

Environmental Assessment of the Alaskan Continental Shelf

Interim Synthesis Report: Kodiak

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CONTINENTAL
SHELF
ENVIRONMENTAL
ASSESSMENT
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INTERIM SYNTHESIS REPORT: KODIAK

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Boulder, Colorado 80303

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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 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 northeastern, 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 environs 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).

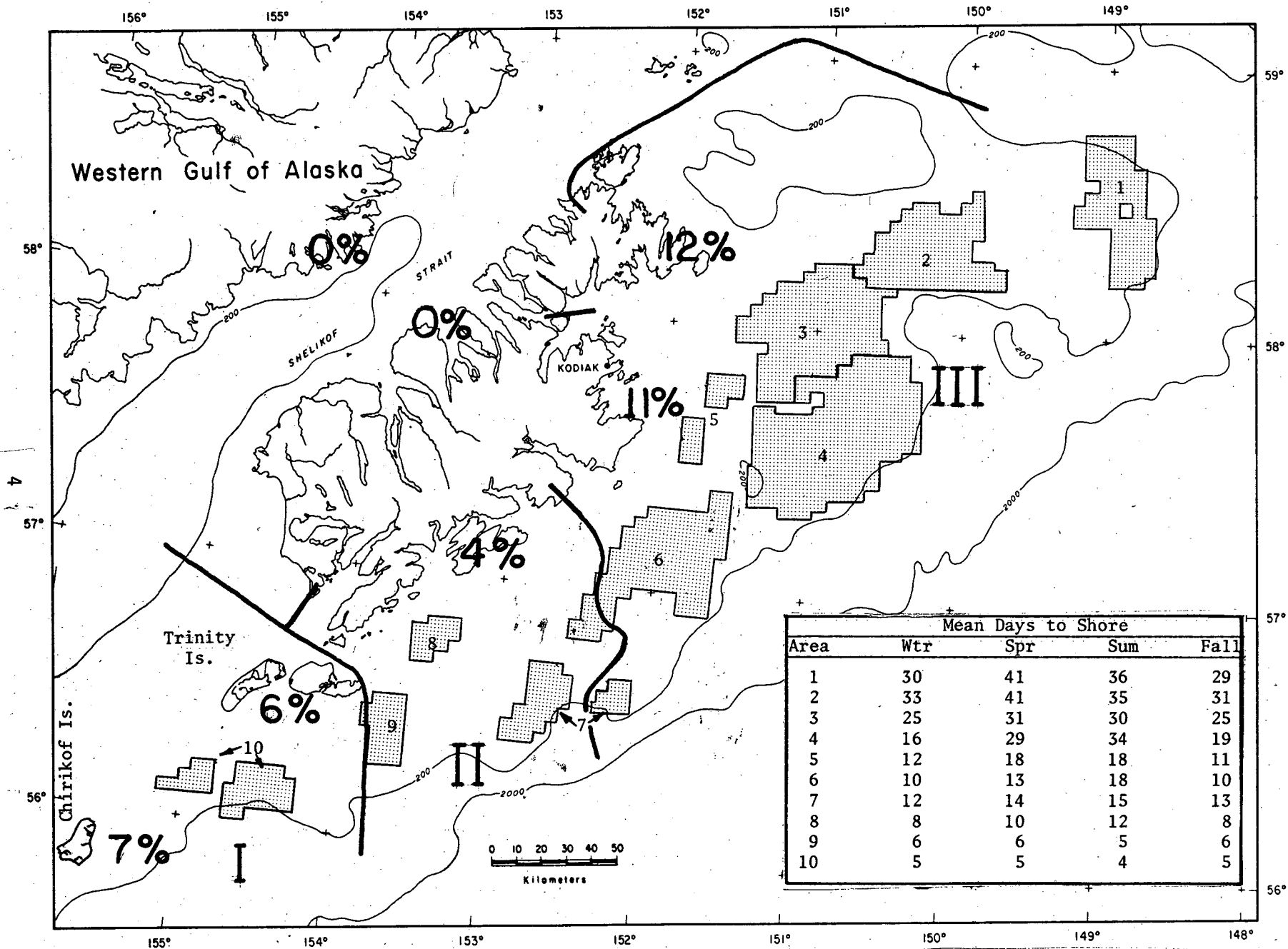


Fig. 2-1 Kodiak Shelf: subregions discussed in this report, proposed lease areas and oil spill trajectory data (Appendix 3). See text for additional explanation.

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/m², 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 (~ 200 m). Flushing rates for contaminants introduced into water trapped behind or below this sill (~ 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 km² 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/cm². 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 contrast 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 murre. 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,

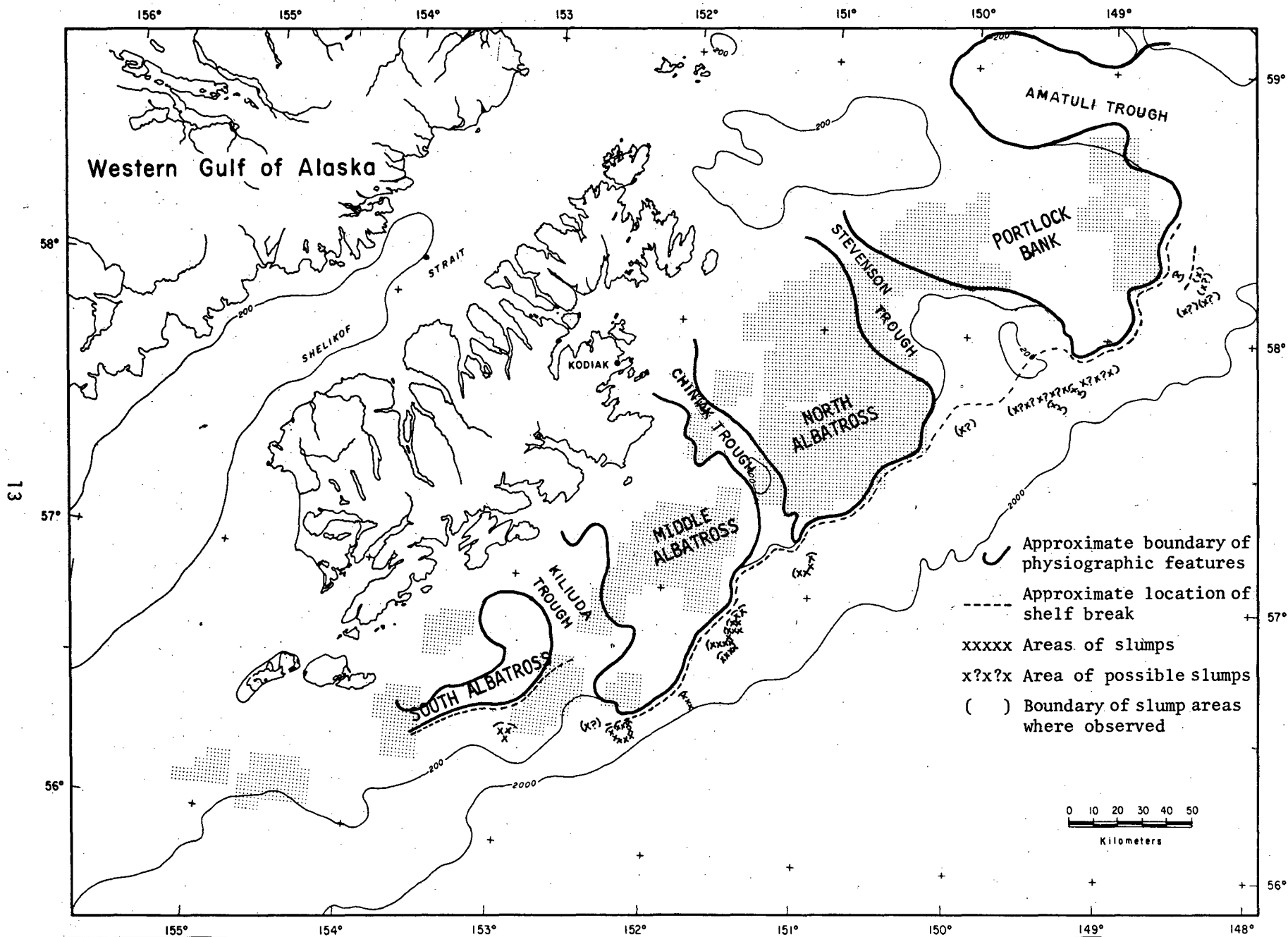


Fig. 2-2 Kodiak Shelf: major physiographic features and location of slumps (Bouma and Hampton, 1977).

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 m³/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/m² -- 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 murre. 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 Peneosa 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 hydrocarbon 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. Hinds, 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.

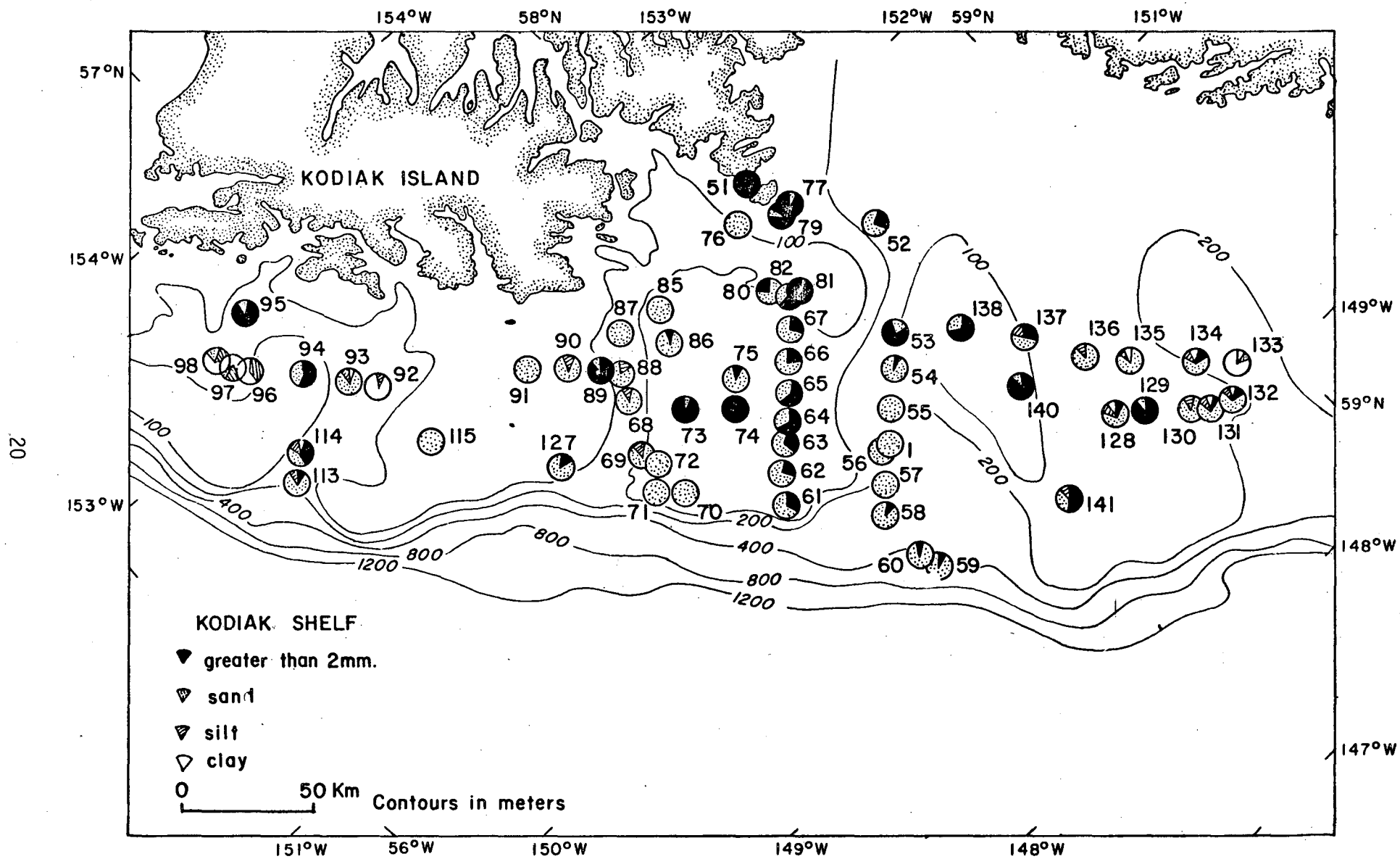


Fig. 3-1 Kodiak Shelf: surficial sediments (Bouma and Hampton, 1977).

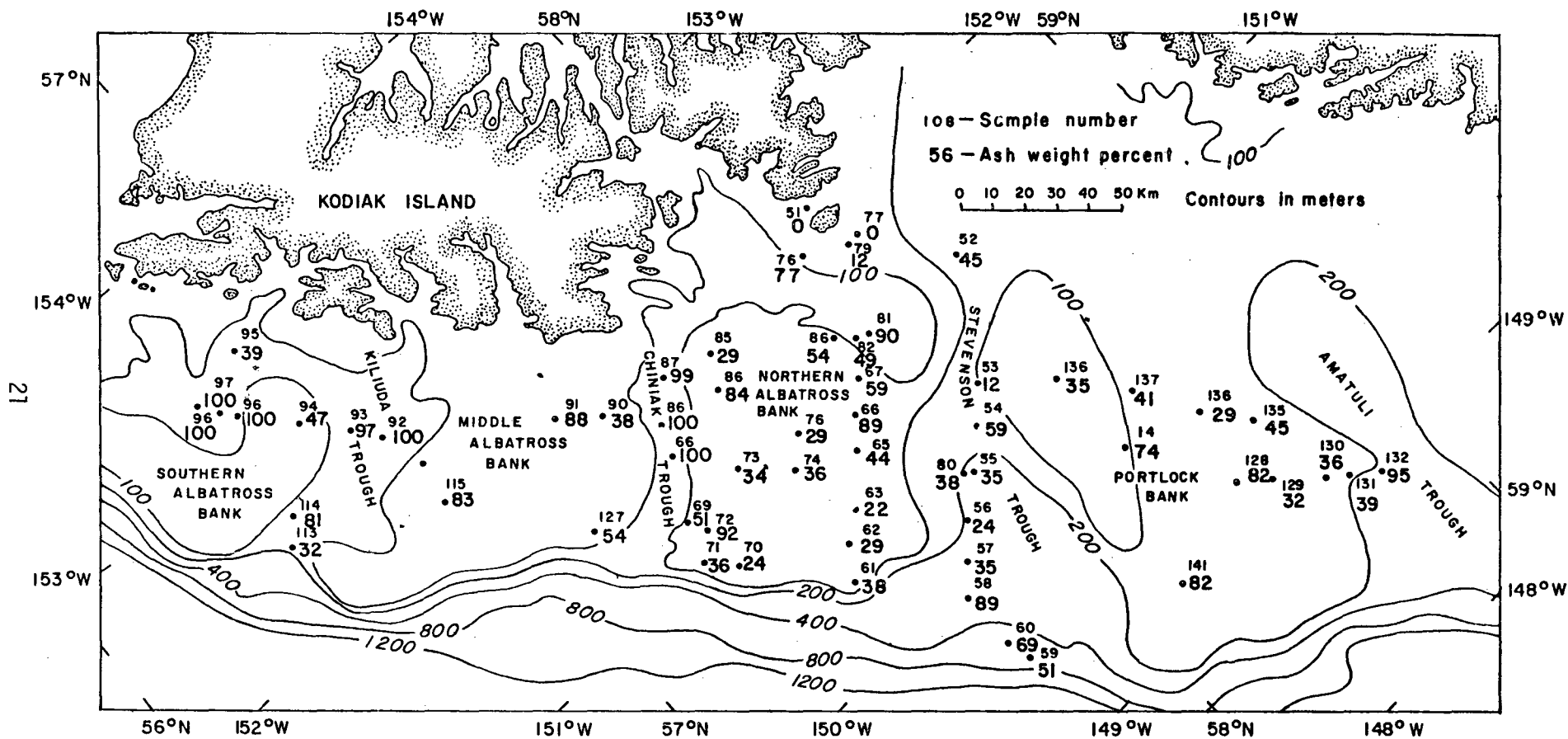


Fig. 3-2 Kodiak Shelf: distribution of Katmai Ash (weight percent) within surficial sediment samples (Bouma and Hampton 1977).

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 features 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 evaluate 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 bathymetric 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

