Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

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National Oceanic and Atmospheric Administration
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Office of Oceanography and Marine Assessment
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ENVIRONMENTAL ASSESSMENT PROGRAM

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Anchorage, Alaska

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VOLUME 38 APRIL 1986

C O N T E N T S

ENVIRONMENTAL CHARACTERIZATION OF THE NORTH ALEUTIAN SHELF NEARSHORE REGION: CHARACTERIZATION, PROCESSES, AND VULNERABILITY TO DEVELOPMENT

by

S. Pace

Kinnetic Laboratories, Inc.

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 645

March 1984

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EXECUTIVE SUMMARY

1. The North Aleutian Shelf Lease Sale 92 area encompasses all of Bristol Bay, from Unimak Pass northward to offshore Cape Newenham. The nearshore habitat of Bristol Bay is an interface between the rich resources of the southeastern Bering Sea and the rich resources of the river/lake and lagoon/estuarine systems. As such, this nearshore interfacial area is extremely important, being heavily utilized for feeding purposes and as critical habitat necessary to many ecologically or commercially important species.

2. The observed high biological utilization of the inshore areas, and subsequent distributions of biota, can be explained by two basic factors, that of food availability and that of suitable habitat.

3. Based upon fragmentary data, it is hypothesized that marine primary productivity accounts for the majority of the organic carbon available to support the inshore food chains, but that overall contributions from rivers and coastal lagoons may be approximately 7-10 percent and about 14 percent respectively, and probably more important locally than indicated by these averages over the entire area. This inshore food web is primarily benthic, in that much of the algal production and detritus is ungrazed by pelagic herbivores and sinks to the bottom.

4. The endemic system thus includes primary productivity (both marine and lagoonal/terrestrial), which is generated within the nearshore zone and which supports most, if not all, of the zooplankton, benthic epifaunal and infaunal, and marine fish productivity of the region. Most or all of the higher trophic level marine mammal and bird species rely on this endemic system for nutritional maintenance to varying degrees. It is also hypothesized that a second, essentially independent, trophic system is operational within the nearshore zone.

This second system, a parallel "import/export" system, seasonal and pulsating in nature, is comprised of the huge runs of anadromous fish, which utilize the area, along with their retinue of predators. The hypothesis in this regard is that these migratory populations of anadromous (and in some cases marine) fish such as salmon, smelt, herring, capelin, and eulachon satisfy most of their energy and growth requirements in other marine or, in the case of juvenile salmon, freshwater environments and "import" this biomass in seasonal pulses into the nearshore zone. Calculations indicate that the carbon available from this import system at the higher trophic levels is at least equivalent to that expected to be derived from the productivity of the first, endemic system. It is conjectured that these seasonal pulses of imported energy resources may be critical to the maintenance of the particularly high populations of some top predators, especially beluga whales, harbor seals, and perhaps Steller sea lions and marine birds which frequent the area.

5. Critical habitats present in the nearshore, interfacial zone, are extremely important to numerous species of both ecological and commercial importance. The distributions of these species in the nearshore zone are often governed by these habitat requirements. Examples include spawning substrate for herring or capelin; haulout or rookery habitats for marine mammals such as walrus, Steller sea lions, or harbor seals; inshore nursery areas for a diverse array of species such as yellowfin sole and crab; and nesting and rookery areas for marine shorebirds.

6. Bristol Bay Basin or Amak Basin, structural depressions of sedimentary material located in the southwestern portion of the proposed lease area and north of the Alaskan Peninsula, are considered to be the most likely sites of petroleum development. Conventional technology is envisioned, both for exploratory drilling (semi-submersibles, drillships, jack-up rigs) and for production platforms (e.g. Cook Inlet structures). Transportation to shore by pipeline and subsequent overland pipeline transport to a port site located on the south coast of the Alaska Peninsula is probable. Statistically, one oil spill of greater than 1,000 barrels but less than 10,000 barrels would be expected during the lifetime of these oil fields, although a small but finite chance exists for a larger spill.

7. Because the area is large compared to the size of an individual spill, because the lifetime of a likely spill as a surface slick is probably limited to 1-2 weeks, and because the transport dynamics are dominated by frequent storm events, mean oceanographic conditions and transport are of limited use when analyzing potential vulnerability. Rather, specific locations and dynamic transport events of 1-14 day time scales will be important.

In spite of incident specificity (locality, volume, meterological history), some generalizations and concerns can be summarized regarding vulnerability of inshore biota and habitats to oil spills. The most vulnerable habitats are clearly the enclosed lagoons, which would retain oil for long time periods with associated toxic effects to a wide range of organisms, from primary producers through infauna to higher predators. Eelgrass itself is only moderately sensitive to oil, reflected in measured lower productivity. However, effects on the eelgrass sediment habitat are felt to be indirect but of more long-term importance. The more open inner bays are also of concern, though a lack of data on their utilization and importance currently exists. Though specific localities (such as rookeries) are vulnerable and are mentioned elsewhere, the sand and gravel habitats in shallow water are generally of concern because oil can be mixed downward by wave action. These habitats are generally utilized by numerous species for spawning areas, as nursery grounds for juveniles, or as feeding areas.

Among the most vulnerable marine mammals will be the sea otter, which is confined to the inshore area and is sensitive to oiling of fur, critical to insulation and buoyancy. Young pups of sea lions and harbor seals could also be vulnerable as they may have not developed protective blubber. Increased air and marine traffic could also be of concern around rookeries or hauling grounds, such as to sea lions on Amak Island, walrus on Round Island, or Harbor seals at Port Moller, Port Heiden or the Cinder River area.

Birds are obviously vulnerable to direct oiling, but may also experience reduced reproductive success through transfer of oil back to nests where eggs are being incubated or by ingestion of oil during preening or feeding. Species which spend a major proportion of time on the water or a large proportion of their life cycle in the area are considered vulnerable, especially if they breed in the area, are highly gregarious, or have low population turnover ratios (one to two eggs/year/breeding pair), such as alcids do. For example, common murres (one egg/year/breeding pair) have up to 80% of their population frequenting cliff area breeding grounds. Kittiwakes (2 eggs/year/breeding pair) are similar. Among waterfowl, black brant are extremely vulnerable since most of the world's population stages in the area of Izembek Lagoon. Not only would they be vulnerable to losses by direct oiling, but also through effects of oil retained in the lagoon and consequent loss of feeding habitat. Similar factors would affect other waterfowl such as eider and Emperor geese, though populations are not as concentrated. However, over 50% of the world's population of Emperor geese is thought to occur in Nelson Lagoon each fall. Shorebirds would probably be less vulnerable, being affected primarily through their food supplies and perhaps being more adaptable through mobility.

Of fishes, capelin and herring are probably most vulnerable since they spawn on beaches or in shallow water. In fact, all osmerids would be vulnerable as their larvae are known to concentrate close to the surface. Outgoing juvenile salmon are also of concern since they frequent the top 1-2 meters of the water column, and are confined to the nearshore area, at least as far out as Port Moller. As adults, yellowfin sole are not likely to be impacted by a spill. The larvae and juveniles released in shallow water, however, may be influenced. Distributional data are currently not adequate to assess the potential exposure of the larvae and juveniles to an oil spill.

Among the invertebrates of concern are the commercially fished populations of crab and the as yet unutilized populations of clams. High among invertebrates of concern would be king crab because they utilize the nearshore area for both spawning and nursery grounds. Tanner crabs generally are deeper offshore, and thus of much less concern. The population of Alaskan surf clam is, however, restricted to the shallow water along the Alaska Peninsula coast.

8. Large data gaps exist which will hamper management decisions regarding Bristol Bay resources, particularly when oil and gas developments are added to the present problems. Among the most obvious data gaps are a) those concerning fundamental food web relationships based upon endemic and import/export carbon sources and b) those concerning utilization of nearshore habitats and the ecologic importance of these zones.

The integration of physical and meteorological oceanographic efforts with ecological studies was a unique and successful feature of previous PROBES and OCSEAP studies in the southeastern Bering Sea. This close cooperation should be continued for the needed studies in both the nearshore zone and in the lagoons and inner bays. The major purpose of such physical support studies is to understand the transport systems important to the food webs described above; however, the movement of oil or other potential pollutants in the inshore zone or into lagoons and bays is also of importance.

The North Aleutian Shelf is apparently on a meteological knife-edge with large interannual variability in storm tracks either north of or along the Aleutian Chain/Peninsula associated with large-scale meteorological patterns (Overland and Pease 1982). Nearshore flow is event dominated, with periods of wind-driven counterflow close to shore, probably statistically very significant but variable, and important to larval distribution of inshore spawning species, to upwelling and density structure, to inshore/offshore mixing of detrital organic matter, and to the movements of food organisms and predators.

Future work must emphasize food web relationships. For example, inshore marine primary productivity and that contributed by lagoonal/riverine systems has been estimated from very sparse data. The critical roles of lower level consumers, and even their inshore distributions, are not documented. Zooplankton grazing rates control the relative importance of pelagic and benthic food chains, the latter postulated above to be the most important in the endemic nearshore system. Mysids and euphausiids potentially have very important food web roles, yet they are essentially unsampled in the inshore zone, particularly the inner bays. The importance of detrital material in the nearshore area, and infaunal standing stock and production estimates are also topics for which research is needed, so that importance and potential vulnerability of food web links may be understood. Similar conditions exist with regard to good data on higher trophic level consumers, starting with almost nothing on major forage fishes, such as smelts, and proceeding with large data gaps on feeding of key marine mammal and bird species (such as otters, sea lions, harbor seals, and seabirds).

A similar situation exists with regard to utilization of nearshore habitats. From other similar situations, it would be expected that the large lagoonal areas would be extensively utilized as nursery grounds for marine species. Yet, sampling designed to look at such broad utilization has been carried out in only one lagoon (Izembek) and only for 3-4 weeks. An assessment of importance cannot be made from such limited data. The extensive shallow estuarine bays surrounding Bristol Bay have also not been studied as to their real importance as nursery or feeding grounds, though some work has been started on the open Peninsula coast regarding inshore utilization and feeding by otters and crabs. Major study efforts should be placed upon these lagoons and embayments in order to document their suspected, multifaceted importance to Bristol Bay food webs, in addition to their obvious bird habitat importance.

INTRODUCTION

1. Purposes

Early oceanographic and ecological studies in the Bering Sea tended to be in the offshore deeper waters, or focused on specific fishery resources. Later, increased emphasis in the form of large, integrated programs has been given to the southeastern Bering Sea as a result of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), as a result of National Science Foundation studies (IDOE, PROBES), and also as a result of continued marine resource related studies by the State of Alaska and by Federal Agencies. Shelf-wide studies in the Bristol Bay region have described the circulation, hydrographic structure, tides, and climatology of the area. Biological studies have defined the utilization of this region by plankton, benthos, fish, birds, and marine mammals. A synthesis report, summarizing and interpreting southeastern Bering Sea data has been issued by the NOAA/OCSEAP program (Hameedi, ed. 1982) for the Saint George Basin area, which extends generally from Unimak Island to the Pribilof Islands. A two volume summary of the oceanography and resources of the eastern Bering Sea shelf was funded by NOAA, Office of Marine Pollution Assessment (Hood and Calder, eds., 1981). This two volume set contains summary and synthesis papers by many active investigators working in the southeastern Bering Sea.

In March of 1982, OCSEAP held a synthesis meeting to assess the status of the scientific knowledge in the North Aleutian Shelf lease area. A synthesis report for this North Aleutian Shelf area is now in rough draft form (L.K. Thorsteinson, ed., 1983 draft). From existing data, participants at this synthesis meeting identified high productivity and extensive utilization of offshore shelf areas, from approximately the 20 meter depth seaward. They were able to characterize in detail the ecological processes involved. Similar high productivity and utilization in the lagoonal systems along the North Aleutian shelf coastline was also reasonably understood in terms of the causative ecological processes, based on previous study results.

Within the nearshore area, however, the workshop participants did not find it possible to define the controlling ecological processes leading to the high biotic utilization known to occur in this area, particularly within five kilometers of the north coast of the Alaska Peninsula. Their difficulties were largely due to a lack of data existing for this nearshore zone, or to the fragmentary nature of these data taken as an incidental part of larger studies. The purposes of this present study, therefore, are to review and interpret the present but limited available data pertinent to the nearshore zone; to hypothesize controlling ecological processes and test them with available data; and to consider the vulnerability of these communities and processes to oil and gas-related effects. Data needs can then be defined and future studies focused on processes or key species, as suitable.

The specific objectives of this study as defined by NOAA/OCSEAP are therefore as follows:

- Describe the present status of knowledge concerning the biotic communities and organic productivity of the nearshore (0-5 km from the coastline) zone along the entire North Aleutian Basin lease area, (Unimak Pass to Cape Newenham), with particular reference to the area adjacent to Izembek Lagoon.

- Describe the ecological processes which might be causing the observed distributions, densities, and interrelationships.

- Discuss potential vulnerability of this region to impacts from offshore oil and gas development.

- Identify significant data and information needs in order to test the hypothesis that organic enrichment by eelgrass detritus, or other related causes, leads to the observed distributions of biota.

2. Study Area

The study area for this project, shown in Figure 1, includes the nearshore coastal zone of the North Aleutian Basin lease area. This area extends from Unimak Pass around the shoreline of Bristol Bay to Cape Newenham, and seaward from shore to a distance of five kilometers.

In actual practice, of course, a seaward boundary of five kilometers does not physically exist. Since some processes acting over the entire southeastern Bering Sea shelf affect this nearshore region, we include some review and interpretation of data from these larger areas. However, the focus is on the nearshore zone. Likewise, a natural hydrographic front exists at about the 50 meter depth contour, defining the outer edge of the coastal domain water. This contour generally lies offshore from the five kilometer distance. Processes, habitats, and utilizations within this wider area are also treated, however, in order to better elucidate the ecology of the nearshore area.

3. Potential Development and Conflicts

The continental shelf of the eastern Bering Sea is considered to be one of the most promising potential

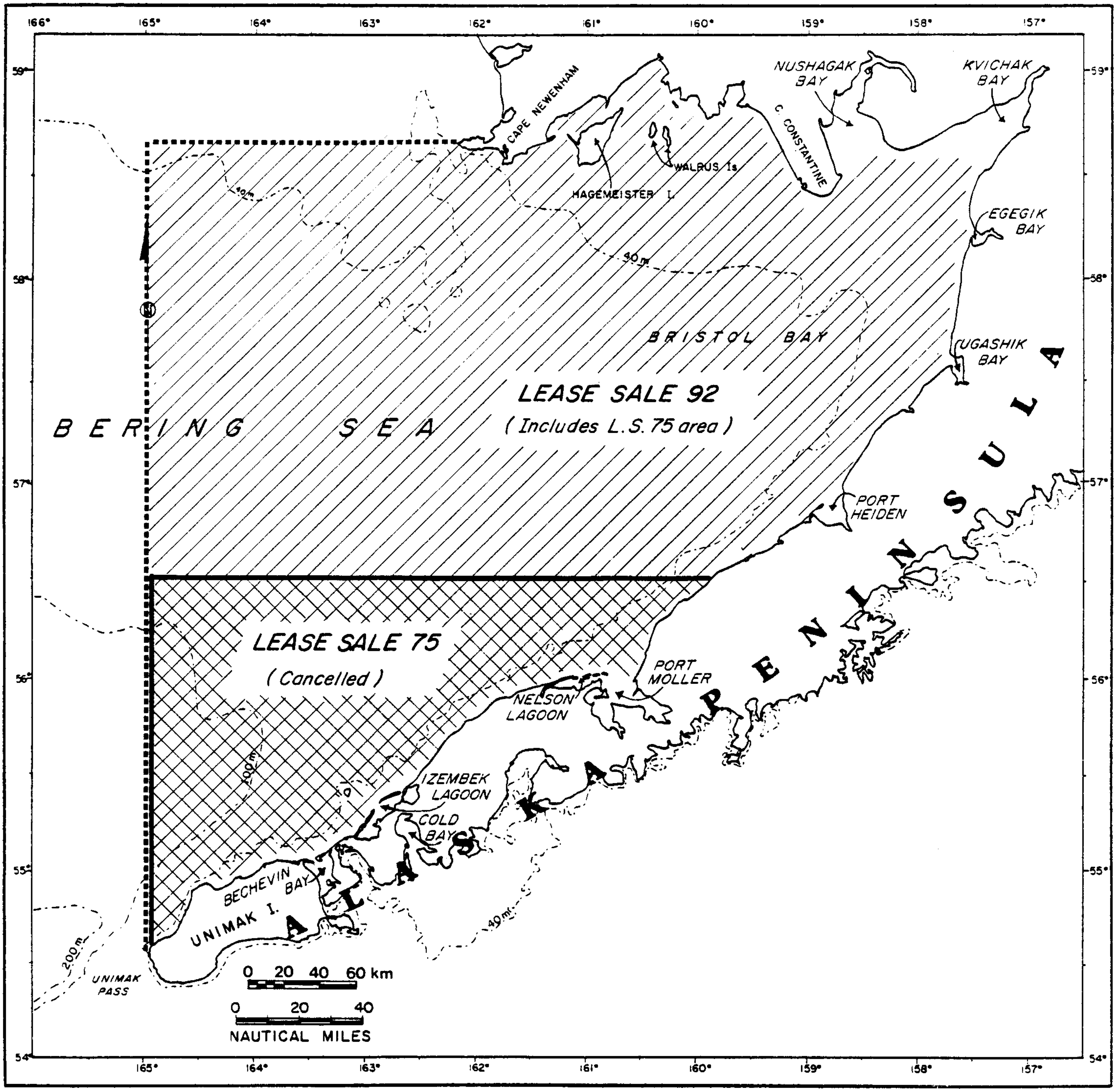


Figure 1. Study area--North Aleutian Shelf nearshore area.

petroleum provinces remaining to be explored off the coast of the United States. The formations which are potential petroleum source rocks occupy a structural depression known as Bristol Basin, Figure 2 (Marlow et al, 1980). This subsidence basin is filled with sedimentary rocks composed of detritus eroded from Alaska mainland mountains and of volcanic debris from the Alaska Peninsula. The maximum thickness of these Cenozoic deposits is poorly known, but may reach eight kilometers in the deepest part of the depression. A large portion of Bristol Basin contains deposits more than three kilometers thick. Offshore strata, considered to have the best potential for petroleum, are flat-lying sandstone, siltstone, and shale which range in age from Eocene (40-60 million years before present) to Holocene (10,000 years to present). These areas of highest interest are shown in Figure 3, designated as the St. George Basin, Amak Basin, and Bristol Bay Basin.

Lease Sale 92 (Figure 1) for the North Aleutian Basin planning unit, consists of all of the Bristol Bay area, and is scheduled for sale April 1985 (July 82 Planning Schedule). Previous lease sales (#51 and #75) scheduled in 1977 and 1983 were cancelled.

Potential conflicts with development of these petroleum resources exist because of the extreme biological productivity of the North Aleutian Shelf-Bristol Bay area. The rich resources existing in this area and the close proximity of lucrative salmon and crab fishing areas, of national wildlife refuges, and of state-owned critical habitats, have made petroleum development very controversial.

4. Approach

Since no new field data are to be obtained for this project, the collection and review of available literature formed the foundation for this study. As identified in the March 1982 synthesis meeting, data within the nearshore zone of the North Aleutian Shelf were known to be deficient. The approach of the present study was to utilize data that did exist and to extrapolate data from adjacent areas where appropriate. The strategy was to concentrate on the basic physical and biological processes controlling the ecology of this nearshore zone, to construct hypotheses concerning these controlling processes, to test these hypotheses with the available data, and to identify data gaps.

Literature of the southeastern Bering Sea is extensive, of course, and may pertain to the nearshore zone only incidently (e.g., one nearshore station on a line extending far offshore) or only by inference. Therefore, discretion was used to include enough of these data for perspective, without repeating unnecessarily the excellent reviews and syntheses that already exist.

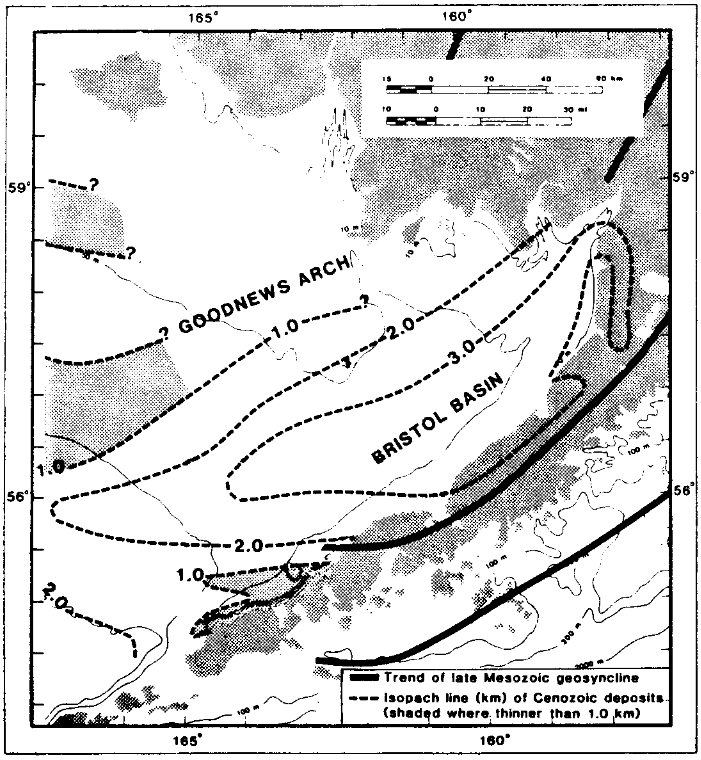


Figure 2. Potential petroleum source rocks, southeastern Bering Sea (Science Application, Inc., 1981, adapted from Marlow et al, 1980).

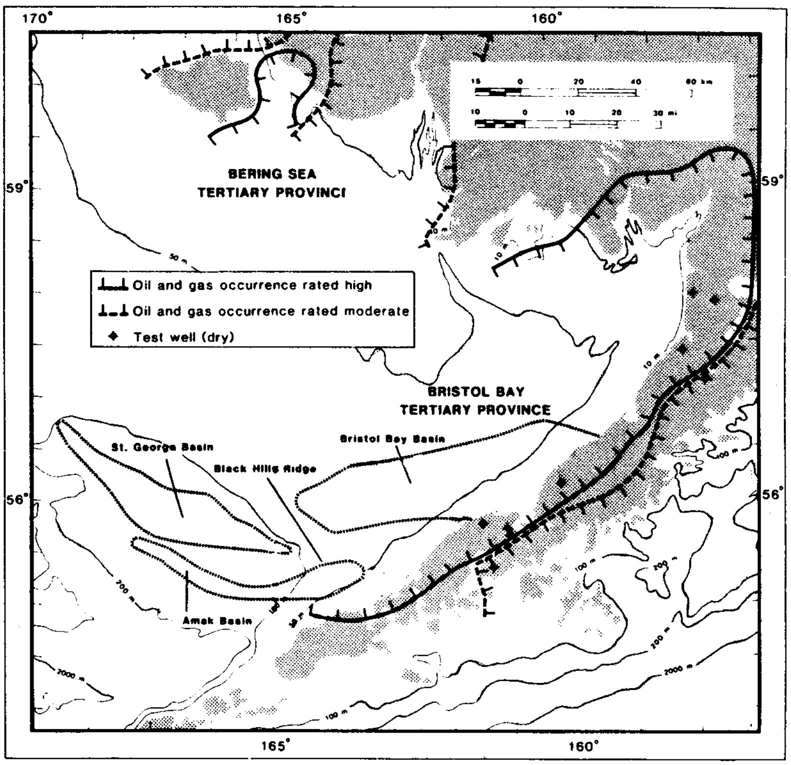


Figure 3. Offshore strata with high potential for petroleum, southeastern Bering Sea (Science Application, Inc., 1981, adapted from Marlow et al, 1980).

1. Physical, Chemical, and Geological Characterization

a. Physical Oceanography and Meteorology

Oceanographic Structure. Before 1975, oceanographic data for the Bering Sea and Bristol Bay were scattered in space and time and were biased toward the deeper portions, rather than on the continental shelf (Kinder, 1981). By necessity, therefore, most work had concentrated on the mean state of the Bering Sea at large spatial scales, with emphasis on the deep basin. Later work shifted to the continental shelves and to shorter temporal and spacial scales, which allowed variability and oceanographic processes to be better addressed. Building on the earlier data base obtained because of oceanographic concerns of fisheries research, the later larger, multidisciplinary programs such as PROBES (Processes and Resources of the Bering Shelf, funded by the National Science Foundation) and OCSEAP (Outer Continental Shelf Environmental Assessment Program, funded by the Bureau of Land Management) have rapidly added to our knowledge of Bering Sea oceanography, particularly on the continental shelf.

Early data, particularly those of the research organizations of the member countries of the North Pacific Fisheries Commission - Canada, Japan and the United States - were summarized by Dodimead, Favorite, and Hirano (1963), as well as earlier by Favorite and Pederson (1959) and Favorite et al (1961). This review of the entire subarctic Pacific also includes portions of the Bering Sea and a special appendix on Bristol Bay. Subarctic boundaries, salinity structures, surface heating/ cooling, and wind mixing were deduced. Currents and gyres were derived from geostrophic analyses of hydrographic data and wind driven transports from meteorological data. Dodimead et al (1963) utilize a concept of oceanographic domains as areas of consistent structure and oceanographic behavior. Building further on such concepts, Takenouti and Ohtani (1974) reviewed Japanese work. Their domains, representing mean conditions, are shown in Figure 4. In our region of immediate interest, they identify "Coastal Water" nearshore in Bristol Bay with a "Convective Area" further offshore over the shelf, and the "Alaskan Stream" intruding through Unimak Pass and northward along the shelf break. Circulation was identified as being counterclockwise in the Bristol Bay region. Similar circulation for our area of interest was also shown by Arsen'ev (1967), Figure 5. Summer mean surface salinities of Figure 6 (Favorite, Dodimead and Nasu, 1976) conform to the general circulation over the deep basins, suggest the front overlying the slope, and indicate the large horizontal salinity (density) gradients important to shelf processes.

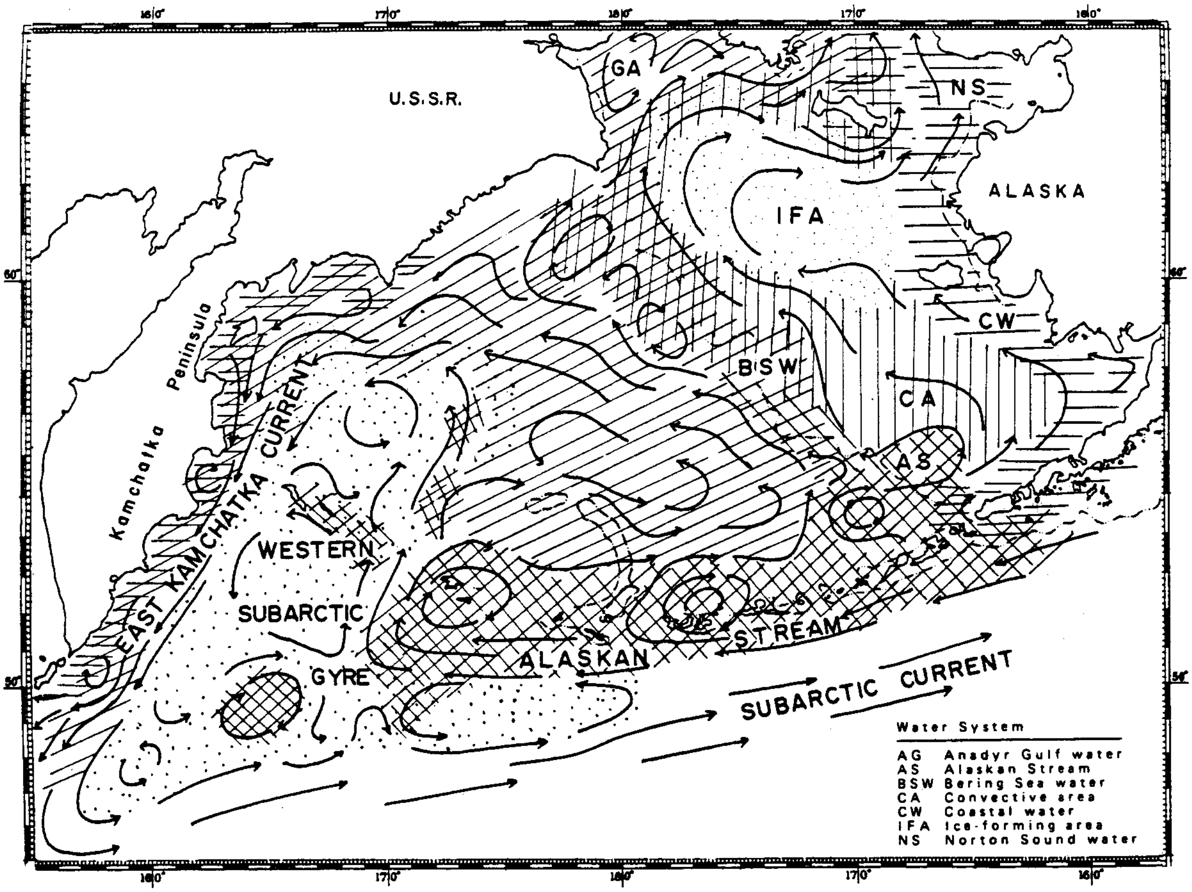


Figure 4. Schematic diagram of circulation and extent of water masses in the Bering Sea and northwestern Pacific Ocean (Takenouti and Ohtani, 1974).

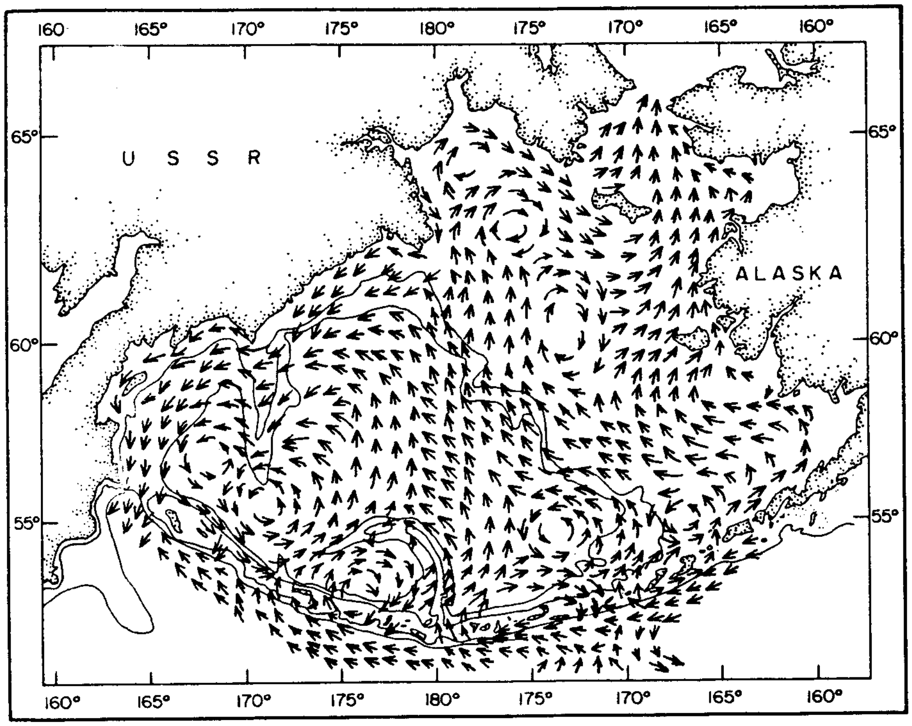


Figure 5. Bering Sea circulation according to Arsen'ev (1967).

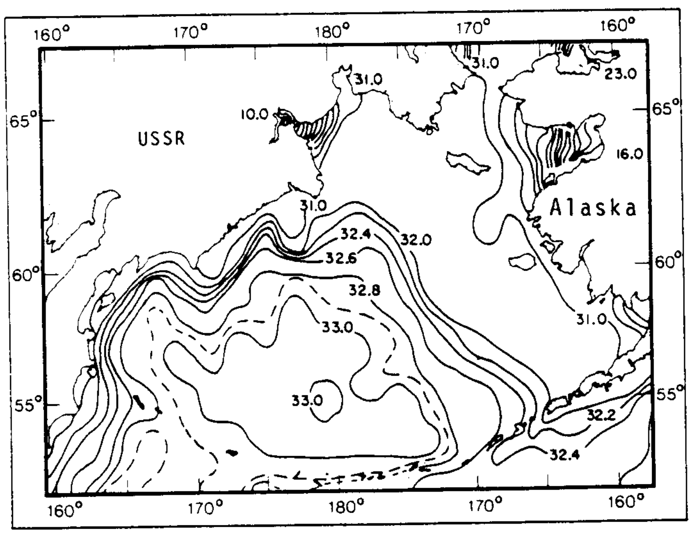


Figure 6. Summer mean surface salinity g/kg (Favorite, Dodimead, and Nasu, 1976).

Since 1975, extensive hydrographic data and some moored current meter data have become available for the southeastern Bering Sea through the OCSEAP and PROBES programs. Kinder and Schumacher (1981a) have synthesized these hydrographic data. Based upon hydrographic structure, the shelf is divided into distinct domains (Figure 7), coinciding with depth intervals and separated by oceanographic fronts.

The shelf break front (Figure 7), separates the outer shelf domain from the oceanic domain. This latter domain consists of Alaska Stream/Bering Sea waters lying off the continental shelf. The shelf break front is broad (50 km) and diffuse, distinguished by a much higher salinity gradient than is the outer shelf domain.

The outer shelf domain itself exists between the 100 m isobath and the shelf break at about the 170 m contour (Figure 7). This domain exhibits a wind mixed surface layer, a tidally mixed bottom layer, and a 20 to 80 m thick middle layer characterized by low turbulent mixing (Figures 8 and 9). In this domain, horizontal mixing of oceanic Alaska Stream/ Bering Sea water with fresher shelf waters manifests itself as interleaving along isopycnal surfaces in the low turbulence middle layer.

The frontal boundary separating this region from the middle shelf domain occurs at about the 100 m depth contour. This boundary is a generally weak front occurring over approximately a 50 km wide band (Figure 8), distinguished by a steeper salinity gradient (0.01 g/kg/km) than exists in the adjacent domains.

The middle shelf domain may be characterized, in general, as a two layer system during the summer. A wind mixed surface layer is typically 15 to 20 m thick, and a tidally mixed bottom layer is typically 50 m thick. In 70 to 100 m of water, this domain thus exhibits a two-layered hydrographic structure, often with a sharp interface and with corresponding low vertical transfer across the interface (Figure 9). The upper layer is warmer and fresher (e.g. 8°C and 31.5 ppt) than the lower layer (typically 3.5°C and 31.8 ppt). This lower layer is essentially a remnant of surface cooling in the winter. During summer, this layer is insulated from warming by stratification. In winter, however, the structure becomes almost vertically homogeneous due to increased wind mixing, surface cooling (Reed, 1978), and the addition of salt at the surface from the formation of sea ice. In the spring, melting of sea ice and freshwater runoff quickly re-establish the sharp, two-layer system, reinforced by surface warming through the summer.

The inner front, at about the 50-meter contour and approximately 10 km wide (Figure 8), is thus a structural front (Schumacher et al, 1979) dividing domains with

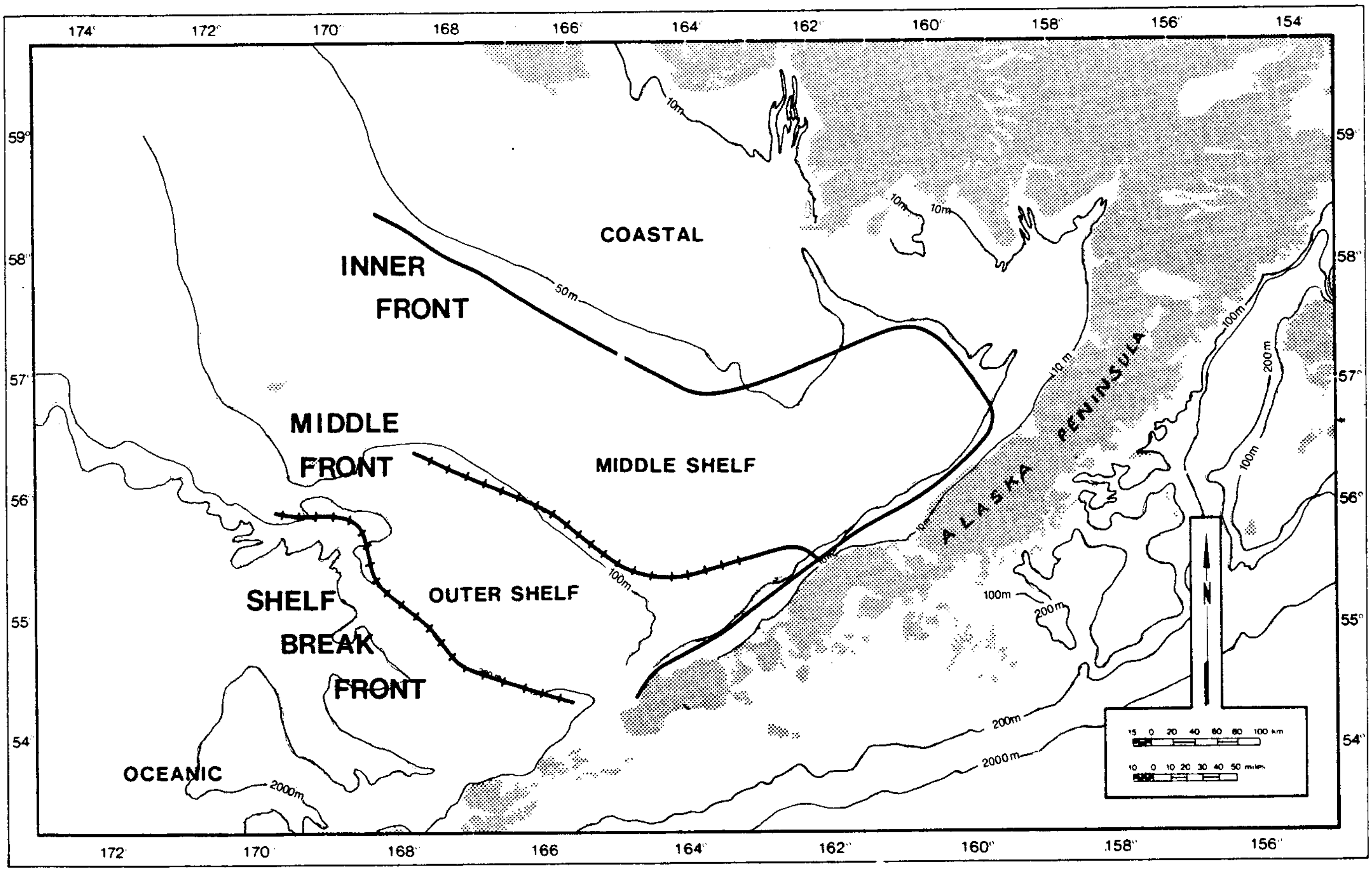


Figure 7. Approximate boundaries separating the three shelf (coastal, middle, outer) and the oceanic hydrographic domains. The boundaries are three fronts: inner, middle, and shelf break. These fronts roughly coincide with the 50 m isobath, the 100 m isobath, and the 200 m isobath (shelf break) (Kinder and Schumacher, 1981a).

different hydrographic structures. Typical salinity and temperature data across this inner front are shown in Figure 10. Inside about the 50 m contour, tidal and wind mixing can efficiently mix the entire water column, resulting in homogeneous vertical structure. The inner front thus separates homogeneous and stratified structural domains, and occurs at a depth where the mixing energy is sufficient to overcome buoyancy.

For this nearshore North Aleutian Shelf study, this coastal domain is of primary interest. This domain (Figure 7) extends from the shoreline out to about the 50 m contour, typically 25 km offshore along the northern shore of the Alaska Pennisula, about 100 km offshore along the northern side of Bristol Bay to Cape Newenham, and about 130 km off the shore of Nunivak Island at the northern extremity of the southeastern Bering Sea area. We will consider this domain, and the nearshore zone, out to five km, in more detail later.

Circulation, Currents, and Tides. Data on circulation on the southeastern Bering Sea shelf have been synthesized by Kinder and Schumacher (1981b), and by Schumacher and Kinder (1983). Current meter mooring locations and mean flows from the data records so obtained are shown in Figure 11. Currents are strongly tidal and can reach speeds of up to 50 cm/second. However, net mean flows averaged over these oscillary motions and effective in the net transport of water, are characteristically low. The current regimes can also be classified according to the structural domains described above as outer shelf, middle shelf, and coastal.

In the outer shelf domain, vector-mean flow was statistically significant, with along- (toward the northwest) and across- (toward the northeast) isobath speeds generally between 1-10 cm s^{-1} and <1-5 cm s^{-1}, respectively. In this regime, tidal kinetic energy accounted for about 81% of the fluctuating kinetic energy. Energy at frequencies related to meteorological forcing, as well as energy at oceanic forcing frequencies, were greater here than in the other regimes. Estimates of both baroclinic geostrophic speeds (Figure 12) and those generated by tidal interaction with shoaling bathymetry (under the middle front) are similar in magnitude and direction to the observed flow along isobaths. The pulses of cross-shelf flow may be a response to wind forcing at higher frequencies. The kinetic energy at oceanic forcing frequencies, however, is of equal magnitude to that in the meteorological forcing frequency and may be responsible for the observed cross-isobath mean flow.

Vector-mean flow within the middle shelf regime was not significant except near its boundaries, where it paralleled isobaths. As is the case with the coastal regime, fluctuating kinetic energy in this regime was mostly at tidal

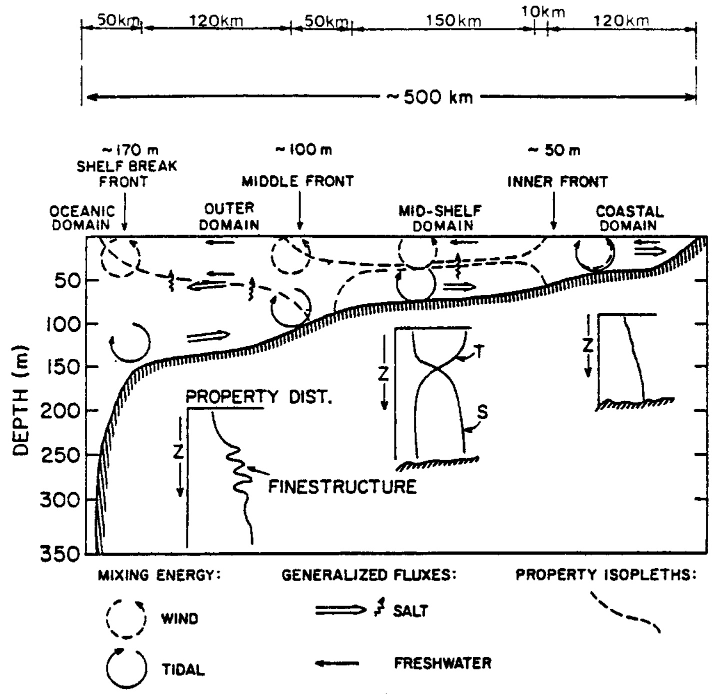


Figure 8. Conceptual advection-diffusion model of the oceanographic structure of water of the continental shelf in the southest Bering Sea (Coachman & Walsh, 1981).

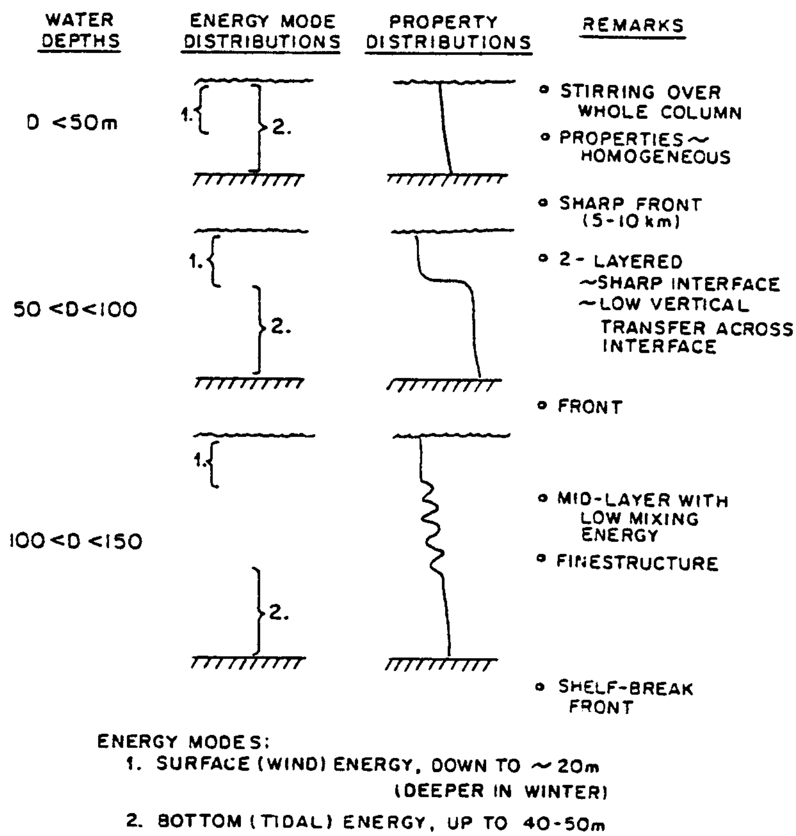


Figure 9. Schematic diagram of energy mode distributions by depth ranges and accompanying water column structure. The inner front, being closely associated with the 50 m depth contour, does not appear in the area of deeper, outer Bristol Bay (Coachman and Charnell, 1979).

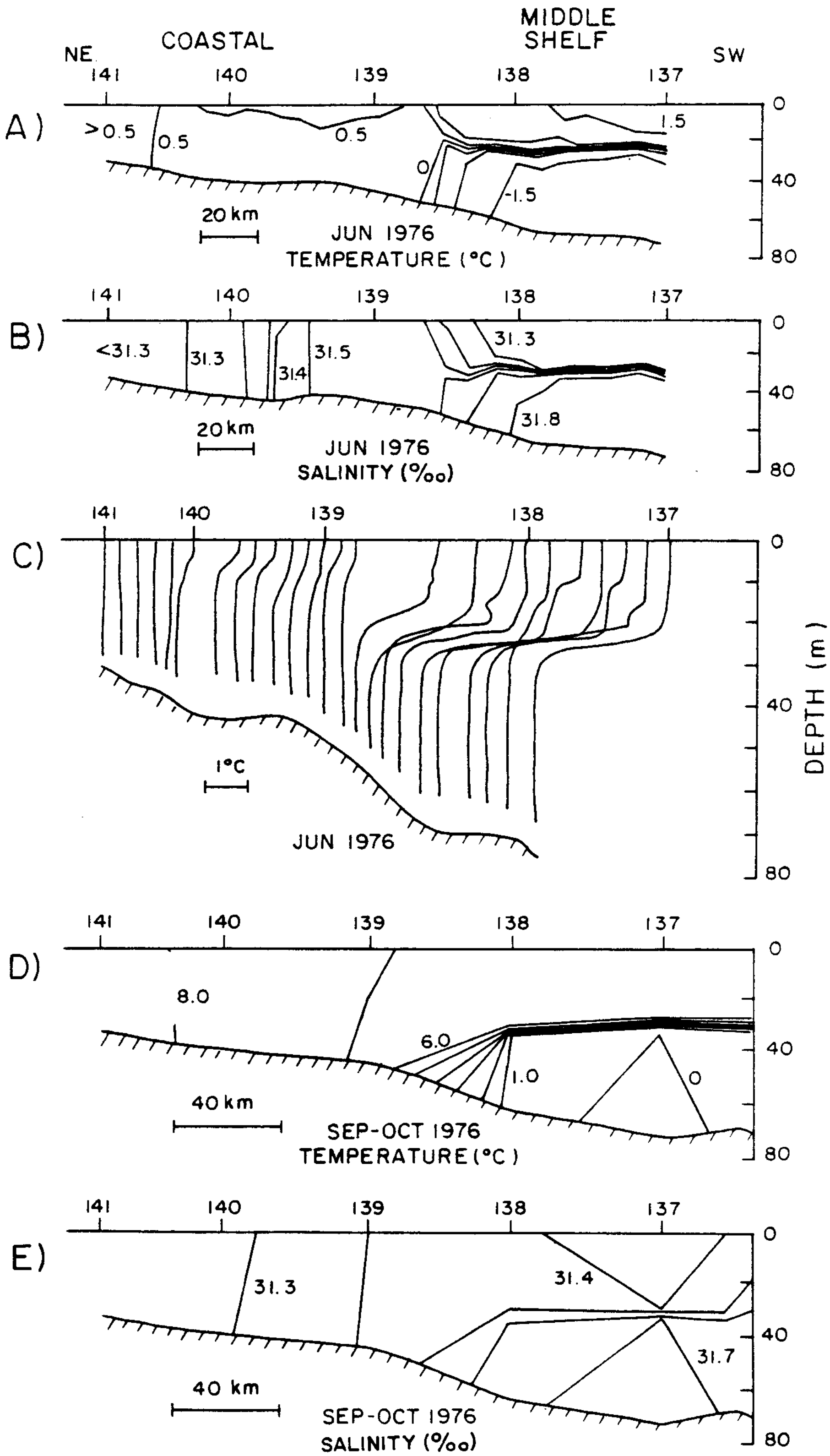


Figure 10. The structural (inner) front separating the coastal and middle domains. This line was between Nunivak Island and the Pribilof Islands. (A, B) Temperature and salinity cross sections, and (C) sequential temperature profiles from June 1976. The sections are based on stations separated by about 10 km. (D, E) The same section based on widely spaced CTD stations in autumn 1976 (Schumacher et al, 1979).

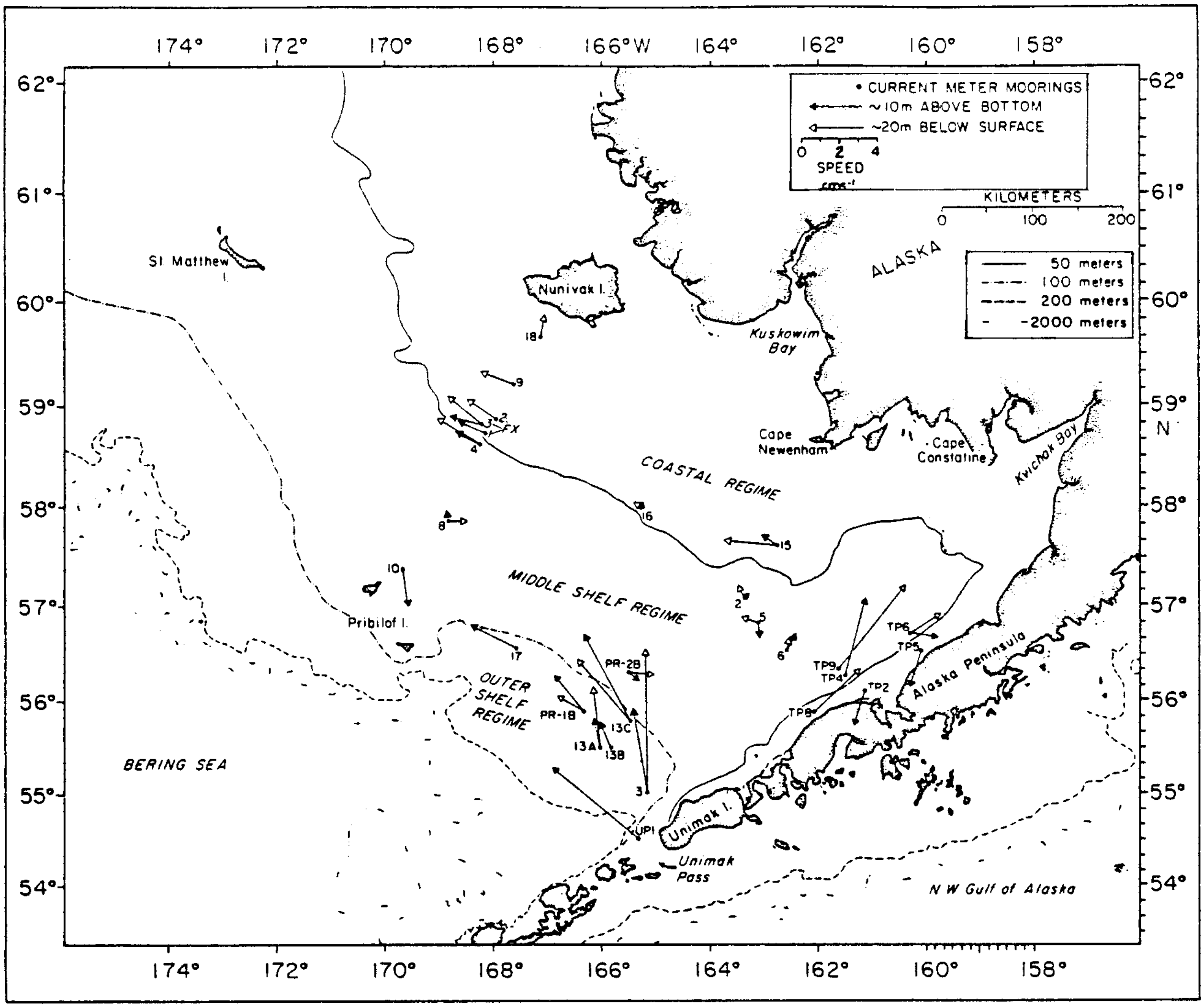


Figure 11. Mean flow based on all records at each mooring site (Schumacher and Kinder, 1983).

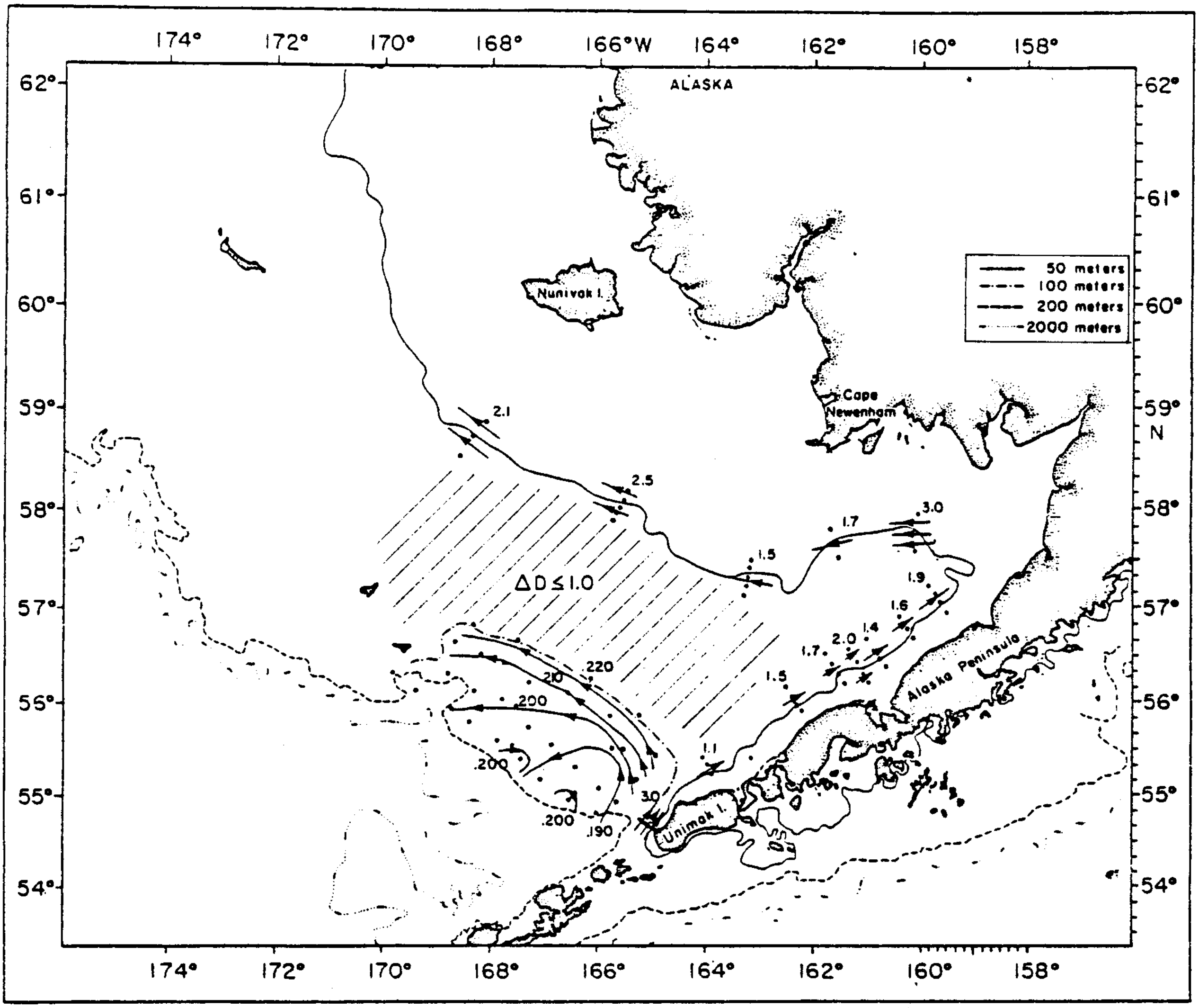


Figure 12. A compilation of hydrographic data from six cruises during summer conditions presented as dynamic height contours (0/80db) for synoptic data from the outer shelf and dynamic height (0/40db) difference along sections occupied various times normal to the inner front. The dots represent CTD station locations and the contour interval is 1 dyn cm. The shaded portion of the middle shelf regime shows that ΔD<1 dyn cm (0/40db) throughout this area for the six cruises ($\overline{1}$02 stations) (Kinder and Schumacher, 1981a).

frequencies, about 92%. Kinetic energy at meteorological frequencies was only slightly less than in the coastal regime, but the lack of coastal boundaries precludes coastal Ekman divergence and generation of pressure-induced alongshore current pulses; instead, currents respond to the wind as rotating vectors.

In the coastal domain, the area of most immediate interest, vector mean flow parallel to the 50 m isobath, i.e. along the inner front, was statistically significant. Speeds paralleling this feature were generally between 1 and 6 cm s^{-1}, with the higher values during winter. The coastal current was observed from the vicinity of Unimak Pass, along the Alaska Peninsula to the vicinity of Nunivak Island. Although fluctuating kinetic energy in this regime is dominated by tides (about 94%), significant energy at meteorological frequencies can be clearly distinguished as current pulses. Because vector-mean winds are weak, wind-driven circulation is believed to contribute little directly to the observed mean flow; instead, a combination of baroclinic geostrophic current (Figure 12) and current generated as a result of interaction between tides and shoaling bathymetry are the primary forcing mechanisms. We consider this coastal domain in more detail below.

Characteristics of these general flow regimes are summarized in Table 1 after Schumacher and Kinder (1983). Generalized mean flow regimes are depicted in Figure 13.

Tidal data in the southeast Bering Sea have been reviewed by Pearson, Mofjeld and Tripp (1981). The tidal distribution is unusually complicated but is generally mixed, in places predominantly mixed semidiurnally and in other places, particularly near the coast, mixed predominantly diurnally. Principal tidal constituents are M_2, N_2, O_1, and K_1. The cotidal charts for the M_2 and K_1 constituents are shown in Figure 14 and the corresponding current ellipses in Figure 15, after Pearson et al, 1981. The M_2 current constituent is largest with amplitudes of 15-30 cm/ sec on the open shelf with those of the N_2 being approximately 25-40 percent of the M_2. The K_1 is the largest diurnal constituent with amplitudes of 10-20 cm/sec on the shelf with the O_1 being about 60-75 percent of these values. Tidal current ellipses in the nearshore areas flatten considerably, showing nearly rectilinear motion near the Alaska Peninsula.

Inshore, tidal heights and currents are amplified in upper Bristol Bay, particularly in the funnel-shaped embayments at the head of Bristol Bay. For example, the mean diurnal tidal range at Kvichak, at the head of Kvichak Bay, is 5.0 m (16.5 ft) and that at Clarks Point in Nushagak Bay is 5.9 m (19.5 ft) with maxima of 7 m (23 ft) (U.S. Department of Commerce, 1981a). Corresponding tidal heights

Table 1. Characteristics of southeastern Bering Sea flow regimes (adapted from Schumacher and Kinder, 1983).

	Outer (100m-shelfbreak)	Middle (50-100m)	Coastal (Coast-50m)
1. Mean	1-10 cm/sec along isobaths, counter-clockwise (due both to baroclinicity and tide-bathymetry interactions. 1-5 cm/sec across isobaths, shoreward (due primarily to oceanic forcing).	Not statistically significant except along middle and outer fronts	1-6 cm/sec, counterclockwise (due both to baroclinicity and tide-bathymetry interaction
2. Fluctuating horizontal kinetic energy	81% tidal-remainder equally due to meteorological and oceanic forcing	92% tidal-remainder primarily meteorological in form of rotating current	94% tidal-remainder primarily meteorological in form of Ekman divergence and associated longshore geostrophic current pulses.*

* See Pearson, Baker, and Schumacher, (1980).

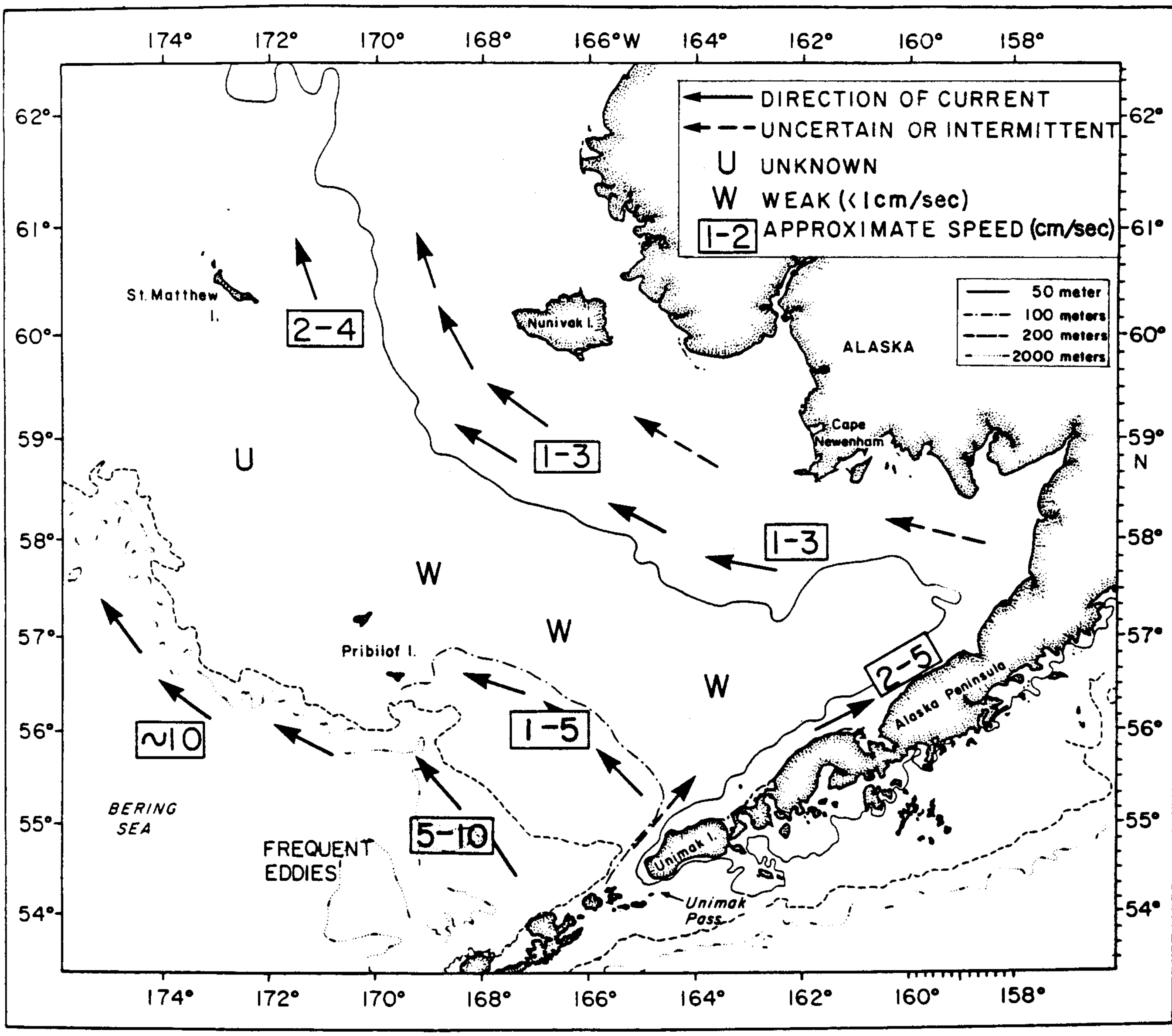


Figure 13. Schematic mean circulation (Kinder and Schumacher, 1981b).

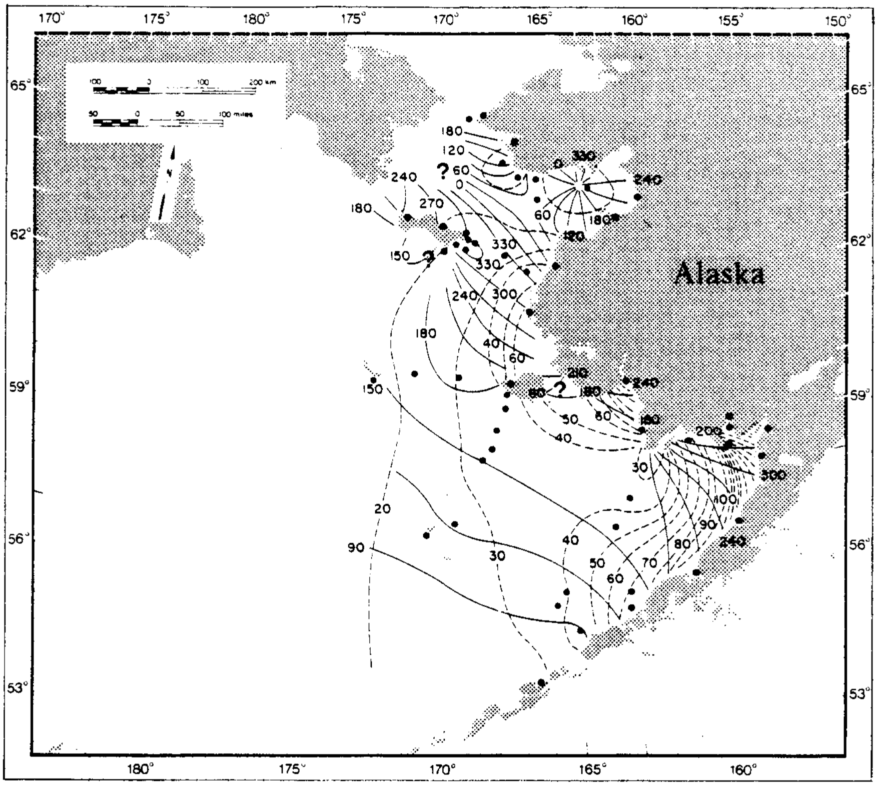


Figure 14a. M_2 cotidal chart based on the new observations. Dots represent locations of stations used in construction of the chart. Solid lines are cophase lines referred to Greenwich. Dashed lines are coamplitude, in centimeters. Areas of major uncertainty are denoted by question marks (Pearson, Mofjeld, and Tripp, 1981).

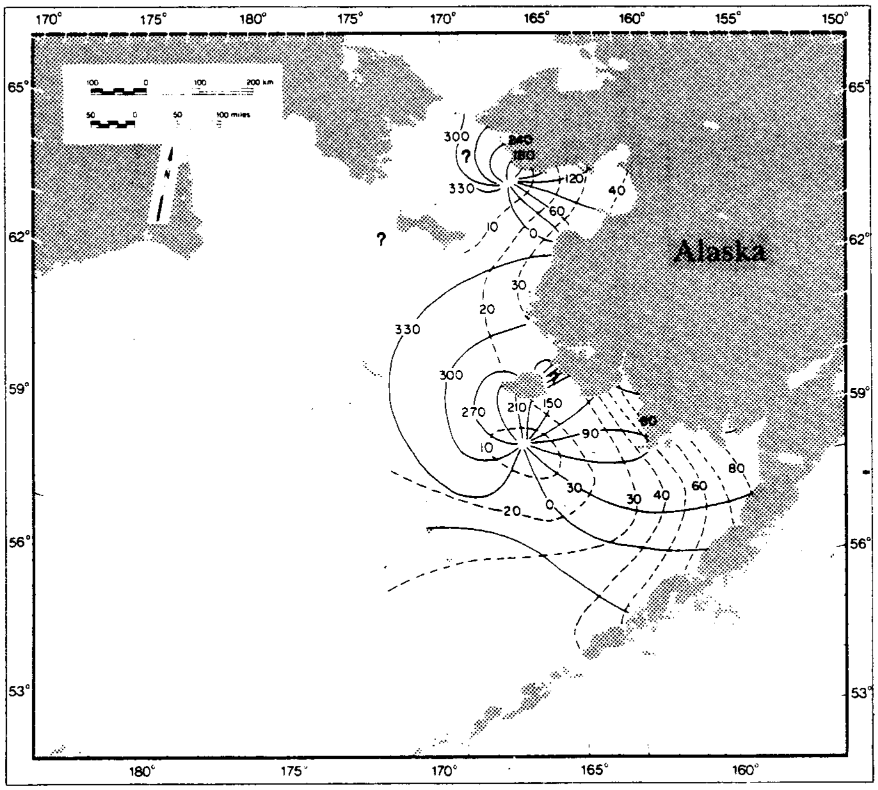


Figure 14b. Same as 14a, but for K_1 (Pearson, Mofjeld, and Tripp, 1981).

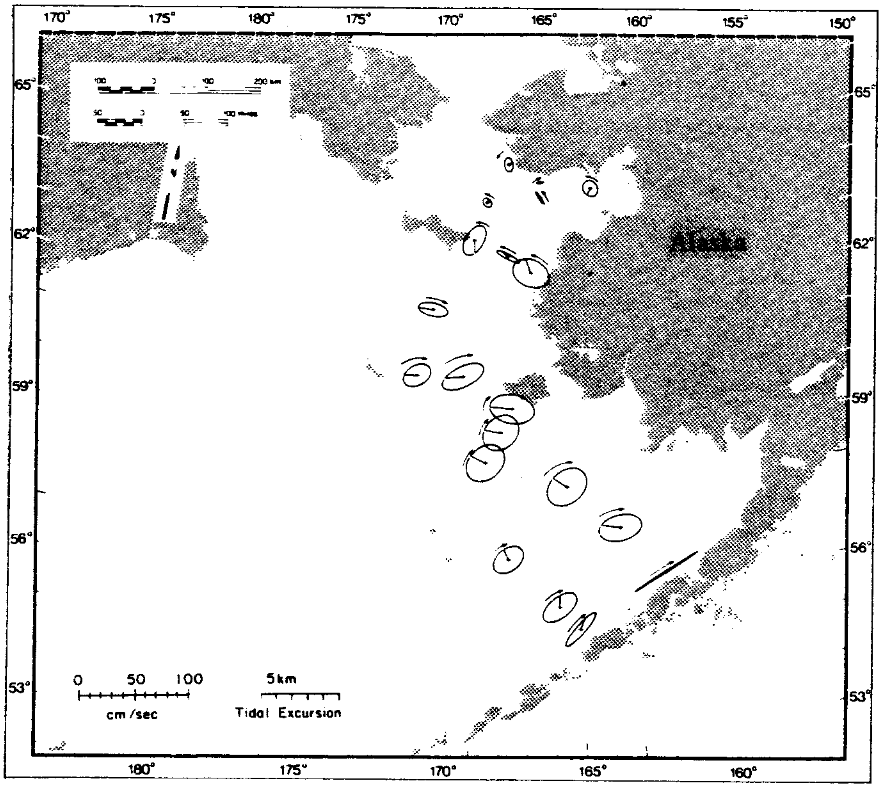


Figure 15a. M_2 current ellipses for stations listed in Table 1. For stations with records from two depths the ellipse for the deeper meter is plotted. Ellipses are centered on station location; line from center indicates constituent current vector when the M_2 Greenwich equilibrium phase angle is 0°. Arrows indicate sense of rotation (Pearson, Mofjeld, and Tripp, 1981).

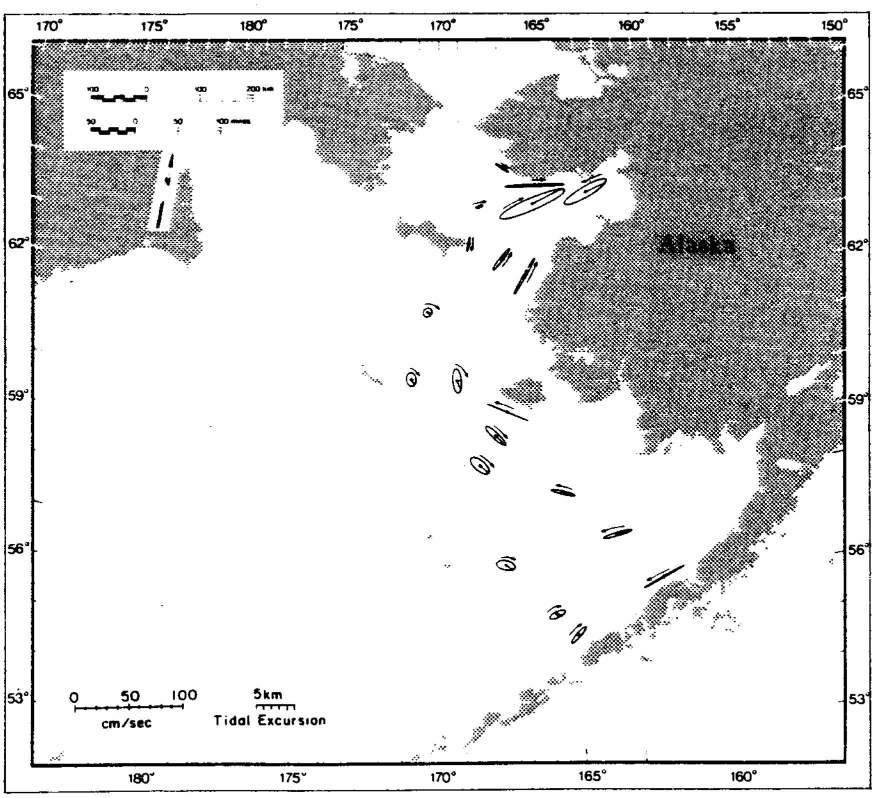


Figure 15b. Same as 15a, but for K_1 (Pearson, Mofjeld, and Tripp, 1981).

at Izembek Lagoon are much lower, being only 2.3 m, while those at Port Moller and Port Heiden are 3.3 m and 3.7 m respectively. Tidal currents are likewise magnified in these entrances and bays (U.S. Department of Commerce, 1981b). In Kvichak and Nushagak Bays at the head, tidal currents of 2-3.5 kts (100-175 cm/sec) form long, linear shoals aligned parallel to the currents and axes of the bays (10 m high, 4 km apart). Along the Alaska Peninsula, the net littoral drift is to the northeast, apparent by the barrier spits across the lagoonal areas. Tidal currents in the entrances are significantly high, however, being 1-2 kts (50-100 cm/sec).

Meteorology. The marine climatology of the Bering Sea has recently been reviewed by Overland (1981). Data have also been summarized in a climatic atlas (Brower et al, 1977). Arctic, continental, and maritime air masses affect the Bering Sea. In summer, the entire region is normally under the influence of maritime air from the Pacific. Strong flow of air from the north and east brings continental and arctic air to most of the area in January and February, as well as in spring and fall for the northern area. The winter circulation pattern persists for nine months, from September through May, indicated by the predominance of an arctic high-pressure air mass over the northern Bering Sea.

A major result of the general circulation is a region of low pressure normally located in the vicinity of the Aleutian chain, referred to as the Aleutian Low. This statistical low appears on monthly mean pressure charts as a low-pressure cell oriented with the major axis in an east-west direction. Pressures are generally lower along this major axis as the result of the passage of low-pressure centers or storms along preferred tracts.

Indeed, storm events are a characteristic feature of the southeastern Bering Sea. The monthly frequencies of low-pressure systems (Figure 16) in the southern Bering Sea are four to five in winter and three to four in summer. Thus this area may be characterized as an event-dominated system.

In winter, the most frequent airflow is from the northeast, around the northern side of the low-pressure cell present at some location along the Aleutian Chain. In summer, with the movement of lows into the Bering Sea, a more southwesterly mean flow develops over the southern two-thirds of the region. In the Aleutian Chain in winter and during the summer in the southern Bering Sea, frontal activity can be severe as very cold arctic or continental air comes in contact with the warm air from the Pacific Ocean, forming a sharp discontinuity.

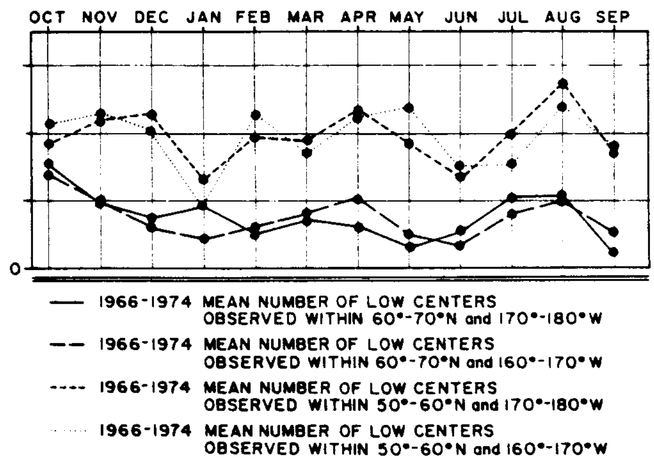


Figure 16. Frequency of low-pressure systems by month for the northern and southern Bering Sea (Overland, 1981).

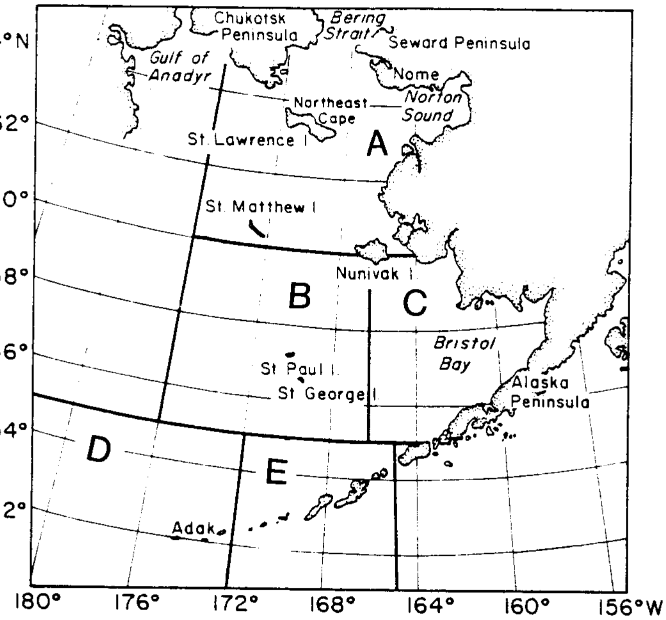


Figure 17a. Location map for the eastern Bering Sea.

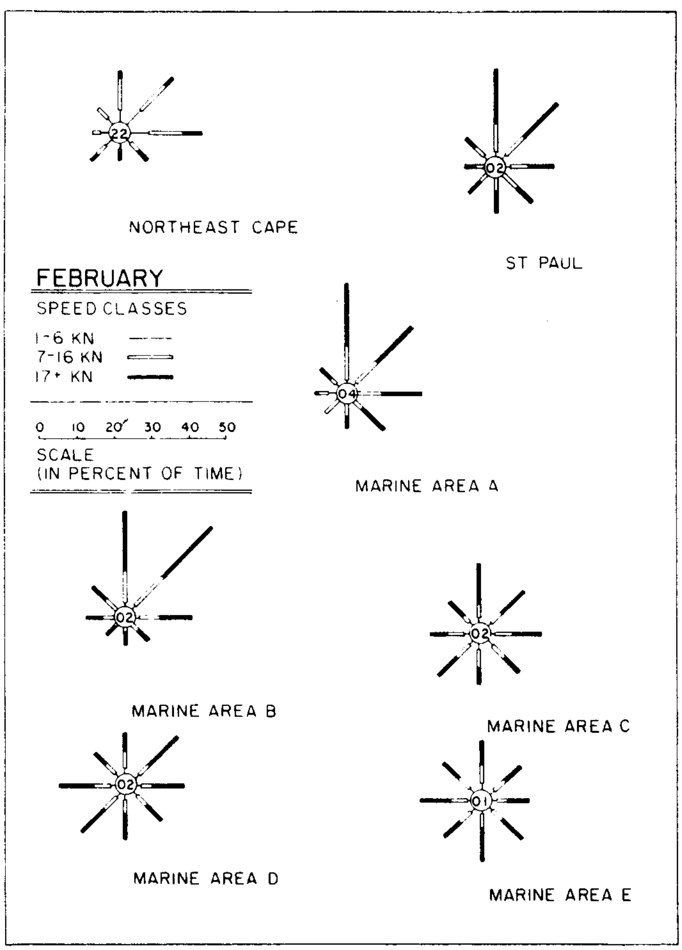


Figure 17b. February wind roses. (Direction from which the wind is blowing.)

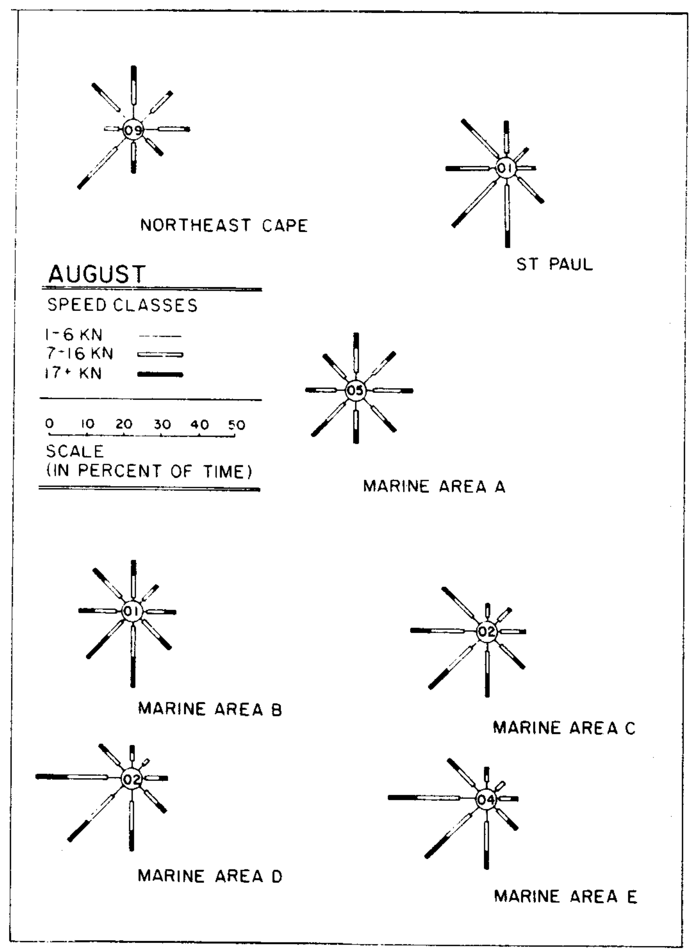


Figure 17c. August wind roses. (Direction from which the wind is blowing.)

Figures 17a, b, and c. Surface winds in the Bering Sea (Overland, 1981).

Surface winds in the Bering Sea are shown in Figure 17 for February and August. In winter, the northern stations show a high percentage of winds over 17 knots from the north or northeast, while in the Bristol Bay area the winds are fairly uniformly distributed over all directions with moderately large speeds, indicative of a fairly continuous progression of storms through the area. In summer, wind speeds are generally lower, and the Bristol Bay area shows a predominance of south and southwest winds.

Mean precipitation for selected stations is shown in Figure 18. Mean annual total precipitation approximates 62 inches/year at Dutch Harbor, but drops rapidly as one enters Bristol Bay. Corresponding yearly totals are 37 inches/year at Cape Newenham and 13 inches/year at Port Heiden. In February, 70-90 percent of precipitaton occurs as snow.

Additional monthly climate variables are shown in Figure 19.

Overland and Pease (1982) and Niebauer (1981) document large interannual variability in ice and oceanographic conditions, apparently related to whether storm tracks curve northward parallel the Aleutian Chain, which in turn, is related to large scale meteorological variations.

Waves. Approximately 3-15 percent of the observed waves, depending on season, exceed 3 to 3.5 meters in height, and may therefore be considered hazardous (Brower et al, 1977). The frequencies and distributions of these hazardous wave conditions are shown in Figure 20.

Design wave conditions have been calculated (Dames & Moore, 1980) as follows for the area of the north side of the Alaskan Peninsula and for comparable areas.

Area	Water Depths (meters)	Maximum Waves 100-Year (meters)
North Aleutian	15-120	23
St. George	91-152	23
Upper Cook Inlet	9-76	8.5
Norton Sound	15-49	6.1

These values were calculated using fetch lengths, wind durations, measured water depths, and extreme wind speeds reported by Brower et al, 1977.

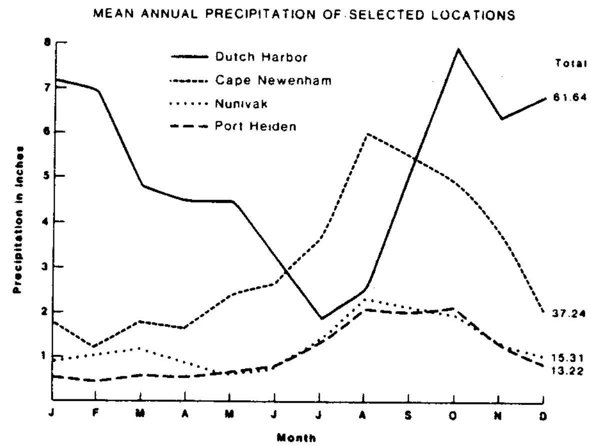
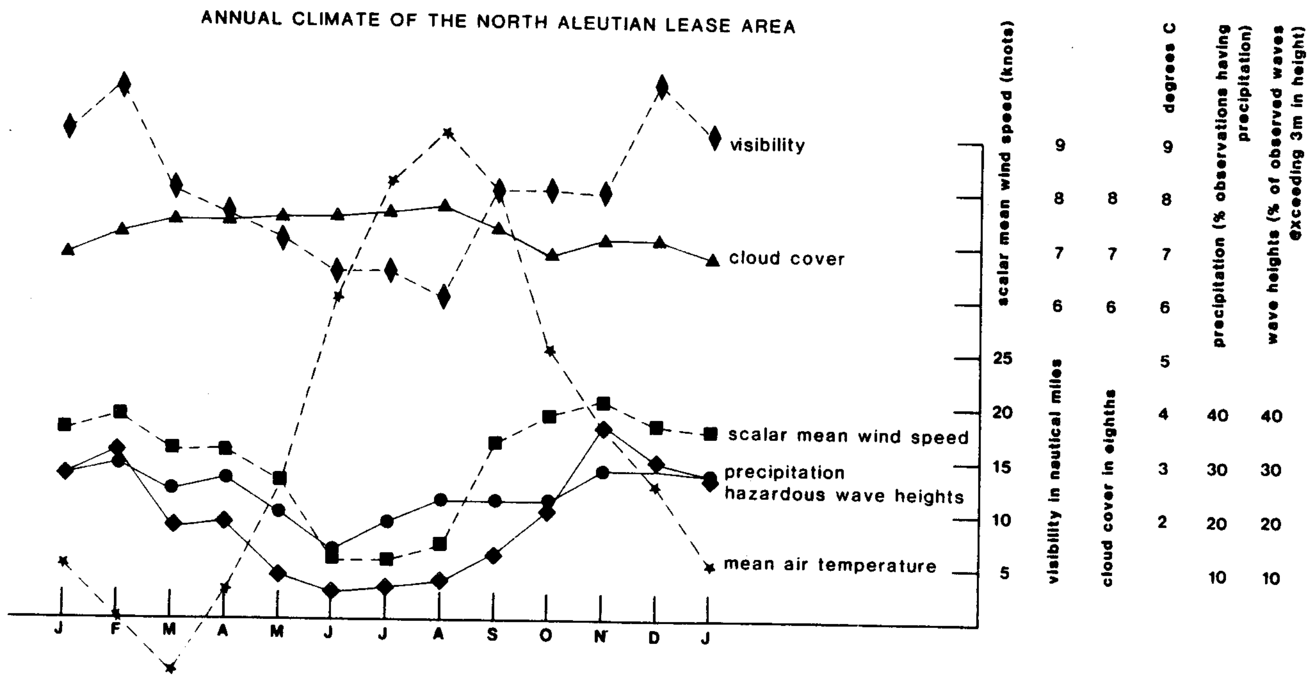


Figure 18. Mean precipitation for selected stations (SAI, 1981).



ANNUAL CLIMATE
Monthly statistics for several climate variables are shown in Fig. 19. Visibility is given in nautical miles. Fifty percent of observations reported visibility less than or equal to the value plotted. Cloud cover is given in eighths (1/8). Fifty percent of observations reported cloud cover less than the value plotted. Temperatures are shown as a value that 50 percent of observations exceeded.

Figure 19. Climatic variables, North Aleutian Shelf (SAI, 1981; Brower et al, 1977).

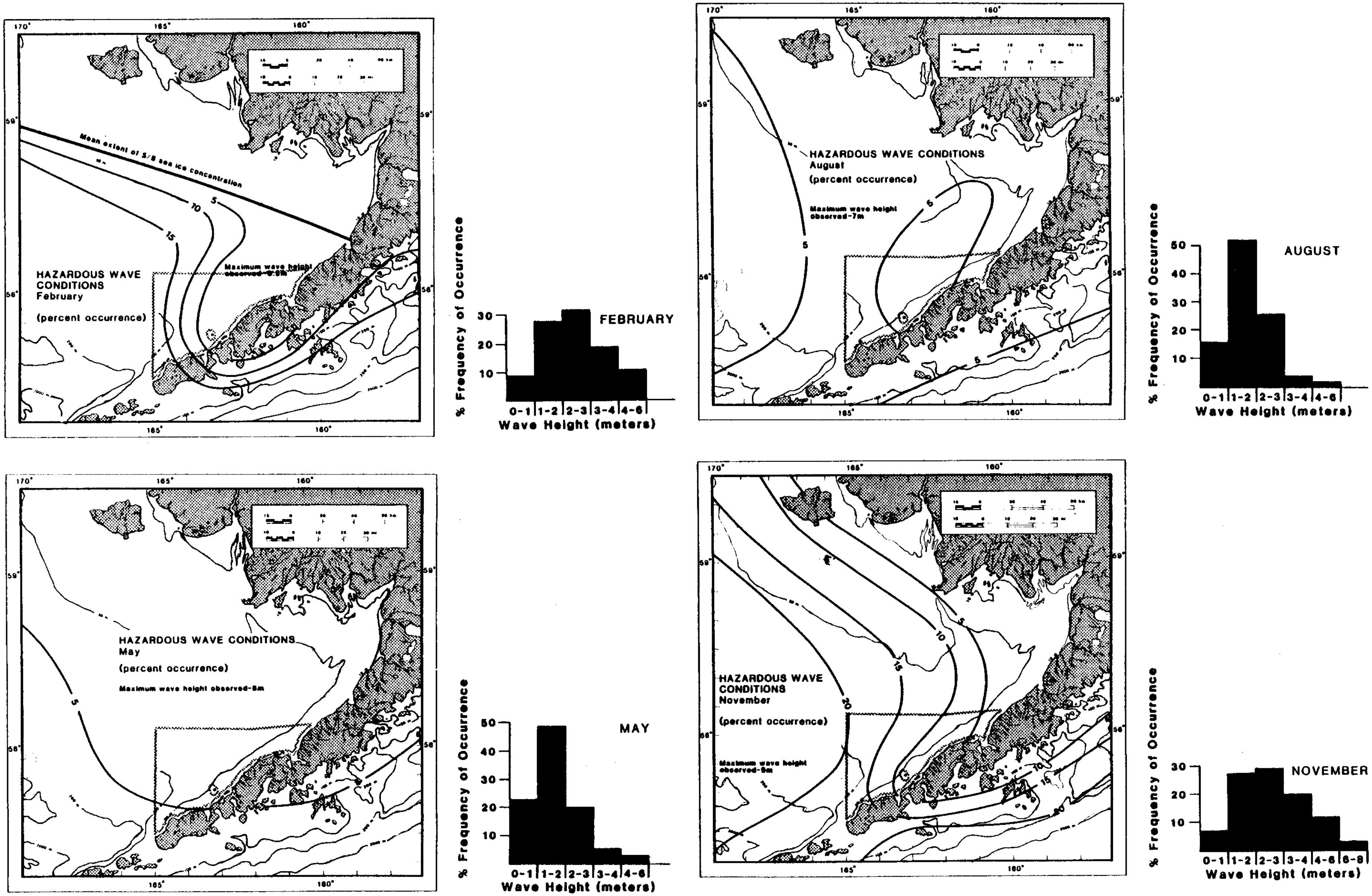


Figure 20. Hazardous wave conditions (SAI, 1981).

