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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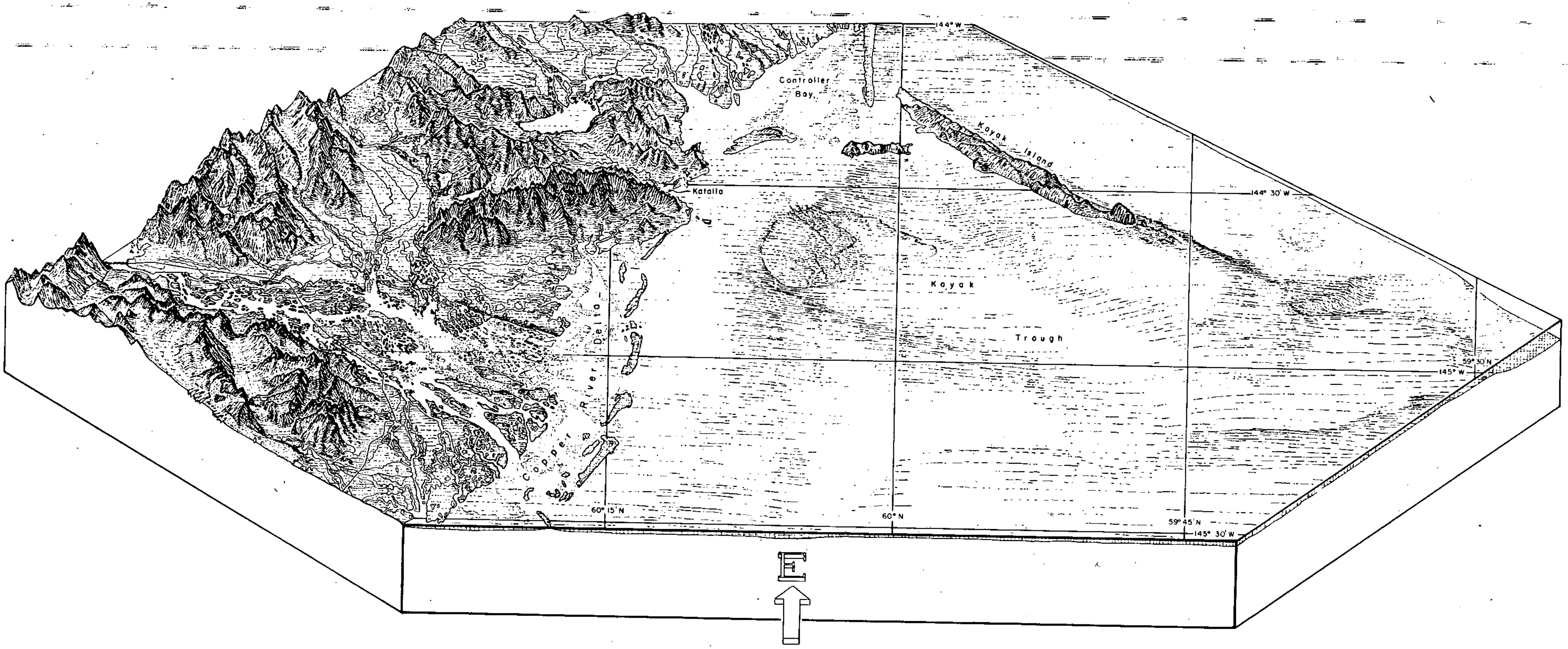


Orthographic drawing, looking east, of the Copper River Delta, Kayak Trough and Kayak Island (T. R. Alpha, USGS 1977; vert. exag. 4:1).

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;

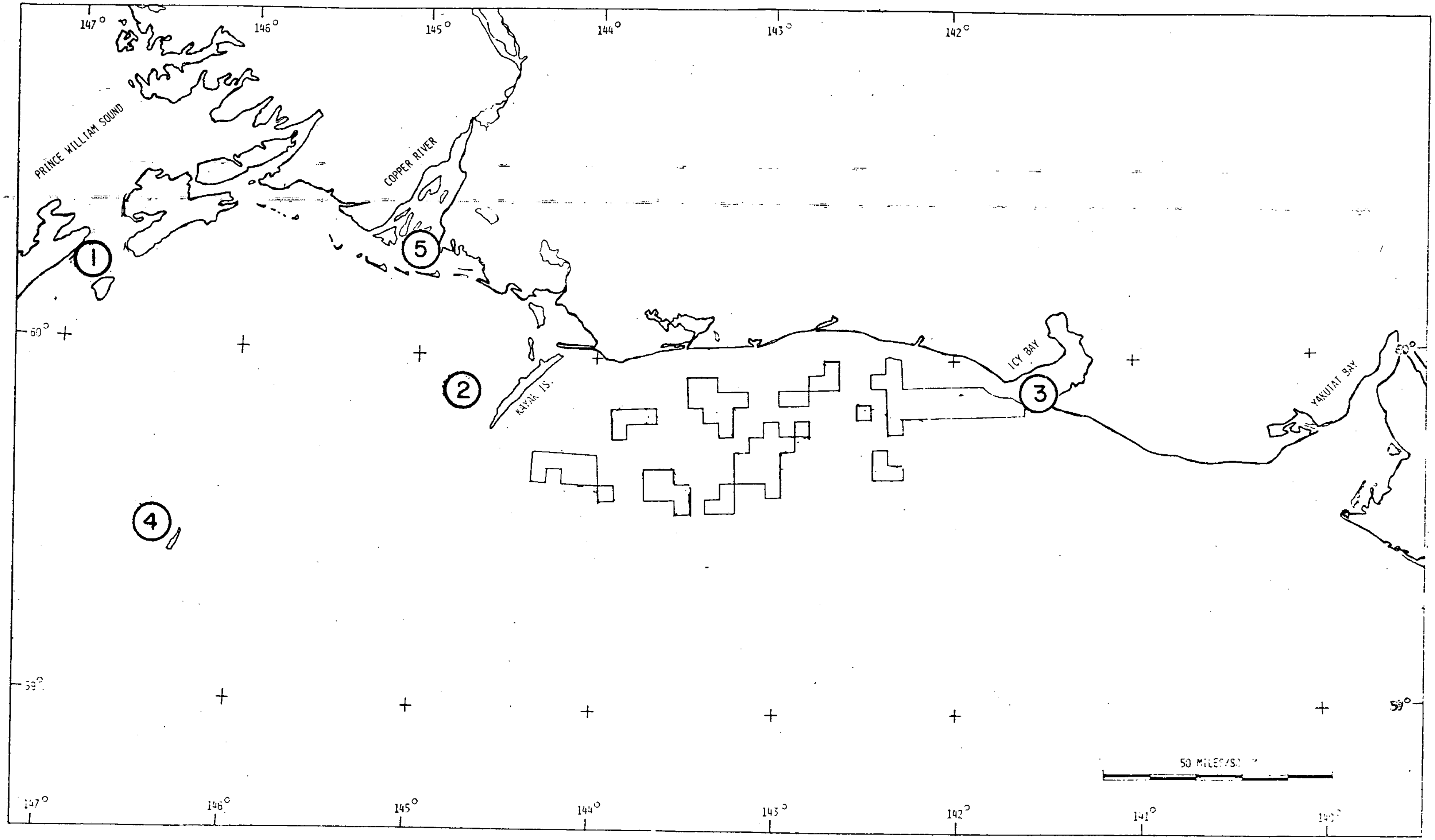


Fig. II-1. Areas identified as critical to the proposed OCS oil and gas development in the Northern Gulf of Alaska. 1: Hinchinbrook Entrance, 2: Kayak Trough, 3: Icy Bay, 4: Middleton Island, and 5: Copper River Delta.

- 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

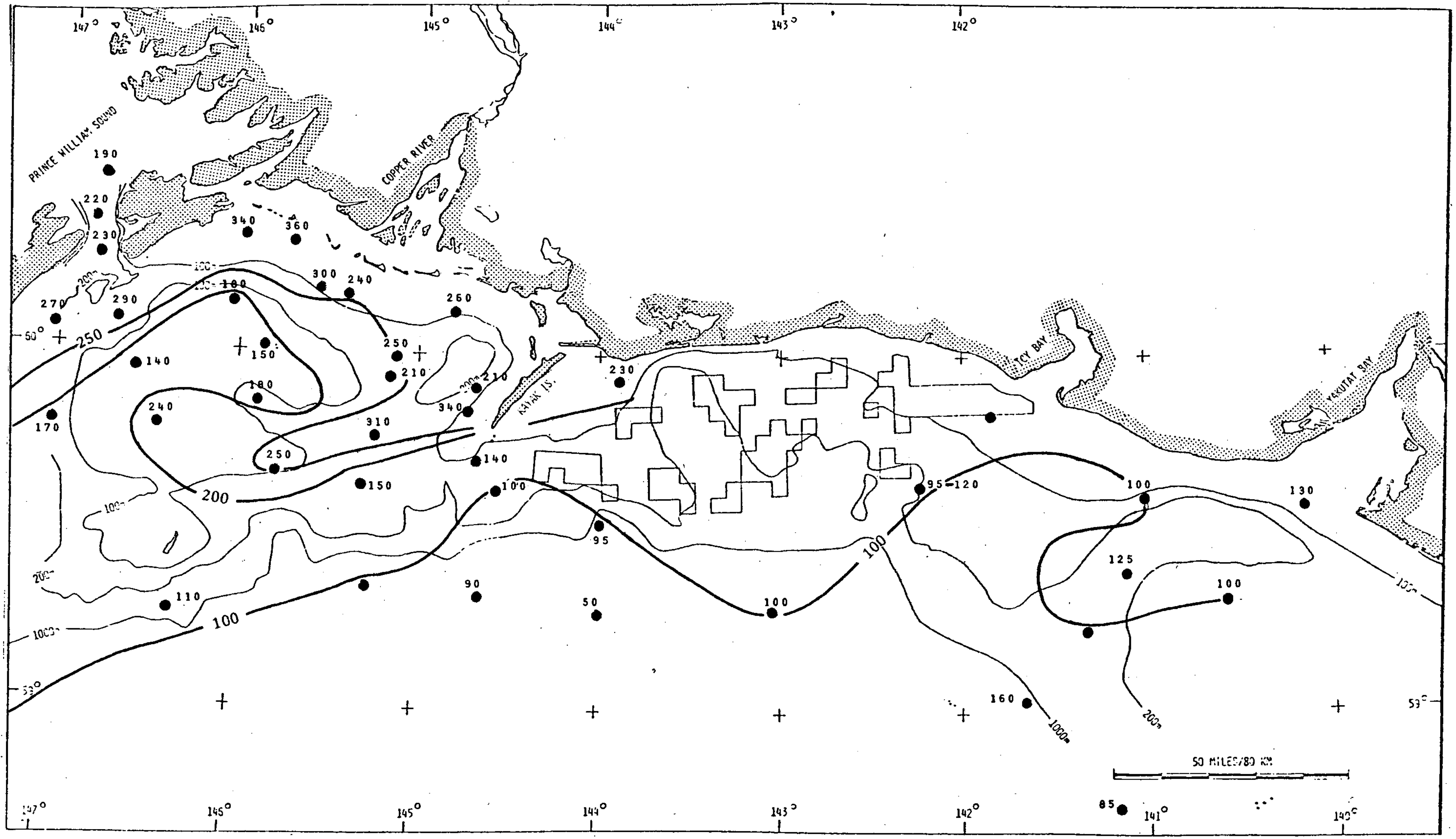


Fig. 111-1 Surface concentration of methane (nl/liter) in NEGOA during April 1976; concentrations rounded to nearest 5 nl/liter (from Cline and Feely, RU#153).

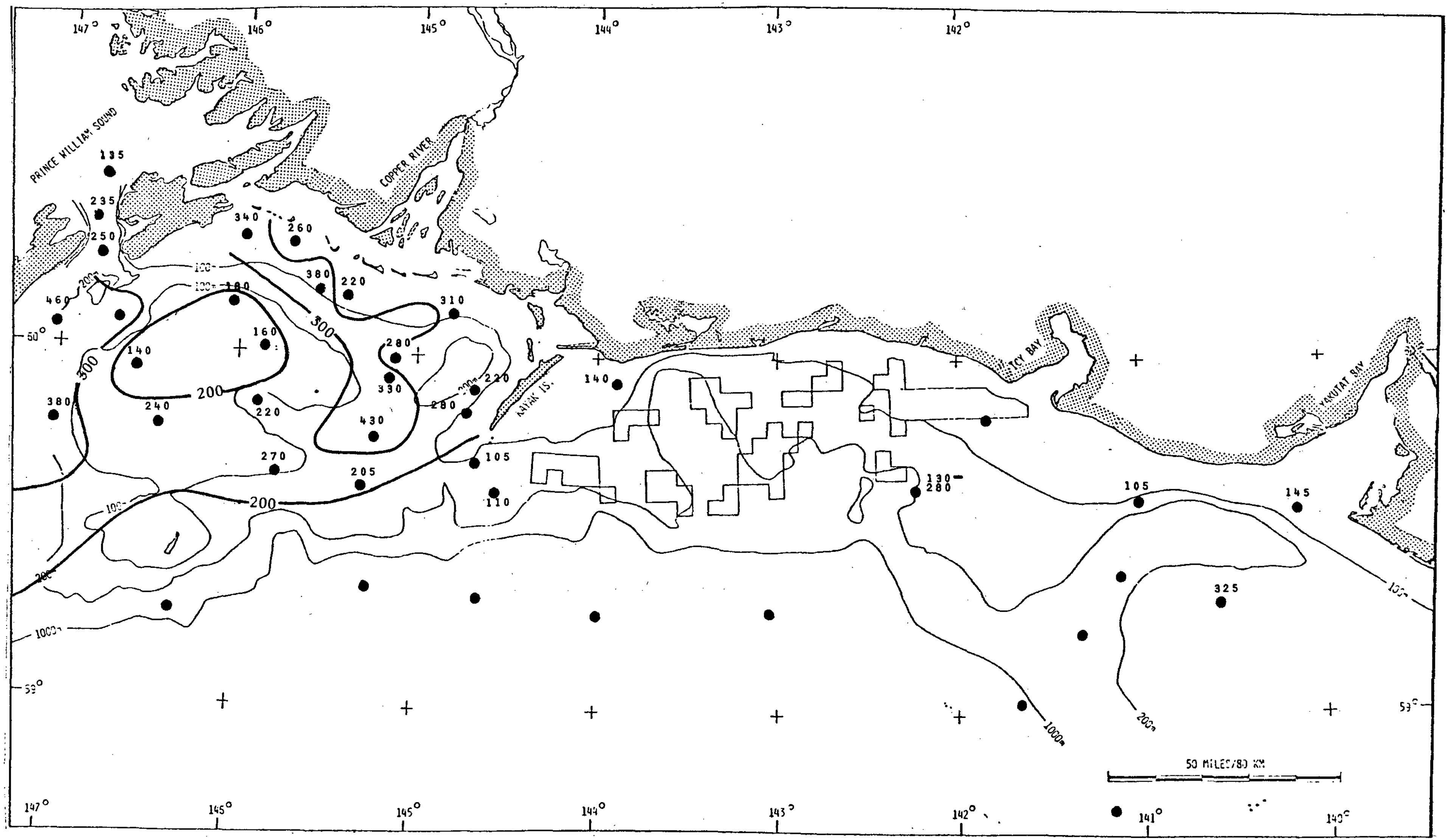


Fig. 111-2 Concentration of methane (nl/liter) within 5m of the bottom on the NEGOA shelf during April 1976 (from Cline and Feely, RU#153).

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

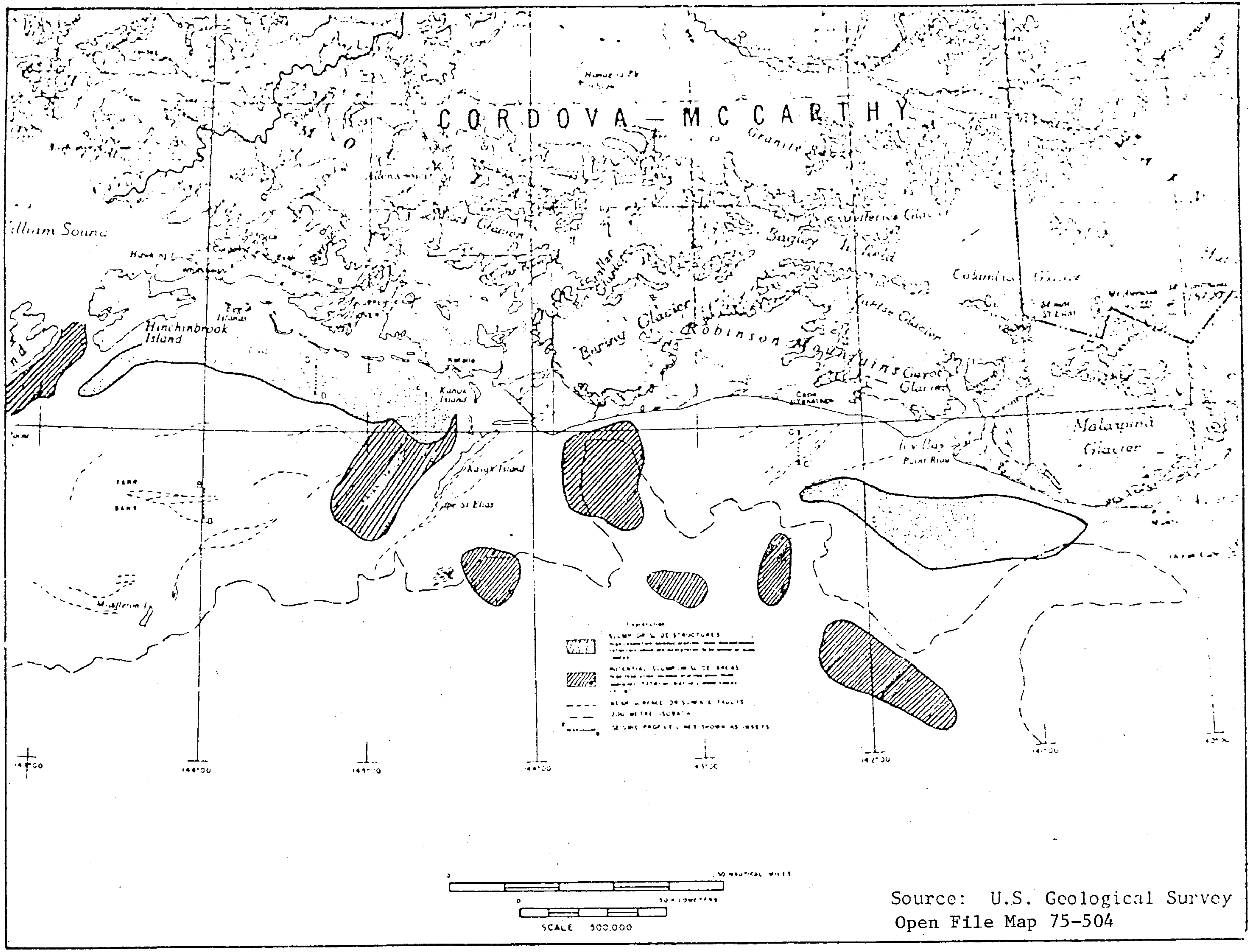
Metal contents of sediment, biota, and water are discussed in the Kodiak section of the NOAA/OCSEAP annual report summary (NOAA/SAI 1976). Burrell (RU #162, 1976) reported that inorganic sediments constitute the largest repository of heavy metals, but those held in the biota are of particular concern 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^o, 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								
	No. of Samples	Plastic Limit		Liquid Limit		Natural Water Content*		Plasticity Index	
Sed. Type		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

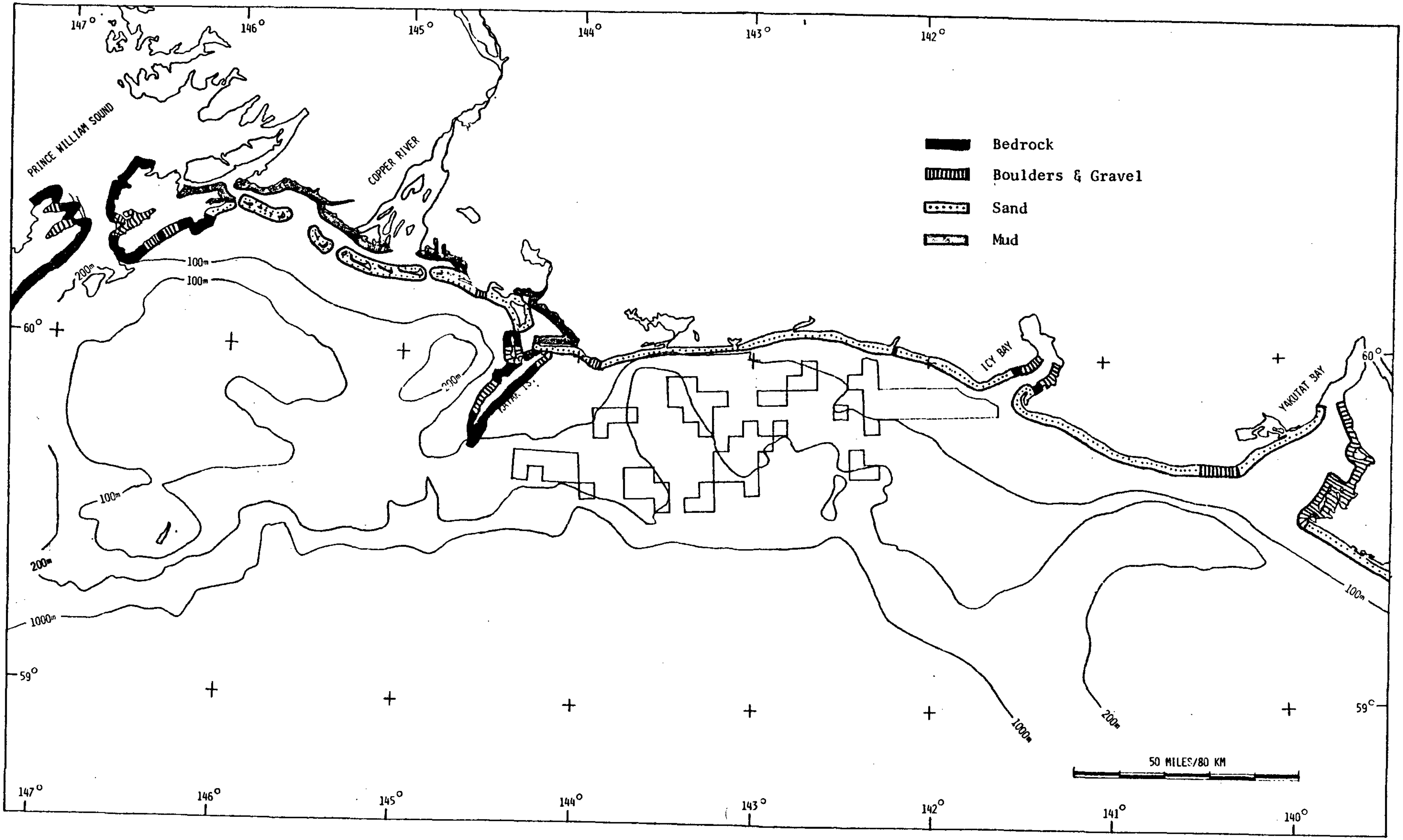


Fig. 111-4 NEGOA shoreline substrate types (J. MacKinnon, unpublished data, NMFS, Auke Bay, 1977).

temperature-minimum layer, ∿3^{0}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^{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

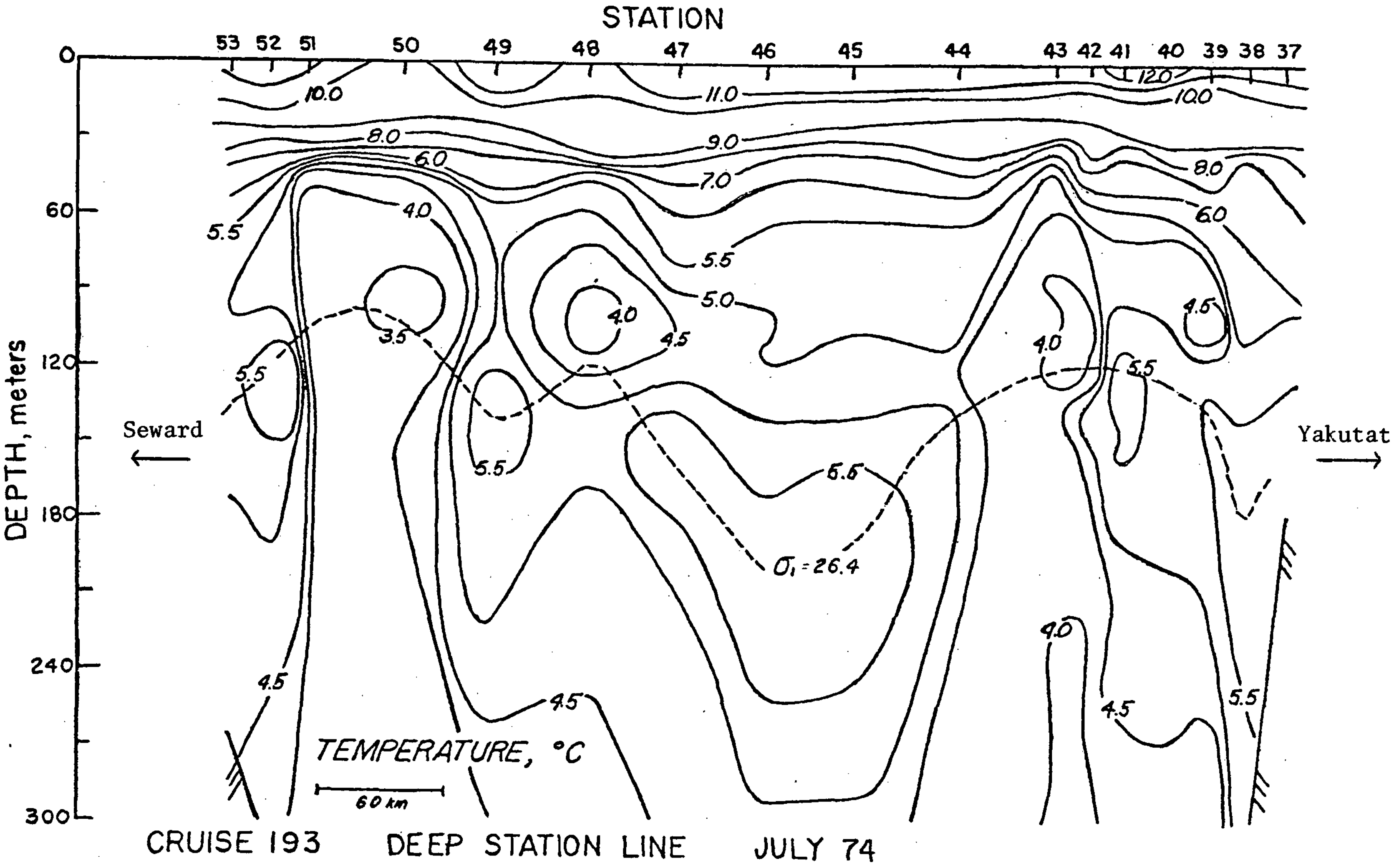


Fig. III-5. Vertical section of temperature versus depth extending offshore from Yakutat (STA 37-STA 43), west across the deeper offshore section of the Gulf of Alaska (STA 43-STA 51), and onshore to the continental shelf off Seward (STA 51-STA 53). The depth of the sigma-T = 26.4 surface is given by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

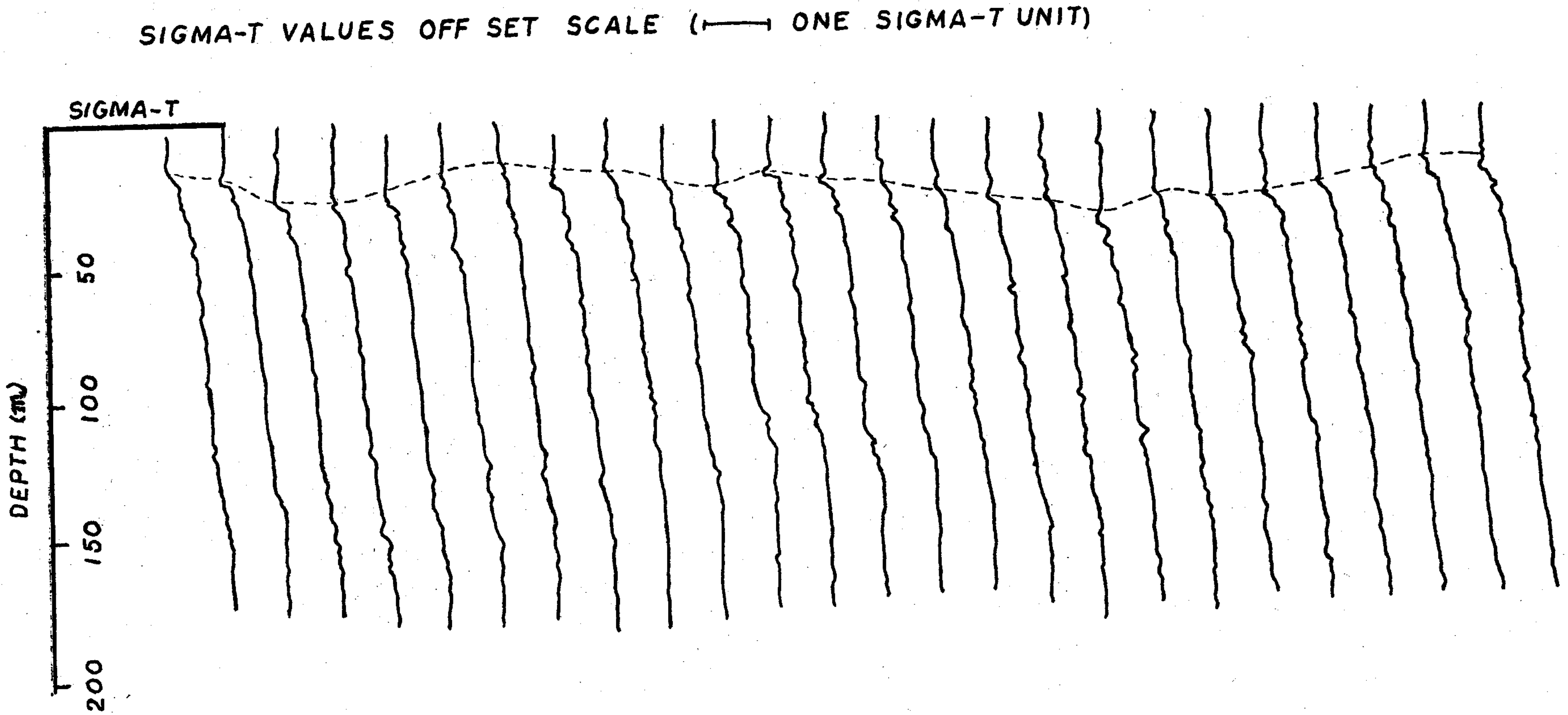


Fig. III-6. Vertical profile of sigma-T at hourly intervals in June 1975 at Station 62. Dotted line indicates mixed layer depth (Royer, RU #289, 1976).

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

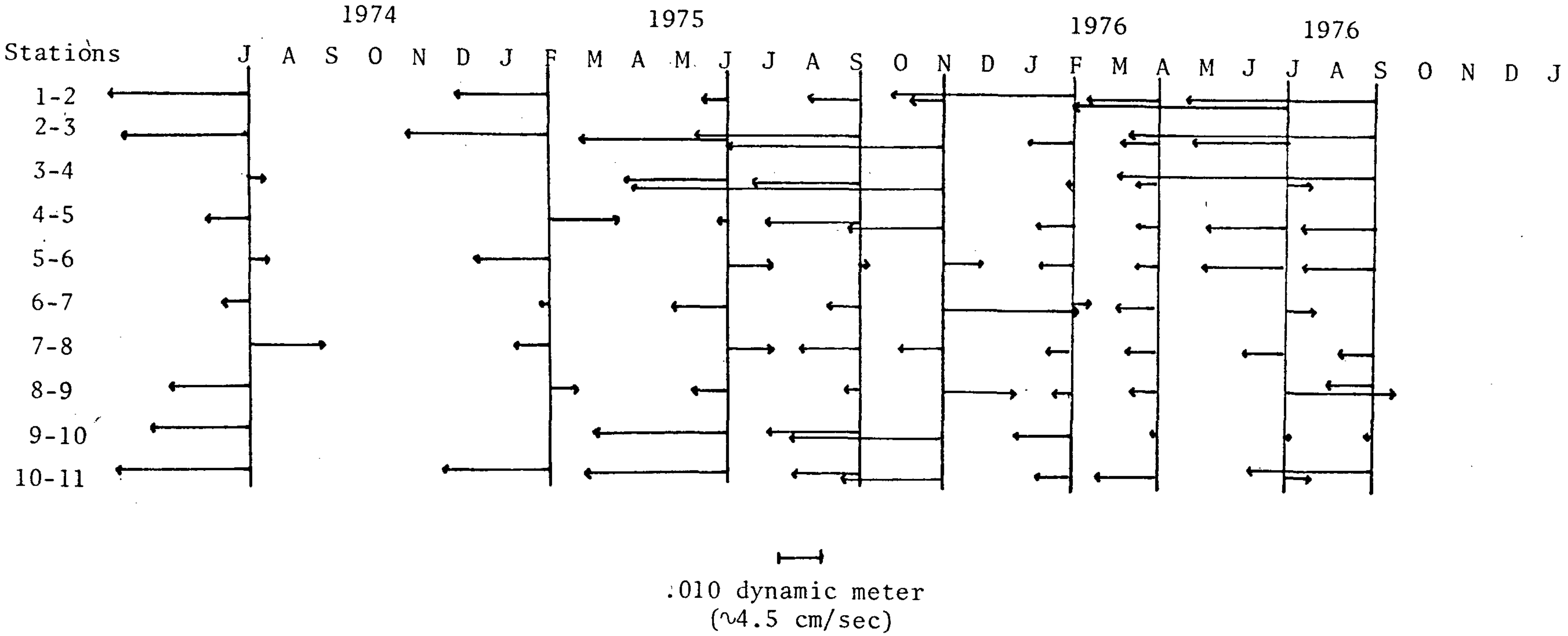


Fig. III-7. Baroclinic current component of Seward Station line, Gulf of Alaska (Royer, RU #289, 1976).

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

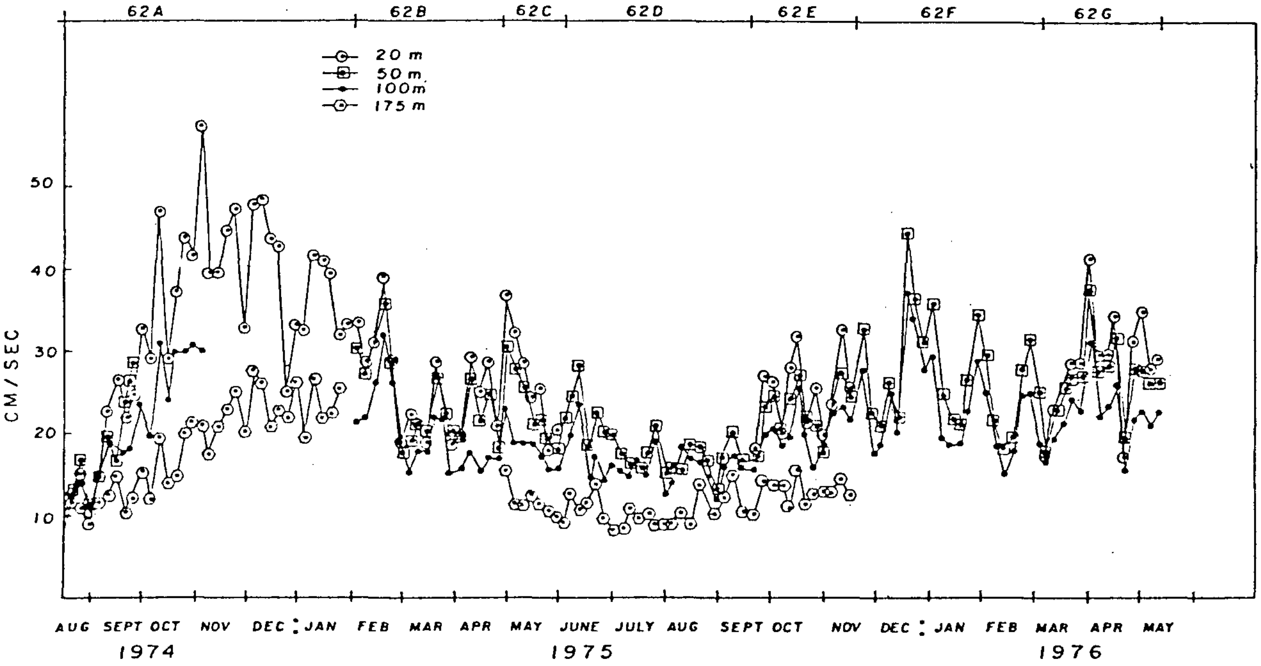


Fig. III-8. Five-day speeds for all available data from Station 62 from August 1974 through May 1976. Data from the 50 m and 100 m current meters were continuous from February 1975 through May 1976. Mean speeds were higher in winter than in summer (Hayes and Schumacher, RU #138, 1976).

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

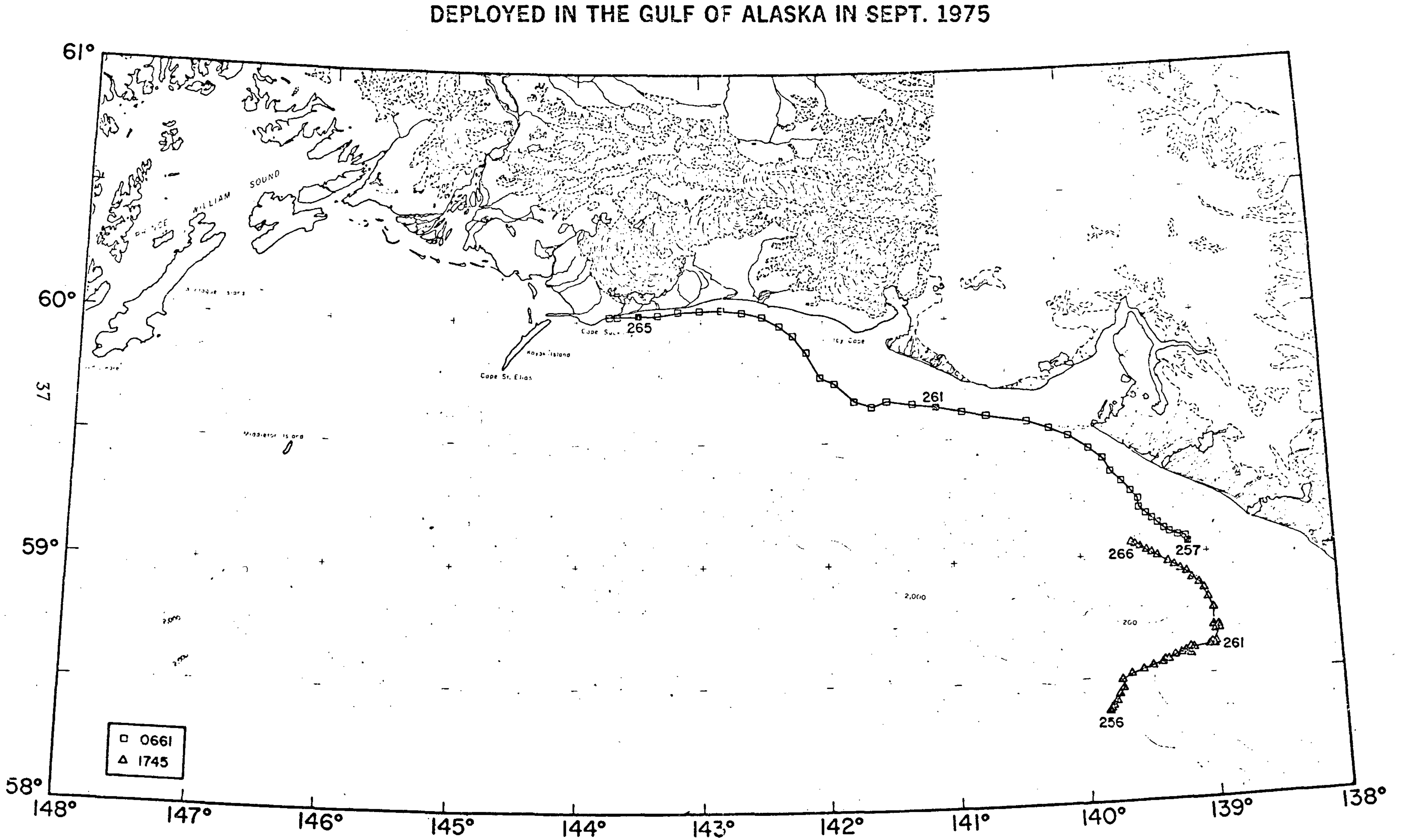


Fig. 111-8a Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

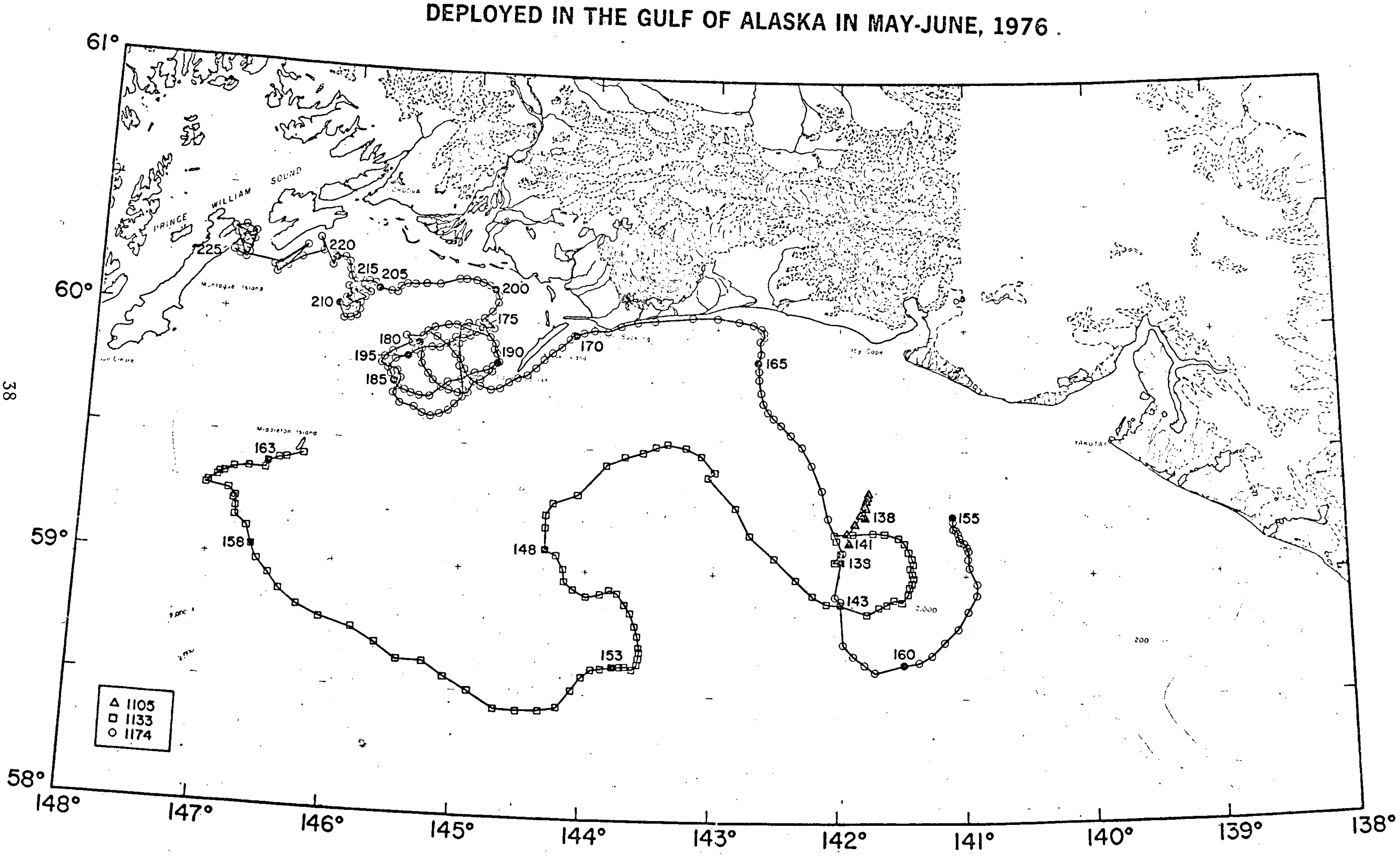


Fig. 111-8b Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

DEPLOYED IN THE GULF OF ALASKA IN JULY 1976.

