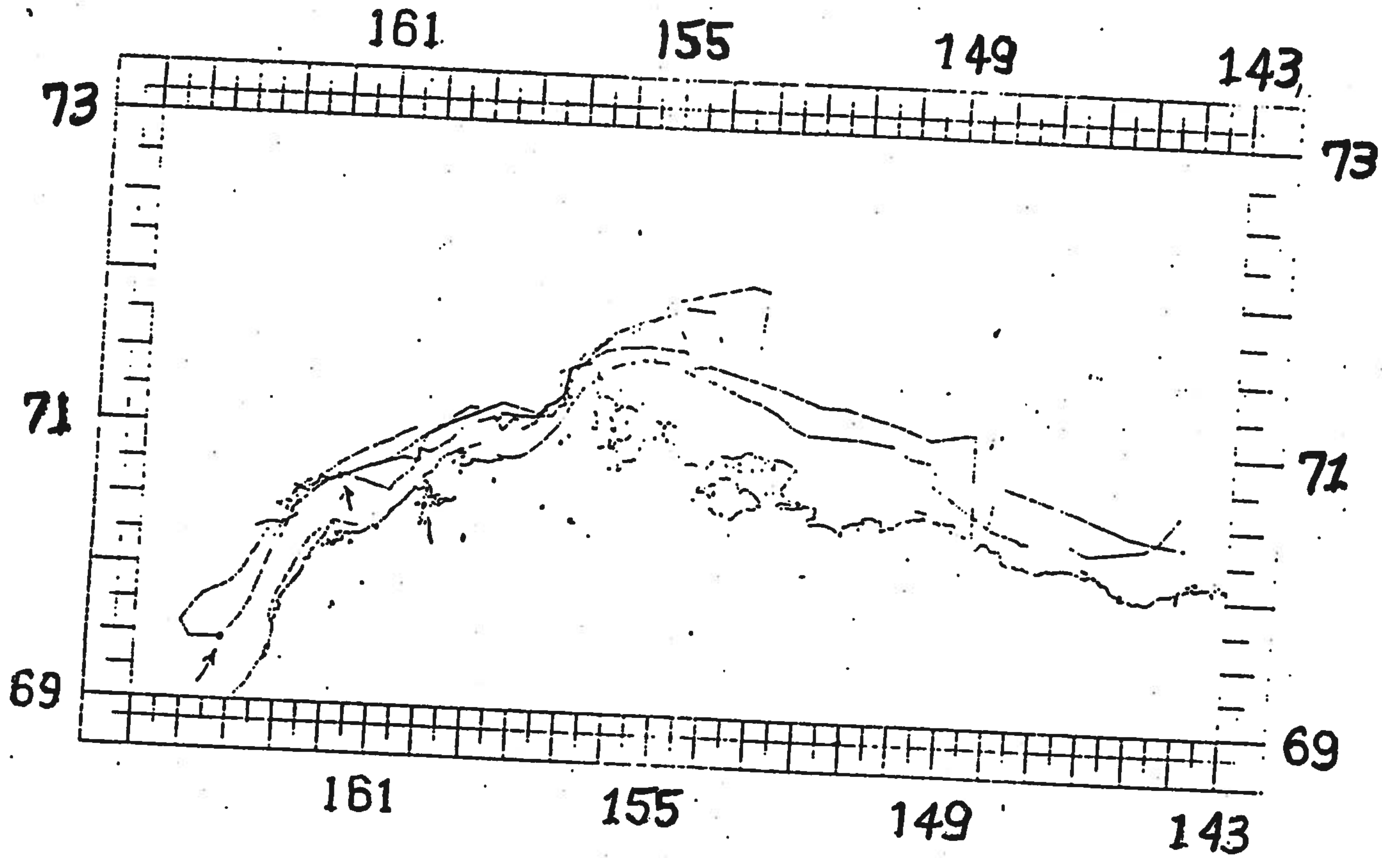


Figure 5.12D. June 18-20, 1979. A total of 73 whales were counted with a mean group size of 36.5 (S.D. 34.6).

1978). These areas are used for feeding, mating, and calving. Others are found widely spread along the pack ice edge.

The fall return migration commences in September and lasts until December if freeze-up and pack ice conditions permit. The return movements of these whales are not known, but are believed to be predominantly offshore in small groups of animals. In the fall, belugas are often seen far offshore near the pack ice edge (Figure 5.12 E-F).

The belugas observed in the Chukchi Sea during the summer are of uncertain origin (Braham et al., 1980a). They are thought to be either 1) late migrants of a single Bering Sea population that remains in shallow water, or 2) stocks of a separate Alaskan or Soviet population. Too little is known of these whales to determine either the origin of these summer populations or the identity of different stocks.

Calving and mating of belugas occurs in May and June, and perhaps earlier since calves have been observed as early as March. Some mating and calving is reported to occur along the northeast Chukchi Sea coast, particularly near Peard Bay and in Kasegaluk Lagoon. The warmer waters of these estuaries may be important to the survival of newborn calves. Belugas feed mainly on fish, frequently in the nearshore estuaries, bays, and river mouths. The principal prey species and feeding areas along the Chukchi coast are not fully known. Prey items variously consumed are given in Table 5.3.

5.4 Other Whales

Pacific Right Whale: The Pacific right whale (*Balaena glacialis*) resides mainly in the waters of the North Pacific and, during the summer, is found along the continental slope of the Gulf of Alaska, Bering Sea, and Gulf of Anadyr. The northern limit of its range is thought to be in the northern Bering Sea, but sightings have been reported north of the Bering Strait (Nasu, 1960). The occurrence of this whale in the northeastern Chukchi Sea would be unusual.

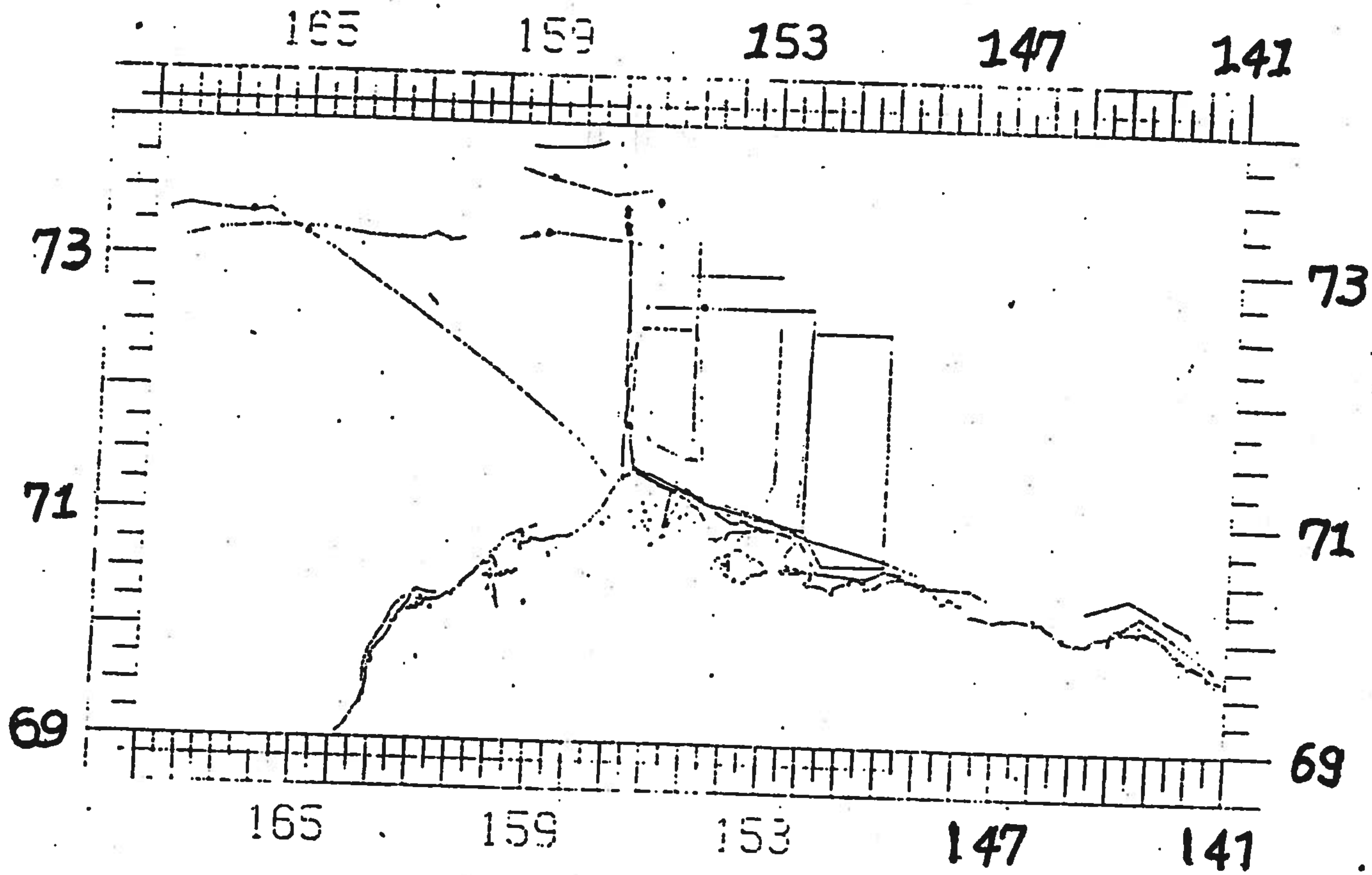


Figure 5.12E. August 26 to October 13, 1976. A total of 89 were counted with mean group size of 4.0 (S.D. 3.5). All but three of the 89 were observed on 10 and 14 September.