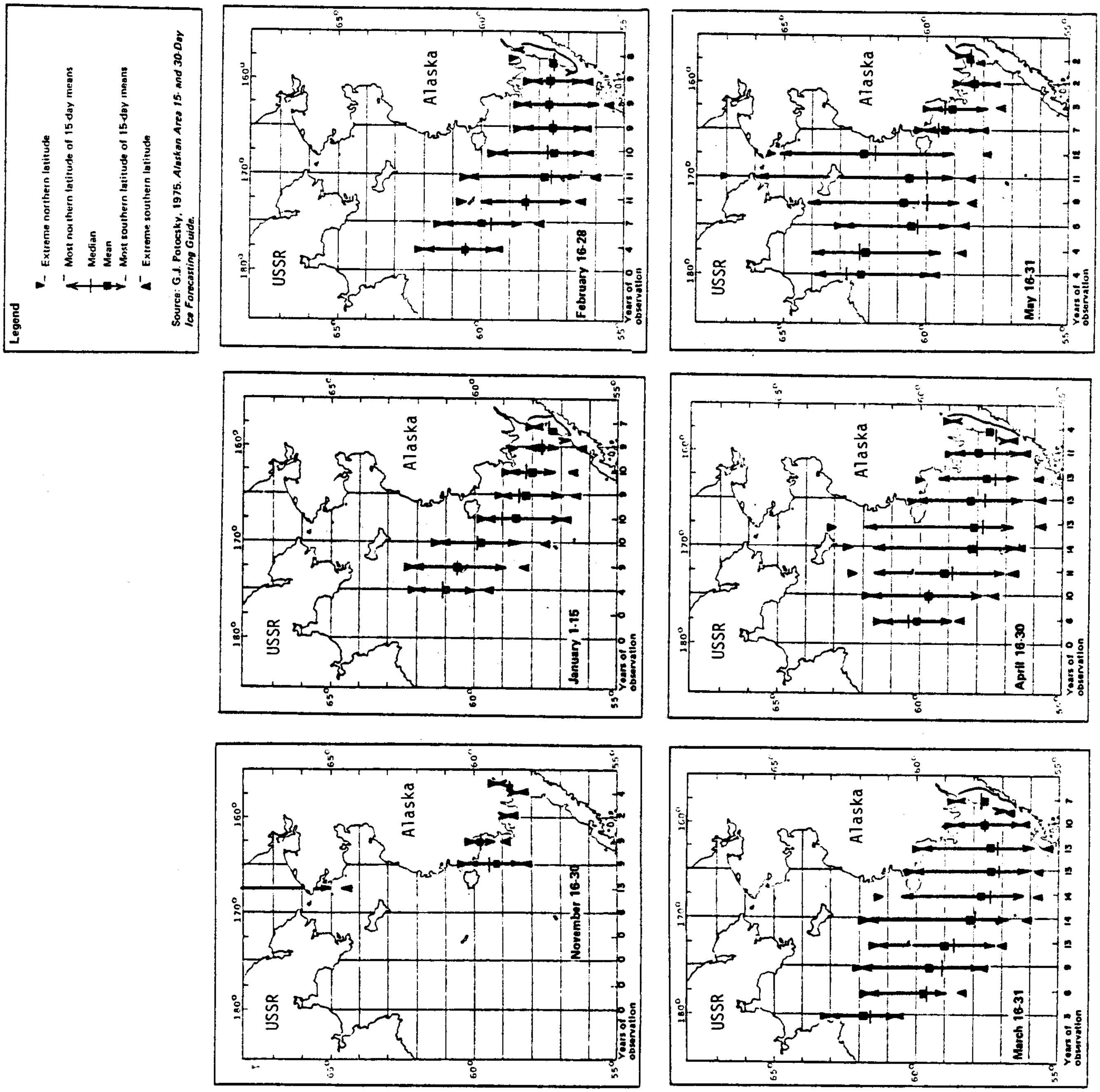


Figure 21. Sea ice extent in the Bering Sea (Brower et al, 1977).

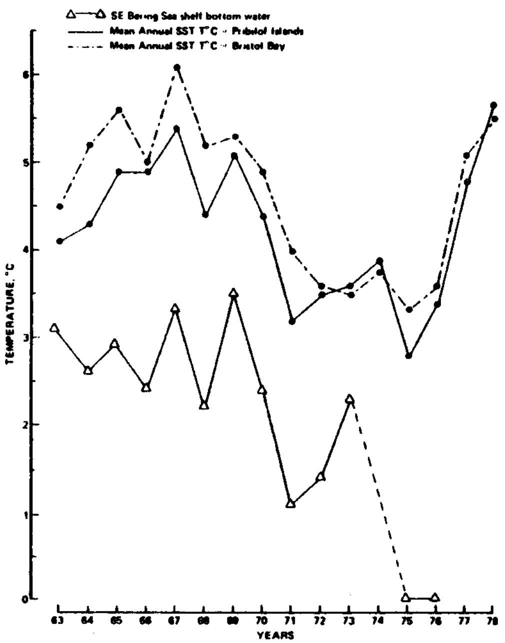
Brower et al, 1977, calculate more conservative values (larger waves) as follows:

Return Period (years)	Significant Wave Height (meters)
5	13.0
10	15.0
25	17.5
50	20.0
100	22.5

Ice. The distribution of sea ice in the Bering Sea is seasonal and shows large interannual variability. The mean and extremes of the seasonal ice extent in the Bering Sea are shown in Figure 21 (Brower et al, 1977). In summer, the entire Bering Sea is free of ice. In early fall, sea ice forms in coastal areas. By early November, sea ice occurs into the southeastern Bering Sea. The maximum extent of sea ice occurs in late March.

Unlike the Arctic Ocean, sea ice in the Bering Sea does not typically form a close pack, and multiyear ice does not exist (McNult, 1981). In October and November, ice forms along the northern coasts. Under the influence of predominantly northeasterly winds, ice formed in the leeward of east-west trending coasts is advected to the south-southwest within the pack, is broken into floes near the ice edge by the effects of wave propagation, and melts at the southerly edge in the warmer waters (McNult, 1981; Muench and Ahlnäs, 1976). Coastal polynyas effective in ice generation thus exist along the southern side of the Seward Peninsula and Saint Lawrence Island, and along the northern coast of Bristol Bay. Martin and Bauer (1981) have described typical ice distribution along a line from open water to the interior zone of the ice to the north. Closest to the open water is the edge zone, characterized by small, heavily rafted and ridged floes about 20 meters in diameter and 2-4 meters thick, typically extending in a 5-10 kilometer band. In the second, or transition zone, floes are also about 20 meters in diameter, but not heavily ridged, being only 0.3-0.6 meter thick. This band is about 5 kilometers wide. In the third zone deeper into the ice, the floes may be several kilometers in diameter but only 0.3 meters thick.

Large interannual variability occurs in sea ice conditions and extent, as well as in Bering Sea surface water temperatures. Niebauer (1981) has analyzed recent fluctuations in ice and sea surface temperatures. Some of his results are illustrated in Figure 22. The period 1973-1979 was shown to be a time of extreme fluctuations, with 1973-1976 characterized by below normal temperatures and above normal ice cover under northerly winds, while 1976-1979 was a period of strong rise in temperatures and retreat of the ice pack under winds with more southerly bias. Overland and Pease (1982) correlated 23 years of storm-track and ice



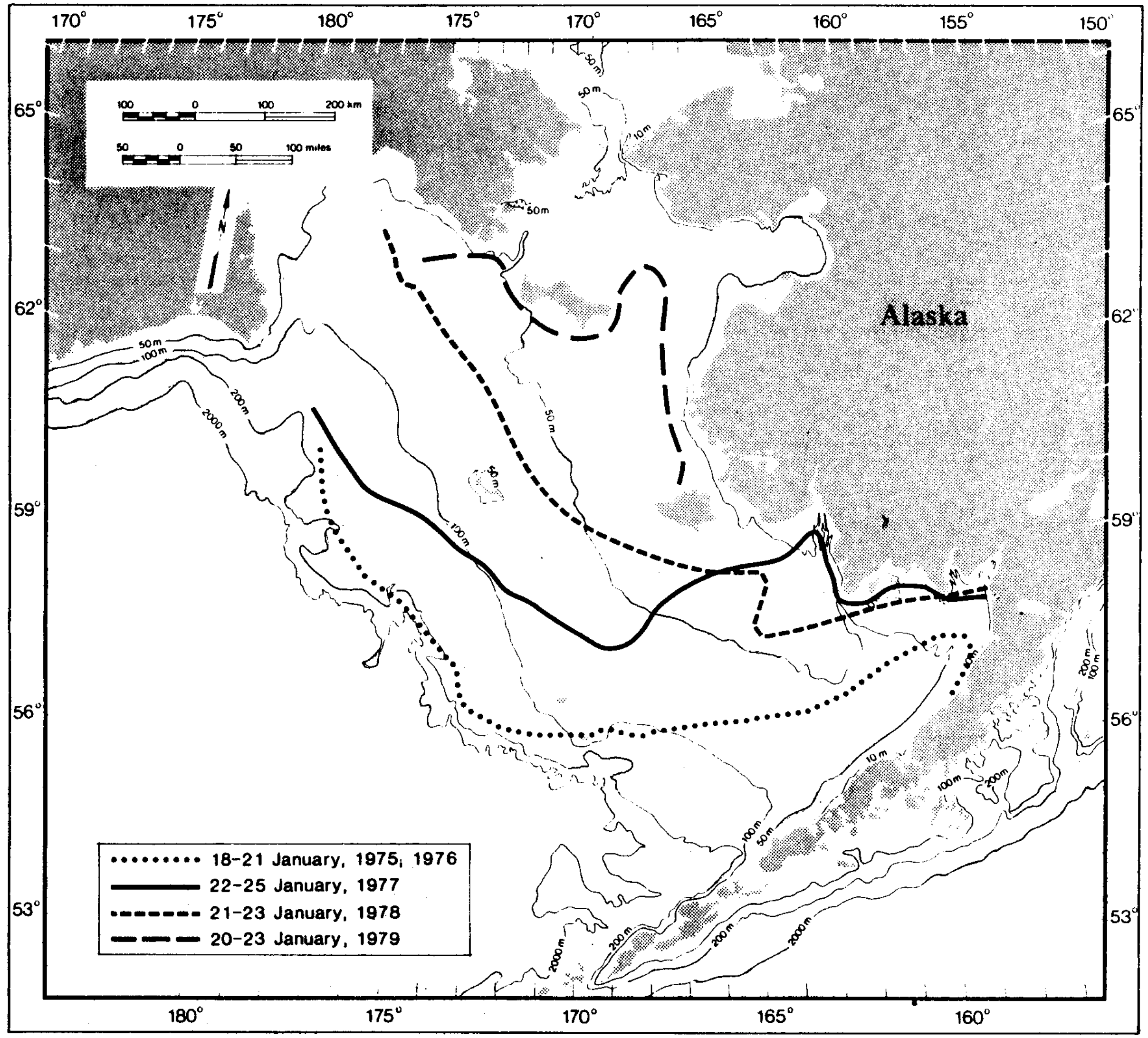


Figure 22. Variability of sea ice extent (Niebauer, 1981).

cover data and conclude that light ice years are correlated with an increased frequency of storm tracks curving northward along the Siberian coast, compared to those paralleling the Aleutian Chain. They therefore conclude that meteorological steering of cyclones, determined primarily external to the Bering Sea, is the primary factor in determining interannual variablility of sea ice extent. Such variability in sea ice has, of course, great influence on the distribution and success of the biota.

Inshore Hydrography and Currents. The major area of interest for the present study is the inshore zone, within the coastal domain (0-50 meters in depth) defined above by hydrographic structure and flow characteristics. Of particular interest are the inshore areas within five kilometers of the coast, which apparently exhibit high utilization by marine biota.

Bristol Bay is essentially a large estuary, with major freshwater additions along its nearshore boundaries, from diffuse sources as well as from large rivers. Typical overall salinity/temperature distributions within Bristol Bay, Figures 23 and 24, show this inshore distribution of fresh water, particularly at the head of the Bay (Institute of Marine Science, 1971).

Freshwater input at the head of Bristol Bay from the Kvichak and Nushagak rivers totals 39 km^3/year, which is about equal to the Kuskokwim (35 km^3/year) though smaller than the Yukon (204 km^3/year) further north (U.S. Geological Survey, 1980). Corresponding estimates of total runoff to the north shore of the Alaska Peninsula were made from mean rainfall data (Arctic Environmental Information and Data Center, 1980) and from topographic maps of drainage areas. This runoff to the nearshore area of the north side of the Alaska Peninsula totaled about 20 km^3/year, or about 34 percent of the total freshwater runoff into Bristol Bay.

Straty (1977) has traced nearshore flow patterns of freshwater from the rivers of the inner Bay using hydrographic stations, drifters, and dye releases. Some of his hydrographic results, summarized in Figure 25, clearly show this freshwater entering the Bay and flowing along the northern side of the Bay. His drifter data, Figure 26, also indicate the counterclockwise flow around the inshore perimeter of the Bay.

Sediment plumes visible in available satellite images (Geophysical Institute, University of Alaska, unpublished data summary,1980), Figures 27 and 28, also illustrate the counterclockwise inshore flow.

Schumacher and Moen (1983) and Schumacher et al (1982) have summarized recent data for the inshore region from Unimak Pass and along the north shore of the Alaska Peninsula.

The station patterns and moorings that they discuss are shown in Figure 31 for the Unimak Pass area and in Figures 32 and 33 for the Alaska Peninsula area.

Scatter plots and progressive vector diagrams from the Unimak Pass moorings are shown in Figure 34 and hydrographic results and dynamic topography in Figure 35. Their results show mean flow from the Gulf of Alaska Shelf westward and then northward through Unimak Pass. Reversals (southward flow) occurred eighteen percent of the time in spring and 31 percent in summer, with mean flow into the Bering Sea during spring being three times greater than in summer. Currents in Unimak Pass at periods between three and ten days correlated with bottom pressure differences through the pass, the latter were in turn related to the longshore winds which induced sea level changes along the Gulf of Alaska coast. The westward coastal flow south of the Peninsula consists of relatively fresh water and appears to be a westward extension of the Kenai Current (Schumacher and Reed, 1980) and the coastal jet in the Gulf of Alaska (Royer, 1979; Royer, 1981a; Royer, 1981b), driven by freshwater discharge into the Gulf. The flow through Unimak Pass has a strong baroclinic component.

Hydrographic data (Schumacher and Moen, 1983) taken along the northern shore of the Alaska Peninsula are shown in Figures 36 and 37, while vertical differences in sigma-t are given in Figure 38.

These results show that while the waters over the continental shelf adjacent to the Alaska Peninsula generally adhere to the previously defined hydrographic domains (Kinder and Schumacher, 1981a), complications exist in the coastal domain. For example, while the coastal domain (less than 50 meters) was generally mixed, the addition of freshwater as a line source (particularly between Ports Moller and Heiden) and from the Kvichak River, can result in significant stratification (Figure 38), up to three sigma-t units, even though the water in the coastal domain is shallow and tidal mixing is strong. There was also a suggestion in the data that melting ice could impact the local buoyancy/tidal mixing balance.

In February, the hydrographic data showed the impact of the seasonal variations in the less saline Kenai current water upon coastal water along the Peninsula. This was most apparent in a reduction of mean salinity between Port Moller and Unimak Island between August 1980 and February 1981. This lends support to a previous hypothesis that the Kenai Current contributes to flow around the perimeter of Bristol Bay and northward toward the Bering Strait (Schumacher et al, 1982). Dynamic topography (Figure 39) also is consistent with northeast flow along the Peninsula.

SURFACE TEMPERATURE

CONTOUR INTERVAL 1.0°C

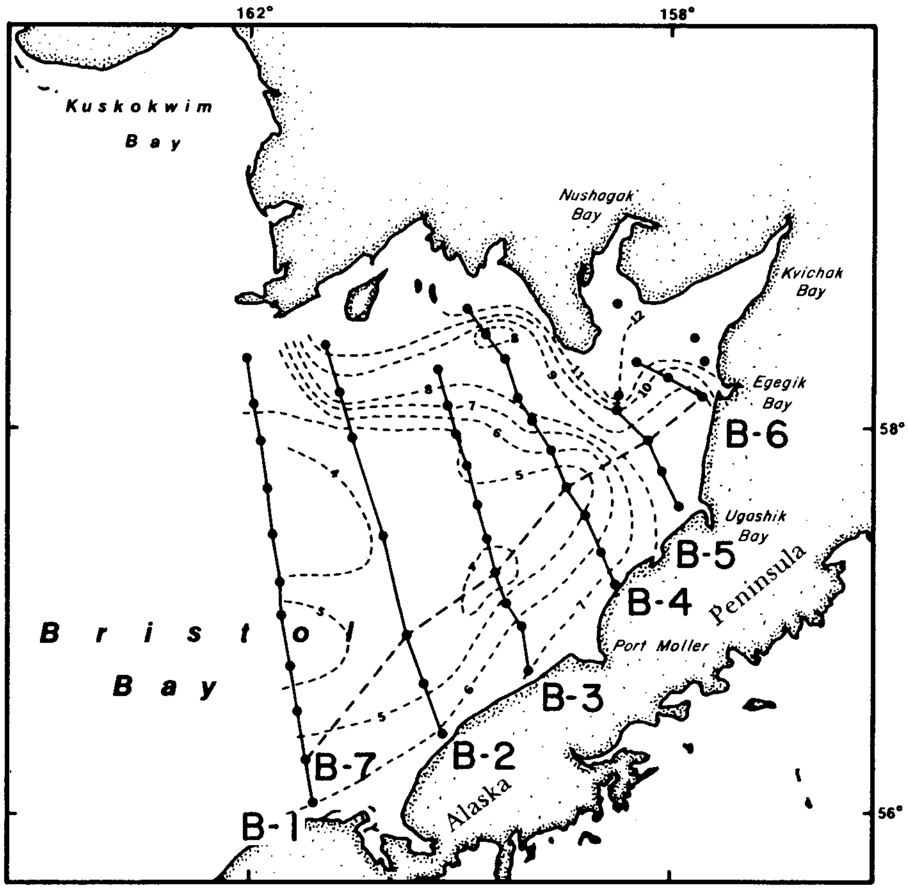


Figure 23. Bristol Bay surface temperature distribution August, 1968 (IMS, 1971).

SURFACE SALINITY

CONTOUR INTERVAL <29.0 = 1.0‰, >29.0 = 0.5‰

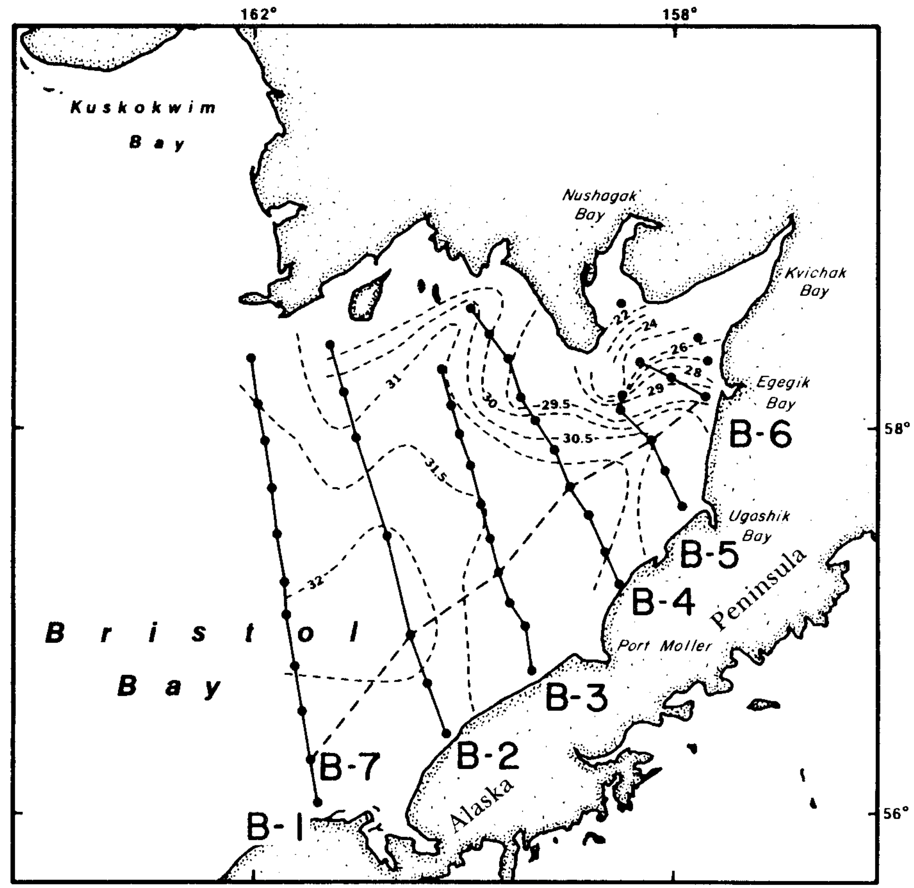


Figure 24. Bristol Bay surface salinity distribution August, 1968 (IMS, 1971).

Station Locations and Section Lines

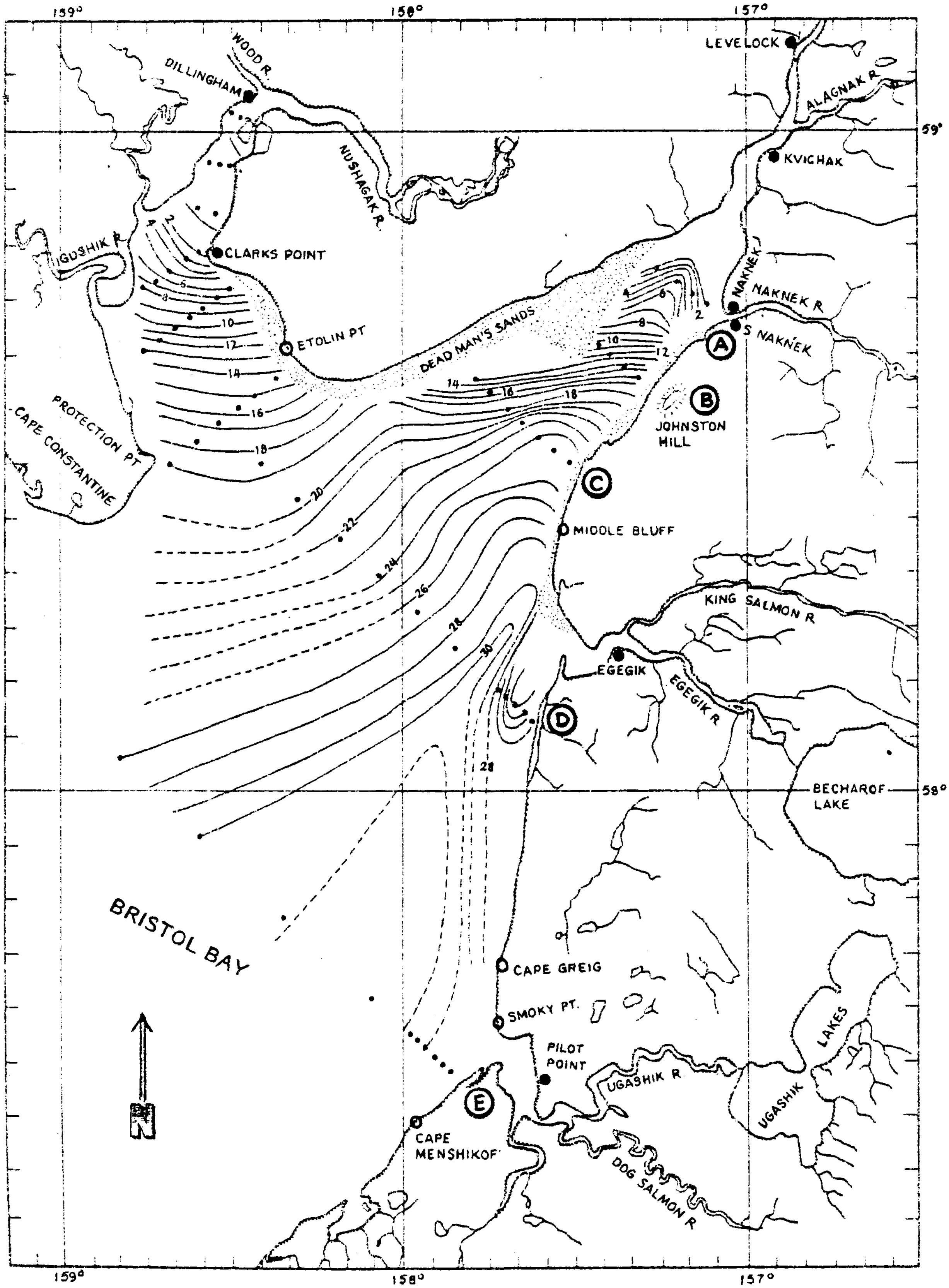


Figure 25. Surface salinity (ppt) at low tide, inner Bristol Bay, July and August, 1966 (Straty, 1977).

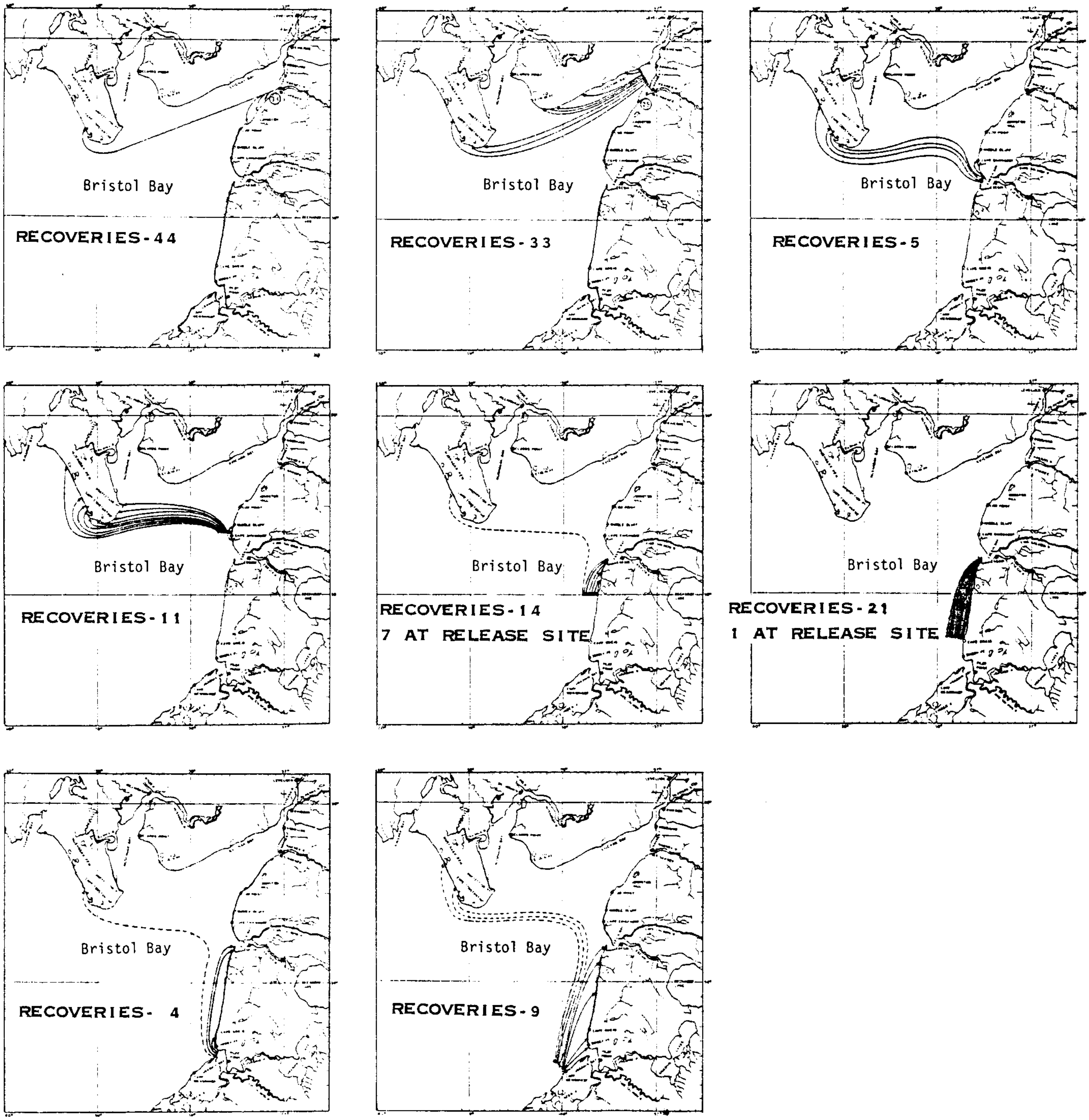


Figure 26. Drifter results, Bristol Bay (Straty, 1977).

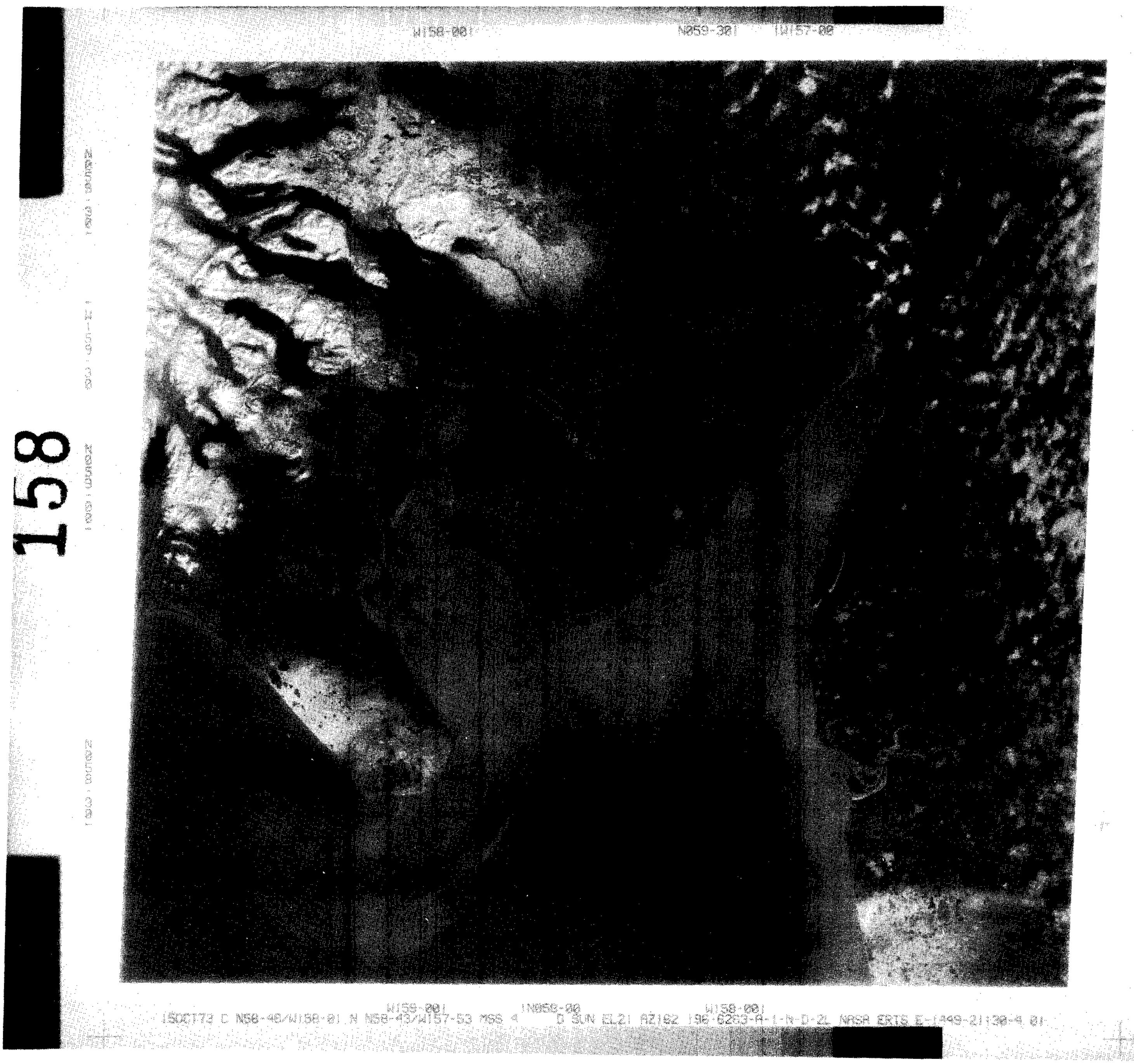


Figure 27. Satellite image, Bristol Bay inshore area, upper Bay (Geophysical Institute, University of Alaska).

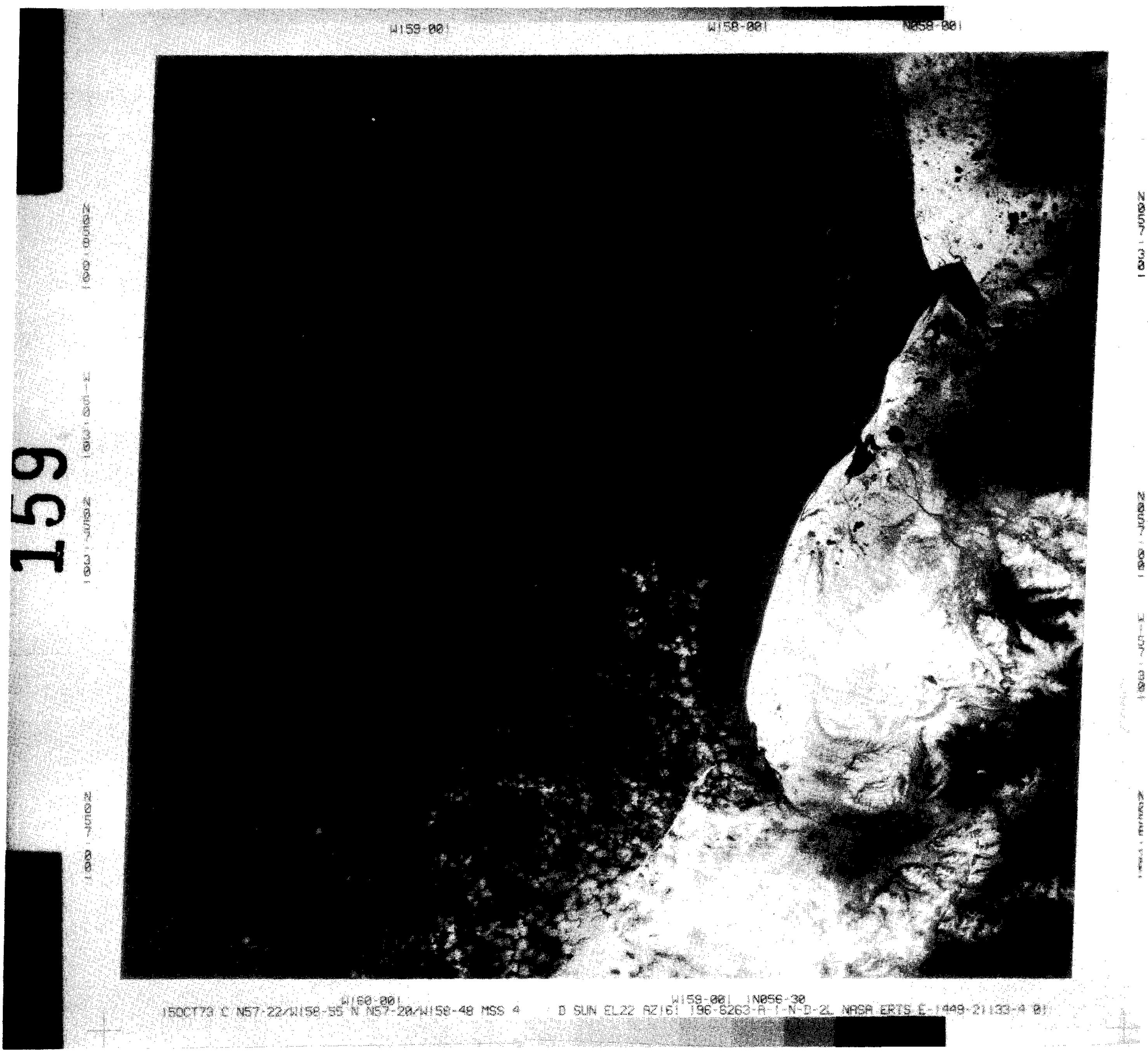


Figure 28. Satellite image, Bristol Bay inshore area, Ugashik Bay/Port Heiden area (Geophysical Institute, University of Alaska).

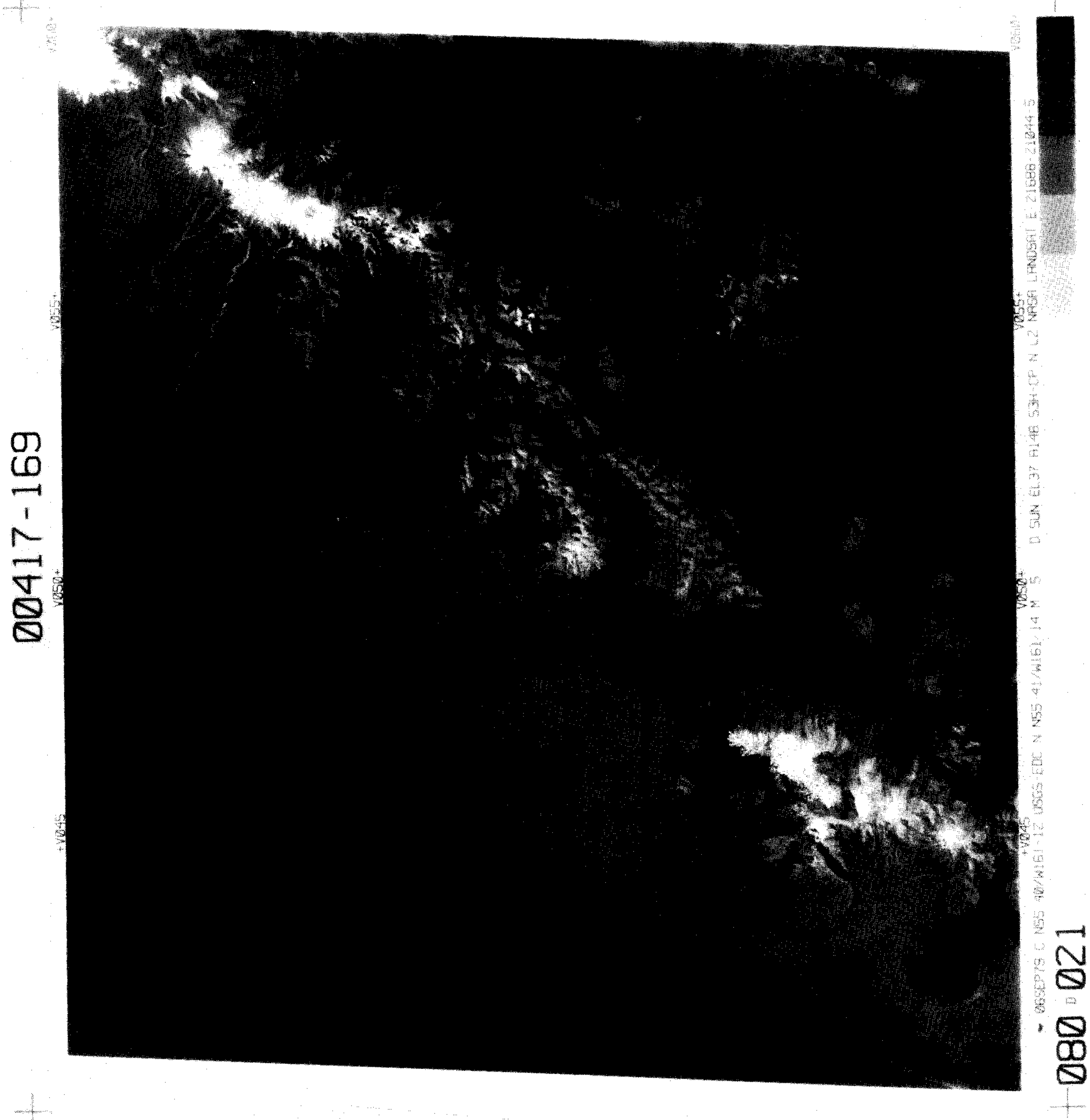


Figure 29. Satellite image, Bristol Bay inshore area, Port Moller area (Geophysical Institute, University of Alaska).

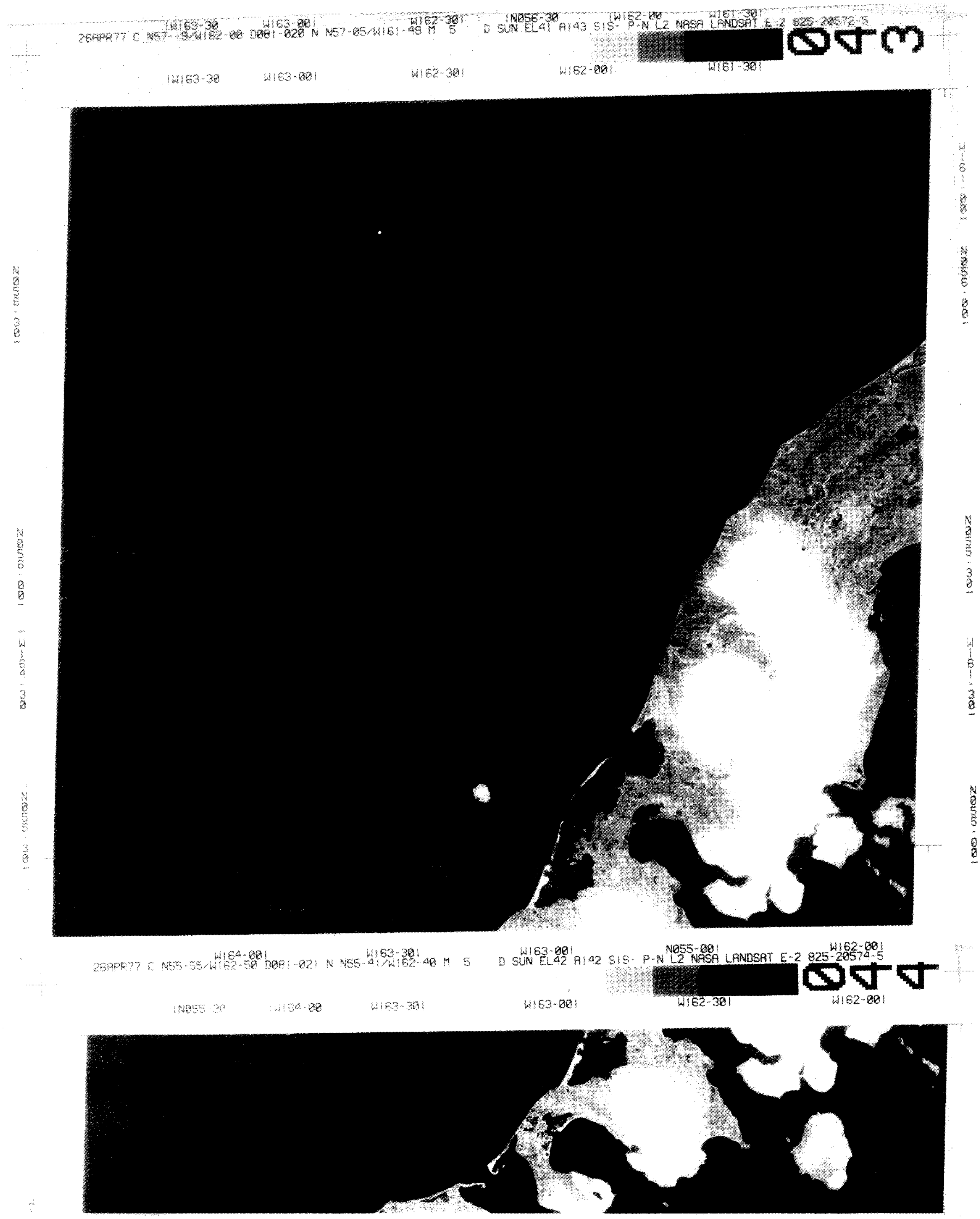


Figure 30. Satellite image, Bristol Bay inshore area, Izembek area (Geophysical Institute, University of Alaska).

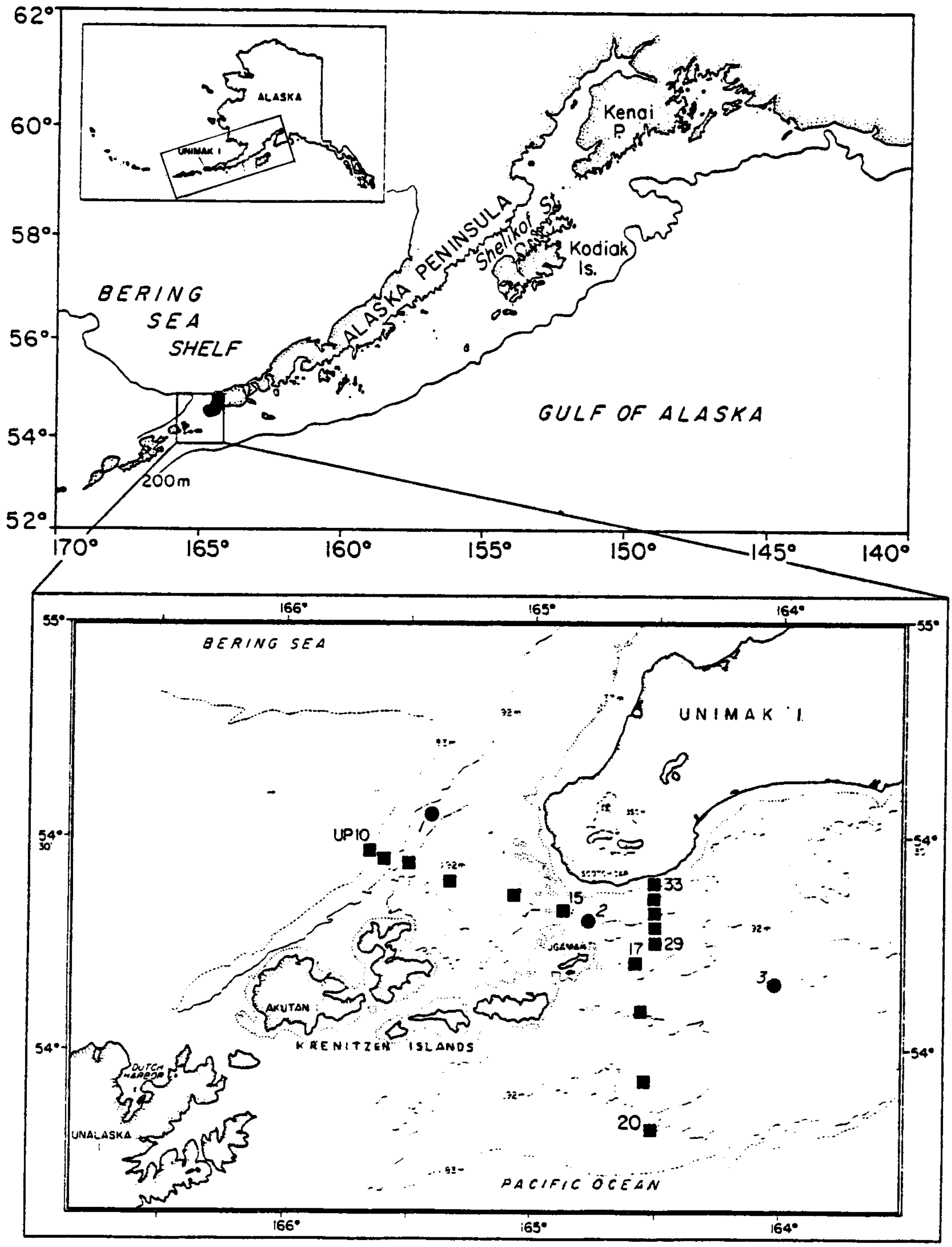


Figure 31. Location of CTD stations, current meters and pressure gauge moorings, Unimak Pass area (Schumacher and Moen, 1983).

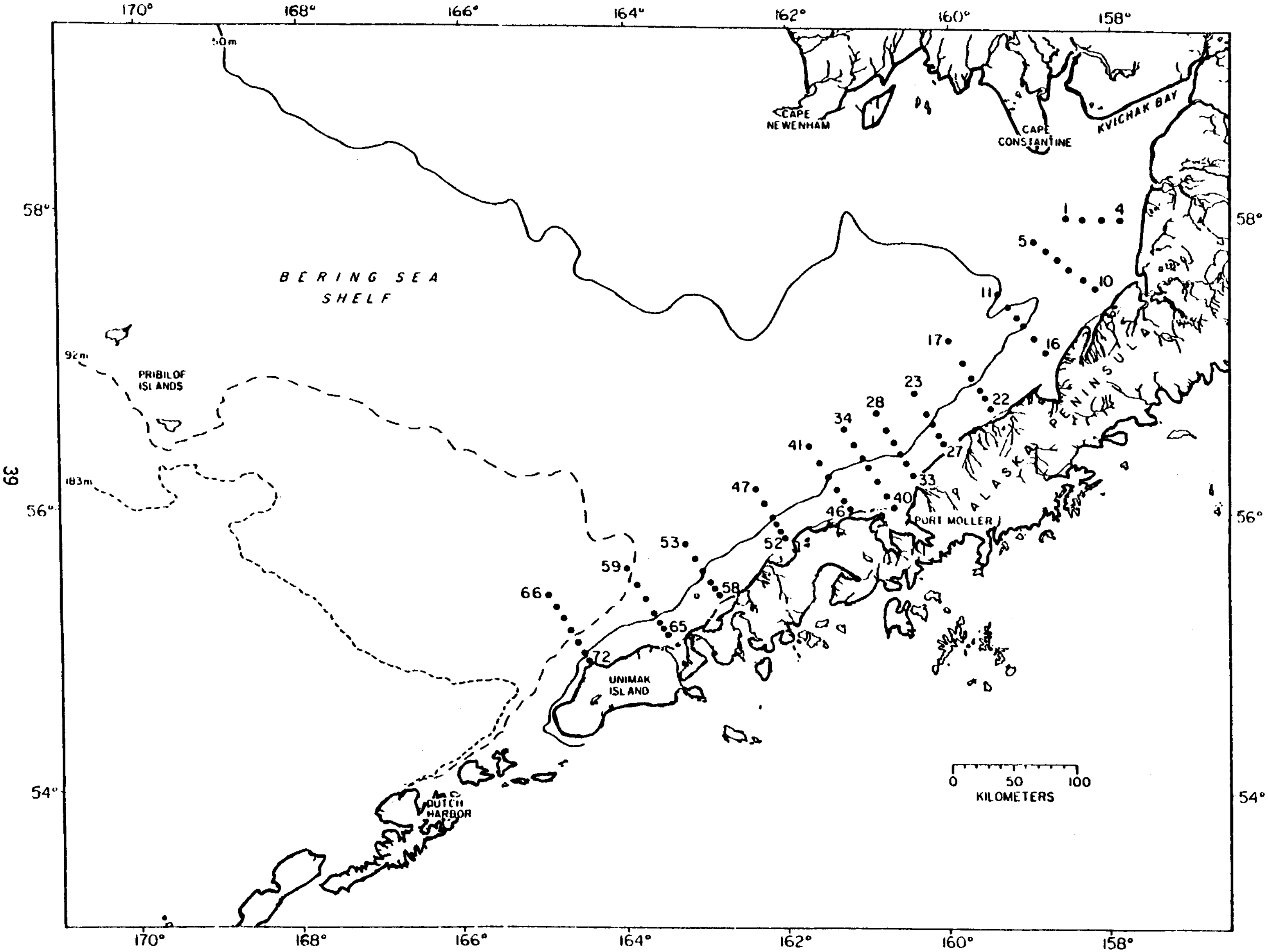


Figure 32. Location of CTD stations (NA 1 to 72) for the North Aleutian Shelf study (Schumacher and Moen, 1983).

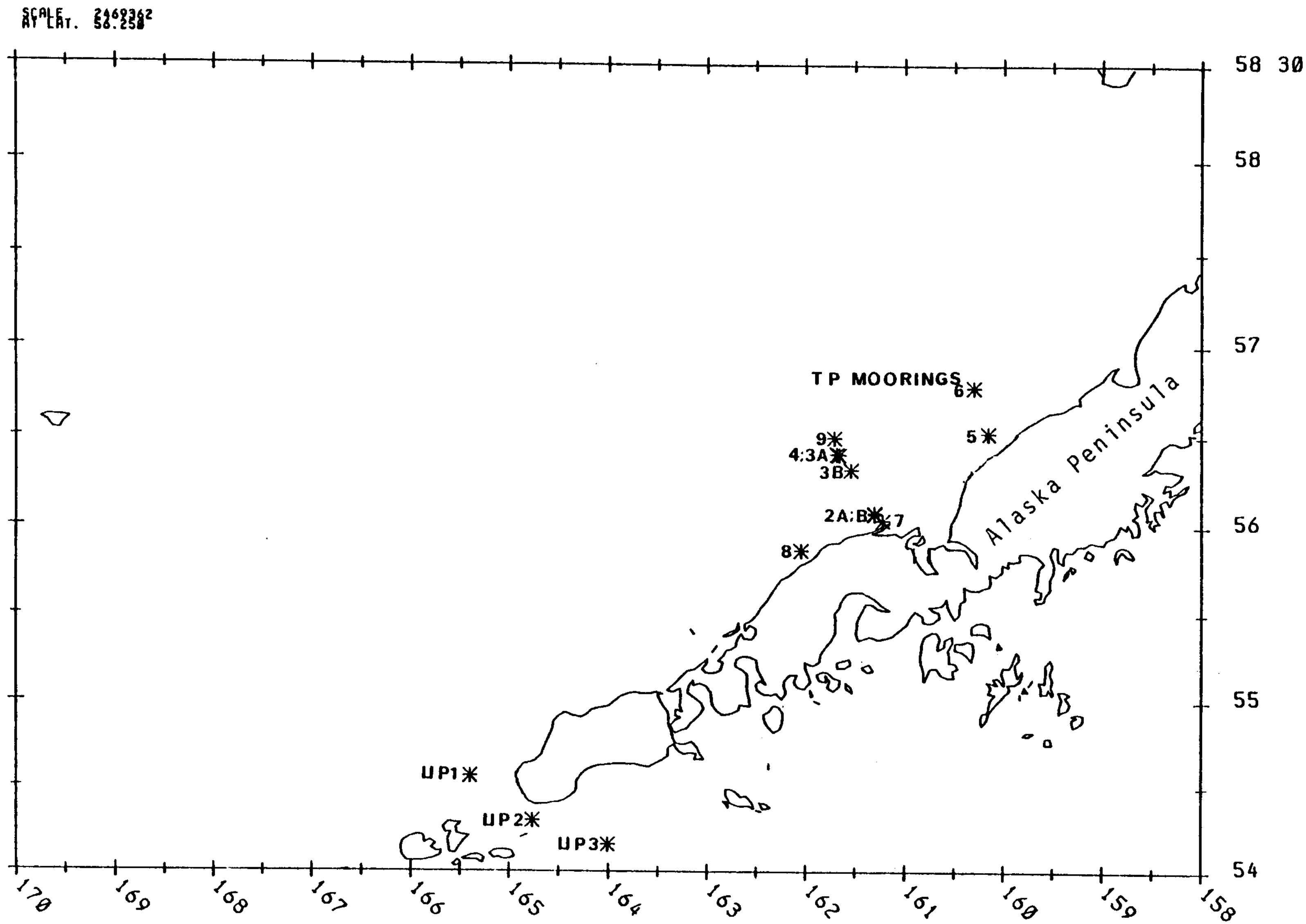


Figure 33. Location of current meter moorings (Schumacher and Moen, 1983).

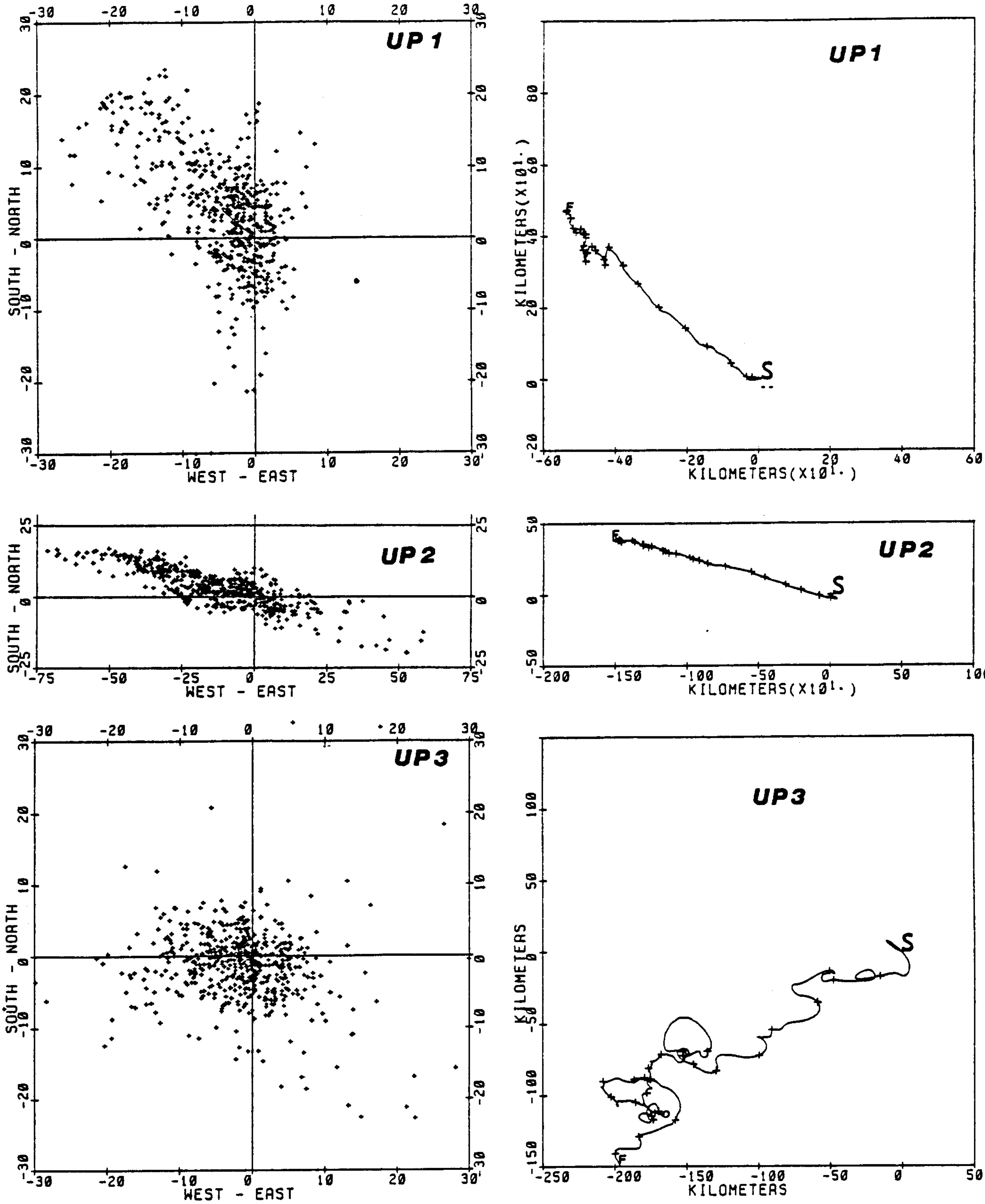


Figure 34. Results from 35 hour filtered current data presented as scatter plots and progressive vector diagrams (S represents the start of the record, and the crosses are at 5-day intervals). Note the different speed and length scales (Schumacher et al, 1982).

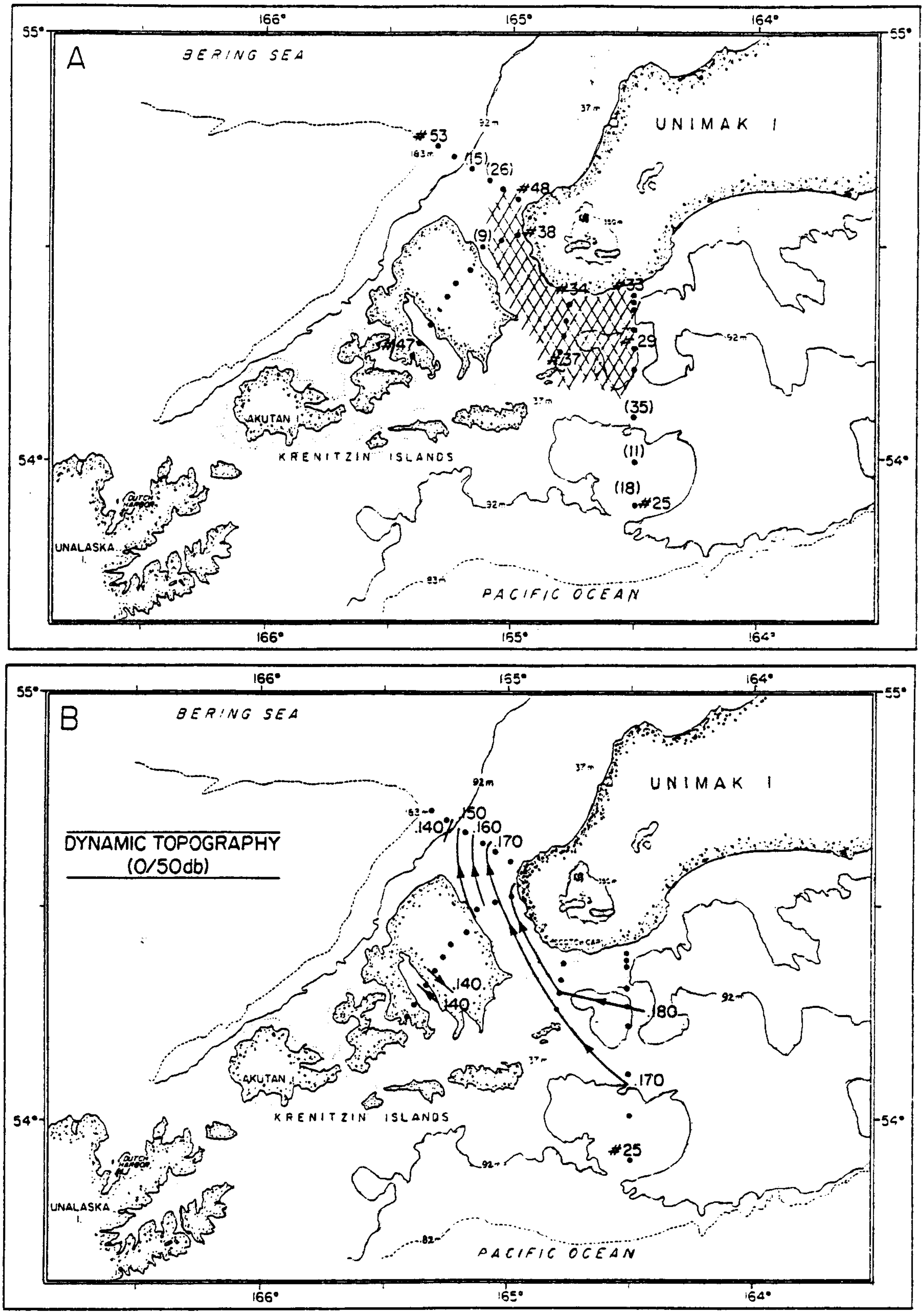


Figure 35. Hydrographic data for September 1981 presented as (a) areal extent of waters with salinity ≥31.75 gm/kg in the upper 50 m (or bottom) where the numbers in parentheses are depths of the low-salinity band for z >50 m and (b) dynamic topography (0/50 d) with a 0.01 dyn m contour interval. CTD station numbers are indicated by the number sign (Schumacher et al, 1982).

Inshore current records (Schumacher and Moen, 1983) support previous results (Kinder and Schumacher, 1981b; Schumacher and Kinder, 1983), which imply a moderate (2 to 6 cm/s) Eulerian mean flow from the vicinity of Unimak Island, counter-clockwise around Bristol Bay, and thence northwest past Nunivak Island. A mechanism for long-term (on the order of months) flow is the persistent cross-shelf density distribution, which resulted in baroclinic speeds of 1 to 5 cm/s, typically concentrated in a 10- to 20-km-wide band in the vicinity of the 50-m isobath. Scaling of Eulerian tidal residual flow suggested a weak contribution, <1.0 cm/s, except where the tidal current was orthogonal to the 50-m isobath off Port Heiden (Schumacher and Kinder, 1983).

Although wind energy was evident in alongshore current pulses, mean winds during the current observations were weak and toward the west, in opposition to the observed mean flow. Cross-shelf current pulses were also evident, and the observed tendency was for offshore flow in the upper water column.

Substantial vertical shear in currents was also observed. The combination of wind-induced shear and geostrophic baroclinic shear accounted for about one-half the observed values.

Because of the frequency of storms in the area, approximating three to five per month, the effects of such events on the oceanography of the area are of prime importance. Schumacher and Moen (1983) and Pearson, Baker, and Schumacher (1980) describe one such storm event, during which moorings were in place and shipboard hydrographic measurements were made in the nearshore region of the Peninsula. The summer structural front, located in the vicinity of the 50 meter isobath, separated the well-mixed coastal domain from the two-layered middle shelf domain of the southeastern Bering Sea. This system was perturbed in mid-August by a strong storm (winds in excess of 30m sec^{-1}) which vertically mixed temperature, salinity and nearshore suspended particulate matter (SPM) throughout the water column. Using CTD and SPM data collected 1, 7, and 14 days after the storm, the subsequent reestablishment of frontal domain characteristics was documented.

The line of CTD stations normal to the Peninsula (Figure 40) was occupied on 19, 24, and 31 August 1980. Temperature, salinity, sigma-t and light attenuation sections are shown in Figures 41, 42, and 43. The time to run a complete line was about six hours. About one day prior to running the first section, the remnants of typhoon Marge passed eastward through the study area. This storm resulted in winds up to 30 ms^{-1} and six to eight meter waves. The turbulence associated with this storm mixed the water column at least 45 km seaward of the coast (Figure 41). Suspended

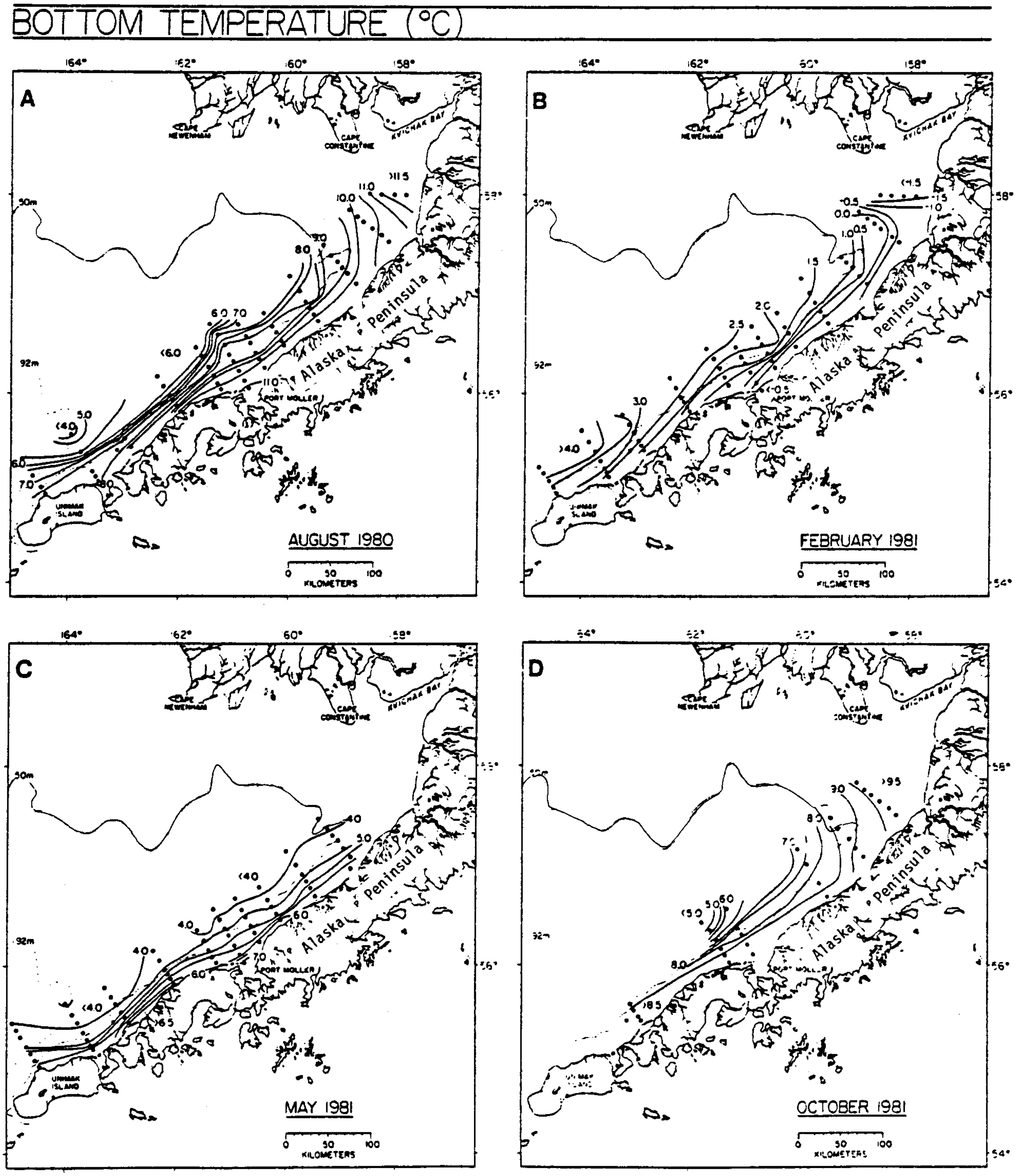


Figure 36. Bottom temperature (°C) contours (Schumacher and Moen, 1983).

SURFACE TEMPERATURE (°C)

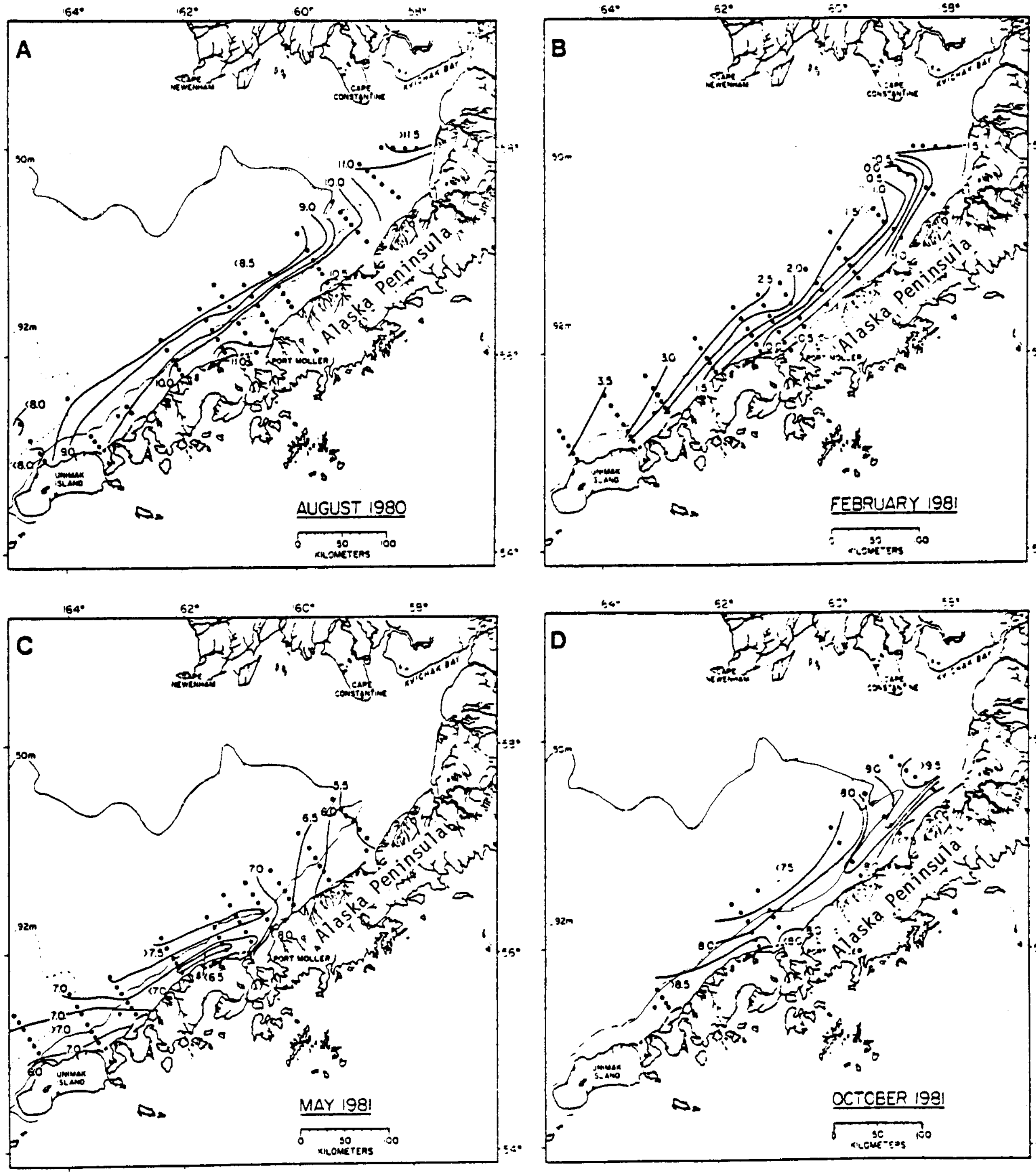


Figure 37. Surface temperature (°C) contours (Schumacher and Moen, 1983).

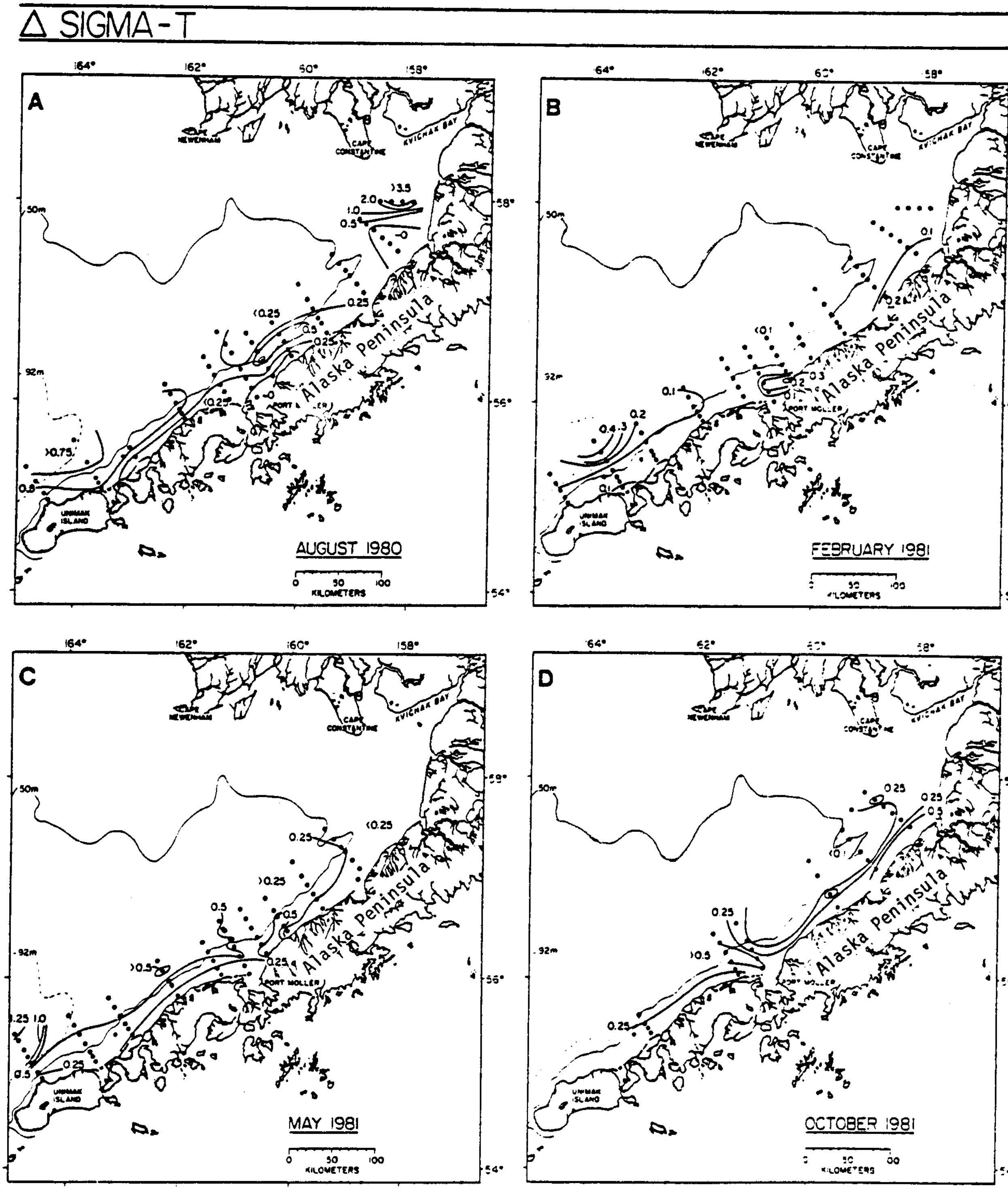


Figure 38. Bottom minus surface sigma-t contours (Schumacher and Moen, 1983).

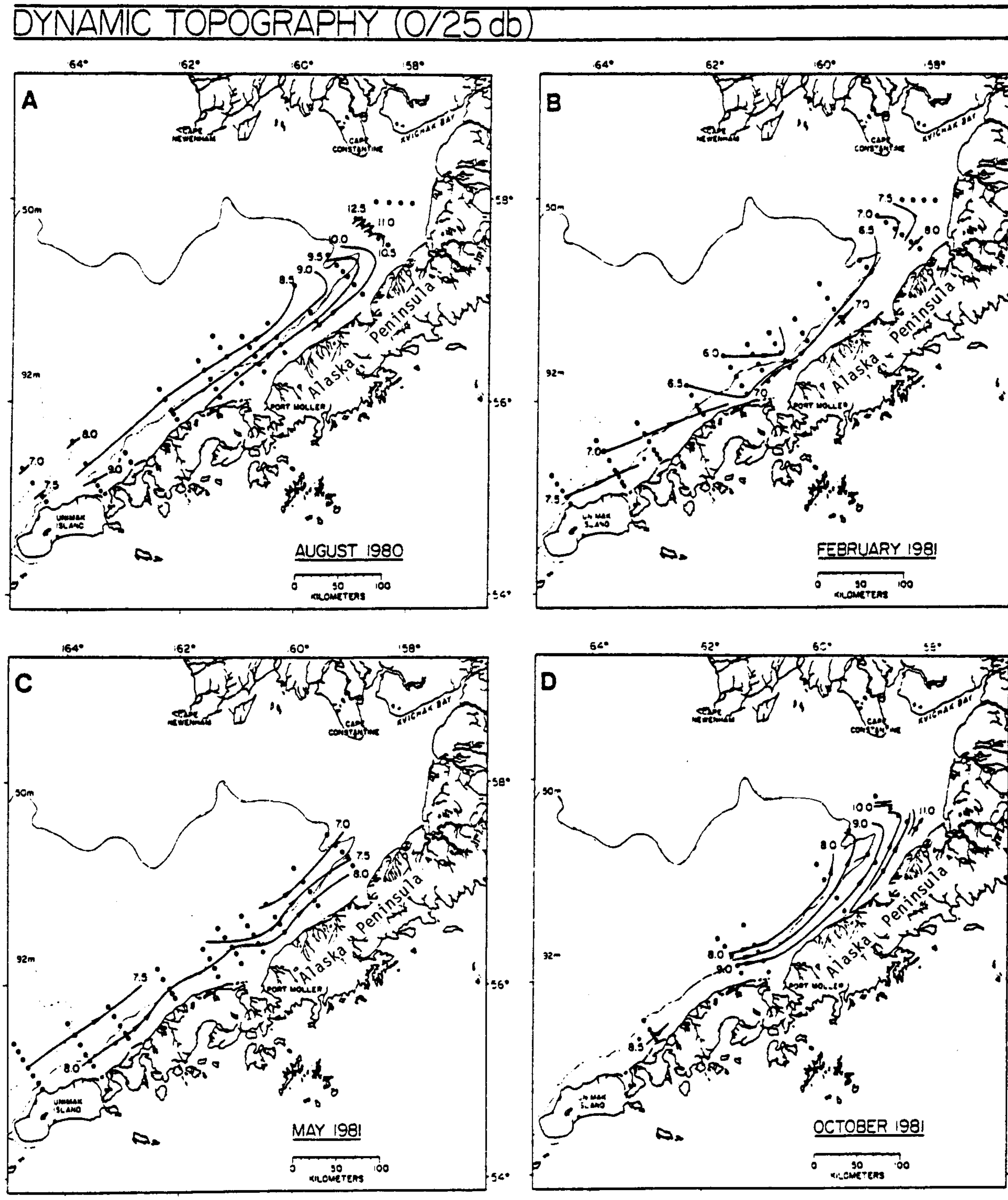


Figure 39. Dynamic topography (0/25 db) (Schumacher and Moen, 1983).

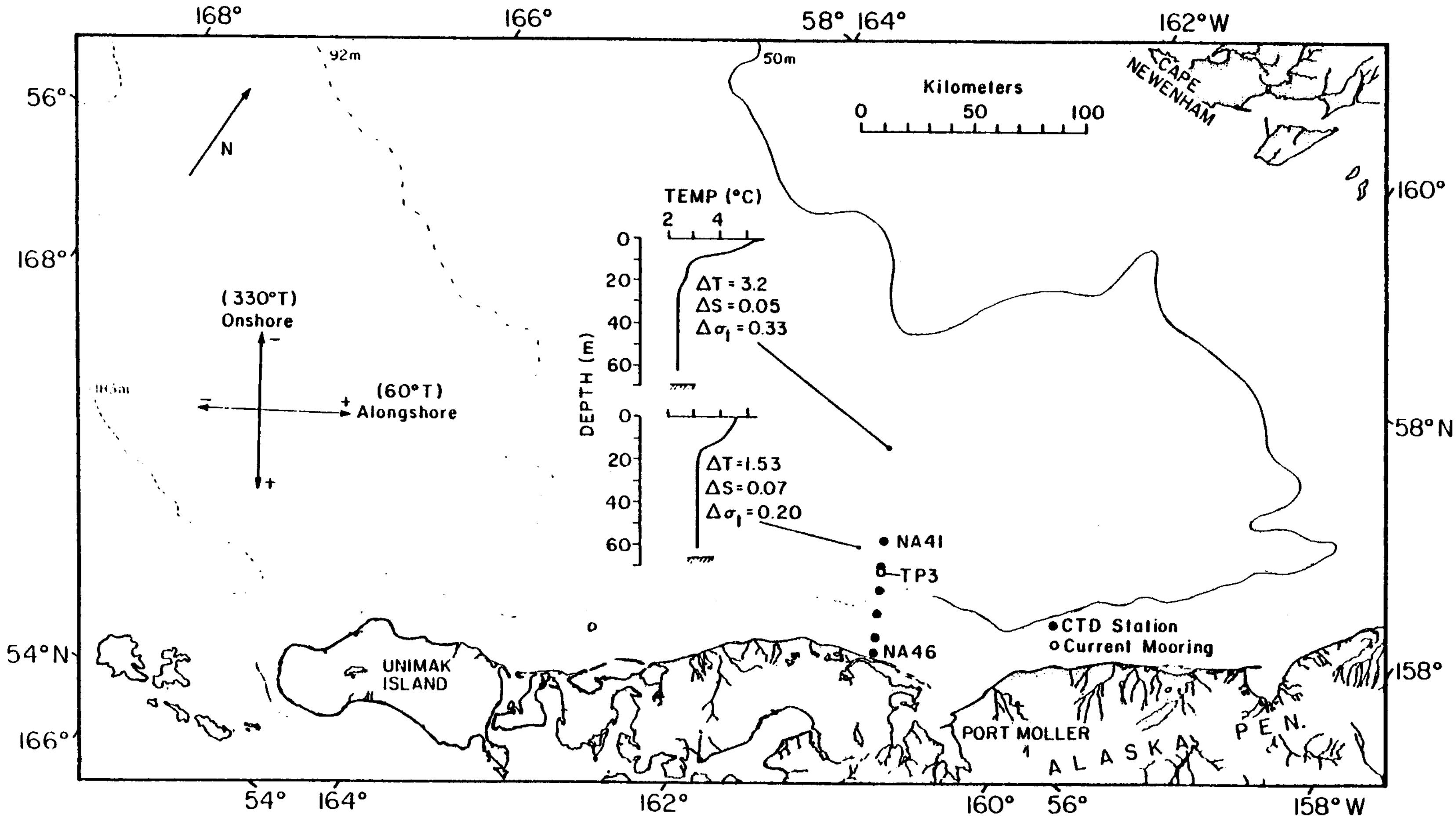


Figure 40. North Aleutian Shelf study area, showing location of hydrographic data section (NA41 to NA46) and mooring TP3A. Also shown are CTD data from 31 May 1980 and axes used for current and wind data (Schumacher and Moen, 1983).

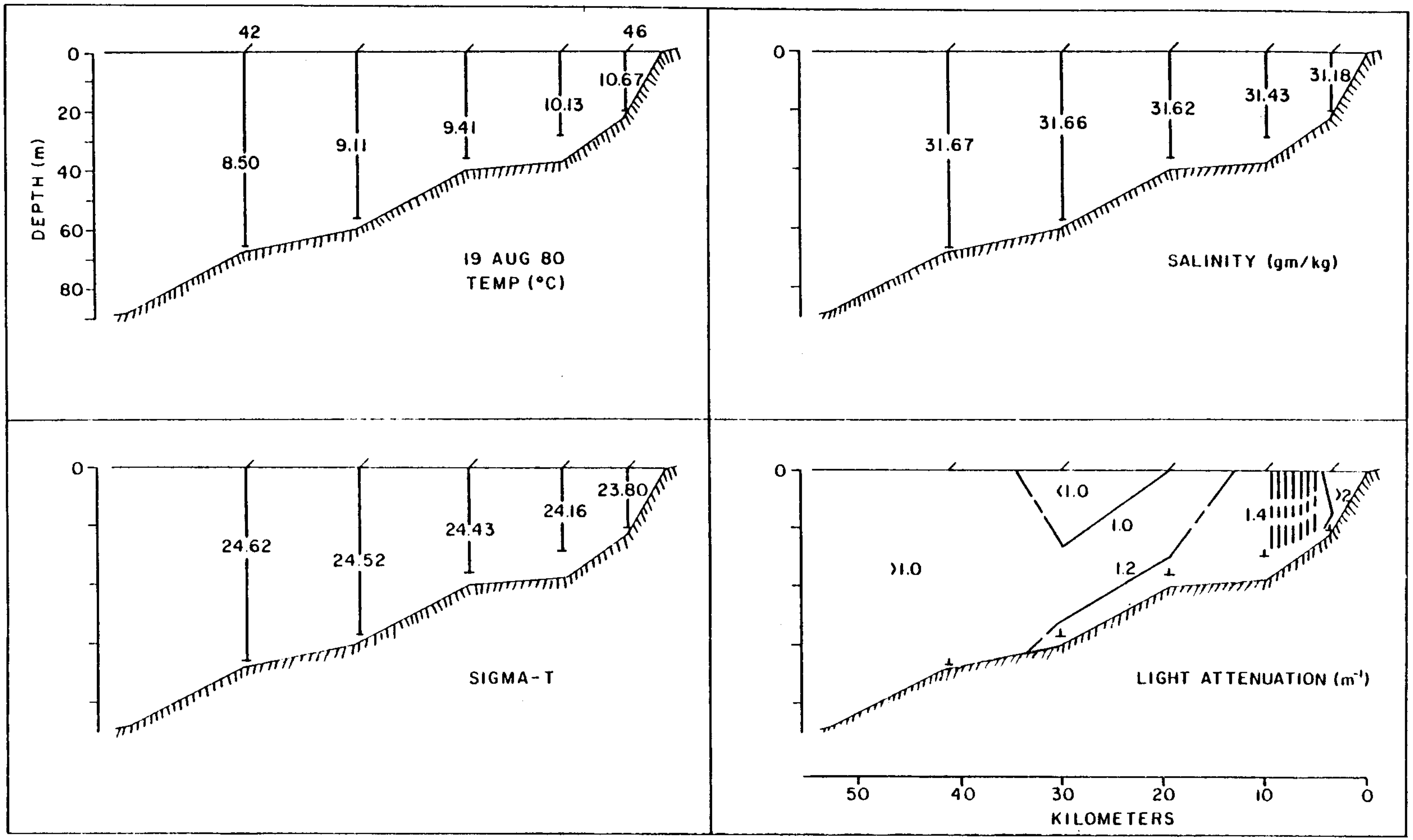


Figure 41. Hydrographic and light attenuation sections from 19 August 1980. Note the location of the 8.5°C isotherm (Schumacher and Moen, 1983).

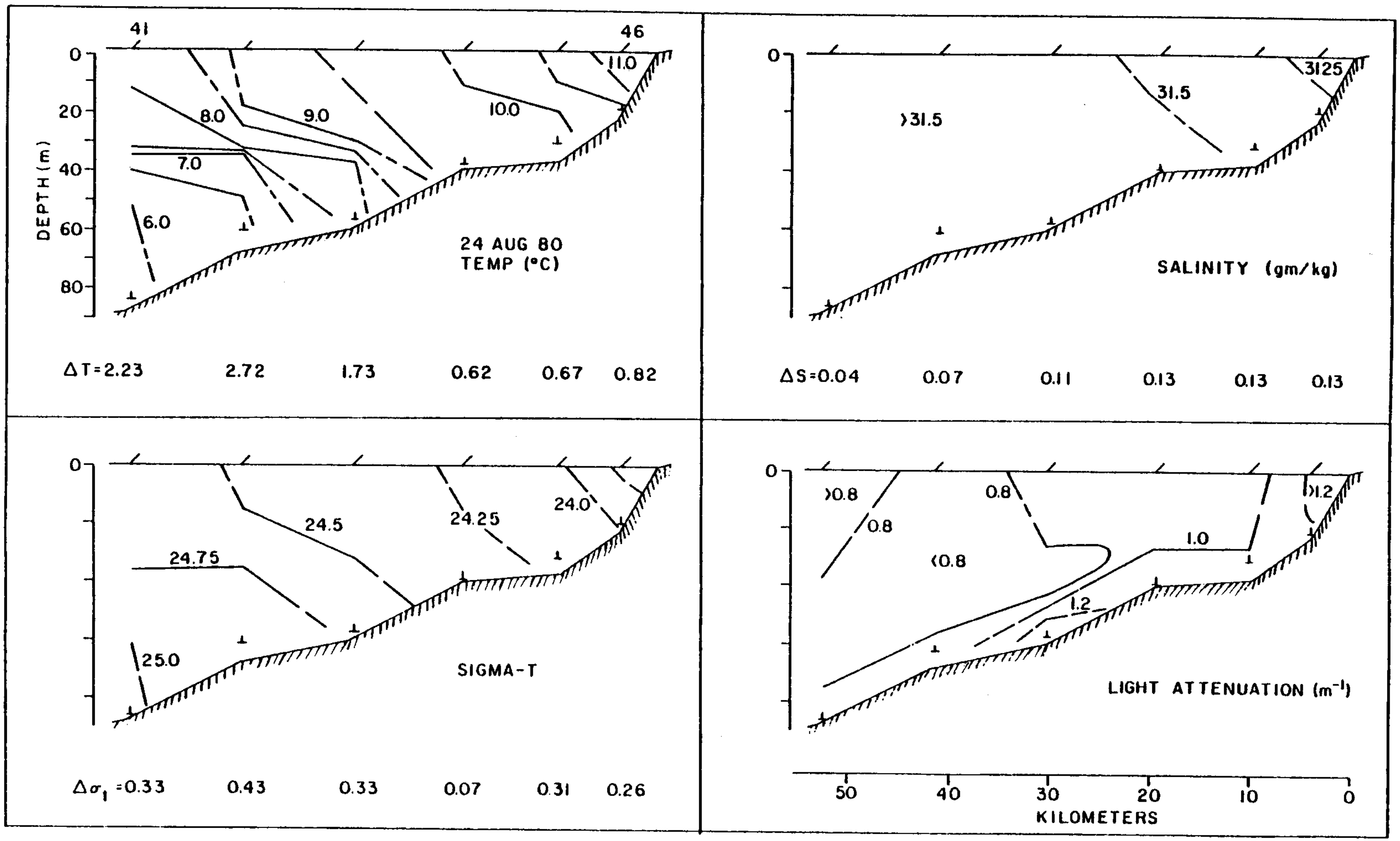


Figure 42. Hydrographic and light attenuation sections from 24 August 1980. Contour intervals are 0.5°C, 0.25 gm kg^{-1}, 0.25 σ_t units and 0.2 m^{-1} for light attenuation. Magnitude of upper minus lowest 1 m average parameter is presented under a given station as a Δ. Note, lowest 1 m average salinity at station 42 was 31.71 gm kg^{-1} (Schumacher and Moen, 1983).

particulate matter was also well mixed within 10 km of the shore, and seaward of station 45, isopleths exhibited weak downward vertical gradients with SPM increasing monotonically.

