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THE BRISTOL BAY ENVIRONMENT

A BACKGROUND STUDY

OF AVAILABLE KNOWLEDGE

by

Arctic Environmental Information and Data Center
University of Alaska
Anchorage, Alaska

and

Institute of Social, Economic, Government Research
University of Alaska
Fairbanks, Alaska

Prepared In Accordance with Contract No. DACW85-73-C-0063

FOR

Department of the Army
Alaska District, Corps of Engineers
P.O. Box 7002
Anchorage, Alaska 99510

January 1974

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THE BRISTOL BAY ENVIRONMENT

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INTRODUCTION

PURPOSE AND SCOPE

This report is designed to provide a comprehensive description of the area known as Bristol Bay as a basis for environmental impact statements. The Corps of Engineers anticipates that such statements will be required under section 102 (2) (C) of the Environmental Policy Act of 1969 for activities relating to the exploration, development, and production of petroleum in this area.

The report consists, first, of a summary of currently available physical, biological, and socio-economic knowledge about the area (sections II through VIII). It describes present conditions in the Bay, either based on current information or inferred from historical data. The text is supplemented extensively with graphics. A comprehensive reference list is included with each section to assist the reader in obtaining additional details on any specific topic.

Section IX delineates the present and potential conflicts and interactions between environmental considerations and resource uses, especially with regard to any future exploration for and production of petroleum. This is not an all-inclusive discussion, but rather a presention of examples of (1) what effect this environment might have on man's activities in the area; (2) what effect man's activity, especially petroleum exploration and production, might have on the environment and on those resources which are now being exploited; (3) conflicts between resource users (e.g., seismic boats vs. crab pots), and (4) what effect petroleum exploration and production might have on the socio-economic environment of this area. Included in this section is a series of descriptions of what could occur in a given set of circumstances. Because of unforeseeable changes in technology and methods of operation, this section is not intended to be comprehensive, but is limited to providing examples of what could occur.

Section X defines critical environmental data still needed to fully assess the impact of petroleum activities on the area.

Section XI discusses alternative petroleum exploration and production technologies and their possible impact on the environment and other human activities.

The discussion of regulatory responsibilities and procedures is restricted to brief comments where environmental conflict is a specific issue.

GENERAL LOCATION AND SETTING

The report area includes all water and submerged land below the mean higher high water of Bristol Bay east of a line drawn from Cape Newenham to Cape Sarichef (Figure 1). The area also includes coastal lands (including islands) directly influenced by, or having some influence upon, the marine environment. Figure 2 identifies the location of place names mentioned in this report.

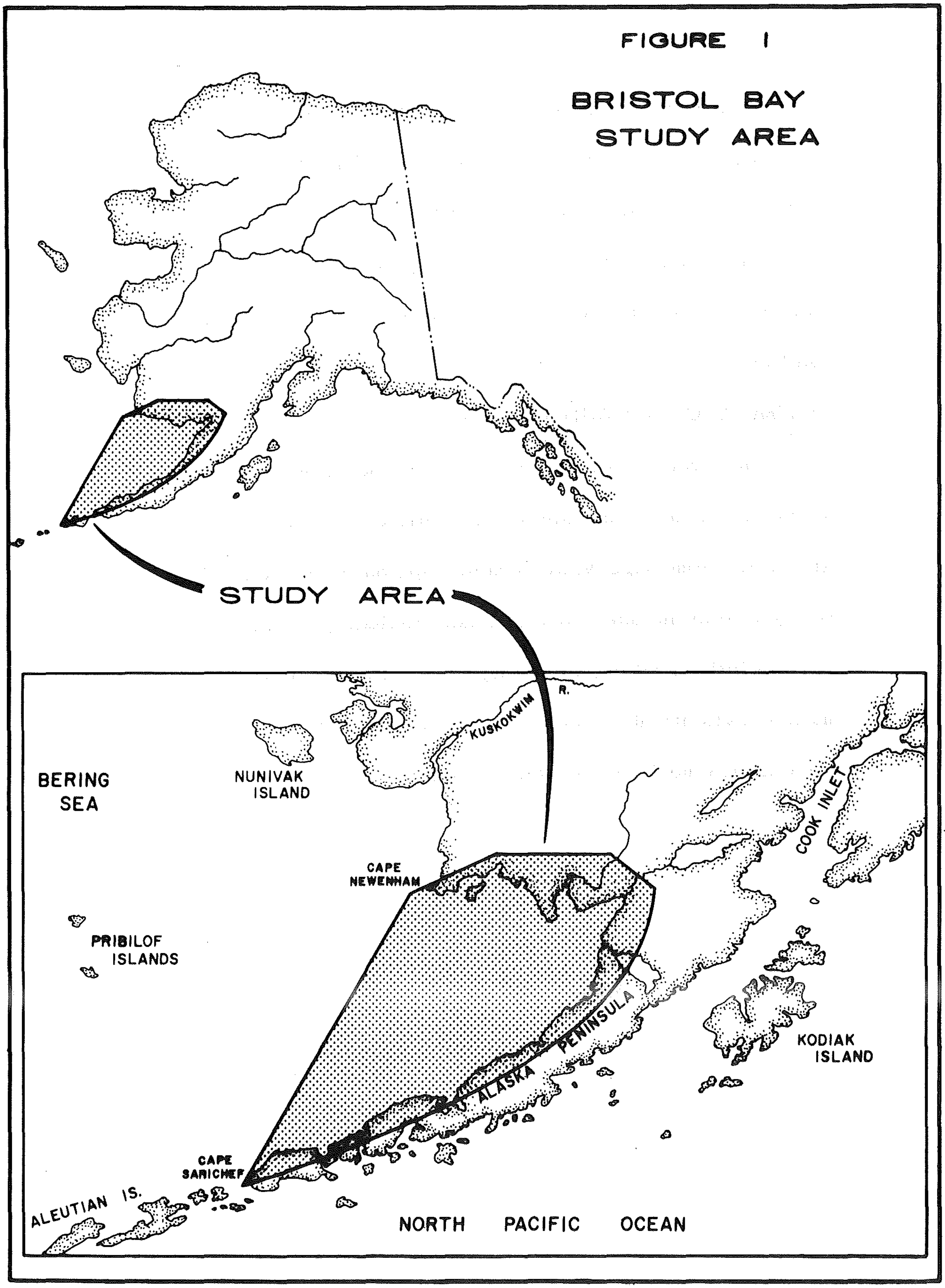
FIGURE 1
BRISTOL BAY
STUDY AREA
STUDY AREA
KUSKOKWIM R.
BERING
SEA
NUNIVAK
ISLAND
CAPE
NEWENHAM
COOK INLET
PRIBILOF
ISLANDS
ALASKA PENINSULA
KODIAK
ISLAND
CAPE
SARICHEF
ALEUTIAN IS.
NORTH PACIFIC OCEAN

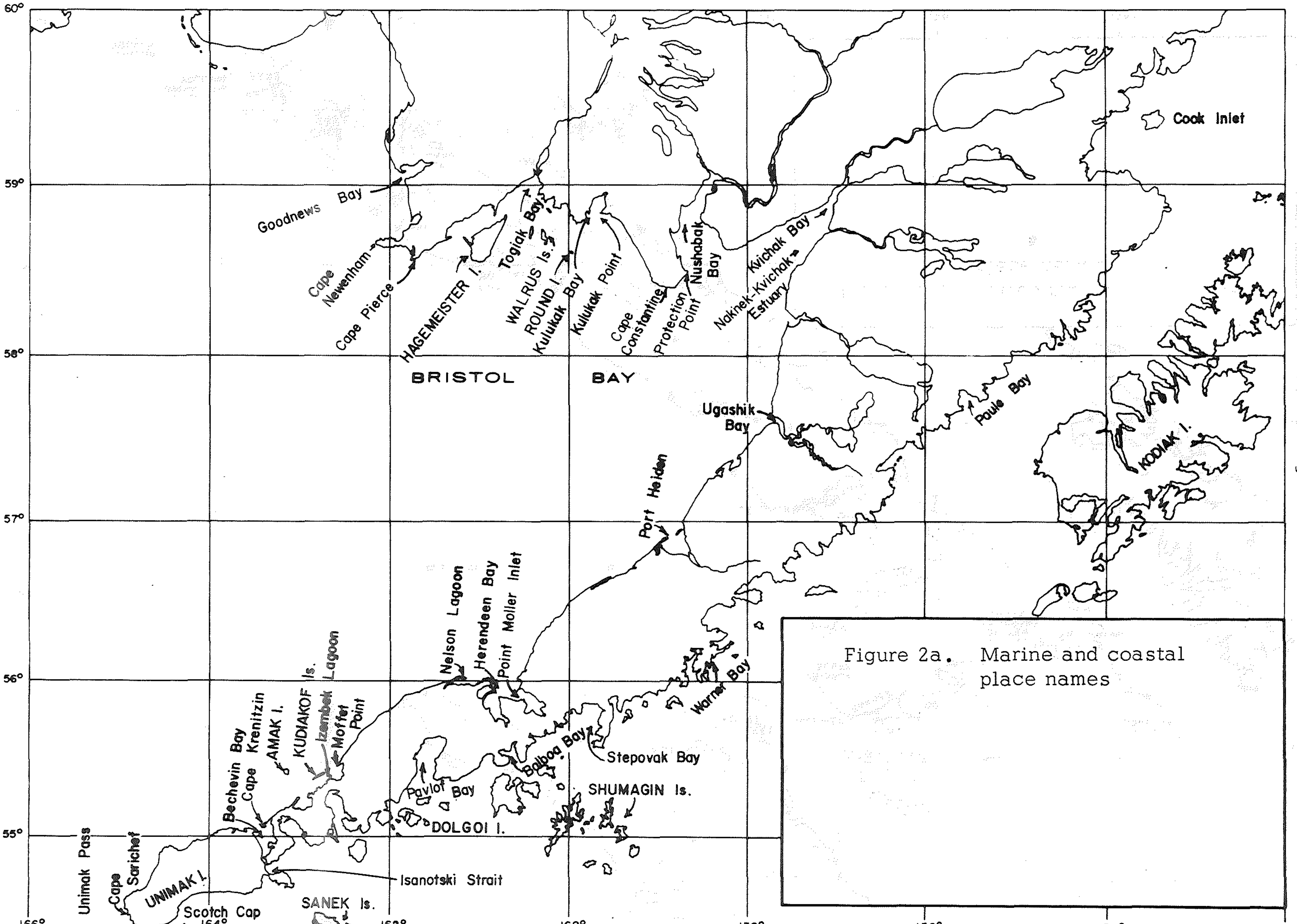

Figure 2a. Marine and coastal place names

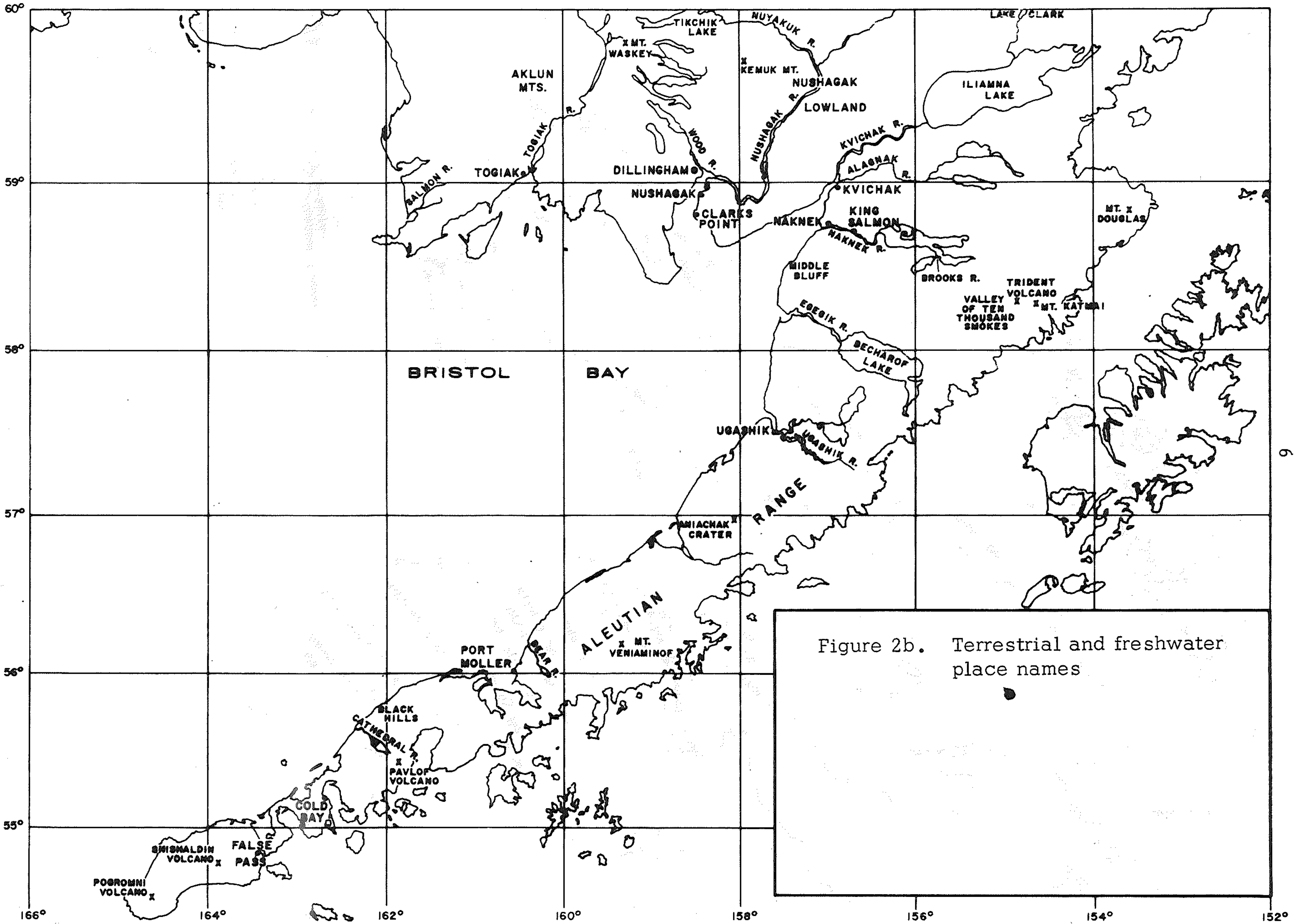

Figure 2b. Terrestrial and freshwater place names

GEOMORPHOLOGY

INTRODUCTION

Bristol Bay is a large, comparatively shallow bay (360 km. wide at its mouth and 380 km. long) immediately surrounded by a combination of lowlands and various mountain systems (Figure 3). Few islands are present. The coastline is relatively regular, marked by sandy beaches over most of the area. A few cliffs, ridges, and hills meet the shore between Cape Newenham and Kulukak Bay and on Unimak Island. A large continental shelf lies seaward from the coast. The outer shelf edge extends from just west of Unimak Island northwesterly past the Pribilof Islands. This portion of the shelf is part of a vast undersea plateau that covers the eastern half of the Bering Sea and extends north through Bering Strait into the Chukchi Sea. It is remarkably flat (average gradient of 0.02 percent), with minimal variations in relief (Figure 4). Beyond this shelf the continental slope is generally dissected and drops to the Aleutian Basin (Figures 3 and 4).

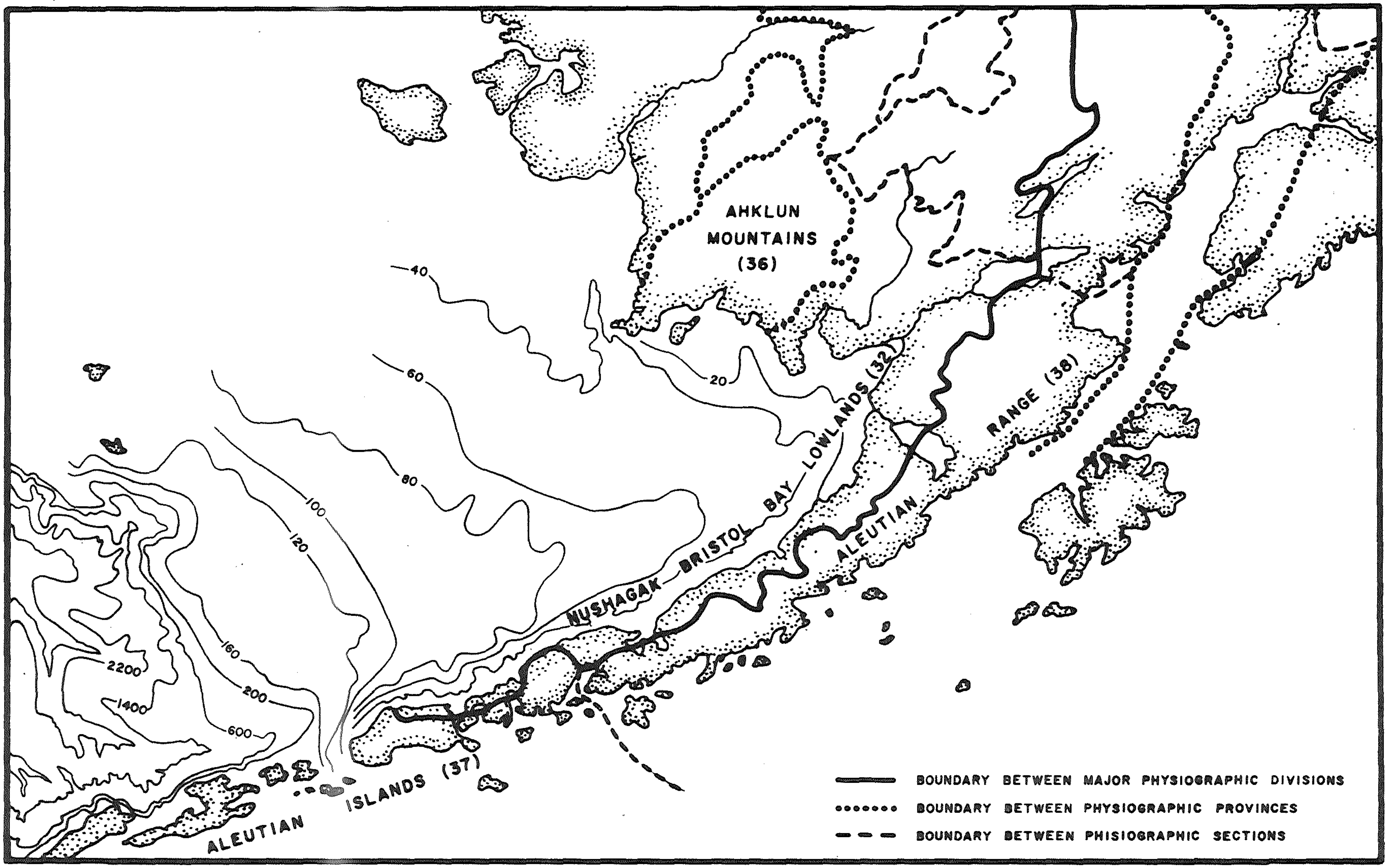

Figure 3. Offshore geomorphology and onshore physiographic provinces (from Wahrhaftig 1965, Scholl et al. 1968, Chase et al. 1970).

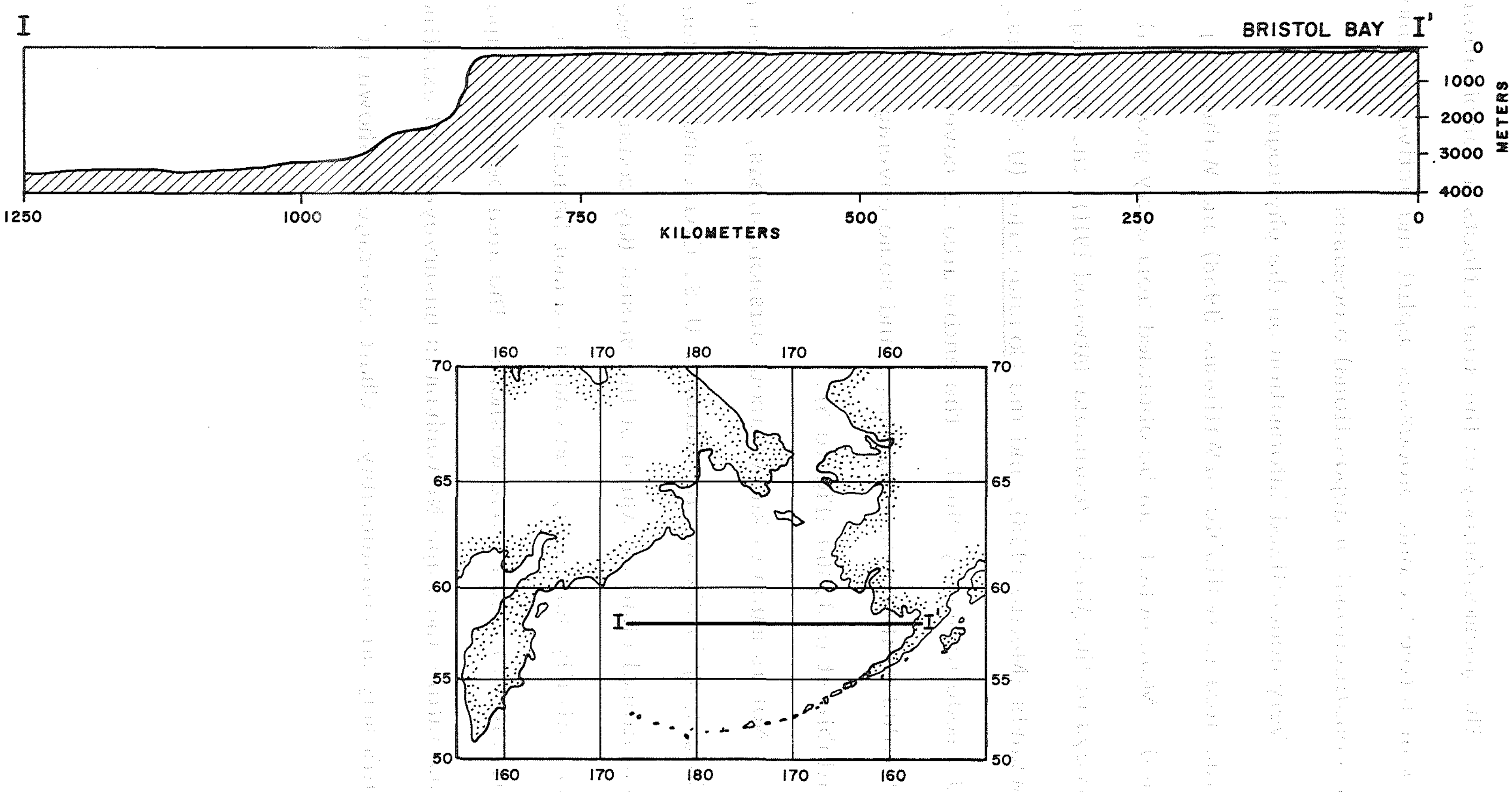

Figure 4. Bristol Bay continental shelf profile (from Lisitsyn 1966).

The geomorphology of the area reflects a combination of both active tectonic processes (uplift and active volcanoes) and constructional or depositional processes.

Very generalized information on the physiography of the area is available in Williams (1958) and Wahrhaftig (1965). More detail can be obtained from early geological surveys of the Alaska Peninsula (Atwood 1911), the Nushagak Lowlands (Mertie 1938), and the Coastal Pilot (U.S. Coast and Geodetic Survey 1964). The entire area is covered by 1:250,000 scale topographic maps and some coverage is available at 1:63,360 (Figure 5).

Not as much is known about offshore areas, but general hydrography is shown on published U.S. Coast and Geodetic navigational charts. Much of the Bristol Bay coast has been only partially surveyed, and charts cannot be relied upon, especially in areas close to shore. The area between Cape Constantine and Cape Newenham is unsurveyed and existing charts may err considerably. Chart coverage is shown in Figure 6.

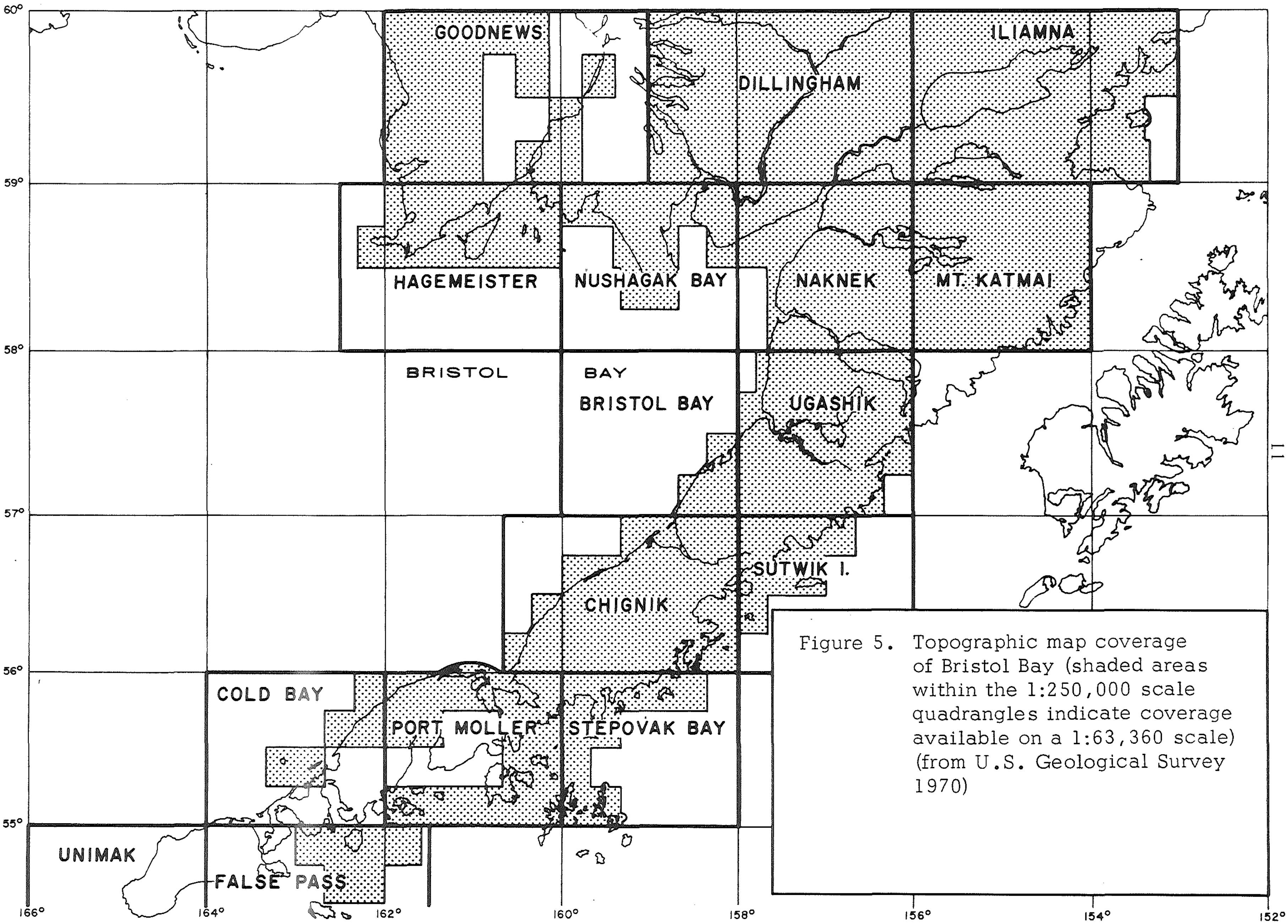

Figure 5. Topographic map coverage of Bristol Bay (shaded areas within the 1:250,000 scale quadrangles indicate coverage available on a 1:63,360 scale) (from U.S. Geological Survey 1970)

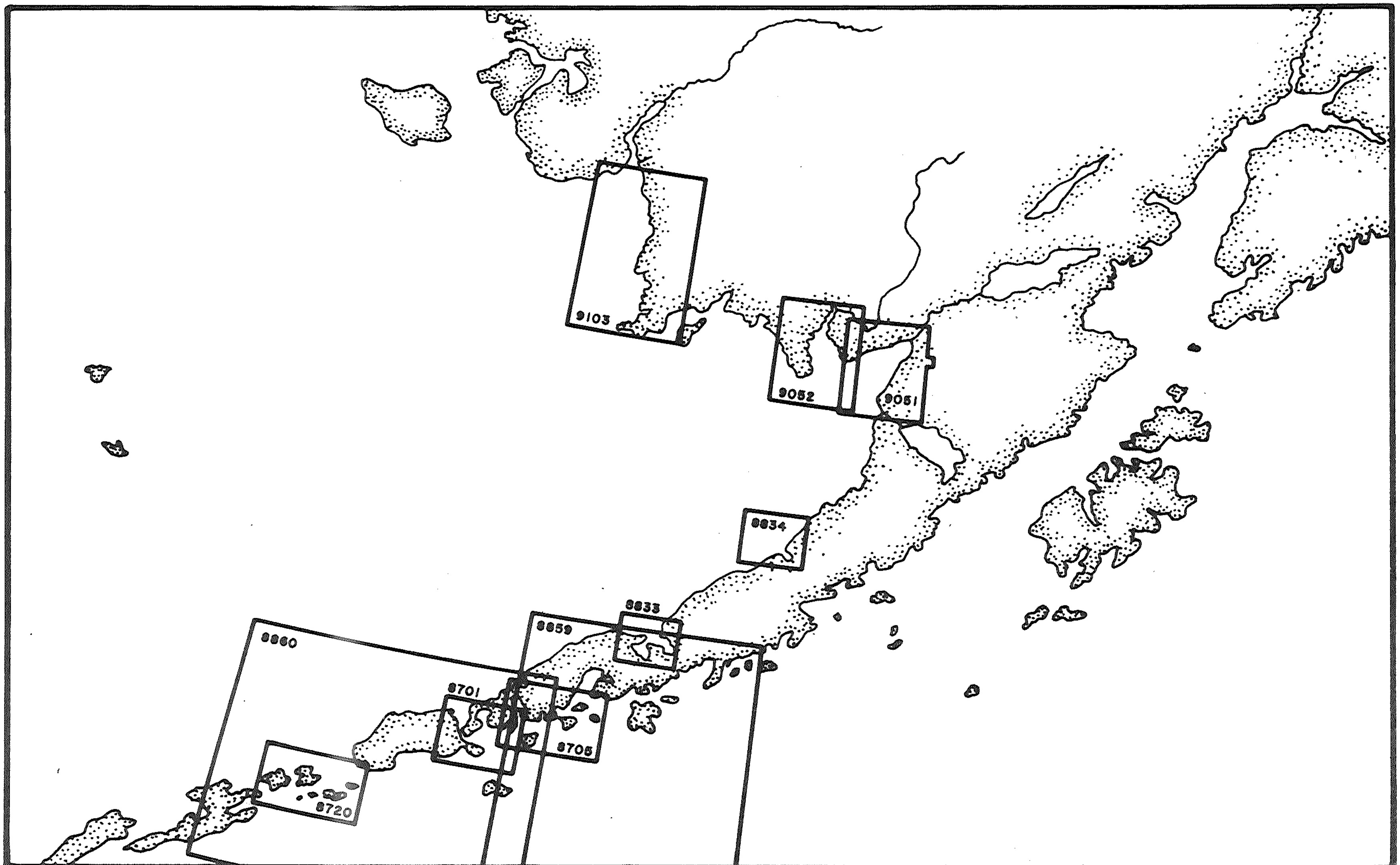

Figure 6. Coverage and index numbers of nautical charts published for the Bristol Bay area (U.S. National Ocean Survey 1971).

Detailed bathymetric maps of the area (including bottom type data where available) have been compiled by Continental Shelf Data Systems at 1:24,000 scale and smaller. These maps, available for a fee, are based upon U.S. Coast and Geodetic Survey soundings in the area.[1] Other bathymetric maps available have been contoured from these same basic data (Sharma 1972, Sharma et al. 1972, Chase et al. 1970), although the studies by Sharma et al. (1972) do contain some additional data (Figure 7). A detailed bathymetry map of the southwest portion of the study area is available from the U.S. National Ocean Survey (U.S. Coast and Geodetic Survey undated). Excellent descriptions of offshore areas are also included in the results of recent Soviet fisheries investigations in the northeast Pacific Ocean and are discussed later (Gershanovich 1963, 1970; Kotenev 1965, 1970).

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1. Continental Shelf Data Systems. 1973. 424 Denver Hilton Office Bldg. Denver, Colorado.

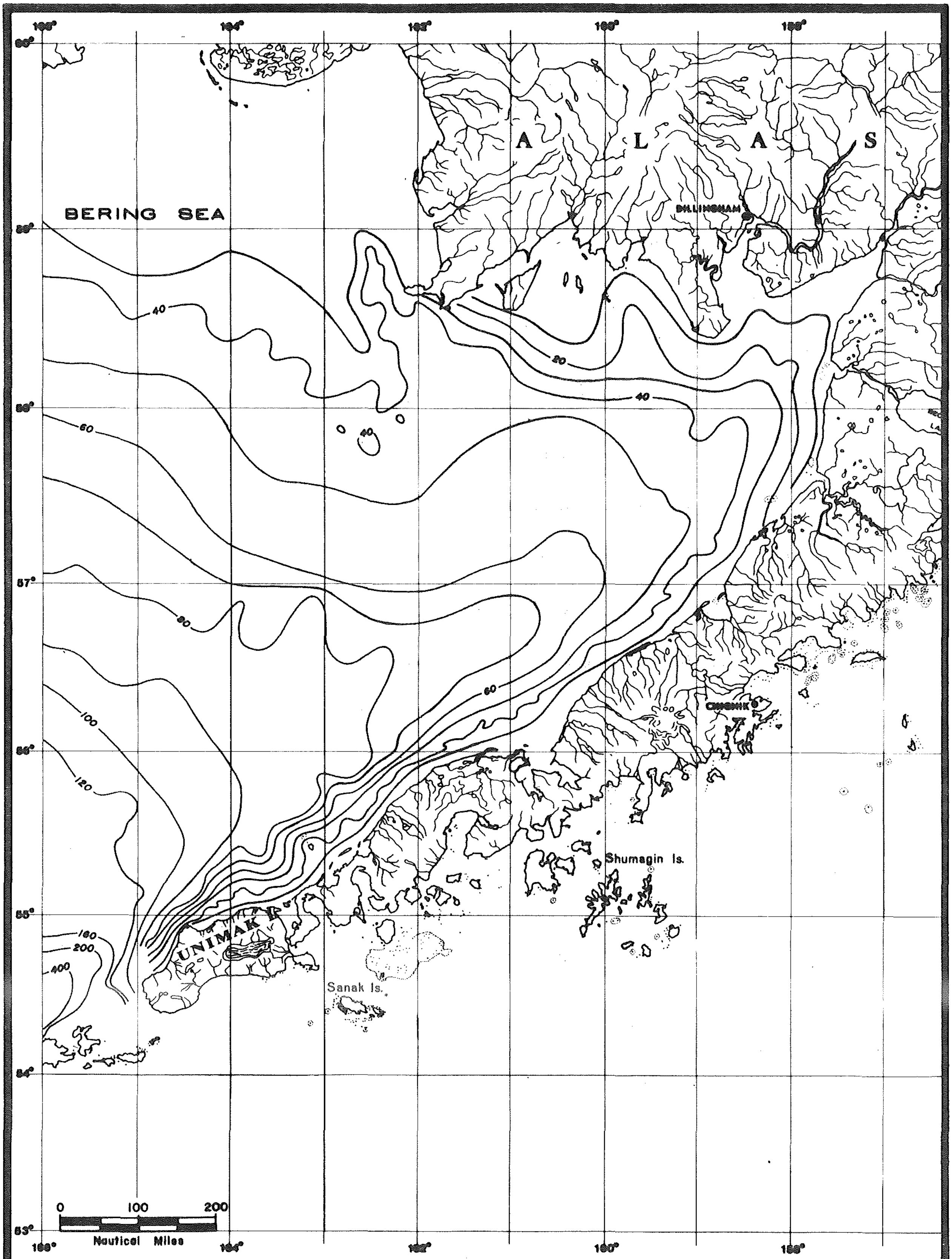

Figure 7. Detailed bathymetry of Bristol Bay (from Sharma et al. 1972).

For purposes of discussion, treatment of the geomorphology of the region will be divided into physiographic provinces or subprovinces. The Aleutian Range, the Aleutian Islands (including Unimak Island, and the southern part of the Alaska Peninsula), the Nushagak-Bristol Bay Lowlands, and the Ahklun Mountains are the onshore provinces. The offshore province of the continental shelf is the Bering Platform (Wahrhaftig 1965) (Figure 3).

ONSHORE AREAS

Aleutian Range

The Aleutian Range forms the high, mountainous backbone of the Alaska Peninsula. The core of the range consists of folded Mesozoic and Tertiary rocks containing very recent and active volcanoes. These volcanoes form the higher peaks, ranging from about 900 m. to more than 2,425 m. (Mt. Veniaminof), and display a spectacular assortment of volcanic features (calderas, cones, etc.). Glacial features abound along the entire length of the range (cirques, v-shaped valleys, paternoster lakes, etc.) and glaciers remain on a few of the higher peaks (Mt. Katmai area and Mt. Veniaminof). The firn line is between 900 m. and 1,000 m. in elevation.

Aleutian Islands

The Aleutian Islands form an arcuate ridge 875 km. long, which rises 3,630 m. above the sea floor. The ridge is capped by at least 57 volcanoes (27 reported active) ranging from 600 m. to more than 2,730 m. above sea level. The section of the study area west of Pavlof Bay is considered part of the Aleutian Islands Province. The islands have rugged and irregular coastlines, similar to the Aleutian Range. Volcanic features (lava flows, cinder cones, warm springs, explosion pits, etc.) are more dominant, and low wave-cut platforms are characteristic features. Volcanic peaks which rise to more than 3,630 m. have been intensely glaciated. A fairly large glacial system still persists on Shishaldin Volcano.

Nushagak - Bristol Bay Lowlands

A moraine and outwash mantled lowland with much more moderate slopes than the western Gulf side forms the Bristol

Bay side of the Aleutian Range. It rises from sea level to a maximum of 170 m. near the mountains; local relief varies from 15 m. to 80 m. The lowlands are dotted with thousands of shallow morainal and thaw lakes and ponds. Several large lakes are also present and occupy ice-scoured basins bordering the upper lowland fringe. The area is drained by several large rivers, including the Nushagak, Kvichak, Alagnak, and the Naknek. Most of these rivers originate from large lakes (Keller and Reiser 1959, Knappen 1929).

Ahklun Mountains

This province borders the northwestern portion of the study area and extends to Cape Newenham. The mountains are rugged and steep with broad, flat valleys separating sharp summits ranging from 600 m. to 1,510 m. above sea level. Streams draining the area are generally shallow and clear contained within bedrock gorges 7 m. to 15 m. deep. This province is known for the beautiful Wood River - Tikchik Lake system of cascading rivers and interconnected lakes in the setting of towering mountains. The numerous lakes are of glacial origin. Most are elongate and at least 40 are more than 3.2 km. in length. Depths of 270 m. have been reported. A detailed description of this lake system is provided by Mertie (1938). A few small cirque glaciers exist north of Mt. Waskey. Permafrost is sporadic (Wahrhaftig 1965, Williams 1958).

Hagemeister Island, the Walrus Island group, and a few other offshore islands form an extension of this mountain system. Their relief includes both steep and rugged, as well as low coastal plain topography. Little surface water is present due to the rough terrain and to the small size of catchment basins.

Earth Resources Technology Satellite photography of a portion of the study area between Hagemeister Island and Kvichak Bay shows many of the characteristic features of the region (Figure 8).

OFFSHORE AREAS

Bering Platform

The continental shelf within Bristol Bay includes part of the Bering Platform province and covers approximately 105,000 square km. east of a line between Cape Newenham

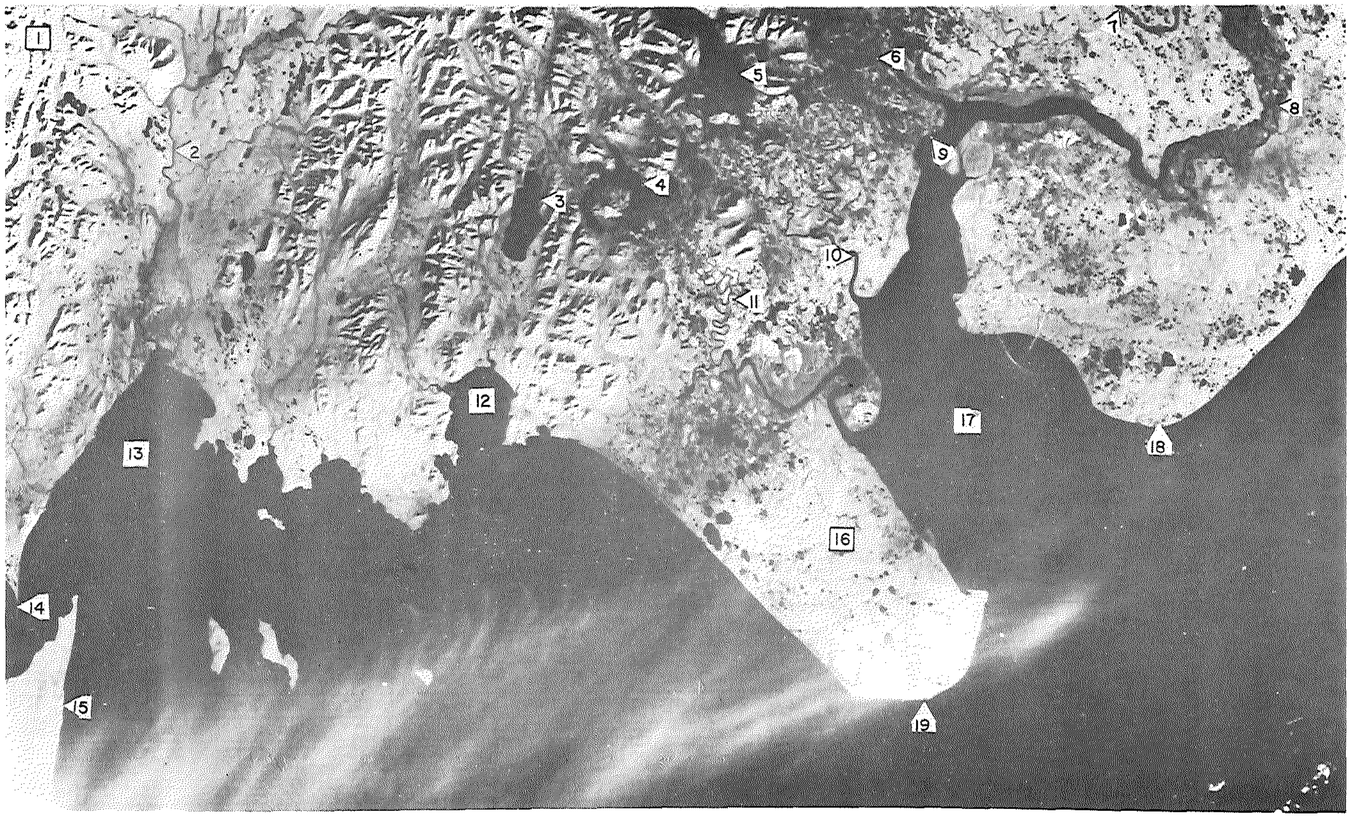

Figure 8. Satellite view of the region between Hagemeister Island and Kvichak Bay (1. Ahklun Mountains; 2. Togiak River; 3. Uakik Lake; 4. Amanka Lake; 5. Nunavaugaluk Lake; 6. Lake Aleknagik, Wood River; 7. Iowithla River; 8. Nushagak River; 9. Dillingham; 10. Snake River; 11. Igushik River; 12. Kulukak Bay; 13. Togiak Bay; 14. Tongue Point; 15. Hagemeister Island; 16. Nushagak Peninsula; 17. Nushagak Bay; 18. Etolin Point; 19. Cape Constantine (from Anderson et al. 1973)

and Cape Sarichef. This is perhaps the flatest and most relief-free of any large, marine physiographic province off Alaska (Moore 1964).

As previously noted extensive geological surveys of the Bering Sea and Bristol Bay areas have been made by the Soviets. Much of the following information is based on reports by Gershanovich (1963, 1970) and Kotenev (1965, 1970) as well as work by U.S. investigators (Scholl et al. 1968).

Researchers have divided the shelf into offshore, central, and outer regions. The offshore portion between 30 m. and 50 m. is subject to intense wave action. The central zone is characterized by gentle gradients at depths between 30 m. and 120 m. Gradients increase in the outer portion of the shelf at depths ranging from 120 m. to 150 m. The bottom contours become especially steep near the continental or insular slope. This is the narrowest and most dissected area of the bottom relief.

The Pribilof-Bristol Bay region has the most complex bottom relief of all of the epicontinental shelves of the Bering

Sea. This is due to its transitional location between the epicontinental and geosynclinal shelves, as well as the current replacement of older geological structures by younger Cenozoic rock. The shelf ranges from 170 km. to 190 km. in width between the mouth of the Kvichak River and the Pribilof Islands. Shallow areas off the northern coast of Bristol Bay are the most dissected. Gradients over the extensive shallows between Bristol Bay and the Pribilof Islands are low, usually within 1 to 3 minutes. Just north of the Alaska Peninsula and Unimak Island gradients may exceed 15 minutes. The outer shelf edge south of the Pribilofs has a more gentle grade than the more northerly portions, because of the presence of a trough north of Unimak Island extending towards Bristol Bay (Gershanovich 1963) (Figure 3).

Presently, the shelf bottom is undergoing levelling and westerly extension due to sedimentation (Sharma 1971).

Areas most affected by intense tides have narrow troughs and ridges of 10 m. or more in relief.

The continental slope, although not part of the study area, is worthy of brief mention here since it is referenced elsewhere in this report. This slope is characterized by intense but variable dissection. Canyons and V-shaped submarine valleys mark the upper and middle portions. The seabed in the Pribilof Islands area is a good example of this intense dissection. Here the upper parts of the submarine valley are marked by short canyons separated by crests and scarps forming a common valley at depths below 1,000 m.

The most complex slope structure occurs between depths of 150 m. and 3,000 m., and is approximately 50 km. to 95 km. wide. Relief here consists of primarily of scarps and graben-type depressions running either parallel or at a slight angle to the slope (Kotenev 1970). The slope is most dissected where slope direction changes.

The lower part of the continental slope, the continental slope, the continental rise (19 km. to 25 km. wide), is a region of sediment accumulation with deposition rates many times that measured in adjacent Pacific areas. The gently sloping plain of the rise lies between depths of 3,000 m. and 3,500 m. and joins the foot of the slope with the Aleutian Basin abyssal plain. Hills, seamounts, ridges, and shallow valleylike depressions are common in this region. Lower portions of the plain are essentially undissected and have little gradient due to sediment accumulation.

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PHYSICAL OCEANOGRAPHY

INTRODUCTION

Bristol Bay, as an oceanographic unit, is larger than the defined study area. It is roughly triangular, bounded by the Alaska Peninsula to the south, a line from Cape Newenham to the Pribilof Islands to the north, and by the edge of the continental shelf between the Pribilofs and Unimak Pass on the west (Figure 9).

It is useful to define the inner and the outer bays by arbitrarily drawing a line from Port Heiden on the Alaska Peninsula northward toward Cape Newenham. The entire unit is roughly 150,000 sq. km. in area with an average depth of about 70 m.; the inner bay is about 25,000 sq. km. in area with depths averaging 40 m. Bristol Bay is a segment of the Bering Sea. It is an area of high biological productivity, heavily stressed by climatic conditions (Shorr and Favorite 1966).

Bristol Bay lies at the southern border of the subarctic climatic zone. Much of its surface has a 50 percent cover of

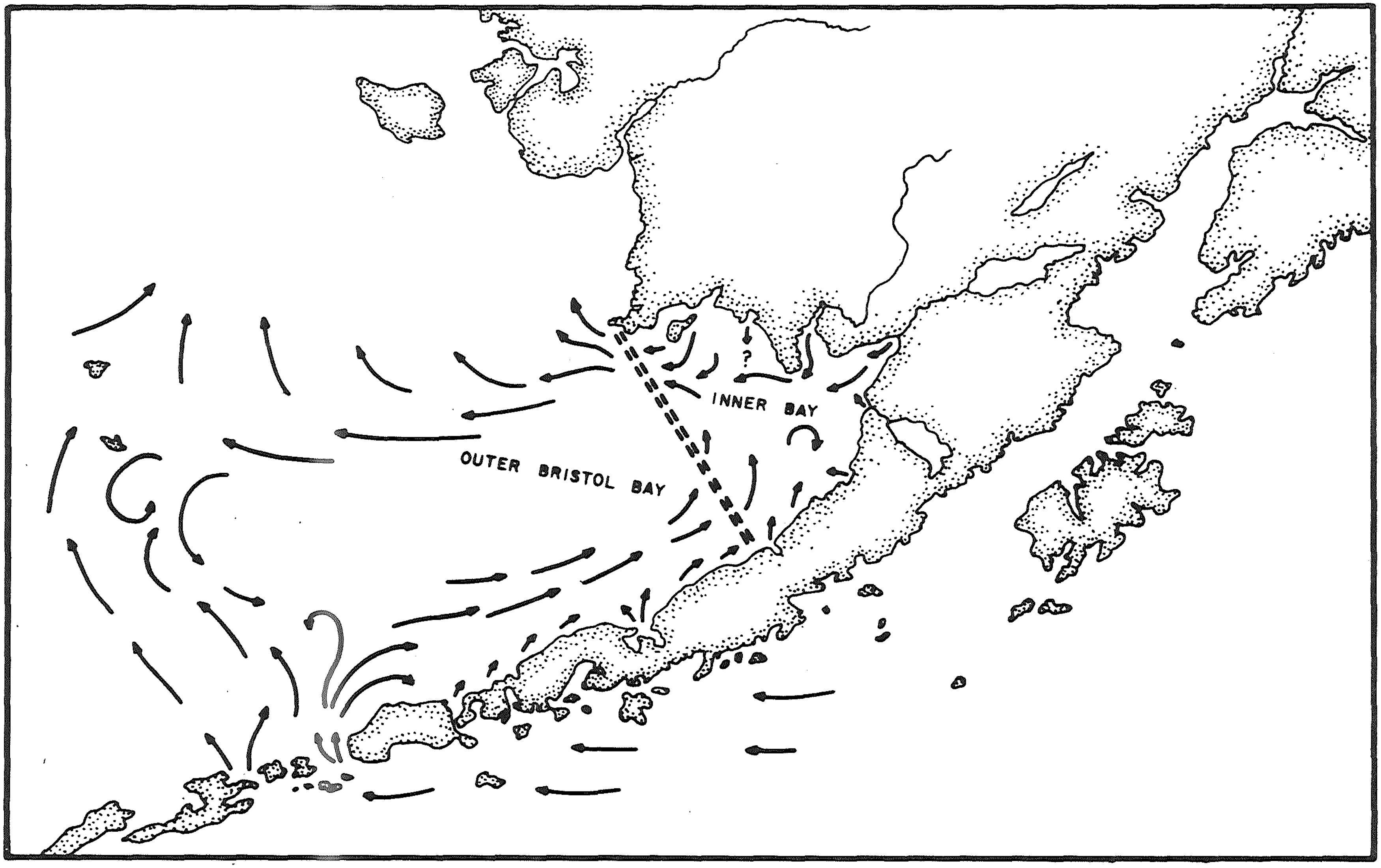

Figure 9. Summer surface circulation in Bristol Bay (Marine Advisory Program, Univ. of Alaska)

sea ice for 5 months of the year. It is an estuarine area with considerable seasonal freshwater inflow, estimated at 112×10^9 cu. m. per year.

The fluctuating inflow of sea waters from the North Pacific into the Bering Sea strongly influences the estuarine character of Bristol Bay. Tidal effects are quite important in the shallow basin of Bristol Bay, and a significant fraction of the waters of the Bay is exchanged on a semidiurnal schedule. Bristol Bay waters are also affected by major storm tracks and its regime tends to respond rapidly to these transitory influences.

All these factors result in tremendous seasonal, annual, and long-term variations in the critical environmental characteristics of water temperature, salinity, dissolved oxygen, and nutrients. These variations have been studied most carefully in relation to the sockeye salmon. Populations of this prime resource have varied more than two orders of magnitude decreasing within a decade from more than 60 million to less than 600,000.

Oceanographic research has been conducted sporadically in the Bristol Bay area for 40 years, making this one of the most intensely studied subarctic marine environments in the world. Much of this research has been closely tied to specific biological problems related to the fisheries, and cruises often have been separated by years of inactivity.

The International North Pacific Fisheries Commission has encouraged studies in the region, and has issued a number of very useful summaries of work accomplished here by Americans, Japanese, Soviets, and Canadians (Barnes et al. 1935; Dodimead et al. 1958).

Among the more systematic series of observations in Bristol Bay in recent years have been those of the Research Institute of North Pacific Fisheries of Hokkaido University, which has sent its major training vessel, Oshoro Maru, into the Bay every summer since 1963. The research of Oshoro Maru has been closely tied to an experimental fishing program, and correlated hydrographic observations have usually required about a month. The data are thus useful for relating fish movements to environmental factors, but are not ideal for defining the details of circulation. Information collected by Hokkaido University is readily available in an extensive series of reports (Faculty of Fisheries 1957-1973).

Soviet oceanographers have also studied the area, particularly emphasizing the relation of the oceanographic conditions to benthic fisheries, and much of their work is available in translation (e.g., Davidovich 1963; Natarov 1963).

In recent years the U.S. Navy and the U.S. National Marine Fisheries Service have taken an interest in hydrographic and fisheries studies in the Bristol Bay area. A systematic program utilizing R/V Oregon has been conducted in the Bay each summer since 1969, and both data reports and summary papers are now available (e.g., Hamilton and Seim 1968; Straty, in press ; and USNODC, unpublished).[1] The University of Alaska has also conducted research in the area with R/V Acona of the Institute of Marine Science. Most of the University's attention has been directed to upwelling and air-sea interaction problems in the Aleutian passes, but several cruises have investigated the productivity and circulation of Bristol Bay (Kelley et al. 1971).

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1. U.S. National Oceanographic Data Center, unpublished station data for Marsden Squares 196 and 197.

The University of Washington's Fisheries Research Institute and Department of Oceanography have also conducted research in the southern Bering Sea, some of it dating back to the 1930's (e.g., Barnes et al. 1935). As a part of the International Decade of Oceanic Exploration, the Universities of Alaska and Washington and Hokkaido University are presently planning joint studies in the Bering Sea, including Bristol Bay, and have already conducted a comprehensive review symposium (Hood and Kelley, in press).

CIRCULATION

Geostrophic circulation in the normal sense does not exist in Bristol Bay. While the possibility of such circulation is suggested by the size of the area, it is precluded by the shallow depth of the waters and particularly by the instability of local meteorologic conditions. Instead of geostrophic flow, estuarine mechanisms must be fitted to explain the system. An idealized chart of net surface flow is shown in Figure 9. It is based upon interpretation of extremely scattered data from drift cards and bottles, fish egg and larval drift, the distribution of water characteristics (temperature, salinity, and dissolved oxygen), and even observations of turbid river waters offshore. It represents a pattern of surface circulation that may, in fact, exist for no more than a few weeks during the ice-free season. As suggested by Straty (in press), the Bay is divided into an inner bay which is completely dominated by estuarine phenomena, and an outer bay with a more oceanic character.

The fundamental circulation pattern in outer Bristol Bay during the ice-free months (April-November) appears to be a simple, counterclockwise gyre. The driving forces for this system are a combination of wind, tide, and estuarine thermohaline effects. Prevailing winds during the open water season trend from the southwest and west; so, in the region just north of the Alaska Peninsula, they tend to move the waters eastward and toward shore. This tends to force into the bay North Pacific water which has just entered the Bering Sea through Unimak Pass and the other eastern Aleutian passes. As well, the incoming tide from the Pacific enters through the passes, is deflected toward the east by Coriolis effect, and thus reinforces the eastward flow. The main stream of this part of the gyre follows the axis of a gentle trough which parallels the Alaska Peninsula, roughly 50 km. offshore. Inshore of the current, during the runoff season, there is a region of brackish coastal waters dominated by very local influences, but with a similar eastward net flow.

At the boundary between the inner and outer bays, northeast of Port Heiden, the eastern segment of the gyre meets the brackish coastal waters of the inner bay. Considerable mixing occurs in this region, particularly in the area between Cape Constantine and Cape Newenham, after which the resulting waters move north and west. An uncertain but large percentage of the bay waters proceeds north in the Bering Sea at all seasons, forming a significant part of the flow which, reinforced with the waters of the Kuskokwim and Yukon Rivers, moves through Bering Strait into the Arctic Ocean Basin. The remainder moves westward toward the Pribilof Islands and ultimately mixes with the waters at the edge of the shelf. Thus the circulation "gyre" of Bristol Bay is really more of a U-shape than a complete circuit, although some indirect evidence from the trajectories of fish eggs and drift bottles suggests that a true gyre exists during some parts of the year (Fadeev 1970, Thompson and Van Cleve 1936).

On one occasion--in connection with studies of the dispersal of planktonic king crab larvae--currents offshore in outer Bristol Bay were physically measured (Hebard 1959). Hebard occupied a series of four Ekman current meter stations for a full tidal day each in June of 1957. The records indicate a strong tidal component with maximum currents offshore of 88 cm./sec. (1.7 knots), and a net flow of approximately 5 cm./sec. (0.1 knot) was inferred (Figure 10). In the inner bay, particularly in the mouths of the rivers, significant local tidal currents are observed.

TIDES AND TIDAL CURRENTS

There is considerable variation in tidal range around the periphery of Bristol Bay (Table 1). The tidal bulge enters from the Pacific with an amplitude on the shelf of approximately 2 m., but amplitudes along the shore range from less than 1 m. to almost 7 m. As in Cook Inlet, there is considerable amplification of the tide toward the head of Bristol Bay. The natural period of oscillation (T) of an open embayment can be calculated from the formula

$$T = \frac{4L}{\sqrt{gd}}$$

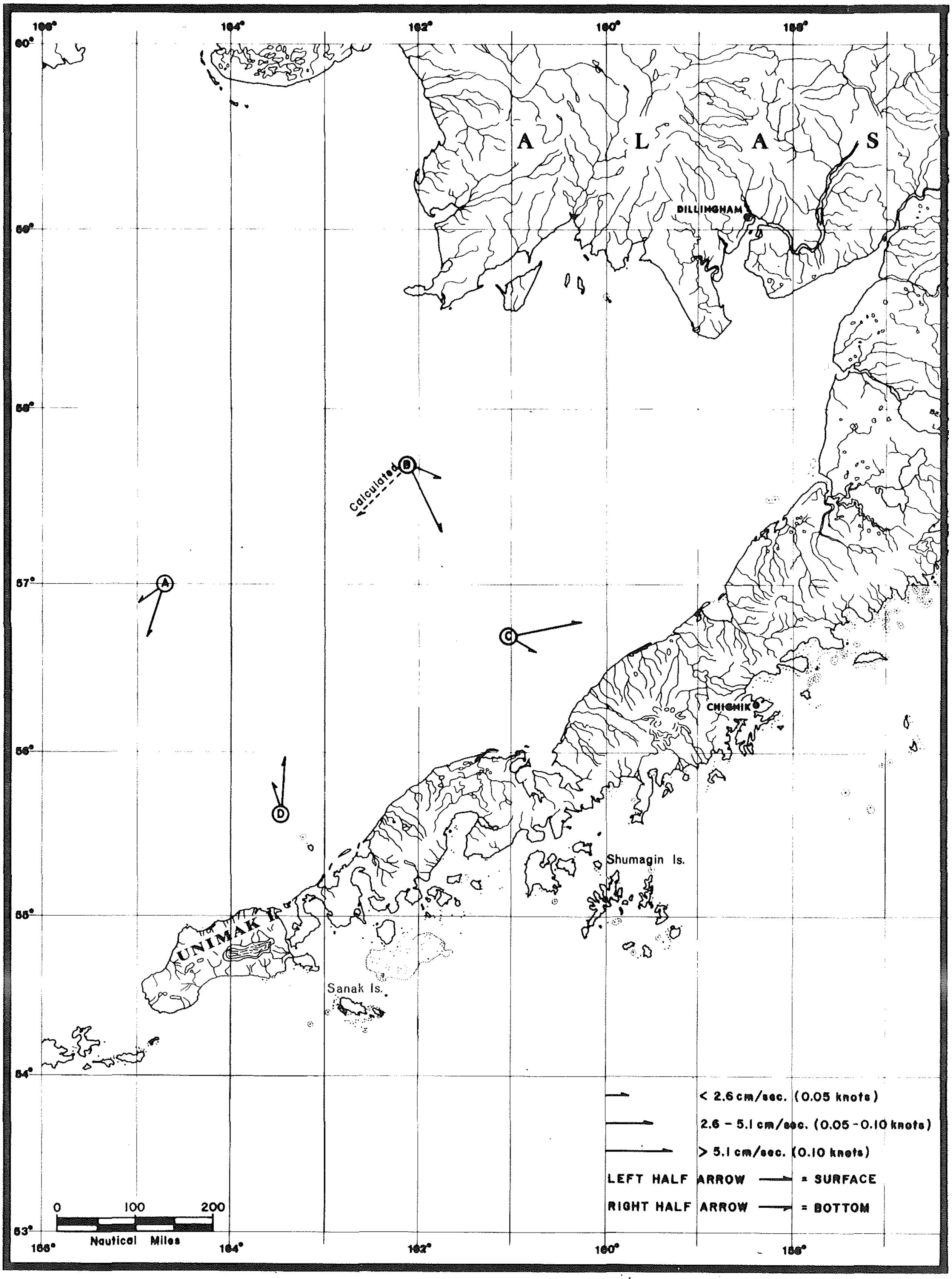

Figure 10. Measured surface and bottom currents in Bristol Bay (from Hebard 1959)

Table 1

Tidal Ranges around Bristol Bay, Alaska
(From U.S. National Ocean Survey 1972a)

Place	Mean range[1] Meters	Diurnal range[2] Meters
Cape Sarichef, Unimak Island	1.0	1.6
Amak Island	1.6	2.3
Izembek Lagoon	1.0	1.4
Port Moller	2.3	3.3
Port Heiden	2.6	3.7
Egegik River (Entrance)	4.2	5.5
Kvichak Bay (Middle Bluff)	4.6	6.0
Naknek River (Entrance)	5.6	6.9
Kvichak	4.2	5.0
Nushagak Bay (Clarks Point)	4.7	5.9
Walrus Islands	1.8	2.9
Goodnews Bay	1.9	2.7
St. Paul Island (Pribilofs)	0.6	1.0

1. Mean range is the difference in height between mean high water and mean low water.

2. Diurnal range is the difference in height between mean higher high water and mean lower low water.

where "L" is the length and "d" is the average depth of the bay, and "g" is the acceleration due to gravity. For the inner bay, with a depth of about 18.5 m. and a length of 150 km., the period is 12.4 hours. This is precisely the period of the major lunar tide, so reinforcement of the tidal amplitude is certain to occur. The resulting tidal range in the inner bay, usually greater than 5 m., is an important influence upon water movements and winter ice conditions. As ice forms in the brackish waters of the estuaries, it is speedily broken up and moved offshore by the tides. Because of continual tidal movement and fracturing, true shorefast ice does not develop around most parts of the head of the Bay, even though temperatures and water characteristics are suitable.

There are swift tidal currents around many parts of the shore of Bristol Bay. At the mouth of the Bay, off Scotch Cap in Unimak Pass, the incoming Pacific tide exceeds 175 cm./sec. (3.4 knots) and the ebb is more than 150 cm./sec. (3.0 knots). Within the Bay proper, there are no greater tidal currents, but there are many comparable (Table 2). As in many estuarine areas, some of the ebb tidal currents considerably exceed the flood, due to the influence of river flow. Appreciable tidal currents have been measured offshore in Bristol Bay (Hebard 1959). Values as high as 67 cm./sec. (1.3 knots) at the surface and 44 cm./sec. (0.8 knots) near the bottom were recorded near the center of the Bay (Table 3). The measured tidal currents are closely comparable to calculated, maximum open water tidal currents for a tidal amplitude of 2 m.

Table 2

Representative Tidal Currents around Bristol Bay, Alaska
(From U.S. National Ocean Survey 1972b)

Place	Flood		Ebb		Difference Flood - Ebb, Cm./sec.
	Cm./sec.	Knots	Cm./sec.	Knots	
Unimak Pass (off Scotch Cap)	175.0	3.4	154.4	3.0	20.6
Amak Island	41.2	0.8	36.0	0.7	5.2
Port Moller	87.5	1.7	102.9	2.0	-15.4
Port Heiden	51.5	1.0	51.5	1.0	0
Naknek River (Entrance)	128.7	2.5	128.7	2.5	0
Kvichak River	87.5	1.7	154.4	3.0	-66.9
Nushagak Bay (Protection Point)	97.8	1.9	159.6	3.1	-61.8
Nushagak Bay (Clark's Point)	164.7	3.2	175.0	3.4	-10.3
Dillingham	175.0	3.4	164.7	3.2	10.3
Goodnews Bay	118.4	2.3	108.1	2.1	10.3

Table 3

Calculated Maximum Tidal Currents on an Open Shelf with a Tidal Amplitude of 2 m., Compared with Maximum Measured Currents in the Middle of Bristol Bay (From Station A, Hebard 1959).

Depth (m.)	Calculated Currents Cm./sec.	Calculated Currents Knots	Measured Currents Cm./sec.	Measured Currents Knots
5	140	2.7	67	1.3
10	99	1.9	72	1.4
20	70	1.4	62	1.2
50	44	0.8	44	0.8

SUMMER WATER TYPES

The outstanding characteristic of the waters of Bristol Bay during the ice-free season is their great, seemingly erratic variability. The entire area can be regarded as an estuary in which North Pacific surface waters and local runoff mix. The situation is complicated by the large size, shallow depth, and above all, by the high latitude and subarctic climate of the region. Particularly important is the influence of the brief, violent storms that can occur here during any season. These alter the density structure of the waters and can cause upwelling or downwelling of large volumes of water, leading to drastic changes in the characteristics of the surface waters, and, in fact, in the character of the entire water column.

The variability of water temperatures from year to year is clearly seen in Figure 11. It is not unusual, when reoccupying an oceanographic station in the middle of the Bay after a two-day storm, to find that the surface temperature has dropped 3 to 5 degrees C. This shift is, of course, a function of both mixing and heat loss to the atmosphere.

The result of all this variability is a system in which there is a very high level of ambient "noise," a system extremely difficult to characterize by conventional oceanographic techniques, and a system in which the definition of internally consistent, long-term trends in conditions has proven, thus far, to be impossible.

Nutrient concentrations (phosphates, nitrates, silica, etc.) are usually quite high throughout Bristol Bay. This is a consequence of the excellent turbulent mixing of deep waters and the large input of terrestrial waters. The limitations on local productivity, then, are primarily physical--temperature, insolation, and suspended sediments.

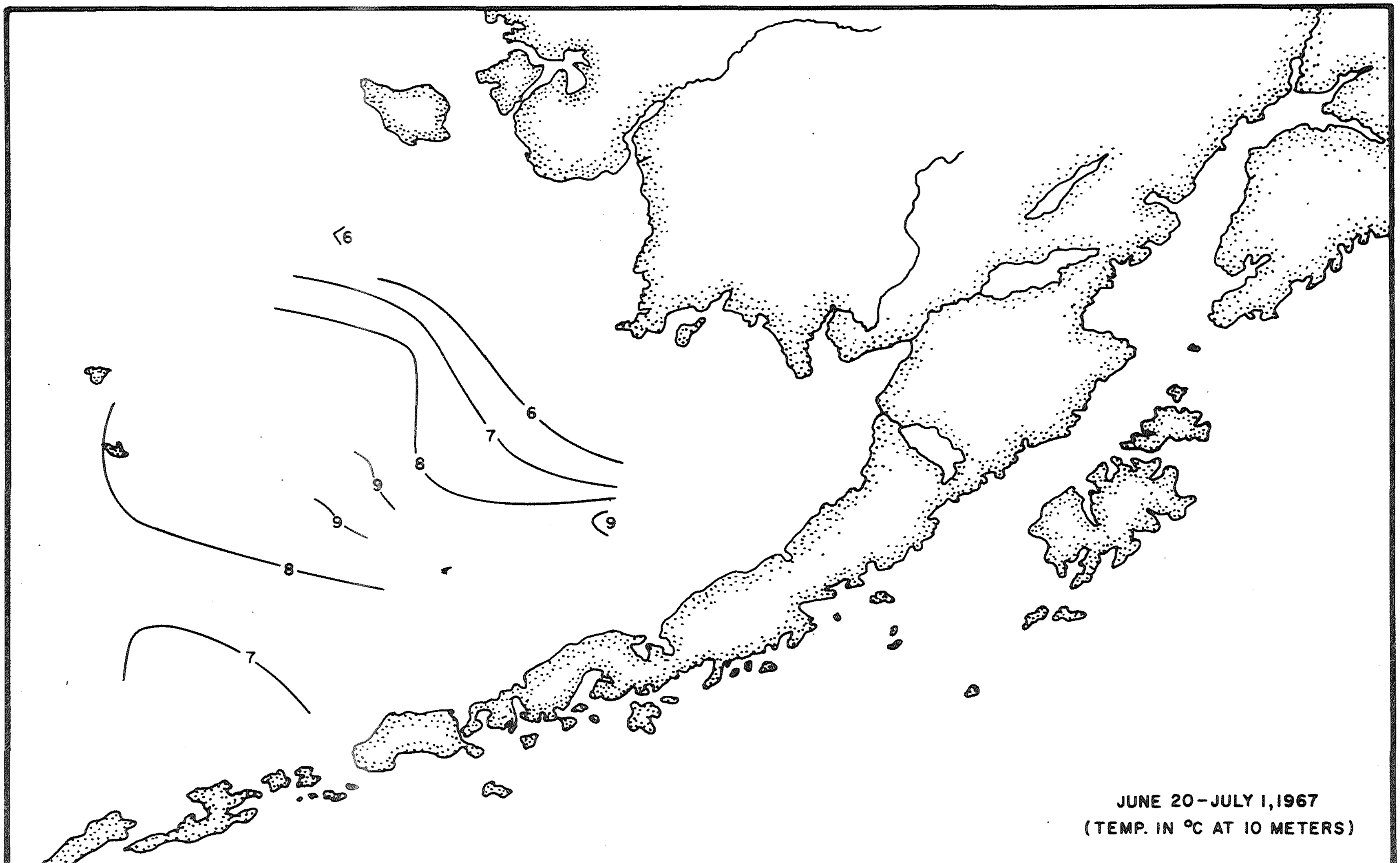

Figure 11a. Temperature distribution in Bristol Bay, summer of 1967 (from Straty, in press).

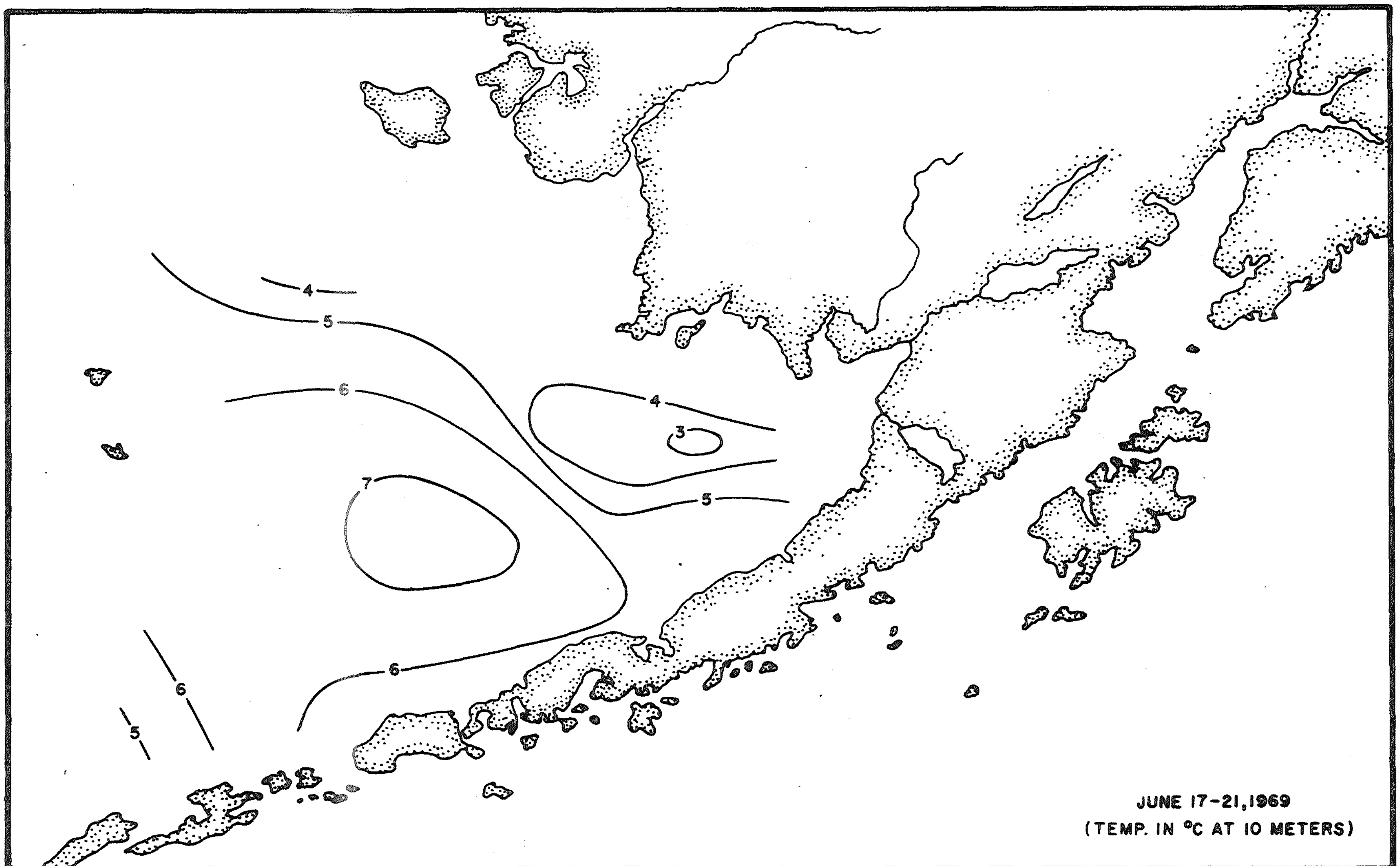

Figure 11b. Temperature distribution in Bristol Bay, summer of 1969 (from Straty, in press).

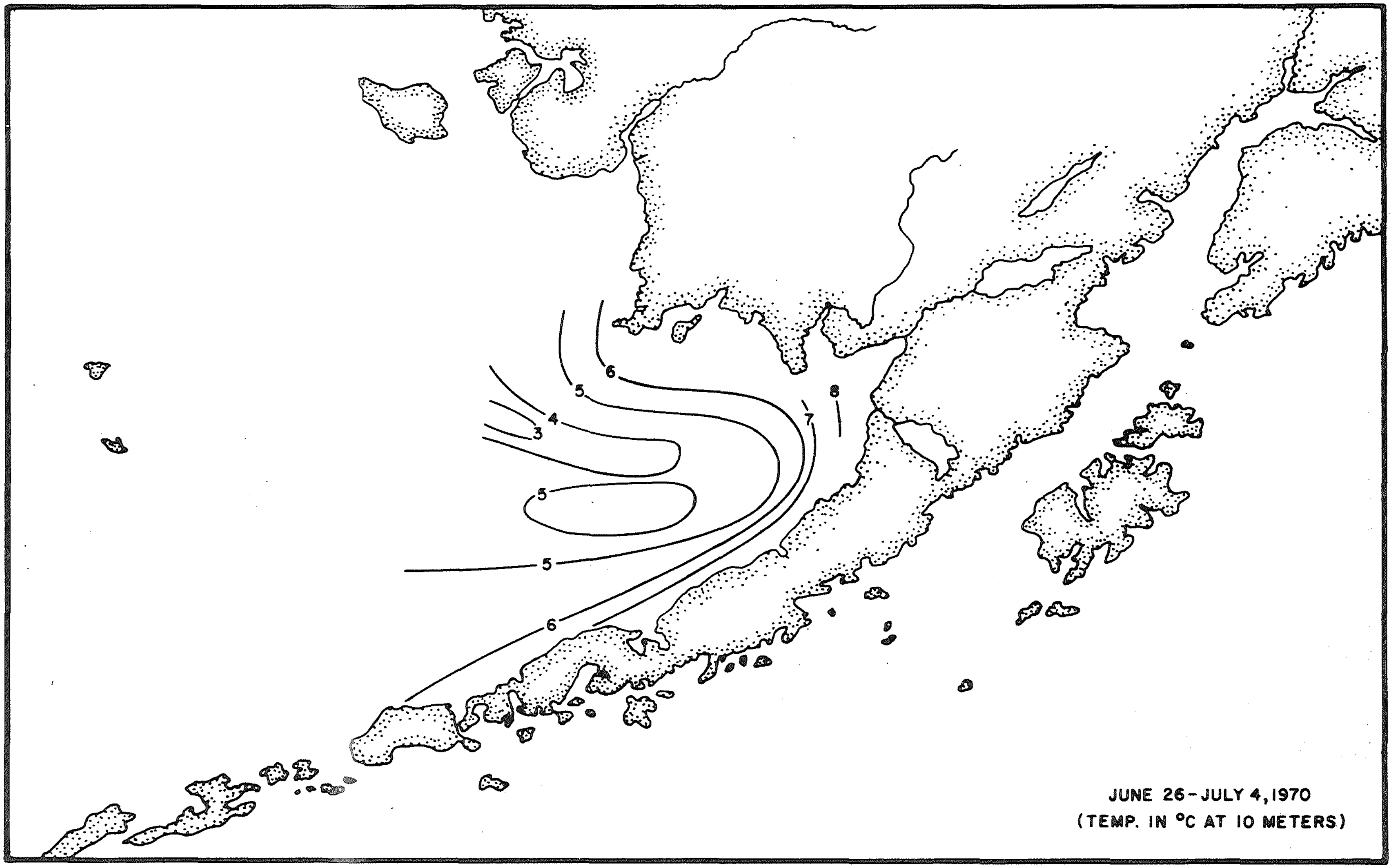

Figure 11c. Temperature distribution in Bristol Bay, summer of 1970 (from Straty, in press).

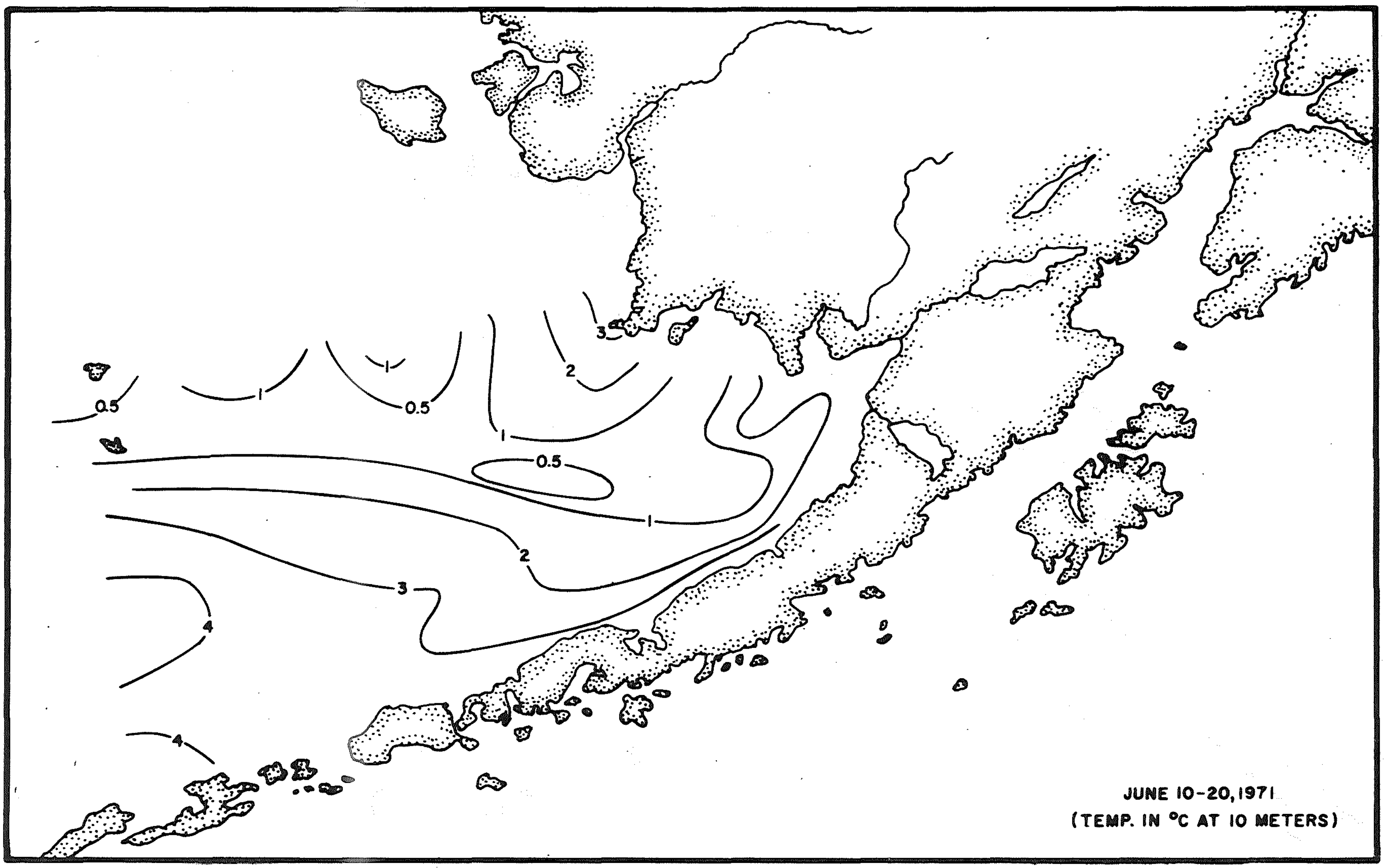

Figure 11d. Temperature distribution in Bristol Bay, summer of 1971 (from Straty, in press).

For purposes of discussion, the waters of Bristol Bay can arbitrarily be divided into four geographical regions by the parameters of temperature and salinity. These "water types" are definitely not analogues to true water masses in normal oceanographic usage. The types are North Pacific Water, relatively normal sea water from the Pacific which occurs just north of Unimak Pass; Bristol Bay Slope Water, mixed water which lies along the continental slope between Unimak Pass and the Pribilof Islands; Bristol Bay Central Water, found in the gyre of the outer bay, and Inner Bay and Coastal Water, the water showing strong terrestrial influence that dominates the head of the Bay. The general characteristics of these water types are given in Table 4; their distribution is shown in Figure 12.

Table 4

Typical Surface Water Characteristics in Bristol Bay, Summer (June-August). Data assembled from University of Alaska, Hokkaido University, U.S. National Marine Fisheries Service, and U.S. National Oceanographic Data Center

Water Type	Temperature (°C)		Salinity (‰)		No. of Observations
	Mean	Range	Mean	Range	
North Pacific (North of Unimak Pass)	7.4	5.0-10.6	32.7	32.3-33.1	42
Bristol Bay Slope	8.6	5.4-10.6	32.0	31.4-32.8	58
Bristol Bay Central	7.9	1.8-12.3	31.4	30.0-32.6	68
Bristol Bay Inner and Coastal	11.4	1.3-18.2	28.9	12.4-31.2	44

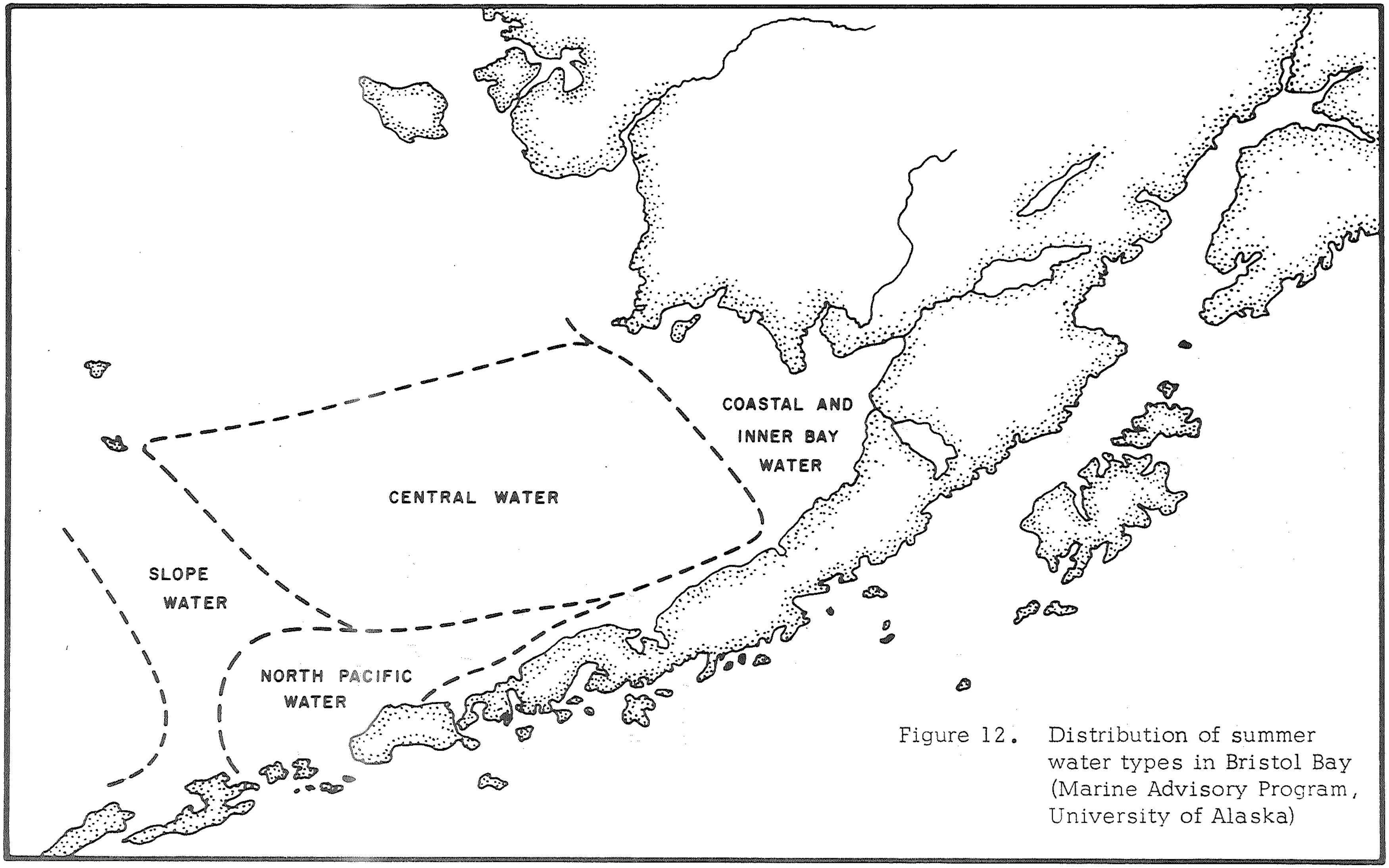

Figure 12. Distribution of summer water types in Bristol Bay (Marine Advisory Program, University of Alaska)

North Pacific Water

Large volumes of water enter the Bering Sea through the major passes of the Aleutian Chain. This is water from the Alaska Stream, part of the counterclockwise gyre formed in the North Pacific Ocean as the high latitude segment of the Kuroshio System. By the time the Alaska Stream reaches the longitude of the Aleutians, it has been well mixed with terrestrial contributions from western and northern North America. This water, which is typically of comparatively high, fairly stable salinity, enters Bristol Bay through Unimak Pass. Unimak Pass is relatively deep, with a sill depth of about 150 m., but there are strong currents causing considerable turbulent mixing within the channel. Flood tide velocities at Scotch Cap are more than 175 cm./sec. (3.4 knots) and they exceed the ebb velocities by about 10 percent, reflecting the net northward movement of waters into the Bering Sea.

The northward current through the Pass may be considerably accelerated by the influence of tropic tides or by the passage of an atmospheric depression north of the chain

(U.S. National Ocean Survey 1964). Under these circumstances, a tremendous volume of water may enter the Bering Sea at velocities that have been estimated at more than 300 cm./sec. (6 knots). Mixing in the Pass tends to function like classic upwelling, bringing nutrient-rich, deep waters to the surface. These fertile waters move into Bristol Bay and are a very significant factor in the high productivity that occurs in summer. In winter, these waters are considerably warmer and more saline than most Bering Sea water, and thus tend to limit the area of ice formation in Bristol Bay.

Bristol Bay Slope Water

Along the western boundary of the Bristol Bay oceanographic unit, between Unimak Pass and the Pribilof Islands, there is a zone characterized by a mixture of North Pacific water, waters from Bristol Bay, and water from elsewhere in the Bering Sea. This is an area with fluctuating boundaries. Its characteristics are strongly influenced by the rate of inflow from the Pacific and by storms which may locally induce true upwelling along the continental margin. This area is the site of a large portion of the primary productivity of the southern Bering Sea and is a critical way-station in the spawning migration of the Bristol Bay salmon stocks.[1] Typical temperature and salinity profiles for the area are found in Figure 13.

Bristol Bay Central Water

Most of outer Bristol Bay is filled with an uneasy amalgam of North Pacific and Inner Bay and Coastal waters. There is often some contribution of colder water moving in at depth from north and west on the continental shelf. The character of this Central water is always highly variable during summer months because of the fluctuating meteorologic and climatic influences to which it is exposed. During the calmer portions of the summer, insolation will warm the surface layer and a definite thermocline will form. This structure may almost disappear after a brief storm. Meltwater from sea ice in the Bay also contributes to the density structure of the Central water in spring, and for a time there may be a shallow halocline. Typical conditions in the Central area in mid-summer include a pronounced but rather shallow thermocline with surface temperatures as high as 11 degrees C overlying waters of 1 to 4 degrees C (Dodimead et al. 1958).

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1. Takeji Fujii, Professor, Fisheries Oceanography, Hokkaido University. Hakodate, Japan. Personal communication.

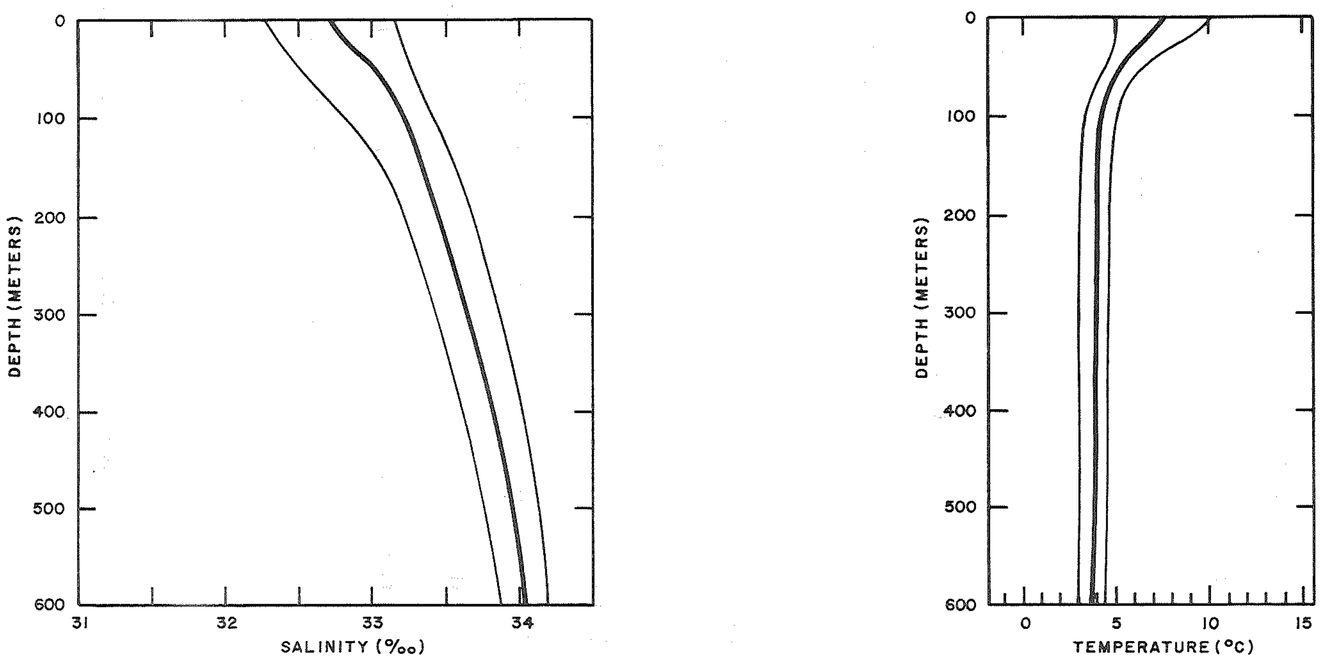

Figure 13. Vertical profiles of water temperature and salinity in the Bering Sea and in western Bristol Bay (from Hamilton and Seim 1968)

The thermohaline structure in the outer and inner bays is very clearly shown in Figure 14.

Inner Bay and Coastal Water

From April through early November, there is significant freshwater runoff into Bristol Bay. Most of the streams draining into the Bay are relatively short and small, draining the glaciated, volcanic terrain of the Alaska Peninsula. The largest inputs are from the Kvichak, Nushagak, and Wood Rivers at the head of the Bay. These rivers drain the foothills of the Alaska Range and the Kuskokwim Mountains and carry tremendous amounts of very fine-grained, glacially-derived sediment. This turbid, fresh water dominates the head of Bristol Bay. Although it introduces large quantities of nutrients, the associated sediment reduces light penetration and limits photosynthesis. Salinities and temperatures in the inshore water are highly variable, depending upon the rate of runoff and the season. In spring, this water is often colder than the Central water, but by mid-summer it is often much warmer. The lagoons and minor bays tributary to Bristol Bay all develop distinctive waters, similar to those

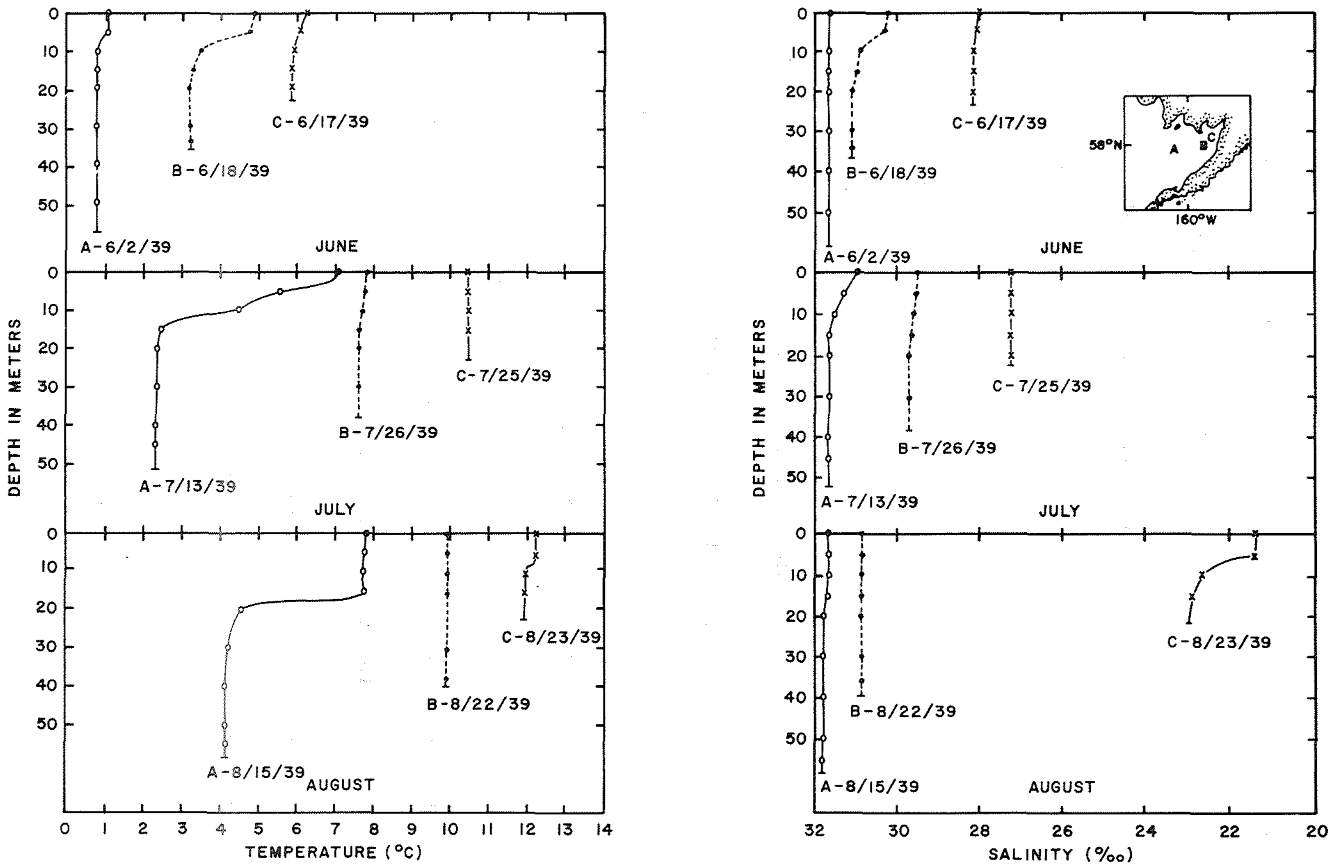

Figure 14. Vertical profiles of water temperature and salinity in central and outer Bristol Bay, summer of 1939 (from Dodimead et al. 1958)

at the head of the Bay, but usually without a high suspended sediment load.

SEA ICE AND WINTER CONDITIONS

Bristol Bay lies at the southern boundary of the area influenced by true seasonal ice. Because of the highly variable temperature, tide, and wind regimes of the Bay, ice here is never really continuous, and consists of a constantly changing mass of irregular floes. Formation of the ice begins in fall; by mid-October the more dilute and sheltered lagoons in the inner bay will start to show ice cover. At this season, considerable freshwater ice formed in the larger tributary rivers may enter the Bay, often carrying considerable loads of fine-grained sediment (Sharma et al. 1972). By December, low air temperatures produce widespread local freezing, Persistent winds move the pack ice from farther north in the Bering Sea producing a situation where more than 50 percent of the inner bay has significant (greater than 10 percent) ice cover. Scattered floes are found south and east as far as a line between Port Moller and the Pribilofs.

The most severe ice conditions occur in February and March, when greater than 10 percent ice cover may persist over the entire Bay. At this season there may be many scattered reaches of shore-fast ice in the inner bay, but the considerable tidal amplitudes tend to keep ice in this area broken up. Serious ice conditions in the outer bay may persist well into spring. A federal survey ship reported solid floes and much drift pack offshore near Port Heiden in May of 1948. In mid-June of 1972, a research ship could not operate in Kvichak and Nushagak Bays because of the large masses of fluvial ice.[1] Satellite imagery of Bristol Bay showed large ice masses randomly scattered in the inner bay in May and June of 1973 (Wright et al. 1973). There are few observations of winter water characteristics, but a U.S. Navy cruise in 1955 established that throughout the Bay the waters become isohaline (31.5 to 21.8 parts per thousand) and isothermal (-0.5 to -1.5 degrees C), but that water dense enough to flow off the shelf as Bering Sea bottom water was not produced (U.S. Navy Hydrographic Office 1958). Temperature and salinity distribution at the mouth of the Bay is seen in Figure 15.

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1. R.G. White, Asst. Professor, Zoophysiology, Institute of Arctic Biology, University of Alaska. Fairbanks. Personal communication.

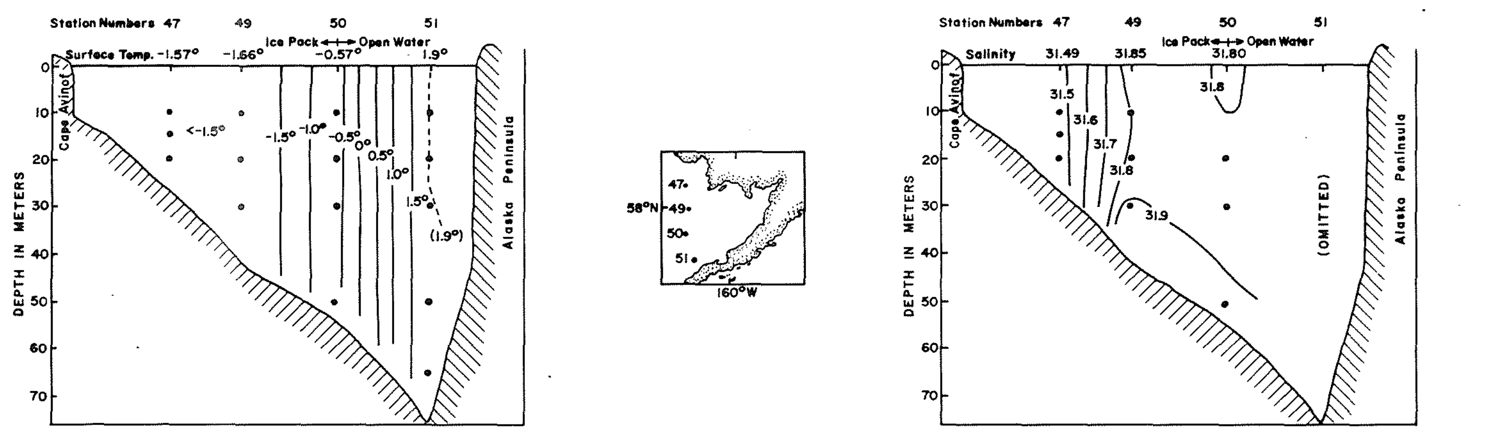

Figure 15. Cross sections of winter water characteristics at the mouth of Bristol Bay, winter of 1955 (from U.S. Navy Hydrographic Office 1958)

WAVES

Wave patterns in Bristol Bay are difficult to characterize. Despite the great fetch available to the west and north, most waves appear to be locally generated, and thus fall into the category of "sea." Sea tends to be irregular, with steep crests and flattened troughs, in constrast to the smooth, sinusoidal form of "swell." Because of the shape, sea waves tend to batter ships out of proportion to their size. There are no recordings and very few reliable reports of wave magnitude in the Bristol Bay area. Experienced mariners have reported no waves in the region greater than 5 m., but theoretical considerations suggest that waves offshore could be as great as 10 m. Possibly the lack of traffic in the area explains the paucity of large wave observations.

Critical factors in local wave patterns are the brief but severe storms, with a relatively limited fetch, and the shallowness of Bristol Bay. Even though persistent winds of about 36 km./hr. (20 knots) are not uncommon, and winds more than 180 km./hr. (100 knots) have been recorded, the wind direction and velocity in the Bering Sea are extremely variable. It is rare in the open water season for a constant wind to blow unobstructed over a broad expanse of water long enough to generate really large waves. The other factor, the shallow depth of the Bay, tends to limit the maximum size of wave that can travel through an area. All of the Bay is of continental shelf depth, as is all of the northern Bering Sea (less than 200 m.). Waves will grow until their height-to-length ratio reaches about 1:7, then, because of gravity, they become unstable and will dissipate some of their energy by breaking, usually as the spilling-type, open water breaker. This means that a wave of 10 m. amplitude could only persist with a crest-to-crest length in excess of 70 m. Such a wave would be retarded and might be forced to break when it entered waters of one-half its wave length (35 m.), thus dissipating much of its energy before reaching shore.

Seismic seawaves--tsunamis--apparently are uncommon in Bristol Bay. There are Native traditions of destroyed villages in the area, but only two records exist of actual tsunamis at Port Heiden on the Alaska Peninsula coast.[1] In 1928, according to the Natives, there was a

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1. B.J. Logan, 1970. Report on Alaskan Ports. unpublished. 145 pp.

tsunami of about 2 m. and again in 1946, at the time of the famous Scotch Cap tsunami, a wave of about 1.3 m. occurred at Port Heiden. Presumably the lack of recorded tsunamis in Bristol Bay is due to the tendency for wave energy to be lost from long passage over the shallow shelf. In addition, many occurrences may have been unreported because of sparse settlement.

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CLIMATE

INTRODUCTION

The maritime location of the study area strongly affects its climate, although such effects are less evident than over the western Gulf of Alaska, on the south side of the Alaska Peninsula. The Bristol Bay region is characterized by cloudy skies, mild temperatures, and--relative to inland stations--moderately heavy precipitation. Surface winds are stronger than at inland stations.

The mountains along the Alaska Peninsula intercept a large portion of the moisture from the prevailing flow of air from the southeast; this results in less precipitation for the southern shoreline of Bristol Bay. A flow of air from the north out of the western Interior periodically replaces the maritime influence along the northern coast causing temperature extremes that are much greater than would result from air with a trajectory over water. A major storm track (southwest to northeast movement of storms) crosses the eastern Bering Sea during the period from late July to early September.

DATA SOURCES

Detailed summaries of climatic data compiled by the Air Weather Service (various dates), are available for Cold Bay, St. Paul Island, Cape Newenham, King Salmon, and Port Moller. Data for all other locations were taken from Environmental Data Service publications (undated). Wind data are available from 6 of the 10 data stations used. The period of record for each station is noted on the appropriate table and figure. Figure 16 shows the location of all weather stations represented in this report. A table showing the parameters observed, the data routinely summarized, and the current status of each station is also included (Table 5). Only one of the 10 data stations (Brooks Lake) is not considered to be a coastal station.

REGIONAL WEATHER PATTERNS

Surface and upper air patterns for the study area have been recorded over a period of 20 years; averages are shown on Figure 17 (U.S. Weather Bureau 1952). Superimposed

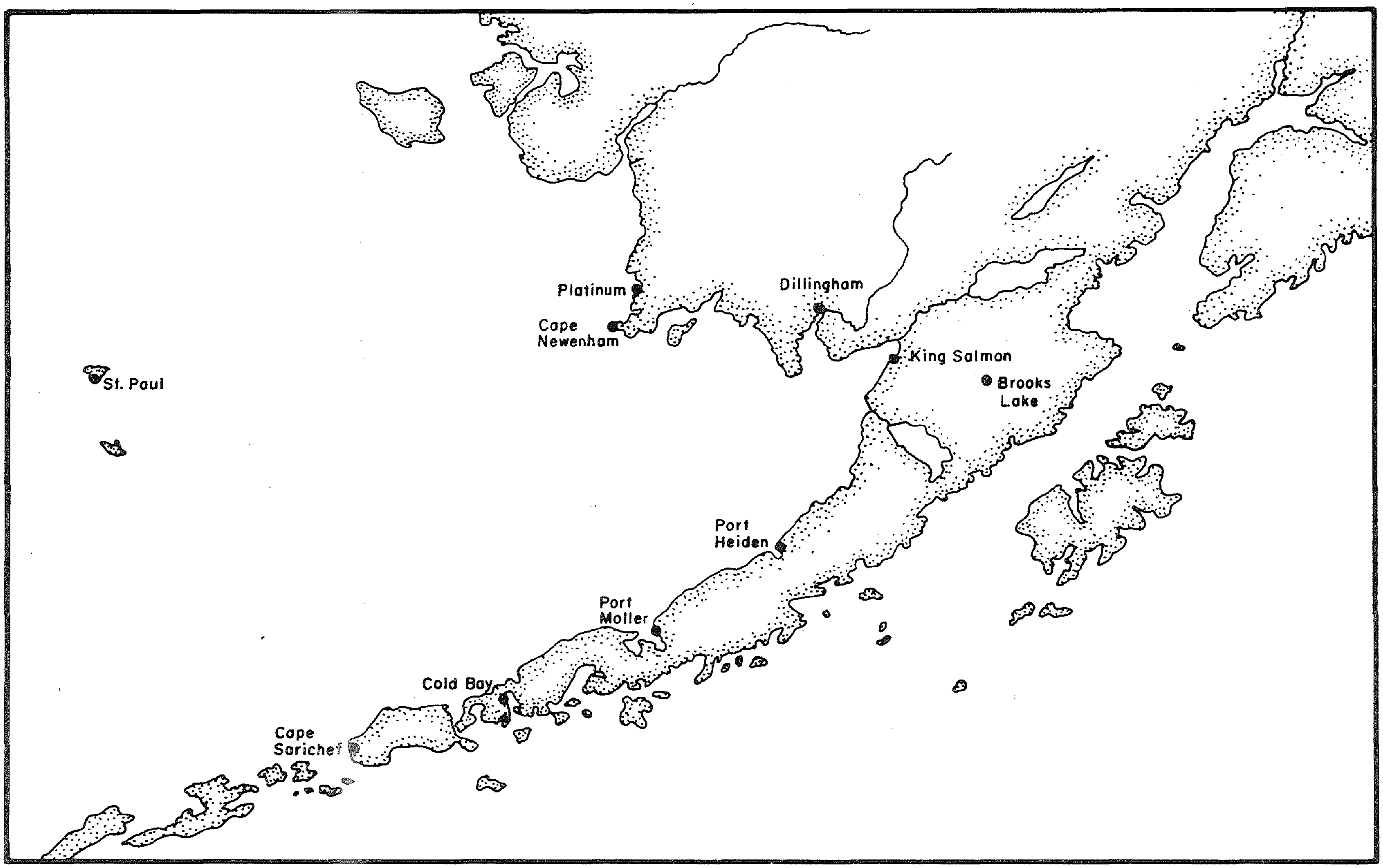


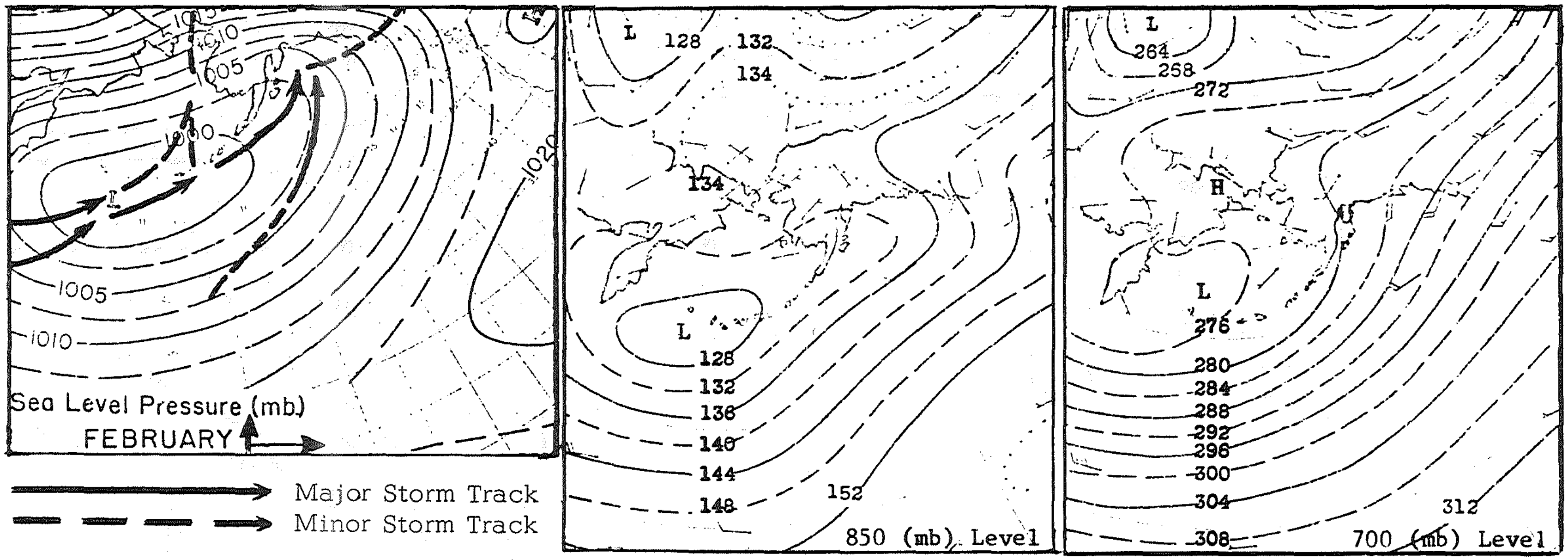
Figure 16. Location of weather stations in the Bristol Bay study area (Arctic Environmental Information and Data Center, Univ. of Alaska).

DATA STATIONS AND PARAMETERS OBSERVED

	Active Station	Inactive Station	Temp at obsn time	Dewpoint at obsn time	Max/min Temp	Precipitation	Pressure	Wind	Sky Cover	Cloud Height	Visibility	Weather at obsn time
Cape Sharichef	X		X	X	X	X	X	X	X	X	X	X
Cold Bay	X		X	X	X	X	X	X	X	X	X	X
St. Paul	X		X	X	X	X	X	X	X	X	X	X
Cape Newenham	X		X	X	X	X	X	X	X	X	X	X
King Salmon	X		X	X	X	X	X	X	X	X	X	X
Platinum		X			X	X						
Dillingham		X	X	X	X	X	X	X	X	X	X	X
Brooks Lake	X				X	X						
Port Heiden	X				X	X						
Port Moller		X			X	X	X	X	X	X	X	X

Parameters listed to the right of "24 hour precipitation" are observed but not routinely summarized except at Cold Bay, King Salmon, and St. Paul. In addition, they are not observed on an hourly basis except at Cold Bay, King Salmon, St. Paul, and Cape Newenham, which is a major reason why they are not summarized. Even limited coverage timewise would have some value, and this data could be summarized if a user felt his needs justified the cost.

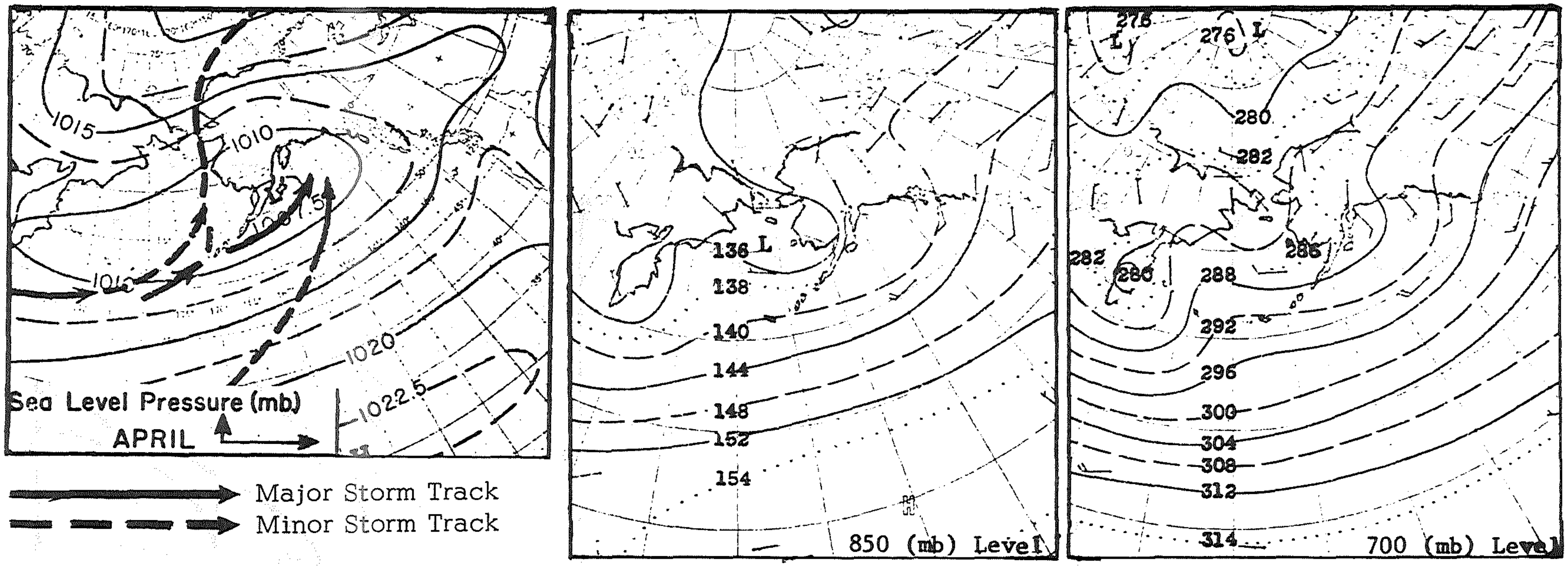
Table 5



Numbers are millibars of pressure Numbers are heights in 10's of meters i.e. 138=1380 meters

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 20 years of record

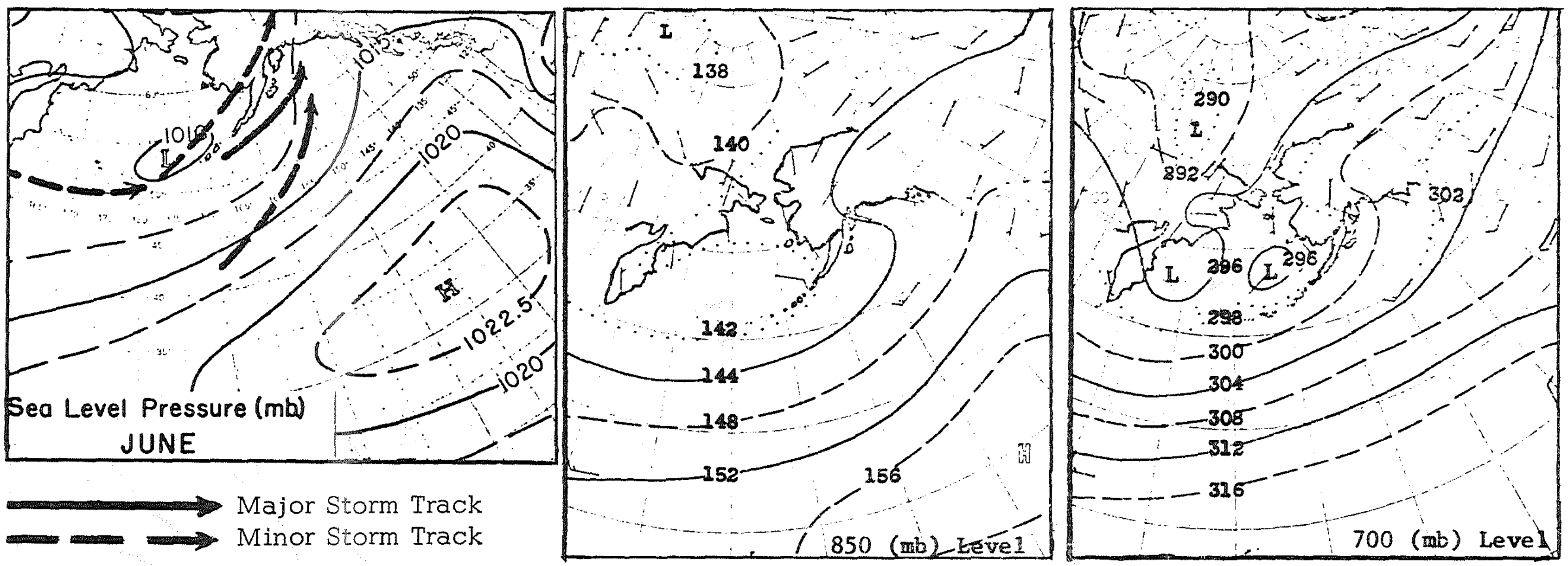
Figure 17a



Numbers are millibars of pressure   Numbers are heights in 10's of meters i. e. 138=1380 meters

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific   20 years of record

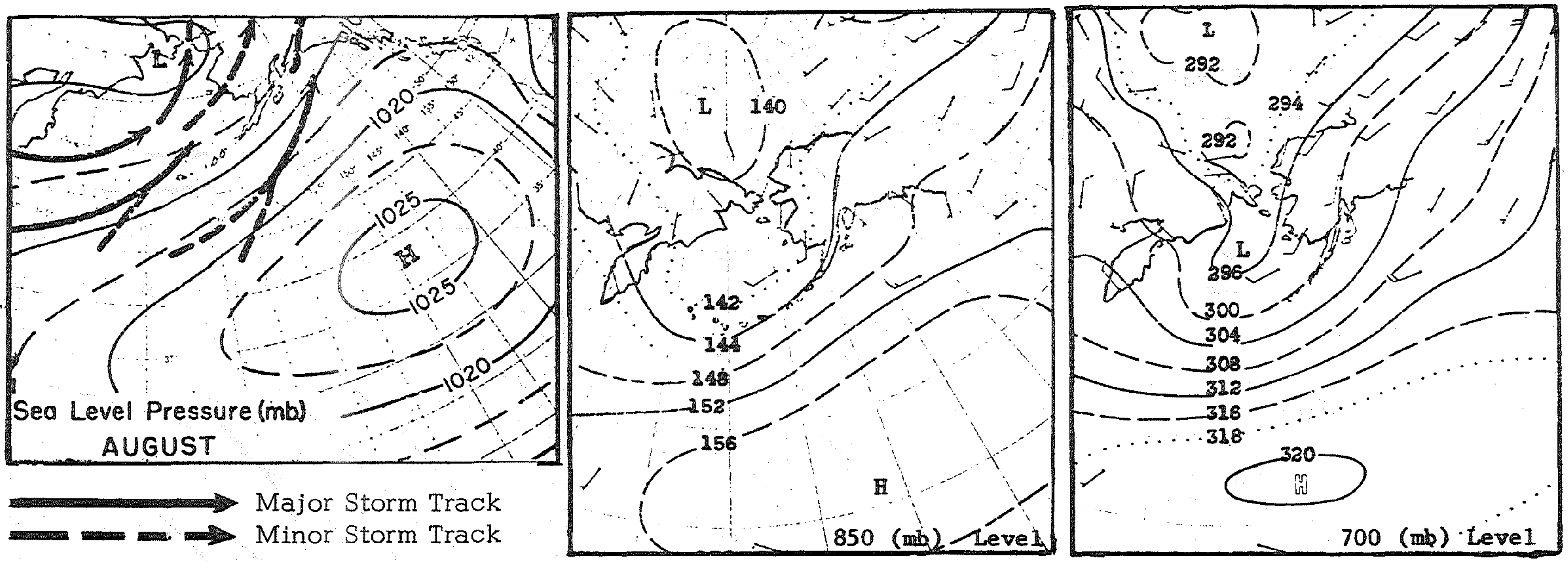
Figure 17b



Numbers are millibars of pressure   Numbers are heights in 10's of meters i.e. 138=1380 meters

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific   20 years of record

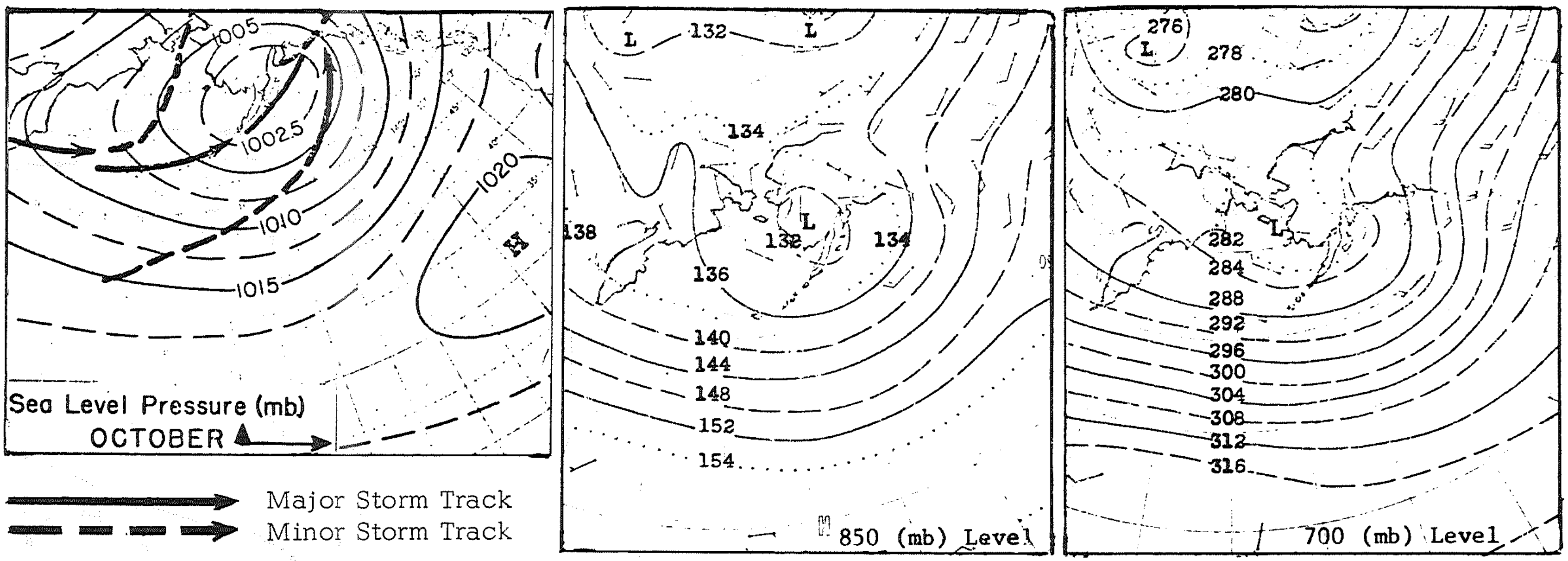
Figure 17c



Numbers are millibars of pressure   Numbers are heights in 10's of meters i.e. 138=1380 meters

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific   20 years of record

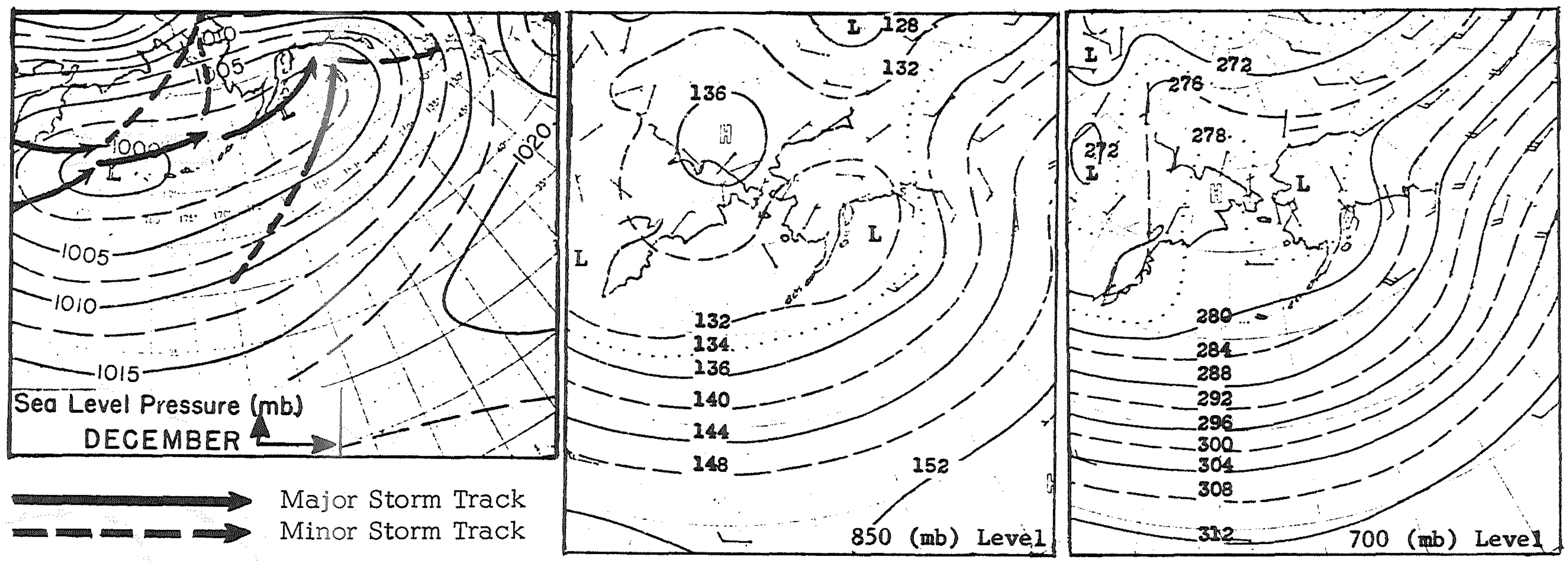
Figure 17d



Numbers are millibars of pressure Numbers are heights in 10's of meters i.e. 138=1380 meters

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 20 years of record

Figure 17e



Numbers are millibars of pressure Numbers are heights in 10's of meters i.e. 138=1380 meters
Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 20 years of record

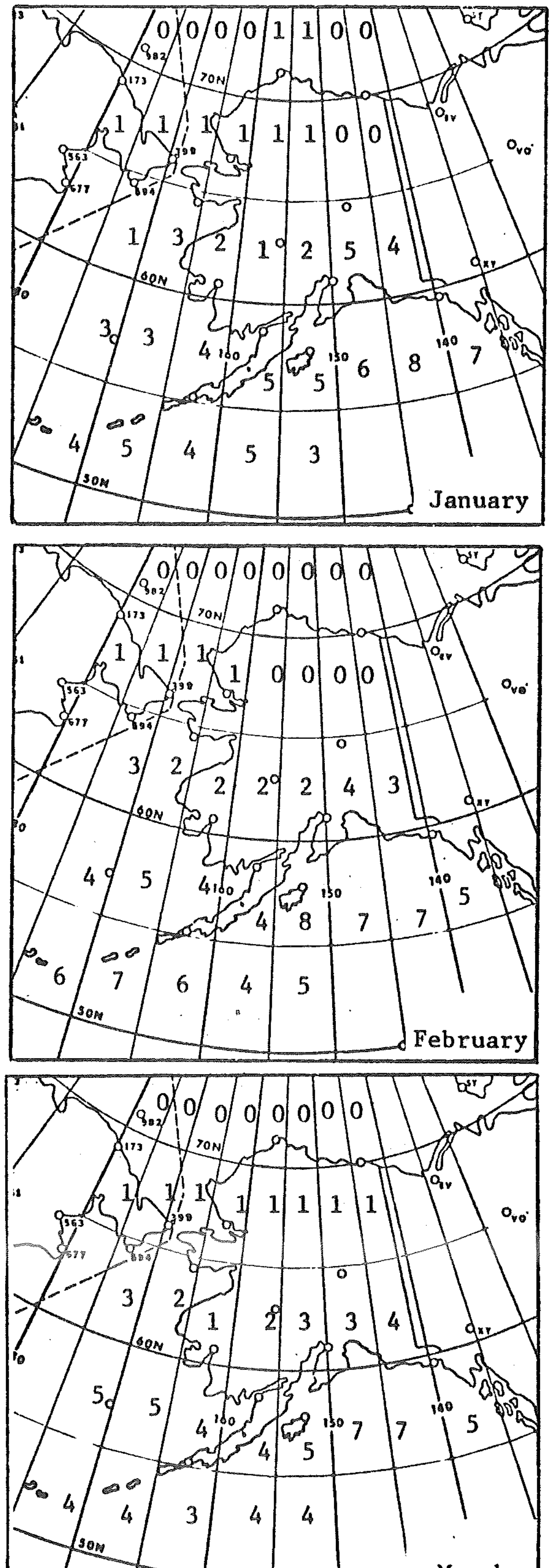
Figure 17f

on the surface charts are the major and secondary storm tracks observed over the same period (Klein 1957). A strong seasonal change in pressure patterns occurs between winter and summer both at the surface and aloft. Based on data collected over a 40-year period, the frequency of storms in the study area is shown in Figure 18 (Klein 1957). Maps showing regional patterns of temperature and precipitation are included in Figures 19 and 20. A detailed description of the various climatic parameters of the study area follows.

TEMPERATURE

Temperature patterns are characterized by cool summers and warm winters, when compared to inland temperatures at similar or more northerly latitudes. Average summer maximum temperatures in the study area range from near 10 degrees C (50 degrees F) to the high 10's (low 60's), and average winter minimums from -14 degrees C (6 degrees F) to nearly zero (upper 20's). In comparison, Fairbanks, a typical inland station, experiences average summer maximums in the low 20's (low 70's) and average winter minimums from

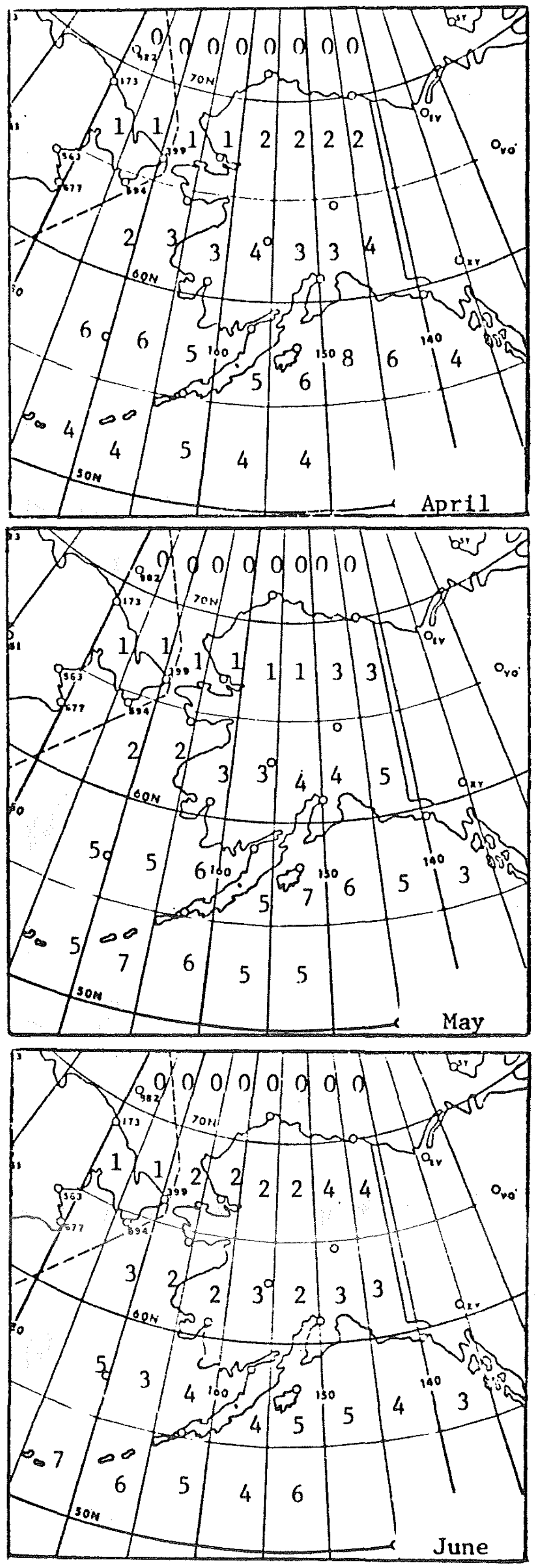
PERCENTAGE FREQUENCY OF NUMBER OF DAYS WITH LOWS IN FIVE DEGREE SQUARES



Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific
40 years of record

Figure 18a

PERCENTAGE FREQUENCY OF NUMBER OF DAYS WITH LOWS IN FIVE DEGREE SQUARES

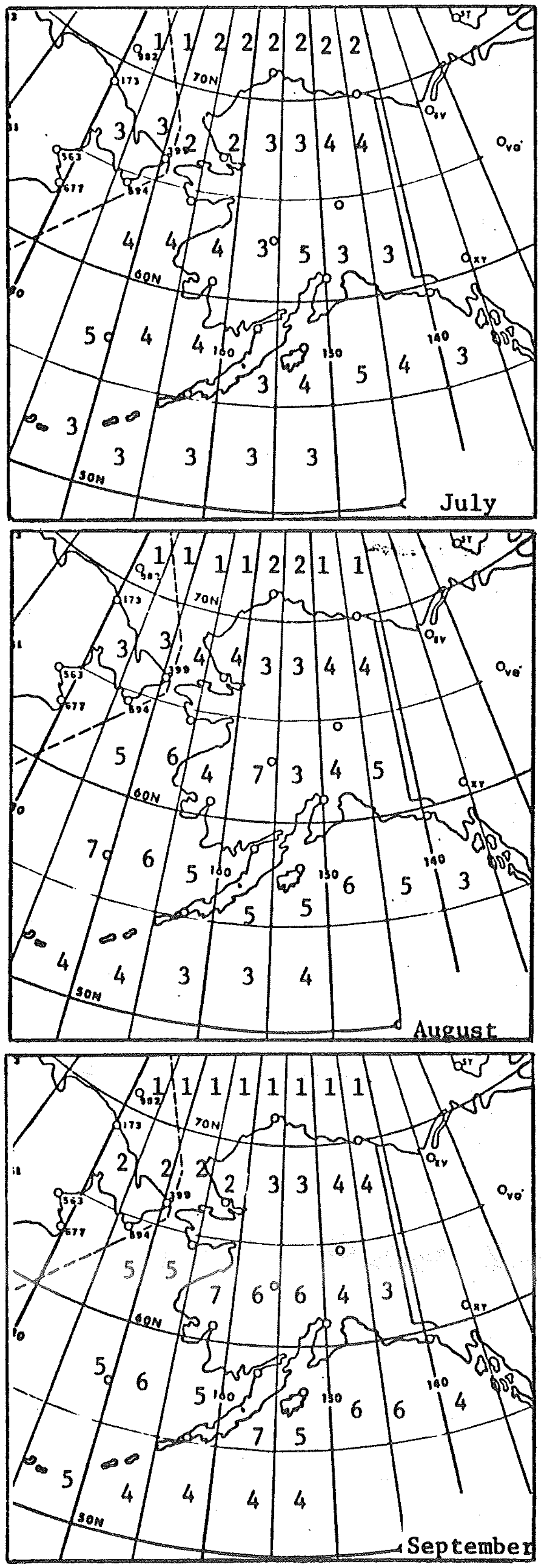


Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific

40 years of record

Figure 18b

PERCENTAGE FREQUENCY OF NUMBER OF DAYS WITH LOWS IN FIVE DEGREE SQUARES

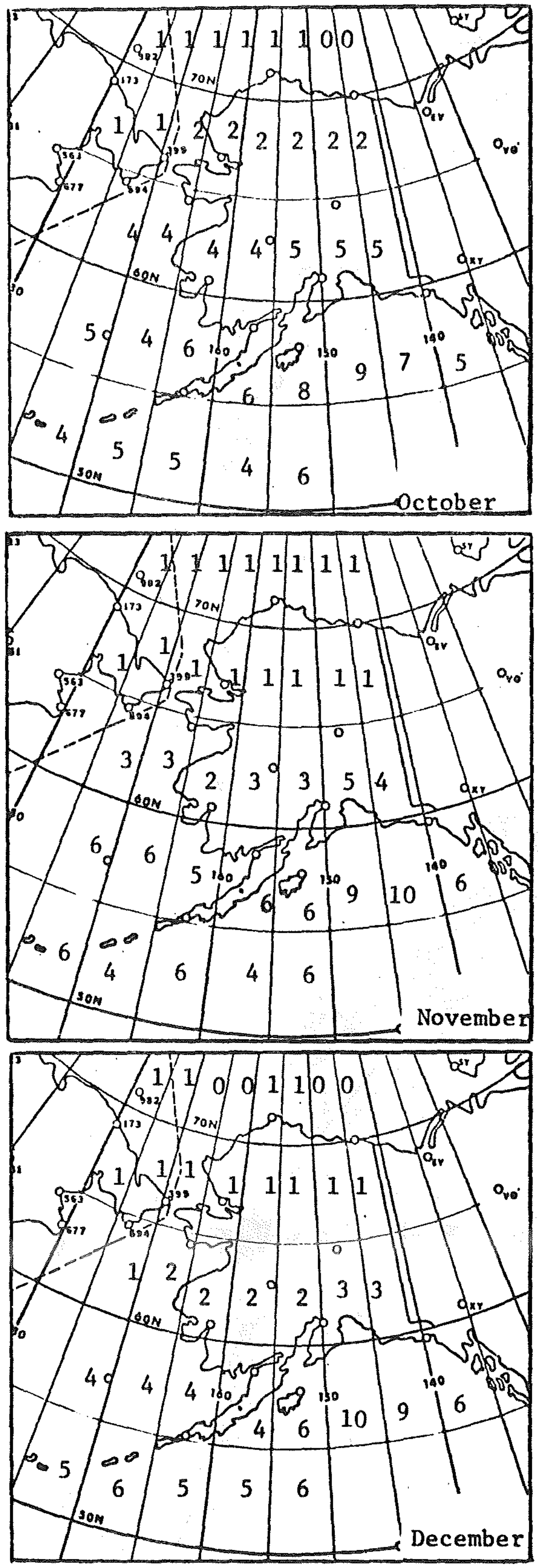


Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific

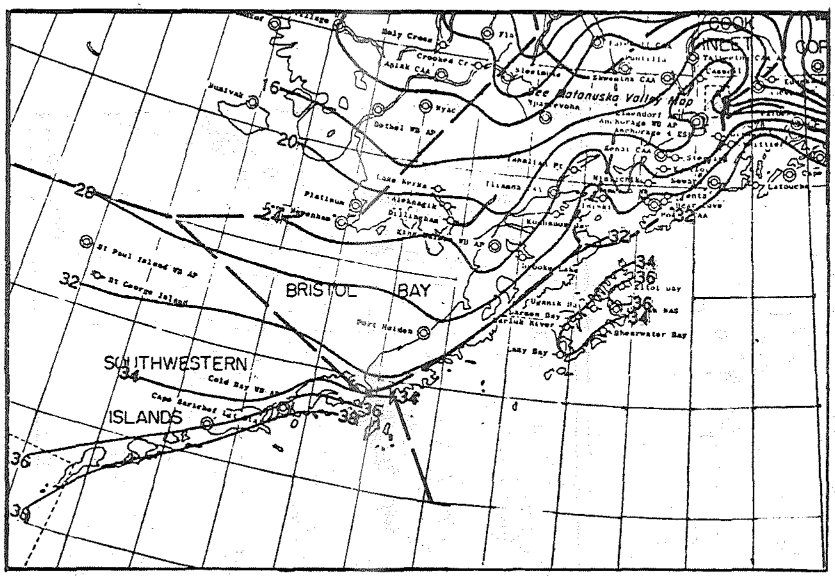
40 years of record

Figure 18c

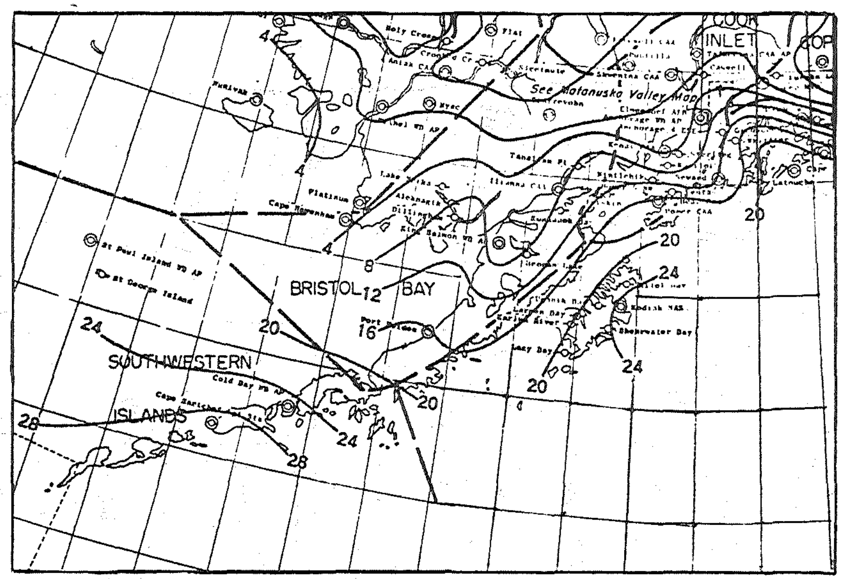
PERCENTAGE FREQUENCY OF NUMBER OF DAYS WITH LOWS IN FIVE DEGREE SQUARES



Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific
40 years of record Figure 18d



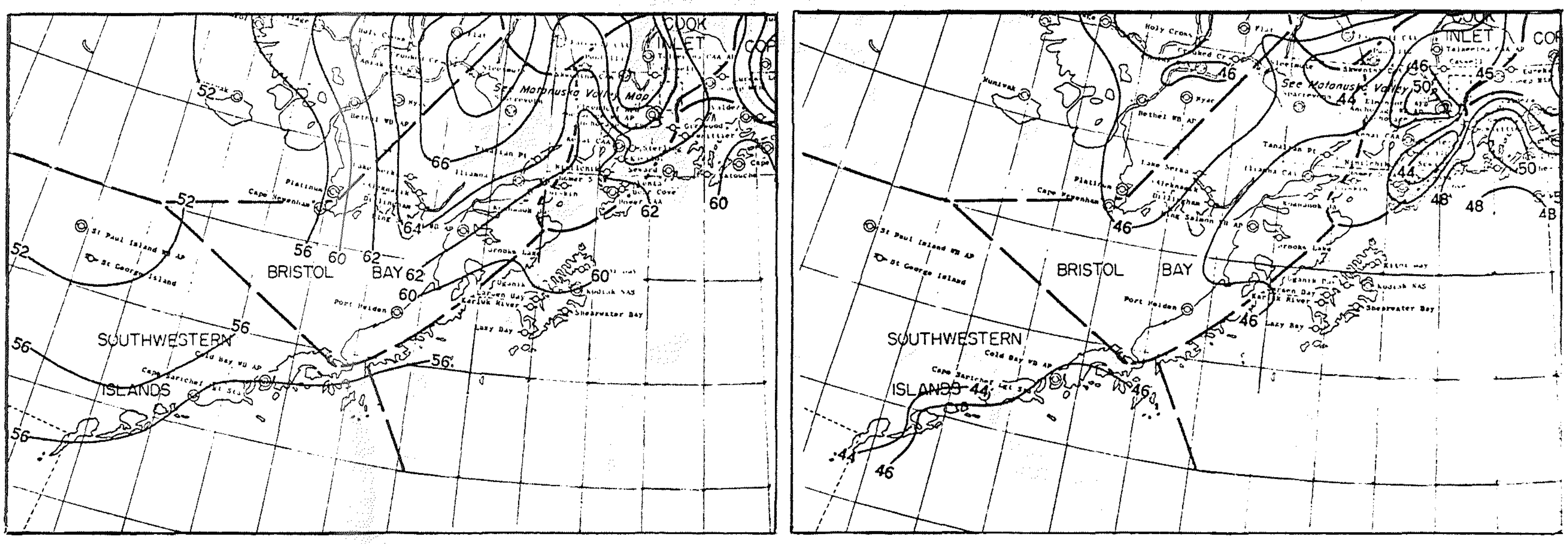
Mean Maximum Temperature (F) January



Mean Minimum Temperature (F) January

Source: Climatography of the United States 60-49, 1968. 30 years of record

Figure 19a



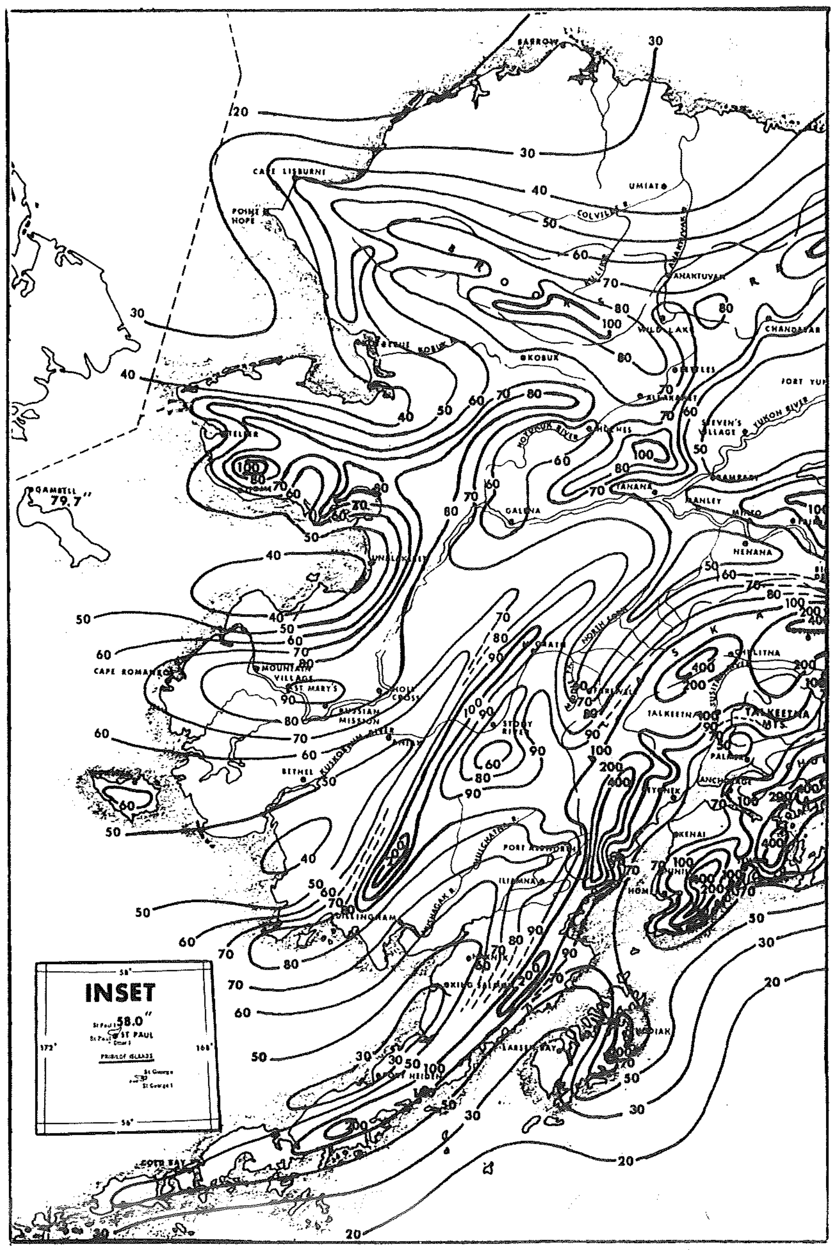
Mean Maximum Temperature (F) July

Mean Minimum Temperature (F) July

Source: Climatography of the United States 60-49, 1968.

30 years of record

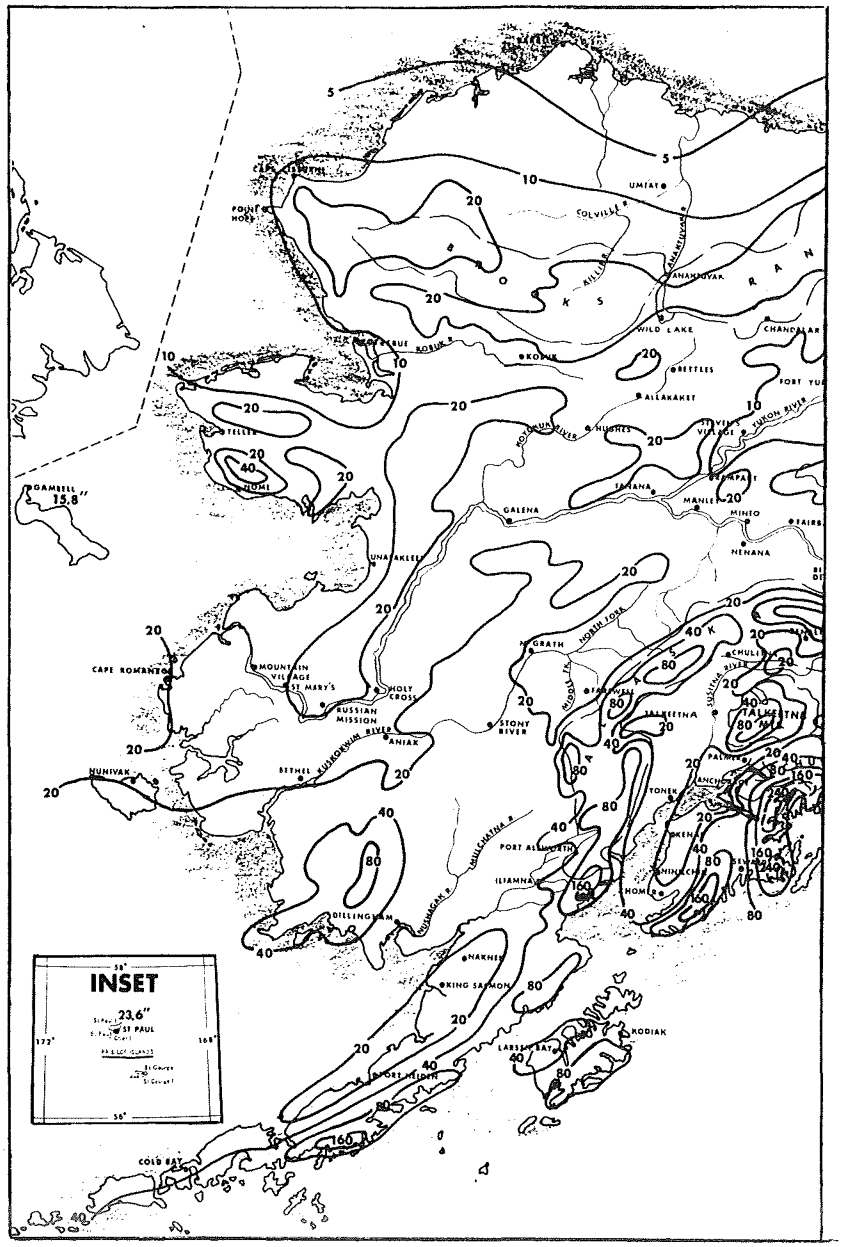
Figure 19b



Mean Annual Snowfall - Inches

Source: Climatography of the United States 60-49, 1968.
30 years of record

Figure 20a



Mean Annual Precipitation - Inches

Source: Climatography of the United States 60-49, 1968.
30 years of record

Figure 20b

-21 to -29 degrees C (-5 to -21 degrees F). The greatest range between extreme temperatures in the state, 92 C degrees (165 F degrees), occurs in Fairbanks. Dillingham approaches this with a range of 74 C degrees (133 F degrees), the highest extreme temperature range in the study area. By comparing Dillingham to Port Heiden, which has a temperature range of 59 C degrees (107 F degrees), and St. Paul with only a 50 C degree (90 F degree) range, it is easy to see the effects of geographical location. Dillingham, located along the north coast, is exposed to both a flow of extremely cold air in winter and the warmer summer extremes of a large land mass. Port Heiden, in the eastern coastal area, is exposed to the temperature extremes of the Interior, but the effects are considerably modified. The temperature extremes of the Interior do not affect St. Paul at all. St. Paul's cold minimum temperatures are due entirely to cold northerly air outbreaks which are only slightly modified by the ice-covered Bering Sea. Significant modification from the water does occur in the summer when St. Paul's highest temperature is 16 C degrees (29 F degrees) lower than Dillingham's. Detailed temperature information is provided in Table 6.

STATION: CAPE SARICHEF, ALASKA LATITUDE: 54° 36'N LONGITUDE: 164° 56'W ELEVATION: 175'

MONTH	TEMPERATURE (°F)						
	Means			Extremes			
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year
(a)	16	16	16	16	-	16	-
J	35.9	27.3	31.6	57	1963	6	1956
F	35.0	25.5	30.3	58	1957	-1	1954
M	36.7	26.5	31.6	58	1967	-5	1956
A	38.8	29.6	34.2	58	1955	13	1956
M	44.1	35.0	39.6	59	1957	14	1953
J	48.3	39.8	44.1	70	1969	23	1960
J	52.4	44.3	48.4	74	1969	34	1954
A	54.1	45.7	49.9	74	1954	28	1956
S	51.0	42.9	47.0	72	1965	25	1956
O	44.2	36.4	40.3	61	1957+	22	1953
N	40.2	32.5	36.4	58	1952	23	1963
D	36.1	27.5	31.8	57	1961	6	1955
YR	43.1	34.4	38.8	74	1969+	-5	1956

MONTH	PRECIPITATION (IN INCHES)														MEAN NUMBER OF DAY				
						Snow, Ice Pellets										Temperature			
																Max		Min	
	Mean	Greatest Daily	Year	Greatest Monthly	Year	Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year		Precipitation .10 Inches or more	70° and Above	32° and Below	32° and Below	0° and Below	
(a)	16	16	-	16	-	13	13	-	13	-	13	-		14	16	16	16	16	
J	1.99	1.50	1964	4.25	1970	5.3	13.7	1960	5.0	1960	10	1961		6	0	8	22	0	
F	1.69	1.50	1966	4.07	1966	9.7	32.2	1961	6.0	1957	7	1965		6	0	9	23	*	
M	1.46	1.73	1963	2.80	1955	6.3	21.1	1961	13	1964	16	1964		4	0	7	24	*	
A	1.16	0.75	1957	2.48	1957	2.6	12.9	1960	2.0	1964+	3	1969+		4	0	4	20	0	
M	1.76	1.20	1957	3.46	1958	0.4	2.0	1960	2.0	1957	1	1965+		5	0	*	8	0	
J	1.49	2.10	1970	6.49	1958	T	T	1962+	T	1962+	0	-		3	*	0	1	0	
J	2.98	1.29	1955	6.99	1955	T	T	1953	T	1953	0	-		8	*	0	0	0	
A	2.89	1.60	1958+	5.93	1956	T	T	1953	T	1953	0	-		8	*	0	*	0	
S	3.64	3.20	1965	16.02	1965	0.0	0.0	-	0.0	-	0	-		7	*	0	*	0	
O	3.25	1.91	1956	5.54	1960	0.5	1.5	1964+	1.5	1963	3	1966		10	0	*	7	0	
N	3.36	1.70	1952	6.62	1960	3.6	9.3	1960	3.0	1965+	6	1968		10	0	1	14	0	
D	1.81	1.43	1970	5.39	1970	8.2	24.6	1960	4.0	1965	9	1958		6	0	6	24	0	
YR	27.48	3.20	1965	16.02	1965	32.2	32.2	1961	13.0	1964	16	1964		77	*	35	143	0	

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6a

STATION: Port Heiden, Alaska LATITUDE: 56° 57' LONGITUDE: 158° 37' ELEVATION: 92'

MONTH	TEMPERATURE (°F) Means: Daily Maximum	Daily Minimum	Monthly	Extremes: Record Highest	Year	Record Lowest	Year	PRECIPITATION (IN INCHES): Mean	Greatest Daily	Year	Greatest Monthly	Year	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	MEAN NUMBER OF DAY: Precipitation .10 Inches or more	Temperature Max: 70° and Above	32° and Below	Min: 32° and Below	0° and Below
(a)	16	16	16	16	-	16	-	16	16	-	20	-	7	7	-	7	-	7	-	8	15	15	15	15
J	26.9	13.8	20.3	53	1963	-25	1965	0.54	0.45	1948	1.74	1945	4.2	11.7	1948	8.2	1948	7	1943	1	0	15	26	7
F	29.2	16.3	22.7	55	1960	-20	1963	0.45	0.49	1943	1.20	1928	5.0	11.5	1945	4.2	1945	14	1943	1	0	15	24	4
M	33.1	18.6	25.9	54	1943	-17	1961	0.56	0.46	1967	4.45	1970	4.3	10.5	1945	3.0	1963	8	1957	1	0	13	28	3
A	39.6	26.5	33.0	62	1965	-5	1943	0.50	1.03	1961	2.42	1970	1.7	4.2	1959	2.0	1943	6	1959	1	0	8	25	*
M	48.2	34.3	41.3	75	1959	14	1951+	0.69	0.44	1962	1.52	1950	0.9	3.3	1954	2.0	1949+	3	1944+	1	*	1	12	0
J	56.6	41.6	49.1	77	1957	29	1950	0.78	0.70	1944	2.00	1943	0.0	0.0	-	0.0	-	0	-	1	*	0	1	0
J	58.6	46.3	52.5	77	1960	32	1948	1.35	0.94	1967	5.01	1970	0.0	0.0	-	0.0	-	0	-	3	1	0	*	0
A	59.0	47.0	53.0	82	1943	30	1962	2.06	2.00	1966	4.75	1966	0.0	0.0	-	0.0	-	0	-	4	1	0	*	0
S	53.2	40.8	47.0	70	1964	25	1965	2.00	1.80	1960	5.55	1962	*	0.3	1957	T	1967+	T	1967+	5	*	0	1	0
O	42.4	30.2	36.3	60	1967	-1	1966	2.13	1.60	1960	5.26	1947	0.9	4.0	1961	4.0	1961	3	1961	5	0	2	16	*
N	34.7	22.7	28.7	55	1959	-8	1963	1.27	0.70	1947	4.77	1958	3.1	6.5	1961	3.0	1949	7	1960	3	0	8	23	2
D	28.4	16.5	22.5	50	1961	-22	1961	0.89	0.52	1961	2.11	1943	8.9	14.7	1951	7.0	1951	13	1959	2	0	16	28	7
YR	42.5	29.5	36.0	82	1943	-25	1965	13.22	2.00	1966	18.15	1948	29.0	14.7	1951	8.0	1948	14	1943	28	2	78	184	23

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service

Table 6b

STATION: Brooks Lake, Alaska LATITUDE: 48° 33' N LONGITUDE: 155° 49' W ELEVATION: 44'

MONTH	TEMPERATURE (°F) Means: Daily Maximum	Daily Minimum	Monthly	Extremes: Record Highest	Year	Record Lowest	Year	PRECIPITATION (IN INCHES): Mean	Greatest Daily	Year	Greatest Monthly	Year	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	MEAN NUMBER OF DAY: Precipitation .10 Inches or more	Temperature Max: 70° and Above	32° and Below	Temperature Min: 32° and Below	0° and Below
(a)	10-24 Years			10-24		10-24		7-25 Years		7-25 Years										3-11	5-24		4-24	
J	29.9	15.2	22.6	46	1960	-26	1959	1.51	0.88	1961	2.25	1960	Data not available							5	0	15	27	6
F	30.8	11.4	21.1	51	1960	-28	1964	0.76	0.30	1959	2.21	1959								1	0	13	27	10
M	28.4	5.2	16.8	53	1963	-26	1961	0.76	0.45	1963	2.06	1963								5	0	17	30	13
A	38.5	21.0	29.8	56	1962	-8	1960	1.41	0.80	1959	2.35	1961								3	0	5	27	1
M	55.6	33.9	44.8	82	1968	20	1962	1.33	0.24	1960	2.96	1959								3	*	0	13	0
J	61.5	39.9	50.7	85	1953	25	1955	1.64	1.55	1948	3.93	1948								5	4	0	3	0
J	64.6	45.4	55.0	90	1942	27	1955	2.50	1.55	1948	4.88	1967								9	8	0	*	0
A	62.9	45.9	54.4	88	1968	28	1969+	4.42	4.55	1948	11.19	1948								11	3	0	*	0
S	57.1	38.5	47.8	72	1962	18	1968+	3.49	1.29	1968	6.63	1961								9	*	0	6	0
O	43.6	27.2	35.4	63	1963	0	1961	1.97	0.79	1960	2.43	1961								7	1	2	17	*
N	32.4	17.9	25.2	53	1962	-20	1964	2.00	0.84	1960	5.15	1959								3	*	12	22	4
D	31.8	16.7	24.3	49	1960	-22	1959	1.56	0.67	1963	2.13	1961								4	0	13	29	6
YR	44.6	26.5	35.6	90	1942	-28	1964	15.47	4.55	1948	30.96	1959								65	16	77	200	40

NOTE: This is a seasonal station with 3-5 years data available for winter months.

