Environmental Assessment of the Alaskan Continental Shelf

Interim Synthesis Report: Northeast Gulf of Alaska

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INTERIM ENVIRONMENTAL SYNTHESIS OF THE NORTHEAST GULF OF ALASKA

A Report Based on NOAA/OCSEAP Synthesis Meeting,
January 11-13, 1977 Anchorage, Alaska

Prepared for the
Outer Continental Shelf Environmental Assessment Program

by

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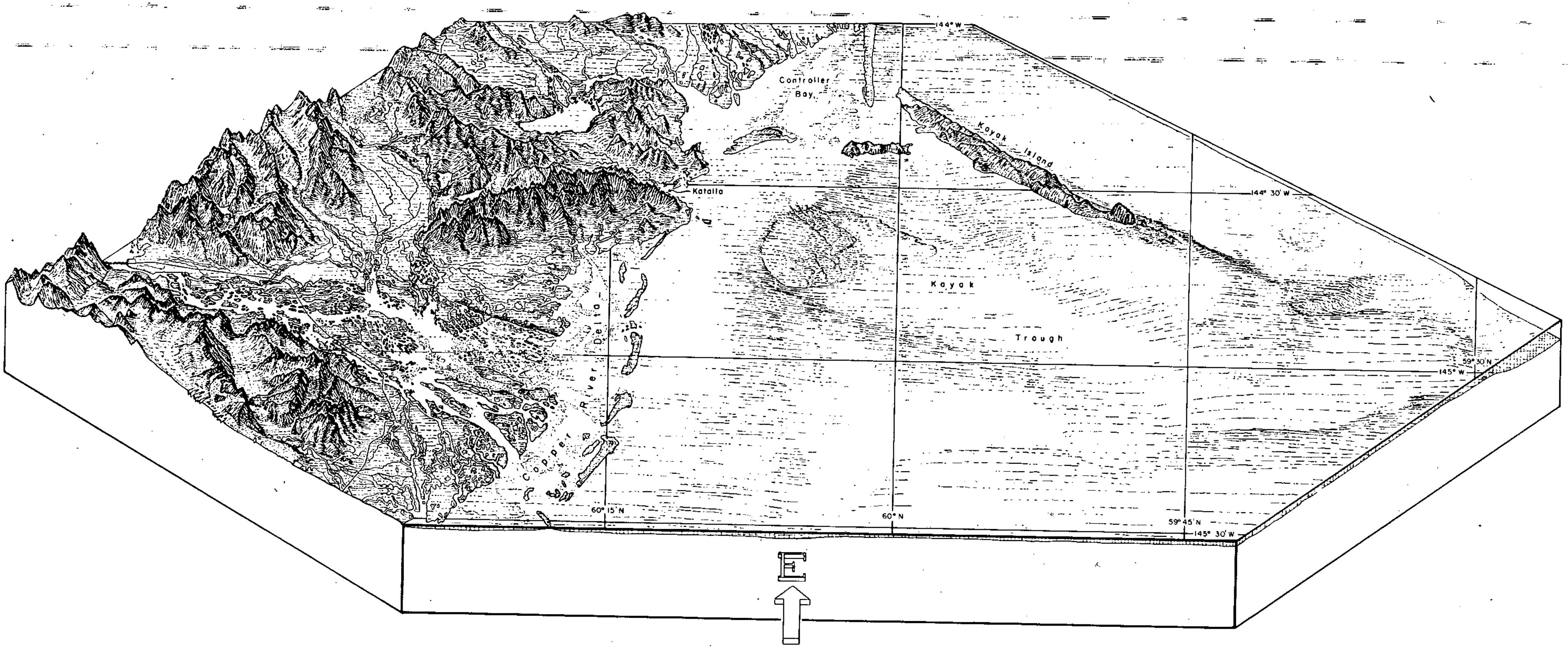


Orthographic drawing, looking east, of the Copper River Delta, Kayak Trough and Kayak Island (T. R. Alpha, USGS 1977; vert. exag. 4:1).

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 Northeast Gulf of Alaska (NEGOA) lease area; (2) to increase and update scientific interdisciplinary understanding of the Northeast Gulf of Alaska region; and (3) to identify important gaps in knowledge of the Northeast Gulf of Alaska marine environment that are relevant to OCS development. Data presented herein were compiled mainly by investigators working under contract to the BLM-funded, NOAA Outer Continental Shelf Environmental Assessment Program (OCSEAP). Some of these investigators participated in a three-day workshop held in Anchorage, Alaska, January 11-13, 1977, for the express purpose of presenting and synthesizing Northeast Gulf of Alaska 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.

The format of the workshop was designed to meet these objectives by: (1) identifying key species, important processes, and their interactions; and (2) identifying and mapping the seasonal geographic distributions of key species, major processes that affect these species, and interactions between the distributions and processes, all in terms of possible impingement from OCS oil and gas development. The primary purpose of the meeting was to achieve an interdisciplinary understanding of the area. Participants were requested to furnish specifically identified background material that would provide the most up-to-date knowledge of the NEGOA lease area. This information was utilized throughout the meeting and is incorporated into this document.

The first day of the workshop included presentations on environmental themes for the NEGOA area and potential oil and gas development activities in NEGOA. A development scenario for the Northern Gulf of Alaska lease sale was provided by the Alaska OCS office, Bureau of Land Management (Appendix 2). The remainder of the day was spent in discipline-oriented workshops where data were compared and integrated to provide a complete but simplified summary of the present state of knowledge within each discipline (i.e., physical oceanography, biology, and chemistry-sedimentology). These disciplinary groups each also produced a set of maps which graphically displayed the current state of knowledge. On the second day of the meeting interdisciplinary working groups identified and discussed environmental interrelationships in the area and attempted to produce maps depicting seasonal correlations between disciplines as these might relate to oil and gas development. Possible "critical areas" were identified, and data gaps were listed. The last day of the workshop included summary presentations and group discussions of the results of the interdisciplinary working groups.

SAI staff took detailed notes of the proceedings and compiled all data products generated. These materials were used to prepare a 302 page *DRAFT SYNTHESIS REPORT* (April 1977). This, in turn, was reviewed by all those who attended the January Anchorage meetings, as well as by several knowledgeable government agency representatives. NOAA/OCSEAP and SAI staff jointly reviewed all comments pertaining to the Draft Synthesis. Rewriting and revision of graphics by SAI staff, together with a final review by Marian Cord, technical editor for NOAA/OCSEAP, produced the present report.

CONTENTS OF THE REPORT

Proceedings of the meeting, material provided by the participants, and recommendations for specific research needs are organized in various chapters. Chapters II (Critical Areas of Possible Impingement), III (State of Knowledge Overview), and IV (Implications of Oil-Related Impingement) contain the bulk of data and information resulting from the meeting. Chapter II provides a description of the areas identified as being critical in view of the OCS oil and gas development and, therefore, should be considered in any relevant decision-making process. Its text is intended for government administrative and scientific personnel, a broad spectrum of the scientific community, and the interested public. The statements are technically correct but do not include detailed and elaborate scientific knowledge of the identified areas. The main body of scientific knowledge is provided in Chapter III. In this chapter, emphasis has been placed on new data presented and pertinent discussions held during the synthesis meeting. Some material from earlier published reports has been used in abridged and summarized form for continuity and completeness of this report. Chapter IV outlines general conclusions reached during Synthesis Meeting discussions of the implications of oil-related impingement on the environment. Chapter V identifies gaps in knowledge and provides a summary of research needs which can be used as input for program direction and emphasis for future research.

LIMITATIONS

This report is essentially a progress report -- an integrated compendium of products resulting from the synthesis workshop. Future meetings are planned to review research programs, to fill data gaps and update this report, and to bring us nearer to a true synthesis of environmental knowledge. Limitations of the data in this report should be apparent from 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 MUST NOT BE VIEWED AS THE DEFINITIVE WORK ON THE NORTHEAST GULF OF ALASKA AREA.* Not all disciplines were represented among the meeting participants. In particular, biological effects studies were not covered.

PREVIOUS PUBLICATIONS

Background information on several aspects of NEGOA and environs is available in the publications listed below. No attempt has been made to abstract or summarize these data in the present report.

A Review of the Oceanography and Renewable Resources of the Northern Gulf of Alaska. University of Alaska, Institute of Marine Science, Fairbanks IMS Report R72-23., 690 pp. (1972).

Alaska Regional Profiles: South Central Region. L.L. Selkregg, Arctic Environmental Information and Data Center, University of Alaska, Anchorage, 255 pp. (July 1974).

Alaska Regional Profiles: Southeast Region. L.L. Selkregg, Arctic Environmental Information and Data Center, University of Alaska, Anchorage, 233 pp. (1976).

Environmental Assessment of the Alaskan Continental Shelf: Northeast Gulf of Alaska. Annual Reports Summary for the Year Ending March 1975. NOAA, Environmental Research Laboratories, Boulder, 292 pp. (May 1977).

Environmental Assessment of the Alaskan Continental Shelf. Annual Reports Summary for the Year Ending March 1976. NOAA, Environmental Research Laboratories, Boulder, 585 pp. (1977).

Northern Gulf of Alaska, Final Environmental Impact Statement. Outer Continental Shelf Proposed Oil and Gas Leasing. 4 vols. U.S. Department of the Interior, Bureau of Land Management (1976).

The Great Alaska Earthquake of 1964. National Academy of Sciences, Washington, D.C., 18 vols. (1971).

The Physical Environment of Biological Systems in the Gulf of Alaska. F. Favorite. Proceedings, Arctic Institute of North America symposium on science and natural resources in the Gulf of Alaska, Anchorage, (October 16-17, 1975).

Suspended Sediment Transport and Deposition in Alaskan Coastal Waters. D.C. Burbank, M.S. Thesis, University of Alaska, Fairbanks, 222 pp. (December 1974).

Alaska's Wildlife and Habitat. Alaska Department of Fish and Game, Van Cleeve Printing, Anchorage (1976).

A Fish and Wildlife Resource Inventory of the Northeast Gulf of Alaska. Compiled by the Alaska Department of Fish and Game under contract to the Alaska Department of Environmental Conservation, 2 vols. (1975).

Marine Bird Populations in Prince William Sound, Alaska, T.J. Dwyer *et al.*, Administrative Report, U.S. Fish and Wildlife Service (1976).

Distribution and Abundance of Marine Mammals in the Gulf of Alaska. D.G. Calkins *et al.*, Alaska Department of Fish and Game, Division of Game (1975).

Chapter II

CRITICAL AREAS OF POSSIBLE IMPINGEMENT

INTRODUCTION

One of the major objectives of the meeting was to synthesize available scientific knowledge and information for the NEGOA lease area and adjacent ocean areas with regard to oil and gas exploration and development. After a thorough review of the status of knowledge, interdisciplinary discussions were held to develop an understanding of the regional environment. These discussions led to the identification of areas that 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. These areas are shown in Fig. II-1. The areas of possible impingement by water transported contaminants were selected in view of circulation patterns, simulated surface particle trajectories, and other important hydrographic features. Attempts were made to delineate areas of important populations and communities as they related to the physical environment, to estimate the level and type of disturbance and insult that regional biota could be expected to tolerate, and to evaluate possible consequences of loss or contamination of significant fractions of specific populations and their recovery potential. Geographically, the selected critical areas are of a much smaller scale than the oceanographic and biotic regimes identified in the Northern Gulf of Alaska, e.g., oceanographic regimes east and west of Kayak Island.

Criteria for identifying areas of critical importance, with regard to OCS oil and gas development, included one or more of the following:

- areas located at or near the end of water-borne contaminants trajectories;
- areas where surface-borne contaminants may be retained or recirculated for longer periods of time, thereby receiving potentially longer contaminant exposure;
- areas of population aggregation and/or feeding activities for important species;
- habitats of species that are highly susceptible to petroleum-related contaminants and other OCS development;

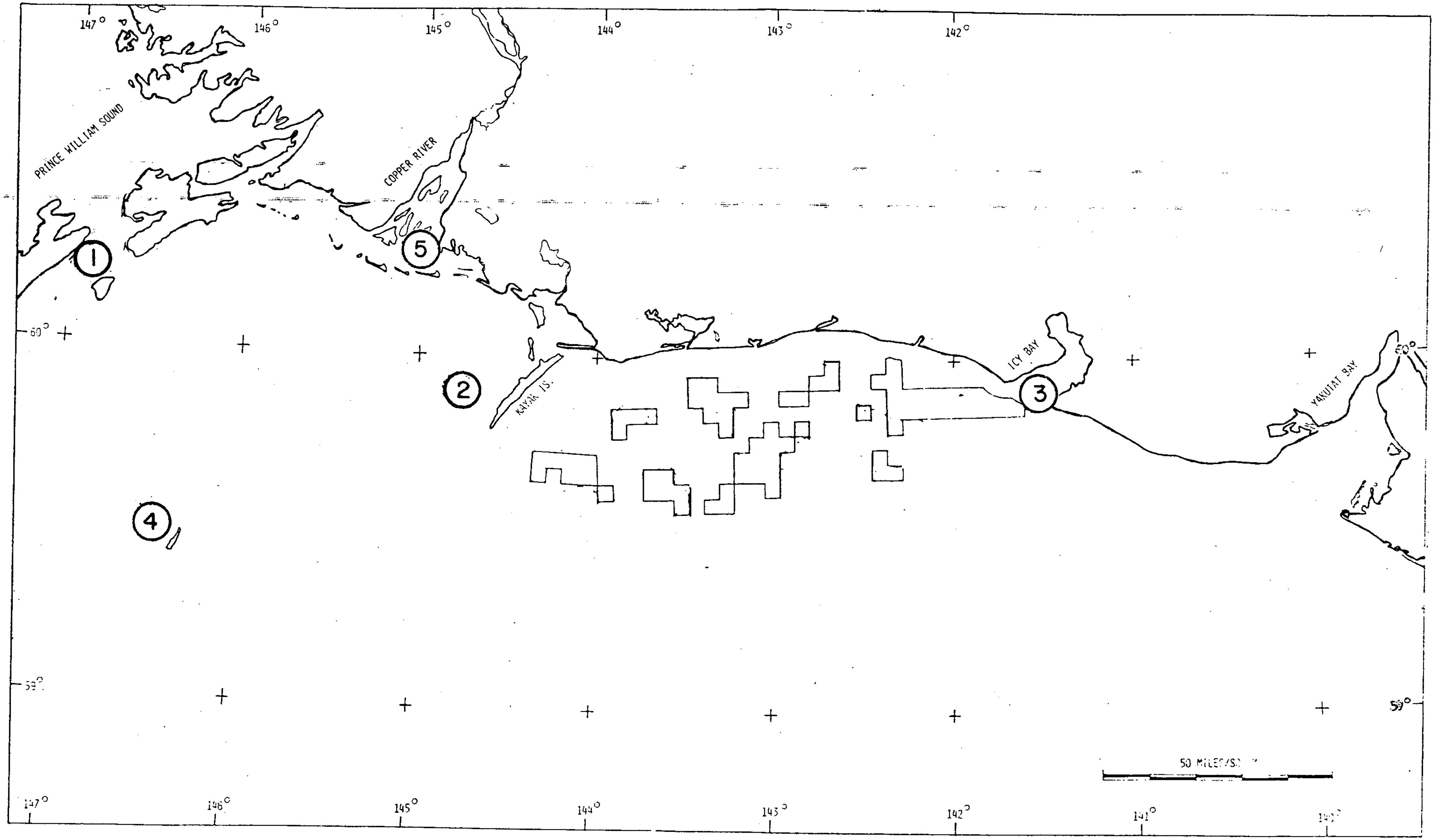


Fig. II-1. Areas identified as critical to the proposed OCS oil and gas development in the Northern Gulf of Alaska. 1: Hinchinbrook Entrance, 2: Kayak Trough, 3: Icy Bay, 4: Middleton Island, and 5: Copper River Delta.

- areas for which only very elementary environmental knowledge is available.

Earlier OCSEAP investigations were conducted on a broad scale with emphasis on geological hazards, meso-scale hydrographic and circulation features, reconnaissance of biota, and areal distribution of petroleum-related contaminants. Scientific data and knowledge of the areas identified herein as being critical or important with regard to OCS oil and gas development were not site-specific but were based on general studies of the Northern Gulf of Alaska. In many instances, the resolution of the available data base was such that only inferences or extrapolations could be made about specific areas. For example, in the case of plankton the spatial coverage was large but seasonal coverage and the number of observations very limited. Similarly, spatial distribution of heterotrophic bacteria is not sufficiently detailed to delineate areas of relative abundance. Data collected so far only indicate that water and sediment collected in the intertidal and shallow subtidal areas contained larger bacterial populations and, consequently, potential for oil degradation was greater there than in the offshore areas. Statements and text presented in this section are elaborated, illustrated, and referenced in the State of Knowledge Overview section of this report (Chapter III). A large number of research projects, many with site-specific objectives, are currently underway or are planned for FY 78. The following general account of the environment and processes of the selected areas should, therefore, be considered as limited in perspective.

HINCHINBROOK ENTRANCE

There is substantial evidence (circulation in Prince William Sound, Lagrangian drifter trajectories, results from surface contaminant distribution model) that Hinchinbrook Entrance, Montague Island, and adjoining areas may receive water-transported contaminants originating in the NEGOA lease area (see Chapter III, Transport Section). Sediments from the Copper River are known to occur in the Prince William Sound basin. Due to differential settling velocities and the absence of additional sediment sources, most of the Copper River Delta bottom sediments become progressively finer as they are carried southwest past Hinchinbrook Island. The central part of Prince William Sound provides a sink for finer sediments, originating both from the fiords and estuaries within the Sound and from the Copper River. The coarser bottom sediments in Hinchinbrook Entrance are probably the result of winnowing of the finer bottom sediments by strong tidal currents. The influence of tides on the distribution of surface sediment plumes is noted from satellite imagery data. An outwardly directed plume at ebbing tide is readily seen at the Hinchinbrook Entrance. An inward directed plume of sediment laden waters occurs at flood tide. However, once inside the Sound, the flood plume loses its identity rapidly and cannot be traced.

Sediment size distributions on the topographic high south of the Hinchinbrook Island appear to be related to local bathymetry. Even though there is a sufficiently large supply of finer sediment in this area to cover the underlying glacial morainal layer, this layer is usually exposed (Burbank 1974). Apparently, the deposition of fine material is prevented by strong current and tidal action on the bottom.

The area south of Hinchinbrook Entrance, within the Hinchinbrook Trough, is recognized as one of the major sources of low molecular weight hydrocarbons. Methane concentration measured near the bottom, 1,577 nℓ/ℓ, was higher than at any other site sampled in the Northern Gulf of Alaska (Cline and Feely, RU #153). Such high methane concentration may indicate accumulation of organic matter. For comparison, it should be noted that methane concentrations near Tarr Bank and the shelf edge were 200 and 100 nℓ/ℓ, respectively.

More than three-quarters of the commercial salmon catch in the Northern Gulf of Alaska is taken in Prince William Sound. Hinchinbrook Entrance appears to be an exit point for juvenile salmon migrating to the North Pacific Ocean. Herring are also abundant in Prince William Sound. Herring spawning and feeding occurs throughout the coastal systems of Hinchinbrook and Montague Islands. Demersal fish resource studies indicate that relatively high numbers of walleye pollock, arrowtooth flounder, flathead sole, Pacific halibut, and Pacific cod occur in all areas adjacent to Hinchinbrook Entrance.

Due to high feeding and spawning activities, spring and summer appear to be the seasons of greatest concern. Major impacts from an oil spill could occur by smothering herring eggs, causing toxic effects on juvenile fish, disrupting migrations, and entering food webs through ingestion. The effect on even-year pink salmon stocks could be devastating. This stock has not recovered to the high abundance levels that existed prior to the 1964 Alaska earthquake and further perturbations could drastically reduce the chance for specific races. Disturbances at any time of the year could have significant deleterious effects, as the pink salmon are present at all times in Prince William Sound in two or more life cycle stages. This is also true for chum salmon.

The area adjacent to Montague Island, just southwest of Hinchinbrook Entrance, is characterized by high concentrations of epifaunal species, particularly the snow crab, *Chionoecetes bairdi*, and the mud star, *Ctenodiscus crispatus*. Trawl samples collected from this area have yielded 47 species--the highest diversity of any region surveyed during OCSEAP studies. The species total included 14 crustaceans, 13 echinoderms, and 13 molluscs.

Clam beds, particularly of *Saxidomus* and *Musculus*, are well developed within Prince William Sound and provide a critical food resource for sea otter populations. Preliminary studies indicate that *Macoma* mortality rates increase significantly following oil pollution (Feder *et al.* 1976) and that oil may cause behavioral changes affecting survival (Taylor *et al.* 1977). Commercial fisheries for snow, Dungeness and king crab, shrimp, and clams are developed within the Sound.

Marine birds and mammals are relatively abundant in this area. Killer whales, humpback, minke, gray and fin whales, and dall porpoises have been sighted here rather frequently. The right whale, an endangered species, is listed as inhabiting the NEGOA area. Following Montague Strait and Cape Cleare, Hinchinbrook Entrance has been the third most productive area in NEGOA for cetacean sightings (H. Braham, NMFS, Seattle, Washington, pers. comm., 1977). Seal Rock in Hinchinbrook Entrance is a large Steller sea lion rookery and hauling ground in NEGOA. It has a population of at least 2,000 animals. Wooded Islands is another, smaller (ca. 50 animals) hauling ground in the Entrance.

Concentrations of both harbor seals and sea otters occur in this area. The sea otter population around Hinchinbrook Island is particularly important because it appears to be the main repopulation source for otters in areas to the southeast, from which the species was once exterminated by commercial hunting (K. Schneider 1977).

Several seabird colonies are located in Hinchinbrook Entrance at Seal Rocks, Porpoise Rocks, Port Etches/Phipps Point, and Cape Hinchinbrook. Approximately 10 to 30 thousand puffins, murres, kittiwakes, cormorants, and gulls nest in these colonies. In addition, Hinchinbrook Entrance is part of the Prince William Sound seabird and waterfowl wintering area and also supports high densities (>30 birds/km^2) of pelagic birds in spring and summer (Dwyer *et al.*, 1976).

KAYAK TROUGH

The existence of eddy-like features west and southwest of Kayak island is manifested in the hydrographic and Lagrangian drifter data and is also apparent from the results of circulation modeling studies (for details see Chapter III, Transport Section). One of the drifting buoys, released in summer, idled in a clockwise manner for about 25 days in this general area before drifting westward. Whether this is only a seasonal phenomenon has not yet been ascertained. Nonetheless, this feature, at least in late spring and summer, represents a holding mechanism for water-borne contaminants, thereby increasing their residence time in this geographically limited area. It has been noted and can be seen from satellite-imagery data that Bering Glacier sediments are held in this clockwise gyre west of Kayak Island. The apparently long residence time coupled with the relatively low energy physical environment allow finer sediments to settle. The greater depth of the basin (Kayak Trough) as compared with surrounding area, has a complementary effect in its ability to retain the finer sediments (Burbank 1974).

Background hydrocarbon concentrations are higher in these fine-grained sediments than elsewhere and a rich bacterial population is present. Concentrations of methane in the trough exceed 300 nℓ/ℓ; the methane is apparently of biogenic origin.

This area is one of the three halibut spawning grounds in the northeastern Gulf. Halibut populations, estimated from commercial catch statistics, appear to be waning. The introduction of contaminants in the spawning area may increase this apparent population decline. Data on the seasonality in their distribution and abundance, applicable to this area, are not currently available.

Major population concentrations of other demersal fish, including arrowtooth flounder, Pacific Ocean perch, and walleye pollock are also found in this area.

This is a biologically important area of generally finer grained sediments containing high numbers and biomass of infaunal deposit feeders. These animals may prove particularly susceptible to the effects of oil-contaminated sediments. Epifaunal species such as the Tanner crab, pink shrimp, and the mud-star, are also very abundant. A local commercial fishery for Tanner crab has been developed.

There is no evidence that this area *per se* is particularly important to marine birds and mammals. However, it is part of a much larger area that supports high densities of seabirds in spring. The nearest concentration of marine mammals in the vicinity is a Steller sea lion rookery and hauling ground (at Cape St. Elias) with a population of about 2,000 animals. To what extent these and other marine mammals feed here is unknown. Although sea otters occur in low densities along coasts of this region, they are confined to waters within the 80 m depth contour; hence they do not utilize the trough area.

ICY BAY

The surface water particle pathway analysis, based on diagnostic circulation model and wind effects on surface drift, showed a substantial number of trajectories ending in the Icy Bay region. As the starting point of the trajectories was southwest of Cape Yakataga, these results indicate an eastward water motion. The observed average current direction in this area (Station 62 current meter data) is west-northwest: 308 T^{o}at 20 m and 311 T^{o}at 100 m. This lack of correspondence between the current meter data and surface particle projections might be traceable to anomalies in like current water or density data on which the model is based. General observations of suspended sediment distributions in the Northern Gulf of Alaska have shown that transport is primarily parallel to the coast in a westward direction. However, due to the presence of sea valleys and canyons, offshore dispersion occurs all along the shelf. The weak eastward flow nearshore, as seen in circulation model results in the vicinity of Icy Bay, is apparently controlled by local bathymetric variations. On the other hand, both the STD data input to the model and the model results have considerable "noise." The eastward flow can only be considered as a limited possibility until more data are incorporated into the model and more simulation results become available.

Notwithstanding the apparent discrepancy in the circulation regime, the Icy Bay region is characterized by the presence of important biological populations and communities. It is considered as an important feeding ground for the starry flounder and butter sole. Trawl catches, exceeding 1,000 kg/hr, were dominated by flatfish, all of which had full stomachs containing the clams *Yoldia* sp., *Siliqua* sp., and *Macoma* sp., almost exclusively. Walleye pollock and Pacific cod were also abundant. Available data suggest that this area may be a nursing ground for walleye pollock. A small run of coho salmon also occurs in this area. The weathervane scallop, *Patinopecten caurinus*, and sunflower sea star, *Pycnopodia helianthoides*, are also very abundant in this region.

The sediments here are predominantly coarse, clean sands that promote the development of rich populations of suspension feeding bivalves.

Coastal erosion and deposition are both very active; Riou Bay on the eastern side of Icy Bay has experienced a shoreline retreat of 1.3 km since 1941. Despite rapid shallowing, this site has been suggested as a potential tanker terminal facility. Sea floor slumping and earthquake hazards have also been noted near Icy Bay.

According to the Alaska Department of Fish and Game, "Icy Bay contains one of the most spectacular concentrations of harbor seals in Alaska. During summer months tremendous amounts of ice are calved from the active glaciers and harbor seals use the floating ice for pupping and hauling out platforms." Although a satisfactory count of these seals has not been made, it is estimated from an aerial survey that several thousands are present. Sea otters occur in very low densities in the Icy Bay region (Calkins *et al.*, 1975). Steller sea lions occur here but not in significant concentrations. Dall and harbor porpoises and minke, humpback, and killer whales are also found here (Fiscus *et al*., 1976).

Alaska Department of Fish and Game (1975) has located three seabird colonies in the Icy Bay-Yahtze River area. A colony of Aleutian terns on Riou Spit numbers approximately 75 pairs; otherwise, information on bird species distribution and abundance are not available. Coasts off Icy Bay and vicinity are also used by birds as feeding and resting concentration areas and as waterfowl nesting and molting areas.

MIDDLETON ISLAND

The hydrographic regime in the general area west-southwest and inshore of Cape St. Elias and Middleton Island is marked by high variability primarily due to the seasonally high freshwater input from coastal runoff and from rivers, fiords, and Prince William Sound. Several small-scale perturbations in water properties offshore are noted which may be caused by the presence of Middleton Island and a change in flow direction from zonal to meridional. There is little or no evidence of the well-defined core of the subsurface water layer over the wide continental shelf in this area. One of the Lagrangian buoys (#1133), released south of Icy Bay in summer 1976, ended up on the shores of Middleton Island, crossing the Alaskan Stream during the drift. Because it lies between the NEGOA and Kodiak lease areas (lease tracts inshore of Middleton Island have been withdrawn), this general area has not yet received concerted and area-specific OCSEAP efforts to study the physical environment and biota. In view of the observed variability in water properties and the flow regime (especially nearshore), the environment can only be characterized by long-term, time-series data.

Middleton Island supports one of the largest seabird colonies in the Northern Gulf, is a seabird wintering area, and also supports populations of pinnipeds. About 200,000 cormorants, gulls, kittiwakes, murres, and puffins nest on the island each summer. Up to 3,000 Steller sea lions haul out on a sand spit at the north end of the island and harbor seals are abundant around the entire island. Harbor seals also are common on Wessel's Reef, 19 miles north of Middleton (Calkins *et al.*, 1975). Concentrations of fur seals occur regularly in waters around Middleton Island (Fiscus *et al.*, 1976).

A large variety of cetaceans are known to occur around Middleton Island. Species usually sighted there are dall and harbor porpoises and sperm, humpback, fin, minke, and killer whales (Fiscus and Braham, RU #67, 1976). An unusually large concentration of over 500 killer whales was observed near Middleton in April of 1973 (Calkins *et al.*, 1975).