Fin Whale: The fin whale (Balaenoptera physalus) enters the Chukchi Sea in low numbers only during the summer. There is no apparent fixed migration pattern, and their distribution and abundance in these waters is uncertain. Like the humpback whale, they are common in low numbers in the southwestern Chukchi Sea (Votrogov and Ivashin, 1980) between August - October, but are irregularly sighted in the Alaska sector.

Sei Whale: The sei whale (Balaenoptera borealis) is the least frequent of the great whales reported from the Chukchi Sea. There is uncertainty as to whether the species even passes the Bering Strait on their northward summer movements, although it has been reported in the Chukchi Sea (Tomilin, 1957).

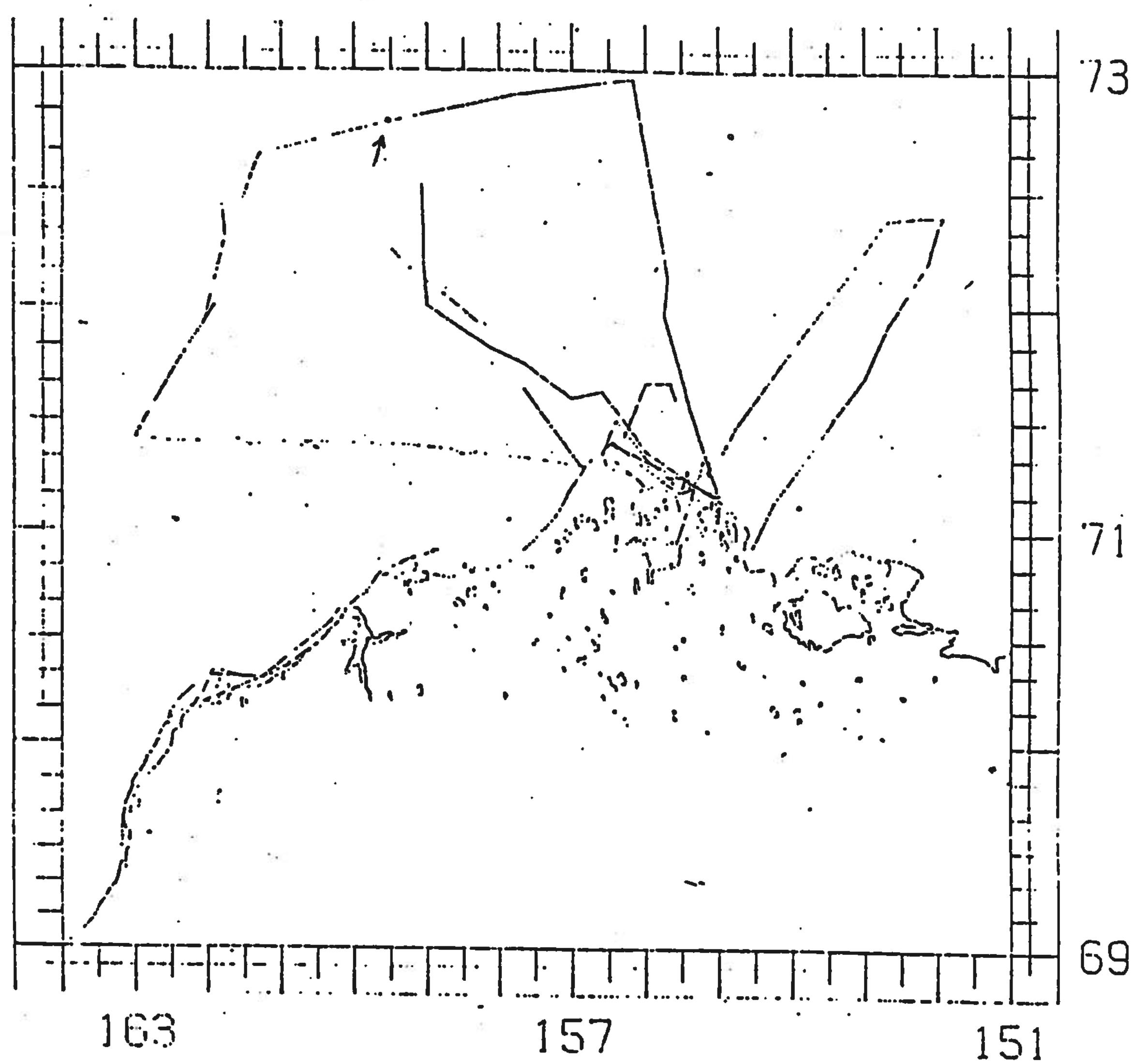


Figure 5.12F. September 20-26, 1976. Only one white whale was seen.

Minke Whale: The minke whale (Balaenoptera acutorostrata) inhabits all oceans except in tropical latitudes. The North Pacific population makes extensive seasonal migrations between high-latitude summering grounds and low latitude wintering grounds. During summer, the minke whale ranges from the Gulf of Alaska, throughout the Bering Sea, and into the Chukchi Sea. Pregnant females migrate to higher latitudes than do the lactating and immature females. Little is known of the movements or habits of this whale in the Chukchi Sea.

Humpback Whale: The humpback whale (Megaptera novaeangliae) ranges into the Chukchi Sea in the summer, where it is can be found in both open and ice-covered waters. They generally arrive in July and August with pregnant females arriving earliest and staying longest. They are regularly found off the Soviet coast of the southern Chukchi Sea (Votrogov and Ivashin, 1980), usually in August - October. They are less frequently reported along the Alaskan coast. Like the gray whale, the humpback is a seasonal feeder, feeding in the summer mainly on euphausiids and occasionally small fish, and fasting during the winter breeding season.

Killer Whale: The killer whale (Orcinus orca) enters the Chukchi Sea during the open water season where it is often sighted along the coast or at the edge of the pack ice.

Narwhal: The narwhal (Monodon monoceros) resides mainly in the northwestern Greenland and eastern Canadian Arctic, especially in Jones and Lancaster Sounds, and along the north and east coasts of Baffin Island. They are rare in the western Canadian Arctic or the Beaufort, Chukchi, or East Siberian Seas. Although they have not been reported from the Chukchi Sea, two specimens have been reported from the Bering Sea (Geist et al., 1960). Old tusks of this unusual whale have been obtained at Wainwright. An encounter with this species in the northeastern Chukchi Sea would be extremely unlikely.

Harbor Porpoise: The harbor porpoise (Phocoena phocoena) occurs in the Chukchi Sea in low abundance only during the summer, primarily in August when the ice is out and waters have warmed. They occupy nearshore areas only, and often enter bays and river mouths. They avoid waters where sea ice is present.

5.5 Ringed Seal

The ringed seal (Phoca hispida) is an ice-associated seal of the Bering, Chukchi, and Beaufort Seas. The smallest of the northern seals, it is the seal most closely associated with the nearshore fast ice environment and is the most abundant marine mammal in the subsistence take of coastal residents of arctic Alaska.

Ringed seals show a strong dependency for sea ice and move seasonally with its advance and retreat. In the winter, the seals are not dependent upon leads, faults, or open water to survive. They are adapted to severe ice conditions, and overwinter along the coast in the narrow fringe of shorefast ice by maintaining breathing holes and haul-out lairs in the ice. They are most abundant in the fast-ice zone over water depths from 3 fathoms out to the shear zone. The highest densities of ringed seals in arctic Alaska are reported from the fast ice zone of the Chukchi coast (Burns and Harbo, 1972; Burns et al., 1980). Densities averaging up to 6.2 seals/nm between Wainwright and Barrow were reported from aerial surveys flown in June 1970, 1975, 1976, and 1977 (Table 5.5 and Figure 5.13). In contrast, ringed seal densities on the pack ice averaged only 0.2 seals observed/nm.

Pups are born in nearshore birth lairs in late March through April. Until they are weaned they are incapable of surviving in the water, and must remain in the lair or hauled-out on the ice, a period of time that generally lasts 4 to 7 weeks. In late spring on sunny days, both adults and young seals can be observed on the ice along cracks and open leads. With breakup of the shorefast ice in late June or July, the ringed seals leave the nearshore zone to inhabit the edge of the pack ice, and will even extend into the consolidated ice pack for some distance. Preceding the formation of the shore ice again, the seals suddenly reappear along the coast in October-November where they remain until the following summer.

5.6 Bearded Seal

The bearded seal (Erignathus barbatus) is the largest and most widely distributed of the phocid seals in the Chukchi Sea. It winters primarily in the Bering Sea near the ice edge and in broken pack ice with suitable open water. It generally prefers the heavier pack ice, and can be found wintering north of the other offshore seals. Some bearded seals overwinter in the Chukchi Sea in the highly fractured ice north of the Bering Strait and in the flaw zone off the Chukchi and Beaufort Sea coasts (see Figure 5.1). Although they can maintain breathing holes in ice, they rarely do so, and seldom occur amid the shorefast ice.