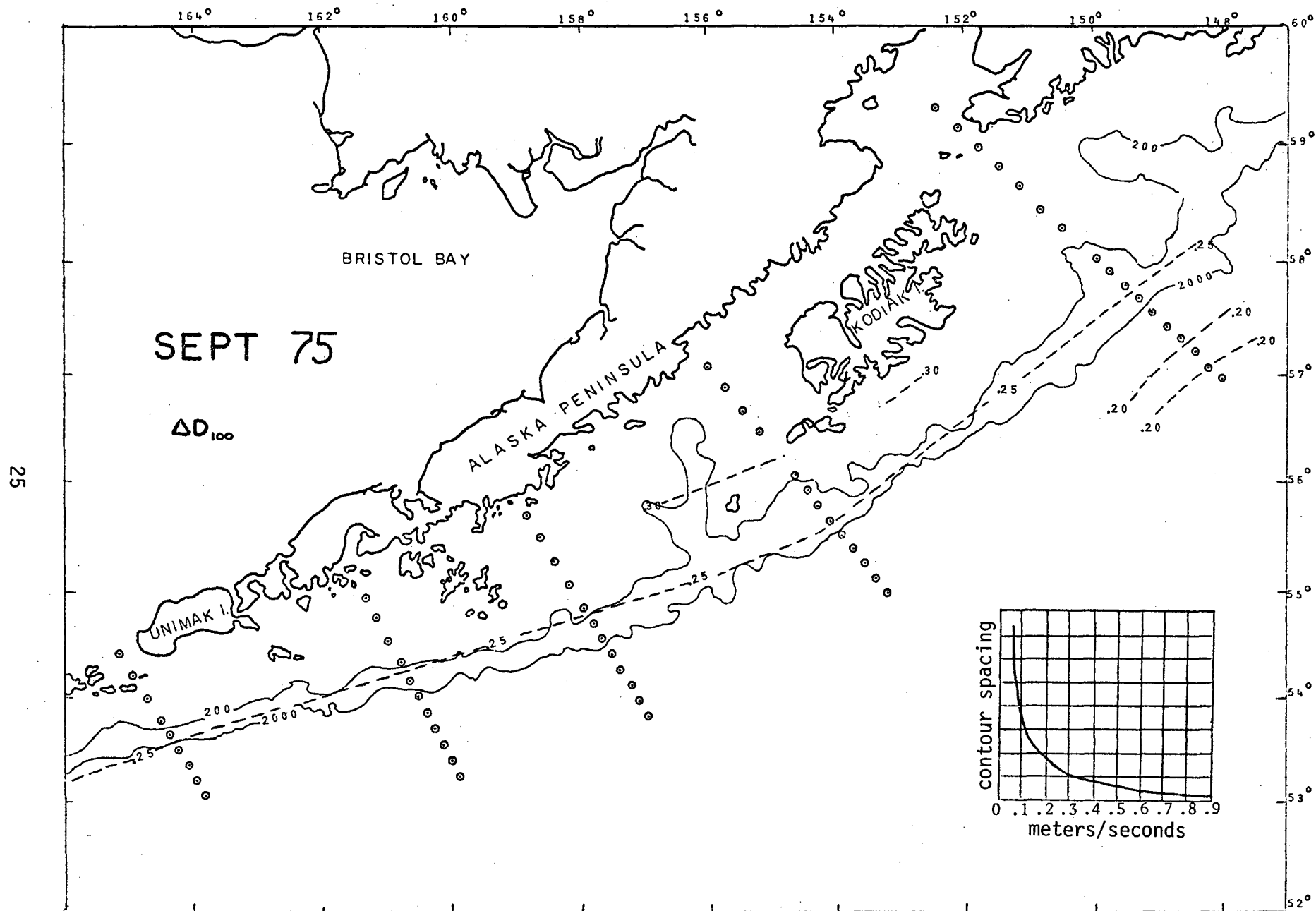


Fig. 3-3a Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

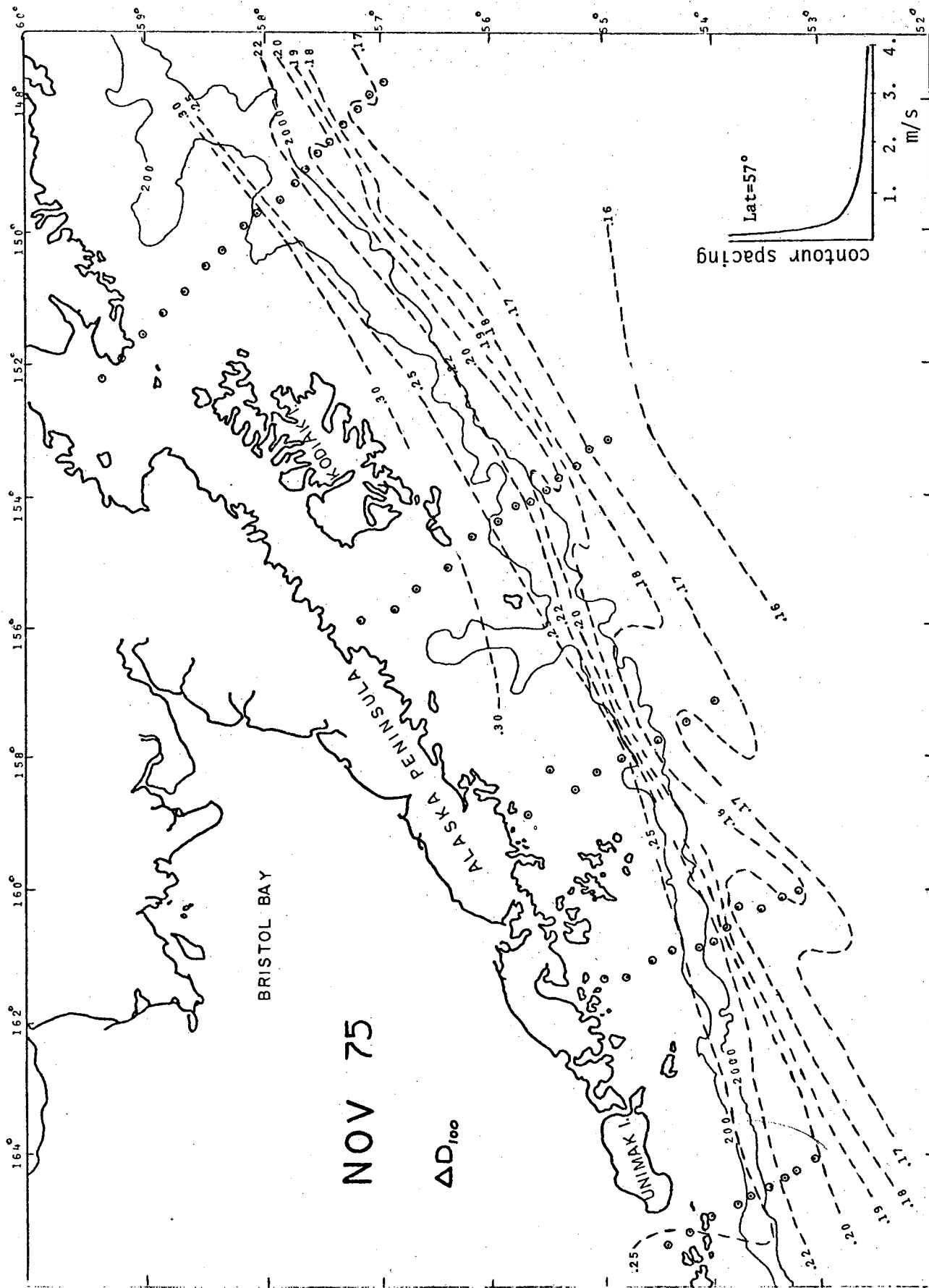


Fig. 3-3b Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

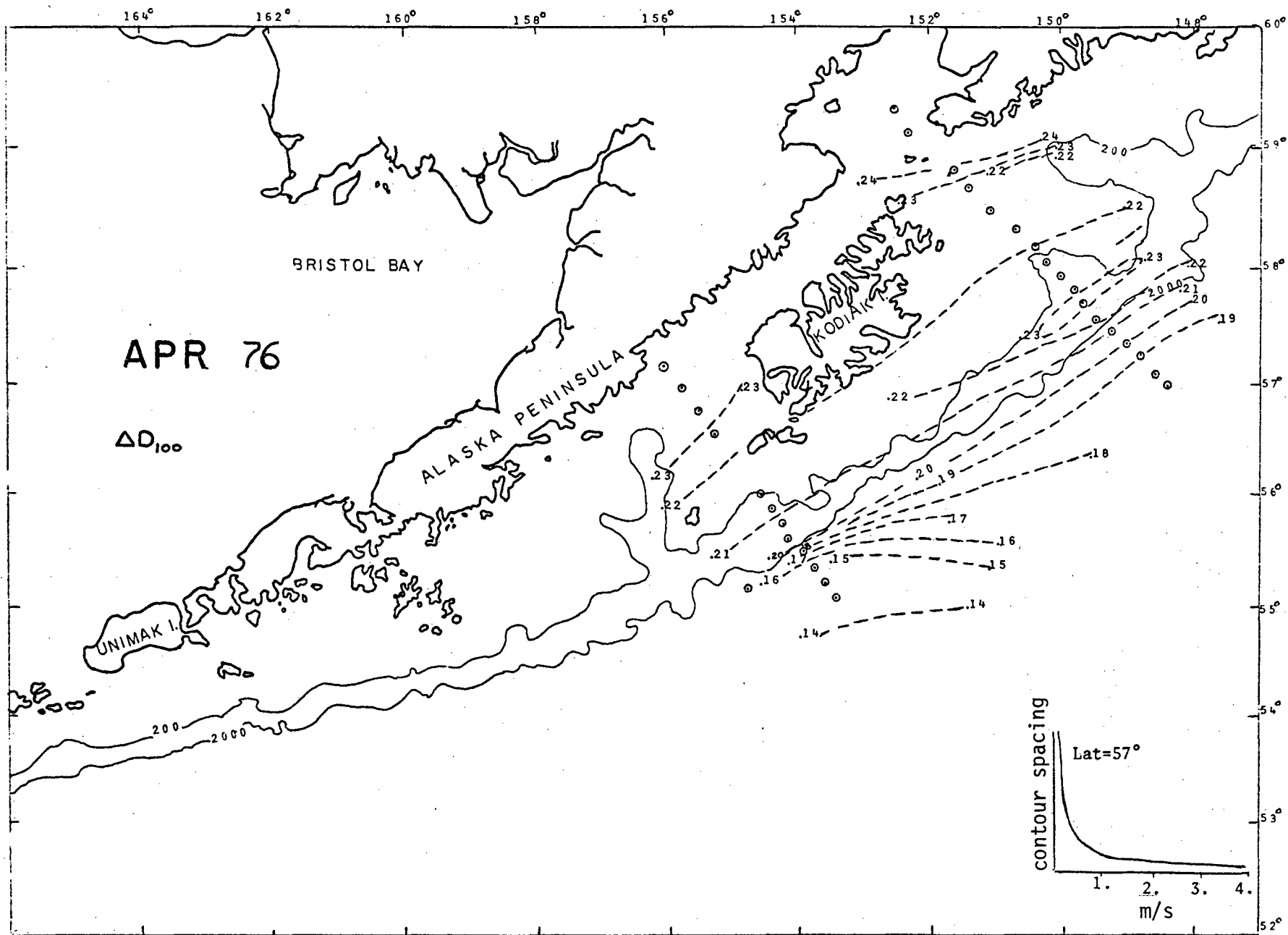


Fig. 3-3c Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

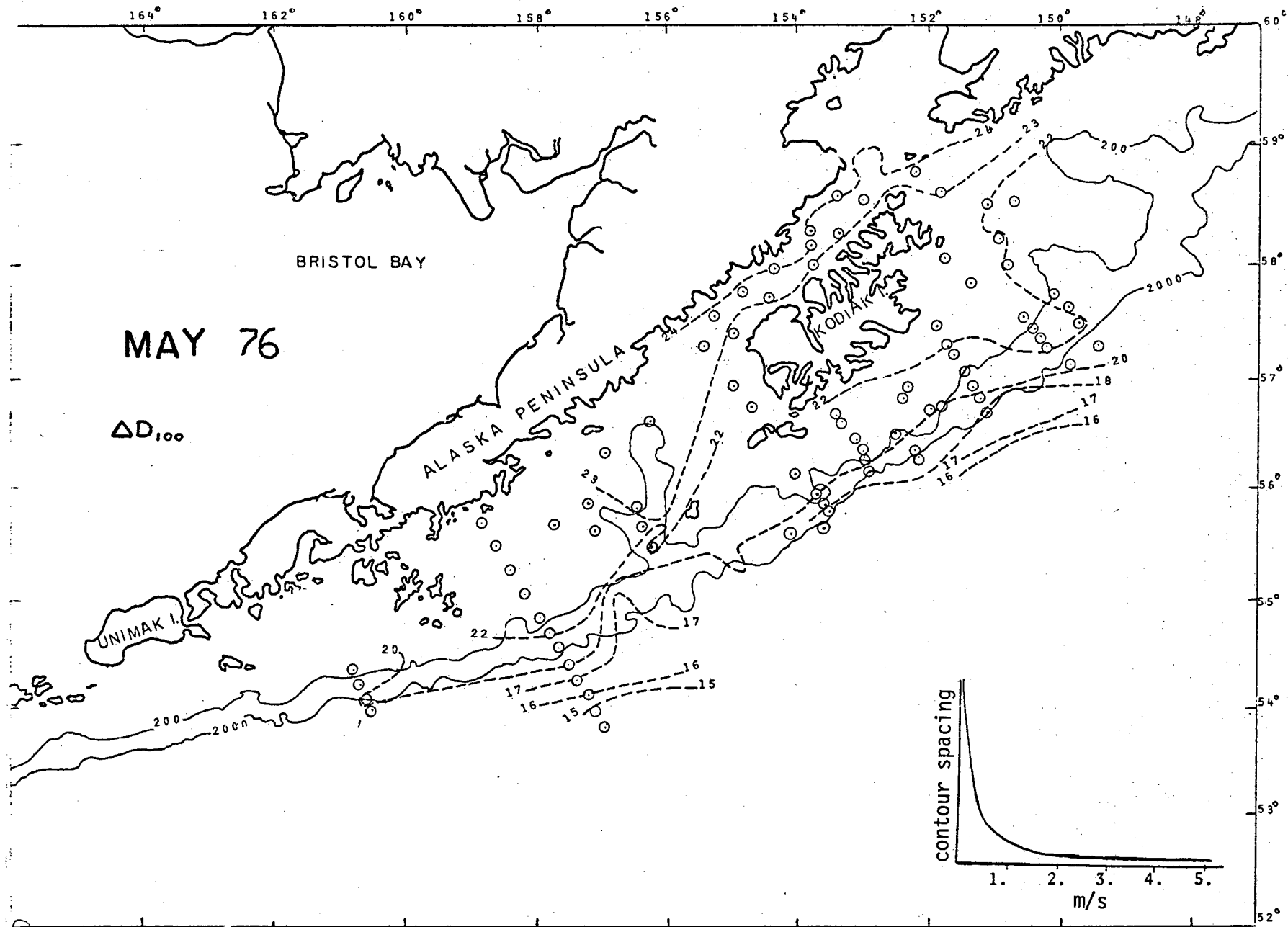


Fig. 3-3d Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Royer, U of AK, Fairbanks, personal communication).

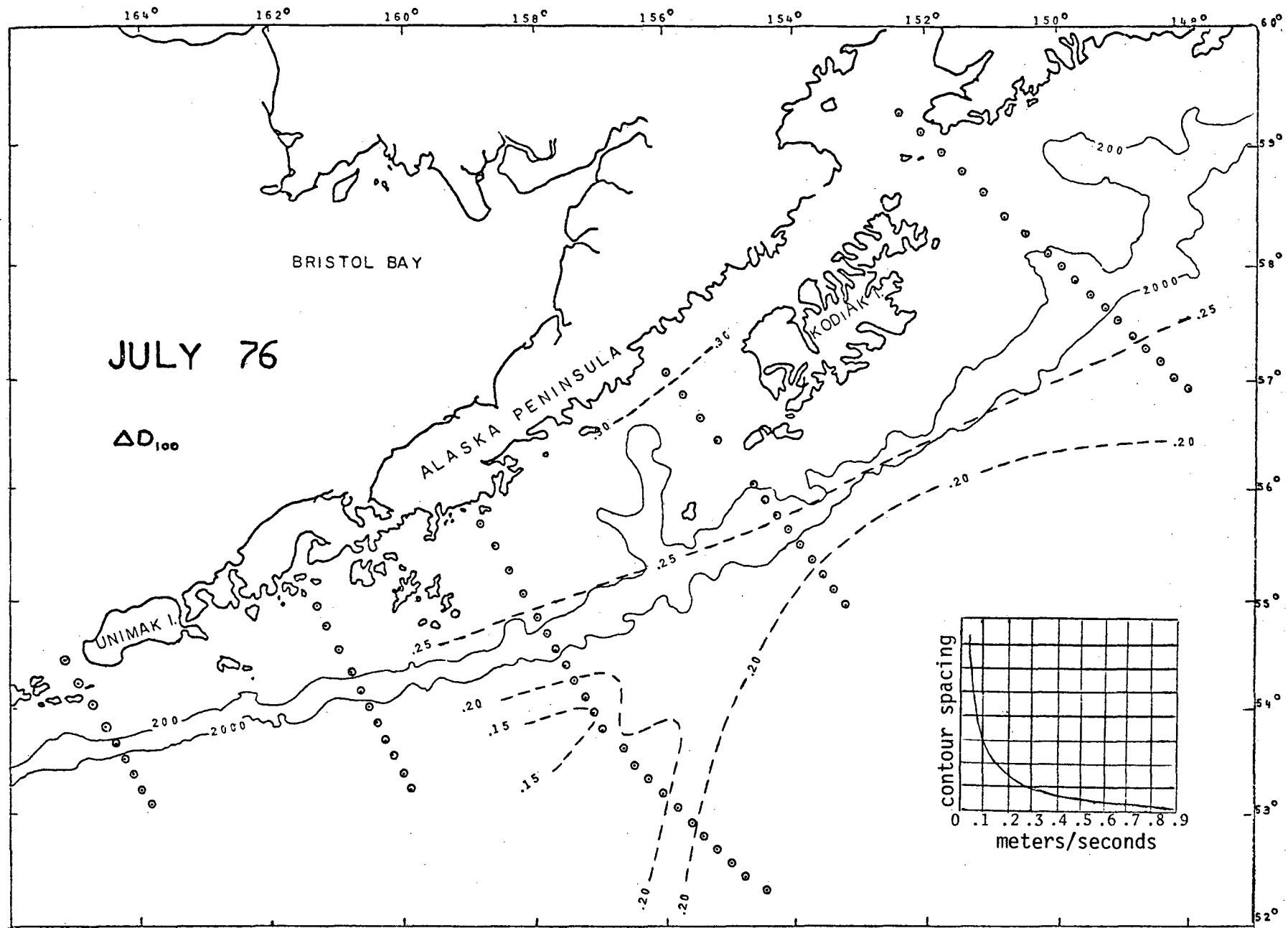


Fig. 3-3e Dynamic topography with reference to 100 decibars in the western Gulf of Alaska (Rover, U of AK, Fairbanks, personal communication).

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 $\pm 25^\circ$. 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

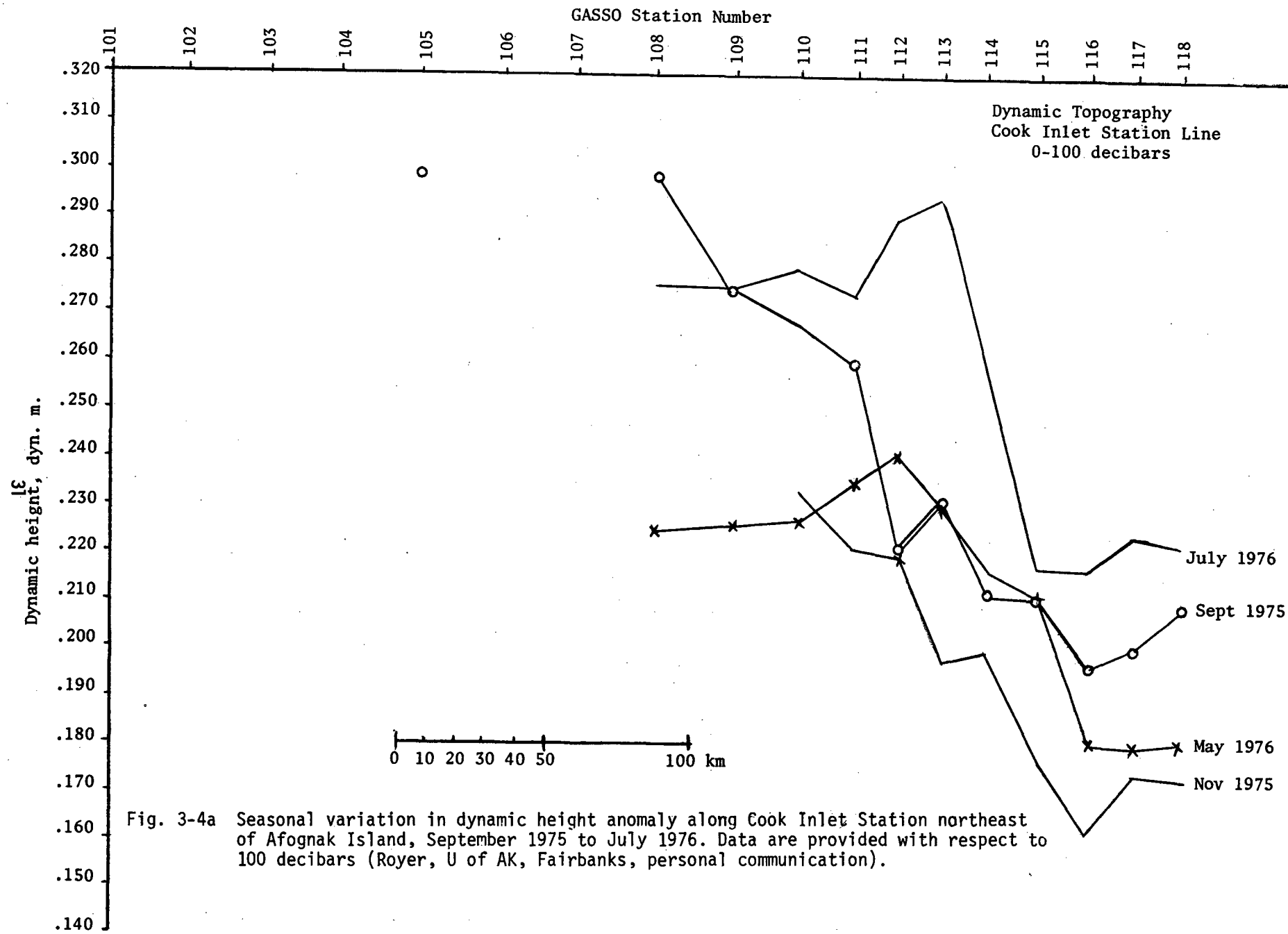


Fig. 3-4a Seasonal variation in dynamic height anomaly along Cook Inlet Station northeast of Afognak Island, September 1975 to July 1976. Data are provided with respect to 100 decibars (Royer, U of AK, Fairbanks, personal communication).