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6c

STATION: Port Moller, Alaska LATITUDE: 56° 00' N LONGITUDE: 160° 31' W ELEVATION: 37'

MONTH	TEMPERATURE (°F)							PRECIPITATION (IN INCHES)												MEAN NUMBER OF DAY				
	Means			Extremes									Snow, Ice Pellets								Temperature			
																					Max		Min	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean	Greatest Daily	Year	Greatest Monthly	Year	Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Precipitation .10 Inches or more	70° and Above	32° and Below	32° and Below	0° and Below
(a)			4					5					5											
J			27.7					3.41					21.6											
F			25.4					1.17					9.3											
M			23.2					1.64					13.7											
A			25.7					2.60					12.8											
M			41.1					2.47					7.1											
J	Data not available		36.9	Data not available				3.86	Data not available				0.8	Data not available						Data not available				
J			47.3					6.67					0.0											
A			48.4					7.76					0.0											
S			44.0					5.14					0.1											
O			36.0					3.87					1.4											
N			31.3					2.67					12.7											
D			24.2					2.15					17.2											
YR			34.3					43.41					96.7											

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6d

STATION: Dillingham, Alaska LATITUDE: 59° 03' LONGITUDE: 158° 27' ELEVATION: 50'

MONTH	TEMPERATURE (°F)							PRECIPITATION (IN INCHES)												MEAN NUMBER OF DAY				
	Means			Extremes									Snow, Ice Pellets								Temperature			
																					Max		Min	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean	Greatest Daily	Year	Greatest Monthly	Year	Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Precipitation .10 Inches or more	70° and Above	32° and Below	32° and Below	0° and Below
(a)	35	35	35	35	-	35	-	32	32	-	30	-	20	20	-	20	-	20	-	12	35	35	35	35
J	22.9	8.5	15.7	53	1937	-41	1902	1.87	1.30	1923	4.21	1937	12.0	29.5	1928	14.0	1924	60	1931	7	0	22	30	10
F	26.1	11.0	18.6	54	1936	-30	1921+	1.52	0.96	1965	4.41	1964	10.4	23.6	1944	12.0	1925	56	1931	6	0	16	27	8
M	29.5	11.1	20.3	60	1931	-27	1966	1.62	1.50	1926	4.35	1930	13.2	41.8	1930	10.0	1929	60	1931	7	0	16	31	7
A	38.9	22.8	30.9	63	1938	-15	1902	1.16	.87	1960	3.33	1938	3.1	15.0	1924	6.0	1924	52	1931+	5	0	4	27	4
M	51.3	32.5	41.9	76	1959	0	1905	1.78	1.11	1968	3.85	1966	00.5	4.0	1933+	4.0	1933	19	1931	8	*	*	14	0
J	62.0	41.6	51.8	92	1953	18	1905	1.69	1.11	1933	4.96	1958	T	T	1954	T	1954	T	1954	8	4	0	1	0
J	64.7	45.6	55.1	87	1960+	31	1966	2.57	1.35	1954	5.90	1928	0.0	0.0	-	0.0	-	0	-	10	7	0	*	0
A	62.8	45.2	54.0	81	1923	26	1956	3.99	1.50	1942	5.95	1940	0.0	0.0	-	0.0	-	0	-	14	3	0	1	0
S	56.2	38.8	47.5	73	1936+	11	1931	3.46	1.36	1932	5.61	1961	0.1	2.4	1930	2.0	1930	2	1930	10	*	0	6	0
O	42.5	26.9	34.7	70	1936	1	1961+	2.54	1.45	1952	4.85	1930	2.0	20.0	1931	6.0	1920	6	1920	7	*	3	21	0
N	31.1	17.0	24.0	52	1928	-26	1963	1.78	1.20	1926	3.95	1929	9.5	32.0	1930	8.0	1929	27	1930	7	0	14	28	3
D	21.8	7.3	14.6	50	1936	-30	1957	1.78	1.27	1965	3.83	1927	14.6	37.0	1930	12.0	1938	64	1930	7	0	23	30	10
YR	42.5	25.7	34.1	92	1953	-41	1902	25.76	1.50	1942	35.45	1960	65.4	41.8	1930	12.0	1938+	64	1930	96	14	98	216	39

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6e

STATION: Cape Newenham, Alaska LATITUDE: 58° 38' N LONGITUDE: 162° 04' W ELEVATION: 475'

MONTH	TEMPERATURE (°F) Means: Daily Maximum	Daily Minimum	Monthly	Extremes: Record Highest	Year	Record Lowest	Year	PRECIPITATION (IN INCHES): Mean	Greatest Daily	Year	Greatest Monthly	Year	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	MEAN NUMBER OF DAYS: Precipitation .10 Inches or more	Temperature Max: 70° and Above	32° and Below	Min: 32° and Below	0° and Below
(a)	16	16	16	16	-	16	-	16	16	-	16	-	15	15	-	15	-	15	-	15	16	16	16	16
J	24.2	14.8	19.5	50	1963	22	1962+	1.73	1.13	1963	5.68	1963	10.1	25.7	1955	11.0	1962	46	1954	5	0	20	28	8
F	22.7	12.4	17.6	50	1957	-28	1954	1.17	0.66	1957	3.22	1955	9.7	23.1	1955	6.5	1965+	49	1954	4	0	19	26	8
M	27.1	17.2	22.2	46	1965	-21	1966	1.78	1.38	1967	5.18	1963	12.4	38.7	1963	10.5	1963	45	1954	4	0	19	30	4
A	31.5	22.7	27.1	46	1956	-6	1956	1.64	1.73	1967	4.09	1967	10.1	27.9	1955	7.0	1964	51	1955	5	0	13	26	*
M	40.9	33.1	37.0	62	1969	15	1964	2.41	1.88	1955	6.30	1955	5.2	19.0	1955	5.4	1966	46	1955	5	0	3	12	0
J	49.0	40.8	44.9	66	1962	29	1956	2.62	1.67	1960	6.49	1958	T	0.1	1969+	0.1	1969+	12	1955	6	0	0	1	0
J	53.5	46.0	49.7	75	1960	37	1955	3.63	2.55	1966	6.89	1966	T	T	1955	T	1955	0	-	9	*	*	0	0
A	52.9	46.9	49.9	67	1968	39	1955	5.93	3.13	1959	10.27	1954	T	T	1955	T	1955	0	-	12	0	0	0	0
S	49.3	43.3	46.3	66	1963	28	1970+	5.52	2.02	1957	9.00	1956	0.1	1.4	1956	1.4	1956	1	1957+	11	0	0	1	0
O	38.1	31.8	35.0	55	1967	9	1966	4.96	2.67	1960	7.91	1954	7.4	21.7	1955	4.6	1966	16	1955	10	*	6	16	0
N	31.9	24.2	28.1	50	1970	-9	1963+	3.81	1.43	1966	7.07	1957	12.9	36.7	1961	13.1	1961	17	1961	9	0	13	23	1
D	23.3	13.6	18.5	45	1970+	-19	1957+	2.04	1.40	1970	5.18	1960	13.3	28.1	1957	5.6	1960	20	1956	6	0	22	29	8
YR	37.0	28.9	33.0	75	1960	-28	1954	37.24	3.13	1959	50.96	1960	81.2	38.7	1963	13.1	1961	51	1955	86	*	115	192	29

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6f

STATION: Platinum, Alaska LATITUDE: 59° 01N LONGITUDE: 161° 47' W ELEVATION: 20'

MONTH	TEMPERATURE (°F) Means: Daily Maximum	Daily Minimum	Monthly	Extremes: Record Highest	Year	Record Lowest	Year	PRECIPITATION (IN INCHES): Mean	Greatest Daily	Year	Greatest Monthly	Year	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	MEAN NUMBER OF DAYS: Precipitation .10 Inches or more	Temperature Max: 70° and Above	32° and Below	Min: 32° and Below	0° and Below
(a)	23	23	23	23	–	23	–	23	23	–	23	–	18	18	–	18	–	18	–	10	23	23	23	23
J	20.6	8.2	14.4	52	1963	-34	1947	1.07	1.05	1962	3.20	1955	8.5	34.8	1949	10.0	1949	21	1949	4	0	21	29	11
F	22.0	9.0	15.5	47	1957	-32	1947	1.24	1.80	1947	3.41	1947	8.9	29.5	1951	18.0	1947	36	1946	3	0	19	27	10
M	24.1	10.8	17.5	44	1962	-26	1956	1.30	1.35	1954	4.06	1954	10.3	30.2	1946	6.0	1947	37	1946	5	0	20	30	9
A	33.8	22.1	27.9	53	1958	-11	1956	0.91	0.65	1956	3.27	1964	2.5	7.5	1944	2.6	1950	43	1946	4	0	10	25	1
M	45.0	33.6	39.3	65	1943	2	1949	1.19	0.79	1955	3.25	1947	0.3	2.2	1949	1.7	1949	29	1946	5	0	1	11	0
J	53,7	41.7	47.7	79	1953	32	1963+	1.20	1.04	1958	3.19	1958	T	T	1963+	T	1963+	T	1964+	5	*	0	*	0
J	57.0	46.2	51.6	82	1960	32	1960	2.02	1.24	1961	4.96	1961	0.0	0.0	–	0.0	–	0	–	8	1	0	*	0
A	56.3	46.9	51.6	73	1950	32	1959	4.18	2.57	1959	10.39	1959	0.0	0.0	–	0.0	–	0	–	11	*		*	0
S	51.5	40.4	46.0	68	1963+	22	1956	3.53	1.73	1962	5.84	1948	T	T	1958+	T	1958	T	1956+	11	0	0	4	0
O	39.6	29.2	34.4	63	1954	6	1956	2,43	1.60	1960	5.82	1960	1.1	4.6	1948	2.5	1948	6	1945	7	0	5	19	0
N	28.7	17.9	23.3	48	1957	-21	1945	1.54	1.20	1960	3.62	1960	4.0	10.9	1946	3.0	1953+	5	1946	6	0	16	26	4
D	18.8	6.8	12.8	44	1963+	-29	1961	1.25	1.90	1961	4.75	1961	7.2	20.5	1948	6.2	1948	14	1948	4	0	23	30	12
YR	37.6	26.1	31.8	82	1960	-34	1947	21.86	2.57	1959	31,30	1955	42.8	34.8	1949	18.0	1947	43	1946	73	1	115	201	47

(a) Period of Record
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6g

STATION: St. Paul Island, Alaska LATITUDE: 57° 09' N. LONGITUDE: 170° 13' W. ELEVATION: 22'

MONTH	Temperature (°F) Means: Daily Maximum	Means: Daily Minimum	Means: Monthly	Extremes: Record Highest	Year	Record Lowest	Year	Precipitation (in inches): Mean	Greatest Daily	Year	Greatest Monthly	Year
(a)	(b)	(b)	(b)	55	-	55	-	(b)	50	-	50	-
J	29.7	21.1	25.4	48	1916	-26	1919	1.81	1.38	1964	4.99	1964
F	27.8	18.7	23.3	44	1917	-15	1971	1.23	1.51	1932	5.69	1964
M	29.0	19.3	24.2	44	1937	-19	1971	1.06	1.04	1929	2.97	1918
A	32.7	24.0	28.4	44	1937+	-2	1960	0.96	1.00	1966	3.10	1967
M	39.2	30.3	34.8	56	1918	8	1971	1.30	1.27	1931	3.11	1931
J	45.3	36.3	40.8	62	1926	24	1968	1.15	1.48	1949	3.59	1958
J	49.4	41.6	45.5	63	1969	28	1961	2.25	1.92	1950	5.85	1950
A	51.0	44.1	47.6	64	1941+	30	1963	3.29	1.91	1953	9.32	1953
S	49.1	40.1	44.6	59	1915	25	1968+	3.07	1.58	1947	6.02	1924
O	41.2	33.1	37.2	54	1916	13	1960	3.15	1.93	1949	5.18	1946
N	36.5	29.2	32.9	50	1915	9	1918	2.50	1.76	1925	5.31	1925
D	30.5	22.3	26.4	52	1936	-5	1916	1.83	1.15	1930	4.18	1949
YR	38.5	30.0	34.3	64	1941+	-26	1919	23.60	1.93	1949	9.32	1953

MONTH	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Mean Number of Day: Precipitation .01 Inches or more	Temperature Max: 70° and Above	Max: 32° and Below	Min: 32° and Below	Min: 0° and Below
(a)	49	49	-	49	-	9	-	54	55	53	55	55
J	12.8	40.6	1931	13.8	1964	20.0	1933	18	0	15	27	1
F	9.9	55.8	1964	13.6	1964	25.5	1933	15	0	17	27	3
M	9.0	28.0	1936	10.5	1929	23.5	1933	15	0	17	30	1
A	5.8	19.1	1928	10.0	1966	20.5	1933	14	0	10	28	*
M	2.2	12.7	1971	4.0	1935	15.0	1928	14	0	2	20	0
J	0.1	2.0	1927	2.0	1927	0.5	1928	12	0	0	3	0
J	0.0	0.0	-	0.0	-	0.0	-	15	0	0	*	0
A	0.0	0.0	-	0.0	-	0.0	-	19	0	0	*	0
S	0.1	1.0	1965+	1.0	1965	T	1927	20	0	0	1	0
O	2.7	12.0	1948	5.3	1968	2.0	1927	22	0	*	10	1
N	6.0	27.3	1964	13.4	1964	3.0	1928	21	0	6	19	0
D	9.7	22.7	1930	8.0	1930	8.0	1935	19	0	13	26	*
YR	58.3	55.8	1964	13.8	1964	25.5	1933	204	0	80	191	5

(a) Period of Record (b) Climatological standard normals (1931-1960)
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6h

STATION: King Salmon, Alaska LATITUDE: 58° 41' N. LONGITUDE: 156° 39' W. ELEVATION: 49'

MONTH	TEMPERATURE (°F)							PRECIPITATION (IN INCHES)												MEAN NUMBER OF DAY				
	Means			Extremes									Snow, Ice Pellets								Temperature			
																					Max		Min	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean	Greatest Daily	Year	Greatest Monthly	Year	Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Precipitation .01 Inches or more	70° and Above	32° and Below	32° and Below	0° and Below
(a)	(b)	(b)	(b)	9	-	9	-	(b)	30	-	30	-	23	23	-	23	-	17	-	27	9	9	9	9
J	20.8	5.9	13.4	47	1968	-34	1972+	1.07	0.87	1953	3.02	1957	6.6	12.6	1955	8.5	1968	12	1944	10	0	25	30	15
F	25.2	9.5	17.4	46	1970+	-35	1969	0.95	1.29	1969	3.00	1943	7.6	15.2	1971	9.3	1962	8	1942	10	0	17	26	12
M	27.8	11.1	19.5	54	1965	-42	1971	0.96	1.03	1953	2.41	1967	7.4	16.2	1962	9.5	1956	12	1951	11	0	15	28	8
A	40.8	24.8	32.8	59	1965	-4	1972	0.64	1.41	1963	2.99	1963	4.8	16.0	1968	4.5	1971	7	1947	10	0	7	25	1
M	51.9	34.7	43.3	75	1964	13	1965	0.96	0.80	1950	2.40	1966	0.9	5.6	1965	1.6	1968+	T	1952	12	1	1	14	00
J	60.9	41.9	51.4	80	1969	29	1965	1.40	0.87	1951+	3.78	1950	0.1	1.3	1972	1.2	1972	0	-	13	2	0	1	0
J	63.0	46.8	54.9	85	1971	33	1966	2.06	1.06	1950	4.32	1947	0.0	0.0	-	0.0	-	0	-	15	5	0	0	0
A	61.4	47.8	54.6	85	1968	32	1971+	3.43	2.00	1963+	6.44	1953	0.0	0.0	-	0.0	-	0	-	18	2	0	*	0
S	55.3	40.5	47.9	71	1964	18	1968	3.08	1.69	1960	7.30	1961	0.1	0.6	1956	0.6	1956	0	-	16	*	0	5	0
O	42.7	28.6	35.7	62	1967	-1	1970+	2.15	1.52	1958	6.35	1946	3.3	14.6	1948	7.3	1944	8	1944	13	0	7	23	1
N	29.4	14.6	22.0	48	1970	-14	1971+	1.46	0.91	1972	2.96	1957	5.9	16.1	1969	8.6	1948	7	1944	11	0	15	26	3
D	20.7	5.6	13.2	48	1970	-30	1965	1.02	0.82	1949	3.42	1971	8.5	16.0	1965	6.4	1960	13	1952	11	0	21	29	15
YR	41.7	26.0	33.8	85	1971	-42	1971	19.18	2.00	1963+	7.30	1961	45.2	16.2	1962	9.5	1956	13	1952	150	10	108	208	55

(a) Period of Record (b) Climatological standard normals (1931-1960)
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

Table 6i

STATION: COLD BAY, ALASKA LATITUDE: 55°12'N LONGITUDE: 162°43'W ELEVATION: 96 feet

MONTH	TEMPERATURE (°F) Means: Daily Maximum	Means: Daily Minimum	Means: Monthly	Extremes: Record Highest	Year	Record Lowest	Year	PRECIPITATION (IN INCHES) Mean	Greatest Daily	Year	Greatest Monthly	Year	Snow, Ice Pellets: Mean	Greatest Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	MEAN NUMBER OF DAYS: Precipitation .01 Inches or more	Temperature Max: 70° and Above	Max: 32° and Below	Min: 32° and Below	Min: 0° and Below
(a)	(b)	(b)	(b)	28	-	29	-	(b)	27	-	27	-	22	22	-	22	-			27	28	28	29	29
J	32.6	22.9	27.8	49	1969+	-5	1962+	2.32	2.49	1948	8.46	1948	8.8	19.9	1971	9.2	1971	24	1948	17	0	12	25	*
F	32.7	23.3	28.0	50	1957	-9	1947	3.17	2.49	1956	7.87	1944	9.9	23.4	1965	9.7	1945	16	1949	16	0	11	24	*
M	33.5	24.0	28.8	54	1948	-13	1971	1.75	1.34	1956	3.89	1948	8.2	17.6	1949	7.1	1949	9	1969+	16	0	12	27	1
A	38.3	28.3	33.3	60	1948	4	1943	1.46	1.76	1951	3.83	1970	5.0	14.7	1959	6.0	1956	9	1966	14	0	6	23	0
M	44.6	34.3	39.5	65	1964	21	1945	2.29	2.22	1958	6.37	1958	2.1	9.3	1971	3.8	1971	2	1970	16	0	1	9	0
J	50.3	40.3	45.3	69	1953	29	1952	1.95	2.10	1971	6.98	1952	T	0.5	1971	2.6	1971	0		15	0	0	*	0
J	54.3	45.0	49.7	77	1960	36	1971+	1.82	1.74	1963	4.63	1966	0.0	0.0		0.0		0		16	*	0	0	0
A	55.7	46.9	51.3	78	1948	33	1946	4.25	2.17	1951	9.97	1951	0.0	0.0		0.0		0		19	*	0	0	0
S	52.5	42.5	47.5	70	1960	27	1970	4.32	3.43	1965	9.79	1965	T	0.2	1972	0.2	1972	T	1965+	20	*	0	1	0
O	44.7	35.5	40.1	69	1964+	12	1966	4.59	4.90	1968	8.02	1968	2.9	15.6	1968	11.4	1968	13	1968	22	0	*	9	0
N	38.6	30.1	34.4	54	1970+	1	1963	3.79	3.43	1972	8.94	1960	5.7	21.6	1948	8.6	1964	11	1948	21	0	3	19	0
D	33.4	24.1	28.8	51	1970	-9	1950	2.59	1.94	1972	6.49	1972	8.4	20.3	1948	8.4	1960	14	1949	18	0	11	26	*
YR	42.6	33.1	37.9	78	1948	-13	1971	34.30	4.90	1968	9.97	1951	51.0	23.4	1965	11.4	1968			210	1	57	162	2

(a) Period of Record (b) Climatological standard normals (1931-1960)
* Less than one half
\+ Also on earlier dates, months, or years
T Trace, an amount too small to measure

Source: Environmental Data Service (NOAA)

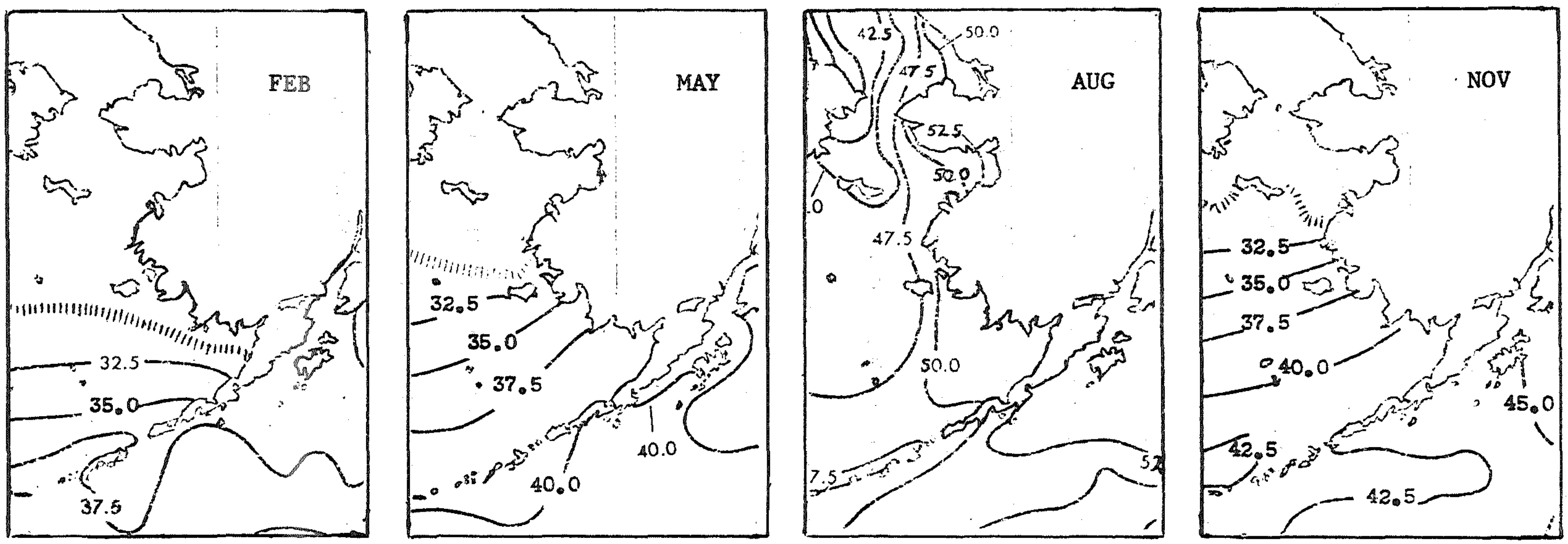
Table 6j

Generally, air temperatures are colder than the water about 9 months of the year. During winter months, the difference is about 4 to 5 C degrees (7 to 9 F degrees). In summer, the air is 0.6 to 1.1 C degrees (1 to 2 F degrees) warmer than the water. Sea temperatures and sea-air temperature differences are presented in Figure 21.

The data represented in Figure 22 show the frequency of occurrence of a selected temperature for the five locations summarized by the Air Weather Service. For three of the locations, Cold Bay, Cape Newenham, and King Salmon, temperature and wind speed have been correlated to give chill temperature, a parameter useful in providing information for planning outdoor operations.

PRECIPITATION

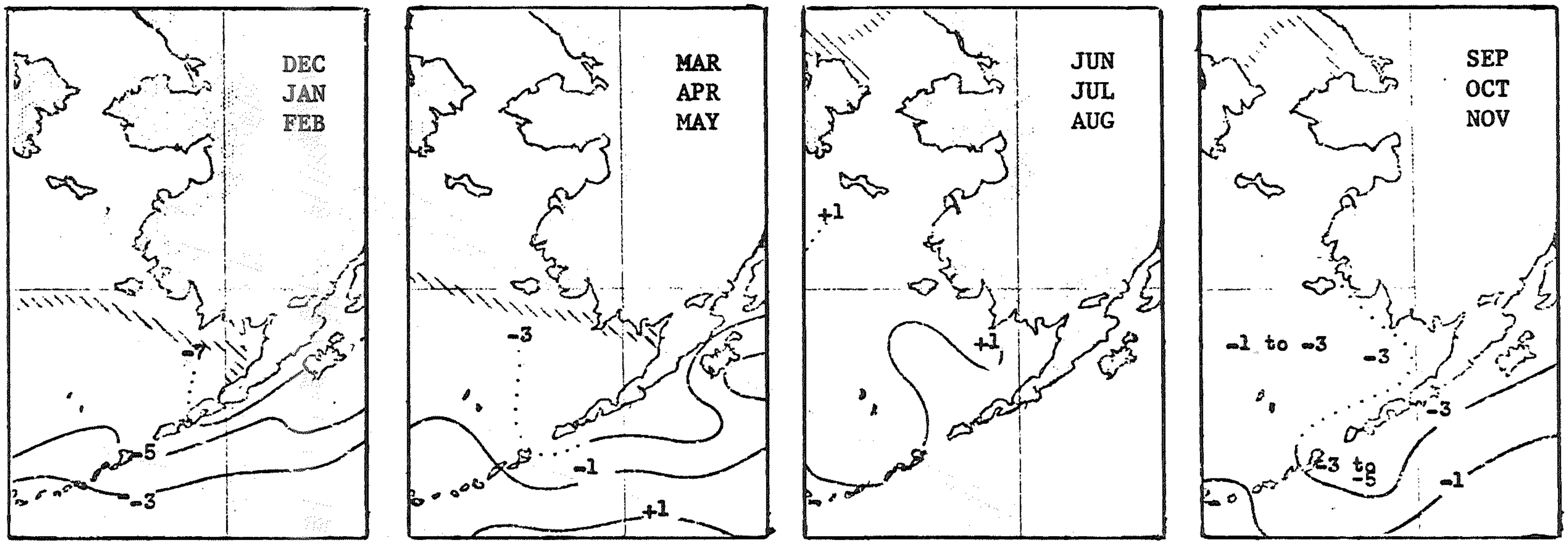
Available data shows that annual amounts of precipitation in the study area range from 33 cm. (13 in.) at Port Heiden to 86 cm. (34 in.) at Cape Newenham. Differences are due to geographical location. Stations along the north



SEA TEMPERATURE (° F) AND AIR-SEA TEMPERATURE DIFFERENCE

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 20 years of record

Figure 21a



SEA TEMPERATURE ($^{\circ}$ F) AND AIR-SEA TEMPERATURE DIFFERENCE

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific   20 years of record

Figure 21b

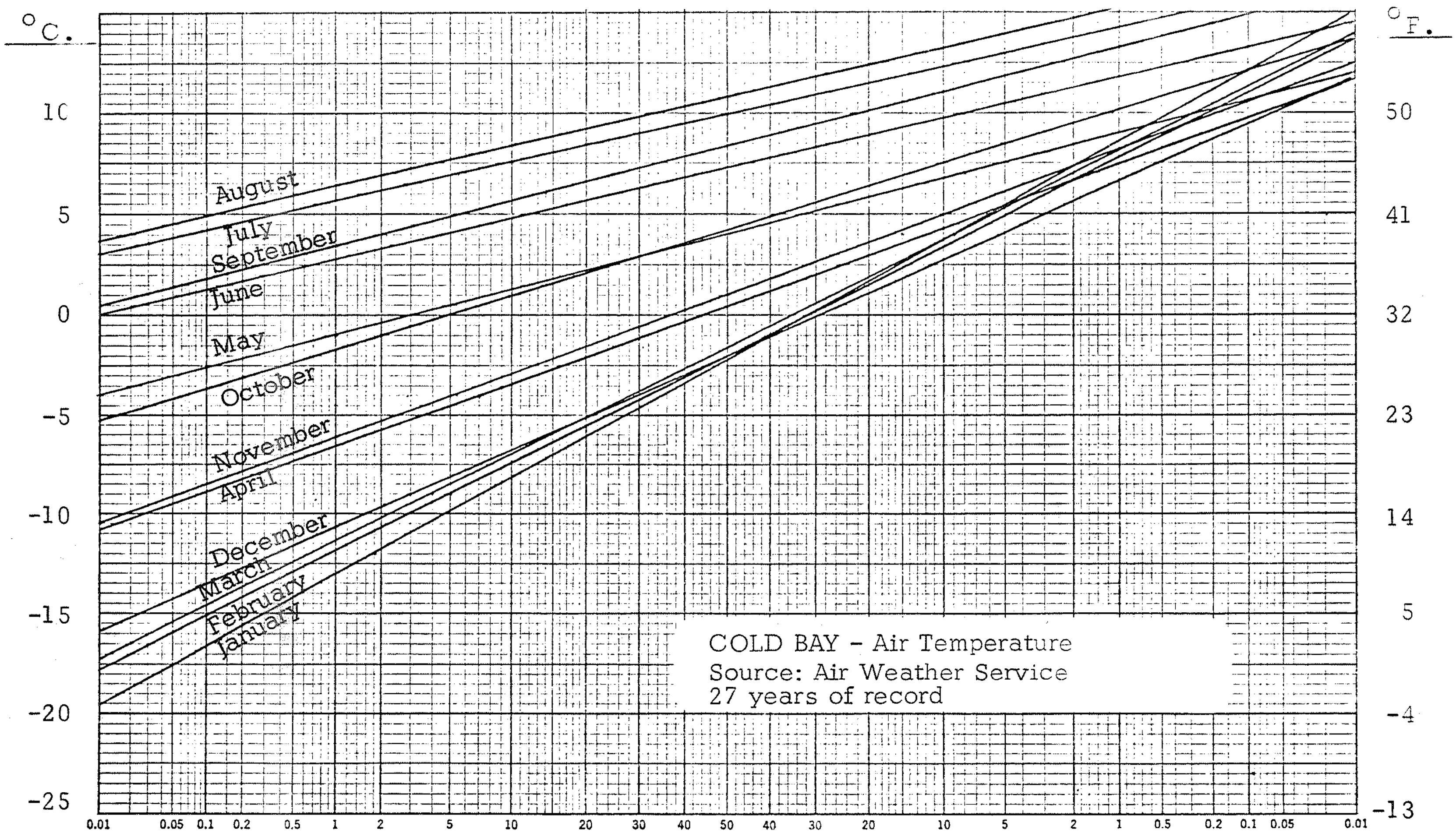

°C.
°F.
10
5
0
-5
-10
-15
-20
-25
50
41
32
23
14
5
-4
-13
August
July
September
June
May
October
November
April
December
March
February
January
COLD BAY - Air Temperature
Source: Air Weather Service
27 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22a

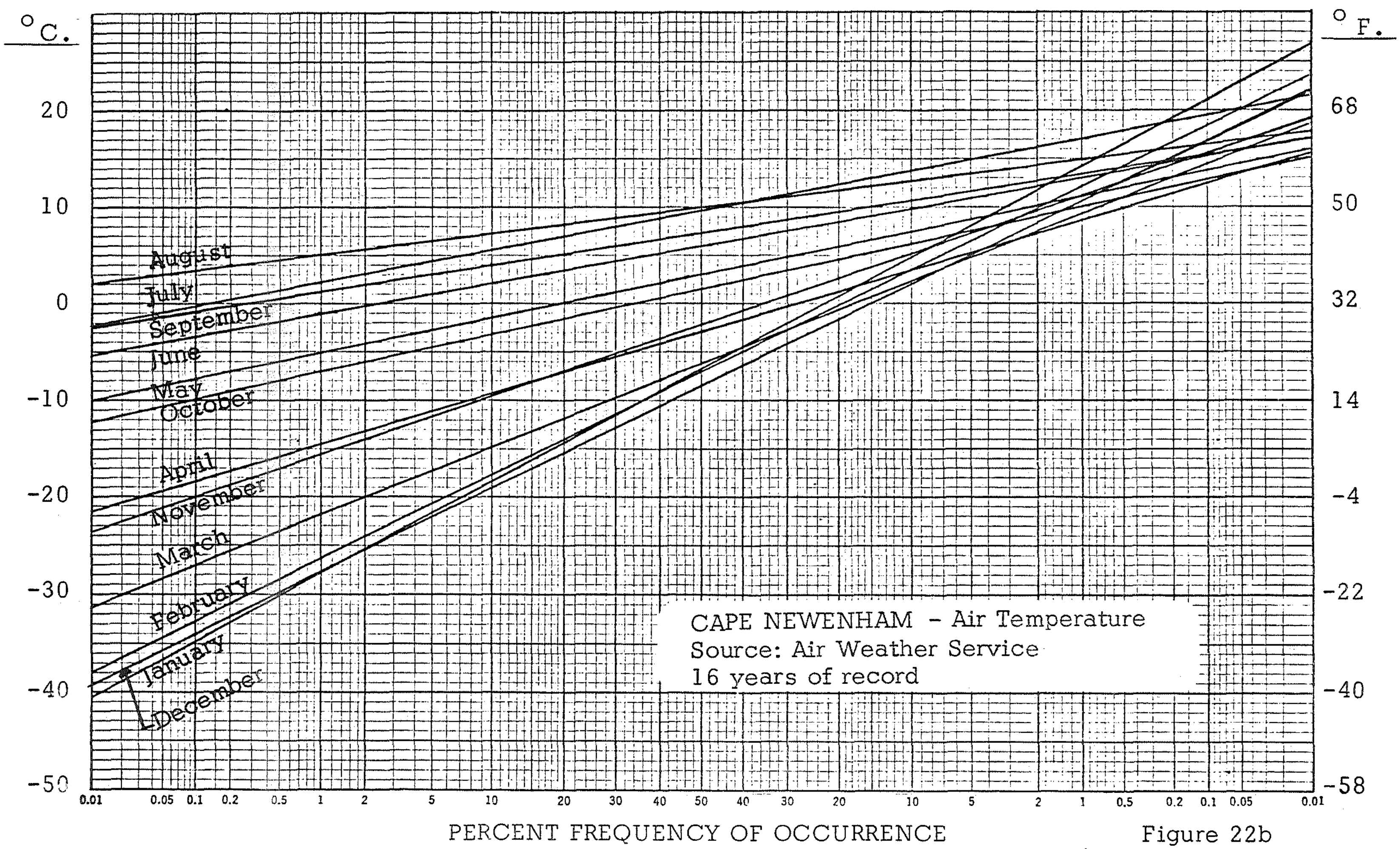

°C.
°F.
20
10
0
-10
-20
-30
-40
-50
68
50
32
14
-4
-22
-40
-58
August
July
September
June
May
October
April
November
March
February
January
December
CAPE NEWENHAM - Air Temperature
Source: Air Weather Service
16 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22b

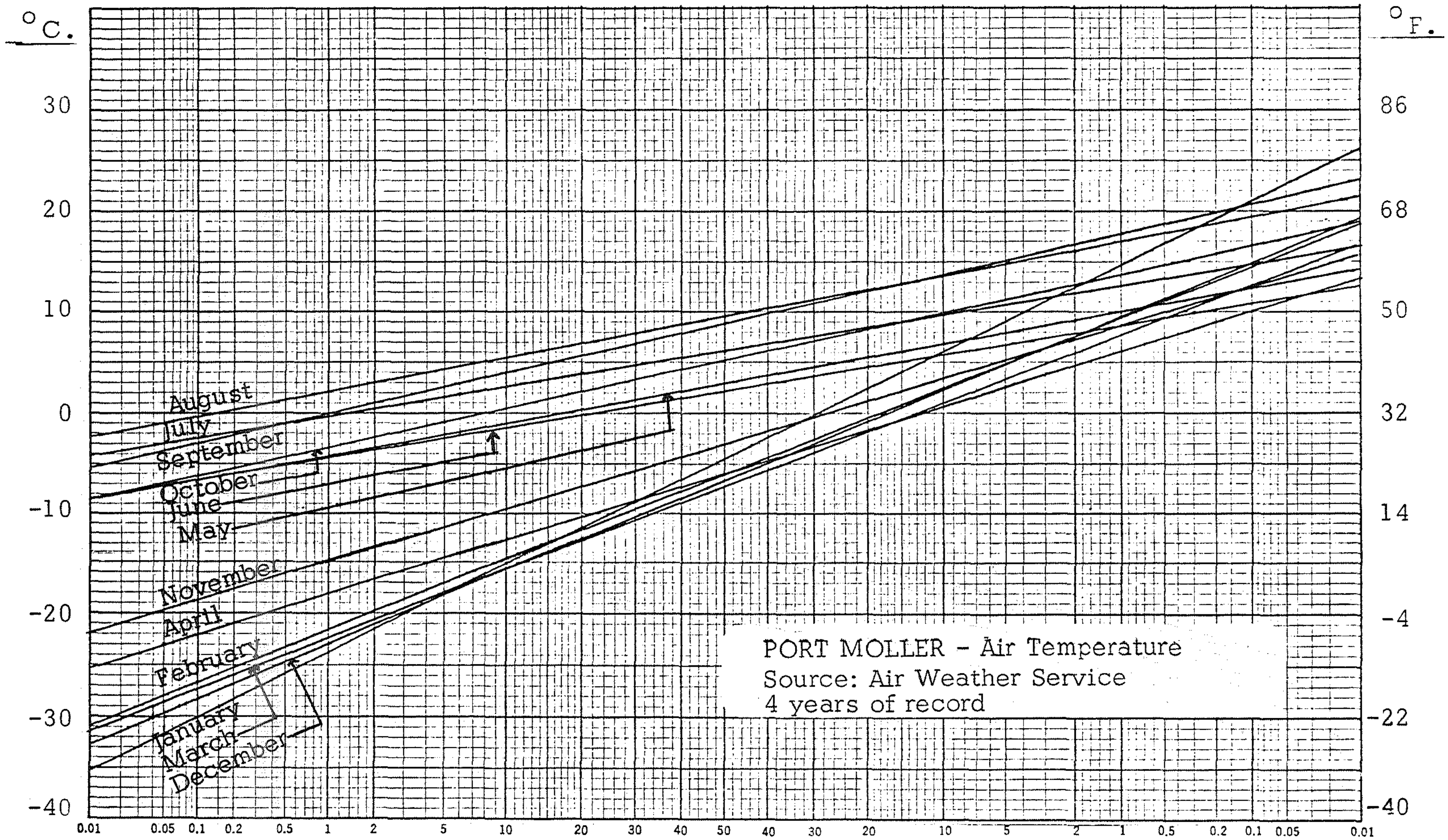
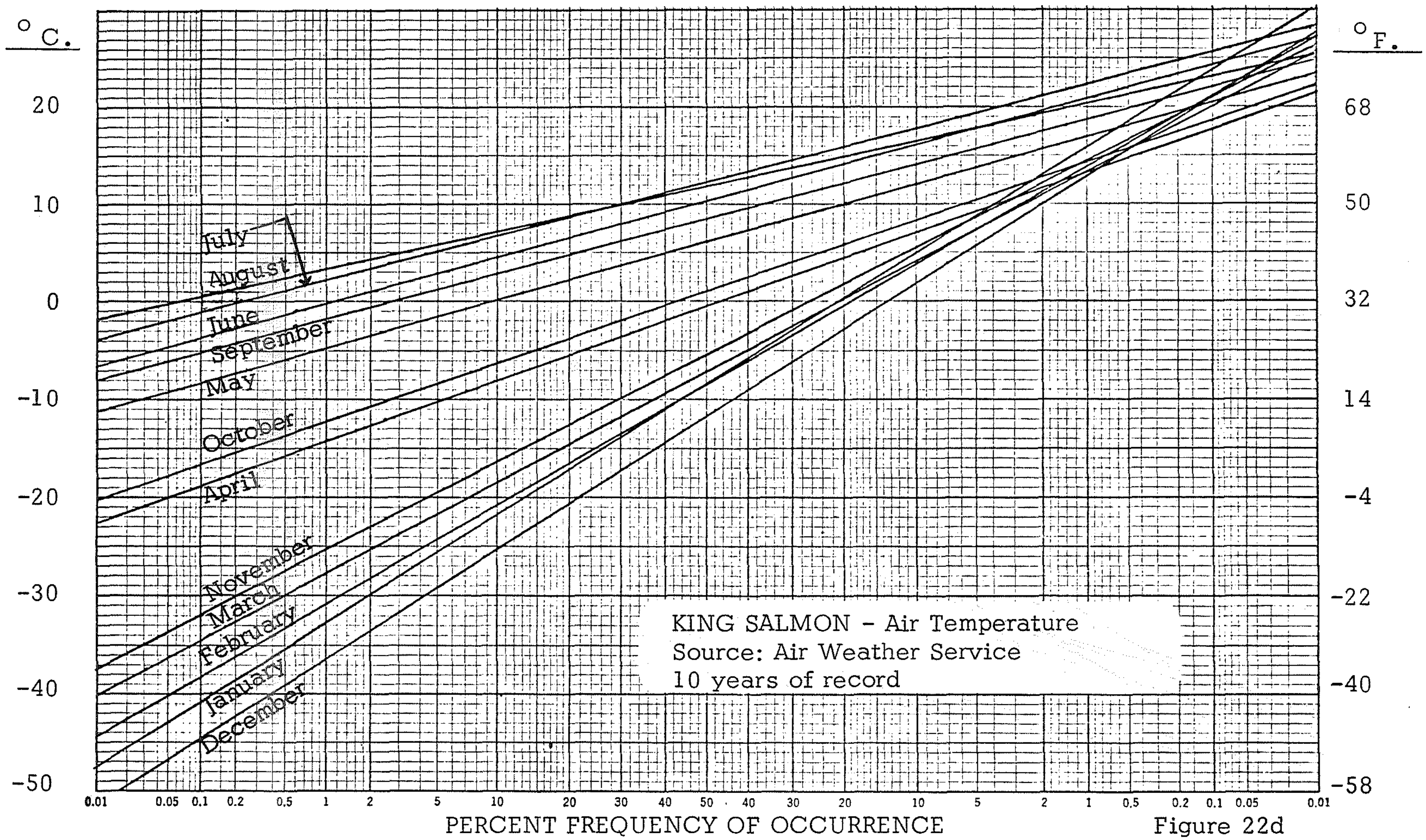
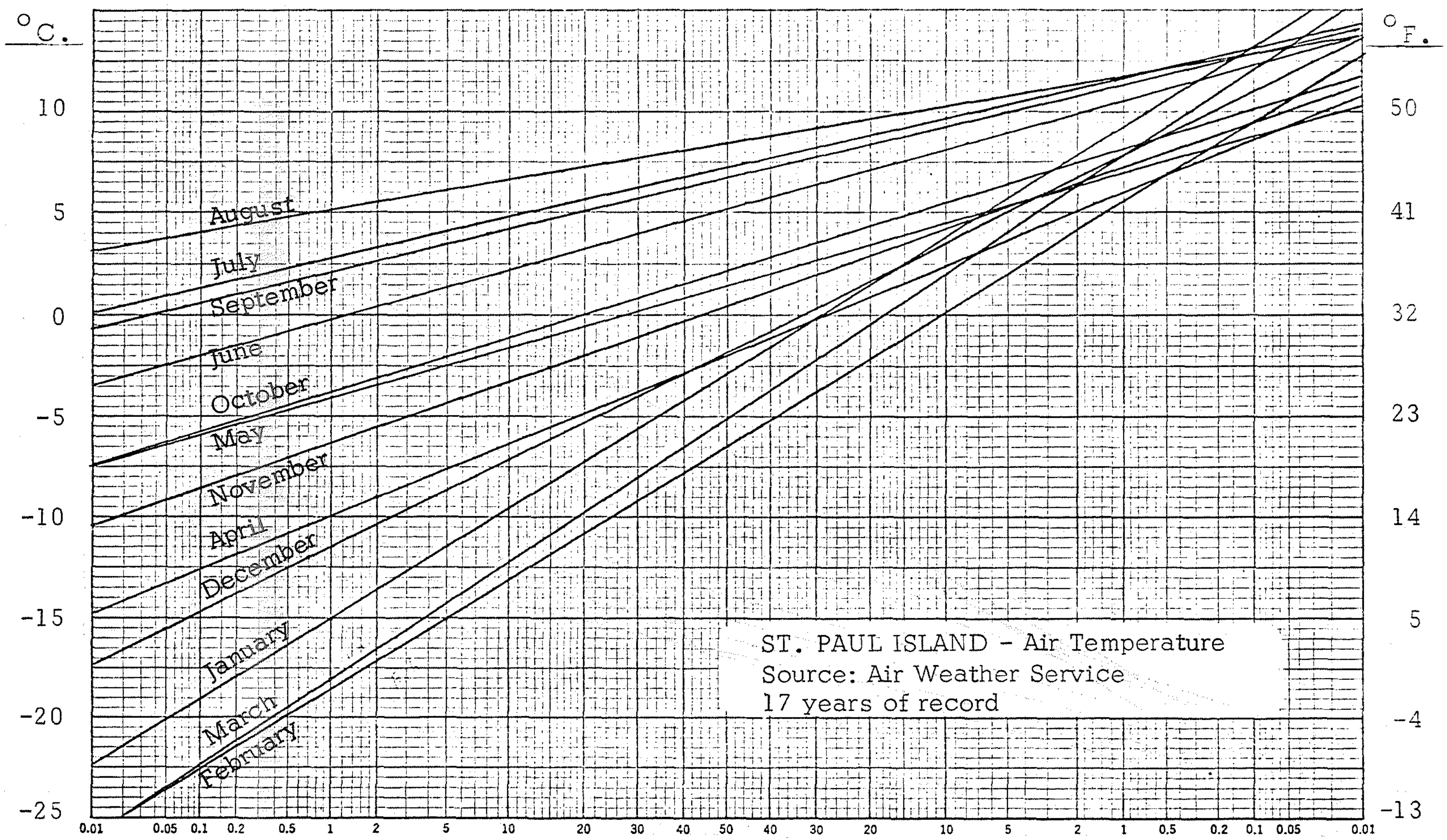

°C.
°F.
30
20
10
0
-10
-20
-30
-40
86
68
50
32
14
-4
-22
-40
August
July
September
October
June
May
November
April
February
January
March
December
PORT MOLLER - Air Temperature
Source: Air Weather Service
4 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
PERCENT FREQUENCY OF OCCURRENCE

Figure 22c



° C.
20
10
0
-10
-20
-30
-40
-50
° F.
68
50
32
14
-4
-22
-40
-58
July
August
June
September
May
October
April
November
March
February
January
December
KING SALMON - Air Temperature
Source: Air Weather Service
10 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22d


°C.
°F.
10
5
0
-5
-10
-15
-20
-25
50
41
32
23
14
5
-4
-13
August
July
September
June
October
May
November
April
December
January
March
February
ST. PAUL ISLAND - Air Temperature
Source: Air Weather Service
17 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE
Figure 22e

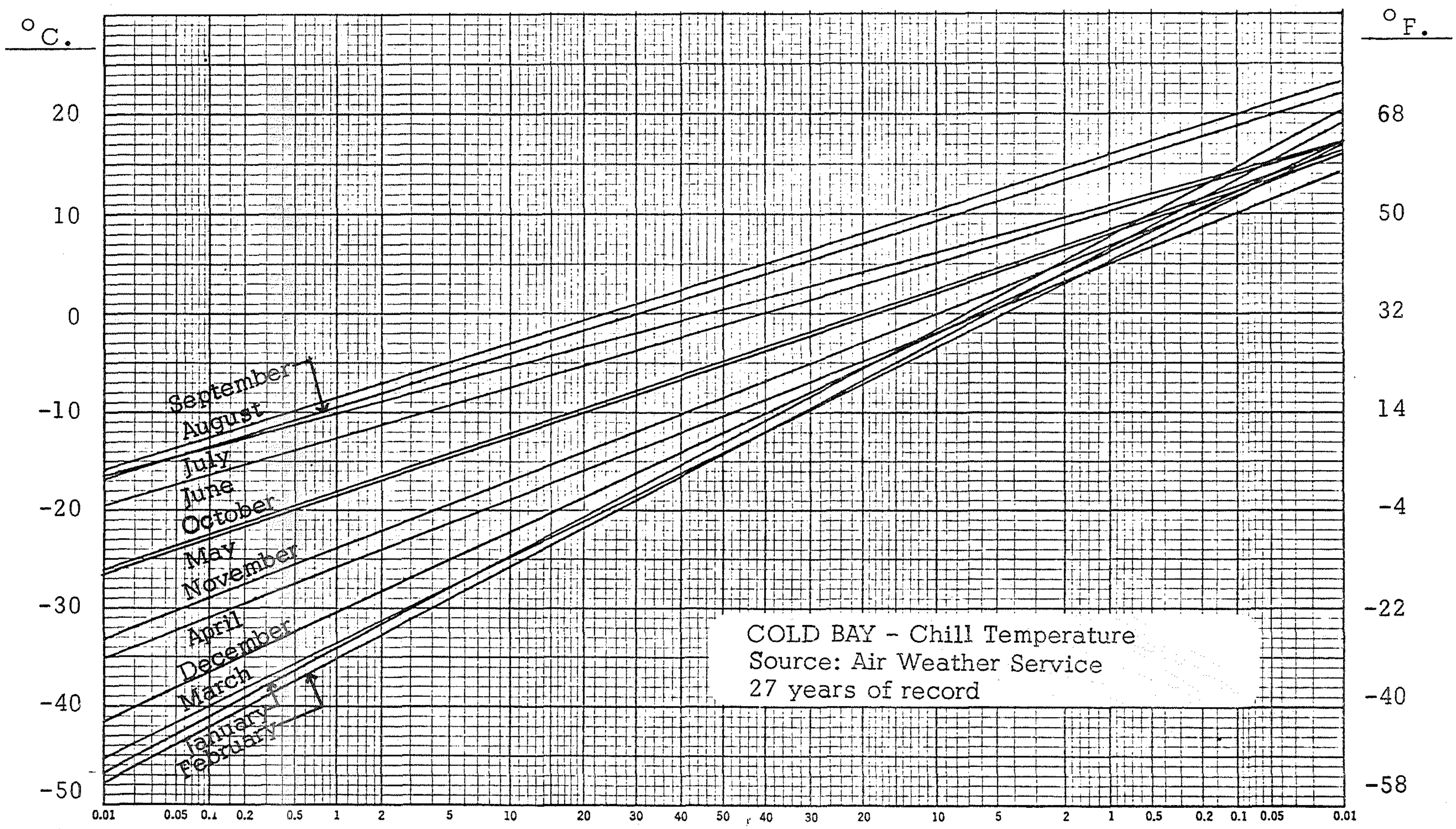
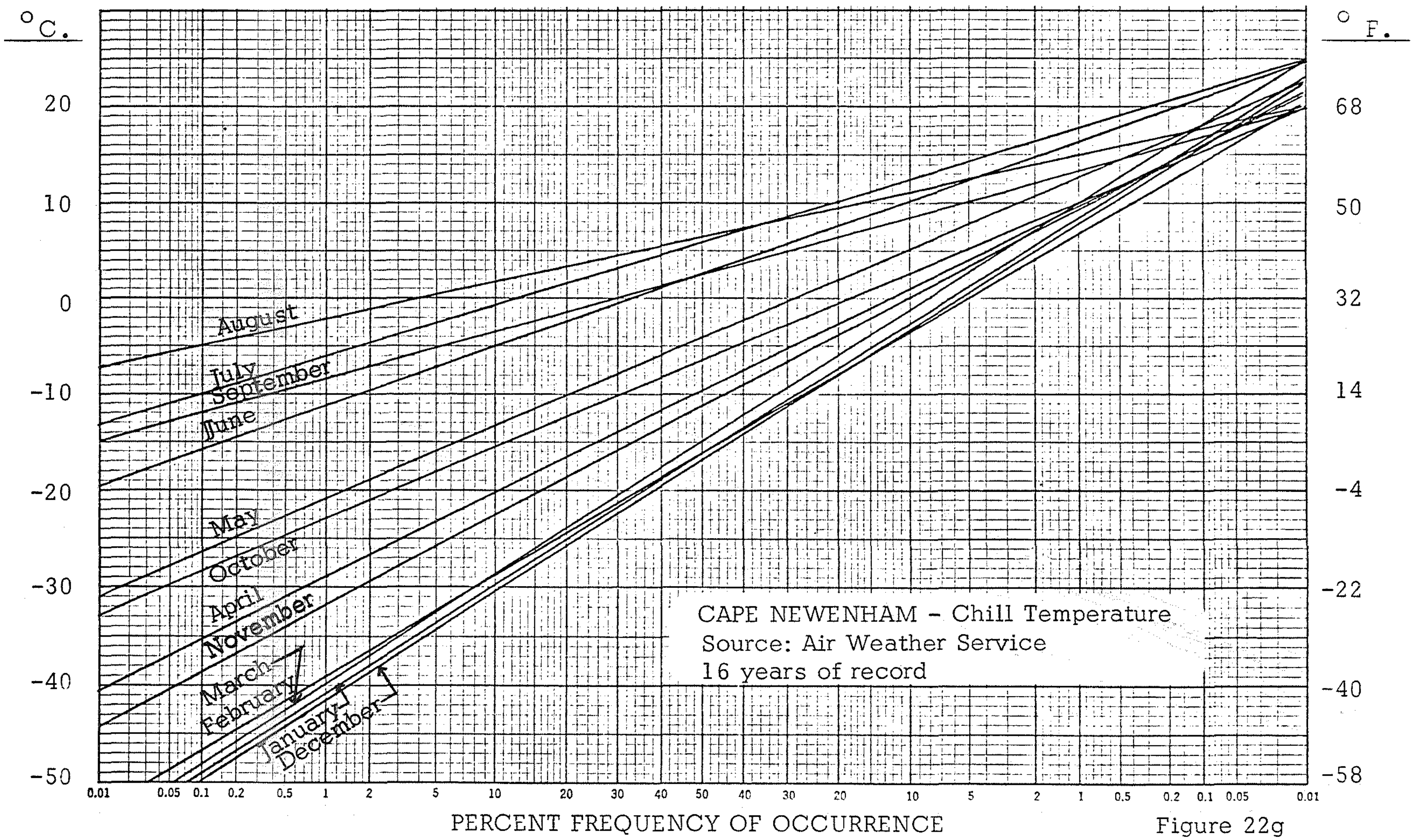

°C.
°F.
20
10
0
-10
-20
-30
-40
-50
68
50
32
14
-4
-22
-40
-58
September
August
July
June
October
May
November
April
December
March
January
February
COLD BAY - Chill Temperature
Source: Air Weather Service
27 years of record
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22f



°C.
°F.
20
10
0
-10
-20
-30
-40
-50
68
50
32
14
-4
-22
-40
-58
August
July
September
June
May
October
April
November
March
February
January
December
CAPE NEWENHAM - Chill Temperature
Source: Air Weather Service
16 years of record
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22g

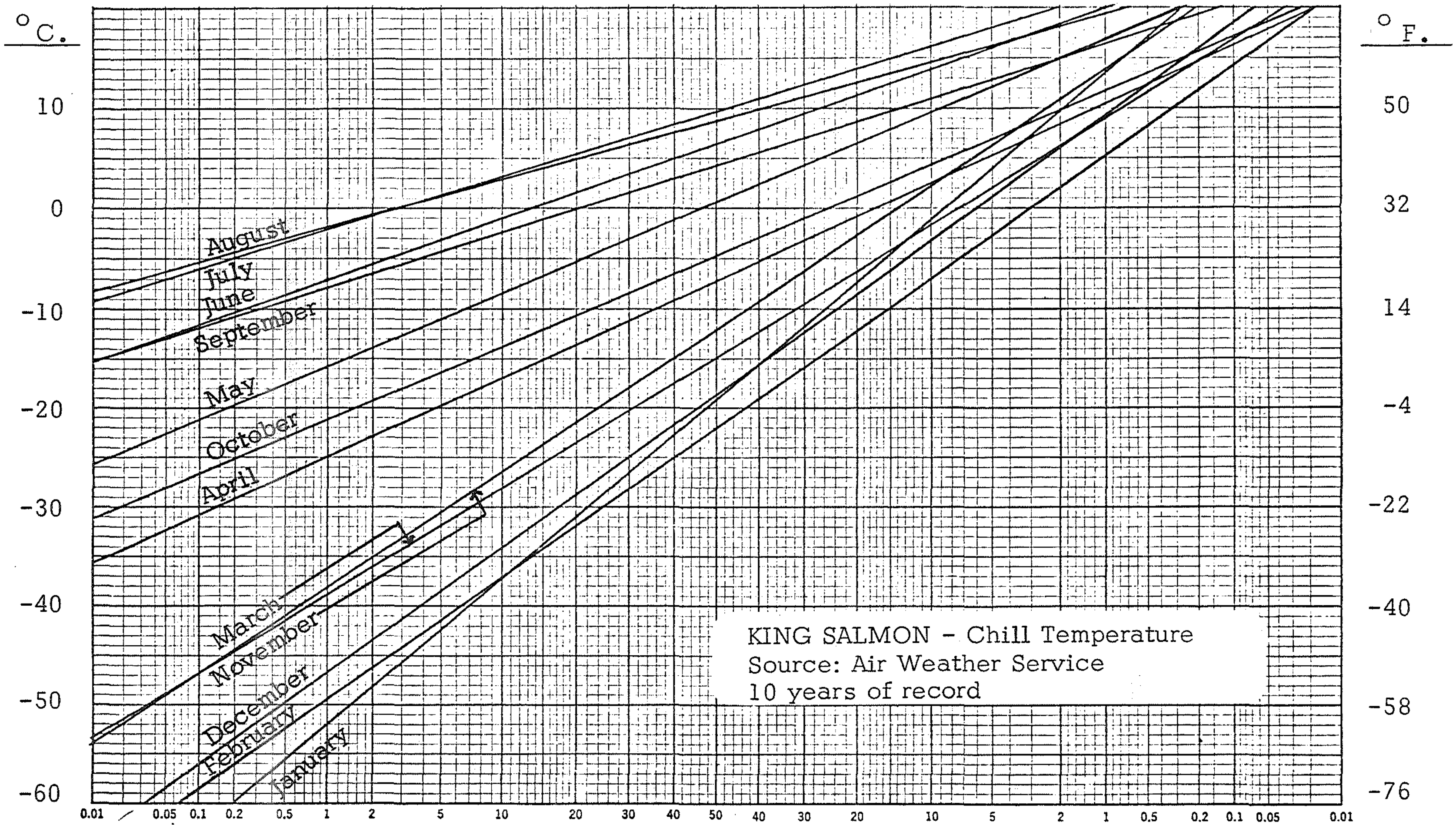

KING SALMON - Chill Temperature
Source: Air Weather Service
10 years of record
°C.
10
0
-10
-20
-30
-40
-50
-60
°F.
50
32
14
-4
-22
-40
-58
-76
August
July
June
September
May
October
April
March
November
December
February
January
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
PERCENT FREQUENCY OF OCCURRENCE

Figure 22h

shore of the Alaska Peninsula are on the leeward side of the mountains, which considerably reduces total annual precipitation. Some of the heavy precipitation that occurs along the top of the Aleutian Range spills over onto the leeward side, but does not show up in measurements made at coastal communities. It may, however, cause streams to flow bankfull or overflow for short periods following heavy rains. The heaviest precipitation in the study area is reported at Cape Newenham and Cape Sarichef, and is a result of the higher elevations of the places.

Two factors contribute to the occurrence of heavy precipitation during summer and fall months. Probably the most important is the ability of the air to hold larger volumes of moisture during the warmer months. In addition, the major storm track crossing the eastern Bering Sea from southwest to northeast carries the moisture-laden air over the study area.

Annual precipitation data include the water equivalent of snowfall. Because most of the precipitation occurs during the warmer months, it falls primarily as rain. Precipitation values are found in Table 6.

Anything in the air that reduces visibility to 10 km. (6 miles) or less is recorded as an obstruction to vision. Fog is the principal cause of reduced visibility in the study area; it is most obstructive during summer months when the air contains the most moisture and is warmer than the sea. Records on "heavy fog" (fog that reduces visibility to 400 m. ($\frac{1}{4}$ mile) or less) are available for Cold Bay, King Salmon, and St. Paul published annually by the Environmental Data Service. The frequency of "heavy fog" days during July, the month of heaviest fog, are as follows: Cold Bay 15 percent, King Salmon 12 percent, and St. Paul 37 percent. With reference to Table 7k, which shows fog as a weather condition that obstructs visibility, caution must be used when comparing Port Moller with other stations. The elevation of the observing site there is approximately 300 m. (1,000 feet), while the remaining stations are much closer to sea level. Therefore, fog observed in Port Moller will often be recorded elsewhere as low clouds. Average sky cover in the form of clouds is extensive over the entire area, although the sky is less often overcast in the eastern part of the study area.

DETAILED WEATHER CONDITIONS

A detailed breakdown of weather conditions for Cold Bay, Port Moller, King Salmon, Cape Newenham, and St. Paul are given in Table 7 and in Figure 22. The table and figure depict the frequency of various weather conditions. This type of information is especially valuable in planning the location and construction of a particular installation. The parameters covered are precipitation (both rain and snow), snow depth, visibility, sky cover, restrictions to visibility, (e.g., fog, smoke) and temperature.

SURFACE WINDS

Wind data for the 6 locations summarized by the Air Weather Service are found in Table 8. All stations show wind speeds in excess of those found at inland stations. Wind speeds at Cape Sarichef, Cold Bay, and St. Paul are appreciably higher than at Cape Newenham, King Salmon, and Port Moller. Seasonal variations in both direction and speed are evident for all locations. Terrain appears to influence wind directions to at least a limited extent, except

Month	SNOW DEPTH: Monthly values below are percentage frequency of occurrence (based on hourly observations). Categories below are in inches: None	Trace	1	2	3	4-6	7-12	13-24	25-36	37-48	Mean Snow Depth in Inches	Mean No. Days with Snowfall ≥ 0.1"	VISIBILITY: Percentage frequency of occurrence. Hourly Obsns/w Vsby <1 mi., caused by: Fog	Smoke and/or Haze	Blowing Snow and/or Dust	Precip-itation	Total obsns vsby <1 mi.	SKY COVER: Percentage frequency of occurrence of sky cover (based on hrly observations). Categories below are tenths of total sky cover: 0-3	4-5	6-7	8-9	10	Avg. Sky Cover in Tenths
J	4	2	2	10	4	7	21	40		10	13.4	29.2	4.1		1.6	0.6	6.3	27.3	5.7	8.3	10.7	48.0	6.7
F	4	8	5	5	5	6	33	16	13	5	12.7	24.9	3.1		1.2	0.6	4.9	25.0	6.6	7.8	12.5	48.1	6.9
M		8	8	5	3	11	19	19	17	10	14.9	28.4	4.8		2.0	1.5	8.3	27.4	5.7	6.8	10.1	50.0	6.8
A		6	4	4	9	13	14	13	22	15	17.6	28.3	5.5		0.7	0.8	7.0	18.3	6.1	6.8	11.9	56.9	7.6
M	11	32	8	5	3	12	6	13	8	2	6.9	17.7	6.0		0.1	0.6	6.6	13.1	4.7	6.2	12.3	63.7	8.2
J	64	32	1	*	*	1	2				0.2	1.2	7.6				7.7	11.0	4.6	4.5	13.3	66.6	8.5
J	94	6									T		6.8				6.8	11.3	3.3	4.2	10.9	70.3	8.5
A	100												6.1			0.4	6.5	3.3	2.6	4.4	12.4	77.3	9.3
S	96	1	3								T	0.8	2.1			0.5	2.6	7.7	3.6	6.3	15.2	67.2	8.7
O	62	17	5	3	7	1	4	1			0.9	6.4	0.9		0.2	0.5	1.6	11.6	4.4	8.4	15.0	60.6	8.2
N	20	15	18	13	10	11	8	4	1		2.9	19.5	3.1		0.7	0.7	4.4	14.2	4.2	7.1	12.9	61.6	8.1
D	1	4	2	11	12	14	29	20	4	3	9.6	29.5	3.5		1.9	1.0	6.4	22.5	5.2	7.1	11.4	53.8	7.2
Yr	38	11	5	5	4	6	11	11	5	4	6.6	185.9	4.5		0.7	0.6	5.8	15.8	4.7	6.4	12.4	60.7	7.9

T - Trace, an amount too small to measure
* - less than one half

Source: Air Weather Service U.S.A.F. — 16 years of record

Cape Newenham — Table 7a

SNOWFALL

Monthly values below are percentage frequency of occurrence of daily amounts. Categories below are in inches.

Month	None	Trace	0.1-0.4	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.4	≥ 6.5	Mean Monthly Snowfall	Maximum Monthly Snowfall	Mean No. Days with Snowfall ≥ 0.1"
J	45	23	14	12	2	2	1		1	10.1	25.7	10.0
F	39	21	10	20	7	1	2			9.7	23.1	11.2
M	34	23	22	14	3	1	1		2	12.4	38.7	13.4
A	40	18	21	15	3	1	1	1		10.1	27.9	12.8
M	64	14	10	7	2	1	1	1		5.2	19.0	6.8
J	93	6	1							T	0.1	0.2
J	100									T	T	
A	100									T	T	
S	93	5	1	1						0.1	1.4	0.4
O	51	20	14	9	3	3				7.4	21.7	8.9
N	35	22	14	18	5	2	3	1		12.9	36.7	12.9
D	35	23	16	14	7	3		2		13.3	28.1	13.1
Yr	63	14	10	9	2	1	1			81.2	38.7	89.7

PRECIPITATION

Monthly values below are percentage frequency of occurrence of daily amounts. Categories below are in inches.

Month	None	Trace	.01	.02-.05	.06-.10	.11-.25	≥ .26	Mean Monthly Precipitation	Mean No. Days with Pcpn ≥ 0.01"	Maximum Monthly	Minimum Monthly	Maximum in 24 Hrs
J	34	22	3	12	8	13	8	1.73	13.7	5.68	0.19	1.13
F	32	24	4	10	12	12	6	1.17	12.3	3.22	0.22	0.66
M	31	21	7	19	7	7	8	1.78	14.7	5.18	0.23	1.38
A	35	20	6	18	9	7	5	1.64	13.6	4.09	0.65	1.73
M	29	19	7	13	10	11	11	2.41	16.0	6.30	0.09	1.88
J	39	30	6	8	2	6	9	2.62	9.4	6.49	0.09	1.67
J	28	24	4	8	7	13	16	3.63	15.1	6.89	1.24	2.55
A	14	17	4	13	7	14	31	5.93	21.5	10.27	2.03	3.13
S	15	14	5	10	10	18	28	5.52	21.4	9.00	0.72	2.02
O	21	20	4	13	8	11	23	4.96	18.5	11.42	0.61	2.67
N	17	21	4	14	8	19	17	3.81	18.6	7.07	0.31	1.43
D	32	23	4	11	7	14	9	2.04	14.1	5.18	0.33	1.40
Yr	27	21	5	12	8	12	15	37.24	188.9	11.42	0.09	3.13

Precipitation includes water equivalent of snow. T - Trace, an amount too small to measure

Source: Air Weather Service U.S.A.F. 16 years of record

Cape Newenham Table 7b

	SNOW DEPTH — MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE (BASED ON HOURLY OBSERVATIONS) — CATEGORIES BELOW ARE IN INCHES											VISIBILITY — PERCENTAGE FREQUENCY OF OCCURRENCE — Hourly Obsns/w Vsby < 1 mi., caused by:					SKY COVER — PERCENTAGE FREQUENCY OF OCCURRENCE OF SKY COVER (BASED ON HRLY OBSERVATIONS) — CATEGORIES BELOW ARE TENTHS OF TOTAL SKY COVER					
Month	None	Trace	1	2	3	4-6	7-12	13-24	25-36	37-48	Mean Snow Depth In Inches	Mean No. Days with Snowdepth ≥ 0.1"	Fog	Smoke and/or haze	Blwg Snow and/or dust	Precipitation	Total Obsns vsby <1 mi.	0-3	4-5	6-7	8-9	10	Avg Sky Cover In Tenths
J	22	30	9	9	9	10	7	2	*	*	NOT AVAILABLE	15	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	13.8	6.5	8.5	15.7	55.5	7.9
F	16	32	16	12	11	10	4	*	0	0		15						13.1	5.2	7.3	14.8	59.6	8.1
M	25	33	13	9	6	10	4	*	0	0		13						13.0	6.5	8.1	15.4	57.0	8.0
A	50	31	8	4	2	4	1	0	0	0		6						8.9	4.7	7.4	16.3	62.7	8.5
M	92	7	7	0	0	0	0	0	0	0		*						5.5	3.6	6.5	18.0	66.4	8.9
J	100	0	0	0	0	0	0	0	0	0		0						5.4	2.7	5.2	15.3	71.4	9.0
J	100	0	0	0	0	0	0	0	0	0		0						3.1	2.2	4.0	12.9	77.8	9.3
A	100	0	0	0	0	0	0	0	0	0		0						3.2	2.8	4.3	12.8	76.9	9.3
S	100	*	0	0	0	0	0	0	0	0		0						4.2	4.5	7.8	17.3	66.2	8.9
O	71	16	2	1	1	1	*	0	0	0		1						8.1	6.7	1[illegible].0	20.9	53.3	8.3
N	79	25	11	6	3	4	1	0	0	0		7						12.3	6.8	10.1	16.8	54.0	8.0
D	51	27	15	8	5	11	7	2	0	0		15						12.9	6.0	9.2	16.1	55.8	8.0
Yr	63	17	6	4	3	4	2	*	*	*		72						8.6	4.9	7.5	16.0	63.0	8.5

* less than one half inch

Cold Bay

Source: Air Weather Service U.S.A.F. 16 years of record

Table 7c

SNOWFALL

Monthly values below are percentage frequency of occurrence of daily amounts. Categories below are in inches.

Month	None	Trace	0.1-0.4	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.4	≥ 6.5	Mean Monthly Snowfall (Inches)	Maximum Monthly Snowfall (Inches)	Mean No. Days with Snowfall ≥ 0.1"
J	34	30	18	12	3	1	1	1	*	10.5	19.9	11
F	26	32	21	15	4	1	*	1	0	9.6	23.4	12
M	27	34	19	14	4	1	*	1	*	9.9	17.6	12
A	38	38	12	10	1	*	*	*	0	5.0	14.7	7
M	73	20	5	2	1	0	0	0	0	1.1	9.3	2
J	99	1	*	0	0	0	0	0	0	T	0.5	*
J	100	0.	0	0	0	0	0	0	0	0	0.0	0
A	100	*	0	0	0	0	0	0	0	T	0.0	0
S	98	2	*	0	0	0	0	0	0	T	0.2	*
O	63	24	7	5	1	*	0	0	0	2.5	15.6	4
N	43	31	12	11	2	1	*	1	*	6.4	21.6	9
D	28	34	17	13	5	2	1	*	*	10.4	20.3	12
Yr	61	20	9	7	2	1	*	*	*	55.4	23.4	69

PRECIPITATION (INCHES)

Monthly values below are percentage frequency of occurrence of daily amts. Categories below are in inches.

Month	None	Trace	.01	.02-.05	.06-.10	.11-.25	≥ .26	Mean Monthly Precipitation	Mean No. Days with Pcpn ≥ 0.01"	Maximum Monthly	Minimum Monthly	Maximum in 24 Hrs.
J	17	28	8	17	10	12	8	2.54	17	8.46	0.60	2.49
F	12	31	8	16	10	12	9	2.62	16	7.87	0.08	2.49
M	14	33	8	21	10	9	6	1.82	17	3.89	0.41	1.34
A	16	42	6	15	9	8	3	1.56	13	3.83	0.02	1.76
M	14	36	7	16	9	10	9	2.15	15	6.37	0.62	2.22
J	15	38	8	14	6	14	6	2.19	14	6.98	0.12	2.10
J	13	33	8	16	9	11	9	2.24	16	4.63	0.28	1.74
A	8	29	7	18	10	13	15	3.89	20	9.97	1.40	2.17
S	11	23	7	19	10	17	14	3.81	20	9.79	0.91	3.43
O	7	22	5	19	13	20	13	4.34	22	8.02	1.88	4.90
N	13	20	5	18	12	16	17	4.27	20	8.94	1.46	3.43
D	12	31	8	19	9	14	9	2.88	18	6.49	0.19	1.94
Yr	13	30	7	17	10	13	10	34.31	208	9.97	0.02	4.90

* means less than one half

T - Trace, an amount too small to measure

Precipitation includes water equivalent of snow

Cold Bay

Source: Air Weather Service U.S.A.F.

16 years of record

Table 7d

	SNOW DEPTH												VISIBILITY					SKY COVER					
	MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE (BASED ON HOURLY OBSERVATIONS) — CATEGORIES BELOW ARE IN INCHES												PERCENTAGE FREQUENCY OF OCCURRENCE — Hourly Obsns/w Vsby <1 mi., caused by:					PERCENTAGE FREQUENCY OF OCCURRENCE OF SKY COVER (BASED ON HRLY OBSERVATIONS) — CATEGORIES BELOW ARE TENTHS OF TOTAL SKY COVER					
Month	None	Trace	1	2	3	4-6	7-12	13-24	25-36	37-48	Mean Snow Depth in Inches	Mean No. Days with Snowfall ≥ 0.1"	Fog	Smoke and/or Haze	Blowing Snow and/or Dust	Precip-itation	Total obsns vsby ≤ 1 mi	0-3	4-5	6-7	8-9	10	Avg. Sky Cover in Tenths
J	10	8	9	19	10	24	19	1			3.7	25	2.0		0.7	0.4	3.2	36.7	4.7	5.9	8.7	44.0	5.9
F	10	9	11	11	15	25	10	9			4.5	23	1.4		0.3	0.7	2.5	34.2	4.8	5.5	9.5	46.0	6.2
M	14	16	14	9	10	16	14	7			3.9	22	1.6		0.4	0.9	2.9	33.8	4.4	5.7	9.5	46.6	6.2
A	51	29	8	3	2	3	4	*			0.7	6	1.2			0.3	1.6	26.0	5.1	7.1	11.9	49.9	6.9
M	96	4									T		1.6			0.1	1.7	14.9	5.7	8.4	17.6	53.4	7.8
J	100												2.7		0.1		2.9	11.7	5.1	7.3	15.9	60.0	8.2
J	100												3.4			0.1	3.5	9.6	4.9	6.0	14.0	65.5	8.5
A	100												3.2			0.1	3.3	9.1	4.7	6.1	14.2	65.9	8.6
S	99	1									T		1.7				1.7	15.1	5.7	8.3	16.4	54.5	7.8
O	83	10	2	2	1	1	1				0.3	2	1.3		0.1	0.5	2.0	23.7	6.2	8.2	13.8	48.1	7.0
N	38	23	15	6	6	9	3				1.1	12	2.5		0.2	0.4	3.1	33.1	5.7	7.0	10.1	44.1	6.2
D	9	17	17	16	8	21	11	1			2.8	23	2.6		0.3	0.9	3.8	31.7	5.0	6.4	10.0	46.9	6.4
Yr	60	10	6	5	4	8	5	2			1.4	113	2.1		0.2	0.4	2.7	23.2	5.2	6.8	12.6	52.2	7.2

T - Trace, an amount too small to measure
* - less than one half

King Salmon

Source: Air Weather Service U.S.A.F.

10 years of record

Table 7e

SNOWFALL

Month	None	Trace	0.1-0.4	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.4	≥ 6.5	Mean Monthly Snowfall	Maximum Monthly Snowfall	Mean No. Days with Snowfall ≥ 0.1"
	MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE OF DAILY AMOUNTS — CATEGORIES BELOW ARE IN INCHES											
J	55	20	12	9	3	1				6.5	12.6	7.9
F	52	20	13	9	3	1		1	1	7.5	13.9	7.7
M	47	23	14	11	4		1			7.9	16.2	9.3
A	54	27	9	7	2		1			4.5	16.0	5.6
M	85	11	3	1						0.9	5.6	1.1
J	99	1								T	T	
J	100									0.0	0.0	
A	100									0.0	0.0	
S	98	2								0.1	0.6	0.2
O	71	18	6	3	1	1				3.3	14.6	3.3
N	55	25	8	8	3	1				5.9	16.1	6.2
D	44	25	15	11	3	2				8.5	16.0	9.7
Yr	72	14	7	5	1	1				45.1	16.2	51.0

PRECIPITATION

Month	None	Trace	.01	.02-.05	.06-.10	.11-.25	≥ .26	Mean Monthly Precipitation	Mean No. Days with Pcpn ≥ 0.01"	Maximum Monthly	Minimum Monthly	Maximum in 24 Hrs
	MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE OF DAILY AMOUNTS — CATEGORIES BELOW ARE IN INCHES											
J	45	22	5	11	6	7	4	1.07	10.1	3.02	0.16	0.87
F	43	22	7	13	6	6	3	0.95	9.9	3.00	0.16	1.29
M	42	23	5	11	7	9	3	0.96	10.9	2.41	0.04	1.03
A	43	27	5	12	5	6	2	0.64	9.0	2.99	T	1.41
M	36	28	6	13	6	8	3	0.96	11.3	2.40	0.11	0.80
J	32	28	5	13	7	10	5	1.40	11.9	3.78	0.00	0.87
J	27	26	6	11	9	12	9	2.06	14.4	4.32	0.32	1.06
A	22	19	5	15	8	16	15	3.43	18.4	6.44	2.05	2.00
S	29	16	5	12	9	15	14	3.08	16.7	7.30	1.00	1.69
O	32	20	5	15	7	12	9	2.15	15.0	6.35	0.20	1.52
N	36	26	4	10	9	10	5	1.46	11.1	2.96	T	0.90
D	36	28	6	13	8	6	3	1.02	11.2	2.47	0.12	0.82
Yr	35	24	6	12	7	10	6	19.18	149.9	7.30	0.00	2.00

Precipitation includes water equivalent of snow.
T - Trace, an amount too small to measure

King Salmon

Source: Air Weather Service U.S.A.F. 10 years of record

Table 7f

Month	SNOW DEPTH — Monthly values below are percentage frequency of occurrence (based on hourly observations) — Categories below are in inches: None	Trace	1	2	3	4-6	7-12	13-24	25-36	37-48	Mean Snow Depth in Inches	Mean No. Days with Snowfall ≥0.1"	VISIBILITY — Percentage frequency of occurrence — Hourly Obsns/w Vsby <1 mi., caused by: Fog	Smoke and/or Haze	Blowing Snow and/or Dust	Precipitation	Total obsns vsby ≤1 mi	SKY COVER — Percentage frequency of occurrence of sky cover (based on hrly observations) — Categories below are tenths of total sky cover: 0-3	4-5	6-7	8-9	10	Avg Sky Cover in Tenths
J	18	13	1	4	13	17	19	15			5.6	21.4	4.6		0.7	3.8	9.0	28.8	6.5	7.6	11.9	45.2	6.6
F	4	26	11	15	9	12	3	20			5.8	19.8	7.8		0.1	2.6	10.5	23.8	5.0	8.1	15.2	47.9	7.1
M	2	15	12	9	10	19	8	7	18		9.2	25.8	9.0		1.0	2.9	13.0	21.0	4.9	4.9	13.9	55.3	7.4
A	4	12	5	12	2	6	27	26	6		8.5	25.0	16.5			3.1	19.7	13.5	4.7	4.8	9.9	67.1	8.2
M	43	27	3	5	4	13	5				1.2	9.3	15.1			1.8	16.9	13.1	5.3	8.1	15.6	57.9	8.0
J	66	30	2	1	1						0.1	1.0	26.9			2.1	28.9	10.4	2.8	5.2	13.6	68.0	8.5
J	75	25									T		29.3			4.0	33.3	9.4	2.8	8.5	13.4	65.9	8.6
A	75	25									T		21.7	0.3		4.0	26.0	6.1	4.2	6.1	16.6	67.0	8.8
S	76	24									T		10.5			1.2	11.7	4.7	4.5	9.1	19.7	62.0	8.7
O	52	31	6	5	1	3	2				0.5	5.0	8.8		0.4	2.4	11.7	11.9	5.1	8.1	20.6	54.3	8.1
N	39	17	7	12	8	11	6				1.6	13.0	8.2		0.8	2.9	12.0	15.5	6.6	8.1	16.7	53.1	7.8
D	23	5	1	5	11	35	14	6			4.3	22.5	6.9		0.8	5.7	13.4	22.7	5.5	5.2	14.1	52.5	7.3
Yr	40	21	4	5	5	10	7	6	2		3.0	142.8	13.8	0.0	0.3	3.1	17.2	15.0	4.8	7.0	15.1	58.1	7.9

T - Trace, an amount too small to measure   * - less than one half

Port Moller

Source: Air Weather Service U.S.A.F.   4 years of record

Table 7g

SNOWFALL													PRECIPITATION												
MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE OF DAILY AMOUNTS — CATEGORIES BELOW ARE IN INCHES													MONTHLY VALUES BELOW ARE PERCENTAGE FREQUENCY OF OCCURRENCE OF DAILY AMOUNTS — CATEGORIES BELOW ARE IN INCHES												
Month	None	Trace	0.1-0.4	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-6.4	≥ 6.5	Mean Monthly Snowfall	Maximum Monthly Snowfall	Mean No. Days with Snowfall ≥ 0.1"	Month	None	Trace	.01	.02-.05	.06-.10	.11-.25	≥ .26	Mean Monthly Precipitation	Mean No. Days with Pcpn ≥ 0.01"	Maximum Monthly	Minimum Monthly	Maximum in 24 Hrs
J	45	15	10	19	3	3	1	1	3	21.6		12.3	J	28	16	3	13	11	16	13	3.41	17.5			
F	48	19	11	14	5	2	1			9.3		9.2	F	37	24	4	10	11	11	3	1.17	10.9			
M	39	26	14	11	6	2	1	1		13.7		11.0	M	33	20	10	13	5	14	5	1.64	14.7			
A	28	33	6	21	6	6				12.8		11.7	A	21	22	7	10	18	11	11	2.60	17.0			
M	73	10	4	8	2	2		1		7.1		5.3	M	27	18	7	16	11	11	10	2.47	17.0			
J	94	3	1	1	1					0.8		0.8	J	25	16	8	16	10	10	15	3.86	17.7			
J	100												J	28	15	3	12	5	14	23	6.67	17.7			
A	100												A	11	11	6	14	11	16	31	7.76	24.0			
S	98	1	1							0.1		0.3	S	13	16	4	11	11	20	25	5.14	21.3			
O	75	14	7	4						1.4		3.3	O	16	19	6	19	10	19	11	3.87	20.0			
N	49	22	6	14	4	2	1	1	1	12.7		8.5	N	18	20	0	22	13	17	10	2.67	18.5			
D	36	25	11	14	9	2	1	1	1	17.2		12.3	D	27	19	7	14	9	17	7	2.15	16.8			
Yr	67	13	6	8	3	2		1		96.7		74.7	Yr	24	18	6	14	10	14	14	43.41	213.1			

Precipitation includes water equivalent of snow.

Port Moller

Source: Air Weather Service U.S.A.F. 4 years of record

Table 7h

Month	SNOW DEPTH: Monthly values below are percentage frequency of occurrence (based on hourly observations). Categories below are in inches: None	Trace	1	2	3	4-6	7-12	13-24	25-36	37-48	Mean Snow Depth In Inches	Mean No. Days with Snowdepth ≥ 0.1"	VISIBILITY: Percentage frequency of occurrence. Hourly Obsns/w Vsby < 1 mi., caused by: Fog	Smoke and/or haze	Blwg Snow and/or dust	Precipitation	Total Obsns vsby <1 mi	SKY COVER: Percentage frequency of occurrence of sky cover (based on hrly observations). Categories below are tenths of total sky cover: 0-3	4-5	6-7	8-9	10	Avg Sky Cover in Tenths
J	19	17	14	8	8	15	13	7	*		9.1	18	DATA NOT AVAILABLE					16.0	5.2	6.0	8.5	64.4	8.0
F	8	16	12	11	6	17	15	11	4		9.2	16.1						15.4	5.1	6.1	11.1	62.4	8.0
M	6	15	11	9	9	14	16	13	7		11.5	15.7						15.9	4.2	6.2	9.3	64.5	8.0
A	13	22	8	5	6	17	16	14	1		10.4	15						10.6	4.2	5.7	10.1	69.4	8.5
M	58	26	2	1	1	5	5	2			3.1	14.7						7.7	2.5	3.0	7.0	79.9	9.0
J	96	3	1	*							.1	12.8						7.0	2.4	2.2	7.0	81.6	9.1
J	100										T	15.5						3.3	1.0	1.6	5.1	89.0	9.5
A	100										T	19.7						3.1	1.6	2.2	5.5	87.6	9.5
S	100										T	19.5						7.4	4.6	8.2	9.6	73.0	8.9
O	76	17	6	2	*						.8	22.4						9.8	7.2	9.3	13.5	60.2	8.3
N	55	22	12	3	3	4	3	*			3.8	21.8						11.8	6.4	7.8	11.8	62.3	8.2
D	21	21	16	12	7	16	6	2			5.8	19.2						13.0	5.4	7.4	11.5	62.6	8.1
YR	54	13	7	4	3	7	6	4	1		16.9	210.4						10.0	4.2	5.3	9.2	71.4	8.6

T- trace, an amount too small to measure

* - less than one half

St. Paul Island

Source: Air Weather Service U.S.A.F.

17 years of record

Table 7i

Month	SNOWFALL: Monthly values below are percentage frequency of occurrence of daily amounts. Categories below are in inches: None	Trace	0.1 - 0.4	0.5 - 1.4	1.5 - 2.4	2.5 - 3.4	3.5 - 4.4	4.5 - 6.4	≥ 6.5	Mean Monthly Snowfall	Maximum Monthly Snowfall	Mean No. Days with Snowfall ≥ 0.1"
J	31	27	22	13	5	1	1	*	1	11.7	35.7	13
F	22	27	28	18	4	1	*	1	*	10.3	55.8	14
M	23	31	23	19	4	1	*	*	*	10.2	18.1	14
A	27	36	23	11	2	*	*		*	6.0	15.7	11
M	60	26	9	4	1	*				2.6	12.7	5
J	94	5	1	*						0.1	1.6	3
J	100									0.0	0.0	
A	100									0.0	0.0	
S	97	3	*	*						0.1	1.0	1
O	56	23	13	8	*			*		3.2	10.1	6
N	35	30	21	10	3	1			*	6.4	27.3	10
D	27	27	26	15	5	1	*	*	*	9.7	18.0	21
YR	56	19	14	8	2	*	*	*	*	60.3	55.8	98

Month	PRECIPITATION: Monthly values below are percentage frequency of occurrence of daily amounts. Categories below are in inches: None	Trace	.01	.02 - .05	.06 - .10	.11 - .25	≥ .26	Mean Monthly Precipitation	Mean No. Days with Pcpn ≥ 0.01"	Maximum Monthly	Minimum Monthly	Maximum in 24 Hours
J	16	26	9	21	10	12	8	1.81	18	4.99	0.25	1.33
F	15	28	10	24	9	11	3	1.23	16	5.69	0.38	1.51
M	16	33	9	21	10	8	3	1.06	15	2.97	0.08	1.04
A	18	32	11	20	9	8	3	0.96	15	3.10	0.16	1.00
M	18	34	9	16	10	9	3	1.30	15	3.11	0.21	1.27
J	25	33	10	15	7	8	4	1.15	13	3.59	0.18	1.48
J	14	36	10	13	9	10	8	2.25	16	5.85	0.32	1.92
A	11	25	10	17	9	14	14	3.29	19	9.32	1.32	1.91
S	16	19	10	20	9	15	12	3.07	20	6.02	1.05	1.58
O	8	20	9	20	16	17	11	3.15	22	5.18	1.03	1.93
N	8	19	9	22	14	18	13	2.50	22	5.31	0.67	1.76
D	12	27	9	24	10	13	5	1.83	19	4.18	0.08	1.15
YR	15	28	9	20	10	12	7	23.60	210	9.32	0.08	1.93

* = less than one-half inch

St. Paul Island

Source: Air Weather Service U.S.A.F.

17 years of record

Table 7j

PERCENTAGE FREQUENCY OF OCCURRENCE OF WEATHER CONDITIONS																				
	Fog					Smoke and/or Haze					Blowing Snow					Percentage Observations with Obstruction to Vision				
Month	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay
J	17.5	21.8	6.7	14.5	12.5	.0		.1			7.2	8.0	2.6	4.3	3.7	24.2	27.5	9.4	17.7	21.1
F	17.8	21.2	5.5	18.6	11.8	.2					13.2	5.9	1.5	4.2	7.3	31.2	25.8	7.0	20.9	19.1
M	16.2	21.8	6.2	23.7	10.8	.0			.2	.1	10.7	8.0	1.6	4.7	6.3	26.9	27.3	7.8	26.2	17.0
A	18.5	26.6	5.4	32.4	10.5	.0		.1			4.4	4.6	.2	4.0	2.2	22.9	29.3	5.7	33.6	12.7
M	30.0	27.4	5.3	23.5	11.5			.1			.4	.1		.3		30.4	27.5	5.6	23.5	12.0
J	40.8	32.2	8.6	35.0	18.0	.0		.1						.1		40.8	32.2	9.0	35.0	18.0
J	56.1	33.1	14.5	40.0	28.3		.7	.8	.1	.1						56.1	33.6	15.4	40.0	28.3
A	43.6	34.2	15.9	34.9	32.3			.1	.4							43.6	34.2	16.0	35.2	32.4
S	23.8	18.9	6.3	17.8	18.0	.1			.3							23.9	18.9	6.3	18.1	18.0
O	8.5	13.2	5.3	17.7	9.3	.0			.1		.0	.8	.2	.9	.2	8.5	14.0	5.6	18.6	9.5
N	10.9	19.2	7.1	18.7	10.2	.1			.2	.1	1.3	4.3	.7	4.6	3.0	12.3	22.4	7.8	22.4	13.4
D	10.9	20.3	8.1	15.8	10.3			.1			6.3	10.1	1.4	11.9	7.4	17.2	28.2	9.6	24.9	17.6
Avg	24.6	24.3	8.0	24.4	15.5	.0	.1	.1	.1	*	3.6	3.4	.7	2.9	2.9	28.2	26.8	8.8	26.4	18.4

Source: Air Weather Service U.S.A.F.
Years of record as noted on other Table 7 charts

Table 7k

PERCENTAGE FREQUENCY OF OCCURRENCE OF WEATHER CONDITIONS																				
	Rain and/or Drizzle					Freezing Rain					Snow and/or Sleet					Percentage Observations with Precipitation				
Month	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay	St. Paul	Cape Newenham	King Salmon	Port Mollor	Cold Bay
J	10.9	5.9	3.9	5.9	13.3	.2	.7	.5	.3	.4	25.8	16.6	11.9	15.8	21.5	36.9	22.6	15.8	22.0	35.7
F	5.9	2.8	4.4	2.4	12.9	.4	.1	.4	.4	.7	34.2	22.4	14.0	13.6	24.7	40.5	24.9	18.0	16.3	37.1
M	5.4	2.8	3.9	3.5	10.5	.4	.3	.2	.1	.3	30.3	22.7	16.3	19.7	25.7	36.1	25.4	19.9	23.3	35.6
A	8.3	3.4	6.6	4.1	15.1	.2	.1	.1	.5	.1	21.9	24.2	11.4	24.5	21.3	30.4	27.3	17.5	29.1	35.3
M	18.8	16.6	15.5	12.5	30.7	.2	.2		.2		11.8	11.0	2.4	7.5	5.3	30.8	27.1	17.4	20.0	34.5
J	24.8	20.8	18.6	15.6	33.8	.1			.2		.8	.8		1.3	.2	25.7	21.5	18.6	17.1	34.0
J	31.9	28.6	22.5	25.2	36.0						.0					31.9	28.6	22.5	25.2	36.0
A	33.4	37.5	27.2	26.5	40.2						.0					33.4	37.5	27.2	26.5	40.2
S	27.3	31.3	21.2	19.9	32.8						.1	.7	.1	.4	.1	27.4	31.8	21.3	20.3	32.9
O	22.6	17.5	14.1	12.0	27.5	.0	.1	.1			8.1	10.3	5.8	6.9	3.4	30.0	27.1	19.4	18.8	32.6
N	17.4	11.5	7.0	9.7	22.3	.1	.2	.3	.1	.2	18.0	20.6	9.3	13.8	7.2	35.5	31.1	16.0	23.5	34.0
D	10.3	3.9	3.5	3.5	13.9	.3	.3	.7	.5	.8	26.9	22.9	14.4	17.3	15.5	37.5	26.1	18.1	21.3	35.8
Avg	18.1	15.5	12.5	11.8	24.6	.2	.2	.2	.2	.2	14.8	12.4	7.0	10.1	6.7	33.1	27.6	19.3	22.0	35.4

Source: Air Weather Service U.S.A.F. Table 71
Years of record as noted on other Table 7 charts

	WIND - PERCENTAGE FREQUENCY OF OCCURRENCE BY SPEED GROUPS														EXTREME WINDS (KTS)									
	COLD BAY							ST. PAUL							Cold Bay		St. Paul		Cape Nwnham		King Salmon		Port Moller	
	Calm	1 to 3	4 to 10	11 to 21	22 to 27	28 to 40	41 and over	Calm	1 to 3	4 to 10	11 to 21	22 to 27	28 to 40	41 and over	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed
Jan	5.0	3.6	26.5	37.6	15.5	10.7	1.0	2.5	2.2	19.7	47.3	17.0	10.7	0.7	SE	58	SSW	55	SE	50	E	56	SSE	35
Feb	4.2	3.5	25.8	41.4	13.9	9.8	1.5	1.6	1.7	19.1	45.9	16.6	13.9	1.2	SSE	64	NNE	60	SSE	52	E	68	SSE	30
Mar	4.1	2.9	24.7	42.3	16.3	8.9	1.0	1.8	2.4	23.7	46.9	14.9	9.6	0.6	ESE	58	NE	63	E	60	E	60	SSE	38
Apr	3.8	2.4	26.2	46.2	13.6	7.1	0.4	1.4	2.2	26.0	52.4	11.2	6.7	0.1	SSE	52	WSW	42	SE	45	E	45	S	38
May	4.4	3.6	29.8	43.1	12.2	6.0	0.3	1.4	2.4	32.6	52.6	8.8	2.3	0	SSE	49	NNW	38	NW	55	ESE	43	S	30
Jun	3.8	3.3	32.3	44.7	10.6	4.9	0.4	1.0	2.8	33.9	48.9	3.1	0.3	0	ESE	55	NE	38	SE	35	E	47	S	30
Jul	4.7	4.5	34.4	41.3	9.8	5.2	0.1	1.7	3.4	47.5	45.4	1.9	0.1	0	SSE	47	SW	32	ENE	28	E	45	S	30
Aug	3.9	3.8	30.2	43.4	12.3	6.2	0.2	1.6	2.1	38.1	51.2	5.7	1.2	0	SSE	47	S	40	ESE	35	E	45	S	26
Sep	3.7	3.8	31.1	46.0	10.4	4.6	0.4	1.8	3.1	34.1	47.7	10.0	3.3	0.1	S	50	SE	46	E	38	E	54	S	35
Oct	4.7	3.6	26.8	42.7	13.8	7.8	0.6	1.5	1.7	23.3	47.9	15.5	9.4	0.6	S	48	W	52	SE	40	E	48	S	44
Nov	4.8	4.2	29.3	38.4	13.2	9.1	0.7	1.4	2.2	22.7	46.1	18.1	8.8	0.6	SE	57	N	71	ESE	45	E	62	S	35
Dec	5.1	3.9	29.1	39.1	13.3	8.8	0.7	1.7	1.9	19.6	45.9	17.8	12.4	0.6	ESE	56	W	54	ESE	58	E	48	S	42
Yr	4.4	3.6	28.9	42.1	12.9	7.4	0.5	1.6	2.3	28.8	48.2	11.9	6.7	0.4	SSE	64	N	71	E	60	E	68	S	44

Years of record as noted on other Table 8 charts
Source: Air Weather Service

Table 8a

WIND - PERCENTAGE FREQUENCY OF OCCURRENCE BY SPEED GROUPS (Kts)

	PORT MOLLER							CAPE NEWENHAM							KING SALMON						
	Calm	1 to 3	4 to 10	11 to 21	22 to 27	28 to 40	41 and over	Calm	1 to 3	4 to 10	11 to 21	22 to 27	28 to 40	41 and over	Calm	1 to 3	4 to 10	11 to 21	22 to 27	28 to 40	41 and over
Jan	16.3	2.9	50.3	26.8	2.5	1.2	0.0	21.8	3.0	26.2	34.4	9.6	4.8	0.3	13.3	9.8	38.1	30.0	6.5	2.1	0.1
Feb	23.7	3.1	52.9	18.1	2.0	0.3	0.0	18.3	3.1	29.8	37.5	6.9	3.9	0.5	10.9	8.5	39.9	33.0	5.2	2.3	0.2
Mar	16.8	2.9	46.4	31.4	1.8	0.6	0.0	17.4	4.0	32.2	37.4	5.5	3.1	0.5	10.9	8.8	41.7	31.7	5.2	1.6	0.0
Apr	18.1	3.5	47.5	29.3	1.2	0.4	0.0	17.3	4.0	34.2	37.7	4.9	1.8	0.0	9.0	8.5	49.2	28.8	3.4	1.0	0.0
May	24.2	3.4	47.6	23.5	1.0	0.3	0.0	18.5	5.2	38.2	35.0	2.5	0.6	0.0	7.7	8.7	48.7	30.0	4.0	1.0	0.0
Jun	20.1	4.5	54.9	18.6	1.6	0.3	0.0	21.6	5.2	45.1	26.1	1.6	0.4	0.0	6.3	9.8	55.7	25.3	2.3	0.5	0.0
Jul	12.3	10.4	54.7	21.2	1.1	0.3	0.0	22.3	4.9	41.9	30.1	0.7	0.0	0.0	8.2	11.8	58.6	20.4	0.8	0.2	0.0
Aug	11.8	5.8	48.8	31.8	1.8	0.0	0.0	13.7	3.7	46.8	34.3	1.3	0.2	0.0	7.7	9.6	53.1	26.7	2.3	0.5	0.0
Sep	10.9	5.1	42.7	38.5	1.9	0.9	0.0	8.5	3.2	46.4	38.1	3.3	0.5	0.0	8.4	11.1	51.3	25.7	2.6	0.8	0.1
Oct	10.8	5.2	47.1	31.9	3.2	1.6	0.1	11.7	3.3	41.2	39.4	3.6	0.7	0.0	9.2	9.9	46.5	29.5	3.8	1.2	0.0
Nov	11.5	5.7	40.2	36.1	4.8	1.7	0.0	13.6	2.8	37.0	37.7	6.6	2.3	0.0	11.2	9.4	43.3	30.3	4.3	1.3	0.2
Dec	12.0	3.3	50.0	30.5	2.9	1.1	0.1	23.8	3.3	29.6	32.7	8.0	2.5	0.1	14.7	8.9	41.0	29.3	4.2	1.7	0.1
Yr	15.7	4.7	48.6	28.2	2.1	0.7	0.0	17.4	3.8	37.6	35.0	4.4	1.7	0.1	9.8	9.6	47.3	28.3	3.7	1.2	0.1

Years of record as noted on other Table 8 charts
Source: Air Weather Service

Table 8b

	WIND DIRECTION (PERCENTAGE FREQUENCY OF OCCURRENCE)												WIND SPEED (MEAN VALUES OF, IN KNOTS)											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
N	18.7	18.3	15.5	11.1	4.9	2.7	2.7	2.8	9.2	13.6	18.8	20.4	11.8	11.4	11.3	10.1	9.4	7.3	6.4	8.0	9.7	11.0	11.1	11.0
NNE	8.4	11.2	7.8	5.9	3.8	2.2	2.2	2.1	5.4	8.5	9.9	10.4	10.1	10.4	10.2	9.5	8.5	6.9	6.9	7.9	8.8	10.1	10.4	10.1
NE	6.7	5.3	4.4	6.1	5.1	3.1	2.5	2.9	5.0	5.6	5.0	4.6	9.7	8.5	7.4	9.5	8.2	6.9	6.4	7.0	7.8	8.5	8.2	8.2
ENE	4.2	3.9	3.4	4.2	5.4	2.8	2.4	2.4	3.6	4.2	3.8	3.1	12.7	11.2	10.4	9.5	9.8	9.3	7.7	9.2	8.7	10.6	11.0	11.3
E	9.2	8.5	6.8	7.8	11.3	6.4	4.0	4.3	5.2	6.2	7.1	6.4	14.7	15.9	13.5	12.1	14.0	13.0	10.5	10.9	10.8	12.4	14.2	15.6
ESE	6.9	5.5	5.1	5.6	7.4	6.8	4.2	4.1	6.3	6.3	7.7	4.4	14.2	13.0	13.3	11.6	12.6	12.1	8.9	9.7	10.8	12.1	13.9	14.2
SE	5.1	4.6	4.2	4.4	6.3	6.6	4.6	5.5	5.8	4.7	5.6	4.7	9.7	11.0	9.7	9.8	9.2	8.2	6.3	8.7	8.6	9.0	9.6	9.3
SSE	4.9	5.2	4.9	5.2	8.3	7.6	6.7	9.1	9.1	6.4	6.3	4.3	12.0	13.9	13.7	12.8	11.9	9.5	8.6	11.2	11.0	10.0	10.1	11.0
S	3.3	4.1	4.9	5.1	9.6	11.4	12.6	11.2	8.0	4.7	3.5	3.4	9.5	11.4	10.3	8.6	10.5	9.9	9.2	10.3	10.5	9.3	8.9	9.3
SSW	2.5	3.0	3.9	4.7	7.2	11.8	14.8	12.4	6.0	4.8	2.7	3.2	10.3	10.5	10.1	8.8	9.2	8.9	8.8	9.4	8.9	9.3	8.9	10.4
SW	2.0	2.6	4.1	4.6	5.9	10.8	12.6	11.5	5.2	3.0	1.3	2.0	9.4	10.1	10.4	8.7	8.6	8.6	8.0	9.0	8.1	8.7	6.9	8.8
WSW	1.6	2.1	3.2	4.7	4.2	6.2	7.6	9.1	4.0	2.4	1.2	1.6	9.9	11.4	11.2	9.8	9.0	8.7	8.1	9.6	8.9	10.2	9.4	9.6
W	1.5	1.8	2.8	4.5	4.0	5.9	5.7	6.0	4.0	3.1	1.3	1.2	9.5	9.1	9.9	9.3	8.3	8.3	7.9	8.8	8.8	9.9	8.5	8.0
WNW	1.3	1.7	2.3	3.4	3.3	4.4	4.4	3.8	3.8	3.1	1.5	1.5	7.9	8.3	9.2	8.3	7.6	8.1	7.5	8.1	7.7	9.1	8.1	7.8
NW	3.1	3.7	4.5	4.3	2.6	2.5	2.5	2.8	4.6	5.1	3.7	3.5	7.5	8.2	9.1	8.4	7.6	7.3	6.9	7.4	8.8	8.9	8.1	8.2
NNW	7.2	7.6	11.2	9.3	3.1	2.4	2.1	2.2	6.3	9.1	9.4	10.4	10.1	10.7	11.4	10.6	9.4	8.0	7.1	8.0	9.5	10.4	10.1	11.0
CALM	13.3	10.9	10.9	9.0	7.7	6.3	8.2	7.7	8.4	9.2	11.2	14.7	MONTHLY AVERAGE SPEEDS											
													9.8	10.1	9.8	9.1	9.4	8.6	7.5	8.6	8.6	9.2	9.4	9.2

KING SALMON

10 years of record
Source: Air Weather Service

Table 8c

	WIND DIRECTION (PERCENTAGE FREQUENCY OF OCCURRENCE)												WIND SPEED (MEAN VALUES OF, IN KNOTS)											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
N	6.1	8.4	11.0	10.1	10.5	8.9	10.2	6.5	5.4	6.7	3.9	6.6	10.1	8.4	10.7	9.2	7.8	6.9	7.2	6.0	9.8	10.7	13.3	10.5
NNE	8.4	8.1	6.9	4.7	2.3	1.4	3.8	1.3	2.5	5.4	3.9	8.8	9.0	8.1	8.1	8.6	7.3	4.6	4.6	5.1	7.6	8.9	10.0	8.6
NE	10.6	13.7	14.5	6.6	3.8	3.3	3.7	3.7	3.9	8.8	7.9	15.4	8.1	7.4	7.6	6.6	5.3	4.8	4.5	4.5	5.1	6.3	7.8	8.7
ENE	2.2	2.2	1.2	.9	.5	.3	.4	.3	1.2	2.2	2.4	2.9	6.6	6.9	7.2	3.8	4.2	3.3	3.0	4.7	5.3	4.3	7.0	7.6
E	3.7	2.4	2.3	1.4	.4	.9	.7	1.5	2.0	2.0	3.9	2.1	8.8	7.8	6.3	5.1	6.5	3.2	3.0	5.7	5.0	5.3	6.3	6.1
ESE	1.3	1.0	.2	.1	.2	.1	.1		.3	1.0	.9	.3	12.4	7.6	14.0	6.0	4.5	4.0	1.0		3.3	9.7	6.3	8.7
SE	4.6	1.6	2.1	.7	2.4	.8	.8	1.9	2.7	2.3	3.6	2.3	11.1	7.0	13.7	13.7	9.5	5.6	11.4	6.4	6.3	9.4	10.6	9.7
SSE	14.7	9.3	4.9	3.2	9.8	4.1	10.1	13.7	12.7	8.1	14.5	8.4	15.1	13.8	15.4	14.6	13.2	14.3	13.4	14.1	13.7	15.6	14.4	15.4
S	16.6	10.9	12.7	10.5	17.4	14.7	13.5	15.5	14.6	10.1	15.5	11.7	11.2	11.5	13.5	13.2	12.1	13.5	13.1	13.1	12.7	10.3	10.7	10.3
SSW	2.1	1.5	2.3	2.5	.9	2.1	2.2	2.8	1.4	2.9	3.6	2.4	8.5	6.1	8.5	8.2	6.1	6.9	5.8	7.3	9.0	8.7	9.0	8.6
SW	4.4	2.0	2.5	3.3	3.9	5.4	6.5	8.0	7.4	9.8	4.6	3.7	8.1	7.1	9.1	8.9	8.4	7.9	6.5	9.3	10.1	10.9	10.8	9.4
WSW	.5	.4	1.6	1.9	.8	1.9	3.7	5.8	3.5	4.3	1.9	1.0	10.6	10.0	9.0	10.3	8.6	9.6	8.2	11.2	11.6	11.5	15.3	9.4
W	1.4	2.1	3.8	5.4	4.6	12.4	14.5	13.2	6.2	4.6	2.9	1.9	8.7	7.4	10.7	7.4	10.0	9.1	8.5	9.8	11.4	12.0	12.6	9.1
WNW	.9	.6	2.0	4.5	3.9	5.9	4.7	5.4	5.2	6.2	1.5	1.7	10.3	7.3	11.1	9.1	8.3	9.3	9.5	10.4	11.5	14.3	12.4	13.9
NW	3.4	7.5	7.0	14.2	9.4	13.3	9.3	6.4	14.8	9.0	9.0	11.7	10.3	9.8	10.4	10.9	8.4	8.0	6.2	9.9	12.4	13.7	14.6	13.5
NNW	2.8	4.7	8.2	11.9	5.3	4.4	3.7	2.1	5.4	5.9	8.8	7.2	11.2	13.1	12.2	12.5	7.5	6.8	7.1	7.7	12.3	14.6	16.3	14.4
CALM	16.3	23.7	16.8	18.1	24.2	20.1	12.3	11.8	10.9	10.8	11.5	12.0	MONTHLY AVERAGE SPEEDS											
													8.9	7.3	8.8	8.4	7.3	7.3	7.7	9.1	9.9	9.9	10.5	9.6

PORT MOLLER

4 years of record
Source: Air Weather Service

Table 8d

Table 8e

17 years of record
Source: Air Weather Service

WIND DIRECTION — PERCENTAGE FREQUENCY OF OCCURRENCE

	J	F	M	A	M	J	J	A	S	O	N	D
N	9.9	12.2	9.4	8.6	9.5	7.1	5.1	4.4	7.7	9.5	9.4	10.4
NNE	10.1	14.8	9.5	7.5	7.5	6.5	3.6	3.1	5.6	6.0	10.2	12.6
NE	7.1	8.8	7.4	8.1	5.8	7.4	3.4	2.6	4.8	3.5	5.7	8.3
ENE	9.0	8.2	9.7	6.3	6.2	7.7	4.2	2.7	3.0	3.3	6.6	7.7
E	10.5	7.0	8.1	5.1	6.1	5.9	6.2	3.5	4.1	3.9	6.3	6.8
ESE	7.5	6.5	6.3	6.6	6.0	7.5	5.4	3.4	3.7	3.5	5.3	6.2
SE	6.5	5.6	4.5	4.3	5.2	6.1	6.2	4.9	4.2	3.1	3.7	5.0
SSE	5.0	4.6	4.5	4.6	5.2	4.5	5.4	5.5	5.2	3.4	4.5	4.5
S	6.0	5.3	5.4	6.7	7.4	8.1	9.4	10.1	7.2	5.8	5.5	5.1
SSW	4.1	4.6	4.7	4.5	6.5	4.3	8.9	10.5	6.5	4.7	4.5	4.0
SW	3.2	3.5	3.3	4.5	4.4	3.8	6.8	10.5	5.2	5.3	5.3	3.6
WSW	2.7	3.6	3.3	5.0	5.1	5.5	8.1	9.4	5.1	5.6	5.2	2.5
W	3.1	3.4	3.7	4.0	4.3	5.7	8.8	9.1	7.5	9.2	6.3	3.8
WNW	3.0	2.6	3.7	5.3	4.0	4.5	4.7	5.5	6.9	8.4	5.1	3.7
NW	4.1	2.7	6.6	8.8	6.8	7.1	6.8	8.0	12.1	13.7	8.6	7.2
NNW	5.5	5.1	8.1	8.7	8.6	7.5	5.2	5.2	9.4	9.4	6.3	6.8
Calm	2.5	1.6	1.8	1.4	1.4	1.0	1.7	1.6	1.8	1.5	1.4	1.7

WIND SPEED — MEAN VALUES, SHOWN IN KNOTS

	J	F	M	A	M	J	J	A	S	O	N	D
N	18.5	19.2	16.9	16.6	14.4	12.1	10.7	12.9	13.5	15.9	16.8	17.0
NNE	17.4	18.3	14.5	14.0	15.5	13.1	11.7	11.9	13.4	16.6	15.6	17.9
NE	19.1	19.8	18.2	14.4	15.4	12.6	11.6	14.0	14.4	16.5	16.6	20.2
ENE	18.9	19.8	19.5	15.4	14.6	11.3	10.8	13.4	13.7	18.7	17.9	19.5
E	18.3	19.4	18.8	16.0	12.7	11.5	10.1	12.5	13.9	19.6	18.4	19.9
ESE	17.1	17.7	16.4	15.0	12.8	10.3	9.7	11.9	13.6	18.1	19.4	19.1
SE	16.8	16.0	14.6	14.4	12.7	11.5	10.4	12.0	13.1	18.9	17.9	19.2
SSE	16.0	16.9	14.5	14.7	12.7	10.1	10.4	11.6	15.8	17.7	17.7	17.8
S	16.5	18.3	15.5	16.1	12.4	10.3	10.4	12.5	14.5	18.1	18.3	16.9
SSW	17.2	18.8	15.7	15.4	13.1	11.3	10.9	13.5	15.0	16.7	17.7	17.9
SW	16.3	16.9	16.1	15.1	13.9	11.5	10.9	13.9	14.6	16.0	16.5	16.4
WSW	15.8	16.5	18.6	14.0	11.8	10.5	11.4	12.4	13.0	16.7	16.7	15.9
W	14.7	15.6	14.5	14.0	11.2	11.2	11.5	11.2	11.5	15.0	14.2	15.5
WNW	14.7	16.1	14.8	13.9	13.1	10.7	11.3	11.9	11.5	14.7	15.1	13.9
NW	16.4	14.8	16.2	16.1	13.9	12.6	12.2	12.9	13.7	16.7	16.3	15.3
NNW	17.7	17.4	16.7	17.1	14.5	12.7	11.2	13.0	14.4	17.5	17.0	16.9
MONTHLY AVERAGE	17.0	17.8	16.3	15.1	13.4	11.4	10.7	12.4	13.5	16.5	16.6	17.4

ST. PAUL ISLAND

	WIND DIRECTION (PERCENTAGE FREQUENCY OF OCCURRENCE)												WIND SPEED (MEAN VALUES OF, IN KNOTS)											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
N	10.5	13.0	13.9	7.5	5.4	6.9	6.6	3.4	9.0	12.8	12.6	14.7	10.6	11.5	11.7	11.2	7.2	5.7	6.2	6.5	11.3	12.2	12.5	12.0
NNE	2.5	3.9	2.4	1.9	1.2	1.3	1.3	1.2	2.0	3.6	3.7	3.6	9.4	8.7	7.7	7.4	5.3	5.1	5.2	7.3	8.1	8.8	8.4	8.2
NE	2.6	3.6	1.8	2.0	2.2	2.1	1.6	1.2	2.1	3.3	3.6	4.2	7.1	8.8	8.8	7.1	7.1	6.8	7.6	8.7	8.5	7.6	8.9	9.0
ENE	3.2	4.1	2.8	2.1	3.4	1.2	1.2	1.7	1.9	4.7	4.0	2.8	14.7	13.7	15.6	12.0	10.4	8.7	10.3	9.6	9.1	10.9	12.6	14.2
E	5.7	7.5	5.6	3.2	7.6	3.6	3.0	3.1	3.7	6.8	8.7	7.4	17.1	18.1	12.9	12.4	11.8	10.7	12.0	10.1	10.1	10.9	13.8	14.5
ESE	10.1	6.6	6.8	4.3	6.4	2.8	2.3	2.9	4.0	5.8	9.4	6.0	18.0	17.2	18.3	17.0	12.2	12.0	13.1	11.9	12.7	12.6	15.2	17.5
SE	13.4	10.1	9.0	7.3	12.8	7.3	6.6	8.8	8.5	6.1	9.9	6.8	19.6	15.8	14.9	15.7	12.7	11.6	10.7	12.8	12.7	11.5	12.6	16.5
SSE	9.7	8.7	7.5	11.0	10.5	8.7	9.1	8.1	9.3	5.6	7.1	5.0	13.3	15.4	12.7	13.9	12.4	11.0	10.8	12.0	12.0	10.3	11.2	12.4
S	5.8	6.4	8.1	8.0	11.2	8.1	12.6	11.9	11.6	5.7	5.7	4.1	11.8	11.9	12.4	10.7	11.6	10.6	11.1	10.2	10.6	9.9	10.3	11.3
SSW	1.1	2.2	2.8	2.3	2.6	2.5	5.3	7.6	5.1	2.6	2.8	1.6	11.9	10.6	11.0	10.0	10.7	10.3	10.6	10.9	10.1	9.4	9.7	10.5
SW	1.4	1.7	2.5	3.4	2.5	3.5	4.0	6.3	4.4	2.4	2.8	1.8	10.1	10.4	9.3	8.6	9.2	9.4	9.2	9.4	8.6	9.7	8.4	9.9
WSW	.6	1.2	1.8	3.7	1.5	2.1	2.0	3.9	2.9	2.3	.9	1.2	12.3	10.4	10.0	10.7	9.0	9.0	8.7	9.4	9.3	10.9	8.1	9.8
W	.5	1.8	2.6	3.3	1.9	4.7	4.5	6.4	5.2	2.8	1.7	1.9	10.3	9.0	11.9	10.0	8.0	10.0	8.9	9.0	9.6	9.1	8.8	13.0
WNW	.9	1.7	2.2	5.5	1.5	4.9	4.2	6.3	4.6	3.7	2.4	1.7	11.5	13.9	13.8	12.1	9.0	10.2	10.0	10.7	10.9	11.2	11.1	14.2
NW	4.6	4.4	6.5	8.1	5.0	10.1	7.5	8.7	7.6	10.0	5.4	4.4	12.6	12.1	11.7	11.7	10.1	9.1	9.3	9.2	10.6	13.0	14.2	12.5
NNW	5.5	5.0	6.6	9.0	5.7	8.6	5.8	4.6	9.6	9.9	5.8	9.0	14.9	13.6	12.8	12.6	9.3	8.1	7.8	7.7	12.5	13.5	16.7	13.9
CALM	21.8	18.3	17.4	17.3	18.5	21.6	22.3	13.7	8.5	11.7	13.6	23.8	MONTHLY AVERAGE SPEEDS											
													11.3	11.0	10.6	10.0	8.8	7.5	7.6	8.8	10.0	10.0	10.7	9.9

CAPE NEWENHAM

16 years of record
Source: Air Weather Service

Table 8f

	WIND DIRECTION PERCENTAGE FREQUENCY OF OCCURRENCE											
	J	F	M	A	M	J	J	A	S	O	N	D
N	6.9	10.4	9.4	7.4	5.1	3.5	3.1	2.6	4.5	5.3	7.9	10.3
NNE	5.7	7.1	5.3	4.1	3.0	2.0	1.6	1.7	3.0	3.0	4.8	6.8
NE	1.6	1.7	1.5	1.5	2.0	1.2	1.4	0.8	0.9	1.4	2.5	1.7
ENE	1.5	1.0	0.8	1.3	1.9	1.4	0.8	0.9	1.0	0.7	1.1	1.0
E	2.1	1.8	1.2	1.4	2.7	2.0	1.3	1.1	1.1	1.0	1.6	1.7
ESE	5.2	4.6	3.7	3.5	6.0	6.1	4.4	4.9	3.4	3.0	3.5	3.4
SE	12.7	12.6	10.6	11.4	15.8	16.5	14.1	15.5	10.7	7.8	9.0	7.7
SSE	15.5	15.3	13.5	12.4	15.3	18.4	18.1	15.5	15.3	9.1	11.8	11.7
S	4.7	4.6	3.9	3.5	5.4	2.8	2.8	2.6	3.2	3.2	4.9	4.4
SSW	1.5	1.9	1.4	1.1	1.4	0.4	0.3	0.6	0.9	1.4	1.7	1.6
SW	1.9	2.5	2.5	1.4	1.7	0.9	1.2	1.6	2.4	3.7	3.4	2.9
WSW	5.2	4.8	5.7	4.2	3.7	3.5	5.5	11.3	3.5	12.0	8.3	6.8
W	4.3	4.1	5.1	7.2	6.4	7.6	12.9	14.4	10.6	9.7	6.4	5.7
WNW	6.0	5.9	7.1	11.0	9.4	13.5	14.0	13.4	11.8	10.5	7.8	7.6
NW	8.1	7.6	9.9	12.6	8.6	10.5	8.7	5.8	9.4	11.5	8.9	8.4
NNW	12.3	10.1	14.2	12.2	7.4	6.0	5.1	3.3	8.5	11.9	11.7	13.1
Calm	5.0	4.2	4.1	3.8	4.4	3.8	4.7	3.9	3.7	4.7	4.8	5.1

	WIND SPEED MEAN VALUES, SHOWN IN KNOTS											
	J	F	M	A	M	J	J	A	S	O	N	D
N	14.0	15.2	14.7	14.0	11.6	9.7	8.4	9.2	11.3	13.7	14.0	15.8
NNE	17.7	15.9	16.7	13.3	11.5	8.6	6.6	8.7	12.3	14.8	15.2	18.1
NE	12.6	11.9	9.3	8.2	9.1	6.8	5.5	5.9	9.0	10.3	15.2	12.4
ENE	17.6	13.0	9.6	11.1	11.2	13.0	6.9	8.2	14.7	11.9	13.9	13.7
E	19.1	16.2	11.3	13.9	13.5	14.8	10.2	10.1	10.8	12.2	15.5	17.3
ESE	20.4	18.9	21.1	18.4	17.6	18.2	19.2	17.3	16.2	16.5	16.6	18.7
SE	20.4	20.6	19.6	18.7	18.1	18.0	16.7	18.5	15.9	17.5	18.0	17.6
SSE	19.3	20.2	19.5	19.4	18.5	18.0	17.7	18.8	17.5	18.5	18.5	19.3
S	14.3	16.1	15.3	17.1	14.6	13.1	12.7	14.5	13.5	13.5	13.6	13.7
SSW	10.7	15.1	14.2	12.9	12.1	6.7	8.2	10.3	7.0	9.7	10.6	10.6
SW	11.9	15.9	15.7	11.0	12.1	11.8	13.7	11.0	10.8	11.7	11.1	12.7
WSW	16.0	15.6	18.7	16.3	13.4	14.3	15.1	16.2	14.3	16.2	15.6	15.6
W	12.3	13.0	14.6	14.5	13.2	12.7	13.3	13.5	13.4	14.9	14.4	12.6
WNW	11.8	11.6	13.8	14.2	12.4	11.5	11.2	12.3	13.1	14.6	13.3	11.4
NW	14.4	13.6	15.8	14.7	12.3	10.7	10.3	10.7	14.2	15.9	14.7	14.2
NNW	16.3	14.7	15.2	15.1	13.5	10.8	9.7	9.7	13.9	17.6	17.6	15.6
Monthly Average Speeds	15.7	15.8	15.8	15.1	14.1	13.7	13.1	14.2	13.8	14.9	14.9	14.8

COLD BAY

27 years of record
Source: Air Weather Service

Table 8g

	WIND DIRECTION												WIND SPEED											
	PERCENTAGE FREQUENCY OF OCCURRENCE												MEAN VALUES, SHOWN IN KNOTS											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
N	4.7	4.6	8.1	7.8	4.0	5.2	3.2	2.0	3.4	4.0	5.4	7.0	16.0	11.3	14.7	11.9	9.5	7.7	6.9	6.0	12.4	13.0	18.9	14.5
NNE	10.6	10.2	7.4	14.8	10.3	14.9	12.4	4.1	9.7	7.0	8.1	12.0	17.5	16.0	12.2	13.3	11.5	8.5	9.1	7.1	13.1	13.5	17.6	17.5
NE	20.7	13.7	5.4	2.4	3.2	4.4	3.3	5.4	4.9	4.2	16.1	14.2	18.2	18.4	13.6	10.2	10.6	8.1	7.4	9.9	13.7	15.8	18.2	14.8
ENE	10.7	9.1	3.0	3.0	2.9	1.6	1.9	2.0	2.1	4.0	7.4	7.3	12.4	14.8	9.7	12.3	12.3	8.0	11.2	11.2	10.0	11.6	14.6	12.0
E	1.0	3.8	4.9	2.4	1.3	0.4	0.6	0.7	1.1	1.0	1.8	3.2	8.4	20.2	15.1	17.7	8.3	6.0	12.0	9.1	10.8	15.0	9.0	8.8
ESE	7.1	6.1	2.6	3.3	3.6	2.3	1.3	1.0	2.4	2.9	4.9	6.0	25.0	16.7	18.4	19.1	18.1	10.5	7.8	17.5	14.6	14.1	13.3	12.9
SE	3.6	5.6	7.6	2.3	4.9	2.2	0.9	2.6	6.0	3.0	5.1	2.8	12.9	17.2	18.7	15.6	17.8	19.3	17.1	12.9	24.4	13.4	13.6	12.0
SSE	11.8	17.4	17.1	13.7	16.3	11.7	19.2	18.0	22.0	8.3	13.0	12.9	14.9	16.6	20.0	17.4	16.1	16.4	17.5	16.6	18.6	16.4	17.1	14.3
S	3.8	2.7	4.8	4.9	4.5	4.9	5.0	6.7	4.0	2.6	3.0	2.2	13.1	15.6	14.8	16.3	19.0	14.0	13.6	8.3	14.1	10.4	13.1	13.9
SSW	4.7	5.6	3.1	5.6	11.2	10.8	18.8	21.5	9.7	4.9	6.8	3.4	15.7	13.3	12.1	12.5	12.5	6.4	9.2	9.9	9.7	13.6	13.9	13.0
SW	3.7	6.0	5.6	7.2	9.5	9.1	7.9	9.3	7.2	4.6	5.5	3.6	17.5	15.7	13.9	17.5	10.9	11.1	8.5	10.8	17.5	18.0	18.5	13.7
WSW	2.4	5.2	5.0	5.9	6.5	10.3	7.9	7.6	5.5	11.7	5.6	3.9	19.5	15.3	16.8	15.0	13.3	11.9	7.8	9.8	10.5	19.6	13.7	14.7
W	2.4	3.7	7.2	4.8	5.9	4.4	2.3	6.0	2.9	5.9	2.7	3.0	10.8	13.2	12.8	9.1	8.8	6.8	4.5	8.0	9.4	13.8	10.5	9.5
WNW	2.7	1.3	7.1	6.7	4.1	5.5	4.1	2.0	6.2	13.3	4.7	5.4	18.0	15.4	15.3	13.0	11.9	7.3	9.2	8.2	11.9	16.7	13.2	16.9
NW	6.8	2.0	5.3	3.6	5.8	3.0	3.0	4.6	5.1	12.6	4.9	6.2	20.2	11.5	15.8	10.1	7.9	6.9	6.3	11.5	11.4	14.3	13.0	19.3
NNW	1.6	2.2	3.9	8.9	4.2	7.2	2.7	5.0	6.4	9.2	4.4	5.6	14.0	15.1	14.4	14.1	11.0	8.5	6.1	8.6	12.4	13.7	10.1	16.7
Calm	1.6	0.8	1.9	2.7	1.8	2.1	5.5	1.5	1.5	0.7	0.6	1.3	Monthly Average Speeds											
													16.5	15.8	15.2	13.9	12.6	9.9	10.1	10.8	14.8	15.1	15.6	14.5

CAPE SARICHEF

4 years of record
Source: Air Weather Service

Table 8h

at St. Paul. This indicates that a general wind flow pattern is difficult to ascertain.

Sustained extreme winds at the reporting stations appear to range from 75 to nearly 130 km./hr. (40 to nearly 70 knots), with gusts as high as 165 km./hr. (90 knots). Wind speeds over water are faster because of less friction, except in cases of funneling through passes where the local wind speed may increase. In the event of an unusually intense storm, a sustained wind of 165 km./hr. (90 knots) is possible, although these occurrences are rare.

Average wind directions can be estimated from Figure 17, which shows surface and upper air patterns. The scale of these charts precludes their use in estimating wind speeds. Information on wind direction and speed is available from the National Weather Service.

ICE CONDITIONS

Average ice conditions of the Bristol Bay-Bering Sea area for each month of the year are given in Figure 23. In an average year, the Arctic ice pack begins to move southward

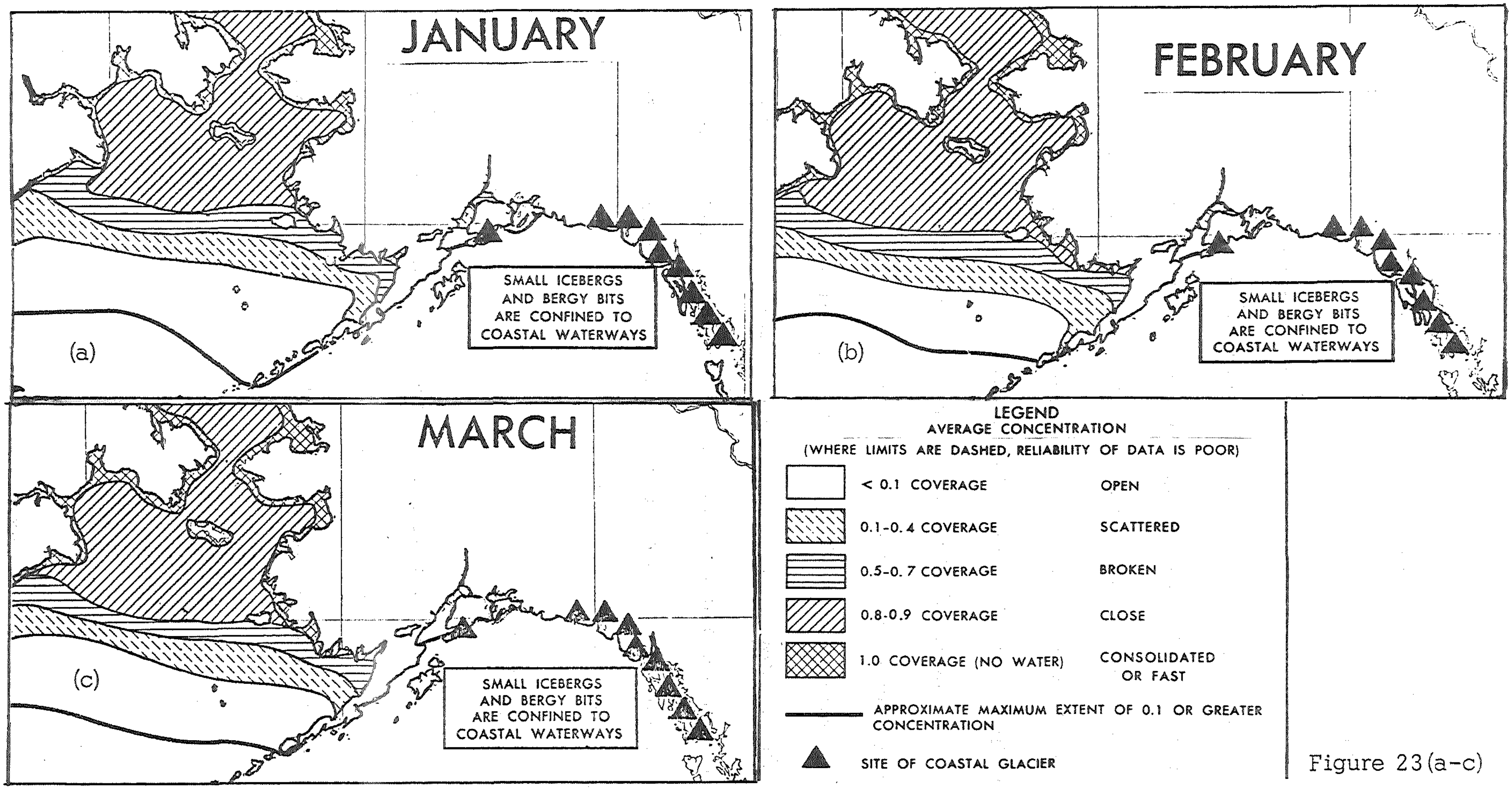


Figure 23(a-c)

ICE CONCENTRATION AND EXTREMES

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 30+ years of record

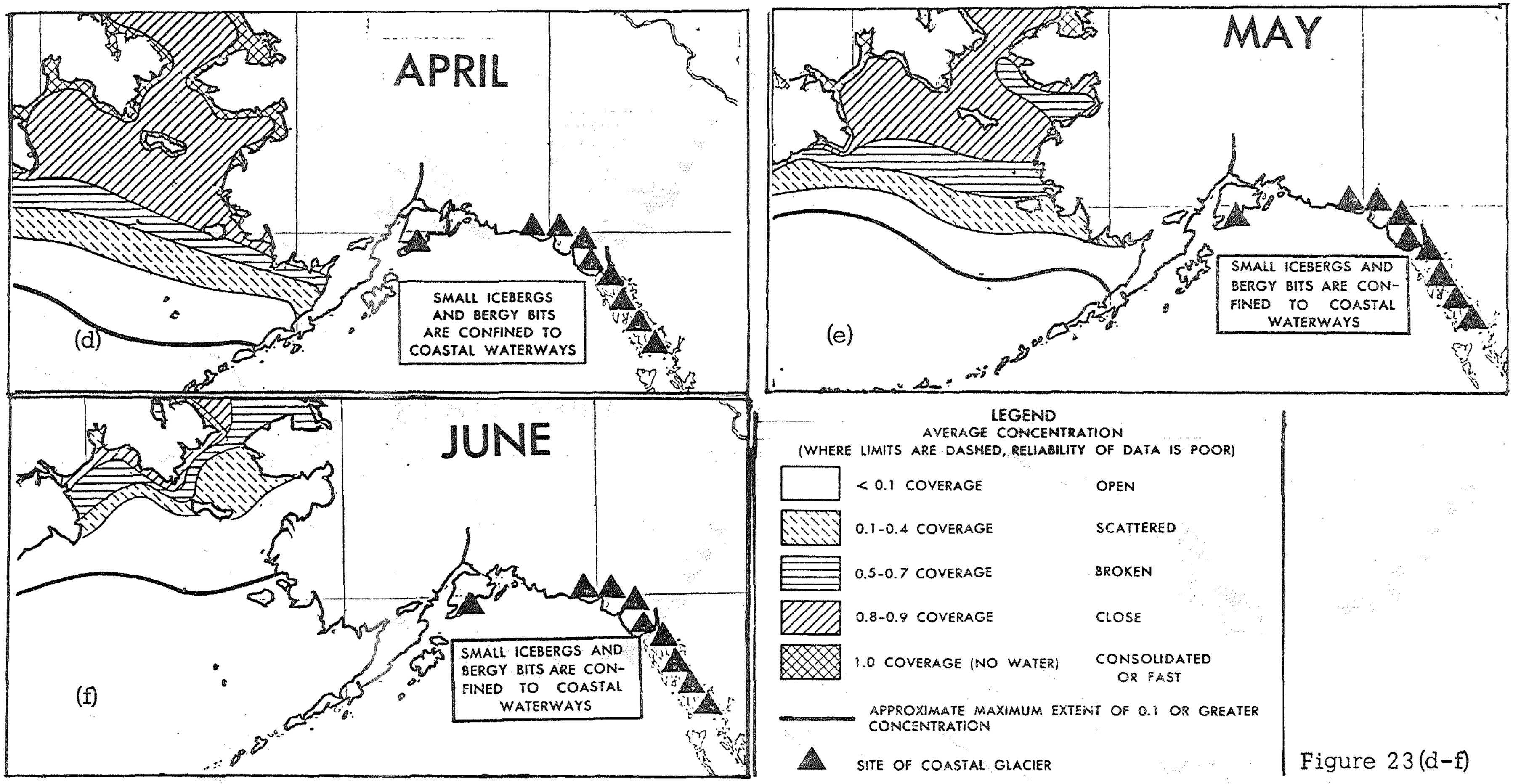


Figure 23(d-f)

ICE CONCENTRATION AND EXTREMES

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 30+ years of record

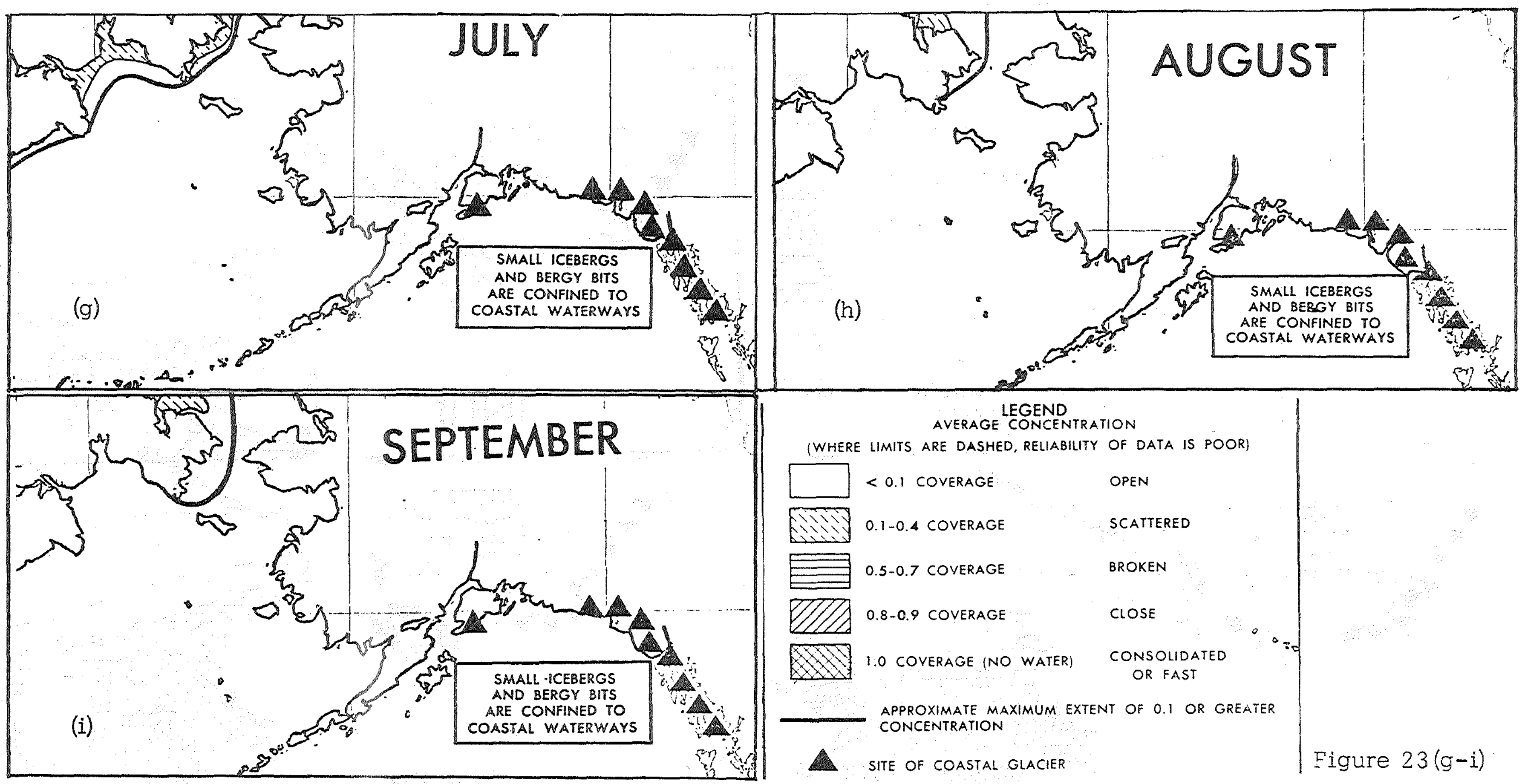


Figure 23(g-i)

ICE CONCENTRATION AND EXTREMES

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific   30+ years of record

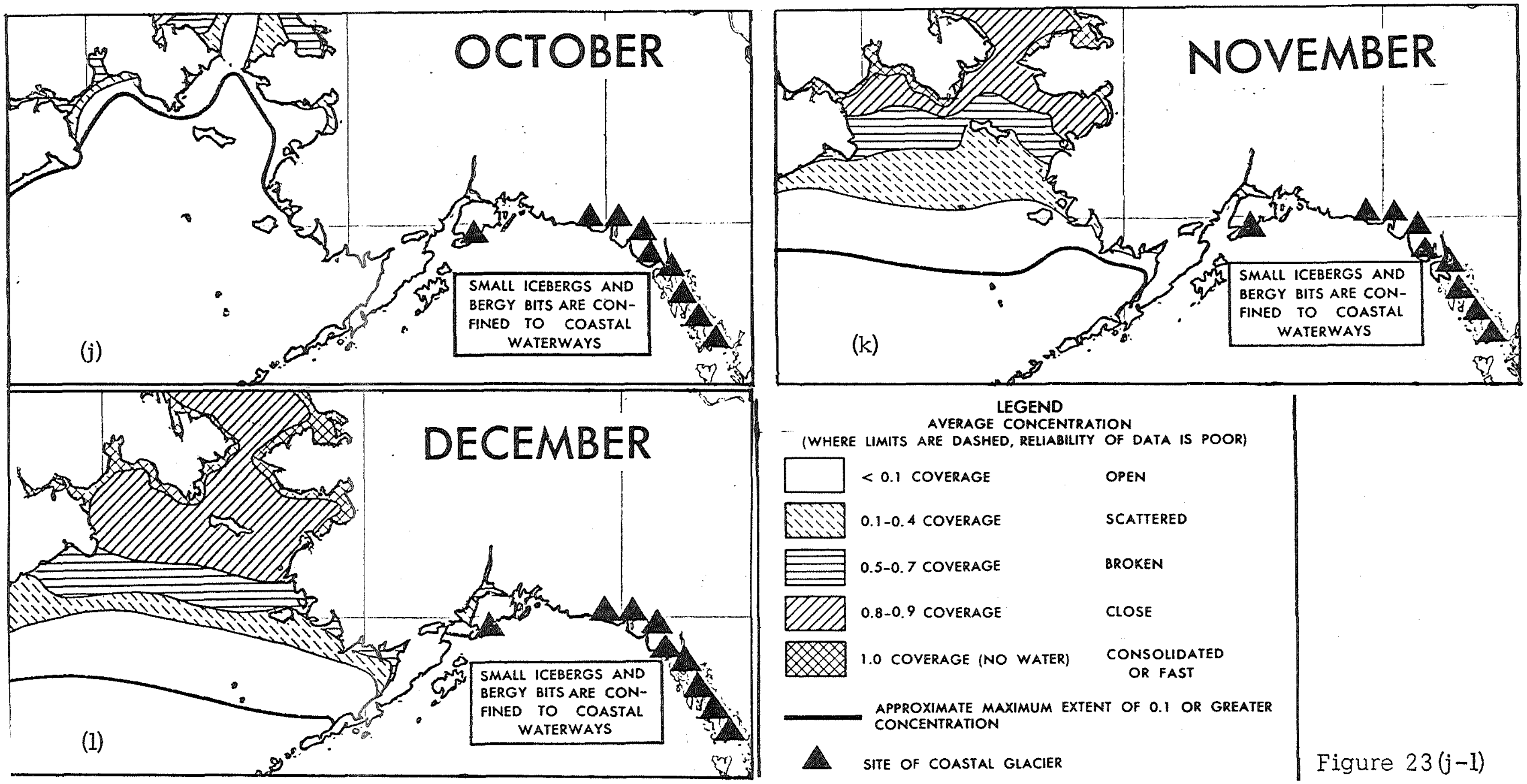


Figure 23(j-l)

ICE CONCENTRATION AND EXTREMES

Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific

30+ years of record

into the Bering Sea during late October, reaching its southernmost extent during February. Coverage is seldom solid, varying between 10 and 70 percent. The small bays and inlets, and the mouths of the streams flowing into them, also contain considerable ice, which except for tidal action, would probably be solid. Tides in inner Bristol Bay and the river estuaries are similar to those found in Cook Inlet and keep the ice from becoming solid. Ice coverage varies according to the height of the tide, with maximum occurring at low tide.

SOLAR RADIATION

The major source of heat reaching the earth's atmosphere is radiation from the sun. How much radiation reaches the earth's surface depends on several factors such as water vapor, clouds (minute liquid droplets), and latitude. Generally speaking, areas situated at higher latitudes receive correspondingly less radiation from the sun.

Thus, if all other conditions were equal, Cold Bay (the only station in the study area where radiation measurements have been made) would receive more radiation than a more northerly location. From 1964 through 1970 a comparison was made between Cold Bay and Palmer. The Cold Bay data[1] and the Palmer data (Branton et al. 1972) are available in langleys, the unit of energy defined as one gram-calorie per square centimeter. The average annual radiation at Cold Bay is 58,353 langleys, and at Palmer, 76,983 langleys. Obviously, conditions other than latitude are not equal at the two locales, and the lesser radiation at Cold Bay is due to the extensive cloud cover there. For comparison with other stations, Fairbanks receives an annual average of 87,235 langleys; Las Vegas, Nevada, approximately 185,000 langleys, and Seattle, Washington, approximately 102,000 langleys.

LENGTH OF DAYLIGHT

The total hours of daylight from sunrise to sunset varies with the latitude of a location; the higher the latitude, the greater the range between the longest and shortest days. Table 9 gives daylight lengths for 5 locations within the study area (U.S. Naval Observatory 1959).

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1. C. Peter McRoy. 1970. Solar Radiation Graph for Cold Bay. Institute of Marine Science, University of Alaska, Fairbanks. Unpublished.

WIND DATA											
	PERCENTAGE FREQUENCY OF OCCURRENCE By Speed Groups (Knots)							FASTEST MILE		HIGHEST GUST	
Month	Calm	1-3	4-12	13-24	25-31	32-46	> 46	Direction	Speed (kt)	Direction	Speed (kt)
J	1.6	3.3	30.5	47.4	12.0	4.7	0.5	ESE	52		
F	0.8	6.0	30.1	48.8	9.0	4.5	1.8	E	53		
M	1.9	5.8	36.0	42.6	8.3	5.0	0.4	SE	48		
A	2.7	6.7	41.1	39.1	6.8	3.1	0.5	S	52		
M	1.8	7.6	46.4	36.0	6.4	1.6	0.2	SE	64		
J	2.1	14.5	54.7	25.0	2.4	1.1	0.3	ESE	58	NNE	74
J	5.5	14.4	51.8	24.4	3.2	0.7	0				
A	1.5	13.2	53.5	26.5	4.1	0.9	0.3	ESE	55		
S	1.5	7.2	41.8	38.7	5.7	5.1	0				
O	0.7	4.7	36.0	44.5	9.0	4.2	0.2	ESE	50		
N	0.6	6.1	33.8	44.0	10.6	4.5	0.4	ESE	54		
D	1.3	5.4	41.3	38.6	9.0	4.3	0.1	SW	54		
YR	1.8	8.1	41.8	37.6	7.1	3.3	0.3	SE	64		

Note: Data not available where entries are omitted.

CAPE SARICHEF

HOURS OF DAYLIGHT

Station	Longest Day	Shortest Day
Port Heiden	17h 54m	6h 42m
Cape Newenham	18h 24m	6h 16m
King Salmon	18h 24m	6h 16m
St. Paul	17h 56m	6h 40m
Cold Bay	17h 26m	7h 07m

The above length of day was computed as the time between sunrise and sunset.

Source: Naval Observatory 4 years of record Table 9

EFFECT OF WEATHER ON MAN'S ACTIVITIES

Flying Weather

Terminal Conditions

Average ceiling and visibility conditions for Cold Bay, Port Moller, King Salmon, Cape Newenham, and St. Paul are given in Table 10. This table permits comparisons between stations, as well as showing seasonal variations at each station. Ceiling and visibility can be seen in combination or separately. Since flight altitudes normally are indicated with reference to sea level, a user of these charts should note the elevation of the data station being used, particularly in the case of Port Moller where the observing site is at 316 m. (1,038 ft.). A 152-meter (500-foot) ceiling here is actually at 469 m. (1,538 ft.), using sea level as a reference.

Average surface wind data are available for the above five locations plus Cape Sarichef.

Current weather data are not available for remote sites; a pilot will have to depend on his own judgment. Wind direction will be the most difficult to determine visually.

ST. PAUL ISLAND

CEILING ↓ vs ↓ ← VISIBILITY →

JANUARY

Ceiling	≥3	≥1½	≥1	≥3/4	≥1/2	≥1/4	≥0
≥ 1800	50.3	51.4	51.9	51.9	52.2	52.5	52.6
≥ 1500	59.6	61.4	62.1	62.2	62.6	63.1	63.3
≥ 1200	63.2	65.3	66.2	66.3	66.7	67.3	67.7
≥ 1000	71.5	74.5	75.7	76.0	76.6	77.2	77.6
≥ 900	72.2	75.4	76.6	76.9	77.5	78.2	78.6
≥ 800	75.0	79.0	80.5	80.9	81.7	82.4	82.8
≥ 700	77.0	81.5	83.4	83.8	84.7	85.5	86.1
≥ 600	78.2	83.4	85.6	86.2	87.3	88.2	88.8
≥ 500	79.4	85.2	88.0	88.8	90.1	91.3	92.0
≥ 400	79.9	86.2	89.5	90.5	92.2	93.6	94.3
≥ 300	80.1	86.7	90.4	91.6	93.7	95.6	96.5
≥ 200	80.1	86.9	90.9	92.1	94.5	96.8	98.2
≥ 100	80.1	86.9	91.0	92.4	94.9	97.4	99.4
≥ 0	80.1	86.9	91.0	92.4	94.9	97.4	100.0

APRIL

Ceiling	≥3	≥1½	≥1	≥3/4	≥1/2	≥1/4	≥0
≥ 1800	45.4	45.9	46.2	46.2	46.4	46.6	46.6
≥ 1500	58.4	59.3	59.8	59.9	60.2	60.5	60.6
≥ 1200	62.9	64.1	64.8	64.9	65.3	65.7	65.9
≥ 1000	72.6	74.5	75.6	75.8	76.3	76.9	77.2
≥ 900	73.4	75.3	76.5	76.7	77.2	77.8	78.1
≥ 800	76.0	78.6	80.0	80.3	81.0	81.6	81.9
≥ 700	77.6	80.5	82.3	82.7	83.4	84.0	84.4
≥ 600	79.7	83.4	85.5	86.1	86.8	87.5	87.9
≥ 500	81.0	85.2	87.8	88.5	89.4	90.2	90.6
≥ 400	82.0	86.9	90.1	90.9	92.1	93.0	93.5
≥ 300	82.8	88.2	91.8	92.7	94.5	95.8	96.4
≥ 200	83.0	88.5	92.5	93.4	95.6	97.5	98.7
≥ 100	83.0	88.5	92.6	93.5	95.8	97.8	99.4
≥ 0	83.0	88.5	92.6	93.5	95.8	98.0	100.0

JULY

Ceiling	≥3	≥1½	≥1	≥3/4	≥1/2	≥1/4	≥0
≥ 1800	17.8	18.1	18.5	18.6	18.8	18.9	19.2
≥ 1500	22.3	22.7	23.1	23.2	23.4	23.7	24.0
≥ 1200	25.9	26.4	26.9	27.0	27.3	27.5	27.8
≥ 1000	33.4	34.0	34.6	34.8	35.1	35.4	35.6
≥ 900	34.8	35.5	36.1	36.2	36.5	36.9	37.1
≥ 800	38.7	39.7	40.3	40.5	40.9	41.2	41.5
≥ 700	42.2	43.4	44.2	44.4	44.8	45.1	45.4
≥ 600	46.4	48.5	49.4	49.6	50.1	50.5	50.8
≥ 500	50.6	53.6	55.0	55.3	56.0	56.6	56.9
≥ 400	54.7	59.7	62.2	63.0	64.2	65.1	65.5
≥ 300	57.2	64.9	70.3	72.1	75.2	77.1	77.7
≥ 200	57.9	66.6	73.7	76.5	82.6	87.6	89.6
≥ 100	58.0	66.8	74.2	77.1	83.7	90.0	94.3
≥ 0	58.0	66.8	74.2	77.1	83.7	90.2	100.0

OCTOBER

Ceiling	≥3	≥1½	≥1	≥3/4	≥1/2	≥1/4	≥0
≥ 1800	57.8	57.9	57.9	58.0	58.0	58.0	58.0
≥ 1500	71.7	71.9	71.9	71.9	72.0	72.0	72.0
≥ 1200	76.7	77.0	77.0	77.1	77.1	77.1	77.1
≥ 1000	87.3	87.7	87.9	88.0	88.0	88.0	88.0
≥ 900	88.0	88.4	88.6	88.7	88.8	88.8	88.8
≥ 800	91.2	91.8	92.0	92.1	92.2	92.2	92.2
≥ 700	93.5	94.3	94.6	94.8	94.8	94.8	94.8
≥ 600	94.7	95.9	96.3	96.4	96.5	96.6	96.6
≥ 500	95.2	96.8	97.3	97.5	97.6	97.7	97.7
≥ 400	95.5	97.4	98.0	98.2	98.5	98.6	98.6
≥ 300	95.7	98.0	98.0	99.0	99.4	99.5	99.5
≥ 200	95.7	98.0	99.1	99.3	99.8	100.0	100.0
≥ 100	95.7	98.0	99.1	99.3	99.8	100.0	100.0
≥ 0	95.7	98.0	99.1	99.3	99.8	100.0	100.0

Due to the cumulative nature of this presentation, it is possible to determine the percentage frequency of occurrence for any given limit of ceiling or visibility separately, or in combination of ceiling and visibility. The totals progress to the right and downward. Ceiling may be determined independently by referring to totals in the extreme right hand column. Also, visibility may be determined independently by reference to the horizontal row of totals at the bottom of the page. The percentage frequency for which the station was meeting or exceeding any given set of minima may be determined from the figure at the intersection of the appropriate ceiling column and visibility row.

17 years of record
Source: Air Weather Service
U.S.A.F.

Table 10a

COLD BAY

CEILING vs VISIBILITY

JANUARY

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	64.3	65.7	66.2	66.3	66.7	66.9	66.9
≥ 1500	72.0	74.3	75.2	75.5	76.3	76.5	76.7
≥ 1200	75.3	78.2	79.3	79.6	80.6	80.9	81.1
≥ 1000	80.2	84.1	85.7	86.1	87.4	87.8	88.0
≥ 900	81.2	85.2	87.0	87.5	88.9	89.2	89.4
≥ 800	82.2	86.6	88.7	89.3	90.8	91.2	91.5
≥ 700	82.8	87.4	89.7	90.3	92.0	92.6	92.8
≥ 600	83.4	88.3	90.7	91.4	93.3	93.9	94.2
≥ 500	83.4	88.6	91.4	92.2	94.5	95.5	95.9
≥ 400	83.6	88.8	91.8	92.6	95.1	96.3	96.7
≥ 300	83.6	88.9	91.9	92.9	95.4	96.9	97.3
≥ 200	83.6	88.9	92.1	93.0	95.8	97.5	98.2
≥ 100	83.6	88.9	92.1	93.1	95.8	97.7	98.6
≥ 0	83.6	89.0	92.1	93.1	95.9	97.7	100.0

APRIL

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	61.9	62.8	63.0	63.0	63.1	63.1	63.2
≥ 1500	70.3	71.6	71.8	71.9	72.0	72.0	72.1
≥ 1200	74.9	76.9	77.4	77.6	77.7	77.8	78.0
≥ 1000	79.4	82.0	82.7	83.1	83.4	83.6	83.7
≥ 900	80.8	83.9	84.7	85.1	85.5	85.7	85.9
≥ 800	82.8	86.3	87.4	87.8	88.4	88.6	88.8
≥ 700	84.2	88.0	89.4	89.9	90.6	90.9	91.1
≥ 600	86.1	90.3	91.9	92.6	93.3	93.7	94.0
≥ 500	87.1	91.9	93.7	94.6	95.7	96.3	96.6
≥ 400	87.9	92.9	94.9	95.9	97.0	97.7	98.1
≥ 300	88.1	93.2	95.4	96.4	97.7	98.6	99.0
≥ 200	88.2	93.4	95.7	96.7	98.1	99.1	99.6
≥ 100	88.2	93.5	95.7	96.9	98.3	99.3	99.9
≥ 0	88.2	93.5	95.7	96.9	98.3	99.3	100.0

JULY

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	39.4	39.6	39.8	39.8	39.8	39.8	39.8
≥ 1500	47.8	48.1	48.3	48.3	48.3	48.4	48.4
≥ 1200	55.6	56.3	56.5	56.5	56.6	56.6	56.7
≥ 1000	63.3	64.7	65.0	65.1	65.2	65.2	65.2
≥ 900	66.5	68.2	68.5	68.6	68.7	68.7	68.8
≥ 800	71.6	74.0	74.4	74.5	74.6	74.6	74.7
≥ 700	75.1	77.9	78.5	78.6	78.7	78.7	78.7
≥ 600	79.1	82.8	83.5	83.7	83.9	83.9	83.9
≥ 500	81.8	86.8	88.0	88.3	88.5	88.6	88.6
≥ 400	83.7	89.8	91.3	91.7	92.1	92.2	92.2
≥ 300	84.9	91.9	93.9	94.5	95.1	95.2	95.3
≥ 200	85.4	93.2	95.8	96.7	97.6	97.8	98.0
≥ 100	85.4	93.4	96.2	97.3	98.4	99.0	99.4
≥ 0	85.4	93.4	96.2	97.3	98.4	99.1	100.0

OCTOBER

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	77.5	78.1	78.1	78.1	78.2	78.2	78.2
≥ 1500	85.2	86.3	86.4	86.5	86.5	86.5	86.5
≥ 1200	89.6	90.9	91.2	91.3	91.3	91.3	91.3
≥ 1000	92.5	94.2	94.6	94.6	94.7	94.7	94.7
≥ 900	93.2	95.1	95.5	95.6	95.7	95.7	95.7
≥ 800	94.3	96.5	97.0	97.0	97.1	97.2	97.2
≥ 700	94.8	97.1	97.7	97.7	97.9	97.9	97.9
≥ 600	95.3	97.8	98.4	98.5	98.7	98.7	98.7
≥ 500	95.5	98.2	98.9	98.9	99.2	99.3	99.3
≥ 400	95.6	98.3	99.1	99.2	99.5	99.6	99.6
≥ 300	95.6	98.4	99.3	99.4	99.7	99.8	99.8
≥ 200	95.6	98.4	99.3	99.4	99.8	99.9	99.9
≥ 100	95.6	98.4	99.3	99.5	99.8	100.0	100.0
≥ 0	95.6	98.4	99.3	99.5	99.8	100.0	100.0

Due to the cumulative nature of this presentation, it is possible to determine the percentage frequency of occurrence for any given limit of ceiling or visibility separately, or in combination of ceiling and visibility. The totals progress to the right and downward. Ceiling may be determined independently by referring to totals in the extreme right hand column. Also, visibility may be determined independently by reference to the horizontal row of totals at the bottom of the page. The percentage frequency for which the station was meeting or exceeding any given set of minima may be determined from the figure at the intersection of the appropriate ceiling column and visibility row.

27 years of record
Source: Air Weather Service
U.S.A.F.

Table 10b

PORT MOLLER

CEILING vs VISIBILITY

JANUARY

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	80.0	80.6	81.1	81.2	81.2	81.2	81.3
≥ 1500	81.9	83.0	83.6	83.7	83.8	83.9	84.0
≥ 1200	82.0	83.3	83.9	84.0	84.1	84.2	84.3
≥ 1000	84.6	86.8	88.0	88.2	88.4	88.5	88.6
≥ 900	84.6	86.8	88.0	88.2	88.4	88.5	88.6
≥ 800	84.8	87.2	88.4	88.6	88.8	88.9	89.0
≥ 700	84.8	87.2	88.4	88.6	88.8	88.9	89.0
≥ 600	85.0	87.6	88.8	89.0	89.3	89.5	89.6
≥ 500	85.6	88.4	89.8	90.9	91.7	92.3	92.5
≥ 400	85.8	88.6	90.0	91.3	92.1	92.8	93.2
≥ 300	86.1	89.0	90.4	91.7	92.7	93.6	94.1
≥ 200	86.1	89.5	91.0	92.3	93.5	95.2	96.4
≥ 100	86.1	89.5	91.0	92.3	93.5	95.3	98.0
≥ 0	86.1	89.5	91.0	92.3	93.5	95.3	100.0

APRIL

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	65.3	65.8	66.0	66.0	66.1	66.1	66.1
≥ 1500	68.7	69.4	69.6	69.6	69.9	69.9	69.9
≥ 1200	69.6	70.6	70.9	70.9	71.2	71.2	71.2
≥ 1000	72.1	73.6	74.1	74.2	74.9	74.9	74.9
≥ 900	72.2	73.7	74.2	74.3	75.0	75.0	75.0
≥ 800	73.5	75.5	76.0	76.1	77.2	77.4	77.5
≥ 700	73.7	75.7	76.2	76.3	77.4	77.7	77.8
≥ 600	73.9	75.9	76.4	76.6	77.7	78.1	78.2
≥ 500	75.0	77.8	78.8	79.1	81.6	82.1	82.4
≥ 400	75.0	77.9	79.0	79.3	81.8	82.7	83.2
≥ 300	75.4	78.6	79.6	79.9	82.9	84.3	85.0
≥ 200	75.7	79.0	80.1	80.4	83.9	86.2	88.4
≥ 100	75.7	79.1	80.3	80.6	84.3	87.3	93.3
≥ 0	75.7	79.1	80.3	80.6	84.3	87.3	100.0

JULY

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	55.0	55.4	55.4	55.4	55.4	55.7	55.7
≥ 1500	58.4	58.8	58.8	58.8	58.8	59.1	59.2
≥ 1200	59.7	60.1	60.1	60.1	60.1	60.4	60.5
≥ 1000	62.4	62.9	63.0	63.0	63.1	63.3	63.4
≥ 900	62.8	63.2	63.3	63.3	63.4	63.7	63.8
≥ 800	63.2	63.6	63.8	63.8	63.9	64.3	64.4
≥ 700	63.2	63.6	63.8	63.8	63.9	64.3	64.4
≥ 600	63.2	63.7	63.9	63.9	64.0	64.4	64.5
≥ 500	64.2	65.0	65.5	65.5	66.3	66.8	67.0
≥ 400	64.2	65.1	65.8	65.8	66.7	67.3	67.5
≥ 300	64.4	65.3	66.0	66.0	67.2	68.3	68.7
≥ 200	64.5	65.5	66.4	66.4	68.1	70.9	71.9
≥ 100	64.6	65.7	66.7	66.7	68.7	73.1	76.4
≥ 0	64.6	65.7	66.7	66.7	68.7	73.3	100.0

OCTOBER

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	71.9	72.1	72.2	72.2	72.3	72.3	72.4
≥ 1500	77.8	78.3	78.4	78.4	78.5	78.5	78.6
≥ 1200	78.7	79.2	79.3	79.3	79.4	79.4	79.4
≥ 1000	82.3	83.2	83.3	83.3	83.3	83.3	83.4
≥ 900	83.0	83.8	83.9	83.9	84.0	84.0	84.1
≥ 800	83.9	84.9	85.0	85.0	85.1	85.1	85.2
≥ 700	84.0	85.0	85.1	85.1	85.2	85.2	85.3
≥ 600	84.4	85.3	85.4	85.4	85.5	85.5	85.6
≥ 500	85.1	86.5	86.8	86.8	87.2	87.2	87.3
≥ 400	85.2	86.9	87.2	87.2	87.5	87.5	87.7
≥ 300	85.4	87.3	87.7	87.8	89.0	89.3	89.6
≥ 200	85.6	87.5	88.2	88.3	89.9	91.1	91.7
≥ 100	85.7	87.6	88.3	88.5	90.4	92.3	94.6
≥ 0	85.7	87.6	88.3	88.5	90.4	92.3	100.0

Due to the cumulative nature of this presentation, it is possible to determine the percentage frequency of occurrence for any given limit of ceiling or visibility separately, or in combination of ceiling and visibility. The totals progress to the right and downward. Ceiling may be determined independently by referring to totals in the extreme right hand column. Also, visibility may be determined independently by reference to the horizontal row of totals at the bottom of the page. The percentage frequency for which the station was meeting or exceeding any given set of minima may be determined from the figure at the intersection of the appropriate ceiling column and visibility row.

4 years of record
Source: Air Weather Service
U.S.A.F.

Table 10c

KING SALMON

CEILING ↓ vs ↓ ← VISIBILITY →

JANUARY

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	83.7	84.9	85.5	85.7	86.2	86.4	86.5
≥ 1500	85.5	87.0	87.7	87.9	88.4	88.7	88.8
≥ 1200	87.2	89.0	89.8	90.1	90.6	90.9	91.0
≥ 1000	88.6	90.7	91.7	92.2	92.8	93.1	93.2
≥ 900	89.1	91.4	92.5	92.9	93.5	93.8	94.0
≥ 800	89.8	92.4	93.6	94.1	94.8	95.1	95.3
≥ 700	90.4	93.2	94.5	95.0	95.7	96.0	96.2
≥ 600	90.8	93.7	95.2	95.7	96.4	96.8	97.0
≥ 500	91.1	94.1	95.8	96.3	97.2	97.6	97.7
≥ 400	91.3	94.5	96.3	96.9	97.8	98.3	98.4
≥ 300	91.4	94.7	96.6	97.3	98.3	98.8	99.0
≥ 200	91.5	94.8	96.7	97.5	98.5	99.2	99.4
≥ 100	91.5	94.9	96.8	97.6	98.7	99.5	99.7
≥ 0	91.5	94.9	96.8	97.6	98.8	99.5	100.0

APRIL

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	81.4	81.9	82.0	82.0	82.1	82.1	82.2
≥ 1500	84.7	85.5	85.6	85.7	85.7	85.8	85.9
≥ 1200	87.5	88.6	88.8	88.9	89.0	89.1	89.1
≥ 1000	89.6	91.0	91.5	91.6	91.7	91.8	91.9
≥ 900	90.3	92.0	92.4	92.6	92.7	92.8	92.9
≥ 800	91.4	93.4	93.9	94.1	94.3	94.4	94.5
≥ 700	92.2	94.5	95.1	95.4	95.5	95.6	95.7
≥ 600	93.0	95.5	96.3	96.6	96.8	96.9	97.0
≥ 500	93.5	96.0	96.9	97.3	97.6	97.7	97.7
≥ 400	93.9	96.6	97.6	98.0	98.3	98.4	98.5
≥ 300	94.1	96.9	98.0	98.4	98.7	98.9	99.0
≥ 200	94.2	97.2	98.3	98.7	99.1	99.3	99.4
≥ 100	94.2	97.2	98.4	98.9	99.3	99.6	99.8
≥ 0	94.2	97.2	98.4	98.9	99.3	99.6	100.0

JULY

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	68.2	68.5	68.6	68.7	69.0	69.2	69.5
≥ 1500	72.4	72.7	72.9	73.0	73.2	73.5	73.8
≥ 1200	76.6	77.1	77.3	77.3	77.6	77.8	78.1
≥ 1000	80.3	80.9	81.2	81.3	81.5	81.8	82.1
≥ 900	82.0	82.8	83.1	83.2	83.4	83.7	84.0
≥ 800	84.1	85.2	85.5	85.7	85.9	86.2	86.5
≥ 700	85.6	87.0	87.4	87.6	87.9	88.1	88.4
≥ 600	87.2	89.0	89.6	89.7	90.0	90.3	90.6
≥ 500	88.7	91.0	91.9	92.1	92.4	92.7	93.0
≥ 400	89.9	92.8	93.9	94.1	94.5	94.9	95.2
≥ 300	90.6	94.0	95.3	95.7	96.2	96.8	97.1
≥ 200	91.0	94.7	96.2	96.7	97.4	98.1	98.6
≥ 100	91.0	94.9	96.5	97.1	97.9	98.9	99.5
≥ 0	91.0	94.9	96.5	97.1	98.0	99.1	100.0

OCTOBER

Ceiling	≥ 3	≥1½	≥ 1	≥3/4	≥1/2	≥1/4	≥ 0
≥ 1800	85.9	86.3	86.5	86.6	86.8	87.0	87.1
≥ 1500	88.6	89.1	89.3	89.4	89.6	89.8	89.9
≥ 1200	90.7	91.3	91.5	91.6	91.9	92.1	92.2
≥ 1000	92.4	93.1	93.5	93.6	93.8	94.1	94.2
≥ 900	92.9	93.7	94.1	94.3	94.5	94.7	94.9
≥ 800	93.6	94.0	95.0	95.2	95.5	95.7	95.8
≥ 700	94.2	95.3	95.8	96.0	96.3	96.5	96.7
≥ 600	94.6	95.8	96.4	96.7	97.0	97.2	97.4
≥ 500	94.9	96.3	97.0	97.3	97.7	97.9	98.1
≥ 400	95.2	96.7	97.4	97.8	98.2	98.5	98.7
≥ 300	95.4	97.0	97.8	98.3	98.8	99.1	99.3
≥ 200	95.5	97.1	98.0	98.5	99.0	99.4	99.6
≥ 100	95.5	97.2	98.0	98.6	99.1	99.6	99.8
≥ 0	95.5	97.2	98.0	98.6	99.2	99.6	100.0

Due to the cumulative nature of this presentation, it is possible to determine the percentage frequency of occurrence for any given limit of ceiling or visibility separately, or in combination of ceiling and visibility. The totals progress to the right and downward. Ceiling may be determined independently by referring to totals in the extreme right hand column. Also, visibility may be determined independently by reference to the horizontal row of totals at the bottom of the page. The percentage frequency for which the station was meeting or exceeding any given set of minima may be determined from the figure at the intersection of the appropriate ceiling column and visibility row.

10 years of record
Source: Air Weather Service

Table 10d

CAPE NEWENHAM

CEILING ↓ vs ↓ VISIBILITY

JANUARY

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	58.9	60.4	61.0	61.1	61.5	61.6	61.6
≥ 1500	62.3	63.9	64.5	64.6	65.1	65.2	65.2
≥ 1200	66.5	68.6	69.4	69.6	70.0	70.1	70.1
≥ 1000	69.8	72.5	73.7	73.9	74.3	74.4	74.4
≥ 900	72.1	75.6	77.0	77.2	77.7	77.8	77.9
≥ 800	74.8	79.3	81.0	81.3	81.9	82.1	82.1
≥ 700	77.6	83.1	85.1	85.5	86.3	86.5	86.6
≥ 600	79.5	85.8	88.6	89.2	90.1	90.4	90.6
≥ 500	80.6	87.9	91.2	91.9	93.0	93.4	93.7
≥ 400	81.3	89.1	92.8	93.6	94.7	95.2	95.5
≥ 300	81.5	89.6	93.4	94.3	95.8	96.8	97.1
≥ 200	81.5	89.7	93.7	94.7	96.4	97.7	98.3
≥ 100	81.5	89.7	93.7	94.7	96.7	98.2	99.1
≥ 0	81.5	89.7	93.7	94.8	96.8	98.4	100.0

APRIL

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	48.0	48.9	49.1	49.2	49.3	49.5	49.7
≥ 1500	54.0	55.1	55.4	55.4	55.5	55.8	55.9
≥ 1200	59.2	60.6	61.0	61.1	61.2	61.4	61.5
≥ 1000	63.5	65.5	65.9	66.1	66.2	66.4	66.6
≥ 900	66.3	68.7	69.2	69.5	69.7	69.9	70.1
≥ 800	69.7	72.8	73.4	73.8	74.1	74.4	74.5
≥ 700	73.4	77.3	78.4	78.8	79.2	79.5	79.7
≥ 600	76.8	81.7	83.2	84.0	84.6	84.9	85.1
≥ 500	79.4	85.7	87.8	88.7	89.4	90.0	90.2
≥ 400	80.4	87.8	90.3	91.3	92.4	93.1	93.3
≥ 300	81.0	89.0	92.0	93.1	94.4	95.5	95.9
≥ 200	81.1	89.4	92.9	94.0	95.7	97.2	98.0
≥ 100	81.2	89.4	93.0	94.1	96.1	97.9	99.1
≥ 0	81.2	89.4	93.0	94.1	96.2	98.1	100.0

JULY

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	43.0	43.7	44.1	44.1	44.4	44.5	44.6
≥ 1500	45.1	45.8	46.2	46.3	46.6	46.6	46.8
≥ 1200	49.0	49.9	50.4	50.4	50.8	50.9	51.0
≥ 1000	51.9	53.0	53.6	53.7	54.1	54.2	54.3
≥ 900	54.4	55.6	56.3	56.4	56.8	56.9	57.0
≥ 800	58.3	60.0	60.8	60.9	61.4	61.5	61.6
≥ 700	63.1	65.2	66.6	66.7	67.4	67.5	67.7
≥ 600	70.4	73.3	75.6	75.7	76.5	76.7	76.9
≥ 500	75.2	79.9	82.7	82.8	83.6	83.8	84.0
≥ 400	78.1	84.3	87.7	87.8	88.7	89.0	89.3
≥ 300	79.4	87.3	91.2	91.5	93.1	93.4	93.8
≥ 200	79.9	88.2	92.7	93.2	95.3	96.2	97.3
≥ 100	79.9	88.6	93.1	93.6	95.9	97.1	98.6
≥ 0	79.9	88.7	93.2	93.7	96.3	97.6	100.0

OCTOBER

Ceiling	≥ 3	≥ 1½	≥ 1	≥ 3/4	≥ 1/2	≥ 1/4	≥ 0
≥ 1800	61.3	61.5	61.5	61.5	61.5	61.5	61.5
≥ 1500	67.7	68.0	68.0	68.0	68.1	68.1	68.1
≥ 1200	74.9	75.4	75.6	75.6	75.6	75.7	75.7
≥ 1000	78.5	79.3	79.5	79.5	79.6	79.6	79.6
≥ 900	81.5	82.7	83.0	83.0	83.1	83.1	83.2
≥ 800	84.7	86.4	86.7	86.7	86.8	86.9	86.9
≥ 700	88.1	90.2	90.6	90.7	90.9	90.9	90.9
≥ 600	90.8	93.4	93.9	94.1	94.2	94.3	94.3
≥ 500	92.2	95.2	95.8	96.0	96.2	96.3	96.3
≥ 400	93.3	96.6	97.5	97.8	98.0	98.1	98.1
≥ 300	93.5	97.1	98.2	98.7	99.0	99.1	99.2
≥ 200	93.6	97.2	98.3	98.9	99.5	99.7	99.7
≥ 100	93.6	97.3	98.4	98.9	99.6	99.8	100.0
≥ 0	93.6	97.3	98.4	98.9	99.6	99.9	100.0

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16 years of record
Source: Air Weather Service

Table 10e

Often a study of the local terrain will give a reasonably good approximation of the wind direction.

Enroute Weather

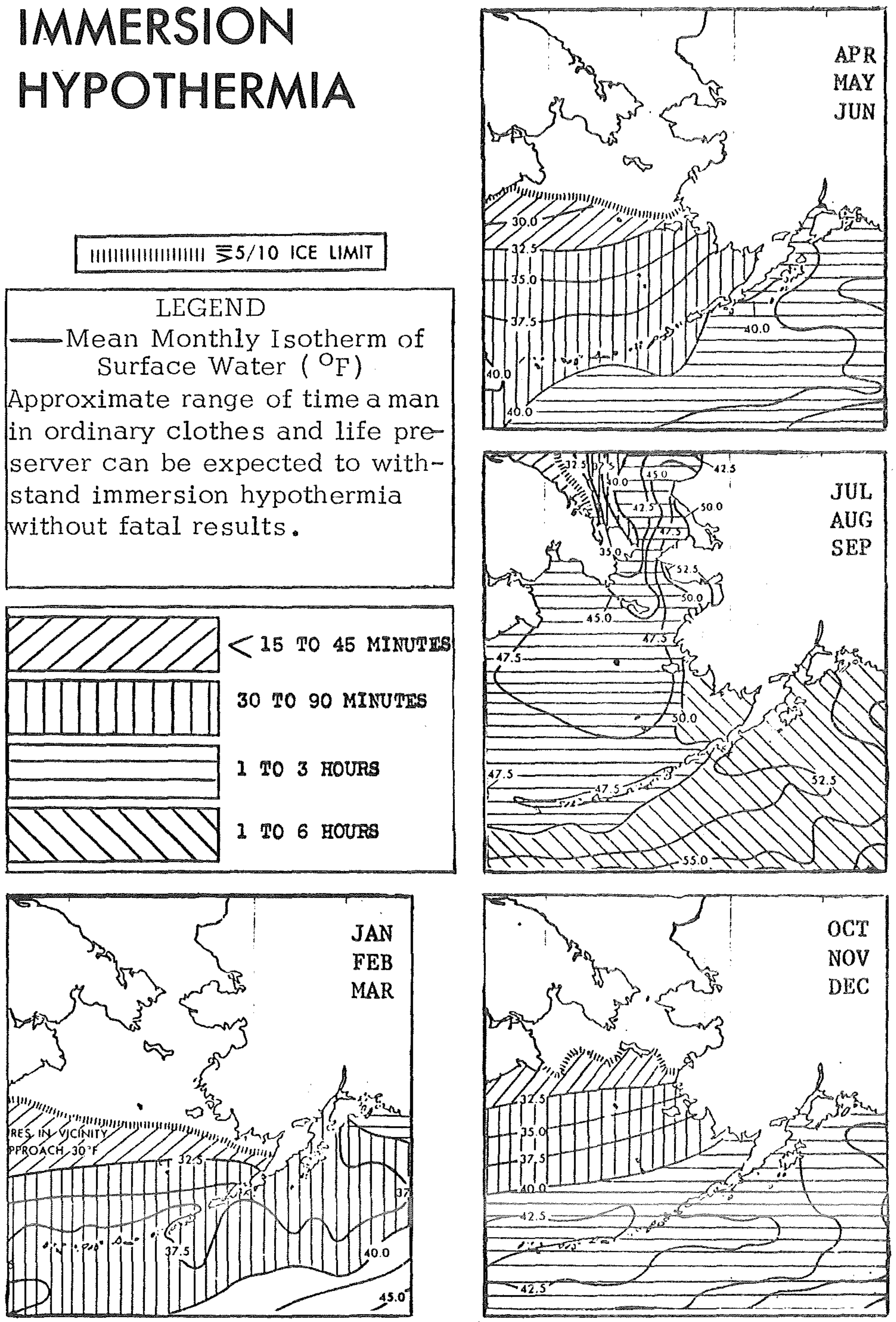
Information on cloud cover, heights of cloud bases and tops, visibility, turbulence, freezing altitude, aircraft icing, and winds at various altitudes are all important ingredients in flight planning. All of these factors will vary in amount or intensity with the season. Actual data for these parameters exist only at specific observation sites. Therefore it is advisable to request a forecast weather briefing from a Federal Aviation Administration Flight Service Station or a National Weather Service office.

Immersion Hypothermia

Hypothermia is defined as a subnormal body temperature (U.S. Navy Hydrographic Office 1961). Immersion hypothermia involves a loss of body heat to the water. It is assumed that a person will die if his rectal temperature, normally 37.6 degrees C (99.6 degrees F), drops below 25.9 degrees C (78.6 degrees F).

The approximate survival time of human beings in the sea is directly related to the sea surface temperatures, although it may also be affected by general physique, position of the body in the water, amount and type of clothing, and amount of subcutaneous fat. Immersion hypothermia showing approximate survival time is depicted in Figure 24 (U.S. Navy Hydrographic Office 1961). Survival times must be viewed as broad estimates because data records do not incorporate many uncontrollable physiological variables. For example, neither quantitative appraisal nor records have been made of such intangible factors as the physical condition of the immersed individual or of his will to survive. Table 11 relates water temperature to approximate survival time of humans immersed in the sea.

There are two principal schools of thought with regard to survival techniques during immersion: (1) vigorous exercise and (2) passive waiting. Vigorous exercise may dissipate heat reserves more rapidly, but within reasonable time limits it may keep muscles warm and prevent them from stiffening. During passive waiting, shivering maintains heat



Source: Climatological and Oceanographic Atlas for Mariners, Vol. II North Pacific 20 years of record

Figure 24

IMMERSION HYPOTHERMIA

Water Temp. (F)	Exhaustion or Unconsciousness	Expected Time of Survival
32.5	15 min.	15-45 min.
32.5-40.0	15-30 min.	30-90 min.
40-50	30-60 min.	1-3 hr.
50-60	1-2 hr.	1-6 hr.
60-70	2-7 hr.	2-40 hr.
70-80	3-12 hr.	3-Indef.
80	Indef.	Indef.

The above table relates water temperature to approximate survival time of humans immersed in the sea.

Source: Climatological and Oceanographic Atlas for Mariners Vol. II North Pacific.

20 years of record

Table 11

production for as long as the rectal temperature remains between 35.0 and 37.6 degrees C (95.0 and 99.6 degrees F). Passive waiting is currently the somewhat favored technique.

Surface Activities

The fog that persists during summer months over the area can pose serious hazards to boats, ships, and aircraft. Dense fog can also create hazardous driving conditions, particularly on roads at higher elevations. Few roads exist in the area at present.

Storms can produce adverse conditions at any time of the year. The greatest storm intensity is during winter months when surface winds over open water will occasionally reach speeds of 130 to 165 km./hr. (70 to 90 knots). With a long fetch, winds will produce waves of 3.7 to 4.5 m. (12 to 15 ft.). While wind speeds over land are not as strong as those over water, they are at times strong enough to damage inadequately designed structures, such as towers and platforms, and improperly secured aircraft. Strong, gusty winds also create problems for aircraft in takeoff and landing. With freezing temperatures, ocean spray, liquid precipitation, and fog will form ice on structures. This can be a particular problem to vessels and platforms. Icing will also pose problems for shore-based structures. During periods of northerly winds, the chill temperature can reach low values. A typical example for the study area is an air temperature of -18 degrees C and a wind speed of 24 km./hr. The resulting chill temperature is -34 degrees C.

Air above the Surface

Adverse conditions above the surface affect flying activities and structures such as mountaintop installations. All of the factors discussed above are applicable above the surface, except for the ocean waves. Wind speeds are stronger, the fog is now clouds, and ice accumulates on aircraft. Hazardous turbulence created by storms or winds in the vicinity of mountains can also be encountered.

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GEOLOGY

BEDROCK GEOLOGY

Introduction

The onshore bedrock geology of the Bristol Bay region can be grouped into 3 crustal subdivisions which correspond to 3 of the 4 major physiographic provinces of the area--the Aleutian Range, the Bristol Bay-Nushagak Lowlands, and the Ahklun Mountains (Figure 3). These subdivisions probably extend offshore beneath the waters of Bristol Bay, but details of the offshore geology are still speculative.

There is little detailed geologic information available about the region; most data are of a reconnaissance nature. Extensive work by petroleum companies in the region has produced some detailed data, but these are of a proprietary nature and not generally available to the public.

Figure 25 summarizes the geologic knowledge that is available; the accompanying index map (Figure 26) indicates the sources of geologic data used to compile Figure 25. More detailed information can be obtained from these sources.

Figure 25. Generalized geologic map of the Bristol Bay region (from Hoare 1961, Mertie 1938 and Burk 1965)

LEGEND

Geologic Units

1-Clastic (shale, sandstone, conglomerate), carbonate, and volcanic rocks (metamorphosed in part) of Paleozoic to Early Jurassic age - "basement."

2-Granitic plutonic rocks of mainly Early to Middle Jurassic age (contains some younger plutonic rocks).

3-Clastic rocks of Middle Jurassic to Late Cretaceous age.

4-Clastic and volcanic rocks of Tertiary age.

5-Granitic plutonic rocks of Middle Tertiary age.

6-Clastic, carbonate and volcanic rocks (eugeosynclinal) of Mississippian to Early Cretaceous age--Gemuk Group.

7-Clastic rocks of Early to Late Cretaceous age--Kuskokwim Group.

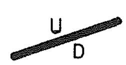
8-Igneous intrusions (mostly granitic) of Late Cretaceous or younger age.

9-Basalt flows of Late Tertiary to Early Pleistocene age.

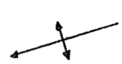
10-Unconsolidated glacial and fluvial sediments of Quaternary to Recent (Holocene) age.

X - Recent and active volcanoes.