Table 5.5. Densities of ringed seals in the fast ice zone of the eastern Chukchi and western Beaufort Seas during aerial surveys in June 1970, 1975, 1976, and 1977. Values are the average number of seals per nm^2 observed on the ice in each sector. Dashes indicate no surveys flown (from Burns et al., 1980)

Sector of Coastline	1970	1975	1976	1977	AVE.
Kotzebue Sound	-	-	0.7	-	
Cape Krusenstern - Point Hope	-	-	2.3	-	
Point Hope - Cape Lisburne	-	-	0.9	-	
Cape Lisburne	-	-	4.9	-	
Point Lay - Wainwright	5.4	2.9	1.9	3.3	3.4
Wainwright - Barrow	3.7	6.2	3.8	2.6	4.1
Barrow - Lonely	2.3	2.8	1.4	1.0	1.9
Lonely - Oliktok	1.0	1.4	1.1	0.5	1.0
Oliktok - Flaxman Island	1.4	1.0	1.4	0.7	1.3
Flaxman Island - Barter Island	2.4	1.8	0.4	1.2	1.5
Chukchi Sea - moving pack ice	-	-	0.2	-	
Beaufort Sea - moving pack ice	-	-	0.1	-	

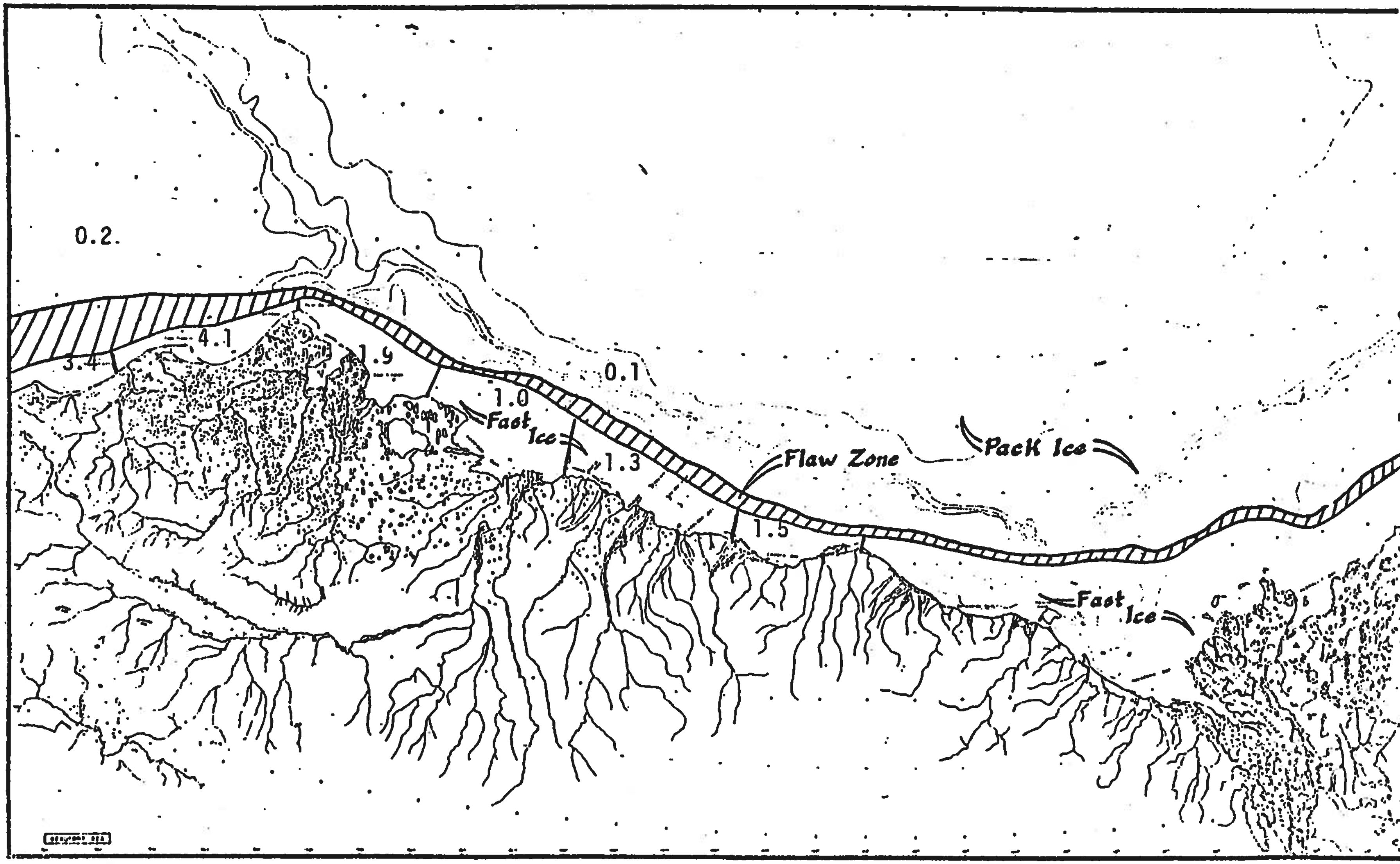


Figure 5.13. Average relative densities of ringed seals in the shore fast ice and pack ice zone along the Alaska Beaufort and Chukchi Sea coasts as determined by aerial surveys conducted in June (data from Burns <u>et al</u>., 1980).

Marked seasonal migrations of bearded seals follow the annual advance and retreat of the seasonal pack ice. These movements involve both active swimming and passive movement with the ice. During the spring, their abundance in the Chukchi Sea increases with the increase in ice leads and as northward drifting ice transports overwintering populations from the Bering Sea.

During summer and autumn, bearded seals migrate to the edge of the polar pack ice and are found in highest abundance when the pack ice edge is close to the coast. Most bearded seals in the Chukchi Sea and Arctic Ocean are adults (Somerville et al., 1972). Although adults are almost always associated with the sea ice, a small portion of subadults inhabit the ice-free waters, particularly in bays and estuaries, but they rarely come ashore. Most of the subadults remain in the Bering Sea and few are found in the open water or nearshore areas of the northeast Chukchi Sea during the summer.

5.7 Spotted Seal

The spotted seal (*Phoca vitulina largha*) is the ice-breeding subspecies of harbor seal. During winter and spring, virtually the entire population of spotted seals is about 250,000) concentrates along the southern margin of the seasonal pack ice in the central and eastern Bering Sea. These seals move northward and toward the coast as the ice retreats and disintegrates. Much of the population passes through the Bering Strait to enter the Chukchi and Beaufort Seas in late spring.

In the Chukchi Sea, the spotted seal is the only seal commonly found in coastal waters during the ice-free season. It occurs regularly in scattered numbers and is particularly common in bays, estuaries, and near river mouths. It is also the only northern seal that will commonly haul-out on land during the ice-free season. Isolated sandy beaches and barrier islands are favorite basking areas for these seals and large numbers are often found there during the summer and early fall. Kasegaluk Lagoon and Peard Bay are common summering areas along the Chukchi Sea coast.

5.8 Pacific Walrus

The Pacific walrus (Odobenus rosmarus) ranges from the Bering Sea to the Arctic Ocean in association with the pack ice (Figure 5.14). They winter almost entirely in the Bering Sea and migrate northward with the receding ice in spring and summer. The main migration route of the walrus after passing the Bering Strait is mainly offshore, but a few pass near the coast. Those migrating close to shore pass Point Hope in early July and Wainwright and Barrow in early August.

In late summer and early fall, walrus, like the bearded seal, congregate along the edge of the polar pack ice from about 170°W east to beyond Point Barrow. The walrus are highly gregarious, and form herds sometimes numbering several hundred animals. They rarely come ashore along the Arctic coasts during the summer.

As the ice begins to form in October, the walrus reverse their migration and return south, generally passing Point Hope in November. These migrations generally precede the southern advance of the pack ice itself, and walrus are often found swimming southward to hauling-out grounds in the southwest Chukchi and northern Bering Seas.

5.9 Other Pinnipeds

Other pinnipeds that occasionally occur in the Chukchi Sea during the summer ice-free period are the northern fur seal (Callorhinus ursinus), the northern sea lion (Eumetopius jubata), the harbor seal (Phoca vitulina richardi), and the ribbon seal (Phoca fasciata). All are common residents of the Bering Sea, but are beyond their normal range when they pass the Bering Strait. The northern fur seal and the northern sea lion have been reported as far north and east as the Canadian Beaufort (McEwen, 1954; Maher, 1960). Ribbon seals are taken annually in small numbers by Point Hope natives, generally in June and again in November.

