# Environmental Assessment of the Alaskan Continental Shelf

## Interim Synthesis Report: Kodiak

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**U.S. DEPARTMENT OF COMMERCE**
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# Outer Continental Shelf Environmental Assessment Program

## Interim Synthesis Report: KODIAK

Prepared Under Contract By
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## Chapter I
## INTRODUCTION

### OBJECTIVES AND HISTORY OF THE SYNTHESIS REPORT

Objectives of this report are: (1) to provide regional environmental information in a form useful to BLM and others in decision-making processes related to OCS oil and gas development in the Kodiak lease area; (2) to increase and update scientific interdisciplinary understanding of the Kodiak region; and (3) to identify important gaps in our knowledge of the Kodiak marine environment that are relevant to OCS development. Data presented herein were compiled mainly by investigators working under contract to the BLM-funded Outer Continental Shelf Environmental Assessment Program (OCSEAP). Some of these investigators participated in a three-day workshop held in Anchorage, Alaska on March 8, 9 and 10, 1977 for the express purpose of presenting and synthesizing Kodiak environmental information.

In addition to investigators, workshop participants (Appendix 1) included OCSEAP personnel, staff members of the BLM office in Anchorage, representatives of the State of Alaska, and personnel from Science Applications, Inc. (SAI). SAI is an OCSEAP contractor whose responsibilities to the program include summarizing, integrating, and synthesizing data generated by OCSEAP investigators into reports such as this one.

Workshop format was designed to foster disciplinary and interdisciplinary team approaches to: (1) identification and mapping of key biotic resources, and their habitats and distributions, including seasonal changes therein; and (2) identification of physical and biological processes influencing distribution of these key biota and predicting their potential susceptibility to impingement by OCS oil and gas development. Participants were requested beforehand to furnish specifically identified background material which would provide the most up-to-date information available to facilitate meeting these objectives. This information was utilized throughout the meeting and in incorporated into this document.

The first day of the workshop included presentations on environmental themes for the Kodiak area and potential oil and gas development activities near Kodiak. A development scenario for the Kodiak lease area was provided by the Alaska OCS office, Bureau of Land Management (Appendix 2). Chairmen of the disciplinary groups summarized their groups' accomplishments during a plenary session, USGS staff showed a cinema film entitled "Consensus of Concern." This film illustrated the role of USGS in monitoring safety procedures required of oil companies in platform operations. The afternoon of the second day of the meeting was devoted to interdisciplinary working groups, which identified and discussed environmental interrelationships in the area, and attempted to produce maps depicting seasonal correlations between data sets of various disciplines as these might relate to oil and gas development. An attempt was made to identify possible "critical areas," and data gaps were listed. The last day of the workshop included summary presentations and group discussions on the results of the interdisciplinary working groups. The meeting concluded with a discussion of its success and recommendations for improvement in future meetings.

CONTENTS OF THE REPORT

Proceedings of the meeting, material provided by participants, and recommendations for specific research needs are organized in various chapters. Chapters II (Critical Regions of Possible Impingement), III (State of Knowledge), and IV (Research Needs) contain the bulk of information resulting from the meeting. Chapter II provides subregional descriptions of north-eastern, eastern, and southeastern Kodiak, areas which may be subject to impingement during OCS oil and gas development. The text is intended for administrators and scientific bureaucrats, a broad spectrum of the scientific community, and interested public. The statements are technically correct, but do not include detailed and elaborate scientific knowledge of the identified areas. The contents also reflect the rather limited available scientific data specific to these areas. For more detailed accounts, various sections of Chapter III can be consulted. The main body of scientific knowledge is summarized in Chapter III; emphasis has been placed on summarizing new data presented and pertinent discussions held during the synthesis meeting. Some material from earlier publications and other reports, such as OCSEAP Principal Investigators' Quarterly and Annual Reports, has been used in abridged and summarized form where required for continuity and thoroughness. Gaps in knowledge and a summary of research needs which can be used as input for program direction and emphasis for future research are provided in Chapter IV.

## LIMITATIONS

This report is essentially a progress report; i.e., an integrated compendium of products resulting from the synthesis workshop. Future meetings are planned to review research programs, to update this report, and to bring us nearer to a synthesis of environmental knowledge. Limitations of the data in this report should be apparent in light of the description of its origin given above. It is not intended to provide a complete review of relevant literature. *IT REPRESENTS AN INTERIM SUMMARY OF KNOWLEDGE AND IS NOT TO BE VIEWED AS THE DEFINITIVE WORK ON THE KODIAK AREA.*

## PREVIOUS PUBLICATIONS

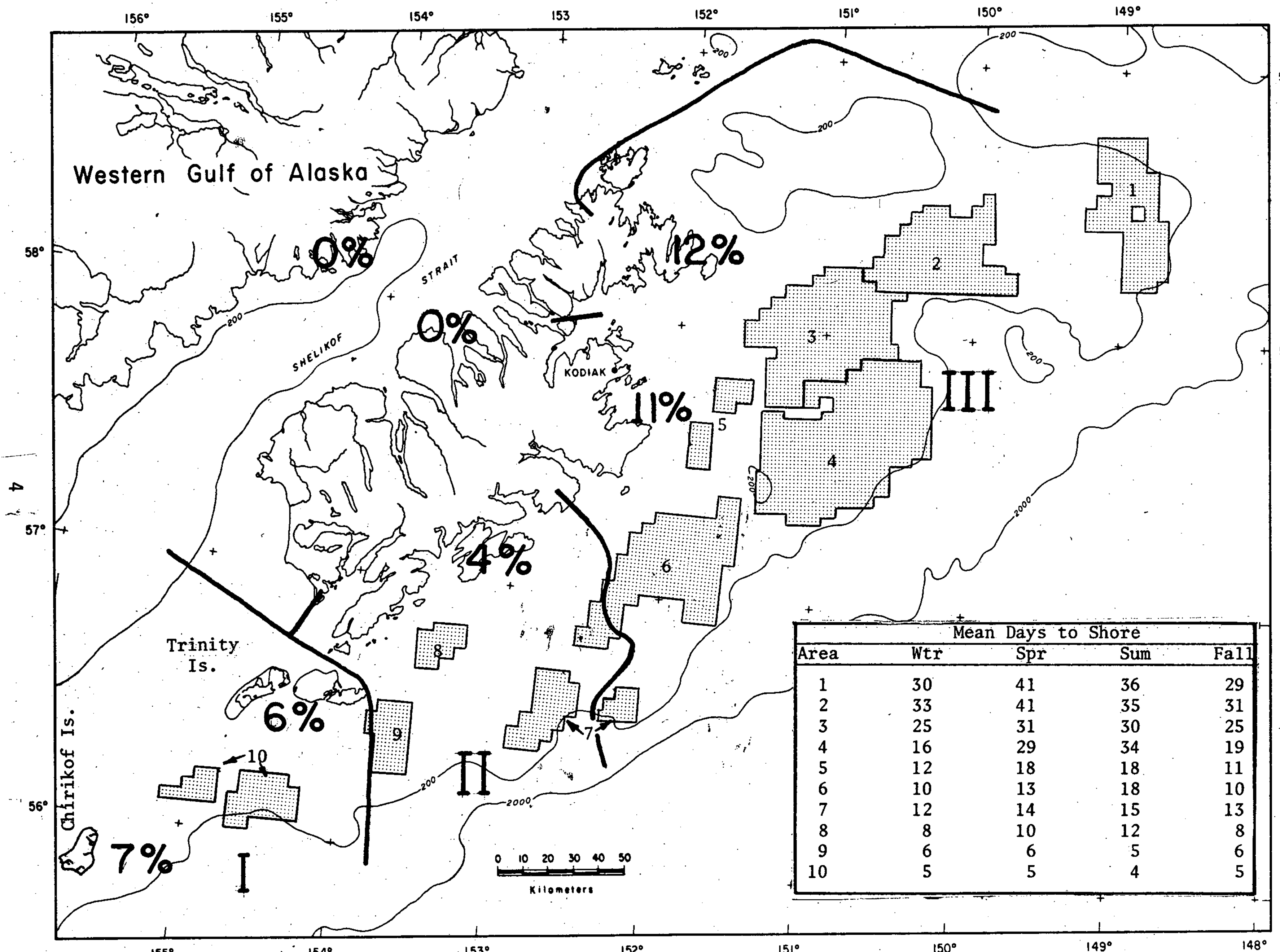
Background information on several aspects of the Kodiak Archipelago and its environrons is available in the publications listed below. Only a limited effort has been made to abstract or summarize these data into this report.


The Western Gulf of Alaska, A Summary of Available Knowledge. D. Hickok *et al.*, Marine Minerals Division, Bureau of Land Management, U.S. Department of the Interior, Washington, D.C., Contract No. 08550-CT3-9, (April 1974).

The Fish and Wildlife Resources of the Gulf of Alaska, Appendix 5, Fishery Resources of the Gulf of Alaska. W.F. Gusey *et al.*, Gulf of Alaska Operators Committee, Shell Oil Company, Houston, Texas, (1975).

Kadyak, A Background For Living. E.H. Buck *et al.*, Alaska Sea Grant Program, NOAA Office of Sea Grant, Department of Commerce, Grant No. 04-3-158-41, (1975).

Western Gulf-Kodiak, Draft Environmental Impact Statement. Alaska Outer Continental Shelf Office Oil and Gas Lease Sale No. 46. U.S. Department of the Interior, Bureau of Land Management. 2 volumes, (April 1977).




| Area | Wtr | Spr | Sum | Fall |
|---|---|---|---|---|
| | Mean Days to Shore | | | |
| 1 | 30 | 41 | 36 | 29 |
| 2 | 33 | 41 | 35 | 31 |
| 3 | 25 | 31 | 30 | 25 |
| 4 | 16 | 29 | 34 | 19 |
| 5 | 12 | 18 | 18 | 11 |
| 6 | 10 | 13 | 18 | 10 |
| 7 | 12 | 14 | 15 | 13 |
| 8 | 8 | 10 | 12 | 8 |
| 9 | 6 | 6 | 5 | 6 |
| 10 | 5 | 5 | 4 | 5 |

Fig. 2-1 Kodiak Shelf: subregions discussed in this report, proposed lease areas and oil spill trajectory data (Appendix 3). See text for additional explanation.

# Chapter II
# REGIONS OF POSSIBLE IMPINGEMENT

## INTRODUCTION

A major objective of the meeting was to initiate a cooperative and, ultimately, a holistic approach to the environmental description and analysis of the Kodiak lease area and its adjacent coastal and OCS regions with regard to oil and gas development. After a thorough review of the status of disciplinary knowledge, interdisciplinary discussions were held to develop a more comprehensive understanding of the regional environment. These discussions led to the identification of areas which may have high probability of impact from OCS development and are habitats of important species (ecologically, commercially, or aesthetically) or biological systems which may receive contaminant exposure.

It emerged in these discussions that the Trinity and Chirikof Islands and the entire eastern coast and shelf of Kodiak Archipelago from Shuyak Island south to Sitkinak Strait support important biological populations and also may be subject to potential impingement by oil during OCS development. Hence, it was not feasible to eliminate particular areas from consideration and produce a list of "critical areas of possible impingement" as was done for the NEGOA lease area (OCSEAP/SAI 1977). However, the preliminary USGS/BLM oil spill trajectory analyses (Appendix 3) do indicate that substantially different probabilities of oil impingement are associated with different stretches of the coastline and southern islands of Kodiak Archipelago (Figure 2-1). Based upon these trajectory data, and as a matter of convenience, we have divided the area of concern into three regions: (1) a southern region consisting of the Chirikof-Trinity Islands area; (2) a middle region, from Dangerous Cape to Alitak Bay, including Southern Albatross Bank, Aiaktalik Island, and the Geese Islands; and (3) a northeastern region, extending from Shuyak Island to the vicinity of Dangerous Cape and including Portlock Bank and Northern and Middle Albatross Banks. Approximate boundaries for these areas are shown in Figure 2-1.

Two products of the USGS/BLM oil spill risk analysis that are particularly germane to these regional descriptions, are shown in Figure 2-1. These are: (1) the probability of impingement of any Kodiak Shelf oil spill upon defined segments of the coastline (i.e., the percentage of 24,000 trajectories, which originate at random points within the proposed lease areas, that "hit" a particular segment of the coast); and (2) the mean lag time between spills in specific lease areas and subsequent drift onto various stretches of coastline in the Kodiak region, according to season. These data, although preliminary, provide some perspective on which segments of the Kodiak coastline have the greatest risk of being impacted by an accidental spill. They also indicate approximately how long oil might remain at sea, undergoing physical, chemical, and biological dispersion and degradation processes, prior to hitting a shoreline.

Earlier OCSEAP investigations were conducted on a broad scale with emphasis on geologic hazards, mesoscale hydrographic and circulation features, reconnaissance of biota, and areal distribution of petroleum-related contaminants. Scientific knowledge of the subregions defined above is mostly based on reconnaissance type studies of the Kodiak region with little site-specific data available. In many instances, the resolution of available data is such that only inferences or extrapolations can be made. For example, data on the distribution of benthic epifauna are limited to Ugak and Alitak Bays, and cover only the three summer months. Information presented in this section is elaborated, illustrated, and referenced further in the State of Knowledge Overview section of this report (Chapter III). A number of research projects, some with site-specific objectives, are currently underway or are planned for FY 78. The following account of the environment and processes of the selected areas should be considered tentative and preliminary, with its limitations kept in perspective.

## REGION I: CHIRIKOF AND TRINITY ISLANDS

This region encompasses the broad shelf extending between the Trinities and Chirikof Islands. It is characterized by varied bottom topography, resulting in a diversity of habitats for offshore benthic organisms. Reconnaissance studies indicate shelf benthos biomass values of 10-500 $gm/m^2$, dominated by mobile filter feeders and browsing detritus eaters. The predominantly southwestward moving currents are strongly affected by bathymetric changes and sometimes show some meandering. Water properties in this area are also influenced by outflow from Shelikof Strait, some of which originates in Cook Inlet. Baroclinic current estimates point toward a weak circulation regime that is distinctly separate from the swifter circulation over the slope. Data obtained in spring 1976 for a closely-spaced station grid indicate current speeds in this area of less than 10 cm/sec. No current meter data are available. Preliminary results of a diagnostic circulation model reproduce the current with weak and inconsistent direction. Such weak currents favor local retention of planktonic larvae, leading to local settling of these larvae. Seasonal differences in stress results in seasonally stronger currents but their direction remains varied. The high biological productivity and importance of this region for commercial shellfish probably reflect the combination of high primary production and detritus inputs, with sluggish net transport and little larval export. Sufficient information is not yet available to indicate that this area is dynamically similar to the shelf regime northeast of Kodiak Island (described below) with respect to long residence time of water and current reversals.

Like southeast Kodiak (below), biological productivity in this area is high. The Trinities and Chirikof have broader, more gently sloping littoral zones, less rocky shores, and more sand/gravel beaches than Kodiak Island. Although the coastline presented by these islands is small, they nonetheless seem to have a high probability of being impinged by oil spills. According to the USGS/BLM model there is a 13% chance that an oil spill in the Kodiak lease area would strike these shores (Figure 2-1). The high proportion of coastal sand and gravel substrates favors long-term entrapment of and contamination by oil in the event of oil spills impinging on beaches here.

Sitkinak and Tugidak Lagoons in the Trinity Islands support extensive eelgrass beds and subtidal attached algae are also abundant (standing crops average 12 $kg/m^2$). Eelgrass beds provide important food and habitat for waterfowl and other organisms; they are also highly susceptible to destruction by oil contamination. The intertidal fauna is generally comparable to that of Kodiak Island. It includes an abundance of forage and commercial fish species which spawn the intertidal area. Pink salmon and capelin are among the most important of these. Large scale oilings of the beaches of the Trinity and Chirikof Islands could severely impact these and other fish which enter the intertidal zone.

ADF&G (1976) has identified major portions of the Trinity-Chirikof Shelf as vital to the reproduction, rearing, and catch of king and tanner crabs. King crab catches are presently among the highest for all Kodiak stocks. The Trinity Islands shelf support a major dungeness crab fishery. The shelf edge immediately to the south of the Trinities is an important habitat and fishing ground for shrimp. Razor clam and weathervane scallop resources have also been defined (ADF&G 1976). Areas adjacent to Chirikof Island are vital to king crab reproduction and catch, as well as important for tanner and dungeness crab.

Shelikof Strait intersects the Kodiak Shelf break just south of Chirikof Island. The Alaska Stream parallels this indentation of the shelf edge promoting water column mixing and nutrient replenishment. This may partially explain the high productivity of the Chirikof Region. The entrance of Shelikof Strait is marked by a submarine sill ($\sim$ 200 m). Flushing rates for contaminants introduced into water trapped behind or below this sill ($\sim$ 300 m) are unknown, but could be slow, which would result in long contaminant residence times.

Foreign fishermen catch demersal species throughout this area, especially along the continental slope. Domestic fishermen have found the Chirikof Island area to be one of the more prolific halibut catch regions in the IPHC statistical area 3A. Pelagic eggs and larvae of demersal fish are also common throughout the water column in this area. Halibut spawn east of Chirikof Island. Pollock larvae and eggs are found in the surface waters between the Trinities and Chirikof in spring. The USGS/BLM oil trajectory analysis (Figure 2-1 and Appendix 3) indicates that 44% of the oil spill trajectories track through this area. This suggests that shell and finfish resources southwest of the lease area may be more susceptible to potential oil contamination than those within the lease area.

Due to the combination of rich food supply and suitable onshore breeding and pupping sites, important populations of seals and sea lions reside here. The largest concentration of harbor seals in the world occurs on Tugidak Island; the estimated standing stock of this population is 13 to 20 thousand animals. Adjacent Sitkinak Island has an additional standing stock of 800 or so harbor seals. Chirikof Island is one of the largest Steller sea lion breeding rookeries in the Gulf of Alaska. Up to 5,300

Steller sea lions have been observed hauling out simultaneously, with possibly an equal number in adjacent waters. An additional 300 or more sea lions haul out at Cape Sitkinak, on Sitkinak Island. Sea lions are known to move between Chirikof Island and northern Kodiak, illustrating the continuity of the Gulf of Alaska population.

Sea otters are present throughout this region, with concentrations of medium to high densities around Chirikof, Tugidak, and western Sitkinak Islands. More than 9,000 $km^2$ of suitable otter habitat south and west of Kodiak is still underpopulated and should eventually support several thousand more otters.

Dall and harbor porpoises and gray, minke and humpback whales are cetaceans which occur regularly in this area. Seabirds nest and winter around Chirikof and the Trinity Islands but data on species occurrence and abundance are not available.

## REGION II: ALITAK BAY TO DANGEROUS CAPE

This subregion includes Kiliuda Trough, South Albatross Bank, and the semi-enclosed Horsehead Basin. Bedrock outcrops are common on outer Albatross Bank, while boulders, gravels, and coarse sands cover the inner bank. Kiliuda Trough and Horsehead Basin are characterized by fine silts and muds. Evidence from the redistribution of Katmai ash confirms that material initially deposited on the shallow banks is resuspended -- probably by winter storm wave action -- and the finer fractions are carried into the adjacent deeper water, trough, and basin (Bouma and Hampton 1977).

Throughout this region the shelf represents an area where swifter offshore flow is separated from a much less energetic inshore regime dominated by tides. Current meter records presently available indicate that the net drift over the shelf is an order of magnitude lower than it is offshore. Circulation over the shelf is greatly affected by winds. Diagnostic circulation model results have shown an increase in current speed from about 20 cm/sec to nearly 100 cm/sec off the Dangerous Cape-Cape Barnabas areas when wind stress was increased by 1 to 4 $dynes/cm^2$. In deeper oceanic waters, the effect of increased wind stress was minimal. In winter, strong winds, primarily from the east and northeast, move surface water toward the east coast of Kodiak Island; southwestward flow in the surface layers and offshelf movement of the bottom waters are favored. In late spring and summer, increased freshwater input from land runoff and precipitation tends to accelerate alongshore counterclockwise circulation. However, variable winds and the weakly developed high pressure system over the Gulf at this time favor moderate upwelling along the coast. The surface water tends to move offshore and there is an onshelf movement of deeper water along the bottom.

Little is known about the composition and abundance of noncommercial species of the shelf benthos. The more turbulent rock and gravel habitats of the banks would probably yield a diverse fauna of epibenthic suspension feeders, scavengers, and predators, while the quiet-water habitats and fine-grained, organic-rich sediments of the troughs probably contain infaunal deposit feeding polychaete-bivalve assemblages. Almost one hundred species were identified in studies of the epifaunal benthos of Alitak Bay. King crab (egg-bearing females and juveniles), tanner crab (adult males), and pink shrimp accounted for the majority of the biomass collected.

Much of the coastline from Alitak Bay to Dangerous Cape consists of rocky headlands and boulder/gravel/sand beaches. Macrophyte primary production is high; eelgrass beds (Geese Islands), offshore kelp, and subtidal brown algae are all abundant. A succession of subtidal algae replace one another year-round and standing crops in excess of 15 kg/m$^2$ have been measured from semiprotected sites (Sitkalidak Strait). Annual production is thought to be nearly double this standing crop value. The abundance of macrophytes (a marked constrast with NEGOA, for example) probably reflects the presence of suitable substrates, clear shallow waters with little suspended sediment, a well-mixed water column promoted by vigorous wave and tidal action, and an adequate supply of nutrients.

In addition to providing food for grazing invertebrates, the macrophytes contribute large quantities of organic detritus to the food source of benthic scavengers and deposit feeders. These smaller organisms, and possibly some of the detritus itself, are taken by larger, important commercial shellfish such as king, tanner, and dungeness crabs. The rich crab and shrimp fishery of Horsehead Basin is thought by some to be based on detritus imported from inshore kelp beds into the Basin by the bottom currents (S. Zimmerman, NMFS, Auke Bay, personal communication). Variable currents and sluggish net transport across the Kodiak Shelf promote invertebrate abundance in this region by minimizing larval transport out of the area. (Contaminants impacting the area might also experience longer residence times.)

ADF&G (1976) has designated major portions of southern Kodiak Shelf as vital to the reproduction, rearing, and catch of king crab, and important both throughout the life history of shrimp and for reproduction and catch of tanner crab. Historically, the area has provided some of the highest king crab catches in the entire Gulf of Alaska. Stocks were severely depleted by over-fishing in the mid-1960s, but are now increasing under more careful management (ADF&G 1976). This area also supports the largest shrimp fishery on Kodiak and provides significant catches of dungeness crab. Shrimp apparently prefer habitats with soft mud bottoms and abundant organic detritus, such areas are particularly abundant in Horsehead Basin.

With regard to fish, the most serious concern arising from OCS development is the abundance of intertidal spawners off southeast Kodiak. Pink salmon make up 80% of the total salmon spawning run, and are noted intertidal spawners. Capelin and chum salmon also spawn in the intertidal region. Large scale oilings of the beaches along the southeast coast of Kodiak Island could severely impact these species.

Major concentrations of pollock, sole, and cod occur along the edge of the Kiliuda Trough. Pollock, sole, and Pacific Ocean perch are abundant along the edge of the continental shelf. Foreign fishing fleets concentrate their efforts along the shelf and in the Kiliuda Trough. Southeast Kodiak is also a critical component of the Kodiak salmon fishery resource. The largest commercial salmon catches in the archipelago are taken in the southeast and southwest sections of Kodiak Island.

Moderate concentrations of pinnipeds occur in this region. More than 1,600 Steller sea lions have been observed hauled out on Twoheaded Island and more than 350 on Cape Barnabas. About 800 harbor seals occur on the Geese Islands and another 600 on Aiaktalik Island. Fur seals tend to concentration over Southern Albatross Bank during migration, presumably for feeding. Harbor porpoises, dall porpoises, and gray, humpback, and minke whales are also present, at least seasonally. Sea otters are present in low densities.

About 30 seabird colonies are located between Dangerous Cape and Alitak Bay. Cumulative population of these colonies is estimated in excess of 200,000 birds. The largest colonies are in the Kiliuda Bay-Sitkalidak Strait region. The Bay and Strait also serve as important wintering areas for murres. Southern Albatross Bank is an important seabird foraging area (ADF&G 1973, 1977; Arneson 1977; Lensink and Bartonek 1976).

Should crude oil or other contaminants be accidentally released into the surface waters of the southern Kodiak region they might well impact susceptible larvae of commercially valuable crabs and shrimp. King and dungeness crabs and shrimp larval abundances peak in spring; tanner crab larvae are released during the summer months. The mucilaginous coating of the kelp fronds provides protection from crude oil contamination; however, the numerous adult and juvenile fish and invertebrates that find food and cover beneath the kelp canopy might be impacted. Unlike kelp, eelgrass is known to be highly susceptible to oil contamination.

Mechanisms by which surface spills reach the seafloor are poorly understood; however, fine-grained contaminated material settling on South Albatross Bank would eventually be carried into Horsehead Basin or the Kiliuda Trough where it would remain until chemically or biologically degraded. Contaminated sediments might impact deposit feeding benthic invertebrates and could in turn impact other trophic pathways.

## REGION III: DANGEROUS CAPE TO SHUYAK ISLAND, INCLUDING OFFSHORE BANKS

This region includes Middle Albatross, North Albatross, and Portlock Banks, and the Chiniak, Stevenson, and Amatuli Troughs that separate them (Figure 2-2). Major embayments along the coast include Ugak, Chiniak, Marmot, and Perenosa Bays.

Portlock and Middle Albatross are similar to South Albatross Bank in that their shelf breaks are tectonically active and the outer banks are characterized by rocky outcrops, while the inner banks are covered with boulders, cobbles, and coarse sands. North Albatross Bank differs from this pattern, in that there is less evidence of shelf-edge tectonism and few rock outcrops. Boulders, cobbles, and sands still predominate across the bank top. Chiniak and Amatuli Troughs probably act as passive sinks for fine-grained sediments much like Kiliuda Trough. Coarser sediments,

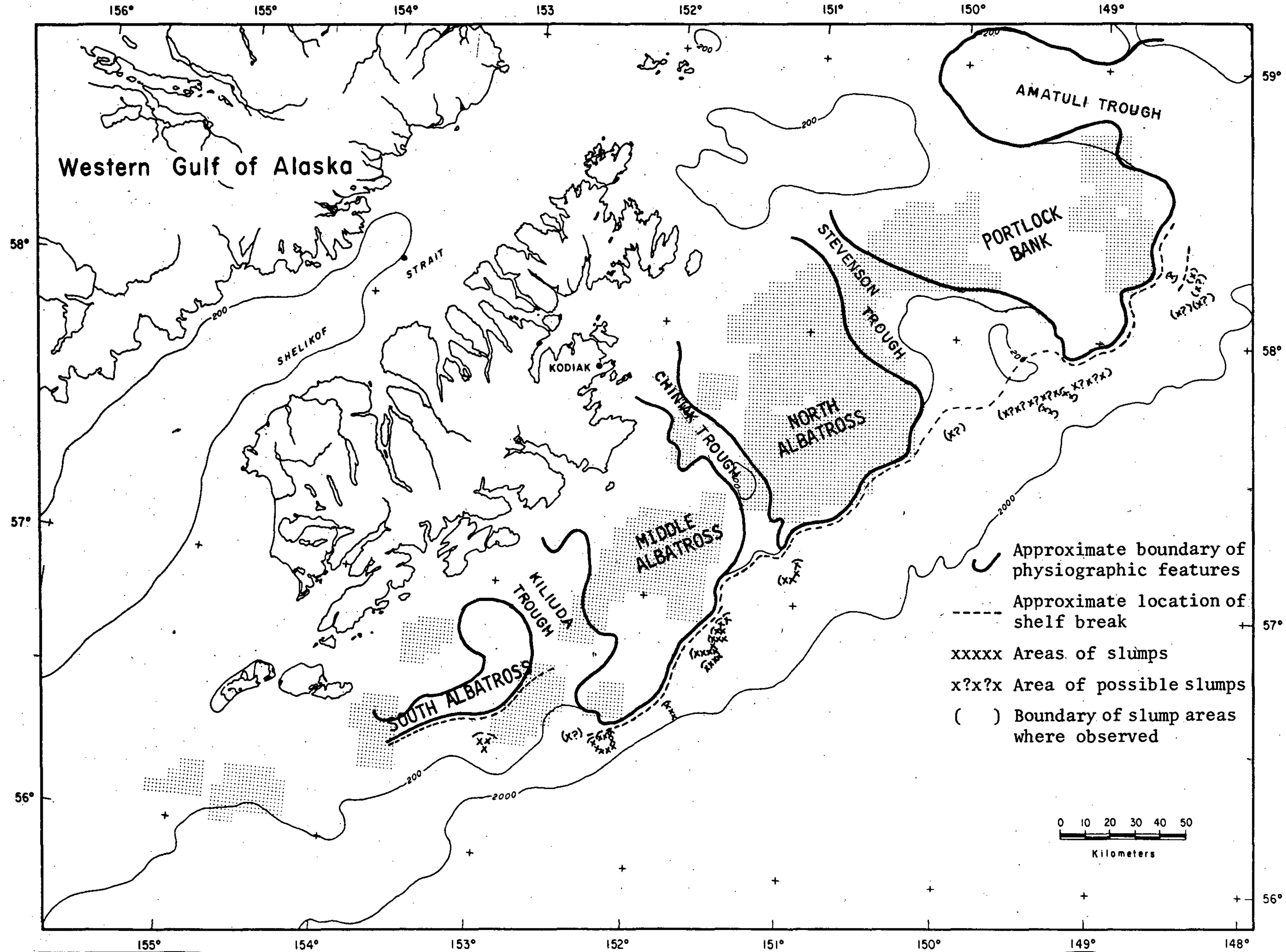



Fig. 2-2 Kodiak Shelf: major physiographic features and location of slumps (Bouma and Hampton, 1977).

lower Katmai ash contents, and dynamic bedforms in Stevenson Trough, suggest active transport between Lower Cook Inlet and the Kodiak continental slope.

Region III represents a zone of highly variable water properties and currents. Seasonal and spatial variability in the temperature and salinity distributions are large. There are indications (surface temperature signatures noted from satellite reconnaissance) that water flowing in and out of Cook Inlet passes through this area. Hydrographic data obtained in July 1976 showed an intrusion of a core of warm oceanic water over the shelf as far as the Marmot Island (12.5-13.5°C). Exceptionally high water transport values, 13 million $m^3$/sec, were estimated from these data. The dynamics of the shelf regime in this area do not appear to be governed by the Alaskan Stream (cf. northern Gulf of Alaska east of Kayak Island). The flow regime appears to be complex and is apparently dominated by localized phenomena. Current meter data from a station located at 58°45'N, 148°25'W show variable current speeds and reversals in direction. Available data indicate that current direction was south to southwest from April to June 1976 but changed to northeast in July 1976. In late summer and early fall currents were relatively weak and inconsistent in direction, but in October-November 1976 they were swifter, persistent and southwesterly. Such reversals can also be noted from drift-buoy trajectories, although data are available for only seven to ten days in September 1976.

Physical oceanographic data reported so far are not conclusive but imply that water could remain in shallow shelf areas for considerable periods of time, possibly for over two months. Such long residence time can promote localized high productivity, limit dispersal of shellfish larvae and ichthyoplankton, and favor their settlement over geographically limited areas. In case of contaminant discharges this same feature would result in longer contaminant exposure and contact with the environment and biota in this region.

The coastal zone in this region is characterized by precipitous rocky shores or boulder/gravel/sand beaches. Tidal ranges diminish from north to south; swift tidal currents move between Kodiak and Afognak Island. Offshore kelp beds and subtidal macrophytes are locally abundant, but few standing crop or productivity data are available. Numerous kelpbeds are present in Ugak Bay, but standing crops of subtidal brown algae -- averaging 4.8 kg/$m^2$ -- are much lower than along the outer coast. This apparently reflects the quality substrates available for attachment.

Sandy beaches bordering Marmot and Chiniak Bays yield hard shelled and razor clams. The ADF&G (1976) has identified the northeast Kodiak embayments as being vital to all phases of king crab and shrimp life history and commercial catch, as vital to tanner crab commercial catch, and as important to dungeness crab and weathervane scallop resources. The second highest yield of king crab in the western Gulf of Alaska is taken on the Northeast Kodiak Shelf.

Nearly one hundred species of the epifaunal benthos were identified in samples collected in Ugak Bay. King crab (mostly juveniles), tanner crab (adult males), and pink shrimp accounted for the majority of biomass. Sandy beaches of the region contain characteristic assemblages of polychaete worms and infaunal clams, including the razor clam, *Siliqua patula*.

Apart from commercial shellfish, little is known of the offshore benthos anywhere in this subregion. ADF&G (1976) has identified Middle Albatross Bank as being vital to weathervane scallop reproduction and catch, important to king crab reproduction and catch, and important to tanner crab reproduction and rearing. Dungeness crabs are also present. Ugak Bay and nearshore areas of Middle Albatross Bank are identified as vital to king crab reproduction, tanner crab catch, and dungeness crab catch. Ugak is also important for king crab rearing and catch. ADF&G (1976) studies also indicate that the landward portions of North Albatross Bank and Stevenson Trough, together with the extreme southwest corner of Portlock Bank (adjacent to Stevenson Trough) are the most significant areas for commercial species -- particularly king and tanner crab reproduction and catch. Shrimp and weathervane scallop are also found in these areas.

Pacific cod, Pacific halibut, sole, and walleye pollock concentrate along the continental shelf edge and the edges of the Stevenson and Chiniak Troughs. All species of Pacific salmon migrating from as far south as Oregon and northern California pass through this region. Herring spawn in Port Hobrom and rear throughout the nearshore areas. Commercial fishing for herring is centered in Chiniak, Marmot, and Afognak Bays. Japan and the USSR fish extensively for demersal species along the continental shelf. The greatest foreign catches in this area are made northeast of the Portlock Banks.

The halibut spawning grounds northeast of Portlock and the sport fishing industry near Kodiak City may be particularly susceptible to oil and gas development. Halibut ova spawned along the shelf edge are carried southwest into the proposed lease area by the Alaska Stream. Larvae may also be swept into areas of OCS development. Halibut in recent years have suffered from overfishing and any perturbations of their environment may further affect the health of this species. Sport fishing is centered in those bays readily accessible from Kodiak City, e.g., Ugak, Chiniak, Women's, Middle, etc. Should sport fishing in these areas be disrupted by oil and gas development and production activities, several million dollars (ADF&G 1976) may be lost from the Kodiak economy.

OCS oil and gas development may also affect the demersal populations occupying Chiniak Trough since it would almost certainly act as a pollutant sink. Although oil deposition in Chiniak Trough may not be directly toxic to demersal fish, the chances of incorporating oil into the food chain are greatly enhanced. Behavioral activities of the demersal species may be adversely affected, causing ramifications in both domestic and foreign commercial fishing industries.

A few thousand seabirds nest in colonies adjacent to Ugak Bay, which is also an important wintering area for murres. An additional 100,000 seabirds nest from Shuyak Island to Cape Chiniak. Chiniak Bay is an important wintering area for seaducks and summer feeding ground for shearwaters. High densities of seabirds occur over Portlock and North Albatross Banks in every season of the year.

Portlock and North Albatross are important foraging areas for Steller sea lions and migrating fur seals. Some fur seals forage over these banks throughout the winter. Sea otters, sea lions, and harbor seals are present throughout the area. Cetaceans are represented by harbor and dall porpoises, and blue, gray, minke, sei, fin, humpback, and killer whales. Small concentrations (< 50 animals each) of harbor seals occur at the following locations in Penerosa Bay: Sea Lion Rocks, Sea Bay, and Big Fort Bay. A notable concentration of 2,500 to 3,000 harbor seals occurs on Ugak Island. Steller sea lions are much more abundant, with important concentrations at Sea Otter Island, Sea Lion Rocks, and Marmot Island. Marmot Island is one of the largest sea lion rookeries in the Gulf of Alaska, with as many as 10,000 sea lions hauled out simultaneously. More than 400 sea lions have been counted hauled out on Sea Lion Rocks and more than 500 on Sea Otter Island. The largest population of sea otters in the western Gulf of Alaska occurs around Shuyak and northern Afognak Islands. This population numbers in the thousands, and "rapid repopulation of Kodiak Island depends on maintenance of a high rate of reproduction in this area" (ADF&G 1977).

# Chapter III
# STATE OF KNOWLEDGE OVERVIEW

## BACKGROUND LEVELS OF PETROLEUM-RELATED CONTAMINANTS

Participants in the Kodiak Synthesis Workshop did not identify any new data on hydrocarbons and trace metal chemistry beyond that which has been summarized in the "Kodiak" section of the 1976 NOAA/OCSEAP Annual Report Summary (NOAA/SAI 1976). Data presented in the Annual Report Summary indicated no evidence of petroleum contamination in sediments or water collected northeast and southwest of Kodiak Island. Methane was the only low molecular weight hydrocrabon measurable in the sediments, approximately 5 ng/g methane dry sediment. Preliminary results also indicated that the hydrocarbon levels in the shelf waters are as low as, or lower than, other areas of the world oceans.

## GEOLOGIC HAZARDS

Background data on the regional geology and geologic hazards (particularly seismicity, tsunamis and volcanic hazards) associated with the Kodiak Shelf have been summarized in AEIDC (1974) and NOAA/SAI (1976). New data are provided by Bouma and Hampton (1977).

### Sediment Distribution and Transport

The Kodiak Shelf consists of a sequence of shallow banks separated by somewhat deeper sea valleys or troughs (Figure 2-2). No substantial present-day sediment source exists, clay mineral analyses (J. Hindes, USGS, Menlo Park, personal communication) suggest that at least some of the finer fraction material reaching Kodiak originates from as far away as the Copper River Delta and Icy Bay. Sediment distributions are semi-relict (i.e., reflect reworking of Pleistocene glacial sediment deposited prior to the last sea level rise) and directly reflect the interacting effects of bottom topography and water transport.

The banks are exposed to wave and current action (particularly during winter storms) that continually resuspend bottom sediments and winnows out the finer sands, silts and clays. Consolidated Pleistocene to Holocene bedrock outcrops occur along the outer edges of the banks. The bank tops are dominated by coarse sands, gravels and boulders (Figure 3-1). While finer sediments accumulate in local depressions on the banks, most such material is probably carried into the deeper, quieter waters of the adjacent troughs.* Sub-bottom profiles confirm the presence of thick wedges of sediment dipping off the banks into the troughs. The age of these clastic wedges remains unknown.

Examination of sediment samples across the Kodiak Shelf revealed the presence of vitric ash from the 1912 Katmai eruption. This ash is highly vesicular, light and readily redistributed. It is assumed to have been deposited more or less uniformly over the shelf; thus analysis of the present ash distribution serves as a good indication of post-depositional sediment dynamics. Surficial sediment samples from Horsehead Basin and the Kiliuda, Chiniak and Amatuli Troughs generally yielded much higher percentages of ash (90-100%) than samples from the adjacent shallow banks (30-80%; Figure 3-2). In every case high ash values from the banks coincided with local depressions. Samples from Stevenson Trough differed significantly from those in other troughs in that they yielded only low to moderate concentrations of ash (10-60%).

These data suggest considerable redistribution of the Katmai ash since 1912. In general, ash has been transported off the banks (or into local scattered depressions across the banks) and deposited in the troughs -- where it has remained. Should crude oil or other contaminants reach the seafloor they too could be expected to accumulate in the troughs. The one exception is Stevenson Trough where lower ash values and dune-like bedforms may suggest more active bottom sediment transport -- possibly reflecting the movement of water across Kodiak Shelf between Cook Inlet and the continental slope.

*This general sediment distribution pattern should allow us to predict an abundant benthic fauna of suspension feeding epifaunal organisms on the current swept banks, while deposit feeding infaunal animals would be more common in the trough silts and muds.

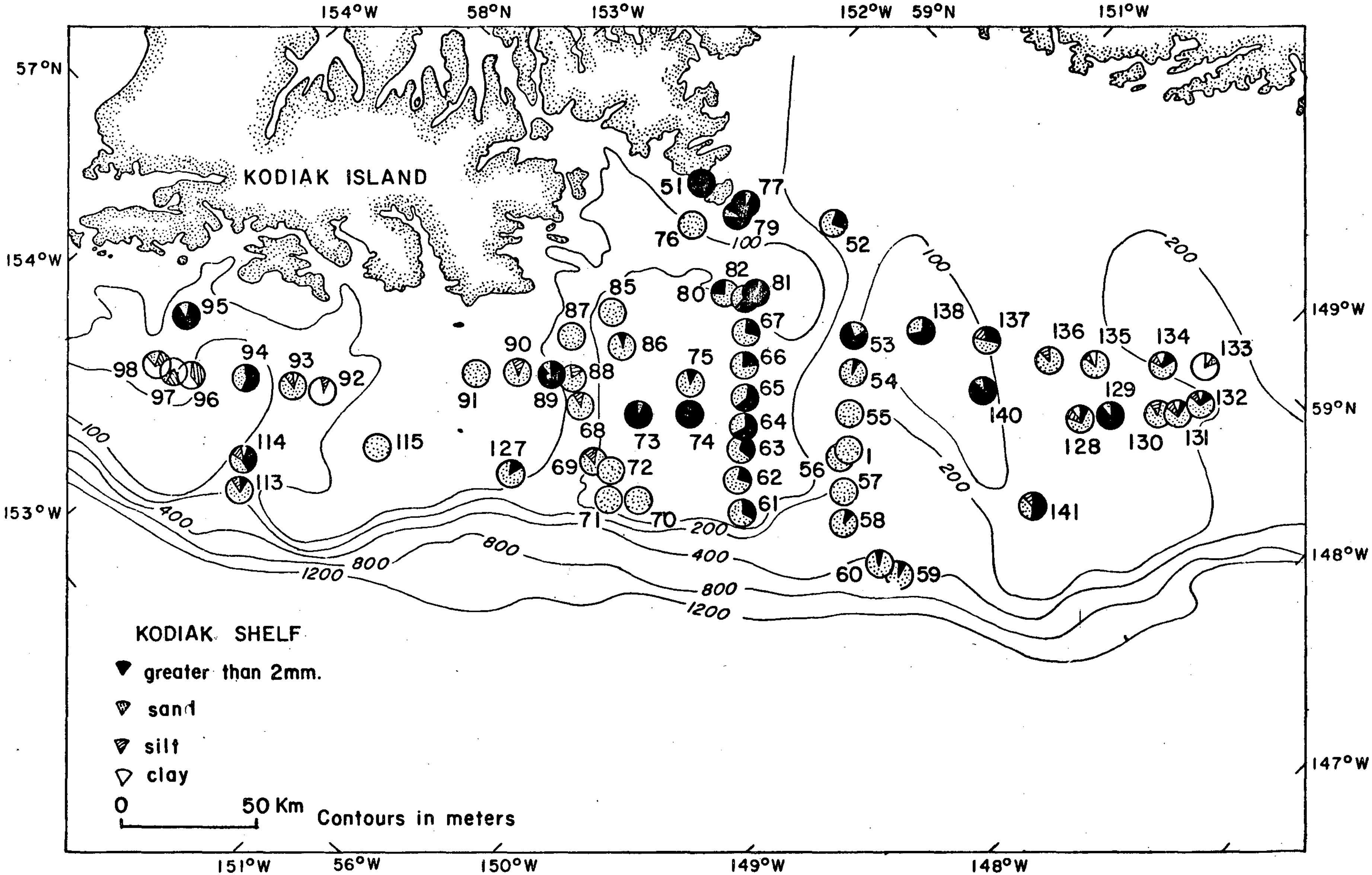



Fig. 3-1 Kodiak Shelf: surficial sediments (Bouma and Hampton, 1977).

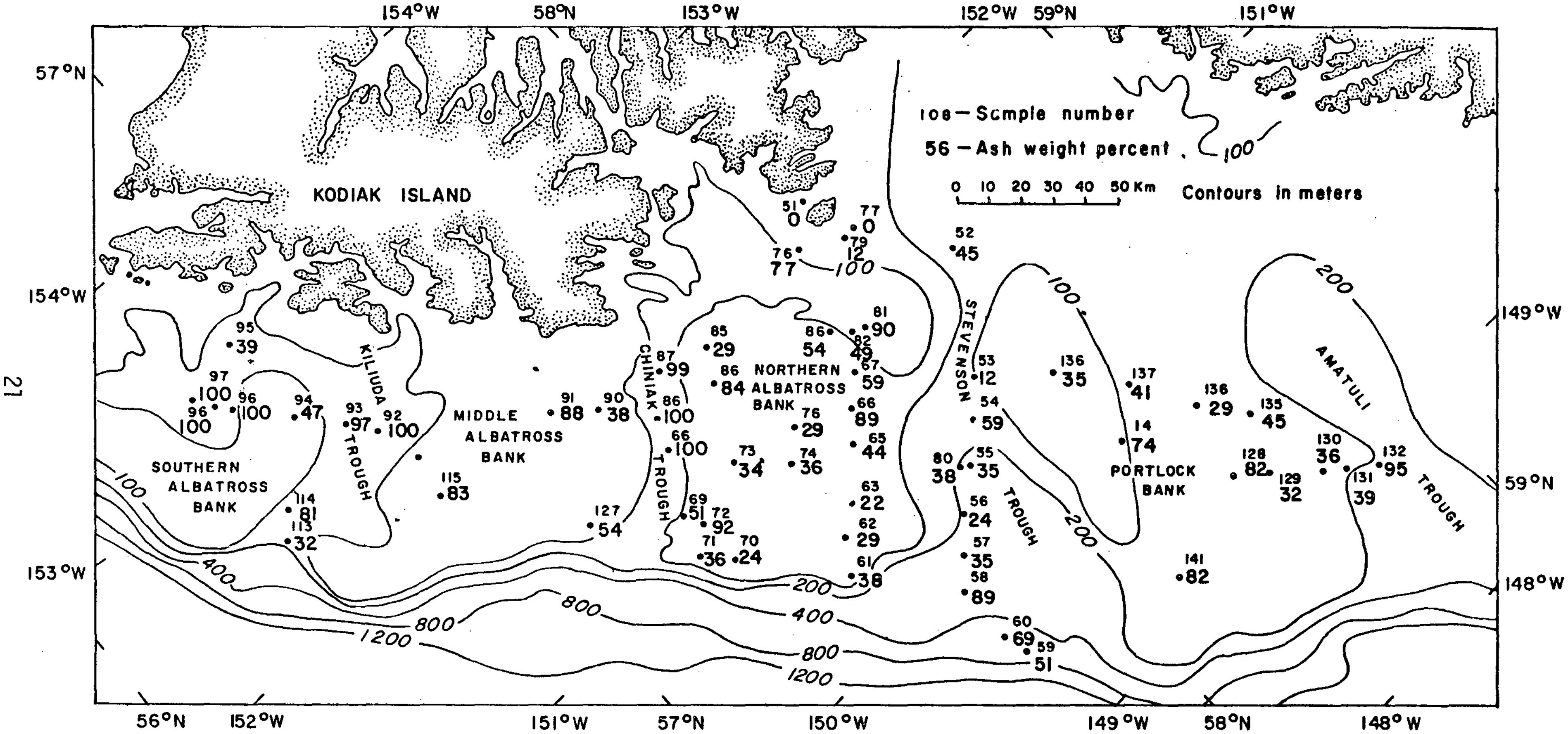



Fig. 3-2 Kodiak Shelf: distribution of Katmai Ash (weight percent) within surficial sediment samples (Bouma and Hampton 1977).

## Structure, Faulting and Slumping

Sub-bottom profiling indicates that most of the Kodiak Shelf is underlain by gently seaward dipping sedimentary sequences. Several faults have been identified but their random orientations suggest local small-scale features. A major fault zone exists along the Kodiak coast trending towards Middleton Island. Several fault traces follow this trend and local movements were identified following the 1964 Alaska earthquake. Von Huene recently confirmed offset of topographic futures along this fault trend (A. Bouma, USGS, Menlo Park, personal communication). The location of this fault trend in the turbulent, nearshore zone has thus far precluded adequate evaluation.

The continental shelf off Kodiak Island shows no evidence of the large-scale slides and slump structures seen in NEGOA. This apparently reflects the lower input of fine-grained sediments off Kodiak and the absence of thick sequences of unconsolidated, saturated Holocene sediments. As yet, no data are available on possible liquefaction hazards in the much coarser-grained Kodiak Shelf deposits.

Major slumps and slides (200 m thick) have been identified on the continental slope off South Albatross, Middle Albatross and Portlock Banks (Figure 2-2). Sub-bottom profiling across the outer bank edges reveals broad, actively rising anticlines that are expressed as topographic highs. Off Southern Albatross and Portlock Banks uplift has already produced a second shelf break, behind which sediments are accumulating. The major slumps are probably caused by tectonic-oversteeping of the continental slope (upper slope 6-9.5°) and seismic shocks. North Albatross Bank shows no evidence of either active tectonism or major slumps. Small sediment slides (10-20 m thick) have been noted all along the Kodiak Shelf break and are probably triggered by seismic shocks. The slumps and slides identified to date in general lie seaward and downslope from proposed Kodiak Shelf lease areas; however, a few slumps just touch certain lease blocks (Bouma and Hampton 1977).

## TRANSPORT PROCESSES

### Introduction

Oceanographic investigations in the Gulf of Alaska have been carried out intermittently for several decades. A substantial amount of historic temperature, salinity, and meteorological data are available for oceanic areas, especially for summer months. The limited amount of existing knowledge on physical oceanographic processes in the western part of the Gulf prior to OCSEAP has been summarized by AEIDC (1974) and Ingraham, Bakun and Favorite (1976).

Earlier OCSEAP oceanographic studies in the Gulf of Alaska were either of a generalized nature (to evalute mesoscale features) or were concentrated in the NEGOA lease area. Systematic studies on Kodiak Shelf were initiated in FY 77. So far data from temperature-salinity surveys, moored current meters, Lagrangian drifters, remote sensing and results from diagnostic modeling have been reported. However, due to the limited amount of field and seasonal coverage, the current state of knowledge is only fragmentary and largely unsatisfactory. Additional data with improved seasonal coverage are still needed to achieve an understanding of the physical transport processes over the Kodiak Shelf and in adjoining areas.

Much of the available data pertinent to the Kodiak lease area were presented and discussed at the Kodiak Synthesis Meeting. The general picture that emerged in the meeting showed that a swifter offshore flow regime is separated from a much less energetic coastal flow dominated by tides and eddies. The nature of the flow regime in the region between Kodiak Island and Kenai Peninsula is apparently quite complex and poorly understood. Apparently, frequent shifts in current direction are also noted for this area. Results from satellite imagery show a bifurcation of the westward flowing current in the northern Gulf of Alaska in an area south of the Middleton Island. A part of this water parallels the coastline, eventually entering Cook Inlet and the rest moves southwesterly along the Kodiak Shelf. There are some indications that a sizable fraction of water flowing toward Cook Inlet enters directly into the Shelikof Strait. In apparent conflict with above, there also is some weak evidence from coarse-grained sediments and bedforms in Stevenson Trough that near-bottom outflowing water from Cook Inlet might move across the Kodiak Shelf via Stevenson Trough (see Geologic Hazards section, this chapter).

It was surmised that the oceanographic regime over the shelf is such that the residence time of water might be considerable, especially northeast of Kodiak Island. This relatively long residence time combined with extensive macrophyte populations and detrital abundance nearshore could explain extensive food resources and provide an environment for containment of planktonic larval forms and juveniles of the commercially important species. A further implication from current meter data along Seward station line is that water could remain in shallow areas northeast of Kodiak Island for over two months. Under certain conditions, there might be a flow from the Kodiak lease area toward Prince William Sound -- in a direction opposite to the generalized mean flow.

A summary of data and results presented at the meeting is given in the following sections. Any conclusions derived from the present state of knowledge would be tenuous and premature.

Currents

*Geostrophic calculations.* Dynamic topography across the shelf in the western Gulf of Alaska has been utilized to infer baroclinic currents. Data relative to 100 decibars (db) are illustrated in Figures 3-3a through 3-3e. If the flow is in geostrophic equilibrium, these contours represent approximate streamlines (a streamline is defined as a line which is tangential at every point to the velocity vector at a given time). Baroclinic current speeds are related to contour intervals. Generally, higher currents are noted for fall (Figure 3-3b) and lower values in spring (Figure 3-3d).

The following assumptions are inherent when describing the relationships between currents and contours of geopotential topography: simultaneous observations, unaccelerated motion, negligible friction forces, and no periodic changes in mass distribution related to internal waves. However, when generalized patterns are considered over large areas and only an approximate velocity field is required, violation of these assumptions does not introduce serious errors.

Currents generally follow bathymetic contours, especially along the shelf break. Considering the nature of bathymetry on the Kodiak Shelf, this suggests a highly irregular flow. The tendency of currents to follow bottom topography is readily seen from data obtained in May 1976 across

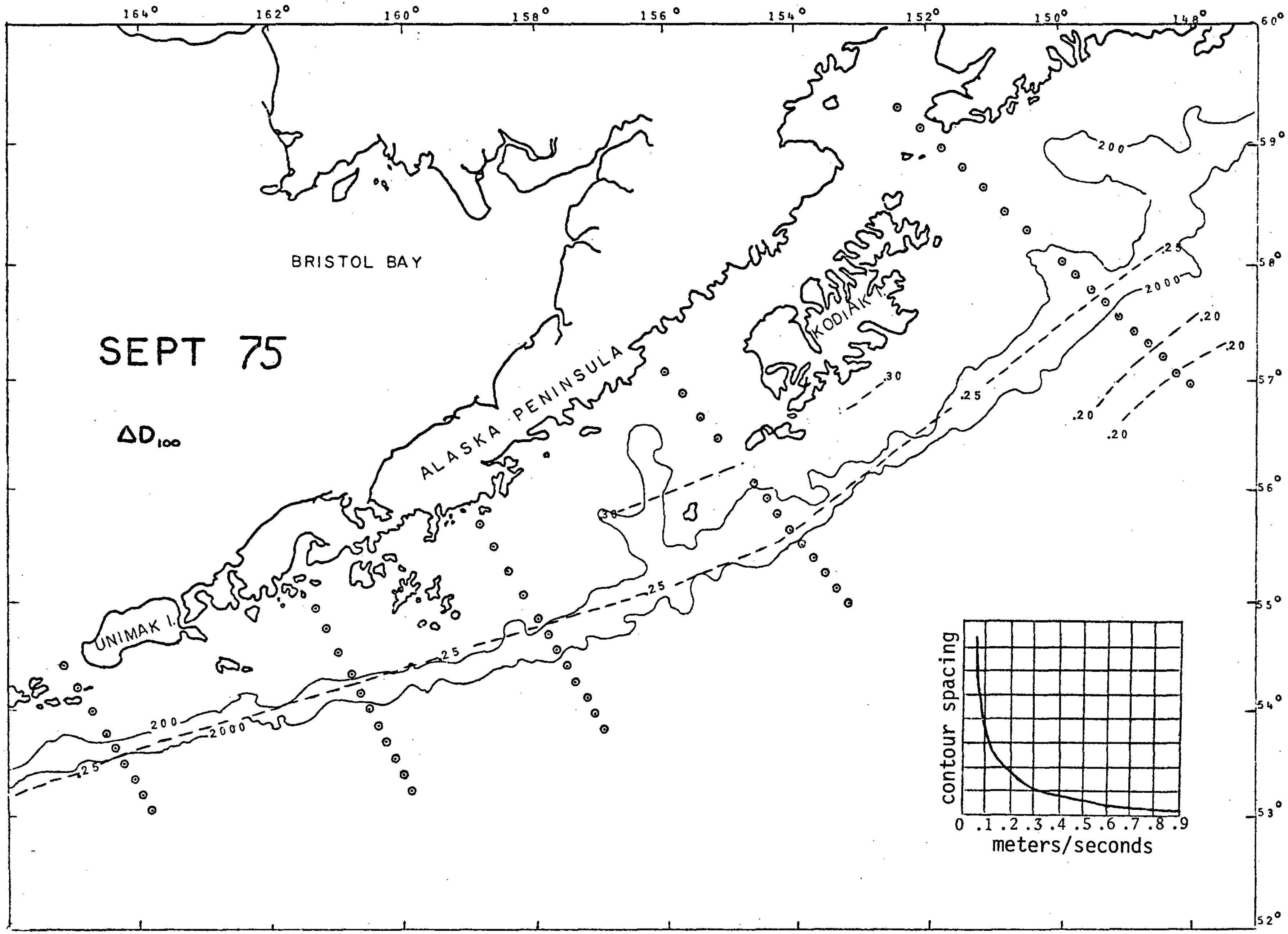



Fig. 3-3a Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

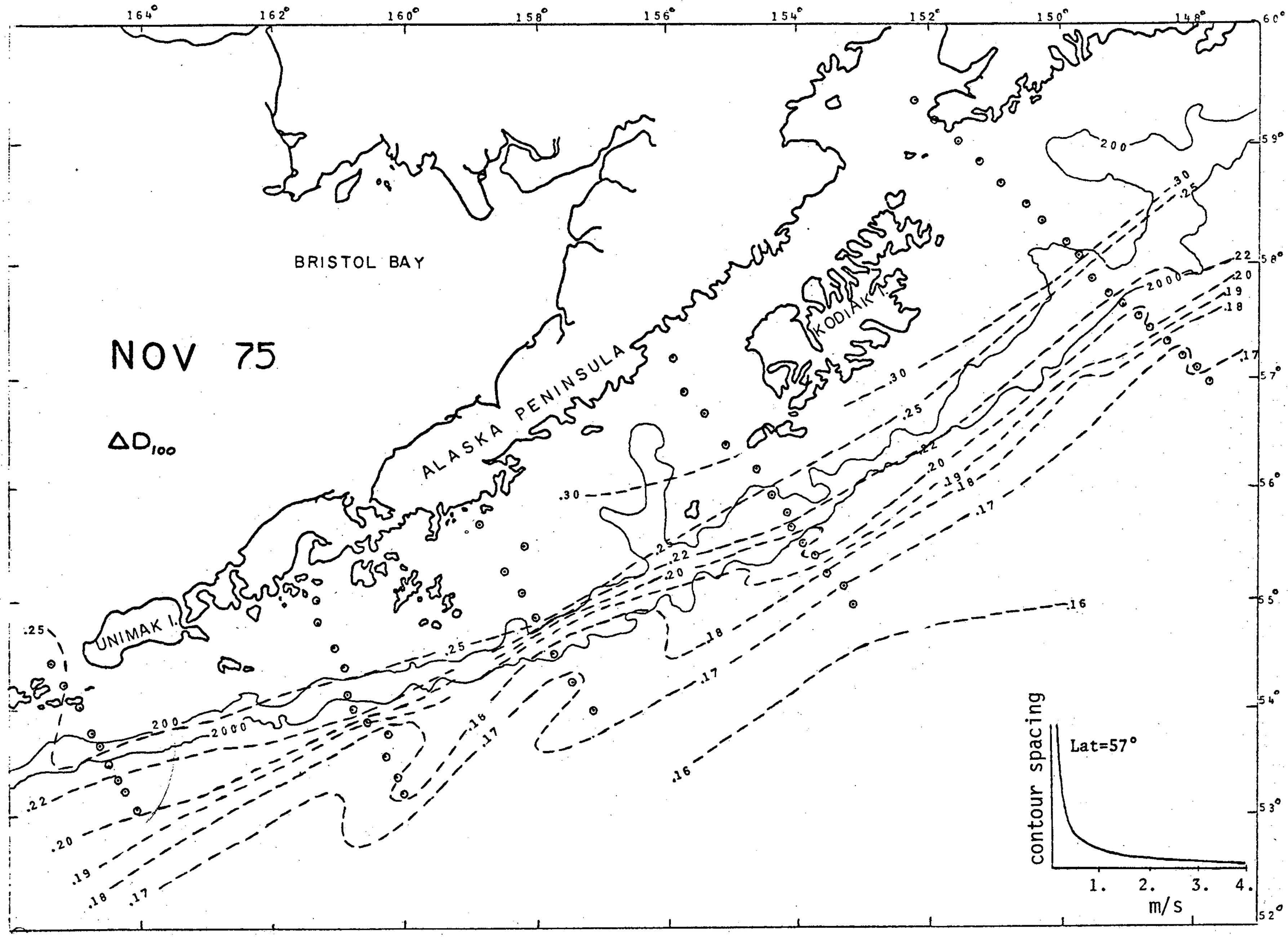



Fig. 3-3b Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

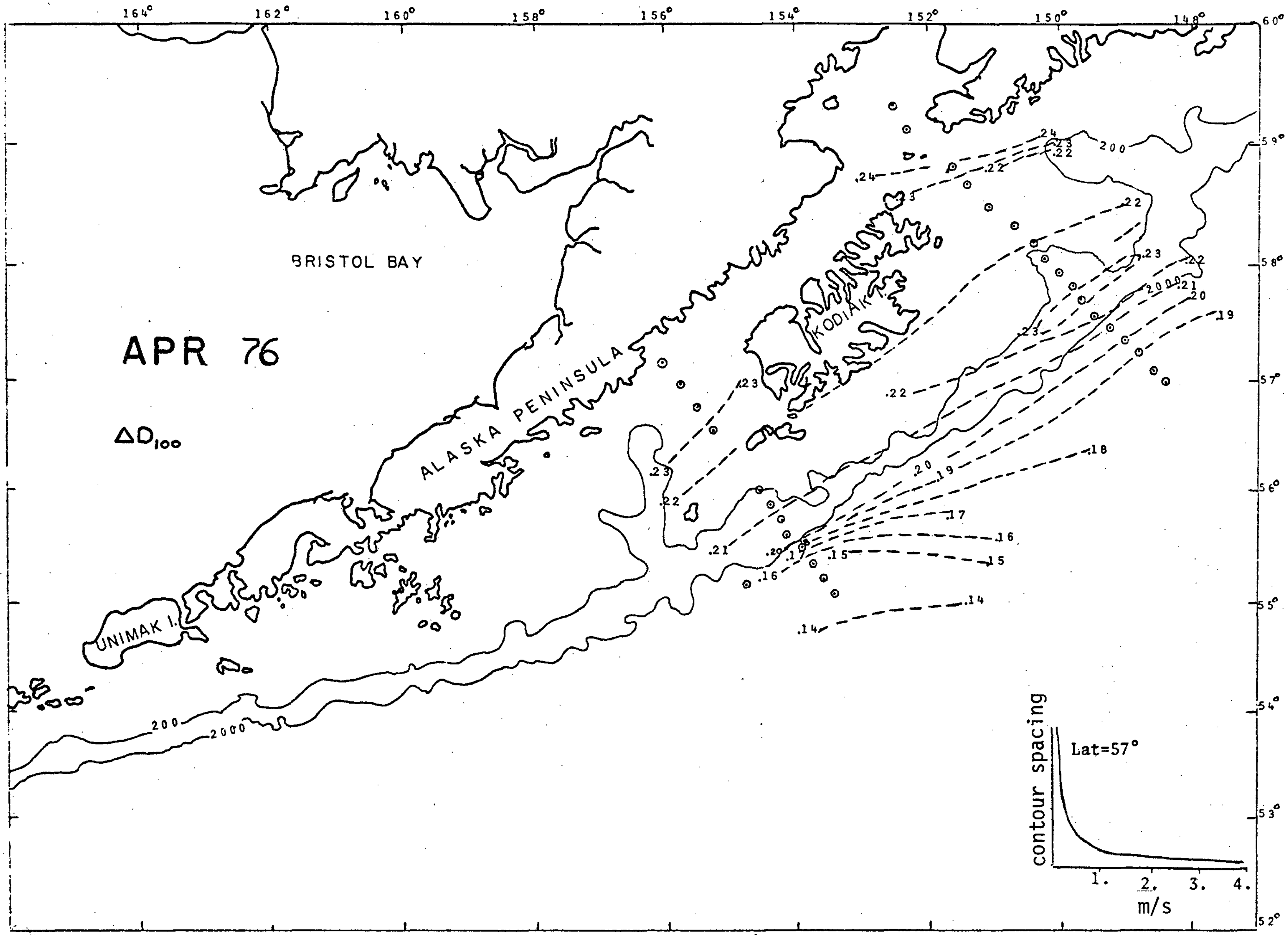



Fig. 3-3c Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

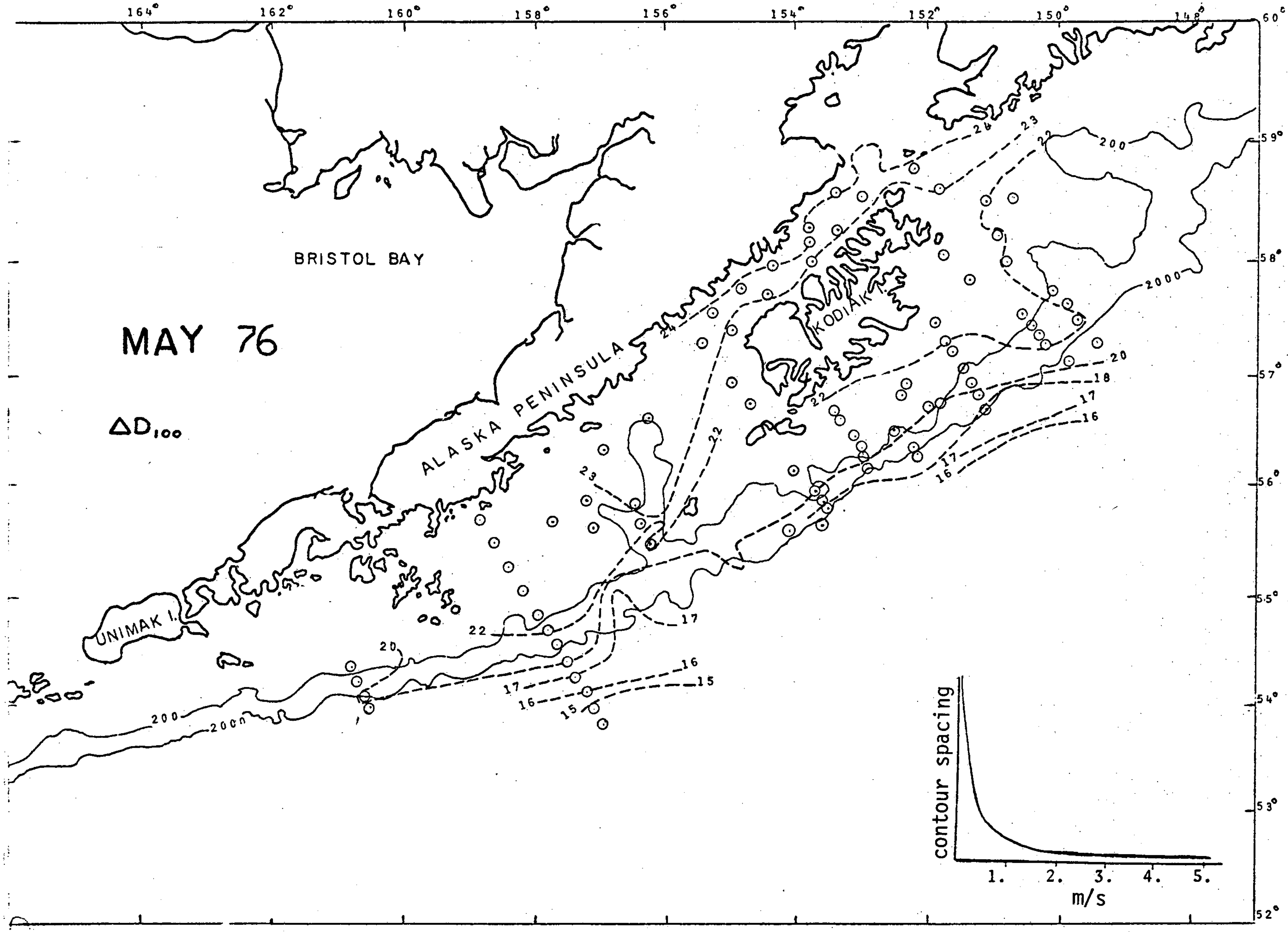



Fig. 3-3d Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

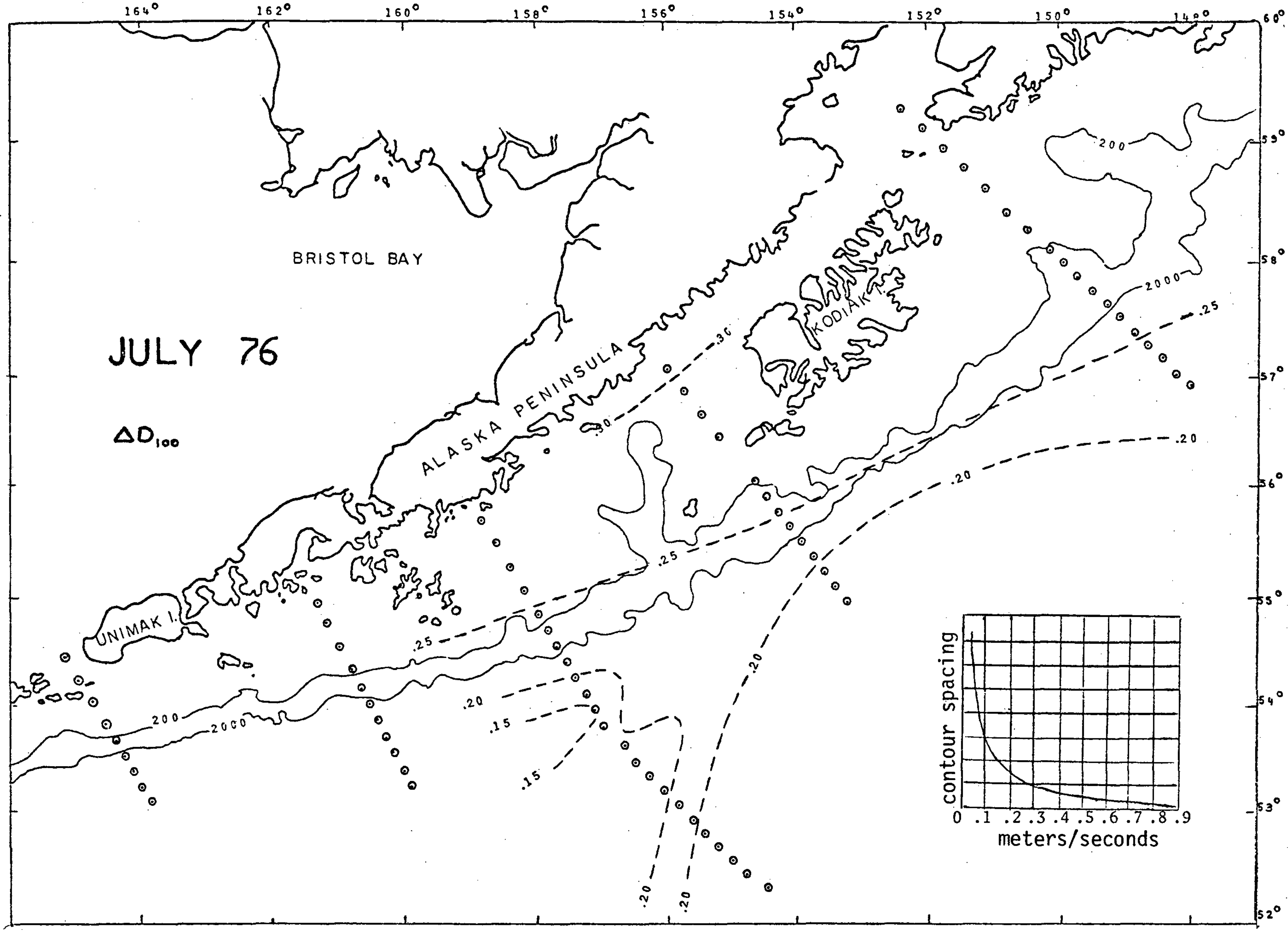



Fig. 3-3e Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

the KISS (Kodiak Island Shelikof Strait) station grid (Figure 3-3d). Possible flow reversals are noted in April 1976 data, especially along the Cook Inlet station line (Figure 3-3c). The apparent "reversals" in flow should be interpreted with caution as they may merely indicate the presence of eddies; furthermore, it cannot be stated whether these features represent actual reversal in water flow directions. Data from May 1976 (Figure 3-3d) indicate that currents south and southwest of Kodiak Island are very weak (note the distance separating dynamic contours) and also variable in direction as shown by diagnostic modeling.