Demersal fish populations are generally high along the peripheral areas of Middleton Island and Tarr Bank. However, because of bottom characteristics it is impossible to trawl this area. It is not known what the population levels are in the area but they are assumed to be similar in kind and number to the peripheral zones, where arrowtooth flounder, flathead sole, Pacific halibut, walleye pollock, and Pacific Ocean perch are abundant.

The benthic fauna of this area is only poorly known for the rough rock and gravel bottom largely precludes effective van Veen grab and otter trawl sampling. It is believed that the area probably harbors a diverse infauna (with significant populations of suspension feeders) and an abundant epifauna (H. Feder, University Alaska, Fairbanks, pers. comm. 1977).

Many small pelagic copepods, such as *Acartia* sp., *Oithona* spp., and *Pseudocalanus* sp., are abundant and widespread over the shelf especially during summer and fall. Snow crab larvae, 1-10 individuals/m^2, are found over the shelf during spring and summer. Highest concentrations of these and other larval forms occur in the coastal areas shallower than 100 m. Larvae reside in the water column for 60 to 90 days, generally from April to August.

COPPER RIVER DELTA

Dynamically this area is a part of the broad continental shelf regime west and southwest of Cape St. Elias. Specific details of the circulation and seasonal effects of the sediment-laden Copper River discharge are not known. Lagrangian buoys drifting from areas east of Kayak Island and grounding in the Prince William Sound and on Montague Island pass through this general area. A relatively weak counterclockwise eddy-like feature is noted south of the Delta. A well-defined plume has been noted from ERTS satellite imagery data acquired during summer. These and other data show a complicated localized flow pattern (eddies, apparent flow reversals) within the nearshore and coastal areas. The flow patterns are further modified by tides, winds, and topography.

The suspended load of the Copper River is entrained by coastal currents, predominantly westward, and carried until it reaches Hinchinbrook Island where a portion passes into Prince William Sound and the remaining part is carried southwest along Montague Island. The total suspended sediment in the surface layers in fall is nearly 4 mg/ℓ near the Delta and an order of magnitude lower near the shelf break and in areas south and west of Montague Island (Feely and Cline, RU #152, 1976).

Copper River Delta and associated barrier islands are well utilized biologically. King and sockeye salmon congregate in the area between the mainland

and the barrier islands before migrating to the headwaters of the Copper River. King and coho salmon may overwinter in this area and in Prince William Sound rather than migrating to the North Pacific. Eighty percent of the Prince William sockeye salmon originate in the Copper River. Sockeye populations are especially dependent on the Copper and Bering River for maintenance of their populations. The 1964 earthquake severely impacted sockeye spawning habitat by blocking access to lake systems vital to their life history. The most severe impact was the drainage of San Juan Lake on Montague Island. The barrier islands are also a spawning ground for Pacific herring.

The intertidal sand and mudflat habitats of the delta yield a rich but as yet poorly known benthic fauna. *Macoma* spp. and *Mya* sp. are all abundant, along with the economically important razor clams and Dungeness crabs.

This area is the most heavily utilized expanse of avian habitat in the northern Gulf of Alaska. During spring migration it is visited by tens of millions of waterfowl and shore birds, which attain densities here in the neighborhood of 100,000 birds/km^2. Copper River Delta also comprises about 800 km^2 of waterfowl nesting habitat, making it the most extensive waterfowl breeding area in NEGOA. In 1976 it had breeding populations, calculated by Alaska Department of Fish and Game, of 19,553 ducks, 21,300 dusky Canada geese, 595 trumpeter swans, and 715 red-throated loons (ADF&G 1976). Levees and marshes over part of the eastern and nearly all of the western portions of the delta are utilized for nesting. According to Isleib (1971), 20% of the world population of trumpeter swans and nearly all of the North American population of dusky Canada geese nest in this area. In addition, an estimated 50,000 gulls and kittiwakes nest on the nearby barrier islands and Boswell Rocks, respectively.

The most abundant marine mammals in this region are harbor seals, which are present in high densities throughout the Delta in summer. Sea otters and Steller sea lions are also present but in smaller numbers. Cetaceans reported to occur in coastal tidewaters of the Delta are dall and harbor porpoises and gray, sei, piked, humpback, and killer whales (Mickelson 1973). The harbor porpoise, like the harbor seal, may ascend rivers several miles inland.

SUMMARY

Five geographically limited areas have been identified as being critical in light of the possible OCS oil and gas development in the Northern Gulf of Alaska. These areas are: Hinchinbrook Entrance, Kayak Trough, Icy Bay, Middleton Island, and Copper River Delta. These areas were selected as critical on the basis of general surface circulation regime, simulated surface water particle trajectories, the presence of important biotic resources, and inferences from hydrographic data, i.e., advective processes. Selection of these areas can only be regarded as tentative and provisional. More research and data are needed to supplement the presently limited environmental knowledge specific to these areas in order to assess their significance. Except for the Icy Bay Region, all selected areas are located west and inshore of the Kayak and Middleton Islands. Lease sales are not presently considered for this general shelf area.

Chapter III

STATE OF KNOWLEDGE OVERVIEW

BACKGROUND LEVELS OF PETROLEUM-RELATED CONTAMINANTS

Low Molecular Weight Hydrocarbons

Cline and Feely (RU #153, 1976) have shown the spatial and fall and spring variations of low molecular weight hydrocarbons (LMWH) in the NEGOA lease area. The fall distributions of LMWH have been previously reported in the NEGOA section of the NOAA/OCSEAP annual report summary (NOAA/SAI 1976).

Methane

Methane concentrations in the near-surface waters ranged from 0.50 nℓ/ℓ seaward of the shelf to 360 nℓ/ℓ midway between Hinchinbrook Island and the Copper River (Fig. III-1). The concentration of methane in oceanic waters was lower in April 1976 than levels measured in October-November 1975, but methane levels in the shelf waters were measurably higher in the spring (360 nℓ/ℓ) than in the fall (250 nℓ/ℓ) sampling period.

The salient feature in the surface layer is a large clockwise gyre west of Kayak Island advecting methane-rich water from the vicinity of Kayak toward the west. This feature was not observed in the data collected from surface samples during the fall 1975 cruise. The source of the methane probably is the organic-rich sediments in the Kayak Trough, as indicated by near bottom methane levels.

Methane concentrations near the bottom reflect both microbial activity in organic-rich sediments and topographic control (Fig. III-2). In the April 1976 data, Hinchinbrook Sea Valley and the Kayak Trough appear to be strong sources of biogenic methane. Similarly in fall 1975, the highest concentrations (1,577 nℓ/ℓ) of methane were measured in Hinchinbrook Sea Valley near bottom water. In contrast, Tarr Bank, a topographic high, is apparently not a source of methane.

A salient feature of the October-November 1976 near bottom data is a plume of high methane content moving east from Montague Island. The authors noted that the plume moved under that of the Copper River, similar to estuarine circulation. This is in sharp contrast to the spatial distribution noted in

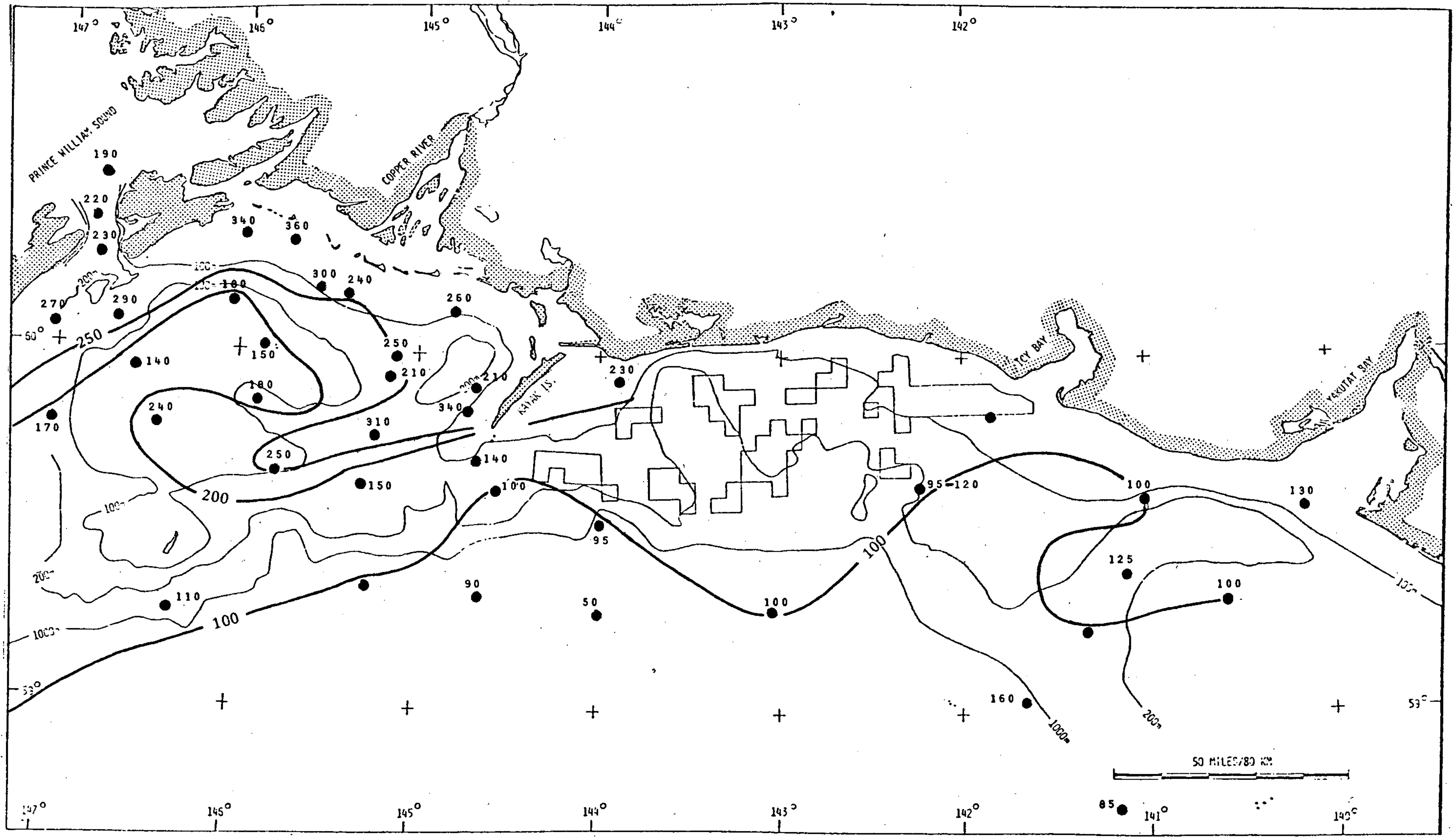


Fig. 111-1 Surface concentration of methane (nl/liter) in NEGOA during April 1976; concentrations rounded to nearest 5 nl/liter (from Cline and Feely, RU#153).

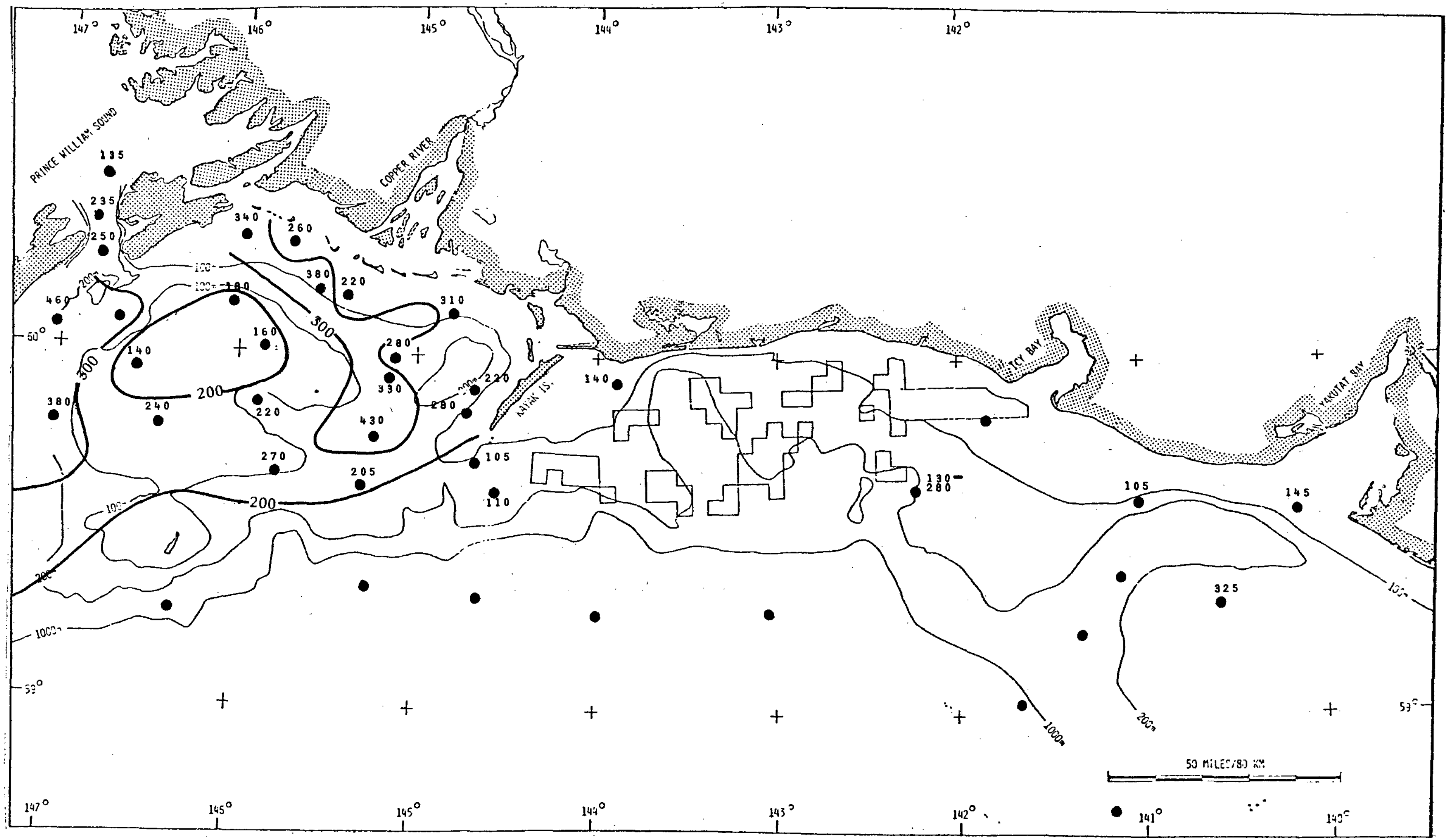


Fig. 111-2 Concentration of methane (nl/liter) within 5m of the bottom on the NEGOA shelf during April 1976 (from Cline and Feely, RU#153).

spring 1976 and may be attributable to a systematic change in the near bottom mean circulation.

The variability in methane concentrations over time was studied at two stations in 1975 and one station in 1976. The data obtained in both sampling periods indicate that methane concentrations were relatively stable (±5% of the mean) in the surface waters. The concentration of methane in the near bottom waters is highly variable. Fluctuations of more than 100 nℓ/ℓ in 12 hours were not uncommon during both sampling periods.

Ethane, Ethylene

Between sampling periods there is very little variation in the ethane concentrations in surface and near bottom waters and in spatial distribution. Ethane concentrations ranged from 0.07 to 0.5 nℓ/ℓ. The various plume and gyral characteristics noted in the methane concentrations are not evident in the ethane distributions.

Ethylene levels in the surface and near bottom waters were generally higher and more variable than for the saturate counterpart. Concentrations of ethylene ranged from 0.45-1.00 nℓ/ℓ at the surface to 0.50-1.50 nℓ/ℓ near the bottom and averaged 0.73 nℓ/ℓ in April and 1.01 nℓ/ℓ in October-November.

Propane, Propylene

In general, the concentrations of these LMWH were uniformly low throughout the NEGOA region. In fall 1975, propylene concentrations ranged from 0.2 to 0.3 nℓ/ℓ. The propane/propylene concentrations are not available for April 1976.

N-butane, Iso-butane

N-butane and iso-butane concentrations were generally at or below the detection limit of the methods employed by Cline and Feely (RU #153).

Other Hydrocarbons

Data collected by Shaw (RU #275, 1976) on higher molecular weight hydrocarbons have been previously discussed in the NEGOA section of the NOAA/OCSEAP annual report summary (NOAA/SAI 1976). Those data illustrate the non-polluted quality of the water and sediments in the NEGOA lease area. The aliphatic contents of the surface water, biota, and sediments were 0.12 ± 0.21 ppb, 5.0 ± 4.4 ppm, and 3.7 ± 5.7 ppm, respectively. The distribution pattern of saturated hydrocarbons showed no pristane or phytane, n or n-alkanes lighter than C_{19}. Based on the odd/even carbon number ratio (1) and the presence of hydrocarbons greater than C_{27}, it is concluded that the hydrocarbon component in NEGOA sediment is derived from a mixture of planktonic and terrestrial plant material.

Although no petroleum hydrocarbons were identified, petroleum seeps have been located in the intertidal sediments collected near the mouth of the Katalla River.

Heavy Metals

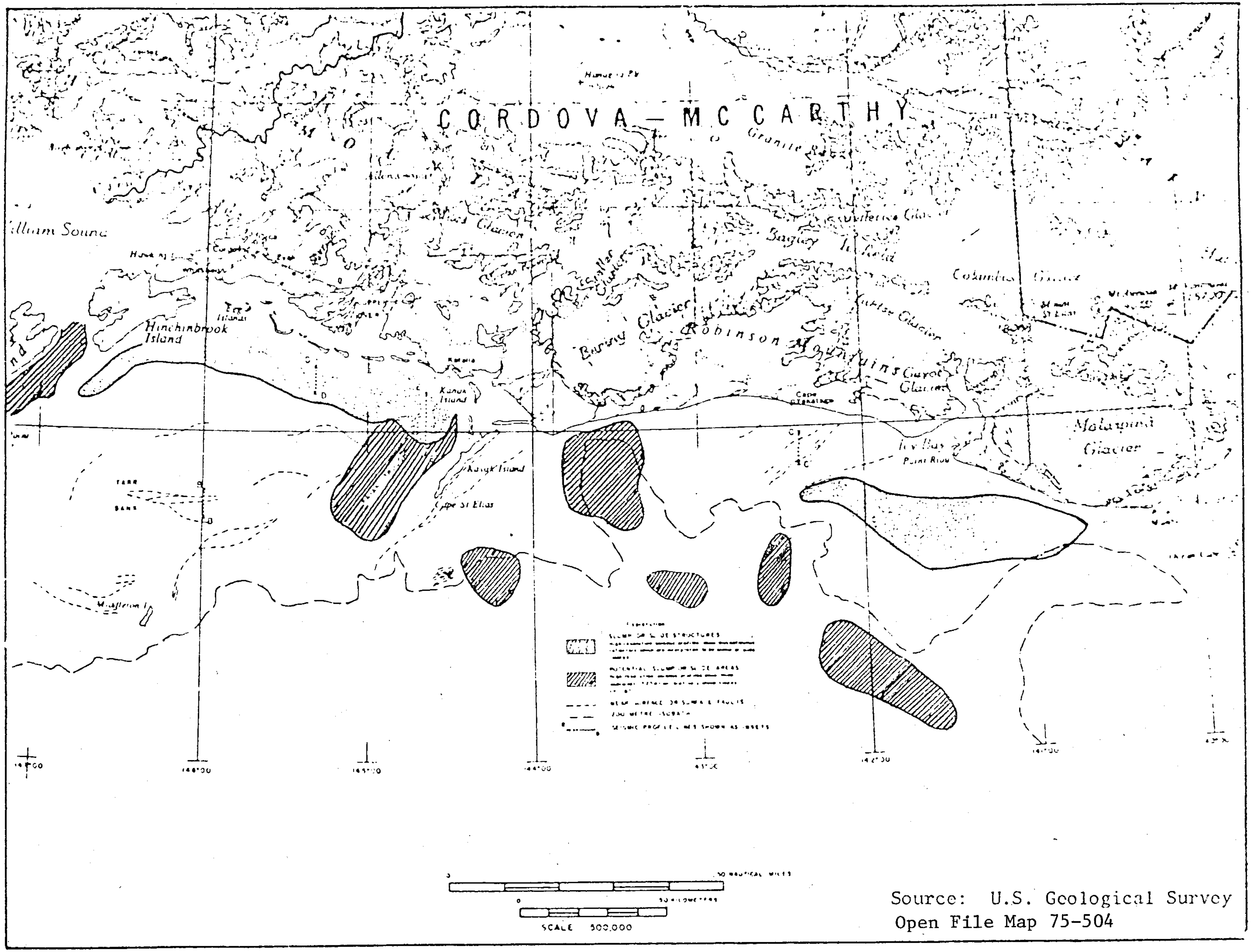
Metal contents of sediment, biota, and water are discussed in the Kodiak section of the NOAA/OCSEAP annual report summary (NOAA/SAI 1976). Burrell (RU #162, 1976) reported that inorganic sediments constitute the largest repository of heavy metals, but those held in the biota are of particular concern to man. The importance of seawater lies not in the absolute amounts of concentration of metals held but in its role as a mobile phase through which, and with which, these trace constituents can be transported. The data indicate that the soluble metal content of the NEGOA water and sediment were as low or lower than for other coastal regions. Levels in the biota were similarly low. Burrell further noted that the Alaskan shelf waters and sediment were nearly pristine and any future anthropogenic perturbations should be detectable.

GEOLOGIC HAZARDS

Seismicity

Due to extreme seismicity (Meyers, RU #352, 1976; NAS 1973), six potentially serious hazards exist in the NEGOA lease area: (1) abrupt fault displacements that can exceed 10 m; (2) pervasive ground shaking; (3) onshore and submarine slumps and slides; (4) turbidity flows; (5) regional uplift or subsidence; and (6) tsunamis.

Lahr and Page (RU #210, 1976) have described three principal sites of offshore seismicity: (1) the entrance of Icy Bay; (2) the Pamplona Ridge located to the southwest of Icy Bay; and (3) a localized area of continental shelf approximately 50 km due south of Yakutat Bay. Carlson and Molnia (RU #216, 1976) have identified probable active faults on Tarr Bank, around Middleton and Kayak Islands, and near structural highs south of Cape Yakataga and adjacent to Pamplona Ridge (Fig. III-3).



Source: U.S. Geological Survey
Open File Map 75-504

Fig. III-3. Submarine slides and near-surface faults, Northern Gulf of Alaska (from Carlson and Molnia, RU #216).

Sedimentation and Sediment Instability

Principal NEGOA sediment sources include the Copper River and the Bering and Malaspina Glaciers. The general transport of these sediments as they enter the Gulf of Alaska is to the west. Sediments in the Bering Glacier runoff plume are transported around Kayak Island and probably settle out over Kayak Trough. Some of the Copper River sediment is carried west into Prince William Sound. Seismic profiles indicate that very little sediment accumulates on Tarr Bank or the Middleton Island platform. This probably reflects scouring by strong bottom currents and frequent winter storm waves (Molnia and Carlson, RU #212, 1976).

High sedimentation rates on the NEGOA shelf result in poorly consolidated deposits with high pore-water pressures. Where sediment slopes exceed 1^{0}, clayey-silts with peak vane shear strengths of 0.01 to 0.09 kg/km^{2} are highly susceptible to slumping, sliding, and turbidity flows (Carlson and Molnia, RU #216, 1976). Atterberg Limit measurements (Table III-1) indicate that clayey-silt and gravelly-mud water contents are greater than those at which the sediments exceed the liquid limits. The implication is that these sediments will liquefy upon shock--perhaps even flow if a gradient is present (Means and Parcher 1966).

Slumping is a common feature on the NEGOA shelf edge and continental slope. Two areas of thick Holocene sediment also show evidence of submarine mass movement: (1) south of Icy Bay area and of the Malaspina Glacier and (2) seaward of the Copper River (Molnia and Carlson, RU #212, 1976).

Hazards and Coastal Zone: Susceptibility to Oil Impact

The following are potential hazards to onshore petroleum-related facilities: (1) flood bursts from ice-dammed glacial lakes; (2) glacial surges--rapid extension of the ice terminus; and (3) stagnant ice masses and buried ice blocks, causing areas of ground instability due to slumping as the ice melts (Boothroyd *et al.*, RU #59, 1976; Hayes and Boothroyd, RU #59, 1976; Cannon, RU #99, 1976).

A significant outcome of OCSEAP coastal zone studies is Hayes' tentative classification of coastal morphologies in order of their increasing susceptibility to oil spill impacts:

TABLE III-1. Atterberg Limits for Northern Gulf of Alaska Sediments**.

	Continental Shelf Sediments								
		Plastic Limit		Liquid Limit		Natural Water Content*		Plasticity Index	
Sed. Type	No. of Samples	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.
Clayey silt	22	17.0-29.3	23.8	23.9-50.8	39.3	24.1-90.2	52.8	6.1-23.5	15.6
Gravelly muds	6	17.0-29.7	23.9	22.7-47.8	36.3	30.9-53.4	41.6	5.7-18.1	12.4

* Water content when samples were tested for Atterberg Limits.

** From Carlson, Molnia, Kittelson and Hamtson, 'Bottom sediments on the continental shelf, Northern Gulf of Alaska' (paper in review).

1. Rocky headlands - Eroding wave cut platforms:

   Most areas of this type are exposed to maximum wave energy. Waves reflect off the rocky scarps with great force, readily dispersing the oil. In fact, waves reflecting off the scarps at high tide tend to generate a surficial return flow that keeps the oil off the rocks, as observed in Spain. There are a number of similar areas in the northern Gulf of Alaska.

2. Flat, fine-grained sandy beaches:

   Oil emplaced on such flat, hard-packed beaches will not penetrate the fine sand. Instead, it usually forms a thin layer on the surface that can be readily scraped off. Furthermore, these types of beaches change slowly, so burial of oil by new deposition would take place at a slow rate. The Copper River Delta barrier islands are good examples of this type of environment.

3. Steeper, medium- to coarse-grained sandy beaches:

   On these beaches, the depth of penetration and rates of burial of the oil would be greatly increased. Based on studies by Hayes' group, 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. Long stretches of shoreline in the Gulf of Alaska fall into this category.

4. Gravel beaches:

   Pure gravel beaches also have large penetration depths (up to 45 cm in Spain). Furthermore, rapid burial is also possible. A heavily-oiled gravel beach would be impossible to clean up without completely removing the gravel. Alaskan beaches downdrift of Sitkagi Bluffs and near rock headlands are composed of pure gravel and would behave similarly.

5. Sheltered rocky headlands:

   Hayes' experience in Spain indicates that oil tends to stick to rough, rocky surfaces. In the absence of abrasion by wave action, oil could remain on such areas for years, with only chemical and biological processes to degrade it.

6. Protected estuarine tidal flats and salt marshes:

   Once oil reaches a backwater, protected estuarine tidal flat or salt marsh, chemical and biogenic processes must degrade the oil if it is to be removed. This is a multiyear process. Much of the area behind the Copper River Delta barrier islands falls into this class.

This classification could be very useful both for identifying beach areas most likely to suffer long-term pollution impacts and for developing spill cleanup contingency plans. John MacKinnon (NMFS, Auke Bay) has provided a preliminary map of NEGOA shoreline substrates (Fig. III-4). Bedrock exposures generally receive maximum wave energy and will in essence be self-cleaning. Gravel and boulder beach areas are subject to deep penetration and oil removal or cleanup would be difficult. Without more specific grain-size data for NEGOA sandy beaches, it is difficult to assess the length of time beached oil will remain.

TRANSPORT PROCESSES

Introduction

Beginning in 1974, OCSEAP studies were designed to advance logically from a descriptive phase of presenting observations of steady-state conditions to the analytical phase of understanding processes and forecasting various time-dependent phenomena. The ultimate objective is to describe how circulation and physical oceanographic factors affect the distribution and seasonality of marine organisms and their vulnerability to impingement of OCS oil and gas development.

So far OCSEAP-related data have been obtained on the temperature-salinity distributions (dilution of seawater, mixing processes, property variability), Eulerian currents (long-term observations but no information on spatial dependence), Lagrangian drifters (spatial scale distributions), pressure measurements (both the internal and external parts, density field and surface tilt, respectively), remote-sensing techniques (suspended sediment plumes, temperature distribution signatures), and modeling (data synthesis, diagnostic extrapolation and interpolation, and particle or plume trajectories). In addition, data and models describing the nearshore meteorological processes are being generated. As a result, a fairly diverse and multidimensional, although not yet totally integrated and complete, picture has been constructed of the physical transport processes in the NEGOA lease area and adjacent waters.