During the second occupation of this section (Figure 42), the entire shelf region was thermally stratified, with surface minus bottom temperature difference (ΔT) from 0.6 to 2.7°C. Colder bottom waters intruded onshore, with a displacement of the 8.5°C-isotherm of about 10 km. A similar change of mixed to stratified structure was observed in isohalines with the strongest stratification ($\Delta S = 0.13$ g kg^{-1}) over the normally mixed coastal domain. These data suggested an onshore deep flux (bottom salinity increased) and an offshore upper flux (upper layer salinities decreased). Light attenuation values indicated a 50 percent reduction in nearshore concentration of SPM, while over the middle shelf domain (>~50 m) a subsurface minimum layer was established.

Hydrographic conditions observed on 31 August (Figure 43) showed a return to more typical stratification distributions; middle shelf waters were stratified with $\Delta\sigma_t > \sim 0.43$ and coastal domain waters were vertically well mixed. SPM profiles also indicated mixed conditions in the coastal domain and a minimum layer was clearly established near or below the pycnocline.

Alongshore (v positive toward 60°T) winds are shown in Figure 44. The passage of the storm resulted in maximum alongshore wind speeds of about 25 ms^{-1}. About 3.5 days after the storm's peak speeds, a period of relatively steady alongshore winds existed for about three days with a mean speed of -5.5 ms^{-1}. With the exception of the storm winds and those on 24 August, onshore wind speeds were only about 1 ms^{-1}.

Currents at 5 and 39 meters below the surface are shown in Figure 44, where the alongshore axis is the same as for the wind and the onshore axis is u positive 150°T. Near-surface currents reversed from onshore to offshore concomitant with the wind reversal and this initial offshore pulse lasted for about three days. While near-surface currents were offshore, those at 39 meters were onshore for the same time period. The visual correlation between wind and near-surface currents did not extend to currents at 39 meters depth. The along-shore current appeared to be similar at the two depths. Figure 44 also shows the cube of the near-bottom tidal current which is a measure of tidal dissipation power. Note that it increases significantly over the periods of measurement.

Thus, the destruction and subsequent reestablishment of typical summer middle shelf and coastal domain hydrographic features was related to winds and tides. The initial vertical mixing of the water column resulted from a combination of wind-wave and current shear turbulence which destroyed vertical structure at least 40 kilometers, or twice the usual distance, from the shore. Longshore winds then reversed and generated an offshore Ekman flux in the near surface waters and a continuity preserving onshore flux at depth. The offshore flux brought warmer, less saline surface water offshore, while the onshore flux at depth provided colder more saline waters; these resulted in stratification across the entire study area. As tidal mixing power increased, coastal domain waters became vertically mixed and middle shelf domain waters returned to a two-layered configuration.

Inshore Ice. Nearshore ice characteristics in the eastern Bering Sea, including the Bristol Bay region have been described by Stringer (1981). Nearshore ice conditions in the Bering Sea differ from those in the Beaufort and Chukchi Seas. Two important factors that are almost totally absent in the Beaufort Sea influence ice behavior in portions of the Bering Sea. These two factors are tides and ice advection. While the Beaufort coast experiences very small tides, tides at many locations on the Bering Sea coast range over several meters. Also, while Beaufort Sea ice is almost always packed against the coast, in many places along the Bering coast the ice is almost continuously being pushed away from shore by winds and currents.

Pack ice in Bristol Bay appears to be greatly influenced by the fact that no barrier exists to keep ice from moving to the southwest, as well as by significant tidal range. These circumstances, combined with the presence in winter of strong offshore winds in the northern part of the bay, results in a general southwestward motion of ice out of Bristol Bay. Normally, this motion is so persistent that LANDSAT and lower-resolution satellite imagery nearly always show open water along the northern side of the bay where ice has been blown offshore. Fast ice is not extensive and is generally found only in highly protected locations.

Due to the nearly constant motion of ice away from the coast and the resulting open water, new ice is often formed along a broad band running east to west across the northern side of the bay. It is often possible to see the transition from open water to new ice, young ice, and first-year pack ice on a single LANDSAT image. Superimposed on this behavioral pattern is a dynamic process: as the ice moves out of Bristol Bay into a less confined area, it breaks up into large pans with dimensions on the order of 10-20 kilometers. The voids between these pans then freeze. This process of breakup and refreezing may then repeat itself several times. Although the characteristic motion is out of Bristol Bay, occasionally a storm can drive ice onto the coast, including the north shore of the Alaska Peninsula. Nearshore ice conditions in the Bristol Bay region are summarized in Figure 45, adapted from Stringer (1981).

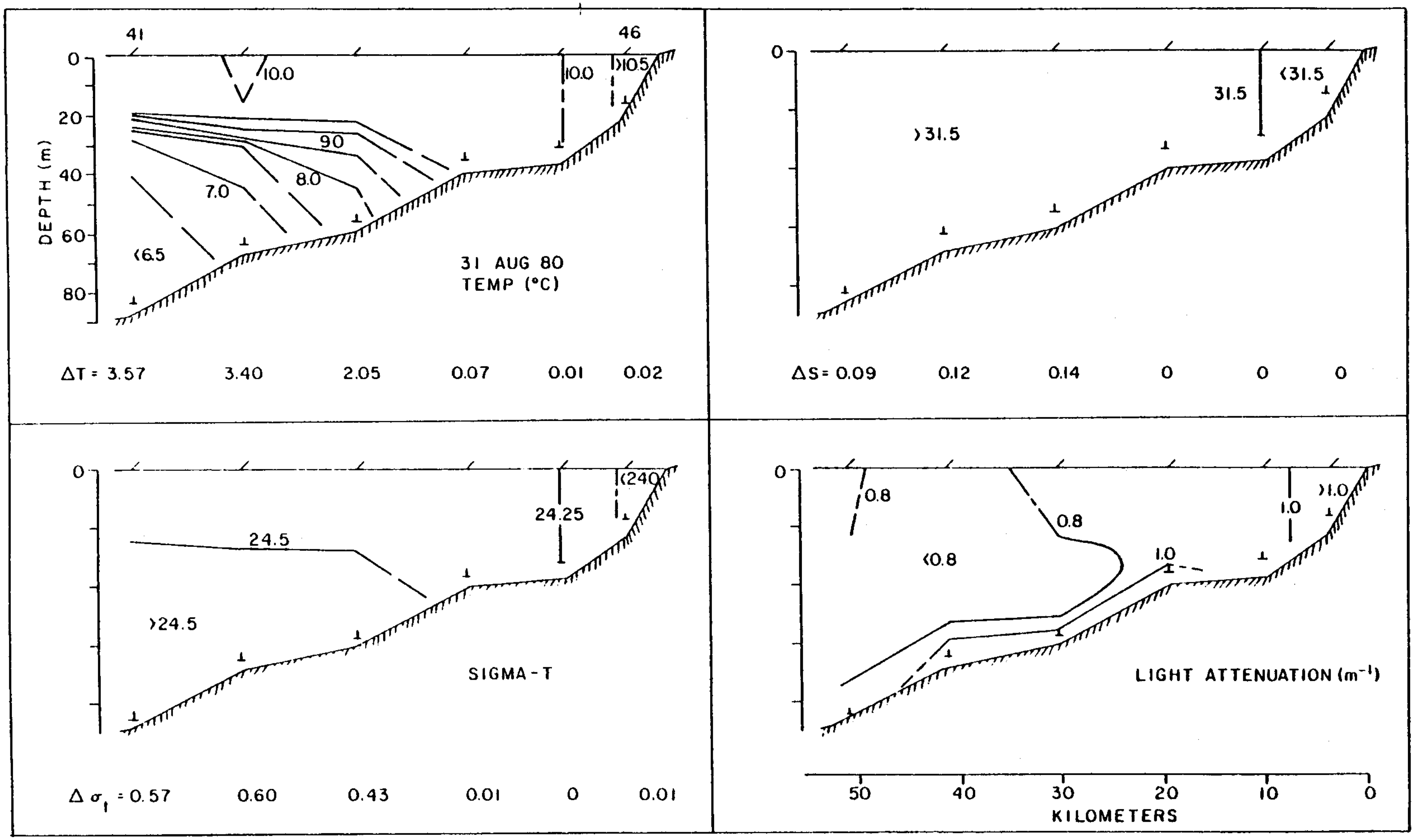


Figure 43. Hydrographic and light attenuation sections from 31 August 1980 (Schumacher and Moen, 1983).

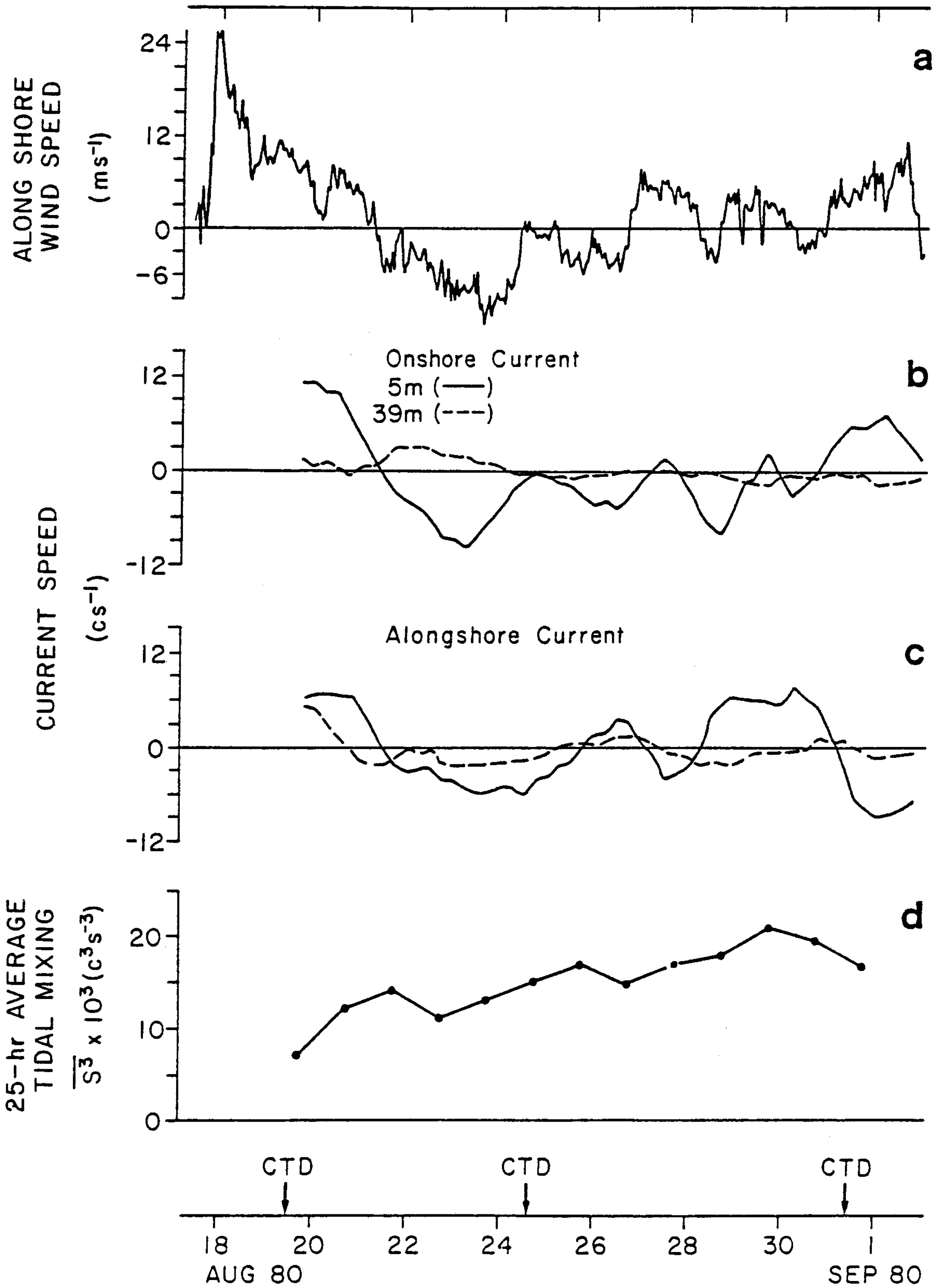


Figure 44. a) Alongshore windspeed, b) onshore current at 5 and 39 m, c) alongshore current at 5 and 39 m, and d) 25-hour average tidal mixing parameter s^{-3} from the 39 m depth current record (Schumacher and Moen, 1983).

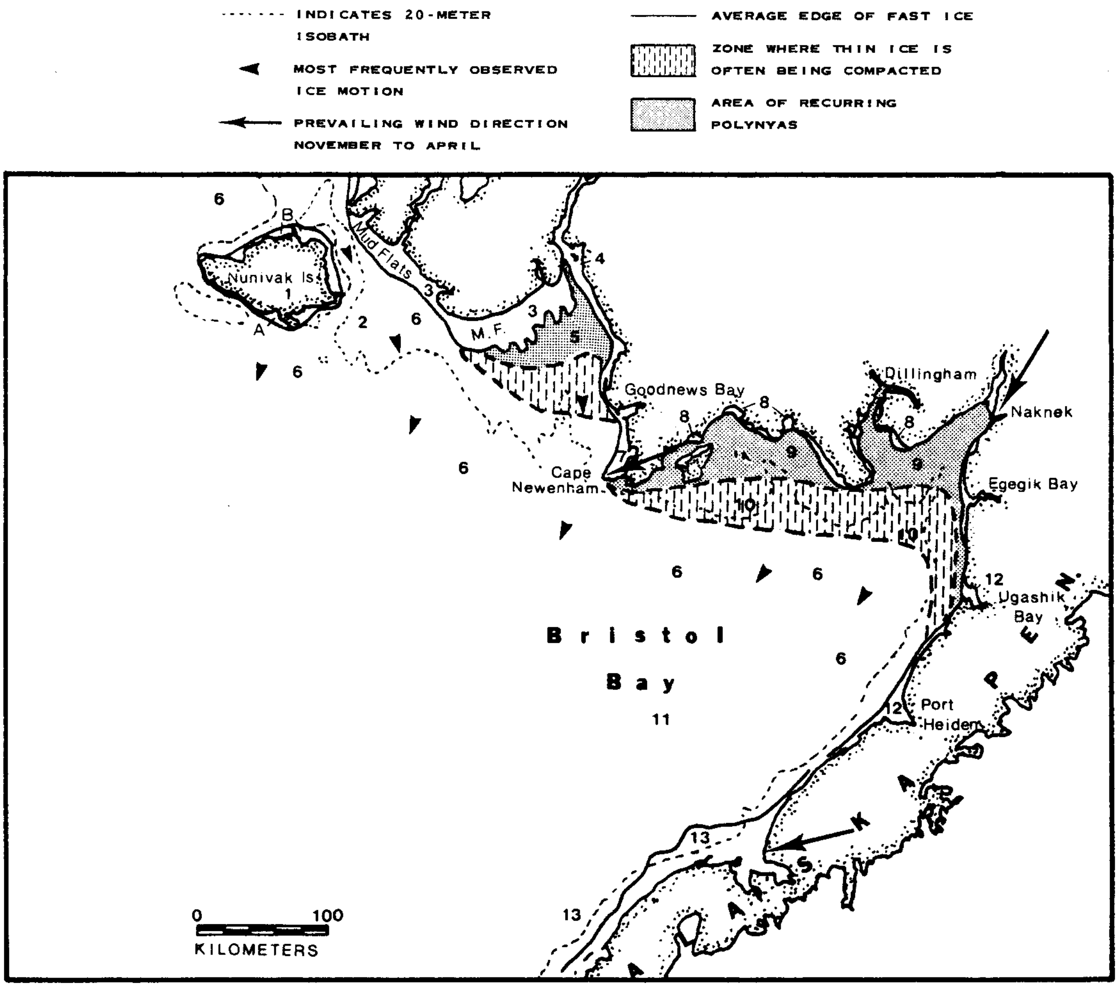
b. Geological and Chemical Setting

Geological Setting. The geology of the Bering Sea has been studied, mainly by Soviet and United States workers, since the middle of the nineteenth century. A thorough review of earlier work with emphasis on the northern and western parts was prepared by Lisitsyn (1966). The greater activity of the post World War II period in marine geology, geomorphology and paleontology was summarized by Hopkins (1967) in "The Bering Land Bridge." Modern geological studies began just after World War II with a series of U.S. Navy Electronics Laboratory cruises, from which data the map of bottom sediments was prepared by Deitz et al (1964). The Cenozoic sedimentary and tectonic history was reviewed by Nelson et al (1974), and the contemporary sediment regimes of the eastern region by Sharma (1974, 1979). Hopkins (1978) and Burrell et al (1981) collected some samples for analysis of geochemical characteristics and sediment/benthic biota relations respectively. The main portion of the samples obtained in the nearshore region (<50m) for sedimentary analysis are shown in Figure 46. Few of these were taken within less than ten meters water depth. Recently, a series of benthic stations were occupied (VTN, 1983e) in the inshore area (10-60m depths) from Unimak Pass to the Port Moller area, Figure 47.

The characterization of the geological processes of the very nearshore region between Unimak Pass and Cape Newenham from existing data will require extrapolation of existing sedimentary data to the shore line and will make use of suspended particulate matter data (Baker, 1981; Baker, 1983), elemental composition of suspended matter (Feely et al, 1981), and other relevant geochemical (Burrell et al, 1981) and physical data (see preceding section).

Geologic History. The abyssal basin of the Bering Sea is thought to be a northern embayment of the Pacific Ocean that became isolated by the development of the Aleutian Ridge prior to late Eocene, but not later than Cretaceous time (Scholl, Greene and Marlow, 1970; Scholl and Buffington, 1970; Scholl et al, 1974). The interaction of oceanic and continental crust was localized at the base of the continental slope of the Bering Sea during most of Mesozoic time. A shift in the subduction to the south, to the present site of the Aleutian trench-arc system, took place at the beginning of the Tertiary period. The southernmost tectonic unit of the southeastern Bering Sea seems to consist of intensively deformed Cretaceous flysch sediments intruded by serpentine. A similar complex is exposed in mainland areas of Alaska and Siberia (Scholl et al, 1974).

Since Tertiary time, the erosional surface represented by the acoustic basement has been flexed upward and downward



1 FAST ICE AROUND NUNIVAK ISLAND IS CONFINED TO WATERS INSHORE OF THE 20 METER ISOBATH WITH EXCEPTION OF TWO LOCATIONS
   A. IN THIS PORTION OF THE SOUTHERN COAST THE 20 METER ISOBATH IS VERY CLOSE TO SHORE YET BECAUSE OF PROTECTION OFFERED IN THIS AREA, FAST ICE EXTENDS FAR SEAWARD
   B. IT APPEARS THAT SOUTHWARD ICE IS PILED IN THIS AREA

2 PACK ICE GENERALLY IN SOUTHWARD MOTION THROUGH ETOLIN STRAITS CAN PILE UP ON SHOALS

3 FAST ICE IS LOCATED OVER MUD FLATS IN WATERS NO DEEPER THAN A FEW METERS

4 TIDAL ACTION (RANGE 5 METERS) IS RESPONSIBLE FOR REMOVING ICE FROM THE KUSKOKWIM CHANNEL

5 THIS AREA OFTEN CONTAINS OPEN WATER AND BROKEN ICE WITH ICE RUBBLE PILES FOUND ON SHOALS

6 PACK ICE OFTEN SHOWS SIGNS OF REPEATED BREAKAGE AND FORMATION OF NEWER ICE

7 FAST ICE SHOWS SOME VARIATION IN EXTENT DUE TO OCCASIONAL GROUNDING ON SHOALS AND IS GENERALLY FOUND IN WATERS LESS THAN 6 METERS DEEP

8 FAST ICE ON THE NORTHERN SIDE OF BRISTOL BAY IS CONFINED TO HIGHLY PROTECTED AREAS WITH WATER DEPTHS LESS THAN 4 METERS. TIDAL RANGE IS AS GREAT AS 7 METERS

9 THIS AREA IS OFTEN A POLYNYA OR CONTAINS NEWLY FORMED ICE

10 ICE IN THIS AREA IS OFTEN COMPACTING AND GROWING IN THICKNESS AS IT MOVES SEAWARD

11 ICE WITHIN BRISTOL BAY IS OFTEN COMPOSED OF SEVERAL AGES, FORMED AS OLDER ICE BREAKS INTO PANS AND THE VOIDS FREEZE WITH NEWER ICE

12 FAST ICE ALONG THE EASTERN END OF BRISTOL BAY IS LIMITED TO AN AREA CLOSE TO SHORE BY OFFSHORE WINDS AND CURRENTS

13 DURING YEARS WITH EXTENSIVE BERING SEA ICE, FAST ICE CAN BE FOUND ALONG THIS COAST. WINDS TEND TO DRIVE ICE ONTO SHORE. ON MARCH 9, 1974 AN EXTENSIVE SHEAR RIDGE WAS OBSERVED HERE.

Figure 45. Map summarizing Bering Sea regional nearshore ice characteristics (Adapted from Stringer, 1981).

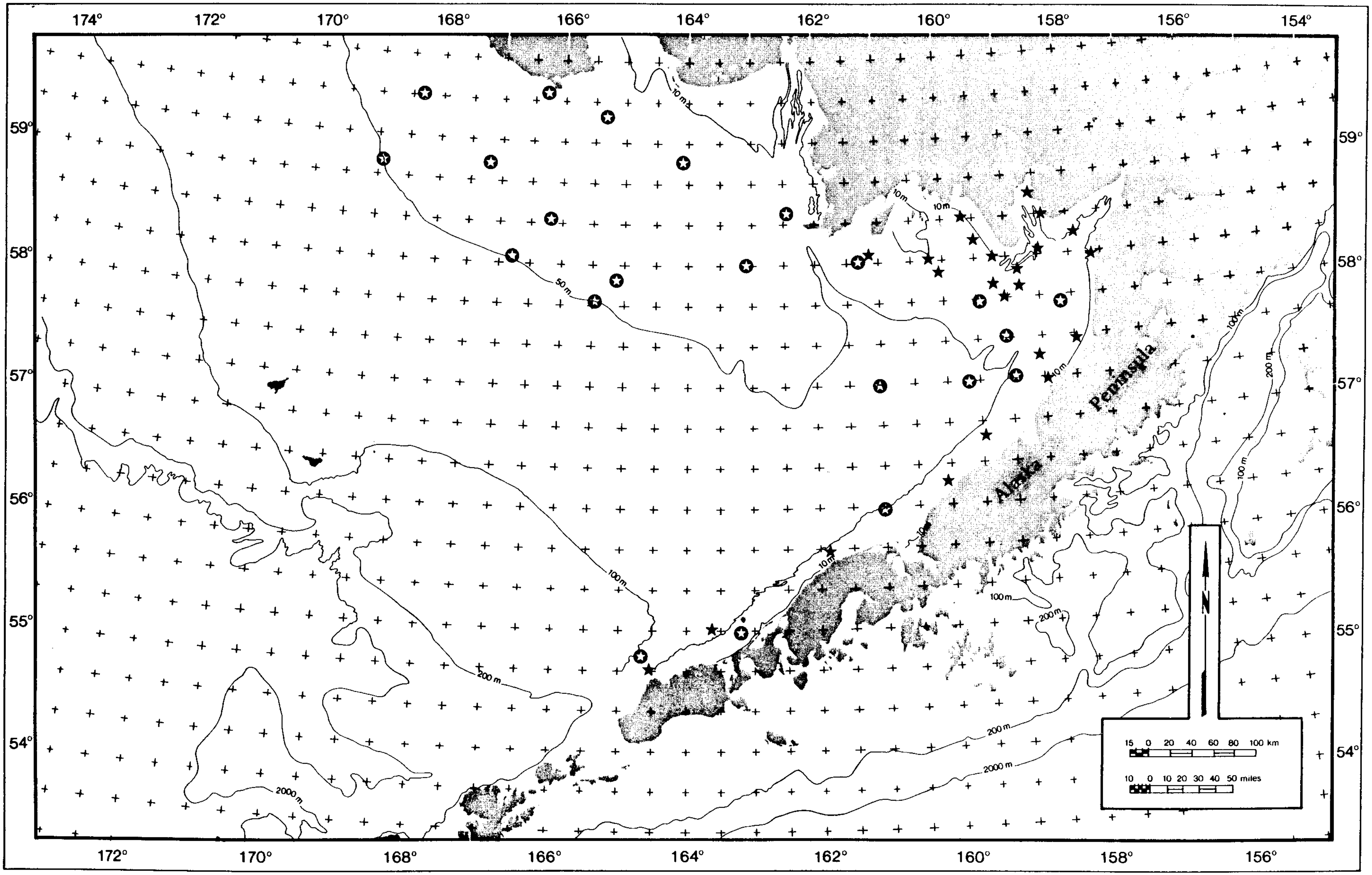
in insular and peninsular areas, where rocks of Paleocene and older age are now exposed, and into sedimentary basins on the continental shelf.

It is possible from available data to postulate the late Mesozoic-early Cenozoic history of the southeast Bering Sea. An episode of volcanism began during Cretaceous time and continued into the Palocene epoch. The Okhotsk volcanic belt extended through the Bering Sea to the Alaska mainland. Soon uplift processes ended the sedimentation and a long period of erosion began throughout Alaska and the continental shelves of the Bering Sea. At the end of the Oligocene time, the north Aleutian shelf was probably a surface of marine and subaerial planations which later warped and formed basins which are now filled with Tertiary sediments of the main layered sequence.

The main layered sequence (MLS) is an acoustic unit that represents greatly deformed sedimentary strata underlying most of the floor of the continental shelf of the Bering Sea. The unit is over 500 meters thick over about two thirds of the shelf area including the North Aleutian Shelf (Nelson et al, 1974). Stratigraphic studies of middle and late Tertiary beds in mainland Alaska [Cook Inlet and Nenana Basins (Wahrhaftig et al, 1969; Kischner and Lyon, 1973)] showed a major change in the drainage patterns in Alaska that must have had pronounced effects on the sedimentary history of the Bering Sea. Central Alaska was drained before Miocene times by tributaries that flowed southward across the present site of the Alaska Range to the area of Cook Inlet and thus to the Gulf of Alaska. The uplift of the Alaskan Range diverted the drainage north to the Yukon River and thus westward to the Bering Sea.

The MLS then began after a prolonged period of denudation through the Eocene into Oligocene time. The erosional detritus from the Bering continental shelf and southwestern Alaska was presumably deposited in the Aleutian and Commander basins. Marine sediments were deposited on the actively subsiding continental margin along the southeast Bering Sea. During late Miocene, the uplift of the Alaska range caused a great increase in the land area shedding sediments to the Bering Sea and probably significantly increased the rates of sedimentation in its offshore basins. Most of the Miocene and Pliocene time was a period of progradational sedimentation at the continental margin; deposition of the MLS built the shelf outward off Bristol Bay.

The MLS is overlain with a complex suite of deposits probably of Quaternary age (Grim and McManus, 1970; Kummer and Creager, 1971). The Quaternary sediments on the continental shelf are rarely thicker than 100 meters and in some places are only a few meters thick. The deep basin is mantled by Quaternary sediments nearly one kilometer thick (Scholl and Creager, 1971).



✪ - Hoskin, Univ. of Alaska Cruise 290, 1978 ★ - Sharma, 1971

Figure 46. Nearshore sediment stations 1975-1980.

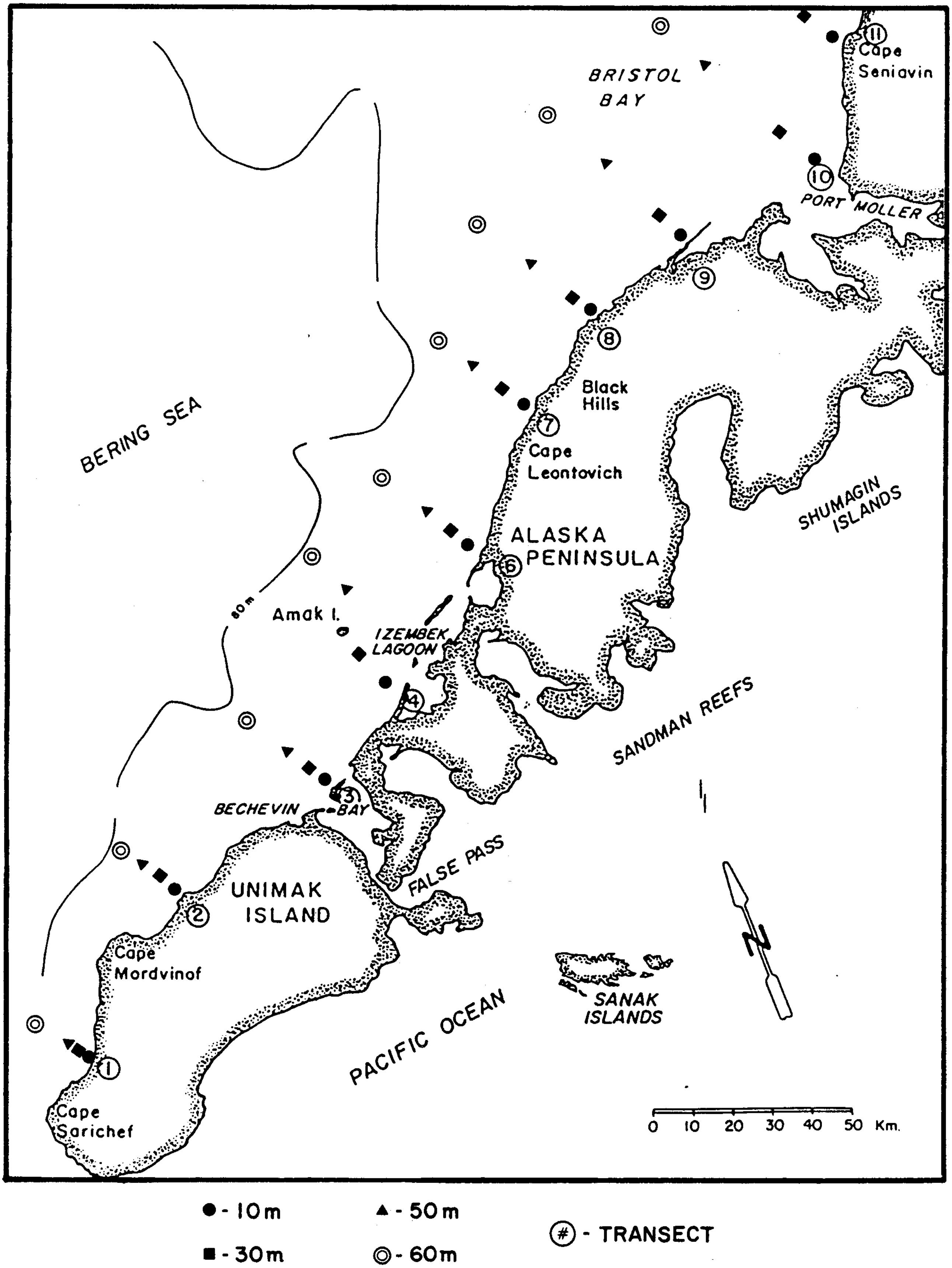


Figure 47. Nearshore benthic biota and sediment stations, Alaska Peninsula (VTN, 1983e).

The Pleistocene history of the southeast Bering Sea shelf is characterized by repeated episodes of subaerial exposure, fluvial sedimentation, and massive glacial encroachment associated with deposition. The distribution of glacial deposits in southwestern Alaska indicates that glaciers extended far into Bristol Bay (Coulter et al, 1965). Approximately 16,000 years ago the Kuskokwim River evidently flowed south to central Bristol Bay and then seaward to the abyssal Bering Sea (Hopkins, 1972).

In Holocene time, the erosional and depositional features of the Pleistocene have been marked by sediments on the southeastern Bering Sea shelf. Offshore from mud-filled local embayments along the shoreline, the Holocene deposits form a classic gradational sequence ranging from nearshore coarse sands to muds at the shelf edge (Sharma, 1974).

Contemporary Sedimentation. Based on the limited data available, Sharma (1974) described the distribution of sediments on the southeast Bering Sea shelf as shown in Figure 48. The texture varies from gravel and coarse sand in the nearshore regions to progressively finer sediments offshore.

The nearshore sediments, as shown in Figure 49, are extremely poorly sorted. The grain size modes for the sand fraction obtained by Hopkins (1978) with Van Veen grabs on a 45 mile grid are shown in Figure 50. In these data, a grain size mode of 149 μm was found to coincide roughly with the 25 m contour in eastern Bristol Bay. This investigator also observed that the largest total number of biological individuals occurred at stations having grain size modes of 125-149 μm (fine sand) with smaller numbers occurring in either the finer or coarser sized sediments.

The sediment types described by VTN (1983e) are shown in Figure 51 for the nearshore area north of the Alaska Peninsula and between Port Moller and Unimak Pass. These data, Table 2, resulting from sampling by an unweighted, 0.25 m^2 Van Veen grab, show coarse sand in this inshore area, with gravel/sand areas lying around 30 meters depth and north of Unimak Island, offshore of the Cape Leontovich/Black Hills region, and offshore Cape Seniavin.

The clay minerals of the southeastern Bering Sea shelf consist of 40-70 percent of an expandable component (Figure 52); 20-50 percent illite (Figure 53); and 30-40 percent chlorite. Kaolinite is generally present in less than 10 percent (Burrell et al, 1981). Nearshore to the Alaska Peninsula the expandable clay exceeds 59 percent of the clay size fraction, while other components contribute only trace amounts. The expandable material represents contributions from bordering volcanic regions whereas other components are presumably introduced by way of the northern and eastern rivers (Naidu and Mowatt, 1977).

The organic carbon content of sediments on the eastern North Aleutian Shelf region has been described by Sharma (1974) as shown in Figure 54. As seen in Figure 46, there are relatively few stations in the nearshore region north of the Alaska Peninsula; however, more intensity was realized in the region of Cape Constantine and Walrus Islands in Togiak Bay. A strong correlation between clay content of the sediments and organic carbon content was found for the southeast Bering Sea Shelf (Figure 55). Concentrations in the range of 0.5 percent were found only off the continental shelf and in an anomalous pocket in Togiak Bay.

Heavy Minerals. There are relatively high concentrations of heavy minerals in sediments along the Alaska Peninsula which can be related to high values in the adjacent beaches. There is 23 percent by weight in the 2.5 - 3.0 size and only eight percent in the 1.5 - 2.0 size range of sediments. The heavy mineral assemblages consist predominantly of hypersthene (green and purplish brown), amphibole (mostly hornblende), and opaques (magnetite and ilmenite). Diopside occurs in minor amounts and traces of garnet, sillimanite, spidote, staurolite, tremolite, sphene, uralite, chlorite and zircon are present. A higher weight percentage of heavy minerals is found near the southern shore than in the center of Bristol Bay. The distribution of heavy minerals in samples analyzed in Bristol Bay is shown in Figure 56.

Heavy metal analyses of surficial sediments on the southeast Bering Sea shelf are very limited (Burrell et al, 1981); however, those data available for iron (Figure 57) and vanadium indicate higher nearshore concentrations in the surficial sediments than is found in deeper water. The mean values observed for heavy metals in surficial sediments along with correlation coefficients are shown in Table 3. These data primarily show a highly significant correlation for structural alumina-silicate elements: Al, Fe, Ca, and Co. More will be said about the heavy metals distribution in sediments, in suspended particulates, and in the water column in the sections on suspended particulate matter and trace metal chemistry.

Suspended Particulate Matter. Several studies have contributed to the understanding of the distribution, composition and flux of suspended particulate matter (SPM) in the nearshore region of the North Aleutian Shelf.

Some SPM data were reported by Sharma (1971, 1974, 1979), Sharma et al (1972) and Burrell et al (1981) for the eastern Bering Sea shelf, but few stations were occupied within the nearshore area of this study. Likewise Loder (1971) and Handa and Tanoue (1981) provided valuable information of the particulate organic matter in the eastern Bering Sea and elsewhere, but not specifically in the region

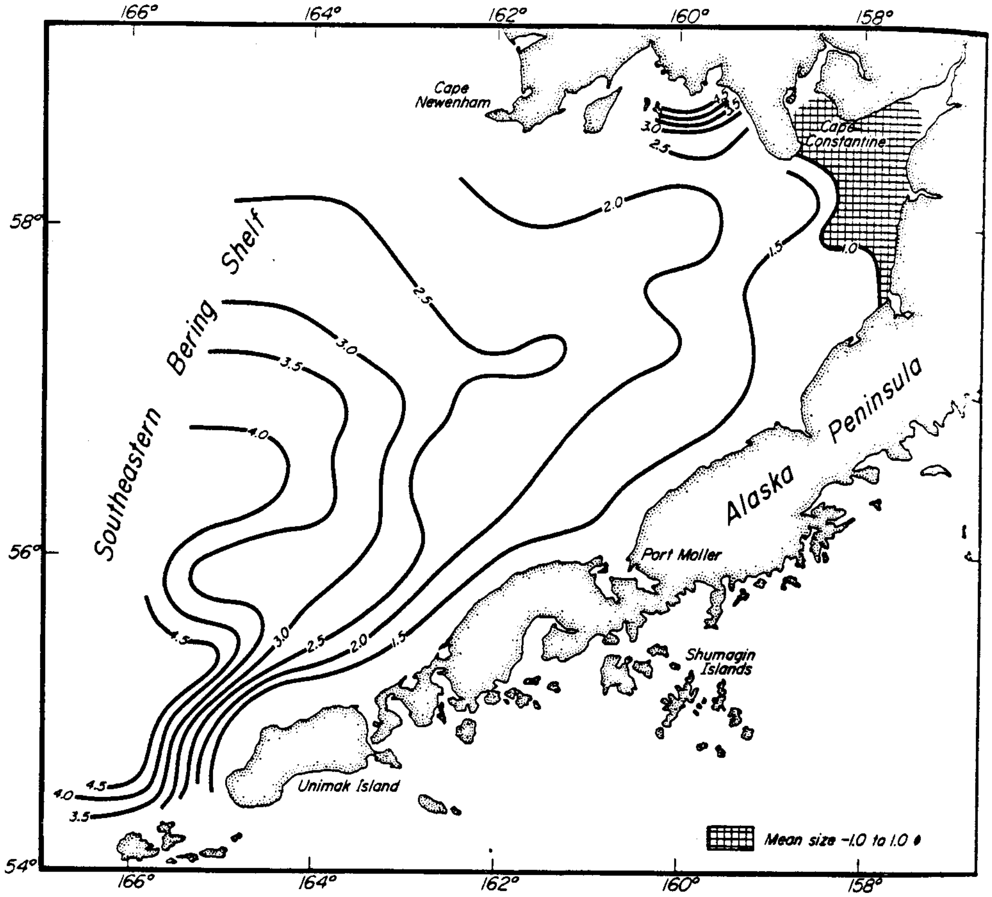


Figure 48. Sediment size distribution (ϕ) on southeastern Bering Shelf (Sharma, 1974).

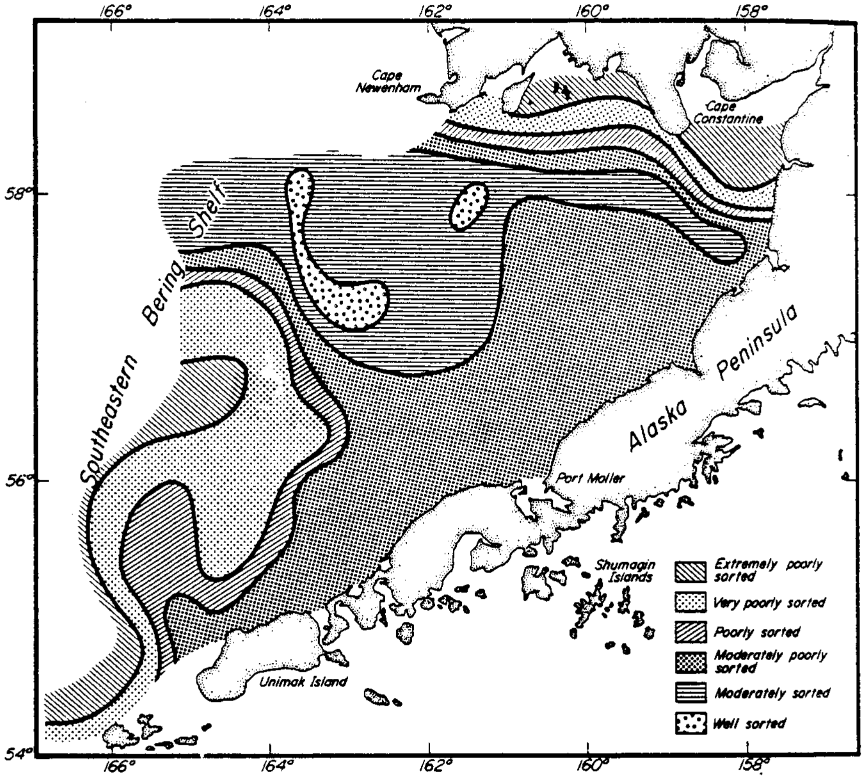
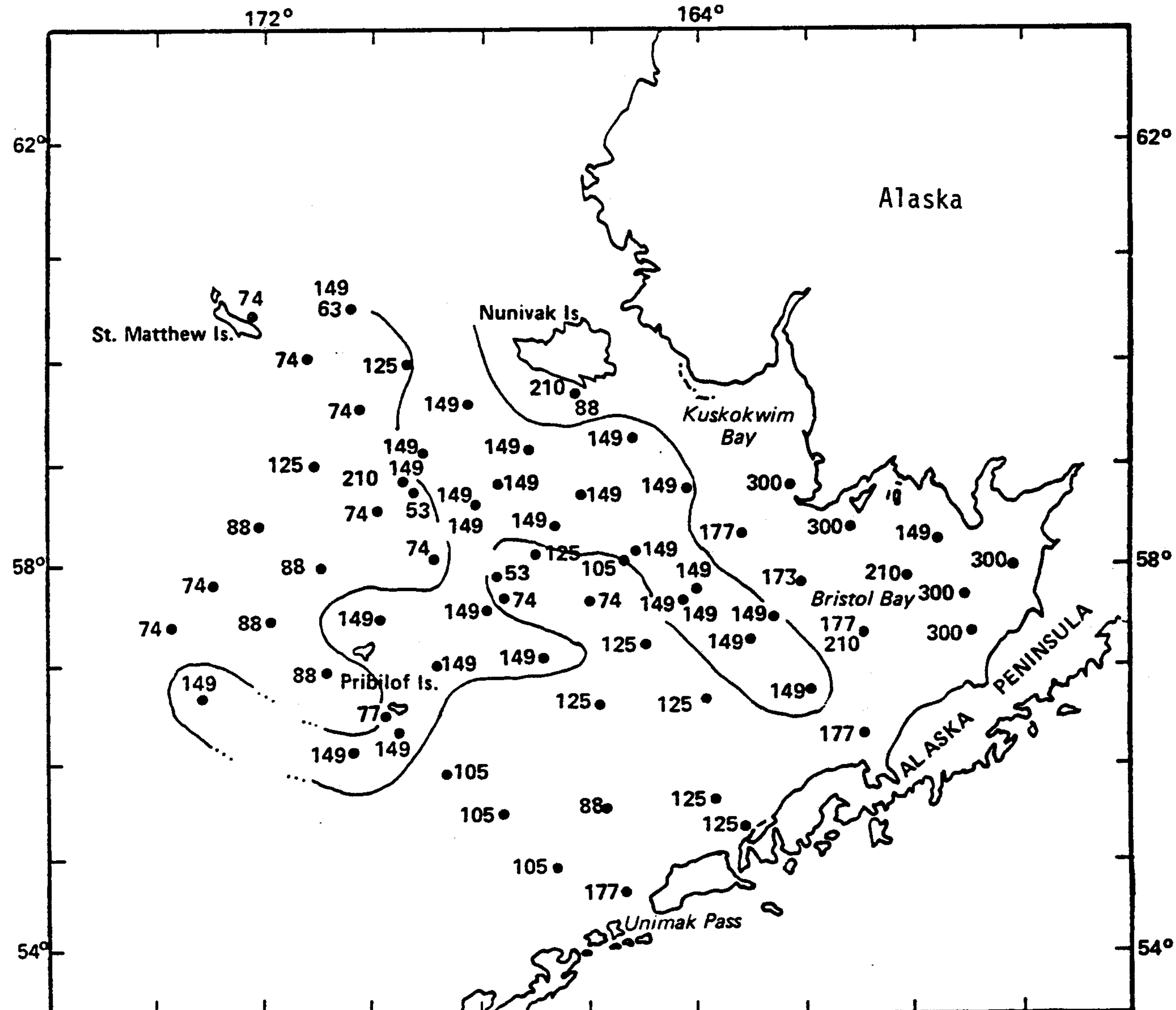


Figure 49. Sediment sorting on southeastern Bering Shelf (Sharma, 1974).



GRAIN SIZE MODES, μm FOR SAND
SAMPLES, n = 66

Figure 50. Map of grain size modes, μm, for the sand fraction. Number of samples = 66 (Hoskins, 1978).

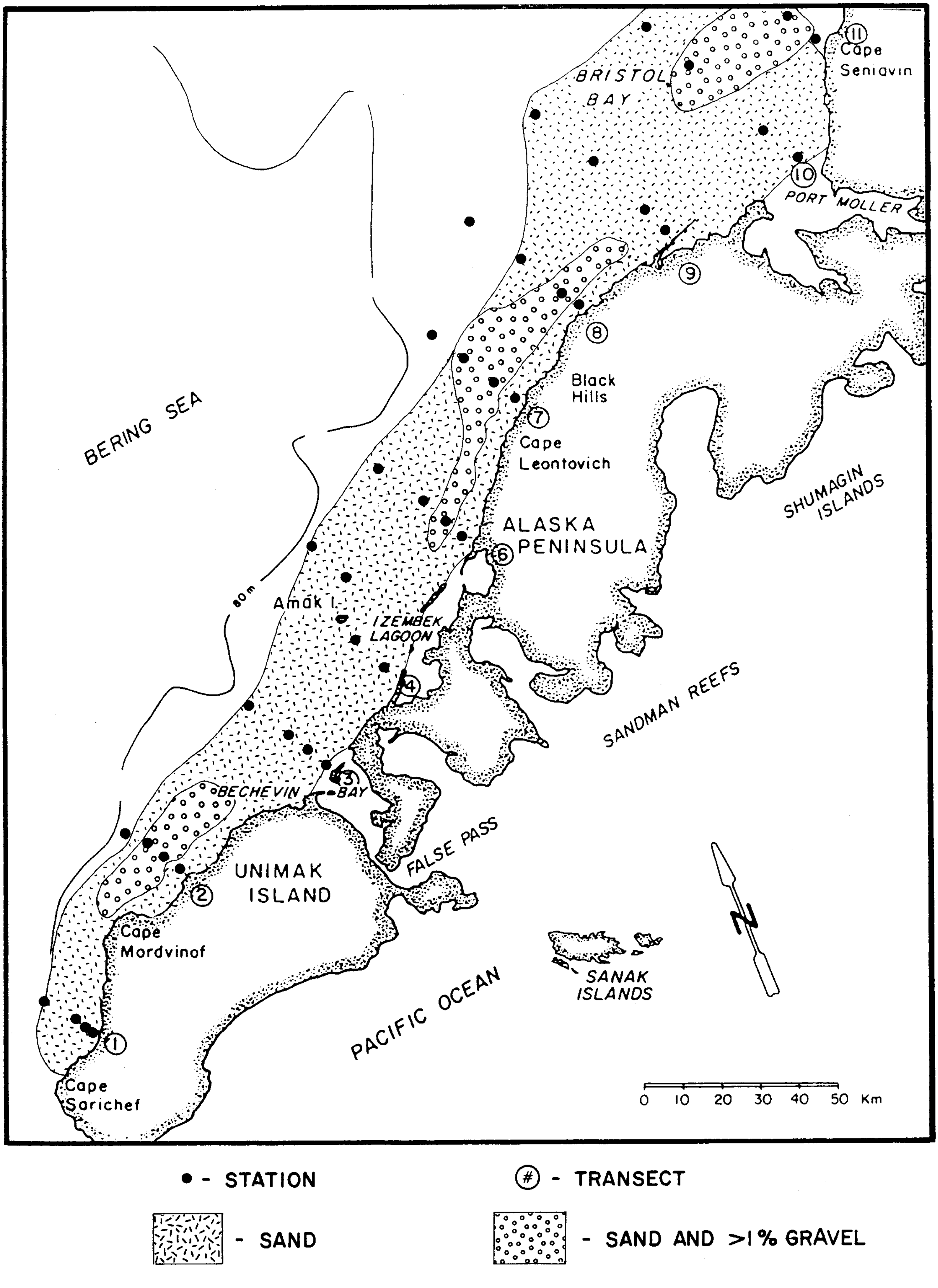


Figure 51. Nearshore sediment types, Alaska Peninsula (VTN, 1983e).

Table 2. Sediment characteristics and benthic communities. (From VTN, 1983e).

Transect	Depth (m)	Month	Infaunal* Community	Gravel (%)	Sand (%)	Silt (%)	Mean Diameter (dg)	Mean (O)	Sorting Index (S_1)
1	30	June	-	0.6	87.4	12.0	0.15	2.74	1.31
1	50	June	-	0.7	85.7	13.6	0.14	2.84	1.31
2	10	June	I	0.1	93.6	6.3	0.15	2.74	1.27
2	30	June	IIA	36.6	62.7	0.7	2.37	-1.24	3.07
2	30	October	IIA	20.6	78.6	0.8	2.02	-1.01	1.77
2	50	June	IIA	6.8	92.9	0.3	1.24	-0.31	1.64
2	60	October	I	0.0	99.2	0.8	0.39	1.36	1.47
3	30	June	IIB	0.1	93.3	6.6	0.15	2.74	1.21
3	50	June	IIB	0.0	94.5	5.5	0.18	2.47	1.29
3	60	October	IIB	0.0	99.3	0.7	0.76	0.40	1.52
4	10	June	I	0.0	97.6	2.4	0.18	2.47	1.28
4	30	August	-	5.2	94.3	0.5	2.06	-1.04	1.34
4	30	October	I	0.0	95.7	4.3	0.17	2.56	1.36
4	30	June	IIB	0.0	99.3	0.7	0.39	1.36	1.37
4	60	October	IIB	0.0	95.6	4.4	0.17	2.56	1.28
6	10	June	-	0.2	99.7	0.1	0.21	2.25	1.18
6	30	June	IIA	65.9	32.3	1.8	4.91	-2.30	1.98
6	30	October	-	46.0	53.3	0.7	4.20	-2.07	1.98
6	50	June	IIB	0.0	98.1	1.9	0.19	2.02	1.25
6	50	August	-	0.0	97.6	2.4	0.23	2.12	1.37
6	60	October	IIB	0.0	97.6	2.4	0.21	2.25	1.26
7	10	June	I	0.0	93.0	7.0	0.14	2.84	1.21
7	30	October	IIA	82.4	16.0	1.6	5.65	-2.50	1.56
7	50	June	IIA	4.3	95.3	0.4	0.93	0.10	1.90
8	50	June	IIB	0.8	99.0	0.2	0.61	0.71	2.29
9	30	June	IIB	4.5	93.7	1.8	1.11	-0.15	1.88
9	30	June	-	0.0	98.0	2.0	0.24	2.06	1.23
9	60	October	-	0.2	99.4	0.4	0.25	2.00	1.26
9	50	June	IIB	0.0	97.2	2.8	0.22	2.18	1.19
10	10	June	I	0.0	97.3	2.7	0.17	2.56	1.28
10	30	June	IIB	0.1	98.0	1.9	0.19	2.40	1.26
10	50	June	IIB	7.0	92.0	1.0	0.77	0.38	2.64
10	60	October	-	0.0	98.8	1.2	0.21	2.25	1.22
10	60	October	-	0.0	99.3	0.7	0.21	2.25	1.22
11	10	October	IIB	3.9	95.6	0.4	1.63	-0.70	1.48
11	30	June	IIA	8.6	88.3	3.1	1.29	-0.37	1.69
11	30	June	-	42.1	57.4	0.5	2.53	-1.34	3.37
11	50	June	IIB	0.5	96.6	2.9	0.31	1.69	1.38

- = Not sampled
* = See text for explanation

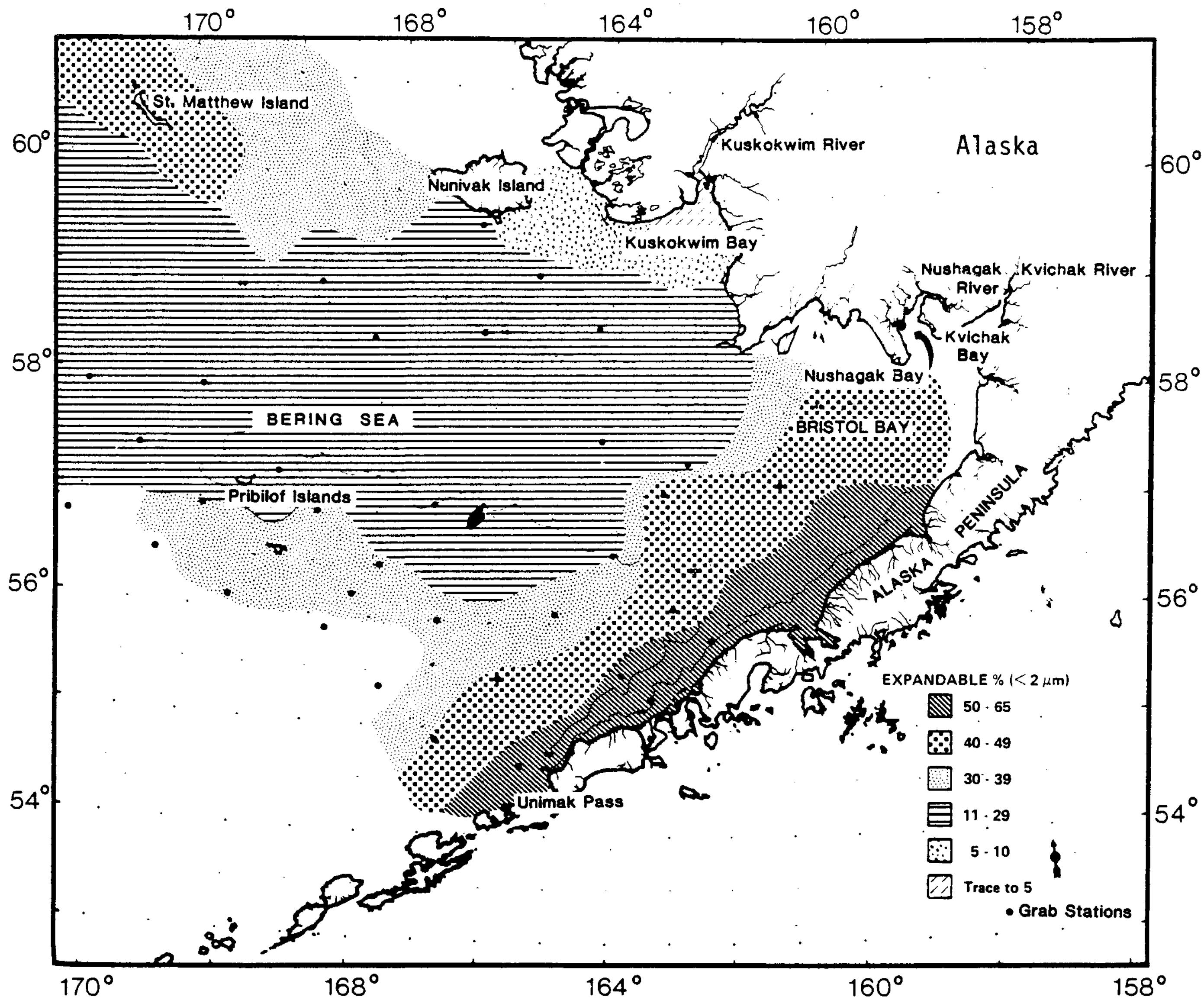


Figure 52. Distribution of expandable mineral component (%) in <2 µm size fraction of southeastern Bering Sea sediments (Burrell et al, 1981).

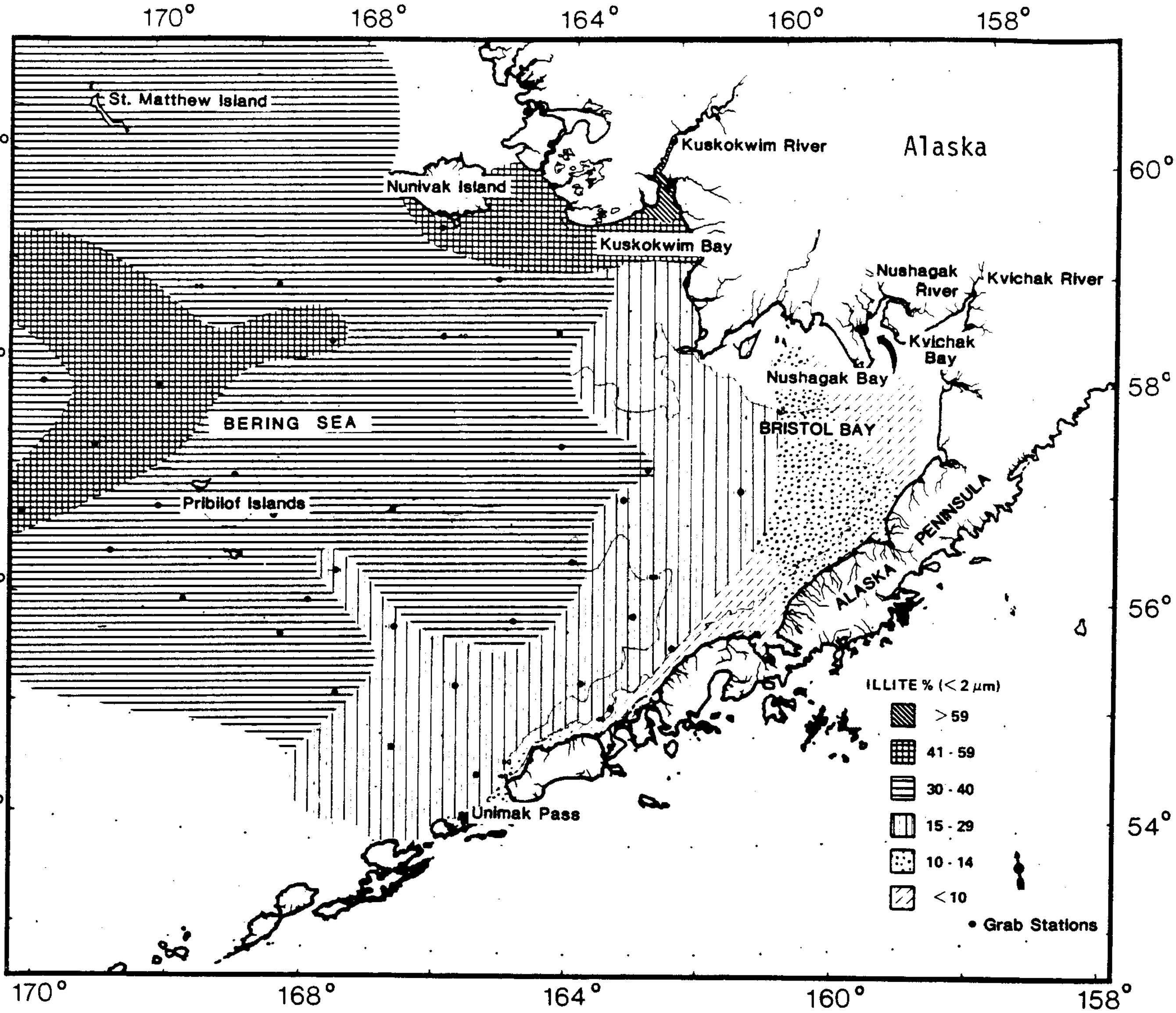


Figure 53. Distribution of illite (%) in <2 um size fraction of surficial sediments of the southeastern Bering Sea (Burrell et al, 1981).

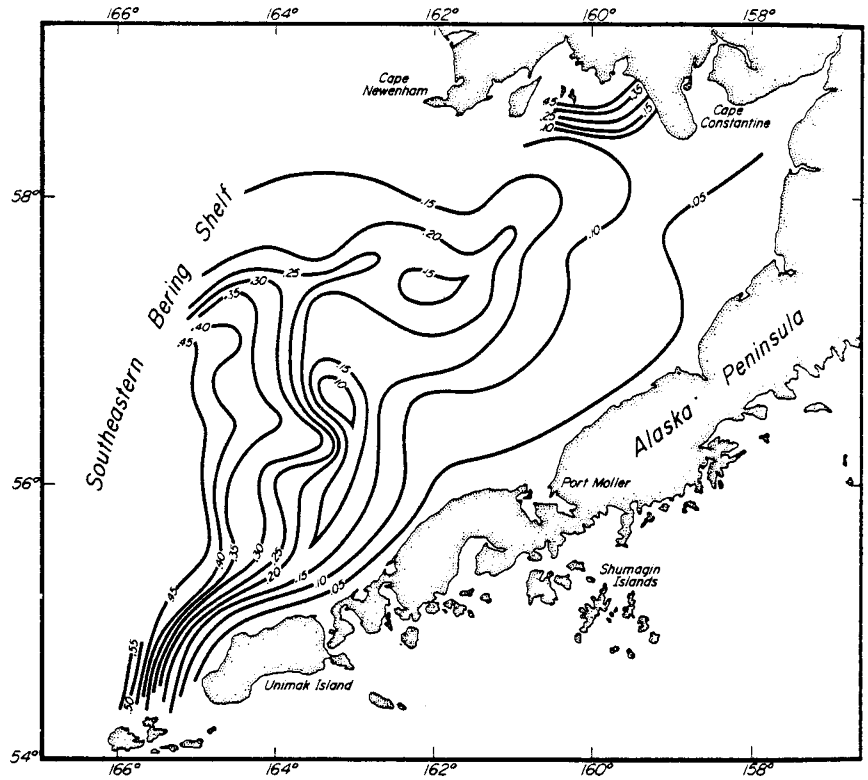


Figure 54. Organic carbon (weight percent) in southeastern Bering Shelf sediments (Sharma, 1974).

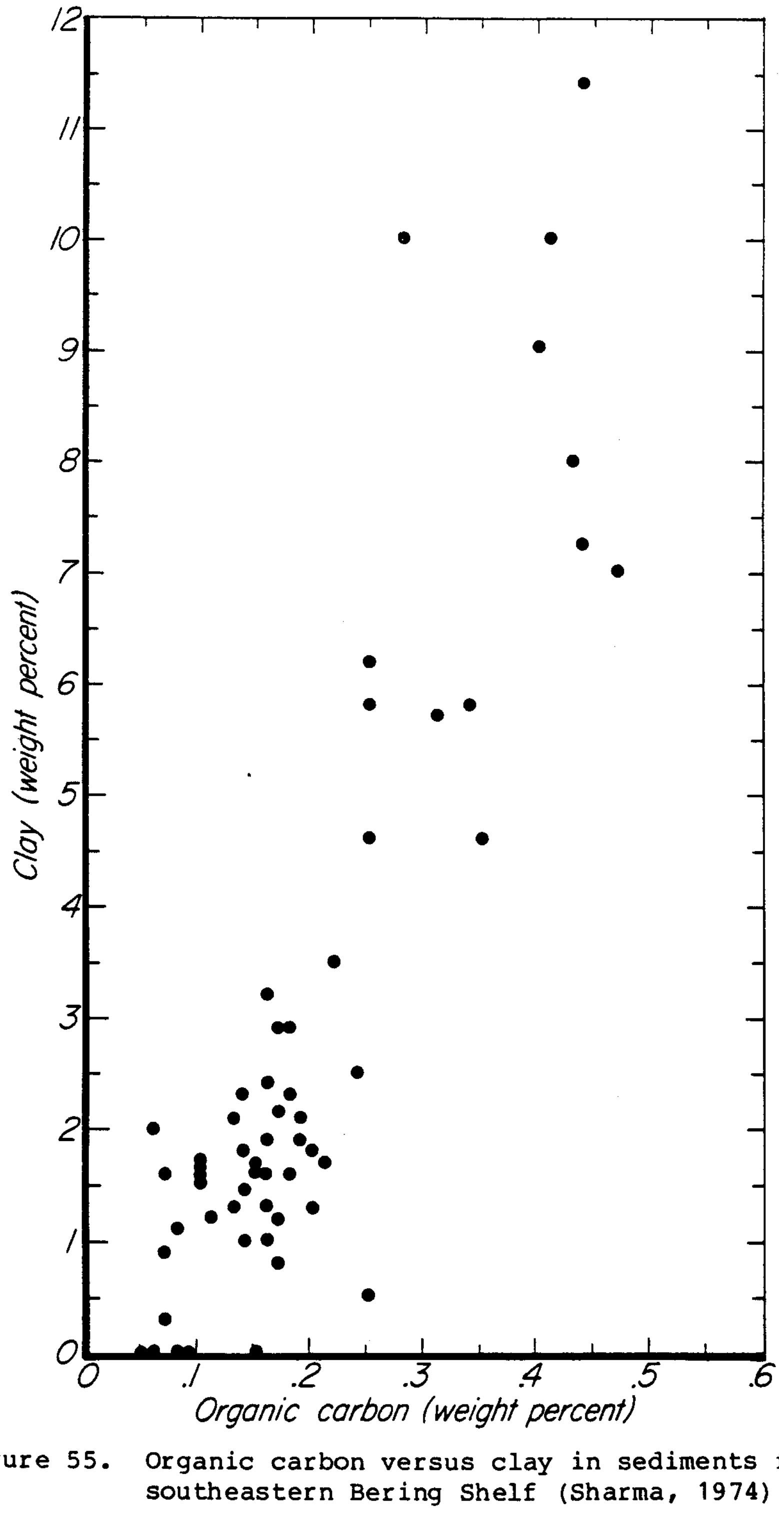


Figure 55. Organic carbon versus clay in sediments from the southeastern Bering Shelf (Sharma, 1974).

of this study. The most relevant data available are those of Baker (1981, 1983) on the SPM on the North Aleutian Shelf, and Feely et al (1981) who investigated both the SPM and its elemental composition for relevant locations in the study area.

Baker and colleagues (1981, 1983) occupied about 72 stations on twelve transects from very shallow water along the beach to offshore beyond the 50 m contour. The transects began east of Unimak Pass and extended beyond Ugashik Bay. Cruises were completed in August 1980, January 1981, and May 1981.

As an example of his results, the areal maps from Baker (1983) of transmissometer readings (light attenuation) and of salinity are shown in Figures 58 and 59 for the nearshore area north of the Peninsula. The salinity distribution observed in the surface water in August 1980 (little difference at depth in nearshore region), Figure 58, showed a strong source of fresh water from the northeast (presumably the Kvichak River and smaller rivers) and a minor source in Heredeen Bay in Port Moller. There is no evidence of freshwater intrusion from Unimak Pass at this time. A plot of surface attenuation values follows much the same pattern (Figure 58) showing highest concentrations in the northeast corner with a decrease seaward but remaining fairly constant along shore to the southwest in the zone occupied by the well-mixed coastal domain. SPM measurements made at five meters (Figure 59) from the bottom show similar results to the surface values inside the coastal domain, but minimum attenuation values were found at or just seaward of the 50 meter contour. These areal distribution maps for this cruise, and for the January and May 1981 cruises, thus depict a SPM distribution in which particles from point sources along the coast are largely retained in the nearshore zone and dispersed parallel to the coast. The particle concentrations along this coast varied less than 25 percent between seasonal cruises.

Offshore, the gradient of mean particle concentration fell rapidly from shore to about the 50 m isobath, then varied little with increasing water depth. Offshore, the middle and outer domains were typified by a three-layer structure: a high-turbidity surface layer resulting from in-situ phytoplankton growth and offshore advection and diffusion from river-derived particles, a broad middle zone of horizontally and vertically uniform particle concentrations, and a bottom layer of increased turbidity largely from local resuspension of sediments. In the middle domain, this vertical structure can be weakened or destroyed by storms. Attenuation and density sections normal to the coast are shown in Figure 60 for a 6-day period following such a storm, and illustrate reestablishment of vertical structure.

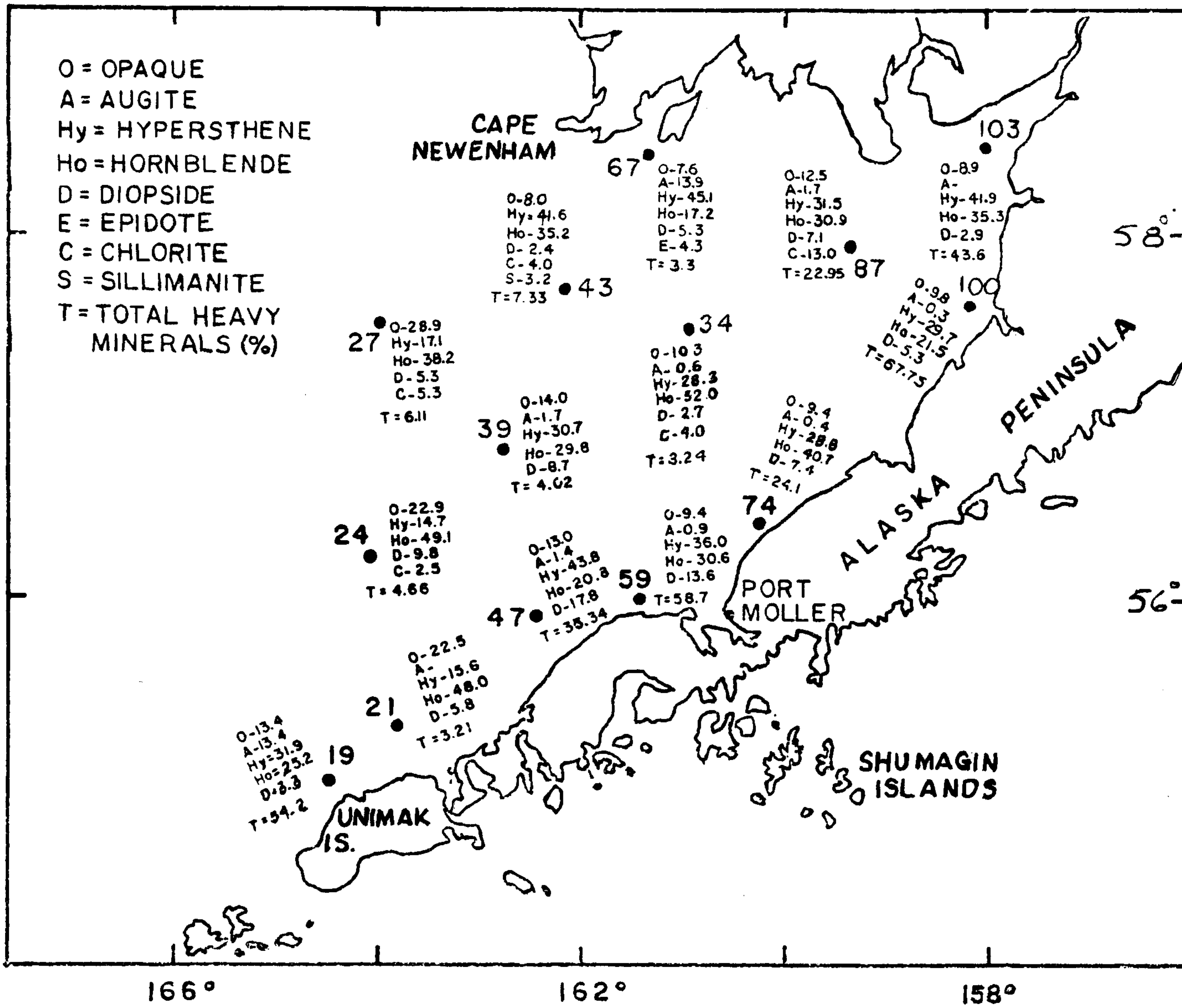


Figure 56. Distribution of total heavy minerals (weight percent) in 0.125 - 0.177 mm size fraction (T), and individual minerals (count percent) in 0.25 - 0.35 mm size fraction (Sharma, 1971).

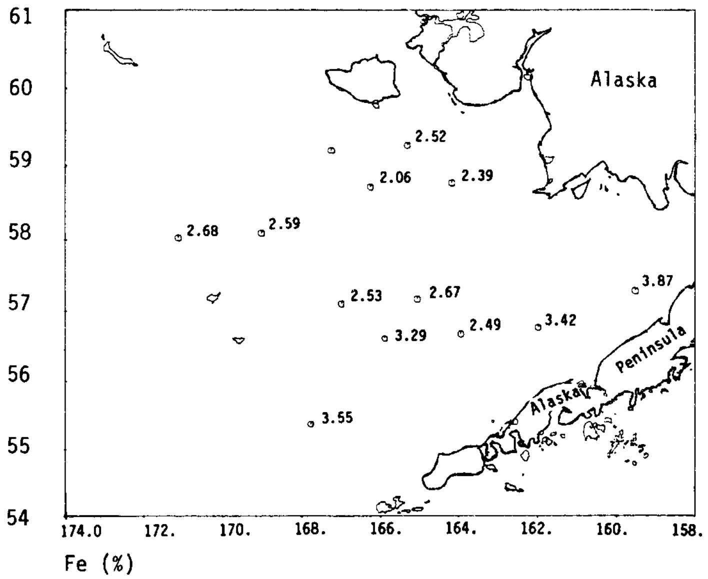


Figure 57. Total iron content (%) of southeastern Bering Sea sediment (Burrell et al, 1981).

Table 3. Mean extractable and total metal concentrations and correlation coefficients of total contents for surficial sediments of the southern Bering Sea. (Burrell et al, 1981.)

Contents			Correlation Coefficients							
Extractable	Total		Al	Ca	Fe	Mn	V	Cr	Co	As
	6.09 ± .96%	Al								
	2.86 ± .9%	Ca	.847							
0.14 .05'7	2.84 ± .55%	Fe	.915	.782						
	494 ± 199ppm	Mn	.733	.361	.715					
	93 ± 17ppm	V	.880	.569	.811	.948				
	64 ± 21ppm	Cr	.570	.774	.648	.337	.435			
	10 ± 2ppm	Co	.863	.738	.950	.629	.745	.596		
	3.6 ± 1.5ppm	As	.466	.338	.713	.642	.582	.534	.707	
	0.6 ± .15ppm	Sb	.500	.544	.658	.495	.474	.679	.706	.661
<2.5ppm		Ni								
11±6ppm		Zn								

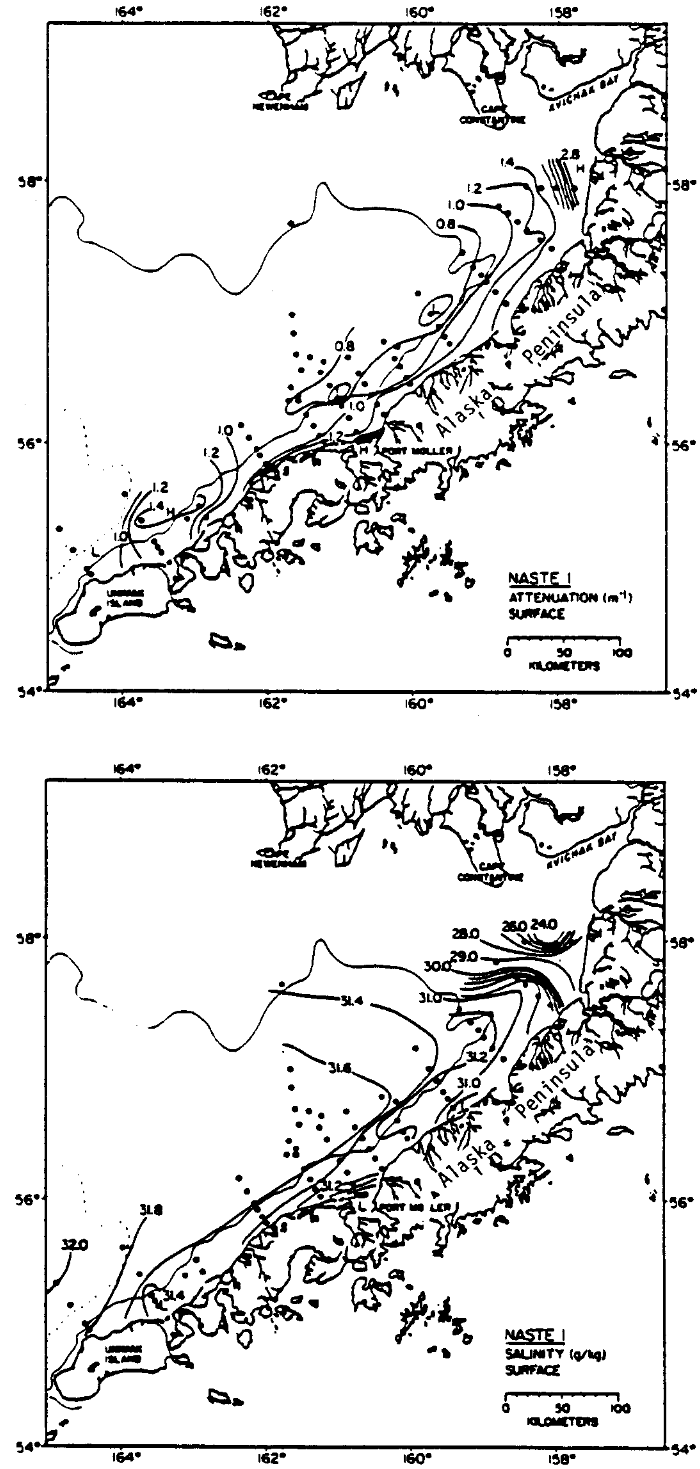


Figure 58. Areal maps of light attenuation (top) and salinity (bottom) at the surface during August 1980. Contour interval is 0.2 m^{-1} for attenuation and 0.2 ppt for salinity (Baker, 1983).

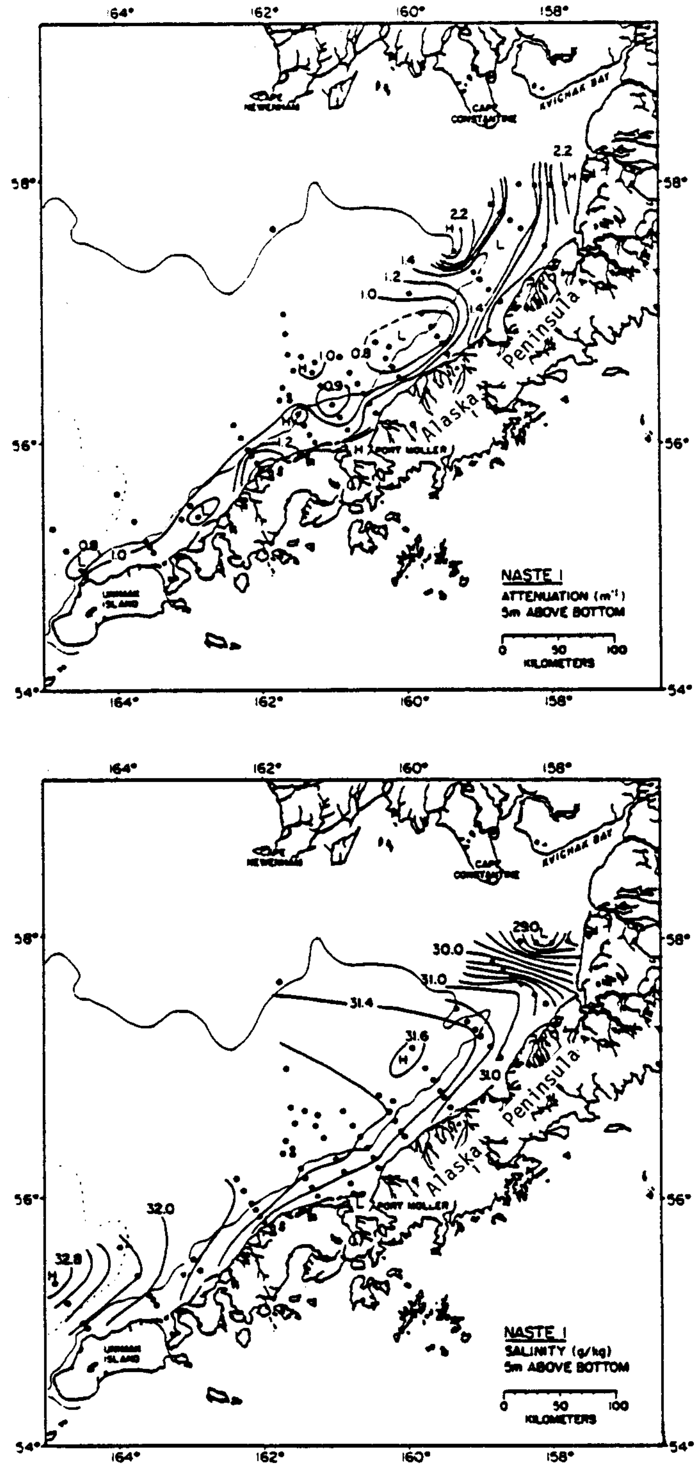


Figure 59. Areal maps of light attenuation (top) and salinity (bottom) at the bottom during August 1980. Contour interval is 0.2 m^{-1} for attenuation and 0.2 ppt for salinity (Baker, 1983).

Attentuation values, as measured by Baker (1983), may be converted to absolute concentration data (mg/l), as measured by Sharma (1972) and Feely et al (1981) by use of their scatter plots which calibrate attenuation values with field determined sediment loads. The concentrations found by Baker are estimated to be about 2.5 mg/l in the head waters of Bristol Bay. Sharma, however, reports concentrations of SPM in the Bay in July 1968 to be between 1.60 mg/l and 12.0 mg/l with lowest values found offshore. He finds the sediment load to be greater at depth with a mean value of between 7.0 and 9.0 mg/l found at 10 to 20 meters in the nearshore area.

Feely et al (1981), who report absolute concentrations for many stations in the study area as well as elemental composition, provide valuable information for purposes of this discussion. Figure 61 shows the distribution of total SPM at five meters above the bottom for all of Bristol Bay. This amount and distribution agrees well with Baker (1983) where the data bases overlap in the nearshore area. The interesting tongue of low SPM water emanating from Unimak Pass and extending to near Port Heiden is noted, but no significance is placed on it at this time. Vertical distribution of SPM for the fall of 1975 (Figure 62) and summer of 1976 (Figure 63) on a cross section from near Cape Newenham to Port Moller shows impressively different patterns, most noteworthy of which is the stratification shown in the shallow water of the nearshore region in the summer of 1976.

The particle size distribution (PSD) patterns in surface and bottom waters are of value in illustrating the differences in the SPM between the coastal and mid-shelf domains. The PSD of surface water and that five meters above the bottom at a section just offshore of Port Moller in the nearshore area is shown in Figure 64. These particle size curves are virtually identical between surface and bottom samples for the inshore stations within the well mixed coastal domain. Surface samples from offshore show lower concentrations than the corresponding bottom samples (or the inshore samples), particularly with respect to coarser-grained particles. Organic matter loading varied from a low of about 25 percent of the SPM for inshore stations in the winter to greater than 50 percent of the SPM for surface samples offshore in the summer.

Composition of Sediments. Elemental composition of the suspended particulate matter transported by the Kuskokwim and Kvichak rivers discharging into northern Bristol Bay is provided by Feely et al (1981) and is presented in Table 4. Comparison of these with the elemental compostion of SPM in Bristol Bay, Table 5, reveals that the group I and II samples, all taken from the surface, are derived from river runoff because of the presence of Mg, Al, K and Ti which are associated with terrestrial sources (Feely, 1975). The

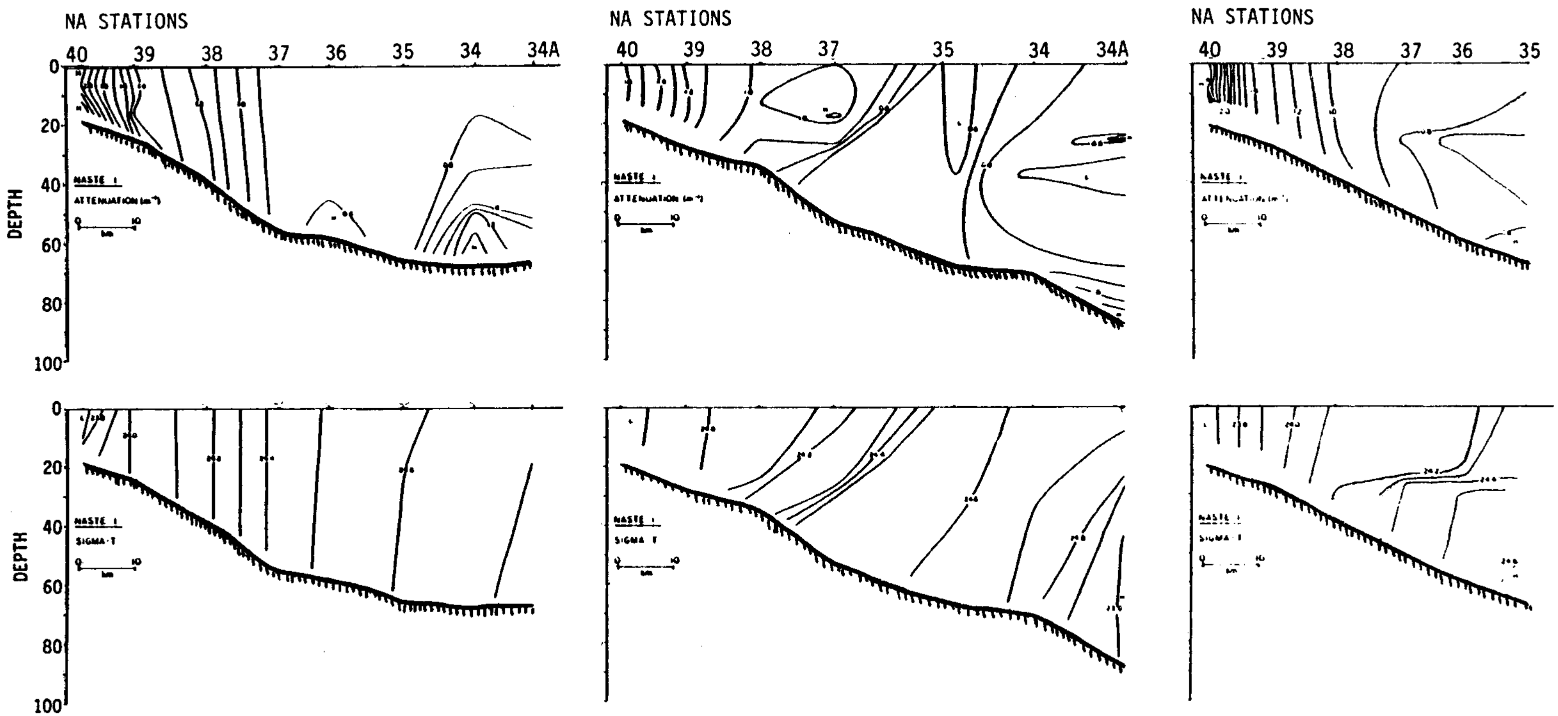


Figure 60. Attenuation (top) and density (bottom) cross-sections for stations NA34-40 normal to coast on August 20 (left), August 24 (middle), and August 31 (right) 1980, following a storm (Baker, 1983).

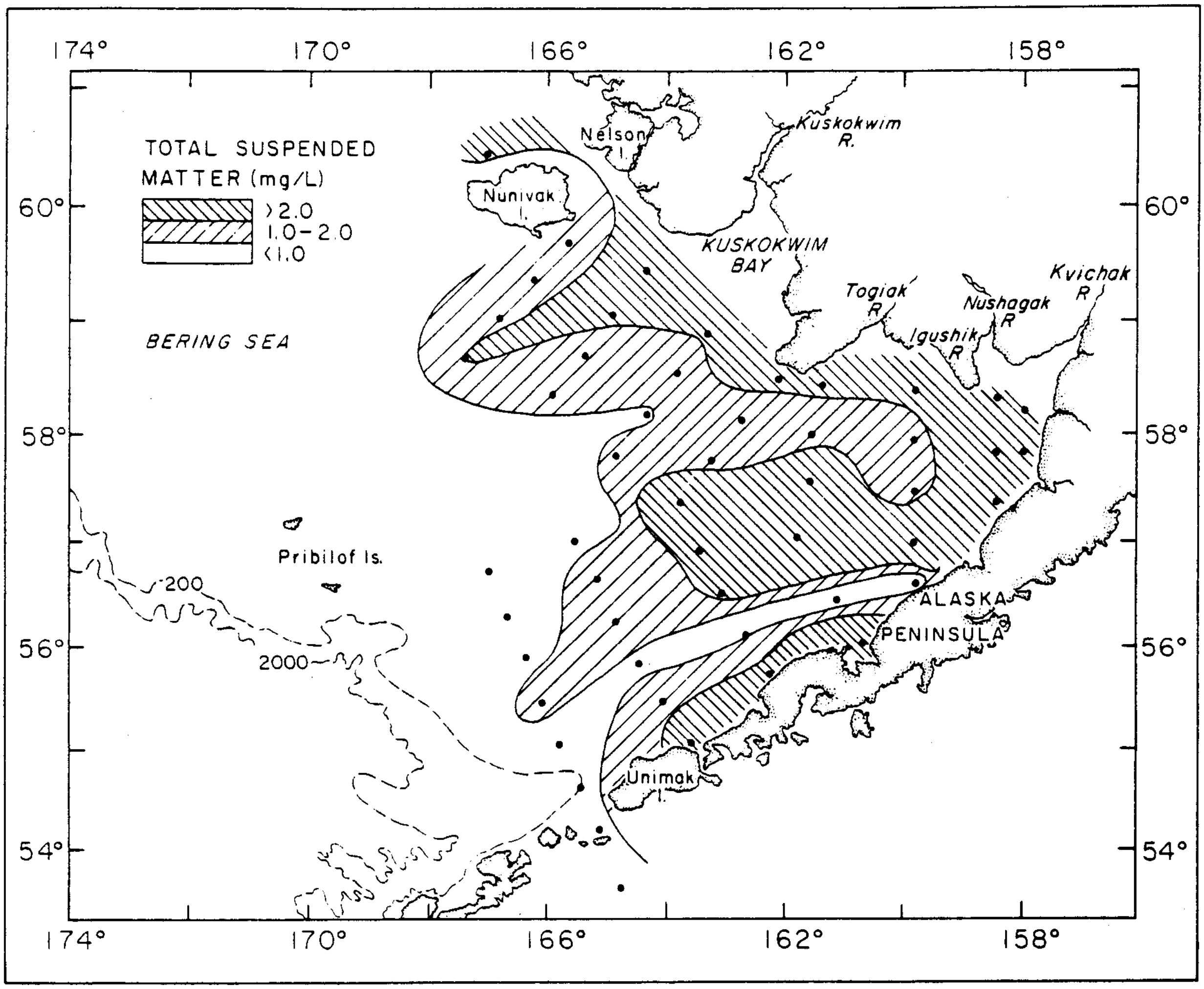


Figure 61. Distribution of total suspended matter 5 meters above the bottom in the southeastern Bering Shelf (Cruise RP-4-MW-76B-VII, 24 June - 9 July 1976) (Feely et al, 1981).

composition of the SPM at five meters above the bottom is likewise of terrestrial origin. The group III stations are significantly depleted in Mg, Al, Si, K, Ca, Ti, Mn and Fe and are enriched in Ni, Cu and Zn.