Seasonal variability in dynamic topography relative to 100 db and 1,000 db along Cook Inlet station line is given in Figures 3-4a and 3-4b. It should be noted that July 1976 data showed higher values. Water transport values, with reference to 1,000 db, calculated from four data sets are: September 1975 - 7.3 Sv; November 1976 - 9.7 Sv; May 1976 - 9.6 Sv; and July 1976 - 13.0 Sv. (One Sv is equal to transport of one million cubic meters of water per second.) As compared to other transport estimates in the Gulf of Alaska, the 13 Sv value is one of the largest, especially for summer.

*Moored Current Meters.* Data from current meter array WBC-2, located near the shelf break southeast of Kodiak Island (57°27'N, 150°29'W, depth of water 190 m) have provided the only relatively long time-series of observations of mean currents in this area. Data collected from 22 September to 28 November 1975 have shown mean flow rates of 30 cm/sec (at 20 m) and 26 cm/sec (at 100 m) directed southwestward (Hayes and Schumacher 1976). A progressive vector diagram (PVD) for data obtained at 20 m is shown in Figure 3-5. Mean flow was directed at 229°T and fluctuated by ± 25°. Additional data, from 10 March to 8 June 1976, obtained at this location, gave similar values -- mean flow of about 30 cm/sec directed southwestward. Estimated net drift was 22 cm/sec.

The array was later moved about 10 km inshore on the shelf (new location, 57°34'N, 150°49'W, depth of water 92 m). Data from this location, obtained from 8 June to 18 October 1976, showed a mean speed of 35 cm/sec at 20 m and 20 cm/sec at 80 m. However, net drift was an order of magnitude lower: 3 cm/sec and directed at 245°T at 20 m, 1 cm/sec and directed at 178°T at 80 m (Table 3-1). Progressive vector diagrams show a considerable amount of perturbation and direction changes in the flow regime (Figures

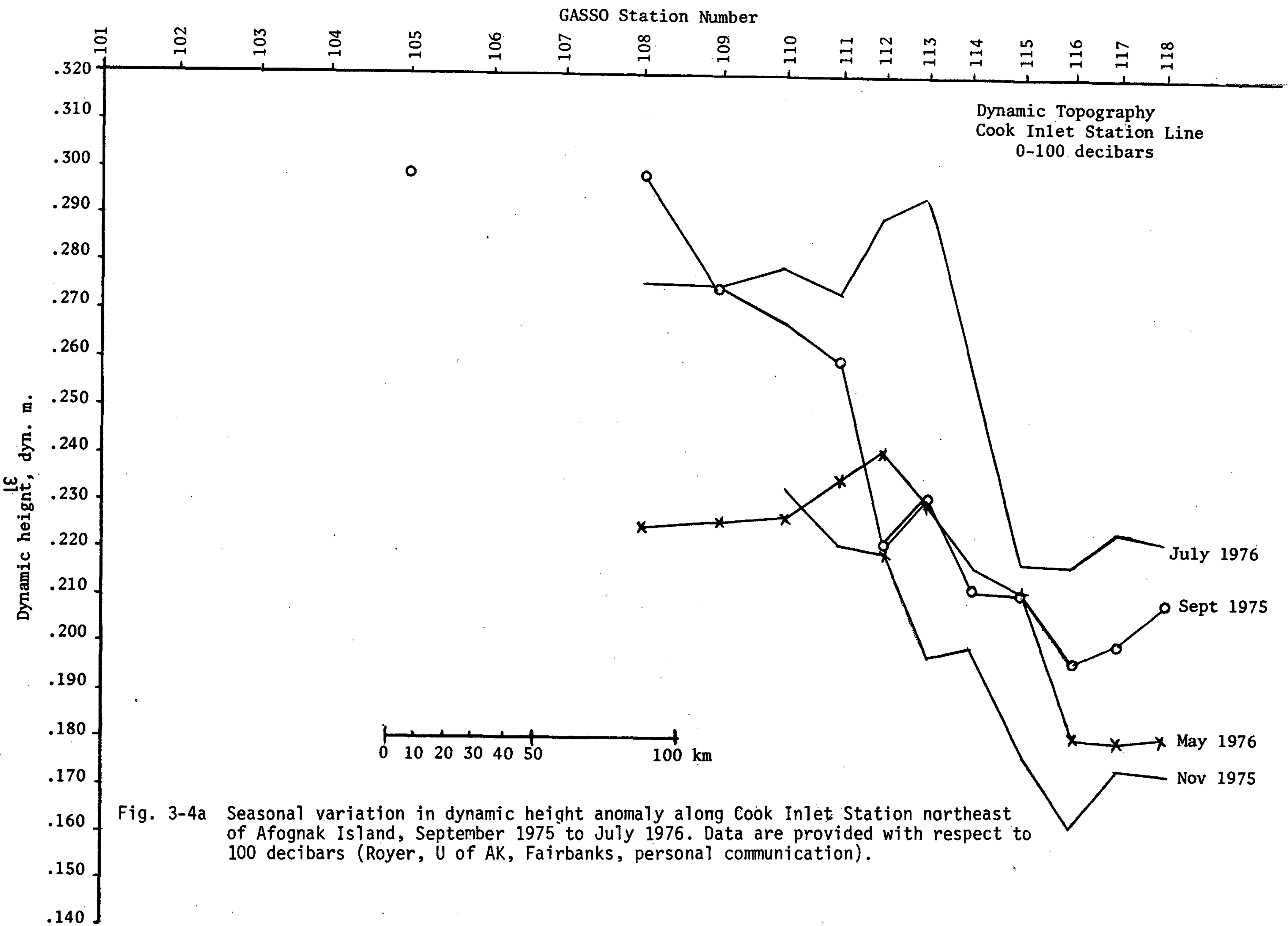



Fig. 3-4a Seasonal variation in dynamic height anomaly along Cook Inlet Station northeast of Afognak Island, September 1975 to July 1976. Data are provided with respect to 100 decibars (Royer, U of AK, Fairbanks, personal communication).

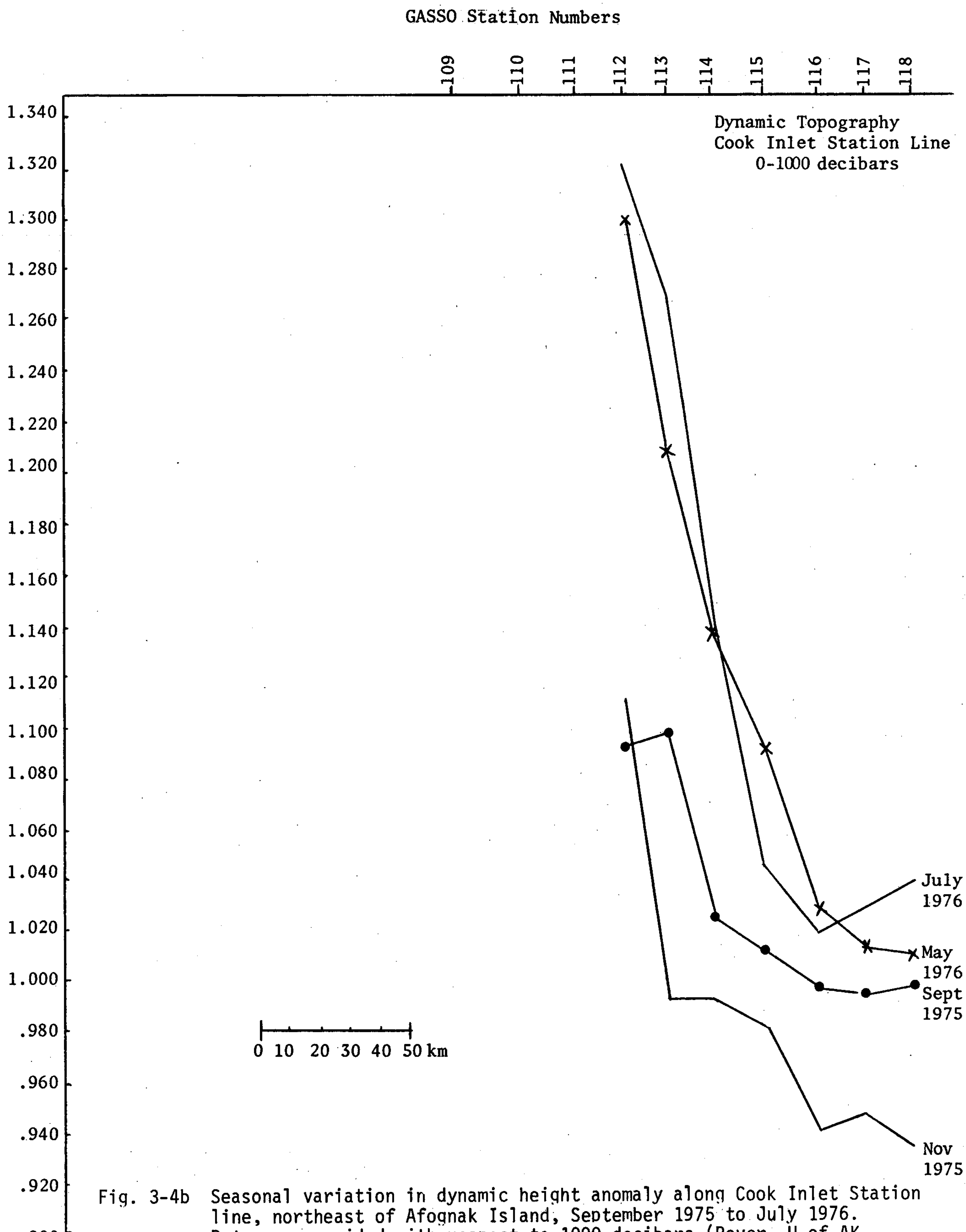



Fig. 3-4b Seasonal variation in dynamic height anomaly along Cook Inlet Station line, northeast of Afognak Island, September 1975 to July 1976. Data are provided with respect to 1000 decibars (Royer, U of AK, Fairbanks, personal communication).

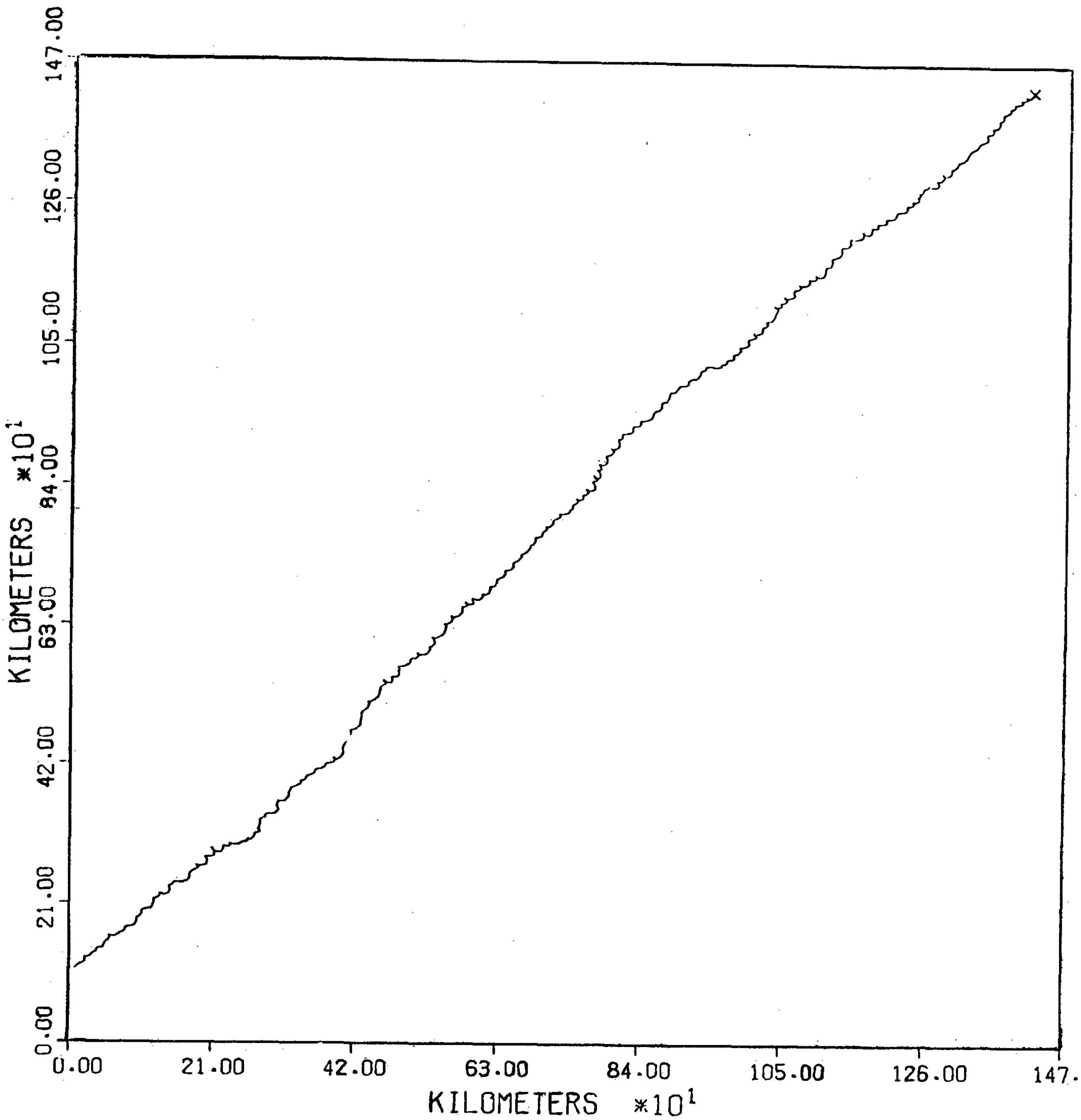



Fig. 3-5 PVD constructed from current measurement data from station WGC-2, September-November 1975. Mean flow is directed at 229° (TN). Figure reproduced from Hayes and Schumacher (1976).

TABLE 3-1

Moored Current Meter Data, June 8 to October 18, 1976, from the Shelf Off Kodiak Island (depth of water 92 m) (data from Hayes and Schumacher, 1976)

| | Current Meter Depth 20 m | 80 m |
|---|---|---|
| Current meter number | 1678 | 1455 |
| Mean speed | 34.67 cm/sec | 20.26 cm/sec |
| Net drift | 3.11 cm/sec ($245^{o}$ T) | 1.10 cm/sec ($178^{o}$ T) |
| U variance | 631 | 177 |
| V variance | 780 | 337 |

Larrance (1976) has studied the distribution pattern and seasonality of phytoplankton biomass and productivity in the Lower Cook Inlet and at a few locations in the northern Gulf of Alaska. Four of his sampling locations were in the vicinity of Kodiak Shelf: Stations 1 and 9 were near the mouth of Cook Inlet, Station 10 northeast of Afognak Island, and Station 11 about 200 miles offshore to the east of Afognak Island (Figure 3-12). Available data on chlorophyll concentration and primary productivity are shown in Table 3-2. It can be noted from the values reported herein that both Stations 1 and 9 showed a similar pattern of increase in chlorophyll concentration, highest concentrations were noted in early July. At Station 10, maximum value was observed in early May -- possibly reflecting a typical shelf bloom of phytoplankton. Chlorophyll concentration at Station 11 did not change markedly over the sampling period, a situation characteristic of deep oceanic waters as exemplified by Station PAPA data (Anderson and Lam 1976).

Reported data on the level of primary productivity are too few to infer seasonal patterns or spatial variability. Highest values reported were from Stations 10 and 11 in early July 1976, 1.6 and 2.6 $gC/m^2/day$, respectively. These values are comparable to rates reported from highly productive areas such as Lower Cook Inlet and Puget Sound. Nitrate concentration at all stations was substantial; minimum average value in the water column, upper 25 m, was 4.4 mg-at $N/m^3$ (Table 3-3). Nutrient availability does not appear to be a limiting factor to primary productivity.

Taxonomic data, primarily from the NEGOA lease area show that microflagellates dominate the phytoplankton in numerical abundance, especially offshore. Nearshore, diatoms such as *Thalassiosira* sp. and *Chaetoceros* sp. may form dominant fractions of the phytoplankton community (Larrance 1976).

OCSEAP data on zooplankton distribution and abundance in this area are not yet available. The NORPAC Committee Atlas (1960) shows that off Kodiak Island zooplankton biomass (presumably settled volume) values were about 200 $cm^3/1000\ m^3$. Higher values, 400 $cm^3/1000\ m^3$, were noted in waters north of Afognak Island. These data are for summer only and are based on very few samples.

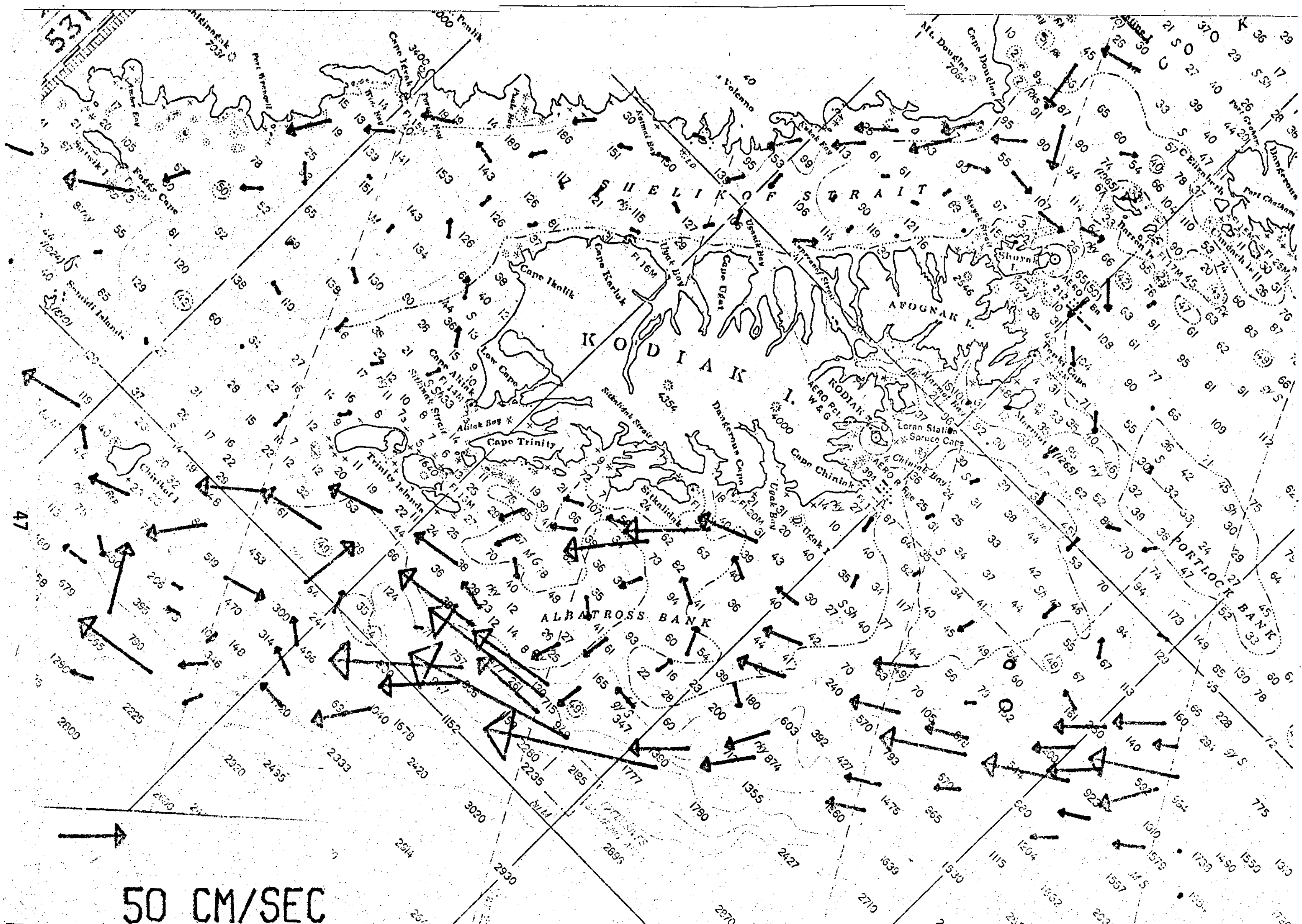



Fig. 3-11b Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 4 dynes/$cm^2$. Results are provided for bottom current patterns (Galt, 1976).

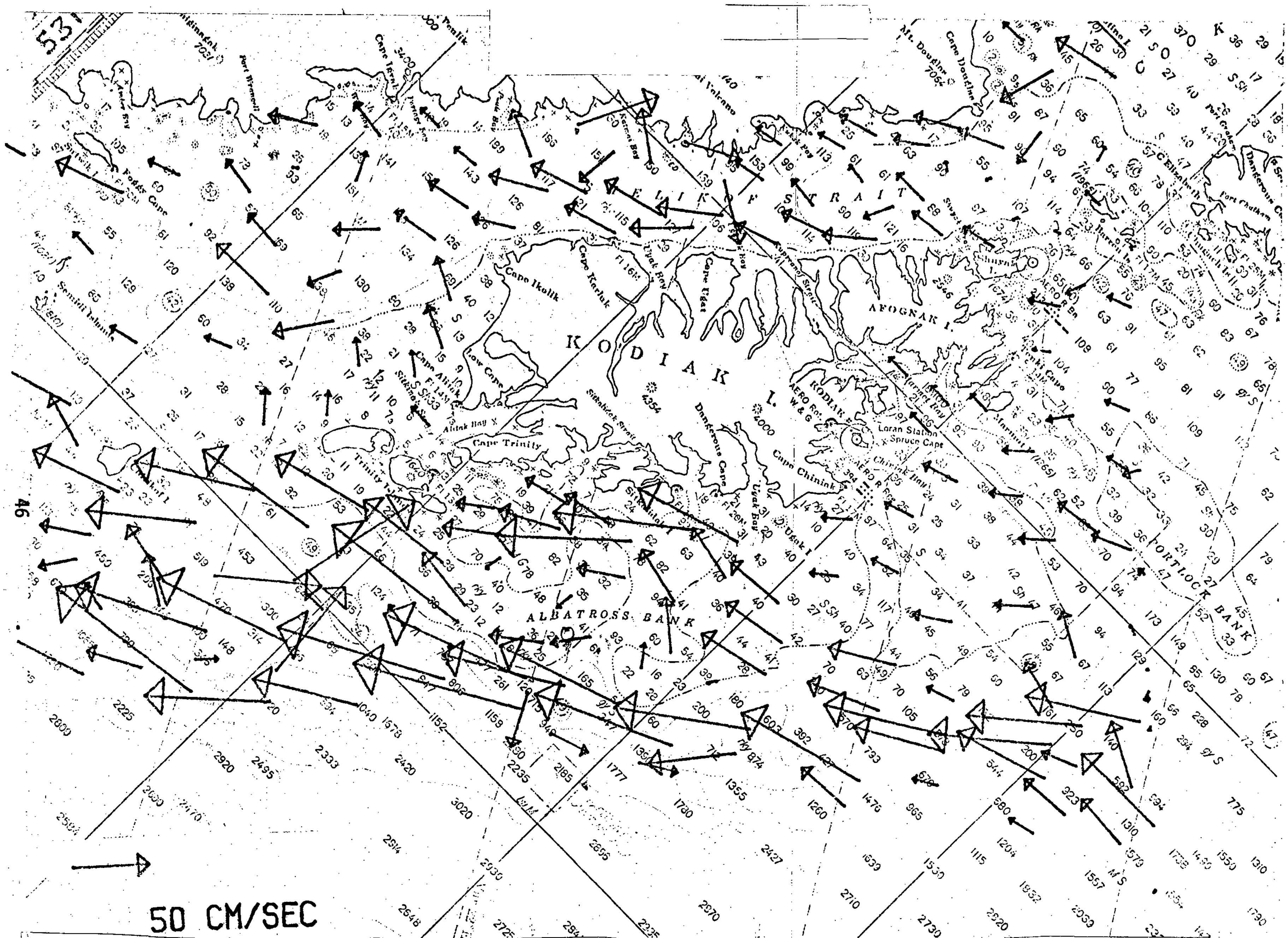



Fig. 3-11a Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 4 dynes/cm$^2$. Results are provided for surface current patterns (Galt, 1976).

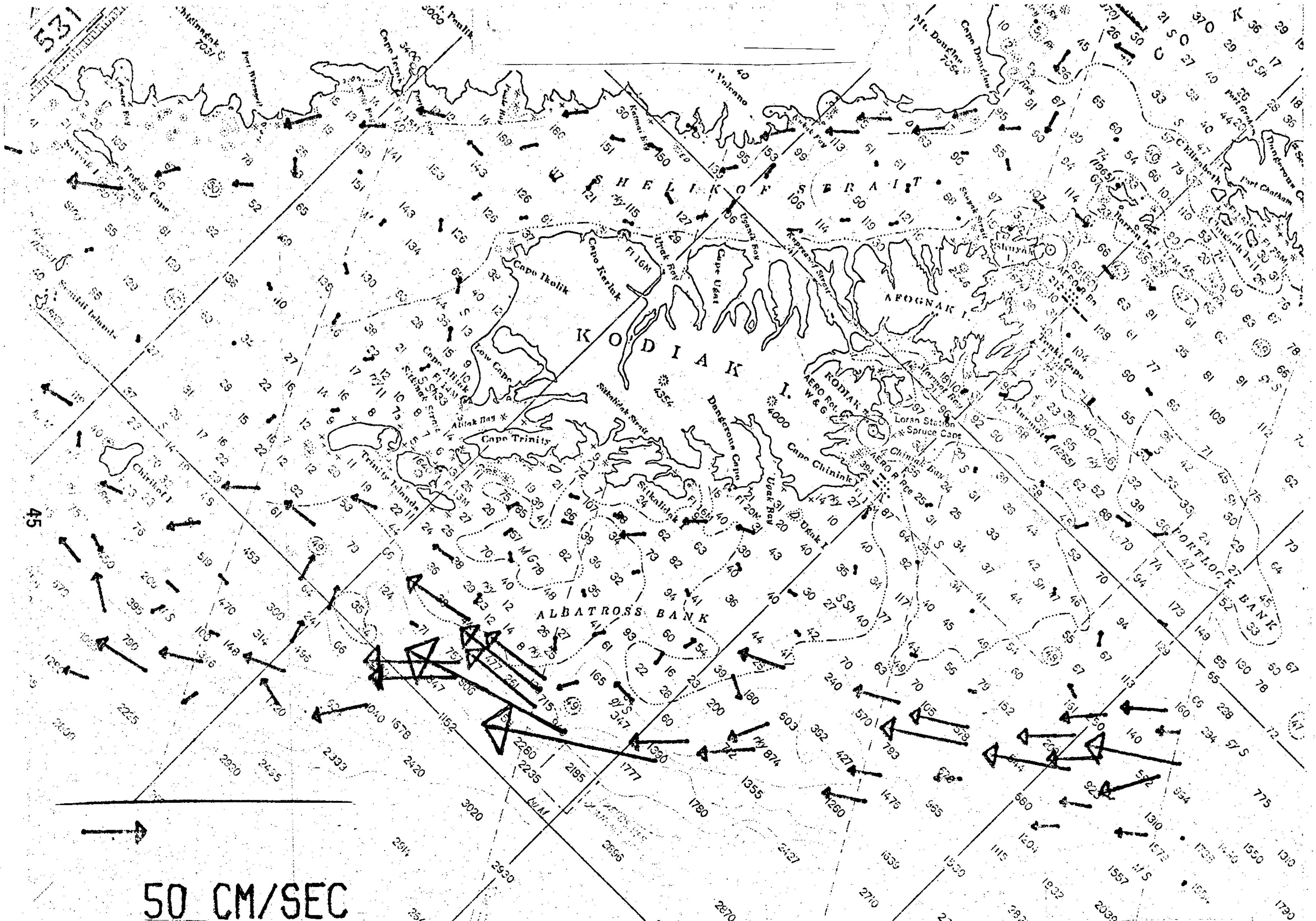



Fig. 3-10b Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 1 dyne/cm$^2$. Results are provided for bottom current patterns (Galt, 1976).

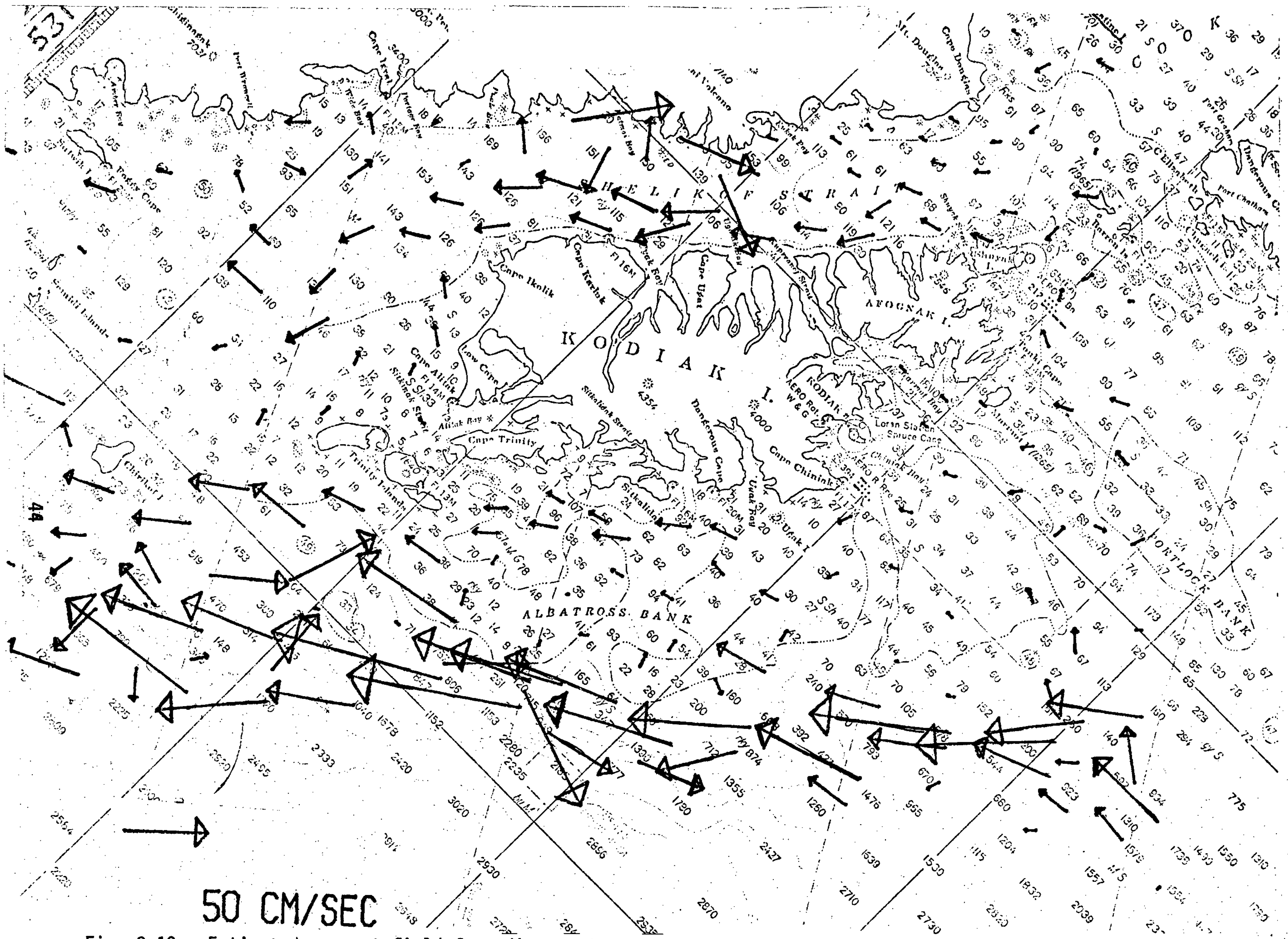



Fig. 3-10a Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 1 dyne/$cm^2$. Results are provided for surface current patterns (Galt, 1976).

### Diagnostic Modeling

Galt (1976) has developed a numerical model for circulation in the NEGOA area. The model includes the first order effects of density variations within ocean waters, complex bathymetry, and coastal configuration as well as wind driven surface flows and frictionally-controlled currents along the bottom. The model is diagnostic in that certain segments of flow are determined from observational data. For example, the model solves for velocity field subject to some observed density distribution and equations of motion. Based on hydrographic data, it also calculates sea surface slope variation. Near the ocean surface, the wind-driven Ekman layer is superimposed on the geostrophic flow. A few preliminary runs of this model utilizing spring 1976 data were presented at the meeting. These simulations depict surface and bottom current patterns along the Kodiak Shelf and Shelikof Strait (KISS) grid under wind stress of 1 dyne/$cm^2$ (Figures 3-10a and 3-10b) and 4 dynes/$cm^2$ (Figures 3-11a and 3-11b) from the northeast. Wind-stress is proportional to the square of wind velocity; 1 dyne/$cm^2$ is equivalent to wind speed of about 7 m/sec. The swift, southwestward moving Alaska Stream is easily recognized. It does not appear to be dependent on winds. Relatively weak onshore movement of surface water along the outer shelf areas and counterclockwise circulation along the eastern coast of Kodiak Island are also seen. Flow direction and strength southwest of Kodiak Island are characterized by high degrees of perturbation. Over the shelf northeast of Kodiak Island, currents are weak and inconsistent in direction. The effect of increase in wind-stress is more pronounced over the shelf in general and over the banks in particular.

## RECEPTORS

### Plankton

No systematic OCSEAP plankton studies have yet been conducted in the Kodiak lease area. A review of available historic data on nutrients, primary productivity, and chlorophyll concentration in the Gulf of Alaska and adjoining North Pacific Ocean has shown that no measurements were available for the Kodiak Shelf waters (Anderson and Lam 1976).

air advection in the Gulf of Alaska associated with the mean position of the low pressure center determine the extent and intensity of winter overturn and wind-induced flow. Storms generally originating in the Bering Sea and North Pacific Ocean move eastward into the Gulf. As they pass over the ocean's warmer waters, extensive heat and moisture exchange occurs. Winter winds in the northern Gulf are strong and primarily from the east. But in the vicinity of Kodiak, the direction is highly variable and depends on position of the west to east moving Aleutian low. In addition to the primary storm tracks caused by the Aleutian low there are secondary tracks that are less frequently travelled. February is the month with the highest storm activity in the area. According to estimates, on the average 100 knot winds are likely to occur once every 25 years and 80 knot winds once every 2 years (AEIDC 1975). Although winds in the area are highly variable, mean wind-stress can set up conditions for onshore-offshore flow. Seasonal mean winds are more or less well defined and fairly consistent on a biannual (summer and winter) basis.

Ingraham, Bakun and Favorite (1976) have characterized various coastal areas around the Gulf of Alaska according to seasonal dominance of divergence or convergence. The divergence of Ekman Transport integrated over the width of coastal divergence/convergence boundary zone, per unit length of the coast, is approximately given by the offshore component, the Coastal Divergence Index (CDI); offshore, it is called Offshore Divergence Index (ODI). The area northeast of Kodiak Island is characterized by 'A' type of situation as it occurs eight months of the year (for details see OCSEAP Annual Technical Summary Report, NOAA/SAI 1976). In this situation surface water is piled toward the coast and coastal convergence (negative CDI) occurs. Furthermore, divergence immediately offshore favors containment of the intensification of the counterclockwise flow to a relatively narrow band inshore. The remaining four months are characterized by a relatively low energy period and weak and variable coastal divergence. A clockwise circulation (or deceleration of counterclockwise circulation) is favored.

Presently, available data on local wind speed and direction and the relationship between local and synoptic wind fields are not available. Quantitative aspects of the nature of coupling of energy between wind-stress and water transport are not known.

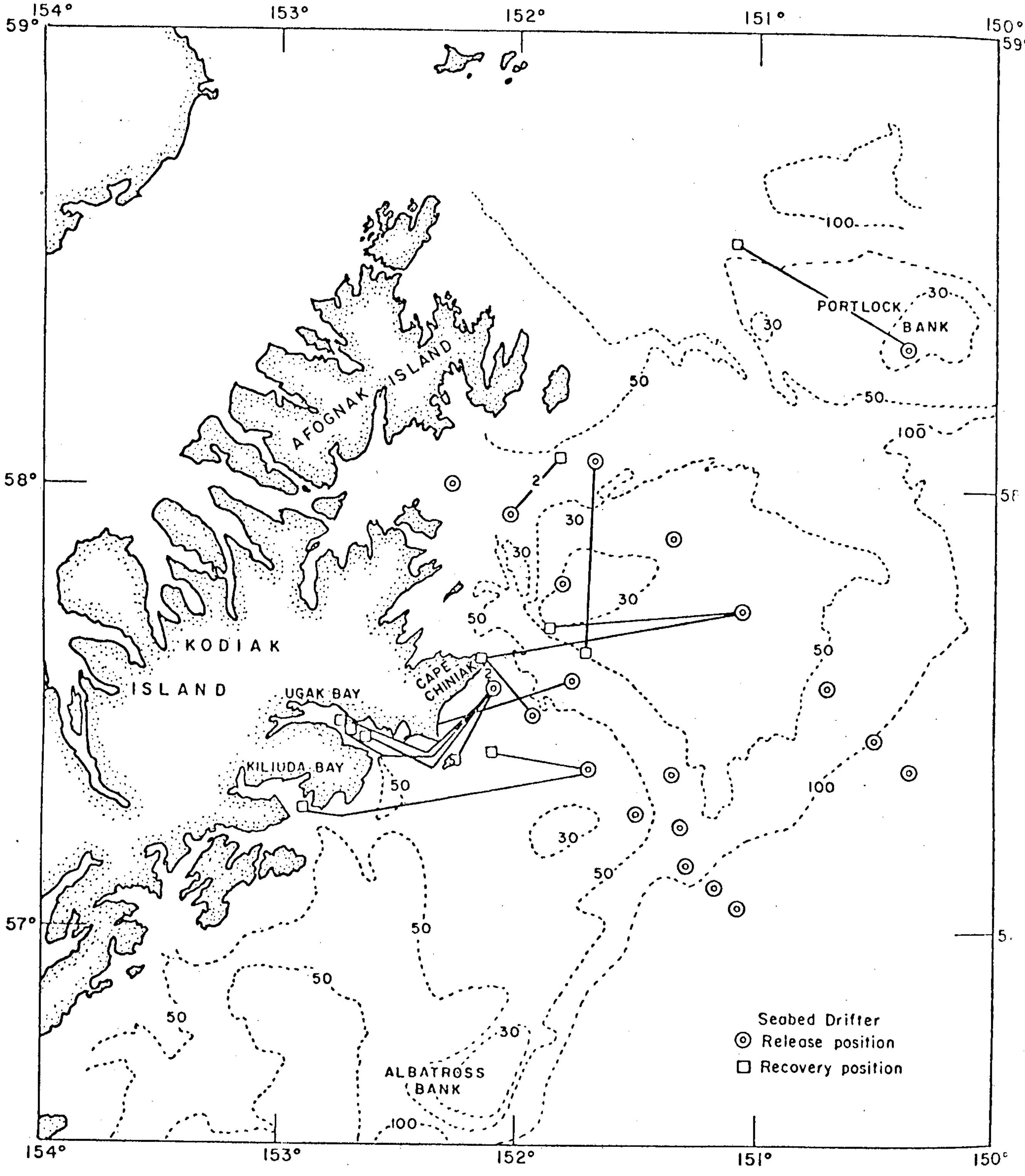



Fig. 3-9 Locations of sea-bed drifter releases and recoveries (depth contours in fathoms) ( from Ingraham and Hastings 1974).

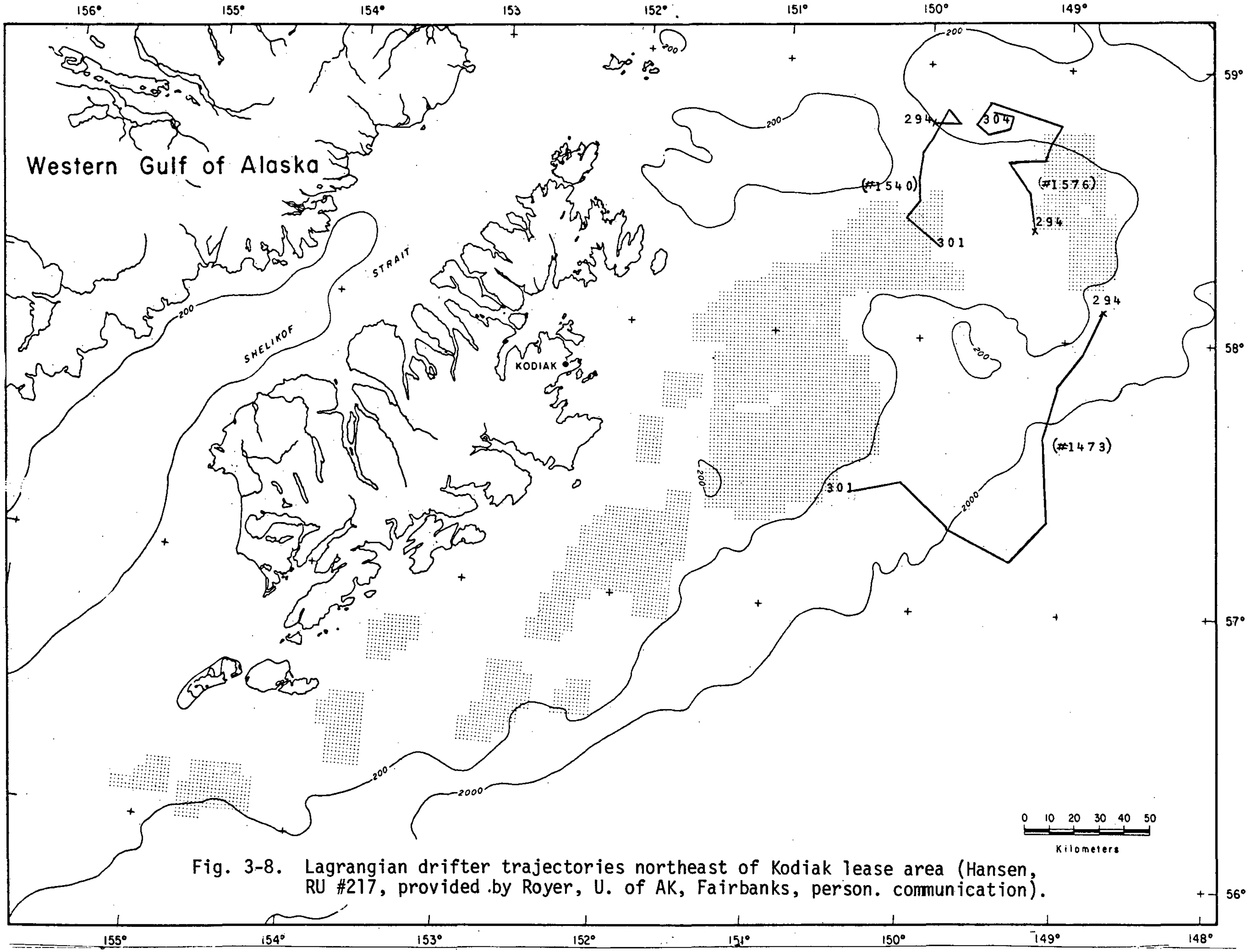



Fig. 3-8. Lagrangian drifter trajectories northeast of Kodiak lease area (Hansen, RU #217, provided by Royer, U. of AK, Fairbanks, person. communication).

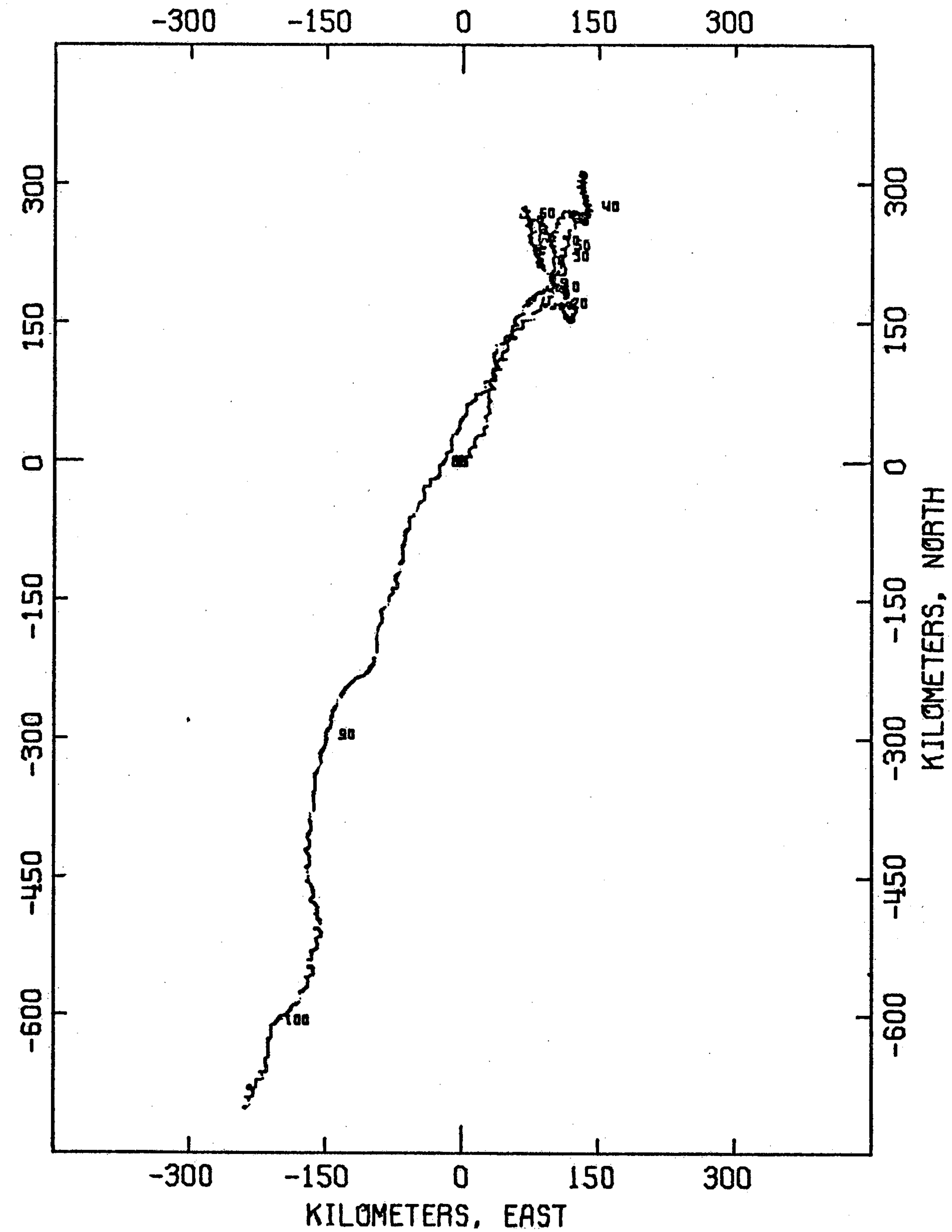



Fig. 3-7b Progressive vector diagram constructed from current meter data obtained at Seward line Station 9 (GASSE 9) from July to November 1976. Data are from current meter moored at about 20m below the surface (Royer, U of AK, Fairbanks, personal communication).

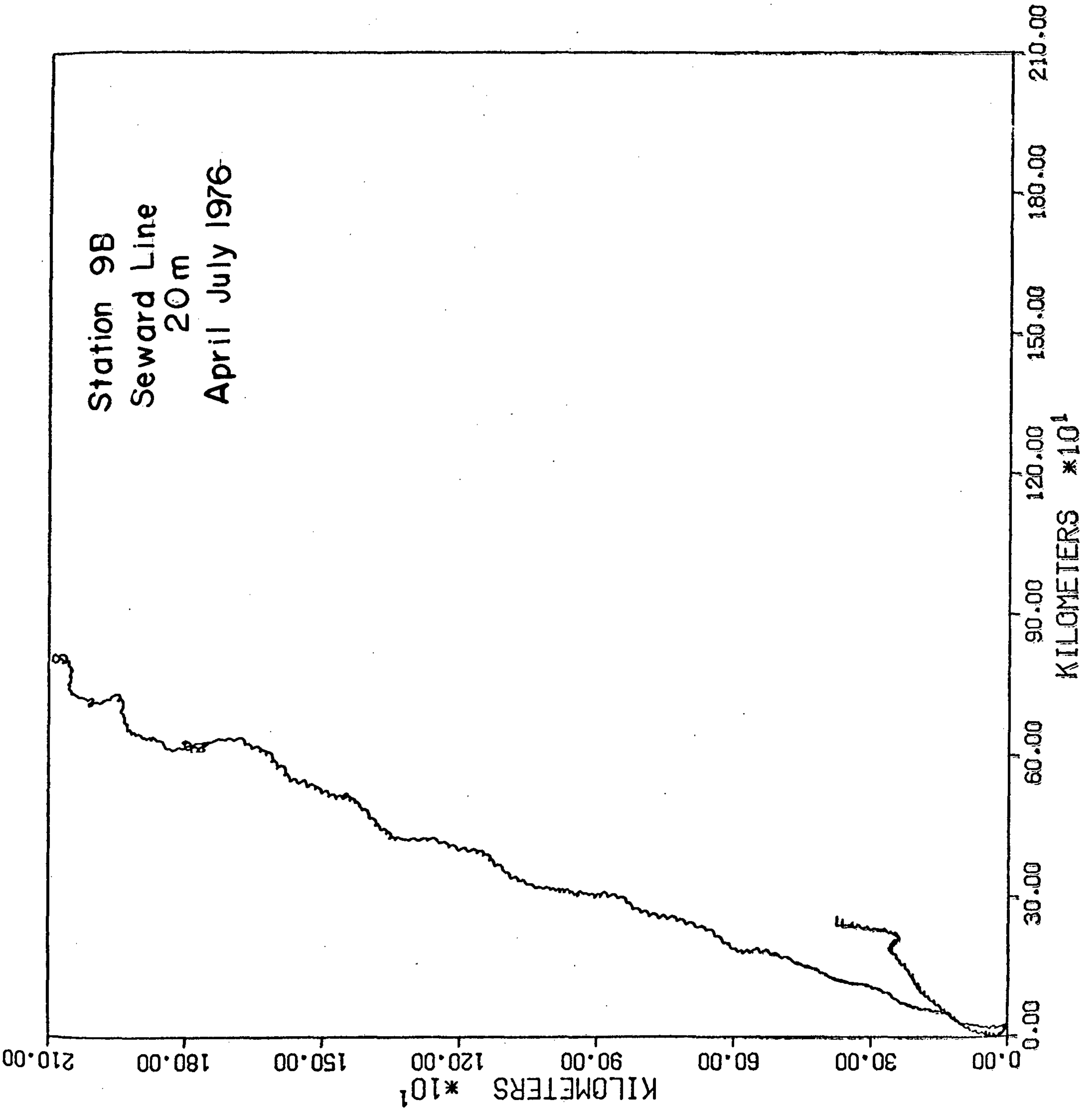



Fig. 3-7a Progressive vector diagram constructed from current meter data obtained at Seward line Station 9 (GASSE 9) from April to July 1976. Data are from current meter moored at about 20m below the surface (Royer, U of AK, Fairbanks, personal communication).

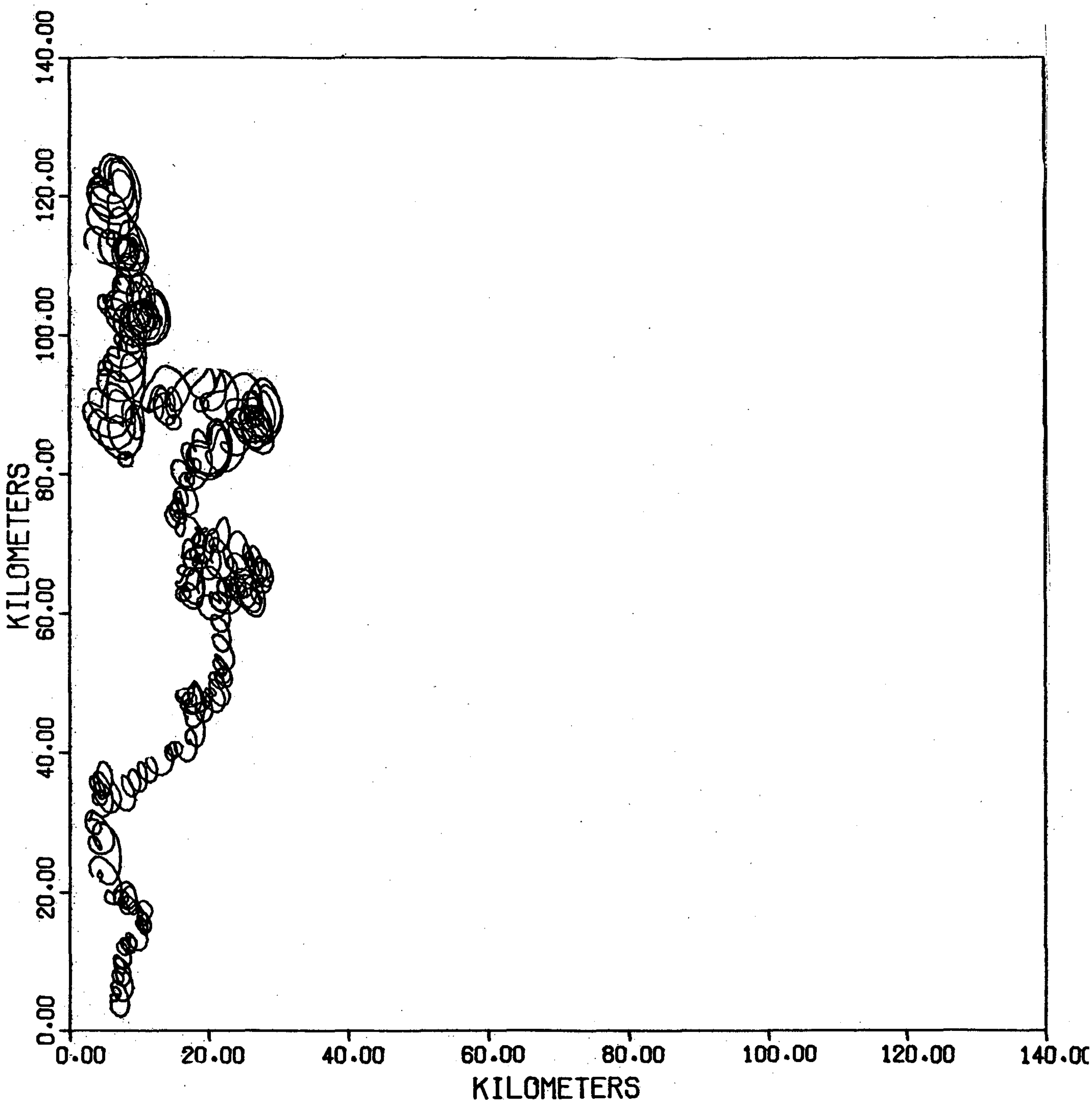



Fig. 3-6b Progressive vector diagram constructed from current meter data obtained over the shelf, depth of water 92m, from June to October 1976. Data are provided for current meter moored at depth 80m below the surface (Hayes and Schumacher, 1976).