Major Hydrographic Features

A representative seasonal cycle of temperature along the periphery of the Gulf is described by Ingraham, Bakun, and Favorite (RU #357, 1976). From January to March near isothermal conditions are present in the upper 100 m in waters over the shelf to a depth of 122 m. This mixed layer represents the winter convective overturn. Winter convection also results in the formation of a

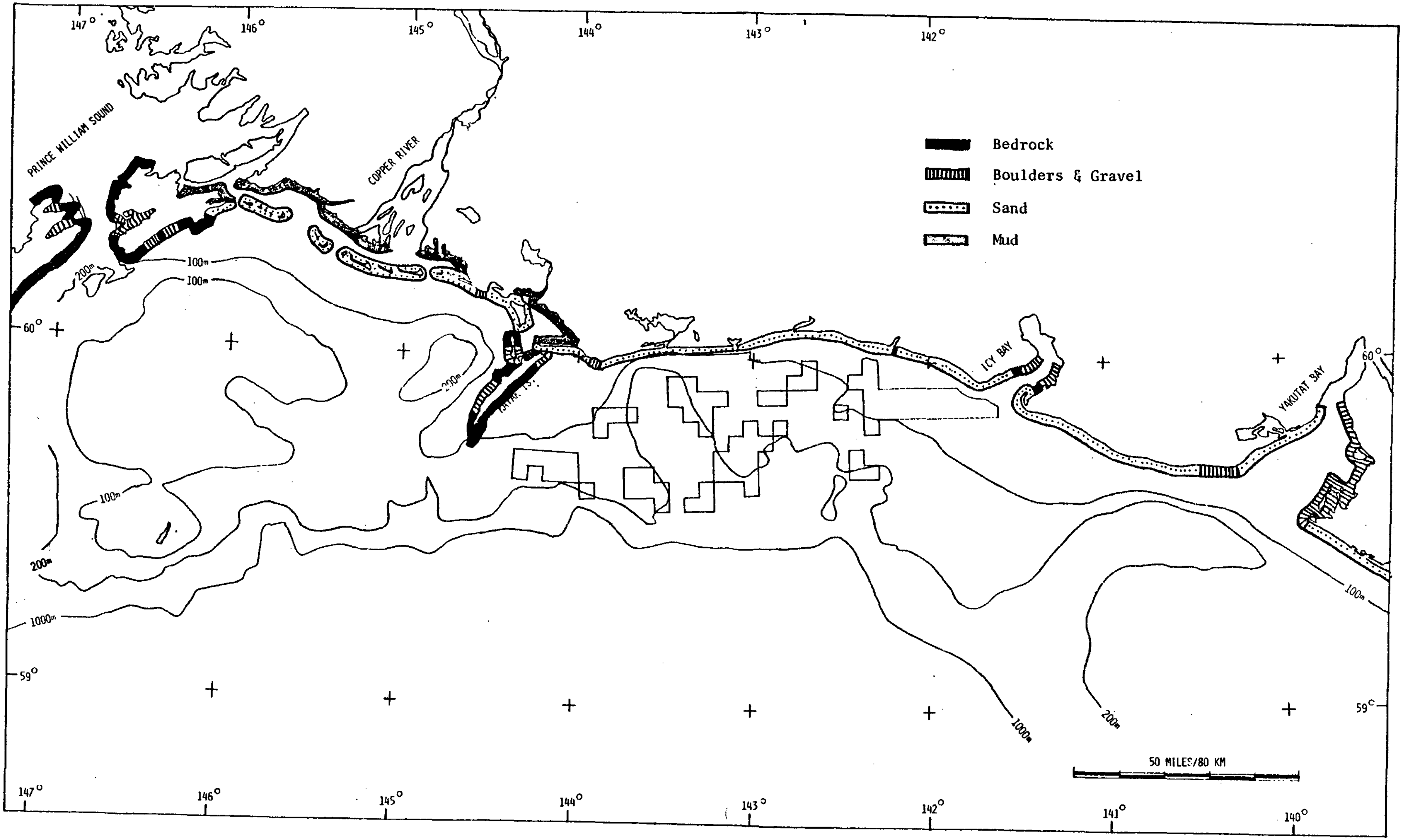


Fig. 111-4 NEGOA shoreline substrate types (J. MacKinnon, unpublished data, NMFS, Auke Bay, 1977).

temperature-minimum layer, ∿3°C at a depth of 75 to 150 m. Warming of the surface layer in summer results in a reduction of the thickness of the temperature-minimum stratum; however, it is not completely eliminated. Over the shelf and slope area, at about 122 m depth, a warm-water layer of 4.5 to 4.0°C is identified as a subsurface temperature-maximum layer. In deep water off Yakutat, Galt and Royer (1975) noted a subsurface temperature-minimum at 80 m and a maximum at 130 m in July 1974 data. According to these authors both of these features indicated water which was not formed locally. The subsurface maximum layer was identified as water that was formed near the surface in the vicinity of the North Pacific drift, probably at subarctic convergence. The water in the temperature-minimum layer was believed to have been formed "south of the region of interest [NEGOA]. . .somewhere in the central part of the gyre."

It can be seen from Fig. III-5 that the warm water is not in the form of a broad uniform layer but as a relatively narrow band. It is also clear that in areas where the warm water advects in and out of the region, the cold water layer becomes more apparent, i.e., at Stations 42-43 and 50. A plot of the layer when sigma-T value is 26.4 connects the isolated parcels of this water. The relatively complex distribution of this layer suggests a clockwise intermediate scale gyre along the boundary of this region.

Additional hydrographic data collected in 1974 and 1975 have also indicated the presence and complex distribution of this subsurface maximum layer although it seems that June 1975 data differed from that of July 1974 with regard to the large clockwise gyre indicated just offshore in July 1974 data. From the small amount of historic data available, it appears that the presence of this gyre may have been anomalous.

It should be noted that complex time-dependent variations may be superimposed on this flow, such as those caused by tides and storms. As an example, oscillations in the mixed layer depth at approximately semi-diurnal tidal frequency show possible effects of an internal wave with amplitude on the the order of 10 m (Fig. III-6).

West of Cape St. Elias, where the continental shelf is wide, there is little evidence of a well-defined core of warm water (Galt and Royer 1975). On the contrary, several small-scale perturbations in water properties are noted west of Cape St. Elias, perhaps caused by the presence of Middleton Island and a

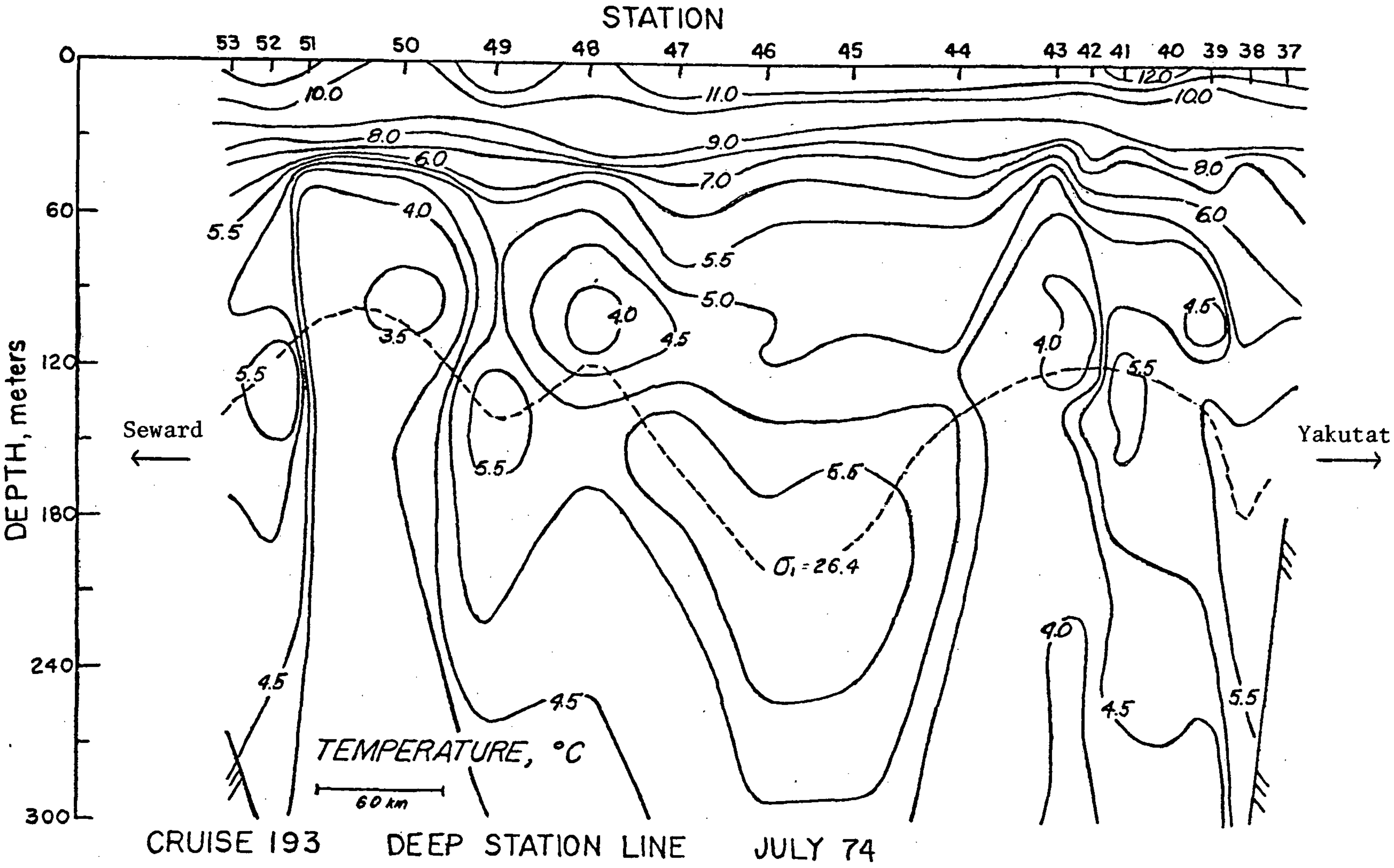


Fig. III-5. Vertical section of temperature versus depth extending offshore from Yakutat (STA 37-STA 43), west across the deeper offshore section of the Gulf of Alaska (STA 43-STA 51), and onshore to the continental shelf off Seward (STA 51-STA 53). The depth of the sigma-T = 26.4 surface is given by the dotted line (Galt and Royer 1975).

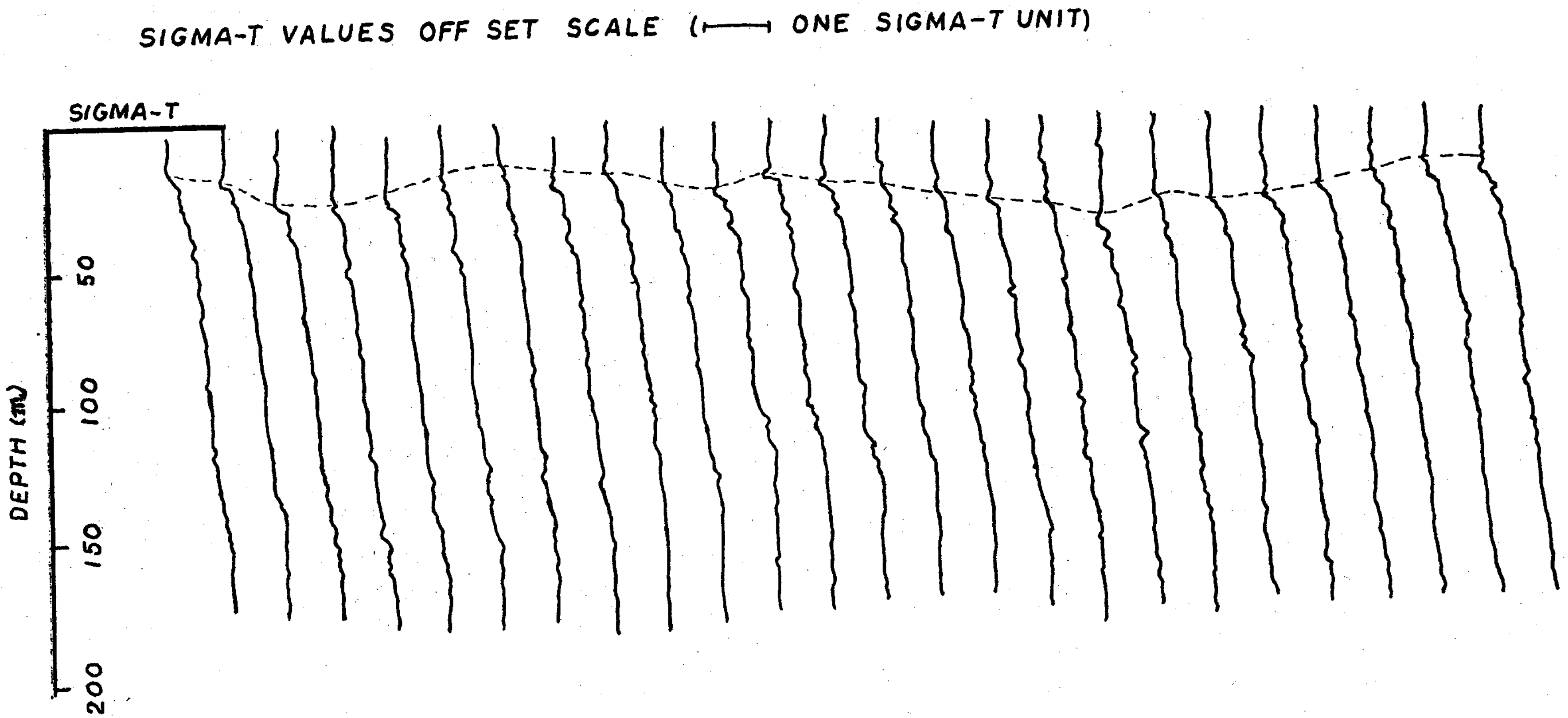


Fig. III-6. Vertical profile of sigma-T at hourly intervals in June 1975 at Station 62. Dotted line indicates mixed layer depth (Royer, RU #289, 1976).

change in flow direction from zonal to meridional (Hayes and Schumacher, RU #138, 1976; Royer, RU #289, 1976).

Extensive seasonal freshwater runoff around the gulf dilutes the coastal water; however, due to the paucity of data, its effect over the shelf has not been quantitatively evaluated. Variation in salinity at Station 1 (innermost of the Seward line) shows strong freshwater input in the surface layers in summer and early fall. It should be noted that accompanying the dilution of surface layers there is an increase in salinity of near-bottom water. This could be due to the large-scale wind stress changes, as the mean upwelling index is correlated with the salinity changes in near-bottom layers. This input represents the onshore-offshore component of the Ekman wind drift transport. According to Galt and Royer (1975), offshore moving surface water is replaced during upwelling by higher salinity near-bottom water moving onshore. Downwelling in winter appears to act as a flushing mechanism to remove the high salinity water from deeper layers.

In summary, the hydrographic data reported so far support the idea of a fairly stable mean circulation dominated by the Alaska Stream and modified by an onshelf-offshelf perturbation correlated with the regional winds. Superimposed on this are significant smaller scale (in both time and space) variations related to storms or tides (and probably many other things as well). There appears to be a difference in the predominance of the Alaska Stream with regard to the regions east and west of Cape St. Elias. To the east, global forcing seems more important and the Stream's influence is seen close inshore. To the west, the Stream is well offshore and local factors appear to be more significant.

Currents

Geostrophic Calculations. Seasonal changes in the dynamic topography across the sampling grid in the northern Gulf of Alaska have been used to infer baroclinic currents. Data relative to 100 decibars are illustrated in Appendix 3. 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. Along the Seward line, dynamic height calculations show a highly variable pattern. Generally high baroclinic flow is noted in fall; low values occur in late winter. It should be noted that several assumptions (simultaneous observations, unaccelerated motion, negligible friction forces, no periodic changes in mass distribution related to internal waves) are inherent when describing the relationship between currents and contours of geopotential topography. 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.

Seasonal currents estimated from data collected along the Seward line are shown in Fig. III-7. The influence of Alaskan Stream at seaward stations is seen by consistent westward flow between Stations 10 and 11. In addition, possible flow reversals are also noted, especially between Stations 5 and 8. Presently, it cannot be stated whether these features represent actual water direction reversals. Barotropic effects have not yet been incorporated.

Baroclinic transport calculations along the Seward transect indicate a mean transport, relative to 120 decibars, of about 1.5 Sv (1 Sv equals transport of 10^6 m^3/sec) westward. Rapid changes in transport occurred in February 1976 (see Table III-2). Typically, a minimum westward flow in the region of Station 6 and 8 are noted; often there exists an eastward flow.

Eulerian Current Measurements. Several sets of current meter data have been obtained in the NEGOA area. In particular, long time-series of data have been collected from current meter arrays at Station 60, located in the western segment on the shelf between the north of the Copper River Delta and Middleton Island, Station 61, located near the edge of the shelf midway between Middleton Island and Cape St. Elias, and Station 62, located near the shelf break offshore from Icy Bay. Available results from these stations are shown in Table III-3. Most of the time the flow is NNW, with weaker flow at depths. Currents generally follow the local isobath. At Station 61, flow is westward and very consistent, particularly for the upper meter. Seasonal buildup is well pronounced in October and November.

A long time-series of current meter data, since August 1974, has been obtained at Station 62. Nominal depths for the current meters at this station have been 20, 50, 100, and 175 m below the surface in 185 m of water. No record is complete for the entire period of observation (up to May 1976), but

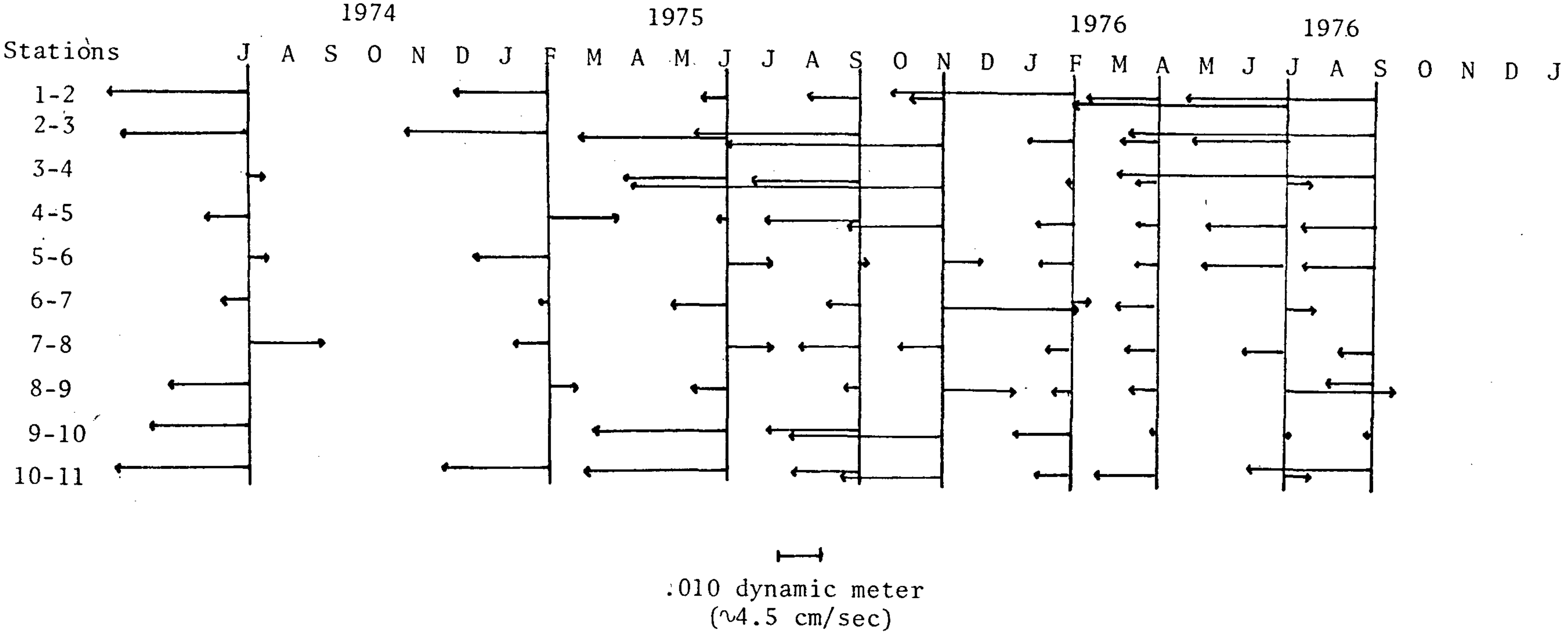


Fig. III-7. Baroclinic current component of Seward Station line, Gulf of Alaska (Royer, RU #289, 1976).

TABLE III-2

Estimated baroclinic water transport in Sverdrups (million cubic meters per second) relative to 120 decibars along the Seward line (Royer, RU #289, 1976).

Date	Transport, Sv.
July 1974	1.65
June 1975	1.69
November 1975	1.44 (.22 eastward)
February 1976	1.43
February 1976	1.94
February 1976	2.36
April 1976	1.52

TABLE III-3

Mean Flow Rates (cm/sec) and Direction (°TN) from Moored Current Meter Arrays, at 20 and 100 m, from Stations in the Gulf of Alaska (Hayes and Schumacher, RU #138, 1976).

Station		Observation Period	Mean Flow	Direction
62E,	20 m	Sept. 20- Nov. 21, 1975	21.9	308
	100 m		13.7	311
61,	20 m	Aug. 16-Nov. 15, 1975	18.9	283
	100 m		1.8	303
60,	20 m	July 2-Aug. 26, 1974	7.3	277
	100 m		1.2	156

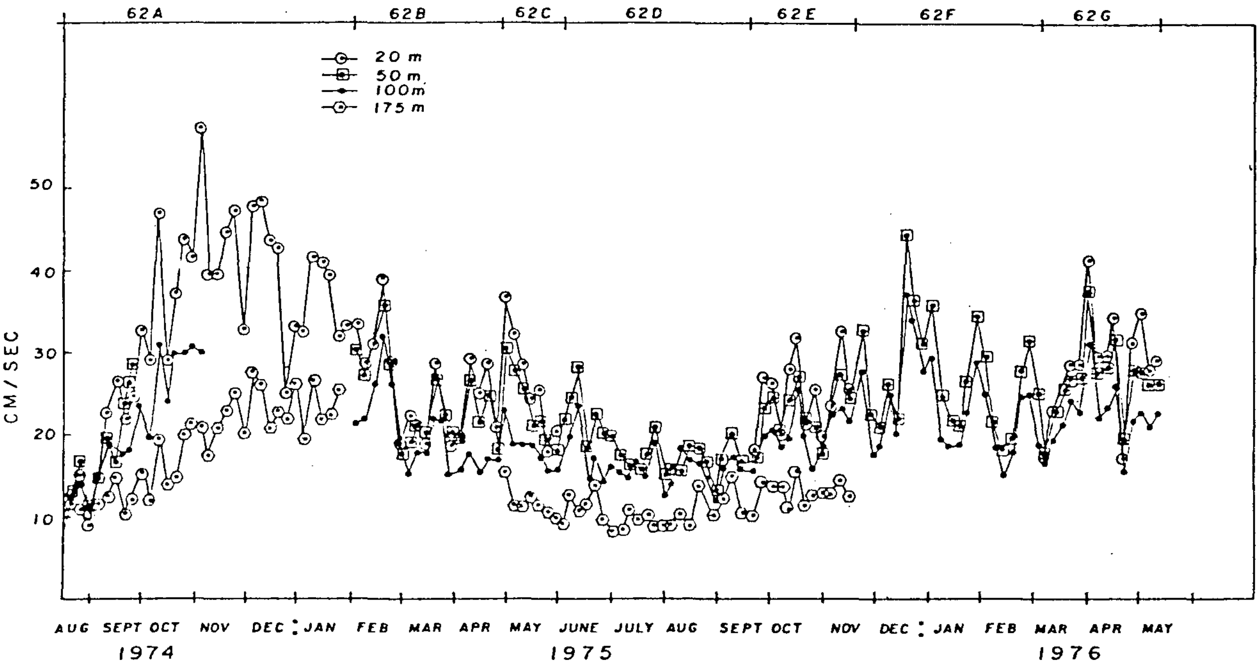


Fig. III-8. Five-day speeds for all available data from Station 62 from August 1974 through May 1976. Data from the 50 m and 100 m current meters were continuous from February 1975 through May 1976. Mean speeds were higher in winter than in summer (Hayes and Schumacher, RU #138, 1976).

for the 50 m and 100 m depths there are continuous records for over 15 months. Current data was processed with a 2.9 hr low pass filter to remove very high frequency noise. The 5-day mean speeds over the entire available record are shown in Fig. III-8. At 20 m, values ranged from 9 to 57 cm/sec while at 175 m the mean current ranged from 8 to 28 cm/sec. Seasonal changes in the flow are easily recognized.

Extreme Value Analysis was applied to 50 m and 100 m continuous current meter observation (15 month period) to estimate extreme flows probable in longer time intervals. It was calculated that for the data at 50 m, a maximum speed of over 112 cm/sec probably will occur in an observation period of 5,000 days. Similarly, extreme flow at 100 m is likely to be 100 cm/sec for the same period of 5,000 days. Furthermore, assuming that the vertical profile of mean speed has a power law dependence on depth, an extreme speed of 155 cm/sec would probably occur at 10 m for the same 5,000 days (Hayes and Schumacher, RU #138, 1976).

Lagrangian Drifters. Results from the release and monitoring of free-drifting buoys have been obtained for September 1975, May-June 1976, and July 1976 (Hansen, RU #217, 1976). The data were obtained via a satellite system (NIMBUS) that telemetered buoy position on each orbit within range. By plotting successive positions, Lagrangian trajectory of the motion is obtained for each buoy.

One of the two buoys released in the vicinity of Fairweather Ground, Buoy #6601, drifted westward apparently showing the strong influence of local bathymetry and grounded off Cape Suckling (Fig. III-8a, Hansen, UR #217). The flow appeared to be intermittent as estimated current speed typically varied between 15 and 51 cm/sec (013 to 1.0 knot). Buoy #1133, released in May, 1976, stayed in offshore water before being grounded near Middleton Island (Fig. III-8b, Hansen, UR #217). The path of this buoy crossed the Alaskan Gyre (the gyre is only weakly developed in summer). Estimated drift speed of this buoy was fairly high; for example, between day 153 and 158 the average speed exceeded 1 knot. Buoy 1174, released in June 1976, moved inshore and then drifted around Kayak Island. West of Kayak Island, it idled in an anticyclonic eddy for about 25 days before moving westward. After a brief cyclonic motion, this buoy landed on the eastern shores of Montague

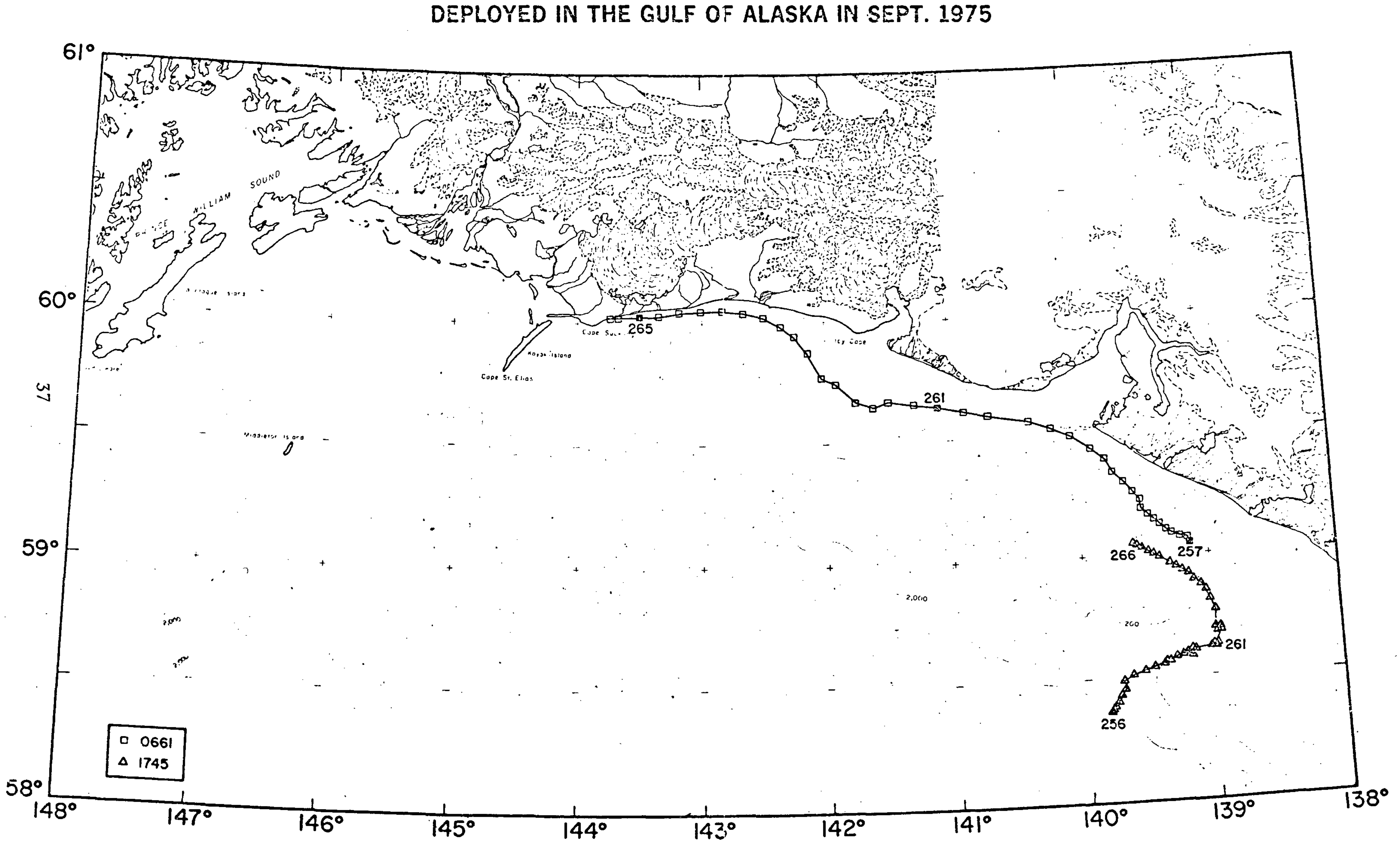


Fig. 111-8a Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

DEPLOYED IN THE GULF OF ALASKA IN MAY-JUNE, 1976.