Particulate carbon has been widely used as a tracer of particulate organic matter in the ocean (Gordon, 1970; Loder, 1971, and Handa and Tanoue, 1981). Gordon suggests a factor of 1.8 to convert organic carbon, the analytical number usually measured, to particulate organic matter. Considering group III data of Table 5, the average organic carbon in these samples would represent about 65 percent organic matter with a C/N ratio of 7.4. Loder and Hood (1972) have found in a glacial inlet of southeast Alaska that river borne (terrestrial origin) organic matter had a C/N ratio of between 15 and 22 whereas organic matter of marine origin has a range of 5 to 15. If the same ratio applies in Bristol Bay, then it is apparent that not only the organic matter in Group III SPM, but that of other groups as well, (including the five meters from the bottom group) is of marine origin.

In a very comprehensive paper, Handa and Tanoue (1981), have carefully examined the distribution and composition of particulate organic matter in the Bering Sea and adjacent areas. Although near the Pribilof Islands was the closest any samples were taken to the area of immediate interest in this study, many representative eastern Bering Sea shelf samples were examined and help give perspective to the few measurements that have actually been made in the near-shore region of the Aleutian Shelf. The particulate organic carbon as percentage of total particulate matter in samples obtained between the Western Aleutians and Nome, Alaska is shown in Figure 65. Coastal domain values of 10 to 15 percent carbon (18 to 27% organic matter) in the SPM rose to 20 to 30 percent (36 to 54% organic matter) in the middle and outer domain.

The concentrations of particulate organic carbon (POC) found averaged 204+/-178 µg C/l and 31+/-25 particulate organic nitrogen (PON) in the coastal domain to 64+/-44 POC and 7.4+/-4.9 PON in the middle and outer domain. The C/N ratio for shallow water (0-100 meters) was 6.4+/-1.9 and 8.3+/- 4.9 for deeper water (100-500 meters), both falling well within the 5 to 15 range indicated for organic matter of marine origin. Loder (1971) found in the Unimak Pass area an average of 435 275 µg C/l in the euphotic zone dropping to values below 100 µg C/l in samples taken from deeper water in this region. Since both Handa and Tanoue (1981) and Loder (1971) sampled in July or August, well after the normal spring bloom occurs for the area, the high POC values are somewhat unexpected. At this relatively late sampling period, the concentrations of particulate organic carbon and nitrogen in the coastal Bering Sea were found to

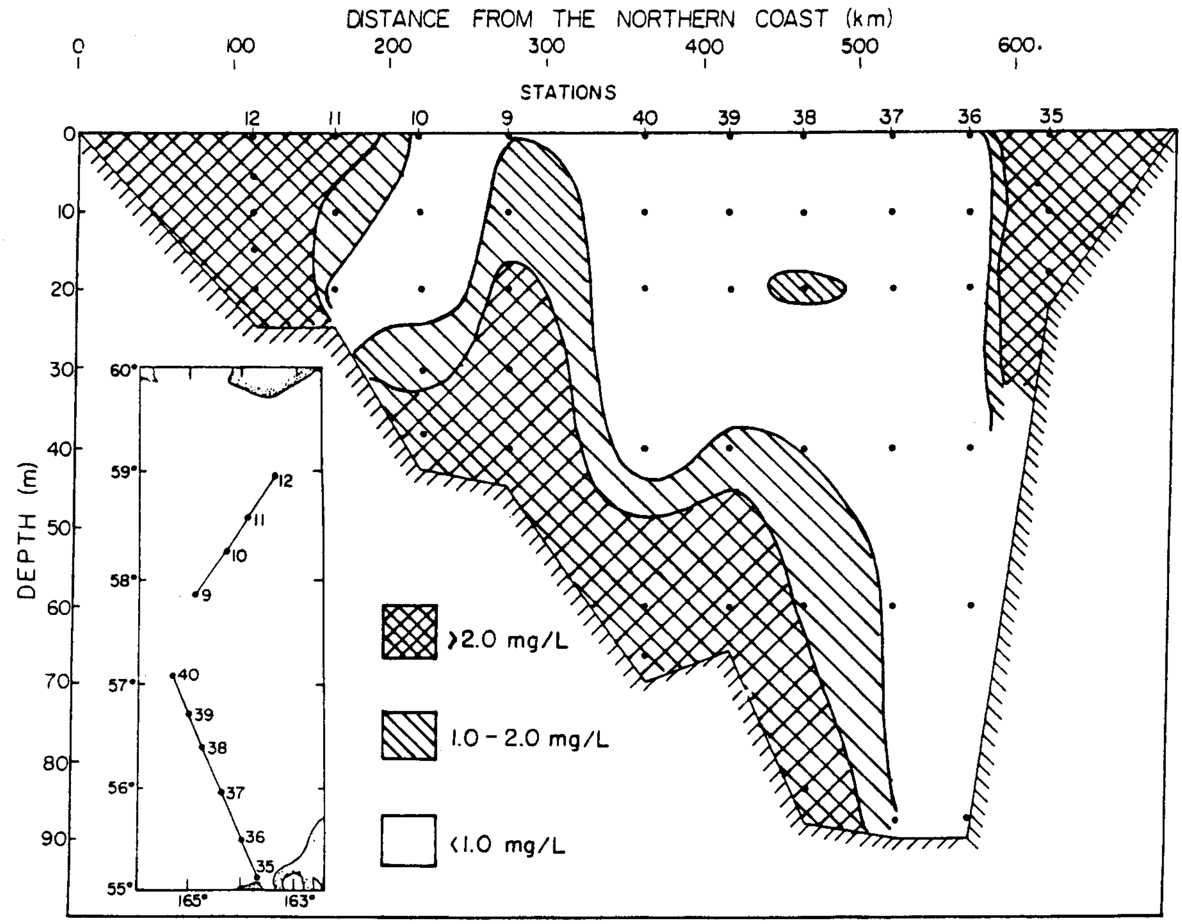


Figure 62. Vertical cross section of the distribution of total suspended matter for stations 9 through 12 and 35 through 40 (Cape Newenham to Port Moller) in the southeastern Bering Shelf (Cruise RP-4-Di-75B-III, 12 September - 5 October 1975) (Feely et al, 1981).

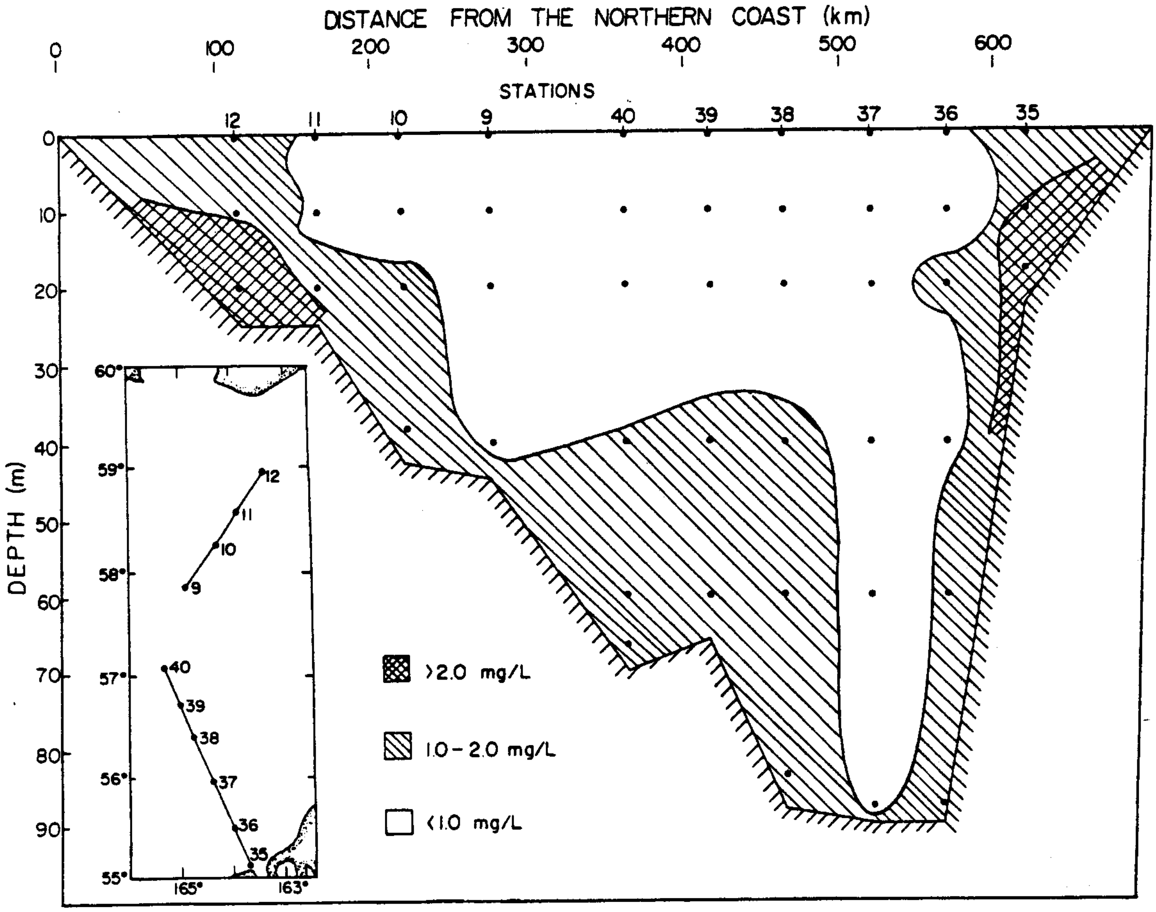


Figure 63. Vertical cross section of the distribution of total suspended matter for stations 9 through 12 and 35 through 40 (Cape Newenham to Port Moller) in the southeastern Bering Shelf (Cruise RP-4-MW-76B-VII, 24 June - 9 July 1976) (Feely et al, 1981).

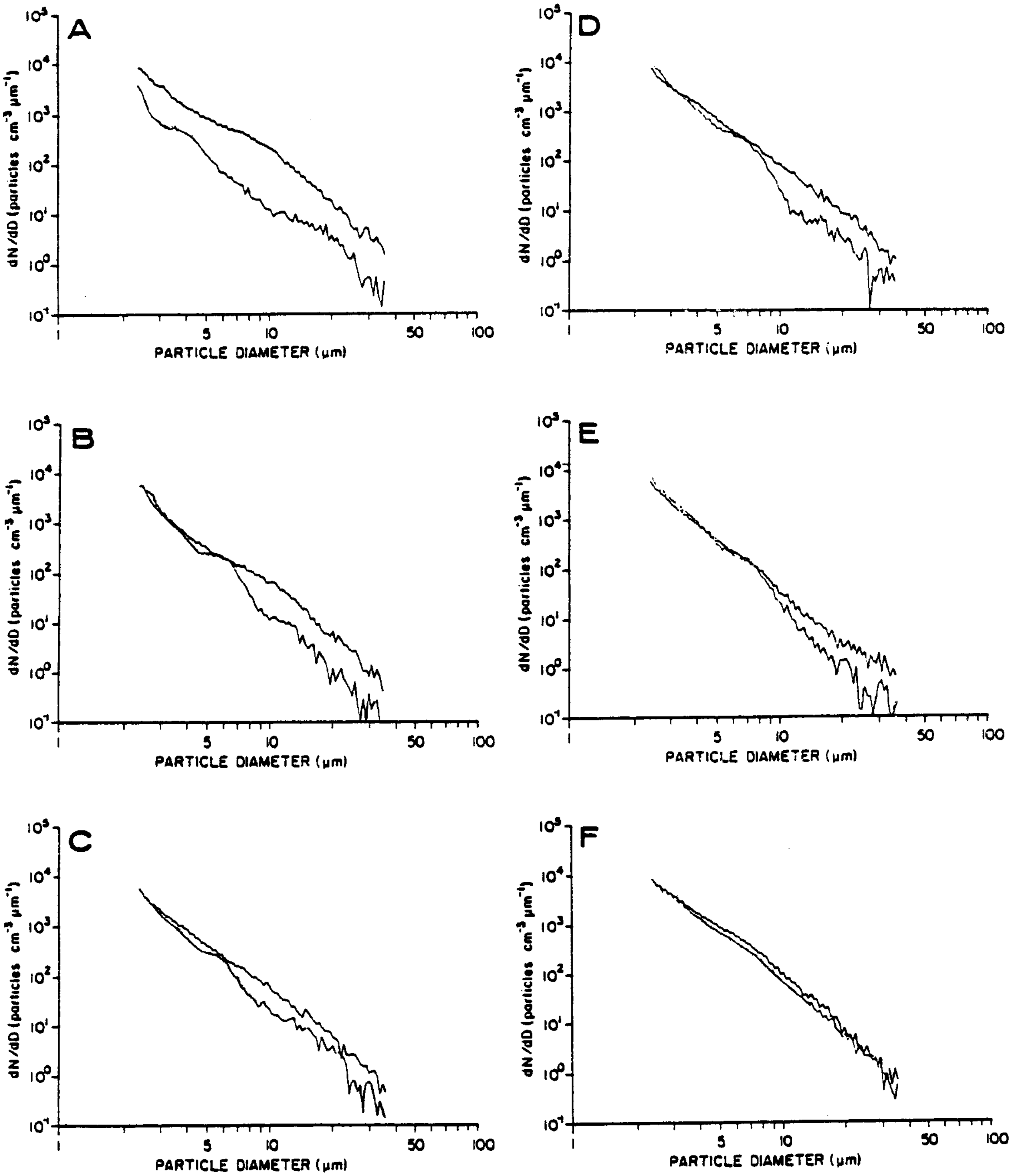


Figure 64. Incremental cumulative curves for particle populations at the surface and bottom at each station (NA34-40 station line) from NASTE 3. A is the outermost station and F is the innermost station (Baker, 1983).

Table 4. Summary of the elemental composition of particulate matter from the major rivers that discharge into the southeastern Bering Shelf. (Surface samples were obtained with a precleaned 4-L polyethylene bottle extended from a helicopter. 12-21 September 1976.) (Feely et al, 1981).

Sample Location	No. of Samples	C wt %	N wt %	Mg wt %	Al wt %	Si wt %	K wt %	Ca wt %	Ti wt %	Cr ppm	Mn ppm	Fe wt %	Ni ppm	Cu ppm	Zn ppm
Kuskokwim River	9	2.96 ±2.63	0.38 ±0.42	2.13 ±0.39	7.77 ±0.98	32.13 ±2.86	1.68 ±0.16	1.59 ±0.07	0.56 ±0.04	105.3 ±14.9	1498 ±105	6.57 ±0.45	69.8 ±4.8	77.6 ±7.3	281.4 ±34.2
Kvichak River	6	2.66 ±0.15	0.23 ±0.15	1.24 ±0.44	4.26 ±1.07	26.78 ±10.30	0.81 ±0.16	0.48 ±0.13	0.42 ±0.11	62.2 ±18.3	941 ±53	4.36 ±1.32	36.3 ±10.9	63.3 ±8.7	232.1 ±108.8

Table 5. Summary of the elemental composition of particulate matter from the southeastern Bering Shelf. (Cruise DP-4-D_1-758-III. 12 September - 6 October 1975). Feely et al, 1981.

Sample Description	No. of Samples	C wt %	N wt %	Mg wt %	Al wt %	Si wt %	K wt %	Ca wt %	Ti wt %	Cr ppm	Mn ppm	Fe wt %	Ni ppm	Cu ppm	Zn ppm
Surface (Group I)	24	17.7 ±10.3	2.1 ±1.3	0.86 ±0.14	3.52 ±2.22	25.85 ±5.28	0.51 ±0.17	1.32 ±0.28	0.24 ±0.06	41.2 ±19.3	893 ±285	2.68 ±0.63	24.1	41.9 ±13.9	210.7 ±88.0
Surface (Group II)	4	22.9		1.75 ±0.08	6.11 ±1.32	31.74 ±6.40	0.37 ±0.14	2.66 ±0.89	0.28 ±0.07		1377 ±519	3.15 ±0.35		42.4 ±21.8	353.0 ±127.0
Surface (Group III)	11	35.3 ±19.3	4.8 ±2.7			10.89 ±6.73	0.26 ±0.20	1.14 ±0.50	0.18 ±0.07	60.4 ±32.2	355 ±233	1.92 ±0.66	56.5 ±11.7	64.0 ±31.4	256.0 ±215.0
5 m above the bottom	42	12.2 ±7.6	1.8 ±1.1	1.45 ±0.66	3.92 ±1.27	29.45 ±6.12	0.53 ±0.17	1.64 ±0.65	0.28 ±0.07	50.0 ±20.9	501 ±306	3.16 ±0.82	30.7 ±17.9	54.2 ±47.7	219.6 ±107.6

Group I. Samples containing over 60% of major inorganic elements as oxides at northern stations.

Group II. Samples containing over 60% of major inorganic elements as oxides at southern stations.

Group III. All stations containing less than 60% major inorganic elements.

be remarkably high, only to be compared by high concentrations in the upwelling area of the South Pacific off Equador (Menzel, 1967). [See Handa and Tanoue (1981) for discussion.]

Feely et al (1981) have published results on particulate organic carbon and nitrogen for the specific North Aleutian coastal region as shown in Figure 66 and Figure 67, respectively. These data were taken in September and October, but still show comparably high values (>300 ug C/1 and >40 ug N/1) to Handa and Tanoue (1981) and Loder (1971).

Sediment Transport. The relationship shown between current speed, particle diameter, and sediment erosion transport or deposition developed by Kennett, 1982 (Figure 68) is of value in considerations of the nearshore area north of the Alaska Peninsula in the Bering Sea.

Since the parameters influencing the movement of sediment, i.e. currents and particle diameter, are reasonably well known (previous discussion this section and physical section), it becomes apparent that net sediment transport probably only occurs under the relatively rare conditions of sustained longshore currents. However, erosion and suspension could occur under short term bursts of energy derived from storm waves and unusual tides. A reasonable model directly related to the resuspension phenomenon resulting from energy dissipation in the bottom boundary layer has been developed by Long (1981), Grant and Glenn (in press) and Businger and Arya (1974). This model is shown below:

$$V_t = \frac{K_o U_* Z}{\phi_m} e^{-Z/N}$$

where V_t is eddy diffusivity, K_o is von Karmen's constant (=0.4), U_* is shear velocity, ϕ_m is stratification correction, N is boundary layer thickness and Z is roughness length established by measuring near bottom average velocity profiles.

From this model, it may be seen that since stratification is zero under most conditions in the coastal domain, the eddy diffusivity is largely a function of shear velocity and roughness length. U_* is the critical parameter to sediment transport because it includes the interaction between wind (waves), tides (currents) and sediment. It determines the friction felt by the large scale flow field and the eddy diffusivity. As is usual on continental shelves, the mean flow on the nearshore region of north of the Alaska Peninsula is driven by wind and tides. The interaction of this flow against the solid sediment boundary

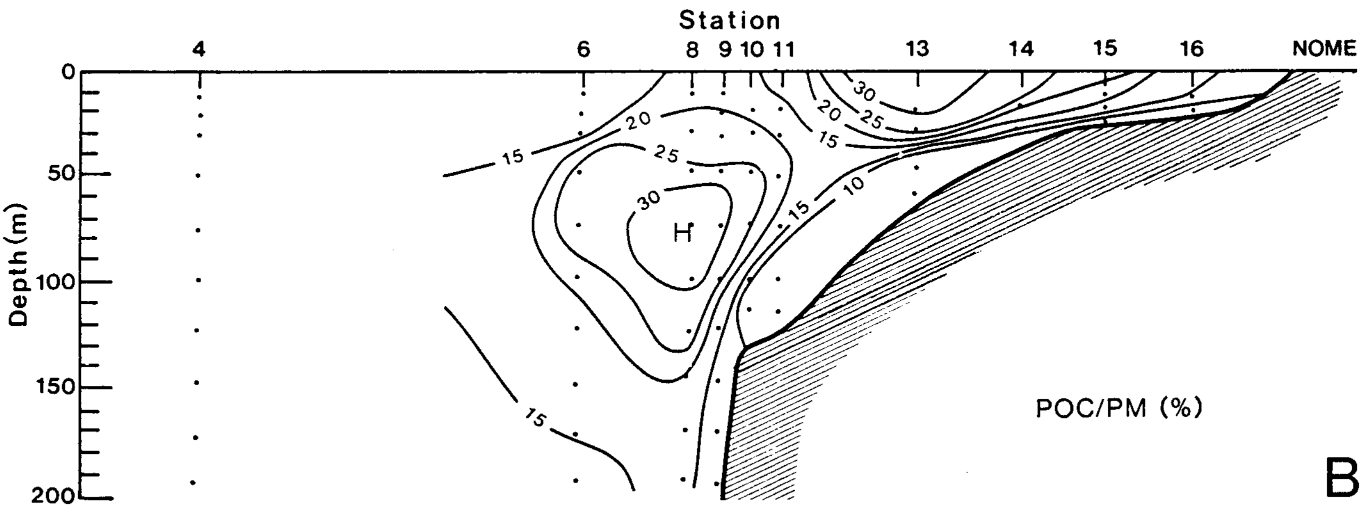


Figure 65. Particulate organic carbon in percentage of total particulate matter in the eastern Bering Sea (Handa and Tanoui, 1981).

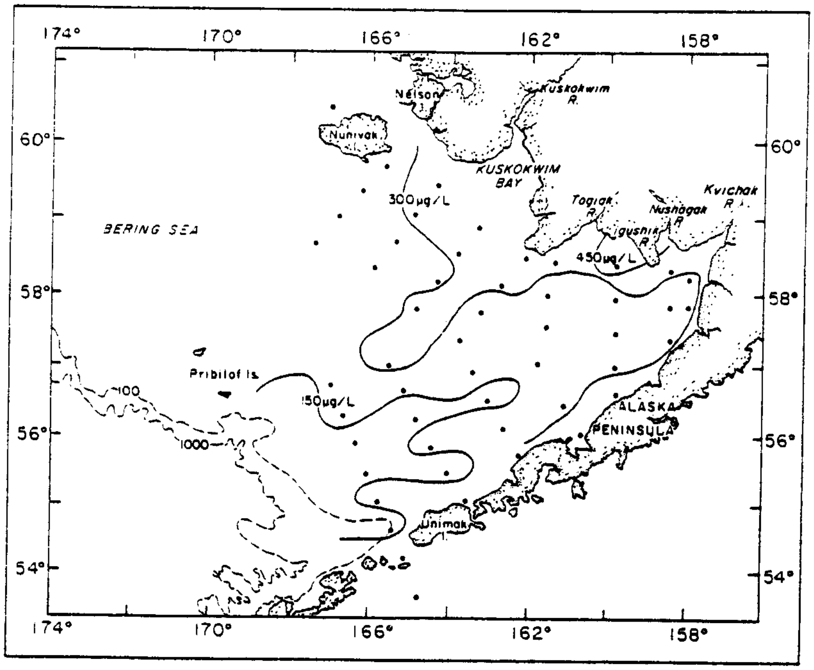


Figure 66. Distribution of total particulate carbon at the surface in the southeastern Bering Shelf (Cruise RP-4-Di-75B-III, 12 September - 5 October 1975) (Feely et al, 1981).

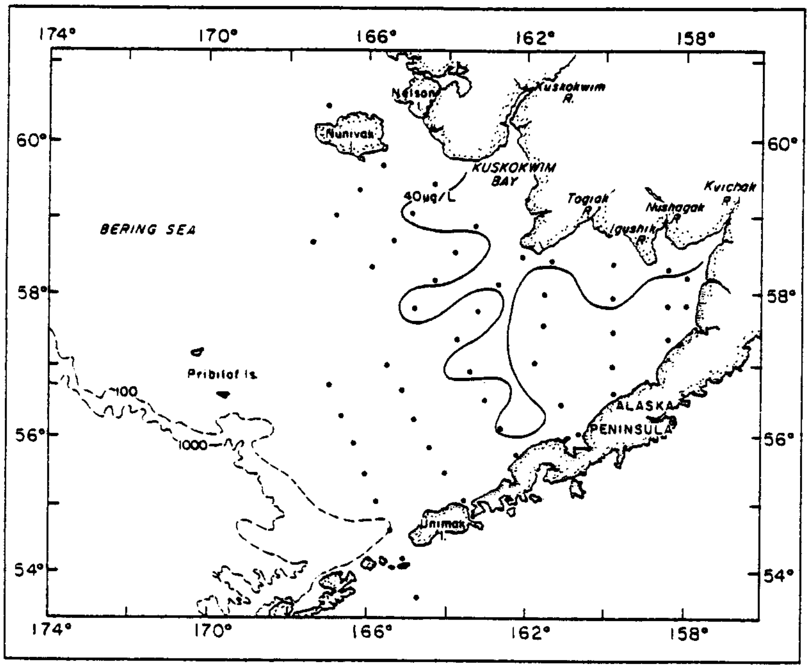


Figure 67. Distribution of total particulate nitrogen at the surface in the southeastern Bering Shelf (Cruise RP-4-Di-75B-III, 12 September - 5 October 1975) (Feely et al, 1981).

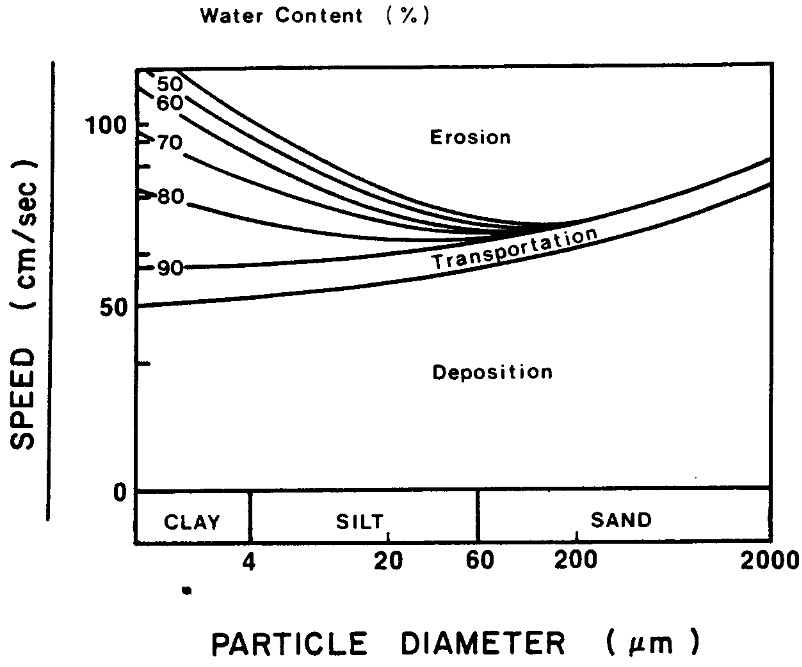


Figure 68. Relationship between current speed, particle diameter, and sediment erosion, transport, or deposition (Kennett, 1982).

leads to a logarithmic relationship to the average velocity profile (Bowden, 1962). The eddy diffusivity generated by the frictional losses from interaction of tidal flow with the bottom then provides the turbulence necessary for the resuspension of sediments and for transport along the boundary layer in the direction of the mean flow.

In addition, the bottom instantaneous stress is associated with wave-caused flow through the non-linear interaction between the steady and oscillatory flow. Above the wave boundary layer region [usually considered the wave length where the energy is about 1/30 of that at the surface (Barber and Tucker, 1962)], the time-mean-stress is enhanced by the wave current interaction above the value for a pure current. This enhancement is established theoretically by Grant and Madsen (1976, 1979) and experimentally in the field by Cacchione and Drake (1982).

Based on measurements of the suspended sediment particulate matter on the North Aleutian Shelf, Baker (1981) has estimated the vertical eddy diffusivity for the region which, based on the above generic discussion, is the most important parameter to measure in consideration of sediment resuspension and transport, particularly in a non-stratified system. To accomplish this, the sediment mass continuity equation was modified to steady state conditions thus eliminating the effect of time. Also, the two horizontal components were eliminated because of their negligible contribution in comparison to the vertical component. This equation then became:

$$K_z = \frac{(\overline{W} - W_s)(Z-A)}{\ln (C_z/C_a)} \quad .$$

where K_z is vertical eddy diffusion coefficient, $\overline{W}$ is the advective flow in the vertical direction, W_s is the SPM settling velocity, Z is some level above a reference level, A, and C is concentration. K_z can be estimated only if the term $\overline{W} - W_s$ is known. W_s, the settling velocity can be estimated from Stokes equation if it is assumed that the particles are spherical and of known density. This velocity is probably in the range of 10^{-2} to 10^{-4} cm/sec. Vertical advection in the frontal areas and in the coastal domain may be on the order of 10^{-3} cm/sec.

The settling velocity can be estimated from Stokes equation:

$$W_s = \frac{2g\ (\rho_s - \rho)\ r^2}{9\eta}$$

if the particles are assumed to be spherical and their radius (r) and net density ($\rho_s - \rho$) are known and if the water viscosity (η) is known. An estimate of the size limits can be obtained from the particle size distribution data in Figure 64, but the *in situ* density is unknown. Based on reasonable estimates of these parameters, K_z may be estimated for the 5 to 15 meter layer in the coastal domain to be on the order of 150 cm^2/sec. for the data available. A rate of vertical eddy diffusivity of this magnitude would be effective in supporting silt-size particles in suspension and transport along the boundary layer, but probably only under conditions of large waves would coarser materials be eroded and transported. Information available at this time does not permit further treatment of this subject for the nearshore area.

Chemical Processes. Unlike other disciplines of oceanography, chemical studies of the Bering Sea have been undertaken only in the last three decades, largely in the interest of investigating changes resulting from biological activity. Nutrient dynamics has been the main focus, but will be treated in the section related to primary productivity and hypotheses. Considerations of the carbon dioxide system, organic matter (including hydrocarbons), and heavy metals will be considered in this section.

Carbon Dioxide System

The carbon dioxide system, composed of all forms of carbon in the water column and their interaction with the overlying atmosphere and the sediments below, is in constant flux. The degree of flux depends on the trophic level and intensity of biological activity and the physical dynamics of the system. Since parameters within and controlled by the carbon dioxide system, i.e. partial pressure of carbon dioxide gas (pCO_2), alkalinity (A), total carbon dioxide (ΣCO_2) and acidity (pH) are relatively easily and accurately measured, examination of this system as a tool to gain understanding of ecosystem dynamics is becoming increasingly important in studies of the marine environment, particularly on the continental shelves and coastal regions. Partial pressure of CO_2 measurements in the air and surface water has been extensively measured in the ocean since the International Geophysical Year (Keeling, 1968) to gain understanding of the distribution and rates of exchange of atmospheric CO_2 and the ocean. These studies have provided analytical techniques and background on carbon dioxide dynamics that have led to methodology for use of this and associated parameters in ecosystem studies (Hood, 1981) that have found particular importance in the Processes and Resources of the Bering Sea Shelf (PROBES) studies completed in 1983 [PROBES Progress Reports (1980, 1981, 1982)].

Beginning in 1971 (Kelley and Hood, 1971), several studies have been made of the pCO_2 relationships in the

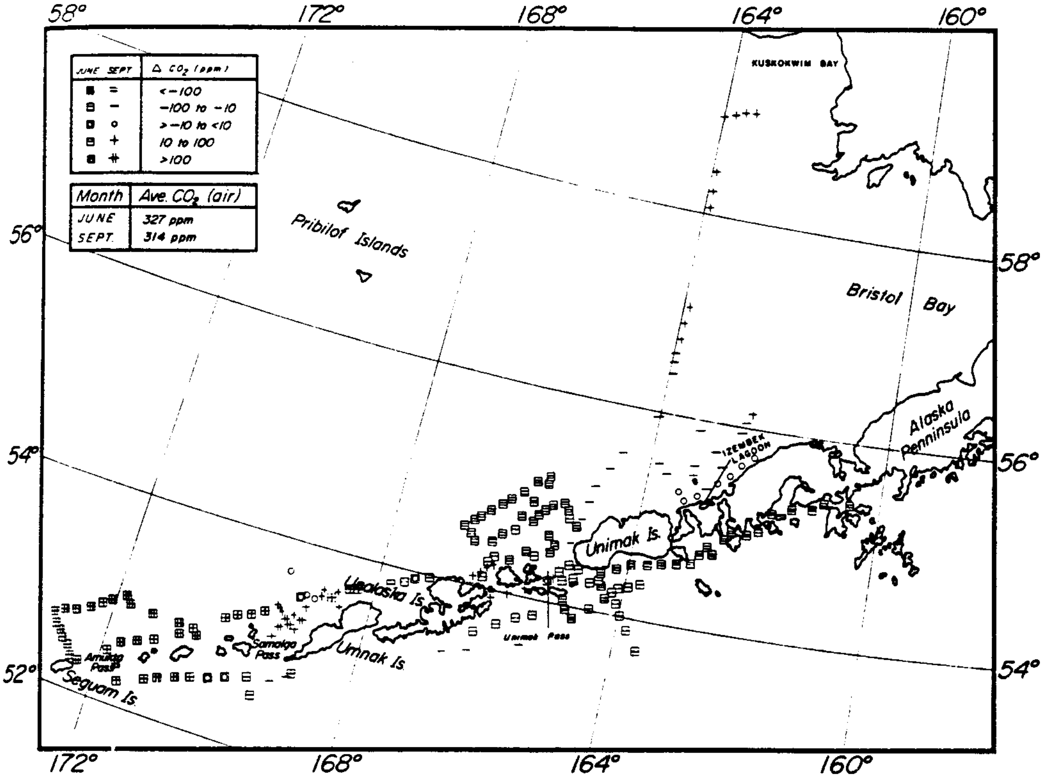


Figure 69. Relative carbon dioxide concentrations between air and surface sea water in the vicinity of the Aleutian Island passes. Cruises of the R V Acona (Kelley et al, 1971).

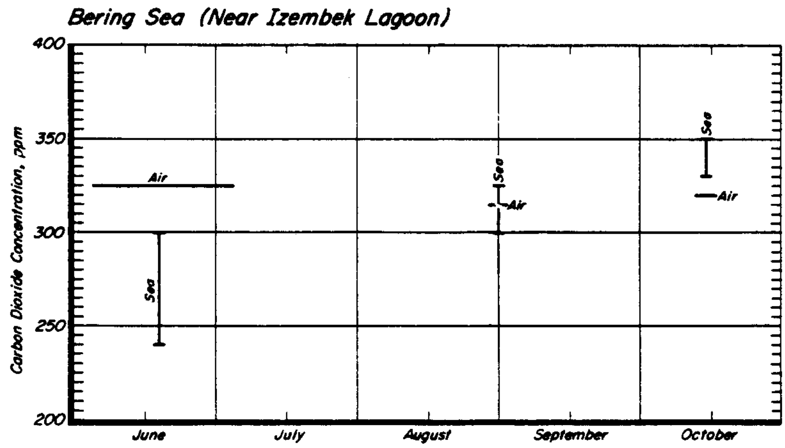


Figure 70. Seasonal (late spring and fall) variation of carbon dioxide in the surface sea water (Kelley et al, 1971).

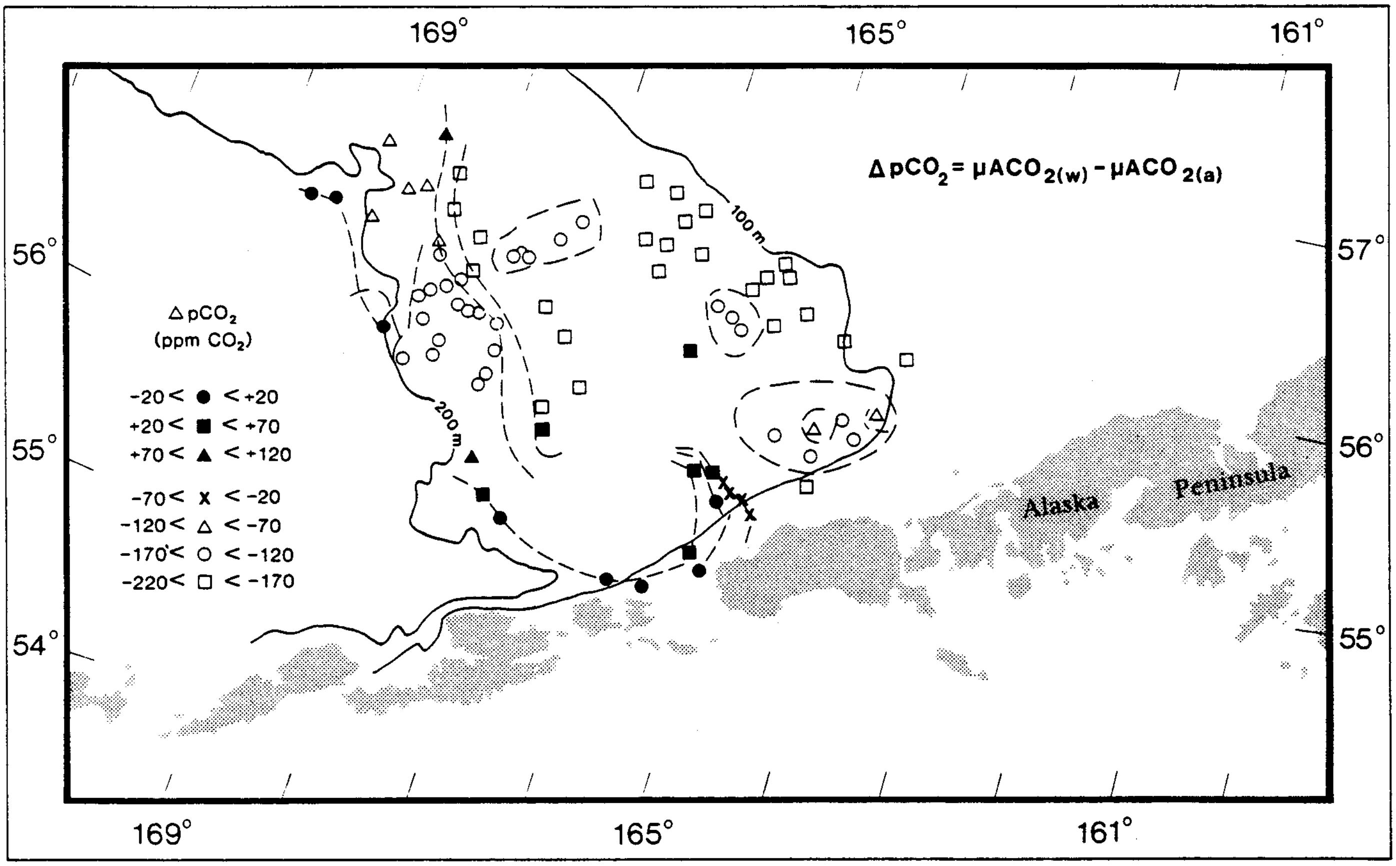


Figure 71. Distribution of pCO_2 in surface water in PROBES study area, May 1976 (Hood, 1981).

Bering Sea, particularly around the Aleutian islands where extensive upwelling occurs. Kelley et al (1971) report on a rather complete seasonal survey of pCO_2 distribution including data in and nearshore to Izembek Lagoon, as shown in Figures 69 and 70. Figure 69 illustrates only September data for the Izembek Lagoon area which shows near equilibrium values between the atmosphere and surface waters. However, in Figure 70, it is seen that in early June the sea is lower than the air by as much as 90 ppm whereas in October the sea exceeds the air by as much as 30 ppm. No winter data are available for this region. The fluctuations seen here clearly show the effect of the spring bloom in depressing pCO_2. CO_2, which closely follows pCO_2 (Codispoti et al, 1982), would also be depressed. This is followed by an increase to near equilibrium in September as a result of respiration and air-sea transfer of carbon dioxide. By October, there is an excess of CO_2 in the water caused by processes not clearly identified, but probably resulting from mixing with deeper water which is rich in molecular CO_2 (Alverez-Borrego et al, 1972).

An extensive survey of carbon dioxide distribution of the eastern Bering Sea Shelf was undertaken in May 1976 (Hood, 1981) as shown in Figure 71. Although the survey did not cover the coastal domain except in Unimak Pass, it does show an increase in differece between air and water at stations eastward of Unimak Pass where pCO_2 in water was found to be near equilibrium or in excess to that of the overlying air. Unpublished data obtained in 1978 (D. Hood, personal communication), given in Table 6, also show pCO_2 concentrations in the Pass at near equilibrium values with overlying air, but the water was deficient at stations east of the Pass including near Amak Island (about 15 km from the entrance to Izembek Lagoon).

Total carbon dioxide concentrations have not been measured in the nearshore area north of the Gulf of Alaska. Extensive data have, however, been taken in the PROBES study area (Codispoti et al, 1982; Hood and Codispoti, in press). The seasonal changes of total CO_2, pCO_2, and NO_3^- concentrations shown in Figure 72 for station 12 (middle domain) on the PROBES line would, except for timing and intensity, be expected to be similar in the near coastal region.

Organic Matter, Including Hydrocarbons

Organic matter in the world oceans was the subject of several extensive reviews (Hood, 1963, 1966, 1970; Williams, 1969; Wagner, 1969; Riley, 1970; Loder, 1971; Hood and Loder, 1973) over a decade ago, which summarized the work up to that time on the distribution and role of organic matter in the ocean. This subject of investigation was first undertaken in the Bering Sea by Loder (1971) who, along with Feely et al (1981) obtained the only data specifically in

TABLE 6

Partial pressure of CO_2 in air and water near Unimak Pass in summer of 1978. Acona cruise 261.5, June 17-24, 1978. (Unpublished data, D.W. Hood, personal communication).

Station	Location	Water depth (m)	pCO_2 (a) ppm	$pCO_{2(w)}$ ppm
1 18/6/78	L 54° 18.3'N; Long. 165° 27.5'W	110	334.3	235.4
2 18/6/78	L 54° 34.3'N; Long. 165° 0'W	68	332.2	313.6
3 18/6/78	L 54° 43.9'N Long 164° 59.5'W	66	333.2	334.0
4 18/6/78	L 54° 28.8'N Long. 165° 36.1'W	84	334.0	312.5
5 22/6/78	L 54° 27.0'N Long. 165° 39.5'W	135	338.0	245.0
6	Amak Island		332.0	261.2
7 23/6/78	L 55° 23.3'N Long. 163° 47.2'W	76	334.0	250.0
8 23/6/78	L 55° 21.4'N Long 164° 4.5'W	76	334.0	250.3
9	L 55° 15.5'N Long. 164° 17.8'W	88	332.0	337.0
10	L 55° 9.3'N Long 164° 31.8'W	85	333.0	325.0
11	L 55° 2.2'N Long. 164° 44.8'W	80	335.0	332.0

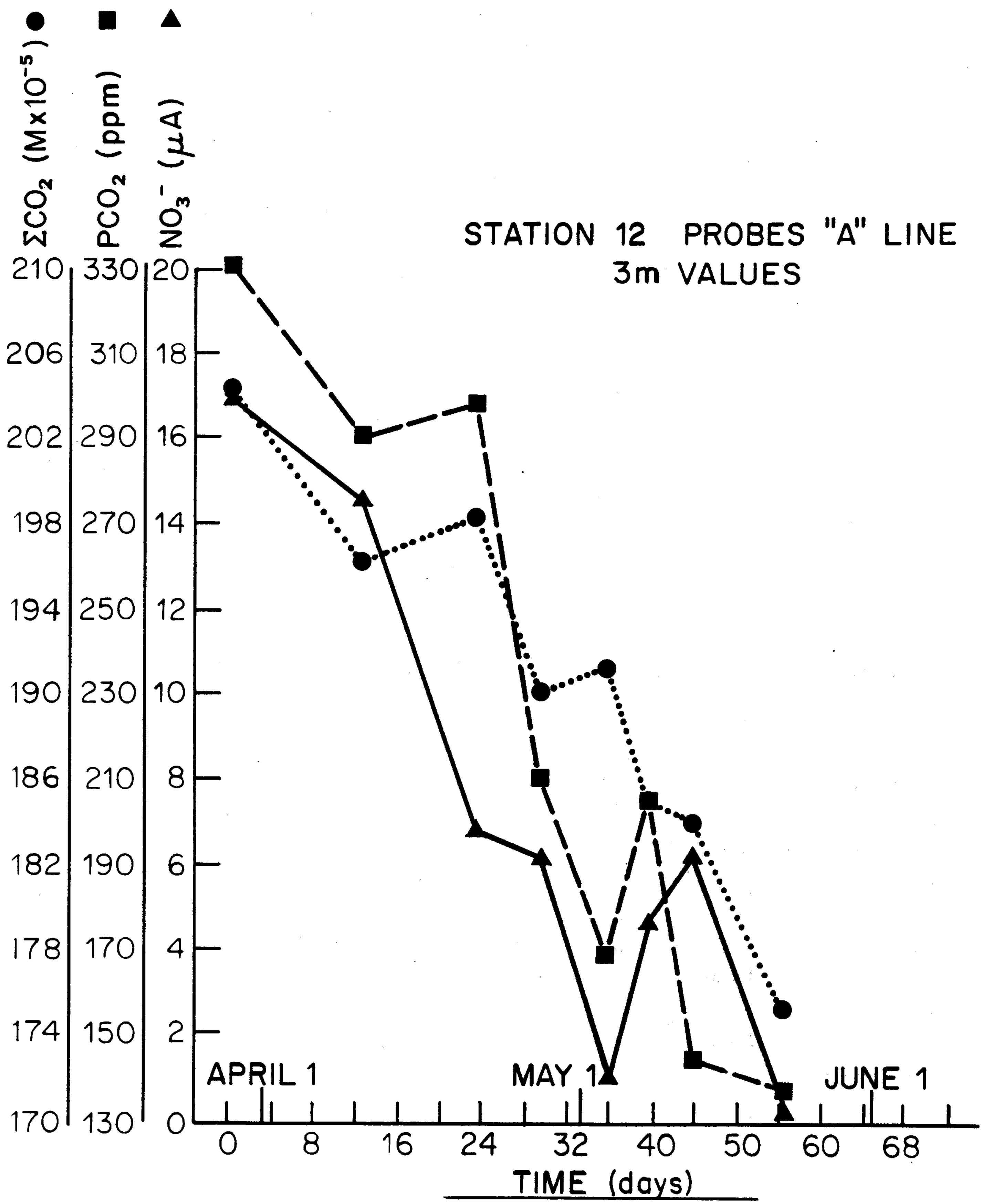


Figure 72. Surface concentration of ΣCO_2, pCO_2 and NO_3^- with time at station 12 (PROBES A line in spring of 1980).

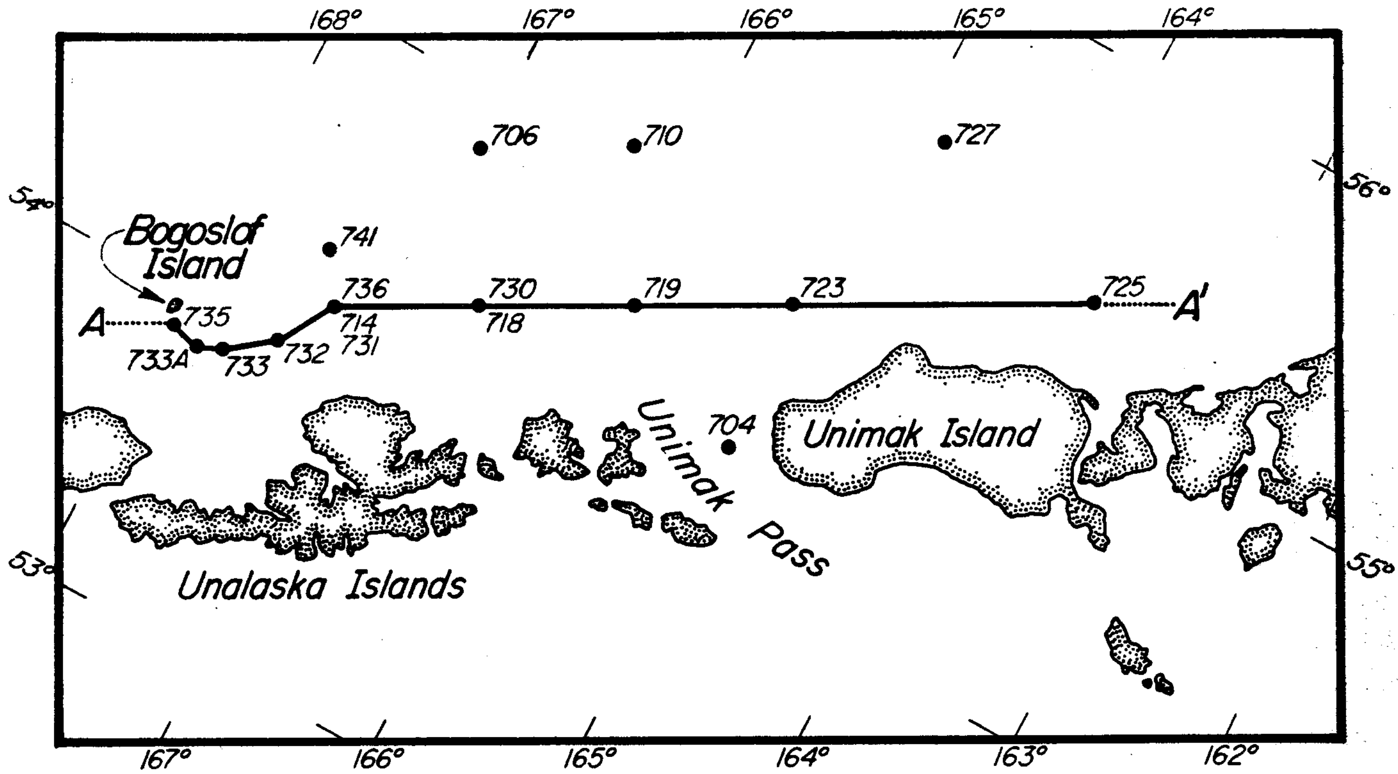


Figure 73. Station locations for samples taken north of Unimak Pass in the southeastern Bering Sea during R V Acona cruise 027, 26 July - 8 August 1966 (Loder, 1971).

TABLE 7

Dissolved and particulate organic carbon concentrations in Unimak Pass area of the southeast Bering Sea in July and August 1966 (Loder, 1971).

Station	Depth (m)	% light penetration	DOC MgC/l	POC ugC/l
704	0	-	1.65	234
	10	-	1.15	164
	20	-	1.10	148
	30	-	1.10	129
	50	-	-	96
719	0	100	1.00	297
	3	50	1.30	419
	7	25	1.35	389
	12	10	1.00	283
	27	1	1.25	216
	50	-	1.30	98
	100	-	1.10	51
723	0	100	1.45	381
	3	50	1.00	303
	5	25	1.45	343
	10	10	1.60	343
	23	1	1.30	220
	50	-	1.45	135
	100	-	1.10	-
725	0	100	1.85	731
	2	50	1.00	747
	4	25	1.15	731
	7	10	1.10	746
	16	1	1.70	751
	50	-	1.50	104
727	0	100	1.10	221
	3	50	1.90	185
	8	25	1.40	180
	17	10	1.15	197
	37	1	0.70	58
	40	-	0.60	55
730	0	100	1.10	811
	3	50	1.05	468
	15	1	1.20	749

the nearshore region north of the Alaska Peninsula. The work until 1974 was summarized by Hood and Reeburgh (1974) and the only contribution since that time is that of Handa and Tanoue (1981) which presents extensive data from cruises of the Hakuho Maru in 1975 and 1978 which occupied stations on the eastern Bering Sea shelf, but none in the study area.

The location of stations occupied by Loder (1971) are shown in Figure 73. The data obtained in the study area are given in Table 7.

In the surface waters, the dissolved organic carbon (DOC) was uniformly between 1.0 and 2.0 mgC/l with a tendency for lower values (0.75-1.50 mg/l) in deeper waters. Particulate organic carbon (POC) was generally high in the nearshore region north and east of the Pass, probably indicative of high productivity in this region even as late as August. Low pCO_2 values (Figure 69) were also found in this region indicating that high rates of primary productivity had recently occurred. Loder (1971) found a high correlation between POC concentrations and absorbance of light in the water column. This would indicate that in this region the major light absorbing agent is particulate organic carbon and also that the particle size distribution of this material is uniform. If skewness in size of particles occurred between stations, light absorbancy would change for a given weight of material because of the dominance of smaller materials in light absorbancy (Beardsley et al, 1970).

Loder's results agree favorably with those of Handa and Tanoue (1981) who sampled on the shelf north of the Pribilof Islands. Handa and Tanoue found 150 to 900 µg C/l south of St. Matthew Island and DOC concentrations between 0.8 and 1.0 mg/l. The C/N ratios for continental shelf particulate matter was between 6.3 and 9.6 for the 17 samples analyzed with an average value of 8.3+/-4.9.

Handa and Tanoue (1981) have reported the only data on the composition of the particulate organic matter in the Bering Sea. It is expected that the organic matter in the study area is of similar composition to that in other similar coastal regions, thus it is appropriate to briefly review these results. A composite of four stations of the 1978 cruise of the Hakuho Maru within the coastal zone off Nome, Alaska was analyzed for monosaccharides. This area is under the influence of the Yukon River and should be similar ecologically to the region west of the Kvichak River. The analysis gave the following data in molar %: rhamnose-3.01, fucose-3.33, ribose-trace, arabinose-5.68, xylose-2.80, mannose-14.5, galactose-5.39, and glucose-65.3 to give a total carbohydrate concentration of 32.1 µg C/l or 13.5% of the total organic carbon. They found these data not to be significantly different than that from samples in the northwestern Pacific Ocean. This comparison gives some credence to limited generalities concerning the composition of particulate organic matter on the continental shelves at least in northern latitudes. Detailed analysis of the carbohydrate composition of marine diatoms conducted by Handa (1969) and Hang and Myklestad (1976) found that cell wall carbohydrates, which are soluble in alkali, consist mainly of mannose with lesser concentrations of fucose, glucose, galactose, rhamnose, xylose and arabinose. The water extractable polysaccharides consisted of 90 percent glucose. These data indicate that the high proportion of mannose found in Bering Sea particulate organic samples must be due to cell wall polysaccharides of diatoms, which are the main primary producers on the Bering Sea shelf (PROBES progress reports 1978-1981).

Amino acids were determined in several particulate samples on the eastern shelf of the Bering Sea. Serine, glycine and alanine were found to be dominant in all samples from all depths, whereas aspartic and glutamic acids dominated below the euphotic zone (50m). At two stations in the coastal domain near Nunivak Island, total amino acid concentrations between 100-150 µg/l were found, which compares with values found on other continental shelves (104-156 µg/l). In general, the ratio of particulate amino acid carbon to POC (PAC to POC) and particulate amino acid nitrogen to PON (PAN to PON) at the Bering Sea stations were found with ranges of 24.6-31.3 and 47.3-62.0, respectively. These ratios are indicative of marine photosyntheis. At the two coastal stations, lower ratios were obtained indicative of contamination by terrigenous materials.

The distribution and concentration of hydrocarbons in the surficial sediments of the continental shelf of the eastern Bering Sea have been carefully examined by Venkatesan et al (1981). Of the thirty two samples collected in the Bristol Bay area, four were in the coastal domain, one was eelgrass and one was sediment obtained within the eelgrass environment of Izembek Lagoon. The location of the samples is shown in Figure 74. The results of analysis are shown in Table 8.

The results show that total hydrocarbon content follows the same trend as organic carbon (see Figure 55) with low concentrations of total hydrocarbons in coarse-grained sediments and higher values in fine-grained sediments near the shelf edge. The organic sulfur content of these sediments is low (0.01-0.13 percent) as compared to other marine sediments (Didyk et al, 1978) and indicates relatively oxidizing conditions within the sediments. The hydrocarbon to organic carbon (HC/OC) ratio of the nearshore sediment samples varied between 0.0002 and 0.005, which is the range reported for unpolluted sediments (Palacas et al, 1976). The total N-alkanes to organic carbon ratio is less than

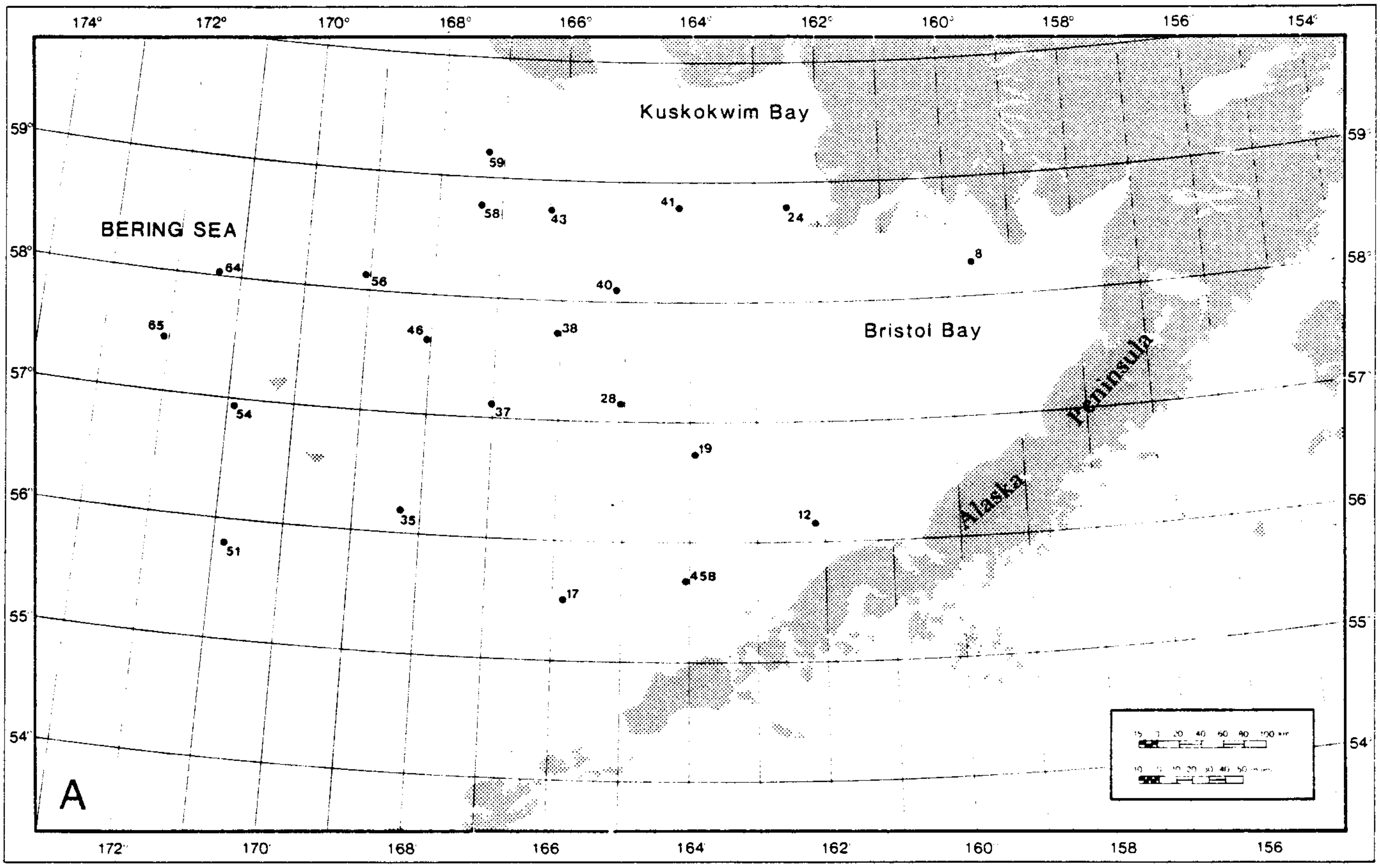


Figure 74. Location of southeastern Bering Sea stations for hydrocarbon analysis (Venkatesan et al, 1981).

Table 8. Gravimetric and gas chromatographic data of southeastern Bering Sea sediment samples (Venkatesan et al, 1981).

Station number*	Aliphatic fraction (μg/g)	Aromatic fraction (μg/g)	n-alkanes (μg/g)	Organic carbon (%)	$\frac{HC}{OC} \times 10^4$	$\frac{\text{n-alkanes}}{OC} \times 10^4$	$\frac{Pr}{Ph}$	$\frac{Odd}{Even}$
8	5.7	2.8	0.56	0.23	36.9	2.4	2.70	2.99
12	3.4	1.4	0.33	0.14	34.3	2.3	3.32	1.75
17	13.0	5.2	1.09	0.76	23.9	1.4	3.97	3.43
19	7.4	4.5	2.57	0.39	30.5	6.6	5.81	3.17
24	6.1	5.4	0.66	0.33	34.8	2.0	3.39	2.96
28	8.7	4.1	2.93	0.59	21.7	5.0	10.20	4.09
35	180.1	60.8	n.r.	0.41	587.6	n.r.	n.r.	n.r.
37	5.8	4.0	0.76	0.41	23.9	1.8	1.76	3.28
38	4.9	10.6	1.64	0.66	23.5	2.5	5.18	4.41
40	1.9	2.6	0.61	0.32	14.1	1.9	3.37	3.41
41	1.4	0.5	0.41	0.37	5.1	1.1	n.d.	3.80
43	2.4	2.7	0.52	0.30	17.0	1.8	2.26	3.08
46	4.3	7.5	0.74	0.42	28.1	1.8	17.90	3.59
51	2.8	0.6	0.77	n.d.	25.4	n.d.	3.49	2.56
54	7.4	9.9	2.10	0.68	25.4	3.1	8.80	2.57
56	10.6	8.5	0.75	0.47	40.6	1.6	2.93	3.78
58	3.8	2.8	0.28	0.31	21.3	0.9	4.80	3.33
59	6.4	6.2	1.55	0.27	46.7	5.7	1.74	2.85
64	12.3	9.8	1.79	0.77	28.7	2.3	2.27	2.75
65	6.9	9.6	1.60	0.67	24.6	2.3	16.43	3.77
45B	3.9	4.9	0.78	0.76	11.6	1.0	3.78	1.96

* Bulk samples of the upper 0-10 cm of surface sediment
Aliphatic = eluted by hexane
Aromatic = eluted by benzene and then cleaned by TCL procedure to remove methyl esters
HC = total hydrocarbons, sum of aliphatic and aromatic fractions in g/g dry sediment
n-alkanes = resolved by gas chromatography
Pr = Pristane
Ph = Phytane
Odd/Even = Summed from C_{15} to C_{34}
n.r. = not resolved
n.d. = not determined

0.0007 for all samples, which is much lower than found in areas where unweathered oil is found in the sediments.

Gas chromatographic analysis revealed that allochthonous lipids are the predominant source of hydrocarbons in shelf sediments. These lipids are characterized by high molecular weight (C_{25} - C_{31}) N-alkanes derived from terrestrial sources, probably spruce-alder woodlands of the Tiaga forest drainage basins. It is surprising to find them distributed throughout the shelf sediments since the waters of the Kuskokwim River are swept north into Norton Sound by the coastal surface currents. The ubiquitous presence of these predominately odd-numbered carbon, high molecular weight compounds cannot be easily explained, but may be related to the relative rates of utilization of low molecular weight hydrocarbons by microorganisms since there is no apparent continuing source of these compounds.

The homologous series of isoprenoids is not found in the shelf samples. Pristane is much more abundant than phytane. Pr/Ph ratios ranging from 2 to 18 (Table 8) suggests the isoprenoids are derived from biogenic materials of the marine environment rather than from petroleum (Farrington et al, 1977; Venkatesan et al, 1980).

Two of the stations taken in the nearshore region north of the Alaska Peninsula (8, 12) showed higher concentrations of the $<C_{24}$ N-alkane hydrocarbons which could be of marine origin and consist of residues from primary production (Han and Calvin, 1969) and from microbiologically altered algal detritus (Johnson and Calder, 1973; Cranwell, 1976; Hatcher et al, 1977).

Eelgrass, which is the dominant plant in the vast lagoonal region of the northern Alaska Peninsula, was analyzed for hydrocarbon composition by Venkatesan et al (1981) in order to compare eelgrass with the sediments on which it grows as well as the sediments of the shelf area. As shown in Figure 75, the hexane extractable fraction of eelgrass consists of a simple mixture of C_{15}, C_{17} and C_{19} N-alkanes with only small amounts of hydrocarbons beyond N-C_{25}. The sediment in the lagoon has a hydrocarbon distribution which cannot be correlated with the allochthonous hydrocarbon distributions found on the shelf. The analysis indicates a mixture of C_{17} to C_{31} odd numbered N-alkanes with predominant alkanes N-C_{21} and C_{23} which is probably a result of microbial degradation of eelgrass detritus (Johnson and Calder, 1973). This differs from shelf sediment hydrocarbons which predominate in C_{25}-C_{31} odd numbered N-alkanes. The authors therefore conclude that the coastal lagoons do not serve as a source of hydrocarbons in the shelf sediments.

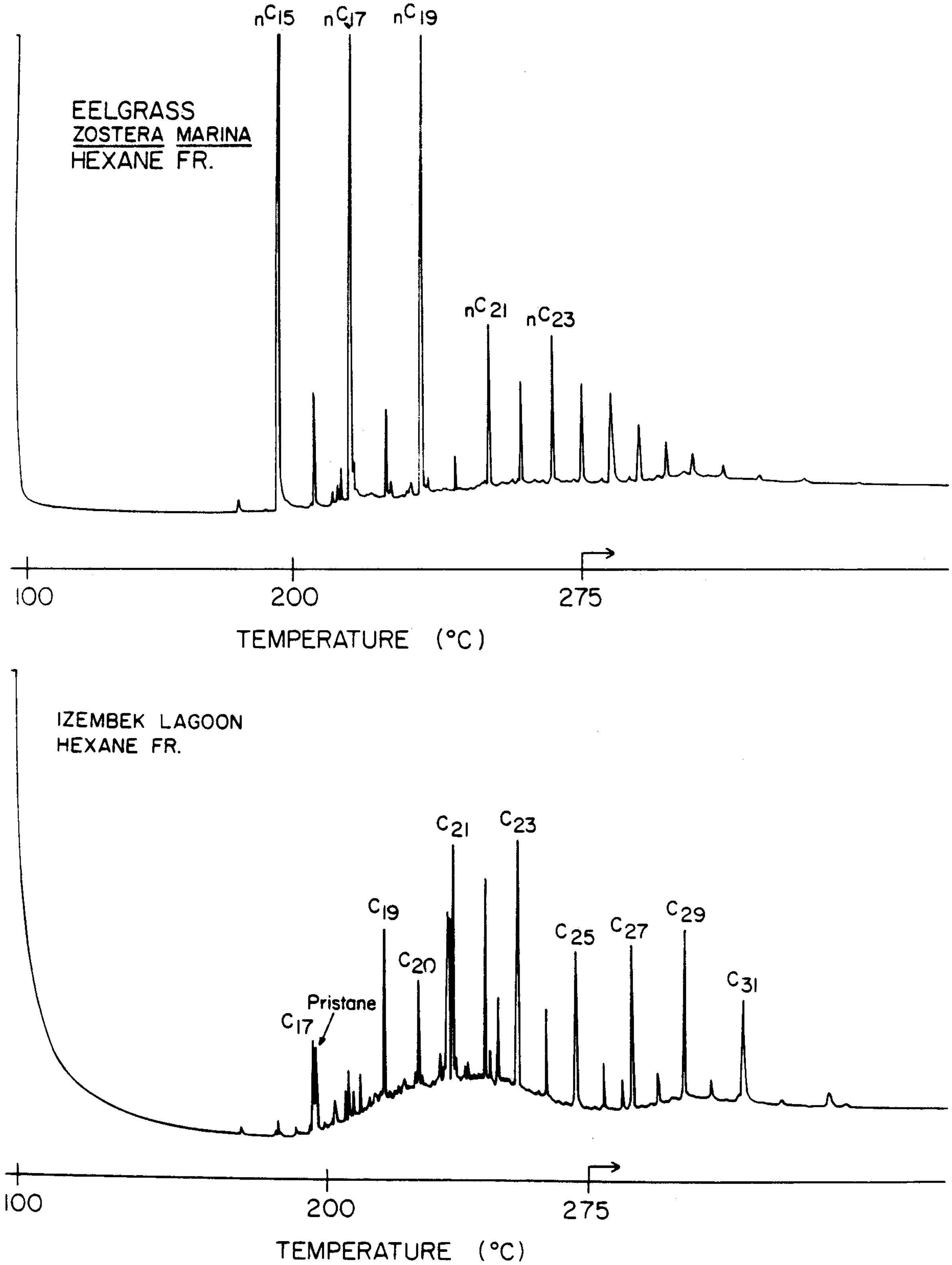


Figure 75. Gas chromatograms of hexane fractions extracted from eelgrass (Zostera marina) leaves and sediments from Izembek Lagoon. Numbers 15-31 refer to carbon-chain length of n-alkanes (Venkatesan et al, 1981).

Isotopic analysis of the humus material isolated from the sediments on the Bering Sea shelf and in Izembek Lagoon (Stuermer et al, 1978; McConnaughey and McRoy, 1979; Gearing et al, 1976) shows that shelf sediments are heavier ($\delta^{13}C$ of -21.3 ppt) than terrestrial humic acids (^{13}C of -26 to -30 ppt) and lighter than the humic acid from Izembek Lagoon ($\delta^{13}C$ of -18 ppt) and eelgrass ($\delta^{13}C$ of - 10.3 ppt). The POC in the lagoon ranges from $\delta^{13}C$ = -19.9 to -17.0 ppt and POC collected at the mouth of the lagoon from -22.1 to -17.3 ppt. It then appears that the humic acid of the lagoon is derived from biodegradation of a mixture of eelgrass, plankton ($\delta^{13}C$ - 24.4%) and detritus. It is also reasonable that, although the hydrocarbons characteristic of the lagoon are not found on the shelf, the more resistant humic substances derived from eelgrass could be mixed with terrestrial material to form the humic materials of the shelf environment.

Shaw and Smith (1981) examined the hydrocarbon content of 34 samples of plankton, fish, marine birds, and marine mammal tissues collected on the Bering Sea shelf. Seal, Phoca vitulina largha, caught in the study area were probably feeding within the coastal domain of Bristol Bay. These animals showed a hydrocarbon distribution including the compound pristane, which appeared to have its origin in the marine pelagic system of the region. Worthy of note is the significance of missing hydrocarbons from the animal organisms examined. The hydrocarbons associated with higher terrigenous plants, commonly found in the sediments, were not observed. Their absence indicates that at least in the spring, terrigenous hydrocarbon sources are minor compared to marine sources. Fossil hydrocarbons were not observed in any samples, indicating that neither natural petroleum seepage nor pollution is resulting in the significant accumulation noted in the above work of petroleum type hydrocarbons in marine animals of the area.

The low molecular weight (LMW) alkanes (C_1 to C_4 homologs) are found in crude oil and natural gas (Clark and Brown, 1977) and as such they have been investigated in Bristol Bay to determine the presence of petroleum or thermogenic gas in these waters (Cline, 1981). Methane is by far the most abundant. Besides its presence in petroleum, it is produced through fermentation of simple organic compounds or in hydrogen reduction of CO_2 by anaerobic microorganisms (McCarty, 1964; Reeburgh and Heggie, 1977); and may be produced in oxic marine waters by organisms living in anoxic microenvironments (Scranton and Brewer, 1977). The origin of C_2 - C_4 compounds also may be biogenic (Smith and Cook, 1974) or photochemical (Wilson et al, 1970). But despite their origin, they are found enriched in ocean surface water (Swimmerton and Lamontague, 1974).

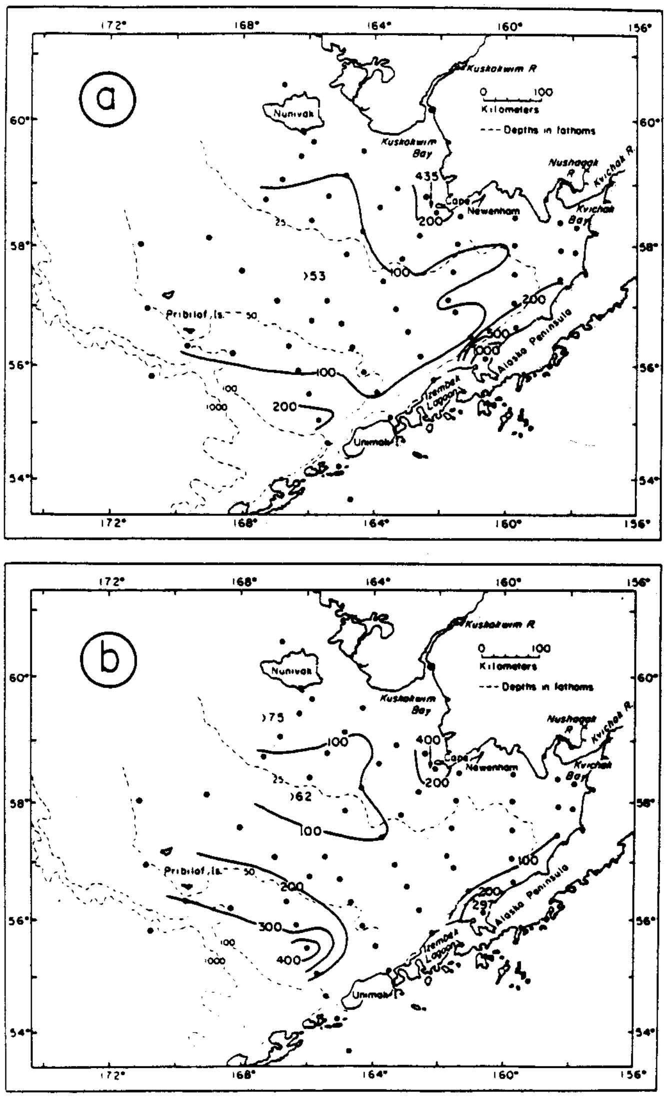


Figure 76. Surface (a) and near-bottom (b) distribution of dissolved methane (nl/l, STP) in July 1976. Near-bottom samples were taken within 5 m of the bottom (Cline, 1981).

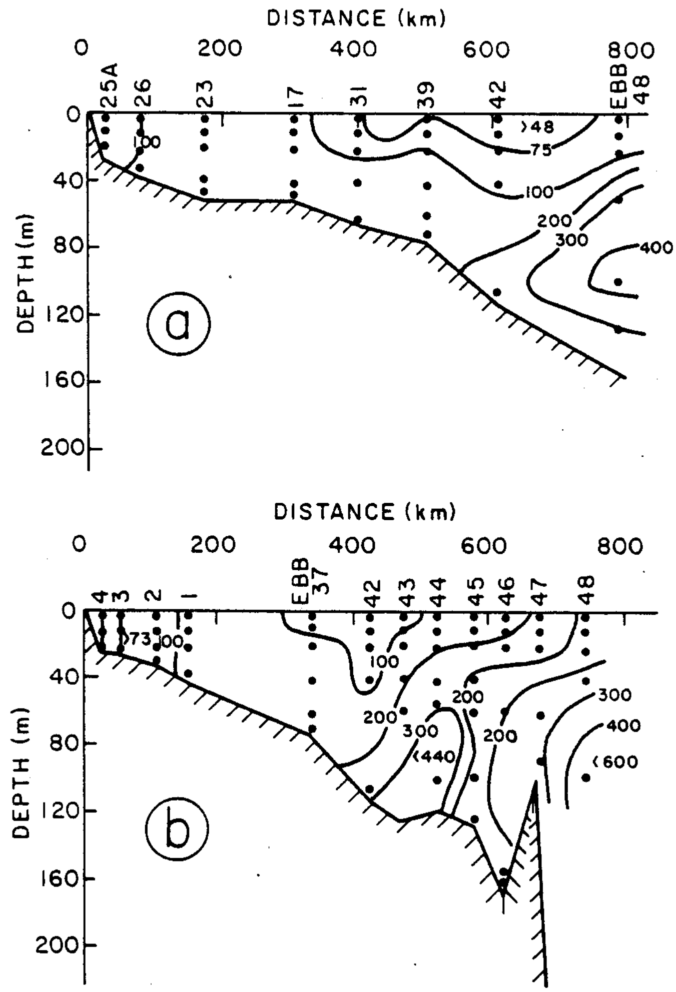


Figure 77. (a) Vertical distribution of dissolved methane (nl/l, STP) along Section II in Bristol Bay. (b) Vertical distribution of dissolved methane (nl/l, STP) along Section I terminating in Unimak Pass. Observations were made in July 1976 (Cline, 1981).

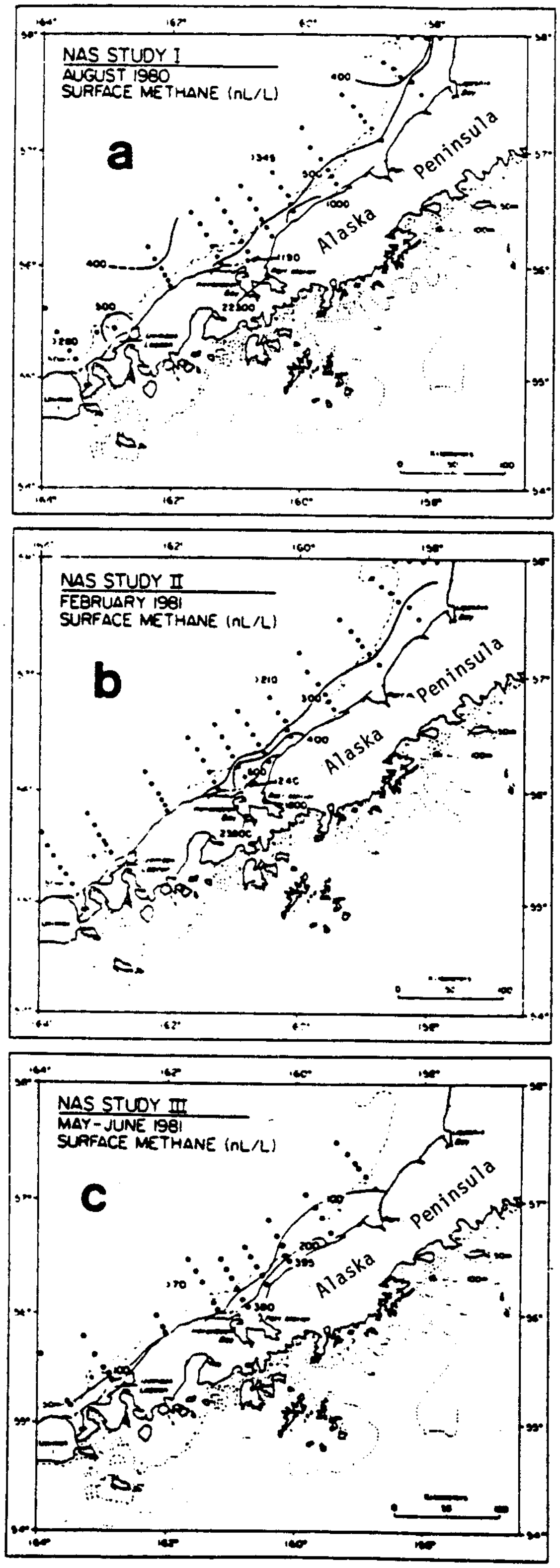


Figure 78. The distribution of methane at the surface along the NAS in (a) August 1980, (b) February 1981, and (c) May 1981. Concentrations are in nl/l (STP) (Cline et al, 1982).

The distribution of methane in Bristol Bay is shown in Figure 76 as reported by Cline (1981). From these data, it is seen that there is a strong source of methane in St. George's Basin just north of Unimak Pass, a strong source in Port Moller and a source near Cape Newenham. In Figure 77, the vertical distribution observed in section (a) originates in Kvichak Bay and ends near St. George Island, and in section (b) originates near Nunivak Island and ends south of Unimak Pass. Methane is vertically homogeneous in the coastal domain, but shows vertical structure in the middle and outer domain. The surface waters in the middle shelf are approximately saturated with respect to air [53+/-3 ml/l (Yamamoto et al, 1976)], but close to local sources and in the coastal region, methane in surface waters is severalfold supersaturated.

An intensive study of the rich methane plume near Port Moller was undertaken by Cline et al (1982) with the specific purpose of establishing a point source tracer for use in circulation and diffusion advection model studies to assist in establishing current velocities and estimating the magnitude of horizontal and vertical mixing processes for the coastal domain in the area north of the Alaska Peninsula. The distribution in this section in August 1980 and February and May 1981 is shown in Figure 78. The concentrations in August are several-fold higher than in May, probably due to a lag in methane generation after the spring bloom. February concentrations are intermediate. Irrespective of the concentrations, there appears to be little tendency for methane to penetrate the inner frontal zone usually occurring at about 40 meters depth. The evidence for a slow moving coastal current is clear here, in that for each case studied, the concentration gradient and thus the diffusive plume moves north-eastward along the north coast of the Alaska Peninsula.

A simple advection-diffusion model was used and resulted in predicted mean velocities along the shelf (less than 50 meters depth) of 3-6 cm/s, in agreement with current meter results quoted earlier. These mean values represent a mean velocity estimate over a scale length of the tracer, which is about two months.

Removal of methane from the aerobic waters of the coastal zone occurs from two known processes: diffusion through the air-sea interface and microbial decomposition. Air-sea exchange rates were estimated from parameters shown in Table 9. The methodology is based on Broeker and Peng (1982) who have estimated the effect of wind velocity on film thickness Z in the diffusion rate equation. It is expected that the resulting exchange rates are correct within +/- 50 percent. Microbial decomposition has been studied by Griffiths et al (1982) in the environment of the southeast Bering Sea. The authors obtained the data shown in Table 10, showing a consistently greater rate of oxidation in bottom than in surface waters and a rate of oxidation dependent on methane concentration in the water, location, and time of the year (temperature). Also, it was found that rarely was methane incorporated into cellular material, but appeared as carbon dioxide. It was found that the most rapid oxidation rates in the water column were only seven percent of that found in the underlying sediments.

The results of analysis for LMW hydrocarbons in the southeast Bering Sea shelf are shown in Table 11. It was found that the C_{2+} fraction showed seasonal variability regulated by biological processes, presumably microorganismal. As is true elsewhere in Alaska coastal waters, the alkenes are more abundant than the alkanes of the same carbon number. The relatively low concentrations of LMW hydrocarbons, a relatively high ratio of C_1/C_2+C_3 of 30 to 500 and a $C_2/C_{2:1}$ ratio of less than one, all suggest a biological source and indicate the absence of significant quantities of petroleum derived hydrocarbons in this region.

Metal Concentrations

Heavy metal concentrations in the water column have been the subject of limited investigations on the southeast Bering Sea shelf. The most notable effort was that of Barsdate et al (1974) who examined in detail the contribution of the eelgrass beds of Izembek Lagoon to the elemental composition of lagoon and nearshore coastal waters. Based on an estimated production of 5×10^5 mt/yr of eelgrass and an elemental analysis of the eelgrass, the amount of various trace elements incorporated on an annual basis was computed. The results of this evaluation are shown in Table 12. The effect of this incorporation on the chemistry of the sea water is evident in the variation of the concentration of some elements between the lagoon and nearby Bering Sea. In the case of phosphorus, which has been examined extensively in Izembek Lagoon (McRoy et al, 1972a), the eelgrass plants remove 62.4 $mgP/m^2/day$ from the sediments, leading to an export of 3 mt of P/day to the coastal water (495 mt/yr calculated on seasonal output basis). This flow may be seen in the Bering Sea as a plume of phosphorus rich water (Figure 79).

Dissolved inorganic nitrogen (NH_4^+, NO_3^-, NO_2^-) concentrations have also been estimated to have a net export of 96 mt per year, much less than that for phosphorus. There is also evidence for the export of dissolved organic carbon (2×10^4 mt/yr) and silica (2.1×10^3 mt/yr).

Some elements from the Bering Sea waters are extracted by Izembek Lagoon. Most notable were copper and lead as

Table 9. A Summary of parameters used to estimate the air-sea exchange rate (R) of methane along the NAS coastal zone. The model is

$$R = - \frac{D}{h \cdot \Delta z} (C) = -K_{a/s}(C)$$

Date month/yr	Wind Speed m/s	Temp. °C	D cm^2/s	Δz m	h μm	$k_{a/s}$ s^{-1}
Aug 80	6	10.7	$1.12x10^{-5}$	40	70	$4.0x10^{-7}$
Feb 81	9.5	0.0	$0.68x10^{-5}$	40	20	$8.5x10^{-7}$
May 81	7.5	6.5	$0.96x10^{-5}$	40	50	$4.8x10^{-7}$

From Cline et al,(1982).

Table 10. Seasonal changes in *in-situ* methane oxidation rates and turnover times in water samples

Cruise	Area sampled	Methane oxidation rate (nl/liter per day)			Turnover time (days/10^2)			No. tested
		Mean	SD	Range	Mean	SD	Range	
Aug	NAS	3	2	0.8-7.8	0.6	0.7	0.12-3.3	29
	SGB	4	9	0.3-37	0.8	0.7	0.05-2.8	25
Jan	NAS	1	3	0.04-7.4	2	2	0.3-7.2	11
	SGB	1	2	0.02-7.9	3	3	0.1-12	17
May	NAS	0.4	0.5	0.02-1.6	1	1	0.1-10	17
	SGB	2	4	0.1-18	0.6	0.8	0.05-4.5	39
	PM"	16	12	2.4-49	0.3	0.2	0.02-1.0	15

PM", Port Moller
From Griffiths et al, (1982).

Table 11. Average surface (a) and near-bottom (b) concentrations (nl/l, STP) of methane, ethane, ethene, propane, and propene for various water depth intervals (Cline, 1981).

CRUISE	DOMAIN		METHANE Mean	METHANE Range	ETHANE Mean	ETHANE Range	ETHENE Mean	ETHENE Range	PROPANE Mean	PROPANE Range	PROPENE[1] Mean	PROPENE[1] Range
Sept.-Oct., 1975	Coastal (<50 m)	a	64	45-94	-	-	0.9	0.3-17	-	-	0.5	0.2-11
		b	59	45-98	-	-	1.0	0.7-1.8	-	-	0.4	0.1-0.6
	Middle Shelf (50-100 m)	a	60	42-83	-	-	0.8	0.3-1.6	-	-	0.4	0.1-1.4
		b	99	65-163	-	-	1.7	1.2-2.7	-	-	0.6	0.3-1.3
	Outer Shelf (100-200 m)	a	76	40-200	-	-	0.5	0.2-0.8	-	-	0.3	0.3-0.4
		b	380	100-615	-	-	1.1	0.7-1.6	-	-	0.3	0.2-0.4
June-July, 1976	Coastal (<50 m)	a	112	74-153	0.9	0.6-1.5	3.8	3.0-4.7	0.4	0.3-0.6	1.4	1.0-2.5
		b	114	73-153	1.0	0.5-2.5	3.4	2.3-4.4	0.4	0.2-0.6	1.2	0.7-1.6
	Middle Shelf (50-100 m)	a	85	52-134	0.6	0.3-1.5	2.9	1.9-4.7	0.3	0.2-0.6	1.1	0.6-1.7
		b	115	62-165	1.3	0.5-2.5	2.2	1.1-4.0	0.5	0.3-0.6	0.5	0.2-1.0
	Outer Shelf (100-200 m)	a	140	53-276	1.1	0.4-2.1	2.3	1.8-2.8	0.4	0.2-0.7	0.7	0.5-1.1
		b	269	164-440	0.9	0.6-1.1	1.2	0.8-1.8	0.3	0.2-0.4	0.3	0.1-0.9

[1]Due to analytical difficulties encountered during the Sept.-Oct. 1975 cruise, concentrations of ethene and propene include ethane and propane respectively.

Table 12. Amounts of various elements annually incorporated in eelgrass in Izembek Lagoon, based on dry weight concentrations from the literature (annual eelgrass production = 4.6 x 10^5 mt/yr dry wt). **(Barsdate et al, 1974).**

Element	Concentration in eelgrass (ppm)	Annual elemental incorporation (metric tons)
Carbon	385,000[b]	177,100
	360,000[f]	166,000
Nitrogen	30,450[a]	14,010
	16,000[f]	7,400
Phosphorus	2,860[a]	1,316
	3,600[f]	1,660
Chlorine	43,680[a]	20,093
Potassium	22,640[a]	10,414
Calcium	20,010[a]	9,205
Sodium	19,590[a]	9,011
Magnesium	7,380[a]	3,395
Sulfur	7,300[a]	3,358
Manganese	1,825[a]	840
Silicon	840[a]	386
Aluminum	500[c]	230
Boron	310[a]	143
Iron	245[a]	113
Iodine	203[a]	93
Zinc	27[d]	13
Bromine	9.59[a]	4.41
Copper	7.50[a]	3.45
Barium	7.2	3.3
Fluorine	3.61[a]	1.66
Molybdenum	3.12[a]	1.44
Lead	<1[f]	<0.5
Nickel	0.4[b]	0.2
Cobalt	0.3[b]	0.1
Cadmium	0.23[b]	0.10
Rubidium	0.14	0.064
Beryllium	0.12[e]	0.055

shown in Figure 80. These elements were found to be five to tenfold more abundant in waters of the coastal domain some distance from the entrance to the lagoon than in the lagoon waters itself.

Data on heavy metals are not available for other coastal lagoons or nearshore areas in this region, but because of the dynamics of the system it would be expected that they are actively interacting between sediments, water column and the biota.

2. Biological Process Characterization

a. Primary Producers and Carbon Sources

Oceanographic studies of the southeastern Bering Sea have defined the shelf as three domains--outer, middle and coastal--divided by distinct, oceanographic fronts (Kinder and Schumacher, 1981). The 5 km nearshore zone of the North Aleutian Shelf occurs within the coastal domain that is defined by a front located approximately over the 40-50 meter isobath. In this zone there are three main sources of organic carbon to the food webs: phytoplankton, macrophytes, and detritus.