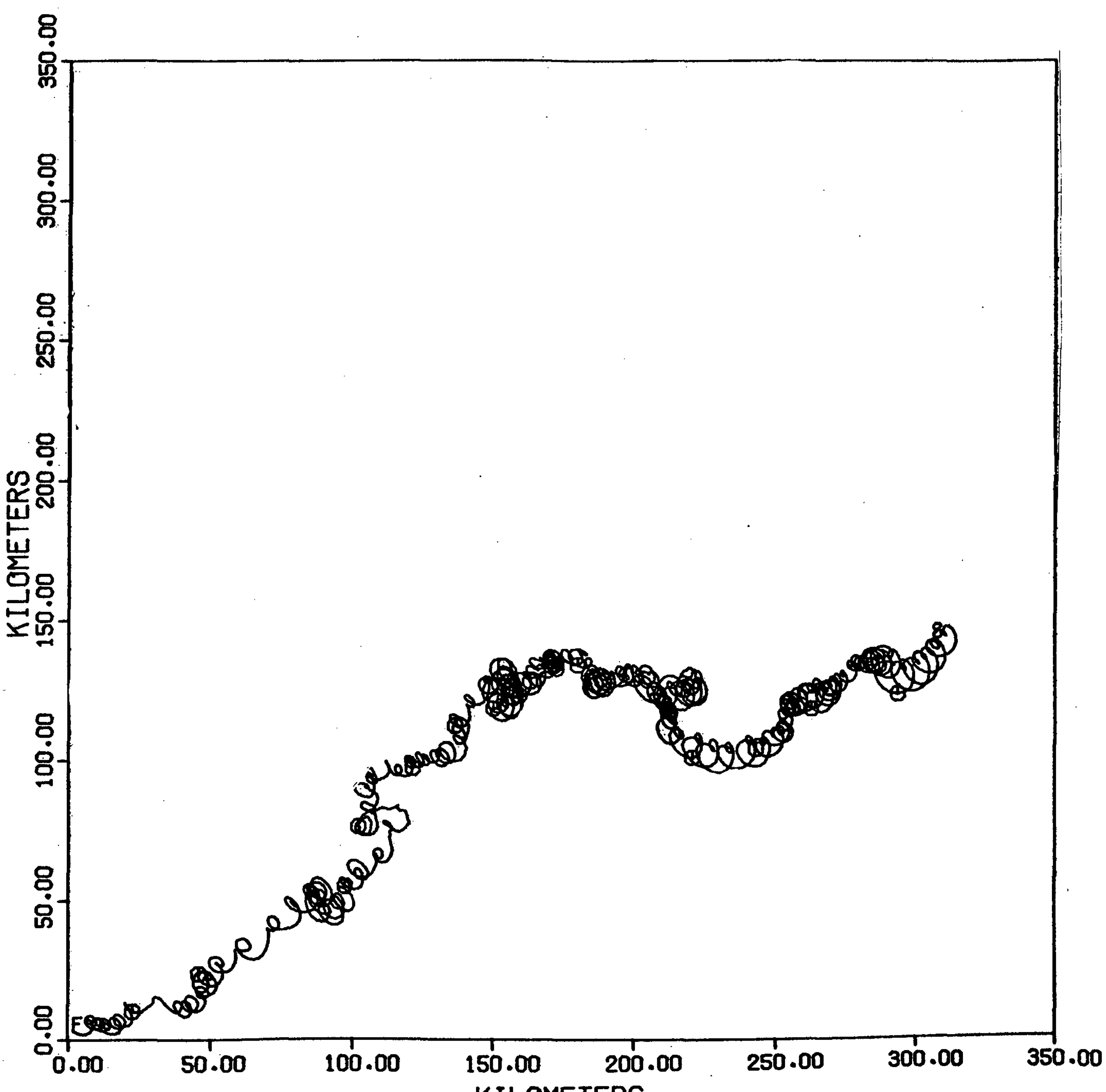



Fig. 3-6a Progressive vector diagram constructed from current meter data obtained over the shelf, depth of water 92m, from June to October 1976. Data are provided for current meter moored at depth 20m (Hayes and Schumacher, 1976).

3-6a and 3-6b). For a comparison with offshore data see Figure 3-5. Additional current meter data from winter 1977 have been obtained by Hayes and Schumacher (1976) from the shelf waters around Kodiak but, at this writing, have not been analyzed.

Moored current meter data from Station 9 along the Seward station line (58°45'N, 148°25'W) show a generally south-southwest flow from April to July 1976, but a brief reversal is noted toward the end of the recording, probably in July 1976 (Figure 3-7a). A longer-lasting reversal of flow, characterized by weak and perturbed currents, was noted during the initial 80 days of the current meter record obtained from July to November 1976 (Figure 3-7b). A swifter southwestward current, occasionally exceeding 100 cm/sec, followed this period. The baroclinic current estimates for Stations 5-9 along the Seward station line showed variable and inconsistent direction and speed and possible flow reversals (for details see NEGOA Synthesis Meeting Report, OCSEAP/SAI 1977).

*Lagrangian Drifters.* Data from the release and monitoring of three free-drifting buoys released over the shelf northeast of Kodiak Island are only of short duration. These buoys were released in September 1976 but functioned for about one week. The resulting rather limited trajectories of buoy #1540 (moving southward) and #1576 (moving northward) manifest a shelf current regime characterized by perturbations and eddy motions. Buoy #1473 released farther offshore moved southward initially but then showed onshore drift (Figure 3-8).

A sea-bed drifter release and recovery was initiated by the National Marine Fisheries Service (NMFS) over the shelf off Kodiak Island in May 1972 (Ingraham and Hastings 1974). After about a year, 15 drifter recoveries (out of 475 released) were made. It was noted that general bottom flow direction was southwestward with estimated speeds ranging from 0.2 to 1.3 km/day (average speed 0.4 km/day). Drifters released near the shelf break were not recovered; those released closer to shore showed a marked onshore movement (Figure 3-9).

### Wind-Stress Effects

The dominant synoptic meteorological feature in the area is the Aleutian low pressure system during late fall and winter. The cyclogenesis and cold

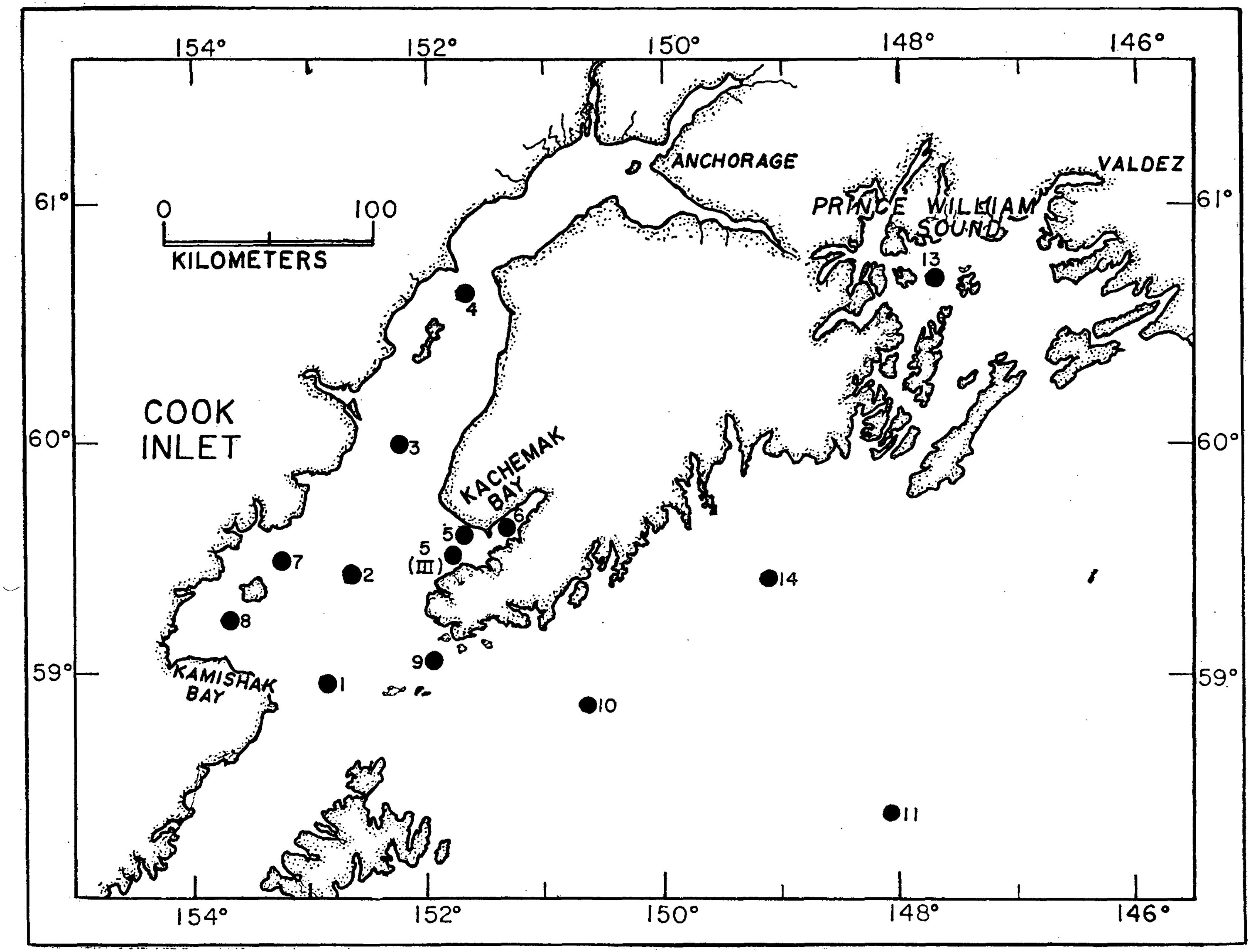



Fig. 3-12  Plankton sampling localities, April to August 1976 (Larrance, 1976).

TABLE 3-2

Data on Chlorophyll *a* Concentration, $mg/m^2$ in the upper 50 m, Primary Productivity, $mgC/m^2/day$ Solar Radiation, Langleys/day, and Estimated Depth of 1% of Surface Illumination at Four Locations in the Vicinity of Kodiak Island. Data were obtained from April to August 1976. Chlorophyll *a* data for August are integrated from surface to 60 m (Larrance, 1976).

| | | Chl $a/m^2$ | Prod./day | Langley/day | 1% Light Depth, m |
|---|---|---|---|---|---|
| April 6-13 | Station 1 | 20.5/50 $m^2$ | 55.3 | 111 | 41 |
| | 9 | 22.5 | | | |
| | 10 | 32.8 | 750.8 | 237 | 30 |
| | 11 | 23.2-25.5 (n=3) | 388.8 | 140 | 30 |
| May 5-9 | 1 | 51.0 | 557.7 | 298 | 27 |
| | 9 | 25.0 | 259 | 312 | 16 |
| | 10 | 155.3 | | | |
| | 11 | 26.9 | | | |
| May 24-30 | 1 | 112.4 | | | |
| | 9 | | | | |
| | 10 | 138.0 | | | |
| | 11 | 30.7-69.4 | | | |
| July 8-15 | 1 | 181/50 $m^2$ | | | |
| | 9 | 240 | | | |
| | 10 | 75 | 1566 | 351 | 16 (assumed) |
| | 11 | 35-61 (n=4) | 2402 | 348 | 22-36 |
| July 19-31 | 1 | 26 | | | |
| | 9 | 48 | | | |
| | 10 | 35 | | | |
| | 11 | 29-48 (n=2) | | | |
| Aug 24-31 | 1 | 46/60 $m^2$ | | | |
| | 9 | 37 " | | | |
| | 10 | 133 " | | | |
| | 11 | 71 " | | | |

TABLE 3-3

Nitrate Concentrations (mg at/$m^2$) Integrated From Surface to 25 m, April-August 1976 (Larrance, 1976)

| Station | Early April | Early May | Late May | Early July | Late August |
|---|---|---|---|---|---|
| 1 | | 414 | 288 | 128 | 87 |
| 9 | 330 | 424 | | 79 | 158 |
| 10 | 307 | 370 | 294 | 44 | 114 |
| 11A | 304 | 434 | 281 | 109 | 131 |
| 11B | 307 | | 238 | 122 | 135 |
| 11C | 342 | | 216 | 144 | |
| 11D | | | | 111 | |

Damkaer (1976) has shown that at Station 11 zooplankton settled volume varied from about 1 to 10 $m\ell/m^3$ in the upper 25 m with maximum values occurring in late May and early July. For the entire water column (1400 m deep) zooplankton volume estimates varied from 750 $m\ell/m^2$ in early April to 1260 $m\ell/m^2$ in early July.

Holozooplankton of the western Gulf are presumed to represent populations and communities continuous with those of NEGOA. Under this assumption, the neritic waters will be characterized by the presence of *Acartia longiremis*, *Pseudocalanus* sp., *Oithona* spp. and euphausiid larvae, and the oceanic waters by *Calanus cristatus*, *Calanus plumchrus*, *Eucalanus bungii bungii*, *Aglantha digitale*, *Euthemisto libellula*, *Euphausia pacifica*, and *Eukrohnia hamata* (Hokkaido University data cited in AEIDC 1974; Cooney 1976). A list of principal zooplankton species and their use of the NEGOA lease area is reproduced here for information pertinent to the Kodiak lease area (Table 3-4, from OCSEAP/SAI NEGOA Synthesis Meeting Report 1977). The presence of large oceanic copepods, such as *Calanus cristatus*, over the shelf may be a result of onshore advection of deeper water in summer (see Transport Section of Chapter III).

Ichthyoplankton

English (1976) has developed an illustrated taxonomic key to aid in identification of marine ichthyoplankton in the Gulf of Alaska. His report also includes aids to identification of larval stages of shrimps and crabs of commercial importance.

Dunn and Naplin (1974), using oblique Bongo net tows, investigated the distribution and abundance of fish eggs and larvae on the eastern Kodiak Shelf in spring 1972. Their data indicated that the highest concentrations of fish eggs and larvae occurred on the shelf between Chirikof Island and the Trinity Islands (Figures 3-13 and 3-14). They also noted that the greatest concentration of larvae occurred offshore and to the south of the maximum egg densities.

Walleye pollock eggs accounted for 97% of the total egg catch. The remaining egg fraction was spawned by three flatfish species: flathead sole, Alaska plaice, and rex sole. Pollock larvae represented 62% of the total larvae catch. Other fish larvae caught included Pacific sand lance (11%), sculpins (7%), and rock sole (7%).

TABLE 3-4. TENTATIVE SUMMARY OF USE OF LEASE AREA BY PRINCIPAL SPECIES (Cooney, 1976).

| SPECIES | PRINCIPAL HABITAT | AREAS OF PEAK ABUND. | SEASON OF PEAK ABUND. | USE OF AREA | PROBABLE VULNERABILITY TO PETROLEUM DEVELOPMENT |
|---|---|---|---|---|---|
| COPEPODA | | | | | |
| *Acartia longiremis* | Surface to 50 m | Near shore & shelf regimes | Summer & Fall | Feeding & reproduction | Plant cell grazer - could injest oil particles |
| *Pseudocalanus* spp. | " | " | " | " | " |
| *Oithona similis* | " | All regimes | Fall & Winter | " | " |
| *Oithona spinirostris* | Probably same as *O. similis* | shelf, slope open ocean | Fall | " | " |
| *Metridia lucens** | Surface to 100 m | All regimes | Spring & Summer | " | " |
| *Calanus plumchrus* | Surface to 500 m | All regimes | Spring | Feeding during late winter-summer | " |
| *Calanus cristatus* | Below 50 m | Shelf, slope open ocean | Spring | " | " |
| *Calanus pacificus* | (not known) | Slope & open ocean | Fall | Feeding & reproduction | " |
| *Eucalanus bungii bungii* | Below 50 m | " | Spring & Summer | " | " |
| CHAETOGNATHA | | | | | |
| *Sagitta elegans* | Surface to 100 m | No preference | Fall | " | Feeding on microzooplankton possible food-web incorporation of petroleum fractions, or disruption |
| *Eukrohnia hamata* | Below 50 m | Slope & open ocean | Winter & Spring | " | |
| AMPHIPODA | | | | | |
| *Parathemisto pacifica** | Below 50 m | Shelf, slope, open ocean | Fall | " | " |
| EUPHAUSIACEA | | | | | |
| Euphausiid larvae | Surface to 50 m | All regimes | Spring | Feeding | Plant cell grazer - could injest oil particles |
| *Euphausia pacifica** | Below 50 m | Slope | Winter | Feeding & reproduction | Plant cell and microzooplankton feeder - could injest oil |
| *Thysanoessa longipes** | " | " | Winter & Spring | " | |
| DECAPODA | | | | | |
| Snow crab larvae | Surface to 50 m | Nearshore & | Spring | Feeding | " |
| HYDROZOA | | | | | |
| *Aglantha digitale* | Upper 50 m | No preference | Winter & Spring | Feeding & reproduction | " |

*Denotes diel migrator where known.

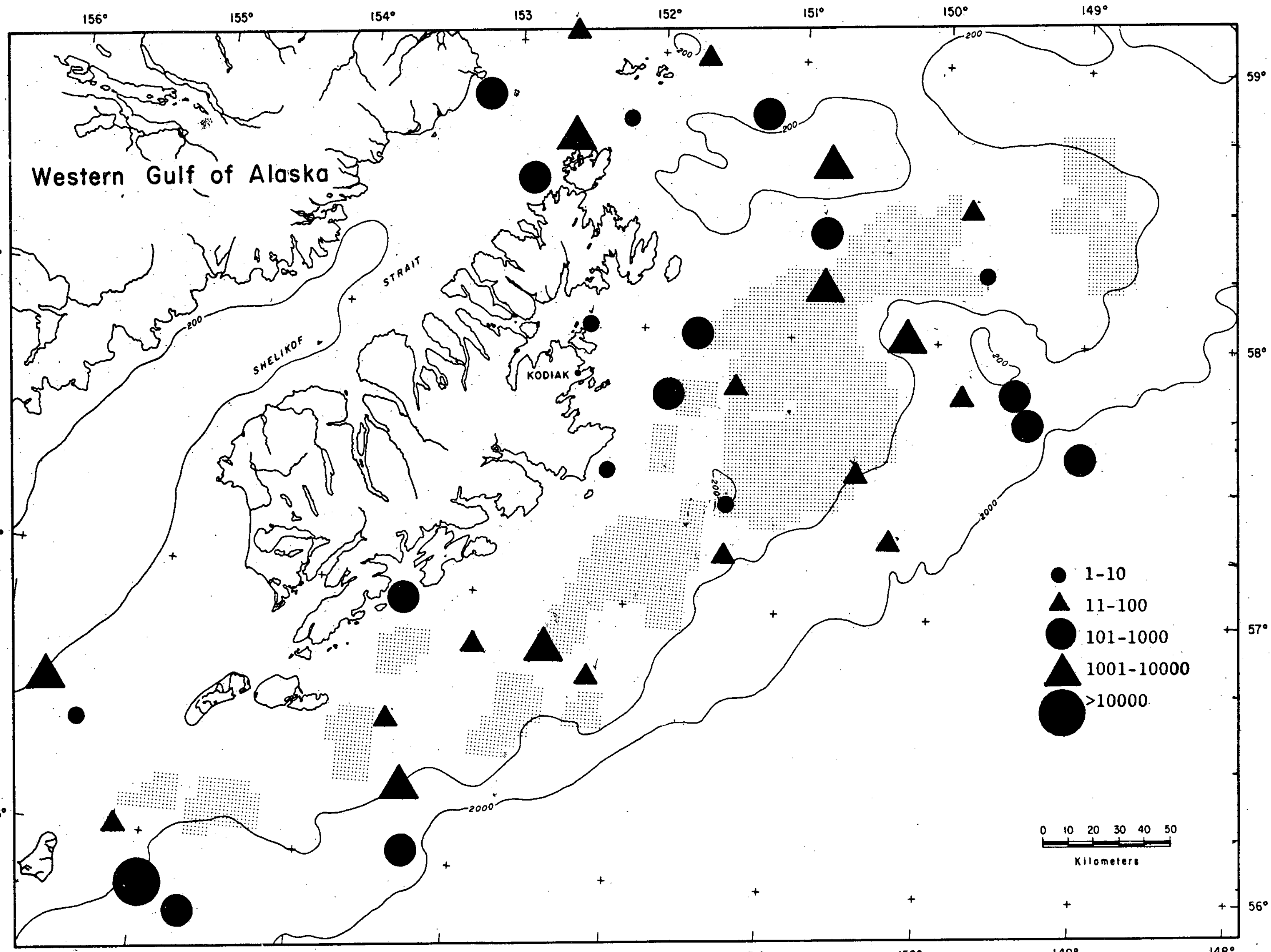



Fig. 3-13 Relative abundance and distribution of fish eggs on the Kodiak Shelf (modified from Dunn and Naplin, 1974).

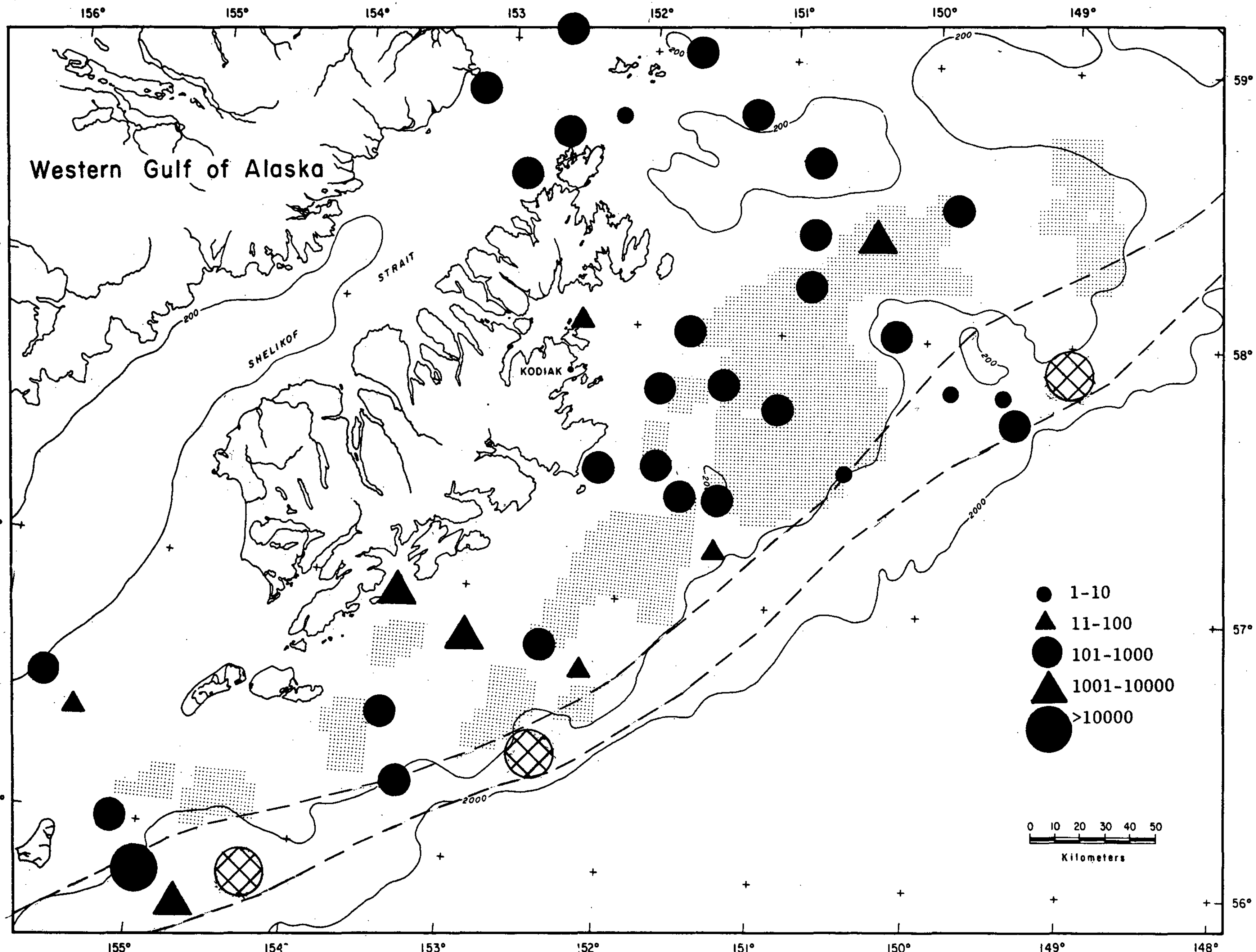



Fig. 3-14 Relative abundance and distribution of fish larvae on the Kodiak Shelf (modified from Dunn and Naplin, 1974; ADF&G 1977).

Concentrations of Pacific Ocean perch larvae ranged from 40 to 50 per $m^2$ and, generally, were caught along the shelf break and upper slope. It was estimated that $1,933 \times 10^8$ perch larvae were released into waters of the Kodiak region (Major and Shippen 1970). Earlier investigations have shown that larval abundance was generally associated with Calanoid copepod populations (Lisovenko 1960, cited in AEIDC 1974).

During the Synthesis Meeting Marmot Flats, Albatross Banks, and Horsehead areas were described as major areas of crab larval release. Crab larvae (ADF&G 1976) are generally liberated in depths of less than 60 m, with the possible exception of king crab. Different shellfish species have distinct seasonal patterns of abundance: tanner crab are present in plankton from January to July; king crab larvae from April to June; dungeness crab larvae from June to November; and shrimp larvae from February to July (pandalid shrimps spawn in early April). Residence time of individual larvae in plankton varies from 40 to 60 days. Production and development of shellfish larvae may be localized to the Kodiak Shelf area with only minimal recruitment from other parts of the Gulf.

## Benthos

*Littoral Biota.* Prior to OCSEAP few studies of Kodiak's littoral biota had been published (AEIDC 1974). Zimmerman and Merrell (1977a and 1977b) have now provided aerial photographic coverage of the entire coast, permitting quantification of major substrate types (Figure 3-15). Detailed species lists and abundance data for several sites around Kodiak are also available and a generalized vertical zonation scheme for the rocky intertidal has been formulated (Table 3-5). Kaiser (1976) has collected complementary data on Kodiak's sandy beach infauna, during razor clam assessment studies.

Precipitous, wave-swept shores dominate the Kodiak Archipelago; outcrops of exposed bedrock, boulder beaches and coarse gravels make up almost 92% of the combined coastline (nearly 2,450 miles). Sandy beaches are rare on Kodiak (3.6% of coastline) but more common in the Trinity Islands and on Chirikof (67% and 44%, respectively). Tidal amplitudes are generally greater on the northern islands (Barren Islands, 4.2 m) and diminish southward (Sitkinak Lagoon, 2.3 m) (Zimmerman and Merrell 1977a and 1977b).

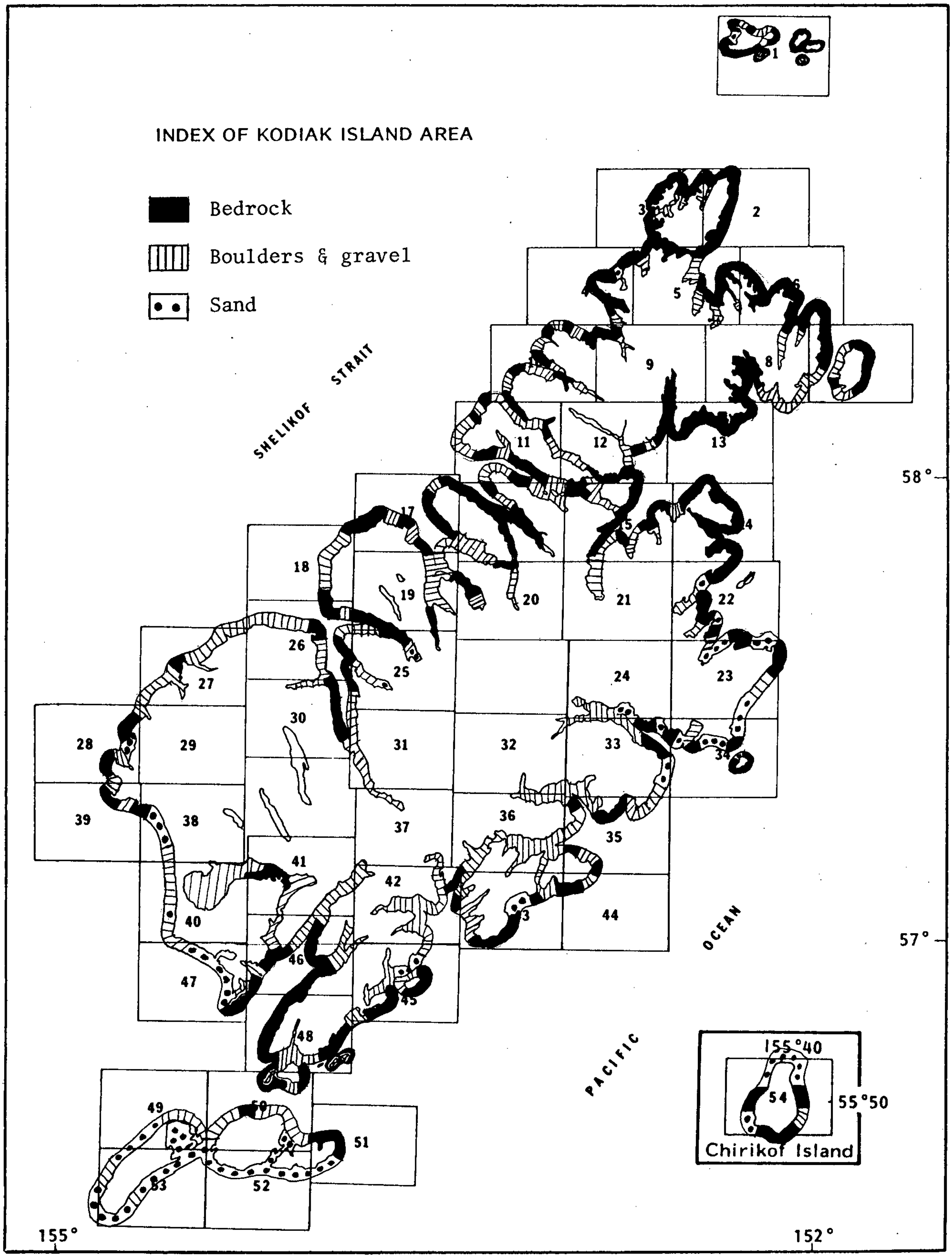



Fig. 3-15 Kodiak Island Area intertidal zone: major substrate types. {Numbers refer to plates in NMFS Aerial Atlas of the Alaskan Intertidal Zone (after Zimmerman and Merrell, 1977a and 1977b)}.

TABLE 3-5

Generalized Zonation Scheme for Kodiak Rocky Intertidal Habitats (Zimmerman and Merrill, 1977a and 1977b)

| Physical Zone | Approximate Range | Approximate Height (ft) | Biological Name | Characteristic Organisms |
|---|---|---|---|---|
| Supralittoral Fringe (1) | Highest reach of spray MHHW | +10-15 | Porphyra-Prasiola Zone | *Prasiola meridionalis* (A)<br>*Porphyra* sp. (A)<br>*Littorina sitkana* (G) |
| Littoral Zone (2A,B,C) | MHHW<br>MHW | + 8-10 | Barnacle-Endocladia Zone | Diatom Colonies (A)<br>*Endocladia muricata* (A)<br>sterile *Fucus distichus* (A)<br>*Acmea digitalis* (G)<br>*Cthamalus dalli* (B)<br>*Balanus glandula* (B)<br>*Littorina sitkana* (G) |
| | MHW<br>MTL | + 4- 8 | Fucus Zone | fertile *Fucus distichus* (A)<br>*Halosaccion glandiforme* (A)<br>*Odonthalia floccosa* (A)<br>*Balanus cariosus* (B)<br>*Mytilus edulis* (P)<br>*Nucella lima, N. lamellosa* (P) |
| | MTL<br>MLLW | 0- 4 | Rhodymenia Zone | *Rhodymenia palmata* (A)<br>*Ulva* sp. - *Monostroma* sp.<br>*Balanus cariosus* (B)<br>*Katherina tunicata* (C)<br>*Cucumeria pseudocurata* (S) |
| Infralittoral Fringe (3A,B) | MLLW<br>Lowest Low Water | - 2- 0 | Alaria Zone | *Alaria* spp. (A)<br>*Lithothamnion* sp. (A)<br>*Ptilota filicina* (A)<br>*Crisia* sp.- *Filicrisia* sp. (E)<br>*Halichondria panicea* (Sp)<br>*Tonicella lineata* (C) |
| | | - 2 | Laminaria Zone | *Laminaria* spp. (A)<br>*Laminaria dentigera* (A)<br>*Lithothamnion* sp. (A)<br>*Corrallina* sp. (A)<br>*Acmea mitra* (G) |

A = Alga, B = Barnacle, C = Chiton, E = Ectoproct (Bryozoan), G = Gastropod, P = Pelecypod, S = Sea cucumber, Sp = Sponge

In northern Kodiak the littoral zone is generally quite narrow and precipitous. It broadens further south so that extensive areas may be exposed at low tide. Extensive beds of eelgrass (*Phyllospadix* sp.) occur in these areas -- Cape Sitkinak and the Geese Islands, for example. Floating kelps and benthic algal floras are also richly developed off southern Kodiak. Zimmerman (NMFS, Auke Bay, personal communication) suggests that the considerable contribution of detritus may help explain the abundance of commercial shellfish such as the king crab, which feeds upon detritivores and, to a lesser extent, upon detritus.

Despite considerable variability among the rocky shore biota sampled from different sites around Kodiak, similarities among vertical zonation patterns of numerically dominant species provide a framework for intersite comparisons. Zimmerman and Merrell (1977a and 1977b) found the Stephensons' zonation scheme (Stephenson and Stephenson 1972) most appropriate for Kodiak. This recognizes three zones: (1) the supralittoral or splash zone which is seldom, if ever, covered by tides; (2) the littoral zone or true intertidal, that is regularly exposed and submerged with each tide; and (3) the infralittoral or upper sublittoral zone which is only exposed by unusually low tides. The vertical distribution of dominant organisms among these three zones is summarized in Table 3-5. Several of these forms are illustrated in Figure 3-16.

*Primary Productivity of Subtidal Brown Algae* -- Subtidal brown algae provide substrate and cover for other organisms and enter the food chain by direct grazing (< 10% of annual production), as detritus and as dissolved organic matter (up to 37% of annual production). Preliminary studies by Calvin and Ellis (1977) identified a broad region off the southeast Kodiak coast -- from the intertidal to depths of 20 m, extending from 0.4-10 km offshore -- suitable for growth of subtidal brown algae. *Laminaria dentigera* usually dominated the benthic flora; other abundant species included *L. yezoensis*, *Pleurophycus gardner*, *Agarom cribrosum*, and *Alaria* spp. (Floating kelps, *A. fistulosa* and *Nereocystis luetkeana*, were excluded from these samples.)

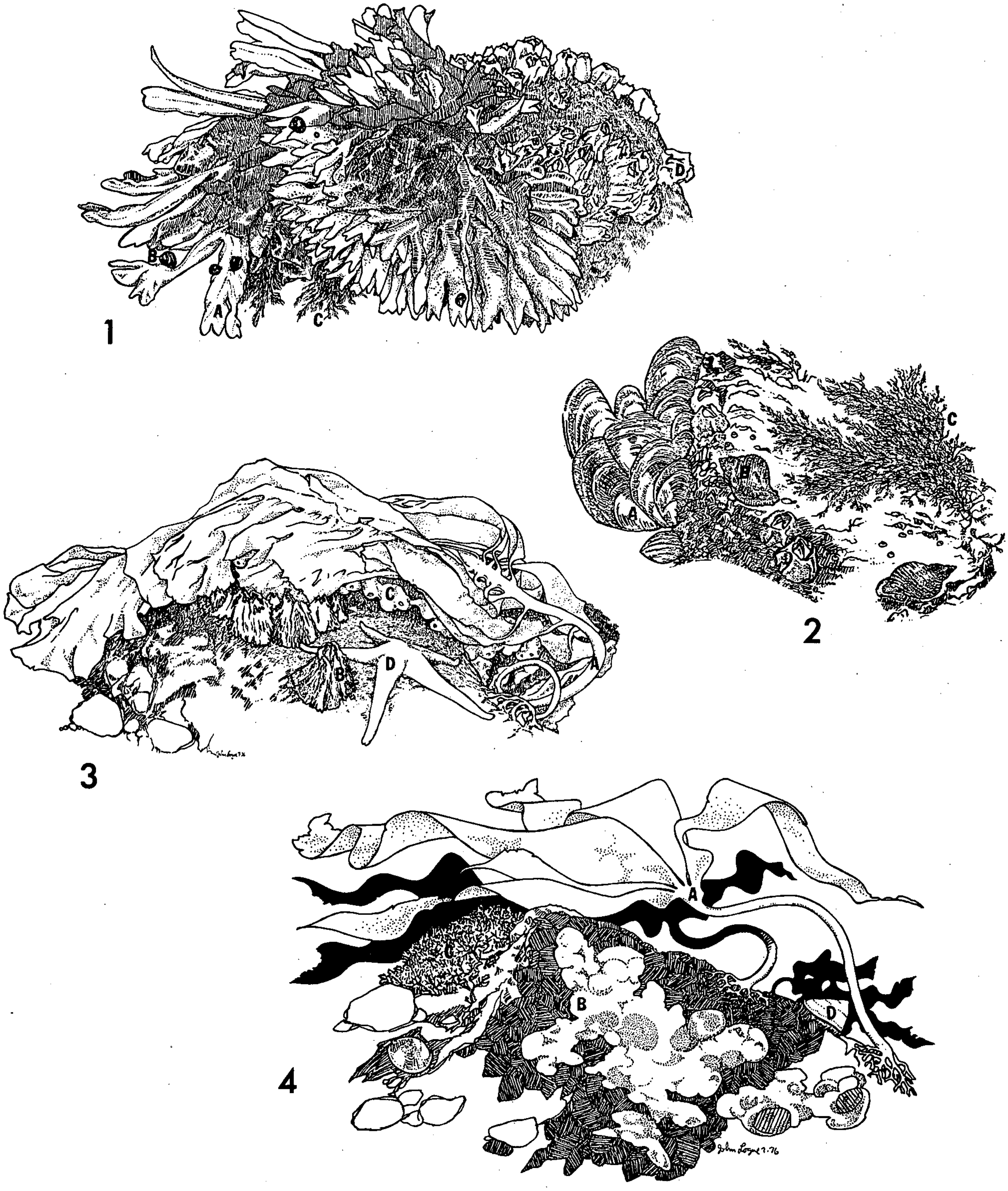


Fig. 3-16 Kodiak rocky coast, character species of: (1) the upper and middle intertidal zones, A. *Fucus distichus* B. *Littorina sitkana* C. *Odonthalia floccosa* D. *Balanus glandula*; (2) the middle intertidal zone, A. *Mytilus edulis* B. *Nucella lima* C. *Pterosiphonia bipinnata*; (3) the lower intertidal and upper infralittoral zones, A. *Alaria* sp. B. *Balanus cariosus* C. *Halichondria panicea* D. *Henrecia leviscula*; (4) the upper infralittoral zone, A. *Laminaria* sp. B. *Lithothamnion* sp. C. *Bosiella* sp. D. *Acmaea mitra*. (Zimmerman and Merrell, 1977a).

Quantitative sampling at nine sites yielded standing crops of Laminareaceae averaging 12 $kg/m^2$, with a range from 2 to 35 $kg/m^2$. These values rank among the highest measured anywhere in the world (Zimmerman, NMFS, Auke Bay, personal communication). Annual production probably exceeds 1.95 times the standing crop, giving brown algal primary production values averaging around 24 $kg/m^2$ per year. Much of this extremely high production undoubtedly goes to support the rich shrimp and crab populations found in the bays and nearshore areas of southern Kodiak Island.

Kaiser (1976) sampled intertidal sandy beach invertebrates at twelve sites on Kodiak Island and the adjacent Alaskan Peninsula during Pacific razor clam (*Siliqua patula*) assessment studies. The total fauna collected is listed in Table 3-6; vertical distribution of key species is shown in Figure 3-17; Table 3-7 summarizes habitat use by selected clams.

Kaiser (1976) found razor clams to occur over a broad tidal range: -1.2 through +1.5 m (-4 to +5 feet); beach sands of fine to medium grainsize (0.125-0.25 mm) provided the most favorable substrate. Due to habitat subsidence caused by the 1964 Alaskan earthquake, razor clams along the eastern shore of Kodiak Island are predominately subtidal. Major intertidal populations occur along the western shore of Kodiak and the Alaskan Peninsula.

*Oil Spill Susceptibility* -- Several summary statements relative to oil impingement on rocky shores can be made. The organisms most likely to be affected would be the dominant algae and invertebrates that provide the framework for vertical zonation (Table 3-5). Larval stages -- usually released during the spring -- would be most susceptible, although more substantiating research is required. Mature intertidal algae tend to secrete mucous to protect themselves. In marked contrast, eelgrass (*Phyllospadix* sp.) is known to be very susceptible to oil pollution effects. Many adult intertidal invertebrates are protected by their ability to withdraw into protective coverings. While larvae would be most vulnerable in the spring, adults would probably be more susceptible during winter, when they are already stressed (Zimmerman, NMFS, Auke Bay, personal communication).

Oil emplaced on flat, hard-packed sandy beaches will not penetrate fine sand. Instead, it usually forms a thin layer on the surface that can be readily scraped off. Such beaches change slowly, so burial of oil by new deposition would take place at a slow rate. On steeper, medium- to

TABLE 3-6

Intertidal Sandy Beach Faunas: Taxonomic Composition of Twelve Samples From Kodiak Island and Adjacent Alaskan Peninsula (Kaiser, 1976)

| MOLLUSCA: | | ANNELIDA: | |
|---|---|---|---|
| Pelecypoda (clams) | | Polychaeta (Segmented worms) | |
| *Siliqua patula* | (1280) | *Scolelipis squamatus* | (2905) |
| *Macoma lama* | (257) | *Nephtys caeca* | (254) |
| *Spisula polynyma* | (116) | *Nephtys californiensis* | (155) |
| *Siliqua alta* | (63) | *Haploscoloplos elongatus* | (181) |
| *Clinocardium nutallii* | (30) | *Ophelia assimilis* | (165) |
| *Macoma balthica* | (30) | *Eteona longa* | (18) |
| *Mya arenaria* | (20) | *Glycinde picta* | (14) |
| *Telina lutea alternidenta* | (20) | *Anaites groenlandica* | (10) |
| *Macoma yoldiformis* | (8) | *Nephtys ciliata* | (3) |
| *Macoma nasuta* | (3) | *Cistemides brevicoma* | (4) |
| *Macoma loveni* | (2) | | |
| *Macoma calcarea* | (2) | Nemertea (Ribbon worms) | |
| *Littorina sitkoma* | (2) | | |
| *Prototheca staminae* | (1) | *Cerebratulus californionsis* | (13) |
| *Tellina nucleoides* | (1) | Other Nemerteans | (14) |
| *Tressus capax* | (1) | | |

TABLE 3-7

Use of Intertidal Sandy Beach Habitats by Selected Clams, Kodiak Island and Adjacent Alaska Peninsula (Kaiser, 1976)

| | SEASON | | | |
|---|---|---|---|---|
| Species | Winter | Spring | Summer | Fall |
| Pacific Razor Clam (*Siliqua patula, S. alta*) | AJ | AELJ | AELJ | ALJ |
| Basket Cockle (*Clinocardium nuttallii*) | AJ | AJ | AELJ | ALJ |
| Pinkneck Clam (*Spisula polynyma*) | AJ | AJ | AELJ | AJ |

E = Eggs, L = Larvae, J = Juveniles, A = Adults

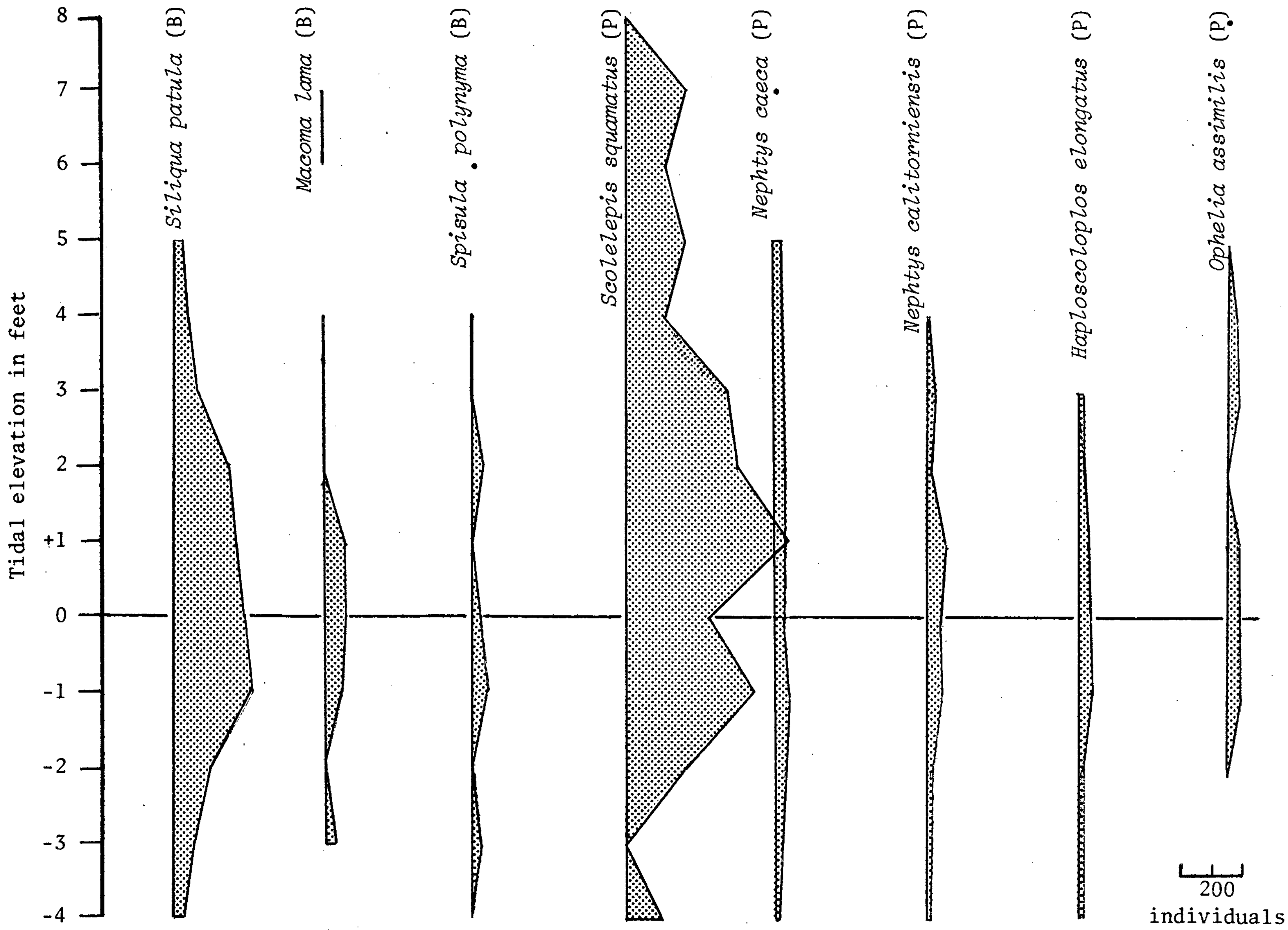



Fig. 3-17 Vertical distribution of abundant sandy beach invertebrates sampled at twelve sites on Kodiak Island and adjacent Alaskan Peninsula. (B=Bivalve; P=Polychaete worm; after Kaiser, 1976).

coarse-grained sandy beaches the depth of penetration and rates of burial of oil are greatly increased. Based on studies by Hayes and Boothroyd (1976), it is possible for oil to be buried as much as 50-100 cm within a period of a few days on beaches of this class. Burial of the oil preserves it for later release during the natural beach erosion cycle, thus assuring long-term pollution of the environment.

Studies by Tayler *et al.* (1976) suggest that clams similar to those found on Kodiak's sandy beaches may be both sensitive to, and adversely affected by, oiled sediments.

*Benthic Fauna.* To date, Russian workers have published the most data about the benthic fauna of the Kodiak Shelf. They have documented the distribution of benthic invertebrate biomass and trophic groups (Figures 3-18a and 18b). Sessile filter feeders predominate on the Albatross Banks which are characterized by coarser sediments and stronger current action. Mobile filter feeders are more abundant on the finer grained sediments of Portlock Bank. Shelikof Strait, west of Kodiak Island, yielded a benthic fauna dominated by non-selective consumers. A list of some 128 benthic species identified from the Gulf of Alaska by Russian workers is included in AEIDC (1974). Benthic invertebrate biomass on the Kodiak Shelf is apparently greater than in the NEGOA area, and a higher percentage of this biomass is believed to be available as food for fish. While difficult to interpret, exploratory fishing drag trawl data provide some idea of the dominant organisms likely to be encountered (Table 3-8). Several benthic invertebrates of major commercial importance occur in abundance on the Kodiak Shelf (see below).

While no OCSEAP sponsored studies of Kodiak offshore shelf benthos have been initiated, Feder *et al.* (1977), in conjunction with ADF&G, recently completed a reconnaissance survey of the epifauna of Alitak and Ugak Bays. Fifty-three permanent stations in the two bays were sampled with a 400-mesh Eastern otter trawl in June, July and August 1976. Ten phyla and 92 species were identified. Arthropoda -- particularly decapods -- dominated species composition and biomass. Echinodermata, Porifera, Mollusca, and Cnidaria were also important but together accounted for only 2.6% of the biomass collected.

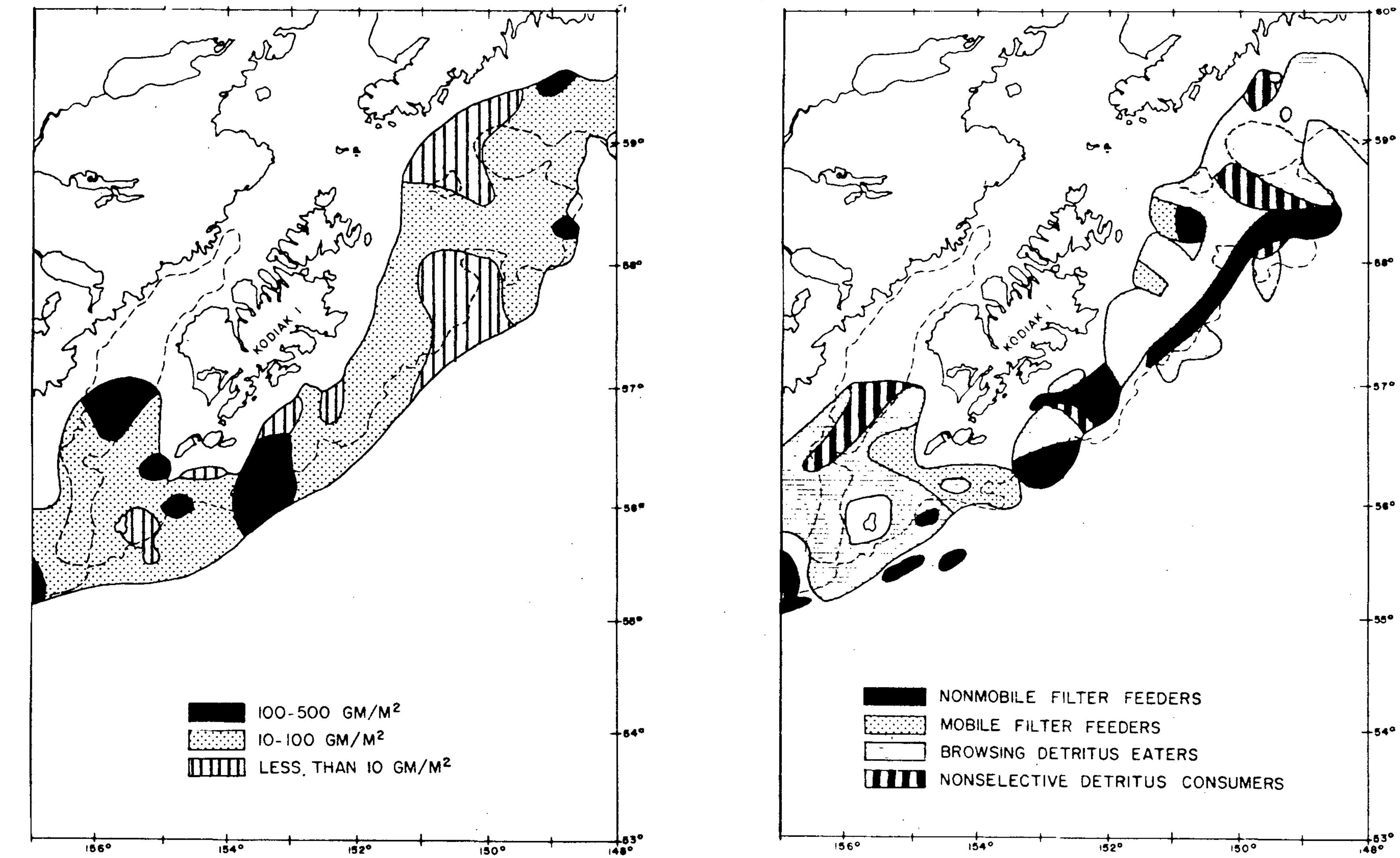



Fig. 3-18. a) Benthic fauna biomass (Shevtsov 1964; Semenov 1965, cited in AEIDC 1974). b) Dominant benthic trophic groups (Shevtsov 1964; Semenov 1964, cited in AEIDC 1974).

## TABLE 3-9

Commercially Important Invertebrates of the Kodiak Shelf (P. Jackson, ADF&G, Kodiak, Personal Communication)

| Scientific Name | Common Name |
|---|---|
| Arthropoda: Decapoda | |
| *Cancer magister* | Dungeness crab |
| *Chionoecetes bairdi* | Tanner (Snow) crab |
| *Paralithodes camtschatica* | King crab |
| *Pandalus borealis* | Pink shrimp |
| *P. hypsinotus* | Coonstripe shrimp |
| *P. goniuris* | Humpy shrimp |
| *P. platyceros* | Spot shrimp |
| *Pandalopsis dispar* | Sidestripe shrimp |
| Mollusca: Pelecypoda | |
| *Patinopecten caurinus* | Weathervane scallop |

## TABLE 3-10

Use of Kodiak Shelf by Commercially Important Invertebrates (P. Jackson, ADF&G, Kodiak, Personal Communication)

| | SEASON | | | |
|---|---|---|---|---|
| Species | Winter | Spring | Summer | Fall |
| King crab | AEJ | AEJL | AEJL | AEJ |
| Dungeness crab | AEJ | AJL | AJL | AEJ |
| Tanner crab | AEJ | AEJ | AELJ | AEJ |
| Pink shrimp | AEJ | AEJL | AJL | AEJ |
| Coonstripe shrimp | AEJ | AEJL | AJL | AEJ |
| Sidestripe shrimp | AEJ | AEJL | AJL | AEJ |
| Humpy shrimp | AEJ | AEJL | AJL | AEJ |
| Spot shrimp | AEJ | AEJL | AJL | AEJ |
| Weathervane scallop | AJ | AJ | AELJ | AJ |

E = Eggs, L = Larvae, J = Juvenile, A = Adult

TABLE 3-11

Average Catch Per Unit Effort (kilograms per hour) of Commercially Important Invertebrates Collected During NMFS Kodiak Shelf Trawl Survey, 1973-75 (Pereyra and Ronholt, 1976)

| | Areas/Depth Zones (meters) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CHIRIKOF | | | | KODIAK | | | |
| Species | 1-100 | 101-200 | 201-400 | All Depths | 1-100 | 101-200 | 201-400 | All Depths |
| Tanner crab | 9.0 | 25.2 | 9.3 | 15.1 | 15.0 | 85.5 | 74.8 | 50.4 |
| King crab | 38.0 | 8.9 | 3.4 | 15.6 | 25.9 | 129.1 | 6.6 | 63.2 |
| Dungeness crab | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Weathervane scallop | 0.1 | 0 | 0 | * | 12.2 | 0 | 0 | 5.8 |
| TOTAL | 47.1 | 34.1 | 12.7 | 30.7 | 53.1 | 214.6 | 81.4 | 119.4 |

(1) = no samples; * = less than 0.1 kg/hour.

Kodiak's shrimp fishery started in 1959, peaked in 1971 (82 million pounds) and has since declined due to the imposition of more conservative management procedures. Principal catch areas have varied since 1959 but presently include Kiliuda Bay, Twoheaded Island (Horsehead Basin), and Marmot Bay.

The Kodiak Shelf also supports a commercial fishery for weathervane scallops (mostly along the east side, north to Portlock Bank) and razor clams (ADF&G 1976).

Fisheries Resources

Twenty-six families and 106 species of fish have been collected from the proposed Kodiak lease area. (Additional species may occur in the area.) Species belonging to the families Gadidae, Salmonidae, Clupeidae, Hexagrammidae, Scorpaenidae, Pleuronectidae, Cottidae, Osmeridae, and Ammodytidae dominate the ichthyofauna and are of particular interest due to their abundance, forage, sport and commercial value (Table 3-12).

Seasonal distribution and abundance data are generally lacking on most fish species within the Kodiak lease area. However, by extrapolating information derived elsewhere and reviewing commercial fishery statistics we can provide a description of seasonal variability in abundance and distribution of selected species (Tables 3-13 and 3-14). Seasonal fluctuations in abundance of salmon, smelt and herring is most notable. During spring and summer, large numbers of adult spawners and juveniles enter the coastal and estuarine regions (Table 3-15). Adults migrate to home spawning streams (Anadromous salmonids, eulachon) and along rocky (herring) and sandy beaches (capelin, surf smelt) throughout the Kodiak Archipelago. After hatching, the juveniles of some of these species feed in estuarine and nearshore areas.