 - Contact between geologic units



- Major faults

 - Major anticlinal axes

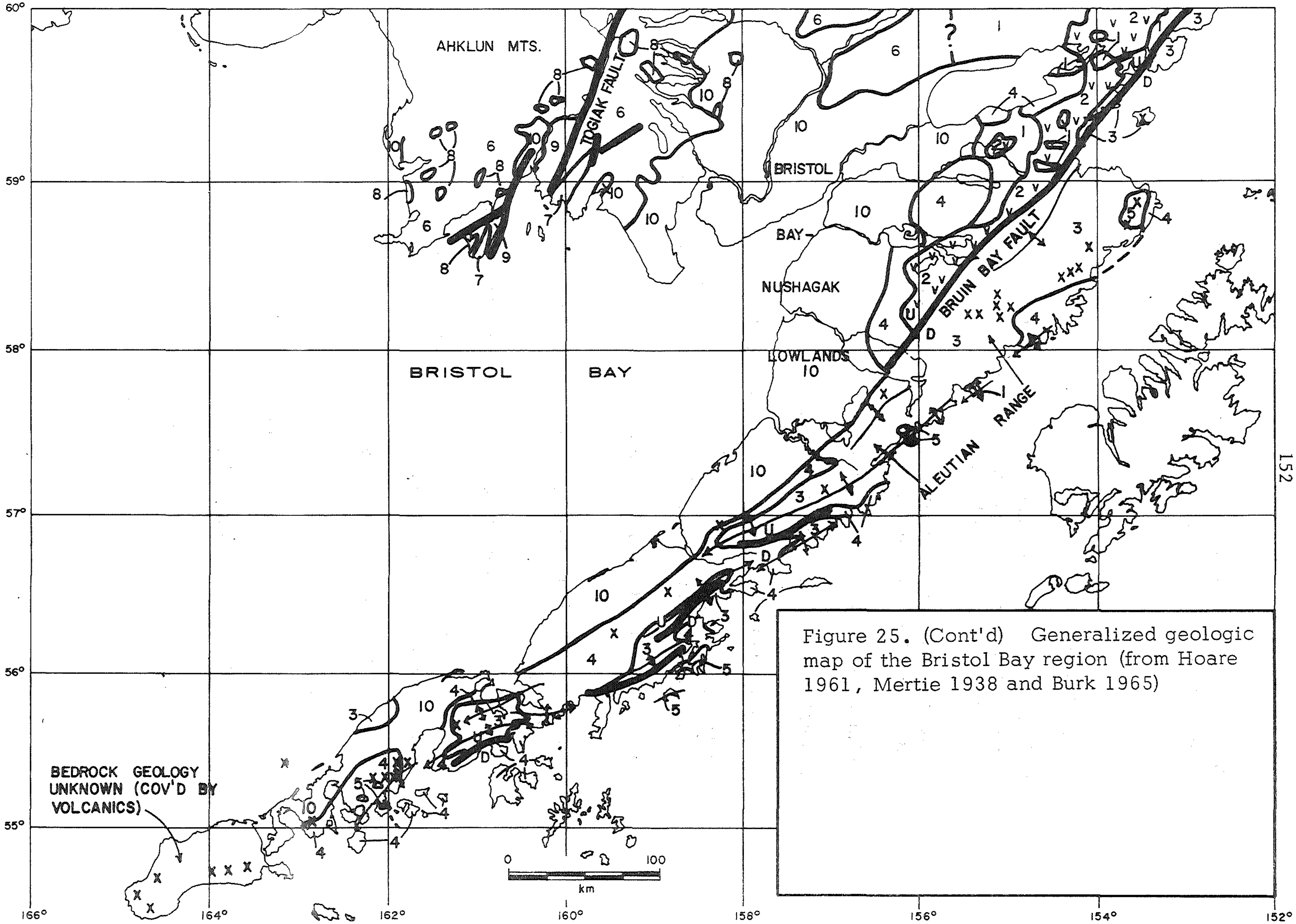


Figure 25. (Cont'd) Generalized geologic map of the Bristol Bay region (from Hoare 1961, Mertie 1938 and Burk 1965)

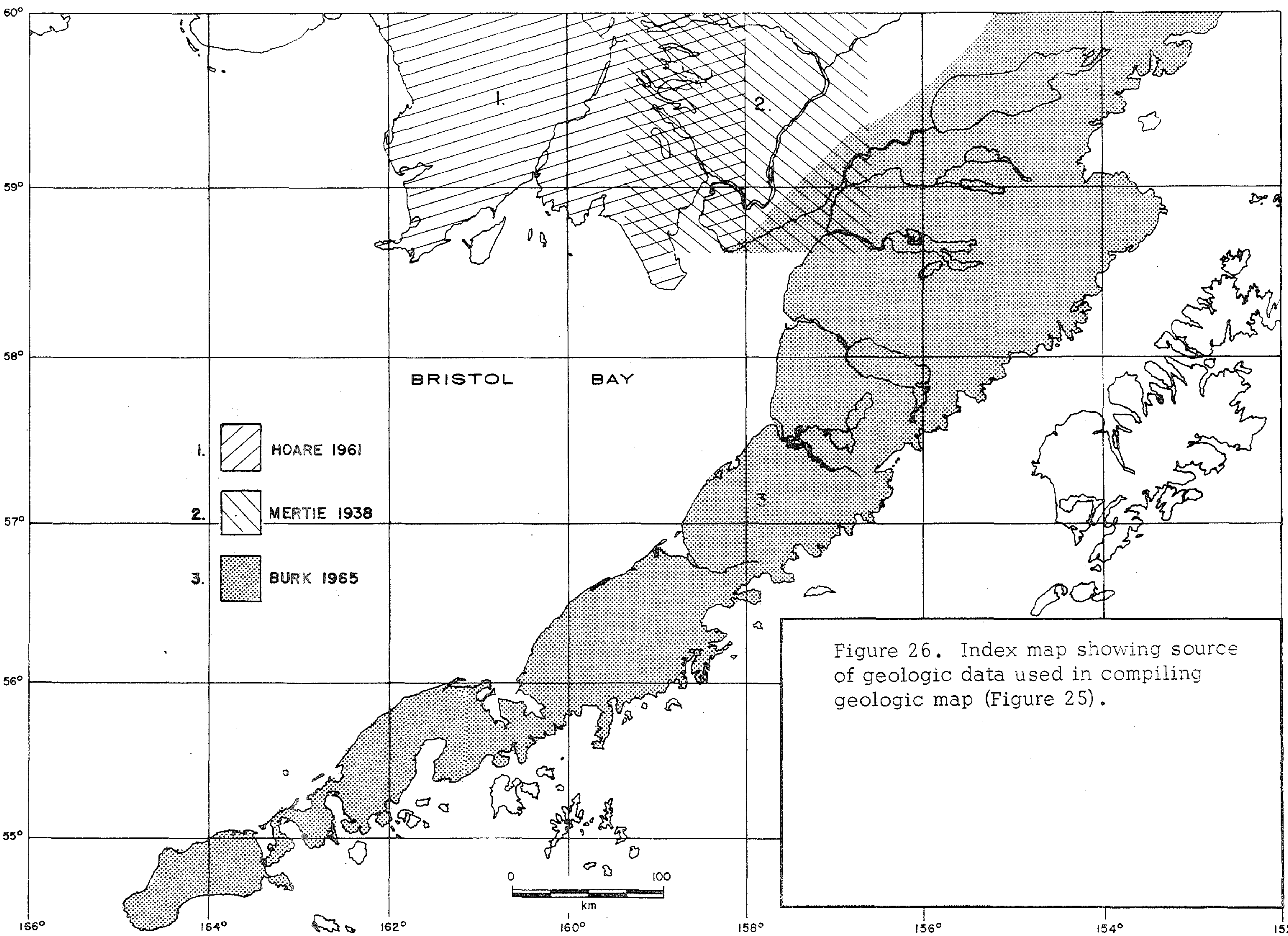


Figure 26. Index map showing source of geologic data used in compiling geologic map (Figure 25).

The units shown on the geologic map represent groupings of rocks of similar lithology and geologic history. Figure 27 shows the various geologic units found in the region, including names, ages, thicknesses, and basic lithologic descriptions. This chart correlates the ages of the various geologic units within the Bristol Bay area.

The bedrock geology of each of the 3 crustal subdivisions and the geology of the offshore area are discussed in more detail below.

Aleutian Range

The Aleutian Range is a broad linear upwarp composed mainly of sedimentary and volcanic rocks ranging in age from Late Paleozoic to Recent. These rocks have been studied by various investigators since the turn of the century (Figure 26), but the best and most complete work is by Burk (1965). That study summarizes what is known about the geologic and tectonic history of the entire area, and has become the standard geologic reference. The Alaska Peninsula portion of the geologic map and accompanying charts were based on data from this report (Figures 25 and 27).

AGE			Southern Alaska Peninsula	Central Alaska Peninsula	N. Alaska Peninsula - Lower Cook Inlet	Ahklun Mountains
Mesozoic	Jurassic	M	Not Exposed	(See above)	(See above)	(See above)
Mesozoic	Jurassic	Early		Largely dark sh., ss., limy concretions in upper 400m. with tuff. and calc. sh., ss. and volc. breccia in lower 300m? (700m.)	Porphyritic flows, breccias, tuffs (latite to basalt), some argillite and graywacke (unfossil.) (+2450m. ?max.)	Gemuk Group Argillite, chert, greenstone, lst. graywacke, tuff. Andesitic and basalt flows, interbed. tuff, breccia, fine-and crs.-gr. sed. rocks. Jur. fossils. Lst. with Monotis. Perm. volc. rocks and lsts. Miss. fossils (4,575-9,150m.)
Mesozoic	Triassic	Late		Thin lsts. with calc. sh., containing Monotis subcircularus. Cherty beds at base (+425m. ?)	Kamishak Fm. Calc. sh. lst., chert, Monotis subcircularus and Halobia spp. (+600 m.) ?	
Mesozoic	Triassic	Mid. & Early		? ? Volc. flows, breccias, tuffs, sills on isolated islets, Mid-Permian fossils collected from single lst. (+1225m. ?) (Probably Permo-Triassic)	Alted. greenstone, volc. flows, tuffs, breccias of unknown thickness; unfossil. (Presumably Permo-Triassic)	
Mesozoic	Permian					
Paleozoic	Carboniferous			? ? ? Not Exposed	? ? Slate, graywacke, chert, lst., marble, calc. schist, gneiss, qtzite, mica schist. Age unknown, prob. Paleozoic	
				Map Unit 1	Map Unit 1	Map Unit 6

Figure 27. Correlation chart of geologic units, Bristol Bay region (from Hoare 1961 and Burke 1965).

AGE			Southern Alaska Peninsula	Central Alaska Peninsula	N. Alaska Peninsula - Lower Cook Inlet	Ahklun Mountains
Mesozoic	Cret.	Early	Map Unit 3: Staniukovich Fm. Arkosic ss., sltst. (0-600m.)	Map Unit 3: Staniukovich Fm. Arkosic ss., sltst. (0-600m.)	Map Unit 3: (hatched)	Map Unit 6
	Jurassic	Late	Naknek Fm. Arkosic ss, sltst., cgl., clyst. (900-1500m.+) ? ? Not Exposed	Naknek Fm. Upper dark sltst. and fine-gr. ss. Lower arkosic ss, cgl. sltst. (1500-3000m.+) Congl., breccia "Chisik Cgl."	Naknek Fm. Arkosic ss., some cgl., tuff. Siltst. and arkose in lower part (1700m.+) Chisik Cgl. Mb. (0-120m.)	Upper Part of Gemuk Group (see description below)
		Middle	Not Exposed	Shelikof Fm. sh., ss., cgl. (1600-2200m.) ? Kialagvik Fm. ss., sh., some cgl. (530 m.)	Chinitna Fm. Sltst., some ss., calc. concretions (600-900m.) ? Tuxedni Group. Cgl., ss., sh., sltst., ash beds (2000m.+), includes Bowser, Twist Ck., Cynthia Falls, Fitz Ck., Gaikema Red Glacier Fms. plus L. Bajocian sltst., ss.	
		E.	Not Exposed	Map Unit 1: ? ? (see below)	Map Unit 2: Granite batholiths (176-154 m.y.)	

Figure 27 (continued)

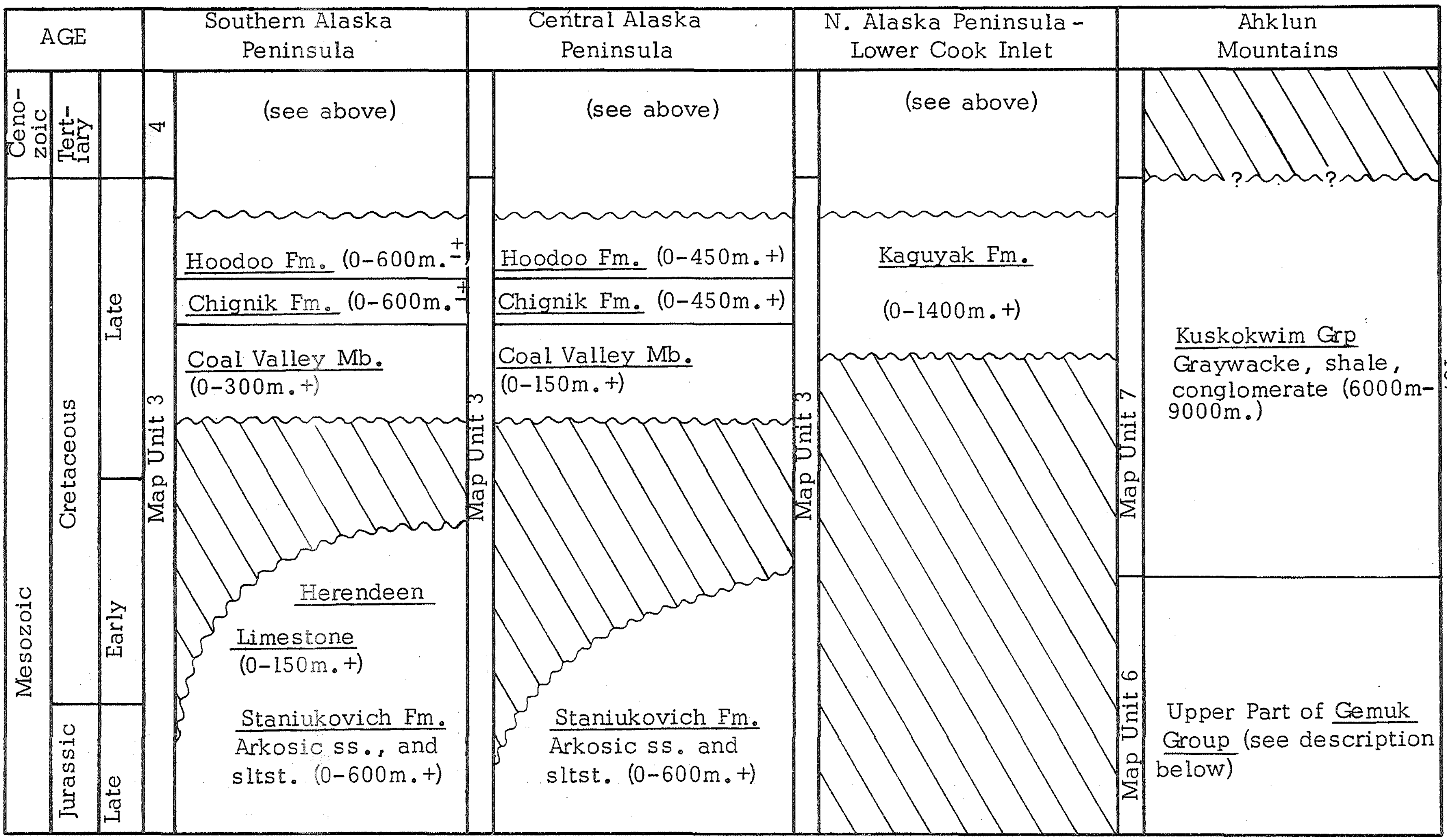


Figure 27 (continued)

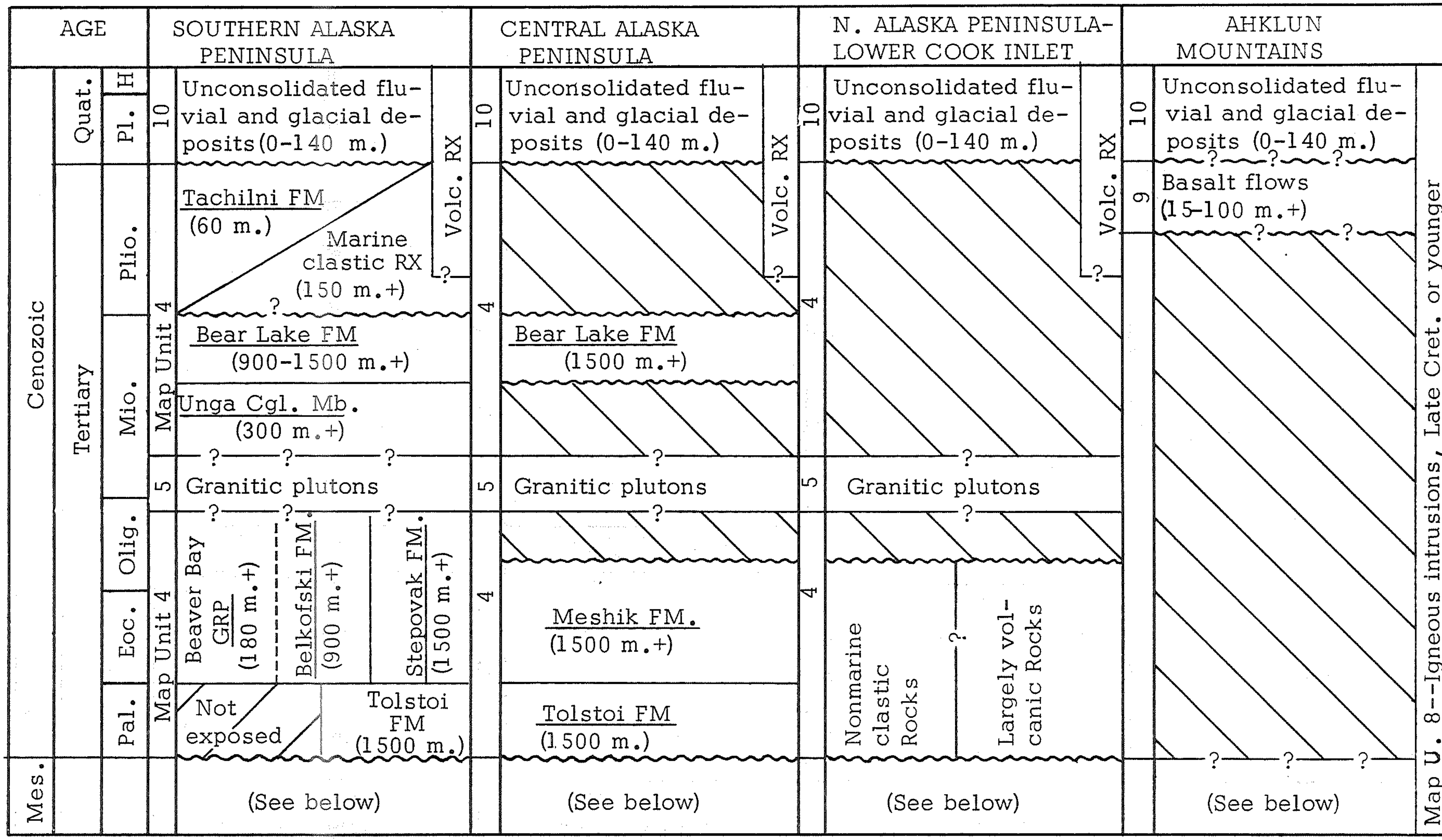


Figure 27. (Cont'd).

The basement rocks of the Aleutian Range-Alaska Peninsula comprise a suite of eugeosynclinal rocks consisting of partly metamorphosed clastics (shales, sandstones and conglomerates) carbonates, and volcanic rocks of presumed Paleozoic age which are overlain by 1,500 to 3,000 m. of limestones, cherts, clastics, and volcanic rocks of Permian through Lower Jurassic age (1).[1] These rocks primarily outcrop north of the Bruin Bay Fault, but they are thought to occur in the subsurface throughout the region. Intruding these basement rocks are a series of granitic batholiths of Early to Middle Jurassic age (176 to 154 million yr.) (2) which are part of a more extensive batholithic belt reaching from Becharof Lake to as far north as the Talkeetna Mountains. A thick sequence of marine-shelf clastic sedimentary rocks of Middle Jurassic through Upper Cretaceous age form the core of the Aleutian Range (3). Superimposed on these rocks are thick sequences of Tertiary shallow-marine and continental clastic rocks mixed with a variety of volcanic rocks (4).

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1. Numbers refer to units on the geologic map (Figure 25).

These sequences have been intruded by a series of Middle Tertiary granitic plutons (5). Extensive volcanism has continued to the present as evidenced by the chain of Recent and active volcanoes along the crest of the Range (Figure 25). An excellent detailed description of all of these rocks is contained in Burk (1965).

The structural geology of the Aleutian Range is characterized by broad anticlinal fold complexes which are paralleled by steeply dipping faults (Figure 25). The northern part of the Alaska Peninsula is dominated by the Bruin Bay Fault, a steeply dipping reverse fault that separates geologic units (1) and (3), and forms the crest of a broad arch. To the southwest, the geological structure is dominated by three large en-echelon anticlinal complexes which contain highly deformed rocks as young as Late Tertiary. The major faults are intimately associated with these folds. No major strike-slip faults are known on the Alaska Peninsula. Except for early movements on the Bruin Bay Fault, all these major tectonic features were formed during Late Tertiary to Recent time. Only the major structural elements are shown on the geologic map (Figure 25).

Ahklun Mountains

The Ahklun Mountains in the western part of the study area form a low but rugged range comprised primarily of Paleozoic and Mesozoic eugeosynclinal rocks. The area has received very little detailed geologic study. The general geologic framework of the area was established by early U.S. Geological Survey reconnaissance of the Nushagak Bay area (Mertie 1938) plus later regional mapping by the U.S. Geological Survey in the Hagemeister and Goodnews Bay Quadrangles (Hoare and Coonrad 1960, 1961). Studies of platinum and mercury deposits in the region have added little to the overall geologic knowledge (Sainsbury and MacKevett 1965, Mertie 1969). The overall geology of the region is summarized by Hoare (1961); most of the following discussion and the Ahklun Mountains portion of the geologic map are taken from this source.

Most of the area is underlain by a thick group of eugeosynclinal rocks, known collectively as the Gemuk Group, ranging in age from Mississippian to Early Cretaceous (6). A breakdown of the Group into stratigraphic units has not been made, but generally the Group can be divided into a fine-grained lower part and a coarse-grained upper part. The lower part consists chiefly of siliceous siltstone, chert, mafic volcanic rocks, and limestones. It has yielded fossils of Mississippian (?), Permian, Triassic, and Jurassic (?) age, and probably is equivalent to the basement rocks (1) of the northern Aleutian Range discussed above. The upper part of the Gemuk Group consists mainly of fine- to coarse-grained volcanic graywackes, conglomerates, argillites, and siltstones with minor amounts of limestones, volcanic rocks, and cherts. These rocks contain Late Jurassic and Early Cretaceous fossils. The entire group probably ranges in thickness between 4,500 and 9,000 m.

Overlying the Gemuk Group is another sequence of graywackes, shales, and conglomerates known as the Kuskokwim Group (7). These rocks are similar to the underlying Gemuk rocks but apparently lack the cherts and volcanics. Most outcroppings of the Kuskokwim Group are located immediately north of the map area; in all, at least 5 separate units have been recognized. The Kuskokwim Group is estimated to be at least 6,000 to 9,000 m. thick and, like the upper part of unit (3) in the Aleutian Range, includes strata ranging in age from Early to Late Cretaceous.

The Gemuk and Kuskokwim Groups have been intruded by a variety of igneous bodies ranging in composition from ultrabasic rocks to granite; most of these are granitic (8). Only the larger intrusions are shown in Figure 25. Since they intrude Late Cretaceous rocks, their age is considered to be Late Cretaceous or younger.

The youngest bedrock unit in the area consists of dark, fresh-appearing, flat basalt flows that occur along the Togiak River and on Hagemeister Island (9). These flows conform generally to major physiographic features but apparently were extruded prior to the earlier glaciations and thus are considered to be of Late Tertiary or early Pleistocene age.

All of the Cretaceous and older rocks in the region have been intensely folded and faulted. The folds range in size from small drag folds to large complex anticlinal and synclinal structures; most trend in a northeast direction. The principal faults in the region dip steeply and also trend in a northeastward direction. Their sharp topographic expression and the occurrence of offset alluvial deposits indicate that some faults are still active, chiefly in a vertical direction. The most significant fault in the area is the Togiak Fault. This fault forms the southwest end of the great Denali Fault system that spans the entire state. The sharp topographic expression of the Togiak Fault indicates a steeply dipping fault plane with vertical displacements. Some evidence indicates, however, that this fault experienced some earlier right lateral strike slip movement in places. This feature is easily observed in ERTS photography (Figure 8).

Bristol Bay-Nushagak Lowlands

The Bristol Bay-Nushagak Lowlands lie between the two previously described geologic subdivisions. These lowlands are mantled by a relatively thin veneer (usually less than 100 m. thick) of unconsolidated sediments which were mainly deposited by glacial and fluvial processes during Quaternary to Recent time.

Beneath these surficial sediements is a sequence of marine and nonmarine, sedimentary rocks of Tertiary age which includes sandstones, siltstones, claystones, and coals. Although these rocks do not outcrop in the Lowlands, they have been penetrated by 8 deep test wells between Cold Bay and Egegik Bay, and are inferred from the results of geophysical surveys. The exact extent and thickness of these rocks, both onshore and offshore, have not been determined, or at least are not public knowledge.

In the northeast part of the Lowlands area between 600 and 5,000 m. of nonmarine and shallow-marine rocks of Paleocene-Eocene through Pliocene (?) age are indicated by limited seismic and well data (Figure 28) (Hatten 1971). These rocks apparently overlie an irregular basement probably composed of the partly metamorphosed Late Paleozoic and Mesozoic sedimentary and igneous rocks comprising unit (1) on the geologic map.

Further south between Ugashik Bay and Port Moller at least 3,800 m. of interfingering marine and nonmarine rocks of Late Tertiary age underlie the Lowlands. These rocks overlie a younger basement consisting of Middle Tertiary volcanic rocks. This basement undoubtedly is part of the Tertiary volcanic rocks which comprise unit (4) along the core of the adjacent Aleutian Range.

South of Port Moller and onward to the continental slope, the effective basement apparently consists of the Mesozoic rocks which comprise the upper part of unit (1) and most of unit (3) on the geologic map (Hatten 1971).

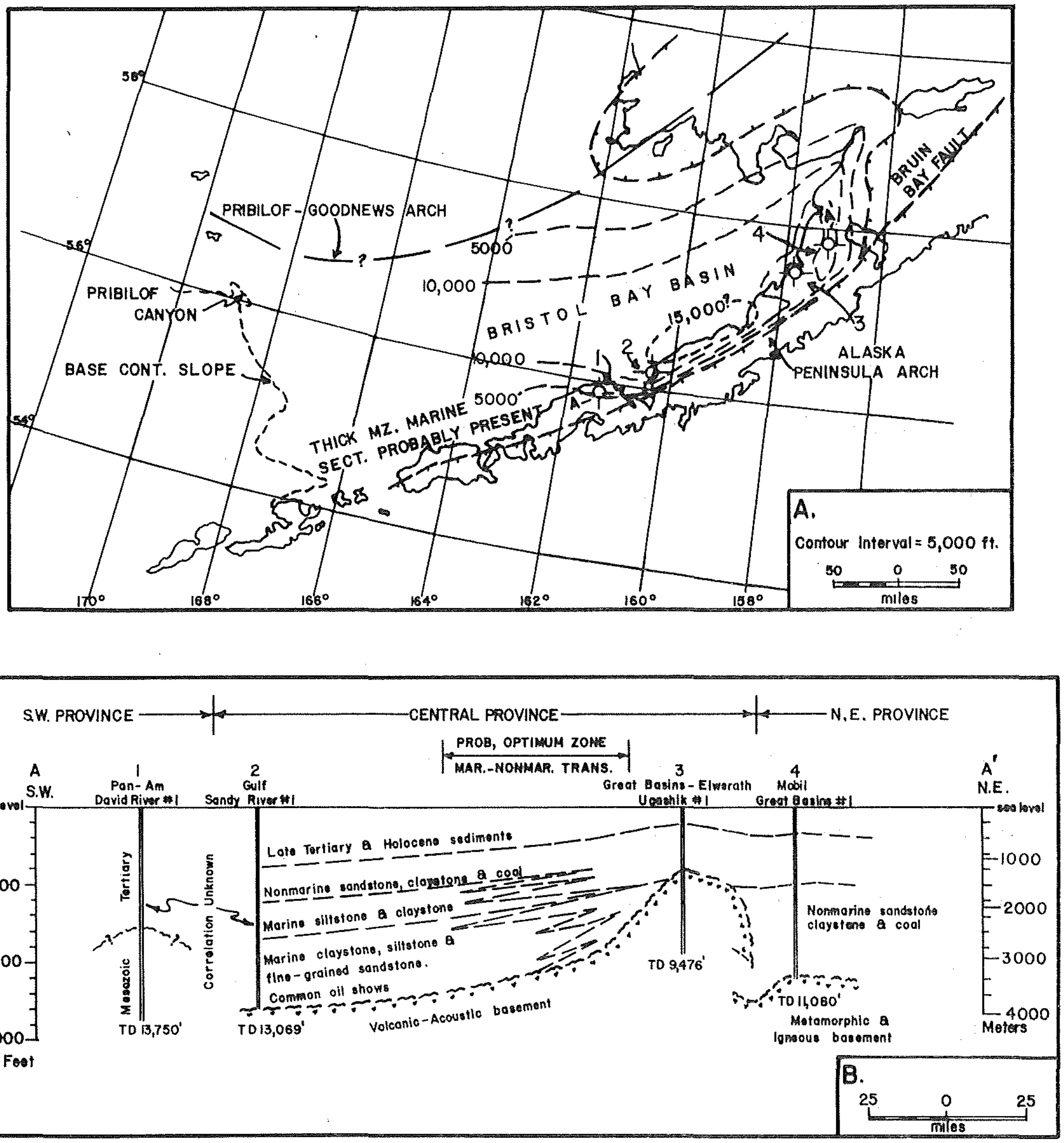

Figure 28. Subsurface geology, Bristol Bay region: A. Isopach map of Tertiary, post-acoustic basement rocks; B. SW - NE correlation section (from Hatten 1971).

Overlying this basement is a marine-nonmarine sequence of Late Tertiary age probably similar to that further north but much thinner (approximately several thousand meters in thickness).

Structural features in the Tertiary rocks and the underlying basement generally trend northeastward, parallel to the regional structural trend, and are probably related to the features found along the adjacent Aleutian Range. Fairly extensive faulting occurs in the basement between Ugashik and Port Moller, and the overlying beds appear to be draped over this irregular surface (Hatten 1971). This may represent a southward continuation of the Bruin Bay Fault system that was reactivated in later Tertiary time in association with reformation along the Peninsula. Cross faulting within the basin, as expressed by westward trending volcanic centers, also occurs along the Alaska Peninsula and may extend beneath the Lowlands.

Offshore Areas

Three broad groups of rocks and sediments have been distinguished on the continental shelf of Bristol Bay and the

Bering Sea. They are 1) the acoustic basement consisting of folded rocks below a strongly reflecting horizon, 2) the main layered sequence (MLS) consisting of gently deformed sediments of Tertiary age above the acoustic basement, and 3) the generally flat-lying sediments of Quaternary age at or near the sea floor (Nelson et al., in press).

The acoustic basement consists of older folded rocks topped by an irregular and deformed erosion surface. The exact nature and distribution of these older rocks is not well known and speculations are based primarily on extrapolations from onshore data, supplemented by magnetic data, seismic profiling, and some dredging. Most of the northern part of Bristol Bay is probably underlain by the offshore extension of the Paleozoic and Mesozoic rocks of the Gemuk Group, Kuskokwim Group, and the partly metamorphosed sediments of Unit (1). Exactly how far south these older rocks extend is still speculative, but a band of magnetic anomalies in Bristol Bay north of Unimak Island is postulated to be the limit of their southern extension (Pratt et al. 1972). These magnetic anomalies may represent, however, the southwestward continuation of the Jurassic plutonic belt of the

Alaska Peninsula (2) that plunges into the subsurface north of Becharof Lake (Reed and Lanphere 1973). This latter interpretation is supported by other magnetic work in the area (Andreasen et al. 1963a, b) and by the presence of arkosic material in sedimentary rocks of Jurassic through Cretaceous age all along the Alaska Peninsula southeast of the presumed batholithic belt (3) (Burk 1965).

Gravity surveys indicate that the arkosic rocks of unit (3) may also extend westward offshore from the Alaska Peninsula (Pratt et al. 1972). They may even extend further west along the continental shelf margin. In addition, the presence of Late Cretaceous turbidities dredged from the continental margin in Pribilof Canyon (Hopkins et al. 1969) suggests that a belt of turbidites found along the Gulf of Alaska shelf also may extend westward offshore but south of the arkosic unit. This suggests that the main northeastward Mesozoic structural trends of the region may bend westward at the southern end of the Alaska Peninsula and extend along the Bering Sea continental shelf margin (Figure 29). The acoustic basement along the shelf edge has been downwarped and covered by the main layered sequence (Figure 30).

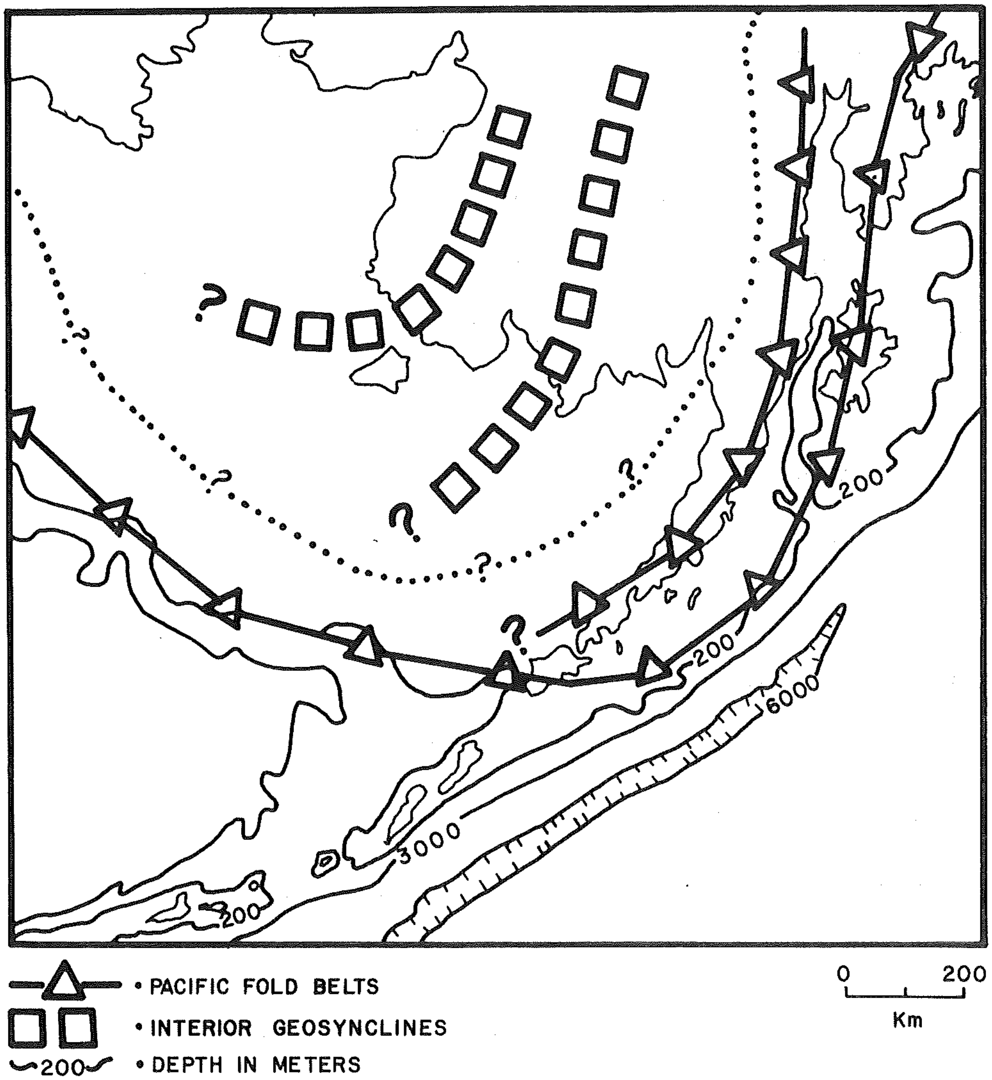

Figure 29. Late Mesozoic structural trends, Bristol Bay region (from Scholl et al. In Press).

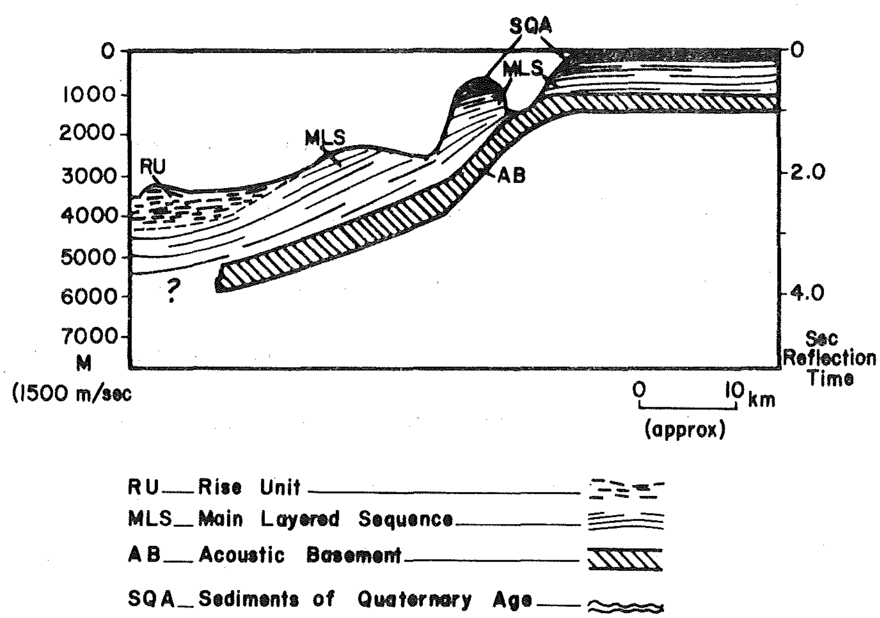

Figure 30. Idealized cross section identifying the major structural-stratigraphic elements of the Bering Sea continental margin (from Scholl et al. 1968).

The volcanic acoustic basement noted in the test wells along the Lowlands probably represents a younger basement complex associated with Tertiary development of the Alaska Peninsula. It is believed that this basement does not project far offshore.

The main layered sequence (MLS) represents a gently deformed group of marine and nonmarine sediments of Middle to Late Tertiary age that cover most of the Bering Sea continental shelf. They are equivalent in part to sediments of similar age found in test wells along the Lowlands. Over much of the shelf these sediments are relatively thin, perhaps 500 m. or so, while locally they may reach thicknesses ranging from 2 to 4 km. in large sediment-filled structural downwarps (Nelson et al., in press; Scholl et al., in press).

One such thick section of marine and nonmarine sediments of Middle to Late Tertiary age forms the Bristol Bay basin (Figure 31) (Hatten 1971, Scholl et al., in press). The axis of the basin occurs offshore, parallel to the Alaska Peninsula, where this section probably exceeds 4 km. in thickness. The Tertiary rocks beneath the Lowlands form the eastern flank of the basin. This thick section may or may not extend southwestward to connect with another thicker section along the continental shelf edge (Figure 31).

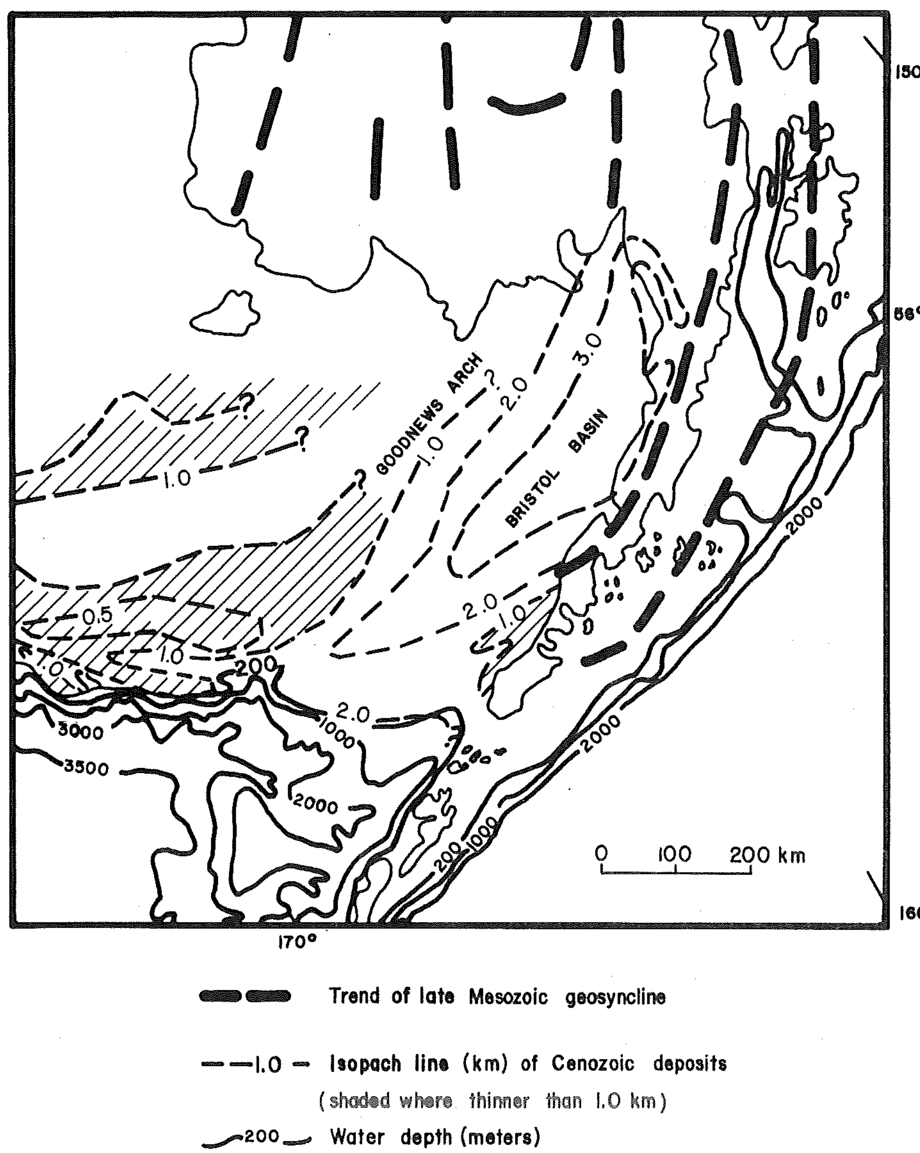

Figure 31. Generalized Isopach map of Cenozoic deposits, Bering Sea continental shelf (from Scholl et al. In Press).

Overlying the MLS on the Bering Sea continental shelf is a thin section of sediments of Quaternary age, rarely more than 100 m. in thickness. Usually these sediments truncate the underlying Tertiary strata. In places these sediments are conformable with the underlying beds. These sediments represent silts, sands, and gravels which were deposited by glaciers and streams during the Pleistocene.

Geologic History

The Precambrian and Lower Paleozoic history of the Bristol Bay region is virtually unknown, and history of the Upper Paleozoic Era is only scantily known. The latter period was one of widespread eugeosynclinal sedimentation characterized by deposition of siliceous clastics and cherts in deep marine basins adjacent to volcanic islands and local carbonate shelves (1 and 6). Similar sedimentation continued through Early Cretaceous time in the Ahklun Mountains, but was interrupted along the Alaska Peninsula in Middle Jurassic time by intrusion and uplift of the Alaska-Aleutian Range batholith (2). This batholith furnished material for a thick section of Middle Jurassic through Late Cretaceous rocks, which were deposited on a shallow marine shelf along the south flank of the Alaska Peninsula. This shelf extended the entire length of the Peninsula and possibly further west offshore along the Bering Sea continental shelf edge.

South of this old shelf lay a deep basin or continental rise that received a thick section of turbidite deposits through Late Cretaceous time. These Cretaceous rocks were intruded by plutons and uplifted to form a younger continental margin extending from Kodiak to the Sanak Islands, and possibly westward along the present Bering Sea continental shelf margin. Also during Cretaceous time, large northeast trending geosynclinal basins in the Ahklun Mountains region were receiving thick sections of graywackes derived from adjacent geanticlines such as the Goodnews Arch (7).

The present-day Aleutian Ridge, which includes the Aleutian Islands, was formed by an outpouring of volcanic material during Early Tertiary time. Uplift, erosion, intrusion, and extensive volcanism continued along the ridge and the Alaska Peninsula throughout Tertiary time. This resulted in thick sections of clastic and volcanic debris deposited in discontinuous basins along the crest or flank of this large volcanic and intrusive welt (4 and 5). During this time, much of the rest of the Bristol Bay region, including the Bering Sea continental shelf, was undergoing erosion, and the extensive erosion surface that truncates the older rocks of the acoustic basement was formed. Following this period of erosion, and continuing until present, terrigenous clastic sediments derived from the Alaska mainland , were deposited on the continental shelf. Thick sections of sediment accumulated in tectonic downwarps and grabens along the shelf edge and in large subsiding basins like the Bristol Bay basin. During Late Tertiary or Early Quaternary time, basaltic flows were extruded along the major faults in the Ahklun Mountains. In Quaternary time, most of the adjacent uplands were extensively glaciated, and thin glacial and fluvial sediments were deposited on the shelf, while thick sections were dumped at the base of the continental slope.

ONSHORE SURFICIAL GEOLOGY

Introduction

Surficial deposits cover almost all of the lowland regions in the study area as well as much of the uplands; they vary in thickness from only a few cm. in the mountains to 75 m. in the Nushagak Lowland to 180 m. at Naknek. These unconsolidated deposits were produced by three principal agents--ice, water, and wind. Volcanic activity in adjacent regions also has influenced the character of the deposits.

Only limited and generalized information is available on surficial deposits of the Bristol Bay area. Little attempt has been made to differentiate surficial deposits on geologic maps beyond the broad classification of alluvium--"Qal." The only information available on surficial deposits is presented in "Surficial Geology of Alaska" (Karlstrom et al. 1964), prepared by the U.S. Geological Survey. This map presents the generalized distribution of various genetic units for the entire state. Figure 32 summarizes the data shown on Karlstrom's map. Additional information on the extent of surficial deposits can be obtained from other geologic sources for this area (Figure 26).

Figure 32. Generalized Surficial Geology, Bristol Bay region (from Karlstrom et al. 1964).

LEGEND

Map Units

1-Existing glaciers.

2-Glacial moraines and associated drift, modified to varying degrees.

3-Glacio-fluvial deposits--outwash and valley-train deposits along glacier fronts and recent moraines grading into fluvial deposits further down-valley.

4-Fluvial deposits--floodplain, terrace, and alluvial fan deposits.

5-Coastal deposits consisting of beaches, spits, bars, deltas, and interstratified alluvial and marine sediments.

6-Coarse- to fine-grained undifferentiated deposits associated with moderate to steep-sloped mountains and hills with many bedrock exposures.

7-Undifferentiated deposits with a high percentage of volcanic rock particles, ash, and pumice flanking volcanic cones and peaks of Quaternary and Tertiary age.

8-Discontinuous alluvial deposits overlying dissected unconsolidated, semiconsolidated, and locally consolidated silt, sand, and gravel of Tertiary and younger age.

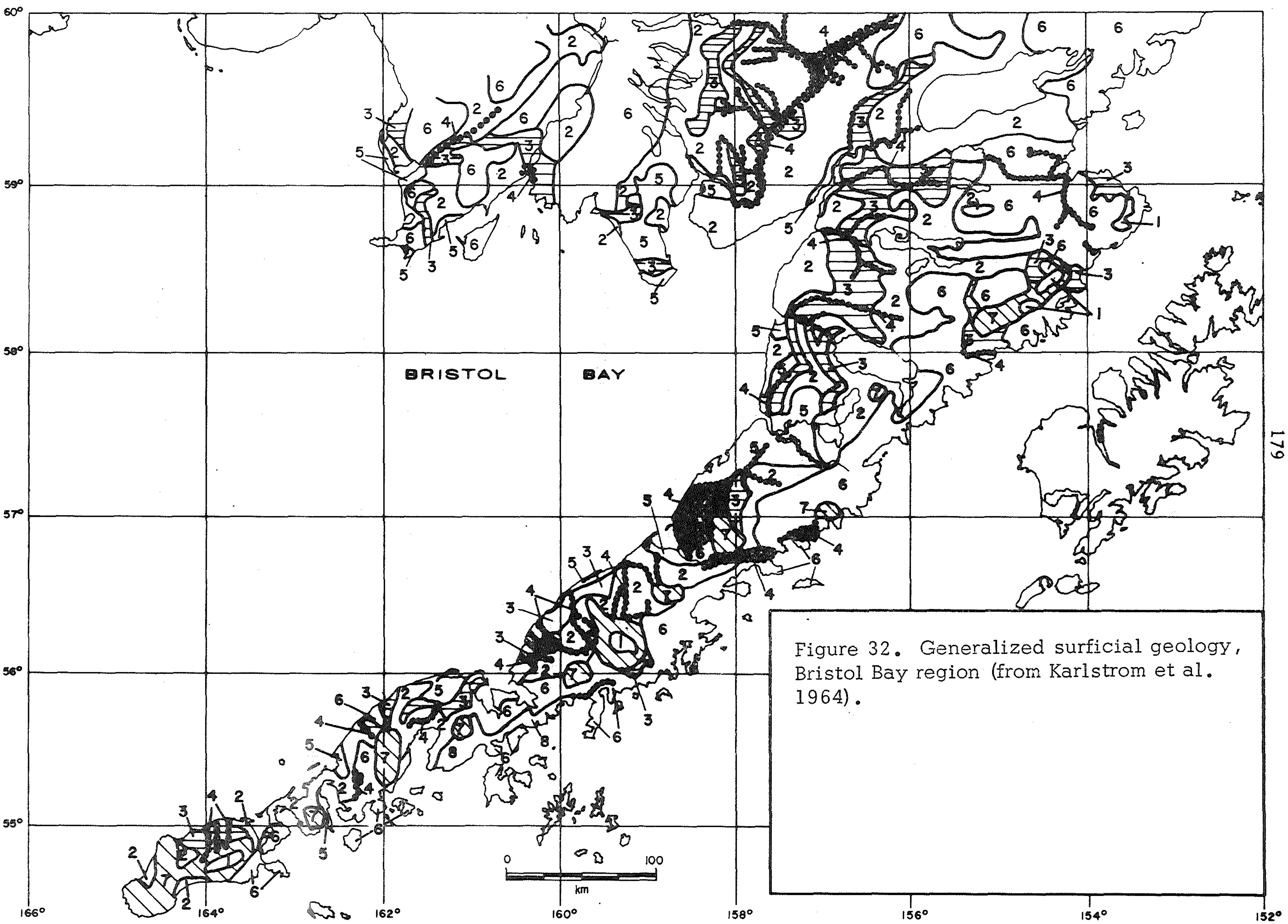

Figure 32. Generalized surficial geology, Bristol Bay region (from Karlstrom et al. 1964).

Volcanic Activity

A host of volcanoes, many of which are still active, border the study area. The cones are flanked with thick deposits of ash, pumice, and other volcanic debris, while lesser amounts of these materials are found at various distances from the cones. Some beach sand deposits are black with pieces of volcanic breccia, pumice, basalt, and obsidian. Many soils contain one or more ash layers which record major eruptions in the recent past.

Glaciofluvial Activity

There are two generally recognized groups of unconsolidated deposits which are differentiated by age (Mertie 1938). The first group is described as glacial and glaciofluvial deposits of Pleistocene age. The Bristol Bay study area evidently underwent at least 3 major periods of glaciation during Pleistocene time (Pewe 1953), the extent of which is shown in Figure 32. These glacial advances produced great quantities of morainal, glaciofluvial and fluvial material which blanket a majority of the land surface and are visible along stream bluffs and terraces. Distinctive arcuate belts of morainal and outwash deposits are prevalent, often located adjacent to lakes which they dam (Figure 32). These deposits also occur along the coast and below sea level on the continental shelf, indicating a lower sea level during Pleistocene time.

The second group of deposits are postglacial materials of Recent (Holocene) age. There are several recognizable types differentiated by location and reworking process involved:

(1) Stream alluvium and outwash form the valley floors and terraces along present streams. Bedrock is exposed at points along some stream courses indicating degradation; however, in many areas streams are still aggrading. Deposits are generally well-rounded and consist of fine to fairly coarse gravel and sand with some larger cobbles and boulders. Sorting is only moderate and there is a general decrease in particle size toward the coast.

(2) Unconsolidated deposits are found along lake shores in the Nushagak Lowland. The lakes are dammed on the southeast shores by glacial moraines which have been

reworked into beach debris characterized by sorted sands and rounded gravels. Old terraces, which bear evidence of past lake levels, also consist of rounded debris moderately sorted by wave action (Mertie 1938).

(3) In more recent times, uplift of about 40 m. along the coast (Knappen 1929) has produced a fairly regular coastline. Shoreline processes have developed modern beaches, spits and bars consisting of fine sand. Onshore winds have created extensive dunes from 15 to 90 m. wide and as high as 18 m. high behind much of the shoreline, especially along the Alaska Peninsula. The shoreline is broken by several large bays characterized by extensive sand and gravel spits, sand reefs, offshore bars, and small islands. Offshore currents, rather than doing much erosional work, shift and redeposit beach materials, producing those structures mentioned above. The nature of these deposits is discussed in more detail by Berryhill (1963). In some places the beaches are composed of gravels that have been derived from coastal deposits of unsorted glacial material.

(4) Sandy, silty and muddy tidal flats line many beaches and form the bottoms of some bays and estuaries such as Nushagak and Kvichak Bays.

(5) Smaller amounts of marine sediments have been recognized, recording a period in the recent past when sea level was higher than it is at present (Knappen 1929).

A few studies have been conducted on surficial materials in some specific localities. In the Dillingham area, unconsolidated deposits have been broken down into four general subdivisions: (1) Glacial drift--unsorted and poorly sorted sands, gravels, and boulders; (2) outwash deposits--poorly to well-sorted sands and gravels with lesser amounts of silts and boulders; (3) silt deposits reworked by streams--silts and sandy silts associated with poor drainage and bogs; and (4) windblown silt and beach deposits (Grumman Ecosystems Corp. 1971).

Eolian Deposits

Windblown silt or loess deposits as much as a meter in thickness have been recognized around Dillingham and throughout much of the Nushagak Lowland (Pewe 1968). Such deposits form the soils of the principal agricultural areas in other parts of Alaska. In general, loess is derived from vegetation-free bars of braided, glacial streams, and is deposited in valleys as well as in some upland areas.

Soils

Figure 33 shows the general distribution of soil types in the Bristol Bay area. It is a generalized version of a soils map covering the entire state (U.S. Army, Corps of Engineers 1961). Four major soil units are summarized in the legend on Figure 33.

The U.S. Department of Agriculture, Soil Conservation Service, has done two detailed soil surveys within the study region (Figure 33), covering the King Salmon-Naknek area (Furbush and Wiedenfeld 1968) and the Dillingham area (Schoephorster et al. 1965). Another soil survey by the Soil Conservation Service covers the Umnak area, outside of and southwest of the study area (Hinton and Herren 1966). Each of these authors described a set of 5 soil series which

Figure 33. Generalized soils map, Bristol Bay region (from U.S. Army, Corps of Engineers 1961).

LEGEND

Map Units

1-Deep interbedded sand and gravel. Occur principally in alluvial fans, outwash aprons, floodplains, and river terraces bordering morainal complexes and along major drainage lines.

2-Deep silty sandy gravel with boulders. Occur principally in hummocky, end-, lateral-, and ground-moraine complexes in lowlands bordering the rugged mountain ranges. Peat and highly organic silt in depressions.

3-Shallow rubble and sandy gravel. Occur principally in fluvial, glacial, and colluvial deposits associated with rugged, steeply sloping mountain areas. Numerous bedrock exposures.

4-Deep interbedded silt, sand, and gravel. Occur principally in mixed marine and terrestrial deposits in flat- to gently-sloping coastal plain areas. Peat and highly organic soils in depressions and abandoned stream channels.

5-Shallow to deep interbedded silt, sand, and gravel. Occur principally in discontinuous eolian, fluvial, and glacial deposits mantling upland surfaces and hills underlain by thick deposits of uncemented to cemented soft bedrock of bedded silt, sand, and gravel.

6-Shallow to deep volcanic silt, sand, and gravel. Occur principally in eolian, alluvial, colluvial, and glacial deposits mantling volcanic peaks, cones, and lava fields.

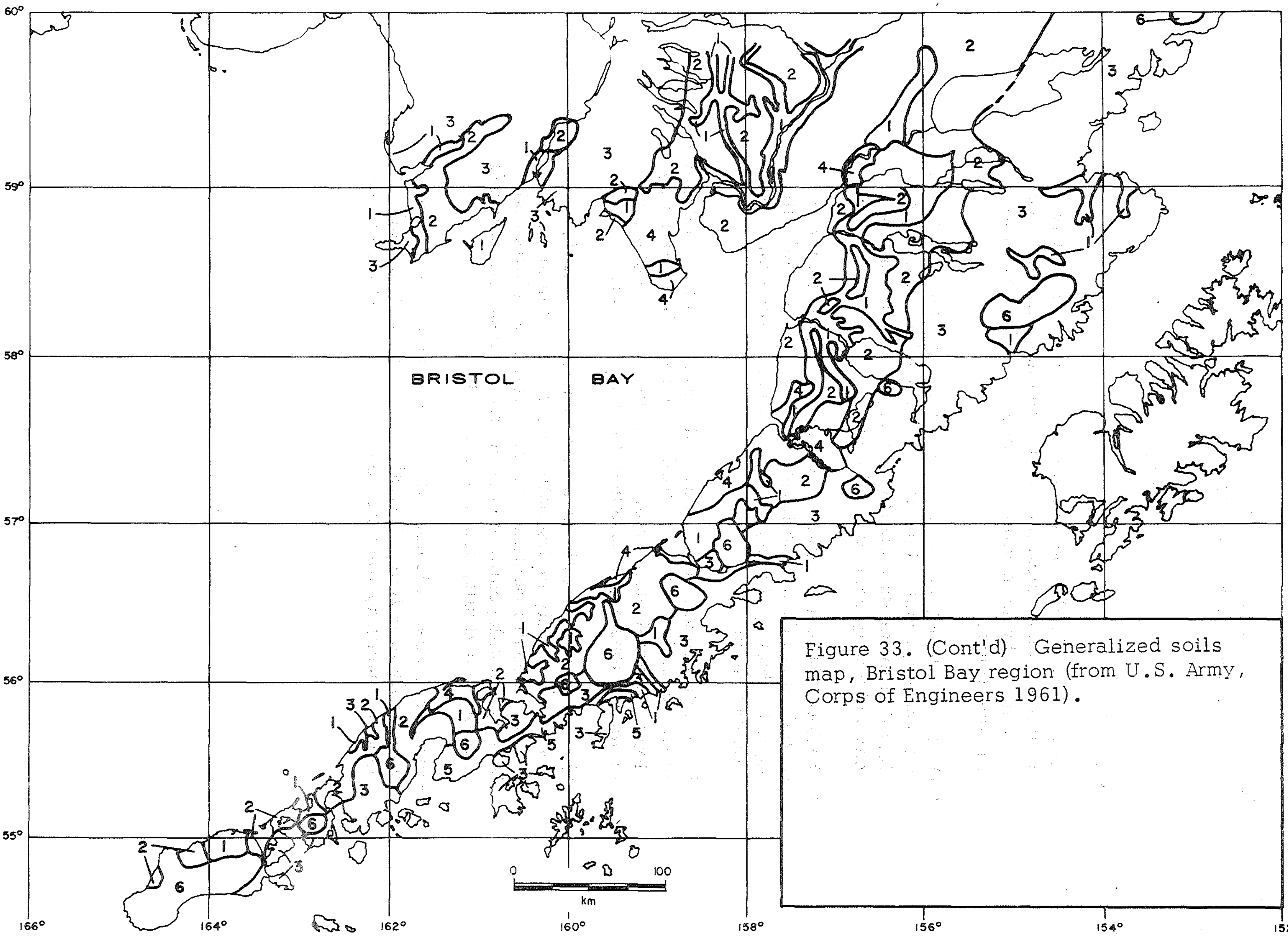

Figure 33. (Cont'd) Generalized soils map, Bristol Bay region (from U.S. Army, Corps of Engineers 1961).

correlates roughly with that of the others. These series occur in varying proportions from one locality to the next. The 5 soil series mapped and defined by Schoephorster et al. (1965) in the Dillingham area and summarized in Table 12 are considered to be representative of soils throughout the area.

In addition to these 5 soil series, 4 land types also were described in these reports--gravelly beaches, tidal flats, tidal marshes and sea cliffs. A reconniassance soil survey of the entire state has recently been completed by the Soil Conservation Service. Boundaries for basic soil groups have been established, and preliminary maps are being finalized. Descriptions of the soil groups are still in preliminary note form. This soil survey is not expected to be available in published form for several years but the preliminary data can now be inspected by contacting the Soil Conservation Service, Palmer, Alaska or the Resource Planning Team of the Joint Federal-State Land Use Planning Commission, Anchorage.

Table 12. A Summary of the Soils of the Dillingham Area, Alaska

Series	Composition	Permafrost	Acid Content	Thickness	Drainage	Occurrence	Vegetation/Capability
Aleknagik	Deep silty deposits overlying gravelly substratum	—	Extremely Acid	60-100 cm.	good	moraine hills slopes 0-20%	White spruce & paper birch Fairly good for agriculture & grazing
Hyer	peaty--raw undecomposed moss	Permafrost 40-75 cm.	—	Variable	poor	steep north-facing slopes of 20-45%	Stunted black spruce, low-growing shrubs & moss. Too wet for agriculture & grazing
Kanakanak	thick silty deposits with surface organic mat.	—	Extremely Acid	Variable	good	Occurs on moraines & terraces; slopes 0-30%	Grasses, alder & white spruce Supports limited agriculture & grazing
Nushagak	Silty with 8-13 cm. moss peat cover	None, but frost remains all but late summer	Strong acidic quality	—	poor, water table near surface	lower slopes of moraines and ridges 0-12%	Moss, lichens, sedges low-growing shrubs. Too wet & cold for crops
Salamatof	Deep peat soils of muskegs, made of undecomposed sphagnum moss	None, but frost remains all but late summer	—	100 cm. or greater	—	low-lying areas, associated with ponds & lakes 0-7%	Low-growing shrubs Too wet & cold for crops.

Source: Schoephorster et al. 1965.

CONTEMPORARY MARINE SEDIMENTS

Introduction

Contemporary sediments cover the entire floor of Bristol Bay and are relatively uncomplicated in composition and distribution. This is a region of high input of terrigenous detritus, high ambient energy levels from currents and waves, and simple, smooth sea floor topography. The sediments tend to be distributed in a systematic fashion, coarser grades being found inshore and finer grades further offshore. The sediments of the entire Bering Sea shelf were once classified as relict (Emery 1968), and were presumed to date from the Pleistocene Epoch. This interpretation has been rejected, however, and the unconsolidated sediments of the southeastern Bering Sea continental shelf are now thought to be related to contemporary processes (Sharma et al. 1972), with the possible exception of a few scattered areas.[1]

The bottom sediments of Bristol Bay have not been studied in great detail, but reconnaissance surveys by both Soviet and U.S. scientists have made the general characteristics of the region well known (Gershanovich 1967, 1968, 1970; Lisitsyn 1959, 1966; Sharma 1972; Sharma et al. 1972).

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1. Nelson, C.H., E. Larson, and R.W. Rowland. The Late Holocene dispersal of Yukon and Kuskokwim sediments on the epicontinental shelf of the northeastern Bering Sea. Unpublished manuscript.

In this review we will discuss the general physical and chemical characteristics of the sediments, their distribution, and their probable provenance. Our primary reference throughout will be the work of Sharma et al. (1972), the most recent and most comprehensive study available of the sediments of this area (Figure 34).

Physical and Chemical Characteristics

Although there are accumulations of silt and clay in some bays and lagoons, particularly off Kulukak Bay, and a few scattered reports of pebbles and cobbles, essentially all the sediments of Bristol Bay can be classified as sand (Figure 35).

The most striking thing about the sand distribution is the extremely regular gradation with water depth, from very coarse sand at the head of the Bay through zones of coarse, medium, fine and very fine sand to coarse silt at the edge of the continental shelf to the west (Figures 35c and 35d).

This offshore gradation of size was once believed to characterize all continental shelves, but modern studies of sea floor sediments have demonstrated that it is really

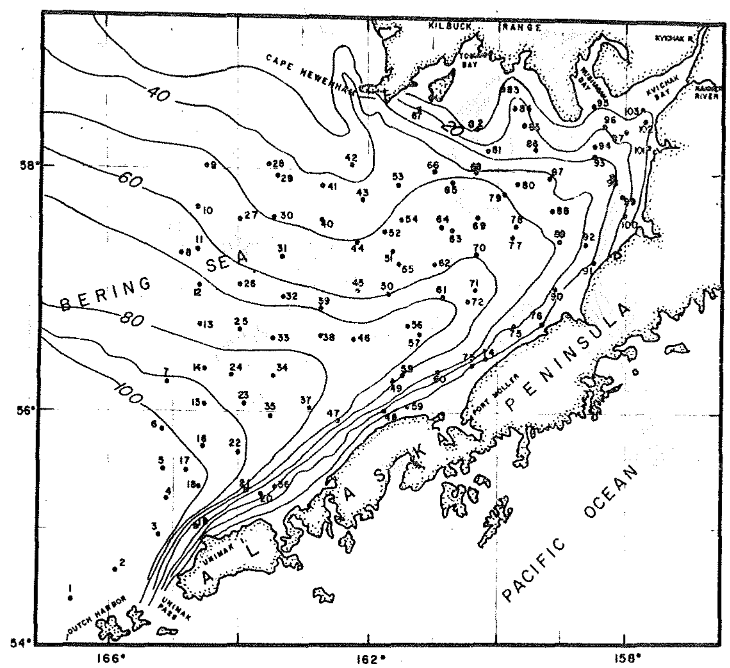
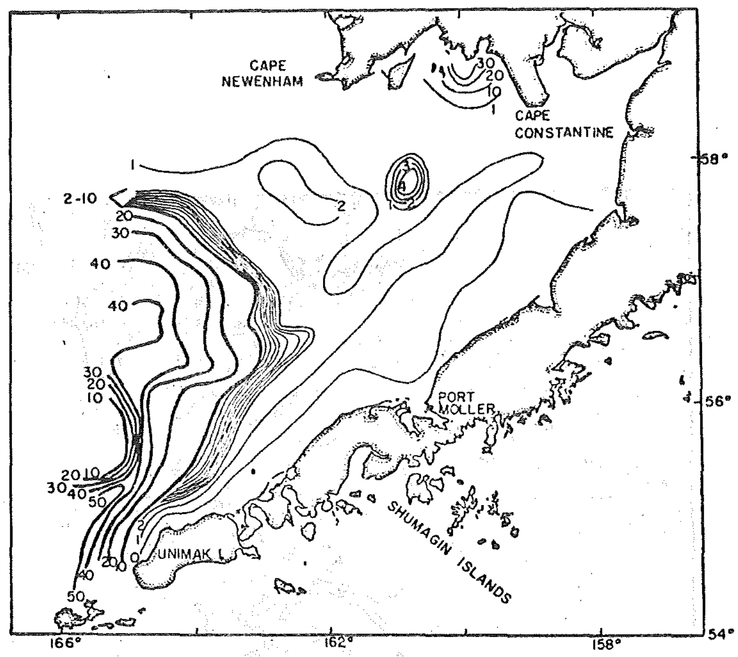
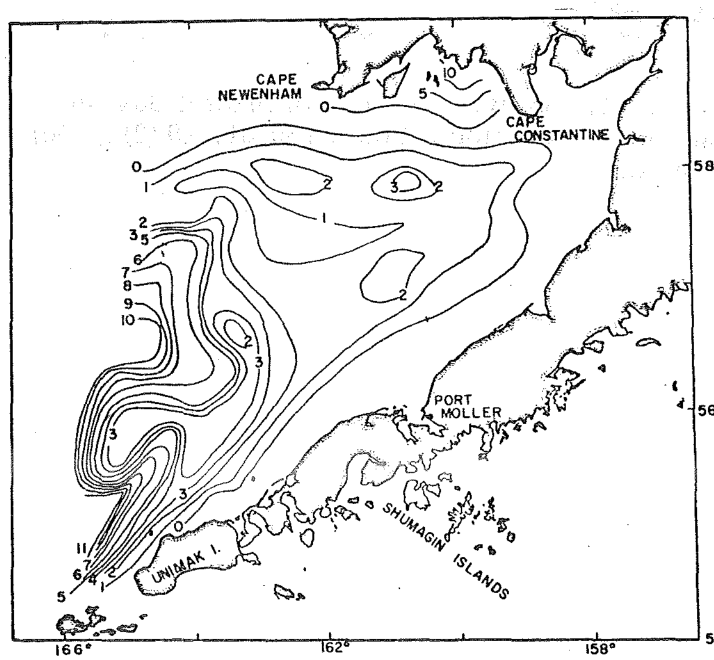


Figure 34. Bathymetric map of Bristol Bay showing sample locations (Sharma et al. 1972). Depth in meters.

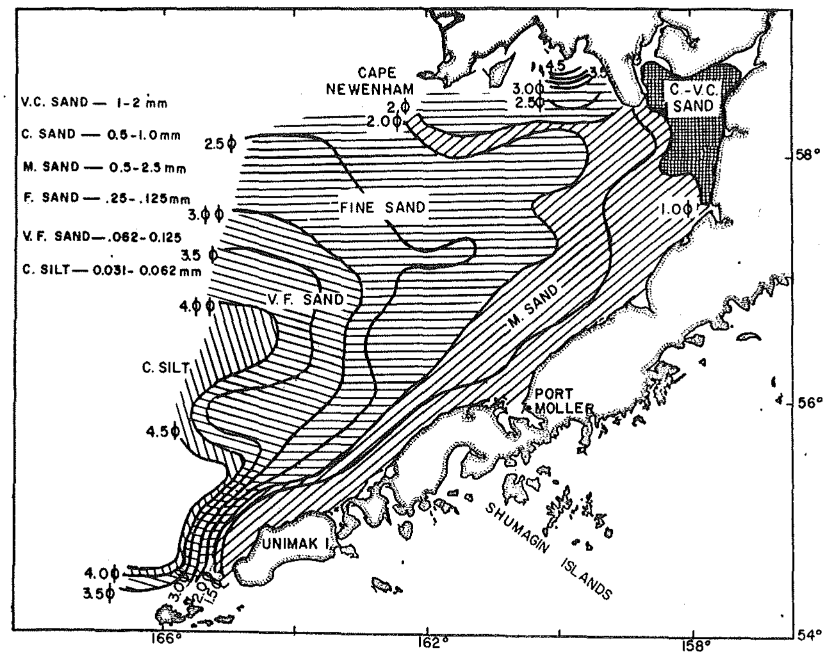


a. Distribution of percent silt.

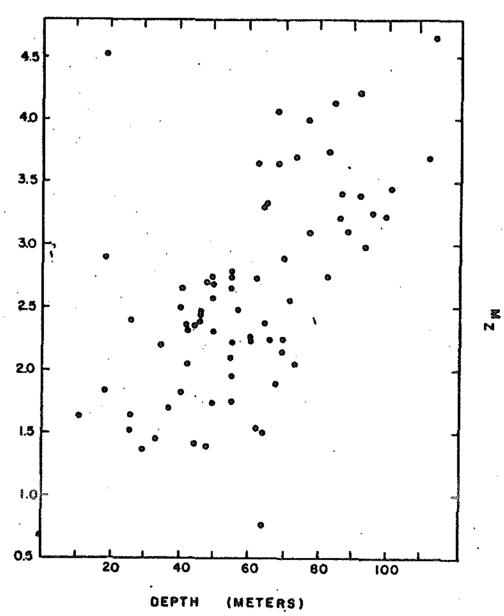


b. Distribution of percent clay.

Figure 35. Size distribution of contemporary sediments, Bristol Bay (from Sharma et al. 1972).



c. Size distribution of sediments.



d. Variations of mean sediment size with depth of water.

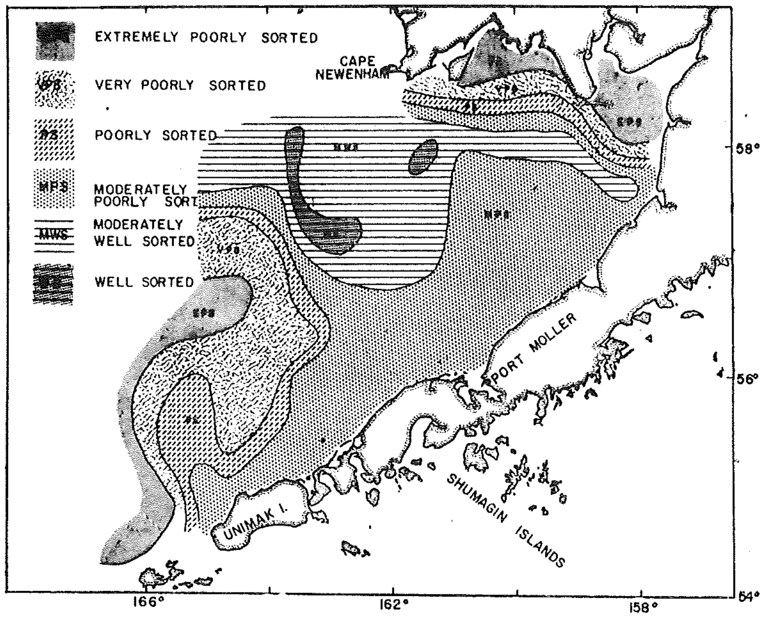
Figure 35. (cont'd).

quite exceptional (Emery 1968). The variety of sediment sources--terrigenous, biogenic, and authigenic--and the variety of physical and chemical processes that act upon them, have tended, when coupled with the drastic Pleistocene sea level oscillations, to produce a much more complex pattern on most continental shelves (Shepard 1963).

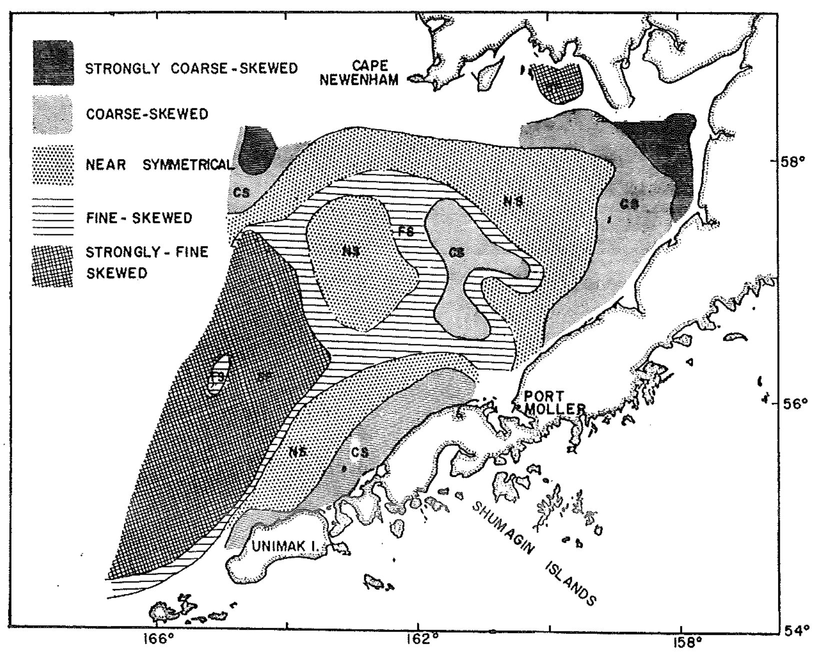
The contemporary sands of the Bristol Bay shelf are, in general, rather poorly sorted (Figure 36a). Sediments within the central part of the Bay have a nearly symmetrical distribution of grain sizes, but they grade into strongly coarse-skewed sediments at the head of the Bay and fine-skewed sediments at the mouth (Figure 36b).

The concentration of organic carbon tends to be quite low, ranging from near zero to about 0.5 per cent in the silt-dominated areas at the very head of the Bay and at the bay mouth (Figure 37).

The mineralogy of Bristol Bay sediments is quite simple; quartz and feldspar sands dominate. There is a relatively high concentration of heavy minerals with a mineralogy similar to that found along the beaches (Berryhill 1963, Sharma et al. 1972). The heavy minerals in a suite of 14 samples from the bay have been analyzed (Figure 38);



a. Variation of sediment sorting.



b. Variation of sediment skewness.

Figure 36. Sorting of contemporary sediments, Bristol Bay (from Sharma et al. 1972).

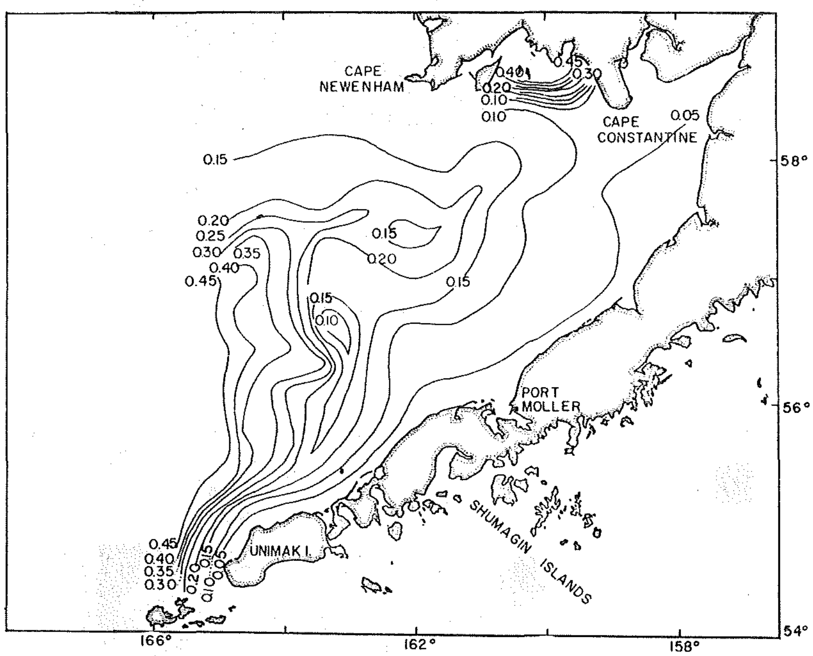


Figure 37. Organic carbon content of sediments, Bristol Bay (percentage) (from Sharma et al. 1972).

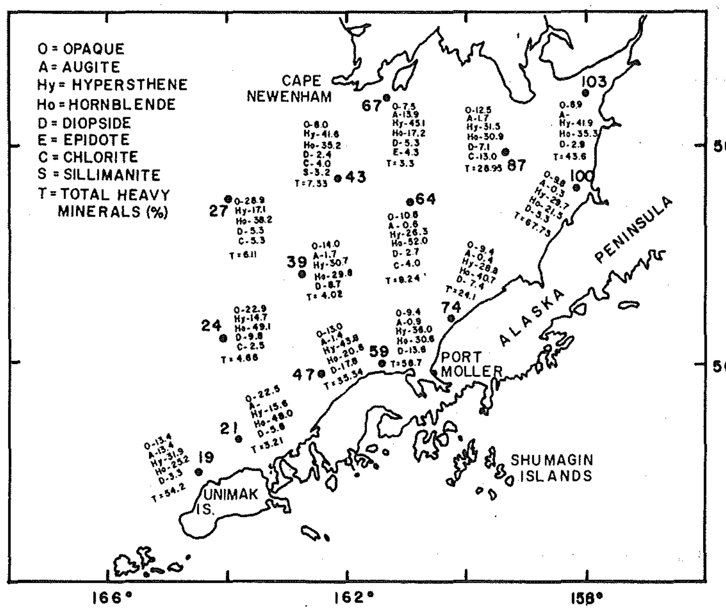


Figure 38. Heavy minerals in sediments, Bristol Bay. Count percent of individual minerals in 0.25-0.355 mm. size fraction and weight percent (T) of total heavy minerals in 0.125-0.177 size fraction (from Sharma et al. 1972).

it has been inferred from their composition and mechanical characteristics that they have not been transported far or subjected to intensive chemical weathering. This apparently reflects concentration of the minerals by contemporary nearshore marine processes. The dominance of illite and chlorite in the clay minerals reported from the area also suggests little alteration or chemical attack. The general mineralogy suggests a high grade metamorphic source, despite the propinquity of many active volcanic centers. Sharma et al. (1972) do not report a significant percentage of volcanic debris; presumably the material is too fine grained to accumulate in the continental shelf sediments. No glacial influence has been noted in the sediments of the area.

Although there is high productivity in the waters of the Bay, no primarily organic sediments--either siliceous or calcareous--have been reported in the Bristol Bay area.

Sedimentary Processes

All Bristol Bay is now interpreted as a region of contemporary sedimentation. The primary sources of the sediments found here are entirely terrigenous, either introduced by rivers or derived locally along the shore by coastal erosion. The mineralogy of the sediments, apparently reflecting a high grade metamorphic source, eliminates the Alaska Peninsula as a significant source area, for the Peninsula is a region dominated by contemporary volcanic activity. The most probable ultimate source areas lie well to the north, in the Alaska Range and the Kuskokwim Mountains drained by the Kvichak, Nushagak, and Wood Rivers. These three rivers all enter the Bay at its extreme head, and they are known to carry very large quantities of fine sediment (Wright et al. 1973). Presumably there is a significant percentage of coarser material as well.

Once introduced into the Bay, sediments are presumably transported by the net counterclockwise circulation, and are sorted by the action of both currents and waves. According to Sharma (1972), the principal agent within the Bay is wave action. He calculated that waves with a height of 10 m. occur in the area and would generate oscillatory currents with velocities as great as 30 cm./sec. on the bottom at depths of 94 m., a current strong enough to transport fine sand grains. As a result of this, essentially all debris finer than fine sand would tend to remain in suspension and be transported out of Bristol Bay. The area influenced in this fashion is indicated as the "inner continental shelf" on Figure 39. These finer sediments are transported beyond, presumably to accumulate on the outer continental shelf and continental slope or to be diverted through submarine canyons and appear as turbidite accumulations in the basin of the Bering Sea (Scholl et al. 1970). This sedimentary regime in Bristol Bay has probably persisted since sea level stabilized at the close of the Pleistocene (approximately 10,000 years ago).

MINERALS

Metallic

Introduction

The metallic mineral potential of the Bristol Bay region is virtually unknown since there has been very little extensive and detailed exploration. There are enough mineral occurrences, however, to indicate the areas that have a potential for mineral development (Figure 40). Four such areas appear to occur in the Bristol Bay region--the Chignik area, the Iliamna Lake area, the coastal beaches of the western Alaska Peninsula, and the Ahklun Mountains. Each of these areas is discussed in more detail below.

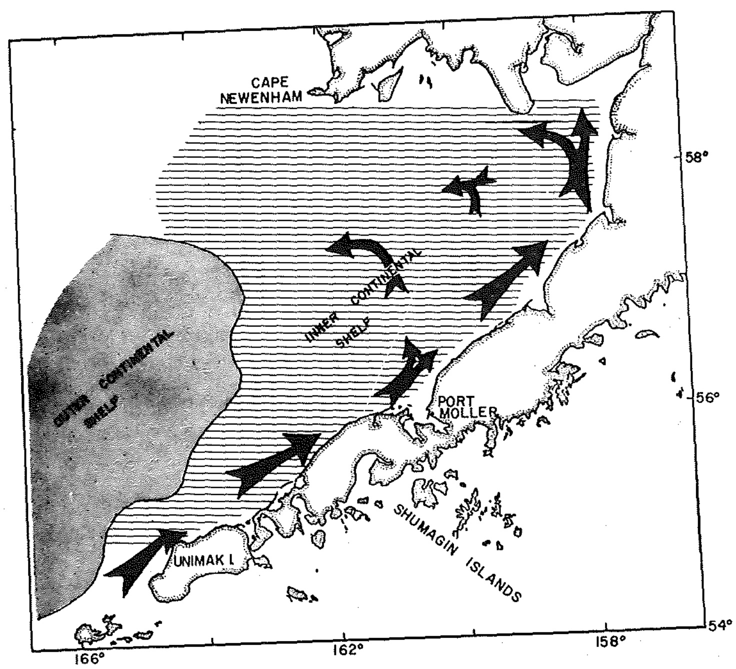


Figure 39. Depositional environments and major currents in Bristol Bay (from Sharma et al. 1972).

Figure 40. Metallic minerals, Bristol Bay region


- Major metal provinces (elements of secondary importance in parentheses) (from Clark et al. 1972).


- Areas with high mineral development potential as identified by Resource Planning Team of the Joint Federal-State Land Use Planning Commission.


- Areas with moderate to low mining claim activity as identified by Resource Planning Team.


- Areas with intensive mining claim activity as identified by Resource Planning Team.

Mineral occurrences as identified on U.S.G.S. M.F. Maps (Cobb 1972a-h, Cobb and Condon 1972, Detterman and Cobb 1972). X - Placer deposits; O - Lode deposits. Number in parentheses indicates M.F. Map number.

1.-Fe-X-(441)
2.-Fe,Au-X-(443)
3.-Fe,Au-X-(443)
4.-Au-O-(443)
5.-Fe,Au-X-(374)
6.-Au-X-(456)
7.-Au-X-(456)
8.-Au,Fe-X-442
9.-Au-X-(442)
10.-Fe-O-(375)
11.-Hq-O-(375)
12.-Mo-O-(375)
13.-Au-X-(447)
14.-Au-X-(447)
15.-Sb,Hq-O-(447)
16.-Au-X-(447)
17.-Cu,Zn-O-(447)
18.-Au-X-(362)
19.-Au-X-(362)
20.-Cr-X-(362)
21.-Cr-X-(362)
22.-Au-O-(362)
23.-Au-X-(362)
24.-Au-X-(362)
25.-Au-X-(362)
26.-Au-O-(362)
27.-Cr-X-(362)
28.-Cu-X-(362)
29.-Cr,Pt,Au-X-(362)
30.-Cu-O-(362)
31.-Cr,Au-X-(362)
32.-Cr,Au-X-(362)
33.-Cr-X-(447)
34.-Au-X-(447)
35.-Au-X-(447)
36.-Au,Pt-X-(447)
37.-Au,Pt-X-(447)
38.-Au,Pt-X-(447)
39.-Au-X-(447)
40.-Au-X-(447)
41.-Au-X-(447)

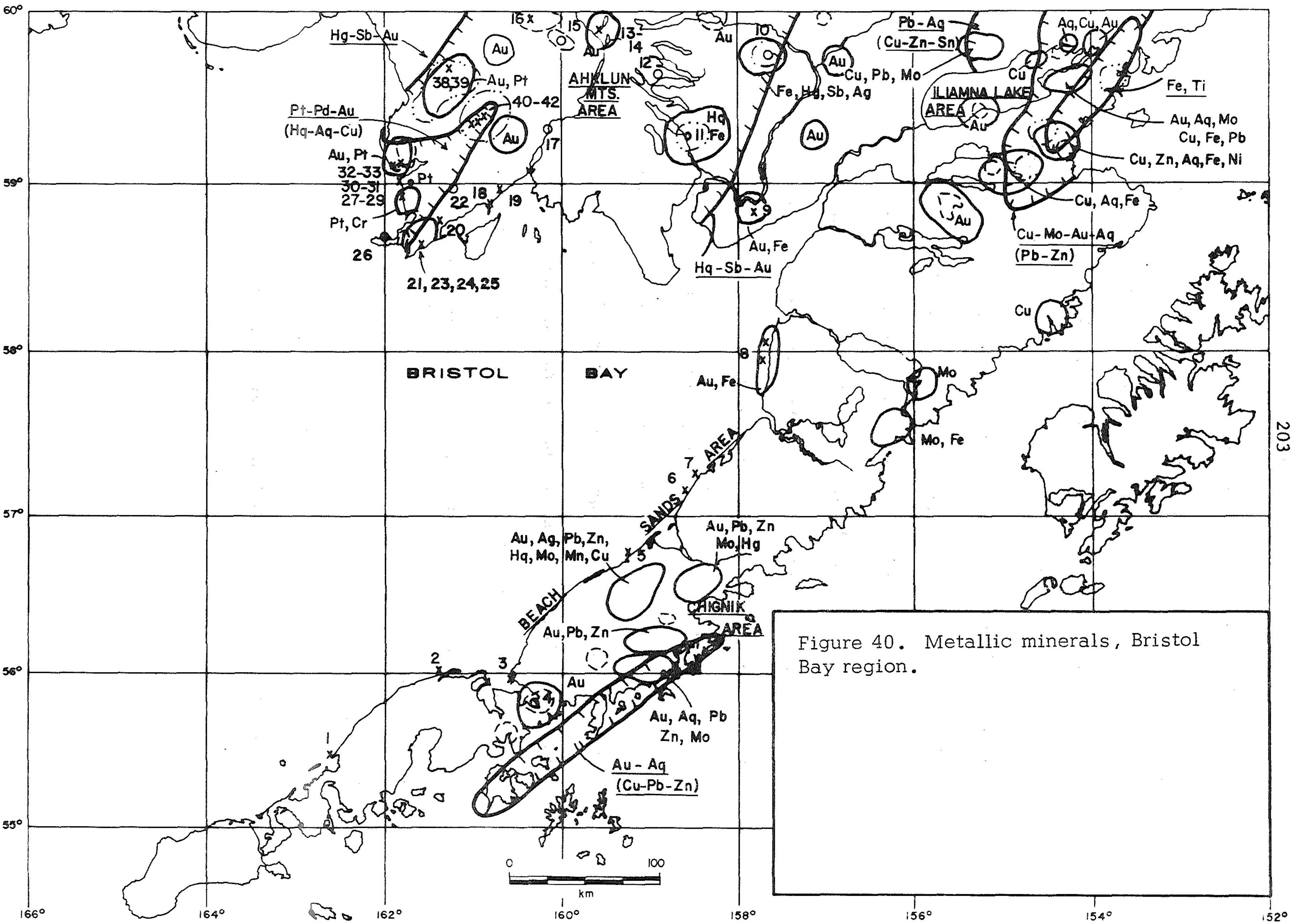


Figure 40. Metallic minerals, Bristol Bay region.

Figure 40 summarizes the distribution of mineral occurrences and provinces within the study area. The primary source of data is maps published by the U.S. Geological Survey, which list all published lode and placer deposits (Cobb 1972 a-h, Cobb and Condon 1972, Detterman and Cobb 1972). Additional details were obtained from other recent publications of the U.S. Geological Survey (Berg and Cobb 1967, Clark et al. 1972, Cobb 1972i, Cobb 1973, and U.S. Geological Survey 1972), and from map overlays prepared by the Resource Planning Team of the Joint Federal-State Land Use Planning Commission. Quadrangle overlays prepared by the U.S. Bureau of Mines that contain the location of all mining claims also were used. These later data are available from the computerized Kardex file for mining claims established and maintained by the Division of Geological and Geophysical Surveys, State of Alaska. This Kardex information also has been summarized on a map of Alaska (Swainbank 1973).

Chignik Area

The Chignik area is a highly mineralized province lying mostly on the Gulf of Alaska side of the Alaska Peninsula. It contains both gold-silver and copper-lead-zinc subprovinces. There has been no production from this region, but there has been considerable activity in recent years. Several local areas are considered to have high mineral potential and have had intense mining claim activity (Figure 40). Several Japanese and French companies have recently shown particular interest in a lead-silver-molybdenum prospect at Chignik and in a copper prospect at Warner Bay just south of Chignik. A copper prospect near Chignik (possibly the one at Warner Bay) was reported to have been drilled in 1971 (Eakins 1972). There was no known exploration in 1972 (Alaska Division of Geological and Geophysical Surveys 1973). This area lies mostly outside the Bristol Bay region and any shipment of ore probably would originate from the Gulf of Alaska side of the Alaska Peninsula. This would not directly interfere with any activities in Bristol Bay, although port facilities developed on the Gulf might have joint uses.

Iliamna Lake Area

Another major mineral province containing deposits of gold, copper, lead, zinc, and low grade titaniferous iron occurs between Iliamna Lake and Cook Inlet. There has been considerable activity in this area during the past few years, but no major production. Although the area lies partly within the Bristol Bay drainage, any shipment of ore probably would be from ports on Cook Inlet, where there are good, ice-free harbor sites.

Beach Sands

Black sand deposits occur offshore and along the beaches between Kvichak Bay and Unimak Island. These deposits consist of iron-rich heavy minerals, including titaniferous magnetite, ilmenite, hypersthene, hornblende, and garnet, apparently concentrated along the shore zone by contemporary marine processes (Sharma et al. 1972).

A reconnaissance sampling and mineral evaluation of the sands were made by the U.S. Bureau of Mines (Berryhill 1963). Some deposits southwest of Kvichak Bay were found to have between 1 and 2 percent iron and titanite but they were too low-grade to justify further investigations. Many of these samples also contained trace amounts of gold.

A more detailed study of the black beach sands between Egegik and Ugashik Bays was conducted in 1969 by the U.S. Bureau of Mines, mainly to determine gold content

(Kimball 1972). Of the 125 samples taken, most contained only traces of gold. The iron-rich sands were found to occur as a thin veneer on the beach or as thin zones below the beach surface. The two largest concentrations ranged between 15 and 30 cm. and covered areas somewhat less than 4,000 sq. m. A magnetometer survey revealed no evidence of large concentrations.

The entire beach zone, especially offshore, has been only lightly explored and evaluated, and many more samples would have to be taken and exploration holes drilled to adequately evaluate the iron and gold potential. The contemporary nature of the concentrating processes plus the sporadic and local occurrence of high concentrations suggest that commercial quantities of black sand and gold will not be found.

Ahklun Mountains Area

The Ahklun Mountains region contains local areas with possible mineral potential. Placer gold has been prospected but probably no more than a few 100 dollars worth has been recovered (Cobb 1972i). This region comprises the southern part of a large mercury province that stretches north to the Kuskokwim River. One small mine (Red Top Mine), 27 km. north of Dillingham, produced approximately 60 flasks in the 1950's (Berg and Cobb 1967), but is presently not in operation.

Several other minor occurrences of mercury have been identified in the area. The present low price of mercury precludes any development at this time. A summary of mercury deposits in southwestern Alaska is contained in Sainsbury and MacKevett (1965).

A large, buried low-grade iron deposit has been discovered near Kemuk Mountain northeast of Dillingham and contains more than a billion metric tons of ore (Berg and Cobb 1967). The prospects for exploiting this deposit are unknown, but the presence of similar deposits further east, closer to potential tidewater ports on Cook Inlet, makes immediate development here less likely.

This region also borders an important platinum province and contains the only producing mine in the area. The Goodnews Mining Company has been seasonally operating a large dredge along the Salmon River for many years, but no data on production are available. Ore is presently being stockpiled awaiting improvement of prices. Minor amounts of gold and other minerals are produced with the platinum. Ultramafic bodies occur in the area and further platinum concentrations should be found, although exploration to date has failed to reveal additional deposits (Cobb 1972i). The area does offer one of the better prospects in the state for offshore placer deposits of gold and platinum (Conwell 1973), and extensive offshore exploration has already been carried out by private interests. A summary of platinum deposits in Alaska and at Goodnews Bay has been made by the U.S. Geological Survey (Mertie 1940, 1969).

Exploration Activity

Mineral exploration in Bristol Bay is being encouraged by the Division of Geological and Geophysical Surveys, State of Alaska. They recently conducted an extensive geochemical investigation in the Wood River-Tikchik Lakes area, and from geochemical anomalies and other field evidence they identified four areas as most favorable for further exploration (Eakins 1968). In addition, the State in cooperation with the U.S. Geological Survey has just completed an extensive aeromagnetic survey of the entire region (Figure 41). The completed maps are at scale 1:63,360 and should aid in future exploration.

There is currently no reported mineral exploration in the Bristol Bay region (Alaska Division of Geological and Geophysical Surveys 1972, 1973), mainly because much of the area is closed to mineral location as a result of the Alaska Native Claims Settlement Act and other land management programs (national wildlife refuges, national monument, etc.) (Fig-

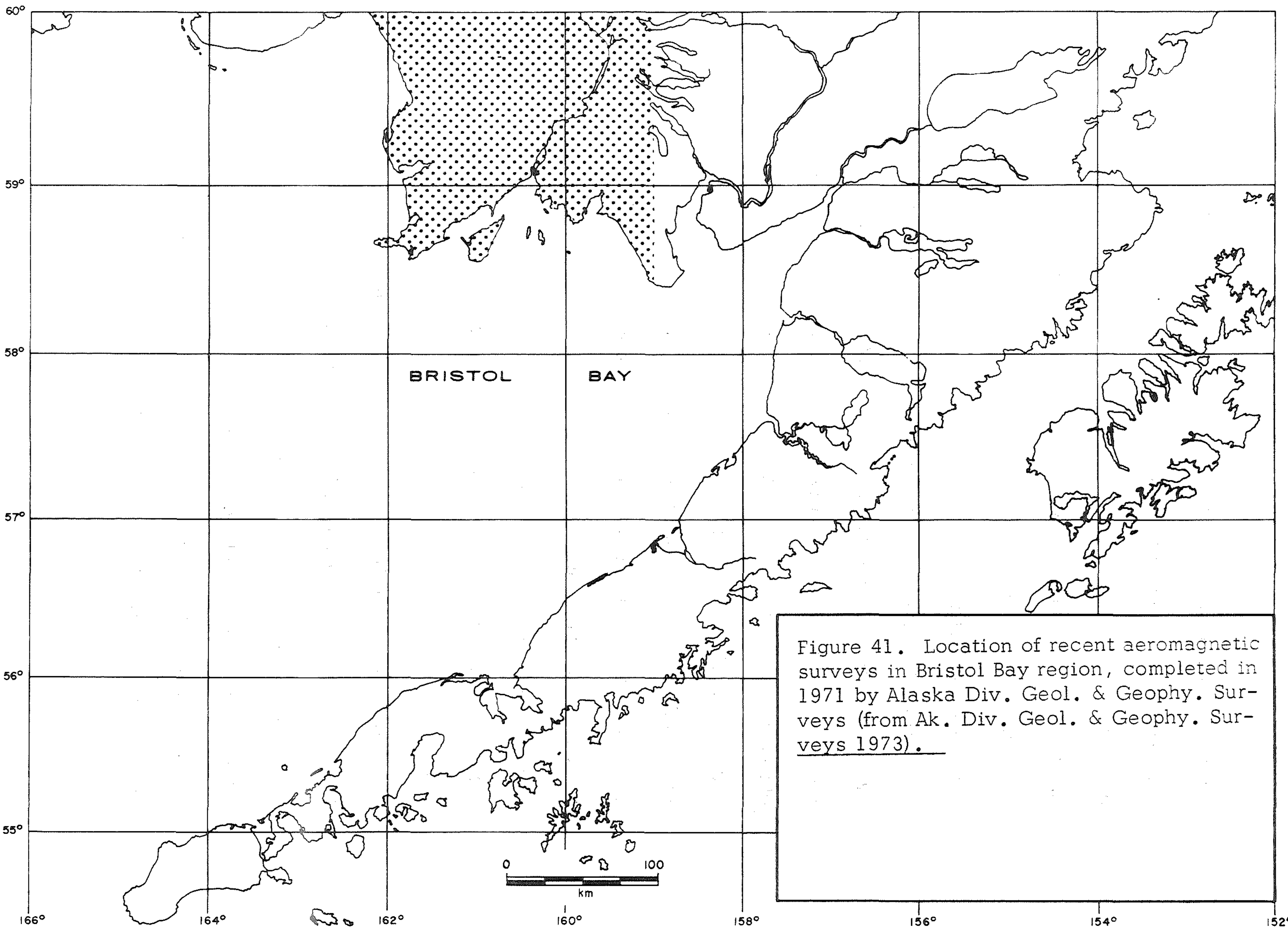


Figure 41. Location of recent aeromagnetic surveys in Bristol Bay region, completed in 1971 by Alaska Div. Geol. & Geophy. Surveys (from Ak. Div. Geol. & Geophy. Surveys 1973).

ure 42). Mining activity probably will not increase until this complex land tenure situation is resolved.

Nonmetallic Minerals

Few nonmetallic minerals are known to exist in the study area (Figure 43). Several coal deposits have been found adjacent to the Bristol Bay drainage, notably at Chignik and Herendeen Bay. A sulphur deposit occurs on the south side of the Alaska Peninsula, and sand and gravel are common along streams and rivers flowing into Bristol Bay. Further exploration may reveal more nonmetallic minerals.

The Late Cretaceous rocks which underlie at least 100 sq. km. of the Peninsula between Herendeen Bay and Port Moller, contain bituminous coal (Barnes 1967). Most of the coal occurs in a large number of closely spaced beds ranging from a few tenths to 2.1 m. in thickness. These beds have not been evaluated, and no reliable estimate of the reserves can be made. Plans for mining the coal beds were developed between 1880 and 1902 but commercial production never occurred. These plans included 24 km. of overland transport from Herendeen Bay to ice-free Balboa Bay. Some Tertiary lignite-bearing rocks also occur in the area, but appear to have little economic value. Late Cretaceous rocks along the northwest shore of Chignik Bay also contain dis-

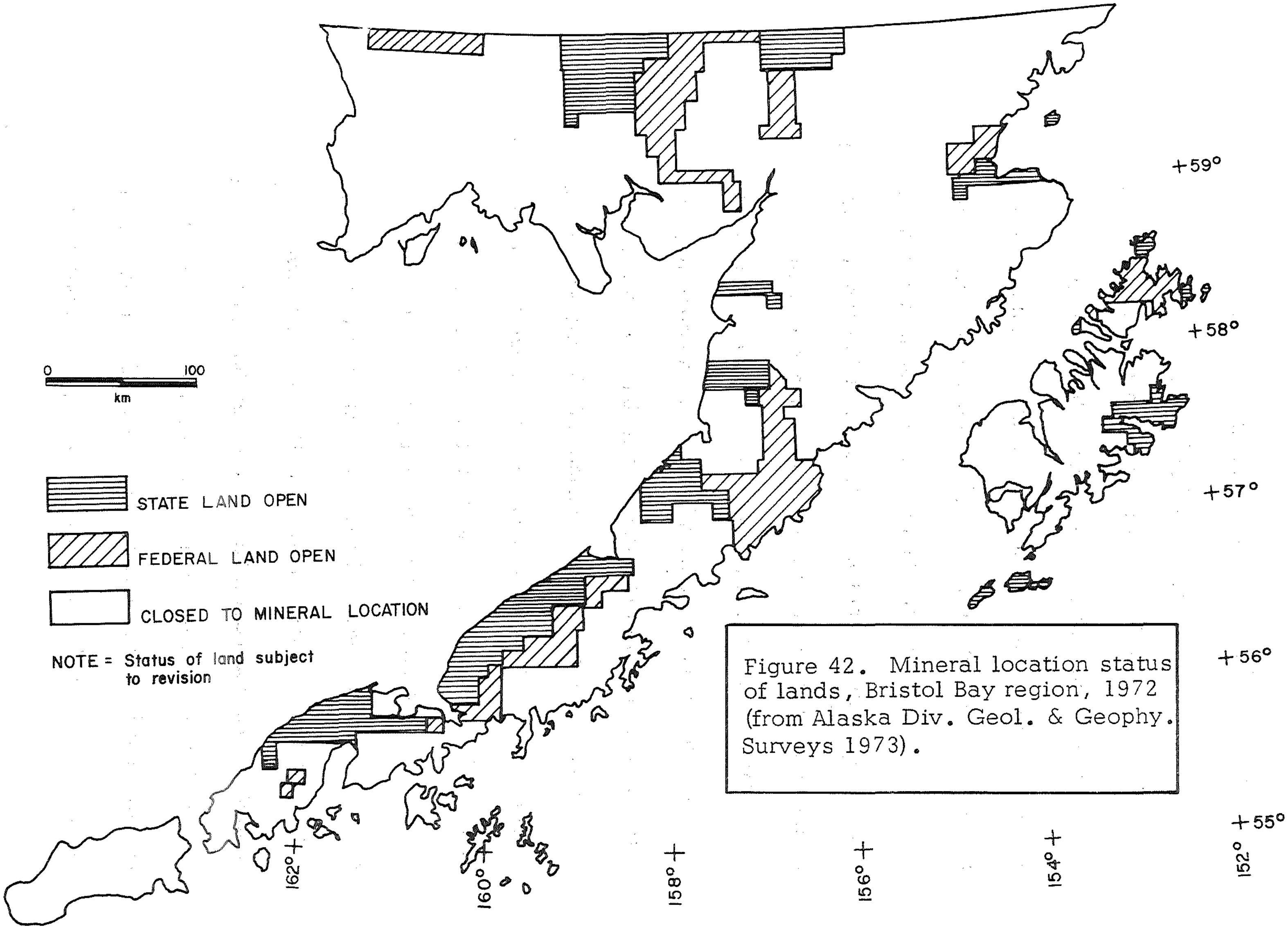


Figure 42. Mineral location status of lands, Bristol Bay region, 1972 (from Alaska Div. Geol. & Geophy. Surveys 1973).

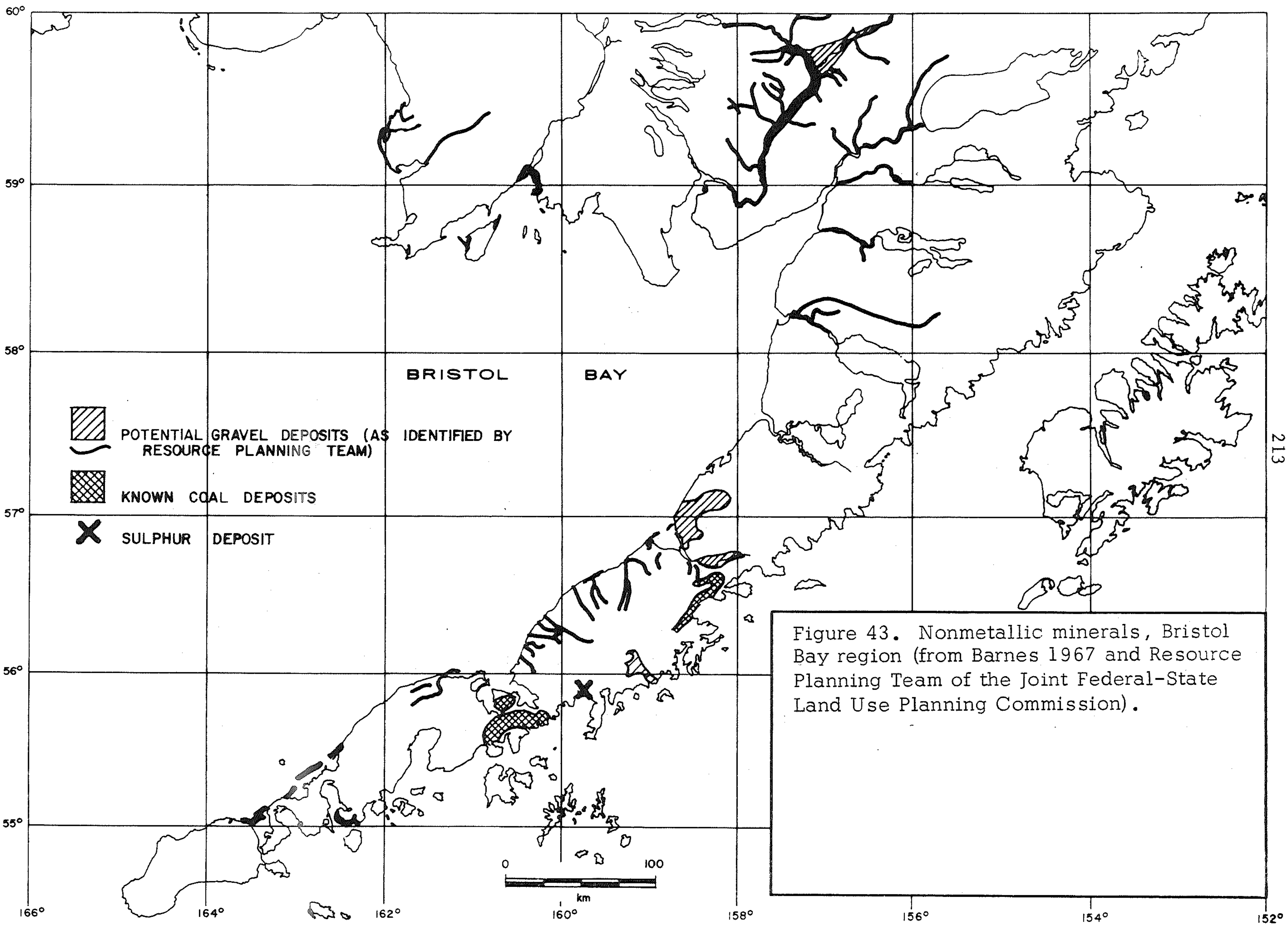


Figure 43. Nonmetallic minerals, Bristol Bay region (from Barnes 1967 and Resource Planning Team of the Joint Federal-State Land Use Planning Commission).

continuous bituminous coal beds ranging from 0.3 to 1.5 m. in thickness, but insufficient data are available to estimate reserves (Barnes 1967).

Sulphur deposits occur in and around the vents of several volcanoes on the Alaska Peninsula. These minor deposits have been prospected and drilled from time to time, depending on the market for sulphur. A significant deposit may be present on the south side of the Peninsula near Stepovak Bay. This deposit occurs on a near-vertical slope covered with ice and snow and has not been closely examined. The quality of debris at the base of this slope, however, does not suggest economically valuable concentrations of sulphur.

Construction materials--gravel and sand--occur throughout the area along most major streams either as floodplain or higher terrace deposits (Figures 32 and 43). In addition, the older outwash and glacial deposits covering the lowlands between streams probably contain good sand and gravel, but they could not be delineated without further exploration. No detailed investigations for sand and gravel have been made in the study area. The Resource Planning Team of the Joint Federal-State Land Use Planning Commission, however, has roughly identified areas with sand and gravel potential (Figure 43) from data presented by Karlstrom et al. (1964).

OIL AND GAS

Introduction

Much of the Bristol Bay study area has a high oil and gas potential and holds promise as a significant future petroleum province. Exploration is still in an early stage, and not enough information is available yet to make accurate estimates of potential reserves. Considering the areal extent and the thickness of sedimentary rocks, however, a recoverable reserve of 1 to 5 billion barrels would not be an unreasonable estimate (Hatten 1971). The U.S. Geological Survey (1972) has estimated that the Alaska Peninsula portion of the area contains approximately 1.5 billion barrels of oil, while the offshore area of Bristol Bay may contain an even greater amount.

There has been significant exploratory activity since about 1958, and oil company interest remains high. Extensive geophysical and geological reconnaissance surveys have been conducted both onshore and offshore. Onshore, 12 deep test wells have been drilled--all dry holes--and one well is currently being drilled. No wells have been drilled offshore, where a large portion of the potential oil and gas province is thought to be located. It is likely that several large oil and gas fields will be found in the study area if exploration continues.

The economics of exploration and production in Bristol Bay are better than in many of the other offshore areas of Alaska. Operating conditions are not particularly difficult and storms here are less severe than in the Gulf of Alaska. The ice in the Bristol Bay study area is one-year ice, and it is believed that reinforced tankers would pass through the area without problems most of the year. Alternatively, oil could be piped across the Alaska Peninsula to ice-free, deepwater harbors. Although this harbor site would be remote, its southern location places it closer to established West Coast markets than Cook Inlet.

There are actually 2 separate geologic provinces in the study area that contain rocks with oil and gas potential--the Alaska Peninsula Mesozoic Province and the Bristol Bay Tertiary Province. These provinces are discussed in separate sections below, followed by a summary of oil and gas activities and interests in the area (Figure 44).

Alaska Peninsula Mesozoic Province

Marine sedimentary rocks ranging in age from Permian through Cretaceous outcrop along the entire length of the Alaska Peninsula (Figure 44 and units (1) and (3) of Fig-

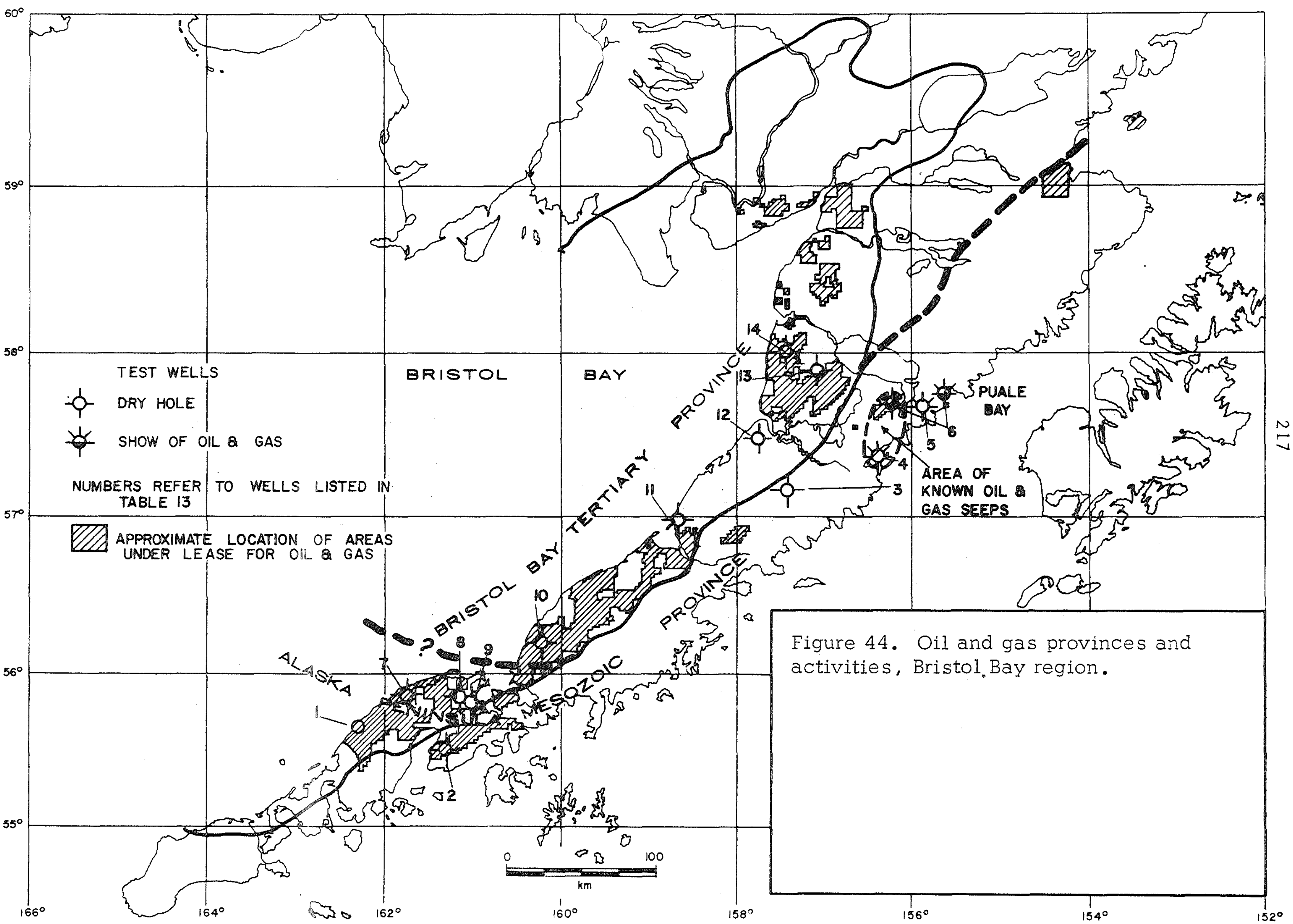


Figure 44. Oil and gas provinces and activities, Bristol Bay region.

ure 25). Oil and gas shows in wells plus shows and seeps at the surface along the south side of the Alaska Peninsula indicate that these rocks have definite petroleum potential.

Although most of this predominantly Mesozoic belt of rocks lies south of the Bristol Bay study area, it apparently extends west across the southern end of the Alaska Peninsula and then offshore across southern Bristol Bay and along the Bering Sea contenental shelf margin. These rocks probably are the objective of the one well now being drilled (December 1973) on the Alaska Peninsula near Cold Bay (Amoco Cathedral River No. 1). They also may be an important objective in future onshore and offshore drilling in southern Bristol Bay; thus, they are discussed briefly below.

Rocks ranging in age from Permian through Lower Jurassic probably occur in the subsurface throughout the southeastern half of the Alaska Peninsula, but they only outcrop in one place south of the Bruin Bay Fault--at Paule Bay. This section at Paule Bay contains abundant limestones and some sandstones that are potential reservoir rocks and dark shales that could be potential source rocks. Petroliferous beds and tar sands have been reported from these rocks (Miller et al. 1959). All these rocks are essentially untested in the subsurface.

More than 6,000 m. of predominately marine clastic rocks ranging in age from Middle Jurassic through Lower Cretaceous age form the rest of the Mesozoic section exposed on the Alaska Peninsula. This section contains abundant sandstones and conglomerates--potential reservoir rocks--intertongued with marine shales, some of which are known to be potential source rocks. These rocks contain numerous oil and gas seeps and petroliferous beds on the south side of the Peninsula. These seep areas are currently being investigated by the U.S. Bureau of Mines as part of an overall research project to evaluate oil seeps in Alaska.[1]

At least 12 shallow test wells were drilled on 2 broad anticlines in the vicinity of the seeps between 1903 and 1940 (Figure 44 and Table 13).

The lack of commercial production from these late Paleozoic through Mesozoic rocks along the Peninsula appears to be due mainly to their poor quality as petroleum reservoirs. Reservoir quality might improve to the southwest, however, where Mesozoic rocks occur in the subsurface. This possibility is apparently being tested onshore by the

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1. Don Blasko, Petroleum Engineer, U.S. Bureau of Mines, Anchorage, Alaska. Personal Communication, October 1973.

Table 13. Wildcat Wells, Bristol Bay-Alaska Peninsula Region

Alaska Peninsula Mesozoic Province

No.	Name	Completion Date	Total Depth (m.)	Status
1.	Amoco, Cathedral River No. 1			Drilling
2.	Pure, Canoe Bay No. 1	10/26/61	2,024	Dry & Abd.
3.	Cities Service, Painter Creek No. 1	7/16/67	2,412	"
4.	Richfield, Wide Bay No. 1	10/17/63	3,830	"
5.	Humble, Bear Creek No. 1	3/04/59	4,382	"
6.	(10 shallow test wells drilled between 1904 and 1940)			"

Bristol Bay Tertiary Province

No.	Name	Completion Date	Total Depth (m.)	Status
7.	Pan Amer., David River No. 1 and 1A	8/18/69	4,197	"
8.	Pan Amer., USA Hoodoo Lake No. 1	1/13/70	2,454	"
9.	Pan Amer., USA Hoodoo Lake No. 2	4/28/70	3,810	"
10.	Gulf, Sandy River Federal No. 1	12/03/63	3,983	"
11.	Gulf, Port Heiden No. 1	9/14/72	4,577	"
12.	Great Basins, Ugashik No. 1	8/25/66	2,888	"
13.	Mobil, Great Basins No. 1	9/14/59	3,377	"
14.	Mobil, Great Basins No. 2	11/12/59	2,702	"

Note: More detailed information about these wells is available from the Alaska Division of Oil and Gas, Anchorage (except No. 11, which has not been released).

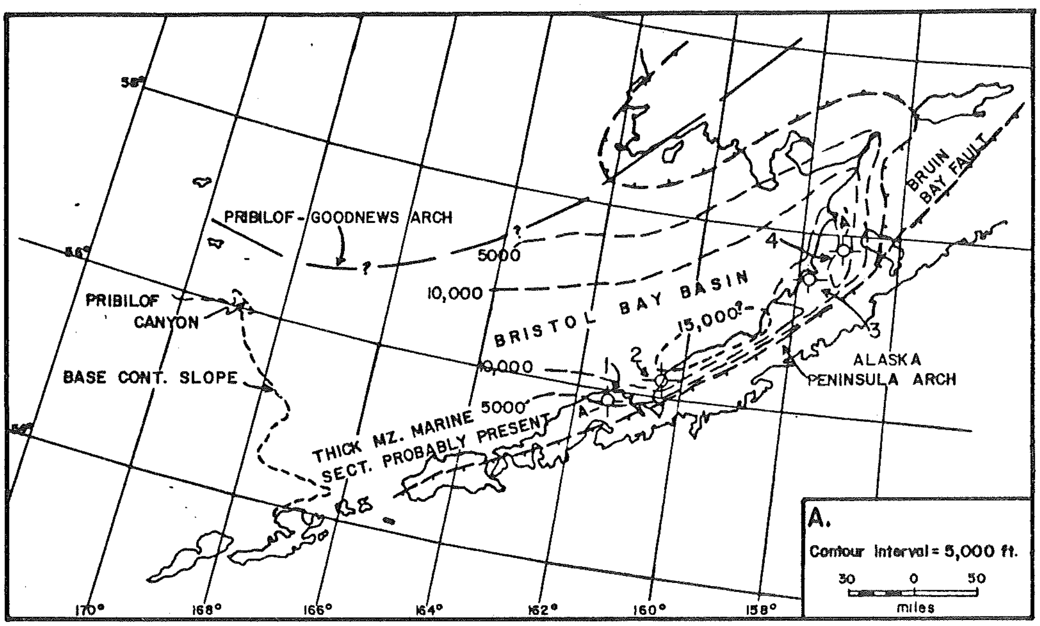
Cathedral River No. 1 well still being drilled (December 1973). Large anticlinal structures apparently project offshore (Pratt et al. 1972), and they probably will be tested in any future offshore exploration in southern Bristol Bay.

There has been no calculation of reserves for this province alone, but it may contain more than 1 billion barrels. Future success depends on finding favorable structural-stratigraphic situations. Even if such favorable situations are found, if adequate reservoir rocks are not available, large commercial production may be difficult to develop.

Bristol Bay Tertiary Province

The Bristol Bay Tertiary Province is a northeast trending structural and sedimentary basin filled mainly with clastic marine and nonmarine sediments of Middle to Late Tertiary age (Figure 45). Little information is available about the basin. It was discussed briefly by Gates et al. (1968) and by Hatten (1971). A large part of the following discussion is derived from the latter source. Much detailed information is contained in petroleum company files, but these data are of a proprietary nature and not generally available to the public.

Eight deep test wells--all dry holes--have been drilled into and through the Tertiary rocks onshore, and have provided much valuable subsurface data. Basic information



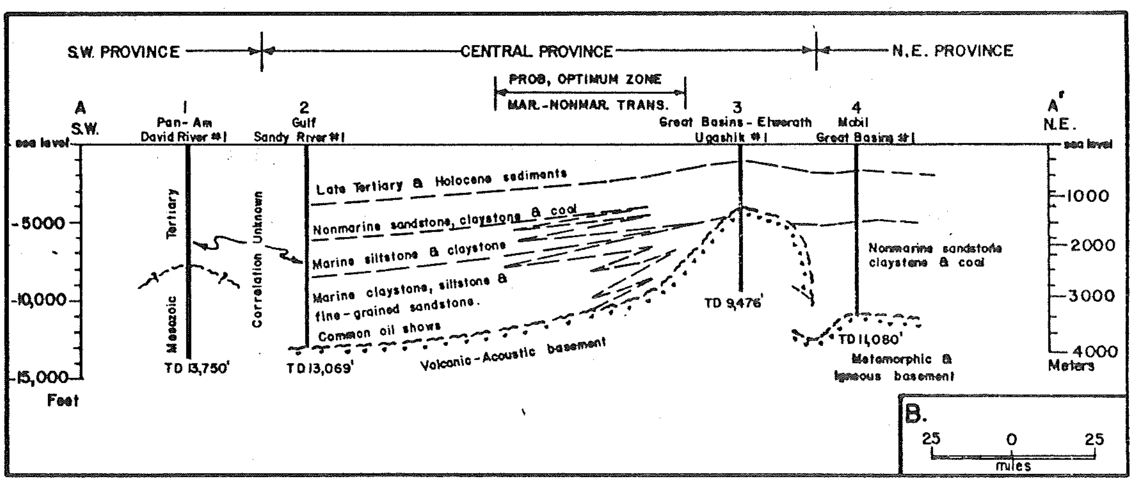


Figure 45. Subsurface geology, Bristol Bay region: A. Isopach map of Tertiary, post-acoustic basement rocks; B. SW - NE correlation section (from Hatten 1971).

(logs, samples, etc.) for all except one of these wells has been released and is available at the Division of Oil and Gas, State of Alaska, Anchorage.

The Bristol Bay basin is an elongate structural depression covering 246,000 sq. km. (Figure 45). It is bounded on the southeast by the Alaska Peninsula Arch and on the northwest by the Goodnews Arch. It may extend southwestward and connect with another Cenozoic basin at the edge of the Bering Sea continental shelf (Scholl and Hopkins 1969, Scholl et al. 1973) (Figure 31).

This basin is filled with a thick sequence of mainly Middle to Late Tertiary rocks consisting of both marine and nonmarine shales, sandstones and low-grade coals. Along the Alaska Peninsula flank of the basin, there may be Early Tertiary rocks equivalent to the Tertiary rocks on the southeast side of the Peninsula. The Tertiary sequence varies in thickness over an irregular basement and probably reaches a maximum thickness of more than 4,500 m. in places. Along the onshore portion of the basin, the basement apparently changes from a Paleozoic-Mesozoic igneous and metamorphic terrane in the north to a mid-Tertiary volcanic complex in the central part to a Mesozoic sedimentary province in the southwest (Figure 45).

The Tertiary rocks in the basin are the major target of exploration. Tertiary sandstone beds are relatively unconsolidated and make good petroleum reservoirs; excellent reservoir beds evidently were found at various levels in several of the wells drilled. Geophysical surveys have identified suggestions of structure, especially along the flank of the Alaska Peninsula paralleling the northeast structural grain. In addition, the cross-basin faulting observed onshore may extend offshore and could provide additional petroleum traps. Although no verified oil seeps have been found around the periphery of the basin, several oil shows have been observed in wells, indicating that a possible source of oil is available. It is still speculative, however, whether adequate source beds are present in Tertiary rocks in the deeper parts of the basin. Even if present, the source beds may not have been buried deep enough or heated enough to have generated and expelled petroleum.

The Mesozoic sedimentary rocks that underlie the southern part of the province probably do contain source beds, however, and they could supply oil vertically to the better reservoirs in the overlying Tertiary sediments.

Similar Mesozoic rocks are thought to be the source of oil for the prolific Cook Inlet Tertiary reservoirs to the north. The southern part of the Bristol Bay province thus might be the more attractive portion of the basin to explore for oil. The presence of coals within the nonmarine portion of the section also could indicate a source of abundant natural gas reserves within the Tertiary beds, such as occurs in the Cook Inlet basin.

Petroleum Company Activities and Interests

Significant exploration activities have been continuing in the Bristol Bay area since about 1958. These activities have included both onshore and offshore geophysical surveys, onshore geologic field work, and the drilling of 12 deep, exploratory test wells. Between 1958 and 1971, the industry spent more than 45 million dollars on exploration in the Bristol Bay area, excluding the 4 wells drilled in the Mesozoic province. A summary of past geologic and geophysical activities and wildcat wells is presented in Table 14. There is one well being drilled on the Alaska Peninsula (Amoco Cathedral River No. 1) just north of Cold Bay (December 1973). The projected depth of this well is about 3,600 m. Minor shows evidently have been encountered, but tests are not

Table 14. Summaries of Exploration Activity in Bristol Bay-Alaska Peninsula Region.

A. Geophysical and Surface Mapping Activity (Excluding U.S. Geological Survey)--Alaska Peninsula-Bristol Bay

Crew Months

	Surface Geology	Geophysical	Total
1970[1]	6	4	10
1971[2]	3	3	6
1972[3]	9	3	12
1973[4]	2	4	6

B. A Roundup of Geophysical Work in Alaskan Waters--Bristol Bay[5]

Year	Operator	No. of Participants	Mileage	Type	Contractor	Gross Cost ($)
1963	Amoco	5	1,163	Reflection	GSI	250,000
1965		16	14,000	Aeromag-netic	Aero	
1966	Union[a]	22	4,356	Reflection	GSI, Western	372,000
1967			2,000	Reflection	Western	
1969		SC	1,000	Reflection	GSI	
1970		SC	500	Reflection	Digicon	
1970		SC	1,500	Reflection	GSI	
1971	Skelly[b]	22	1,700	Reflection, Gravity	GSI	754,000

a. Southeast sector
b. Southwest sector

Table 14. (Continued)

C. Yearly Summary of Industry Drilling, Seismic and Geological Field Effort--Bristol Bay Region.[4]

Year	Total exploratory depth, each well (km.)	Offshore Seismic Crew Mo.	Onshore Seismic Crew Mo.	Geological Field Crew Months
1956	-	-	-	-
1957	-	-	-	-
1958	-	-	3.5	7.00
1959	3.4, 2.7	-	6.0	11.50
1960	-	-	-	2.75
1961	-	-	6.50	1.25
1962	-	-	10.75	0.50
1963	4.0	2.00	11.50	4.75
1964	-	2.00	-	2.00
1965	-	7.00	-	3.75
1966	2.9	7.75	2.75	6.50
1967	-	4.00	6.75	11.00
1968	0.7	0.50	8.75	7.50
1969	4.2	-	12.00	1.75
1970	2.4, 3.8	0.50	-	6.75
1971	-	1.00	-	3.50

1. Lian 1971
2. Adams 1972
3. Harrison 1973
4. Compiled from various industry sources
5. Wilson 1972

planned until after the well has been drilled to its total depth.

Interest by petroleum companies is still high, as evidenced by the amount of area still under lease (Figure 44). Detailed up-to-date maps showing lease information are available for a fee from Alaska Map Service, Anchorage, Alaska. Exploration activities are now at a minimum, mainly due to the land tenure situation involving the Alaska Native Claims Settlement Act, the lack of offshore lease sales, environmental concerns, and the unknown impact on the region's fisheries. Oil companies are now in a "holding pattern" awaiting further developments. Enough reconnaissance geologic and geophysical work has been done to outline major areas of interest, and no further major activity is expected until some of the above mentioned problems are resolved, the "energy crisis" forces exploration to expand, or there is a petroleum discovery. For example, a significant discovery at the Cathedral River well could alter the onshore exploration pattern almost overnight. Such a discovery could also encourage the entension of exploration into adjacent offshore areas.

Many of the lands along the eastern shore of the Bay have been tentatively approved for transfer to the State of Alaska. Presumably onshore exploration in the area will be encouraged when the State receives title. Much of this area presently is under federal oil and gas lease (Figure 44). Some parts, however, have been withdrawn under the Alaska Native Claims Settlement Act (PL 92-203), and are subject to selection by native villages (Figure 42). These changes in tenure would not invalidate any current lease holdings, but will have some bearing on future leasing. Additional lands along northern Bristol Bay have been withdrawn as village selections, national interest lands (d-1 or d-2 lands) under the Alaska Native Claims Settlement Act, or are part of the present National Wildlife Refuge system. All such lands are now closed to mineral exploration, but much is outside the major areas of petroleum interest.

Future offshore exploration in the area depends entirely on lease sales by the state and federal governments. In 1968 the State of Alaska held Offshore Lease Sale No. 21, the only sale held in Bristol Bay. Approximately 66,650 hectares were leased within the 3 mile (4.8 km.) limit, and bonus money of more than 3 million dollars was paid. The State currently has no plans for any additional offshore leasing until the federal government shows some further interest in the outer continental shelf or a discovery is made.

There is currently a restriction on oil and gas activities in the state waters of inner Bristol Bay. Due to concern for the fisheries, the Alaska State Legislature in 1972 passed a resolution limiting oil and gas activities north of 57 degrees 30 minutes N latitude (Figure 46), which is generally north of the main area of exploration interest.

A proposed schedule for provisional outer continental shelf leasing indicates that a sale on the Alaska Bering Sea continental shelf may be possible in 1977-1978 (Figure 47). Presumably, the sale will involve offshore tracts in the Bristol Bay basin, since it is the only basin on the Bering Sea shelf that has had any significant exploration. It also offers the greatest potential on this shelf for oil and gas discoveries. The impending "energy crisis" or a discovery at the Catherdral River No. 1 well could change this schedule and allow offshore drilling to take place much sooner in Bristol Bay.

Figure 46. Limitations on oil and gas leasing, Bristol Bay region.

LAWS OF ALASKA
1972

Source
CSSB 2 am

Chapter No.
102

AN ACT

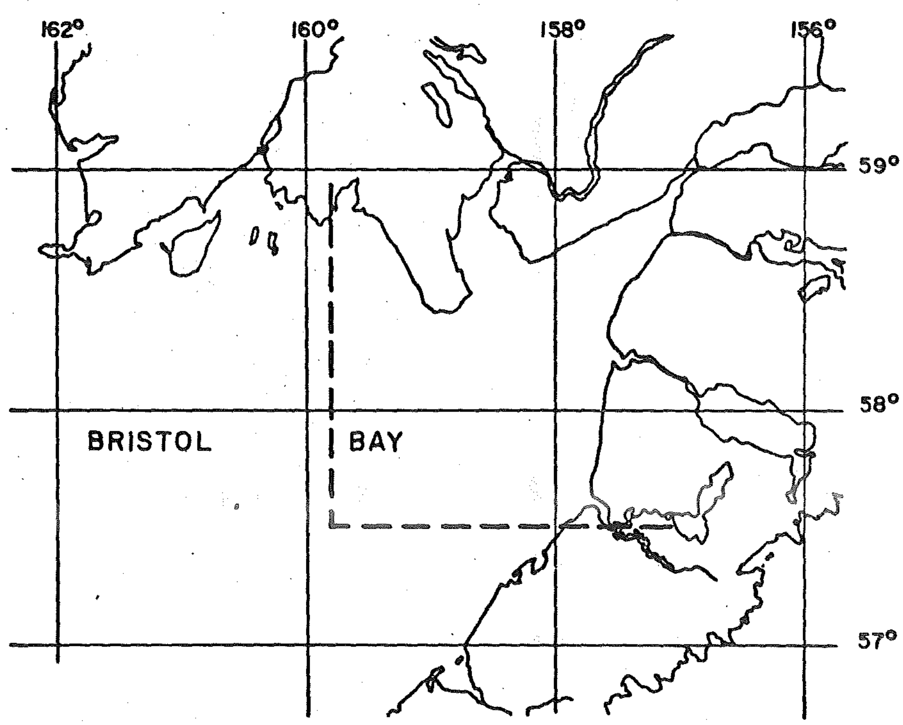
Relating to limitations upon oil and gas leases in certain areas.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

Section 1. AS 38.04.140 is amended by adding a subsection to read:

(f) The submerged and shorelands lying north of 57° 30 minutes north latitude and east of 159°, 49 minutes west longitude within the Bristol Bay drainage are designated as the Bristol Bay Fisheries Reserve. Within the Bristol Bay Fisheries Reserve no surface entry permit to develop an oil or gas lease may be issued on state owned or controlled lands until the legislature by appropriate resolution shall specifically find that such entry shall not constitute danger to the fishery.

(From Laws of Alaska)



SALES	1976												1977												1978											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
43 ALASKA (LOWER COOK INLET)		C		ND			T			DES	PH				FES	N	SALE																			
46 ALASKA (BERING SEA SHELF)														C		ND			T			DES	PH				FES	N	SALE							

C= CALL FOR NOMINATION
ND= NOMINATIONS DUE
T= ANNOUNCEMENT OF TRACTS

DES= DRAFT ENVIRONMENTAL STATEMENT
PH= PUBLIC HEARING

FES= FINAL ENVIRONMENTAL STATEMENT
N= NOTICE OF SALE

A decision whether to hold any of the lease sales listed will not be made until completion of all necessary studies of the environmental impact and the holdings of public hearings; as a result of the environmental, technical and economic studies employed in the decision-making process, a decision may, in fact, be made not to hold any sale on this schedule.

If CEQ's study of the environmental impact of oil and gas production on the Atlantic Outer Continental Shelf and in the Gulf of Alaska, determines that development in these areas can proceed in an environmentally satisfactory manner, lease sales in one or both areas will be added to the proposed schedule at the earliest practicable time.

The holding of sale 43 is contingent upon the outcome of pending litigation with Alaska regarding jurisdiction over this area.

Figure 47. Proposed schedule by the Bureau of Land Management for provisional OCS leasing (from Federal Register, V. 38, No. 132, Wed. July 11, 1973).

Regardless of the petroleum potential and the favorable operating conditions of the Bristol Bay area, it ranks lower than several other Alaska offshore areas in regard to exploration priorities within the petroleum industry. The Gulf of Alaska apparently has the highest priority, since it is the closest to West Coast markets and has reserves estimated as high as 40 to 60 billion barrels, an order of magnitude higher than the estimated reserves of Bristol Bay. Even Lower Cook Inlet has a higher priority at this time, but as mentioned above, this could change if a significant discovery were made onshore in the Bristol Bay area.

In addition to exploration activities, the petroleum companies have made some effort to collectively gather additional data about the Bristol Bay region, especially environmental information, that could aid in future exploration programs and help minimize their impact on the environment.

OTHER ENERGY RESOURCES

Geothermal Energy

The Alaska Peninsula has a high potential for geothermal energy. All recent or active volcanic centers contain potential geothermal systems that could be exploited for energy (Figure 48). There are no "Known Geothermal Resource Areas" which require a competitive lease sale prior to exploration (Godwin et al. 1971). The U.S. Geological Survey and the Resource Planning Team of the Joint Federal-State Land Use Planning Commission have designated these volcanic centers as valuable areas for potential geothermal energy development.

Hot springs are generally the surface manifestation of geothermal systems, and at least 13 such springs have been reported on the Peninsula (Biggar 1971, Miller 1973). All of these springs are associated with volcanic rock. Temperature and chemical data are available for only a few of them. Other hot springs undoubtedly exist in the study area.

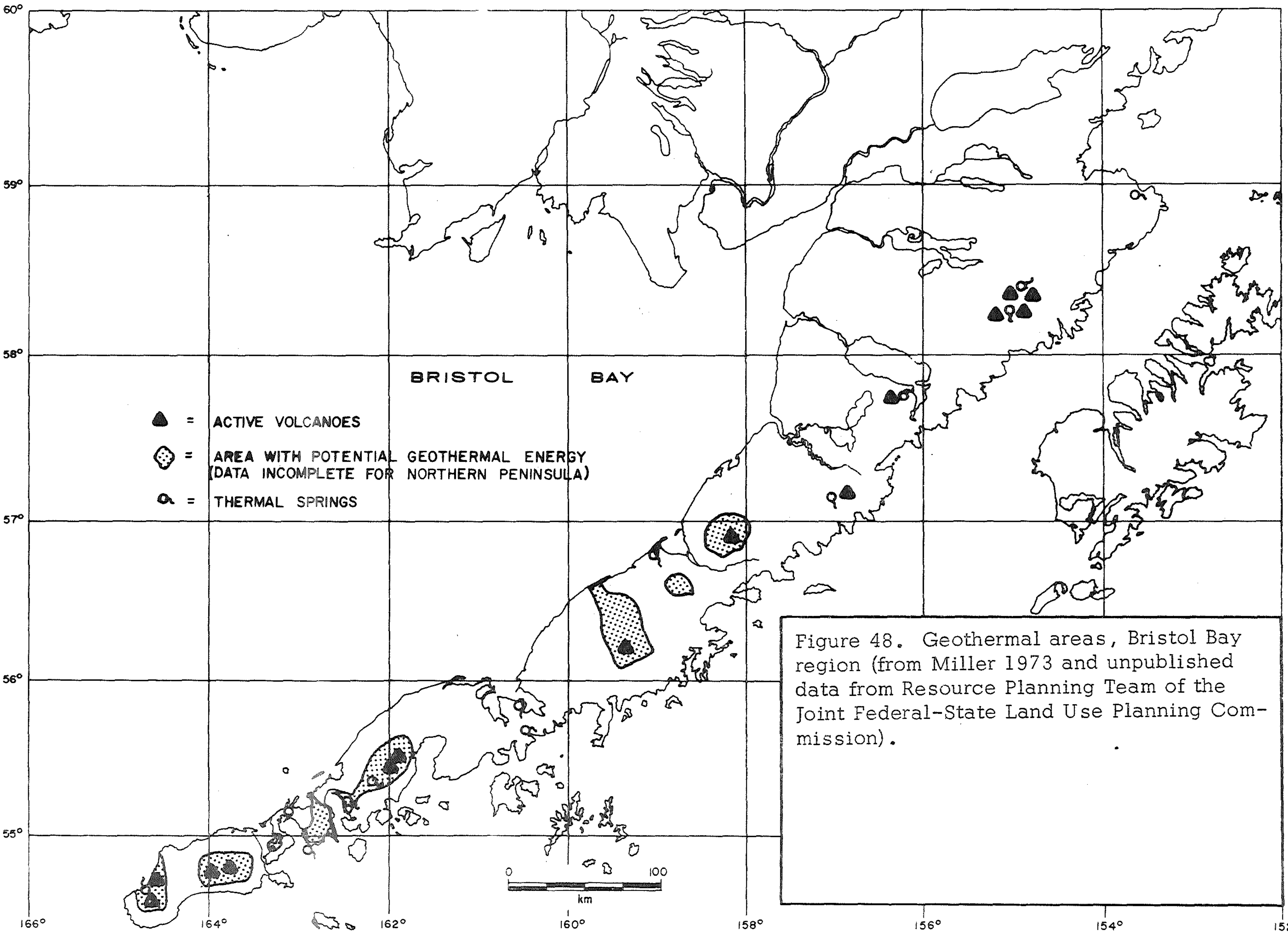


Figure 48. Geothermal areas, Bristol Bay region (from Miller 1973 and unpublished data from Resource Planning Team of the Joint Federal-State Land Use Planning Commission).

A research program has been initiated recently by the U.S. Geological Survey to study Alaska geothermal areas, including the recent volcanic centers of the Alaska Peninsula.[1] In the summer of 1973, samples were collected from recent and active volcanoes and hot springs on the Peninsula during 3.5 weeks of reconnaissance field work. Data obtained on the chemistry, age, and volume of ejected and extruded material possibly can be used to determine the stage of the volcano in its life cycle. The chemistry of thermal springs and adjacent deposits is believed to indicate the temperature of deeper waters. All this information can then be used to evaluate the potential of an area as a geothermal energy source. More detailed work, including geophysics and possibly drilling, may follow these preliminary studies if conditions appear favorable.

No estimate of potential energy available from geothermal systems on the Alaska Peninsula is possible at this time, but this potential is expected to be substantial.

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1. Tom Miller, geologist, U.S. Geological Survey, Anchorage, personal communication.

Hydroelectric

Alaska has the greatest undeveloped potential for production of hydroelectric power in the nation; some of this potential occurs within the Bristol Bay region. Studies by the U.S. Army, Corps of Engineers (1954) and the U.S. Bureau of Reclamation[1] have identified many sites in the area which have hydroelectric potential (Tables 15 and 16). Of these sites the most promising are Nuyakuk Lake, Lake Iliamna, Tazimina Lakes, Ingersol Lake, Kukaklek Lake, Kontrashibuna and Naknek Lake (Figure 49). Reports summarizing these 7 projects have been compiled recently by the Alaska Power Administration as part of an overall evaluation of lands withdrawn under the Alaska Native Claims Settlement Act (PL 92-203). These reports and additional data on hydro-electric power in the region can be obtained through the Alaska Power Administration, Juneau, Alaska.

In view of the high costs indicated for development of these sites, plus the remoteness of the area and the

1. U.S. Bureau of Reclamation unpublished studies conducted during the period 1963-1966 and available from the Alaska Power Administration, Juneau.

Table 15. U.S. Army, Corps of Engineers Study Results, Potential Hydroelectric Sites.

Site		Prime kw	Annual Energy (millions kwh)
Lake Nerka		24,000	213
Grant Lake		2,900	26
Nishlik Lake		2,200	20
Upnuk Lake		5,850	52
Chikuminuk Lake		29,400	296
Nuyakuk-Tikchik Lake		45,500	404
Kulik Lake (Wood River)		21,400	190
Lake Kontrashibuna		10,400	92
Ingersol Lake		35,800	320
Kukaklek Lake		64,300	570
Kulik Lake (Alagnak River)		3,500	21
Grosvenor Lake		11,300	100
Tazimina Lakes	Alt. I	27,600	242
	Alt. II	37,900	332

Source: U.S. Army, Corps of Engineers 1954.

Table 16. U.S. Bureau of Reclamation Statewide Inventory Study Results, Potential Hydroelectric Sites.

Site	Prime kw	Annual Energy (millions kwh)
Upper and Lower Ugashik Lakes	3,400	30
Becharof Lake	8,700	76
Naknek Lake	54,000	470
Contact Creek	1,500	13
Ukak River	3,400	30
American Creek	13,700	120
Nonvianuk Lake	7,200	63
Lake Kulik	10,800	95
Nuyakuk Lake	63,300	555
Lake Iliamna	156,500	1,370
Kukaklek Lake	26,500	232
Alagnak River	5,400	47
Kakhonak Lake	5,180	45
Tazimina Lakes	26,000	228
Upnuk Lake	4,500	40
Chikuminuk Lake	17,600	154
Kontrashibuna Lake	9,500	83
Ingersol Lake	72,000	630

Source: U.S. Bureau of Reclamation unpublished studies conducted during the period 1963-1966 and available from the Alaska Power Administration, Juneau.

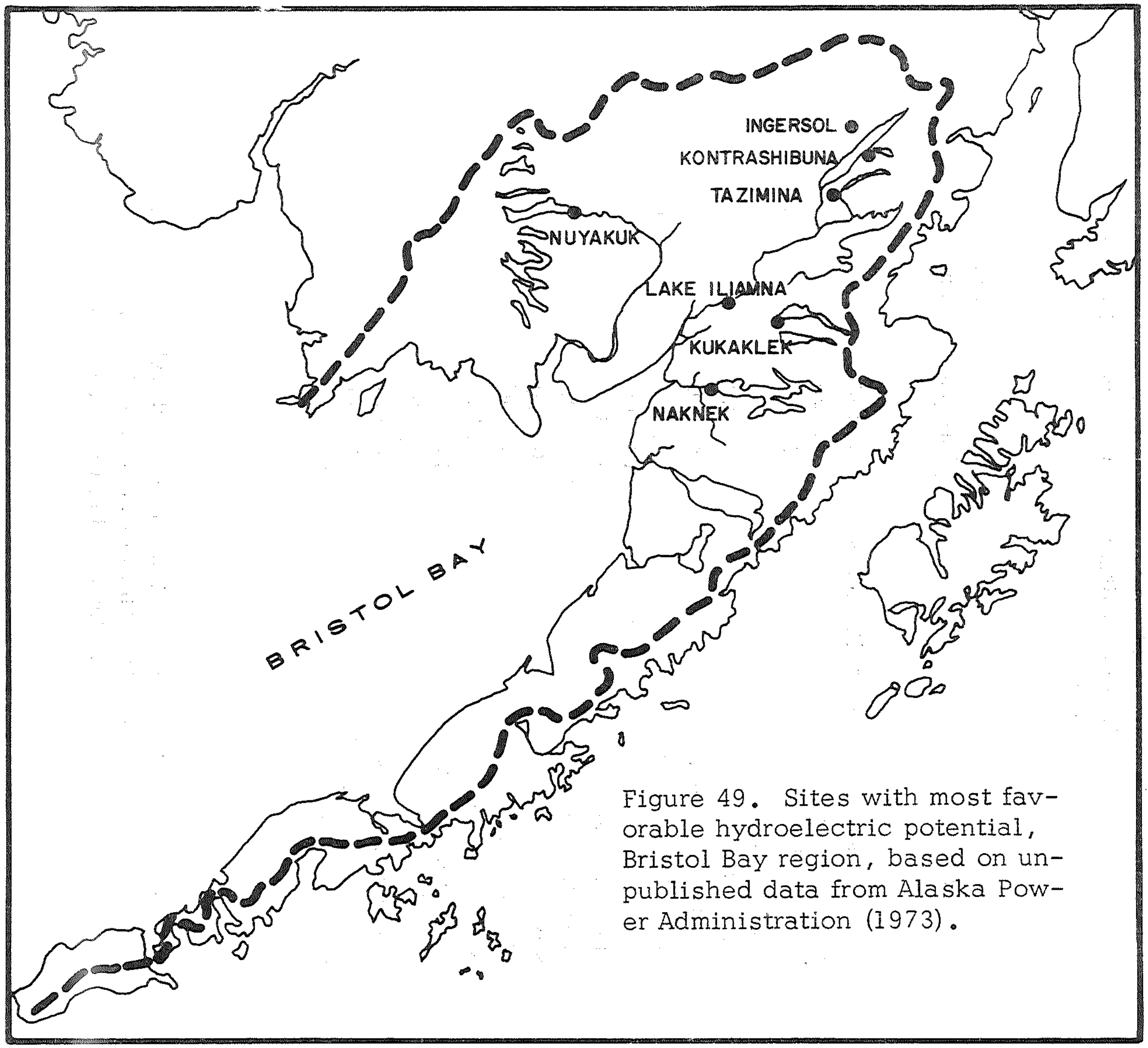

Figure 49. Sites with most favorable hydroelectric potential, Bristol Bay region, based on unpublished data from Alaska Power Administration (1973).

limited local use, it is not likely that any large-scale hydroelectric development will take place in the study area in the foreseeable future.[1]

Wind Power

The potential in Alaska for power production from wind is very large, and represents a yet untapped energy resource that could be "packaged" and exported or used locally. Power generated from windmills is especially attractive as a low-cost energy source well suited for residences, villages, or other small onshore facilities. Use of such power would be dependent on developing adequate storage capacity for continued use during periods of low wind.

The Geophysical Institute, University of Alaska is currently making an assessment of the potential in Alaska for power production from wind. This assessment includes conducting wind surveys at various locations to characterize wind regimes. The Bristol Bay area offers an

1. J. V. House, Alaska Power Administration, Juneau, Alaska. personal communication, November 1973.

excellent laboratory for these studies, since the wind blows hard a large percentage of the time in this region. Several sites within the area are being studied as part of this project, and one location, Cold Bay, is being considered as a prime candidate for further large-scale wind power investigations. Wind data for Cold Bay and for Cape Sarichef on the west end of Unimak Island are presented in Table 17. Further inquiries concerning the potential for power production from wind and investigations in progress should be directed to Dr. Tunis Wentink, Jr., Geophysical Institute, University of Alaska, Fairbanks.

Table 17. Time Percentage of Selected Wind Velocities

Location	Annual Mean Velocity (knots)	Percent of Time Between 7 and 21 Knots	Percent of Time Greater Than 21 Knots
Cape Sarichef Air Force Station	13.7 (1952-56?)	57.5	18.5
Cold Bay Commercial Airport	15.1 (1956-60)	64.0	24.0
	14.8 (1965-71)	Data discrepancies need resolution	

VOLCANISM

A symmetrical arcuate belt extending over 1,609 km. from Mt. Spurr to the tip of the Aleutians contains most of the recent and active volcanoes in Alaska (Figure 50). This belt is only a section of the poetically named "Ring of Fire" which encircles the entire Pacific Ocean (Figure 51). This "Ring" is a narrow zone characterized by active tectonism and seismicity, as well as volcanic activity, landward of the deep-sea trench. Recent plate tectonics theories suggest that tectonic, seismic, and volcanic activity are all related to the underthrusting of one crustal plate beneath another along a subduction or "Benioff" zone (Figure 52). Lavas erupted by Pacific Rim volcanoes are probably generated by the partial melting of oceanic crust and upper mantle rocks as they are thrust under the adjacent plates.

The portion of the "Ring" in Alaska contains at least 60 centers that have erupted during the last 10,000 years. Since 1700 A.D., activity has been recorded at about 40 of these volcanoes. An overall summary of volcanic activity in Alaska is presented by Coates (1950) and Powers (1958).

Thirty-one of these recent and active centers occur adjacent to the study area between Pogromni Volcano on

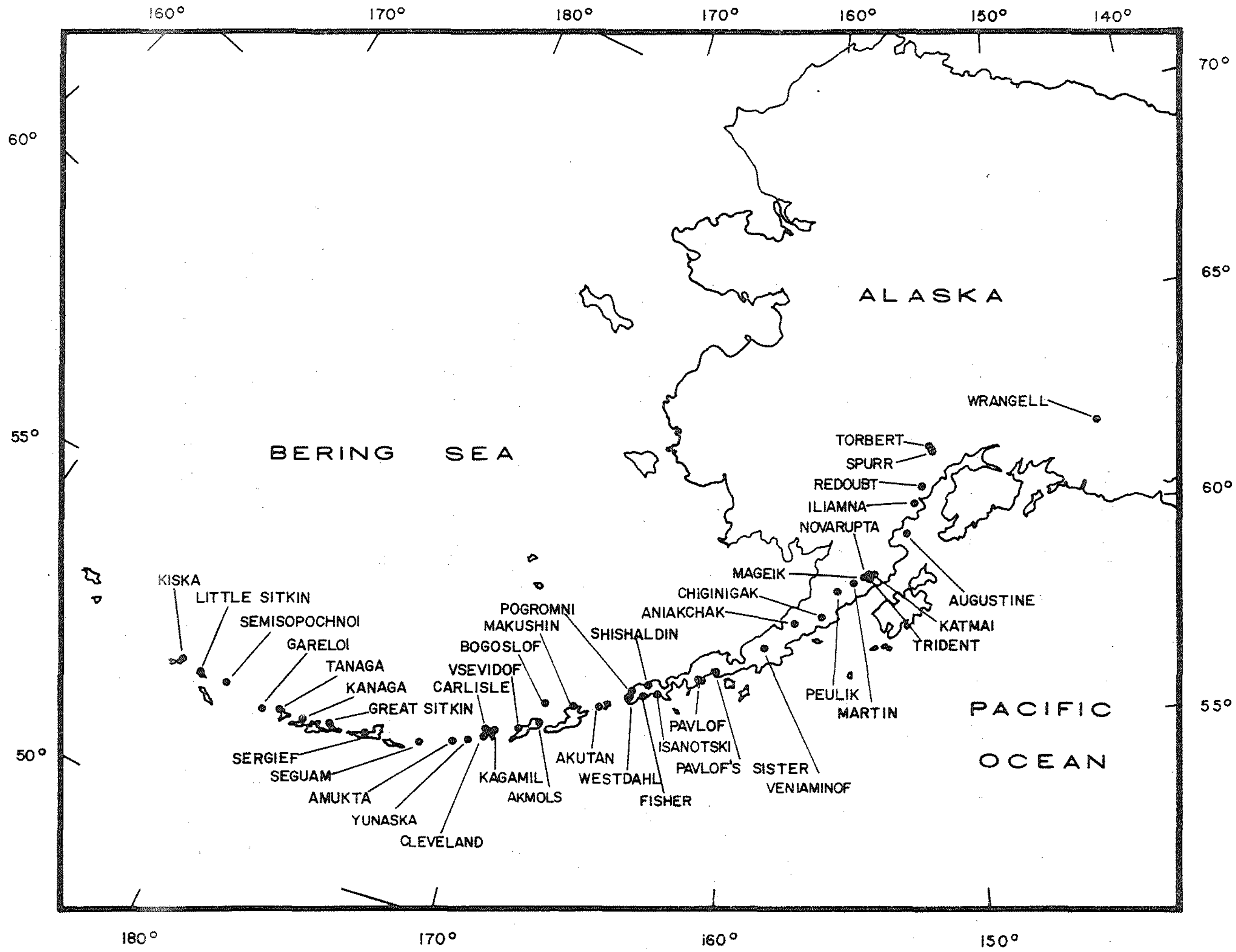

Figure 50. Active volcanoes in Alaska (from Forbes, In Press).

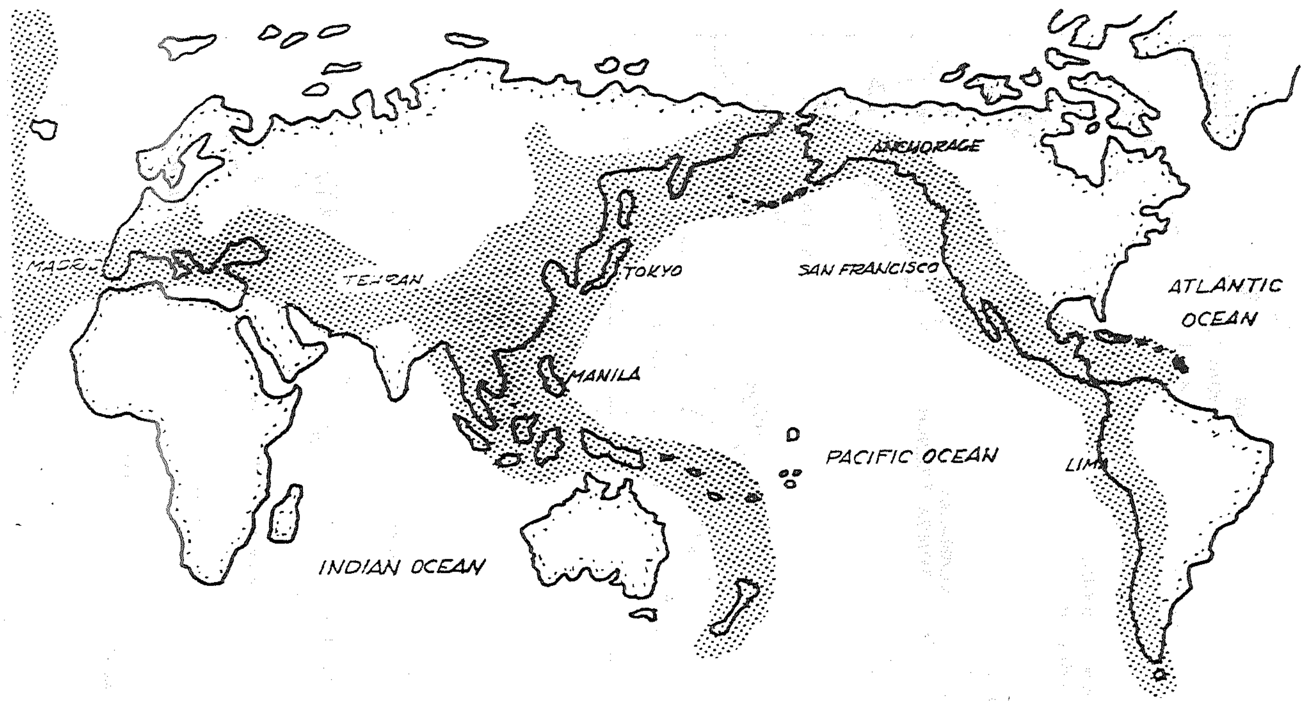

Figure 51. Pacific rim belt of active tectonism, seismicity and volcanism--the "Ring of Fire" (from Hansen and Eckels 1971).

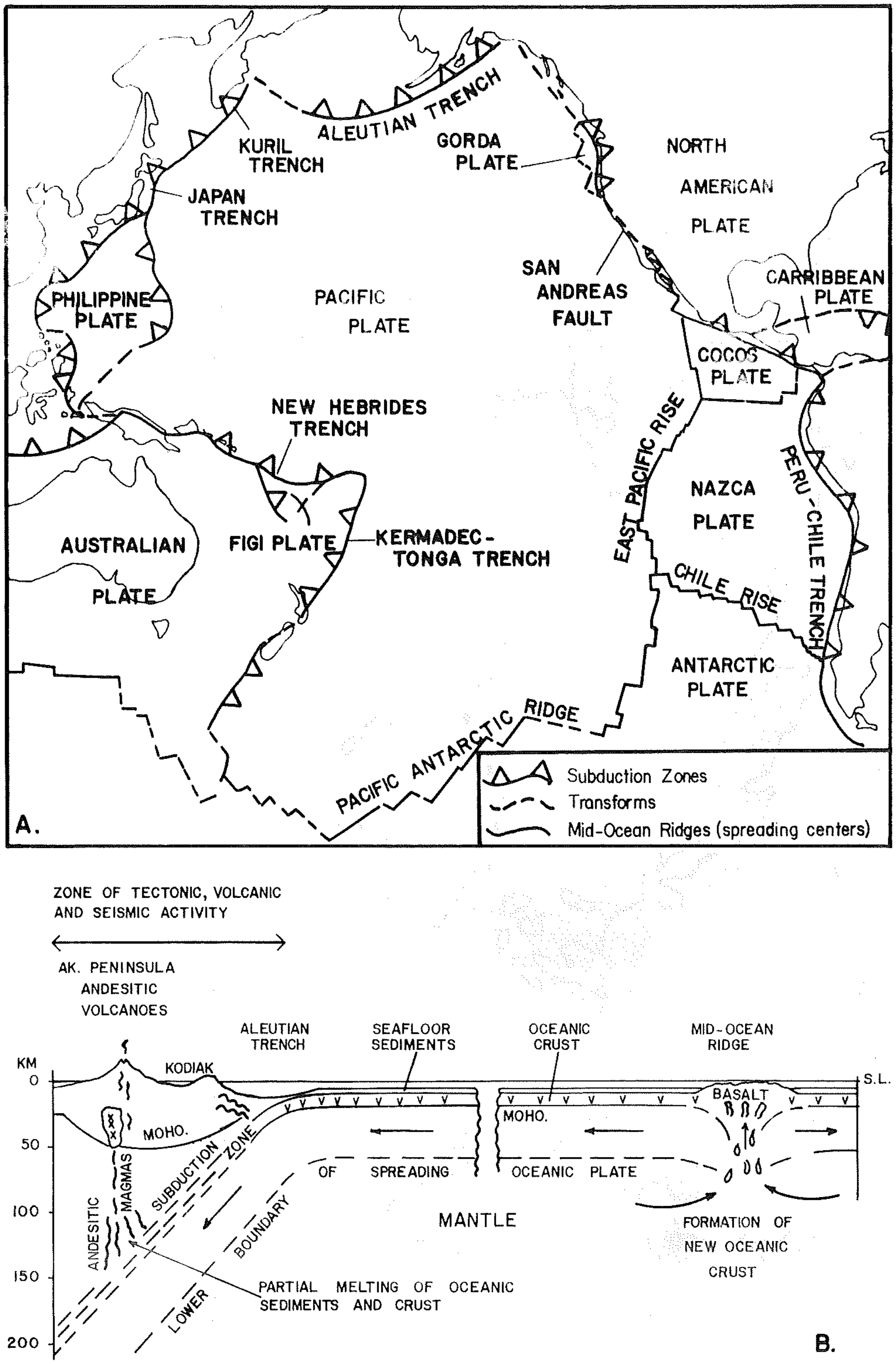

Figure 52. Schematic diagrams showing major elements and mechanisms of plate tectonics theory, Pacific area. A.-Map showing major crustal plates as defined by zones of seismicity, volcanism and active tectonism. B.-Cross section showing mechanisms as applied to southern Alaska.

Unimak Island to Mt. Douglas on the north end of the Alaska Peninsula. The location and the summary of activities of these volcanoes are presented in Figure 53 and Table 18. Any of these centers could erupt at any time.

Volcanoes form most of the high peaks of the Alaska Peninsula, ranging in height from 1,068 m. to more than 2,745 m. at Shishaldin Volcano. In addition to spectacular scenery, these volcanoes offer fine examples of volcanic features such as cones and craters. The Katmai volcanic group is a National Monument, while Mt. Veniaminof, Pavlof and Shishaldin Volanoes, and Aniakchak Crater are being considered for inclusion in one of the national management systems.

Generally, volcanoes on the Pacific Rim are andesitic. They produce magmas which contain more silica and are of higher viscosity than other oceanic basalts such as found in Hawaii. Eruptions of andesitic magmas are violent and explosive, producing large composite cones composed mainly of pyroclastic material (material ejected in a fragmental condition such as ash, lapilli, or bombs). Finer material ejected into the air is often carried downwind, and its distribution depends on the frothiness or fineness of the material, and the direction

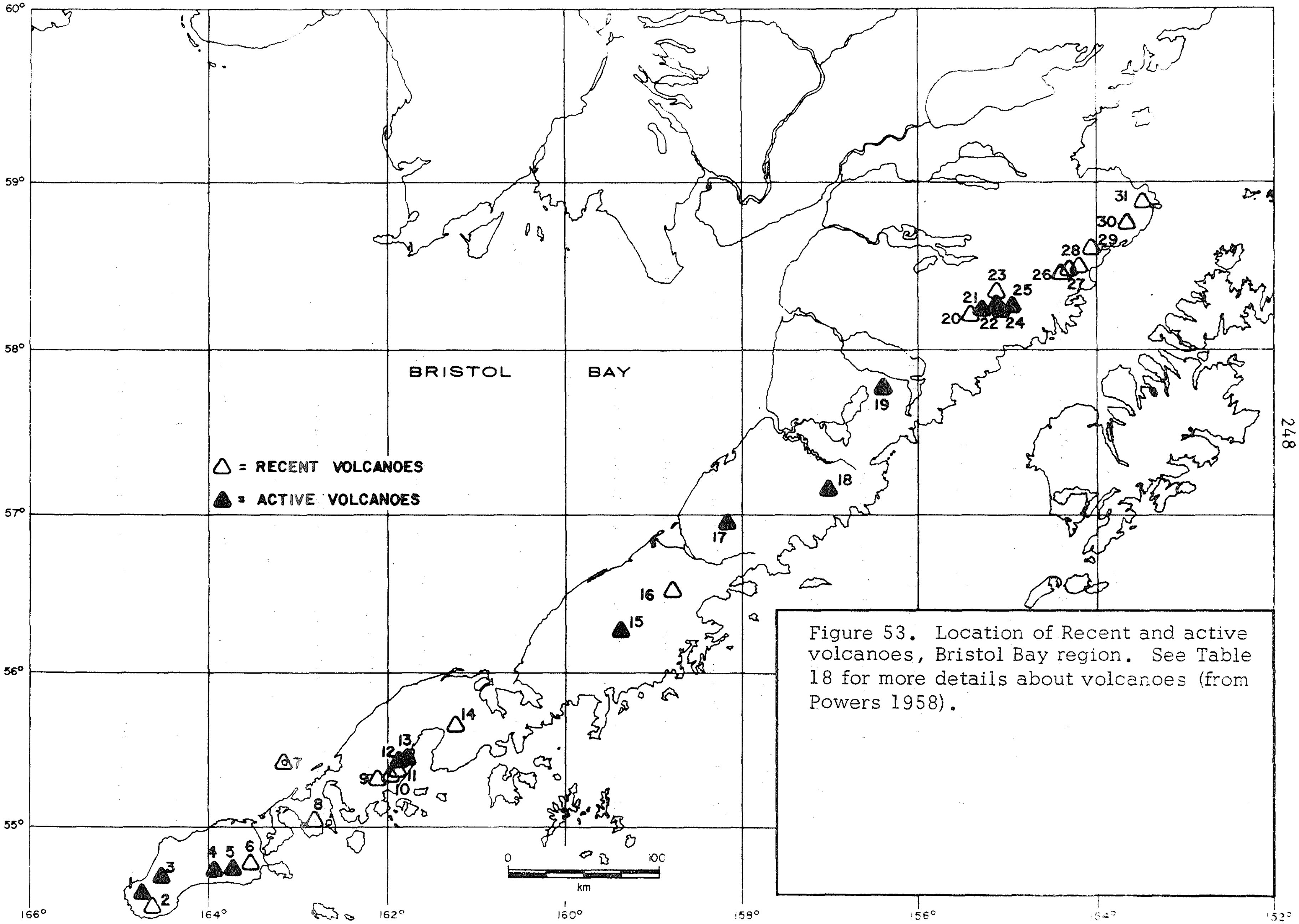

Figure 53. Location of Recent and active volcanoes, Bristol Bay region. See Table 18 for more details about volcanoes (from Powers 1958).

Table 18. Summary of recent and active volcanoes, Alaska Peninsula [A,B]
(Adapted from Powers 1958, MacDonald 1972, Forbes, in press)

No. [B]	Name	Approx. summit ht. (meters)	No. of eruptions since 1700 A.D.	Date of last eruption	type of activity [C]	Remarks on Activity
1.	Pogromni	2,300	4	1830	a,b	Ash eruptions-1795,1820,1827-30; lava flow-1796
2.	Westdahl	1,540	1	1964	a,b,c	Ash and lava, March 10-April 16, 1964
3.	Fisher	1,080	1	1826	a ?	Possible ash eruption
4.	Shishaldin	2,875	23	1967	a,b,c	Active-1775-78; smoke-1790,1865, 1880-81,1897; ash eruptions-1824-26, 1827-30, 1838, 1842, 1883, 1898, 1922, 1925, 1928-29, 1946-53, 1955, 1963, 1967. Explosive clouds of ash followed by intense steam emission, no lava reported-January 28, 1967.
5.	Isanotski	2,495	4	1845	a	Ash eruptions-1795,1830,1845; possibly some are Roundtop eruptions.
6.	Roundtop	1,870	1 ?	1825 ?	a	Ash eruption-1825; possibly some eruptions reported for Isanotski should be credited to Roundtop.
7.	Amak	575				Probably no historic activity.
8.	Frosty	1,775				Probably no historic activity.
9.	Emmons	1,280				Probably no historic activity.

Table 18, Cont.

10.	Hague	1,310				Probably no historic activity except intermittent steaming.
11.	Double Crater	1,310				Probably no historic activity.
12.	Pavlof	270	25	1973	a,b,d	Active-1970,1880,1892; smoke-1838, 1852; ash eruptions-1846,1866,1901, 1917,1922-24,1929-31,1936-45,1948, 1950-53,1963; ash and lava-1966; eruption of cloud of ash and smoke over 6,000 m. high on November 13, 1973.
13.	Pavlof Sister	2,150	1	1786	a ?	Active 1762-1786
14.	Dana	1,280				Probably no historic activity.
15.	Veniaminof	2,575	8	1944	a,b	Smoking-1830-38,1852,1874;active-1944; ash eruptions-1838,1892,1939; lava eruption-1930.
16.	Purple	995				Probably no historic activity.
17.	Aniakchak	1,355	1	1931	a,b	Steaming, ash and lava eruption-1931.
18.	Chiginagak	2,435	2	1929	a	Smoke and intermittent steaming-1852
19.	Peulik	1,535	2	1852	a	Ash eruption-1814, Smoke-1852
20.	Martin	2,210	2+	1960	a	Steaming intermittently since 1912; ash eruption ? -1912
21.	Mageik	2,225	4	1946	a	Ash eruptions-1912,1927,1936,1953; Active-1929,1946

Table 18, Cont.

22.	Novarupta	825	1	1912	a,e,f	Vent breached during 1912 Katmai eruption; pyroclastics erupted first followed by extrusion of plug dome. Vent believed to be one of main sources for ash and pumice flow deposits (glowing avalanche) in Valley of 10,000 Smokes.
23.	Knife Peak	2,135				No historic activity, but has 2 sulfurous fumaroles on summit and flank.
24.	Trident	2,080	3	1968	a,c,e, g	Steaming-1912; lava eruption-1953; explosive, ash charged vapor columns to great heights-April, 1963 and May, 1964; vent clearing explosions plus ash eruptions-December, 1967 to February, 1968, November, 1968.
25.	Katmai	2,300	7	1931	a,b,d	Explosive eruption with vast pumice and ash deposits accompanied by caldera collapse-1912; steam-1931.
26.	Denison	2,195				Probably no historic activity.
27.	Steller	2,105				Probably no historic activity.
28.	Kukak	2,045				Probably no historic activity.
29.	Kaguyak	855				Probably no historic activity.
30.	Fourpeaked	2,105				Probably no historic activity.
31.	Douglas	2,155				Probably no historic activity, except for intermittent steaming.

Table 18, Cont.

A Recent volcanoes are defined as those that probably have erupted during the past 10,000 years, but have no historic record of activity. They could erupt at any time. Active volcanoes are defined as those that have had reported activity in historic time (since 1700 A.D.).

B Location of volcanoes are shown by number on Figure 53.

C Types of activity

a. normal explosion (gas)

b. lava flow

c. lateral crater

d. central crater

e. dome

f. glowing avalanche

g. mudflow

and intensity of the wind. Only minor amounts of lava erupt as flows. Lava flows, ash flows, volcanic landslides and mudflows, ash falls, and gases are phenomena associated with these eruptions.

The Katmai eruption of 1912 is an exception to the generally moderate size of the eruptions of Alaska Peninsula volcanoes (Wilcox 1959). More than 25 cu. km. of ash and pumice were blown into the air or flowed into the Valley of Ten Thousand Smokes. As much as 0.3 m. of ash fell on Kodiak, 160 km. away (Figure 54). A summary of volcanic activity in the Katmai region is contained in a book soon to be published by the University of Washington Press (Forbes, in press).

The eruptions of Trident Volcano in 1952 and of Mt. Spurr in 1953 are more typical of andesitic eruptions (Wilcox 1959). These eruptions consisted of bursts of gas and ash that rose vertically as a cloud to altitudes as high as 20,000 m. These bursts were accompanied by small, viscous, block lava flows in the vent area. Mudflows of ash and meltwater that coursed down flanks of the mountains were mistaken for lava flows. flows. More recently, on November 13, 1973, Pavlof Volcano spewed a 6.5 km. wide cloud of smoke and ash almost 6,100 m. high.[1]

1. Anchorage Daily News, Wednesday, November 14, 1973

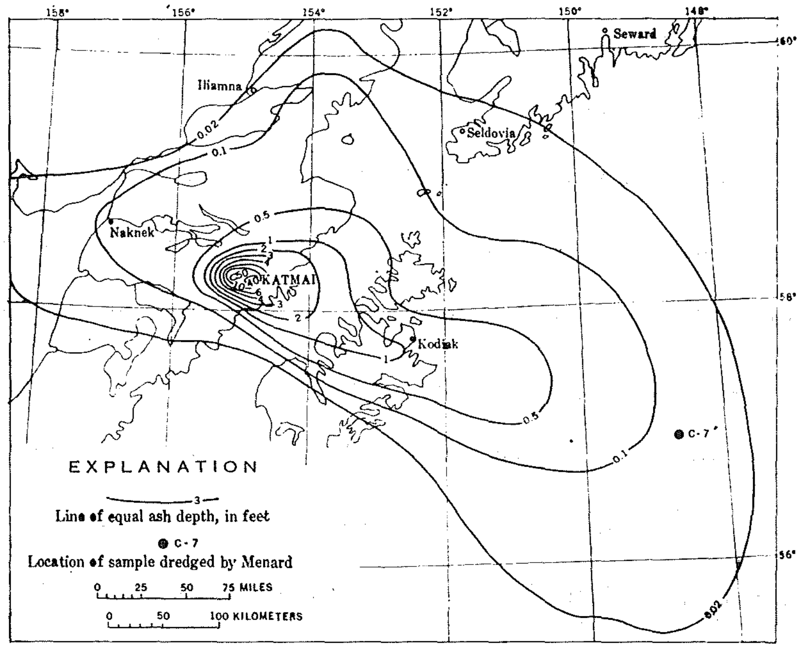

Figure 54. Distribution of ash erupted from Katmai volcano, 1912 (from Wilcox 1959).

SEISMICITY

Alaska is one of the most seismically active areas of the world, both in numbers of earthquakes and in the energy they release. Most earthquakes occur along an arcuate belt extending from the western end of the Aleutian Islands to Prince William Sound (Figure 55).

This belt is part of a narrow, almost continuous earthquake zone that rims the entire Pacific (Figure 56). This zone, which is also characterized by active volcanism and tectonic deformation (Figure 51), defines the margins of the large Pacific Plate. According to recent theories of plate tectonics, the Pacific Plate is being thrust under the North American Plate along the Aleutian Trench (Figure 52), thus providing a mechanism for generating the seismicity.