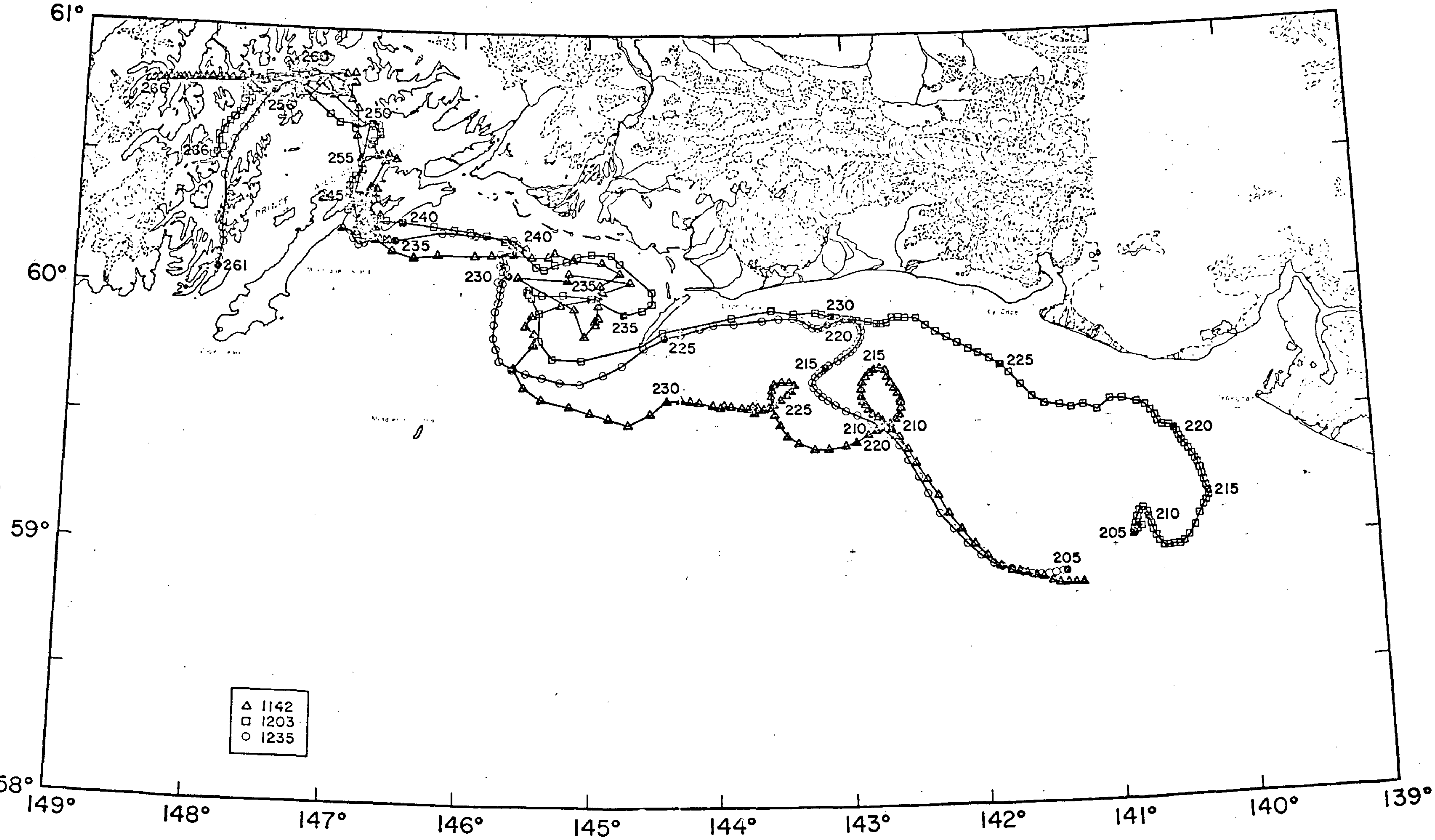


Fig. 111-c Satellite-tracked drift buoy trajectories in the northern Gulf of Alaska.

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

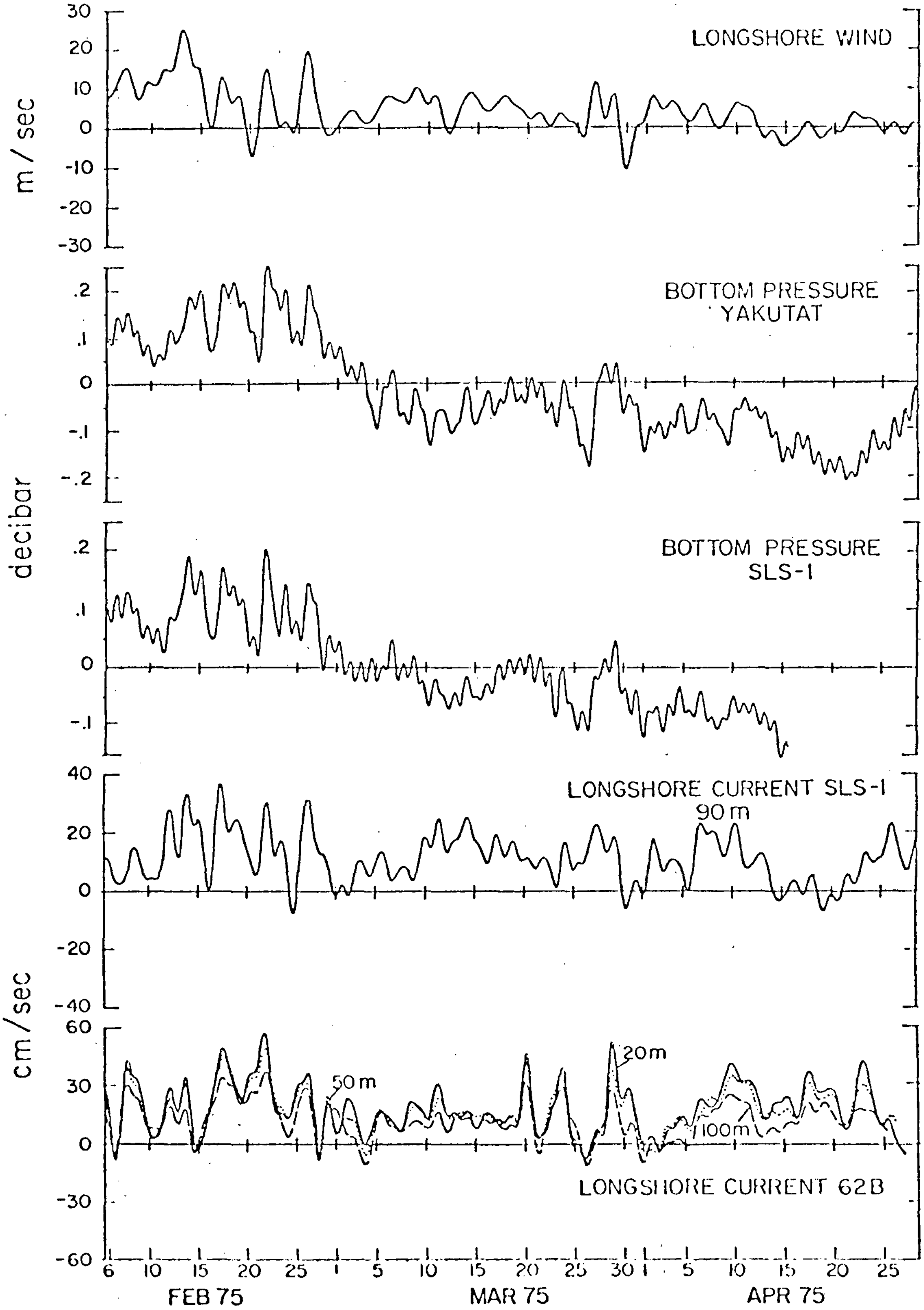


Fig. III-9. Time series of measurements from Icy Bay pilot experiment February to May 1975 (Hayes and Schumacher, RU #138).

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.

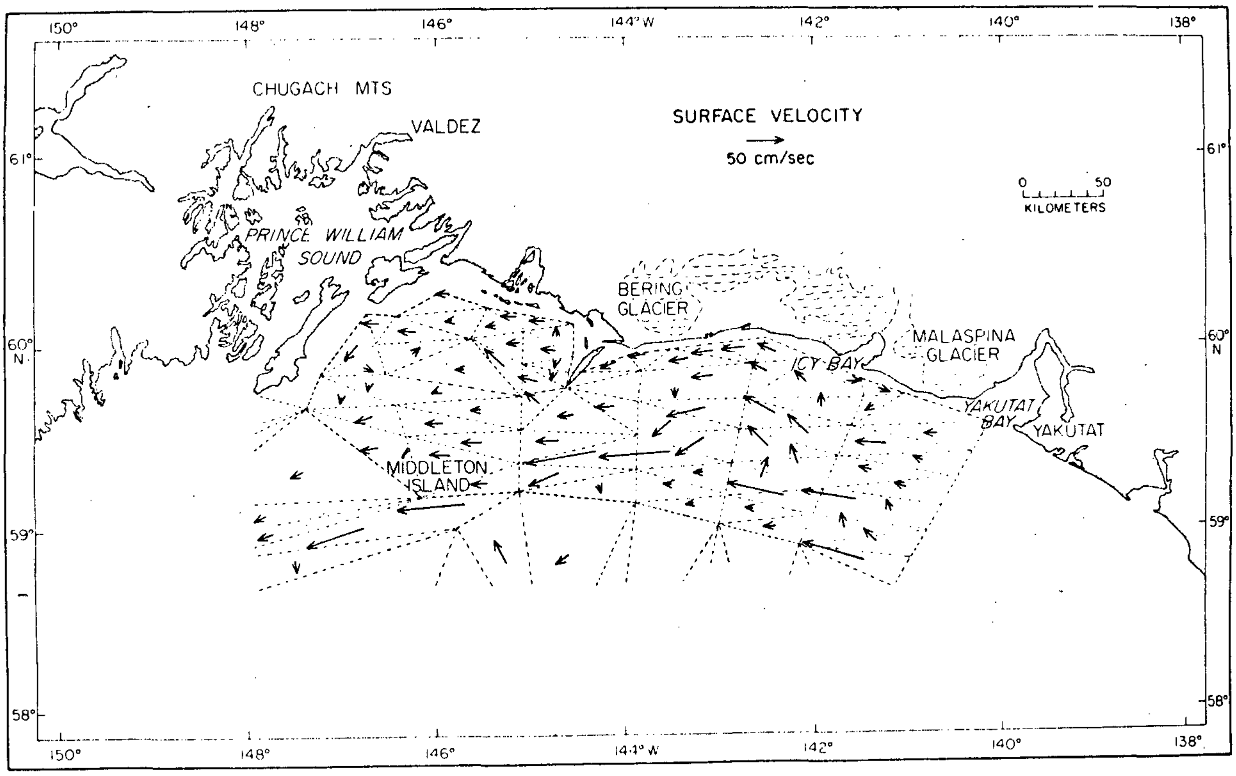


Fig. III-10. Numerical model results for test case using density data collected in July 1974. Vertices of triangles indicate oceanographic station locations used for input data (Galt, RU #140, 1976).

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

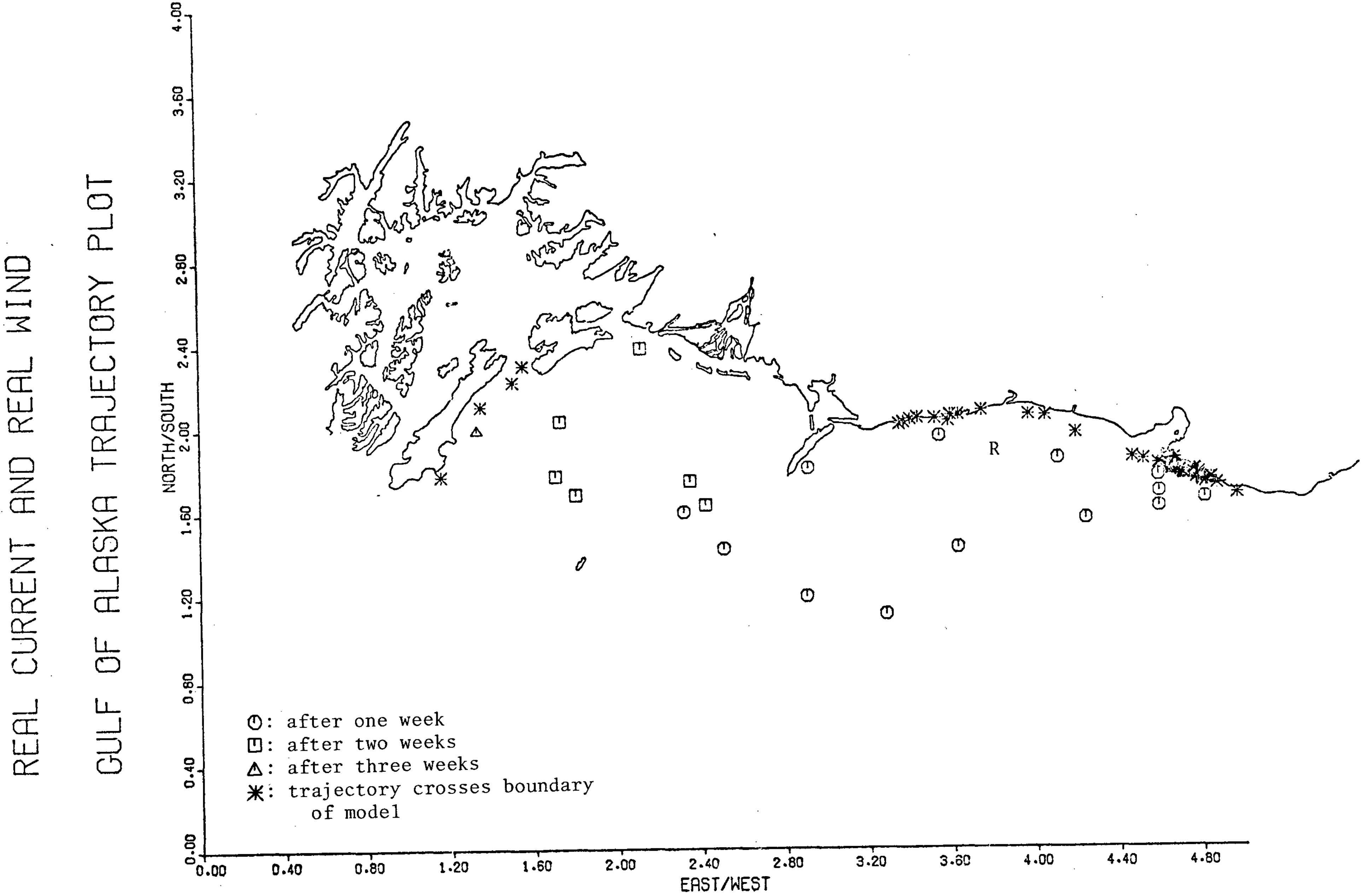


Fig. III-11Simulated surface particle trajectories in the NEGOA lease area and adjacent waters. "R" is the approximate release site (Galt, RU #140).

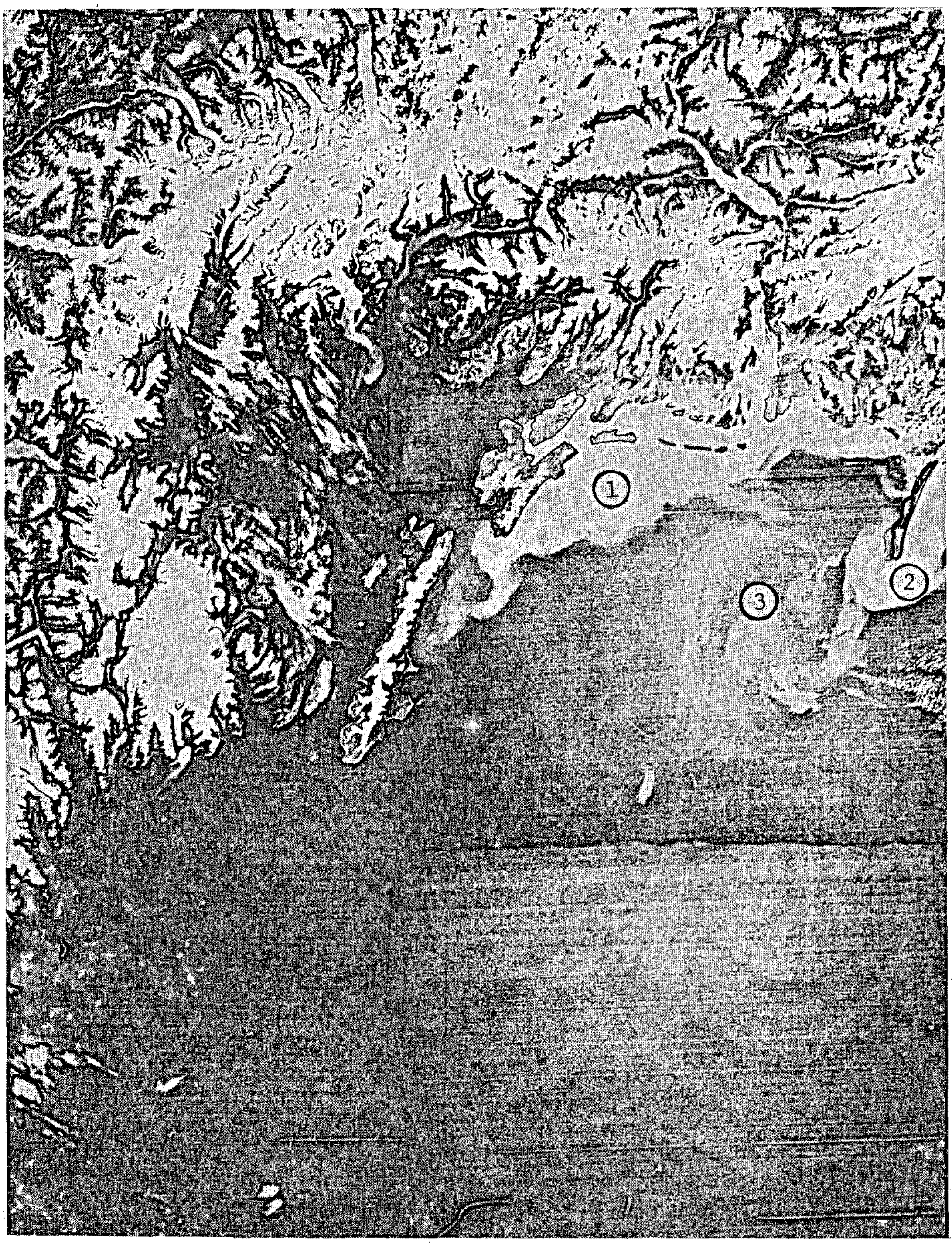


Fig. III-12. Distribution of sediment plumes as seen by composite of ERTS images acquired on August 14-16, 1973 (Muench and Schmidt 1975). See text for additional explanation.

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.

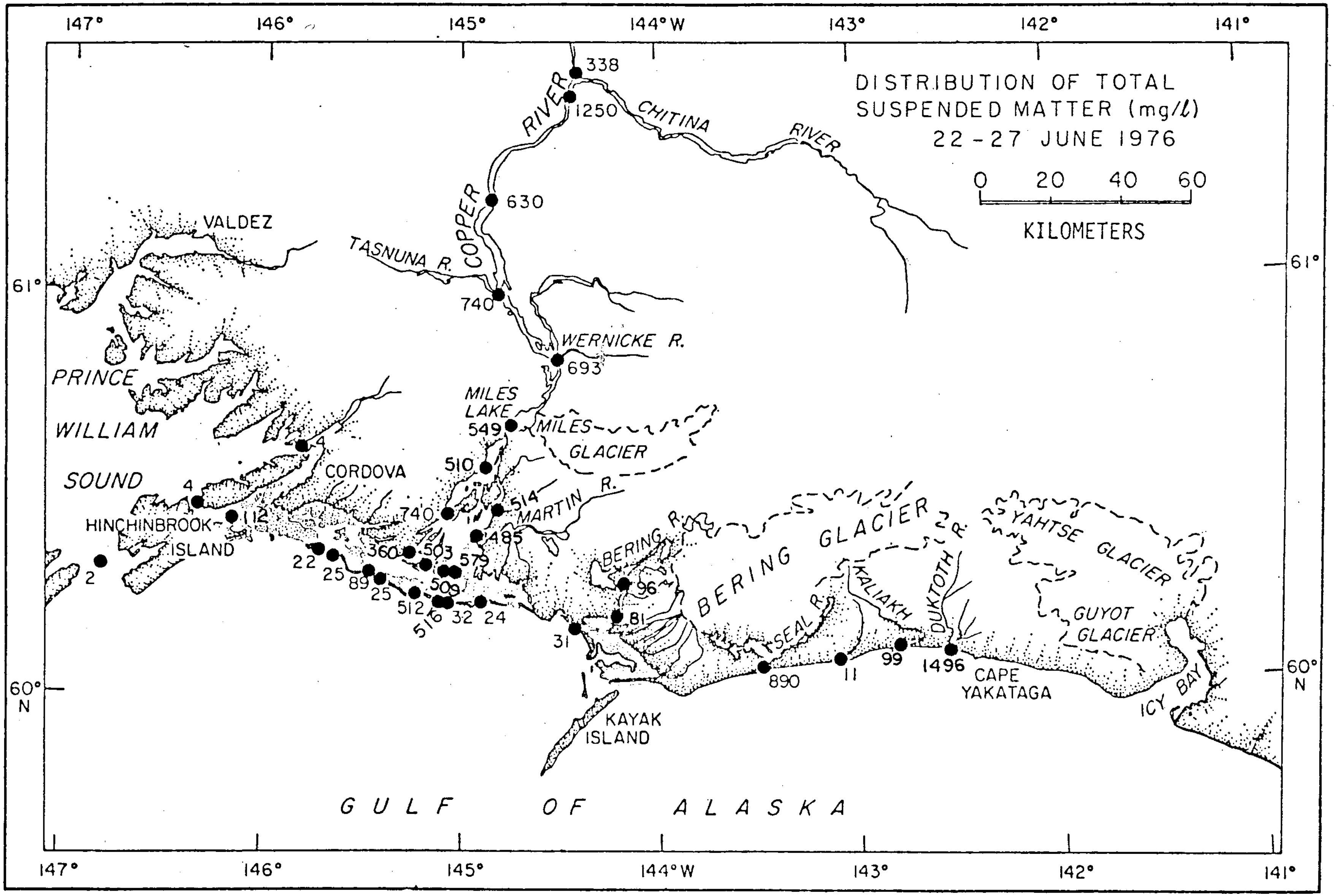


Fig. III-13 Distribution of total suspended matter at the surface in the major rivers draining into the Northeastern Gulf of Alaska (22-27 June, 1976) (Feely and Cline, RU #152, 1976).

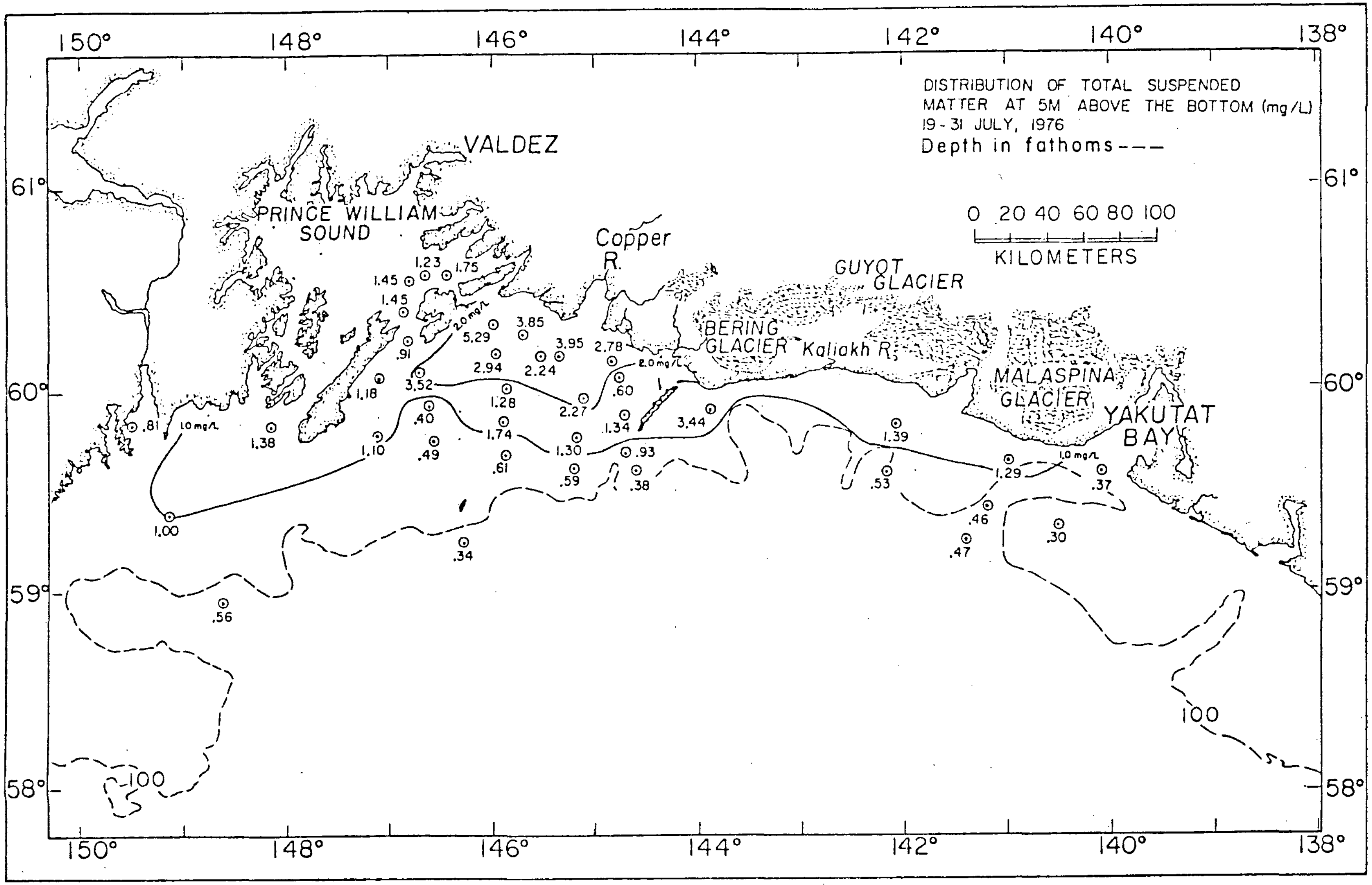


Fig. III-14. Distribution of total suspended matter at 5 m above the bottom in the Northeastern Gulf of Alaska (19-31 July, 1976) (Feely and Cline, RU #152, 1976).

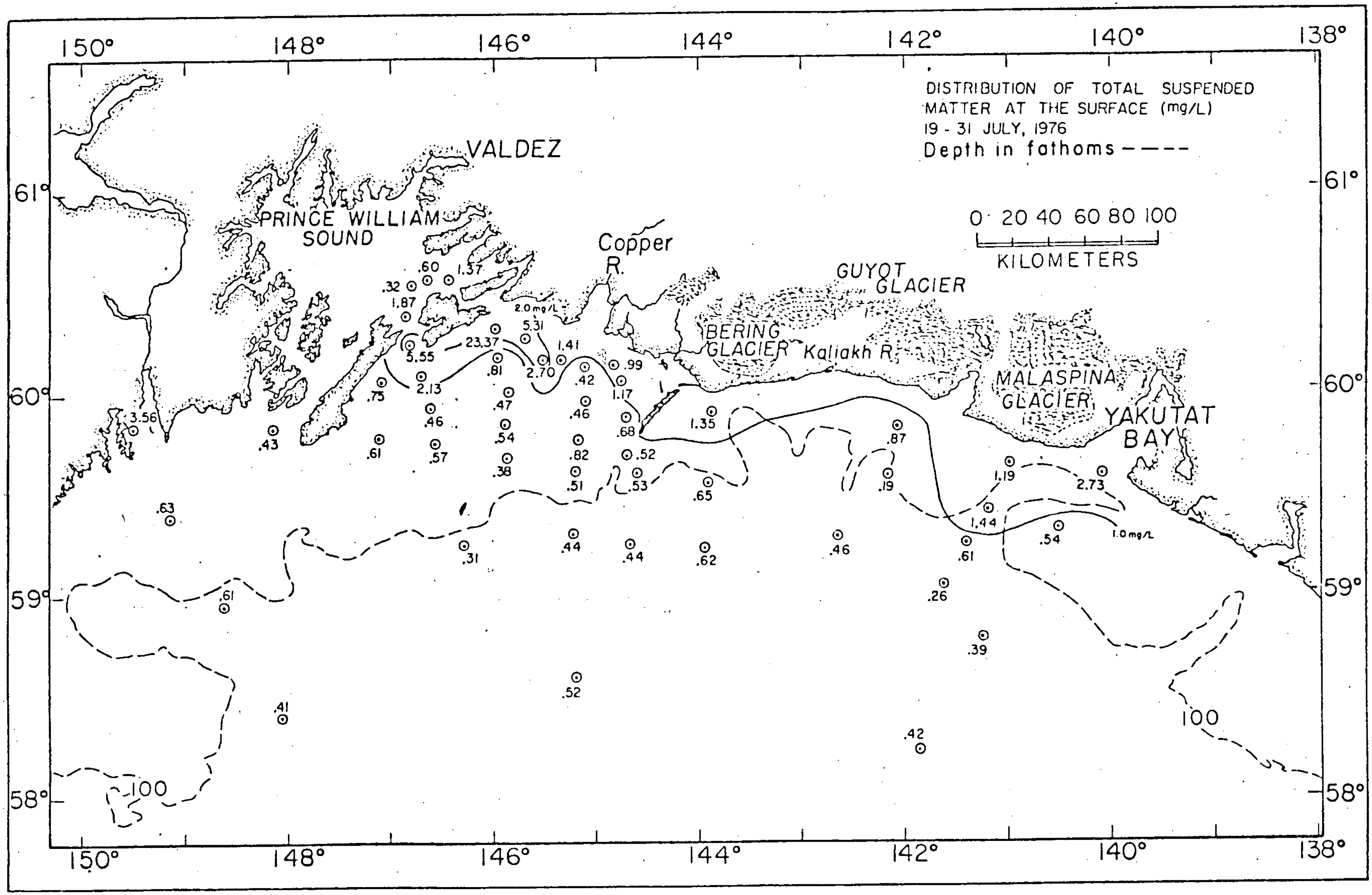


Fig. III-15. Distribution of total suspended matter at the surface in the Northeastern Gulf of Alaska (19-31 July, 1976) (Feely and Cline, RU #152, 1976).

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 x 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

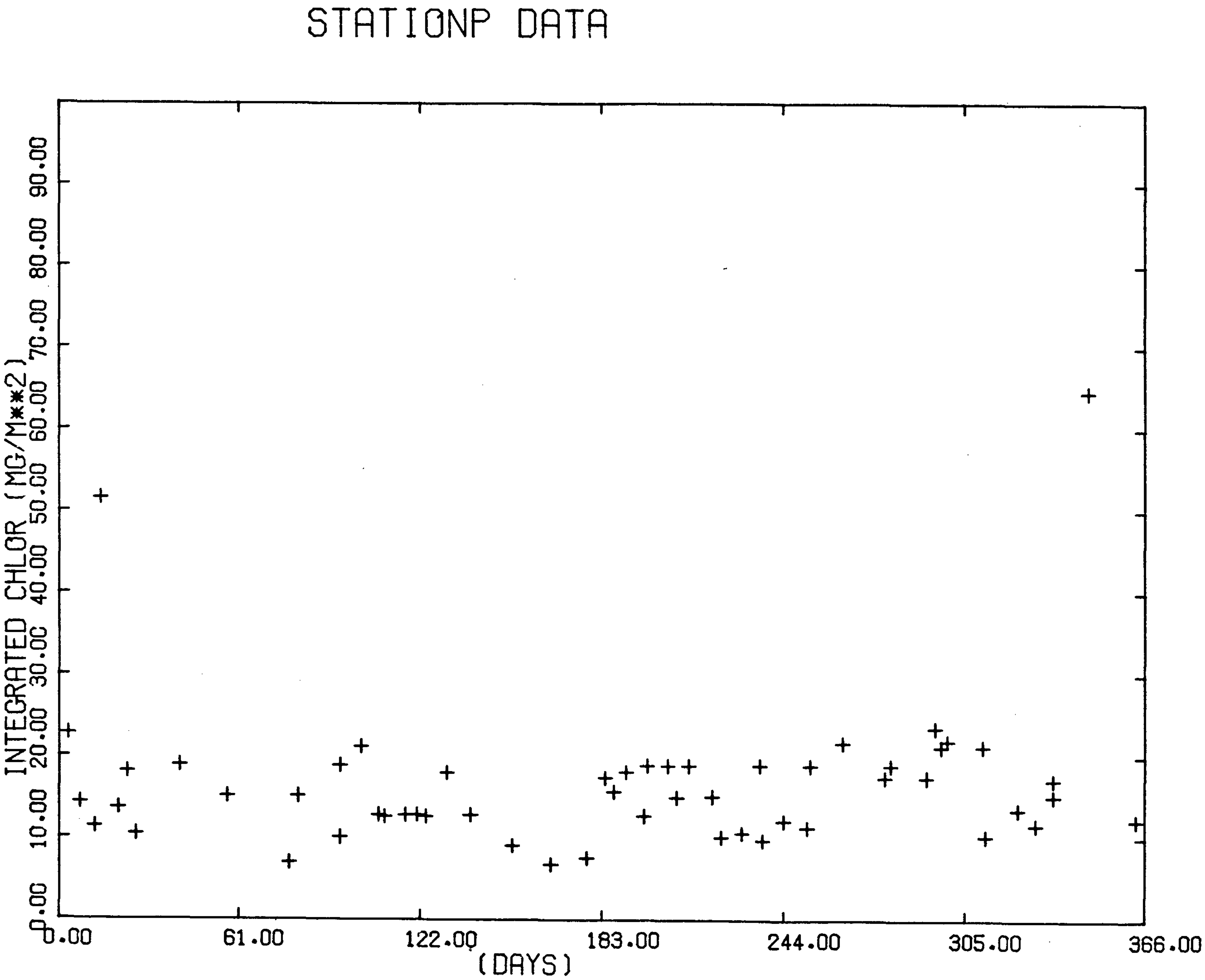


Fig. III-16. Observed chlorophyll *a* concentration at Station PAPA, 1959-1967 (Anderson and Lam, RU #58, 1976).

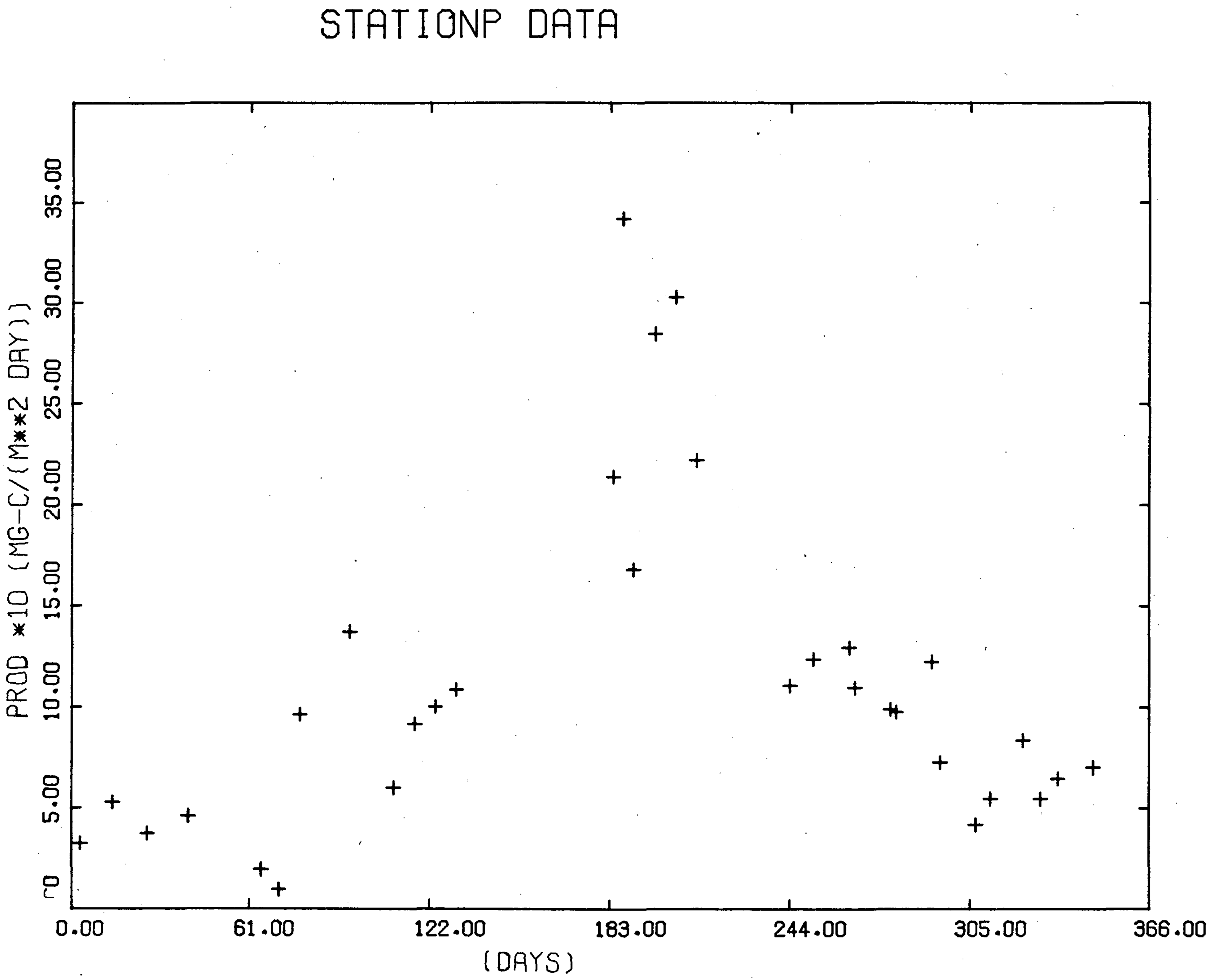


Fig. III-17. Observed primary productivity data at Station PAPA, 1961-1963 (Anderson and Lam, RU #58, 1976).

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 homata* (chaetognath), *Calanus cristatus*, *Calanus pacificus*, *Eucalanus bungii bungii* (copepods), and *Euphausia pacifica* (euphausiid)

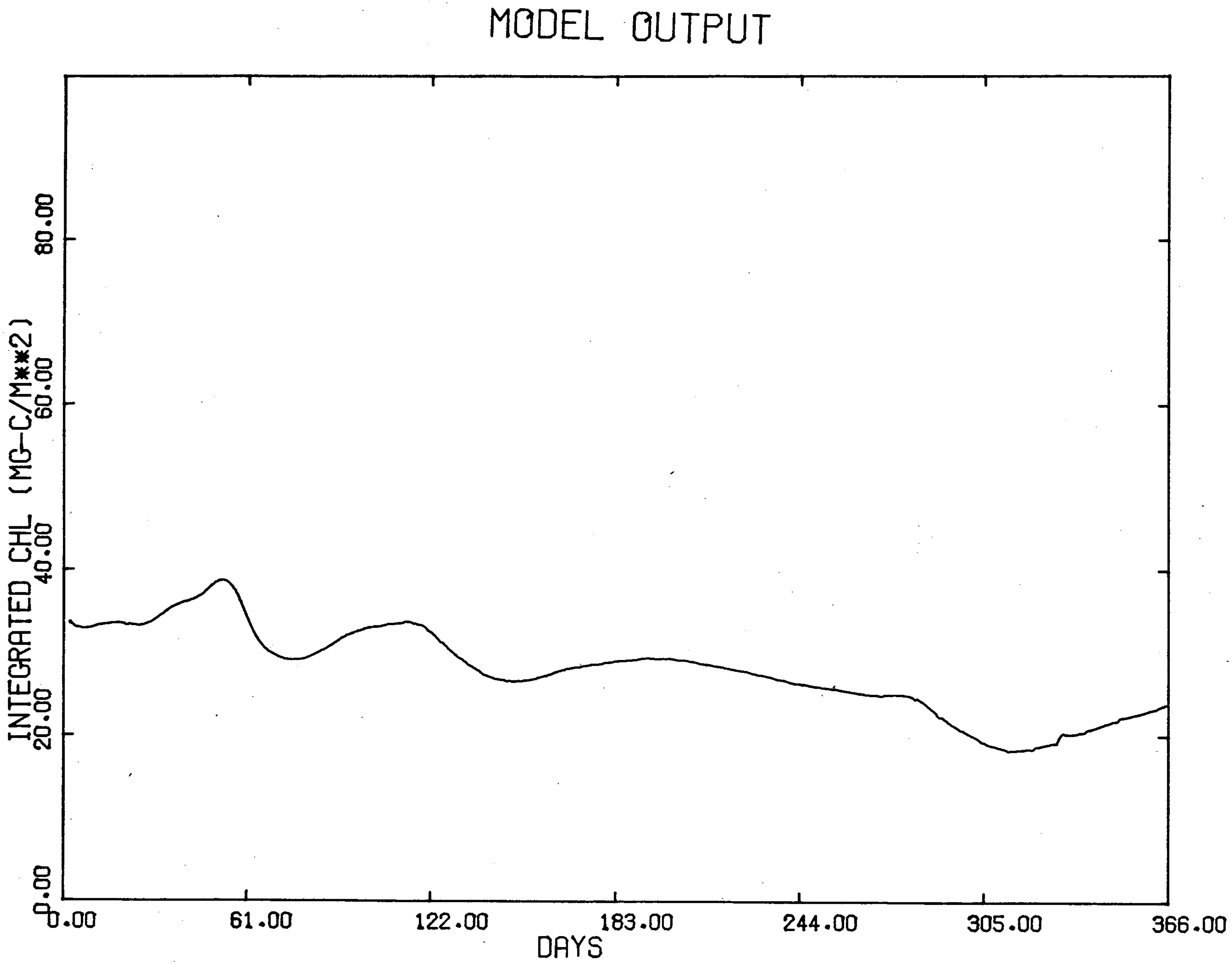


Fig. III-18. Simulated seasonal profile of chlorophyll *a* concentration at Station PAPA (Anderson and Lam, RU #58, 1976).

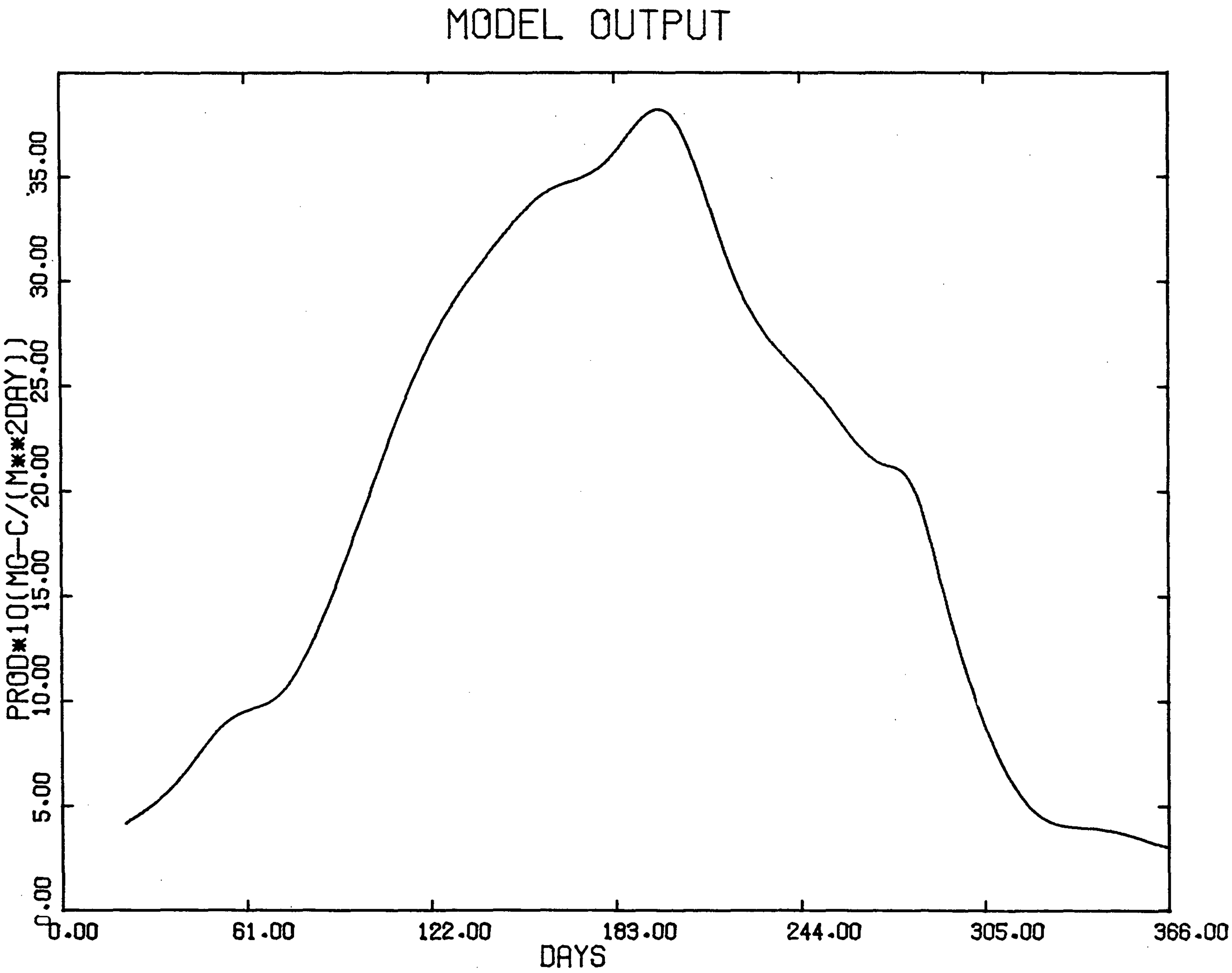


Fig. III-19. Simulated seasonal profile of primary productivity at Station PAPA (Anderson and Lam, RU #58, 1976).