In the Kodiak lease area, all suitable streams are entered by one or more salmonid species (ADF&G 1976). Dolly Varden are nearly ubiquitous in this area, spawning in all suitable streams (Figure 3-20). Two hundred and forty streams contain pink salmon runs; 31 of these account for 60 to 85% of the total Kodiak pink salmon escapement (Figure 3-21). Sockeye, coho, and chinook salmon and steelhead trout are limited to the stream systems with lakes (Figures 3-21 and 3-22). The Kodiak, Red, and Upper Station systems are the most significant to total Kodiak salmon production and the

TABLE 3-12

List of Key Fish Species in Kodiak Lease Area
(Compiled by Participants, Kodiak Synthesis Meeting, Fisheries Workshop)

| Species | Rationale |
|---|---|
| Pacific herring | Forage species; Commercial catch; Intertidal spawner; Abundance |
| Pink salmon | Intertidal spawner; Abundance; Commercial catch |
| Sockeye salmon | Commercial catch |
| Chum salmon | Commercial catch; Intertidal spawner |
| Dolly Varden | Abundance; Sport catch |
| Capelin | Abundance; Forage species; Intertidal spawners |
| Walleye pollock | Forage species; Commercial catch; Abundance |
| Pacific cod | Commercial catch |
| Pacific ocean perch | Commercial catch |
| Greenlings | Shallow subtidal spawner; Juveniles extremely vulnerable to oil |
| Atka mackerel | Commercial catch |
| Sablefish | Commercial catch |
| Great sculpin | Abundance |
| Yellow Irish lord | Abundance |
| Pacific sandfish | Abundance; Forage species |
| Pacific sand lance | Forage species; Abundance |
| Arrowtooth flounder | Abundance |
| Flathead sole | Commercial catch |
| Rock sole | Abundance |
| Yellowfin sole | Abundance |
| Halibut | Commercial catch |

TABLE 3-13

Tentative Summary of Use of Epipelagic and Littoral Zones by Principal Species of Fish, Kodiak (Compiled by Participants, Kodiak Synthesis Meeting, Fisheries Workshop)

| Species | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| Sablefish | E L | L | J | |
| Pacific herring | A | Ⓐ Ⓔ Ⓛ | A Ⓔ Ⓛ Ⓙ | A J |
| Pacific sand lance | A E J | A L J | Ⓐ L Ⓙ | A J |
| Walleye pollock | A E L | L J | J | J |
| Lingcod | A Ⓔ | | J | |
| Atka mackerel | | | A J | |
| Surf smelt | Ⓐ Ⓔ Ⓛ | Ⓐ Ⓔ Ⓛ | Ⓐ Ⓔ Ⓛ | Ⓐ Ⓔ Ⓛ |
| Capelin | A | Ⓐ Ⓔ L J | Ⓐ Ⓔ L J | L J |
| Eulachon | A J | A Ⓙ | A Ⓙ | A J |
| Pacific halibut | | | J | |
| Arrowtooth flounder | | L | L | |
| Yellowfin sole | | A L J | A Ⓙ | A Ⓙ |
| English sole | Ⓐ Ⓔ Ⓛ | L J | | |
| Rock sole | | A L J | A Ⓙ | A Ⓙ |
| Starry flounder | Ⓐ Ⓔ Ⓛ | L J | J | |
| Flathead sole | | | J | |
| Pink salmon | Ⓔ Ⓛ | A E Ⓛ Ⓙ | A Ⓔ Ⓙ | Ⓔ J |
| Chum salmon | Ⓔ Ⓛ | E Ⓛ Ⓙ | Ⓐ Ⓔ Ⓙ | Ⓔ J |
| Coho salmon | | Ⓙ | Ⓐ Ⓙ | A J |
| Sockeye salmon | | A Ⓙ | Ⓐ Ⓙ | A |
| Chinook salmon | | A Ⓙ | A Ⓙ | J |
| Steelhead trout | | Ⓐ Ⓙ | Ⓐ Ⓙ | A J |
| Dolly Varden | | Ⓐ Ⓙ | Ⓐ Ⓙ | A J |
| Pacific cod | | A L J | A J | |
| Prowfish | A J | A J | A J | A J |
| Pacific sandfish | A Ⓔ J | L J | Ⓛ Ⓙ | J |
| Yellow Irish lord | | A L J | A L J | |
| Great sculpin | | A L | A Ⓙ | A Ⓙ |
| Other sculpins | A J | A L J | A L J | A J |
| Masked greenling | Ⓐ | Ⓐ J | Ⓐ E L Ⓙ | Ⓐ L Ⓙ |

- continued -

TABLE 3-13 (Cont.)

| Species | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| Whitespotted greenling | Ⓐ | Ⓐ J | Ⓐ E L Ⓙ | Ⓐ L Ⓙ |
| Rock greenling | Ⓐ | Ⓐ | Ⓐ E L Ⓙ | Ⓐ L Ⓙ |
| Prickleback | | A L | Ⓐ L Ⓙ | Ⓐ Ⓙ |
| Rockfish | | | J | |
| Poacher | | | J | |

A = adults; E = eggs; L = larvae; J = juvenile

○ = special dependence on littoral zone

TABLE 3-14

Tentative Summary of Use of Benthic Zone by Principal Species of Fish, Kodiak (Compiled by Participants, Kodiak Synthesis Meeting, Fisheries Workshop)

| Species | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| Sablefish | A J | A J | A J | A J |
| Pacific herring | A J | A | A | A J |
| Pacific sand lance | A E J | A L J | A L J | A J |
| Pacific cod | A E J | A J | A J | A J |
| Walleye pollock | A J | A E L J | A J | A J |
| Lingcod | A E J | A J | A J | A J |
| Atka mackerel | A | A | A E | * |
| Surf smelt | A L J | A J | A J | A L J |
| Capelin | A J | A E L J | A E L J | A J |
| Eulachon | A | A | A | * |
| Arrowtooth flounder | A J | A J | A J | A J |
| Yellowfin sole | A J | A L J | A J | A J |
| Rock sole | A J | A L J | A J | A J |
| Pacific halibut | A J | A J | A J | A J |
| Butter sole | A | A | A | A |
| Dover sole | A E L J | A L J | A J | A J |
| Flathead sole | A J | A J | A J | A J |
| English sole | A J | A J | A J | A J |
| Rex sole | A J | A J | A J | A J |
| Starry flounder | A J | A J | A J | A J |
| Alaska plaice | A | A | A | A |
| Pacific ocean perch | A J | A J | A J | A J |
| Other rockfish | A J | A J | A J | A J |
| Pacific tomcod | A | | A | * |
| Yellow Irish lord | A J | A J | A J | * |
| Great sculpin | A J | A L | A J | A J |
| Other sculpins | A J | A | A | * |
| Sturgeon poacher | A | A | A | * |
| Pacific sandfish | A J | A L J | A L J | A J |
| Pricklebacks | A | A L | A L J | A J |

- continued -

TABLE 3-14

| Species | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| Searcher | A J | A | A | * |
| Eelpouts | A J | A J | A J | A J |
| Rattails | | A | A | * |
| Skates | A | A | A | * |
| Spiny dogfish | A | | | * |
| Prowfish | A | A | | * |
| Wrymouths | A | A | | |
| Lumpsuckers | | A | A | * |
| Whitespotted greenling | A L J | A L J | A E L J | A E L J |
| Masked greenling | A L J | A L J | A E L J | A E L J |
| Rock greenling | A L J | A L J | A E L J | A E L J |

* = No data during fall season

A = adult; E = eggs; L = larvae; J = juvenile

TABLE 3-15

Ecology and Probable Oil Interactions -- Kodiak Fisheries
(Compiled by Participants, Kodiak Synthesis Meeting, Fisheries Workshop)

| Species or Biota Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Area Use by Biotic Group | Potential Oil Biota Interaction |
|---|---|---|---|---|---|
| Salmonidae (Adults) | | | | | |
| Sockeye | Congregate in Estuaries | Nearshore; Anadromous Streams with Lakes; Karluk, Uganik, Red, and Upper Station Areas | Mid May - Early October | Spawning migration | Behavioral; Block access to spawning streams |
| Pink | Congregate in Estuaries | Nearshore; Anadromous Streams; Intertidal; Karluk, Red, and Upper Station | Lage June - Late August | Spawning; spawning migration | Behavioral; Block access to spawning areas; Toxic to spawn |
| Chum | Congregate in Estuaries | Nearshore; Anadromous Streams; Intertidal; East side of Kodiak | Mid June - Mid September | Spawning; spawning migration | Behavioral; Block access to spawning areas; Toxic to spawn |
| Coho | Congregate in Estuaries | Nearshore; Anadromous Streams with lakes | Late July - Late September | Spawning migration | Behavioral; Block access to spawning streams |
| Chinook | Congregate in Estuaries | Nearshore; Anadromous Streams with lakes; Karluk and Red River systems | Early June - Mid August | Spawning migration | Behavioral; Block access to spawning streams |
| Steelhead | Congregate in Estuaries | Nearshore; Anadromous Streams with lakes | Mid August - Fall | Spawning migration | Behavioral; Block access to spawning streams |
| | Estuaries; Seaward migration | Nearshore | Fall and Early Winter | Feeding; over-wintering; outmigration | Additional stress on spent spawners; Ingestion;Behavioral |
| Dolly Varden | Congregate in Estuaries | Nearshore; All Anadromous Streams | July - September | Spawning migration | Behavioral; Block access to spawning streams |

- continued -

# TABLE 3-15 (continued)

| Species or Biota Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Area Use by Biotic Group | Potential Oil Biota Interaction |
|---|---|---|---|---|---|
| Dolly Varden | Estuaries; Coastal | Nearshore; Anadromous Streams with lakes; Uganik, Little, Karluk and Red River systems | Early April - Fall | Feeding; Migration to overwintering streams; Spawning migration | Block access to overwintering streams with lakes; Added stress to spent spawners; Ingestion; Behavioral; Reduced food supply |
| Commerical fisheries | Offshore | Southeast and southwest coastal regions | Late July - Late September | Commercial harvest | Taint catch; Foul gear |
| | Nearshore, Estuaries | Olga Bay; Karluk, Red, and Uganik River systems; Alitak Bay | Early June - Late September | Commercial harvest | Taint catch; Foul nets |
| Sport fisheries | Nearshore, Estuaries | Pagashak, Woman's Middle, Kalsin, Monashka, and Anton Larsen Bays | Spring, Summer, Fall | Sport catch; Recreation | Loss of aesthetic appeal; Taint catch |
| Salmonidae (Juveniles) | | | | | |
| Sockeye | Estuary | Nearshore; Surface; Karluk, Red, and Upper Station River systems | April - Early August | Smolting; Feeding | Toxicity; Reduced food supply; Behavioral; Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | 4 to 6 weeks after entering estuary | Outmigration; Feeding | Toxicity; Behavioral; Ingestion |
| Pink | Estuary | Nearshore; Surface; Karluk, Red, and Upper Station River systems | April - June | Smolting; Feeding | Toxicity; Reduced food supply; Behavioral; Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | 90 days after entering estuary | Outmigration; Feeding | Toxicity; Behavioral; Ingestion |

- continued -

TABLE 3-15 (continued)

| Species or Biota Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Area Use by Biotic Group | Potential Oil Biota Interaction |
|---|---|---|---|---|---|
| Chum | Estuary | Nearshore; Surface; East side of Kodiak Island | April - Early September | Smolting; Feeding | Toxicity; Reduced food supply; Behavioral; Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | 4 to 6 weeks after entering estuary | Outmigration; Feeding | Toxicity; Behavioral; Ingestion |
| Coho | Estuary | Nearshore; Surface | May - Mid October | Smolting; Feeding | Reduced food supply; Behavioral;Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | 4 to 6 weeks after entering estuary | Outmigration; Feeding | Behavioral; Ingestion |
| Chinook | Estuary | Nearshore; Surface; Karluk and Red River systems | Late June - Late July | Smolting; Feeding | Reduced food supply; Behavioral;Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | 4 to 6 weeks after entering estuary | Outmigration; Feeding | Behavioral; Ingestion |
| Steelhead | Estuary | Nearshore; surface | May - Late July | Smolting; Feeding | Reduced food supply; Behavioral;Ingestion |
| | Seaward migration | South and west along the Continental Shelf; Surface; Offshore to Gulf of Alaska | Late May - Mid September | Outmigration; Feeding | Behavioral; Ingestion |
| Dolly Varden | Coastal estuary | Nearshore; Surface | May - November | Smolting; Seeking overwintering streams with lakes; Feeding | Toxicity; Reduced food supply; Behavioral; Block access to overwintering streams; Ingestion |
| Salmonidae (Eggs & Hatching) | | | | | |
| Pink | Intertidal | | July - May | Incubation; Hatching; Emergence | Smothering; Toxicity |

- continued -

TABLE 3-15 (continued)

| Species or Biota Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Area Use by Biotic Group | Potential Oil Biota Interaction |
|---|---|---|---|---|---|
| Chum | Intertidal | | July - May | Incubation; Hatching; Emergence | Smothering; Toxicity |
| Clupeidae (Adults) | | | | | |
| Herring | Rocky beach | Intertidal; East side of Island in Port Hobrom; Shallow subtidal; West side of Island in Uyak, Uganik, and Viekoda Bays | Late April - Early June | Spawning | Inhibit spawning; Toxic to spawn; Behavioral |
| | Benthic overwintering | Near Bottom; appx. 50 fathoms | Late Fall through Winter | Overwintering; No feeding | Behavioral |
| | Pelagic | Near Surface; Nearshore | Spring - Fall; Spring | Feeding; Spawning migration | Reduced food supply; Food chain; Ingestion |
| Commercial fisheries | Nearshore | Intertidal; Shallow Subtidal; Zachar and Uyak Bays; Afognak, Chiniak and South Marmot Bays | Mid May - Mid June | Commercial harvest | Taint catch; Foul net |
| Clupeidae (Eggs & Larvae) | | | | | |
| Herring | Rocky beach | Intertidal; Shallow Subtidal | March - May | Incubation; Hatching | Toxicity; Smothering; Reduced health |
| | Nearshore | Nursery Intertidal; Shallow Subtidal | May - November | Feeding; Rearing | Reduced food supply; Toxicity; Ingestion |
| Clupeidae (Juveniles) | | | | | |
| Herring | Nearshore | Surface; Intertidal | June - November | Feeding; Rearing | Reduced food supply; Behavior; Toxicity; Ingestion |
| Anoplopomatidae | | | | | |
| Sablefish (eggs through post larvae) | Pelagic | Surface | Early Spring - Late May | Incubation; Hatching; Feeding | Toxicity; Reduced food supply; Ingestion |

- continued -

## TABLE 3-15 (continued)

| Species or Biota Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Area Use by Biotic Group | Potential Oil Biota Interaction |
|---|---|---|---|---|---|
| Capelin (adults) | Pelagic | Near surface | February - Fall | Spawning migration; Feeding | Behaviora;; Ingestion Reduced food supply; Toxicity |
| Capelin (eggs & larvae) | Sandy beach | Intertidal | Late April - Early May | Incubation; Hatching | Toxicity; Smothering; Reduced hatch |
| | Nearshore | Intertidal | Late April - Early May | Feeding; Rearing | Toxicity; Reduced food supply; Ingestion;Behavioral |
| Cottidae | | | | | |
| Great sculpin (adults) | Demersal | Nearshore; Bays | Summer | Feeding | Reduced food supply; Ingestion |
| Great sculpin (juveniles) | Demersal | Nearshore; Intertidal; Bays | Summer | Feeding | Toxic; Reduced food supply; Ingestion |
| Gadidae | | | | | |
| Walleye pollock | Demersal | Near Bottom; Kiliuda Trough; Chiniak Trough; Horsehead area of Chiniak Trough | Spring and Summer | Feeding; Growth; Spawning | Ingestion; Behavioral |
| Pacific cod | Demersal | Near Bottom; Kiliuda Trough | Spring; Summer | Feeding; Growth; Spawning | Ingestion; Behavioral |
| Commercial fishery | Offshore | Near Bottom; Continental Slope; Gullies and canyons on Albatross Bank | | Foreign Nationals | Taint catch; Foul gear |
| Ammodytidae | | | | | |
| Pacific sandlance (adult and juveniles) | Nearshore | Sandy Intertidal; Sandy Subtidal | Year round | Growth; Feeding; Spawning | Toxic; Behavioral; Ingestion; Toxic to spawn; Smothering |
| Pacific sandlance (eggs) | Nearshore | Sandy Intertidal; Sandy Subtidal | Mid December - Late March | Incubation | Inhibit hatching; Toxic; Smothering |

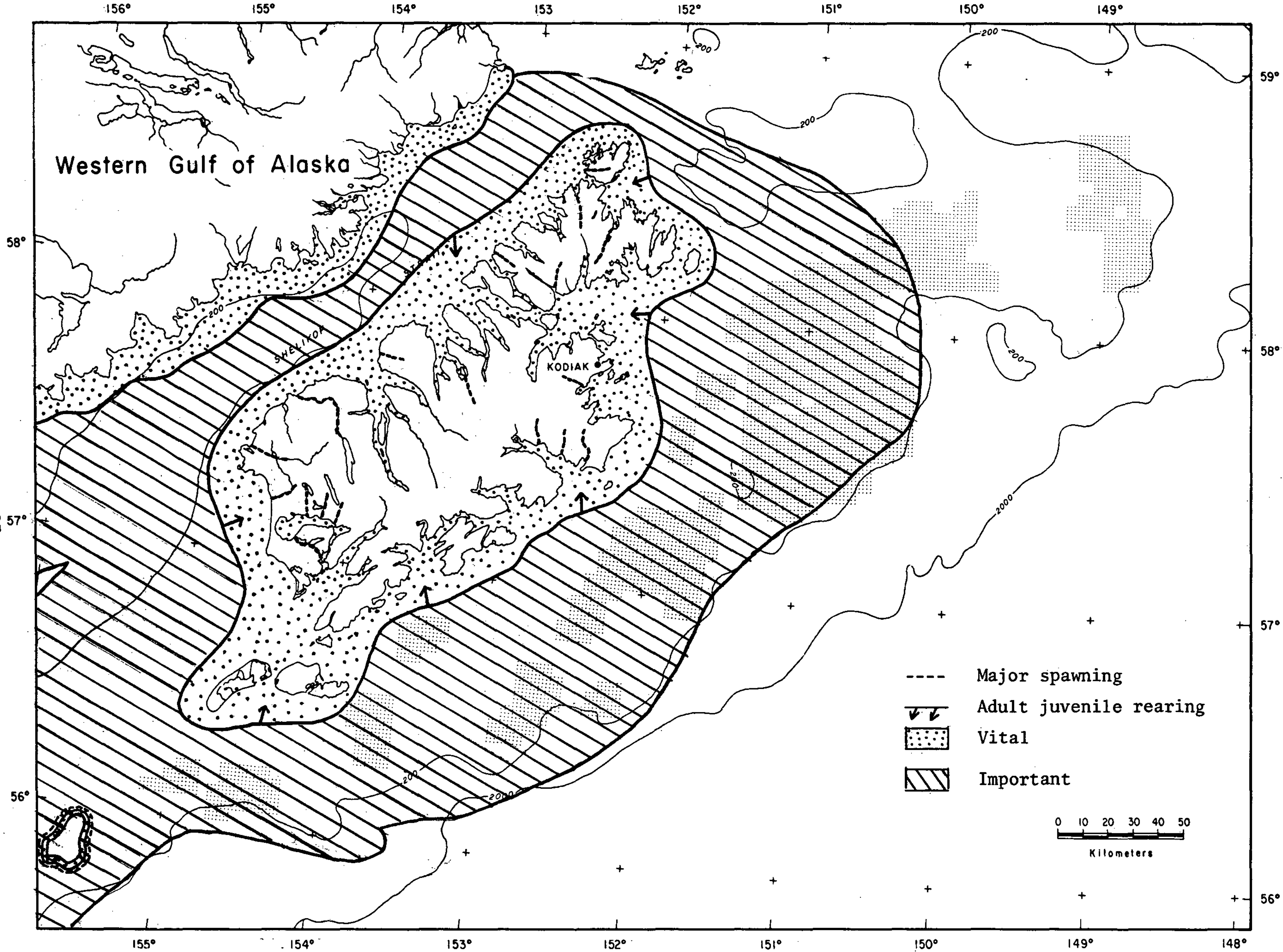



Fig. 3-20 Dolly Varden distribution spawning and rearing (modified from ADF&G, 1976; ADF&G, 1977).

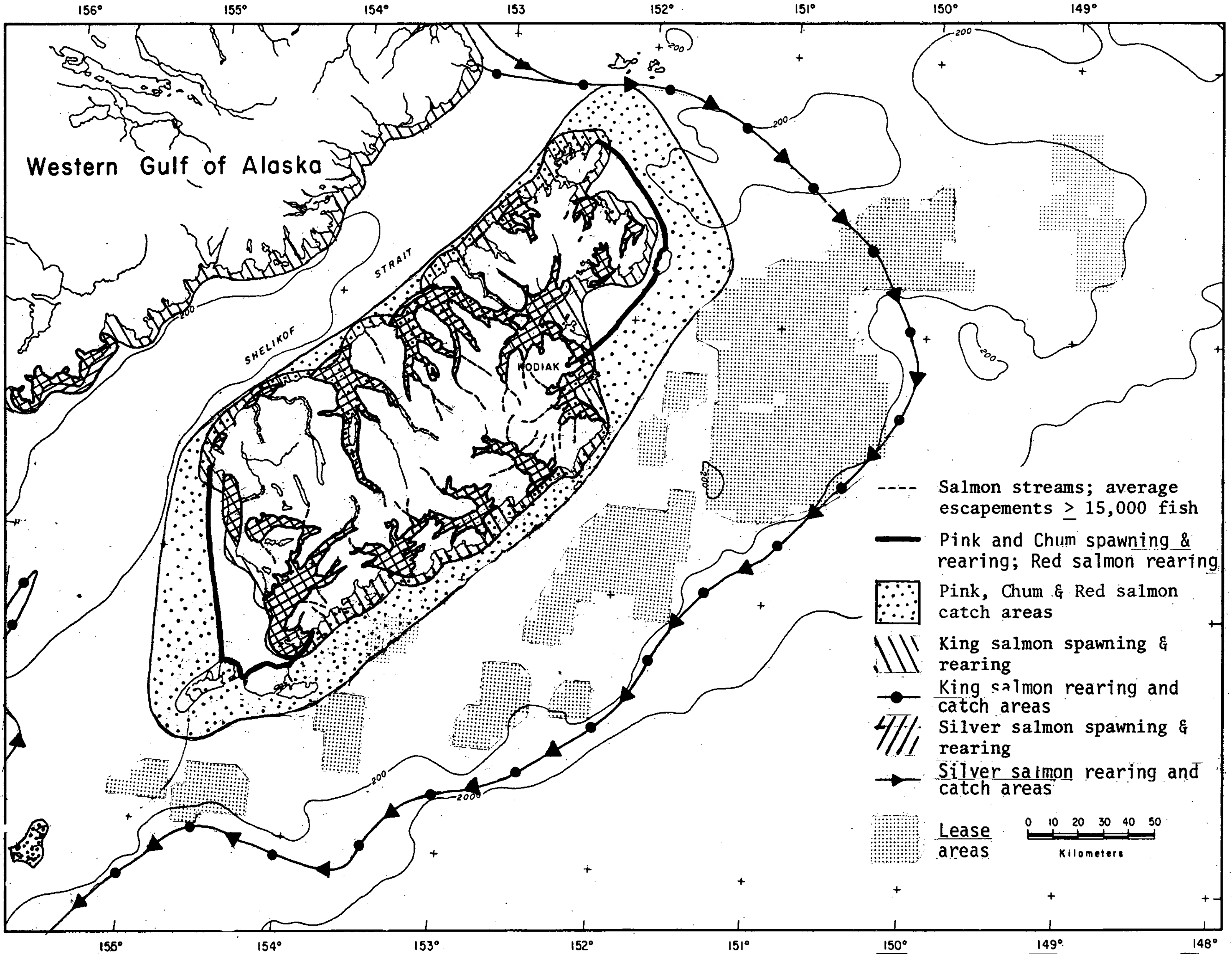



Fig. 3-21 Pacific salmon spawning, nearshore rearing, and commercial harvest areas (modified from ADF&G, 1976; ADF&G, 1977).

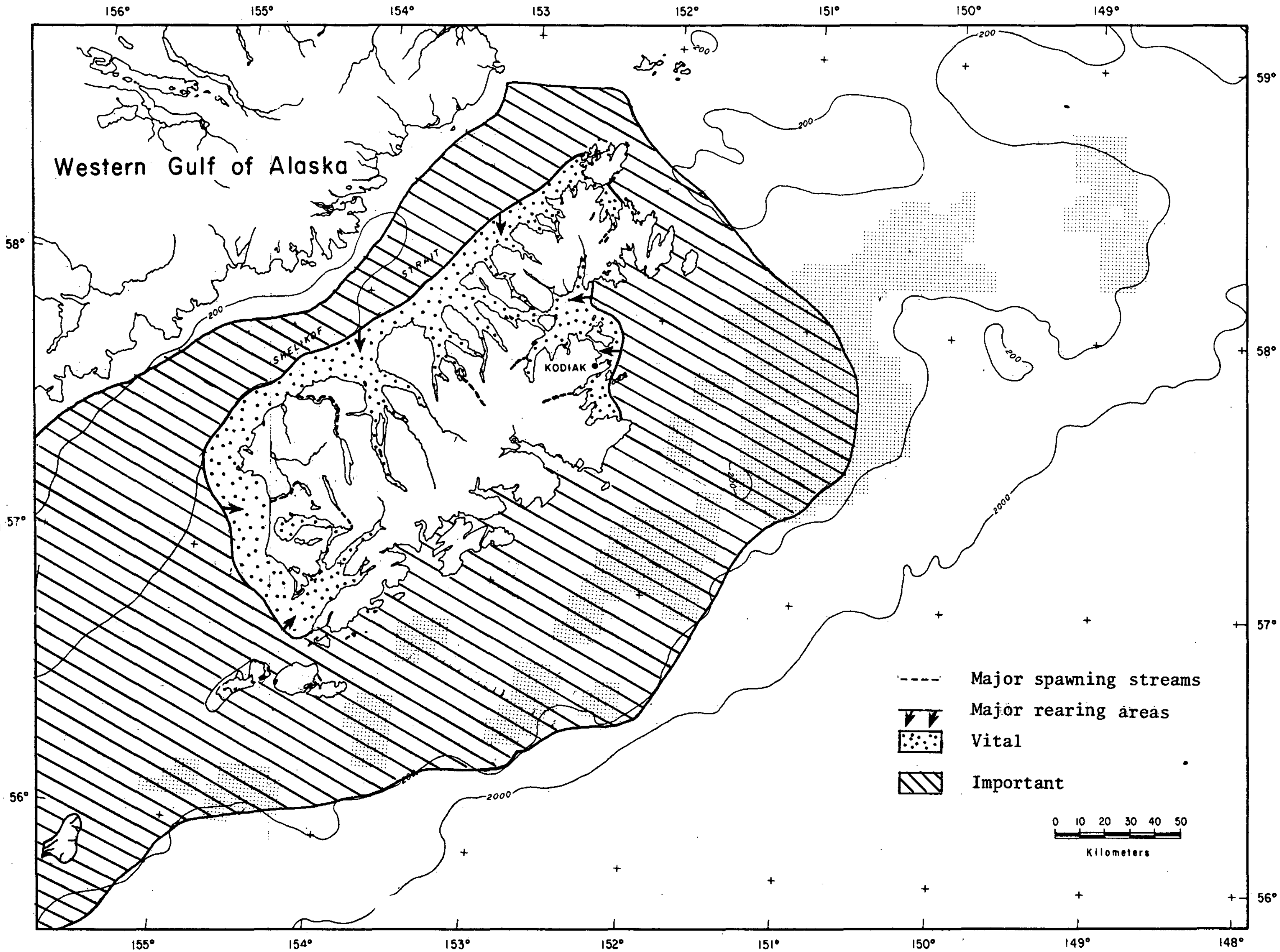



Fig. 3-22 Steelhead distribution spawning and rearing (modified from ADF&G, 1976; ADF&G, 1977).

Karluk and Red Rivers have the only natural chinook runs (ADF&G 1976). Chinook spawning runs in other streams have resulted from successful transplants.

On an island-wide basis, 70% of the sockeye production occurs on the west side. Pink salmon are most abundant in the southeast and southwest areas. Chum salmon catch rates are greatest along the eastern side of Kodiak (Stern *et al.* 1976). Specifics on the abundance and distribution of steelhead trout and Dolly Varden are unknown; however, sport catch statistics indicate reasonable numbers in accessible regions.

The 48 year (1925-75) mean spawning run size has been estimated at 11.6 million salmon, with a peak of 28.9 million fish. Pink salmon make up about 80% of the total spawning migration. The number of juvenile salmon leaving the Kodiak region has been estimated at 330.7 million fish, with a peak abundance of 809.2 million fish.

Most juvenile salmonids migrate from the parent stream during the spring and summer (Stern *et al.* 1976) (Tables 3-14 and 3-15). Pink and chum salmon fry usually spend several months in coastal estuaries before going to sea. Sockeye, coho, chinook, steelhead, and Dolly Varden are much larger when they leave their parent streams and may proceed offshore immediately. Dolly Varden smolts rarely go beyond 50 miles offshore but remain in the coastal region (ADF&G 1976).

Data summarized by Stern *et al.* (1976) indicate that coho salmon are the first to migrate offshore, showing up in offshore, research purse seine catches in May and June. In July, sockeye, coho, and steelhead were caught over the shelf; steelhead were also seined in offshore waters. In August, purse seine catches over the shelf included all Pacific salmon species and steelhead trout; however, only coho, chinook and steelhead were taken at sampling stations further offshore. During the September-October sampling period, purse seine catches over the shelf contained all species of Pacific salmon and steelhead trout. Pink salmon were most abundant. At those stations located further from shore, the catch included coho, sockeye and chinook salmon, and steelhead trout. In the October to March period, the only salmon collected on the shelf and offshore was the sockeye; no steelhead trout were taken in either area.

Royce *et al.* (1968) report that the primary juvenile salmonid outmigration route is around the periphery of the northern Gulf of Alaska, then southward past Kodiak Island (Figure 3-23). The juvenile salmonid migration over the Kodiak Shelf includes not only locally spawned fish but also some spawned in streams as far south as Oregon and northern California (Stern *et al.* 1976; ADF&G 1976). Migration in the Kodiak area continues into October and November.

Immature sockeye were present on the Kodiak Shelf in January. It is unlikely that these fish were ready to approach spawning streams; however, it is apparent that they feed in the area and are joined later by maturing adults. In April, maturing chum were caught on the shelf and by June maturing adult Pacific salmon species were present in shelf waters. Peak abundance occurs in July and as the maturing fish move into natal streams, abundance decreases to minimal levels in September (Stern *et al.* 1976).

The general migratory pattern for salmonid spawners is from the northeast and much "to" and "fro" movement may occur before adults enter spawning streams (Figure 3-24). The exact migratory pathway varies from year to year but the arrival time is nearly the same each year (Royce *et al.* 1968; Stern *et al.* 1976).

A third salmonid migration occurs on the Kodiak Shelf annually. This involves the feeding migration of immatures which will not spawn that year but have been at sea at least one winter. Immature salmonids are abundant in coastal areas throughout the summer and move southwestward during the fall (Stern *et al.* 1976).

Additional data on salmonid habitat preference, areas of peak occurrence, seasonality, area use, and potential oil interactions are listed in Table 3-15.

Few data are available on smelt and herring abundance, migration, and distribution. Herring typically spawn in the spring, along rocky beaches in the intertidal to shallow subtidal zone. In the Kodiak area spawners are not noticeable every year and it is suspected that some deep water spawning occurs (ADF&G 1976). When observed, herring spawning is most abundant along the west coast of Kodiak (Figure 3-25). On the west side of Kodiak Island, herring have been observed spawning in Uyak, Uganik, and Viekoda Bays; on the east side spawners were noted in Port Hobrom (ADF&G 1976).

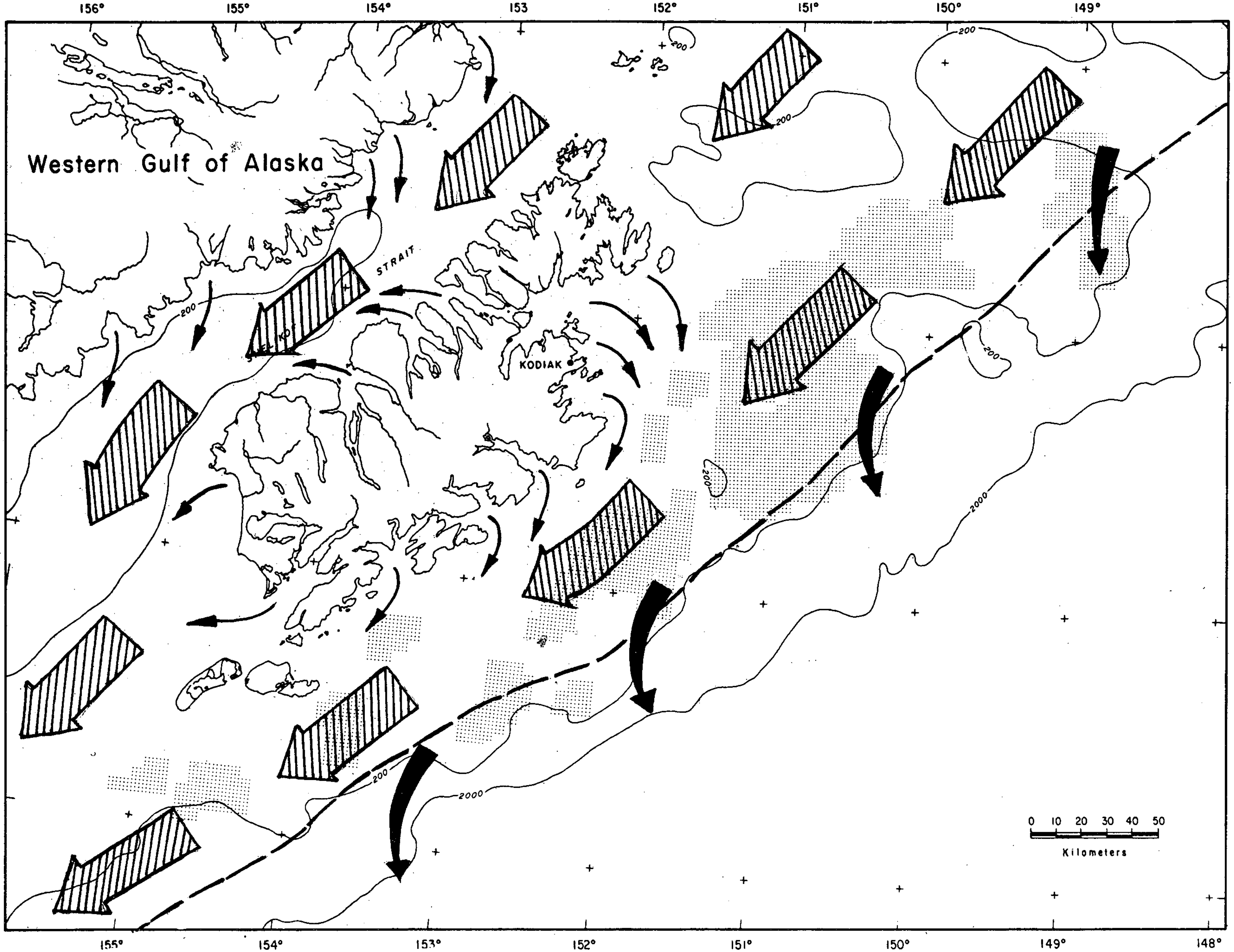



Fig. 3-23 Primary migratory pathway of juvenile salmonoids in the western Gulf of Alaska (modified from Stern et al., 1976).

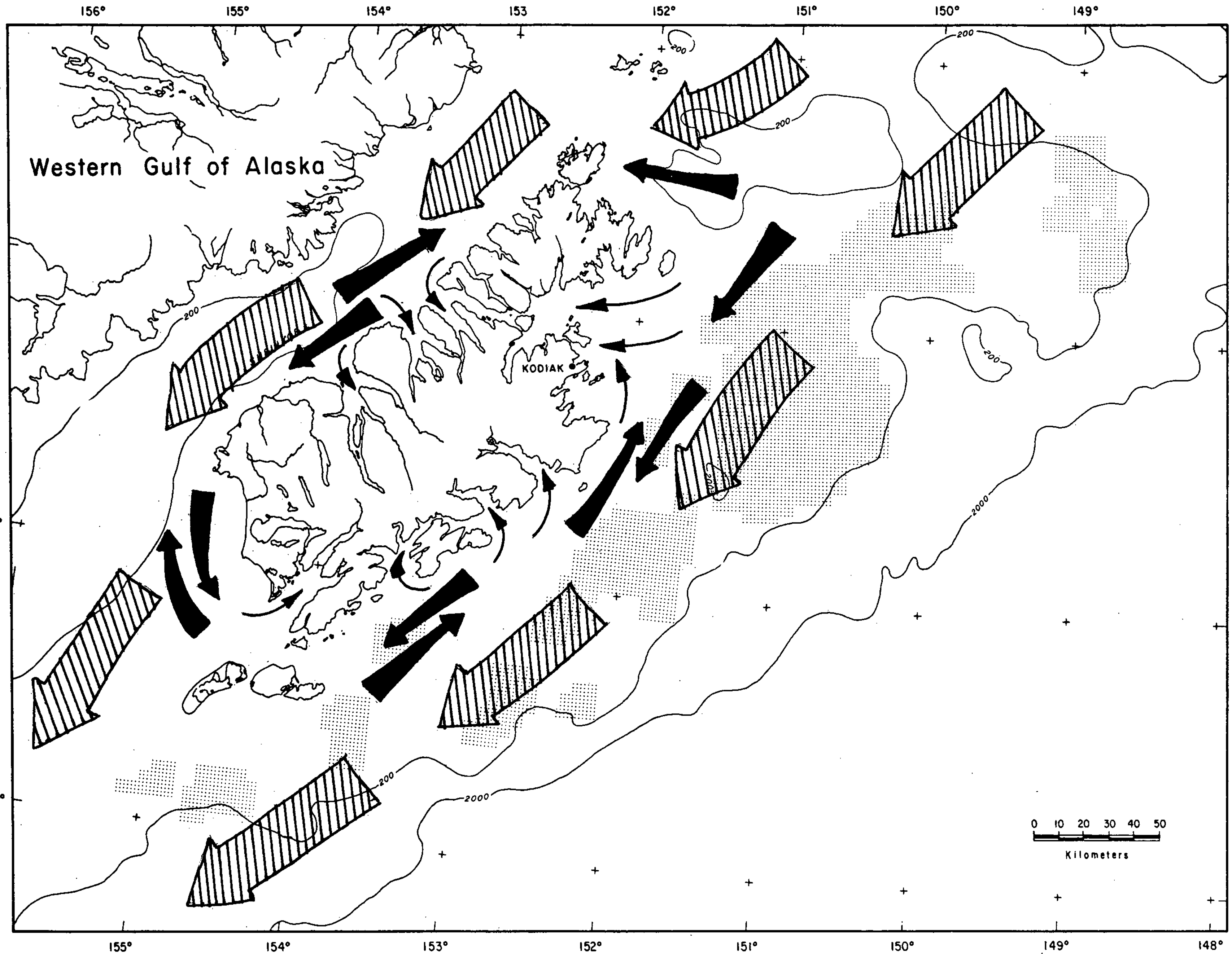



Fig. 3-24 Primary migratory pathway of salmon spawners in the western Gulf of Alaska (modified from Stern et al., 1976).

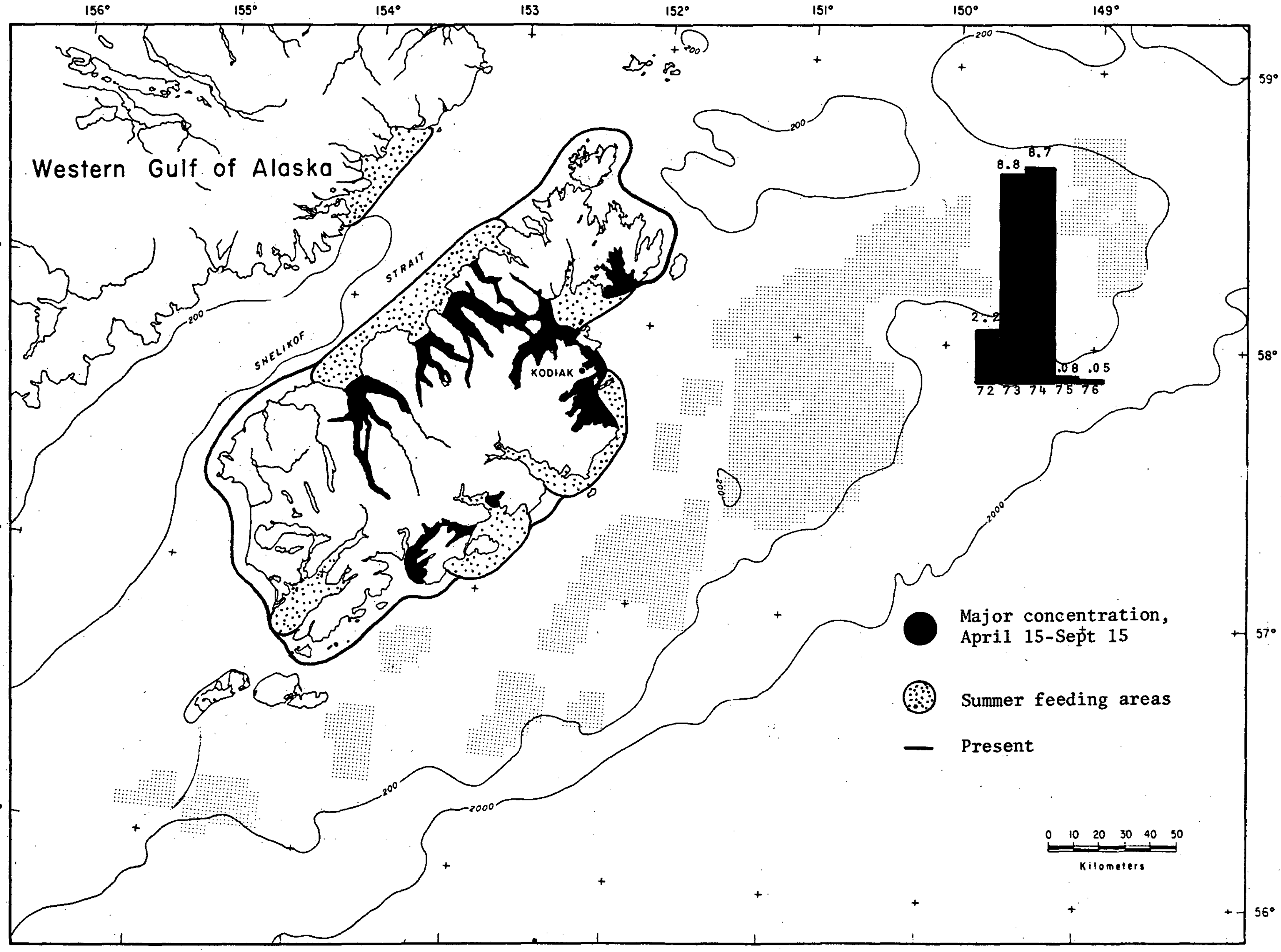



Fig. 3-25 Major concentrations of herring, April 15-September 15, and herring catch in hundreds of tons, 1972-76 (modified from ADF&G, 1977).

Anadromous smelt (Eulachon) spawn in various streams throughout the area; however, no specific streams have been identified as having smelt runs. Non-anadromous smelt species (surf smelt, capelin) spawn on sandy beaches (Figure 3-26). Small sections of sandy beach occur throughout most bays in eastern Kodiak; however, the only extensive sandy beach systems are located on the southwest end of the Island, west of Alitak Bay. The sandy beach system of the Trinity Islands (approximately 50% of the coastline) is used extensively by capelin for spawning. Historical catch statistics reported by Macy (1977) indicate that larvae and juveniles of herring, capelin, and eulachon are distributed throughout much of the nearshore zone of the Kodiak Archipelago (Figure 3-27).

Additional data on time of spawning, habitat preference, areas of peak occurrence, and oil interaction of some of these forage species are listed in Table 3-15.

Other species resident in the lease area include those belonging to the families Gadidae, Cottidae, Hexagrammidae, Pleuronectidae, Scorpaenidae, and Ammodytidae. Of these species, only Pacific halibut is known to undertake extensive migrations (Hart 1973). Other demersal species generally move up and down the shelf and slope seasonally; some may also migrate laterally along the shelf (Macy 1977; Hart 1973; Alverson 1960; Edson 1954; Phillips and Imamura 1954; Holmberg and Jones 1954). In general, these migrations are limited to a few miles. Examples of species undertaking limited migrations include walleye pollock, Pacific Ocean perch, sablefish, arrowtooth flounder, rock sole, etc.

Pacific halibut are distributed throughout the lease area and migrate extensively during maturation and to spawn (Figure 3-28; ADF&G 1976; Pereyra and Ronholt 1976). Spawners deposit neutrally buoyant eggs at depths of 150 to 200 fathoms. Eggs and larvae drift passively with the currents. Larvae continue drifting westward as they develop, but tend to move up the water column and closer to shore as they mature. After settling on the bottom the enlarging halibut move again into deeper water and upon maturation return to specific spawning sites. In the Kodiak lease area, one spawning area has been identified east of Chirikof Island, another lies northeast of Portlock Bank (Figure 3-28; ADF&G 1976).

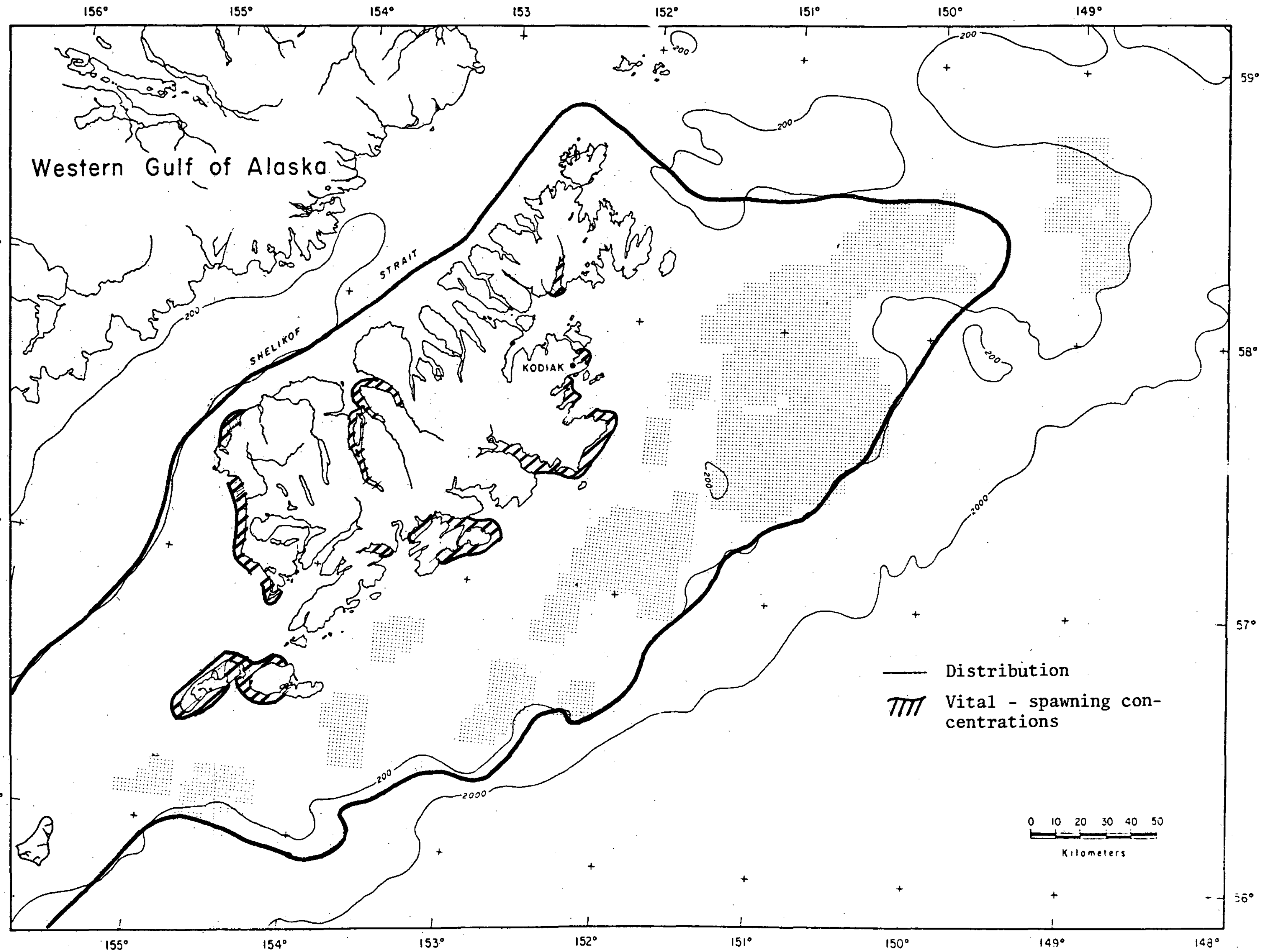



Fig. 3-26 Capelin distribution and important spawning grounds in the Kodiak lease area (from ADF&G, 1977).

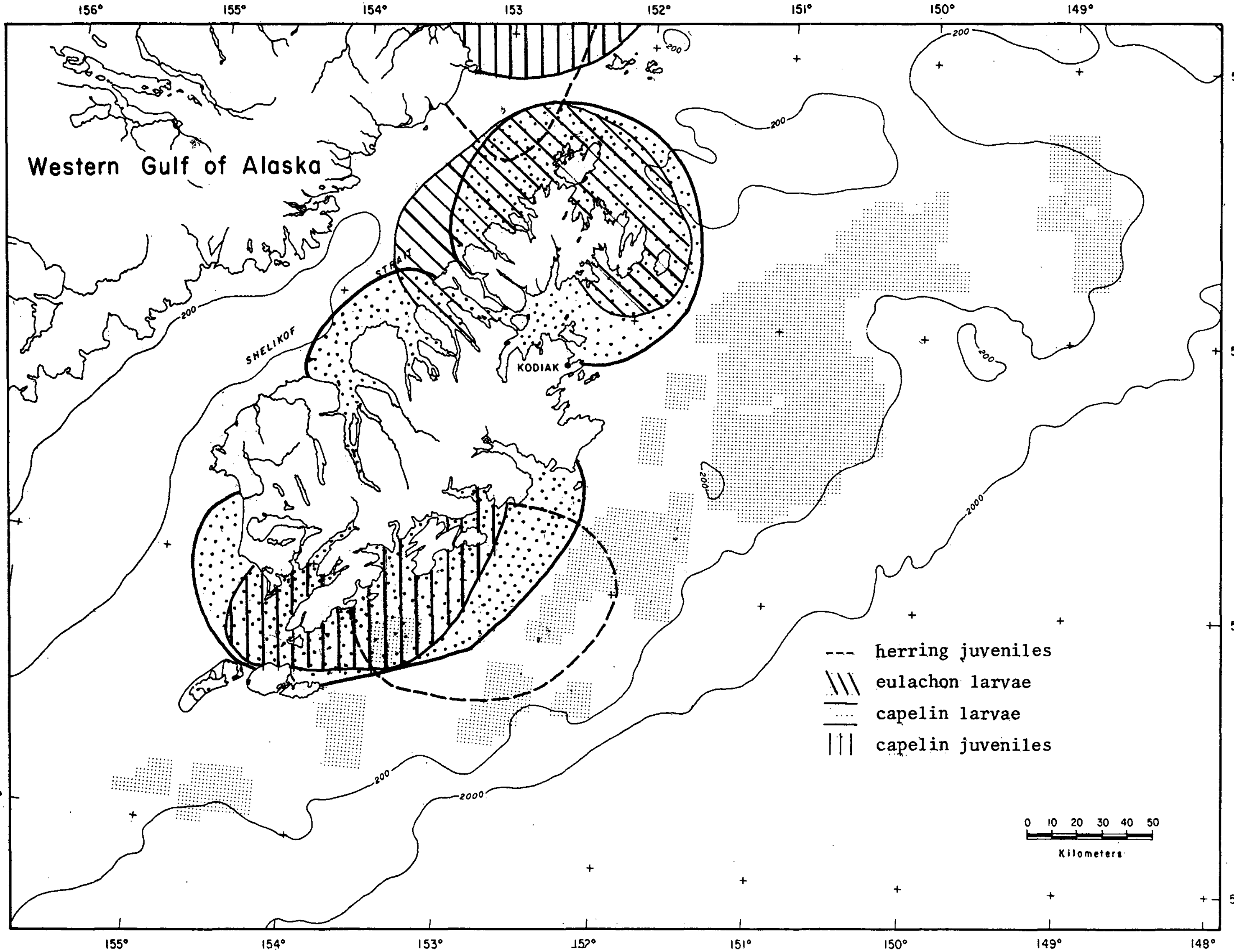



Fig. 3-27 Historical catch distributions of larval and juvenile herring, capelin and eulachon (modified from Macy, 1977).

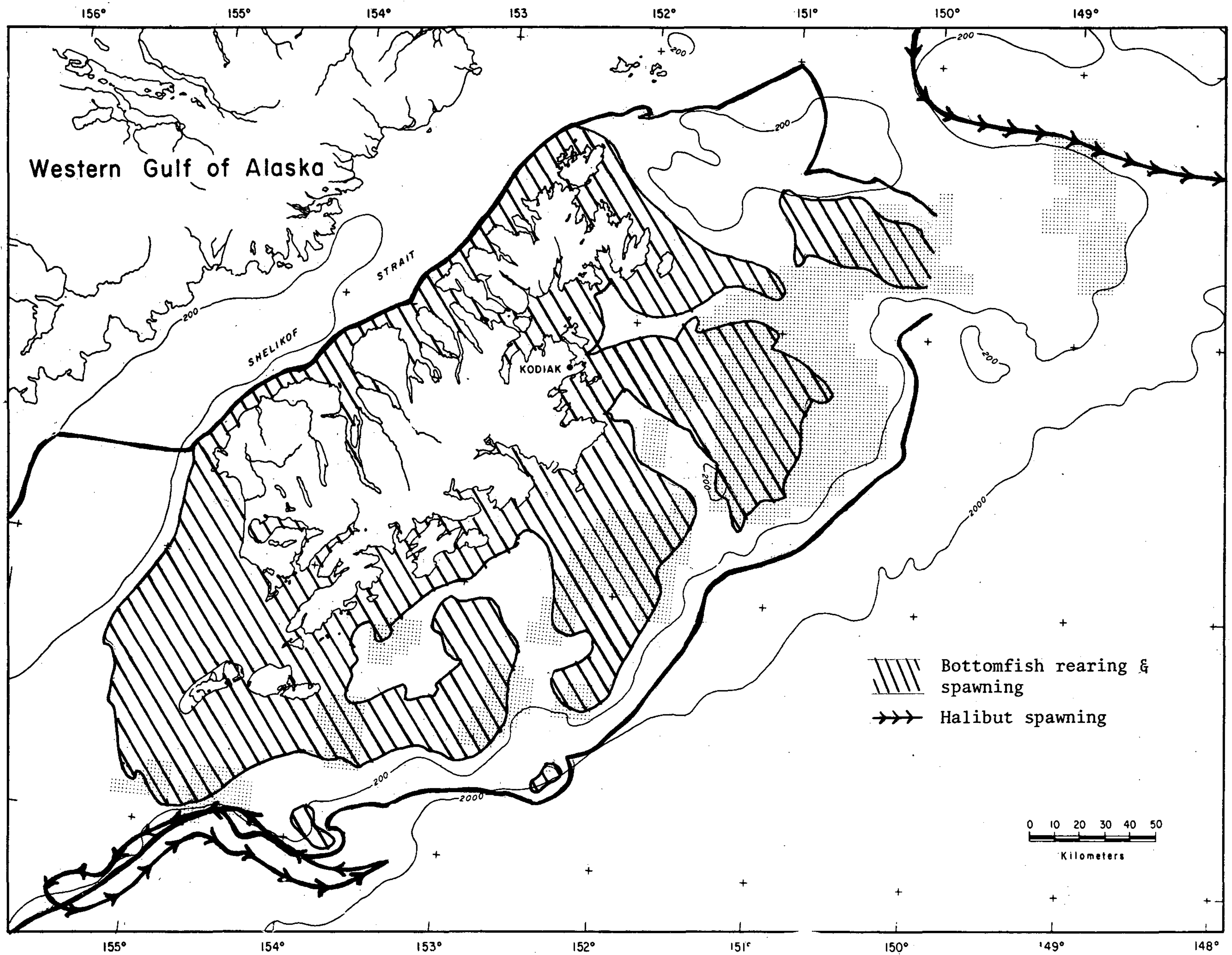



Fig. 3-28 Halibut and bottomfish distribution, halibut spawning, and bottomfish rearing and spawning in the western Gulf of Alaska (modified from ADF&G, 1977; ADF&G, 1976).

Various demersal fish species in the Kodiak area are typically associated with specific bottom habitats. Greenlings prefer rocky intertidal and nearshore zones. Pacific sandlance and Pacific sandfish are commonly found buried to various depths in the nearshore sandy subtidal regions. Pacific Ocean perch, Atka macherel, and sablefish live along the continental slope. Pacific Ocean perch are most abundant on the eastern slope of the Kodiak Shelf. Walleye pollock and Pacific cod are most abundant along the edges of canyons and gullies of the Albatross Banks (Figures 3-29 and 3-30). Specific areas of Pacific halibut abundance include the edges of the Portlock Banks and Albatross Banks and around Chirikof Island. In general, sole are distributed throughout the eastern Kodiak Shelf, including gullies, canyons, and slope (Figures 3-29 and 3-30).

The data indicate that rock and flathead soles are distributed equally throughout the area; however, yellowfin sole are restricted during the spring to the Middle Albatross Bank (Figures 3-29 and 3-30). Dover and rex soles appear limited to the continental slope during spring and summer (ADF&G 1977).

In 1961 and again in 1973-1975, demersal fish surveys were conducted in the western Gulf of Alaska to assess the status of this resource (Pereyra and Ronholt 1976; Hughes 1974). Overall the results of the two studies indicate a general decrease in catch rates from 1961 to 1975 (Figures 3-31 and 3-32). Specific points of comparison between the two surveys indicate that:

(1) There was a 16% decrease in flatfish catch during the 14 year interval.

(2) The flatfish catch per unit effort (CPUE) increased in Kodiak area about 2 to 1 but decreased by one-third and one-fourth in the Chirikof Island and Shelikof Straits regions, respectively.

(3) Arrowtooth flounder was the dominant flatfish during both surveys.

(4) The catch rate of arrowtooth flounder was similar to the overall flatfish catch, except the catch rate decreased about five-fold in the Shelikof Straits.

(5) Pacific halibut catch rates decreased slightly overall. A small decrease in the CPUE occurred on the Kodiak Shelf but a three-fold decrease occurred in the Chirikof and a four-fold increase in the Shelikof areas.

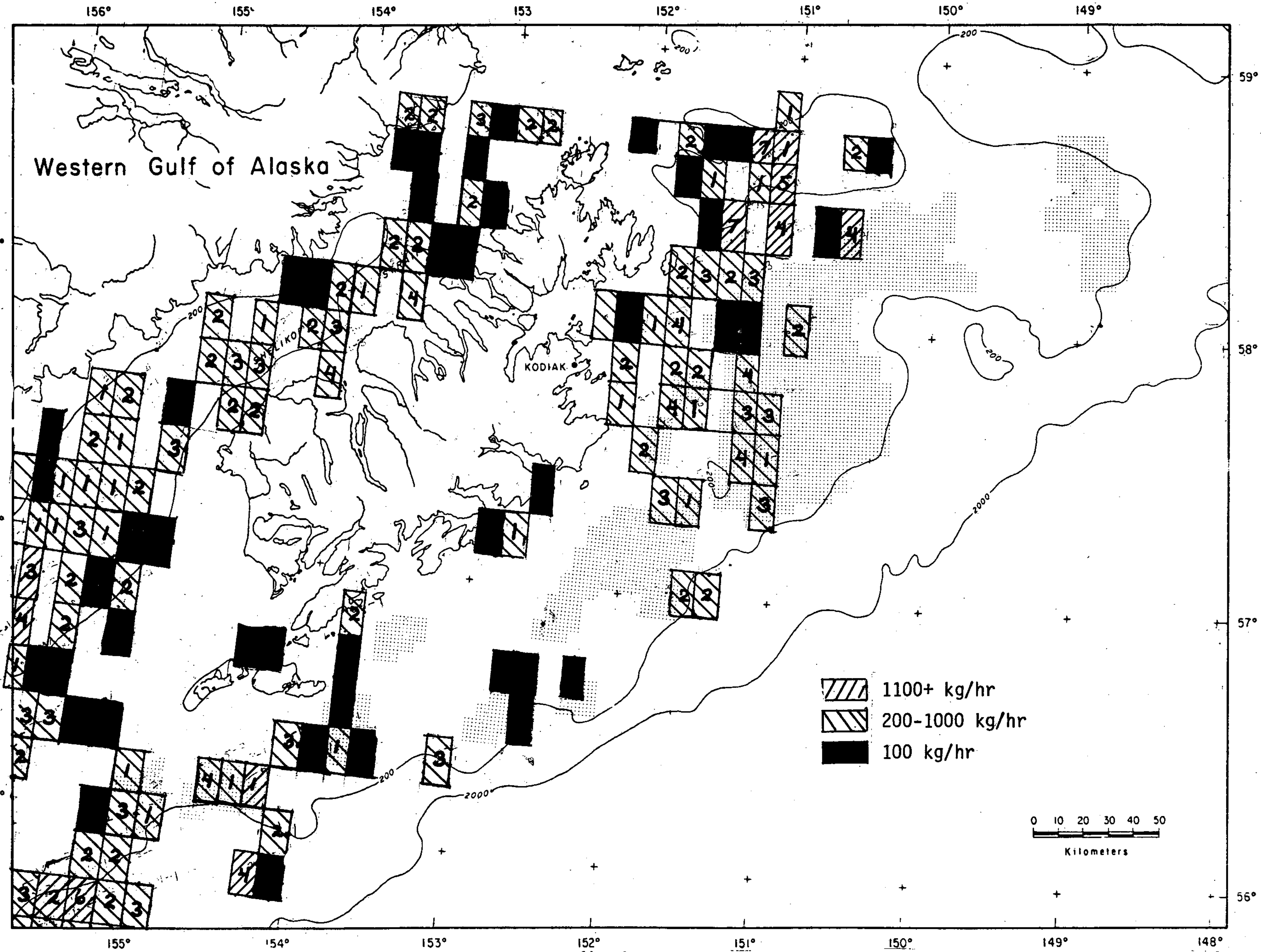



Fig. 3-31 Composite summaries of demersal fish species catches in 1961 above 100 kg/hr and the number of species contributing to the summary catch (modified from Pereyra and Ronholt, 1976).

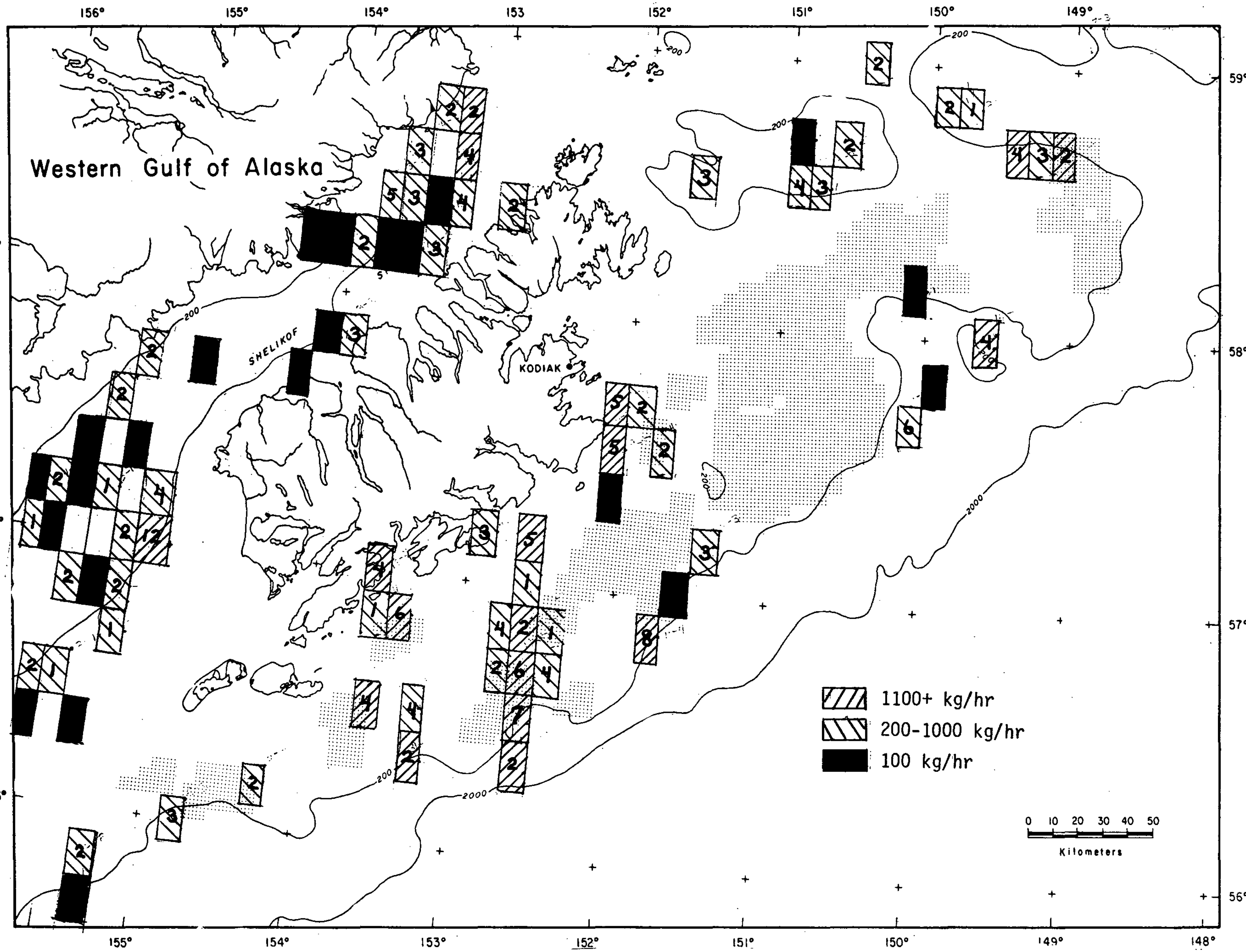



Fig. 3-32 Composite summaries of demersal fish species in 1975 above 100 kg/hr and the number of species contributing to the summary catch (modified from Pereyra and Ronholt, 1976).

(6) The roundfish catch increased in the northern Gulf three-fold in the 14 year interval. The rate of increase in catches on the Kodiak Shelf was similar (three-fold) but only small changes were noted in the Chirikof and Shelikof regions from 1961 to 1975.

(7) Pollock was the dominant roundfish species and also contributed 45% of the total fish catch in 1975.

(8) The CPUE of pollock increased 36-fold on the Kodiak Shelf; eight-fold around Chirikof Island; and nine-fold in the Shelikof Straits. The most substantial increase occurred on the Kodiak upper slope, 485-fold.

(9) Pacific cod was the most abundant roundfish in 1961 and second most abundant in 1975; however, the CPUE of this species generally increased from 1961 to 1975.

(10) The CPUE of rockfish decreased significantly in all areas sampled except a nine-fold increase occurred on the Kodiak upper slope.

(11) Pacific Ocean perch, the most abundant rockfish, decreased similarly but only increased five-fold on the Kodiak upper slope.

(12) Elasmobranchs (sharks and skates) were the least abundant group of fish caught during both sampling efforts.

Historical catch distributions of juvenile deepsea smelt, Pacific sandfish, prowfish, Pacific sandlance, and Atka macherel are illustrated in Figure 3-33.

*Commercial Fisheries.* Except for halibut and salmon, commercial exploitation of the fisheries resource is conducted mainly by foreign nationals. Most of the foreign catch is taken by the Soviet Union and Japan, other nations participating include South Korea, Poland, and Taiwan (Pereyra and Ronholt 1976). The Japanese target their efforts on three species: Pacific Ocean perch, walleye pollock, and sablefish (Pereyra and Shippen 1976). These species comprise approximately 90% of the catch. The incidental catch is composed of arrowtooth flounder, other flatfish, other rockfish, Pacific cod, other fish and shrimp. The total Japanese catch from 1964 to 1974 was 327,398 metric tons of which 195,333 metric tons were Pacific Ocean perch.

Pereyra and Shippen (1976) have plotted the areal distribution of the Japanese commercial catch (Figure 3-34). It is obvious that Japan operates throughout the Kodiak lease area and the highest catches are made along the continental slope and in northern and southern regions of the lease areas.