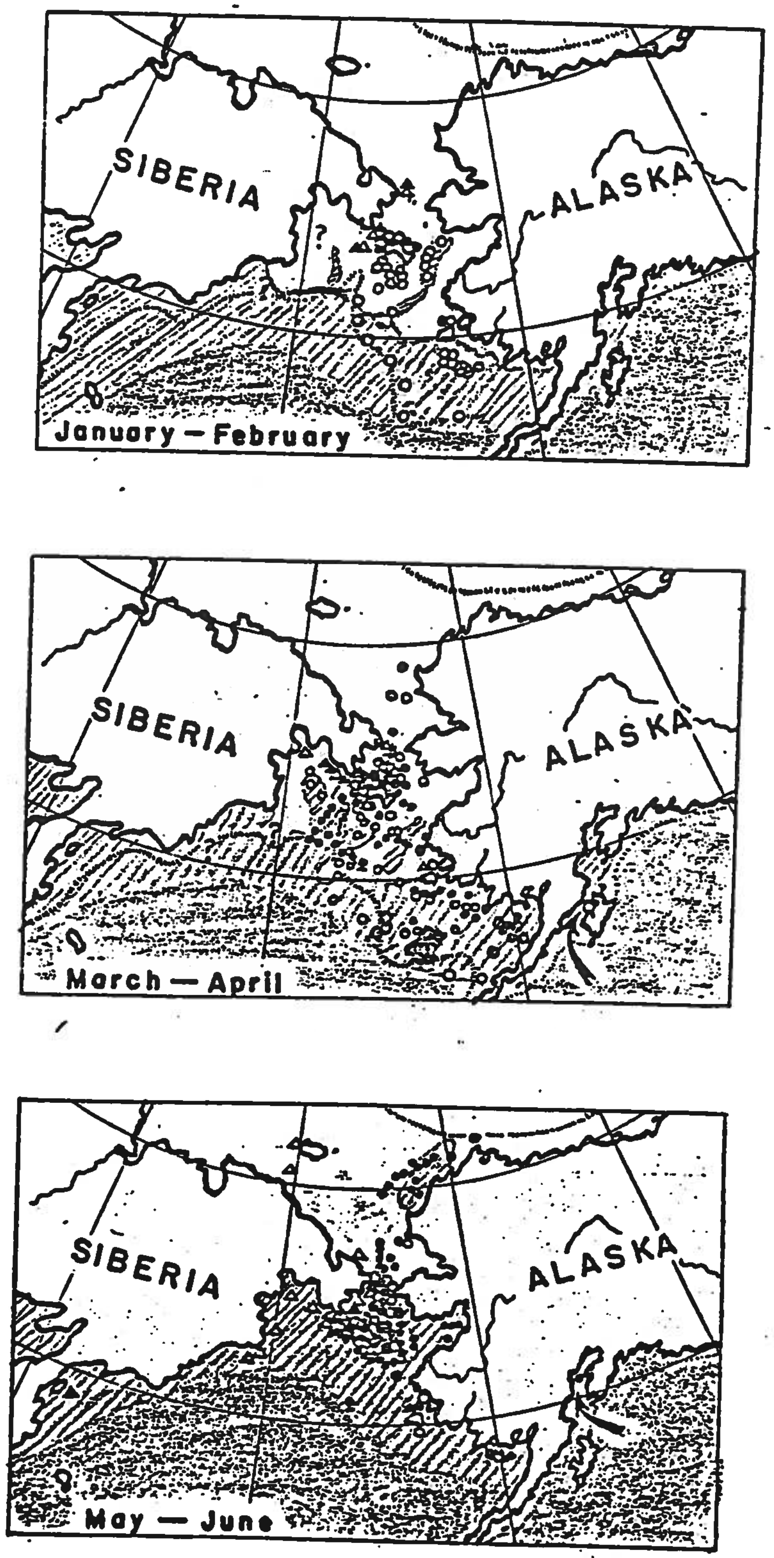


Figure 5.14 Distribution of walruses in the Bering and Chukchi areas, in relation to approximate mean ice conditions. Each symbol represents the position of one or more animals, as reported in a published (▲△) or unpublished (●○) account. Solid symbols are for the first month of each 2-month set; open symbols are for the second month. The minimal extent to 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 (from Burns et al., 1977).

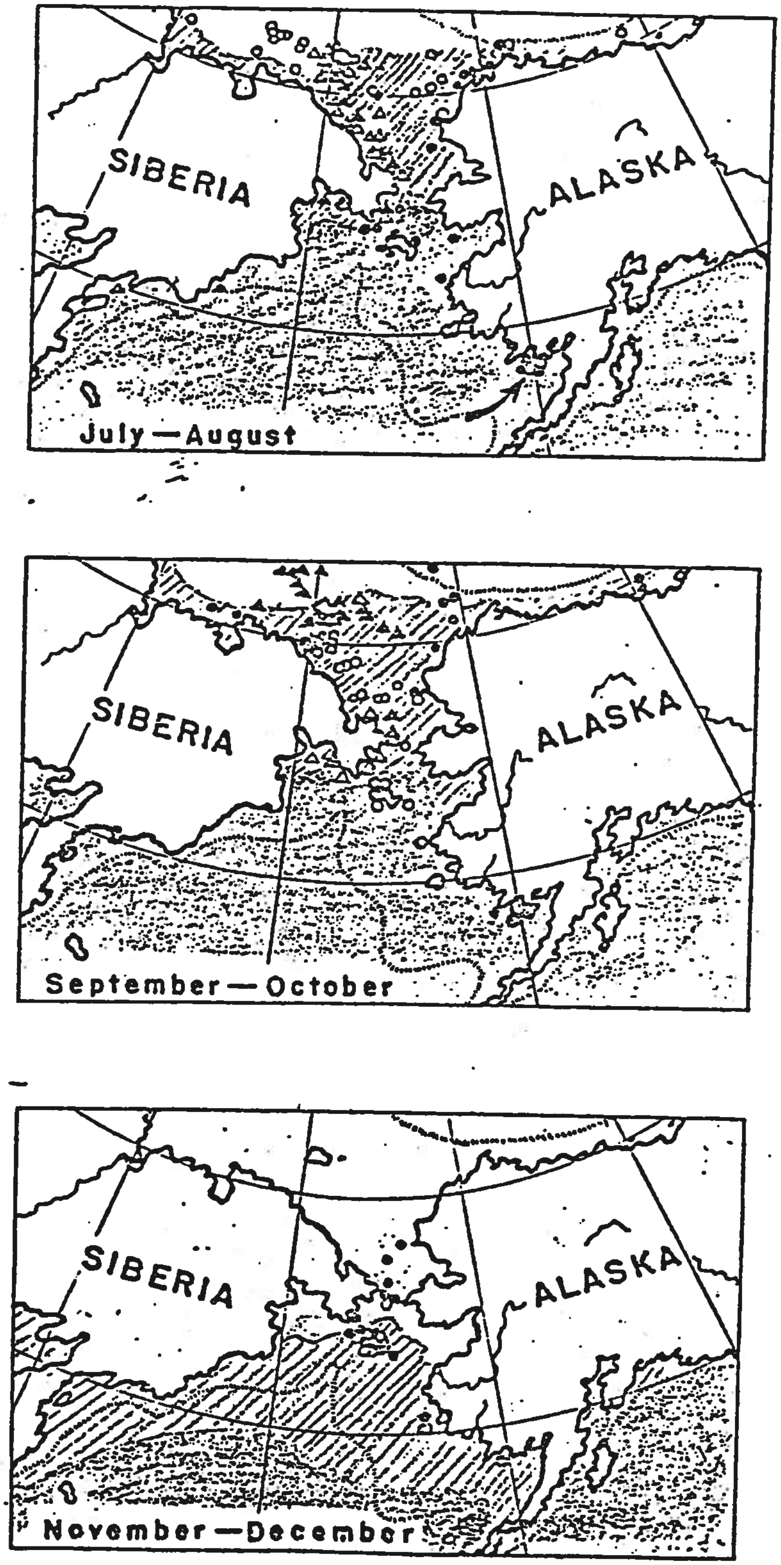


Figure 5.14 (Continued)

5.10 <u>The Polar Bear</u>

The polar bear (Ursinus maritimus) is both terrestrial and marine. Since it is considered primarily as a "marine mammal", it is included in this report. Polar bears are common inhabitants of the Chukchi Sea. Their occurrence (see Figure 5.1 and 5.2) is directly tied to the presence of the sea ice. They live primarily on the outer edge of the polar pack ice during summer, and during winter, when the pack ice is adjacent to the coast, they are most numerous at the flaw zone between the moving pack ice and the fast ice. They frequently enter the shorefast ice zone and often come onto land in search of food.

The polar bear is the largest carnivore of the Arctic and occupies the top level of a relatively simple trophic pyramid. The principal prey species are bearded and ringed seals. They are also known to consume carcasses of other mammals and occasionally eat plants and various small mammals. During the summer, they are found most commonly at the pack ice edge, preying chiefly on walrus calves and bearded seals.

It is believed that there are two populations of polar bears in the Arctic; a Chukchi Sea stock and an Arctic Ocean stock. The Chukchi Sea population (numbering about 6500-7000) is centered around the Wrangel Island area north of the Soviet Union, where they regularly den and rear their cubs. The Arctic Ocean population dens along the Beaufort Sea coast of Alaska and Canada. This population is estimated at about 2500. Little interchange is thought to exist between these two populations. Most of the polar bears along the northeast Chukchi coast are believed to come from the Arctic Ocean population.

Polar bears travel extensively over the pack ice in search of food and mates, as well as drift with the seasonal movements of the ice. In the winter the bears travel southward, occasionally as far as St. Lawrence Island. The population shifts northward in the spring prior to breakup to maintain the association with the permanent pack ice. These polar bears pass northward through the Bering Strait beginning in March and travel eastward along the Beaufort coast in late April and May.

Polar bears mate in the spring, primarily in April when females have abandoned their two-year old cubs. After mating, the females remain active all summer. In October they establish a den. Usually two cubs are born in the dens in late November or early December. The dens are vacated in late March to early April, but the female and her cubs remain close to the dens until the cubs are acclimated to the cold temperatures. Breeding occurs every three to four years.

Most denning in Alaska waters occurs on offshore islands and the associated pack ice along the Beaufort coast between the Colville and Canning Rivers. Dens are sometimes only hollows made in the snow. Occasional denning occurs in the shorefast ice and river mouths along the northeast Chukchi Sea coast.