GASSO Station Numbers

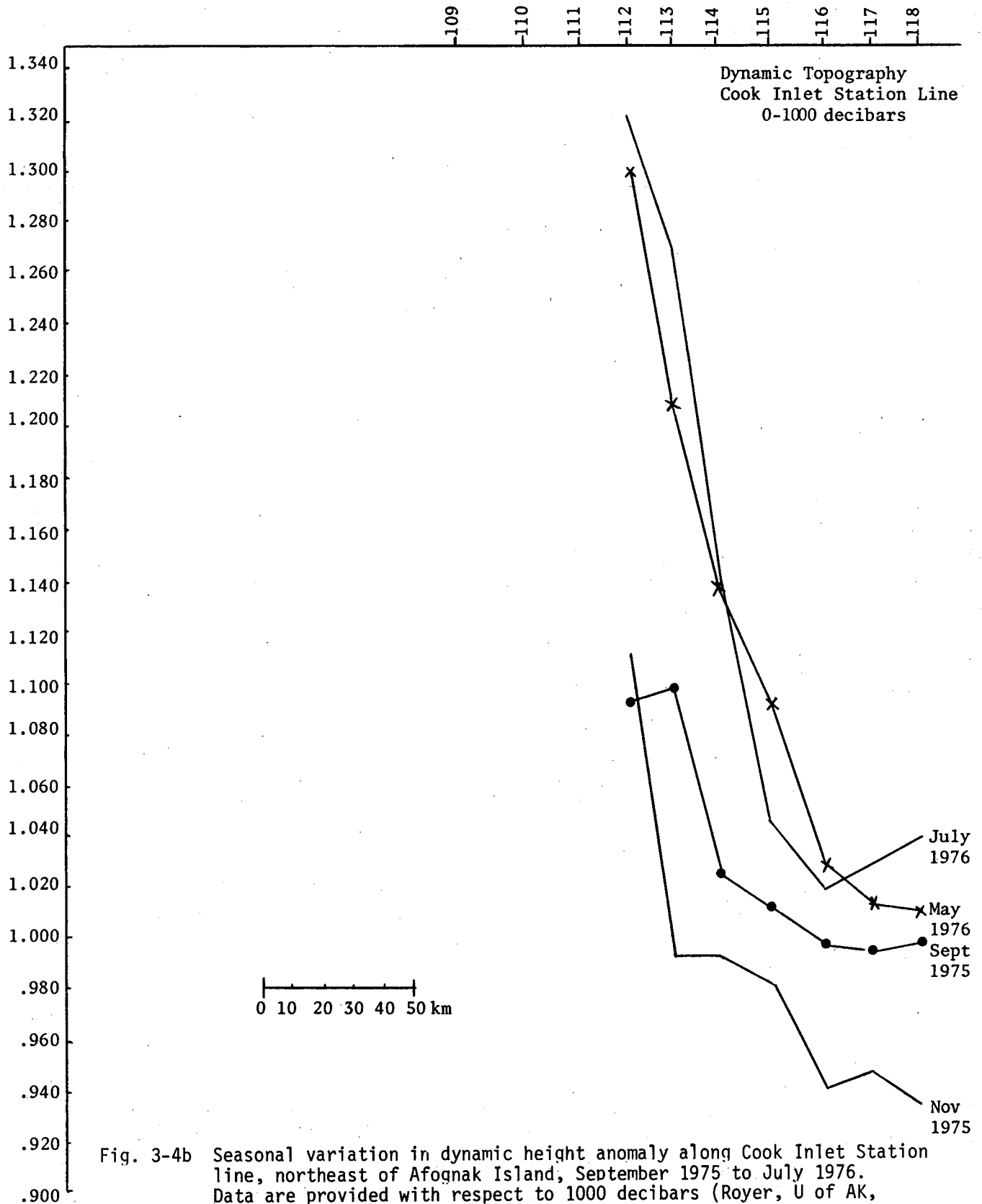


Fig. 3-4b Seasonal variation in dynamic height anomaly along Cook Inlet Station line, northeast of Afognak Island, September 1975 to July 1976. Data are provided with respect to 1000 decibars (Royer, U of AK, Fairbanks, personal communication).

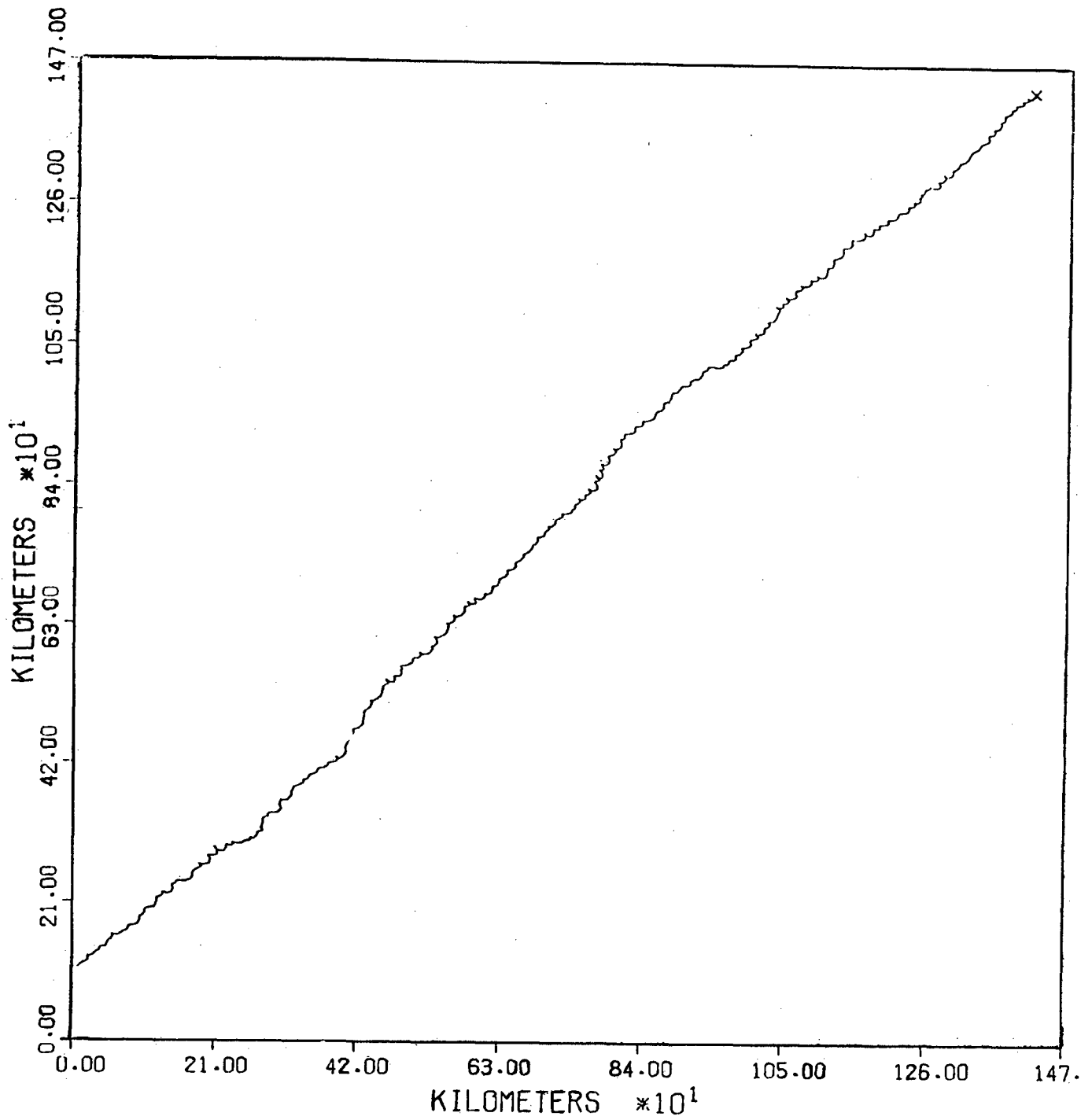


Fig. 3-5 PVD constructed from current measurement data from station WGC-2, September-November 1975. Mean flow is directed at 229° (TN). Figure reproduced from Hayes and Schumacher (1976).

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)

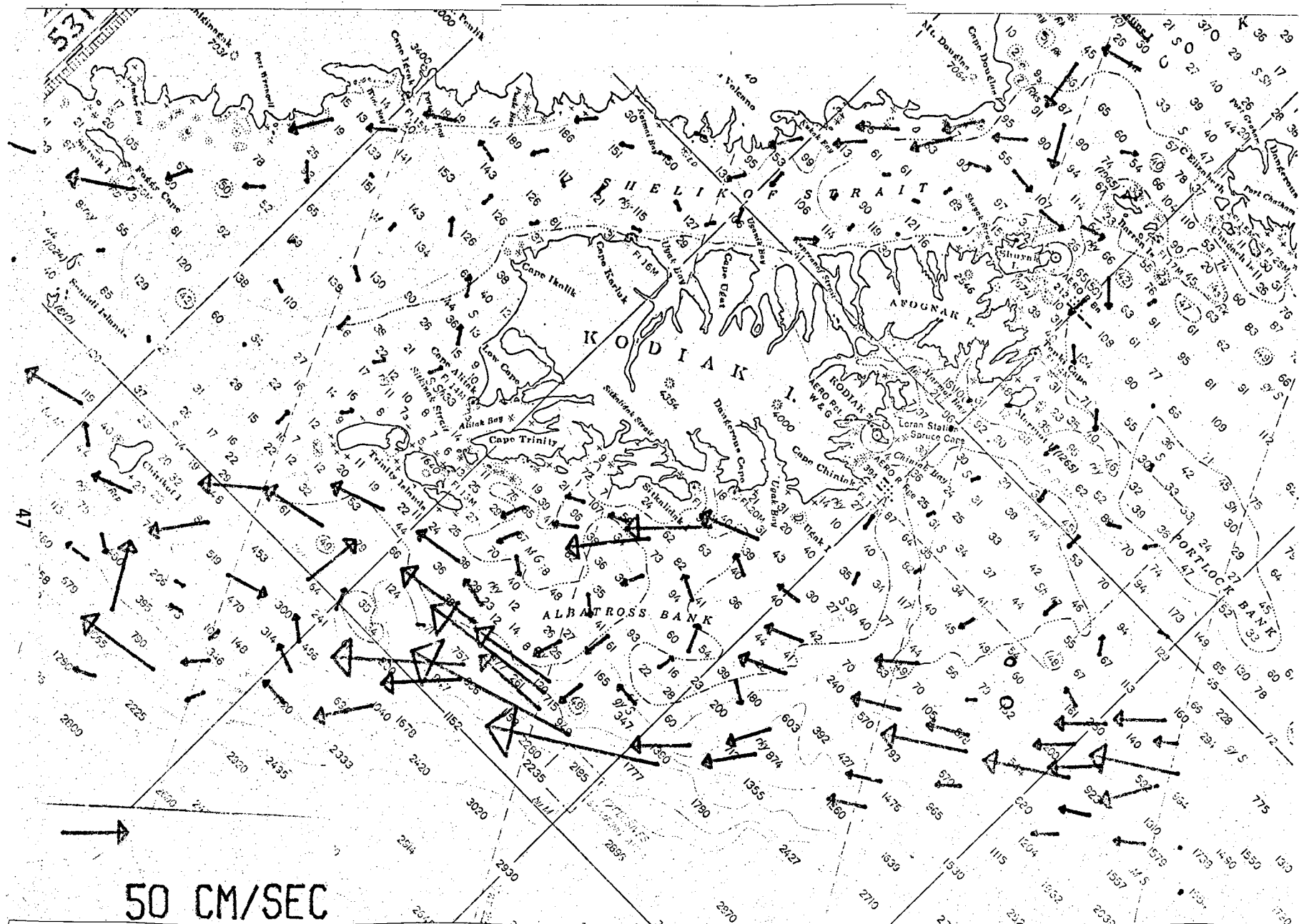
	Current Meter Depth	
	20 m	80 m
Current meter number	1678	1455
Mean speed	34.67 cm/sec	20.26 cm/sec
Net drift	3.11 cm/sec (245 ⁰ T)	1.10 cm/sec (178 ⁰ T)
U variance	631	177
V variance	780	337

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/m²/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/m³ (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 cm³/1000 m³. Higher values, 400 cm³/1000 m³, were noted in waters north of Afognak Island. These data are for summer only and are based on very few samples.



50 CM/SEC

Fig. 3-11b Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 4 dynes/cm². Results are provided for bottom current patterns (Galt, 1976).

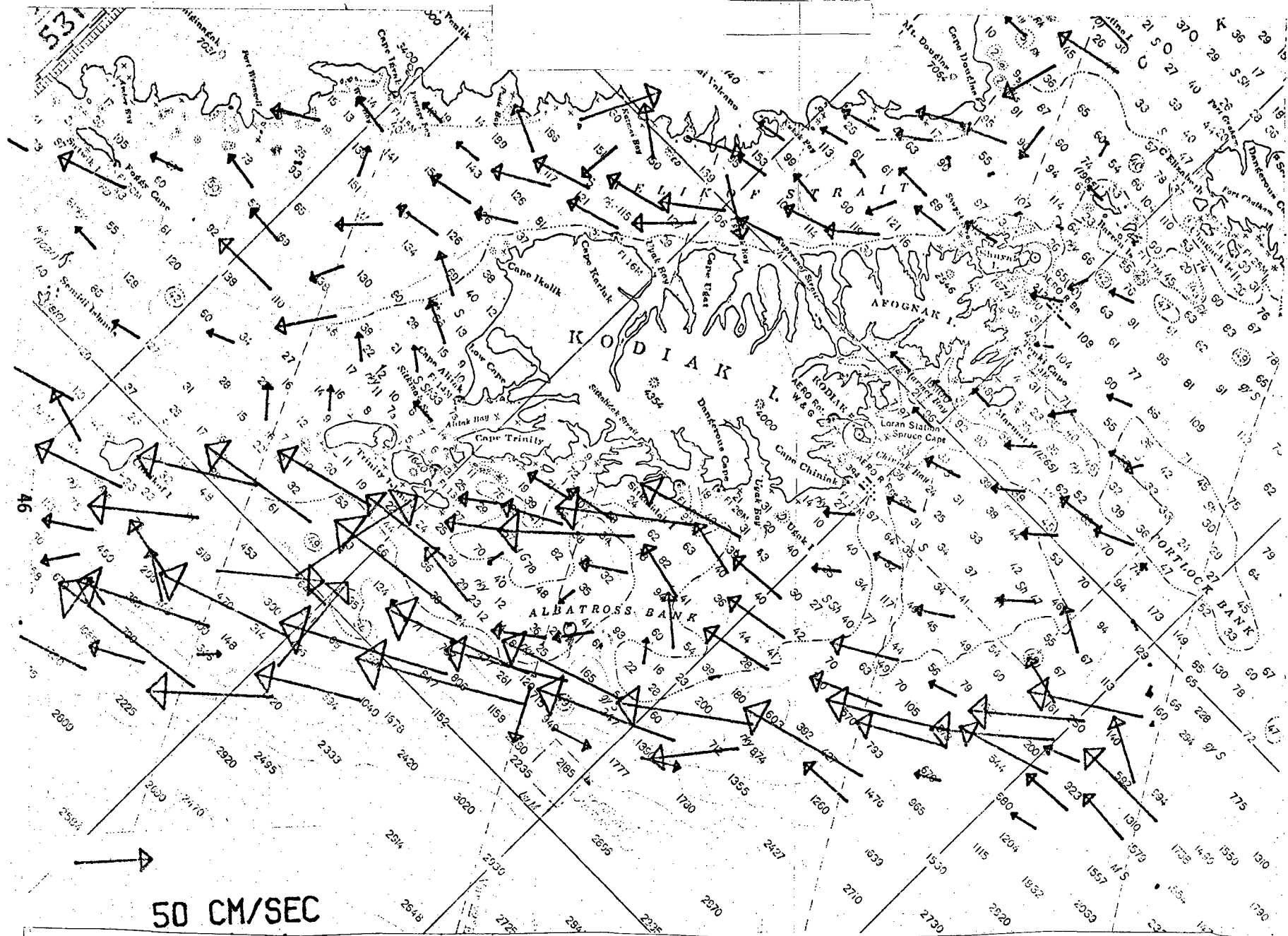


Fig. 3-11a Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 4 dynes/cm². Results are provided for surface current patterns (Galt, 1976).