The Bristol Bay study area lies just north of the main seismic belt and has experienced relatively few major earthquakes (Figure 57). Most of the earthquakes south of the Alaska Peninsula are shallow-focus, originating at depths of less than 70 km. The depths of the earthquake hypocenters

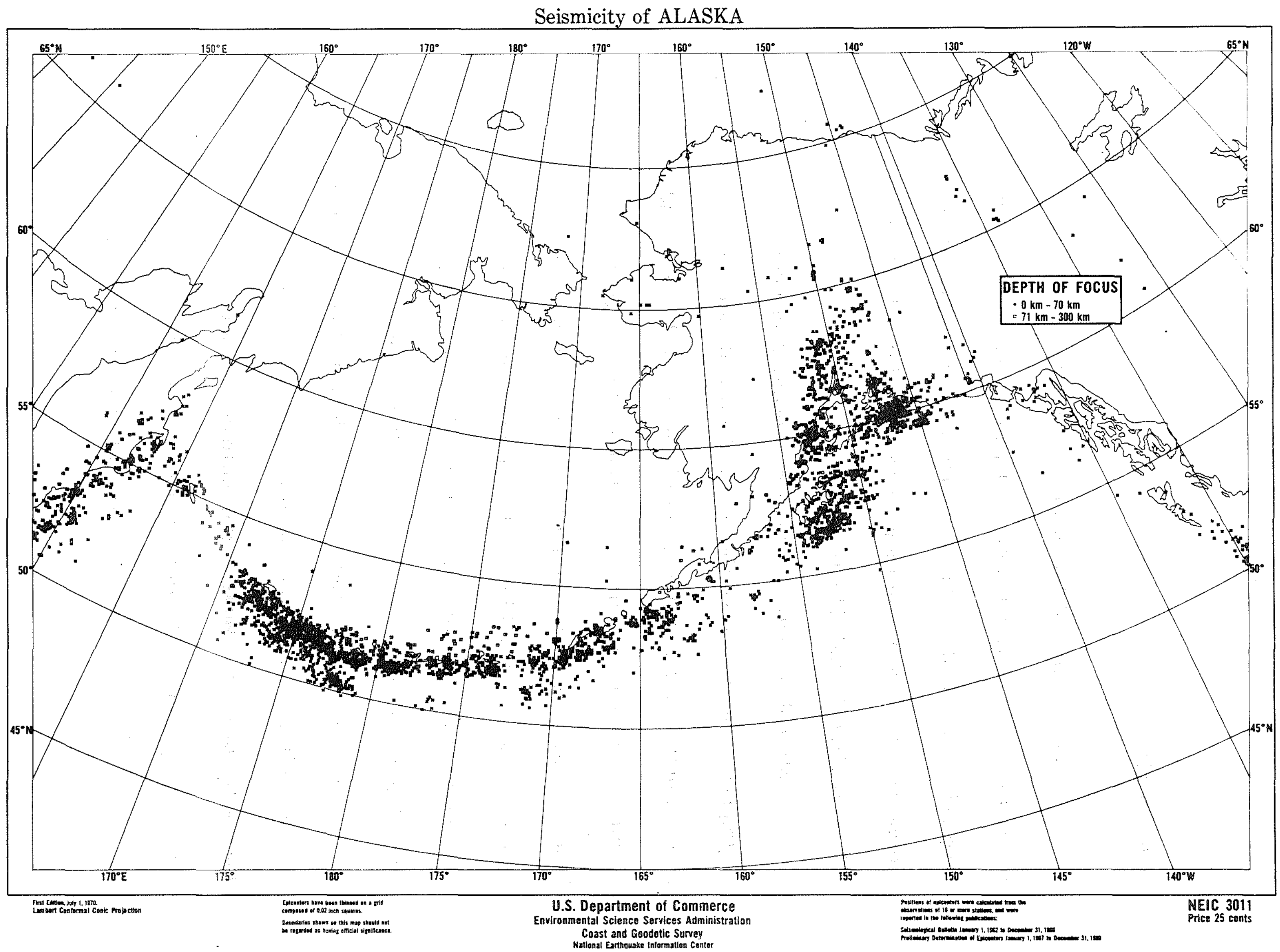

Figure 55. Seismicity of Alaska, 1962-1969.

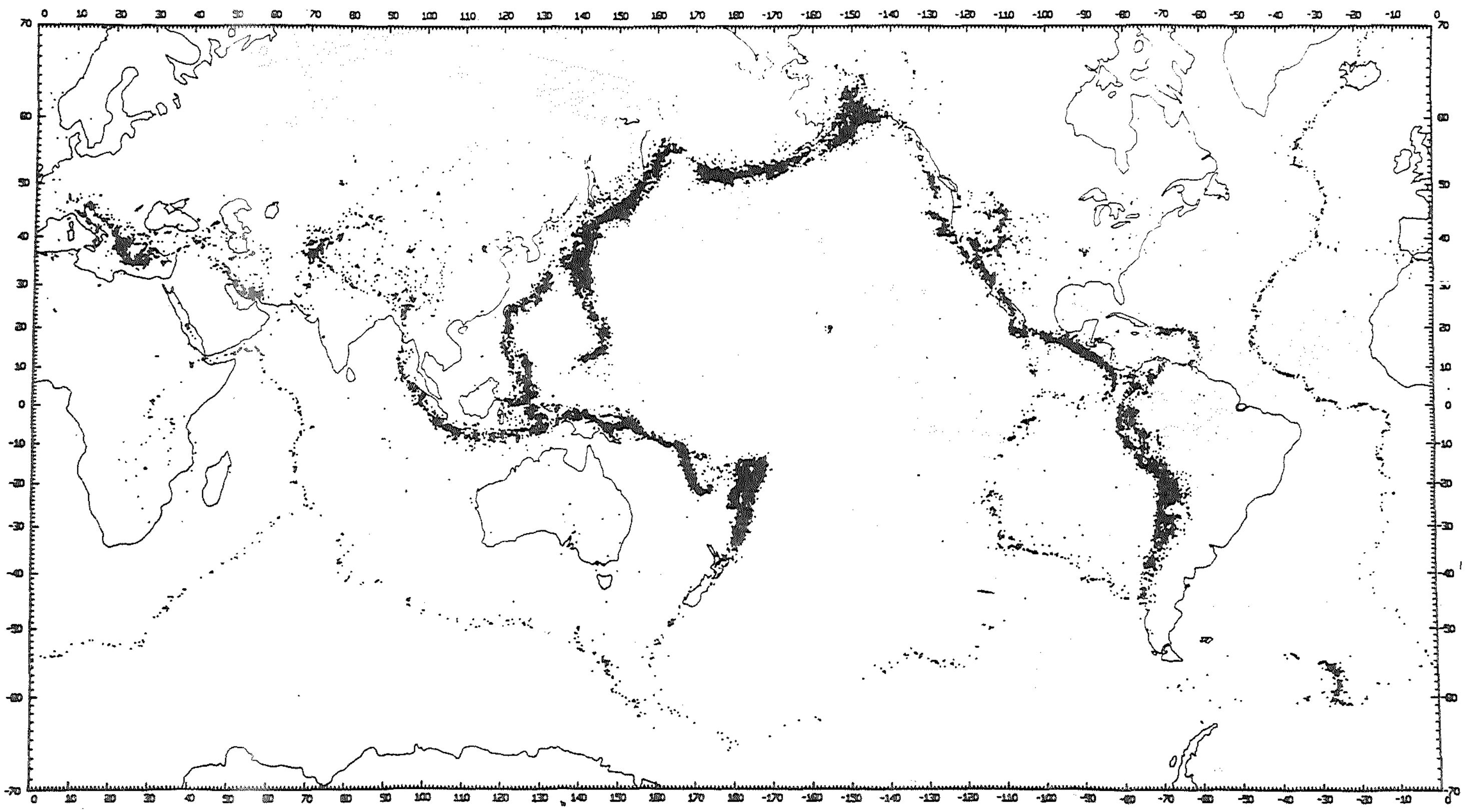

Figure 56. Shallow focus earthquakes (0-100 km. deep) for 1961-1967 (from Sykes 1972).

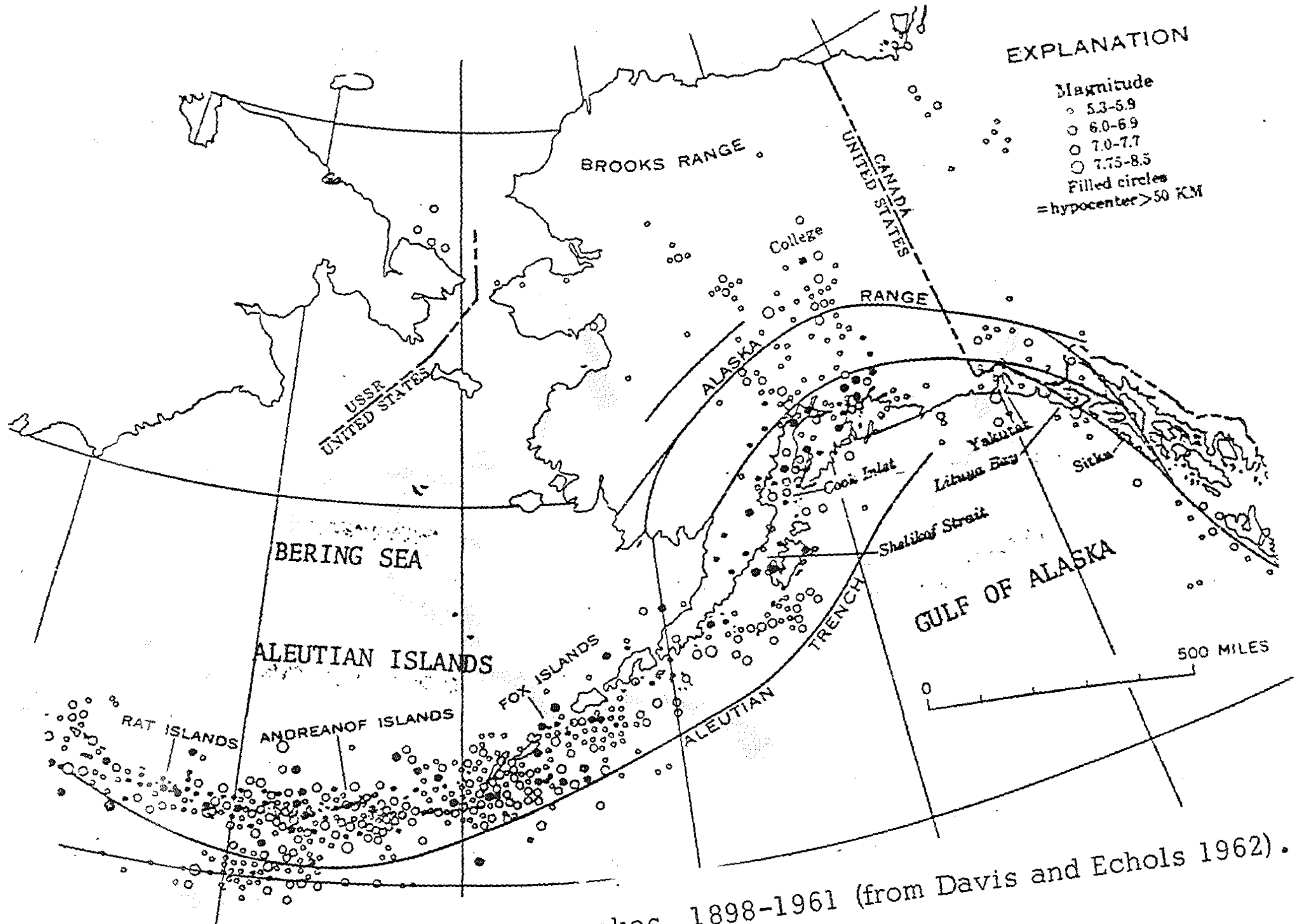

Figure 57. Major Alaskan earthquakes, 1898-1961 (from Davis and Echols 1962).

appear to increase in a northerly direction away from the Aleutian Trench. Most of the earthquakes north of the Alaska Peninsula in Bristol Bay occur at depths greater than 70 km.

This distribution of hypocenters approximately defines the upper boundary of the downgoing plate, or the zone of underthrusting. The scarcity of very deep earthquakes (200 to 400 km. in depth) may reflect the relatively young age of the underthrusting and the lack of any deep penetration of the Pacific Plate into the upper mantle.

About 7 percent of the total earthquake energy released annually, originates in the Alaska seismic zone (Hansen and Eckel 1971). Most of this energy is released during large earthquakes. Between 1899 and May 1965, nine Alaska earthquakes have equalled or exceeded Richter magnitude 8; more than 60 have equalled or exceeded magnitude 7.

Large earthquakes appear to be generated by the slippage of large blocks. These blocks are outlined by the distribution pattern of aftershocks (Sykes 1972). Aftershock zones of all earthquakes registering a magnitude of 7.0 or larger in the Alaska-Aleutian Zone from 1930 to 1970 have been plotted by Sykes (1972) in Figure 58. This figure suggests a space-time relationship for many of the earthquakes--movement along one block follows, in time, movement along the next adjacent block. This figure also identifies 3 main gaps in activity for large seismic disturbances. These gaps are regarded as likely sites for future large earthquakes (Sykes 1972). Significantly, the single large earthquake in Alaska during 1972 occurred in one of these seismic gaps--the Sitka earthquake of July 1972, of magnitude 7.2. Note also that the block defined by the aftershocks of the 1964 earthquake had experienced no previous large activity since at least 1900.

Kelleher (1970) also noted that the block near the Alaska Peninsula between Kodiak and the Shumagin Islands had experienced no recent large earthquakes. This seismic gap is especially well depicted on the epicenter distribution map (Figure 55). From an analysis of space-time sequences, Kelleher predicted that a large earthquake would occur in this area sometime between 1974 and 1980.

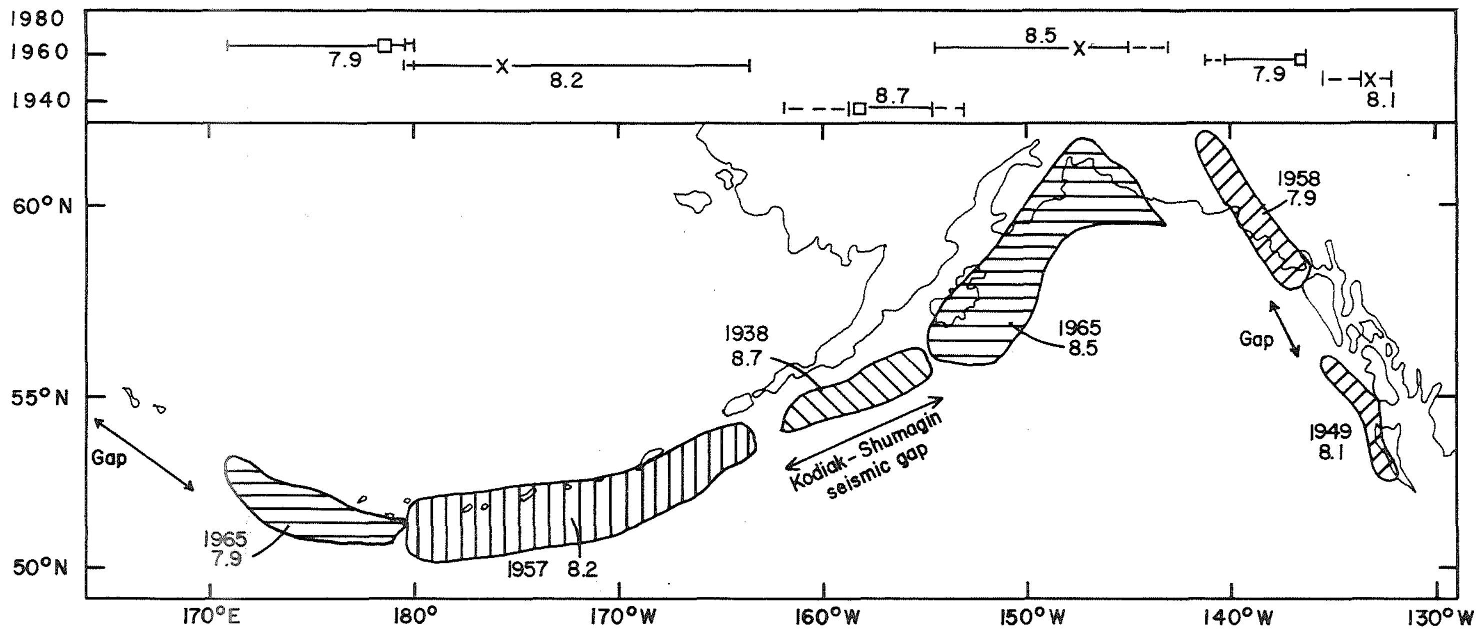

Figure 58. Aftershock areas of great Alaska earthquakes (magnitude greater than 7.9) since 1930. These areas tend to abut without significant overlap and probably represent rupture along major crustal blocks. Gaps in activity are regarded as sites for future very large earthquakes (from Sykes 1972). The apparent space-time relationship of the areas may provide a tool for earthquake predictions.

This seismic gap is directly south of the Bristol Bay region and currently is the focus of a joint research effort by Lamont-Doherty Geological Observatory of Columbia University and the University of Alaska. In the summer of 1973, a seismic net of 9 stations was established in the Shumagin Islands; 6 more stations are planned for 1974 (Figure 59). In addition, there are several other stations in the area run by the National Oceanic and Atmospheric Administration and the U.S. Geological Survey, which also will be used to monitor seismic activity.

This project aims to delineate in detail the spatial distribution of low-level seismicity in the Alaska Peninsula seismic gap, and to obtain a qualitative measure of change in activity that might occur prior to any large event. This type of detailed seismic information may or may not provide a direct means of predicting earthquakes, but it certainly is a prerequisite for any seismic prediction program.

The lack of high seismic activity in the Bristol Bay area plus the deep focus of most of the earthquakes that do occur there, make the area less susceptible to earthquake damage than the area south of the Alaska Peninsula. The

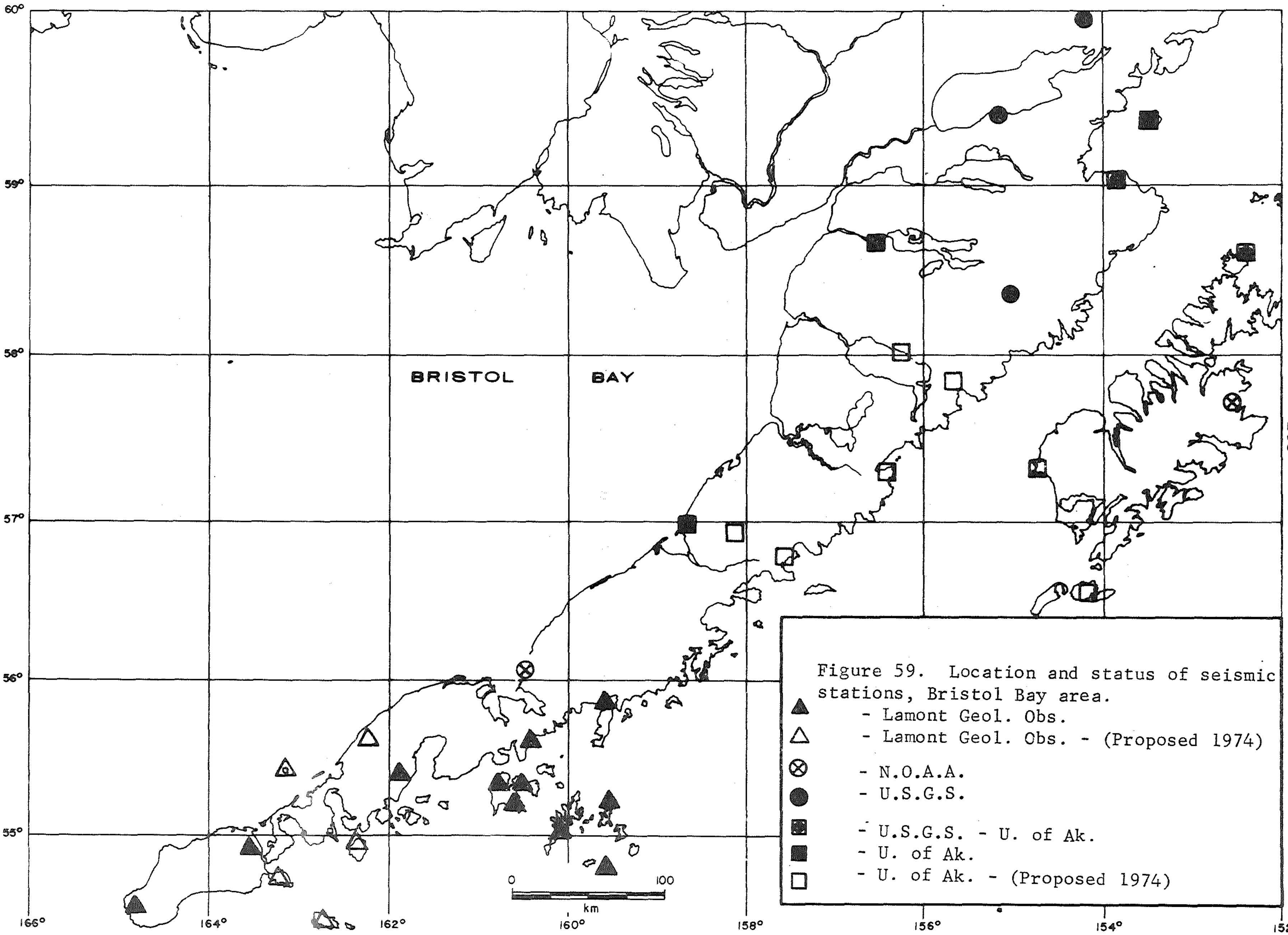

Figure 59. Location and status of seismic stations, Bristol Bay area.

- ▲ - Lamont Geol. Obs.
- △ - Lamont Geol. Obs. - (Proposed 1974)
- ⊗ - N.O.A.A.
- ● - U.S.G.S.
- ▩ - U.S.G.S. - U. of Ak.
- ■ - U. of Ak.
- □ - U. of Ak. - (Proposed 1974)

Bristol Bay area, however, is close enough to the seismic belt that moderate structural and other damage could occur during a large earthquake. The seismic gap discussed previously lies just south of the study area, and any large earthquake in this gap certainly would be felt in the Bristol Bay-Nushagak Lowlands. The presence of relatively unconsolidated glacial and fluvial sediments in the Lowlands increases the susceptibility of this area to damage due to ground breakage, local subsidence, and sliding along sea bluffs.

COASTAL PROCESSES AND EROSION

Beaches and adjacent uplands are constantly being worn away by natural processes. Erosion occurs when more material leaves a local site than is deposited. The amount of erosive action is a direct function of the geologic composition of the shoreline material and the sequence and magnitude of the erosional processes. In areas of bedrock cliffs, such as the northwest and southwest portions of the Bristol Bay coastline, erosion is relatively slow. The coast adjacent to the Lowlands, however, is composed largely of unconsolidated glacial and fluvial deposits overlying relatively soft Tertiary sediments. Rates of erosion are locally much greater in this area.

Wind-generated waves and currents are major factors producing coastal erosion, especially during severe storms. A severe storm may move more sediment in several days than normally would be moved in many years.

Extreme ranges in tidal height are also characteristic of Bristol Bay. These tides exposed large vertical sections of the coast to wave action, resulting in high erosional scarps and increased bluff failure. Portions of the Lowlands are subject to recurrent tidal flooding. The shores of the lower Nushagak River are particularly susceptible to this tidal flooding. The upstream limit of this flooding is characterized by an abrupt termination of the well-defined meanders and oxbows which characterize the lower portion of the river (Anderson et al. 1973).

In 1970-71 the U.S. Army, Corps of Engineers conducted a survey of Alaska's coastal problems as part of an overall National Shoreline Study for the entire United

States (U.S. Army, Corps of Engineers 1971). Only 2 villages reported erosion problems--Clarks Point and Dillingham. A study of the erosion problem at Dillingham was authorized. Results were published in 1972 and are summarized below (U.S. Army, Corps of Engineers 1972).

Dillingham, a small town of around 900 persons, depends largely on its harbors for economic support. It is the site of a salmon cannery and is the distribution center for most of the upper Bristol Bay area. Clockwise currents in Nushagak Bay, induced by prevailing westerly winds and freshwater discharge, are eroding the bluff along the waterfront areas of the town. Bluffs in the area consist of fine-grained soils and range in height from 3 to 21 m. The slope of these bluffs is so steep that, when they are undercut, huge blocks fall off into the Bay. The maximum rate of bank retreat is estimated to be 3.7 m. per year. The salmon cannery, the public sewage treatment plant, and the sewer outfalls, along with other private property along the waterfront, are threatened by this erosion.

A new dock, wharf, and cold storage plant have been constructed and their plans included protection from erosion. It was concluded that an abbreviated groin field would help alleviate the erosion problem, but it also was decided that the benefits would be insufficient to economically justify this protective measure. Federal participation in this project was not recommended.

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HYDROLOGY

INTRODUCTION

Information on the hydrology of the Bristol Bay area is minimal. Surface water data is limited to a few U.S. Geological Survey gaging stations shown in Figure 60 and Table 19. Records from these stations include streamflow, water quality, and sediment load. Only 2 of the 7 gaging stations have continuous records of streamflow (Table 20). Water quality and sediment data shown in Tables 21 and 22 were obtained at the gaging stations or along the streams sporadically during the period extending from October 1, 1970 to September 30, 1971.

Groundwater data for the region is limited to a few well logs available at the U.S. Geological Survey, Division of Water Resources, Anchorage.

SURFACE WATER

The Bristol Bay area can be considered one major drainage system. This system covers approximately 100,000

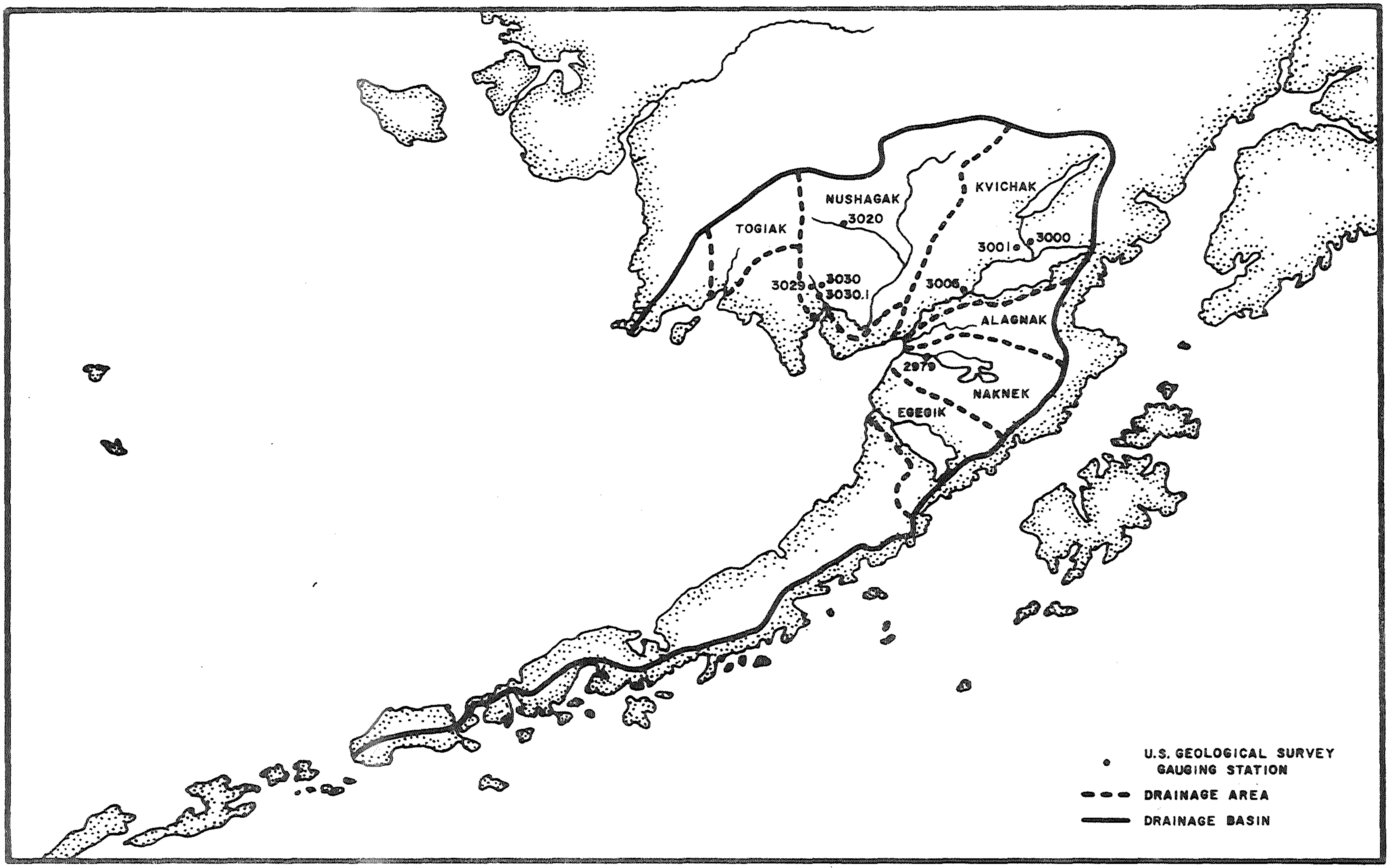

Figure 60. Bristol Bay drainage area (Arctic Environmental Information and Data Center, Univ. of Alaska).

Table 19. U.S. Geological Survey Water Data Stations in the Bristol Bay Area.

Station No.	Station Description	Station Status - Water Year 1971
1.	Naknek River below FAA station near King Salmon	*
2.	Eskimo Creek at King Salmon (2979)	Partial crest record * **
3.	Kvichak River at Igiugig (3005)	Continuous gaging station * **
4.	Nushagak River at Portage Creek	*
5.	Moody Creek at Aleknagik (3029)	Partial crest record *
6.	Wood River at Aleknagik (3030)	*
7.	Silver Salmon River near Aleknagik (3030.1)	Partial crest record * **
8.	Nuyakuk River near Dillingham (3020)	Continuous gaging station **
9.	Newhalen River near Iliamna (3000)	Partial crest record
10.	Bear Creek (Newhalen River tributary) (3001)	Partial crest record

* = miscellaneous site - water quality
** = miscellaneous site - suspended sediment content

Source: U.S. Geological Survey 1972.

Table 20. Streamflow Data

Station No.	Water Year or Date	Drainage Area (sq. miles)	Total Discharge (cu. ft./sec.)	Mean Discharge (cu. ft./sec.)	Maximum Discharge (cu. ft./sec.)	Minimum Discharge (cu. ft./sec.)
2.	6/?/71	16.1	--	--	168	--
3.	1970	6500	6,140,300	16,820	25,800	12,000
3.	1971	6500	6,586,080	18,040	42,100	8,600
5.	6/7/71	1.28	--	--	55	--
7.	6/?/71	4.46	--	--	170	--
8.	1969	1490	2,611,870	7,156	29,900	1,500
8.	1970	1490	2,495,480	6,837	18,500	1,600
8.	1970	1490	2,066,050	5,660	18,500	1,600
8.	1971	1490	2,219,250	6,080	21,600	1,400
9.	9/15/69	3478	--	--	21,300	--
9.	8/16/71	3478	--	--	44,200	--
10.	5/?/65	2.59	--	--	58	--
10.	1968	2.50	--	--	56	--

Source: U.S. Geological Survey 1972.

Table 21. Water Quality Data

Station No.	Date	Discharge cfs	Silica (SiO_2) mg/l	Total Iron (Fe) ug/l	Dissolved Iron (Fe) ug/l	Dissolved Calcium (Ca) mg/l
1	1/15/71	-	6.5	20	-	23
2	7/7/71	9.4	14	80	-	8.2
2	9/17/71	19	14	-	690	6.6
3	7/7/71	20,600	1.3	-	20	5.6
3	8/17/71	37,200	-	-	-	-
3	9/17/71	38,000	1.4	-	40	5.5
4	1/13/71	-	8.3	0	-	6.9
5	7/7/71	-	9.4	-	40	6.4
6	1/13/71	-	5.0	0	-	6.8
6	1/12/71	-	3.0	0	-	5.4
7	9/17/71	14	7.5	-	100	5.6

Table 21. (continued)

Station No.	Date	Dissolved Magnesium (Mg) mg/l	Sodium (Na) mg/l	Potassium (K) mg/l	Bicarbonate (HCO_3) mg/l
1	1/15/71	3.7	8.0	1.3	47
2	7/7/71	3.2	6.7	1.1	42
2	9/17/71	2.7	5.7	0.7	36
3	7/7/71	0.8	1.5	0.5	18
3	8/17/71	-	-	-	18
3	9/17/71	0.9	1.5	0.5	20
4	1/13/71	1.9	2.5	0.4	29
5	7/7/71	1.2	1.8	0.2	25
6	1/13/71	1.2	1.5	0.2	21
6	1/12/71	0.8	1.2	0.4	16
7	9/17/71	1.0	1.6	0.1	19

Table 21. (continued)

Station No.	Date	Sulfate (SO_4) mg/l	Chloride (Cl) mg/l	Dissolved Fluoride (F) mg/l	Nitrate (NO_3) mg/l	Total Dissolved Solids mg/l
1	1/15/71	38	9.6	0.4	0.3	114
2	7/7/71	6.7	4.2	0.1	0.3	0.8
2	9/17/71	3.4	4.2	0.1	0.8	57
3	7/7/71	3.6	2.0	0.0	0.1	24
3	8/17/71	-	-	-	-	-
3	9/17/71	3.4	1.8	0.1	0.1	25
4	1/13/71	4.1	1.2	0.2	0.0	40
5	7/7/71	2.6	1.5	0.0	0.0	35
6	1/13/71	4.1	1.5	0.2	2.3	33
6	1/12/71	4.7	1.2	0.1	0.6	25
7	9/17/71	3.4	1.8	0.0	0.4	31

Table 21. (continued)

Station No.	Date	Hardness (Mg, Ca) mg/l	NonCarbonate Hardness mg/l	Sp. Conductance microohms	pH (units)
1	1/15/71	72	33	200	7.6
2	7/7/71	34	0	95	6.0
2	9/17/71	28	0	78	7.0
3	7/7/71	18	3	43	7.2
3	8/17/71	16	1	43	7.1
3	9/17/71	17	1	43	7.1
4	1/13/71	25	1	61	7.6
5	7/7/71	21	1	50	6.9
6	1/13/71	22	5	53	7.5
6	1/12/71	17	4	42	7.2
7	9/17/71	18	2	43	6.8

Table 21. (continued)

Station No.	Date	Color (Platinum cobalt Units)	Temperature (degrees C.)
1	1/15/71	-	-
2	7/7/71	5	7.5
2	9/17/71	40	6.5
3	7/7/71	0	5.0
3	8/17/71	-	0.0
3	9/17/71	5	9.0
4	1/13/71	-	-
5	7/7/71	0	3.0
6	1/13/71	-	-
6	1/12/71	-	-
7	9/17/71	10	6.0

Table 22. Suspended Sediment Data

Station No.	Date	Temperature (degrees C)	Specific Conductance (micromhos)	Turbidity (Jackson turb. units)	Discharge (cu. ft./sec.)	Suspended Sediment (mg./l.)	Suspended Sediment Discharge (tons/day)
2.	7/7/71	9.5	95	-	9.4	22	0.56
2.	8/17/71	10.0	64	-	52	54	7.6
2.	9/17/71	6.5	77	-	19	13	0.6
3.	8/17/71	0.0	43	1	37,200	--	-
7.	7/7/71	11.0	45	-	12	2	0.06
7.	8/17/71	6.5	40	-	38	5	0.51
7.	9/17/71	6.0	43	1	14	3	0.11
8.	7/8/71	11.0	59	-	18,300	9	445
8.	8/17/71	9.5	63	-	12,500	2	67
8.	9/18/71	6.0	69	0	6,330	2	34

Source: U.S. Geological Survey 1972.

sq. km. and includes the drainage basins of several rivers (Figure 60). These basins contain large lakes of glacial origin; long and relatively narrow with depths reaching more than 100 m. below sea level (Berwick et al. 1964). Iliamna Lake, the largest lake in the State, is part of the Kvichak River drainage basin. Stream profiles are generally steep above the larger lakes and quite moderate in the lower reaches where the rivers meander through braided channels across the coastal lowland (Berwick et al. 1964). The major streams are the Kvichak and Nushagak Rivers. Other smaller streams include the Togiak, Alagnak, Naknek, and Egegik Rivers.

Distribution of Runoff

The mean annual runnoff in the region is variable, ranging from less than 22 liters/sec./sq. km. (2 cu. ft./sec./sq. mile) in the central Lowlands to more than 44 liters/sec./sq. km. (4 cu. ft./sec./sq. mile) in the mountains surrounding the area (Feulner 1973). The average rate of runoff is probably about 33 liters/sec./sq. km. (3 cu. ft./sec./sq. mile) (Figure 61a).

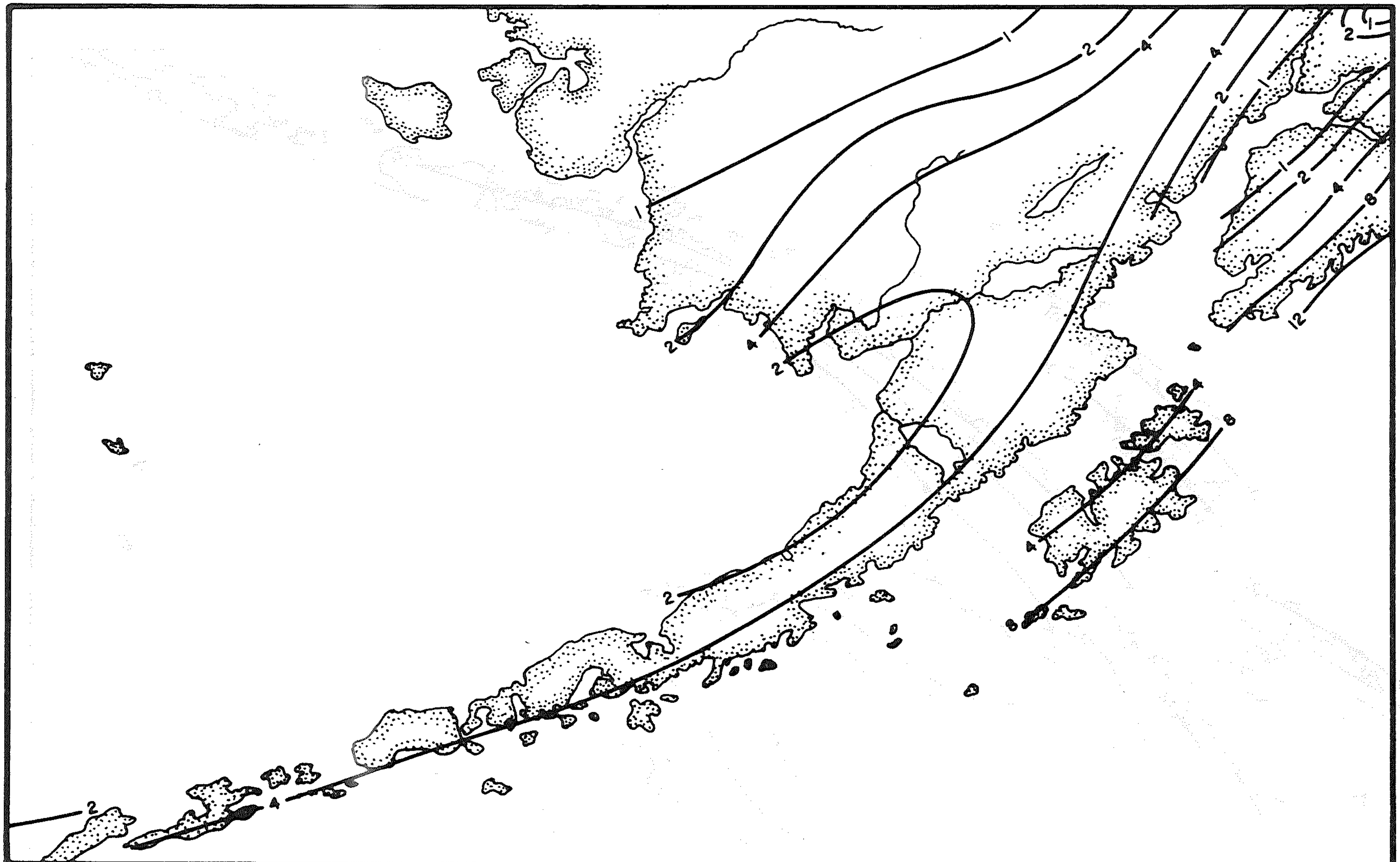

Figure 61a. Mean annual runoff in cu. ft./sec./sq. mile (from Feulner 1973).

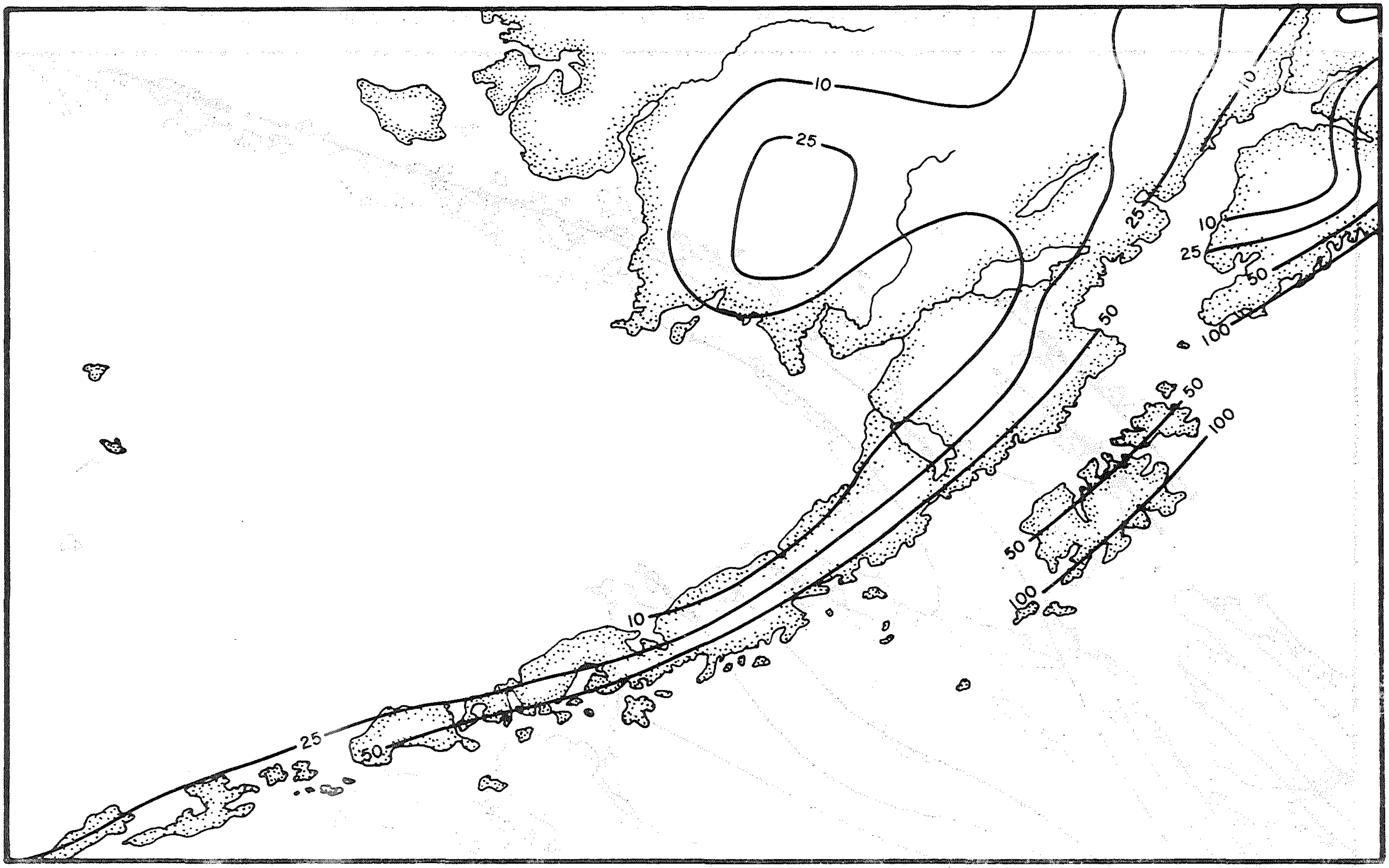

Figure 61b. Mean annual peak runoff in cu. ft./sec./sq. mile (from Feulner 1973).

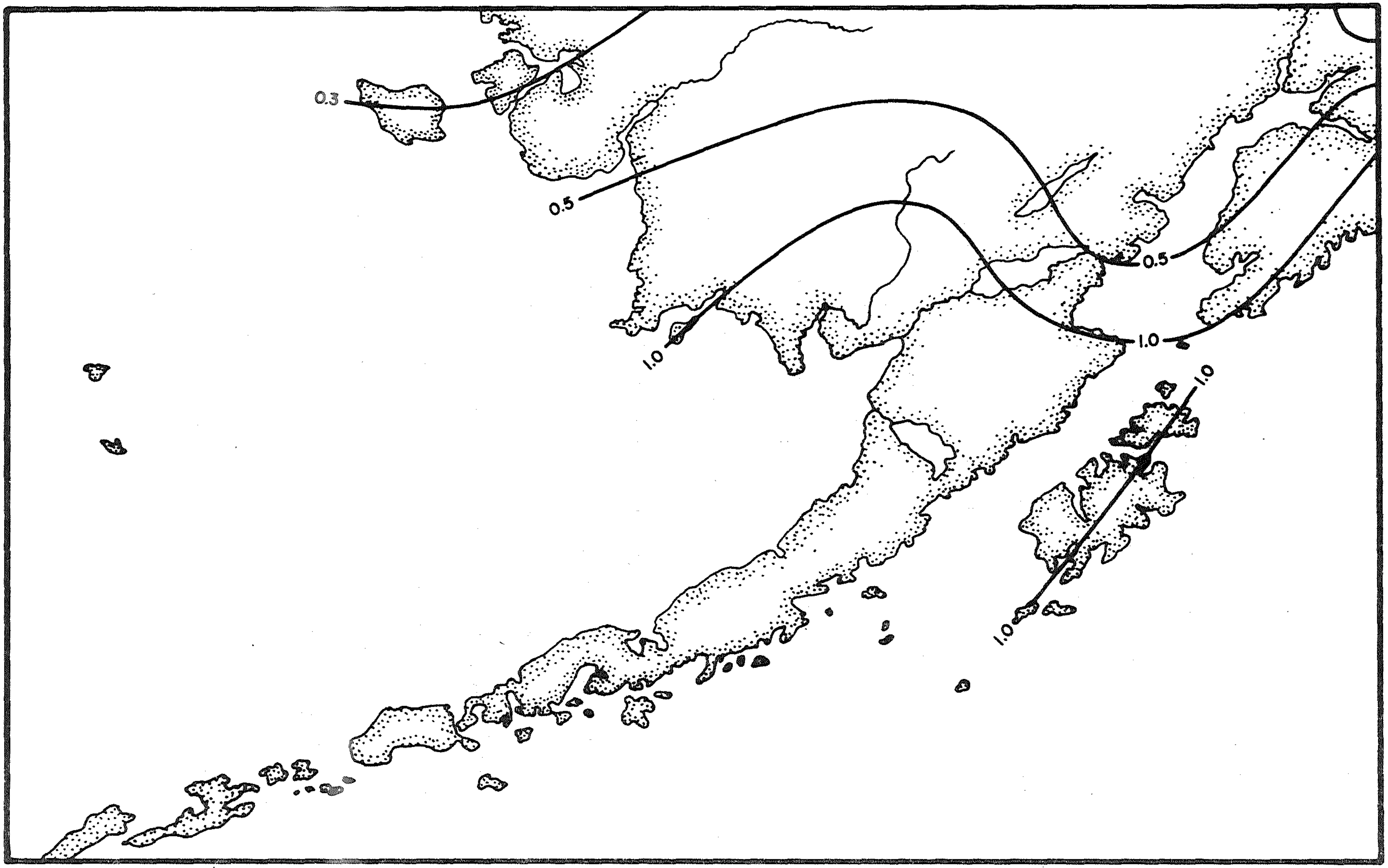

Figure 61c. Mean annual low monthly runoff in cu. ft./sec./sq. mile (from Feulner 1973).

The mean annual peak runoff ranges from less than 110 to more than 550 liters/sec./sq. km. (10 to 50 cu. ft./sec./sq. mile) throughout the area (Figure 61b). The average peak runoff in the area is probably about 220 liters/sec./sq. km. (20 cu. ft./sec./sq. mile) (Feulner 1973). Lakes in the central part of the area have a moderating effect upon runoff.

The mean annual low monthly flow of streams in the area probably averages a little more than 10 liters/sec./sq. km. (1 cu. ft./sec./sq. mile) (Figure 61c) (Feulner 1973).

Quality of Surface Water

The surface water quality within the region is good. All mineral concentrations shown in Table 21 are within the U.S. Public Health Service water quality standards for potable supplies, and water treatment is not generally necessary. The concentration of dissolved solids is low, ranging from 25 to 75 mg./l. Dissolved solids are probably higher during winter (station 1, Table 21); they are believed to range between 80 and 100 mg./l. (Feulner 1973). Lakes have not been sampled. Coastal lakes probably contain a sodium-bicarbonate-type water, while inland lakes and all streams contain a calcium-bicarbonate-type water (Feulner 1973).

Suspended Sediment Load

Very little data are available on the sediment load carried by streams in this region (Table 22). Streams originating in the Aleutian Range, at the eastern boundary of the study area, are estimated to have sediment concentrations during summer ranging between 500 and 2,000 mg./l. This is based on a study of sediment discharge in streams flowing into Cook Inlet on the eastern side of the Range (Feulner 1973).

Lakes present within a drainage system act as settling basins, and streams drainage these glacial lakes probably have sediment concentrations of less than 500 mg./l. Streams flowing through the central part of the area probably carry less than 100 mg./l. (Feulner 1973). The sediment load of streams draining the Alaska Peninsula may be high due to the presence of volcanic ash.

Temperature

Temperature data for streams are available only for a few stations (Tables 21 and 22). Average surface water temperatures range from 0 degrees C to 13 degrees C. The higher temperatures are recorded in lakes, probably in July (Feulner 1973).

Floods

Floods have been studied in the area (Berwick et al. 1964, Childers 1970). The highest floods on record occurred in the summer of 1971. In that year southern Alaska experienced record July floods due to the melt of a snow cover 50 percent above average, and August floods due to high precipitation. In the Kvichak River basin, peak discharges of 1.25 million liters/sec. (44,200 cu. ft./sec.) below Lake Clark and 1.22 million liters/sec. (43,000 cu. ft./sec.) below Iliamna Lake were recorded (Lamke 1972).

The U.S. Army, Corps of Engineers (1973) have been involved in navigation projects in this region, but no flood control projects.

Many smaller streams in the region are subject to flash floods or brief periods of high discharge.

Glaciers do not contribute significantly to surface water storage or runoff in this area since their distribution is limited.

GROUNDWATER

Occurrence

Much of the Bristol Bay study area is blanketed by unconsolidated deposits, shown on the generalized surficial geology map (Figure 32). Moraines and undifferentiated materials associated with steeper slopes are generally poor groundwater sources due to the unsorted character of these deposits. Proglacial lake deposits are also poor water sources because fine-grained silts prevent percolation downward. The best groundwater supplies can be expected in floodplains, terraces, and alluvial fan deposits. Glaciofluvial outwash and coastal deposits may yield fair to good groundwater supplies. A few known yields of 375 liters/min. (100 gallons/min.) have been reported for the central Lowlands and 750 liters/min. (200 gallons/min.) for one well in Dillingham (Feulner 1973). Bedrock yields very little groundwater. There are many springs in the Aleutian Range, but flow and chemical quality are unknown (Feulner 1973).

Chemcial Quality

Well data is limited, but most wells in the area contain water of acceptable quality with low iron content and no other objectionable minerals (Feulner 1973). This water generally contains less than 250 mg./l. dissolved solids. A coastal well at Togiak, however, yields water of a sodium-chloride type (Feulner 1973), which is typical of wells drilled near seacoasts where saltwater intrudes the groundwater aquifer.

Permafrost

In the northern part of the Bristol Bay region, permafrost is found in isolated masses in areas of predominately fine-grained deposits (Ferrians 1965). It is generally absent in areas adjacent to streams and lakes but may be present in scattered localities along the coast (Figure 62). Permafrost acts as "an impermeable layer which (1) restricts recharge, discharge, and movement of groundwater, (2) acts as a

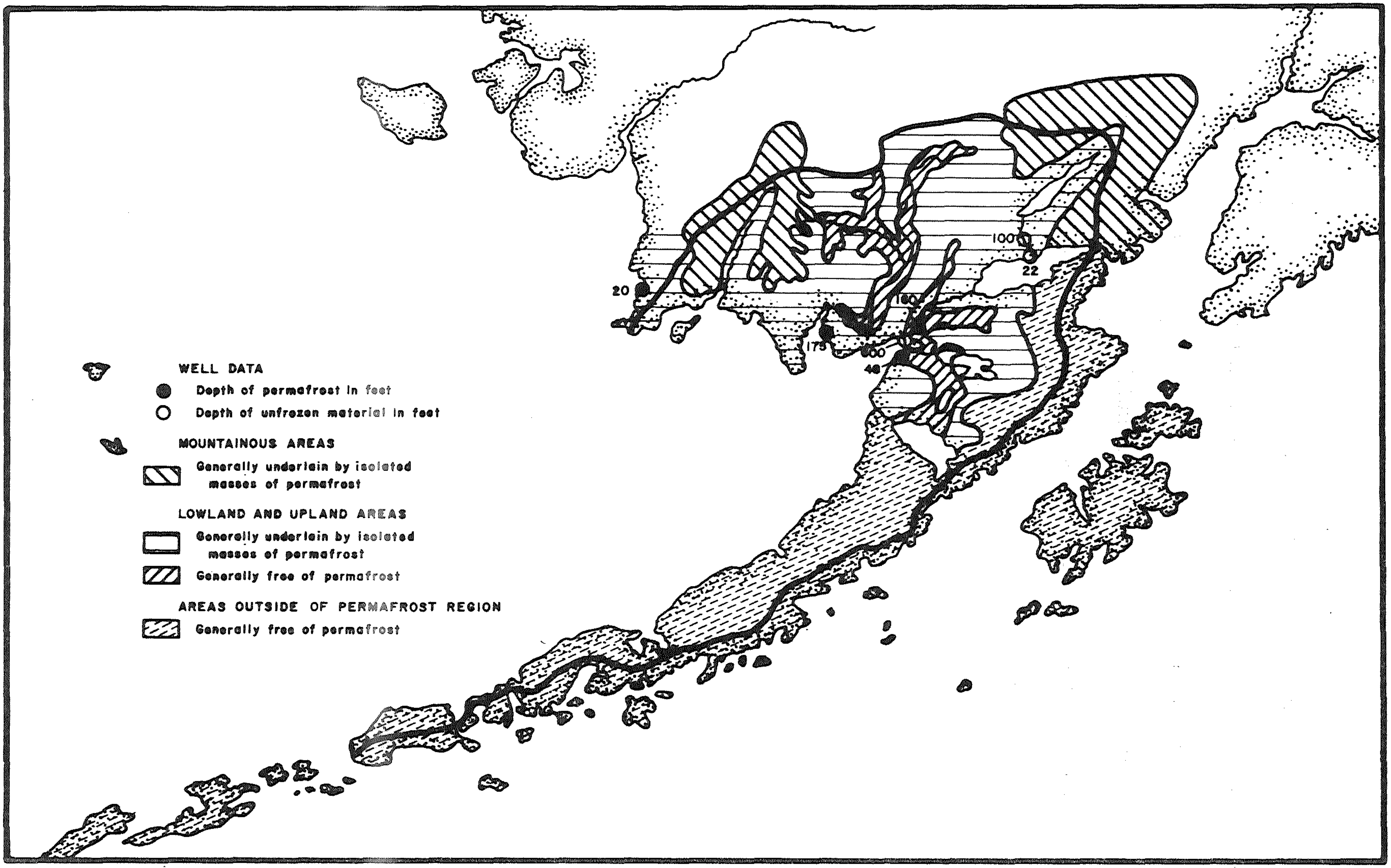

Figure 62. Permafrost distribution in the Bristol Bay drainage area (from Ferrians 1965).

confining layer, and (3) limits the volume of unconsolidated deposits and bedrock in which liquid water may be stored" (Williams 1970). Therefore, the presence of permafrost will affect the groundwater potential of specific areas. Figure 63 shows the depth of permafrost encountered in drilling wells.

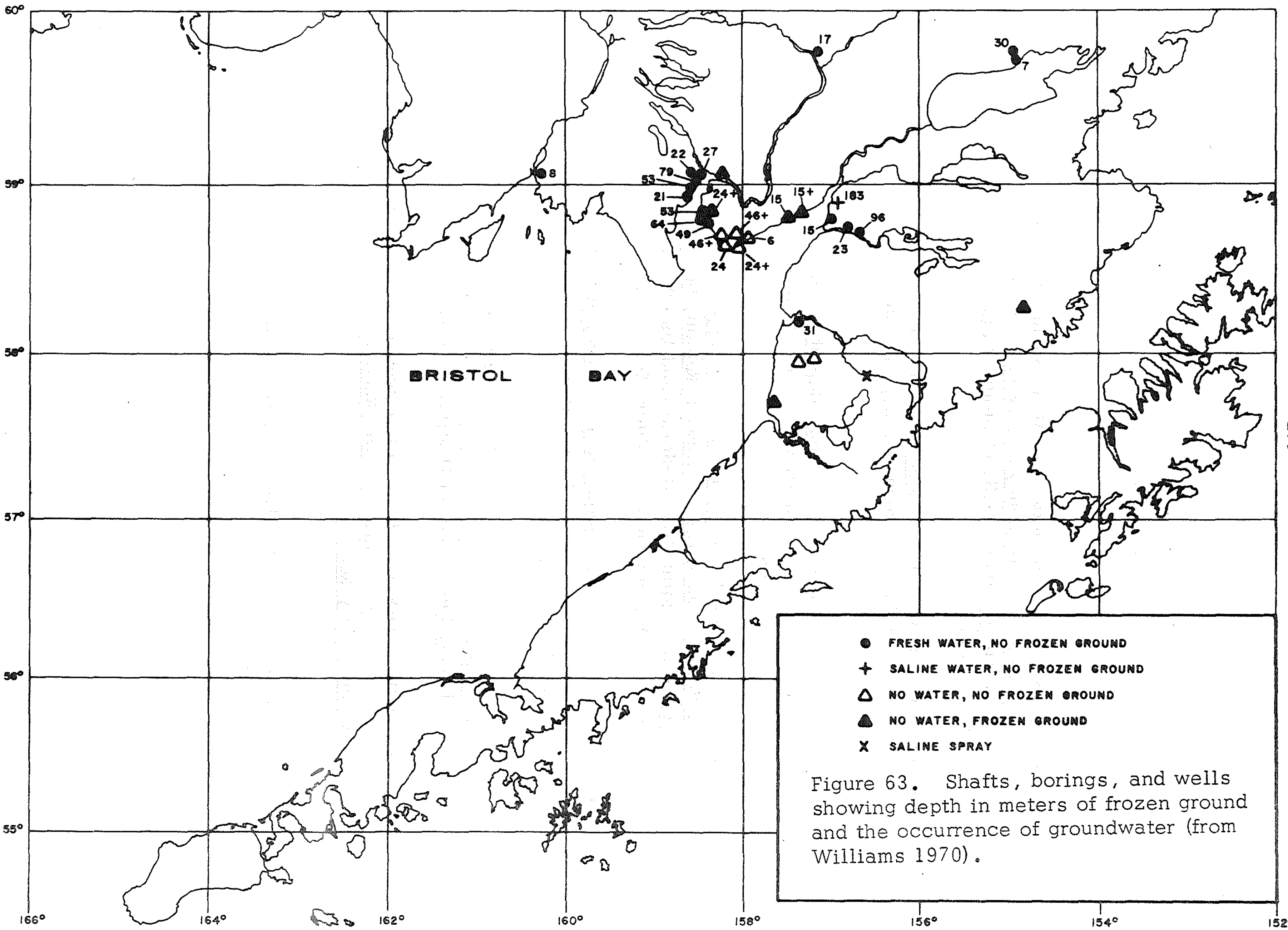

Figure 63. Shafts, borings, and wells showing depth in meters of frozen ground and the occurrence of groundwater (from Williams 1970).

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BIOTA OF BRISTOL BAY

MARINE BACTERIA

Knowledge of marine bacteria in the study area is meager. Only one series of samples has ever been taken for bacterial analysis (Faculty of Fisheries 1961). In that case, bacterial samples were taken at depths ranging from the surface to 100 m. Most of the bacteria were found at depths less than 10 m. In these surface waters ammonifiers, hydrogen sulfide producers, nitrate reducers, and sulfate reducers were found. At depths between 10 and 100 m. only ammonifiers, nitrate reducers, and hydrogen sulfide producers were identified (Figure 64).

Moderately high concentrations of bacteria are known to occur in surface waters and in marine environments close to estuaries where nutrient levels are high (Firth 1969).

PLANKTON

Phytoplankton

Primary productivity is generally higher in the lagoons and coastal basins of Bristol Bay than in the adjacent offshore waters (McRoy et al. 1972). Productivity--the rate at which new organic matter in the form of phytoplankton is created--in

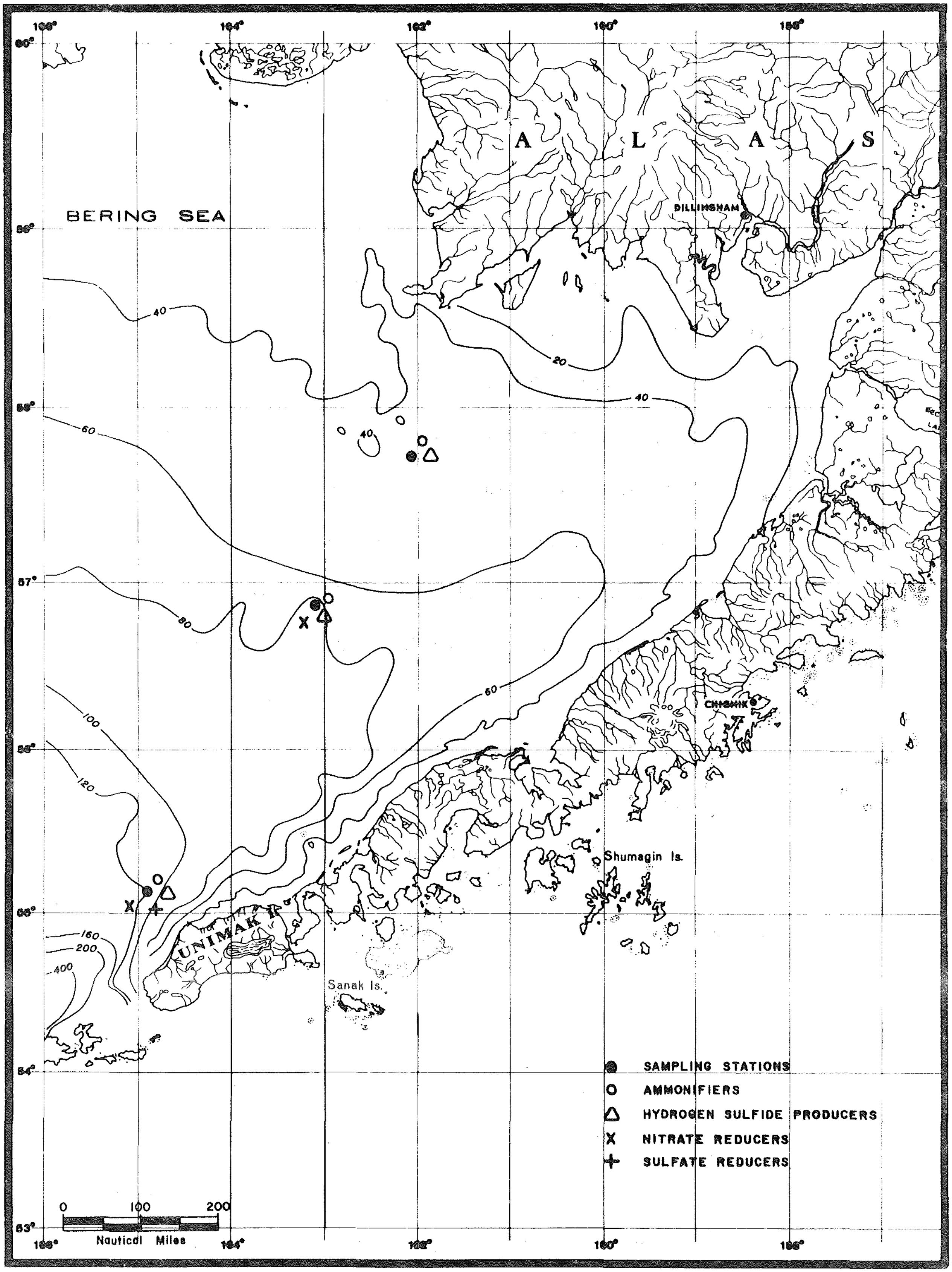

Figure 64. Bacterial activity in Bristol Bay waters (from Faculty of Fisheries 1961).

Izembek Lagoon ranged from 2.2 to 16.2 mg. carbon/cu. m./hr. in surface waters or a rate of from 26.8 to 194.0 mg. carbon/cu. m./day during July. Average standing stock--the amount of organic matter in the form of phytoplankton measureable at a point in time--was 1.24 mg. chlorophyll a/cu. m. Taniguchi (1969) reports an average offshore primary productivity of 1.46 mg. carbon/cu. m./hr. and an average standing stock of 0.57 mg. chlorophyll a/cu. m. for the study area.

Characteristic species of Izembek Lagoon and Bristol Bay were not mentioned by McRoy et al. (1972). They state that phytoplankton blooms generally occur in the lagoons and offshore from major river drainages, where advective processes contribute to high productivity in adjoining waters. Figure 65 indicates summer stations of the R/V Acona cruise (McRoy et al. 1972). Data from these stations show an average standing stock of 3.24 mg. chlorophyll a/cu. m.

Clasby et al. (1973) report that a significant phytoplankton population develops near the bottom surface of sea ice in late spring. Pennate diatoms are the dominant flora

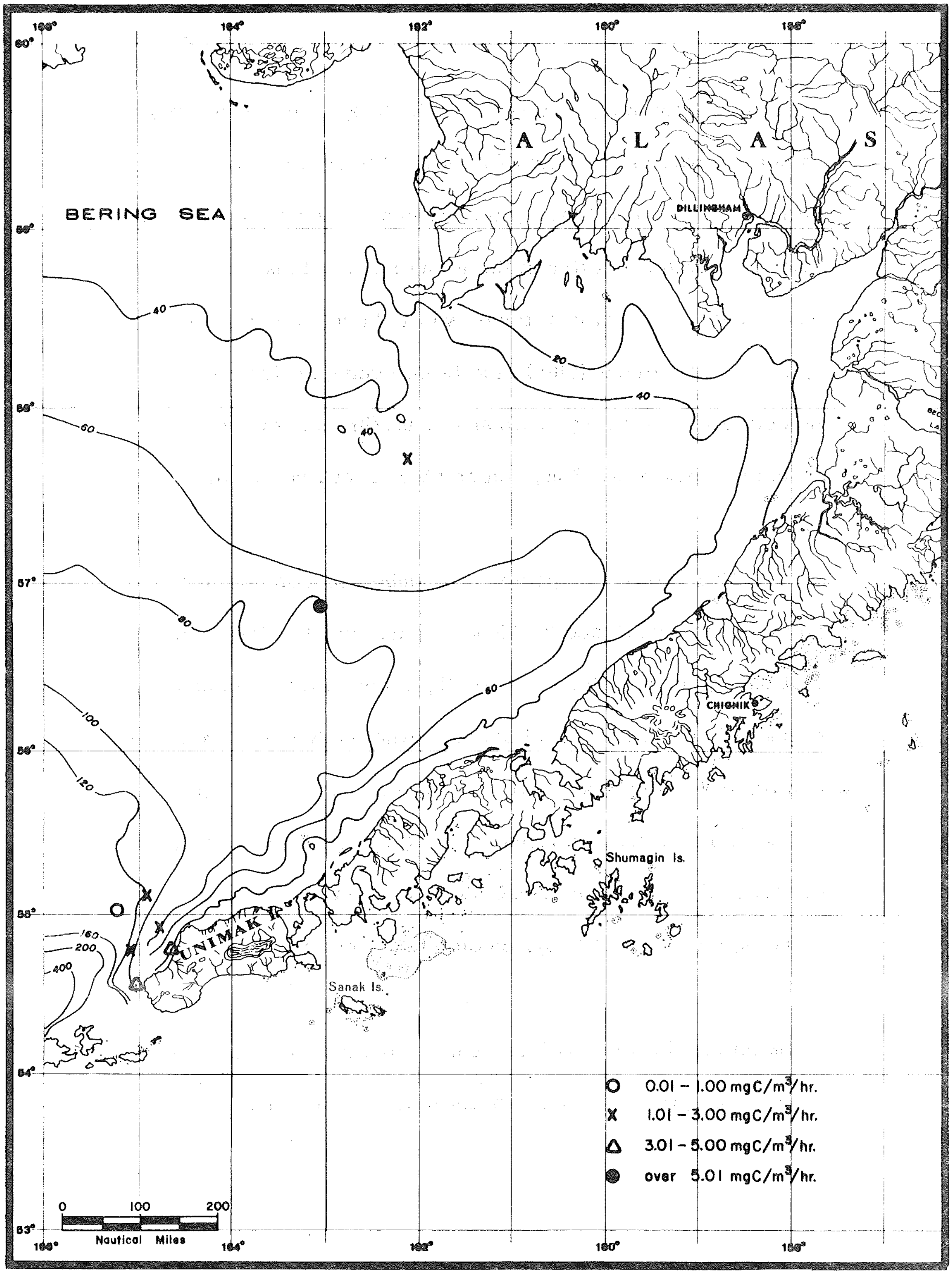

Figure 65. Primary productivity in Bristol Bay surface waters (from Faculty of Fisheries 1961, McRoy et al. 1972).

observed. In the northern part of Bristol Bay, where ice conditions are consistent year after year, this algal layer may provide significant production in the early part of the growing season.

Plankton investigations conducted by the Soviet 1958 and 1959 expeditions identified large quantities of *Chaetoceros*, *Rhizosolenia*, and *Thalassiothrix* near Cape Krenitzin and Port Moller Inlet in July (Meshcheryakova 1964). During the second half of September 1959, a large algal bloom was noted in the Cape Pierce area. The dominant species found in the study area were oceanic diatoms. Dinoflagellates did not occur in large numbers. Species reported are included in Table 23. Meshcheryakova (1970a) reported a large bloom of *Coscinodiscus* and *Chaetoceros* offshore of Izembek Lagoon in late May and June, 1961.

Table 23. Phytoplankton Species Identified in Bristol Bay.

Diatoms

Biddulphia sinensis
Chaetoceros concovicornia
Chaetoceros convolutus
Chaetoceros atlanticus
Chaetoceros debilis
Coscinodiscus curvatulus
Coscinodiscus radiatus
Gonyaulax tamarenis
Melosira sulcata
Nitzschia pacifica
Nitzschia closterium
Rhizosolenia hebetata
Synedra sp.
Thalassiosira gravida
Thalassiosira nordenskioldi
Thalassiosira rotula
Thalassiothrix sp.
Thalassiothrix longissima

Dinoflagellates

Peridinium sp.

Azova (1964) found that the highest primary production occurred offshore in the inner and outer bays during the summer (Figure 66). In autumn, the inner bay was more productive than the outer bay (Figure 67). Starodubtsev (1970) summarizes the Soviet knowledge of phytoplankton in Bristol Bay.

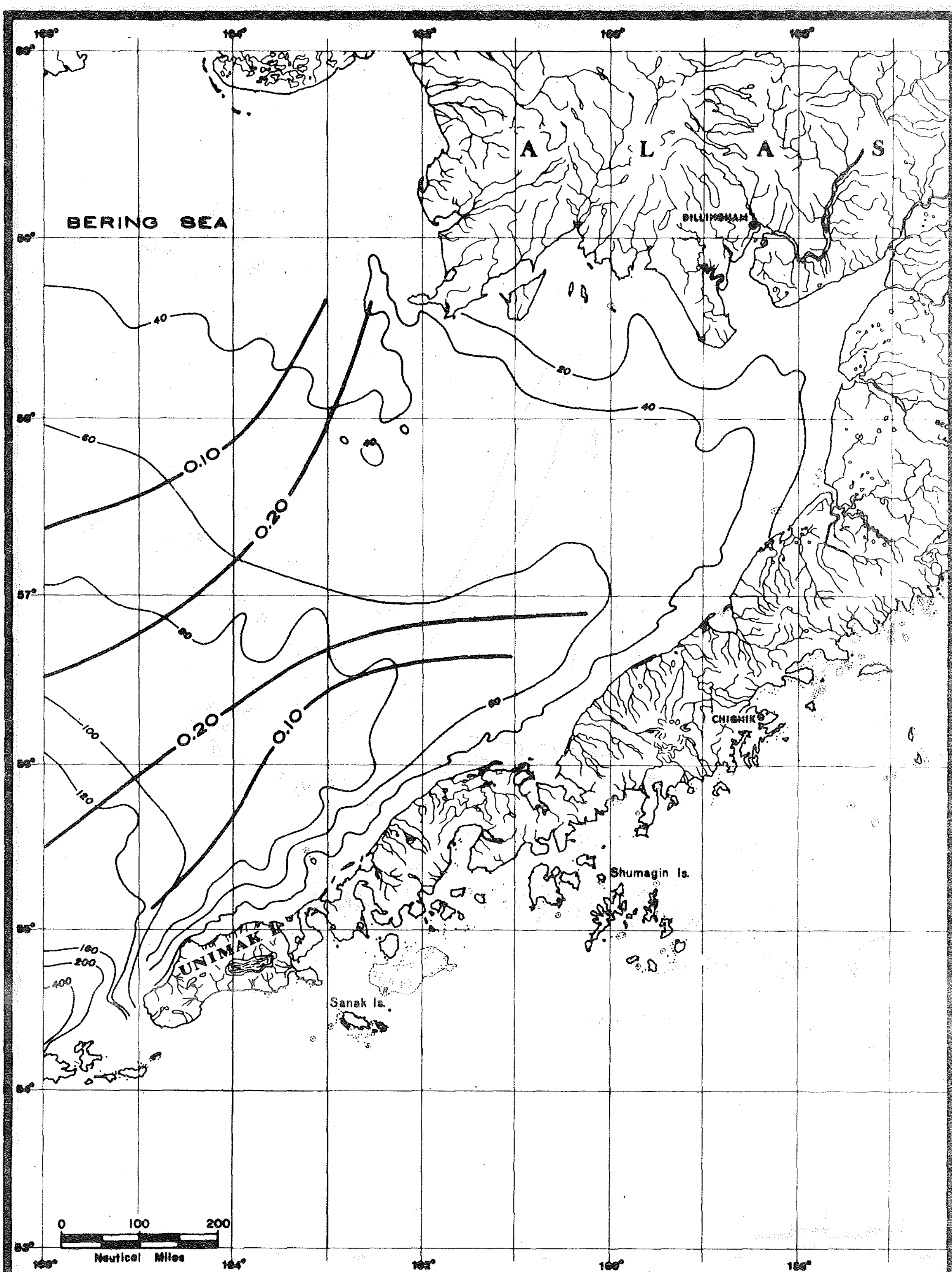

Figure 66. Primary productivity (gm C/m^3/day) in Bristol Bay surface waters in summer (from Azova 1964).

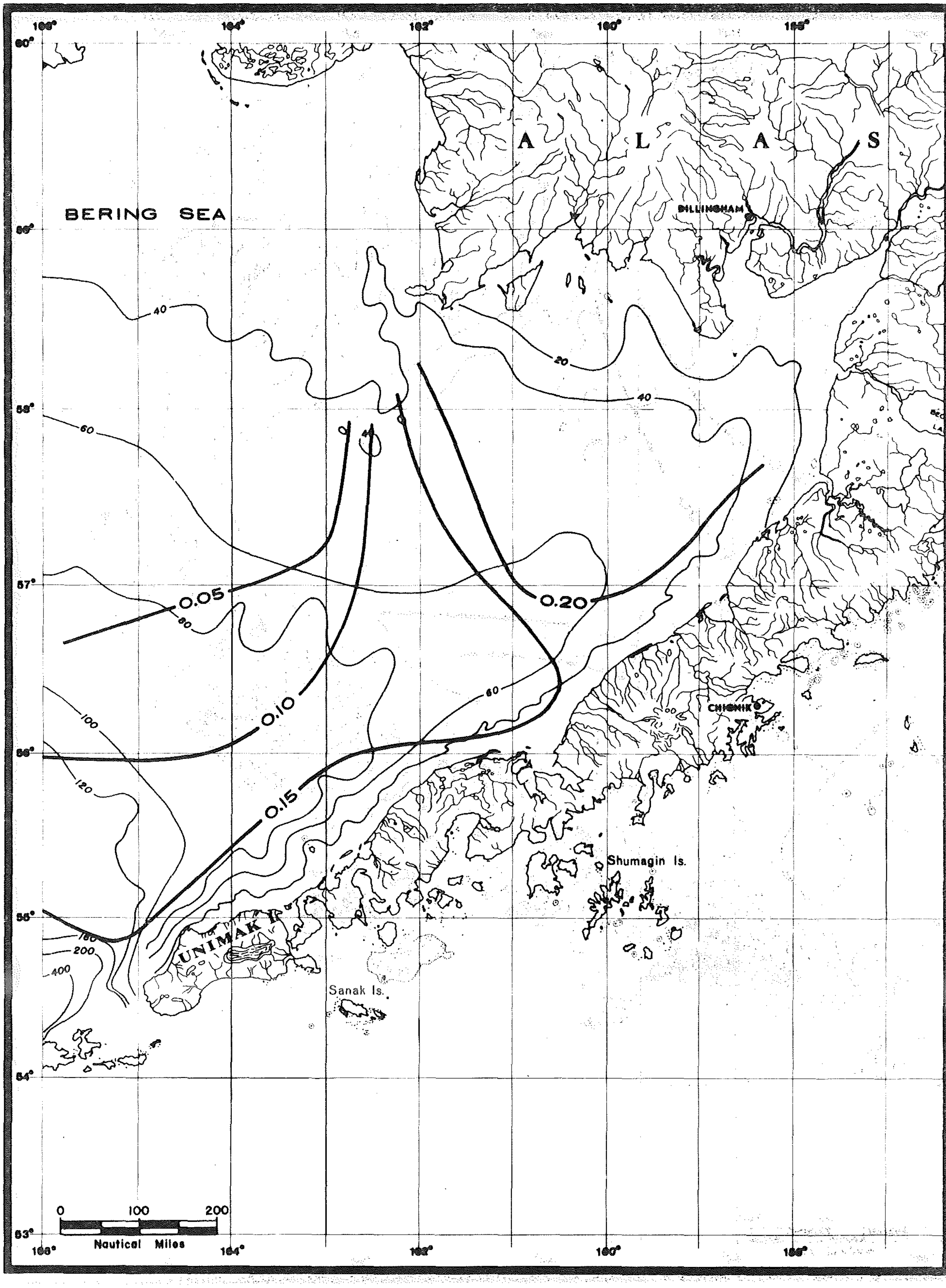

Figure 67. Primary productivity (gm C/m^3 /day) in Bristol Bay surface waters in autumn (from Azova 1964).

He reports that an annual bloom begins in May or June each year and reaches a maximum standing crop of 3 g./cu. m. in the center of the Bay. Productivity here, measured in terms of the entire water column, reaches a maximum between 3.6 and 5.0 g. carbon/sq. m./day and declines to 1.5 g. carbon/sq. m./day during the summer. This decline extends into autumn with no substantial secondary bloom. In coastal areas from Nelson Lagoon counterclockwise around the Bay, standing crops are generally less than 0.5 g./cu. m. and productivity is between 0.5 and 1.0 g. carbon/sq. m./day. Genera in the spring bloom are predominantly *Thalassiosira* and *Biddulphia* with *Chaetoceros* becoming dominant in summer.

During the 1955 *Oshoro Maru* cruise (Faculty of Fisheries 1957) diatoms were sampled throughout the study area. Diatoms recorded on this cruise were not identified. Diatoms and dinoflagellates were recorded during the 1960 cruise (Faculty of Fisheries 1961). Dominant species are included in Table 23. Primary productivity values measured in July 1960 are plotted in Figure 65.

Zooplankton

Zooplankton sampling during the 1958 Soviet cruise indicated a high zooplankton biomass along the western boundary of the study area (Figure 68). The highest zooplankton biomass, 200 to 500 mg./cu. m., was reported from inshore waters north of Unimak Island and from the offshore waters south of Cape Pierce (Meshcheryakova 1964). Meshcheryakova (1970b) reports large variability in Bristol Bay zooplankton numbers and species depending upon the degree of penetration of North Pacific water into the Bay in early spring.

These Soviet investigations correlate well with work done by Straty (in press). Straty states that zooplankton was abundant in the offshore waters of outer Bristol Bay. Lower zooplankton populations occur in the waters of inner Bristol Bay. Zooplankton also was more abundant in the clearer offshore waters of the outer Bay than in the more turbid inshore waters of either the inner or outer Bays (Straty, in press). Monthly zooplankton volumes are presented in Table 24.

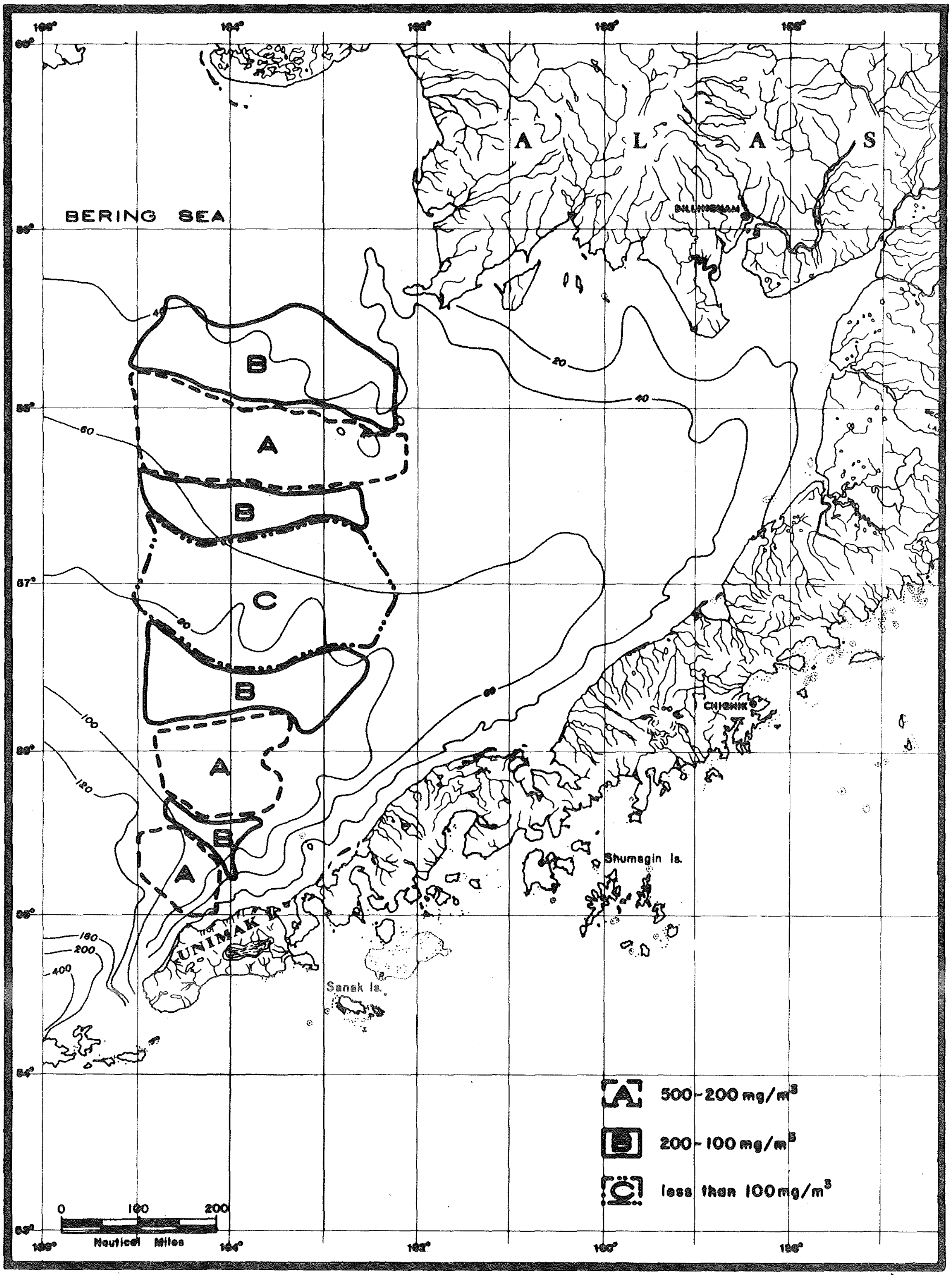

Figure 68. Soviet measurements of zooplankton biomass in late summer (from Meshcheryakova 1964).

Table 24. Zooplankton volumes (cu. cm. per cu. m.) by month in inner and outer Bristol Bay, 1969-71

	Inner Bristol Bay				Outer Bristol Bay			
Year	June	July	August	September	June	July	August	September
1969	0.15	0.18	0.43	-	0.74	0.61	0.59	-
1970	0.23	-	0.28	0.16	0.36	-	0.29	0.33
1971	0.22	-	0.14	0.24	0.48	-	0.53	0.47

Source: Straty, in press.

Straty notes that a decrease in zooplankton volume in the inner Bay coincides with the increase in sockeye population during the months of June and July. When the sockeye population declines, during August and September, zooplankton volume increases. Zooplankton volumes remain high in the outer Bay during June and July when most sockeye are moving inland to spawning grounds. In early fall, when the seaward migrating smolts enter the outer Bay near Port Moller, zooplankton volumes decline. The occurrence of offshore, outer Bay sockeye with full stomachs, as opposed to inshore and offshore, inner Bay sockeye with partially filled or empty stomachs, suggests that zooplankton is more abundant in the offshore outer Bay (Straty, in press). It would appear that zooplankton abundance in this area is crucial to sockeye production. Malick et al. (1971) took only a few zooplankton samples in the estuary of the Naknek River and did not find a great abundance there.

Japanese oceanographic observations (Faculty of Fisheries 1957, 1961, 1966, 1967, 1968, 1973) show the general abundance and distribution of zooplankton along the western boundary of the study area during the summer. Figure 69 presents zooplankton densities measured during these cruises.

Varied taxa of zooplankton occur in the study area. Table 25 lists zooplankton groups and species which have been identified. Concentrations of larval bivalve mollusks and euphausiids in egg and other early developmental stages, were reported north of Unimak Island (Meshcheryakova 1964). Near Cape Pierce, larval polychaetes, bivalve mollusk larvae, and echinoderm larvae were found in abundance (Figure 68).

Ichthyoplankton occur in considerable numbers in the study area (Musienko 1963, Kashkina 1970). Capelin, Mallotus villosus; walleye pollock, Theragra chalcogrammus; flathead sole, Hippoglossoides elassodon; yellowfin sole, Limanda aspera; and rex sole, Glyptocephalus zachirus, are common.

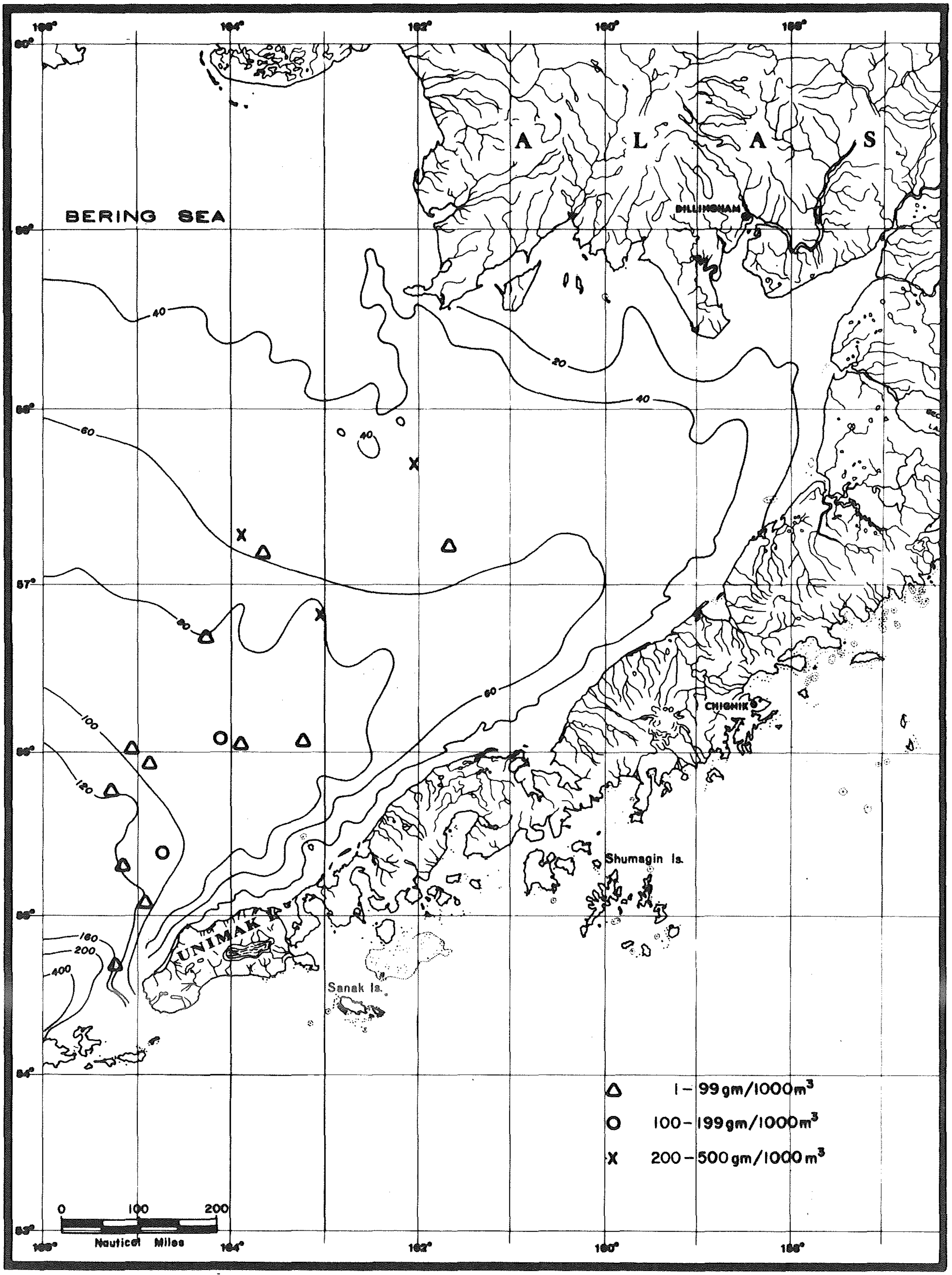

Figure 69. Japanese measurements of zooplankton biomass in summer (from Faculty of Fisheries 1957, 1961, 1966, 1967, 1968, 1973).

Table 25. Zooplankton Species Reported From Bristol Bay

Coelenterata

- *Aglantha* sp.
- Hydromedusae
- Jellyfish

Chaetognatha

- *Sagitta* sp.

Annelida

- Larval polychaetes

Arthropoda

- *Acartia longiremis*
- *A. tonsa*
- *Calanus* sp.
- *C. cristatus*
- *C. finmarchicus*
- *C. plumchrus*
- *Centropages mcmurrichi*
- *Eucalanus bungii*
- Euphausiids
- *Eurytemora* sp.
- *Euthemisto libellula*
- *Metridia lucens*
- *M. pacifica*
- Mysidae (unidentified)
- *Parathemisto japonica*
- *Pseudocalanus elongatus*
- Zoea

Mollusca

- Bivalve larvae
- *Clione limacina*
- *Limacina helicina*

Echinodermata

Larval echinoderms

Ichthyoplankton

Ammodytes hexapterus
Glyptocephalus zachirus
Hexagrammus sp.
Hippoglossoides elassodon
Limanda aspera
Mallotus villosus
Theragra chalcogrammus

Zooplankton is an important food of many fish species. Principal food items of juvenile sockeye salmon and other species of fish are listed in Table 26 (Meshcheryakova 1964; Straty, in press). Euphausiids are a major food source for the flatfish, family Pleuronectidae (Musienko 1963). Euphausiids are sometimes abundant enough to serve as a major food source for baleen whales (Gosner 1971).

Table 26. Zooplankton, Listed According to Their Relative Importance as a Food Source (from Straty, in press).

- Pacific sand lance, *Ammodytes hexapterus*, larval and young stages.
- Euphausiid eggs and larval stages
- Copepods, all stages
- Cladocera, *Podon* sp.
- Pteropods
- Decapod larvae
- Other fish, larval stages
- Many unidentified invertebrate eggs and larvae

MARINE MACROPHYTES

With the exception of C. P. McRoy of the University of Alaska, who has done extensive studies on eelgrass, little has been published concerning the higher marine producers in Bristol Bay.

McRoy (1968b) reports eelgrass meadows in 17 coastal lagoons along the eastern Bering Sea coast. Eelgrass, Zostera marina, is a marine vascular plant which grows in the soft, muddy sediments of shallow, protected bays and inlets in a distinct subtidal zone (Barsdate et al. 1972). Figure 70 shows the location of eelgrass in the study area. McRoy (1966) reports that Izembek Lagoon contains the largest and most important eelgrass meadows in the study area and possibly in the entire world. The standing stock of eelgrass in this lagoon averages 1,510 g./sq. m. (McRoy 1970). Dense eelgrass beds provide a concentrated source of food for hundreds of thousands of migrating waterfowl, commercially important fish, and numerous invertebrates. Hulten (1960) reported eelgrass in Izembek Lagoon and along Unimak Island.

McRoy (1970) reports a low standing stock of the filamentous green alga, Chaetomorpha, in Izembek Lagoon. Chaetomorpha was found in well-sorted sediments and entangled in the eelgrass. Fucus and Ulva were found attached to stones.

McRoy (1968a) identified brown algae, Fucus inflatus and F. latifrons, in Izembek Lagoon. These two species are not common in the study area.

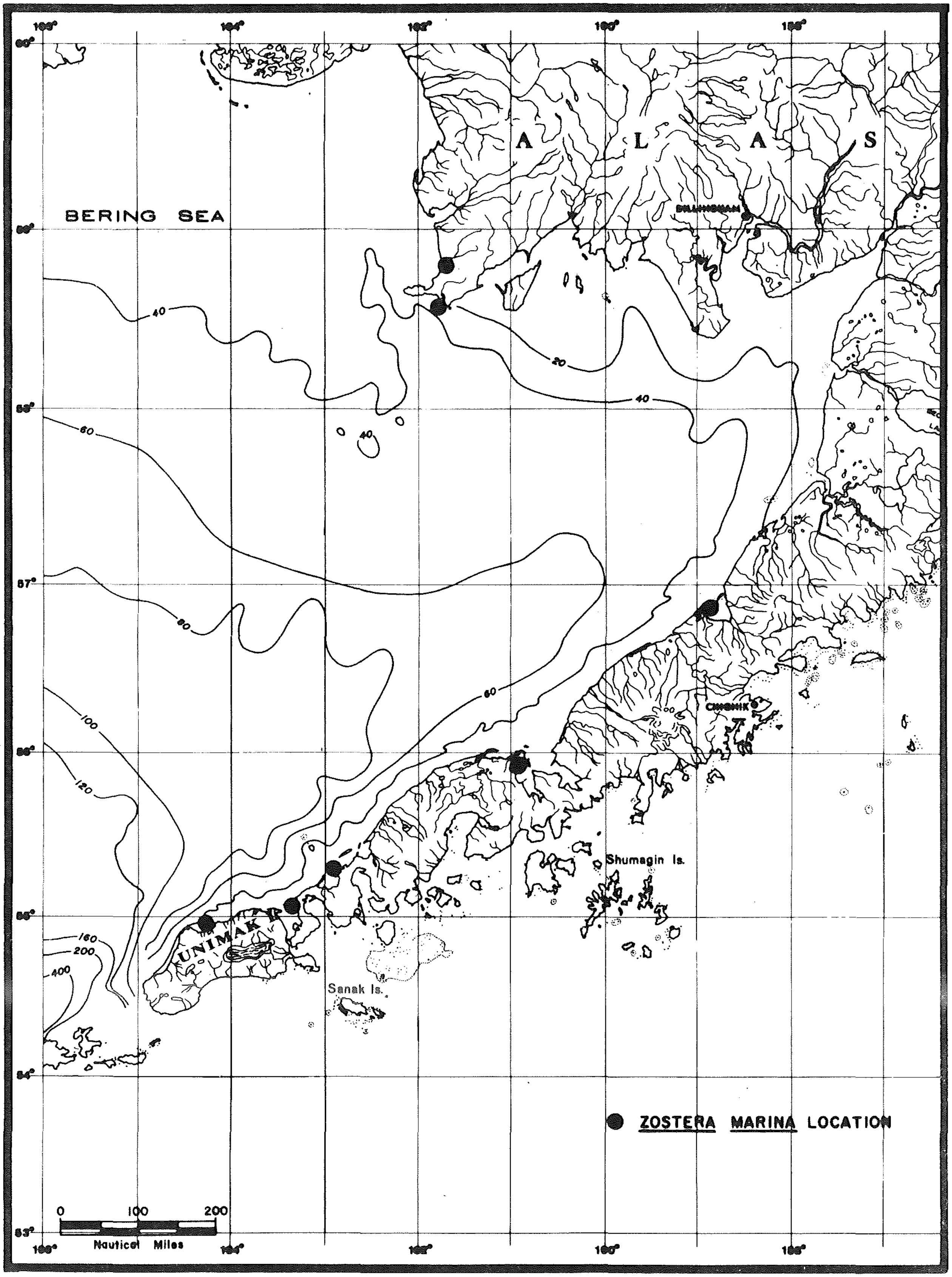

Figure 70. Distribution of eelgrass, Zostera marina, in Bristol Bay (from McRoy 1968b).

A list of species occurring in the study area is presented in Table 27.

Table 27. Marine Macrophyte Species Reported from Bristol Bay.

Thallophyta

Chlorophyta

Chaetomorpha sp.
Ulva sp.

Phaeophyta

Fucus sp.
F. inflatus
F. latifrons

Spermatophyta

Angiospermae

Zostera marina

BENTHIC AND INTERTIDAL INVERTEBRATES

Intertidal Fauna

The development of diverse intertidal communities in the study area, particularly in the Naknek-Kvichak estuary, is hampered by the following: Extreme tidal ranges which expose vast expanses of the shoreline twice daily; variable salinities; irregular currents and current velocities, and winter ice which scours tidal flats and coastal lagoons (Malick et al. 1971). Table 28 lists intertidal invertebrates sampled in the Naknek-Kvichak area.

Table 28. Intertidal Invertebrates Reported from the Naknek-Kvichak Area.

Annelida

- Arenicola sp.
- unidentified polychaete worms

Arthropoda

- Crangon sp.
- Gammarus sp.
- Idothea entomon
- Pontoporeia affinis

Mollusca

- Macoma sp.
- Mya arenaria

In Izembek Lagoon, McRoy (1966) noted a characteristic intertidal fauna due to the scouring effects of winter ice on the tidal flats. Here unidentified worms and clams were the dominant invertebrates in a soft mud substrate (McRoy et al. 1969).

Clams

The U.S. Bureau of Sport Fisheries and Wildlife (1972) reports that razor clams, *Siliqua patula*, occur in large numbers in the shallow inshore waters and lagoons of Unimak Island. Scheffer (1959) also reports razor clams in the Unimak Island area. These clams live in the lower intertidal zone and are quite difficult to harvest. Razor clams are reported from Izembek Lagoon and the Kudiakof Islands.[1] This species is important for personal use by local residents.

The giant cockle, *Clinocardinum nuttalii*, is abundant in the study area and is also utilized for food by local residents. These clams are present on sandy beaches.

Butter clams, *Saxidomus giganteus*, and littleneck clams, *Protothaca staminea*, are also present and harvested by local residents in the Unimak Island area. Butter clams are found in Izembek Lagoon and various other lagoons along the north shore of the Alaska Peninsula.[2] These clams are found in sandy beaches and lagoon mud flats.

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1. Marlin Bricker, Assistant Area Management Biologist, Alaska Department of Fish and Game, Cold Bay. Personal communication.

2. Ibid.

A species of softshell clam is found in Togiak, Kulukak, and Nushagak Bays.[1] These clams are found along shorelines where the substrate is mud with small amounts of sand. These clams provide subsistence for local residents.

Most clams feed on plankton which they filter from surrounding waters. Little is known about their food preference.

Life histories of clams have not been studied in Bristol Bay. Elsewhere in Alaska and British Columbia, clams reproduce by shedding eggs and sperm into the water, where fertilization occurs. Developing larvae are free-swimming for 3 to 16 weeks, and live in and on the sand near where they were spawned. Spawning takes place during the summer, when the water reaches a suitable temperature (13 degrees C for razor clams, 20 degrees C for butter clams). Larvae settle onto the bottom when still quite small. They burrow into the sediments where they spend the remainder of their life cycle (Nosho 1972). Figure 71 depicts the annual and life cycles of the razor clam.

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1. Mike Nelson, Assistant Area Management Biologist, Alaska Department of Fish and Game, Dillingham. Personal Communication.

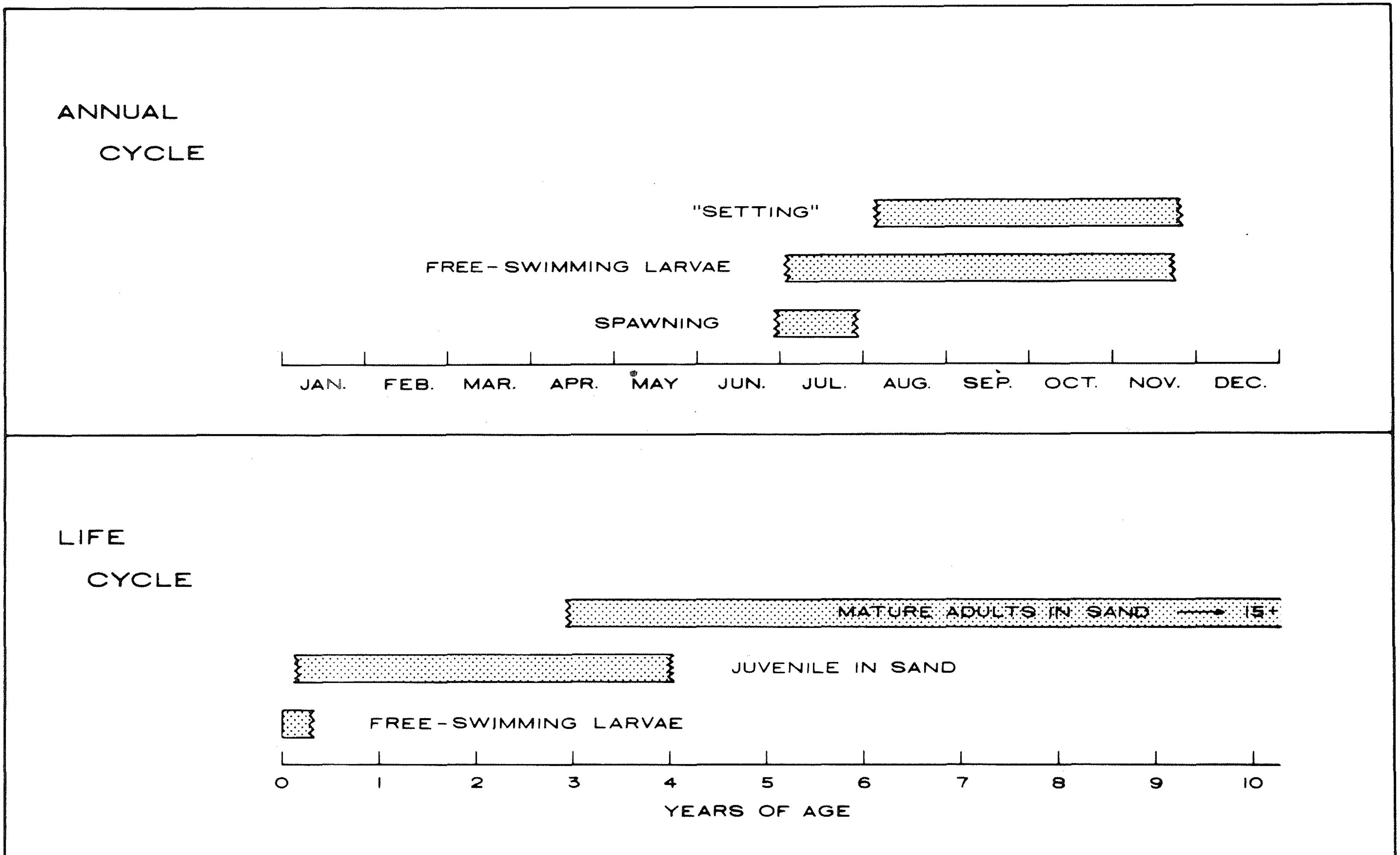

Figure 71. Annual and life cycles of the razor clam, Siliqua patula (AEIDC, Univ. of Alaska).

Razor clams spawn for the first time at the end of their 3rd year, when they are about 8.5 cm. in length. Butter clams spawn at 4 years, when they are about 5 cm. in length. Littleneck clams spawn first at 2 or 3 years when slightly more than 2.5 cm. long. Clams may live for a maximum of 15 to 20 years (Nanaimo Biological Station 1966a).

Benthic Fauna

The benthic fauna of Bristol Bay is sparse. The central part of the Bay supports a biomass which rarely exceeds 10 g./sq. m. The largest biomass (50 to 100 g./sq. m.) occurs on the sandy mud bottoms north of Unimak Island and Bechevin Bay. The smallest biomass (less than 30 g./sq. m.) occurs on muddy sand bottoms. Benthic population density increases on the periphery of the Bay. Figure 72 indicates the distribution of benthos in the study area during two separate summers (Semenov 1964, Neiman 1963).

The USSR has made the most extensive investigations of benthic fauna in the study area. Most of the biomass is composed of polychaetes, mollusks, and echinoderms. Amphipods were present in lesser numbers while sponges, hydroids, and bryozoans were present but not identified (Semenov 1964).

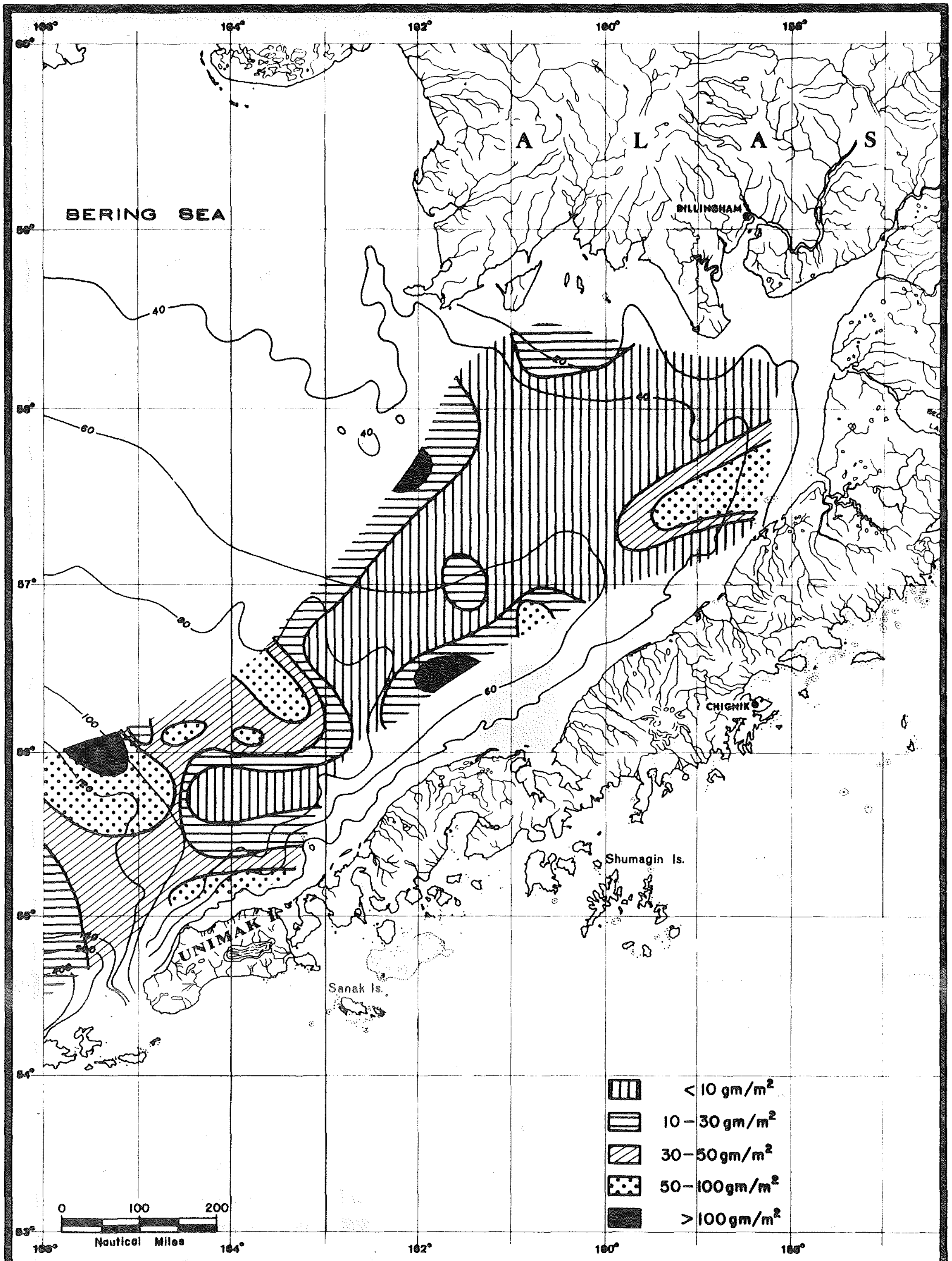

Figure 72a. Benthos biomass in Bristol Bay (from Semenov 1964)

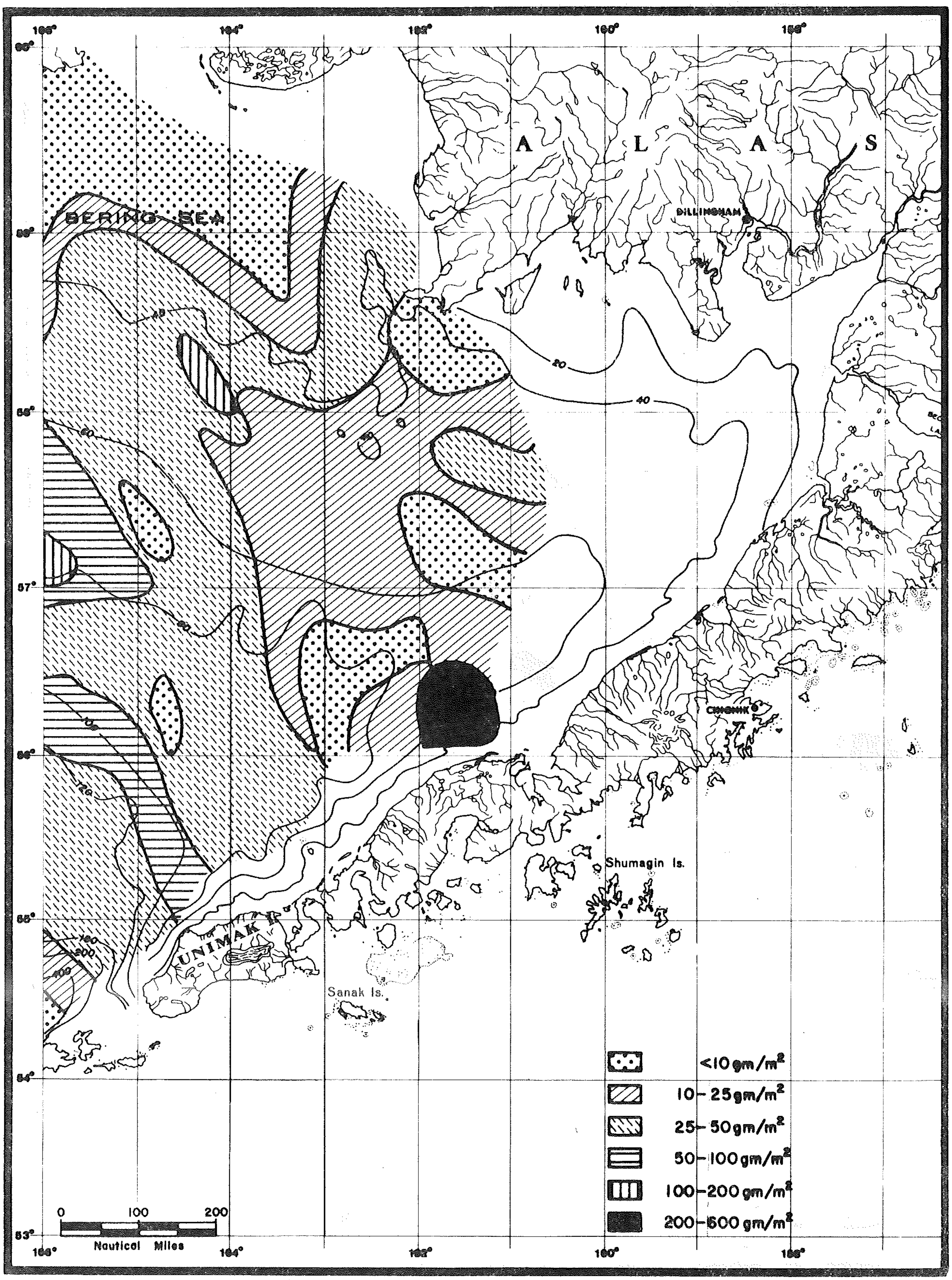

Figure 72b. Benthos biomass in Bristol Bay (from Neiman 1963)

Benthic species were divided into three trophic groups by Soviet investigators: Filter feeders (mobile and sessile); browsers (detritus collectors and bottom sediment browsers), and nonselective consumers of the sediments (Vinogradov 1963, Neiman 1963). Filter feeders (average biomass 1 to 10 g./sq. m.) were distributed evenly over shallow, sandy bottoms. The limited quantity of suspended matter may explain the low average biomass present in this area. Browsers are most abundant in the lower sublittoral zone where the bottom substrate is sandy mud. The distribution of nonselective consumers is similar to that of the browsers. Nonselective consumers occur in fine sand and in sediments with high organic content. Their biomass is generally less than 50 g./sq. m. Table 29 lists species characteristic of the study area. Figure 73 illustrates the areas of dominance for each of these trophic groups. Lus' (1970) has reported an average benthic biomass of 57g./sq. m. in the Unimak Island area. The bulk of the benthic fauna in this area are polychaetes and bivalve mollusks which serve primarily as food organisms for fishes.

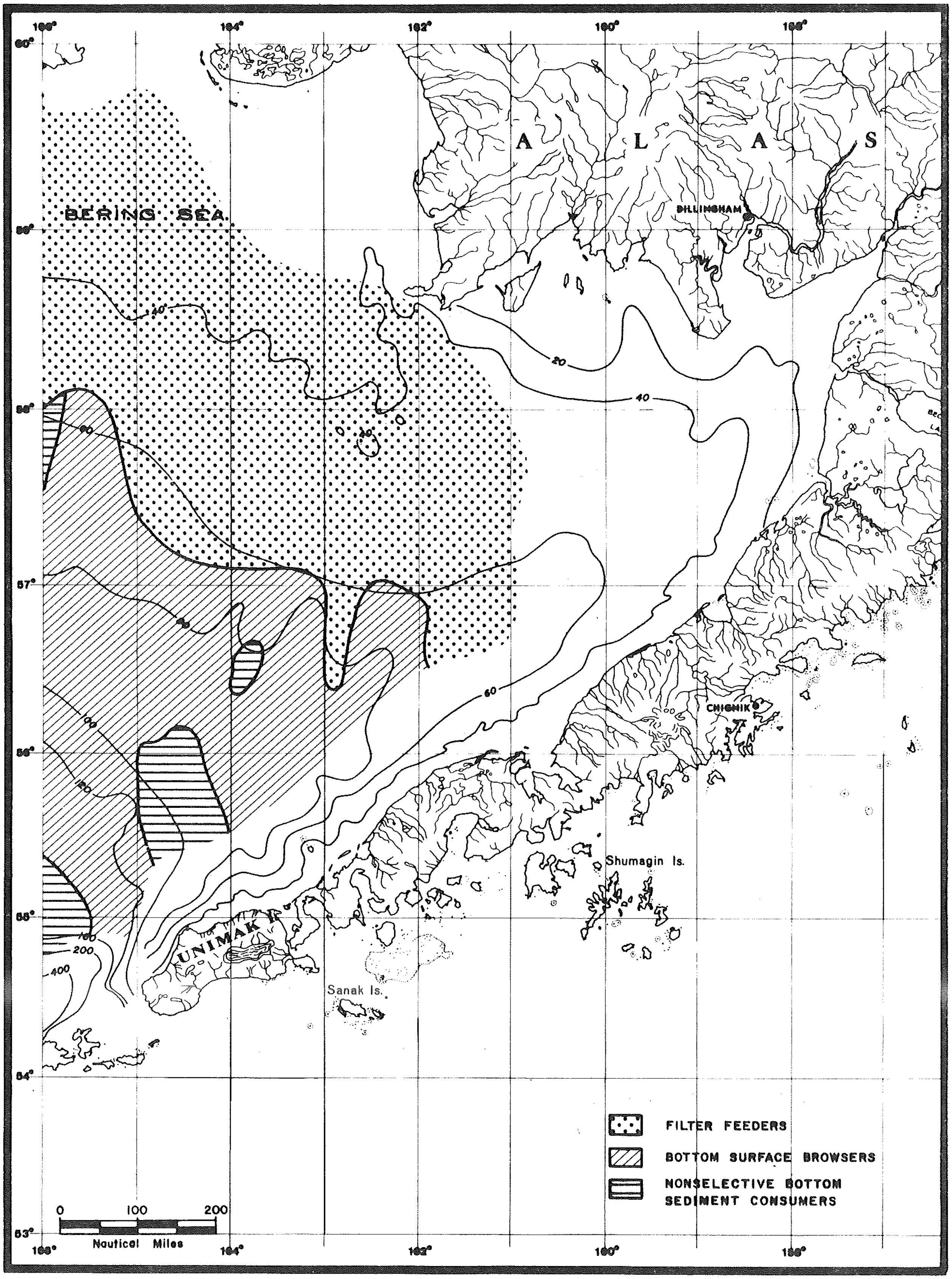

Figure 73. Dominance of different trophic groups (from Neiman 1963)

Table 29. Benthic Invertebrates of Bristol Bay.

Annelida

Ammotrypane omlogaster
Ampharete acutifrons
Artacama proboscidea
Axiothella catenata
Echiurus echiurus
Idanthyrsus armatus
Maldane sarsi
Myriochelle oculata
Nicomache lumbricalis
Ophelia limacina
Pista cristata
Scalibregma inflatum
Scoloplos armiger
Spiophanes bombyx
Sternaspis scutata
Terebellides stroemi
Travisis forbesii

Sipunculida

Golfingia margaritacea

Arthropoda

Ampelisca catalinensis
A. macrocephala
Bathymedon langsdorfi
Campylaspis crispa
Diastylis paraspinulosa
Eudorella dentata
E. emarginata
E. pacifica
Eudorellopsis deformis
Hyas coarctatus
Lamprops serrata
Leucon kobjakovae
Melita amoena
Pagurus ochotensis
P. splendescens
P. tanneri
Pandalus goniurus
Podoceropsis nitida
Pontarpinia longirostris
P. nasuta

Mollusca

Astarte borealis
Cardium ciliatum
Crenella columbiana
Gomphina fluctuosa
Leda pernula
Macoma calcarea
Mactra sp.
Mytilidae
Nucula tenius
Serripes groenlandicus
Siliqua sp.
Solariella obscura
S. varicosa
Spisula polynima
Tellina lutea
Turitella erosa
Venericardia crebricostata
Yoldia hyperborea
Y. traciaeformis

Echinodermata

- *Amphiodia craterodmeta*
- *Amphioplus macraspis*
- *Asterias rathbuni*
- *Brisaster latifrons*
- *Chiridota ochotensis*
- *Ctenodiscus crispatus*
- *Cucumaria calcigera*
- *Echinarachnius parma*
- *Gorgonocephalus caryi*
- *Leptasterias arctica*
- *L. polaris*
- *Lethiasterias nanimensis*
- *Ophiopholis pilosa*
- *Ophiura leptoctenia*
- *O. sarsi*

Ascidians

- *Molgula* sp.

Others

- Bryozoans
- Hydroids
- Spongia

Barysheva (1964) has summarized cumacean arthropod fauna characteristic of the study area, but confined his samples to the western area of the Bay, from Cape Newenham to Unimak Island. Fauna further inside the study area were not explored during this expedition. All recorded cumaceans were found between depths of 40 and 100 m. The dominant taxa occurring in the survey area were *Eudorella*, *Eudorellopsis*, *Diastylis*, *Campylaspis*, and *Lamprops*. Species are included in Table 29.

Ivanov (1964) summarized the echinoderm fauna occurring in the study area. Species were found in two distinct zones along its western boundary. The nearshore shallow waters from Cape Newenham south to latitude 56 degrees N were inhabited primarily by Echinarchinus parma, Asterias rathbuni, and Leptasterias polaris. E. parma was particularly abundant north of Port Moller. Echinoderm biomass averaged less than 10 g./sq. m. in this zone. The deeper waters were inhabited by Ophiura sarsi at densities exceeding 25 g./sq. m. Large biomasses were most common in areas experiencing low temperatures throughout the year and which had predominantly muddy bottom sediments. Figure 74 presents the distribution of echinoderm biomass in the study area.

Neiman (1963) surveyed the distribution of the mollusk, Venericardia crebricostata (Figure 75).

Aristova (1963) reported amphipod fauna in the study area from Unimak Island along the Alaska Peninsula to Port Moller and northward to Cape Newenham. Bathymedon langsdorfi, Pontarpinia nasuta, Melita amoena, and Podoceropsis nitida were the dominant species. Species near the Alaska Peninsula were warm water types, supported by the warm ocean currents from the Pacific.

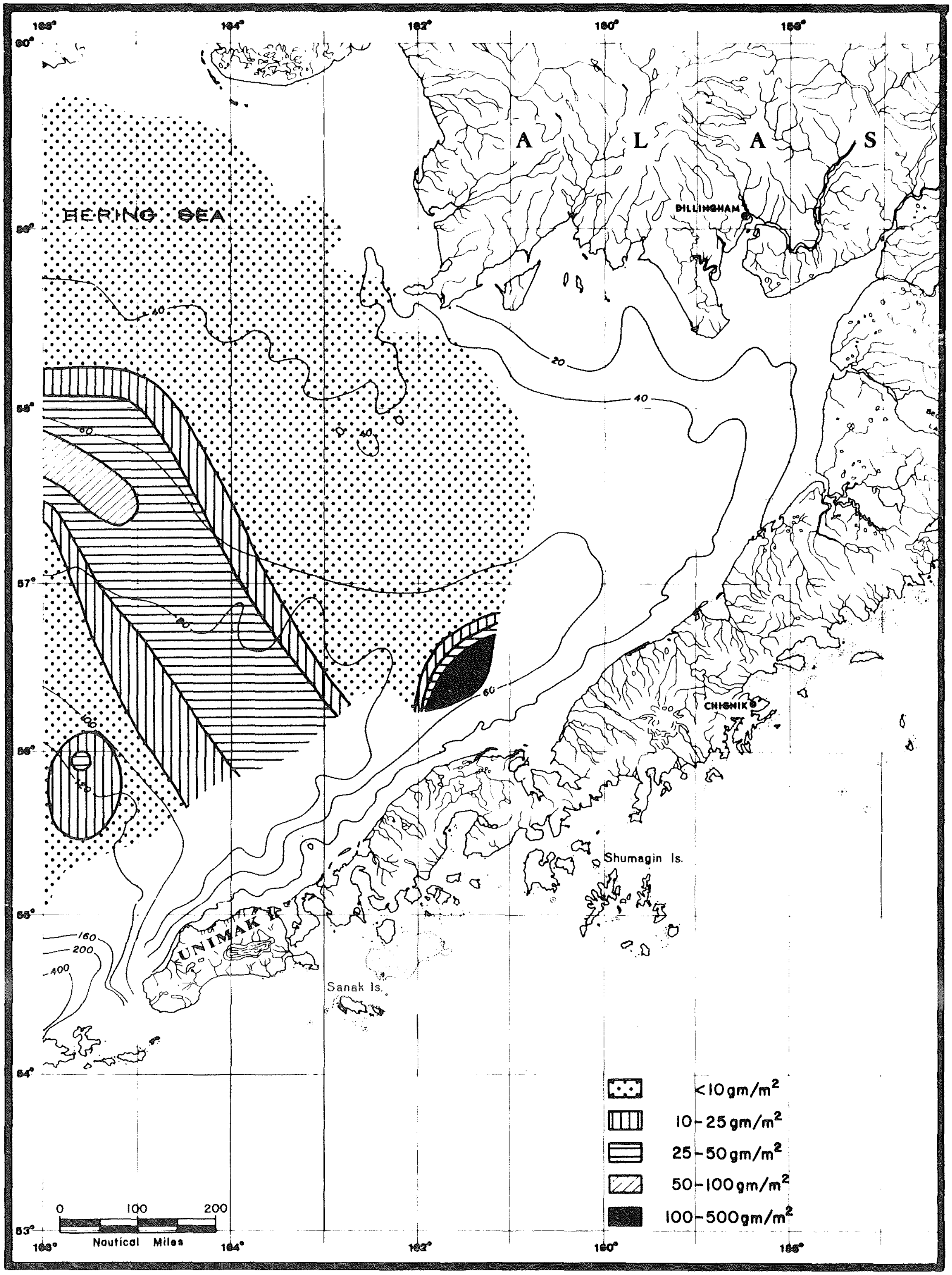

Figure 74. Echinoderm biomass in Bristol Bay (from Ivanov 1964)

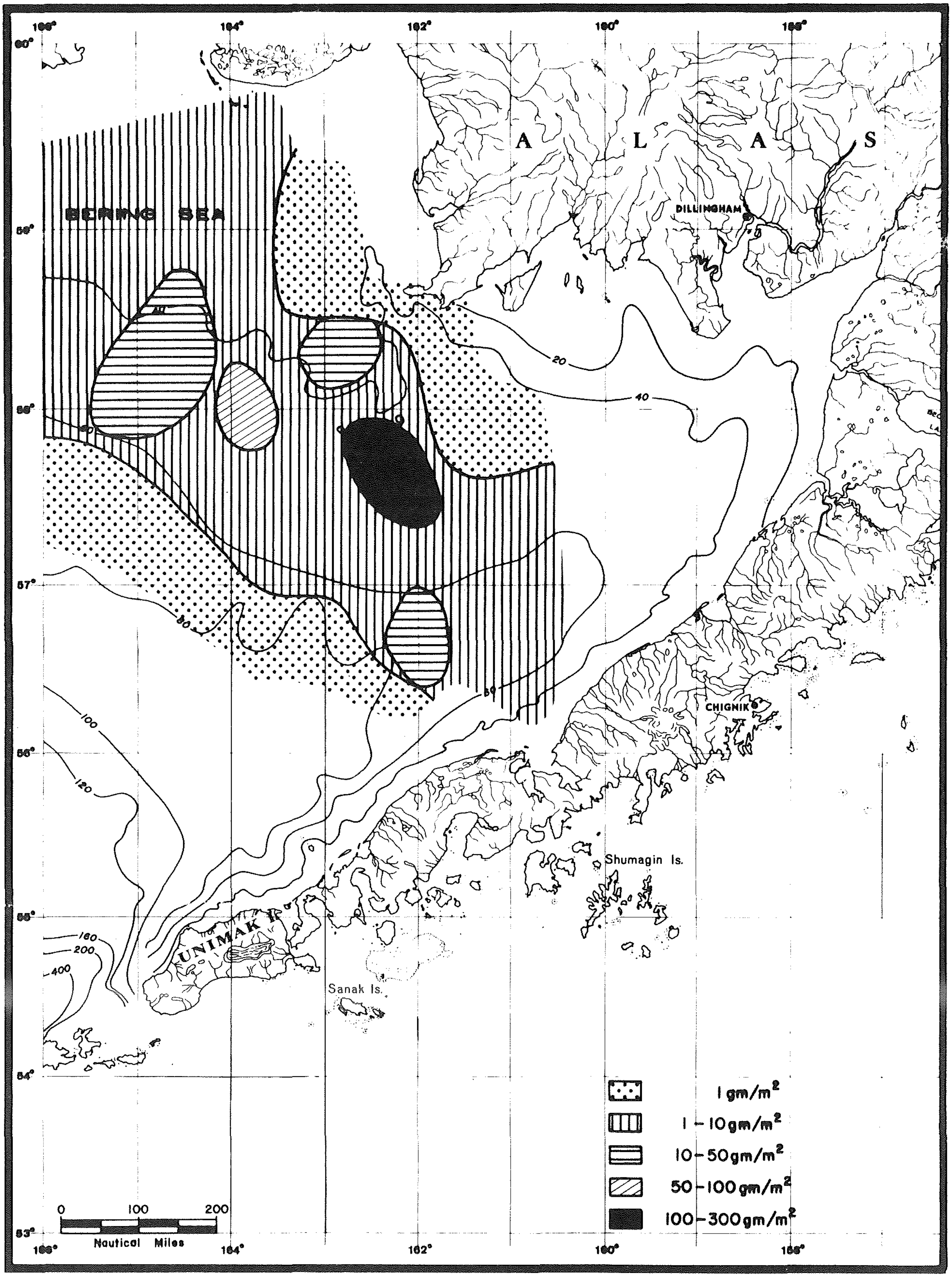

Figure 75. Biomass of Venericardia crebricostata (from Neiman 1963)

The Faculty of Fisheries (1961) has conducted only a limited sampling of benthic fauna in the study area. During this sampling cruise, north of Unimak Island and the tip of the Alaska Peninsula, only amphipods were collected. The bottom sediments in this area were sandy mud and muddy sand between 72 and 105 m.

Neiman (1964) summarized the utilization of benthic invertebrates by flatfish in the study area. Crustaceans, bivalve mollusks, ascidians (Molgula sp.) and polychaetes made up the major portion of the diet of the yellowfin sole. Rock sole fed upon a large variety of polychaetes and mollusks. Polychaetes, mollusks, and crustaceans made up approximately equal proportions of the diet of the Alaska plaice. Crustaceans and echinoderms dominated the diet of the flathead sole (Skalkin 1963).

King Crab

Bristol Bay has a commercial king crab fishery that has been of particular interest to the Japanese, who first harvested from the area in 1930; to the Soviets, who began fishing the area in 1959; and to the Americans, whose interest in the area began in the late 1950's (U.S. Bureau of Commercial Fisheries 1968, Chitwood 1969). International agreements governing the king crab fishery in the study area have been negotiated between the United States and Japan and the United States and the USSR (Naab 1971). Haynes and Lehman (1969) indicate the king crab fishing area as being inshore, east of Unimak Pass (Figure 76).

Tagging studies have shown that king crab in Bristol Bay are of a discrete stock, separate from those found in the Gulf of Alaska and Kodiak Island (Haynes and Lehman 1969).

Korolev (1964), in his studies of the king crab in the southeastern Bering Sea, has shown that commercial densities of crab occur primarily in the shallows along the north coast of the Alaska Peninsula and Unimak Island (Figure 77).

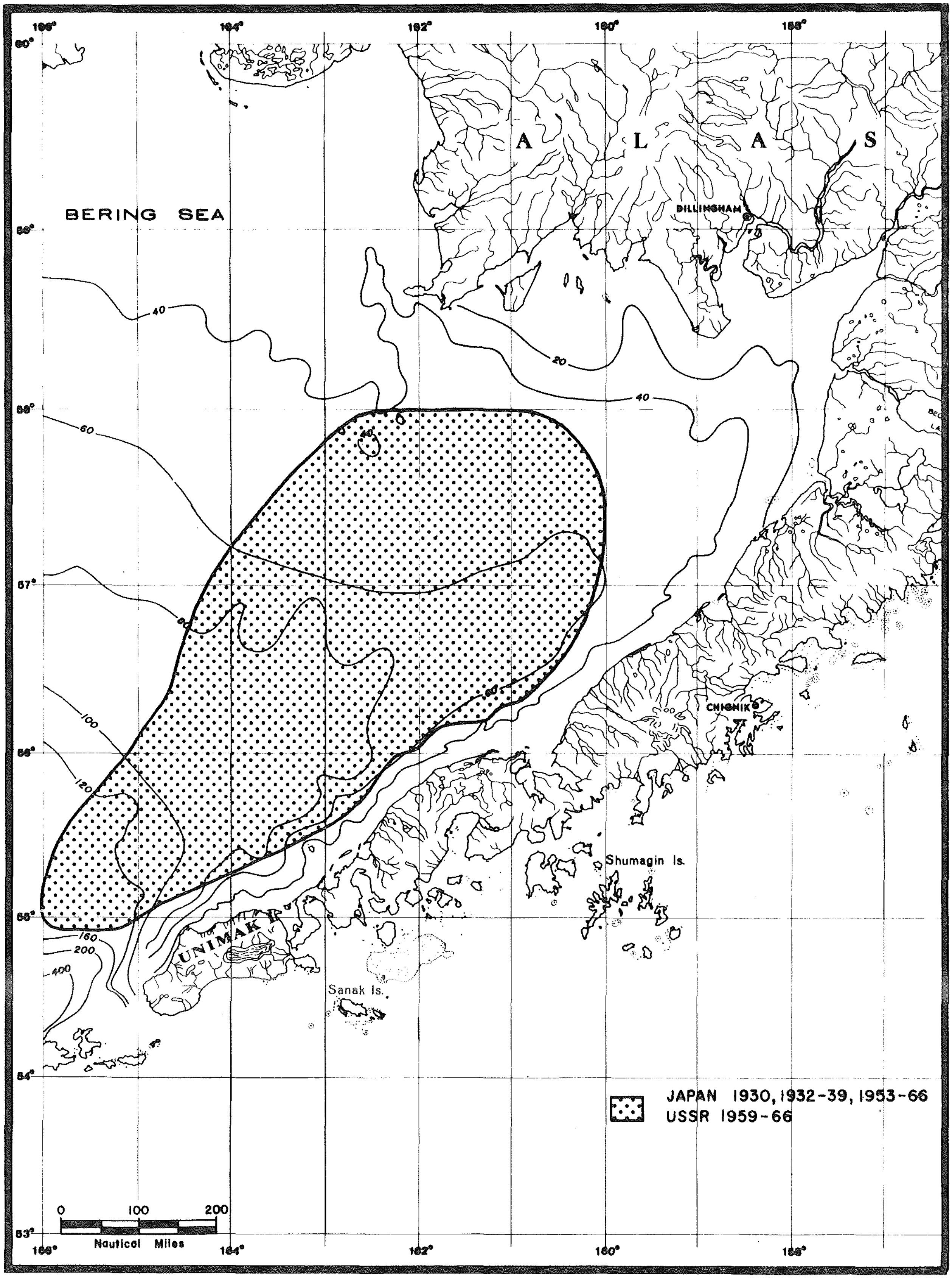

Figure 76. Eastern Bering Sea king crab fishing area (from Chitwood 1969)

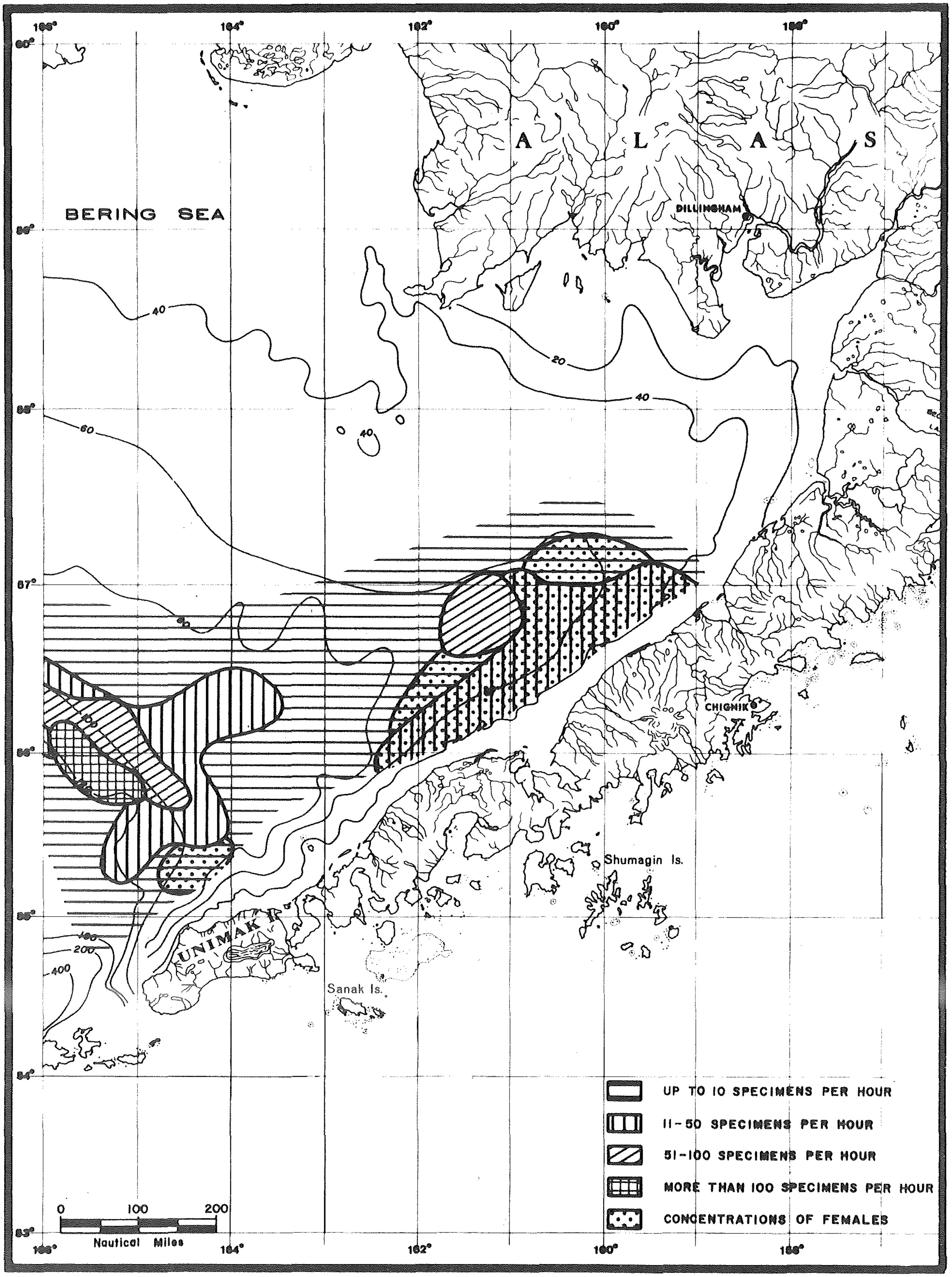

Figure 77. Soviet king crab catches (from Korolev 1964)

Exploratory fishing drags of the National Marine Fisheries Service (undated) have identified summer crab concentrations between Port Heiden and Cape Newenham in the center of Bristol Bay (Figure 78). The International North Pacific Fisheries Commission (1959) has estimated the abundance of king crab in the study area by sampling crabs according to the station pattern shown in Figure 79. The population of male king crabs exceeding 135 mm. in carapace length was calculated to be 22 million in this area. Estimates of abundance were not given for smaller males or for females.

Crab catches by Soviets trawling in Bristol Bay have shown that the distributions of males, of both commercial and sublegal size, and of females were not uniform (Korolev 1964). However, it was possible to divide Bristol Bay into three sectors, each with different population characteristics (Table 30). The sector east of 161 degrees 25 minutes W was predominately inhabited by females. The second sector was dominated again by females, but more males of commercial size were present. The portion of the second sector adjacent to the

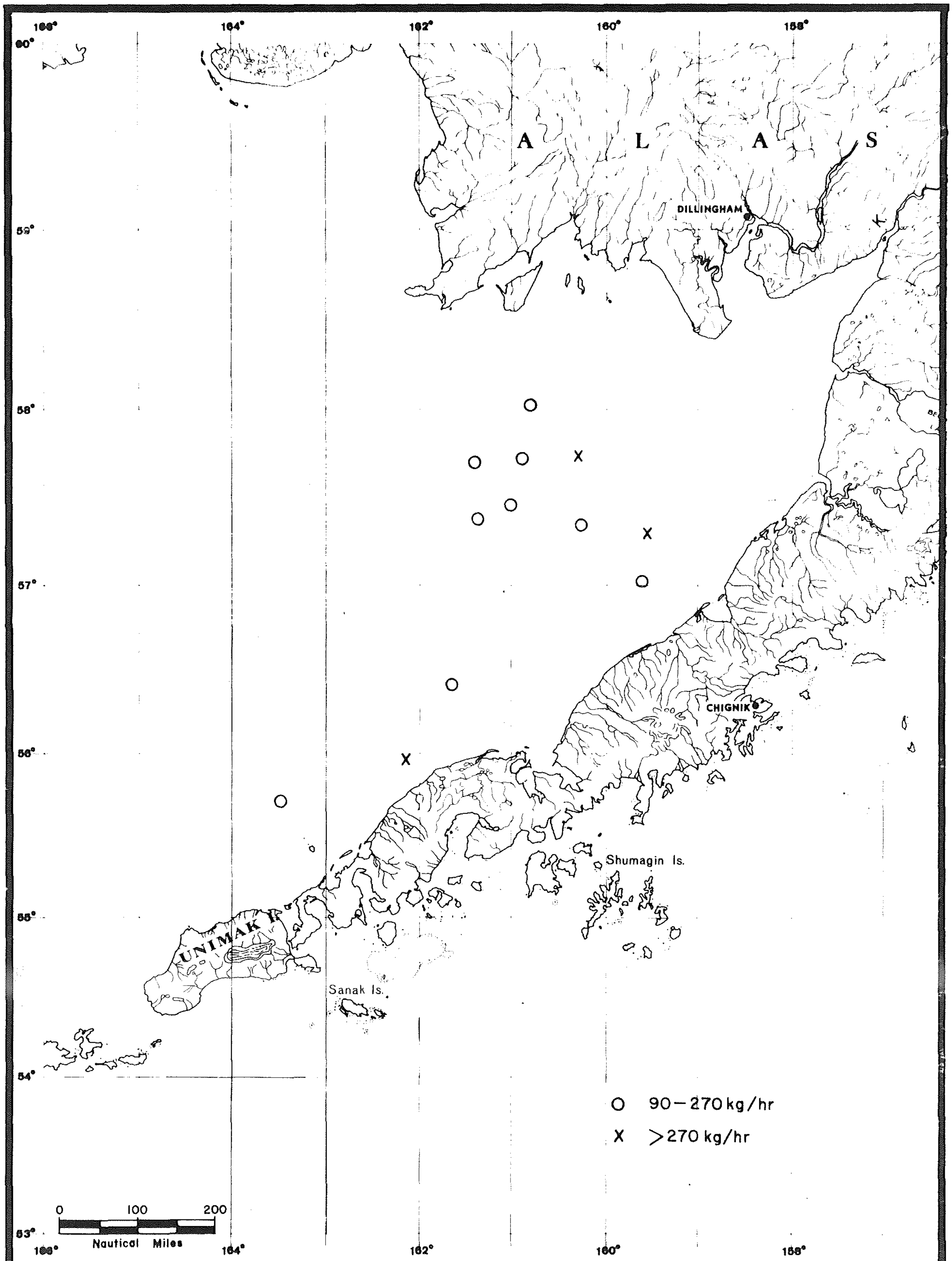

Figure 78. Location of large catches of king crab taken in National Marine Fisheries Service exploratory fishing program.

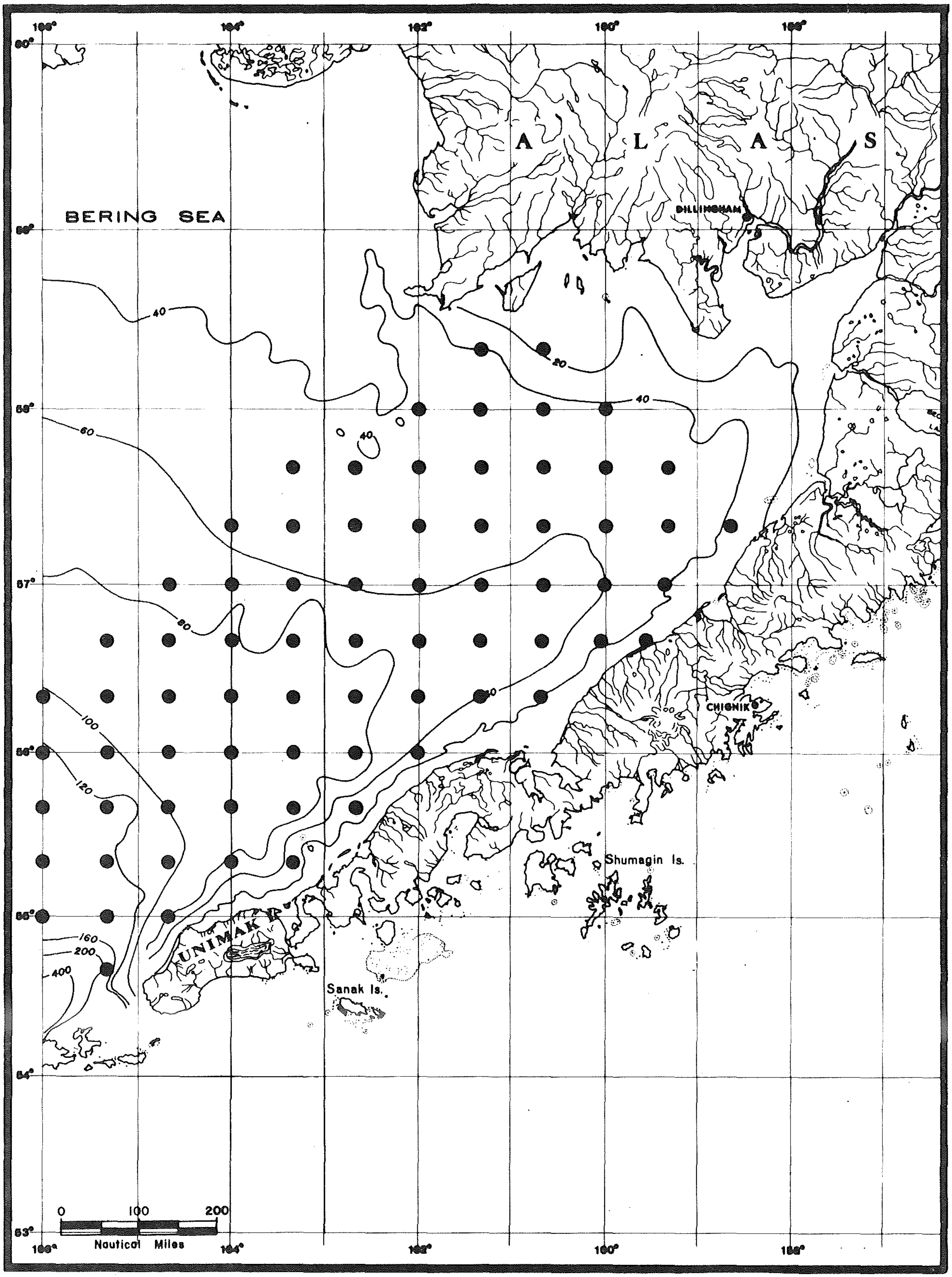

Figure 79. King crab sampling pattern utilized by the International North Pacific Fisheries Commission.

Table 30. King Crab Trawl Catch in Bristol Bay

Sector	Number of trawls	King Crab catch per hour of trawling					
		males				females	
		commercial-size		undersized			
		specimens	%	specimens	%	specimens	%
First (east of 161° 25'W.)	36	21.6	12.6	37.3	21.6	113.4	65.8
Second (161° 25' to 164° 10'W.)	57	20.1	33.8	10.7	18.2	28.7	48.0
Third (west of 164° 10'W.)	58	41.0	65.9	2.1	3.4	19.0	30.7
For the whole region	151	28.5	32.6	13.7	15.7	45.2	51.7

Source: Korolev 1964.

first sector was also considered part of the major breeding area. The third sector was dominated by males of commercial size. Within the third sector, mass hatching of larvae from individual females was observed from the end of April through the first half of May. Overall, the greatest number of females was observed in the inner Bristol Bay shallows, and progressively fewer females were observed towards Unimak Island. The greatest number of males of commercial size occurred north of Unimak Island along the 100 m. isobath. Rodin (1970a) found a similar distribution in the summer of 1965, with Bristol Bay indicated to be a major breeding and rearing area for this species (Figure 80).

The character of the ocean bottom, such as substrate type, temperature, and the degree of silting, significantly influences king crab distribution. Korolev (1964) reported that crabs concentrated on muddy, sandy bottoms, while they avoided the heavily silted bottoms, which are usually found at depths of more than 100 m. (Table 31). During the spring (April-May), trawl catches indicated that the limits of crab concentrations were bounded on the north by the

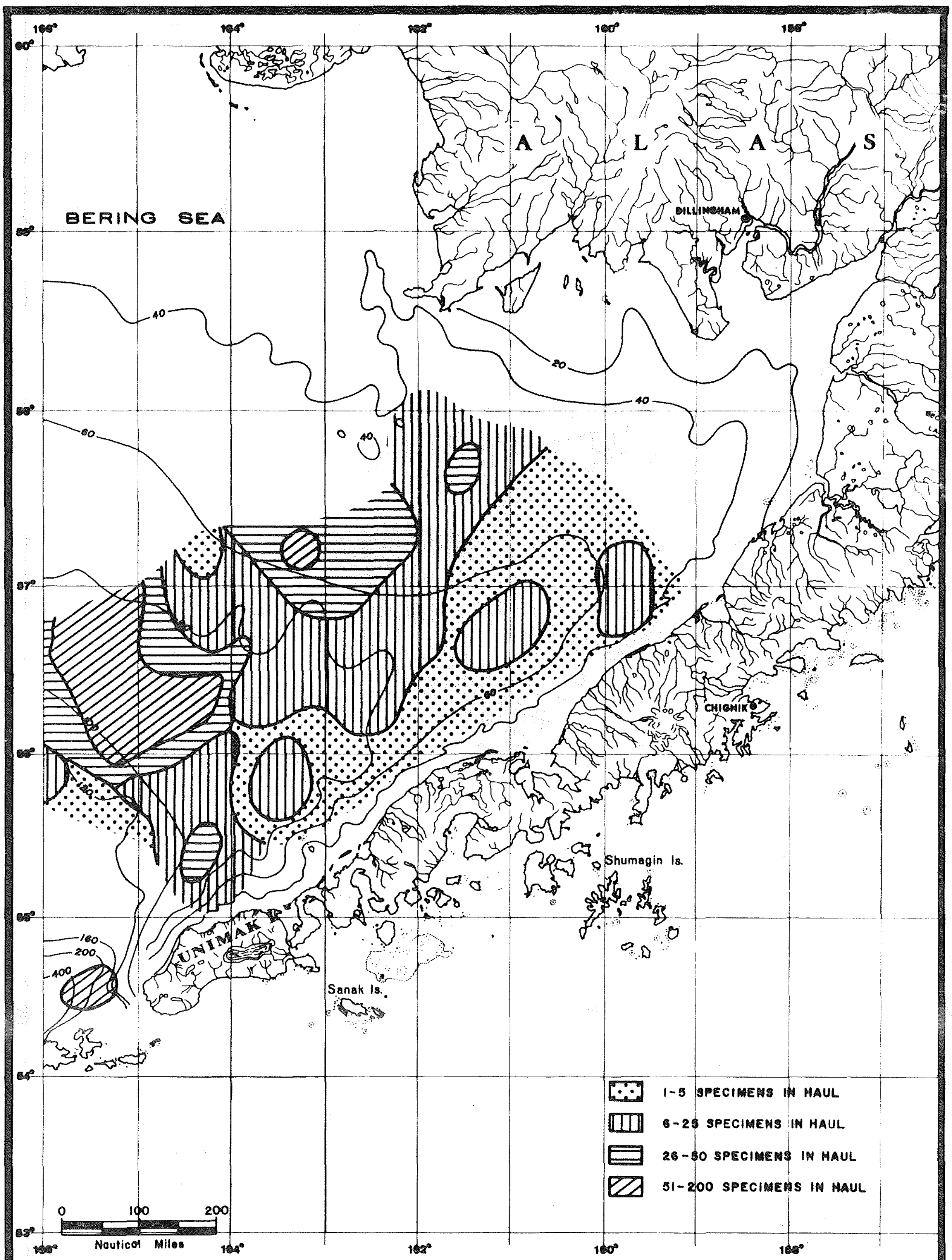

Figure 80a. Distribution of commercial size male king crab in summer (from Rodin 1970a).

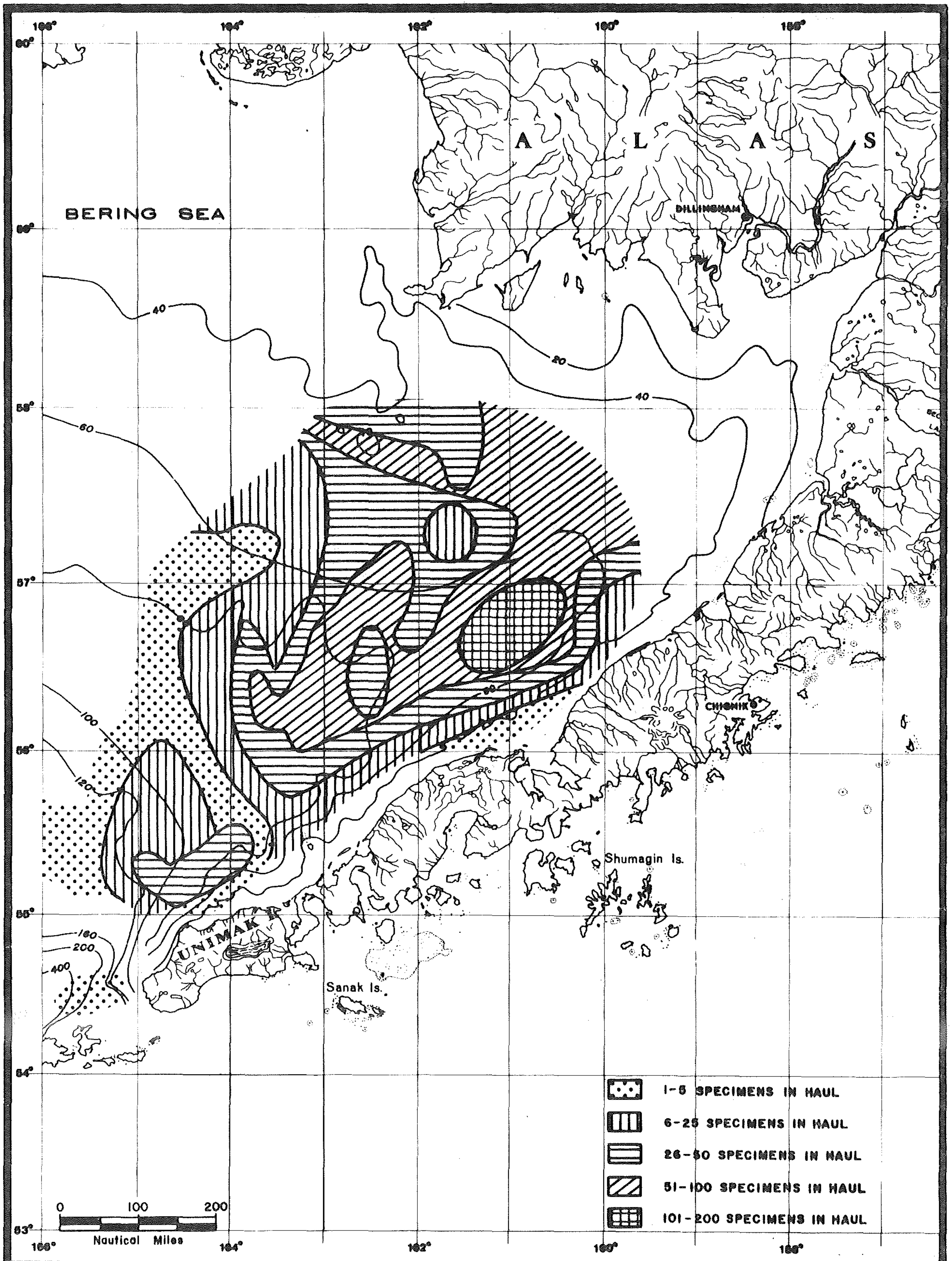

Figure 80b. Distribution of female king crab in summer (from Rodin 1970a).

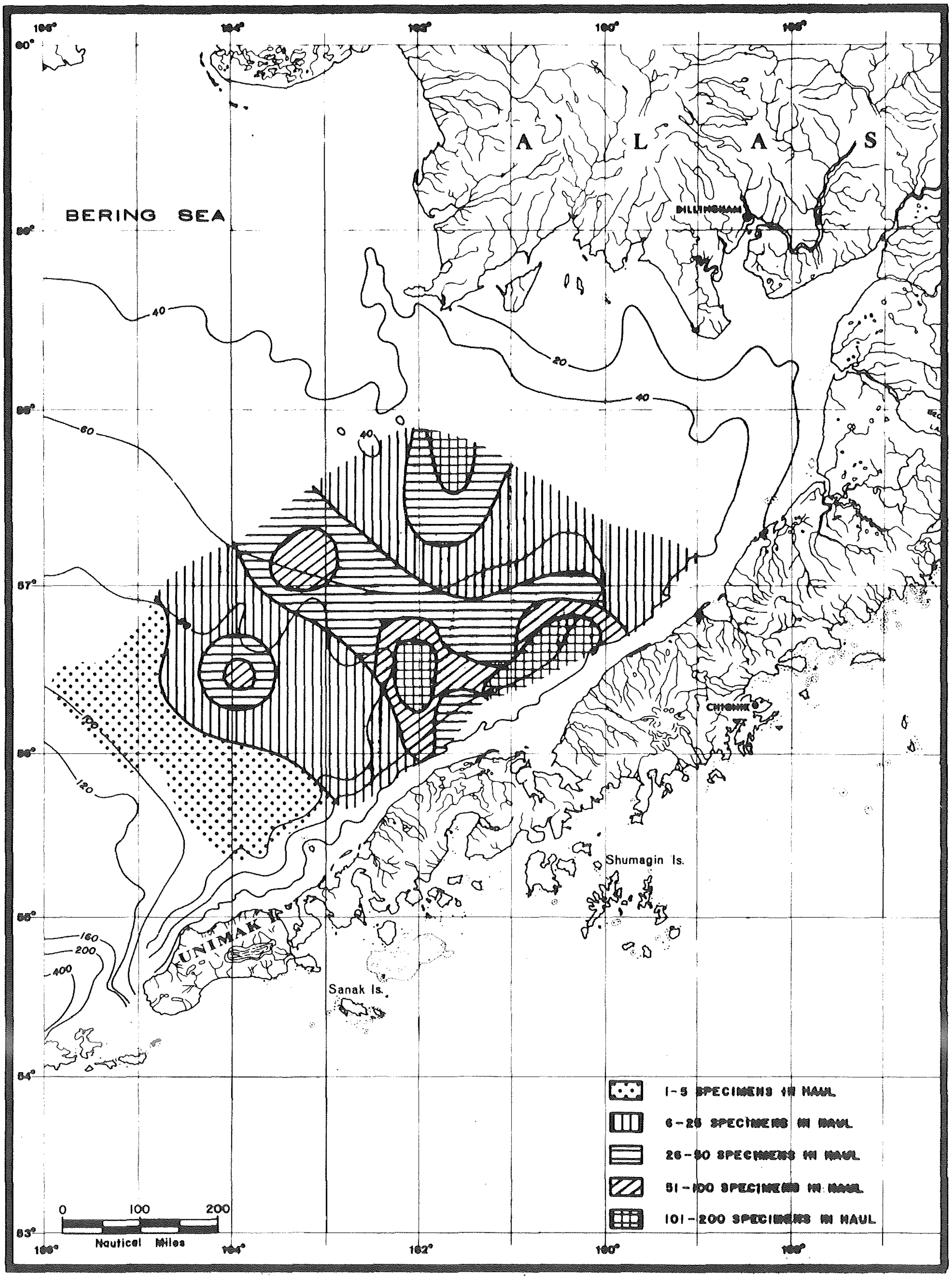

Figure 80c. Sublegal male king crab distribution in summer (from Rodin 1970a).

Table 31. King Crab Distribution on Two Bottom Types

Trawl number	Coordinates		Depth, m.	Catch (in specimens/hr.)
	N.	W.		
	Silty sand bottom			
1	56°04'	165°55'	106	285
2	55°51'	165°44'	113	104
3	55°03'	165°07'	108	53
4	56°01'	166°19'	118	42
	Silted bottom			
5	56°28'	166°55'	109	1
6	56°20'	166°55'	115	3
7	55°41'	166°19'	122	2
8	56°13'	166°55'	122	1

Source: Korolev 1964

0 degree C isotherm, which passes roughly along the 57 degree parallel, and on the west by the heavily silted bottoms (Figure 81). During these spring months, crabs were concentrated in a relatively small area. In summer (June to August), the bottom temperature was at least 4 degrees C throughout the study area. During this season crabs ranged over a much larger area, northward to 58 degrees N and westward onto the continental slope.

Chebanov (1965) stated that the winter distribution of crabs was bounded by the 4 degree C isotherm and that crabs did not extend into cooler waters (Figure 82).

Both sexes of king crab attain sexual maturity between 5 and 7 years of age (Powell and Gray 1964). Males molt once a year in their 6th, 7th, and 8th years, but in later years molt biennially or, rarely, triennially (Jackson and Manthey 1969). Powell in Haynes and Lehman (1969) believed males who skip molting for 2 consecutive years might die after their next mating. A male may add as much as 20 mm. to the length of his carapace with each molt.

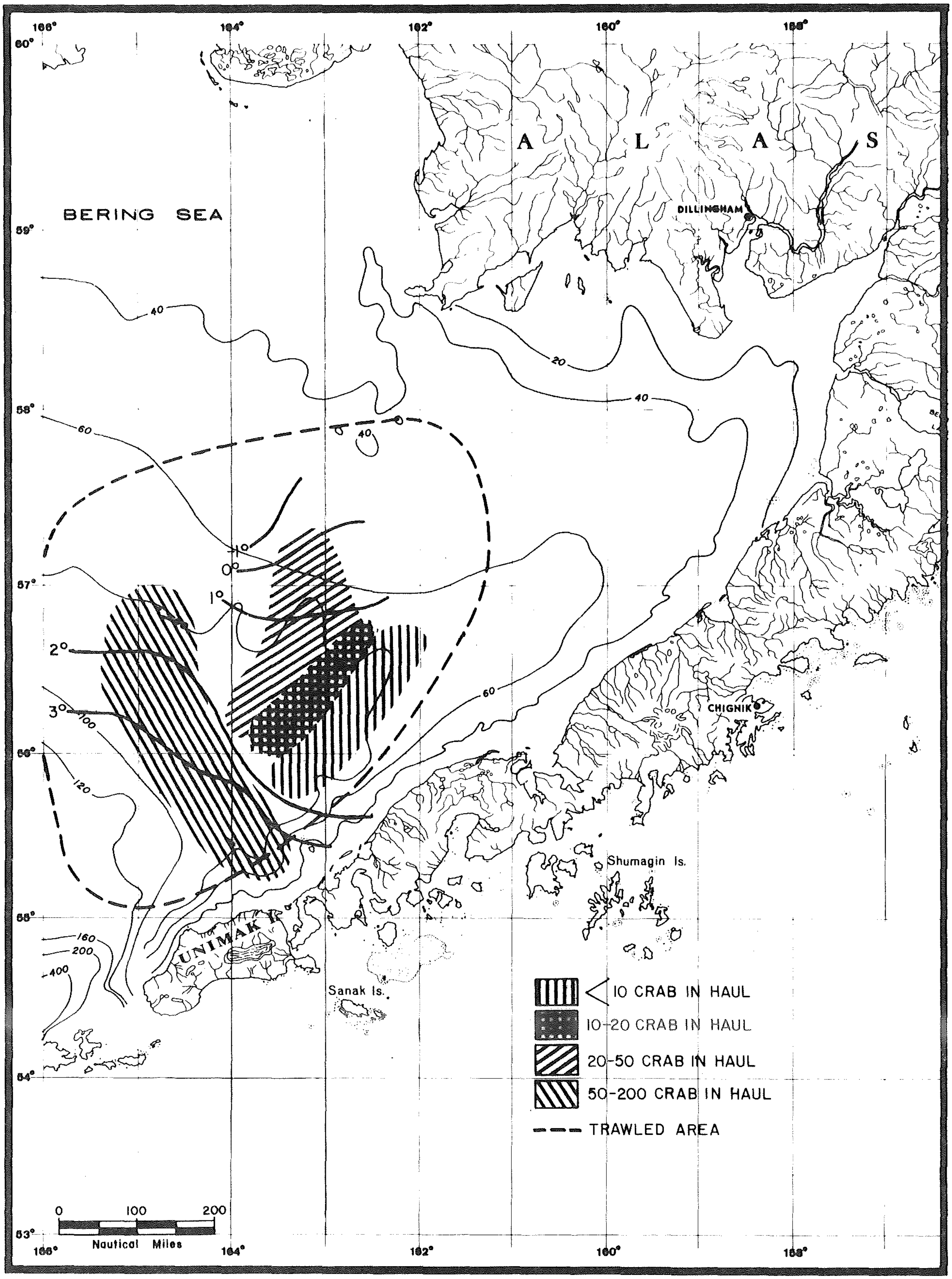

Figure 81. Winter distribution of king crabs in Bristol Bay (from Chebanov 1970).

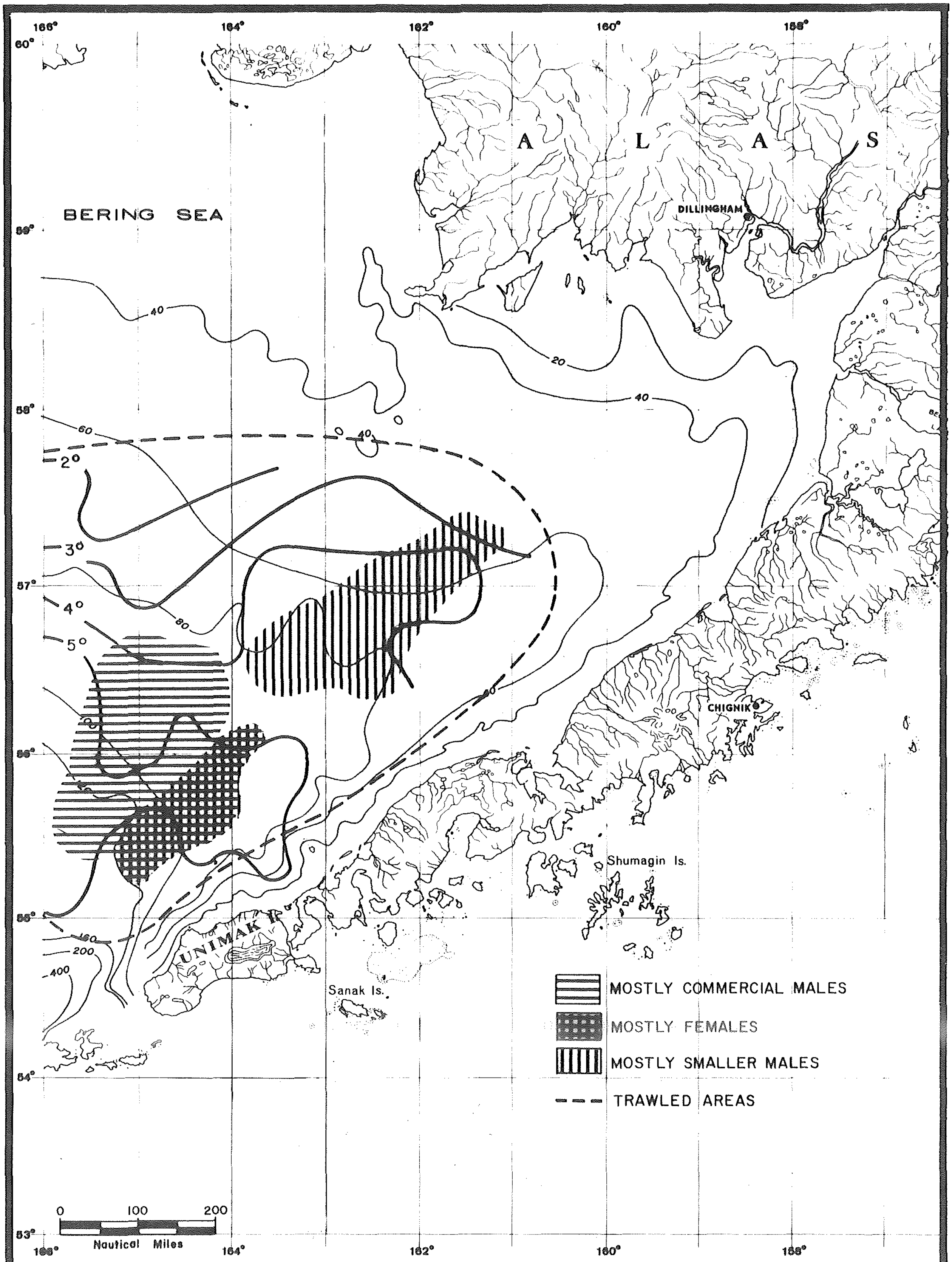

Figure 82. Winter distribution of king crab in Bristol Bay (from Chebanov 1965).

Chebanov (1965) stated that male crabs molt near feeding grounds north of Unimak Island. Brittle stars were found to be the best food for newly molted crabs since this diet promoted carapace growth and helped in the construction of a rigid exoskeleton.

Korolev (1964) reported males molting in the vicinity of the 100 m. isobath off Unimak Island during April through June. Crabs further east in Bristol Bay had evidently molted earlier as their carapaces were more encrusted with associated marine organisms.

Powell and Nickerson (1965) stated that females must molt before ovulation. Within two hours after the female molts, ovulation and fertilization are accomplished. Mated females leave the spawning area immediately, while males may remain for more than one month to continue breeding (Powell in Haynes and Lehman 1969). If females are not bred within nine days of molting, considerable reproductive failure occurs. Females carry out molting, mating and ovulation in a few hours time each year; the entire population accomplishes breeding within a few weeks (International North Pacific Fisheries Commission 1962).

Adult king crabs migrate to shallows of less than 100 m. to breed in the spring and return to deeper waters in the summer and early autumn (Figure 83). Immature crabs remain in inshore shallows separate from the adults. Young females and older males are the last to breed and may continue breeding into late May (Gray and Powell 1966). Spawning occurs from the subtidal zone to depths of 100 m. on both inshore shallows and offshore banks. Breeding crabs do not feed.

Males are polygamous and, even when newly matured, appear able to breed 5 to 7 females successfully. Rodin (1970a) observed few recently molted males on the breeding grounds in Bristol Bay. Males who had recently molted were found segregated from the females and in concentrations northwest of Unimak Island. Gray and Powell (1966) raise the question of whether older males who have not molted prior to the breeding season might be more virile than males who have more recently molted.

An adult female carries her eggs externally on her abdomen for 11 months before they hatch (Figure 84).

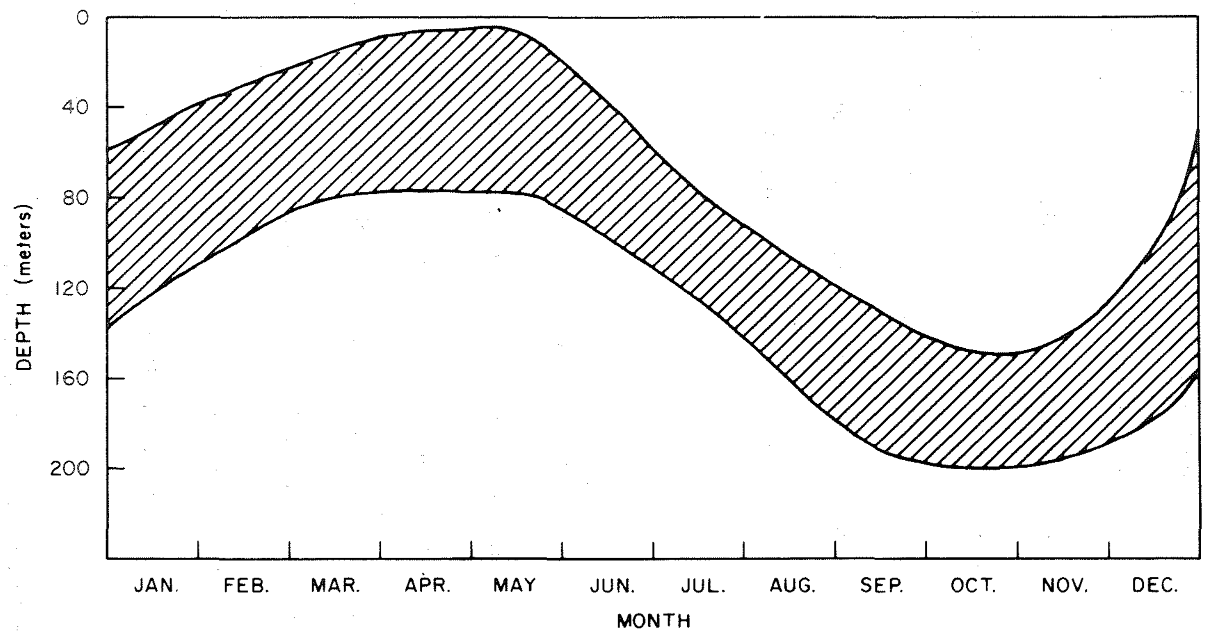

Figure 83. Seasonal vertical migration of adult king crabs. Patterned area indicates depth of major concentrations.