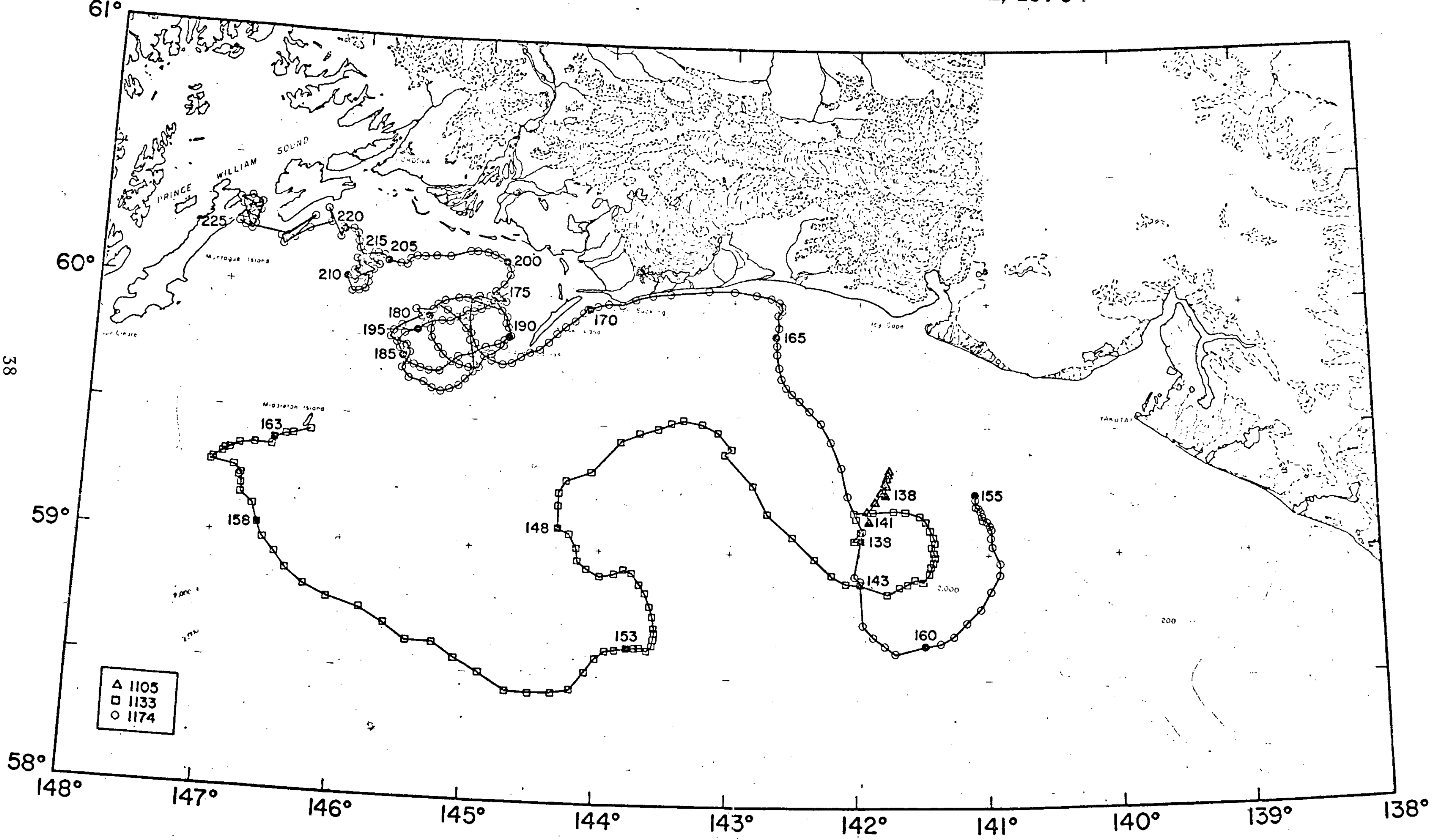


Fig. 111-8b Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

DEPLOYED IN THE GULF OF ALASKA IN JULY 1976.

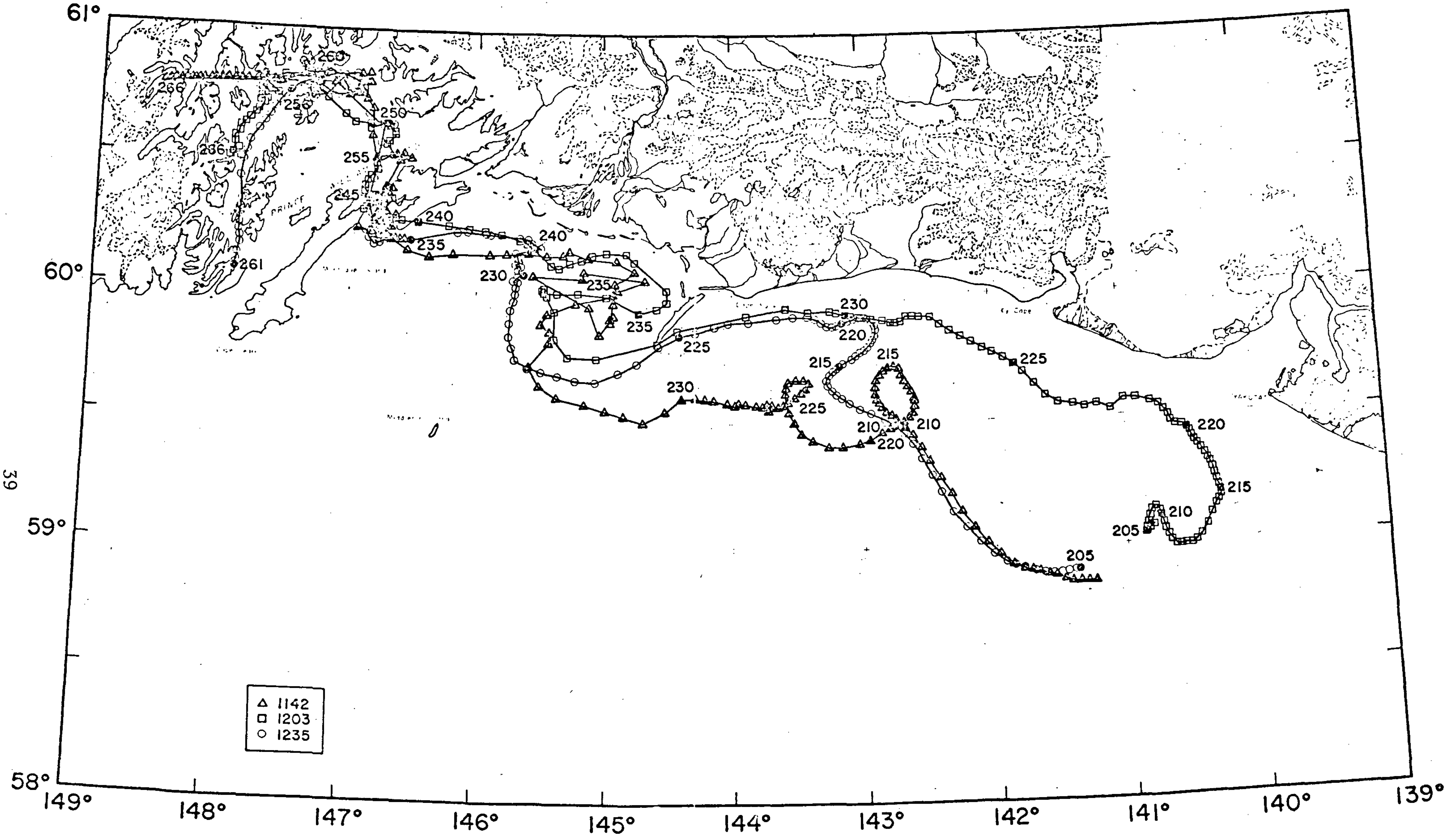


Fig. 111-c   Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

Island at the Hinchinbrook Entrance (Fig. III-8c, Hansen, RU #217). Buoys deployed in July 1976 generally followed the path of buoy 1174. All three buoys (1142, 1203, 1235) drifted to positions west of Kayak Island. After idling in an eddy for a few days, all ended up in Prince William Sound. It took approximately 45 days from the release of the buoys off Yakutat Bay to their entry into Prince William Sound.

The presence of an anticyclonic eddy west of Kayak Island, as demonstrated by buoy tracks, has been affirmed by hydrographic and satellite imagery data. There are indications of a minor, and possibly incomplete, cyclonic gyre farther west. However, the reasons for the entry of buoys into the Prince William Sound are not clearly understood. It should be emphasized that in nearshore and shallow waters, the drift of these buoys would not represent near-surface flow. The deep drogue is about 30 m below the surface and may be drifting beneath the thermocline. There is a possibility that buoys enter the Sound with inflowing deeper water (a manifestation of positive estaurine circulation). There might well be an outflow in the surface layers.

Wind-Induced Responses

Monthly mean conditions of coastal and offshore divergence indices at various locations in the NEGOA, as identified by combinations of wind stress, Ekman transport and upwelling-downwelling vectors, show a stable and possibly low energy situation in summer. Winter is characterized by highly energetic pulsations and relaxations throughout the area (Ingraham, Bakun, and Favorite, RU #357, 1976).

Data from a field experiment (February to May 1975) have been analyzed to show wind-induced response in current and bottom pressure measurements off Icy Bay, in the vicinity of Station 62 (Hayes and Schumacher, RU #138, 1976). The results show a definite change from winter conditions to a spring transition period. The February velocity and pressure data were linearly correlated; correlation was insignificant for spring data.

High wind velocities in February, especially on February 17, 22, and 26, were reflected in increased bottom pressure and current speeds (Fig. III-9). Increase in daily mean alongshore velocity of about 40 cm/sec were observed at 20 m and 50 m. These velocity changes were accompanied by 15 cm increase in bottom pressure. It should also be noted that ocean response to wind changes was quite rapid. Storm-induced velocity changes were of about the same

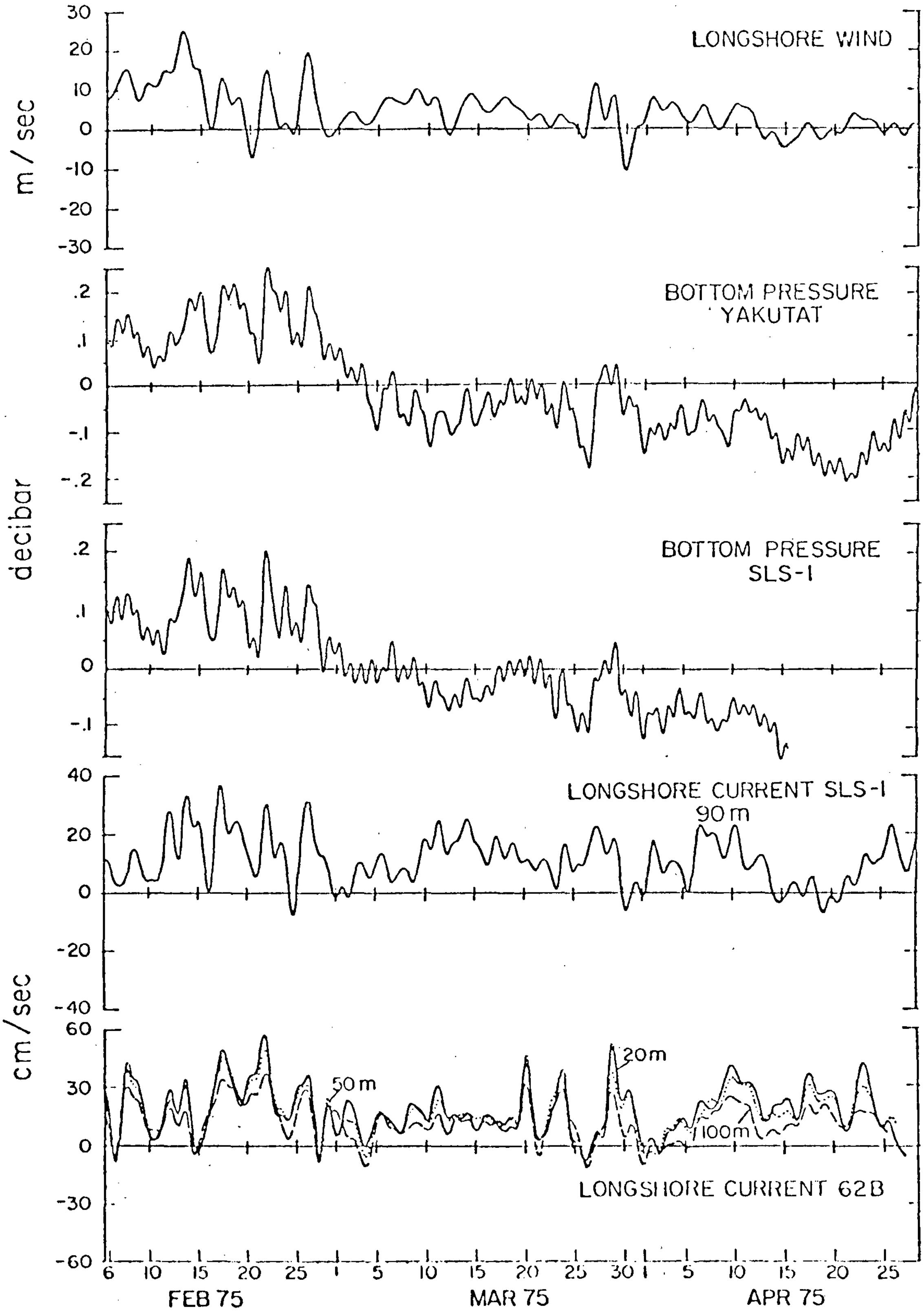


Fig. III-9. Time series of measurements from Icy Bay pilot experiment February to May 1975 (Hayes and Schumacher, RU #138).

magnitude as the mean flow. On March 20, on the other hand, current meter records at Station 62-B at 20 m showed a large increase, up to 50 cm/sec, but this increase was not associated with changes in bottom pressure. A lack of significant coherence between bottom pressure at Yakutat and calculated wind field was also noted for spring data. It has been suggested that either the baroclinic or non-local effects may be more important in spring.

Circulation in Prince William Sound

Prince William Sound is a semi-enclosed body of water located in the northern Gulf of Alaska and may be classified as a fiord-type estuary. Local bathymetry and physiography of the Sound are complex and varied but a deep basin, nearly 800 m, connected to the Gulf of Alaska is a highly significant feature. Hinchinbrook Entrance and Montague Strait are the two major channels with direct access to the sea outside. The following account is based principally on a report on the general hydrographic regime and inferred circulation scheme for the Sound (Muench and Schmidt 1975).

Major inflow of deep oceanic water into the Sound occurs through the Hinchinbrook Entrance as the water flows directly into the basin. Inflow via Montague Strait (as it pertains to deep water exchange) is only of limited significance due to the shallower sill depth and also because it is a relatively long passage, interspersed with numerous small passages where local dilution of inflowing water may occur.

The hydrographic features observed within Prince William Sound reflect the varying characteristics of the Gulf of Alaska source waters, as noted from the temperature and salinity distributions. The effect is most pronounced in the salinity distribution, with a winter decrease in salinity below approximately 150 m as reflected in the downward migration of the 32.5 o/oo isohaline and a late spring-summer increase as evidenced by upward migration of the same isohaline. This coincides with the occurrence off Hinchbrook Entrance of low salinity water during the winter and high salinity water during the summer. The salinity fluctuations are correlated to the extent that it seems reasonable for at least part of the variation to be due to advective inflow of water through Hinchinbrook Entrance. Moreover, the deep salinity increase occurs at a time when the near-surface salinity is decreasing and vice-versa, suggesting that different mechanisms are responsible for deep and near-surface variations.

Data from direct current measurements in the Prince William Sound are not available. The circulation regime can only be inferred from the observed distribution of temperature and salinity (and hence also of density).

The prominent subsurface structural feature observed in the Sound is the dome-like rise in the isolines of salinity, temperature, and density in the central eastern portion. This structure suggests the occurrence of a cyclonic circulation pattern with a tendency for upwelling, particularly during winter. Such a circulation is manifested in higher salinities and temperatures in the central Sound when the feature is well developed. The most pronounced example of a surface distribution that suggested a circulation cell occurred during June and September 1972 when high salinity occurred at the surface in the center of the gyre region. The lower surface salinities from Hinchinbrook Entrance probably reflect the influence of the Copper River plume, which enters the Gulf of Alaska upstream from the Entrance. Although it seems unlikely that such a gyre would be in geostrophic equilibrium, due to the probable presence of frictional and time-dependent terms, a cyclonic circulation would in fact tend to satisfy the force balance suggested by the isopycnals. The inclination of the isopycnals, possibly related to the strength of the cyclonic circulation, varies considerably from virtually horizontal (during May 1973) to extreme upward bowing (during March 1972).

The cyclonic gyre may be a consequence of a Kelvin wave circulation associated with strong local tides. At flood tide, there would be inertial tendency for water flowing through Hinchinbrook Entrance to continue northward along the eastern edge of the basin. The ebb tide would have no specific directional tendency within the Sound. The net effect would be a cyclonic circulation. Surface currents through Hinchinbrook Entrance have been reported to be on the order of 2 to 3 knots; currents of such magnitude would be expected to play a significant role in circulation dynamics inside the Sound. The seasonality, however, suggests that they may also be related to local climatic variability, possibly through wind stress and thermohaline mixing.

Numerical Modeling & Trajectory Simulation

Galt (RU #140, 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. Similarly, wind-driven currents are determined once the surface wind-stress distribution is known. Results of a typical model run are shown in Fig. III-10.

The predominantly westward flow is evident on the shelf east of Cape St. Elias. The presence of two gyres is also evident in the region just to the west of Cape St. Elias. The one nearest to shore is the weaker; it moves counter-clockwise and carries water from offshore in toward the coastline immediately south of the Copper River. The second gyre, just offshore from the first, is the stronger and clockwise, carrying water in an offshore direction past Cape St. Elias. These gyres are obviously related to the density distribution; close examination of the data reveals that runoff from the Copper River introduces lower salinity water that contributes to this region of lower density. The weak eastward flow nearshore in the vicinity of Icy Bay is apparently controlled by bathymetric variation in this area and farther east due to presence of the Yakutat Sea Valley. It may be recalled that an apparent eastward current (baroclinic) was noted from hydrographic data along Seward Line.

In general, the model results reflect the mean speed and direction of the flow. Trajectory data from Lagrangian drogue studies appear to support large scale current patterns and the presence of gyres west of Kayak Island shown by model results. It should be noted that certain details in flow characteristics will not be represented. In particular, shelf wave phenomena cause oscillations in the speed and direction of flow which are not reproduced by the model. In addition, the spatial resolution of the model is limited and the exact position of current features cannot be predicted to any greater accuracy than the available input data. This means that although the model clearly recognizes the local dynamics that lead to gyres, its resolution with respect to position is no better than that enabled by station spacing.

Based on this model, trajectories of sea surface particles were also simulated. Trajectories were calculated by advecting marked particles and incorporating wind effects. Results obtained so far are only preliminary.

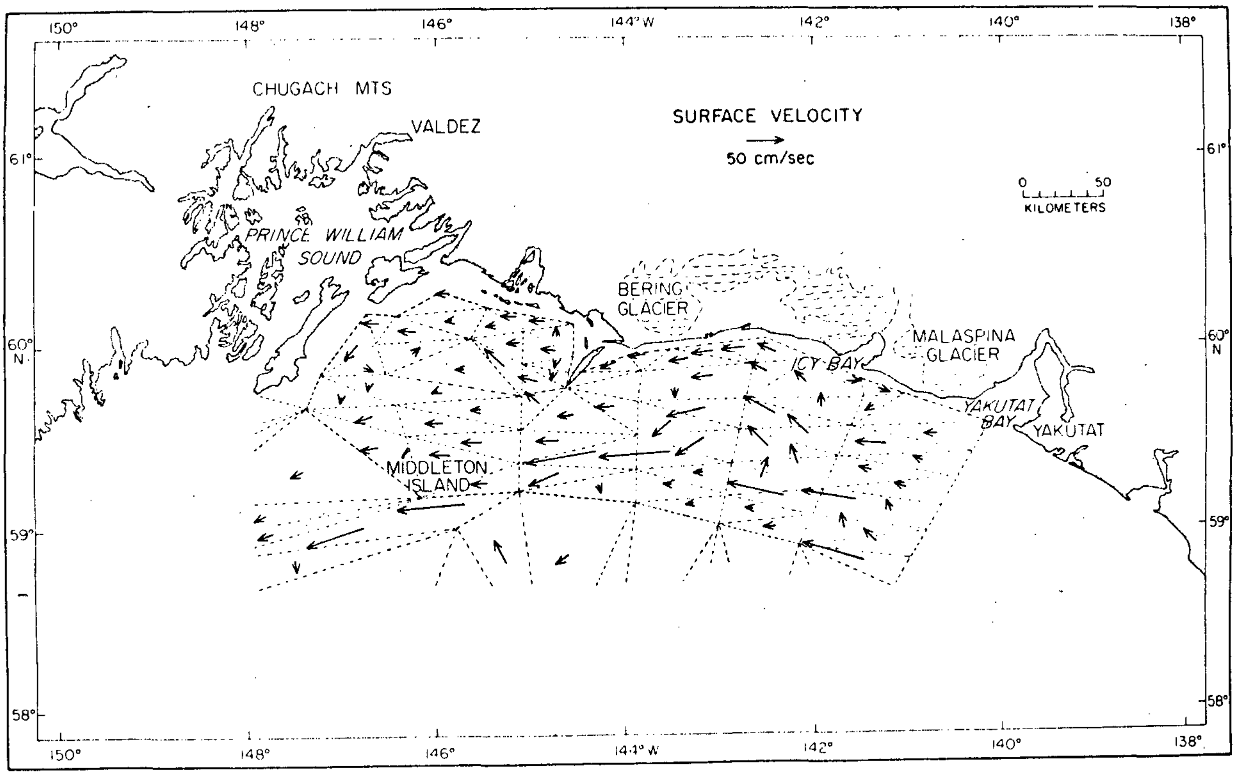


Fig. III-10. Numerical model results for test case using density data collected in July 1974. Vertices of triangles indicate oceanographic station locations used for input data (Galt, RU #140, 1976).

A case in which real current and real wind data were used as input is illustrated in Fig. III-11. The starting point for trajectories is 59° 47.9'N and 142° 52.0'W, a location southwest of Cape Yakataga. The origin of the plot (0,0) corresponds to 58° 12.5'N and 149° 30.5'W. Each point is stepped for 30 days until it leaves the triangle grid. If a point reaches the grid boundary prematurely, a star is printed over its location. Each point location is printed at the end of the first week, a square for the second, and a triangle for the third.

It can be noted from Fig. III-11 that several locations north and east of the start location were impinged within a time scale of 1-7 days. A substantial number of trajectories ended at Pt. Riou (Icy Bay region). After one week, particle trajectories were generally found in areas west of Kayak Island. Only one trajectory continued for three weeks. Three trajectories also ended in the vicinity of Hinchinbrook Entrance.

It should be re-emphasized that model results be considered in view of their preliminary nature and model limitations. The present model has inherent "noise." Continued efforts involving various combinations of stochastic and/or measured input data, varying surface wind effects on particle drift angle, and other refinements will help put a degree of confidence in simulated trajectories.

Sediment Plumes and Transport

ERTS-1 data from the area west of Kayak Island, shows the distribution of suspended sediment plumes. When sources of sediment plumes are identified, the downstream plume distribution can be used to infer patterns of circulation. It can be seen (Fig. III-12) that sediment plume from the Copper River (1) is very well developed. Its westerly extension could be a manifestation of local density induced currents as well as nearshore remnants of the Alaskan Stream. It is not possible to conjecture on the time and space scales of the apparent irregularities in the shape of the plume. The sediment plume originating upstream (to the east), principally from the Bering Glacier, is also seen (2). An outward flowing plume seaward of Hinchinbrook represents the effect of ebbing tides (a time when this portion of Fig. III-12 was obtained). A lee vortex is visible on the downstream side of Kayak Island. A clockwise, eddy-like feature, with considerably more diffused sediment content southwest

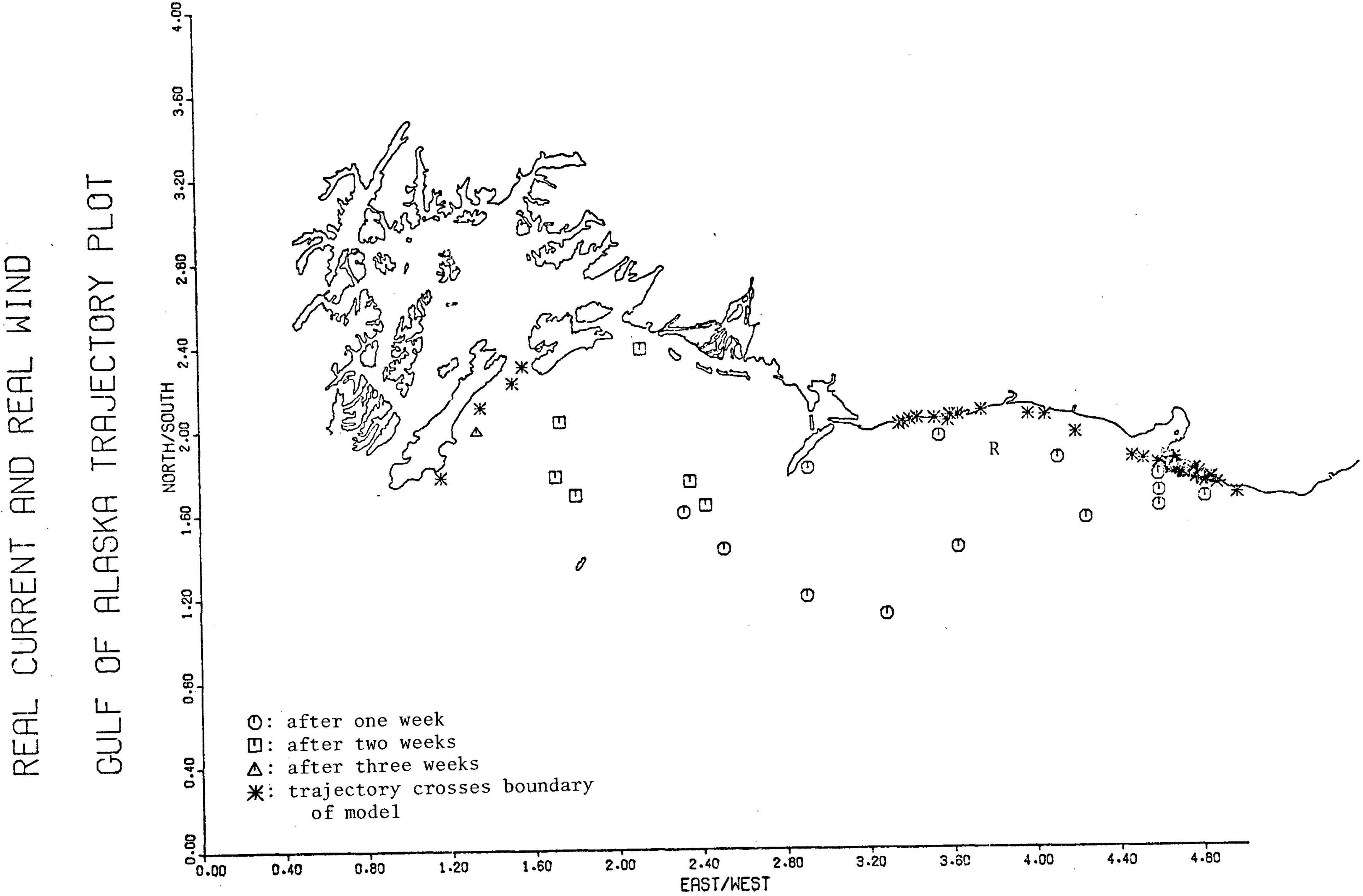


Fig. III-11Simulated surface particle trajectories in the NEGOA lease area and adjacent waters. "R" is the approximate release site (Galt, RU #140).