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)	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

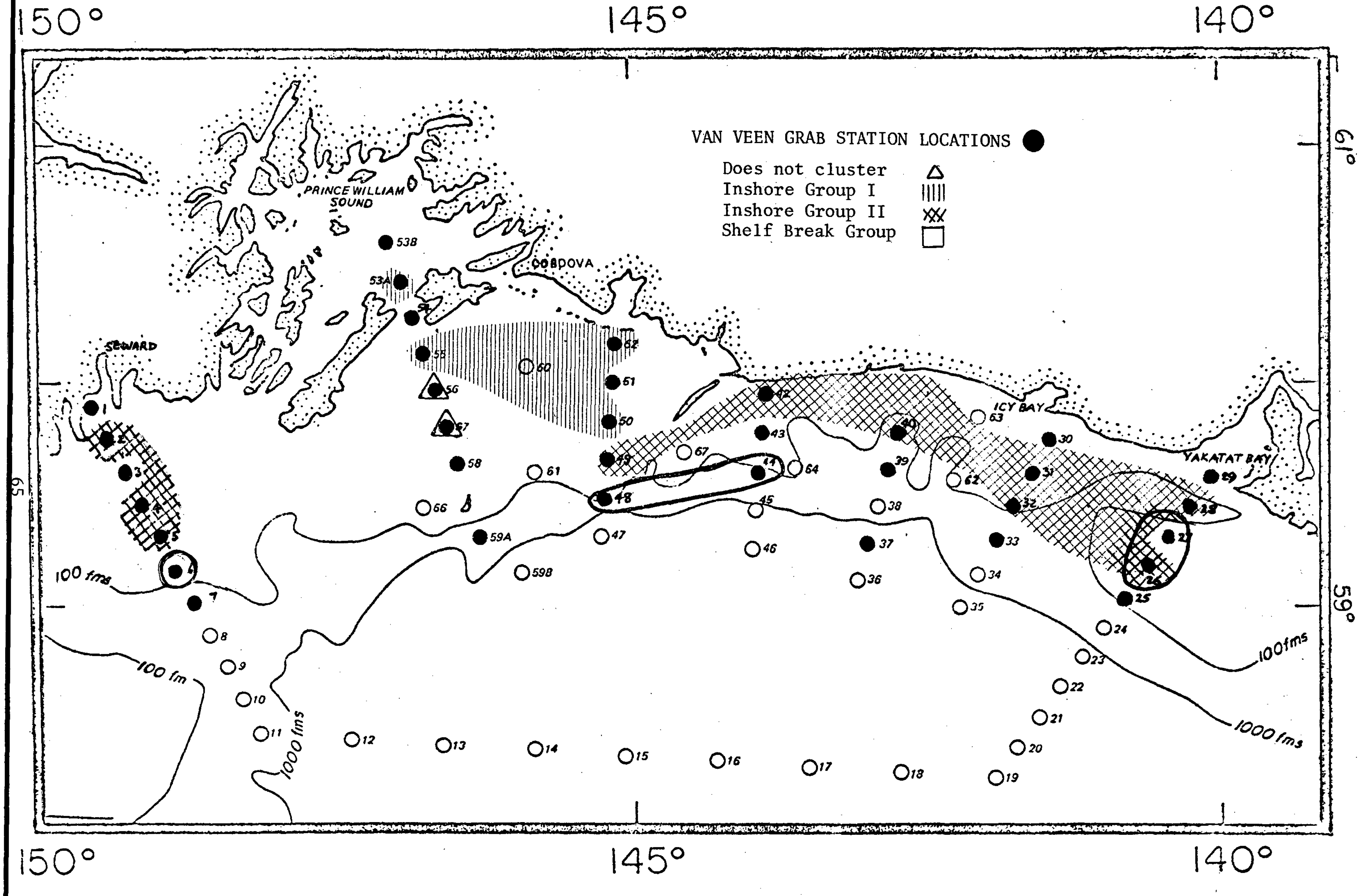


Fig.III-20. Station groups formed by cluster analysis of quantitative stations using the number of individuals/m^2. Only major station clusters are shown (Feder, Univ. Alaska, Fairbanks, unpublished data).

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.

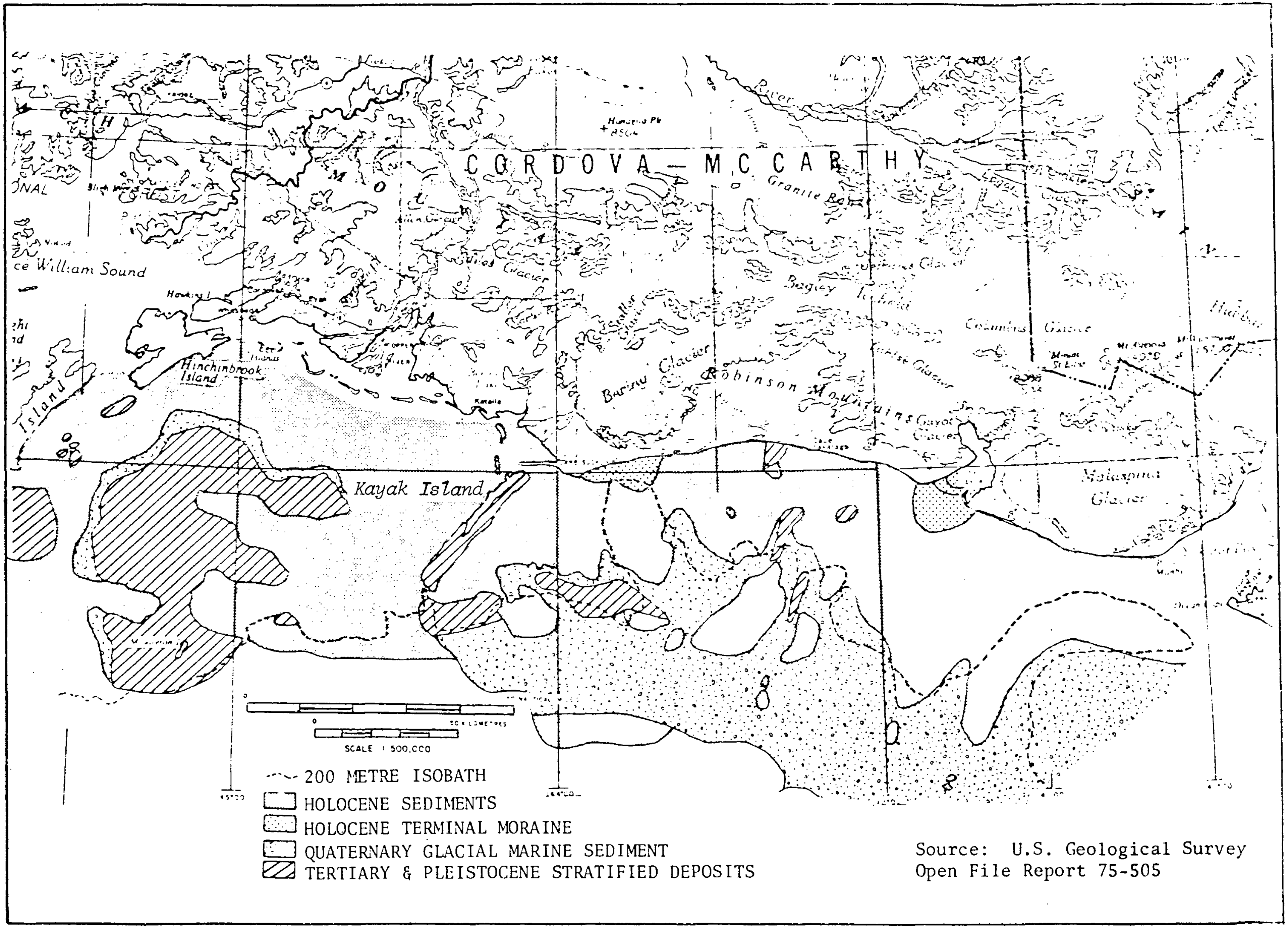
Benthic Epifauna. Of the 168 species of epibenthic invertebrates collected by Feder and others from the Northeast Gulf of Alaska, molluscs, crustaceans, and echinoderms accounted for 47, 42, and 36 species, respectively (Table III-9).

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	71.4%	*Chionoecetes bairdi*	454 g		92.6	66.2
(42 species)		*Pandalus borealis*	8 g		4.0	2.9
		Lopholithodes foraminatus	420 g		0.6	0.4
				Subtotal	97.2	69.5
Echinodermata	19.0%	*Ophiura sarsi*	6 g		23.2	4.4
(36 species)		*Ctenodiscus crispatus*	10 g		15.7	2.9
		Cucumariidae	400 g		15.0	2.8
				Subtotal	53.9	10.1
Mollusca	4.6%	*Patinopecten caurinus*	350 g		43.4	2.0
(47 species)		*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

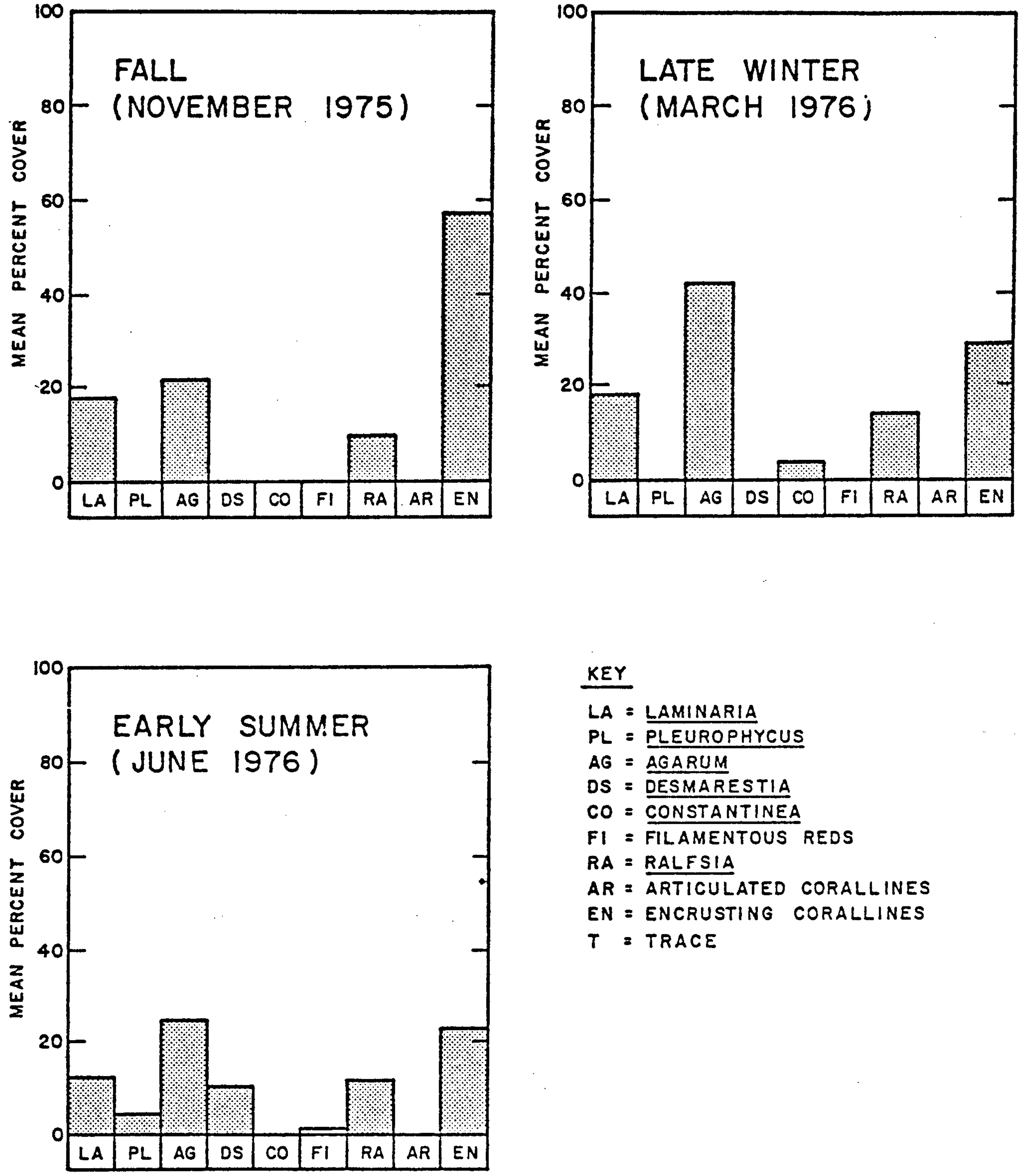


Fig. III-22. ALGAL COVER AT ZAIKOF BAY (Dames and Moore 1976).

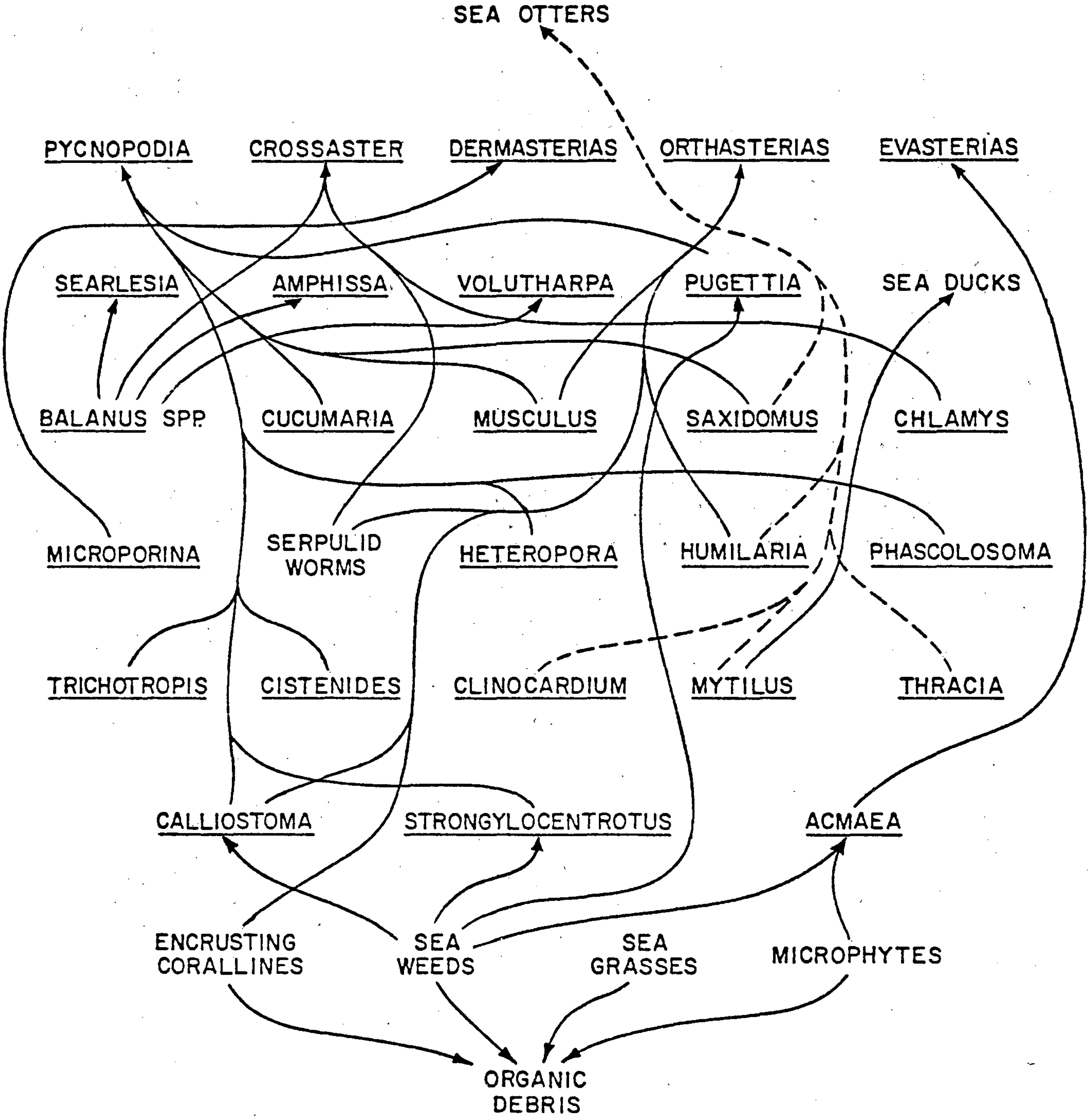


Fig. III-23. FOOD WEB FOR THE CONSPICUOUS SPECIES IN THE SHALLOW SUBLITTORAL ZONE AT ZAIKOF BAY, MONTAGUE ISLAND (Dames and Moore 1976).

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.

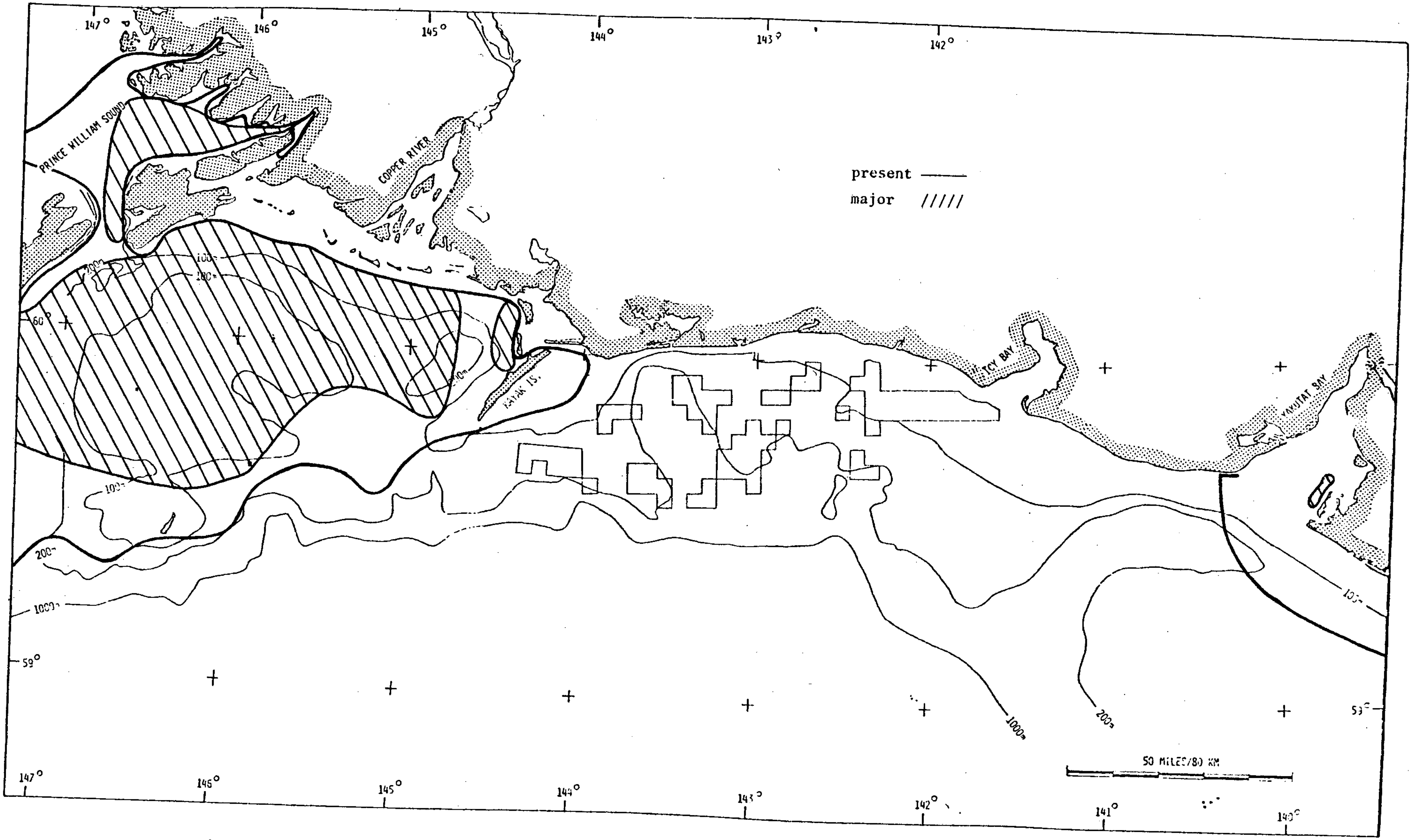


Fig. III-24. Tanner crab fishing areas (ADF&G 1975)

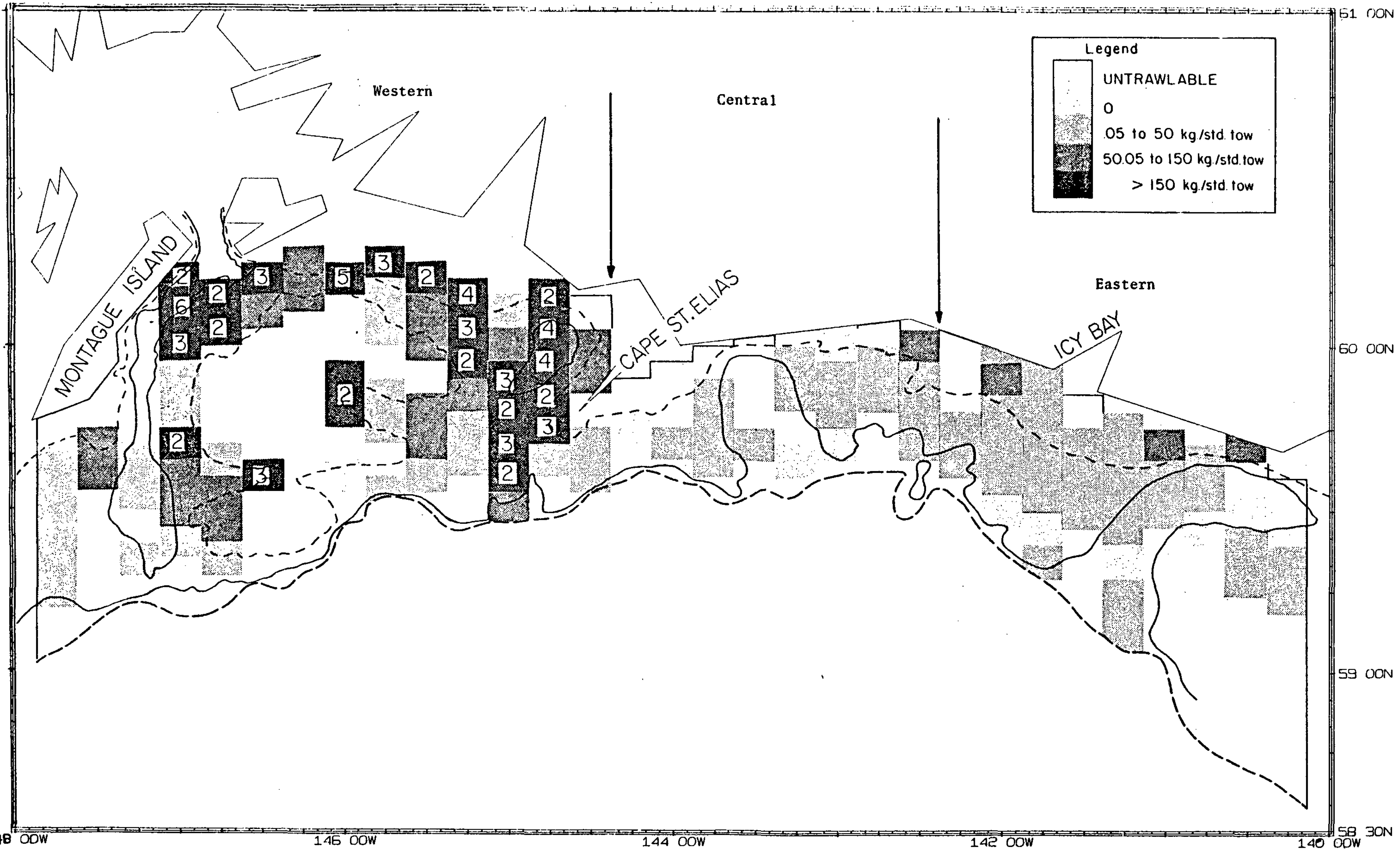


Fig. 111-25. Distribution and relative abundance of Tanner crab (*Chinoecetes bairdi*) May-August 1975 (Ronholt *et al.*, 1976).

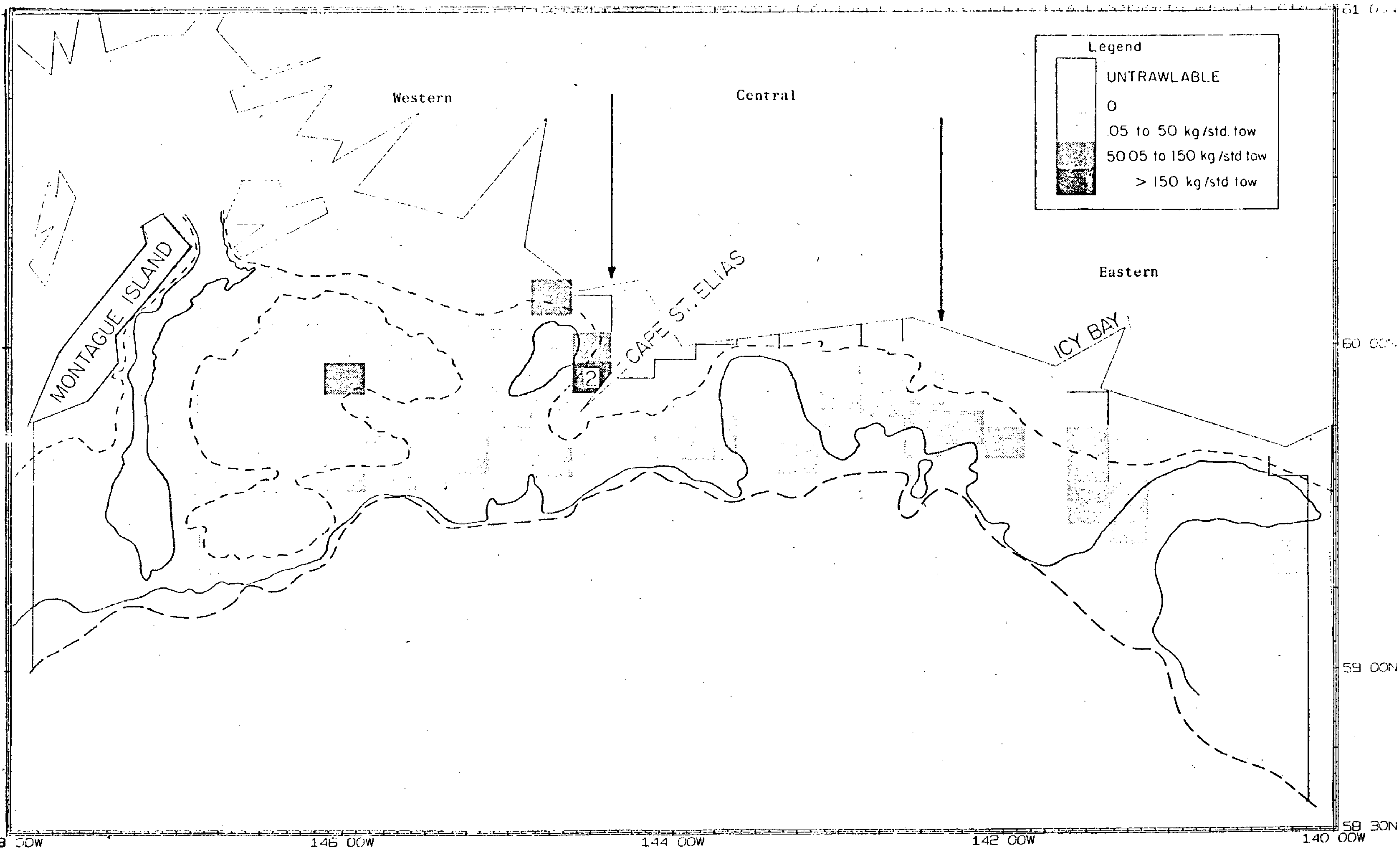


Fig. 111-26. Distribution and relative abundance of Pink shrimp (*Pandulus borealis*) May-August 1975 (Ronholt *et al.*, 1976).

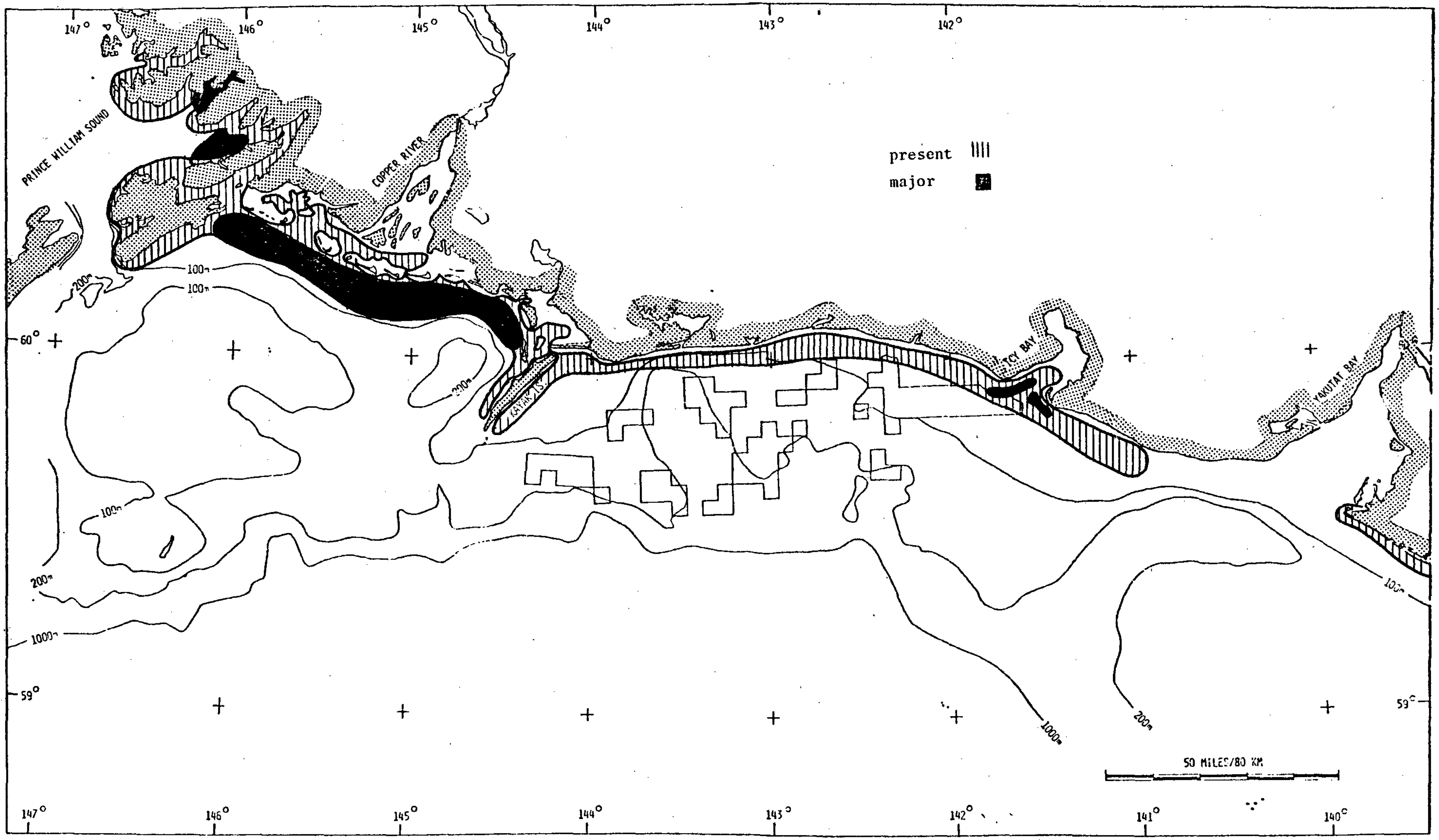


Fig. III-27. Dungeness crab fishing areas (ADF&G 1975).

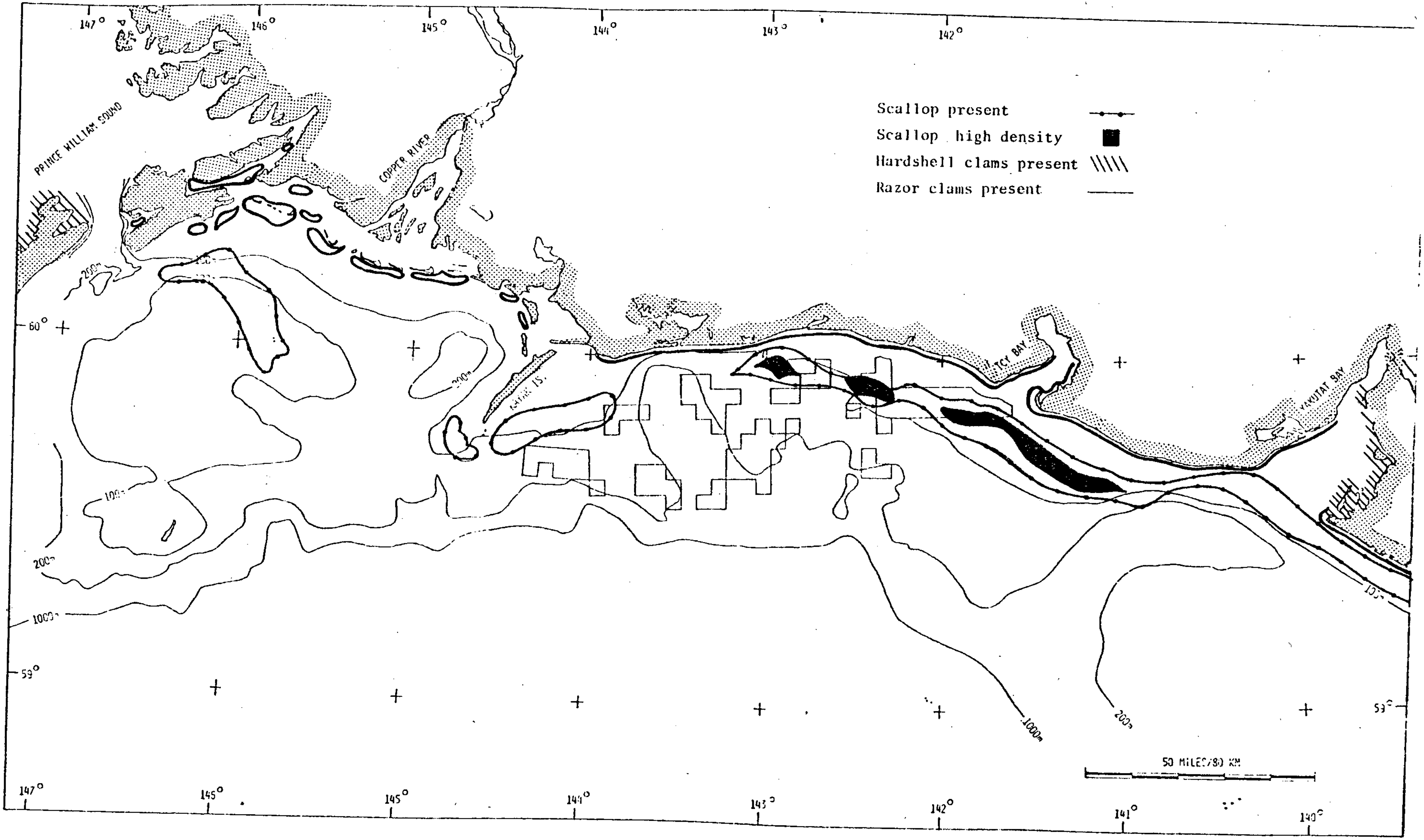


Fig. III-28. Commercial shellfish distributions (ADF&G 1975).

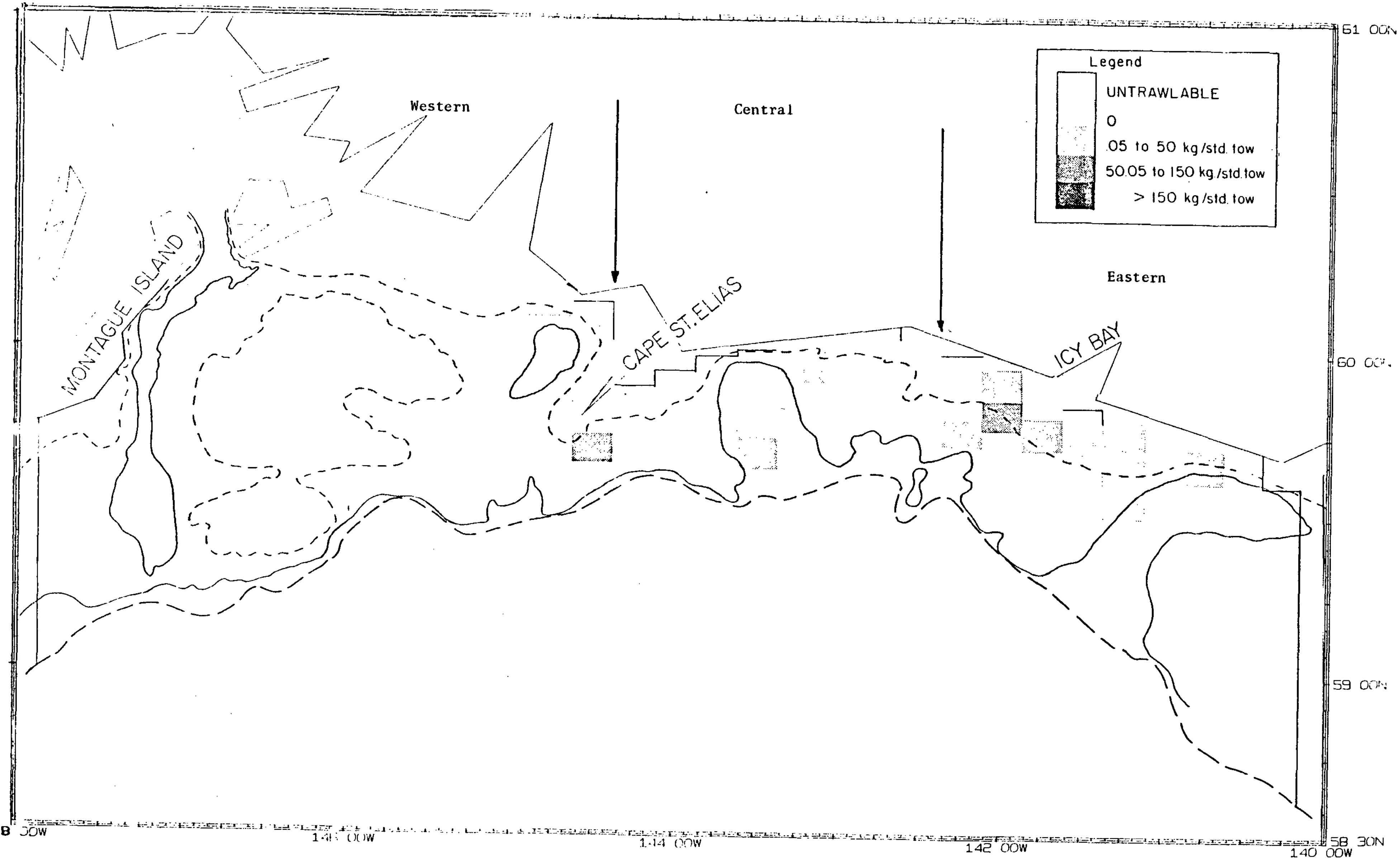


Fig. III-29. Distribution and relative abundance of Weathervane scallop (*Patinopecten caurinus*) May-August 1975 (Ronholt et al., 1976).

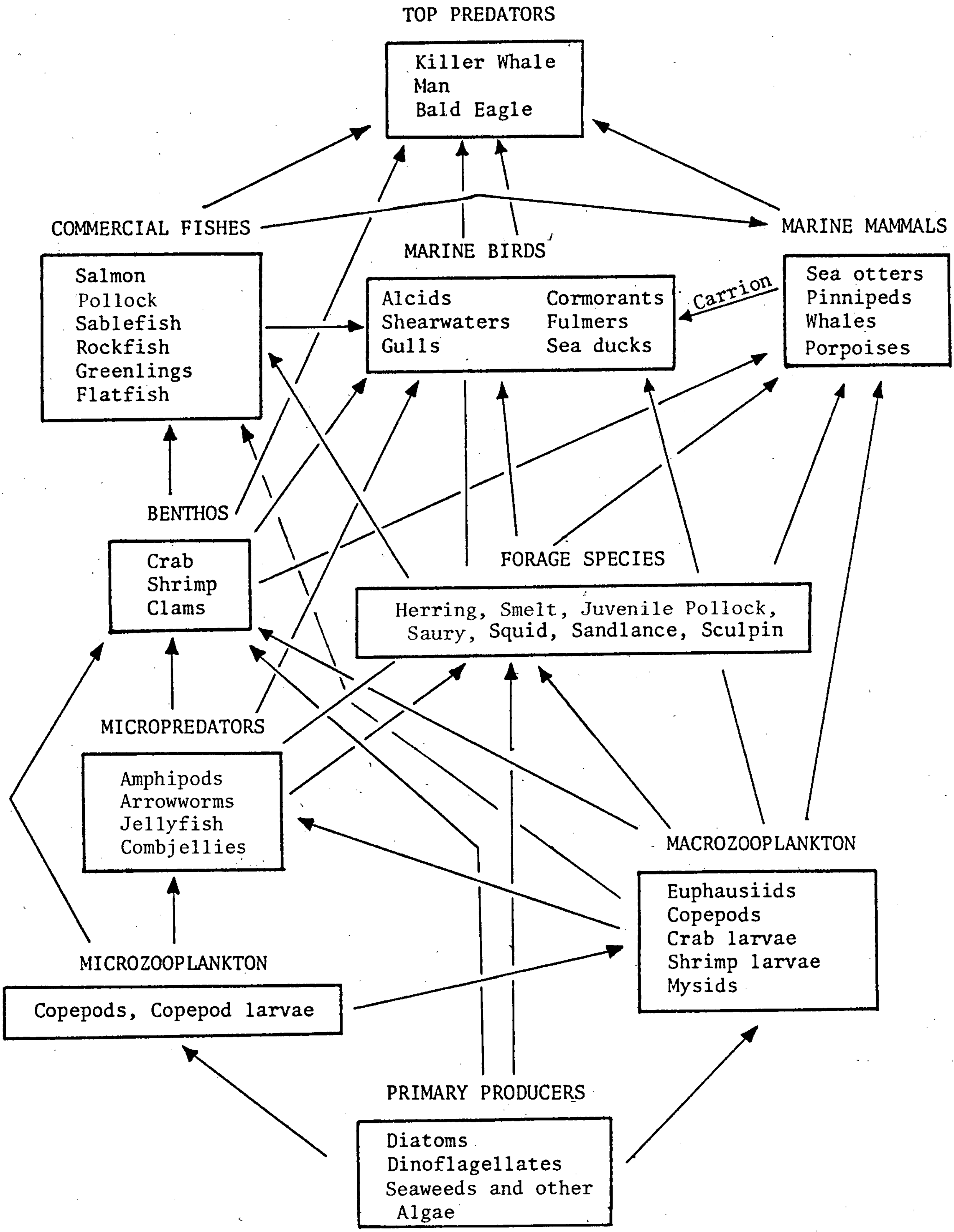


Fig. 111-30. Generalized Food Web for NEGOA, based largely on a diagram of the planktonic food web, provided by T. Cooney.

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*.