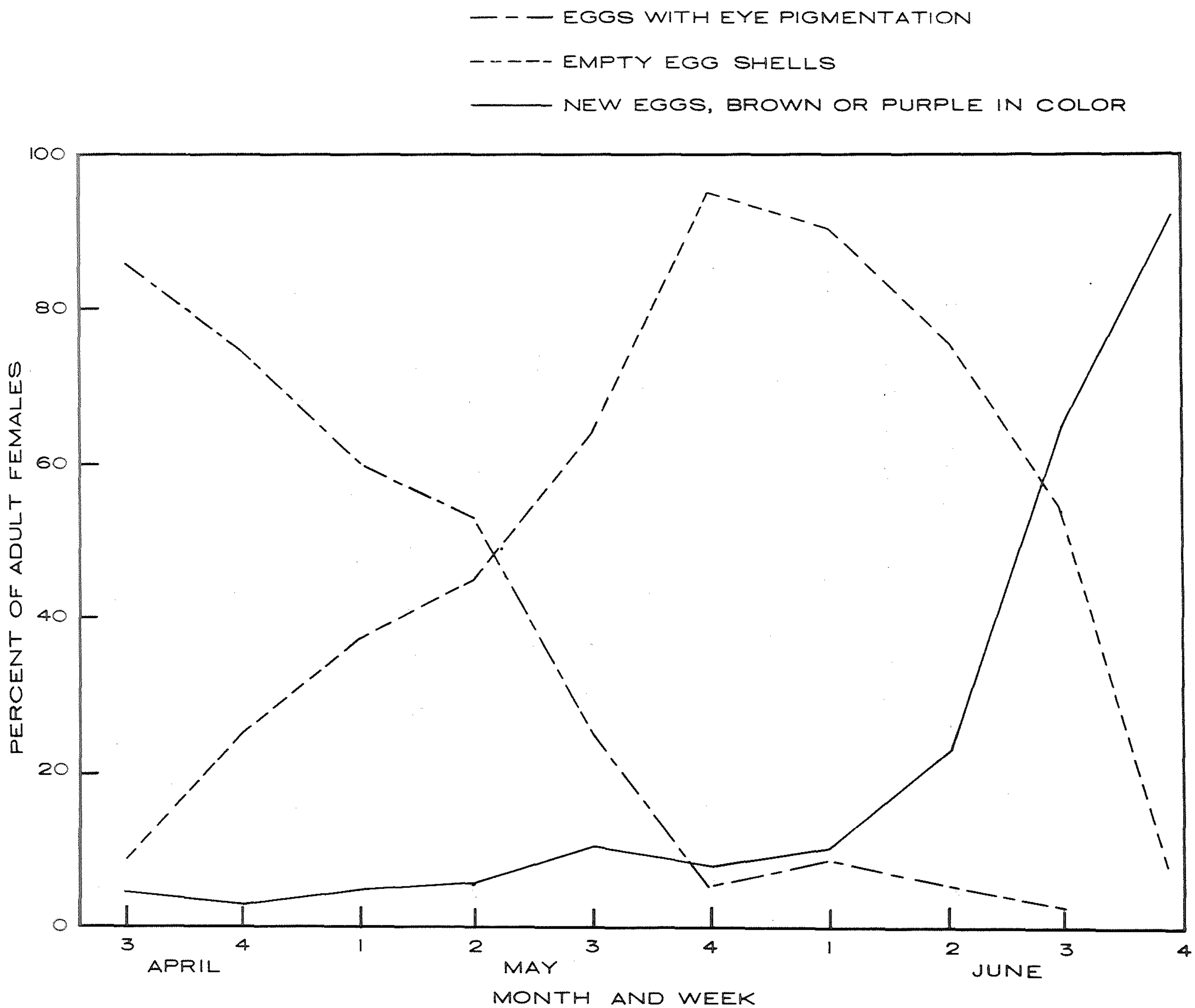

Figure 84. Phases in the reproductive condition of adult female king crabs (from International N. Pac. Fish. Comm. 1962).

Haynes, in Haynes and Lehman (1969), indicated increased fecundity with incrased size; the largest females produced as many as 40,000 eggs (Figure 85). After being carried externally 11 months by the female, eggs hatched into zoea larvae. The zoea larvae were planktonic and fed upon diatoms. Rodin (1970b) found concentrations of larvae northeast of Port Moller (Figure 86). After approximately 60 days these larvae molted and became benthic in habit for the remainder of their life cycle. Crab larvae spent the transition period, while they changed from planktonic to demersal life form, on sponges, hydroids, and algae (Korolev 1964). The annual and life cycles of the king crab are illustrated in Figure 87.

Eldridge (1972a) reported benthic king crabs to be omnivorous. Crab concentrations generally coincided with recognized areas of high benthic biomass in Bristol Bay.

Tanner Crab

There is predominantly only one species of tanner crab, Chionoecetes opilio, found in Bristol Bay. A

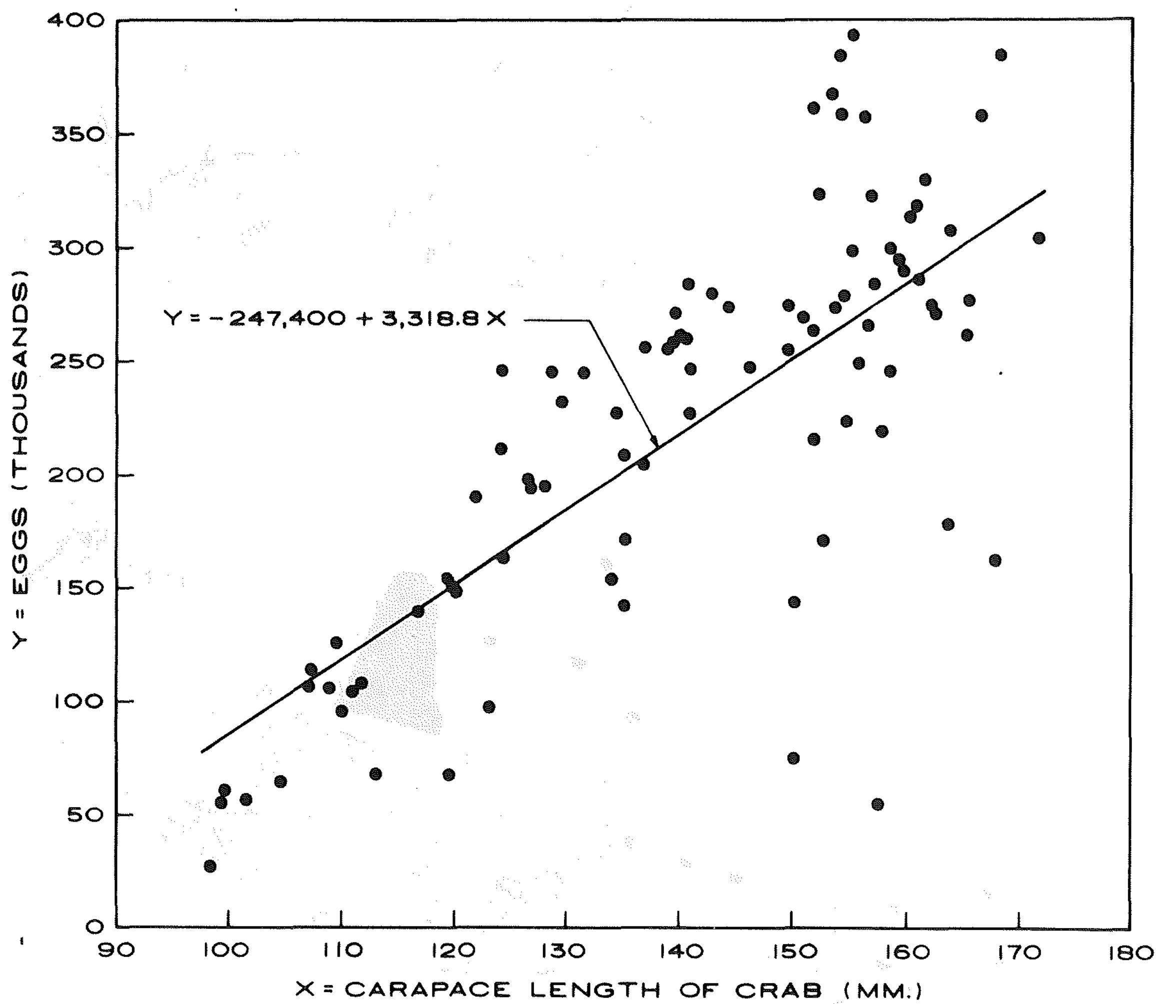

Figure 85. Relation of number of eggs to carapace length in king crab (from Haynes and Lehman 1969).

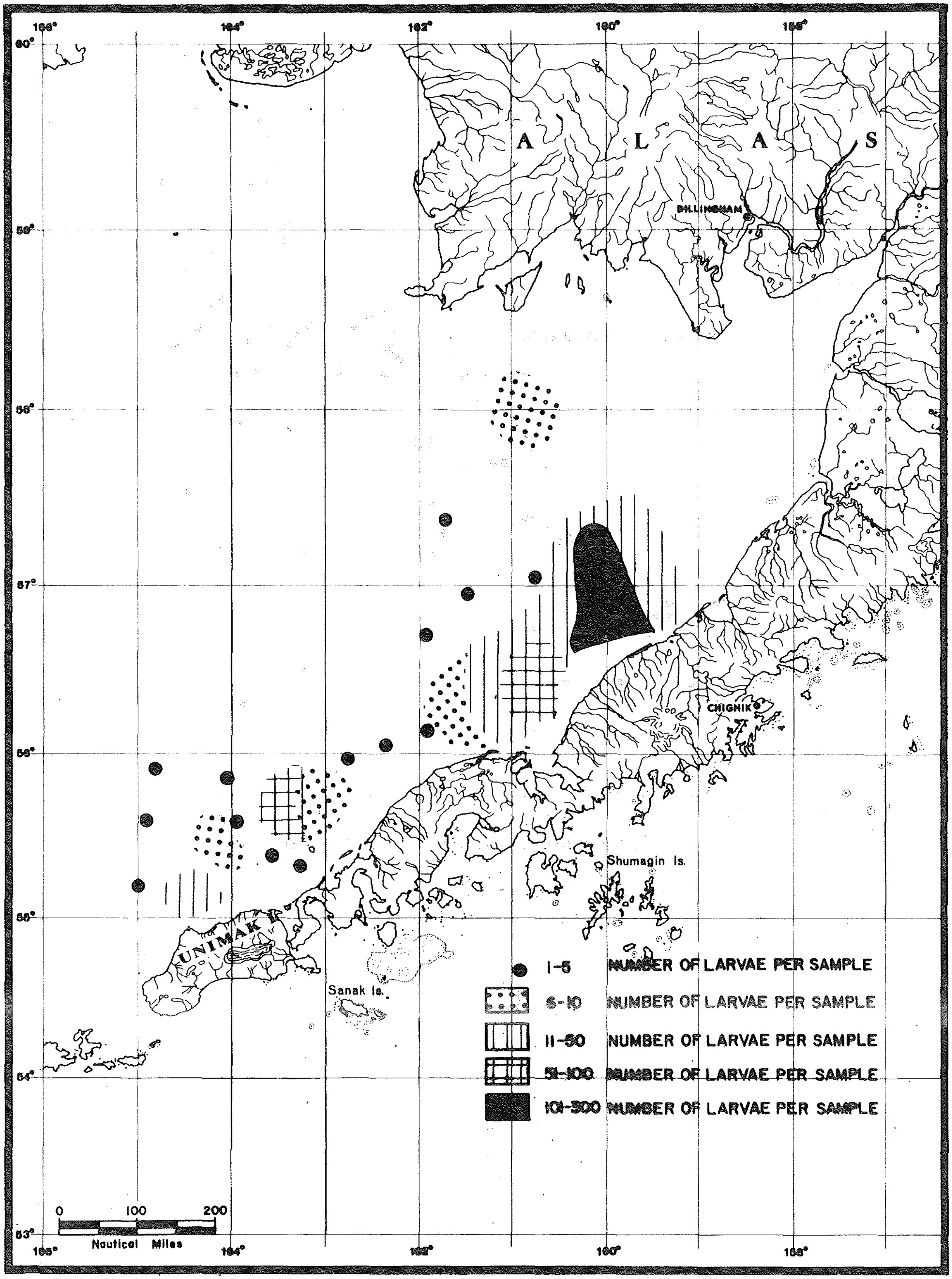

Figure 86. Distribution of king crab larvae in the summer of 1965 (from Rodin 1970b).

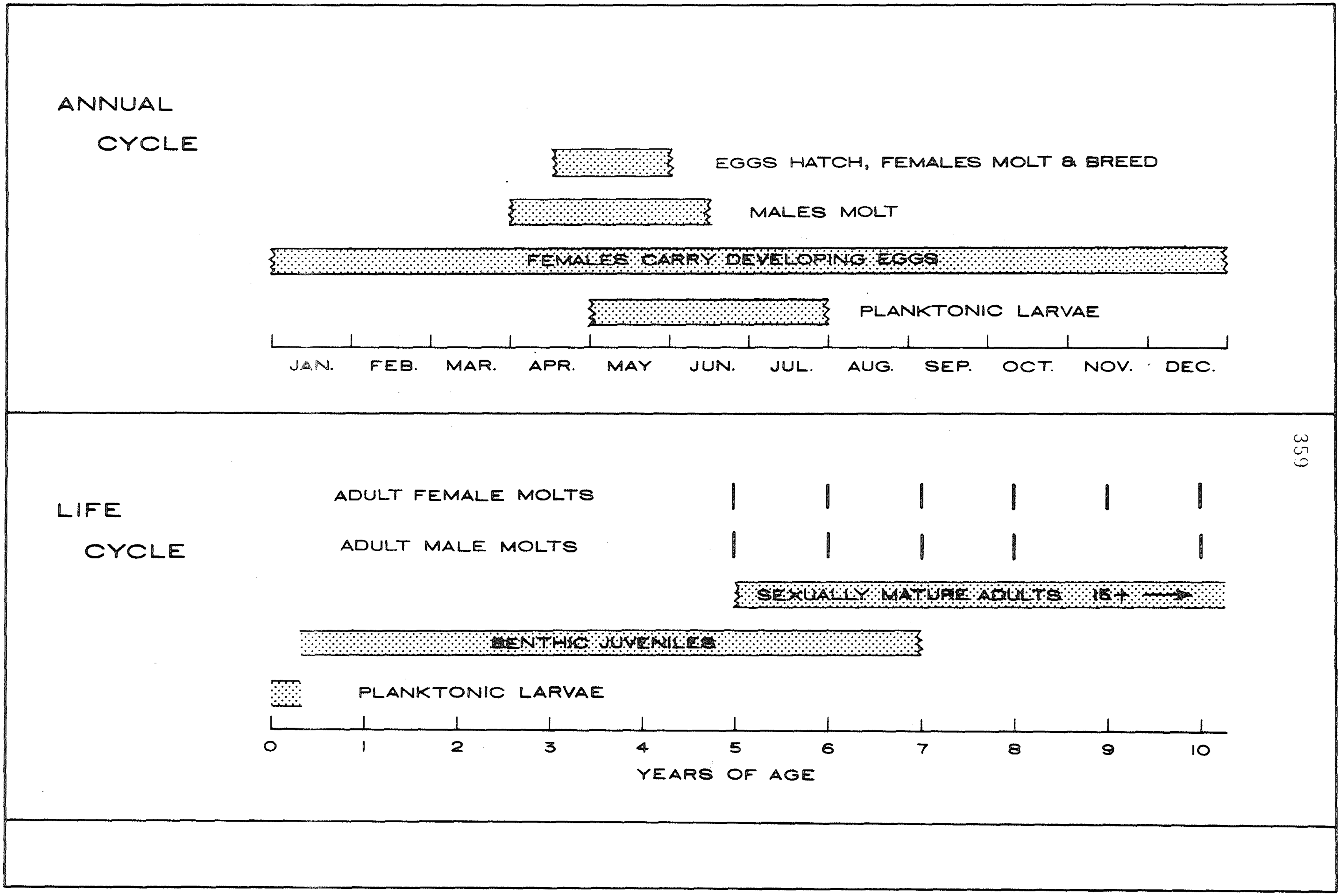

Figure 87. Annual and life cycles of the king crab in Bristol Bay (AEIDC, Anchorage).

fishery for this species has developed in recent years to compete with the king crab fishery (Brown 1971, Eldridge 1972b).

Zahn (1970) has summarized tanner crab resources in the eastern Bering Sea and describes their distribution as very similar to that of the king crab (Figure 88).

Haynes and Lehman (1969) report the distribution and abundance of *Chionoecetes opilio* in the study area. Crab catch data indicate that both male and female tanner crabs of all sizes were most abundant at depths where male and female king crabs were infrequently encountered. His observations also indicate that male and female tanner crabs were generally concentrated between depths of 55 and 90 m. (Figure 89). Female tanner crabs were concentrated in areas where bottom temperatures ranged from 1 to 5 degrees C. Male tanner crabs were present in noticeable concentrations over the entire temperature range from 1 to 7 degrees C.

Relative abundance of male and female tanner crabs is shown in Figures 90 and 91. Male tanners were observed throughout the sampling area, forming their largest

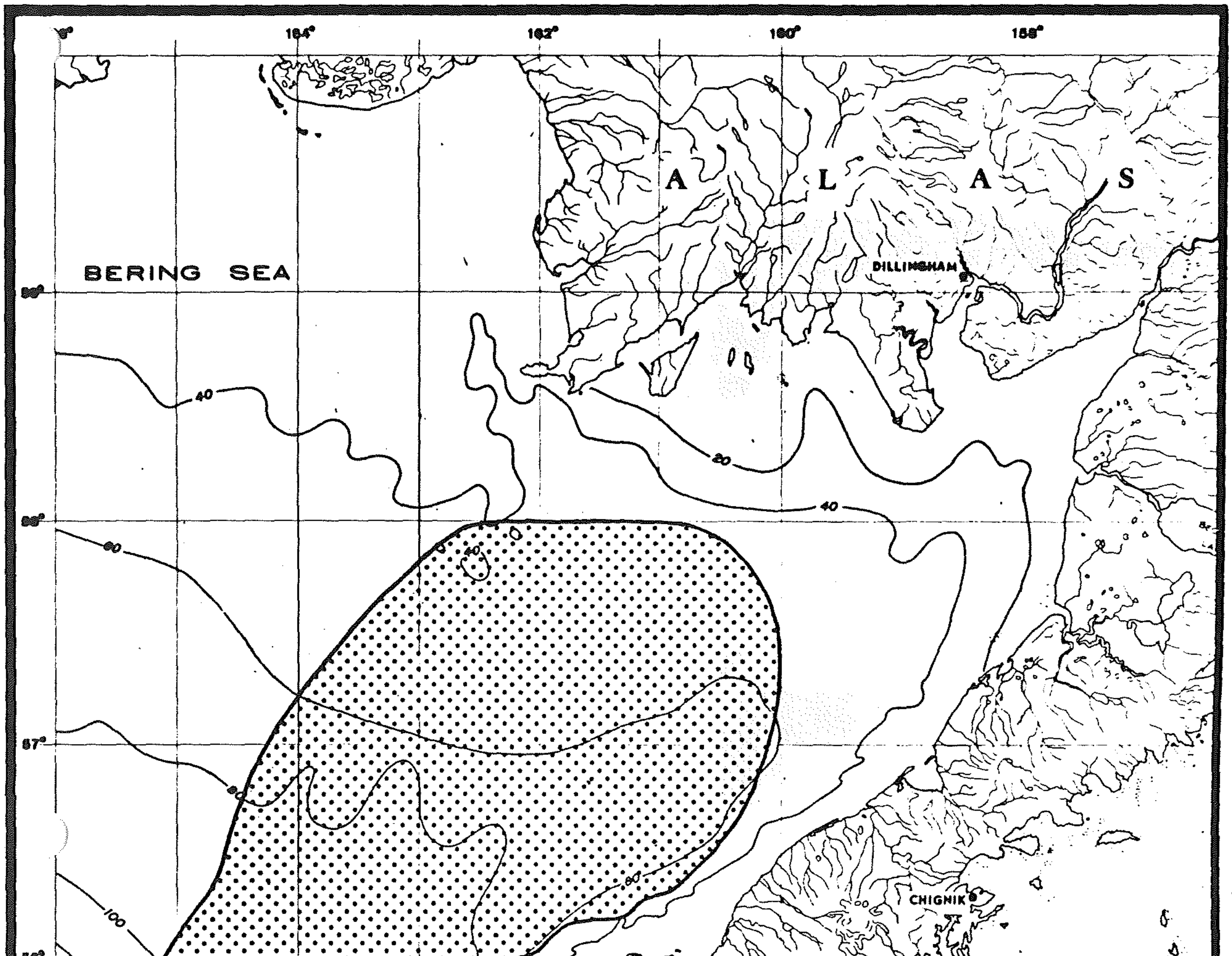

Figure 88. Japanese tanner crab fishing areas in Bristol Bay (from Zahn 1970).

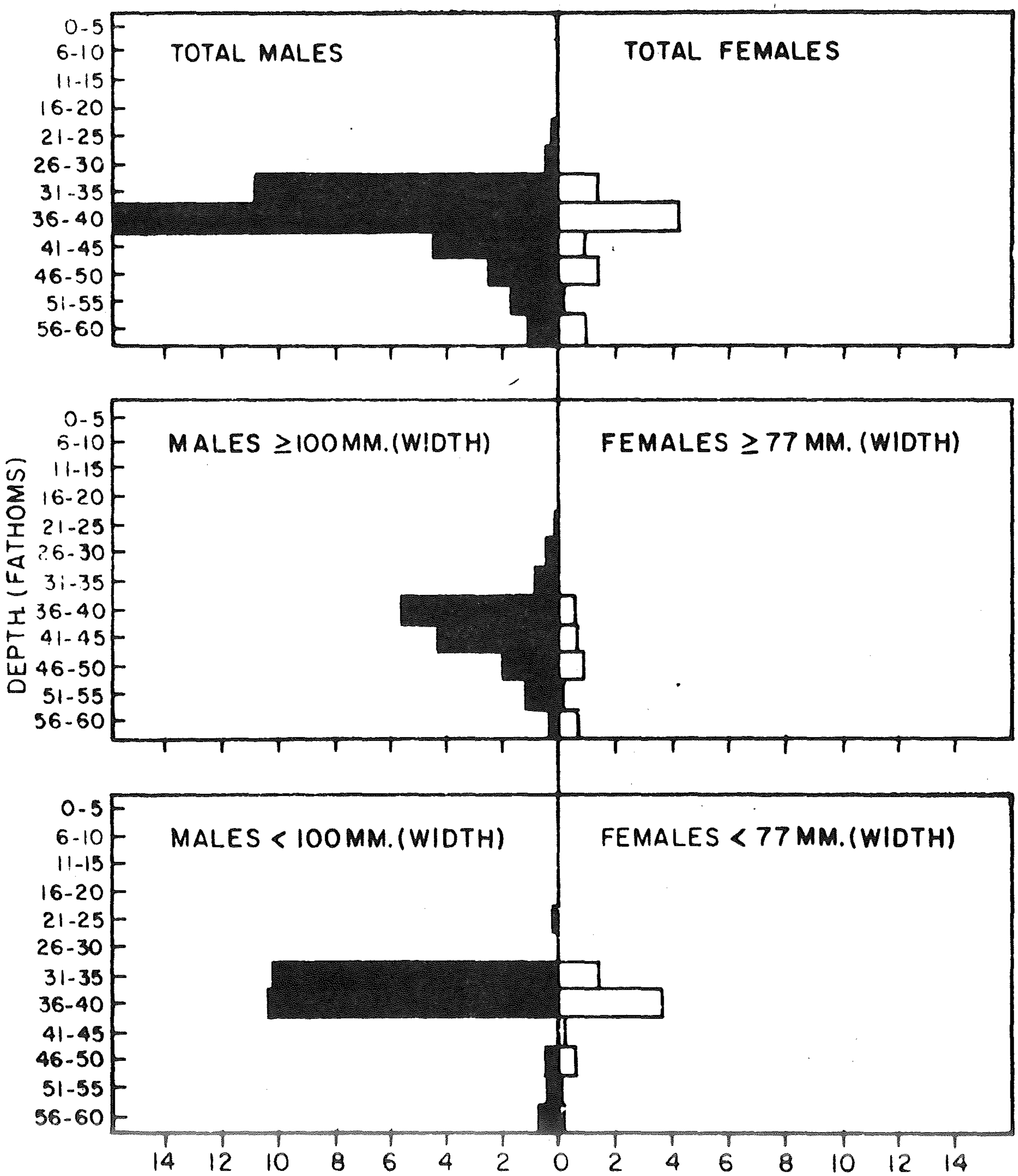

Figure 89. The distribution of tanner crabs by depth in the southeastern Bering Sea during September 1968 (from Haynes and Lehman 1969).

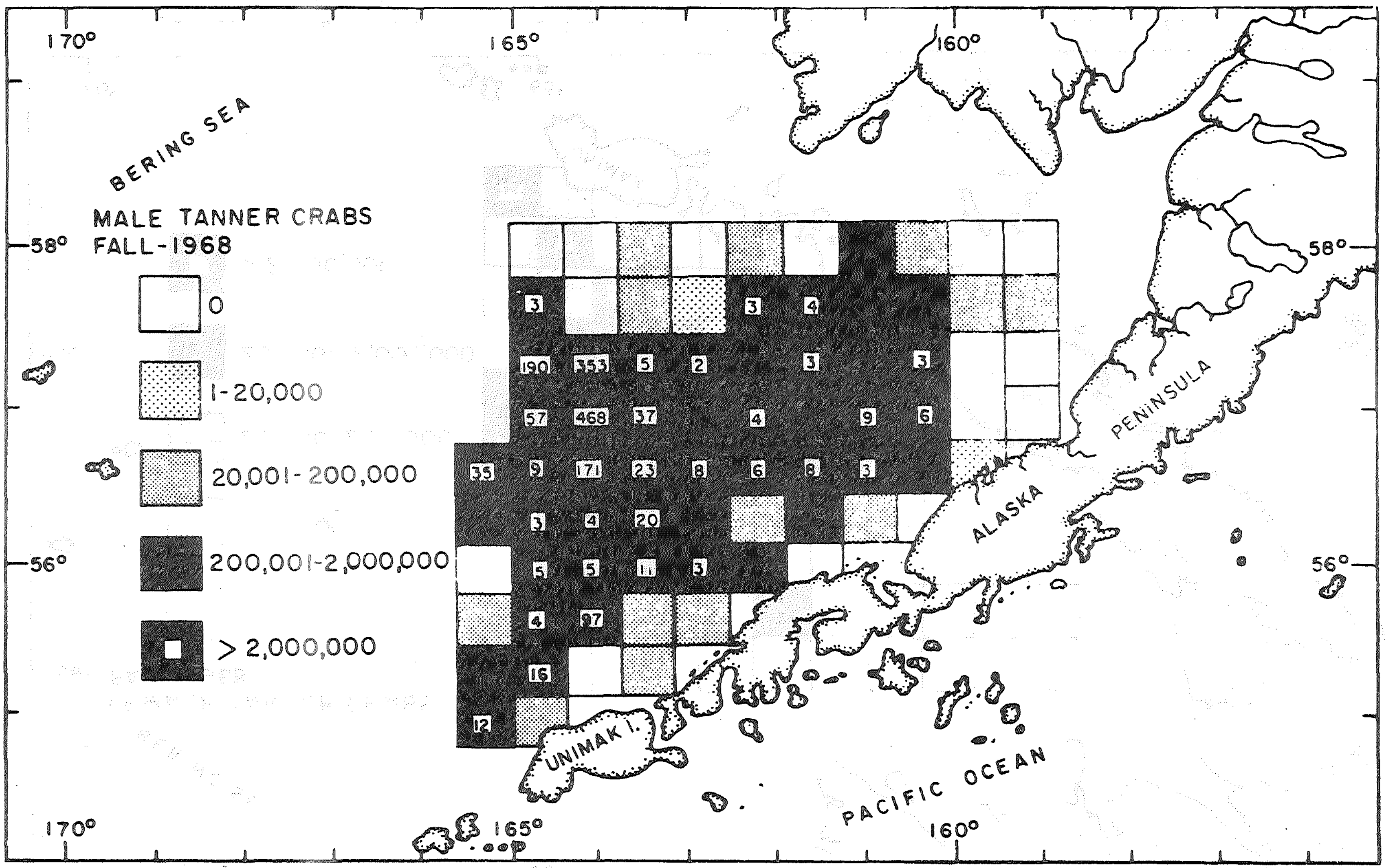

Figure 90. Relative distribution and abundance of male tanner crabs in the southeastern Bering Sea during September 1969 (from Haynes and Lehman 1969).

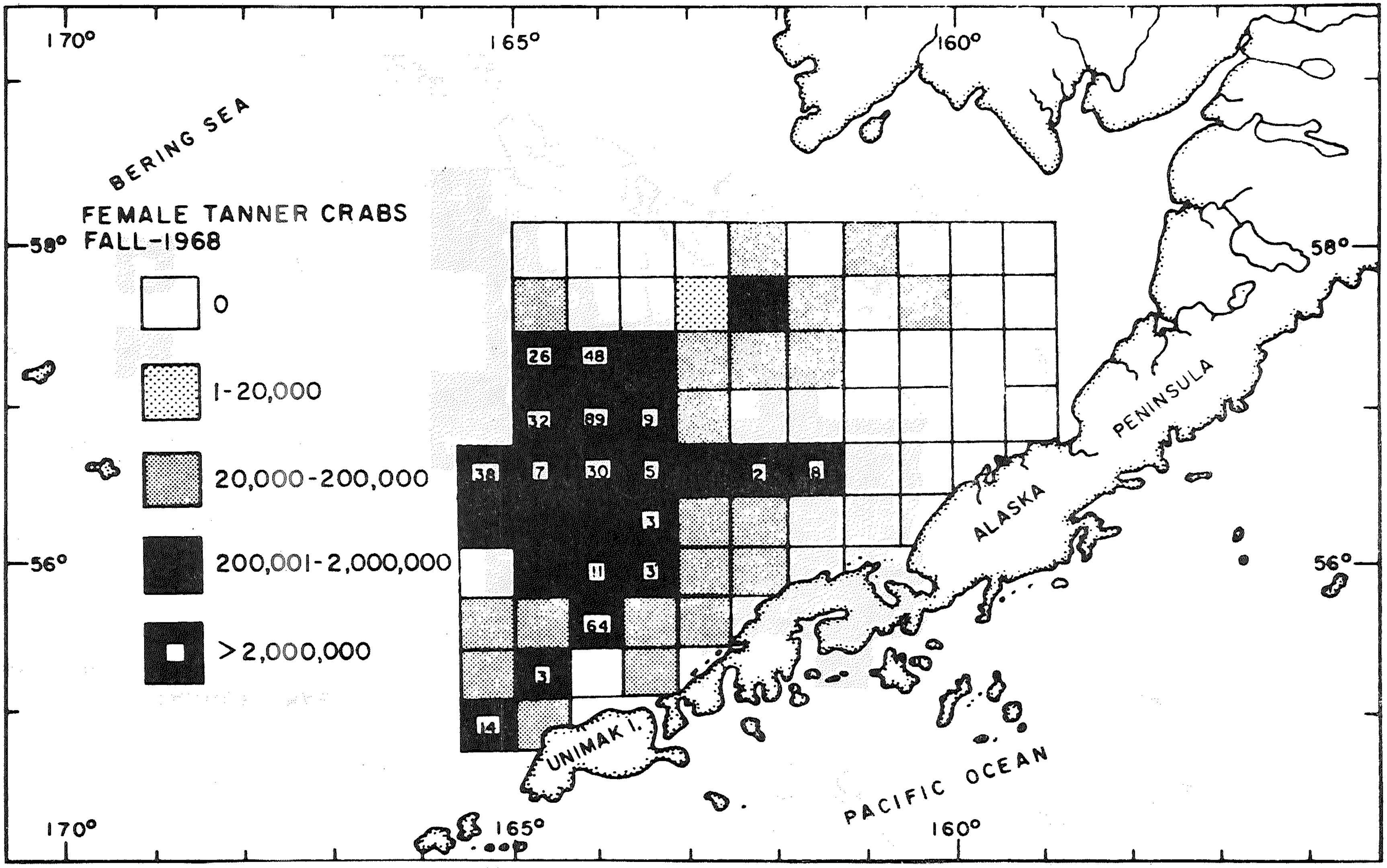

Figure 91. Relative distribution and abundance of female tanner crabs in the southeastern Bering Sea during September 1968 (from Haynes and Lehman 1969).

concentrations west of 163 degrees W longitude. Females were less abundant and most were captured in the same area as the males.

Exploratory fishing drags of the National Marine Fisheries Service (undated) found tanners to be most abundant in the center of Bristol Bay and, to a lesser extent, northwest of Unimak Island (Figure 92).

The International North Pacific Fisheries Commission (1962) has compared the relative abundance of king crabs with tanner crabs in five fishing areas in Bristol Bay (Table 32). The occurrence of male tanner crabs overlaps that of king crabs closely; tanner crabs appear to occur in inverse proportion to female king crabs. Eldridge (1972b) suggests that tanner crabs and king crabs may compete for either food or space, and that king crabs may prey on soft-shelled tanners.

Brown (1971) reports that male tanner crabs landed by the fishery rarely exceed 190 mm. in carapace width. Females rarely exceed 120 mm. in carapace width, and because of regulatory prohibitions, are not retained by the commercial fishery when caught. Brown and Powell (1972) have summarized their research on the size and reproductive characteristics

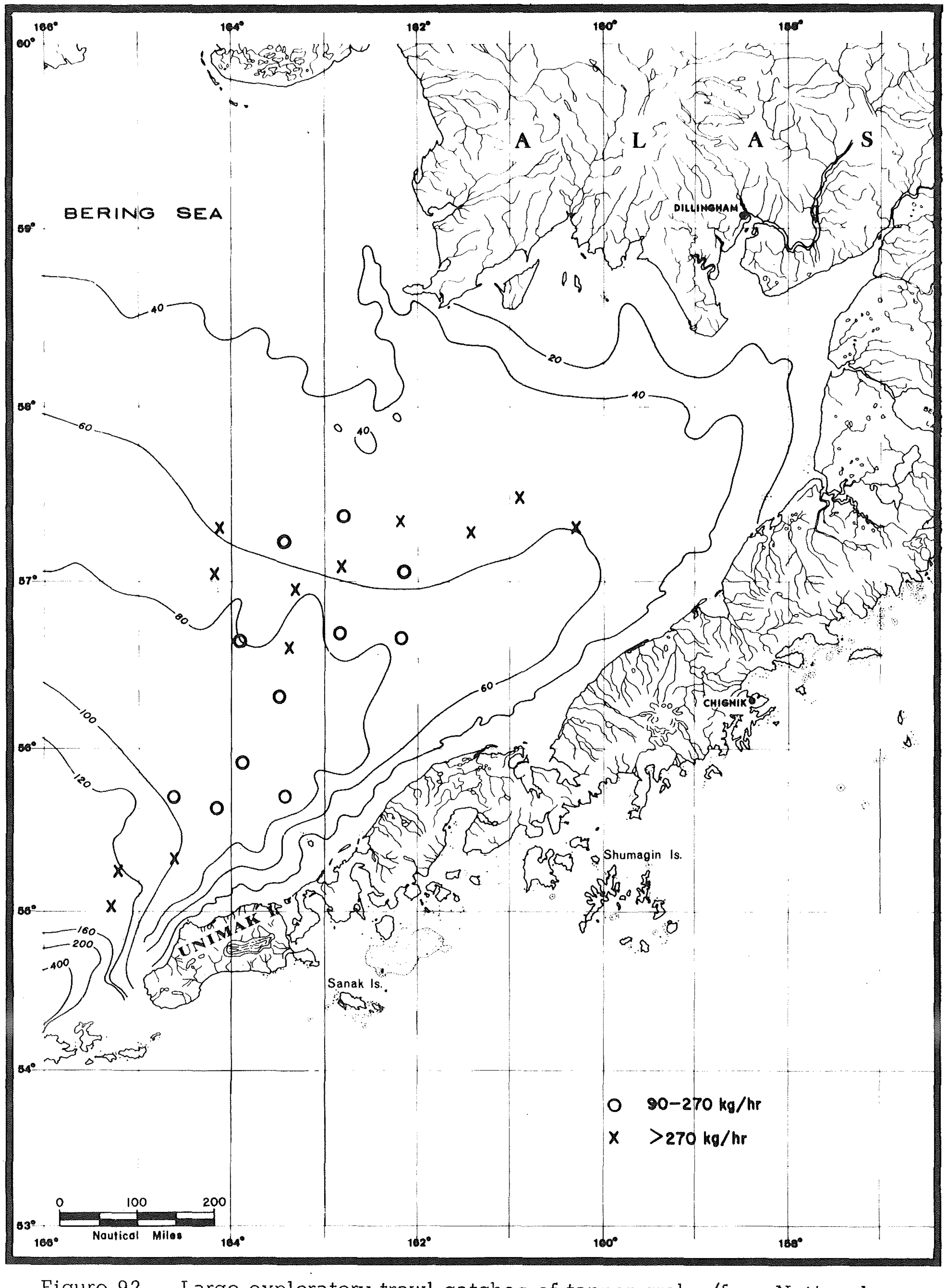

Figure 92. Large exploratory trawl catches of tanner crabs (from National Marine Fisheries Service, undated).

Table 32. Records of exploratory fishing for king crabs, 1961 spring season.

Fishing areas	Periods of operation	No. of crabs caught	Total catch composition (percent)				
			Males	New-shelled males	Under-sized males	Females	Tanner crabs
Amak							
Inshore	Apr. 19-May 3	4,656	31.1	1.5	1.1	12.0	54.3
Offshore	Apr. 11-25	10,628	37.6	0.8	1.3	7.3	53.0
Black Hills	Apr. 25-26	631	36.8	2.9	0.8	7.0	52.5
Port Moller							
Inshore	May 7-June 5	10,857	45.5	0.9	6.5	18.9	28.2
Onshore	May 17-June 2	11,738	46.2	1.0	6.9	36.5	9.4
Total		38,510	41.6	1.1	4.4	20.0	32.9

Source: International North Pacific Fisheries Commission 1962.

of the tanner crab. An average carapace width of 110 mm. was indicative of maturation in males. Male crabs attain maturity when they reach a carapace width of between 90 and 140 mm. Females attained maturity at an average carapace width of 90 mm. Eldridge (1972b) states that it is difficult to determine the age of crustaceans, and that the age of maturity of the tanner crab is not known.

Brown and Powell (1972) consider the mating season of tanner crabs to be from early January to mid-May. Mating activities take place at depths of less than 25 m. (Watson 1970). Watson reports that females can produce more than one mass of fertile eggs from each mating. Females may carry between 5,000 and 150,000 eggs, although the majority carry between 30,000 and 80,000. After mating, the crabs carry the fertilized eggs for almost twelve months.

After hatching the larvae are planktonic and may drift for 63 to 66 days. These megalopic larvae then settle to the bottom and begin to feed on debris. The habits of juvenile crabs are not well known and need research. Annual and life cycles are presented in Figure 93.

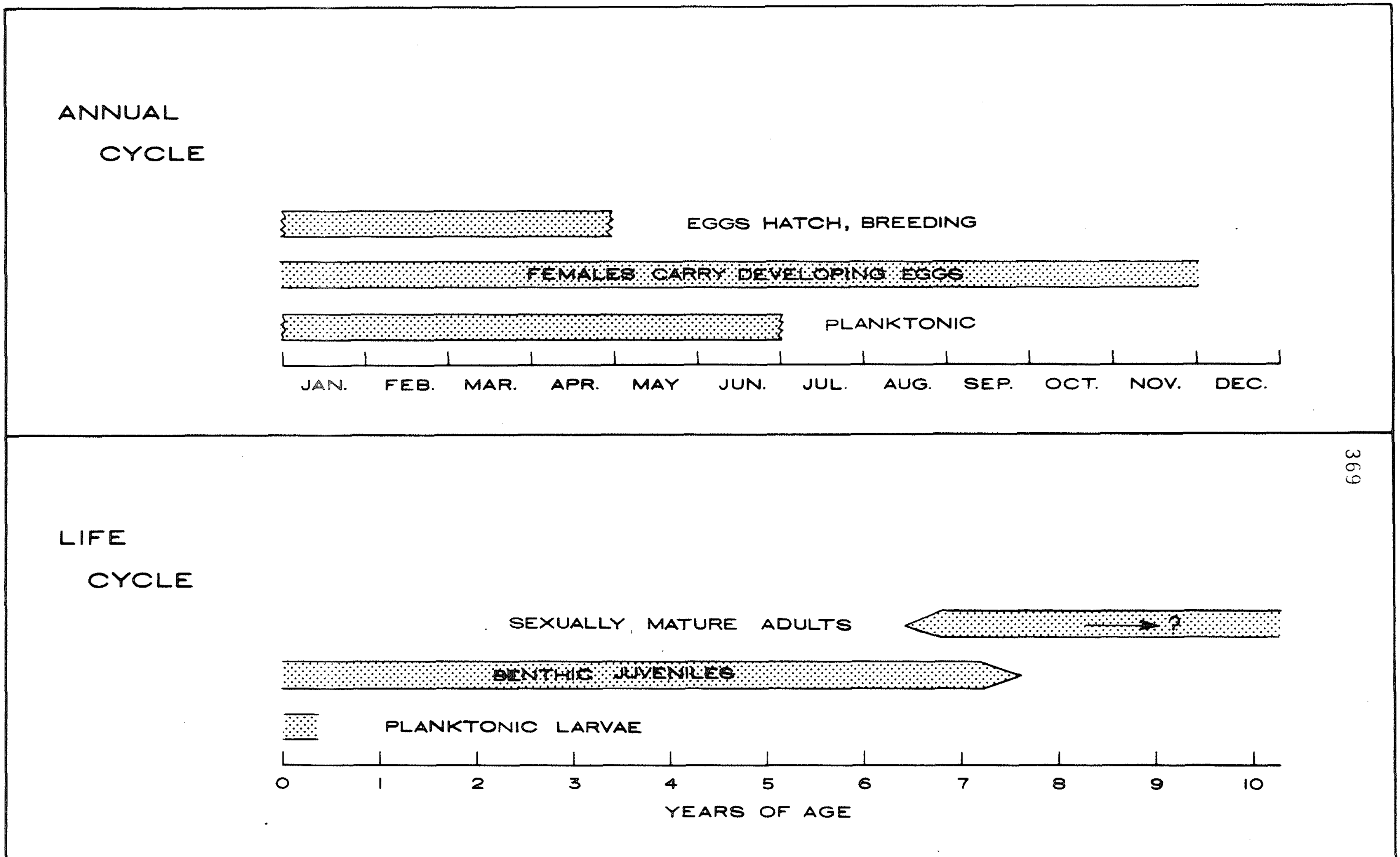

Figure 93. Annual and life cycles of the tanner crab in Bristol Bay (AEIDC, Anchorage).

Dungeness Crab

The Dungeness crab, *Cancer magister*, resource in Bristol Bay is reported to be minimal with no commercial fishery on the existing stock.[1,2]

Phinney reports a small population of Dungeness off the extreme northwestern corner of Unimak Island. Trawls by the National Marine Fisheries Service (undated) recorded a small catch of Dungeness crabs in the Unimak Pass area. Davenport believes that the occurrence of crabs in the Unimak Pass area and on the north side of the Alaska Peninsula is an extension of existing crab stocks south of the Alaska Peninsula.

Crabs begin migrating from deeper to shallower water in December or January. The males molt during the migration period. Adult males and females enter the shallows and begin mating in April and May.[3]

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1. Glenn Davenport, Area Management Biologist, Alaska Dept. of Fish and Game, Cold Bay. Personal communication.

2. Dwayne Phinney, Shellfish Project Leader, Westward Region, Alaska Dept. of Fish and Game, Kodiak. Personal communication.

3. Ibid.

Copulation occurs approximately 1.5 hrs after the female molts. Eggs are extruded in fall and fertilization occurs.[1] A single egg mass may contain up to 1,500,000 eggs; a female may spawn 3 to 5 million eggs during a lifetime.

Upon the hatching of the eggs, the larvae pass through a prezoeal stage, five zoeal stages, and one megalopic stage (Poole 1966). These larvae are planktonic for 111 days. Thereafter, the young crabs settle to the bottom and pass the remainder of their lives in a benthic form. Annual and life cycles are presented in Figure 94.

Shrimp

Five species of Pandalid shrimp exist within the study area.[2] None of these species occurs in commercial quantities and therefore does not support a shrimp fishery.

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1. Ibid.

2. Jerry McCrary, Regional Research Supervisor, Westward Region, Alaska Dept. of Fish and Game, Kodiak. Personal communication.

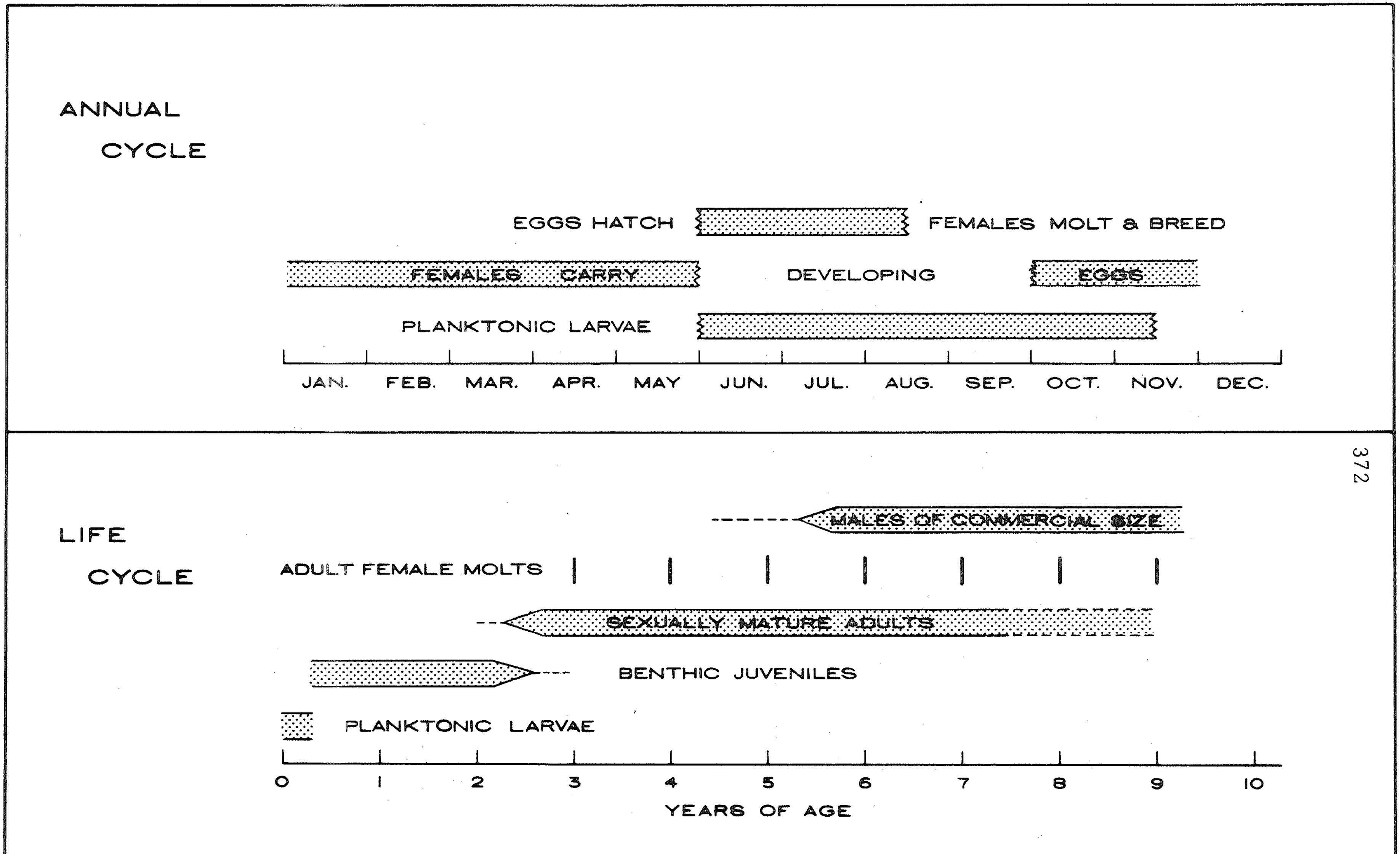

Figure 94. Annual and life cycles of the Dungeness crab in Bristol Bay (AEIDC, Anchorage).

The five species reported are Pandalus borealis, pink; P. goniurus, humpy; P. hypsinotus, coonstripe; P. platyceros, spotted; and Pandalopsis dispar, side-stripe. All species may be found in small numbers off the extreme northwest corner of Unimak Island. Neiman (1963) recorded P. goniurus in trawls south of Cape Newenham. The U.S. Bureau of Sport Fisheries and Wildlife (1970) has reported the presence P. borealis in Bristol Bay.

Ivanov (1963, 1969) comprehensively studied the distribution and biology of P. borealis in the Pribilof Islands area. This concentration of shrimp appears to be of the stock nearest to the study area with commercial potential. Shrimp are confined to this area by late winter water temperatures. Near the Pribilof Islands, water temperatures remain higher than in Bristol Bay because of the introduction of warmer waters from the Pacific.

P. borealis and Pandalopsis dispar generally inhabit waters of 90 m. or more above soft green mud bottoms. P. goniurus and P. hypsinotus, tend to inhabit 20 to 30 m. shallows during their first 2 years of life, and then move to deeper waters, usually over rough bottoms, for the remainder of their lives. P. platyceros inhabit 30 to 55 m. and prefer rough bottoms. All species begin to migrate in autumn to waters about 20 m. deep to breed. In winter, the shrimp migrate to deeper waters.[1] Barr and McBride (1967) report a large daily vertical movement by P. borealis (Figure 95).

The generalized life histories of the five shrimp species are nearly the same. Growth patterns, age at sexual maturity, and transition to functional females may vary with the species and by geographical location within the species. All species of Pandalid shrimp are bisexual (Fox 1973). Ivanov (1969) observed P. borealis to sexually mature as males at ages of 2.5 years, when they participate for the first time in autumn breeding. At ages of 3.5 years nearly all shrimp observed were males; a small number had changed into females. Most individuals at 4.5 years were still observed to function as males, but in the fifth year most were breeding females. Individuals called "primary females" are believed to exist in every shrimp population. These individuals never function as

1. Ibid.

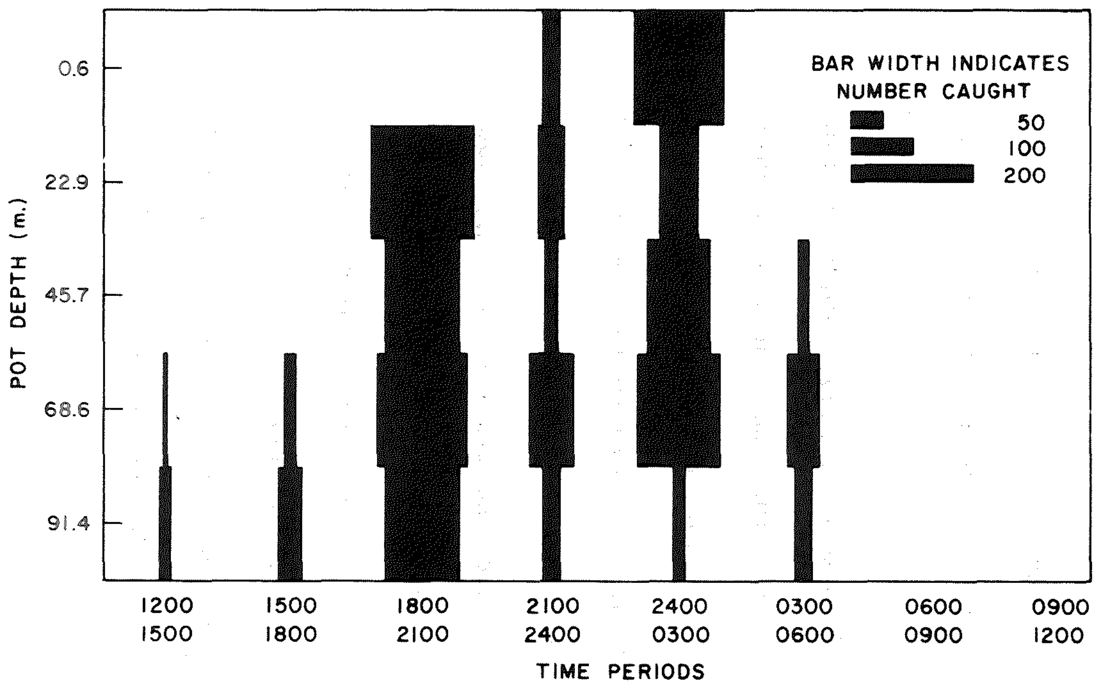

Figure 95. Vertical daily movements of pink shrimp, Pandalus borealis (from Barr and McBride 1967).

males, and their early maturation as females serves as a survival mechanism beneficial to the population (Butler 1964). Most shrimp live 6.5 years; the few observed to have lived longer are usually sterile females (Ivanov 1969).

In August and September, eggs begin to ripen in the ovaries of the female. The female then molts into a breeding carapace, and within 36 hours copulation occurs (Needler 1931). The eggs are extruded and attach to the pleopods and abdominal segments where they are carried from 5 to 7 months. After completion of spawning, adult shrimp migrate to deeper waters. The number of eggs extruded increases with the size of the shrimp.[1] Most Pandalid shrimp carry eggs in masses of 500 to 4,000 (Hynes 1929). Hatching usually occurs from February to May. Figure 96 presents the annual and life cycles of P. borealis.

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1. Ibid.

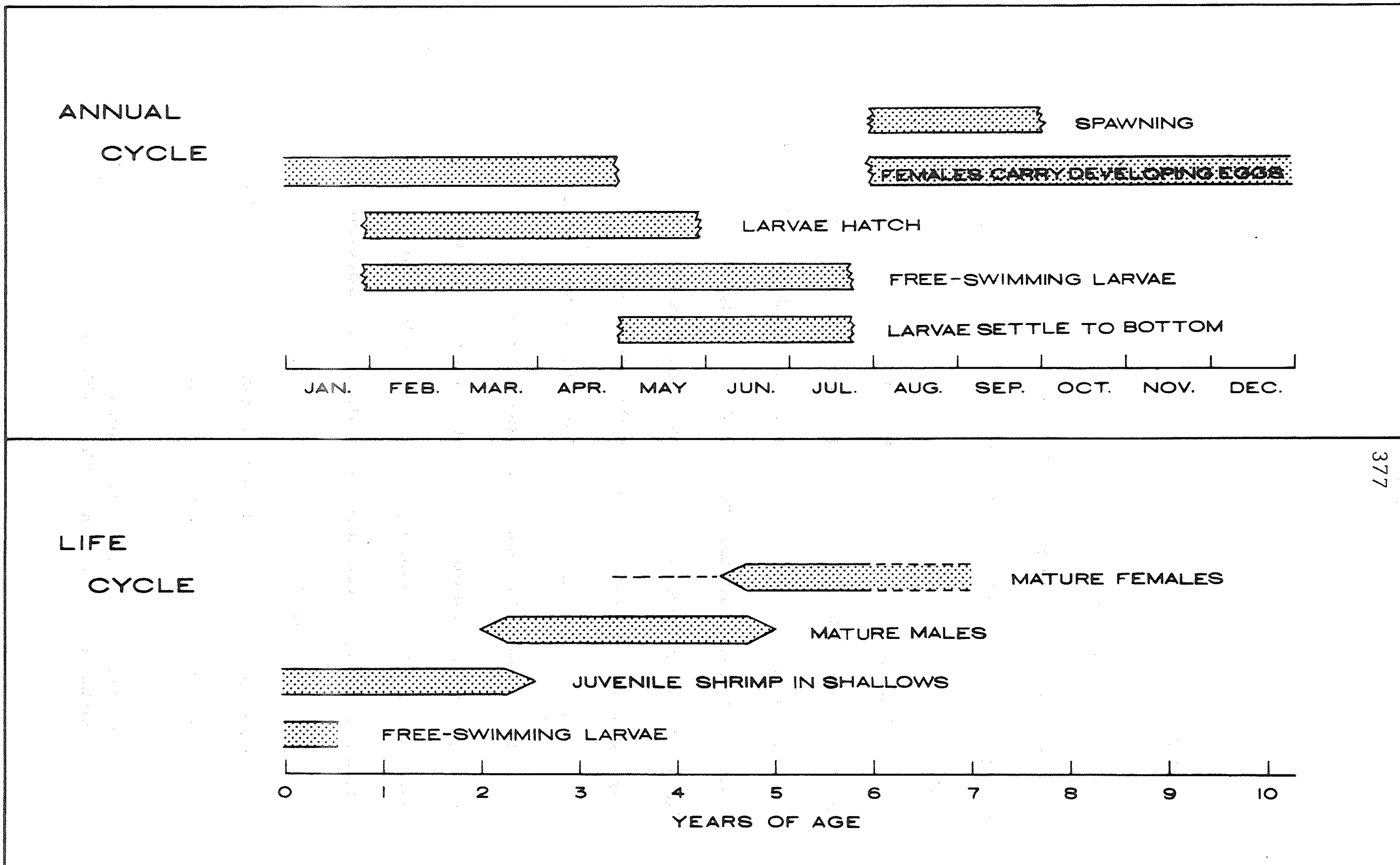

Figure 96. Annual and life cycles of the pink shrimp in Bristol Bay (AEIDC, Anchorage).

Scallops

There are eight species of scallops within Alaska coastal waters; but only the weathervane scallop, Patinopectin caurinus, is large enough to be commercially exploited.

Few scallops are reported in Bristol Bay.[1] In 1969, scallop resources in the Bristol Bay area were briefly explored in waters from Unimak Pass to the northwestern corner of Unimak Island. The catch was insignificant. Hennick (1970a) reported that surveys have not disclosed any extensive beds of scallops in the Bering Sea.

Scallops mature sexually in their 3rd year when they may be 80 to 125 mm. from umbo to outer shell margin. Scallops do not migrate to special areas for breeding. Individuals spawn annually between early June and mid-July (Hennick 1970b). Weathervane scallops are dioecious. At spawning, male and female release sperm and eggs into the water where fertilization occurs. Fecundity has not been studied in this species. Fertilized eggs settle

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1. Glenn Davenport, Area Management Biologist, Alaska Department of Fish and Game, Cold Bay.

to the bottom and adhere to the substrate. After two or three days these eggs hatch and larvae begin a 2.5 to 3.0 week planktonic phase. At the end of this time, larvae settle to the bottom and assume the adult form. Circulating water within the mantle cavity and gills provides a continuous source of food to the organism (Hennick 1973).

Figure 97 presents the annual and life cycles of the weathervane scallop. Hennick (1970b) believes a single concentric ring is added to the dorsal valve of the shell each year. Scallops are known to live more than 15 years; 1 exceptional specimen has been reported with 28 annual rings (Hennick 1973).

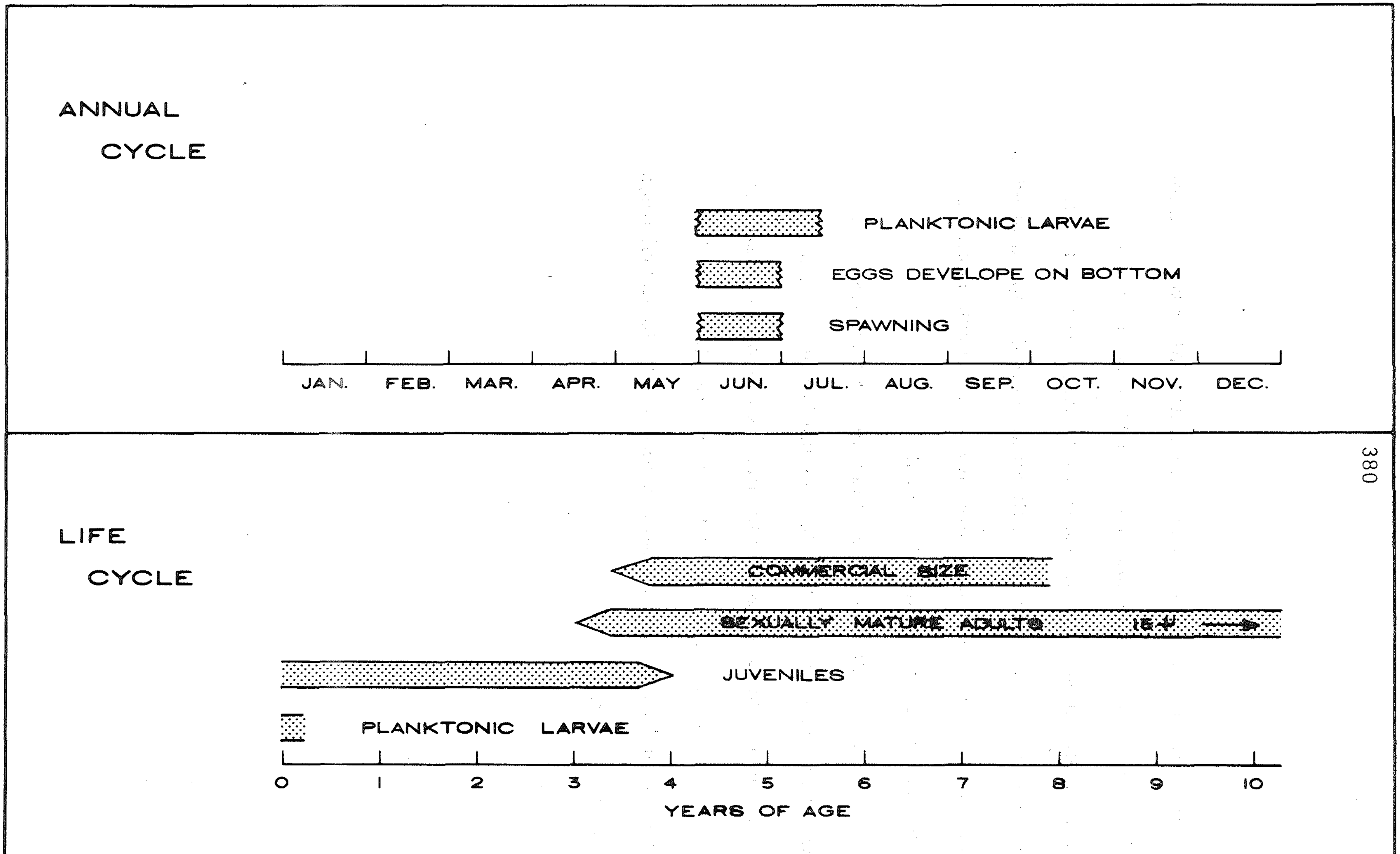

Figure 97. Annual and life cycles of the weathervane scallop in Bristol Bay (AEIDC, Anchorage).

PELAGIC FAUNA

Pelagic Invertebrates

No pelagic invertebrates are mentioned in the literature as significant in Bristol Bay. Kodolov (1970), however, reports that squid compose the bulk of the diet of sperm whales in the Bering Sea.

Fish

Noncommercial species of fish, as well as undeveloped commercial stocks, have been identified in Bristol Bay.

Exploratory fishing drags of the National Marine Fisheries Service (undated) contained 5 groups (Table 33), although only one of their drags yielded more than 90 kg./hr. This was a catch of sculpins taken just south of Cape Newenham.

Table 33. Noncommercial Fish Reported From Exploratory Fishing Drags in Bristol Bay

Group	Occurrence	Maximum Catch (kg./hr.)
1. Sculpin	occasional	450
2. Saffron cod	occasional	70
3. Poachers	occasional	65
4. Skates	occasional	35
5. Sandfish	occasional	15

Table 34 lists taxa which have been reported in Bristol Bay from all sources. Quast and Hall (1972) have systematically reviewed Alaskan fishes. All species they recorded in the study area are included in Table 34. Heard (1966) reports the presence of the anadromous Arctic lamprey, *Lampetra japonica*, in the Naknek River.

Three groups of rockfish, *Sebastes aleutianus*, *S. polyspinus*, and *Sebastolobus* sp. were reported to be common west of the study area along the outer continental shelf (Alverson et al. 1964).

Table 34. Noncommercial Fishes of Bristol Bay

1. Family Agonidae (poachers)
   1. Asterotheca infraspinata
   2. Occella dodecaedron
   3. O. verrucosa
   4. Podothecus acipenserinus
   5. Sarritor frenatus

2. Family Ammodytidae (sandlances)
   1. Ammodytes hexapterus

3. Family Anarhichadidae (wolffishes)
   1. Anarhichas orientalis

4. Family Bathymasteridae (ronquils)
   1. Bathymaster sp.

5. Family Cottidae (sculpins)
   1. Dasycottus setiger
   2. Eurymen gyrinus
   3. Gymnocanthus detrisus
   4. G. galeatus
   5. G. pistilliger
   6. Hemilepidotus gilberti
   7. H. hemilepidotus
   8. Icelus bicornis
   9. I. uncinalis
   10. I. vicinalis
   11. Megalocottus laticeps
   12. Myoxocephalus joak
   13. M. polyacanthocephalus
   14. M. scorpius
   15. M. verrucosus
   16. Porocottus sellaris
   17. Triglops pingeli

6. Family Cyclopteridae (lumpsuckers)
   1. Careproctus phasma
   2. Liparis agassizi

7. Family Hexagrammidae (greenlings)
   1. Hexagrammos stelleri

8. Family Gadidae (cods)
   1. Eleginus gracilis

9. Family Osmeridae (smelt)
   1. Hypomesus olidus
   2. Mallotus villosus
   3. Osmerus eperlanus
   4. Thaleichthys pacificus

10. Family Petromyzontidae (lampreys)
    1. Lampetra japonica

11. Family Pholididae (gunnels)
    1. Pholis fasciata
    2. Pholis gilli

12. Family Ptilichthyidae (quillfishes)
    1. Ptilichthys goodei

13. Family Rajidae (skates)
    1. Raja parmifera

14. Family Stichaeidae (pricklebacks)
    1. Acantholumpenus mackayi

15. Family Trichodontidae (sandfishes)
    1. Trichodon trichodon

16. Family Zoarcidae (eelpouts)
    1. Lycodes palearis

Skates and rays were encountered in small numbers at all depths.

The Faculty of Fisheries, Hokkaido University (1957, 1960, 1964, 1965, 1966, 1967, 1968, 1969) reports species identified from larvae obtained in plankton tows and adults caught in bottom trawls. Kashkina (1970) and Musienko (1963, 1970) review Soviet collections of ichthyoplankton - fish eggs and larvae - in the southeastern Bering Sea. Kobayashi and Ueno (1956) review early Japanese data on fish caught in Bristol Bay.

Pollock

Pollock, *Theragra chalcogrammus*, support one of the largest annual harvests of food fish in the world and certainly the largest harvest in the Bering Sea. Catches have grown dramatically in the past decade with major harvests by Japan and the USSR. The United States has never harvested this species in quantity (Buck 1973). The importance of this fishery, presently valued at 500 million dollars annually to the United States, will change dramatically with regimes proposed in current Law of the Sea discussions.

Exploratory fishing drags of the National Marine Fisheries Service indicate a major concentration of pollock in outer Bristol Bay and along the north side of the Alaska Peninsula (Figure 98). Catches exceeding 90 kg./hr. were made more frequently in early summer at depths between 45 and 80 m., although good quantities were evident at depths from 45 to 110 m. Catches exceeding 1,800 kg./hr. were reported.

The Faculty of Fisheries, Hokkaido University (1964, 1965, 1966, 1967) conducted a trawling program in Bristol Bay. Their largest catches exceeded 3,000 kg./hr. and were taken at depths between 70 and 100 m. (Figure 98).

An early estimate by the U.S. Bureau of Commercial Fisheries (1965) placed the potential annual harvest of pollock from the Bering Sea between 86 and 110 thousand metric tons. Japanese-caught pollock from the Bering Sea ranged in length from 23 to 69 cm. and averaged 47 cm. In the Bering Sea,

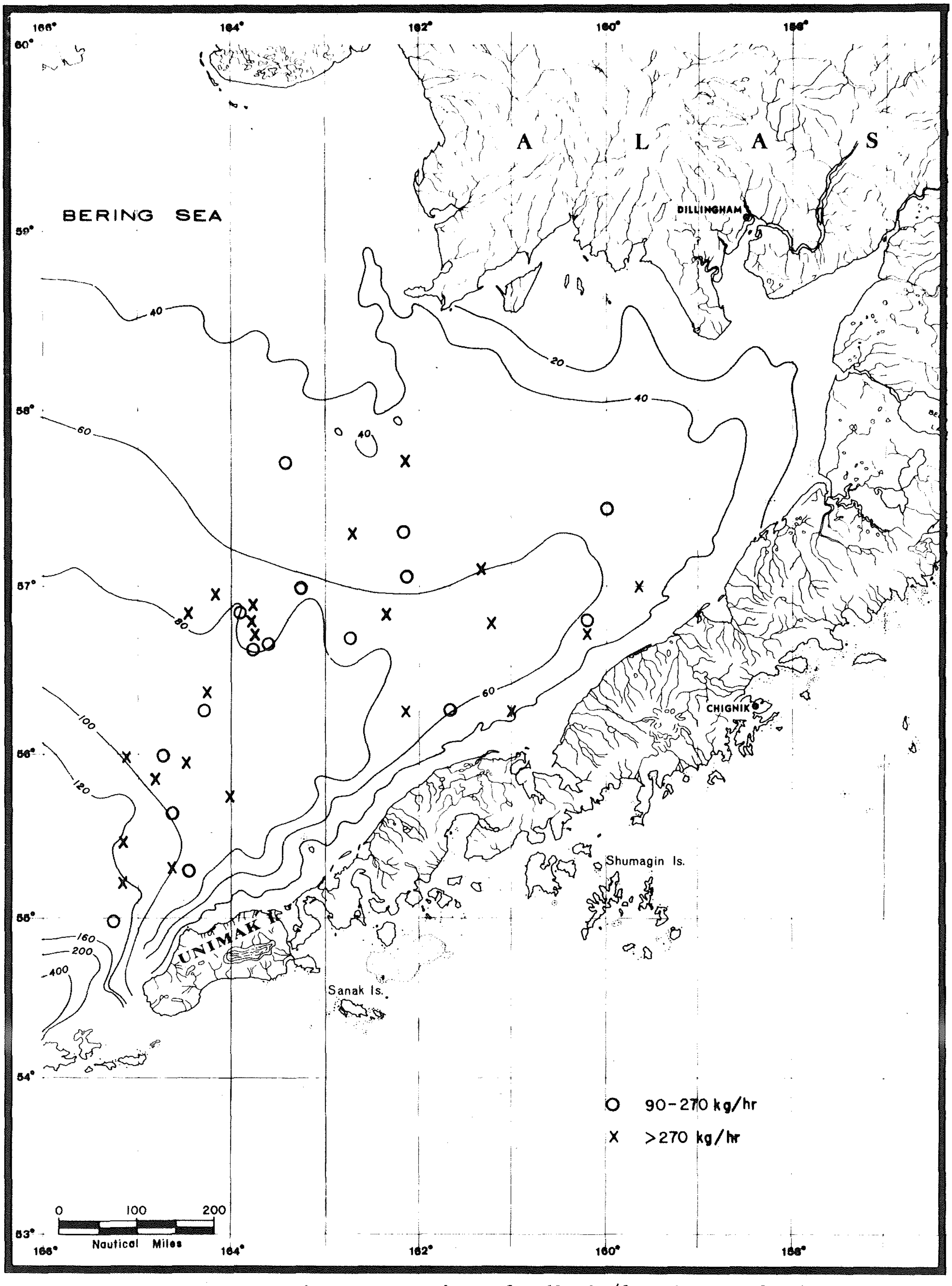

Figure 98. Large exploratory catches of pollock (from National Marine Fisheries Service, undated and Faculty of Fisheries 1964, 1966, 1967).

pollock comprised 82 percent of the experimental trawl catch (Alverson et al. 1964).

Pollock spawn at depths between 50 and 200 m., producing between 100,000 and 1.5 million eggs during the spring and early summer. Figure 99 indicates the presence of a large spawning concentration northwest of Unimak Island during this season (Serobaba 1970). Pollock spawn in Bristol Bay intermittently with only part of the ovary ripening at one time. Eggs are pelagic, and hatch in the upper 10 m. of the surface waters as they float with the currents. As juveniles develop, they become progressively more demersal in habit. Pollock mature at 3 to 4 years when males are 32 cm. and females are 40 cm. in length (Krivobok and Tarkovskaya 1964). Pollock may live as long as 12 or 15 years (Alton and Nicholl 1973). Annual and life cycles are depicted in Figure 100.

Pollock prefer zooplankton and small fish as food. Alton and Nicholl (1973) report nocturnal upward movements of both juveniles and adults, that are probably related to feeding habits. Reeves (1972) reports that temperature is an important factor in areal and vertical distribution.

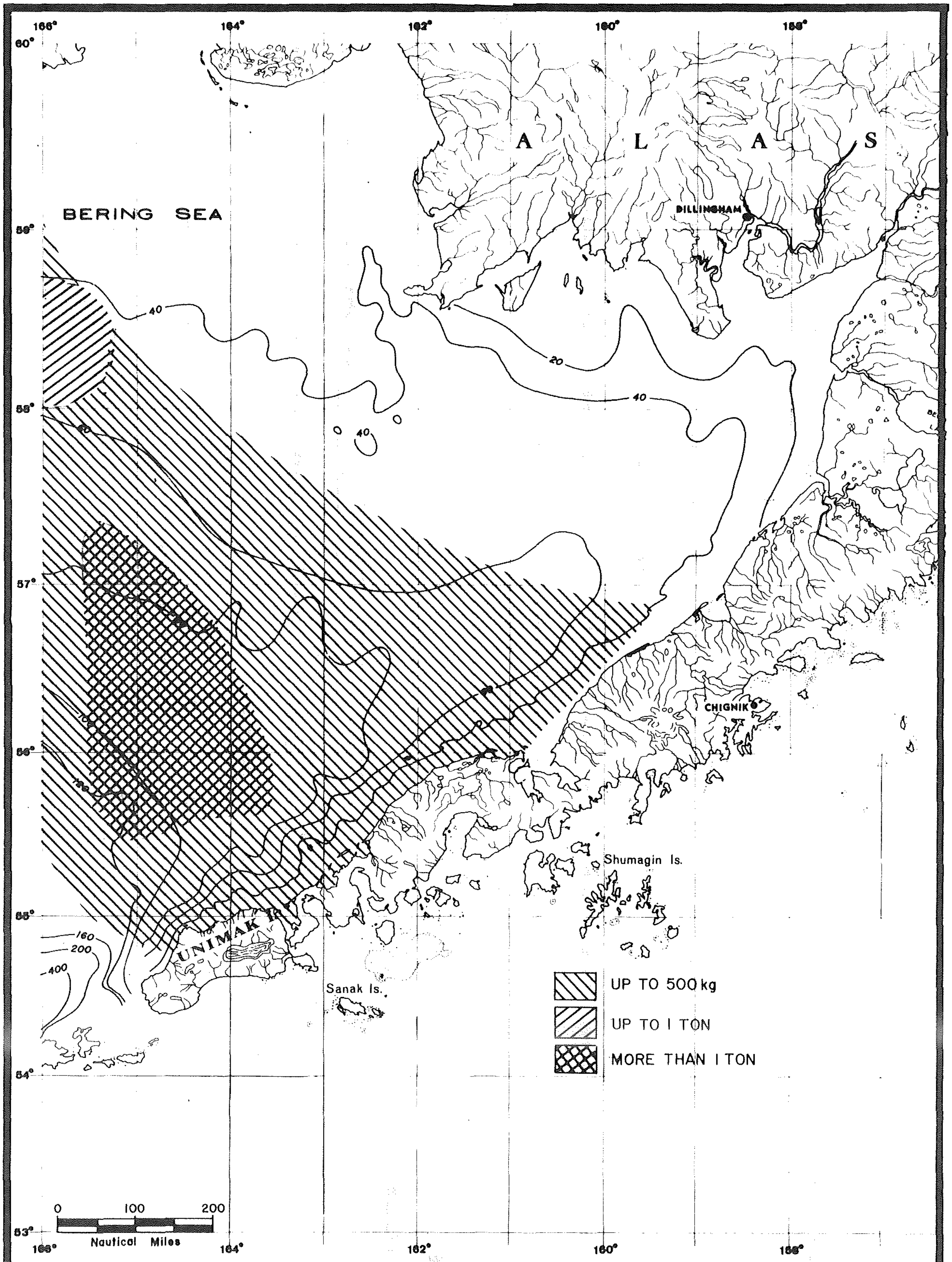

Figure 99. Distribution of pollock in the spring and summer of 1965 (from Serobaba 1970).

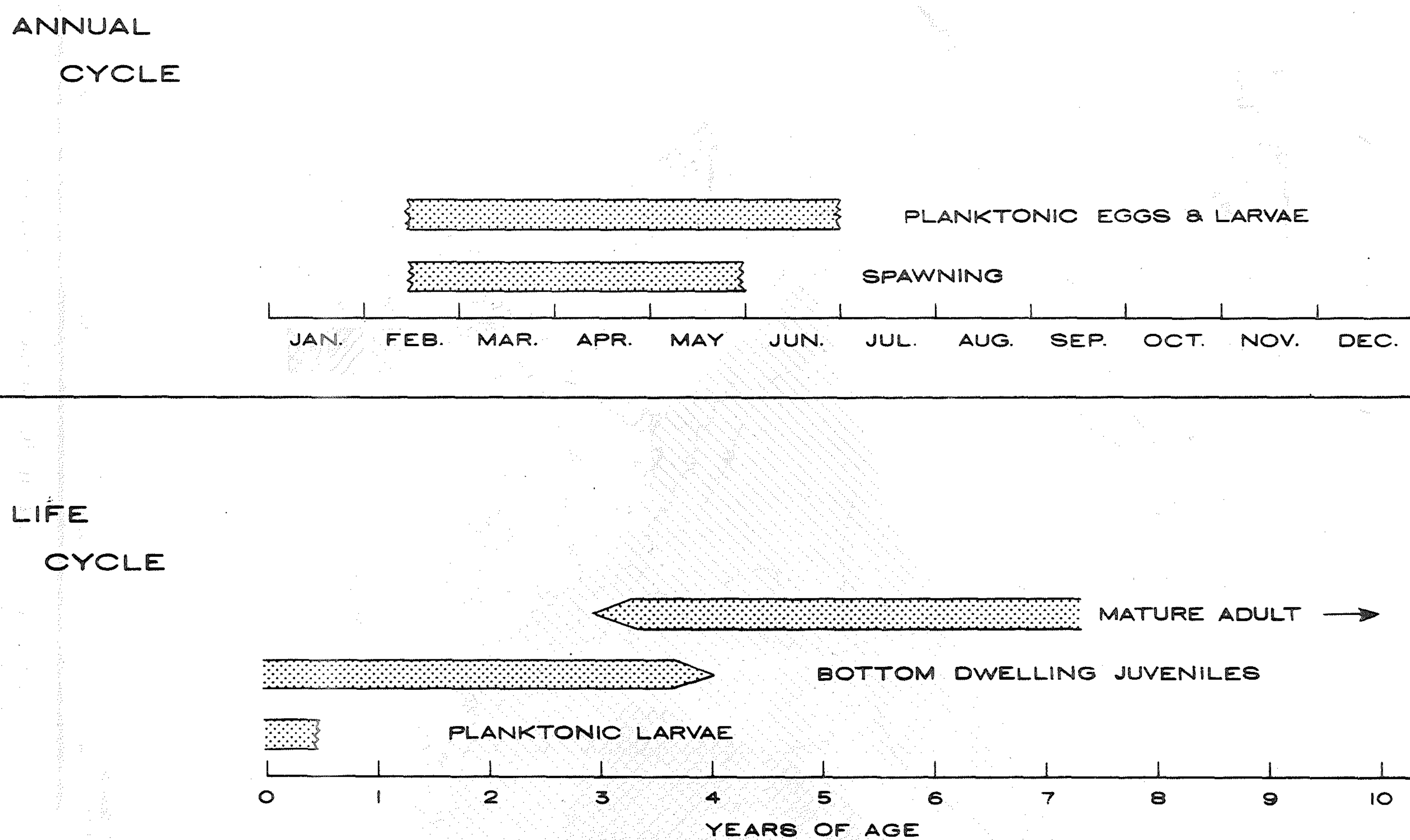

Figure 100. Annual and life cycles of the pollock in Bristol Bay (AEIDC, Anchorage).

Pacific Cod

The earliest commercial fishery in the study area was based on Pacific cod, Gadus macrocephalus. This fishery was developed by the United States shortly after the purchase of Alaska but U.S. participation has since declined. More than 50,000 metric tons of this species are now being harvested annually by Japan and the USSR along the continental shelf and slope of the Bering Sea (Buck 1973).

One concentration of Pacific cod, recorded south of Cape Newenham, was located by exploratory fishing drags of the National Marine Fisheries Service (undated) (Figure 101). Large quantities were found by Japanese exploratory trawling in offshore waters at depths between 65 and 80 m. Maximum catches exceeded 1,300 kg./hr. (Faculty of Fisheries 1964, 1965, 1966, 1967).

The U.S. Bureau of Commercial Fisheries (1965) found Pacific cod most abundant at depths between 55 and 90 m. in Bering Sea waters. In the eastern Bering Sea, the potential annual yield was estimated between 17.2 and 22.7 thousand

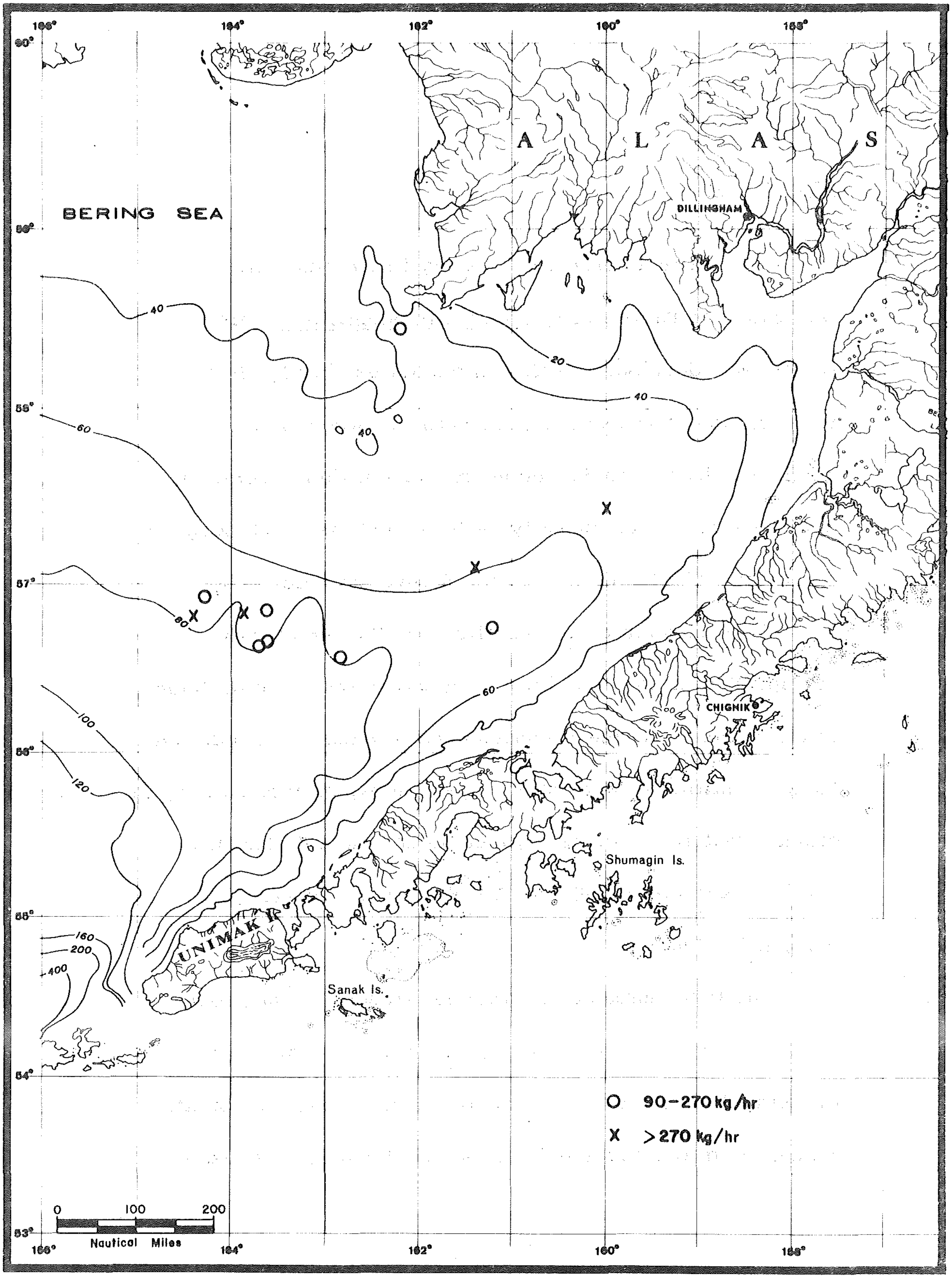

Figure 101. Large exploratory trawl catches of Pacific cod (from National Marine Fisheries Service, undated and Faculty of Fisheries 1964, 1965, 1966, 1967).

metric tons. Alverson et al. (1964) found that this species comprised 18 percent of the roundfish catch in the Bering Sea. Fish averaged 50 cm. in length for the Bering Sea region.

Pacific cod have well-defined seasonal movements which appear to be controlled by temperature. They migrate to deeper offshore waters for the winter (U.S. Bureau of Commercial Fisheries 1965). Spawning generally takes place at depths between 100 and 250 m. during the late winter; the eggs sink to the bottom where they develop and hatch (Reeves 1972). Maturity is reached in 2 to 3 years, when males are still less than 40 cm. in length. Individuals may live to 8 years of age (Nanaimo Biological Station 1966b). Annual and life cycles are shown in Figure 102.

This species feeds upon other bottomfish and crustaceans. Growth is rapid; individuals may reach a length of 60 cm. in 3 years. Large individuals may exceed 90 cm. in length (Krivobok and Tarkovskaya 1964).

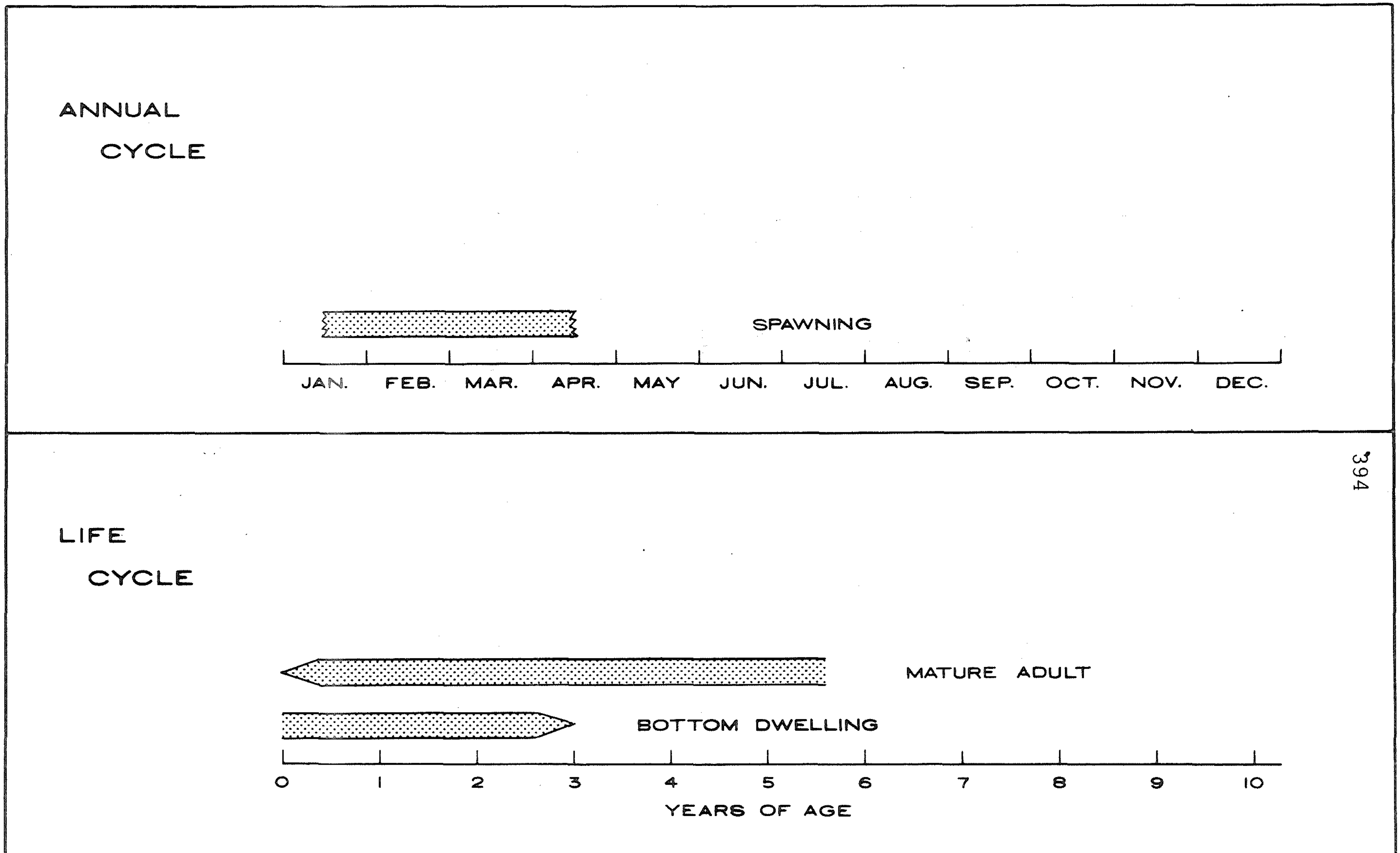

Figure 102. Annual and life cycles of the Pacific cod in Bristol Bay (AEIDC, Anchorage).

Blackcod

Blackcod, also called sablefish, have supported a substantial Soviet and Japanese fishery along the continental shelf edge west of the study area for the past decade (Buck 1973).

Blackcod, Anoplopoma fimbria, were absent from exploratory fishing drags of the National Marine Fisheries Service (undated) within the study area because they inhabit deeper waters than occur within Bristol Bay. Vertical migrations may bring blackcod closer to the surface during daylight hours (Kulikov 1965).

The U.S. Bureau of Commercial Fisheries (1965) found blackcod to be the dominant deep water fish in the eastern Bering Sea. Blackcod were found to be most abundant at depths between 365 and 730 m. on the continental slope. The potential annual yield from the eastern Bering Sea was calculated to be between 13.6 and 22.7 thousand metric tons of fish averaging 55 cm. in length.

Only a few scattered blackcod are recorded from Japanese experimental trawls north and west of Unimak Island along the western boundary of the study area (Faculty of Fisheries 1966, 1967).

Spawning takes place in the late winter after which developing eggs and larvae float in surface waters. Immature fish, less than 30 cm. in length, may school in surface coastal waters and at shallow depths. Annual and life cycles are depicted in Figure 103.

Blackcod mature in 6 to 8 years, although they may reach commercial size in only 5 years. Food consists of small fish, worms, and crustaceans (Nanaimo Biological Station undated). Individuals may live 9 years or more (Reeves 1972) and exceed 4 kg. in weight and 75 cm. in length (Shubnikov 1963).

Herring

A substantial herring fishery in the eastern Bering Sea has been developed by Japan and the USSR in the past decade. Large numbers of herring, Clupea harengus pallasii, use the north and south shores of Bristol Bay as spawning areas. Herring spawn between Kulukak Point and Togiak, and along the shores of Hagemeister Island.[1] Along the Alaska

1. Thomas R. Schroeder. Assistant Area Management Biologist, Commercial Fisheries Division, Alaska Department of Fish and Game, Dillingham. Personal communication.

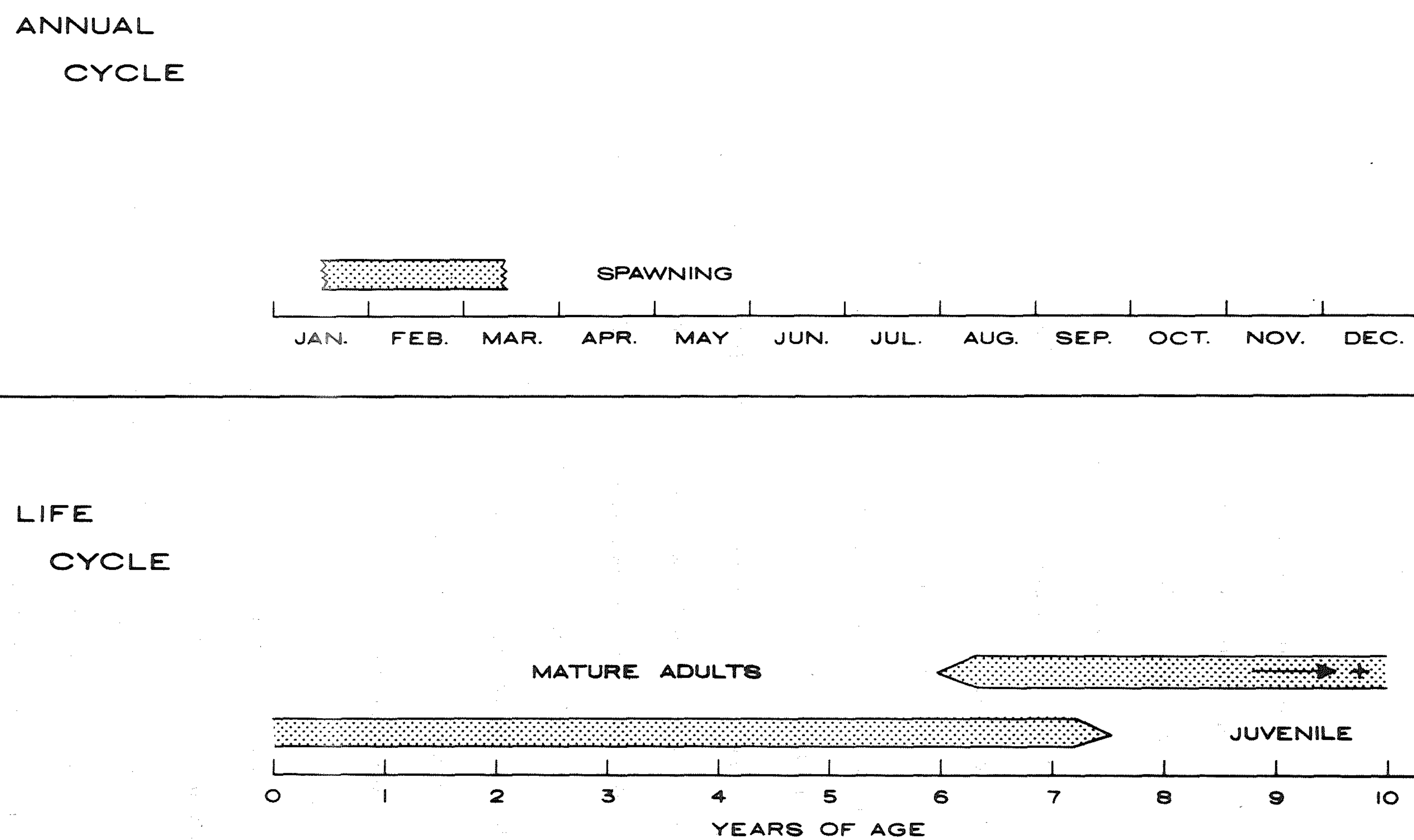

Figure 103. Annual and life cycles of the blackcod in Bristol Bay (AEIDC, Anchorage).

Peninsula, herring spawn abundantly in the shallows near Port Moller (Shaboneev 1965).

Few large catches of herring were recorded by the Japanese in an exploratory trawl program (Faculty of Fisheries 1960, 1966). All catches exceeding 90 kg./hr. are plotted in Figure 104.

Herring are found in Bristol Bay from the surface to depths of 70 m. between late spring and early autumn (Rumyantsev and Darda 1970).

Spawning takes place from late April to early June in bays along the north shore of the Alaska Peninsula and Unimak Island, and along the northern shores of Bristol Bay. Females discharge eggs which are fertilized by milt (spermatozoa) released by the males. Fertilized eggs adhere to kelp, eelgrass, or any convenient substrate. Individual females deposit an average of 20,000 eggs each year (Nanaimo Biological Station 1966c).

Eggs develop for 23 days at 6 to 8 degrees C before hatching into planktonic larvae (Musienko 1970). Mortality in the egg and larval stages can be quite variable. It may be excessive in some years resulting in the dominance of individual year classes in herring populations. Herring gradually develop

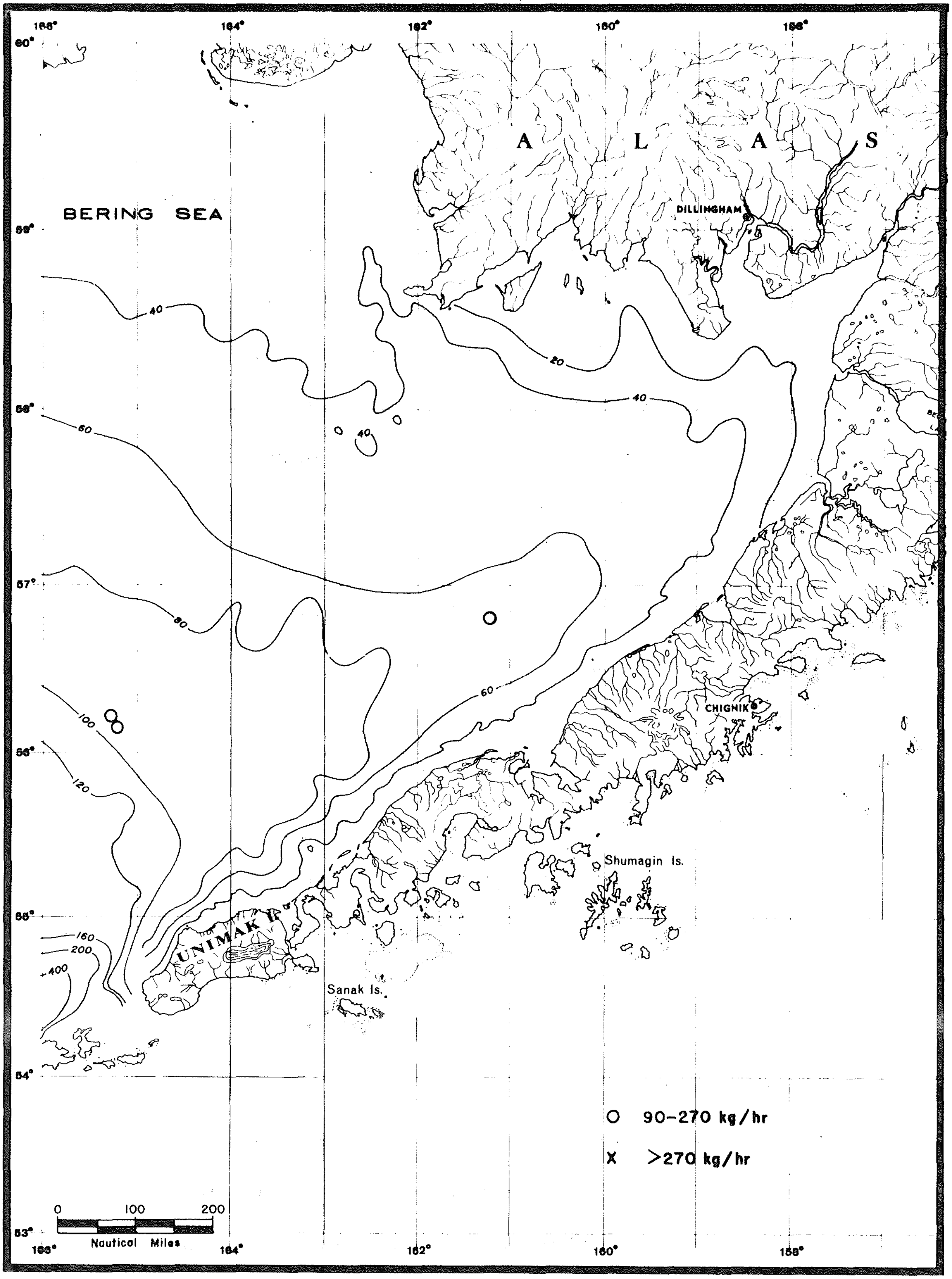

Figure 104. Large exploratory trawl catches of herring (from Faculty of Fisheries 1960, 1966)

from larvae into juveniles during a 2-month planktonic existence. Juvenile herring form schools and frequent kelp beds for protection during the summer.

Juveniles move slightly offshore in early autumn. Few details are known about juvenile life history prior to 3 to 5 years of age, when most individuals first return to spawn (Nanaimo Biological Station 1966c). Tagging programs may delineate separate migratory populations, but no studies of this scope have been undertaken within Bristol Bay. Annual and life cycles are shown in Figure 105.

Adult herring remain in inshore waters and bays throughout the summer. Adult herring leave Bristol Bay in September and October to form wintering schools northwest of the Pribilof Islands and along the southern margin of the ice pack. Schools of herring lie densely on the bottom and are restricted to waters deeper than 100 m. (Dudnik and Usol'Tsev 1964). Herring leave the wintering area in late March and April to spawn (Figure 106).

Herring feed upon zooplankton, primarily euphausiids, and migrate vertically toward the surface at night in pursuit of this diet. Growth rate has been studied in Bristol Bay; fish

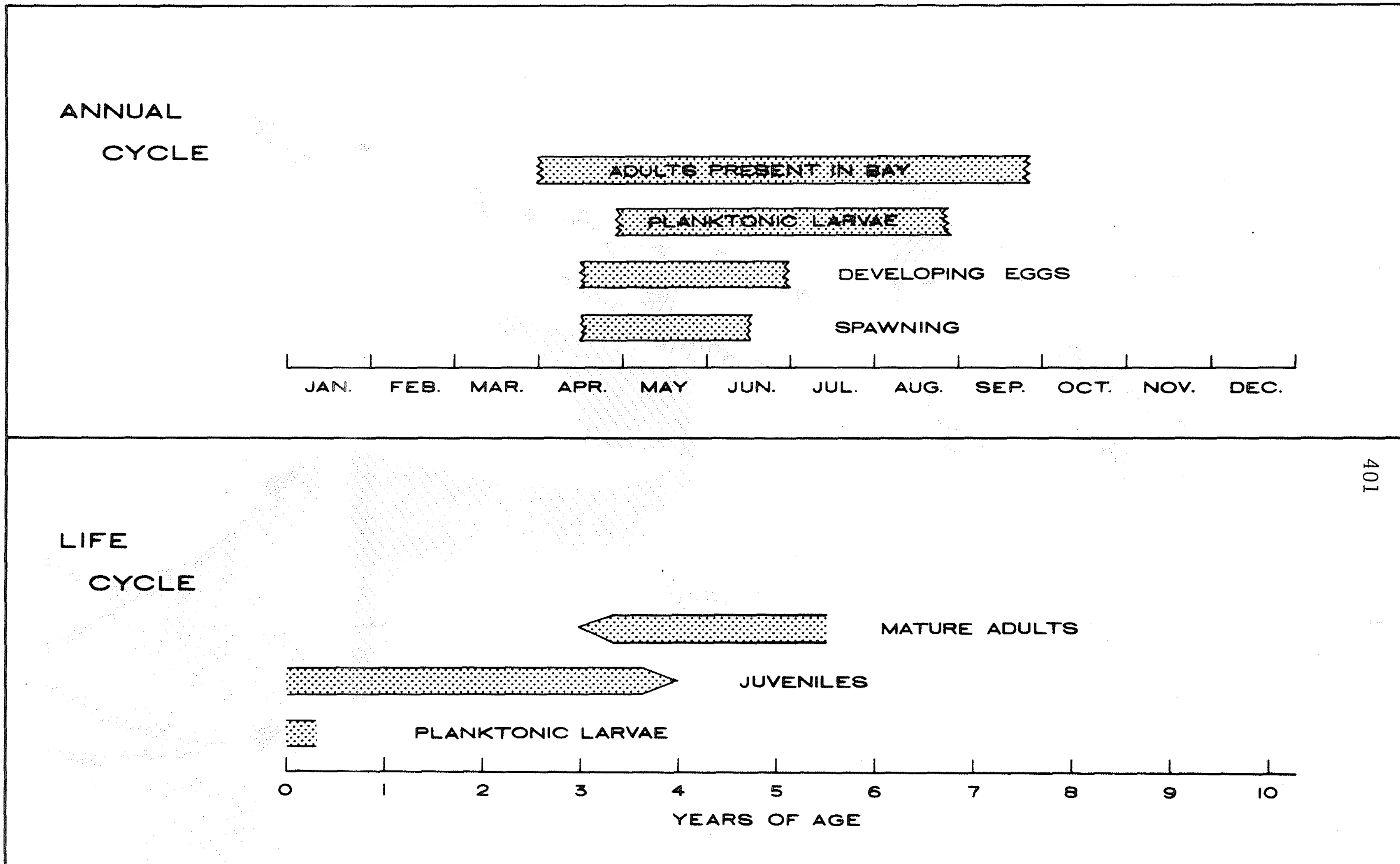

Figure 105. Annual and life cycles of the herring in Bristol Bay (AEIDC, Anchorage).

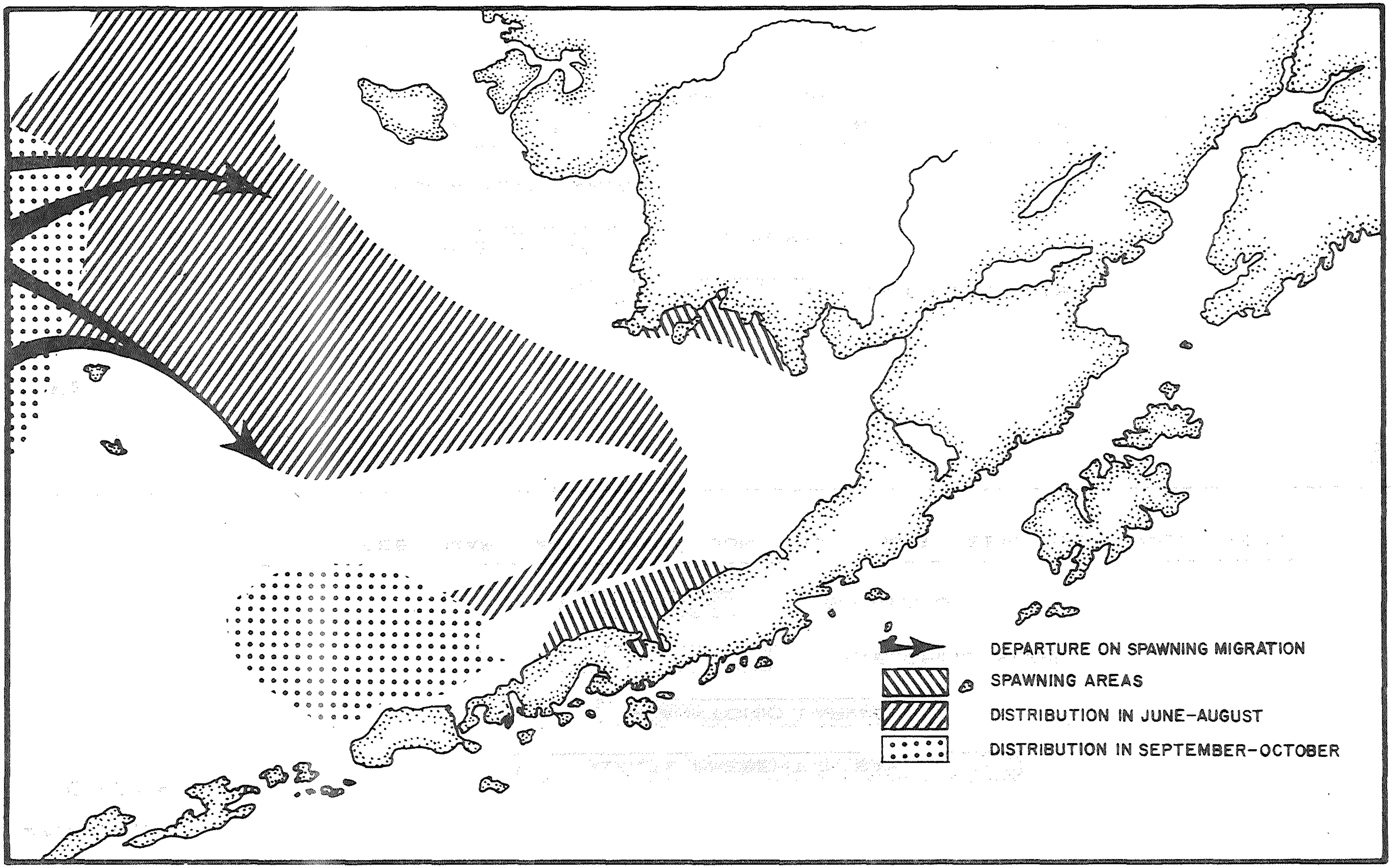

Figure 106. Distribution of herring in the southeastern Bering Sea (from Dudnik and Usol'Tsev 1964).

as old as 11 years were encountered that measured 33 to 34 cm. in length (Shaboneev 1965).

Pacific Ocean Perch

Soviet and Japanese trawlers have fished extensively for Pacific Ocean perch, Sebastes alutus, along the continental shelf edge west of the study area throughout the past decade (Buck 1973). Soviet literature has contributed substantially to our understanding of this species of rockfish and its life history.

The U.S. Bureau of Commercial Fisheries (1965) reported large Soviet and Japanese catches at depths between 145 and 460 m. in the Bering Sea, west of the study area. Generally, fish were encountered at depths between 20 and 60 m. above rocky bottoms, and in submarine canyons and gullies. Fish averaged 37 cm. in length. The potential annual yield for the Bering Sea region was calculated to be between 22.7 and 45.4 thousand metric tons.

Pacific Ocean perch mature in 5 to 7 years when they are 24 to 27 cm. in length. Fertilization in late September and October is internal. Female perch carry between 30,000 and

350,000 eggs, depending upon size of the female. These eggs develop internally until the larvae are expelled from March to May. Larvae may be released just above the bottom at depths between 360 and 420 m. southeast of the Pribilof Islands (Paraketsov 1963). Juvenile rockfish are generally found in cooler, shallower waters. They gradually become more demersal in habit during their second or third year. Annual and life cycles are depicted in Figure 107.

Growth of individuals may continue 30 to 35 years, reaching a maximum length of 50 cm. (Reeves 1972). Although their diet is composed primarily of planktonic crustaceans and small fish, some feeding occurs upon benthic species of mollusks. Diurnal vertical movements of Pacific Ocean perch are believed to be associated with feeding behavior (Lyubimova 1965). Individuals may reduce their food intake in autumn and winter; adults usually do this to a greater extent than young fish.

Flatfish (excluding Halibut)

Flatfish accounted for more than 50 percent of all fish caught during exploratory trawling on the inner continental shelf (Alverson et al. 1964). Seven species of flatfish, excluding halibut, are recorded from exploratory fishing drags of the

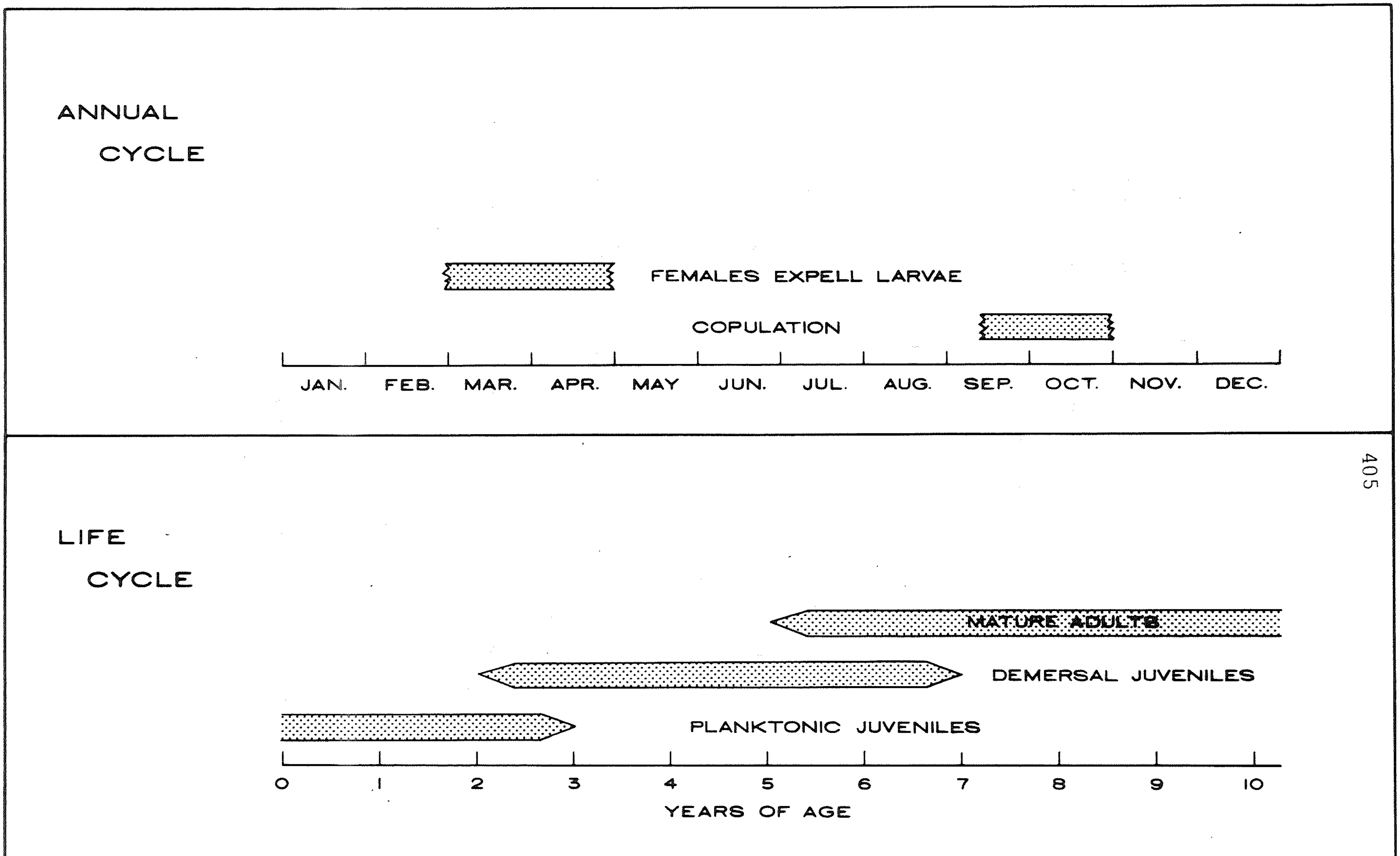

Figure 107. Annual and life cycles of the Pacific Ocean perch in the southeastern Bering Sea (AEIDC, Anchorage).

National Marine Fisheries Service (undated) in Bristol Bay (Table 35). Two additional species are listed from Japanese trawl records (Faculty of Fisheries 1960, 1964, 1965, 1966, 1967). Only 4 species were caught at a rate of 90 kg./hr. or greater within the study area. The distribution of significant trawls for these species is indicated in Figure 108. Many large catches were taken throughout the study area. The greatest number of large catches were of yellowfin and rock sole. These could be considered the most abundant species of flatfish with potential commercial value in Bristol Bay.

Distribution of species is related to depth (Alverson et al. 1964). All Bristol Bay species can be considered shelf inhabitants. Most large concentrations of turbot and Kamchatka flounder were confined to the southwest corner of the study area at depths exceeding 100 m.

Fadeev (1965) provides the most comprehensive discussion of the flatfishes inhabiting Bristol Bay.

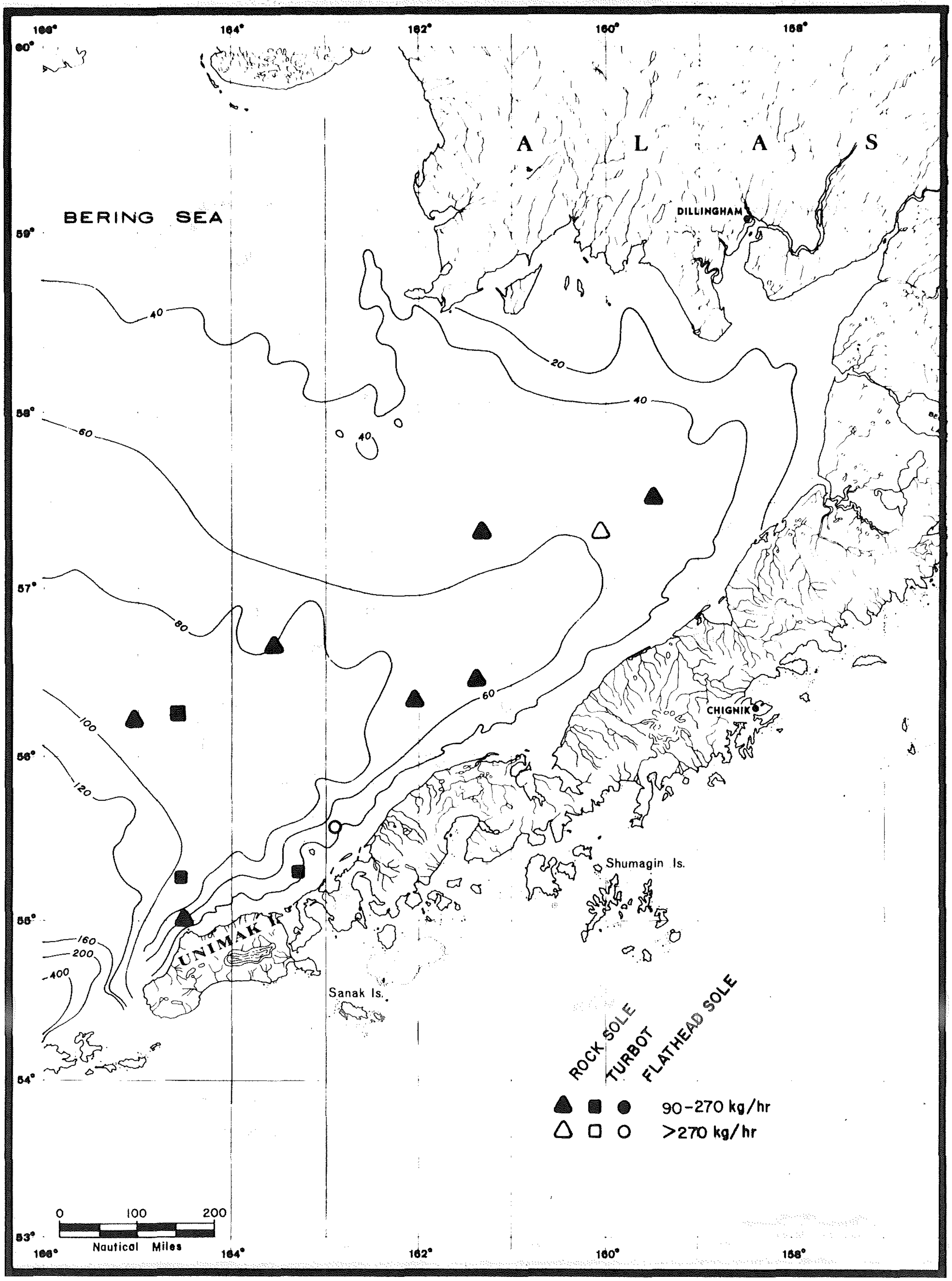

Figure 108a. Location of large catches of flatfishes taken in National Marine Fisheries Service exploratory fishing program.

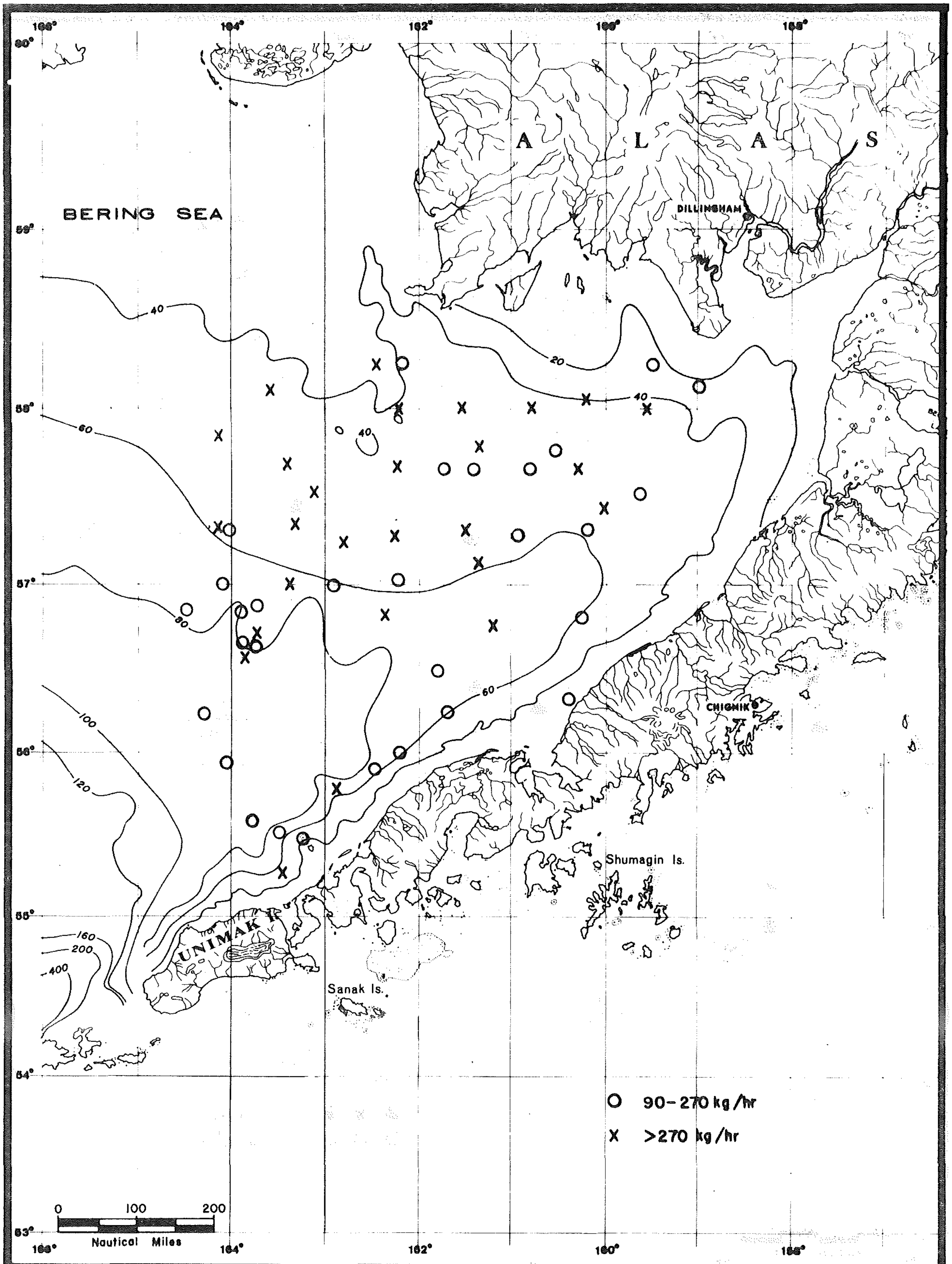

Figure 108b. Location of large catches of yellowfin soles taken in National Marine Fisheries Service exploratory fishing.

Table 35. Flatfish (excluding halibut) species of Bristol Bay

	Scientific Name	Common Name
1.	Atheresthes evermanni	Kamchatka flounder
2.	Atheresthes stomias	Turbot
3.	Hippoglossoides elassodon	Flathead sole
4.	Leoidopsetta bilineata	Rock sole
5.	Limanda aspera	Yellowfin sole
6.	Limanda proboscidea	Longhead dab
7.	Platichthys stellatus	Starry flounder
8.	Pleuronectes quadrituberculatus	Alaska plaice
9.	Reinhardtius hippoglossoides	Greenland halibut

Yellowfin sole are the dominant flatfish in Bristol Bay. Alverson et al. (1964) found that this species accounted for 53 percent of the total flatfish catch taken during experimental trawling in the Bering Sea. This species is the dominant flounder in Japanese and Soviet Bering Sea catches. The U.S. Bureau of Commercial Fisheries (1965) estimated the potential annual yield for yellowfin sole in the eastern Bering Sea at between 180 and 270 thousand metric tons.

Fadeev (1970) has summarized extensive Soviet research on this species. In winter, this species forms dense concentrations north of Unimak Island between depths of 90 and 100 m. on the lower continental shelf (Figure 109). Juveniles may form winter schools offshore within Bristol Bay. In April or May, depending upon water temperatures, larger individuals begin to move into Bristol Bay, possibly arriving from the Pribilof and Unimak areas. As summer progresses, these fish gradually move toward the outer shelf south of the Pribilof Islands, arriving there in July through September.

Yellowfin sole feed primarily upon planktonic crustaceans, small bivalve mollusks, and ascidians (Skalkin 1963). During the summer, yellowfin sole feed most extensively in waters less than 60 m. deep.

Maximum age recorded for this species is 19 years. Individual fish more than 10 years of age are not uncommon (Fadeev 1970). Females may attain maturity at 5 years of age although most do not mature until 9 years. Most males mature at 5 years of age (Fadeev 1963). Maximum length attained rarely exceeds 45 cm.

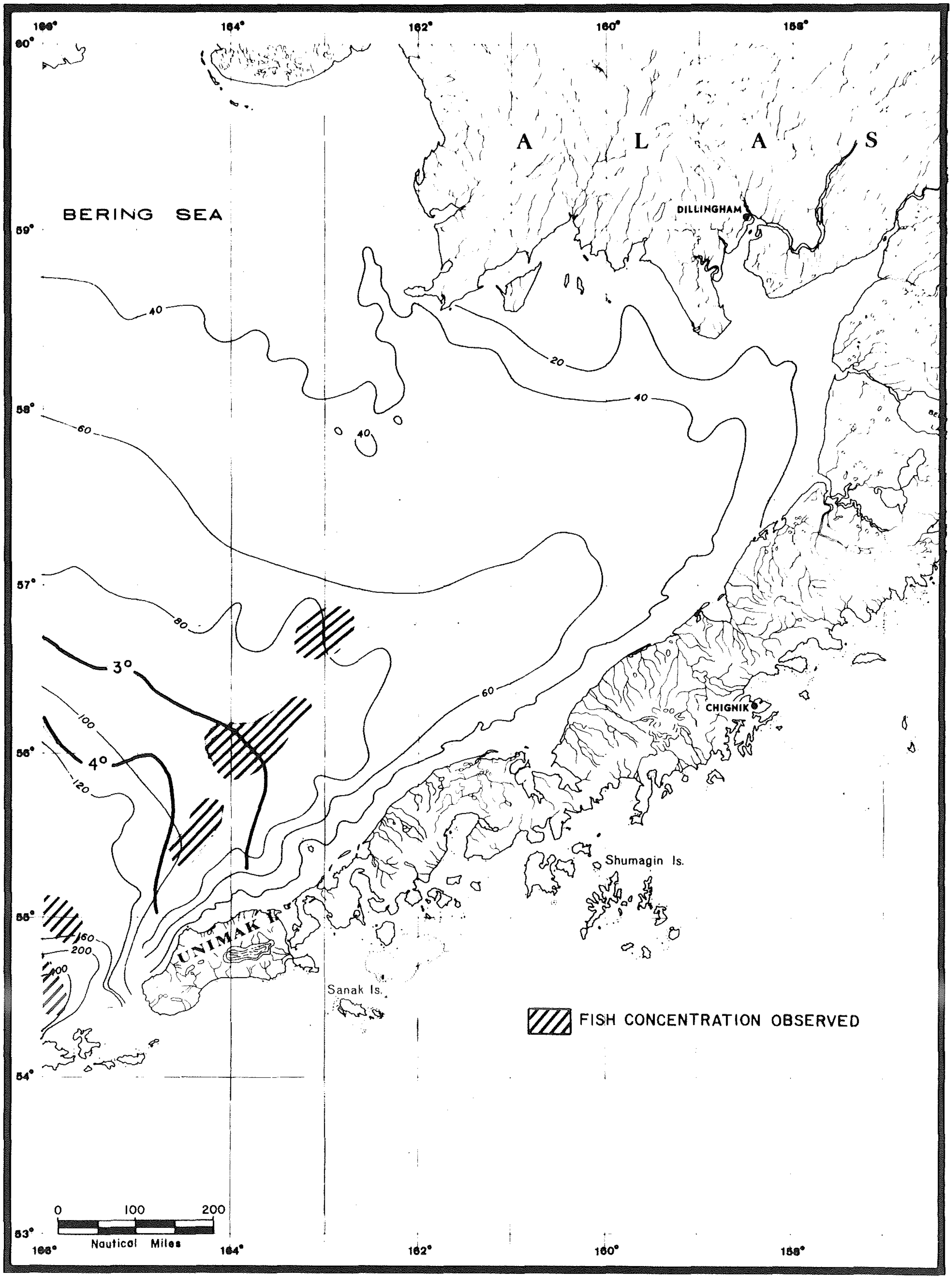

Figure 109. Winter distribution of yellowfin soles in Bristol Bay in 1964 (from Fadeev 1970).

Of all regions surveyed, Alverson et al. (1964) found rock sole to be most abundant in the eastern Bering Sea. The estimated potential annual yield for the entire eastern Bering Sea is 90.7 to 136 thousand metric tons of rock sole - a yield of flatfish second only to yellowfin sole (U.S. Bureau of Commercial Fisheries 1965).

Shubnikov and Lisovenko (1964) describe seasonal movements of rock sole which appear to be similar to those of the yellowfin sole (Figure 110).

Rock sole feed primarily upon polychaete worms and small mollusks (Skalkin 1963). Large rock sole may exceed 55 cm. in length and 13 years of age. Rock sole mature at 5 to 7 years of age.

Flathead sole and turbot are also common in outer Bristol Bay. Their respective potential annual yields for the eastern Bering Sea have been estimated between 27.2 and 36.3 thousand metric tons and between 18.1 and 36.3 thousand metric tons (U.S. Bureau of Commercial Fisheries 1965). Mineva (1964) summarized Soviet knowledge of flathead sole in Bristol Bay.

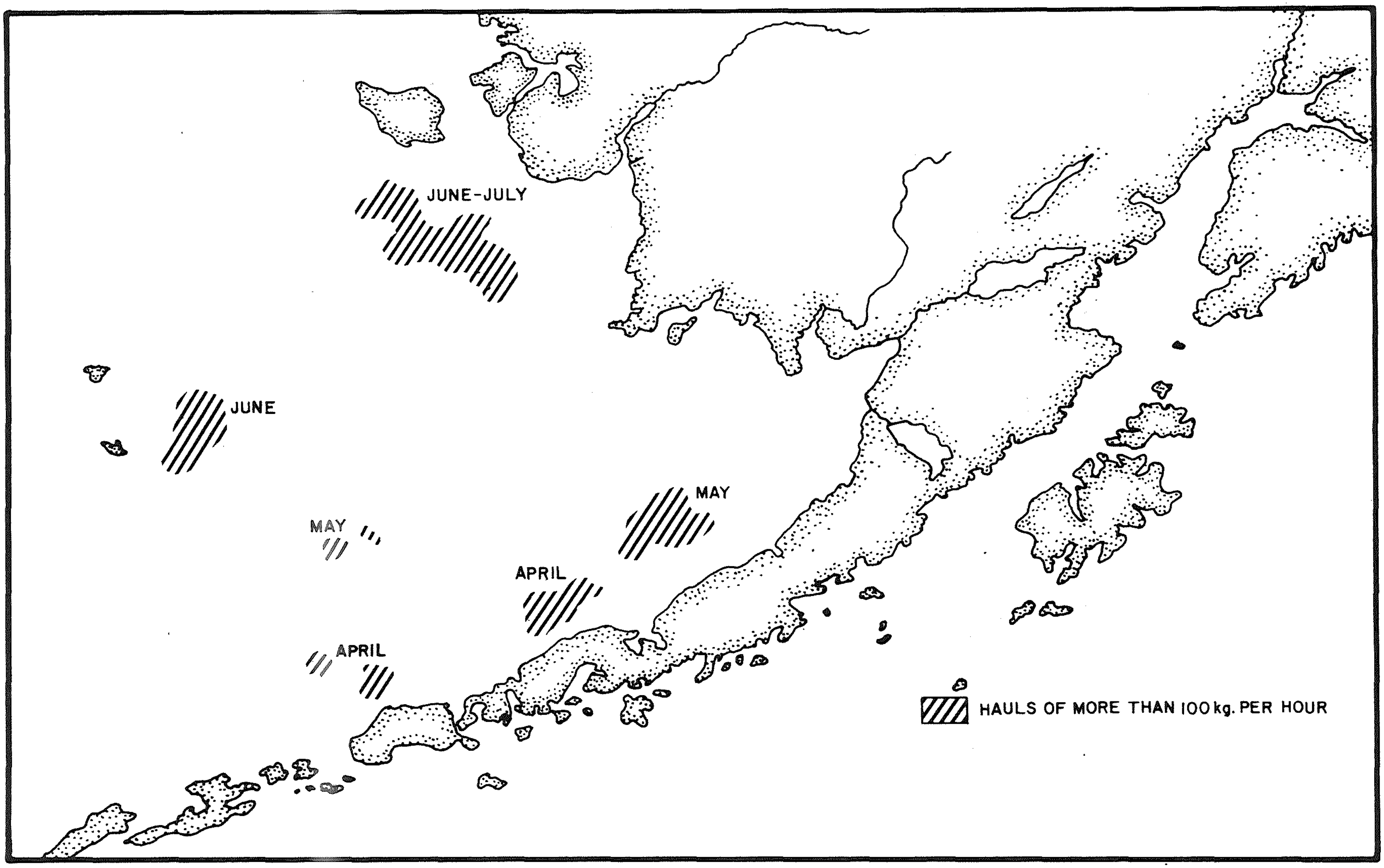

Figure 110. Distribution of rock sole in Bristol Bay (from Shubnikov and Lisovenko 1964).

Flatfish reproduction and life cycles are not well known. Spawning of rock sole is believed to occur from March to mid-June at depths between 100 and 200 m. and of yellowfin sole in late June through September (Musienko 1963). Eggs of such species as yellowfin sole are believed to be pelagic while others, such as rock sole, are considered demersal. Large yellowfin sole may spawn in excess of 3 million eggs in a season while rock sole rarely exceed 400,000 (Fadeev 1965).

Halibut

A complex commercial fishery for halibut, *Hippoglossus stenolepis*, has developed in Bristol Bay in the past 25 years. Participation in this fishery by the USSR, Japan, Canada, and the United States has made management of this species difficult due to gear conflicts and an inadequate exchange of catch statistics.

Both the National Marine Fisheries Service (undated) and the Faculty of Fisheries, Hokkaido University (1964) have done exploratory fishing for halibut in Bristol Bay. Large catches were rare in waters less than 80 m. deep. Trawls yielding more than 90 kg./hr. are plotted in Figure 111.

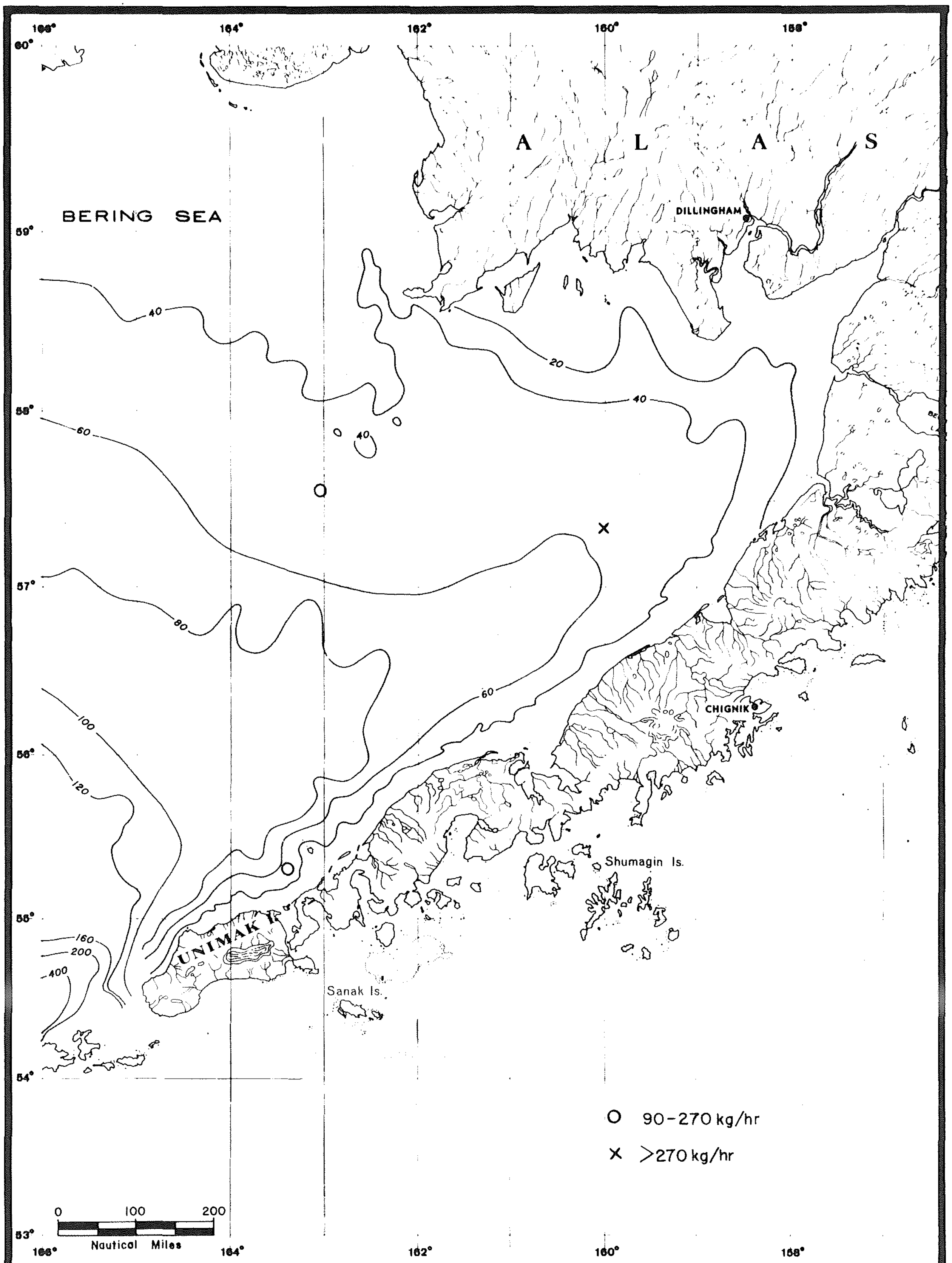

Figure 111. Experimental drag catches of halibut in Bristol Bay (from National Marine Fisheries Service, undated and Faculty of Fisheries 1964).

Halibut spend most of the winter on the continental slope, west of the study area. In spring they migrate to the shelf and a small segment of the population enters the study area (Figure 112). These movements are primarily temperature related (Natarov and Novikov 1970) and confine individual fish to bottom zones where water temperatures range from 3 to 8 degrees C (Bell and St. Pierre 1970). On the average, halibut in Bristol Bay are younger and smaller than those taken in adjacent areas (Novikov 1964). The U.S. Bureau of Sport Fisheries and Wildlife (1972) cites the area north of Unimak Island as an important halibut rearing area.

Female halibut usually do not mature until 10 to 12 years of age. Males may mature at 7 to 8 years (Bell 1972). Spawning takes place from November to February at depths between 275 and 400 m. at the edge of the continental shelf. Large females may produce more than 2.5 million eggs during a spawning season. After about 15 days these eggs hatch.

The specific gravity of the eggs and larvae enables them to remain suspended at mid-water depths as they drift

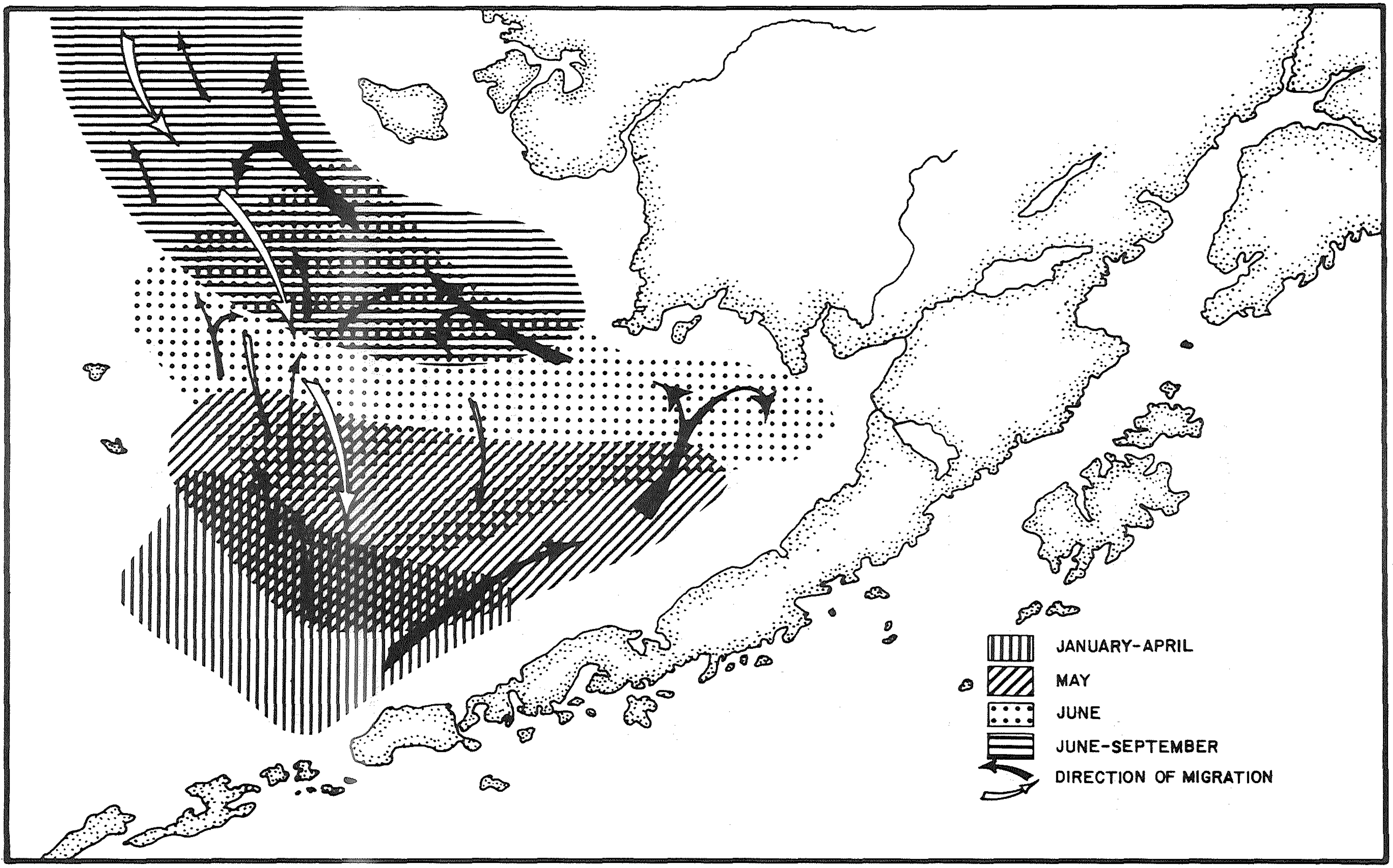

Figure 112. Distribution and migration of halibut in the southeastern Bering Sea (from Natarov and Novikov 1970).

with ocean currents. As development proceeds, larvae rise closer to the surface. Inshore surface currents carry many larvae into coastal shallows favorable for growth. At an age of 6 to 7 months, juvenile halibut settle to shallow bottoms. As they grow, they move into progressively deeper waters.

While juvenile halibut may move only short distances, mature fish participate in extensive migrations (Figure 112). In recent years, the recorded relative abundance of juvenile halibut has fluctuated greatly. Mortality is observed to increase greatly after age 4 (Table 36), possibly due to vulnerability of halibut above this age to the large trawl fishery (International Pacific Halibut Commission 1973).

Table 36. Relative abundance of juvenile halibut in the Bering Sea, 1966-1972. (from International Pacific Halibut Commission 1973).

	Number of fish per hour of trawl					
Date	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1966	0.2*	16.8	4.8	7.4	0.9	0.2
1967	0.6	4.6*	4.9	6.4	0.6	0.6
1968	0.3	6.8	1.9*	3.2	0.5	0.5
1969	2.6	4.0	4.6	0.4*	0.7	0.2
1970	0.4	8.7	1.9	0.7	0.2*	-
1971	3.8	2.6	7.5	0.3	0	-*
1972	0.1	9.3	1.8	0.8	0.1	-

*1964 year class.

Female halibut grow to a larger size than males. Males may attain ages of 25 years, weights up to 55 kg. and lengths to 140 cm. Females may attain ages exceeding 35 years, weights of 210 kg., and lengths of 240 cm. (Nanaimo Biological Station 1966d). Annual and life cycles are depicted in Figure 113.

Halibut feed primarily upon benthic fauna, with yellowfin sole and pollock being staples for medium and large individuals (Shuntov 1965). Normally, temperatures between 3 and 9 degrees C are optimum for this species (Thompson and Van Cleve 1936).

Chinook Salmon

Chinook salmon, Oncorhynchus tshawytscha, are relatively common within the study area. Chinook were caught off Port Moller (Figure 114) in offshore test fishing with gill nets (Seibel 1967, Paulus 1968, 1969, 1970, 1971, 1972, 1973). Approximately 75 percent of the chinook were taken at stations 7, 8, 9 and 10 (65 to 90 km. offshore) between June 14 and June 28.

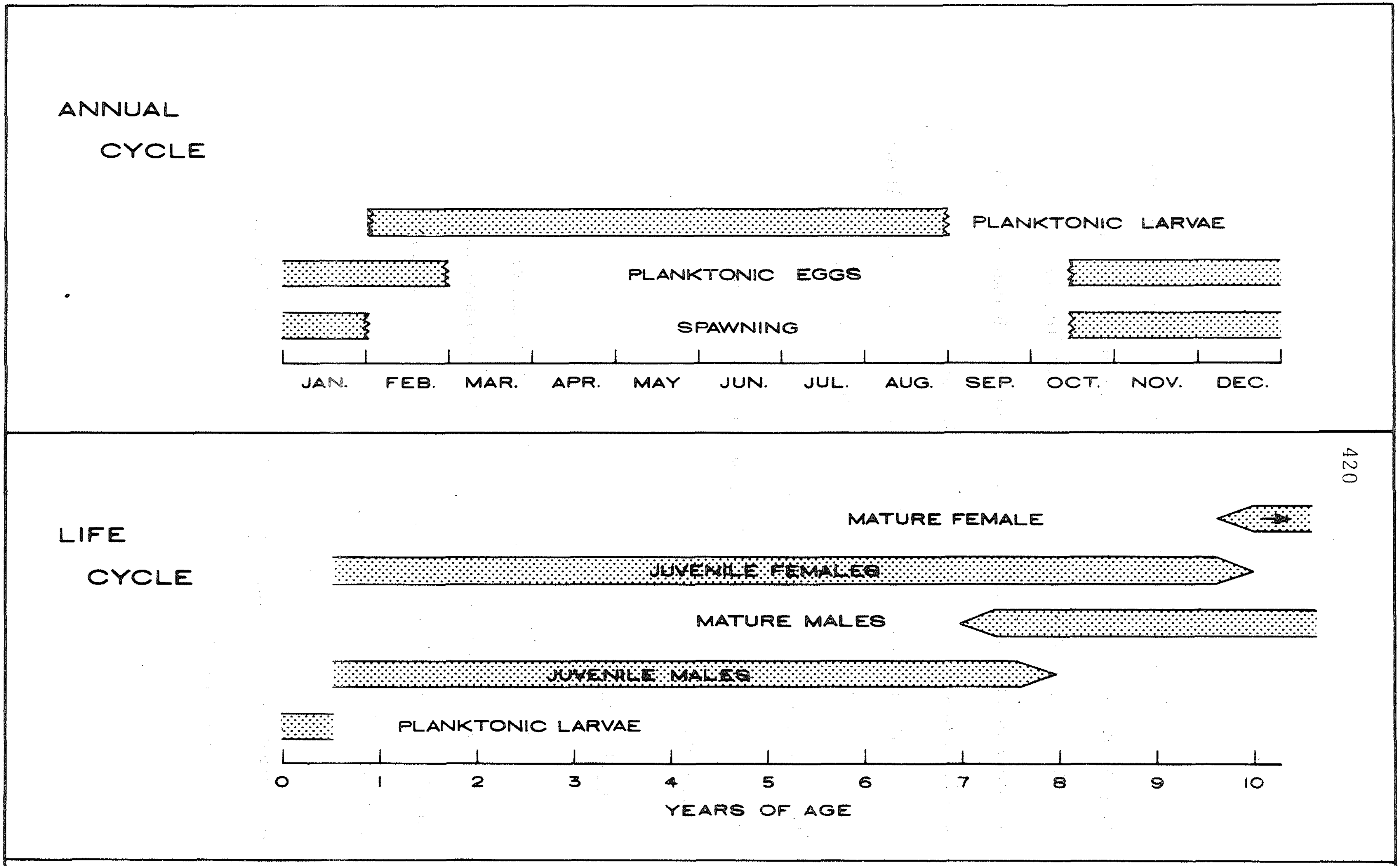

Figure 113. Annual and life cycles of halibut in Bristol Bay (AEIDC, Anchorage).

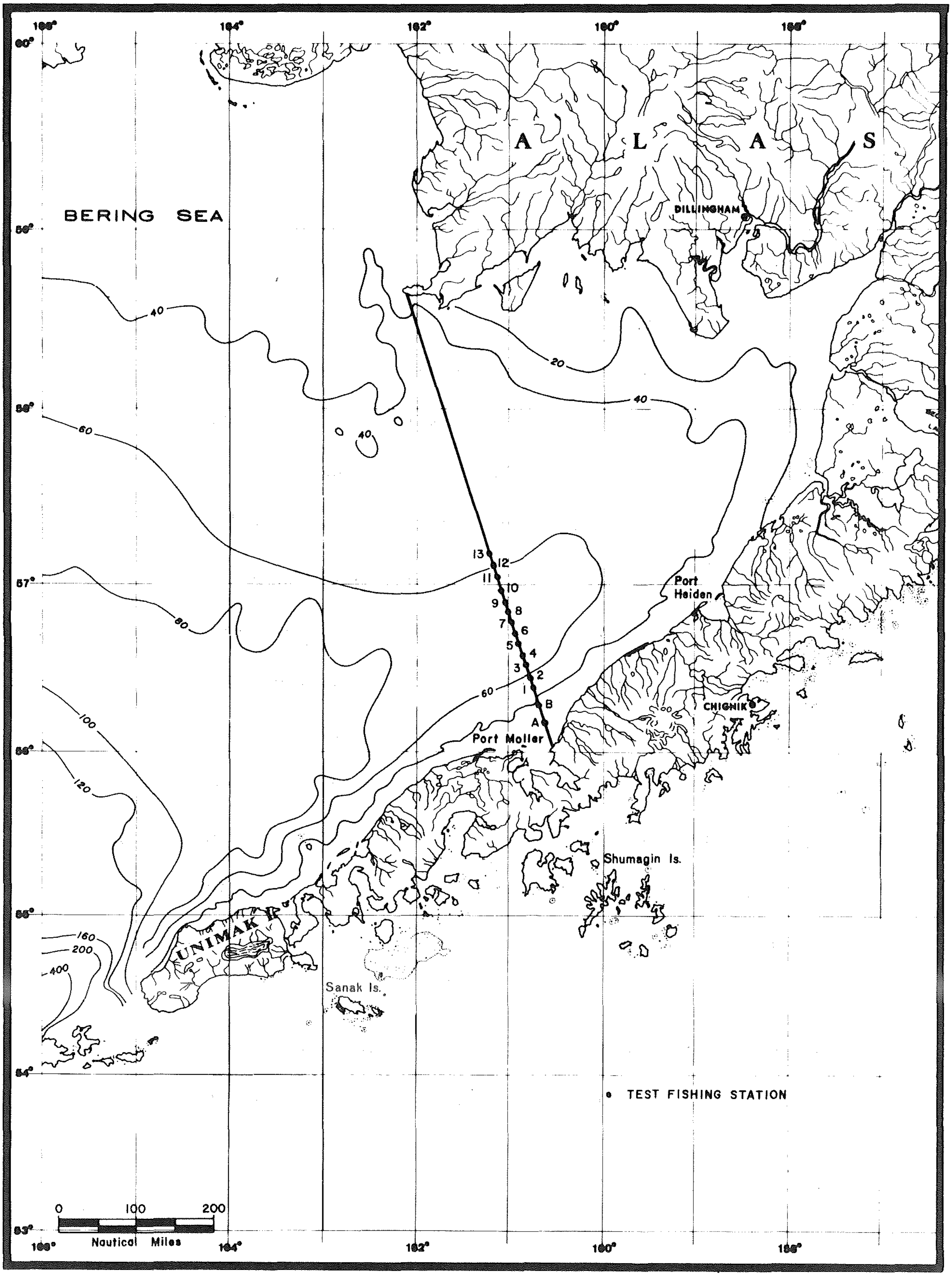

Figure 114. Offshore Bristol Bay salmon test fishing station location (from Paulus 1968).

In the North Peninsula district, Bear River and small streams entering Izembek Lagoon, Nelson Lagoon, and Port Heiden are significant spawning areas for chinook (Figure 115). Of these, the streams entering Nelson Lagoon consistently produce the largest number of chinooks. Altogether this district produces less than 5 percent of the chinook catch reported for the study area. Most large commercial catches in this district are taken between Port Moller and Moffet Point and are probably Nelson Lagoon stock (International North Pacific Fisheries Commission 1961-1970). Chinooks arrive in numbers in the North Peninsula district during the entire month of June; the run peaks at mid-month (Figure 116).

Three river systems in the Bristol Bay district consistently support major spawning populations of chinooks: the Nushagak, Naknek, and Togiak River systems (Figure 115). More than 75 percent of this district's chinook catch is normally taken offshore from the Nushagak River system. Chinooks arrive in numbers in early June, and are available to the fishery through early July (Figure 116). Peak catches are normally

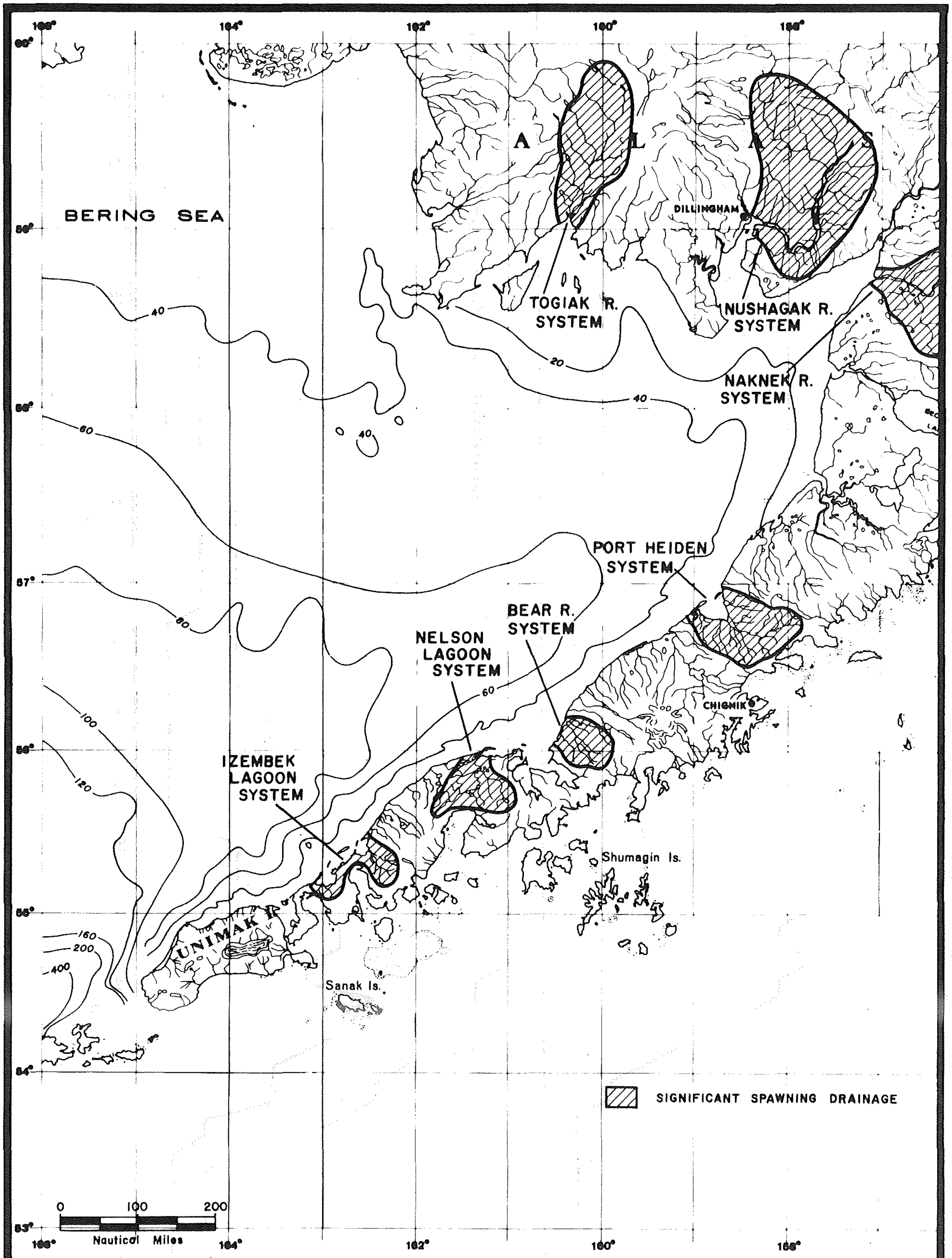

Figure 115. Significant chinook salmon spawning drainages in the Bristol Bay area (from International N. Pac. Fish. Comm. 1961-70).

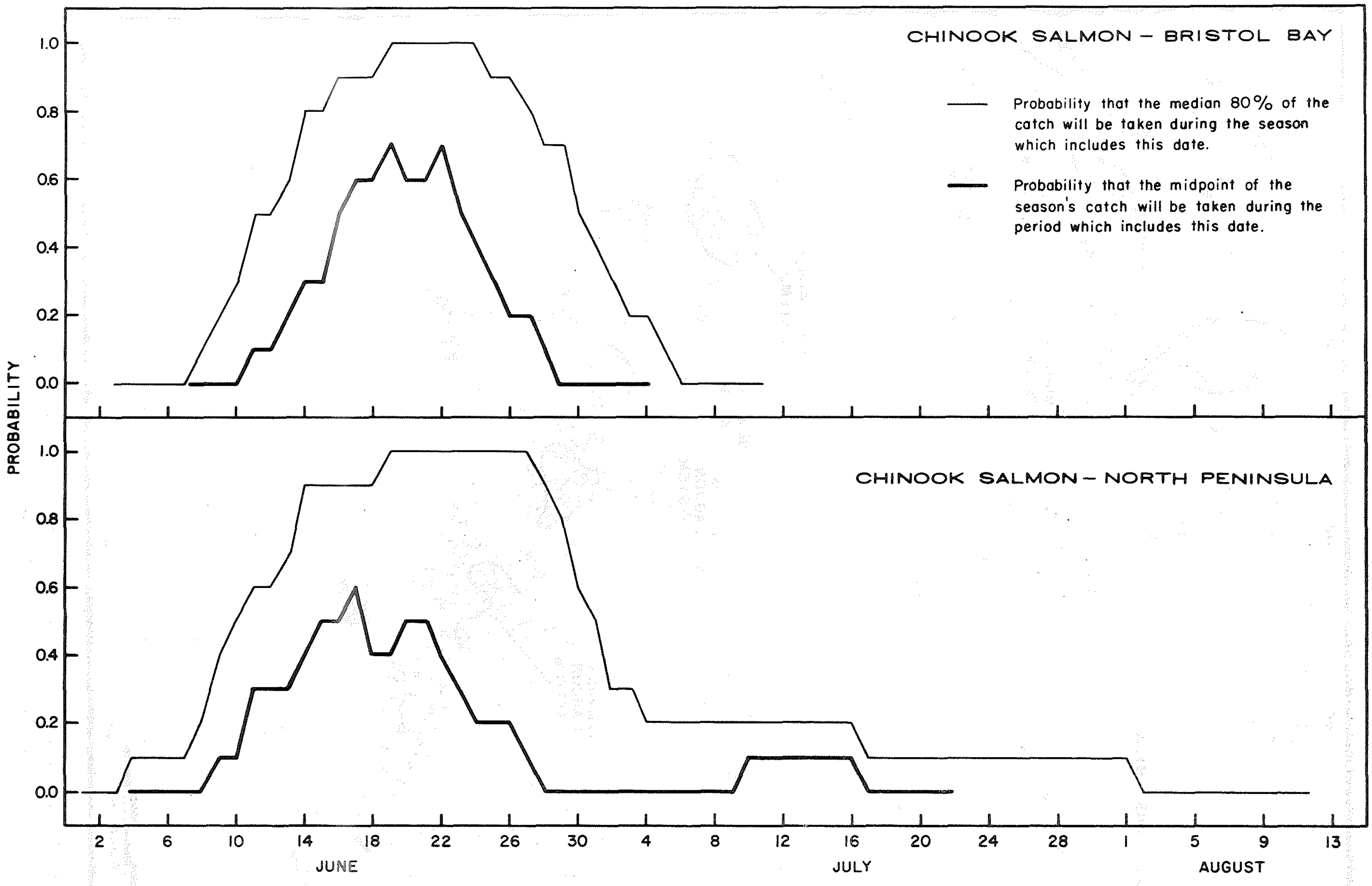

Figure 116. Timing of chinook salmon commercial catches in the Bristol Bay region (from International North Pacific Fisheries Commission 1961-70).

taken between mid-and late June. Almost all chinooks pass upstream beyond the Brooks River weir in the Naknek River system by mid-July (Hartman et al. 1962, Hartman et al. 1964).

Chinook females spawn an average of 5,000 eggs during August and September. Eggs incubate in stream gravel, overwintering to hatch in late winter or early spring. Young may migrate immediately to the ocean or spend as much as 2 years in freshwater. Normally they spend 2 to 4 years in the ocean before returning to spawn. In extreme cases, individuals may not return to spawn until 8 years of age (Burner 1963). While they are in the ocean, chinooks feed upon herring and sand lance, utilizing other small fish, crustaceans, and squid when available (Nanaimo Biological Station undated).

Coho Salmon

According to commercial catch data, coho salmon, Oncorhynchus kisutch, are the least abundant of the 5 salmon species in the study area, except in odd-numbered years when they are more abundant than pink salmon. Coho are not recorded from offshore test fishing, since their runs arrive after this program completes its annual count. Each district accounts for approximately half the total catch of coho taken in the study area.

According to commercial catch data, cohos of the North Peninsula district are most abundant between Port Moller and Moffet Point (International North Pacific Fisheries Commission 1961-1970). These fish are probably spawners bound for the Nelson Lagoon system. Streams entering Port Heiden also support a significant spawning population (Figure 117). Cohos arrive in late August, and are commercially harvested into September. Abundance peaks during the last half of August (Figure 118).

In the Bristol Bay district, most cohos spawn in the Nushagak and Togiak River systems, with smaller populations in the Naknek, Ugashik, and Egegik River systems (Figure 117). The Nushagak subdistrict has produced more than 60 percent of this district's commercial coho catch in the last

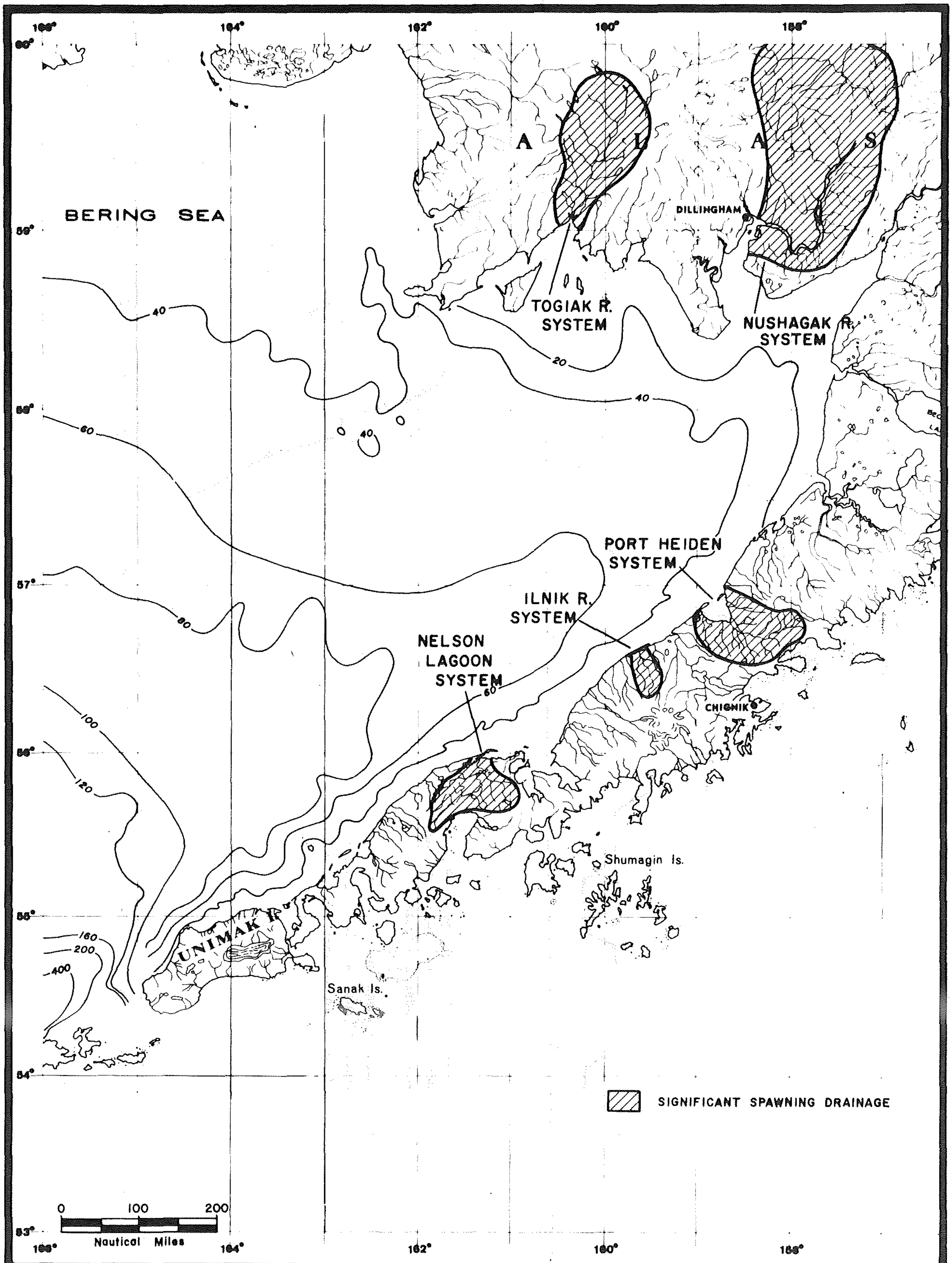

Figure 117. Significant coho salmon spawning drainages in the Bristol Bay area (from International N. Pac. Fish. Comm. 1961-70).

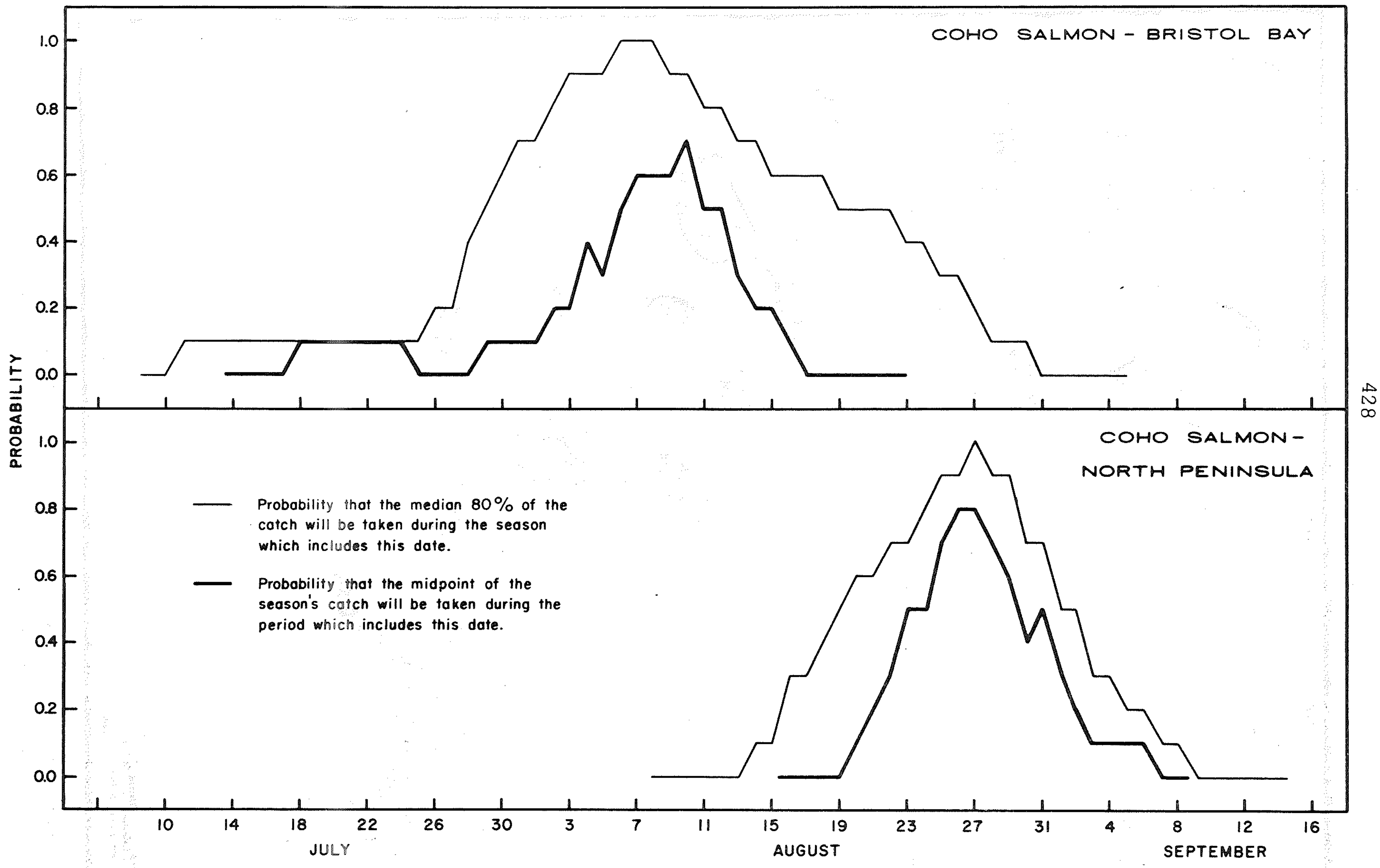

Figure 118. Timing of coho salmon commercial catches in the Bristol Bay region (from International North Pacific Fisheries Commission 1961-70).

10 years (International North Pacific Fisheries Commission 1961-1970). Cohos are taken from late July into late August with catches peaking in early August (Figure 118). More than 90 percent of the cohos that passed the Brooks River weir during their migration up the Naknek River system, did so after August 20 (Hartman et al. 1962, Hartman et al. 1964).

During autumn, cohos spawn an average of 3,500 eggs per female in freshwater streams. Eggs develop in gravel, overwintering to hatch in late winter or early spring. Juvenile cohos spend 1 to 2 years in fresh water before migrating out to salt water. After an additional year or two in salt water, cohos return to spawn and die (Burner 1963). In the marine environment, cohos feed upon herring and sand lance, as well as other small fish, squid, and crustaceans (Nanaimo Biological Station undated).

Chum Salmon

Chum salmon, *Oncorhynchus keta*, spawn throughout the study area. Approximately 90 percent of the chum harvest in the study area is taken in the Bristol Bay district. Chums were caught in quantity off Port Moller (Figure 114) in offshore test fishing with gill nets (Seibel 1967, Paulus 1968, 1969, 1970, 1971, 1972, 1973). Approximately 90 percent of the chum were taken at stations 3 through 11 (40 to 95 km. offshore) with stations 6 and 7 together producing 30 percent of the catch. More than 90 percent of these fish were caught between June 19 and July 9.

Compared to the Bristol Bay district, the North Peninsula district produces small numbers of chums. Most are caught near Bechevin Bay and Izembek Lagoon (Figure 119). Large catches are also taken in the vicinity of Port Moller and Nelson Lagoon. Fish are present from early July through late August, with peak runs in late July (Figure 120).

In the Bristol Bay district, chums spawn most abundantly in the Nushagak, Kvichak, and Togiak River systems (Figure 119). Smaller numbers spawn throughout the area. On an average, the Nushagak River system alone produces half the commercial catch of this district (International North Pacific Fisheries Commission 1961-1970). Chums appear in late June and remain abundant into mid-July. Peak runs normally arrive during early July (Figure 120).