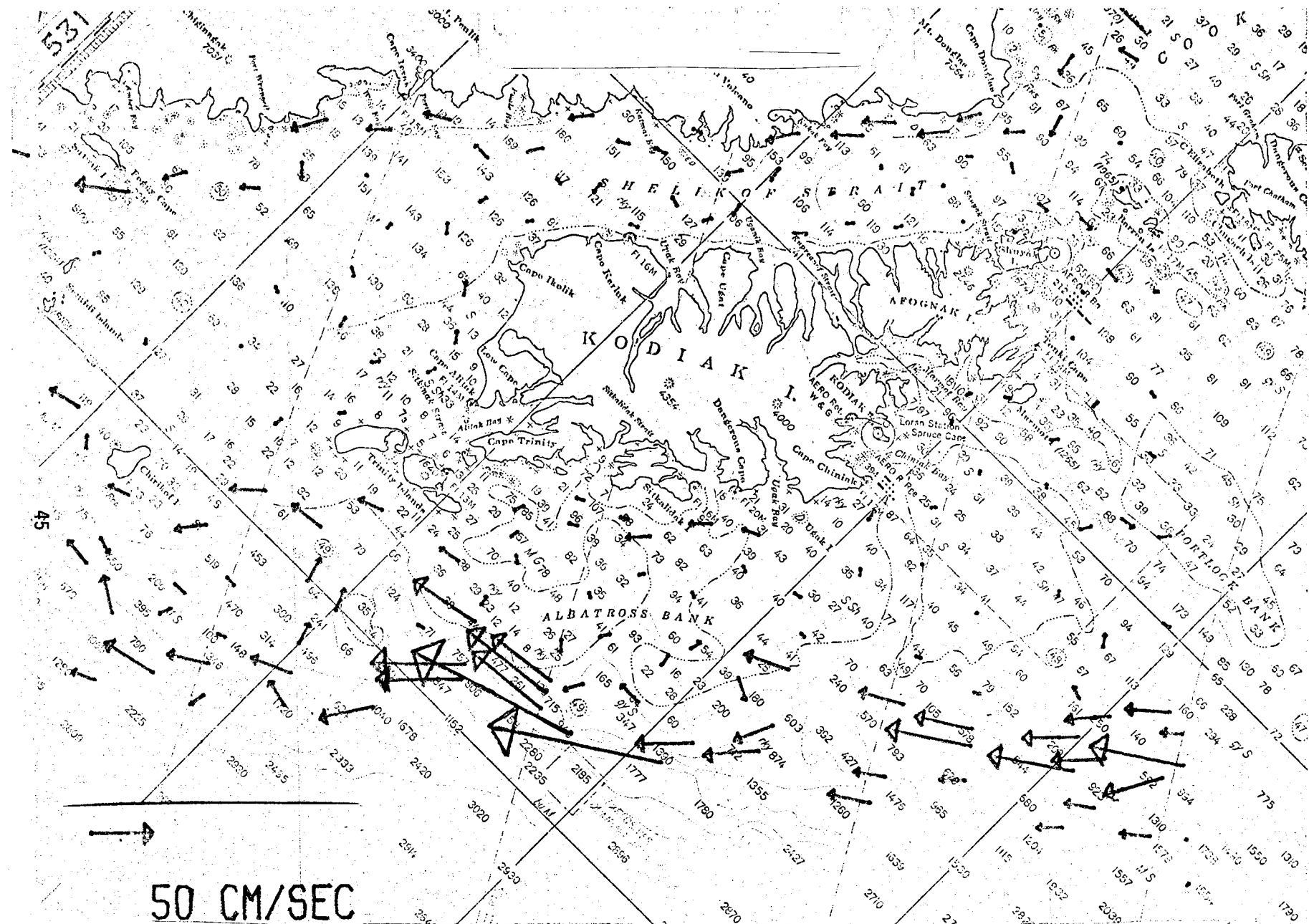
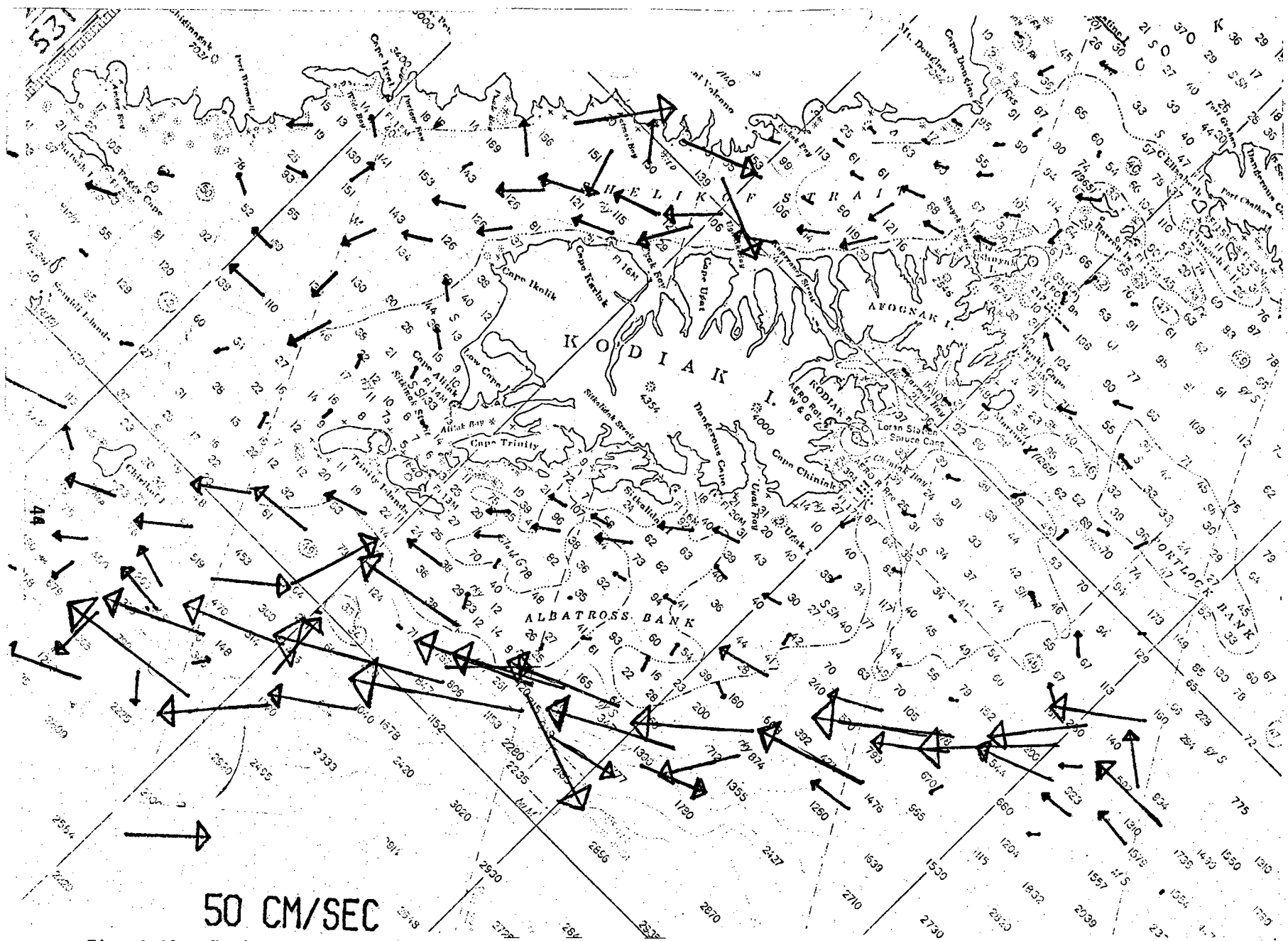


Fig. 3-10b Estimated current field from diagnostic modeling based on spring 1976 data. Surface wind stress is 1 dyne/cm^2 . Results are provided for bottom current patterns (Galt, 1976).



50 CM/SEC

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.

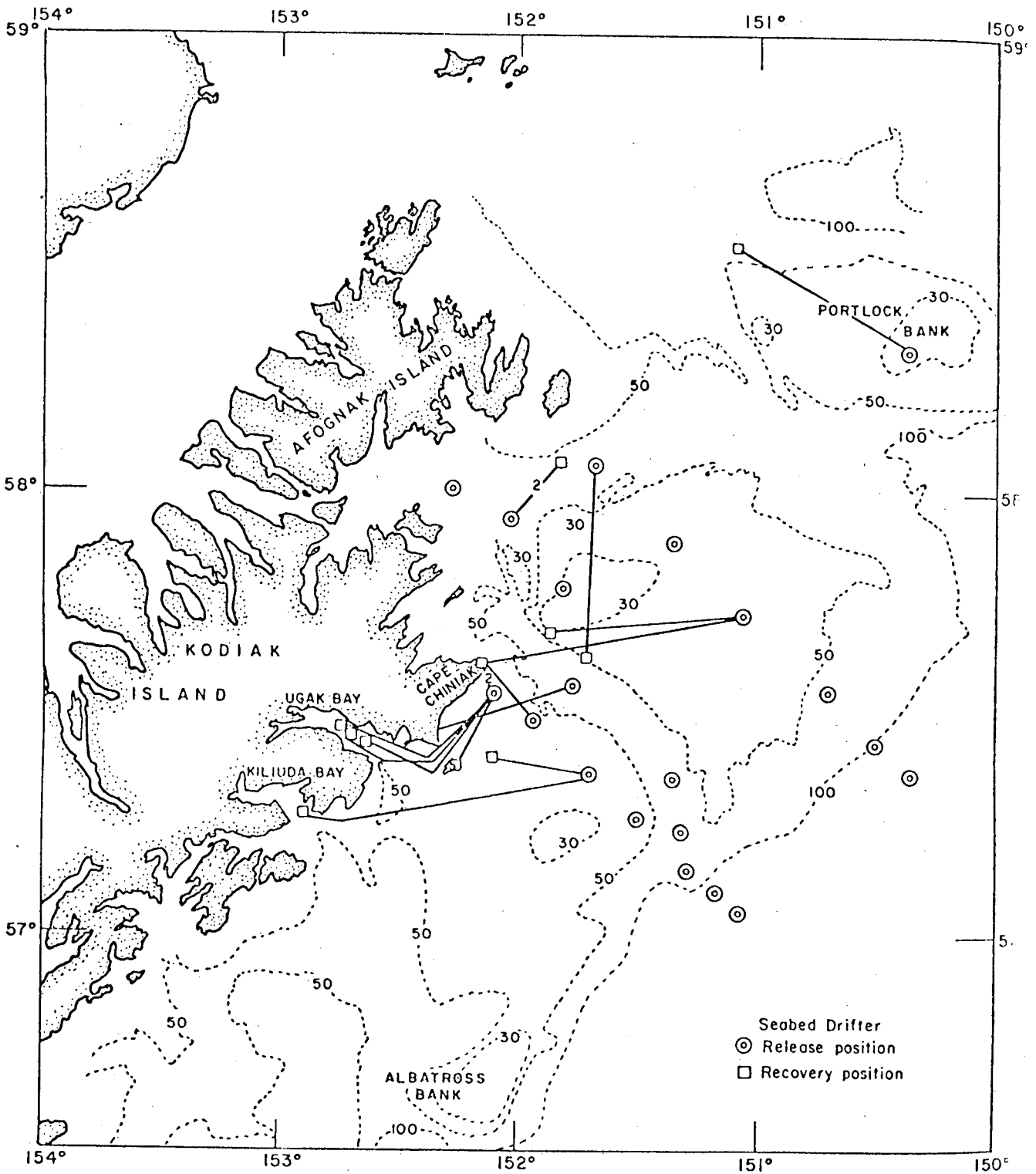


Fig. 3-9 Locations of sea-bed drifter releases and recoveries (depth contours in fathoms) (from Ingraham and Hastings 1974).

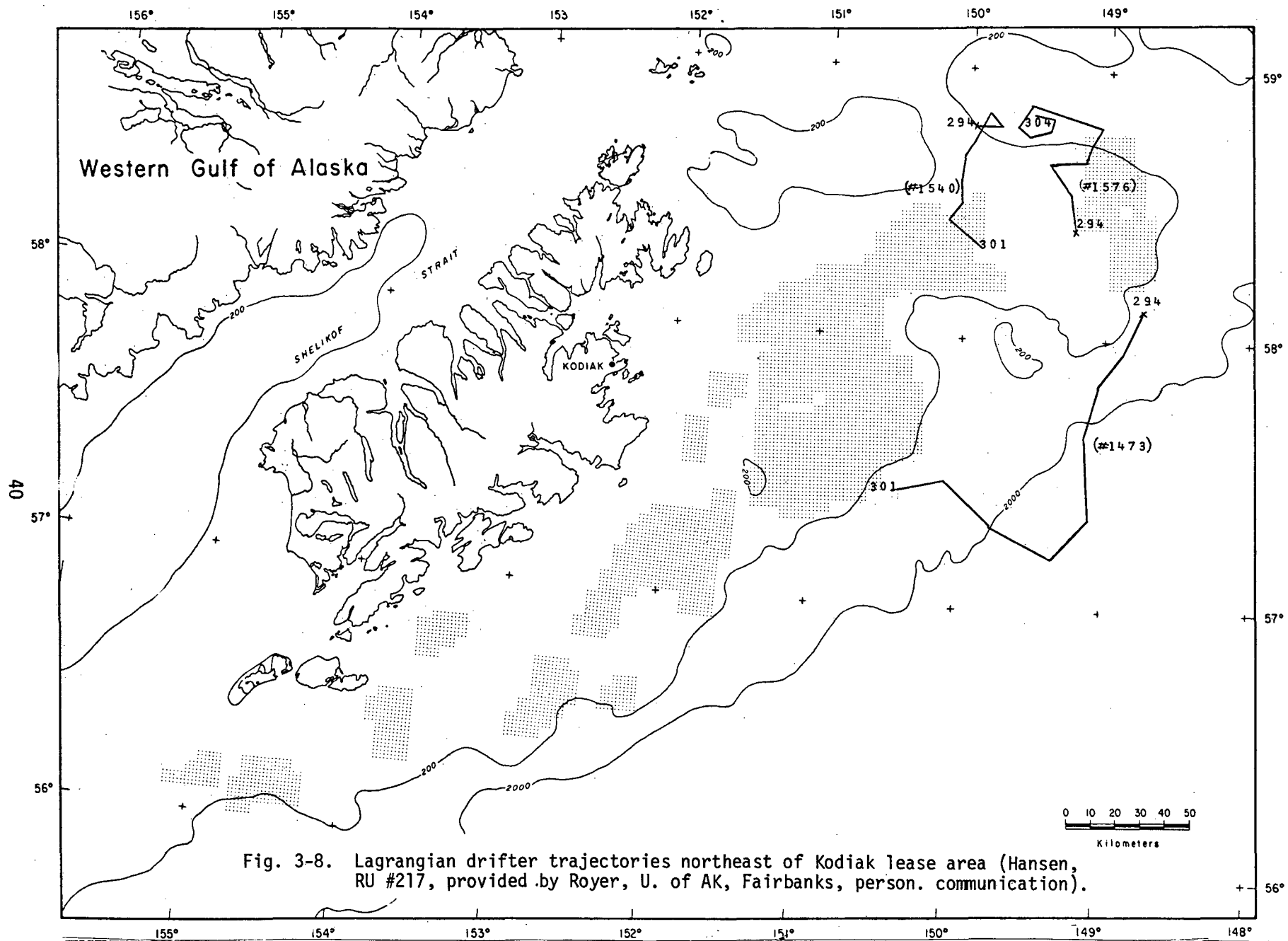


Fig. 3-8. Lagrangian drifter trajectories northeast of Kodiak lease area (Hansen, RU #217, provided by Royer, U. of AK, Fairbanks, person. communication).

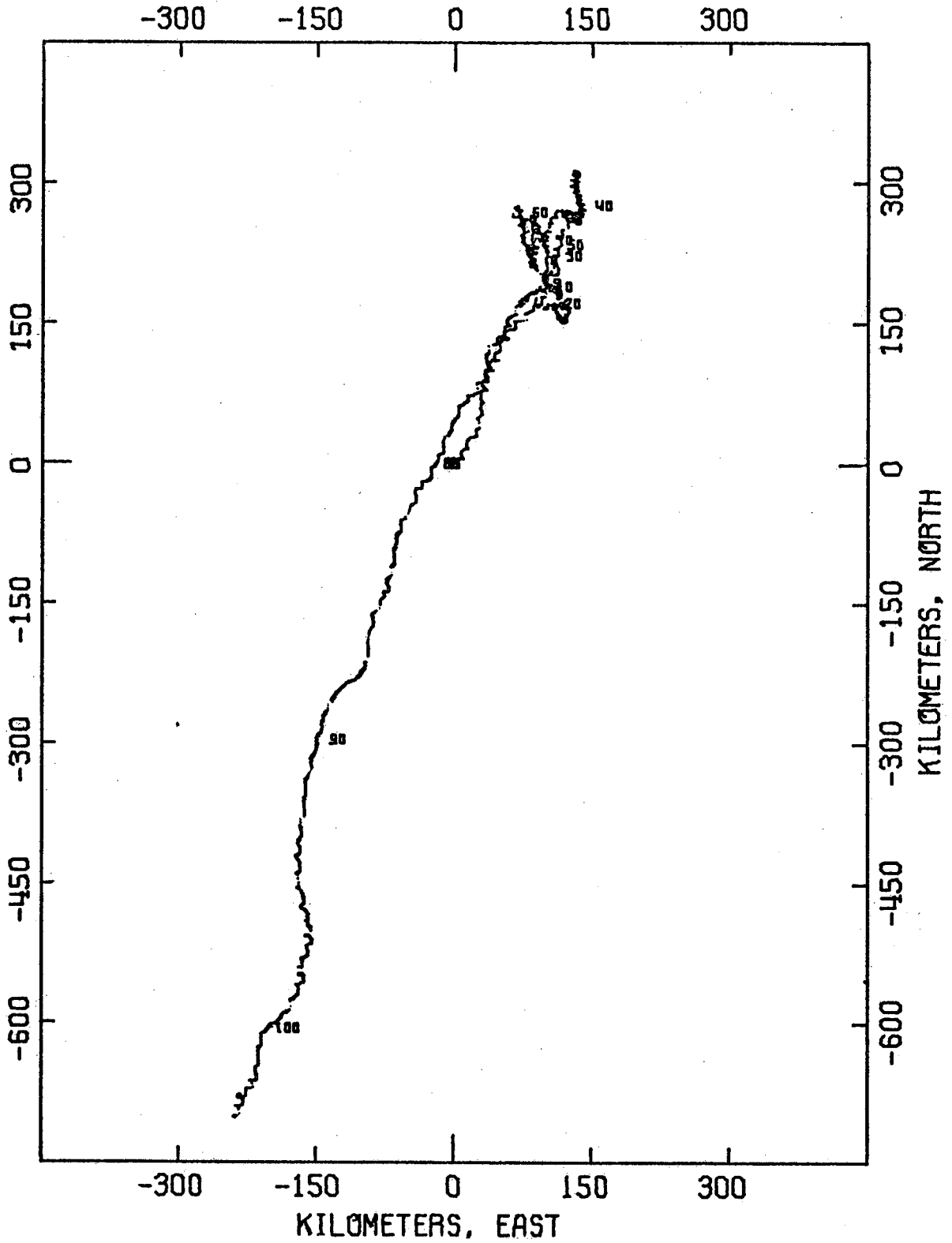


Fig. 3-7b Progressive vector diagram constructed from current meter data obtained at Seward line Station 9 (GASSE 9) from July to November 1976. Data are from current meter moored at about 20m below the surface (Royer, U of AK, Fairbanks, personal communication).

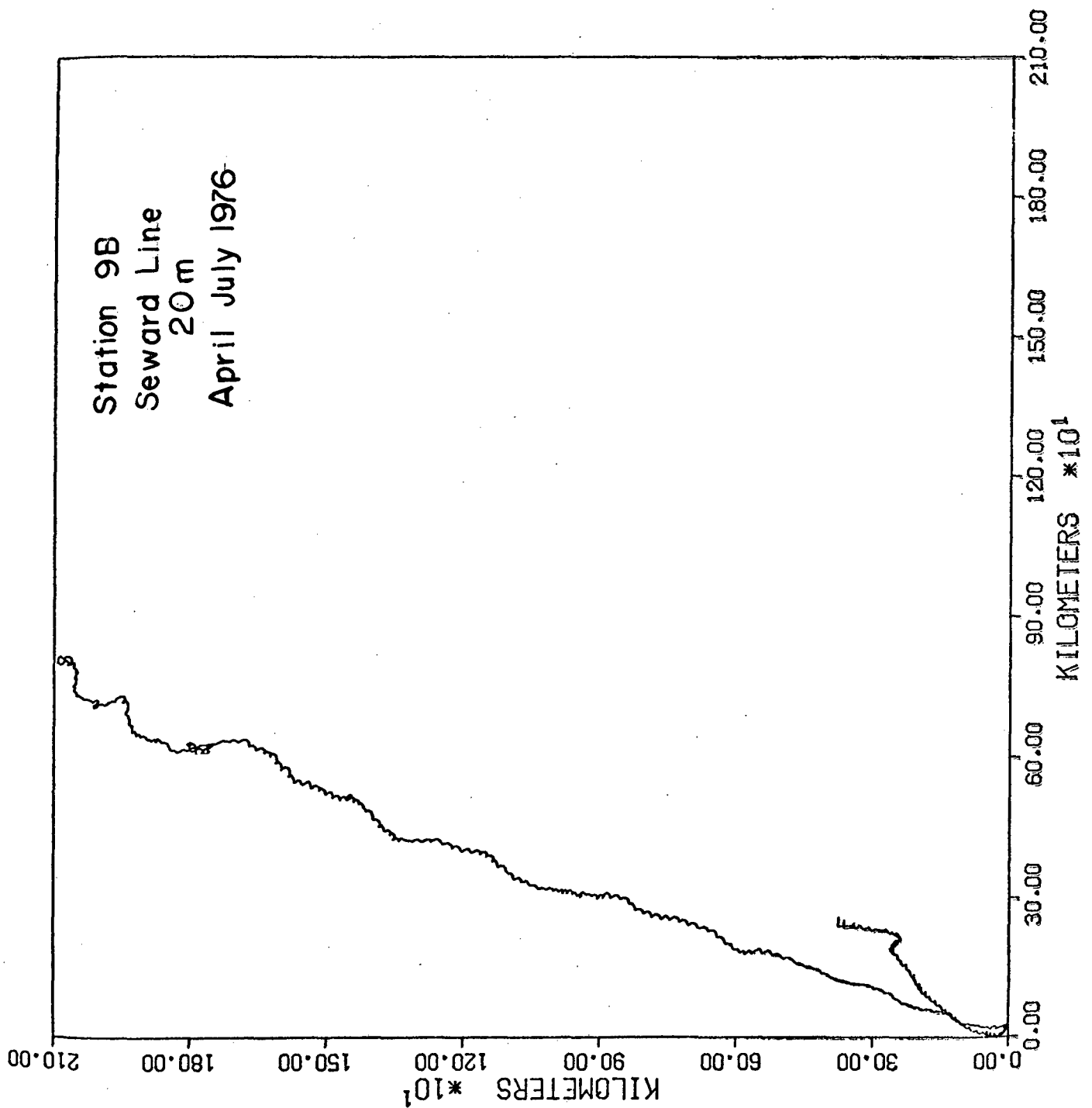


Fig. 3-7a Progressive vector diagram constructed from current meter data obtained at Seward line Station 9 (GASSE 9) from April to July 1976. Data are from current meter moored at about 20m below the surface (Royer, U of AK, Fairbanks, personal communication).