	SEASON			
Species	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

---

*(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

---

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

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

TABLE III-16

Ecology and Probable Oil Interactions -- NEGOA Fisheries

Species or Biota Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Area Use by Biotic Group	Potential Oil Biota Interaction
Salmonidae (Adults)					
Sockeye	Congregate in Estuaries	Nearshore; Anadromous Streams with Lakes; Copper River Delta; Bering River	Mid May - Early September	Spawning migration	Behavioral; Block access to spawning streams
Pink	Congregate in Estuaries	Nearshore; Anadromous Streams; Intertidal; Prince William Sound; Yakutat Bay	Late June - Early September odd years	Spawning; spawning migration	Behavioral; Block access to spawning areas; Toxic to spawn
Chum	Congregate in Estuaries	Nearshore; Anadromous Streams; Intertidal; Prince William Sound	Early June - Late September	Spawning; spawning migration	Behavioral; Block access to spawning areas; Toxic to spawn
Coho	Congregate in Estuaries	Nearshore; Anadromous Streams; Cape Suckling to Icy Cape; Bering River	Late June - Late September	Spawning migration	Behavioral; Block access to spawning areas
	Pelagic, surface	Throughout NEGOA	Winter, Spring	Feeding	Deplete food source; Behavioral; Ingestion
Chinook	Congregate in Estuaries	Nearshore; Anadromous Streams; Copper River Delta	Mid May - Late August	Spawning migration	Behavioral; Block access to spawning streams
	Pelagic	Surface; Prince William Sound; Yakutat Bay	Winter, Spring	Feeding	Deplete food source; Behavioral; Ingestion
Steelhead	Congregate in Estuaries	Nearshore; Anadromous Streams; Copper River Delta; Yakutat Region	Spring and Fall	Spawning migration	Behavioral; Block access to spawning stream
	Estuaries	Nearshore	Fall and Early Winter	Feeding; overwintering	Additional stress on spent spawners; Ingestion
Dolly Varden	Congregate in Estuaries	Nearshore; All Anadromous Streams	Late June - October and Early Winter	Spawning migration	Behavioral; Block access to spawning streams
				Feeding; Migration to overwintering streams	Block access to overwintering streams with lakes; Added stress to spent spawners; Ingestion
Commercial Fisheries	Offshore	Yakutat; Yakutat Bay	Late July - Late September	Commercial harvest	Taint catch; Foul gear
	Nearshore, estuaries	Yakutat; Copper River Delta; Prince William Sound; Yakataga	Early June - Late September	Commercial harvest	Taint catch; Foul nets
Sport Fisheries	Nearshore, estuaries	Yakutat; Cordova; Prince William Sound	Spring, Summer, Fall	Sport catch; Recreation	Loss of aesthetic appeal; Taint catch

TABLE III-16 (continued)

Species or Biota Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Area Use by Biotic Group	Potential Oil Biota Interaction
Salmonidae (Juveniles)					
Sockeye	Enter estuary	Nearshore; Surface; Copper River Delta; Bering River; Entrances to Prince William Sound	Early June - Early July	Smolting; Feeding	Toxicity, Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along the Continental Shelf; Surface	Early August - Early Fall	Outmigration; Feeding	Toxicity, Behavioral; Ingestion
Pink	Enter estuary	Nearshore; Surface; Prince William Sound; Entrances to Prince William Sound; Yakutat Bay	Early June - Mid July	Smolting; Feeding	Toxicity, Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along the Continental Shelf; Surface	Early August - Late September	Outmigration; Feeding	Toxicity; Behavioral; Ingestion
Chum	Enter estuary	Nearshore; Surface; Prince William Sound; Entrances to Prince William Sound	Early June - Mid July	Smolting; Feeding	Toxicity, Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along the Continental Shelf; Surface.	Mid August - Late Fall	Outmigration; Feeding	Toxicity; Behavioral; Ingestion
Coho	Enter estuary	Nearshore; Surface; Cape Suckling to Icy Cape; Bering River; Entrances to Prince William Sound	Early June - Early August	Smolting; Feeding	Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along Continental Shelf; Surface	Late Summer - Early Winter	Outmigration; Feeding	Behavioral; Ingestion
Chinook	Enter estuary	Nearshore; Surface; Copper River Delta	Early June - Early August	Smolting; Feeding	Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along Continental Shelf; Surface	Late Summer - Early Winter	Outmigration; Feeding	Behavioral; Ingestion
Steelhead	Enter estuary	Nearshore; Surface	Early June - Mid July	Smolting; Feeding	Reduced food supply; Behavioral; Ingestion
	Seaward migration	North and West along Continental Shelf; Surface	Unknown	Outmigration; Feeding	Behavioral; Ingestion
Dolly Varden	Enter estuary	Nearshore; Surface	Early April - Late June; September - October	Smolting; Seeking overwintering streams; Feeding	Toxicity, Reduced food supply; Behavioral; Block access to overwintering streams; Ingestion
Salmonidae (Eggs & Hatching)					
Pink	Intertidal	Prince William Sound; Yakutat Bay	July - May	Incubation; Hatching; Emergence	Smothering; Toxicity
Chum	Intertidal	Prince William Sound	July - May	Incubation; Hatching; Emergence	Smothering; Toxicity

TABLE III-16 (continued)

Species or Biota Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Area Use by Biotic Group	Potential Oil Biota Interaction
Clupeidae (Adults)					
Herring	Rocky beach	Intertidal; Shallow Subtidal; Prince William Sound; Copper River Delta	Mid May - Mid June	Spawning	Inhibit spawning; Toxic to spawn
	Benthic overwintering	Near Bottom; appx. 50 fathoms	Late Fall through Winter	Overwintering; No feeding	Behavioral
	Pelagic	Near Surface; Prince William Sound	Spring - Fall	Feeding	Reduced food supply; Food chain; Ingestion
Commercial Fisheries	Nearshore	Intertidal; Shallow Subtidal; Prince William Sound	Mid May - Mid June	Commercial harvest	Taint catch; Foul net
Clupeidae (Eggs & Larvae)					
Herring	Rocky beach	Intertidal; Shallow Subtidal; Prince William Sound; Copper River Delta	May - June	Incubation; Hatching	Toxicity; Smothering; Reduced hatch
	Nearshore	Nursery Intertidal; Shallow Subtidal; Prince William Sound; Copper River Delta	May - Late Fall	Feeding	Reduced food supply; Toxicity; Ingestion
Commercial Fisheries	Rocky beach	Intertidal; Shallow Subtidal; Prince William Sound	April - May	Commercial harvest	Render roe on kelp unpalatable
Clupeidae (Juveniles)					
Herring	Nearshore	Surface; Prince William Sound; Copper River Delta; Yakutat Bay	Fall, Winter, Spring, Summer	Feeding	Reduced food supply; Behavior; Toxicity; Ingestion
Anoplopomatidae					
Sablefish (eggs through post larvae)	Pelagic	Surface	Early Spring - Late May	Incubation; Hatching; Feeding	Toxicity; Reduced food supply; Ingestion
Trichodontidae					
Pacific sandfish (eggs)	Demersal	Sandy Bottom; Subtidal; Nearshore	Winter	Spawning; Incubation	Toxicity; Smothering spawn; Behavioral
Pacific sandfish (juveniles)	Demersal	Sandy bottom; Subtidal; Nearshore	Winter - Spring	Feeding	Toxicity; Behavioral; Reduced foody supply; Ingestion

TABLE III-16 (continued)

Species or Biota Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Area Use by Biotic Group	Potential Oil Biota Interaction
Carangidae					
Jack mackerel	Pelagic	Near Surface; Locates near 11°C Isotherm	Late Summer	Feeding	Ingestion
Scombridae					
Chub mackerel	Pelagic	Near Surface; Coastal areas	Occasional	Feeding	Ingestion
Hexagrammidae					
Atka mackerel	Demersal	10-20 m depths Nearshore; Rocky, swift current areas	Summer	Spawning	Toxicity; smothering spawn
Lingcod (adults)	Demersal	Rocky; Shallow Subtidal; Intertidal	December - March	Spawning	Toxic to spawn; Inhibit spawning
Lingcod (eggs)	Demersal	Rocky; Shallow Subtidal;	December - March	Incubation; Hatching	Behavior of male; Smothering; Toxicity
Lingcod (larvae)	Demersal	Rocky; Shallow Subtidal; Intertidal	January - Late June	Feeding	Toxicity; Reduced food supply; Ingestion
Scorpaenidae					
Pacific ocean perch	Demersal	Shelf break and slope; Yakutat Canyon	Year round	Spawning; Maturation; Feeding	Possible ingestion
Other rockfish	Demersal	Shelf break and slope; Yakutat Canyon	Year round	Spawning; Maturation; Feeding	Possible ingestion
Commercial Fishery	Offshore	Shelf break and slope;		Foreign Nationals	Taint catch

TABLE III-16 (continued)

Species or Biota Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Area Use by Biotic Group	Potential Oil Biota Interaction
Pleuronectidae					
English sole (adults)	Demersal	Nearshore	Winter	Spawning	Toxic to spawn; Behavioral
English sole (eggs & larvae)	Pelagic	Surface; Nearshore	Winter; Spring	Incubation; Feeding	Toxicity; reduced food supply; Ingestion
Petrale sole (adults)	Demersal	Move on to Continental Shelf after spawning	Spring, Summer	Feeding	Ingestion
Dover sole (adults)	Demersal	Move on to Continental Shelf after spawning	Spring, Summer	Feeding	Ingestion
Starry founder (adults)	Demersal	Nearshore; Yakutat	Winter	Spawning	Toxic to spawn
Starry flounder (eggs & larvae)	Pelagic	Near Surface; Yakutat	Winter, Spring	Incubation; Feeding	Toxicity; reduce food supply; Ingestion
Pacific halibut (adults)	Demersal	Near bottom; Near 200 m isobath; Bering Canyon; Kayak Gyre, West side of Yakutat Canyon	Winter	Spawning	Toxic to spawn; Behavioral
Commercial Fishery	Demersal	Yakutat Canyon; Cape Suckling; Icy Canyon	Fall, Winter, Spring, Summer	Commercial catch	Taint catch; Foul gear
Sport Fishery	Demersal	Yakutat Bay	Summer	Sport catch; recreation	Taint catch; Loss of aesthetic appeal
Osmeridae					
Capelin (adults)	Pelagic	Nearshore; Near Surface; Sandy beaches	Late Spring - Early Summer	Spawning	Toxicity; Toxic to spawn; Behavioral

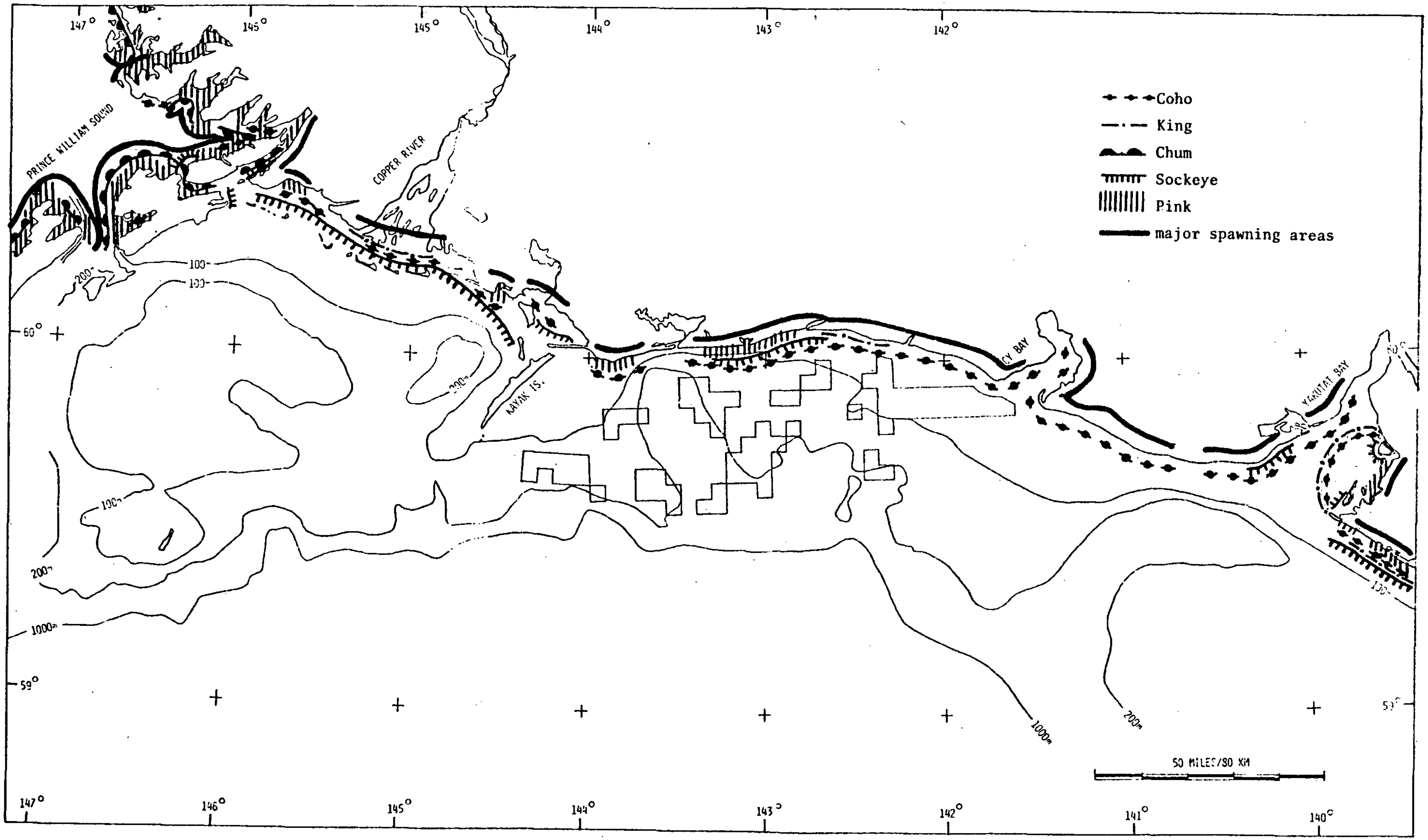


Fig. III-31. Salmon distribution (modified from ADF&G 1975).

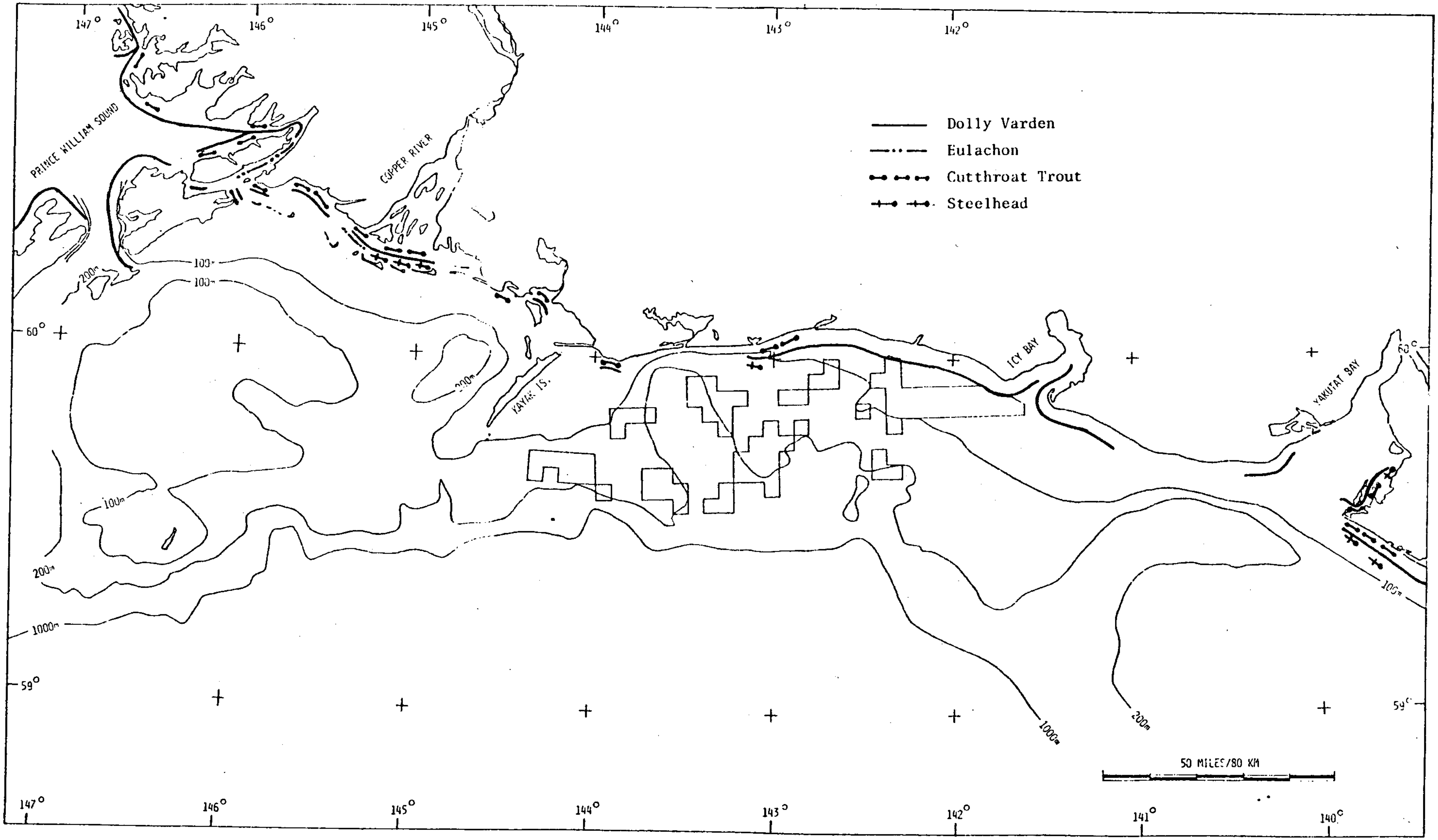


Fig. III-32. Sport fish distribution in the Gulf of Alaska (modified from ADF&G 1975).

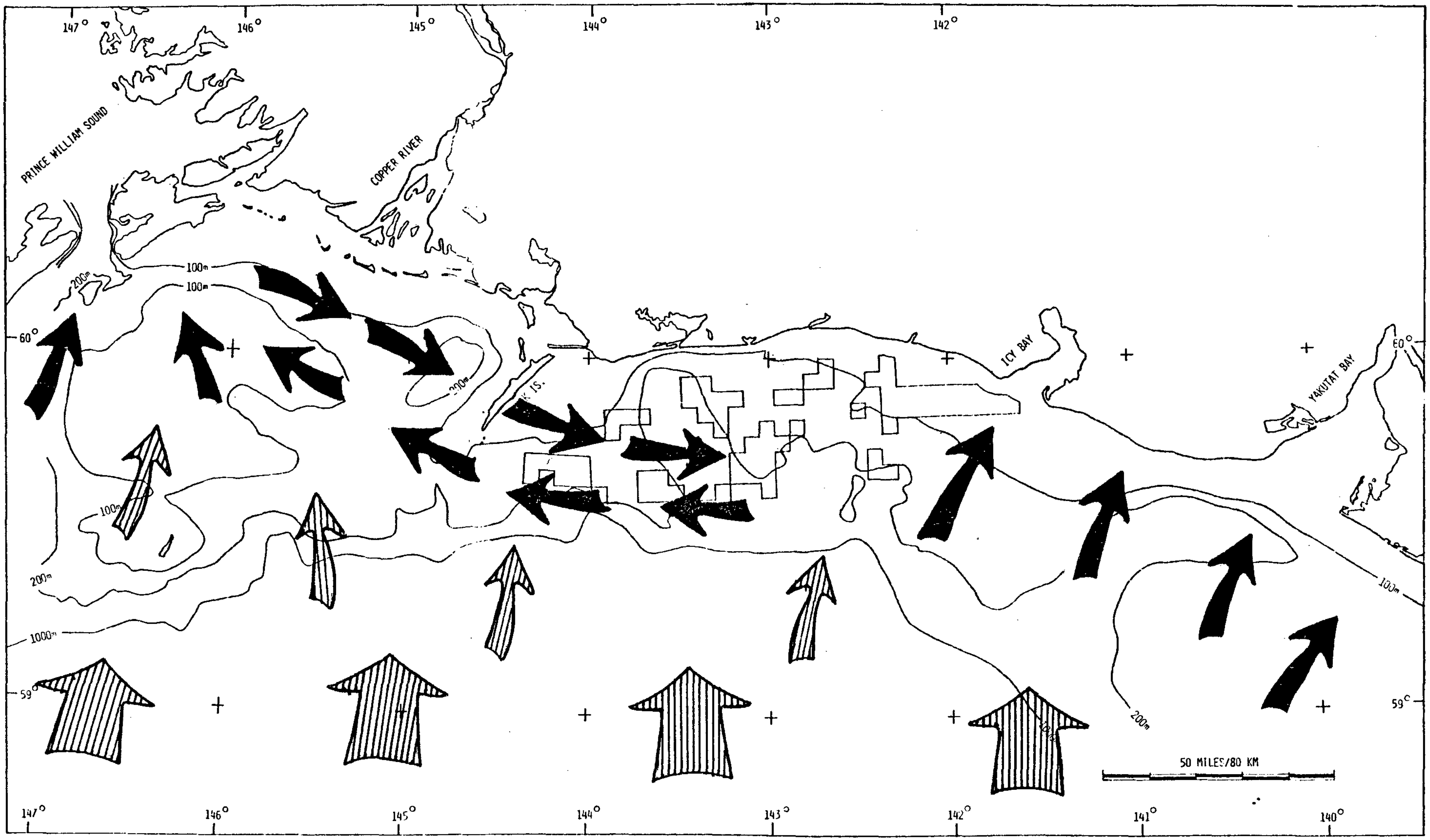


Fig. III-33. The general onshore migrations of adult salmon spawners (modified from Stern, Hartt and Rogers, RU #353, 1976).

as the Copper River Delta, or undertake to and fro movements along the coast before entering the spawning streams. Those spawners destined for streams in Prince William Sound usually enter the Sound through Montague Strait, Bainbridge Passage, and Elrington Strait.

Juvenile salmonids typically enter the estuarine nurseries during spring and summer. The young salmon remain in the estuaries several months before migrating to offshore maturation regions. In the NEGOA region, the juvenile salmonid migratory route is generally along the continental shelf, following the coast towards Kodiak (Fig. III-34) (Stern *et al.*, RU # 353, 1976; Royce *et al.*, 1968). Recruitment to the migration, which began in California, is greater than the loss to oceanic dispersal. Thus, in the NEGOA region the migration contains not only locally spawned juveniles but also those originating in streams far to the south. Royce *et al.* (1968) estimated that in 1964 three-quarters of a million salmon daily pass a given point of latitude off southeast Alaska during the peak of migration (30 to 60 days) (Table III-16). These migratory statistics are variable from year to year but the number of migrants should increase north and westward. The migratory characteristics, i.e., following the continental shelf and little dispersal to oceanic areas, result in higher concentrations of fish where the shelf narrows as in the region from Icy Bay to Cape Suckling.

The status of the salmon population has remained relatively stable during recent years. However, sockeye and even year pink stock have never fully recovered from the effects of the 1964 Alaska earthquake. The quake blocked access to or caused drainage of lake systems essential in the life history of sockeye. The most critical was the drainage of San Juan Lake on Montague Island. Even year pinks are primarily intertidal spawners and due to tectonic subsidence and uplift, many intertidal spawning areas are now inadequate, inaccessible or no longer in existence. New areas created by tectonic uplift have not adequately developed to provide replacement sites and the even year run remains severely depressed.

Data on salmonid habitat preference, areas of peak occurrence, seasonality, area use, and potential oil interactions are listed in Table III-16.

Smelt and herring abundance, migrations, and distributions are poorly defined in the NEGOA lease area (ADF&G 1975; Paul Macy. Unpublished

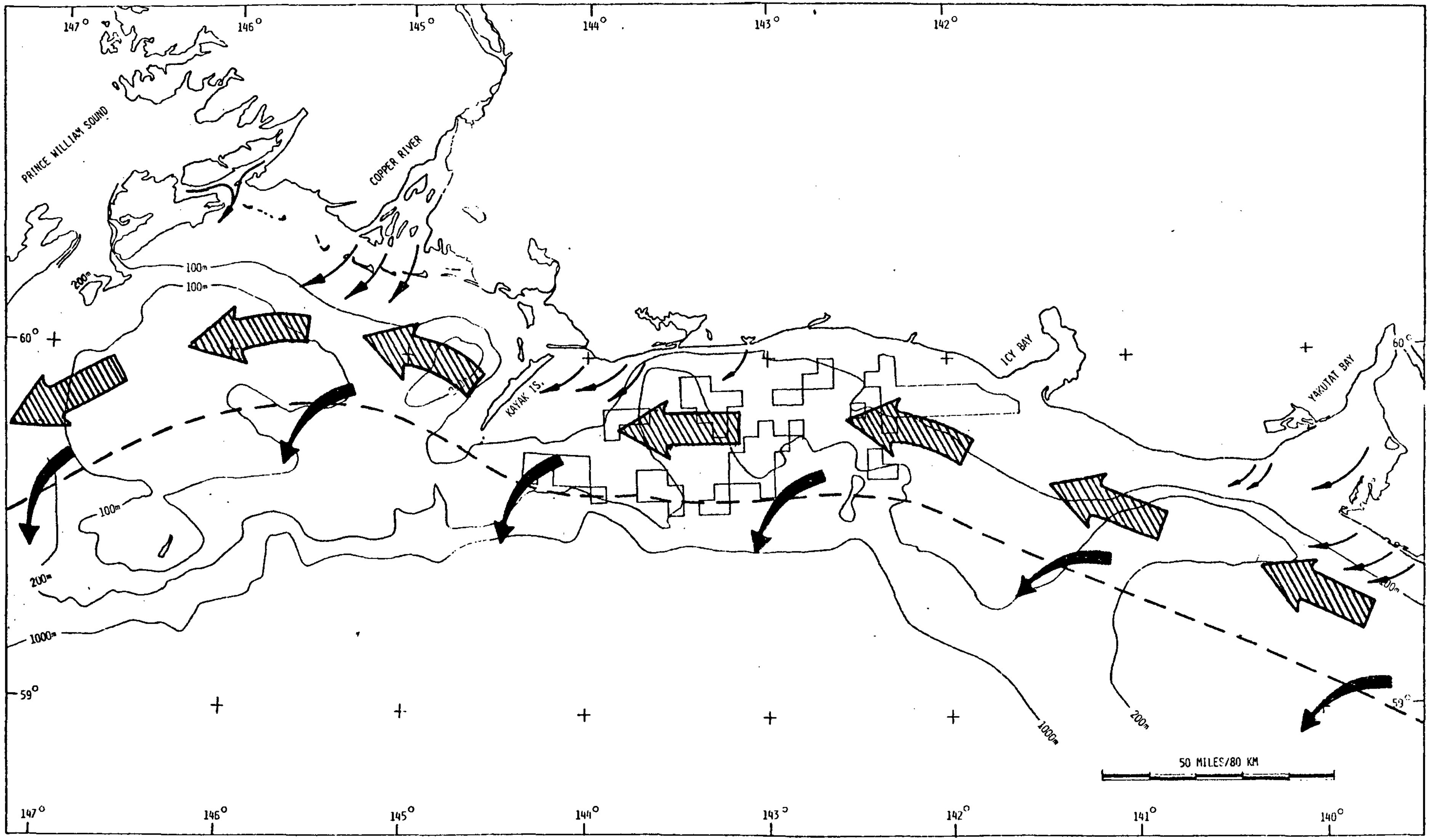


Fig. III-34. The general migratory pathways of juvenile salmonids in the Northeast Gulf of Alaska (modified from Stern, Hartt and Rogers, RU #353, 1976).

Data. NMFS/NWAFC, Seattle, Wa. 1977). Spawning preferences would appear to segregate surf smelt, rainbow smelt, and capelin to the coastal region from Cape Suckling to Point Manby. Herring prefer the rocky beaches typical of the fiords of Prince William Sound (Fig. III-35). Spawning habitats essential to smelt and herring are found in the Yakutat area. The Copper River Delta region has mostly mud flats which are less desirable to these spawners. Herring do spawn on some of the river islands and outer barrier islands. Other anadromous smelt species; i.e., pond smelt, eulachon, and longfin smelt, spawn in the numerous streams throughout NEGOA and Prince William Sound.

The timing of spawning, habitat preferences, areas of peak occurrence, and oil interaction of some of these forage species are listed in Tables III-14, III-15, and III-16. These data are limited, and the distribution may range throughout the NEGOA region.

Data on juvenile forage species (smelt and herring) are even more limited than for the spawning adults. Juvenile herring seldom occur offshore; however, maturing fish overwinter near the bottom (50 fathoms, 90 m) in dense schools. Juveniles form dense feeding schools after hatching and remain nearshore until fall when most move into deeper water.

Other more resident species in the lease area include those belonging to the families Cottidae, Gadidae, Hexagrammidae, Pleuronectidae, Scorpaenidae, Stichaeidae, and Zoarcidae. Of all the species in these families, only Pacific halibut and some sablefish are known to undertake extensive migrations (Hart 1973). Other species generally move up and down the shelf seasonally; some also move laterally along the slope and shelf (Paul Macy. Unpublished Data. NMFS/NWAFC, Seattle, Wa. 1977; Hart 1973; Alverson 1960; Edson 1954; Phillips and Imamura 1954; Holmberg and Jones 1954). Starry flounder, rock sole, English sole, Pacific sandfish, and lingcod migrate to shallow waters in winter for spawning. Spent spawners return to deeper waters, except lingcod. Behavioral characteristics of lingcod require the male to maintain and defend the nest until the eggs hatch. Petrale sole, Dover sole, Pacific cod, and sablefish spawn in deep waters but in spring move into the shallow zones of the shelf to feed. English sole and Petrale sole, which winter in British Columbia and Southeast Alaska, migrate north during the summer months.

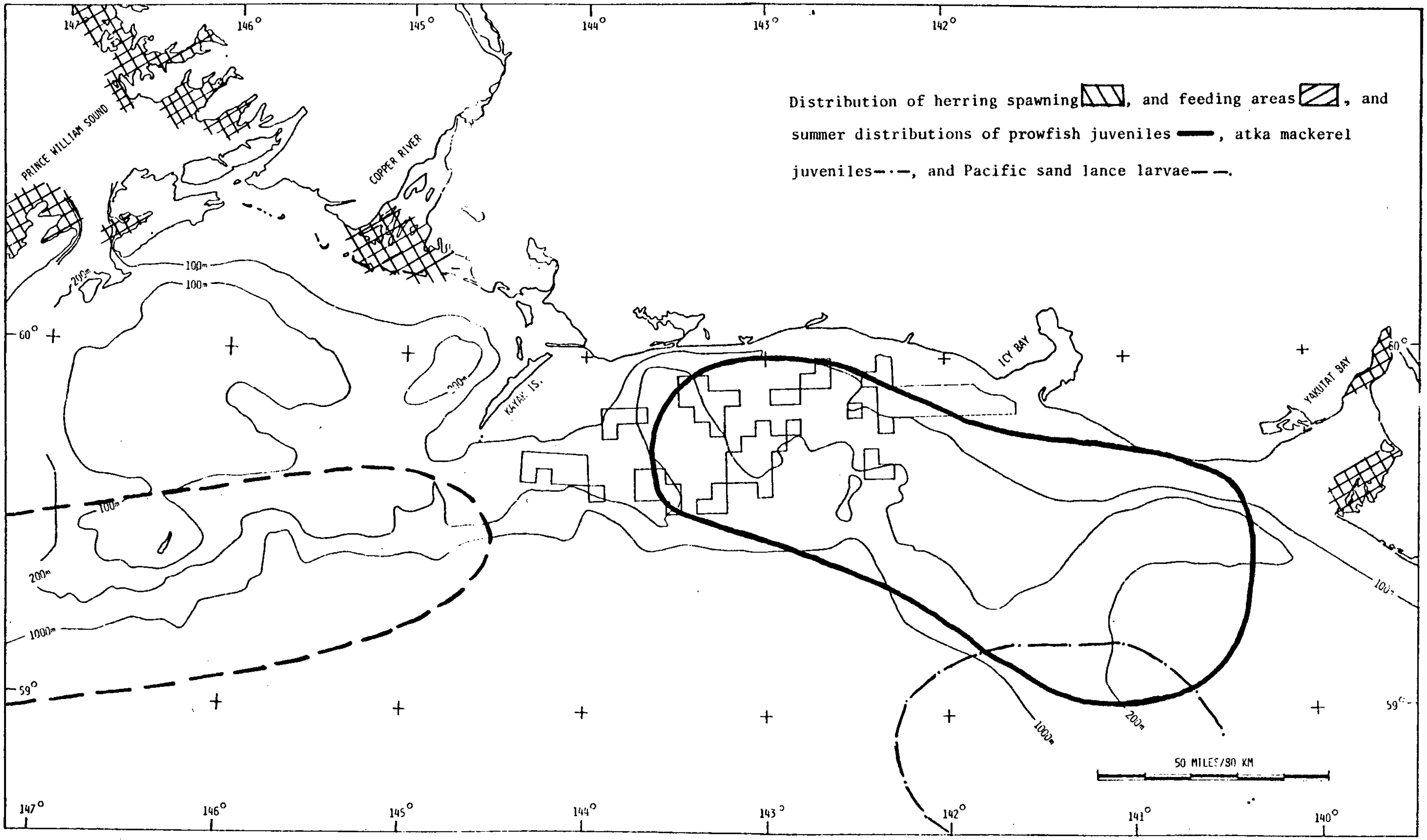


Fig. III-35. Distribution of herring spawning and feeding areas and summer distributions of prowfish juveniles, Atka mackerel juveniles and Pacific sand lance larvae (adapted from Macy 1977 and ADF&G 1975).

Pacific halibut are distributed throughout NEGOA and migrate extensively during maturation and spawning (ADF&G 1975; Hart 1973; Thompson and Herrington 1930). Spawners deposit neutrally buoyant eggs which drift passively with the currents on the outer shelf and slope. As the eggs hatch and larvae mature there is a progressive movement to shallower waters. As the halibut mature, they migrate into deeper waters. Spawners then move into general areas known to be specific for halibut spawning. In the NEGOA lease area, three spawning areas have been identified (Fig. III-36, ADF&G 1975).

In 1961 and again in 1975 demersal fish trawls were conducted to assess the status of this fishery in the Gulf of Alaska (Pereyra and Ronholt, RU #174, 1976; Ronholt *et al.*, 1976; Hughes 1974). Results from the 1961 studies, conducted by the International Pacific Halibut Commission and Bureau of Commercial Fisheries, indicate that the highest concentrations of demersal fish were between Icy Bay and Yakutat Bay (Fig. III-37). In 1975, data collected by the National Marine Fisheries Service indicate an overall increase in relative abundance, a dramatic increase in biomass west of Kayak Island, and a more uniform distribution than noted in 1961 (Fig. III-38). Specific points of comparison between the two studies indicate that:

1. The flatfish catch decreased from 52% to 36% of the total finfish catch.
2. The flatfish catch per unit effort increased slightly during the 12 year interval.
3. Arrowtooth flounder were the most abundant and widely distributed pleuronectids in the northeast gulf.
4. Roundfish comprised 23% of the total finfish catch in 1961 but this percentage more than doubled to 51% in 1975.
5. The catch per unit effort for roundfish increased 3-fold during the 12 year period.
6. Walleye pollock was the dominant roundfish and finfish in 1975, making up 76% of the roundfish catch and 45% of the total catch.
7. The pollock catch per unit effort increased approximately 3-fold east of Kayak Island and 18-fold west of the island in the 12 year interval.
8. In the 12 year period rockfish catch per unit effort decreased in all areas sampled, except in the area between Kayak Island and Yakutat Bay.

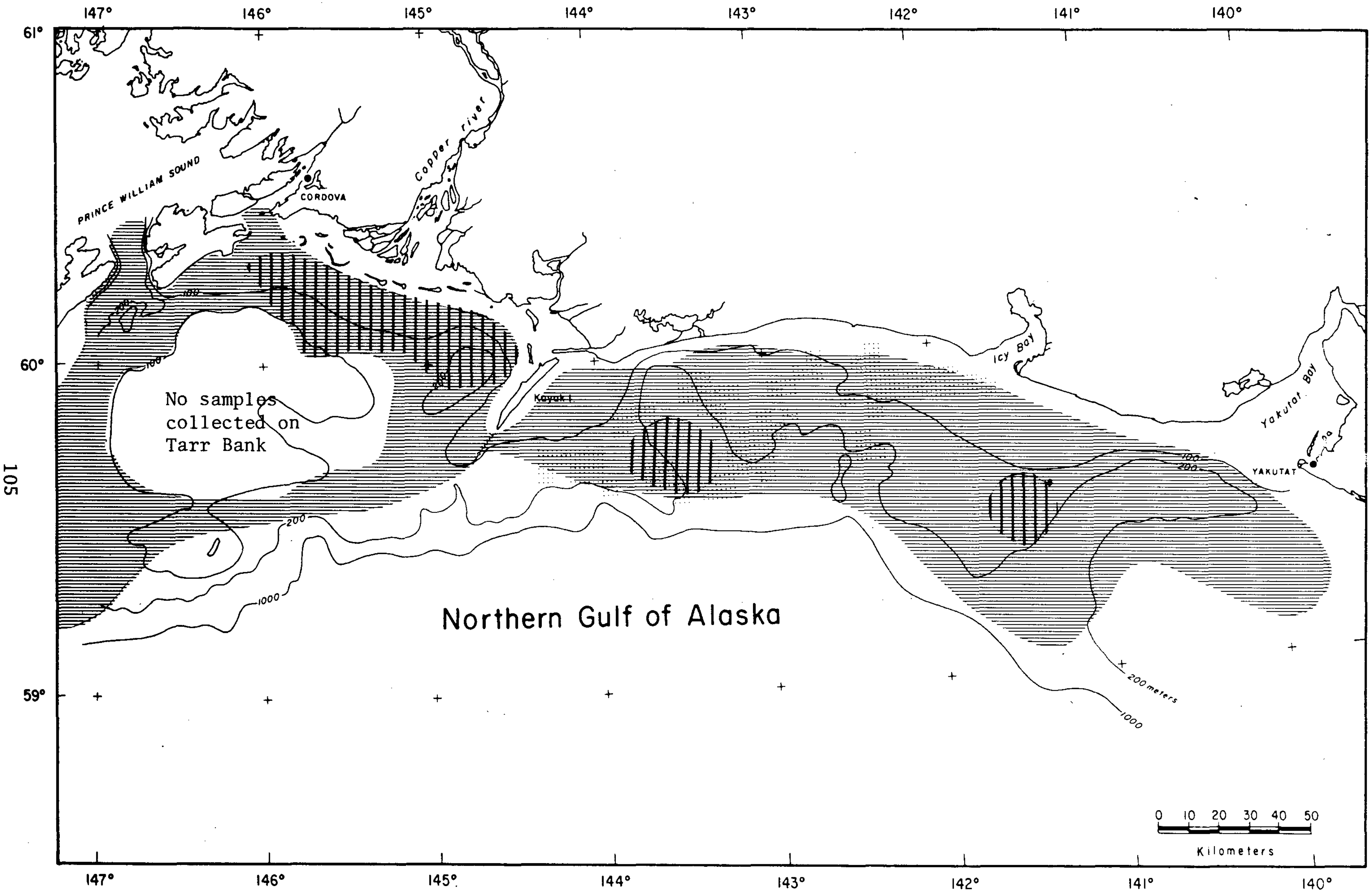


Fig. III-36. Halibut distribution ▤ and spawning areas ▥. (Adapted from ADF&G 1975, Hart 1973, Hughes 1974, Pereyra and Ronholt 1976).

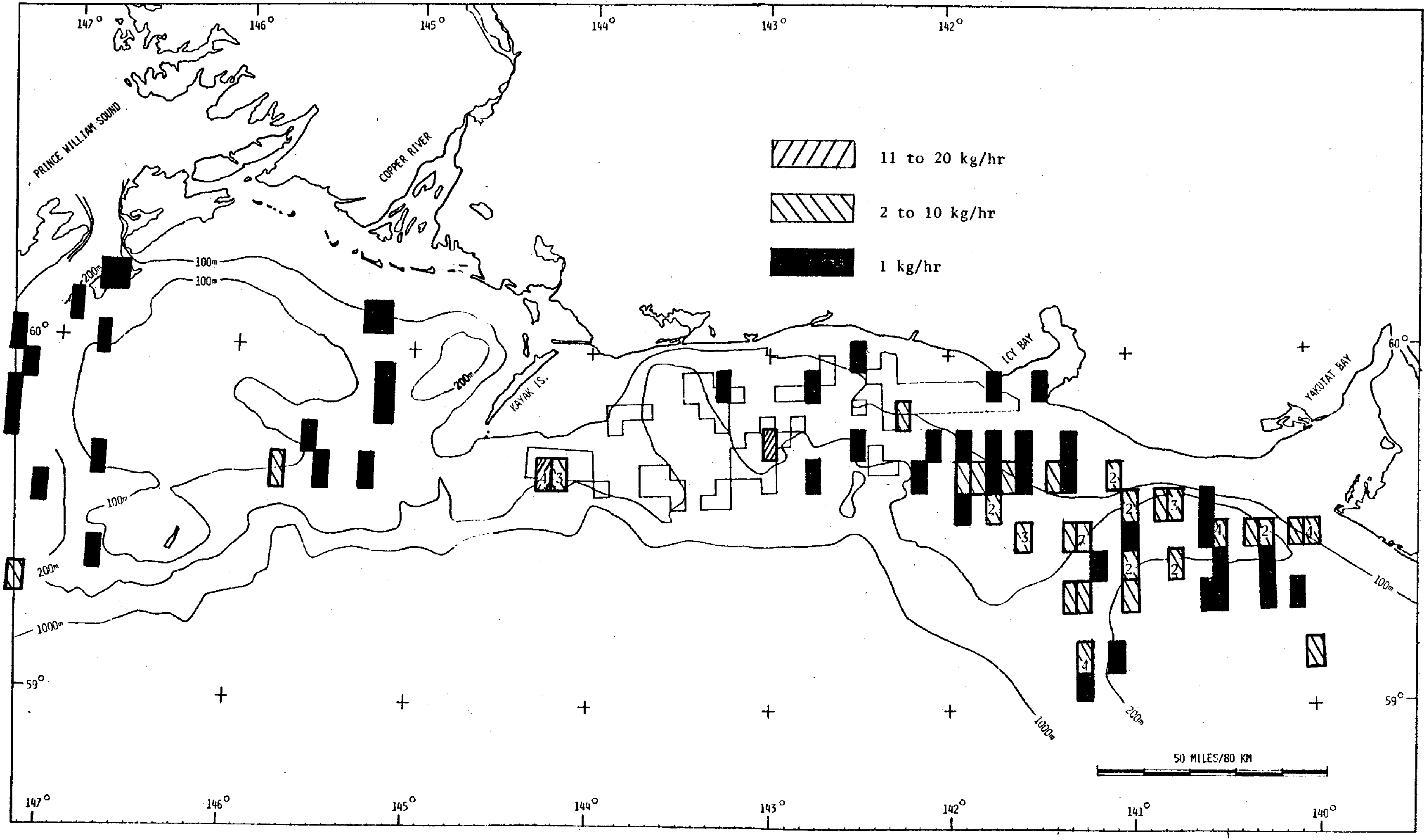


Fig. III-37. Composite summaries of demersal fish species catches in 1961 above 100 kg/hr and the number of species contributing to the summary catch (modified from Pereyra and Ronholt 1976).

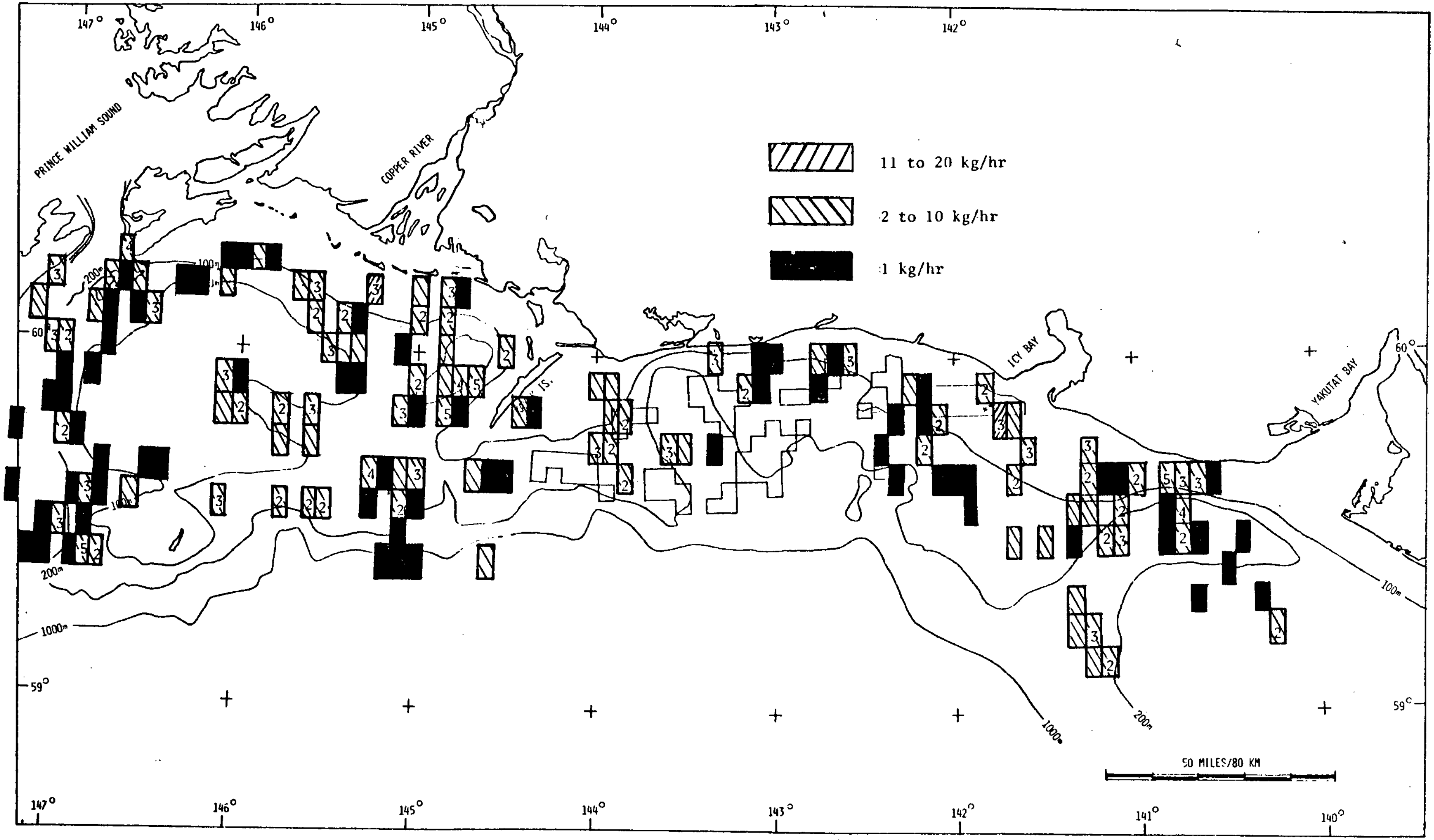


Fig. III-38. Composite summaries of demersal fish species catches in 1975 above 100 kg/hr and the number of species contributing to the summary catch (modified from Ronholt et al. 1976).