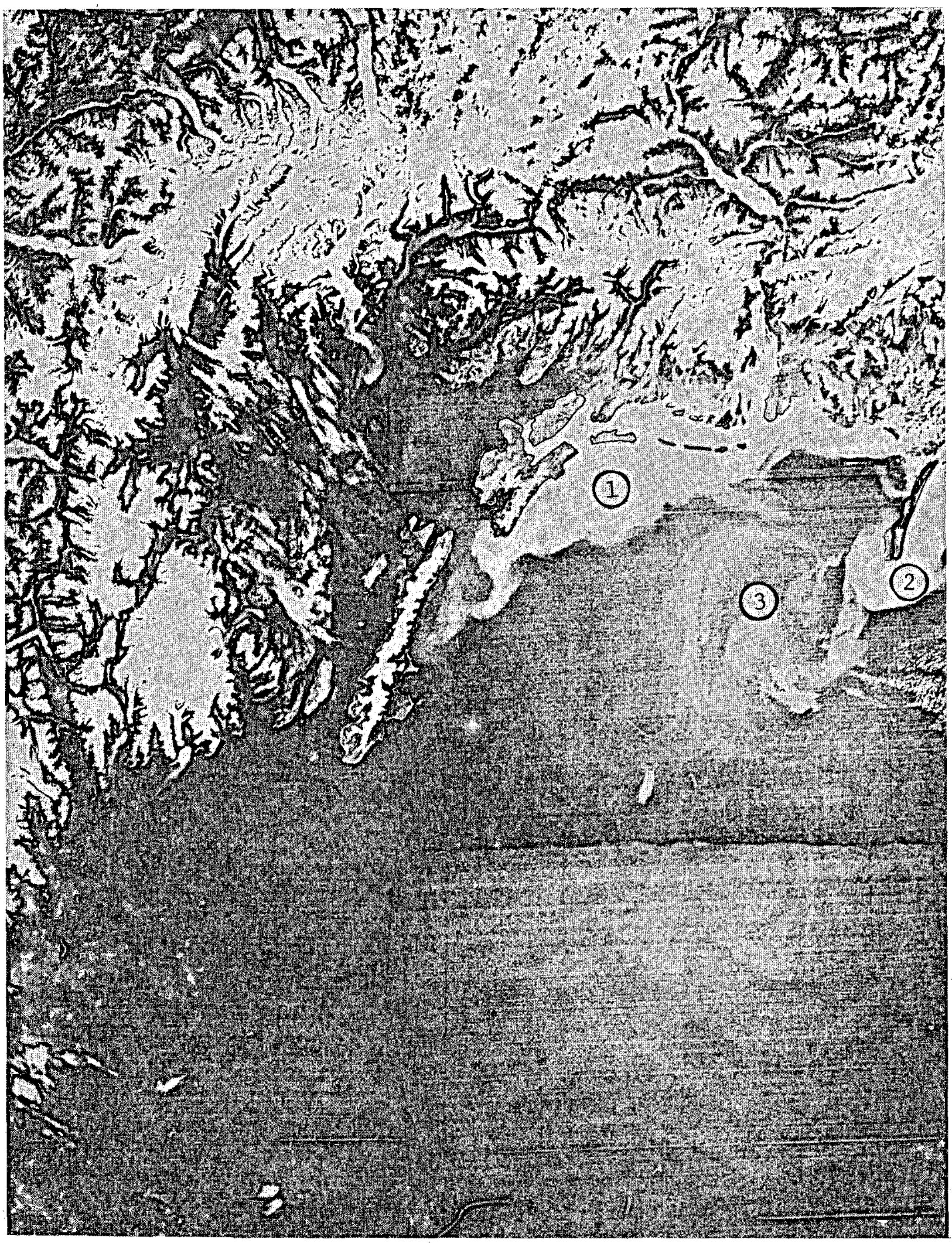


Fig. III-12. Distribution of sediment plumes as seen by composite of ERTS images acquired on August 14-16, 1973 (Muench and Schmidt 1975). See text for additional explanation.

and west of Kayak Island (3), may be due to vortex shedding downstream. It seems more likely, however, that this sediment distribution pattern represents a clockwise gyre being controlled by both the westward flowing Alaskan Stream and density flows governed by Copper River freshwater discharge. (It is not likely that this pattern represents an inertia current, i.e., one controlled by the earth's rotation.)

Suspended Particulate Distribution

Feely and Cline (RU #152, 1976) have documented spatial and temporal distributions of suspended particulate matter within NEGOA (NOAA 1975; NOAA/SAI 1976). Surface concentrations are greatest off the Copper River Delta (Fig. III-13) and decline rapidly away from the coast. Due to increased river runoff, summer surface concentrations exceed winter values. Suspended matter declines with depth but increases sharply again within a few meters of the seafloor (compare Figs. III-14 and III-15). The thickness of the bottom nepheloid layer varies from less than 20 m over topographic highs such as Tarr Bank to greater than 50 m in topographic depressions experiencing rapid sedimentation rates, such as Kayak Trough.

While surface suspended particulate concentrations peak in summer, reflecting maximum river outflow and sediment influx, near-bottom values peak in the winter. Sediments settling out from summer runoff are apparently resuspended during the subsequent fall and winter by storm-induced bottom currents.

Persistent scouring of topographic highs will preclude the accumulation of pollutants. However, the deposit feeding benthic communities of topographic depressions such as the Kayak Trough (an important area for snow crab and pink shrimp) would be receptors of any resuspended toxic substances moving down slope.

ERTS imagery indicates that Copper River sediments are entrained by northwest flowing currents and divide at Hinchinbrook Island with a portion entering Prince William Sound. Surface particulate concentrations near Hinchinbrook Entrance are relatively high but decrease rapidly within the Sound indicating rapid dispersal and settling (Feely and Cline, RU #152, 1976). Sub-bottom profiling confirms the presence of a landward-thinning wedge of sediments carried in through Hinchinbrook. Prince William Sound (highly productive and yielding several commercially important species) thus appears to be a potential principal receptor for pollutants associated with suspended particulate matter originating in the NEGOA region.

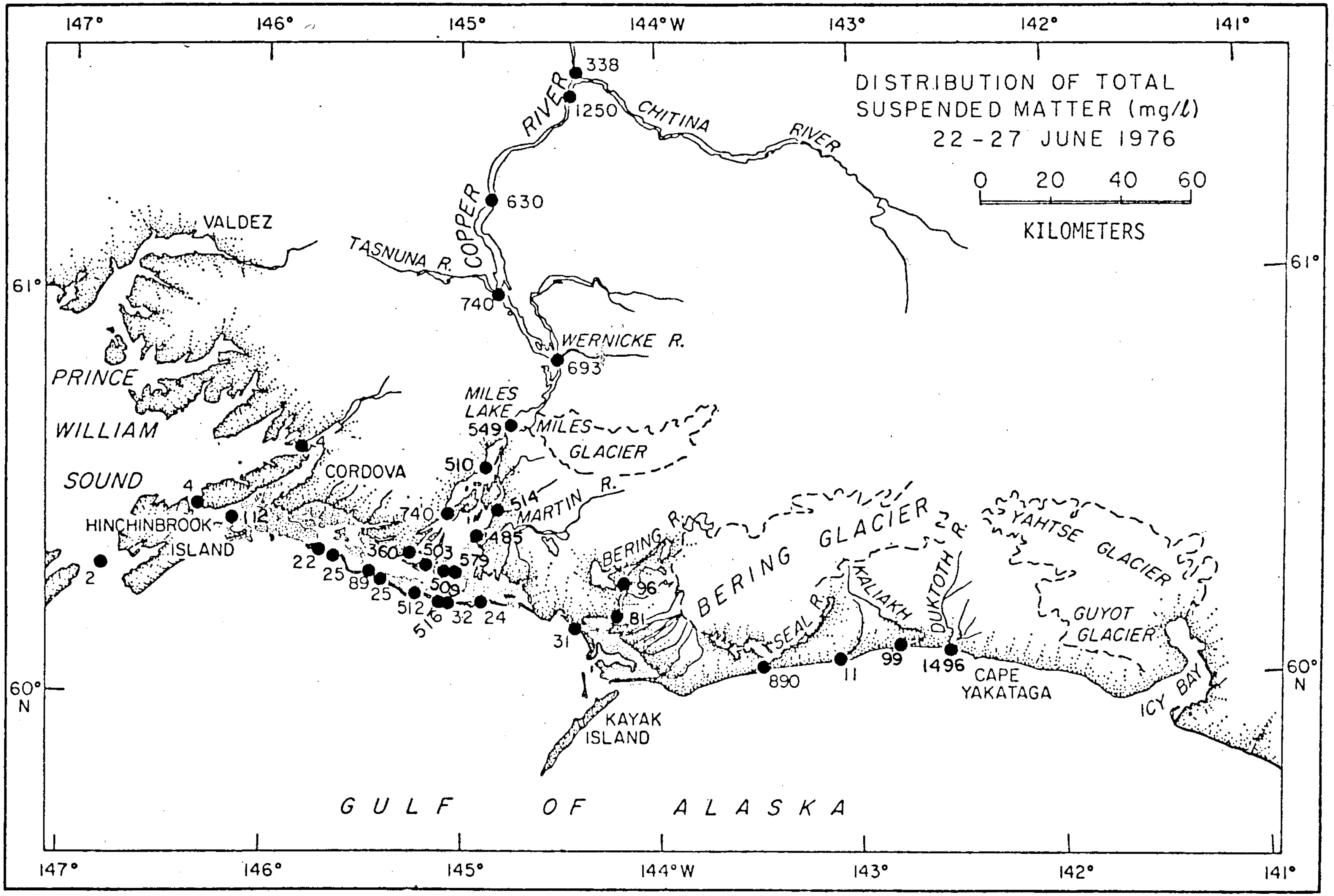


Fig. III-13 Distribution of total suspended matter at the surface in the major rivers draining into the Northeastern Gulf of Alaska (22-27 June, 1976) (Feely and Cline, RU #152, 1976).

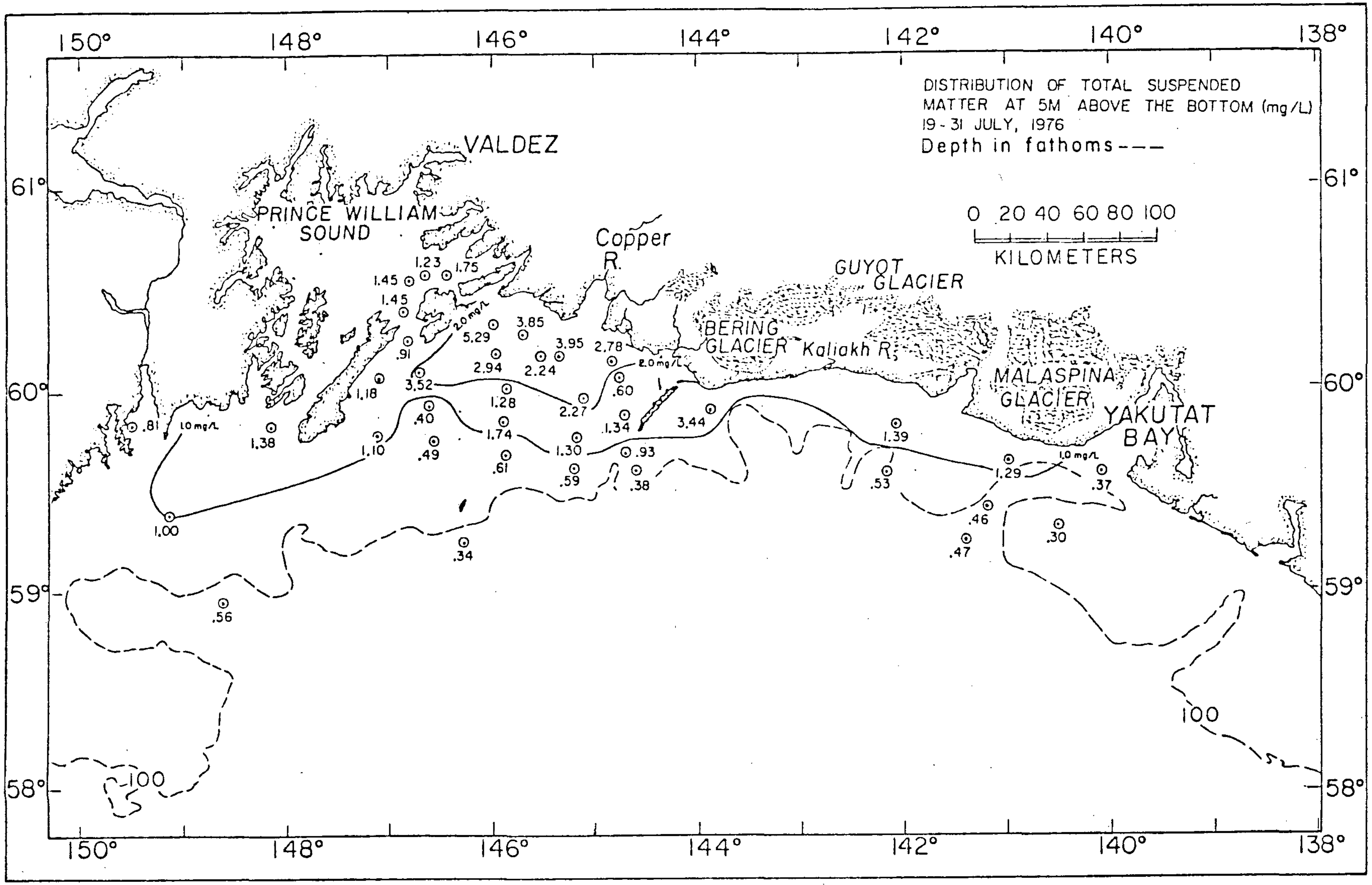


Fig. III-14. Distribution of total suspended matter at 5 m above the bottom in the Northeastern Gulf of Alaska (19-31 July, 1976) (Feely and Cline, RU #152, 1976).

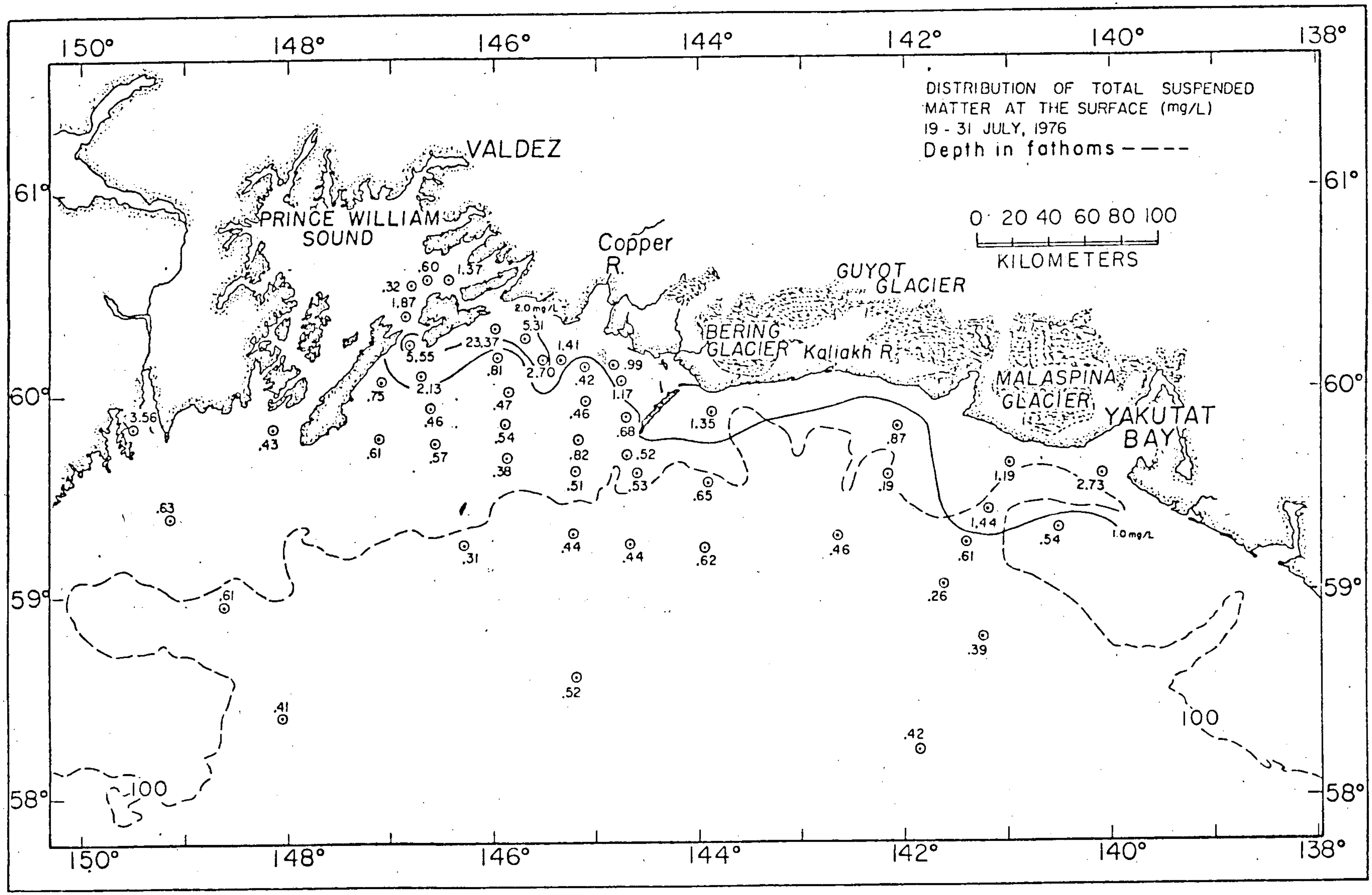


Fig. III-15. Distribution of total suspended matter at the surface in the Northeastern Gulf of Alaska (19-31 July, 1976) (Feely and Cline, RU #152, 1976).

RECEPTORS

Plankton

Phytoplankton and Primary Productivity. Available historic data, prior to OCSEAP investigations, on the distribution of nutrients, phytoplankton and plankton primary productivity in the Gulf of Alaska and adjoining North Pacific Ocean are being tabulated by Anderson and Lam (RU #58, 1976) to describe temporal and geographic variability. The regional and seasonal coverage of these data is not uniform; a vast majority of data is from one location only, the Canadian Weather Ship Station 'PAPA' (50°N, 145°W). Primary productivity data have so far been compiled and reported. Available data covering the NEGOA lease area are sparse ; the number of primary productivity observations is 4 for winter, 6 for spring, and none for summer and fall. Based on these data, the primary productivity in the upper 10 m is about 2 $mgC/m^3/hr$ in spring and 1.4 in winter. The following phytoplankton species are numerically abundant and had widespread distribution:

Diatoms: *Corethron hystrix, Coscinodiscus oculis iridis, Denticula semina, Fragilariopsis* sp., *Rhizosolinia alata, Thalassiosira lineata*
Dinoflagellates: *Ceratium pentagonum*
Coccolithophorids: *Coccolithus hyxleyi, C. pelagicus*
Others: *Halosphaera viridis* (microflagellate)

Only very few OCSEAP-related measurements on phytoplankton and primary productivity have been made in the northern Gulf of Alaska. Larrance (RU #156-C, 1976) has reported preliminary results from data obtained for various locations between Yakutat Bay and Resurrection Bay in Fall 1976. A detailed account of this study and the results obtained was given in FY 76 OCSEAP Research Project for the NEGOA lease area (NOAA 1976). It was noted that in the upper 50 m, higher chlorophyll concentrations were found in oceanic waters than in waters over the shelf. Primary productivity showed high spatial variability (between stations) over the shelf, probably associated with changes in surface insolation and concentration of suspended particulate matter in water. A subsurface maximum in primary productivity usually occurred between 5 and 15 m. Nitrate-N concentration in surface layers was between 3 and 12 mg-at/m^3; other inorganic nutrients were also present in appreciable quantities. Phytoplankton productivity was probably not nutrient limited; light may have been a major controlling factor at the time of observations.

Unidentified microflagellates, 5-25 µ in diameter, were found to be ubiquitous in the research area. They comprised the most abundant group at 15 of the 31 stations and were among the top five most abundant groups in the examined samples from all stations, except at Station 40 in the Prince William Sound. The distribution of substantial numbers of cells, > 100/ℓ, of two species, *Thalassionema nitzschioides* and *Fragillariopsis* sp., were nearly mutually exclusive. Mean concentration of *T. nitzschioides* was 2,000 cells/ℓ; the species was abundant east of Kayak Island. *Fragillariopsis* sp., mean concentration 1,700 cells/ℓ, was found in substantial numbers only south and west of the Copper River Delta. The silicoflagellate, *Dictyocha fibula,* was also limited to the western part of the gulf. In the Prince William Sound diatoms accounted for almost all the phytoplankton; *Skeletonema costatum* was highly abundant, up to 1.7×10^6 cells/ℓ (Larrance, RU #156-C, 1976).

Numerical Model of Chlorophyll a and Primary Productivity. Preliminary results from a numerical model describing changes in chlorophyll *a* and primary productivity for station PAPA have shown a good correspondence between the observed average and simulated data. For chlorophyll data, observations between the years 1959 and 1967 were averaged in order to obtain an adequate time coverage (Fig. III-16). Depth integrated primary production was averaged for the years 1961-63 (Fig. III-17). The time rate of change of chlorophyll, an estimator of phytoplankton biomass, at a given point, is given by:

$$\frac{d\,(\text{chlorophyll})}{dt} = \text{vertical mixing} + \text{sinking} + \text{gross production} - \text{respiration} - \text{zooplankton grazing}$$

The major inputs into the equation included the turbulent mixing coefficient, the nutrients and light which control gross production, and the changing population of herbivores which graze on the phytoplankton. Model coefficients were derived from literature data. Measured light and zooplankton data were utilized. Profiles of the vertical mixing coefficient, K_z, with depth were

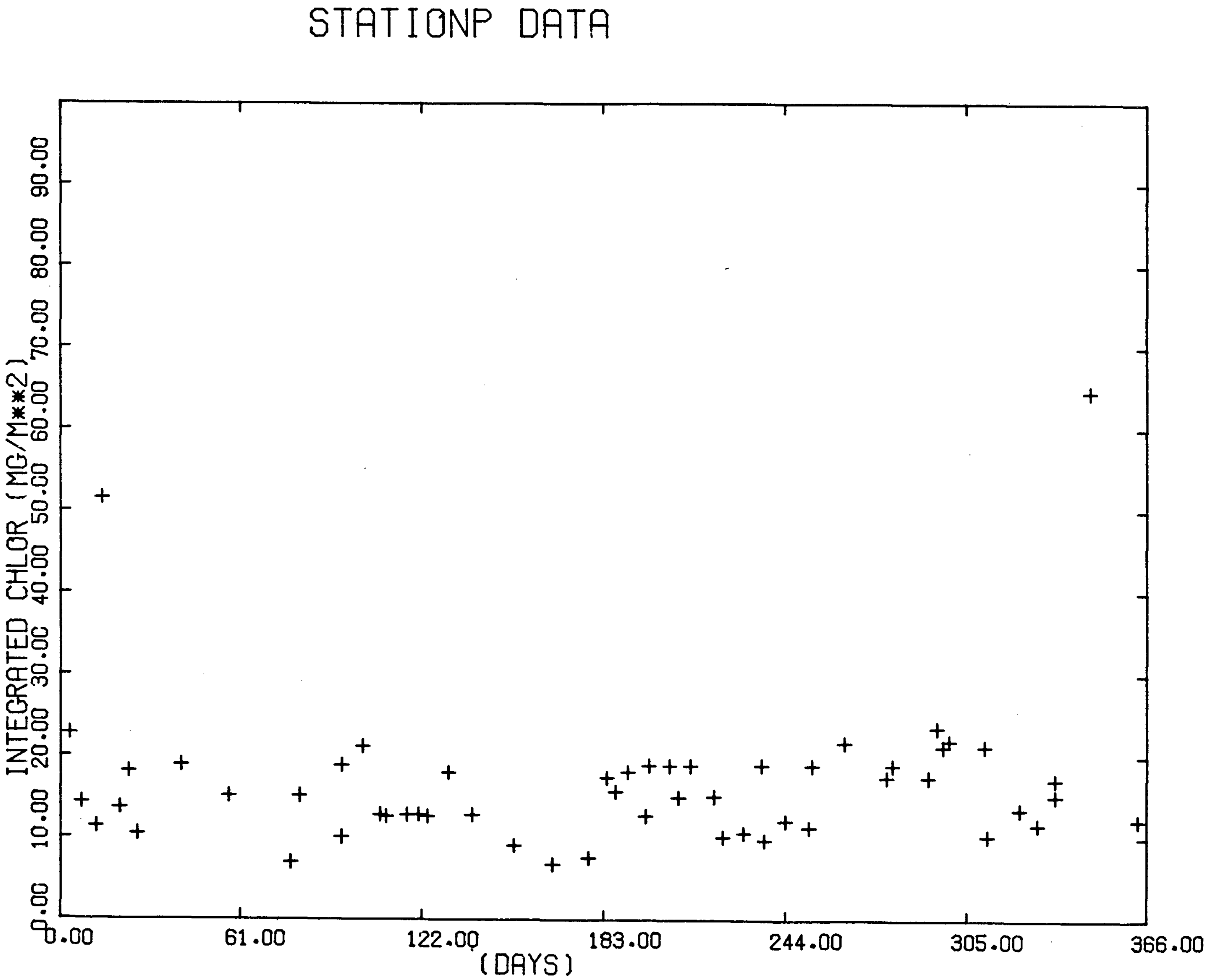


Fig. III-16. Observed chlorophyll *a* concentration at Station PAPA, 1959-1967 (Anderson and Lam, RU #58, 1976).

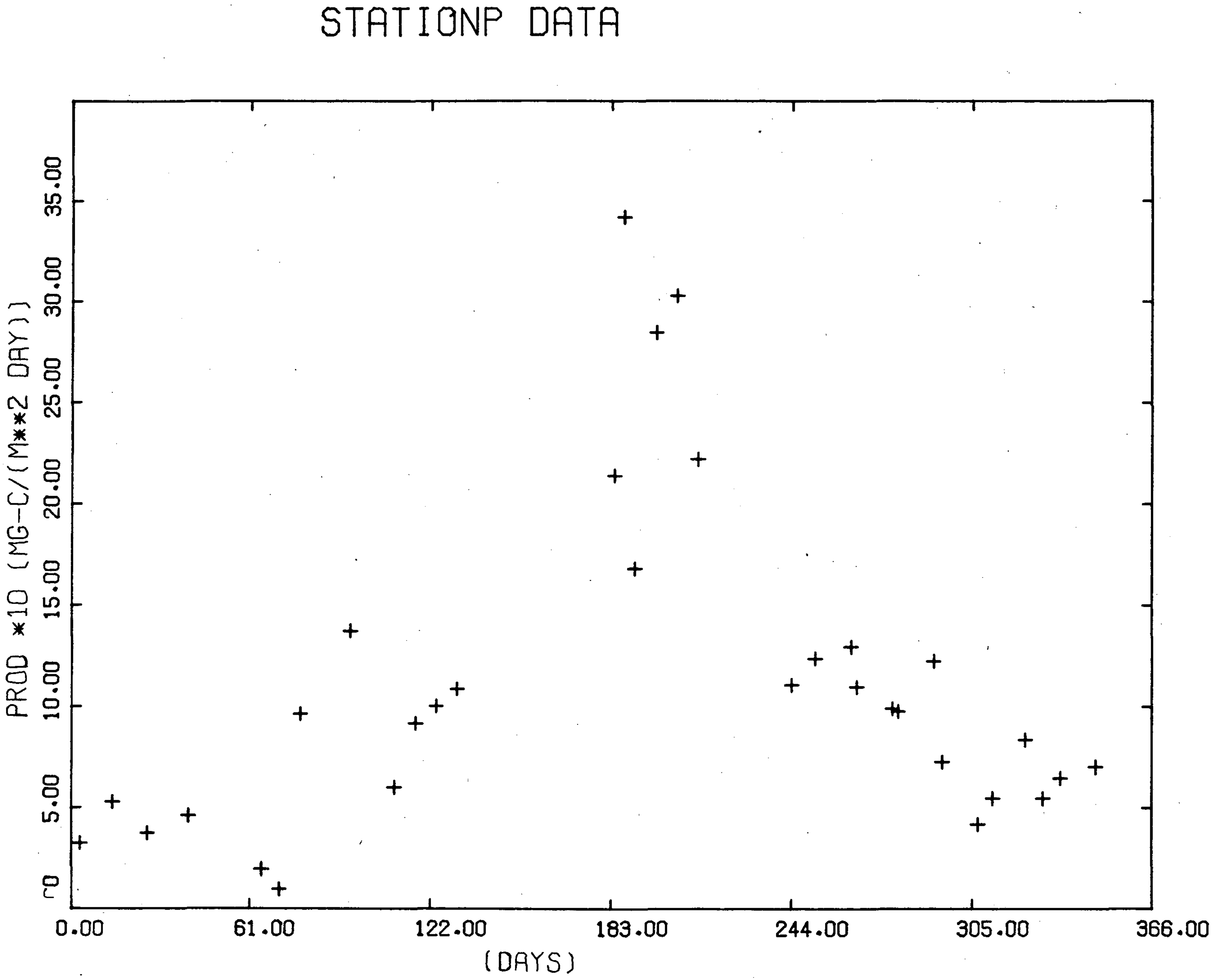


Fig. III-17. Observed primary productivity data at Station PAPA, 1961-1963 (Anderson and Lam, RU #58, 1976).

calculated from temperature data from station PAPA obtained in 1970, following $K_z \propto \left(\frac{\partial T}{\partial z}\right)^{-1}$. Maximum surface K_z value of 60 cm^2/sec was estimated from winter data. Simulated seasonal distribution of chlorophyll *a* and primary productivity are given in Figs. III-18 and III-19, respectively.