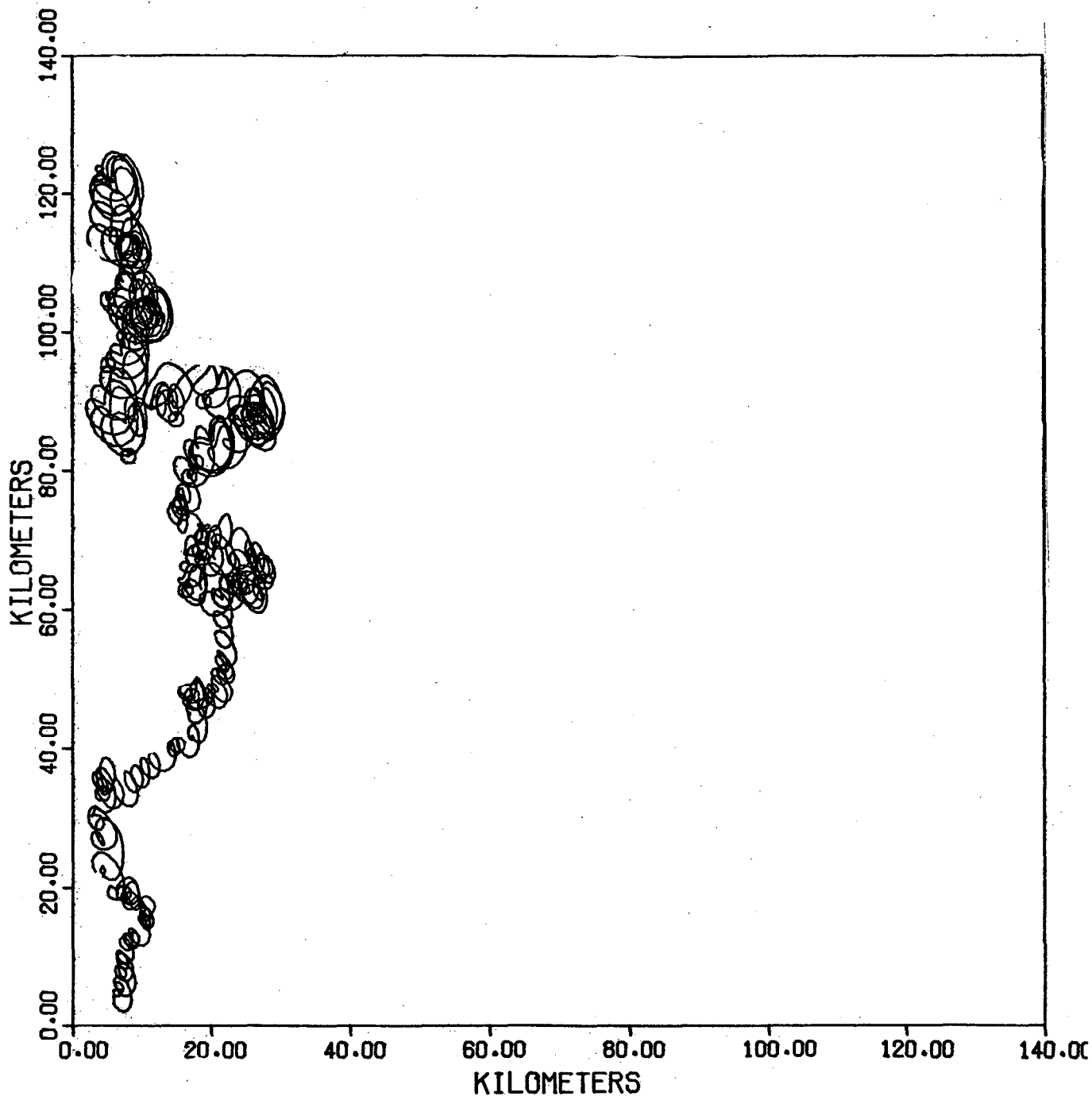


Fig. 3-6b Progressive vector diagram constructed from current meter data obtained over the shelf, depth of water 92m, from June to October 1976. Data are provided for current meter moored at depth 80m below the surface (Hayes and Schumacher, 1976).

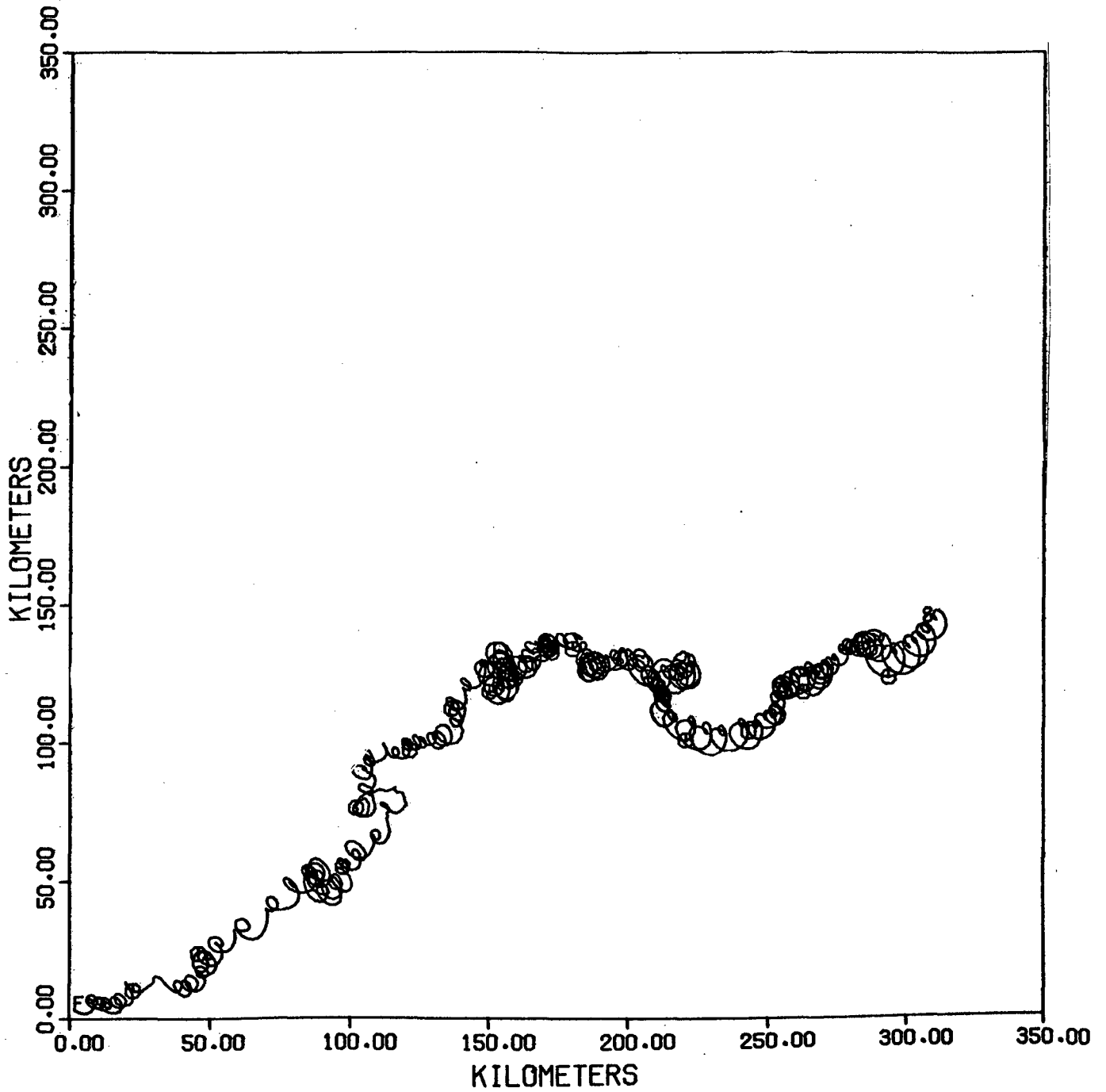


Fig. 3-6a Progressive vector diagram constructed from current meter data obtained over the shelf, depth of water 92m, from June to October 1976. Data are provided for current meter moored at depth 20m (Hayes and Schumacher, 1976).

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

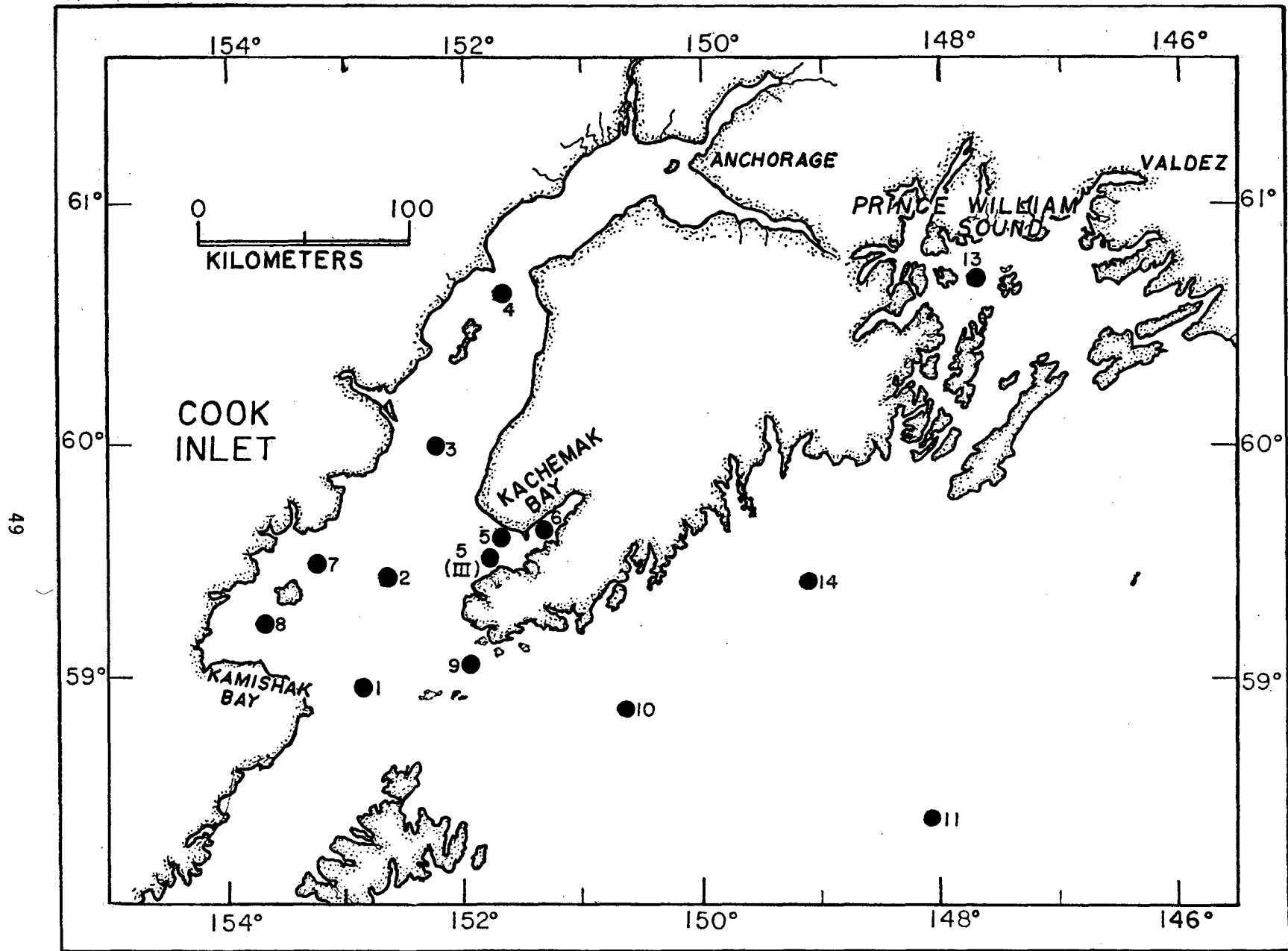


Fig. 3-12 Plankton sampling localities, April to August 1976 (Larrance, 1976).

TABLE 3-2

Data on Chlorophyll a Concentration, mg/m^2 in the upper 50 m, Primary Productivity, $\text{mgC}/\text{m}^2/\text{day}$ 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/m²) 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 ml/m³ 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 ml/m² in early April to 1260 ml/m² in early July.

Holozooplankton of the western Gulf are presumed to represent populations and communities continuous with those of NEGQA. 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 NEGQA lease area is reproduced here for information pertinent to the Kodiak lease area (Table 3-4, from OCSEAP/SAI NEGQA 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					
<i>Acartia longiremis</i>	Surface to 50 m	Near shore & shelf regimes	Summer & Fall	Feeding & reproduction	Plant cell grazer - could ingest oil particles
<i>Pseudocalanus</i> spp.	"	"	"	"	"
<i>Oithona similis</i>	"	All regimes	Fall & Winter	"	"
<i>Oithona spinirostris</i>	Probably same as <i>O. similis</i>	shelf, slope open ocean	Fall	"	"
<i>Metridia lucens</i> *	Surface to 100 m	All regimes	Spring & Summer	"	"
<i>Calanus plumohrus</i>	Surface to 500 m	All regimes	Spring	Feeding during late winter-summer	"
<i>Calanus cristatus</i>	Below 50 m	Shelf, slope open ocean	Spring	"	"
<i>Calanus pacificus</i>	(not known)	Slope & open ocean	Fall	Feeding & reproduction	"
<i>Eucalanus bungii bungii</i>	Below 50 m	"	Spring & Summer	"	"
53 CILIAETOGNATHIA					
<i>Sagitta elegans</i>	Surface to 100 m	No preference	Fall	"	Feeding on microzooplankton possible food-web incorporation of petroleum fractions, or disruption
<i>Eukrohnia hamata</i>	Below 50 m	Slope & open ocean	Winter & Spring	"	
AMPHIPODA					
<i>Parathemisto pacifica</i> *	Below 50 m	Shelf, slope, open ocean	Fall	"	"
EUPHAUSIACEA					
Euphausiid larvae	Surface to 50 m	All regimes	Spring	Feeding	Plant cell grazer - could ingest oil particles
<i>Euphausia pacifica</i> *	Below 50 m	Slope	Winter	Feeding & reproduction	Plant cell and microzooplankton feeder - could ingest oil
<i>Thysanoessa longipes</i> *	"	"	Winter & Spring	"	
DECAPODA					
Snow crab larvae	Surface to 50 m	Nearshore &	Spring	Feeding	"
HYDROZOA					
<i>Aglantha digitale</i>	Upper 50 m	No preference	Winter & Spring	Feeding & reproduction	"

*Denotes diel migrator where known.

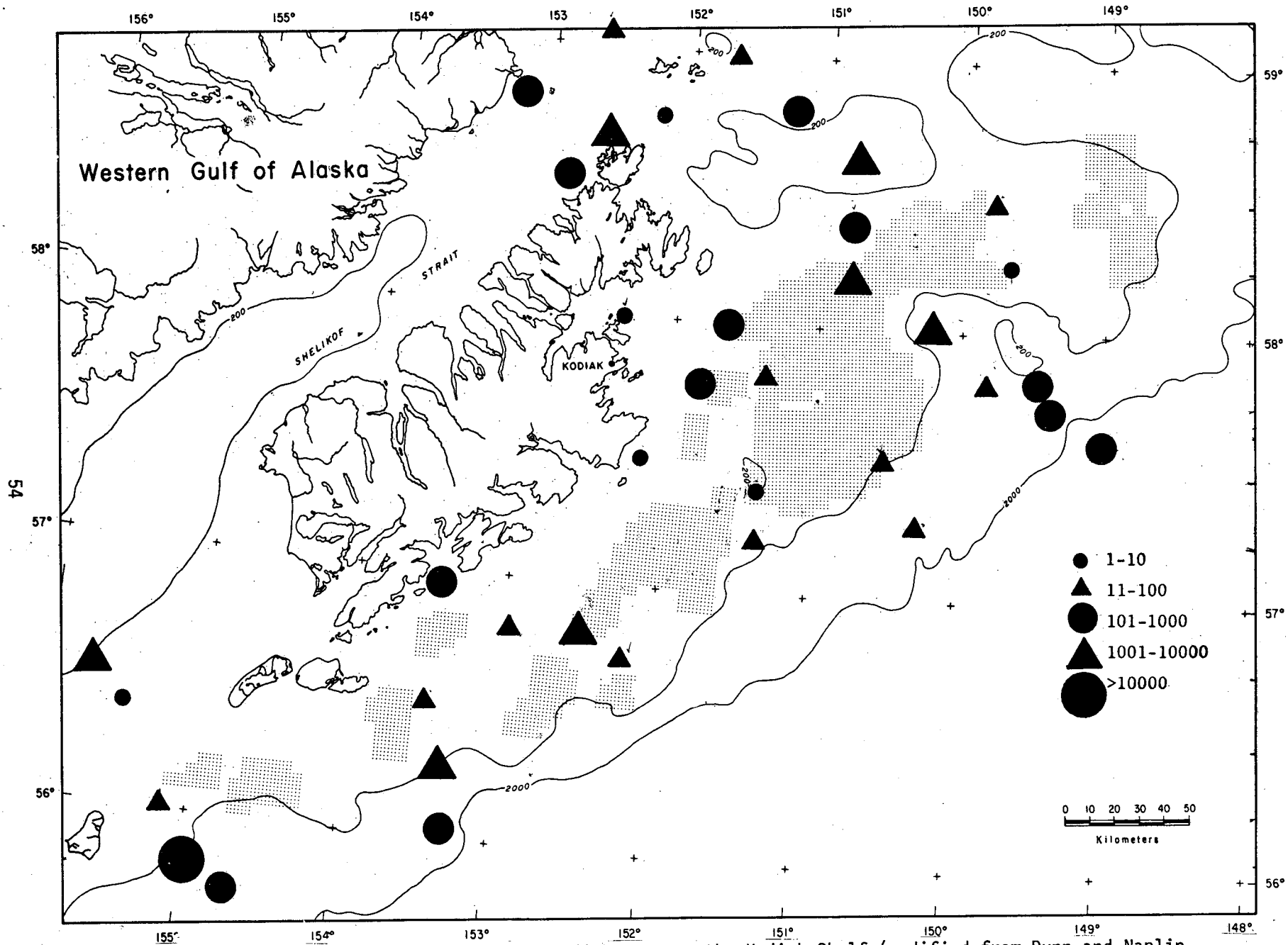


Fig. 3-13 Relative abundance and distribution of fish eggs on the Kodiak Shelf (modified from Dunn and Naplin, 1974).