9. Pacific ocean perch were the dominant rockfish during both sampling periods.
10. Elasmobranchs (sharks and skates) were the least abundant group of fish caught during both sampling efforts.
11. The elasmobranch catch per unit decreased about 42% from 1961 to 1975.

Another finding of note in the 1975 survey was that starry flounder was the second most abundant flatfish caught, even though it was collected only on the inner shelf just south of Icy Bay.

The distribution, abundance, and frequency of occurrence of most species listed in Appendix 8 are unknown. Historical catch distributions of Atka mackerel, prowfish, and Pacific sand lance are illustrated in Fig. III-35 (Paul Macy. Unpublished Data. NMFS/NWAFS, Seattle, Wa. 1977.) The reader is also referred to the 1975 Annual Reports Summary (NOAA 1975) for specific distribution and abundances of demersal fish in the NEGOA lease area.

Commercial Fisheries. Except for halibut and salmon, commercial exploitation of the fisheries resource is solely in the hands of foreign nationals. Most of the foreign catch is taken by the Soviet Union and Japan; other nations include South Korea, Poland, and Taiwan (Pereyra and Ronholt, RU #174, 1976). The Soviet catch includes walleye pollock (45%), Atka mackerel (20%), Pacific Ocean perch (11%), and Pacific cod (4%). Their effort is almost exclusively by trawling. The Japanese use several types of gear to catch sablefish, arrowtooth flounder, other flatfish, Pacific cod, walleye pollock, Pacific Ocean perch, and other rockfish.

For the period 1969 to 1974, foreign fishermen took approximately 500,000 metric tons of demersal fish out of the Gulf of Alaska. Approximately one third of this catch originates from the NEGOA lease area. The recent trend in effort and total catch is that of a sharp increase. However, with the imposition of the 200 mile limit, the fishing effort may stabilize or decrease in an effort to maintain maximum sustained yields.

Canadian and U.S. nationals share in the commercial catch of Pacific halibut (Pereyra and Ronholt, RU #174, 1976; ADF&G 1975). The halibut catch statistics do not permit breakdown for the NEGOA area. However, the catch for the total northern gulf from 1969 to 1974 was approximately

83,000 metric tons. Nearly 17,000 metric tons of this catch came from the Yakutat area, almost exclusively within the Yakutat Sea Valley. Principal halibut fishing grounds in the NEGOA lease area are illustrated in Fig. III-39.

The local commercial fishermen concentrate their efforts on the various species of salmon. Throughout the Cape Suckling to Point Manby area, the commercial salmon catch is limited due to the lack of processing facilities. Long running times from catch areas to processing ports result in increased spoilage, reduced quality, and longer down times, all of which reduce the value of the catch. Most of the catch east of Cape Suckling is taken in Yakutat Bay or near streams east of Yakutat Bay. The catch from this area is relatively insignificant to the total state salmon catch; however, salmon are the principal source of revenue in the Yakutat community.

The average annual salmon catch for Prince William Sound is 4.7 million fish or 87% of the total NEGOA average annual catch. Within this total are included those fish caught in the Copper and Bering River areas. Nearly 70% of the Prince William catch is pink salmon. The value of this fishery is approximately 13 million dollars annually and represents 60 to 75% of the total fin and shellfish harvest.

The commercial herring fishery in NEGOA is concentrated within Prince William Sound (ADF&G 1975). No herring are taken commercially in any other area of the NEGOA region. In the Sound fishermen take herring as eggs on kelp, adults for sac roe, and juveniles and adults for crab and sport fish bait. Eggs on kelp and sac roe are the principal revenue sources to herring fishermen. Most of the harvest is processed locally but sold to the Japanese. This fishery has a local value of about $800,000 annually; however, in 1974 the harvest yielded approximately 1.4 million dollars to the Sound economy.

Sport Fisheries. Sport fishing in marine waters is generally limited to local residents. This is the result of hazardous waters and a limited number of charter vessels. Sport fishing, even for local residents, is limited to Yakutat Bay and the Cordova-Hinchinbrook area (Fig. III-39) (ADF&G 1975). The sport catch is made up primarily of salmon and halibut.

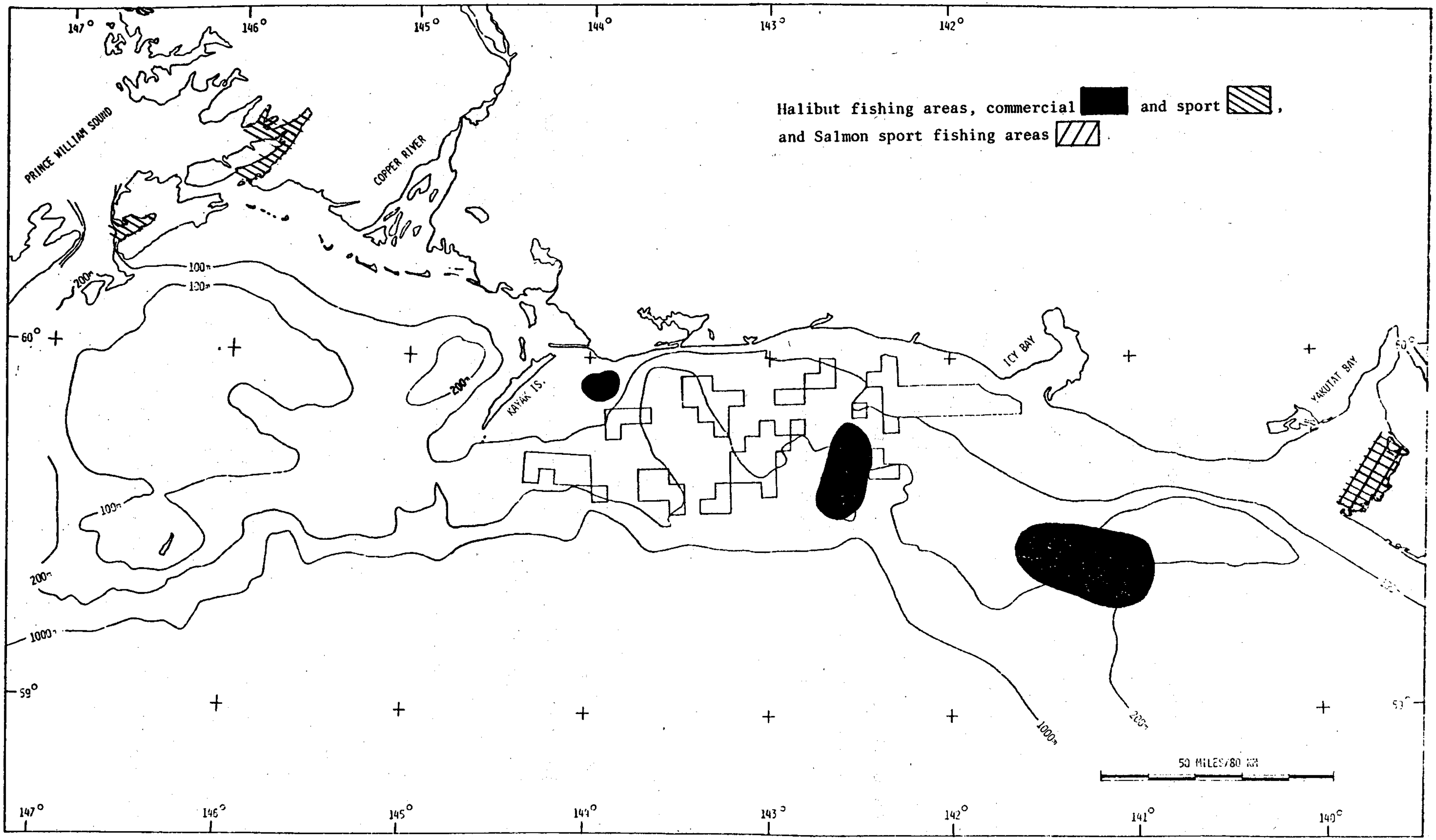


Fig. III-39. Halibut fishing areas (modified from ADF&G 1975).

Most of the salmon catch, including Dolly Varden and steelhead trout, is taken in streams after these species have left the marine environment.

Birds

More than 130 species of birds utilize the NEGOA region (Table III-17, Fig. III-40). According to Isleib (1971):

> Sixty-two of these species occur in the area in numbers exceeding tens of thousands, seven (sooty shearwater, fork-tailed petrel, pintail, western sandpiper, northern phalarope, black-legged kittiwake and common murre) in the millions. Although there is a high turnover of individuals from season to season, 121 species occur in the spring, 100 in summer, 108 in fall, and 71 in winter. Largely because of the year-round ice-free waters, 60 species are resident throughout the year.
>
> In offshore waters along, the U.S. Fish and Wildlife Service (1975) has estimated from census data that NEGOA has a standing stock of 1.5 million birds in winter and as many as 48 million during spring migration. The caveat is added that "the number of birds actually dependent on the region may be substantially larger because population estimates do not take into account turnover of individuals within the population." (USFWS 1975)

A gross overview of habitat use, vulnerability to petroleum development, and relative seasonal concentrations of principal marine birds in NEGOA is provided in Appendix 4. Isleib (1971) and Isleib and Kessel (1973) have classified water bird habitats of the northern gulf into four major divisions: offshore, inshore, tidal (intertidal), and land. Avian usage of these habitats by season is summarized in Table III-18.

U.S. Fish and Wildlife Service (Lensink and Bartonek, RU #338, 1976) and Alaska Department of Fish and Game (ADF&G 1975) have identified 27 seabird colonies fronting NEGOA between Hinchinbrook Entrance and Yakutat Forelands (Fig. III-40 and Table III-19). The six largest colonies, with populations ranging from 10,000 to 200,000 birds, were singled out at the NEGOA synthesis meeting, as being particularly important because of their sizes. Principal species in these colonies are fork-tailed storm petrel, tufted and horned puffins, rhinoceros auklet, glaucous-winged gull, black-legged kittiwake, common murre, and pelagic cormorant.

Greatest abundance of birds on pelagic waters of NEGOA occurs in spring, when millions of shearwaters start arriving from their breeding grounds in the southern hemisphere. Mean bird density observed in spring is 137 birds/km^2, of which 90% are shearwaters (principally sooty

TABLE III-17

Families and species of marine birds using littoral and inshore areas of the Northeast Gulf Coast of Alaska (prepared by Paul Arneson, adapted from Isleib and Kessel 1973).

Family	Species
Gaviidae	Common Loon
	Yellow-billed Loon
	Arctic Loon
	Red-throated Loon
Podicipedidae	Red-necked Grebe
	Horned Grebe
Diomedeidae	**Short-tailed Albatross*
	**Black-footed Albatross
	**Laysan Albatross
Procellariidae	**Fulmar
	**Pink-footed Shearwater
	**Pale-footed Shearwater
	**Sooty Shearwater
	**Slender-b Shearwater
Hydrobatidae	**Scaled Petrel*
	Fork-tailed Petrel
	**Leach's Petrel
Phalacrocoracidae	Double-c Cormorant
	Brandt's Cormorant*
	Pelagic Cormorant
	Red-faced Cormorant
Ardeidae	Great Blue Heron
Anatidae	Whistling Swan
	Trumpeter Swan
	Canada Goose
	Black Brant
	Emperor Goose
	White-fronted Goose
	Snow Goose
	Mallard
	Gadwall
	Pintail
	Green-winged Teal
	Blue-winged Teal
	European Wigeon*
	American Wigeon
	Shoveler
	Redhead*
	Ring-necked Duck
	Canvasback
Anatidae	Greater Scaup
	Lesser Scaup
	Common Goldeneye
	Barrow's Goldeneye
	Bufflehead
	Oldsquaw
	Harlequin Duck
	Steller's Eider
	Common Eider
	King Eider
	White-winged Scoter
	Surf Scoter
	Common Scoter
	Hooded Merganser
	Common Merganser
	Red-breasted Merganser
Accipitridae	Sharp-shinned Hawk
	Rough-legged Hawk
	Bald Eagle
	March Hawk
Pandionidae	Osprey
Falconidae	Peregrine Falcon
	Merlin
Gruidae	Sandhill Crane
Hematopodidae	Black Oyster-catcher
Charadriidae	Semipalmated Plover
	Killdeer*
	American Golden Plover
	Black-bellied Plover
	Ruddy Turnstone
	Black Turnstone
Scolopacidae	Common Snipe
	Whimbrel
	Bristle-thighed Curlew*
	Spotted Sandpiper
	Solitary Sandpiper
	Wandering Tattler
	Greater Yellowlegs
	Lesser Yellowlegs
	Knot

(continued)

TABLE III-17 (continued)

Family	Species	Family	Species
Scolopacidae	Rock Sandpiper	Strigidae	Short-eared Owl
	Sharp-tailed Sandpiper*	Alcedinidae	Belted Kingfisher
	Pectoral Sandpiper		
	Baird's Sandpiper	Corvidae	Black-billed Magpie
	Least Sandpiper		Common Raven
	Dunlin		Northwestern Crow
	Short-billed Dowitcher	Motacillidae	Water Pipit
	Long-billed Dowitcher		
	Semipalmated Sandpiper	Fringillidae	Fox Sparrow
	Western Sandpiper		Song Sparrow
	Bar-tailed Godwit		Lapland Longspur
	Hudsonian Godwit		Snow Bunting
	Sanderling		
	Surfbird		
Phalaropidae	Red Phalarope		
	Northern Phalarope		
Stercorariidae	Pomarine Jaeger		
	Parasitic Jaeger		
	Long-tailed Jaeger		
	Skua*		
Laridae	Glaucous Gull		
	Glaucous-winged Gull		
	Herring Gull		
	New Gull		
	Bonaparte's Gull		
	Black-legged Kittiwake		
	Sabine's Gull		
	Arctic Tern		
	Aleutian Tern		
Alcidae	Common Murre		
	Thick-billed Murre		
	Pigeon Guillemot		
	Marbled Murrelet		
	Kittlitz's Murrelet		
	Ancient Murrelet		
	Cassin's Auklet*		
	Parakeet Auklet		
	Crested Auklet		
	Rhinoceros Auklet		
	Horned Puffin		
	Tufted Puffin		

*Species of rare or "accidental" occurrence (following Isleib and Kessel 1973).

**Offshore species.

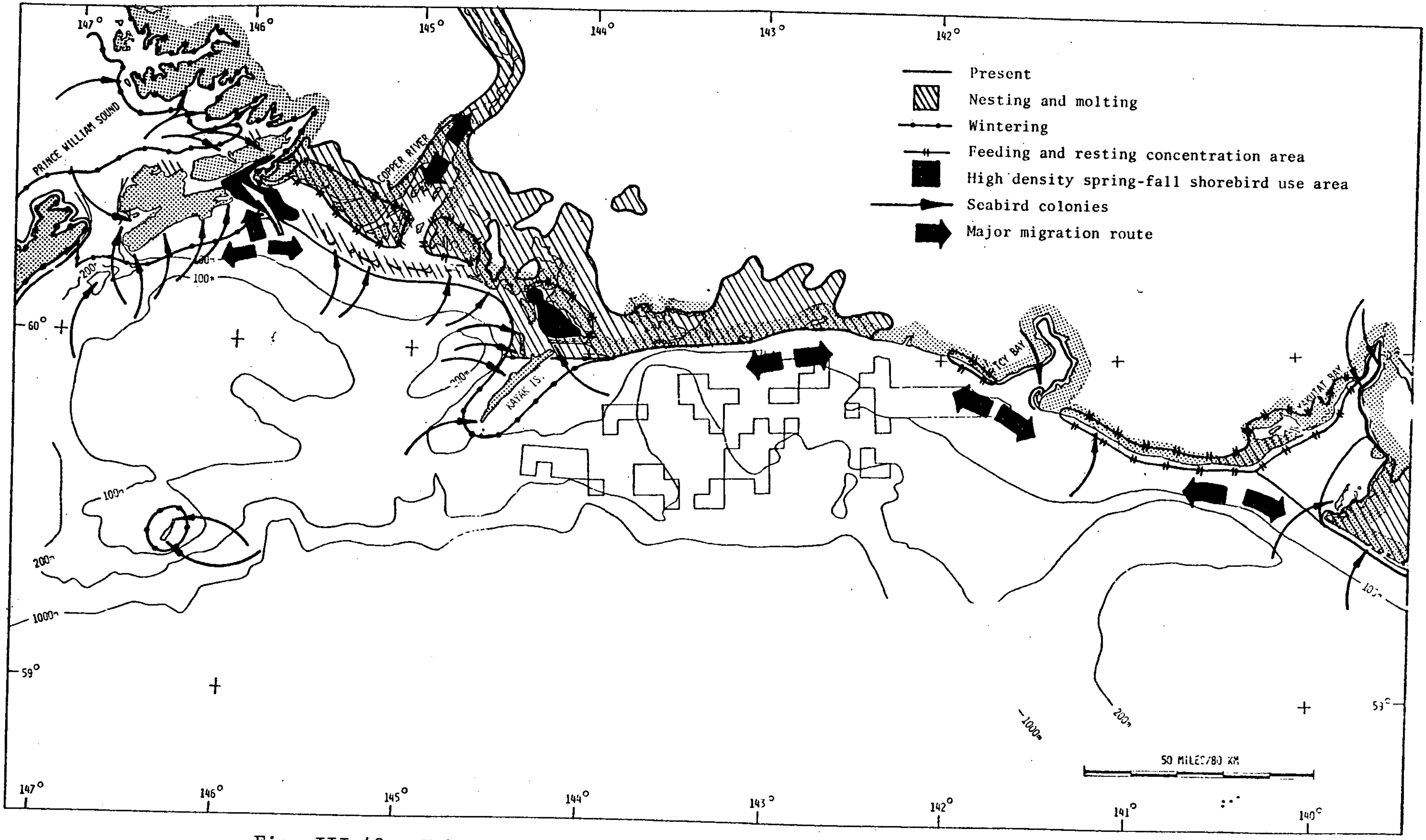


Fig. III-40. Habitat use by seabirds, shorebirds, and waterfowl in NEGOA (after ADF&G 1975 and Lensink and Bartonek, RU #338, 1976).

TABLE III-18.. Seasonal Utilization of Avian Habitat Zones in the Northern Gulf of Alaska (after Isleib 1971).

Season	Habitat Zone			
	[1]Offshore	[2]Inshore	[3]Intertidal	[4]Onshore
Spring	Millions of kittiwakes, alcids, terns phalaropes, storm petrels, and jaegers stop here to rest and feed while enroute to their breeding grounds. Geese, swans, loons, plover, tattlers, and turnstones migrate through. Millions of shearwaters arrive.	Migrating loons, grebes, waterfowl, hawks, eagles, cranes, shorebirds, and gulls moving along the coast. Gulls, kittiwakes, scoters, oldsquaws, scaup, and cormorants feeding heavily upon spawning herring and roe in April and May.	Copper River Delta intertidal is particularly important. From late April to mid-May it is utilized by more than 20 million shorebirds and waterfowl, attaining densities in the neighborhood of 100 thousand birds/km^2. The rocky intertidal of Montagu Island hosts similar numbers of turnstones, plovers, surfbirds, whimbrels, and tattlers.	Large concentrations of gulls are attracted to fish processing plant wastes at Yakutat, Cordova, Seward and other locations.
Summer	Areas adjacent to colonies of kittiwakes, alcids, and storm petrels heavily utilized for feeding. Large numbers of non-breeding southern latitude shearwaters, albatrosses, and petrels present.	Heavily utilized by seabirds breeding along the coast and by large non-breeding populations of scoters and other species that spend the summer here.	Utilized by large numbers of non-breeding shorebirds and gulls throughout the summer. Gulls, eagles, and fish-eating ducks begin gathering at salmon spawning areas in late summer (see below).	Seabird colonies are inhabited. Peregrine falcons and golden eagles start nesting along coast.
Fall	Period of peak utilization in fall, as post-breeding birds move in prior to migration. Millions of phalaropes (early fall), storm petrels, and kittiwakes involved. Shearwaters still present.	Severe southeast storms in Sept. and Oct. drive large numbers of ducks, geese, swans, and cranes into Copper River and Bering River deltas. Massive movements out of these deltas when storms subside. Storms tend to coincide with fork-tailed petrel migratory waves, driving thousands of petrels into inshore areas.	Thousands of gulls, hundreds of eagles, and fish-eating ducks gather at salmon streams and intertidal spawning locations to feed upon dead salmon and salmon roe.	Migrating waterfowl and landbirds favoring coastal movements are often funneled through this zone by mountain, glacial, and sea barriers. Bald eagles concentrate along the coast.
Winter	Alcids and fulmars are probably the most abundant birds present, followed by kittiwakes and glaucous-winged gulls (see Table 5).	Tens of thousands of harlequin ducks, scoters, oldsquaw, eiders, mergansers, goldeneyes, and scaup winter here. Smaller numbers of loons, grebes, and cormorants also winter here.	A primary winter feeding habitat of resident eagles, ravens, crows, and gulls. Rock sandpipers, dunlins, surfbirds, black turnstones, and black oystercatchers are common along rocky shores. In heavy snow years, land birds and deer are forced to feed in this habitat.	

1. Area of the gulf beyond the 50 fathom line or, regardless of depth, more than 2 nautical miles from shore.
2. Area between the 50 fathom line and the intertidal, except where the 50 fathom line exceeds 2 nautical miles from shore.
3. Coastal area between extreme high and low tide marks, including sloughs and river mouths as far inland as they are subject to tidal influence. This is the most heavily utilized avian habitat of the northern gulf.
4. Land adjacent to the sea.

TABLE III-19

Preliminary Inventory of NEGOA Seabird Colonies
(after Lensink and Bartonek, RU #338).

Colony Location	Species	Population Estimates	Colony Totals
Situk River	Glaucous-winged Gull	500	700
	Mew Gull	100	
	Arctic Tern	100	
	Aleutian Tern	present	
Yakutat Bay Islands	Glaucous-winged Gull	3,000	3,300
	Arctic Tern	300	
Logan Bluffs	Pelagic Cormorant	100's	100's
Haenke Island	Glaucous-winged Gull	500	500
Wingham Island	Tufted Puffin	10	10
Kayak Island	Double-crested Cormorant	46	236
	Pelagic Cormorant	28	
	Red-faced Cormorant	4	
	Glaucous-winged Gull	50	
	Horned Puffin	8	
	Tufted Puffin	100	
Cape St. Elias Pinnacle	Double-crested Cormorant	32	8,912
	Pelagic Cormorant	82	
	Red-faced Cormorant	118	
	Glaucous-winged Gull	220	
	Black-legged Kittiwake	present	
	Common Murre	2,460	
	Ancient Murrelet	offshore	
	Tufted Puffin	6,000	
Middleton Island	Pelagic Cormorant	5,548	176,454
	Glaucous-winged Gull	2,602	
	Mew Gull	12	
	Black-legged Kittiwake	144,942	
	Common Murre	11,540	
	Tufted Puffin	11,810	
Okalee Spit	Glaucous-winged Gull	400	600
	Arctic Tern	200	

(continued)

TABLE III-19 (continued)

Colony Location	Species	Population Estimates	Colony Totals
North Wingham Island	Double-crested Cormorant	188	19,596
	Pelagic Cormorant	98	
	Red-faced Cormorant	44	
	Glaucous-winged Gull	190	
	Black-legged Kittiwake	14,256	
	Common Murre	4,620	
	Thick-billed Murre	present	
	Tufted Puffin	200	
Martin Island	Pelagic Cormorant	12	20,274
	Glaucous-winged Gull	400	
	Black-legged Kittiwake	13,420	
	Common Murre	4,238	
	Pigeon Guillemot	present	
	Tufted Puffin	2,200	
	Black Oystercatcher	4	
Copper River Delta	Glaucous-winged Gull	20,000	22,000
	Arctic Tern	2,000	
Boswell Rocks	Double-crested Cormorant	54	10,226
	Pelagic Cormorant	82	
	Glaucous-winged Gull	148	
	Black-legged Kittiwake	9,872	
	Pigeon Guillemot	10	
	Tufted Puffin	60	
Pinnacle Rock	Black-legged Kittiwake	1,400	1,460
	Tufted Puffin	60	
Point Bentinck	Glaucous-winged Gull	suspected	unknown
	Arctic Tern	suspected	
Point Steel	Double-crested Cormorant	4	114
	Glaucous-winged Gull	4	
	Black-legged Kittiwake	104	
	Pigeon Guillemot	2	
Hook Point	Double-crested Cormorant	4	124
	Black-legged Kittiwake	110	
	Pigeon Guillemot	10	

(continued)

TABLE III-19 (continued)

Colony Location	Species	Population Estimates	Colony Totals
Hinchinbrook Island	Double-crested Cormorant	6	2,490
	Pelagic Cormorant	128	
	Glaucous-winged Gull	50	
	Pigeon Guillemot	200	
	Horned Puffin	106	
	Tufted Puffin	2,000	
Cape Hinchinbrook	Double-crested Cormorant	60	684
	Pelagic Cormorant	64	
	Glaucous-winged Gull	200	
	Black-legged Kittiwake	180	
	Horned Puffin	30	
	Tufted Puffin	150	
Porpoise Rocks	Glaucous-winged Gull	40	4,661
	Black-legged Kittiwake	1,950	
	Common Murre	1,510	
	Thick-billed Murre	1	
	Horned Puffin	20	
	Tufted Puffin	1,140	
Port Etches	Tufted Puffin	100	100
Seal Rocks	Black-legged Kittiwake	550	561
	Brandt's Cormorant	11	
Gravina Rocks	Black-legged Kittiwake	67	77
	Arctic Tern	8	
	Black Oystercatcher	2	
Canoe Passage	Black-legged Kittiwake	94	94
Sheep Bay	Mew Gull	present	100
	Arctic Tern	100	
Hell's Hole	Glaucous-winged Gull	100	244
	Mew Gull	40	
	Arctic Tern	100	
	Black Oystercatcher	4	
Gull Island	Glaucous-winged Gull	40	52
	Arctic Tern	10	
	Black Oystercatcher	2	

shearwaters; Table III-20). Fulmars, phalaropes, glaucous-winged gulls, black-legged kittiwakes, and murres are also fairly common (1 to 2 birds/km^2), though overshadowed by the superabundant shearwaters. Shearwaters in NEGOA decline after sping, but they still remain the most abundant bird in the region until fall, when they migrate southward to their breeding grounds. In winter, the most numerous birds observed on pelagic waters of NEGOA are fulmars, glaucous-winged gulls, black-legged kittiwakes, and murres, which are all present in average densities of 2 to 3 birds/km^2 (Table III-20). Pelagic areas of high seabird density are illustrated by season in Fig. III-41.

U.S. Fish and Wildlife Service estimates indicate that Prince William Sound (PWS) is inhabited by about three to four hundred thousand waterbirds in winter and about five to six hundred thousand in summer (Table III-21). It is likely that even greater numbers are present in spring (Lensink and Bartonek, RU #337, 1976). The winter population is dominated by scaup (37% of total) and by gulls and kittiwakes (25%), with dabbling ducks and geese, alcids, cormorants, and grebes also numbering in the tens of thousands. In summer, gulls and kittiwakes (42%), alcids (26%), scaup (10%), terns (4%), and cormorants (3%) are the most abundant species in PWS. More than a thousand bald eagles are present the year round (Table III-20). More detailed information on the birds of PWS is provided by Dwyer *et al.*, 1976.

The Copper River Delta is the most extensive breeding ground in NEGOA and is heavily utilized by millions of additional shorebirds and water fowl as a feeding, resting, and staging ground during migrations. Avifauna of this region has been described by Isleib (1971), Isleib and Kessel (1973), and Mickelson (1973). A quantitative summary of breeding water fowl and their habitats is provided in an Alaska Department of Fish and Game report entitled "Birds of the Copper River Delta" (ADF&G, 1976b).

Mammals

Sea otters, fur seals, Steller sea lions, harbor seals, occasional elephant seals and California sea lions, and various cetaceans occur in NEGOA (Table III-22). Sea otters are reaching carrying capacity in Prince William Sound and expanding their range southeastward along the NEGOA coast,

TABLE III-20

Estimated Seasonal Seabird Densities in the Northeast Gulf of Alaska, based on USFWS censuses in 1972, 1975 and 1976 (compiled by Pat Gould, NSFWS, Anchorage).

	Shipboard Transects				Aerial Transects		
	Spring	Summer	Fall	Winter	March	June	October
Number of Km^2 Sampled:	540.9	171.16	300.96	233.67	187.02	197.55	126.55
SPECIES:							
Common Loon	0.1	-	-	-	+	-	-
Yellow-billed Loon	+	-	-	-	-	-	-
Arctic Loon	0.1	+	-	-	-	-	-
Unidentified Loon	0.3	0.1	+	+	-	-	-
Horned Grebe	+	-	-	-	-	-	+
Black-footed Albatross	+	0.1	0.1	-	-	0.1	+
Laysan Albatross	-	-	+	-	-	-	+
Northern Fulmar	1.5	2.1	2.6	3.0	0.7	0.6	1.3
Sooty/Short-tailed Shearwater	122.4	23.5	3.2	+	0.1	1.2	0.2
Pink-footed Shearwater	-	-	-	-	-	+	+
New Zealand Shearwater	-	-	-	-	-	-	+
Scaled Petrel	-	-	-	-	-	+	-
Fork-tailed Storm Petrel	0.4	2.1	1.2	0.1	0.4	0.2	1.1
Leach's Storm Petrel	-	0.3	-	-	-	0.1	-
Unidentified Storm Petrel	+	0.2	+	-	+	+	+
Double-crested Cormorant	+	+	-	-	-	-	-
Pelagic Cormorant	0.1	+	+	-	-	-	-
Red-faced Cormorant	-	-	+	-	-	-	-
Unidentified Cormorant	0.1	+	0.1	+	+	0.2	0.1
Black Brant	+	-	-	-	-	-	+
Canada Goose	-	-	-	-	-	-	0.2
Unidentified Goose	+	-	-	-	-	-	-
Mallard	+	-	+	-	-	-	-
Pintail	+	-	+	-	-	-	-
American Wigeon	+	-	-	-	-	-	-
Greater Scaup	-	-	+	-	-	-	-
Oldsquaw	0.2	+	0.1	-	0.1	+	-
Common Eider	-	-	-	-	+	-	-
White-winged Scoter	+	-	+	-	+	-	0.6
Surf Scoter	*	+	-	-	-	-	+
Black Scoter	-	-	-	-	0.1	-	-
Red-breasted Merganser	+	-	+	-	+	-	-
Unidentified Duck (mostly scoters)	0.1	+	+	+	0.1	+	1.9
Bald Eagle	+	-	-	-	-	+	+
Red Phalarope	+	-	-	-	-	-	-
Northern Phalarope	1.5	0.1	+	-	-	0.1	-
Unidentified Phalarope	+	-	+	-	+	0.1	-
Pomarine Jaeger	+	+	+	-	-	-	-
Parasitic Jaeger	+	0.1	-	-	-	+	-
Long-tailed Jaeger	+	+	+	-	-	-	-
Unidentified Jaeger	+	+	+	-	-	+	+
Glaucous Gull	+	-	-	+	-	+	-
Glaucous-winged Gull	1.6	0.2	0.6	2.3	0.6	0.4	1.0

(continued)

TABLE III-20 (continued)

Estimated Seasonal Seabird Densities in the Northeast Gulf of Alaska, based on USFWS censuses in 1972, 1975 and 1976 (compiled by Pat Gould, USFWS, Anchorage) (continued).

	Shipboard Transects				Aerial Transects		
	Spring	Summer	Fall	Winter	March	June	October
Number of Km^2 Sampled:	540.9	171.16	300.96	233.67	187.02	197.55	126.55
SPECIES:							
Herring Gull	0.8	0.4	0.1	0.1	+	+	0.1
Mew Gull	0.1	-	+	0.1	-	+	-
Bonaparte's Gull	*	-	-	-	-	-	-
Black-legged Kittiwake	2.3	4.3	1.0	2.1	1.3	4.8	0.4
Sabine's Gull	-	0.4	+	-	-	+	+
Unidentified Gull	0.2	0.1	0.2	0.1	0.7	4.0	0.1
Arctic Tern	0.7	1.6	+	-	-	0.1	-
Aleutian Tern	+	+	-	-	-	+	-
Unidentified Tern	-	-	-	-	-	1.2	-
Common Murre	+	+	-	-	0.2	-	-
Unidentified Murre	1.9	0.4	0.5	1.9	0.5	0.2	+
Pigeon Guillemot	+	-	-	-	-	-	-
Marbled Murrelet	0.2	0.2	+	0.1	-	-	-
Kittlitz's Murrelet	+	+	-	-	-	-	-
Ancient Murrelet	0.1	0.1	+	-	-	+	-
Cassins Auklet	+	+	+	-	-	-	-
Parakeet Auklet	+	-	+	-	-	+	-
Rhinoceros Auklet	+	+	+	-	+	-	-
Horned Puffin	0.1	-	-	0.1	-	-	+
Tufted Puffin	0.4	0.3	0.4	0.2	0.6	0.3	0.1
Unidentified Alcid	1.3	1.2	0.3	0.2	1.5	0.6	0.4
Total Birds	136.6	37.7	10.4	10.3	7.5	14.3	7.8

+ = less than 0.05 birds/Km^2

* = present but not seen on transect

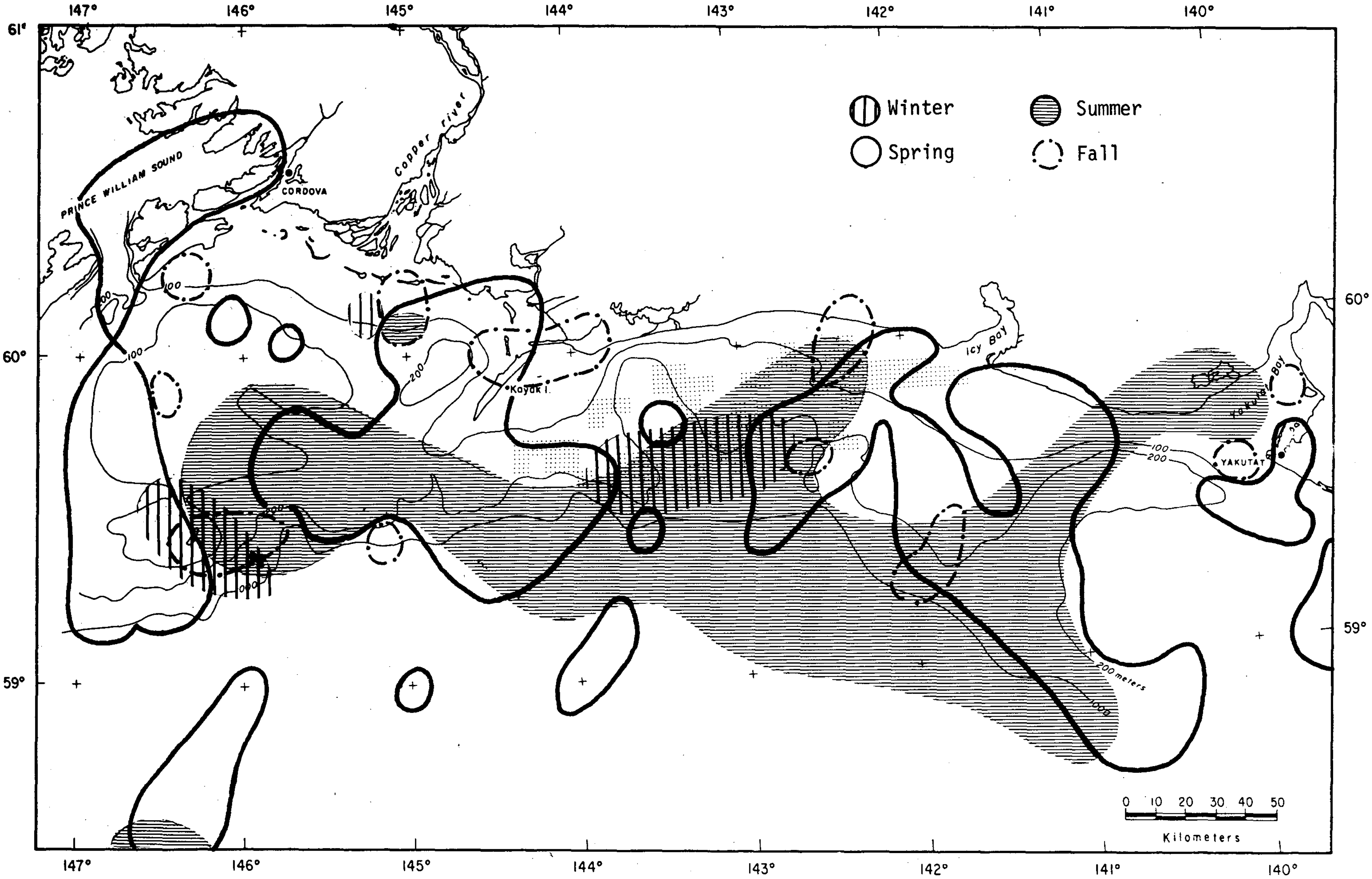


Fig. III-41. Areas of NEGOA determined by U.S. Fish and Wildlife Service censuses to have high (30/km^2) seabird densities (data provided by Pat Gould and Kent Wohl).

TABLE III-21

Population Estimates by Major Groups of Marine Birds in Prince William Sound* (based on USFWS surveys; after Dwyer *et al.*, 1976).

Bird Taxa	Estimated Populations	
	March-April	July-August
Loons	4,852 ± 1,733	2,355 ± 491
Grebes	11,587 ± 1,907	421 ± 104
Shearwaters		3,709 ± 1,984
Storm Petrels		9,346 ± 3,600
Cormorants	22,074 ± 3,375	14,682 ± 6,170
Geese and Dabblers	27,347 ± 23,841	15,255 ± 7,749
Scaup	128,831 ± 16,469	52,339 ± 14,946
Eiders, Scoters, Oldsquaw, Harlequin, Mergansers, Goldeneyes	4,482 ± 1,103	3,345 ± 927
Hawk and Eagles	1,706 ± 161	1,338 ± 148
Gulls and Kittiwakes	87,260 ± 33,186	220,323 ± 39,799
Terns		19,936 ± 3,504
Alcids	33,230 ± 4,454	137,192 ± 13,110
All birds	346,228 ± 57,749	523,387 ± 56,765

* - Combined average of 1972 and 1973 shoreline and open water surveys ± S.E.

TABLE III-22

Marine Mammals of the Northern Gulf of Alaska (adapted from USDI 1976 with amendments by NMFS, Seattle).

Species	Residence Status	Occurrence Coastal	Occurrence Offshore	Foods
Northern Elephant Seal	Rv		x	Fish, squid
Sea Otter	Pr	x	x	Benthos Demersal Fish
Northern Sea Lion	Pr	x		Fish, cephalopods
Northern Fur Seal	Se†		x	Fish, cephalopods
Harbor Seal	Pr	x		Fish, cephalopods
California Sea Lion	Rv	x		Crustaceans, Molluscs
Gray Whale*	Se		x	Amphipods
Fin Whale*	Se		x	Euphausiids, fish
Sei Whale*	Se		x	Euphausiids
Minke Whale	Pr	x	x	Euphausiids, fish
Blue Whale*	Se		x	Euphausiids
Black Right Whale*	Se		x	Copepods
Humpback Whale*	Se	x	x	Euphausiids, fish
Sperm Whale*	Se		x	Squid, fish
Belukha Whale	Pr	x		Squid, fish, crustaceans
Killer Whale	Pr?	x	x	Fish, pinnipeds, cetaceans, birds
Bering Sea Beaked Whale	Pr		x	Fish, squid
Goose-Beaked Whale	Pr		x	Fish, squid
Giant Bottlenose Whale	Pr		x	Fish, squid
Dall Porpoise	Pr	x	x	Fish, squid
Harbor Porpoise	Pr	x		Fish
North Pacific White-side Dolphin	Se		x	Fish, squid

Pr - Permanent Resident Se - Seasonal Entrant Rv - Rare Visitor
* - Endangered Species
† - Adult males overwinter in the gulf

repopulating areas from which they were once exterminated by commercial hunting (Figs. III-42 and III-43).

Steller sea lions are present in NEGOA year round. Concentrations occur at several locations, particularly in winter (Fig. III-42). Many of the Steller sea lions that winter in NEGOA breed on the Barren Islands (K. Pitcher and K. Schneider, ADF&G, Anchorage, pers. comm. 1977). Harbor seals occur over the entire NEGOA coastline the year round, though the distribution of major concentrations shelve seasonally (Fig. III-42). Elephant seals and California sea lions are rare winter visitors from the south.

Fur seals are present the year round in NEGOA. They attain peak abundance in April-June, as females arriving from wintering grounds to the south traverse the gulf enroute to their breeding grounds on the Pribilof Islands. Adult males winter in the gulf. Fur seals occur mainly over the shelf break but sometimes move inshore, where they feed upon schooling fishes, and offshore to epiabyssal regions of the gulf. Fur seal concentrations occur regularly around Middleton Island (Fiscus *et al.*, RU #77, 1976).

At least eight species of whales and porpoises are present the year round in the gulf, and eight others enter seasonally (Table III-22). The gray whale's annual migration between Baja California and the Bering-Chukchi Seas goes through the Gulf of Alaska; so far as is known they migrate coastally, close to shore (Fiscus *et al.*, RU #77, 1976). The gray whale and six other cetaceans in the Gulf of Alaska are listed in the Federal Register as endangered species (Table III-22).

Twenty-one belukha whales were sighted in Yakutat Bay in the summer of 1976 (O. Calkins, ADF&G, Anchorage, pers. comm.). The nearest known belukha population to Yakutat is in Cook Inlet. Whether the Yakutat animals were simply visitors from Cook Inlet is unknown.

A gross summarization of habitat utilization, seasonality, and vulnerability to petroleum development is provided in Appendix 4.

Microbiology

Morita and Griffiths (RU #190, 1976) found that the microbial abundance (2×10^7 to 3.1×10^9 cells/gm dry weight) in the NEGOA lease area sediments was generally lower than that found in Lower Cook Inlet. The average V_{max}, the maximum potential uptake velocity, for the sum of both macromolecular synthesis and respiration, was 4.5 μg glutamic acid/gm

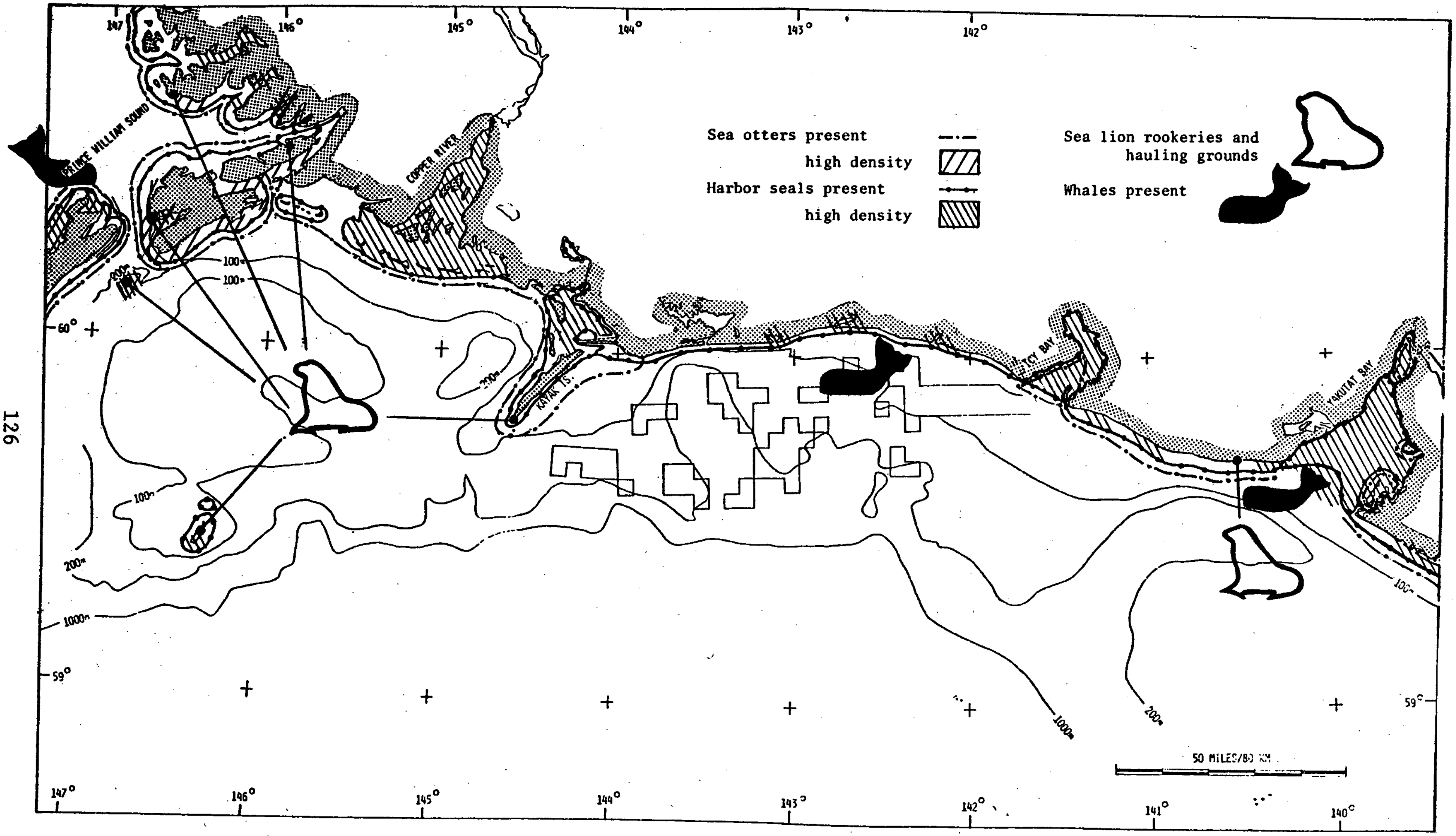


Fig. III-42. Distribution of marine mammals in NEGOA (from ADF&G 1975 and D. Calkins, K. Pitcher and K. Schneider, unpublished).