It should be noted that input data are averaged values over differing lengths of time and even for differing periods. As a result time variations in the property distribution over the years, which may be very high in some cases, could not be considered. It would be desirable to select specific years to model. It might then be possible to predict changes in chlorophyll production in response to man-induced variations in the input variables and parameters.

Zooplankton. Cooney (RU #156-D, 1976) obtained plankton samples from 1 m diameter net (mesh size, 0.3 mm) and Tucker midwater trawl in the NEGOA area in 1974-75. The results and interpretations based on these samples are included in FY 75 NEGOA report (NOAA 1976). Only the mean features of the results of this study will be reported herein.

Nearly 200 species ranging from Coelentrata to Chordata were recognized in samples from the plankton net and midwater trawl. This inventory, though large, is not complete because a significant, and possibly quite large, fraction of plankton forms could not have been retained by the mesh size used. Furthermore, only a limited number of observations were available for each season-locality combination.

Principal zooplankton species (n=21) were examined quantitatively for their seasonal and temporal distribution. The following species were classified according to their apparent habitat preference:

Neritic Areas: *Acartia longiremis* and *Pseudocalanus* sp. (copepods), euphausiid larvae, and Oregoniinae (snow crab) larvae

Shelf and Slope Areas: *Parathemisto pacifica* (amphipod) and *Thysanoessa longipes* (euphausiid)

Oceanic Area: *Aglantha digitale* (coelentrate), *Eukrohnia hamata* (chaetognath), *Calanus cristatus*, *Calanus pacificus*, *Eucalanus bungii bungii* (copepods), and *Euphausia pacifica* (euphausiid)

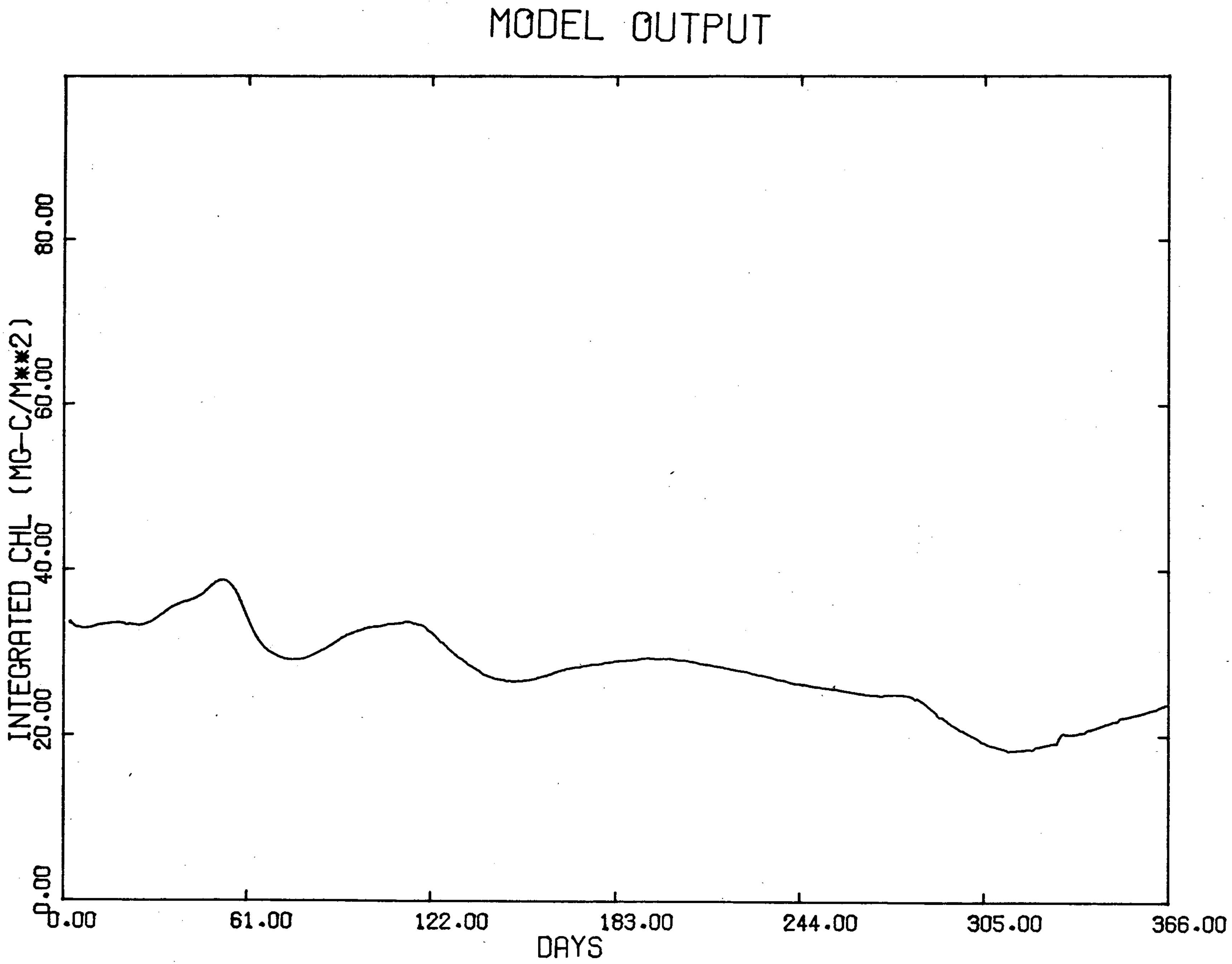


Fig. III-18. Simulated seasonal profile of chlorophyll *a* concentration at Station PAPA (Anderson and Lam, RU #58, 1976).

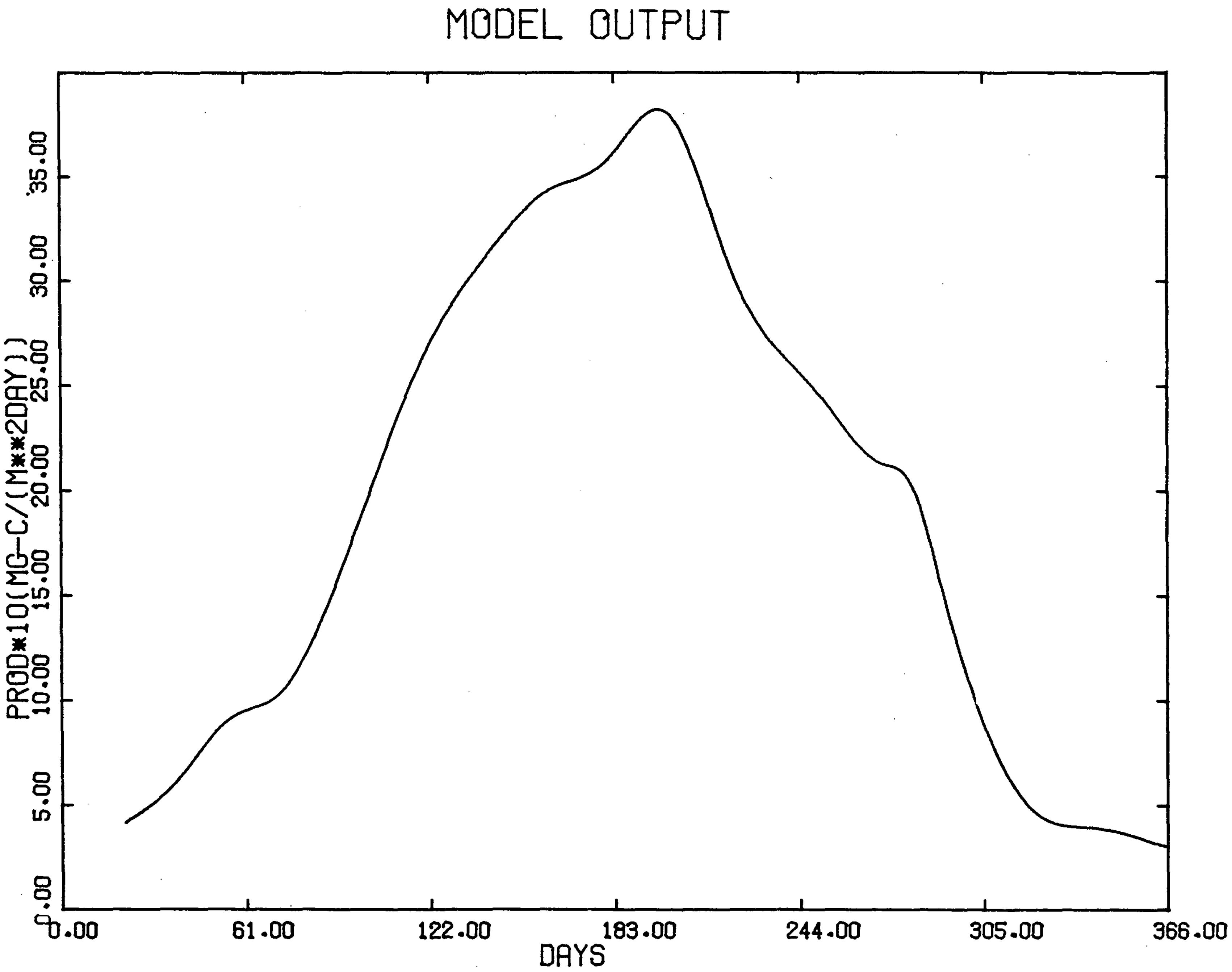


Fig. III-19. Simulated seasonal profile of primary productivity at Station PAPA (Anderson and Lam, RU #58, 1976).

Several species, including *Sagitta elegans* (chaetognath), *Calanus plumchrus*, *Oithona* spp. (copepods), and *Oikopleura* (appendicularian) showed no apparent environmental preference and were found widespread. No distribution pattern could be established for *Parathemisto libellula*, *Cyphocaris challengeri* (both amphipods), and *Metridia okhotensis* (copepod) as these species were represented in only a few samples.

Confidence limits (p=0.05) of geometric mean abundance of various zooplankton species from four observations per regime ranged from 21.8 (for *Metridia okhotensis*) to 2.5 (for *Euphausia pacifica*). This means that for *Metridia okhotensis* population differences between regimes less than a factor of 22 are not discernible, whereas for *Euphausia pacifica* differences of the order of 2.5 can be considered significant.

Cooney has also provided a list of principal species that occur in the neritic and epipelagic zone (Table III-4). Among the species listed *Acartia longiremis*, *Pseudocalanus* sp., and *Oithona similis* are numerically very abundant. A detailed listing of seasonal occurrence and habitat utilization of selected zooplankton species is also provided (Table III-5).

Damkaer (RU#156-B, 1976) has identified about 30 species of zooplankton from samples collected in the Prince William Sound in fall 1976. A detailed account of the results for this study is provided in FY 76 OCSEAP Research Report for the NEGOA lease area (NOAA 1976). Zooplankton settled volume, a measure of biomass, varied from 0.1 to 7.4 ml/m^3. A consistently higher settled volume was noted in samples collected at night in the upper 100 m than those collected in the day; the corresponding increase in numerical abundance was small. It could have been due to diel migration of predominantly large zooplankters. Small copepods, such as *Acartia longiremis*, *Oithona similis*, and adult *Pseudocalanus* spp., were most abundant in upper layers, up to 2,000 individuals/m^3. *Metridia lucens* and *M. okhotensis* were abundant and showed diel vertical migration. Species found in deeper water included *Calanus cristatus*, *Calanus marshallae*, and *Calanus plumchrus*. These species, when abundant, have a marked effect on spring primary productivity by grazing down and maintaining the phytoplankton standing stock to low levels.

Five species of euphausiids were found: *Euphausia pacifica*, *Thysanoessa inermis*, *Thysanoessa longipes*, *Thysanoessa raschii*, and *Thysanoessa spinifera*.

TABLE III-4

Tentative Summary of Use of Epipelagic (Near-surface) Zone of Lease Area by Principal Species of Zooplankton and Micronekton (Cooney, RU #156, from NOAA 1975).

SPECIES	SEASON			
	WINTER	SPRING	SUMMER	FALL
Acartia longiremis	AJ	AJ	AJ*	AJ*
Pseudocalanus spp.	AJ	AJ	AJ*	AJ*
*Metridia lucens***	AJ	AJ*	AJ*	AJ
Calanus plumchrus	J	J*	AJ	-
Oithona similis	A*	A	A*	A*
Sagitta elegans	AJ	AJ	AJ	AJ*
Euphausiacea	L	L*	L*	L
*Euphausia pacifica***	AJ*	AJ	AJ	AJ
*Thysanoessa longipes***	AJ*	AJ*	AJ	AJ
Snow crab	-	L*	L*	L

A=Adult
J=Juvenile

* denotes season of maximum abundance in epipelagic zone.
** denotes diel migrator visiting epipelagic zone at night.

TABLE III-5. TENTATIVE SUMMARY OF USE OF LEASE AREA BY PRINCIPAL SPECIES (Cooney, RU #156, from NOAA 1975).

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

*Denotes diel migrator where known.

T. longipes adults were relatively most abundant, 1 to 3 individuals/m^3, and showed some vertical migratory patterns. Juvenile euphausiids were restricted mostly within the upper 25 m, day and night.

Benthos

OCSEAP studies have provided the first intensive qualitative and quantitative examination of the infaunal and epifaunal benthic biota of the Gulf of Alaska (Feder, RU #281, 1976). A large number of grab and trawl samples have been collected since July 1974. The benthic infauna (van Veen grab samples) and epifauna (otter trawl data) differ significantly. A comparison of the phyla, subgroups, and numbers of species identified from the two sets of samples (Table III-6) shows the infauna to be much more diverse--14 phyla and 318 species versus 9 phyla and only 168 species of epifauna. In terms of numbers of species, the benthic infauna is dominated by polychaete worms (132 species or 42%), followed in descending order by molluscs (22%), arthropods (21%), and echinoderms (7%). Polychaetes are much less diverse in the benthic epifauna, accounting for only 30 species (18%), while molluscs (28%), arthropods (25%), and particularly echinoderms (21%) are all relatively more diverse than in the infauna.

Benthic Infauna. Species distribution patterns among benthic infauna (grab samples) have been examined through cluster analyses data collected from July 1974 through May 1975. Two or three station groups were identified in all analyses. Two of these groups consist of inshore stations while the third is composed of stations at or near the shelf break (Fig. III-20). Cluster analysis of presence-absence data resulted in the inshore stations merging into a single larger group. In addition, new station groups were identified from continental slope localities--further offshore than the inshore and shelf break groups (Feder, RU #281, 1976).

Species-by-species analyses resulted in the identification of some 32 distinctive infaunal species groups (H. Feder, Univ. Alaska, Fairbanks, pers. comm., 1977). Those groups that account for a major proportion of the total individuals collected from each of the station groups mapped in Fig. III-20 are listed in Table III-7. It is important to note that while a particular group of species may be more characteristic of a certain set of sampling stations, some of these same species also occur at other localities. In

TABLE III-6. The invertebrate phyla, subgroups, and numbers of species collected by van Veen grab (principally infauna) and commercial otter trawl (principally epifauna) in the Northeast Gulf of Alaska (Feder, RU #281, 1976).

Phylum	Subgroup	Number of Species van Veen Grab (infauna)	Number of Species Otter Trawl (epifauna)
Annelida	Polychaeta (sea worms)	132	30
	Oligochaeta	1	-
	Subtotal	133	30
Mollusca	Aplacophora	1	-
	Polyplacophora (chitons)	4	1
	Gastropoda (snails, nudibranchs)	22	24
	Pelecypoda (clams, scallops)	39	18
	Scaphopoda (tusk shells)	2	-
	Cephalopoda (octopus, squid)	-	4
	Unidentified	1	-
	Subtotal	69	47
Arthropoda	Pycnogonida (sea spiders)	1	-
	Ostracoda	1	-
	Harpacticoida (copepods)	1	-
	Thoracica (barnacles)	3	4
	Cumacea	14	-
	Isopoda	6	2
	Amphipoda	33	-
	Decapoda (crabs, shrimp)	7	36
	Subtotal	66	42
Echinodermata	Asteroidea (sea stars)	3	24
	Ophiuroidea (brittle stars)	14	5
	Echinoidea (sea urchins)	2	3
	Holothuroidea (sea cucumbers)	4	3
	Crinoidea (feather stars)	1	1
	Subtotal	24	36
Protozoa		1	-
Porifera (sponges)		1	1
Cnidaria (hydroids, anemones)		4	6
Rhynchocoela (ribbon worms)		1	-
Sipunculida		2	-
Echiuroidea		3	-
Ectoprocta (moss animals)		3	1
Brachiopoda (lamp shells)		9	3
Chordata	Tunicata (sea squirts)	2	2
	TOTAL	318	168

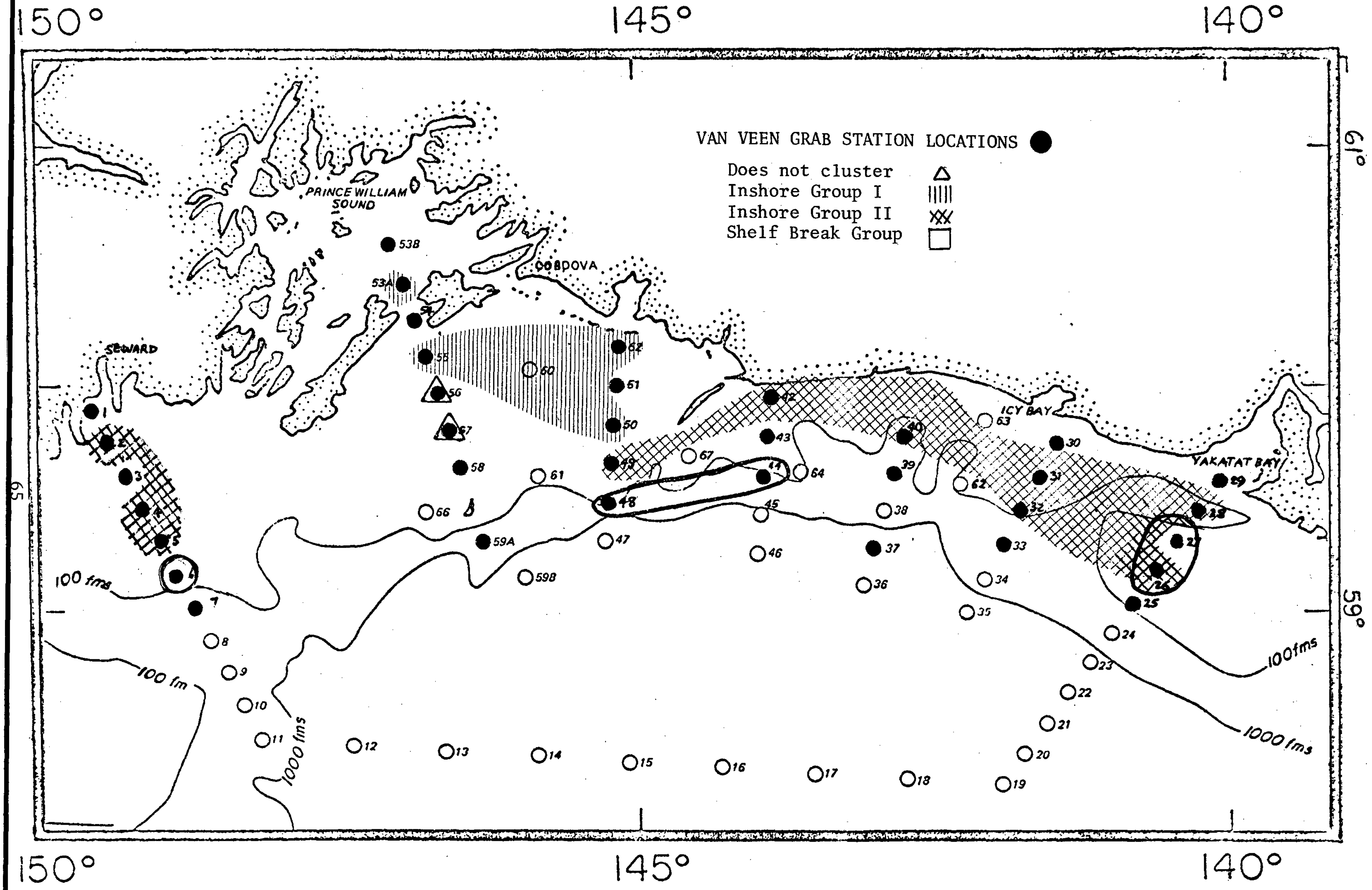


Fig.III-20.Station groups formed by cluster analysis of quantitative stations using the number of individuals/m^2. Only major station clusters are shown (Feder, Univ. Alaska, Fairbanks, unpublished data).

TABLE III-7. Species groups accounting for a major proportion of the individuals collected at each of the Station groups shown in Fig. III-20. Delineated by Cluster Analysis based on the number of individuals per square meter (H. Feder, Univ. of Alaska, Fairbanks, unpublished data, 1977).

INSHORE GROUP I
(Species Groups #15-17, 23, 28, 30, and 32)

Polychaeta:
- *Capitella capitata*
- *Caulleriella* sp.
- *Goniada annulata*
- *Haplosyllis spongicola*
- *Herperonoe complanata*
- *Heteromastis filiformis*
- *Magelona japonica*
- *Paraonis gracilis*
- *Rhodine bicorquata*

Echiuroidea:
- *Priapulus caudatus*

Cnidaria:
- Anthozoa "Sea Pen"

Amphipoda:
- *Harpinia emeryi*
- *Lepidepecreum comatum*

Cumacea:
- *Eudorella emarginata*
- *Eudorellopsis integra*

Pelecypoda:
- *Macoma calcarea*
- *Thyasira* sp.

Asteroidea:
- *Ctenodiscus* sp.

Ophiuroidea:
- *Ophiopenia disacantha*
- *Ophiura* sp.

INSHORE GROUP II
(Species Groups #4, 7, 8, 20-22, and 24)

Polychaeta:
- *Aricidea suecica*
- *Goniada annulata*
- *Lumbrineris* sp.
- *Praxillella* sp.
- *Proclea emmi*
- *Spio filicornis*
- *Travisia* sp.

Asteroidea:
- *Ctenodiscus crispatus*

Ophiuroidea
- *Pandellia carchara*

Echinoidea:
- *Brisaster townsendi*

Amphipoda:
- *Aceroides* sp.
- *Hippomedon propinquus*
- *Phoxocephalus* sp.

Isopoda:
- *Gnathia* sp.

Cumacea:
- *Leucon acutirostris*

Pelecypoda:
- *Odontogena borealis*
- *Portlandia arctica*

Gastropoda:
- *Oenopota* sp.

Polyplacophora:
- *Mopalia* sp.

TABLE III-7 (continued)

SHELF BREAK GROUP
(Species Groups #9-12 and 26)

Polychaeta:
- *Ampharete arctica*
- *Aricidea jeffreysii*
- *Chone gracilis*
- *Euchone analis*
- *Eusyllis blomstrandi*
- *Garryana treadwelli*
- *Haplosyllis spongicola*
- *Maldane glebifex*
- *Megalomma splendida*
- *Nephtys ferruginea*
- *Notoproctus pacificus*
- *Owenia fusiformis*
- *Peisidice aspera*
- *Pista cristata*
- *Pista fasciata*

Sipunculida:
- *Golfingia margaritacea*

Ectoprocta:
- *Microporina borealis*

Brachiopoda:
- *Terebratulina unguicula*

Ophiuroidea:
- *Diamphiodia periercta*

Amphipoda:
- *Acanthonatosoma inflatum*
- *Anonyx ochoticus*
- *Byblis crassicornis*
- *Byblis* sp.
- *Ericthonius heunteri*
- *Halosoma* sp.
- *Haploops tubicula*
- *Harpinia* sp.
- *Harpiniopsis sandpedroensis*

Isopod:
- *Gnathia*

Cumacea:
- *Diastylis*

Thoracica:
- *Scapellum columbianum*

Copepoda:
- Harpacticoidea

Pelecypoda:
- *Clinocardium ciliatum*
- *Cyclopecten randolphi*
- *Dacrydium* sp.

Holothuroidea:
- *Psolus* sp.

STATION 56
(Species Groups #1 and 2)

Polychaeta:
- *Ceratonereis paucidentata*
- *Eteone langa*
- *Eunice* sp.
- *Haploscoloplos panamensis*
- *Harmothoe imbricata*
- *Nephtys* sp.
- *Nephtys caeca*
- *Phloe minuta*
- *Syllis* sp.
- *Syllis selerolema*

Brachiopoda:
- *Dietrothyris frontalis*
- *Laqueus californianus*
- *Terebratulina crossei*

Amphipoda:
- *Ampeliscida birulai*
- *Byblis gaimandi*
- *Paraphoxus robustus*

Thoracica:
- *Balanus rostratus*

Pelecypoda:
- *Astarte esquimalti*
- *Astarte polaris*
- *Megacrenella columbiana*
- *Thracia beringi*

Gastropoda:
- *Amphissa columbiana*
- *Amphissa reticulata*
- *Cylichna alba*

TABLE III-7 (continued)

Ophiuroidea:
Pandellia charchara

Polyplacophora:
Hanleya sp.
Hanleya hanleyi
Ischnochiton albus

STATION 57
(Species Groups #3, 7, 13-15, and 25)

Polychaeta:
Amphorete goesi
Aricidea suecica
Asychis similis
Chone infundibuliformis
Exogene sp.
Gattyana ciliata
Goniada maculata
Hesperonoe complanata
Idanthyrsus armatus
Laonice cirrata
Lumbrineris sp.
Nephtys ciliata
Rhodine birorquata
Scalibregma inflatum
Travisia sp.

Echiuroidea:
Priapulus caudatus

Cnidaria:
Anthozoa "Sea Pen"

Ectoprocta:
Clavipora occidentalis

Ophiuroidea:
Diamphiodia craterodmeta

Amphipoda:
Ampelisca macrocephala
Caprella striata
Hyssura sp.
Paraphoxus simplex

Isopoda:
Gnathia sp.

Decapoda:
Pinnixa occidentalis

Cumacea:
Lamprops fuscata
Leucon nasica

Pelecypoda:
Astarte montegui
Clinocardium fucanum
Crenella dessucata
Cyclocardia ventricosa
Yoldia sp.

Gastropoda:
Lepeta caeca

general, however, species that are abundant in one station group tend to be less common in the others.

The results of Feder's studies to date indicate that the inshore, shallow-shelf benthic infauna (Fig. III-20, Inshore Groups I, II) differs significantly from that of both the shelf break (Fig. III-20) and the continental slope beyond. Besides differences in taxonomic composition, the inshore infaunal groups (19-20 species each) are less diverse than those at the shelf break (37 species; Table III-7). Deposit feeding species dominate (61-65%) inshore, while suspension feeders (32%) and deposit feeders (26%) are more evenly balanced in the shelf break assemblages (Table III-8).

There appears to be a slight change in inshore infauna from east to west across NEGOA. The fauna east of Kayak Island differs from that found south of Prince William Sound, but appears again further west off Seward (Fig. III-20). Stations 56 and 57 remained unclustered throughout Feder's analyses and appear to host faunas somewhat intermediate between inshore and shelf break groups.

Feder concluded that there is a change in the composition of the infaunal community along a gradient that is related to changes in depth. Gross observation of sediment types (Fig. III-21); Table III-8) suggests that one of the controlling factors in the composition of the infauna is grain-size distribution. As expected, deposit feeders are most abundant in silts and clays -- usually noted for their high content of organic matter. Suspension feeders are at a disadvantage for readily resuspended fine-grained sediment can easily clog their feeding structures. As sands and gravels become more abundant, they provide increased substrate for attachment and reduce siltation hazards, thus favoring suspension feeders.