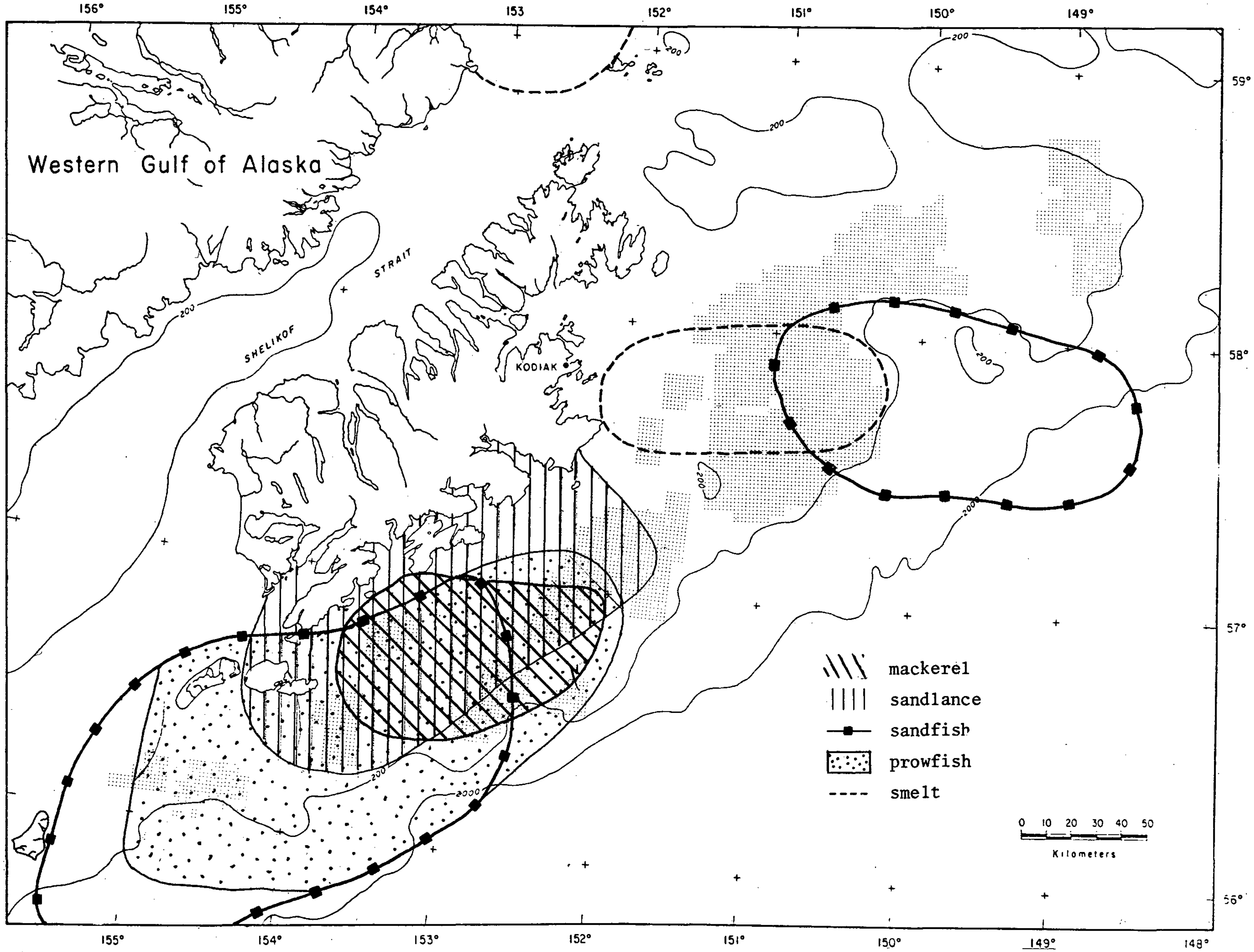



Fig. 3-33 Historical catch distributions of Atka mackerel, Pacific sandlance, Pacific sandfish, prowfish and deepsea smelt (modified from Macy, 1977).

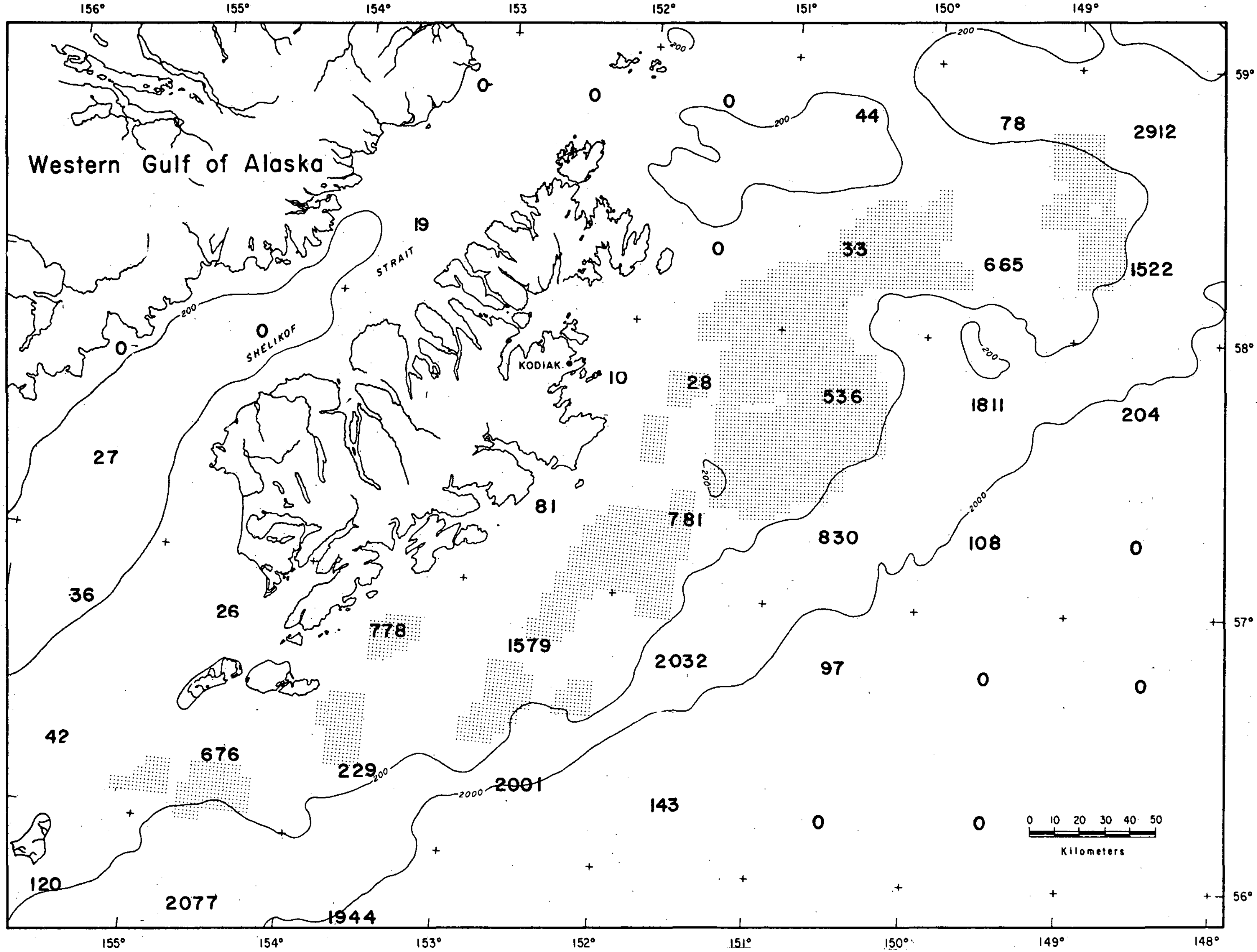



Fig. 3-34 Japanese demersal fish catch, all species and gears, in metric tons, 1964-74 (modified from Pereyra and Shippen, 1976).

Data on Soviet fishing efforts are limited. Recent figures indicate that walleye pollock make up 45% of their total fish catch (Pereyra and Ronholt 1976). Other species caught include Atka macherel (20%), Pacific Ocean perch (11%) and Pacific cod (4%).

U.S. Fishermen also catch some ground fish; however, market conditions are such that the catch is sold primarily for bait. In 1974 U.S. nationals caught approximately 400 metric tons of Pacific cod and flatfish (other than halibut) in the Kodiak lease area (ADF&G 1976).

Canadian and U.S. nationals share in the commercial catch of Pacific halibut throughout the Gulf of Alaska (Figure 3-35). The International Pacific Halibut Commission has regulatory powers over the fishery and maintains statistical data on halibut catches. This organization lumps the Gulf catch into statistical area 3A; however, they do differentiate the catch volume around Chirikof Island. The total halibut catch from 1969-74 in the Gulf was approximately 83,000 metric tons, of which 25,219 metric tons were caught near Chirikof (Pereyra and Ronholt 1976). The Chirikof area was the single greatest producing area during the six year period. However, in this same period the catch from Chirikof decreased eight-fold but less than three-fold throughout the rest of the statistical area 3A.

Salmon are the principal commercial species caught by local fishermen. The average annual salmon catch (1925-1972) for the Kodiak region is 8.1 million fish, 84% of which are pink salmon (Stern *et al.* 1976; ADF&G 1976). Chum and sockeye salmon make up 9% and 6% of the salmon catch, respectively. Little effort is put toward catching coho, because the run occurs late in the year, and chinook, due to the low abundance.

Salmon catches are made throughout the Kodiak district (Figure 3-35) but the most abundant stocks are located in the southeast and southwest areas of the Island (Figure 3-36; Stern *et al.* 1976). Seventy percent of the sockeye catch is from the west side of Kodiak Island; catches of chum salmon are greatest on the east side.

The commercial herring fishery in the Kodiak area is concentrated in Zachar and Uyak Bays. Herring are caught in this area primarily for the sac roe. Other uses include reduction of herring for meal and bait for crab and halibut fisheries. The annual average catch from 1964 to 1974 was 1,034 tons; a peak harvest of 2,769 tons was taken in 1966. A reduction

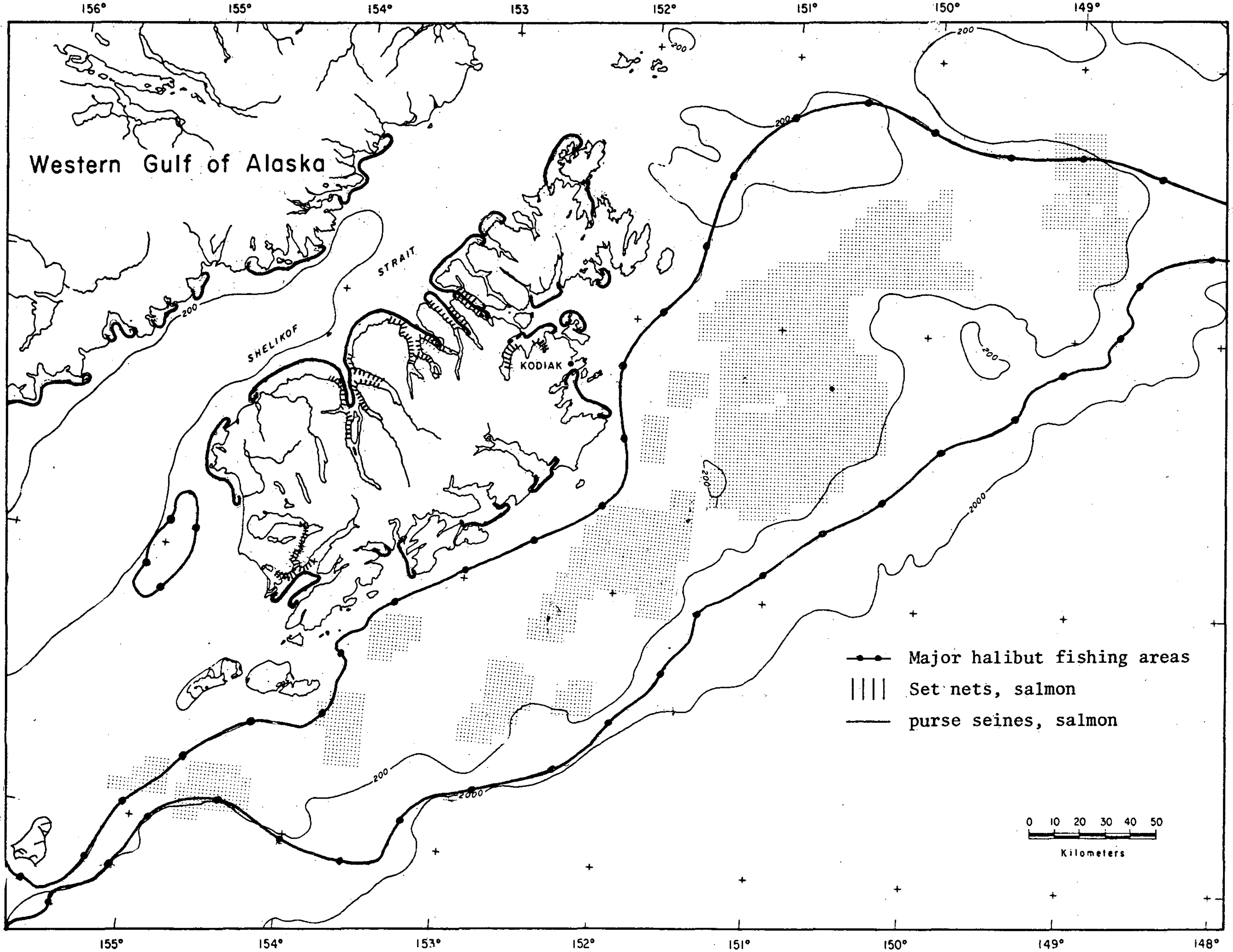



Fig. 3-35 Halibut fishing grounds and salmon catch areas by principal gear usage (modified from ADF&G, 1976).

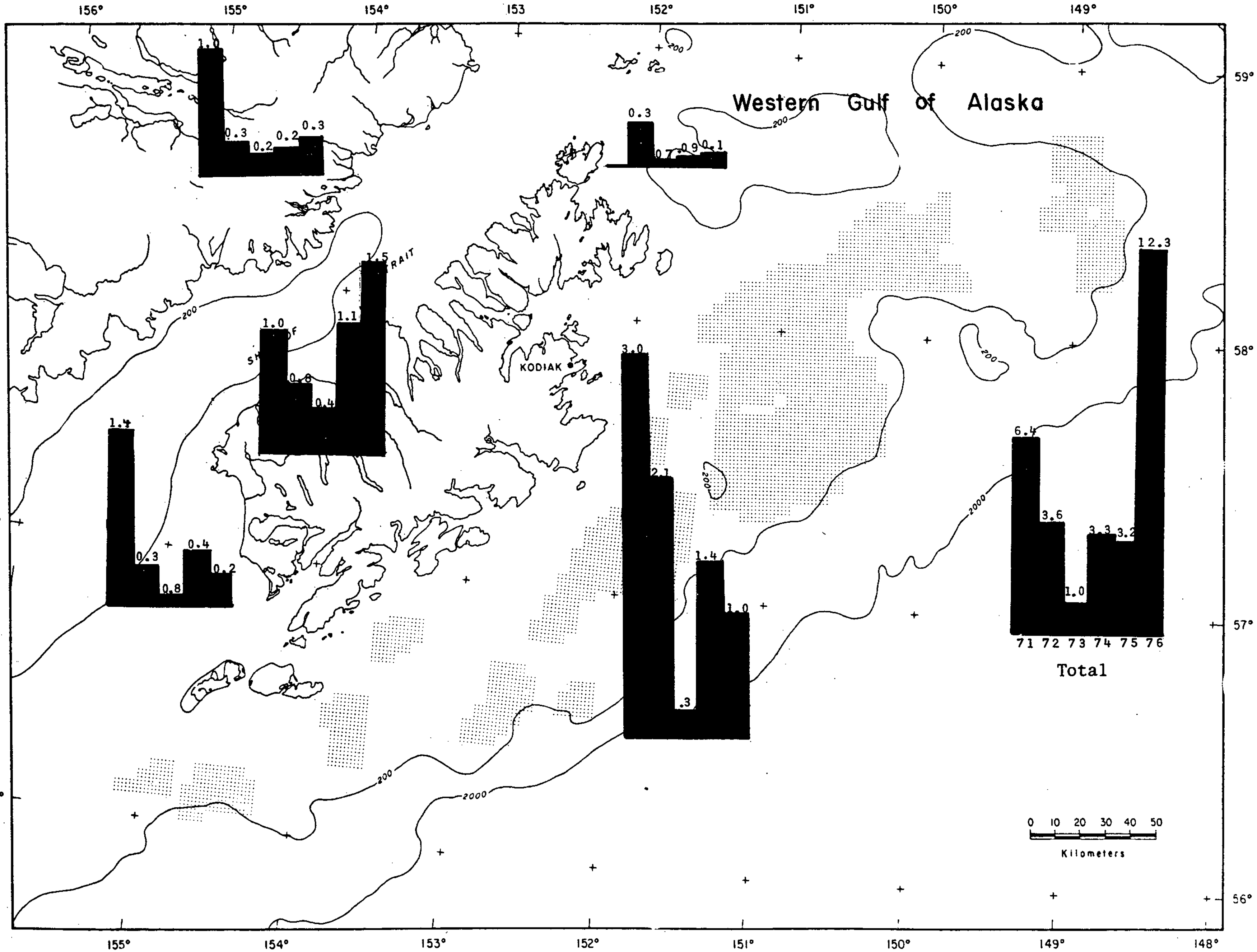



Fig. 3-36 Salmon catch by geographical district by year in millions of fish, 1971-75 and total island wide catch including 1976 (from ADF&G, 1977).

plant operates in Zachar Bay, utilizing waste from roe processing and purchases catches made in late spring and summer.

*Sport Fisheries.* Sport fishing is most common in fresh water systems for salmon and Dolly Varden, in those areas accessible by highway. The marine sport fishery is generally limited to those areas adjacent to Kodiak City and the highway system. Pagashak, Woman's, Middle, Kalsin, Monaskha, and Anton Larsen Bays are utilized mostly for salmon sport fishing (Table 3-15).

Halibut and rockfish are also taken by sport fishermen in the proposed lease area. Halibut and rockfish are caught in Chiniak Bay, halibut in Ugak and Kizhuyak Bays, and rockfish in Monaskha Bay (Table 3-15).

## Birds

About 130 species of birds are associated with the marine environment of the Kodiak Archipelago during at least part of their life cycle. In addition to seabirds, shorebirds, and waterfowl, these include several species of landbirds that feed or breed or both in beach habitats.

To date, the U.S. Fish and Wildlife Service (1976) has identified 251 seabird nesting colonies on Kodiak with a total of more than 400,000 birds (Figure 3-37). Colonies vary in size from as few as 10 birds to large colonies such as Cathedral Island (88,000 birds) and Boulder Bay (101,000 birds). An additional 450,000 birds nest in 14 colonies on the Barren Islands. Altogether, at least 21 species nest in the Kodiak colonies (C. Lensink, USFWS, Anchorage, personal communication):

1. Common Eider
2. Red-breasted Merganser
3. Northern Fulmar
4. Fork-tailed Storm Petrel
5. Double-crested Cormorant
6. Pelagic Cormorant
7. Red-faced Cormorant
8. Glaucous-winged Gull
9. Mew Gull
10. Black-legged Kittiwake
11. Arctic Tern
12. Aleutian Tern
13. Common Murre
14. Thick-billed Murre
15. Pigeon Guillemot
16. Ancient Murrelet
17. Parakeet Auklet
18. Rhinoceros Auklet
19. Horned Puffin
20. Tufted Puffin
21. Black Oystercatcher

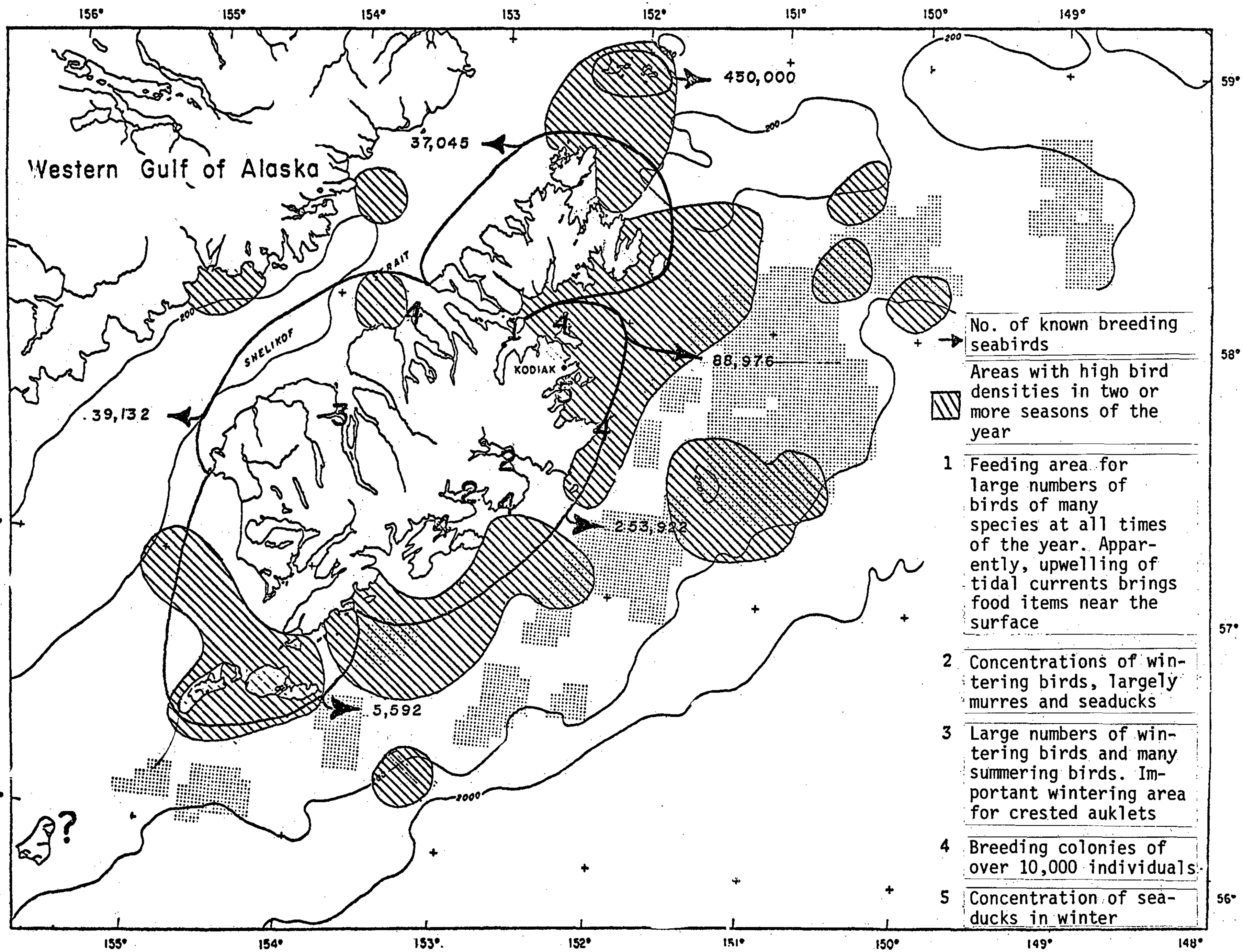



Fig. 3-37 Seabird distribution in the Kodiak Archipelago. Marine birds breed and winter on Chirikof Island but no other data are available (ADF&G, 1973 and 1977; P.Arneson, 1977; USFWS, 1976).

Shipboard surveys conducted in the Kodiak region in 1975 revealed the presence of 38 species of seabirds and waterfowl. Greatest densities of birds in Shelikof Strait and over the Kodiak Shelf were recorded in May (Figure 3-38; Lensink and Bartonek 1976).

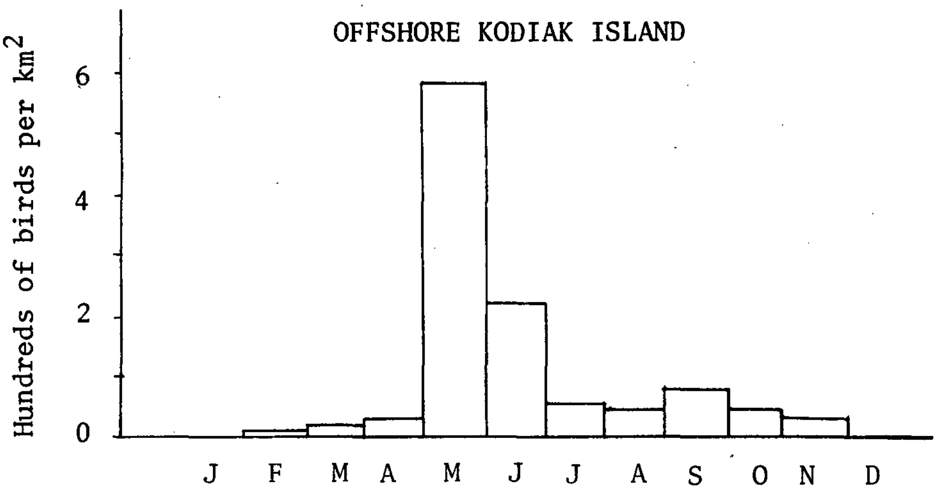
From May through August, shearwaters were the most abundant birds on Alaskan marine waters, including the Kodiak area. They contribute nearly 80% of the total bird density on oceanic waters and 30% over the continental shelf (Figure 3-39). Alaskan shearwaters breed in Chili, New Zealand, and Australia during the austral summer, then migrate to their boreal summer feeding grounds in the North Pacific, Bering Sea, and Arctic Ocean. They are widespread around Kodiak from approximately March or April until November or December (Figure 3-39). Large numbers of shearwaters are present throughout the summer in outer Chiniak and Marmot Bays.

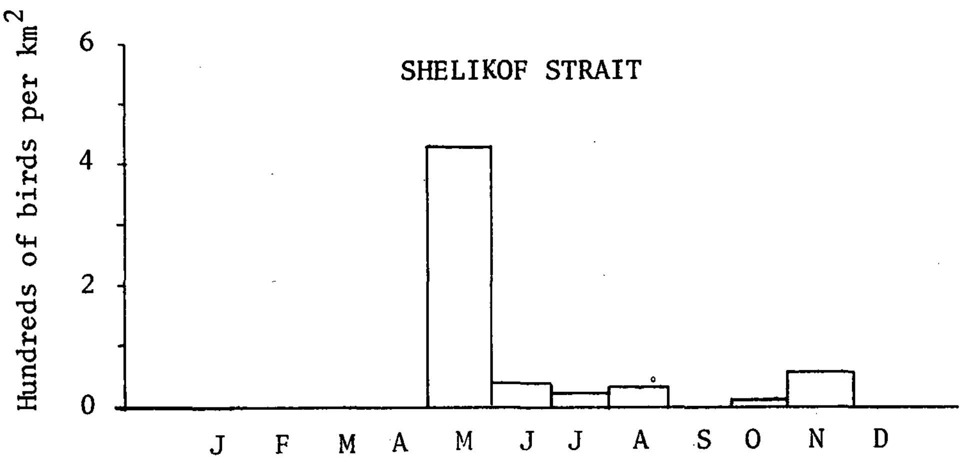
Although their total abundance has not been determined, large numbers of marine birds, more than 30 species, winter along the coast and in protected bays of Kodiak (Figure 3-37 and Table 3-16). This wintering avifauna is dominated by anatids and alcids, the most numerous of which are murres, crested auklets, and several species of seaducks. Some important wintering areas are Chiniak Bay (seaducks), the Kiliuda Bay-Sitkalidak Strait area (murres), Ugak Bay (murres), the Uyak Bay-Spiridon Bay region (crested auklets), and Whale Passage (several species). Many new data on winter abundance, distribution, and habitat preferences of coastal birds in Kodiak have been obtained by Paul Arneson (1976); analyses of these data are still in progress. Preliminary information on habitat use, relative seasonal and regional abundance, and vulnerability to petroleum development of some of these birds are presented in Table 3-17.

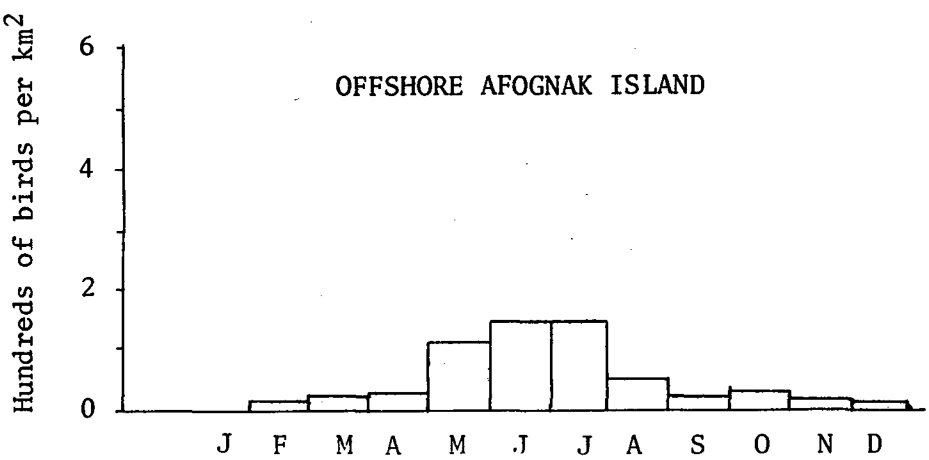
Mammals

The coast and shelf of the Kodiak Archipelago supports the largest concentrations of marine mammals in the Gulf of Alaska, including an abundance of harbor seals, Steller sea lions, sea otters, and cetaceans (Table 3-18). The largest single concentration of harbor seals in the world is the 13 to 20 thousand animals inhabiting Tugidak Island (K. Pitcher, ADF&G, Anchorage, personal communication). Harbor seals occur elsewhere in the archipelago (Figure 3-40), including a population of 2,500 to 3,000 on Ugak Island and populations of 600 to 800 on Sitkinak, Geese, and Aiaktalik Islands.

Fig. 3-38 Seasonal changes in bird density (all species) in offshore habitats (prepared by G.A. Sanger, 1976).



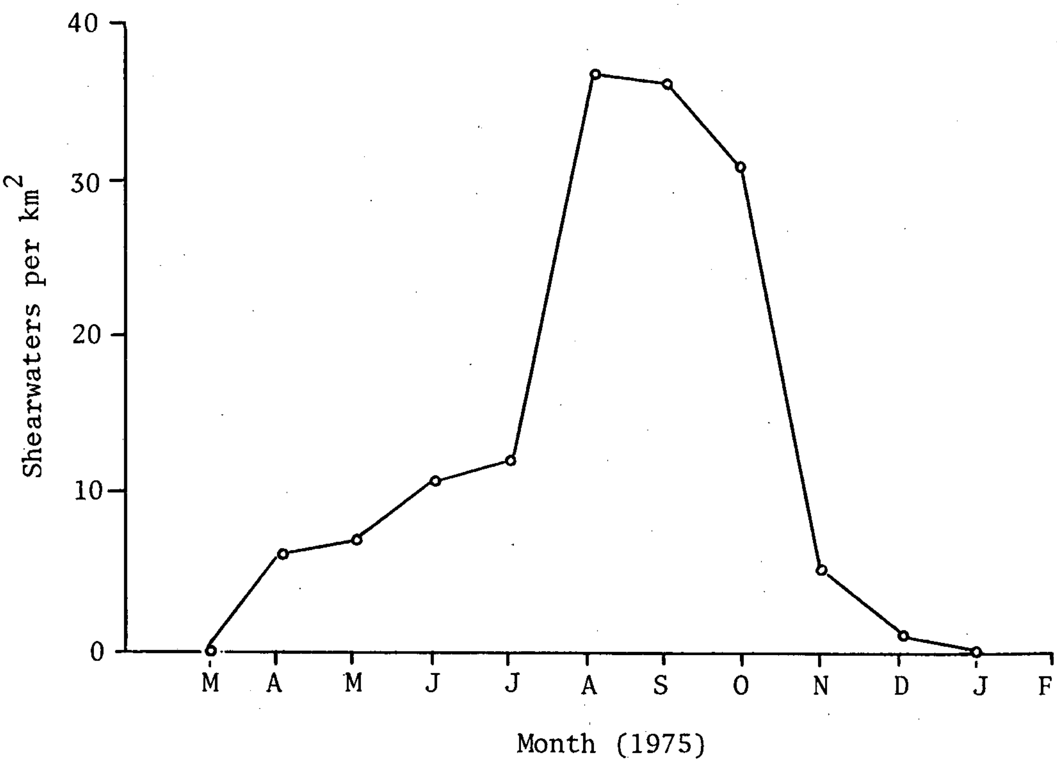



Fig. 3-39 Seasonal density of shearwaters (all species) on waters of Kodiak Basin. The curve has been smoothed by using a 3-point moving average and assuming zero birds present from December to March. These are the most abundant birds on Alaskan offshore waters in summer (from Lensink and Bartonek, 1976).

TABLE 3-16

Numbers of swimming birds counted during shipboard surveys by Kodiak National Wildlife Refuge personnel, Jan. 25-Feb. 8, 1973 and Feb. 5-22, 1975. The survey also included corvids, raptors, and shorebirds, which are excluded from this list (adapted from Arneson 1976).

| | 1973 | 1975 |
|---|---|---|
| Loon sp. | 424 | 83 |
| Grebe sp. | 7 | 72 |
| Red-necked | 1 | |
| Cormorant sp. | 1,982 | 1,728 |
| Emperor Geese | 621 | 52 |
| Mallard | 700 | 2,556 |
| Pintail | 200 | 4 |
| Gadwall | 30 | 75 |
| Dabbler sp. | - | 50 |
| Scaup (Greater) | 80 | 15 |
| Goldeneye sp. | 1,142 | 1,205 |
| Common | 146 | |
| Barrows | 24 | 30 |
| Bufflehead | 36 | 27 |
| Harlequin | 691 | 675 |
| Eider sp. | 67 | 1,745 |
| Common | 4,512 | 58 |
| King | | 4,654 |
| Steller's | 340 | 1,176 |
| Oldsquaw | 7,863 | 9,410 |
| Scoter sp. | 3,192 | 994 |
| Black | 2,154 | 1,402 |
| White-winged | 3,059 | 2,073 |
| Surf | 1,194 | 327 |
| Merganser sp. | 39 | 27 |
| Common | 21 | 21 |
| Red-breasted | 13 | 34 |
| Gull sp. | 124 | 1,589 |
| Glaucous-winged | 32 | 923 |
| Mew | 356 | 731 |
| Murre sp. | 8,420 | 14,994 |
| Common | | 179 |
| Thick-billed | 66 | |
| Pigeon guillemot | 46 | 106 |
| Horned Puffin | | 1 |
| Tufted Puffin | | 1 |
| Crested Auklet | 15,033 | 7,011 |
| Murrelet sp. | 63 | 280 |
| Ancient | 3 | |
| TOTALS | 52,731 | 54,303 |

TABLE 3-17

Summary of use of Kodiak lease area by principal shoreline marine birds
(Paul Arneson, ADF & G, Anchorage, Personal Communication)

| Family/Group | Principal Habitat | Areas of Peak Occurrence | Season of Peak Occurrence | Use of Area by Biotic Group | Special Vulnerability To Petroleum Development |
|---|---|---|---|---|---|
| Gaviidae | Nearshore | Nearshore in Bays | April-May<br>Sept.-Nov. | Migration, breeding<br>Feeding, wintering | Oil on feathers<br>Reduced food supply |
| Podicipedidae | Protected near-shore waters | Nearshore | Nov.-April | Migrating, wintering | Oil on feathers<br>Reduced food supply |
| Phalacrocoracidae | Rocky, exposed Coast | Nearshore | Resident | Migrating, summering<br>Wintering, breeding | Oil on feathers, eggs<br>Reduced food supply |
| Anatidae | | | | | |
| Geese & Swans | Heads of bays<br>Lagoons, stream deltas | Heads of bays | Late Mar.-May<br>Late Aug.-Nov. | Migrating<br>(Emperors winter) | Reduced food supply |
| Dabblers | Heads of bays<br>Lagoons, stream deltas | Heads of bays | Late Mar.-May<br>Late Aug.=Oct. | Migrating, some breeding and wintering | Reduced food supply<br>Oil on feathers |
| Seaducks | Nearshore coastal waters, Bays | Nearshore | Oct.-April | Wintering, migrating<br>Some breeding | Oil on feathers<br>Reduced food supply |
| Mergansers | Nearshore<br>Outer coasts | Bays, Inlets | Resident<br>Apr.-May, Sept.-Nov. | Migrating, breeding<br>Wintering | Oil on feathers<br>Reduced food supply |
| Accipitridae }<br>Falconidae } | Beaches,<br>Heads of Bays | Beaches<br>Stream deltas | Mostly residents | Migrating, breeding<br>Wintering | Reduced food supply, eating toxic oil-killed animals |
| Haematopodidae | Rocky shores | Rocky coast | Resident | Breeding, wintering<br>Feeding | Reduced food supply |
| Charadriidae | Heads of bays<br>Beaches/rock | Tide flats at heads of bays | Late Apr.-May<br>Mid July-Sept. | Migrating, some breeding and wintering | Reduced food supply |
| Scolopacidae | Heads of bays<br>Beaches/rock | Tide flats at heads of bays | Late Apr.-May<br>July-Oct. | Migrating, some breeding and wintering | Reduced food supply |
| Phalaropodidae | Nearshore waters<br>Offshore waters | Offshore waters<br>Bays | May-Mid June | Migrating, some breeding | Oil on feathers<br>Reduced food supply |
| Stercorariidae | Offshore waters<br>Inshore waters<br>Beaches | Nearshore | April-June<br>July-Aug. | Migrating, some breeding | Reduced food supply |
| Laridae | | | | | |
| Gulls | Bays, Islands | Throughout<br>Canneries | April-Sept.<br>Resident | Breeding, migrating wintering | Oil on feathers, eggs<br>Disturbance to colonies |
| Terns | Heads of Bays<br>Beaches | Islands<br>Sand Spits | Late Apr.-May<br>Late July-Mid Aug. | Migrating, breeding | Reduced food supply |
| Alcidae | Exposed rocky coast & Bays | Breeding colonies on open coasts | June-Aug. | Breeding, wintering<br>Some resident | Oil on feathers, eggs<br>Reduced food supply<br>Disturbance to colonies |
| Corvidae | Beaches | Throughout | Resident | Feeding, breeding wintering | Ingesting oil-killed animals, reduced food supply |
| Fringillidae | Beaches, both rocky and sandy | Rocky beaches, Heads of bays | May-Aug. | Migrating, breeding, wintering | Reduced food supply |

TABLE 3-18

Summary of population size estimates of marine mammals and regions of the Gulf where individual species are most likely to frequent. General food resources and vertical zone of the ocean where animals feed are also included. NE=no estimate available (from Fiscus et al., 1976).

| Marine mammal species | Approximate population size1/ | Region of the gulf2/ | Principal food type | Feeding strata3/ |
|---|---|---|---|---|
| N. fur seal | 1,189,000 (NP) | OS | fish, squid | MW |
| N. sea lion | 100,000 (NP) | C | fish | S,MW |
| Harbor seal | 100,000? (GA) | C | fish | S,MW |
| Gray whale | 11,000 (W) | C | amphipods | B,S |
| Minke whale | NE | C,OS | fish, copepods | S |
| Sei whale | 8,600 (NP) | OS | copepods | S |
| Fin whale | 9-16,000 (NP) | OS | euphasiids copepods | S |
| Blue whale | 1,600 (NP) | O | euphasiids | MW |
| Humpback whale | 1,400 (NP) 60 (GA) | C | euphasiids, fish | S |
| N. Pacific white-side dolphin | NE | C | fish | MW |
| Killer whale | NE | C | fish, cephalopods pinnipeds | S |
| Harbor porpoise | 1,000+ (GA) | C | fish | S |
| Dall porpoise | 2,000+ (GA) | C,OS | fish | S |
| Beluga | 150-400 (CI) | C | fish | S |
| Sperm whale | 150,000 (NP) | O | cephalopods fish | B,MW |
| Pilot whale | NE | OS | cephalopods fish | |
| Grampus | NE | OS | | |
| Right whale | 200 (NP) | OS | copepods euphasiids | S |
| N. right whale dolphin | 10,000+ (NP) | OS | | |
| Giant bottlenose whale | NE | O,OS | fish cephalopods | B,MW |
| Bering Sea beaked whale | NE | O,OS | | |
| Goose-beaked whale | NE | O,OS | cephalopods fish | |

1/ Cook Inlet (CI), Gulf of Alaska (GA), eastern N. Pacific (NP), and World (W) population(s).

2/ Coastal (C), offshore (OS--continental shelf), oceanic (O-shelf slope and ocean floor).

3/ Surface (S-photic zone), mid-water (MW), benthic (B-ocean floor).

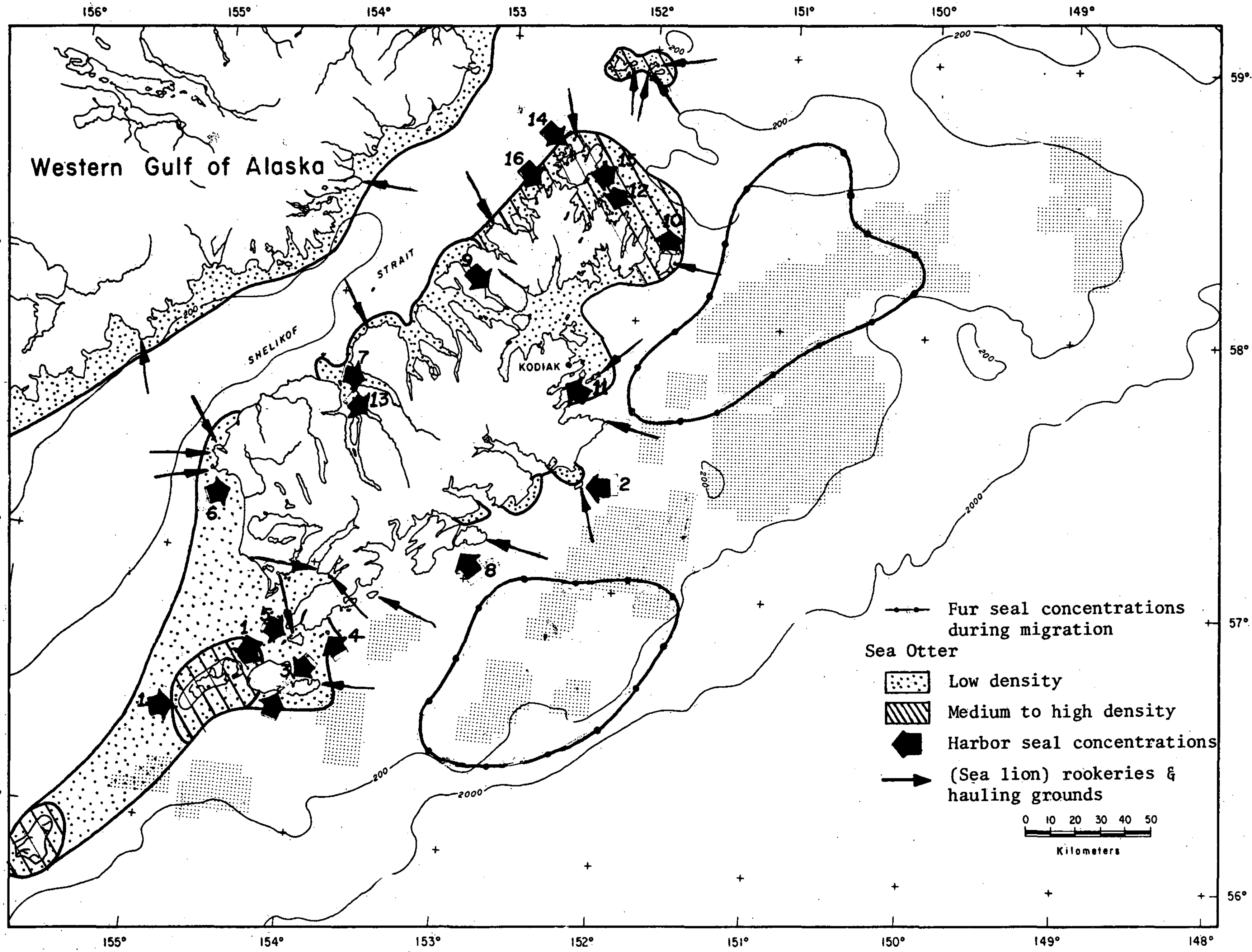



Fig. 3-40 Distribution of marine mammals in the Kodiak Archipelago (after Niggol et al., 1960 and D.Calkins, K.Pitcher and K.Schneider, ADF&G, Anchorage, personal communication).

The Steller sea lion is abundant in all areas of the Kodiak Archipelago. Animals born on Sugarloaf and Marmot Islands, the two largest rookeries, have been found as far away as Cape St. Elias to the west and Chirikof Island to the south. On the most recent survey over 25,000 sea lions were counted from photographs of the 30 different hauling areas and breeding rookeries in the Kodiak area (Figure 3-40). The numerical abundance does not include animals which were in the waters adjacent to Kodiak at the time of the survey; it may represent only one-half of the total sea lion population in the Kodiak area at any one time. Many of the hauling areas are used continuously by all segments of the population while others are used on an irregular basis or by only certain sex and age classes. Seasonal shifts in distribution exist but are not well understood.

Areas critical to the Kodiak sea lion population include Barren, Marmot, Twoheaded, and Chirikof Islands. These four locations constitute the major breeding rookeries of sea lions in the Kodiak area, supplying the majority of pups to the sea lion population in the Gulf of Alaska. Each year, over 12,000 pups are born at these four locations. Portlock Bank and Albatross Bank as well as Marmot Flats should be considered critical feeding areas for sea lions (D. Calkins, ADF&G, Anchorage, personal communication).

Many of the 1.2 million fur seals that breed on the Pribilof Islands migrate by Kodiak in spring and fall. During migration, concentrations of fur seals occur off the east coast of Kodiak, particularly over Portlock and southern Albatross Banks (Niggol *et al.* 1960). They apparently pause here to feed, mainly on capelin and sandlance (Figure 3-41).

Three more or less geographically discrete sea otter populations, totaling about 4,000 animals, presently occupy the Kodiak Archipelago. They are located at: (1) the Barren Islands, (2) the Shuyak-Afognak Islands area, and (3) the Trinity Islands-Chirikof Island areas (Schneider 1976). The Barren Islands population appears to be near carrying capacity, about 300 animals. The Shuyak-Afognak population at the north end of Kodiak appears to be expanding rapidly, and probably is supplying animals for repopulation of areas to the south. The Trinity Islands population at the south end of Kodiak also is expanding. It is anticipated that eventually the southern and northern populations will become continuous, as considerable areas of suitable intervening habitat are occupied. Sighting of otters midway between

TABLE 3-19

Commonly occurring and endangered (*) marine mammals (those likely to be seen out to the continental slope) near Kodiak Is. with respect to use. (Compiled by participants, Kodiak synthesis meeting, Bird and Mammal Workshop).

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

TABLE 3-19 (continued)

| Species/Group | General Habitat Type | Areas of Peak Occurrence | Time of Peak Occurrence | Critical Area Usage | Special Vulnerability to Petroleum Development |
|---|---|---|---|---|---|
| Sea Otter | All waters less than 80m deep | Barren Islands, Shuyak Island, Afognak Island, Marmot Island, Trinity Islands and Chirikof Island | Year around resident | Breeding, pupping, feeding occurs at all times of year | Direct contact with even small amount of oil usually fatal; food availability a major limiting factor; repopulation of large areas of former habitat can be retarded by a localized reduction in numbers. |
| Sea Lion | All waters of Gulf of Alaska | Barren Islands, Marmot Island, Twoheaded Island. Chirikof Island, Portlock Bank, and Albatross Bank | Year around resident numbers highest in late winter & early spring | Breeding and pupping in spring and early summer. Feeding at all times of year | Direct contact causes eye irritation, injestion can be fatal; reduction in prey species causes reduced population; contamination of breeding rookeries and hauling areas would be detrimental; fouling during pupping. |
| Harbor Seal | All waters less 100 fms | Tugidak Island, Sitkinak Island, Geese Island, Aiaktalik, Ugak Island | Year around resident, most abundant on Copper River Delta in summer | Breeding and pupping in summer; feeding at all times of year | Direct contact causes eye irritation, injestion can be fatal; reduction in prey species causes reduced population; contamination of breeding rookeries and hauling areas would be detrimental. |
| Fur Seal | All GOA waters | Portlock Bank, Albatros Bank | Late winter & spring | Feeding at all times of year | Much the same as sea otter principally fouling of pelage. |
| Brown & Black Bear | Terrestrial & intertidal | Concentrate along beaches and streams | Spring - beaches and sedge meadows;summer - salmon spawning streams | Feeding | Loss of critical food source injestion of oil on contaminated food. |

TABLE 3-19 (continued)

| Species/Group | General Habitat Type | Areas of Peak Occurrence | Time of Peak Occurrence | Critical Area Usage | Special Vulnerability to Petroleum Development |
|---|---|---|---|---|---|
| Deer | Terrestrial & intertidal | Concentrate along beach fringe in winter; Feed extensively on intertidal beaches | Almost entirely dependent on beach and intertidal areas during periods of high snow accumulation | Feeding | Loss of critical food source, injestion of oil on contaminated food |
| Furbearers (otter, mink, fox, etc.) | Terrestrial, intertidal and nearshore | Beaches and estuaries | All year | Feeding | Contamination of fur, loss of food, injestion of oil on contaminated food |

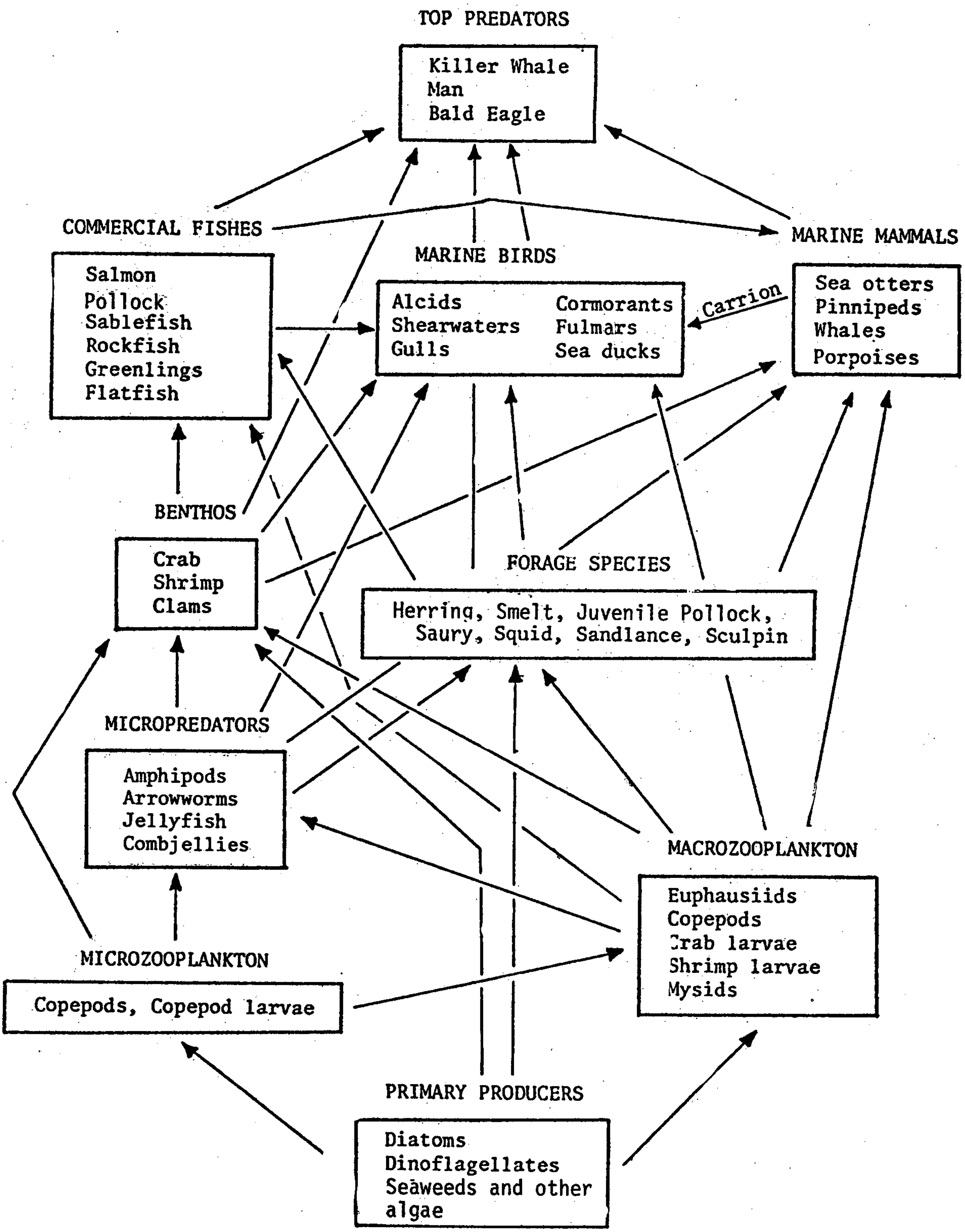
Trophic Relationships and Potential Contaminant Transport Pathways Through Food Webs

A few species of copepods, euphausiids, amphipods, chaetognaths, and pteropods are responsible for the majority of matter and energy flowing through planktonic food webs in the Gulf of Alaska. Copepods are particularly important because of their numerical dominance and biomass. Three species of large copepods, *Calanus cristatus*, *Calanus plumchrus*, and *Eucalanus bungii bungii*, are found in the epipelagic zone, principally during spring and summer, and when present, constitute a large fraction of total zooplankton biomass. Species such as *Metridia* spp.; *Euchaeta elongata* (copepods); *Thysanoessa longipes* (euphausiid); *Cyphocanis challengerii* (amphipod); *Acartia longiremis*, *Oithona similis*, and *Pseudocalanus* sp. (small copepods); and *Sagitta elegans* (chaetognath) constitute an important fraction of the diet of juvenile and larval fish in coastal and oceanic areas in the northern Pacific Ocean.

Larvae of shrimp, molluscs, and king, tanner and dungeness crabs are released in coastal waters of less than 100 m depth in spring. From April to August these larvae reside in the plankton and are an important component of the zooplankton community and the marine food web (Figure 3-42).

Copepods are consumed by a variety of commercial and forage fish and baleen whales (Figure 3-42 and Table 3-20). Matter and energy assimilated by copepods flows to marine birds, mammals, and larger fish mainly through the forage fish. Euphausiids and amphipods are eaten by fish, whales, and birds. Shearwaters number in the tens and perhaps hundreds of millions in the Gulf of Alaska each summer (Guzman 1976; Lensink and Bartonek 1976). They feed mainly on euphausiids and probably consume hundreds of thousands of metric tons per day (cf. Ainley and Sanger 1976 and Sanger 1976). Diets of some important forage fish, such as pollock and herring, also contain significant quantities of euphausiids.

Stomach analyses of 67 tanner crabs, 17 king crabs, and numerous fish, together with a literature review, permitted Feder *et al.* (1977) to develop a preliminary food web for inshore waters around Kodiak Island, including Alitak and Ugak Bays (Figure 3-43), as well as detailed food webs for the two crab species (Figures 3-44 and 3-45). Data are still insufficient to quantify major trophic pathways.




Based largely on a diagram of the planktonic food web, provided by T.Cooney, U of AK, Fairbanks, personal communication.

Fig. 3-42 Generalized food web for the Gulf of Alaska OCS

TABLE 3-20. Trophic Relationships of Major Marine Organisms in Kodiak.*

| RECEPTORS \ DONORS | Phytoplankton | Kelp | Copepods | Mysids | Euphausiids | Amphipods | Cumaceans | Other zooplankton | Insects | Shrimp | Crabs | Benthic invertebrates** | Octopus & squid | Other crustaceans | Bivalves | Other molluscs | Salmon | Pacific herring | Smelt | Capelin | Eulachon | Other forage fish†† | Greenlings | Pacific ocean perch | Other rockfish | Pacific halibut | Flounders | Pollock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pelagic invertebrates† | | | | | | | | | | | | | | | | | | x | | | | x | | | | | | |
| Salmon | x | x | x | x | x | x | x | x | x | x | x | | x | x | | x | x | x | x | x | x | x | x | | | | | |
| Dolly Varden | | | | x | | x | x | x | | | | | | x | | | x | | | | | | | | x | | | |
| Pacific herring | x | | x | | x | x | | x | | | | x | | | | x | | | | | x | x | | | | | | |
| Lingcod | | | x | | | | | | | | | | x | x | | | | x | x | | x | x | x | | x | | x | x |
| Atka mackerel | | | x | | x | | | x | | | | x | | x | | x | | | | | | x | | | | | | |
| Greenlings | x | | x | x | x | x | | x | x | x | | x | | x | | x | | | | | | | x | | | | | |
| Pacific cod | x | | x | x | x | x | x | x | | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pollock | | | x | | x | x | | x | | x | | x | x | | | x | | | | | | x | | | | | | |
| Sablefish | | | | | | | | x | | x | | x | | x | | | | | | | | x | | x | | | | |
| Pacific halibut | | | | | | | | | | x | x | x | x | x | x | x | | x | x | x | | x | x | x | | | x | x |
| Arrowtooth flounder | | | | | x | | | | | | x | x | | | | x | | x | | x | | x | | | | | x | x |
| Starry flounder | x | | | | x | x | | x | | x | x | x | | x | x | x | | | | | | x | | | | | | |
| Flathead sole | | | | x | | x | | x | | x | x | x | | | x | x | | x | | | | x | | | | | | |
| Rock sole | x | | | x | | x | x | | | x | x | x | | x | x | x | | | | | | x | | | | | | |
| Rex sole | | | | | x | x | x | | | x | x | x | | | | x | | | | | | x | | | | | | |
| Sand sole | | | | x | | x | | | | | | | | x | | | | | | | | | | | | | | |
| Dover sole | | | | | | | | | | | | x | | x | | | | | | | | | | | | | | |
| Yellowfin sole | x | | x | x | | x | x | | | | | x | | x | | x | | | | | | | | | | | | |
| Pacific ocean perch | | | | | x | | | | | x | | | x | x | | | | | | | | x | | | | | | |
| Other rockfish | x | | | | | | | x | | | | x | x | x | | | | x | | | | x | | | | | | |
| Eulachon | x | | x | x | x | | x | x | | | | x | | | | | | | | | | | | | | | | |
| Capelin | | | x | | x | | x | x | | x | x | x | | | | x | | | | | | x | | | | | | |
| Other smelt | x | | x | x | x | x | x | x | x | | | x | x | | | | x | | x | | | x | | | | | | x |
| Pacific sand lance | x | | x | x | | x | | x | | x | x | x | | x | | x | | | | | | x | | | x | | x | |
| Sculpins | x | x | x | x | | x | x | x | | x | x | x | | x | | x | | x | | | | | | | | | | |
| Sharks | | | | | | | | | | | | | | | | | | x | | x | x | | | | | | | |
| Pricklebacks | x | | x | x | | x | x | | | | | x | | | | x | | | | | | | | | | | | |
| Pacific sandfish | | | | x | | x | x | | | x | x | | | x | | | | | | | | | | | | | | |
| Commercial catch | | | | | | | | | | | | | | | | | x | x | x | x | x | x | x | x | x | x | x | x |
| Foreign catch | | | | | | | | | | | | | | | | | | x | | | | x | x | x | | | x | x |
| Sport catch | | | | | | | | | | | | | | | | | x | x | | x | | | | | | x | x | |
| Sperm whale | | | | | | | | | | | | | x | | | | | x | | | | x | x | x | | | | |
| Belukha whale | | | | | | | | | | | | | x | | | | x | x | x | x | | x | | | | | | |
| Killer whale | | | | | | | | | | | | | x | | | | | | | x | x | x | | | | | | |
| Sei whale | | | x | | x | | | | | | | | | | | | | x | | | | x | | | | | | x |
| Humpback whale | | | | | | | | | | | | | | x | | | | | | | | | | | | | | |
| Minke whale | | | x | | x | | | | | | | | x | | | | | x | | | | x | x | | | | | x |
| Fin whale | | | x | x | x | | | | | | | | x | | | | | x | | | | x | | | | | | |
| Gray whale | | | x | | | x | | | | | | x | | | | | | x | | | | | | | | | | |
| Dall porpoise | | | | | | | | | | | | | x | | | | | x | | x | x | x | | | | | | |
| Harbor porpoise | | | | | | | | | | | | | x | x | | | | x | | | | | | | | | x | x |
| Fur seal | | | | | | | | | | | | | x | | | | x | x | x | x | x | x | x | x | | | | x |
| Sea lion | | | | | | | | | | | | | x | | | | | x | | x | x | x | x | x | x | x | x | x |
| Harbor seal | | | | | | | | | | | | | x | | | | | x | | x | | x | x | x | x | x | x | x |
| Sea otter | | | | | | | | | | x | x | x | | | | x | | | | | | x | | | | | | |
| Land otter | | | | | | | | | | | | x | | | | x | | | | | | | | | | | | |
| Bears, foxes, wolves | | | | | | | | | | | | | | | | | x | x | | x | x | | | | | | | |
| Gull | | | | | | | | | | | x | x | | | | | x | | x | x | x | x | | | | | | |
| Terns | | | | | x | | | | x | | | | | | | | x | | | x | | | | | | | | |
| Puffin | | | | | x | | | | | | | | x | | | | | | x | | | x | | | | | | |
| Bald eagles | | | | | | | | | | | | | | | | | | | | | | | x | | | | | |
| Cormorants | | | | | | | | | | x | | | | | | | x | | | x | | x | | | | | | |
| Scaup | | | | | | | | | | | | x | | | x | | | | | | | | | | | | | |
| Goldeneye | | | | | | | | | | | | | | | x | | | | | | | | | | | | | |
| Oldsquaw | | | | | | x | | | | | | x | | | x | | | | | | | | | | | | | |
| Steller's eider | | | | | | | | | | | | x | | | x | | | | | | | | | | | | | |
| Common eider | | | | | | | | | | | | x | | | x | | | | | | | | | | | | | |
| Scoters | | | | | | | | | | | | | | | x | | | x | | | | | | | | | | |
| Black Oystercatcher | | | | | | | | | | | | x | | x | x | x | | | | | | | | | | | | |
| Dunlin/Sandpiper | | | | | | x | | | | | | | | | x | | | | | | | | | | | | | |
| Black-legged kittiwake | | | | | x | | | | | | | | | | | | | | | x | | x | | | | | | |
| Common Murre | | | | | | | | | | x | | | | x | | | | x | x | x | | x | | | | | | |
| Pigeon guillemot | | | | | | | | | | x | | | | | | | | | | x | | x | x | | | | | |
| Murrelets | | | | | x | | | | | | | | | | | | | x | | | | x | | | | | | |
| Shearwaters | | | | | x | | | | | | | | x | x | | | | | | x | | | | | | | | |
| Albatrosses | | | | | | | | | | | | | x | | | | | | | | | | | | | | | |
| Parasitic jaeger | | | | | | | | | | | | | | | | | | | | x | | | | | | | | |
| Auklets | | | | | x | | | | | | | | | x | | | | | | x | | x | | | | | | |
| Fulmar | | | | | | | | | | | | x | x | | | | | | | | | | | | | | | |

- continued -

TABLE 3-20 (continued)

| DONORS \ RECEPTORS | Pelagic invertebrates† | Salmon | Dolly Varden | Pacific herring | Lingcod | Atka mackerel | Greenlings | Pacific cod | Pollock | Sablefish | Pacific halibut | Arrowtooth flounder | Starry flounder | Flathead sole | Rock sole | Rex sole | Sand sole | Dover sole | Yellowfin sole | Pacific ocean perch | Other rockfish | Eulachon | Capelin | Other smelt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other codfish | | x | | x | x | | | x | x | | | | | | | | | | | | | | | x |
| Sablefish | | | | | | | | | | | | | | | | | | | | | | | | |
| Sculpin | | | | x | | | | x | | | | | | | | | | | | | | | | |
| Pacific sandlance | | x | x | x | x | | | x | | | x | | | | | x | | | | | | | | |
| Carrion | | | | | | | | | | | | | | | | | | | | | | | | |
| Garbage | | | | | | | | | | | | | | | | | | | | | | | | |
| Misc. Seabirds | | | | | | | | | | | | | | | | | | | | | | | | |
| Sea lions | | | | | | | | | | | | | | | | | | | | | | | | |
| Seals | | | | | | | | | | | | | | | | | | | | | | | | |
| Porpoises | | | | | | | | | | | | | | | | | | | | | | | | |
| Small whales | | | | | | | | | | | | | | | | | | | | | | | | |

| DONORS \ RECEPTORS | Pacific sand lance | Sculpins | Sharks | Pricklebacks | Pacific sandfish | Commercial catch | Foreign catch | Sport catch | Sperm whale | Belukha whale | Killer whale | Sei whale | Humpback whale | Minke whale | Fin whale | Gray whale | Dall porpoise | Harbor porpoise | Fur seal | Sea lion | Harbor seal | Sea otter | Land otter | Bears, foxes, wolves |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other codfish | | | | | | x | x | | x | | | x | x | x | x | | | x | x | x | x | x | | |
| Sablefish | | | | | | x | x | | | | | | | | | | | | x | | | | | |
| Sculpin | x | | | | | | | | | | | | | | | | | | | | | | | |
| Pacific sandlance | x | | | | | | | | | | | x | | x | | | x | | x | x | x | | | |
| Carrion | | | | | | | | | | | | | | | | | | | | | | | | |
| Garbage | | | | | | | | | | | | | | | | | | | | | | | | |
| Misc. Seabirds | | | | | | | | | | | | | x | | | | | | x | | | | | |
| Sea lions | | | | | | | | | | | x | | | | | | | | | | | | | |
| Seals | | | | | | | | | | | x | | | | | | | | | | | | | |
| Porpoises | | | | | | | | | | | x | | | | | | | | | | | | | |
| Small whales | | | | | | | | | | | x | | | | | | | | | | | | | |

| DONORS \ RECEPTORS | Gull | Terns | Puffin | Bald eagles | Cormorants | Scaup | Goldeneye | Oldsquaw | Steller's eider | Common eider | Scoters | Black Oystercatcher | Dunlin/Sandpiper | Black-legged kittiwake | Common Murre | Pigeon guillemot | Murrelets | Shearwaters | Albatrosses | Parasitic jaeger | Auklets | Fulmar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other codfish | | | | | | | | | | | | | | | | | | | | | | |
| Sablefish | | | | | | | | | | | | | | | | | | | | | | |
| Sculpin | x | | | | | | | | | | | | | | | x | x | | | | | |
| Pacific sandlance | x | | x | | x | | | | | | x | | | x | x | | x | x | | x | x | |
| Carrion | x | | | x | | | | | | | | | | | | | | | | | | x |
| Garbage | x | | | | | | | | | | | | | | | | | | x | | | x |
| Misc. Seabirds | | | | x | | | | | | | | | x | | | | | | | | | |
| Sea lions | | | | x | | | | | | | | | | | | | | | | | | |
| Seals | | | | x | | | | | | | | | | | | | | | | | | |
| Porpoises | | | | | | | | | | | | | | | | | | | | | | |
| Small whales | | | | | | | | | | | | | | | | | | | | | | |

*This table is based on a comprehensive literature review that included the following references; complete citations are available from SAI upon request: ADF&G CHPP 1975-76; Alverson 1960; Arneson, pers. comm. 1977; Bailey 1969; Blaxter 1965; Brice et al. 1898; Buck 1973; Calkins and Pitcher, RU #243; Edson 1954; Environment Canada-Fish and Mirine Service 1973; Gabrielson 1959; Godfrey et al. 1975; Gould, pers. comm. 1977; Harris, RU #485; Holmberg et al. 1954; Hughes 1974; Kenyon 1969; Ketchon et al. 1971; Lensink and Bartonek, RU #341; Macy 1977; Major et al. 1970; Merrell 1970; Nichiwaki 1972; North Pacific Fur Sea Commission 1962,1969,1971, 1975; Outram et al. 1972; Phillips et al. 1954; Pitcher and Calkins, RU #229; Reid 1972; Royce et al. 1968; Royer 1977; Sanger, pers. comm. 1977; Smith 1976; Stern 1976; Stevenson 1962; Sutherland 1973; Tester 1935; Thompson et al. 1930; Trumble 1973; Wall et al. 1976; Westrheim 1968; Westrheim et al. 1976; Wohl, pers. comm. 1977.