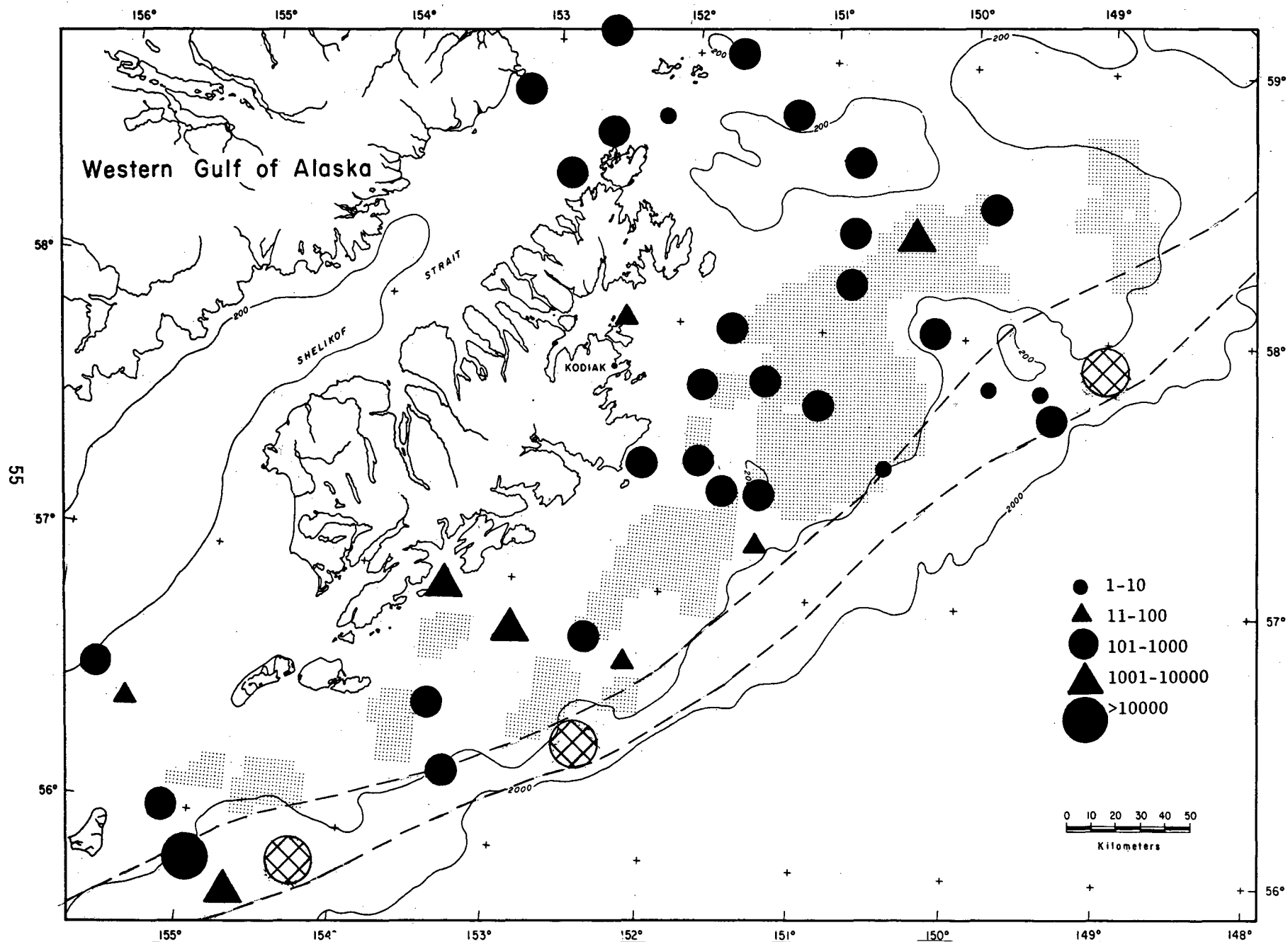


Fig. 3-14 Relative abundance and distribution of fish larvae on the Kodiak Shelf (modified from Dunn and Naplin, 1974; ADF&G 1977).

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).

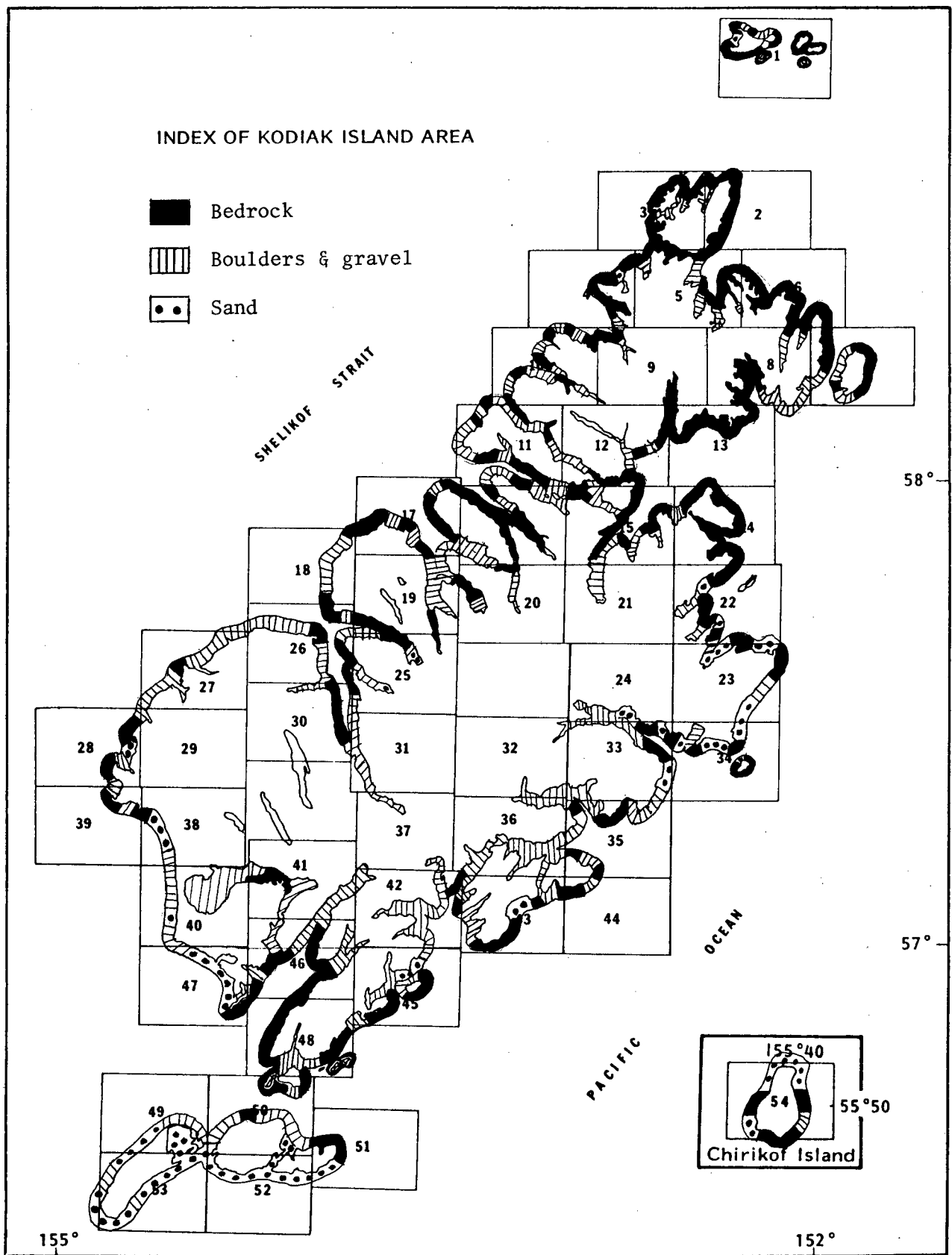


Fig. 3-15 Kodiak Island Area intertidal zone: major substrate types. [Numbers refer to plates in NMFS Aerial Atlas of the Alaskan Intertidal Zone (after Zimmerman and Merrell, 1977a and 1977b)].

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	<i>Prasiola meridionalis</i> (A) <i>Porphyra</i> sp. (A) <i>Littorina sitkana</i> (G)
Littoral Zone (2A,B,C)	MHHW MHW	+ 8-10	Barnacle-Endocladia Zone	Diatom Colonies (A) <i>Endocladia muricata</i> (A) sterile <i>Fucus distichus</i> (A) <i>Acmea digitalis</i> (G) <i>Cthamalus dalli</i> (B) <i>Balanus glandula</i> (B) <i>Littorina sitkana</i> (G)
	MHW MTL	+ 4- 8	Fucus Zone	fertile <i>Fucus distichus</i> (A) <i>Halosaccion glandiforme</i> (A) <i>Odonthalia floccosa</i> (A) <i>Balanus cariosus</i> (B) <i>Mytilus edulis</i> (P) <i>Nucella lima</i> , <i>N. lamellosa</i> (P)
	MTL MLLW	0- 4	Rhodymenia Zone	<i>Rhodymenia palmata</i> (A) <i>Ulva</i> sp. - <i>Monostroma</i> sp. <i>Balanus cariosus</i> (B) <i>Katherina tunicata</i> (C) <i>Cucumberia pseudocurata</i> (S)
Infralittoral Fringe (3A,B)	MLLW Lowest Low Water	- 2- 0	Alaria Zone	<i>Alaria</i> spp. (A) <i>Lithothamnion</i> sp. (A) <i>Ptilota filicina</i> (A) <i>Crisia</i> sp. - <i>Filicrisia</i> sp. (E) <i>Halichondria panicea</i> (Sp) <i>Tonicella lineata</i> (C)
		- 2	Laminaria Zone	<i>Laminaria</i> spp. (A) <i>Laminaria dentigera</i> (A) <i>Lithothamnion</i> sp. (A) <i>Corrallina</i> sp. (A) <i>Acmea mitra</i> (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 Stephenson's 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*, *Pleurophyucus gardneri*, *Agarum cribrosum*, and *Alaria* spp. (Floating kelps, *A. fistulosa* and *Nereocystis luetkeana*, were excluded from these samples.)

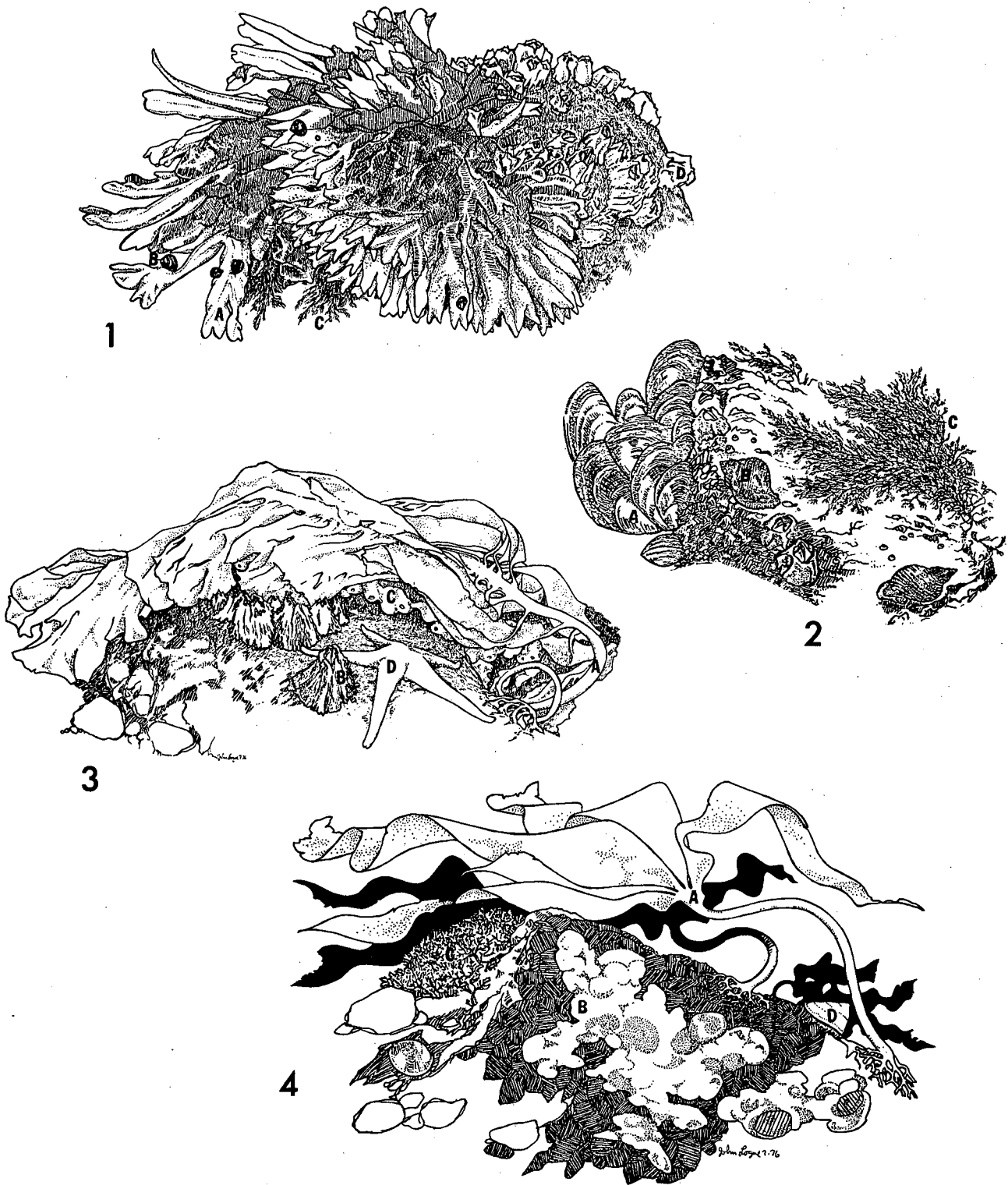


Fig. 3-16 Kodiak rocky coast, character species of: (1) the upper and middle intertidal zones, A. *Fucus distichus* B. *Littorina sitkana* C. *Odonthalia floccosa* D. *Balanus glandula*; (2) the middle intertidal zone, A. *Mytilus edulis* B. *Nucella lima* C. *Pterosiphonia bipinnata*; (3) the lower intertidal and upper infralittoral zones, A. *Alaria* sp. B. *Balanus cariosus* C. *Halichondria panicea* D. *Henricia 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 grain size (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)	
<i>Siliqua patula</i>	(1280)	<i>Scolelepis squamatus</i>	(2905)
<i>Macoma lana</i>	(257)	<i>Nephtys caeca</i>	(254)
<i>Spisula polynyma</i>	(116)	<i>Nephtys californiensis</i>	(155)
<i>Siliqua alta</i>	(63)	<i>Haploscoloplos elongatus</i>	(181)
<i>Clinocardium nuttallii</i>	(30)	<i>Ophelia assimilis</i>	(165)
<i>Macoma balthica</i>	(30)	<i>Eteona longa</i>	(18)
<i>Mya arenaria</i>	(20)	<i>Glycinde picta</i>	(14)
<i>Telina lutea altermidenta</i>	(20)	<i>Anaites groenlandica</i>	(10)
<i>Macoma yoldiformis</i>	(8)	<i>Nephtys ciliata</i>	(3)
<i>Macoma nasuta</i>	(3)	<i>Cistemides brevicoma</i>	(4)
<i>Macoma loveni</i>	(2)		
<i>Macoma calcarea</i>	(2)	Nemertea (Ribbon worms)	
<i>Littorina sitkoma</i>	(2)		
<i>Prototheca staminea</i>	(1)	<i>Cerebratulus californionsis</i>	(13)
<i>Tellina nucleoides</i>	(1)	Other Nemerteans	(14)
<i>Tressus capax</i>	(1)		

TABLE 3-7

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

Species	SEASON			
	Winter	Spring	Summer	Fall
Pacific Razor Clam (<i>Siliqua patula</i> , <i>S. alta</i>)	AJ	AELJ	AELJ	ALJ
Basket Cockle (<i>Clinocardium nuttallii</i>)	AJ	AJ	AELJ	ALJ
Pinkneck Clam (<i>Spisula polynyma</i>)	AJ	AJ	AELJ	AJ

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

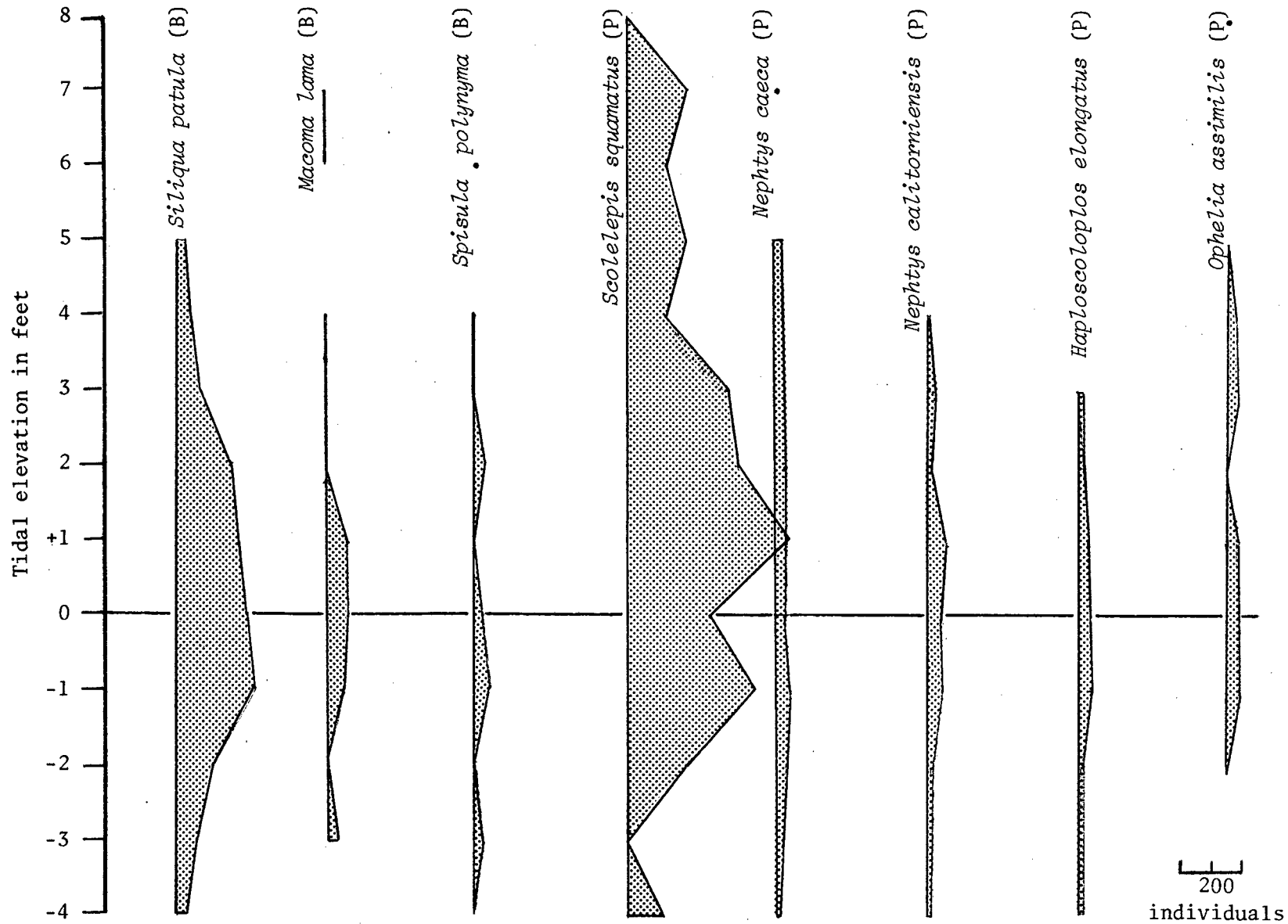


Fig. 3-17 Vertical distribution of abundant sandy beach invertebrates sampled at twelve sites on Kodiak Island and adjacent Alaskan Peninsula. (B=Bivalve; P=Polychaete worm; after Kaiser, 1976).

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.