6. SUBSISTENCE AND COMMERCIAL IMPORTANCE

6.1 Commercial Fishery Potential

Trawl surveys in 1959 (Pruter and Alverson, 1962) and in 1976 (Wolotira et al., 1977) indicate that the population density of commercially valuable fish resources in the Chukchi Sea is low. The 1959 trawl surveys caught less than 23 kg of flatfish (289 flounders) in a total of 59 hauls of 30 minute duration each. The total catch of all trawl- caught fish was less than 180 kg. The 1976 trawl surveys confirmed these findings and showed that the greatest proportion of the trawl-caught biomass in these northern waters was benthic echinoderms and miscellaneous other invertebrates (see Table 4.1). Fish composed only 14% of the trawl catch of the 1976 surveys. It is not believed that there are any fishery resources in this region of interest to commercial harvest.

6.2 Subsistence Fishing and Hunting

The villages along the Chukchi Sea coast rely heavily on subsistence hunting and fishing for their food (Figure 6.1 and 6.2). Sea mammals and caribou provide the major food resource, but fish and fowl provide important supplements to the native diet. In recent years, over 7,000 spotted seals, 6,000 bearded seals, 14,000 ringed seals, about 185 beluga, and 18 bowhead whales have been taken annually by North Slope villagers. Salmon, because of their low number, do not form an important part of subsistence take. Whitefish, cisco, and Arctic char are the fish most frequently taken. The main fishing activity occurs in the summer and fall. An excellent account of subsistence fishing at Kivalina is given by Saario and Kessel (1966).

Invertebrates are not a major food resource of Chukchi villages. Shrimp and crabs are the principal shellfish sought. Tanner crab, and occasionally king crab, appear in the subsistence diet of villagers from Point Hope to Barrow.

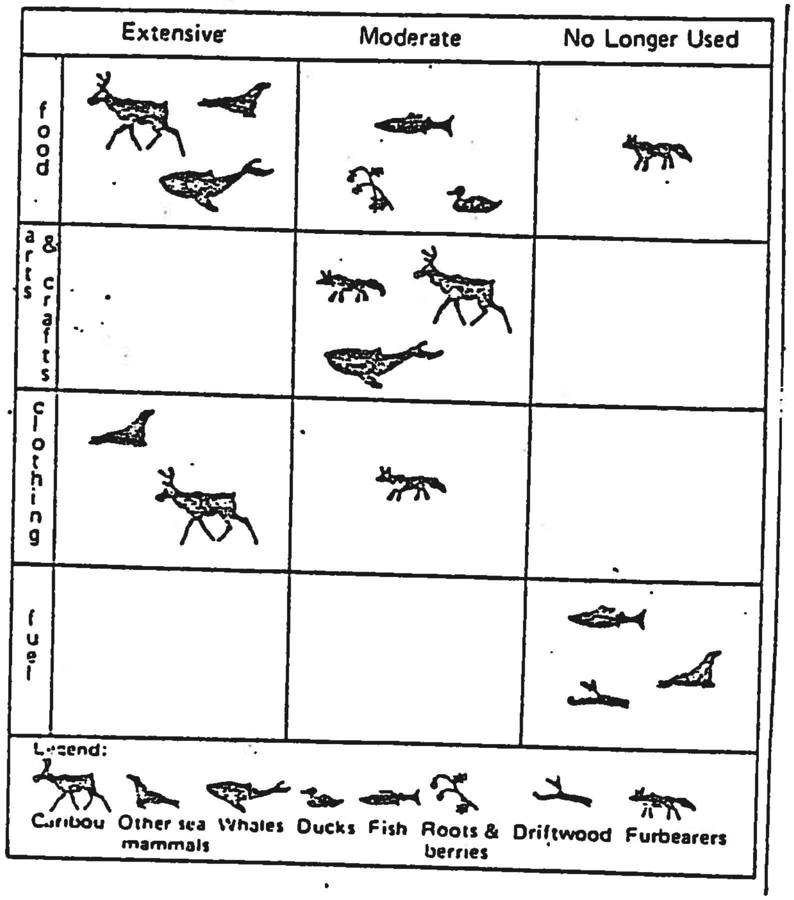


Figure 6.1. Major subsistence resources of the Chukchi Sea and their use by native villagers (from AEIDC, 1978). Seals and whales are used extensively for food, while seals also provide skins for clothing. Marine and anadromous fish are an important supplement to their primarily meat diet.

In both Wainwright and Point Hope, crab fishing, mainly for Tanner crab, is conducted from late February to breakup. Crab are fished by lowering a small wire grid baited with meat into the water in leads or through holes in the ice. The grid is left on the bottom for up to an hour, and when hauled up usually catches crab which were feeding on the bait.

Shrimp are often abundant. According to AINA (1974), large populations of small shrimp 1 to 2 inches in length were washed on shore at Wainwright in the late fall of 1964 when new sea ice was pushed onto the beach. Whaling camps are reported to occasionally net shrimp in the spring, when they are of a larger size, and utilize them for soup.

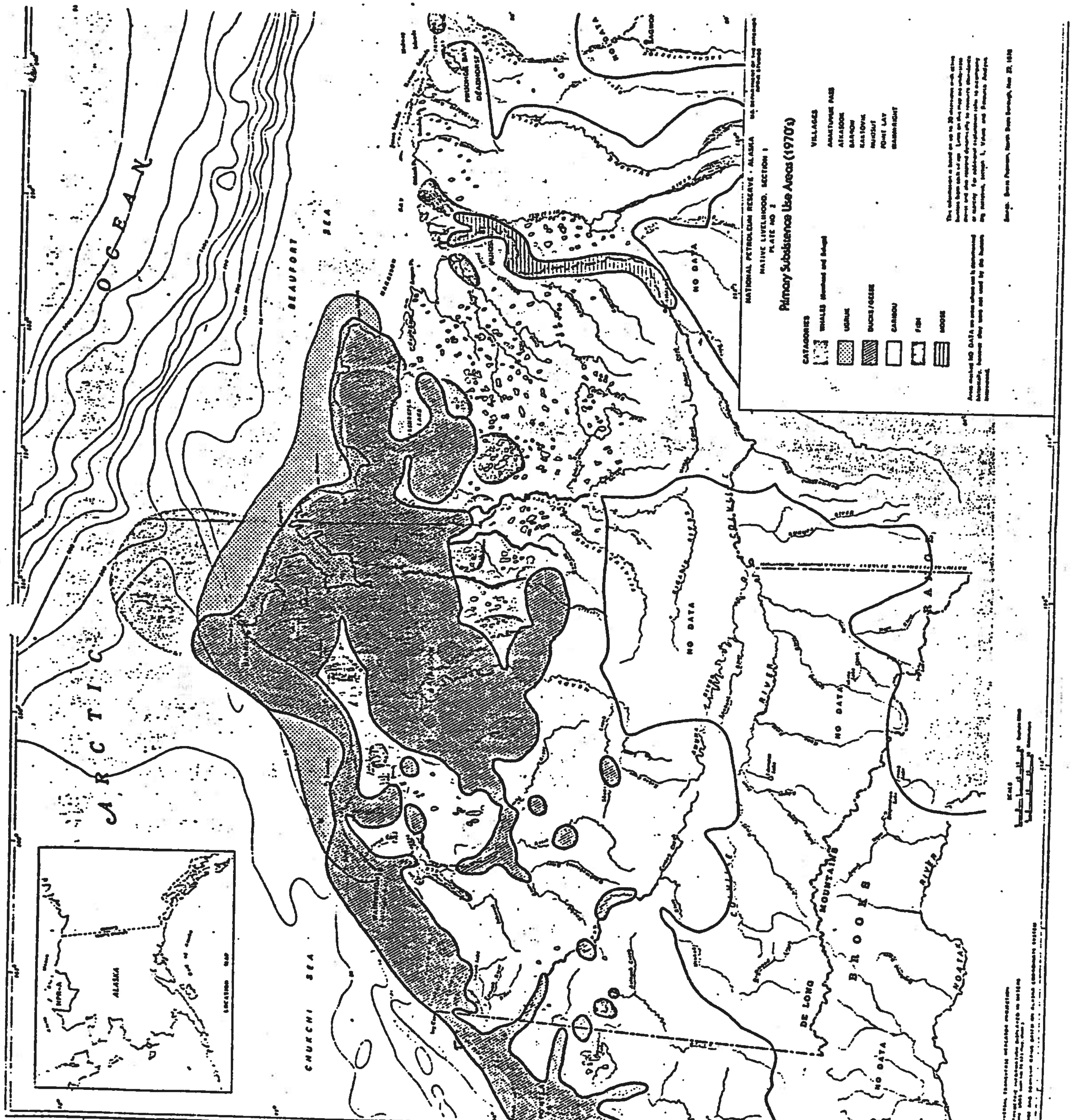
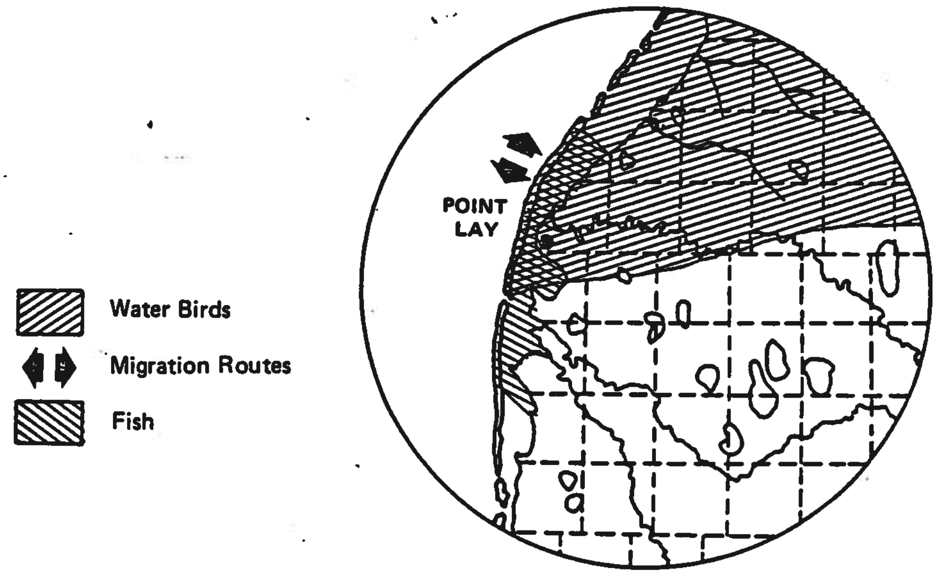


Figure 6.2. Principal subsistence use areas of the villages of Point Lay, Wainwright, and Barrow (from NPR-A, 1979). Ugruk (or oogruk) is the native name for the bearded seal.