†Pelagic invertebrates include: Combjellies, Arrowworms, Jellyfish, Squid

††Other forage fish include: Saury, Prickleback, Poachers, Zoarchids, Myctophids, Eelpout, Ronquil, Lanternfish

**Benthic invertebrates include: Annelids, Marine Worms, Polycheates, Worms, Worm larvae, Brittle star

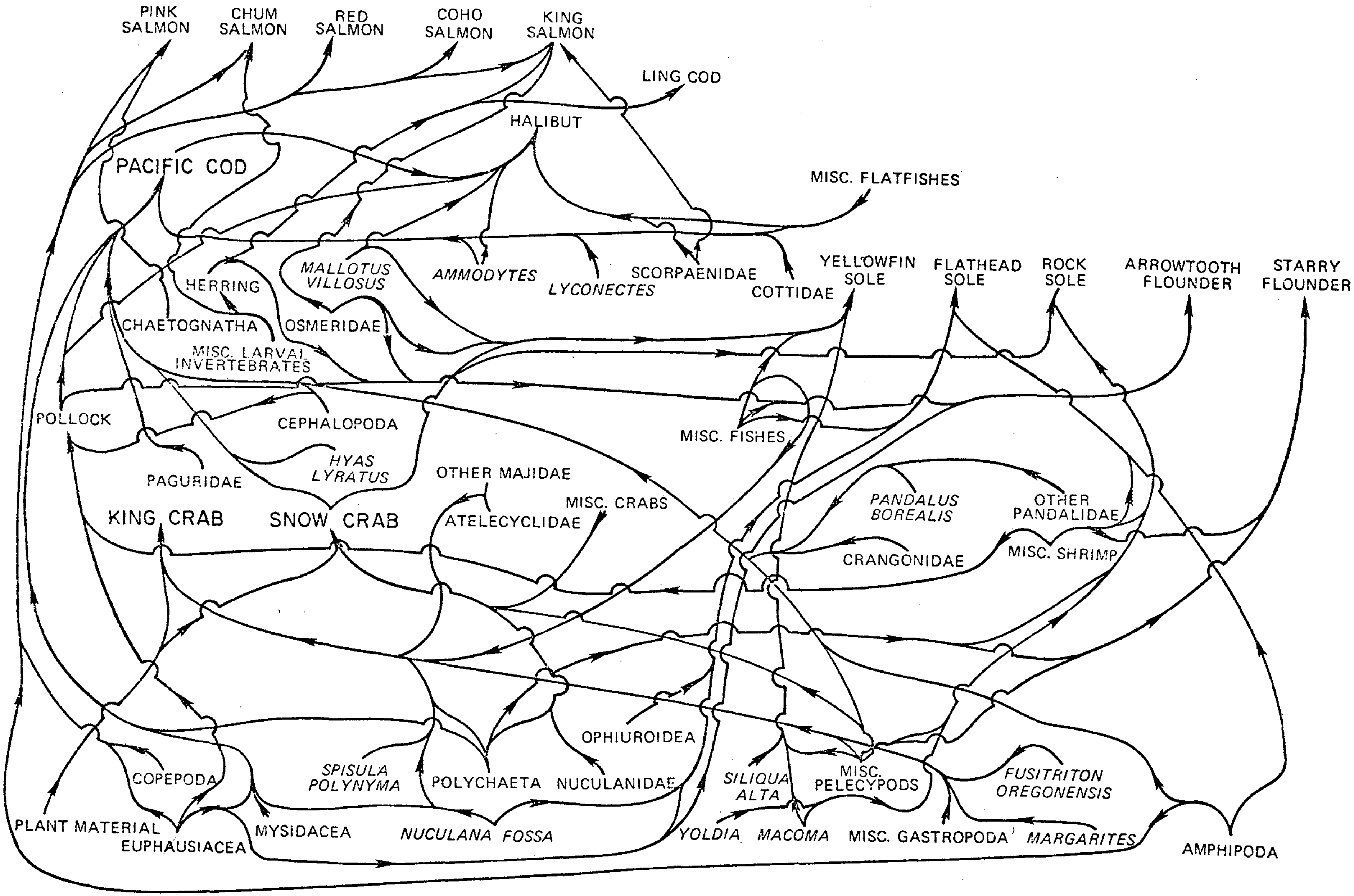



Fig. 3-43 Alitak and Ugak Bays and Inshore Waters around Kodiak Island - Food Web (from Feder et al., 1977).

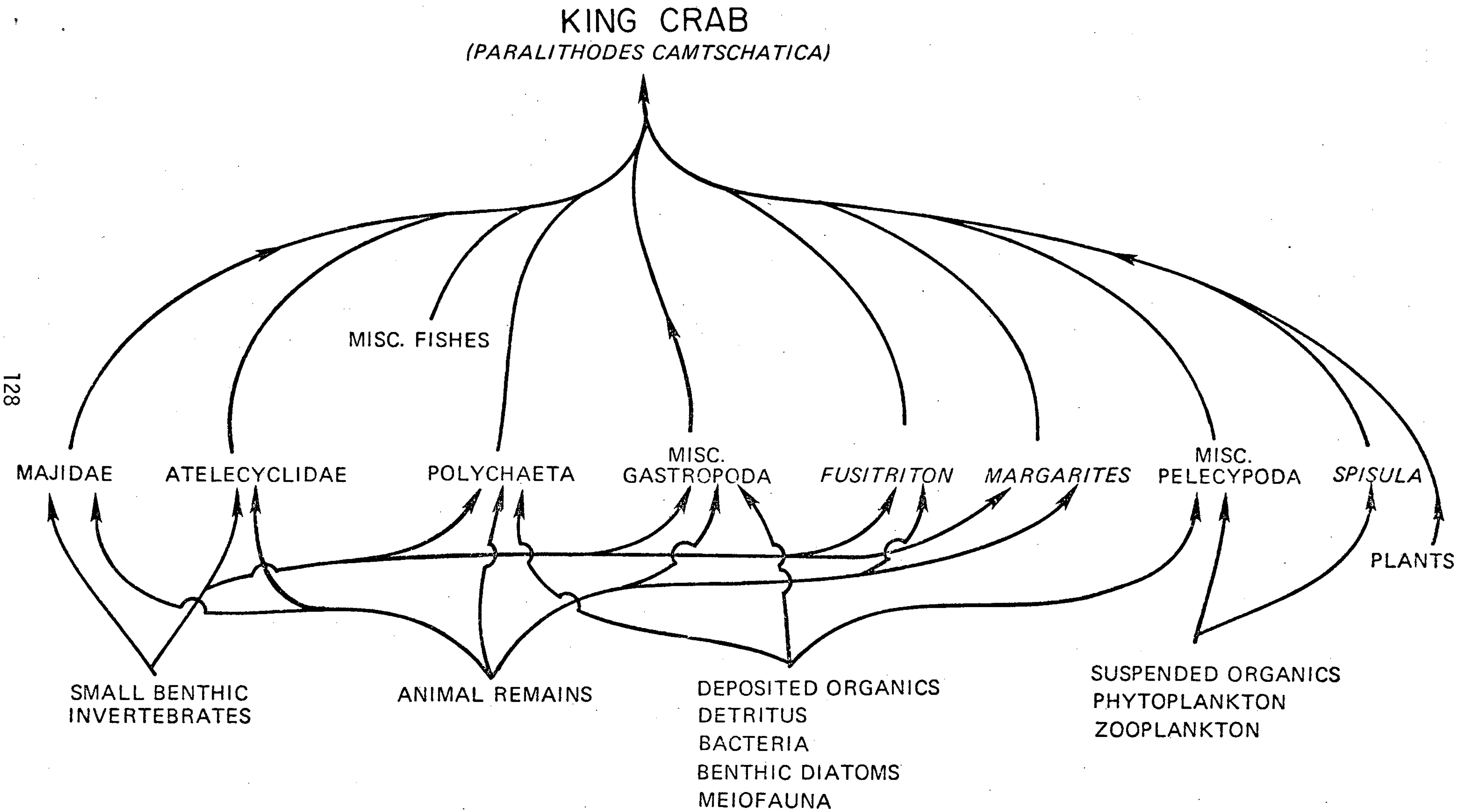



Fig. 3-44 Food Web - Kodiak Island (from Feder et al., 1977).

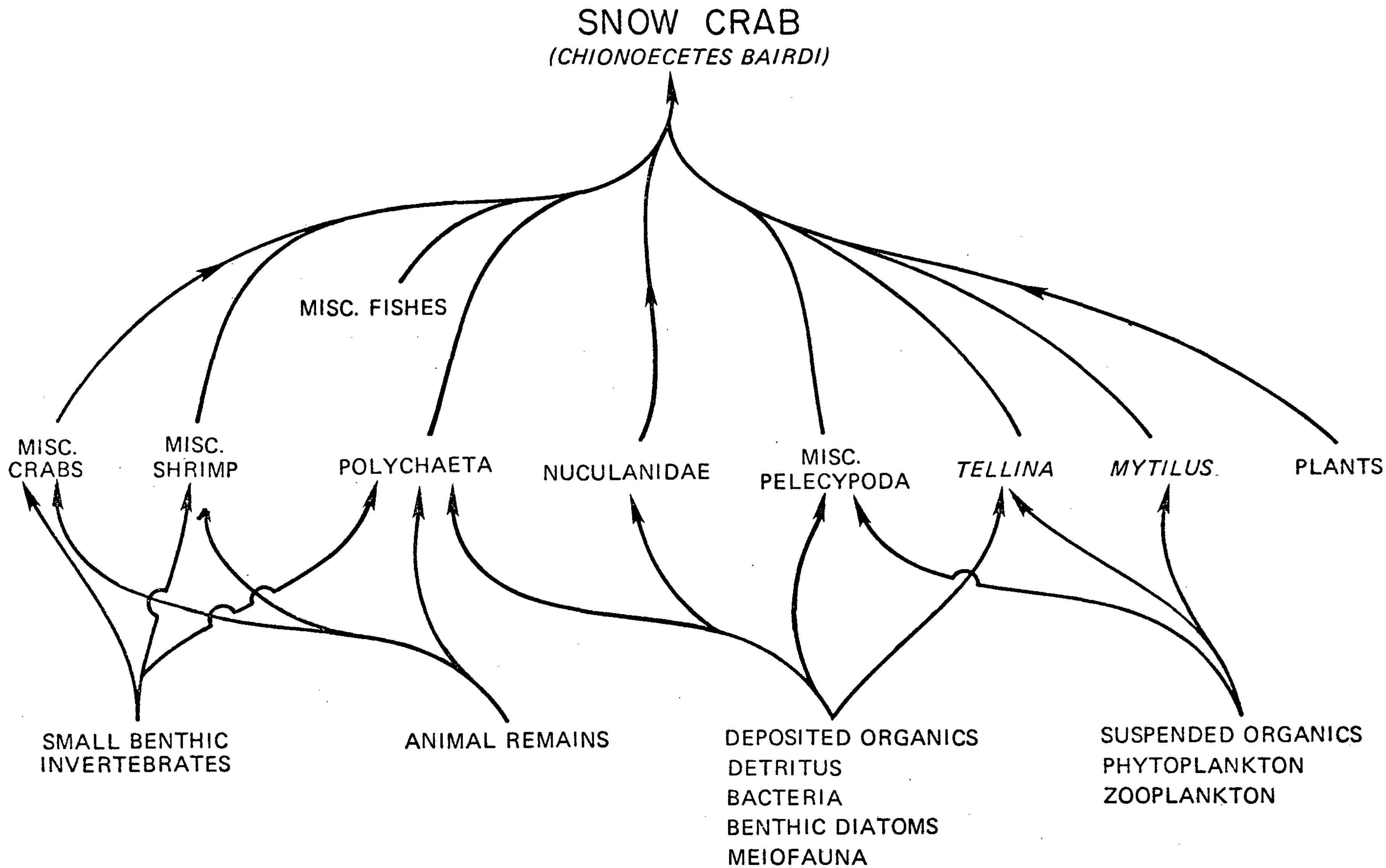



Fig. 3-45 Food Web - Kodiak Island (from Feder et al., 1977).

Both crabs feed intensively in comparable habitats but apparently with little overlap. King crab consumed primarily *Nuculana fossa* (a deposit feeding clam), *Margarites* sp. (a small snail), and miscellaneous clams and fish. This diet is comparable to that recorded for king crab collected in Lower Cook Inlet and the Bering Sea. Tanner crab feed primarily on polychaete worms, nucularid and other clams, caridean shrimps, and plant matter. Sediment was present in nearly half the crab stomachs examined but its significance is not clear (i.e., food source or incidental?). Since this diet differs from that recorded for tanner crab in Lower Cook or Bering Sea, it suggests an area specific (opportunistic?) feeding behavior. Feder *et al.* (1977) stress that detritus is the "driving energy source" for benthic organisms, which in turn support higher trophic levels within regional food webs.

Trophic relationships among some of the principal organisms recorded from Kodiak's littoral zone are outlined in Figure 3-46.

Harris (1976) analyzed stomach contents of 18 species of fish collected in summer in Ugak, Alitak, and Kaiugnak Bays. Habitats of these species range from demersal to pelagic and from offshore to intertidal. Harpacticoid copepods were the most important food item in stomachs of 48 juvenile pink salmon caught nearshore. The stomach contents of 59 juvenile chum salmon collected inshore were more diverse, with teleost fish, mysids, gammarids, and harpactacoids represented nearly equally by weight. Stomachs of 70 juvenile pink salmon caught offshore most frequently contained calanoid copepods, but capelin were most abundant by weight. The diet of 15 juvenile coho salmon caught offshore consisted mainly of gammariids.

Stomachs of 83 juvenile and adult capelin, a common forage fish, most often contained euphausiids and calanoid copepods. By weight other planktonic crustaceans and various fish larvae were also important. Calanoid copepods were the most abundant food item by weight in stomachs of 0 age greenlings, occurring offshore. Stomachs of 0 age greenlings collected nearshore included gammarids, harpactacoids, polychaetes, and caprellid amphipods.

The stomach contents of three species of sculpin were also analyzed. Flatfish, sandlance, and rockfish were the most abundant food items by weight in the stomachs of adult great sculpin; whereas, juveniles consumed

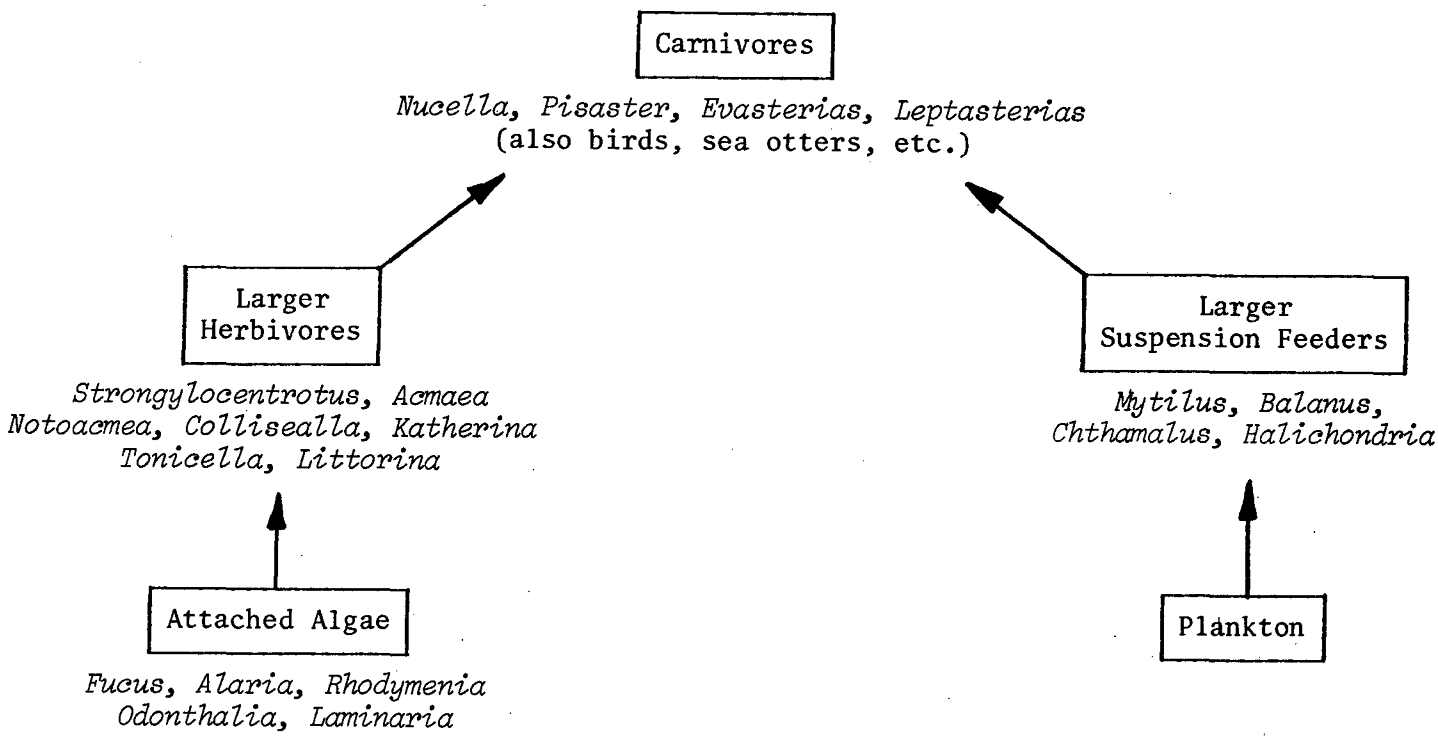



Fig. 3-46 Trophic relationships among Kodiak's principal littoral biota (S.Zimmerman, NMFS, Auke Bay, personal communication).

by weight a higher proportion of gammarid amphipods. Teleost fish were most important in terms of weight in the diets of yellow Irish lords. Polychaete worms and crab larvae were the most abundant food items of the sculpin, *Gymnocanthus*.

Although all of the 86 Pacific sandlance sampled for food habits were caught in the intertidal zone, they had been feeding primarily on planktonic organisms, particularly calanoid copepods. Sixteen pelagic, juvenile Pacific sandfish ate mainly gammarids, harpactacoids, and polychaetes by weight. Ten starry flounder, mostly juveniles, consumed almost exclusively gammarids. Sand sole ate mostly mysids in terms of both numbers and weight. Juvenile and small adult rock sole (n = 114) and yellowfin sole (n = 59) ate mostly fish by weight, but primarily invertebrates, e.g., gammarids, polychaetes, pelecypods, and cumaceans, in terms of numbers and frequency of occurrence. Feder *et al.* (1977) collected data on stomach contents of Pacific cod caught in crab pots during their benthic surveys. Their data were insufficient to identify major or primary pathways but they did construct a food web on the basis of their findings (Figure 3-43). Harris (1976) did identify gammarids and isopods as the most abundant food items, by weight, in stomachs of juvenile Pacific cod. Additional predator-prey relationships have been summarized in Table 3-20.

Marine birds and mammals are dependent, either directly or through trophic transfers, upon planktonic and benthic communities. Baleen whales and shearwaters, tufted puffins, and small alcids feed directly upon zooplankton; they also consume planktivorous fish, squid, and micronekton. Sea otters and diving ducks feed on benthic invertebrates and fish in the littoral zone. Shorebirds prey on infaunal and epifaunal invertebrates in the intertidal and splash zones, and upon zooplankton stranded on the beach. Sea lions and harbor seals, and pigeon guillemots eat mainly demersal fish and benthic invertebrates but also prey on pelagic biota. Fur seals take pelagic and demersal fish and an occasional seabird. The highest level marine predators in the Kodiak area are bald eagles, killer whales, and man. Bald eagles feed mainly on seabirds and carrion but also eat pinniped pups and placentae, fish and land animals. Killer whales prey on fish, squid, pinnipeds, whales, and porpoises (Table 3-20).

Principal prey species of any widely distributed predator vary from area to area, probably depending on availability. For example, although food habits of harbor seals in northern and southern Kodiak overlap extensively, diets of those in the south include nearly 20% sandlance; whereas, seals in the north eat little or no sandlance (K. Pitcher, ADF&G, Anchorage, personal communication). Diets of fur seals and tanner crab are also known to vary with location.

Pollutants such as petroleum hydrocarbons can be incorporated into and transported through these complex food webs. For example, saury, an important forage fish, is known to ingest tar balls. Predators, such as fur seals and murres, that eat contaminated saury also ingest this oil (Revelle and Revelle 1974). Little is known about effects of ingested oil in mammals but in birds it may cause abnormal egg development and reduced production and hatchability of eggs (Grau *et al.* 1977). Birds that become oiled ingest oil in the process of preening it from their feathers.

Filter feeders, such as pelecypods, filter oil from contaminated waters and may retain it in their body tissues for considerable periods of time, perhaps for life (Wagner 1976). This problem is compounded by the fact that, at least in some cases, petroleum pollutants may degrade very slowly and last in bottom sediments for years, providing a persistent source of contaminants (Blumer and Sass 1972). Feder *et al.* (1977) draw particular attention to the importance of deposit feeding clams in the diets of both king and tanner crabs, and to the widespread presence of sediment in tanner crab stomachs. If bottom sediments in inshore crab-feeding grounds are impacted by oil spills, then both the clams and the commercially important crabs could be adversely affected, as could other predators of the clams and crabs.

Oil can also enter trophic webs through other contaminated foods such as carrion or algae. Bears, bald eagles, and gulls are examples of prominent scavengers that are likely to ingest oil by eating carcasses of oil-killed animals, e.g., seabirds, crabs, fish, mammals, etc. Sea urchins, limpets, chitons, and other animals that graze on marine algae are contaminated and may be killed if the algae is polluted with oil. The algae may survive with little or no ill effect.

# Chapter IV
# RESEARCH NEEDS

Participants at the synthesis workshop were asked to identify major gaps in knowledge and to provide input to future research plans. On the basis of the gaps identified and from the discussion of the attendees, the need and rationale for future OCSEAP research in the western Gulf of Alaska are outlined below.

## PHYSICAL OCEANOGRAPHY

Earlier OCSEAP transport studies in the Gulf of Alaska addressed mesoscale circulation features or were concentrated in the NEGOA lease area. Systematic studies over the Kodiak Shelf and the western Gulf were initated in FY 77. There has been limited field and seasonal coverage in data collection. Current state of knowledge is therefore only fragmentary. A large number of gaps in the state of knowledge were identified at the meeting. Many of these gaps are being addressed by ongoing research units or are planned for future OCSEAP research.

Data reported have provided a preliminary regional circulation scheme for the Kodiak Shelf and adjoining waters. Research currently underway will provide substantial data on currents and hydrography that would help describe seasonal variability of water properties and circulation. Once these data have been obtained and interpreted, a stronger emphasis on coastal and nearshore processes will be required. The primary purpose of studying nearshore circulation dynamics would be to identify significant local currents with emphasis on their direction and persistence. Additionally, the knowledge would help verify model-generated trajectories nearshore. Existing data on drift-buoy and seabed drifter trajectories are meager.

It was pointed out at the meeting that if current reversals, as evidenced by one current meter data set and inferred from hydrographic data and to some extent from drift buoy trajectories, occur frequently over the shelf northeast of Afognak Island, then a program of research specific to this area should be formulated. It was also suggested that additional current meter data be obtained in Stevenson and Chiniak Troughs. Such measurements are needed to substantiate the apparently varied circulation patterns over the banks and in the troughs inferred on the basis of sediment size distribution and probable accumulation rates.

Initial diagnostic modeling studies have shown encouraging results as they reproduce the main features of circulation under different conditions of wind-stress. As more model components become operational and validated from field data, the model will be used to simulate probable particle or plume trajectories of spilled contaminants. Since currents over the shelf are predominately tidal, it was proposed that a hydrodynamic-numerical (HN) model be adopted to simulate these currents for this area. A two-layered tidal current model covering the area from Kodiak Island to Unimak Pass has already been formulated (Harding 1976). It may, however, be necessary to retune this model for finer spatial resolution and verify the model output for the area east of Kodiak-Afognak Islands.

As in the case of NEGOA lease area, quantitative nearshore meteorological data and correlation between synoptic and local wind fields are sorely needed to improve circulation models.

## BIOLOGY

Both the seasonal and spatial coverage of phytoplankton, zooplankton, meroplankton, and especially ichthyoplankton, are inadequate. It is essential that data be collected on these trophic levels, especially with reference to growth and utilization by herbivores and carnivores. A survey of planktonic fish eggs and larvae should be conducted in conjunction with trawl surveys in order to accomplish the following prioritized objectives:

(1) Spawning and nursery areas and seasons for economically and ecologically important species should be identified. Adult aggregations may occur during spawning and are vulnerable to a variety of impacts. Similarly, egg, larvae and juvenile aggregations may be vulnerable.

(2) Identification of neustonic (surface dependent plankton) stages of important Kodiak Shelf species is important. Some life history stages of some species are entirely neustonic; however, vertical distribution of larval stages of important Kodiak Shelf species is poorly known and surface dwelling plankton are vulnerable to oil spills.

There is a paucity of information available on the migratory, spawning, and feeding habits of most nearshore fish populations in Kodiak lease area. Such data are essentially nonexistent for most demersal fish species. Among the important species, herring, pollock, cod, smelt, sandlance, greenlings, etc., seasonal and spatial distributions are not well known; such data are particularly lacking on larval and juvenile forms.

Several research needs due to deficiencies in our knowledge of marine birds and mammals in the Kodiak region were brought to light by personnel of ADF&G and USFWS. Most of them relate to trophodynamics of the populations. These include:

(1) Food habits and trophic webs of key bird species (sooty and short-tailed shearwaters, black-legged kittiwake, tufted puffin, cormorants, seaducks, rock sandpiper, least sandpiper).

(2) Relative importance of key foraging areas (e.g., Portlock and Albatross Banks) to bird and mammal populations.

(3) Summer food habits of sea lions and harbor seals on Kodiak (some winter data are available).

(4) Food habits of Kodiak sea otters (no data to date).

(5) Data on distribution, abundance, life history and susceptibility to petroleum development of principle forage species (e.g., pollock, capelin, *Macoma*, etc.).

(6) Relationships of seasonality in food availability to breeding chronology of birds and mammals.

A need for demographic, productivity and food habits data for the Barren Islands sea lion population and the Tugidak Island harbor seal population was also emphasized.

At this time no data are available on the abundance of microbial organisms and the hydrocarbon degrading potential within the proposed lease area. Such data are essential for predicting the fate of hydrocarbons, as biodegradation is the major natural removal process. Data collections should reflect the seasonal and spatial distribution of microflora. Laboratory studies should be conducted to determine potential degradation rates in the event that oil is accidentally released into the Kodiak marine environment.

Followup studies should be conducted in the Chiniak Bay area to identify the area polluted by sewage effluents. The source should be eliminated and the utilization of shellfish in Chiniak Bay should be restricted. Additional studies should investigate the possible contamination of other shellfish and finfish species.

The need to identify driving mechanisms in areas of high biological productivity was stressed. Where is the carbon fixed? What are the relative contributions of phytoplankton versus macrophytes (eelgrass, and kelp, subtidal algae)? What is the quantitative significance of detritus? Do we need to know -- are these questions (or answers) relevant to oil and gas development?

An increasing need to integrate population distribution studies, trophic links, and oil pollution effects studies was noted. More rigorous data on the impacts of oil on organisms are needed. At present there is too much conjecture.

## SOURCES

Data on background levels of hydrocarbon and trace metal contamination are sorely lacking. Prior to OCS oil and gas development it is essential that a thorough understanding exists on the levels of contamination. Such data can provide guides as to potential environmental effects of spills or to address the level of responsibility to be levied in case of oil spillage. Measurements of organic carbon in shelf sediments would be useful to the biologists looking at benthic feeding patterns.

The need for broadscale, integrated studies of oil spill behavior -- transport, mixing rates, oil-sediment interactions, chemical and biological weathering processes and rates -- was stressed.

## GEOLOGIC HAZARDS

The geologists expressed interest in working closely with the physical oceanographers to gain a better understanding of near-bottom circulation and its role in sediment transport. Current meter data from Stevenson Trough would be particularly informative.

The depressions on the banks require study to establish if they are important as sinks and also the susceptibility of their sediments to stirring up by storm waves. Study of the sand particles in different areas to see if such sand is relict or recent and how much physical action it is exposed to would be very informative.

A geotechnical study on the different sediments in different settings to identify stability, liquefaction, erodability, etc., and the effects generated by earthquakes is needed. Earthquake studies with on-bottom seismometers would more clearly define seismic and faulting hazards. More detail on the major fault zone along the Kodiak coast is required.

## Chapter V

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## APPENDIX 1

## LIST OF PARTICIPANTS AT KODIAK SYNTHESIS MEETING
March 1977
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APPENDIX 2

# DEVELOPMENT SCENARIO FOR THE POTENTIAL WESTERN GULF OF ALASKA (KODIAK) OCS LEASE SALE: 1977

by

The BLM/Alaska OCS Office

NOAA Kodiak Synthesis Workshop
8-10 March 1977
Anchorage, Alaska

# DEVELOPMENT SCENARIO FOR THE POTENTIAL WESTERN GULF OF ALASKA (KODIAK) OCS LEASE SALE: 1977

Michael L. Walker[1]

## I. INTRODUCTION

A potential federal action which is designed to help meet the Department of the Interior's objectives for the management of marine minerals is a November 1977[2] sale (#46) of oil and gas leases in the western Gulf of Alaska (Table 1 and Figure 1). The proposed lease sale includes 564 tracts with an area of about 1.3 million hectares (3.2 million acres) (Figure 2).

## II. PURPOSE

The theme of this workshop is "Circulation as a Primary Factor in Determining the Distribution and Seasonality of Various Life Stages of Marine Organisms and the Probable Impingements on Components of the Ecosystem From OCS Oil and Gas Activities." The purpose of this paper is to briefly examine one petroleum development scenario which might result as a consequence of the potential forthcoming western Gulf of Alaska lease sale, and where possible to translate it into space and time relationships.[3] It is to be stressed that the scenario is meant to serve the very practical and useful purpose of identifying the geographical and time boundaries around <u>one</u> potential oil and gas development activity pattern and <u>is not</u> to be viewed as <u>the</u> definitive petroleum development scenario for the potential lease sale.

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[1]Michael L. Walker is a staff regional planner with the Alaska Outer Continental Shelf Office, Bureau of Land Management, Department of the Interior.

[2]In August 1977, the Department of the Interior published a revised OCS Planning Schedule in which the proposed Kodiak lease sale was deferred until October 1980 (Table 1).

[3]The scenario is based on the forthcoming DEIS Western Gulf of Alaska. The simply stated intent of the DEIS is to aid the Secretary of the Department of Interior in his decision making process and to act as a disclosure document to inform the public of a proposed major federal action. The method elected to develop the DEIS revolves around the concept of a petroleum development scenario which leads to a maximum impact assessment.

TABLE 1

Proposed Alaskan OCS Planning Schedule

## PROPOSED OCS PLANNING SCHEDULE

August 1977

| SALE AREA | 1977 S | 1977 O | 1977 N | 1977 D | 1978 J | 1978 F | 1978 M | 1978 A | 1978 M | 1978 J | 1978 J | 1978 A | 1978 S | 1978 O | 1978 N | 1978 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CI Cook Inlet | N | S | | | | | | | | | | | | | | |
| Federal/State Beaufort (Near shore) | | C | | D | | | | T | | | | | | | | |
| 55 Gulf of Alaska | | | | | | | | | C | | D | | | T | | |
| 46 Kodiak | | | | | | | | | | | | | | | | |
| 60 Cook Inlet | | | | | | | | | | | | | | | | C |
| 57 Bering - Norton | | | | | | | | | | | | | | | | |

| SALE AREA | 1979 J | 1979 F | 1979 M | 1979 A | 1979 M | 1979 J | 1979 J | 1979 A | 1979 S | 1979 O | 1979 N | 1979 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CI Cook Inlet | | | | | | | | | | | | |
| Federal/State Beaufort (Near shore) | | | E | | H | | | F | | | N | S |
| 55 Gulf of Alaska | | | | | | | | E | | H | | |
| 46 Kodiak | | | | | | | | | | | | E |
| 60 Cook Inlet | | D | | | T | | | | | | | |
| 57 Bering - Norton | | | | C | | | | | | | D | |

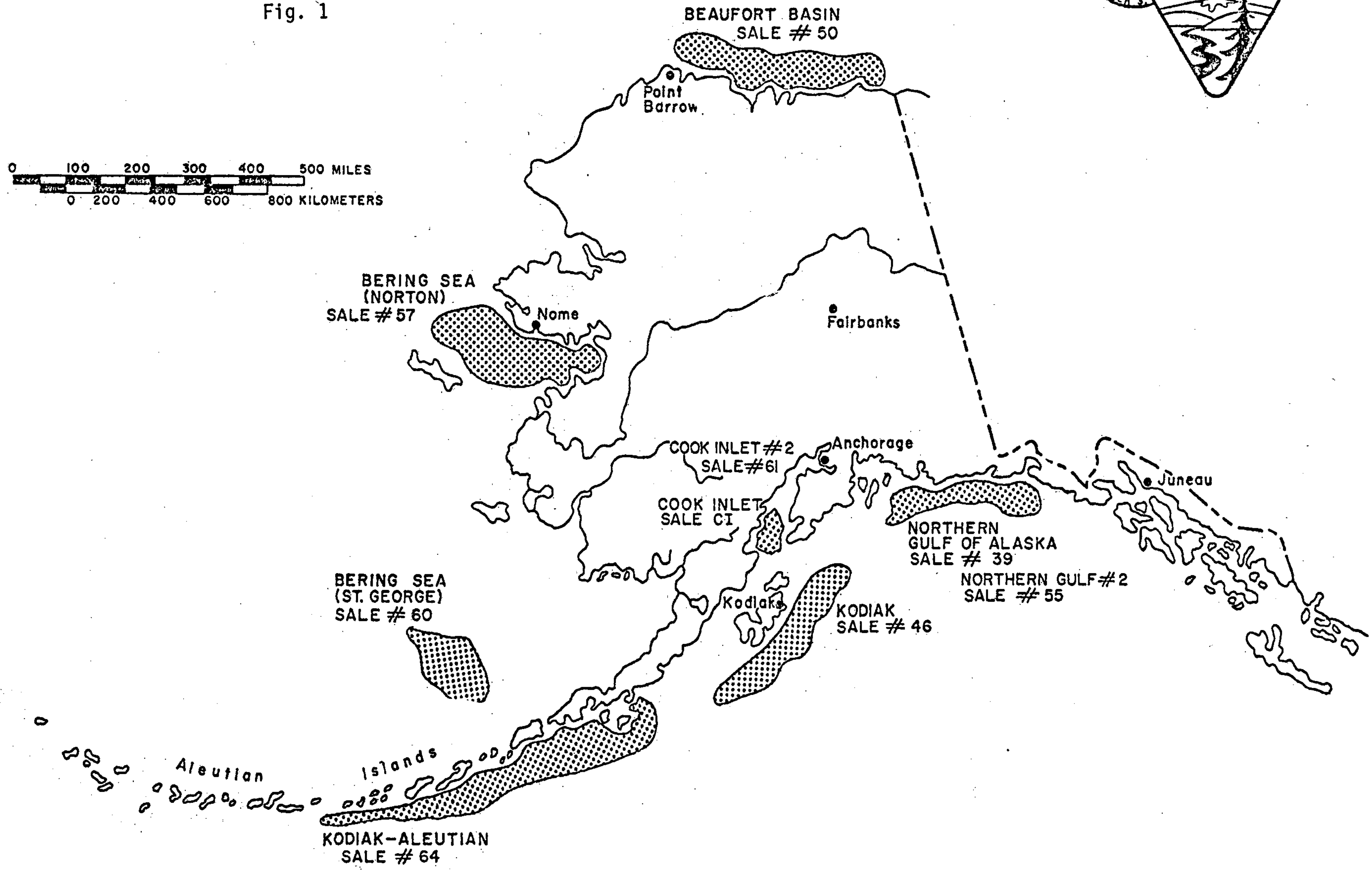
| SALE AREA | 1980 J | 1980 F | 1980 M | 1980 A | 1980 M | 1980 J | 1980 J | 1980 A | 1980 S | 1980 O | 1980 N | 1980 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CI Cook Inlet | | | | | | | | | | | | |
| Federal/State Beaufort (Near shore) | | | | | | | | | | | | |
| 55 Gulf of Alaska | F | | P | | N | S | | | | | | |
| 46 Kodiak | | H | | | F | | P | | N | S | | |
| 60 Cook Inlet | | E | | | | H | | | | F | | P |
| 57 Bering - Norton | | T | | | | | | | | | | E |

| SALE AREA | 1981 J | 1981 F | 1981 M | 1981 A | 1981 M | 1981 J | 1981 J | 1981 A | 1981 S | 1981 O | 1981 N | 1981 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CI Cook Inlet | | | | | | | | | | | | |
| Federal/State Beaufort (Near shore) | | | | | | | | | | | | |
| 55 Gulf of Alaska | | | | | | | | | | | | |
| 46 Kodiak | | | | | | | | | | | | |
| 60 Cook Inlet | N | S | | | | | | | | | | |
| 57 Bering - Norton | | H | | | | | F | | P | | N | S |

C - Call for Nominations
D - Nominations Due
T - Announcement of Tracts
E - Draft Environmental Statement
P - Proposed Notice of Sale
H - Public Hearing
F - Final Environmental Statement
N - Notice of Sale
S - Sale

# ALASKA
## OUTER CONTINENTAL SHELF
### Areas Under Consideration For Leasing

Fig. 1



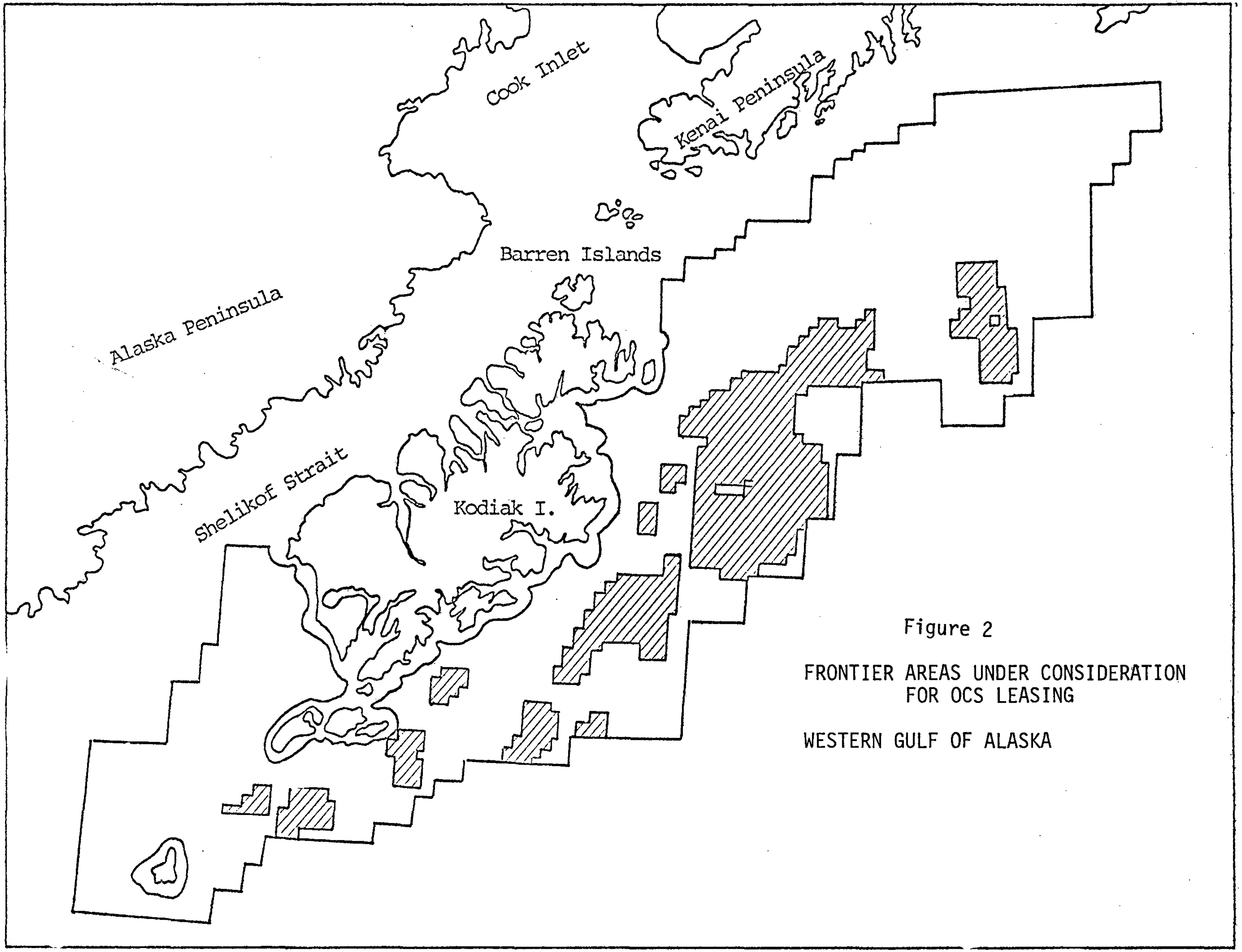



Figure 2

FRONTIER AREAS UNDER CONSIDERATION FOR OCS LEASING

WESTERN GULF OF ALASKA

TABLE 2

Schedule and Summary of Production - Western Gulf of Alaska

| Year | Expendable Exploratory & Deliniation Wells[1/] | Number of Exploration Units | Platforms and Equipment | Production & Service Wells[2/] | Onshore Facilities | Large Pipelines[3/] Miles | Terminals Onshore[4/] | Production Oil Mil bbls | Production Gas Bil cf |
|---|---|---|---|---|---|---|---|---|---|
| 1978 | 6 | 2 | | | | | | | |
| 1979 | 10 | 3 | | | | | | | |
| 1980 | 16 | 4 | | | 1 | | | | |
| 1981 | 16 | 4 | | | | | | | |
| 1982 | 12 | 3 | 1 | | 1 | 225 | | | |
| 1983 | 8 | 2 | 3 | 16 | | 225 | 1 | 12 | 6 |
| 1984 | | | 4 | 64 | | | | 48 | 24 |
| 1985 | | | 2 | 120 | | | 1 | 94 | 47 |
| 1986 | | | | 120 | | | | 156 | 78 |
| 1987 | | | | 64 | | | | 188 | 94 |
| 1988 | | | | 16 | | | | 184 | 92 |
| 1989 | | | | | | | | 160 | 80 |
| 1990 | | | | | | | | 142 | 71 |
| 1991 | | | | | | | | 128 | 64 |
| 1992 | | | | | | | | 112 | 56 |
| 1993 | | | | | | | | 98 | 49 |
| 1994 | | | | | | | | 84 | 42 |
| 1995 | | | | | | | | 74 | 37 |
| 1996 | | | | | | | | 66 | 33 |
| 1997 | | | | | | | | 60 | 30 |
| 1998 | | | | | | | | 54 | 27 |
| 1999 | | | | | | | | 50 | 25 |

Continued next page

TABLE 2 (Continued)

Schedule and Summary of Production - Western Gulf of Alaska

| Year | Expendable Exploratory & Deliniation Wells1/ | Number of Exploration Units | Platforms and Equipment | Production & Service Wells2/ | Onshore Facilities | Large Pipelines3/ Miles | Terminals Onshore4/ | Production Oil Mil bbls | Production Gas Bil cf |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | | | | | | | | 44 | 22 |
| 2001 | | | | | | | | 40 | 20 |
| 2002 | | | | | | | | 34 | 17 |
| 2003 | | | | | | | | 28 | 14 |
| 2004 | | | | | | | | 22 | 11 |
| 2005 | | | | | | | | 16 | 8 |
| 2006 | | | | | | | | 6 | 3 |
| 2007 | | | | | | | | | |
| TOTALS | 68 | 18 | 10 | 400 | 2 | 450 | 2 | 1900 | 950 |
| | | | | | Average Annual Production | | | 79 | 40 |

1/ Includes 17 delineation wells.
2/ Includes 100 service wells.
3/ Includes 50 miles of onshore pipelines.
4/ Production treatment facilities are assumed to be collocated with terminals.

Source: Alaska OCS Office. Anchorage, Alaska.

the deck structures containing the necessary facilities assembled and installed on the platform. During subsequent years, additional platforms will be installed and additional drilling undertaken. The drilling of the wells will take place between 1983 and 1988 at an estimated rate of eight development wells per drilling rig per year.

- Peak oil production would occur approximately nine years after the lease sale.

- The life expectancy of the oil fields would be 25 years, and the last platforms would be removed about 40 years after production has commenced. The 40-year spread takes into account the time differential in bringing different fields into full production.

- No petroleum refineries are expected to be constructed in Alaska as a result of the sale.

Onshore And Offshore Facilities Development Assumptions

Many variables will affect the types and locations of facilities required to support the exploration, development, and production of oil and gas resources, if discovered, and a number of facility combinations is possible. Among these variables are included the policies and controls of local, regional, State, and Federal governments, and those of private, corporate, institutional, and industrial landholders.

In order to evaluate the biological, physical and socioeconomic impacts of the proposed sale, it is first necessary to make certain assumptions concerning the development that will result from the proposal. The alternative sites for onshore development are shown on Figure 3 (Table 3). They are a compilation of alternatives suggested by the U.S. Geological Survey, the State of Alaska, and the Department of the Interior, Bureau of Land Management, Outer Continental Shelf Office (Alaska OCS Office). This range of potential industrial sites represents one conditional and qualified example of a possible development scenario. This figure is not intended to imply or suggest a specific onshore development scheme for the impact

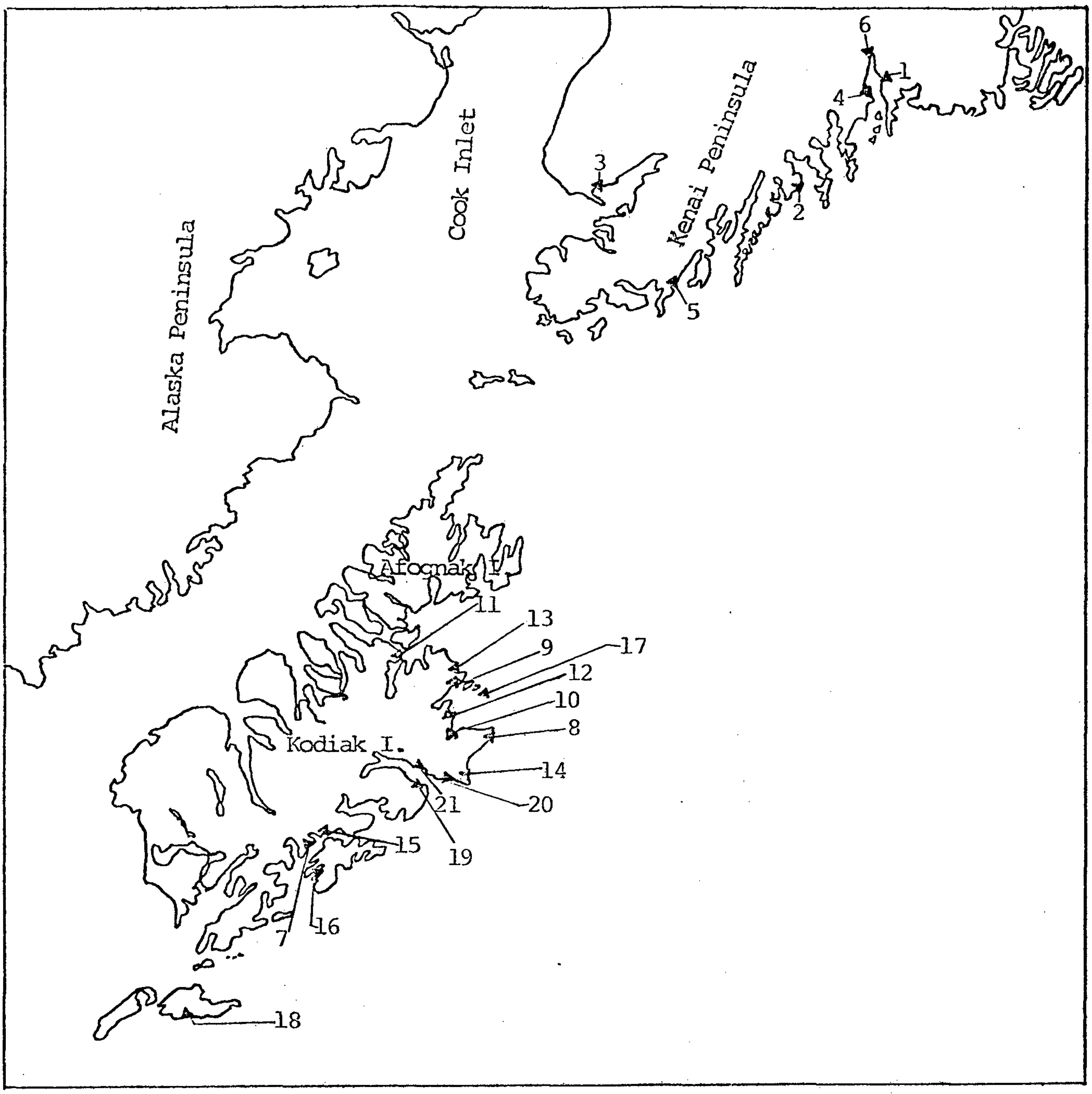



Figure 3

POTENTIAL INDUSTRIAL ONSHORE DEVELOPMENT LOCATIONS
(Source: Alaskan OCS Office, USGS, Anchorage)

Table 3

POTENTIAL INDUSTRIAL ONSHORE DEVELOPMENT LOCATIONS

| Site Number | Potential Industrial Sites | USGS 1/ Terminals | USGS 1/ Support and Supply Bases | Community & Regional Affairs 2/ Terminals | Community & Regional Affairs 2/ Support and Supply Bases | OCS 3/ Terminal | OCS 3/ Support and Supply Bases |
|---|---|---|---|---|---|---|---|
| Kenai | | | | | | | |
| 1 | Ressurrection Bay (4th of July Creek) | | | x | x | | |
| 2 | Kenai Peninsula-Harris Bay | | | x | | | |
| 3 | Kenai-Ketchemak Bay | | | | | | x |
| 4 | Resurrection Bay Lowell Point | | | x | x | | |
| 5 | Kenai Peninsula Nuka Passage | | | x | | | |
| 6 | Resurrection Bay Seward | | | x | x | | |
| Kodiak | | | | | | | |
| 7 | Barling Bay | | | x | x | | |
| 8 | Cape Chiniak | x | x | | x | | |
| 9 | Corporate Area (Kodiak) | x | x | | | | |
| 10 | Kalsin Bay | | | x | x | | |
| 11 | Kizhuyak Bay | | | x | | | |
| 12 | Middle Bay | | | | x | | |
| 13 | Monashka Bay | | | x | | | |
| 14 | Narrow Cape | x | x | | | | |
| 15 | Old Harbor | | | | x | | |
| 16 | Sitkalioak Is. | | | | | x | |
| 17 | St. Paul's Harbor | | | | x | | |
| 18 | Trinity Islands | | x | | | | |
| 19 | Ugak Bay Eagle Harbor | | | x | | | |
| 20 | Ugak Bay Pasagshak Bay | | | | | x | x |
| 21 | Ugak Bay Saltery Cove | | | x | x | | |

Footnotes, see following page.

## Table 3 FOOTNOTES

1/ USGS response to BLM request for information on proposed OCS lease sale No. 46, Kodiak Shelf. USGS states the present facilities at Cape Chiniak, Narrow Cape, and Kodiak might be utilized as the location of crude oil terminals and storage facilities and that supply and support facilities might be located at Cape Chiniak, Narrow Cape, Kodiak, and the Trinity Islands.

2/ Unpublished inhouse study by the State of Alaska, Department of Community and regional Affairs, entitled, "Methodology for Facility Siting," June 10, 1976. The State's efforts are to be commended. Based on several selection criteria the study has identified several geographic areas capable of handling marine terminals and support and supply bases. The study does not suggest that these sites are the only possible ones which might satisfy the selection criteria.

3/ Alaska OCS Office Staff Analysis has expanded the possible range of onshore industrial locations only slightly.

Source: Alaska OCS Office

* The Department of Community and Regional Affairs, State of Alaska, responded to a request by the Alaska OCS Office for a preliminary review of the use of the State's unpublished inhouse study entitled, "Methodology for Facility Siting." Their response is as follows:

Potential Industrial Onshore Development Locations 1-4/

| | | Service Base (temporary) | Service Base (permanent) | Oil Terminal |
|---|---|---|---|---|
| 1. | Latouche | | | X |
| 2. | Seward | X | X | |
| 3. | Port Lions (Port Wakefield) | X | | |
| 4. | St. Paul Harbor | X | | |
| 5. | Old Harbor | X | | |
| 6. | Kazakof Bay | | X | X |
| 7. | Kalsin Bay (in conjunction with Cape Chiniak) | | X | |
| 8. | Three Saints Bay | | X | X |

1. The present configuration of tracts in the western Gulf injects considerable uncertainty into facility siting analyses for that area at this time. Consequently, the potential facility locations suggested by this Department should not be considered predictions or recommendations, but rather areas that should receive closer scrutiny.

2. Note the distinction between a temporary service base and a permanent service base. A temporary service base supports exploration and exploratory drilling. A permanent service base is established after a commercial find has been made and supports exploration and development drilling, and production. The Department estimates a demand for one to two temporary service bases and one to two permanent service bases.

3. The Department estimates a demand for only one oil terminal.

4. The number of designated locations exceeds the estimated demand to compensate for the effect of new information on our assessment of potential development locations in the western Gulf.

area, and should not be considered as a prediction or forecast of the site-specific allocation of these facilities. All site-specific facilities would be subject to all existing Federal, State, and local regulations, land use plans, policies, or controls.

The location of support and supply facilities, crude oil terminal sites, and onshore production treatment facilities would depend mainly upon the location of producing fields in relation to the physical environment. The support and supply facility is the only onshore industrial development which is operational as exploration begins and may initially utilize existing facilities such as harbors and airstrips. Fifteen potential support and supply locations have been identified. This analysis assumes that two of these fifteen sites (or other unidentified sites), will be developed. Onshore terminals and production treatment facilties could be located both near existing communities and remote from them.

Sixteen potential crude oil terminal locations have been identified. The analysis assumes that two of these sixteen sites (or other unidentified sites) will be developed.

Shore bases are assumed to be phased into operation preparatory to development and production activity; i.e., bases would become operational (or expanded) in 1980 and 1982.

Pipelines linking the platforms to terminals must be fabricated and installed using a pipe-lay barge. Offshore pipelines will be constructed by means of pipe-lay barges working primarily during the summer season. It is anticipated that the major effort of onshore pipeline construction will also occur during the summer months. It is anticipated large pipe-lay barges similar to those utilized in the North Sea would be used for offshore pipeline construction. It is estimated two lay barges would be required, per construction season, in the installation of offshore pipelines. A summary of the basic scenario assumptions are listed in Table 4.

TABLE 4

Summary of Basic Assumptions

Western Gulf of Alaska Sale

| Activity | This Proposed Sale |
|---|---|
| Sale acreage offering | 1,300,000 hectares (3,200,000 acres) |
| Recoverable oil (maximum) | 1.9 billion barrels |
| Recoverable gas (maximum) | 0.95 trillion cubic ft. |
| Peak production oil | 515,000 bbls/day<br>188 million bbls/year |
| Peak production gas | 258 million/cf/day<br>94 billion cf/year |
| Platforms | 10 oil - at peak production |
| Exploratory wells | 68 |
| Production wells | 300 |
| Service wells | 100 |
| Pipelines | 720 km (450 miles) 640 km (400 miles offshore)<br>80 km (50 miles onshore) |
| Pipeline burial excavation volume | 4,200 to 11,000 $m^3$/km |
| Onshore pipeline acreage required | 126 hectares (315 acres) permanent right-of-way |
| Onshore oil terminal facilities number and acreage required | 2; (49 hectares (120 acres) each |
| Support/supply facilities number and acreage required | 2; 16-32 hectares (40-80 acres each |
| Production treatment facilities (probably will be combined with terminals) | 2; 16-32 hectares (40-80 acres) each |
| Total direct land requirements | 321-354 hectares (680-760 acres) |
| Petroleum refineries in Alaska | 0 |
| Platform fabrication in Alaska | 0 |
| Supply and support boats | 4-13 |
| Annual crude shipped by tanker | Up to 188 million bbls/year |

## IV. POTENTIAL LOCAL LOCATIONS OF IMPACTS RESULTING FROM THE PETROLEUM DEVELOPMENT SCENARIO

The location of producing fields is unavailable for the analysis because there are no existing fields. Inference about the location of potentially producing fields from geological and geophysical data is impossible because of the confidentiality of such data. However, the OCS planning and development phases of the Department of Interior's leasing process include a call for nominations and comments requesting industry, governmental, and environmental groups to show their interest in the area. Industry (oil and gas) nominations indicate areas in which industry has an interest and would like to see leased. This interest may or may not indicate the location of potentially producing fields. However, there seems to be a relationship between the number of nominations and the number of bids on an individual tract.

For the western Gulf/Kodiak sale areas, the intensity of tract nominations, which show degree of company interest, is a reasonable barometer indicating how competitive company bidding might be at the sale. The number of nominations on a per tract basis are analyzed and the company interest is divided into high and low interest categories.

The high nomination tracts for the potential western Gulf of Alaska (#46) sale are in proximity to and east of Kodiak Island. For the purposes of this analysis, it will be assumed that the frontier areas under consideration for OCS leasing (Figure 2) that correspond with high industry interest, represent the area with the highest probability of having producing oil fields located and developed within its boundaries (Figure 4).

An identification of a coastal high probability area for potential industrial onshore development is based on the density of identified onshore sites (Figure 2 and Table 3); the location of the offshore area assumed to have the potentially producing fields (Figure 4); and land suitability studies by Simpson Usher Jones Inc. (Figure 5). The coastal high probability area for industrial onshore development is approximated by coastal arc from Port Lions to Ugak Bay (Figure 6). Figure 6 is not a forecast or prediction of the future. It is based on a hypothetical development case and is an estimated approximation only if the assumptions of the hypothetical base case prove to be true.