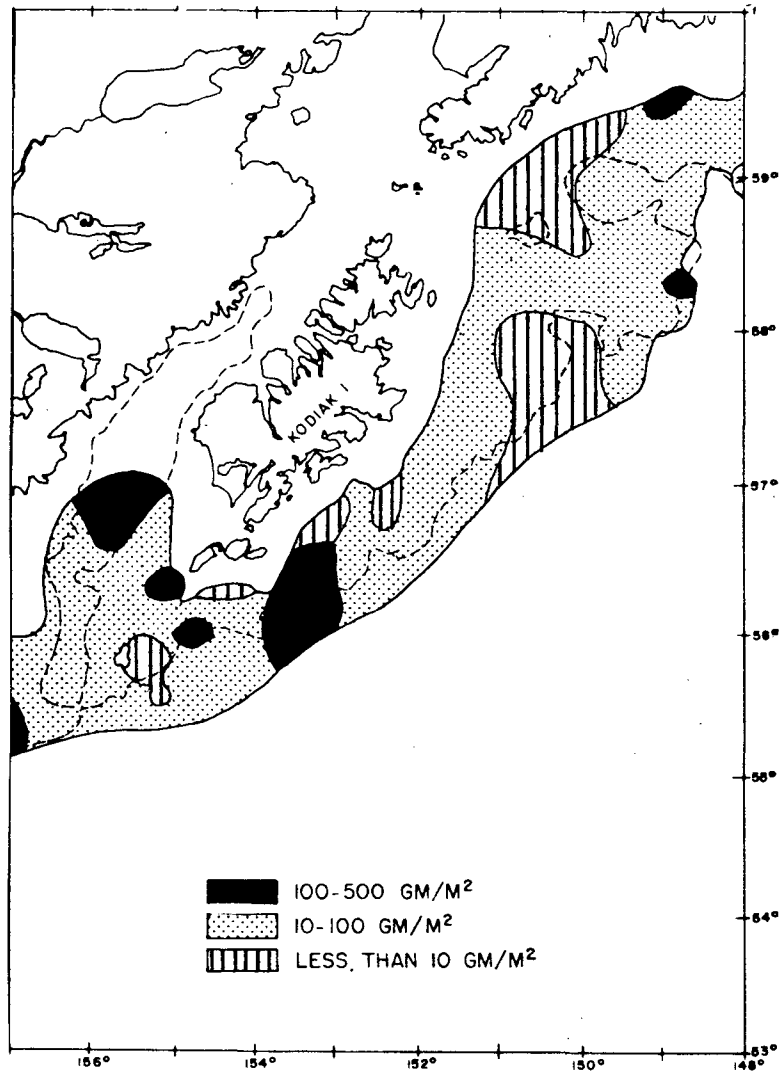
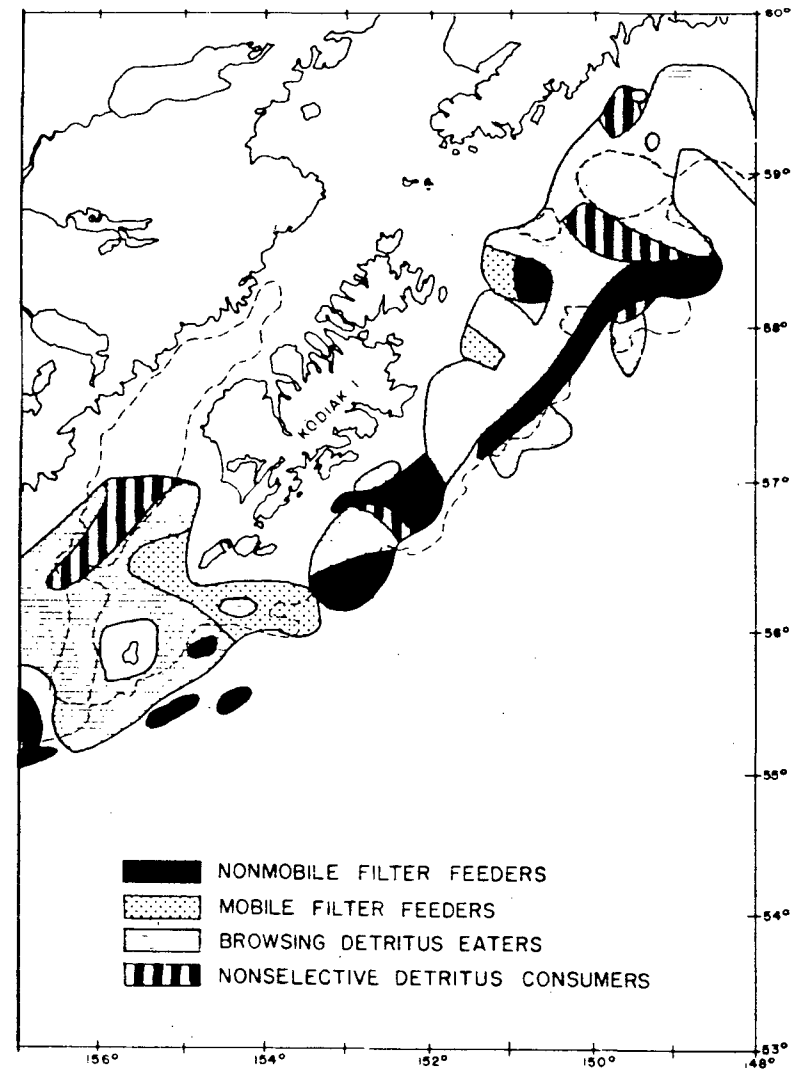


Fig. 3-18. a) Benthic fauna biomass (Shevtsov 1964; Semenov 1965, cited in AEIDC 1974).



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)

<u>Scientific Name</u>	<u>Common Name</u>
Arthropoda: Decapoda	
<i>Cancer magister</i>	Dungeness crab
<i>Chionoecetes bairdi</i>	Tanner (Snow) crab
<i>Paralithodes camtschatica</i>	King crab
<i>Pandalus borealis</i>	Pink shrimp
<i>P. hypsinotus</i>	Coonstripe shrimp
<i>P. goniurris</i>	Humpy shrimp
<i>P. platyceros</i>	Spot shrimp
<i>Pandalopsis dispar</i>	Sidestripe shrimp
Mollusca: Pelecypoda	
<i>Patinopecten caurinus</i>	Weathervane scallop

TABLE 3-10

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

<u>Species</u>	<u>SEASON</u>			
	<u>Winter</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>
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)

Species	Areas/Depth Zones (meters)							
	CHIRIKOF				KODIAK			
	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) (E) (L)	A (E) (L) (J)	A J
Pacific sand lance	A E J	A L J	(A) L (J)	A J
Walleye pollock	A E L	L J	J	J
Lingcod	A (E)		J	
Atka mackerel			A J	
Surf smelt	(A) (E) (L)	(A) (E) (L)	(A) (E) (L)	(A) (E) (L)
Capelin	A	(A) (E) L J	(A) (E) L J	L J
Eulachon	A J	A (J)	A (J)	A J
Pacific halibut			J	
Arrowtooth flounder		L	L	
Yellowfin sole		A L J	A (J)	A (J)
English sole	(A) (E) (L)	L J		
Rock sole		A L J	A (J)	A (J)
Starry flounder	(A) (E) (L)	L J	J	
Flathead sole			J	
Pink salmon	(E) (L)	A E (L) (J)	A (E) (J)	(E) J
Chum salmon	(E) (L)	E (L) (J)	(A) (E) (J)	(E) J
Coho salmon		(J)	(A) (J)	A J
Sockeye salmon		A (J)	(A) (J)	A
Chinook salmon		A (J)	A (J)	J
Steelhead trout		(A) (J)	(A) (J)	A J
Dolly Varden		(A) (J)	(A) (J)	A J
Pacific cod		A L J	A J	
Prowfish	A J	A J	A J	A J
Pacific sandfish	A (E) J	L J	(L) (J)	J
Yellow Irish lord		A L J	A L J	
Great sculpin		A L	A (J)	A (J)
Other sculpins	A J	A L J	A L J	A J
Masked greenling	(A)	(A) J	(A) E L (J)	(A) L (J)

- 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	Late 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

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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

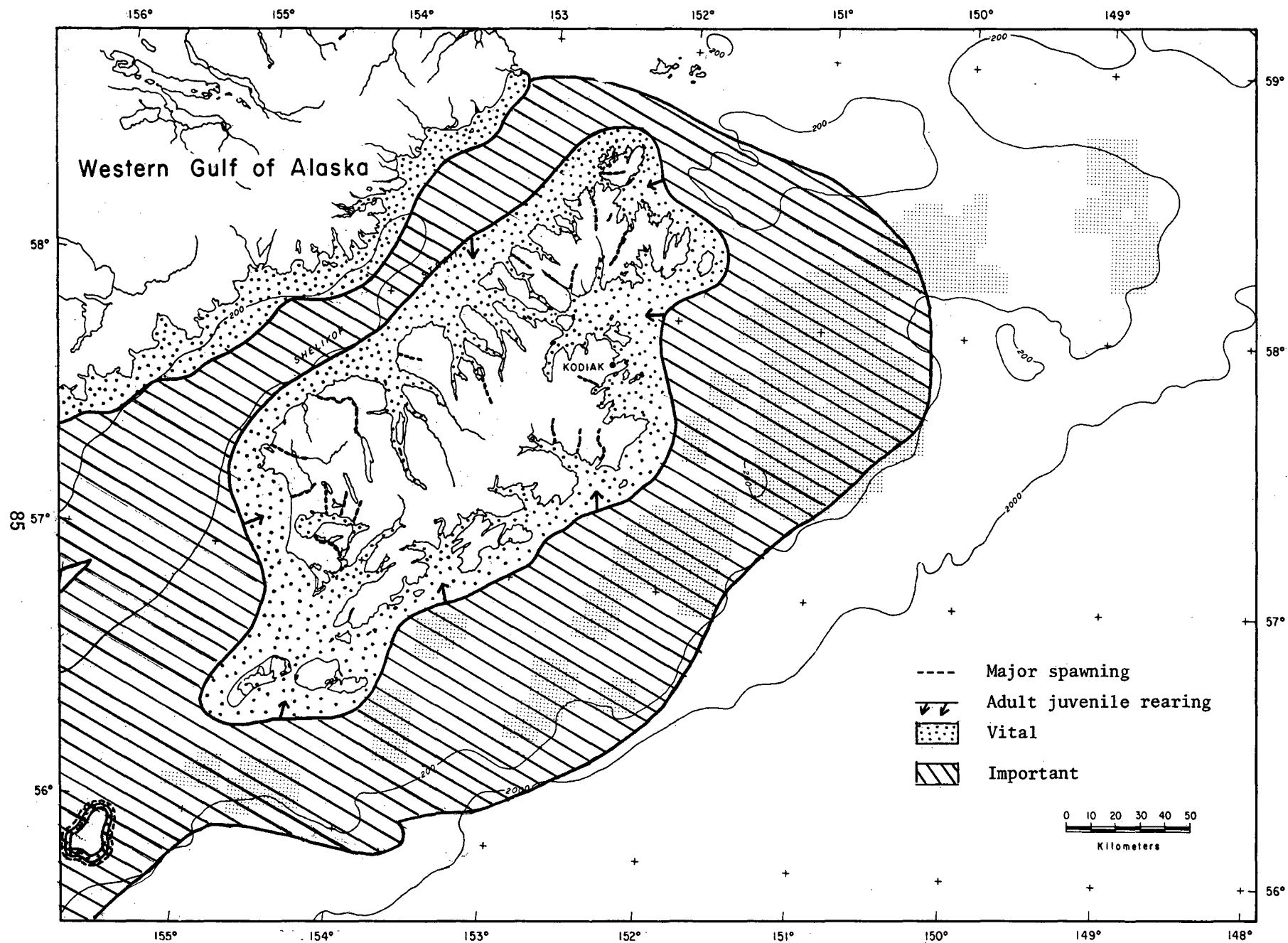


Fig. 3-20 Dolly Varden distribution spawning and rearing (modified from ADF&G, 1976; ADF&G, 1977).

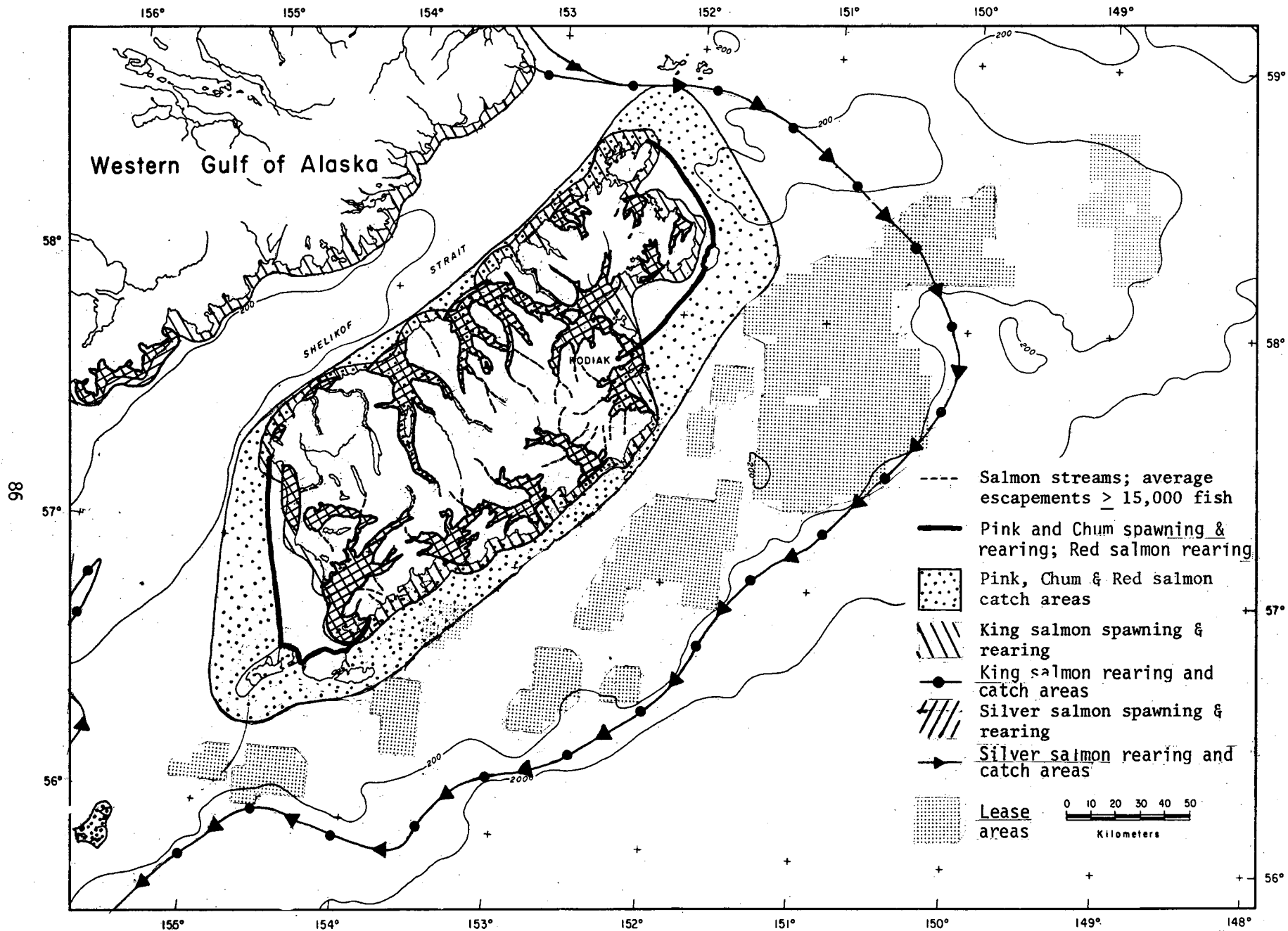


Fig. 3-21 Pacific salmon spawning, nearshore rearing, and commercial harvest areas (modified from ADF&G, 1976; ADF&G, 1977).

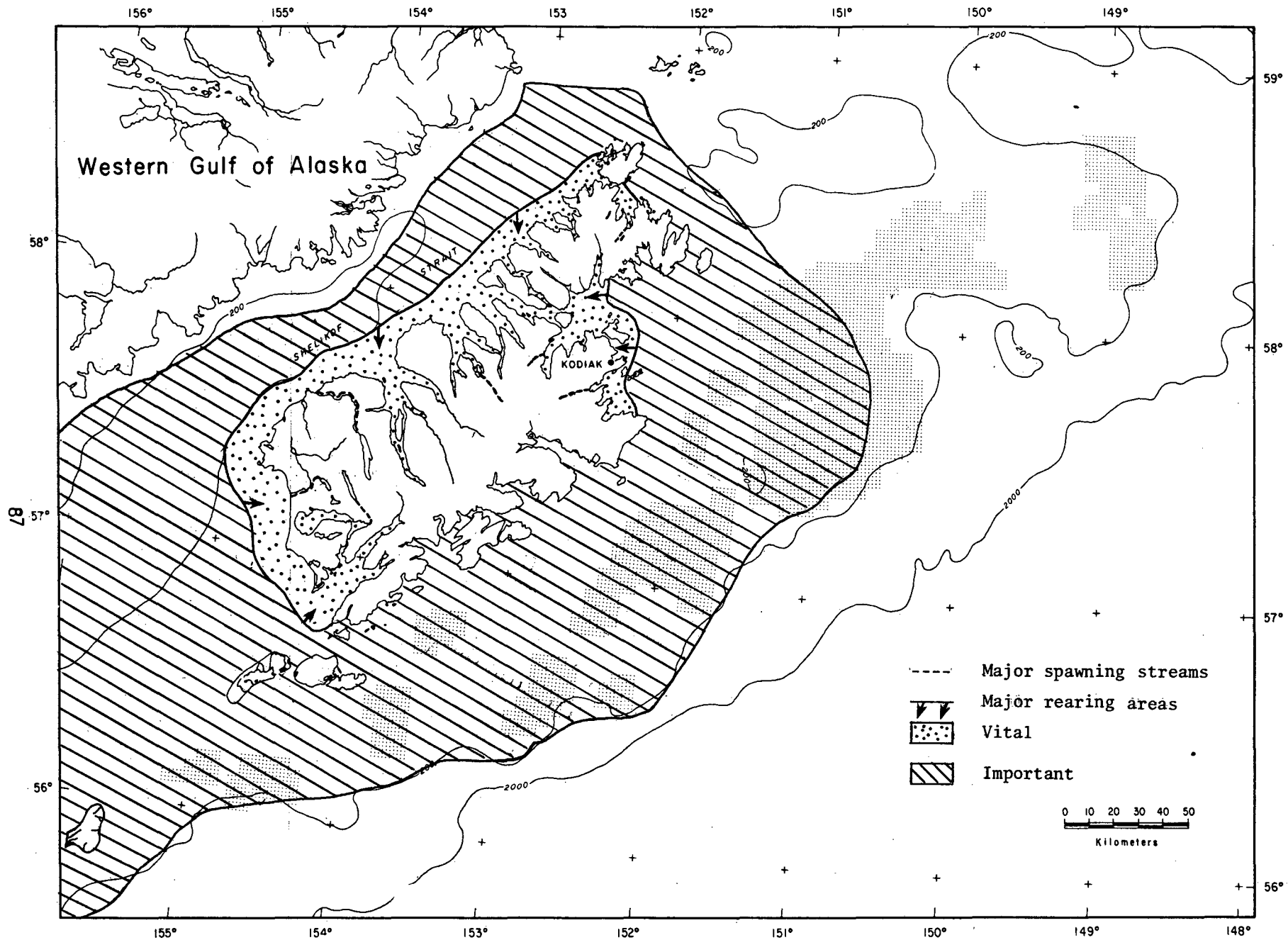


Fig. 3-22 Steelhead distribution spawning and rearing (modified from ADF&G, 1976; ADF&G, 1977).