During late summer, chum salmon spawn in freshwater gravel averaging 3,000 eggs per female. Eggs develop in

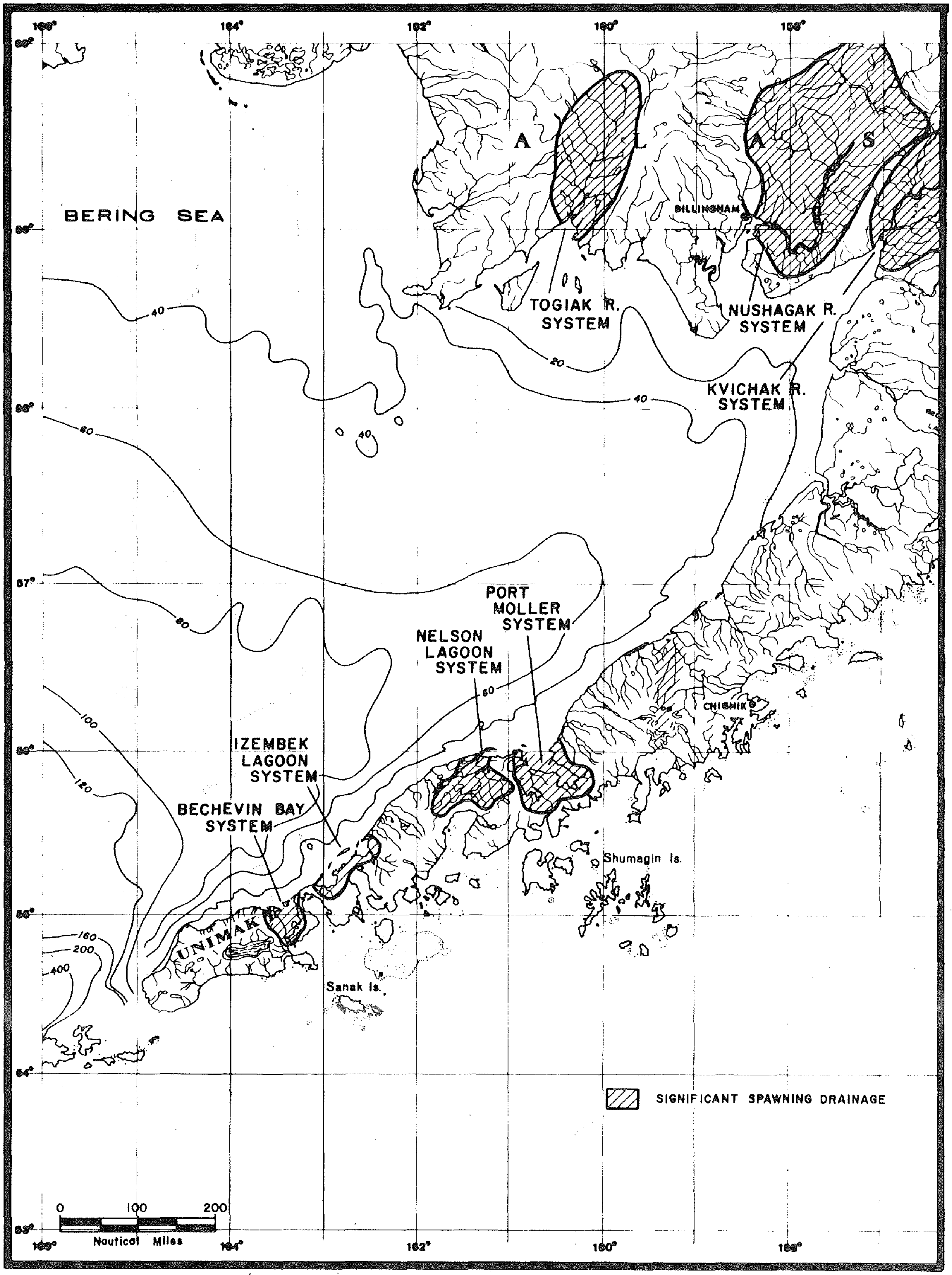

Figure 119. Significant chum salmon spawning drainages in the Bristol Bay area (from International N. Pac. Fish. Comm. 1961-70).

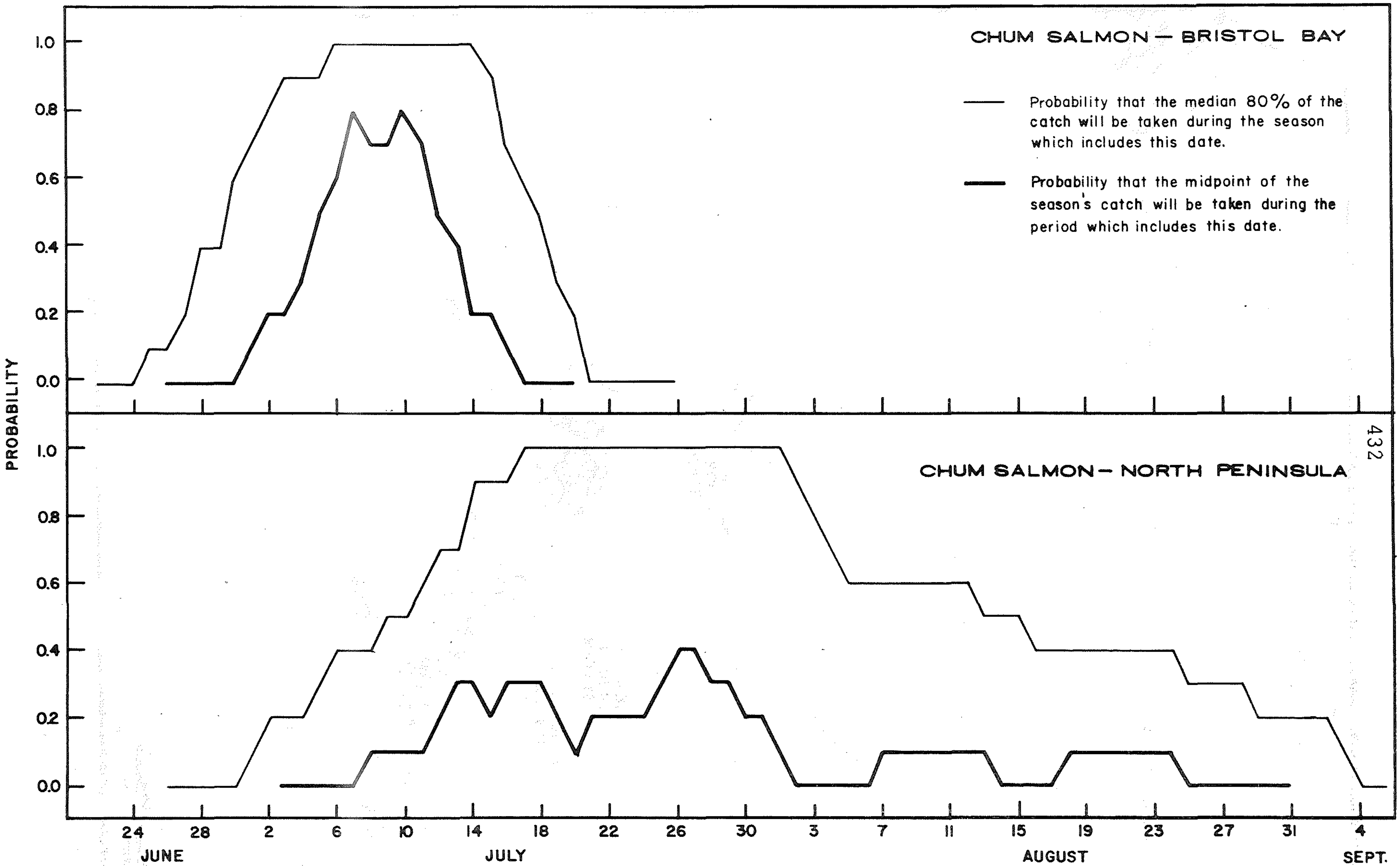

Figure 120. Timing of chum salmon commercial catches in the Bristol Bay region (from International North Pacific Fisheries Commission 1961-70).

the gravel to hatch in late winter or early spring. Young chums move directly to salt water where they spend 4 years or less growing and maturing. At the end of this period, adults return to the coastal environment to spawn (Burner 1963). Chums feed primarily on small crustaceans (Nanaimo Biological Station 1967).

Pink Salmon

The abundance of pink salmon, Oncorhynchus gorbuscha, varies significantly within the study area; even year catches are consistently several hundred times larger than the odd year harvests (International North Pacific Fisheries Commission 1961-1970).

Pink salmon are harvested in small numbers in the North Peninsula district with Bechevin Bay producing more than 90 percent of the catch (Figure 121). In even years, the North Peninsula catch comprises less than 1 percent of the total pink harvest within the study area. In odd years, North Peninsula pink salmon, although less abundant than in even years, comprise more than 70 percent of the total pink harvest within the study area, since odd year Bristol Bay pink runs are almost nonexistent. Pink salmon arrive in

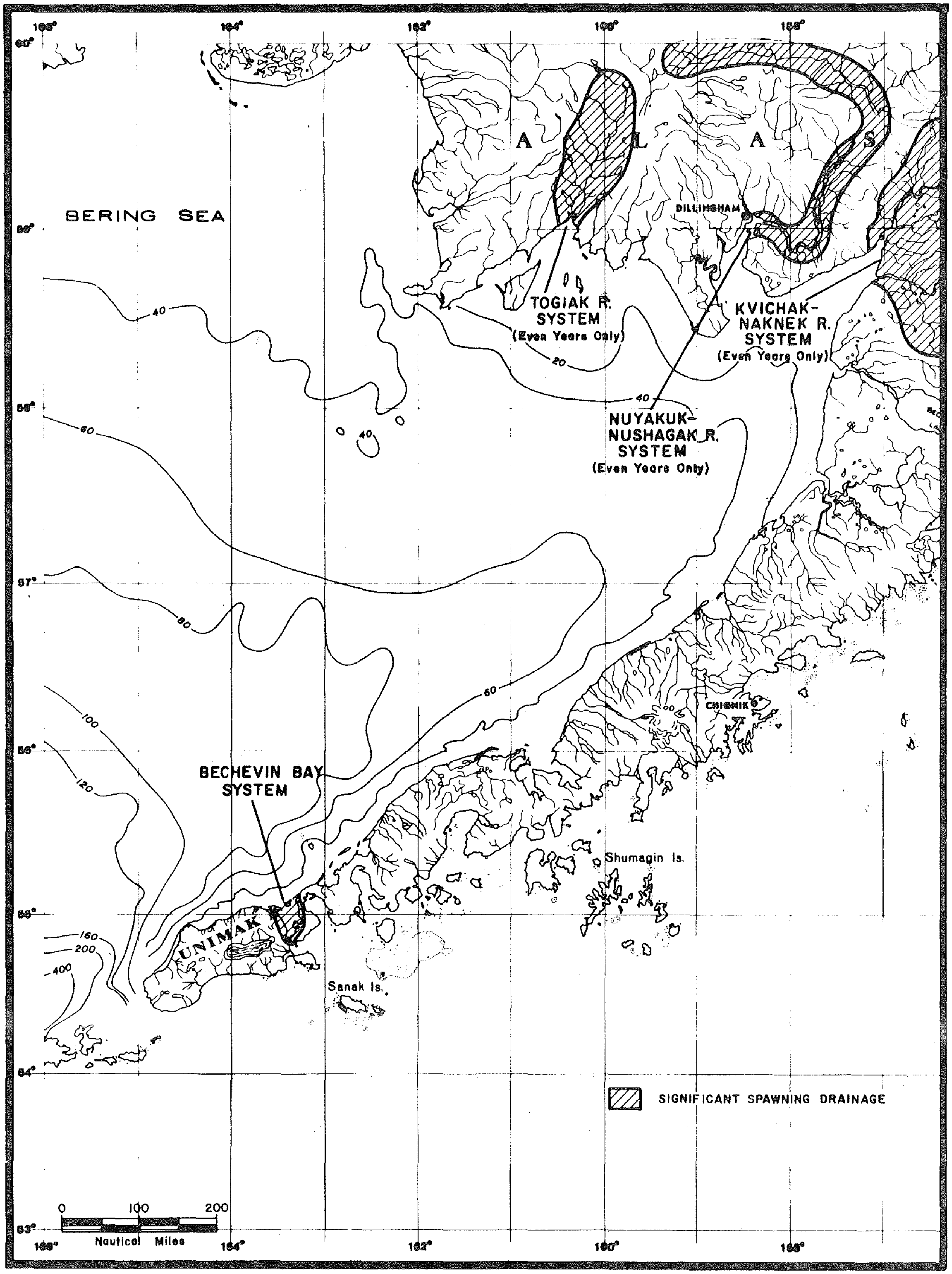

Figure 121. Significant pink salmon spawning drainages in the Bristol Bay area (from International N. Pac. Fish. Comm. 1961-70).

early July and are numerous through mid-August. Peak abundance occurs in early Ausust in even years (Figure 122).

Bristol Bay district pinks spawn in the Togiak, Nushagak (Nuyakuk R.), and Kvichak-Naknek River systems (Figure 121). Largest catches are recorded in even years from the Nushagak subdistrict; these catches comprise more than 90 percent of the total district pink harvest (International North Pacific Fisheries Commission 1961-1970). Pinks arrive in numbers by mid-July and are abundant through the first of August in even years. Peak catches are generally recorded in late July (Figure 122). In odd years, pink salmon arrive approximately two weeks earlier. More than 80 percent of those pink salmon which pass upstream beyond the Brooks River weir in the Naknek River system, do so between July 10 and August 5 in both odd and even years (Hartman et al. 1962, Hartman et al. 1964).

Pink salmon spawn an average of 2,000 eggs per female during late summer in freshwater streams. Eggs develop in the gravel and hatch in late winter and early spring. Upon emerging from the gravel, young pinks move immediately into salt water where they spend the next 1.5 years. All pink

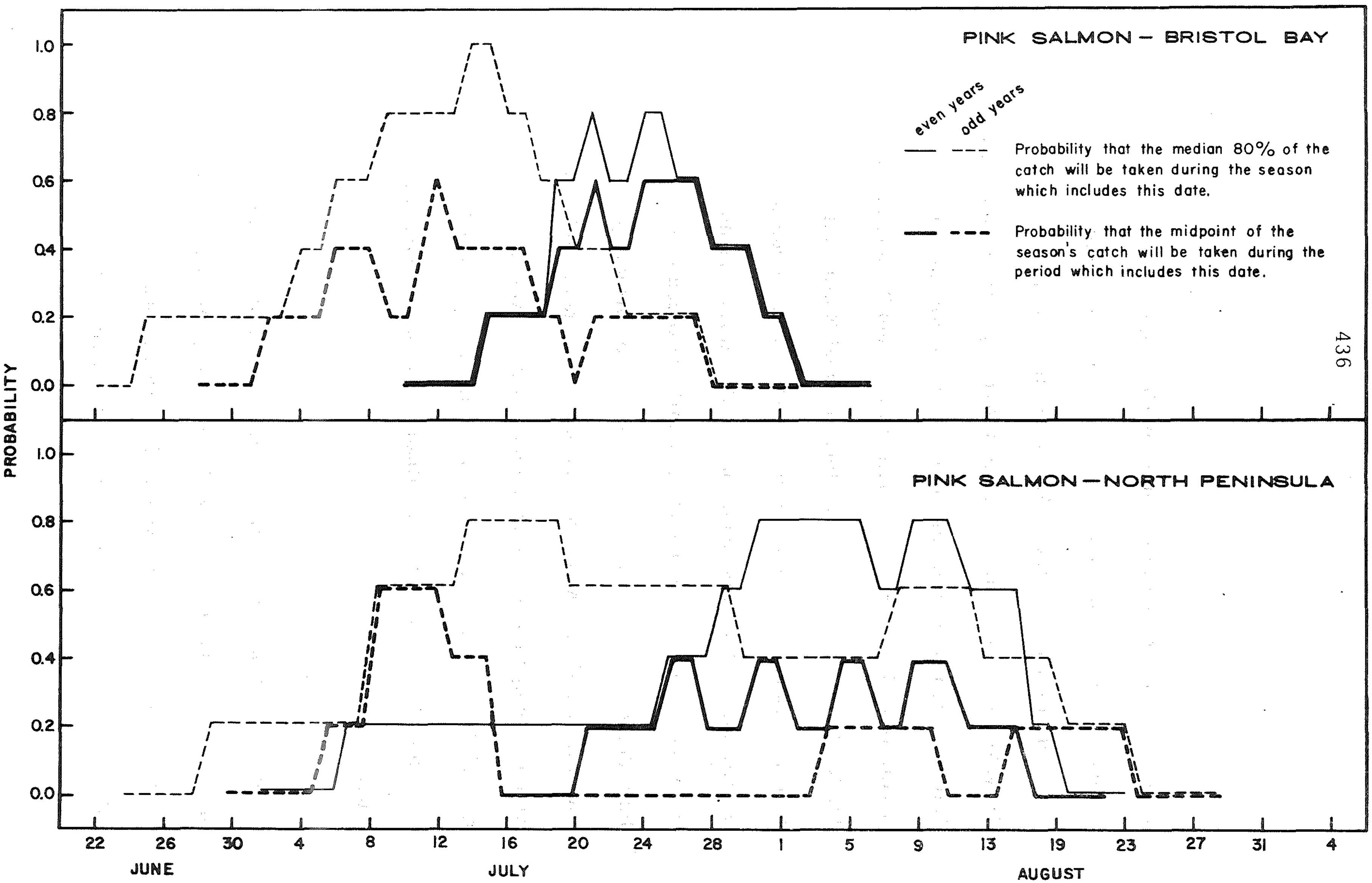

Figure 122. Timing of pink salmon commercial catches in the Bristol Bay region (from INPFC 1961-70).

salmon mature by 2 years of age and at that time return to spawn. Pink salmon feed primarily upon planktonic crustaceans while in salt water (Burner 1963).

Sockeye Salmon

Sockeye salmon, Oncorhynchus nerka, are the most abundant of the salmon species in the study area. Straty (1969), in summarizing test fishing results from outer Bristol Bay and the eastern Bering Sea, found that sockeyes inbound on their spawning migration were concentrated offshore, north and south of the Pribilof Islands (Figure 123). In the inner Bay, inbound sockeye stocks begin to separate as they approached river mouths (Figure 124).

In the North Peninsula district, Bear River and Nelson Lagoon support large runs of sockeyes (Figure 125). Fish arrive in late June and remain abundant into late July, apparently peaking during early July (Figure 126).

In the Bristol Bay district, sockeye spawn most abundantly in the Wood, Kvichak-Naknek, and Egegik River

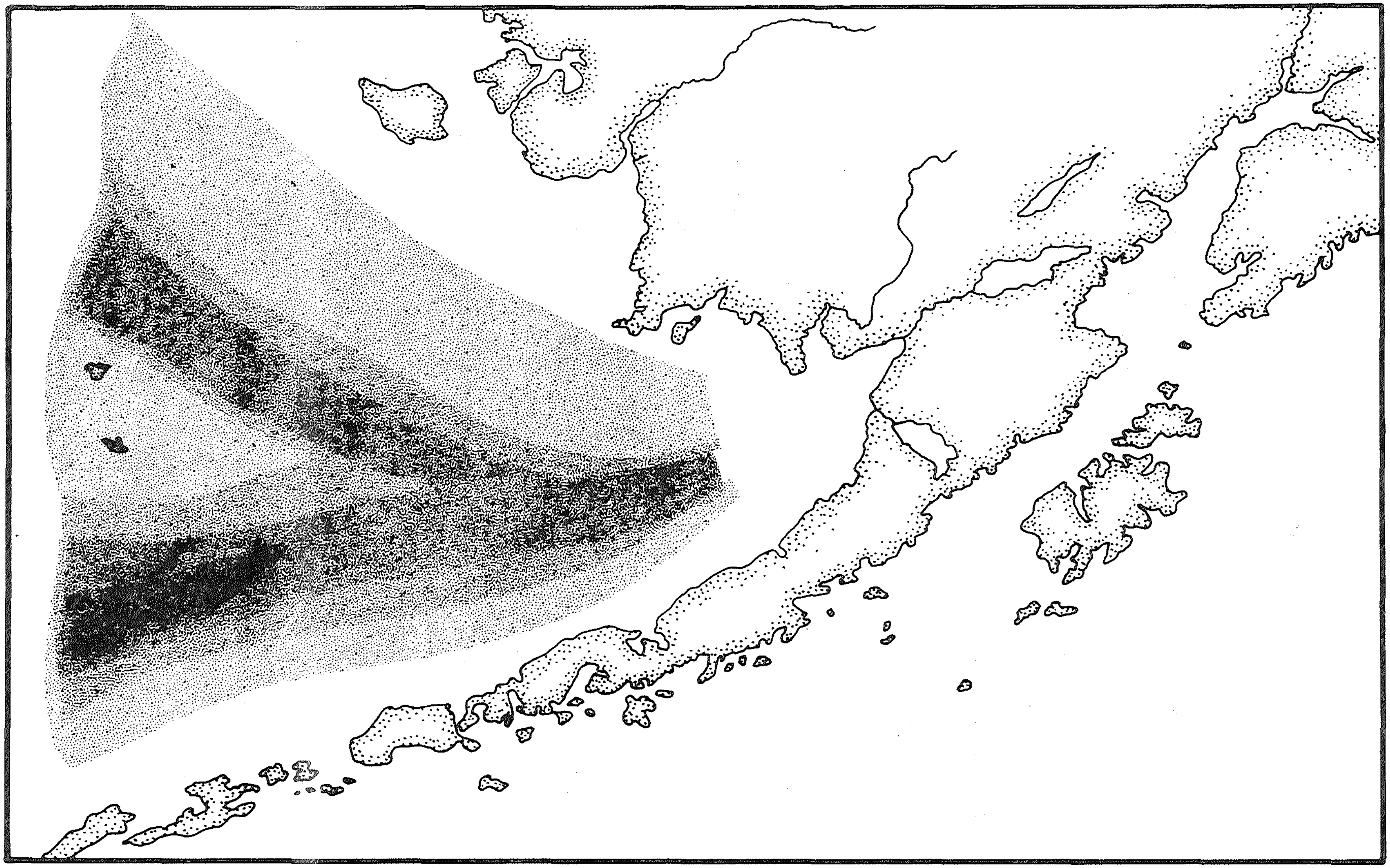

Figure 123. Distribution of sockeye salmon in outer Bristol Bay during spawning migration, showing areas of relative abundance (from Straty 1969).

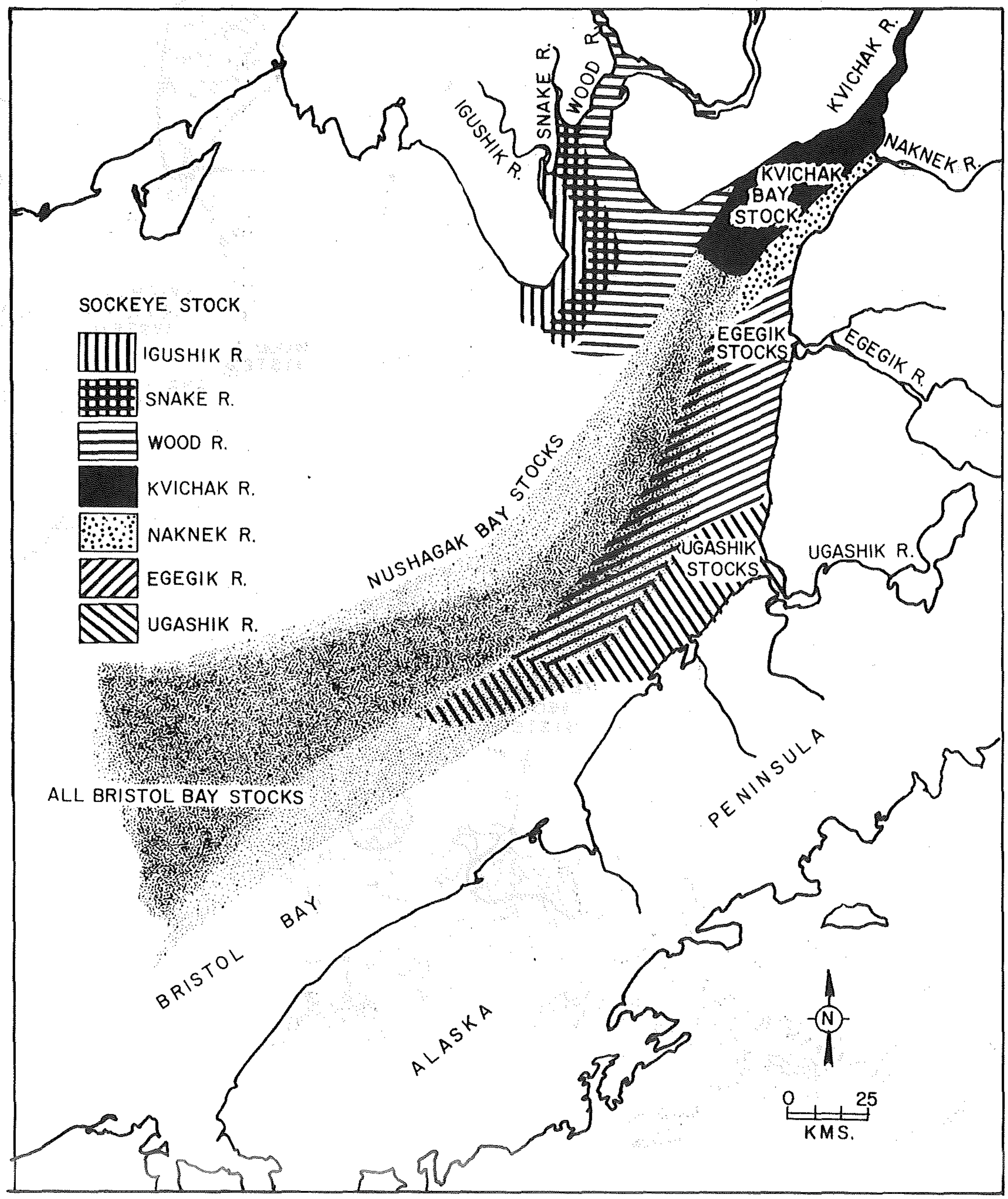

Figure 124. General distribution of Bristol Bay stocks of sockeye salmon, showing areas of greatest stock abundance (from Straty 1969).

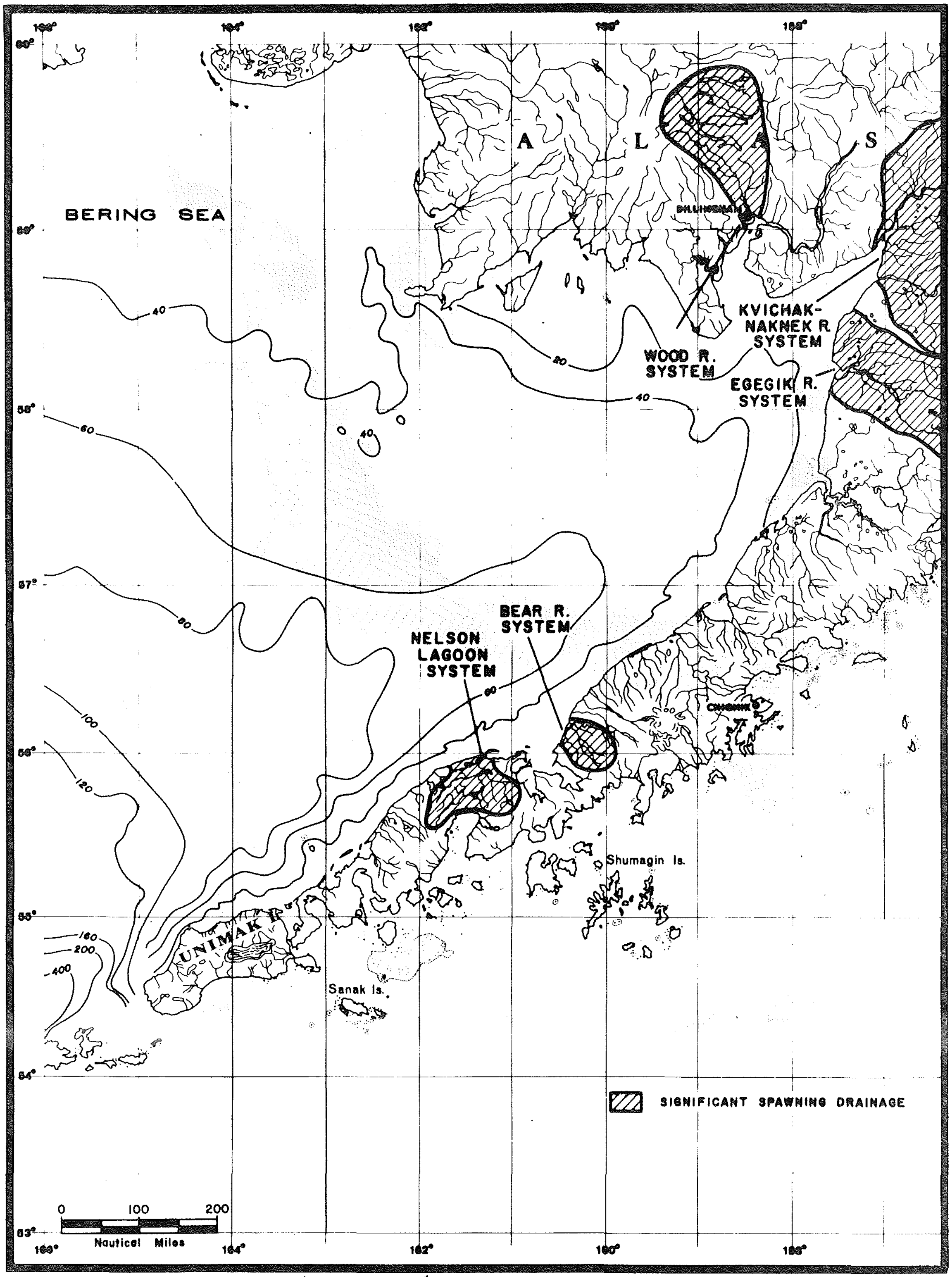

Figure 125. Significant sockeye salmon spawning drainages in the Bristol Bay area (from International N. Pac. Fish. Comm. 1961-70).

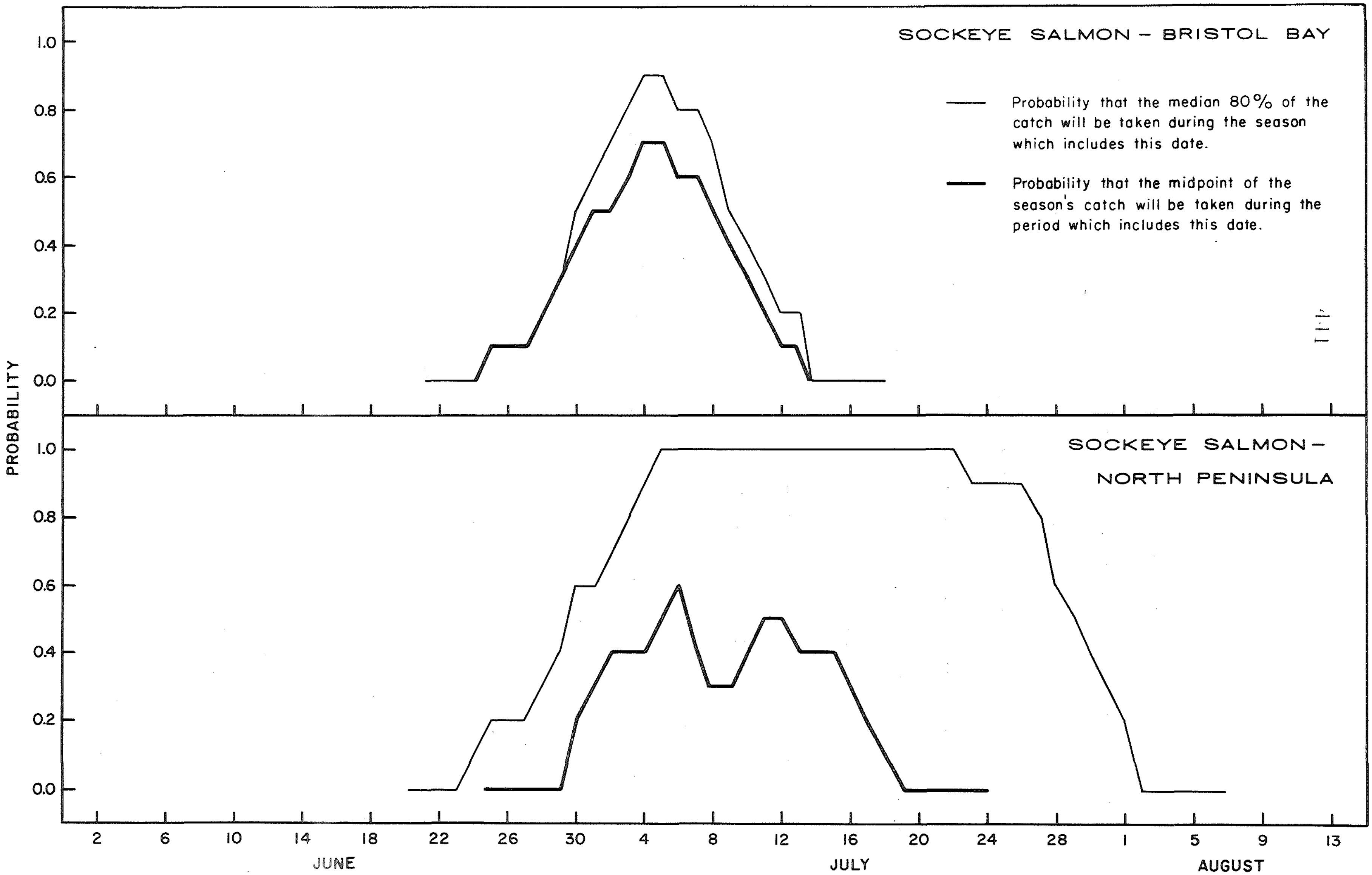

Figure 126. Timing of sockeye salmon commercial catches in the Bristol Bay region (from International North Pacific Fisheries Commission 1961-70).

systems (Figure 125). More than 70 percent of the Bristol Bay sockeye catch is on stocks originating in the Kvichak-Naknek drainages. Sockeyes normally become abundant the last week in June and are numerous through mid-July. These fish arrive about the same date year after year (Figure 126). Almost all sockeyes in the Naknek River system that pass upstream through the Brooks River weir, do so between early July and early August (Hartman et al. 1964).

Sockeyes spawn between 2,000 and 4,500 eggs per female, depending upon size, in freshwater streams and lakes during late summer or early autumn (Hartman and Conkel 1961). Eggs develop in the gravel substrate to hatch in late winter and early spring. Young sockeyes migrate to lakes within the river system soon after hatching. The timing of this migration to Brooks Lake in the Naknek River system may vary from late April to mid-June, depending upon water temperature of the spawning stream (Hartman et al. 1967). Juveniles may spend as long as 3 years in fresh water before they migrate to salt water. Outmigration normally occurs from mid-May through mid-July in Bristol Bay drainages (Table 37). Straty (in press) found that outmigrating smolt in the inner Bay crossed to the north shore of the Alaska Peninsula and migrated southwestward slightly offshore. Beyond the Port Moller area, Straty believes that the smolt move offshore, but insufficient data exist at present to support this generalization. He further reports that smolts take an average of 6 weeks to move through the inner Bay. The inner Bay therefore will contain seaward-migrating sockeye smolts for a total of 2 to 2.5 months. Straty believes that sockeye smolts remain in the outer Bay for several months, though winter sampling is insufficient to substantiate this assumption. Straty found these outmigrating smolts to be concentrated in the upper few meters of surface waters in small scattered schools throughout the study area After 1 to 4 years in salt water mature adults return to spawn, completing the cycle. Sockeyes feed primarily upon planktonic crustaceans during their marine life (Burner 1963).

Table 37. Average dates by which 50 percent of sockeye smolts leave major Bristol Bay river systems (from Hartman et al., 1967).

River system	Date	Number of years of observation
Ugashik	May 30	6
Egegik	June 1	3
Kvichak	June 2	9
Naknek	June 16	7
Wood	June 22	7

Trout and char

Arctic char/Dolly Varden, Salvelinus sp., inhabit the coastal marine environment of Bristol Bay for a portion of their life cycle. Char abound in almost all freshwater systems within the study area, and portions of many populations are anadromous. Rainbow trout, Salmo gairdneri, are not as widely distributed as the char. Rainbow populations in Bristol Bay drainages are not believed to be anadromous and rarely enter salt water.[1]

1. R. Russell Redick, Biologist, Sport Fisheries Division, Alaska Department of Fish and Game, Anchorage. Personal communication.

The Togiak River system contains one of the largest char populations in the study area. Native residents take an annual subsistence harvest of between 50,000 and 100,000 returning char from this population. The Nushagak and Ugashik Rivers also support sizeable anadromous populations (Figure 127). Char numbers increase from south to north in the study area.[1]

Both marine juveniles and adult spawners overwinter in freshwater lakes. The fish return to fresh water from late July through freeze-up, with the peak return in September.[2] Spawning occurs in October when females, depending upon size, deposit between 600 and 7,000 eggs in freshwater stream gravels. After spawning in stream gravels, adults join migrating juveniles in freshwater lakes where they spend the winter. Eggs develop through the winter and young char emerge from the gravel in spring.

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1. Donald L. Siedelman, Area Management Biologist, Sport Fisheries Division, Alaska Department of Fish and Game, King Salmon. Personal communication.

2. Ibid.

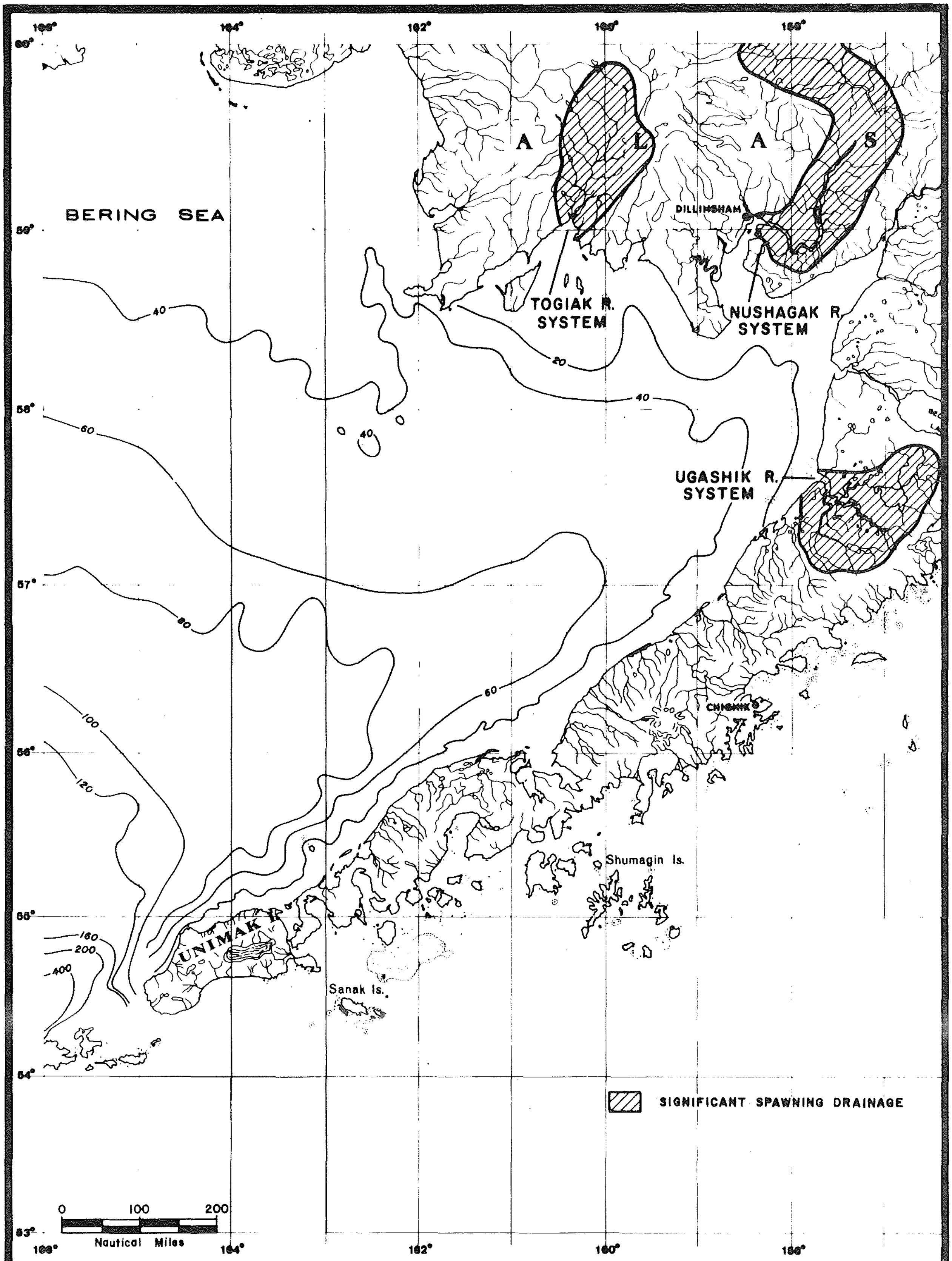

Figure 127. Significant Dolly Varden/Arctic char spawning drainages in the Bristol Bay area (from Donald L. Siedelman, Pers. comm.).

Juvenile char remain in fresh water until their 3rd or 4th year, usually reaching maturity in 5 to 6 years. After overwintering in fresh water, surviving adults outmigrate in spring. Juveniles may outmigrate to the ocean in late spring and early summer, but defintive information is not available. Since char overwinter in freshwater lakes, a return migration each year in late summer and early autumn brings marine juveniles and ripening adult spawners back into fresh water. This pattern is repeated each year (Armstrong 1969).

Armstrong (1969) doubts if more than half the char spawners survive to spawn a second time. Various populations may spawn annually or biennially; stocks further north show a tendency toward biennial spawning. Char may live to a maximum age of 8 years.

Birds

Birds are abundant throughout the Bristol Bay area and several refuges have been created for them (Figure 128).

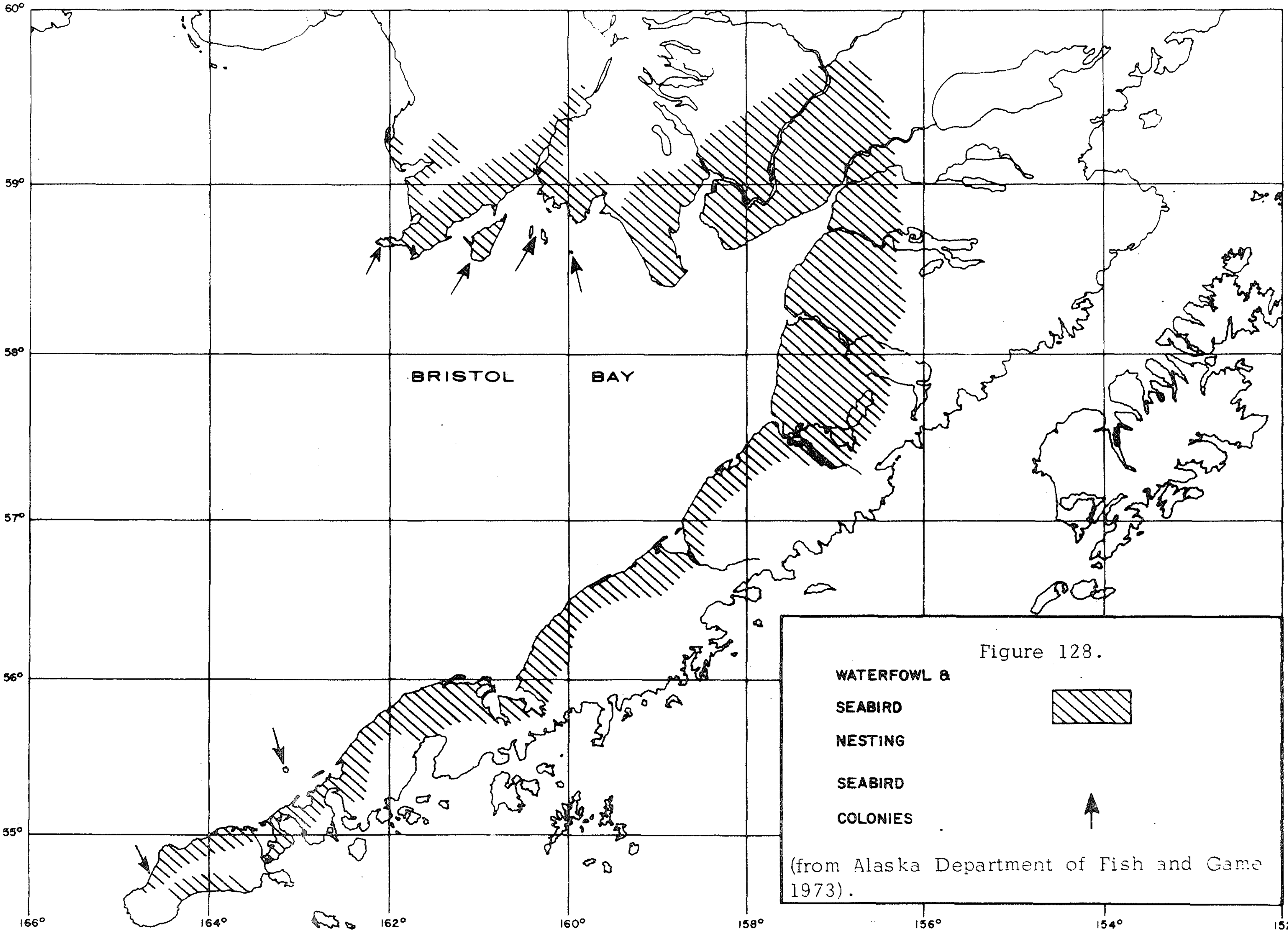

Figure 128.

(from Alaska Department of Fish and Game 1973).

The waterfowl are a source of food for Bristol Bay residents and are a valuable source of recreation for hunters, birdwatchers and others throughout their range. They are also a source of food for many animals in the area. Large numbers of birds reproduce in the Bristol Bay area in summer, and migrate to other, more temperate climates in winter. Guano dropped by birds makes a fine fertilizer. Murie (1959) speculated that the marine bird guano provided a readily available source of nutrients for microscopic plants and animals, and accounted for the high plankton productivity in the Aleutian Island area.

Raptors

Bristol Bay raptors which interact frequently with marine life are the northern bald eagle, *Haliaeetus leucocephalus*; the peregrine falcon, *Falco peregrinus*; and the gyrfalcon, *Falco rusticola*. These birds habitually nest along the coastal cliffs, where they feed largely on sea birds, fish, and crustaceans.

Kenyon (1969) reports that bald eagles often scavenge sea otter remains in the Aleutians, but seldom kill the otters.

Eagles also prey on spawning salmon, especially the dead ones which require less energy to catch (Bent 1938).

The peregrine falcon feeds largely on birds. Bent (1938) listed grebes, auklets, murrelets, small gulls, terns, petrels, wild ducks from the size of mallards down to teal and small shearwaters as peregrine prey. A report by Craddock and Carlson (1970) describes a peregrine resting on a ship 418 km. from land at 48 degrees 30 minutes N, 168 degrees 40 minutes W. This peregrine was feeding on storm petrels. Observers could not see the method of capture, but noted that the falcon was "wet when it returned to the ship." The subspecies observed was the American peregrine, *Falco peregrinus anatum*, which is currently on the list of endangered species.

Gyrfalcons nesting along the coast also prey extensively on pelagic birds. A gyrfalcon nest located just north of the study area was found to contain remains of the following: A ptarmigan, *Lagopus* sp. (23.8 percent); 5 unidentified shorebirds (13.2 percent); 4 unidentified songbirds (10.5 percent); 3 unidentified waterfowl (7.9 percent); 2 western sandpipers, *Ereunetes mauri*, 2 Sabine's gulls, *Xema sabini*, and 2 unidentified gulls or terns (5.3 percent each), and one each of the following species: green-winged teal, *Anas crecca carolinensis*; redbreasted merganser, *Mergus serrator*, common snipe, *Capella gallinago*, pectoral sandpiper, *Erolia melanotos*, dunlin, *E. alpina*, northern phalarope, *Lobipes lobatus*, long-tailed jaeger, *Stercorarius longicaudus*, mew gull, *Larus canus*, Arctic tern, *Sterna paradisea*, redpoll, *Acanthis* sp. and Savannah sparrow, *Passerculus sanwichensis*, (2.6 percent each) (White and Springer 1965). White and Springer also noted possible commensal nesting associations between gyrfalcons and waterfowl; and various waterfowl nests located near the gyrfalcon nest remained undisturbed.

Waterbirds

Anatidae - Ducks, Geese and Swans: One of the striking features of the Bristol Bay area is the variety and abundance of marine and coastal waterbirds. The southern coast of the Bay, especially, is characterized by flat plains with many small lakes and ponds and extensive littoral marshes. Probably the most spectacular bird which occurs in this area is the whistling swan, Olor columbianus. This swan nests in the Lowlands immediately adjacent to the coast, but probably has little direct contact with Bristol Bay waters, as it feeds and nests in small freshwater ponds.

Many species of ducks that are abundant in the area spend most of their time in and around fresh water and seldom come in contact with the marine environment. The mallards, Anas platyrhynchos, and teal, Anas crecca carolinensis, however, have a tendency to gorge themselves on the rotting flesh of spawned salmon. During the winter, these ducks often frequent the mouths of rivers and bays which are not frozen, where they feed on mollusks and crustaceans (Kortright 1967). Pintails, Anas acuta, also frequent the tidal lagoons in great numbers in the summer.

Other species, the diving and sea ducks, such as scaup, Aythya marila; buffleheads, Glavcionetta albeola; oldsquaw, Clanula hyemalis; harlequin, Histrionicus histrionicus; eiders, Polysticta sp. and Somateria sp.; the scoters, *Melanitta* sp., and the mergansers, *Mergus* sp., are more likely to be affected by the condition of the coastal zone, since they inhabit bays and estuaries, feeding largely on aquatic fauna (Table 38).

Swans and many ducks migrate further south in winter.

The Canada goose, *Branta canadensis*, occurs in the study area in great numbers, occasionally feeding along coastal beaches. The geese most frequently found along the shore of Bristol Bay, however, are emperor geese, *Philacte canagica*, and black brant, *Branta nigricans*. These geese are almost totally maritime, although they will graze on shore. Their preferred food is eelgrass, *Zostera marina*, which is particularly abundant in the lagoons along the north side of the Alaska Peninsula, notably Izembek Lagoon in the Izembek National Wildlife Refuge. The seeds of eelgrass are a concentrated energy source. Black brant nest on the Yukon and Kuskokwim deltas (Alaska Department of Fish and Game 1973), but concentrate for several weeks feeding extensively

TABLE 38

FOOD HABITS OF DIVING DUCKS

Name	Percentage of Total Diet						
	Pondweeds	Misc. plant	Molluscs	Insects	Crustaceans	Fishes	Misc. animal
Scaup	19	25	39	7	7		
Goldeneye	9	17	10	28	32	3	1
Bufflehead	7	14	16	41	17	4	1
Oldsquaw	2	10	16	11	48	10	3
Harlequin		1.5	25	10	57	2.5	4
Steller eider	3	10	19	13	45	2	8
Common eider		4	82	2	7		5
King eider		5	46	5	19		25
Spectacled eider	7	16	42	32	3		
White wing scoter		6	75	2	13	2	2
Common scoter	5	5	65	3	17	3	3
Surf scoter	3	9	61	10	10	3	4

Source: Cottam and Knappen 1939.

in Alaska Peninsula lagoons to build up energy for the long flight over water to the California-Oregon coast.[1] The entire population of black brant concentrates around Izembek Lagoon prior to leaving in early November, and again passes through the Refuge on returning in spring. A few thousand brant winter in the Western Gulf of Alaska.

Emperor geese also breed on the Yukon and Kuskokwim deltas and in Siberia, and winter along the Aleutians and the western part of the Alaska Peninsula. In late October, emperor geese concentrate and feed along the north coast of the Alaska Peninsula prior to dispersing to their winter habitat. These geese are reported to feed on algae (30.73 percent); eelgrass and other pond weeds (13.91 percent); grasses and sedges (24.94 percent); undetermined plant fiber (22 percent); bivalve mollusks, (3.66 percent); crabs and other crustaceans (2.18 percent); rodents and fishes (1.76 percent); and miscellaneous animal life (0.82 percent) (Cottam and Knappen 1939). The entire population of emperor geese, some 100,000, lies within the State of Alaska. Since there are no other

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1. Edgar G. Bailey. Former Asst. Refuge Manager (1969-1973), Izembek National Wildlife Refuge, Cold Bay, Alaska. Personal communication.

populations available for restocking, this species is especially vulnerable to eradication.

Gaviidae-Loons: Of the four Alaskan loon species, three are residents of Bristol Bay. Murie (1959) states that the red-throated loon, *Gavia stellata*; the Pacific Arctic loon, *Gavia arctica*, and the common loon, *Gavia immer*, all nest in the margins of tundra ponds around Bristol Bay. Bartonek and Gibson (1972) noted 8 Arctic loons at sea, and a number commuting from tundra ponds (Figure 129). As soon as the young are hatched, they venture into saltwater bays and estuaries. Loons feed mainly on small fish in both salt and fresh water. Although they are extremely awkward on land, they are experts in the water, and can dive to depths of 60 meters (Figure 130). A few loons overwinter along the Bristol Bay coast but most move further south.

Podicipedidae-Grebes: Both the Holboell's red-necked grebe, *Podiceps grisegena*, and the American horned grebe, *Podiceps auritus*, are found in the area. The red-necked grebes nest in the area, and were reported by Jacques (1930) to nest near Port Moller. Like the loon, the grebe nests inland on a pond

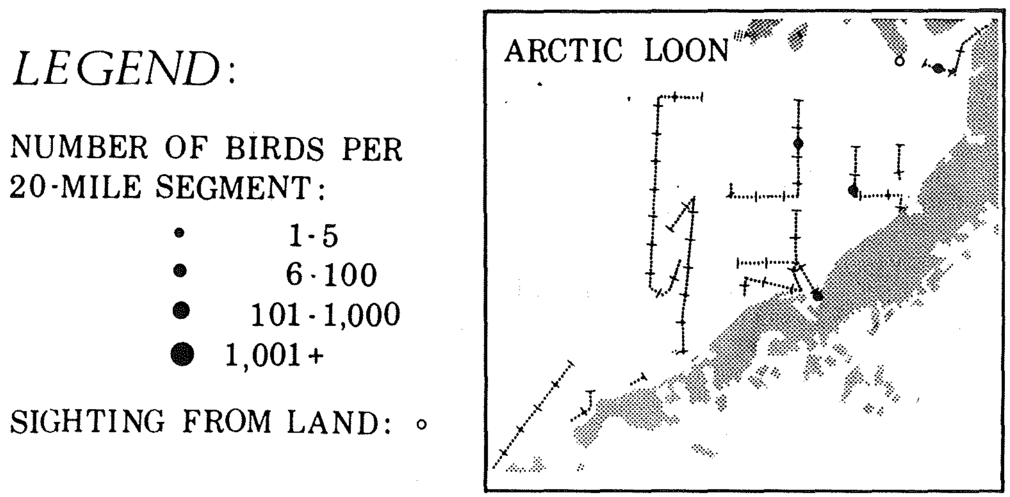

Figure 129. Distribution and numbers of Arctic loon observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

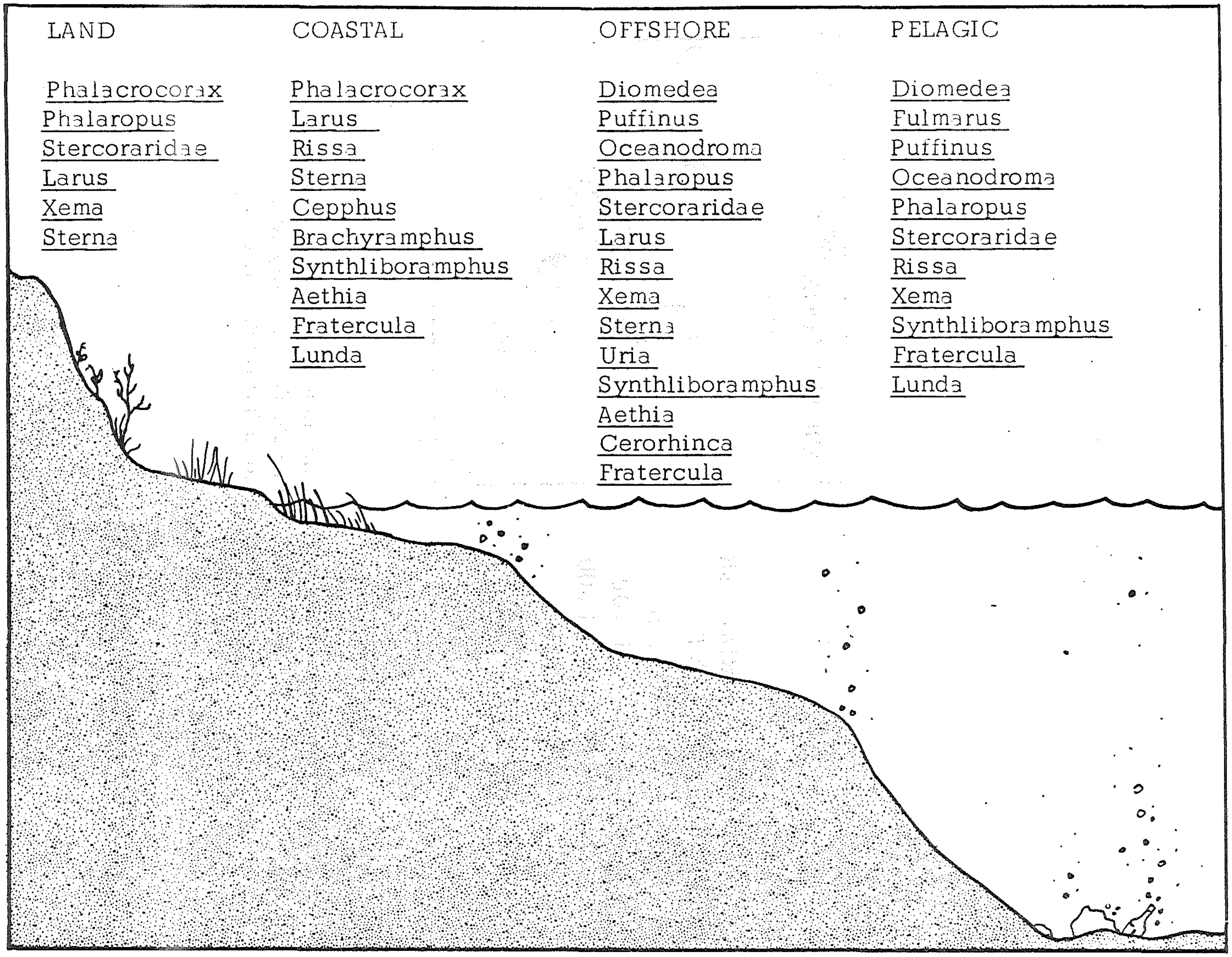

Figure 130. Feeding habitat of sea birds (from Ashmole 1971).

or lake where it builds a platform of rotting vegetation. The decay of the vegetation provides heat and helps to incubate the eggs (Murie 1959). During winter, most of these birds migrate to more temperate areas although a few remain along the Bristol Bay coast. They often resemble small periscopes, since they are able to partially submerge. Like loons, they are expert divers and both have essentially the same food habits.

Diomedeidae-Albatross: During the summer months, the black-footed albatross, Diomedea nigripes, is found in the entire North Pacific; it seems to be expanding its range northward (Murie 1959). Turner (1886) saw a number of these birds near Cape Newenham. Turner also noted a number of short-tailed albatross, Diomedea albatrus, in the Cape Newenham area. Unfortunately, due to excessive hunting on its breeding grounds in Japan, populations of this bird declined and it was believed extinct (Gabrielson and Lincoln 1959). Several recent sightings, however, confirm its continued existence (Sanger 1968). The Laysan albatross, Diomedea immutablis, may visit the Bristol Bay area on occasion, although its normal range is along the Aleutian Chain.

Albatross are noted as ship followers and will feed on almost anything on the surface of the ocean. They are occasionally found feeding in tide rips (Murie 1959), but usually stay further out in the ocean. Their wings are ideal for riding sea breezes.

Procellaridae-Shearwaters, Fulmars and Petrels: The only representatives of this family likely to occur in this area are the sooty shearwater, Puffinus griseus, the short-tailed shearwater, P. tenuirostris, and the Pacific fulmar, Fulmarus glacialis. None of these birds nest in the area, although the fulmar nests on the Pribilof Islands. The sooty and short-tailed shearwaters were counted by Bartonek and Gibson (1972), and numbered more than 108,000 in the Bristol Bay area, all west of 158 degrees 30 minutes W (Figure 131). The sooty shearwater breeds mainly off the coast of New Zealand, where there is a small harvest of these colloquially-named "muttonbirds." The flightless young are reported to taste like sheep, and are relished by the coastal people. The short-tailed shearwater breeds off the coast of Australia, where it is known as the "Tasmanian muttonbird," and is also harvested (Falla et al. 1966).

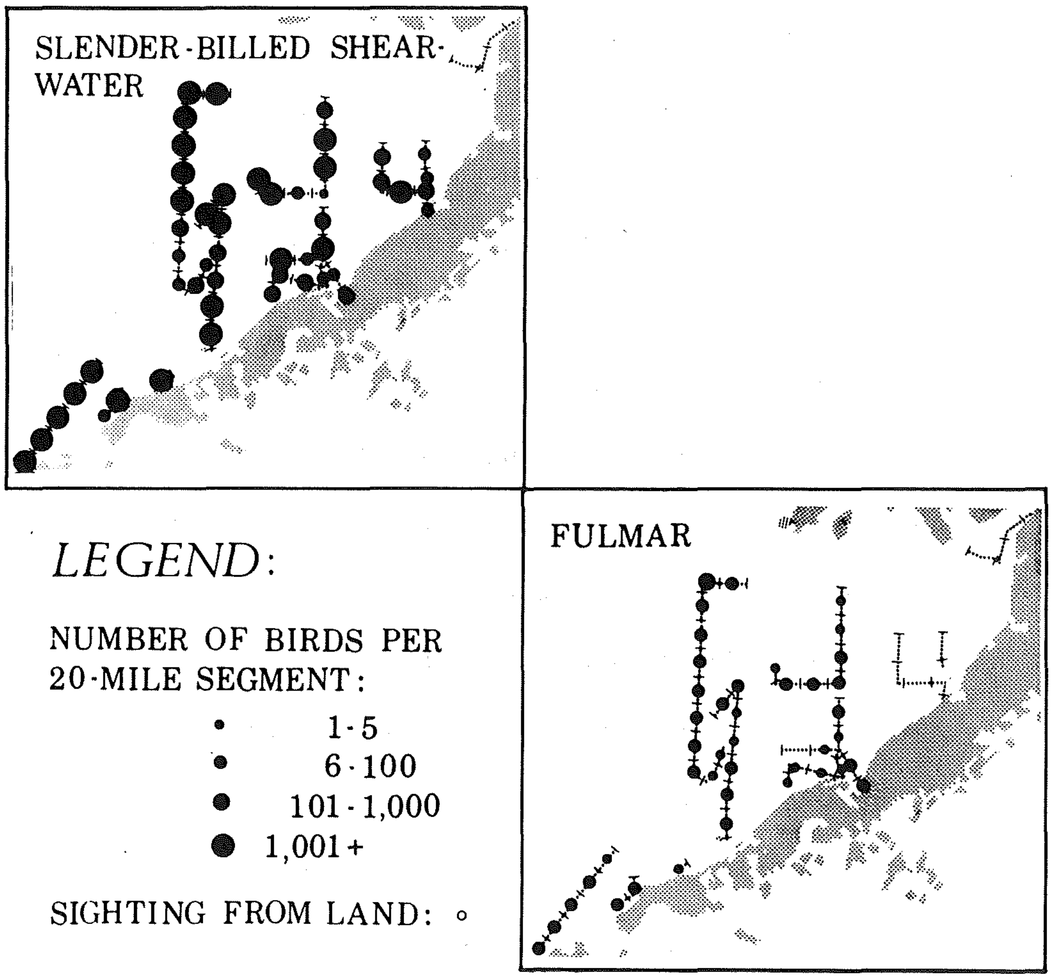

Figure 131. Distribution and numbers of fulmar and short-tailed shearwater (slender-billed shearwater) observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

Shearwaters and fulmars have very similar food habits, and are often found together in large groups. Arnold (1948) estimated sighting 38,000 fulmars and 160,000 shearwaters in Unimak Pass on June 9, 1943. They were feeding on a reddish-orange marine organism. Fulmars are also attracted to jellyfish, Cyanea capillata, which shearwaters and most other birds will not eat. Cottam and Knappen (1939) obtained 10 shearwater stomachs from Alaska. They reported the organic contents of these stomachs to be amphipods, 13 percent; schizopods, 15 percent; undetermined crustaceans, 20.8 percent; squid, Loligo sp., 16.1 percent; undetermined marine invertebrate flesh (possibly squid), 29.4 percent; and fish, 5.7 percent. Gravel composed almost 40 percent of the total stomach contents.

Hydrobatidae-Storm petrels: The 2 species of storm petrels likely to occur in the Bristol Bay area are the fork-tailed petrel, Oceanodroma furcata, and Leach's petrel, Oceanodroma leucorhoa. They are known in literature as "Mother Carey's chickens," and are surrounded by superstition because of their habit of following ship's lights at night. Although they are nocturnal, Bartonek and Gibson (1972) counted 98 fork-tailed petrels in Bristol Bay during daytime surveys. Only a single Leach's petrel was observed (Figure 132).

Petrels nest in burrows, and each female lays a single egg. Peterson (1961) says they feed on plankton, crustaceans, and small fish. Petrels feed by "pattering" just above the water surface (Ashmole 1971). They often regurgitate a smelly oil when disturbed, and there are reports that they occasionally feed on oil extruded from wounded whales or seals (Murie 1959). Since wounded whales or seals are infrequently encountered, it is unlikely that this is a major portion of the bird's diet.

Phalacrocoracidae-Cormorants: The pelagic, *Phalacrocorax pelagicus*; red-faced, *P. urile*, and double-crested, *P. auritus*, cormorants all commonly nest in cliffs bordering Bristol Bay (Bartonek and Gibson 1972) (Figure 133). The double-crested cormorant frequently nests on flat islands in the middle of lakes. Cormorants nest in small colonies and lay 3 to 5 bluish eggs on a mass of vegetation--usually seaweed. The young remain in and about the nest until they are mature enough to join their parents in foraging for small fish that abound along the coast (Alaska Department of Fish and Game 1973). They may also consume crustaceans when available.

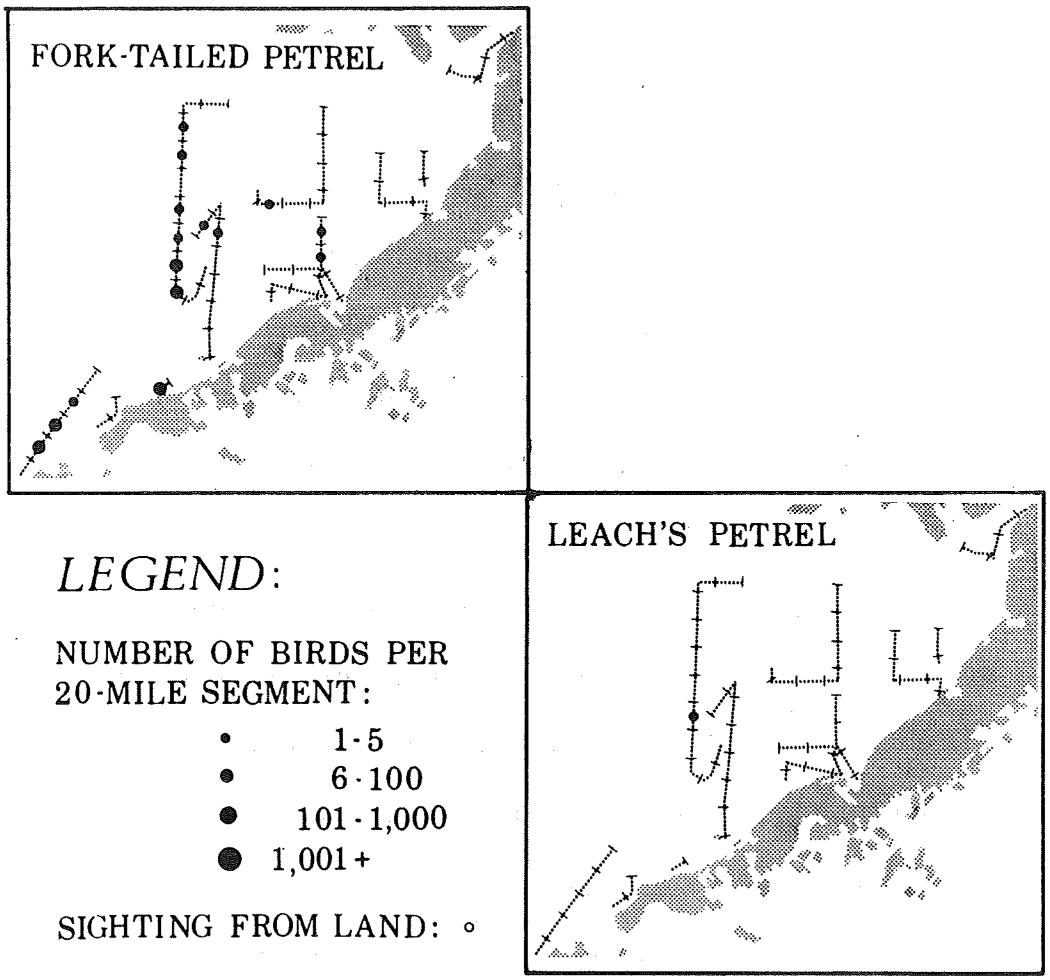

Figure 132. Distribution and numbers of Leach's petrel and fork-tailed petrel observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

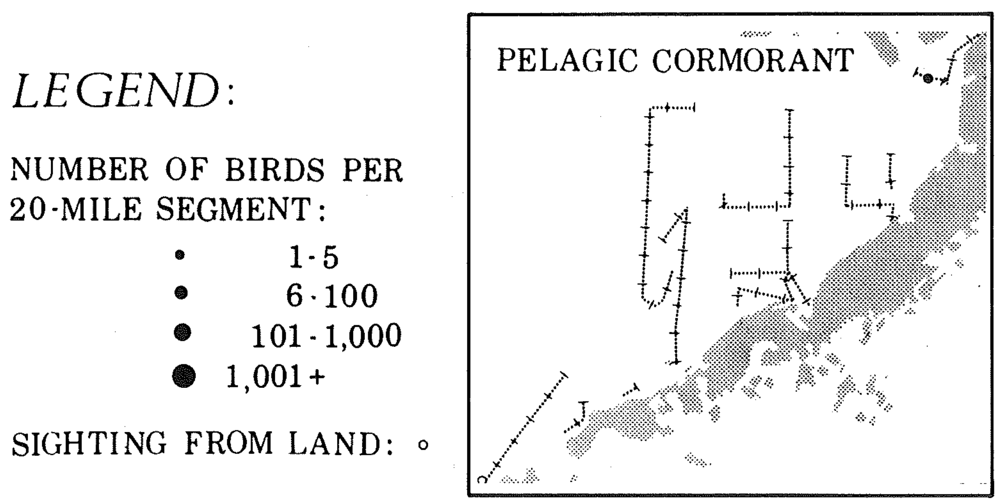

Figure 133. Distribution and numbers of pelagic cormorant observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972)

Cormorants often congregate on piers, docks, and old trees remote from humans, where they have a habit of spreading their wings to dry. These birds are excellent divers. Unlike many birds, which use their wings in swimming underwater, cormorants propel themselves with their feet.

Haematopodidae-Oystercatchers: The black oystercatcher, *Haematopus bachmani*, is a permanent resident in Alaska, inhabiting rocks along the shore. Jacques (1930) noted 1 near Unimak Island, probably the northern limit of this bird's range (Peterson 1961). Oystercatchers forage below the high tide mark, looking for bivalves, oysters, crabs, and marine worms. The primitive nest may be simply the rocks of the beach or perhaps a small depression in a large rock, where the female lays 2 or 3 eggs in late spring. Towards the end of summer, the whole family forages together, while the young are taught the specialized skills needed to find and break open their food.[1] Its preference for rocky habitat precludes the likelihood that it is found much farther east than Unimak Island on the north side of the Alaska Peninsula.

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1. Nikko Tinbergen. 1973. Special Television Program on Oystercatchers, "The Specialist." Time-Life Films, Inc. New York, N.Y.

Charadriidae-Plovers: The semipalmated plover, Charadrius semipalmatus, and the American golden plover, Pluvialis dominica, are the most frequently encountered of these shorebirds in the Bristol Bay area. These plovers may nest along the shores of the Bay (Murie 1959).

These birds frequent the shoreline, where they feed predominantly on small marine life.

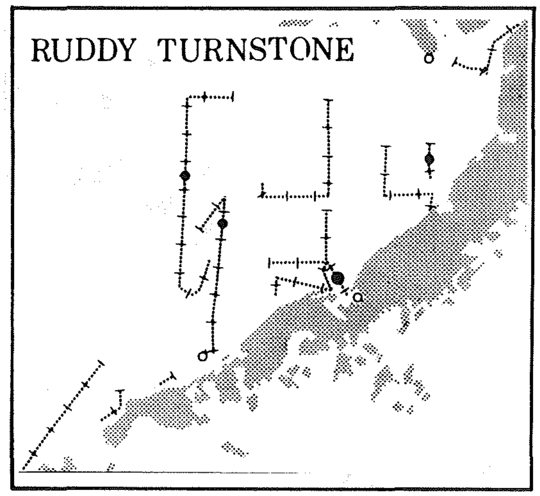
Scolopacidae-Snipes, Sandpipers, Yellowlegs and Turnstones: This is a large family, with a number of representatives in the Bristol Bay area. The species which breed here include the common snipe, Capella gallinago; the wandering tattler, Heteroscelus incanum; the greater yellowlegs, Totanus melanoleucus; the Aleutian sandpiper, Calidris ptilocnemis; the least sandpiper, C. minutilla; the dunlin, C. alpina; the shortbilled dowitcher, Limnodromus griseus; the ruddy turnstone, Arenaria interpres, and the black turnstone, A. melanocephala (Murie 1959).

Although the black turnstone nests at Nushagak, Kvichak, and Ugashik (Murie 1959), the ruddy turnstone is not known to nest south of the Yukon Delta (Gabrielson and Lincoln 1959). During the summer of 1969, Bartonek and Gibson (1972) observed 37 ruddy turnstones at sea (Figure 134).

These birds have diverse habitat preferences, but many are fond of mud flats and marshes, where their long legs and slender bills enable them to catch insects, crustanceans, mollusks, worms, and other invertebrates (Peterson 1961).

Phalaropodidae-Phalaropes: The northern phalarope, *Lobipes lobatus*, breeds in the area (Murie 1959) and the red phalarope, *Phalaropus fulicarius*, is often seen migrating through the Bristol Bay area (Bartonek and Gibson 1972) (Figure 135).

This may be the only bird which reflects the concepts of women's liberation. The female is larger and gaudier than the male, and she does the courting. The male builds the nest and acts as parent after the eggs are laid. This bird has an unique habit of spinning rapidly in the water while dabbing for its food--plankton, marine invertebrates, shrimp, mosquito larvae, and insects (Peterson 1961).



LEGEND:

NUMBER OF BIRDS PER
20-MILE SEGMENT:

- 1-5
- 6-100
- 101-1,000
- 1,001+

SIGHTING FROM LAND: ∘

Figure 134. Distribution and numbers of ruddy turnstone observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

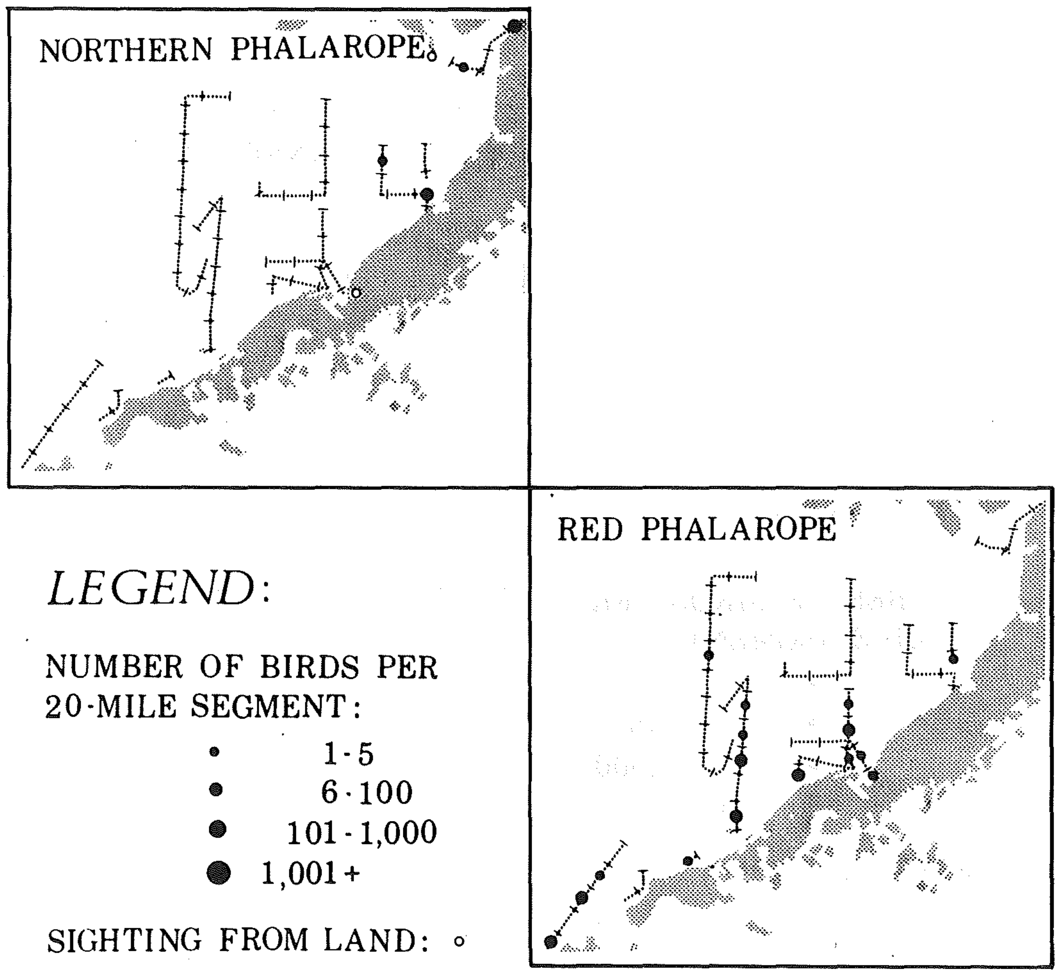


Figure 135. Distribution and numbers of red phalarope and northern phalarope observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

Stercoraridae-Jaegers: Jaegers most frequently found in Bristol Bay are the pomarine, *Stercorarius pomarinus*; the parasitic, *S. parasiticus*; or the long-tailed, *S. longicaudus*. The pomarine and long-tailed jaegers seldom come ashore in the Bristol Bay area, but the parasitic jaeger commonly nests along the coast of the Bay. Jaegers will eat the eggs and young of other nesting birds, as well as rodents and rotting salmon--in short, almost anything they can find. Murie (1959) reports that they even feed on ripe crowberries, *Empetrum nigrum*.

Laridae-Gulls and Terns: These colonial nesters are found in large groups throughout the Bristol Bay area (Bartonek and Gibson 1972) (Figure 136). The glaucous-winged gull, *Larus glaucescens*, is the most common gull. It frequently nests near other colonial birds and shares the predatory instincts of the jaeger. These gulls are also scavengers, and are frequently observed harassing brown bears for fish during salmon runs. Glaucous-winged gulls feed

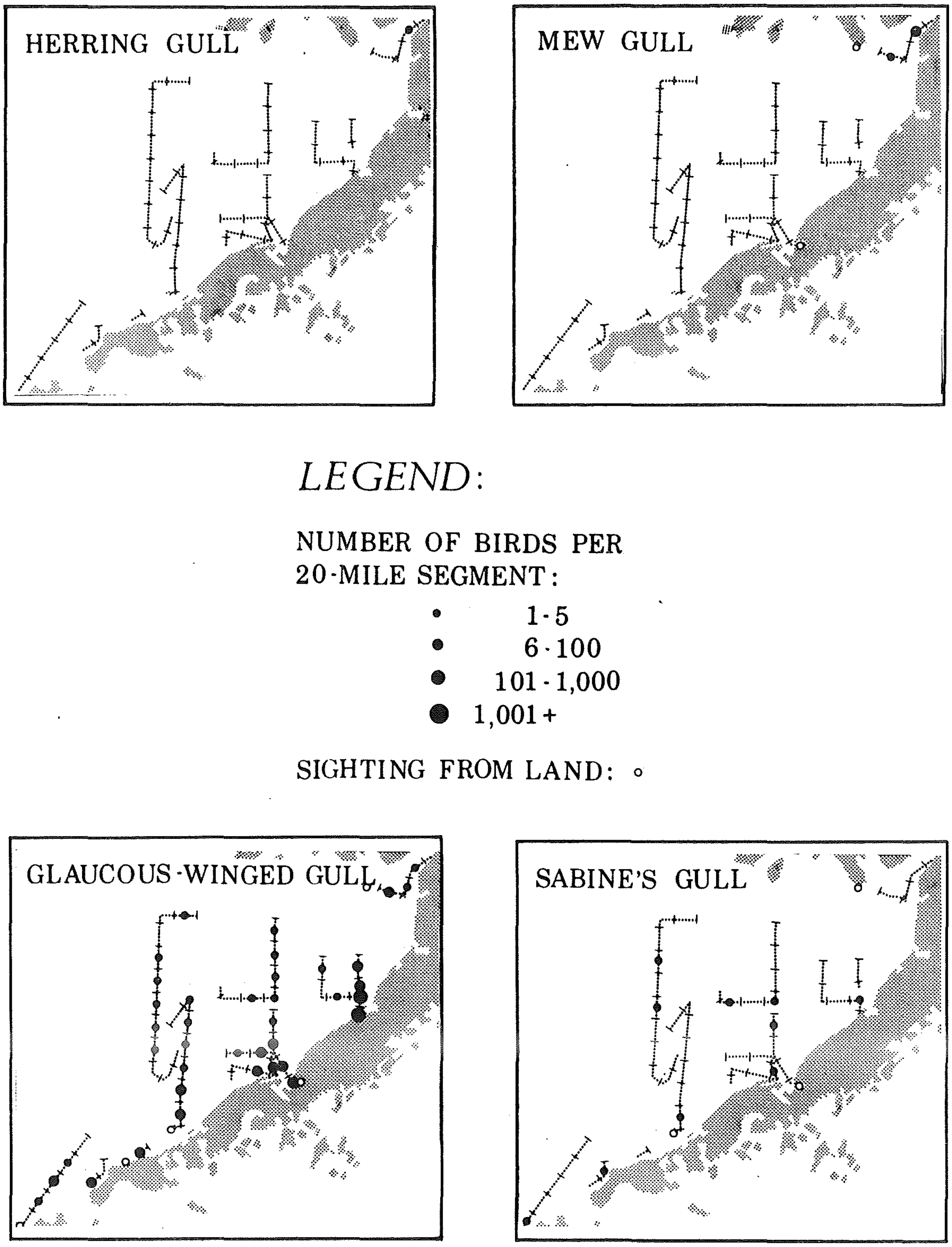


Figure 136. Distribution and numbers of Sabine's gull, glaucous-winged gull, herring gull, and mew gull observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

on ground squirrels and might feed on other rodents.[1] Young gulls are able to accompany their parents at sea shortly after fledging.

Other gulls which occur in the area, but are less common, include the mew gull, Larus canus; the herring gull, L. argentatus, and Sabine's gull, Xema sabini.

Kittiwake are common in the Bristol Bay area (Figure 137). Large nesting colonies of the black-legged kittiwake, Rissa tridactyla, occur along the northwestern shore, on the Walrus Islands, and on Unimak Island. Bartonek and Gibson (1972) observed red-legged kittiwakes, R. brevirostris, feeding along with black-legged kittiwakes on whiting, Theragra chalcogrammus. The red-legged kittiwake does not breed in this area.

The black-legged kittiwake nests on cliffs, usually on the seaward side. Its young are reared in a deeply cupped nest in a cliff crevice or on a ledge. The young hatch about the end of July, but are probably flightless well into August (Gabrielson and Lincoln 1959). Adults skim the water surface feeding on small fish. Like other members of the family Laridae, they will scavenge when fish become scarce.

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1. Leroy Sowl. Unpublished field notes compiled during special studies for the U.S. Bureau of Sport Fisheries and Wildlife 57 pp.

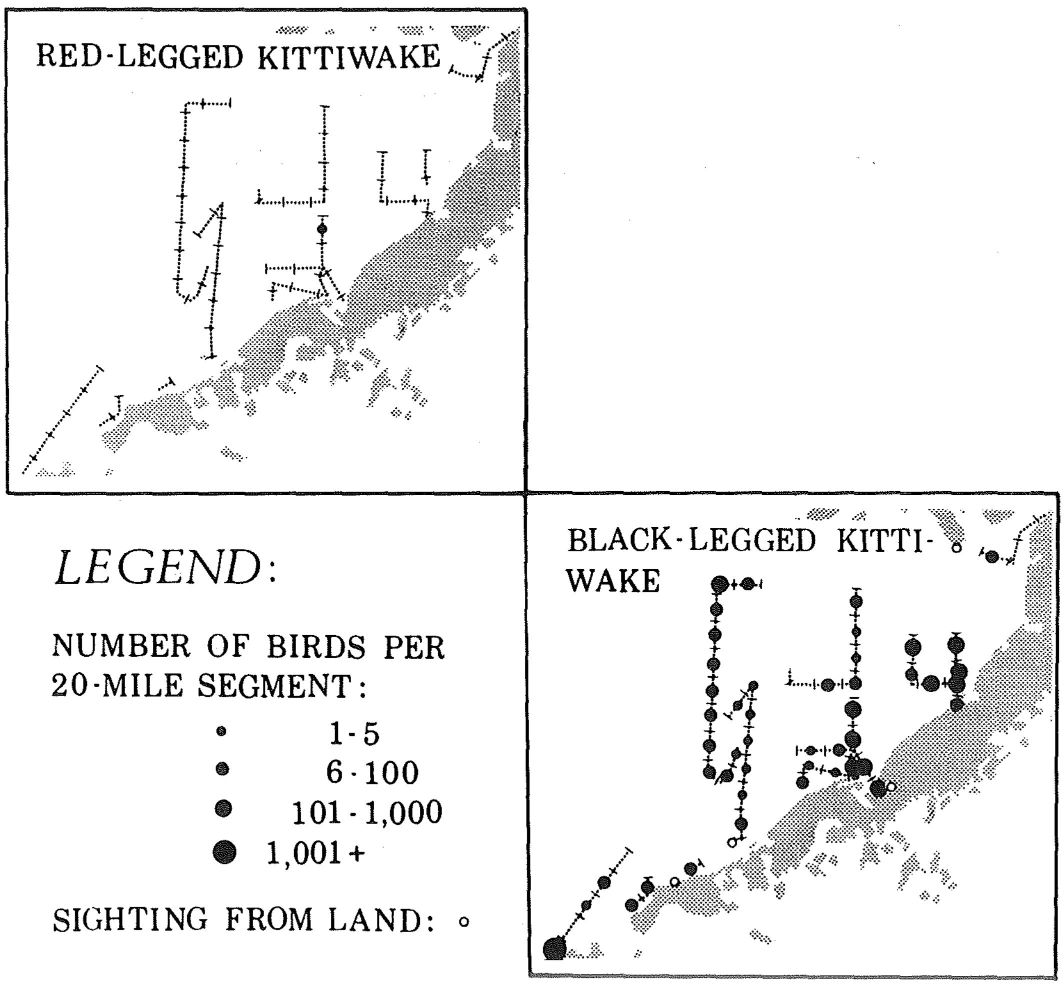


Figure 137. Distribution and numbers of black-legged kittiwake and red-legged kittiwake observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

The nesting habits of the Arctic tern, Sterna paradisaea, closely resemble those of the gulls. The female tern lays 2 or 3 eggs in a shallow depression on a flat island. When the chicks hatch in 3 to 4 weeks, they are fed fish by the parents, and leave the nest in about another month (Orr 1970). The unique characteristic of these birds is that they travel the longest migration route known. Arctic terns from Alaska migrate down the west coast of North and South America, often continuing to the edge of the Antarctic pack ice--a total distance approaching 20,000 km.

The Aleutian tern, Sterna aleutica, breeds along the Alaska Peninsula and is seldom found in the Aleutians (Figure 138). Although the bird is thought to be rare, Bartonek and Gibson (1972) observed a total of 21 representatives in their survey of Bristol Bay in the summer of 1969.

Alcidae-Auks, Murres, and Puffins: This family is the northern counterpart of the penguin family of the southern hemisphere (Peterson 1961). All members of this family live in colonies and feed predominantly on fish. No detailed population surveys of these birds have been made, but many colonies number in

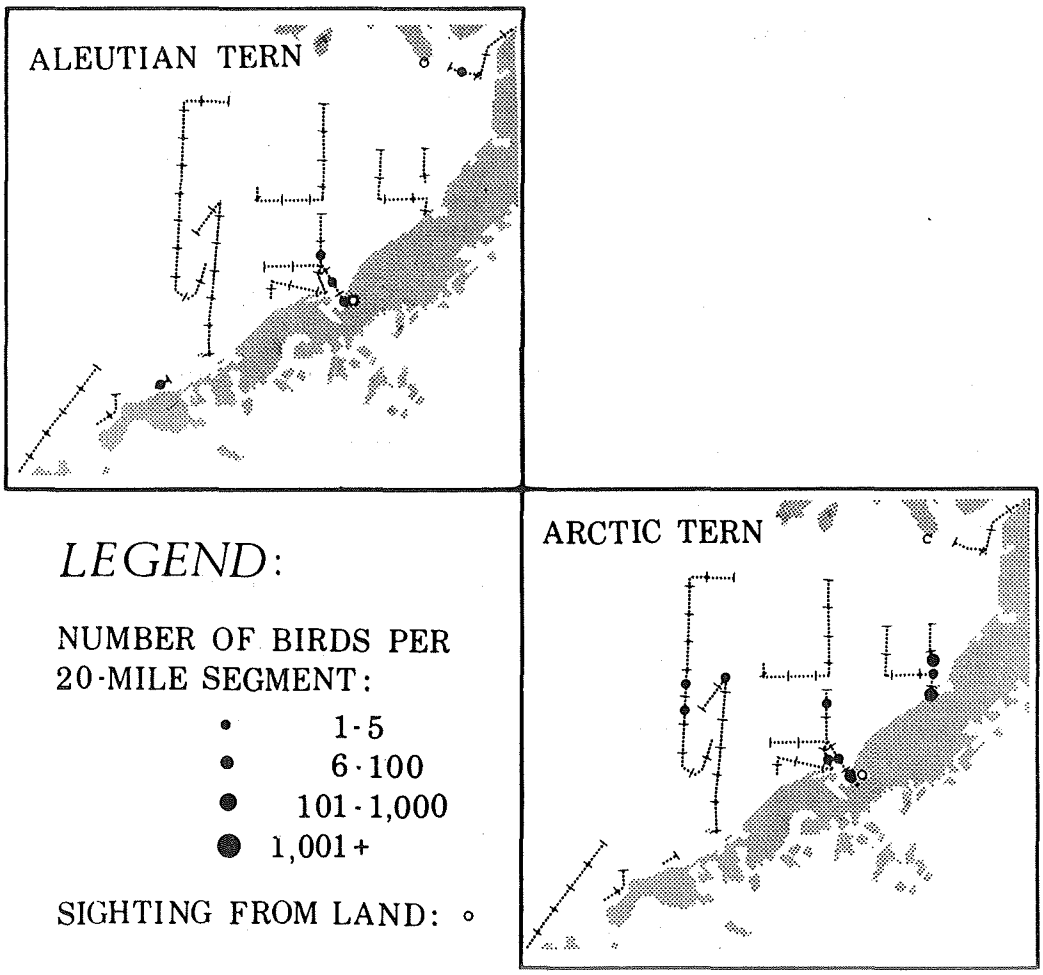


Figure 138. Distribution and numbers of Aleutian tern and Arctic tern observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

the tens of thousands. Bartonek and Gibson (1972) tallied more than 2,700 murres on a series of aerial transects over open waters of the Bay (Figure 139).

The common, Uria aalge, and thick-billed, U. lomvia, murres are found in Bristol Bay. The two species are difficult to distinguish without close inspection. Murie (1959) examined several colonies and felt that the thick-billed murres were most common on the Aleutians. But the common murre becomes predominant northward and outnumbers the thick-billed in Bristol Bay (Bartonek and Gibson 1972).

Murre eggs are highly variable and individual differences may aid in their identification by the parent. The eggs are laid on a bare rock ledge where their pear shape allows them to roll in circles rather than off the ledge. The eggshells are also very tough. In some areas of Alaska, murre eggs are harvested by Natives as provided for in the Migratory Bird Treaty Act of 1918. Murre parents are unwary, and allow people to approach closely before panicking. The hurried exit of the parents may cause a pileup of murre eggs at the bottom of the cliff in various stages of "Humpty-Dumpty." Such human intrusion, if repeated frequently, could conceivably affect the murre population.

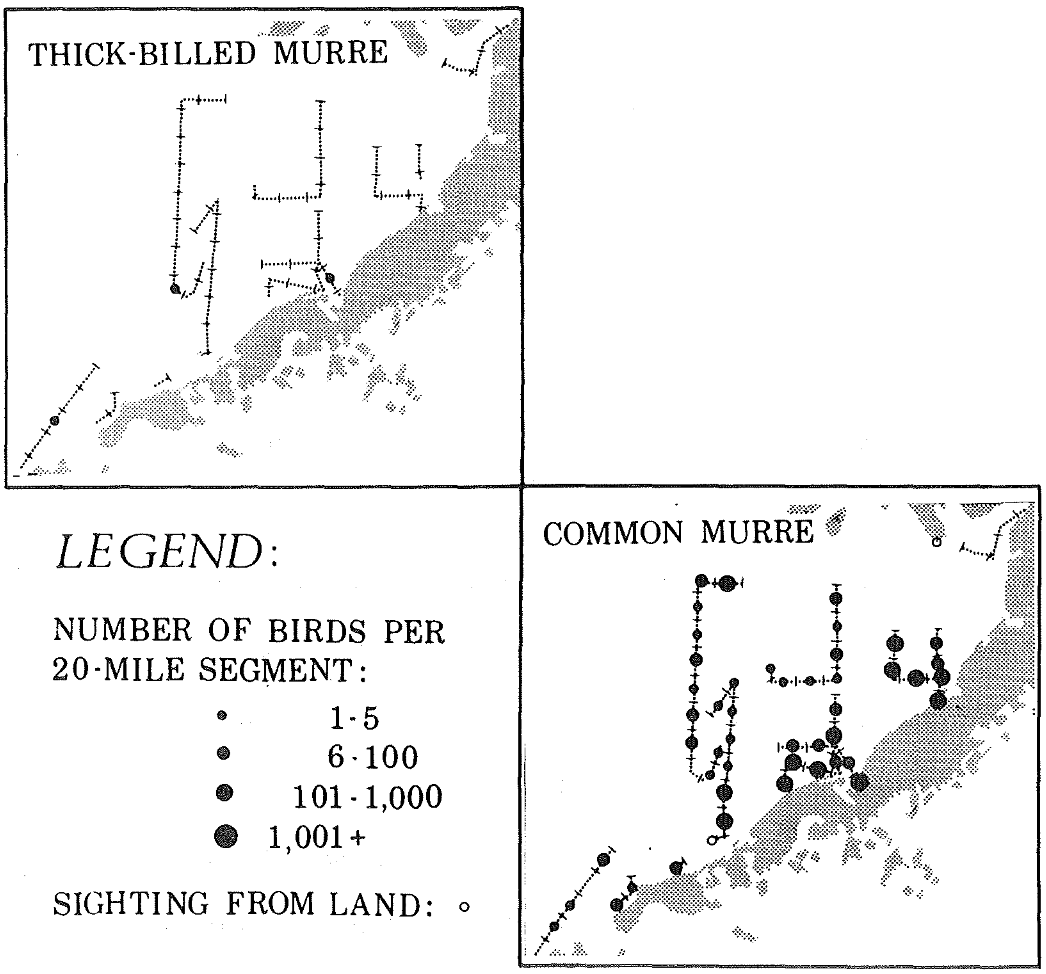


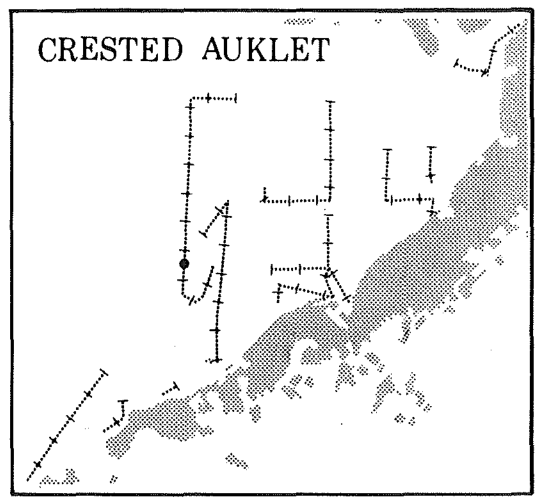
Figure 139. Distribution and numbers of thick-billed murre and common murre observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

The flightless chicks leap off the edge of the cliff, where their parents hurry them into the water. Their light weight and fluffy plumage protect them from injury. Though subject to regular predation by gulls, murre populations apparently reproduce rapidly and their numbers remain stable. Large flocks winter in the open ocean, and occasionally a massive die-off of thousands of murres will occur following storms in a hard winter (Bailey and Davenport 1972).

The pigeon guillemot, Cepphus columba, is a small bird common in this region. It does not build a nest, but deposits its eggs on pebbles at the top of a sheer cliff, just above high tide in rocks, or in caves along the coast (Drent 1965). Guillemots usually start to nest in June, and the young are fledged by mid-July. In common with other alcids, they use their wings to literally fly underwater in pursuit of small fish and crustaceans.

Marbled, Brachyramphus marmoratus; Kittlitz's, B. brevirostris, and the ancient murrelets, Synthliboramphus antiquus, are all found in Bristol Bay. The marbled murrelet keeps its nest so well concealed that only one was found prior to 1959 (Gabrielson and Lincoln 1959). The nest was located above timberline in a rockslide, which might be a typical nest site. Kittlitz's murrelet is believed to nest in similar habitat (Jones 1972). The ancient murrelet is nocturnal and, though fairly common, is seldom observed. Murie (1959) thought it would not occur north of the Alaska Peninsula, but Bartonek and Gibson (1972) reported several birds on Bristol Bay. The ancient murrelet will sometimes nest on bare rock, but prefers a crevice lined with grass (Gabrielson and Lincoln 1959).

The only auklet species found in the area is the crested, *Aethia cristatella* (Bartonek and Gibson 1972) (Figure 140). Auklets usually remain at sea, but come ashore in April or May when they nest in cliff colonies. Each female lays a single egg in a crevice in the cliff. Bartonek and Gibson believe these birds do not nest in the Bristol Bay area. Auklets often congregate in tiderips along the coast where they feed on marine invertebrates (Murie 1959).



LEGEND:

NUMBER OF BIRDS PER
20-MILE SEGMENT:

- • 1-5
- • 6-100
- ● 101-1,000
- ● 1,001+

SIGHTING FROM LAND: ∘

Figure 140. Distribution and numbers of crested auklet observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

The horned puffin, *Fratercula corniculata*, and the tufted puffin, *Lunda cirrhata* (Figure 141) are both year-round residents of Bristol Bay. They eat small fish, primarily sand lance, which they pursue underwater. Puffins nest in colonies, sometimes by the hundreds of thousands.[1] Size of the nesting colony is difficult to estimate, however, since puffins nest in burrows or crevices. In June, each female puffin deposits 1 egg at the end of a burrow. The nests often make the colonies easy to locate, because the soil is disturbed and fertilized, and characteristically supports a bright green cow parsnip, *Heracleum* sp.[2]

Marine Mammals

Sea Otter

By 1911, the sea otter, *Enhydra lutris*, had been hunted to near extinction. Although biologists believed it to be extinct, it

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1. Leroy Sowl. U.S. Bureau of Sport Fisheries and Wildlife. Anchorage. Field notes compiled during special studies. 57 pp.

2. Ibid.

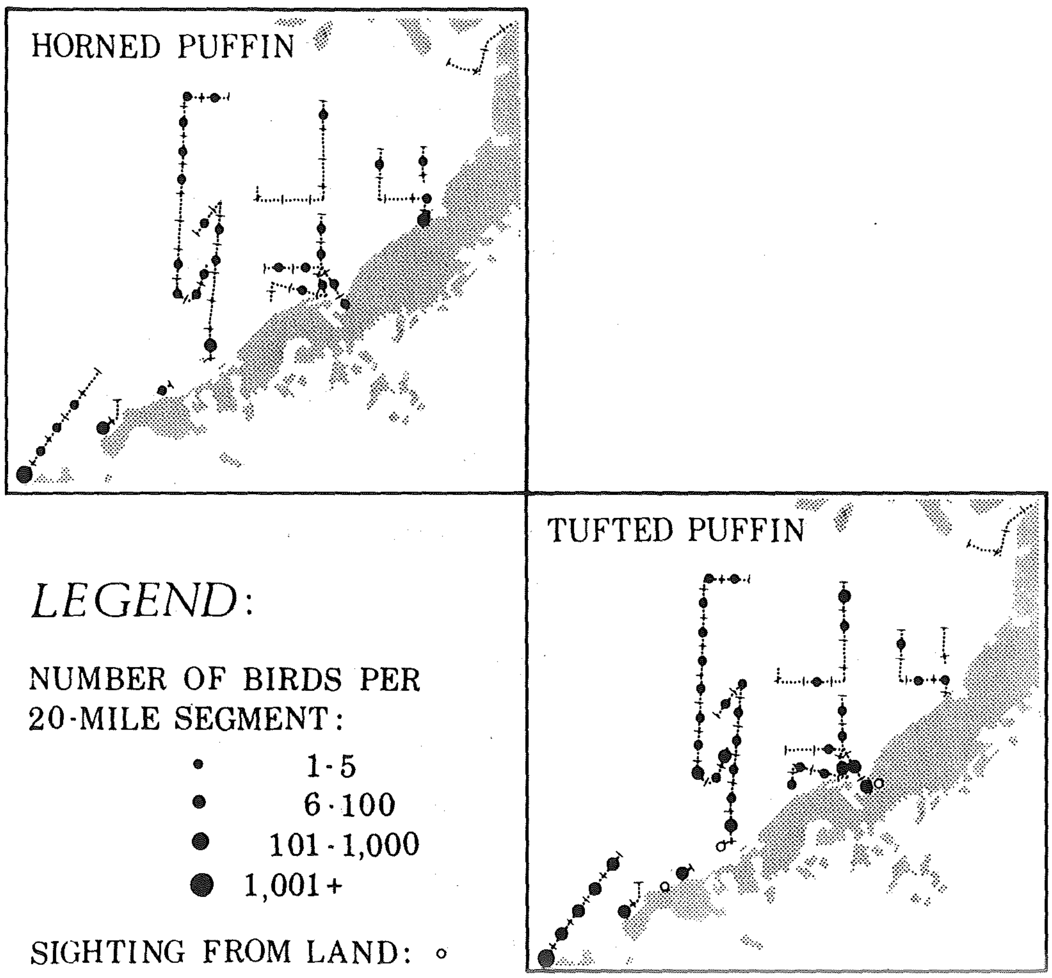

Figure 141. Distribution and numbers of tufted puffin and horned puffin observed in Bristol Bay, 13 July to 20 August 1969 (from Bartonek and Gibson 1972).

was included in an international treaty signed by Woodrow Wilson in that year which extended protection to the fur seal (Kenyon 1969). At that time, probably fewer than 2,000 sea otters remained in Alaska (Alaska Department of Fish and Game 1973). Since then, the sea otter population has expanded rapidly, and biologists believe it can inhabit all of its former ranges with the exception of polluted areas.[1]

The sea otter is the only member of the genus *Enhydra*, but is closely related to and resembles the land otter, *Lutra canadensis* (Burt and Grossenheider 1964). Along the north coast of the Alaska Peninsula, both otters often share the same habitat, as it is not unusual for the land otter to be seen in the ocean (Murie 1959). Observers often confuse the two otters, but sea otters can be identified by their distinctive habit of swimming on their backs (Kenyon 1969).

Sea otters may be found throughout the North Pacific area, occurring on the southern shore of Bristol Bay, about as far north as Port Moller. In the winter of 1971-72, ice formed as far south as Cold Bay and many otters died (Jones 1972).

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1. John S. Vania, Marine Mammals Coordinator, Alaska Dept. of Fish and Game, Anchorage, Alaska. Personal communication.

Males and females tend to segregate. Males prefer the exposed points along the shore surrounded by shallow waters while females congregate along the coast between these exposed points (Kenyon 1969). Sea otters prefer habitats with many offshore reefs and kelp beds. The reefs provide abundant food, and the kelp is used to anchor the pups when the females leave to feed. This preference in habitat limits the distribution of sea otters in the Bristol Bay area (Figure 142).

Otters do not often dive deeper than 75 meters (Figure 143). Although the U.S. Bureau of Sport Fisheries and Wildlife now has jurisdiction over the sea otter, these animals will usually be found within the 3-mile state limit, except for occasional foraging activities on shoals and reefs further out (Alaska Department of Fish and Game 1973).

Otters reproduce only once every two years, but the females care for their pups so diligently that infant mortality is very low and otters are capable of rapid population expansion in areas where food is plentiful. Sea otters breed year-round, but the peak of the pupping season comes in April, May, and June. According to Kenyon (1969), gestation

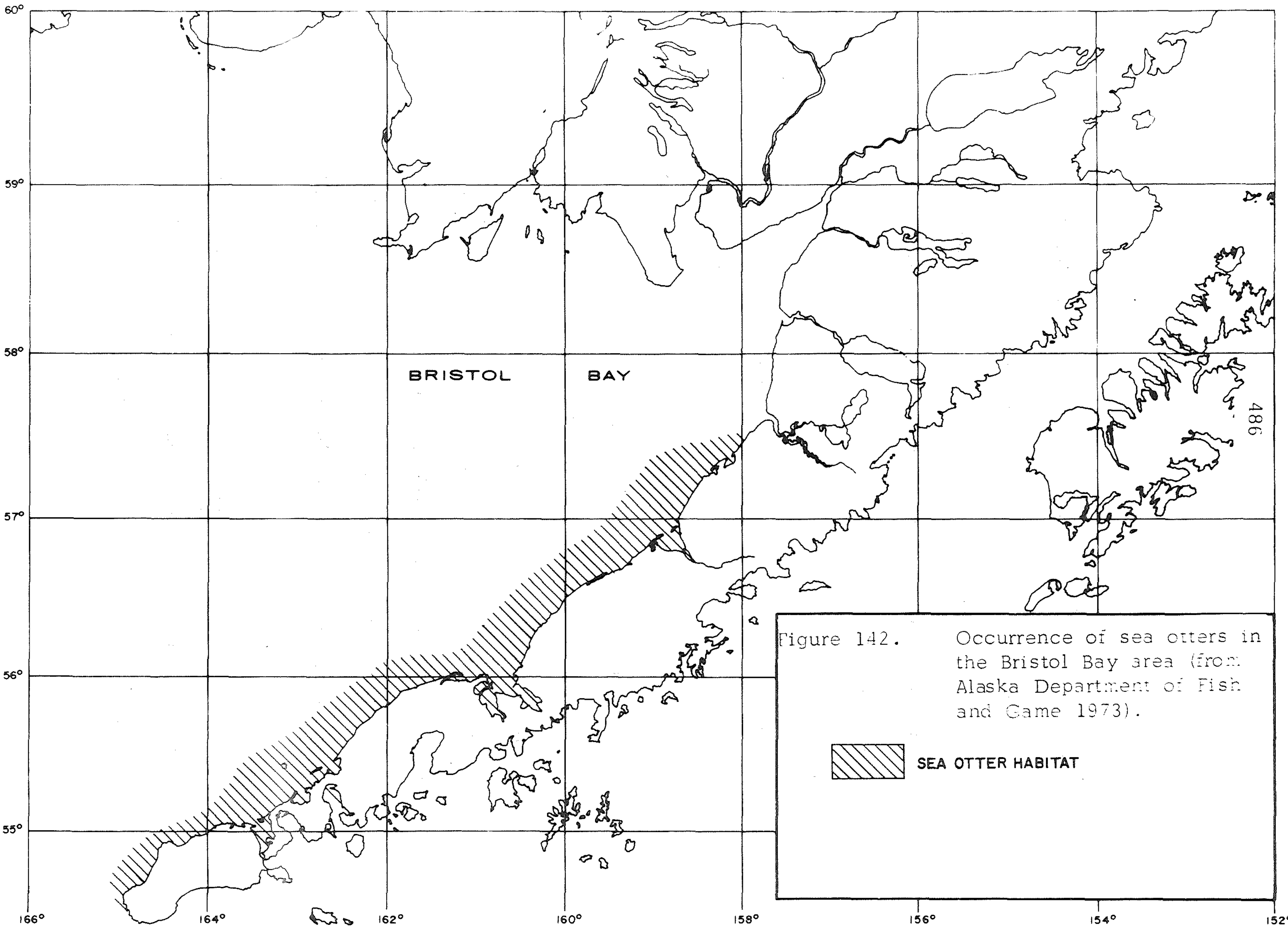

Figure 142. Occurrence of sea otters in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

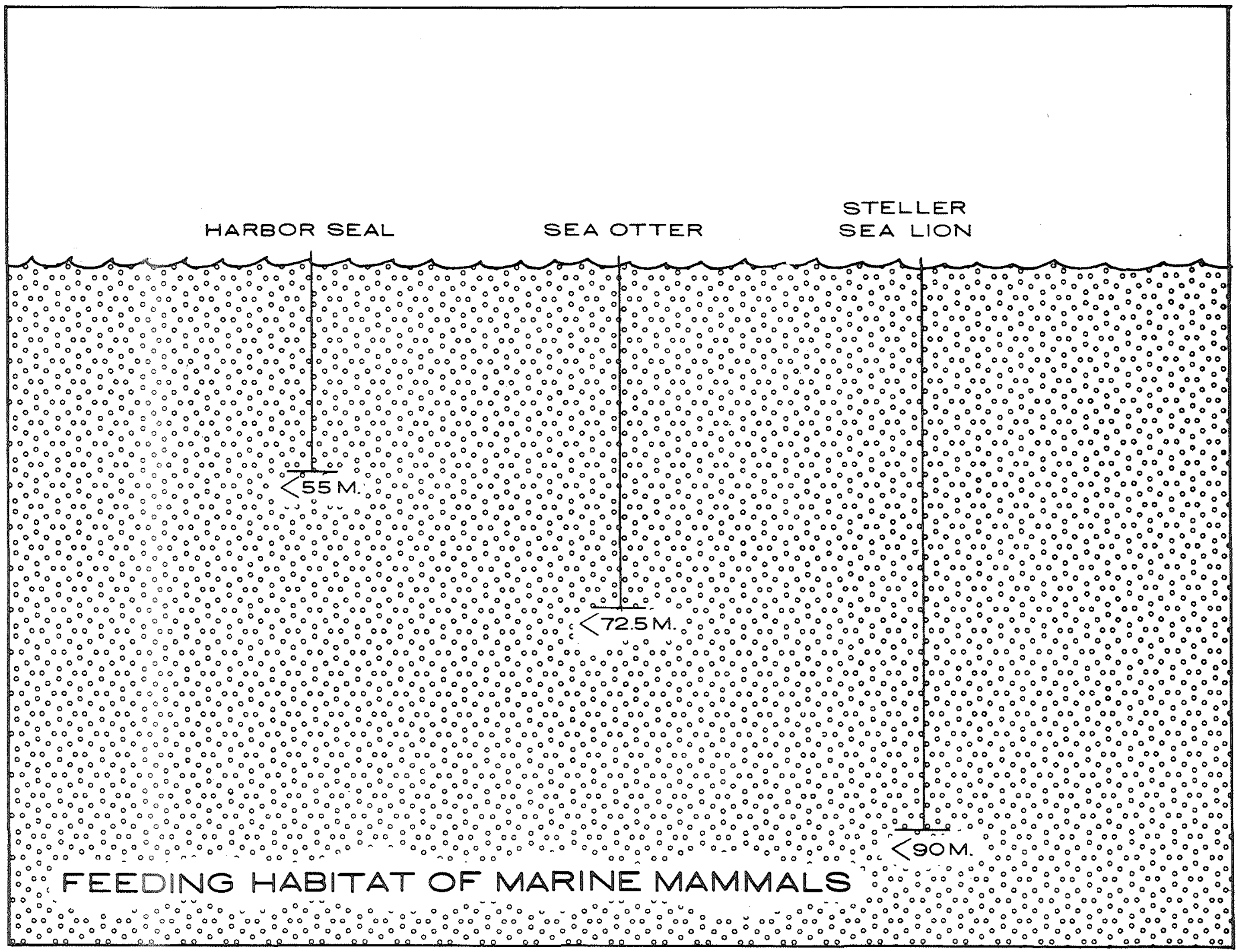

Figure 143. Feeding habitat of marine mammals (from Alaska Department of Fish and Game 1973).

takes about 13 months, due to several months of delayed implantation (Figure 144). In severe winters, when waters are ice-covered and food is difficult to obtain, pups born in the fall often survive because they are small enough for the mother to suckle through the winter (Kenyon 1969). The larger pups are often abandoned in the late winter months by the female who can no longer feed both herself and her young.

Under the Marine Mammal Protection Act of 1972, sea otters, which had been protected, are now subject to harvest by Alaskan Natives. The ultimate effects of this Act, on populations of sea otters is uncertain.

Steller Sea Lion

The Steller sea lion, *Eumetopias jubata*, is abundant in the Bristol Bay area. Both male and female sea lions winter in sheltered bays and river mouths, using rocky outcrops as "hauling grounds"-- areas where they haul themselves out of the water to rest. Their preference for rocky habitat generally confines them to the northwest and southwest portions of the Bay (Figure 145). Like the sea otter, they

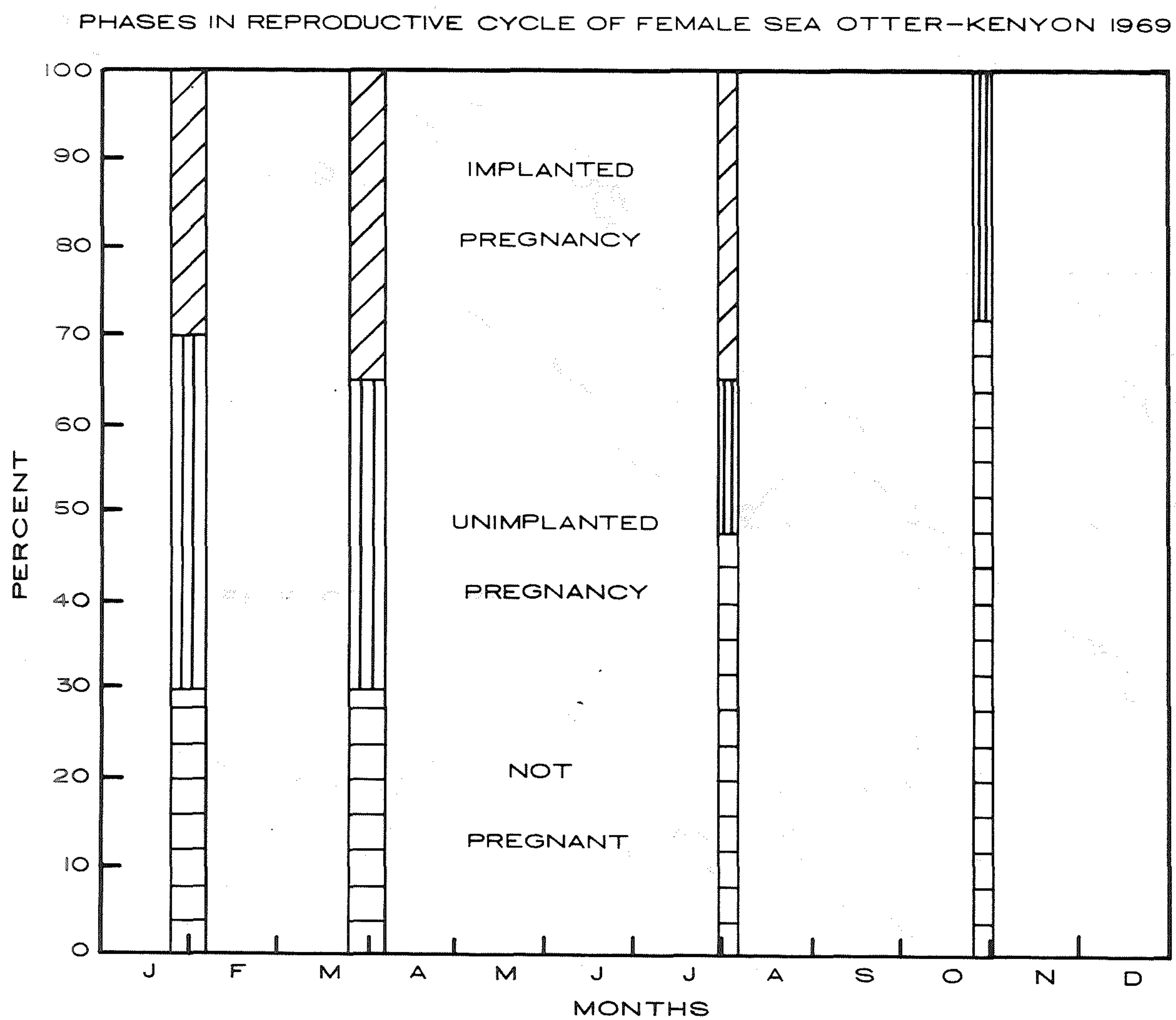

Figure 144. Phases in the reproductive cycle of the female sea otter (from Kenyon 1969).

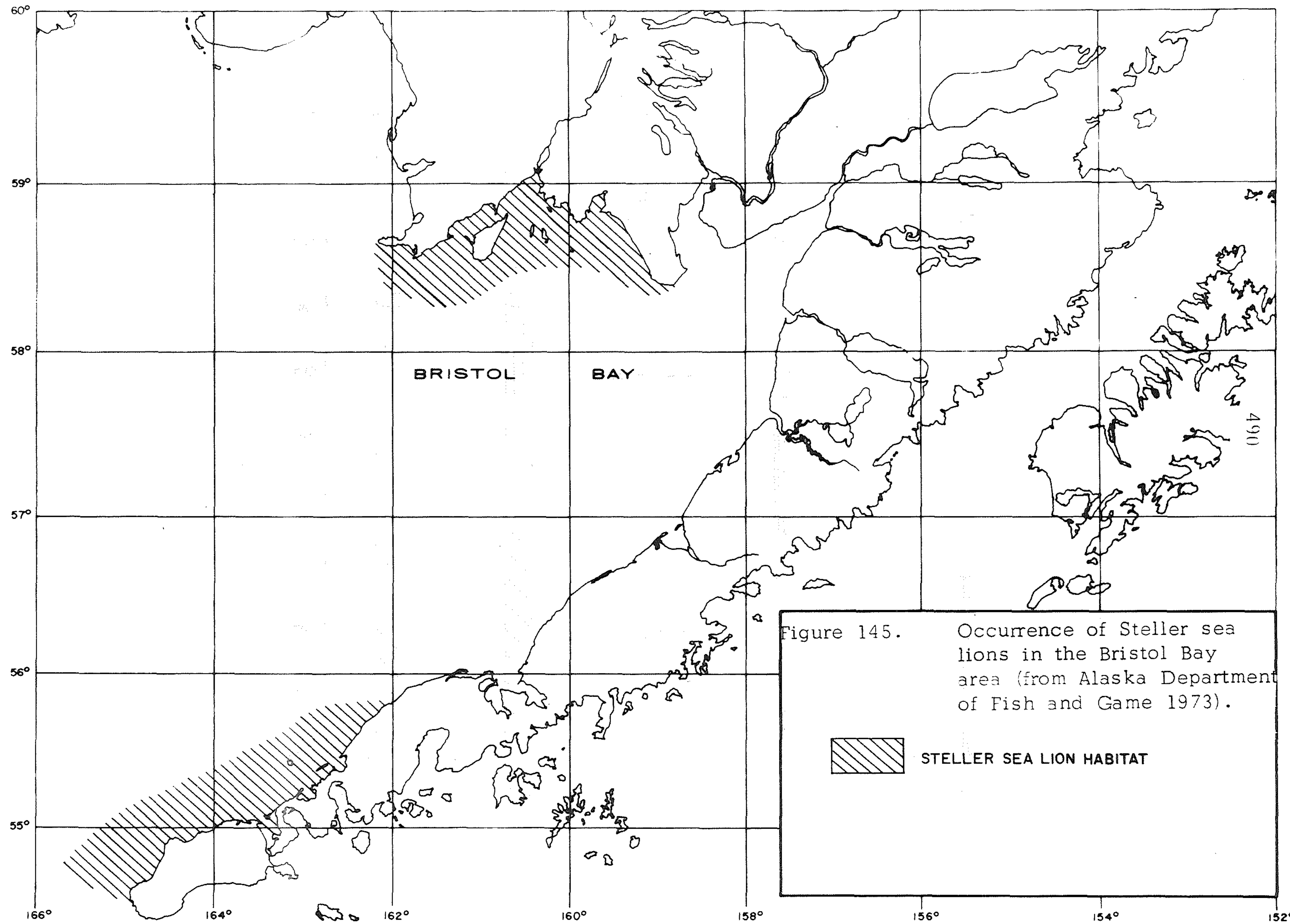

Figure 145. Occurrence of Steller sea lions in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

prefer relatively shallow water, but are sometimes found at sea far from land. Although sea lions do not appear to undergo regular migrations, cyclical population fluctuations may indicate movements of animals (Scheffer 1972).

In May each male begins to defend a territory from other males, but will usually tolerate the presence of females, Pupping occurs in June, and most females will breed within a week or so after giving birth. Although sea lion pups are able to swim at birth, they seldom leave the land during their first month, during which period the females continue to care for them. After this critical time, the females and their pups leave these defended areas, and the bulls cease to guard their territories (Alaska Department of Fish and Game 1973).

Sea lions tend to disperse along the coast during the winter, where they concentrate on foraging for their food--rockfish, sculpin, greenling, sand lance, smelt, salmon, halibut, flounder, octopus, shrimp, and crab. There is evidence that sea lions eat harbor seals, but whether the seals are dead or alive when eaten is not certain (Tikhomirov 1964b). There have been reports that sea lions are attracted to crabbing operations and become trapped in tangle nets. These nets are no longer legal.

The Northern or Alaskan Fur Seal

Occasionally, the northern fur seal, Callorhinus ursinus, is found in outer Bristol Bay during spring, summer, and fall. The males migrate from Southeast Alaska, up through False Pass, Isanotski Strait, and the passes in the Aleutians, to set up territories in the Pribilofs (Kenyon 1971) where the entire northern population of these seals breeds. The females follow shortly after, migrating from the coast of British Columbia and points south. Individual seals occasionally forage for their food as far east as outer Bristol Bay. Fur seals are harvested in accordance with The Fur Seal Act of 1966.

The Harbor Seal

Land-breeding harbor seals, Phoca vitulina, (sometimes referred to as "hair seal") are common throughout the study area. Like sea otter and sea lions, harbor seals prefer water that is relatively shallow, usually not more than 55 meters deep (Figure 143). Their preferred foods here are crustaceans and fish, including herring, flounder, eulachon, salmon, rockfish, cod, sculpin, octopus, squid, and small crab (Alaska Department of Fish and Game 1973). Harbor seals are less adapted to a land environment than sea lions and fur seals, and need gentle slopes to haul out. Consequently, these seals will usually be found on sand bars, beaches, and low rocks, especially along the southern coast of the Bay (Figure 146).

Harbor seals do not usually congregate in huge colonies as do fur seals and sea lions and generally remain in groups of 100 or less. Females give birth to one or occasionally two pups between late May and early July. These pups are able to swim at birth, but may be abandoned if their mothers are disturbed during the first month of nursing (Alaska Department of Fish and Game 1973). With the exception of this critical time, harbor seals are quite tolerant of men and boats.

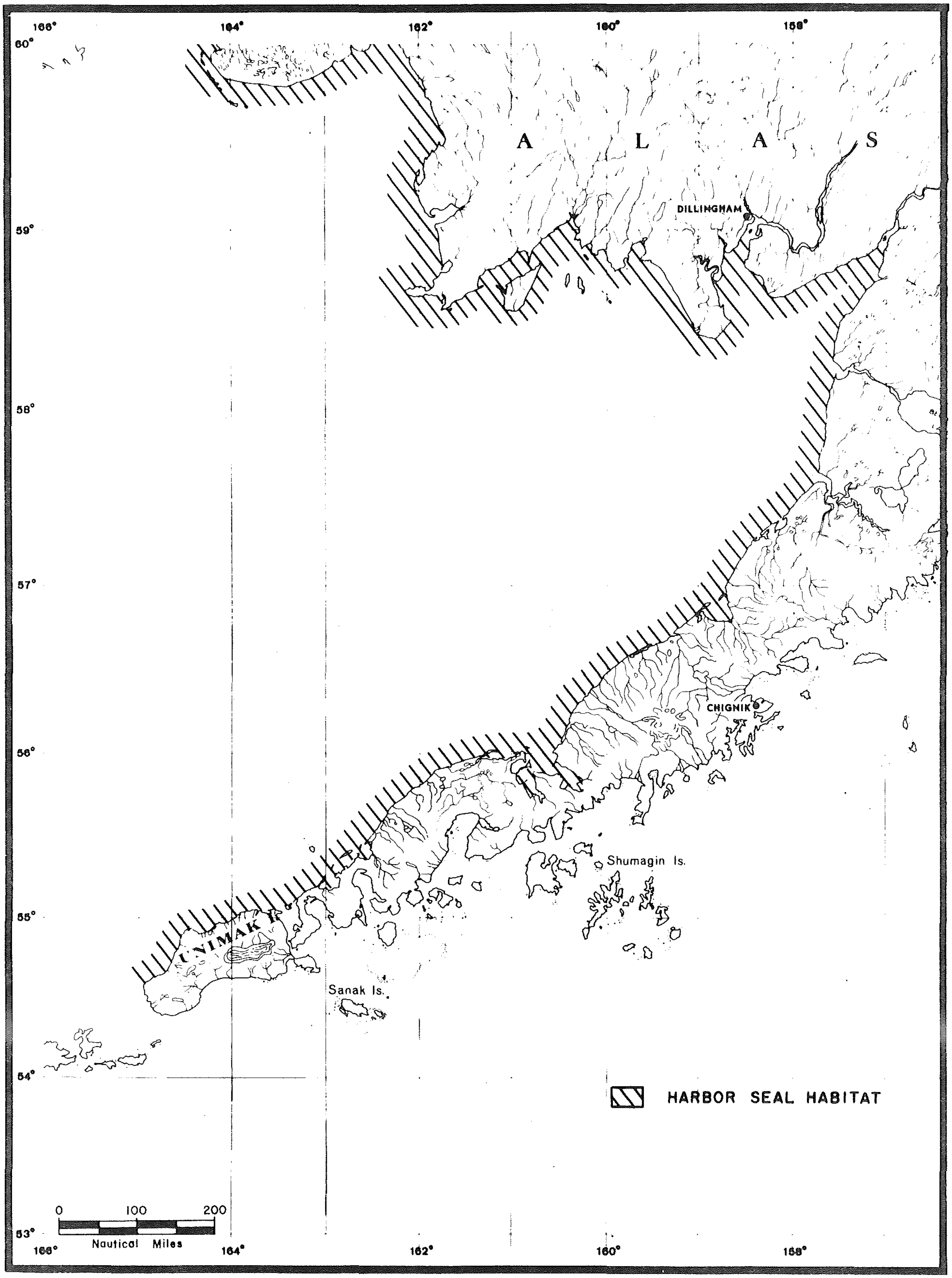

Figure 146. Occurrence of harbor seals in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

During salmon runs, seals conflict with Bristol Bay fishermen. This is a minor problem during years of high runs, but when the salmon population is low, seals may become a real economic threat. When salmon are scarce, seals move farther up the river estuaries than normally, causing an even more direct conflict with the fishermen.[1] Passage of the Marine Mammal Protection Act has intensified the fishermen's hostile feelings about these seals.

Walrus

Walrus, *Odobenus rosmarus*, in Bristol Bay are unique. The herd which occupies the Walrus Islands east of Hagemeister Island (not to be confused with Walrus Island west of Port Moller) is composed almost entirely of old bulls. The islands are a state game refuge, but walrus more than 3 miles offshore (beyond the limits of state jurisdiction) can be harvested by Natives under the provisions of the Marine Mammal Protection Act of 1972.

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1. Darwin Biwer, Area Management Biologist, Bristol Bay Area, Alaska Dept. of Fish and Game, Anchorage. Personal communication.

Walrus are usually found along the edge of the ice pack; the herds found in Bristol Bay are at the southern limit of their range (Alaska Department of Fish and Game 1973). Round Island in the Walrus Island group is the most frequently utilized hauling ground, but nearby Hagemeister Island, and Amak Island near Cold Bay are also used occasionally (Figure 147). During the summer, walrus feed largely upon mollusks, but Russian scientists believe that the winter diet is composed mostly of crab and shrimp (Tikhomirov 1964a). An occasional "rogue" walrus will develop a taste for seal, but this is not a common preference.

Except for the bulls which inhabit Bristol Bay, most walrus follow the ice pack as it recedes, hauling out on the edges of the polar ice pack in summer. Since the hauling grounds in Bristol Bay are frequented only during the summer and fall months (Alaska Department of Fish and Game 1973), it would seem that the bulls that use them rejoin the herds on the ice pack in the winter and spring.

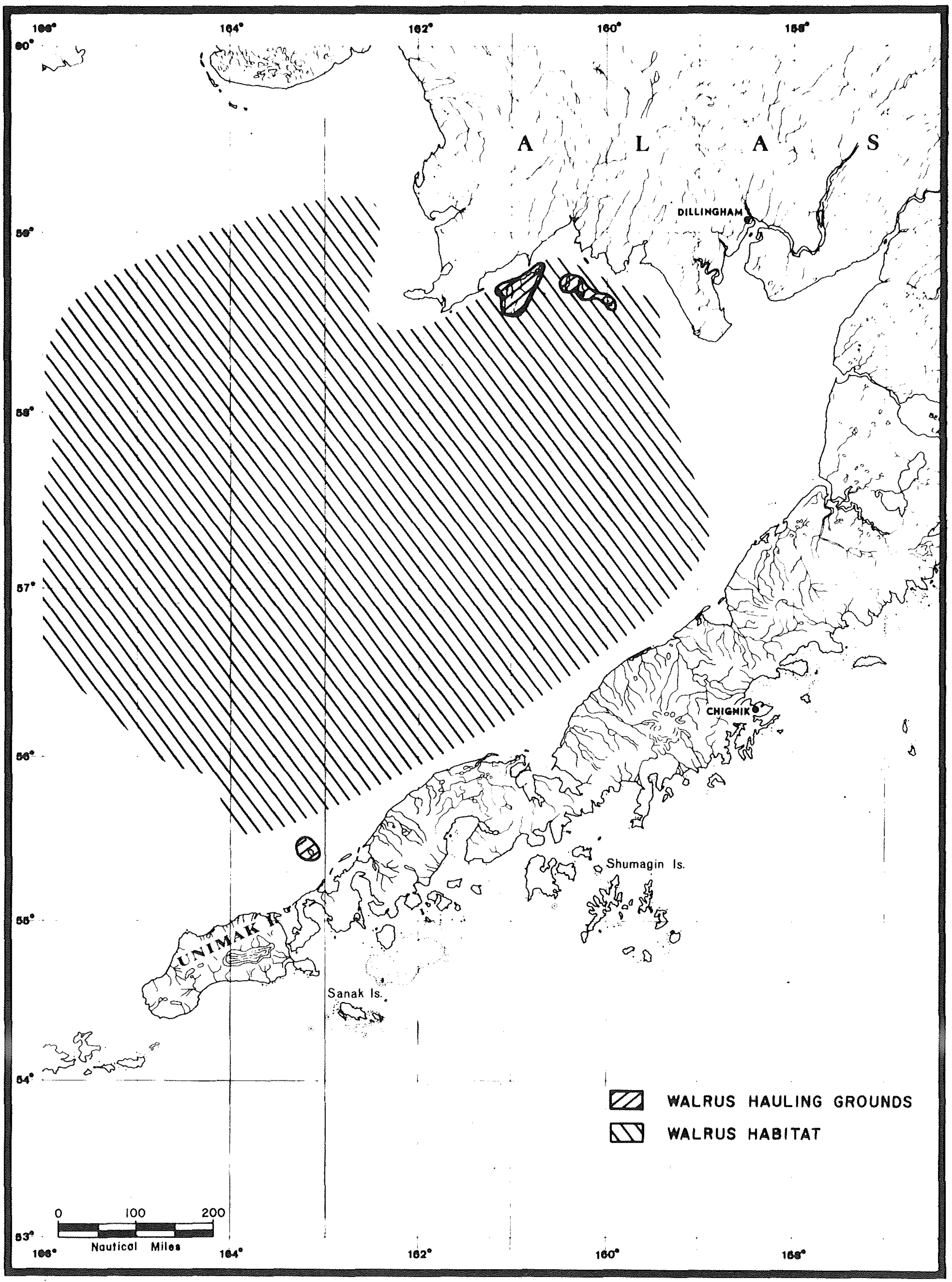

Figure 147. Occurrence of walrus in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

Odontoceti-the Toothed Whales

A list of the whales and their relative abundance in the Bristol Bay area appears in Table 39 . Whales are difficult to study in the wild because of their exclusively marine habitat. In addition, with the exception of the sperm whale, Physeter catoden, toothed whales were not economically important until the last few decades, when they became popular as aquarium specimens (Scheffer 1972). The Odotoceti have peg-like teeth, which enable them to feed on fish, squid, and octopus. In Bristol Bay, there are a number of harbor porpoise, Phocoena phocoena, which consume small fish and squid. Belugas, Delphinapterus leucas, feed extensively on salmon and are quite common in Bristol Bay. These white whales travel in groups, and often run up the estuaries of rivers (Matthews 1968). The Alaska Department of Fish and Game has been experimenting with underwater sound to frighten belugas away from the mouths of salmon spawning streams, especially the Kvichak River.

Recorded calls of the killer whale, Orcinus orca, are being played, and the Department reports a high rate of success with this method (Alaska Department of Fish and Game 1973).

Although the killer whale is hunted in Norway, where its intelligent makes it difficult to catch (Matthew 1968), it is of no direct economic importance in Bristol Bay. It is, however, an important predator and a spectacular part of the landscape. Killer whales taken in other areas may command prices in the tens of thousands of dollars as aquarium specimens (Scheffer 1972).

The sperm whale, although not common in Bristol Bay, was in other areas the mainstay of the Yankee whalers. Most of the sperm whales taken by the whalers, however, were taken in temperate waters. This meant that a disproportionate percentage of females were killed, since only the males migrate north as far as the Bristol Bay area where they feed mainly on squid (Kodolov 1970). Even though populations are low, sperm whale are still being exploited by the Soviets and probably the Japanese who have not signed international whaling treaties (Berzin 1964, Matthew 1968).

Table 39. Distribution and Abundance of Whales in Bristol Bay[1]

rare (+), moderately common (++), common (+++)

Species	Abundance
Toothed Whales	
Killer whale (*Orcinus orca*)	++
Harbor porpoise (*Phocoena phocoena*)	++
Beluga (*Delphinapterus leucas*)	++
Baleen Whales	
Minke whale (*Balaenoptera acutorostra*)	+++
Gray whale (*Eschrichtius robustus*)	++

The intelligence of the toothed whales is the subject of much research. These animals learn quickly, and have an undefined ability to communicate with their own kind. Their use of echolocation makes it possible for them to navigate in the often silty waters of Bristol Bay (Matthews 1968).

1. Dale Rice, Marine Mammal Biologist, National Marine Fisheries Service, Seattle. Personal communication.

Mysticeti-the Baleen Whales

The baleen whales are generally the larger whales, and include the blue, the largest animal ever to exist. Specimens of this mammoth species have been found measuring 32 meters and weighing up to 108 metric tons (Storer and Usinger 1965). Baleen whales feed on plankton, especially euphausiids, pteropods, and Calanus sp. (Matthews 1968). In the study area, these zooplankton (krill) are generally concentrated between Unimak Island and the Pribilofs, although some are carried into the Bay on the currents which sweep around Unimak Island (Meshcheryakova 1970b). Baleen whales might be found near these plankton concentrations (Figure 148).

The bowhead or Greenland right whale, Balaena mysticetus, may occasionally be found at the entrance of Bristol Bay. At present the bowhead is utilized as a food source by some Arctic Eskimos. In the past, intensive Yankee whaling depleted bowhead stocks, but sightings and hunting records indicate that they have at least partially recovered. Although knowledge of its present population is uncertain, the bowhead is designated an endangered species along with all other whales.

The gray whale, Eschrichtius robustus, also occurs

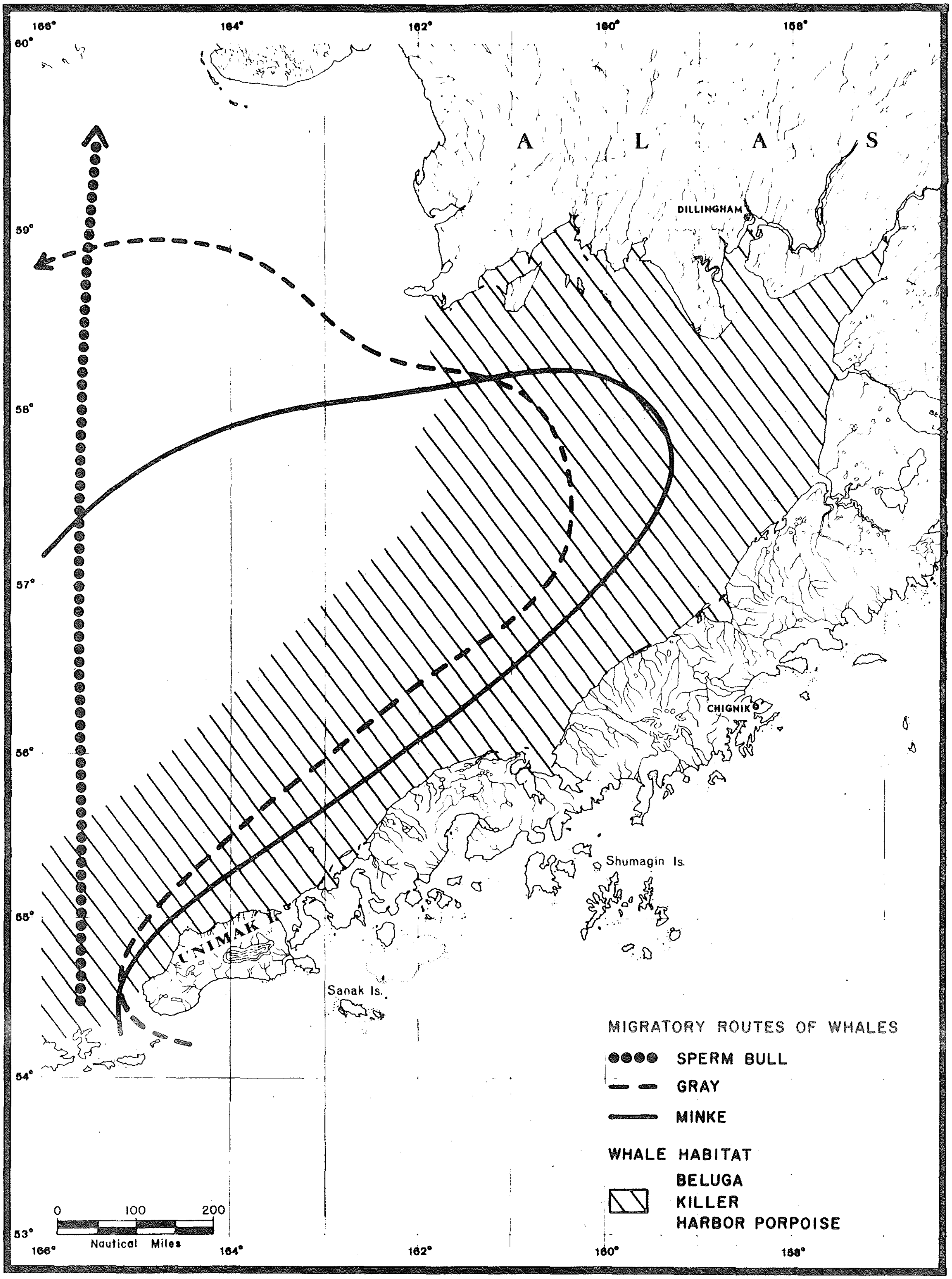

Figure 148. Occurrence of whales in the Bristol Bay area (from Matthews 1968, Shurunov 1970).

in Bristol Bay. Following the discovery of its calving grounds in the lagoons of Baja California, the gray whale was hunted almost to extinction. By the year 1946-47, there were only about 250 gray whales known to exist in the Pacific (Matthews 1968). These whales have been protected, and presently the stocks have increased to more than 6,000. This statistically large increase indicates a rapid recovery, but is probably due in part to better census techniques.

After calving in warm California waters, gray whales begin to migrate up the coast, staying close to the shoreline (Scheffer 1972). After moving through the passes along the Aleutian chain, they concentrate in the northern Bering Sea (Shurunov 1970). Their preference for shallow habitat brings them near the continental shelf, especially the area of high productivity where the shelf drops into the depths. The humpback whale, Megaptera noveangliae, also likes shallow waters, and might use similar habitats.

The minke whale, Balaenoptera acutirostra, is a small whale moderately common in the Bristol Bay area. With the depletion of the stocks of the larger species, these smaller whales are becoming increasingly important to whalers.

The Marine Mammal Protection Act makes it illegal, except for certain Alaskan Natives, to take or import any species of marine mammal without a special permit, except where a previous international treaty, convention, or agreement was signed by the United States.

TERRESTRIAL BIOTA

Coastal Vegetation

The shores of Bristol Bay are characterized by thick tundra vegetation and many potholes. The beaches are narrow and flat, especially on the south side where a stand of beach rye, *Elymus arenarius*, will generally be found along the crest of the wave-cut beach above the black sand. Associated with the rye grass will be *Senecio pseudoarnica*, an attractive yellow flower resembling a daisy; *Lathyrus maritimus*, a beach pea; *Honckenya peploides*, seabeach sandwort; and *Mertensia maritima*, the common oysterleaf (Bank 1953). The proportion and degree of dominance is related to the composition of the soil, which varies in the coastal areas from mud to rock (Hulten 1937).

The rock slopes of the northern areas support little vegetation close to the coast, with the exception of rock-loving species, such as certain *Potentilla* sp., which nestle in pockets of soil formed by the constant erosive action of the wind and waves.

Farther inland, the lowland vegetation is characterized by lichens; mosses; sedges, *Carex* sp.; crowberry, *Empetrum nigrum*; cranberry, *Vaccinium oxycoccus*; and prostrate willows, *Salix* sp. These species comprise a wet tundra association where there is standing water most of the time and poor drainage, despite the general absence of permafrost. Here, too, will be found the plants associated with standing water, such as cottongrass, *Eriophorum* sp.; horsetail, *Equisetum* sp.; and *Potamogeton* sp. (Hulten 1968). The last genus is particularly attractive to waterfowl, especially the dabbling ducks which feed selectively on these plants (Kortright 1967).

Sparse timber of the spruce-alder association dominates the Wood River-Tikchik Lakes region to the north. Although not of commercial quality, it is intrinsically important to the area (U.S. Department of Agriculture 1967). Many scientists believe that the forest edge on the Alaska Peninsula is advancing westward from the present limit-- about 157 degrees West longitude (Griggs 1934, Capps 1934). Bank (1953) postulates that a lack of summer heat prevents spruce cones from maturing.

Coastal Fauna

Soricidae

Small rodents are numerous along the Bristol Bay shoreline, where they nest among the roots of grasses. The family Soricidae is represented by three species in the study area: the cinereous shrew, *Sorex cinereus*; the tundra saddle-back shrew, *S. tundrensis*, and the dusky shrew, *S. obscurus*. Shrews prefer a moist habitat with an abundance of insects. These shrews are particularly plentiful around Izembek Bay (Murie 1959), and Osgood (1904) reported shrews to be numerous all along the coast of the Alaska Peninsula.

Ursidae

The brown/grizzly bear, Ursus arctos, and the black bear, U. americanus, are found in the Bristol Bay area (Figure 149). Both are omnivorous. While the black bear does scavenge along the coast, and feeds heavily on spawning salmon, it prefers forested areas. The brown bear often scavenges along the shoreline, especially in the early spring (Clark 1957). Brown bears congregate along the lowlands of the Alaska Peninsula during spring and summer, but the Alaska Department of Fish and Game (1973) doubts that these are critical habitat areas. Because of public pressure, however, some areas are closed to hunting of this valuable animal.

In the summer, brown bears are found along salmon streams, and feed almost exclusively on spawning salmon until the berries ripen (Figure 150). At that time, the bears start moving into the hills, where they feed on a variety of berries, supplementing their diet with salmon until denning time. In late fall, the bears find a south-facing slope and den at an elevation of about 300 m. when possible.[1]

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1. Willard A. Troyer, and Richard J. Hensel. 1965. The Brown Bear of Kodiak Island. U.S. Bureau of Sport Fisheries and Wildlife, Anchorage. Unpublished. 233 pp.

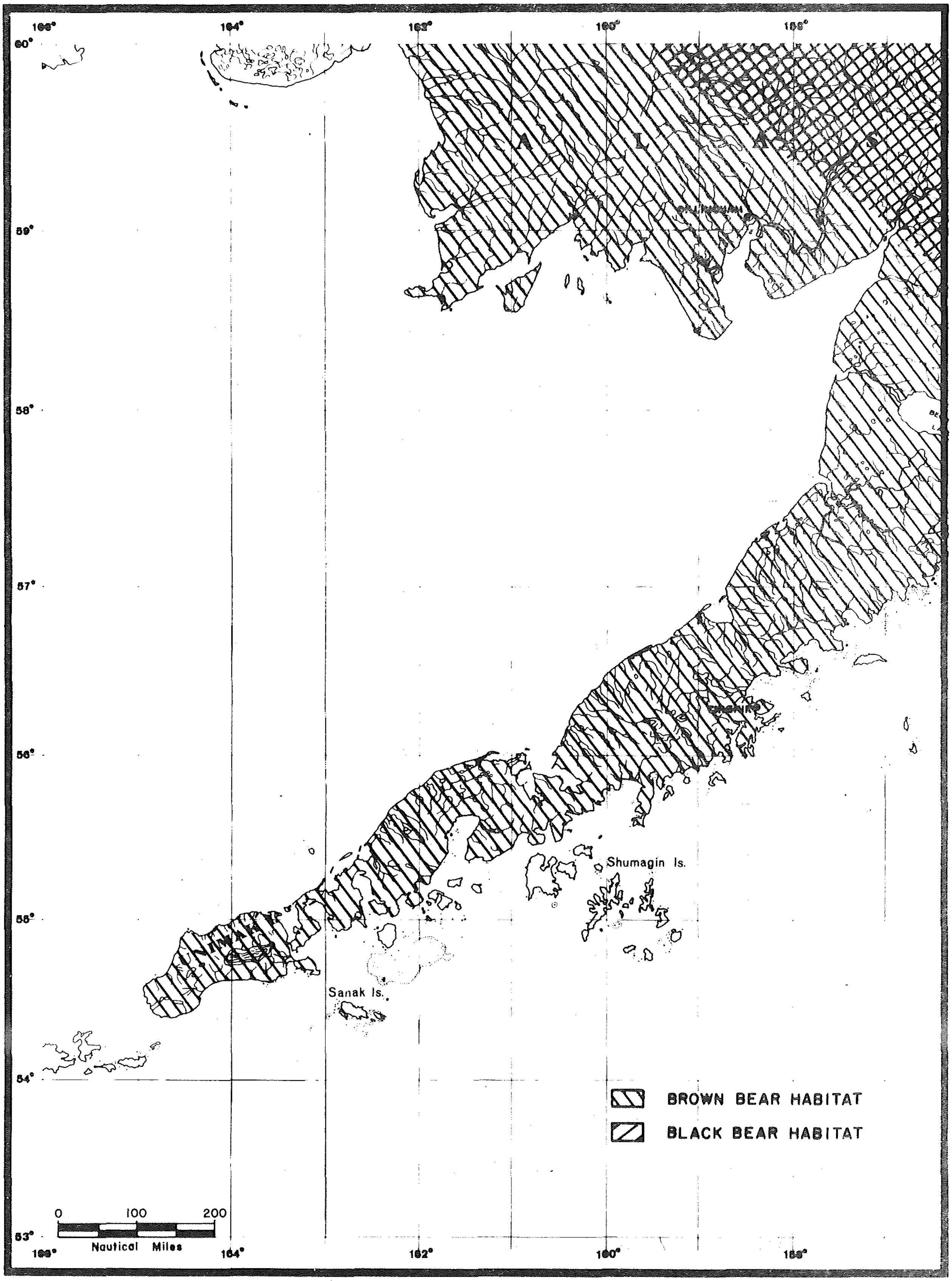

Figure 149. Occurrence of bears in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

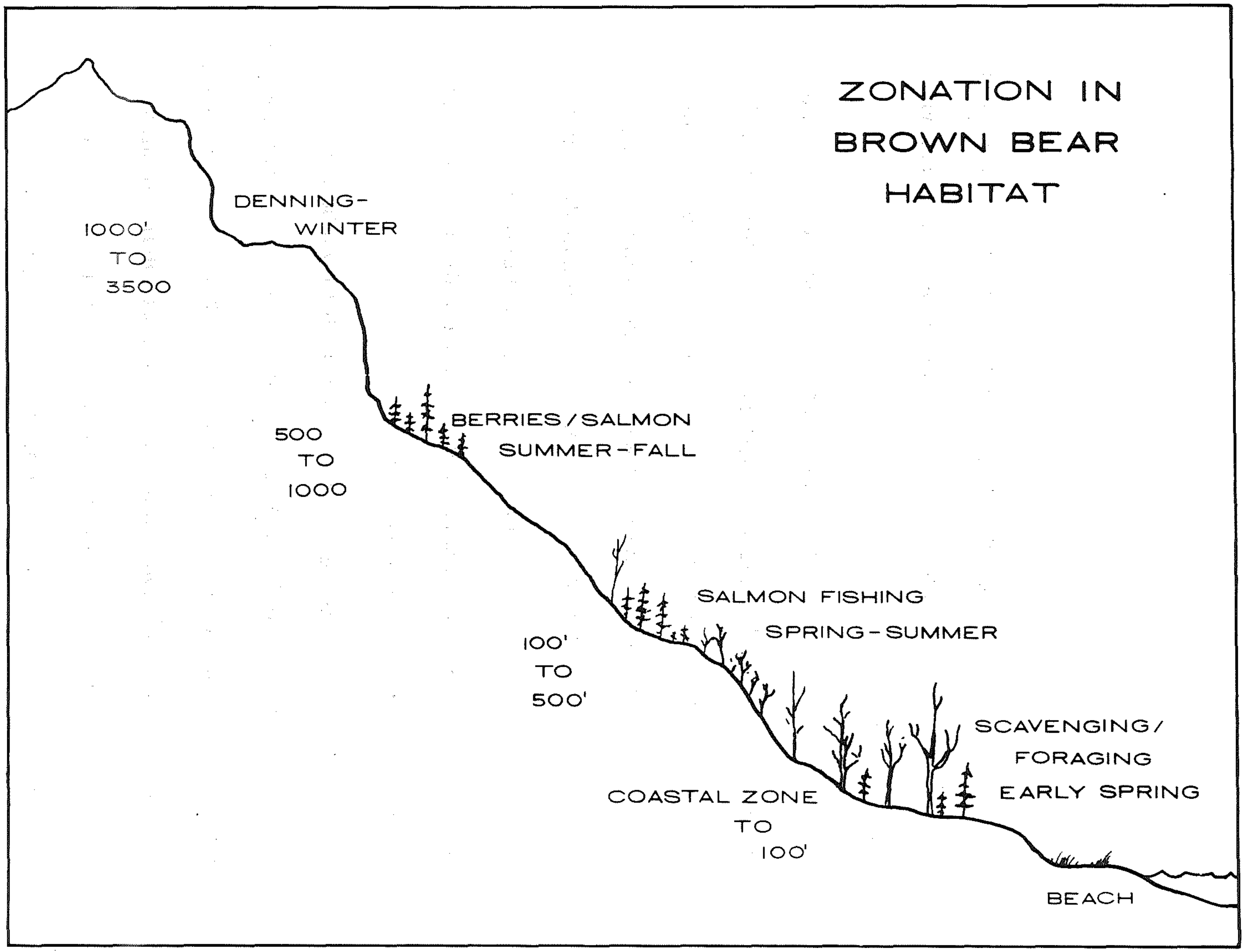

Figure 150. Zonation in brown bear habitat (from Troyer and Hensel, unpublished).

Mustelidae

Marten, Martes americana, inhabit the Bristol Bay area but prefer forested uplands, and seldom come in contact with the coastal zone.

Two weasels are known to inhabit the study area--the shorttailed weasel, Mustela erminea, and the least weasel, Mustela rixosa. The least weasel is more likely to be found near the shore, as it inhabits meadows and grassy areas, as well as brush. Shorttailed weasels prefers brush (Burt and Grossenheider 1964). Generally, weasels subsist on voles and small birds, but Schiller and Rausch (1956) noted a weasel feeding on a glaucous-winged gull.

The mink, Mustela vison, is common throughout the area. It lives along the banks of streams and lakes, and is influenced by the condition of the marine environment because it preys on bird's eggs and fish (Burt and Grossenheider 1964). A mink caught by Schiller and Rausch (1956) died from a fish bone piercing its abdomen which might indicate that the size of fish they can eat is limited.

The wolverine, Gulo luscus, is nowhere common, but does occur throughout the Bristol Bay area (Figure 151). These omnivorous animals are voracious. Beals and Longworth (Murie 1959) reported tracks on Unimak Island "on practically all the beaches from Swanson Lagoon to Banjo Bay." Alaska Department of Fish and Game (1973) reports that wolverines relish dead marine mammals which have partially decomposed on the beaches.

The river otter, Lutra canadensis, is found throughout the area of study along streams and in lakes. They are also reported to share the coastal salt waters with their close relatives, the sea otter (Murie 1959). Wetmore et al. (1945) reported that land otters were frequently seen "swimming boldly out to the islands, lying off the coast." Otters eat crayfish, fish, and invertebrates in their freshwater habitat, so it is possible that they also consume marine vertebrates and invertebrates.

Canidae

The wolf, Canis lupus, ranges throughout the regions bordering Bristol Bay (Figure 152). Wolves prefer big game

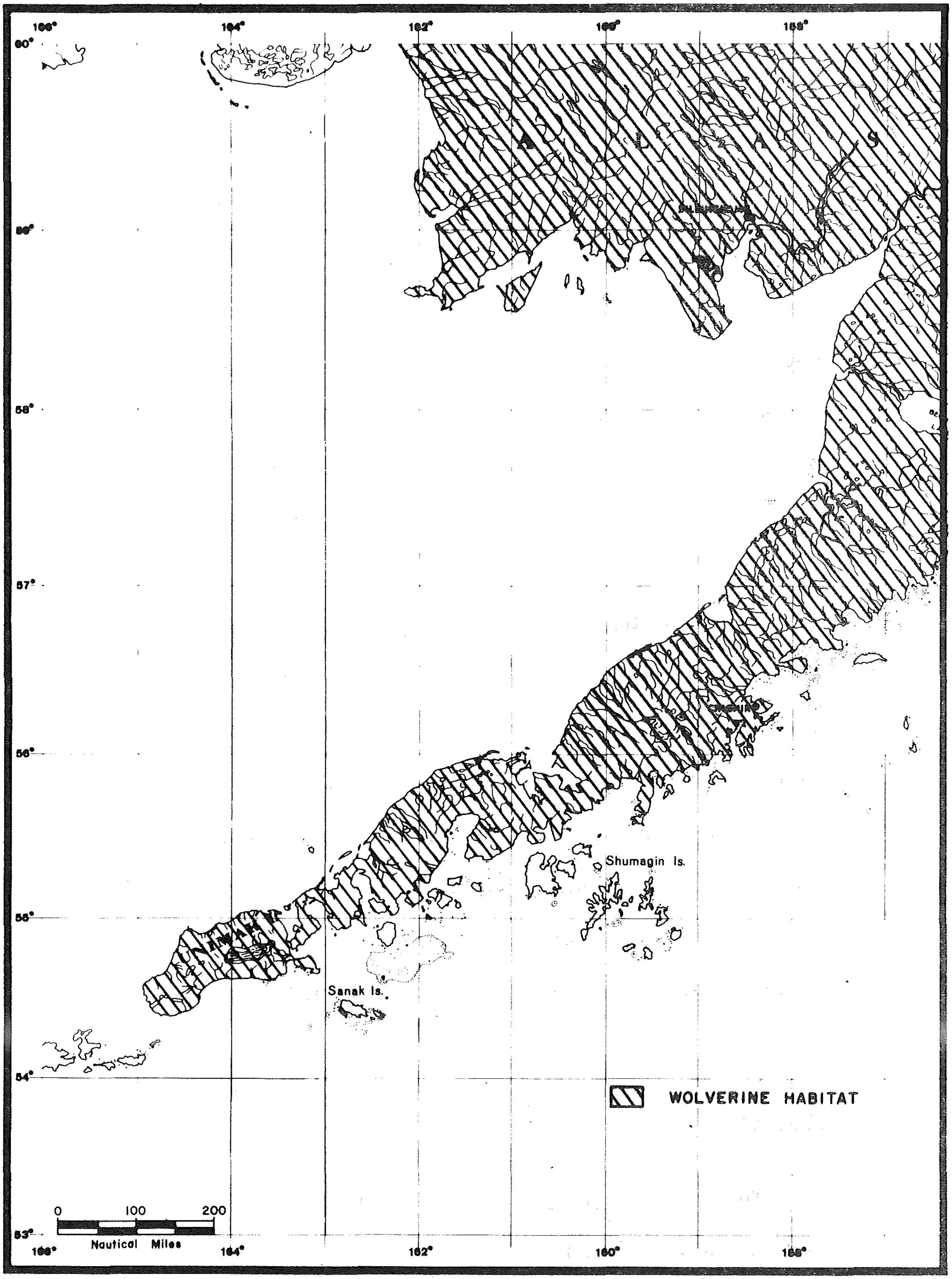

Figure 151. Occurrence of wolverine in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

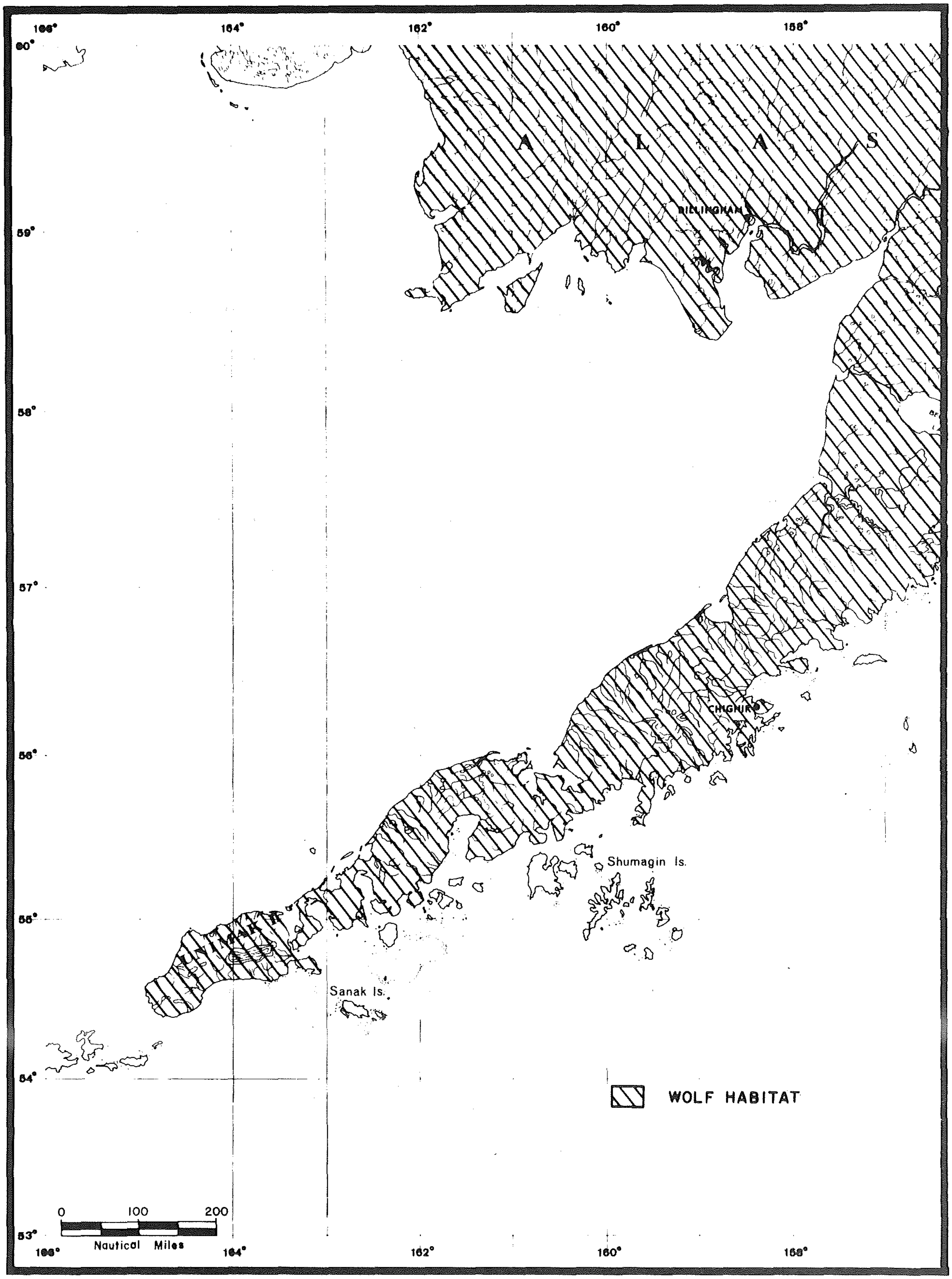

Figure 152. Occurrence of wolves in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

animals for food, and Mech (1970) reports that caribou remains were identified in six of sixteen stomachs of wolves collected on the Alaska Peninsula, while moose occurred in seven of the sixteen. Alaska Department of Fish and Game (1973) considers salmon and waterfowl important secondary prey species for wolves.

Red fox, Vulpes fulva, are native to the Bristol Bay area and very plentiful. Murie (1959) postulates that the fox formerly occurred in both the red and black phase, but selective killing of the dark phase, because of its superior value on the fur market, has eliminated the black fox from the Alaska Peninsula. Foxes forage frequently along the beaches, where Murie (1959) observed that red foxes "spent much time on the beaches...where they dug for clams they located by scent. They also picked up crabs at low tide and ate codfish or other carrion thrown up on the beach." This was observed in the Aleutians, but presumably the foxes in the study area would develop some of the same habits. At Dolgoi Island, Murie examined 57 red fox scats. One dropping contained 100 percent sea urchin and three others contained 100 percent beach fleas. According to Table 40, foxes will eat a variety of marine related objects.

Table 40. Composition of 27 red fox scats

Item	Occurrence	Percent
Microtus	38	52
Bird	16	21.9
Beach fleas	6	8.2
Sea urchin (_Strongylocentrotus_ sp.)	4	5.4
Mussel (_Mytilus_ sp.)	2	2.7
Heavy cloth	2	2.7
Brown paper	2	2.7
Hair seal (_Phoca_ sp.)	1	1.3
Small fish	1	1.3
Large bone	1	1.3

Source: Murie 1959

Arctic or blue fox, Alopex lagopus, have been introduced so widely that it is difficult to determine their original distribution. At present, this fox is found along the entire coast of Bristol Bay. It is a true scavenger and in the Arctic it follows polar bears and feeds off the polar bear kills (Burt and Grossenheider 1964). In the area of study, these foxes live mainly on carrion and various invertebrates which they find along the beaches. In the Aleutian Islands, blue foxes are a major threat to several endangered species of birds, but they do not appear to threaten birds colonies in the Bristol Bay area. In 1970, there was a massive rabies epidemic from which fox populations are still recovering (Jones 1972).

Felidae

The cat family is represented by only one species--the lynx, Lynx canadensis. This cat is cyclically abundant, generally following the cycle of the hares on which it prefers to feed. Lynx are generally found only in forested areas, but they were reported in the tundra region west of Nelson Lagoon in 1911 (Murie 1959).

Sciuridae

The ground squirrel, Citellus parryii, is the only member of this family which might come in contact with marine waters. Murie (1959) reports that a ground squirrel had been seen swimming across a bay in Isanotski Strait. They are more common inland.

Castoridae

Beaver, Castor canadensis, are abundant in the study area and adjacent lands to the north of Bristol Bay. In fact, Dillingham claims the title of "The Beaver Capital of the World." Beaver prefer inland fresh waters, and would seldom be affected by Bristol Bay waters, except in the case of large storms and flooding.

Cricetidae

The voles most likely to come in contact with the coastal zone in the study area are the tundra vole, Microtus oeconomus; and the meadow vole, M. pennsylvanicus. These small rodents burrow in the grasses along the coast of the Bay, and depend on beach and other grasses for their nourishment (Murie 1959). There is some evidence that their numbers are cyclic, possibly influenced by large populations of parasites (Murie 1959). Lemmings, _Dicrostonyx_ sp., also occur on the tundra in this area, but their only contact with the marine environment would be their sporadic mass migrations to the ocean.

The muskrat, _Ondatra zibethica_, generally remains far from salt water, but has been known to consume marine clams and fish (Burt and Grossenheider 1964).

Erethizontidae

The porcupine, _Erethizon dorsatum_, is generally a denizen of the inland forests, but Wetmore et al. (1945) observed one walking along the beach, apparently sniffing the kelp at the water's edge. Whether or not they actually eat kelp is uncertain, but their fondness for salt makes it likely that they might periodically come in contact with the coastal zone environment.

Cervidae

Moose, Alces alces, are common around Bristol Bay (Figure 153). This big game species utilizes the willows on the Alaska Peninsula for food and cover.

Barren ground caribou, Rangifer tarandus granti, another big game species, occur in three herds in the study area; the Alaska Peninsula herd that numbers between 12,000 and 13,000, the Mulchatna herd of about 5,000, and the Unimak Island herd which various observers estimate to number between 1,500 and 4,000 (Figure 154). These herds seldom come in direct contact with the marine environment, but the flats near Egegik and south of Port Moller and habitats on the north side of Unimak Island are critical wintering areas for the Alaska Peninsula and Unimak herds.

Reindeer, Rangifer tarandus tarandus, have been introduced on Hagemeister Island.

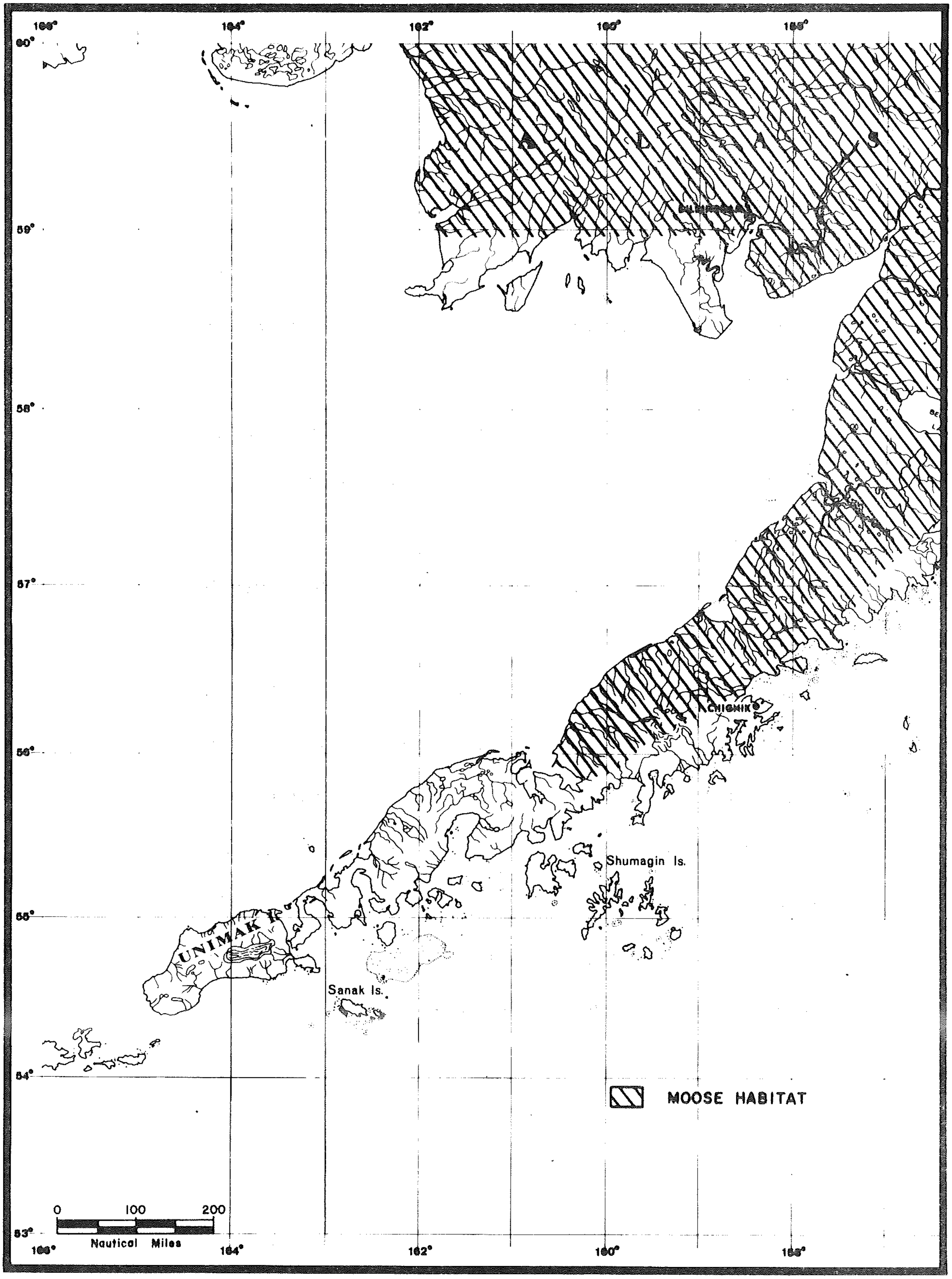

Figure 153. Occurrence of moose in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

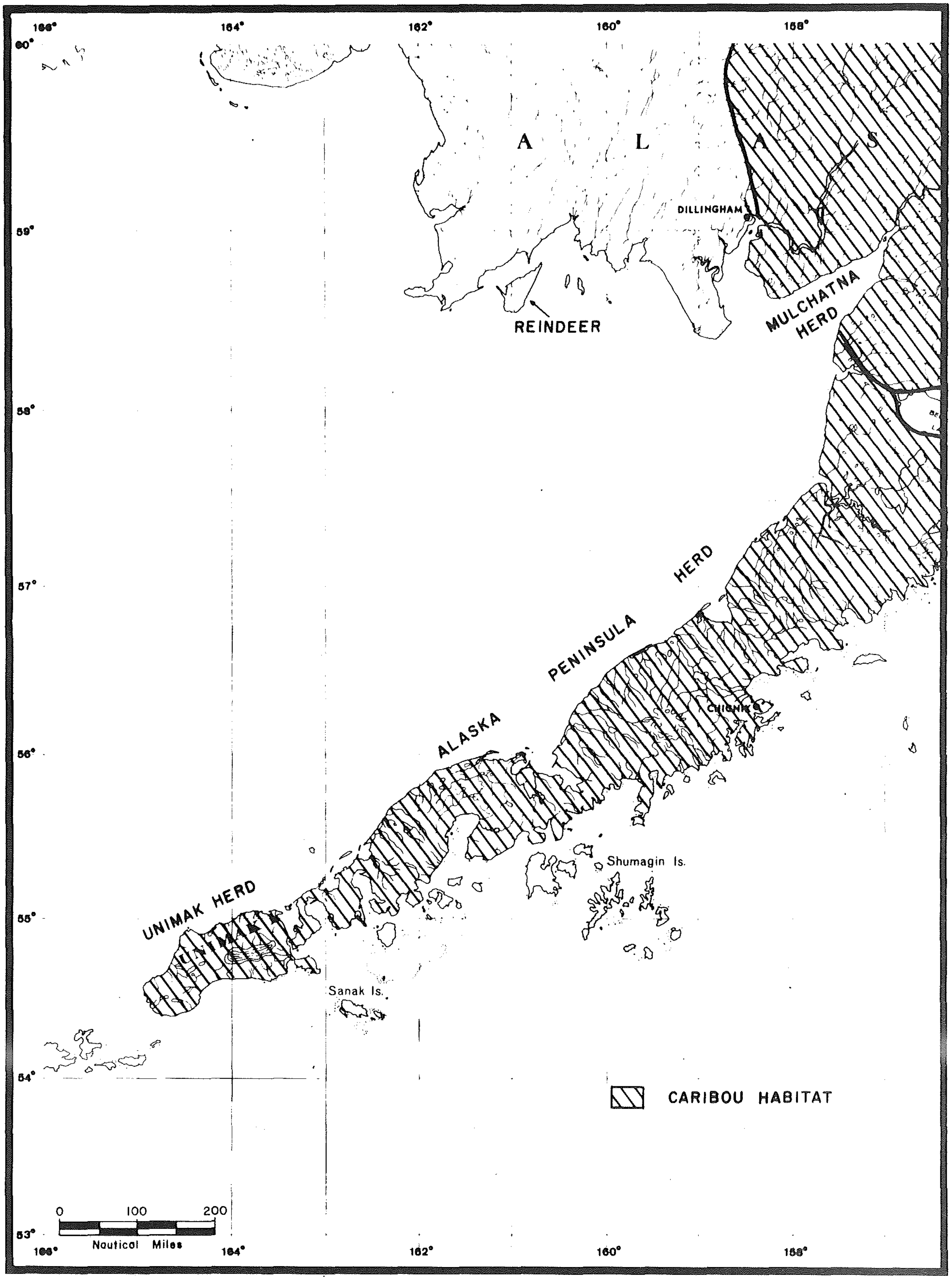

Figure 154. Occurrence of caribou in the Bristol Bay area (from Alaska Department of Fish and Game 1973).