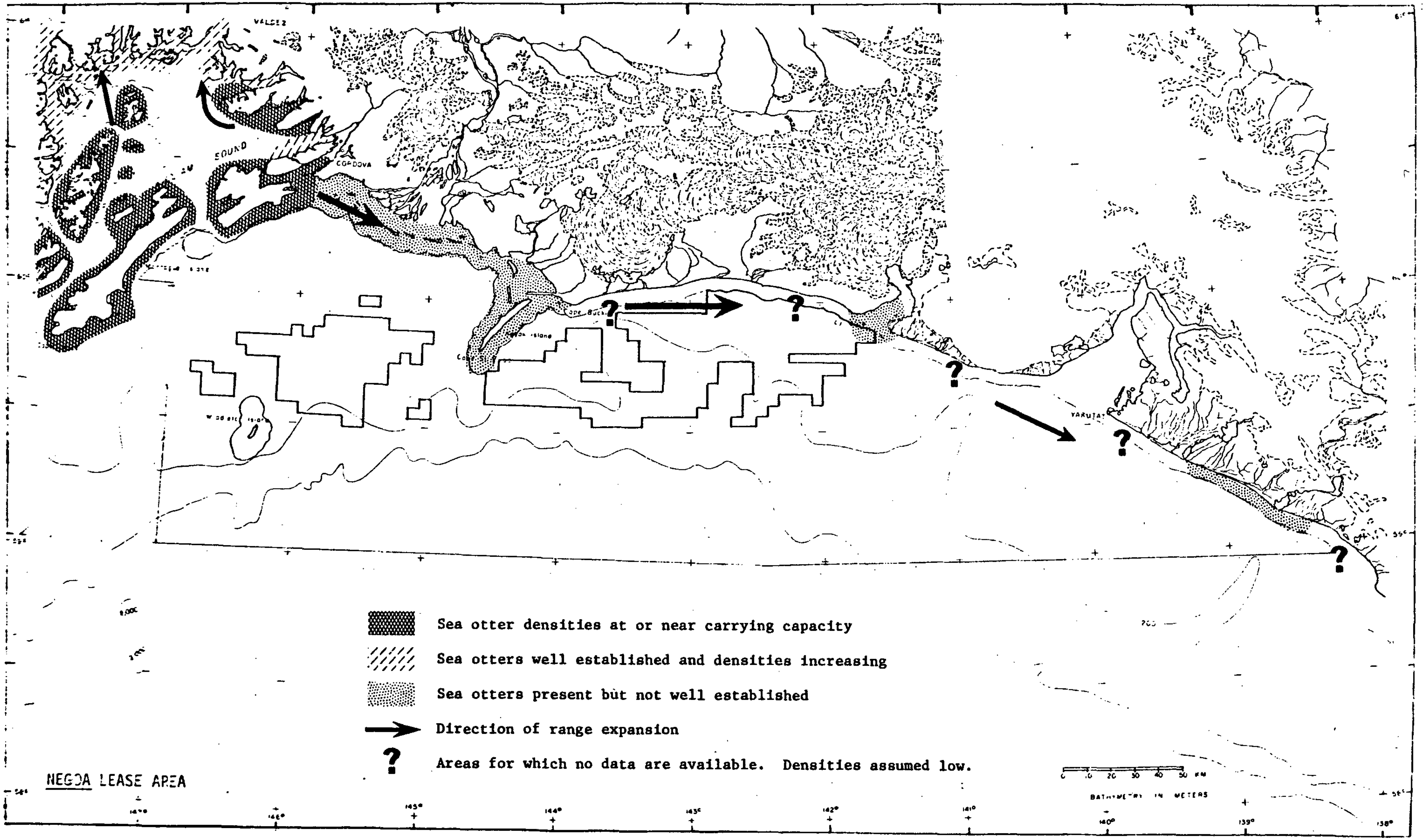


Fig. III-43. Distribution of sea otters in the Northeast Gulf of Alaska (prepared by K. Schneider).

dry weight/hr. in sediments. These data suggest that should an oil spill occur, the degradation potential in these sediment is much higher than in other Alaskan shelf areas. The microbial abundance, 1.9 x 10^5 cells/mℓ, in the water column was relatively low.

The average value for microbial abundance in the offshore water samples was 1.7 x 10^5 cells/mℓ, lower than 2.2 x 10^5 cells/mℓ found in the nearshore water. The V_{max} potential of the microbial populations in the water column averaged 1.4 ng glutamic acid/ℓ/hr. offshore and 63.0 ng glutamic acid/ℓ/hr. in the nearshore waters. These data suggest that the potential for crude oil degradation may be higher along the beach than in open waters. These potentially higher rates of microbial activity would undoubtedly be more than offset by the fact that crude oil floating on the surface would tend to collect along the shoreline.

Trophic Relationships and Potential Contaminant Transport Pathways Through Food Webs

Zooplankton in the Northern Gulf of Alaska are dominated by copepods, euphausiids, amphipods, chaetognaths, and pteropods. Only a few species in these taxa are responsible for the majority of transfer and conversion of matter and energy within the ecosystem. Copepods are particularly important because of their numerical abundance and contribution to the zooplankton biomass. Zooplankton biomass on the shelf and in Prince William Sound appears to be greater than in oceanic waters. Three species of large copepods in the area, *Calanus cristatus, Calanus plumchrus,* and *Eucalanus bungii bungii,* show ontogenetic seasonal migration as they are found in the epipelagic zone principally during spring and summer. These species, when present, constitute a large fraction of total zooplankton biomass (stage V copepodite sizes vary from 6 to 10 mm). Few species such as *Metridia* spp., *Euchaeta elongata* (copepods), *Thysanoessa longipes* (euphausiid), and *Cyphocanis challengerii* (amphipod) are diel vertical migrators and are found in the surface layer, primarily at night. *Acartia longiremis, Oithona similis,* and *Pseudocalanus* sp. (all small copepods) and *Sagitta elegans* (a carnivorous chaetognath) are found in large numbers in the upper 50 m (Damkaer, RU #156B, 1976). All of these species constitute an important fraction of juvenile and larval fish in coastal and oceanic areas in the northern Pacific Ocean.

Larvae of shrimp, molluscs, and king, Tanner, and Dungeness crabs are released in coastal waters of less than 100 m depth in spring. From April to August these larvae reside in the plankton and are important components of the zooplankton community and the planktonic food web (Fig. III-30).

Copepods are consumed by a variety of commercial and forage fishes and baleen whales (Fig. III-30 and Table III-23). Mainly through forage fishes, matter and energy stored in copepods are also transferred to marine birds. Euphausiids and amphipods are eaten by fishes, whales, and birds. Shearwaters are one of several major predators on euphausiids. These birds number in the tens and perhaps hundreds of millions in the Gulf of Alaska each summer (Guzman, RU #239, 1976; Lensink and Bartonek, RU #337, 1976), and feed mainly on euphausiids. The shearwater population probably consumes hundreds or thousands of metric tons of euphausiids per day (cf. Ainley and Sanger 1976 and Sanger, RU #77, 1976). Diets of important forage fishes such as pollock and herring also consist largely (up to 70%) of euphausiids.

Marine birds and mammals are dependent, either directly or through trophic transfers, upon planktonic and benthic communities. Species such as baleen whales, shearwaters, tufted puffins, and small alcids feed directly upon zooplankton, and also eat planktivorous fishes, squid, and micronekton. Sea otters and diving ducks feed on benthic invertebrates and fishes in the littoral zone, both subtidal and intertidal. Shorebirds prey on infaunal and epifaunal invertebrates in the intertidal and splash zones, and upon zooplankton stranded on the beach. Sea lions, harbor seals, and pigeon guillemots eat mainly benthic fishes and invertebrates but also prey on pelagic forms. Fur seals take pelagic and benthic fishes and an occasional seabird. Highest level marine predators in NEGOA are bald eagles, killer whales, and man. Bald eagles feed mainly on seabirds and carrion but also eat pinniped pups and placentae, fish, and land animals. Killer whales prey on fishes, squid, pinnipeds, whales, and porpoises (see Table III-23 and Fig. III-30). Principal prey species of a particular predator vary from area to area, probably depending

TABLE III-23. Trophic Relationships of Major Marine Organisms in NEGOA.

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

TABLE III-23 (continued)

RECEPTORS DONORS	Pelagic invertebrates†	Salmon	Dolly Varden	Pacific herring	Lingcod	Atka mackerel	Greenling	Pacific hake	Pacific cod	Pollock	Sablefish	Pacific halibut	Arrowtooth flounder	Starry flounder	Flathead sole	Rock sole	Rex sole	Dover sole	Pacific ocean perch	Other rockfish	Eulachon	Capelin	Smelt	Chub mackerel	Jack mackerel	Pacific sand lance	Sculpins	Sharks	Other fish	Commercial catch	Foreign catch	Sport catch	Sperm whale	Belukha whale	Killer whale	Sei whale	Humpback whale	Minke whale	Fin whale	Gray whale	Dall porpoise	Harbor porpoise	Fur seal	Sea lion	Harbor seal	Sea otter	Land otter	Bears, foxes, wolves Gulls	Terns	Puffin	Bald eagles	Cormorants	Scaup	Goldeneye	Oldsquaw	Steller's eider	Common eider	Scoters	Black Oystercatcher	Dunlin/Sandpiper	Black-legged kittiwake	Common Murre	Pigeon guillemot	Murrelets	Shearwaters	Albatrosses	Parasitic jaeger	Auklets	Fulmar
Carrion																																																x			x																		x
Garbage																																																x																		x			x
Misc. Seabirds																																					x						x								x									x									
Sea lions																																			x																x																		
Seals																																			x																x																		
Porpoises																																			x																																		
Small whales																																			x																																		

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

[†] Pelagic invertebrates includes: Combjellies, Arrowworms, Jellyfish, Squid.

[††] Other forage fish includes: Smelt, Saury, Prickleback, Poachers, Zoarchids, Myctophids, Eelpout, Ronquil, Lanternfish.

[**] Benthic invertebrates includes: Annelids, Marine Worms, Polycheates, Worms, Worm larvae, Brittle star.

mainly on availability (e.g., see Fig. III-44).

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

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

Filter feeders, such as pelecypods, filter oil from contaminated waters and may retain it in their body tissues for considerable periods of time, perhaps for life (Wagner 1976). This problem is confounded by the fact that, at least in some cases, petroleum pollutants may degrade very slowly and last in bottom sediments for years, providing a persistent source of contaminants (Blumer and Sass 1972).

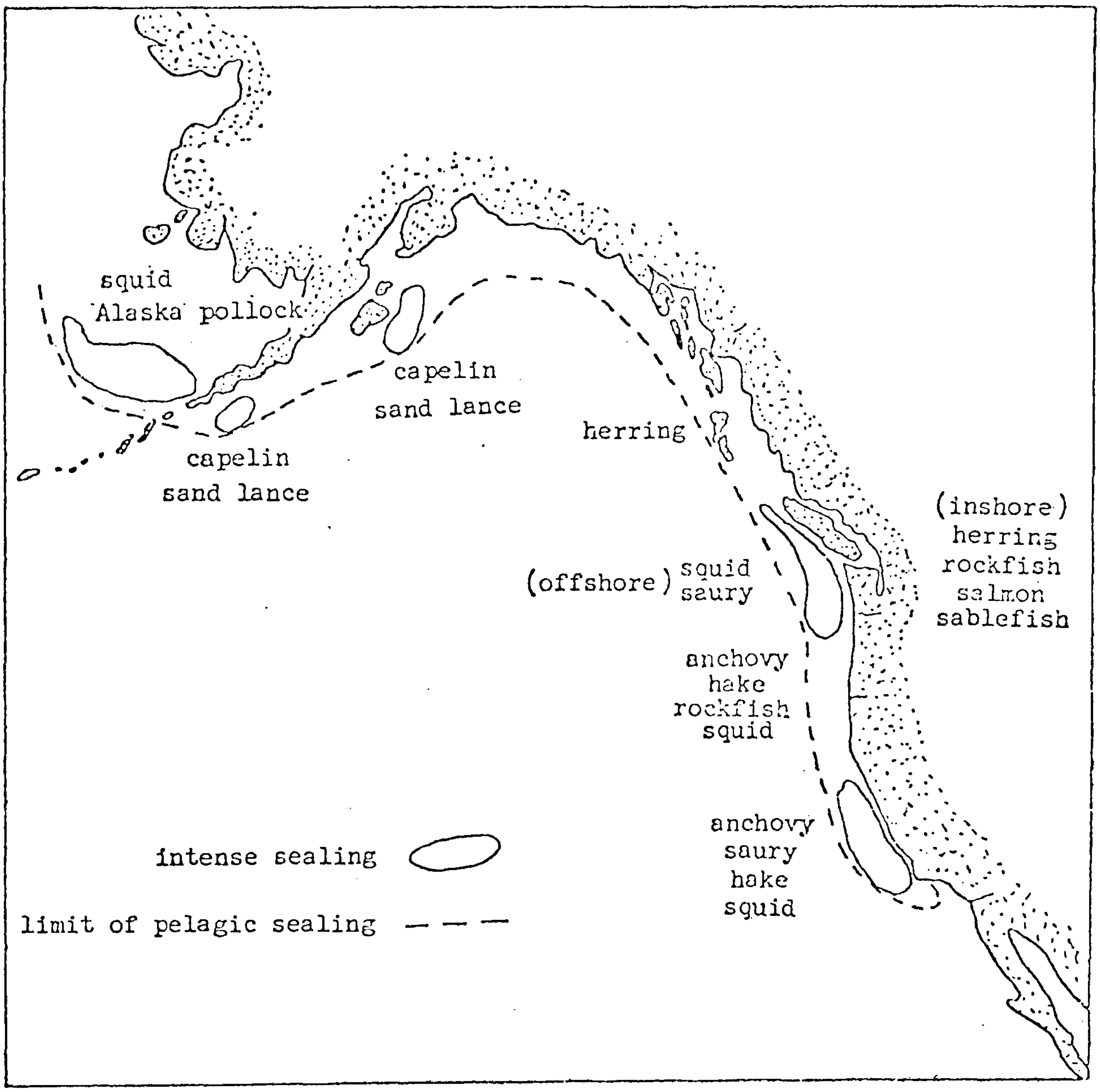

Fig. III-44. Dominant species from fur seal stomachs collected in the eastern North Pacific Ocean (from Trumble 1973).

CHAPTER IV

IMPLICATIONS OF OIL-RELATED IMPINGEMENT ON THE ENVIRONMENT

The possible effect of environmental contamination by oil on important regional biota were discussed in order to evaluate the level and type of habitat disturbance and insult that could be tolerated and to estimate potential recovery rates of affected populations. A basic problem in answering such questions is the degree of confidence that can be placed on the estimates. For example, if a resident biotic population size is not known within a factor or two, possible effects of the loss of 50% of this population cannot be evaluated. Furthermore, the effects of natural mortality and fishing pressure on commercial species should also be considered. Except for a few species, these effects are virtually unknown. An overall conclusion of the synthesis meeting was that precise estimates of the population loss and recovery potential could not be made. It was also stated that there was a need to consider changes in the physical-chemical state of oil in and on water when attempting to predict its effects on regional biota. The processes largely responsible for changes in oil state and composition are evaporation, dissolution, emulsification, oxidation, microbial degradation, and interaction with suspended sediment. A review of spilled oil behavior in the sea is given in a NOAA Special Report on ARGO MERCHANT oil spill (NOAA 1977).

DISPERSION, WEATHERING, AND ECOLOGICAL IMPLICATION OF SPILLED CRUDE OIL

In the event of a well blowout or tanker accident it is important to consider not only the potential trajectory of the spilled oil but also its physical weathering and biological degradation. In the event of an oil spill impingement on coastal habitats several days after its release, its physical-chemical state would have changed significantly from its original form.

Physical Processes

Spilled crude oil floats on seawater; it absorbs energy from small capillary waves and is pushed along over the ocean surface. The volatile fractions (C-10 or less) rapidly evaporate:

- "The half life of a C-8 hydrocarbon component in a slick on the ocean is about two hours." (Button 1975)
- "Evaporation effectively removes components smaller than about C-12 within 8 hours." (Kinney *et al.*, 1969).

Turbulent mixing through wind and wave action increases the processes of emulsification, dissolution, and dilution. This is the most critical variable in dispersing an oil slick. Immediately beneath the slick dissolved oil concentrations or parts per million or parts per billion are typical. At water depths of 10 m this drops to parts per trillion, at or below ambient levels.

Shaw (RU #275, 1977) reported that glacially derived rock flour washed with H_20_2 took up at most 20.1% and more commonly less than 1% of the dissolved biphenyl from the water (salinity = 35 ^{o}/oo or 0 ^{o}/oo). Increasing the concentration of biphenyl in water increased the percentage associated with sediment only when biphenyl was present in excess of its solubility. Shaw further points out that biphenyl particles when present and their association properties are probably quite different from dissolved biphenyl.

However, these data do not imply that particulate matter would not play a significant role in transporting floating oil to the sea floor in the NEGOA region. Cline and Feely (PMEL, Seattle, pers. comm.) indicate that, in their experiments, Cook Inlet glacial sediment removed significant quantities of Prudhoe Bay crude oil from contaminated sea water.

A major limitation in the prediction of spilled oil trajectories is the sparse knowledge of differential velocities of oil and surface water, particularly with reference to wind intensity and direction. There is practically no field data base. Few such measurements were made off Nantucket Island after the ARGO MERCHANT accident December 15, 1976, which resulted in a large spill of No. 6 fuel oil. Preliminary results indicate that at wind speeds of 10 knots from 250°T, the differential velocity was equal to 1.1% (±0.1%) of the wind speed. Mean surface current velocity was 1.6 knots (±5 to 10%). On another occasion differential oil/water velocity was 1.1 to 1.2% wind speed. Wind speed was 17 knots and surface current velocity was 1.3 knots (NOAA 1977). In the model runs to simulate oil-slick drift, it was assumed that the wind induced a surface drift in the direction of the wind at 3.5% of the wind velocity. This drift was accounted for by about 1.5% for the wind-induced water motion and about 2.0% for the relative oil-to-water motion. These models were generally successful in depicting the direction of drift in the open water offshore. Transport was dominated by winds. However, in areas with complex coastal morphology and dominant advective field, complex, but largely unknown, behavior and transport patterns of spilled oil are anticipated. Much of the available data on the weathering and behavior of oil slicks is presently being reviewed and synthesized by Mattson (RU #499).

Chemical Processes

Crude oil is a complex and highly variable "soup." Some of its primary constituent include alkanes, alkenes, aromatic (including naphthenic compounds), asphaltines, tars, sulphur and nitrogen based compounds, trace metals, and complexes of all of these. Each of these groups behaves differently and much remains to be learned of their weathering behavior and breakdown rates.

Photo-oxidation acts primarily on aromatic ring hydrocarbons (ring compounds) breaking them into straight chain aliphatic hydrocarbons. Chemical oxidation and low temperature cracking can also break down large hydrocarbon molecules (Cline and Feely, RU #153, 1976).

Biological Processes

"Biodegradation of crude oil is essentially the incorporation of hydrocarbons into microbial oxidative pathways" (Button 1975). Suitable heterotrophic populations must be present, of course, along with sufficient nutrients. Population levels of $10^5/\ell$ for yeasts, actinomycetes and bacteria are fairly typical. Addition of one gram of hydrocarbons can yield 10^{12} organisms (i.e., about one gram of bacteria). Simple C_6 - C_{12} straight chain aliphatic hydrocarbons are usually first to be attacked by heterotrophs.

Certain physical variables such as availability of suitable substrate surfaces and the diffusion rates of both nutrient and hydrocarbon substrates may slow down the rate of bacteria degradation.

Button (personal communication) suggested that the heterotrophs probably do not become nutrient limited (phosphorous) until bacterial concentrations of $10^{10}/\ell$ are reached. Molecular diffusion is temperature controlled and may be rate limiting. The ultra-violet component of sunlight can kill many bacteria.

There is also some evidence (Morita and Griffiths, RU #190-E, 1977) that hydrocarbons may be toxic to certain bacteria. For example, Prudhoe Bay crude oil may inhibit production of the enzyme chitinase in certain chitinoclastic bacteria.

EFFECT ON BIOLOGICAL POPULATIONS

Important (ecologically, economically, aesthetically) species at risk from oil contamination are listed in Tables IV-1 (zooplankton), IV-2 (benthic fauna: IV-2a for infauna and IV-2b for epifauna), IV-3 (fishes), IV-4 (birds), and IV-5 (mammals). As stated earlier, precise estimates of population damage and recovery rates after a 50% or 95% loss cannot be made. Population damage would be dependent on the level of habitat contamination, the nature of spilled oil at the time of impact, duration of exposure, and tolerance limits of individual populations. Table IV-6 summarizes discussions pertaining to population damage and recovery in the event of significant oil contamination, assuming that population mortality or damage would occur. All important species listed in Tables IV-1 to IV-5 were not considered due to the lack of relevant information. It should be emphasized that statements in Table IV-6 are mostly conjectural in nature and should be viewed as such.

TABLE IV-1

Tentative Summary of Principal Zooplankton Species Found in the Upper Pelagic Zone and Their Habitat Utilization (Cooney, RU #156D from NOAA, 1975).

Species	Areas of Peak Abundance	Season of Peak Abundance	Use of Area
COPEPODA			
Acartia longiremis	Nearshore and shelf regime	Summer & Fall	Feeding and reproduction
Pseudocalanus spp.	Nearshore and shelf regime	Summer & Fall	Feeding and reproduction
Oithona similis	All regimes	Fall & Winter	Feeding and reproduction
Metridia lucens	All regimes	Spring & Summer	Feeding and reproduction
Calanus plumchrus	All regimes	Spring	Feeding during late winter-summer
CHAETOGNATHA			
Sagitta elegans	No preference	Fall	Feeding and reproduction
EUPHAUSIACEA			
Euphausiid larvae	All regimes	Spring	Feeding
Euphausia pacifica	Slope	Winter	Feeding and Reproduction
DECAPODA			
Snow crab larvae	Nearshore and shelf	Spring	Feeding

TABLE IV-2a

Key species among the benthic infauna of the Northeast Gulf of Alaska: selection criteria and feeding types (Feder, Univ. Alaska, Fairbanks, Unpublished Data, 1977).

KEY SPECIES	SELECTION CRITERIA				
	Ubiquitous	Abundant	High Biomass	Ecologically Important	FEEDING TYPE*
Polychaeta					
Onuphis geofiliformis	X	X	X		DF
Lumbrineris similabris	X	X	X		DF?
Sternaspis scutata		X		X	DF
Heteromastus filiformis		X		X	DF
Asychis similis			X		DF
Pista cristata			X		DF
Mollusca					
Aplacophora					
Chaetoderma robusta		X		X	DF
Pelecypoda					
Nucula tenuis	X	X	X	X	DF
Nuculana pernula	X	X	X	X	DF
Yoldia sp.		X			DF
Astarte montequi			X		SF
Astarte polaris			X		SF
Axinopsida serricata	X	X	X		SF
Macoma calcarea			X		SF, DF
Scaphopoda					
Dentalium sp.		X			DF?
Crustacea					
Thoracica					
Scalpellum columbianum			X	X	SF
Echinodermata					
Asteroidea					
Ctenodiscus crispatus		X	X	X	DF
Echinoidea					
Brisaster townsendi			X		S
Ophiuroidea					
Unioplus macraspis		X	X		DF
Ophiura sarsi		X	X		P, DF
Holothuroidea					
Molpadia sp.			X	X	DF

*DF = Deposit Feeder, SF = Suspension Feeder, S = Scavenger, P = Predator

TABLE IV-2b

Key Species among the Benthic Epifauna of the Northeast Gulf of Alaska (Feder, Univ. Alaska, Fairbanks, Unpublished Data, 1977).

	SELECTION CRITERIA				
KEY SPECIES	Ubiquitous	Abundant	High Biomass	Ecologically Important	Commerical Catch
Molluscs:					
Fusitriton oregonensis (snail)	X			X	
Neptunea lyrata (snail)	X			X	
Patinopecten caurinus (scallop)	X			X	X
Arthropods:					
Chionoecetes bairdi (Tanner crab)	X	X	X	X	X
Lopholithodes foraminatus (box crab)			X	X	
Pandalus borealis (pink shrimp)	X		X	X	X
Echinoderms:					
Ctenodiscus crispatus (sea star)		X	X	X	
Ophiura sarsi (brittle star)	X	X		X	
Cucumariidae (sea cucumber)			X	X	

TABLE IV-3

List of Important Fish Species in the Northern Gulf of Alaska (Compiled by SAI from various sources cited in the text).

Species	Rationale
Anoplopoma fimbria Sablefish	Commercial catch
Ammodytes hexapterus Pacific sand lance	Major forage species; abundance
Clupea harengus pallasi Pacific herring	Major forage species; abundance; intertidal spawner; commercial catch
Cottidae Sculpins	Major forage species
Gadus macrocephalus Pacific cod	Commercial catch
Theragra chalcogramma Walleye pollock	Commercial catch, abundance; forage species
Pleurogrammus monopterygius Atka mackerel	Commercial catch
Hypomeus pretiosus Surf smelt	Major forage species; abundance
Mallotus villosus Capelin	Major forage species; abundance; intertidal spawner
Osmerus mordax Rainbow smelt	Major forage species; abundance; intertidal spawner
Thaleichthys pacificus Eulachon	Major forage species; abundance
Atheresthes stomias Arrowtooth flounder	Abundance; commercial catch
Hippoglossoides elassodon Flathead sole	Abundance; commercial catch
Hippoglossus stenolepis Pacific halibut	Commercial catch
Platichthys stellatus Starry flounder	Abundance
Oncorhynchus gorbuscha Pink salmon	Commercial catch; abundance
O. keta Chum salmon	Commercial catch; abundance
O. kisutch Coho salmon	Commercial and sport catch
O. nerka Sockeye salmon	Commercial catch
O. tshawytscha Chinook salmon	Sport catch
Salmo gairdneri Steelhead trout	Sport catch
Salvelinus malma Dolly Varden	Abundance, sport catch
Sebastes alutus Pacific Ocean perch	Commercial catch
Glyptocephalus zachirus Rex sole	Abundance; commercial catch
Microstomus pacificus Dover sole	Abundance; commercial catch

TABLE IV-4

Key Species of Water Birds in NEGOA
(Compiled by SAI from Synthesis Meeting Inputs).

	Selection Criteria		
	One of the most abundant bird species in NEGOA	High vulnerability to oil on the sea	Significant proportion of total species population breeds in NEGOA
Puffinus griseus Sooty shearwater	X	X	
Oceanodroma furcata Fork-tailed petrel	X		
Olor buccinator Trumpeter swan			X
Branta canadensis occidentalis Dusky Canada goose			X
Anas acuta Pintail	X		
Aythyinae Seaducks		X	
Ereunetes mauri Western sandpiper	X		
Lobipes Lobatus Northern phalarope	X		
Rissa tridactyla Black-legged kittiwake	X		
Uria aalge Common murre	X	X	
Alcidae Other alcids		X	

TABLE IV-5

Key Species of Marine Mammals in NEGOA
(Compiled by SAI from Synthesis Meeting Inputs).

	Selection Criteria				
	Endangered species	High vulnerability to oil	Major summering ground in NEGOA	Most or all of population migrates through NEGOA	Relatively abundant, year-round resident
Enhydra latris Sea Otter		X			X
Eumetopias jubatus Steller sea lion					X
Callorhinus ursinus Fur seal		X		X	
Phoca vitulina Harbor seal					X
Eschrichtius gibbosus Gray whale	X			X	
Balaenoptera physalus Fin whale	X		X		
Balaenoptera acutorostrata Minke whale			X		
Megaptera novaeangliae Humpback whale			X		
Orcinus orca Killer whale					X
Phocoenoides dalli Dall porpoise					X
Phocoena phocoena Harbor porpoise					X

TABLE IV-6

Population Reduction and Recovery Estimates After
Oil-Related Impingement
(Compiled by SAI from Synthesis Meeting Inputs)
mostly conjectural

Plankton	Plankton within the surface layers of the area traversed by a major slick might well be killed; however, once the oil had dispersed, comparable plankton populations from adjacent areas would soon be carried into the affected region. The nature and extent of the effects of oil contamination on plankton primary productivity has not been established.
Benthic and Intertidal Invertebrates	Major natural disasters such as the Katmai volcanic eruption and ash fall of 1914, the great Alaska Earthquake of 1964, and the 1976 red tide in Saide Cove, Kachemak Bay have each killed off major portions of local benthic floras and faunas. Many benthic plants and animals possess motile larval stages capable of being transported considerable distances. Successful establishment will depend on the availability of suitable unpolluted substrates. Continuing research suggests that such denuded areas are recolonized within a decade. Intertidal and shallow subtidal species of particular concern include those taken in large numbers by birds: *Macoma*, *Mytilus*, *Mya*, *Nuculana*, and other dominant bivalves. *Musculus* occurring in dense beds to water depths of 30-40 m is a key food species for sea stars, greenling, and sea otters. Based on results from a study on butter clams, a fairly long rate of recovery was indicated. It was stated that population recovery of the mussel *Mytilus* sp. took about 10 years after the 1964 earthquake.
Fish	Species subject to extensive commercial fisheries are harvested every year and their numbers significantly reduced. Provided harvests remain at or below maximum sustainable yields these populations continue to maintain an optimum size. Species subject to the greatest risks are those whose adults or juveniles aggregate in shallow-water habitats. In nearshore rocky reef areas, particularly in spring and summer, these would include greenling, herring, rockfish, and salmon. In quiet waters characterized by soft sediment bottoms they would include flatfish and gadids. Herring mortality from egg to adult stage is usually in excess of 99%, predominantly during the egg and early

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TABLE IV-6 (continued)

	larval stages. Depending upon the timing of the impact, recovery may be essentially instantaneous or it may be several years before full recovery. If the adult salmon population is reduced to 25% or 50% of the present levels, the return to normal would require two to eight years depending on the species. Commercial fishing impacts the populations by this level each year, and the stocks are able to maintain maximum yields with this degree population loss. If the juvenile population is reduced by 75% or 50% the recovery may be longer. However, significant mortalities do occur to the juvenile salmon before they mature. The effect may be mitigated through reduction in the fishing mortality. If both the adult and juvenile age classes were reduced to 50% of present levels, then recovery would be extremely slow. It is also possible that some races would never recover.
Birds	For the majority of seabirds (e.g., alcids, larids, cormorants) oil spill impacts would be seen more in offshore feeding areas than onshore breeding grounds. These seabirds apparently vary greatly in their terms of recolonization potential: Alcids such as crested auklets occupy long-standing ancestral breeding colonies. Even when heavily preyed upon, as crested auklets are by foxes at Shumagin Island colonies, they show no evidence of starting new colonies. Gulls and terns on the other hand are more opportunistic, readily settling in new colonies. Storm petrels represent a still different case. They appear to have already colonized all suitable nesting sites, thus any disturbance or loss of these areas will probably result in reduced nesting populations. In all cases, if a single year class were wiped out, it would probably be several years later before an overall population reduction was noted. Groups of birds that might be severely compromised by impingement of major oil slicks on the shoreline include the following: cormorants that roost along rocky shores, as on Middleton Island; oyster catchers and pigeon guillemots that feed around rocky intertidal and nearshore areas; shorebirds that use the sandbars and mudflats of the Copper River Delta as a major feeding and staging area during their spring and fall migrations; scoters and other seaducks that feed in protected bays and coastal shallows; bald eagles that are known to feed extensively on dead fish washed onto ocean beaches.

- continued -

TABLE IV-6 (continued)

	Population recovery will also be dependent on factors currently limiting natural increase in population size. For example, in a species whose productivity (population fecundity) is limited by shortage of nesting sites, a 25% reduction in population size might not affect productivity at all, in which case recovery could be very rapid. A population under independent density control would likely recover more slowly. Recovery rate also depends on reproductive potential, e.g., a murre pair can raise a maximum of one young in a year compared to cormorants which can raise up to five young in a year.
Mammals	Sea otters and fur seals are known to be highly susceptible to oil pollution; coating of oil on their skins affects their regulatory mechanism. Their population recovery rates are not well known. Calkins estimated that it may be 20 years if the present population of sea otters was reduced by 50%. The time span required to totally repopulate the area to its current population was 65 years (1911-1976). Similar information on other mammals is presently lacking.

CHAPTER V

RESEARCH NEEDS

Participants to the synthesis meeting were also asked to identify major gaps in knowledge and provide input to future research plans. A large number of gaps in data and scientific knowledge were suggested. All reported research needs are listed as they comprise the "wish list" of meeting participants. A few of these, such as the seasonal distribution of cetaceans and pinnipeds, are of a very broad scope, whereas others (such as the determination of the probability of impingement of Copper River Delta intertidal zone by oil spill) are quite specific. A considerable amount of research efforts, facilities, and funding will be required to address and bridge these data gaps. On the basis of the listed data gaps and discussion among meeting participants, the needs and suggested rationale for future OCSEAP research in the Northern Gulf of Alaska are outlined below.

PHYSICAL OCEANOGRAPHY

As a result of OCSEAP investigations, a general understanding of the physical oceanographic processes in the NEGOA lease area and adjoining ocean waters has been achieved. Additional data currently being obtained and analyzed as FY 77 Transport studies will help integrate and complete various aspects of research, especially in offshore waters. A shift in emphasis in field data collection from offshore to nearshore is now underway. Presently, there is only a limited knowledge of nearshore circulation and dynamics. The primary purpose of the proposed nearshore circulation and mixing studies would be to identify key circulation features that might retain or transport water-borne contaminants into critical habitats. Additionally, this knowledge would help verify model-generated nearshore pollutant trajectories.

DATA GAPS IDENTIFIED IN THE SYNTHESIS MEETING

1. Knowledge of seasonal variation of both the circulation and biota is incomplete.
2. Nature of the circulation in Prince William Sound, especially flow regime at Hinchinbrook Entrance.

3. Identify importance of gyres west of Kayak Island.
4. River discharge data are needed east of Kayak Island and at Copper River mouth so that sediment fluxes could be estimated.
5. Surficial sediment dynamics and features.
6. Nearbottom water circulation patterns, sediment transport processes.
7. Seasonal variation of micronutrient distribution is unknown.
8. Relationship of meroplankton to holoplankton in the area, seasonal changes.
9. Benthos:
    a. Seasonal data on suspended sediment load in Prince William Sound.
    b. Settling rates of sediments and where sediments are coming from and going to; resuspension data on seasonal basis.
    c. Ability of sediments to sequester oil.
    d. Amount of organic carbon available in sediments - bacterial biomass - turnover rates.
    e. Carbon flow from sediments to infauna and epifauna and eventually to the water column.
    f. Benthic diatom population information.
    g. Meroplankton - what is thereon seasonal basis? Recruitments of some of these organisms.
    h. Overall trophic relationships.
10. Life stages of commercially important invertebrates.
11. Tanner crab life histories; population sizes, frequency distribution, food habits.
12. Migratory routes of salmon, distribution.
13. Influence of physical and chemical factors to salmon migration and life history.
14. Winter distribution of birds east of Kayak Island.
15. Marine mammals -- distribution and abundance of cetaceans and pinnipeds, especially seasonal coverage.
16. Probability of physical impingement on Copper River Delta intertidal zone.
17. Disturbance to bird habitat from placement of platform sites and helicopter traffic.
18. Persistence of oil in Barrier Islands -- efforts on coastal vegetation which influence several bird species.
19. Susceptibility of Tanner and Dungeness crab and shrimp to oil.
20. Potential rates of biodegradation of oil.
21. How is microbial function affected by presence of crude oil?

Continued drift buoy tracking studies are still needed in the general NEGOA area as seasonal coverage has been limited to summer season only. Gyres and eddy-like features, observed west of Kayak Island, may be only weakly developed in winter. Continued development and stimulation of modeling of particle trajectories with observed and stochastic wind data, observed and inferred property distributions, and observed and interpolated current meter data, are expected to provide refined and more realistic information about possible contaminant trajectories. Additional modeling studies are expected to incorporate existing and proposed sub-models to stimulate the physical state and chemical nature of oil slicks along and at the end of trajectories. Quantitative nearshore meteorological data and correlations between synoptic and local wind fields are needed to improve our understanding of mesoscale meteorological processes and to provide input to contaminant trajectory and circulation models.

From the data and information obtained so far, it is apparent that two regions, Kayak Trough and Hinchinbrook Entrance, represent key localities where water transported contaminants may be retained or deposited. Both of these locations are outside the proposed lease area but are expected to receive contaminants discharged upstream. The gyre or eddy-like features are present west of Kayak Island virtually all of the time in summer, although the position and details of the patterns are varied. During periods of low runoff, i.e., winter, it is possible that the gyre formations would be less developed. A program of research for this general area (from Kayak Island to the Hinchinbrook Entrance) including hydrographic measurement, buoy trajectories, and current meter measurement is needed to establish seasonal patterns and norms of the complex flow characteristics.

BIOLOGY

Both the seasonal and spatial coverage of plankton data are inadequate at present. Zooplankton and micronekton data obtained in 1974-75 by Cooney (RU #156-D) have provided useful information of seasonal abundance of principal species. Statistical analyses of zooplankton data (the number of observations were very few) have shown that the number of samples needed to detect population differences larger by a factor of 1.5 requires from 20 (for *Euphausia pacifica*) to 231 (for *Metridia okhotensis*) samples per regime (broad geographical areas such as shelf, slope, Prince William Sound). The number of samples required to detect population differences larger than an order of magnitude is from 1 to 7 per regime. It is apparent that a very large sample size will be required to detect small changes in zooplankton populations. More research on population dynamics of meroplankton, especially the larvae of the commercially important shellfish, is needed. Because of the already available primary productivity and zooplankton data and relatively easy accessibility and simpler logistic requirements, Prince William Sound may be an ideal location to study seasonal plankton distributions and dynamics, especially with reference to zooplankton growth and utilization by carnivores.

Broad reconnaissance surveys of both littoral and offshore benthic communities have been completed in the Northern Gulf of Alaska. Spatial coverage remains incomplete (Tarr Bank fauna is virtually unknown) and seasonally balanced data are not yet available. Trophic relationships for selected macrofauna species in a very few areas can be formulated, but potential pollutant pathways through the food web cannot be ascertained. The relative contributions of phytoplankton and macrophytes to both primary production and the role of detritus in food webs should be assessed, as should the vulnerability of larval stages to pollution. Data on the meiofauna and microfauna (including bacteria) are still lacking. The greatest immediate need is for increased information on the nearshore zone. This is the area most likely to be impacted by oil slicks driven ashore. It is also a very dynamic zone -- both in terms of wave and current action and in terms of its continually changing biological populations. The benthic studies proposed for FY 78 will provide more site-specific studies and complete a reconnaissance of the nearshore zone. Multispectral scanning of the littoral zone will also permit mapping of intertidal algal communities.

There is little information available on migration, spawning, and feeding for most nearshore fish populations in the NEGOA lease area. Among the important species, seasonal distribution and population dynamics of salmon, herring, sand lance, and smelt are not well known. This is an extremely important omission in view of possible oil spill impingement in the Copper River Delta and parts of Prince William Sound and the very high economic value of salmon and herring. Information is particularly lacking for the Cape Suckling to Yakutat Bay region. Knowledge of the population size and dynamics of the commercially important as well as abundant forage species is currently inadequate. Such data are needed throughout the NEGOA region. Due to the high concentration of starry flounder, the Icy Bay region should be of particular interest.

At this time, there is not enough data available on the seasonal changes in the concentration and activity of heterotrophic bacteria of this region to make a reasonable estimation of the effect of crude oil on indigenous microflora. No data are available on potential *in situ* rates of crude oil degradation. Data are also lacking on critical microbial functions which might be altered by crude oil pollution. Estimates of this nature are essential to the assessment of potential effects of oil and gas development on the Alaskan OCS. Such studies should be concentrated in areas identified as critical to OCS oil and gas development.

The pelagic distribution and abundance of marine birds in NEGOA in winter is poorly known, particularly for regions east of Kayak Island, including the oil lease sites. Data are also lacking on distribution of foods and on other parameters influencing the distribution and abundance of marine birds. Although food habits of several species are reasonably well known from stomach content analyses (mainly from areas outside of NEGOA), what these habits mean in terms of population, community and ecosystem dynamics is poorly understood (cf. Ainley and Sanger 1976).

Sea lions from the western Gulf of Alaska winter in NEGOA and Prince William Sound but the magnitude of such seasonal movements is not known. It is important to determine, for example, the extent to which sea lion populations that breed in the large rookeries on Kodiak and the Barren Islands depend upon NEGOA and Prince William Sound for winter subsistence and survival. The extent to which sea otters in NEGOA undergo seasonal movement likewise is not known. Seasonal distribution and abundance of cetaceans in NEGOA and Prince William Sound are even more poorly known than for otters, sea lions, and birds.

GEOLOGIC HAZARDS

OCSEAP studies have already yielded excellent basic information on the geologic hazards of the area, including the location of potentially unstable substrates, probable active faults, and areas of erosion and deposition on the shelf. A major data gap exists for nearshore subtidal environments which are either unsuitable or too shallow for shipboard data collection work yet beyond the scope of shore based studies. Erosion and deposition are often intense in this zone. This information gap will be addressed in FY 77-78 when geologic hazard studies will focus on inshore sites (critical areas for pipelines coming ashore, moving structures, and so on).

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APPENDICES

APPENDIX 1

LIST OF PARTICIPANTS
at
NEGOA SYNTHESIS MEETING

January 11-13, 1977
Anchorage, Alaska

APPENDIX 1

List of Participants at NEGOA Synthesis Meeting
January 11-13, 1977
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APPENDIX 2

DEVELOPMENT SCENARIO FOR THE NORTHERN GULF OF ALASKA OCS LEASE SALE

by

Tom Warren
The BLM/Alaska OCS Office

NEGOA Synthesis Meeting
January 11-13, 1977
Anchorage, Alaska

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INTRODUCTION

A Federal action, which was designed to meet the Department of the Interior's objectives for the management of marine minerals, was the sale of oil and gas leases in the Northern Gulf of Alaska (Figure 1). Seventy-six tracts of OCS land were leased April 13, 1976. The tracts are located offshore in a coastal arc between Icy Bay and Kayak Island with distance from shore ranging from 3 to 30 miles. The tracts are situated in water depths that range from approximately 60 meters to 180 meters.

PURPOSE

The purpose of this paper is to examine the petroleum development scenario as it was described in the Northern Gulf of Alaska FEIS and subsequently modified by the actual lease sale and actual exploration activity. The information in this scenario may be used to help allocate baseline study resources. It is necessary to clarify the assumptions and meaning of our development scenario. The method elected to develop the scenario revolves around the concept of the petroleum scenario which leads to a maximum impact assessment.

The resource and production assumptions are "high case" and made for the purpose of estimating maximum impact. This leads to an analysis of maximum resource conflict and/or competition. This specific intent in maximizing the potential impacts reduces the value of the scenario for planning purposes because it is not the "most likely case" and therefore not a prediction or forecast of the future. However, the spatial expressions of human activity described here are considered reasonable within a broad range of resource and production assumptions.

Tom Warren is a staff economist with the Alaska Outer Continental Shelf office, Bureau of Land Management, Department of Interior.