Phytoplankton Production. Measurements of primary productivity of the southeastern Bering Sea are numerous for the middle and outer shelf but are very limited for the coastal domain and, with the exception of Izembek Lagoon, there are few stations within the 0-5 km zone. Furthermore, since there has been no concerted effort to study the seasonal cycle in the coastal domain, we can only extrapolate from what is known in the adjacent domains. As in other shelf regions, the determinant of phytoplankton primary production, once sufficient light is available in the spring, is the nutrient supply, primarily inorganic nitrogen. The water column in the coastal domain, unlike that of the middle and outer domains, consists of a single layer, mixed in this shallow water by the overlapping tidal energy from the bottom and the wind energy from the top (Coachman et al, 1980). This oceanographic condition probably results in a single spring bloom that is dependent on the nitrate available at the end of winter. Hence the disappearance of nitrate can be used to calculate the magnitude of the spring bloom. In the middle and outer shelf domains, this has been calculated as about 100g C/m^2 for the period of late April through May (Sambrotto, 1983). This estimate has been verified by direct carbon uptake experiments. In the coastal domain the spring bloom may begin earlier than in the outer shelf due to warming of the shallow water, but the total production will still be determined by the ambient

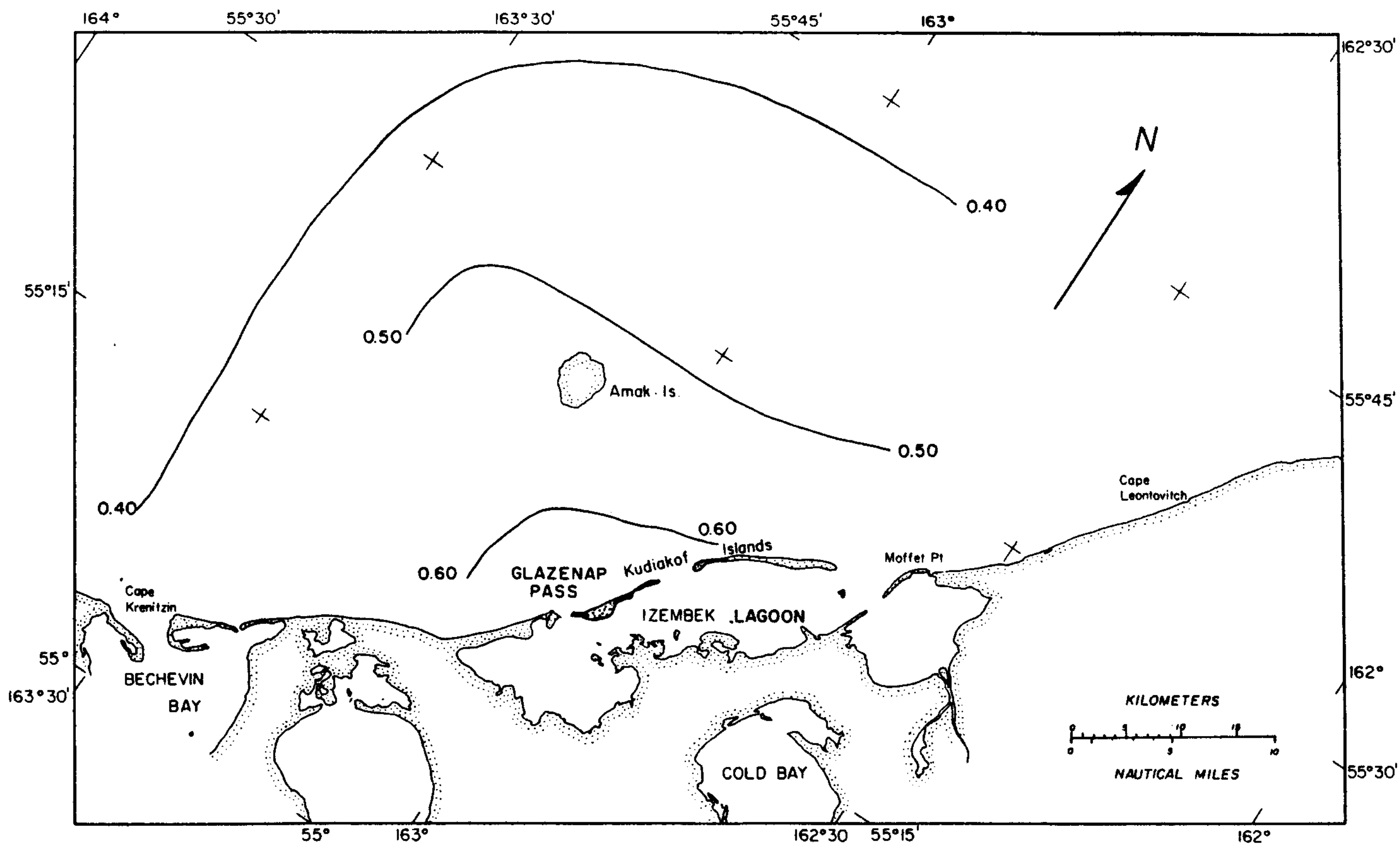


Figure 79. Dissolved reactive phosphorus distribution (μg-atoms P liter) in the Bering Sea adjacent to Izembek Lagoon June 1968 (R V Acona cruise 066) (Barsdate et al, 1974).

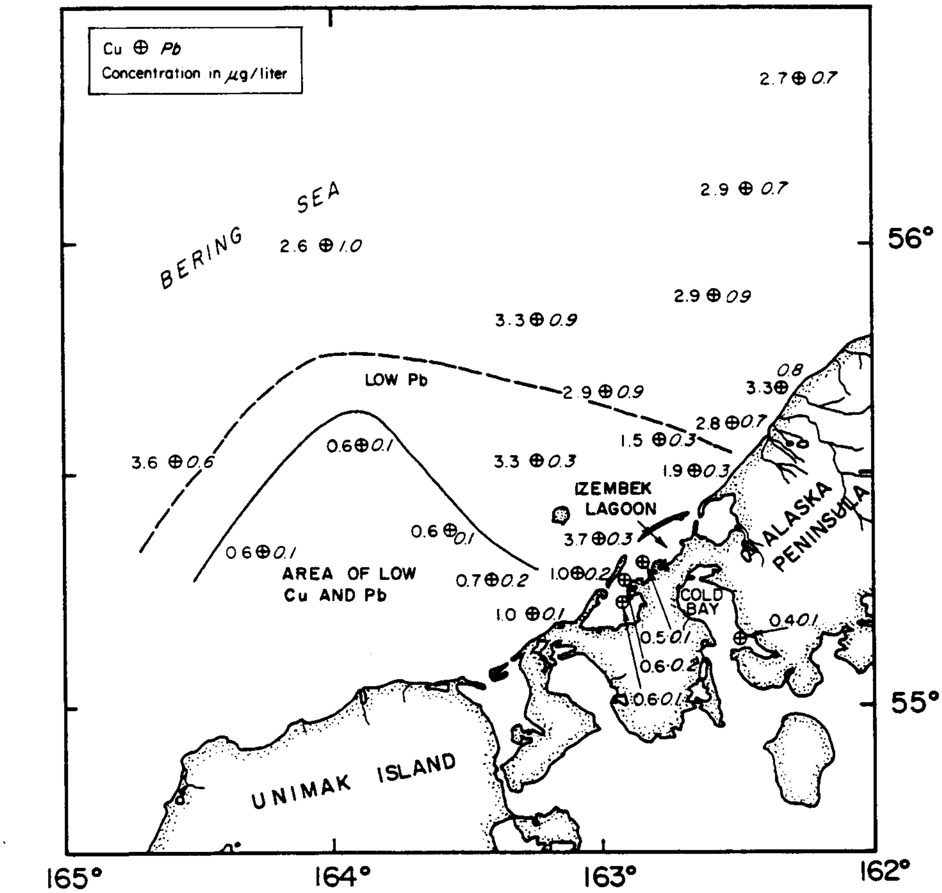


Figure 80. Surface distribution of copper and lead in the Izembek Lagoon sampling grid. September 1970 (R V Acona cruise 103) (Barsdate et al, 1974).

nitrogen content and hence should be similar for the period. The nitrogen content in early spring is about 15 µM (PROBES data) and using an average water column depth of 30 meters, the net production would be 6.3gN/m^2 of organic nitrogen and with a C/N ratio of 15:1 (J. Goering, personal communication), the production for the period would be about 95g/m^2. The spring bloom occurs over approximately 45 days so the average daily production is about 2g C/m^2/day.

Modifications to this pattern will exist if nutrients are supplied from other sources such as from rivers and lagoons, from advection, or from diffusive resupply across the inner front. Runoff can also reduce productivity by increasing turbidity, thus reducing the depth of the euphotic zone. Existing data indicate post-bloom, summer production rates of about 0.24g C/m^2/day from the nearshore waters by Unimak Island (McRoy et al, 1972b). Seaward of this area primary production was considerably higher, probably due to upwelling in Unimak Pass, but the data suggest that this has little or no effect on the coastal domain (i.e. inshore of the 50 m isobath). Apparently, the coastal domain has a single spring bloom of phytoplankton production followed by low, nutrient limited production through the summer and fall.

Macrophyte Production. Eelgrass, *Zostera marina*, is the major marine macrophyte on this coast. This seagrass forms dense, extensive meadows in the protected bays and lagoons of the region (McRoy, 1970). Izembek Lagoon is the only area that has been studied, but presumably the work from this area is representative of the entire region. This lagoon contains the most extensive stands of seagrasses in Alaska and is a major feature of the coast.

The average biomass of eelgrass in Izembek Lagoon is 1kg dry/m^2 (380g C/m^2) with a range of 0.06-1.8 kg dry/m^2 (McRoy and McMillan, 1977). Productivity values range from 3 to 4 g C/m^2/day. In Izembek Lagoon, eelgrass is estimated to cover some 68% of the total area (116 km^2) and the total standing stock is on the order of 1 x 10^5 mt dry weight. The total eelgrass production in the lagoon is estimated to be about 5 x 10^5 mt dry (or 2 x 10^5 mt C) per year (Barsdate et al, 1974). A significant proportion, perhaps as much as 75 percent, of this production is exported to the adjacent sea from the lagoon as particulate and dissolved organic matter. Although most of the bays and lagoons on this coast contain eelgrass, other than for Izembek Lagoon there are no quantitative measurements of either the areal extent of the populations or of their productivity.

An associated component of primary production in eelgrass beds is production by epiphytic and benthic algae. The surface area of the leaves can be as high as 24 times the bottom area (Dennison, 1979) and this provides an extensive habitat, not unlike a coral reef, for epibiota. There are no direct measurements of epiphytic production in Izembek lagoon but work elsewhere indicates that rates can be as high as 20 percent that of the eelgrass (McRoy and McMillan, 1977). There are no measurements of benthic algal production in the eelgrass beds, but the biomass averages about 2g dry/m^2 and the total standing stock is about 230 mt (McRoy, 1970).

Detritus. The coastal domain of the shelf receives particulate organic matter from the adjacent land margin. The nature of this material is eelgrass detritus from the bays and lagoons and terrestrial detritus from the rivers and marshes. These carbon sources, with the exception of eelgrass from Izembek Lagoon, have not been studied. However, it is likely that there are two major seasonal peaks of the addition of this material. One is expected to coincide with the seasonal maximum in runoff occurring in June and the other is the result of the annual sloughing of eelgrass leaves which occurs in September. Izembek Lagoon has been estimated to annually contribute as much as 1.5 x 10^5 mt C to the coastal domain (Barsdate et al, 1974). Data on the organic carbon content of the many small streams along the Alaska Peninsula are non-existent, but the few measurements from the rivers in Bristol Bay indicate a particulate concentration of 0.1-0.8g C/m^3 and 2.5 to 4.9g C/m^3 as dissolved carbon (U.S. Geological Survey, 1980). The average runoff along the Alaska Peninsula into the Bering Sea is estimated to be 2 x 10^{10} m^3/yr (P. Kinney, personal communication) whereas that from inner Bristol Bay is estimated to average about 4 x 10^{10} m^3/yr (U.S. Geological Survey, 1980). These freshwater sources could contribute about 1.1 x 10^5 mt C/yr for the Alaska Peninsula (i.e. the North Aleutian Shelf) and about 2.3 x 10^5 mt C/yr for inner Bristol Bay.

b. Secondary and Higher Producers

Although there are voluminous accounts on invertebrates and marine fishes from the southeastern Bering Sea, there is a paucity of information on these two groups within the 0-5 km nearshore zone. Since recent investigations (PROBES) have delineated the 40-50 meter depth contour as the ecological boundary between the coastal and middle domains, the following characterization of invertebrates and marine fishes of the nearshore zone focuses on accounts from within the 50 meter depth zone.

Invertebrates. Invertebrates fall into three broad categories: 1) zooplankton - those invertebrates which live all or part of their lives within the water column (larval fishes are also included in this category); 2) infauna - those invertebrate organisms that live beneath the surface of the ocean floor; and 3) epifauna - those invertebrate organisms that live on the surface of the sea floor.

Zooplankton

Our knowledge of the species composition, distribution, abundance and biomass of pelagic invertebrate fauna within the nearshore zone of the North Aleutian Basin is limited.

Zooplankton distribution and abundance data can only be inferred from the limited amount of inshore data available from the broad coastal region near Cape Newenham and Hagermeister Island that was part of the PROBES study area. Virtually no information is presently available on the zooplankton populations along the narrow coastal domain of the Alaska Peninsula or near the large freshwater inputs within Bristol Bay. Data regarding the distribution of mysids in this region is particularly lacking.

The PROBES studies found that two zooplankton groups are consistently present in hydrographically-defined domains in the nearshore (<50 m) regions of the eastern Bering Sea (Cooney, 1981). Middle-shelf and coastal communities are dominated by the small copepods Acartia longiremis, Pseudocalanus spp., and Oithona similis, supplemented by lesser numbers of Calanus glacialis and C. marshallae. The amphipods Parathemisto libellula, the chaetognath Sagitta elegans, and the euphausiid Thysanoessa raschii are the other abundant species. The second nearshore group is associated with the brackish coastal lagoons and estuaries and is dominated by the copepods Acartia clausi, Pseudocalanus spp., Centropages adominalis, Eurytemora pacifica, E. herdmani, and Tortanus discaudatus and the cladocerans Podon and Evadne (Cooney, 1981). Most of the other zooplankton data address the larvae of commerically important decapod crustaceans collected beyond the 50 meter depth zone (e.g. Armstrong et al, 1981, 1982). Zooplankton samples have recently been collected within the nearshore zone, however, these samples were collected specifically for red king crab larvae (VTN Oregon, 1983a,b,c), and it is doubtful if other zooplankters will be included in a final report.

Infauna

Haflinger (1978, 1981) examined the infaunal community of the southeastern Bering Sea and, through station clustering, found a split between the inshore and mid-shelf stations indicating an abrupt faunal transition at the general depth of 50 meters. This boundary coincides with a frontal zone at the transition from coastal to mid-shelf water domains. Infaunal biomass was higher nearshore than in mid-shelf waters and other parts of the southeastern Bering Sea. Most feeding types in this area were predators, scavengers, and deposit feeders. Highest standing stock values were evident at localized areas adjacent to the coast of the Alaska Peninsula and in Bristol Bay. Infaunal wet-weight values exceed 675 g/m^2 near Izembek Lagoon and Port Heiden. Feder and Jewett (1981) also reported high infaunal biomass (exceeding 200 g/m^2 wet-weight) along the 50 meter isobath from Amak Island to upper Bristol Bay. High productivity in localized nearshore communities may depend on detritus of terrestrial origin i.e., from Izembek Lagoon and coastal rivers (i.e., Kvichak, Ugashik, and King Salmon). Relatively low standing stock values were found in northern Bristol Bay, presumably because this region is heavily used by benthic-feeding fishes in the summer months (i.e., yellowfin sole) (Stoker, 1981). Infaunal species typical of nearshore areas were the polychaetes Ophelia limacina and Spiophanes bombyx, the amphipods Corophium crassicorne and Haustorius eous, the clams Spisula polynyma and Tellina lutea, and the sand dollar Echinarachnius parma (Haflinger, 1981).

Four species of bivalves dominate the nearshore zone. A 1977 exploratory survey of subtidal clam resources in the southeastern Bering Sea revealed extensive concentrations of Alaska surf clams (Spisula polynyma) along the north coast of the Alaska Peninsula (Hughes and Bourne, 1981). An area of 6,800 km^2 between Port Moller and Ugashik Bay had an estimated exploitable biomass of 329,000 +/- 52,000 mt and potential annual yield of 17,800 mt of whole clams. Highest densities were found at depths of 30-32 meters. Other dominant clam species reported within the 50 meter zone in the southeastern Bering Sea are Macoma cal carea, Tellina lutea, and Cyclocardia crebricostata (McDonald et al, 1981; Hughes et al, 1977). However, of these three, only Tellina lutea occurred in high numbers (more than 72 individuals/m^2).

Preliminary results of a more recent survey (VTN Oregon, 1983e) of the infaunal communities of the inshore areas of the Alaska Peninsula, between Cape Sarichef and Cape Seniavin, indicate the presence of three different community types separated primarily on the basis of depth and sediment type. A shallow, sand-bottom community is composed of the bivalve Siliqua patula along with the polychaetes Capitella capitatta, Magelona sacculata, Nephtys longosetosa, Scoloplos armigera and Travisia pupa. This community was a subset of a deeper water sand bottom community which was dominated by the sand dollar Dendraster. In addition, the polychaetes Ophelia limacina, Spio nr. filicornis and Spiophanes bombyx were important in this community. The deep-sand-gravel community was comprised of many of the ephemeral species of the nearshore sand communities, including Scoloplos armiger and Spiophanes bombyx as well as the polychaetes Owenia fusiformes, Eteone longa, Glycera capitata, Megacrenella columbiana and Polygordius sp.

Epifauna

Trawling surveys for epifauna in the southeastern Bering Sea in 1975-76 revealed that the lowest biomass values (1.9 g/m^2) came from waters between 20 and 40 meters (Jewett and Feder, 1981). Although 36 stations were sampled at this depth, only 10 stations were sampled between Unimak Pass and Cape Newenham. The 20-40 meter depth stratum was dominated (biomass) by echinoderms, particularly the sea star Asterias amurensis. Mollusks and arthropods accounted for most of the species within this area. Asterias accounted for 84.4 percent of the total biomass at the 20-40 meter stratum. The average density of Asterias at this stratum was 158 individuals/km; the average density of 18 dominant epifaunal species combined at this stratum was 174 individuals/km. The unidentified seastar that dominated the biomass of trawl catches within the area in question in the summers of 1979-82 (NW&AFC, 1979-82) was also presumably Asterias amurensis. Epifauna data collected within 50 meter waters along the North Aleutian Shelf in 1982 were dominated by a clam (Astarte sp.), hermit crabs, starfish (presumably Asterias amurensis), and a sand dollar (Echinarachnius parma) (Armstrong et al, 1982).

Among 15 biomass-dominating gastropod species occurring within the southeastern Bering Sea, only five occur within the 50 meter contour between Unimak Pass and Cape Newenham (MacIntosh and Somerton, 1981). Of these five species, only Neptunea ventricosa occurs throughout this zone.

Benthic trawling surveys in the southeastern Bering Sea have revealed that red king crab (Paralithodes camtschatica), Tanner crab (Chionoecetes bairdi) and Korean hair crab (Erimacrus isenbeckii) all occur within the 50 meter zone (Pereyra et al, 1976; Jewett and Feder, 1981; Otto et al, 1981). In late winter and early spring, adult male red king crab apparently migrate from deeper, offshore areas to join females in shallow water for breeding. Larval hatching occurs prior to breeding. Larval occurrence within the Black Hills - Port Moller area has identified this area as a major red king crab spawning and breeding ground (Takeuchi, 1962; Haynes, 1974; VTN Oregon, 1983a,b,c; Armstrong, et al, 1982). As the season progresses, the center of larval abundance moves northwestward with the prevailing currents along the Alaska Peninsula, toward the head of Bristol Bay, where metamorphosis and settlement occurs (Haynes, 1974; VTN Oregon, 1983a,b,c). Juveniles have only been found in nearshore rocky areas where dense substrate cover is present (e.g., colonial tube-forming polychaetes). This typifies the substrate preference of early post-larval red king crab elsewhere. Recent data showing a scarcity of adult ovigerous females, larvae, and juveniles point to a depressed commercial fishery in the southeastern Bering Sea in the immediate future (VTN Oregon, 1983a,b,c; R. Otto, personal communication, 1983). In fact, the Alaska Department of Fish and Game has recently completely closed this fishery to commercial utilization.

Although small concentrations of large male and female Tanner crab occur along the Alaska Peninsula from Unimak Pass to Port Moller, greatest densities occur beyond the 50 meter zone (Jewett and Feder, 1981). A distinct pocket of small male Korean hair crab occurs just north of the Alaska Peninsula adjacent to Izembek Lagoon (Otto et al, 1981). Recently, large populations of Telemsus sp. (horse-crab, or locally known as Bristol Bay hair crab) have been reported in test fishing carried out in the northern part of Bristol Bay in the region of Togiak Bay and Round Island (Dames and Moore, 1983). This crab should not be confused due to its local name with the Korean hair crab (Erimacrus isenbeckii). An average of 7.5 crabs/pot at a size of 0.4 lb/crab were obtained in this area in 3-14 fathoms of water with about 21 hours soak time.

Marine Fishes. The dominant marine fishes, in terms of biomass and density, in the nearshore region of the southeastern Bering Sea are Pacific herring, capelin, and yellowfin sole. Sandlance may also be important in this inshore zone, but sufficient data does not exist at this time.

Pacific Herring (Clupea harengus pallasi)

Abundance of herring in the eastern Bering Sea appears to have increased since 1978 in all major coastal areas. Total spawning biomass is estimated to have ranged from 187,210 to 334,723 mt in 1978, and from 258,079 to 637,583 mt in 1979, an indicated 27% increase at the lower range (Wespestad and Barton, 1981). Studies have shown that Bristol Bay contains the largest assemblage of spawning herring within the entire State of Alaska. In 1981, about 144,000 mt of herring arrived to spawn within Bristol Bay (Fried and Skrade, 1982). Herring usually spawn in areas where the shoreline morphology includes cliffs or bluffs with large jagged outcroppings; where beaches occur in such areas, they are usually intertidal only. Spawning substrates consist primarily of rocks covered with rockweed kelp (Fucus sp.). However, almost any substrate (e.g., Laminaria sp., bare rocks, gillnets) are used under conditions of dense spawning. In northern Bristol Bay, most spawning is confined to the intertidal zone down to depths of five meters. Herring also spawn in shallow bays, beaches or slough areas where eelgrass (Zoestera sp.), and roots of rye-grass (Elymus sp.) and sedges (Carex sp.) are exposed at low tide. The main spawning areas between Ugashik Bay and Cape Newenham are in Metervik Bay and along the coast west to the village of Togiak (Barton et al, 1977; Wespestad and Barton, 1981). The majority of herring fishing by local residents in this area is for commercial purposes, although most fishermen retain a limited amount for subsistence needs. The primary onshore herring spawning areas between Ugashik Bay and Unimak Island are Herendeen Bay, Port Moller Bay, Port Heiden and, to a lesser extent, the north coast of Unimak Island (Barton et al, 1977); Wespestad and Barton, 1981).

Capelin (Mallotus villosus)

In 1976, capelin was the most geographically widespread forage fish species encountered in the eastern Bering Sea and constituted the second most abundant species (next to herring) captured at onshore stations between Ugashik Bay and Unimak Island (Barton et al, 1977). Capelin typically spawn along clean, fine gravel beaches. Barton et al (1977) and Baxter (1976) reported that the only spawning areas that capelin have been observed to utilize between Ugashik Bay and Cape Newenham occur in Togiak Bay, north of Hagemeister Strait, and around Hagemeister Island. They also were observed washed up on the beaches from Cape Krenitzen north to Smoky Point at Ugashik Bay.

Yellowfin sole (Limanda aspera)

Yellowfin sole is by far the species which most dominates the biomass of marine fishes within the nearshore zone of the North Aleutian Basin (Bakkala, 1981a). Perhaps in response to the easing of fishing pressure, fish populations have, since the mid-1970's, steadily approached and perhaps exceeded pristine stock levels. Current biomass estimates for this species are in the two to four million mt range, making it the most common flatfish found on the shelf of the eastern Bering Sea, second only to Alaska pollock in biomass (Bakkala, 1981a; McRoy and Haflinger, 1983). Yellowfin sole migrate seasonally from outer continental shelf and slope waters (>100 m) occupied in winter and early spring to inner shelf waters (15-75 m), where spawning occurs in summer (Bakkala, 1981a). The timing of spring inshore migrations is not well-defined although they have been observed starting from late April to mid-May over the three-year period 1959-61. Ice-induced delays to spring migrations are probably infrequent and of relatively short duration. Unlike the adults, the young remain in shallow nearshore nursery areas throughout their first few years of life. They begin to disperse to more offshore waters at three to five years of age.

Anadromous Fish. Included in this category are salmon and boreal smelt.

Salmon

Historically, the sockeye salmon run of inner Bristol Bay has supported the most important salmon fishery in North America (Stern et al, 1976). Though all five species of Alaskan salmon are taken commercially in the Bristol Bay region (sockeye, pink, chum, coho, and chinook), the sockeye (red) comprises an average of 86 percent of the total catch at inner Bristol Bay, and 60 percent of that along the remainder of the Alaska Peninsula Bering Sea coast. About 90 percent of the average total run is associated with five river systems (Nushagak, Kvichak-Naknek, Egegik, Ugashik, and Togiak) which empty into inner Bristol Bay (Stern et al, 1976).

The average annual catch for the region, including all five species, is about 12 million fish, ranging to as high as 32.5 million. Of this average annual total of 12 million, 10 million are sockeye.

The average total run for the period 1955-1974 was estimated at 19.6 million fish for the St. George Basin area, 18.3 million of which spawn in inner Bristol Bay. Of the average total of 19.6 million, 16.4 million are estimated to be sockeye, of which 15.7 million return to the rivers of inner Bristol Bay (Stern et al, 1976).

Runs of returning salmon fluctuate widely from year to year, ranging (all species) from an estimated 2.4 million in 1973 to 62.3 million in 1980 (Thorsteinson and Thorsteinson, 1983).

The escapement of juvenile salmon into Bristol Bay is estimated to average 582.5 million smolt, 313.3 million of which are sockeye. About 461.6 million smolt outmigrate from inner Bristol Bay each year, including 299.5 million sockeye (Stern et al, 1976).

Sockeye smolt begin their seaward outmigration from the spawning lakes about the middle of May, with dates varying according to temperature, ice, and climatic conditions (Straty and Jaenicke, 1980; Favorite et al, 1977). Smolt migrate outward from inner Bristol Bay in a belt from the coast offshore to about 48 km until they reach the vicinity of Port Moller (Figures 81 and 82), after which they swing out to sea and eventually make their way through the Aleutian passes into the North Pacific. Under normal conditions, the greatest numbers of smolt within Bristol Bay are found northeast of Port Heiden from late May through late July (Straty and Jaenicke, 1980). Juveniles generally take six months or longer to reach the North Pacific, where they remain for one to four years (Table 13) before returning to Bristol Bay. On their outward migration along the coast of the Alaska Peninsula, most sockeye smolt remain in the upper meter or two of the water column where they feed on zooplankton and smaller fishes. Preferred prey items seem to be euphausiids, copepods, cladocerans, and sandlance (Straty and Jaenicke, 1980).

The migratory route of outgoing smolt is apparently determined by salinity gradient and water temperature (Straty and Jaenicke, 1980; Favorite et al, 1977), at least during the early stages. The smolt's activity level, and thus the speed of migration, appears to be directly related to water temperature (Straty and Jaenicke, 1980). Higher temperatures result in increased activity levels, more rapid migration, and faster growth. Increased growth rates are thought to be related both to elevated feeding activity resulting from higher temperatures and to earlier arrival into the zooplankton-rich waters offshore of the Alaska Peninsula (Straty and Jaenicke, 1980).

Adult sockeye salmon re-enter the Bering Sea from the North Pacific in early May, arriving in Bristol Bay starting about mid-June and peaking between 1 and 10 July. By late July to early August all adults have entered the river systems enroute to the nursery lakes (Straty and Jaenicke, 1980).

Though the inward migration of adult salmon occurs at the same time as the outmigration of juveniles, the migration routes of the two do not, in general, overlap. Adults usually stay well offshore until within the proximity of their home rivers (Figure 83), while juveniles remain close inshore until they reach the Port Moller vicinity. Though both are thought to be responding to environmental parameters such as salinity and temperature gradients, they apparently do so in slightly different ways. It is thought (Favorite et al, 1977) that juveniles remain close to shore on their outmigration principally in response to warmer water temperatures inshore, while adults may be directed primarily by salinity gradients and olfactory and physiochemical stimuli. Whatever the reasons for this separation of migration routes, it serves to reduce competition between the two age classes for food, and probably avoids consumption of the smolt by returning adults.

Unfortunately, data are inadequate to describe in any detail the migration routes or dates for salmon species other than sockeye in the Bristol Bay region. Salmon of one species or another, however, are known to be present in the area, either as juveniles or adults, from May through at least October (Figures 83-87) and probably constitute major food resources for several species of marine mammals and birds, including beluga whale, harbor seal, and probably Steller sea lion and northern fur seal.

From the limited data available, it appears that pink salmon smolt outmigrate later than sockeye, probably

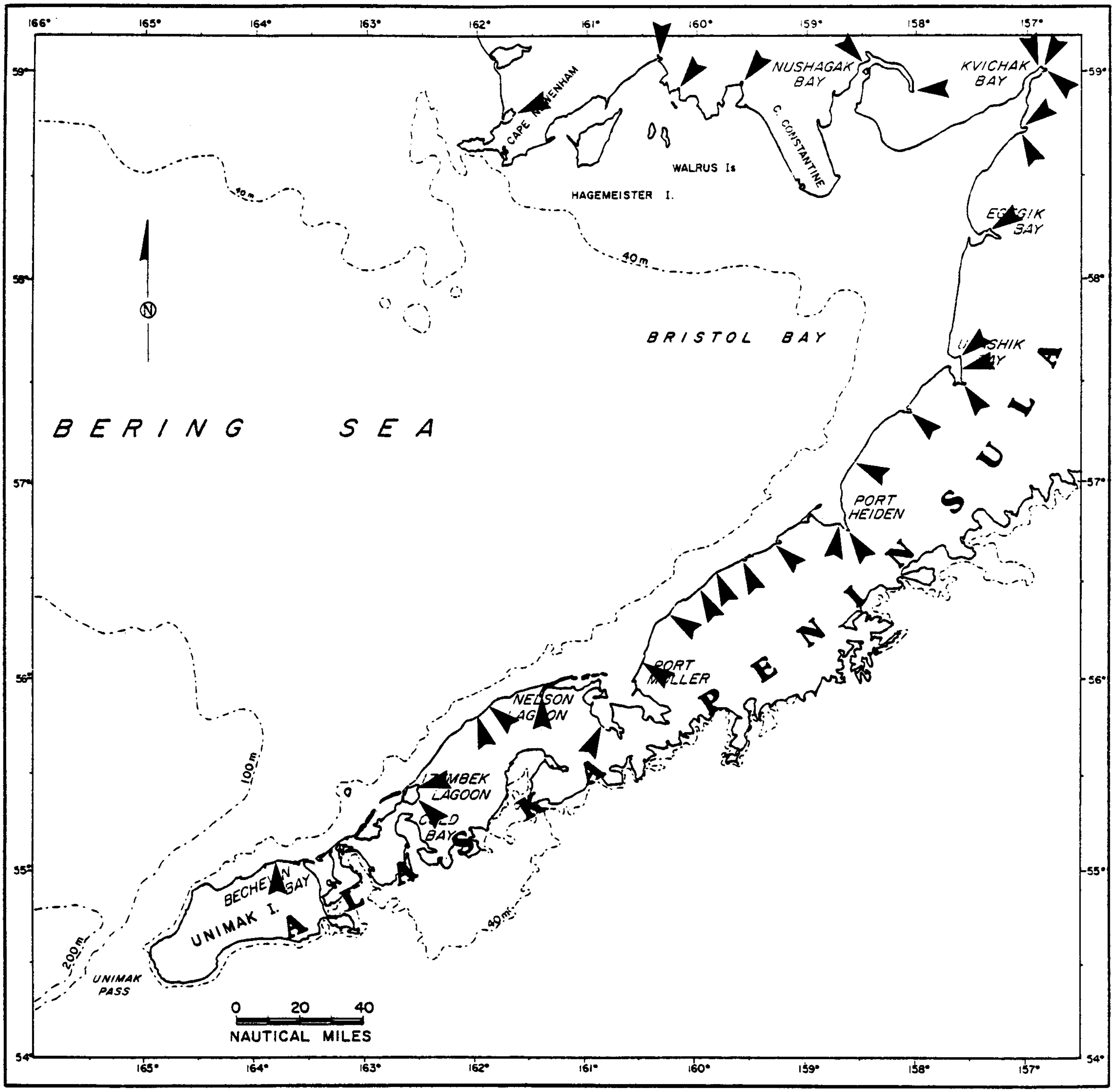


Figure 81. Locations of juvenile sockeye salmon entry into nearshore waters of the St. George Basin region (Stern et al, 1976).

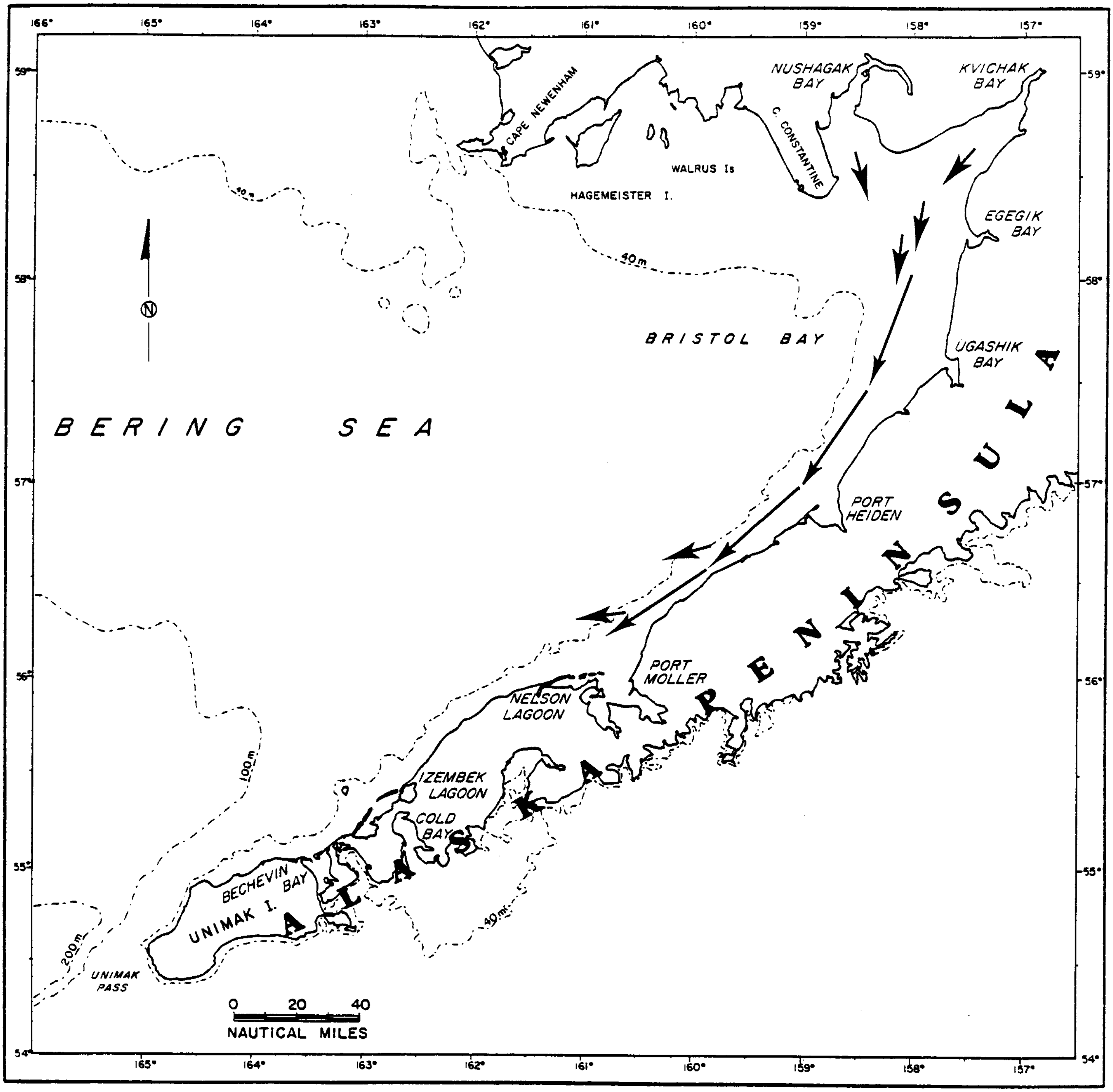


Figure 82. The migration route of juvenile salmon in coastal waters of the St. George Basin region as determined by experimental fishing (Stern et al, 1976).

Table 13. Summary of general life history features of salmonids in Alaska

Species	Fresh-water habitat	Duration of time in freshwater as juvenile	Duration of time in marine habitat (years)	Year of life at spawning	Average weight (pounds)	Average fecundity (eggs)
Pink	Short coastal streams	Less than one day	2	2	4.0	2,000
Chum	Short coastal streams and major rivers	Less than one month	2-6	3-7	8.0	3,000
Sockeye	Short streams and lakes	12-36 months	1-4	3-8	6.0	3,500
Coho	Short coastal streams, lakes and tributaries of major rivers	12-24 months	0-2	2-4	9.0	3,500
Chinook	Major rivers	3-12 months	1-6	2-8	20.0	4,000
Sea-run cutthroat	Short coastal streams	12-14 months	1-3	2-10	2.5	800
Steelhead	Short and long streams	12-48 months	1-5	2-7	8.0	8,000
Pacific char	Short streams	36-48 months	2-3	5-6	2.0	2,000

Sources: Sterns et al,(1976),p 63.

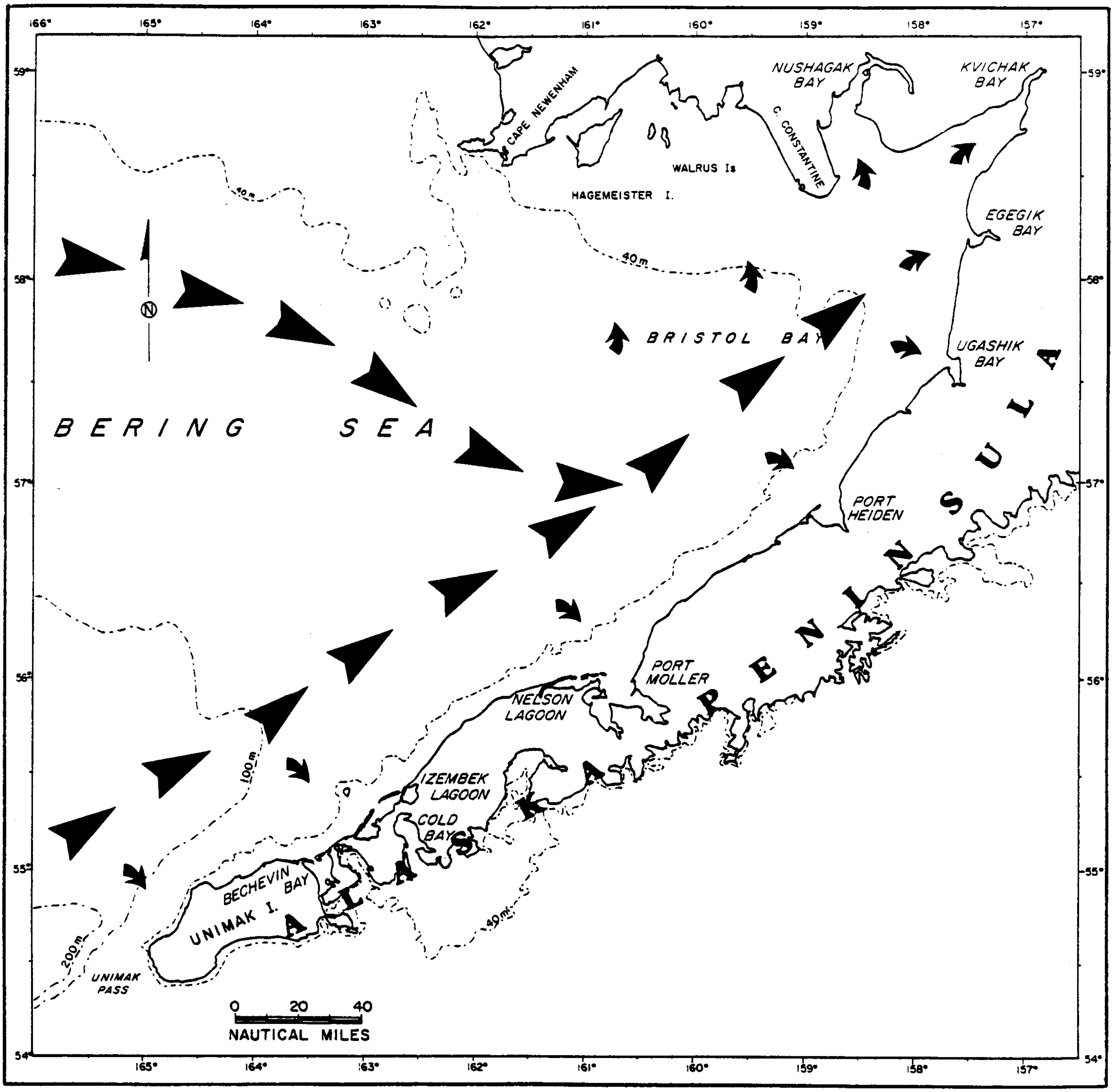


Figure 83. Migration routes of sockeye salmon bound for spawning grounds in northern Alaska (Stern et al, 1976).

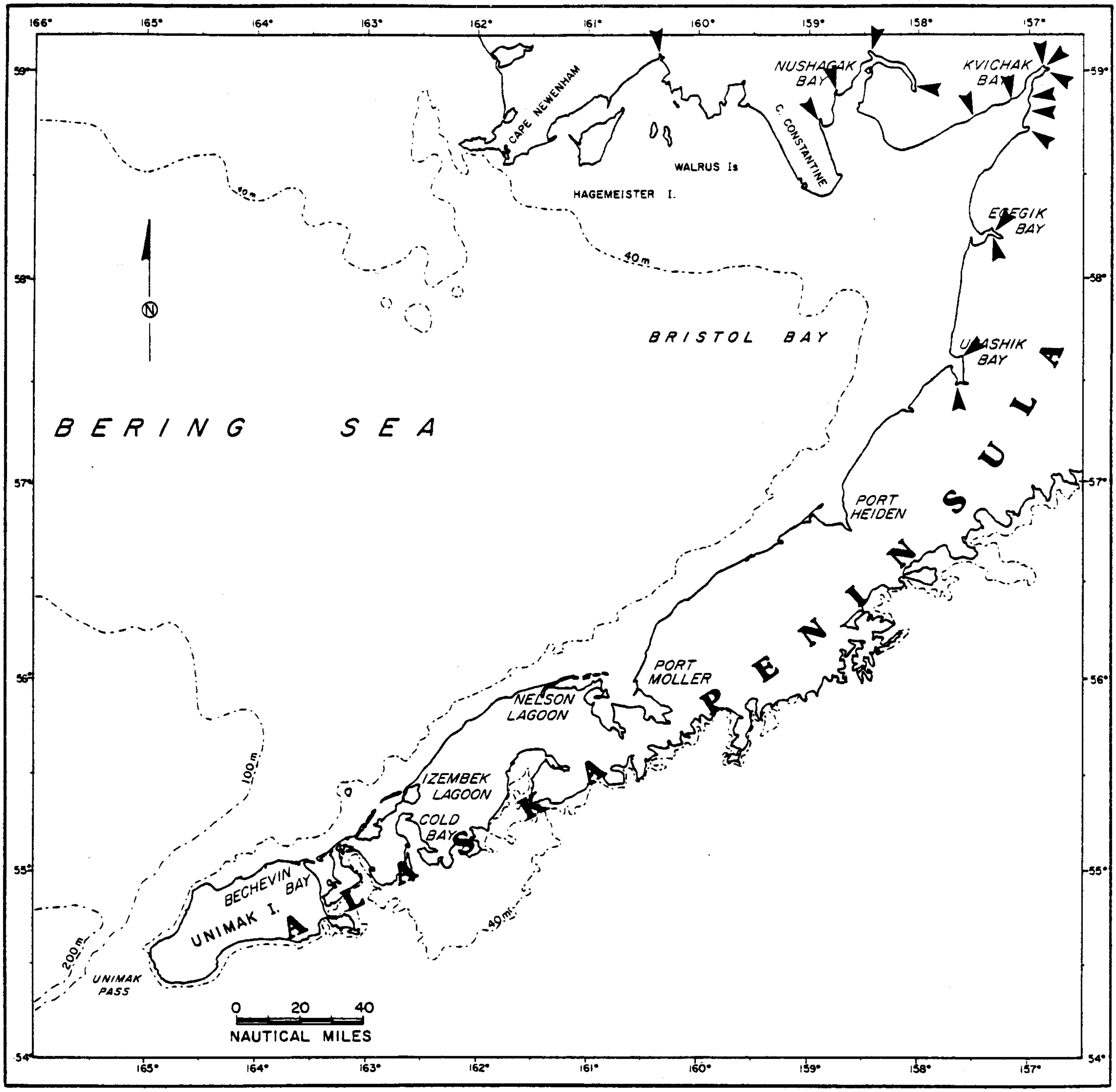


Figure 84. Locations of juvenile pink salmon entry into nearshore waters of the St. George Basin region (Stern et al, 1976).

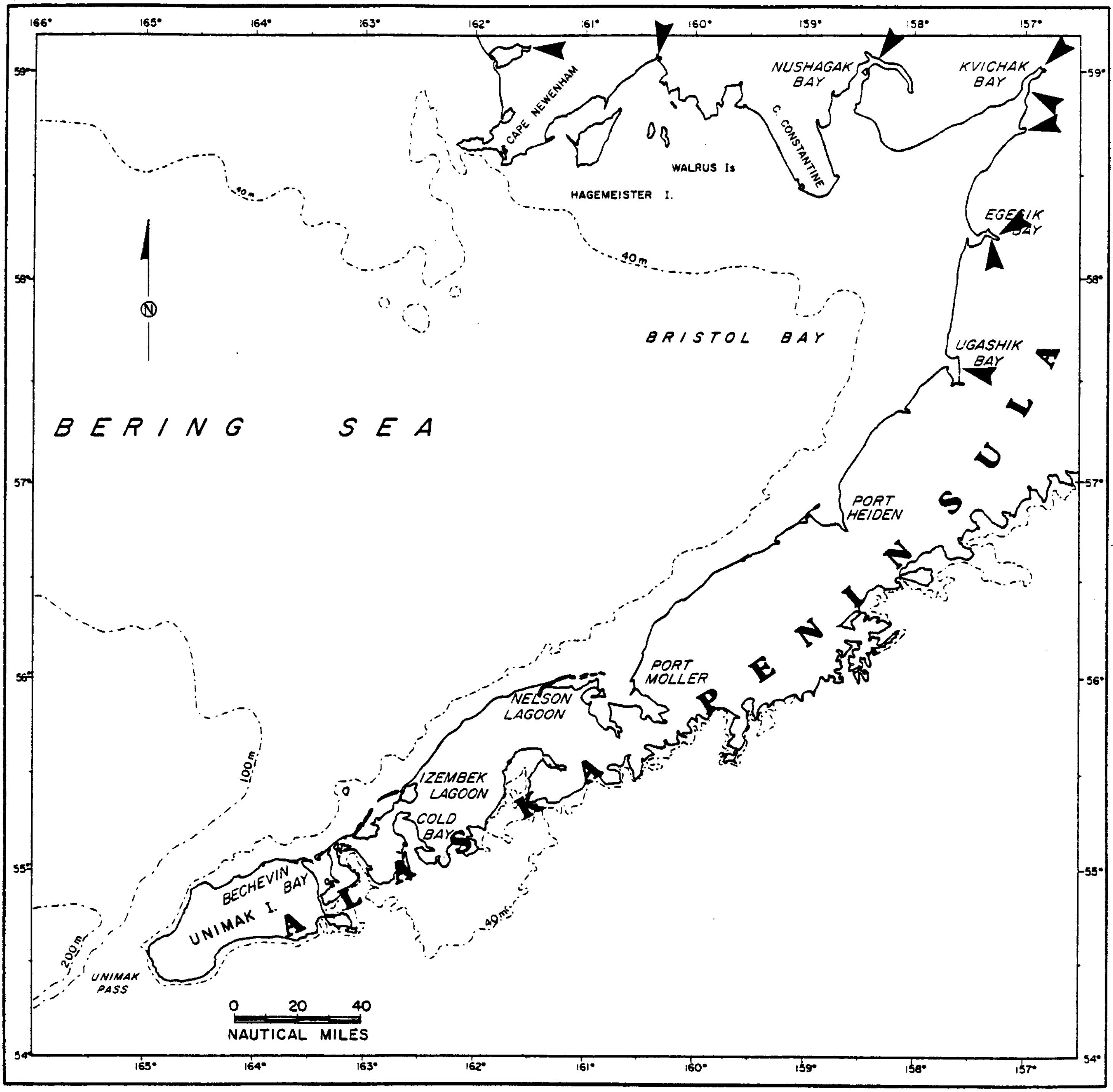


Figure 85. Locations of juvenile coho salmon entry into nearshore waters of the St. George Basin region (Stern et al, 1976).

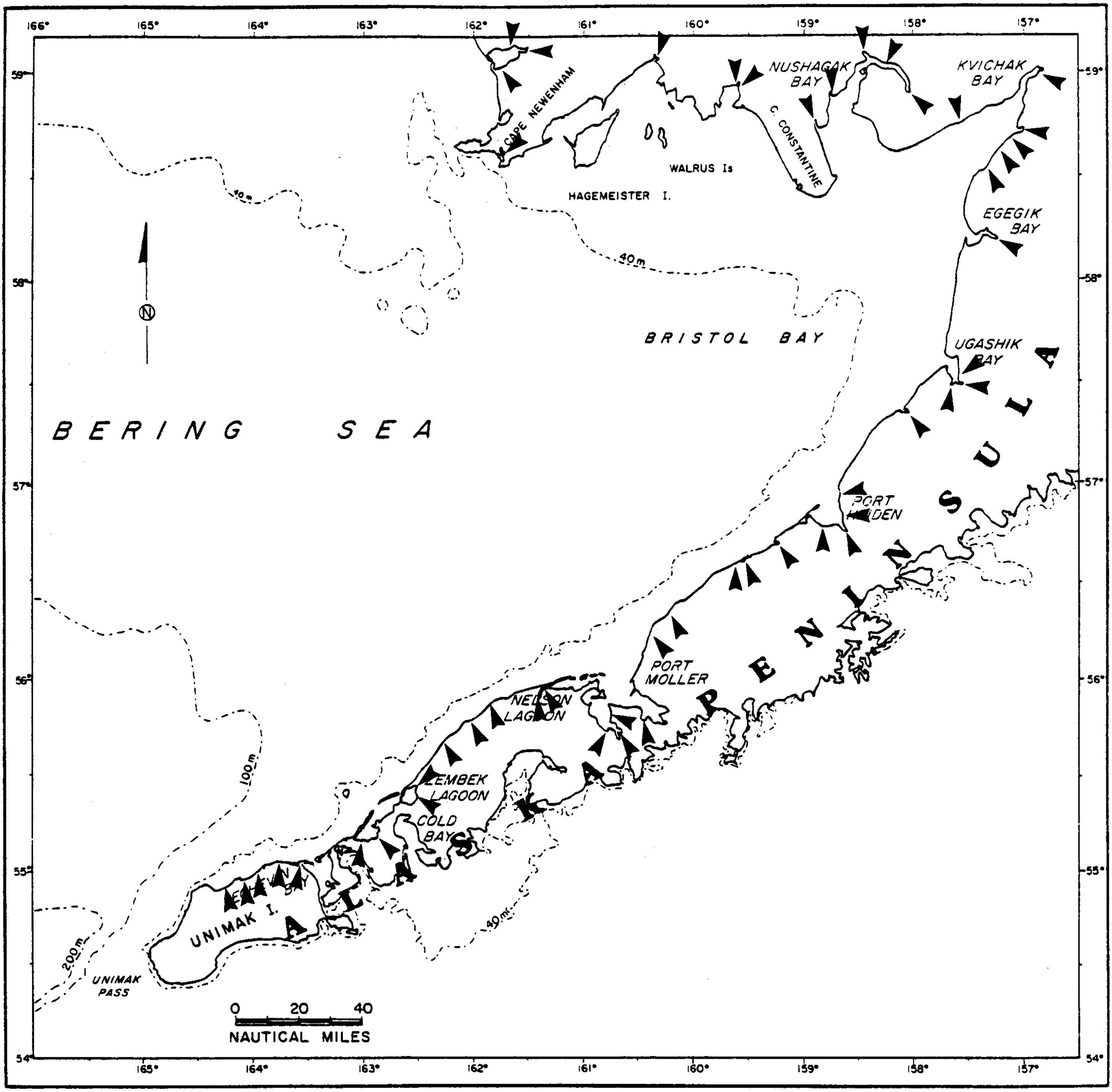


Figure 86. Locations of juvenile chum salmon entry into nearshore waters of the St. George Basin region (Stern et al, 1976).

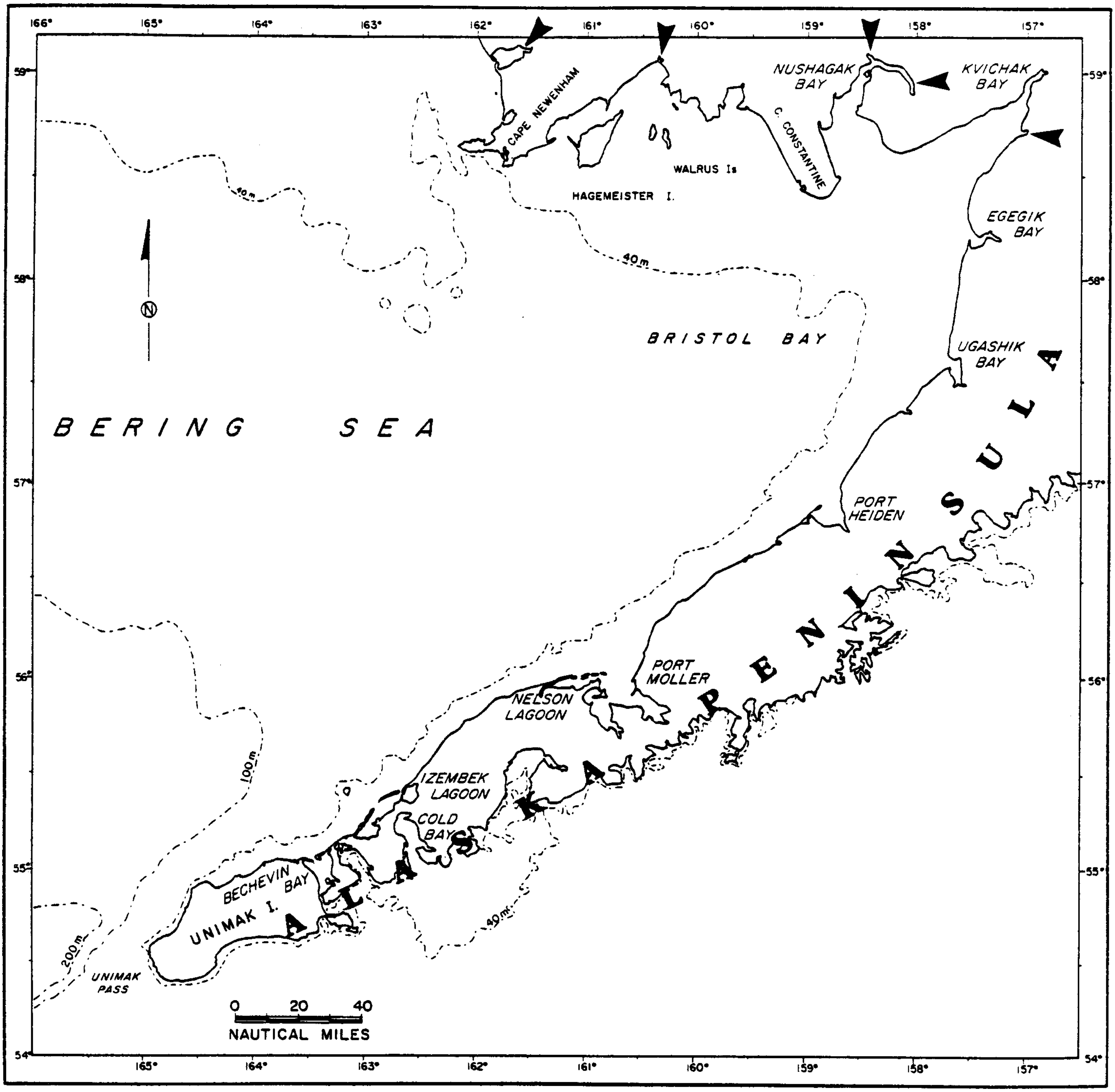


Figure 87. Locations of juvenile chinook salmon entry into nearshore waters of the St. George Basin region (Stern et al, 1976).

entering Bristol Bay waters from late June through mid-August (Thorsteinson and Thorsteinson, 1983). Chinook smolt, on the other hand, outmigrate earlier than sockeye, probably during May and early June. It also seems likely, from experimental fishing results (Thorsteinson and Thorsteinson, 1983), that chinook juveniles move offshore faster than other species and vacate the Bristol Bay-Aleutian Shelf area earlier.

Coho are probably the last species of salmon to outmigrate into Bristol Bay. Although they are recorded from the bay as early as mid-June, they do not become abundant in the nearshore waters until late June or early July and remain throughout August or even September (Thorsteinson and Thorsteinson, 1983).

In the case of returning adult salmon, chinook enter the Bristol Bay region earliest, followed by sockeye, summer chum, pink, fall chum, and finally coho. Adults seem to migrate in a belt extending 162 km offshore along the southeastern Bering Sea coast (Thorsteinson and Thorsteinson, 1983). Chinook begin entering the area in mid-to late May, with coho arriving last in mid-to late July.

Boreal Smelt

In addition to the various salmon species, large numbers of boreal (rainbow) smelt spawn in the rivers of inner Bristol Bay. Smelt seem to prefer rivers with large estuary systems, and probably do not venture far from these estuaries (Warner and Shafford, 1981). In the Port Heiden area they are considered to be the most common forage fish (smelt, herring, capelin, eulachon), and, though not fished commercially, are important for subsistence use by local residents (Barton et al, 1977).

Smelt normally spawn when two or three years old, and may spawn for several consecutive years. In most regions they overwinter upstream and spawn in tributaries soon after breakup, then migrate down to the estuaries to feed until autumn (Warner and Shafford, 1981). There are some indications, however, that in the Port Heiden area smelt remain year-round in the estuary, moving upstream to spawn during the day and back into the estuary at night (Barton et al, 1977).

Avifauna. The northern coast of the Alaska Peninsula and Bristol Bay region is recognized as an area of major or critical importance to numerous species of marine birds, waterfowl, and shorebirds. In the case of waterfowl and shorebirds, the region is used primarily for staging and foraging habitat during the spring and fall migrations to and from the nesting areas and, in some cases, as overwintering habitat. The most heavily used habitats for waterfowl and shorebirds are the lagoons and estuaries along the north coast of the Alaska Peninsula, some of which are considered critical as staging, moulting, and foraging areas. Gill and Handel (1981), consider the northern coast of the Alaska Peninsula to be the most extensive and diverse expanse of intertidal shorebird habitat along the Pacific coast of the Americas.

The region also provides important nesting habitat and summer food resources for very large numbers of seabirds. The primary nesting habitats for seabirds occur in the Cape Newenham and Cape Peirce vicinity, Amak Island, the islands of northern Bristol Bay, and some of the lagoons and promontories of the Alaska Peninsula. Feeding seabirds (especially shearwaters, kittiwakes, and murres) seem to rely heavily on the nearshore zone (less than 50 meters depth) of Bristol Bay and the Alaska Peninsula-northern Aleutian shelf, and on the oceanic front associated with the shelf break.

Seabirds

Seabirds rely very heavily on the Bristol Bay and Alaska Peninsula area both for feeding and nesting. During the summer, very dense populations of birds, particularly short-tailed shearwaters, common murres, and blacklegged kittiwakes, occupy the shelf and nearshore zone of Bristol Bay and the Alaska Peninsula (Figure 88). The highest concentrations of seabirds are found in Bristol Bay and along the Peninsula from June through October, with high concentrations remaining in the vicinity of Unimak Pass all year (Gould et al, 1982; Lensink and Bartonek, 1976). During summer, the most common birds in the area are short-tailed shearwaters, followed by common murres and black-legged kittiwakes. During fall and winter, common murres are numerically dominant. Northern fulmars and storm petrels are common in Unimak Pass and along the shelf break, but do not appear to frequent the nearshore shelf of Bristol Bay or the Peninsula in large numbers (Hunt et al, 1981c).

The total population of seabirds in the eastern Bering Sea is estimated at over 50 million birds (Hunt et al, 1981c). Estimates of species populations vary considerably. Hunt et al (1981c) estimate the shearwater population of the eastern Bering, during summer, to be at least 9 million birds, and feel that it may average as high as 20 million. Pelagic murre populations on the eastern Bering Shelf (common and thick-billed) are estimated at 5 million during summer and 2.5 million during fall by Hunt et al (1981c), while Sowls et al (1978) estimate a breeding population of 7.3 million. Conversely, Sowls et al (1978) estimate the breeding population of black-legged kittiwakes at 1.1 million, while Hunt et al (1981c) estimate a pelagic population (summer) of 2 to 3 million. Populations of tufted puffins in the eastern Bering Sea in summer are generally

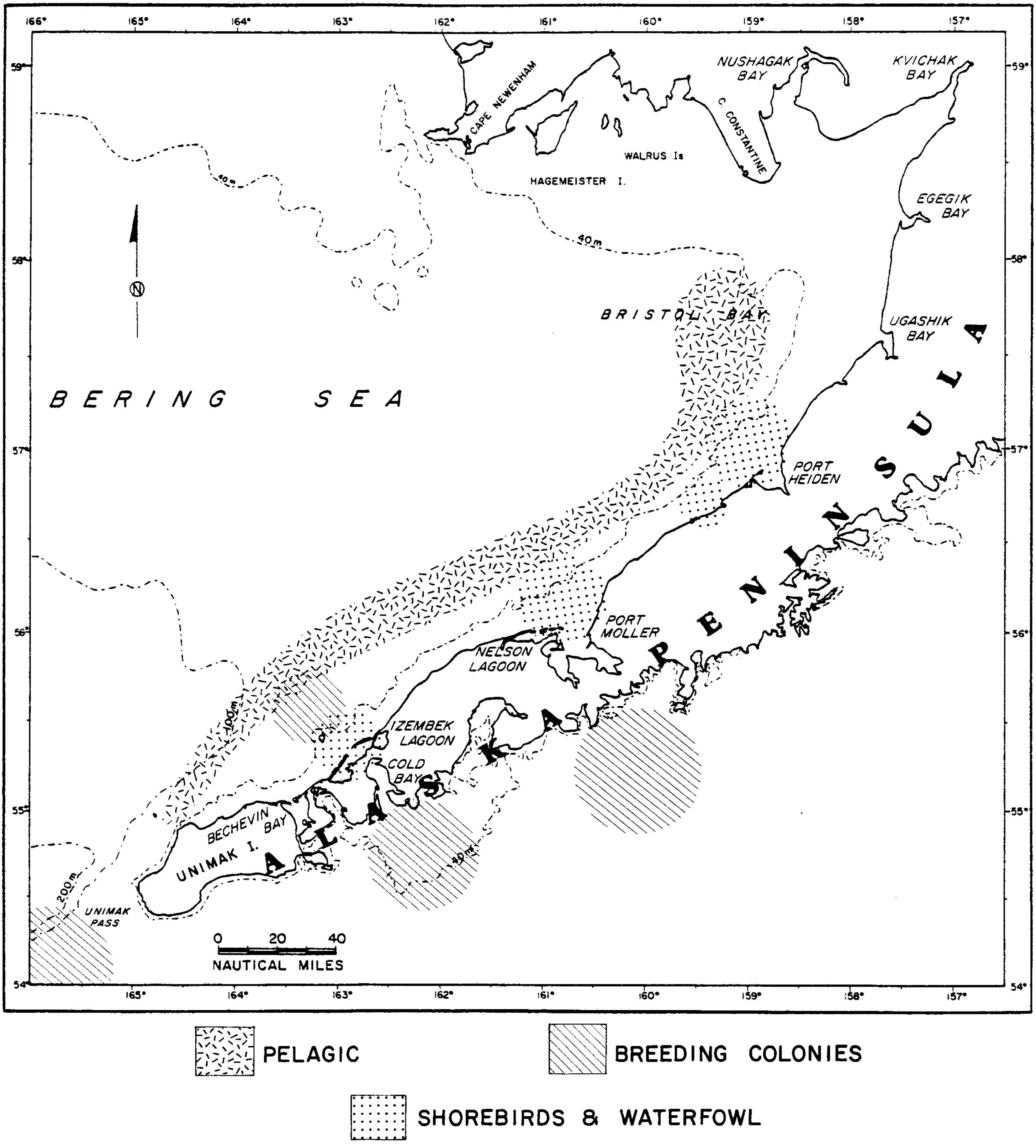


Figure 88. Generalized distribution and location of breeding areas for seabirds, shorebirds, and waterfowl of the North Aleutian Shelf (L.K. Thorsteinson ed, 1983 draft).

estimated to be about 1.5 to 1.7 million birds, horned puffins about 350,000 birds, and glaucous-winged gulls about 250,000 birds (Hunt et al, 1981c; Sowls et al, 1978).

Most breeding populations of seabirds in the Bristol Bay-Alaska Peninsula region are concentrated within large colonies in a few specific locations. This is particularly true of cliff-nesting species such as murres and kittiwakes, which are concentrated primarily on Cape Newenham, Cape Peirce, the islands of northern Bristol Bay, Amak Island, and a few minor locations on Unimak Island and along the Alaska Peninsula coast (Figure 89). It is estimated that at least one million common murres and between 300,000 and 500,000 black-legged kittiwakes, along with lesser numbers of at least eleven other species of seabirds, nest in this region (Sowls et al, 1978; Bartonek and Sealy, 1979). Trapp (1979) ranks the Cape Peirce colony as the eleventh most important seabird colony in the state, while the Walrus Island complex is ranked fifteenth and Amak Island sixteenth in importance. All in all, some 45 species of seabirds use the region for nesting, feeding, or migration (Hunt et al, 1981c).

Though dates are probably variable, most of the cliff-nesting species seem to lay from mid-May to early June, with the young fledging in late August or early September (Petersen and Sigman, 1977). Reproductive success seems strongly dependent on weather, particularly for surface-feeding species such as kittiwakes. Adverse weather during the spring and early summer not only results in destruction of the nests, eggs and young, but can curtail feeding activity to a serious degree (Hunt et al, 1981b; Threlfall et al, 1974).

In addition to cliff-nesting species, large nesting concentrations of glaucous-winged gulls occur in the Port Moller vicinity. Sowls et al (1978) estimate this nesting population at 13,000 to 14,000, one of the largest gull nesting colonies in the eastern Bering Sea.

Though the food preferences of seabirds vary somewhat from area to area, within each given area usually only a few species constitute the vast bulk of prey consumed. In general, fish (especially walleye pollock) form the mainstay of seabird diets (70% total), followed by euphausiids, squid, amphipods, and other crustaceans. The total consumption by seabirds in the eastern Bering Sea is estimated to be between 550,000 and 1,200,000 metric tons per year, including about one-half as much walleye pollock as are landed each year (in the form of adults) by commercial fisheries (Hunt et al, 1981a). In general, shearwaters seem to prefer euphausiids, followed by amphipods, squid, and fish, while murres feed primarily on fish (especially pollock), supplemented by some euphausiids, amphipods, and squid. Blacklegged kittiwakes are seasonally variable in

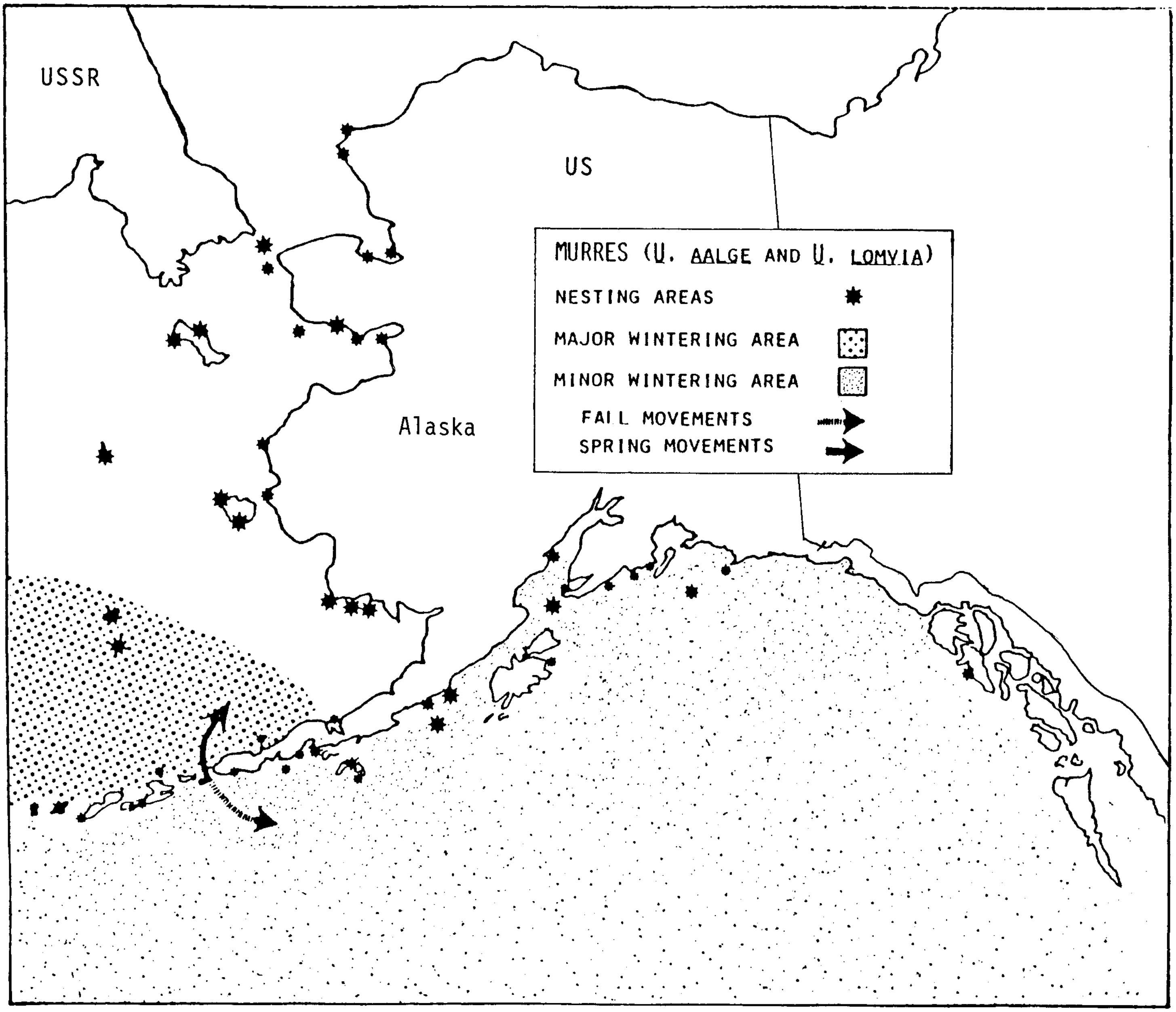


Figure 89. Breeding and winter distribution of murres in Alaska (Gill et al, 1979).

their food preferences, but eat primarily fish (especially pollock), along with some euphausiids and amphipods. Both murres and kittiwakes, and even more particularly arctic terns, are known to feed heavily on juvenile salmon in the region during certain times (Hunt et al, 1981a; Flock, 1932).

Populations of seabirds within this region, particularly cliff-nesting species, are probably limited either by habitat availability, by food resources, or by both (Hunt et al, 1981a). It seems that productivity levels and stability within colonies is dependent primarily on the availability, stability, and diversity of food resources. These factors are, in turn, dependent to a large degree on weather and oceanic conditions. For instance, in April of 1970 a massive die-off of common murres was observed along the coast of the Alaska Peninsula and Unimak Island. First attributed to an unreported oil spill, the mass mortality was later assigned to starvation resulting from adverse weather conditions (Bailey and Davenport, 1972). Surface feeders, such as kittiwakes, fulmars, and petrels, are probably more subject to feeding limitations caused by adverse weather and are thus more prone to reproductive failure than are subsurface feeders such as murres, auklets, puffins, and shearwaters.

In general, seabird distributions within the region are the result of complex interactions between biotic and abiotic factors, including extent and duration of ice cover, oceanographic frontal systems, regional weather patterns, availability of nesting habitat, and food availability.

Shorebirds

The intertidal zone of the Alaska Peninsula and Bristol Bay is used to varying degrees by shorebirds as foraging habitat on the spring migration when en route to summer nesting grounds, as post-nesting feeding grounds, and as staging grounds during the fall migration. In most cases, however, use by shorebirds of this region is less intense in terms of both numbers and duration of occupancy during the spring migration than later in the season, after nesting is completed (Gill and Handel, 1981). Species most commonly encountered in this region during the spring migration are rock sandpipers, bar-tailed godwits, red knots, American golden plovers, and black-bellied plovers (Gill and Jorgensen, 1979; Gill and Handel, 1981; Gill et al, 1981; Figure 90). Upon completion of this brief spring migration period (mid-April to late May for most species), shorebirds generally move onto the inland breeding grounds and do not return to intertidal areas until after nesting is over.

The coastal fringe of the southeastern Bering Sea is an important nesting habitat for at least eight species of

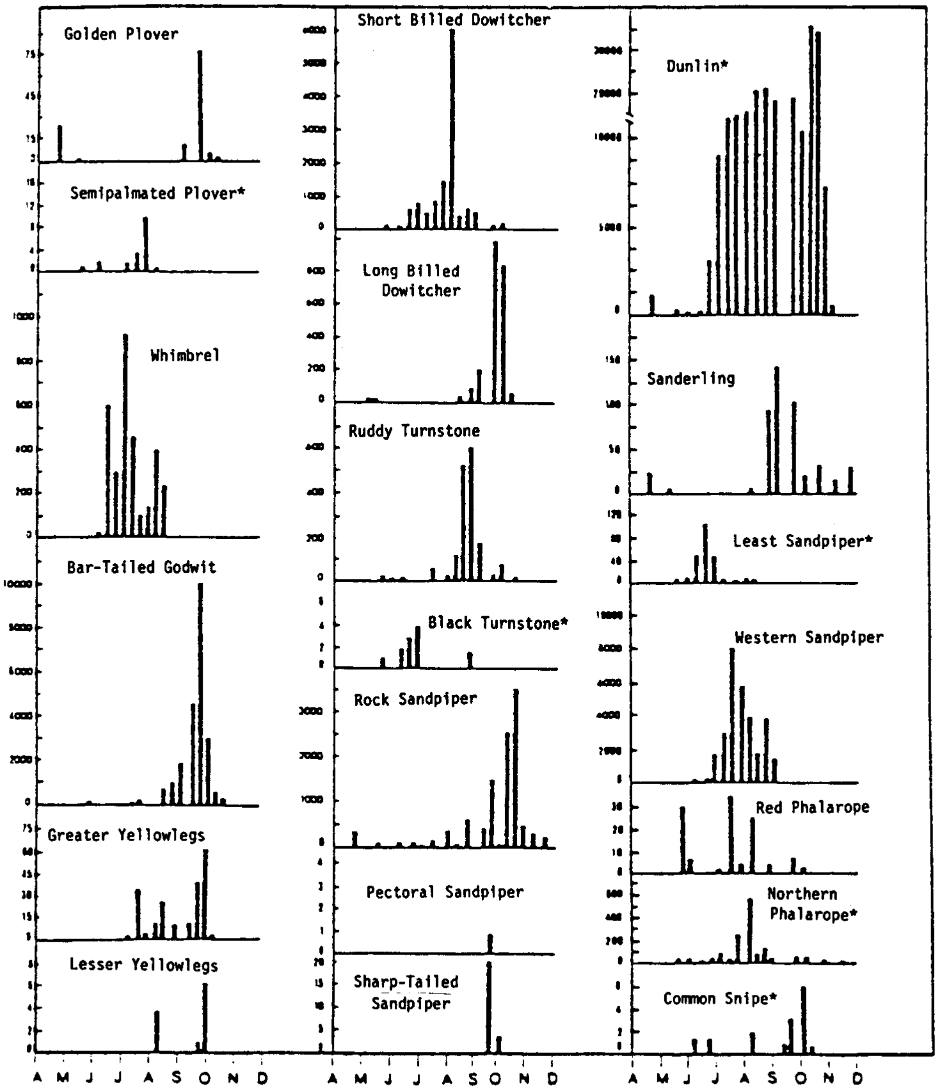


Figure 90. Comparative temporal abundance of 20 shorebird species at Nelson Lagoon, 22 April - 1 December 1976. Species histograms incorporate aerial as well as ground census data obtained prior to migratory buildups beginning in late June. Numbers prior to 1 July do not necessarily reflect overall shorebird use of the study area but do accurately reflect timing of migratory buildups. Species noted by an asterisk nested on the study area (Gill and Jorgensen, 1979).

shorebirds: semi-palmated plover, black turnstone, long and short-billed dowitcher, red and northern phalarope, semi-palmated sandpiper, and dunlin. The principal nesting grounds, in terms of numbers of birds, is the Yukon Delta, though some nesting occurs throughout the Bristol Bay and Alaska Peninsula region as well (Gill and Handel, 1981).

Upon completion of nesting, shorebirds generally move back into the intertidal foraging habitats. Again, the Yukon-Kuskokwim Delta is probably the most heavily occupied area, though the bays and estuaries of the Alaska Peninsula also support sizeable shorebird post-nesting populations (Gill and Handel, 1981). On the other hand, for reasons unknown, the extensive intertidal zones of northern Bristol Bay are used only slightly.

The post-breeding and fall migration occupancy by shorebirds of the intertidal zone of the region is much more intense and protracted than that occurring in the spring, often lasting from late June through September for many species. There is a major buildup of western sandpipers along the Alaska Peninsula coast in July and August, followed in September by an even larger buildup of dunlins. Some species, including dunlin, often remain in the area until mid-or even late October (Gill and Handel, 1981).

Some 30 species of shorebirds are known to occupy the area seasonally (Gill and Handel, 1981). Studies by Gill and Jorgensen (1979) indicate that about 326,000 shorebirds occupy the Nelson Lagoon area between July and December, of which roughly 80% (260,000) are dunlin. Other species of importance using this Nelson Lagoon area are western sandpiper (36,000), bar-tailed godwit (13,000), and short-billed dowitcher (8,600).

Other than Nelson Lagoon, the most important areas in the Bristol Bay-Alaska Peninsula region for shorebird habitat are Bechevin Bay, Izembek Lagoon, and Port Heiden. The Nelson Lagoon-Herendeen Bay-Port Moller complex is estimated to contain 44% (540 km^2) of the total estuarine habitat of the region (Gill and Jorgensen, 1979).

Unlike most marine birds, shorebirds generally do not follow along the coast and through Unimak Pass on their migrations to and from the region, but instead cross the Alaska Peninsula (Gill and Jorgensen, 1979).

Waterfowl

Some 33 species of waterfowl are known to frequent the Bristol Bay-Alaska Peninsula region. Seventeen of these are considered to be non-breeders in this area, another 16 are known or probable breeders (Gill et al, 1981). In general, however, most use of the region by waterfowl is for staging, moulting, and foraging during spring and fall migrations, and for wintering areas (King and Dau, 1981).

Principal habitats used for staging and foraging are, as with shorebirds, the lagoons and estuaries along the north side of the Alaska Peninsula. Waterfowl are most abundant in these lagoons and estuaries from August through October, during the fall migration.

An area of particular importance for this fall staging and migration is Izembek Lagoon, which seasonally supports the entire world's population of black brant (about 150-200,000), as well as large numbers of emperor geese, Steller's eiders, and Canada geese (U.S. Fish and Wildlife Service, 1980).

Most or all of the west-coast populations of several species, including black brant, emperor goose, red-throated loon, king and Steller's eiders, and cackling Canada goose migrate through the region during spring and fall (Petersen and Sigman, 1977; Petersen and Gill, 1982; Petersen, 1983; King and Dau, 1981), as well as large numbers of common eider, black scoter, common goldeneye, harlequin duck, greater scaup, green-winged teal, widgeon, oldsquaw, pintail, and red-breasted merganser (Petersen and Sigman, 1977).

The spring migration, of relatively short duration, normally occurs in April and May for most waterfowl species of the area. Peak concentrations of Steller's eider occur in April at Nelson Lagoon, Izembek Lagoon, and Bechevin Bay (Jones, 1965; Petersen, 1980). At Nelson Lagoon large numbers of king eider, common scoter, and oldsquaw are also present in April, as are black brant at Izembek and emperor geese at Izembek and Bechevin Bay (Jones, 1965; U.S. Fish and Wildlife Service, 1981; Gill et al, 1981). Somewhat further north, in the Cape Peirce area, spring migrations of black brant, emperor geese, and king and Steller's eider occur slightly later, in May and early June (Petersen and Sigman, 1977).

The fall migration, which is more protracted, lasts from August through October in most areas. At Izembek, black brant normally arrive sometime in September or early October, after molting, and remain in the area feeding on eelgrass until late October or early November (Jones, 1970; U.S. Fish and Wildlife Service, 1981). Some 10,000 brant normally overwinter at Izembek (U.S. Fish and Wildlife Service, 1982). At Nelson Lagoon, approximately 53,000 subadult Steller's eiders arrived in early August of 1977, with about the same number of adults arriving in late September (Petersen, 1980). In normal years, Steller's eiders molt in Nelson Lagoon and other lagoons and estuaries of the Alaska Peninsula, departing in October (Petersen, 1980; Jones, 1965), though Jones (1965) reports that in some years the birds do not arrive until after the molt, as late as November. Petersen (1980) reports that at Nelson Lagoon almost all of the diet of Steller's eiders is made up of 0-1 year class mussels (Mytilus edulis) and amphipods (Anisogammarus pugettensis).

While most waterfowl depart the area in October or November, the open-water areas of Bristol Bay, the Alaska Peninsula coast, and Unimak Island are important wintering habitats for several species, including king and Steller's eider, scoters, scaup, and oldsquaw (Harrison, 1977; Lensink et al, 1976; F.H. Fay, personal communication). In addition, the primary wintering grounds of the whistling swan in the lease area is on Unimak Island, particularly at Peterson Lagoon and Otter Point (U.S. Fish and Wildlife Service, 1981 and 1982).

In the case of both waterfowl and shorebirds it should be noted that, although virtually all of the lagoons and estuaries of the Alaska Peninsula support considerable numbers of birds during the spring and fall migrations and, in some cases, during the winter months, the habitats, food resources, and consequent avifaunal compositions are quite variable from one locale to another, making extrapolation of findings from area to area difficult to perform with any degree of confidence (Gill et al, 1978).

Marine Mammals. Though some 25 species of marine mammals are known to frequent the southeastern Bering Sea and Bristol Bay region upon occasion (Lowry et al, 1982), less than half this number can be considered major species in terms of abundance or trophic interaction within the nearshore zone. For these species, however, the Bristol Bay and northeastern Aleutian area constitutes important, if not critical, habitat in terms of food resources, hauling and breeding grounds, and migration routes. Species of particular importance or concern within the nearshore zone are harbor seal, Steller sea lion, Pacific walrus, sea otter, gray whale, and belukha whale. The following presentation is a synopsis of available information relating to population size and stability, seasonal and areal distribution, life history, and food preferences of these species. Ranges of marine mammal prey items and residence times of marine mammals in Bristol Bay are summarized in Figures 91 and 92.

Harbor Seal (Phoca vitulina)

This is certainly the most abundant marine mammal within the nearshore zone of the region, with conservative population estimates of 28,000 to 30,000 animals based on aerial counts at major hauling grounds (Everitt and Krogman, 1979; Everitt and Braham, 1980). There is some feeling that this population may have been significantly underestimated using these methods, and that the actual population could be as high as 60,000 (F.H. Fay, personal communication). If

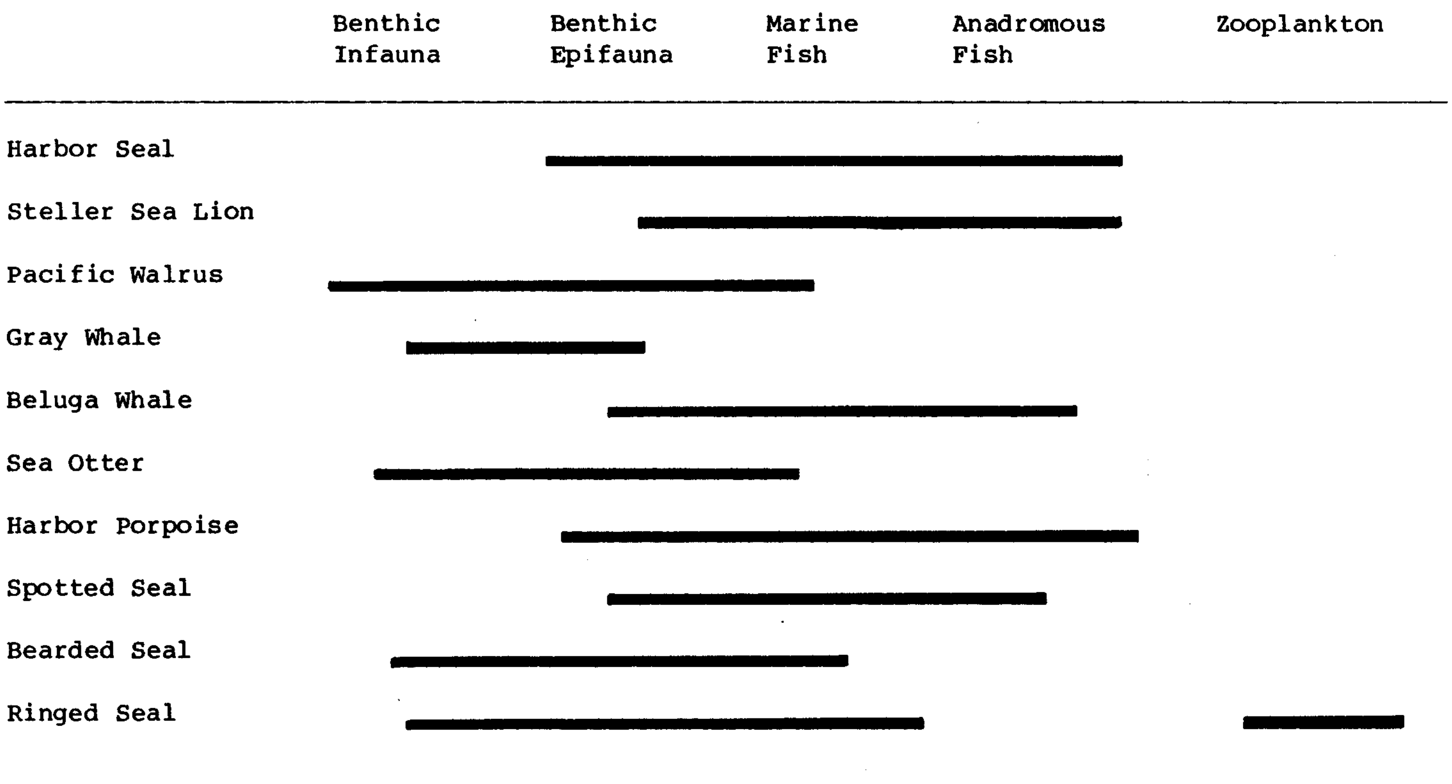


Figure 91 Ranges of prey items consumed by major marine mammal species of the Bristol Bay-northern Aleutian region.

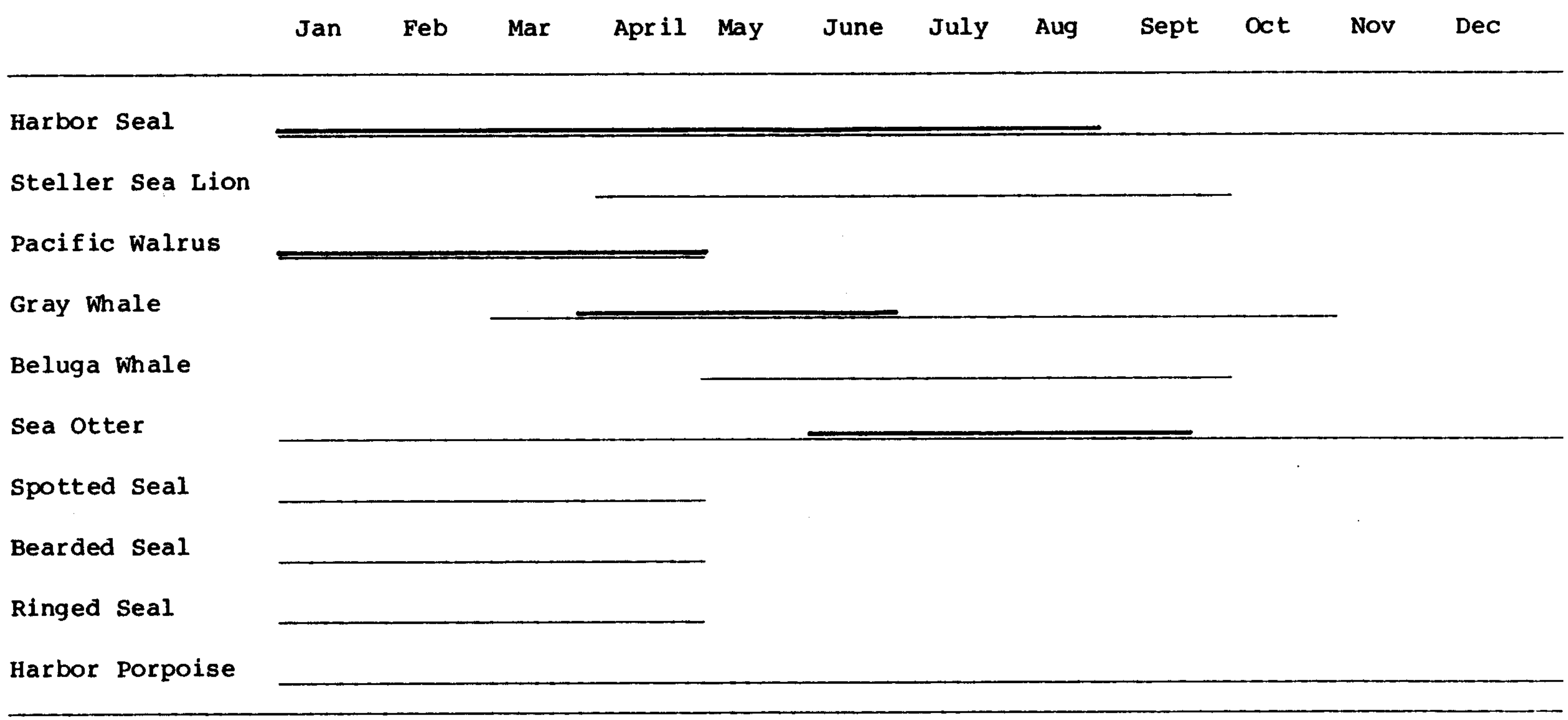


Figure 92 Residence times of major marine mammal species in the Bristol Bay - northern Aleutian area. Double horizontal lines indicate periods of peak populations in normal years.

Table 14. Concentration areas of harbor seals on the north side of the Alaska Peninsula, with highest total sighted at each location by Everitt and Braham (1980) from 1975-77.

Reference no.	Location name	Highest count
1	Egegik Bay	70
2	Ugashik Bay	438
3	Cinder River	4,503
4	North Point Heiden	48
5	Point Heiden	10,548
6	Seal Islands	1,137
7	Cape Seniavin	71
8	Port Moller	7,968
9	Cape Leiskof	199
10	Izembek Lagoon	2,034
11	Izanotski Islands	511
12	Amak Island	61

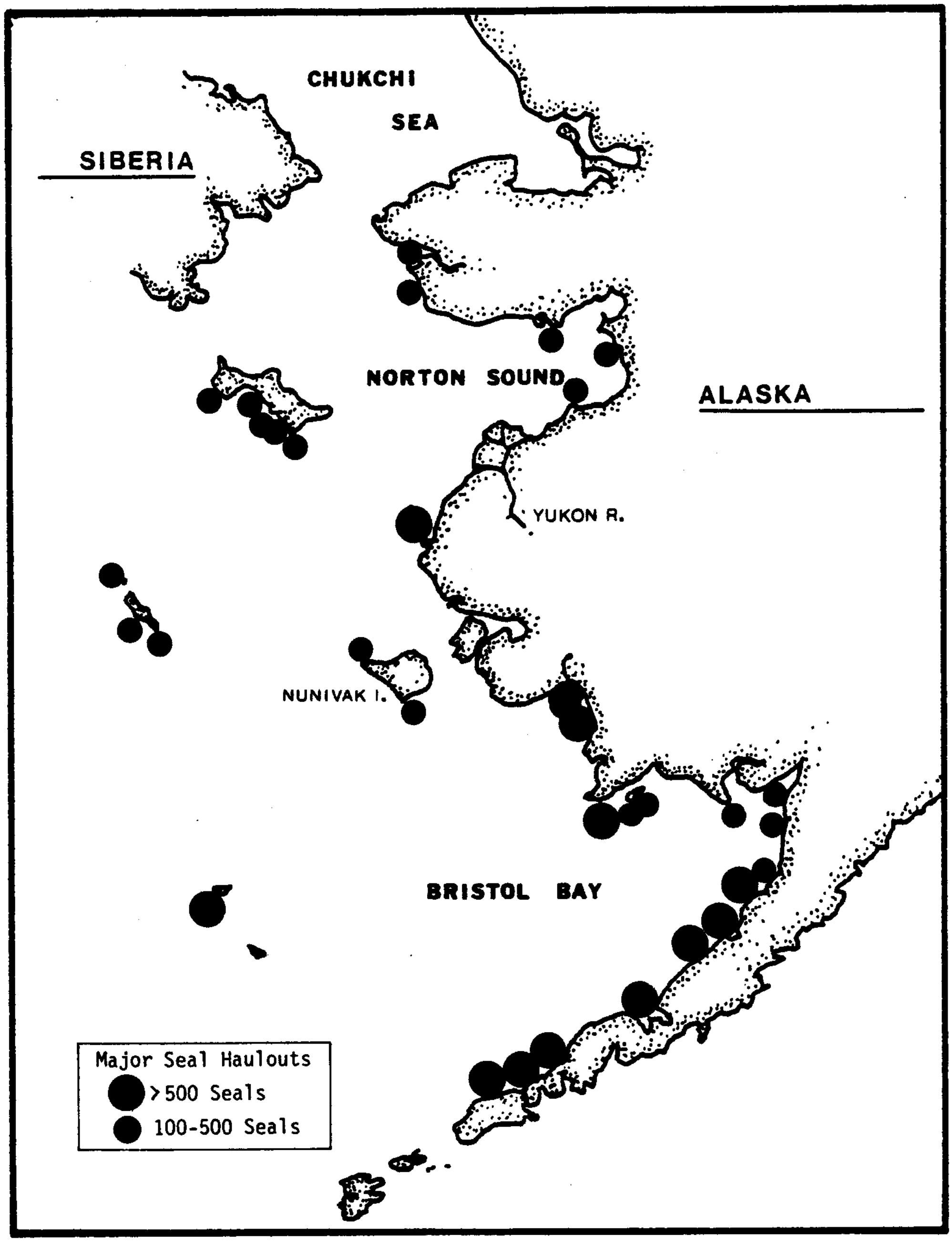


Figure 93. Map of the eastern Bering Sea showing major haulouts used by harbor and spotted seals. Large dots represent areas with maximum reported numbers of greater than 500 seals. Small dots represent haulouts of 100 - 500 seals (Frost et al, 1982).

the lower estimate of 28,000 to 30,000 is adhered to, then this Bristol Bay population of harbor seals constitutes roughly 15 percent of the total estimate for Alaskan waters (Everitt and Braham, 1980). Though little is known about the stability of this Bristol Bay population, there are some indications, again based on counts at the summer hauling grounds, that it may have declined somewhat in recent years (U.S. Fish and Wildlife Service, 1982).