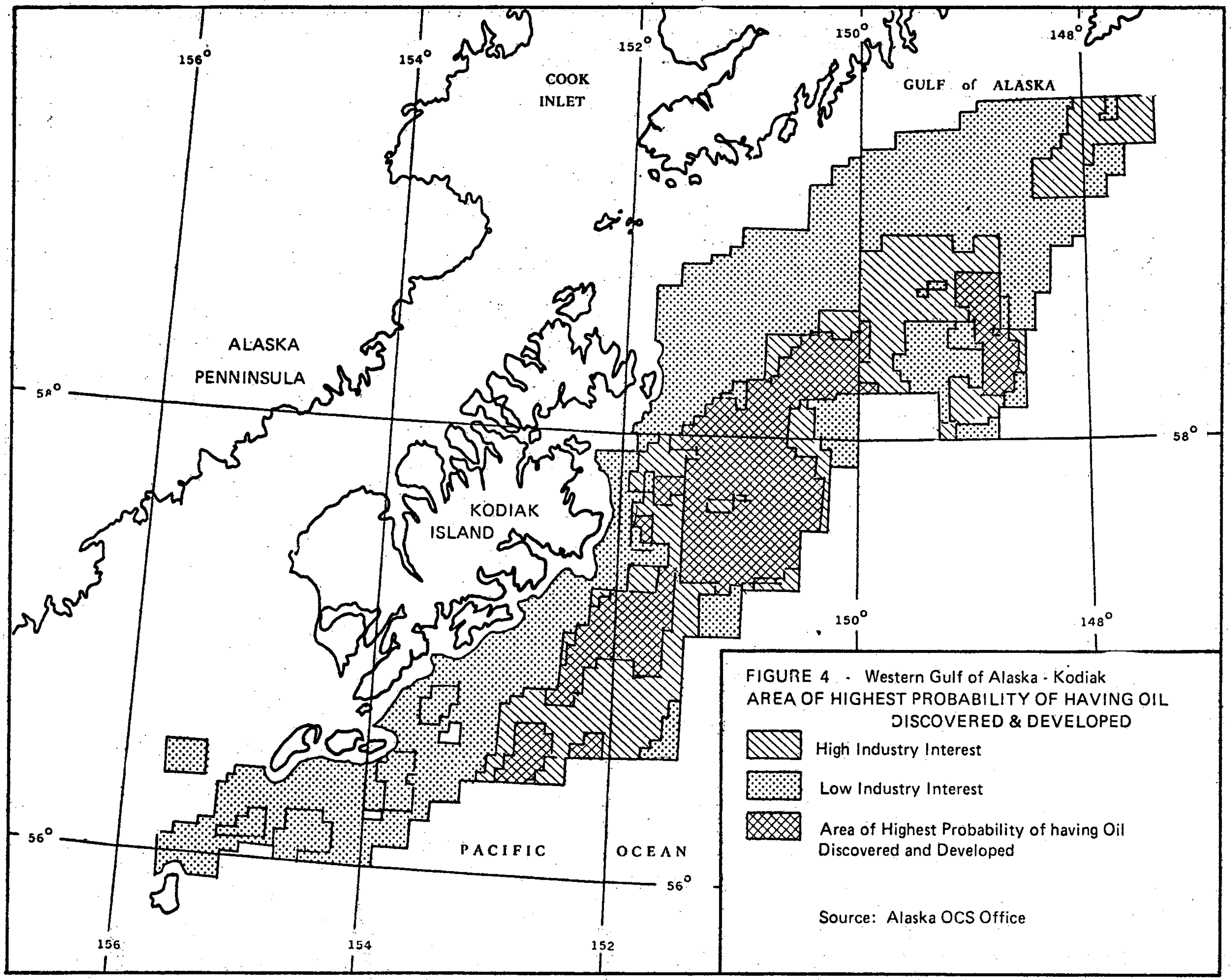



FIGURE 4 - Western Gulf of Alaska - Kodiak
AREA OF HIGHEST PROBABILITY OF HAVING OIL DISCOVERED & DEVELOPED

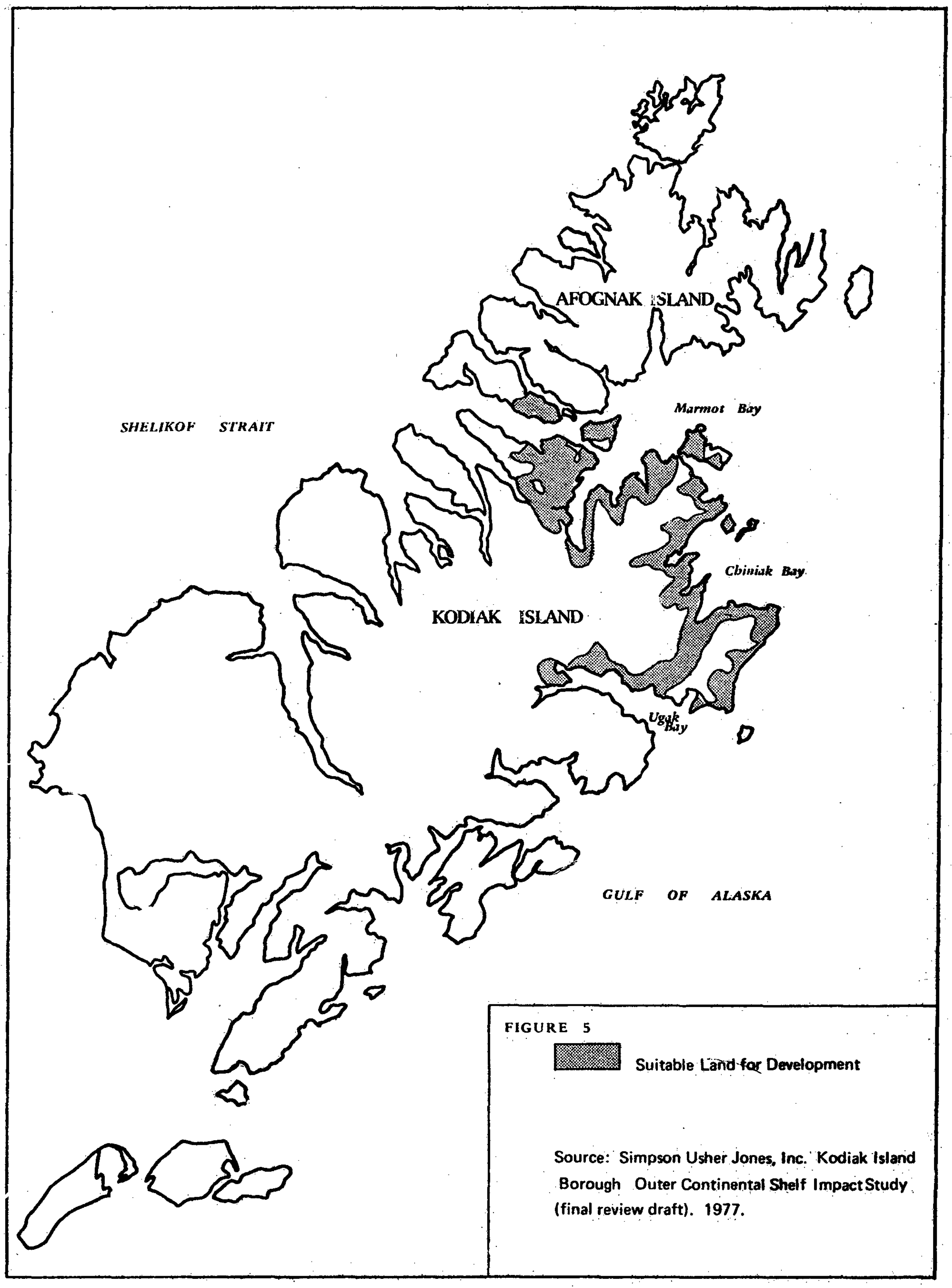



FIGURE 5

Source: Simpson Usher Jones, Inc. Kodiak Island Borough Outer Continental Shelf Impact Study (final review draft). 1977.

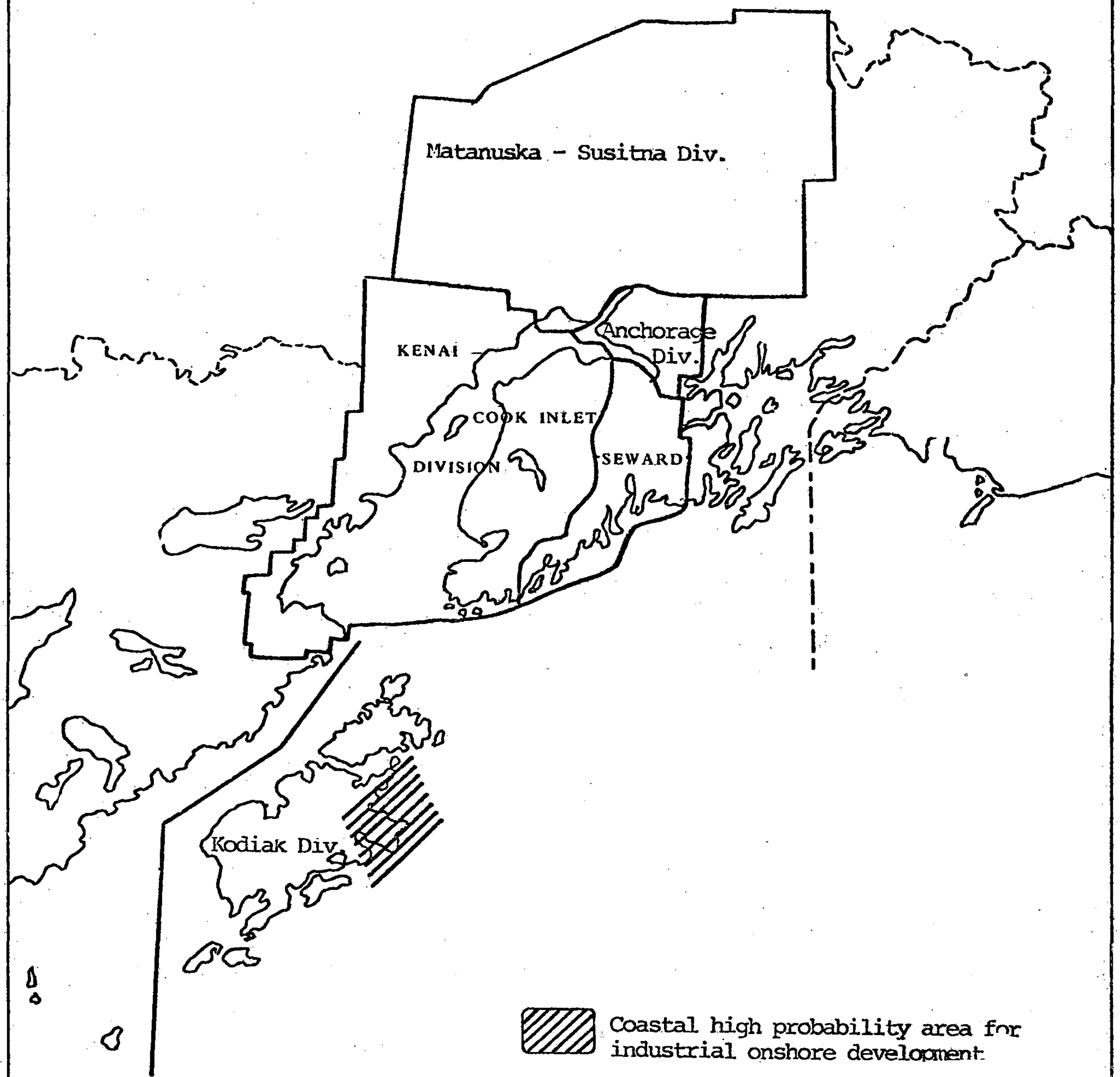



Figure 6

COASTAL HIGH PROBABILITY AREA FOR

INDUSTRIAL ONSHORE DEVELOPMENT

Source: OCS Office

Synthesizing the analysis embodied in Figures 3, 4, 5, and 6 identifies a geographical area in which the major oil activities and facilities are likely to occur (i.e., sites for support and supply bases, exploratory drilling rigs platform sites; crude oil terminal sites, production treatment facilities, pipeline corridors, distribution of local net population impacts, surface marine transportation impacts, and local oil introduction into the marine environment) (Figure 7, entitled "Potential Local Locations of Impacts Resulting From the High Case Petroleum Development Scenario"). An exception, is the assumption that initial exploration activities will also be logistically supported from Seward, Alaska.

## V. POTENTIAL OIL INTRODUCTION INTO THE MARINE ENVIRONMENT

An estimated maximum of 10,740 barrels of oil will be spilled (Table 5) in the western Gulf of Alaska during peak production of one year. This does not include the 2,100 barrels spilled from the projected blowout of one well sometime during the life of production. A total of 30,000 barrels will be spilled by tankers either in this area, along the transportation routes, or at their destination. Over the 25-year production life, about 433,000 barrels would be spilled using the projected yearly production.

## VI. SUMMARY

In summary, the geographic area and timeframe in which the preponderant amount of the oil and gas activities associated with a high case development scenario have been estimated (Table 2 and Figure 6). The space and time parameters identified are portions of a scenario that assumes new offshore and onshore activities and facilities. There will be impacts to the natural environmental systems occurring as a result of these development activities. Examples are: accidental acute oil spills, low-level chronic oil pollution, marine dredging during pipeline laying, and drill cuttings and mud disposal. Estimates of oil spillage were developed (Table 5). Some or all of these impacts would occur during all phases of exploration, development, and production over the life of the field. Hopefully the information presented will be useful in the allocation of baseline study resources.

APPENDIX 3

# WESTERN GULF OF ALASKA OIL SPILL RISK ANALYSIS

BLM/OCS OFFICE

NOAA Kodiak Synthesis Meeting
Workshop March 8-11, 1977
Anchorage, Alaska

An oil spill risk analysis was performed by Messrs. Slock, Smith, and Wyont of the USGS, Reston, Virginia for the Western Gulf in October and November of 1976. They have published a report of the analysis under Open File Report No. .

This discussion was taken from their report and presents a brief summary of the results of the oil spill risk analysis. The study had the objective of determining relative risks associated with oil and gas development in different regions of the proposed lease area and was undertaken to facilitate final selection of tracts to be offered for sale. The analysis was conducted in three more or less independent parts corresponding to different aspects of the overall problem. The first part dealt with the probability of spill occurrence, the second with likely spill trajectories for the times and places spills might occur, and the third part with the spatial and temporal location of specific biological and recreational resources thought to be vulnerable to oil spills. Results of the individual parts of the analysis were then combined to give estimates of the overall oil spill risk associated with oil and gas development in the lease area.

Statistical distributions for estimating probabilities of oil spill occurrence were taken from work by Devanney and Stewart. In addition to the fundamental assumption that realistic estimates of future spill frequency can be based on past OCS experience, use of these distributions requires the further, specific assumptions that spills occur independently of each other and that accident rate is dependent on volume of oil produced and handled.

Spill frequency estimates were calculated separately for ten subdivisions of the proposed lease area (Figure A-1) and two probable transportation routes based on estimated petroleum resources for individual prospects within those areas. Use of the Devanney and Stewart distributions permitted separate estimates of platform, pipeline, and tanker spill frequency which could then be combined to compare the two alternative modes of transport of crude to shore. Spill frequency estimates were further categorized for spills between 50 and 1,000 bbls, and greater than 1,000 bbls in size.

An oil spill trajectory model was constructed and used to analyze movements of hypothetical oil slicks on a digital map of the Western Gulf of Alaska between about 55°N and 61°N latitude and about 147°W and 157°W longitude.

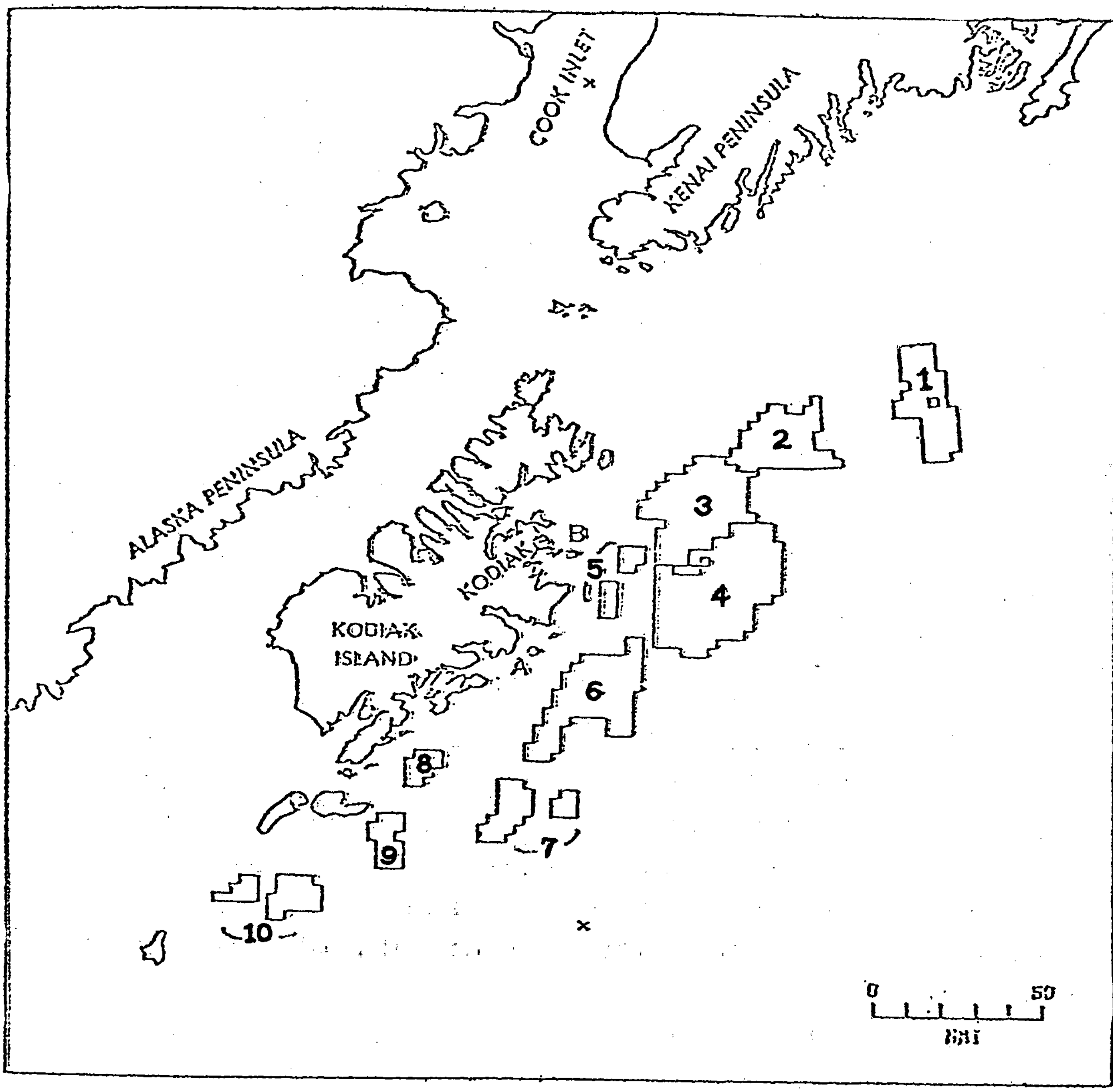



Fig. A-1 Map of the Western Gulf of Alaska Outer Continental Shelf showing subdivisions of the lease area (1-10) and the mid-points of two possible oil transport routes to shore (A-B).

The coordinate system for this area was established with a grid size of one nautical mile. Surface current velocity fields were provided by National Oceanic and Atmospheric Administration. Short-term patterns in wind variability were characterized with a probability matrix for successive three hour velocity transitions. Wind transition matrices were evaluated from U.S. Weather Service records from the Kodiak, Alaska and Middleton Island, Alaska weather stations and were established separately for four seasons.

Trajectories of 500 hypothetical oil spills were simulated in Monte Carlo fashion for spill sites within each of the ten subdivisions of the lease area and along two hypothetical transportation routes, under wind and current conditions for the four seasons, yielding a total of 24,000 trajectories. The next figure is an example of the results. Surface transport of the oil slick for each spill was simulated as a series of straightline displacements of a point in space, each representing the joint influence of wind and current on the slick for a three hour period. Wind transition probability matrices were randomly sampled each period for a new wind speed and direction, and the current velocity was updated as the spill changed location in the velocity field. The wind drift factor was taken to be 0.035 with a drift angle of 20°.

The final product of trajectory model runs consists of a large number of simulated oil spill trajectories or pathways which collectively reflect both the general trend and variability of winds and currents and which can be summarized in statistical terms. It should be emphasized that these trajectories represent only hypothetical pathways for the transport of oil slicks and do not involve any consideration of cleanup, dispersion, or weathering processes which would determine the quantity and quality of oil that may eventually come in contact with biological populations or other important resources.

The locations of 25 categories of biological, recreational, and other resources were digitized in the same coordinate system as that used in trajectory simulations. The monthly sensitivity of these resources (e.g., spawning period or migration period) was also recorded. Resource groups were as follows:

Group 1. Dungeness crab spawning, rearing and catch areas. (Figure A-2)

2. Foreign fishing areas. (Figure A-3)

3. Salmon purse seining and set net areas. (Figure A-4)

4. Pink and chum salmon intertidal spawning areas. (Figure A-5)

5. Shrimp fishing areas. (Figure A-6)

6. Tanner crab fishing areas. (Figure A-7)

7. Onshore kelp 100% cover. (Figure A-8)

8. Sea otter concentration areas. (Figure A-9)

9. Harbor seal rookeries and hauling grounds. (Figure A-10)

10. Marine mammal foraging areas. (Figure A-11)

11. Sea lion rookeries and hauling grounds. (Figure A-12)

12. Bird distribution - summer (June, July, August). (Figure A-13)

13. Bird distribution - fall (September, October, November). (Figure A-14)

14. Bird distribution - winter (December, January, February). (Figure A-15)

15. Bird distribution - spring (March, April, May). (Figure A-16)

16. Seabird colonies. (Figure A-17)

17. Shrimp reproduction and hatching areas. (Figure A-18)

18. Tanner crab mating and hatching areas. (Figure A-19)

19. Tanner crab vital rearing areas.
    (Figure A-20)

20. Tanner crab important rearing areas.
    (Figure A-21)

21. King crab mating and hatching areas.
    (Figure A-22)

22. Vital king crab rearing areas.
    (Figure A-23)

23. Important king crab rearing areas.
    (Figure A-24)

24. Archeological sites.
    (Figure A-25)

25. Kodiak and Afognak Islands.
    (Figure A-26)

The probability distribution on the frequency of oil spills greater than 1,000 bbls in size during the production life of the proposed lease area was determined. Probabilities apply to the total of production platform spills and pipeline spills assuming transport of the total product to shore via pipeline. Figure A-1 shows the transportation points used. Although transport by pipeline is the preferred method, tanker or barge transport is considered as a possibility, at least for the early years of production. The corresponding frequency distribution for the total of platform and tanker spills was determined. It was assumed that transport for sites 1-5 would pass through site A, and that transport for sites 6-10 would pass through site B. Furthermore, for each transport method, the potential for spillage was divided equally between the originating site and the designated transport site A or B.

The results of trajectory model runs consist of 24,000 hypothetical oil spill trajectories which collectively reflect both the general trend and variability of winds and currents and which can be described in statistical terms. Trajectories based on wind and current conditions for each of the four seasons have been randomly selected as examples from a total of 2,000 trajectories released from location five near the center of the lease area. The spring trajectories are shown in Figure A-27. The patterns evident in the trajectory simulations are roughly similar over all seasons

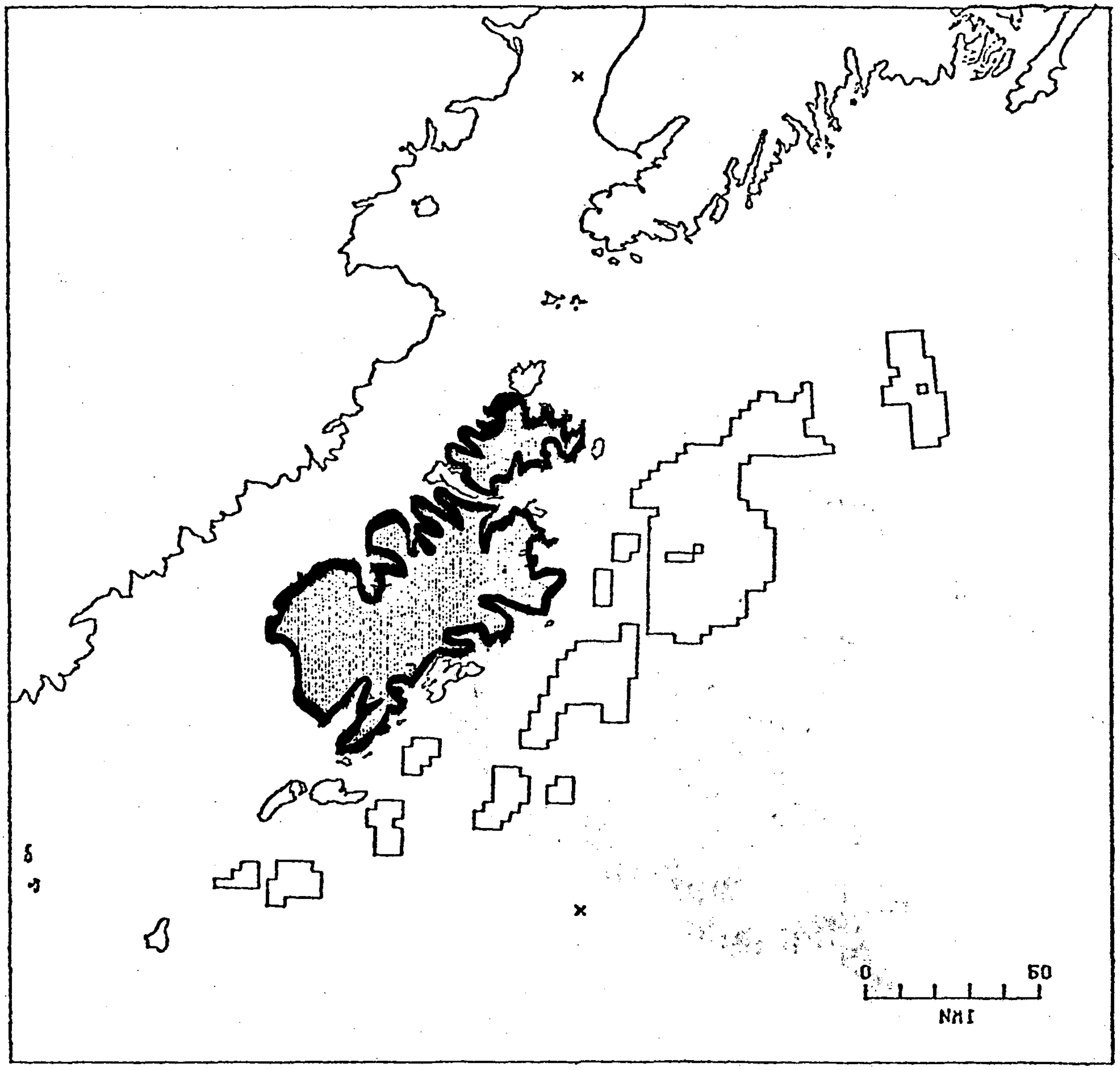



Fig. A-2 Hatched area indicates spatial extent of dungeness crab spawning, rearing and catch areas.

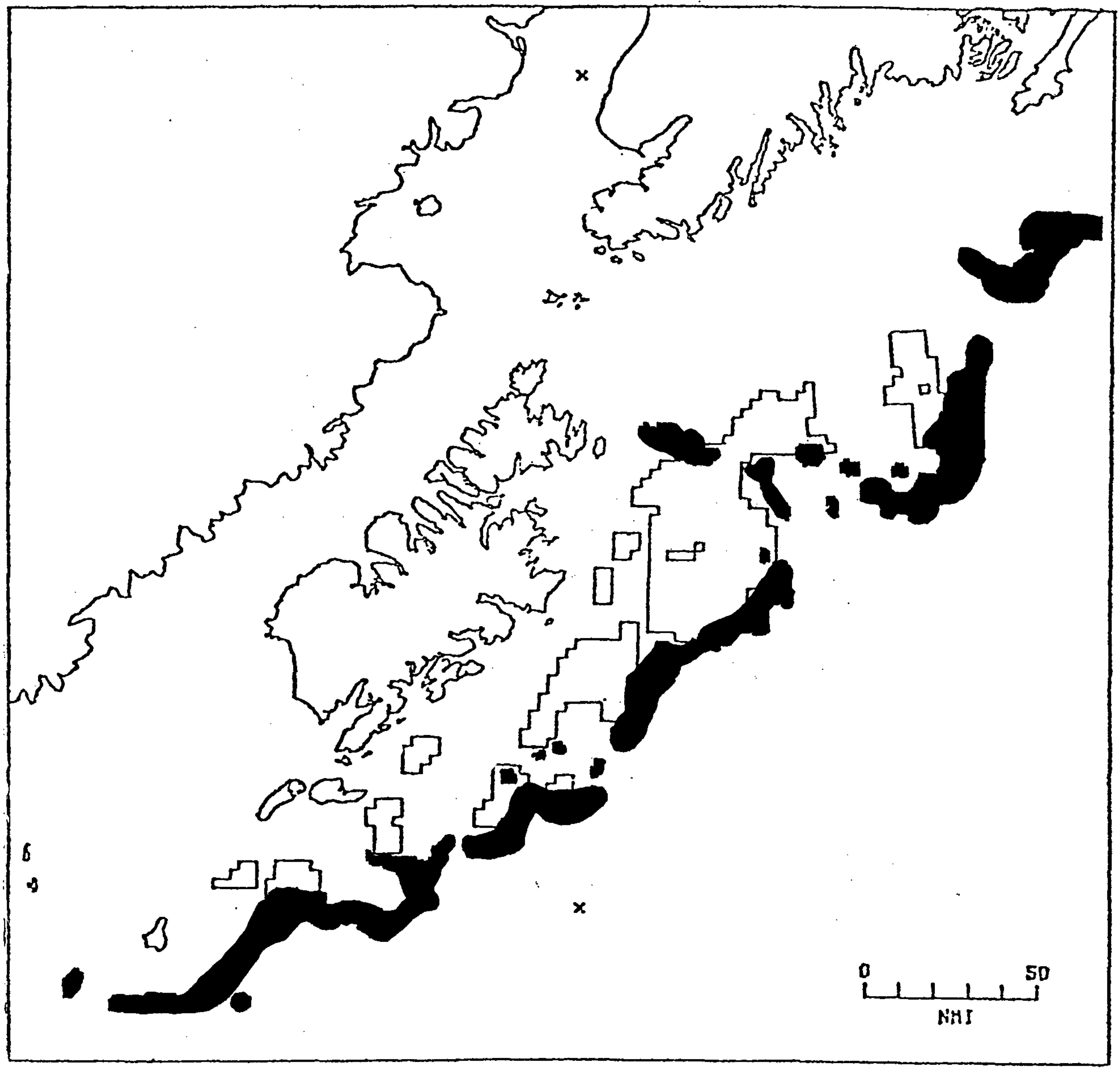



Fig. A-3 Dark area indicates spatial extent of foreign fishing areas.

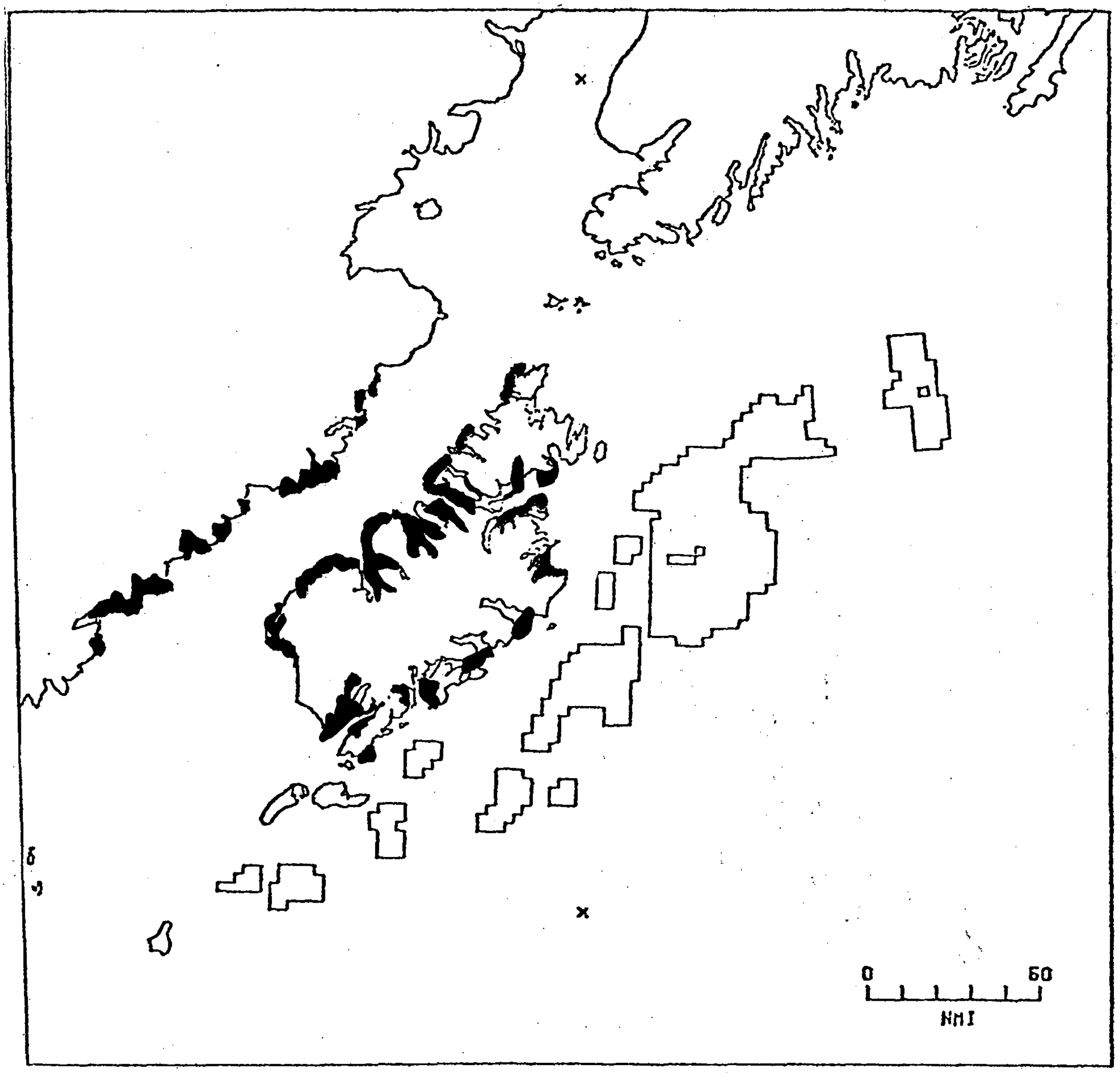



Fig. A-4 Dark area indicates spatial extent of salmon purse seining and set net areas.

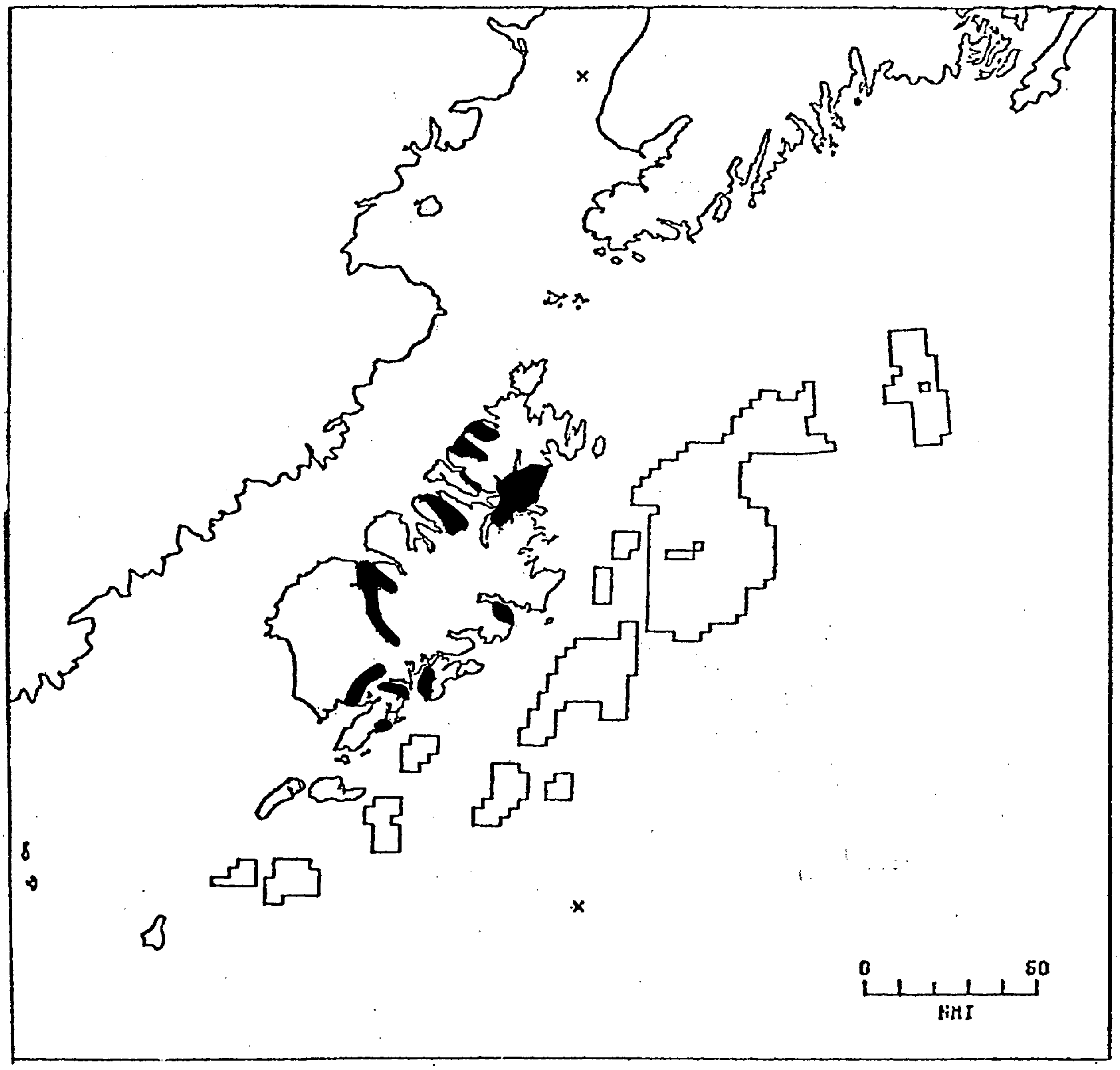



Fig. A-5 Dark area indicates spatial extent of pink and chum salmon intertidal spawning areas.

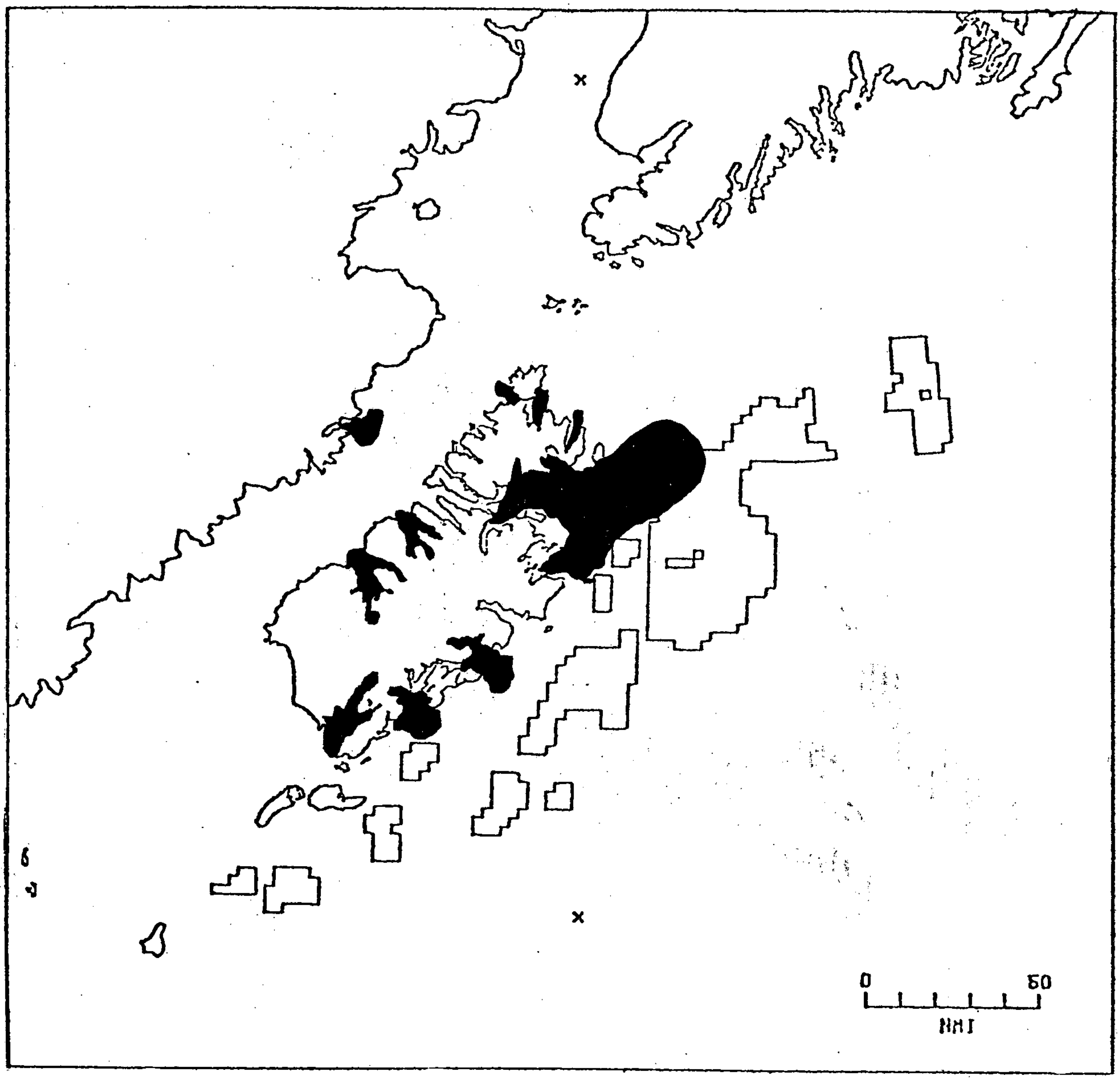



Fig. A-6 Dark area indicates spatial extent of shrimp fishing areas.

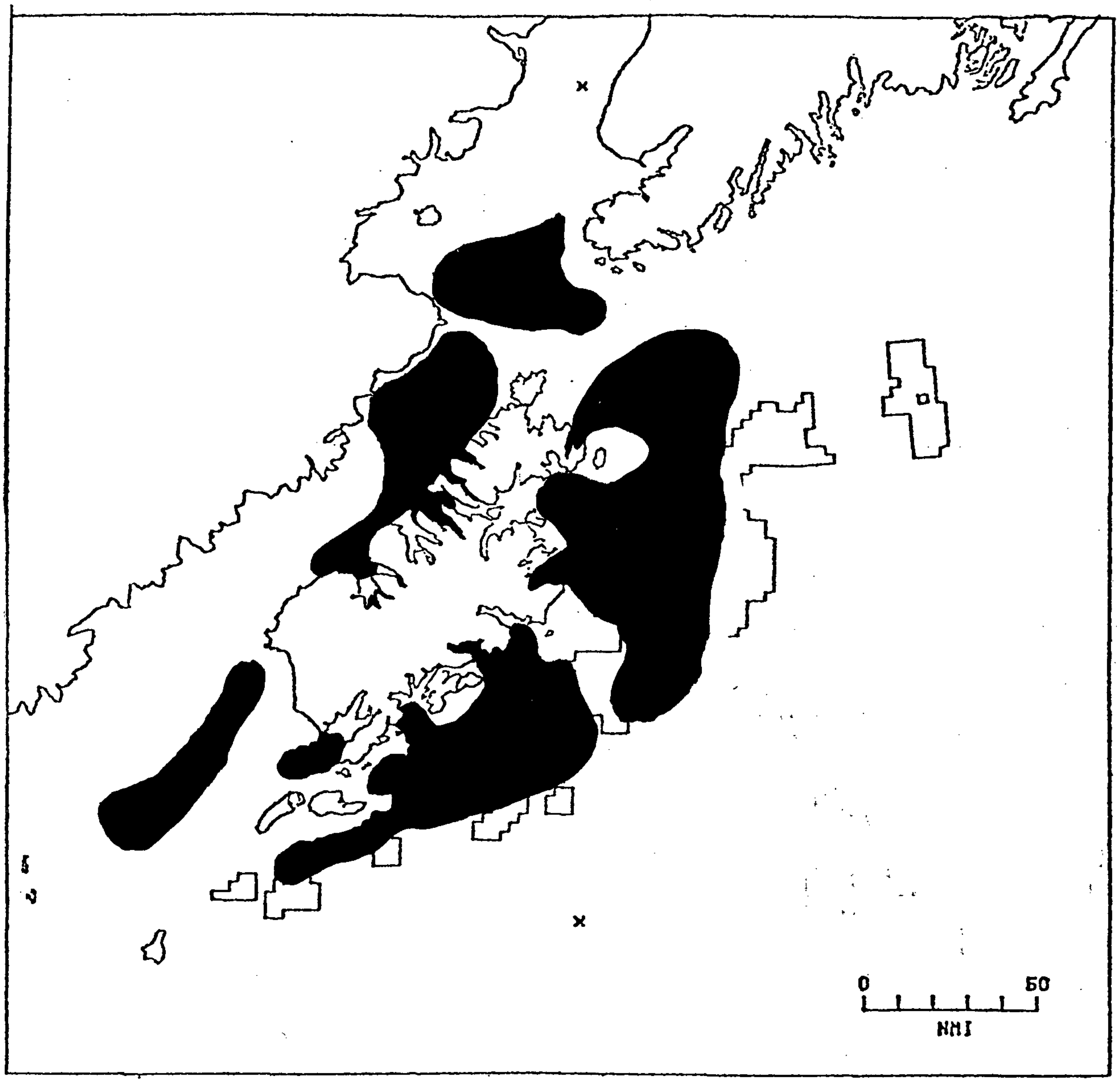



Fig. A-7 Dark area indicates spatial extent of tanner crab fishing areas.

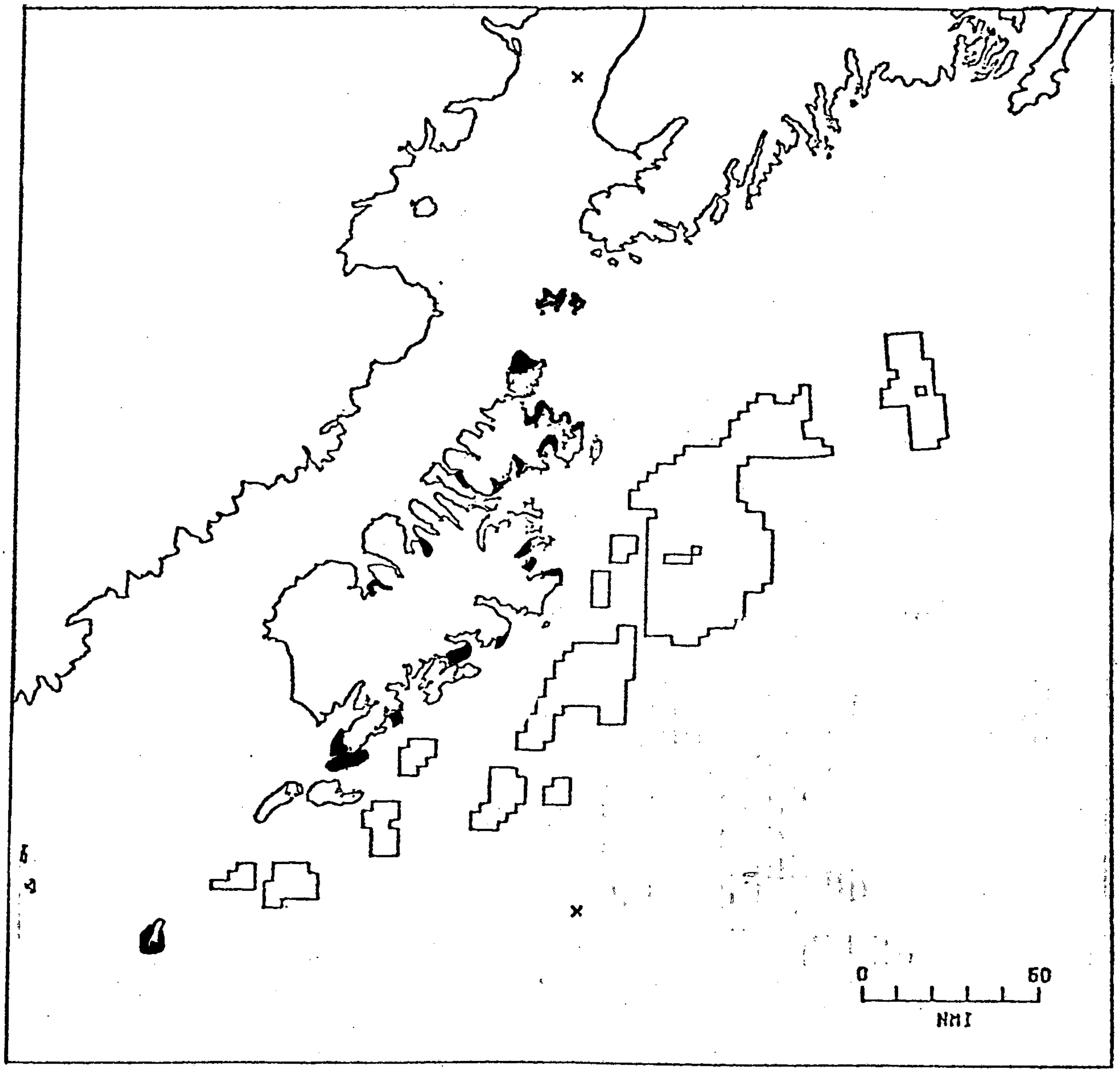



Fig. A-8 Dark area indicates spatial extent of onshore kelp 100 percent cover.

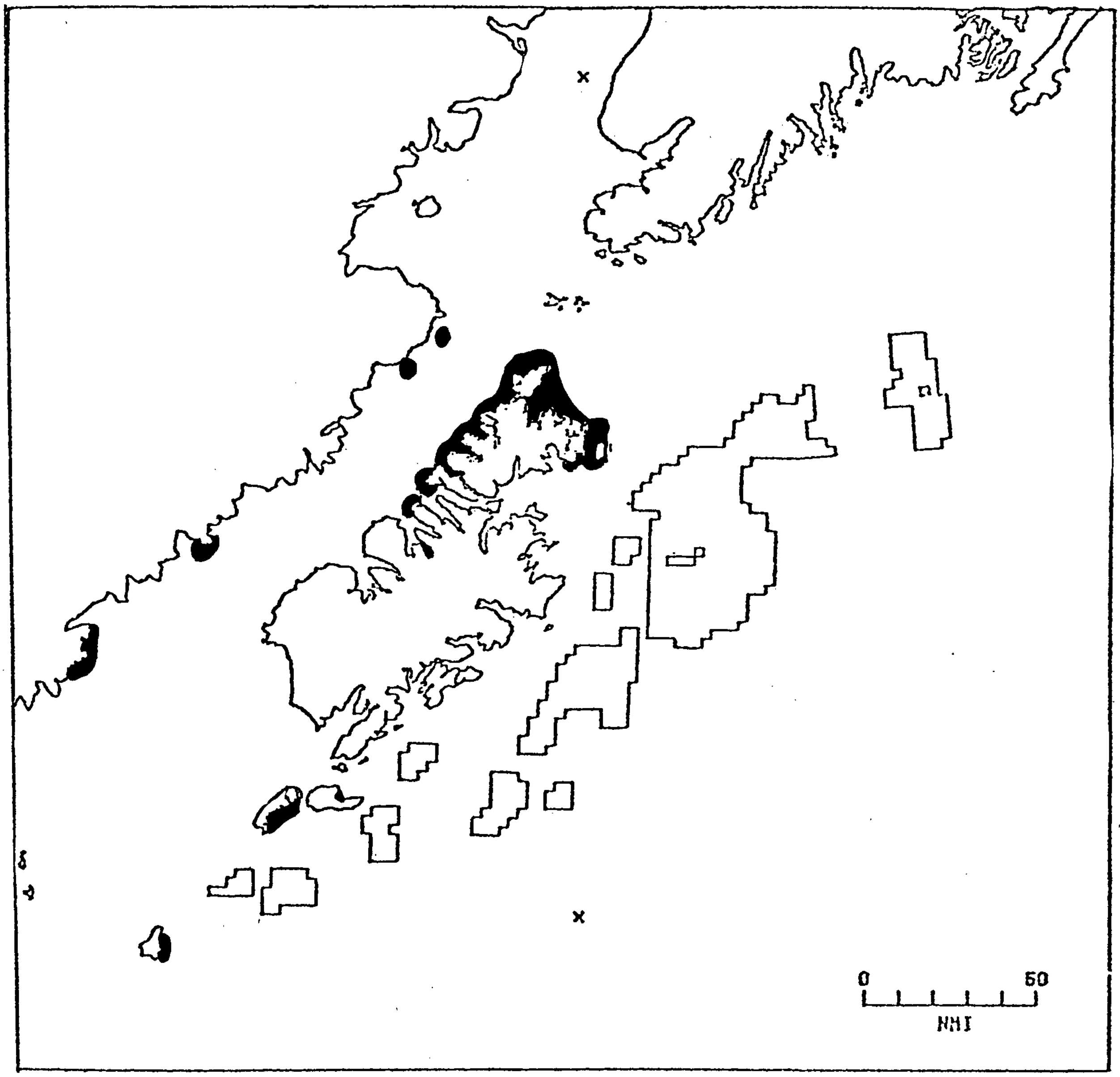



Fig. A-9 Dark area indicates spatial extent of sea otter concentration areas.

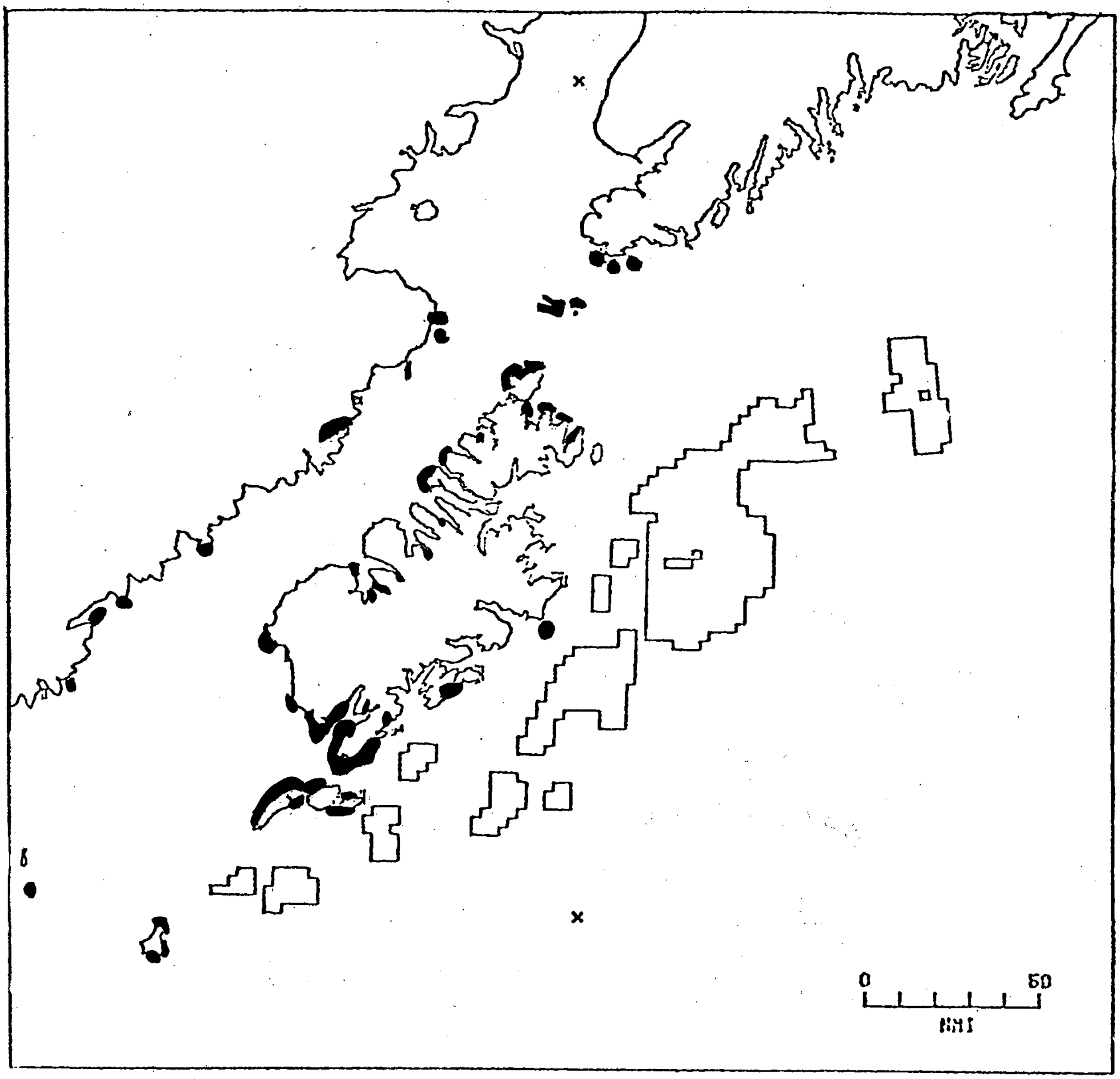



Fig. A-10 Dark area indicates spatial extent of harbor seal rookeries and hauling grounds.

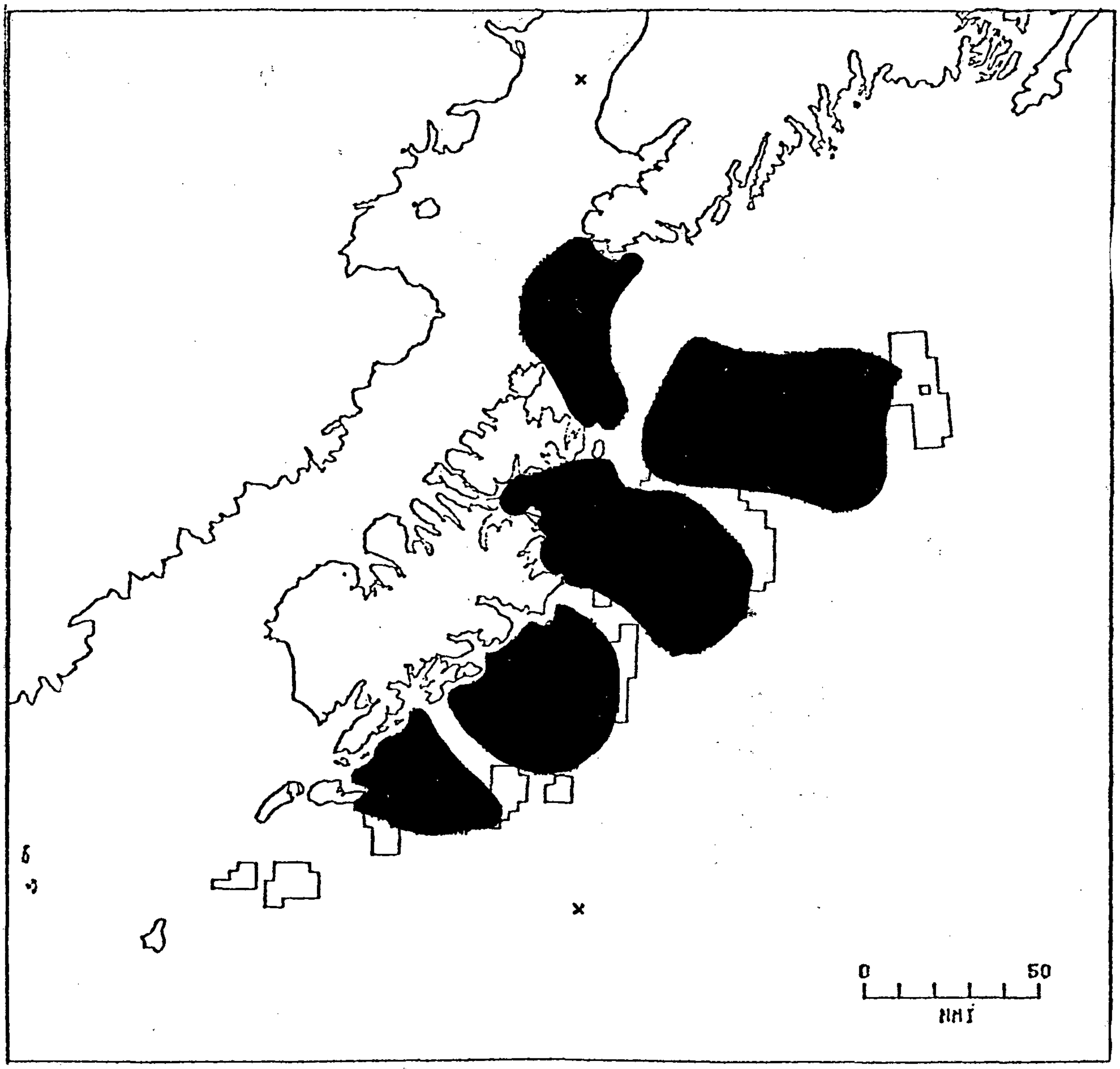



Fig. A-11 Dark area indicates spatial extent of marine mammal foraging areas.

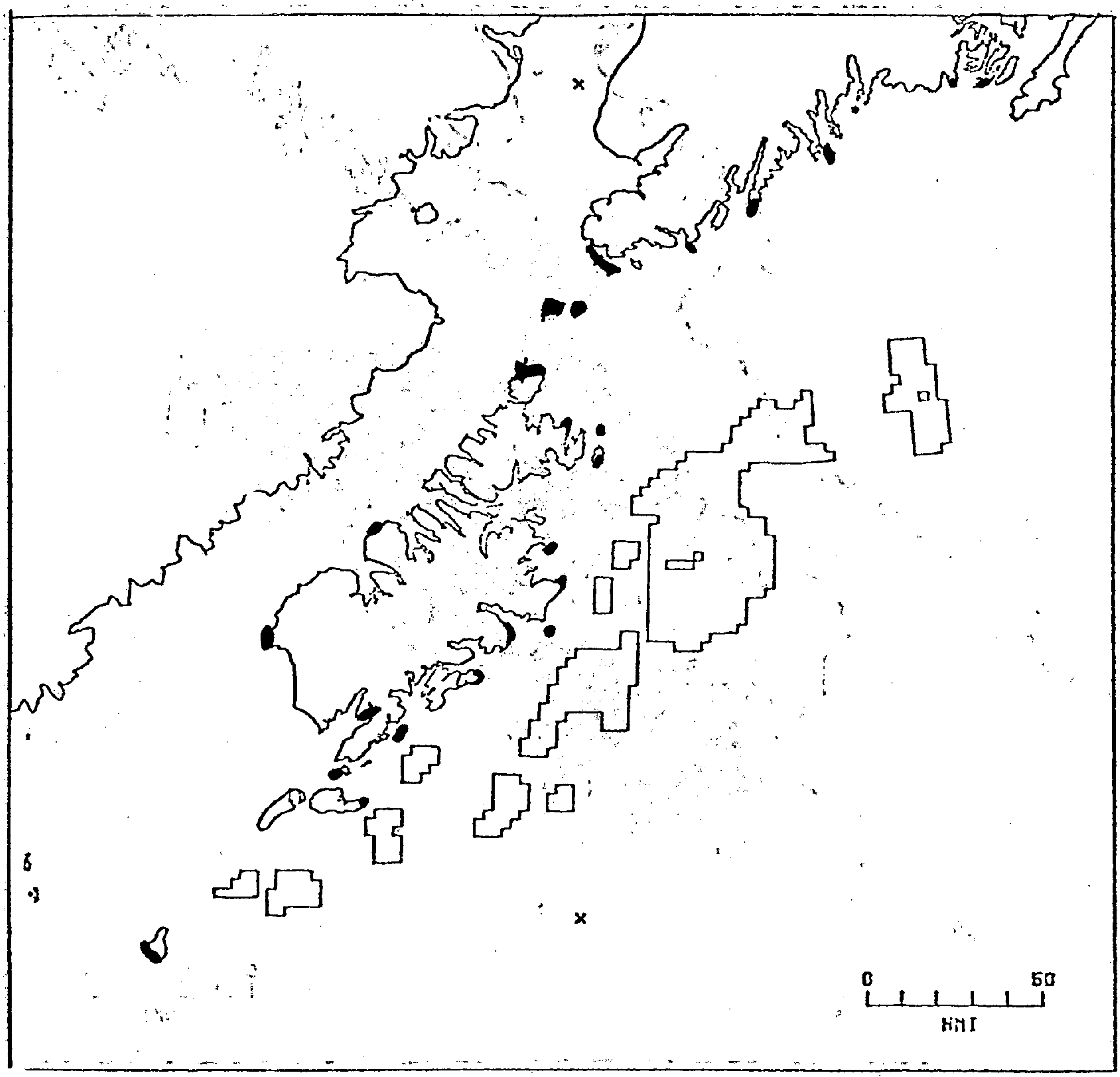



Fig. A-12 Dark area indicates spatial extent of sea lion rookeries and hauling grounds.