ECOLOGICAL SYSTEMS AND MECHANISMS

Ecologists often disagree on terminology and subdivisions of the environment. Classification in the Bristol Bay area is particularly difficult, because almost no ecological research has been done--either in terrestrial regions, the intertidal zone, offshore waters, or on the outer continental shelf. Most marine ecological data pertain to primary productivity and salmon life history. For example, energy flow, predation, competition, critical limiting factors and other aspects of food chain dynamics are not well known. Most terrestrial information derives from reconnaissance and is descriptive in nature.

According to Rickets et al. (1968), 3 important interlocking factors--degree of wave shock, the bottom type, and tidal exposure--determine the distribution of marine fauna, particularly invertebrates, within a specific habitat.

Wave shock is determined by the size of the unbroken water body, water depth, and wind velocity and direction. The presence of eelgrass and other factors which modify wave force determine the species composition of animal communities. The greatest modification of wave force is evident in closed bays, sounds, and estuaries, where fauna are different from those which inhabit the open coast. Some species occur in both closed and open areas, but those found in closed locations frequently differ in habit and habitat from those found in exposed areas.

The bottom type (clay, sand, gravel, silt, etc.) is important, because the various species of benthos have different requirements that can be satisfied only by specific bottom types. For instance, some animals with holdfasts require a rocky substrate while others, such as some clams, require sandy bottoms.

Tidal exposure--the length of time that intertidal fauna are exposed to air--varies from zones above the level of high spring tides, where animals are splashed by waves or spray only a few times each month, to the level of low spring tides, where species are uncovered only a few hours each month. In the Naknek River estuary, the scouring effect of tides and wind exposure are reported to limit development of faunal communities (Malick et al. 1971).

On the northern coast of the Bay, winter ice conditions abrade attached marine organisms and erode mud flats and sand beaches where burrowing animals might exist. Similar conditions exist on the south side of the Bay where frequent storms and intense wave action erode the beaches. Rocky outcrops are uncommon along the southern coast until the Unimak Island vicinity is reached where attached organisms, whose larvae and eggs probably have drifted in with North Pacific waters through Unimak Pass, can be found.

Many protected estuaries and intertidal waters exist within the broad category of "ice affected coast" (Figure 155). These waters are among the most productive in the world. Mechanisms and conditions interplay here to maintain energy transport at rates often considerably greater than those in offshore waters. Tidal action promotes rapid circulation of nutrients and food, and aids in the rapid removal of waste products. Diverse plant species and life forms--phytoplankton, benthic microflora, seaweeds, and sea grasses--provide a relatively continuous photosynthetic production, during the growing season throughout the water mass. The close contact

Figure 155. (inclosed copy of Ecosystem Map of Alaska from Joint Federal-State Land Use Planning Commission)

between producers and consumers enhances biomass productivity. Large eelgrass beds provide some protection for communities by partially dissipating wave and tidal forces (Odum 1963).

High turbidity in inner Bristol Bay restricts photosynthesis and limits productivity. Bottom substrates are relatively unstable and do not support a large benthic biomass. Winter water temperatures are often 0 degrees C. or lower.

The outer contintental shelf area of the Bay is highly productive due to an abundance of nutrients from upwelling along the contintental slope and Aleutian passes, the turbulent mixing of these waters by storm and wind activity, and an abundance of sunlight during summer. Primary productivity, zooplankton density, benthic biomass, and summer concentrations of commercial crab and bottomfish appear greatest here. According to McRoy et al. (1972), highest primary productivity occurs in summer near the retreating edge of the sea ice. Summer residents of the central Bay use this area as a prime feeding ground and migrate to the continental shelf edge in winter.

The central Bay is one of the richest areas of the North Pacific. At times, deeper waters flow into this area along the bottom from the north and west, bringing nutrients which stimulate productivity as they rise into the upper lighted waters.

Low temperatures and decreased sunlight limit production in winter in the outer Bay area. In late winter, highest primary productivity occurs at the underside of the sea ice to a depth of several centimeters within the sea ice. In general, seasonal differences which affect the extent and range of the sea ice, greatly affect the biology and primary productivity of the area.

The abyssal depths west of the study area are a "semidesert," with relatively little biomass per unit area. Compared to the total depth of the water column, the photosynthetic zone in this region is extremely small, and productivity may often be limited by an insufficient nutrient supply.

Three ecological zones have been described for the Bristol Bay shelf based on the distribution of shrimp species(Ivanov 1969). Temperature differences related to depth appear to be the controlling factor in the delineation of these zones (Figure 156). These zones parallel the mainland and are:

zone 1 - sharp seasonal temperature fluctuations (warm in summer, cold in winter);

zone 2 - constant low temperature near the bottom;

zone 3 - waters warmed by deep continental slope waters.

Each zone contains distinctive species. Zone 1 consists of sandy coastal areas not exceeding 50 m. in depth, inhabited by species requiring comparatively warm water in summer and with the ability to withstand or escape seasonal cold. Zone 2 extends from a depth of 50 m. to depths between 60 and 100 m. on generally muddy bottoms. Other species of pelagic and benthic fauna dominate in waters with depths greater than 100 m. Interfaces vary between zones 2 and 3. Zone 2 expands in winter. Zone 3 decreases correspondingly, and some species migrate to seek optimum temperatures.

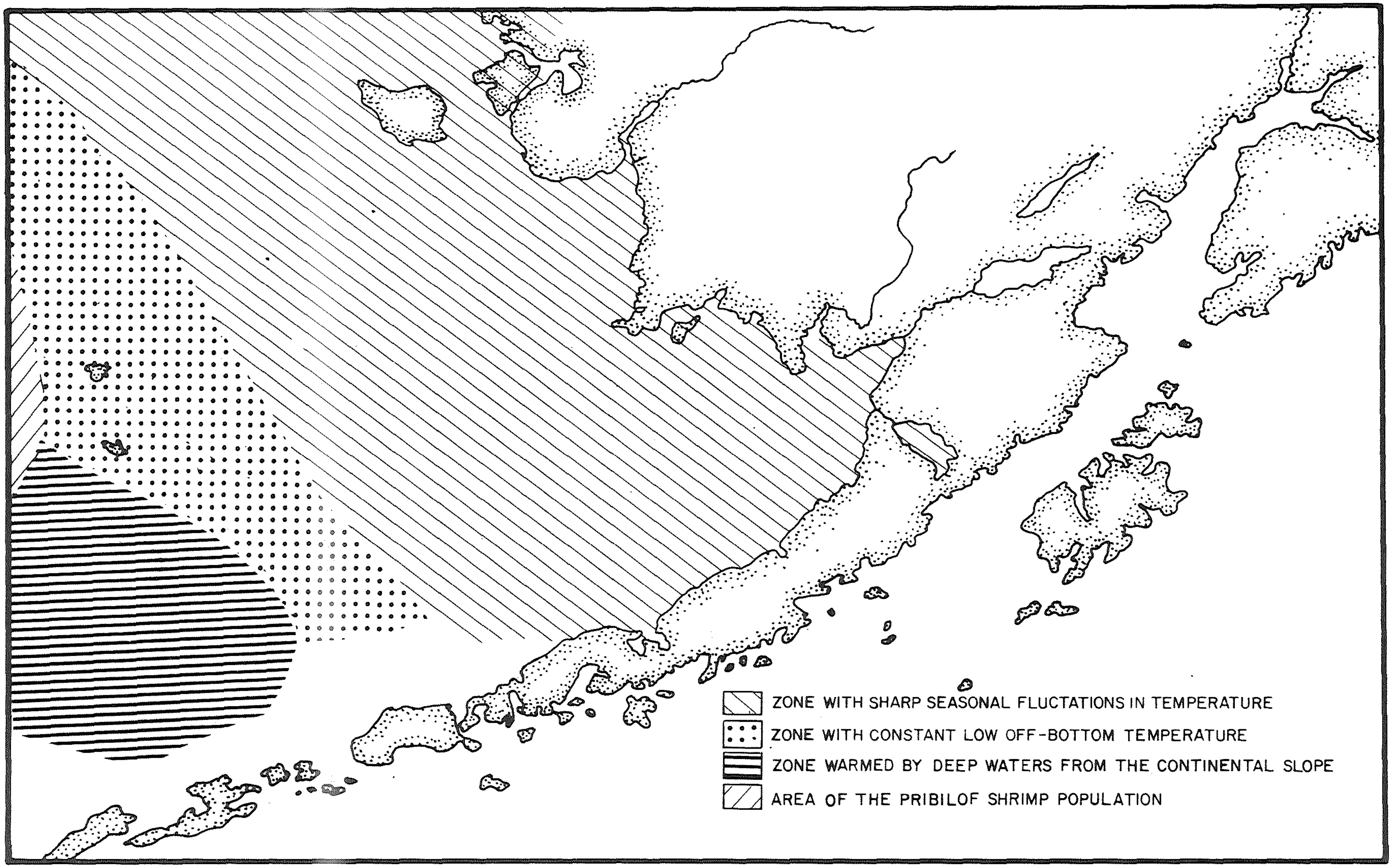

Figure 156. Location of marine ecological zones in association with shrimp concentrations (from Ivanov 1969).

The variable character of the physical environment in Bristol Bay exerts much stress on the biological communities and results in considerable variation in biological activity between seasons and years. Extreme stress occurs during 5 or 6 months of the year (October or November through March) primarily caused by low temperatures, low amounts of light, and intertidal ice abrasion. During these months biological activities are minimal, and crab and bottomfish species maintain limited juvenile stocks.

Most summer residents of the study area migrate to warmer and deeper waters along the continental shelf edge between the Pribilof Islands and Unimak Pass. Here shrimp, halibut, crab, herring, and most bottomfish spend the winter months in concentrated groups which are attractive to a variety of commercial fishery ventures.

In the extreme southwest corner of the study area, warm North Pacific waters enter Bristol Bay through Unimak Pass. Such species as Dungeness crab and razor clams found there are probably brought in by these warm waters as larvae and may not reproduce there.

Perhaps the best freshwater ecological work in the study area is summarized in a report by Burgner et al. (1969), dealing with the biology of sockeye salmon in major southwestern Alaska river systems. Basic physical characteristics such as area, depth, volume, shoreline length, water chemistry, and temperature, as well as primary productivity and standing crop were described for important salmon spawning lakes and river systems (Igushik, Snake, Wood, Kvichak, Alagnak, Naknek, Egegik, and Ugashik). The Igushik and Wood River systems were found to have the highest primary productivity and to produce the most adult salmon per square kilometer. Standing crops of phytoplankton and concentrations of total dissolved solids were not clearly related to salmon production. Sockeyes were found to use 4 main types of spawning grounds:--lake tributaries, rivers connecting lakes, outlet rivers, and lake beaches. The utilization of each type of spawning ground varies with the river system and differs from year to year within the systems. Particular spawning areas may be overcrowded or underutilized, depending on escapement. In some areas, returning salmon of different ages indicate a preference for a specific habitat type.

Gravel size, water depth, bottom gradient, and water velocity are critical in determining the suitability of spawning areas in Bristol Bay systems. The space required by a spawning female in each system was also estimated. Sockeye populations appeared to be controlled by the capacity of nursery areas. The annual return of salmon to the different systems varies greatly.

Plant communities have been defined by grouping species. The predominance of an individual species within a plant community may vary greatly from place to place. Together, the plants and animals in an area comprise the biotic community, and in conjunction with their accompanying physical setting, form an ecosystem. The ecosystems depicted in Figure 155 characterize the Bristol Bay area and conform to geologic formations and general soil groups in the area. (Joint Federal-State Land Use Planning Commission 1973, Viereck and Little 1972).

The maritime climate of Bristol Bay moderates the temperature but creates a heavy cloud cover with a resultant decrease in solar energy. Consequently, most of the land surrounding the Bristol Bay area is covered with low, slowly growing vegetation. Primary consumers are herbivores and are widely distributed in both terrestrial and marine ecosystems. Secondary consumers, predators, also utilize both land and marine life. The intertidal zone is relatively bountiful in winter when food may be scarce elsewhere.

Many species living on land forage far out at sea and enrich the land with nutrients from the sea. In addition, oceangoing species such as salmon, spawn and die in fresh water. Their carcasses contribute significant nutrients to the land. In return, the nutrients from the land leach to the ocean.

In ages past, the environment was quite different. For about 500 million years, the world climate has alternated between warm periods of extensive tropical flora and ice ages. An ice sheet, centered on the U.S.-Canadian border and believed to have been as much as 4.3 km. thick, once covered all of Bristol Bay. Between

4,500 and 7,500 years ago, temperatures were about 2C degrees warmer than now; the Arctic Ocean, for example, was ice-free. Presently, the worldwide temperature appears to be decreasing. Current glacier recession will halt if the temperature continues to decrease.[1]

Flora in the study area have changed considerably in response to these climatic changes. Fossilized trees as large as 3 m. in diameter are found along the northwest coast of Unga Island, the largest island of the Shumagin Group, south of the Alaska Peninsula. Such trees probably existed on the Peninsula north of the Aleutian Range, but no evidence has yet been found.[2] These fossils have been identified as belonging to the genera Sequoia or Metasequoia, which were widespread over the northern hemisphere from about 35 degrees North latitude to beyond the Arctic Circle during warmer times. Mastodons and mammoths

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1. M. Mitchell, Jr., Project Scientist for Climatic Change, Environmental Data Service. Silver Springs, Maryland. Personal communication.
2. K. Rein, Forester, Resource Planning Team, Joint Federal-State Land Use Planning Commission for Alaska. Anchorage. Personal communication .

also flourished in what are now Arctic and sub-Arctic regions. Metasequoia sp. flourished more than 20 million years ago. Its growth was apparently restricted to valleys and areas of low to moderate elevation, possibly flood plains, where humidity was high. Temperatures were moderate, rarely dropping to the freezing point. The trees on Unga Island were covered with sedimentary material between 11 and 25 million years ago (Eakins 1970).

Many reports clearly indicate the advance of Sitka spruce from Afognak Island, across Kodiak Island and toward the Alaska Peninsula (Griggs 1934; Lutz 1963; Murie 1959). Sitka spruce were planted on Unalaska Island in the Aleutians in 1805, and have produced cones and seedlings. There is great disagreement, however, as to whether such forests have existed in the Aleutians in the past. The forest edge on the Peninsula is advancing at a rate of approximately a mile per year. If current conditions prevail, these trees might, in time, cover the entire Alaska Peninsula.

The biotic environment of Bristol Bay is presently, and has always been, in a state of constant change.

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SOCIOECONOMICS

GENERAL DESCRIPTION

Introduction

The Bristol Bay region is in the southwestern corner of Alaska on the southern coast of the Bering Sea. The land area is in a basin between 2 major mountain ranges: The Kuskokwim Mountains to the west and north; and the Aleutian Range to the south and east. This basin forms the watershed for the river and lake system that supports the tremendously valuable Bristol Bay salmon fishery. For present purposes, the study region will be defined as the area encompassed by the Bristol Bay Borough and the surrounding Bristol Bay Census Division (Figure 157).

A recent study by Rogers provides an excellent summary of the economic history of this region (Rogers 1972).

> In aboriginal times it was inhabited by four major Eskimo tribes living on salmon, sea mammals and upriver land mammals. Fisheries and fur resources have been the source of income and employment in the region from the beginning of "historic time" until the present with the addition of some defense and other government spending. The Wood and Nushagak Rivers were prodigious breeding grounds for beaver, mink and muskrat and the fur trade was the first source of outside contact and commercial development.
>
> The first salmon cannery was erected near the Moravian mission at Carmel in 1884 followed by the rapid multiplication of plant and gear engaged in the harvesting and canning of the salmon runs of the Bay.

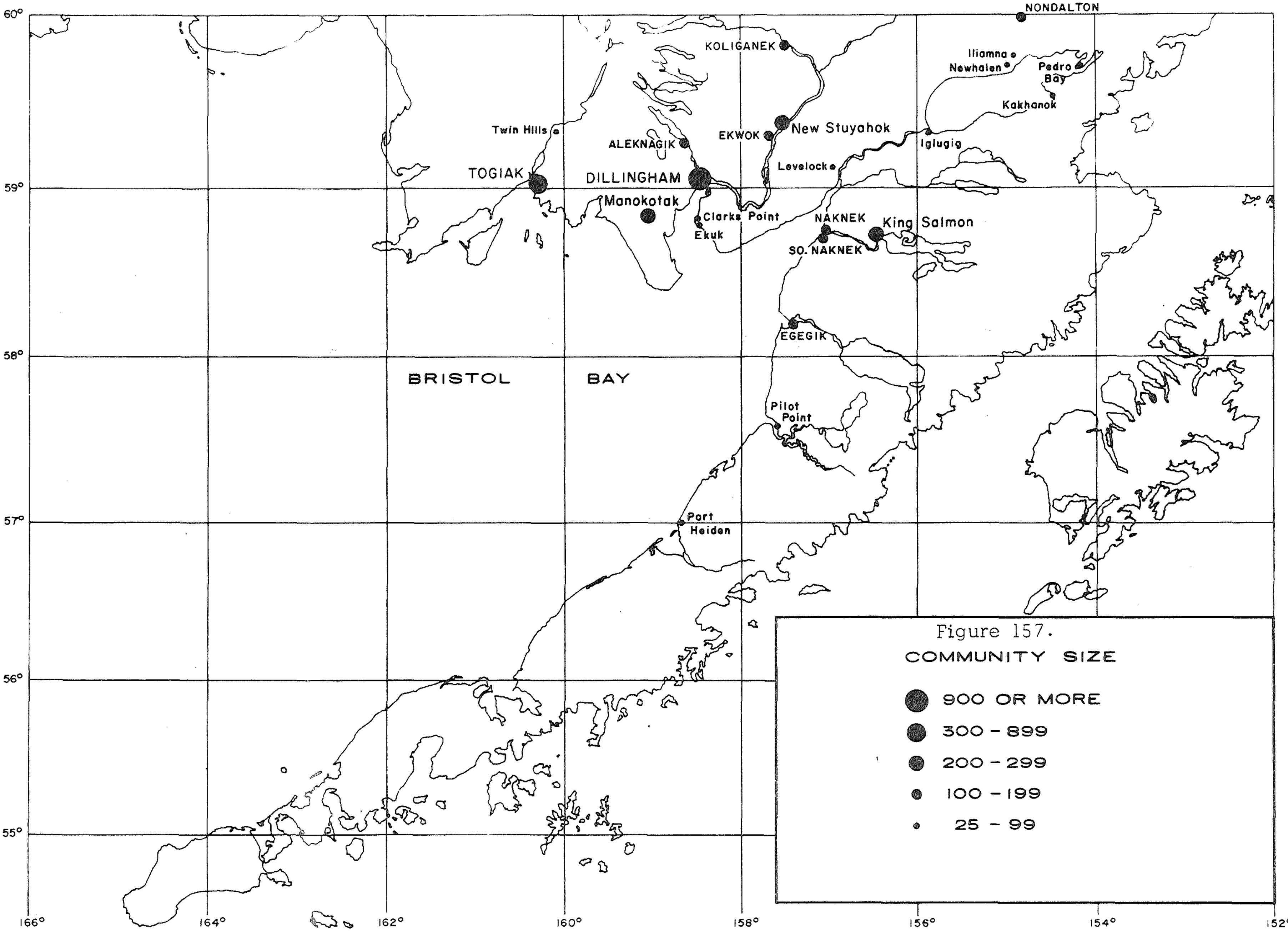

Figure 157.
COMMUNITY SIZE

Until recently, this commercial exploitation of the region's principal resource supported little permanent local economic activity. Initially the total shore work force was made up of Chinese transported by sailing ships from San Francisco each season along with cannery supplies and returned with the canned salmon pack. Fishermen were Italians and Scandinavians from California and the Pacific Northwest. Some residents began to become involved in the 1920's and after. A special 1939 study of employment and income in the region's salmon fisheries reported that of 8,227 employed in the industry at that date, 496 were Natives and 1,387 non-Native residents of Alaska. No indication was given of how many of these last were residents of the region. Fifteen years later another report state "of a total of about 6,000 men presently employed in the fishing industry in the Bristol Bay area, 4,000 are brought in from the United States; 1,000 are recruited from other parts of the Territory; and only 1,000 are provided locally."

Other marine resources are abundantly present in the region, but exploitation of these has been minimal because of the remoteness of the region from markets and sources of supply. Tourism and outdoor recreation potential remain underdeveloped. Fur harvests today are minor in importance. There are some indications of mineral potential, but development has been minor and sporadic with some petroleum exploration during the last decade. The advent of World War II brought the establishment of permanent defense base at King Salmon near Naknek and temporary smaller stations elsewhere. For the most part, the residents of the region have continued to follow a subsistence existence supplemented by cash income employment in commercial salmon fishing and welfare. None of these developments brought any change in the basic transportation systems of the region beyond defense stimulated improvement in air service and some minor road extensions.

In 1970, there were about 4,600 persons living in the

Bristol Bay region (Table 41). About one-third of the population

Table 41

SUMMARY STATISTICS, 1960 and 1970, BRISTOL BAY

	1960	1970		
	Bristol Bay	Bristol Bay Borough	Bristol Bay Division	Total
Population	4,024	1,147	3,485	4,632
White	1,423	922	671	1,593
Native		186	2,763	2,949
Eskimo	2,601	35	1,656	1,691
Other		39	51	90
Military Personnel	536	434	5	439
Civilian Labor Force	657	224	658	882
Employment	514	165	584	749
Private	309	54	298	352
Government	205	111	286	397
Unemployment (Percent)	143 (21.5)	59 (26.3)	74 (11.2)	133 (15.1)
Median Family Income	$5,955	$12,390	$6,671	$7,784

Source: U.S. Bureau of the Census 1963,1971d; Institute of Social, Economic, and Government Research 1972.

is white and two-thirds are Native. Eskimos are the largest Native group and account for nearly 60 percent of the Native population. Much of the non-Native population is concentrated around the King Salmon Air Force Base within the Bristol Bay Borough.

As shown in Figure 157 and Table 42, the population is scattered throughout the region in more than 20 small towns and villages. Dillingham and the Bristol Bay Borough are the only 2 concentrations of population and together they account for less than half of the region's population. Furthermore, there is no indication of increasing concentration over time. If anything, the reverse is true--several of the remote areas are growing more rapidly than the relatively urbanized areas. This dispersion of settlements may simply reflect individuals' personal preferences or it may be necessitated by the economy's continued reliance on subsistence activities. Given the nature of the environment, subsistence activities require large land areas around each settlement. It may be that more concentrated settlement is not feasible under present conditions.

Table 42

Community Size, Bristol Bay 1970

900 or more population	Population
Dillingham	914
300 - 899 population	
Togiak	383
200 - 299 population	
King Salmon	202
Manokotak	212
New Stuyahok	216
100 - 199 population	
Aleknagik	128
Egegik	148
Ekwok	103
Kolignek	142
Naknek	178
Nondalton	184
South Naknek	154
25 - 100 population	
Clarks Point	95
Ekuk	51
Igiugig	36
Iliamna	58
Kakhonak	88
Levelock	74
Newhalen	88
Pedro Bay	65
Pilot Point	68
Port Heiden	66
Twin Hills	67

Source: U.S. Bureau of the Census 1971f.

The only significant source of private employment in the region is provided by the fishing industry during the annual salmon runs. Since these runs last only about 6 weeks, the extreme seasonality of the fishing industry makes it very difficult to describe employment patterns accurately. For example, the average annual employment was about 450 in commercial fishing and about 700 in fish processing during 1970. But in July, at the peak of the salmon run, there were 3,000 persons employed in commercial fishing and another 3,300 were working in the canneries (Rogers 1972). Clearly, a substantial number of these people had to be from outside the Bristol Bay region but, for the local residents, the fishing season may offer the only employment during the entire year. At the end of the season, the Bristol Bay Natives collect their wages, return to their villages from the fishing camps, and simply drop out of the labor force until the next season.

Since the census data shown in Table 41 were collected in late March or early April, they provide useful information on the pattern of permanent, or year-round, employment. It is apparent that the government sector is the major source of permanent employment. Government jobs account for more than half of the total and, if the military were included, the proportion would rise to 70 percent. In the private sector, a small amount of permanent employment is provided by the local canneries. Also, the transport sector provides crucial air services to the region throughout the winter, and thus, is an important year-round employer.

The median family income in Bristol Bay is 7,800 dollars as compared to 12,400 dollars for the state as a whole. Due to the influence of the King Salmon Air Force Base, income in Bristol Bay Borough is about the same as the state average, but in Bristol Bay Division median family income is 6,700 dollars, only slightly more than half of the state average. In addition, the difficulty in getting supplies to Bristol Bay substantially raises the cost of living in the region. Thus, the relative gap in real incomes is even larger than that shown by the money income. It seems clear that subsistence activities are necessary in the Bristol Bay region to augment the available money incomes.

Major Communities in Bristol Bay

The communities in Bristol Bay, included in the 1970 census, are listed in Table 42 and shown on Figure 157 . In discussing these communities, it is helpful to combine them into 6 groups on the basis of geographic and economic linkages. The first group consists of the villages around Nushagak Bay and centers on Dillingham, the largest city in Bristol Bay. Dillingham also serves as the commercial center for the second group, the Nushagak River villages of Koliganek, New Stuyahok, and Ekwok. In terms of fishing activity and trade, these villages might be regarded as part of the general Dillingham area. However, on the basis of other socioeconomic characteristics, particularly population growth, they display a distinctly different pattern and need to be treated separately.

The next major group contains Naknek, South Naknek, and King Salmon, which are linked through the governmental structure of Bristol Bay Borough, as well as through economic ties. The 7 villages in the fourth group are located around Iliamna Lake. For much of the year, they are relatively isolated from the rest of Bristol Bay, but during the summer, fishing activities and trade bring them in close contact with the Naknek region.

The 2 remaining groups are located at the extreme western and southern corners of Bristol Bay. Togiak and the nearby village of Twin Hills carry on trade with Dillingham, but the development pattern seems quite independent of the rest of the Bristol Bay region. In particular, Togiak has been growing extremely rapidly, despite an almost complete absence of the public facilities usually found in growing communities. The final group of villages contains those located on the Alaska Peninsula: Egegik, Pilot Point, and Port Heiden. These are all essentially fishing villages with stable populations.

In general, the study region is the same as the region encompassed by the Bristol Bay Native Corporation. However, the Corporation does include several communities (Chignik, Chignik Lagoon, Chignik Lake, Ivanof Bay, and Perryville) which are located on the south side of the Alaska Peninsula. Because these communities are well outside the geographic region being studied, they have not been included in the discussion below.

Dillingham and Nushagak Bay Villages

Dillingham, with a population of 914 in 1970, is the largest community in Bristol Bay (Table 42). It is located 560 km. by air southwest of Anchorage at the extreme northern end of Nushagak Bay near the mouths of the Nushagak and Wood Rivers. Nushagak Bay flows into Bristol Bay about 55 km. to the south.

In 1818, a Russian post was established in the Bristol Bay region on the east side of Nushagak Bay. By 1822, an active fur trade was being carried on through this post. The population in the area grew and the fur trade continued after the purchase of Alaska in 1867. The first salmon cannery in Bristol Bay was established in 1884 at the same location as the fur trading post. Two more canneries were built in the next 2 years, but these were located on the west side of Nushagak Bay in the vicinity of the present town of Dillingham. In the following years, more canneries were built and between 1908 and 1910 there were 10 canneries operating on Nushagak Bay. The town of Dillingham was officially name in 1904 for William Paul Dillingham, a U.S. Senator who conducted the first comprehensive investigation of Alaska by a congressional committee.

The population of Dillingham reached 280 in 1939 and then more than doubled by 1950. Population declined between 1950 and 1960, but then shot up to more than 900 persons in 1970. However, much of the increase shown in the 1970 census is due to the fact that the city of Dillingham incorporated more than a 57 sq. km. area in 1963. As a result, the city absorbed the populations of the nearby settlements of Kanakanak, Nelsonville, and Wood River Village. The incorporation also added to the population of Dillingham all the households residing along the roads leading to those villages. If a comparable area had been encompassed by the 1960 census, Dillingham's 1960 population would have been about 800 persons (Alaska State Housing Authority 1971).

About two-thirds of Dillingham's population are Natives. Aleuts are the largest racial group and constitute more than 40 percent of the total population. There were 325 whites in Dillingham in 1970, about one-third of the total population of the city. During the summer fishing season, the population in the Dillingham area may double as residents of the Nushagak Bay and Nushagak River villages come to Dillingham for the salmon season (Van Stone 1967). Many of these people live in established summer camps on the outskirts of town.

Historically, the growth of Dillingham has been closely linked to the development of the salmon canning industry. In recent years, Dillingham has also come to serve as a regional center for trade and services. Kodiak Western Alaska Airlines, a local carrier which serves most of the villages of the region, operates out of Dillingham, thus making the city a transfer point for passenger and freight traffic. Wien Air Alaska also provides service connecting Dillingham to Anchorage, as well as to other communities in the Bristol Bay region. A number of charter flying services also operate out of the city.

As the regional commercial center, Dillingham has general merchandise stores, a hardware store, a lumber yard, a bank, food stores, liquor stores, and a post office. It also has recreational facilities, such as a movie theater and pool halls. It offers the services of hotels, restaurants, and bars.

Dillingham has a much more extensive set of community facilities and services than anywhere else in the area. A new high school was constructed in 1961 and a small boat harbor was completed in 1962. There is a city water system and a sewer system was installed in 1964. The residents of the Dillingham area have telephone service, both local and long-distance. A local generating plant provides electric power to Dillingham, the surrounding area and Aleknagik. Medical services are available through the U.S. Public Health Service Hospital at Kanakanak, the public health nurse in residence at Dillingham, and a private practitioner in Dillingham.

The economy of Dillingham is significantly strengthened by a substantial amount of employment in various government agencies. These agencies include the Federal Aviation Administration, the U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, the Alaska Department of Highways, the city school district, and the U.S. Public Health Service Hospital at Kanakanak. The employment and income generated by these agencies is particularly important because,in contrast to employment in the fishing industry, it is quite stable with little seasonal variation. It should also be noted that,unlike many areas in Alaska, the government employment in Dillingham is entirely civilian; there are no military bases in the area.

The communities around Nushagak Bay include Aleknagik, Manokotak, Clarks Point, and Ekuk. Due to the economic ties through commercial fishing activities and geographic proximity, Dillingham serves as the commercial center for all these villages. Aleknagik has particularly close linkages with Dillingham because of a 39 km. road connection. The village is located north of Dillingham on Lake Aleknagik, the southernmost of the 5 lakes in the Wood River lake system. After the Eskimo population was virtually wiped out in the influenza epidemic of 1918-1919, families began to move back into the area starting in about 1928 (Van Stone 1967). Population grew steadily reaching a peak of 231 in the 1960 census, but then dropped abruptly to 128 in 1970. About 75 percent of the residents in 1970 were Eskimos and most of the other residents were whites. The only significant source of employment for the Natives is the Bristol Bay salmon fishery. During the salmon runs, almost the entire Native population moves to various fish camps to work on the fishing boats, to set nets, or to work in the canneries. The non-Native families in Aleknagik are generally employed as school teachers, postmaster, and business operators.

Manokotak is a rapidly growing Eskimo community about 40 km. southwest of Dillingham on the Igushik River which empties into Nushagak Bay. All but a few of the 214 residents of Manokotak are pure blood Eskimo. The U.S. Bureau of Indian Affairs (1966d) observed that

> One of the Eskimo dialects is used almost exclusively for communication among the people. Most often English interpreters are needed for meetings with government officials. English is taught in the school but is little used at home.

Commercial fishing in Nushagak Bay provides the major source of income. Until recently, almost all goods were brought from Dillingham by boat in the summer. In 1969, a village cooperative store went into operation and began to purchase goods directly from Seattle. More than half of the village houses were replaced with new units in 1971 (Federal Field Committee for Development Planning in Alaska 1971) and plans are being made to provide electric power for the village.

Clarks Point and Ekuk are located on the opposite side of Nushagak Bay and to the south of Dillingham. Although Ekuk was once an Eskimo village, the present communities are mainly cannery towns built around canneries located about 3 km. apart. In recent years, only the cannery at Ekuk has been in operation. Although the summer population is quite substantial due to the fishing camps in the area, the population reported in the 1970 census is only 95 for Clarks Point and 51 for Ekuk. In general, the permanent population seems to be declining and Clarks Point has petitioned to be moved to a new site due to recurrent flooding problems.

Nushagak River Villages

The Nushagak River villages of Koliganek, New Stuyahok, Ekwok, and Portage Creek had a total population of roughly 520 persons at the time of the 1970 census. However, the population of the individual villages fluctuates a great deal due to the high degree of mobility generally observed in the Nushagak River region. Some families move to Nushagak Bay for several years and then return and it is not uncommon for a family to maintain a cabin in more than 1 community. As a whole, the river villages grew by nearly 50 percent between 1960 and 1970. It appears that during recent years these villages have been drawing families from the communities located on the coast of Nushagak Bay (Van Stone 1967).

Koliganek, with a 1970 population of 142, is the village located farthest up the Nushagak River. The present village site was just established in 1964 and is the third location for the village, although it is only 11 km. from the original site and 5 km. from the previous location. Until recently, almost all supplies were brought during the summer by boat from Dillingham, a trip requiring three days or more depending on shifting sand bars and water flow in the Nushagak River. A cooperative store was established in 1970 and prices of goods in the village are estimated to have decreased approximately 15 percent due to its activities (Community Enterprise Development Corporation 1972). The population is almost entirely Eskimo, and despite the lack of employment opportunities, the village grew by more than 40 percent between 1960 and 1970. This may have been due, in part, to the new school that was constructed by the U.S. Bureau of Indian Affairs in 1965. With the exception of a small amount of trapping and a few temporary jobs, the only source of income and employment is the salmon fishery in Bristol Bay.

New Stuyahok is a rapidly growing community on the Nushagak River about 65 km. downstream from Koliganek and about 85 km. by air northeast of Dillingham. Nearly all of the 216 residents are Eskimo and the spoken language is mainly Eskimo; English is used only when necessary. Like the other villages in the region, the economy of New Stuyahok is almost entirely dependent upon the commercial fishing in Bristol Bay. However, the village has a relatively high level of services and facilities. A large school was constructed in 1960 and a post office was established in 1961. The village has electricity and recently a sewerage system was put in by the U.S. Public Health Service (Rogers 1973). Prior to 1971, many of the homes in the village were considered substandard; but in that year, more than half of the housing units were replaced by new ones (Federal Field Committee for Development Planning in Alaska 1971). In 1970, a cooperative store was established and its activities are estimated to have reduced prices to consumers by about 25 percent (Community Enterprise Development Corporation 1972).

In contrast to the other river villages, the population of Ekwok seems to be holding constant or perhaps declining slightly. There are about 100 persons in the village, a third of whom are Aleut and most of the others are Eskimo. Since there are no stores in Ekwok, all supplies come from Dillingham, about 65 km. southwest of the village. Except for a small school and a post office, Ekwok has no community facilities.

Although the 1970 census does not include Portage Creek, the population of this village is estimated to be at least 60 persons.[1] Located about 50 km. from Dillingham, the village is the most accessible of the Nushagak River communities. Many of the residents of Portage Creek have moved there from Koliganek and from Dillingham (Van Stone 1967). The village location seems attractive to those who do not want to live in the city of Dillingham, but do not want to be too far away from the services it offers.

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1. Rogers (1973) p.21 gives the population as 60. Alaska State Housing Authority (1971) p. 33, estimates the population as 70. The application submitted in November 1970 for incorporation as a fourth class city gives the population as being 90.

Bristol Bay Borough

The communities of Naknek, South Naknek and King Salmon comprise the Bristol Bay Borough, a 3,100 sq. km. area in the Kvichak Bay region. Naknek is located on the north bank of the Naknek River near the point where it empties into the Kvichak Bay. South Naknek is situated 1.6 km. south,on the other side of the Naknek River. King Salmon and the Air Force Station are about 25 km. east of Naknek.

The local economy of the twin communities of Naknek and South Naknek is based almost exclusively upon the salmon industry. The first salmon cannery began operations near Naknek in 1890. Other canneries were soon built in the area as the Naknek-Kvichak River region was recognized as one of the most abundant sources of red salmon in Bristol Bay. The harvesting of salmon took place only a few weeks each year, but soon some of the seasonal residents made the area adjacent to the canneries their permanent home. As the communities of Naknek and South Naknek grew as cannery towns, their populations were drawn from many other areas. In a 1966 survey of heads of households, the U.S. Bureau of Indian Affairs found that 25 percent were born locally, 25 percent came from outside Alaska, 42 percent were from villages within an 80 km. radius of Naknek, and 8 percent were from other villages within Alaska. Today the residents represent a diverse ethnic mixture of white, Eskimo, Aleut, and Indian. Over the years, the racial lines have been blurred further by intermarriage (U.S. Bureau of Indian Affairs 1966e).

The 1970 census estimated that there were 1,147 persons residing within the limits of Bristol Bay Borough. Of these, about 425 were military personnel stationed at King Salmon Air Force Base. The civilian population of King Salmon is about 200 persons and there are 150 persons in South Naknek. Most of the other families in the Borough are located in Naknek or its immediate vicinity. The 1970 census actually listed only 178 inhabitants in Naknek, but it is likely that its population is between 300 and 350. In 1965, the U.S. Bureau of Indian Affairs estimated that there were 306 persons in Naknek (U.S. Bureau of Indian Affairs 1966e), in 1966 the public health nurse stationed in the community listed the population as about 350,[1] and in 1973, the Bristol Bay Native Corporation held that the population was 327 (Rogers 1973). If, on the basis of these estimates, the population of Naknek is taken to be roughly 325, it seems that the Naknek area has grown steadily since 1939 when the population was 152.

Naknek is the center of fishing and canning activities, since most operating canneries are located east and west of the village center. It is also the point through which most supplies are hauled and through which the salmon pack is carried to outside markets. Following the establishment of a road link between Naknek and King Salmon airport in 1949, Naknek became clearly established as the trade center for the Kvichak Bay area. Later, government agencies were headquartered in the community and, when the Borough was established, Naknek became the seat of local government for the region. At present, Naknek offers the highest concentration of goods and services in this por-

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1. Community Survey of Naknek by itinerant public health nurse, Alaska Department of Health and Social Services, January 1966.

tion of Bristol Bay. It has a general store, a hotel, several restaurants, fuel distributors, a civic center, and recreational facilities. Electric power is supplied by a local co-operative but, as yet, there is no community water and sewer system. The Borough school, covering grades kindergarten through high school, is located in Naknek. A U.S. Public Health Service district nurse maintains an office in Naknek that serves most of the Alaska Peninsula as well as the Borough (Alaska State Housing Authority 1966).

In contrast to Naknek, the growth of South Naknek has been minimal. The population in 1970 was 154, as compared to 134 in 1939. A major deterrent to development is the fact that the Naknek River separates South Naknek from the bulk of the population and economic activity in the rest of the Borough. This sharply curtails South Naknek's access to trade facilities and public services. The school in the village is only an elementary school. High school students from South Naknek must commute by an "air school bus" to attend the school in Naknek.[1] South

1. Jay Hammond, mayor of Naknek and former senator, Alaska State Legislature, Naknek, Alaska, personal communication.

Naknek has a meeting hall, a post office, and a small airstrip. Electric power is available from the plant in Naknek. Of the three communities in the Borough, South Naknek has the least adequate housing. A substantial portion of the housing is substandard due to overcrowding, inadequate facilities, and poor structural quality (U.S. Bureau of Indian Affairs 1966e).

The third community in the Borough, King Salmon, is almost entirely dependent upon the activities of the various federal and state agencies located there. The most important of these is the King Salmon Air Force Base. The site of what is now King Salmon was first surveyed by the U.S. Civil Aeronautics Administration (now the Federal Aviation Agency) in 1941 (U.S. Air Force 1973). The U.S. Civil Aeronautics Administration acquired 1,556 hectares of land and began construction of an airfield and requisite support facilities. When the United States entered World War II at the close of 1941, the U.S. Army assumed control of the airfield. During the war, the airfield, named Naknek

Army Air Base, was a fuel stop, weather information point, and rest stop. After the war, the base was placed on inactive status and administration of the facility was taken over by the U.S. Civil Aeronautics Administration. In 1947, the base was reactivated and renamed King Salmon Air Force Base and made a satellite base of Elmendorf Air Force Base. The new station was part of a network of mainland bases to be used in the air defense of Alaska. The King Salmon Station was to serve as an advanced staging field on the Alaska Peninsula from the mainland to Aleutian Island stations.

In 1949, the U.S. Army, Corps of Engineers built a road to connect the King Salmon Air Force Station with Naknek. The road, which is now maintained by the State, links King Salmon air transportation facilities with the major population centers of the Bristol Bay Borough. The new road greatly increased the accessibility of the area to air transportation and played a major role in facilitating its future growth and development.

During the 1950's, King Salmon continued to develop. Construction was begun on an Alaska Coast and Weather station in 1951 and a 10 million dollar modernization of the facility was completed in 1955. Today, King Salmon is a forward fighter base and an alternate landing site for Elmendorf Air Force Base.

King Salmon has a total population of about 625, of which 425 are military personnel stationed on the U.S. Air Force site. The remainder are largely government employees of the Federal Aviation Agency, U.S. Weather Bureau, Alaska Department of Fish and Game, National Park Service, or U.S. Fish and Wildlife Service.[1] Both the civilian and military populations are highly mobile. King Salmon is classified as a remote duty site and most military personnel are stationed there for only one year. The tenure of government personnel with the various agencies averages two years.[2] Of the civilian population of 202, 94 percent is white. The few Natives who live in the community are government employees and their dependents.

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1. Community Survey of Naknek by itinerant public health nurse, Alaska Department of Health and Social Services, January 1966.

2. Ibid.

Iliamna Lake and Vicinity

About 600 persons live in 7 scattered villages in the Iliamna Lake area (Table 42). Levelock and Nondalton are situated near rivers which connect with the lake. The other villages, Iliamna, Newhalen, Pedro Bay, Kakhonak, and Igiugig are located near the shores of the lake. The village of Iliamna is the only predominantly white settlement. Most of its residents are the employees, and their dependents, of the Federal Aviation Agency stationed at the Iliamna Airport.[1] Of 58 persons living in the village in 1970, 35 were white and 23 were Natives, most of whom were Indian.

The Iliamna Lake region is the only area in Bristol Bay with a significant Indian population. The northeastern end of the lake has been inhabited by Tanaina Athapascans since aboriginal times (Oswalt 1967). Nondalton, with a population of 184, is the largest village in the Iliamna area and the largest Indian village in Bristol Bay. The other Indian village is Pedro Bay, a community of 65 persons on the eastern end of the lake. All of the 88 residents of Kakhonak on the southern shore of the lake are Eskimos.

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1. Community Survey of Iliamna-Newhalen by itinerant public health nurse, Alaska Department of Health and Social Services, 1966.

The other predominantly Eskimo village is Igiugig, with a population of 36, which is located on the western end of the lake. The residents of Newhalen, population 88, and Levelock, population 74, are primarily Aleuts. Between 1950 and 1960, the total population of these Iliamna villages increased 45 percent. In the 1960's, the growth rate slowed to 16 percent. All of the villages except Levelock and Nondalton appear to have had moderate population increases between 1960 and 1970.

Many of the settlements have developed long standing ties. Newhalen and Iliamna are 8 km. apart, but they are connected by a road and served by the same school, airport, and store.[1] Before a school was built at Igiugig, families with children lived in Levelock during the school year and returned to their home villages during vacations (U.S. Bureau of Indian Affairs 1966c).

There is general seasonal population movement in all these villages as the residents move to the shores of Bristol Bay for the salmon runs. A large proportion of Iliamna villagers move to communities, particularly Naknek, for employment as commercial fishermen or cannery workers.

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1. _Ibid._

In addition to this seasonal cash employment, nearly all Iliamna villagers are heavily dependent on subsistence activities (U.S. Bureau of Indian Affairs 1966b, c,f and g). Travel connected with such pursuits is an additional component in the mobility pattern.

Supplies for the Iliamna Lake region have to be brought in by air or, during the summer, by boat. Despite the high cost of air freight, this is the only means of acquiring supplies during much of the year. When water shipment is feasible, goods come up the Kvichak River from Naknek or to Iliamna Bay on the Cook Inlet coast. The goods landed at Iliamna Bay must be trucked over the 25 km. Portage Road to Iliamna Lake. This road is primitive and traverses very rugged terrain (Alaska Department of Highways 1969). In all, the relative inaccessibility of the villages around Iliamna Lake makes it very difficult to obtain supplies and adds substantially to the cost of living.

Togiak Area

The villages of Togiak and Twin Hills, located about 110 km. west of Dillingham, are the most northwestern settlements in Bristol Bay. Total population for the area in 1970 was 450 persons (Table 42). Togiak, which has a population of 383, is the largest Native village in Bristol Bay. Twin Hills, which was first enumerated in the 1970 census, is a small village of 67 persons located about 5 km. north of Togiak. The population of the communities is 98 percent Eskimo and the Eskimo culture has a strong influence in the area (U.S. Bureau of Indian Affairs 1966i). Many residents still speak Yupik Eskimo and they rely very heavily on traditional subsistence pursuits for their livelihood.

The Togiak area has exhibited by far the most rapid population growth of any area in Bristol Bay. The village of Togiak grew from 108 in 1950 to 220 in 1960, an increase of 104 percent. It increased another 74 percent between 1960 and 1970. If the population of Twin Hills is taken into account, the regional population increased by more than 100 percent for the 1960-70 period. This growth rate is due in part to a high rate of natural increase, but it also reflects a substantial amount of migration into the area.

Although it is a relatively large and very rapidly growing village, Togiak is at present able to provide limited community services. It has no water system (U.S. Bureau of Indian Affairs 1966i). However, electricity is now being supplied by a recently installed Alaska Village Electric Cooperative facility. The primary source of income and employment is the cannery located just across the mouth of the Togiak River. According to a U.S. Bureau of Indian Affairs report (1966i), that cannery has provided unusually attractive employment opportunities for the Natives in Togiak and this has been a major factor contributing to rapid population growth. That same report estimates the average annual household income in Togiak to be more than 5,000 dollars. The average household income was estimated to be between 2,000 and 3,000 dollars for the period 1960-62 (U.S. Bureau of Indian Affairs 1966i). Nonetheless, it does appear that the fishermen in Togiak are comparatively well-off with a relatively stable source of income.

Until recently, the only store in Togiak was run by the cannery. In 1970, a cooperative store was established with financing from the Community Enterprise Development Corporation (CEDC). It is estimated that within the first two years of operation, consumer prices in Togiak were reduced by 25 percent (Community Enterprise Development Corporation 1972). Supplies are also available from Dillingham which is about 110 km. east of Togiak. Dillingham is accessible by boat during the summer and by snow machine over a trail that is maintained in the winter.

North Peninsula Villages

There are 4 small villages in the North Peninsula region--Egegik, Pilot Point, Ugashik, and Port Heiden. Between 1960 and 1970 the population in each of these villages remained nearly constant or declined somewhat. In 1970, most of the estimated 300 persons in these villages were Natives of Aleut ancestry. Salmon fishing is the primary source of cash income in these communities. Wage income is supplemented by subsistence fishing and hunting and a small amount of trapping.

The largest of these villages is Egegik, located 65 km. by air south of King Salmon. The village population rose from 86 in 1929 to 150 in 1960, an increase of 74 percent. However, it declined slightly to 148 in 1970. There are 3 salmon canneries in Egegik and, due to the poor salmon runs in recent years, these are the only ones still operating in this part of Bristol Bay.

Pilot Point is a predominantly Native village 130 km. from King Salmon. The community is adjacent to a salmon cannery which is no longer operating. An air-taxi which serves the Alaska Peninsula is headquartered in the village. Pilot Point's population has remained relatively constant in the past 20 years with counts of 67 in 1950, 61 in 1960, and 68 in 1970.

Ugashik, located about 11 km. from Pilot Point, is the smallest village in the North Peninsula area. A cannery once operated in the community, but is now closed. The population of Ugashik declined steadily from 84 in 1929 to 36 in 1960. It was not enumerated in the 1970 census--indicating that the population was less than 25. However, in 1973, the Bristol Bay Native Association estimated that Ugashik had a population of 25 persons (Rogers 1973).

Port Heiden, located about 240 km. by air from King Salmon, is the most remote community in Bristol Bay. During the summer, most of the residents move to the Pilot Point area to fish for salmon. Some trapping and seal hunting is also done (U.S. Bureau of Indian Affairs 1966h). Port Heiden was first enumerated by the census in 1960 as a community of 74 persons. In 1970, the population declined about 11 percent to a total of 66. In addition to the village population, there are about 25 personnel based at a U.S. Air Force radar station and White Alice site about 11 km. from the town.[1] Reeve Aleutian Airways maintains a small station at the Port Heiden Airport, midway between the town and the U.S. Air Force station (U.S. Bureau of Indian Affairs 1966h).

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1. Community Survey of Port Heiden by itinerant public health nurse, 1969.

POPULATION AND EDUCATION

Historical Patterns of Population Change

Archeological and ethnohistorical evidence indicates that there were about 2,400 aboriginal inhabitants in Bristol Bay prior to white contact (Figure 158). More than 60 percent of this population was centered in the vicinity of the Nushagak-Togiak Bay and River system. About 400 persons were located in the vicinity of Iliamna Lake and another 500 inhabited the Kvichak Bay-North Peninsula area. With the exception of a small number of Tanaina Athapascans on the eastern end of Lake Iliamna, all of Bristol Bay's aboriginal inhabitants were Yupik (Southern) Eskimos (Oswalt 1967).

In 1778, Bristol Bay was first visited and described by English Captain James Cook. However, it was not until 1818 that the Russians built trading posts in the region at Iliamna and Nushagak Bay (Van Stone 1967, Lantin 1970). In other parts of Alaska, Native populations were often decimated by warfare and disease in the early years after white contact. There were scattered reports of epidemics in Bristol Bay and a few villages were plundered by the Russians, but there was no massive reduction in

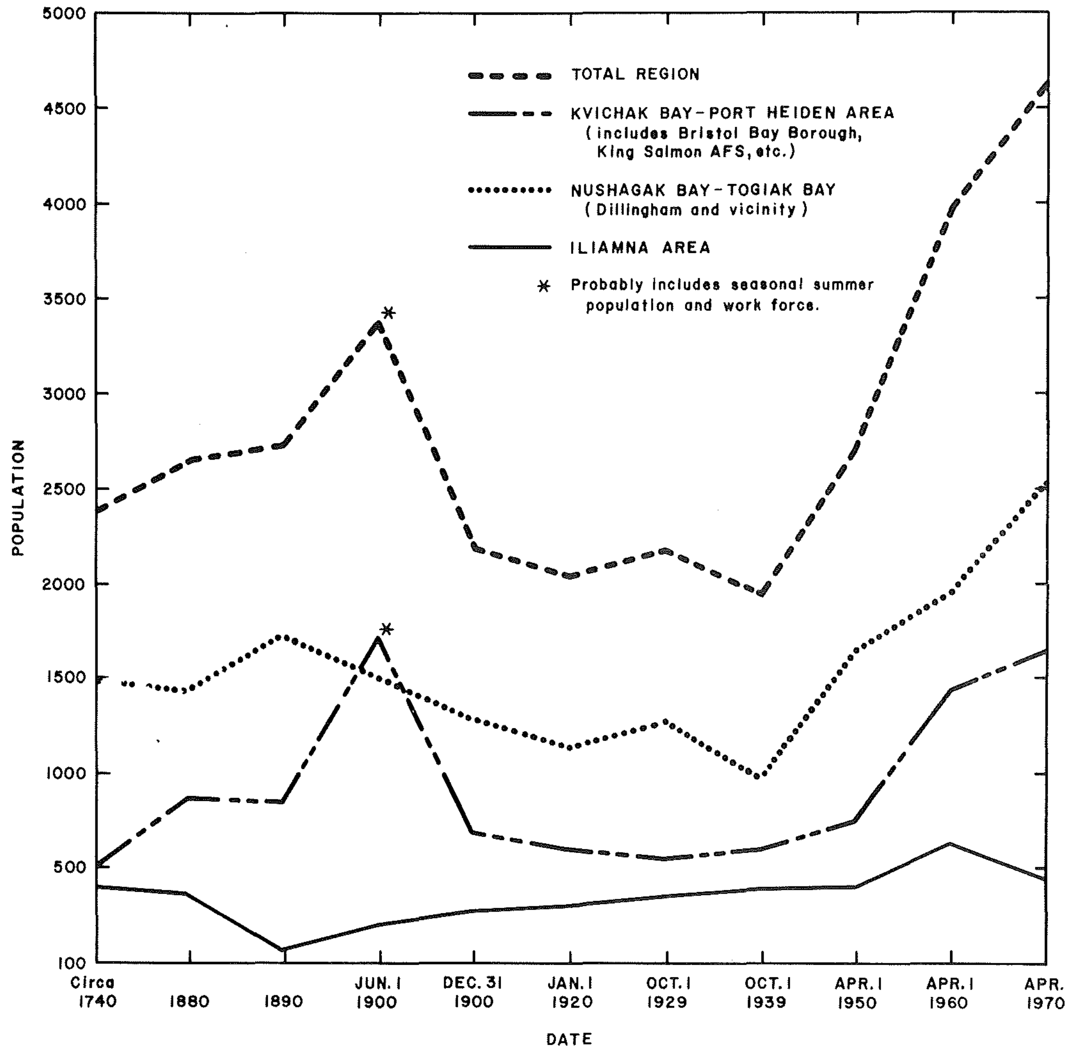

Figure 158. Regional distribution of population in the Bristol Bay area, 1740-1970 (from Rogers 1972).

the Native population. The probable explanation for this is that white interaction with the Native populations was minimal. In other regions of Alaska, Natives often lived in large permanent coastal settlements. However, in Bristol Bay much of the population lived inland and ventured down the rivers for only a few weeks each year to harvest the salmon runs or to trade furs. Additionally, most of the Natives were widely dispersed in small villages in a vast uncharted region.

Russian interest in Bristol Bay centered on the fur trade, but their sphere of influence was generally limited to Natives living in the immediate area. Around 1830, Russian Orthodox missionaries began attempts to convert the Native peoples to Christianity, but their influence on the scattered, mobile population was limited (Van Stone 1967). Except for its broad outlines, most of Bristol Bay was almost unknown to the Russians when Alaska was sold to the United States in 1867. By 1880, Bristol Bay's estimated population was 2,679, an increase of only 12 percent over the estimated pre-

contact population. Thus, from aboriginal times up to the beginning of the commercial exploitation of Bristol Bay's salmon resources, there were few changes in the area's population.

The establishment of the commercial fishing and salmon canning industries in Bristol Bay in the 1880's brought about much more extensive contact between whites and the Native populations (Van Stone 1967). The increased interaction exposed the Natives to diseases for which they had no natural immunity and there were several epidemics in the region. The population in Bristol Bay reached a peak around the turn of the century and then declined slowly throughout the period up to the start of World War II. By 1939, the population had fallen more than 25 percent below the level observed in 1890.

Primarily as a result of World War II military activity, the Bristol Bay region exhibited nearly a 40 percent population increase between 1939 and 1950. One direct cause of the growth was the establishment of Naknek Army Air Base (later renamed King Salmon) and other defense sites. By 1950, the population in the Kvichak Bay-North Peninsula area was 752, an increase of 25 percent over the 1939 level.

However, most of the increase was registered in the Nushagak Bay region. Shortly before the war there were less than 1,000 persons in the area and by 1950 there were 1,636.

By 1960, Bristol Bay's population exceeded 4,000 persons, an increase of more than 45 percent in the preceding decade. During this period, most of the growth was concentrated in the Kvichak Bay area, which exhibited a 90 percent population gain. This was largely due to the expansion and modernization of the facilities at the King Salmon Air Force Base and airport. The other portions of the Bristol Bay region grew by about 30 percent during the 1950's.

Recent Population Patterns

The rate of population growth in Bristol Bay dropped sharply between 1960 and 1970. The increase for the decade was just 15 percent, an average annual increase of about 1.4 percent. That rate is clearly lower than the rate of natural increase due to births and deaths and, thus, implies that people were migrating from the Bristol Bay region. As shown in Table 43, a part of the population slowdown is attributable to the reduction in military personnel stationed in the area. The civilian population

TABLE 43

POPULATION GROWTH 1960-70

BRISTOL BAY

	1960 CENSUS			1970 CENSUS			% Change of Total
	Male	Female	Total	Male	Female	Total	1960-1970
Total Population	2,404	1,620	4,024	2,632	2,000	4,632	15.1
Civilian	1,868	1,620	3,488	2,197	1,996	4,193	20.2
Military Personnel	536	---	536	435	4	439	-18.1
White	1,039	384	1,423	1,042	551	1,593	11.9
Nonwhite	1,365	1,236	2,601	1,570	1,449	3,039	16.8
Negro	26	1	27	32	4	36	33.3
Indian	115	118	233	144	148	292	16.6**
Aleut	---	---	---	494	472	966	
Eskimo	---	---	---	880	811	1,691	
Other	1,224*	1,117*	2,341*	40	14	54	

* In 1960 Census Aleut and Eskimo are lumped in the "other" category.

** Represents approximate % change in the Native population.

Source: U.S. Bureau of the Census 1963, 1971d and Institute of Social, Economic and Government Research 1972.

increased by 20 percent while the military personnel were being reduced by 18 percent.

As shown in Table 43, roughly two-thirds of the residents of Bristol Bay are nonwhites. In 1970, more than 97 percent of the nonwhites were Natives (Indians, Aleuts, and Eskimos.) Throughout the remainder of this report, the term "Native" will be used synonomously with "non-white." The Native population in Bristol Bay gained less than 17 percent between 1960 and 1970, an average annual increase of 1.6 percent. That growth is clearly far below the rate of natural increase. It is apparent that there have been particularly significant amounts of Native migration out of the Bristol Bay region. The figures in Table 44, although only approximations, provide estimates of natural increase and migration as the sources of population growth. The estimated net increase in civilian Native population was 448 persons while the natural increase was 859 persons. Thus, there was a net out-migration of more than 400 persons. In contrast, two-thirds of the growth in the civilian white population was due to net migration into the area. The total white population in-

TABLE 44

COMPONENTS OF POPULATION CHANGE 1960-1970

BRISTOL BAY

	ALL RACES			WHITE			NONWHITE		
	1960	1970	Change 1960-70	1960	1970	Change 1960-70	1960	1970	Change 1960-70
Population	4024	4632	608	1423	1593	170	2601	3039	438
Military Personnel	536	439	-97	482	395	-87	54	44	-10
Civilian Population	3488	4193	705	945	1198	253	2547	2995	448
Births	157	102	1263	29	16	179	128	86	1082
Deaths	26	29	316	3	5	89	23	22	223
Natural Increase	131	73	947	26	11	90	105	64	859
Rate of natural increase (total pop.)	3.26	1.58	2.19	1.83	0.69	0.60	4.04	2.11	3.05
Rate of natural increase (civ. pop.)	3.76	1.74	2.46	2.75	0.92	0.84	4.12	2.13	3.10
Migration			-339			80			-421
Civilian Migration			-242			163			-411

Sources: U.S. Bureau of the Census 1963; Alaska Dept. of Labor 1961, 1963; Alaska Dept. of Health and Social Services, undated; and Institute of Social, Economic and Government Research 1972.

creased by 170 persons despite a reduction in military personnel and a very low rate of natural increase.

Table 44 also contains estimates of the rates of natural increase for 1960, 1970, and average rates over the decade. For all population groups shown, there is an extremely sharp drop in the rate of natural increase between 1960 and 1970. This is due to the reduction in the birthrate during that period (Rogers 1971). This phenomenon occurred throughout the country and is generally attributed to several factors. There were improvements in birth control methods, programs to provide information on family planning, and a general change in social attitudes regarding family planning. In the Bristol Bay region, the Native rate of natural increase was cut nearly in half, falling from 4 percent in 1960 to 2 percent in 1970. Further evidence confirming the drop in birthrates is provided by the fertility ratios in Figure 159. A fertility ratio is the number of children under 5 years of age per 1,000 women of childbearing age, which is taken to be all women between 15 and 49 years old (Rogers 1963). By including data for Alaska and the United States, Figure 159 shows that the decline in the birthrate was indeed

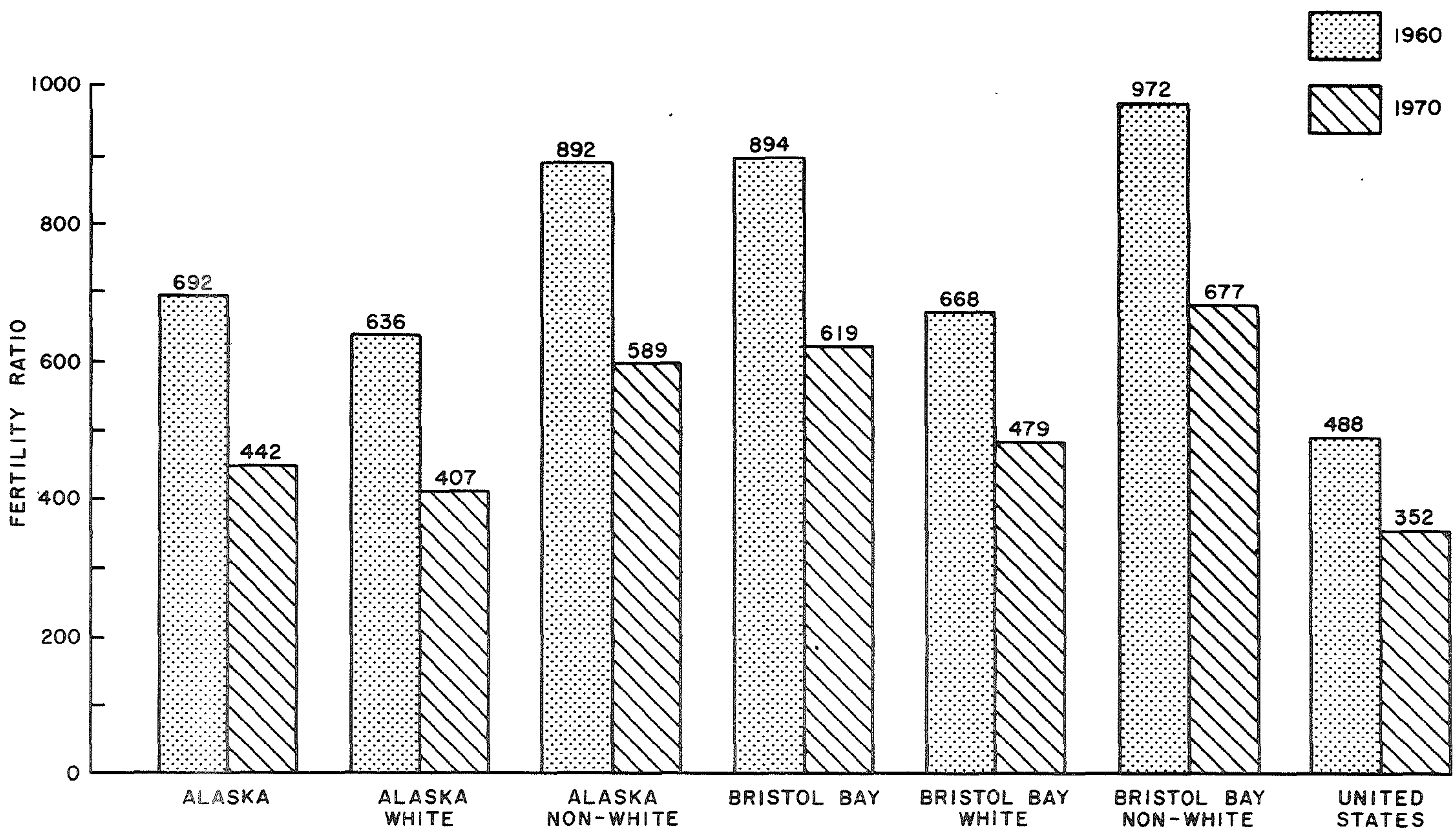

Figure 159. Fertility ratios by race in the Bristol Bay area, 1960 and 1970 (from Rogers and Cooley 1963; U.S. Bureau of the Census 1963, 1971c, 1971e).

widespread. Despite the recent decline, the Bristol Bay fertility ratios for both whites and nonwhites remain high relative to United States and Alaska averages. Also, the fertility ratio for nonwhites in Bristol Bay remains much higher than the ratio for whites.

As shown in Table 45, Bristol Bay has only 2 modest concentrations of population, Dillingham and Bristol Bay Borough. Together these 2 areas contain about 40 percent of the civilian population of the Bristol Bay region.

The rest of the population is dispersed widely over the 19 communities reported in the 1970 census and several smaller villages not reported in the census. It is difficult to make comparisons over time because both Dillingham and the Bristol Bay Borough were incorporated between 1960 and 1970. However, if the 1960 population of the Dillingham area is estimated at 800 (Alaska State Housing Authority 1971), the growth for Dillingham is 14 percent. The growth of the towns in Bristol Bay Borough is 10 percent. Thus, the relatively urbanized areas are growing at significantly slower rates than the 20 per-

TABLE 45

POPULATION OF TOWNS AND VILLAGES

BRISTOL BAY 1929-1970

	1970	1960	1950	1939	1929	% Change 1950-1960	% Change 1960-1970
TOTAL BRISTOL BAY REGION	4,632	4,024	2,756	1,992	2.198	46.0	15.1
NUSHAGAK BAY REGION	1,402	982	1,062	491	287	- 7.5	NA
Aleknagik	128	231	153	78		51.0	-44.6
Clarks Point	95	138	128	22	25	7.8	-31.2
Dillingham	914[1]	424	577	278	85	-36.1	NA[1]
Ekuk	51	40					27.5
Kanakanak			54	113	177		
Manakotak	214	149	120			24.2	43.6
Tuklung			30				
KVICHAK BAY REGION	1,106	1,087		286			1.7
Bristol Bay Borough	1,147						
King Salmon	202	227					-11.0
Naknek	325[2]	249	174	152	173	43.1	30.5
South Naknek	154	142		134			8.5
King Salmon Air Force Station	425	469					-10.0
TOGIAK BAY REGION	450	220	108	10	71	103.7	104.5
Togiak	383	220	108	10	71	103.7	74.1
Twin Hills	67						
NUSHAGAK RIVER REGION	521	351	309			13.6	48.4
Ekwok	103	106	131	68	40	-19.1	- 2.8
Koliganek	142	100	90			11.1	42.0
New Stuyahok	216	145	88			64.8	49.0
Portage Creek[3]	60						
ILIAMNA LAKE REGION	593	547	402	167	124	36.1	8.4
Igiugig	36						
Iliamna	58						
Kakhonak	88	57	39			46.1	54.4
Levelock	74	88	76			15.8	-15.9
Newhalen	88	63	48	55		31.3	39.7
Nondalton	184	205	103	82	24	99.0	-10.2
Pedro Bay	65	53	44			20.5	22.6
Pile Bay			48				
Port Alsworth		34					
ALASKA PENINSULA REGION	282	321	234	294	170	37.2	-12.1
Egegik	148	150	119	125	86	26.1	- 1.3
Pilot Point	68	61.	67	114		- 9.0	11.5
Port Heiden	66	74					-10.8
Ugashik		36	48	55	84	-25.0	

Source: U.S. Bureau of the Census 1952, 1960, 1971f.

[1]Dillingham incorporated between 1960 and 1970. The 1970 population estimate covers a much wider geographic area than did the 1960 estimate. On a comparable basis, the 1960 population would have been about 800.

[2]The 1970 Census estimate is 178 for the population of Naknek. This seems to be error or based on a different geographic area than the 1960 Census. The estimate shown, 325, is more nearly comparable to the 1960 figure.

[3]Portage Creek was omitted from the 1970 Census but recent enumerations have estimated the population at roughly 60 in 1970.

cent increase in the civilian population for the region as a whole.

Perhaps the most striking feature of the population change is the extremely rapid growth in the Eskimo communities of Koliganek, Manokotak, New Stuyahok, Togiak, and Twin Hills. The population of these villages went from 600 persons in 1960 to 1,000 in 1970, an increase of 66 percent. In each of the villages, virtually the entire population is Eskimo (Table 46) and the influence of the Eskimo culture is very strong. An Eskimo dialect is generally spoken with English used only as necessary. Also, the villages are relatively remote from any urban centers. The pattern of population change among the Bristol Bay Eskimos might almost be described as a process of "de-urbanization." Clearly, a substantial part of the very rapid growth in the Eskimo communities must be due to migration either from other villages or from outside the region. Unfortunately, the 1960 data do not provide separate estimates for the Eskimo population so the precise changes cannot be traced.

TABLE 46

COMMUNITY POPULATION BY RACE AND SEX

BRISTOL BAY 1970

PLACE	ALL RACES			WHITE			NEGRO			INDIAN			ALEUT			ESKIMO			OTHER		
	Male	Female	Total	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Tot	M	F	Total	M	F	Tot
Bristol Bay Borough	788	359	1,147	668	254	922	30	1	31	8	12	20	59	72	131	16	19	35	7	1	8
King Salmon	98	104	202	95	95	190	0	0	0	1	3	4	1	6	7	1	0	1	0	0	0
Naknek	91	87	178	76	62	138	0	1	1	5	7	12	6	7	13	4	9	13	0	1	1
South Naknek	84	70	154	43	26	69	0	0	0	0	0	0	36	39	75	5	5	10	0	0	0
Bristol Bay Division	1,844	1,641	3,485	374	297	671	2	3	5	136	136	272	435	400	835	864	792	1,656	33	13	46
Aleknagik	71	57	128	13	14	27	0	0	0	0	0	0	3	0	3	54	40	94	1	3	4
Clarks Point	47	48	95	10	10	20	0	0	0	0	0	0	18	23	41	11	14	25	8	1	9
Dillingham	465	449	914	167	158	325	0	1	1	5	8	13	191	195	386	96	87	183	6	0	6
Egegik	78	70	148	41	31	72	1	1	2	0	0	0	33	37	70	3	1	4	0	0	0
Ekuk	28	23	51	0	0	0	1	0	1	0	0	0	2	2	4	17	17	34	8	4	12
Ekwok	54	49	103	4	4	8	0	0	0	0	0	0	16	16	32	33	29	62	1	-	1
Igiugig	20	16	36	1	1	2	0	0	0	1	0	1	15	10	25	3	5	8	0	0	0
Iliamna	34	24	58	21	14	35	0	0	0	11	7	18	1	1	2	1	2	3	0	0	0
Kakhonak	43	45	88	9	6	15	0	0	0	0	0	0	0	0	0	32	35	67	2	4	6
Koliganek	71	71	142	5	3	8	0	0	0	0	0	0	0	0	0	66	68	134	0	0	0
Levelock	40	34	74	9	5	14	0	0	0	0	0	0	23	20	43	8	9	17	0	0	0
Manokotak	107	107	214	3	6	9	0	0	0	0	0	0	0	0	0	104	101	205	0	0	0
Newhalen	54	34	83	3	2	5	0	0	0	3	0	3	48	32	80	0	0	0	0	0	0
New Stuyahok	118	98	216	6	2	8	0	0	0	0	0	0	0	0	0	112	96	208	0	0	0
Nondalton	92	92	184	2	0	2	0	0	0	90	92	182	0	0	0	0	0	0	0	0	0
Pedro Bay	35	30	65	6	2	8	0	1	1	21	26	47	1	1	2	2	0	2	5	0	5
Pilot Point	40	28	68	6	4	10	0	0	0	0	0	0	31	23	54	3	1	4	0	0	0
Port Heiden	37	29	66	4	4	8	0	0	0	0	0	0	33	25	58	0	0	0	0	0	0
Togiak	204	179	383	2	4	6	0	0	0	0	0	0	0	0	0	202	175	377	0	0	0
Twin Hills	35	32	67	1	0	1	0	0	0	0	0	0	0	0	0	34	32	66	0	0	0
TOTAL - BRISTOL BAY	2,632	2,000	4,632	1,042	551	1,593	32	4	36	144	148	292	494	472	966	880	811	1,691	40	14	54

Source: Institute of Social, Economic and Government Research 1973.

In 1970, about 37 percent of the Bristol Bay population was Eskimo (Table 46). Nearly 60 percent of the Eskimo population is located in the villages discussed above. Whites make up 34 percent of the population and they are concentrated largely in the urbanized areas. Three-fourths of the whites live in Dillingham or Bristol Bay Borough. Dillingham also has a substantial number of Aleut residents. In fact, Aleuts are the largest single ethnic group in Dillingham and account for about 40 percent of its population. The Indian population in Bristol Bay is almost entirely concentrated in the villages of Nondalton and Pedro Bay, both near Iliamna Lake.

In general then, the population of Bristol Bay is characterized by a wide diversity of racial and cultural backgrounds--no single group predominates. However, in some important instances the ethnic groups have tended to concentrate in specific communities rather than being dispersed throughout the region. Examples of this are found in the purely Eskimo or purely Indian villages. The most outstanding aspect of population change in recent years is the extremely rapid growth of the pure Eskimo communities. There has been a major population shift into these communities during the past decade.

Education Programs

In the nineteenth century, Russian Orthodox and Moravian missionaries attempted to initiate educational programs among the Natives of Bristol Bay, but their sporadic efforts had little lasting effect. Van Stone (1967) related the following illustration:

> During the summer of 1908 an official of the Bureau of Education made his annual inspection of the federally supported schools and visited the Nushagak Bay region to inspect two schools at Carmel and Dillingham. However, he broadened the scope of his inquiry in order to ascertain the educational needs of the people... In talking with people in unspecified places in the area, he was shocked to discover that they had no knowledge of the United States Government and believed themselves still under the rule of Russia...his comments suggest that in spite of canneries, missionaries, and other agents of contact, culture change in the Nushagak River region was progressing very slowly.

Of the small number of students educated in Bristol Bay in early years, most were mixed bloods. A vast majority of the population received little or no education until after World War II (Van Stone 1967).

By the time of statehood, there were about 700 students enrolled in the schools in Bristol Bay. Within the next few years and with the completion of a new high school in Dillingham, the enrollment approached 1,000 students. Between 1960-61 and 1970-71, total school enrollment in Bristol Bay rose from 919 to 1,395, an increase of about 52 percent (Table 47 and Figure 160). Since 1970-71, the enrollment has remained constant at approximately 1,400 students. The leveling off in school enrollments is attributable to the decline in the birthrate and to the outmigration of families with school-age children.

Elementary school enrollments have declined from a peak of 1,156 students in 1968-69 to 1,039 students in 1972-73, a drop of 10 percent in 4 years. About one-third of the elementary school students attended district schools in Dillingham and the Bristol Bay Borough. In both areas, Native students constitute the majority--about 60 percent in the Bristol Bay Borough and 80 percent at Dillingham

TABLE 47

TOTAL SCHOOL ENROLLMENT

BRISTOL BAY 1958-59 to 1971-72

	ELEMENTARY SCHOOL				HIGH SCHOOL					
YEAR	WHITE	NATIVE	OTHER	SUBTOTAL	WHITE	NATIVE	OTHER	SUBTOTAL	TOTAL	% Increase from previous year
1958-59	96	628	0	724	0	0	0	0	724	--
1959-60	91	720	14	825	5	53	0	58	883	22%
1960-61	131	742	0	873	0	46	0	46	919	4%
1962-63	116	858	4	978	7	65	0	72	1050	--
1963-64	129	900	2	1031	22	73	0	95	1126	7%
1964-65	93	955	0	1048	18	87	0	105	1153	3%
1965-66	123	953	0	1076	18	94	0	112	1188	3%
1966-67	155	942	0	1097	16	115	0	131	1228	4%
1967-68	160	977	0	1137	22	136	0	158	1295	5%
1968-69	207	949	0	1156	25	127	0	152	1308	1%
1969-70	171	943	0	1114	44	153	0	197	1311	0.2%
1970-71	137	979	0	1116	61	218	0	279	1395	6%
1971-72	150	968	0	1118	66	224	0	290	1408	1%
1972-73	130	909	0	1039	83	269	0	352	1391	-1%

Source: Sullivan and Rose 1970.

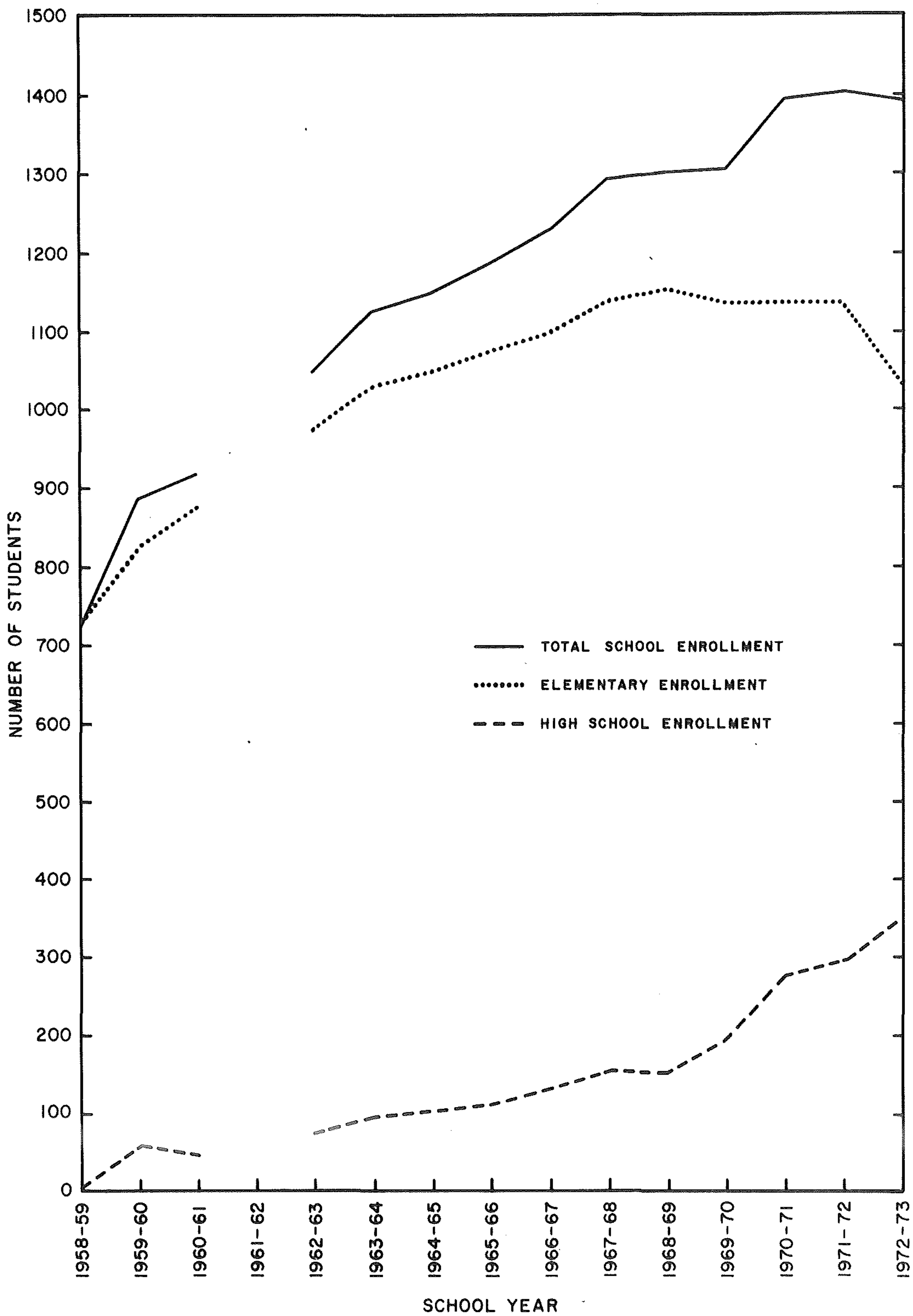

Figure 160. School enrollment in the Bristol Bay area, 1958-59 to 1971-72 (from Sullivan and Rose 1970).

elementary school. In rural areas, state-run elementary schools are operated in 19 villages (Table 48). These rural schools vary in size from 93 at Togiak to 7 at Pedro Bay. The average village school enrollment is 35 students. Of 678 village elementary students enrolled in Bristol Bay in 1972-73, all but 19 were Natives.

In contrast to the elementary trend, high school enrollments have exhibited a steady rise from about 60 students in 1960-61 to 280 in 1970-71, a five-fold increase for the decade. This trend has continued with a 1972-73 high school enrollment of 352--an increase of 26 percent in just 2 years. However, the decline in elementary school enrollment indicates that there will be a leveling off in the number of high school students within a few years.

Dillingham and the Bristol Bay Borough offer the only complete high school program in Bristol Bay, though schools at Togiak, Igiugig, and Nondalton offer a few secondary courses. The lack of high school programs in the village is due to low population and the scattered distribution of settlements. Some village students attend U.S. Bureau of Indian Affairs high schools in Alaska, or other

TABLE 48

SCHOOL ENROLLMENTS BY COMMUNITY

BRISTOL BAY 1971-72

	ELEMENTARY			HIGH SCHOOL			
	White	Native	Subtotal	White	Native	Subtotal	Total
District Schools							
Bristol Bay	56	87	143	51	85	136	279
Dillingham	43	161	204	30	128	158	362
Subtotals	99	248	347	81	213	294	641
Rural Schools							
Aleknagik	7	23	30				30
Clarks Point		22	22				22
Egegik	1	33	34				34
Ekuk		12	12				12
Ekwok		28	28				28
Igiugig		11	11	3		3	14
Kokhanok		28	28				28
Koliganek		43	43				43
Levelock		28	28				28
Manokotak	2	82	84				84
Newhalen	5	34	39				39
New Stuyahok		75	75				75
Nondalton	2	63	65	2	7	9	74
North Aleknagik		14	14				14
Pedro Bay		7	7				7
Pilot Point	2	16	18				18
Port Heiden		22	22				22
Togiak		93	93		46	46	139
Twin Hills		25	25				25
Subtotals	19	659	678	5	53	58	736
Private and Denominational Schools							
Dillingham SDA	12	2	14				14
TOTALS	130	909	1,039	86	266	352	1,391

Source: Alaska Dept. of Education files, Juneau.

states, but most go to Dillingham High School and live with local families under the state Boarding Home Program.[1]

Although the availability of education has increased tremendously in the past 20 years, the traditional school program has often failed to meet the needs of many students, particularly Natives. A staff member of the Alaska Department of Education (Jones 1972) explained the situation at Dillingham High School:

> ...isolation, combined with the fact that about 90 percent of the villagers have some degree of Alaska Eskimo or Aleut background, created educational needs that the traditional school program was not meeting. Because of language and cultural barriers, the typical Native students were often three years behind national norms in reading and composition skills by the time they entered the ninth grade. Though there were indications that they were just as intelligent as the white students, they had lost confidence in their ability to compete with them academically. As a consequence, many Native students dropped out before completing high school, and very few ever attempted college. Indeed, no more than five students out of a class of 30 had ever gone to college and survived the first year.

In an innovative attempt to broaden the experiences and increase the potential of Bristol Bay students, Dilling-

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1. Ron Klemm, Regional Superintendent, Southwest Area, State Operated Schools, Dillingham, Alaska, personal communication.

ham High School initiated a Japan Study Program in 1970-71.[1] The school district funded the program from federal sources and from funds available under the state's Boarding Home Program. The Japan Study Program, which included both Native and white students, began with intensive instruction in Japanese language and culture. Following this training, 28 students traveled in Japan and took courses from teachers in the group. Upon their return to Alaska, some students completed their high school requirements by taking courses at the University of Alaska. During the 1971-72 school year, the Japan Study Program was expanded to 49 students--18 from Bristol Bay and the remainder from other rural Alaska communities. In 1972-73, students from Bristol Bay were among 140 students who participated in study-travel programs to Japan and Spain.

Although the study-travel programs have been termed a "success" by the students who participated and persons evaluating the programs, they are extremely expensive to operate. In addition, it is difficult to quantify the effects of these programs on the students and their particular home communities. It would seem that students who took part in the pro-

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1. Diana Holzmeuller, Assistant Educational Program Developer, Center for Northern Educational Research, University of Alaska, Fairbanks, personal communication.

grams broadened their educational goals and occupational expectations. There was also an increase in the number of students who succeeded in college work. For example, 36 students graduated from Dillingham High School in 1971 and a year later 21 were enrolled in college programs.[1]

Educational Attainment

Alaska has historically had a relatively high educational attainment level (Rogers 1971). This trend continued in 1970 as the median school years completed by both males and females were higher in Alaska than in the total U.S. (Table 49). However, the lack of educational opportunities in Bristol Bay until the recent period is reflected in much lower than average education levels.

One measure of educational attainment is the percentage of high school graduates in the segment of the population older than 25 years of age. Bristol Bay's figures of 45.8 percent for males and 34.2 percent for females are far below state averages of 66.3 percent for males and 67.1 percent for females. When these statistics are separated out by race, it is apparent that the low percentage

1. Ibid.

TABLE 49

EDUCATIONAL ATTAINMENT

BRISTOL BAY 1970

Years of School Completed	BRISTOL BAY TOTAL TOTAL Number	Percent	WHITE Number	Percent	NONWHITE Number	Percent	ALASKA TOTAL Number	Percent	WHITE Number	Percent	NONWHITE Number	Percent	U.S. TOTAL Number	Percent
MALES, 25 yrs. old and over	1,083	100.0	520	100.0	563	100.0	73,963	100.0	61,189	100.0	12,774	100.0	51,869,770	100.0
No school years completed	129	11.9	0	-	129	22.9	1,774	2.4	267	0.4	1,507	11.8	852,851	1.6
Elementary: 1-4 years	192	17.7	13	2.5	179	31.8	2,612	3.5	435	0.7	2,177	17.0	2,299,323	4.4
5-6 years	55	5.1	0	-	55	9.8	2,180	2.9	656	1.2	1,524	11.9	3,082,912	5.9
7 years	73	6.7	34	6.5	39	6.9	1,883	2.5	1,024	1.7	859	6.7	2,392,567	4.6
8 years	80	7.4	28	5.4	52	9.2	5,653	7.6	4,378	7.2	1,275	10.0	6,708,041	12.9
High School: 1-3 years	58	5.4	44	8.5	14	2.5	10,858	14.9	9,116	14.9	1,742	13.6	9,633,537	18.6
4 years	281	25.9	218	41.9	63	11.2	26,684	36.1	24,258	39.6	2,426	19.0	14,365,218	27.7
College: 1-3 years	111	10.2	88	16.9	23	4.8	10,829	14.6	9,994	16.3	835	6.5	5,526,759	10.7
4 years	64	5.9	60	11.5	4	0.7	5,612	7.6	5,359	8.8	253	2.0	3,518,159	6.8
5 years or more	40	3.7	35	6.7	5	0.9	5,878	7.9	5,702	9.3	176	1.4	3,490,403	6.7
High School Graduates	457	45.8	401	77.1	95	16.9		66.3	45,313	74.1	12,774	28.9		51.9
FEMALES, 25 yrs. old and over	763	100.0	276	100.0	487	100.0	60,985	100.0	49,717	100.0	11,268	100.0	58,029,589	100.0
No school years completed	123	16.1	4	1.4	119	24.4	1,565	2.6	177	0.3	1,388	12.3	914,902	1.6
Elementary: 1-4 years	161	21.1	5	1.8	156	32.0	2,009	3.3	197	0.4	1,812	16.1	1,972,238	3.4
5-6 years	46	6.0	5	1.8	41	8.4	1,944	3.2	456	0.9	1,488	13.2	3,134,180	5.4
7 years	32	4.2	8	2.9	24	4.9	1,248	2.0	486	1.0	762	6.8	2,423,053	4.2
8 years	69	9.0	21	7.6	48	9.9	3.974	6.5	2,570	5.2	1,404	12.5	7,307,323	12.6
High School: 1-3 years	71	9.3	26	9.4	45	9.2	9,294	15.2	7,676	15.4	1,618	14.4	11,652,385	20.1
4 years	119	15.6	93	33.7	26	5.3	24,136	39.6	22,285	44.8	1,851	16.4	19,792,833	34.1
College: 1-3 years	64	8.4	46	16.6	18	3.7	9,223	15.1	8,604	17.3	619	5.5	6,123,971	10.6
4 years	46	6.0	42	15.2	4	0.8	4,872	8.0	4,622	9.3	250	2.2	3,139,445	5.4
5 years or more	32	4.2	26	9.4	6	1.2	2,720	4.5	2,644	5.3	76	0.7	1,569,259	2.7
High School Graduates	261	34.2	207	75.0	54	11.1		67.1	38,115	76.7	11,268	24.8		52.8
TOTAL, 25 years old and over	1,846	100.0	796	100.0	1,050	100.0	134,948	100.0	110,906	100.0	24,042	100.0	109,899,359	100.0
No school years completed	252	13.7	4	0.5	248	23.6	3,339	2.5	444	0.4	2,895	12.0	1,767,753	1.6
Elementary: 1-4 years	353	19.1	18	2.3	335	31.9	4,621	3.4	632	0.6	3,989	16.6	4,271,561	3.9
5-6 years	101	5.5	5	0.6	96	9.1	4,124	3.1	1,112	1.0	3,012	12.5	6,217,092	5.7
7 years	105	5.7	42	5.2	63	6.0	3,131	2.3	1,510	1.4	1,621	6.7	4,815,620	4.4
8 years	149	8.1	49	6.2	100	9.5	9,627	7.1	6,948	6.3	2,679	11.1	14,015,364	12.6
High School: 1-3 years	129	7.0	70	8.9	59	5.6	20,152	14.9	16,792	15.1	3,360	14.0	21,285,922	19.4
4 years	400	21.7	311	39.1	89	8.5	50,820	37.6	46,543	42.0	4,277	17.8	34,158,051	31.1
5 years or more	72	3.9	61	7.7	11	1.0	8,598	6.4	8,346	7.5	252	1.0	5,059,662	4.6
High School Graduates	757	41.0	608	76.4	149	14.2		66.6		75.3		26.9		52.4

Source: U.S. Bureau of the Census 1971d, 1971e.

of high school graduates is only characteristic of the Native population. Among whites, more than 75 percent are high school graduates, which is approximately the statewide average for whites. However, among Natives, less than 15 percent are high school graduates.

At the other end of the scale, Alaska also tends to have a relatively large proportion of persons older than 25 years of age who have no education at all. In the United States, only 1.6 percent of the population has no education, while the Alaska average is 2.5 percent. In Bristol Bay, the proportion of the population older than 25 years of age with no education is 11.9 percent for males and 16.1 for females. Again, this indication of educational deficiency is characteristic only of the Native population. Less than 1 percent of the white population older than 25 years of age had no education. Among Natives, nearly 24 percent had no education, a figure double the state average.

LABOR FORCE AND EMPLOYMENT

Labor Force

The size of the labor force in any region is determined jointly by the characteristics of the local population and by the availability of employment opportunities. It is obvious that in the long-run there has to be a close relationship between the size of the population base and the size of the labor force. However, this relationship is not necessarily constant over time nor is it the same for all regions. In particular, there can be large differences in the observed proportion of the population that chooses to seek employment (participation rate). One of the key factors determining the participation rate is the availability of employment opportunities. When jobs are easy to find, more people decide to seek employment thus causing an increase in the participation rate and in the labor force.

In the Bristol Bay region, both the size of the local population and the employment opportunities are subject to large fluctuations due to outside forces. This is most evident in the fishing and fish processing industry which exhibits wide variation seasonally and from one year to another due to weather conditions and cycles in the fish populations. In light of this, it is not surprising to find that the work force in Bristol Bay, while trending upward, displays considerable variation around the long-run growth trend (Figure 161). In Bristol Bay, the average civilian work force in 1971-72 was 30 percent larger than the average work force in 1961-62.

The data in Table 50 show how the participation and unemployment rates in the Bristol Bay region compare to the state averages. Participation rates in Bristol Bay are extremely low for both men and women. The male participation rate in Bristol Bay is 49 percent, compared to 79 percent for the State. At the same time, the average unemployment rate is 15 percent, much higher than the rest of the State. A high unemployment rate accompanied by a low participation rate is precisely what would be expected. The lack of employment opportunities has caused people to drop out of the labor force. Furthermore, this picture is consistent with the migration patterns discussed previously.

Figure 161. Workforce in the Bristol Bay area, 1961-1972 (from Alaska Department of Labor 1961-1972).

TABLE 50

LABOR FORCE AND EMPLOYMENT 1970

BRISTOL BAY

	Bristol Bay Borough	Bristol Bay Division	Bristol Bay Total	Alaska
Total Civilian Population, 16 years old and over	371	1,830	2,201	159,702
Civilian labor force	224	658	882	98,296
Percent of total (participation rate)	60.4	36.0	40.1	61.5
Employed	165	584	749	89,236
Unemployed	59	74	133	9,060
Percent of civilian labor force	26.3	11.2	15.1	9.2
Male, 16 years old and over, civilian	205	954	1,159	76,547
Civilian labor force	170	399	569	60,293
Percent of total (participation rate)	82.9	41.8	49.1	78.8
Employed	111	333	444	54,114
Unemployed	59	66	125	6,179
Percent of civilian labor force	34.7	16.5	22.0	10.2
Female, 16 years old and over, civilian	166	876	1,042	83,155
Civilian labor force	54	259	313	38,003
Percent of total (participation rate)	32.5	29.6	30.0	45.7
Employed	54	251	305	35,122
Unemployed	0	8	8	2,881
Percent of civilian labor force	0.0	3.1	2.6	7.6

Source: U.S. Bureau of the Census 1971d.

The lack of employment opportunities is a factor contributing to the observed outmigration from the Bristol Bay region.

Due to seasonal factors, the unemployment rates are probably overestimated and the participation rates are underestimated by the data in Table 50. The 1970 census was taken on April 1 and that is just about the seasonal low point for employment in the Bristol Bay region. The comparison of the different rates at that point in time would, however, still produce relevant results particularly with regard to permanent or year-round employment opportunities.

Seasonal Variation in Employment

In tracing the movements over time, the pattern of employment in Bristol Bay is dominated by the pronounced seasonal fluctuations in the fishing industry. Figures 162 and 163 show the movement in the average annual employment and the monthly variations around the average. The figures illustrate how closely the seasonal movements in the labor force, due to changes in participation rates and an influx of non-residents, match the movements in employment.

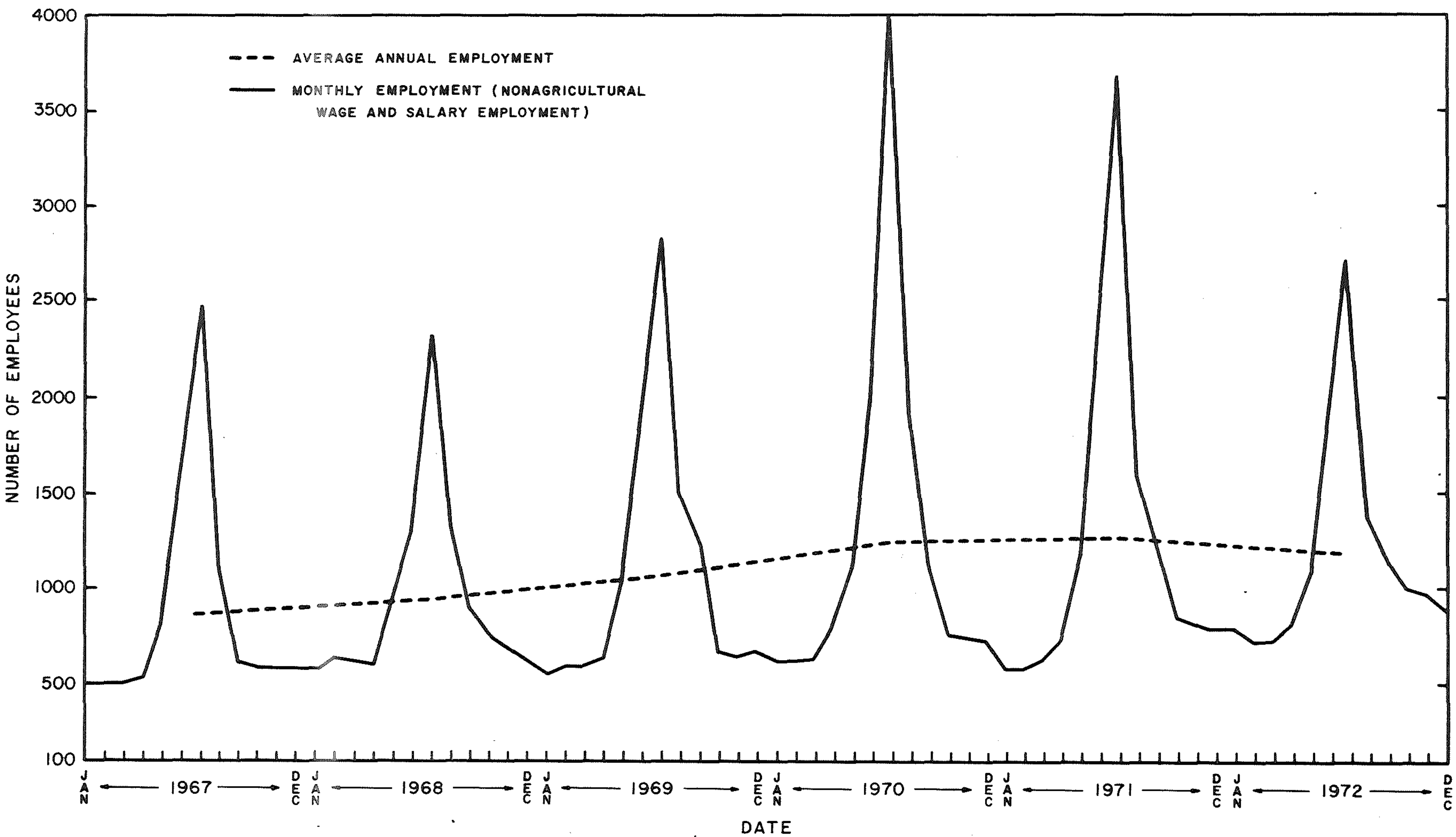

Figure 162. Employment in the Bristol Bay area, 1967-1972 (from Alaska Department of Labor 1961-1972).

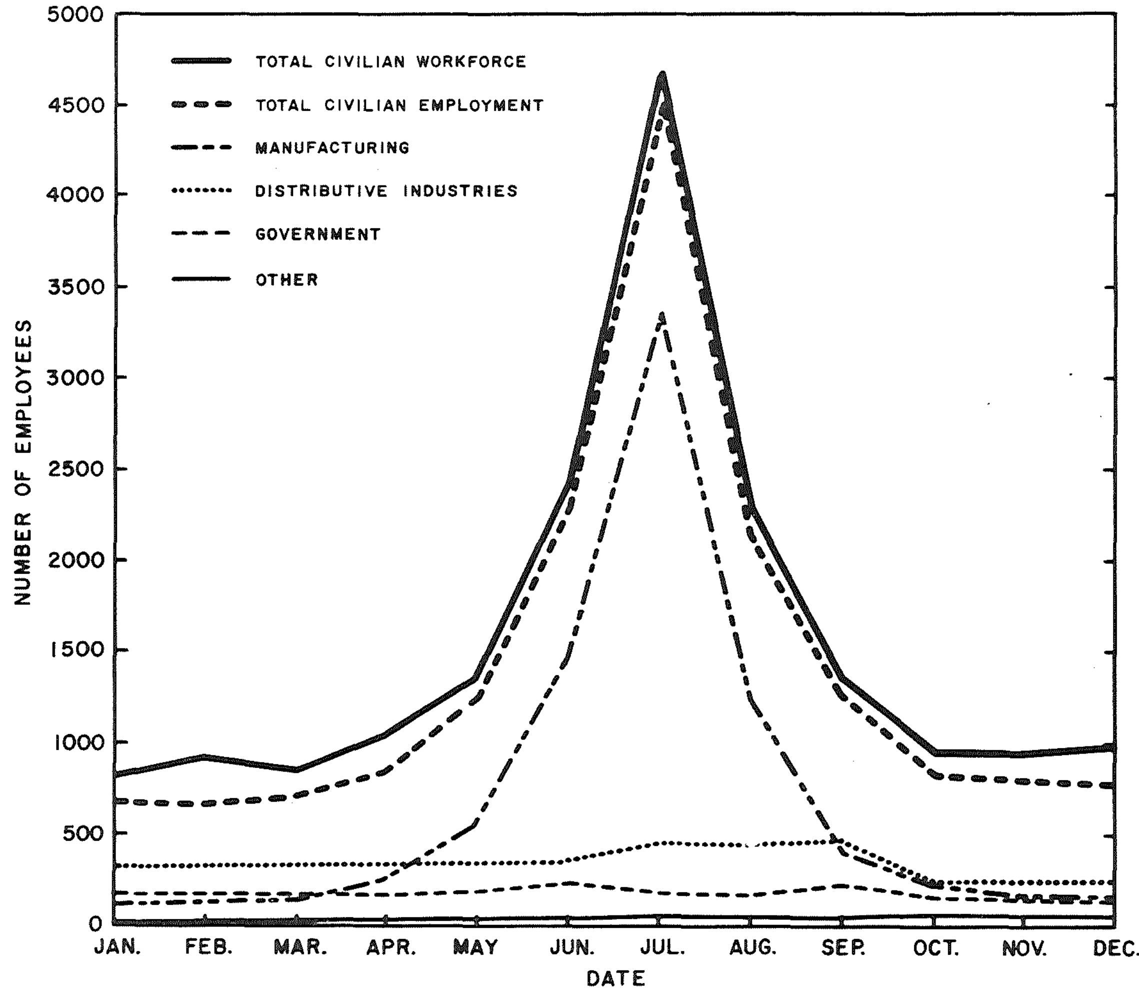

Figure 163. Employed workforce in the Bristol Bay area during 1970 (from Alaska Department of Labor 1961-1972).

During the winter, when jobs are not available, the non-residents leave and many of the residents simply drop out of the labor force. This process is clearly illustrated in Figure 163 by the enormous increase in the labor force during the summer. Furthermore, the increase shown is a significant underestimate of total expansion since the work force data used in Figure 163 are based primarily on wage and salary employment. Most of the self-employed commercial fishermen are not included. Rogers (1972) estimates that there were nearly 3,000 commercial fishermen in Bristol Bay in the summer of 1970. If commercial fishermen were added to the data in Figure 163, the estimated labor force and employment would exceed 7,500 persons in July 1970.

Because the Bristol Bay economy is dependent upon the highly seasonal salmon fishery, a large proportion of the resident labor force is employed for only part of the year. During 1969, about 30 percent of the Bristol Bay population over 16 years old was employed for 13 weeks or less and 36 percent was employed for 40 weeks or more (Table 51).

TABLE 51

WORKERS BY WEEKS WORKED

BRISTOL BAY 1969

	Bristol Bay						Alaska					
	Total Number	Percent	White Number	Percent	Nonwhite Number	Percent	Total Number	Percent	White Number	Percent	Nonwhite Number	Percent
MALE, 16 years old and over	1,594		797		797		107,277		88,945		18,332	
40-52 weeks	742	46.5	600	75.3	142	17.8	75,249	70.1	67,992	76.4	7,257	39.6
14-39 weeks	273	17.1	105	13.2	168	21.1	15,219	14.2	11,591	13.0	3,628	19.8
13 weeks or less	451	28.3	80	10.0	371	46.5	9,253	8.6	4,374	4.9	4,879	26.6
Did Not Work	128	8.0	12	1.5	116	14.6	7,556	7.0	4,988	5.6	2,568	14.0
FEMALE, 16 years old and over	1,046		296		750		83,850		67,631		16,219	
40-52 weeks	198	18.9	113	38.2	85	11.3	24,023	28.6	21,337	31.5	2,686	16.6
14-39 weeks	111	10.6	61	20.6	50	6.7	14,637	17.5	12,165	18.0	2,472	15.2
13 weeks or less	348	33.3	34	11.5	314	41.9	10,647	12.7	7,602	11.2	3,045	18.8
Did Not Work	389	37.2	88	29.7	301	40.1	34,543	41.2	26,527	39.2	8,016	49.4
TOTAL, 16 years old and over	2,640		1,093		1,547		191,127		156,576		34,551	
40-52 weeks	940	35.6	713	65.2	227	14.7	99,272	51.9	89,329	57.1	9,943	28.8
14-39 weeks	384	14.5	166	15.2	218	14.1	29,856	15.6	23,756	15.2	6,100	17.7
13 weeks or less	799	30.3	114	10.4	685	44.3	19,900	10.4	11,976	7.6	7,924	22.9
Did Not Work	517	19.7	100	9.1	417	27.0	42,099	22.0	31,515	20.1	10,584	30.6

Source: U.S. Bureau of the Census 1972b.

In contrast, for the State as a whole, only 10 percent was employed for less than 13 weeks and 52 percent was employed for more than 40 weeks. Among the nonwhite population, the limited time span of employment is particularly striking. Forty-four percent of the Natives in Bristol Bay were employed for 13 weeks or less, and of those who worked at all, fully 60 percent worked less than 13 weeks. Clearly, on an annual basis, only a fraction of the available labor force is being utilized in the Bristol Bay region.

The local economy is affected not only by the seasonal fluctuations during the year but also by the inherent cyclic variability in the salmon run from year to year:

> The fish are well known to run in severe fluctuations of four or five year "cycles" which affects the personal income of most of the...residents, and in poor years local purchasing power decreases. When this occurs people will cut down either on their consumption of goods, or take advantage of credit, or both. A small business affected so heavily by the variability of the salmon runs will find it difficult to operate under these circumstances, especially with the good years difficult to predict and the poor ones occurring frequently. As a result, the Borough can maintain only those retail stores and services that are reasonably certain of profitable survival, even during the period of two or three "bad catch" years (Alaska State Housing Authority 1966).

In view of the low income levels in Bristol Bay, the resident commercial fisherman must forego necessary expenditures for food, clothing, housing and the like to finance the acquisition of a fishing boat and gear. If the boat cannot be purchased outright, he must make large annual payments until a loan is repaid. The fisherman often obligates nearly all of his capital to purchase highly specialized equipment which can only be used during the brief salmon season. In a bad year, he may fall behind in his payments, and even in a bonanza year, the fisherman may have to allocate a major portion of his earnings to cover the indebtedness of former seasons. A string of bad years may result in financial disaster.

Employment by Industry

Employment in each of the major industries in the Bristol Bay area is shown in Table 52 for the period from 1961 to 1972. The discussion below outlines the factors which have produced the observed development of each sector.

TABLE 52

NONAGRICULTURAL WAGE AND SALARY EMPLOYMENT BY INDUSTRY

BRISTOL BAY LABOR AREA

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
TOTAL EMPLOYMENT	897	765	780	743	1084	1022	866	943	1062	1253	1242	1171
Manufacturing	525	370	382	334	626	515	371	418[2]	515[2]	691[2]	638[2]	402
Transportation, Communication, and Public Utilities	65	67	68	73	89	94	95	113	117	110	110	104
Trade	39	34	28	24	29	28	30	35	42	47	46	59
Service	28[3]	24[3]	22[3]	31[3]	31	27	38	29	25	23	33	45
Government	229	251	270	275	287	309	317	340	336	366	384	488
Other[1]	11	19	10	6	22	49	15	8[2]	27[2]	16[2]	31[2]	73
INDUSTRIAL DISTRIBUTION OF EMPLOYMENT (PERCENT)												
Manufacturing	58.5	48.4	49.0	45.0	57.7	50.4	42.8	44.3	48.5	55.1	51.4	34.3
Transportation, Communication, and Public Utilities	7.2	8.6	8.7	9.8	8.2	9.2	10.1	12.0	11.0	8.8	8.9	8.9
Trade	4.3	4.4	3.6	3.2	2.7	2.7	3.5	3.7	4.0	3.8	3.7	5.0
Service	3.1	3.1	2.8	4.2	2.9	2.6	4.4	3.1	2.4	1.8	2.7	3.8
Government	25.5	32.8	34.6	37.0	26.5	30.2	36.6	36.1	31.6	29.2	30.9	41.7
Other	1.2	2.5	1.3	0.8	2.0	4.8	1.7	0.8	2.5	1.3	2.5	6.2

[1] Includes contract construction; finance, insurance, and real estate; and miscellaneous.
[2] Due to disclosure regulations, averages computed using less than a full year's data.
[3] Includes miscellaneous in these years.

Source: Alaska Department of Labor 1961-1972.

Manufacturing

In Bristol Bay, manufacturing is virtually synonymous with salmon processing. Between 1961 and 1972, the industry averaged 53 percent of the total wage and salary employment, however this proportion does seem to be declining somewhat over time. In 1961, 58 percent of total employment was in manufacturing, compared to 34 percent in 1972. Even in 1970, when Bristol Bay experienced one of the largest salmon harvests in history, manufacturing employment averaged only 55 percent of the total.

Due to the highly seasonal nature of the industry, computing average annual monthly employment by adding average monthly employment and dividing by 12 grossly underestimates the importance of seafood processing. For example, in 1972, an "average" of 402 people were employed in manufacturing, but the average monthly employment ranged from 38 persons in March to 1,835 persons in July. The employment during the peak month corresponds closely with the total number of people engaged in seafood processing in the course of a year.

Additionally, the impact of the fishing industry has been understated in Alaska's employment statistics because there have been no reliable estimates of the direct employment in commercial fishing. Since most commercial fishermen are self-employed, they are generally not included in the estimates of total employment. Rogers (1972) estimated that 2,980 fishermen were employed in Bristol Bay during July 1970. This implies that the work force estimates shown in Table 52 underestimate the importance of the fishing industry by nearly 50 percent.

Trade and Service

Trade and service firms account for relatively small proportions of Bristol Bay's employment. The number of persons employed in trade rose from 39 in 1961 to 59 in 1972, while service employment increased from 28 to 45 persons. The month-to-month variation in these industries is minimal and does not follow a consistent pattern from year to year. There are 18 retail trade firms in Bristol Bay, a third of these are eating and drinking establishments.

Most of the stores are located in Dillingham or the Bristol Bay Borough, but Togiak and Manokotak have village cooperative stores.

Transportation, Communication and Public Utilities

The number of persons employed in transportation, communication, and public utilities rose from 65 in 1961 to 104 in 1972. In that interval, the proportion of employment in these industries rose from 7.2 percent to 8.9 percent of the total work force. There is some decline in employment during the winter months, but the seasonal variation is not very large. Transportation companies in Bristol Bay include 3 airlines, 2 air-taxi services, a taxicab company, and 2 lighterage firms. There are 2 electric companies, 1 telephone utility, and an American Forces Radio and Television Service originating in King Salmon.

Government Employment

The government sector has historically been one of the most important in Alaska's economy. In Bristol Bay, the fishing industry accounts for the largest proportion of total annual employment, but the government sector offers the greatest number of year-round jobs. In many of the small villages, the only persons with wage income throughout the year are the postmaster, health aide, school teachers and other school employees. Over the period from 1961 to 1972, the government sector has accounted for roughtly one-third of the total employment in the Bristol Bay region (Table 52).

In 1972, the federal government employed 170 persons (Table 53). The Kanakanak U.S. Public Health Service Hospital, Federal Aviation Agency and civilian personnel employed by the U.S. Air Force accounted for most of these positions. Other federal employment in Bristol Bay was provided by the U.S. Post Office, U.S. Weather Bureau, U.S. Fish and Wildlife Service, and the National Park Service. Of the 197 state personnel employed in 1972, about 57 percent were teachers, administrators, and other employees of State Operated Schools which maintains 19 village schools in Bristol Bay. The Alaska Departments of Public Works, Health and Social Services, Fish

TABLE 53

GOVERNMENT EMPLOYMENT 1972 BRISTOL BAY LABOR MARKET AREA

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
State Government	177	199	190	199	187	185	136	153	207	221	250	254	197
Governor's Office	3	16	3	3	2	1	1	1	1	1	1	1	3
Health and Social Services	11	11	13	14	12	12	12	15	13	12	11	12	12
Labor	1	1	1	1	1	1	1	1	1	1	1	1	1
Public Safety	6	6	7	7	5	6	5	11	9	8	10	10	8
Public Works	26	33	25	25	25	21	20	21	28	27	26	27	25
Highways	7	7	7	7	8	8	13	25	28	24	24	11	14
State Operated Schools	101	108	118	129	119	121	70	65	112	123	148	141	113
Community and Regional Affairs	-	-	-	-	-	-	-	-	-	10	15	36	20
Legislative Affairs	2	2	2	2	2	2	2	2	2	2	2	2	2
Court System	3	3	3	3	3	3	3	3	3	3	3	3	3
Federal Government	153	155	160	149	157	169	165	169	167	203	197	199	170
Transportation	53	51	51	50	49	50	49	49	48	47	49	48	50
Air Force	53	58	60	53	57	57	54	53	52	46	40	46	52
Interior	12	13	14	14	15	25	23	25	22	11	12	11	16
Commerce	8	8	8	6	8	9	11	16	17	7	10	10	10
Post Office	27	25	27	26	28	28	28	26	28	28	26	28	27
Health Education and Welfare	-	-	-	-	-	-	-	-	-	64	60	56	60
Local Government	119	110	121	132	116	92	107	112	137	141	134	136	121
Military													435

Source: Alaska Department of Labor file, Juneau.

and Game, and Highways averaged at least 10 employees each. Local government employment in 1972 averaged 121 persons. Virtually all of this employment was concentrated in the City of Dillingham or the Bristol Bay Borough, which has its headquarters in Naknek. The 1970 census reported that government employment in Bristol Bay accounted for 50 percent of the male work force and 57 percent of the female work force (Table 54). However, these proportions are inflated because the percentages were based solely on employment during the census reference week (around April 1, 1970) when employment in the commercial fishing and fish processing industry was very low (U.S. Bureau of the Census 1971d). The census information does, however, provide a good measure of the composition of permanent, year-round employment. The proportion of year-round employment attributable to the government sector is much higher in Bristol Bay than in Alaska as a whole, or in the United States. White employees hold over half of the government jobs although whites account for only 28 percent of the civilian population. There is a particularly high proportion of whites employed by local government units; only 28 percent of the jobs in local government are held by nonwhites.

TABLE 54

CLASS OF WORKER

BRISTOL BAY

1970

CLASS OF WORKER	BRISTOL BAY Total Number	BRISTOL BAY Total Percent	BRISTOL BAY White Number	BRISTOL BAY White Percent	BRISTOL BAY Nonwhite Number	BRISTOL BAY Nonwhite Percent	ALASKA Total Percent	ALASKA White Percent	ALASKA Nonwhite Percent	U.S. Total Percent
MALES										
Employed, 16 years old and over	439		238		201					
Employee of Private Company	167	38.0	77	32.4	90	44.7	57.8	59.0	48.0	75.5
Government Employees	223	50.8	132	55.5	91	45.3	33.6	31.9	47.0	14.1
Federal	100	22.7	66	27.7	34	16.9	17.1	15.8	27.1	4.6
State	81	18.5	34	14.3	47	23.4	9.4	9.0	12.2	3.4
Local	42	9.6	32	13.4	10	5.0	7.2	7.1	7.7	6.1
Self Employed Workers	49	11.2	29	12.2	20	10.0	8.4	8.9	4.9	10.2
Unpaid Family Workers	-	-	-	-	-	-	0.2	0.2	0.2	0.2
FEMALES										
Employed, 16 years old and over	305		159		146					
Employee of Private Company	113	37.0	60	37.7	53	36.3	53.9	55.0	46.9	75.9
Government Employees	174	57.0	81	50.9	93	64.0	40.9	39.6	49.0	19.5
Federal	67	22.0	16	10.1	51	34.9	17.0	15.5	26.2	3.8
State	37	12.1	16	10.1	21	14.4	11.5	10.9	15.1	4.9
Local	70	23.0	49	30.8	21	14.4	12.5	13.2	7.7	10.8
Self Employed Workers	18	5.9	18	11.3	-	-	4.3	4.5	3.1	3.7
Unpaid Family Workers	-	-	-	-	-	-	0.9	0.9	1.0	1.0
TOTAL										
Employed, 16 years old and over	744		397		347					
Employee of Private Company	280	37.6	137	34.5	143	41.2	56.2	57.5	47.5	75.7
Government Employees	397	53.3	213	53.6	184	53.0	36.5	34.9	47.9	16.1
Federal	167	22.4	82	20.7	85	24.5	17.1	15.7	26.7	4.3
State	118	15.9	50	12.6	68	19.6	10.2	9.7	13.5	3.9
Local	112	15.0	81	20.4	31	8.9	9.3	9.5	7.7	7.9
Self Employed Worker	67	9.0	47	11.8	20	5.8	6.8	7.2	4.1	7.7
Unpaid Family Workers	-	-	-	-	-	-	0.5	0.4	0.6	0.5

Source: U.S. Bureau of the Census 1971d, 1971e.

INCOME AND COST OF LIVING

Distribution of Income

The 1970 census estimated that median family income in Bristol Bay for 1969 was 7,785 dollars (Table 55), about 60 percent below the median family income for the State as a whole. As shown in Table 55, the distribution of income in Bristol Bay differs from the statewide pattern. Roughly one-third of the families in Bristol Bay have incomes less than 5,000 dollars; one-third, 10,000 dollars and above; and one-third in the intermediate range. By comparison, the statewide data show that 14 percent of the families fall in the lower income bracket, 24 percent in intermediate and 62 percent in the higher. The income patterns of Bristol Bay white families more closely approximate the state distribution, except that there is a larger proportion in the lower income categories than for whites statewide. Income levels of Bristol Bay Native families are very low. Only 15 percent of the Native families have incomes in excess of 10,000 dollars--a figure less than half the statewide average for nonwhites. Nearly 30 percent of Bristol Bay's

TABLE 55

INCOME OF FAMILIES

BRISTOL BAY 1970

	BRISTOL BAY									ALASKA					
	Total			White			Nonwhite			Total		White		Nonwhite	
	Number	Percent		Number	Percent		Number	Percent		Percent		Percent		Percent	
All Families	765	100.0		315	100.0		450	100.0		100.0		100.0		100.0	
Less than $1,000	62	8.1		18	5.7		44	9.8		2.2		1.6		5.6	
$1,000 to 1,999	45	5.9	20.9	5	1.6	8.9	40	8.9	29.4	2.3	7.2	1.4	4.7	7.5	21.4
2,000 to 2,999	53	6.9	31.9	5	1.6	15.6	48	10.7	43.4	2.7	14.1	1.7	9.9	8.3	37.7
3,000 to 3,999	42	5.5		11	3.5		31	6.9		3.2		2.2		8.6	
4,000 to 4,999	42	5.5		10	3.2		32	7.1		3.7		7.0		3.7	
5,000 to 5,999	52	6.8		6	1.9		46	10.2		5.0		4.3		8.8	
6,000 to 6,999	76	9.9		15	4.8		61	13.6		4.9		4.6		6.8	
7,000 to 7,999	37	4.8	31.7	15	4.8	16.9	22	4.9	42.3	4.6	23.6	4.5	22.4	5.2	30.1
8,000 to 8,999	50	6.5		5	1.6		45	10.0		4.8		4.7		4.9	
9,000 to 9,999	28	3.7		12	3.8		16	3.6		4.3		4.3		4.4	
10,000 to 14,999	167	21.8		134	42.5		33	7.3		24.6		25.5		19.2	
15,000 to 24,999	101	13.2	36.3	74	23.5	67.6	27	6.0	14.4	28.2	62.4	31.3	67.7	11.0	32.1
25,000 or more	10	1.3		5	1.6		5	1.1		9.6		10.9		1.9	
Median Income	$7,785									$12,443		$13,464			

Source: U.S. Bureau of the Census 1971d.

Native families have annual incomes less than 3,000 dollars. The median income for Natives in Bristol Bay is less than 6,000 dollars which is less than half of the statewide median for all families and almost 2,000 dollars less than the state median for nonwhite families.

Earnings and Wage Rates

The earnings data in Table 56 show that the observed differences in regional incomes are not due solely to differences in the relative importance of various occupations. There is a consistent earnings differential in virtually all occupational categories. Although there is considerable variation in the size of this gap, males in Bristol Bay typecally earn about 40 percent less than the statewide averages. Among females, earnings in Bristol Bay average 25 percent below the state levels.

Table 57 gives Bristol Bay average annual wage rates by industry for the 1960-72 period. The following discussion of wage rates lists the industries in descending order from the highest total payroll in 1972 to the lowest. In 1972, manufacturing (fish processing) ranked first with

TABLE 56

EARNINGS BY OCCUPATION GROUPS 1970

BRISTOL BAY

Median earnings for selected occupation groups	Bristol Bay Borough	Bristol Bay Division	Bristol Bay Total	Alaska
MALE, 16 years old and over with earnings	$8,800	$6,212	$6,859	$11,242
Professional and managerial	10,147	10,794	10,581	13,796
Craftsmen and foremen	11,176	7,600	8,479	12,098
Operatives	-	-	-	9,566
Laborers	2,250	4,400	4,179	6,747
FEMALE, 16 years old and over with earnings	2,200	4,500	4,092	4,818
Clerical and kindred workers	-	1,885	1,885	5,296
Operatives	-	-	-	2,274

Source: U.S. Bureau of the Census 1971d.

TABLE 57

BRISTOL BAY AREA AVERAGE ANNUAL WAGE

1960–1972

Industrial Classification	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Manufacturing *	3295	2278	1631	1501	1565	2348	1606	1496	1589	1695	2254	1944	1529
Transportation, Communication & Public Utilities	6453	6582	7127	5384	5820	5631	5889	6517	5903	6723	7339	8085	8858
Wholesale & Retail Trade	4012	4851	3797	4124	3746	3921	4661	4243	4062	4154	4280	5148	4382
Services	3130**	5090**	2504	2558	3726	3820	3668	3580	4321	4432	5438	5327	4452
Federal Government	NA	NA	NA	NA	6260	5334	5852	6997	7281	7622	9459	11917	9921
State & Local Government	NA	NA	NA	NA	3500	5397	5262	6000	6702	7261	8352	10027	10505

* Calculated by dividing the annual payroll by the number of persons employed during the peak month of the salmon season.

** Based on data for less than a full year to comply with disclosure regulations.

Source: Alaska Department of Labor 1960-1972.

a payroll of 4.2 million dollars, but 70 percent of these wages were earned in July, August, and September (Table 58 presents payrolls by quarter for 1968-72). Wages in manufacturing have been the most unstable of Bristol Bay industries, a reflection of the cyclic nature of seafood processing. Annual earnings in manufacturing peaked in 1960, 1965, and 1970--years of peak salmon runs in the Bristol Bay region. The average earnings in manufacturing shown in Table 57 were computed by dividing the total payroll for the year by the employment during the peak month of the salmon run. As discussed previously, the seasonal nature of the salmon fishery makes it inappropriate to measure employment by computing an annual average of monthly employment levels. Employment during the peak month is a more accurate measure of the total number of people who earn income through employment in seafood processing.

The payroll for state and local government in 1972 was 3.3 million dollars. Since 1967, the annual average wage for state and local government workers has steadily increased from 6,000 dollars to 10,500 dollars in 1970, a rise of 75 percent. Over this same period, the total pay-

TABLE 58

QUARTERLY PAYROLLS BY INDUSTRY 1968-1972

BRISTOL BAY

	Total	Manufacturing	Transportation Communication & Public Utilities	Wholesale & Retail Trade	Services	Federal Government	State & Local Government
1968							
First Quarter	$ 910,950	*	$134,244	$ 31,603	$ 35,233	$ 288,784	$ 262,956
Second Quarter	1,527,224	685,875	159,862	33,038	27,795	341,523	272,016
Third Quarter	3,432,951	2,548,150	211,219	39,465	32,687	275,602	312,042
Fourth Quarter	1,160,237	*	161,777	37,817	29,590	311,077	319,171
Total	7,031,362	*	677,066	142,193	125,305	1,215,986	1,166,185
1969							
First Quarter	926,243	*	153,182	34,493	21,305	230,170	294,158
Second Quarter	1,694,257	788,637	202,124	43,608	25,520	301,762	313,799
Third Quarter	4,494,796	3,465,212	237,503	48,149	30,467	294,887	374,075
Fourth Quarter	1,284,025	*	193,835	48,224	33,515	285,972	397,530
Total	8,399,321	*	786,644	174,474	110,807	1,112,791	1,379,562
1970							
First Quarter	1,138,164	209,423	156,534	36,225	24,333	328,037	375,876
Second Quarter	2,612,783	1,451,169	215,500	45,745	24,840	464,942	397,315
Third Quarter	8,129,496	6,808,413	257,985	63,430	28,905	478,375	427,076
Fourth Quarter	1,670,392	*	177,277	55,783	47,009	261,056	503,636
Total	13,550,835	*	807,296	201,183	125,087	1,532,410	1,703,903
1971							
First Quarter	1,229,243	35,757	176,552	48,314	19,891	270,580	620,218
Second Quarter	2,891,692	1,348,698	230,168	56,320	41,923	548,625	596,017
Third Quarter	6,869,187	5,530,108	265,437	65,983	52,166	333,118	603,792
Fourth Quarter	1,705,742	*	217,205	66,180	61,825	277,707	827,123
Total	12,695,864	*	889,362	236,797	175,805	1,430,030	2,647,150
1972							
First Quarter	1,593,013	95,300	190,727	63,238	30,220	386,757	816,112
Second Quarter	2,531,425	926,677	214,172	93,781	41,970	372,129	770,362
Third Quarter	4,975,612	2,895,064	273,902	78,725	59,794	419,029	764,422
Fourth Quarter	2,260,529	242,135	242,458	90,215	68,348	518,736	979,412
Total	11,360,579	4,159,176	921,259	325,959	200,332	1,696,651	3,330,308

Source: Alaska Department of Labor 1960-1972.

roll nearly tripled. Prior to 1969, the total payroll of federal government workers exceeded that of state and local government employees. Additionally, the average annual wage in federal employment exceeded that of state and local government workers through 1971. Between 1971 and 1972, the average annual federal wage dropped from 11,900 to 9,900 dollars. In that same interval the average state and local government wage rose from 10,000 to 10,500 dollars. The federal, state, and local government wages are the most important source of stable year-round income in Bristol Bay.

Transportation, communications, and public utilities wages, after moving erratically in earlier years, have increased steadily between 1969 and 1972. Average wages in the industry rose 32 percent during this period to an average annual wage of 8,858 dollars. The total payroll in 1972 was 921,000 dollars. Wholesale and retail trade wages have remained virtually constant. In 1960, the average worker in these industries earned 4,012 dollars. In 1972, the average annual earnings were 4,382 dollars, and averaged 4,260 dollars over the period. Total payroll in 1972 was 326,000 dollars. Services ranked last with a 1972 payroll of 200,000 dollars. Average annual wages in service industries increased steadily from 3,580 dollars in 1967 to 5,327 dollars in 1971, but fell to 4,452 dollars in 1972, just slightly above earnings in the trade sector.

Public Assistance Income

The 1970 census reported that one-sixth of the Bristol Bay families received public assistance or public welfare income in the preceding year (Table 59). This is more than 3 times the statewide average. Of those families receiving assistance, 96 percent were Native. About 27 percent of all Native families in Bristol Bay received some public assistance income. For the State as a whole, 21 percent of the nonwhite families receive some form of public assistance or welfare payments.

U.S. Bureau of Indian Affairs general assistance, State public assistance and Food Stamps are the 3 major forms of public assistance available to Bristol Bay residents. The State public assistance programs include payments for old age assistance, aid to the blind, aid to the disabled, and aid to dependent children. Table 60 shows the number

TABLE 59

SOURCES OF INCOME 1970

BRISTOL BAY

	BRISTOL BAY						ALASKA		
	Total		White		Nonwhite		Total	White	Nonwhite
	Number	Percent	Number	Percent	Number	Percent	Percent	Percent	Percent
Total Families	765	100.0	315	100.0	450	100.0	100.0	100.0	100.0
Wage and Salary	663	86.7	282	89.5	381	84.7	94.8	95.3	91.8
Self Employment	337	44.1	134	42.5	203	45.1	14.9	15.3	12.7
Social Security or Railroad Retirement	99	12.9	26	8.3	73	16.2	5.5	4.4	11.6
Public Assistance or Welfare Payments	128	16.7	5	1.6	123	27.3	4.9	2.0	20.8
All Other Income	122	15.9	38	12.1	84	18.7	27.5	29.3	17.4

Source: U.S. Bureau of the Census 1971d.

TABLE 60

PUBLIC ASSISTANCE

BRISTOL BAY October 1970, 1971, 1972

	Number of Cases					Dollar Payments				
	OAA	AB	AD	AFDC	TOTAL	OAA	AB	AD	AFDC	TOTAL
1970	37	6	12	61	116	$5,383	$1,175	$2,320	$15,532	$24,410
1971	59	4	26	75	164	8,188	805	4,492	18,402	31,887
1972	73	4	30	95	202	8,670	805	4,870	21,184	35,529

Source: Alaska Department of Health and Social Services 1970-1972.

of cases and dollar payments in each category for October 1970, 1971, and 1972. For October 1972, the total amount of state public assistance in Bristol Bay was 35,529 dollars. Comparable statistics are not available for years prior to 1970 because regulations for receiving assistance under these programs were changed in that year. Between 1970 and 1972, the number of Bristol Bay residents receiving state assistance increased from 116 to 202 and the amount of dollar payments rose from 24,410 to 35,529 dollars. The Alaska Department of Health and Social Services does not provide data on yearly total assistance, but if the October 1972 figure is typical, it can be inferred that the programs distributed about 426,000 dollars to Bristol Bay residents in 1972.

U.S. Bureau of Indian Affairs general assistance is available only to Natives. In 1968, these outlays in Bristol Bay totaled 395,318 dollars with payments to 367 cases (Table 61). After that time, the number of cases and payments were cut sharply and by 1971 total expenditure in Bristol Bay was only 46,065 dollars and the case

TABLE 61

BUREAU OF INDIAN AFFAIRS GENERAL ASSISTANCE

BRISTOL BAY COMMUNITIES FISCAL YEARS 1968 - 1972

Community	F.Y. 1968		F.Y. 1969		F.Y. 1970		F.Y. 1971		F.Y. 1972	
	Amount	Cases	Amount	Cases	Amount	Cases	Amount	Cases	Amount	Cases
Aleknagik	$ 27,137	26	$ -	-	$ 6,113	9	$ -	-	$ -	-
Clarks Point	11,082	13	6,135	8	2,306	3	916	2	1,183	3
Dillingham	67,820	62	31,225	32	18,523	22	2,309	5	4,508	10
Egegik	18,039	19	3,301	5	1,279	2	1,861	2	6,620	6
Ekuk	2,840	4	639	2	--	-	-	-	-	-
Ekwok	22,453	20	20,447	15	29,458	14	5,363	6	3,005	3
Igiugig	6,879	5	7,962	6	5,542	5	1,476	1	3,900	2
Iliamna	9,783	9	8,495	5	400	1	1,128	3	5,041	4
King Salmon	-	-	121	1	1,002	1	-	-	-	-
Kanakanak	960	1	-	-	39	1	-	-	-	-
Kokhanok	12,458	9	11,410	8	9,912	7	984	1	10,646	7
Koliganek	11,527	11	12,733	11	11,005	9	2,306	4	3,116	3
Levelock	4,504	5	1,638	2	3,868	5	2,264	3	903	6
Manokotak	32,573	30	21,924	25	27,192	21	750	3	6,821	8
Naknek	-	-	-	-	-	-	-	-	1,225	1
South Naknek	12,645	8	3,400	4	4,376	4	260	2	284	1
North Naknek	-	-	2,090	2	-	-	262	1	-	-
Newhalen	4,050	3	3,214	3	1,288	1	1,000	1	4,976	3
New Stuyahok	41,892	28	29,041	29	64,067	28	1,916	4	1,491	1
Nondalton	36,112	33	46,193	28	6,512	12	17,845	13	28,188	26
Nushagak	-	-	310	1	-	-	-	-	-	-
Pedro Bay	7,026	6	6,742	6	5,213	6	400	1	865	3
Pilot Point	2,980	9	693	2	1,458	4	1,637	5	1,993	1
Port Alsworth	-	-	-	-	-	-	488	1	840	1
Port Heiden	5,003	8	4,184	4	7,115	9	2,126	5	714	2
Togiak	54,666	51	22,078	25	15,496	15	302	2	4,506	13
Twin Hill	1,030	3	1,647	3	-	-	472	2	300	1
Ugashik	1,859	4	742	2	778	2	-	-	-	-
TOTAL	$395,318	367	$246,364	229	$222,933	181	$ 46,065	67	$ 91,125	105
Average Monthly Payment	$90		$90		$102		$57		$72	

Source: U.S. Bureau of Indian Affairs file, Anchorage.

load was 67. In 1972, U.S. Bureau of Indian Affairs assistance increased to 105 cases and total payments of 91,125 dollars.

The Food Stamp Bonus Coupon Program receives funding from the U.S. Department of Agriculture, but is administered by the State. Administration of this program for Bristol Bay recipients is handled through the Dillingham office of the Alaska Division of Family and Children's Services. During the fiscal year 1968-69, the first full year the program was available to Bristol Bay residents, the bonus value of the coupons was 23,947 dollars. In fiscal year 1972-73, the bonus value of the coupons increased to 363,562 dollars (Table 62). Between July of 1972 and June of 1973, an average 1,192 persons (241 households) in Bristol Bay received Food Stamps each month. This means that over one-fourth of the families in Bristol Bay received Food Stamps that year. The bonus value of the coupons averaged 125 dollars per family per month.

In July of 1972, only 226 Bristol Bay residents were using Food Stamps, but in July 1973, the figure jumped to 988. Generally, the salmon run peaks in July and is accompanied by high employment and incomes. However, the

TABLE 62

PARTICIPATION IN THE FOOD STAMP PROGRAM

BRISTOL BAY FISCAL YEAR 1972-73

Date	Number of Participants	Number of Households Participating	Dollar Value of Coupons -	Cost to Recipients =	Bonus Value of Coupons
July 72	226	64	$ 10,392	$ 2,078.75	$ 8,313.25
Aug. 72	916	169	29,279	4,143.75	25,135.25
Sept.72	938	188	30,598	4,180.50	26,417.50
Oct. 72	1,284	253	41,588	6,262.75	35,325.25
Nov. 72	1,364	272	44,980	7,643.00	37,337.00
Dec. 72	1,321	271	43,183	7,696.00	35,487.00
Jan. 73	1,335	273	43,125	9,778.75	33,346.25
Feb. 73	1,387	285	44,544	11,509.75	33,034.25
Mar. 73	1,397	286	45,232	12,704.25	32,211.75
Apr. 73	1,411	286	45,514	13,274.00	32,240.00
May 73	1,400	278	44,703	12,500.00	32,213.00
June 73	1,328	261	42,509	9,997.25	32,511.75
Fiscal Year 1972 Totals	14,307	2,886	$ 465,647	$101,768.75	$363,562.25
Monthly Averages	1,192	241	$ 38,804	$ 8,480.73	$ 30,296.85
July 73	988	183	$ 33,457	$ 5,207.00	$ 28,248.00

Source: Rod Betit, Food Stamp Program Manager, Alaska Department of Health and Social Services, Division of Family and Children Services, Anchorage.

1973 run was disastrously low. The percentage of Bristol Bay residents using Food Stamps will continue to rise. One state official said that many residents are given the stamps outright because they have no money to buy them. The regulations governing the Food Stamp Program have recently been revised to allow Food Stamps to be used for the purchase of nonfood items for subsistence hunting and fishing. However, stamps cannot be used for the purchase of guns or ammunition.[1]

Cost of Living

The Quarterly Report on Alaska Food Prices is the data series commonly used to make differential cost of living estimates between Alaska communities and other parts of the United States (Agricultural Experiment Station,various dates). The report is based on a nationwide "market basket" survey of 45 food items. Unfortunately, to date, no Bristol Bay community has regularly been surveyed in the report. However, a 1972 state employee cost of living study by the Alaska Division of Personnel provided information on food

1. Phyllis Williams, Alaska Department of Health and Social Services, Food Stamp Supervisor, Fairbanks. Personal Communication.

costs in Dillingham (Table 63). This survey found that food prices in Dillingham in October of 1972 were 73 percent higher than in Seattle and 42 percent higher than in Anchorage.

Except for the food price information, the state cost of living survey covered state employees only. The survey measured food and beverage purchases exclusive of alcoholic beverages, tobacco, and nonfood products, and made adjustments for special diets, hunting, fishing, gardening or maintenance of livestock. Housing expenditures included rent, mortgage payments, utilities, taxes and insurance. The survey concluded that state employee food expenditures in Dillingham averaged 1,319 dollars per person per year, about 35 percent higher than the Anchorage figure and statewide average (Table 64). However, average annual housing expenditures of 1,041 dollars per person in Dillingham were 6 percent less than the state average, and 15 percent less than Anchorage. This was because the houses in Dillingham tended to be smaller than average. Housing costs per square meter in Dillingham were found to be 28 percent higher than statewide and 42 percent higher than Anchorage. Furthermore, the condition of housing in Dilling-

TABLE 63

Relative Costs of 44 Selected Food Items in 14 Alaska Cities and Towns
October 1972

City	Cost	% of Seattle	% of Anchorage
Soldotna	$38.36	137.1	112.1
Cordova	41.96	149.9	122.6
Palmer	35.49	126.8	103.7
Kenai	38.18	136.4	111.5
Fairbanks	37.91	135.5	110.8
Juneau	36.46	130.2	106.5
Anchorage	34.23	122.3	100.0
Ketchikan	35.38	126.5	103.4
Seward	37.80	135.0	110.4
Sitka	38.25	136.6	111.7
Haines	38.61	137.9	112.8
Bethel	53.61	191.5	156.6
Dillingham	48.44	173.1	141.5
Kodiak	$39.12	139.8	114.3

Source: Alaska Department of Administration 1972.

COSTS OF FOOD AND HOUSING FOR STATE EMPLOYEES 1972

	DILLINGHAM						STATEWIDE		ANCHORAGE	
			DILLINGHAM/STATE RATIO		DILLINGHAM/ANCHORAGE RATIO					
	HOUSEHOLD	PERSON	HOUSEHOLD	PERSON	HOUSEHOLD	PERSON	HOUSEHOLD	PERSON	HOUSEHOLD	PERSON
Average Annual Food Expenditures	$4,420	$1,319	139	135	149	136	$1,185	$ 978	$2,960	$ 971
Average Annual Housing Expenditures	3,489	1,041	97	94	94	85	3,605	1,109	3,724	1,223
Average Housing cost per square foot	$4.53	—	128	—	142	—	$3.54	—	$3.19	—

Source: Alaska Department of Administration 1972.

ham was found to be lower than in Anchorage. Thus 42 percent is actually an underestimate of the true differential in cost of housing. Based on the study's findings, the Division of Personnel recommended that Bristol Bay employees should rate 7 to 8 salary steps above Anchorage employees. That would amount to about a 34 percent cost of living adjustment for state employees in Bristol Bay.

HOUSING AND PUBLIC SERVICES

Housing

Housing in Bristol Bay is commonly overcrowded, dilapidated and in short supply. The 1970 Census of Housing (U.S. Bureau of the Census 1971a, b and 1972a) reported that 53 percent of the housing units lacked piped-in water, an amenity present in all but 12 percent of the households statewide, and all but about 2 percent nationally (Table 65). Only 42 percent of Bristol Bay's housing units had complete kitchen facilities--a proportion less than half state and national averages. Overcrowded conditions were evidenced in the fact that over a third of the units had more than 1.5 persons per room. Statewide only

TABLE 65

HOUSING CHARACTERISTICS

BRISTOL BAY CENSUS DIVISION-1970

	Borough		Division		Total		Alaska	U.S.
	Number	Percent	Number	Percent	Number	Percent	Percent	Percent
Total Population	1045		3587		4632			
All Year Round Housing Units	199	100.0	866	100.0	1065	100.0	100.0	100.0
Population								
Population in housing units in 1970	579		3550		4129		276,918	
Per occupied unit	3.4		4.0		4.5		3.5	
owner	3.8		5.1		---		3.8	
Piped Water in Structure								
Hot and Cold	134	67.3	268	30.9	402	37.7	85.8	95.2
Cold Only	16	8.0	83	9.6	99	9.3	2.6	2.3
None	49	24.6	515	59.5	564	53.0	11.6	2.4
Flush Toilet								
For exclusive use of household	136	68.3	282	32.7	418	39.2	85.3	95.0
Also used by another household	5	2.5	—	—	5	0.5	1.1	1.0
None	58	29.1	584	67.4	642	60.3	13.6	4.0
Bathtub or Shower								
For exclusive use of household	129	64.8	263	30.4	392	36.8	84.9	94.2
Also used by another household	5	2.5	—	—	5	0.5	1.1	1.0
None	65	32.7	603	69.6	668	62.7	14.0	4.8
Complete Kitchen Facilities								
For exclusive use of household	150	75.4	292	33.7	442	41.5	85.4	95.4
Also used by another household	—	—	—	—	—	—	0.3	0.2
No complete kitchen facilities	49	24.6	574	66.3	623	58.5	14.4	4.4
Rooms								
1 room	5	2.5	173	20.0	178	16.7	9.2	1.9
2 rooms	43	21.6	150	17.3	193	18.1	10.6	3.3
3 rooms	25	12.7	183	21.1	208	19.5	14.8	11.2
4 rooms	60	30.2	134	15.5	196	18.2	22.4	22.0
5 rooms	40	20.1	130	15.0	170	16.0	20.9	24.9
6 rooms	21	10.6	30	3.5	51	4.8	11.6	19.9
7 rooms	--	--	23	2.7	23	2.2	5.6	9.4
8 or more rooms	5	2.5	43	5.0	48	4.5	4.9	8.1
Persons								
All occupied units	169	100.0	747	100.0	916	100.0	100.0	100.0
1 person	17	10.1	113	15.1	130	14.2	13.7	17.6
2 persons	42	24.9	81	10.8	123	13.4	24.7	29.6
3 persons	45	26.6	70	9.4	115	12.6	17.3	17.2
4 persons	18	10.7	100	13.4	118	12.9	17.1	15.4
5 persons	21	12.4	111	14.9	132	14.4	12.1	9.8
6 persons	16	9.5	87	11.6	103	11.2	7.1	5.3
7 persons	10	5.9	82	11.0	92	10.0	4.5	2.7
8 or more persons	--	--	103	13.9	103	11.2	3.6	2.4
Persons per room								
All occupied units	169	100.0	747	100.0	916	100.0	100.0	100.0
1.00 or less	117	69.2	359	47.8	476	52.0	81.0	91.8
1.01 - 1.50	34	201.	95	12.7	129	14.1	10.0	6.0
1.51 or more	18	10.7	293	39.2	311	34.0	9.0	2.2

Source: U.S. Bureau of the Census 1971a, 1971b, 1972a.

9 percent of all households were this crowded, and even the average for Alaska's rural areas was 15 percent. Most of the better housing in the region is concentrated in Dillingham, Naknek and King Salmon. Families with better housing characteristically have higher incomes, greater educational attainment and are white (Alaska State Housing Authority 1966, 1971).

A basic obstacle to improving housing conditions is the instability in the local economy due to the seasonal nature of the fishing industry. Sources of credit are inadequate and very few homes are purchased through bank or other financing. High construction and maintenance costs are also a problem. Much of the higher construction costs are related to transportation costs. The area lacks a highway or rail connection with major sources of supply. Most construction materials are brought in by boat during the brief ocean shipping season. The cargo must be lightered to shore or brought in by barge. Shipping to the more distant points in the region then compounds the transportation costs even further. An additional obstacle is that the fishing season corresponds with the months when conditions are most favorable for housing construction (Alaska State Housing Authority 1971).

Even in Dillingham, the largest population center, housing conditions were described by the Alaska State Housing Authority (ASHA) as "a handicap to the welfare of the community." An ASHA housing survey in 1970 revealed that 70 percent of all units were unsound. About 20 percent of Dillingham's housing was termed "dilapidated"--too costly to repair and often dangerous to health and safety. The remaining 50 percent was classified as "deteriorating,"--structurally sound but in need of repair. The units were also more crowded than average with about 4 persons per unit, compared to an average 3.5 per unit statewide (Alaska State Housing Authority 1971). In addition to these poor conditions, housing is in short supply:

> There are virtually no houses of any kind of quality available for sale, and the vacancy rate is very low for rental units and apartments. There is a problem also which compounds the situation in the summer when the population nearly doubles during the fishing season (Alaska State Housing Authority 1971).

The ASHA study (1971) of Dillingham concluded that there was a need for low and middle income housing in Dillingham. In 1971, the city approved a plan to establish Turnkey-type housing in Dillingham; however, the proposal fell through, and the housing conditions found in the 1970 ASHA survey have not changed much. Some new homes have been constructed and several mobile homes have been brought in.

In the Bristol Bay Borough, the best housing is found in King Salmon.[1] Most of the housing is apartment units with central water and sewer facilities. Housing units here are a combination of government-built units, which are occupied by state and federal personnel, and privately owned single family dwellings. There are also some mobile homes in the community. An ASHA survey (1966) found that South Naknek had the poorest housing in the Borough. More than 84 percent of the units were inadequate in terms of size or facilities or both. Housing in Naknek falls in the intermediate range between South Naknek and King Salmon with about 57 percent of the units classified by ASHA (1966) as inadequate.

In the remote outlying villages, housing conditions vary widely, but on the whole are substandard. Since 1970,

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1. Sam Coxson, City Manager, Dillingham, Alaska. Personal communication.

most of the new village housing units have been built at Manokotak, New Stuyahok and Nondalton (Federal Field Committee for Development Planning in Alaska 1971). In most of these communities, any major improvements in housing would also require the acquisition of electric power, piped water and improved sewage disposal.

Utilities

Dillingham is the only community in Bristol Bay which provides centralized water and sewer. Even in Dillingham, many families are not served because they live in remote, low population areas of the city's 57 sq. km. boundaries (Alaska State Housing Authority 1971). In 1970, the Alaska State Housing Authority (1971) concluded that except for the city proper and Kanakanak:

> The remainder of the township population is not, nor will it be in the near future, of sufficient density to justify additional or greatly extended community or centralized water or sewer systems.

Families in outlying areas of Dillingham utilize private wells and septic tanks or seepage pits. ASHA (1971) described Dillingham's water and sewer systems as being in a "sad state of repair." The city built an extended aeration sewage treatment facility, but it was oversized for the community's needs. The operating costs were so high that the plant was shut down in 1966 after only 4 months of operation. Since that time the plant has been bypassed and raw sewerage has been dumped into the Nushagak River (Alaska State Housing Authority 1971). The water and sewer systems at Kanakanak are owned and operated by the U.S. Public Health Service. ASHA (1971) rated the systems as in "perfect condition" and termed the Dillingham water and sewer systems the "antithesis" of those at Kanakanak.

The remainder of Bristol Bay's residents rely on private wells, rivers, streams or springs for their water. In larger communities, some residents have septic tanks, but sewage disposal is commonly primitive. One exception is the King Salmon Air Force Station which has its own water and sewer facility.[1]

The Nushagak Electric Cooperative, Inc. supplies power to Dillingham and Aleknagik. The U.S. Air Force

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1. Lt. Records, Public Information Officer, King Salmon Air Force Station, King Salmon, Alaska. Personal communication. August 1973.

Station at King Salmon has a self-contained power plant.[1] The Naknek Electric Association supplies power to Naknek, South Naknek, and the village of King Salmon.[2] The Alaska Village Electric Cooperative (AVEC) provides power for the communities of Togiak and New Stuyahok. AVEC has plans to extend service to Koliganek, Manokotak, and Nondalton in the near future.[3]

Dillingham, King Salmon, Naknek, and King Salmon Air Force Station have direct dial telephone service through North State Telephone Company.[4] All others rely on single sideband radios or RCA "bush" radiotelephone service. RCA's "bush" service is an automatic radio system which offers direct dialing capability.[5] As of August 1973 RCA had installed

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1. Ibid.

2. Dave Bouker, Manager, Nushagak Electric Co-op., Inc., Dillingham, Alaska. Personal communication.

3. Dunkel Barger, Manager, Education Programs, Alaska Village Electric Co-op., Inc., Anchorage, Alaska. Personal communication. August 1973.

4. Caroline Gilbert, owner, North State Telephone Company, Anchorage, Alaska. Personal communication. August 1973.

5. Marie I. Morrison, Public Affairs, RCA Alaska Communications, Inc., Anchorage. Personal communication. August 1973.

"bush" phones in Egegik, South Naknek, Levelock, Igiugig, Kakhonak, Newhalen, Pedro Bay, and Nondalton. The company plans to extend service to Koliganek, Aleknagik, Twin Hills, Togiak and Manokotak in late 1973. The communities of Pilot Point, Port Alsworth, and Ugashik are scheduled to have "bush" radiophones installed in the spring of 1974.[1]

Medical Care

A devastating influenza epidemic swept through Bristol Bay during 1918-19, wiped out several villages and decimated the population of others. In the aftermath, the Territorial Bureau of Education Building at Kanakanak was enlarged and remodeled as a hospital to meet the chronic need for medical services in the area. The hospital was the first permanent health facility in the Bristol Bay area and remains the major medical service center. In 1932, the small hospital was destroyed by fire and was replaced by a 32-bed unit in 1940 (Van Stone 1967).

The Kanakanak hospital is now an Alaska Native Health Service Hospital administered by the Department of

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1. Ibid.

Indian Health of the U.S. Public Health Service. The hospital, which was renovated in 1972, has a bed capacity of 29 and an average patient load of 12.[1] The hospital can handle most general medical services including surgery, obstetrics, and communicable diseases. However, in cases requiring specialized surgery or extended medical care, patients are often sent to the U.S. Public Health Service Hospital in Anchorage. In addition to hospital services, the facility operates an outpatient clinic. The clinic and hospital are staffed by 2 doctors and 2 dentists. Hospital and outpatient services are available to both Natives and non-Natives, though Natives have priority and whites with the ability to pay are charged for services. A doctor in Dillingham operates a small clinic which offers the only private year-round medical services in Bristol Bay.[2]

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1. Lloyd Hermansen, Service Unit Director, Alaska Native Hospital, U.S. Public Health Service, Kanakanak, Alaska. Personal communication. August 1973.

2. Ibid.

Each of Bristol Bay's villages has a health aide who has been trained by the Indian Health Service, U.S. Public Health Service, under a program run by the Alaska Federation of Natives, Inc. Since few medical facilities have been built in the villages, the health aides operate out of their homes or the school. The health aides call the Kanakanak Hospital on a regular basis via a radio communication system to report medical problems in their villages and receive instructions. For cases requiring hospitalization or a doctor's care, patients generally are flown to Dillingham.[1]

In addition to village health aides, the services of state itinerant public health nurses are available on a regular basis. The nurse stationed in Dillingham serves the city and the adjacent communities of Aleknagik, Clarks Point, Ekuk, and Portage Creek. Another Dillingham-based nurse serves Ekwok, Koliganek, Manokotak, New Stuyahok, Togiak and Twin Hills. The communities of Naknek, Egegik, King Salmon, South Naknek, Levelock, Pilot Point and Port Heiden are served by a nurse stationed at the Public Health

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1. Ibid.

Center in Naknek, which has operated since 1948. During the fishing season, the services of a doctor employed by one of the canneries are also available (Alaska State Housing Authority 1966). A public health nurse from Anchorage visits the Iliamna Lake communities of Igiugig, Iliamna, Newhalen, Kakhonak, Nondalton and Pedro Bay.

In 1973, the Bristol Bay Area Health Corporation (BBAHC) signed a contract with the Alaska Federation of Natives, Inc. (AFN) to coordinate a program for improved medical services in the region.[1] AFN has provided 45,000 dollars for the project and an additional 39,000 dollars is being made available through government funding. The BBAHC plans to establish 5-member health councils in each Bristol Bay village to define community health problems. Each council will have one member on the BBAHC Board. The Corporation hopes that the Board will be able to influence the delivery of services and distribution of funds for the Kanakanak service unit. The BBAHC favors further training and higher pay for village health aides who currently earn 500 dollars per month. The Corporation noted that each village health aide sees about 20 patients per week and is also on call 24 hours a day, seven days a week.[2]

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1. Tundra Times, October 3, 1973, p. 1.
2. Ibid, p. 6.

INDUSTRIAL ACTIVITY

Commercial Fishing and Fish Processing

Introduction

The Bristol Bay economy is almost totally dependent upon fisheries, particularly the salmon fishery. From 1961 through 1972, the region's fishery had an average wholesale value of 30 million dollars (Alaska Department of Fish and Game 1972). In 1970, it contributed 48 million dollars to the region's economy. However, the full economic impact of this value is not felt in Alaska because much of the money leaves the State as payments to nonresident workers, profits to companies based outside Alaska and purchases of supplies and equipment (Rogers 1972).

Historically, the Bristol Bay fishery has followed a cyclic pattern. George W. Rogers (1972) reports:

> The history of the Bristol Bay salmon fishery has been a pattern of boom, bust, and modest recovery typical of all Alaska fishing regions. From an annual average catch of four million fish for 1893-1900, the harvest rose to an average of twelve million for 1900-04, and with cyclical fluctuations, to an annual average of nineteen million fish for 1934-38. After that

peak, there was a precipitous decline, but research and improved management programs in the 1950's led to a recovered annual average catch of nine million fish for the 1960's.

Since 1970, the salmon catch has declined precipitously. The catch amounted to approximately 22.1 million fish in 1970, declined to 10.4 million fish in 1971 (Governor's Study Group on Limited Entry 1973), and dropped to a record low of 2.4 million in 1972.[1] The 1973 salmon catch proved to be the worst on record for Bristol Bay with only 1.5 million fish being harvested.[2]

The Bristol Bay region contains 5 major fishing districts which encompass the area immediately adjacent to the mouths of the region's major river systems (Figure 164). The districts are the Naknek-Kvichak, Egegik, Ugashik, Nushagak, and Togiak. The Naknek-Kvichak district is the largest producer of red salmon, the most important species of the region. During the 1960's, this species accounted for 86 percent of the region's total salmon catch (Rogers 1972).

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1. Richard C. Randall, Assistant Area Biologist, Bristol Bay area, Alaska Department of Fish and Game, Anchorage. Personal communication. October 26, 1973.

2. Ibid.

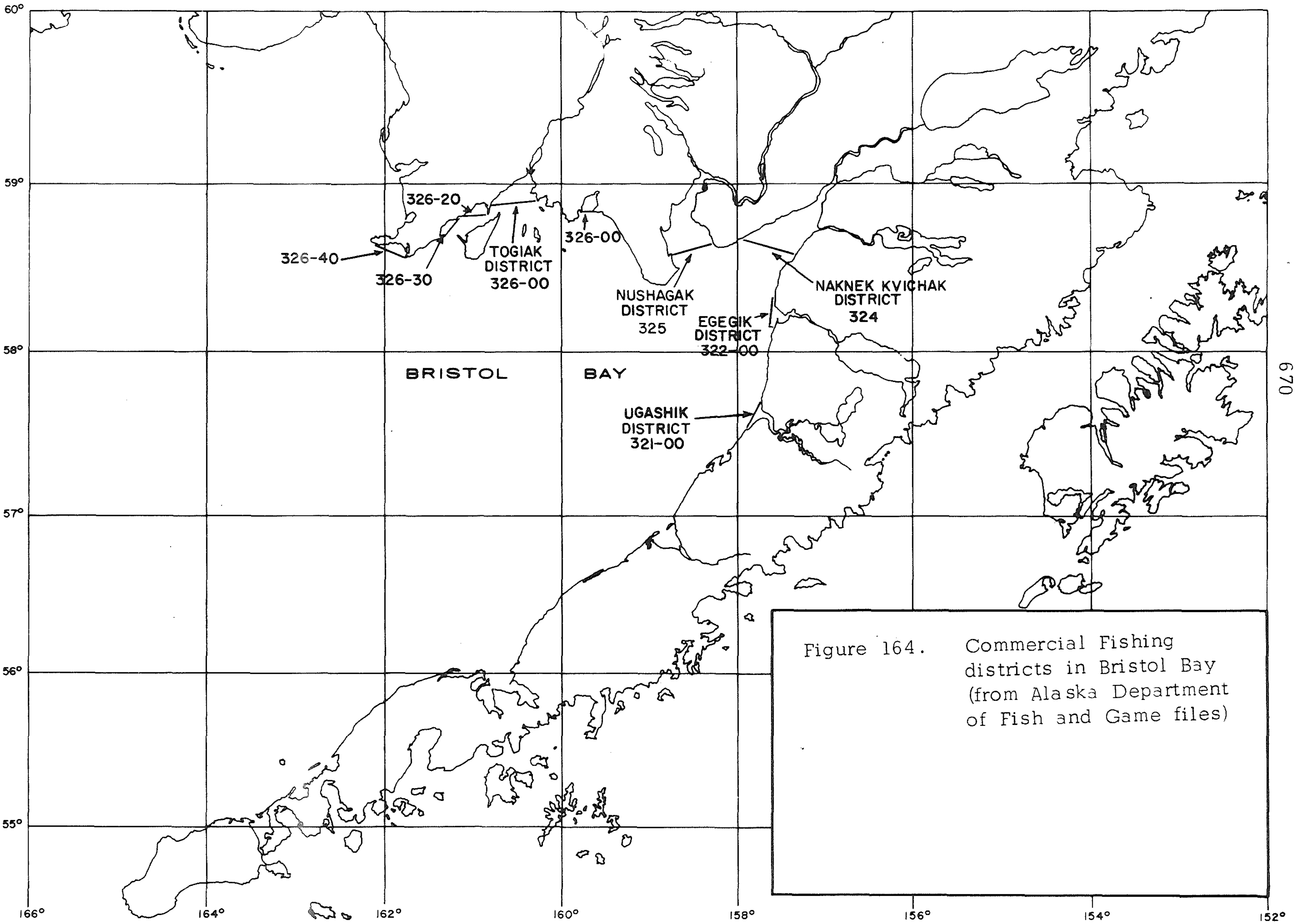

Figure 164. Commercial Fishing districts in Bristol Bay (from Alaska Department of Fish and Game files)

The commercial fisheries harvest began in Bristol Bay in 1884 in the Nushagak district (Governor's Study Group on Limited Entry 1973). At first, salmon were harvested with gill nets and traps. By the end of 1923, traps were prohibited and gill nets were then used exclusively. In 1922, power boats were introduced but they were immediately outlawed. The prohibition on power boats remained in effect until 1951. During this period, most of the fishermen used sailboats. Staked or set gill nets were also utilized along the beaches during this time.

Prior to World War II, except when there were complete closures, the units of fishing gear being utilized in the region remained fairly constant. During the War, the number of units decreased significantly. Regulations were relaxed during the war years to permit the use of motor powered auxiliary vessels in the fishery to tow the fishing vessels to and from the fishing grounds. After the War, the number of vessels fishing at first increased slowly and then increased more rapidly with the legalization of power fishing boats. There was a 100 percent increase in the units of fishing gear in Bristol Bay during the 1960's.

The regulation of fishing has undergone a significant change since statehood. Prior to statehood, fishing time was set before the run materialized and remained more or less constant. This permitted gear to operate with equal pressure on all runs whether large or small. With statehood, the concept of the emergency order was introduced. Openings and closures are set from day to day, based upon daily catch figures and estimated escapements. Emergency orders are used during the red salmon runs which usually last from 3 to 4 weeks.

Fishing activity in the region is intense and the season is relatively short. The Alaska Department of Fish and Game (1972) reports:

> Fishing activity commences in early June on king salmon with most effort concentrated in the Nushagak district. The king salmon run generally peaks during the last two weeks in June when effort then shifts to red salmon in all fishing districts. The red salmon run generally begins during the last week in June, peaks around July 4, and is essentially over by mid-July. Timing of the chum salmon and red salmon runs are nearly identical, although chum catches are usually sustained an additional week as red catches diminish. Pink salmon runs occur only during even years primarily in the Nushagak district. Pink fishing commences in mid-June and is essentially over by the second week in August. Minimal fishing activity exists

on cohos after the pink salmon run diminishes. Residents of the Bristol Bay area comprise the bulk of the fishing effort on the coho salmon run, which begins in mid-July and lasts through the month of August. Peak catches are generally made from the last week of July through mid-August; however, timing varies considerably between districts.

Value of Catch

The average yearly salmon catch from 1960 through 1971 was 60 million pounds with an average yearly value to fishermen of 12 million dollars (Table 66). The statistics for this period reflect the cyclic nature of the region's salmon fishery. The value to fishermen of other fish such as herring and bottomfish amounted to only 20,000 dollars in 1970 and 5,000 dollars in 1971, the only years for which figures are available (Rogers 1972).

As shown in Table 67, canned salmon is the primary fish product of the Bristol Bay region. During the decade of the 1960's, more than 95 percent of all the salmon caught was canned. In 1970 and 1971, about 90 percent of the catch was canned. The data in Table 68 show how the proportion of value added in canning salmon has changed relative

TABLE 66

BRISTOL BAY REGION - COMMERCIAL SALMON CATCH AND VALUE TO FISHERMEN

1960 - 1971

YEAR	POUNDS	VALUE
1960	78,712,574	$ 14,253,471
1961	77,052,410	12,643,634
1962	35,463,811	5,770,382
1963	18,369,937	3,168,970
1964	41,533,243	7,351,301
1965	112,715,000	23,775,885
1966	68,884,072	11,807,385
1967	33,363,905	5,817,149
1968	26,485,303	5,595,575
1969	46,827,723	10,811,624
1970	116,440,704	27,028,586
1971	64,652,815	16,040,319
Average	60,041,791	12,013,690

Source: Rogers 1972.

TABLE 67

WHOLESALE VALUE OF SALMON PRODUCTS

BRISTOL BAY REGION - SELECTED YEARS

Product	Pounds	Total Value[1]	Wholesale Value per Pound	Percent of Total Salmon Catch
1962				
Fresh	-	-	-	-
Frozen	242,053	90,648	$ .37	1.10
Canned	22,956,048	15,441,397	.67	98.70
Cured	58,650	51,883	.88	.20
Roe	-	-	-	-
TOTAL	23,256,751	15,583,878	.67	100.00
1964				
Fresh	6,000	2,400	.40	.02
Frozen	181,022	60,269	.33	.69
Canned	25,989,312	18,304,112	.70	98.52
Cured	166,178	105,078	.63	.60
Roe	37,453	14,860	.40	.14
TOTAL	26,379,965	18,486,719	.70	100.00
1965				
Fresh	-	-	-	-
Frozen	377,024	138,850	.37	.52
Canned	72,207,312	53,428,291	.74	99.40
Cured	48,175	23,350	.48	.07
Roe	8,100	630	.08	.01
TOTAL	72,640,611	53,591,121	.74	100.00
1966				
Fresh	26,822	10,878	.41	.06
Frozen	292,034	105,789	.36	.68
Canned	42,193,776	30,355,452	.72	98.81
Cured	16,333	10,561	.65	.04
Roe	173,660	164,435	.95	.41
TOTAL	42,702,625	30,647,115	.72	100.00
1968				
Fresh	-	-	-	-
Frozen	858,750	300,870	.35	5.72
Canned	12,902,160	9,923,270	.77	86.05
Cured	575,418	215,672	.37	3.84
Roe	657,747	748,654	1.14	4.39
TOTAL	14,994,075	11,188,486	.75	100.00
1970				
Fresh	170,000	151,229	.89	.26
Frozen	4,921,675	2,030,153	.41	7.53
Canned	58,219,392	45,915,431	.79	89.13
Cured	251,767	162,646	.65	.39
Roe	1,759,699	1,826,026	1.04	2.69
TOTAL	65,322,726	50,085,485	.76	100.00
1971				
Fresh	324,039	127,978	.39	.79
Frozen	2,173,072	974,563	.45	5.20
Canned	37,181,088	33,227,107	.89	89.01
Cured	49,081	25,892	.53	.12
Roe	2,037,454	2,313,144	1.14	4.88
TOTAL	41,764,734	36,668,684	.82	100.00

[1] Total value is wholesale value to processor

Source: Governor's Study Group on Limited Entry 1973.

TABLE 68

SHARES OF VALUE ADDED IN CANNED SALMON

Year	Total Pounds of Salmon Canned (Millions of pounds)	Wholesale Value Per Canned Pound	Value to Fishermen Per Processed Pound	Percent Value Added By Processing
1965	72.2	$ .74	$ .33	55
1966	42.2	.72	.28	61
1968	12.9	.75	.37	51
1970	58.2	.79	.41	48
1971	37.1	.89	.38	57

Sources: Table 6-2

Source: Rogers 1972.

to the value added by fishermen. In the years for which data are available, the share of value added, attributable to both processing and prices paid to fishermen, has remained rather constant. On the average, 54 percent of the wholesale value of canned salmon is due to processing and 46 percent is value added by fishermen.

Other salmon products from Bristol Bay include fresh, frozen, and cured salmon and salmon roe. In 1971, the last year for which data are available, frozen salmon and salmon roe each amounted to 5 percent of the total processed salmon. Fresh salmon amounted to about 1 percent and cured salmon to 0.1 percent of the total production.

Other fish products of the region include cured herring and herring roe on kelp (Rogers 1972). In 1970, the 3,150 kg. of cured herring prepared for market had a wholesale value to the processor of 48 cents per kg. Production of herring roe on kelp amounted to 18,150 kg. and had a wholesale value of 88 cents per kg.

Fish Processing

The fish processing plants which operated in Bristol Bay in 1972 are listed in Table 69. Of the 45 canning lines available in the Bristol Bay region, only 25 were operated in 1972 (Alaska Department of Fish and Game 1973). Salmon roe was processed at most of the canneries, and fresh fish were prepared at 3 of the plants. Frozen and salted fish were processed at 4 plants, while only 1 plant processed smoked salmon and herring products.

Recently a cold storage plant with dock facilities was constructed in Dillingham at a cost of 1.24 million dollars. It processed only salmon during 1973. Most of the king salmon processed were shipped to Denmark via Seattle. Frozen red, pink, and chum salmon were sold on the Japanese market. There are plans to freeze tanner crab in 1974. Due to engineering difficulties, the plant is currently operating at half capacity. At full capacity it can sharp freeze 18,150 kg. of fish every 24 hours.[1]

1. Anchorage Daily Times, August 6, 1973, p. 9.

TABLE 69

FISH PROCESSING PLANTS - 1972

BRISTOL BAY

Operation	Location	Salmon Products: Canned	Salmon Products: Fresh	Salmon Products: Frozen	Salmon Products: Smoked	Salmon Products: Salted	Salmon Products: Eggs	Herring Products: Cured	Herring Products: Eggs
Alaska Packers Assoc. Inc.	So. Naknek	X					X		
Bumble Bee Seafoods	Naknek	X					X		
Cascade America	Nushagak River		X				X		
Clark Fishing and Packing	Egegik					X			
Columbia Wards Fisheries	Ekuk	X		X			X		
Grindle Saltry	Egegik					X			
Kachemak Seafoods	Togiak		X			X			
Kayak Packing Company	Naknek River	X					X		
Marubeni America Corp.	Bristol Bay						X		
Mitsui and Company	Naknek						X		
Nelbro Packing Company	Naknek	X					X		
New England Fish Company	Egegik	X					X		
Peter Pan Seafoods, Inc.	Naknek	X					X		
W. A. Peterson Company	Egegik			X					
Queen Fisheries Inc.	Nushagak	X					X		
Red Salmon Company	Naknek	X					X		
Surfline Seafood	Naknek				X	X			
Togiak Fisheries Inc.	Togiak	X	X	X					
Western Alaska Enterprises Inc.	Dillingham						X		
Whitney Fidalgo Seafoods Inc.	Naknek	X		X			X		
Alaska Marine Resources	Togiak							X	X

Source: Alaska Department of Fish and Game 1973.

The State of Alaska has an administrative policy, without statutory support, which requires that primary processing be done to salmon and most other fishery resources prior to their export from the State. A study made in 1970 has concluded that the primary processing policy in effect subsidizes the fish processors of the state at the expense of Alaska's fishermen (Harrison 1970). The study indicates that this policy prevents the purchase of fresh fish by Japanese freezer ships which pay higher prices for salmon than do domestic processors, and that prices paid for salmon remain at the level set by established operators. This difference in price represents a cost to the fishermen, most of whom are state residents. It also represents a cost to the state economy because the policy subsidizes a processing industry which, for the most part, is based on nonresident capital.

Employment, Productivity and Income

The employment impact of the fishing industry is significant. Rogers (1972) reports that for the period 1965 through 1970:

> ...95 percent of the total annual man-months of employment were in the months of June and July, when the main red salmon runs materialize. On a weekly basis this concentration would be even more dramatic. Except for very minor catch of other species of lesser commercial value in May and extending into August, this is the total extent of annual employment for most fishermen. The cyclical pattern of total annual man-months of employment exhibits peaks in the even numbered years and lows in the odd numbered years.

Unemployment is very high in the Bristol Bay region except during salmon season. The unemployment rate was estimated by the Alaska Department of Labor to be 26 percent during February 1970. This compared to a statewide average of 10 percent. The seasonal absence of employment opportunities can also be expressed as percent employed people in the total population 18 years old and older. In February 1970, this ratio was 43.5 percent in Bristol Bay compared with 69.4 percent for the State (Governor's Study Group on Limited Entry 1973).

Historically, nonresident fishermen have been more productive than their resident counterparts. In 1939, the nonresident catch per fisherman was 2.7 times as much as the resident's catch. Rogers (1972) argues that the observed difference in productivity can be attributed in part to the favored relationship that nonresidents have with the canneries. The Alaska Department of Fish and Game has suggested that some of the difference in the comparative production of resident and nonresident fishermen can also be attributed to differences in motivation and objectives.

> Most of the nonresident fishermen are high-liners, that is, they consistently make large catches and are able to do so due to better gear and boats than possessed by many resident fishermen. A nonresident who comes all the way up from outside is going to fish pretty hard. Many of these fishermen have fished Bristol Bay for many years. On the other hand, there are about three major groups of resident fishermen: (1) the high-liners, who consistently make good catches and can and do compete with the nonresident; (2) the part-time or weekend fishermen who cannot compete. Most of these vacation fishermen use either skiffs and/or older gear and vessels which cannot compete with the larger mobile high-liner fleet; (3) the last group of resident fishermen are the upriver Native fishermen--they largely cannot compete due to inadequate vessels... Further, these upriver fishermen have entirely different approach to fish as a livelihood. They normally catch just what they need to get through the next season (Rogers 1972).

A factor more directly responsible for the difference in productivity is that residents and nonresidents have generally employed different types of gear. The drift gill net, which is more productive than the set gill net, is used by a greater percentage of nonresidents. For the years 1970, 1972 and 1973, 89 percent of the nonresidents have been licensed for drift gill nets compared to 63 percent of the residents (Rogers 1972).[1] For the period 1965-1970, the average return per man-month fishing effort for a drift gill net was 3,162 fish compared with 757 fish for a set net (Rogers 1972).

Table 70 shows the gross receipts of fishermen according to gear type, regardless of residency. The average gross receipts per man-month for the 6-year period 1965-1970 was 3,487 dollars for drift gill nets and 854 dollars for set gill nets. On the average, drift nets are more than 4 times as productive as the set nets.

Rogers (1972) has calculated the gross receipts according to residency and found that, in 1970, the gross receipts per resident amounted to 3,871 dollars, and that nonresidents earned 8,415 dollars. It should be recalled that a much larger proportion of the nonresidents utilized drift nets than did the residents. Rogers (1972) also estimated the gross receipts and net income for resident and

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1. Richard C. Randall, Assistant Area Biologist, Bristol Bay area, Alaska Department of Fish and Game, Anchorage. Personal communication. October 26, 1973.

TABLE 70

BRISTOL BAY REGION--GROSS RECEIPTS ACCRUING

TO FISHERMEN ACCORDING TO TYPE OF GEAR

1965-1970

Year	Value to Fishermen per Man-Month* Drift Gill Nets	Set Gill Nets
1965	$6,169	$1,089
1966	2,527	724
1967	1,535	414
1968	1,312	401
1969	2,992	1,228
1970	6,385	1,265
Six year average	3,487	854

* Value allocated to gear on basis of number of fish caught. Assumes same price paid for drift and set net fish.

Source: Rogers 1972.

nonresident drift net vessel operators based on a sample of 455 resident and 319 nonresident tax returns for 1969. Gross receipts were calculated to be 4,660 and 3,871 dollars for nonresidents and residents respectively. After deducting operating costs, Rogers estimated the net return per resident fisherman to be 1,936 dollars as compared to 2,149 dollars for nonresidents. Thus, when the same gear is employed, the residents earn only 10 percent less than the nonresidents. This indicates that most, if not all, of the apparent difference in productivity is actually attributable to the different types of gear used by the two groups of fishermen.