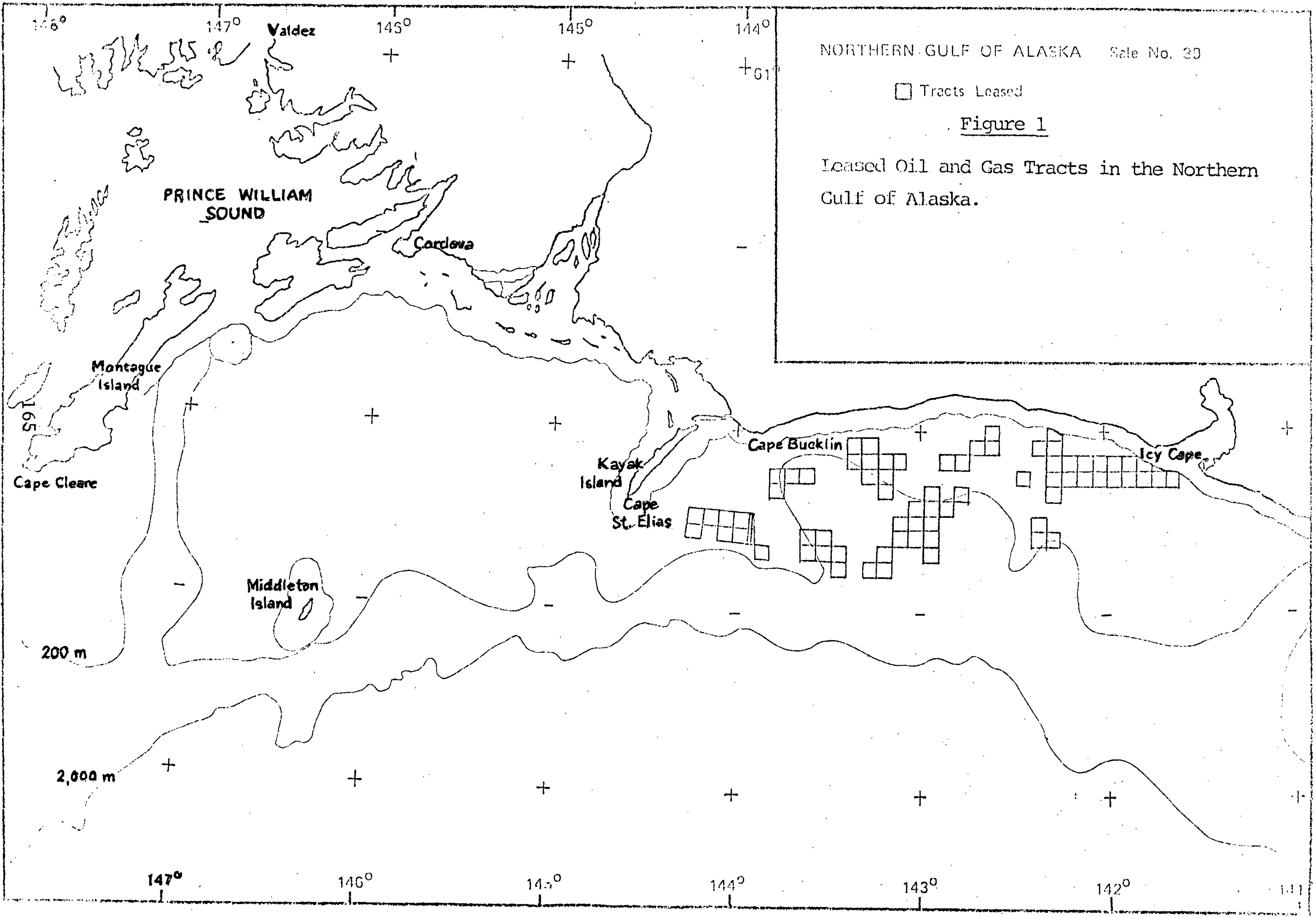

Figure 1

Leased Oil and Gas Tracts in the Northern Gulf of Alaska.

THE HIGH CASE PETROLEUM DEVELOPMENT SCENARIO

Petroleum develpment in the Northern Gulf of Alaska depends in large part upon the volume of recoverable oil and gas resources, current technology, economic incentives, and the availability of capital, manpower, and equipment. Because the sale was the first ever held on the Alaska OCS, and because historical data is not available, detailed information useful for projecting future production activities is lacking. The resource supply and production and development timetable assumptions which follow are based on interpretation of geologic data and the anticipated development requirements.

Our scenario will be presented keeping two ideas in mind. The resource estimates and development assumptions are those as presented in the Northern Gulf of Alaska FEIS. Although exploration activity is underway, little or no basis exists upon which to meaningfully refine these development assumptions. But, because exploration is in progress, the FEIS scenario is here modified with actual sale data and known exploration activities.

NORTHERN GULF OF ALASKA FEIS SCENARIO

Resource Supply And Production Assumptions

The scenario assumes the sale area would produce 2.8 billion barrels of oil and 9.0 trillion cubic feet of gas.

The estimated peak volume of crude oil produced would be 548,000 bbls/day or 200,000,000 bbls/year, and the peak gas production would be 465 million cf/day or 330 billion cf/year.

Development Timetable Assumptions

- Exploratory drilling would begin the year after leases are issued and would be completed at the end of the seventh year.
- Onsite platform construction and installation would begin during the fifth year after the lease sale and continue through the tenth year.
- Peak oil production would occur 10 to 11 years after the lease sale.
- The life expectancy of each of the 7 oil and gas fields would be 25 years, and the last platforms would be removed about 40 years after production has commenced.
- At assumed peak production, 22 platforms would be required -- 18 oil platforms and 4 gas platforms.

- Exploratory wells would range from 70 to 100 and production wells would total 800, for a total of 870 to 900 wells. Of the 800 development wells, 640 would be platform wells and 160 would be subsea wells.
- There would be 7 to 14 major pipelines totalling 300 miles in length, of which 50 miles would be constructed onshore and 250 miles would be submarine.
- Of total annual production, 120 million bbls would be transported from production platforms to shore by pipeline and from shore storage to market areas by tanker. About 80 million bbls would be loaded from offshore terminals in the vicinity of the field for direct transport to market areas by tanker. Future pipeline management studies will delineate specific pipeline corridors. (Table 1).

Onshore Facilities Development Assumptions

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

In order to address biophysical and socioeconomic impacts of the sale, it is first necessary to qualify certain assumptions from within a framework of feasible alternatives. The sites shown on Figure 2 generally represent the ranges of feasible alternatives suggested by the U.S. Geological Survey and the Alaska OCS Office. This range of potential industrial sites is the assumed onshore development scheme and represents one conditional and qualified example of a possible development scenario. It is not intended to imply or suggest specific onshore development for the impact area, and should not be considered a prediction or forecast of the site-specific allocation of these facilities. Any regional development scheme and all site-specific facilities would be subject to all existing federal, state, and local regulations, land use plans, policies, or controls.

The location of support and supply facilities, crude oil terminal sites, and onshore production treatment facilities would depend mainly upon the location of production fields in relation to the physical environment. In actuality, support and supply facilities are located at Yakutat, Yakataga, Seward, and Anchorage. Potential onshore crude oil terminal and treatment

TABLE 1

Northern Gulf of Alaska Development Timetable

	Production		Exploratory Drilling (# of wells)	Development Drilling (# of wells)	Number of Platforms	Miles of pipe-line constructed (miles)	Number of Terminals	Number of LNG Plant
Year	Oil Mil bbls	Gas Bil cf						
1975			0					
1976			6					
1977			15					
1978			26					
1979			26					
1980			15		2	50		
1981	15		9	40	4	75	1	
1982	45		4	120	6	75	2	
1983	80	100		200	6	50	2	1
1984	120	260		220	2	50		
1985	185	330		180	2			
1986	200	330		40				
1987	200	330						
1988	195	330						
1989	185	330						
1990	175	330						
1991	165	330						
1992	155	330						
1993	145	330						
1994	135	330						
1995	125	330						
1996	115	330						
1997	105	330						
1998	95	330						
1999	85	330						
2000	75	330						
2001	65	330						
2002	50	330						
2003	40	280						
2004	30	260						
2005	20	190						
2006		130						
2007		40						
Total			100	800	22	300	5	1

sites (tanker terminals) are Yakutat, Icy Bay, Kayak Island, Katalla-Kanak Island area, Middleton Island, Montague Island, and Hinchinbrook Island. These latter sites assume potential future sales in these areas. For the purposes of this FEIS, three onshore loading, storage and treatment facilities are assumed with all other production going to the two offshore facilities. Three supply and staging facility areas are assumed. (Figure 2)

A summary of the above basic assumptions is listed in Table 2.

POTENTIAL LOCATIONS OF IMPACTS RESULTING FROM THE PETROLEUM DEVELOPMENT SCENARIO

Platform Sites

Geological and geophysical information which is available to the federal government is proprietary and not useable for making public inferences concerning the locations of assumed oil and gas resources. But obviously since exploratory activity has already begun and additional tracts are scheduled to be explored in the near future, the assumption of this scenario is that most of the assumed 22 platforms will be placed near these locations. (Figure 3)

Crude Oil Terminal Sites

It is assumed the most likely onshore crude oil terminal sites near the area already leased include Monti Bay and Icy Bay. Other sites to the west may be examined if future lease sales and discoveries are made in the Northern Gulf area. Offshore storage and loading facilities are considered possible. Gathering lines between platforms and trunk pipelines to terminal sites would have to be constructed. (Figure 3)

Production Treatment Facilities

Typically, initial production treatment is performed on board the production facility and final treatment accomplished at the terminal site. It is possible, however, given the distances between potential pipeline landfalls and onshore terminal sites, or other unique production, environmental, or economic constraints, that production treatment facilities may be located near pipeline landfalls. (Figure 3)

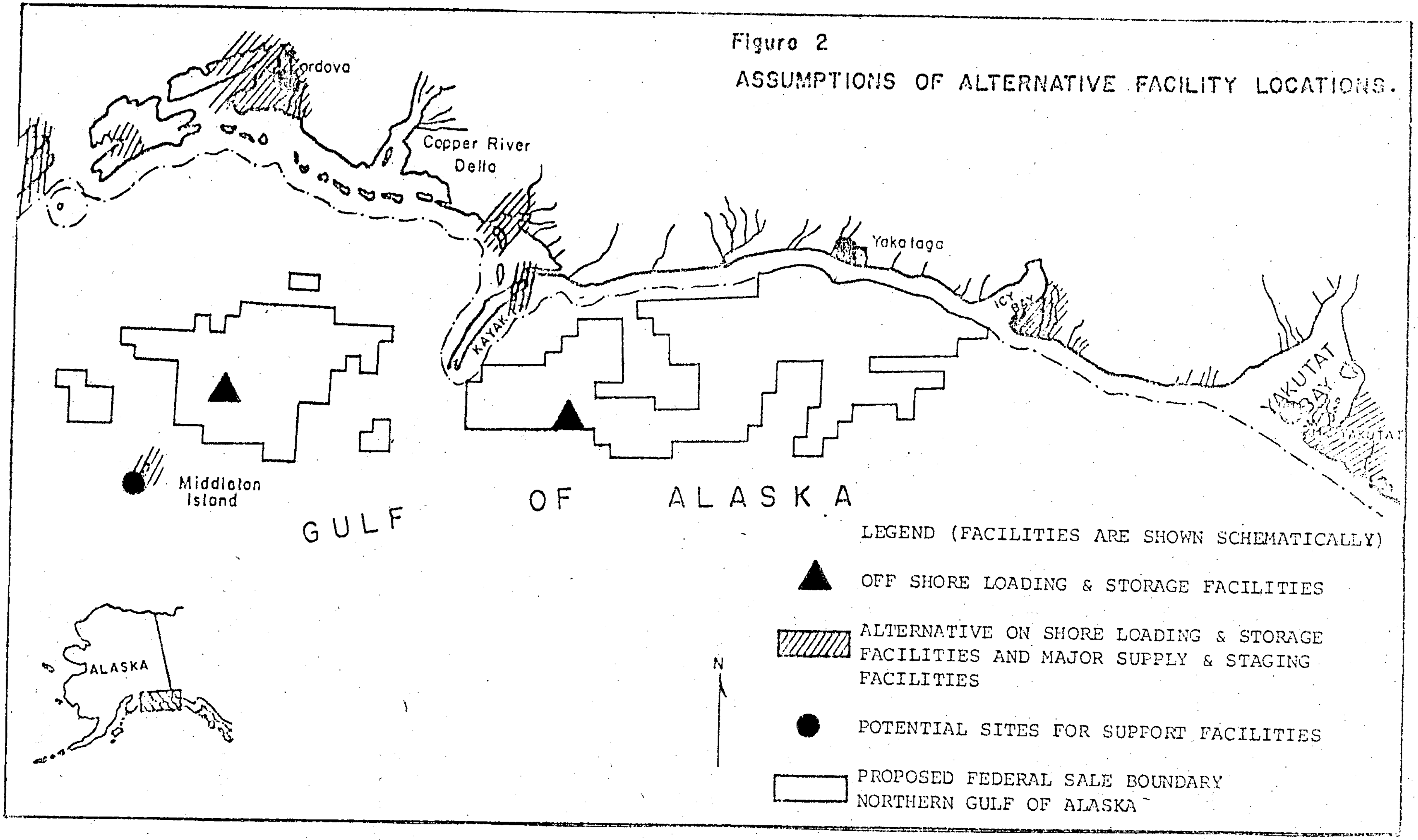

Figure 2

ASSUMPTIONS OF ALTERNATIVE FACILITY LOCATIONS.

TABLE 2

Summary of Basic Assumptions.

Activity	This Proposed Sale
Sale acreage offering	1.8 million acres
Anticipated sale	1.4 million acres
Oil and gas fields	7
Average distance of oil fields from shore	22 miles[1]
Recoverable oil (5% probabilities)	2.8 billion bbls (b.bbls)[2]
Recoverable gas (5% probabilities)	9 trillion cubic feet (t.cu.f.)[2]
Peak production oil	550,000 bbls/da 200 million bbls (m.bbl)/yr[2]
Peak production gas	1.0 billion cu.ft./da 365 billion cu.ft./yr[2]
Platforms	22[2]
Wells	900[2] (100 exploratory, 800 development)
Pipelines	7 to 14
Total miles of pipeline	300 (50 onshore; 250 offshore)
Pipeline burial excavation volume	.9 to 2.4 million cu.ft.[2]
Offshore terminal facilities	2
Onshore pipeline acreage required	315 acres
Onshore terminal facilities	3 (360 acres)
Support/supply facilities	3 (240 acres)
LNG plant	1 (120 acres); 0 if combined with terminal[2]
Onshore land requirements	1,035 acres
Offshore land requirements	800 to 7,700 acres (4 to 350 acres per flatform)*
Petroleum refineries/ platform fabrication	0
Servicing fleet (boats & ships)	20 to 60[2]
Annual crude shipped by tanker	200 million bbls/yr

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* Based on four acres for a jack-up rig and 350 acres for each semi-submersible rig and offshore terminal, and their attendant guy lines.

1/ - USDI 1974d
2/ - USDI 1975b

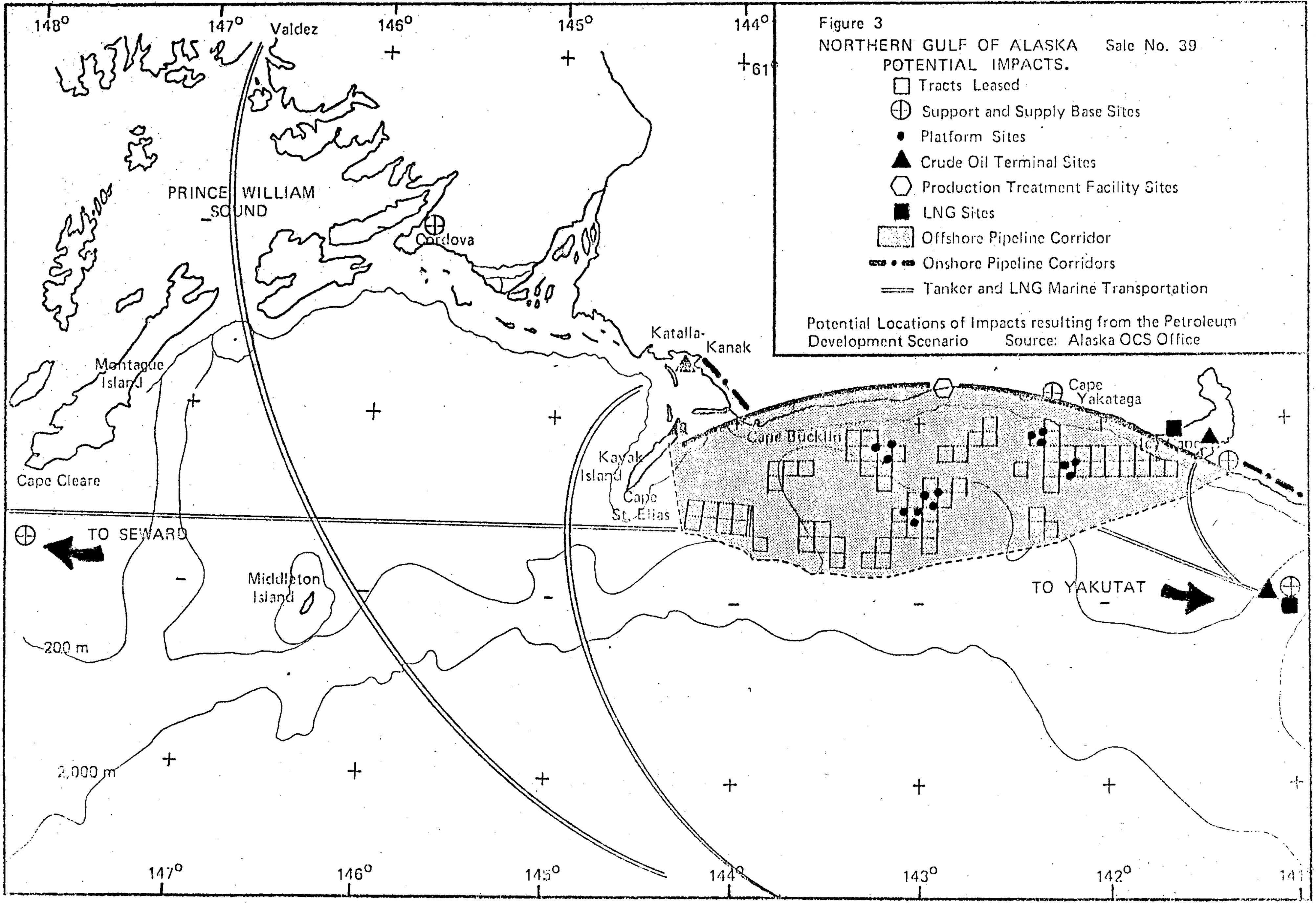


Figure 3
NORTHERN GULF OF ALASKA Sale No. 39
POTENTIAL IMPACTS.

Potential Locations of Impacts resulting from the Petroleum Development Scenario Source: Alaska OCS Office

LNG Sites

The recoverable resource estimates indicate sufficient natural gas for construction of an LNG plant. Monti Bay, Icy Bay, and the northern end of Kayak Island are potential sites. Pacific Alaska LNG, in cooperation with the Yak-Tat-Kwaan Corporation, is already investigating the physical feasibility of locating a LNG plant in the Monti Bay area. (Figure 3)

Pipeline Corridors

The location of the specific areas within the lease sale in which producing fields will be discovered is unknown. Therefore, the pipeline corridors can only be very generally approximated as originating from the hypothesized platforms to the potential crude oil terminals, production treatment facilities, and LNG plant sites. (Figure 3)

Distribution of Net Population Impact

The net population impact was defined as all additional people (direct and indirect employees, dependencies, and other associated non-workers) who will establish their primary residence in Alaska. It was estimated that during 1984, the peak year for population increases, the entire south-central region will receive approximately 14,000 additional people. It is felt that the majority of this population impact, about 8,500 persons, will live in the Anchorage area. About 3,000 persons would choose to live in the coastal area adjacent to the sale area, and the remainder choosing residences in areas such as Juneau, Kodiak, and the Kenai Peninsula.

Surface Marine Transportation Impacts

The major surface marine competitors for space will be the exploration drilling vessels, support and supply boats, crude oil and LNG tankers. The locational patterns will be determined primarily by the location of the producing fields, the onshore support facilities, and the potential markets. An estimate of the possible range of these patterns is given in Figure 3.

Support and Supply Bases

Since exploration activity in the Northern Gulf is currently underway and supply lines and facilities established, supply support functions can be described in detail with an eye toward the future as well.

Figure 4 shows the tracts leased rigs currently drilling and those tracts tentatively scheduled to be explored this year. The Ocean Ranger (Arco) is drilling in block 72, the Sedco 706 (Shell) in block 106, the Alaska Star (Exxon) is estimated to arrive in February to begin exploration activity at block 284, and the Ocean Bounty (Texaco) may be on station in March. Other possibilities for activity this year are the Sedco 708 (Sun-Mobil) and the Aleutian Key (Gulf Oil) for total of 6 semisubmersibles active in the Gulf.

The Ocean Ranger is supplied via 2 210' workboats and 2 S-61 helicopters. It is reasonable to assume each active rig will require 2 similar workboats and 2 helicopters of the S-61 type, depending upon equipment and facility sharing arrangements which may be worked out among operators. The Ocean Ranger uses Monti Bay as a primary supply point, Seward as a supplemental base for some commodities, and airfields at Yakutat and Cape Yakataga for personnel movements. (Table 3)

The Sedco 706 likewise is supplied out of both Yakutat and Seward. Helicopters utilize Yakutat and Cape Yakataga. Exxon's Alaska Star will have its primary supply base at Seward with supplemental capability at Yakutat. Helicopters can be expected to use the Yakutat airport. Similarly, the Ocean Bounty will use Seward as a primary supply support base with backup capability at Yakutat. The Cape Yakataga and Yakutat airports will be used for personnel transfers.

Assuming supply support, land and facility arrangements can be agreed upon between industry, the city of Yakutat and Yakutat Native groups, increased use of the Yakutat area as a support base can be expected.

Chugach Natives, Inc. has developed plans for comprehensive exploration support facilities on their Icy Bay lands. These plans include consideration of potential production processing facilities. From a locational and engineering viewpoint, use of Icy Bay as a support base is feasible; however, no facilities have yet been developed.

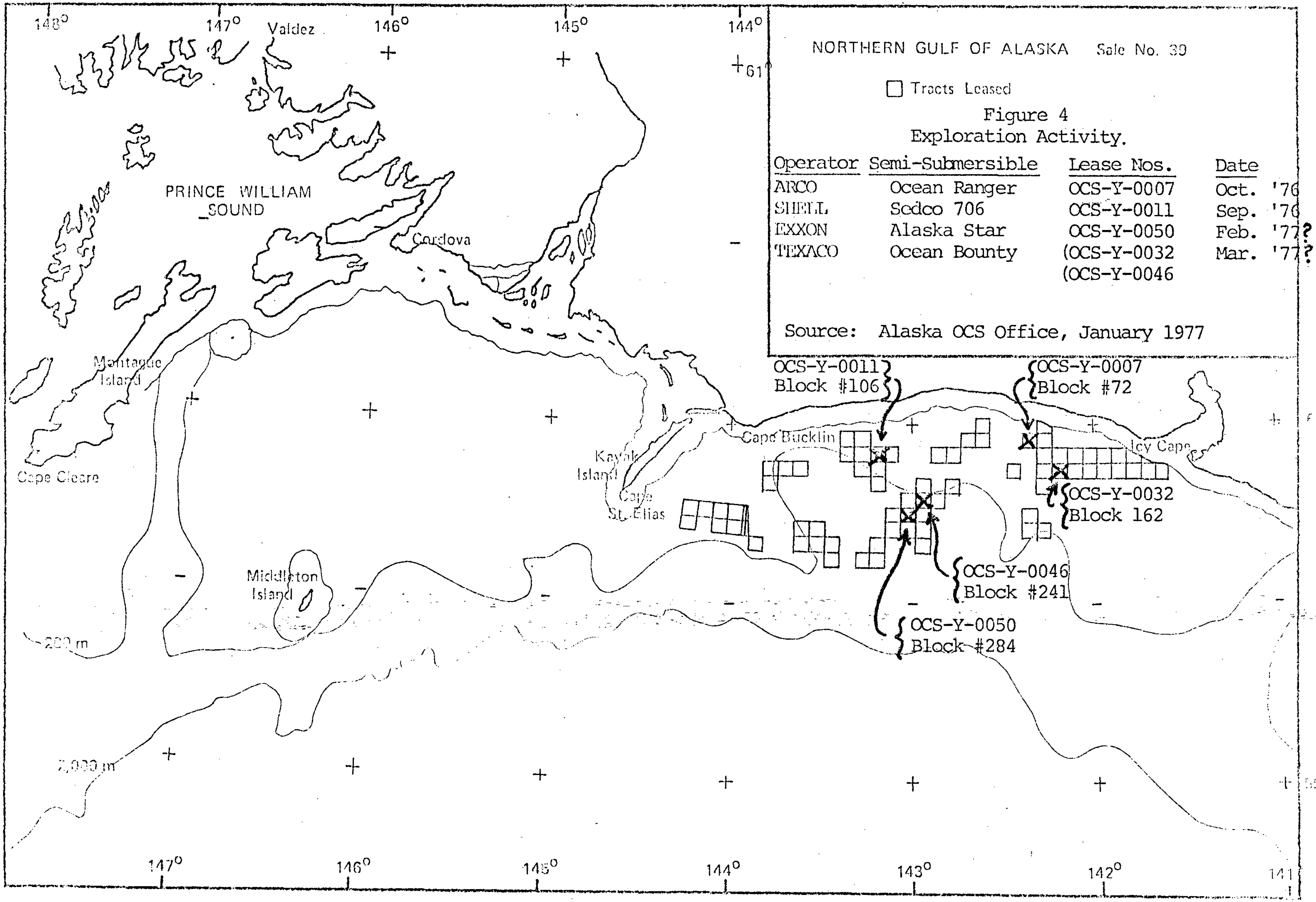


Figure 4
Exploration Activity.

Operator	Semi-Submersible	Lease Nos.	Date
ARCO	Ocean Ranger	OCS-Y-0007	Oct. '76
SHELL	Sedco 706	OCS-Y-0011	Sep. '76
EXXON	Alaska Star	OCS-Y-0050	Feb. '77?
TEXACO	Ocean Bounty	(OCS-Y-0032 (OCS-Y-0046	Mar. '77?

Source: Alaska OCS Office, January 1977

TABLE 3

NORTHERN GULF OF ALASKA

Actual and Planned Exploration Activity - 1977.

ARCO - OCEAN RANGER OCS-Y-0007	SHELL - SEDCO 706 OCS-Y-0007	EXXON - ALASKA STAR OCS-Y-0050	TEXACO - OCEAN BOUNTY OCS-Y-0032, OCS-Y-0046
Two 210' work boats		Two anchor/supply vessels 210'	
Two helicopters (primary & backup) (S-61)			
Support Bases	Support Bases	Support Bases	Support Bases
Primary-Monti Bay, Yakutat	Water & fuel out of Seward	Primary-Port of Seward	Primary-Seward
Supplemental-Seward		Supplemental-Yakutat	Supplemental-Yakutat one crew boat stationed in Yakutat
Airfields	Airfields	Airfields	Airfields
Cape Yakataga Yakutat	Helicopter to Yakataga	Yakutat Airport	Primary-Yakataga to Anchorage Secondary-Yakutat
	Commercial a/c Yakutat		

SUPPLY and SUPPORT ROUTES (Figure 5)

Six Semisubmersibles by 1977.

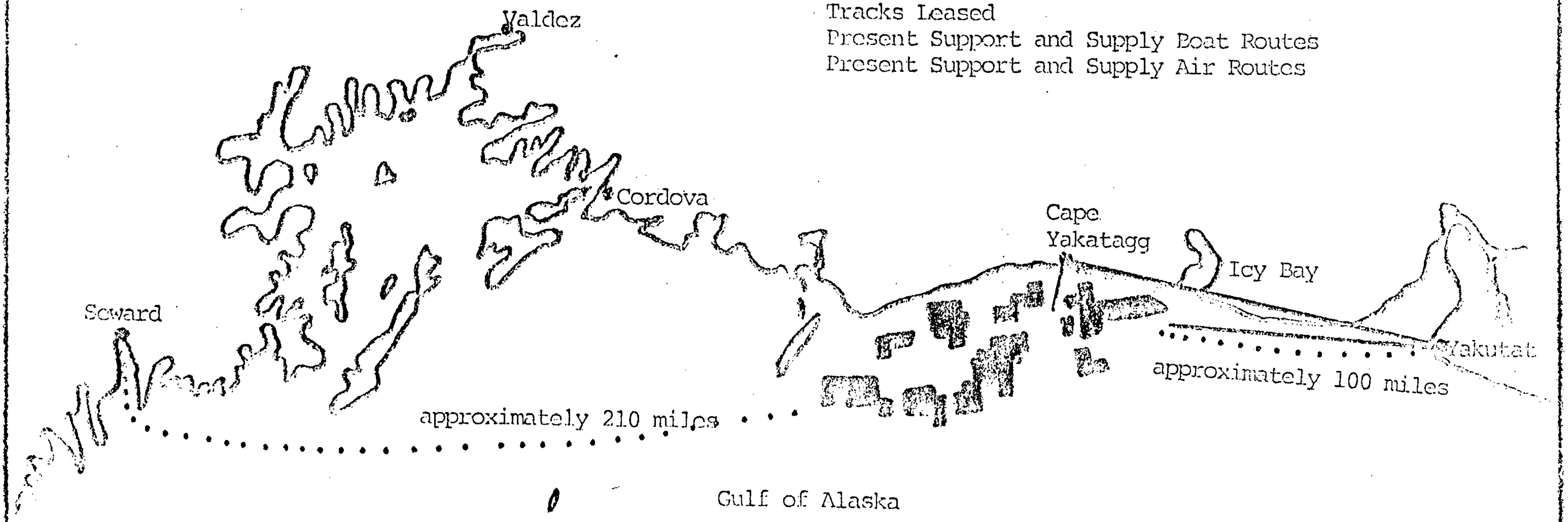
Operator	Semisubmersible	Arrival Date
Shell	Sedco 706	September, 1976
Arco	Ocean Ranger	October, 1976
Texaco	Ocean Bounty	ETA March, 1977
Exxon	Alaska Star	ETA February, 1977
Gulf Oil	Aleutian Key	May, 1977?
Sun-Mobile	Sedco 708	1977?

Legend

Tracks Leased

Present Support and Supply Boat Routes

Present Support and Supply Air Routes



Oil Introduction to the Marine Environment

The previously discussed activities will have a certain likelihood of causing pollution to the marine environment. The estimated oil introduction to the Northern Gulf of Alaska as a result of the maximum impact assessment scenario is described in Table 4.

TABLE 4

Anticipated Annual Oil Spillage During Peak Production
Resulting From the Proposed Sale

Location	Sources	Maximum Annual Spillage (bbls)
Gulf of Alaska	Pipeline accidents	3,400
	Formation water*	2,800
	Spills from platform fires	5,800
	Overflow, malfunction, or rupture	100
	Minor spills (less than 50 bbls -- all sources	500
	Subtotal	12,650
Transportation Route Tankers		32,000
TOTAL		44,650

* Assuming all formation water is discharged.

In summary, an estimated 12,650 barrels of oil will be spilled annually in the Northern Gulf of Alaska. This does not include 2,100 barrels spilled from a projected blowout of one well sometime during the life of production. A total of 32,000 barrels will be spilled by tankers either in this area, along the transportation routes, or at their destination.

SUMMARY

Figure 3 entitled "Potential Locations of Impacts Resulting from the Petroleum Development Scenario" is a general spatial expression of the maximum development case. It is not a prediction or forecast of site-specific impacts. It is the "best estimate" of human spatial activity that would result from the defined maximum development scenario. For specific detailed information on the scenario the reader is referred to the DEIS and FEIS for the Northern Gulf of Alaska.

APPENDIX 3

SEASONAL CHANGES IN THE DYNAMIC TOPOGRAPHY (WITH REFERENCE TO 100 DECIBARS) IN THE NORTHERN GULF OF ALASKA

Data are provided for July 1974,
February 1975, June 1975, November 1975,
February 1976, and April 1976
(from Royer, RU #289, 1976)

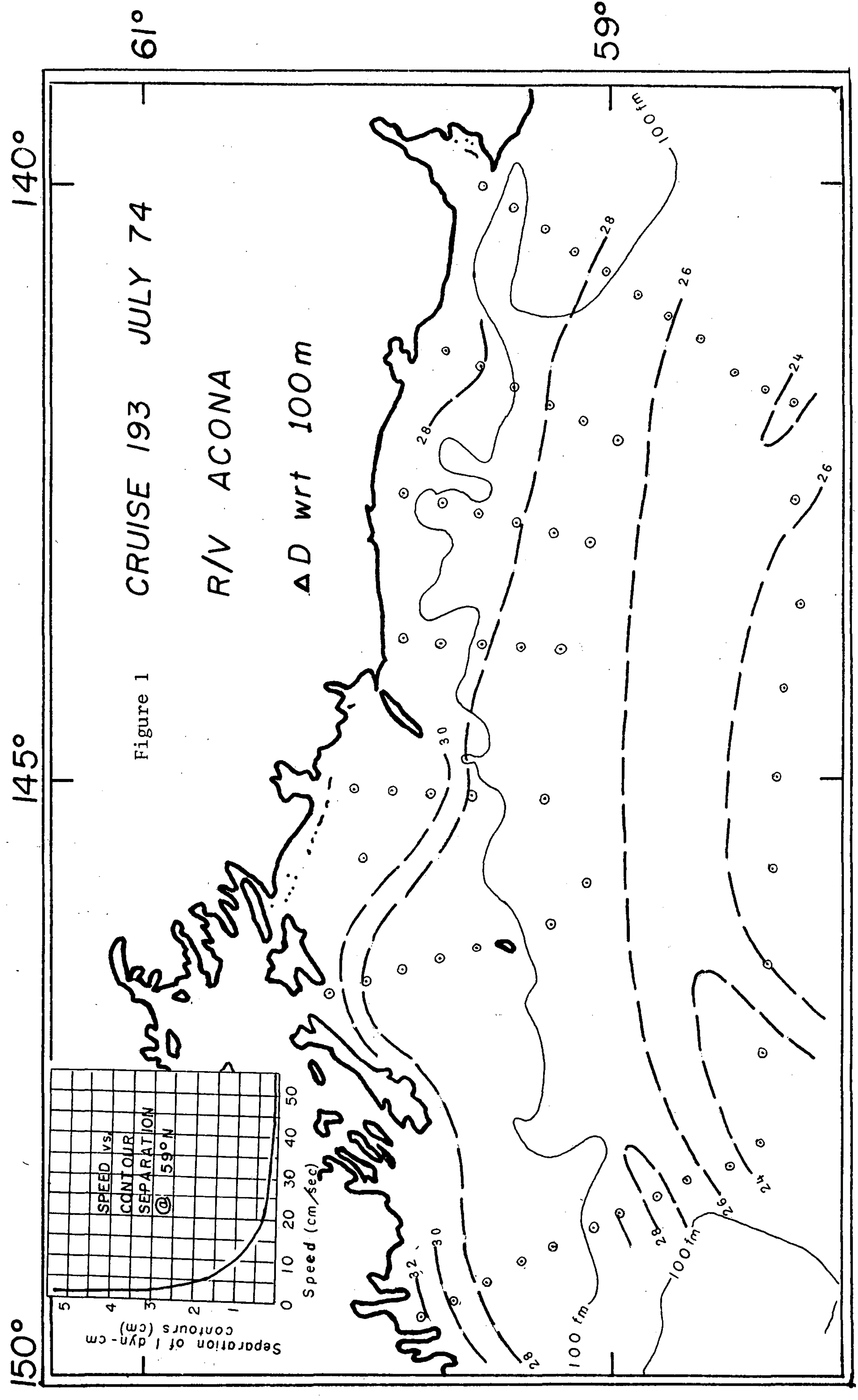

CRUISE 193 JULY 74
R/V ACONA
ΔD wrt 100m
61°
59°
140°
145°
150°
28
26
24
30
32
100 fm
SPEED vs. CONTOUR SEPARATION @ 59°N
Speed (cm/sec)
Separation of 1 dyn-cm contours (cm)
0
10
20
30
40
50
1
2
3
4
5

Figure 1

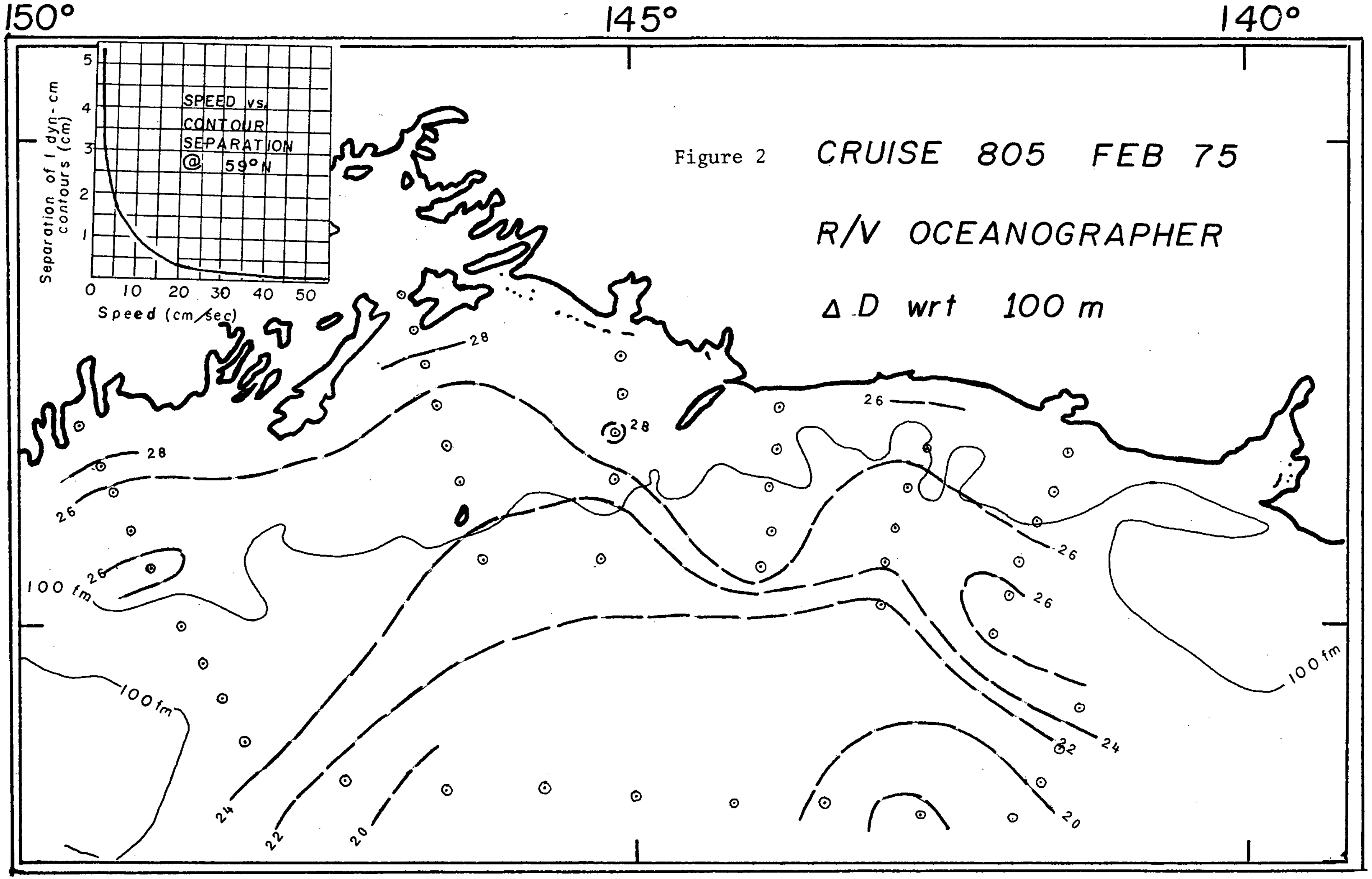

150°
145°
140°
61°
59°
SPEED vs. CONTOUR SEPARATION @ 59°N
Separation of 1 dyn-cm contours (cm)
Speed (cm/sec)
0
10
20
30
40
50
1
2
3
4
5
CRUISE 805 FEB 75
R/V OCEANOGRAPHER
Δ D wrt 100 m
28
28
28
26
26
26
26
26
24
24
22
22
20
20
100 fm
100 fm
100 fm

Figure 2

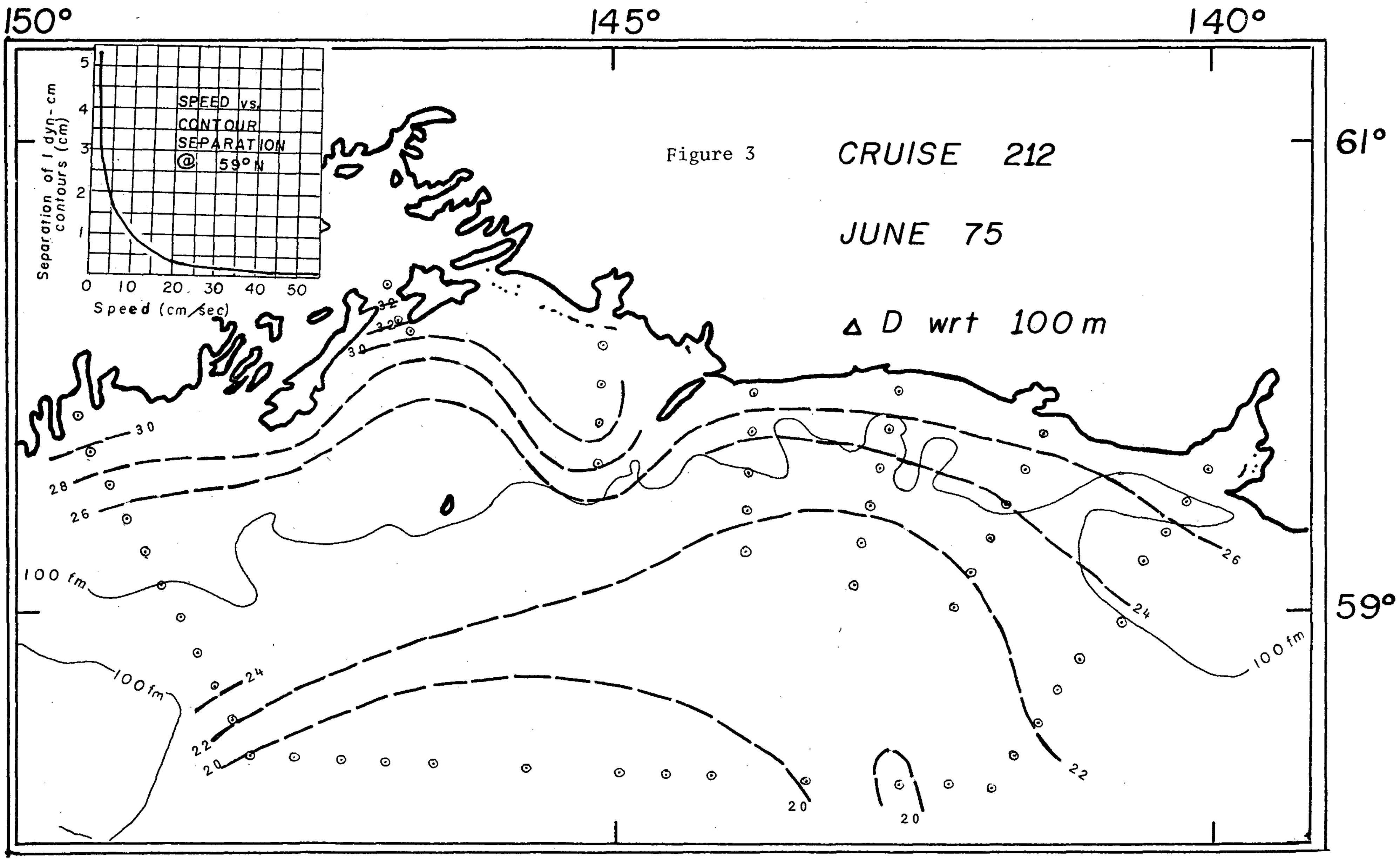


Figure 3

CRUISE 212
JUNE 75
Δ D wrt 100m
SPEED vs. CONTOUR SEPARATION @ 59°N
Separation of 1 dyn-cm contours (cm)
Speed (cm/sec)
0
10
20
30
40
50
1
2
3
4
5
150°
145°
140°
61°
59°
32
32
30
30
28
26
24
22
20
20
20
22
24
26
100 fm
100 fm
100 fm