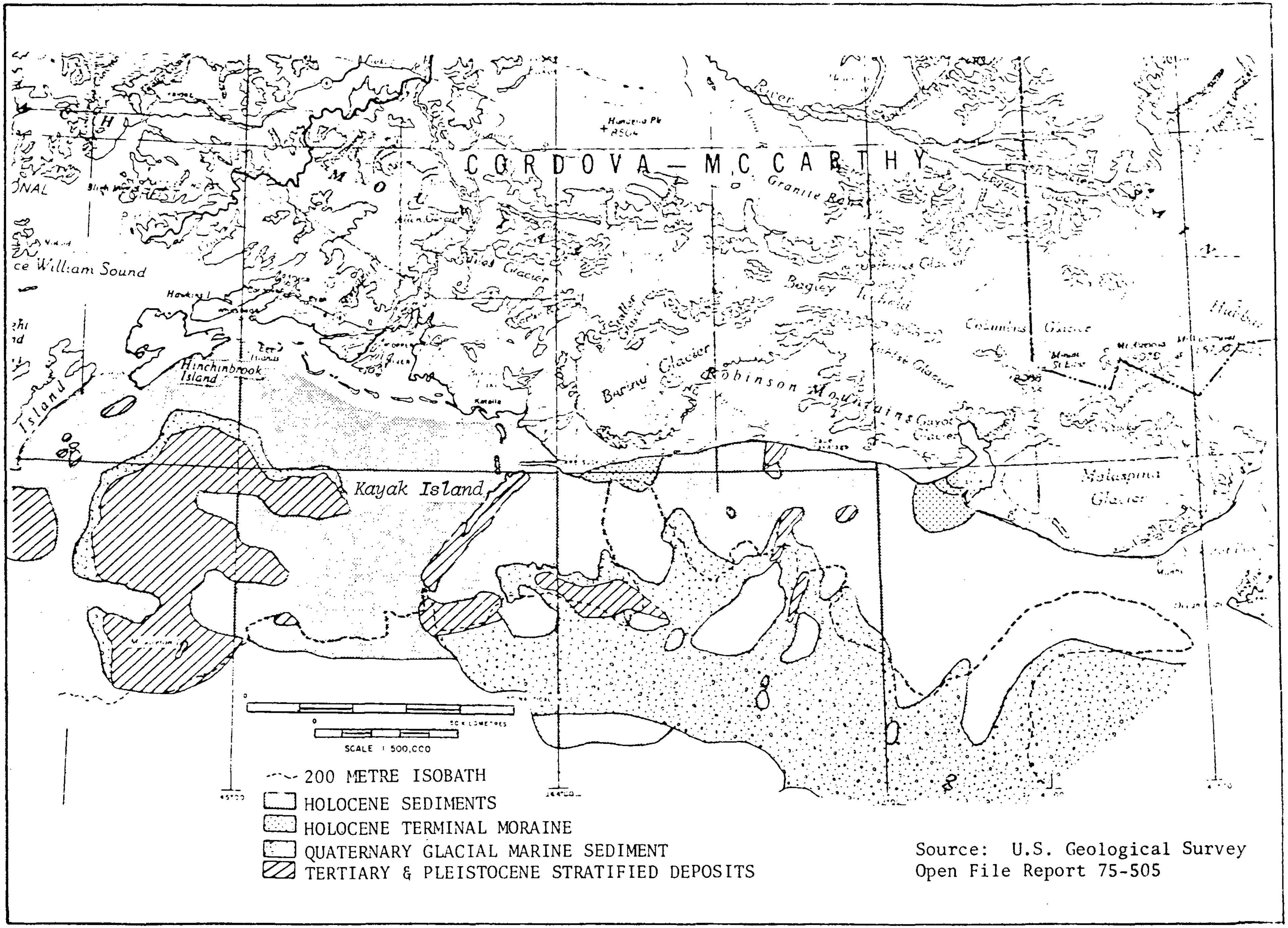
Benthic Epifauna. Of the 168 species of epibenthic invertebrates collected by Feder and others from the Northeast Gulf of Alaska, molluscs, crustaceans, and echinoderms accounted for 47, 42, and 36 species, respectively (Table III-9).

The snow crab *Chionoecetes bairdi* dominated the benthic epifauna, contributing more than 66% of the total biomass. Pink shrimp *Pandalus borealis* accounted for nearly 3% of the biomass and the box crab *Lopholithodes foraminatus* was the third most important crustacean. Most stations yielded a diverse echinoderm

TABLE III-8. A Comparison of Diversity Index, Sediment Type, and Feeding Type Characteristics of station groups delineated by cluster analysis based on the number of individuals per square meter (Fig. III-20). Feeding types are as follows: SF = Suspension Feeder, DF = Deposit Feeder, P = Predator, S = Scavenger (Feder, RU #281, 1976).

	Brillouin	Sediment				Feeding Type			
Station Groups	Index of Diversity	% Gravel	% Sand	% Silt	% Clay	% SF	% DF	% P	% S
Inshore Group 1	1.11 ± 0.05	0	5.21	40.67	59.92	4	61	21	14
Inshore Group 2	1.12 ± 0.12	0.63	7.48	40.55	47.22	15	65	12	3
Station 56	1.31	26.59	14.20	29.39	26.83	28	21	34	7
Station 57	1.42	24.39	42.49	18.05	15.07	38	34	8	20
Shelf Break Group	1.38 ± 0.09	9.39	24.56	35.39	30.69	32	26	12	30

Note that the shelf break stations and stations 56 and 57 have a higher diversity, a higher percentage of sand and gravel, and a higher percentage of suspension feeders than the inshore groups.



Source: U.S. Geological Survey
Open File Report 75-505

Fig. III-21. Surface sediment distribution, Northern Gulf of Alaska (from Molnia and Carlson, RU #212, 1976).

TABLE III-9. Percentage composition by weight of leading invertebrate taxa collected during Northeast Gulf of Alaska otter trawling investigations, April through August 1975 (Feder, RU #281, 1976).

Phyla	Percentage of Weight	Leading Species	Average Weight per Individual		Percentage Weight within Phylum	Percentage Weight from all Phyla
Arthropoda (42 species)	71.4%	*Chionoecetes bairdi*	454 g		92.6	66.2
		Pandalus borealis	8 g		4.0	2.9
		Lopholithodes foraminatus	420 g		0.6	0.4
				Subtotal	97.2	69.5
Echinodermata (36 species)	19.0%	*Ophiura sarsi*	6 g		23.2	4.4
		Ctenodiscus crispatus	10 g		15.7	2.9
		Cucumariidae	400 g		15.0	2.8
				Subtotal	53.9	10.1
Mollusca (47 species)	4.6%	*Patinopecten caurinus*	350 g		43.4	2.0
		Neptunea lyrata	180 g		12.5	0.6
		Fusitriton oregonensis	100 g		11.5	0.5
				Subtotal	67.4	3.1
GRAND TOTAL	95%					82.6%

fauna, but each species was usually represented by only a few individuals. A brittle star (*Ophiura sarsi*), two sea stars (*Ctenodiscus crispatus* and *Pycnopodia helianthoides*), and a heart urchin (*Brisaster Townsendi*) were all found in large quantities. Sea cucumbers occurred at only seven stations yet accounted for nearly 3% of the total epibenthic biomass. The weathervane scallop (*Patinopecten caurinus*, accounting for 2% of the total biomass), the whelk (*Neptunea lyrata*), and the Oregon triton (*Fusitriton oregonensis*), dominated the molluscan material.

Highest densities of *Chionoecetes bairdi*, *Pandalus borealis*, *Ophiura sarsi*, *Ctenodiscus crispatus*, and fishes were recorded in the vicinity of the Copper River Delta southeast to Kayak Island (see Ronholt *et al*., 1976, for distribution and density data for fishes there). Little is known about the productivity of this area, but Jewett and Feder (1976) speculate that primary and secondary production may be higher there both as a result of nutrients supplied by the Copper River and the presence of gyres that extend vertically from the water surface to the bottom. They also draw attention to two other areas of particular biological interest. The first, immediately south of Hinchinbrook Entrance, yielded 47 invertebrate species, the highest diversity of all stations sampled. This total included 14 crustaceans, 13 echinoderms, and 13 molluscs. Seven species of fish, including numerous Pacific halibut were also taken from this location. The second area of interest, immediately west of Icy Bay, yielded numerous fish but a low diversity of invertebrates fauna. The starry flounder (*Platichthys stellatus*) dominated the trawl catch at both stations. The flounder stomachs were all filled with clams--*Yoldia seminuda*, *Siliqua sloati*, and *Macoma dexiosttera*. Jewett and Feder (1976) concluded that clam population in the Icy Bay area play a vital role in the trophic dynamics of the flounder. A large catch of juvenile walleye pollock (*Theragra chalcogramma*) suggested that the area may also be a nursery ground for this ecologically important species.

The Tanner crab (*Chionocetes bairdi*) is the most abundant Gulf of Alaska invertebrate and an important commercial species, feeding principally upon clams, shrimps, crabs, and barnacles, and, in turn, is the main food of the Pacific cod. The large sea star, *Pycnopodia helianthoides*, feeds principally upon gastropods and the more numerous smaller echinoderms, *Ctenodiscus* and *Ophiura*. The sea star *Ctenodiscus crispatus* is a deposit feeder, while the brittle star *Ophiura sarsi* probably combines browsing, detritus feeding, and predation (Jewett and Feder 1976).

Littoral and Nearshore Communities. The generalized distribution of shoreline substrate types within NEGOA is shown in Fig. III-4. Table III-10 summarizes data on the approximate mileages of beaches of various types, while Table III-11 provides representative data on the mean numbers of species and wet weight biomass characteristic of communities associated with different shoreline habitats (Zimmerman and Merrell 1976).

Sandy beaches -- occupy approximately 36% of the NEGOA coastline. Primary production and species diversity are both very low. Amphipods, abundant in the swash zone, are a distinctive element of a meager transient littoral fauna. Evidence from beach flotsam (drift) indicates that subtidal populations of razor clams, *Siliqua patula*, and Dungeness crab, *Cancer magister*, are also typical.

The potential impact of oil pollution on sandy beaches may be high if the oil becomes incorporated into the sediments and then leaches out slowly, exposing the intertidal fauna to possible sub-lethal chronic effects.

Table III-10. Approximate mileage of beaches of various types surveyed from Point Carew (Yakutat Bay) to Cape Puget. Includes Russell Fiord to entrance of Nunatak Fiord. (Zimmerman *et al.*, RU #78-79, April 1976).

Type	Miles	Percentage
Bedrock	185.0	19.9
Boulder/Rubble	136.0	14.6
Gravel	200.0	21.5
Sand	336.0	36.1
Mud	73.0	7.8
TOTAL	930.0	99.9

Table III-11. Comparison of mean numbers of species and wet weight biomass from three different beach habitat types. (s = standard deviation). (Zimmerman & Merrell, RU #78-79, Final Report, April 1976).

Habitat Type	Mean number of species	± s	Mean biomass (grams)	± s	Number of Samples	Sample Area or Volume
Rocky (Macleod Harbor)	30.3	±14.5	243.6	±231.4	15	1/16 m^2
Muddy (Boswell Bay)	21.6	± 5.6	8.5	± 8.5	14	1ℓ
Sandy (Yakutat - Yakataga)	1.5	± 1.1	0.02	± 0.02	6	1ℓ

Muddy beaches, protected lagoonal areas -- poorly represented in NEGOA, these habitats account for less than 8% of the coastline. If protected, shallow subtidal areas were included, the percentage would increase significantly. Primary production and species diversity are both significantly higher than on sandy beaches, but well below that typical of rocky shores (Table III-11). In areas of mixed sand and mud, occasional nereid or sabellid worms and the detritus feeding pelecypod, *Macoma baltica,* are typical. *Macoma* is a key species in protected, muddy areas where it is abundant, has high biomass, and occupies a key position in nearshore food webs (e.g., Boswell Bay).

Rocky intertidal and nearshore bedrock -- rocky coasts account for 20% of the NEGOA shoreline, mostly along Cape Yakataga, Kayak Island, Montague Island, and Hinchinbrook Island (Fig. III-4).

The rocky subtidal in the Gulf of Alaska is usually colonized to depths of about 30 m by a diverse and highly productive assemblage of macrophytes. Typically multilayered, this association often includes a floating canopy of annual bull kelp, *Nereocystis,* a second canopy of perennial kelps *(Laminaria, Pleurophycus),* and a third of *Agarum,* with foliose and encrusting algae growing on the seafloor beneath. The macrophytes provide food and cover for a wide variety of invertebrates; gastropods and sea stars are conspicuous. Fish, water-associated birds, and marine mammals also utilize these rich inshore areas.

Rocky shores are generally regarded as having a high recovery potential after suffering oil impingement. The greatest risk of shipping and pollution accidents probably comes during fall and winter after kelp canopies have been shed (making a major contribution to detritus food chains) and much of the associated fish and invertebrate fauna has moved offshore. Spill events occurring in spring and summer would potentially affect more organisms, for while kelp fronds are protected from oil impact by a mucilaginous coating, the multilayered macrophyte canopy hosts a diverse fauna that includes juveniles of many fish and invertebrate species. Kelp, particularly the annual species, may be more susceptible during fall and winter. Oil contamination may be most damaging during the microscopic reproductive stage or the new sporophyte stage.

Boulder and gravel beaches -- these account for 15 and 20% of the NEGOA coastline, respectively. Primary productivity and faunal diversity are variable but generally less than typical of the rocky intertidal. Hayes (RU #59) indicates that these habitats would be subject to rapid, deep (40-50 cm) penetration by grounded oil. Cleanup would be very difficult and long-term impacts should be anticipated.

Detailed quantitative tabulations of the littoral biota of several NEGOA coastal sites are provided by Zimmerman and Merrell (RU #78/79, 1976). Rosenthal and Lees (Dames and Moore 1976) document seasonal changes in algal cover and present food web diagrams for rocky sublittoral habitats near Prince William Sound. Data from Zaikof Bay on the south shore of Hinchinbrook Entrance are shown in Figs. III-22 and III-23.

Commerical Shellfish Resources. Two important resource assessments of commercial invertebrates from NEGOA have recently been published. The Alaska Department of Fish and Game (ADF&G 1975) has documented species distribution data and population estimates based on fisheries catch statistics. Ronholt *et al.* (1976) reported the Northwest Fisheries Center's demersal fish and invertebrate assessment, based on the same otter trawl data used in Feder's epifaunal benthos study (see above). While the results of both studies share much in common, there are also significant differences between them.

Commercially important invertebrates found in the NEGOA region are listed in Table III-12; NWFS trawl survey data are summarized in Table III-13. Tanner crab are by far the most abundant commercial species in the region. ADF&G data (Fig. III-24) indicate the species occurs at Yakutat Bay and west of Kayak Island, but not across the proposed NEGOA lease area. NWFS trawl data (Fig. III-25) however, indicate that Tanner crabs occur throughout the NEGOA shelf region, with peaks in abundance west of Kayak.

Pink shrimp apparently also occur throughout NEGOA with maximum population densities recorded immediately west of Kayak Island (Fig. III-26). ADF&G catch statistics indicate that at present the species is only fished in Yakutat Bay and within Prince William Sound.

Dungeness crab are present in shallow nearshore habitats throughout NEGOA. Major fishing areas lie off the Copper River Delta and inside Prince William Sound (Fig. III-27). King crab populations, according to ADF&G data, are restricted to Yakutat Bay and Prince William Sound. Distributions of weathervane scallops, razor clams, and hardshell clams are indicated in Figs. III-28 and III-29. It should be noted that ADF&G figures indicate a more limited distributional range for the weathervane scallop than do NWFS data.

Generalized feeding relationships among these commercial shellfish have already been summarized in Fig. III-30.

TABLE III-12.

Commercially Important Invertebrate Phyla, Class, and Species Encountered in the NEGOA Trawl Survey Area (Ronholt *et al.*, 1976).

Scientific Name	Common Name
Arthropoda: Decapoda	
Cancer magister	Dungeness crab
Chionoecetes bairdi	Tanner (Snow) crab
Lithodes aequispina	Golden king crab
Pandalus borealis	Pink shrimp
Pandalus danae	Dock shrimp
Pandalus hypsinotus	Coonstripe shrimp
Pandalus montagui tridens	
Pandalus platyceros	Spot shrimp
Pandalopsis dispar	Sidestripe shrimp
Mollusca: Pelecypoda	
Patinopecten caurinus	Weathervane scallop

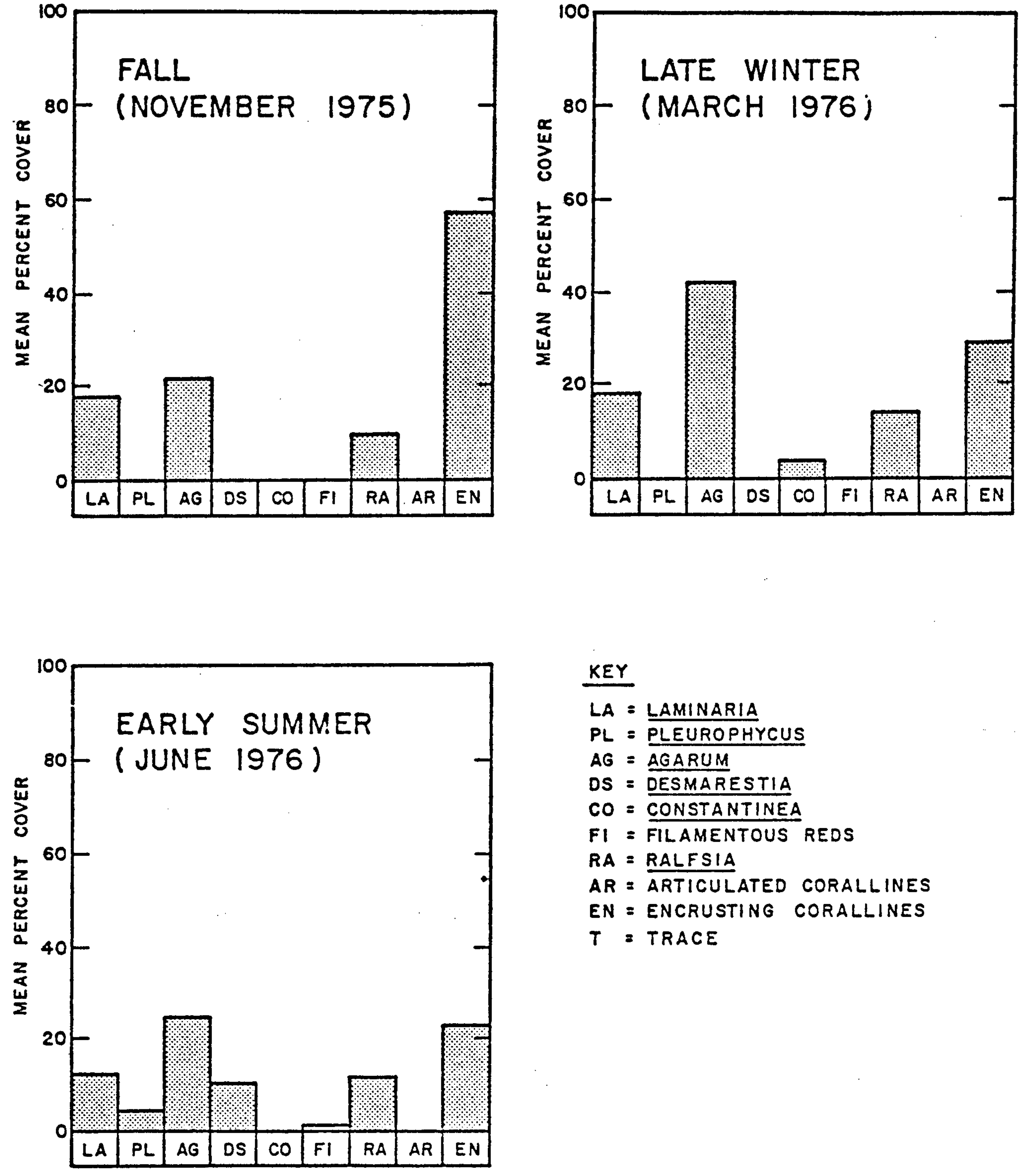


Fig. III-22. ALGAL COVER AT ZAIKOF BAY (Dames and Moore 1976).

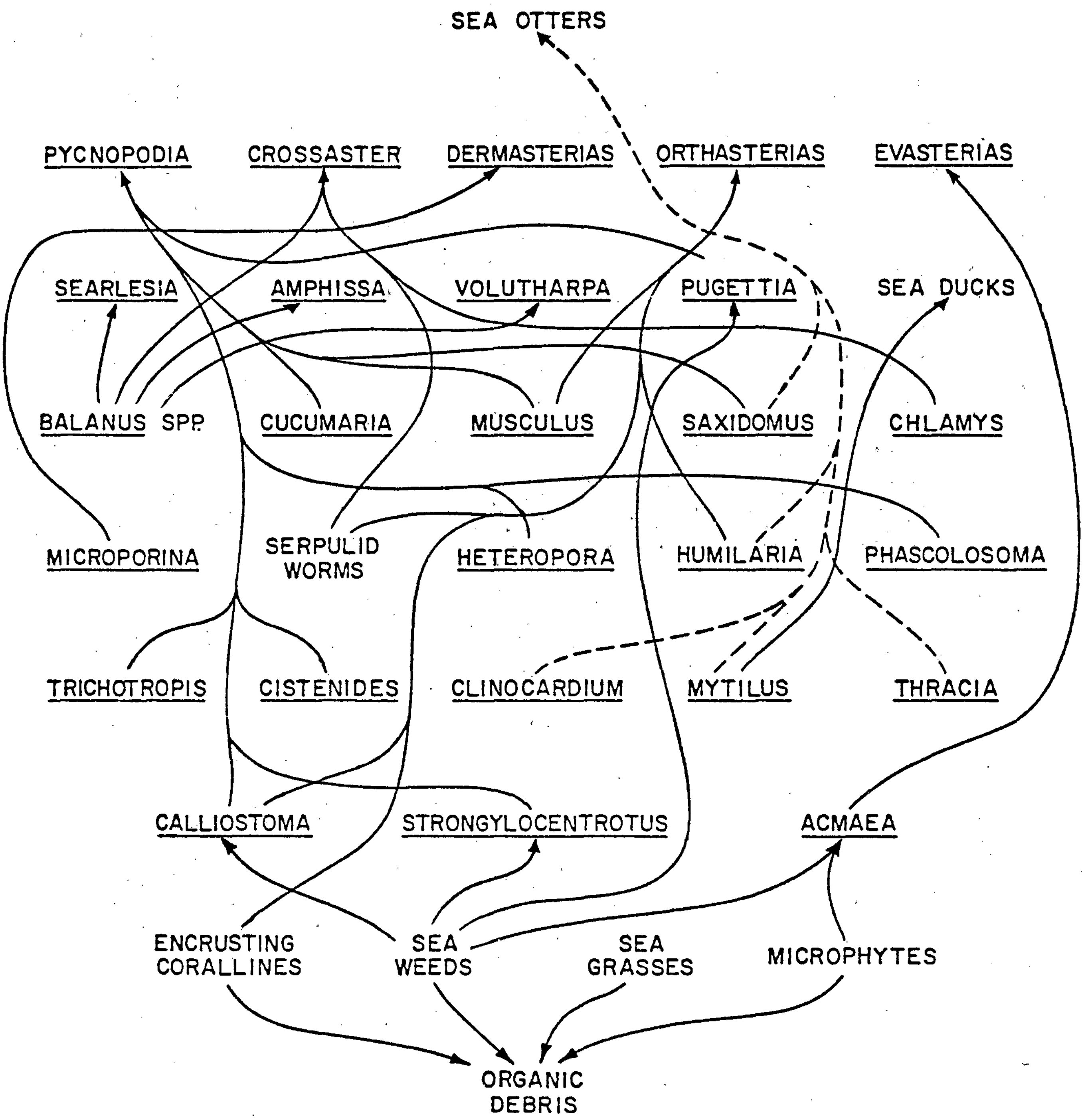


Fig. III-23. FOOD WEB FOR THE CONSPICUOUS SPECIES IN THE SHALLOW SUBLITTORAL ZONE AT ZAIKOF BAY, MONTAGUE ISLAND (Dames and Moore 1976).

TABLE III-13.

Average catch per unit effort of commercially important invertebrates collected during the trawl survey on the continental shelf of the Northeastern Gulf of Alaska, April-August 1975 (Ronholt *et al.*, 1976).

	Areas/Depth Zones (meters)											
	Eastern				Central				Western			
	1-100	101-200	201-400	All Depths	1-100	101-200	201-400	All Depths	1-100	101-200	201-400	All Depths
Chionoecetes bairdi	24.8	2.7	1.5	6.7	26.7	8.2	0.1	11.4	127.3	110.3	218.4	131.6
Pandalus borealis	*	0.5	0	0.3	0	2.5	*	1.1	26.0	6.4	1.3	13.7
Pandalopsis dispar	0	*	0.6	0.1	0	*	7.4	2.1	4.3	0.7	0.5	2.1
Pandalus jordani	*	0.4	*	0.2	0	0.1	0	*	0.4	*	0	0.2
Patinopecten caurinus	14.8	0	0	2.9	12.5	5.7	0.1	6.1	2.4	0.3	0.2	1.1
Others	0.9	0.1	0.4	0.4	*	*	7.6	2.2	2.8	*	*	1.1
TOTAL	40.5	3.7	2.5	10.6	39.2	16.5	15.2	22.9	163.2	117.7	220.4	149.8

*Less than 0.1 kilogram per six kilometers.