Though harbor seals are ubiquitous throughout the region, approximately 80 percent of the animals counted during aerial surveys were observed at three hauling sites - Port Moller, Port Heiden, and Cinder River (Table 14). Other major hauling sites (Figure 93) along the north side of the Alaska Peninsula are Egegik Bay, Ugashik Bay, Seal Islands, Izembek Lagoon, and Bechevin Bay (Braham et al, 1977; Everitt and Braham, 1980). Though data for winter months are generally lacking, the assumption is that the population disperses somewhat with the onset of winter ice. Some of the animals may shift southward into the Aleutian Islands and even the North Pacific, while others appear to move into the fringe ice where they intermingle with seasonal (winter) populations of the closely related spotted seal (F.H. Fay, personal communication).

Harbor seals pup on the beaches of Bristol Bay in June and July, and nurse for a period of from 3 to 6 weeks (Lowry et al, 1982). During this period the pups normally double in weight. As described by Johnson (1977), this is a somewhat critical period in that disturbance, particularly from low-flying aircraft, frequently results in separation of mothers and pups and starvation of the latter.

Harbor seals continue to grow rapidly after weaning, though at a reduced rate, until approximately ten years old. Average adult weights at this age are 85 kg for males and 76 kg for females, though body weights vary considerably between individuals and seasons, being generally highest in winter and lowest in summer during lactation and molting. Peak use of hauling areas occurs during pupping and molting in June and July, declining by September and October as seals spend increasing amounts of time feeding at sea.

Though the food of harbor seals is not well documented for the region in question, they are known to be opportunistic feeders on a wide variety of fishes, cephalopods, and crustaceans. Stomach contents of harbor seals collected along the north side of the Alaska Peninsula during October, 1981, indicated sandlance, sculpins, and smelt as major prey items of the 12 seals taken from the Cape Peirce-Port Heiden -Port Moller vicinities. Other items of significance were various flatfishes, pollock, Pacific cod, and greenling (Lowry et al, 1982). Based on dietary studies from adjacent areas, it is likely that they also take, during certain times of year, herring, capelin, yellowfin sole, salmon, halibut, shrimp, Tanner crab, and king crab. The seasonal migration of herring into the Togiak spawning area may provide the most important source of nutrition to prelactating seals and, therefore, is very important to the well-being of the seal population (Bruce Mate, personal communication). The food intake of harbor seals ranges from 13 percent of total body weight daily during the first year to 3 percent per day at age nine (Ashwell-Erickson et al, 1978).

Steller (Northern) Sea Lion (Eumetopias jubatus)

Recent estimates (Braham et al, 1977, 1980; Braham and Rugh, 1978) place the sea lion population of the northeastern Aleutian-Bristol Bay region at between 15,000 and 25,000 animals. About 80 percent frequent rookeries in the Fox Islands, with most of the remainder at Amak Island (Figure 94). Minor, non-breeding rookeries have also been observed on Hagemeister Island, Crooked Island, Cape Newenham, the Twins, and other locations in northern Bristol Bay (U.S. Interagency Task Group, 1976).

It appears (Braham et al, 1980) that the sea lion population of the region may have declined by as much as 50 percent since the late 1950's and early 1960's, for reasons which are as yet undetermined. Possible explanations which have been offered are increased incidence of disease, particularly Leptospira pomona, commercial harvesting of pelts from 1970-1972, or decreased food resources and carrying capacity of the area due to commercial fisheries.

Females produce a single pup, born at coastal rookeries between May and early July. Most pups nurse for one year, though some continue to nurse until three years old. Though specific data are not available for this area, it is probable that low-flying aircraft or boat disturbance results in some pup mortality on the rookeries.

Little is known concerning seasonal movements and distributions of this population after they abandon the rookeries in the fall. It appears (Braham et al, 1977) that much of the population vacates the region during the winter months, possibly moving into the central Bering Sea along the edge of the ice front (Lowry et al, 1982).

Though data concerning feeding and food requirements of sea lions in the Bristol Bay region are sparse, studies from other areas indicate that they are broadly opportunistic feeders on many types of finfish, squid, and octopus. In recent years increasing numbers of animals have been observed at non-breeding rookeries in northern Bristol Bay, even though the overall population has apparently continued to decline (Lowry et al, 1982). Though reasons for this

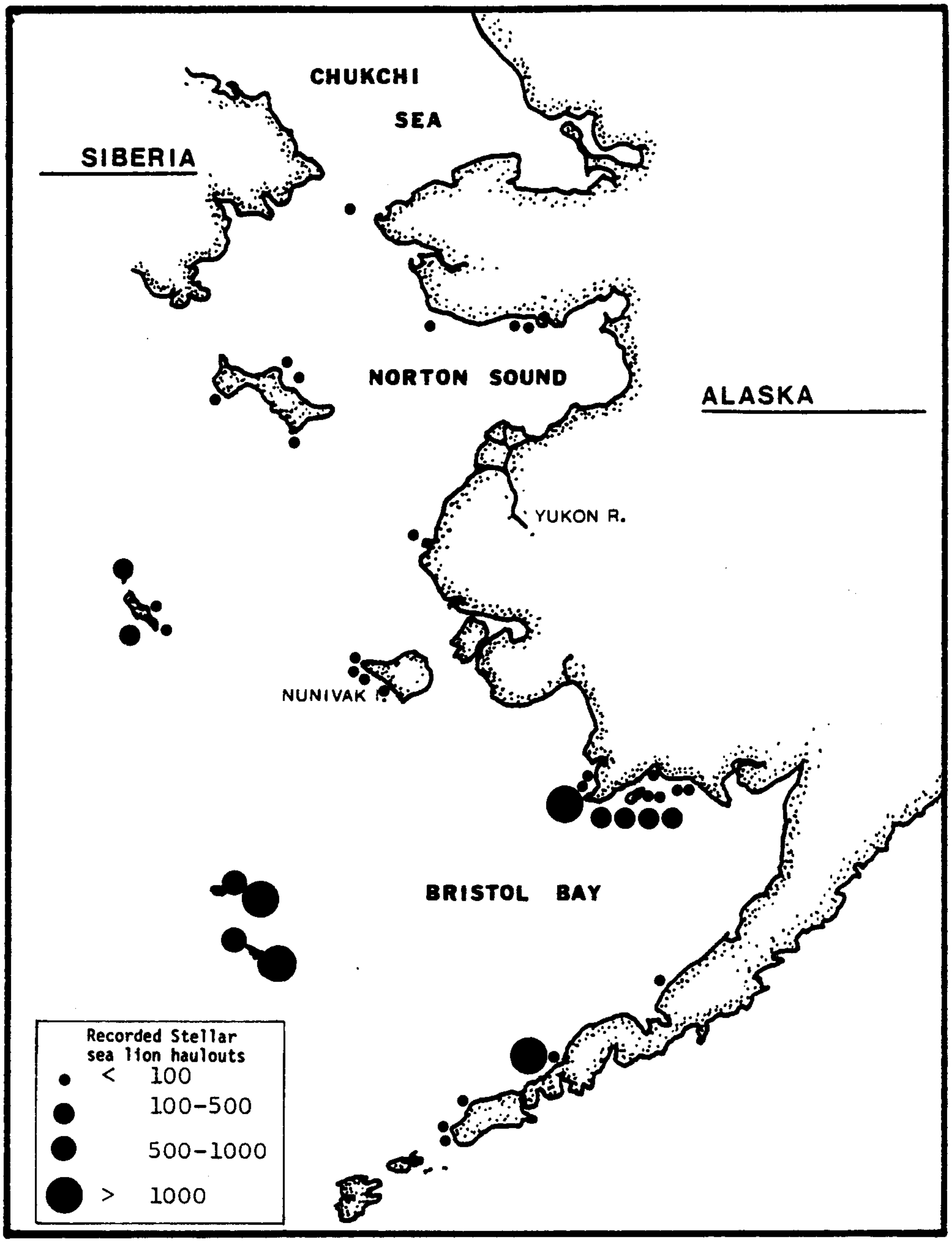


Figure 94. Map of the eastern Bering Sea showing locations where Stellar sea lion haulouts have been recorded (Frost et al, 1982).

trend are unclear, one possible explanation is that, because of reduced fish stocks in the southern areas, increasing numbers are attracted to the large spawning runs of capelin and herring in inner Bristol Bay.

Pacific Walrus (Odobenus rosmarus divergens)

The population of walrus in Bristol Bay, and the distribution of that population, varies seasonally and from year to year in response to winter ice conditions (Fay and Lowry, 1981; Burns et al, 1980). In winters of extensive sea ice, large numbers of animals utilize the area, with correspondingly fewer numbers during winters of light ice. On the average, this winter concentration in northern Bristol Bay constitutes about a quarter of the total Alaskan population, and forms a semi-discrete breeding population (Fay, 1982).

The migratory segment of the Bristol Bay walrus population (primarily cows and calves) moves into the area in late winter with the advance of the seasonal pack ice and remains until spring, when they follow the retreating ice northward. A resident population of between 12,000 and 20,000 animals, all males, normally remains through the summer months. Populations are usually highest from about February or March until the retreat of the pack ice in spring, and are less abundant and more widespread through the summer, fall, and early winter (Fay and Lowry, 1981).

The principal hauling ground for the summer population of males is Round Island, though they also haul on Walrus Island and, irregularly, on Amak Island, Cape Seniavin, Cape Constantine, and Cape Newenham (Figure 95). During the summer months, bulls normally spend one to six days ashore at a time on Round Island, separated by periods of two to eighteen days when they are at sea, presumably on feeding forays (Fay and Lowry, 1981).

The walrus population has increased rapidly during the last several decades, and has more than doubled since 1960. At present this population is estimated to be at least 250,000 animals, and is probably at or near maximum for the carrying capacity (food resources) of the environment. Recent studies (Fay et al, 1977; Fay and Stoker 1982 a and b) indicate that the population may be stressing its food resource, at least in the northern Bering Sea.

Females normally give birth to a single calf every other year. Calves are born from late April until early June on the pack ice during the northward migration. Weighing between 45 and 75 kg at birth, calves triple their weight in the first year, when they are solely dependent on nursing. Females reach their average maximum weight of 880 kg at 12 to 14 years of age, while males continue to grow

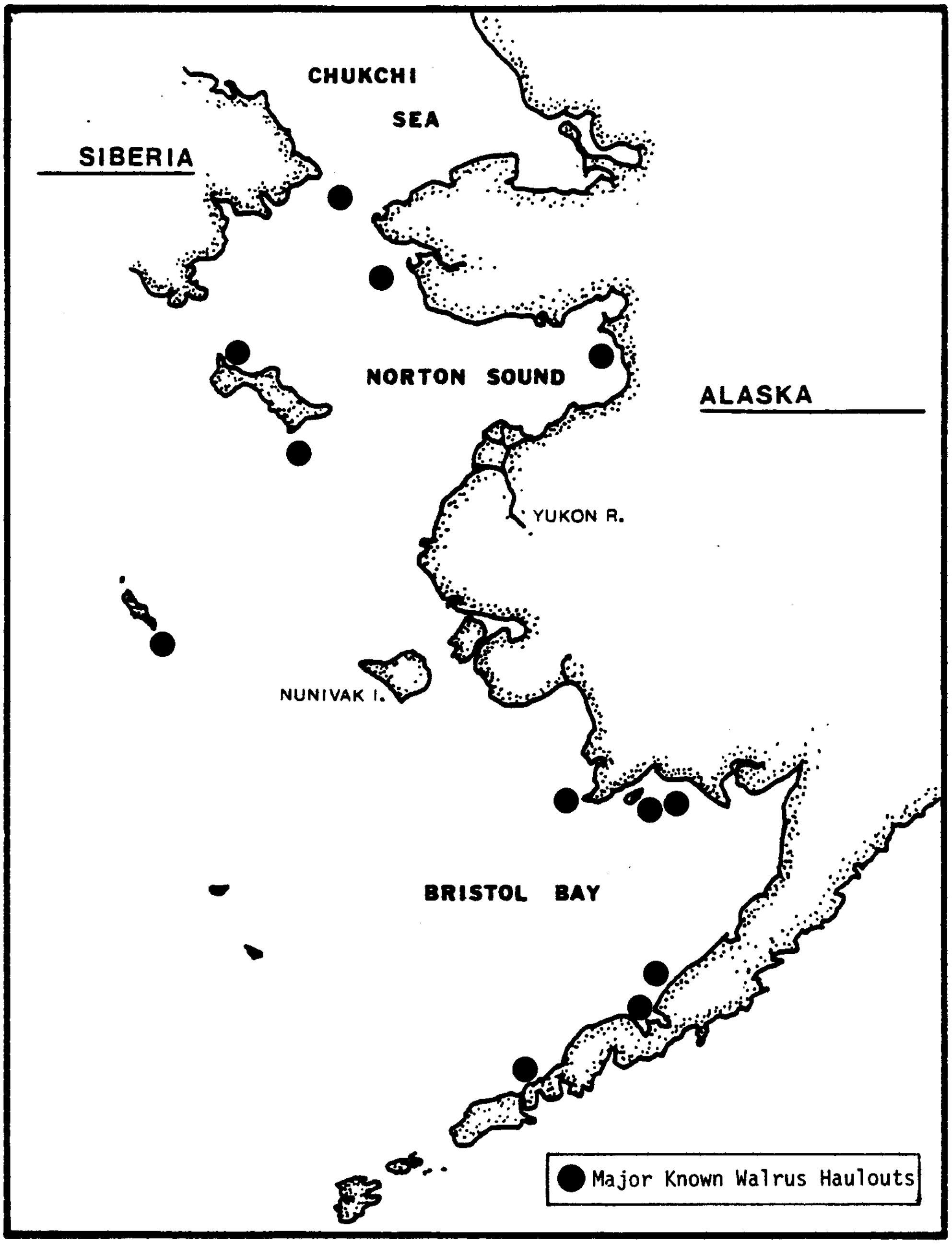


Figure 95. Map of the eastern Bering Sea showing major known haulouts of walruses (Frost et al, 1982).

until at least 16, when they attain an average maximum weight of 1,200 kg (Fay, 1982). In recent years there are indications that the birth rate has dropped somewhat (Fay and Stoker, 1982 a and b), and that the overall population is subject to some degree of physiological stress (reflected in decreased average blubber thickness), with an attendant increase in natural mortality (F.H. Fay, personal communication).

Walrus feed primarily on benthic infaunal and epifaunal invertebrates, relying heavily on bivalve mollusks for the bulk of their diet (Fay et al, 1977; Fay and Stoker, 1982 a and b). During a recent study (Fay and Lowry, 1981), a total of 22 genera of benthic invertebrates were identified from stomach contents of walrus collected in the Bristol Bay area. More than 90 percent of the stomach content biomass, however, was comprised of five genera of bivalves (Serripes, Tellina, Spisula, Siliqua, Mya). The genera Tellina and Siliqua made up, jointly, 75 percent of the total content. Fay (1982) estimates that, for adult animals, the average daily net food consumption is about 6.2 percent of total body weight, or 16,300 kg per year for the average individual.

Sea Otter (Enhydra lutris)

Though population data on sea otters in the northeastern Aleutian-Bristol Bay area are somewhat sketchy, estimates range from 8,000 to 10,000 animals as of 1976 (Schneider, 1976) to 11,700 to 17,200 at present (Lowry et al, 1982). Apparently the range of the sea otter has expanded in this region over the same time period, indicating that the larger, more recent estimate may reflect a real population increase. The bulk of this population ranges between Cape Mordvinof (Unimak Island) to about Cape Leontvich, with lesser densities extending as far north as Port Heiden (Schneider and Faro, 1975). Results from recent aerial sea otter surveys conducted during 1982-83 in this region indicate that their abundances underwent significant seasonal and spatial changes (VTN Oregon, 1983e). Summer abundances were found to be over seven times greater than were winter abundances. (Otters were also significantly more abundant in the Unimak and Izembek areas than in the Black Hills - Port Moller area). During years of extensive sea ice this population shifts southward, and sometimes suffers significant mortality as the result of a rapid onset of winter ice.

Sea otters are voracious predators, consuming between 20 and 25 percent of their body weight daily (Estes and Palmisano, 1974; Schneider, 1976). For juveniles, requirements are probably higher, ranging between 25 and 30 percent body weight per day. This equates, on the average, to between 3 and 5 kg per otter per day.

Though sea urchins seem to be preferred prey when available (Kenyon, 1969), otters will consume practically any available invertebrate species, including sea stars, and will prey upon slow-moving fish when the choicer invertebrate species are depleted (Lowry et al, 1982). In rocky intertidal and shallow subtidal areas, otter predation on invertebrate grazers results in significantly altered habitat characteristics and community structure, with greatly increased standing stocks of macrophytes (Estes and Palmisano, 1974). The small amount of data (9 scat samples taken from a single location over a two day period) available regarding sea otter feeding habits in the Bristol Bay Region indicates that yellowfin sole and rock sole may be important prey species (VTN Oregon, 1983d,e). These analyses also suggested reliance upon bivalve mollusks, gastropod mollusks, and various species of crabs.

In the Bristol Bay region, otters commonly occur in large pods, sometimes in excess of 1,000 animals per pod. They have been observed feeding in depths down to 60 meters and range as far as 30 miles offshore (Schneider, 1976), though such extremes are probably uncommon.

Though otters can and do breed and give birth at almost any season over most of their range (Kenyon, 1969), in the Aleutian and Bristol Bay area mating seems to normally occur in the fall (September-October), with birth of a single pup in the spring (Lowry et al, 1982). Pups are tended by their mothers for one year, with a pup born, on the average, every other year in the Aleutian area. Newborn pups weigh about 1.75 kg (average). Average adult weights are 28.3 kg for males and 21.1 kg for females in the Amchitka vicinity (Kenyon, 1969).

From available information relating to habitat requirements and food resources, it seems probable that the otter population of the proximal Aleutian Island-Bristol Bay region is near maximal for the carrying capacity of the environment. During years of extensive sea ice, substantial sea otter mortality due to malnutrition has been documented for Bristol Bay (Schneider and Faro, 1975).

Gray Whale (*Eschrichtius robustus*)

The present population of gray whales is estimated to be at least 15,000 (Rugh and Braham, 1979; Lowry et al, 1982), almost all of which migrate seasonally into and from the Bering Sea via Unimak Pass.

The spring migration into the feeding grounds of the Bering and Chukchi Seas passes through Unimak from March until June, follows around Bristol Bay to the Nunivak Island vicinity (Figure 96) and from there across the northern Bering Sea past St. Lawrence Island and through the Bering Strait into the Chukchi Sea. Some animals make this entire journey, continuing to the northern limits of the Chukchi

Sea and even, rarely, venturing into the Beaufort Sea; others drop out along the way to spend the summer feeding on the benthos of the northern Bering and southern Chukchi Seas. Recent sightings indicate that this spring migration stays well inshore during its swing around Bristol Bay, and that some animals probably remain in Bristol Bay throughout the summer (Braham et al, 1977; Alaska Department of Fish and Game, unpublished observations). Gray whales have been reported in Nelson Lagoon from late April until late November (Gill and Hall, 1983), and are most numerous in August and September. As many as 8-10 whales have been observed at one time feeding in Nelson Lagoon, as evidenced by mud trails (R. Gill, personal communication).

The entire population migrates southward again in advance of the formation of seasonal sea ice, moves through Unimak Pass from late October until early January, and makes its way from there down the Pacific Coast to wintering grounds in Baja California.

Gray whales breed in the sheltered, shallow lagoons of Baja California from mid-November through early January, with a 13-month gestation period. Females give birth, on the average, every two years (Rice and Wolman, 1971). Calves average about 4.75 meters in length at birth, grow to seven to eight meters by weaning (August of the same year), and are a little over nine meters in length by the time of their first return migration from the Bering/Chukchi in early winter (Rice and Wolman, 1971). After this initially rapid growth, development slows as the average adult length of twelve meters is approached. Adult gray whales weigh as much as 34,000 kg (Lowry et al, 1982).

Gray whales are benthic feeders on epifauna and shallow infauna. The mainstay of their diet, in the northern Bering and southern Chukchi Seas at least, consists primarily of gammarid amphipods of the genera _Ampelisca_, _Lembos_, _Anonyx_, and _Pontoporeia_. Daily consumption, based on field observations, is estimated at 1,200 kg per animal per day (Lowry et al, 1982). Though grays do feed to some extent in their breeding and calving grounds in Baja California and along the Pacific coast and North Aleutian Shelf migration routes, the bulk of their energy requirements are apparently obtained and stored, as fat reserves, during their summer feeding migrations into the Bering and Chukchi Seas.

Though no firm estimates are available as to the number of gray whales which existed prior to commercial exploitation in the 19th century, the present population is probably approaching pre-exploitation levels, is increasing slowly, and may be near maximal for the carrying capacity of its food resource in the Bering and Chukchi Seas.

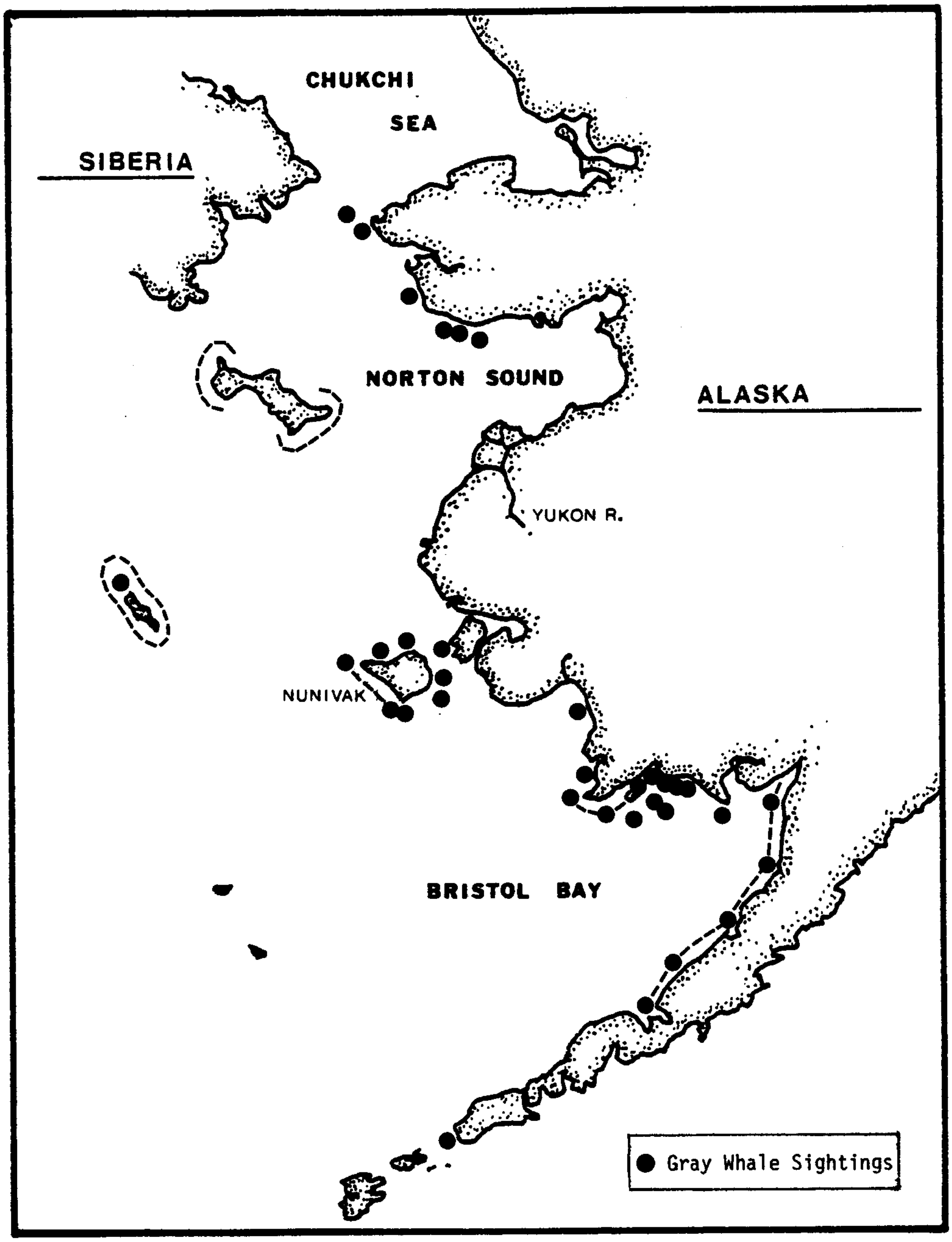


Figure 96. Map of the eastern Bering Sea showing locations where gray whales have been sighted (Frost et al, 1982).

Beluga Whale (*Delphinapterus leucus*)

Though the population of belugas in Bristol Bay is seasonally and, probably, annually variable, most authorities agree on average estimates of 1,000 to 1,500 animals (Brooks, 1955; Alaska Department of Fish and Game, unpublished data). Most of these are concentrated, during summer, in upper Bristol Bay near the Nushagak and Kvichak River mouths (Figure 97). This population represents almost ten percent of the total Bering/ Chukchi/Beaufort beluga population (estimated at 15,000 to 18,000), and may or may not be a genetically discrete subpopulation (F.H. Fay, personal communication). Both the general Bering/Chukchi/Beaufort and the Bristol Bay beluga populations appear to be stable at present.

Most beluga calves are born in July or early August, and nurse for a period of two years (Lowry et al, 1982). Females generally produce calves every third year. Newborn calves are about 150 cm in length and weigh about 80 kg. Like most marine mammals, they grow very rapidly at first, more than doubling their weight in the first year. By the age of ten they have normally attained physical maturity with an average length for males of 3.2-4.4 m (520-1,200 kg), 3.1-3.6 m (480-700 kg) for females.

Belugas are known to consume a wide variety of fish and invertebrates, though smelt and salmon seem to comprise a major part of their diet in the Bristol Bay region from May through August when they are present in large numbers in the vicinity of Kvichak and Nushagak Bays (Brooks, 1955). During May they apparently feed heavily on outmigrating smelt, shifting to sockeye salmon fingerlings in late May and June when smolt begin their seaward migration. About mid-June, belugas switch from outmigrating fingerling smolts to inmigrating adult sockeye salmon enroute to the spawning grounds (Lowry et al, 1982).

During the winter months, the Bristol Bay population of belugas seems to disperse along the edge of the seasonal sea ice, where they probably depend heavily on pollock for their winter fare (Seaman et al, 1982).

Records from six captive belugas indicate a daily consumption rate of between four and seven percent of total body weight per day. If an average body weight of 700 kg is assumed, this equates to between 28 and 49 kg per day.

In addition to the species described above, numerous other marine mammals are seasonal or occasional visitors to the nearshore Bristol Bay and Aleutian region. Prominant among these are spotted seal, bearded seal, ringed seal, and harbor porpoise.

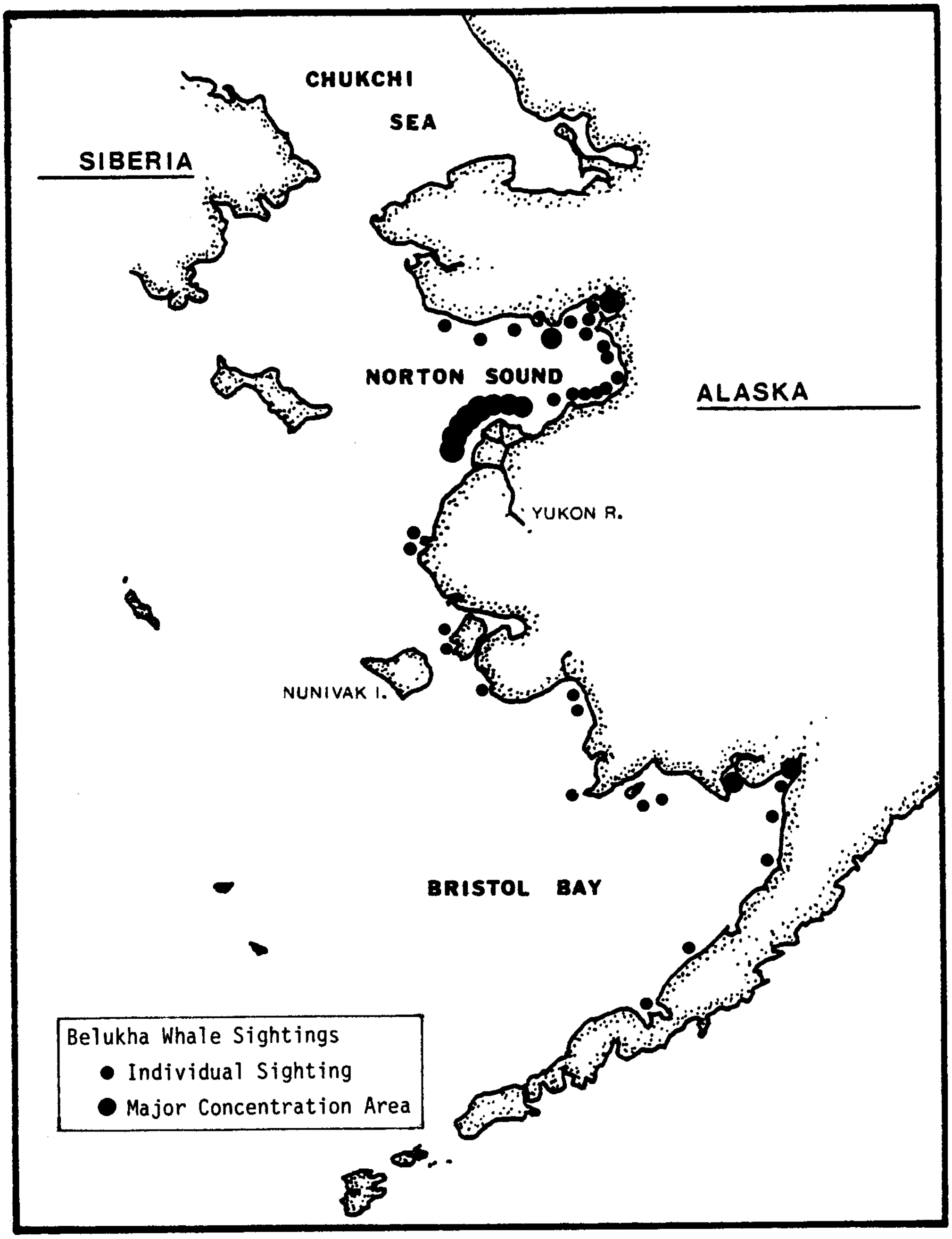


Figure 97. Map of the eastern Bering Sea showing sightings of beluga whales in the coastal zone. Small dots represent individual sightings. Large dots represent major concentration areas (Frost et al, 1982).

Spotted Seal (*Phoca largha*)

Spotted seals are primarily seasonal visitors to the Bristol Bay area, arriving with the onset of sea ice in late winter and, generally, departing with the retreat of the ice in spring (Burns et al, 1980; Braham et al, 1977). As the winter ice melts and retreats, however, some spotted seals remain in northern Bristol Bay and assume an ice-free coastal existence for the summer months, mingling with the closely related harbor seals of the area (Lowry et al, 1982). Spotted seals are considered to be one of the most numerous species in the ice front of the Bristol Bay region during late winter and early spring, with populations varying according to ice conditions and extent (Burns et al, 1980; Braham et al, 1977). The total population of spotted seals in the Bering-Chukchi region is estimated at 280-330,000, and is probably stable (Lowry et al, 1982). In years of normal sea ice, spotted seals are pretty much confined to the ice front extending across northern Bristol Bay, and normally occur offshore of the five km nearshore zone (Figure 98).

Females usually give birth to a single pup each spring. Pups are born on the ice, normally in March or April, and nurse for a period of five to six weeks (Lowry et al, 1979). Spotted seal pups weigh 9.5 to 11.8 kg at birth, and by about four years of age have attained their maximum adult weight of 82 to 109 kg (Lowry et al, 1982).

During spring in the southeastern Bering Sea, spotted seals apparently feed heavily on capelin, though numerous other fish species (especially pollock and herring), octopuses, and shrimps are also eaten (Lowry et al, 1982). Ashwell-Erickson and Elsner (1981) estimate that the total spotted seal population of the Bering-Chukchi consumes about 216,700 metric tons of food per year, or about one metric ton per animal per year.

Bearded Seal (*Erignathus barbatus*)

Bearded seals, like spotted seals, walrus, gray whales, and ringed seals, are seasonal visitors to Bristol Bay, with numbers and distribution dependent on winter ice conditions. In years of extensive sea ice, bearded seals are common and widespread within the ice front of northern and central Bristol Bay; in years of light ice they are uncommon in the area (Burns et al, 1980; Braham et al, 1977; Lowry et al, 1982). When ice is present, bearded seals are more or less uniformly distributed throughout the ice front (Figure 98). The entire Bering-Chukchi population of bearded seals is estimated at about 300,000 (Lowry et al, 1982).

Females normally give birth to a single pup each spring. Pups are born on the ice from late March through

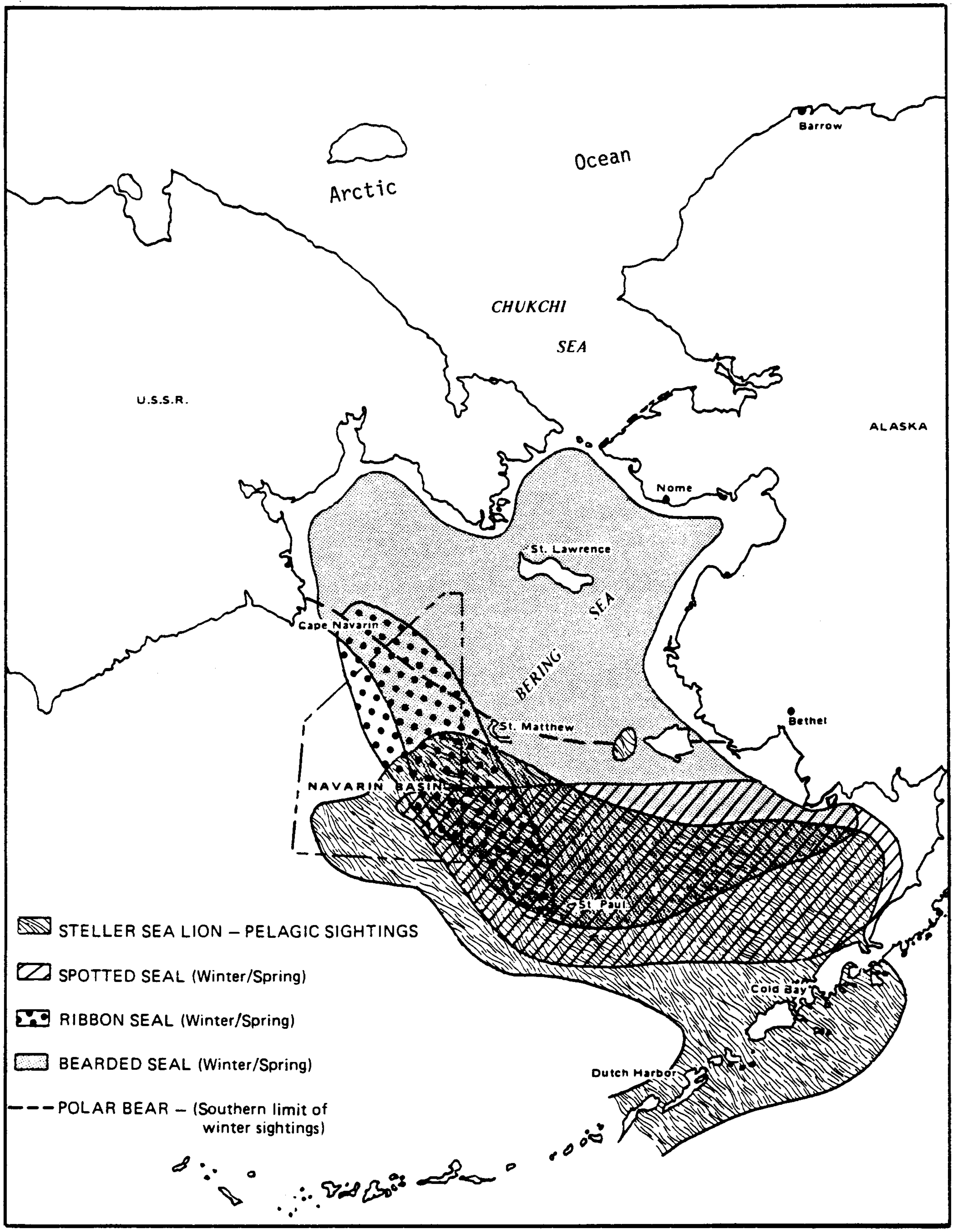


Figure 98. Distribution of breeding ice seals, sea lion pelagic sightings, and southern limit of polar bear sightings (Thorsteinson, 1983).

early May, with mid-April as the peak period. Pups weigh about 34 kg at birth, and nurse for a period of only 12-18 days by which time their weight has increased to approximately 85 kg (Burns, 1967). By nine years of age they have attained their maximum adult weight of about 248 kg (Lowry et al, 1982).

Bearded seals feed on a wide range of invertebrates and fishes (Kosygin, 1976; Lowry et al, 1982). Favored foods seem to be brachyuran crabs (Chionoecetes opilio and Hyas spp.), crangonid and pandalid shrimps, bivalve mollusks, octopuses, cod, pollock, sculpins, and various flatfishes. No data are available pertaining to normal energy requirements or intake rates.

Ringed Seal (Pusa hispida)

Like the other ice-inhabiting marine mammals of the Bering-Chukchi, the numbers and distribution of ringed seals in northern Bristol Bay varies from year to year depending on the extent of winter sea ice. In years of extensive sea ice, large numbers have been observed in northern Bristol Bay (F.H. Fay, personal communication), though densities are probably never as high as those encountered further north (Lowry et al, 1982; Burns et al, 1980). Ringed seals are the most numerous marine mammal found in Alaskan waters, with the total population estimated at about 1.5 million. Popov (1976) estimated that about 70-80,000 ringed seals inhabit the Bering Sea during winter.

Ringed seals are the smallest Alaskan phocid with adult weights, attained by about eight to ten years of age, of 48.1 kg for females and 51.6 kg for males. Pups weigh about 4.5 kg at birth and nurse for a period of five to seven weeks. A single pup is normally born to females every year. Females give birth in dens on the shorefast ice, usually in March or early April (Frost and Lowry, 1981).

The diet of adult seals is varied, including crangonid and pandalid shrimps, hyperid and gammarid amphiphods, mysids, euphausids, cod, sculpins, and sandlance. Daily food intake probably ranges from 2 to 9.5 percent of body weight, depending on the caloric value of the prey (Lowry et al, 1982).

As in the case of spotted seals and bearded seals, ringed seals are probably never numerous within the five km nearshore zone of Bristol Bay.

Harbor Porpoise (Phocoena phocoena)

No data are available regarding population densities of harbor porpoise in Bristol Bay. Though they are observed there fairly commonly, populations are probably rather low (Lowry et al, 1982).

Though no information is available regarding feeding or food requirements of harbor porpoises in the Aleutian-Bristol Bay region, studies from other areas indicate that they feed on a wide range of finfish and invertebrates. Adults probably weigh 45 to 60 kg, and consume about ten percent of their body weight per day in food (Lowry et al, 1982). Little is known about the life history of this species, and it is unclear whether they calve every year or at longer intervals.

Other marine mammals known to occur at times in the northern Aleutian Island-Bristol Bay region are northern fur seal, ribbon seal, fin whale, minke whale, blue whale, sei whale, humpback whale, Pacific right whale, bowhead whale, sperm whale, Cuvier's beaked whale, Baird's beaked whale, Stejneger's beaked whale, killer whale, and Dall's porpoise. Most of these species are seasonal visitors, and none of them is ever numerous or common in the nearshore region (Fay, personal communication).

c. Feeding Relationships

Available data regarding the feeding relationships of dominant or otherwise important invertebrate, fish, mammal, and bird species were compiled in order to gain a better understanding of the functional operation of the food web in the nearshore area. Feeding relationships for each species are synthesized in the form of food web segments (Figures 99 through 117) which illustrate both primary predators and prey. Large gaps, however, exist in our qualitative as well as quantitative knowledge of the food webs of the nearshore zone.

Invertebrates. Included in this treatment will be red king crabs, the sea star, Asterias amurensis, and two bivalve mollusks, Spisula polynyma and Tellina lutea.

Red King Crab

A summary of the literature on red king crab food and feeding habits is reported in Feder and Jewett (1981), and partially presented here. A study by W. Pearson at Battelle, N.W. Laboratories is underway but results are unavailable at this time. Little is known about the food and feeding habits of red king crabs while they occupy the coastal waters of the southeastern Bering Sea; however, data from four studies are available for this species from deeper waters. In the summer and fall of 1975 and 1976 king crabs were examined from various depths. The dominant prey items, in decreasing percent frequency of occurrence, were a cockle (Clinocardium ciliatum), a snail (Solariella sp.), a clam (Nuculana fossa), brittle stars (Amphiuridae), a polychaete

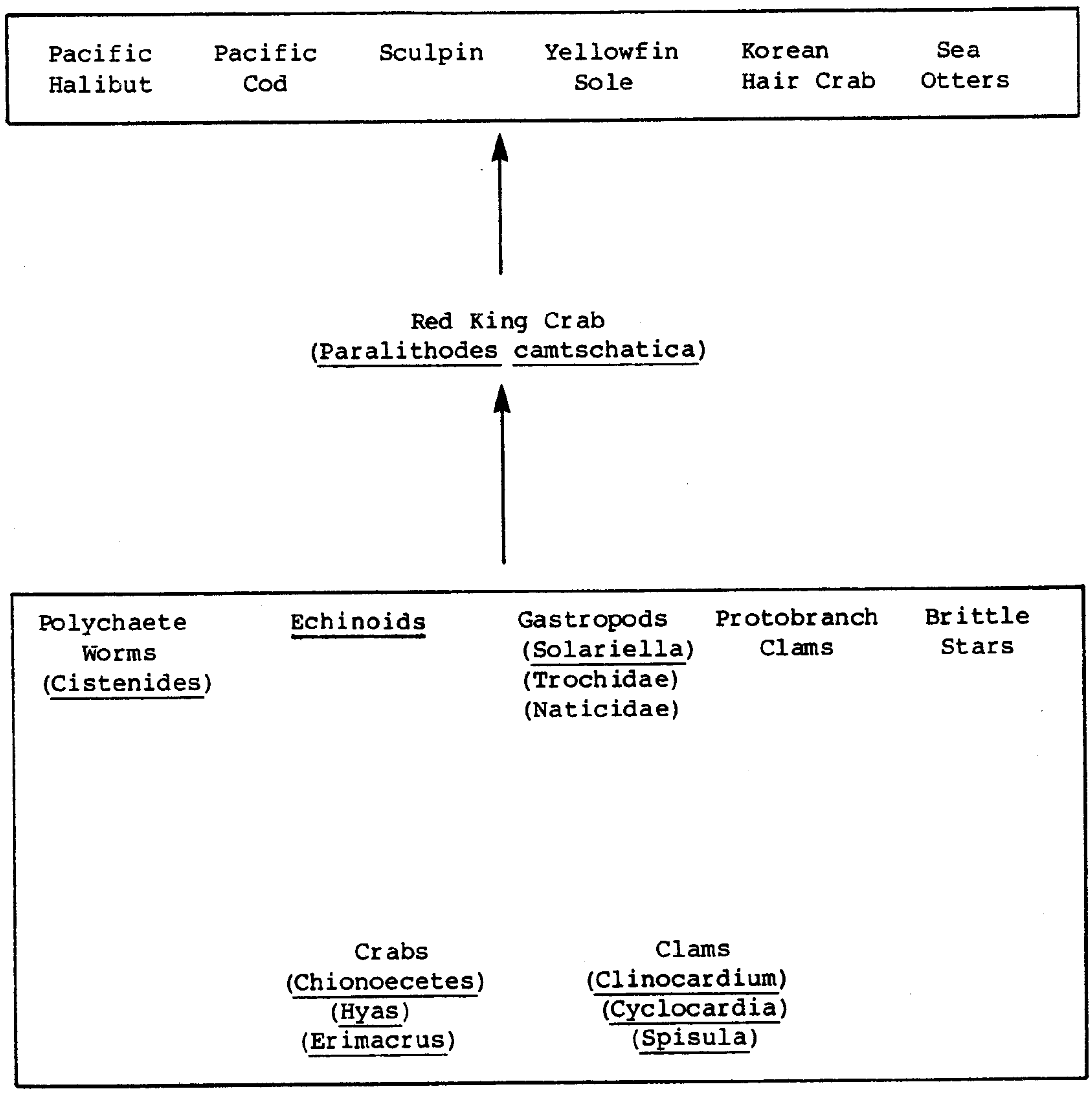


Figure 99. Basic trophic interactions of red king crab.

worm (Cistenides sp.), and Tanner crabs (Chionoecetes sp.) (Figure 99) (Feder and Jewett, 1980).

In a second study conducted in September and October 1972, food of red king crabs from 40-50 m depths of Bristol Bay were mainly polychaete worms, sand dollars (Echinarachnius parma), gastropods of the families Trochidae and Naticidae, and pelecypods (Yoldia, Nuculana, Nucula and Cyclocardia) (Tarverdieva, 1976).

In a third study where crabs were examined in July and August 1967 from depths of 78-90 m, echinoderms (a brittle star, Ophiura sarsi; a basket star, Gorgonocephalus sp.; a sea urchin, Strongylocentrotus sp; and a sand dollar, Echinarachnius parma) were the most important food, by percent of total food weight (49.1%) in the crab stomachs analyzed. Mollusks (bivalves-Nuculana radiata, Clinocardium californiense, Chlamys sp; snails-Solariella sp and Buccini-dae) and crustaceans (crabs-Hyas coarctatus alutaceus, Erimacrus isembeckii, and Pagurus sp) and sand fleas (Amphipoda) were next in importance by weight with 37.2 percent and 10.1 percent, respectively (Cunningham, 1969).

A fourth study examined crabs from various depths during June and July 1957. Primary foods were bivalve mollusks, echinoderms (asteroids, ophiuroids, and echinoids), and decapod crustaceans (shrimps) (McLaughlin and Hebard, 1961).

King crabs collected in shallow bays (5-10 m) of Kodiak Island mainly feed on clams (primarily Protothaca stamineas, Macoma spp.), cockles (Clinocardium spp.), and acorn barnacles (mainly Balanus crenatus). Analysis of king crab feeding data from the area of Kodiak and Afognak islands revealed significant differences in quantity of food consumed between sampling areas, periods, depths, and crab sizes and classes. Presumably these differences also exist among king crabs in the southeastern Bering Sea (Jewett and Feder, 1982).

The extensive Alaska surf clam (Spisula polynyma) resource along the North Aleutian Shelf is presumably prey for red king crab since this clam has been identified as an important prey species for king crab in Kachemak Bay (Cook Inlet), (Feder and Jewett, 1981).

Various predators of red king crabs have been identified, i.e., Korean hair crab, Pacific halibut, Pacific cod, sculpin, yellowfin sole, and sea otters (Figure 99). Korean hair crab have been observed preying on podding juvenile king crab in the nearshore waters of Kodiak Island (Powell and Nickerson, 1965). Pacific halibut are known to prey on king crab from waters deeper than 50 meters in the Gulf of Alaska (Gray, 1964). A study in 1980-81 from various depths of the southeastern Bering Sea was the first to document consumption of red king crab by Pacific cod in the southeastern Bering Sea (Shimada and June, 1982). The proportion of king crab in the diet of Pacific cod was approximately eleven percent by weight and seven percent by frequency of occurrence. The sculpin, Hemilepidotus hemilepidotus is a known predator of small king crab. As many as five two-year old king crab (25 mm carapace length) have been found in the stomach of a single sculpin; stomachs of 56 sculpins from the nearshore waters off Kodiak Island contained 110 crab (Powell, 1974). In thousands of demersal fish stomachs examined from Gulf of Alaska and Bering Sea waters during the years 1975-80, king crab were rarely found (Feder and Jewett, 1981). Glaucothoe larvae of king crab have recently been found in the stomachs of yellowfin sole along the Alaska Peninsula in the southeastern Bering Sea (Haflinger and McRoy, 1983).

Sea otters have been observed to prey upon adult king crab from Prince William Sound waters (S. Jewett, personal observation); therefore, king crab are presumably taken by otters along the North Aleutian Shelf. Currently, an OCSEAP study is underway to examine the food of sea otters along the North Aleutian Shelf (VTN Oregon, 1983e). The distribution of sea otters and the distribution of the mating king crab is similar (Haynes, 1974; Armstrong et al, 1981; Schneider, 1981). Recent expansion of a sea otter population in Prince William Sound, Alaska, into previously unoccupied habitat coincided with the demise of the Dungeness crab fishery through otter predation (Garshelis, 1983).

Asterias amurensis

The sea star Asterias amurensis feeds on a variety of organisms in the southeastern Bering Sea (Feder et al, 1978). It has been estimated that food, primarily clams, consumed annually by A. amurensis in Japanese waters amounts to 8×10^3 mt, approximating the annual consumption of food (primarily clams) taken by bottom fishes (Hatanaka and Kosaka, 1958). The large standing stock of A. amurensis in the shallow waters of the southeastern Bering Sea prey intensively on the bivalve resources of the region (i.e., Tellina lutea, Cyclocardia spp., Macoma calcarea, and Spisula polynyma), and sand dollars (Echinarachnius parma) (Figure 100). The food requirements for sea stars, crabs, and some species of bottom fishes in the coastal regions of the southeastern Bering Sea are similar, thus the size of seastar populations must have an important bearing on the production of commercially important crabs and fishes.

Sea stars are rarely preyed upon as adults (predator exceptions are king crabs and sea otters), and they are typically thought to be a "dead end" in the food web (Feder

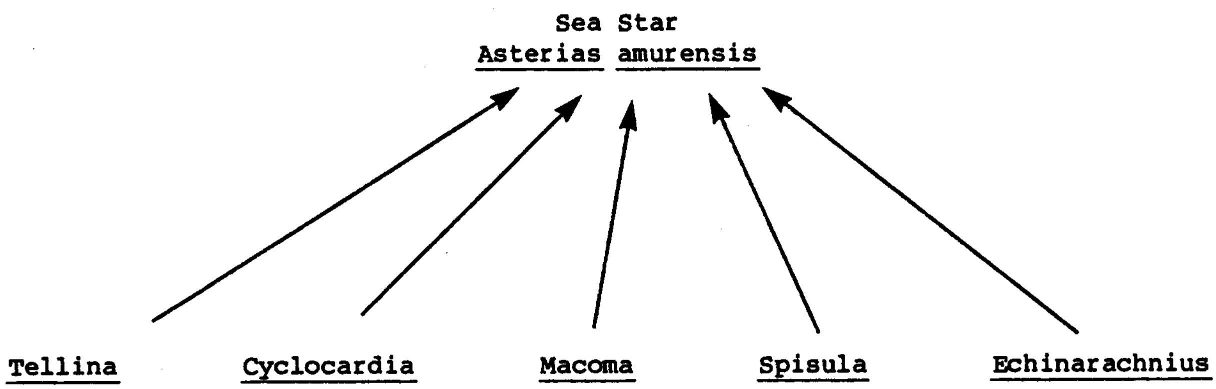


Figure 100. Basic trophic interactions of the sea star, *Asterias amurensis*.

and Jewett, 1981). However, a considerable portion of seastar carbon is, in fact, returned to the sea annually as gamete production. It has been calculated that 20-30 percent of the weight of adult Asterias is gonodal material which is extruded during spawning (Hatanaka and Kosaka, 1958). Such pulses of high-energy organic material released during spawning must represent important components of secondary production to the water column and the benthos (Feder and Jewett, 1981).

Spisula polynyma and Tellina lutea

The two bivalves, Alaska surf clam (Spisula polynyma) and great Alaska tellin clam (Tellina lutea), are both filter feeders, utilizing detritus and phytoplankton as carbon sources. They both are important prey items for red king crab, yellowfin sole, otters, and walrus (Figures 101 and 102).

Marine Fishes. Included in this section are Pacific herring, capelin, and yellowfin sole.

Pacific Herring

The following summary of Pacific herring food and feeding habits from throughout the Bering Sea is taken from Wespestad and Barton (1981). The first food of herring larvae is usually limited to small and relatively immobile plankton organisms. Microscopic eggs sometimes make up more than half of the earliest food; other items include diatoms and nauplii of small copepods. Herring do not have a strong preference for certain food species but feed on the comparatively large organisms that predominate in the plankton of a given area. Feeding generally occurs before spawning, and intensifies afterward. Feeding declines during winter, then ceases in late winter.

Stomachs in August were 84 percent filled with euphausiids, 8 percent with fish fry, 6 percent with calanoid copepods, and 2 percent with gammarid amphipods. Fish fry, in order of importance, were walleye pollock, smelt, capelin, and sandlance. In spring, food was mainly pelagic amphipods (Themisto), and chaetognaths (Sagitta). After spawning, the main diet was euphausiids, Calanus spp., and Sagitta spp. (Figure 103). Nearly 75 percent of herring stomachs examined in the spring from Bristol Bay to Norton Sound either were empty or contained only traces of food. Only 25 percent of the stomachs examined were at least 25 percent or more full, and only 3.4 percent were completely full. Major food items were cladocerans, flatworms, copepods, and cirripeds.

Herring are important prey for marine mammals (i.e., harbor seals, sea lions and beluga whales) and sea birds (i.e., black-legged kittiwakes and glaucous gulls). All of

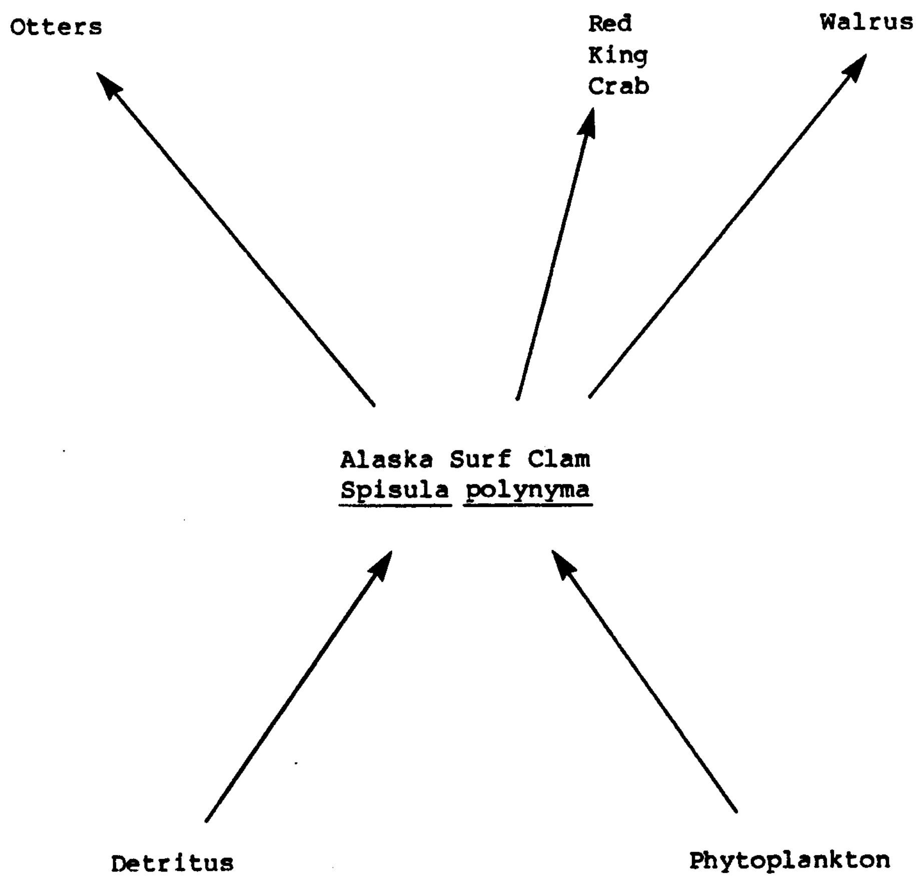


Figure 101. Basic trophic interactions of the Alaska surf clam.

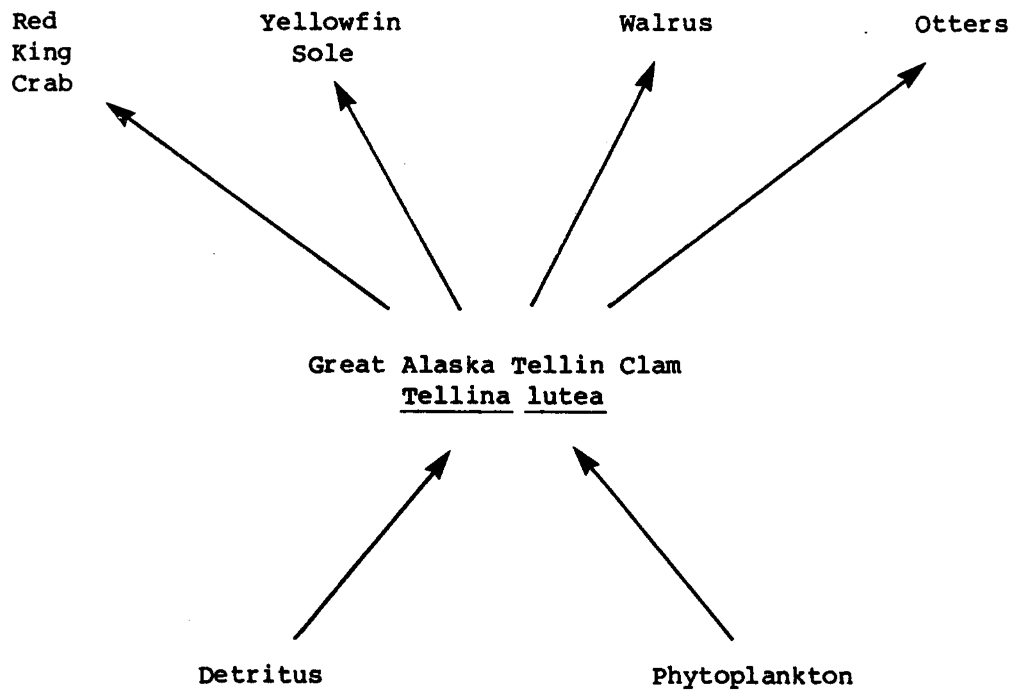


Figure 102. Basic trophic interactions of the great Alaska tellin clam.

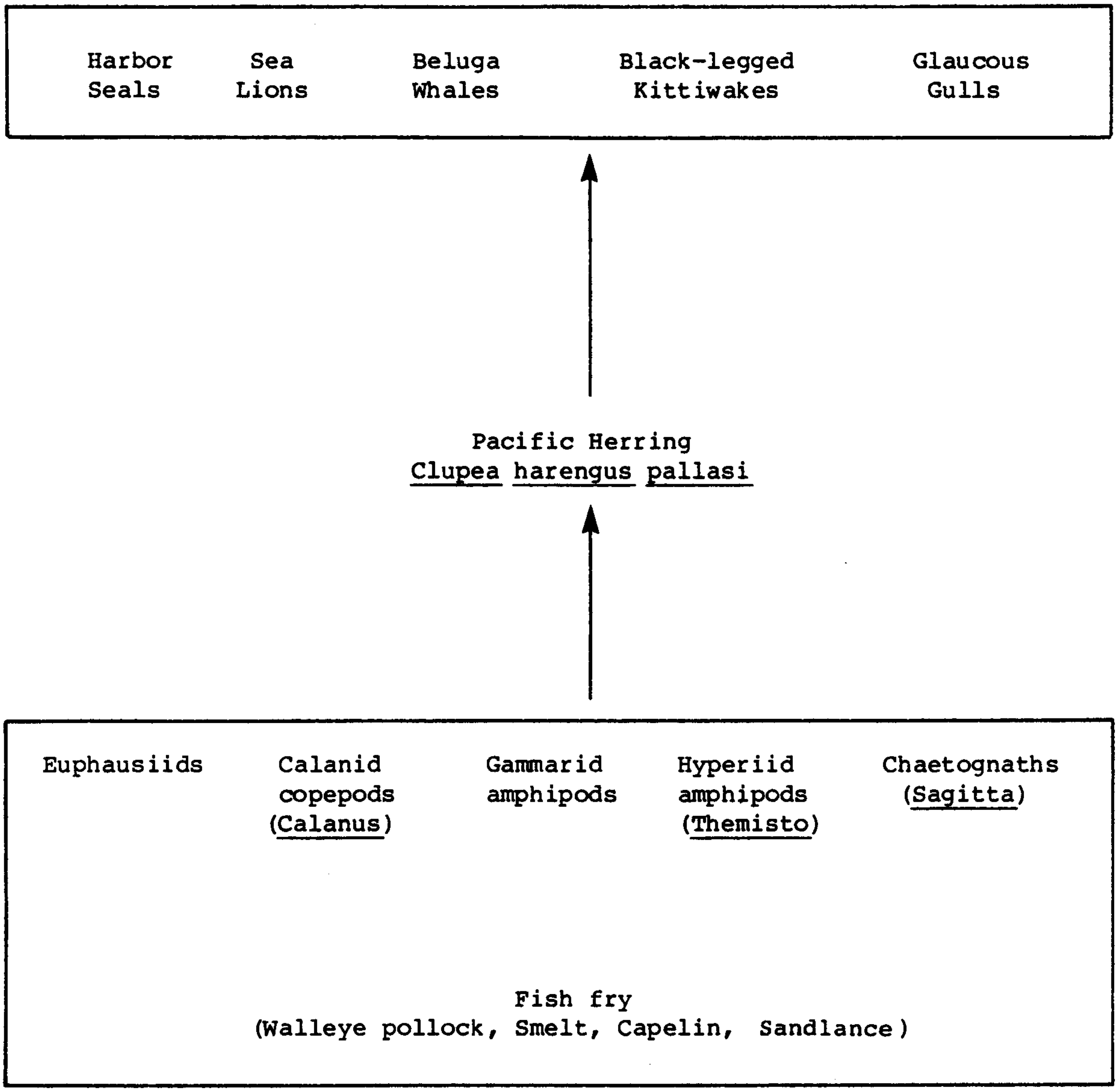


Figure 103. Basic trophic interactions of Pacific herring.

the commercial quantities and most of the subsistence quantities of herring come from the Togiak region of northern Bristol Bay (Barton et al, 1977).

Capelin

Little is known about the food and feeding habits of the capelin from the eastern Bering Sea. Smith et al (1978) examined the stomach contents of 135 feeding individuals from the southeastern Bering Sea. All specimens were captured during the period from late spring to early fall. Therefore, no information is available on seasonality of feeding in the Bering Sea capelin. Only two phyla were represented among food organisms, the Arthropoda (all crustaceans) and the Chaetognatha. The most numerous prey organisms were calanoid copepods. The only identifiable genus was *Calanus*. Virtually all of the amphipods present were members of the pelagic Hyperiidae. Identifiable euphausiid specimens were all of the genus *Thysanoessa*. The smallest food item, copepods, had its greatest volumetric and relative importance in the smallest fish. The same is true of the next smallest food items, the mysids (Figure 104).

Capelin are food for a variety of predators including seabirds of the family Alcidae, and fishes (e.g., arrowtooth flounder, pollock, and Greenland halibut) (Smith et al, 1978).

Yellowfin Sole

Recent findings on the food of yellowfin sole in the southeastern Bering Sea along the Alaska Peninsula revealed that newly recruited surf clams *Spisula polynyma* (1-2 mm) were often encountered in the range of 100-500/stomach in the deeper waters (>30 m) off Port Moller, while various groups of polychaete worms, benthic amphipods, and the sand dollar *Echinarachnius parma* dominated the shallow water and Bristol Bay (Haflinger and McRoy, 1983). King crab glaucothöe larvae and Tanner crab (*Chionoecetes bairdi*) zoea were also taken as food; however, only two of 557 fish examined accounted for nearly all the crab consumption reported here. The overall incidence of king crab was 0.69/stomach. The overall incidence of Tanner crab was 0.27/stomach. Extrapolations from these rates to total numbers of crab consumed for one month in this area were 11.5×10^9 king crab and 4.5×10^9 Tanner crab.

A characterization of yellowfin sole food and feeding habits is presented in Bakkala (1981a) and summarized here. Yellowfin sole are capable of feeding on a variety of animals, from strictly benthic forms, such as clams and polychaete worms to zooplankton (mysids and euphausiids), to pelagic fishes (capelin and smelt).

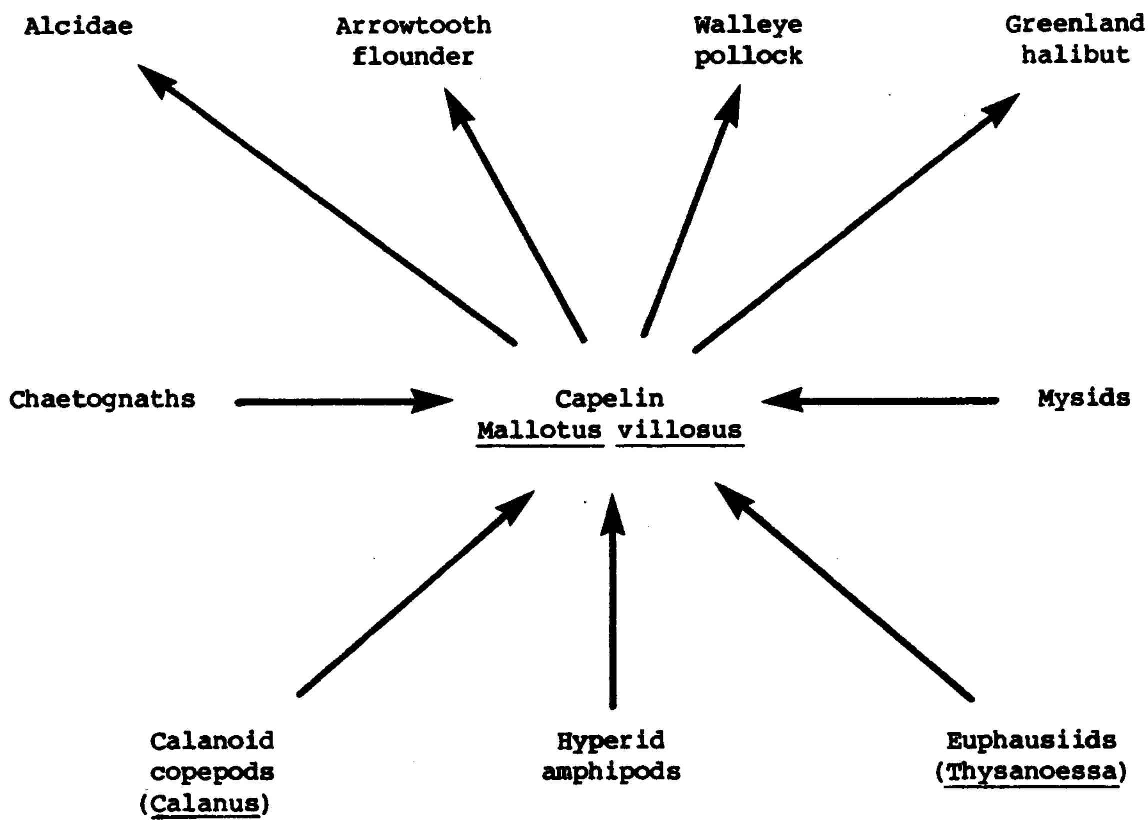


Figure 104. Basic trophic interactions of capelin.

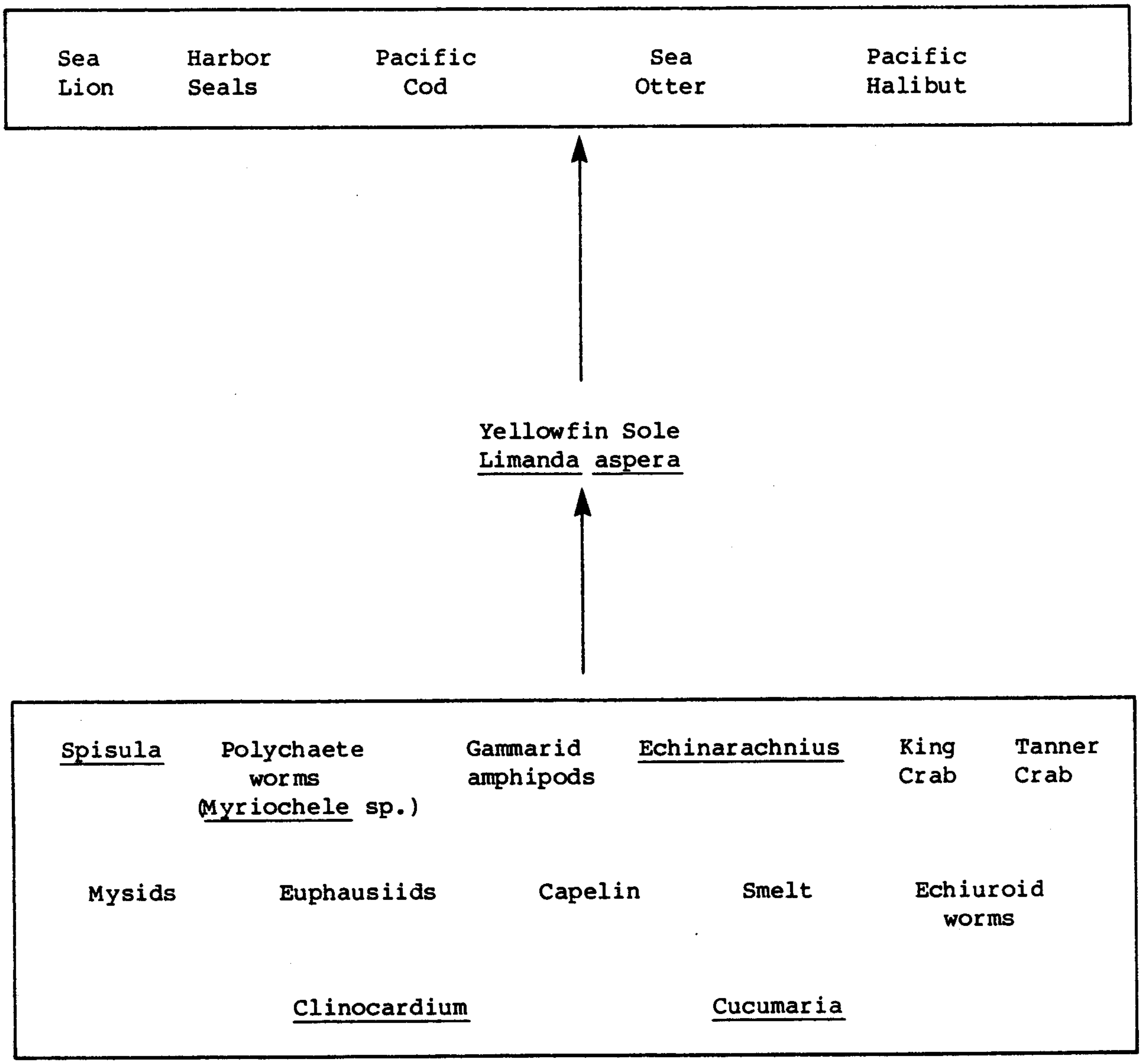


Figure 105. Basic trophic interactions of yellowfin sole.

About 50 different taxa have been found in stomachs of yellowfin sole in the eastern Bering Sea. The kinds of organisms consumed vary by season, area, and size of fish. Although feeding generally stops in winter, instances of fairly intense winter feeding have been recorded. During the onshore migrations in May and June 1971, 73 percent of the fish that had wintered near Unimak Island were feeding, but feeding intensity was low for fish that had wintered near St. George Island (0.05 percent), St. Paul Island (19 percent), and in Bristol Bay (0 percent). They fed more intensively as they moved onto the central shelf; diet varies by region, apparently depending on the availability of food organisms.

Contents of 2,357 stomachs taken over a broad area of the eastern Bering Sea show that the primary food items, representing 65 percent of stomach contents by weight, were bivalves, amphipods, polychaete worms, and echiuroid worms. Polychaetes and amphipods were the principal food items in smaller fish (10-20 cm), polychaetes and bivalves; echiuroids and amphipods in larger fish (20-30 cm); and bivalves and echiuroids in fish longer than 30 cm (Figure 105).

A recent OCSEAP study conducted by VTN Oregon (1983e) examined the feeding habits of this species along the North Aleutian Shelf. Contents of 40 stomachs taken in two areas (off Port Moller and Bechevin Bay) and at 30 and 60 meters depth were summarized. The major taxa in their diets representing 51.2 percent of the total stomach volume were crustaceans (20.7 percent), bivalves (12.3 percent) echinoderms (9.5 percent), and polychaetes (8.7 percent). They found that prey items and age varied with transect and depth. Fish taken at 30 meters were found to be younger (three to four years) and ate fewer prey taxa (16 to 17) than fish taken at 60 meters (five to 10 years, 21 taxa).

In recent years the Port Moller area has yielded approximately 35,000 mt of yellowfin sole to the commercial fishery (Bakkala, 1981a).

Pacific halibut are a dominant predator of yellowfin sole in the southeastern Bering Sea (Bakkala, 1981a; Pereyra et al, 1976). A close relationship between the distribution of halibut and yellowfin sole during the summer and fall suggests that the movements of halibut are governed to a large degree by the movements of its principal prey, yellowfin sole (Bakkala, 1981a). Yellowfin sole are also taken by Pacific cod (Shimada and June, 1982). A recent OCSEAP study has identified that sea otters also consume yellowfin sole along the North Aleutian Shelf (VTN Oregon, 1983d).

Anadromous Fish. Included in this category are salmon and boreal smelt.

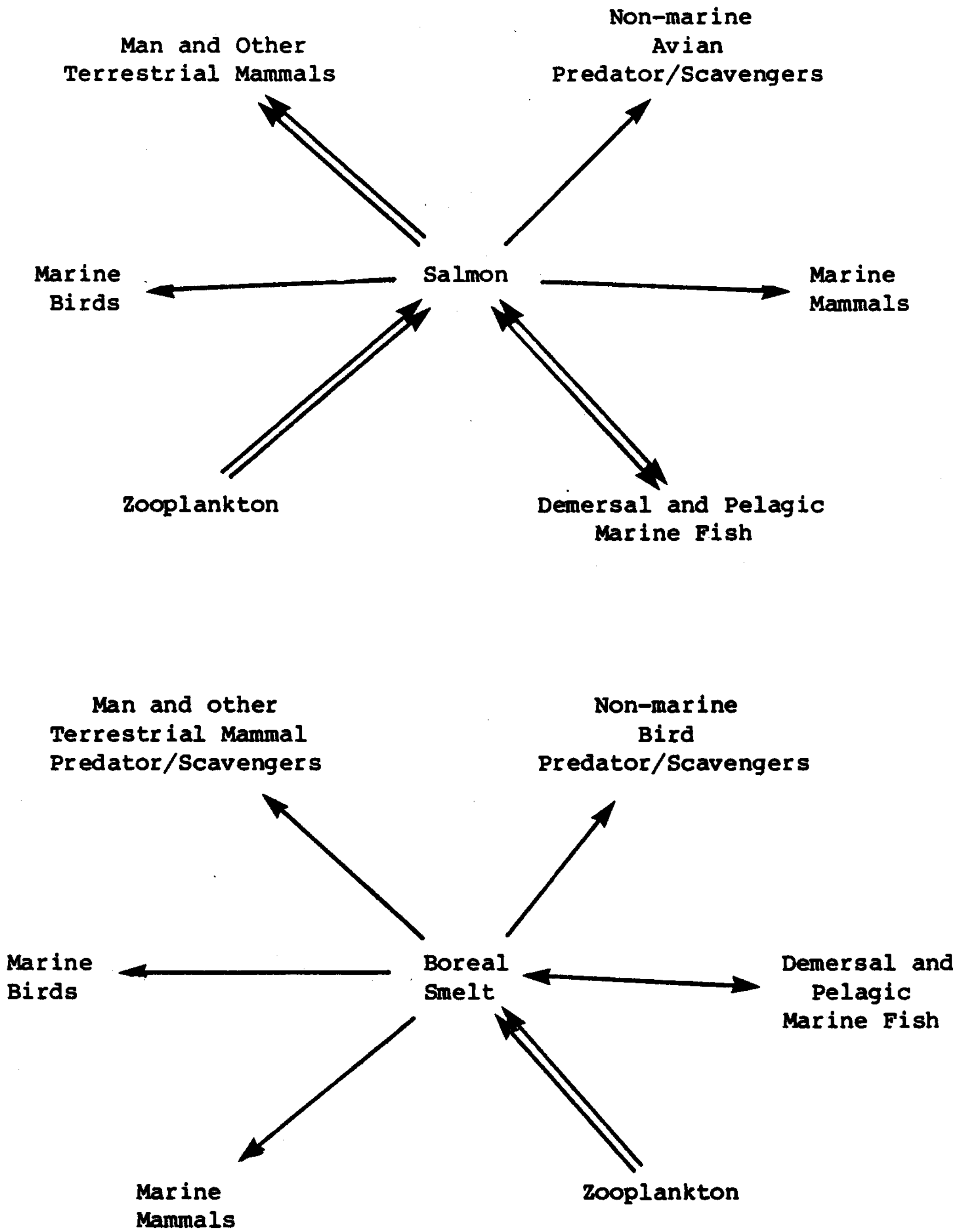


Figure 106. Basic trophic interactions of salmon and smelt. Double lines indicate primary reliance.

Salmon

Though all five species of Pacific salmon spawn in streams and lakes of the Bristol Bay-Alaska Peninsula region, sockeye salmon are the only species for which detailed information regarding life history and feeding habits within this area is available. Both adults and juveniles of sockeye feed on zooplankton (euphausiids, amphipods, copepods, cladocerans) and small fishes (particularly sandlance), though the species and age/ size composition of prey necessarily differs to some extent (Straty and Jaenicke, 1980). The prey of other salmon species is probably similar, though varying from species to species in proportions, so that all salmon can be classified as third and fourth trophic level predators.

Salmon in turn provide an important food resource for numerous fish, invertebrates, marine and terrestrial mammals, marine bird species, and man (Figure 106). Though quantitative data from the Bristol Bay-Alaska Peninsula area are generally sparse or lacking, it can probably be assumed that both smolt and adults are fed upon by beluga whale, harbor seal, Steller sea lion, and perhaps to a minor extent by spotted seal. Marine birds, probably including shearwaters, kittiwakes, murres, and certainly glaucous-winged gulls and Arctic terns, also consume juvenile and adult salmon to varying degrees when they are available (Flock, 1932; Mossman, 1958). The impact of marine mammal and marine bird predation upon the population is unknown.

Boreal Smelt

Though boreal smelt are probably the numerically dominant forage fish within the Bristol Bay and Alaska Peninsula nearshore zone (Warner and Shafford, 1981), very little is known about their trophic status other than that the adults prey upon mysids, amphipods, other fish, and polychaete worms (Warner and Shafford, 1981). This probably places them in the third or fourth trophic level.

Essentially no information is available as to consumption of smelt by other predators, though it can probably be assumed with some degree of confidence that, since they are the most available forage fish in at least some locales, they are utilized to a considerable degree by coastal marine mammals (beluga whale and harbor seal) and coastal marine birds (arctic terns, glaucous gulls, probably murres, kittiwakes, puffins, cormorants, guillemots) when the ranges of these species and smelt overlap (Figure 106).

Marine Mammals. All of the marine mammals of the region are apex predators. Other than man and killer whales, virtually no natural enemies prey on them. Diet and

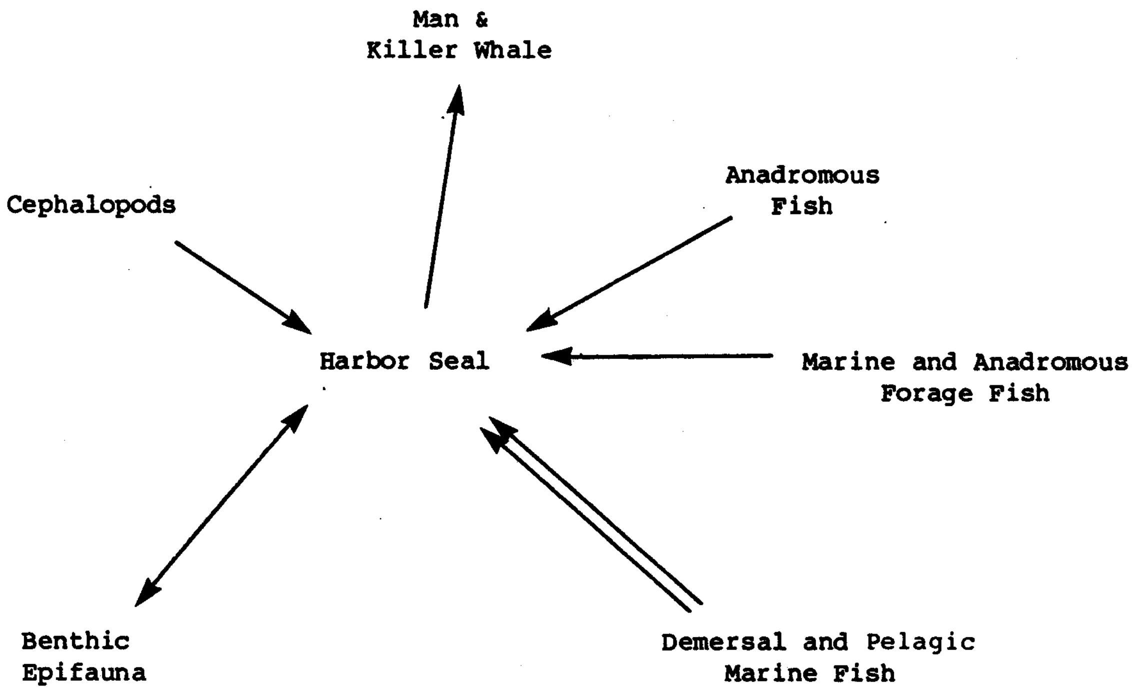


Figure 107. Basic trophic interactions of harbor seals. Double lines indicate primary reliance.

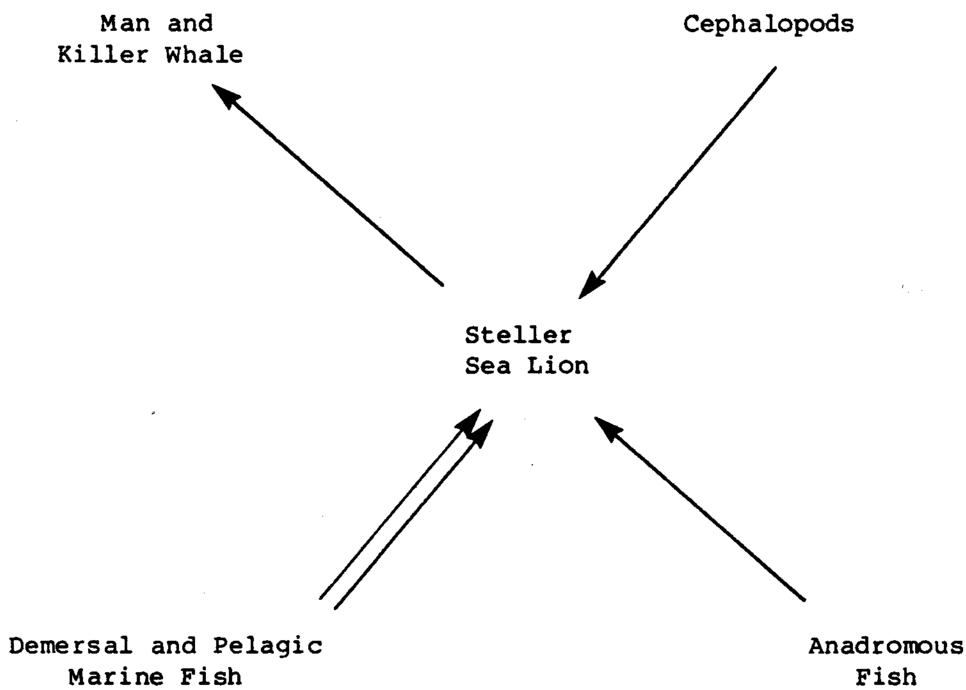


Figure 108. Basic trophic interactions of Steller sea lions. Double lines indicate primary reliance.

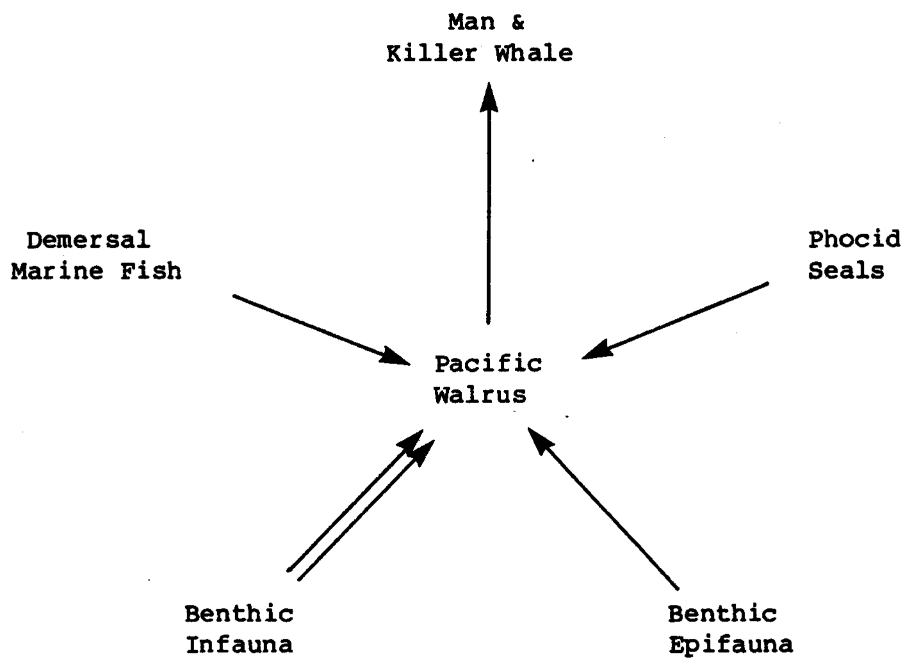


Figure 109. Basic trophic interactions of Pacific walruses. Double lines indicate primary reliance.

preferred prey species vary from species to species; in some cases seasonally ranging from marine and anadromous fish to benthic invertebrates. For major marine mammal species of the region, consumption rates and principal prey items are discussed briefly below.

Harbor Seal

Consumption by harbor seals ranges from 13% of total body weight daily during the first year, to three percent per day at age nine (Ashwell-Erickson et al, 1978). They are opportunistic feeders on a wide range of marine and anadromous fishes, shrimp, epibenthic crustaceans, and cephalopods (Figure 107). From limited numbers of stomach analyses in the Bristol Bay region (Lowry et al, 1982) it appears that, during fall at least, prey species include boreal (rainbow) smelt, sandlance, greenling, sculpins, pollock, various flatfishes, Pacific halibut, Pacific cod, and octopuses. It is also likely that they take, during certain times of the year, herring, capelin, yellowfin sole, salmon, shrimp, Tanner crab and king crab.

Stellar Sea Lion

Though data are sparse, it appears that Steller sea lions probably consume food weighing between six and ten percent of their body weight per day (Keyes, 1968). Sea lions are opportunistic feeders on a wide variety of finfish, squid, and octopuses (Figure 108). Available data indicate that preferred food items are (not necessarily in this order) capelin, sandlance, pollock, sculpins, flatfishes, cod, halibut, squid, octopus, and Atka mackerel (Lowry et al, 1982).

Pacific Walrus

Daily food consumption by adults is estimated (Fay, 1982) at 6.2 percent per day. Walrus are, primarily, feeders on benthic infauna and epifauna (Figure 109). In the Bristol Bay region, they have been found to take at least 22 genera of benthic invertebrates, including bivalve mollusks, gastropod mollusks, crabs (*Hyas* and *Chionoecetes* spp.), hermit crabs, crangonid shrimps, octopuses, tunicates, anemones, priapulids, echiuroids, and polychaete worms. More than 90 percent of their diet, however, seems to be composed of five genera of bivalve mollusks (*Serripes*, *Mya*, *Spisula*, *Tellina* and *Siliqua*), followed in importance by other bivalves (such as *Macoma*, *Astarte*, *Hiatella*), gastropods, and other minor taxa (Fay and Lowry, 1981). They are also known, on rare occasion, to prey on other seals (Fay et al, 1977), and to consume such diverse items as sandlance and jellyfish (Fay and Stoker, 1982a,b).

Sea Otter

Adult otters are known to consume between 20 and 25 percent of their body weight per day (Estes and Palmisano, 1974). They will prey on a wide range of benthic invertebrates and fish (Figure 110), though their favored food item seems to be sea urchins.

Information on the feeding habits of sea otters within the Bristol Bay region is limited to analyses of nine scat samples obtained over a two day period from Glazenap Island. This limited data indicated that crustaceans (crabs, shrimp, and amphipods), mollusks (clams and mussels), echinoderms (sand dollars) and chordates (fish) were the most frequently consumed prey. While crustaceans and mollusks were consumed more often, fish were suggested by this study to be the most important prey in terms of biomass.

Beluga (Belukha) Whale

Records of captive belugas indicate that they consume between four and seven percent of their body weight per day. Belugas are known to consume a wide variety of fish and invertebrates (Figure 111). Smelt and salmon seem to comprise a major part of their diet in the Bristol Bay area from May through August, when belugas are present in large numbers in the vicinity of Kvichak and Nushagak Bays (Brooks, 1955). During winter they apparently shift to the ice edge further offshore, where they probably rely heavily on pollock (Seaman et al, 1982). In other areas, they are also known to feed extensively on herring, saffron cod, and crangonid shrimps (Lowry et al, 1982).

Gray Whale

Gray whales probably consume food weighing between three and five percent of their body weight on the average, or about 1,200 kg, per day. They are known to feed extensively on gammarid amphipods of the genera *Ampelisca*, *Lembos*, *Anonyx*, and *Pontoporeia* in the shallow water summer feeding grounds of Norton Sound (Figure 112) (Lowry et al, 1982). During the spring migration through the North Aleutian Shelf area, however, gray whales feed on unknown quantities and species of invertebrates (Gill and Hall, 1983).

Birds. Birds being included in this section include seabirds, waterfowl, and shorebirds.