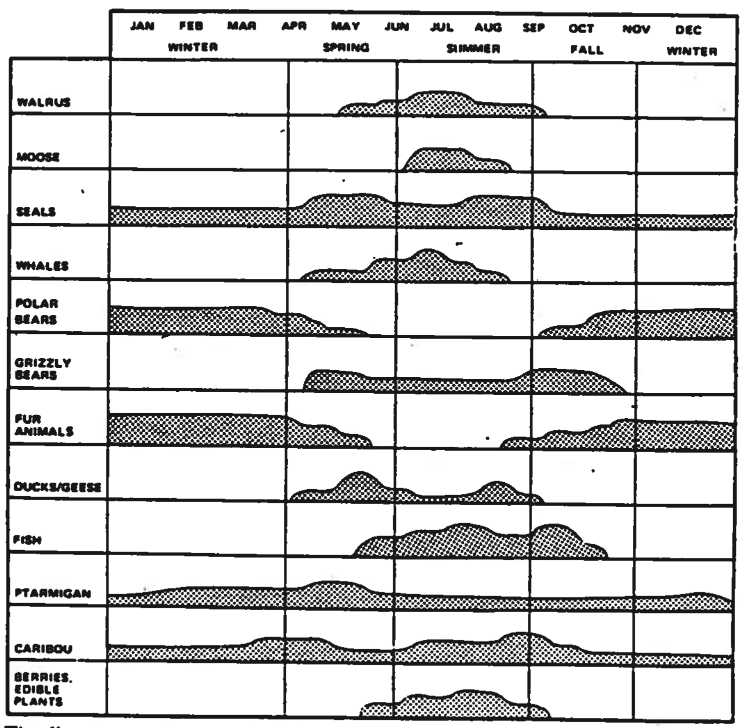
Point Lay: The small village of Point Lay depends heavily on subsistence hunting and fishing (Figure 6.3a). Caribou, fish, seals and beluga are their three most important food resources. The activity of the villagers extends north along the coast as far as Icy Cape and south to near Cape Sabine. Summer fishing in Kasegaluk Lagoon begins in July and peaks in August. The fish taken include chum and pink salmon, king salmon (rare), flounder, smelt, herring, whitefish, and occasionally, char. In the past, the people have also gathered mussels, clams, and other invertebrates during this time. Fall fishing takes place at fish camps along the Kukpowruk River. Net fishing in the autumn is followed by jigging when the river ice sets up. Fall fish camps are traditional, and constitute a major family and community activity of the village.

Wainwright: Wainwright utilizes both marine and terrestrial food resources (Figure 6.3b). The annual harvest ratio (based on pounds) for the Wainwright area is about 760 mammals: 2 water fowl: 1 fish (AINA, 1974). Caribou, whales and to a lesser extent walrus and seals are the principal mammals taken. Whaling occurs in spring for bowhead whales and summer for beluga whales. Nets are set out around Wainwright Lagoon to catch salmon, char, and whitefish beginning in July. As the fish leave the coastal waters to move upstream, the villagers move to fall fishing camps along the Utokok and Kuk Rivers. Fishing for smelt is done in January through March in Wainwright Inlet.

Barrow: The subsistence range of Barrow natives, including those from the interior village of Atkasook, extends down the Chukchi coast as far as Peard Bay. Whaling, fishing, and caribou hunting are the main subsistence activity (Figure 6.3c). Seals, walrus, and waterfowl are seasonally important. The coastal zone is used primarily for hunting marine mammals, and less for fishing. After storms, clams and other invertebrates are sometimes collected on the beaches. Subsistence fishing takes place mainly from fish camps along rivers, streams, and deeper lakes. Four techniques are used: summer gill-netting, jigging through the ice after freeze-up, winter gill-netting, and hook-and-line fishing. Summer gill-netting for whitefish and grayling is the most productive method.



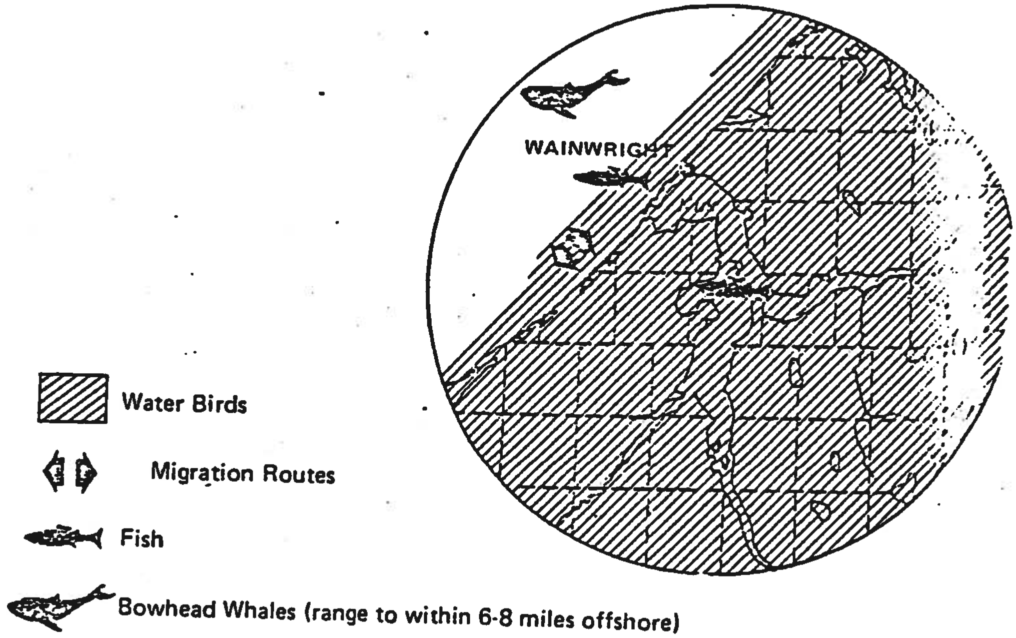
Note: Polar bear range throughout the entire map area. Caribou and moose range throughout the entire land area. Seal range throughout the entire water area outside the Barrier Islands.



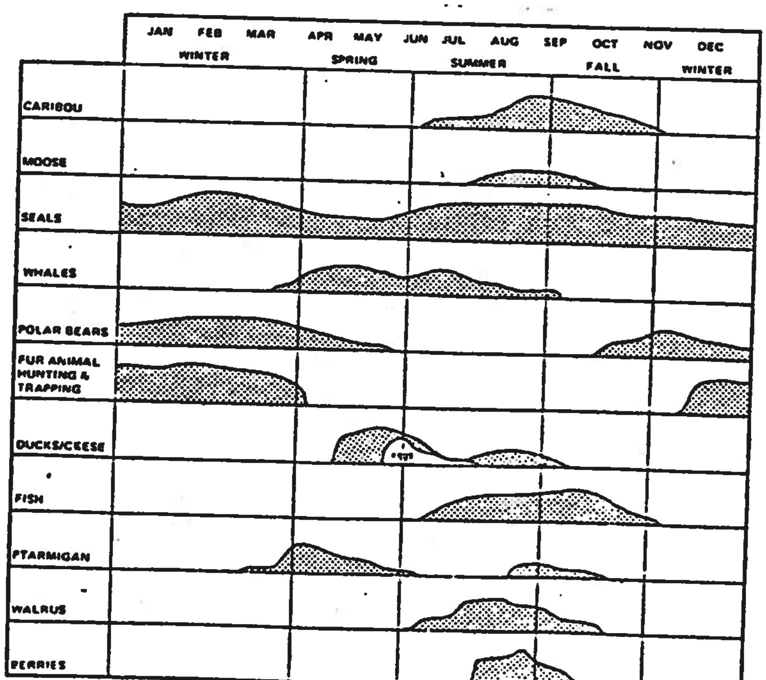
The figures on the chart represent cycles and intensities of subsistence activities based on seasonal availability of resources.

A - Point Lay

Figure 6.3. Subsistence use areas and the calender of relative intensity of seasonal subsistence activities of villages along the Chukchi Sea coast (from AEIDC, 1978). A) Point Lay; B) Wainwright; C) Barrow.