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 out-migration 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).

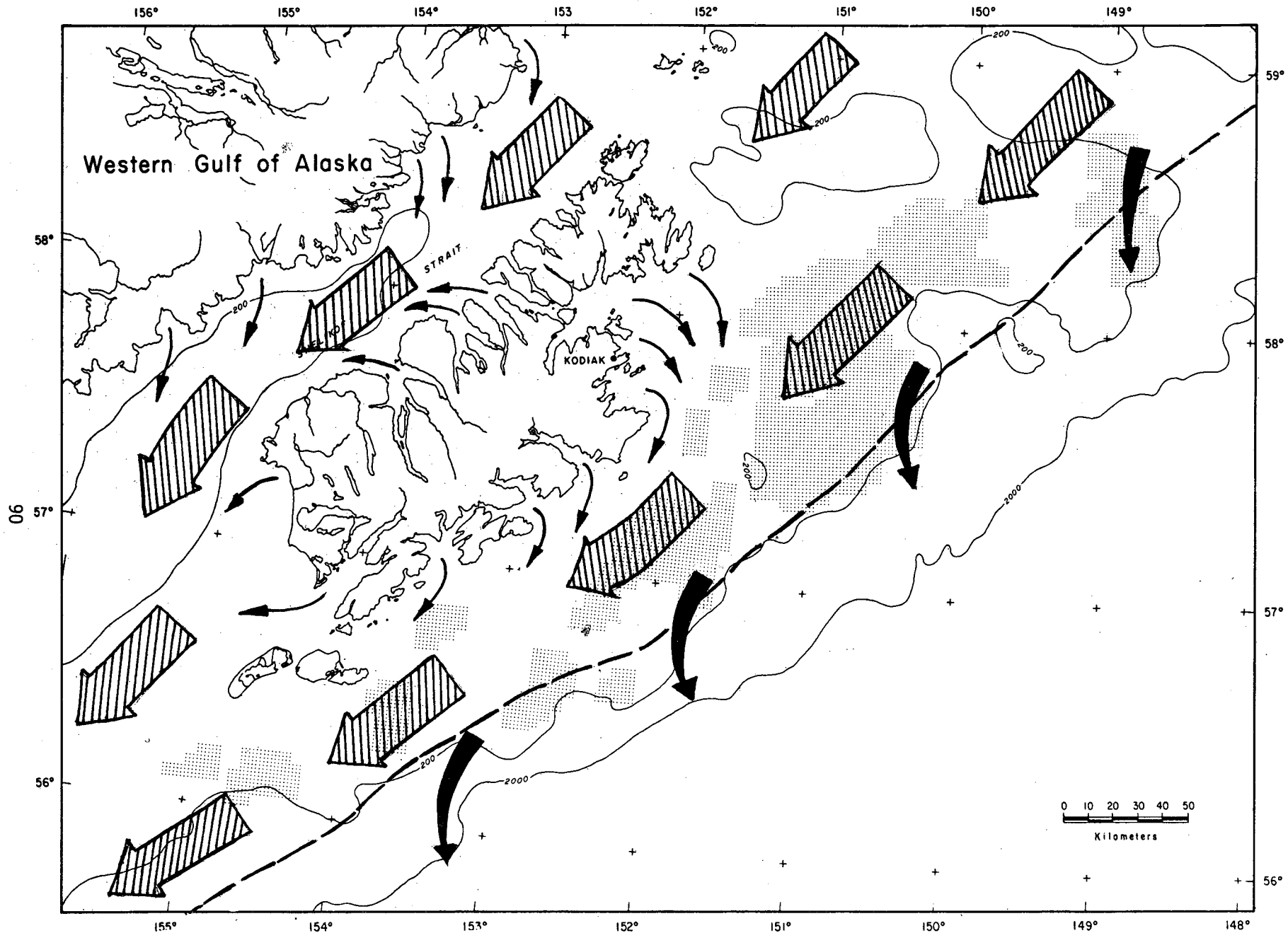


Fig. 3-23 Primary migratory pathway of juvenile salmonoids in the western Gulf of Alaska (modified from Stern et al., 1976).

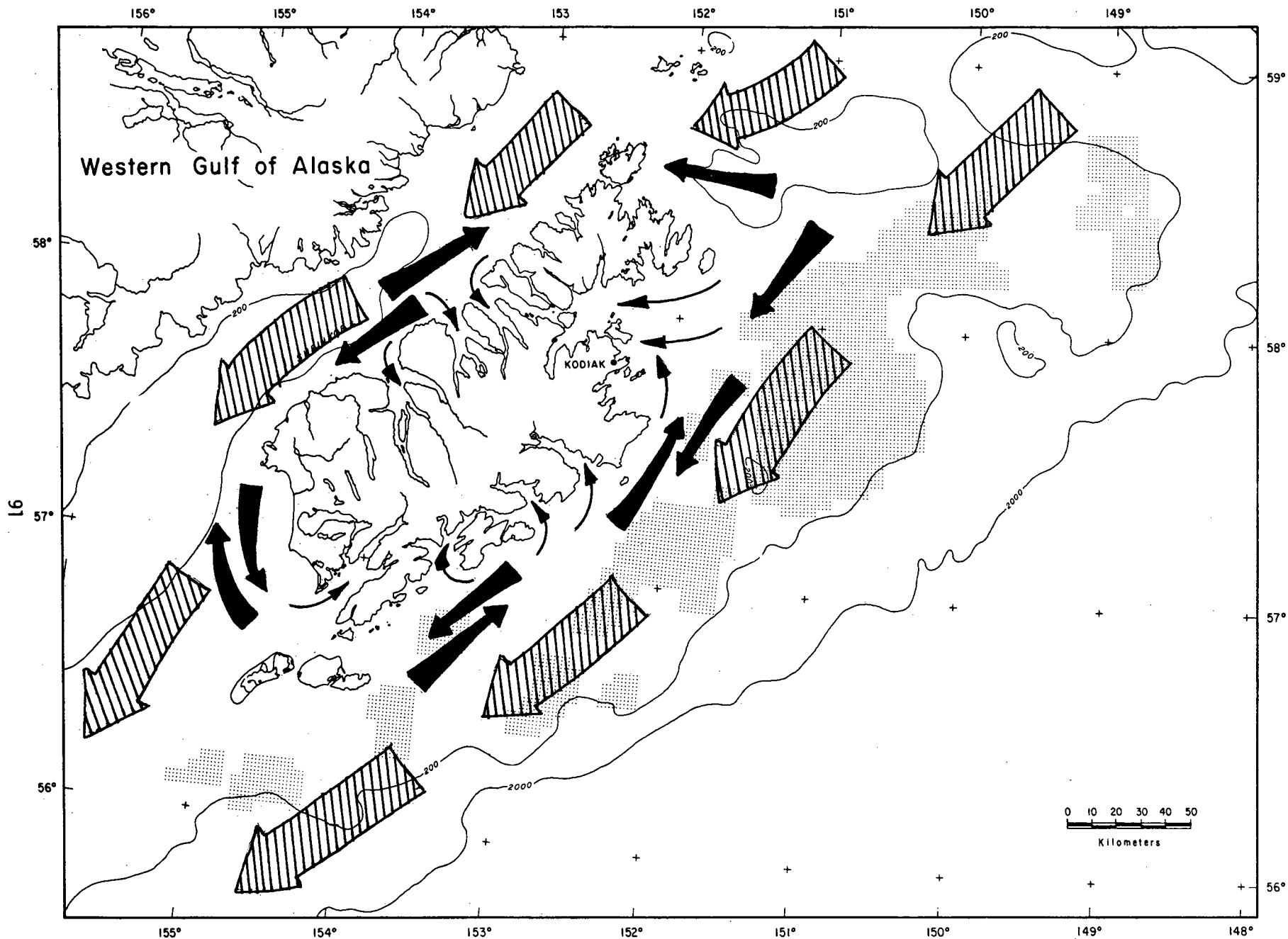


Fig. 3-24 Primary migratory pathway of salmon spawners in the western Gulf of Alaska (modified from Stern et al., 1976).

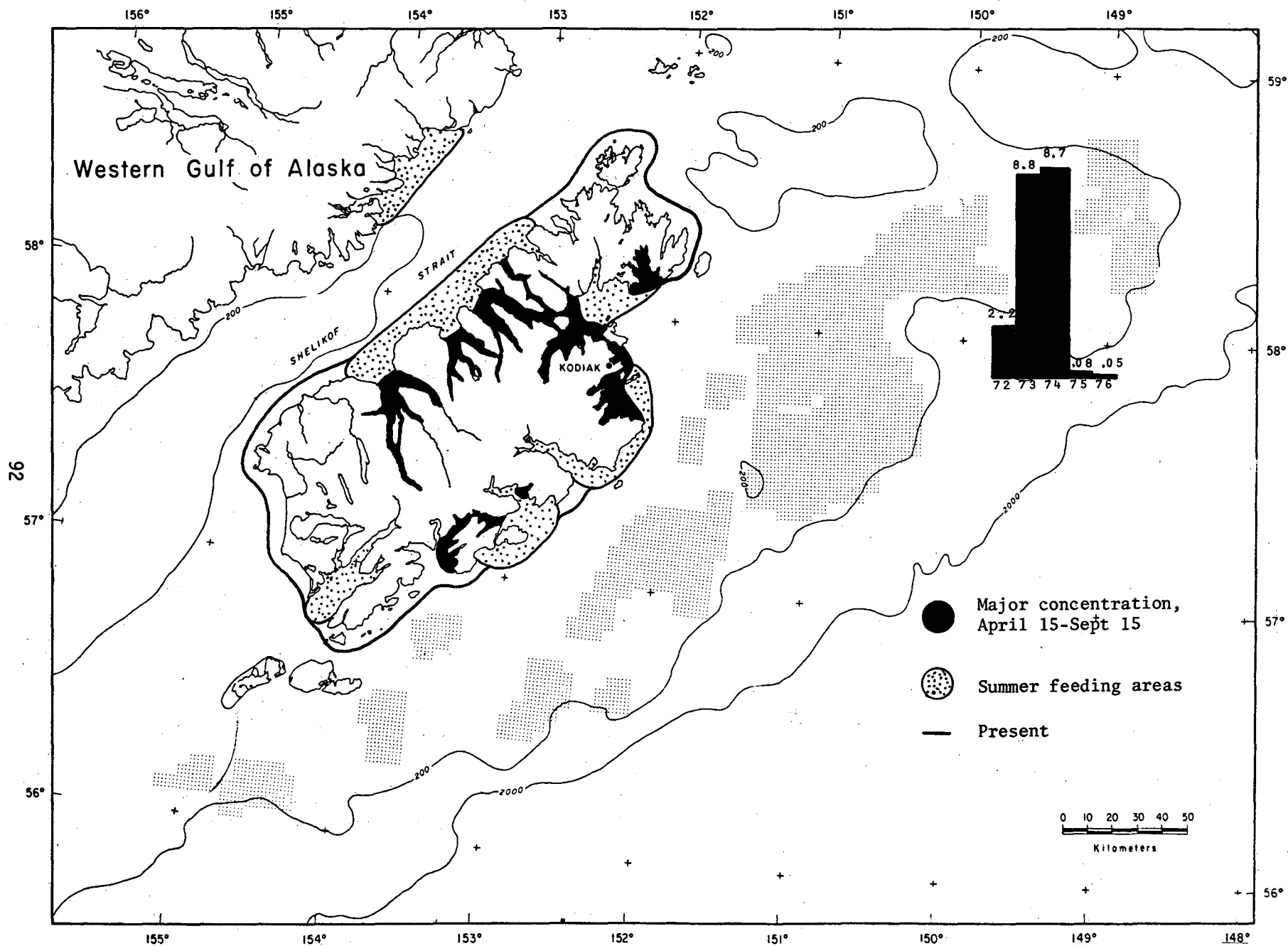


Fig. 3-25 Major concentrations of herring, April 15-September 15, and herring catch in hundreds of tons, 1972-76 (modified from ADF&G, 1977).

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).

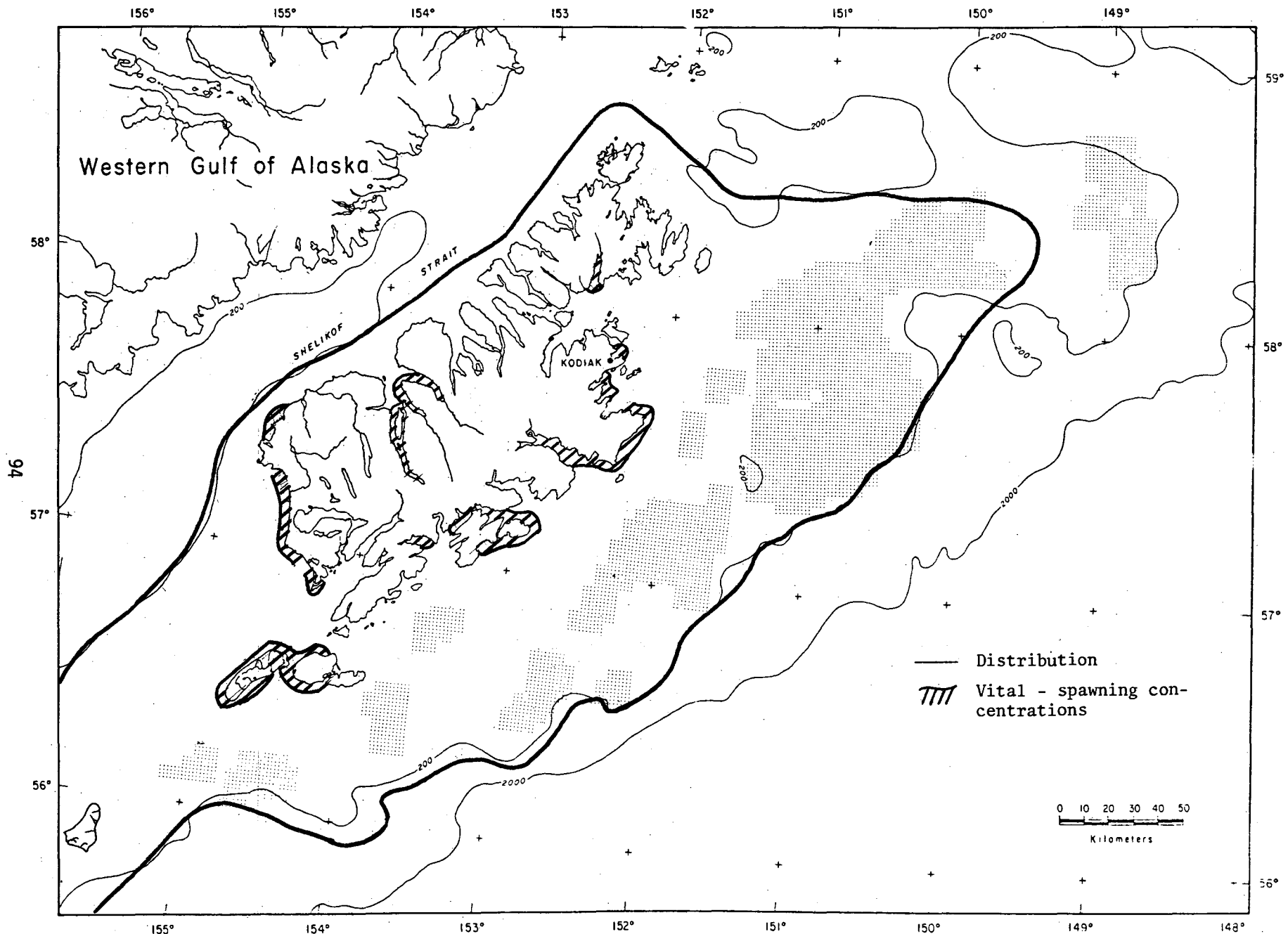


Fig. 3-26 Capelin distribution and important spawning grounds in the Kodiak lease area (from ADF&G, 1977).

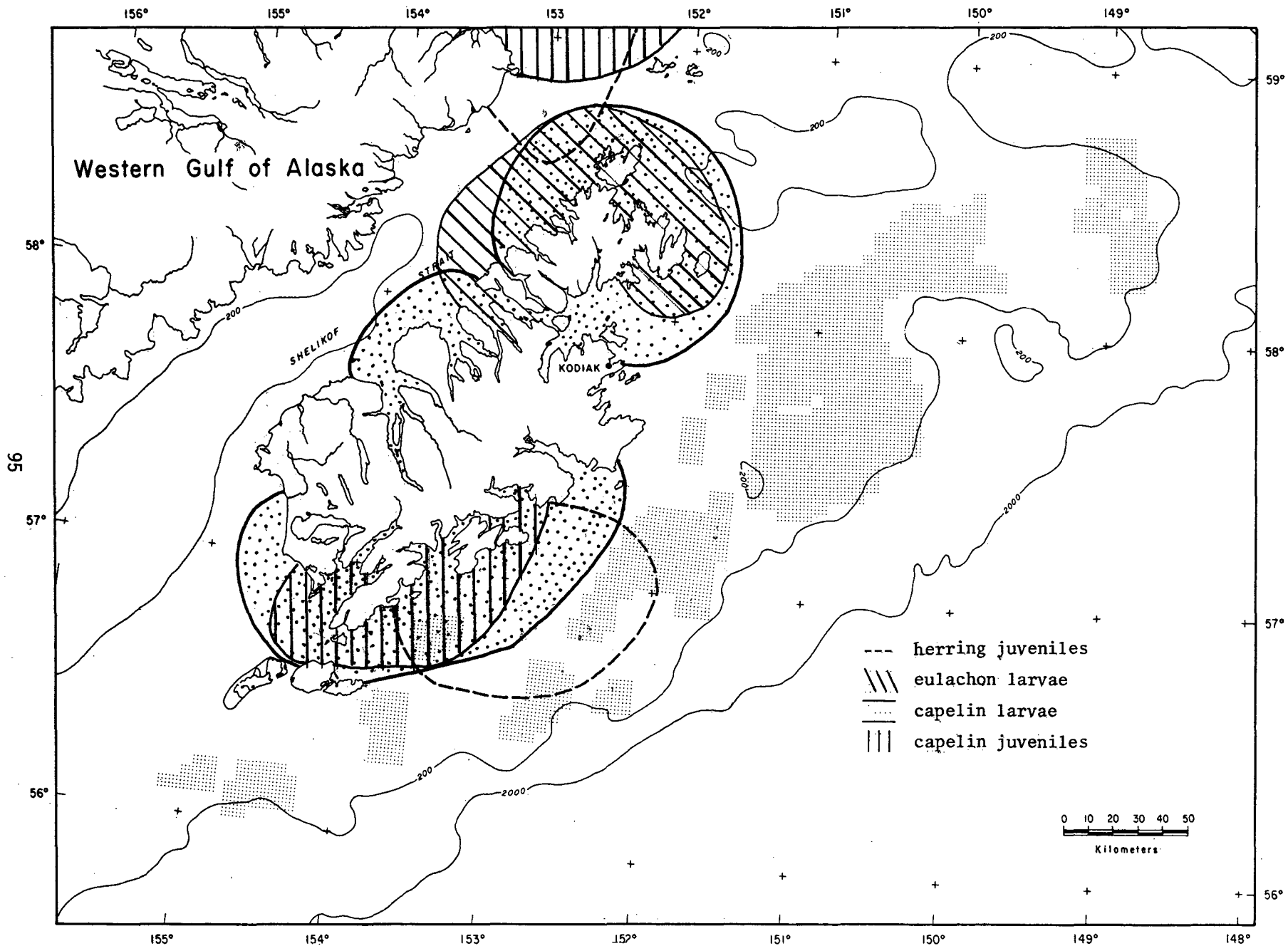


Fig. 3-27 Historical catch distributions of larval and juvenile herring, capelin and eulachon (modified from Macy, 1977).