Seabirds

Though data are incomplete as to the nutritional requirements of seabirds, the total consumption by seabirds in the

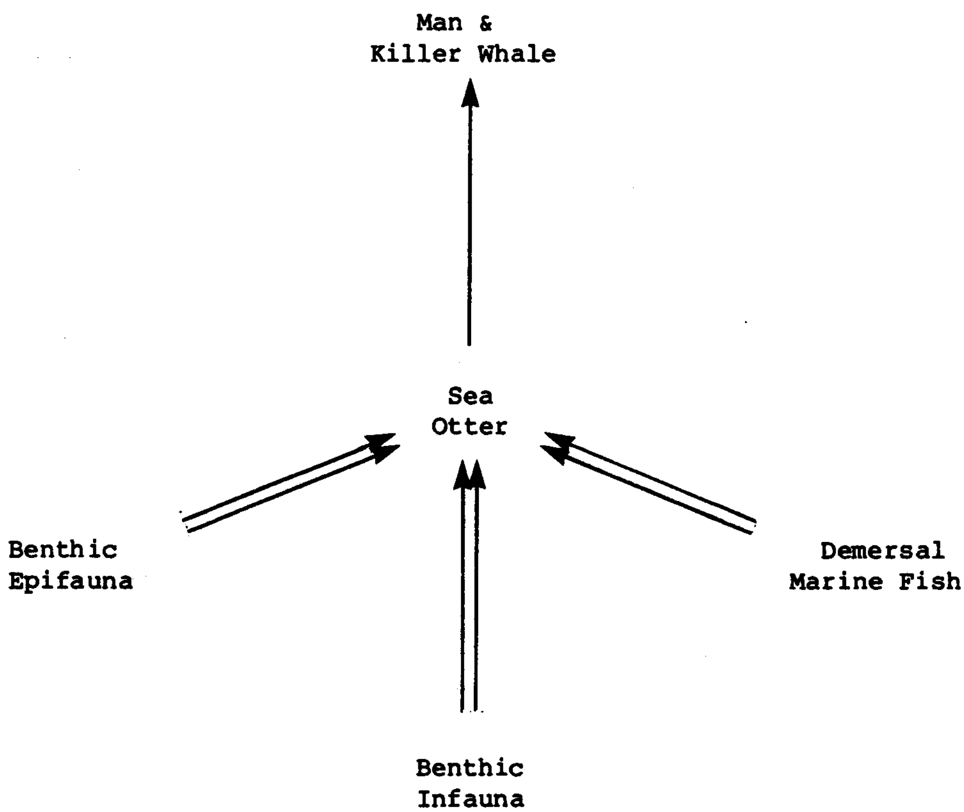


Figure 110. Basic trophic interactions of sea otters. Double lines indicate primary reliance.

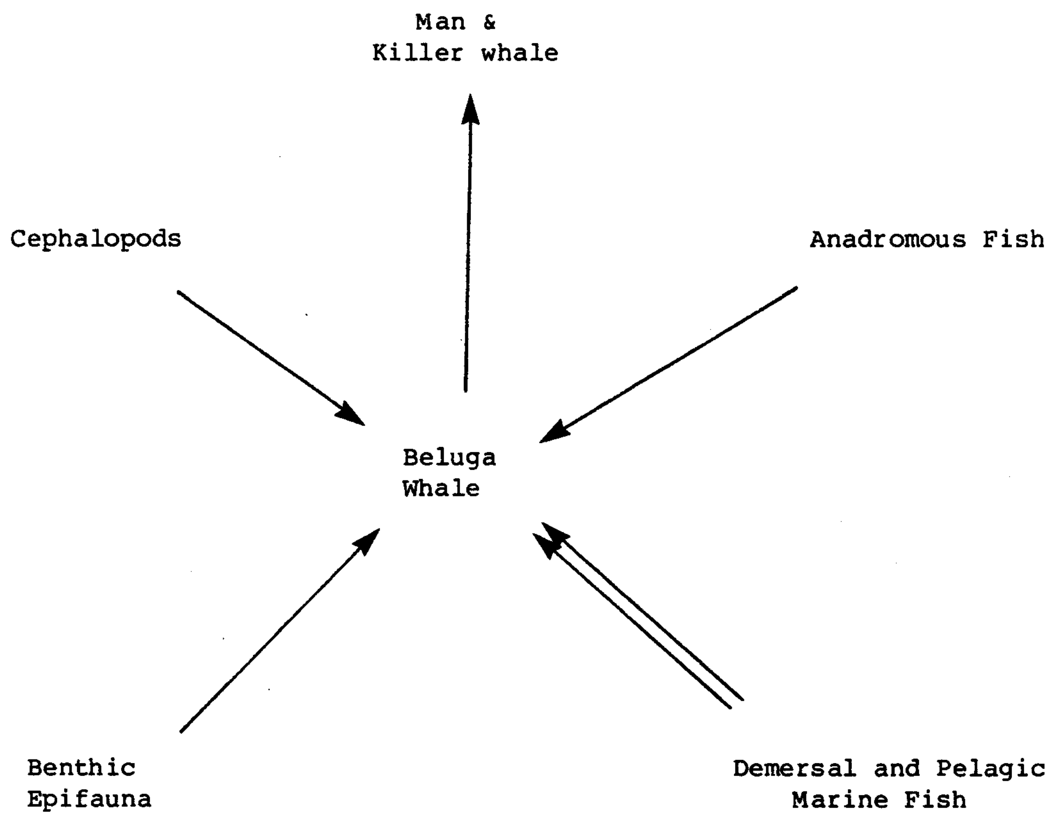


Figure 111. Basic trophic interactions of beluga whales. Double lines indicate primary reliance.

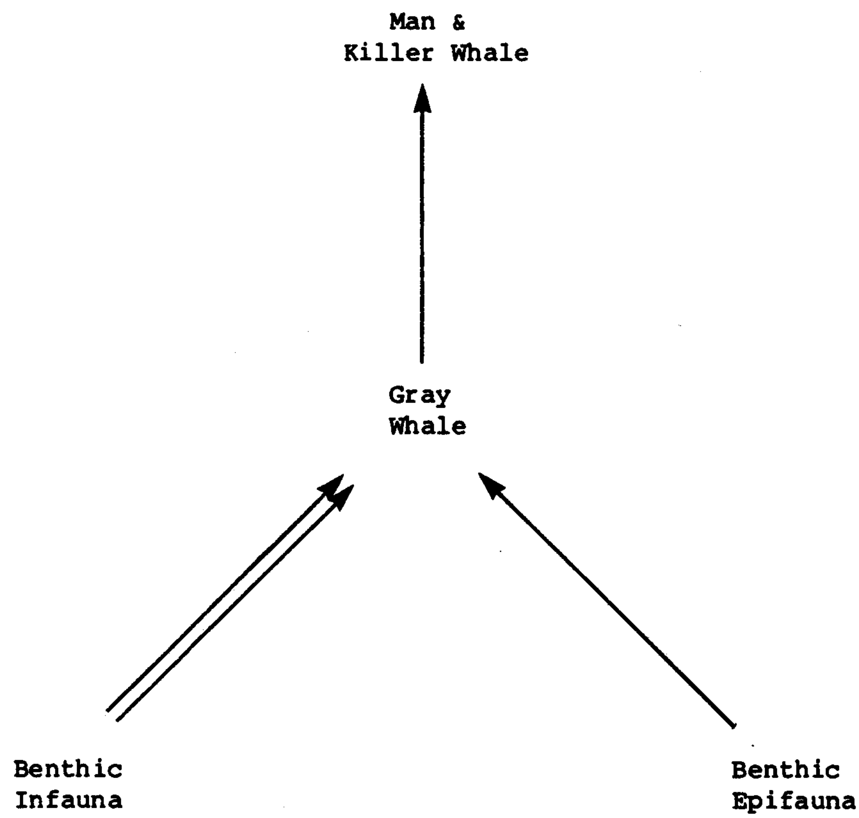


Figure 112. Basic trophic interactions of gray whales. Double lines indicate primary reliance.

eastern Bering Sea is estimated at between 550,000 and 1,000,000 metric tons per year (Hunt et al, 1981a). If a total population estimate of 53 million seabirds frequenting the eastern Bering Sea is applied to this figure (Hunt et al, 1981a), it appears that the annual consumption in this geographical region amounts to between 10 and 20 kg per bird. Such estimates are admittedly crude, and do not account for what are undoubtedly great differences in feeding rates from species to species depending on the caloric value of prey consumed. Hunt et al (1981a) assumes, for purposes of feeding calculations, that daily seabird consumption rates range between 10 and 20 percent of their body weight.

All seabirds of this region are predators, feeding on zooplankton, fish, and bivalves. In general, it is estimated that fish probably make up about 70 percent of the diet of seabirds of the area, followed in importance by zooplankton and squid (Hunt et al, 1981a). Pollock are probably the principal fish species consumed, with an estimated 150,000 metric tons eaten annually by seabirds on the eastern Bering Sea shelf (Hunt et al, 1981a). An additional 170,000 mt of other fish are eaten by seabirds annually over this shelf, as well as an estimated 80,000 mt of euphausiids, 80,000 mt of amphipods (primarily Parathemisto libellula), and 70,000 mt of squid [Figure 113 (Hunt et al, 1981a)]. In the nearshore zone, it is considered likely that seabirds also feed heavily, at least during certain times of year, on forage fish such as herring, capelin, and smelt, and on outmigrating juvenile salmon.

For the most part, seabirds seem quite prey-specific in their diets, with each species relying on a very few prey items (Hunt et al, 1981a; Ainley and Sanger, 1979). In summer, short-tailed shearwaters apparently feed very heavily on euphausiids in the Bering Sea (70% of their total diet), while amphipods, especially Parathemisto libellua, constitute 60% of the fall diet in the same area (Hunt et al, 1981a). In addition to these crustaceans, shearwaters are known to take squid, capelin, and probably other small fish (Ainley and Sanger, 1979). Shearwaters probably are restricted to feeding in the upper five meters of the water column (Hunt et al, 1981a).

Fish seem to constitute the mainstay of the diet of common murres over the eastern Bering Sea shelf (Figure 114), though cephalopods, crustaceans, and even polychaete worms are also eaten, with diets varying from location to location (Hunt et al, 1981a; Ainley and Sanger, 1979). Principal fish species consumed appear to be pollock, sandlance, capelin, and possibly juvenile salmon (Hunt et al, 1981a; Ainley and Sanger, 1979; Ogi and Tsujita, 1973). At times at least, and in certain areas, amphipods, euphausiids, cephalopods, and polychaetes are also known to contribute significantly to the diet of common murres (Hunt et al, 1981a; Ogi and Tsujita, 1973).

The diet of black-legged kittiwakes seems to be somewhat variable, differing from season to season and probably from area to area (Hunt et al, 1981a). In the Pribilof Island region, kittiwakes rely primarily on amphipods (notably *P. libellula*) and euphausiids before nesting, shifting to fish (primarily pollock and myctophids) during incubation. Principal euphausiid species taken are *Thysanoessa inermis*, *T. longipes*, and *T. raschii* (Hunt et al, 1981a). In addition to pollock, kittiwakes are known to consume sandlance, cod and several other small fish species. Cephalopods are also taken to some extent (Figure 115).

Seabirds are essentially top predators, at the third or fourth trophic level, and are themselves rarely preyed upon by other marine species. A few are taken by falcons and hawks. Eggs and young are preyed upon by gulls; when accessible, by foxes and humans.

Waterfowl

Waterfowl represent a mixture of trophic levels and feeding types, from secondary consumers of eelgrass and other vegetation to predators, depending on species (Figure 116). While in general, geese and non-marine ducks, including black brant, emperor goose, pintail, teal, and widgeon, are herbivores, in the lease area, *Macoma* is the primary food item. Sea ducks such as eiders, scoters, oldsquaw and scaup are predators. The prey consumed by sea ducks varies from species to species and probably seasonally and from area to area, ranging from fish to zooplankton to benthic invertebrates. With the exception of oldsquaw, which takes a wide variety of food, most are probably rather prey-specific. Steller's eiders in the Nelson Lagoon area, for instance, feed almost exclusively on 0-1 year age class mussels (*Mytilus edulis*) and amphipods (*Anisogammarus pugettensis*) (Petersen, 1980).

Non-human predation on waterfowl is probably most intense during the nesting season. Eggs and young are eaten, when the opportunity arises by virtually all terrestrial mammal and avian predators. Adult birds are preyed upon by falcons, hawks, eagles, and by man.

Shorebirds

Shorebirds forage primarily in the intertidal zone on exposed beaches and mudflats of estuaries and lagoons along the Alaska Peninsula-Bristol Bay coast. Though detailed information is not currently available, it is presumed that principal prey items are infaunal and epifaunal crustaceans and polychaete worms (Figure 117).

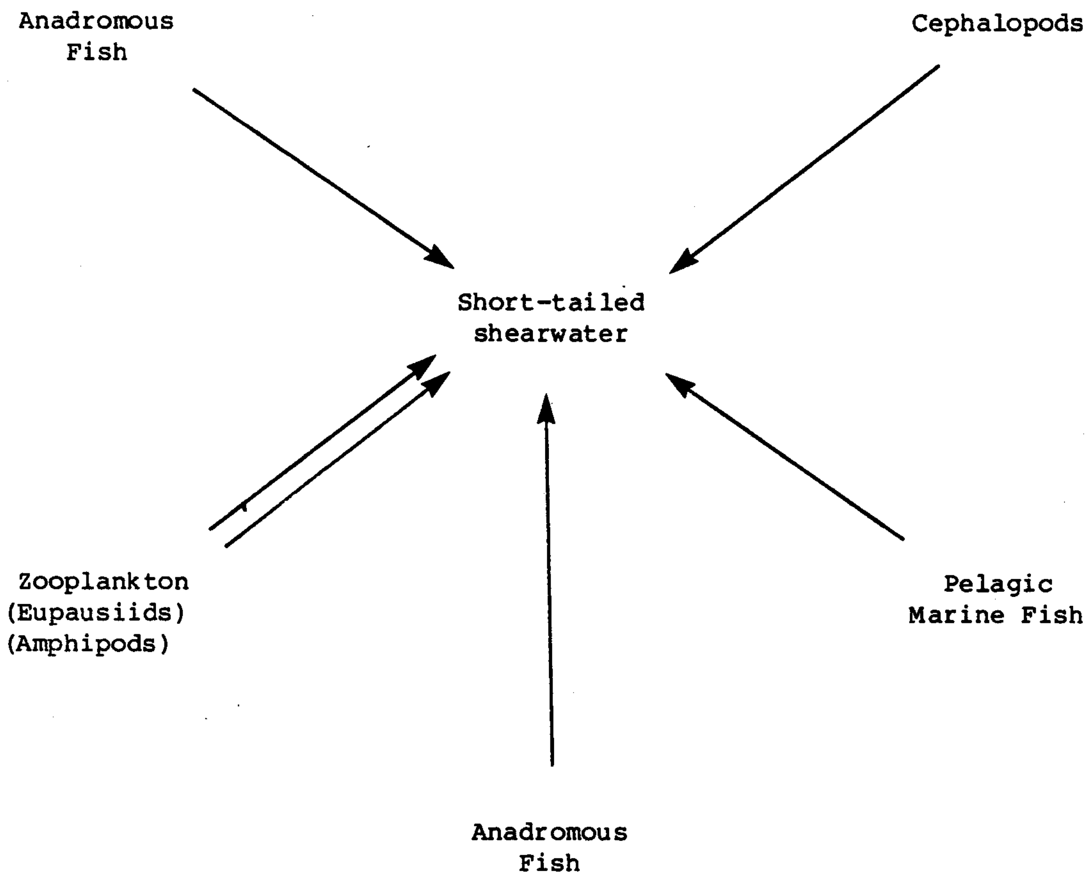


Figure 113. Basic trophic interactions of short-tailed shearwaters. Double lines indicate primary reliance.

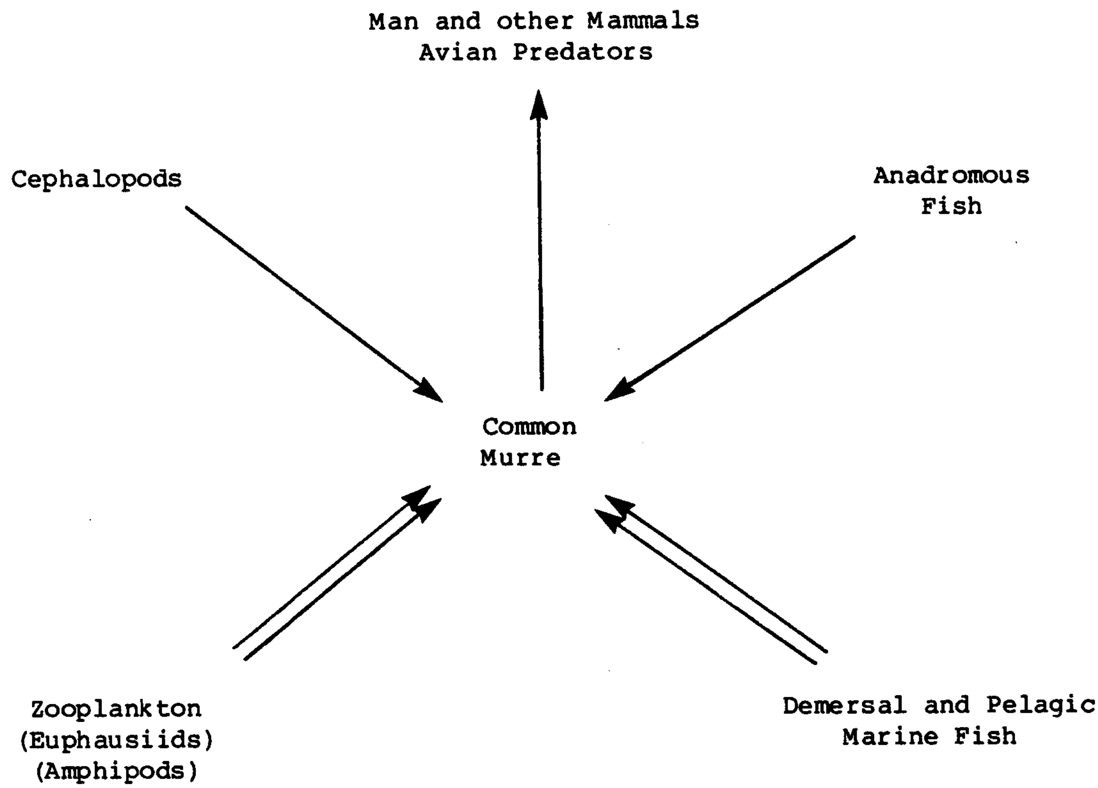


Figure 114. Basic trophic interactions of common murres. Double lines indicate primary reliance.

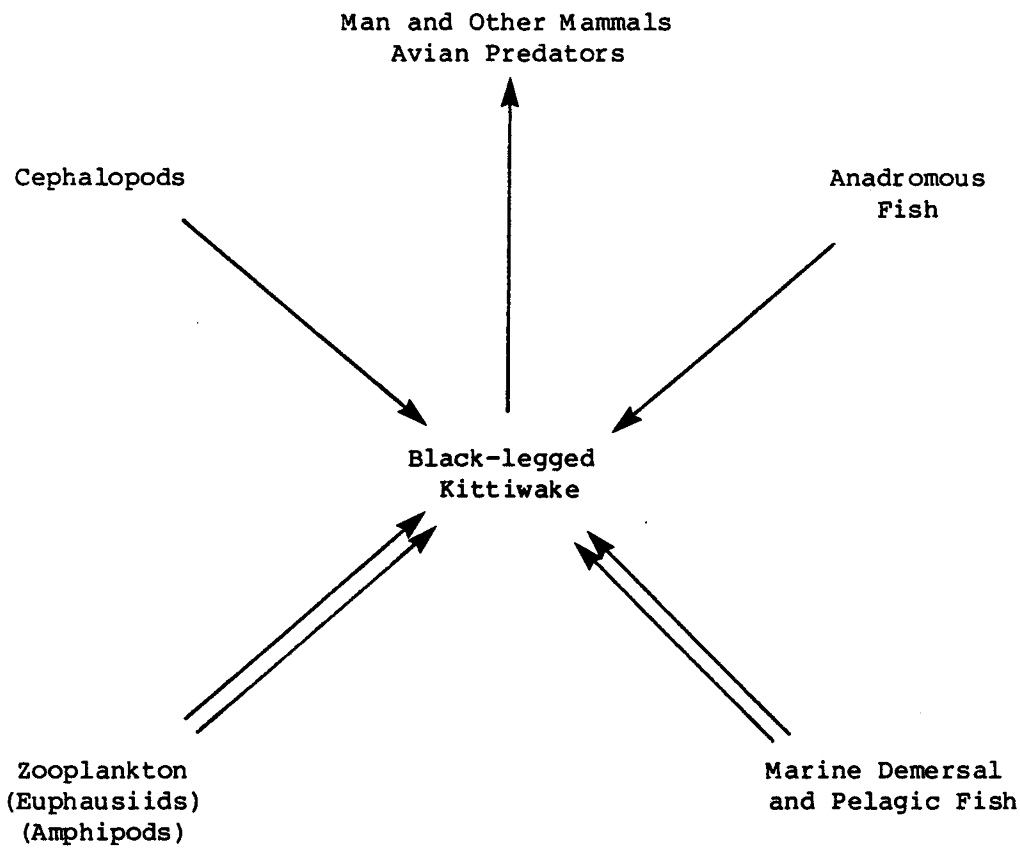


Figure 115. Basic trophic interactions of black-legged kittiwakes. Double lines indicate primary reliance.

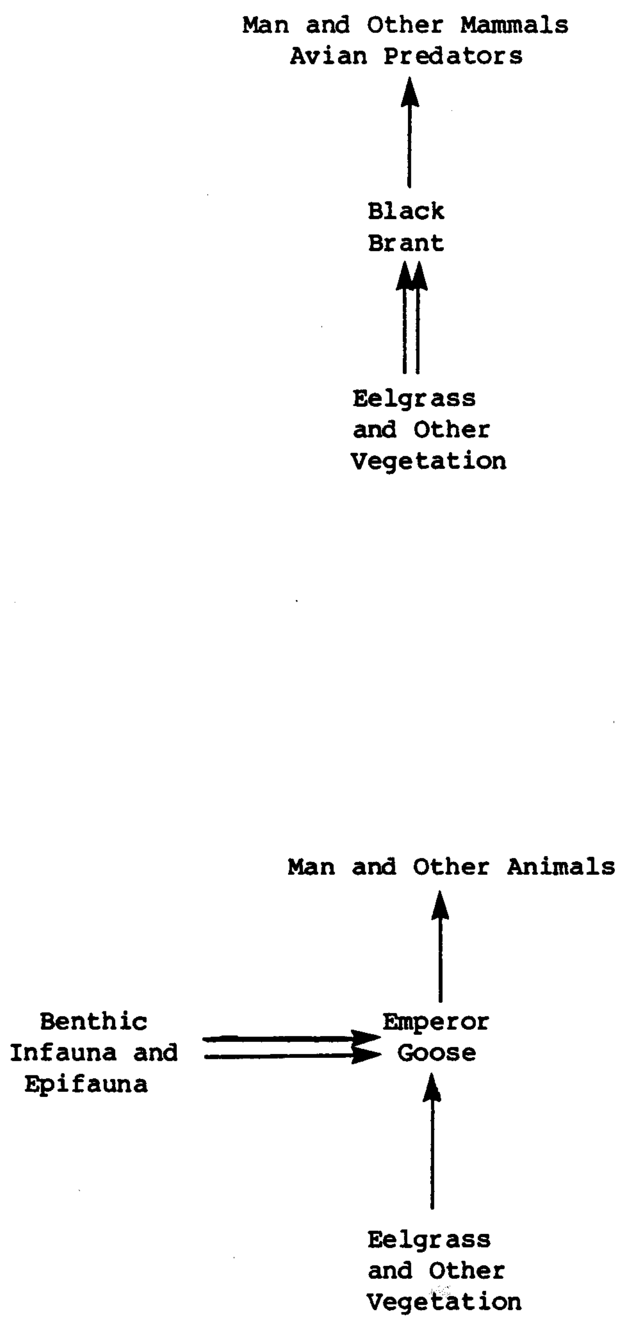
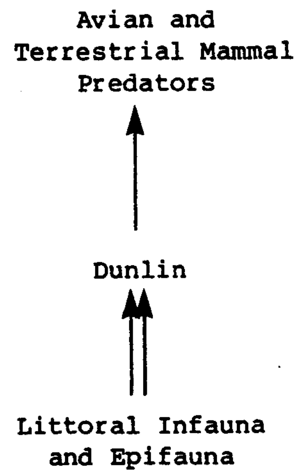


Figure 116. Basic trophic interactions of waterfowl. Double lines indicate primary reliance.



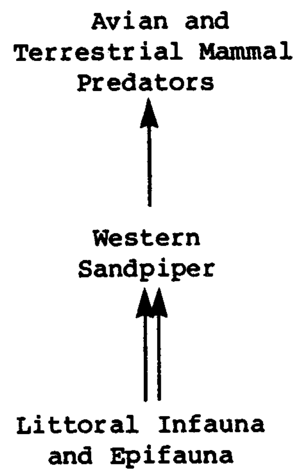


Figure 117. Basic trophic interactions of shorebirds. Double lines indicate primary reliance.

Shorebirds are considered to be primarily third trophic level predators (Gill and Handel, 1981).

Like waterfowl, shorebirds are most vulnerable to predation during the nesting period, when young and eggs are consumed by most terrestrial mammal and avian predators of the region. At other times, they are taken to some extent by avian predators such as hawks and falcons.

d. Habitat Characterization

A classification of all shoreline types from Unimak Island to Cape Newenham is presented in Michel et al (1982), supported by earlier reconnaissance studies by Sears and Zimmerman (1979). A physical description of exposed coastal waters and protected nearshore waters from Unimak Island to Port Heiden is summarized in Armstrong et al (1982). The unprotected shoreline from Unimak Island to Port Heiden is comprised, for the most part, of large segments of coarse-grained sand beaches. This shoreline is also interspersed with small sections of mixed sand and gravel beaches. Coarse-grained beach vegetation is dominated by American dune grass (Elymus sp.), forming a dense carpet on the sand dunes backing beaches (Armstrong et al, 1982). The major embayments (i.e., Izembek Lagoon, Port Moller, Nelson Lagoon and Port Heiden) mainly consist of sheltered tidal flats and marshes (Armstrong et al, 1982). Bristol Bay is made up of a variety of shoreline types; however, mixed sand-grain beaches and exposed tidal flats dominate (Michel et al, 1982).

The north coast of the Alaska Peninsula is generally characterized by long stretches of high-energy beaches interrupted by major estuaries and lagoons such as Bechevin Bay, Izembek Lagoon, Port Moller, Port Heiden, Ugashik Bay, and Egegik Bay. Inner Bristol Bay consists, on the eastern side, of low, broad tundra flats separated by large estuaries such as Kvichak Bay, Nushagak Bay, and Kulukak Bay. The coastal habitat of the western part of inner Bristol Bay consists primarily of steep, rocky headlands and nearshore islands dissected by estuaries and straits such as Togiak Bay and Hagemeister Strait.

The nearshore subtidal substrates throughout most of the North Aleutian Shelf and Bristol Bay region is mainly composed of medium-grained sand (0.25-0.5 mm). Portions of inner and northern Bristol Bay are composed of coarse (0.5-1.0 mm) and very coarse (1.0-2.0 mm) sand. Grain size sorting in the surface sediment is described as "moderately poorly sorted" to "extremely poorly sorted" for most of the shelf; in Bristol Bay the sand is described as "moderately well sorted" to "well sorted" (McDonald et al, 1981). Existing data on distributions of the inshore sediments have been presented as maps in the earlier section on Geological Setting.

For purposes of physical and biological description, the region may be divided into two major zones or areas: the coast north of the Alaskan Peninsula from Unimak Pass to about Ugashik Bay, and Inner Bristol Bay from about Ugashik Bay around to Cape Newenham. Shoreline habitats of this Bristol Bay area are summarized in Figures 118 through 122. Location of macrophyte habitats are given in Figure 123.

Alaska Peninsula Coast. The northern coast of the Alaska Peninsula can be further subdivided into a western zone, including Unimak Pass, Unimak Island and the tip of the peninsula, and the eastern peninsula from about Izembek Lagoon to Ugashik Bay. Coastal habitats of the western zone would include Unimak Pass and the rocky capes and headlands of Unimak and Amak Islands. The eastern zone is more properly characterized by high-energy sand and gravel beaches interrupted by major estuaries and lagoons and, infrequently, by headlands such as Cape Seniavin.

Within the western zone of this northern Peninsula coast, sensitive habitats are considered to be Unimak Pass, the capes and headlands of Unimak Island, and Amak Island.

Unimak Pass is of particular importance for several species of marine mammals, marine birds and anadromous fish, both as forage grounds and as a migration route. The entire gray whale population enters and exits the Bering Sea twice a year via Unimak Pass, as does most of the northern fur seal population, along with the central Bering Sea complement of sperm whales, and numerous other cetaceans and pinnipeds.

Unimak Pass is also the principal migration route for major marine bird and waterfowl populations, including shorttailed and sooty shearwaters, common and thick-billed murres, Leach's and fork-tailed storm petrels, fulmars, and various species of gulls, guillemots, puffins, auklets, eiders, scaups and scoters. In addition to its importance as a migratory route, Unimak Pass provides a year-round feeding habitat for large numbers of marine birds and sea ducks, and for marine mammals such as harbor seals and sea lions.

Severe ecological disruption of Unimak Pass habitats might be particularly disastrous during spring and fall when migrations of marine mammals and birds are at their peak. Catastrophic or chronic perturbations of Unimak Pass at any time of year would have negative impacts on at least several species of marine mammals and birds; particularly harbor seals, sea lions, sea otters, possibly gray whales and fur

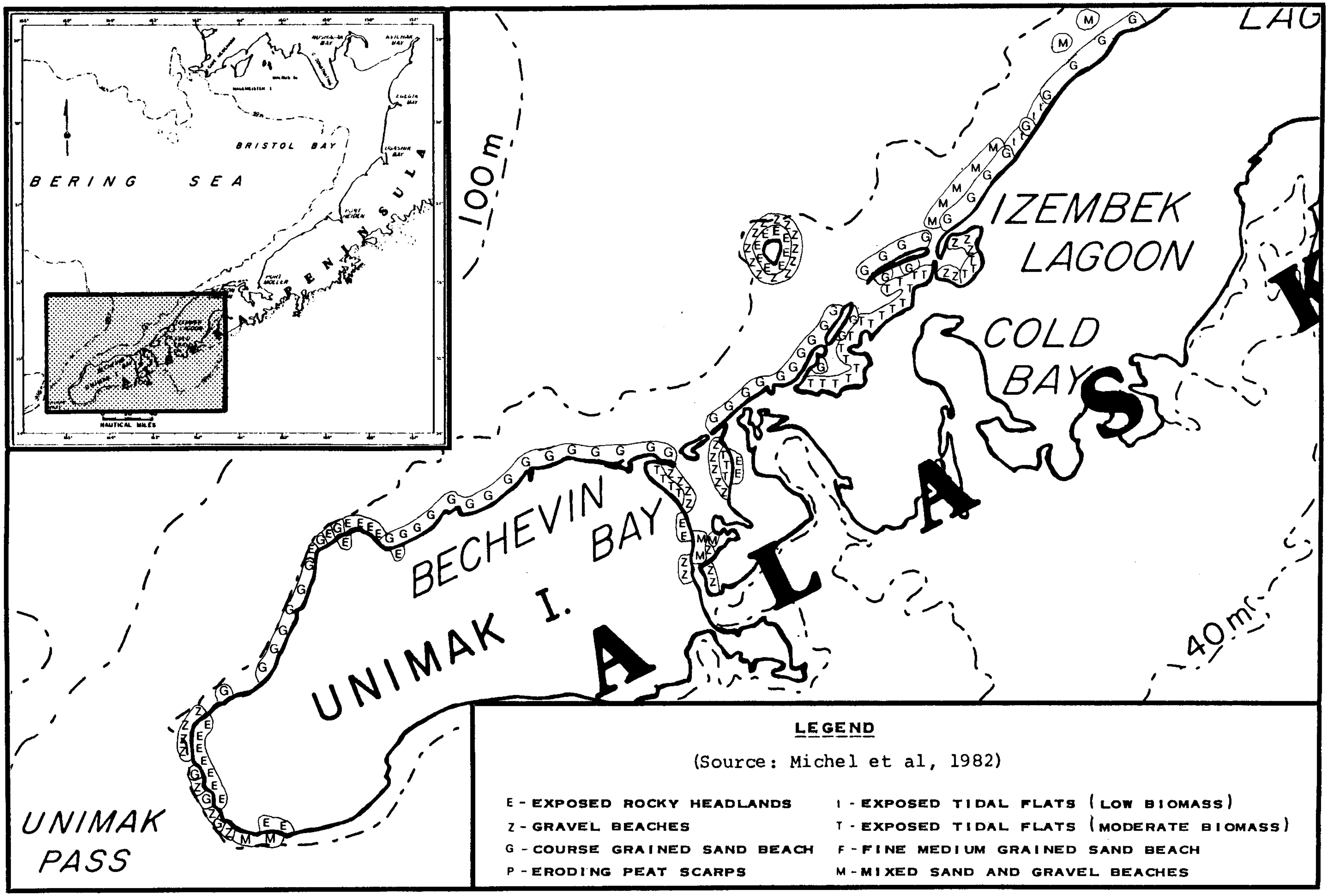


Figure 118. Bristol Bay coastal habitats, Unimak Island - Izembek Lagoon area.

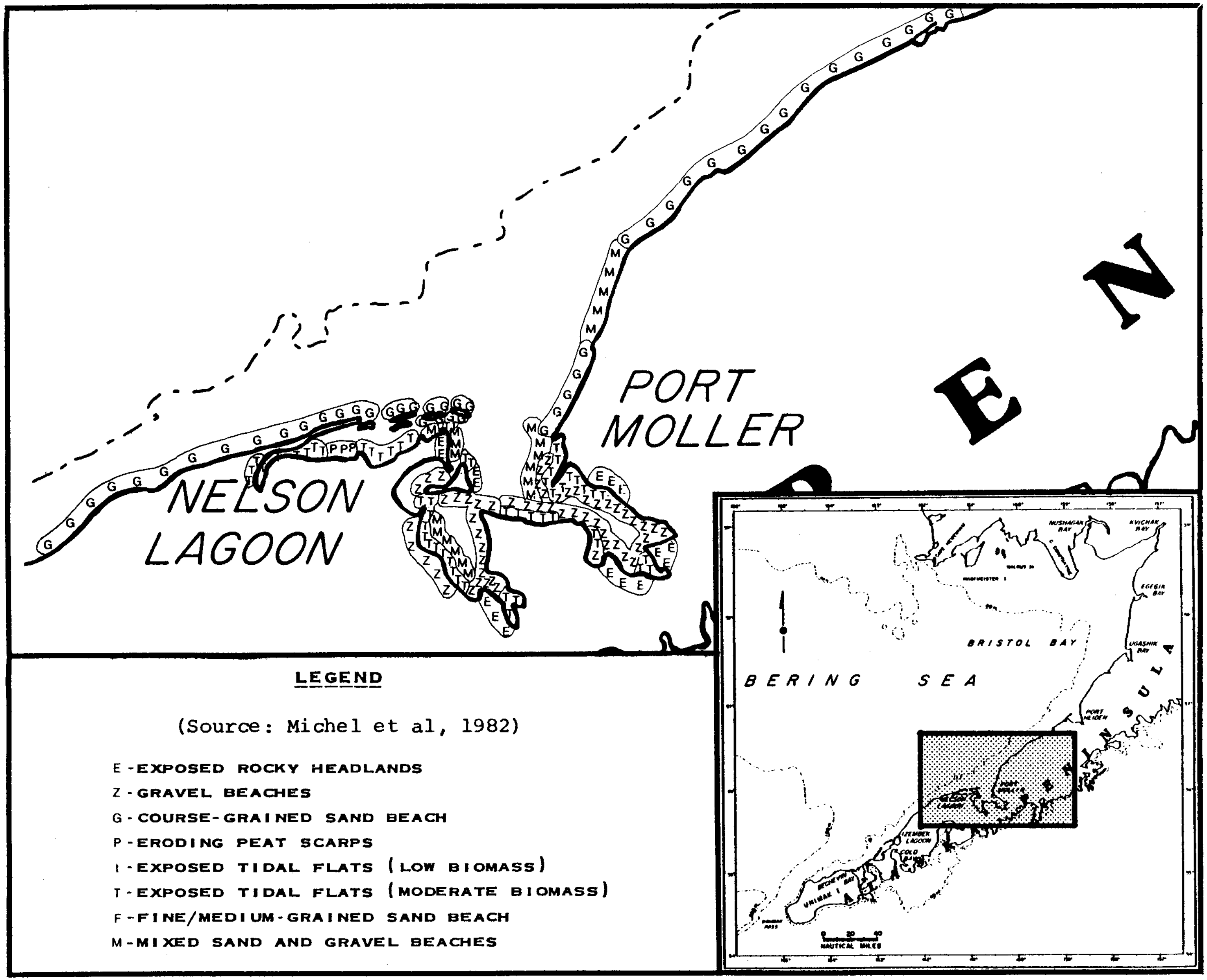


Figure 119. Bristol Bay coastal habitats, Port Moller area.

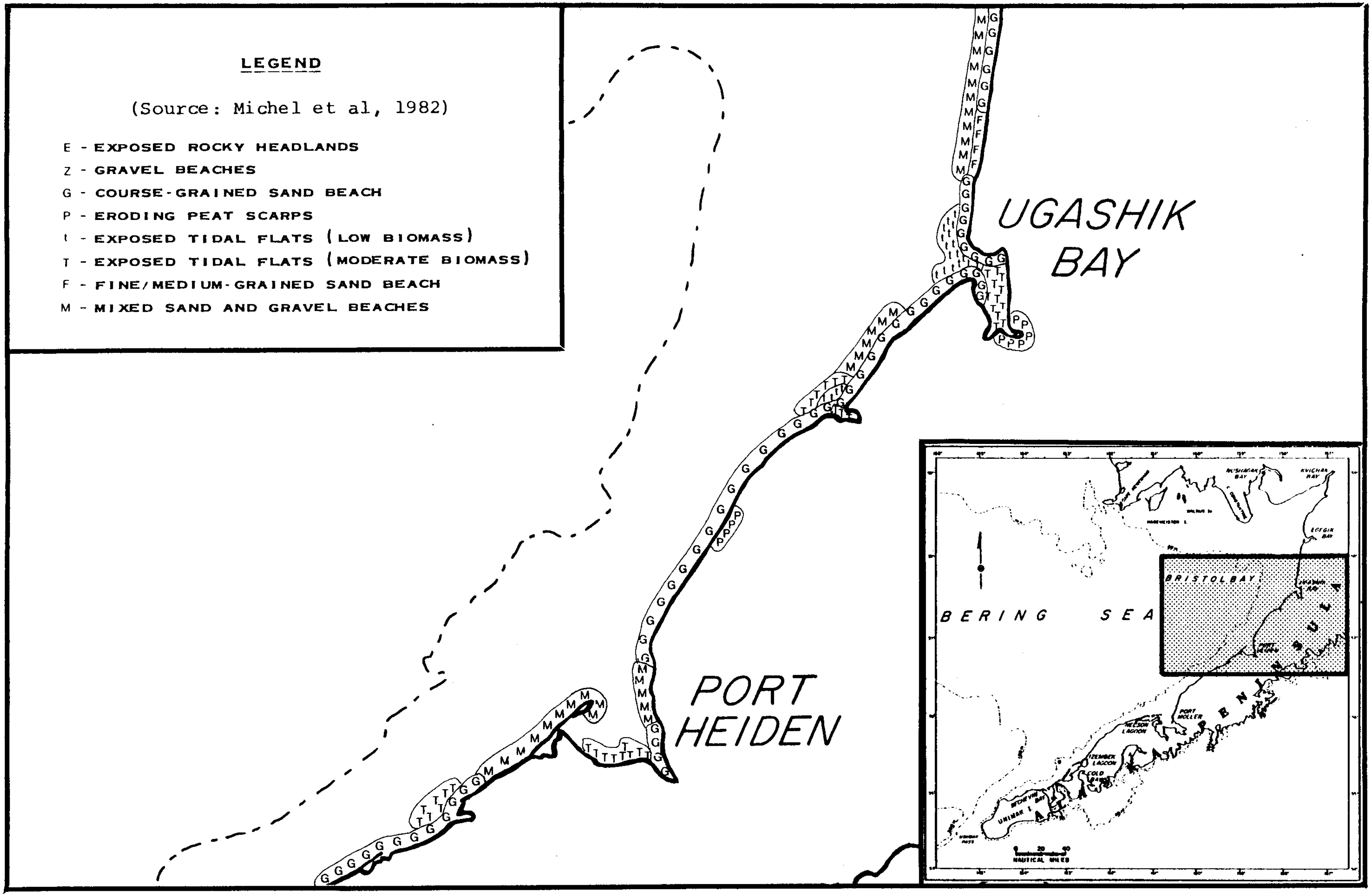


Figure 120. Bristol Bay coastal habitats, Port Heiden - Ugashik Bay area.

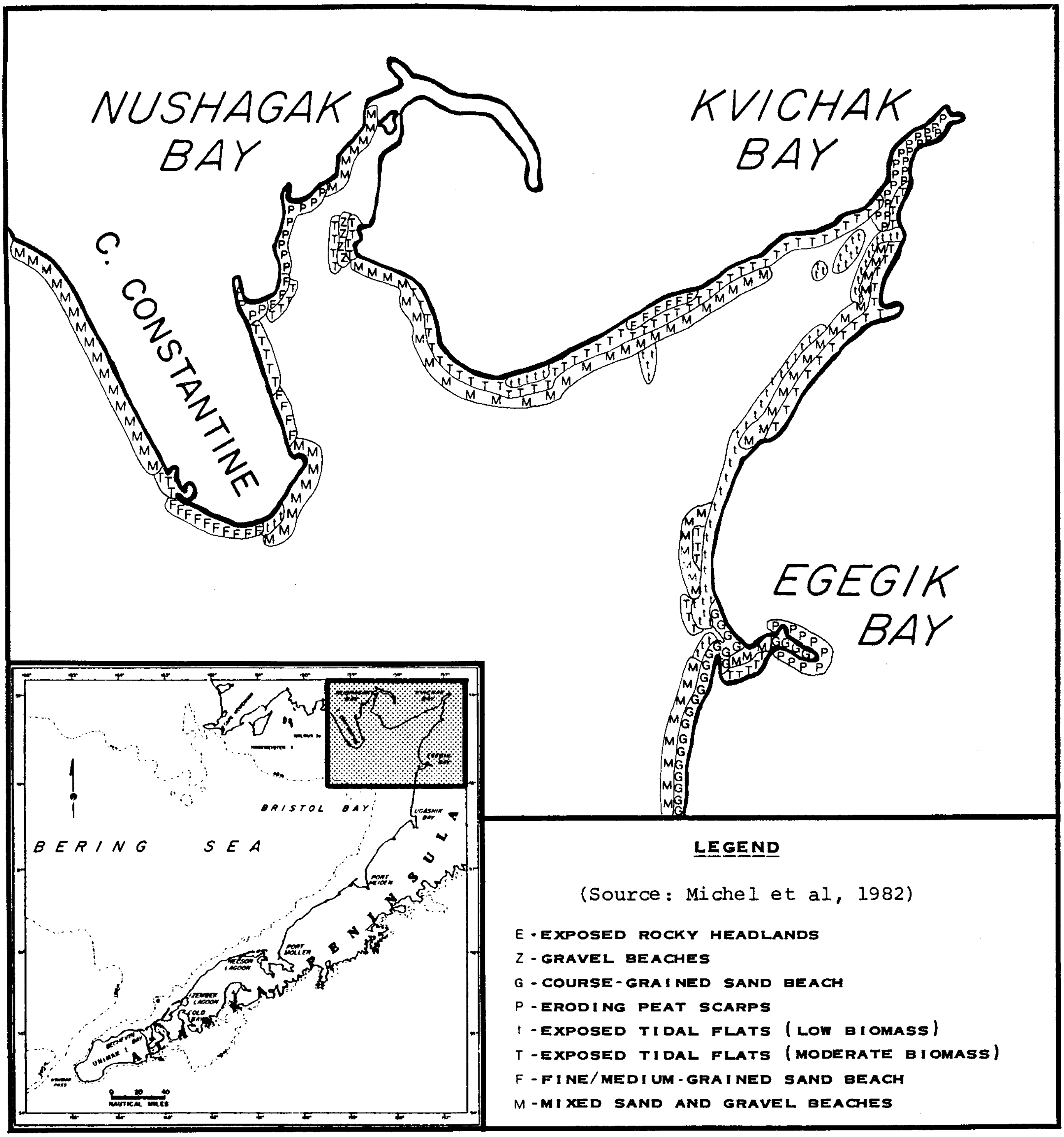


Figure 121. Bristol Bay coastal habitats, Kvichak Bay area.

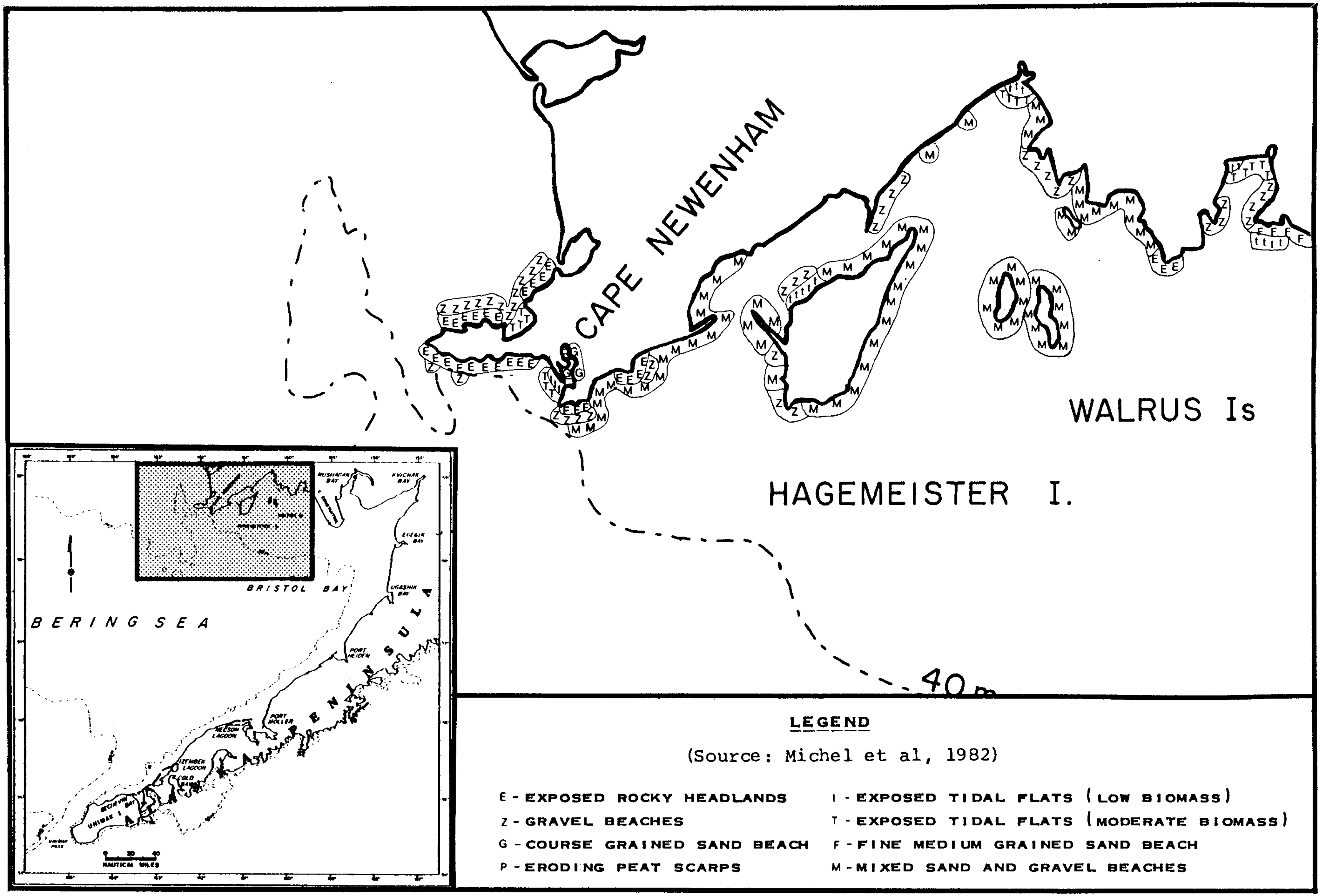
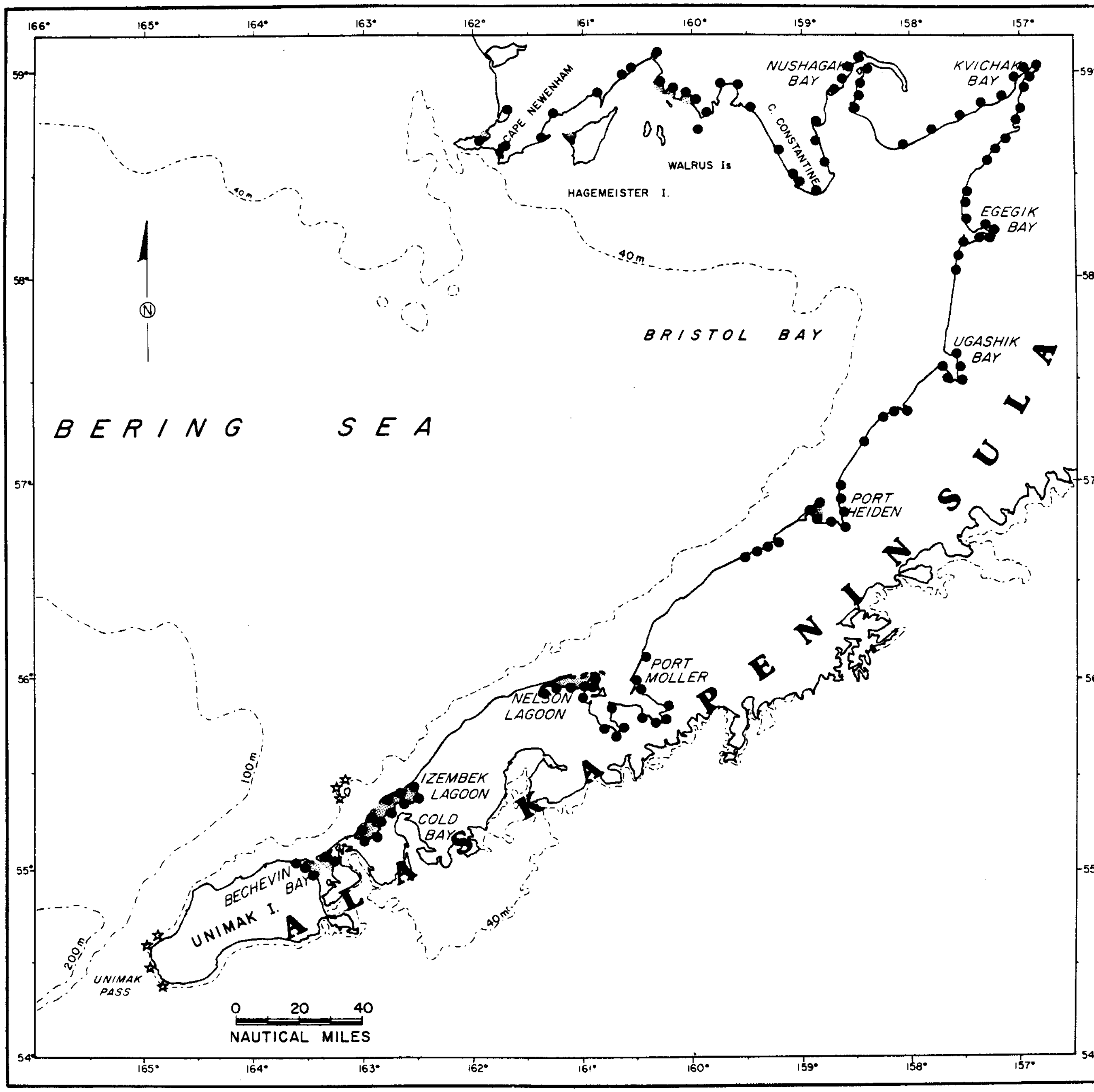


Figure 122. Bristol Bay coastal habitats, Togiak Bay - Cape Newenham area.



• - MARSHES (after Michel et al, 1982)   ▒ - EELGRASS (McRoy, 1970)

☆ – KELP BEDS (McRoy - personal observation)

Figure 123. Locations of major macrophyte habitats.

seals, murres, shearwaters, petrels, puffins, fulmars, kittiwakes, terns, eiders, scoters, scaups, cormorants, guillemots, gulls, and auklets.

Also, Unimak Pass is the principal migration route for both juvenile salmon exiting the region and for adult salmon returning from the North Pacific (Straty and Jaenicke, 1980). Though disturbance effects, other than some knowledge concerning oil toxicity, are not well known for salmon, disruption of these migrations through Unimak and adjacent passes could have deleterious impacts on the largest salmon fishery in North America.

In addition to Unimak Pass itself, sensitive habitats within this western subzone include Cape Mordvinof, Cape Serichef, Otter Point, Urilia Bay and Cape Lapin on Unimak Island, Bechevin Bay on the Alaska Peninsula, and certainly Amak Island. All of these locales provide nesting habitats for marine birds, particularly cormorants and puffins on Unimak Island and for murres, kittiwakes and gulls on Amak Island (Sowls et al, 1978). These locales also are used intermittently as hauling sites, breeding rookeries, or forage zones for marine mammals such as harbor seals, Steller sea lions, and sea otters. Amak Island supports the only breeding rookery of Steller sea lions within the area (Braham et al, 1980).

Along the eastern region of the Alaska Peninsula coast, locales of critical or sensitive habitat include the lagoon estuary systems which seasonally support almost all of the region's population of harbor seals (Everitt and Braham, 1980). These areas are used also as molting, feeding, and staging areas for the world population of black brant, emperor goose, and Steller's eider. They are probably also critical for cackling Canada goose, dunlin, western sandpiper, and other species of shorebirds and waterfowl, and provide nursery grounds for anadromous and marine fish, including various salmon species, smelt, herring, capelin, and eulachon. The lagoons and estuaries are used extensively as forage, hauling, pupping, and molting habitat by harbor seals and as a forage and calving grounds by beluga whales (Straty and Jaenicke, 1980; Warner and Shaffold, 1981; Everitt and Braham, 1980; Brooks, 1955; Alaska Department of Fish and Game, unpublished data).

The critical or sensitive estuary and lagoon systems under consideration are Izembek Lagoon, the Port Moller complex including Nelson Lagoon, Port Heiden, Cinder River, and Ugashik Bay. It is known that shorebird and waterfowl abundances in the lagoons and bays steadily increase along the coast from Ugashik Bay to Izembek Lagoon (Gill et al, 1981). Sources of the birds' nutrition also increase along the coast in a southwesterly direction (Gill, personal communication). If this same trend also is true for other trophic levels and groups of consummers, then the major bay and lagoon habitats could be ranked in importance to the well-being of the communities they support.

Other sensitive habitats along the northern coast of the Alaska Peninsula include Cape Seniavin, Seal Island, and other islands, capes and headlands which are used, seasonally and/or intermittently, as nesting habitats for marine birds (particularly glaucous-winged gulls) and as hauling and/or pupping and moulting grounds for walrus, harbor seals, and sea lions.

Disturbance of these areas would have maximum impact during spring (April-May), summer (June-August) and early fall (September-October), when shorebirds and waterfowl are congregating in the estuaries and lagoons during the spring and fall migrations, during the post-breeding and molting period (Gill et al, 1981), and when marine mammals (beluga whale and harbor seal) are concentrated within and adjacent to lagoons and estuaries (Lowry et al, 1982).

Inner Bristol Bay. Like the Alaska Peninsula-Aleutian area, inner Bristol Bay can be viewed as essentially two habitat zones - eastern Bristol Bay and western Bristol Bay.

Eastern Bristol Bay includes the vast estuaries, intertidal flats, and low tundra coasts of Egegik Bay, Nushagak Bay and Kvichak Bay. These estuaries are known to support very large populations of forage fish (e.g. smelt, herring, capelin, and eulachon) and host the largest and most productive salmon fishery in North America (Stern et al, 1976). Probably because of this, they are also concentration areas for beluga whales, harbor seals, and harbor porpoises during the summer, and provide overwintering habitats for sea ducks (e.g. eiders, scoters, and scaups) (Gill et al, 1981). For reasons which probably relate more to migratory pathways than to forage potential, the extensive intertidal flats of eastern Bristol Bay are not used extensively by waterfowl and shorebirds as staging areas during spring and fall migrations (Gill et al, 1981).

Sensitive habitats within this eastern Bristol Bay area are Egegik Bay, Kvichak Bay, and Nushagak Bay. Perturbation effects might be particularly critical during the late spring and summer when the estuaries are most heavily used by forage fish, inmigrating and outmigrating salmon, and marine mammals and birds. Chronic or periodic perturbations, however, could have long-term effects on any or all of these populations. The open-water zones of this region are also used as an overwintering habitat by large numbers of sea ducks (e.g. Steller's and king eiders, scoters, scaups, and oldsquaws), during which time they would be particularly susceptible to oil spills.

Sensitive and critical habitats of western Bristol Bay are primarily rocky headlands, capes and nearshore islands such as Round Island, Walrus Island, Cape Peirce, Cape

Newenham, Hagemeister Island, The Twins, High Island and Rocky Point. The rock cliffs of these locales provide nesting habitats (along with Amak Island and Capes Mordvinof and Seniavin) for almost all of the seabirds of the region including about one million common murres and several hundred thousand black-legged kittiwakes (Sowls et al, 1978). They also (primarily Round Island) are the focal point and principal hauling ground of the summer populations of walrus and Steller sea lions (Fay, 1982; Lowry et al, 1982). The vicinity of Cape Peirce is also used to a major extent by waterfowl (particularly black brant, emperor goose, and Steller's eider) during spring and fall migration to and from breeding grounds on the Yukon-Kuskokwim Delta and the Alaska-Siberia coast of the Bering and Chukchi Seas (Petersen and Sigman, 1977).

Effects of man-induced disturbance would be felt most during late spring and summer (May-August), when marine birds are nesting and when walrus and sea lions are concentrated on non-breeding hauling grounds.

Summary of Distribution of Key Biota. The biological utilizations of these nearshore habitats have been described earlier in the characterization of biological processes. Figures 125 through 130 summarize the resulting distributions of important or key species within these inshore habitats of Bristol Bay.

Conclusions. Critical or sensitive habitats within the region include Unimak Pass, Cape Mordvinof, Cape Sarichef, Cape Lapin, Otter Point, Bechevin Bay, Kudiakof Island, Izembek Lagoon, Amak Island, Cinder River, the Port Moller complex, Cape Seniavin, Seal Islands, Strogonof Point and the Port Heiden complex, Ugashik Bay, Egegik Bay, Kvichak Bay, Nushagak Bay, Kulukak Bay, Togiak Bay, Hagemeister Strait, Hagemeister Island, Cape Newenham, Cape Peirce, Round Island, Walrus Island, Crooked Island, The Twins and High Island.

Habitats or migratory routes used intensively within the regions of the Alaska Peninsula and inner Bristol Bay are important to several species of marine mammals, birds, and fish. Particularly critical areas include Unimak Pass, Izembek Lagoon, Amak Island, the Port Moller and Port Heiden complexes, Cinder River, Cape Seniavin, Ugashik, Egegik and Kvichak Bays, Nushagak Bay, Kulak Bay, Round Island, Cape Peirce and Cape Newenham.

Wider dispersed habitats, such as spawning and juvenile rearing areas for crab, sole, and forage fish are also of prime importance. Of similar importance are those areas utilized by sea otters, other marine mammals, migratory and feeding salmon, and for inshore bird feeding.

e. Key Species

Descriptions of key or indicator species at the upper trophic levels can be found in Appendix B. The format in which this material is presented is descriptive and includes distributions, commercial importance, population status, and life history and ecosystem relationships.

The species listed have been selected on the basis of 1) importance in food web relationships, 2) commercial value, 3) vulnerability to oil-spill effects, and 4) the amount of information available. Species selected are listed below.

Marine mammals

Harbor Seal
Steller Sea Lion
Pacific Walrus
Gray Whale
Beluga Whale
Sea Otter

Birds

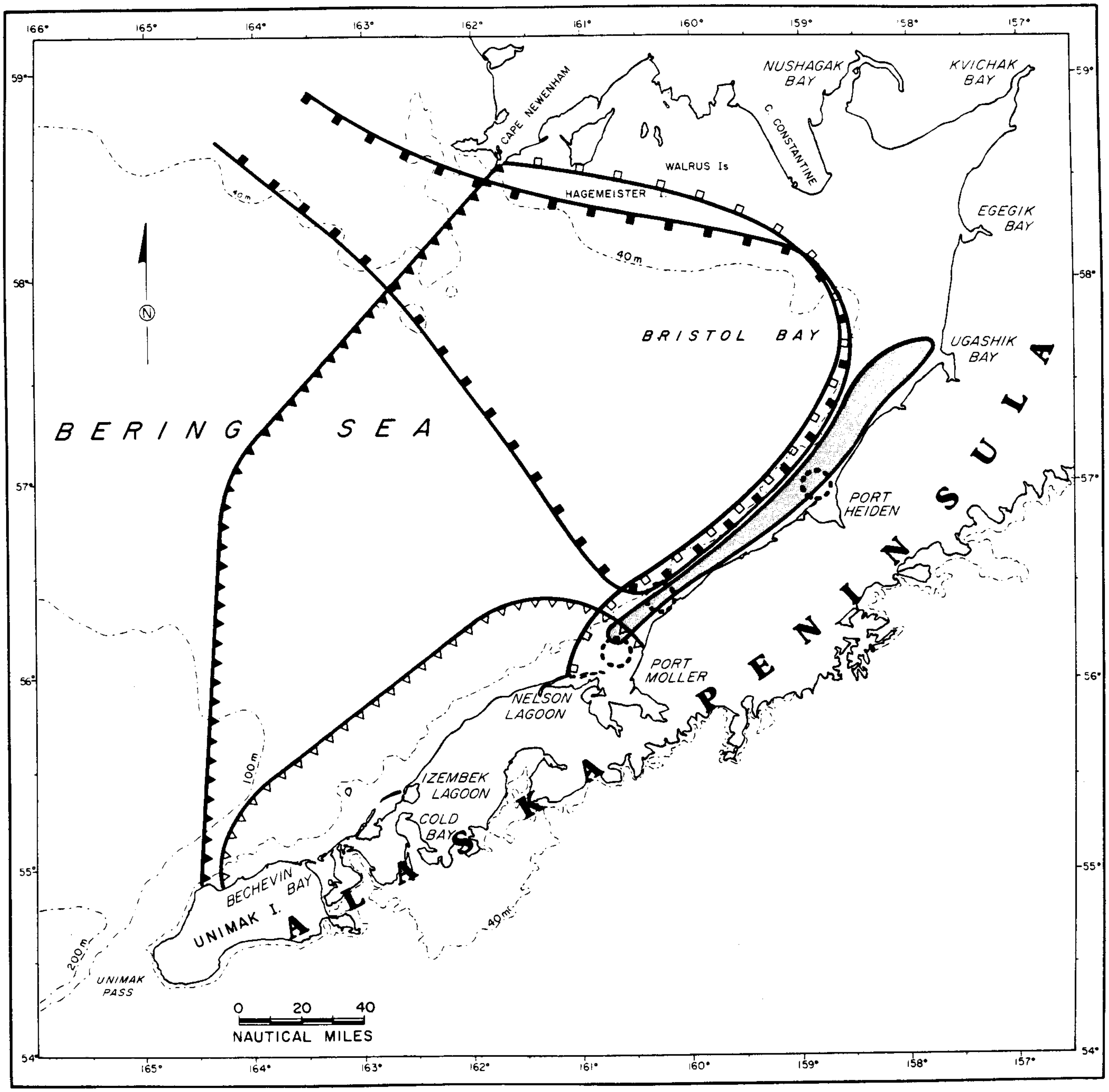
Common Murre
Short-Tailed Shearwater
Black-Legged Kittiwake
Black Brant
Emperor Goose
Steller's Eider
Dunlin
Western Sandpiper

Invertebrates

Red King Crab
Great Alaska Tellin
Asterias amurensis
Alaska Surf Clam

Fish

Sockeye (Red Salmon)
Boreal (Rainbow) Smelt
Yellowfin Sole
Pacific Herring
Capelin



RED KING CRAB
OVERALL DISTRIBUTION
(after Otto et al, 1981)

RED KING CRAB
AREA OF MAJOR LARVAE HATCHING, MATING & SPAWNING
(after Takeuchi, 1962; Haynes, 1974; ARMSTRONG et al, 1981; Otto et al, 1981; VTN Oregon, 1983 a, b, c)

RED KING CRAB
AREA OF MAJOR LARVAE SETTLEMENT AND JUVENILES (after Haynes, 1974; Armstrong et al, 1981; Otto et al, 1981; VTN Oregon, 1981 a, b)

GREAT ALASKAN TELLIN
(after McDonald et al, 1981)

ALASKAN SURF CLAM
(Pinkheck Clam)
(after Hughes & Bourne, 1981)

Fig. 124. Distribution of red king crab and clams in Bristol Bay.

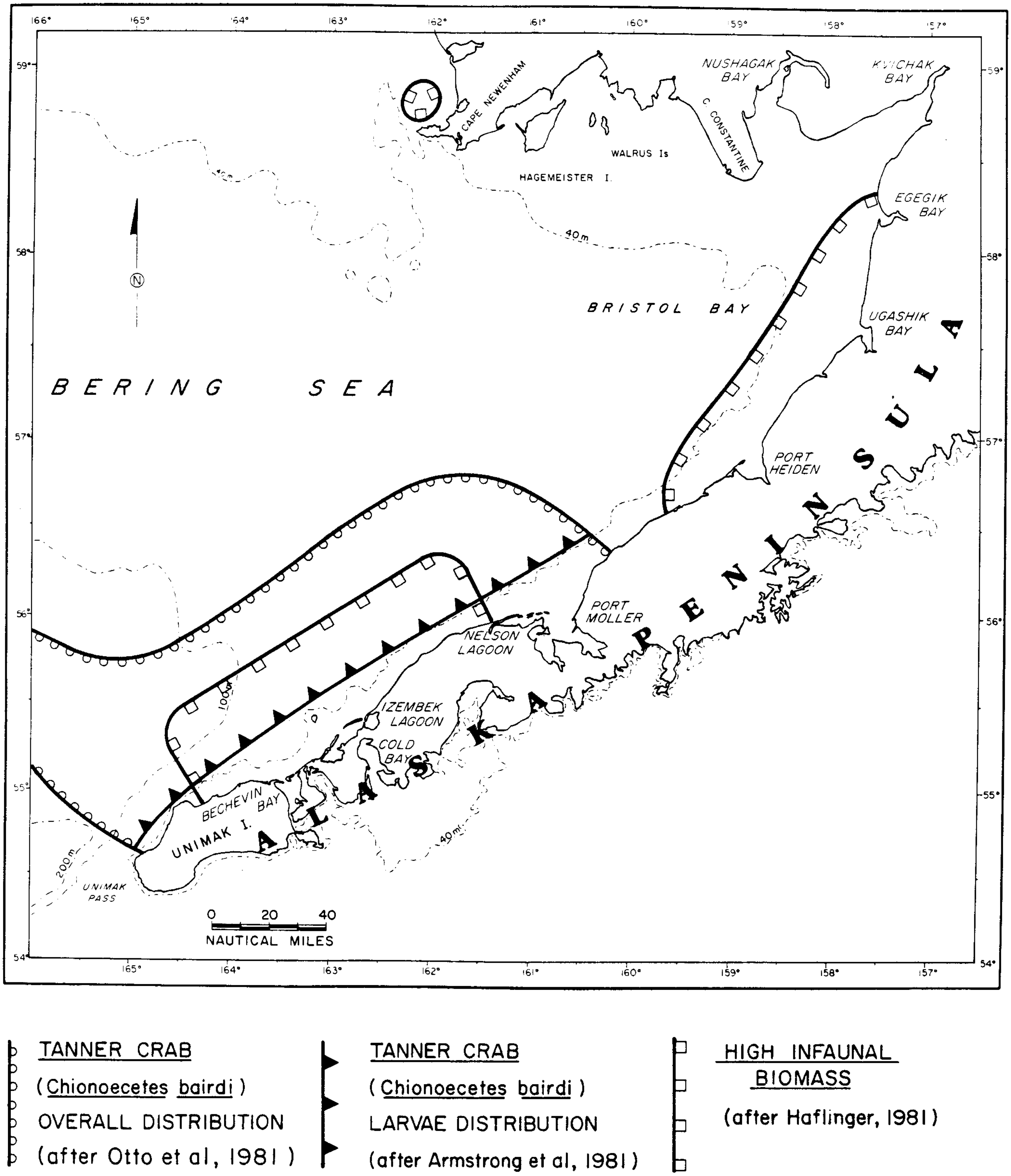


Fig. 125 . Distribution of Tanner crab and areas of high infaunal biomass in Bristol Bay.

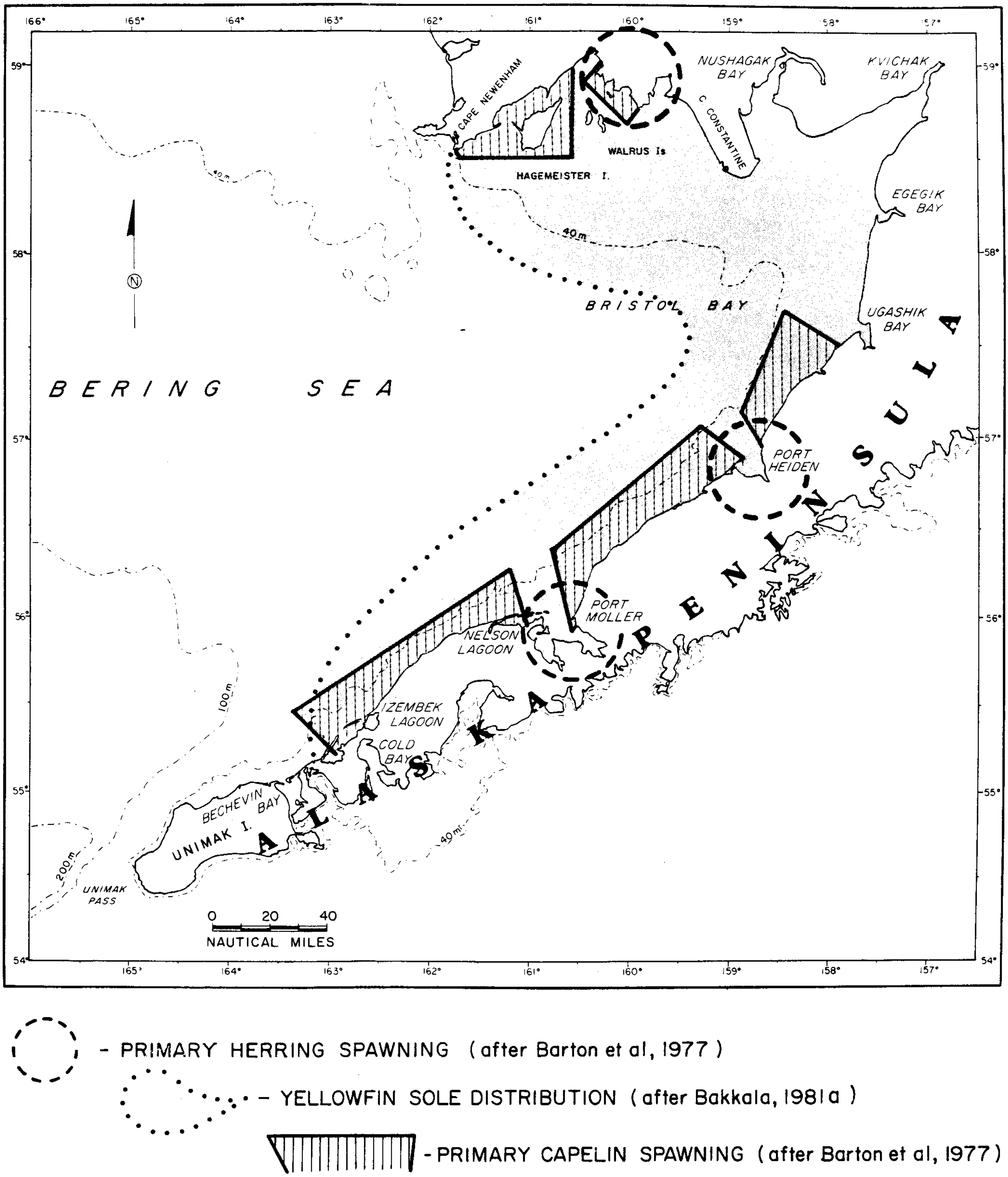


Fig. 126 . Distribution of important inshore fishes in Bristol Bay.

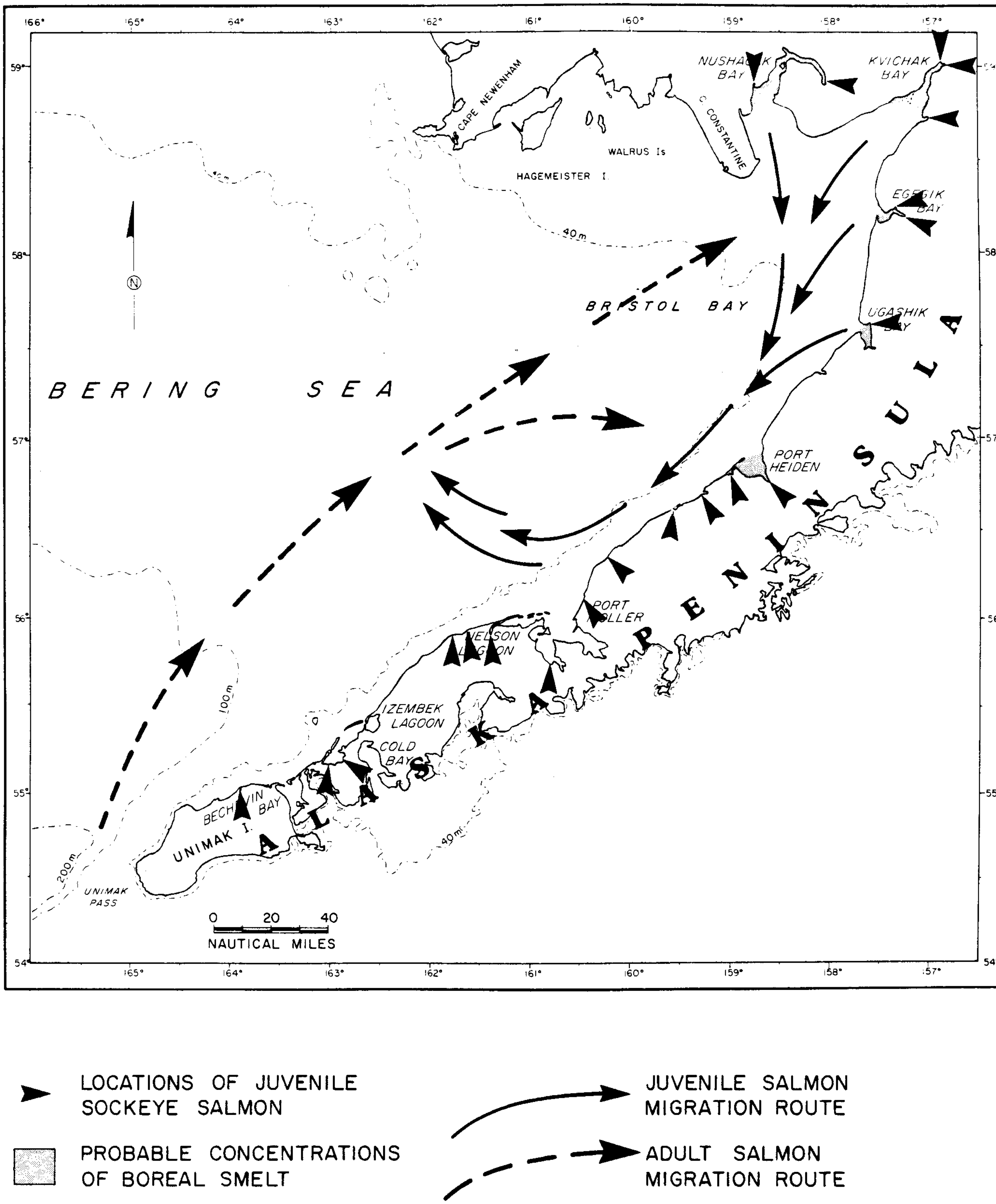


Figure 127. Salmon migration paths in Bristol Bay.

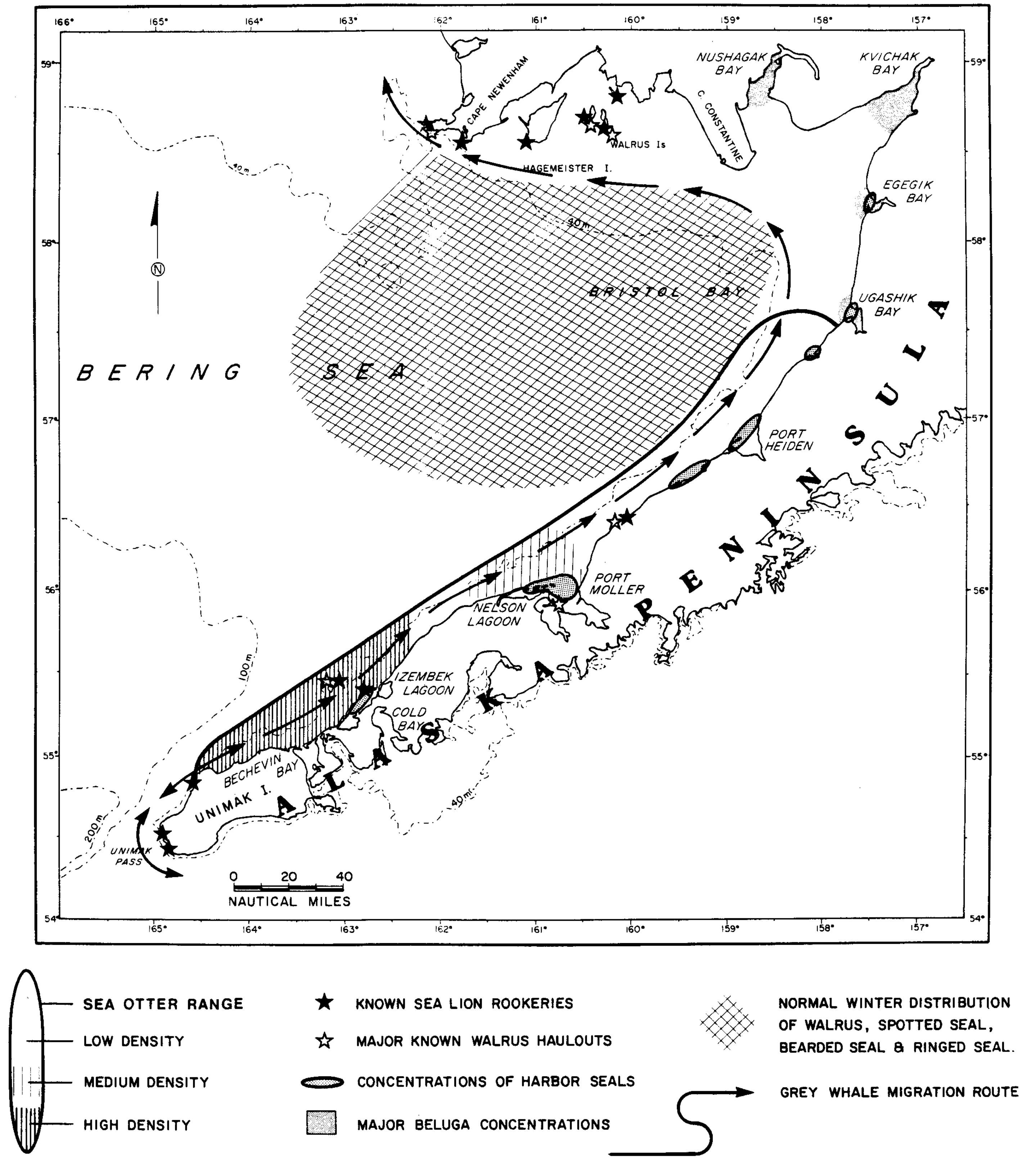
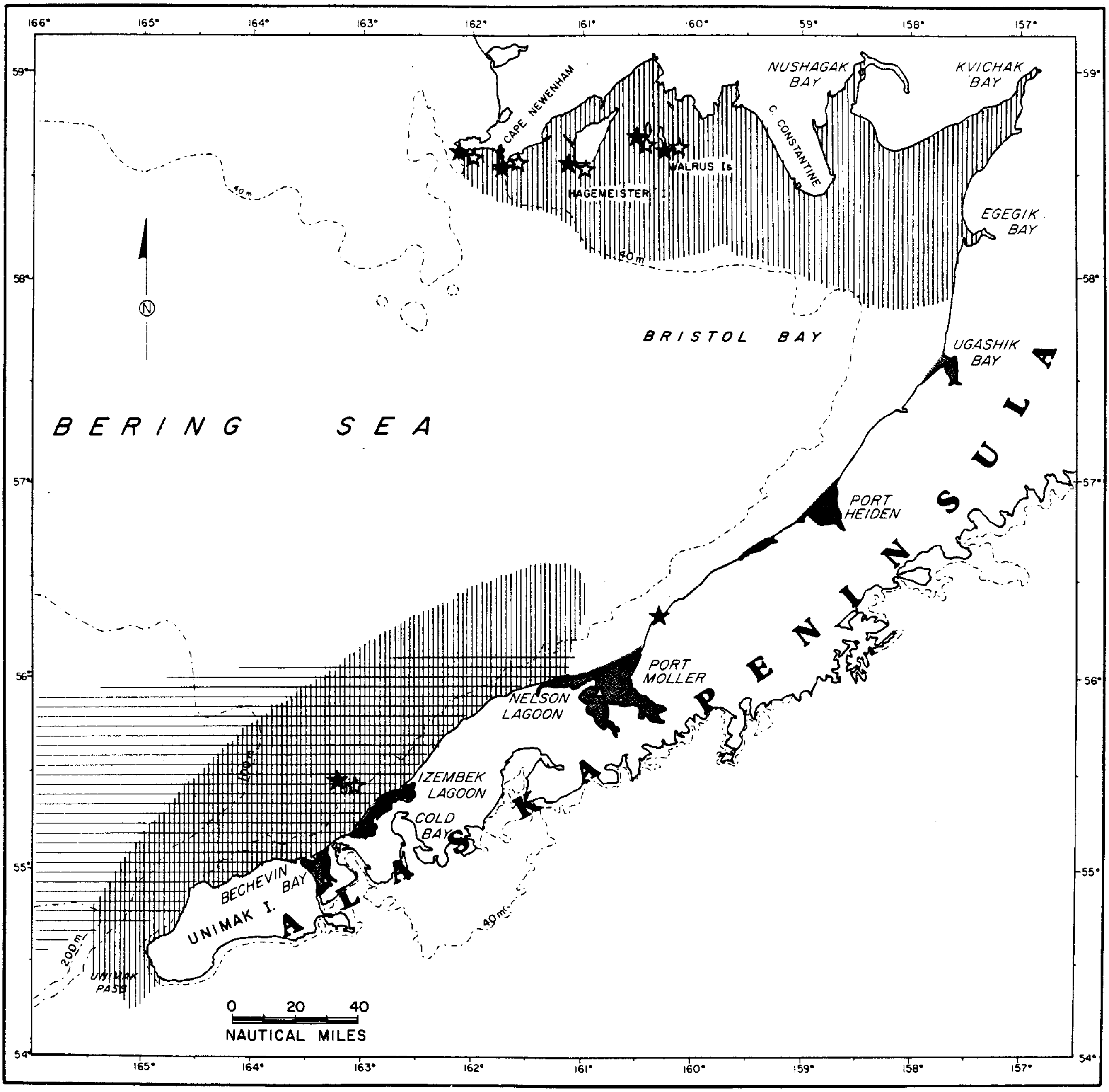


Figure 128. Distribution of important inshore marine mammals in Bristol Bay.



- SHOREBIRD & WATERFOWL SEASONAL CONCENTRATIONS

☆ - BLACK-LEGGED KITTIWAKE NESTING COLONIES

- AREAS OF SHEARWATER ABUNDANCE

★ - MURRE NESTING COLONIES

- MURRE WINTER CONCENTRATIONS

Figure 129. Inshore distribution of key marine bird species in Bristol Bay.

HYPOTHESES OF ECOLOGICAL PROCESSES

The Bristol Bay area is exceptionally rich in wildlife and marine resources. The inshore regions of Bristol Bay have been shown in particular to be heavily utilized by ecologically important species and by those of major commercial importance. An understanding of these ecological processes which govern the inshore system is fundamental to the management of these resources. In particular, such an understanding is essential to assessing vulnerabilities and conflicts associated with oil and gas development.

The observed high utilization of these inshore areas is explained by two basic factors, that of food availability and that of suitable habitat. Sufficient food resources to support the high utilization must either be produced within the nearshore zone, or be transported into this zone by physical processes or by biological migratory processes.

In the case of Bristol Bay, the nearshore habitat is an interface between the rich marine resources of the southeastern Bering Sea and the rich resources of the river/lake and lagoon/estuary systems. Thus, in addition to feeding activity, much of the distribution of biota in this nearshore zone can be explained by the habitat requirements necessary to life cycle needs, such as spawning substrates, haulout sites, migratory corridors, and so on.

The first section of the hypotheses of controlling ecological processes explains the possible organic carbon budget used to examine the basic food relationships operative in the nearshore zones of Bristol Bay. The second section summarizes the habitat factors that contribute to the observed biotic distributions.

1. Carbon Budgets for the Coastal Domain

a. In-situ and Terrestrial Sources

Ecosystem dynamics in the coastal domain are determined in a basic way by the oceanography. To the extent that the physical oceanography of the region is understood, it is possible to construct a hypothesis explaining the functional controls of the food webs and how material and energy are transferred in the system. We have approached this problem by constructing carbon budgets for the region. We divided the inner shelf into two regions, the north Peninsula coast, and inner Bristol Bay (Figure 130). The justification for this division, although somewhat arbitrary, is based on the oceanography. The boundary approximately follows the position of the 31 ppt isohaline in summer (Ingraham, 1981).

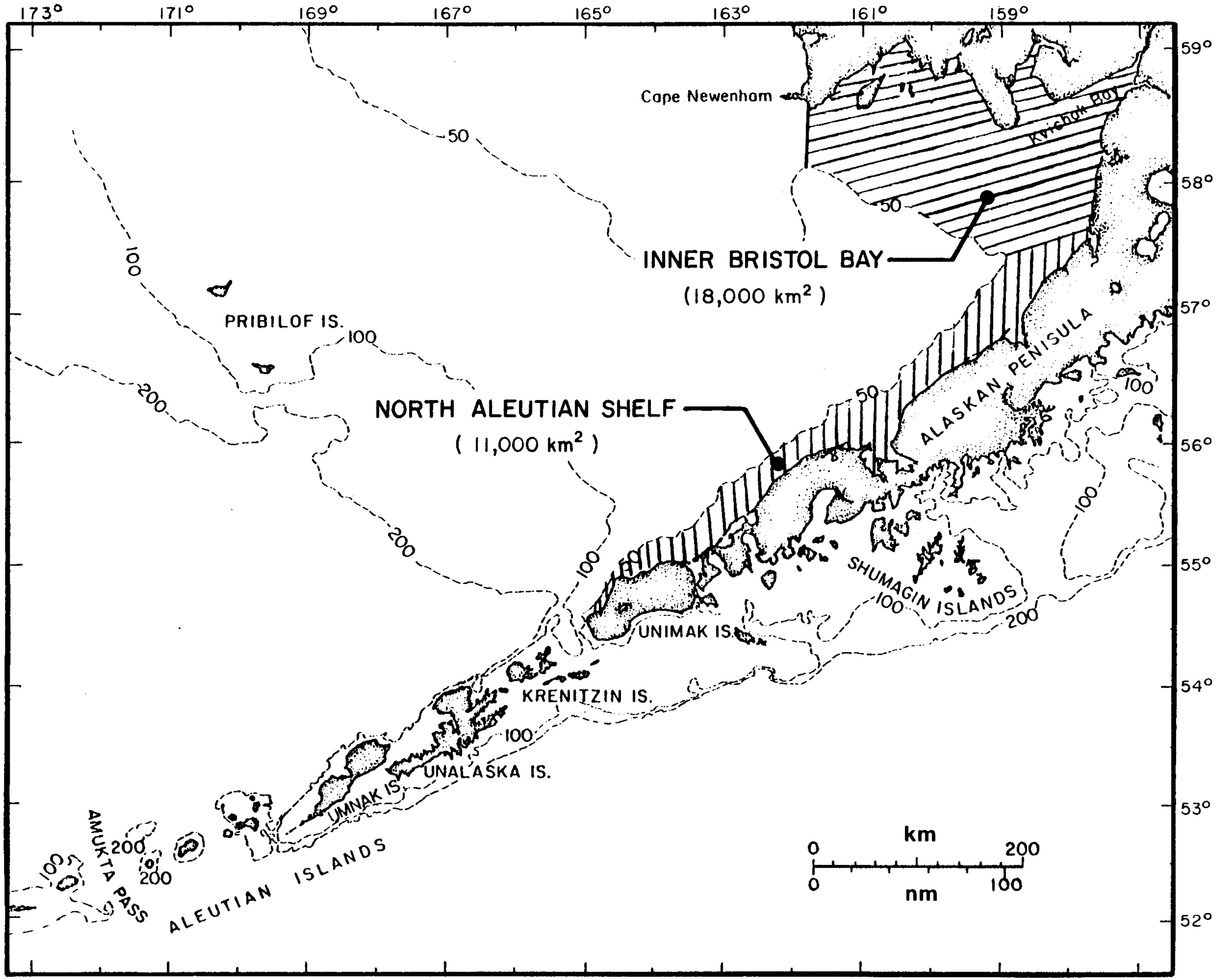


Figure 130. Subareas utilized for carbon budget calculations.

Inside this boundary the shelf is characterized by low salinity due to the several rivers emptying into Bristol Bay, to less concentrated sources of run-off along the Alaska Peninsula, and to inflow of low salinity water with the coastal current.

As reviewed earlier in the physical oceanography section, the shelf of the southeastern Bering Sea is characterized by three fronts that divide the shelf into three oceanographic domains (Coachman et al, 1980). The 0-5 km zone of the shelf is an indistinguishable part of the inner shelf or coastal domain. Consequently, we treat this as a single biological and oceanographic region bounded by the inner front, occurring over the 40-50 meter isobath, and the land boundary. This domain is normally characterized by an unlayered, well-mixed water column in which tidal mixing from the bottom overlaps with wind mixing from the surface. The mean flow acts as a conveyor belt, transporting water (2-5 cm/sec) parallel to the coast along the Alaska Peninsula and into Bristol Bay (Kinder and Schumacher, 1981b), and then outward along the northern coast. This mean inshore flow may be more or less continuous with coastal flow southward along the south coast of the Peninsula and through Unimak Pass. However, cylonic storm events, on the frequency of approximately three to five events per month, undoubtedly dominate processes such as onshore/offshore transport and transport of nutrients from offshore into the coastal domain, including periods of longshore current reversals. Under these conditions, stratification can also develop within the coastal domain.

The inner Bristol Bay region receives more than twice the volume of freshwater from rivers as does the North Aleutian Shelf (50 vs 20 km^3/yr; U.S. Geological Survey, 1980). We calculate the area of the North Aleutian Shelf to be 11 x 10^9 m^2 and that of inner Bristol Bay to be 18 x 10^9 m^2; the area of adjacent bays and lagoons is estimated to be 2 x 10^9 m^2.