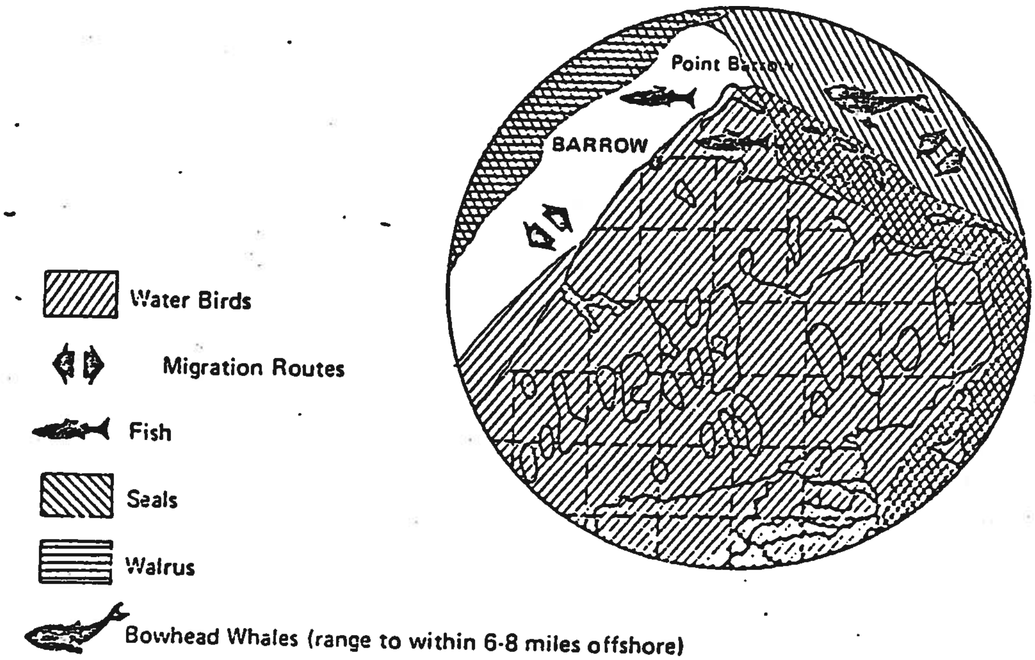


Note: Polar bear range throughout the entire map area.
Caribou and moose range throughout the entire land area.
Seal range throughout the entire water area.

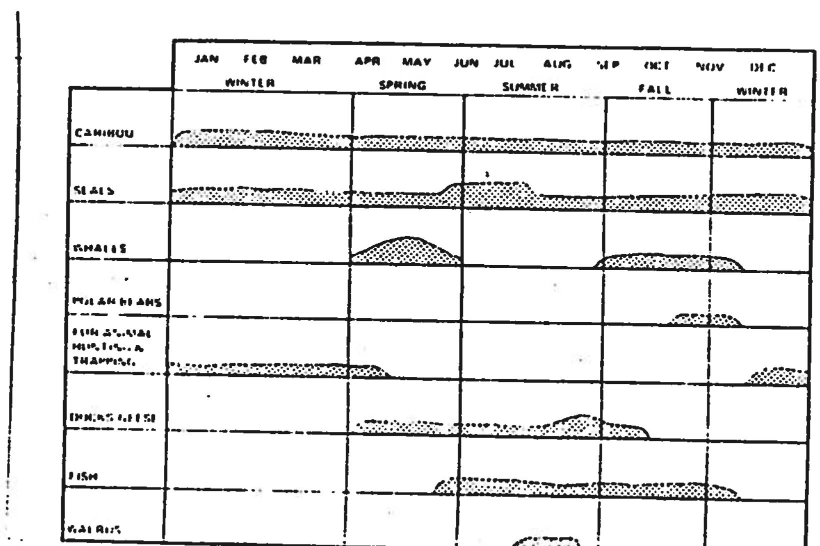


The figures on the chart represent cycles and intensities of subsistence activities based on seasonal availability of resources.

6.3 b - Wainwright



Note: Polar bear range throughout the entire map area. Caribou and moose range throughout the entire land area.



The figures on the chart represent cycles and intensities of subsistence activities, based on seasonal availability of resources.

6.3 c - Barrow

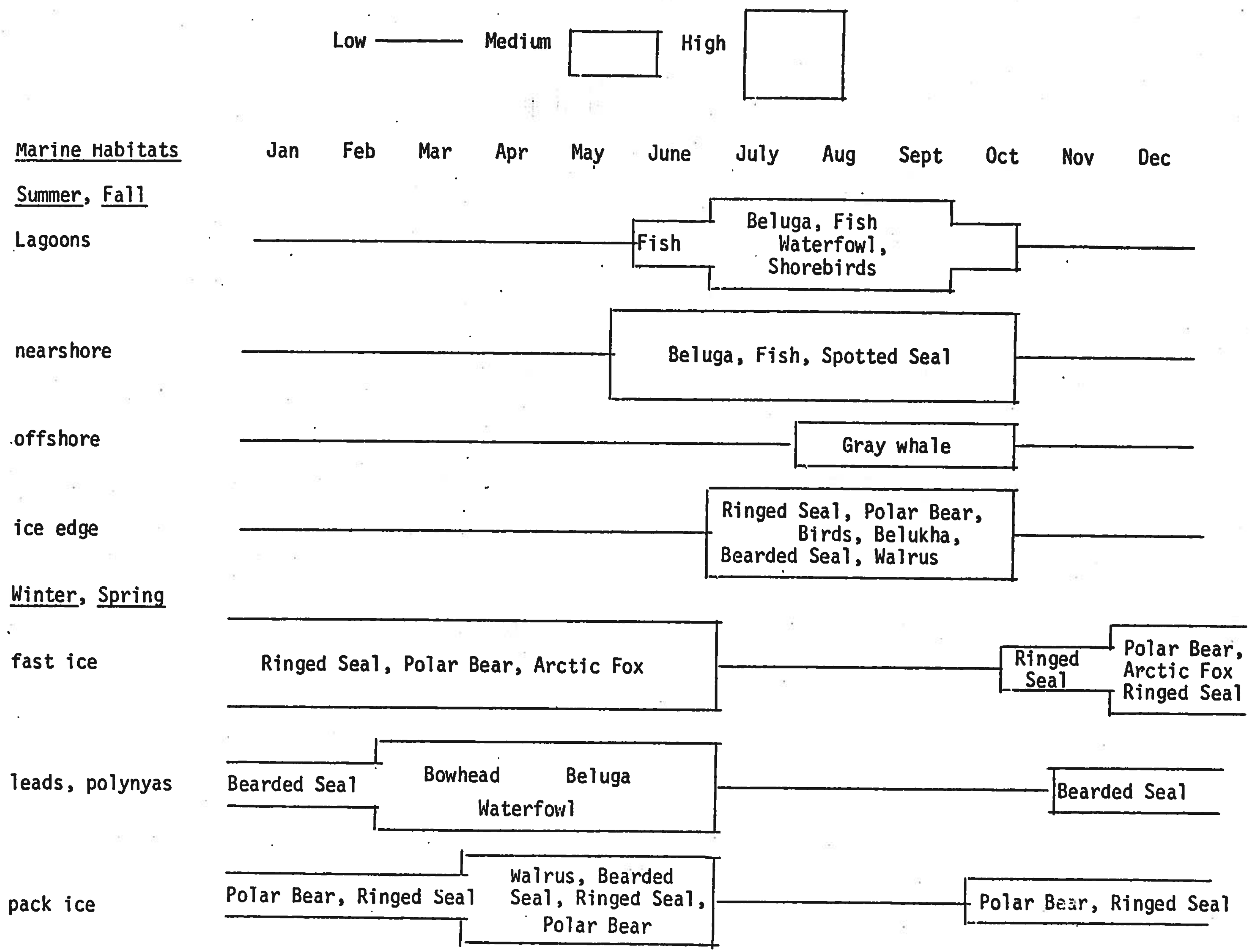
7. POTENTIAL IMPACTS

The major concern about oil and gas operations in the northeast Chukchi Sea is the possible effects on the marine mammals of this region and their habitats. Of somewhat lesser concern are the impacts to coastal anadromous fish, key prey species of marine fish and benthos, and to their coastal habitats. A third concern that spans each of the others is the effect on native subsistence harvests resulting from impacts to these resources.

Sensitivities of marine mammals, birds, and fish to OCS impacts differs seasonally with the changes in their distribution and abundance. In the Chukchi Sea this general relationship of sensitivity between habitat, species, and month of year is shown in Figure 7.1.

The subject of effects on living resources from oilspills and industry activities has been extensively reviewed and need not be repeated here. The impacts to marine mammals have most recently been reviewed in Geraci and St. Aubin (1980). Figure 7.2 diagrams the various OCS activities and their associated potential effects on marine mammals. Impacts to fish and shellfish resource were discussed in Higgins (1978) and NMFS (1979). Potential impacts are usually similar to those faced in the Beaufort Sea, which are extensively discussed in OCSEAP (1978).