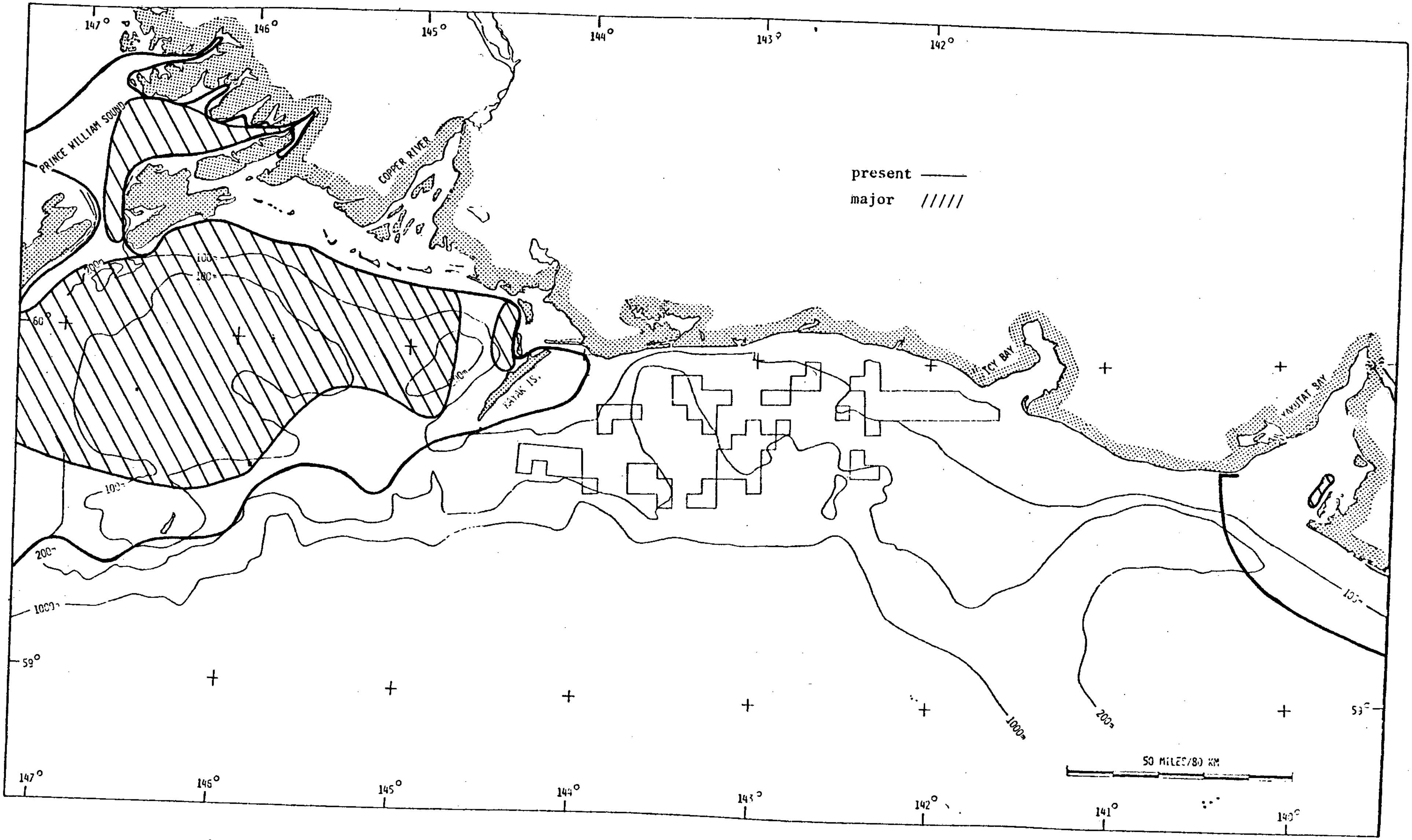


Fig. III-24. Tanner crab fishing areas (ADF&G 1975)

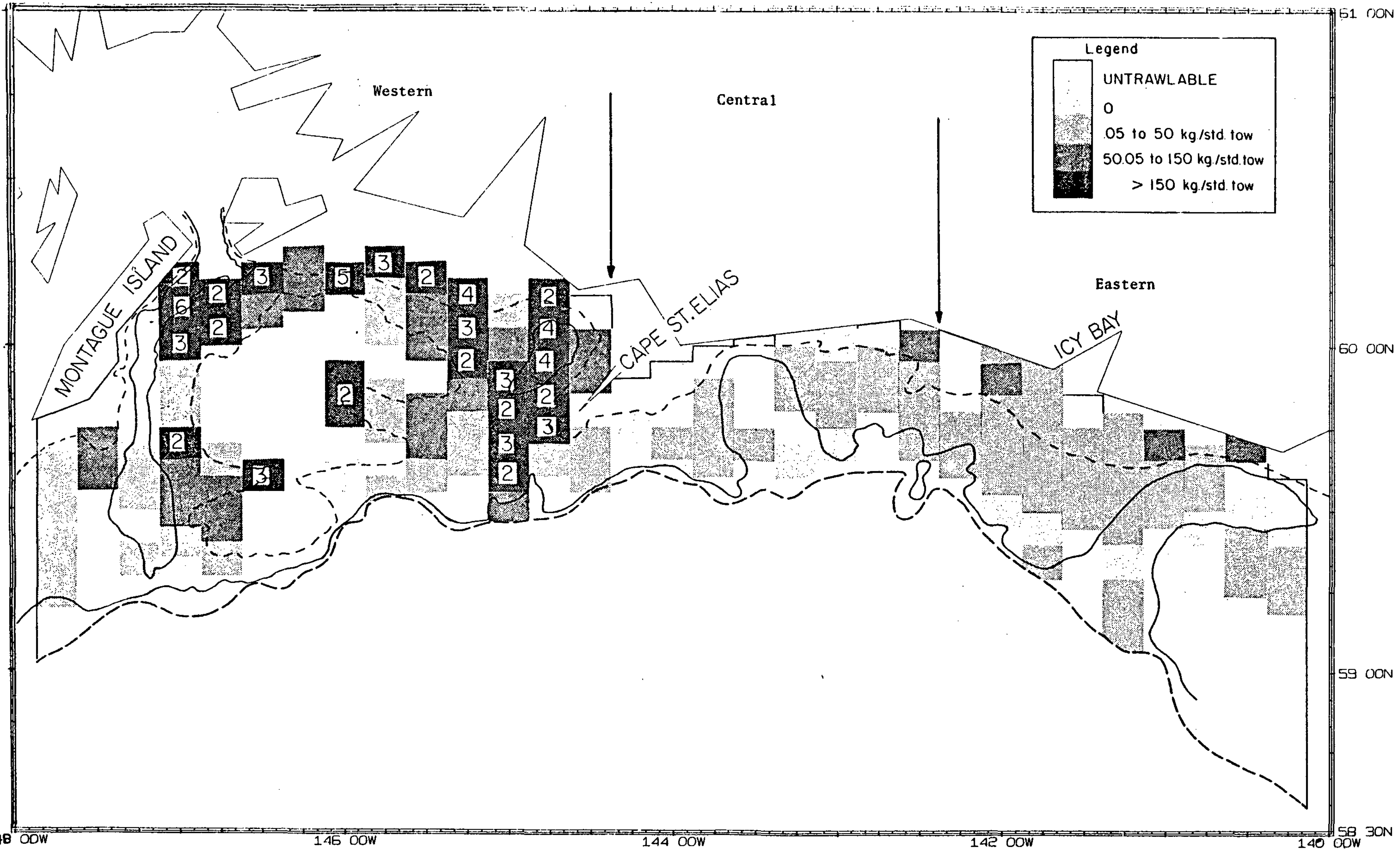


Fig. 111-25. Distribution and relative abundance of Tanner crab (*Chinoecetes bairdi*) May-August 1975 (Ronholt *et al.*, 1976).

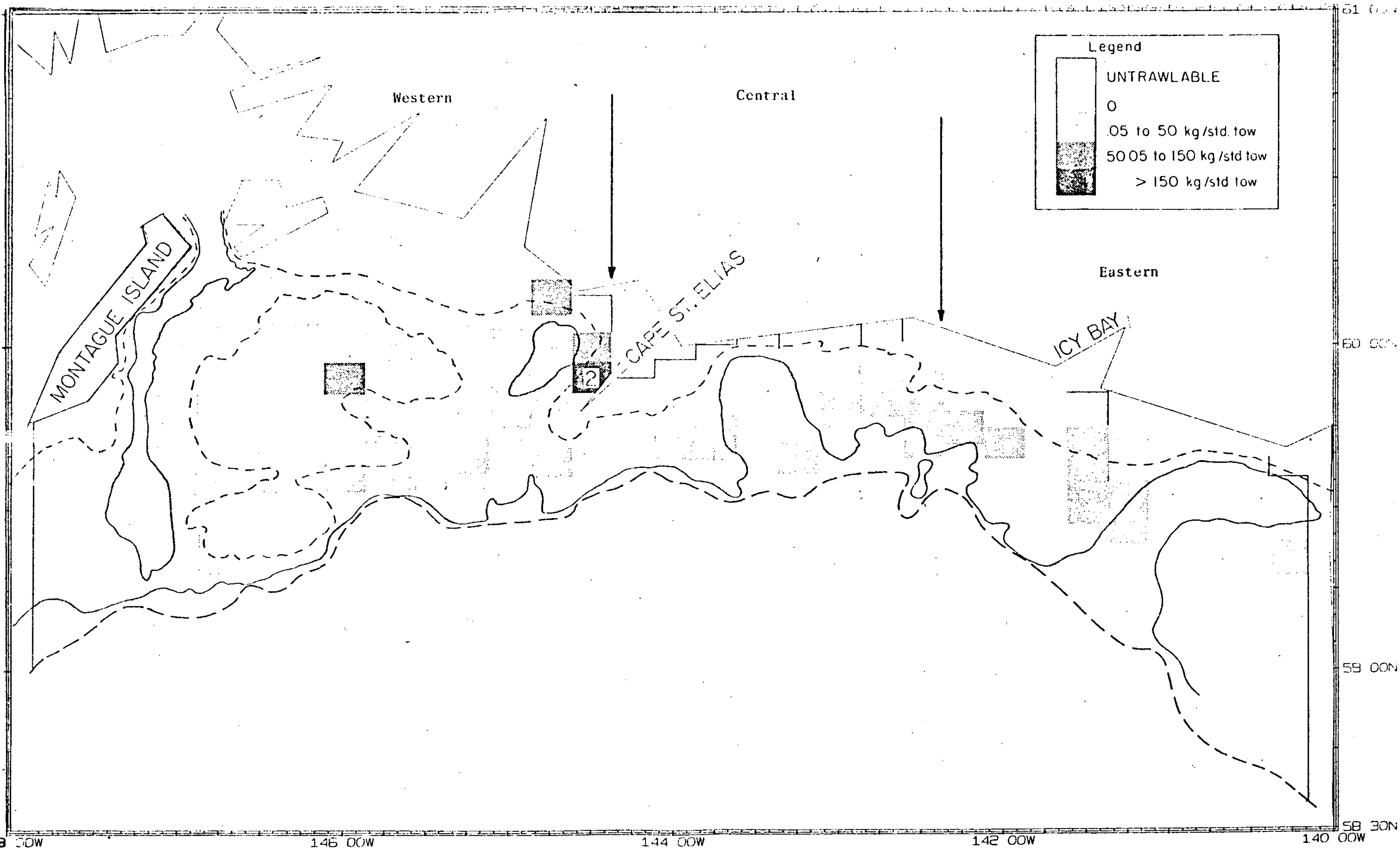


Fig. 111-26. Distribution and relative abundance of Pink shrimp (*Pandulus borealis*) May-August 1975 (Ronholt *et al.*, 1976).

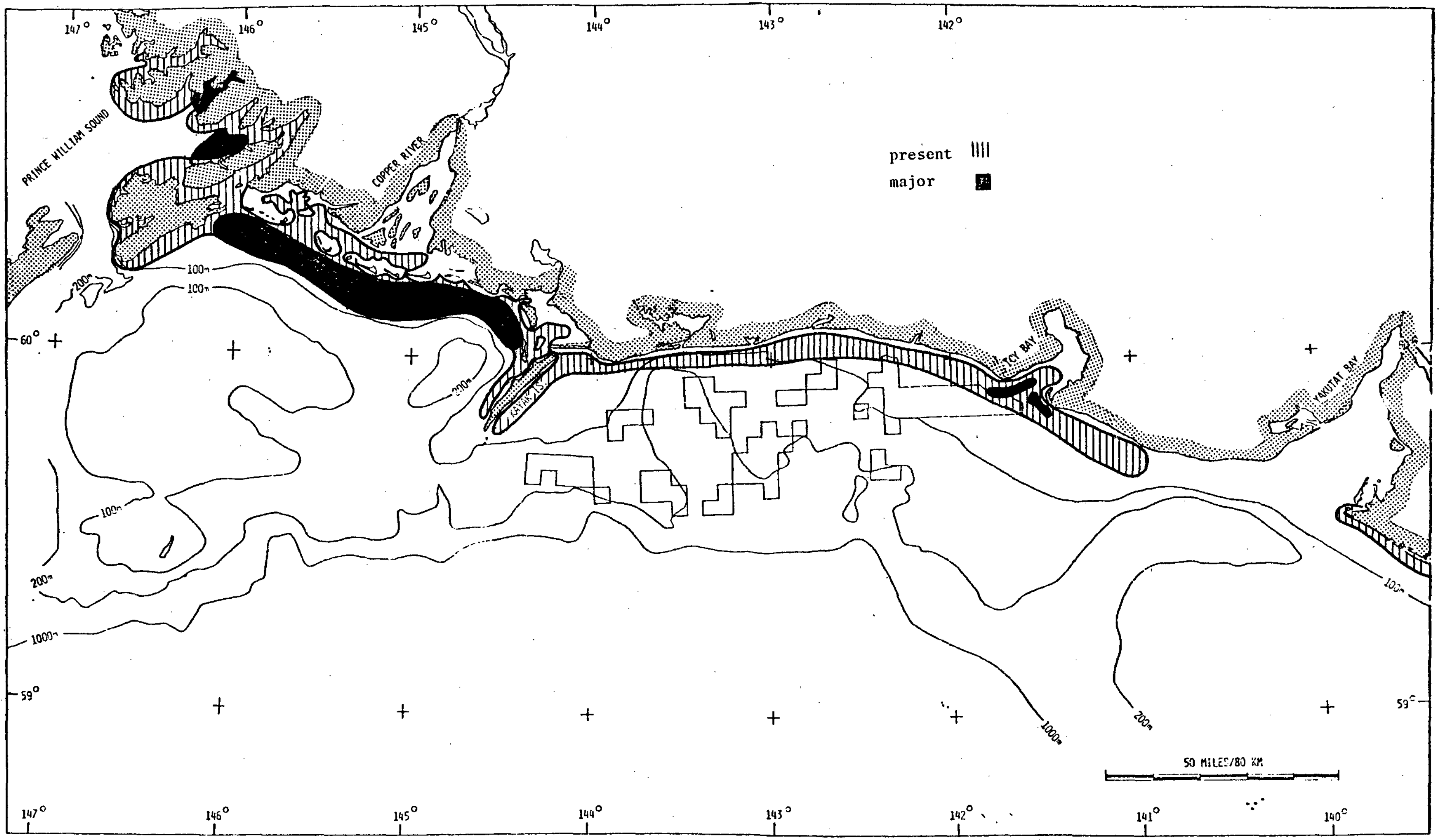


Fig. III-27. Dungeness crab fishing areas (ADF&G 1975).

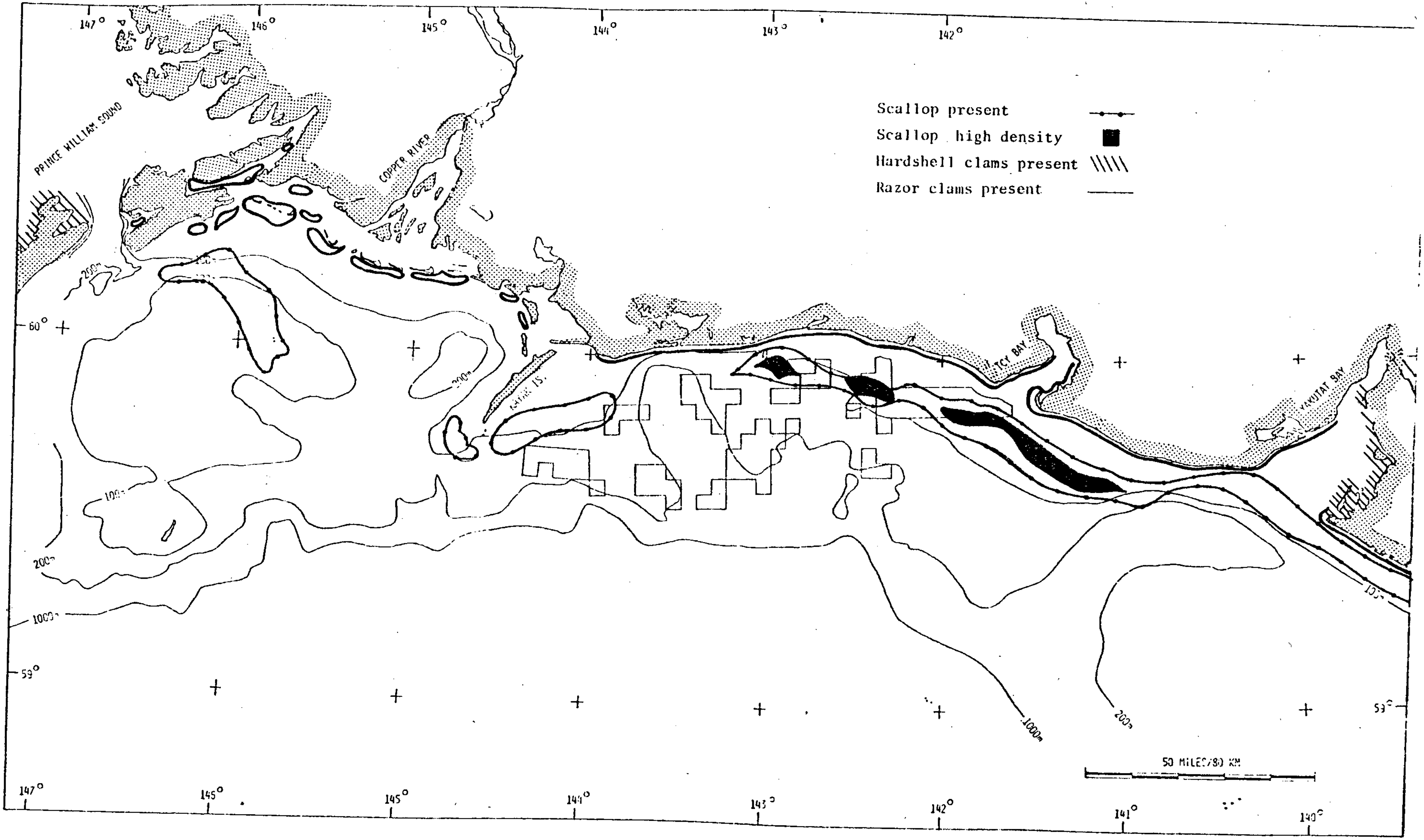


Fig. III-28. Commercial shellfish distributions (ADF&G 1975).

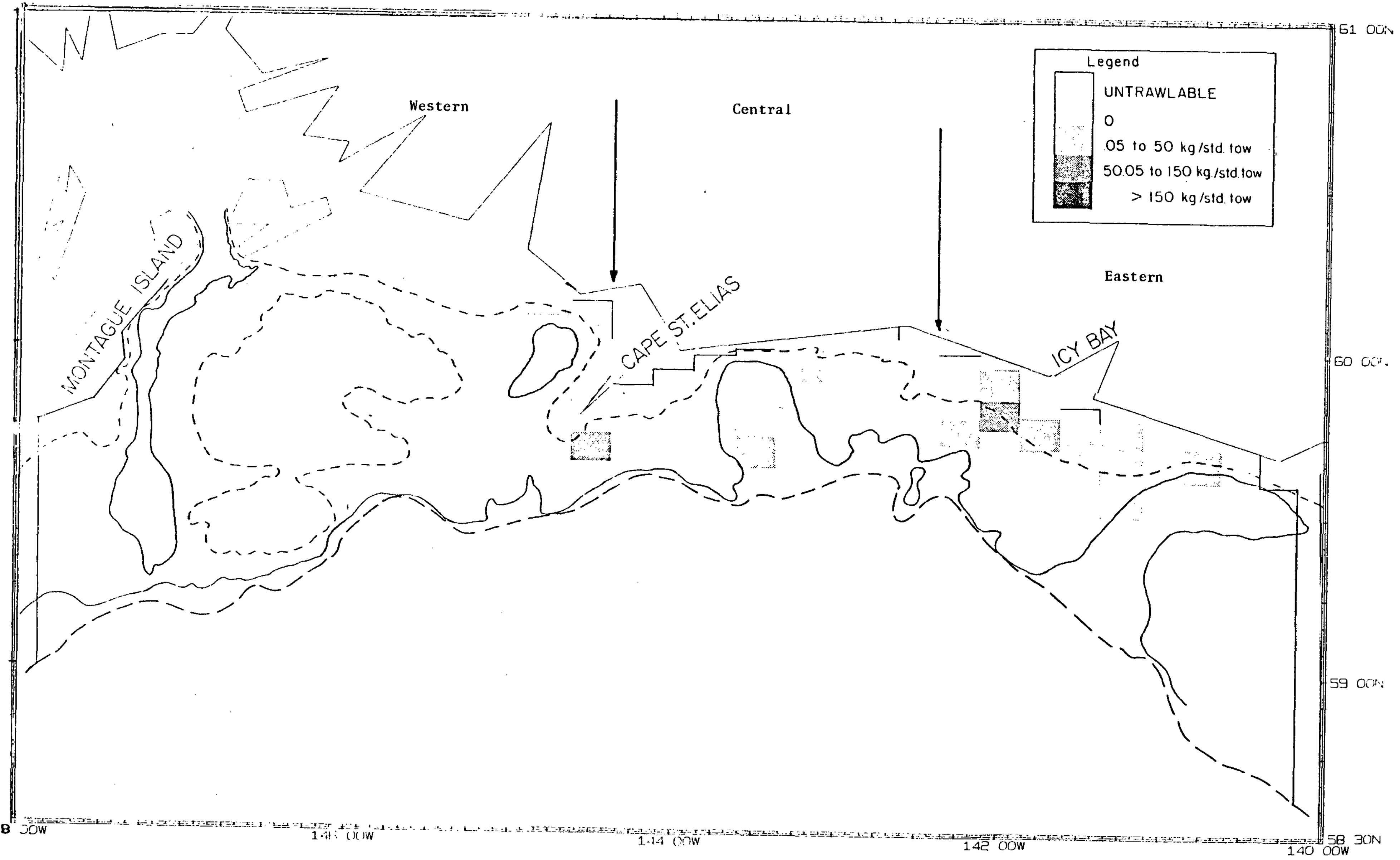


Fig. III-29. Distribution and relative abundance of Weathervane scallop (*Patinopecten caurinus*) May-August 1975 (Ronholt et al., 1976).

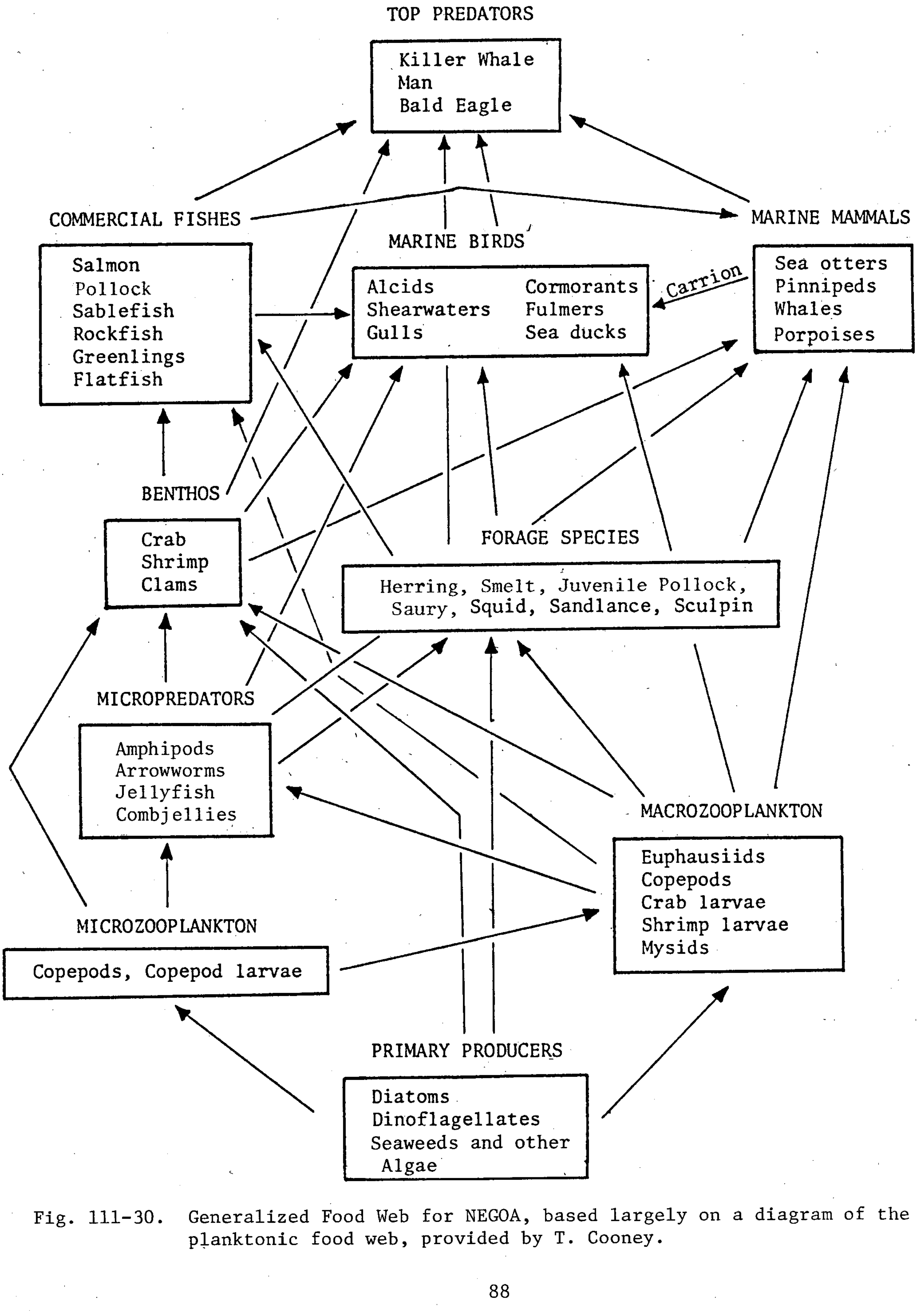


Fig. 111-30. Generalized Food Web for NEGOA, based largely on a diagram of the planktonic food web, provided by T. Cooney.

Fisheries Resources

Species belonging to the families Clupeidae, Cottidae, Gadidae, Hexagrammidae, Osmeridae, Pleuronectidae, Salmonidae, and Scorpaenidae dominate the fishery resource in the Gulf of Alaska.

Major fluxes in population abundance occur seasonally and spatially throughout the Northeast Gulf of Alaska (Tables III-14 and III-15). The most significant of these are the seasonal fluctuations in salmon, smelt, and herring abundances. During the spring and summer large numbers of adult spawners and juveniles enter the estuarine and near coastal zones (Table III-16). Adult populations migrate to and congregate at the mouths of "home" streams (salmon, smelt), and along rocky streams into estuarine nursery areas, herring and some smelt larvae hatch and feed nearshore. All of these fish generally congregate in large schools before dispersing offshore.

In the NEGOA region, all suitable spawning streams are entered by one or more of the salmonid species (ADF&G 1975). Sockeye are generally limited by the availability of streams with lakes (Fig. III-31). Suitable streams include those south of Yakutat Bay and the Copper, Eyak, and Bering Rivers. Coho are most abundant in rivers between Pt. Manby and Cape Suckling (Fig. III-31). Pink and chum usually spawn in short streams, within the zone of tidal influence, and in the intertidal zones adjacent to stream outlets. Most suitable streams and intertidal spawning areas are located within Prince William Sound (Fig. III-31). However, a commercially exploitable run of pink salmon occurs in Yakutat Bay. Small populations of chinook salmon occur throughout the area, specifically south of Yakutat Bay and in the Copper River (Fig. III-31). Steelhead trout and sea run cutthroat trout runs enter many streams in the regions, and Dolly Varden spawn in all salmon spawning streams (Fig. III-32).

It should be noted also that no stream system in the NEGOA region dominates the salmon fishery. Each stream is considered of equal importance in the maintenance of a healthy salmon fishery in NEGOA (ADF&G 1975).

Adult salmon spawners enter the shelf region from the oceanic region through a multidirectional front(Fig. III-33) (Stern *et al.*, RU #353, 1976; Royce *et al.*, 1968; Godfrey *et al.*, 1975). Once on the shelf some spawners proceed directionally to their "home" streams. Others mill in areas such

TABLE III-14

Tentative Summary of Use of Epipelagic and Littoral Zones by Principal Species of Fish, NEGOA*.

Species	SEASON Winter	Spring	Summer	Fall
Sablefish	E L	L	J	
Pacific herring	A J	Ⓐ Ⓔ Ⓙ	A Ⓛ Ⓙ	A J
Pacific sand lance	A E J	A J	A J	A J
Walley pollock	A E L	L J	J	J
Lingcod	A Ⓔ			
Atka mackerel			A J	
Pond smelt	A J	A J	A J	A J
Surf smelt	Ⓐ Ⓔ Ⓛ	Ⓐ Ⓔ Ⓛ	Ⓐ Ⓔ Ⓛ	Ⓐ Ⓔ Ⓛ
Capelin		Ⓐ Ⓔ	Ⓐ Ⓔ	
Rainbow smelt	A J	A E Ⓛ J	A Ⓛ J	A J
Longfin smelt		A Ⓙ	A Ⓙ	A
Eulachon	A J	A Ⓙ	A Ⓙ	A J
Arrowtooth flounder		L	L	
English sole	Ⓐ Ⓔ Ⓛ	L J		
Starry flounder	Ⓐ Ⓔ Ⓛ	L J		
Pink salmon	Ⓔ Ⓛ	Ⓔ Ⓛ Ⓙ	A Ⓔ Ⓙ	Ⓔ J
Chum salmon	Ⓔ Ⓛ	Ⓔ Ⓛ Ⓙ	A Ⓔ Ⓙ	Ⓔ J
Coho salmon	A	A Ⓙ	A Ⓙ	A J
Sockeye salmon		A Ⓙ	A Ⓙ	
Chinook salmon	A	A Ⓙ	A Ⓙ	A
Steelhead trout	A	A Ⓙ	A Ⓙ	A
Dolly Varden	A	Ⓙ	A Ⓙ	A J
Cutthroat trout	Ⓐ J	A Ⓙ	A Ⓙ	A J
Pacific saury			A J	
Pacific cod		L		
Prowfish	A J	A J	A J	A J
Pacific sandfish	A Ⓔ J	J		
Jack mackerel			A J	
Chub mackerel			A J	
Sculpins	A J	A L J	A L J	A J

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*(Prepared by SAI staff from various sources cited in the text.)

A = Adults
E = Eggs
L = Larval
J = Juvenile
◯ = Special dependence on littoral zone

TABLE III-15

Tentative Summary of Use of Benthic Zone by Principal Species of Fish, NEGOA*.

Species	Winter	Spring	Summer	Fall
Sablefish	A J	A J	A J	A J
Pacific herring	Ⓐ J			A J
Pacific sand lance	A Ⓔ J	A J	A J	A J
Pacific cod	A Ⓔ J	A J	A J	A J
Walley pollock	A E J	A J	A J	A J
Lingcod	A Ⓔ J	A J	A J	A J
Atka mackerel			A E	
Surf smelt	J	J	J	J
Capelin	A J	A E L J	A E L J	A J
Arrowtooth flounder	A J	A J	A J	A J
Petrale sole	Ⓐ Ⓔ L J	A L J	A J	A J
Pacific halibut	A E J	A J	A J	A J
Dover sole	Ⓐ Ⓔ L J	A L J	A J	A J
English sole	A J	A J	A J	A J
Starry flounder	A J	A J	A J	A J
Pacific ocean perch	A J	A J	A J	A J
Flathead sole	A E J	A	A J	A J
Rex sole	A E J	A	A J	A J
Sculpins	A	A	A	A

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* (Prepared by SAI staff from various sources cited in the text.)

A = Adults
E = Eggs
L = Larval
J = Juvenile
◯ = Special dependence on benthic zone