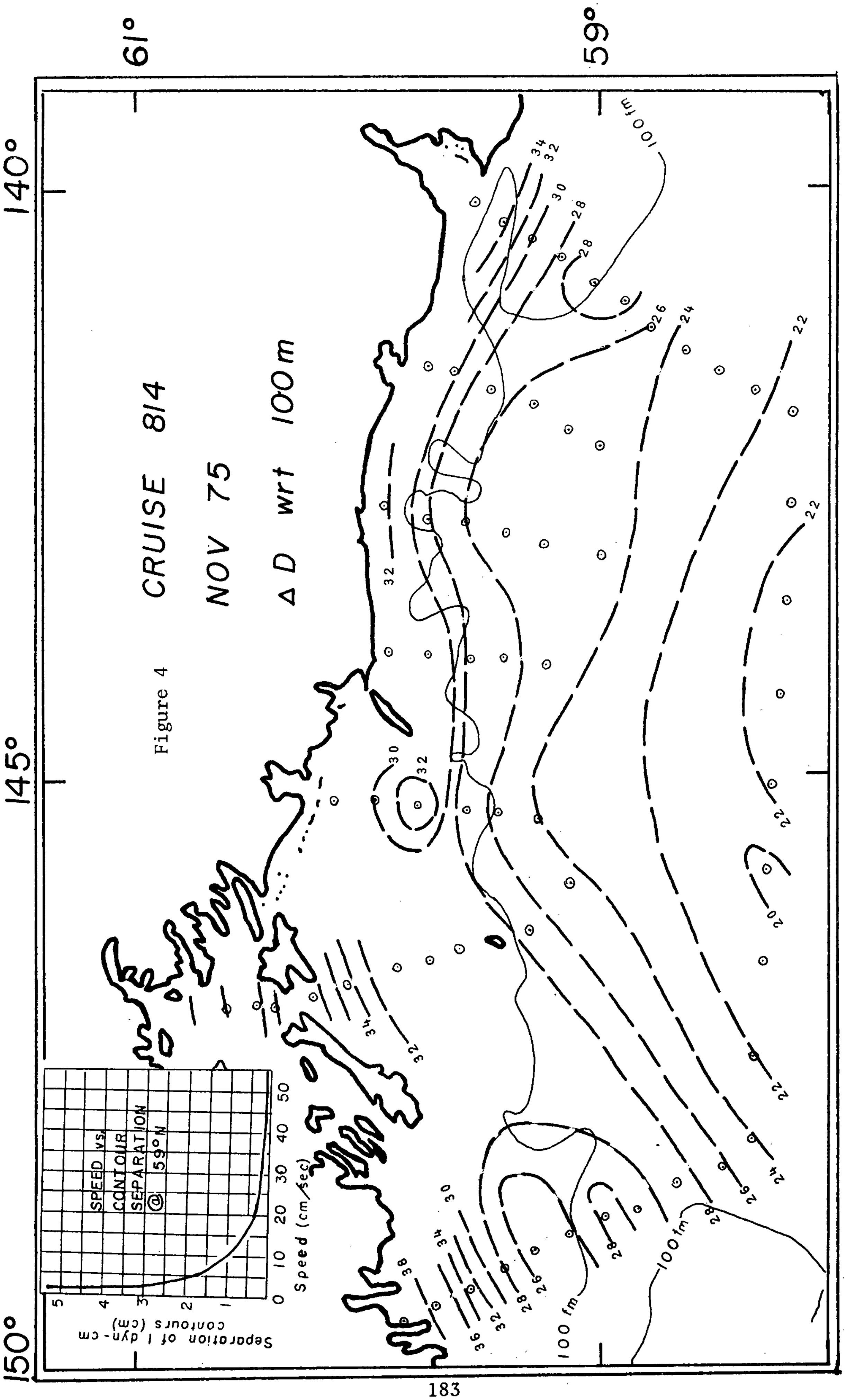
CRUISE 814
NOV 75
ΔD wrt 100m
61°
59°
140°
145°
150°
SPEED vs. CONTOUR SEPARATION @ 59° N
Separation of 1 dyn-cm contours (cm)
Speed (cm/sec)
0
10
20
30
40
50
1
2
3
4
5
100 fm
38
36
34
32
30
28
26
24
22
20

Figure 4

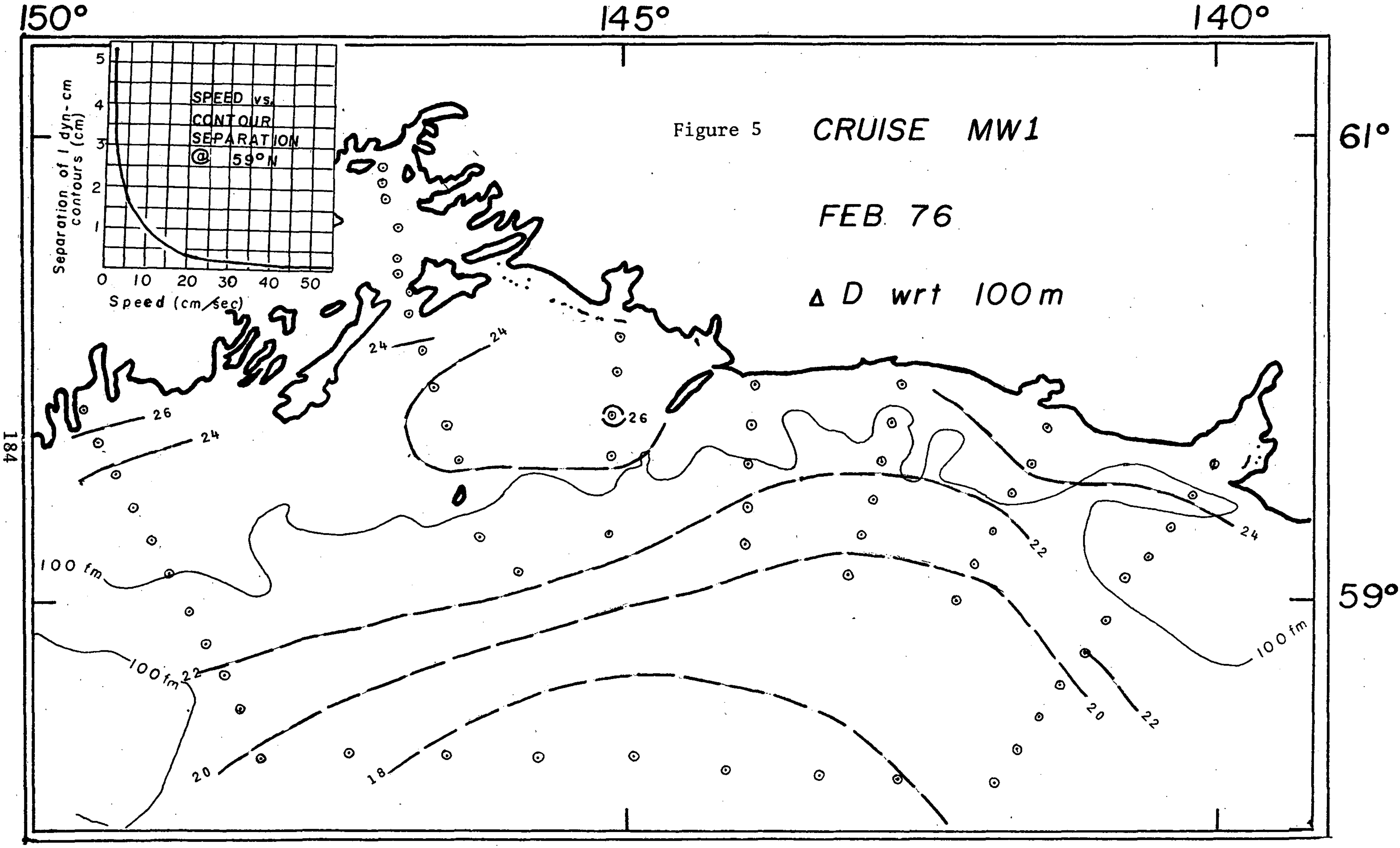


Figure 5 CRUISE MW1

FEB 76

Δ D wrt 100m

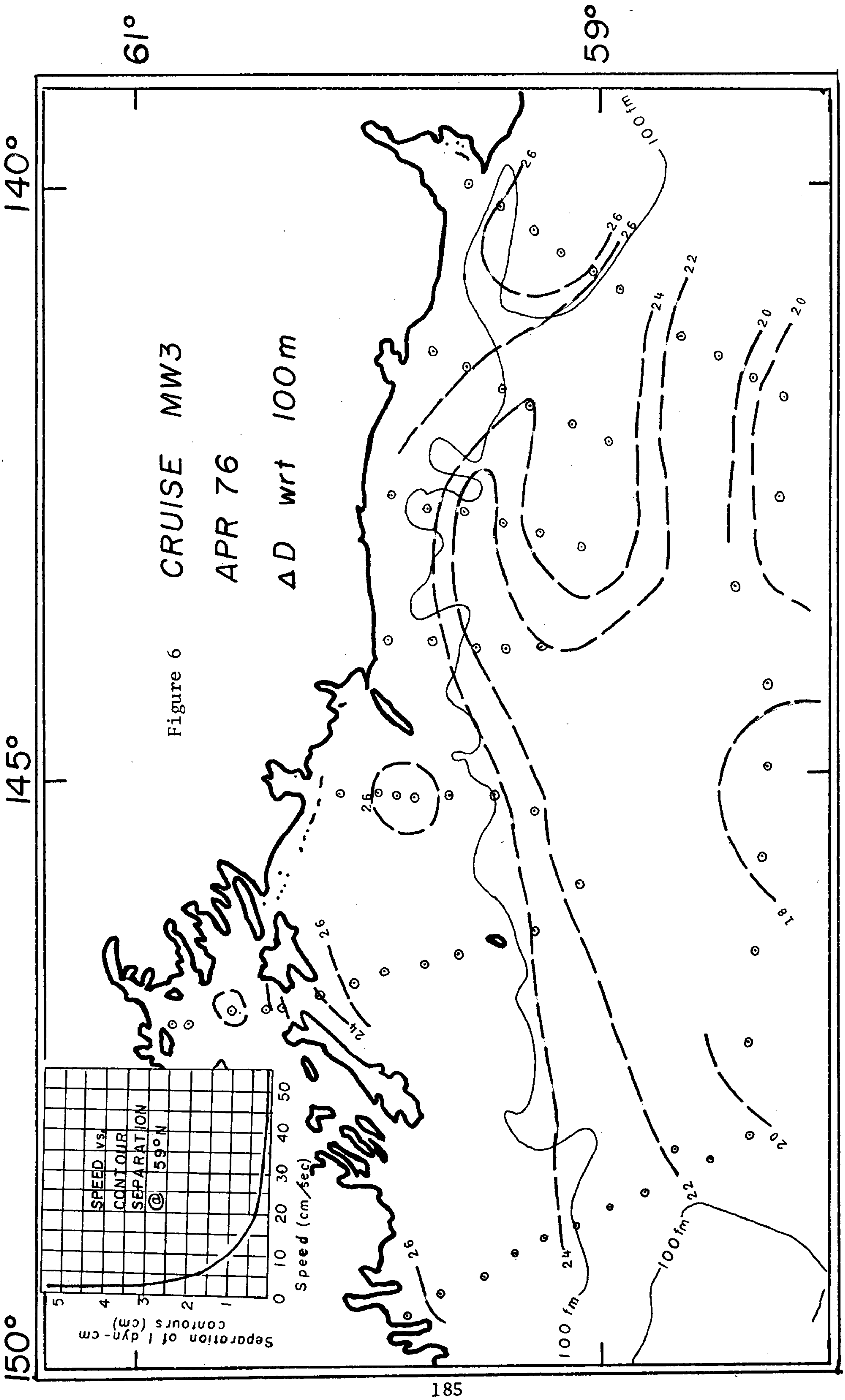

CRUISE MW3
APR 76
ΔD wrt 100m
61°
59°
140°
145°
150°
100 fm
100 fm
100 fm
26
26
26
26
26
26
24
24
24
22
22
20
20
20
18
SPEED vs. CONTOUR SEPARATION @ 59°N
Separation of 1 dyn-cm contours (cm)
5
4
3
2
1
0
10
20
30
40
50
Speed (cm/sec)

Figure 6

APPENDIX 4

NORTHEAST GULF OF ALASKA BIOTA ECOLOGY AND PROBABLE OIL INTERACTIONS

- Birds
- Mammals

Compiled from Synthesis Meeting Inputs
and the Published Literature

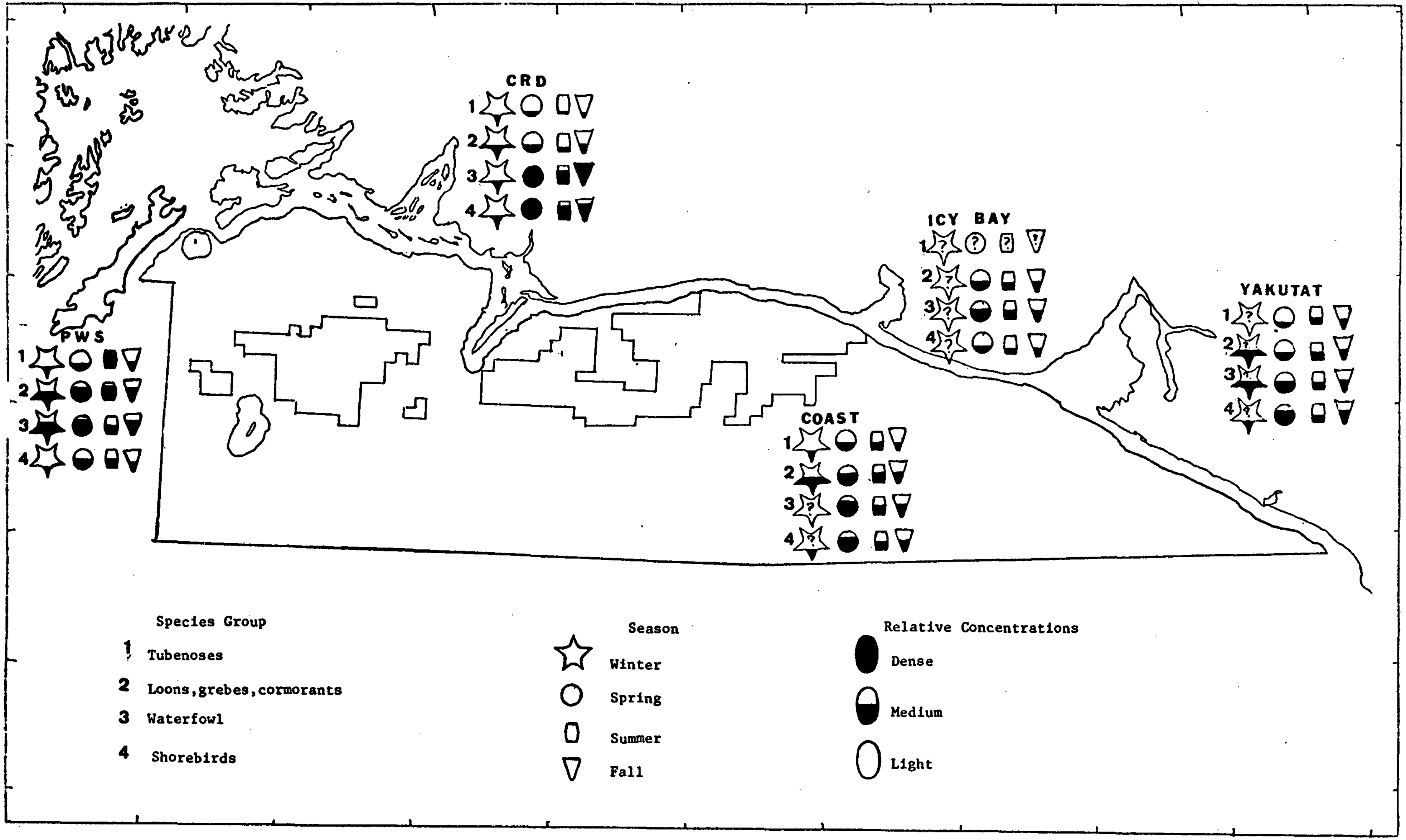
APPENDIX 4A-1. Summary of use of NEGOA lease area by principal marine birds (prepared by P. Arneson ADF&G, Anchorage, and W. Hoffman, Oregon State University).

Family/Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Use of Area by Biotic Group	Special Vulnerability To Petroleum Development
Loons	Nearshore rivers	Nearshore	April-May Sept.-Nov.	Migration, breeding Feeding, wintering	Oil on feathers Reduced food supply
Grebes	Protected nearshore waters	Nearshore	April-May Aug.-Oct.	Migrating, wintering	Oil on feathers Reduced food supply
Black-footed and Laysan Albatrosses	Oceanic 100+F	Around shelf break and off shelf	May-Nov. Peak: Aug.-Oct.	Nonbreeding dispersal	Ingestion of contaminated food, vulnerability may be low
Fulmar	Oceanic	Continental shelf and off shelf	All year?	Feeding, both breeding & nonbreeding seasons	At-sea vulnerability may be low
Sooty/short-tailed Shearwaters	Oceanic	Inshore and at shelf break - upwelling areas	May-Oct.	Wintering area	Food chain
Forktailed & Leach's Petrel	Oceanic	Offshore	May-Oct.	Feeding-breeding season	Fouling of plumage, ingestion, possibly immolation in gas torches
Cormorants	Rocky, exposed coast	Nearshore	Residents	Migrating, summering Wintering	Oil on feathers Reduced food supply
Geese & Swans	Coastal floodplain, Tide flat	River deltas	Late Mar.-May Late Aug.-Nov.	Migrating, breeding	Reduced food supply
Dabblers	Coastal floodplain, Tide flat	River deltas	April-May Late Aug.-Oct.	Migrating, breeding	Reduced food supply
Seaducks	Nearshore coastal waters, Bays	Nearshore	Resident but possibly Apr.-May, Sept.-Nov.	Migrating, feeding Wintering	Oil on feathers Reduced food supply
Mergansers	Nearshore on outer coasts	Bays, Inlets outer coasts	Resident Apr.-May, Sept.-Nov.	Migrating, breeding Wintering	Oil on feathers Reduced food supply
Hawks & Eagles	Beaches, coastal floodplain	Beaches	April-May Aug.-Nov.	Migrating, breeding Wintering	Reduced food, supply, eating toxic oil-killed animals
Black Oystercatcher	Rocky shores	Rocky coast of P.W.S.	Resident	Breeding, wintering Feeding	Reduced food supply
Plovers & Turnstones	Tide flats Beaches/rock	Tide flats	Late Apr.-May Mid July-Sept.	Migrating, breeding some wintering	Reduced food supply

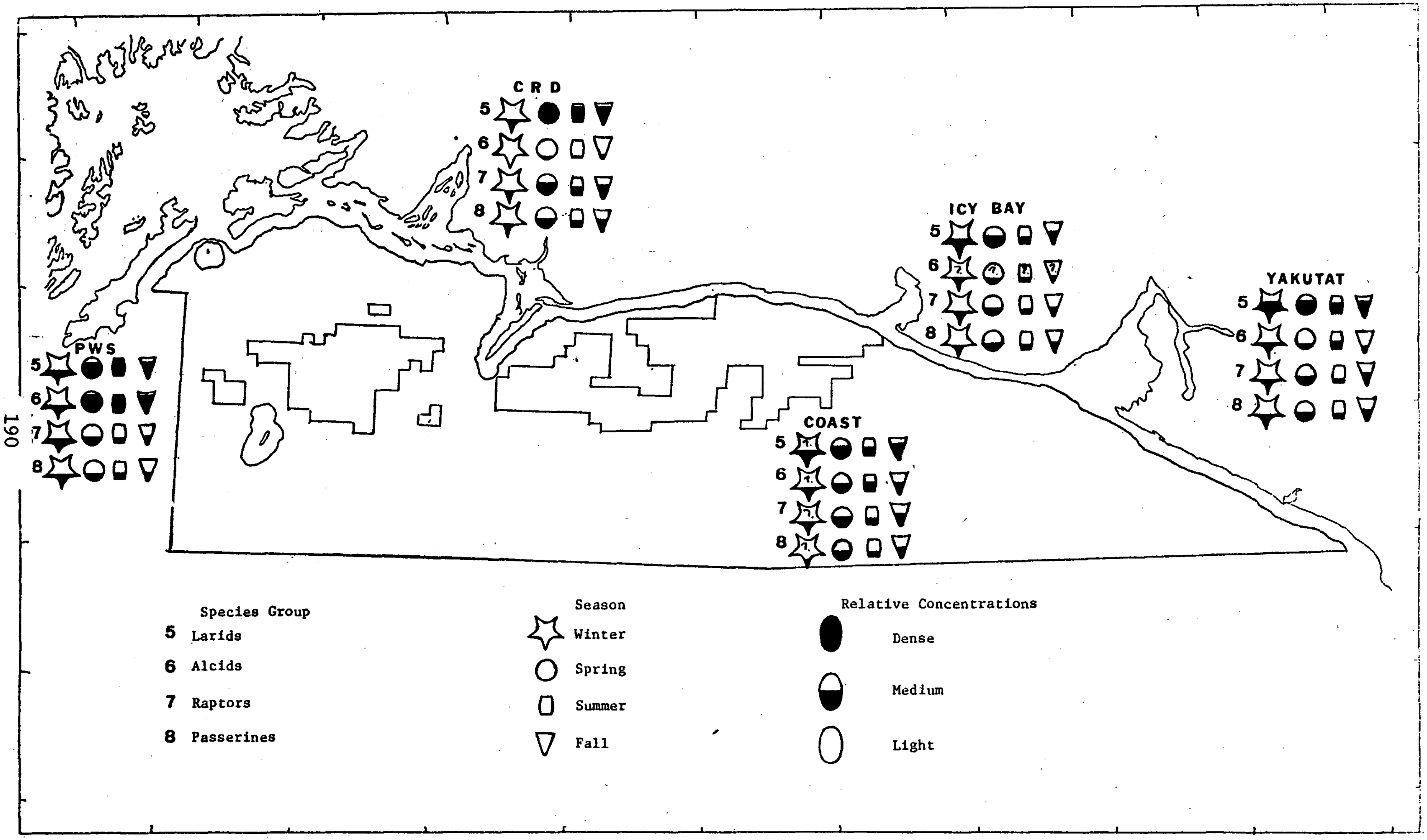
APPENDIX 4A-1. Summary (continued)

Family/Group	Principal Habitat	Areas of Peak Occurrence	Season of Peak Occurrence	Use of Area by Biotic Group	Special Vulnerability To Petroleum Development
Scolopacid Shorebirds	Tide flats Beaches/rock	River deltas Beaches/islands	Late Apr.-May July-Oct.	Migrating, breeding some wintering	Reduced food supply
Phalaropes	Nearshore waters Offshore waters	Sites at upwelling river mouth entrances	May-Mid June July-Sept.	Migrating, breeding	Oil on feathers Reduced food supply
Jaegers	Inshore waters Coastal floodplain	Nearshore River deltas	April-June July-Aug.	Migrating, breeding	Reduced food supply
Glaucous-winged Gull	Ocean, beaches	Beaches, ocean, all depths	All year	Feeding, migration	Food chain, ingestion of contaminated food
Herring Gull	Ocean, beaches	Throughout area	Sept.-May	Wintering	Food, chain, ingestion of contaminated food, vulnerability is probably low
Mew Gull	Coastal	Inshore, beaches	April-Sept.	Breeding, feeding	Food chain, ingestion of contaminated food
Black-legged Kittiwake	Oceanic	Offshore-shelf	April-Oct.	Breeding, feeding	Food chain, ingestion of contaminated food, fouling The most vulnerable gull??
Terns	Estuaries Coastal floodplains	Islands Sand spits	Late Apr.-May Late July-Mid Aug.	Migrating, breeding	Reduced food supply
Common Murre	Oceanic	Shelf	April-Oct.	Breeding, feeding	Fouling, food chain
Pigeon Guillemot	Coastal	Nearshore, rocky	?	Resident?	Fouling, food chain
Marbled Murrelet Kittlitz' Murrelet	Oceanic	Fairly nearshore	?	Resident?	Fouling, food chain
Ancient Murrelet	Oceanic	Shelf	April-Aug.	Breeding, feeding	Fouling, food chain
Cassin's Auklet	Oceanic	Shelf and beyond	?	Breeding, feeding	Fouling, food chain
Rhinoceros Auklet	Oceanic	Shelf and beyond	April-Oct.	Breeding, feeding	Fouling, food chain
Horned Puffin	Oceanic	Shelf and beyond	May-Sept.	Breeding, feeding	Fouling, food chain
Tufted Puffin	Oceanic	Shelf and beyond	April-Oct.	Breeding, feeding	Fouling, food chain
Crows, Ravens, Magpies	Beaches	Throughout	Residents	Feeding, breeding	Ingesting oil-killed animals, reduced food supply
Fringillids	Beaches, both rocky & sandy	Beaches Coastal floodplain	April-May Aug.-Oct.	Migrating, breeding	Reduced food supply

APPENDIX 4A-2 : Relative seasonal and regional abundance of major nearshore and littoral zone bird groups in NEGOA (prepared by Paul Arneson, ADF&G, Anchorage).



APPENDIX 4A-2 : Relative seasonal and regional abundance (continued).



APPENDIX 4A-3

Seasonal usage of NEGOA marine habitat zones by principal marine bird species (prepared by P. Arneson, ADF&G, Anchorage; P. Gould, USF&WG, Anchorage, W. Hoffman, Oregon State Univ., Corvallis; and K. Wohl, BLM, Anchorage).

Species	Littoral				Inshore				Shallow Pelagic (< 100 F)				(100-1,000 F)				Epiabyssal			
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Common Loon					M	M	L	M		L				L		L		L		L
Yellow-billed Loon					M	L	V	L		L	V									
Arctic Loon					L	M	L	M		L	L									
Red-throated Loon					L	M	M	M		L		L								
Horned Grebe					M	M	L	M		L		L								
Red-necked Grebe					M	M	L	M		L		L								
Black-footed Albatross										V	V	V		L	L	L		L	L	L
Laysan Albatross														V	V	V		V	V	V
Fulmar									M	M	M	M	M	M	M	M	M	M	M	M
Sooty/Short-tailed Shearwater									V	A	H	M	V	A	H	M	V	H	M	M
Scaled Petrel																		L	L	L
Fork-tailed Storm Petrel								V	L	M	M	M	L	M	M	M	L	M	M	M
Leach's Storm Petrel														L	L			L	L	
Double-crested Cormorant	L	M	L	M	L	M	L	M												
R.F. & Pelagic Cormorant	M	M	M	M	M	M	M	M		V		V								
Great Blue Heron	V	V	V	V																
Trumpeter Swan	V	H	M	H																
Whistling Swan	V	H	V	H																
Black Brant	L	L	V	V		L	V	V												
Canada Goose	V	H	M	H																
Emperor Goose	V	V		V																
White-fronted Goose	-	M	V	M																
Snow Goose	-	H	-	H																
Mallard	L	H	M	H	L															
Gadwall	V	L	V	L																
Pintail	V	A	L	A																
Teal	V	M	L	M																
American Wigeon	V	M	L	M																
Shoveler	-	L	V	L																
Canvasback	-	V	V	V		V	V	V												
Greater Scaup	L	M	L	M	L	M	L	M												
Common Goldeneye	L	L	V	L	M	L	V	L												
Barrow's Goldeneye	L	L	V	L	M	L	V	L												
Bufflehead					M	M	V	M												
Oldsquaw					H	M	L	M		L	V	L								
Harlequin Duck	M	M	M	M	M	M	M	M		L	V	L								
White-winged Scoter	L	L	L	L	M	H	M	H												
Surf Scoter	L	L	L	L	M	H	M	H												
Black Scoter					L	L	L	L												
Common Merganser					L	L	V	L												
Red-breasted Merganser	-	-	M	-	L	M	V	M	L	L	L	L								
Bald Eagle	L	L	L	L																
Peregrine Falcon	V	L	V	L																
Sandhill Crane	-	L	V	M																

(continued)

APPENDIX 4A-3

Seasonal usage of NEGOA marine habitat zones by principal marine bird species (continued).

Species	Littoral				Inshore				Shallow Pelagic (< 100 F)				(100-1,000 F)				Epiabyssal			
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Black Oystercatcher	L	L	L	L																
Semipalmated Plover	-	L	L	L																
Golden Plover		M		H																
Black-bellied Plover	V	M	V	M																
Surfbird	L	M	V	M																
Black Turnstone	V	H	V	H																
Ruddy Turnstone		H	V	M																
Common Snipe	V	M	L	M																
Whimbrel	-	L	V	V																
Spotted Sandpiper	-	L	L	L																
Wondering Tattler	-	L	L	L																
Greater Yellowlegs	-	M	L	M																
Lesser Yellowlegs	-	L	V	L																
Knot	-	M	-	V																
Rock Sandpiper	M	M	L	M																
Pectoral Sandpiper	-	L	-	L																
Baird's Sandpiper	-	L	-	L																
Least Sandpiper	-	H	M	H																
Dunlin	L	A	V	A																
Short-billed Dowitcher	-	M	L	M																
Long-billed Dowitcher	-	M		N																
Semipalmated Sandpiper	-	V	V	V																
Western Sandpiper	-	A	L	A																
Sanderling	V	H	V	H																
Red Phalarope					-	L	-	L	-	M	-	M	-	L	-	L	-	L	-	L
Northern Phalarope	-	V	-	V	-	A	L	A	-	H	L	H	-	H	L	H	-	A	L	H
Pomarine Jaeger					-	L	L	L	-	L	L	L	-	L	L	L	-	L	L	L
Parasitic Jaeger					-	L	M	L	-	L	M	L	-	L	L	L	-	L	L	L
Long-tailed Jaeger					-	V	V	V	-	V	V	V	-	V	V	V	-	V	V	V
Glaucous Gull	L	V	V	V	L	V	V	V	L	V	V	V	L	V	V	V	L	V	V	V
Glaucous-winged Gull	H	H	H	H	H	H	H	H	H	H	H	H	M	M	L	M	M	M	L	M
Herring Gull	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Thayer's Gull						L	L	L	-	L	-	L	-	L	-	L	-	V	-	V
Mew Gull	L	H	M	H	L	H	M	H	L	L	L	L	L	L	L	L	V	V	V	V
Bonaparte's Gull	-	M	-	M	-	M	-	M	-	V	-	V	-	V	-	V	-	V	-	V
Black-legged Kittiwake	L	M	M	M	L	M	H	M	L	M	H	M	L	M	M	M	L	M	M	M
Sabine's Gull		L	L	L	-	L	L	L	-	L	-	L	-	L	-	L	-	L	-	L
Arctic Tern	-	A	H	A	-	A	H	A	-	A	H	A	-	A	L	A	-	A	L	A
Aleutian Tern	-	L	M	L	-	L	M	L	-	V	-	V	-	V	-	V	-	V	-	V
Common Murre					L	L	M	L	M	L	M	L	V	V	V	V				
Pigeon Guillemot	M	M	M	M	M	M	M	M	L	L	L	L								
Marbled Murrelet					?	M	M	?	?	M	M	?								
Kittlitz's Murrelet					?	L	L	?	?	L	L	?								

(continued)

APPENDIX 4A -3

Seasonal usage of NEGOA marine habitat zones by principal marine bird species (continued).

Species	Littoral	Inshore	Shallow Pelagic (< 100 F)	(100-1,000 F)	Epiabyssal
	W S S F	W S S F	W S S F	W S S F	W S S F
Ancient Murrelet		? L L L	? L L L		
Cassin's Auklet		? V V V	? V V V	? V V V	
Parakeet Auklet		V V V V	V V V V	V V V V	V V V V
Rhinoceros Auklet		L L L L	L L L L	L L L L	L L L L
Horned Puffin		- L L L	- L L L	- L L L	- L L L
Tufted Puffin		V M M M	L M M M	L L L L	L L L L
Black-billed Magpie	M M L M				
Northwestern Crow	M M M M				
Common Raven	M M M M				

V = Very low density
L = Low density
M = Moderate density
H = High density
A = Abundant density

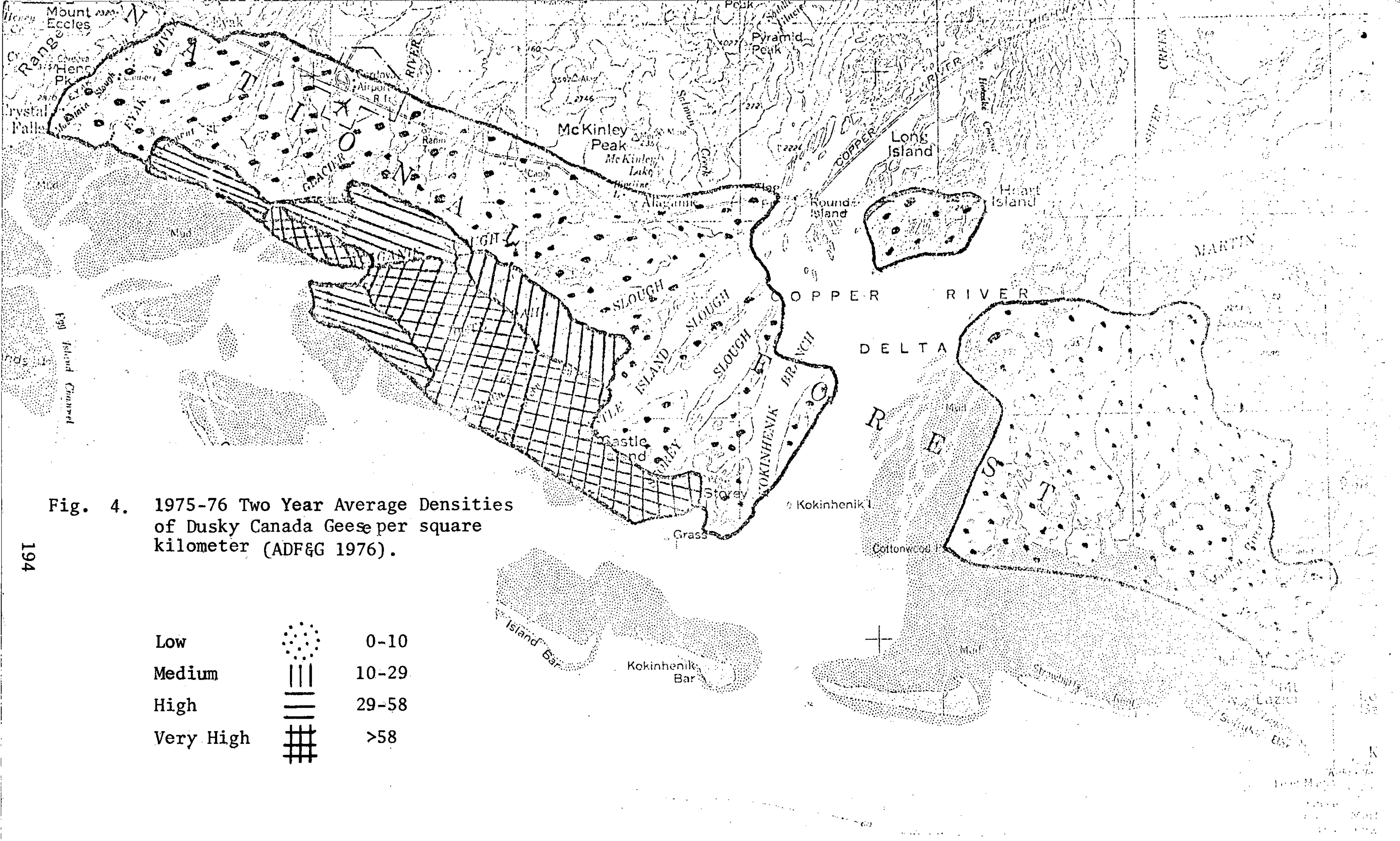


Fig. 4. 1975-76 Two Year Average Densities of Dusky Canada Geese per square kilometer (ADF&G 1976).

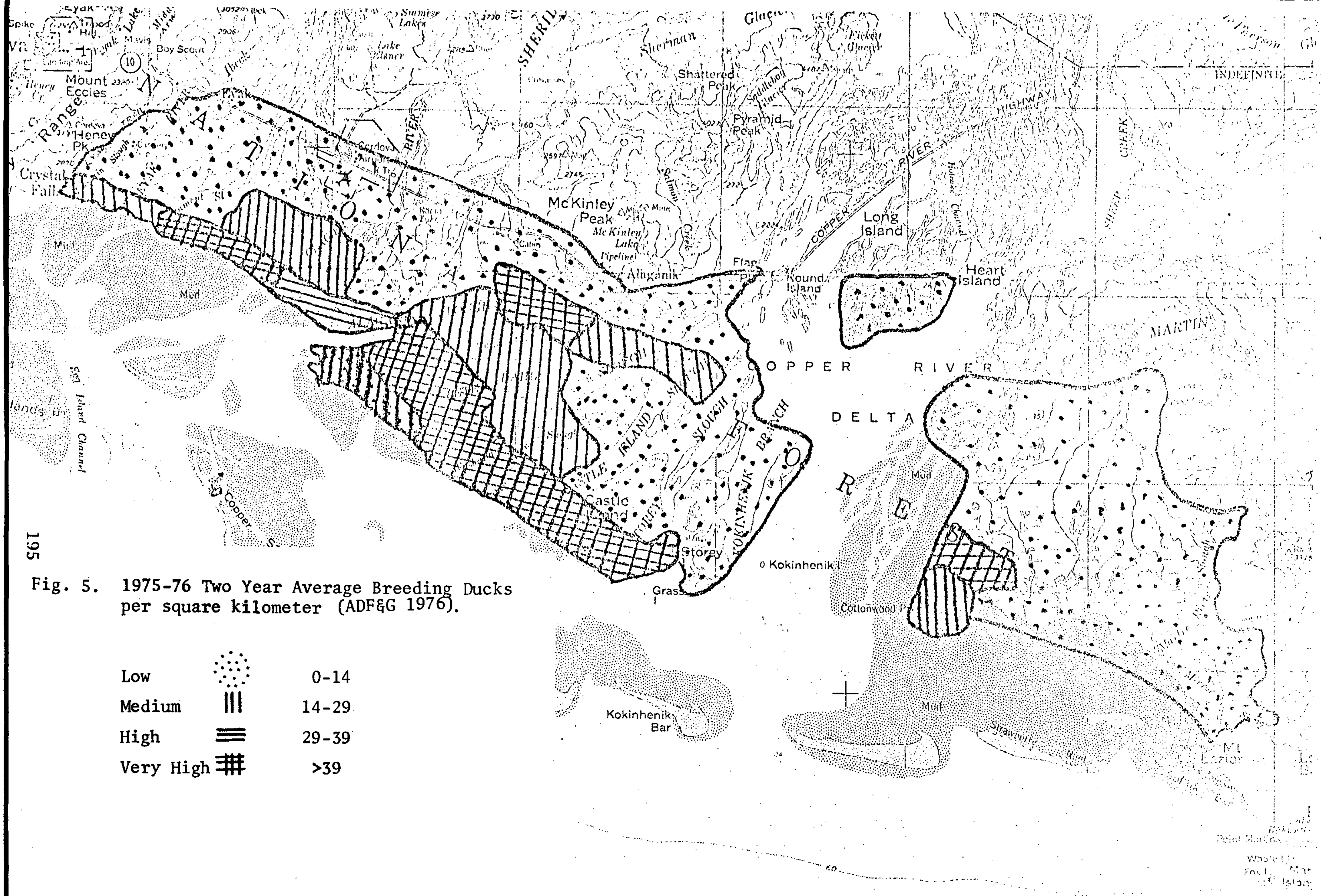


Fig. 5. 1975-76 Two Year Average Breeding Ducks per square kilometer (ADF&G 1976).

Low	⁘	0-14
Medium	▥	14-29
High	☰	29-39
Very High	▦	>39

APPENDIX 4B-1

Commonly occurring and endangered (*) cetaceans and pinnipeds (those likely to be seen out to the Continental Slope) in the NEGOA with respect to use (prepared by H. Braham, NOAA/NMFS-NWFC, Seattle, Washington).

Species/Group	General Habitat Type	Areas of Peak Occurrence	Time of Peak Occurrence	Critical Area Usage	Special Vulnerability to Petroleum Development
Cetaceans					
Minke	coast waters/ photic zone	near shore, NW-NEGOA	May-Sept.	feeding	toxicity to large schools of small fish locally
Sei* Fin*	photic zone pelagic	outer shelf and slope upwellings?	summer	feeding	important areas of high productivity and surface pollution
Blue*	photic zone pelagic	shelf upwellings?	June-July?	feeding	important areas of high productivity
Humpback*	photic zone	near shore NW-NEGOA	April-Sept.	feeding, migration	interference of food and movement into, e.g. Prince William Sound
Gray*	coast waters	shelf near coast	May; Dec.?	migration, feeding?	may have restricted spring migration corridors
Right whale*	surface	near shore and shelf?	summer	feeding	oil fouling baleen plates during surface skimming?
Killer	bays, harbors, coastal	near shore, NW-NEGOA	Mar.-Oct., year round?	feeding, calving	local movements in Prince William Sound; oiled prey (seals)?
Sperm*	deep waters	shelf/slope	summer	feeding	
Belukha	bays, rivers, estuaries	coast, NE-NEGOA	year round?	feeding, calving	development may alter local movements, behavior, feeding
Dall porpoise	deeper bays/ shelf slope	entire shelf	spring-summer; year round?	feeding, migration? calving	local calving areas may be disrupted by heavy activity
Harbor porpoise	shallow bays, rivers, estuaries	entire coastal area	year round	feeding, calving	dependent upon shallow water spawning fish
Pinnipeds					
Northern fur seal	pelagic waters	shelf and slope	April-June	migration, feeding	oil fouling pelage
Northern sea lion	haul-out islands, photic zone	entire shelf	April, May, Sept.	pupping, feeding	fouling during pupping period -- June-July

APPENDIX 4B-2

Tentative summary of use of Epipelagic and Littoral Zones of NEGOA lease area by principal species of the sea otter and pinnipeds (prepared by R. Tenaza, SAI, Boulder, Colorado).

Species	Season			
	Winter	Spring	Summer	Fall
Sea Otter	ⒶⓅⒿ	ⒶⓅⒿ	ⒶⓅⒿ	ⒶⓅⒿ
Sea Lion	ⒶⓅⒿ	ⒶⒿ	ⒶⓅⒿ	ⒶⓅⒿ
Fur Seal	M J	F J P	J	J
Harbor Seal	ⒶⓅⒿ	ⒶⓅⒿ	ⒶⓅⒿ	ⒶⓅⒿ

A - Adults P - Pups J - Juveniles M - Adult Males

○ - Special dependence on Littoral Zone F - Adult Females

APPENDIX 4B-3

Projected seasonal habitat use of pelagic marine mammals in the NEGOA* (prepared by H. Braham, NOAA/NMFS-NWFC, Seattle, Washington).

Species	Season			
	Winter Dec-Feb	Spring Mar-May	Summer Jun-Aug	Fall Sept-Nov
Northern fur seal	FM	FM		
Gray whale	Ⓜ?	Ⓜ		
Minke whale		F	Ⓕ	M
Sei whale		F	F	
Fin whale		F	F	
Blue whale			F?	
Humpback whale		FM	Ⓕ	M
Black right whale			F	
Sperm whale			F?	
Killer whale		C?FM?	FM	M?
Belukha whale	F?	C?F	Ⓕ	F
Giant bottlenose whale[+]				
Pilot whale[+]				
Northern Pacific whiteside dolphin			F?	
Dall's porpoise	F?	C?FM?	FM?	F
Harbor porpoise	F?	C?	Ⓕ	F
Northern right-whale dolphin[+]				
Bering Sea beaked whale[+]				
Goose-beaked whale[+]				

*approximately 140° W. - 148° W. Long.; 59° N. - 61° N. Latitude

C = suspected calving area
F = feeding grounds
M = migration route
○ = near-shore environs may represent a critical habitat type
+ = no known information available

APPENDIX 4B-4

Tentative summary of use of lease area by sea otters, pinnipeds, and land mammals (prepared by D. Calkins and K. Schneider, ADF&G, Anchorage, Alaska).

Species	Principal Habitat	Area of Peak Occurrence	Season of Peak Occurrence	Use of Area by Biotic Group	Special Vulnerability to Petroleum Development
Sea Otter	All waters less than 80 m deep	Prince William Sound, small groups at Kayak Island, Icy Bay and between Yakutat and Cape Fairweather	Year-round resident	Breeding, pupping, feeding occurs at all times of year.	Direct contact with even small amount of oil usually fatal; food availability a major limiting factor; repopulation of large areas of former habitat can be retarded by a localized reuction in numbers.
Sea Lion	All waters of Gulf of Alaska	Sitkagi bluffs, Cape St. Elias, Middleton Island Seal Rocks, Prince William Sound	Year-round resident; numbers highest in late winter and early spring	Breeding and pupping in spring and early summer; feeding at all times of year	Direct contact causes eye irritation; ingestion can be fatal; reduction in prey species causes reduced population; contamination of breeding rookeries and hauling areas would be detrimental.
Harbor Seal	All waters less 100 fms	Copper River Delta, Controller Bay, Icy Bay, Yakutat Bay, Middleton Island	Year-round resident, most abundant on Copper River Delta in summer	Breeding and pupping in summer; feeding at all times of year	Direct contact causes eye irritation; injection can be fatal; reduction in prey species causes reduced population; contamination of breeding rookeries and hauling areas would be detrimental; effects may be most severe on pups.
Fur Seal	All NEGOA waters		Winter and spring	Feeding at all times of year	Oil fouling destroys thermal insulation, causing death from exposure; other effects as for harbor seal and sea lion (above).
Brown and Black Bear	Terrestrial and intertidal	Concentrate along beaches and streams	Spring - beaches and sedge meadows; Summer - salmon spawning streams	Feeding	Loss of critical food source; ingestion of oil on contaminated food.
Deer	Terrestrial and intertidal	Concentrate along beach fringe in winter; feed extensively on intertidal beaches	Almost entirely dependent on beach and intertidal areas during periods of high snow accumulation	Feeding	Loss of critical food source; ingestion of oil on contaminated food.
Furbearers (otter, mink, fox, etc.)	Terrestrial, intertidal and nearshore	Beaches and estuaries	All year	Feeding	Contamination of fur; loss of food; ingestion of oil on contaminated food.

*U.S. Government Printing Office: 1978-777-063/237 Region 8