Figure 7.1 Relative Sensitivities of Chukchi Sea Habitats



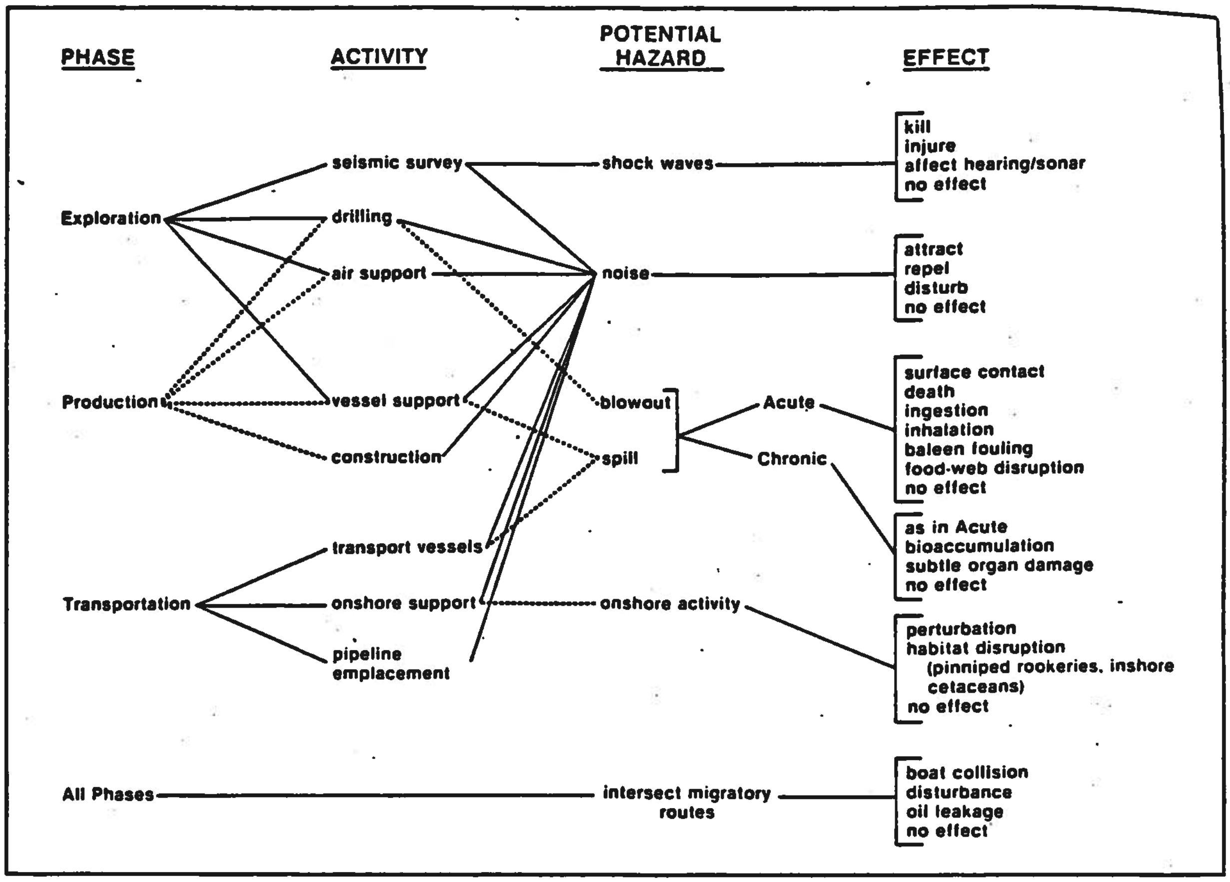


Figure 7.2. Impacts associated with OCS oil and gas activities and their potential effects of marine mammals (from Geraci and St. Aubin, 1980).

8. RECOMMENDATIONS

All stages of potential oil and gas activities in the Chukchi Sea, beginning with pre-lease geophysical exploration, pose significant threats to marine fish and mammals and their environment. The severity of these impacts will depend on the type of activities allowed, their timing and their location. Potentially severe impacts can be mitigated to some extent by regulating the types of activities allowed and by placing constraints on when and where they can occur. The purpose of this section is to distinguish between some of these choices and where necessary to identify research needed to acquire the information necessary to make these choices.

1. An initial lease sale in the Chukchi Sea should be restricted to the stable shorefast ice zone south of Icy Cape; subsequent sales beyond this zone should require a demonstrated ability on the part of industry to deal with the moving ice conditions.

Much of the Chukchi Sea area of call is a dynamic moving ice environment with shear zones, pressure ridging, pack-ice incursions, ice override and grounding, and sea floor gouging. Technology has not been developed or tested to withstand these forces. Until test structures have been proven capable of countering these forces, activities should be restricted to technologies that are already in operation and proven. North of Icy Cape, summer pack ice incursion is sufficiently common to pose similar risks to structures even in shallow water close to shore. Studies should continue to measure ice forces; to determine the frequency, location, and characteristics of sea ice hazards; and to ultimately develop useful sea ice reconnaissance and forecasting techniques.

As industry develops the capability to design structures that are resistant to the forces of moving ice, consideration could be given to extending leasing into the offshore zone. Test structures should be required to demonstrate this capability prior to leasing in these offshore areas.

2. Pre- and post-lease geophysical exploration should be restricted in the winter period to prior to March 20 for on-ice operations in the nearshore zone beyond 3 fathoms, and in the summer period from July 1 to October 1 for the offshore open water work.

On-ice geophysical seismic exploration has the potential for adversely impacting ringed seal populations at the time of pupping. The Chukchi Sea fast ice zone supports the highest densities of ringed seals in Arctic Alaska, and may be a critical breeding area for recruitment into adjacent regions. Pupping occurs in birth lairs in the shorefast ice, particularly beyond the 3-fathom depth in April and May. Seismic geophysical work should be completed by March 20 to avoid disturbing these animals during a critical time.

Vessel surveys should be restricted to the openwater period (approximately July 1 to October 1) to avoid disturbance of migrating bowhead and beluga whales. These surveys should avoid summering populations of beluga whales in nearshore waters.

Studies should be continued to determine the extent of impacts of seismic surveys to ringed seals from on-ice activity and to both bowhead and beluga whales from vessel activity.

3. Before the exploration phase, studies should be completed in sufficient detail to provide information on the following subjects:

a) Oilspill trajectory analyses should be conducted to determine the direction and rate of movement of oilspills in the coastal zone during both openwater and ice-covered seasons. Information will have to be collected on nearshore currents, wind regimes, under-ice circulation, oil-ice interactions, and behavior of oil slicks in relation to under-ice topography.

b) The locations of critical habitats and the key ecological parameters that characterize these habitats in the northeast Chukchi Sea should be determined for:

1. Beluga whale populations in summer feeding, breeding, and calving areas.

2. Ringed seal pupping, breeding, and overwintering habitats.

3. Polar bear high density use areas and the extent of denning along the Chukchi coast.

4. Winter habitat utilization by fish and invertebrates, especially the life history of key prey species such as Arctic cod, saffron cod, and shrimp.

5. Locations of concentration areas and movements of anadromous fish along the coast, in bays, lagoons, and river mouths, in both summer and winter seasons.

c) The fall migration routes of bowhead and beluga whales should be determined for their southward return through the Chukchi Sea.

d) Offshore demersal fish and shellfish resource surveys similar to NMFS surveys conducted in Hope Basin should be extended northward to improve on the inadequate information that presently exists for the northeast Chukchi Sea.

e) Ecological studies and habitat surveys of the coastal lagoons should be undertaken before any potential construction or habitat alteration activities are conducted.

f) Studies in subsistence use areas should address interactions and potential impacts that may develop between whaling and other subsistence activities of the natives and the activities of the petroleum industry.

g) Non-site specific studies should be conducted on the effects of seismic disturbance, noise disturbance from industry facilities, aircraft and vessel traffic, and other associated activities on bowhead and beluga whales, ringed seals, and polar bears.

h) Non-site specific studies should be conducted on the effects of oil on marine mammals by direct contact through ingestion; inhalation; coating of hair, skin or eyes; fouling of baleen; or indirectly through destruction of food supplies from contamination; or by alteration of habitat.

4. Exploratory drilling should initially be limited to the stable ice zone only, and should be restricted to allow sufficient time for clean up of oilspills or control of blowouts by April 15.

An oilspill in the nearshore environment in the spring has the potential of severely harming the bowhead whale during their migration through nearshore leads along the Chukchi Sea coast. Because the entire population of this endangered whale migrates through this area between mid-April and June, drilling dates should be established that allow for sufficient time to regain any loss of well control and to contain and cleanup any spilled oil by April 15. This situation is even more severe than in the Beaufort Sea because the whales are closer to the nearshore environment, they arrive earlier and they group closely together on their path through the area. The drilling date restriction of March 31 in the Beaufort Sea should be reviewed to see if the same restriction for exploratory drilling in the Chukchi Sea would allow sufficient time to mitigate the threat of an oilspill before the whales arrive. Down-hole activity that poses the risk of a blowout should only be permitted during of times that would still allow time for a relief well to be drilled by mid-April.

Whether exploratory drilling in the openwater season (July to October), either from drilling rigs or artificial islands, should be allowed needs further analysis and review. Location of leases in proximity to critical habitats, oilspill risk analysis, and hazards from pack-ice incursions require better information than is currently available.

Exploratory drilling should not be allowed during the winter in or beyond the shear zone until drilling structures are tested and proven.

5. Before the development phase, additional studies should be completed that will acquire detailed information on the following subjects:

a) Locations and times of use of critical habitats by marine mammals, fish, and birds on a site specific basis.

b) Quantitative characterization of natural hazards of sea ice, ice override, ice gouging, permafrost, storms, storm surges, and sea floor geotechnical properties.

c) Identification of freshwater and sand/gravel resources, their availability for industrial use, and the habitat impacts of their removal.

d) Studies on the fate and effect of discharged formation waters, muds and cuttings, and hydrocarbons into coastal waters in open water and under the ice.

e) Effects of noise and activity on the behavior and migration of the marine mammals of the region.

9. ACKNOWLEDGEMENTS

Dr. Howard Braham of the National Marine Mammal Laboratory (NMFS), Seattle, provided much of the information used in the cetacean section. Staff of the Environmental Assessment Division, NMFS, Anchorage reviewed the document and provided comments. Marbeth Steele and Cindy Mittasch patiently toiled to put it all together and deserve my special appreciation.

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