Foreign Fisheries Involvement in the Bristol Bay Area

Direct competition exists between Japanese and U.S. fishermen for the Bristol Bay salmon resource. Although U.S. fishermen harvest all of the salmon in the Bristol Bay and Eastern Bering Sea areas, salmon of Bristol Bay origin are harvested outside this area by the Japanese fleet on the high seas west of 175 degrees W longitude (Buck 1973). Many of these salmon would return to the

Bristol Bay fishery if not caught by Japanese fishermen. From 1950 through 1969, the Japanese high seas harvest of sockeye salmon east of 170 degrees E longitude accounted for only 11 percent of the total harvest for these years. However, when North American runs are low, as has been the case in 1972 and 1973, this percentage is several times greater. In 1973, for example, 757,000 sockeye salmon of Bristol Bay origin were harvested by Bristol Bay fishermen, and 630,000 were taken by Japanese fishermen.[1] In this low run year, the Japanese catch equaled nearly half of the total Bristol Bay salmon harvest.

Table 71 shows the extent to which other nations harvest the fish resources of the waters adjacent to the Bristol Bay region. It also gives an idea of the type and, to some extent, the quantity of fish that could be harvested by U.S. fishermen if they should so choose. The waters adjacent to Bristol Bay coincide with the area known as the Eastern Bering Sea (Figure 165). It extends from Bristol Bay

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1. Tom Schroeder, Fisheries Biologist, Alaska Department of Fish and Game, Dillingham, Alaska. Personal communication. December 11, 1973.

TABLE 71

FOREIGN FISHERIES INVOLVEMENT IN BRISTOL BAY

Species	Year of First Recorded Catch	Total Historic Catch[a] (millions of pounds)	National Distribution of Catch (Approx. percentage)	
King Crab	1930	514.9	Japan	70
			USSR	20
			USA	10
Pollock	1933	6325.2[b]	Japan	92
			USSR	8
Pacific Cod	1905	743.4[c]	Japan	70
			USSR	30
Halibut	1905	112.7	USSR	44
			USA	24
			Canada	24
			Japan	8
Flatfish (excluding Halibut)	1933	5797.2[b]	Japan	70
			USSR	30
Salmon (all species)	1905	5098.7	USA	100

[a] From first recorded catch to 1969.

[b] Entire Eastern Bering Sea catch, Bristol Bay harvest would be less than 30% of this total.

[c] Entire Bering Sea catch, Bristol Bay harvest would be less than 10% of this total.

Source: Buck 1973.

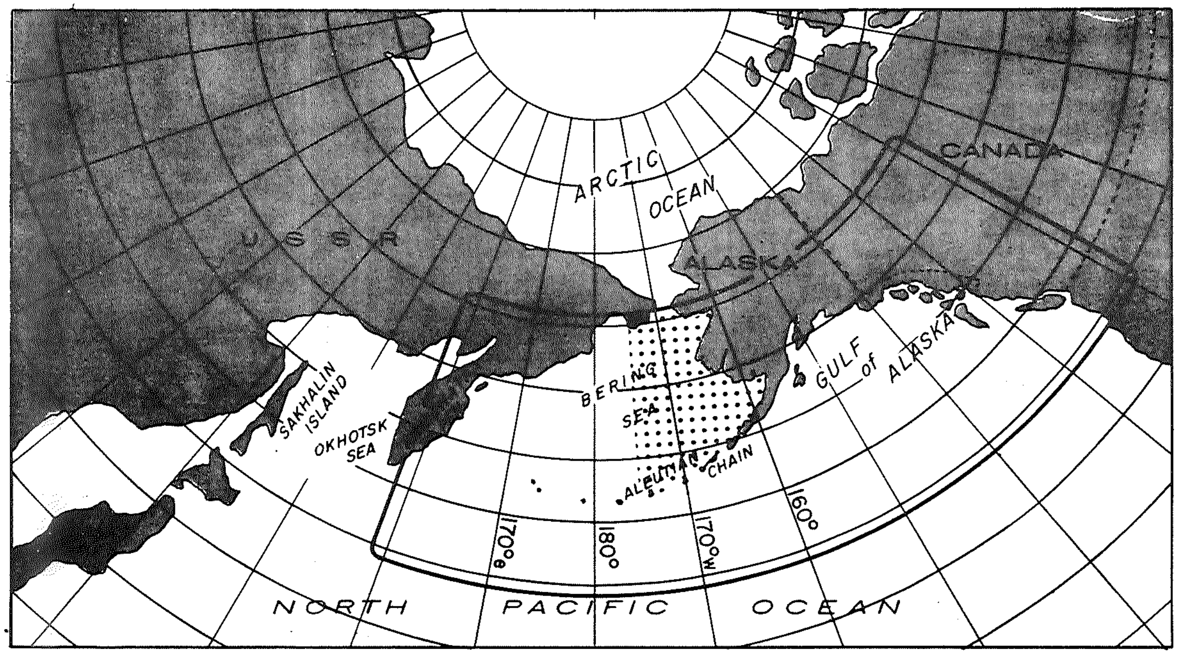

Figure 165. Eastern Bering Sea fishing region (from Buck 1973).

westward to 175 degrees W longitude and northward from the Aleutians to the Bering Strait.

U.S. fishermen have provided very little competition for their foreign counterparts fishing in the Eastern Bering Sea, even for those species currently of economic importance in other parts of Alaska such as shrimp, king crab, herring and halibut. From the beginning of the first recorded catch of each species through 1969, foreign fishermen harvested 90 percent of the king crab, almost 100 percent of the herring, and about 44 percent of the halibut. More recently, the annual catch of king crab by U.S. fishermen has exceeded that of foreign fishermen in this area. Fish resources such as pollock and flatfish remain untouched by U.S. fishermen. As of 1969, foreign fishermen were harvesting over a million metric tons of these species from the Southeastern Bering Sea. The above statistics indicate that a good potential exists for diversification of the fishing industry in Bristol Bay. This may be an economic alternative for that area should the salmon fishery continue to decline.

Subsistence Fishing, Hunting, and Trapping

Subsistence fishing provides an important part of the diet of residents of Bristol Bay, especially those living upriver or on the lakes. According to a recent study not yet released by the Alaska Department of Fish and Game,[1] estimates of the yearly average subsistence catch for the years 1963 through 1973 are as follows:

SPECIES	ANNUAL AVERAGE NUMBER OF FISH CAUGHT 1963-1973
Red Salmon	104,800
King Salmon	5,400
Chum Salmon	9,400
Silver Salmon	3,900
Pink Salmon	4,600 (even years only)

The Alaska Department of Fish and Game describes the present Bristol Bay subsistence fishery as follows:

> Salmon subsistence catches for personal use and dog food consumption have been recorded since 1963 in Bristol Bay. This subsistence fishery is primarily centered around the Naknek-Kvichak and Nushagak drainages where local inhabitants, especially outlying villagers, are still dependent on salmon for

1. Unpublished statewide subsistence statistics, Commercial Fisheries Division, Alaska Department of Fish and Game, Anchorage.

winter dog food and augmentation to their own diets. Salmon subsistence catches in the two major drainages approach 130,000 to 170,000 fish annually.

In the Togiak district, the only other area where considerable subsistence fishing takes place, main reliance is placed on sea-run char, which apparently winter in the Togiak River. From interviews with knowledgeable persons in the Togiak area, it is conservatively estimated that over 100,000 char are harvested annually from the Togiak River with small mesh gill nets between September and May. It is further estimated that between 5,000 to 10,000 salmon of all species are taken for subsistence purposes, almost all of which originate from the Togiak River drainage.

Considerable winter fishing takes place through the ice in all districts of Bristol Bay. Winter catches consist primarily of arctic char, whitefish, pike, burbot and some rainbow and grayling. However, the large area involved and the sporadic fishing efforts have precluded efforts to monitor these catches.

The 1971 subsistence salmon catch was over 120,000 fish of all species for the Naknek-Kvichak and Nushagak districts. Since 1963, the average subsistence salmon harvest for the two major districts has averaged 128,000 fish of all species, with over 56 percent coming from the Naknek-Kvichak area (Rogers 1972).

Annual subsistence records for the Naknek-Kvichak and the Nushagak districts show a relatively stable production for salmon subsistence regardless of the fluctuations of the commercial catch. From 1963 through 1971, the year-to-year variation in the subsistence catch averaged less than 10 percent of the mean subsistence catch (Rogers 1972).

These fluctuations reflected variations in the commercial catch but were of a much smaller magnitude. This indicates that subsistence fishing is primarily a function of resident need rather than a response to the amount of fish available.

Hunting and trapping are not as important to the Bristol Bay economy as they were prior to the development of the commercial salmon fishery when wildlife was the major source of food, clothing, and cash needed to purchase supplies. Income earned from the fishing industry has removed most families from complete dependence on subsistence activities. However, according to a study made by the Federal Field Committee for Development Planning in Alaska (1968), wildlife still remains an important food source as well as a supplementary source of money income. Trapping has declined in the past because of the falling price of furs and the scarcity of furbearers due to overtrapping in some parts of the region. The important furbearers trapped in the region include beaver, muskrat, mink, land otter, and red fox. For the period 1958-1968, a yearly average of 1,500 beaver, 200 muskrat, 400 mink, 200 land otter and 300 red fox were trapped.

Moose and caribou are important sources of fresh meat in the Bristol Bay region. It was estimated by the Federal Field Committee (1968) that for the period 1958-1968, the yearly harvest of moose and caribou averaged 500 animals each. The total brown and black bear harvest for this period was about 225 animals per year. Along the coastal areas about 1,000 harbor seals were taken annually. The Federal Field Committee also estimated that 100,000 waterfowl were harvested yearly between 1958 and 1968. Rogers (1972) points out the subsistence activities have an extremely important economic value to those who engage in them because these substitutes for the food supply would otherwise have to come from cash purchases requiring either increased wage employment not available in the region, or welfare payments.

Agriculture

Agriculture is practically nonexistent in the Bristol Bay region. There are no commercial feed crops or vegetables produced. There is, however, a small reindeer herd on Hagemeister Island (Figure 166) which was started in 1965 with reindeer loaned from the U.S. Bureau of Indian Affairs herd on Nunivak Island (U.S. Bureau of Indian Affairs 1966a). This first herd was under the ownership of 3 individuals from the village of Togiak. There are now 450 animals grazing on federally leased land on Hagemeister Island, and it is estimated that the island could support 1,000 reindeer (Joint Federal-State Land Use Planning Commission 1973). During 1973, some reindeer were harvested from the Hagemeister Island herd, processed at the cold storage plant in Togiak, and marketed locally.[1] Data on this reindeer operation are limited.

Minerals and Petroleum

No major mineral or petroleum production activity currently takes place in the Bristol Bay region, although considerable exploration, especially for oil, occurred in

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1. Tom Schroeder, Fisheries Biologist, Alaska Department of Fish and Game, Dillingham, Alaska. Personal communication. December 11, 1973.

the past. The Bristol Bay region makes up part of a large sedimentary basin which has a high potential for oil and gas development. During the late 1960's, several oil companies conducted extensive offshore exploration in the region. In 1968, the State of Alaska sponsored a competitive oil and gas lease sale for offshore tracts in the Bristol Bay area. The state offered to lease 141,640 hectares and ended up leasing 66,773 hectares at 44.50 dollars per hectare, which resulted in a total bonus of about 3 million dollars (Alaska Department of Natural Resources 1972a). Federal onshore leases in the Bristol Bay area as of 1971 totaled about 259,000 hectares (Alaska State Housing Authority 1971). Federal and state leases in effect as of November 1973 can be seen on Figure 166. Currently, on the north shore of the Alaska Peninsula at Cape Leonivitch (Figure 166), an exploratory well is being drilled and is at a depth of 4,500 m.[1] The results of this drilling are not yet known.

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1. Thomas R. Marshall, Chief Petroleum Geologist, Division of Oil and Gas, Department of Natural Resources, State of Alaska, Anchorage. Personal communication.

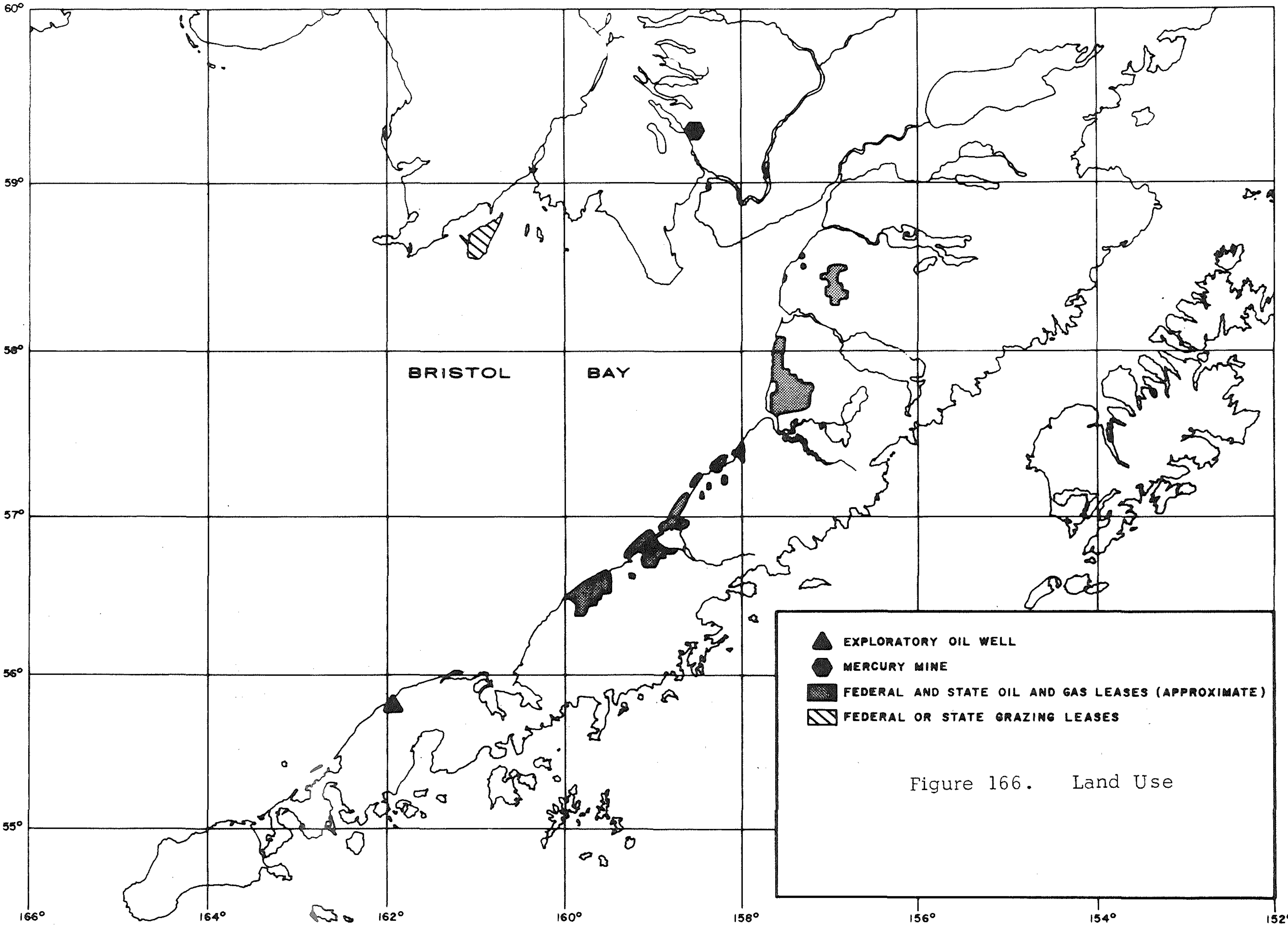

Figure 166. Land Use

Roughly 20 active and 130 inactive mining claims exist in the Bristol Bay area according to a listing of mining claims made by the Mineral Industry Research Laboratory at the University of Alaska (Heiner and Porter 1972). The most promising mine in the region is the mercury mine located 40 km. north of Dillingham near Marsh Mountain. This mine has been sporadically active for the past several years. If the price of mercury should rise sufficiently to make the operation profitable, the mine would become active again.

Tourism and Recreation

Tourism and recreation are not major activities in the Bristol Bay region. Although available data are quite sketchy, significant numbers of tourists visit only one area in the region, Katmai National Monument (Figure 167). Most Katmai visitors are members of tour groups and fishermen (Rich and Tussing 1973). The National Monument is also used by military personnel from the King Salmon Air Force Base, researchers, backpackers, and local residents. In 1972, a total of 16,700 people visited Katmai (Alaska

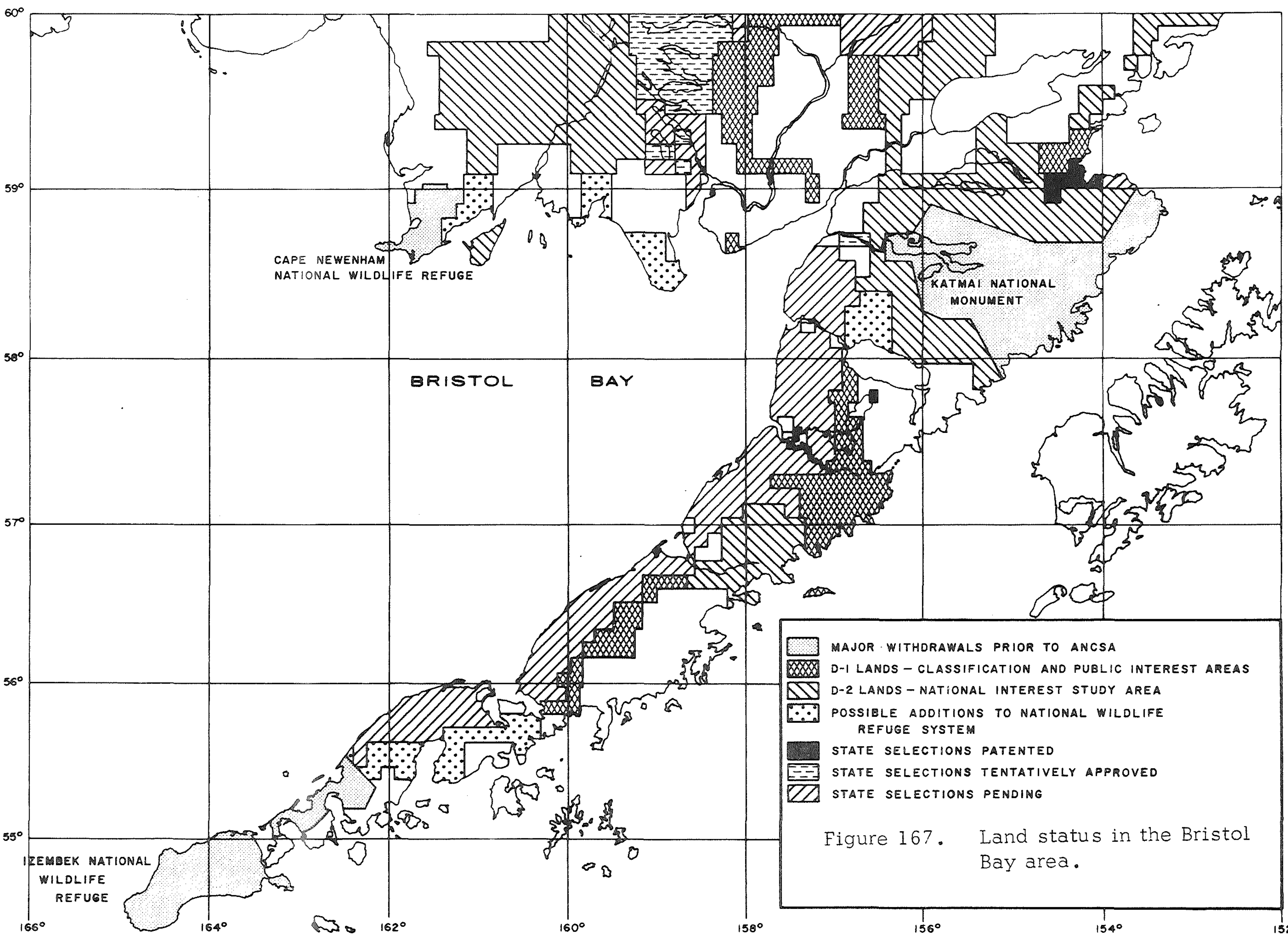

Figure 167. Land status in the Bristol Bay area.

Department of Natural Resources 1972a). No figures are available which would indicate what proportion of these were tourists.

In addition to Katmai National Monument, excellent outdoor recreation opportunities will attract an increasing number of tourists, both from within and outside the State. The Iliamna Lake and Wood River-Tikchik Lakes areas are famous for their trophy trout fishing and big game hunting. There are numerous hunting and fishing lodges and camps in the region, and nearly half of the state's registered guides are licensed to guide there (U.S. Department of Commerce 1973). No statistics are available which would show the amount of business done at the lodges and by the guides of the Bristol Bay area.

TRANSPORTATION FACILITIES AND COSTS

Introduction

Essentially, the Bristol Bay region is a mountain bordered basin which opens away from the state's population centers and shipping lanes. This is one of the most isolated areas of Alaska since it is not accessible by Alaska's highway, railroad or marine highway systems. The region lacks deepwater ports making it necessary to lighter most sea cargo to shore. The shipping season only lasts from May to November because of sea ice conditions. Because of these problems, air transportation plays a key role in the transport system. The general lack of easy access, combined with a relatively low volume of freight and passenger traffic, makes transportation costs very high.

Transportation Facilities

Airports

There are airports or float plane landing sites for nearly every village in the region. Its many lakes and rivers provide adequate landing sites for floatplanes in summer and ski-equipped planes in winter.

The Bristol Bay area has 9 trunk airports which have runways 1,050 m. or longer and are capable of accommodating large aircraft. Five of these are lighted and can handle nighttime traffic. Jet aircraft regularly use the airports at Dillingham and King Salmon. Only the King Salmon airport has a paved runway and facilities for plane handling, maintenance and traffic control. The remaining airports and landing sites in the region are suitable only for small aircraft. They have runways shorter than 1,050 m. and are unlighted. There is a heliport located at the Alaska Native Service

Hospital at Kanakanak. Statistics on the region's airports can be seen in Table 72.

Roads

The Bristol Bay region has approximately 165 km. of permanent roads and jeep trails. Most of the distance is in 6 short unconnected roads. The remaining distance is in local service roads such as those which connect some of the villages to their airports. The major roads are shown on Figure 168 and information concerning their length and type can be found in Table 73.

The Dillingham-Aleknagik road provides the residents of Aleknagik (which has no stores) with access to one of the region's major distribution centers. Dillingham is also connected by road to the Alaska Native Service Hospital at Kanakanak. Part of the supplies for Iliamna Lake communities are shipped over the Iliamna-Portage road, which connects Iliamna Lake with Iliamna Bay. According to an Alaska Department of Highways (1969) study, approximately 410 metric tons of supplies and from 10 to 40 boats move across this road annually. The road is very difficult to traverse and is closed in the winter. The Newhalen River road runs north from Newhalen on Iliamna Lake toward Lake Clark but stops short of the lake. The Katmai National Monument jeep trail is used only during the summer months by a concessionaire who takes tourists from Brooks Camp on Naknek Lake to the Valley of Ten Thousand Smokes. The Naknek-King Salmon road connects the 2 largest towns of the Bristol Bay Borough and carries freight between Naknek harbor and King Salmon.

During the next 5-year period, construction and upgrading of the region's roads will take place on a small scale, according to

TABLE 72

AIRPORTS IN THE BRISTOL BAY AREA

1973

Location	Operator	Length (feet)	Width (feet)	Surface Type	Population Served[4]	Largest Aircraft[4]
Aleknagik	Private	1,400				
Aleknagik Mission	Private	1,200				
Bear Creek		1,600				
Big Mountain (L)[1]	Air Force	4,000				
Clarks Point	State	2,000		Gravel	171	206
Dillingham		1,200				
Dillingham (old)		2,100				
Dillingham Mun. (L)[1]		5,000	150	Gravel	500	Boeing 737
Egegik	State	1,900	95	Gravel	148	206
Ekuk		1,500		Silt		
Ekwok		2,200	80	Silt	103	Twin Otter
Igiugig	State	2,700	150	Sand and Gravel	36	
Iliamna (L)[1]	FAA	3000/5000[2]	200/160	Gravel and Silt	58	F27 & Hercules
Jensens		4,700				
Kakhonak	State	2000/1200[2]	100/100	Gravel	88	206
King Salmon (L)[1-3]	FAA	8500/5000[2]	150/300	Asphalt	202	DC-8
King Salmon	None	Naknek River		Seadrome		
Koggiung	State	1,000	40	Sand		
Kulik Lake	Private	4,600	140	Sand and Gravel		
Kulik Lake	Private	Lake		Seadrome		
Kvichak	Private	800/800[2]	50/50	Silt and Sand		
Levelock	State	1600/1500[2]	100/50	Silt	74	206
Nakeen		1,300				
Naknek	State	1,700	90	Silt	178	180
New Stuyahok		1,500		Silt		
Nondalton	State	2,225	100	Gravel	74	402
Nushagak		2,500				

(Continued)

Table 72

AIRPORTS IN THE BRISTOL BAY AREA - 1973 - (Continued)

Location	Operator	Length (feet)	Width (feet)	Surface Type	Population Served[4]	Largest Aircraft[4]
Painter Creek	Private	5,000	150	Gravel		
Pedro Bay	State	1,600	50	Sand	65	206
Pilot Point	State	1,860	50	Silt and Gravel	68	Goose
Port Alsworth		2,500				
Port Heiden (L)[1]		7,500	300		66	
South Naknek	None	1,350	75	Silt	154	
Togiak		3,500		Silt and Gravel		
Ugashik	None	1,245	65	Silt		

1 (L) denotes lighting facilities available.

2 Two runways

3 King Salmon FAA facility also provides controlled approach systems and direction finding station.

4 Where data is available.

Source: Governor's Study Group on Limited Entry 1973.

TABLE 73

PERMANENT ROADS

BRISTOL BAY REGION 1973

Name	Length (miles)	Width (feet)	Type
Dillingham-Aleknagik Road and Kanakanak Spur	26.1	18	Graded and drained
Iliamna Portage Road	15.5	10	Graded and drained
Katmai Jeep Trail	20.0	10	Unimproved
King Salmon AFB - Fishing Camps Road	8.0	14	Graded and drained
Naknek-King Salmon Road	15.5	24	Graded and drained
Newhalen River Road	18.0	18	Unimproved
TOTAL	103.1		

Source: Alaska Department of Highways 1969.

current Alaska Department of Highways plans. The estimated cost of these activities for the period 1973 through 1977 will be slightly over 7 million dollars (Table 74). Preliminary engineering and right-of-way work should begin within the 1973-77 period on the proposed trunk road between Kamishak Bay and Naknek. The road will pass south of Iliamna Lake and will be approximately 210 km. long (Figure 168). The construction plans and timing for this road are not yet definite. It was estimated that the approximate cost of the road would be 20 million dollars (Alaska Department of Highways 1968).

Harbors

Harbor facilities in the Bristol Bay area are severely limited due to the complete lack of deepwater ports. Deep draft vessels must unload their cargo as much as 9 km. from shore and have it lightered into the region's ports (U.S Coast and Geodetic Survey 1971). The majority of the harbor facilities are owned and operated by fish processing plants. Some of the harbors have equipment to haul boats out of the water for minor repairs and some can provide supplies such as food and marine hardware. Fresh water is available at practically all harbors. Information concerning the facilities and supplies available at each harbor in the region is provided in Table 75.

Transportation Services

Passenger Service

Virtually all passenger traffic in and out of the Bristol Bay area is carried by aircraft. Three certificated route carriers--Kodiak Western Alaska Airlines, Wien Air Alaska, Inc. and Reeve Aleutian Airways--serve the region along with 9 fixed-wing air taxi

TABLE 74

PROPOSED HIGHWAY AND SERVICE ROAD CONSTRUCTION ACTIVITIES

FOR BRISTOL BAY - 1973-77

Project Location	Project Description	Estimated Total Cost (Dollars)	Yearly Subtotal	Total
	Construction and Improvement of Major Roads			
	1973 None			
	1974 None			
	1975			
Dillingham-Kanakanak	Reconstruction and new construction and pave 5.7 miles	$2,610,000	$2,610,000	
	1976			
Naknek-King Salmon	Pave 15.5 miles on existing alignment	$2,040,000	$2,040,000	
	1977			
Newhalen-Nondalton	Reconstruction and new construction and gravel surface 22.3 miles including construction of one bridge	$2,385,000	$2,385,000	$7,035,000
Preliminary engineering and/or right of way work expected to commence within this five-year program on the following project:				
Alaska Peninsula Crossing	Kamishak Bay to Naknek			
	Construction and Improvement of Local and Service Roads			
	1973			
Bristol Bay Borough	Construct various Borough roads	$ 20,000	$ 20,000	$7,055,000
New Koliganek	Reconstruct various village streets	*		
	1974			
Dillingham	Reconstruct 1st Avenue and "D" Street	*		
Ekwok	Reconstruct access road from village to airport	*		
Twin Hills	Construct access road from village to airport	*		
	1975			
Bristol Bay Borough	Reconstruct various borough roads	$ 20,000	$ $ 20,000	$7,075,000
	1976 & 1977 None planned to date			

*Specific cost information not available

TABLE 74

PROPOSED HIGHWAY AND SERVICE ROAD CONSTRUCTION ACTIVITIES

FOR BRISTOL BAY - 1973-77

Project Location	Project Description	Estimated Total Cost (Dollars)	Yearly Subtotal	Total
	Construction and Improvement of Major Roads			
	1973 None			
	1974 None			
	1975			
Dillingham-Kanakanak	Reconstruction and new construction and pave 5.7 miles	$ 2,610,000	$ 2,610,000	
	1976			
Naknek-King Salmon	Pave 15.5 miles on existing alignment	$ 2,040,000	$ 2,040,000	
	1977			
Newhalen-Nondalton	Reconstruction and new construction and gravel surface 22.3 miles including construction of one bridge	$ 2,385,000	$ 2,385,000	$ 7,035,000
Preliminary engineering and/or right of way work expected to commence within this five-year program on the following project:				
Alaska Peninsula Crossing	Iniskin Bay to King Salmon			
	Construction and Improvement of Local and Service Roads			
Twin Hills	Construct access road from village to airport	NA*		
	1975			
Bristol Bay Borough	Reconstruct various borough roads	$ 20,000	$ 20,000	$ 20,000
	1976 and 1977 None planned to date			
		GRAND TOTAL		$ 7,055,000

*Specific cost information not available

Source: U.S. Coast and Geodetic Survey 1964, Alaska Department of Highways 1972.

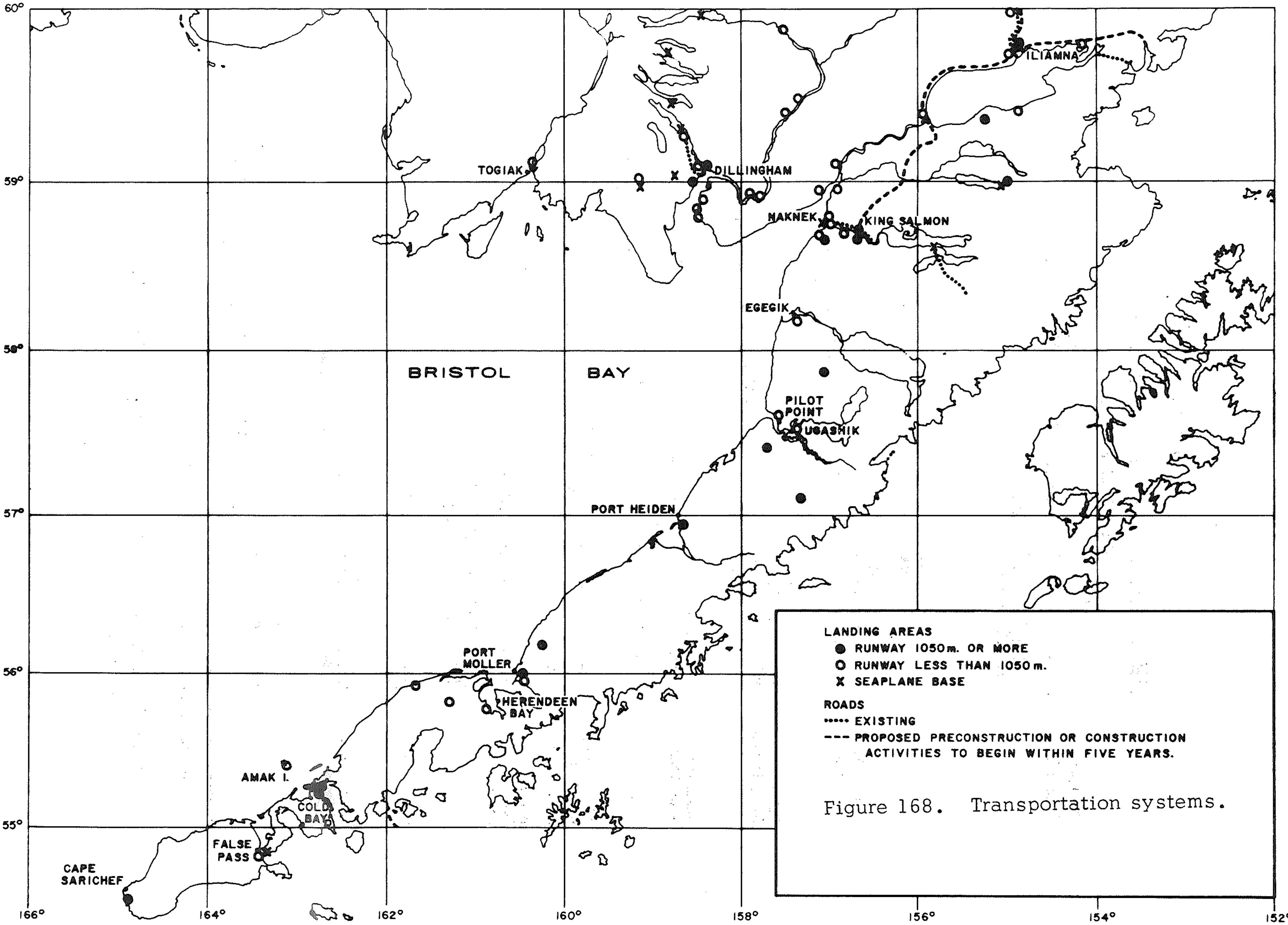

Figure 168. Transportation systems.

TABLE 75

HARBOR FACILITIES - BRISTOL BAY

Harbor	Description
Pilot Point	Cannery owned dock with 144-foot face which dries at low tide; fresh water available; cannery facilities include: fuel storage tanks, machine shop, 4-ton crane and scowway.
Ugashik	Cannery owned wharf with 200-foot face which dries at half tide; cannery facilities include: fuel storage tanks, machine shop, 2-ton crane and scowway.
Egegik	Cannery owned wharf with 150-foot and 80-foot faces which dry at low tide; fresh water, food staples and clothing available; marine railway and 5-ton crane.
Naknek	Numerous cannery docks; large fuel tank form and tidal dock belonging to standard oil, some supplies available at canneries; boat repairs made by canneries only for boats fishing for them.
Koggiung	Numerous cannery wharf longest of which is 450 feet. All dry at low tide. Fresh water available. Marine railway at 450-foot dock can haul out vessels up to 160 tons.
Ekuk	Cannery wharf with 150-foot face; cannery facilities include fuel storage tanks, fresh water and a marine railway with a 60-ton capacity.
Clarks Point	Cannery wharf with 175-foot face; cannery facilities include: general store; fuel storage tanks, a marine railway with 150-ton capacity, and a small machine shop; fresh water available.
Dillingham	Cannery wharf with 178-foot face; cannery facilities include fuel storage tanks and a marine railway with 100-ton capacity.

Source: U.S. Coast and Geodetic Survey 1964 (1971 Supplement) operators. Certified air carrier routes for the region can be seen on Figure 169. Approximately 80 percent of the villages listed by the U.S. Bureau of the Census receive scheduled commercial air service at least once a week. The majority receive scheduled service 3 or more times a week (Table 76). King Salmon has daily flight connections with Anchorage and there are flights between Dillingham and Anchorage every day except Sundays. Due to the current "energy crisis", some of these flights have been suspended for an indefinite time.

Dillingham and King Salmon are by far the region's busiest airports (Table 77). In fiscal year 1970-71, the number of passengers enplaning at Dillingham totaled 12,611, or 40 percent of the region's total commercial enplanements. King Salmon accounted for 42 percent of the region's enplanements, 13,250 passengers. Between 1963 and 1971, the total yearly enplanements at Dillingham increased by 102 percent. The increase at King Salmon was 138 percent (Table 78).

Air taxi passenger activity in the region is also significant. According to statistics for 1972 compiled by the Alaska Transportation Commission, more than 28,000 passengers were carried by the authorized air taxi operators in the area (Table 79). Thus, in terms on enplanements, the air taxis carried at least as much passenger traffic as the commercial airlines.

Freight Service

The bulk of the air freight and U.S. mail are carried by the certificated air route carriers serving the region. The authorized air taxis carried less than 20 percent of the air freight and only 1 air taxi operator carried U.S. mail in 1971. Villages with

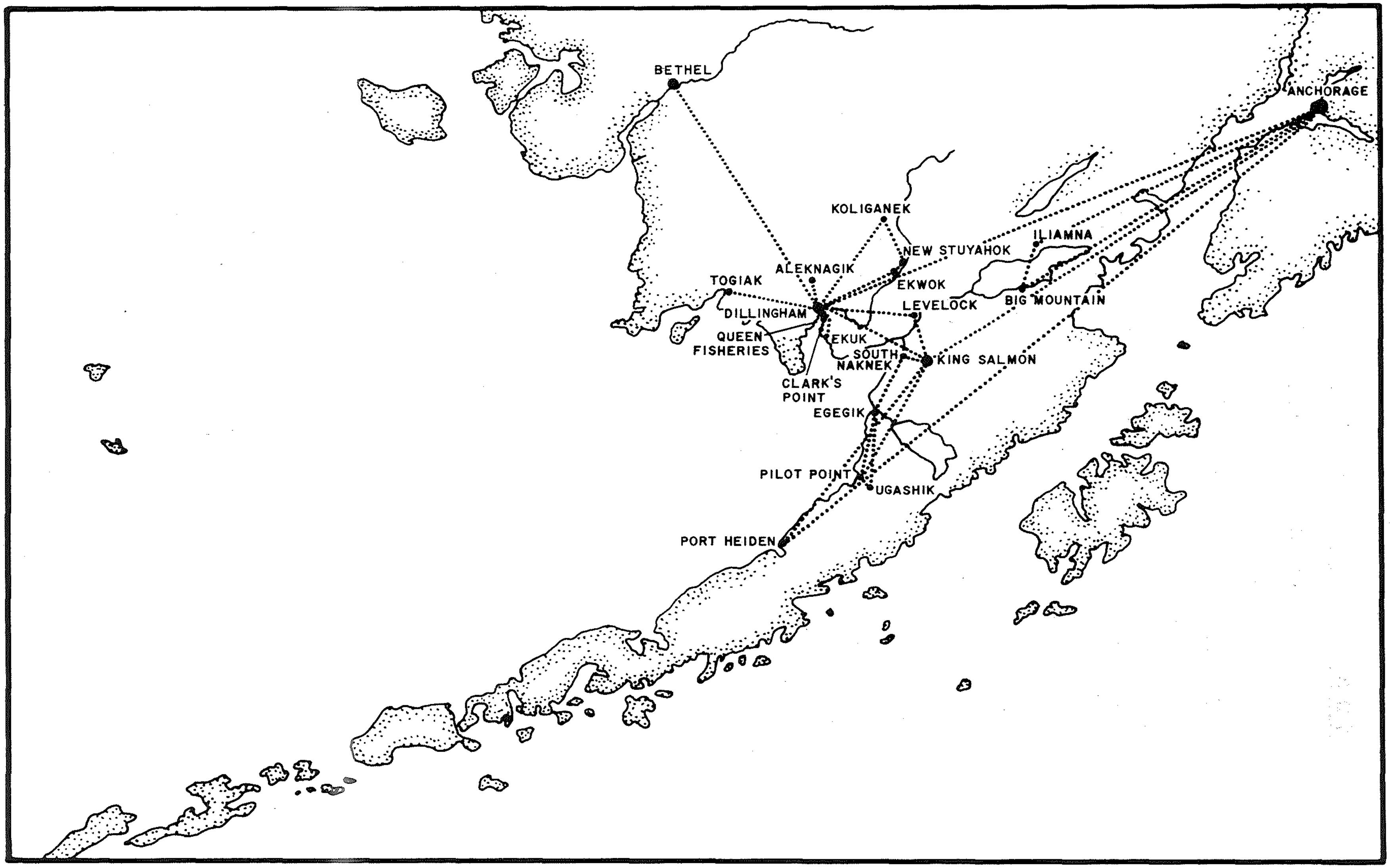

Figure 169. Certified air carrier routes in the Bristol Bay area, August 1973 (from Reeve Aleutian Airways, Inc.; Wien Air Alaska; Western Airlines).

Table 76

NON-STOP AIRLINE FLIGHTS

BRISTOL BAY AUGUST 1973

TO:	FROM:	Flights per week	Flight time	One-way fare	Type of Aircraft*
Alegnagik	Dillingham	3	15 min.	$11	PRP
Anchorage	Big Mountain	3	1 hr. 5 min.	38	F27
Anchorage	Dillingham	7	1 hr. 30 min.	55	F27
Anchorage	King Salmon	7	55 min.	46	737
Anchorage	Port Heiden	2	1 hr. 40 min.	87	Y11
Bethel	Dillingham	1	1 hr. 20 min.	28	PRP
Big Mountain	Iliamna	3	15 min.	7	F27
Clarks Point	Queen Fisheries	14	15 min.	6	PRP
Dillingham	Alegnagik	3	30 min.	11	PRP
Dillingham	Anchorage	7	1 hr. 30 min.	55	F27
Dillingham	Bethel	1	1 hr. 25 min.	28	PRP
Dillingham	Ekuk	14	25 min.	11	PRP
Dillingham	King Salmon	7	25 min.	18	F27
Dillingham	King Salmon	5	35 min.	22	PRP
Dillingham	Koliganek	5	55 min.	22	PRP
Dillingham	Levelock	3	1 hr.	17	PRP
Dillingham	New Stuyahok	10	1 hr. 25 min.	17	PRP
Dillingham	South Naknek	7	35 min.		PRP
Dillingham	Togiak	12	55 min.	22	PRP
Egegik	Pilot Point	13	20 min.	14	PRP
Egegik	Ugashik	1	45 min.	14	PRP
Ekuk	Clarks Point	14	15 min.	6	PRP
Ekwok	Dillingham	15	20 min.	14	PRP
Igiugig	King Salmon	2	30 min.	22	PRP
Iliamna	Anchorage	3	1 hr. 5 min.	35	F27
King Salmon	Anchorage	7	55 min.	46	737
King Salmon	Dillingham	7	25 min.	18	F27
King Salmon	Dillingham	8	35 min.	22	PRP
King Salmon	Igivgig	2	45 min.	22	PRP
King Salmon	South Naknek	35	20 min.	10	PRP
Koliganek	New Stuyahok	5	30 min.	11	PRP
Levelock	King Salmon	3	20 min.	12	PRP
New Stuyahok	Ekwok	15	25 min.	6	PRP
Pilot Point	King Salmon	14	1 hr. 10 min.	27	PRP
Port Heiden	Ivanoff Bay	2	1 hr. 50 min.	35	PRP
Port Heiden	King Salmon	3	45 min.	42	Y11
Port Heiden	Sand Point	2	1 hr. 40 min.	44	Y11
Queen Fisheries	Dillingham	14	10 min.	11	PRP
South Naknek	Dillingham	7	30 min.		PRP
South Naknek	Egegik	14	30 min.		PRP
South Naknek	King Salmon	21	10 min.	10	PRP
Togiak	Dillingham	12	40 min.	22	PRP
Ugashik	Pilot Point	1	5 min.	6	PRP

*PRP=Prop Aircraft, type varies, F27=Fokkor Friendship Turbo-Prop F27, 737=Boeing 737, Y11= Namco YS-11

Source: Reeve Aleutian Airways, Inc.; Wien Air Alaska; Western Airlines.

Table 77

AIRPORT* ACTIVITY STATISTICS OF CERTIFICATED ROUTE AIR CARRIERS

BRISTOL BAY F.Y. 1971

Airport	Enplaned Passengers	Freight (tons)	Mail (tons)	Total Cargo & Mail (tons)
Aleknagik	124	0.65	6.56	7.21
Clarks Point	219	3.60	5.12	8.72
Dillingham	12,611	417.06	432.09	849.15
Egegik	382	4.34	7.47	11.81
Ekuk	603	3.54	1.68	5.22
Ekwok	568	0.25	1.76	2.01
Igiugig	38	0.09	0.18	0.27
King Salmon	13,280	405.65	263.85	669.50
Levelock	376	0.14	2.00	2.14
Monokatek	541	4.52	3.59	8.11
New Stuyahok	594	0.81	3.44	4.25
Pilot Point	166	0.22	3.06	3.28
Port Heiden	293	19.08	14.70	33.78
South Naknek	41	0.11	0.29	0.40
Togiak	1448	3.69	8.95	12.64
Ugashik	110	0.03	12.14	12.17
TOTALS	31,434	863.78	766.88	1,630.66

*Principal airports only

Source: Federal Aviation Agency 1971.

Table 78

AIRPORT ACTIVITY STATISTICS - CERTIFICATED AIR ROUTE CARRIERS

BRISTOL BAY F.Y. 1963, 1966, 1971

Dillingham	Enplanements	Freight (tons)	Mail (tons)
1963	6,238	124	110
1966	7,853	185	165
1971	12,611	417	432
Percent Increase 1963-1971	102	236	292
King Salmon			
1963	5,585	160	115
1966	9,673	185	163
1971	13,280	406	264
Percent Increase 1963-1971	138	153	130

Source: Federal Aviation Agency 1971.

Table 79

AIR TAXI ACTIVITY

Bristol Bay - 1972

LOCATION OF OPERATORS	TOTAL PASSENGERS CARRIED	TONS OF FREIGHT CARRIED	TONS OF U.S. MAIL CARRIED	TOTAL TONS FREIGHT AND MAIL
Dillingham	4,981	20.7	0	20.7
King Salmon	11,226	156.6	69.3	225.9
Naknek - So. Naknek	12,215	10.2	0	10.2
TOTAL	28,422	187.5	69.3	256.8

Source: Alaska Transportation Commission files, Anchorage.

scheduled air passenger service also receive air freight service on a scheduled basis, but it is often delayed.

Almost all air freight in the region passed through either the Dillingham or King Salmon airports. Of the cargo transported by commercial carriers, the Dillingham airport handled 770 metric tons of freight and mail in fiscal year 1970-71, and the King Salmon airport handled 610 metric tons (Tables 77 and 78). The 2 airports accounted for 93 percent of the commercially carried cargo in the region. Between 1963 and 1971, the amount of air freight and mail handled at the Dillingham airport by commercial carriers increased by 236 and 292 percent, respectively. The amount of air freight and mail handled by the King Salmon airport for the same period increased by 153 and 130 percent, respectively. Air taxi operators carried a total of 233 metric tons of freight and mail in 1972 (Table 79).

It will be noted in Table 77 that mail accounts for nearly half of all the air cargo carried in the region. This is due to the applicable postal service regulations for transport of intra-Alaska mail which permit the shipping by parcel post of a wide range of goods that are not permitted to be shipped elsewhere. The parcel post rate is lower than the air freight rate because of a subsidy paid to the airlines by the U.S. Postal Service. This encourages shippers to use the U.S. Postal Service as a major freight mover in rural Alaska. Much of the freight that previously moved by barge or ship is shifting to parcel post as stores find that they can operate with lower inventory investment by paying just a little more for mail delivery of their goods (Alaska Legislative Council 1972).

Freight service by sea to the region is infrequent and unscheduled. The area is serviced by tug and barge approximately 3 times per year. The U.S. Bureau of Indian Affairs freighter, Northstar III, will visit some villages in the area upon request, usually once a year. Charter barge service is available from Anchorage or Seattle to haul large quantities of freight. The Alaska Legislative Council (1972) reports that there is general dissatisfaction throughout rural Alaska with present tug and barge service from Seattle. It cites the following complaints from rural Alaskans:

1. High cost of both ocean freight and lighterage;
2. Excessive damage of cargo;
3. Undependability of delivery;
4. Lack of refrigeration service;
5. Slow settlement of loss or damage claims;
6. All freight must be prepaid to Alaska destinations.

The principal harbors in Bristol Bay are Dillingham and Naknek. Table 80 shows the quantity of freight traffic moving through the 2 harbors. Naknek has handled an average of about 50,000 metric tons of cargo per year from 1961 through 1971. The average for Dillingham for the same period has been about 11,000 metric tons. The majority of the freight shipped through both harbors is composed of 3 items--fuel oil, gasoline and outbound fish and fish products. The yearly fluctuations in tonnage are mostly due to the fluctuations in outbound fish and fish products which vary according to the year's catch.

Freight deposited at Naknek is either trans-shipped to King Salmon via barge or other shallow draft boat via the Naknek River or by truck via the Naknek-King Salmon road. At high water, freight can be trans-shipped by launch to Iliamna Lake via the

Table 80

FREIGHT TRAFFIC MOVING THROUGH BRISTOL BAY PORTS 1961-1971

TONS OF FREIGHT RECEIVED, SHIPPED OR TRANSFERRED

Year	Naknek	Dillingham
1961	65,145	8,181
1962	31,858	15,368
1963	15,183	6,085
1964	60,679	7,479
1965	79,564	13,975
1966	44,074	17,332
1967	34,566	10,006
1968	18,920	6,896
1969	34,889	12,427
1970	149,339*	19,996
1971	68,554	10,079
Average/year	54,797	11,620

*includes 64,160 tons of liquified gases.

Source: U.S. Army, Corps of Engineers 1961-1971.

Kvichak River. The freight going to Aleknagik is carried from Dillingham by truck or is shipped by boat via the Wood River. Nushagak River communities within about 160 km. by river from Dillingham have freight trans-shipped up the river by launch.

Transportation Costs

One-way commercial airline passenger fares for some of the direct flights within the region and flights between Bristol Bay communities and Anchorage are shown in Table 76. In general, the passenger cost per km. tends to be higher in Alaska than for comparable distances in the contiguous United States due to the lower traffic volume and higher operation and maintenance costs in Alaska (Table 81).

Air freight rates for general commodities and selected items between Bristol Bay communities and Seattle are shown in Table 82. These rates are considerably higher than the rates for the same items between Anchorage and Seattle, even when the extra distance is taken into account. Rates from Seattle to Iliamna or King Salmon are more than a third higher than rates to Anchorage, while the distance is less than 15 percent greater. Compared to the rates to Anchorage, costs to Dillingham are about 50 percent higher. The average rates for southbound canned seafood to Seattle, when compared to the rates from Anchorage, are roughly 50 percent higher from Iliamna, 70 percent higher from King Salmon, and 90 percent higher from Dillingham.

Sea freight rates to Bristol Bay communities run substantially higher than rates to other communities in the southwestern corner of Alaska. The higher costs are attributable to these factors: The greater distances involved, lighterage costs, difficult

Table 81

COMPARISON OF COMMERCIAL AIRLINE FARES

WITHIN BRISTOL BAY AND BETWEEN BRISTOL BAY AND ANCHORAGE WITH FARES FOR COMPARABLE DISTANCES IN THE CONTIGUOUS UNITED STATES

Pair	Tourist One-way Fare (tax included)	Distance	Cost per Mile* (cents)
Anchorage-Dillingham	$ 55.00	330 mi.	.17
Anchorage - King Salmon	46.00	292	.16
Dillingham - King Salmon	18.00	67	.27
Port Heiden - King Salmon	42.00	140	.30

* Cost per mile computed from Direct Distance Between Points and Tourist Fare as of Sept. 1, 1973

Source: Reuben H. Donnelley Corp. 1973.

Table 82

COMPARATIVE GENERAL AND SPECIFIC COMMODITY AIR FREIGHT RATES

BETWEEN SEATTLE COMMUNITIES OF THE BRISTOL BAY REGION
(dollars per 100 lbs)

From Seattle	To Anchorage	To Iliamna	To King Salmon	To Dillingham
General Commodities	$ 22.10	$ 28.40	$ 29.10	$ 32.65
Meat	19.20	25.50	24.20	29.75
Milk	16.90	23.20	23.90	27.45
Eggs	22.10	28.40	29.10	32.65
Produce	19.20	25.50	26.20	29.75
Household Goods	22.10	28.40	29.10	32.65
Personal Effects	22.10	28.40	29.10	32.65
To Seattle	**From Anchorage**	**From Iliamna**	**From King Salmon**	**From Dillingham**
Fresh Frozen Seafood	12.00	17.50	17.60	18.30
Canned Seafood	10.20	15.70	17.20	19.20

Source: Reeve Aleutian Airways, Inc.; Wien Air Alaska; Western Airlines.

shipping conditions, and low freight volumes. Rates to Bristol Bay are approximately double the rates to Kodiak (Table 83). Lighterage costs of about 1.40 dollars per 100 kg. in Bristol Bay account for a part of this difference. Most of the cost difference, however, is due to the distance, shipping conditions, and low volume and could not be alleviated by improvements in harbor facilities.

Table 83

COMPARATIVE SEA FREIGHT RATES

From Seattle	Cost per hundredweight: To Kodiak	Cost per hundredweight: To Bristol Bay (Lighterage included)*
Cement, sand, gravel	$1.70	$ 4.19
Building woodwork	8.34	15.29
Metal collapsed cans in package	2.20	4.49
Fruits, vegetables - frozen	7.92	14.57
Motor vehicles	8.51	14.58
Iron and steel articles	3.01	6.28
Lumber, rough or surfaced (strapped in bundles)	2.62	5.02
Eggs (in wooden cases)	4.66	8.59
Meat, fresh (not frozen)	8.21	19.47
Compressed gases	3.17	5.97
Salt	2.32	4.34
Fish canned (southbound)	2.32	4.88

*$0.63 per hundredweight (from Bureau of Indian Affairs Tariff No. 3)

Source: Sea Land Services, Inc., Anchorage.

LAND USE AND LAND STATUS[1]

Introduction

This discussion will include all the land encompassed by the Bristol Bay Native Corporation with the exception of the land which drains southward into the Western Gulf of Alaska (Figure 166). This southward draining land area will not be considered because it pertains to the Western Gulf of Alaska geographically and has stronger economic ties with that area than with the Bristol Bay region.

The Bristol Bay region is currently undergoing a redistribution of land under the provisions of both the Alaska Statehood Act (PL 85-508) and the Alaska Native Claims Settlement Act (ANCSA) (PL 92-203). Until the final implementation of both Acts, land ownership patterns and the uses permitted on the land will be changing constantly. These Acts will eventually produce 3 major land owners in the region: the federal government, the State and its municipalities, and the Alaska Natives. The Alaska Statehood Act passed in 1959 provided a grant of federal lands to the State amounting to 42.3 million hectares. These lands will be selected by the State from any open public domain lands owned by the United States. The State has selection rights until January, 1984. State land selections in Bristol Bay are shown on Figure 167.

ANCSA, passed in 1971, provides for selection and conveyance of 16.2 million hectares (40 million acres) of Alaska to Alaska Natives and provides for the redistribution of most of the state's

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1. Information contained in this section is based upon the land tenure status as of September 1, 1973.

lands. The provisions of the Act have priority over the land selection provisions in the Alaska Statehood Act. Because of this priority, state selection rights have been nullified on some lands and delayed on others. Under provisions of ANCSA, the Secretary of the Interior has withdrawn from the jurisdiction of the public land laws most of the public domain lands of Alaska. For the State as a whole, these withdrawals include:

* Approximately 42.9 million hectares (106 million acres) from which the Natives of Alaska can select their 16.2 million hectare (40 million acre) entitlement.
* 3.0 million hectares (7.5 million acres) for utility corridors.
* 0.8 million hectares (1.9 million acres) for possible additions to the National Wildlife Refuge System.
* 32.4 million hectares (80 million acres) of lands of significant national importance to merit classification as a National Forest, Park, Wild or Scenic River or Wildlife Refuge (d-2 Lands).
* 30.8 million hectares (76 million acres) of lands of significant public interest to warrant future classification by the Secretary of the Interior (d-1 Lands).

With the exception of utility corridor withdrawals, all of these categories of lands are represented in the Bristol Bay region and are shown on Figures 167 and 170.

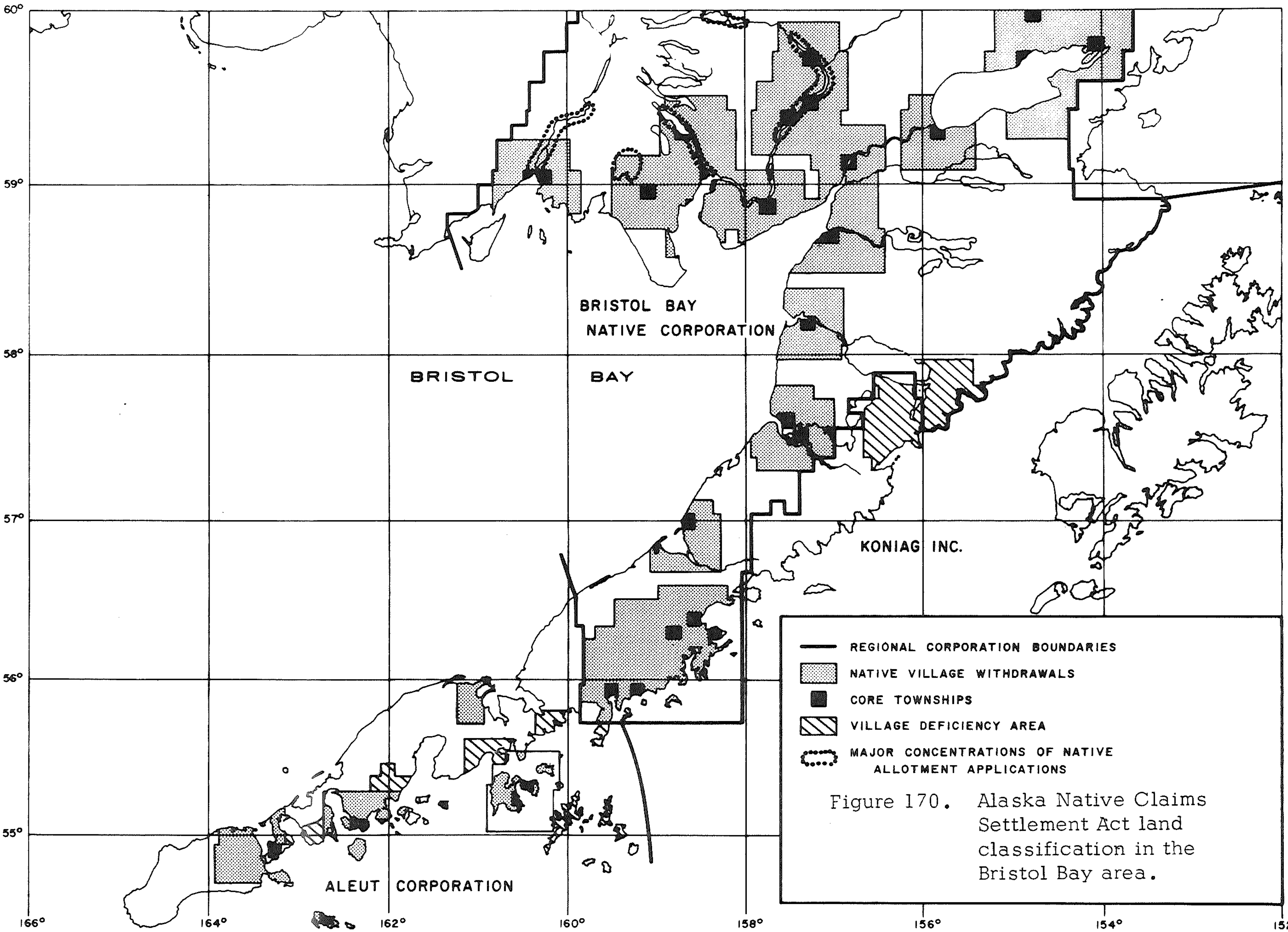

Figure 170. Alaska Native Claims Settlement Act land classification in the Bristol Bay area.

Current Land Use

The economy of the Bristol Bay region is based primarily on the resources of the sea. Intensive use of the land occurs only in settled areas. Currently there are no other intensive uses of the land resources in the Bristol Bay area. The land area of the region is, however, used extensively for subsistence and recreational activities. Subsistence activities on the land primarily consist of hunting for moose and caribou and trapping for beaver, muskrat, mink, and red fox. Furbearers are particularly sought as a source of income when the salmon runs are low (Federal Field Committee for Development Planning in Alaska, 1968). Very little information is available concerning the specific subsistence areas used by the residents of the region; records do not show the numbers of animals harvested for subsistence purposes.

Recreational use of the Bristol Bay region centers around hunting, fishing, and sightseeing. Iliamna Lake attracts many trout fisherman for its trophy rainbow trout fishery. There are nearly 30 hunting and fishing lodges in the Bristol Bay region. The majority of these are located in the Iliamna Lake area.[1] The areas adjacent to the Lake and to Katmai National Monument are popular with brown bear and moose hunters. Katmai National Monument is the major sightseeing attraction in the region.

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1. Jay Hammond, Mayor of Bristol Bay Borough and former Senator, Alaska State Legislature, Naknek, Alaska, personal communication.

Archeological sites represent land use for historic preservation purposes. The approximate location of these sites can be seen on Figure 171. Probably only half of the sites in the area have been discovered, especially on the coastal areas which historically supported greater human populations because of the more reliable food supply provided by the sea.[1] Many sites exist around Iliamna Lake; along the Naknek, Newhalen, and Kvichak Rivers, and at Dillingham. The Iliamna area is extremely important for the determination of the Eskimo-Athapascan boundaries and the contact between these ethnic groups. Dillingham has a documented history of human occupation which spans 6,000 years and its archeological potential is just being uncovered. The Naknek River drainage has an archeological sequence spanning more than 4,000 years.

The Bristol Bay region as defined on Figure 166 contains approximately 9.7 million hectares (24 million acres) which includes 15 categories of lands (Table 84). Some of these categories represent a permanent determination of land status; others have an indefinite status while the remaining categories are of a temporary nature. The total area in the different categories exceeds that of the region by about 2 million hectares (5 million acres). This has resulted because the withdrawals created by ANCSA overlap with previously withdrawn federal lands and with lands previously selected by the State in accordance with the provisions of the Statehood Act. In addition,

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1. Karen Workman, Archeologist, Alaska Department of Natural Resources, Anchorage, personal communication, July 31, 1973.

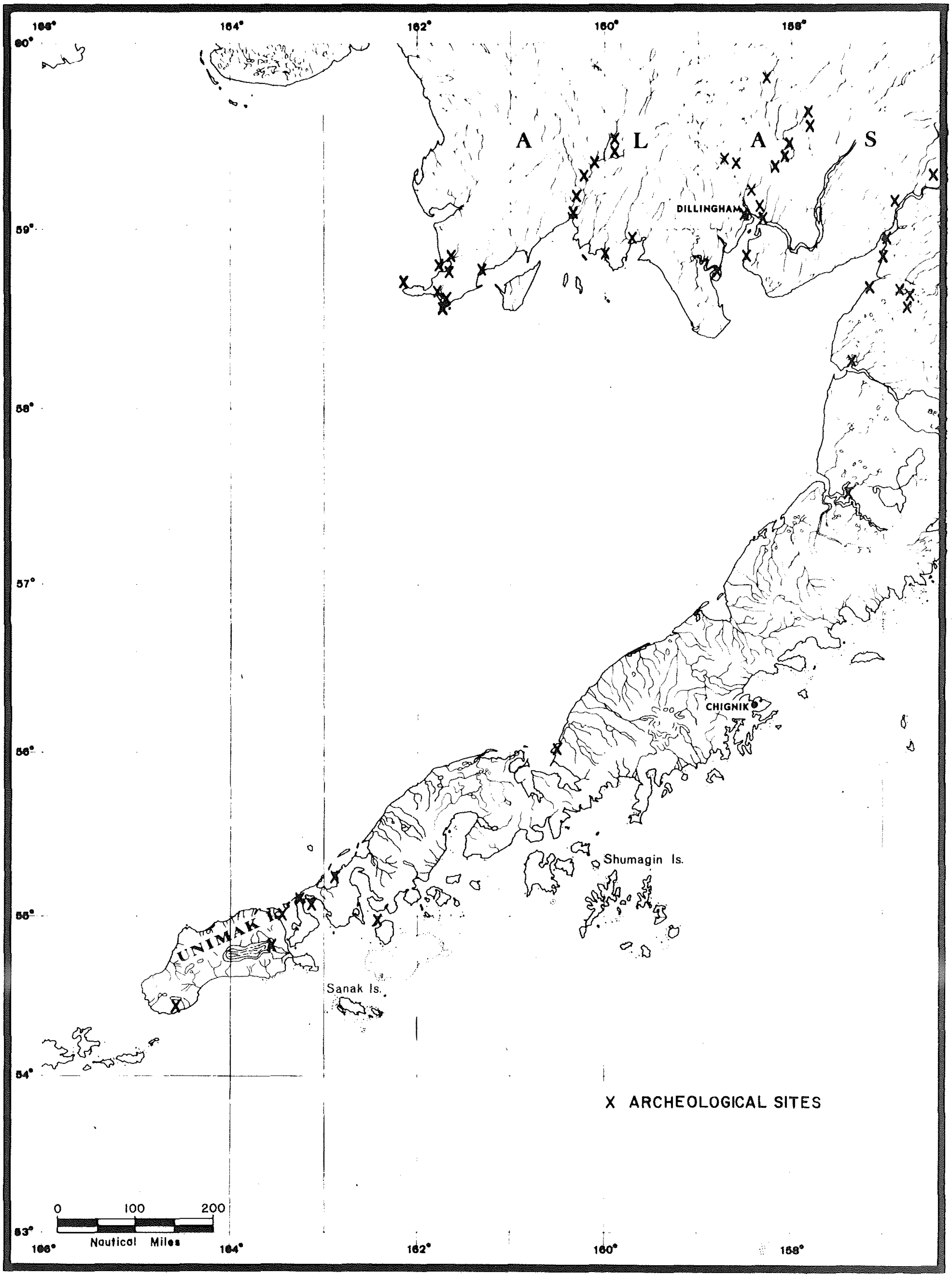

Figure 171. Known archeological sites in the Bristol Bay area (from the files of the Alaska Department of Natural Resources).

Table 84

LAND STATUS

BRISTOL BAY - 1973

STATUS CATEGORY	ACRES*
Patented Lands	
Private	8,560
State	87,072
State Selections	
Tentatively Approved	1,190,857
Pending	10,588,130
Native Allotment Applications	132,081
Other Applications	8,492
Indian Reserves	1,376
Military Reservations	2,524
National Monument	1,490,712
Power Site or Project and Other Withdrawals	54,681
Land Withdrawn by ANCSA	
Classification and D-1 Lands	1,907,385
D-2 Lands	5,103,669
Wildlife Refuge Replacement	587,324
Village Withdrawal	7,487,599
Village Deficiency	188,981
Regional Deficiency	0
Total Land Acres Withdrawn	28,839,443
Total Land Acres in Region	26,021,012

*Land acres only

Source: U.S. Bureau of Land Management files, Anchorage.

some of the Native village withdrawals overlap each other. A discussion of each land category, including the present status and the constraints on use, follows. The land use constraints of each category can be seen in Tables 85, 86, and 87.

Lands With a Permanent Status Classification

Lands in the Bristol Bay region which have permanent status due to the nature of their withdrawal include Katmai National Monument, outer continental shelf lands and state patented and private lands. Lands within Katmai National Monument and state patented lands are shown on Figure 210. The land area for all categories except continental shelf lands are shown in Table 84.

Katmai National Monument - Approximately 0.6 million hectares (1.5 million acres) of Katmai National Monument are in the Bristol Bay drainage. Land use in this area is quite restricted because the area, originally withdrawn to protect unique geologic features, was later expanded for wildlife habitat protection (Table 86). The National Monument is withdrawn from appropriation under the public land laws, location and entry under the mining laws and leasing under the Minerals Leasing Act. No hunting is allowed but subsistence fishing is permitted along with sport fishing, berry picking and other recreational uses. The State does not have selection rights on lands in Katmai National Monument.

Table 85

CONSTRAINTS TO USE ON LANDS WITHDRAWN UNDER ANCSA AND REVOKED INDIAN RESERVE LANDS

Expiration Date	D-2 Lands 12/18/78	Village Withdrawals 12/18/78	Village Deficiency Withdrawals 12/18/78	Regional Deficiency Withdrawals 12/18/78	D-1 and Classification Lands Indefinite	Wildlife Refuge Replacement Lands Indefinite
Appropriation Under Public Land Laws	No	No	No	No	No	No
Location and Entry Under Mining Laws	No	No	No	No	For metaliferous minerals only	No
Leasing under Minerals Leasing Act of 1920	No	No	No	No	No	No
Hunting, fishing and other forms of recreational use	Yes	Yes	Yes	Yes	Yes	Yes
Grazing	Yes[a]	Yes[a]	Yes[a]	Yes[a]	Yes[a]	Yes[a]
Timber Harvesting	Yes[a]	Yes[a]	Yes[a]	Yes[a]	Yes[a]	Yes[a]

[a]Provisions for interim administration in Section 17 of ANCSA authorize the Secretary of the Interior to make contracts to grant leases, permits or easements on these lands. Under present Bureau of Land Management policy this authority is rarely exercised and very few uses are permitted on the land.

Sources: Public Law 92-302 (ANCSA); Public Land Orders 5169 through 5188.

Table 86

CONSTRAINTS TO USE ON LANDS WITHDRAWN PRIOR TO ANCSA AND PENDING STATE SELECTIONS

	Katmai National Monument	Military Reservations	Power Sites or Projects	Outer Continental Shelf	Pending State Selections
Appropriation Under Public Land Laws	No	No	No	No	No
Location and Entry Under Mining Laws	No	No	Yes	No	No
Leasing Under minerals leasing Act of 1920	No	No	Yes	Yes	No
Hunting, fishing and other forms of recreational use	Yes (No Hunting)	Yes	Yes	N/A	Yes
Grazing	No	Yes	Yes	N/A	Yes[a]
Timber harvesting	No	Yes	Yes	N/A	Yes[a]

[a]The Secretary of the Interior has interim administrative authority on these lands giving him the right to make contracts and to grant leases or easements on these lands.

Sources: Public Law 92-203 (ANCSA); Public Land Orders 5169 through 5188.

Table 87

LAND USE CONSTRAINTS GOVERNING LAND UNDER THE JURISDICTION OF THE STATE OF ALASKA

Classification	Disposal	Mineral Deposits Acquired	Disposal of Timber and /or Materials	Grazing	Recreation
Unclassified lands	no	claim staking	no	no	yes
Agricultural lands	lease or sale	leasing	yes	short term lease	yes
Commercial lands	lease or sale	leasing	yes	short term lease	
Grazing lands	lease only	claim staking	yes	yes	yes
Industrial lands	lease or sale	leasing	yes	short term lease	yes
Material lands	no	claim staking	yes	yes	yes
Mineral lands	no*	claim staking	yes	yes	yes
Public recreation lands	no	leasing	yes	no	yes
Private recreation lands	lease or sale	leasing	yes	short term lease	yes
Residential lands	lease or sale	leasing	yes	short term lease	yes
Reserved use lands	no	leasing	yes	no	yes
Timber lands	no	claim staking	yes	yes	yes
Utility lands	lease or sale	claim staking	yes	short term lease	yes
Watershed lands	no		yes	yes	yes
Open-to-entry	lease or sale	leasing	yes	no	yes
Tide and submerged lands	lease or sale	leasing	yes	n.a.	yes

* except those acquired by escheat or foreclosure

Source: Alaska Statutes, Title 38; Alaska Administrative Code, Title II.

Outer Continental Shelf Lands - These lands include the seabed and subsoil beyond the territorial limits of 4.8 km (3 miles). The jurisdiction of the federal government prevails in this zone to the 200 m. isobath and the U.S. could exploit the subsoil and seabed resources beyond this depth (Hickok and Wunicke 1970).

The laws and regulations which pertain to the other public lands of the United States are not applicable to continental shelf lands. These lands cannot be appropriated and are not open to entry under the mining laws. Geological and geophysical explorations can take place and oil and gas can be extracted through lease. The United States reserves the right to the helium from all gas produced in the area and to fissionable materials such as thorium and uranium.

State and Private Patented Lands - State patented lands total approximately 35,200 hectares (87,000 acres) in the Bristol Bay region. These include state selections to which the State has received patent, mineral estate patents, airport conveyances and quitclaim deeds. The land area figure shown in Table 84 does not include tidelands, submerged lands, and shorelands granted to the State in the Statehood Act.[1] State patented lands now represent

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1. Title 11 of the Alaska Administrative Code defines these lands as follows:

Submerged lands: "... covered by tidal waters between the line of mean low water and seward to a distance of 3 geographical miles or further as may hereafter be properly claimed by the State."

Tidelands: "... periodically covered by tidal waters between elevation of mean high tide and mean low tides."

Shorelands: "... covered by non-tidal waters that are navigable under the laws of the United States up to ordinary highwater mark as modified by accretion, erosion or reliction."

a very small portion of the region but if all the lands which are tentatively approved or are pending approval are eventually patented, the State will have title to 4.8 million hectares (11.9 million acres), nearly half of the entire region, exclusive of tide or submerged lands or lands under non-tidal navigable water.

State patented lands, as well as those tentatively approved by the U.S. government for patent under the Statehood Act, are under the management of the State. These lands first fall into an unclassified status and are subject to eventual classification. The various classifications determine the use permitted. The land use constraints governing each classification are summarized in Table 87. All land categories can be utilized for purposes "other than for which classified, provided such use is consistent with the public interest."[1]

There are 3,464 hectares (8,560 acres) of private patented lands in the Bristol Bay region. The owner determines the use of the surface resources of the land and of its subsurface resources, if he has subsurface rights. If the subsurface rights are reserved to the government, prospecting and oil and gas exploration can be conducted on the land by the owner, or by someone other than the owner, if a permit is obtained from the government. Because of their small size and scattered nature, private lands are not shown on the Figures.

<u>Lands Having an Indefinite Status</u> - Military reservations and power site withdrawals have an indefinite status. There are

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1. Alaska Administrative Code Title 11.

approximately 1,000 hectares (2,500 acres) of military reservations in the region. Most of this area is contained with the King Salmon Air Force Base. Under provisions of Public Land Order 5187, all military reservations are closed to appropriation, mining, and mineral leasing to protect the public interest in the lands for use when they are no longer needed for military or defense purposes. Some uses are permitted at the discretion of the agency administering the lands. While any of the area remains a military reservation, the State has no selection rights.

About 22,300 hectares (55,000 acres) are withdrawn for power sites or projects and other miscellaneous withdrawals. Power sites or power project area are closed to appropriation under the public land laws but other uses may be permitted.

Lands With a Temporary Status Classification

State Selected Lands - The State has selected and not yet received patent for a total of 4.8 million hectares (11.8 million acres) under provisions of the Alaska Statehood Act (Table 84). Of this total, 0.5 million hectares (1.2 million acres) have been tentatively approved for patent and about 4.3 million hectares (10.6 million acres) are pending approval. The location of the tentatively approved and pending areas can be seen on Figure 167. Under the provisions of ANCSA, each Native village corporation can select up to 27,972 hectares (69,120 acres) or 3 townships from state selected or tentatively approved land which was selected before January 17, 1969. There is no upper limit on the land area the Native village corporations can select from state selections made after this date. Approximately 24 villages could select lands from state selections, and the amount each village corporation selects will not be known until after December 18, 1974, the deadline for village selections. State lands selected by village corporations will be made up from other land areas but not necessarily from within Bristol Bay.

Tentatively approved lands are under the management of the State. The lands are also subject to classification and to the same land use constraints as patented state lands. State selected lands which are pending approval are administered by the Secretary of the Interior, who has the authority to make contracts, issue leases, permits, rights-of-way, or easements. Prior to any of these, the Secretary of the Interior would obtain the views of the State. The land uses permitted on these lands can be seen in Table 87.

Native Allotment Applications - Native allotment applications do not constitute a land withdrawal in themselves. Under Sec. 14(h) of ANCSA, a portion of 0.8 million hectares (2 million acres) will be conveyed to Alaska Natives throughout the State to cover applications that were applied for under the Native Allotment Acts of 1887, 1906, and 1910 which were extinguished by ANCSA. This area will also cover additional applications authorized by Section 12(b) of ANCSA which conveys to a Native up to 64.7 hectares (160 acres) of land applied for within 2 years after the enactment of ANCSA if said land was a primary place of residence as of August 31, 1971. There are 53,400 hectares (132,000 acres) of allotment applications made prior to and after ANCSA in the Bristol Bay area. The major portion of these are located along the river systems which drain into the northern portion of Bristol Bay (Figure 170).

Lands Withdrawn Under Section 17 d-2 of ANCSA - Under Section 17 d-2 of ANCSA, lands were withdrawn for study and for possible recommendations to Congress as additions to or creation of a National Park, National Forest, Wildlife Refuge, or Wild and Scenic River. This withdrawal expires on December 18, 1978. The amount of d-2 land withdrawn in the region totals 2.1 million hectares (5.1 million acres). The land use constraints for these lands are indicated in Table 86.

These lands were reviewed by the Secretary of the Interior who then submitted to Congress legislative proposals for their inclusion in one of the 4 management systems. Lands originally withdrawn under the d-2 classification and not recommended for one of the 4 management systems will be available for selection by the State, regional corporations and for appropriation under the public land laws. Congress has until December 18, 1978 to act upon the Secretary's recommendations. After this date lands not so acted upon will be open to state selection and appropriation under the public land laws. Prior to December 18, 1978, the Native Claims Settlement Act permits the State and the Native regional corporations to identify d-2 lands desired for selection but these can only be conveyed if they are not incorporated into one of the 4 management systems.

The Secretary of the Interior can make contracts, grant leases, permits, rights-of-way, or easements. Mineral lease applications will be rejected until the public land order classifying d-2 lands is modified or the lands are reclassified to permit mineral leasing.

Native Selections Under ANCSA - Lands withdrawn under ANCSA for Native selections also have a temporary status. The following statement explains for the State as a whole, the Native land selection process and the role of and time limits attached to each withdrawal category:

> The village land selection of 22,000,000 acres (8,900,000 hectares) for the whole State must be selected from lands designated as: a) village withdrawal area or b) village deficiency land if the regular withdrawal is insufficient. This land is selected by the village corporation. First to be selected are all available lands in the townships in which the village is located. Then additional land is selected based on village enrollment. The minimum entitlement for an incorporated village with an enrollment of at least 25 is three townships. This selection must be completed by December 18, 1974 and will result in surface lands going to residents, businesses, subsistence sites, non-profit organizations, municipal corporations or other selected users. The subsurface rights go to the regional corporation.
>
> If the entitlement of all the villages in the State does not total 22 million acres, the remaining acreage is divided amongst the regions on a population basis. The regional corporations then allocate these acres to their village corporations, based upon need, population and historic uses. The villages then select where the acres are to be used within their village withdrawal or deficiency areas in order to complement their original entitlement selections. As in other village selections, the subsurface rights accrue to the regional corporations.
>
> The regional land selection of 16,000,000 acres (6,500,000 hectares) for the whole state must be selected from lands designated as: a) village withdrawal lands remaining or b) regional deficiency land if insufficient village withdrawal remains. This land is selected by the regional corporation. Each region's entitlement is based on the size of the region's area with deductions for previous village selection. Land is selected on the basis of the regional corporation's management decisions for

the future of the region. This selection must be completed by December 18, 1975 and will result in the land being used according to the regional corporation's plan for the future of the region.

Selection from unreserved and unappropriated public lands outside the withdrawal areas of 2,000,000 acres (800,000 hectares) for the whole State must be selected for the preservation of historical places and cemetary sites and residence land for small non-village groups and individuals. Selection of the place of residence for non-village individuals must be completed by December 18, 1973. This will result in the preservation of sites of importance to the region as well as residence land outside the established villages.

Selection of any remaining lands to fulfill the 40 million acre (16.2 million hectare) entitlement of the Act must be selected from remaining withdrawal or deficiency lands. The regional corporation selects these lands based on regional enrollment. Through this selection the entire 40 million acre entitlement is insured in accordance with the Act. (Arctic Environmental Information and Data Center 1972)

The land from which Native village corporations and regional corporations can select their entitlement totals approximately 3.2 million hectares (7.8 million acres), of which 3.0 million hectares (7.5 million acres) are classified as village withdrawals and 120,000 hectares (0.3 million acres) are classified as village deficiency withdrawals. Under Section 11, 12 and 14 of ANCSA the following villages are eligible to select land:

Village	Maximum Land Area Allowed (in hectares)
Aleknagik	37,296
Clarks Point	27,972
Dillingham	65,268
Egegik	37,296
Ekuk	27,972

Ekwok	37,296
Igiugig	27,972
Iliamna	27,972
Kakhonak	27,972
Koliganek	37,296
Levelock	27,972
Manokotak	46,620
Naknek	37,296
Newhalen	27,972
New Stuyahok	46,620
Nondalton	37,296
Pedro Bay	27,972
Pilot Point	27,972
Portage Creek	27,972
Port Heiden	27,972
South Naknek	27,972
Togiak	46,620
Twin Hills	27,972
Ugashik	27,972

Land use constraints on land withdrawn for Native selections can be seen in Table 85. After December 18, 1975, most lands not selected by the Native corporations will be classified by the Secretary of the Interior to protect the public interest. The State will have selection rights on most of these lands.

Miscellaneous Land Withdrawals - Lands designated under Section 17(d) (1) of ANCSA and Public Land Orders 5180 and 5186 were withdrawn to determine their proper classification in order to protect the public interest. There are 0.8 million hectares (1.9 million acres) of these public interest areas. The land use constraints imposed on these so-called d-1 lands are similiar to those for d-2 lands except that location and entry for metalliferous minerals is permitted on d-1 lands (Table 85). Wildlife refuge replacement lands were withdrawn to serve as possible replacements for existing refuge lands that are selected by the

Native village corporations. There are 240,000 hectares (0.6 million acres) in this classification and they are under the same land use constraints as d-2 lands (Table 85). The Secretary of the Interior is under no time constraints to rescind or reclassify either Section 17(d) (1) or wildlife replacement lands.

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POTENTIAL CONFLICTS OF RESOURCE USE

EFFECTS OF THE ENVIRONMENT ON RESOURCE USE

Geomorphology

The rugged, mountainous terrain and generally poor weather conditions make flying extremely hazardous within the study area, and between the study area and adjacent regions. The magnitude of this hazard was emphasized by the recent crash of a U.S. Air Force cargo plane near Cold Bay in September 1973.

Parts of the offshore area are extremely hazardous for marine navigation; navigation is especially difficult around islands where there are shoals, as between Cape Constantine and Cape Newenham. Much of the nearshore area is poorly charted, and much of the area further offshore is only lightly charted. Charts are not available for the coast between Cape Constantine and Cape Newenham.

There are few bays and lagoons in the area that offer natural harbors for refuge from storms. The coastline is best described in the Coast Pilot (U.S. Coast and Geodetic Survey 1964) and in an interesting personal description of the coast by B. J. Logan.[1]

Climate-Oceanography

Occasionally, weather and wave conditions in the region make human activities difficult. Sustained winds, especially those associated with summer storms traveling northeastward along the storm track, may range from 55 to 110 km./hr. and gust to more than 150 km./hr. above open water. Aircraft operations, especially landings and takeoffs, can be extremely hazardous during these storms. In addition, wind velocities are strong enough to damage offshore structures if they are not adequately designed and constructed. Strong winds in the vicinity of mountains, particularly on the north side of the Alaska Peninsula, can cause severe turbulence that is hazardous to aircraft and buildings. Short but violent local storms commonly develop with almost no warning.

Storms often move slowly or remain stationary for several days; this creates substantial wave activity. Theoretically, waves as high as 10 m. could be generated, but waves greater

1. B.J. Logan. 1970? Report on Alaska Ports. unpublished. 145 pp. (mimeo).

than 4 to 5 m. are not generally observed. The steep trochoidal shape of the waves is potentially more damaging to ships than the actual wave height.

Tidal currents in the area are generally not as extreme as they are in Cook Inlet to the east. Diurnal variations in tidal height are fairly high in the northeastern part of the study area, especially in the large river estuaries, and can generate significant current velocities.

Usually temperatures in the area are not extreme and do not hamper outdoor activities to any extent. Occasionally, however, extremely cold northerly winds cause temperatures to drop the chill factor to -50 degrees C along the north coast. Sea water temperature varies about 12 C degrees through the season decreasing to near 0 degrees C during the coldest months. Someone falling overboard in winter could perish with as little as 15 to 30 minutes exposure in the water. During periods of critically low temperatures, ice can form on the superstructure of ships, oil platforms, and onshore structures. Icing of aircraft is often a problem under a variety of conditions.

The presence of sea ice in Bristol Bay, beginning in mid-October and persisting into late May or early June, may cause specific engineering and transport problems. Since ice does not persist beyond 1 year nor form large shorefast masses, icebreakers or reinforced tankers should find little difficulty with transport in this area except under extreme conditions. Normally ice will not exceed 1 to 1.5 meters at it maximum thickness in February and March.

A great variation in tidal height assists navigation by breaking ice into smaller pieces, though these smaller pieces are still able to cause considerable propeller and rudder damage to vessels. The situation is complicated by large piles of ice formed on the tidal flats from beach ice which has broken free, been deposited higher on the flats, and frozen to the underlying mud. Ice floes are then piled on top and, as the tides recede, the overhanging portions break off leaving stacks of layered ice (stamukhi) with nearly straight sides. These may go adrift in abnormally high tides. Some, which were grounded in the shallower areas of Cook Inlet in 1970-71, were observed with thicknesses greater than 12 m.

Generally, design criteria similar to those required for the petroleum industry in Cook Inlet should be followed, with additional allowance for mass stress imposed by solid pack ice movement. Sufficient knowledge is currently unavailable to determine additional design criteria required in this environment.

Ceiling and visibility in the area are extremely low much of the time and can severely restrict the use of aircraft. Areas can be "socked in" for extended periods, and aircraft structural icing can be extremely hazardous. Scarcity of alternative landing facilities creates an especially critical problem. Dense fog, especially during summer months, also poses a serious hazard and can hamper both onshore and offshore surface operations.

Geology

Engineering Considerations

The absence of substantial bathymetric relief on the continental shelf within Bristol Bay may reduce engineering complexity in the design of offshore structures. Sandy substrates may provide a stable base for structures. Pipelines would be much easier to construct and bury in this marine environment than in one of a more rocky character with higher relief and stronger tidal currents.

Coastal erosion is a constant problem throughout the area and will require great care in the placement and design of structures along the tide line. Erosive processes are constantly changing entrance channels into harbor areas and will require dredging to keep transportation lanes open.

Seismicity

The Bristol Bay area lies adjacent to an active seismic belt. Most of the area is included in seismic risk zone 2 (Figure 172), defined as an area where moderate structural damage could occur (Federal Field Committee for Development Planning in Alaska 1971). As seen in Figure 57, few earthquakes with magnitudes greater than 6.0 have occurred in the study area during this century. Hypocenters of these earthquakes are generally very deep and thus are unlikely to cause great damage.

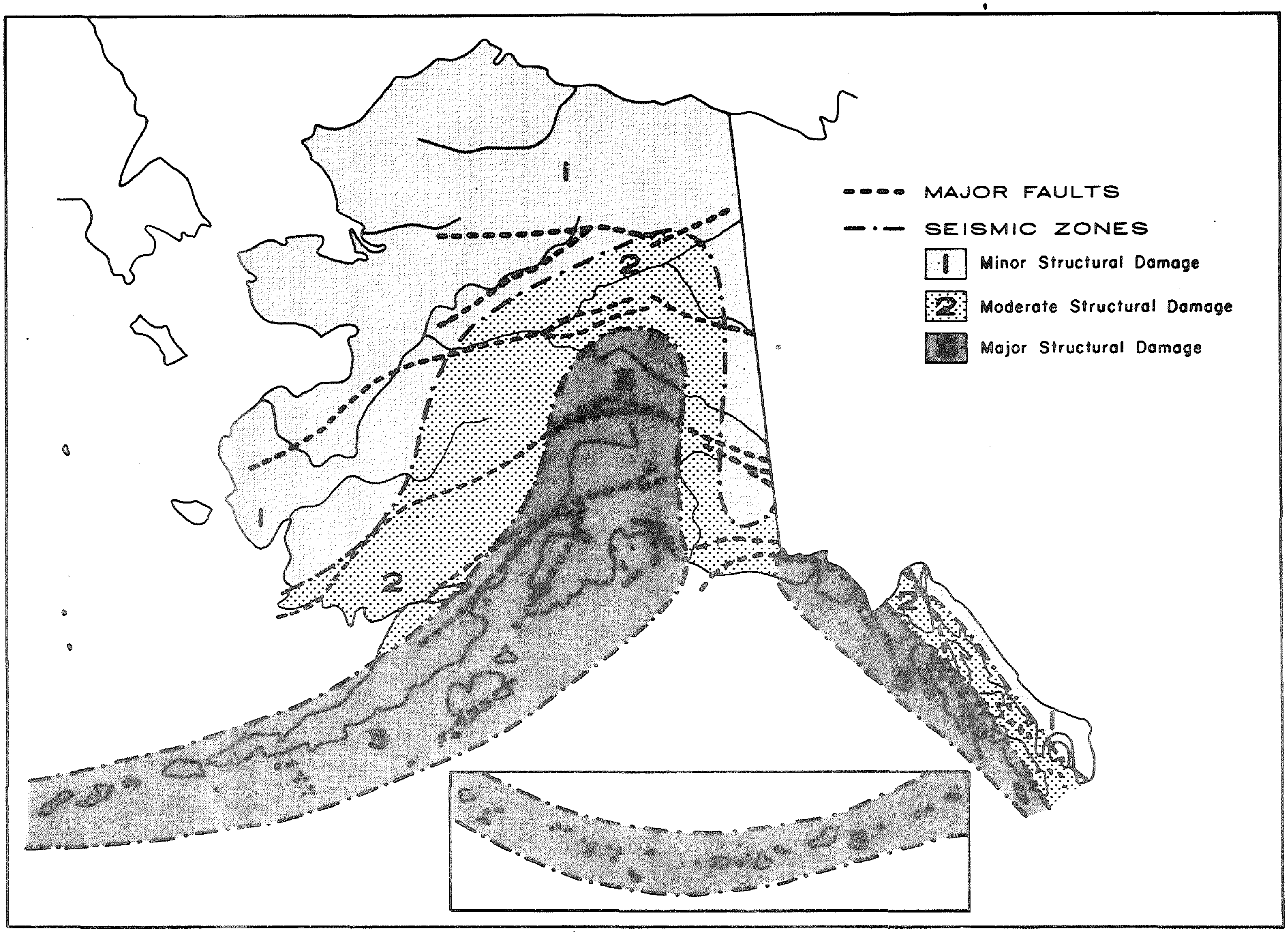

Figure 172. Faults and seismic areas (compiled in 1971 by the Federal Field Committee for Development Planning in Alaska).

The area between Kodiak and Unimak Island, which is adjacent to the study area, has not experienced an earthquake greater than 7.0 since 1938. Time-space studies of large earthquakes along the Aleutian Trench and vicinity suggest that this region may experience a large earthquake in the near future, perhaps sometime between 1974 and 1980 (Kelleher 1970). Such an earthquake could result in considerable damage within the Bristol Bay area.

Earthquake damage can be caused by a variety of factors. Primary effects are due to direct seismic vibration of the ground, which causes ground breakage, mud or sand emission from cracks, ground lurching and shaking, and local subsidence of unconsolidated sediments. Damage to structures is the main result of this ground motion.

Secondary effects caused by earthquakes include fires, seismic sea waves, and both subaerial and submarine landslides. Large-scale tectonic changes, such as uplift and subsidence, can also have widespread effects. In addition, earthquakes can cause local and regional effects on the biology, hydrology, atmosphere, and magnetic field of the area.

The great 1964 Alaska Earthquake illustrates the potential impact of earthquakes. Late in the afternoon of March 27, 1964, one of the greatest geotectonic events of our time occurred in southcentral Alaska. Its magnitude has been computed by various observers to range from 8.3 to 8.75 on the Richter Scale. The epicenter of this earthquake was located at the head of Prince William Sound on the south flank of the Chugach Mountains, about 130 km. east-southeast of Anchorage. The hypocenter, or point of origin, was at a depth of 20 to 50 km. The duration of the earthquake can only be estimated because of the lack of instrumentation; observers estimated the duration of the shock to be between 3 and 4 minutes.

This earthquake has become renowned for its long duration and great destructiveness. Thousands of people lost their homes, 114 people were killed, and the economy of the entire State was drastically affected. Seismic seawaves swept the Pacific Ocean from the Gulf of Alaska to Antarctica.

The 1964 earthquake provided a natural laboratory for studying the cause and effects of large earthquakes. The results of numerous investigations were published following the earthquake. Perhaps the most significant of these is the series of 8 volumes now being published by the National Academy of Sciences (in press). A volume will cover each of the following topics: Geology, Seismology and Geodesy, Hydrology, Biology, Oceanography, Engineering, Human Ecology, and a Summary with Recommendations.

The eastern part of the study area around King Salmon was directly affected by the 1964 earthquake. Widespread ground breakage and ice cracking were reported on the coastal Lowlands and in the larger river valleys, as far southwest as Ugashik. A few small landslides, rockfalls, and avalanches were reported along the Aleutian Range front. Property damage was minimal in the area and reported only at King Salmon (Plafker et al. 1966).

Many low-lying coastal areas of Bristol Bay are susceptible to inundation and damage by tsunamis or seismic seawaves. Tsunamis generated by large-scale seafloor displacements south of the Alaska Peninsula would be blocked by the Peninsula and would not affect Bristol Bay. However, tsunamis generated in the Aleutian Islands or along the Kamchatka Peninsula could generate waves in the Bering Sea. For example, a large earthquake in the seismic gap west of Attu Island could generate a wave with a clear path into Bristol Bay. Much of the energy of the wave would be dissipated as it crossed the shallow Bristol Bay shelf, reducing its potential for damage to upper portions of the Bay. Many waves have been reported in Bristol Bay.[1] In 1928 and 1946, waves 1.8 and 1.2 m. in height entered Port Heiden. The latter was associated with the massive wave that took out the lighthouse located 30 m. above sea level at Scotch Cap on Unimak Island. Native folklore also contains many accounts of villages destroyed by waves.[2] Any coastal facilities should be built on high ground to avoid possible damage from tsunamis.

Most ground damage and foundation failure due to partial soil liquefaction and differential settlement during the

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1. Ibid.

2. Ibid.

1964 earthquake occurred in areas of saturated, unconsolidated sediments or fill. Most of the Bristol Bay coastal zone consists of unconsolidated Quaternary and Holocene surficial deposits which make the area more susceptible to damage than bedrock areas. Lands away from bluffs and underlain by older morainal material offer the most stable building sites. Onsite evaluation of soil conditions should precede any development.

Earthquake prediction is becoming a practical reality (Scholz et al. 1973). Primarily this is due to recent studies of phenomena premonitory to earthquakes, such as crustal movements and anomalous changes in tilt, fluid pressure, electrical and magnetic fields, radon emission, the frequency and occurrence of small local earthquakes, and the ratio of the number of small to large shocks. Most significant is the possible premonitory change in the ratio of the seismic compressional velocity to the seismic shear velocity (Scholz et al. 1973). It may soon be possible to predict large earthquakes in the study region. To this end, a detailed seismic net is being established in the Shumagin Islands.

Volcanism

The Bristol Bay area includes a chain of active and potentially active volcanoes along the Alaska Peninsula which are potentially hazardous to nearby activities. These volcanoes tend to erupt andesitic lavas and ejecta which are more viscous than normal oceanic lavas. Eruptions associated with these andesitic volcanoes tend to be more violent and explosive and, therefore, more hazardous. Primary eruptive phenomena include:

1. Krakatoan eruptions--large violent explosions involving a voluminous outpouring of ejecta and destruction of large portions of the volcano summit, mainly because of collapse.

2. Nueé ardente (ash flow, "flowing cloud")--clouds of incandescent gases and ejecta that flow down swiftly from the volcano summit. They can flow away from the volcano for many km. and are potentially hazardous and extremely destructive.

3. Pyroclastic eruptions--pyroclastic ejecta can range in size from blocks and bombs to fine-grained ash, and is the main type of material forming andesitic cones.

Deposition of significant thicknesses of ash can occur 150 km. away from the volcano depending on the direction and magnitude of the wind.

4. Turbulent ash clouds and columns--bursts of gas, steam and ash that rise vertically to heights of 15,000 to 30,000 m. can be especially hazardous to aircraft in the area.

5. Lava flows--generally of minor importance in the formation of andesitic volcanic centers. The flows generally congeal near the eruptive center due to the viscous nature of the lava.

In addition to the primary eruptive phenomena, various secondary phenomena that could be hazardous are associated with eruptions:

1. Volcanic mudflows and landslides--mixtures of ejecta and meltwater that flow off the flank of volcanoes after eruption.

2. Flash floods--sudden melting of snow and ice following an eruption, or possibly the breakup of ice-dammed lakes.

3. Lightning discharges--often associated with volcanic eruptions.

4. Corrosive rains--acidic volcanic gases that mix with precipitation.

5. Earthquakes--volcanic processes within the plumbing system of the volcano can generate seismic activity.

6. Seawaves--submarine eruptions, large mudflows, and nuée ardentes flowing into the ocean can cause tsunamis.

Examples of almost all of these eruptive phenomena have occurred in areas near Bristol Bay during historic times. The 1912 Katmai eruption is an excellent example of a large violent explosion; it ranks as one of the greatest eruptions in recorded history. More than 25 cu. km. of material was ejected and produced a thick blanket of ash around Katmai. This ash blanket was 0.3 m. thick on Kodiak Island, more than 160 km. away. The eruption also produced a massive nuée ardente that filled a valley northwest of Katmai and formed the Valley of Ten Thousand Smokes. Large earthquakes also were associated with this eruption. A detailed summary of the volcanic activity of the Katmai region is contained in a book soon to be published by the University of Washington Press (Forbes, in press).

The violent 1883 eruption of Augustine Volcano, located in Lower Cook Inlet, created a large summit crater. Associated with this eruption was a massive mud slide down the north flank of the mountain. This slide apparently caused a large seawave which reached English Bay with a maximum amplitude of 6 meters.

Volcanism can disrupt man's activity. The Katmai ashfall created numerous problems on Kodiak and caused "acid rains" in Seward and Cordova. In 1953, Mt. Spurr showered ash on Anchorage, causing damage to aircraft and necessitating an expensive cleanup. This eruption produced a mushroom cloud that rose to an estimated height of 18,000 to 21,000 m. in 40 minutes, a good example of a violent, turbulent ash cloud eruption. The 1966 eruption of Mt. Redoubt caused a massive mudflow and flash flood that threatened the pipeline terminal at Drift River. Pavlof Volcano erupted recently in November 1973, producing a cloud as high as 6,000 m. and a lava flow down the northeast side. This volcano could disrupt activities at Cold Bay, only 50 km. away. Prevailing winds make some areas more susceptible to ashfall or other volcanic distrubances. Such ash persists in soils and results in dust problems for many years.

Volcanic prediction is becoming a practical reality. Premonitory effects include increases in microseismic activity, tilting of the inflating volcano, increased fumarolic activity, changes in the local magnetic and telluric field, and even changes in the ionospheric reflecting layer. Perhaps the most promising predictive tool available today is the monitoring of microearthquakes which apparently increase in frequency prior to eruptions, a response to increasing seismic strain associated with the resurgent growth of a lava dome. This method is used extensively by Japanese scientists, but is new to this country. Augustine Island, now being studied by Dr. Jurgen Kienle of the Geophysical Institute, University of Alaska, is one of the few places in the United States where microearthquakes and other premonitory phenomena are now being studied.

Hydrology

Precipitation along the north slope of the Alaska Peninsula is often very heavy for short periods of time. This results in high, rapid runoffs which cause local flooding of short duration along streams, especially those having no lakes at their headwaters. This factor should be considered in the placement of onshore facilities.

An adequate supply of good water for onshore facilities might be another problem. The normally high sediment load of streams often restricts the use of untreated surface water supplies. Coastal waters with high suspended sediment content could also be treated for industrial use. Groundwater tends to be highly mineralized or saline at the coast and is generally not potable. The presence of permafrost further limits the availability of groundwater.

Potable groundwater supplies do not currently yield enough water for community-wide use. The demand for large supplies of potable water will require surface water utilization. As there are many lakes in the region with potable water, pumping from them to storage tanks is a possibility. This may have advantages over dam and reservoir construction, which would restrict the movement of salmon.

Biology

Man's activities can be affected by the environment in many ways. Foremost is the presence of biological hordes of mosquitoes and flies. Because of adverse effects on natural ecosystems, the State of Alaska, Department of Environmental Conservation has regulations governing the use of insecticides. Permits for their use are required on a project-by-project basis.[1]

A less common, but more serious factor, is the behavior of cliff nesting birds in response to aircraft. When an aircraft approaches, they commonly dive from their nests into the ocean, often in dense swarms. Aircraft flying close to a cliff below nest level can be in considerable danger of hitting these relatively large birds. Helicopter rotor blades are particularly vulnerable.

Black and brown bears are a valuable resource, but can be a nuisance around a camp. Carelessly handled food and garbage can attract bears and lead to their eventual

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1. Kyle Cherry, Alaska Department of Environmental Conservation. Anchorage, Alaska. Personal communication.

destruction. Brown bears, with low populations and relatively low reproductive potential, are particularly vulnerable and can be easily eliminated from an area. Bears are often dangerous when they become accustomed to humans.

EFFECTS OF RESOURCE USE ON THE ENVIRONMENT

Pollution

Past and Present Sources

Cannery wastes are a problem in the Naknek-Kvichak district, where 7 processing plants have been dumping untreated wastes into the estuary Malick et al. (1970) report that these wastes, which they estimated at more than 8,600 metric tons, have a negligible effect on water quality in the estuary. They believe this is because of the large variation in tidal height and its assóciated currents.

Sewage is habitually dumped into the nearest convenient water body in most communities in the study area. Dillingham's treatment plant has been by-passed for several years because of cost. Residents now dump raw sewage into the Nushagak River. The U.S. Environmental Protection Agency, U.S. Public Health Service, and the Alaska Department of Environmental Conservation are developing plans to control the problem. The U.S. Environmental Protection Agency is instituting a discharge permit system (U.S. Environmental Protection Agency 1973) that requires implementation of sewage treatment standards by July 1, 1977. Application of these regulations to small settlements may be difficult because of high costs, but wastes from canneries and industrial operations should receive adequate treatment by that date.[1]

Two major oil pollution incidents are known to have occurred recently near the study area. The Kodiak oil spill of 1970, presumably from a tanker discharging crude oil ballast, caused considerable damage to biotic resources as documented by the Federal Water Pollution Control Administration (U.S. Dept. of Interior 1970b)

Effects from this incident were observed for nearly two months. Observers estimated that at least 1,600 kilometers of beachline were affected during the Kodiak incident. It is estimated that an average of 16 dead birds

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1. Steven Provant, Chemist, U.S. Environmental Protection Agency, Alaska Operations Office. Anchorage, Alaska. Personal communication.

was found per kilometer of beach inspected. At least 10,000 sea birds, mainly murres, auklets, guillemots, gulls, goldeneyes, and old squaws, were killed and washed up on beaches. No estimate was made of birds that might have been killed but did not wash up on beaches. Numerous seals and sea lions were also reported to be covered by oil.

No in-depth studies were conducted to appraise damage to lower life forms. Background studies recommended during the course of the investigation have not been carried out.

In March 1972, a tanker grounding at Cold Bay in the Alaska Peninsula released portions of its cargo of diesel fuel and gasoline into Cold Bay, an area adjacent to Izembek Lagoon in the study area. This is an important habitat for fish and wildlife including brant and emperor geese. The total amount of fuel lost was about 4,600 barrels. An in-depth appraisal of possible damage to marine organisms was not made. No significant damage was documented and winds kept the oil from areas where birds concentrated (U.S. Coast Guard 1973)

During the development of the Cook Inlet oil field, intermittent surveillance was conducted by several state and federal agencies. During the period between May 1966 and 1968, oil pollution incidents were logged by various agencies conducting surveillance or responding to reports of spills. These reports include 122 observations estimated to be at least a barrel or more. Five spills were estimated to be more than 1,000 barrels. Several more were large spills of unestimated size. These spills resulted from pipeline breaks, tanker accidents, overfilling of tanks, leaks aboard platforms, and leaks and spills from various appurtenances aboard platforms and docks. Concentrations of mud sacks, pallet boards, and garbage were also frequently observed, but are not included in this list. The number of spills was greatest during the development phase of the Cook Inlet field. By 1969, when most of the field had been developed, the occurrence of incidents dropped off significantly (U.S. Department of Interior 1970a). The frequency of oil pollution incidents is suggested by selecting 47 random aerial surveillance flights conducted during the height of development operations between June 1966 and April 1968. These flights were not made in response to any reported spills, but were merely routine patrols. These flights discovered 9 spills described as "significant," containing dark ropy masses of oil at least 0.3 sq. km. in area or 0.8 km. in length. Seven of the 9 spills were considerably larger. These observations imply that during the development of a small offshore oil field, significant amounts of oil can be found on the water 19 percent of the time. Small patches of irridescent sheen could be found on most flights (Evans 1969).

No in-depth studies of possible damage to the ecosystem were conducted during the development of the Cook Inlet field. The most serious known damage involved oil from an unknown source, which killed an estimated 1,800 to 2,000 sea ducks (Evans 1969).

Subsequent to the development of the Upper Cook Inlet oil field, the National Environmental Policy Act of 1969 has been enacted. The effectiveness of this legislation on future such operations in Alaska has not been demonstrated.

Shipping operations can result in chronic spills in ports. The U.S. Army, Corps of Engineers (1973) cites Speyer and Tolkoff (1970) who conducted studies in Woman's Bay at Kodiak, an area where Navy and Coast Guard ships had been moored and fueled for about 30 years. This study concluded that the oil and fuel, accumulated from years of seepage, tank cleaning, deballasting, and normal shipping operations, had made the soft muddy bottom in the vicinity of the Coast Guard pier relatively barren of marine flora and fauna as compared to other areas within Woman's Bay.

Future Sources

Marine shipping in Bristol Bay has always been a minor activity. Marine transport activities related to petroleum development would greatly increase the amount of shipping in the study area. Much of this increase would probably be tankers.

In the past tanker traffic has resulted in spilled oil. U.S. Department of Interior (1970b) discusses in detail the problems of washing cargo tanks and disposing of the oily residues either at sea or to shore-based ballast treatment facilities. Although it is impossible to determine the exact amount of oil spilled into the ocean as a result of these operations, it is clear that it can amount to several hundred barrels per tanker per trip. Even under optimum conditions, when all residual oil from tank cleaning and ballasting in cargo tanks is pumped ashore into ballast treatment facilities, a large amount of oil will reach the sea. The best available treatment for North Slope crude oil at Valdez will result in 10 parts per million of oil remaining in the effluent from the facilities (U.S. Department of Interior 1972). This will amount to about 12 barrels of oil per day when the trans-Alaska pipeline is operating at capacity. The exact composition of the oil remaining in the effluent is unknown, but it seems likely that the soluble fractions would remain to be discharged into the sea.

Experience in Cook Inlet also indicates that shipping can be an important source of accidental spills, either from ship collisions or human error in loading operations (U.S. Department of Interior 1970b). The larger spills resulted from these two causes. Unless conditions change drastically, the number of oil pollution incidents associated with transportation will trend upward as traffic increases.

Production of oil in Bristol Bay would increase shipping activity in the area. Some information about the effects of oil production in the Bay can be gained from the experience in Cook Inlet, although there are differences between the two projects. For example:

1. Most operations in Bristol Bay would be in deeper waters than those in Cook Inlet, but would not be subject to such tidal currents as found in the Inlet.
2. Surveillance and enforcement of regulations would be more difficult in Bristol Bay. Flying weather is adverse and major operating bases and agency offices are distant from Bristol Bay. These difficulties are magnified significantly by the unreliability of forecasts.

3. It is impossible to predict what special problems would be created by pipelines, loading facilities, or undersea completions due to uncertainties as to how oil would be produced and transported. It is not known whether platforms would be permanent or whether undersea completions would be utilized. Tankers could be loaded from offshore platforms or onshore facilities that would require feeder pipelines.

Oil spills in a developing and producing oil field can result from a number of causes including blowouts, minor emissions from wells and drilling platforms, pipeline breaks, spills during loading and offloading of tankers, cleaning of ballast tanks and deballasting of tankers, ruptures of tankers, and ruptures of storage tanks ashore. It is difficult to estimate the amount of oil which could be spilled from such operations.

Kinney et al. (1970) estimate that 0.3 percent of the oil produced and handled in Cook Inlet ended up in the Inlet as effluents or spills. This is probably a conservative figure because it is based on estimated volumes of reported spills. Neither the amount of oil lost in unreported spills, nor the results of offshore tanker operations, is included in this estimate.

Hoult (1971) estimates that 0.1 percent of all oil transported or produced offshore is spilled on the sea. The U.S. Department of Interior (1972) includes a much lower estimate based on operations that would be comparable to the proposed trans-Alaska pipeline. Their estimates range from 0.007 percent forecasted for trans-Alaska pipeline oriented operations to .231 percent for world-wide operations, assuming non-use of "load on top" procedures on tankers.[1] The Federal Water Pollution Control Administration, in their assessment of the 1970 Kodiak pollution incident (U.S. Dept. of Interior 1970b), made an appraisal of the

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1. "Load on top" is a procedure for management of "slops" (residual oil remaining aboard a tanker after its cargo has been unloaded). The purpose is to reduce the amount of oil wasted overboard during deballasting operations.

handling of slop oil and tank cleaning residues from tankers serving Cook Inlet. They estimated the volume of slop oil to be 3,000 barrels for a 250,000 barrel tanker. At that time, the practice was to dump slop oil at sea. This represents a spillage of slightly more than 1 percent of the oil handled. Based on industry estimates of 100 barrels of slop oil per tanker, the loss would be .033 percent of the oil handled, assuming the average capacity of a tanker to be 300,000 barrels. Little use was apparently made of on-shore deballasting facilities at that time.

The potential for oil spills is somewhat greater if the possibilities of well blowouts are considered. Kash et al. (1973) state that outer continental shelf operations during the period 1953 to 1971 resulted in one blowout per 500 holes drilled. They also cite a U.S. Geological Survey study (1971) for the same period that listed 19 blowout accidents that resulted in personal injury or damage to property and the environment.

The U.S. Coast Guard states that a policy established by Presidential Executive Order will permit no further discharge of ballast at sea by United States registered tankers after 1980.[1] If this policy becomes fully effective, it will do much to alleviate a segment of the problem, but only where a large portion of the vessels are of U.S. registry.

Regardless of which estimates of quantities of oil spilled are more accurate, it is clear that a considerable amount enters the sea. Appraisal of the impact from oil pollution requires knowledge of how much oil will be spilled, what kind of oil it is, where it will go, what resources will be affected, and how vulnerable these resources are to damage from the type of oil involved. Few data are available on which to base such appraisals.

Fluids used when drilling for petroleum may be toxic. Falk and Lawrence (1973a) investigated drilling and sump fluids. Drilling fluids were found to be acutely toxic to fish, while sump fluids were highly variable and generally lower in toxicity. It seems doubtful that waste drilling fluids would

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1. David Binns, Lt. (Jg), U.S. Coast Guard, Anchorage, Alaska. Personal communication.

reach toxic limits in Bristol Bay. However, Falk and Lawrence recommend that toxic materials used during a drilling operation not be released into water bodies without meeting a prescribed toxicity limit.

Flaring of gas from producing wells and burning off of sump pits has polluted the air in some areas (Evans et al. 1972). The Alaska Department of Environmental Conservation has established that operations on lands and waters under state jurisdiction must meet state air quality standards. These require that there be no significant degradation of air quality.[1] The U.S. Environmental Protection Agency may not have jurisdiction on the outer continental shelf under the Clean Air Act of 1970. This is presently being researched and a legal opinion is being sought.[2]

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1. Kyle Cherry, Alaska Department of Environmental Conservation, Anchorage. Personal communication.

2. Steven Provant, Chemist, U.S. Environmental Protection Agency, Anchorage. Personal communication.

Impact of Spilled Oil on Marine Biota

Table 88 summarizes the impact of spilled oil on the biota with which it might come in contact. Several sources were consulted to determine the toxicity of crude oil (Templeton 1972, Hufford 1971, Oguri and Kanter 1971). The use of chemical dispersants on spilled oil could increase the damage to marine organisms significantly.

Dean (1968) pointed out that medium molecular weight, aromatic hydrocarbons have greater solubility than the heavier elements in crude oil. He emphasized that these medium weight elements would also be the most toxic. The heavier tars and asphalts, while less soluble and less toxic, would not evaporate readily and would have more of a mechanical impact on such items as the feathers on birds. Toxic soluble elements would evaporate slowly in the cold waters of Bristol Bay and their impact would last longer than in warm waters.

The Massachusetts Institute of Technology (MIT) Offshore Oil Task Group (1973) summarized the impacts of petroleum derivatives on various groups of marine organisms. They emphasized the significant toxicity of the soluble

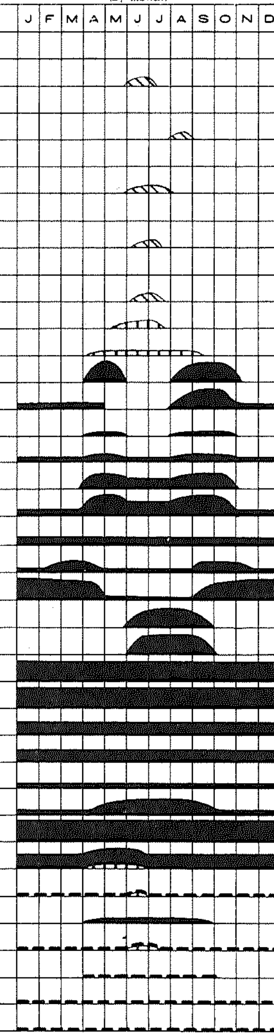
TABLE 88 SUSCEPTIBILITY OF MARINE ORGANISMS TO INJURY FROM CRUDE OIL

BIOTIC GROUP	HABITAT	AREAS OF PEAK ABUNDANCE	SEASON OF PEAK ABUNDANCE	VULNERABILITY TO DAMAGE BY CRUDE OIL (by month) J F M A M J J A S O N D	REMARKS	SOURCE
Marine Bacteria	Pelagic, Surface to 100 m. Most less than 10 m.	Close to estuaries	?		Speculative and not highly probable	Friede et al. 1972
Phytoplankton - Diatoms predominant	General. Highest concentration in areas of upwelling and bottom surface of sea ice	Lagoons and estuaries. Offshore in summer	April - October			MIT 1972
Zooplankton and Micronekton	Pelagic	Inshore waters near Unimak Island and offshore waters near Cape Peirce. In outer Bay.	June through September		Speculative	Friede et al., 1972
Marine Macrophytes	Lagoons and protected bays. Intertidal to 20 m. Eelgrass on muddy sediments of protected bays	Izembeck Lagoon	Growing season		Mortality low unless contamination severe	Templeton 1972
Intertidal fauna - including clams	Intertidal or subtidal. Clams on sandy beaches	Throughout	Yearlong		Vulnerability moderate	MIT 1972
Clam Adults	Intertidal or subtidal. Various substrates, depending on species	Razor clams on Western Alaska Peninsula. Soft shell clams on north coast.	Yearlong		Vulnerability low	Blumer et al., 1971
Clam larvae	Shallows		July - November			MIT 1972
Benthic invertebrates	From shallow sandy bottoms to 100 m. Variable	Scarce. Density highest on periphery of bay	Yearlong		Low probability of impact except in shallows	
King Crab - Adults	Shallows. Males concentrate at 100 m. shallower waters in spring	Inshore, east of Unimak Pass. Summer concentrations in center of Bristol Bay	Summer concentrations		Vulnerability low owing to habits	
King Crab - Spawning	Subtidal to 100 m.	Inshore, east of Unimak Pass. Summer concentrations in center of Bristol Bay	April - May			
King Crab - Immature	Inshore shallows	Inshore, east of Unimak Pass. Summer concentrations in center of Bristol Bay				
King Crab - Larvae	Semi-pelagic to benthic	Inshore, east of Unimak Pass. Summer concentrations in center of Bristol Bay	Semi-pelagic, May-July			
Tanner Crab - Adults	Generally concentrate at 55-90 m. depth or less	West of 163° W. Long. and at center of Bay			Low probability of impact in deep water	
Tanner Crab - Spawning		West of 163° W. Long. and at center of Bay	January - mid May			
Tanner Crab - Larvae	Semi-pelagic to benthic	West of 163° W. Long. and at center of Bay	Semi-pelagic January - July			
Dungeness Crab - Adults		Scarce in Bristol Bay			Habits and vulnerability unknown in Bristol Bay	
Dungeness Crab - Spawning	Shallows	Scarce in Bristol Bay				
Dungeness Crab - Larvae	Semi-pelagic to benthic	Scarce in Bristol Bay	Semi-pelagic, January - July			
Shrimp (5 species) - Adults	Variable depths. Daily vertical migration. All rare in Bristol Bay. All occur on NW side of Unimak Is.	Scarce in Bristol Bay			Low probability of impact in deep water	U.S. Department of the Interior 1971
Shrimp - Spawning		Scarce in Bristol Bay				
Shrimp - Larvae	Semi-pelagic and benthic	Scarce in Bristol Bay	Free swimming larvae			
Scallops - Adults	Few in Bristol Bay	Scarce in Bristol Bay			Probably too deep for tainting	
Scallops - Larvae	Planktonic	Scarce in Bristol Bay	June and July			
Pelagic Invertebrates - Squid	None reported as significant	Unknown	Unknown			
Fish - non-commercial (16 families)	Varied habitats and depths	Varied	Yearlong		Variable exposure, depending on habits	Gutsell 1921
Pollock - Adults	45-110 m. depth or deeper	Outer Bristol Bay and north side of Alaska Peninsula			Deep water, no exposure	
Pollock - Spawning	50-200 m. depth	northwest of Unimak	March - May		Pelagic eggs	
Pacific Cod	55-90 m. or more. Spawn at 100-250 m. Eggs sink to bottom	South of Cape Newenham Offshore in winter			Deep water. Low probability of impact	
Black Cod	365-730 m. depth. Not in Bristol Bay	Not in Bristol Bay	Not in study area		Eggs and larvae float at surface	
Herring - Adults	Surface to 70 m. depth late spring - early autumn. Offshore in winter. Spawn along shore		Present in study area April, October. Spawn May & June		Damage to kelp would reduce spawning habitat	
Herring - Larvae		Shores of Bristol Bay. Kulukak Point to Togiak. Hagemeister Island. Shallows near Port Moller	Planktonic larvae			
Pacific Ocean Perch	145-460 m. depth along rocky bottoms	Edge of continental shelf west of the study area			Deep water. Low probability of impact	
Pacific Ocean Perch - Larvae	Pelagic in cooler, shallower waters for 2 or more years					
Flatfish (excluding Halibut)	Deep waters. Eggs of some may be pelagic	General distribution			Deep water. Low probability of impact except eggs of some species may be pelagic	
Halibut - Adults	More than 80 m. deep	Winter west of study area. Migrate east of study area in spring			Low probability of impact in deep water	
Halibut - Eggs and Larvae	Midwater eggs and larvae	North of Unimak Island	November - February		Eggs and larvae pelagic at mid depths	

TABLE 88 (cont.)

BIOTIC GROUP	HABITAT	AREAS OF PEAK ABUNDANCE	SEASON OF PEAK ABUNDANCE	REMARKS	SOURCE
Chinook Salmon - Adults	Shallow waters	Bear River, Izembek Lagoon streams, Nelson Lagoon, Port Heiden, Nushagak, Naknek and Togiak Rivers	June	Possible interference with migration	Rice 1973
Chinook Salmon - Immatures	2-4 years. Feed on small fish and crustaceans	Unknown	Unknown	Exposure uncertain	
Coho Salmon - Adults		Togiak, Nushagak and Ilnik Rivers, Port Heiden and Nelson Lagoon	August	Possible interference with migration	Rice 1973
Coho Salmon - Immatures	1-2 years, Feed on small fish and crustaceans	Unknown	Unknown	Exposure uncertain	
Chum Salmon - Adults		Togiak; Nushagak, Kvichak Rivers, Port Moller, Nelson Lagoon, and Izembek and Bechevin Bays	June and July	Possible interference with migration	Rice 1973
Chum Salmon - Immatures	4 years. Feed on small crustaceans		Unknown	Exposure uncertain	
Pink Salmon - Adults		Even years - Togiak, Nushagak, Kvichak Rivers Odd years - Bechevin Bay more important	Late June, early July	Possible interference with migration	Rice 1973
Pink Salmon - Immatures	1½ years. Feed on planktonic crustaceans		Unknown	Exposure uncertain	
Sockeye Salmon - Adults		Immigration offshore. Spawn mainly in Wood, Kvichak, Naknek, Egegik, Bear Rivers and Nelson Lagoon	Late June, early July	Possible interference with migration	Rice 1973
Sockeye Salmon - Immatures	1-4 years. Feed on planktonic crustaceans	Migrate slightly offshore of North Peninsula	Outmigration in mid-May - mid July	Smolts migrate at surface	Straty 1973
Trout and Char	Rainbow rarely in salt water in Bristol Bay	Char widespread, particularly in Togiak, Nushagak and Ugashik Rivers	Overwinter in fresh water	Exposure uncertain	
Black Brant	Bays with eelgrass and other vegetation. Marine feeders	Lagoons on North Peninsula, especially Izembek	Autumn, Spring	No data to adequately assess possible habitat damage	
Emperor Geese	Bays with eelgrass and other vegetation. Marine feeders	Lagoons on North Peninsula, especially Izembek. Winter in Aleutians and Western Peninsula	Autumn, Winter	No data to adequately assess possible habitat damage	
Canada Geese	Occasionally along coastal beaches	Numerous throughout	Autumn, Spring	No data to adequately assess possible habitat damage	
Puddle Ducks (mallard, teal, pintails, baldpates)	Bays, marshes, river mouths. Sometimes feed on salmon carcasses	Throughout. Some yearlong	Autumn, Spring	No data to adequately assess possible habitat damage	
Diving Ducks (Scaup)	Bays, shallow protected waters, Marine feeders	Throughout. Some yearlong	Autumn, Spring	No data to adequately assess possible habitat damage	
Sea Ducks (eiders, scoters, old squaws, harlequins)	Bays, estuaries, sometimes unprotected waters. Marine feeders	Throughout. Some yearlong	Autumn, Spring	No data to adequately assess possible habitat damage	
Mergansers	Bays, estuaries. Marine feeders	Throughout. Some yearlong	Yearlong	No data to adequately assess possible habitat damage	
Loons	Bays, estuaries. Marine feeders	Throughout	Fall and winter	No data to adequately assess possible habitat damage	
Grebes	Bays, estuaries. Marine feeders	Throughout	Fall and winter	No data to adequately assess possible habitat damage	
Albatross	Surface of open ocean and occasionally in tiderips	Not abundant	Summer	No data to adequately assess possible habitat damage	
Tubenoses (Shearwaters, fulmars, petrels)	Channels, passes. Marine feeders	Generally in western part of study area	Summer	No data to adequately assess possible habitat damage	
Storm petrels	Channels, passes. Marine feeders	Unknown	Yearlong	No data to adequately assess possible habitat damage	
Cormorants	Coastal waters. Dive for food. Nest in cliffs	North coast	Yearlong	No data to adequately assess possible habitat damage	
Oystercatchers	Intertidal rocks	Mostly west of Unimak Island	Scarce in study area	No data to adequately assess possible habitat damage	
Shorebirds	Intertidal or marine - mud flats	Throughout	Yearlong	No data to adequately assess possible habitat damage	
Jaegers	Partly marine feeders in open waters	Throughout	Yearlong	No data to adequately assess possible habitat damage	
Gulls and Terns	Colonial nesters, partly marine feeders	Throughout	Some yearlong	No data to adequately assess possible habitat damage	
Auks, murres, puffins	Colonial nesters, totally marine feeders in open waters	Throughout	Most yearlong	No data to adequately assess possible habitat damage	
Sea Otters	Offshore reefs and kelp beds to 75 m. depth	Southern shore of Bristol Bay from Port Moller west	Peak pupping April - June	Significant matting of fur eliminates insulation	Kenyon 1970
Steller Sea Lion	Along coast, rocky habitat. Winter in shelf and bays and river mouths	Shifting population centers. Disperse in winter. Northwest and southwest portions of Bay	Pupping in June	Susceptibility appears slight	Straugham 1973
Northern Fur Seal	Sometimes in outer Bristol Bay	Occasional only	Spring, summer & fall	Exposure uncertain	
Harbor Seal	Shallow water to 55 m. Sandbars and beaches	Southern coast of Bay	Pupping late May to early June	Susceptibility appears slight	
Walrus	Edge of ice pack	Walrus Island, Hagemeister Island and Amak Island	Summer & fall	Susceptibility appears slight	
Toothed Whales	Mostly offshore	Unknown	Unknown	Susceptibility appears slight	
Baleen Whales	Mostly offshore	Unknown	Unknown	Susceptibility appears slight	

VULNERABILITY TO DAMAGE BY CRUDE OIL (by month)



Key to Effects:

- Lethal toxicity
- Sublethal disruption of physiological and behavioral activities
- Effects of direct coating by oil
- Incorporation of hydrocarbons in organisms which cause tainting and/or accumulation of hydrocarbons in food
- Changes in biological habitats

aromatic derivatives, and stressed the high variability of results from studies, depending on type of oil, circumstances, and method of study. They classified impacts of hydrocarbons on organisms in five categories as follows:

1. Lethal toxicity.
2. Sub-lethal disruption of physiological or behavioral activities.
3. Effect of direct coating by oil.
4. Incorporation of hydrocarbons in organisms which cause tainting or accumulation of hydrocarbons in food chains.
5. Changes in biological habitats.

The first 2 categories refer to interference with cellular and subcellular processes. Effects of direct coating are the purely mechanical results that would occur from coating by any compound with physical characteristics similar to crude oil. Incorporation of hydrocarbons in organisms is important because of the potential for accumulation of carcinogens and tainting of human food supplies. These 5 categories are useful for analysis.

Table 88 lists the biotic groups that occupy the waters of Bristol Bay, characterizes their habitat (column 2), and points out areas and seasons of peak concentrations where known (columns 3 and 4).

These authors (MIT 1973) also provide a table interpreted from information of various studies, which outlines the estimated toxicity ranges of certain general biotic groups. These estimated ranges of critical concentrations of crude oil are in parts per million, as follows:

Flora	$10^4 - 10^5$
Finfish	$10^4 - 10^5$
Larvae	$10^2 - 10^3$
Pelagic crustaceans	$10^3 - 10^4$
Gastropods	$10^4 - 10^5$
Bivalves	$10^4 - 10^5$
Benthic crustaceans	$10^3 - 10^4$
Other benthic invertebrates	$10^3 - 10^4$

These figures, as well as other available data, have been used to estimate relative vulnerability of the marine biotic groups of Bristol Bay to oil pollution. Table 88 exhibits this vulnerability on a monthly basis in conformity with the life history of each group. The key at the bottom of the table indicates the category of impact. Its estimated relative severity is indicated by the thickness of the bar in Column 5. The severity is estimated relative to the population present in the study area, so even though a species might be scarce in the area, those individuals present might be very vulnerable. In this case the bar would be thick. Conversely, an abundant species might have a low susceptibility to damage and the bar in Table 88 would be thin, even though the population was large. Habitat damage is indicated in only a few places. Although habitat damage would be a factor in almost all cases, too little is known to appraise its extent.

Marine Bacteria. Crude oil can be a food for certain marine bacteria (Kinney et al. 1969, Friede et al. 1972). Friede et al. (1972) suggest the possibility that carcinogenic petroleum hydrocarbons could be concentrated by bacteria and passed up the food chain.

Phytoplankton. Although MIT (1973) reports highly variable results from this group, the toxicity effects appear low.

Zooplankton. MIT (1973) states that most zooplankton are filter-feeding crustaceans commonly found in the surface layers of coastal waters. They would, therefore, be subject to concentrations of oil-water emulsion. Friede et al. (1972) also points out that zooplanktonic filter feeders may also concentrate carcinogenic compounds and pass them up the food chain or deposit them on the bottom as fecal pellets.

Marine Macrophytes. Little is known about the effects of oil on marine macrophytes. However, Templeton (1972) stated that plants covered with oil produce new shoots unless the plant bases and surrounding soil have become contaminated. Individual seedlings and annuals rarely recover. Overall effects on macrophytes appear moderate.

Intertidal Fauna. MIT (1973) considered findings from a number of studies that showed highly variable effects in this group. Susceptibility appears low in bivalve mollusks and periwinkles. Some groups, such as limpets, exhibited high susceptibilities even at low concentrations of oil.

Clams. Blumer et al. (1970) reported prolonged tainting of commercial clams resulting from a spill of fuel oil. MIT (1973) treated larvae as a single group with relatively low resistance to the toxic effects of oil.

Benthic Invertebrates. This group contains many species and forms living in various habitats. Most are in deep water, however, and are assumed to be relatively invulnerable to oil. Egg and larval stages of many species, however, float on the surface or with the current (Wilber 1969) and would be vulnerable.

Crabs. Most adults are deep water dwellers and are assumed to be relatively immune to damage. During spawning, they move into the shallows and their exposure would increase at that time. In summer, Dungeness move into shallower water.

Some heavier fractions of oil may sink to the bottom (Friede et al. 1972) and remain for some time. Shellfish have been tainted and their marketability reduced by exposure to even slight amounts of oil (Blumer et al. 1970, Wilber 1969). No such instance has been reported in Cook Inlet, however, where active crab fisheries have undoubtedly been exposed (Kinney et al. 1969, Evans et al. 1972). The importance of this factor in Bristol Bay cannot be forecast.

Larvae are assumed to be vulnerable during the period they are planktonic. Immatures could also be vulnerable in shallow water. The National Marine Fisheries Service is conducting studies of the toxic effects of crude oil on tanner crab.

Shrimp. The northern shrimp, *Pandalus borealis*, has commercial potential in the study area. It prefers depths of 90 m. or more. Other species prefer shallower waters. Shrimp undertake a vertical migration toward the surface at night and would be more exposed at that time. Shrimp are most vulnerable in the larval stage.

A catch of shrimp at Kodiak was reported to be coated with oil during the 1970 Kodiak oil spill incident (U.S. Department of Interior 1970b). The effect of sinking oils on the potential marketability of commercial shrimp in Bristol Bay is not predictable, although shrimp could be tainted, particularly during their nocturnal migrations to the surface.

Scallops. Only the weathervane scallop is large enough to be of commercial quality, but it is rare in Bristol Bay. Blumer et al. (1970) cite serious and long-lasting tainting of scallops as a result of a spill of fuel oil near West Falmouth, Mass. If scallops in Bristol Bay prefer depths greater than 60 m. as they do in the Gulf of Alaska, it seems unlikely that many of them would be affected. Planktonic larvae would be the most vulnerable.

Pelagic invertebrates. No pelagic invertebrates are listed as significant in Bristol Bay, although squid are mentioned as food for sperm whales in the Bering Sea. MIT (1973) reports pelagic crustaceans are moderately vulnerable to toxic effects of oil. Although effects on squid are unknown, it would affect their food supply.

Fish, Noncommerical. Numerous species in the 16 families of noncommerical fish use various habitats ranging from the surface to considerable depths. Most of the deep water species would probably be immune to the effects of oil. A species living in shallow water, either permanently or during a shallow-water stage of its life cycle, could be susceptible.

Wilber (1969) quotes Gutsell (1921) as follows: "The eggs of sea fishes which do not seek fresh, brackish, or shore waters in which to spawn, differ from the eggs of all these and of fresh water species in that they are typically floating. In many cases, at least, the larvae for a time are also floating." Most of these species would thus be susceptible to damage from oil at some stage in their life cycle.

Pollock, Pacific Cod, Pacific Ocean Perch, and Flatfish. These are all benthic forms living in deep water. They would be vulnerable only for short periods during spawning and in the larval stages.

Herring. This shallow water species spends most of its life cycle near shore. Planktonic larvae and spawning adults are particularly susceptible to toxic effects (Kunhold 1970). Their spawning activities would also be affected if the kelp upon which they deposit their eggs were damaged.

Salmon. Salmon adults are usually found in shallow habitats and could be affected by toxic elements in the water. More importantly, Rice's (1973) work indicates that crude oil could upset migration patterns by upsetting their olfactory senses. This might cause heavy losses to an entire year class if the spawning migration were unduly delayed. Smolt and fry migrate in shallow water and would be highly vulnerable. On the other hand, his work also demonstrates that pink salmon fry avoid crude oil and might escape its effects if an alternate migration route were available.

Trout and Char. The rainbow trout of Bristol Bay does not migrate to salt water. Not enough is known about the habits of char in salt water to appraise its vulnerability. Presumably, it would be similar to salmon.

Black Brant and Emperor Geese. These are entirely marine feeders and would be highly vulnerable to losses from the mechanical effects of oil.

Erickson (1963) and Aldrich (1970) describe the effects of oil on birds. Oil mats their feathers, reducing their buoyancy and insulation ability. Not only is the affected bird chilled and hindered in its mobility, but it may, while preening, ingest some oil and be subject to its toxic qualities. Birds cannot recognize oil spills and avoid the danger. Birds whose habits bring them into closest contact with oil would be most susceptible.

Canada Geese and Puddle Ducks. To the extent that these species are less oriented to marine habitats, they would be less susceptible than emperor geese and brant.

Diving Ducks. These species use the study area all year, but nest in fresh water. They would be most vulnerable in fall winter, and early spring when they are on salt water.

Sea Ducks. Except for nesting of scoters and the harlequin duck, sea ducks are entirely maritime in habit and would be vulnerable most of the year. The greatest numbers of these birds would be in the study area during spring and fall migration.

Mergansers, Loons, and Grebes. These species nest on fresh water and winter on salt water. Their vulnerability would be similar to that of the diving ducks.

Albatrosses. These birds are found in Bristol Bay in summer and could become trapped in any oil spilled in their feeding areas, particularly in tiderips, where both spilled oil and birds tend to concentrate.

Tubenoses and Storm Petrels. These birds are totally marine feeders and would be highly susceptible to mortality from oil.

Cormorants. Although the double-crested cormorant sometimes nests in fresh water, the two other cormorant species nest adjacent to marine habitats. In winter, all feed on exposed open water and could be caught in spilled oil during that period.

Oystercatchers and Shorebirds. Birds of this group feed in the intertidal zone and could be affected by oil washing ashore.

Jaegers. All the jaegers are associated with salt water, the parasitic and pomarine jaeger more so than the long-tailed which nests inland. These birds do not feed on the water but could come in contact with food contaminated by oil. Their risk of exposure to oil is not as high as marine feeders.

Gulls and Terns. Birds of these groups that nest in colonies adjacent to salt water or that winter on salt water would be highly vulnerable to oil pollution.

Auks, Murres, and Puffins. These birds spend all their time in or on salt water, except for the periods these birds are engaged in nesting activities. This group is probably the most susceptible of all birds to losses from oil.

Sea Otters. A sea otter depends on the cleanliness of its fur for warmth; consequently, anything that would mat its coat could be fatal. These animals spend their entire lives in salt water and could suffer high mortality from spilled oil.

Other Marine Mammals. Straughan (1973) reports no detectable damage to sea lions or elephant seals as a result of oiling during the Santa Barbara oil spill. Marine mammals of Bristol Bay, with the exception of sea otters, are assumed to be relatively resistant. Nursing young, however, might ingest toxic quantities and suffer damage. Any loss of food supplies would be injurious to their populations.

Special Circumstances. Species at the end of their range, already stressed by environmental conditions to which they are not well adapted, and species already harvested at or beyond their limit, could be particularly vulnerable to any additional stress.

Impact of Spilled Oil on Upland Biota

A combination of storm and high tides could drive oil onto coastal marshes and beaches and would cause losses in such groups as puddle ducks and shorebirds. A large number of terrestrial mammals such as mink, weasels, river otters, foxes, muskrats, beavers, bears, and otters could be exposed to oil either directly or through their food supply. Impacts from such contact would probably not be severe. Damage to their habitat, however, would be significantly destructive. Repeated severe contamination could eliminate important habitats. The degree to which chronic low level pollution could alter habitats is unknown, although it is obvious that such polluted harbors, as Kodiak, are not productive marine habitats.

Other predominantly terrestrial species which occasionally contact salt water while feeding, such as eagles and some hawks and falcons, could also be affected.

EFFECT OF PETROLEUM DEVELOPMENT ON OTHER RESOURCE USES

Impact on Fisheries

Presently, the only major industry in the study area is fishing. Conflicts with other industries are minimum. If another large industry, such as petroleum, were to move into the area, certain impacts and conflicts with the fisheries might arise.

Ships and boats needed to support petroleum activities would considerably increase traffic in the area, causing additional navigational hazards to the fishing fleet. Increased traffic would also increase competition for the already overcrowded port facilities. Presently, no major harbor facilities exist in the study area.

Petroleum development activities would take up space now being used for fishing activities; this problem is discussed by the U.S. Department of Interior (1973). Allowing for a navigation safety zone, it estimates that each platform would occupy between 8,000-20,000 sq. m. Other obstructions, such as unburied pipelines, seafloor completions, wellhead stubs and debris, could be hazards for trawling operations.

Petroleum developments almost anywhere in Bristol Bay would interfere with some type of fishing activities. Summer activity near major salmon runs could cause conflict. King crab fishing takes place in the North Peninsula district during autumn and early winter. Tanner crab fishing takes place in the same area, and activities of surface vessels could conflict with crab fishing operations.

Gravel extraction from streams could affect fish spawning habitats. Such activities in anadromous fish streams require a permit from the Alaska Department of Fish and Game which would include stipulations for protection of fish resources. Similar activities on other streams and on tidelands require a permit from the Alaska Department of Natural Resources. The proposal would then be reviewed by the Alaska Department of Fish and Game which would recommend stipulations.[1] Activities on navigable waters would be by permit from the U.S. Army, Corps of Engineers. Applications for Corps permits are circulated to interested parties for comments and recommendations. Such recommendations may be included in the permit as stipulations to protect resources. In some cases, permits may be denied by these agencies.

Spilled oil can have direct impact on fishing activities. During the development phase of the Cook Inlet oil field, fishermen frequently complained that even a thin film of oil on their nets, rendered them stiff and difficult to handle and accelerated deterioration. The 1970 Kodiak incident also resulted in oily gear. That same autumn, prior to the Kodiak incident, a shrimp fisherman reported his trawl had picked up a tar-like substance that contaminated his shrimp catch (U.S. Department of Interior 1970b).

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1. Jay Bergstrand, Assistant Chief, Habitat Section, Alaska Dept. of Fish and Game, Anchorage, Alaska. Personal communication.

Geophysical surveys using high velocity explosives, such as dynamite, nitromon, or geogel, have resulted in mortality to fish under varying circumstances. Falk and Lawrence (1973b) discuss both refraction and reflection surveys conducted with a variety of devices including vibroseis, dinoseis, flex-o-gun, pan air gun, seismogen air gun, aquapulse, and sparker. They experimented with various charges and determined that the air guns are relatively harmless to fish. This is substantiated by experiments conducted by Weinhold and Weaver (1972) on coho salmon in Alaska.

The major conflicts presented by marine geophysical surveys result from the use of high velocity explosives and through the disturbance of fishing activities. Surveys are now being conducted successfully without explosives and there is little indication that they will be used in the Bristol Bay (Alaska Oil and Gas Association 1973).

Conflicts between seismic operators and fishermen may be resolved by avoiding the use of explosives and planning surveys outside the neighborhood of fishing activities. Such coordination and planning probably could have avoided the recent (September 1973) incident in Kachemak Bay, where seismic boats became entangled in and destroyed crab pot floats. A review of proposed programs by the Alaska Department of Fish and Game or the National Marine Fisheries Service should minimize such problems.

EFFECTS OF RESOURCE USE ON THE SOCIO-ECONOMIC CHARACTER OF THE AREA

The study area is largely rural and much of it is undisturbed wilderness showing little evidence of man's activities. More than 8,000 sq. km. on the Bristol Bay side of the Alaska Peninsula are in permanent status as National Monument or National Wildlife Refuge. These areas are managed by agencies with responsibility for considering at least a portion of these lands for primitive and wilderness status under the Wilderness Act of 1964 (Public Law 83-577). Additional lands are withdrawn under the Alaska Native Claims

Settlement Act of 1971 (Public Law 92-203) for possible inclusion into one of these management systems. Proposals include a Togiak National Wildlife Refuge spanning Hagemeister Island and the upper Togiak drainage, additions to Katmai National Monument, and an Iliamna National Ecological Range to be managed like the refuges. The rugged coastlines and islands and extensive lagoons form a spectacular landscape.

Outside of the Bristol Bay Borough (80 percent non-Native) and Cold Bay (mostly non-Native), most of the residents of the study area are Natives--Unalaska Aleuts to the southwest, Aglemiut Eskimos to the southeast, Kiatagmiut Eskimos in the Kvichak River basin, Nushagagmiut Eskimos in the Nushagak River basin and Togiagmiut Eskimos in the Togiak River basin. These village people are predominately maritime (Hickok 1968). Hickok (1968) emphasizes that the Aleuts depend on their knowledge of the sea for a livelihood. This is also true to a large extent of the Aglemiut, Kiatagmiut, Nushagagmiut and Togiagmiut, although they are converting more rapidly than the Aleuts from a subsistence economy to dependence on the commercial fishery. To these people, the sea is a way of life that has undergone only gradual change for generations.

Arnold (1968) described village Alaska with all its economic, educational, health, and service problems. He summarized as follows: "Village Alaska will persist because of circumstances and choice. What this means is suggested in the remarks (relating to American Indians generally) of an Indian Association spokesman." Arnold then goes on to quote Munschenheim[1] as follows:

> I am never surprised, but always dismayed, when well-meaning but poorly informed people ask why do not the Indians integrate themselves more effectively into the general society. . . to reply simply that probably they'd rather not, or, contrariwise, that they do not have the opportunity to integrate, would not, either way, properly answer the question. Nor would it be very informative to reply that for the most part they do not have the opportunity and that, in any case, they have strong attachment to their own cultural heritage and are understandably ambivalent in their reactions to the alien society which has engulfed them. This is, it seems

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1. Carl Munschenheim, "The National Significance of Indian Health," speech delivered before the Fourth National Conference on Indian Health, Nov. 30, 1966.

> to me, a reasonable statement of the case, but it is quite meaningless to anyone who is unfamiliar with the values on the one side of the equation, namely the character and quality of the cultural heritage to which Indians are attached.

The primitive maritime lifestyle of the Natives in the study area seems well established. The adherence of the approximately 600 non-Natives in the villages, and the non-native residents of the Bristol Bay Borough and Cold Bay, to such a lifestyle is more difficult to appraise. Most of the military are transient and any impact on them would be temporary. Many other non-Natives are, however, permanent or semi-permanent residents of the area. Perhaps they feel this same quality of life compensates for generally low incomes, inconveniences, and high priced manufactured goods.

Steinhoff (1969), in a study of the value of wildlife and related recreation on the Kanai National Moose Range, analyzed how Alaska residents rated the values of accessibility, facilities, wilderness, wildlife, and scenery. He determined that 76 percent of the Alaska-resident respondents to his questionnaire listed the Moose Range as one of the factors that induced them to stay in Alaska. A large preponderance of Idaho residents listed similar amenities of environment, open space, hunting and fishing, and outdoor recreation as their major reasons for remaining in Idaho.[1]

Pearse (1971), in discussing the proposal for an International Arctic Wildlife Range, emphasized the non-industrial values that, though difficult to measure, must be recognized and equated with industrial values. Large expanses of wilderness with its wildlife and the existing way of life of the Native people are among these values. He emphasized that once destroyed, neither can be reconstructed.

Weeden (1969) suggested that petroleum development could be carefully controlled and could provide economic benefits to the state with minimum disruption of these values. He stressed that this would require a rigid acceptance of a middle course of restrained development which has not yet been achieved in Alaska. Petroleum development in Cook Inlet has had considerable impact on these non-industrial values (Evans 1969). A sizeable petroleum development anywhere in Bristol Bay would have significant impact on

1. R. Knight and M. Hornocker. A Quality Life in Idaho. College of Forestry, Wildlife and Range Sciences, University of Idaho. Unpublished manuscript.

many miles of shoreline and would destroy the wilderness character of the area. The haste to explore the Arctic Slope oil fields has also led to the visual and erosional impact described by Brooks et al. (1971). The "Hickel Highway," pushed through the Brooks Range without advance notice, consideration of impact on other resources, or consultation with affected peoples, is a case in point. The Natives of the Arctic Slope, and Anaktuvuk Pass in particular, are most concerned about the effect this type of access will have on their way of life (Upicksoun 1973). Norgaard (1972) believes that the major costs to Alaskans of petroleum development will be in terms of wilderness, hunting and fishing, and outdoor recreation--the amenities that have great value to many of the state's citizens.

Even if not a drop of oil is spilled, there will still be roads, increased traffic, construction of shore-based facilities, removal of construction materials, and new population centers which will have tremendous impact on the aesthetic and wilderness character of the study area.

For instance, the stimulus of petroleum development might accelerate construction of a highway connection between Anchorage and Naknek that will greatly affect residents of the area. These activities, the lure of jobs (however transitory), probable increased cost of living, and unplanned access to the land will cause changes in the lifestyle of village Alaskans within the study area. Whether or not these changes are desirable in the long run, they will, as Pearse (1970) pointed out, be irreversible. Arnold (1968) indicated that they may be undesirable, particularly if they occur too rapidly. Only the people involved can make this decision.

Population data may even indicate a shift toward deurbanization by Native residents, who are emigrating from the Bristol Bay Borough and Dillingham, back to such villages as Togiak, Twin Hills, Manokotak, and New Stuyahok. These smaller Native villages are currently growing much faster than can be accounted for by natural rate of increase. This could mean that Native residents wish to maintain a subsistence economy and avoid many of the complexities which development is bringing to the larger Bristol Bay towns. If this is the case, petroleum development and its ensuing economic stimulus to the surrounding area could further aggravate the current Native concern over the imminent loss of a traditional life style.

DEVELOPMENT SCENARIO

In this segment of the report a series of events common to petroleum development will be presented. Its interactions with the environment, the existing people, and other industries will also be discussed. Since possible combinations of events are unlimited, this discussion indicates only the more probable occurrences and is in no way an exhaustive presentation. Three stages of developmental interaction will be discussed--exploration, construction, and long-term impact. In addition, the effects of a major oil spill in the study area will be considered.

Exploration

Geophysical exploration in the marine environment could be conducted from a base of operations outside the study area. Survey vessels could work in Bristol Bay during ice-free months with only a rare call at a Bristol Bay port for supplies or a medical or mechanical emergency.

Exploratory test drilling in the offshore area might demand more calls at Bristol Bay ports because it requires large amounts of supplies which would be flown in and shipped to the drilling site. The Bristol Bay Borough would probably receive much of the traffic for exploratory work in the inner Bay, while Cold Bay might handle such activities for work in the outer Bay. Dillingham would probably handle smaller amounts of traffic due to its location.

Exploratory work could be conducted with little damage to the marine and coastal environment. New methods of seismic exploration are relatively harmless to the environment (Falk and Lawrence 1973b). On the other hand, toxic drilling fluids, various spills, and debris could cause limited damage around drilling sites (Falk and Lawrence 1973a).

The extent of damage would depend upon the depth of water at the drilling site and the strength of local currents acting to disperse pollutants. Activity in shallow water with little current flow could probably damage such benthic and intertidal organisms as are unable to avoid pollutants.

Conflicts with other resource users could arise if exploratory activities were to occur in the same area as intense fisheries for crab, groundfish, or sockeye salmon. Disputes could arise over destruction or damage to stationary fishing gear (crab pots, set nets) by an exploratory drilling vessel on an important fishing ground at the peak of the fishing season or from the disruption of an anticipated movement of commercial stock due to activity or an encounter with pollutants along their migratory route. The coastal zone might be littered with debris or garbage dumped from vessels and floated onto the beaches.

Construction

Once a significant petroleum discovery has been made, several alternatives for development are available. Three of the more viable alternatives for Bristol Bay are: (1) an offshore collecting and port facility; (2) an onshore collecting and port facility; and (3) an onshore collecting facility with a pipeline crossing the Alaska Peninsula to a port on the Gulf of Alaska. The first and third alternatives are more viable since the second choice would necessitate expensive port construction and maintenance in the shallow Bristol Bay coastal zone. The first alternative would require year-round ship traffic in Bristol Bay, whereas the third choice, after construction, would reduce the need for permanent facilities and personnel in the Bristol Bay area.

The greatest socio-economic impact would occur during the construction phase. In most cases crews could be restricted to camps and isolated from Bristol Bay communities. Construction of an airfield at the development site would permit supplies, materials and personnel to be shipped directly to the site. Under these circumstances, local residents willing to live in isolated construction camps could be hired without development activities intruding on local communities.

If the subsistence capabilities of the area are to be maintained, planning and control of access will be needed to minimize disturbance and competition from sport hunters and camp personnel. When construction occurs near a critical seasonal habitat of waterfowl, salmon, crab, or other species, special precautions should be taken during the critical season to reduce detrimental interaction. It might be helpful to allow local labor to participate in the sockeye salmon fishery. This might give local residents the option of participating in construction activity without disrupting seasonal subsistance activities

In the past, construction activities have led to large accumulations of debris. Proper planning could eliminate this problem. Deep sandy sediments present few engineering problems for offshore construction. Bristol Bay, however, has a seasonal ice pack which, combined with winds and tides, necessitates careful design.

Long Term Impacts on Communities in the Study Area

Petroleum development in Bristol Bay would have a permanent impact on residents of the area, most of whom depend primarily on biotic resources of the sea and adjacent uplands. Quite apart from the possible long-term effects of oil pollution, any alteration of habitats on which fish and wildlife resources depend will affect the economy of these communities.

Even if the petroleum development and production activities were carried out entirely by imported personnel isolated in company camps or towns on a rotation basis, their presence and the accompanying development would stimulate increased transportation and supply activities. Airline and shipping personnel in nearby communities could be expected to increase with a concurrent increase in state and federal employees. Governmental agencies would also undergo expansion to cope with the petroleum development activity itself. For instance, the U.S. Coast Guard, with its responsibility for pollution control in navigible waters , would have a greatly expanded area of responsibility.

A productive oil field would almost certainly stimulate such permanent developments as airfields, highways, and harbor facilities that might not otherwise have been constructed. These activities would have two possible results:

1. If the local labor force were not absorbed into these activities, there would be a cash-oriented population superimposed on the subsistence-oriented residents of the study area. These two populations would then compete for goods and services and cause increases in the price of consumer goods. This would also increase the demand for public services and create new tax loads.

2. If the local labor force were absorbed in these activities, they would adopt a more cash-oriented life style. To the extent that this provided permanent opportunity for suitable employment, it might be a benefit. If, however, it proved to be a temporary employment situation, it would probably encourage

a more costly life style and a greater desire for services that could not be supported once the activity subsided. This would be particularly true if subsistence skills were lost through disuse.

If secondary industrial developments occurred as a result of petroleum production such as gas liquifaction plants or refineries, the impact on the cost of living and the tax base would be prolonged.

Oil Spill Incident

Given the present state of knowledge, the total impact of a given pollution situation on the biotic productivity of the study area cannot be predicted with any degree of accuracy. However, two points should be stressed. First, the Bristol Bay area is a highly productive ecosystem. Among its resources are internationally important salmon fisheries, as well as bottomfish, and shellfish stocks. The area supports essentially the entire world population of emperor geese, and spectacular populations of other birds, sea mammals, and riparian wildlife. Secondly, the economy of the entire Bristol Bay area is based upon its fisheries and related subsistence resources.

The potential for diversification in this area is limited. Attempts have been made to develop freshwater commercial fisheries, but have not met with success since production rates are low and costs of operation are high (Metsker 1967, Yanagawa 1967).

Significant damage to biological resources or habitats in Bristol Bay would be a disaster of greater magnitude than if it occurred in an area with a broader economic base.

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DATA GAPS

INTRODUCTION

Except for local areas, little environmental information about the study area is available. The amount of detail available varies with the topic, location, and time of year of observations. There are enough data to provide a general understanding of the study area, but detail is not available to provide an adequate baseline to determine change which might result from development. A few of the more significant data gaps are discussed below.

GEOMORPHOLOGY

Perhaps the most significant lack of data under this category is the absence of detailed bathymetry in the nearshore zone. This area is poorly charted, and existing charts become quickly outdated as beach lines erode and migrate. Navigation in many coastal bays and lagoons requires local pilots for all but the smallest vessels, due to shifting channels and bars. No detailed navigation charts exist for the coast between Cape Constantine and Cape Newenham. Any offshore development would require bathymetric studies.

OCEANOGRAPHY

Oceanographic investigations in the Bristol Bay area have been conducted sporadically during the past 45 years. These studies have mainly been oriented towards evaluating the fisheries of the region. Only recent studies have gathered baseline data that could lead to a basic understanding of the entire air-sea system. Most of the data have been collected in the offshore central Bay; few data exist for the inshore areas. Such observations as have been made in the inshore area are scattered in location and time. Most observations have been made during summer months, usually between mid-June and mid-July. Because of unfavorable weather conditions at other times of year and the remote location of the study area, no systematic studies of the physical environment in Bristol Bay have been conducted.

Lack of repeated sampling of sites over an extended period limits the knowledge of the variability of physical and chemical parameters in this environment. Since "normal" conditions have not been sufficiently defined, "abnormal" conditions which may substantially affect the character of this environment cannot be recognized.

Most of the physical oceanographic parameters collected yeild little insight into the short-term variations of conditions over the continental shelf. Apparently, the air-sea interaction over the shelf modifies oceanographic conditions to a large extent and requires local data before local dynamics can be completely understood. Synoptic surveys are required before the entire Bay system, which responds so rapidly to changing weather, can be comprehended. In order to define short-term variations over this vast and changeable area, sampling of the entire area within a short period of time is required, otherwise variations within the system will confuse the analysis. Several ships should be coordinated in order to sample the entire Bay in a week or less.

Studies are lacking which would document the frequency, conditions of generation, and extent of the inflow of cold, deep water from the north and west into Bristol Bay.

Limited chemical data are available for this area and have been gathered sporadically. Chemical properties change daily and seasonally. Water chemistry is closely related to the physical transport and dispersion of water masses. Most of the present data consist of short-term observations of specific chemical parameters. These data are of little value in evaluating long-term changes. No information exists on the seasonal effects or dynamic processes which control these concentrations.

Circulation patterns are only generally understood, and existing knowledge is insufficient to predict the movement of oil spills in the marine environment. An extensive drift card study is required, with a coordinated shoreline survey for stranded cards.

CLIMATE

Available climatic information is of limited value. Development at a specific location will require detailed local data. Gathering of data will be difficult and costly because of the remoteness of the area and the lack of local personnel to run stations. Even then, data for a specific site may not become useful until that site has been occupied for some time.

Specific information on reported wind speeds and directions is currently insufficient to use for predicting the movement and dispersion of oil spills.

Knowledge of offshore weather could be increased by weather buoys. Such a buoy is currently operating in the Gulf of Alaska, southeast of Kodiak, but is still being tested and is encountering operational difficulties. There are no plans for use of any buoys within the study area. Some offshore data could be gathered on platforms if they are constructed in the area.

GEOLOGY

Only a basic geologic framework can be established from existing reconnaissance work. No detailed reports or geologic maps on a scale of 1:63,360 have been published for the area. Offshore information is almost entirely lacking. Although some detailed information about the area has been obtained by petroleum and mining companies, most is of a proprietary nature and is not available to the public.

The oil and gas potential of the study area is essentially unknown. The actual outlines of potential basins, especially offshore, have not been adequately defined. This potential will remain purely speculative until more wells are drilled and the area is adequately tested, particularly offshore. Apparently no large scale efforts will be made by petroleum companies to obtain additional geologic data in the study area until there is some assurance of a lease sale, although some companies may continue reconnaissance studies. Exploration interest and activity in the area could change drastically, however, if a significant discovery were made at the Cathedral River well, which is presently being drilled just north of Cold Bay.

Other physical resources of the area have not been evaluated. Mineral potential is probably high in certain areas, especially at Goodnews Bay area and north of Dillingham. Further intensive exploration probably will not be carried out, however, until land status is decided. The geothermal and wind power potential is also high, and may be further evaluated in the near future. The University of Alaska, Geophysical Institute is investigating the feasibility of an experimental windmill farm at Cold Bay.

Knowledge of sand and gravel resources will be critical for development of onshore facilities. The Resource Planning Team of the Joint Federal-State Land Use Planning Commission has tentatively identified streams that could have sand and gravel resources.

The overall extent and rate of coastal beach erosion in the area is unknown, but it is known to be a problem in certain communities such as Dillingham. Soils and surficial deposits have not been mapped. Constraints on coastal engineering procedures in the area cannot be formulated until this information is obtained.

Another geologic problem is the prediction of earthquakes and volcano eruptions. The establishment of a seismic net in the Shumagin Islands in the summer of 1973 is the first step toward earthquake prediction in that area. With recent breakthroughs in earthquake prediction capabilities, there is a good chance that some major losses at present and future facilities in the study area could be avoided. Volcanic eruptions probably could be predicted also. The seismic stations on Augustine Volcano do not provide the data needed to predict volcanic eruptions in Bristol Bay.

HYDROLOGY

No detailed hydrologic data are availalbe for the study area, except for the Nushagak-Kvichak area where water quality and sediment samples are collected at a few stream-gaging stations.

Development of onshore facilities would require a careful evaluation of water availability at the site. Observations of streamflow and assessment of water quality over several years would be necessary to evaluate potential for stream water utilization, and test wells would have to be drilled to evaluate groundwater yield and permafrost conditions. Careful evaluation of potential flood hazards for onshore facility sites also would be an important aspect of any development plans.

BIOLOGY

Life history information is deficient for many species inhabiting Bristol Bay, particularly marine bacteria, phytoplankton, and zooplankton. Information on seasonal abundance is fragmentary at best. For most species, qualitative and quantitative data are totally lacking.

Migration patterns of many species are totally unknown. Although the migration of sockeye has been studied in some detail (Straty 1969), such information is lacking for other commercially important species. Only fragmentary information is available on inshore and offshore movements. There are also few data on environmental conditions that limit species at the extremes of their range.

Little has been done to correlate bottom sediments with observed habitat utilization by marine fauna. Such information is crucial if future changes are to be analyzed with reference to the environment existing prior to any petroleum development. The factors in the marine environment that might cause sockeye salmon populations to fluctuate widely are unknown. For most commercially important species, data on which to establish optimum harvest rates are lacking. Therefore, the impact of changing the habitat through petroleum development cannot be appraised.

The interrelationships among marine species and their habitats are unclear. For instance, the extent and duration of the impact of damage to zooplankton or to marine macrophytes on higher trophic levels is unknown. The effect of cumulative stresses, including those resulting from development, are not known for any species.

The effect or significance of an environmental change cannot be measured because baseline data in this ecosystem are totally lacking. For instance, Black (1973) points out that knowledge of the normal growth rates of a mollusk's shell could be used as a rough measure of the impact on it resulting from an alternation of its habitat. No such growth information is available for species in the study area. The National Marine Fisheries Service has initiated studies in Prince William Sound to establish present hydrocarbon levels in invertebrates. Similar studies should be conducted in Bristol Bay.

In general, the basic effects of oil on organisms and their food chains are poorly understood. Although the MIT (1973) Offshore Oil Task Group lists the impact of oil on many species, little work has been done in cold water areas that could be applied to Bristol Bay. Few comprehensive studies have been conducted of oil spills. The work of Blumer et al. (1970) on the West Falmouth, Massachusetts, oil spill is probably the most comprehensive. Even that, however, lacked baseline data to compare with changes that might have resulted from the spill. The mechanisms of toxicity have not been worked out, particularly with regard to the ability of organisms to concentrate potentially carcinogenic compounds which may be passed upward through the food chain.

Some studies have opened up entirely new questions. Rice's (1973) study of avoidance of oil by pink salmon fry raises the possibility of interference with olfactory mechanisms that guide migration of both fry and adults. On the other hand, these fish might have the capacity to avoid oil whenever they have the opportunity.

Some work has been done on predicting the course and dispersion of an oil spill. Warner et al. (1972) applied the factors of Coriolis force and vertical kinematic eddy viscosity to wind and current data to derive a model that would have predicted the course of the Chedabucto Bay spill.

With data available from local sources, such as fishermen and weather forecasters, the course of a spill in Bristol Bay could, within resnable limits, be predicted about two days in advance.[1] Long-term predictions would, however, require better data on winds and currents than are available at present for most of the study area. More climatological stations could provide such data.[2]

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1. F. F. Wright, Oceanographer, Marine Advisory Program, University of Alaska, Anchorage, Alaska. Personal communication
2. H. W. Searby, Climatologist, Arctic Environmental Information and Data Center, Anchorage. Personal communication.

Some work has been done on rates of biodegradation of oil (Kinney et al. 1969, Friede et al. 1972). It is known that the rate varies inversely with temperature, but much has yet to be learned about the rate at which oils will change form and toxicity under various conditions.

SOCIO-ECONOMIC

A review of the socio-economic data for the study area reveals several particular data gaps.

1. Ethnology of Rural Populations. Although current and past life styles have been described, it is not known how rural inhabitants feel about the desirability, extent, and direction of future change. Natives may develop this information as they proceed with land selection under the Alaska Native Claims Settlement Act (PL-92-203).

2. Land Tenure. Perhaps the most significant data gap involves future land tenure. The land situation is currently in a state of flux pending settlement of the Alaska Native Claims Settlement Act (PL-92-203). It is probable that a large portion of the coastal zone

probably will be under either private ownership or controlled by individuals, Native villages, and regional corporations. This could include most of the north shore of Bristol Bay from Naknek to Togiak. How this private control of a large portion of the coastal zone will affect development in the area remains to be seen.

3. Tourism. Data on the potential for tourism in the Bristol Bay area is not adequate. Some studies have been made in adjacent areas being considered for parks and monuments.

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ALTERNATIVE METHODS FOR PETROLEUM DEVELOPMENT

INTRODUCTION

Environmental conditions characteristic of Bristol Bay do not appear to pose any insurmountable technological problems for petroleum exploration and development. Weather conditions in the Bay can be severe, but are not as extreme as in other areas such as the North Sea or the Gulf of Alaska, where petroleum operations are or will be conducted. Frequent periods of low visibility, both at the surface and in the air, could interrupt operations as well as require sophisticated navigational aids. Stress from the waves in the Bay is anticipated to be less than in other offshore areas, and no design problem is expected.

Perhaps the most obvious potential design concern is the Arctic ice pack which extends into Bristol Bay during winter. Normally, the northern half of the Bay is covered with ice between December and April. This one-year ice usually varies from 0.6 to 1.2 m. in thickness and has a fairly low failure strength. The southern half of the Bay is ice-free except in unusual winters when the pack extends further south, primarily along the shore. Ice conditions would not be much worse than those experienced in Cook Inlet. In fact, they may even be less of a problem due to the absence of extreme tidal currents. In addition, the higher salinity of water gives the ice in Bristol Bay less strength than the fresh water ice in Cook Inlet. The failure strength of ice is one of the most important factors in design of structures.

Water depth also affects development. Since most of the Bay is less than 100 m. deep, depth presents no great problem unless development were to extend further southwest toward the edge of the continental shelf.

Another consideration in planning any development is that Bristol Bay lies on the fringe of an active earthquake zone. Seismic design loads in Cook Inlet are actually only one-third the ice loads and probably will be even less of a problem in Bristol Bay.

Generally, contemporary technology is sufficient to conduct offshore development in the Bristol Bay area. Centain techniques or designs may be more suited to Bristol Bay, but basically no anticipated problems will require new technology. Some minor modifications of present technologies may be needed in order to lessen environmental impact and damage during petroleum development.

A brief review of current exploration and development methods, and their application to the Bristol Bay area follows. Much of this section has been adapted from Kash et al. (1973) and personal interviews with petroleum industry personnel.[1]

EXPLORATION

Geophysical Surveys

Geophysical surveys have been carried out in Bristol Bay since the late 1950's without any apparent difficulty or known significant effects on the environment. Passive surveys (gravity and magnetics) have been used extensively with negligible impact on the environment. Active surveys

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   Personal communications.

(seismic) generally no longer use high velocity explosives as energy sources. Exploding gas mixtures and variable frequency vibrators are equally effective and cause little damage to the environment.

Presently, geophysical surveys in Bristol Bay require no new technology. The only limiting factor is the restriction of vessel operations by winter storms and ice. Since marine surveys generally take no longer than several months, adequate time exists to conduct them during the summer when conditions are most favorable. So far, there has been no need to conduct surveys during the winter, and no change is anticipated in this procedure. It would be difficult to operate effectively in winter ice conditions because of possible ice damage to the vessel, and interference with recording equipment and navigation.

Drilling

Present exploratory drilling practices are believed to be adequate for offshore exploration in Bristol Bay. Any wells drilled near shore probably could be slant-drilled from onshore. The distance reached offshore by a slanthole corresponds roughly to the total depth of the well. A well 3,000 m. deep could be drilled about 3 km. offshore.

Offshore exploratory drilling is normally conducted from one of 3 basic platforms--surface floaters (barges or vessels), jack-ups (temporary rigs with legs adjustable to water depth), or semi-submersibles (water-flooded for stability). All of these could be used in most of Bristol Bay, and the decision to use a particular type would depend on conditions at the site such as weather, waves, bottom conditions and depth of water, as well as the availability of a rig. It is basically an economic decision. Jack-up rigs can now drill in water as deep as 100 m., which includes most of Bristol Bay. Semi-submersibles are the newest type of rig, and are built especially for drilling under severe weather conditions, such as in the Gulf of Alaska. Although the weather conditions in Bristol Bay are less severe, the stability of semi-submersible rigs would be a desirable feature there. These rigs are limited to water less than 600 m. deep, which does not restrict their use in Bristol Bay.

Normally, offshore drilling in Bristol Bay would be conducted during the non-winter months, especially in the northern ice-covered sections. Most wells can be drilled during the ice-free season, and modifications of exploratory drilling platforms to handle ice conditions probably will not be needed. If a drilling operation were caught by the ice pack, drilling could be suspended and the rig moved off the hole for the winter. The hole could be re-entered after the ice receded in spring.

DEVELOPMENT

Offshore Production

Presently, 2 principal alternatives exist for offshore production facilities--fixed platforms and subsea production systems. Fixed platforms have been used for many years and are fairly standardized. These platforms are permanently attached to the ocean floor by pilings, and are presently restricted to depths less than 100 meters. New platforms scheduled for the North Sea will operate in waters as deep as 150 m. and Exxon is planning to use a fixed platform in 250 m. of water in the Santa Barbara channel. Platforms become more expensive with increasing water depth, and anticipated profits from oil and gas must justify the expense of a platform. Water depth probably will not be a problem in platform design for Bristol Bay unless production extends beyond the edge of the continental shelf.

Since conventional platforms of current design appear adequate for Bristol Bay, no new technology will be required. Fourteen platforms have been successfully constructed to withstand ice in Cook Inlet and similar structures could be constructed in Bristol Bay. The Union Oil Co. monopod (one leg) platform has withstood ice conditions in Cook Inlet and this design may be adaptable to similar areas. Its prime advantage is that the single leg reduces the platform area subjected to ice stress and allows ice to flow around the structure. This structure is limited to depths less than 100 m. because the leg becomes less stable as its length increases.

Comfort and safety of platform crews working in Arctic conditions could be improved. For example, better platform evacuation techniques could be developed that would increase speed and protect personnel from severe Arctic conditions.

An alternative for offshore production facilities--the subsea production system (SPS)--is now being developed and is not yet widely used. Three basic designs are presently being used under field conditions although others are in various design stages. In this system, wellheads are located on the ocean floor rather than on platforms. The wellhead can be either exposed to the water or contained in a water-tight work chamber. The liquids or gases produced are either transferred to a nearby fixed platform or shore facility for further transport or processing.

The SPS is being developed to accommodate anticipated deepwater operations. It will incorporate many fail-safe and redundancy characteristics and also will be more automated. These features tend to increase reliability and will reduce the likelihood of accidents.

Even though the SPS is being developed mainly for deep water operations, certain advantages could encourage their use in the Bay. For example, if a producing horizon is at a very shallow depth, such completions could significantly reduce the number of platforms needed. Also, the added safety features might improve their acceptability to people concerned about the environment and other resources, especially the fisheries industry in Bristol Bay. Since SPS operations take place mainly beneath the water, the threat of damage from storms or ice is minimized. This system also reduces the navigational hazard posed by platforms. The aesthetic objection that platforms spoil the wilderness character of the Alaska coastline would be avoided or reduced.

This system still has its problems, however, and needs to go through a process of development and refinement before it is widely used. One such problem involves the separation of oil and water, which would require either extensive onsite underwater operations or an associated platform. The former may prove to be too difficult and expensive. An alternative to onsite treatment is the transport of oil to onshore treatment facilities. If this oil contains large amounts of water, however, it then may be uneconomical to carry this water in the transportation systems (pipeline or tankers). The distance from shore to the wellhead is another major factor entering into the economics of establishing these systems.

Certain new innovative technologies are now being researched and developed by some oil companies that would allow year-round drilling and development in highly ice-stressed waters such as the Arctic coast. Although these methods might not be necessary in Bristol Bay, they may prove to be more economical in some cases. A most advanced concept, the dredged island, may be constructed by piling up bottom materials using a suction dredge. This method depends on the availability of suitable bottom material and is now limited to shallow depths no greater than 5 to 10 meters. Dredging disturbs a large expanse of seafloor, and the potential environmental damage would have to be assessed in each case. Such an island has successfully been constructed and is now being used by the Imperial Oil Co. off the Mackenzie Delta in Canada. Other new drilling platform concepts being investigated include:

1) Structures fixed to the bottom and designed to withstand maximum ice stresses, 2) structures that float on the ice or water using an air-cushioned vehicle, and 3) a strengthened floating hull that is anchored in such a way that it can drift if ice stress exceeds an established limit.

Petroleum Transportation

Most offshore production in the United States is transported ashore by pipelines, and pipeline laying is now a fairly sophisticated art. Most pipelines are buried to avoid damage from storms, dragging anchors, fishing trawls, and other marine operations. The Bristol Bay bottom is fairly regular and flat and poses few problems to laying a buried pipeline. In fact, the conditions here are less severe than in Cook Inlet, where extreme tidal currents have made pipelaying very difficult. Buried pipelines will probably be the preferred method used to transport ashore any oil and gas produced.

Offshore storage and loading facilities combined with tankers might be another method of transporting oil.

This technology is being developed for other areas such as the North Sea. Its use in Bristol Bay would depend on the distance to the facility from various wellheads, the distance to market, and the accessibility of the facility to tankers. For year-round operations, especially in the northern Bay, tankers with reinforced hulls would be needed.

The decision to transport oil ashore, treated or untreated, depends on economics. If the oil is piped untreated, treatment facilities will generally be located near the place where the pipeline comes ashore, since it is uneconomical to transport the untreated product any further than is necessary.

The next economic decision is whether or not to build a tanker terminal on the Bristol Bay coast or to transport the product across the Alaska Peninsula to an ice-free deepwater port on the Gulf of Alaska side. There are certain advantages to the latter alternative. The Bristol Bay coast offers a difficult environment in which to locate a tanker terminal. The nearshore area is generally very shallow and consists of either sandy tidal flats or shifting loose sand.

The coastline is flat, regular and unprotected and contains very few good harbor sites. If harbor sites were dredged, severe silting problems might result. In addition, reinforced hulls for tankers might be required because of the ice.

In contrast, the Gulf of Alaska side of the Alaska Peninsula offers excellent ice-free, deep water, protected harbor sites, generally carved out of bedrock and without severe erosion problems. There are several low passes across the Peninsula and use of these routes probably would not require laying more than 80 additional km. of pipe. For instance, Amoco is considering Pavlof Bay as a harbor for tankers if petroleum is discovered in the Amoco Cathedral River Unit No. 1 well north of Cold Bay.

CONCLUSIONS

It is thought that adequate industrial technology is available to handle the exploration and development of petroleum in offshore waters. No new basic systems will be required in the next 15 years (Kash et al. 1973). In order to make offshore operations safe and efficient and to minimize harmful effects on the environment, major modifications in social technologies (rules, regulations, procedures, etc.) are required (Kash et al. 1973). Unless these rules, regulations and procedures are followed, the best industrial technologies are useless.

Environmental concerns in Bristol Bay will demand the best use of available technologies when development occurs. The fisheries industry, which has gone on record as opposing the development of petroleum in Bristol Bay, will be foremost in its demands.

The petroleum industry has done little in developing detailed plans for exploration and production in Bristol Bay, mainly because there has been no formal announcement of a lease sale. Ocean Science and Engineering, Inc. of Rockville, Md., under contract to 8 industry participants has gathered physical environmental data for Bristol Bay. A 3 volume report has been prepared but is not presently available to the public.

Probably little further work will be done in Bristol Bay until a lease sale is announced. Details of the specific technologies needed in Bristol Bay will not be determined until specific areas are put up for sale. Even then, some of the details can not be worked out until specific drill sites are selected and petroleum is discovered.

It is clear that decisions on exploration, development, production and transportation of petroleum are made solely by industry based largely on economics. The foregoing report has outlined the considerations that affect the public interest. Environmental information on which development decisions can be based, must be available to the public. The public interest is protected best when the public is able to participate intelligently in the decision-making process.

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