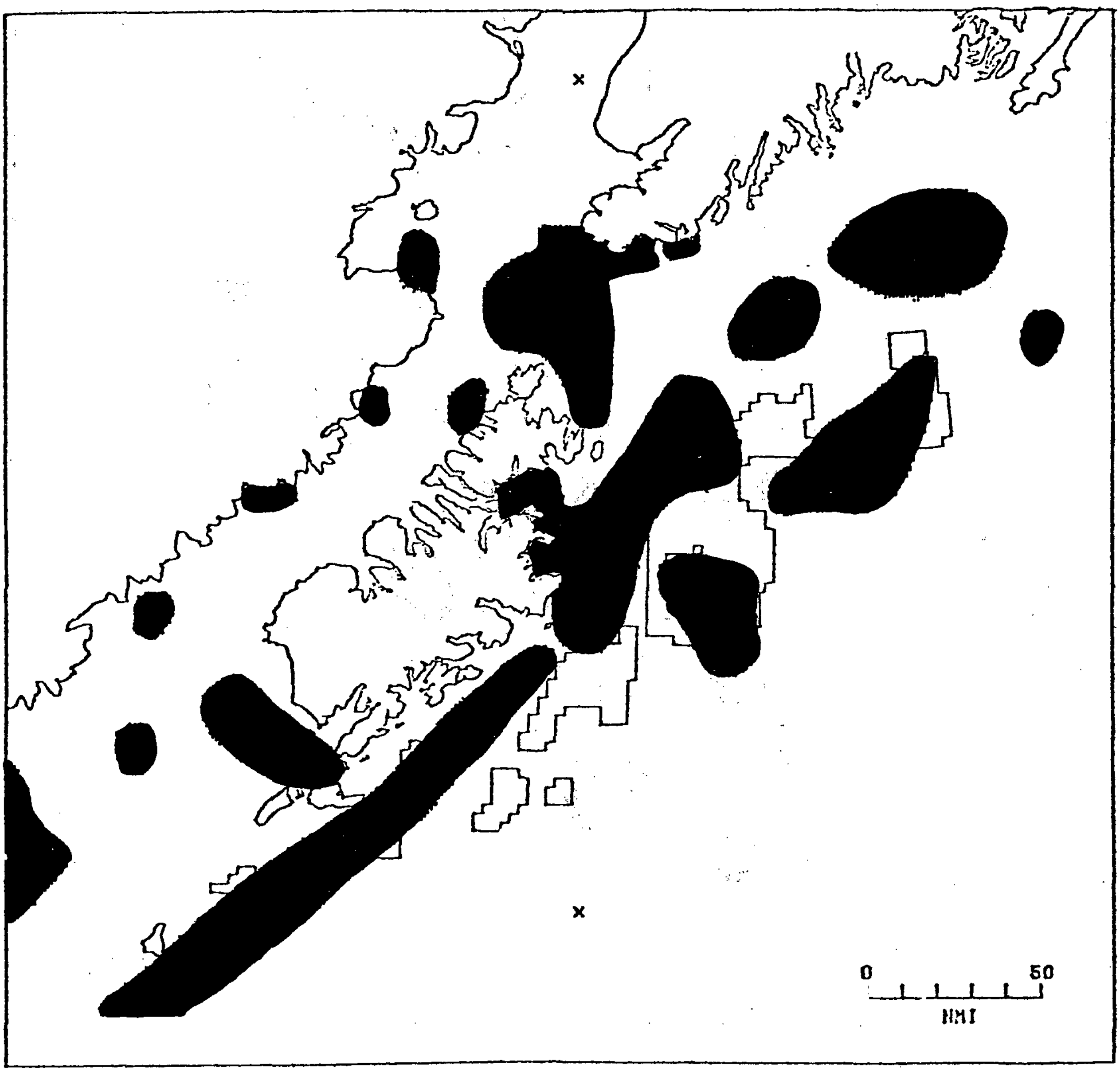



Fig. A-13 Dark area indicates spatial extent of bird distribution - summer (June, July, August).

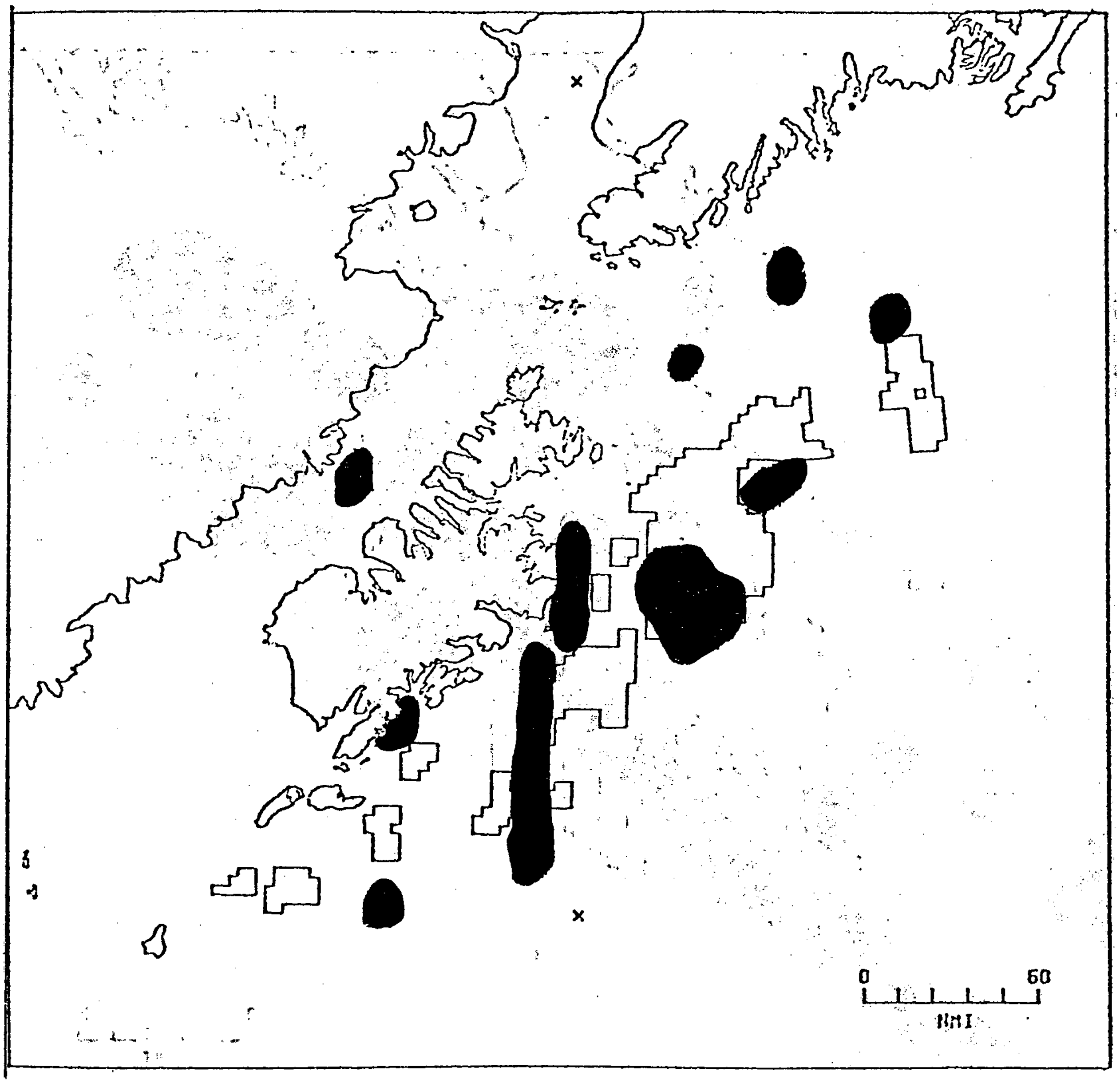



Fig. A-14 Dark area indicates spatial extent of bird distribution - fall (September, October, November).

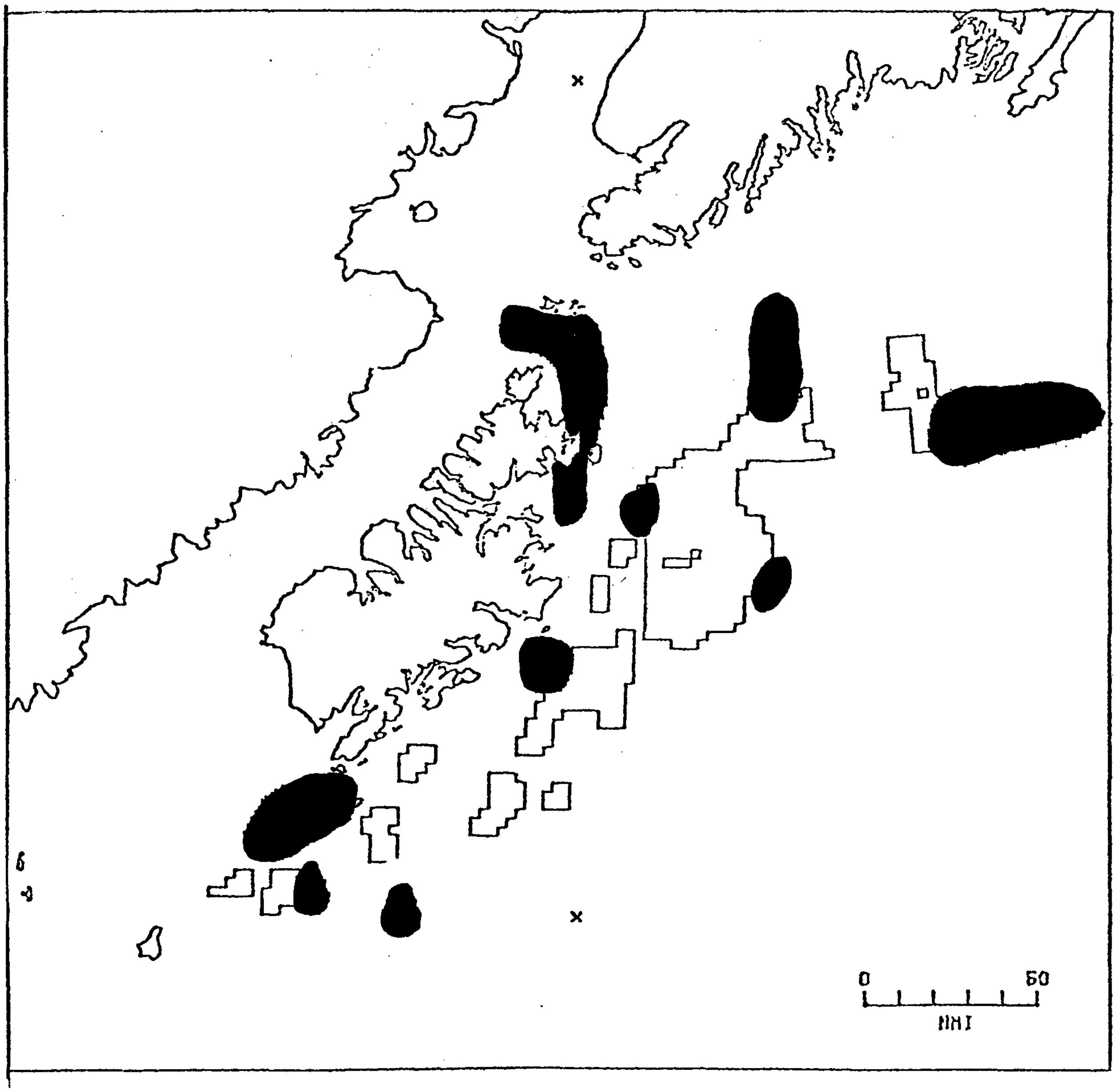



Fig. A-15 Dark area indicates spatial extent of bird distribution - winter (December, January, February).

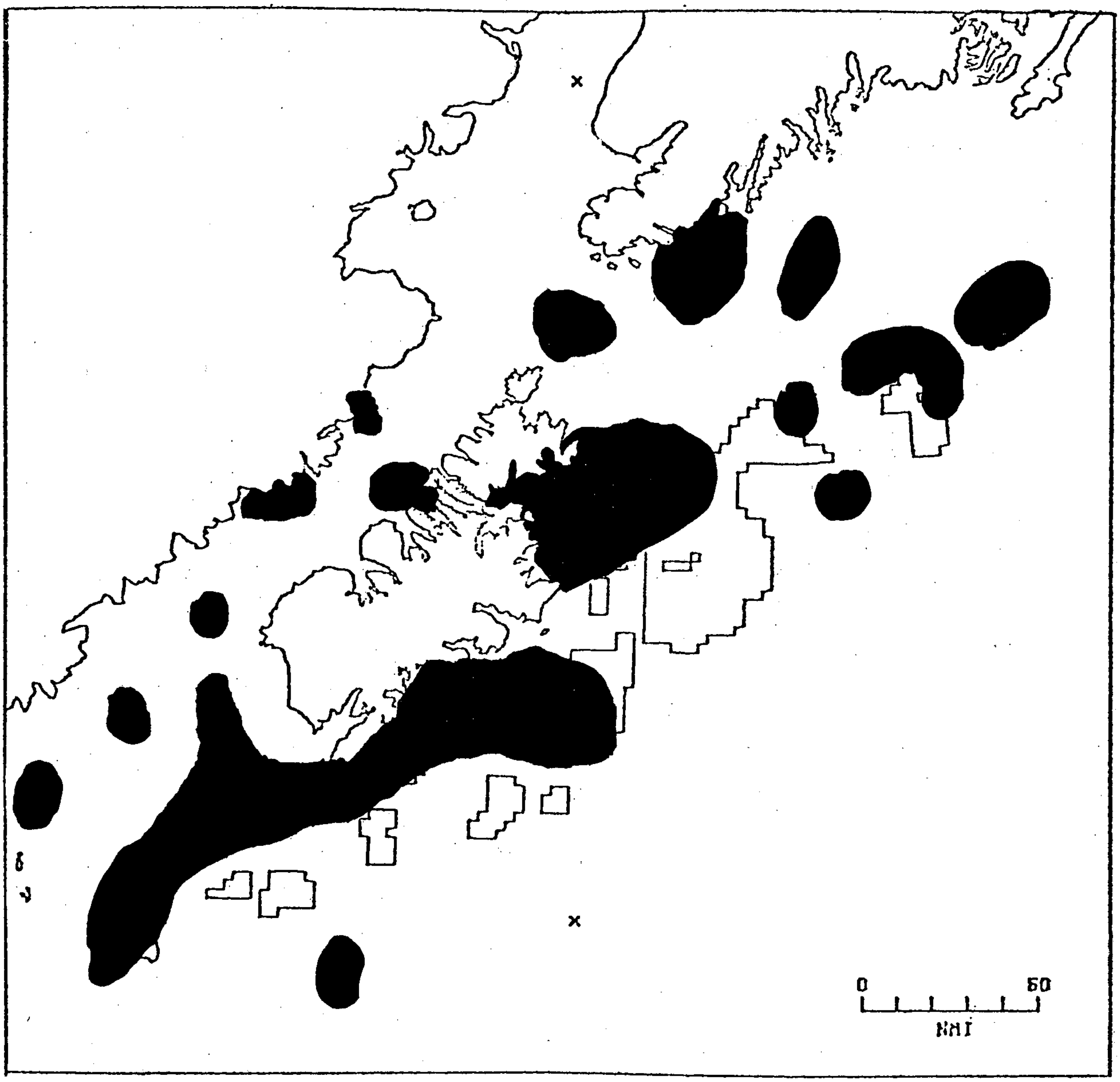



Fig. A-16 Dark area indicates spatial extent of bird distribution - Spring (March, April, May).

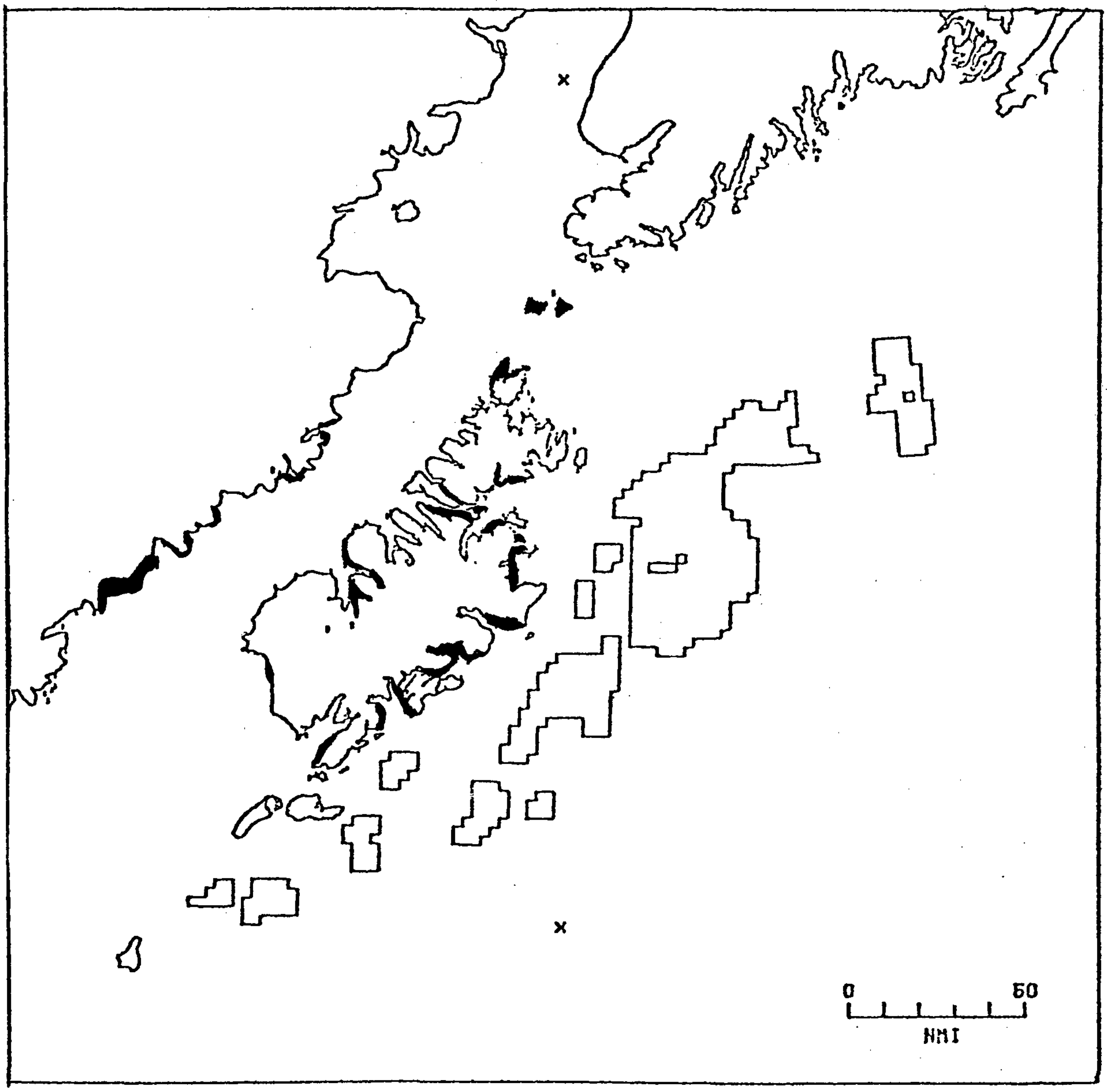



Fig. A-17 Dark area indicates spatial extent of seabird colonies.

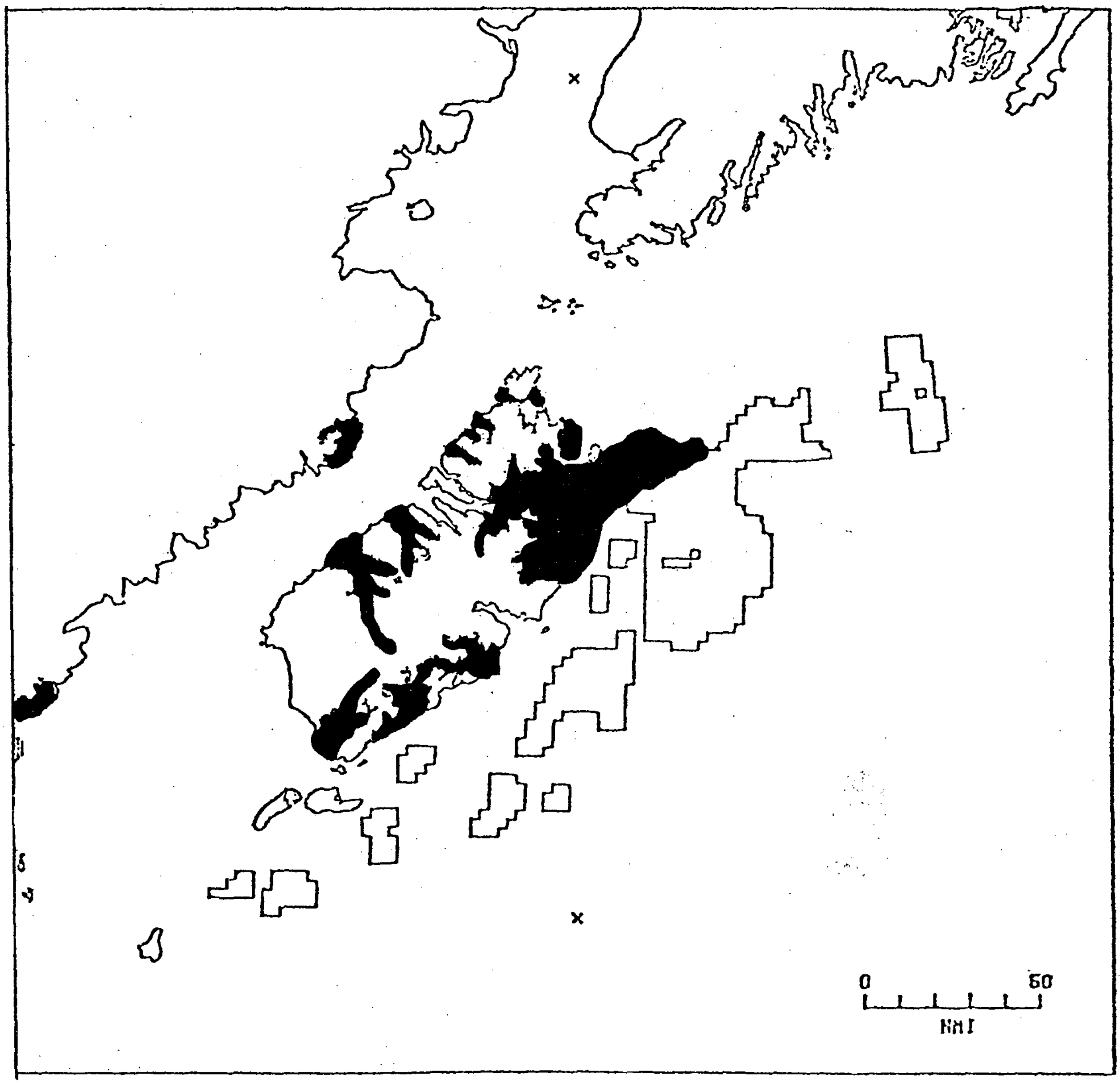



Fig. A-18 Dark area indicates spatial extent of shrimp reproduction and hatching areas.

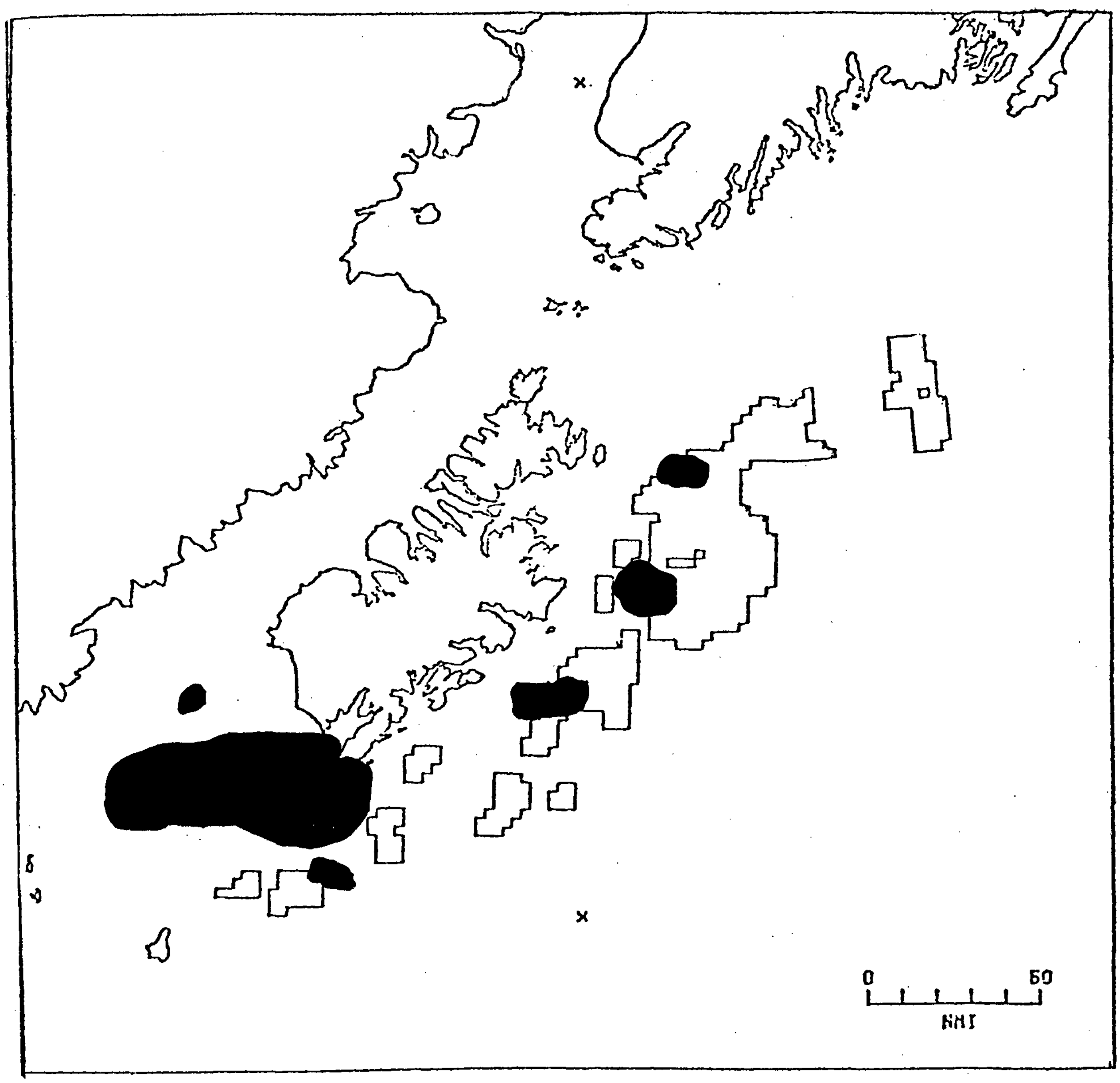



Fig. A-19 Dark area indicates spatial extent of tanner crab mating and hatching areas.

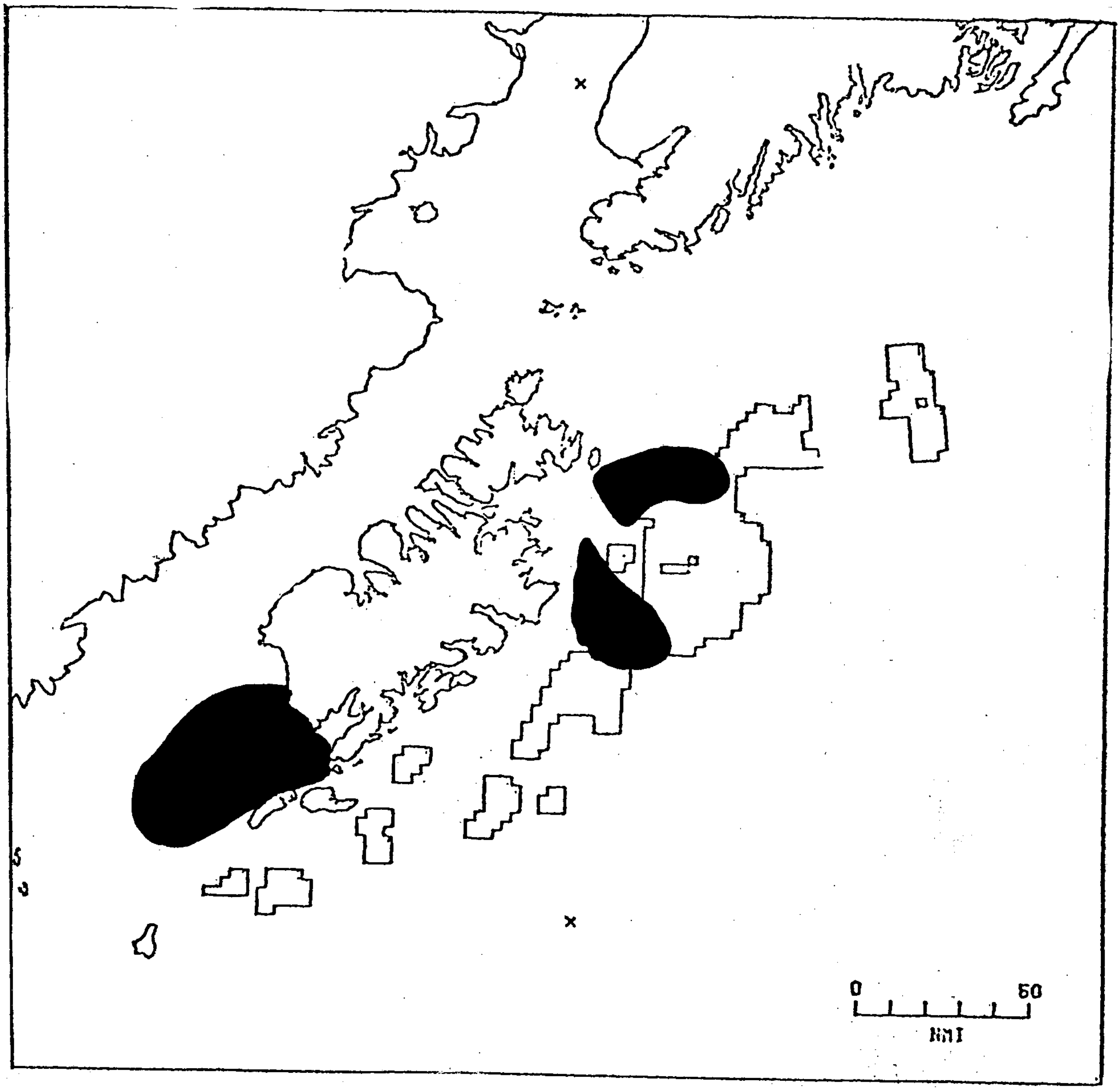



Fig. A-20 Dark area indicates spatial extent of tanner crab vital rearing areas.

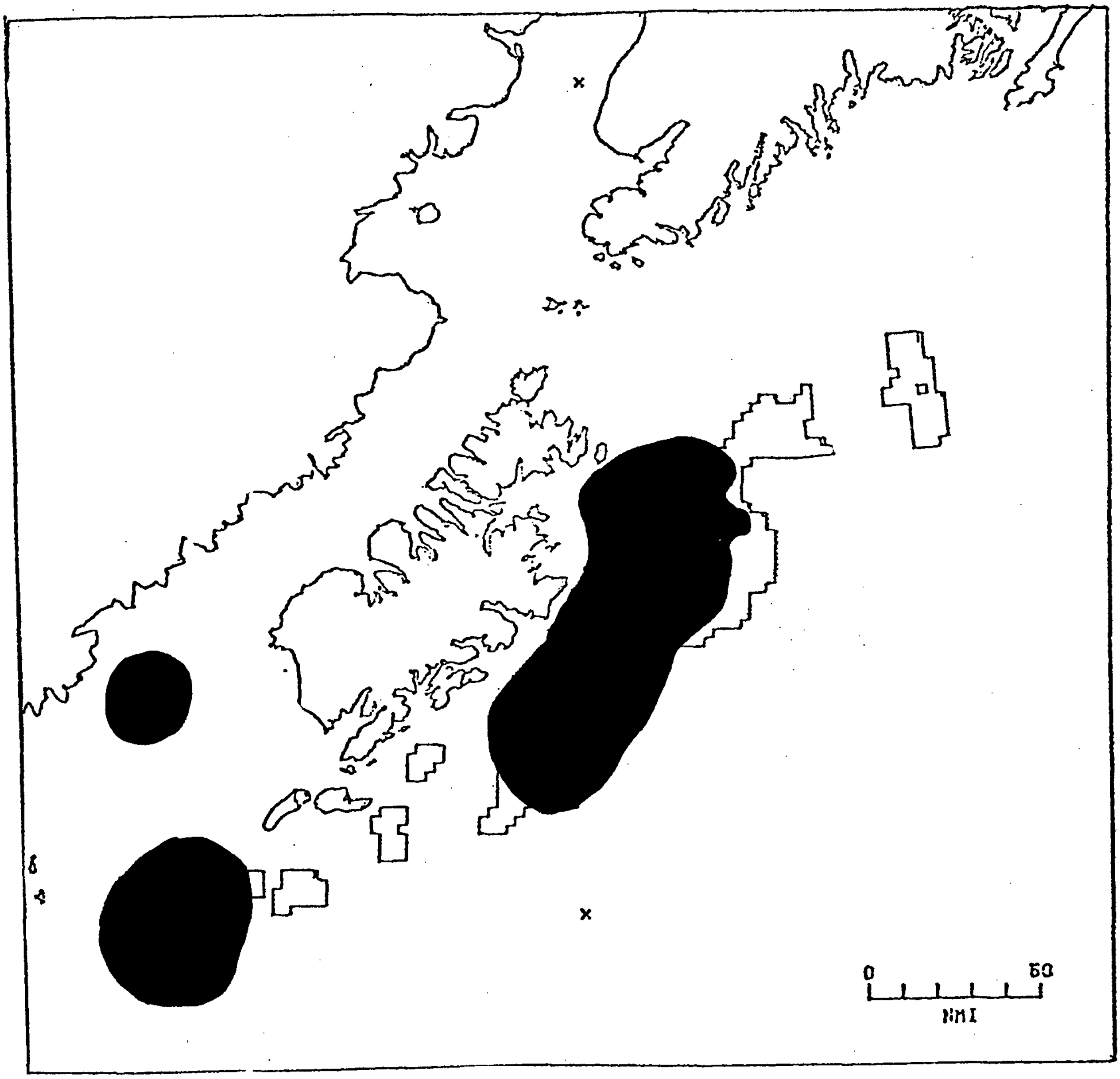



Fig. A-21 Dark area indicates spatial extent of tanner crab important rearing areas.

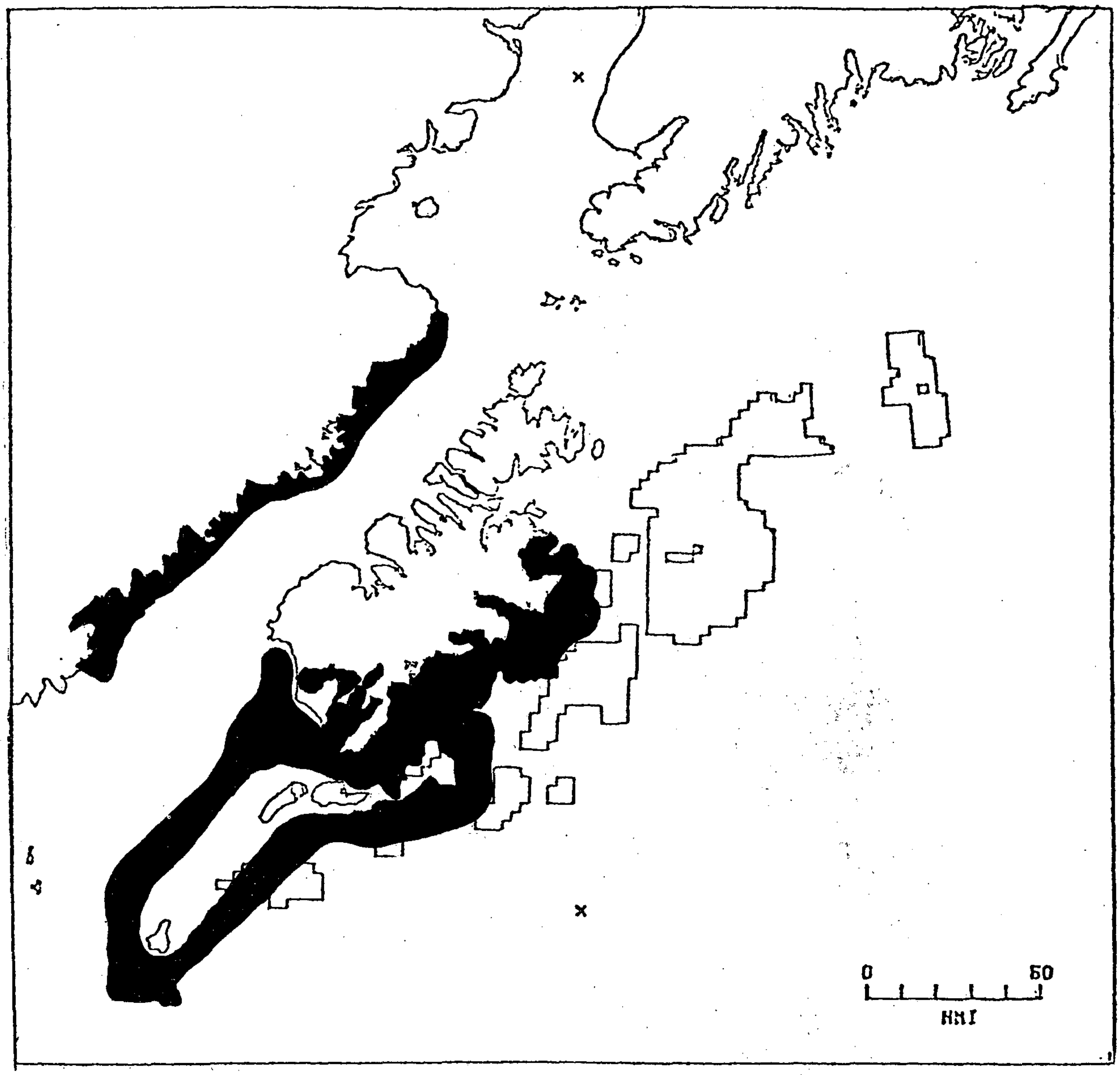



Fig. A-22   Dark area indicates spatial extent of king crab mating and hatching areas.

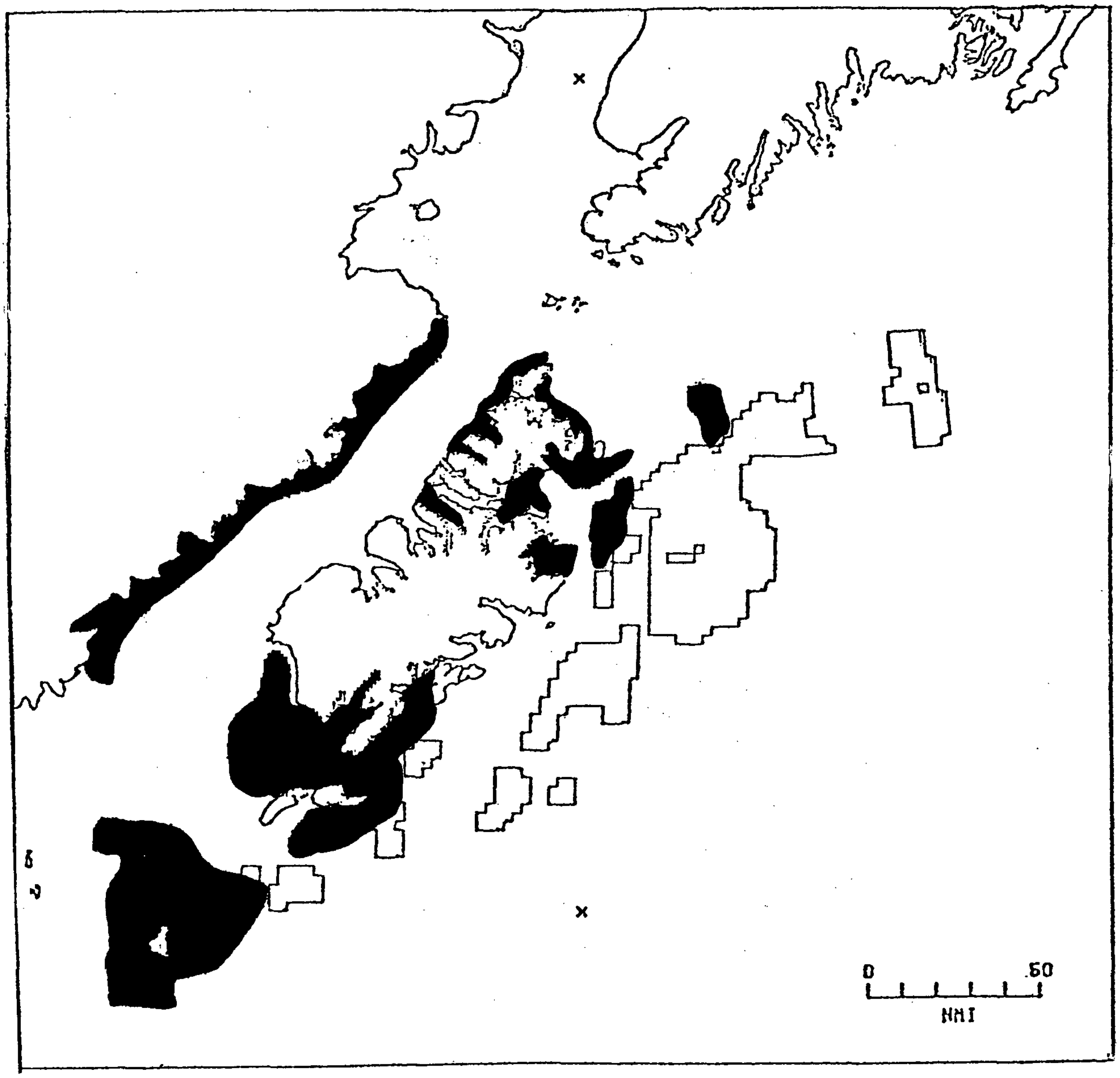



Fig. A-23 Dark area indicates spatial extent of king crab vital rearing areas.

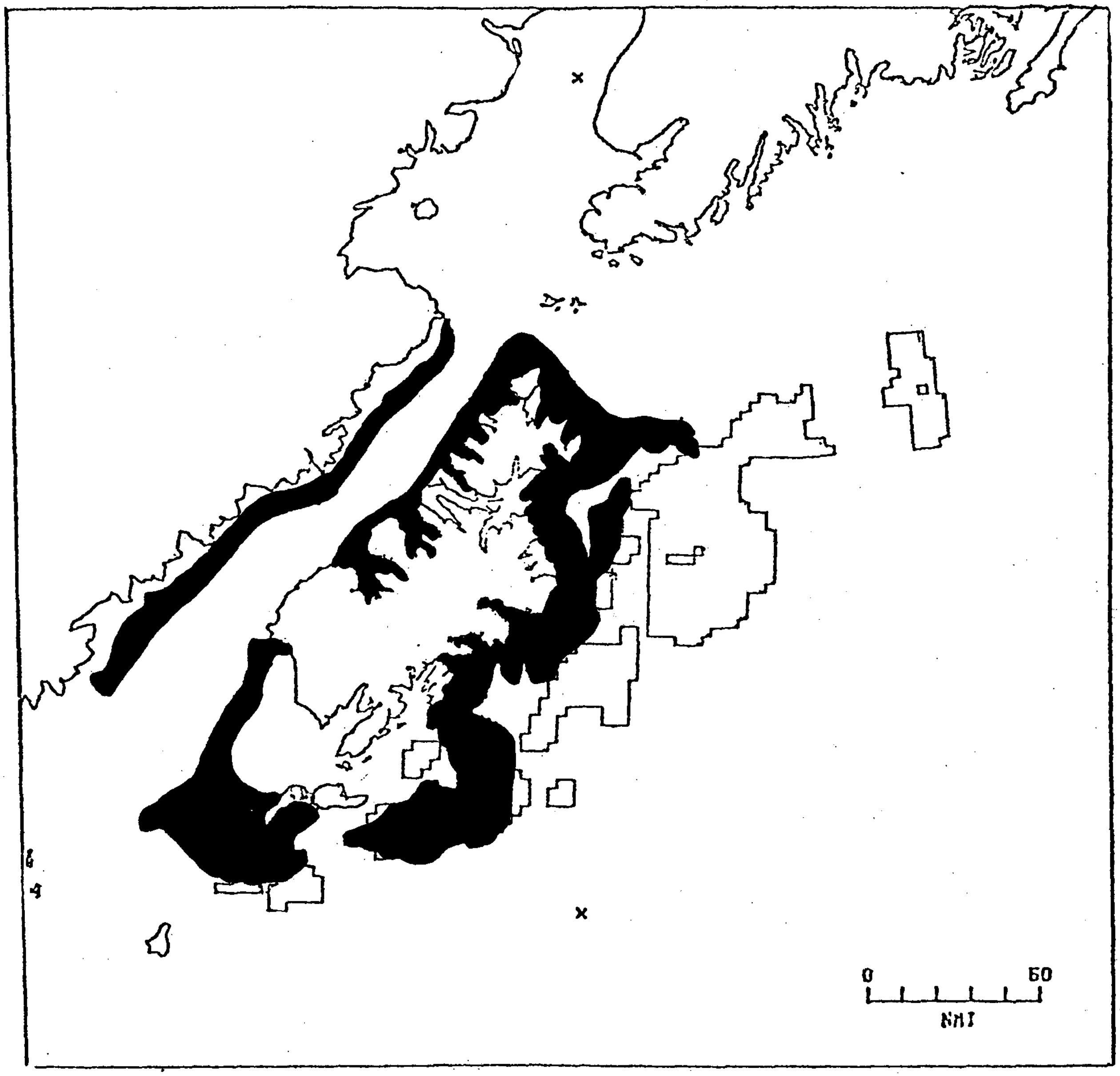



Fig. A-24 Dark area indicates spatial extent of king crab important rearing areas.

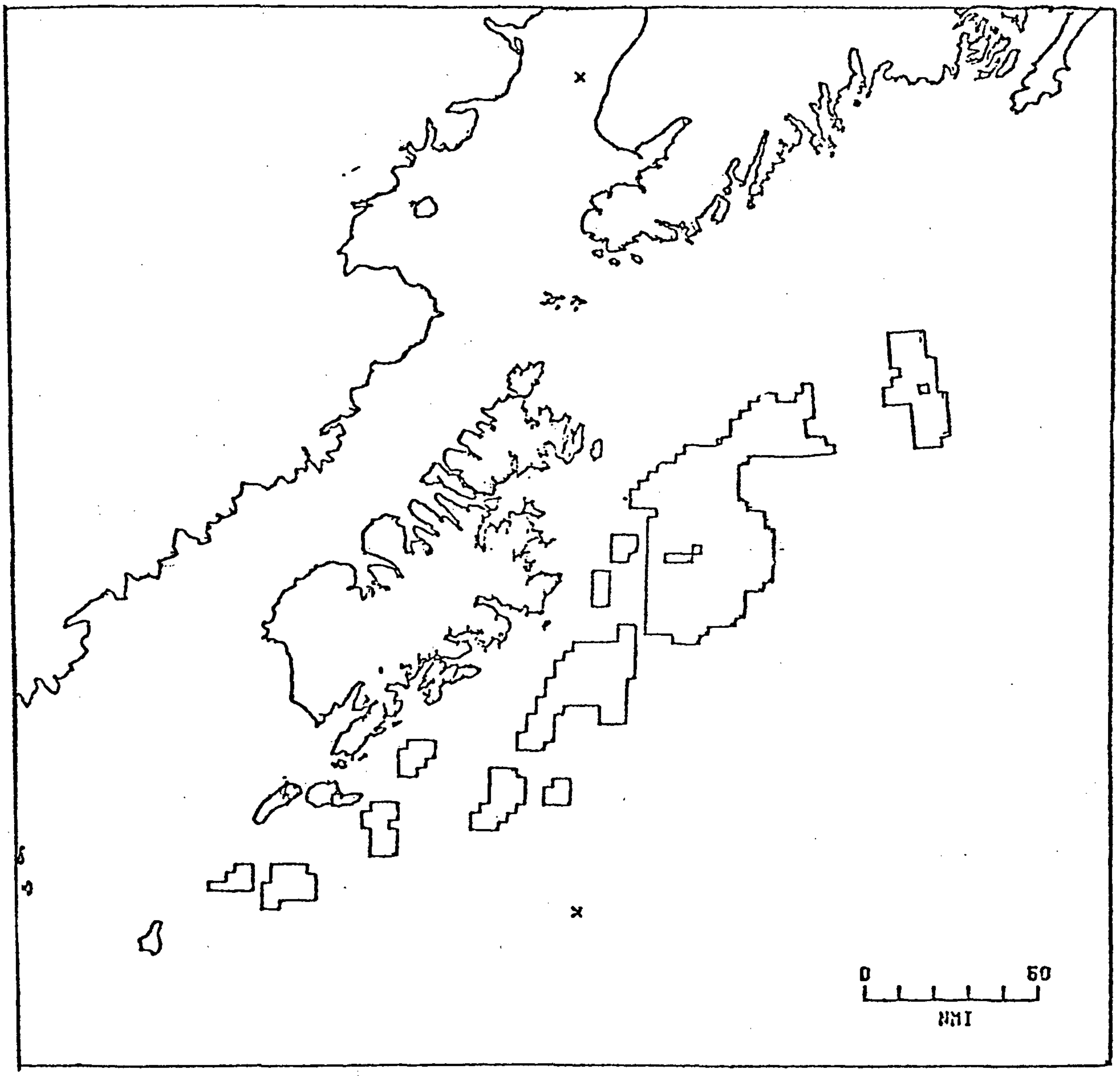



Fig. A-25 Hatched area indicates spatial extent of archaeological sites. (None evident at present time.)

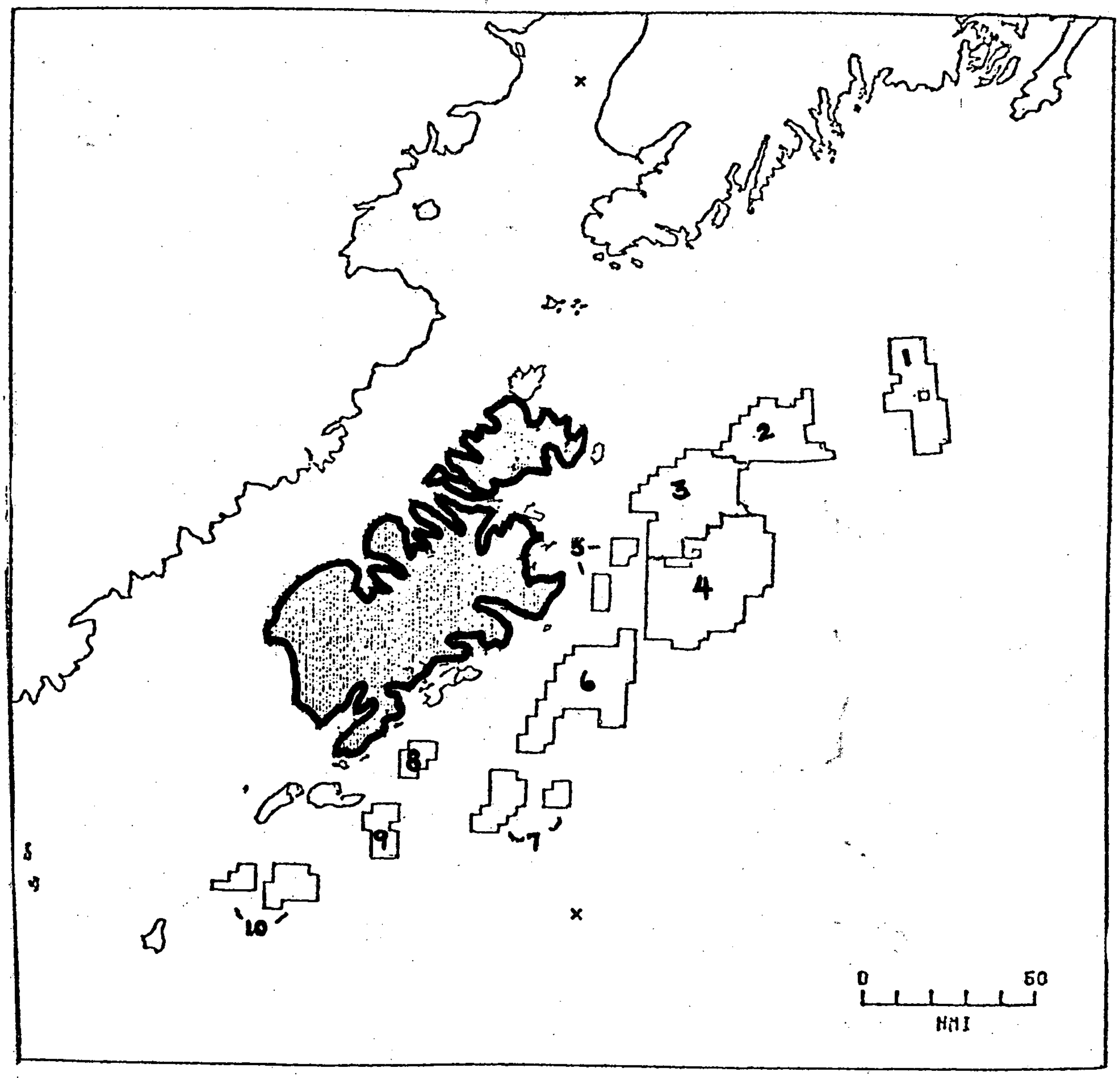



Fig. A-26 Hatched area indicates spatial extent of Kodiak and Afognak Islands.

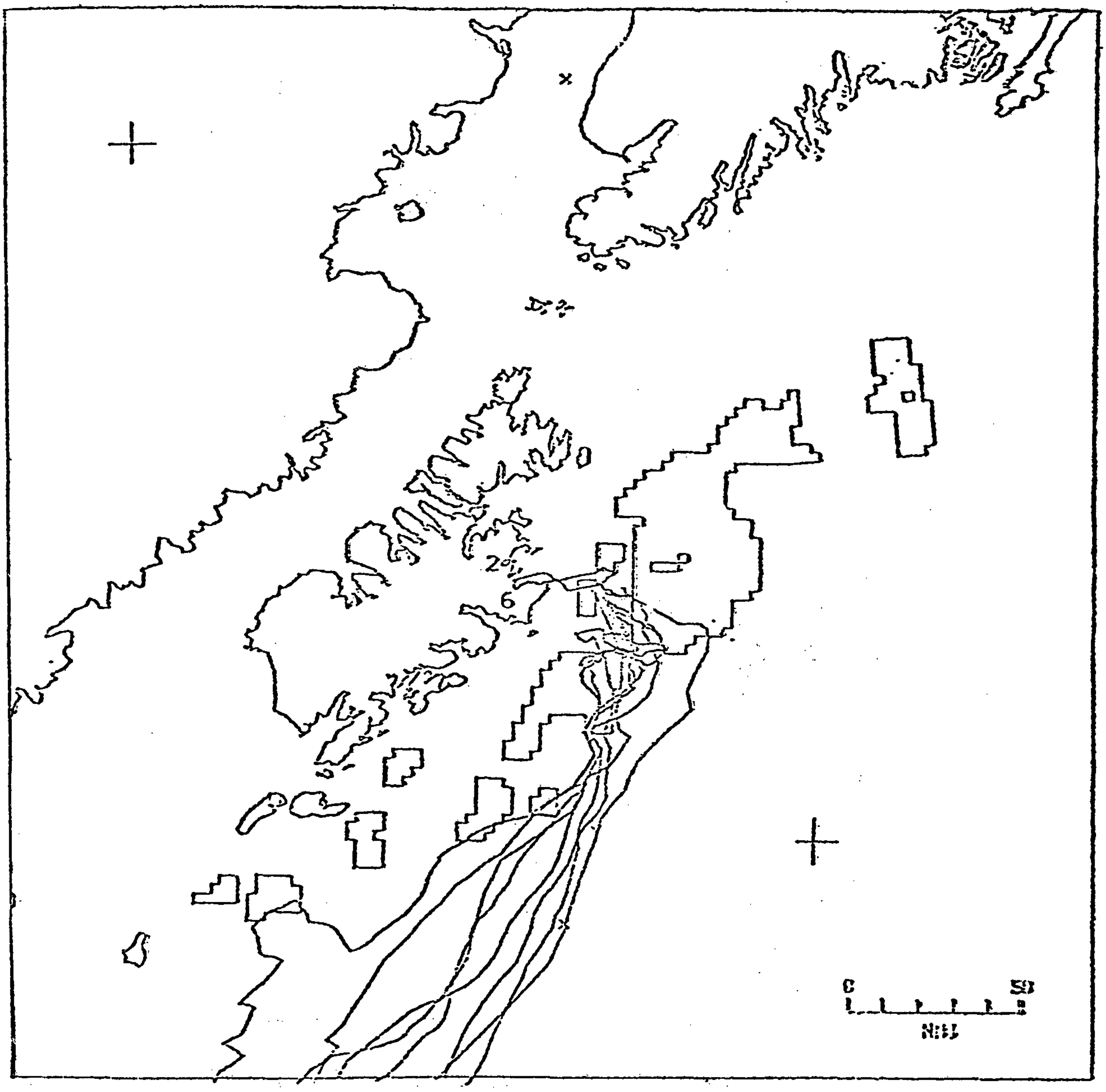



Fig. A-27 Spring hypothetical oil spill trajectories.

and all sites tending either south or southwest depending on whether the simulated spill moves outside the lease area away from Kodiak Island or not. Those trajectories that happen to move toward shore tend to wander about in the region from the proposed tracts to the Kodiak coast. Those trajectories that move east (and south) of the tracts quickly travel south-southwest, leaving the area of consideration.

The spatial disposition of the trajectory simulations is shown in Figure A-28. The final location of each trajectory was recorded and the results for each spill (weighted by the estimated spill frequencies) were averaged. Thus, according to Figure A-28, 12 percent of the spills moved ashore on or near Afognak Island, 11 percent on the Northern Kodiak coast, about four percent on the Southern Kodiak coast, about 6 percent on the Trinity Islands, and about 7 percent on Chirikof Island. Two percent of the trajectories were left at sea; i.e., after 90 days of tracking they had neither beached nor left the map. The tendency for trajectories to travel south-southwest, as seen in Figure A-27, is also reflected in Figure A-28. About 56 percent of the simulated spills left the area of consideration by traveling south and southwest from the lease area. Heading in this direction the spills would be in the open waters of the Pacific Ocean.

Oil spill trajectory simulations were conducted keeping track of the frequency with which trajectories intersected the locations of biological and recreational resources. Trajectories were recorded as impacting a resource only in cases whre the resource was listed as being vulnerable to oil spills in the month the impact took place. This table (1A, not available to SAI staff) gives the probability of impact on selected categories of biological resources. As one would expect, the likelihood that a given spill trajectory would beach at the location of a specific land based resource during critical seasons is generally smaller than the 44 percent probability of coming ashore anywhere.

It must be emphasized that up to this point the analysis has dealt only with trajectories for the transport of surface oil by winds and currents and has not involved any consideration of dispersion or weathering processes which would progressively reduce the quantity of oil contained in the slick as it traveled towards shore. The probabilities given in the table, therefore represent a worst-case analysis in the sense that some fraction

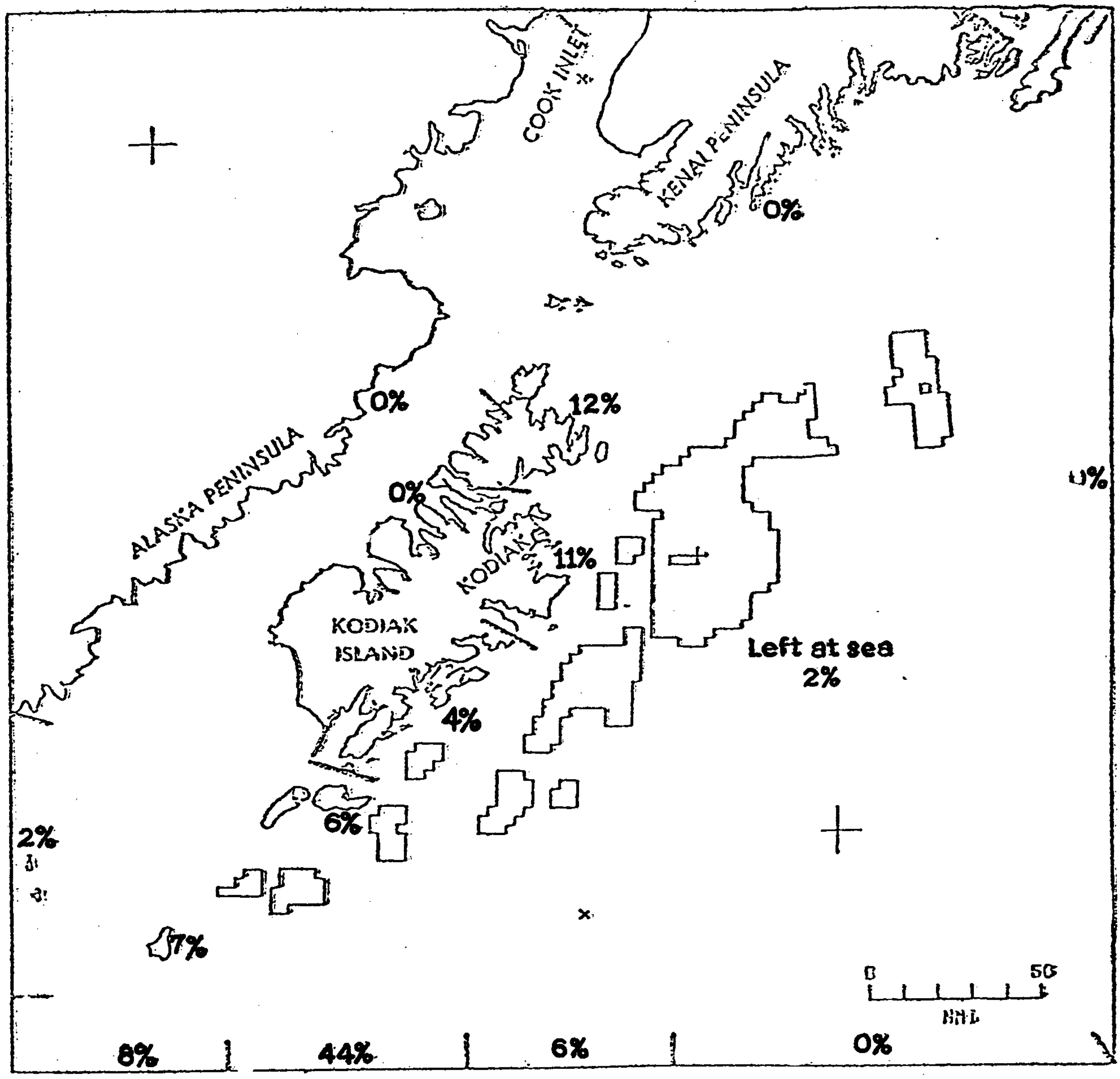



Fig. A-28 Spatial disposition of oil spill trajectories.

of the spills occurring more than 50 miles off shore in the lease area would be expected to deteriorate to the point of insignificance before reaching land. Some attempt at quantifying weathering and dispersive effects and accounting for them in probability estimates is thus in order.

One important factor determining the significance of weathering in reducing oil spill impacts is the time required for spills to reach land. Times to land for simulated trajectories, in fact, covered a very wide range, and it is therefore particularly important to consider this factor in interpreting results of the spill trajectory analysis. The mean number of days at sea for trajectories which reached the coast

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