The basis of any marine food web is the primary production of phytoplankton plus any organic detritus, added to the system by advection. In the coastal domain organic detritus can become quantitatively important and this is the major difference in similar budgets constructed for the outer and middle domains of the southeastern Bering Sea (Walsh and McRoy, 1983). In both the north Peninsula coast area and inner Bristol Bay we estimate the production by phytoplankton to be 90 g C/m^2 for the spring bloom and 25 g C/m^2 for the summer, resulting in a total annual production of 115 g C/m^2 (Figures 131 and 132). The contributions of dissolved and particulate carbon from rivers in these two areas are 12.4 g $C/m^2/yr$ for inner Bristol Bay and 10 g $C/m^2/yr$ for the north Peninsula coast area. These estimates were calculated from the carbon concentration and river flow data in each area. In the Peninsula

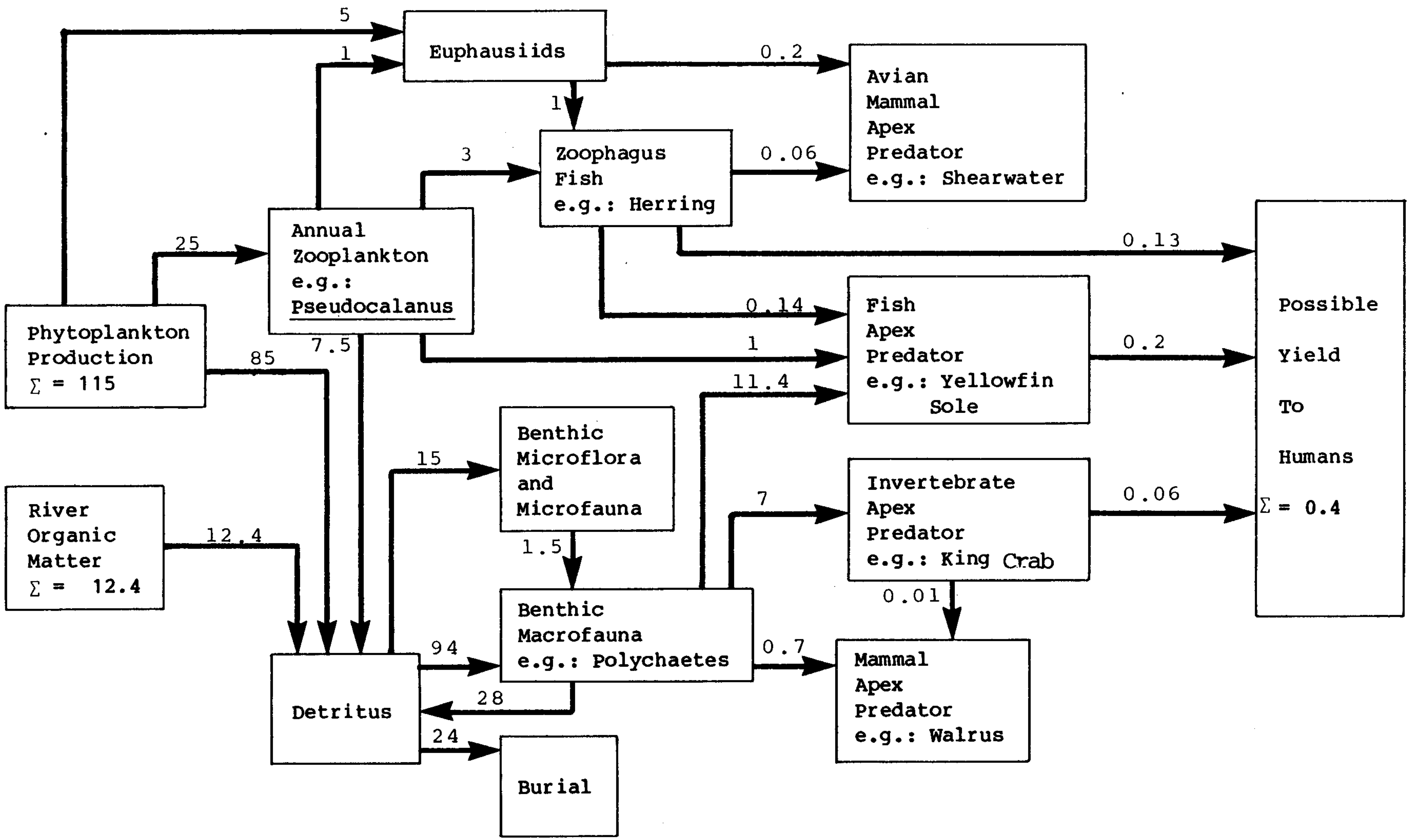


Figure 131. Hypothetical carbon budget (g m^{-2} yr^{-1}) for inner Bristol Bay (18 x 10^9 m^2).

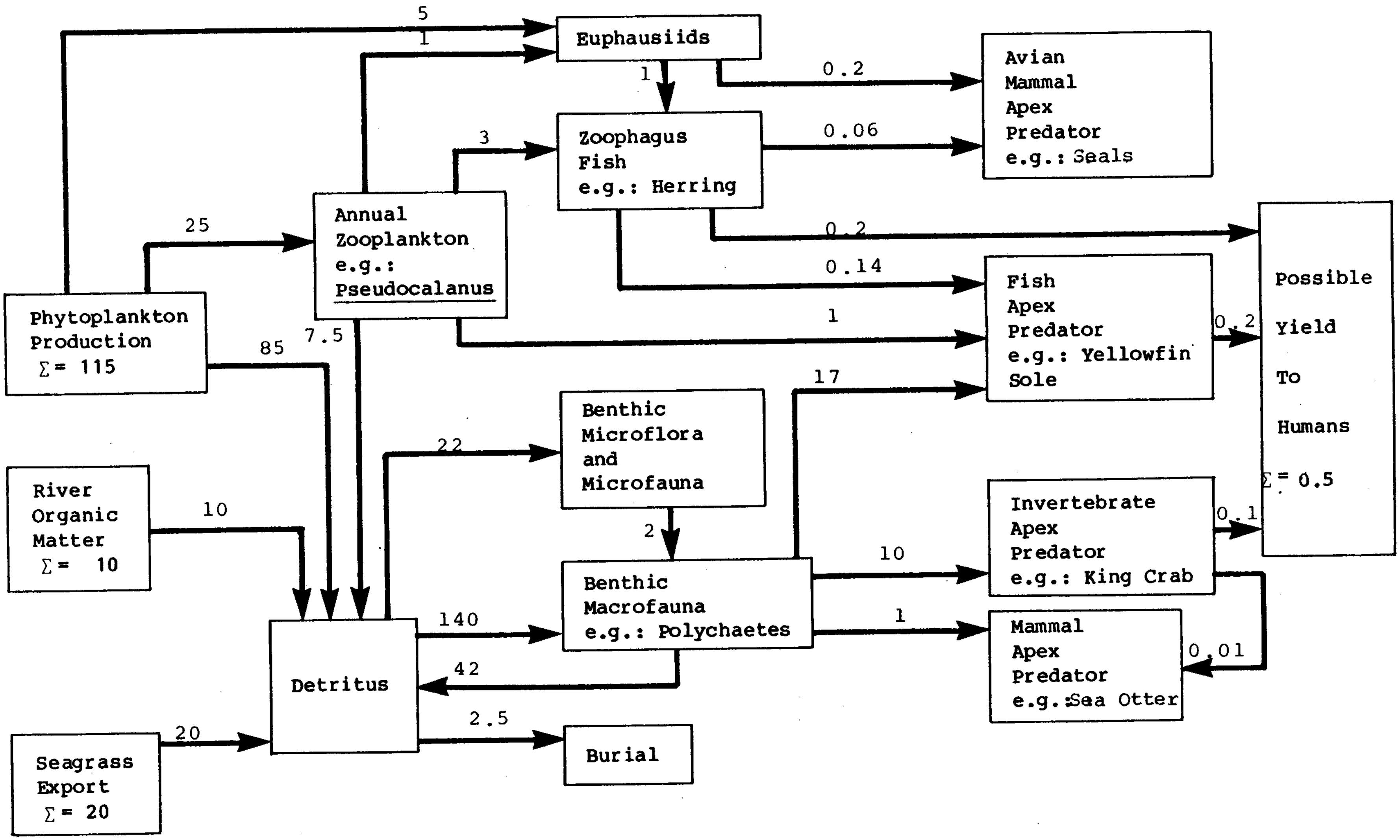


Figure 132. Hypothetical carbon budget (g m^{-2} yr^{-1}) for the North Aleutian Shelf (11 x 10^9 m^2).

area there is a third component in the budget, that of eelgrass detritus from the bays and lagoons. The major stand of eelgrass on this coast is in Izembek Lagoon and it is estimated that this single lagoon exports as much as 14 g $C/m^2/yr$ to the ocean. Further, we estimate that other eelgrass areas may contribute as much as 6 g $C/m^2/yr$ for a total of 20 g $C/m^2/yr$. This budget assumes that the eelgrass is distributed evenly across the shelf, but this is probably not true. A given area, such as that just north of Izembek Lagoon, may receive a much higher amount.

Using the extensive work done in the southeastern Bering Sea under PROBES and OCSEAP, we propose that the coastal domain supports primarily a benthic food web (Iverson et al, 1979). Consequently, due to the low abundance of zooplankton (Cooney and Coyle, 1982), most of the algal production and other detritus is probably ungrazed by pelagic herbivores and sinks to the bottom. In the coastal shelf as in the middle shelf, the macrobenthos reaches its highest recorded abundance (Haflinger, 1981). The estimate for zooplankton consumption in the coastal shelf is the same as that calculated for the middle shelf by PROBES investigators (Walsh and McRoy, 1983). As in other studies, we use an assimilation efficiency of 70 percent, hence, 30 per cent of ingestion is returned as fecal matter. The same assumption was used for benthic macrofauna. Ecological transfer efficiencies of 20 per cent were assumed for zooplankton, euphausiids, and benthic macrofauna, while for other trophic components 10 per cent was used. In the absence of data, we assumed the euphausiid ingestion to be half that of the middle shelf since the water is shallower than their preferred depth range (S. Smith, personal communication).

The benthic food web is the major feature of the coastal shelf. Haflinger (1981) indicates that benthic biomass in the north Peninsula coastal area is approximately the same as that in the middle shelf; whereas that in inner Bristol Bay is only about two-thirds of the middle shelf. We have used these proportions in our calculations of benthic trophic dynamics. The carbon transfer to the benthic microflora and microfauna in both the outer and middle shelf is estimated to be 22-29 g $C/m^2/yr$ (K. Haflinger and H. Feder, personal communication) and we used this value for the coastal area (applying the above proportions). Again relying on the calculations of Feder and Haflinger, we used their estimate of 28 g $C/m^2/yr$ for middle shelf secondary production to get a consumption of 142 and 95.5 g $C/m^2/yr$ in the two areas (Figures 131 and 132).

The middle and coastal shelf of the Bering Sea is the habitat of numerous benthic predators. The region has large fisheries for yellowfin sole and king crab and contains large numbers of walruses, sea otters, and gray whales. The amount of carbon consumed by these upper trophic levels in the coastal zone is largely guess work, and the same proportions were used here as those calculated for the middle shelf by Walsh and McRoy (1983). A further assumption was necessary to deal with animal populations in upper trophic levels in which the life of the animal can span several harvestable year classes. For estimating the yield to humans of fish and invertebrate predators, a Production/Biomass ratio of 0.1 was used. In contrast, for zoophagous fish such as herring and smelt, a P/B ratio of one was used.

As a check on the budget, we can calculate the carbon requirement of the 10,000 to 20,000 walrus that are resident in the area. Stoker (1981) calculates that a walrus can consume 16,300 kg wet wt/animal/yr which is five percent carbon. If the walrus only feed in the north Peninsula coastal area (probably not true) they would consume 1.1 g $C/m^2/yr$. The carbon budget predicts 1.01 g $C/m^2/yr$ for this trophic level. This is a good agreement but suggests that the mammals, king crab and yellowfin sole may be competing for the benthos or we have overestimated the requirement of apex fish, birds, and invertebrate predators.

The carbon budget estimated for the north Peninsula coastal area, with only 1.5 percent of the carbon left for burial, is balanced but that for inner Bristol Bay has 18 percent of the carbon left for burial or export. Further, in both regions there is potentially a large yield of herring, smelt and similar fishes. Both budgets indicate the importance of detritus to the food webs of the coastal shelf. The potential yield of both regions is less than the 0.6-0.7 estimated for the middle and outer shelf.

b. Migratory Sources

The above carbon budget for the coastal domain is based upon in-situ productivity and carbon input from lagoons and rivers. Upon consideration of the information available, it seems likely that two, essentially independent, trophic systems are operational within the nearshore shelf zone of Bristol Bay, the Alaska Peninsula, and the proximal Aleutian Islands. One of these systems is probably more or less self-contained and endemic. The other is probably a seasonal "import-export" system. Of course, the two systems overlap to some degree.

The endemic (so to speak) system includes primary productivity, both marine and lagoonal/terrestrial, which is generated within the nearshore shelf zone, and which supports most, if not all, of the zooplankton, benthic epifaunal and infaunal, and marine fish productivity of the region. Most or all of the higher trophic level marine mammal and bird species probably rely on this endemic system for nutritional maintenance to varying degrees.

There may also be a parallel "import/export" system, seasonal and pulsating in nature, comprised of the huge runs of anadromous fish which utilize the area, and their retinue of predators. The hypothesis in this regard is that these migratory populations of anadromous (and in some cases marine) fish such as salmon, smelt, herring, capelin, and eulachon satisfy most of their energy and growth requirements in other marine or, in the case of juvenile salmon, freshwater environments and "import" this biomass in seasonal pulses into the nearshore zone.

Supportive data are lacking but are needed. Some estimate of the relative importance of such an import system to the nearshore zone can be made, however, by considering just the out-migrating salmon smolt and the in-migrating adult salmon. Data given earlier in the characterization sections indicate that mean numbers of 500 million out-migrating smolt and 18 million in-migrating adult salmon pass through the inshore area each year. Converting this biomass to carbon on a year basis yields some 10^{10} gm C/yr, compared to some 10^{12} gm/yr contributed by primary productivity. Considering these migratory fish to be two to three trophic levels above primary productivity, and assuming a ten percent transfer efficiency, this amount of carbon is at least roughly equivalent to the amount at this trophic level expected to be derived from the in-situ primary productivity. Of course, much of this migratory carbon is not utilized in the inshore system, but is simply passed through.

It is conjectured, however, that these seasonal pulses of imported energy resources may be critical to the maintenance of the particularly high populations of some top predators, especially beluga whales and harbor seals; perhaps also to Steller sea lions and marine birds which frequent the area. It is perhaps of some significance in this regard that all of these predators either disperse or depart from the area in the fall, coinciding with the departure from the area of such migratory fish species.

2. Habitat Requirements

A consideration of key species serves to illustrate the high utilization of habitats in the coastal zone. In many cases, the distributions of these species in the nearshore zone are determined by specific habitat requirements. Table 15 summarizes the use of, and requirements for, various nearshore habitats for the selected key species. Many of the species that occupy the nearshore region of Bristol Bay and the Alaska Peninsula do so either on a seasonal basis or only during certain stages of their life cycle. It should be emphasized that these species may be critically dependent on their habitats for reproduction or growth even though the time span they inhabit the neritic zone is limited.

One example of a required habitat is the macrophyte beds consisting of kelps, rockweeds and eelgrass along the shallow coastal waters of the eastern Bering Sea. These areas are utilized as a spawning substrate by the Pacific herring during the spring. Subsequent to spawning and summer feeding in the nearshore zone, herring migrate offshore to overwinter in colder, deeper waters.

Dunlin extensively utilize the littoral and supra-littoral areas of Bristol Bay and the Alaska Peninsula. They use these areas upwards of six months for nesting, breeding, foraging, and roosting prior to the fall migration. Also, approximately one-half of the world's population of black brant seasonally depends upon the habitat of Izembek Lagoon.

The sea otter population is concentrated in the nearshore zone (although they have been sited as far out as 30 miles) primarily due to feeding habitats. Sea otters mainly consume sessile invertebrates, and feed on these between the intertidal zone and depths of 40-60 meters. Apparently their distribution is further limited by prey availability coastal configuration, and the extent of winter sea ice.

Table 15. Inshore habitat usage by key species.

Key Species	Use of Habitat	Inshore Habitat Requirements
Marine Mammals		
Harbor Seal (*Phoca vitulina*)	Haul-out, Pupping, Molting, and Feeding	Sheltered rocks and beaches Inshore food resources: fish, cephalopods, crustaceans.
Stellar Sea Lion (*Eumetopias jubatus*)	Haul-out Rookeries	Rocks and beaches throughout Bristol Bay Rookeries in the Fox Islands and on Amak Island.
	Feeding	Opportunistic feeding: finfish, squid, octopus.
Pacific Walrus (*Odobenus rosmarus divergius*)	Haul-out	Rocky areas or beaches, especially northern islands in Bristol Bay.
	Feeding	Benthic feeding: bivalve mollusks.
Gray Whale (*Eschrichtius robustus*)	Migratory Corridor	Migration in inshore zone, some summer use.
	Feeding	Benthic feeding inshore: benthic infauna and epifauna, especially gammmarid amphipods.

Table 15. Inshore Habitat Usage by Key Species (continued).

Key Species	Use of Habitat	Inshore Habitat Requirements
Marine Mammals (cont.)		
Beluga Whale (*Delphinapterus leucas*)	Feeding	Inshore feeding, primarily in the upper part of Bristol Bay near Nushagak and Kvichak Rivers. Marine and anadromous fish, particularly salmon, smelt, and capelin.
Sea Otter (*Enhydra lutris*)	Haul-out	Rocks and beaches, primarily between Unimak Island and Cape Leontovich.
	Feeding	Inshore (to 50-60 meters depth); wide range of invertebrates and slow moving fish.

Table 15. Inshore Habitat Usage by Key Species (continued).

Key Species	Use of Habitat	Inshore Habitat Requirements
Birds		
Common Murre (*Uria aalge*)	Nesting/Breeding	Broad cliff ledges and flat rocky islands.
	Over-wintering	Unknown - probably ice edge.
	Feeding	Food source: fish, zooplankton, and squid.
Short-tailed Shearwater (*Puffinus tenuirostris*)	Migration	Summer utilization of eastern Bering Sea.
	Feeding	Food source: euphausiids, fish, carrion.
Black-legged Kittiwake (*Rissa tridactyla*)	Nesting/Breeding	Vertical cliffs and rocky ledges on the Alaska Peninsula.
	Feeding	Variable: small fish and crustaceans.
Black Brant (*Branta bernicla nigricans*)	Migratory staging	Protected lagoons, principally Izembek Lagoon.
	Feeding	Shallow feeding on eelgrass.

Table 15. Inshore Habitat Usage by Key Species (continued).

Key Species	Use of Habitat	Inshore Habitat Requirements
Birds (cont.)		
Emperor Goose (Philacte canagica)	Migratory staging	Lagoons and estuaries, vegetated intertidal zone.
	Feeding	Food source: bivalves, dune-associated vegetation, and eelgrass.
Steller's Eider (Polysticta stelleri)	Migratory staging and moulting	Protected lagoons of Bristol Bay and Alaska Peninsula during late summer.
	Feeding	Intertidal and shallow feeding on bivalve mollusks and amphipods.
Dunlin (Calidris alpina)	Nesting/Breeding Moulting Roosting Feeding Migratory staging	Coastal fringe: Upper littoral areas of the Alaska Peninsula, primarily within estuaries and lagoons.
Western Sandpiper (Calidris mauri)	Feeding Roosting Migratory staging	Littoral and supra-littoral areas of lagoons on the Alaska Peninsula.

Table 15. Inshore Habitat Usage by Key Species (continued).

Key Species	Use of Habitat	Inshore Habitat Requirements
Fishes		
Sockeye (Red) Salmon (*Oncorhynchus nerka*)	Spawning	Stream-lake systems tributary to Bristol Bay and the Alaskan Peninsula; gravel beds.
	Seaward migration (juveniles)	General nearshore migration route along north side of the Alaska Peninsula (mid-May through Sept.) Upper water column during seaward migration.
	Feeding	Food source: zooplankton and small fish.
Boreal (Rainbow) Smelt (*Osmerus mordax*)	Spawning	Freshwater streams.
	Feeding	Inshore food resources: amphipods, polychaete worms, and small fish.
Yellowfin Sole (*Limanda aspera*)	Spawning, Nursery	Broad, nearshore area used for spawning.
Pacific Herring (*Clupea harengus pallasi*)	Spawning	Protected intertidal and shallow subtidal bays, inlets and channels for spawning on macrophytes: kelp, eelgrass, rockweeds, and other substrates.
	Migration	Summer route through nearshore Bristol Bay and Alaska Peninsula.
Capelin (*Mallotus villosus*)	Spawning	Beaches with fine gravel, also subtidal spawning to 60 meters.

Table 15. Inshore Habitat Usage by Key Species (continued).

Key Species	Use of Habitat	Inshore Habitat Requirements
Macroinvertebrates		
Red King Crab (*Paralithodes camtschatica*)	Mating/Spawning and Juvenile development	Broad, shallow area (<50m) along Alaskan Peninsula and northern and inner Bristol Bay.
Great Alaska Tellin (*Tellina lutea*)	-	Occurs on inner and middle shelf of Bristol Bay; primarily medium to fine sands.
Asterias amurensis	-	Common in shallow waters (<40m).
Alaska Surf Clam (*Spisula polynyma*)	-	Shallow depths between Port Moller and Ugashik Bay; medium sands to medium silt.

VULNERABILITY TO OIL AND GAS RELATED DEVELOPMENT

1. Identification of Development Activities

The boundaries of the proposed Lease Sale 92 encompass all of Bristol Bay (Figure 133) with probabilities of oil and gas occurrence rated high in much of this offshore area. Therefore, it is not known with surety which offshore locations will experience exploratory drilling and subsequent development. Thus the locations of activities likely to affect the nearshore areas are not known at this time. However, some reasonable estimates of these locations may be made from existing knowledge of the distribution of offshore source rocks and from the geographic locations of suitable onshore support sites.

The Bristol Bay Tertiary Province (Marlow et al, 1980) is a northwest trending elongate sedimentary basin that parallels the long axis of the Alaska Peninsula and is located on the north side of the Peninsula. The basin extends northeast from the Black Hills for 595 km (370 miles) to about the west edge of Iliamna Lake. The greatest potential for hydrocarbons exists in the southwestern area, the Bristol Bay basin (Figure 133), between Port Moller and Amak Island where the thickest Cenozoic sediment (5000 ft) exists (Marlow et al, 1980). Similar thick potential source rocks exist in the Amak basin (Figure 134) just southwest of the Black Hills uplift. Conditional estimates (Marlow et al, 1980) for these areas of the North Aleutian Shelf for oil and gas resources are as follows:

	Probability		Statistical Mean
	95%	5%	
Oil (billions of barrels)	0.1	2.3	0.7
Gas (trillions of cubic feet)	0.1	5.8	1.5

Therefore, the nearshore areas along the Alaska Peninsula are likely to be affected by development from offshore drilling and production. Also, onshore facilities, particularly those associated with transportation of oil and gas products, are likely to be located along the Alaska Peninsula.

The likely technologies to be used to develop these petroleum resources have been reviewed by Dames and Moore (1980). For exploratory drilling, conditions prevailing in the area are within the present operational capabilities of semi-submersibles, drillships and jackup rigs (in the shallower portions).

The principal technical problem may occur if year-round capability is desired in areas where sea ice is a possibility between January and April. Following the lead of Dome Petroleum in the Canadian Beaufort Sea, where

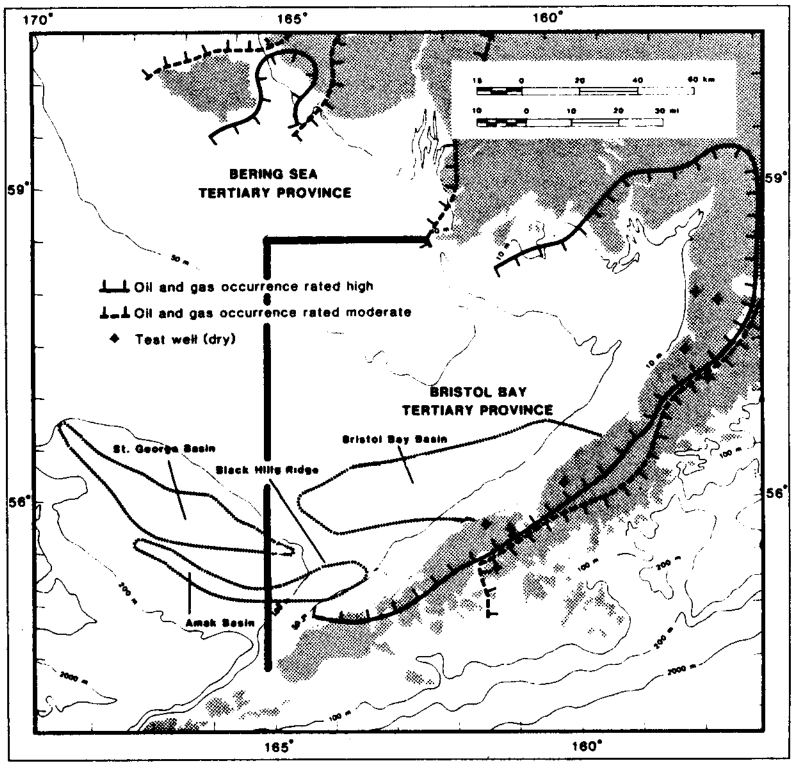


Figure 133. Offshore strata with high potential for petroleum, southeastern Bering Sea (SAI, 1981).

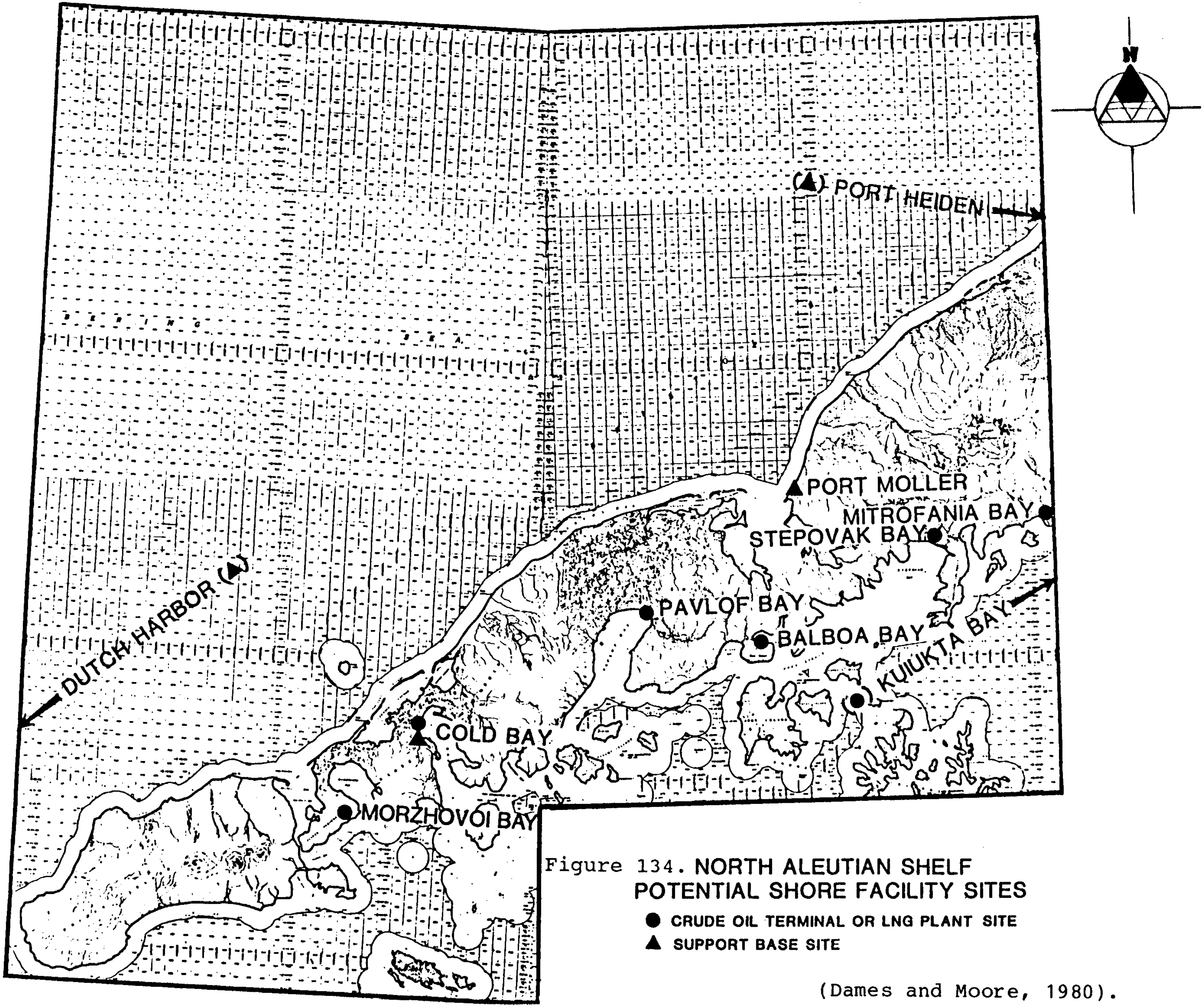


Figure 134. NORTH ALEUTIAN SHELF POTENTIAL SHORE FACILITY SITES

● CRUDE OIL TERMINAL OR LNG PLANT SITE

▲ SUPPORT BASE SITE

(Dames and Moore, 1980).

reinforced drillships supported by icebreakers drill well into the fall, similar equipment and techniques could make winter drilling feasible in this area of significantly less severe ice conditions. Dynamically positioned semi-submersibles or drillships, possibly supported by icebreakers, may also be an option for winter drilling. Other problems facing exploratory drilling in this area would include the high frequency of summer fogs and potentially severe structural icing in the winter that would pose hazards for both the rigs and their support vessels.

Conventional technology is likewise adequate for production platforms. Dames and Moore (1980) consider three representative water depths in the North Aleutian Shelf area: 15 meters (50 feet), 46 meters (150 feet), and 91 meters (300 feet). Conventional production platforms feasible for these representative water depths are presented below.

a. Steel Jacket

This could be a Cook Inlet structure, at least for the two shallower water depths (15 and 46 meters). The deep water structure (91 meters) probably would be one wherein the jacket would be supported by external skirt piles. A typical structure would have four legs. The platforms for the 15- and 46-meter sites would have internal piles; all would have conductors inside the legs. Until additional ice data are available, the necessary conservative approach requires that platforms must be designed for ice conditions, no matter how minimal the forces appear. External (or conventional) conductors would not be feasible. Steel jacket structures with well conductors protected from ice have successfully operated in Cook Inlet for over ten years.

b. Steel Gravity Structure

The North Aleutian Shelf is a high seismic risk area. Due to the possibility of seismic activity, conventional concrete gravity structures are not recommended. This is particularly true since problems have been encountered with them in the North Sea in the past. However, the steel gravity platform may be feasible, depending on bottom conditions. This platform probably would be a single leg or monopod structure with all conductors internal in the "neck". Although it may have more than one leg, all conductors would be internal. A steel gravity structure is now in operation in the North Sea (Maureen Platform) where wave conditions are significantly greater but where seismic conditions are much less.

The most likely method of transporting oil and gas will be by pipelines to shore terminals. Distances of offshore pipelines will likely be less than 90-100 miles maximum, and must be buried in water depths of less than 200 feet (60 m). Another possible development which might be seen in the North Aleutian area is floating production systems. New technology would be required here because of the potential ice hazards. The technique utilizes a converted tanker or some other permanently moored floating system to produce oil and then transfer it to a transhipment tanker. The incentive for using this method is the short time frame required to get the production stream going and the smaller capital investment required. This scenario could make relatively small reservoirs economic to produce. The hazards here would be the increased exposure to the Bristol Bay side of the Aleutian Chain due to transferring and transporting crude. However, offshore loading is a common practice in the North Sea, where more extreme sea conditions are encountered.

Dames and Moore (1980) also considered the onshore petroleum facilities that may be required for oil and gas development. These onshore petroleum facilities include temporary exploration support bases, construction support bases, permanent operation support bases, crude oil terminals, and an LNG plant. Possible support base sites are Cold Bay, Dutch Harbor, Port Moller and Port Heiden, which appear to be the only communities capable of acting as bases without major capital improvement.

The following sites were identified as potential locations for a crude oil terminal or LNG plant (from west to east on the Pacific Ocean coast of the Alaska Peninsula):

- Morzhovoi Bay
- Cold Bay
- Pavlof Bay
- Balboa Bay
- Stepovak Bay
- Mitrofania Bay
- Kuiukta Bay

Each of these sites has environmental or geotechnical limitations. Except for Cold Bay and the northern portion of Pavlof Bay, all of these sites lie within the Alaska Peninsula National Wildlife Range. Depending upon discovery location and the pipeline landfall, the sites to the east of Pavlof Bay will require longer overland pipelines through more rugged terrain than those from Pavlof Bay westward. For example, the minimum overland distance to Cold Bay from the Bristol Bay coast would be about 19 kilometers (12 miles), but through or near the environmentally sensitive Izembek Lagoon area. The overland distance to Mitrofania would be about 105 kilometers (65 miles).

The northwest coast of the Alaska Peninsula does not appear to offer any particularly attractive site for a shore terminal. While use of this shoreline for a terminal site would eliminate an overland pipeline that could be as much as 97 kilometers (60 miles) long, there are several negative aspects. These negative aspects include extreme distance to deep water, lack of natural shelter and increased potential for ice encounter.

These disadvantages could be overcome by using a combination of offshore loading, as at Drift River, with shelter provided by an offshore breakwater. It is possible that the additional costs of these facilities would be comparable to constructing 64-80 kilometers (40-50 miles) of pipeline across the Alaska Peninsula. Because of the similar nature of most of the coastal area on the Bristol Bay side of the Peninsula, individual sites have not been identified.

Because of the necessity of developing a port if a site on the north coast were selected, it is most likely that the selection would be on the south side of the Peninsula. Such a port on the southern side would avoid a longer tanker trip around the Peninsula through Unimak Pass as well as avoiding tanker operations in ice during the winter.

2. Spill and Discharge Scenarios

Oil spills occur during development, production and transportation of petroleum resources. They can occur from platforms (spills and blowouts), from pipelines, and from tankers. Lanfear and Amstutz (1983) have recently examined the occurrence rates of oil spills on the U.S. outer continental shelf from all sources. The USGS has also examined recent data involving blowout accidents (Fleury, 1983).

Oil spills of 1000 barrels or more from platforms on the U.S. continental shelf between 1964-1980 are summarized in Table 16 (Lanfear and Amstutz, 1983). Blowouts for the period 1979-1982 (Fleury, 1983), summarized in Tables 17 and 18, indicate that for frontier OCS areas, 91 wells were spudded without a blowout. This includes eleven wells off Alaska, 30 off the Atlantic coast, ten in the eastern Gulf of Mexico and 40 off southern California. In non-frontier areas, there were eight blowouts during exploratory drilling for the 1979-1982 period, none of which resulted in release of hydrocarbons. Tabulations of blowouts on the OCS (Table 17) and OCS drilling, production and spillage data during blowouts (Table 18) show a total of 64 barrels were spilled over the four year period due to blowouts during exploratory and production activities.

Table 16 from Lanfear and Amstutz (1983), summarizing data on spills from all sources for the 1964-1980 period,

Table 16. Oil spills of 1,000 barrels or more from platforms on the U.S. Outer Continental Shelf, 1964-1980.

DATE	MMS DATA-BASE ID NO.	LOCATION	SIZE (BBL)	CAUSE
8 Apr 64	200	Eugene Island 208	5,108	Collision
3 Oct 64	220-280	(7 Platforms)	17,500	Hurricane
19 Jul 65	360	Ship Shoal 29	1,688	Blowout
28 Jan 69	990	Santa Barbara	77,000[1]	Blowout
16 Mar 69	1,060	Ship Shoal 72	2,500	Blowout, weather
17 Aug 69	1,220	Main Pass 41	16,000	Tank spill, weather
10 Feb 70	1,430	Main Pass 41	30,500	Blowout
1 Dec 70	1,580	South Timbalier 26	53,000	Blowout
20 Jul 72	2,000	(Unspecified, Gulf of Mexico)	4,300	Unspecified
9 Jan 73	2,130	West Delta 79	9,935	Tank spill
23 Nov 79	4,230	Main Pass 151	1,500	Tank spill
17 Nov 80	4,590	Galveston	1,500	Tank spill

[1]Estimates vary

Lanfear and Amstutz (1983).

Table 17. Number of blowouts on the OCS, 1979 - 1982.

	DRILLING			NONDRILLING				
Year	Exploration	Development	TOTAL	Completion	Production	Workover	Total	TOTAL
1979	3	2	5	0	0	0	0	5
1980	3	1	4	1	1	2	4	8
1981	2	1	3	5	0	2	7	10
1982	0	4	4	1	0	3	4	8
	8	8	16	7	1	7	15	31

Fleury, (1983).

Table 18. OCS drilling, production and spillage data, 1979 - 1982.

	PRODUCTION			OIL SPILLAGE* DURING BLOWOUTS				
Year	New Wells Started	Oil and Gas Condensate (Million Barrels)	Gas (Billion MCF)	Exploration	Development	Completion	Production	Workover
1979	1,109	285.6	4.7	0	0	0	0	0
1980	1,079	277.4	4.6	0	0	0	1	0
1981	1,106	286.6	4.8	0	0	0	0	64
1982	1,155	321.1	4.7	0	0	0	0	0
	4,449	1,170.7	18.8	0	0	0	1	64

*Barrels of oil and oil condensate. Fleury, (1983).

shows that the last blowout which resulted in a spill during this period was in 1970 when 53,000 barrels were lost in the Gulf of Mexico. When data from Tables 16 and 17 are combined, it is obvious that the oil and gas industry has a better record during the more recent years.

Lanfear and Amstutz (1983) compute a spill rate from platforms of 1.0 spill per billion barrels for spills of 1000 barrels or more.

It is expected that platforms would be located some 90-100 miles from land and the most likely mode of transporting oil to a shore facility would be via pipelines. Lanfear and Amstutz (1983) indicate that "using USGS accident data from 1964 through 1979 and basing exposure on U.S. OCS production (almost all U.S. OCS oil is transported by pipeline), a computed rate would indicate 1.82 spills per billion barrels for spills of 1.000 barrels or more." However, they further indicate that anchor dragging was the cause of 75 per cent of the larger pipeline spills. Since pipelines in water depths less than 200 feet must be buried, the exposure in the North Aleutian Shelf area will be limited to the deeper areas.

Depending on the shore crossing location, onshore pipelines will range between 15-100 miles and will probably transport oil to a terminal on the south side of the Aleutian Chain. Tankers will then take on the crude oil and transport it south. Lanfear and Amshutz (1983) show crude oil spills of 1,000 barrels or more resulting from spills in the open sea to be 0.9 spills per billion barrels transported. For spills in port, 0.4 spills per billion barrels is projected. Based on the most likely location of processing and shipment facilities, any spill that would occur from these sources would take place on the Pacific side of the Aleutian Chain.

In summary of past spill data and using a 0.7 billion barrels of oil projected as the mean reserves for the North Aleutian Shelf (Marlow et al, 1980), it would be expected that one spill greater than 1,000 barrels, but probably less than 10,000 barrels, would occur during the life of the field. However, there always exists a very small, but finite, possibility of a larger spill.

Other than oil, discharges of drilling fluids and cuttings from platforms will introduce contaminants into the marine waters. A well might typically produce 12,000-24,000 barrels of waste, consisting of about 2,500 barrels of cuttings, 7,000-17,000 barrels of drilling mud waste and some 3,500 barrels of washwater waste.

3. Spill Movements and Concentrations

The Bristol Bay area of Lease Sale 92 is a large area. The distance from Unimak Pass to Kvichak Bay is approximately 490 nmi and the distance across the mouth approximately 270 nmi, with a total area of over 3.6×10^4 nmi^2, or 1.2×10^5 km^2. A likely oil spill will occupy only a fraction of this large area at any given time. Thus the persistence and movement of this spill over time will be very important as to the actual total damages that occur.

For example, the maximum slick size versus volume of oil spilled can be approximated by the results of Fay (1971) shown in Figure 135, based upon observations of real spills. Thus a spill of 1,000 to 10,000 barrels would cover an area of 10 to 100 km^2 (10^{7-8} m^2) or 0.01 to 0.1 percent of the total area, with a 100,000 barrel spill (Santa Barbara class) covering approximating 0.5 percent. For the case of the inshore area within the 50 mile depth contour, a major spill in this smaller area (1.1×10^4 km^2) would cover several percent of this inshore zone.

A spill of a given size is not stationary, of course, but will move with the wind and currents. Thus a spill of a given area will affect a much larger area over its total lifetime. Oscillatory tidal currents in the inshore areas will streak oil out over six to twelve nautical miles during a tidal cycle. The mean currents within the coastal domain, 2 to 5 cm/sec, are very slow and will usually have less effect on intermediate time movements of an oil slick than will the local winds. For example, a 5 cm/sec mean current (0.1 kt) would require about 40 days to transport oil 100 nautical miles. A 30 kt wind will move an oil slick (not the water column) at about 0.9 kt.

In this regard, the frequency of three to five storms per month is important. The cyclones that propagate through the area make this an event-dominated system. For the inshore area, strong onshore and longshore winds occur as the cyclone storm systems move through the area. Thus, oil slicks can be driven onshore or longshore by winds during storm events. Coastal currents, as reviewed earlier in the oceanography chapter, also respond as pulses of flow, reacting to local wind events. For example, longshore winds from the northeast will cause temporary reversals in the coastal flow along the Peninsula, and also cause offshore movement of surface waters and onshore movement of water at depth. Storms will also act to disperse an oil slick, dispersing oil down into the water column and into shallow sediments. Because of increased mixing from waves, the frequent storms in the North Aleutian Shelf region will probably shorten the lifetime of a spill to one to two weeks maximum.

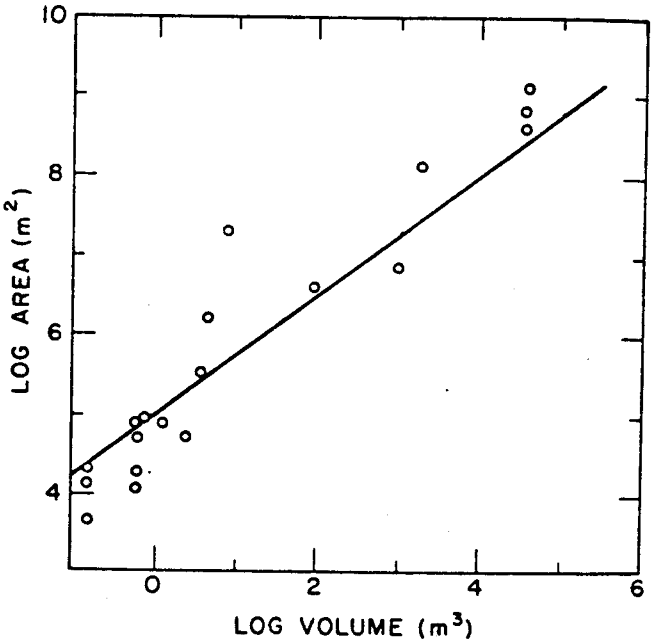


Figure 135. Maximum slick area as a function of volume (Fay, 1971).

A wind rose for the North Aleutian Shelf area indicates about an equal chance of wind from any direction, and is essentially an average of many cyclonic storm events. Because of low mean currents, movement of an oil slick will be greatly determined by this local wind. A reasonable likelihood therefore exists that oil released offshore can be brought ashore and into the lagoons and estuaries by storm associated wind events.

A number of large lagoons and embayments exist along the northern side of the Alaska Peninsula. Among them are Bechevin Bay, Izembek Lagoon, Herendeen Bay, Port Heiden, Ugashik Bay, and Egegik. The upper Bristol Bay and northern coast also have important estuaries which include Kvichak Bay, Nushagak Bay, Togiak Bay, and Kulukak Bay. Inshore movement of oil driven by wind could threaten such a bay or lagoon, if spill location and wind happened to act in concert. Information on exchange and residence times in these bays and lagoons is not presently available.

Manen and Pelto (1983) estimate from literature on field and laboratory experiments, as well as from a model, the concentrations of crude oil that might be expected in the water column and in the sediments under an oil spill on the North Aleutian Shelf. Their review of laboratory and field experimental data of oil concentrations in the water column show median values of from 300 to 1,000 ppb oil in the upper water column. From their model of two 10,000 barrel continuous oil spills in the North Aleutian Shelf area, they predict 650 ppb maximum concentrations in the water under the slick if the wind remains constant and there are no transverse currents.

Baker (1983) used literature data of laboratory loading of oil on sediment, along with his suspended sediment and sediment trap data from the North Aleutian Shelf. He estimated that sediment absorbed oil loadings might be 0.7 to 7 ppb in the inshore water column and 0.06 to 1 ppb in the offshore zone. Using sediment trap data and assuming particles caught in the trap were sedimenting to the bottom, he estimated that a flux of oil to the benthos could be 1-10 mg m^{-2} day^{-1} if the sediment were fully loaded with oil.

4. Toxicity Data

a. Petroleum Hydrocarbons

A thorough review of the petroleum hydrocarbon (PHC) toxicity literature (Appendix B) for eight taxonomic groupings of marine organisms was conducted to assist in assessing the vulnerability of these groups to potential oil spills. This review is synthesized in Tables 19 through 26.

Marine Macrophytes

Type of Test (acute/chronic/ field)	Test material (refined/ crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations <100 hours	# of tests	>100 hours	# of tests	N/A
Acute	Refined	L J A							
	Crude	L J A							
	WSF	L J A							
Chronic	Refined	L J A	3	2			2,000 ppm	2	
	Crude	-L J A	3	1			2,000 ppm	1	
	WSF	L J A							
Field	Refined	L J A	3	2				3	3
	Crude	J A							

Table 19. Synthesis of petroleum toxicity literature for marine macrophytes (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Annelids

Type of Test (acute/chronic/field)	Test material (refined/crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations: <100 hours	# of tests	>100 hours	# of tests	N/A
Acute	Refined	L	3	1	0.5%	3			
		J	4	1	4.0-8.7 ppm	4			
		A	10	2	0.9-8.7 ppm	14	1.4-7.3 ppm	5	
	Crude	L							
		J	4	1	15.2-19.8 ppm	4			
		A	9	5	9.8->19.8 ppm	14	7.9-17.8 ppm	5	
	WSF	L							
		J							
		A	3	1	9.5-15.0 ppm	3	4-5 ppm	2	
Chronic	Refined	L							
		J							
		A	1	3				3	3
	Crude	L							
		J							
		A	1	1			250-1,000 ppm	1	
	WSF	L							
		J							
		A							
Field	Refined	L							
		J							
		A							
	Crude	J							
		A							

Table 20. Synthesis of petroleum toxicity literature for annelids (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Mollusks

Type of Test (acute/chronic/ field)	Test material (refined/ crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations <100 hours	# of tests	Range of Concentrations >100 hours	# of tests	N/A
Acute	Refined	L	8	14	194-3.8K ppm	19			
		J	1	1	0.006-0.54 ppm	1	10.6 ppm		
		A	15	5	0.006-15.6 ppm (1 @ 500 ppm)	14	0.51 ppm	6	2
	Crude	L	3	2	500-1000 ppm	4			
		J	1	1	<1000 ppm	1			
		A	29	24	3.94-148 ppm (1 @ approx. 1,000 ppm)	56		7	33
	WSF	L	2	3	1 ppm	12			9
		J							
		A	3	4	4-168 ppm	5	4-14 ppm	2	
Chronic	Refined	L	1	3	1 ppm	3			
		J	2	1	15 ppm	1	10-100 ppm	1	
		A	7	6	1.7-59 ppm	5		5	1
	Crude	L							
		J							
		A	6	4	4.3-24.9 ppm (one @ approx. 1,000)	3	3-10 mg/l	5	3
	WSF	L							
		J							
		A	3	4	0.67-24.9 ppm	5	0.036-35 ppm	4	1
Field	Refined	L							
		J							
		A	6	4		1	35-2,086 ppm	10	7
	Crude	J							
		A	5	5		1		6	5

Table 21. Synthesis of petroleum toxicity literature for mollusks (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Echinoderms

Type of Test (acute/chronic/field)	Test material (refined/crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations: <100 hours	# of tests	>100 hours	# of tests	N/A
Acute	Refined	L	4	3	0.5-12.5%	6	0.5%	1	
		J							
		A	2	1	>3.36->6.9 ppm	2			
	Crude	L	1	1	12.5%	1			
		J							
		A	5	2	>6.84->14.7 ppm	7			
	WSF	L	1	1	100%	1			
		J							
		A							
Chronic	Refined	L							
		J							
		A							
	Crude	L	1	4	up to 100%	4			
		J							
		A							
	WSF	L							
		J							
		A							
Field	Refined	L							
		J							
		A							
	Crude	J							
		A							

Table 22. Synthesis of petroleum toxicity literature for echinoderms (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Arthropods

Type of Test (acute/chronic/ field)	Test material (refined/ crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations: <100 hours	# of tests	>100 hours	# of tests	N/A
Acute	Refined	L	7	6	0.17-100 ppm (1 @ 0.5%)	8			1
		J							
		A	42	10	0.006-350 ppm (2 @ >3K ppm)	72	1.95-5.24 ppm	3	11
	Crude	L	9	4	0.22-500 ppm (1 @ approx.1K)	16		1	
		J	3	2	1-560 ppm	2		1	
		A	27	9	0.87-1,000 ppm	46	1-1,000 ppm (one @ 10K)	6	1
	WSF	L	10	4	0.008->19.8 ppm	13			
		J							
		A	23	9	0.4-8.9 ppm	49	0.5-4.9 ppm	6	2
Chronic	Refined	L	3	3		1	0.008-0.22 ppm	3	1
		J	1	1			6 ppb	1	
		A	1	2	1.44 ppm	3	0.24 ppm	1	
	Crude	L	2	1	100-1,000 ppm	3			
		J							
		A	2	2	350 ppm	1			1
	WSF	L	3	2			0.008-1.87 ppm	3	1
		J							
		A	5	4	10,000 ppm	8	11 ppm	2	3
Field	Refined	L							
		J							
		A	1	1			>6,000 ppm	1	
	Crude	J							
		A	1	1			up to 500 ppm	1	

Table 23. Synthesis of petroleum toxicity literature for arthropods (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Fish

Type of Test (acute/chronic/ field)	Test material (refined/ crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations: <100 hours		>100 hours		N/A
						# of tests		# of tests	
Acute	Refined	L	9	7	<10-100 ppm (one @ 0.1%)	10	2-10 ppm (one @ 0.1%)	2	
		J	6	5	11-1,952 ppm	10	100-398 ppm	1	
		A	26	4	0.15-2,200 ppm (1 @ > 10K)	31	0.1-250 ppm	5	
	Crude	L	11	7	0.01-3 ppm (5K to 100K)	7	10-10,000 ppm	4	1
		J	3	3	42-840 ppm	6			
		A	17	4	2-80,000 ppm	25			
	WSF	L	6	6	3.0-10,000 ppm	4	10-10,000 ppm	7	1
		J	4	4	<1.0-10,000 ppm	11	2-3.4 ppm	2	
		A	10	4	1.3-19.8 ppm	15			
Chronic	Refined	L	2	3			0.01-10 ppm	3	
		J							
		A	8	8	0.2-10 ppm	10	0.4-5.6 ppm (one @ 3K)	3	2
	Crude	L	3	3	240 ppm	1	0.01-1 ppm	2	1
		J							
		A	6	4	0.2 ppm	2	520-700 ppm	8	7
	WSF	L	3	4	10,000 ppm	6	10,000 ppm	5	3
		J	1	1			0.4 ppm	1	
		A	4	2	0.35-2.22 ppm	3	0.8 ppm	2	
Field	Refined	L							
		J							
		A	1	1				1	1
	Crude	J							
		A							

Table 24. Synthesis of petroleum toxicity literature for fish (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Birds

Type of Test (acute/chronic/field)	Test material (refined/crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations: <100 hours	# of tests	>100 hours	# of tests	N/A
Acute	Refined	L	1	2			oil coverage	2	2
		J							
		A							
	Crude	L							
		J	1	1			oral dose	1	1
		A	1	2			oral dose	2	2
	WSF	L							
		J							
		A							
Chronic	Refined	L	1	1			oil coverage	1	1
		J							
		A	2	3			oral dose	3	3
	Crude	L							
		J	1	1			oral dose	1	1
		A	2	4			oral dose	4	4
	WSF	L							
		J							
		A							
Field	Refined	L							
		J							
		A							
	Crude	J							
		A							

Table 25. Synthesis of petroleum toxicity literature for birds (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

Marine Mammals

Type of Test (acute/chronic/field)	Test material (refined/crude/WSF)	Life Stage	Number animal types tested	Number of chemicals tested	Range of Concentrations				
					<100 hours		>100 hours		N/A
						# of tests		# of tests	
Acute	Refined	L							
		J							
		A							
	Crude	L							
		J							
		A	1	1	oil on water	1			1
	WSF	L							
		J							
		A							
Chronic	Refined	L							
		J							
		A							
	Crude	L							
		J							
		A	3	2			oil on coat	3	3
	WSF	L							
		J							
		A							
Field	Refined	L							
		J							
		A							
	Crude	J							
		A							

Table 26. Synthesis of petroleum toxicity literature for marine mammals (WSF = water soluble fraction of crude oil, L = larva or egg, J = juvenile stage, and A = adult plus all unspecified life stages).

In general, the petroleum toxicity literature is characterized by a wide variation in reported test organism responses. This is due to a combination of three factors: 1) Experimental approaches, techniques, and test endpoints may vary radically, 2) organism sensitivities vary among species, life stages, and with specific testing conditions, and 3) toxicities of different test materials (sources of crudes, degrees of refinement, aging, and so on) vary markedly among reported experiments.

However, among the variability, a number of trends have become evident:

1. Acute lethal effects generally begin to appear in some testing situations in the 1-10 ppm range, usually within 48 hours.

2. Sub-lethal or chronic effects are occasionally evident in the sub-ppm range and often within one hour of exposure.

3. Most sub-lethal effects observed in the laboratory would probably be mortality in actual, long-term field situations.

Rice et al (1979) recently suggested a general pattern of sensitivity to oil for major phyletic groups of Alaskan species within different habitats (Table 27). Sensitivities to water soluble fractions of Cook Inlet crude oil tended to be greatest for pelagic fish and Crustacea. Benthic organisms tended to be less sensitive, and intertidal organisms were the least sensitive. While the general hydrocarbon toxicity data base indicates much higher variability than suggested by Rice et al, it does appear that adaptations of species to specific conditions within various habitats has served to influence general sensitivity to petroleum hydrocarbons.

Organism group	96-h LC50 in ppm HABITAT		
	Pelagic	Benthic	Intertidal
Fish	1-3	4->5	>12
Crab & Shrimp	1-5	3-5	8->10
Mollusk	--	4->8	8

From: Rice et al (1979).

Table 27. Ranges of sensitivities for different habitat groups exposed to Cook Inlet WSF.

Sensitivity of all species to petroleum hydrocarbons varies with life stage (Tables 19-26). Larvae are consistently more sensitive than either juveniles or adults.

Moore and Dwyer (1974) indicate that larvae of marine organisms are typically 10-100 times more sensitive to the water soluble fractions of petroleum than adults. This general pattern of increasing sensitivity with younger life stages is altered slightly in the case of egg stages of most species. Egg stages are often not as sensitive to short term exposures due to slow transfer of hydrocarbons across the membranes. Under conditions allowing long-term exposure at low levels, eggs are often at least as sensitive as larvae.

b. Drilling Fluids

The discharge of muds utilized during the process of drilling provides another source of contaminants which could potentially impact species occupying nearshore habitats. Available literature on the sensitivities of marine organisms has recently been reviewed by a panel of experts assembled by the National Research Council (NAP, 1983). In addition, Rice et al (1983) have reviewed recent drilling fluid bioassays conducted at the Auke Bay Laboratory on larvae of Alaskan species of shrimp and crab.

NAP (1983) provided a synthesis of 400, 96-hour acute bioassays conducted with 62 different species utilizing 72 different drilling fluids (Table 28). Lower trophic levels (e.g. phytoplankton and copepods) were generally most sensitive to drilling fluids. One hundred percent of the thirteen tests performed with phytoplankton resulted in LC50 values of less than 10,000 ppm drilling fluids. Eighty percent of the tests performed using copepods as test organisms also resulted in LC50 values of less than 10,000. LC50's for all other species were predominantly between 10,000 and 100,000 ppm for 96-hour bioassays. As a whole, nearly 80 percent of the tests performed on all organisms, including many tests conducted with early life stages, resulted in LC50 values greater than 10,000 ppm.

Recent unpublished tests conducted by Carls and Rice (Rice et al, 1983) indicate comparable sensitivities for larvae of Alaskan species of shrimp and crab (Table 29). LC50 values for 144 hour bioassays conducted on king crab and Dungeness crab ranged from 2,000 to 4,800 ppm for whole mud, and from 14,100 to 33,400 ppm for water-soluble fractions. Larvae of kelp *Eualus suckleyi*, and dock shrimp *Pandalus danae*, were found to be generally more sensitive.

Table 28. Summary of results of acute lethal bioassays with drilling fluids and marine/estuarine organisms.[a] (NAP, 1983).

Organism	Number of Species Tested	Number of Fluids Tested[c]	Number of Bioassays
Phytoplankton	1	9	12
Invertebrates			
Crustaceans			
Copepods	2	17	39
Isopods	2	4	6
Amphipods	4	8	19
Mysids[b]	5	18	35
Shrimp[b]	10	40	76
Crabs[b]	6	18	35
Lobsters[b]	1	2	7
Mollusks			
Gastropods	5	5	10
Bivalves[b]	7	14	33
Echinoderms			
Sea Urchins[b]	1	2	4
Polychaetes	6	14	28
Finfish[b]	12	32	90
TOTALS	62	72	400

[a]Most median lethal concentration (LC50) values are based on 96-hour bioassays and results are expressed as parts per million (mg/l or μ l/l) mud added (Based on review of Petrazzuolo, 1981, with data from Carls and Rice, 1980; ERCO, Inc., 1980, Gilbert, 1981, Marine Bioassay Labs, 1982 and Conklin et al., in press, added).

[b]Includes results for embryonic, larval and early life stages.

[c]In many cases, the same drilling fluid was used for bioassays with several species. In a few cases, more than one investigator evaluated the toxicity of a single drilling fluid.

Table 28. continued

Organism	Number of LC50 Values (ppm) Not Determinable	100	100-999	1,000-9,999	10,000-99,999	100,000
Phytoplankton	5	6	0	7	0	0
Invertebrates						
Crustaceans						
Copepods	4	2	11	15	7	0
Isopods	0	0	0	0	1	5
Amphipods	0	0	0	0	5	14
Mysids[b]	1	0	1	0	21	18
Shrimp[b]	0	0	12	15	31	18
Crabs[b]	1	0	0	5	16	13
Lobsters[b]	0	0	0	1	3	3
Mollusks						
Gastropods	0	0	0	0	2	8
Bivalves[b]	0	0	0	1	15	17
Echinoderms						
Sea Urchins[b]	0	0	0	0	1	3
Polychaetes	0	0	0	0	9	19
Finfish[b]	0	0	0	3	52	35
TOTALS	11	2	24	47	163	153
Percentage, as a fraction of the total number of drilling fluid bioassays.	2.8	0.50	6.0	11.75	40.75	38.25

[a]Most median lethal concentration (LC50) values are based on 96-hour bioassays and results are expressed as parts per million (mg/l or μ l/l) mud added (Based on review of Petrazzuolo, 1981, with data from Cares and Rice, 1980; ERCO, Inc., 1980, Gilbert, 1981, Marine Bioassay Labs, 1982 and Conklin et al., in press, added).

[b]Includes results for embryonic, larval and early life stages.

[c]In many cases, the same drilling fluid was used for bioassays with several species. In a few cases, more than one investigator evaluated the toxicity of a single drilling fluid.

Table 29. Tolerance of shrimp and crab larvae to suspensions and water-soluble fractions (WSF) of Cook Inlet mud.

Species	144-h LC50 in %(vol/vol)	
	Complete mud	Mud WSF
King crab	0.48	3.34
Dungeness crab	0.20	1.41
Kelp shrimp	0.44	0.47
Dock shrimp	0.05	0.3

From: Rice et al (1983)

Sublethal and chronic effects of drilling fluids to marine organisms (Table 30) varies substantially between species tested and endpoint responses (NAP, 1983). In the case of mollusks, inhibition of initial shell formation has been identified at concentrations as low as 100 ppm for 96-hour exposures. Minimum concentrations at which responses have been identified for Crustacea are similar to those observed for Mollusca. However, larvae of king and tanner crabs exposed to used euochrome lignosulphate fluids indicated a relatively low sensitivity to lower concentrations. In the case of king crab larvae, responses (indicated by cessation of swimming by 50 percent of the larvae) were elicited for whole mud at a concentration of 2,800 ppm over a 144 hour exposure period, and for water soluble fractions at 12,900 ppm. Tanner crab larvae tested in a similar manner responded to slightly lower concentrations of water soluble mud fractions.

Since acute toxicity tests are seldom carried out on fish, information on the sublethal and chronic effects of drilling fluids on fish (Alaskan species particularly) is almost nonexistent. A single test conducted by Houghton et al (1980), however, indicated that a relatively high concentration of drilling fluids (30,000 ppm) affect gill tissues of pink salmon.

Based upon review of drilling fluid toxicity data and both theoretical calculations and empirical observations of dispersion rates in the water column, it has been estimated that toxic responses of pelagic organisms would need to occur within an hour at concentrations lower than 100 ppm (NAP, 1983). Since the zone around a discharge where concentrations exist at levels greater than 100 ppm would typically be on the order of tens of meters, it is expected that drilling fluids would have little impact on pelagic species.

Studies conducted to date indicate the benthos is the principal habitat where the effects of drilling fluids

Table 30. Summary of investigations of sublethal and chronic effects of drilling fluids on Marine animals (the lowest concentation of drilling fluid eliciting a particular response) (NAP, 1983).

Species	Drilling Fluid Type	Exposure Concentration and Duration	Responses	References
Coelenterates (corals) Montastrea cavernosa Montastrea annularis Diploria strigosa	Used FeCr-lignosulfonate	25 ml., 1:1 seawater:fluid	Unable to clear horizontal surfaces	Thompson and Bright, 1977
Montastrea annularis	Freshly prepared FeCr-lignosulfonate	2-4 mm layer applied 4 times at 2.5 h intervals	Decreased growth rate at 6 months	Hudson and Robbin, 1980
Montastrea annularis Porites asteroides	Used Cr-lignosulfonate, offshore Louisiana	Burial under 10-12 cm for 8 h	All colonies dead after 10 days	Thompson, 1980
Montastrea annularis	Used Cr-lignosulfonate, offshore Louisiana	Thin covering	Partial clearing in 26 h, some dead polyps, extruded zooxanthellae	Thompson, 1980
Madracis decactis	Used Mobil Bay Cr-lignosulfonate with added Cr-lignosulfonate	100 ppm	Depressed respiration and NH_3 excretion rate	Krone and Biggs, 1980
Porites furcata, P. astroides, Montastrea annularis, Acropora cervicornis, Agaricia agaricites	Used Cr-lignosulfonate, offshore Louisiana	100 ppm, 96 h	Partial polyp retraction, excess mucus production	Thompson, 1980; Thompson and Bright, 1980; Thompson et al., 1980
Porites divaricata	Used Cr-lignosulfonate, offshore Louisiana	316 ppm, 96 h	Partial polyp retraction, excess mucus production	Thompson, 1980; Thompson and Bright, 1980; Thompson et al., 1980
Dichocoenia stokesii	Used Cr-lignosulfonate, offshore Louisiana	1,000 ppm, 96 h	Partial polyp retraction	Thompson, 1980; Thompson and Bright, 1980; Thompson et al., 1980
Montastrea annularis	Used Cr-lignosulfonate with diesel, Jay Field, Fla.	100 ppm, 6 weeks, flowthrough	84% reduction in calcification rate, 40% reduction in respiration rate, 26% reduction in photosynthesis, 49% reduction in NO_3 and NH_3 uptake, inhibition of feeding	Szmant-Froelich et al., 1982
Montastrea annularis	Used Cr-lignosulfonate with diesel, Jay Field, Fla.	100 ppm, 6 weeks, flowthrough	Reduction in skeletal growth rate	Dodge, 1982
Montastrea annularis	Used Cr-lignosulfonate with diesel, Jay Field, Fla.	1-100 ppm, 6 weeks, flowthrough	Growth inhibition, alteration of biochemical pathways and composition, bacterial infection	White et al., 1982

Table 30. continued

Species	Drilling Fluid Type	Exposure Concentration and Duration	Responses	References
Mollusks				
Pacific oyster *Crassostrea gigas*	Used medium- and high-weight Cr-lignosulfonate, Gulf of Mexico	5,000 ppm, 6 weeks, static	Decreased shell growth, decreased condition index	Neff, 1980
Atlantic oyster *Crassostrea virginica*	Used Cr-lignosulfonate, Mobile Bay, Ala.	100 ppm, 100 days, flowthrough	Reduced rate of shell regeneration	Rubenstein et al., 1980
C. virginica	Unidentified Cr-lignosulfonate	4,000 ppm	Altered tissue-free amino acid concentrations and ratios	Powell et al., 1982
Mussel *Modiolus modiolus*	Used high-weight Cr-lignosulfonate, Cook Inlet, Alaska	30,000 ppm	Reduced rate of byssus thread formation	Houghton et al., 1980
Mussel *Mytilus edulis*	Used medium- and high-weight Cr-lignosulfonate, Gulf of Mexico	33,000 ppm	Decreased filtration rate, increased rate of respiration and NH_3 excretion	Gerber et al., 1980
M. edulis	Used medium- and high-weight Cr-lignosulfonate, Gulf of Mexico	250 ppm[a]	Decreased rate of shell growth	Gerber et al., 1980, 1981
Ocean scallop *Placopecten magellanicus* (juveniles)	Used medium- and high-weight Cr-lignosulfonate, Gulf of Mexico	49.4 ppm[a]	Decreased rate of shell growth	Gerber et al., 1981
P. magellanicus (2-day larvae)	Filtered suspension (liquid phase) of used Cr-lignosulfonate, Mobile Bay, Ala., May 15 fluid	1,000 ppm, 96 h	Significant inhibition of shell formation	Gilbert, 1981
	May 29 fluid	100 ppm, 96 h	Significant inhibition of shell formation	Gilbert, 1981
P. magellanicus (2-day larvae)	Liquid phase of used Cr-lignosulfonate fluid, Mobile Bay, Ala., September 4 fluid	<100 ppm, 96 h	Signific at inhibition of shell formation	Gilbert, 1981
P. magellanicus (2-day larvae)	Liquid phase of used "Gilsonite" fluid	3,000 ppm, 96 h	Significant inhibition of shell formation	Gilbert, 1981
P. magellanicus (2-day larvae)	Liquid phase of used low-density lignosulfonate	10,000 ppm, 96 h	Significant inhibition of shell formation	Gilbert, 1981

Table 30. continued

Crustaceans				
Opossum shrimp *Mysidopsis bahia*	Used Cr-lignosulfonate Mobile Bay, Ala.	50 ppm, 42 days, flowthrough	50% survival from postlarva to adult	Conklin et al., 1980
M. almyra	Liquid phase of used Cr-lignosulfonate, Gulf of Mexico	10,000 ppm, 7 days	Decreased food assimilation and growth efficiency, reduced growth rate	Carr et al., 1980
Coonstripe shrimp *Pandalus hypsinotus* (adults)	Used high-weight Cr-lignosulfonate, Cook Inlet, Alaska	100,000-ppm suspension	Gill histopathology	Houghton et al., 1980
P. hypsinotus (Stage I larvae)	Used FeCr-lignosulfonate Cook Inlet, Alaska	2,000-ppm suspension, 144 h, 3,250-ppm liquid phase, 144 h	Cessation of swimming by 50% of larvae	Carls and Rice, 1980
Dock shrimp *Pandalus danae* (Stage I larvae)	Used FeCr-lignosulfonate Cook Inlet, Alaska	500-ppm suspension, 144 h, 1,050-ppm liquid phase, 144 h	Cessation of swimming by 50% of larvae	Carls and Rice, 1980
Kelp shrimp *Eualus suckleyi* (Stage I larvae)	Used FeCr-lignosulfonate Cook Inlet, Alaska	5,000-ppm suspension, 144 h	Cessation of swimming by 50% of larvae	Carls and Rice, 1980
Grass shrimp *Palaemonetes pugio* larvae	Used medium- and high-weight Cr-lignosulfonate, Gulf of Mexico	10,000-15,000 ppm liquid phase for duration of larval development	No effect on duration of any intermolt periods or on duration of larval development, significantly increased mortality at molting	Neff, 1980
Sand shrimp *Crangon septemspinosa*	Used low-weight Cr-lignosulfonate, mid-Atlantic OCS	33,000-ppm liquid phase, 96 h	Decrease in activity of the enzyme glucose-6-phosphate dehydrogenase in muscle tissue	Gerber et al., 1980
Atlantic Cancer crab *Cancer irroratus*	Liquid phase of used Cr-lignosulfonate, Mobile Bay, Ala., September 4, 1979	100 ppm, 20 days, flowthrough	No effect on survival or molting rate	Gilbert, 1981
C. irroratus (Stage III larvae)	Liquid phase of used Cr-lignosulfonate, Mobile Bay, Ala., September 4, 1979	100 ppm, 4 days	Temporary inhibition of feeding	Gilbert, 1981
Cancer crab *Cancer borealis*	Used medium-weight Cr-lignosulfonate, Gulf of Mexico	160,000-ppm suspension, 96 h 33,000-ppm liquid phase, 96 h	Increase in activity of enzymes aspartate aminotransferase and glucose-6-phosphate dehydrogenase in heart tissue	Gerber et al., 1981

Table 30. continued

Species	Drilling Fluid Type	Exposure Concentration and Duration	Responses	References
Crustaceans (continued) Green crab *Carcinus maenus*	Used low-weight Cr-lignosulfonate, mid-Atlantic OCS	33,000-ppm liquid phase, 96 h	Increase in activity of enzymes aspartate aminotransferase and glucose-t-phosphate dehydrogenase in muscle	Gerber et al., 1980
King crab *Paralithoides camschatica* (Stage I larvae)	Used FeCr-lignosulfonate, Cook Inlet, Alaska	2,800-ppm suspension, 144 h 12,900-ppm liquid phase, 144 h	Cessation of swimming by 50% of larvae	Carls and Rice, 1980
Tanner crab *Chionoecetes bairdi* (Stage I larvae)	Used FeCr-lignosulfonate, Cook Inlet, Alaska	2,800-ppm liquid phase, 144 h	Cessation of swimming by 50% of larvae	Carls and Rice, 1980
Mud crab *Rhithropanopeus harrisii* larvae	Used low-weight Cr-lignosulfonate, Jay Field, Fla.	100,000-ppm fluid aqueous fraction and suspended particulate phase, complete larval development	No effect on survival or development rate to first crab stage	Bookhout et al., 1982
Blue crab *Callinectes sapidus* larvae	Used low-weight Cr-lignosulfonate, Jay Field, Fla.	50,000-ppm fluid aqueous fraction and suspended particulate phase, complete larval development	Significant decrease in survival of megalopa, altered larval behavior	Bookhout et al., 1982
American lobster *Homarus americanus* (adults)	Used low-weight Cr-lignosulfonate, mid-Atlantic OCS	10,000-ppm liquid phase, 96 h	Increase in activity of the enzyme aspartate aminotransferase and decrease in activity of enzyme glucose-6-phosphate dehydrogenase in heart tissue	Gerber et al., 1980
H. americanus (larvae)	Used medium-weight Cr-lignosulfonate, Gulf of Mexico	2,000-ppm liquid phase	Increase in duration of larval development by 3 days	Gerber et al., 1981
H. americanus (adults)	Used medium- and high-weight Cr-lignosulfonate, Mobile Bay, Ala.	10-ppm suspension, 3-5 min	Decreased chemosensory response of walking leg chemosensors to food cues	Derby and Atema, 1981
H. americanus (adults)	Unknown	1-2 mm layer, 4 days	Inhibition of feeding behavior	Atema et al., 1982

Table 30. continued

Crustaceans (continued)				
H. americanus (adults)	Used Cr-lignosulfonate, Mobile, Ala., June 26, 1979	7-mm layer, 4 days	No effect on feeding behavior	Atema et al., 1982
H. americanus (Stage IV larvae)	Used Cr-lignosulfonate, Jay Field, Fla., July 29, 1980	7.7-ppm suspension, 36 days	Partial inhibition of molting, delayed detection of food cues	Atema et al., 1982
H. americanus (Stage IV and V larvae)	Used Cr-lignosulfonate fluids, Jay Field, Fla., and Mobile Bay, Ala.	1-4 mm layer	Delays in burrow construction, altered burrowing behavior	Atema et al., 1982
Polychaete Worms				
Lugworm Arenicola cristata	Used Cr-lignosulfonate fluids, Mobile Bay, Ala.	10-ppm suspension flowthrough with an accumulation of 4.5 mm at 100 days	33% mortality	Rubinstein et al., 1980
Echinoderms				
Sand dollar Echinarachnius parma (embryos)	Used Cr-lignosulfonate, MobileBay, Ala., June 26, 1979	3,816-ppm[a] suspension, duration of development	Depressed fertilization, delayed development, developmental anomalies	Crawford and Gates, 1981
Bat starfish Patiria miniata (embryos)	13 used Cr-lignosulfonate fluids, Santa Barbara Channel, Calif.	500-100,000 ppm fluid aqueous fraction, 48 h	Significant decrease in growth rate, increased incidence of developmental abnormalities	Chaffee and Spies, 1982
Teleost Fish				
Killifish Fundulus heteroclitus (embryos)	Used Cr-lignosulfonate, MobileBay, Ala., June 26, 1979	3,816-ppm[a] suspension, duration of development	Retarded embryonic development, depressed embryonic heart beat rate	Crawford and Gates, 1981
F. heteroclitus (embryos)	Used freshwater Cr-lignosulfonate Gulf of Mexico	10,000-ppm liquid phase, duration of development	Depressed hatching success, depressed embryonic heart beat rate, developmental anomalies	Sharp et al., 1982
Pink salmon Oncorhynchus gorbuscha	Used high-weight Cr-lignosulfonate Cook Inlet, Alaska	30,000-ppm suspension	Gill histopathology	Houghton et al., 1980

[a]Concentrations originally reported as ppm suspended solids, converted here to estimated ppm total fluid added.

would be evident. Under high energy regimes characteristic of much of the nearshore areas of the North Aleutian Shelf, a conservative estimate of the largest distance of impact to the benthos from a point source would probably be less than 1,000 meters. In field studies conducted around drilling fluid discharges in low to moderate energy regimes, the furthest point of detectable influence on the benthic community has been 1,000 meters (NAP, 1983). The primary concern of most researchers in this field is for discharges in the vicinity of hard substrates where habitat is limited and communities longer-lived.

5. Vulnerability Analysis

The vulnerability of a given species to potential disturbances resulting from oil and gas development is extremely difficult to determine with a high degree of certainty. Vulnerability is a complex function of numerous factors. Among the more important factors influencing vulnerability are the sensitivities of each organism to various types of disturbances (e.g. oil spills, drilling fluid discharges, increased air and marine traffic), temporal and life cycle differences in geographical ranges, population size and productivity, feeding habits, and general behavioral characteristics.

While many of the various disturbances associated with development of oil and gas reserves may be of major importance to one or several taxonomic groups, a potential catastophic oil spill in the coastal zone is of paramount concern. In assessing the vulnerability of the flora and fauna of species utilizing coastal areas of the North Aleutian Shelf, it is important to consider the differences in vulnerability of the principal habitats to an oil spill.

The location of an oil spill in the coastal zone is a major factor controlling its ultimate influence on the wildlife resources. The physical characteristics of different coastal environments largely control the behavior and persistence of the oil. A spill occurring in a high energy, rocky intertidal area would be expected to coat the rocks with a tough, tarry "skin" resulting in direct mortality of plants and animals due to smothering. With the constant exposure to wave action, sunlight, and air, this tarry layer of oil would gradually be altered and eroded from the surfaces of the rocks. Erosion rates would decrease with increased weathering of the oil. Up to 50 percent of the oil may be removed within 1.5 to 2 years but the remainder could persist for many more years. Oil stranded in pools in the upper intertidal may remain for many years virtually unaltered beneath a weathered film. Spills occurring on cobble and coarse sand beaches can penetrate well into the interstices of the substratum where the oil may be retained in relatively unaltered form, slowly leaching back into the overlying water. In finer substrates, oil penetration would be expected to be minimal. Areas with fine sediments, however, are typically low energy environments where dilution and dissipation of oil might be extremely slow, allowing the oil to persist in a concentrated form for long periods of time. Oil entering embayments along the Alaska Peninsula such as Izembek Lagoon could be retained for many years.

Thorsteinson (1983) provides a thorough review of the vulnerability of most key species present in the study area. The following discussion is a brief synthesis of the key points addressed in Thorsteinson's review, along with information specifically relevant to the vulnerability of key species in other areas of Bristol Bay. The reader should refer to this review for further insight into the vulnerability of species common to the entire Bristol Bay region.

a. Marine Mammals

Fur-bearing mammals are likely to be the most vulnerable of the marine mammals that utilize the nearshore habitat of the North Aleutian Shelf and Inner Bristol Bay. These species rely in varying degrees on both their specialized pelts and layers of blubber to assist in thermoregulation. Oil deposited directly on the fur can severely reduce the ability of the animal to thermoregulate and may result in direct mortality. This group of species would be particularly vulnerable to an oil spill due to their direct dependence upon the air/sea interface and haulout areas.

Sea otters are clearly the most vulnerable of the furbearing mammals to a potential oil spill. Both the young and adult sea otters rely upon their pelts for thermoregulation. In other species present in the region, only young pups that had not yet developed adequate layers of blubber for insulation would be extremely sensitive to oiling (Brahm et al,1982).

Distributional limitations of sea otters, both longshore and offshore, during the spring and summer months tend to concentrate a large proportion of the population into a relatively small area. With the bulk of the estimated population of 11,000 to 17,000 animals distributed in the coastal region between Cape Mordvinof and Cape Leontvich and occurrence of occasional pods in excess of 1,000, the population could suffer extremely high mortality due to the direct effects of even a small spill.

Indirect impacts on the sea otter population might also result through decreased abundance of prey or ingestion of prey contaminated by petroleum hydrocarbons. Data are presently inadequate regarding both the feeding habits of sea otters and sublethal or chronic effects of exposure to hydrocarbons through foodweb relationships. However, based upon present information that suggests that the sea otters are near the present carrying capacity of the environment, any reduction in food resources associated with a catastrophic oil spill could reduce the present population abundances (Schneider and Faro, 1975; Lowry, 1922; Kenyon, 1969).

The harbor seal and Steller sea lion populations are considered far less vulnerable to oil pollution due to their primary reliance on protective layers of blubber rather than fur to reduce heat loss associated with oiling as well as to their much broader distribution. For both harbor seals and sea lions, oiling is primarily a problem with young pups that have not yet developed adequate layers of blubber (Braham et al, 1982). Vulnerability of harbor seals to a spill would therefore be highest in the vicinity of Port Moller, Port Heiden and the Cinder River areas during pupping in the months of June and July. Similarly, the sea lion population would be most susceptible to an oil spill occurring between May and July in the vicinity of either Fox Islands or Amak Island. The rookeries of the Fox Islands, which are frequented by approximately 80 percent of the population, would be the most critical habitat.

There is little evidence that non-furbearing mammals would be directly affected by short-term exposure to water accommodated petroleum hydrocarbons or to surface oil. Gray whales which utilize the nearshore region as a migratory pathway, principally between April and July, could potentially encounter a spill but can likely avoid it without problems. Other whales, such as Belugas, would also be expected to be capable of avoiding an oil spill or minimizing contact with the surface slick. While it is suspected that an oil spill would have little impact on these mammals, current data are far from sufficient to determine their vulnerability.

Many of the marine mammals found in this region may also be sensitive to increased air and marine traffic associated with oil and gas development. This is of particular concern in the vicinity of rookeries. These types of disturbances could result in increased pup mortalities (Johnson, 1977).

b. Birds

Oil spills in regions of high densities of birds can result in significant mortalities due to direct physical effects of contact with the oil. Upon contact with surface oil, a bird's feathers rapidly become matted, losing both their waterproofing and insulating qualities. The loss of waterproofing results in absorption of water into the feathers and consequently requires substantially more energy to fly, swim, or dive for food. The loss of thermal insulation also results in a significant expenditure of energy due to the increased metabolic rates necessary to maintain body heat. Ultimately, a heavily oiled bird will succumb to exhaustion, unable to obtain even maintenance rations.

A lightly oiled bird may be capable of preening the oil from its feathers; however, temperature plays an important role in the ability of an oiled bird to survive. Birds tend to be more sensitive to oiling in colder climates where loss of body heat can rapidly deplete energy reserves.

One of the most devastating and longlasting effects that an oil spill could have on bird populations would be a decrease in reproductive success. Transport of oil back to nests containing incubating eggs can result either in direct mortality or reduced hatching success. In laboratory tests, coverage of only 5 percent of the total surface area of mallard eggs has resulted in substantially lower hatching success (Albers, 1977). Ingestion of lubricating oil under laboratory conditions has been demonstrated to temporarily inhibit egg formation and laying (Gray et al, 1977).

The ecological impact of reduced reproductive success is directly related to the reproductive strategies of each particular species. Populations of short-lived species with high fertility rates would be least vulnerable to impacts of an oil spill. Longer lived species with lower turnover rates (one to two eggs/yr/pair, e.g. alcids) could be extremely vulnernable to an oil spill.

The major factors influencing the vulnerability of various bird species to an oil spill include the amount of time they spend on the water, how strongly they tend to aggregate, the proportion of their life spent in the study area, whether or not they breed in the region, and their population turnover rate. The indirect influence of an oil spill on food resources of limited distribution may also contribute to the vulnerability of several species. Birds most vulnerable to an oil spill include seabirds that breed in the Bristol Bay region, such as the alcids (primarily the common murre), the black-legged kittiwake, and the waterfowl that heavily utilize the coastal lagoons.

Many of the species that utilize the lagoons and marshes are particularly vulnerable to oil spills. Increased retention times would increase the possiblity of direct contact with the oil as well as exacerbating the situation by prolonging exposure to food resources. A major spill in Izembek Lagoon, for instance, could drastically reduce the population of black brandt, eiders, and Emperor geese.

c. Fish

The sensitivity of fish to oil pollution varies both with life stage and habitat type. As a general rule, early life stages are more sensitive than adults and pelagic species tend to be more sensitive than either demersal or benthic species. Also, many larvae concentrate near the surface where potential damage from oil is highest.

In the nearshore zone of the Bristol Bay region, species most vulnerable to an oil spill would be littoral spawners such as capelin and Pacific herring. Other species, such as the osmerids (eulachon and boreal smelt), which enter the rivers to spawn but utilize the nearshore zone as a nursery ground and adult habitat would also be considered vulnerable. Yellowfin sole larvae may also be abundant and potentially vulnerable in the region. Older life stages susceptible to oil pollution would include primarily pelagic species. Since older juveniles and adults are more mobile and less sensitive to water soluble petroleum hydrocarbons, they are generally considered to be far less vulnerable. Outmigrating salmon may be an exception since they are initially limited to surface waters of the inshore region.

Capelin are extremely vulnerable to an oil spill during much of their life history. Oil spills encountering the fine gravel beaches utilized as spawning habitat by capelin may penetrate well into the substratum where it would slowly leach back into the water column, subjecting deposited eggs to continuous low level concentrations of petroleum hydrocarbons. Upon hatching, capelin larvae, like most osmerids, are found in larger abundance in the surface waters. Neuston nets have been found to be more effective than standard bongo nets at collecting osmerid larvae in the Bering Sea region (Waldron, 1981). Under a spill situation, their location in the water column would thus expose them to high concentration of petroleum. It is postulated that larvae of other smelts (mostly boreal smelt and eulachon) that spawn in rivers would drift out into littoral nursery areas where they would be subject to similar exposure to petroleum hydrocarbons.

Pacific herring populations could also be heavily impacted by oil releases. As adults, herring remain offshore but yearly enter the nearshore zone for spawning, when hydrocarbons in the environment may be accumulated in the eggs. Once the eggs are spawned and become water hardened, uptake of lower molecular weight hydrocarbons would be minimal. Upon hatching, larvae are likely to be highly concentrated due to the relatively restricted spawning habitat. During this time period the population could suffer substantial losses from a major spill event. As the larvae disperse and further develop into juveniles, it is unlikely that a spill could impact the population.

The migratory patterns of salmon (primarily sockeye), through the Bristol Bay region are such that only juvenile salmon would be potentially subject to impacts of a spill. Adults are typically well dispersed offshore as they return to their spawning rivers. Outmigrating juveniles, however, are relatively restricted in their distribution. Juvenile salmon leaving the spawning rivers remain in a relatively narrow band along the Alaska Peninsula until reaching the region of Port Moller where they veer out to sea. During their outward migration juvenile salmon remain in the upper one to two meters where they would most likely encounter high levels of petroleum hydrocarbons from a major spill. Laboratory bioassays suggest that losses could occur at hydrocarbon concentrations of greater than 1 ppm for a period of 3-5 days. However, it is not known how they may immediately respond to a spill under field conditions nor what sublethal effects may eventually affect their survival.

d. Invertebrates

The red king crab is considered to be the most vulnerable invertebrate species and certainly one of the most sensitive of all fauna in the Bristol Bay region to oil and gas development. Release of larvae and mating occur in the inshore areas of Bristol Bay which also have the greatest potential petroleum reserves. Larvae released between April and June remain in the nearshore zone, drifting further into Bristol Bay before settling out to take up a benthic existence. King crabs may remain in the coastal regime for 4 to 5 years prior to initiation of adult migratory behavior (Powell and Nickerson, 1965).

Crustacean larvae are among the most sensitive to petroleum hydrocarbons. Bioassays conducted with red king crab larvae have resulted in 96 hour LC50's as low as 1.3 ppm. This suggests that a large-scale spill occurring along the coast between Cape Mordvinof and Port Moller between April and May could have a significant effect on the larval crab population. Thorsteinson (1983) estimated a potential loss of 3-5% of the population from a 10,000 barrel spill.

Due to the current scarcity of data regarding the distribution and habitat requirements of juvenile king crab it is difficult to assess their vulnerability to oil development. The difficulties in locating habitats utilized by these juvenile crabs may suggest that either suitable habitats are extremely limited or that sampling methods have been inadequate. If juveniles are found to be densely aggregated into limited areas, they would be extremely vulnerable to a variety of different types of disturbances.

RESEARCH NEEDS AND DATA GAPS

Bristol Bay is a region of unmatched commercial importance. The bay is also of major ecological importance to numerous species of birds, fishes, and mammals. Nevertheless, large data gaps exist which hamper management decisions regarding these resources, particularly when oil and gas developments are added to the present problems.

As a framework for consideration of these data needs the conceptual model developed in the earlier hypotheses section is utilized. The conceptual ecological model developed in this earlier section is first summarized. Then testable hypotheses are formulated regarding the important processes involved and data gaps are identified which are associated with each hypothesis. The conceptual model thus serves as a guide to the interpretation and synthesis of the future data for the North Aleutian Shelf.

1. Conceptual Model Summary

The conceptual ecological model formulated in the earlier hypotheses section is summarized in Figures 136, 137, and 138. This conceptual model is based upon the premise that the observed richness of biological resources in the nearshore area can be explained by two factors, 1) food availability and 2) suitable habitat.

The first factor, that of high biological productivity within the nearshore shelf zone of Bristol Bay, is hypothesized to be based upon two somewhat independent trophic systems. One of these systems is more or less self-contained and endemic. The other system is a seasonal "import-export" system. Of course, the two systems overlap to some degree.

a. Endemic Trophic System

A conceptual model of the endemic trophic system is given in Figure 136 for the north Alaska Peninsula coast, and in Figure 137 for the inner Bristol Bay region. This endemic trophic system is heavily dependent on marine productivity. However, seagrass imported from the lagoons may contribute about 14% of the available organic carbon, if averaged over the north Peninsula nearshore coast, and perhaps more locally. Detrital material from rivers also adds approximately 7 and 10% respectively to the north Peninsula and inner Bristol Bay nearshore zones. This input from rivers and lagoons is as detrital organic matter, not as soluble nutrients. From the conceptual model and using available data, it appears that this endemic trophic system is a benthic-rich system in that much of the detrital carbon and in-situ phytoplankton production reach the benthos,

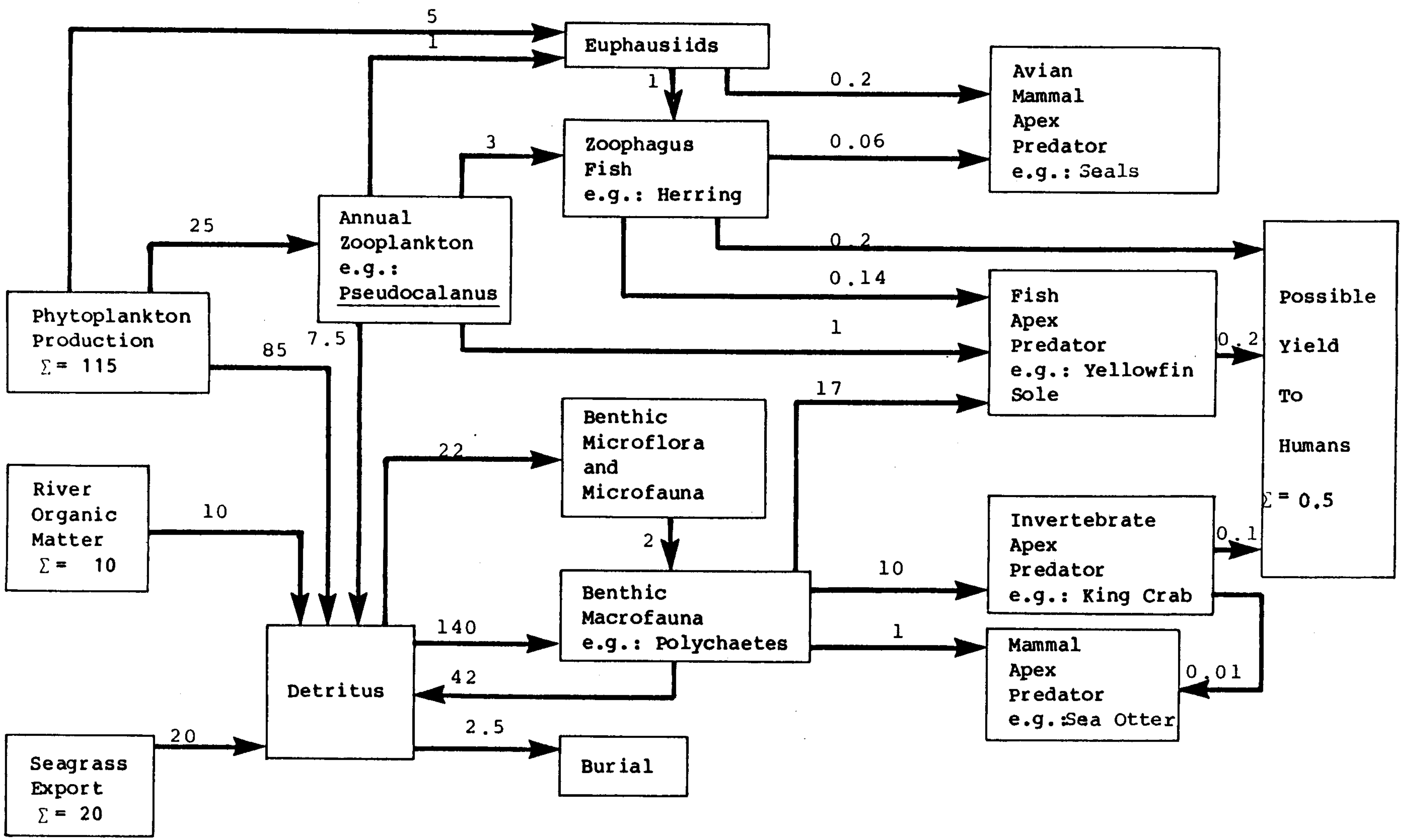


Figure 136. Conceptual endemic system model for the North Aleutian Peninsula nearshore zone. Hypothetical carbon budget in g m^{-2} yr^{-1}.

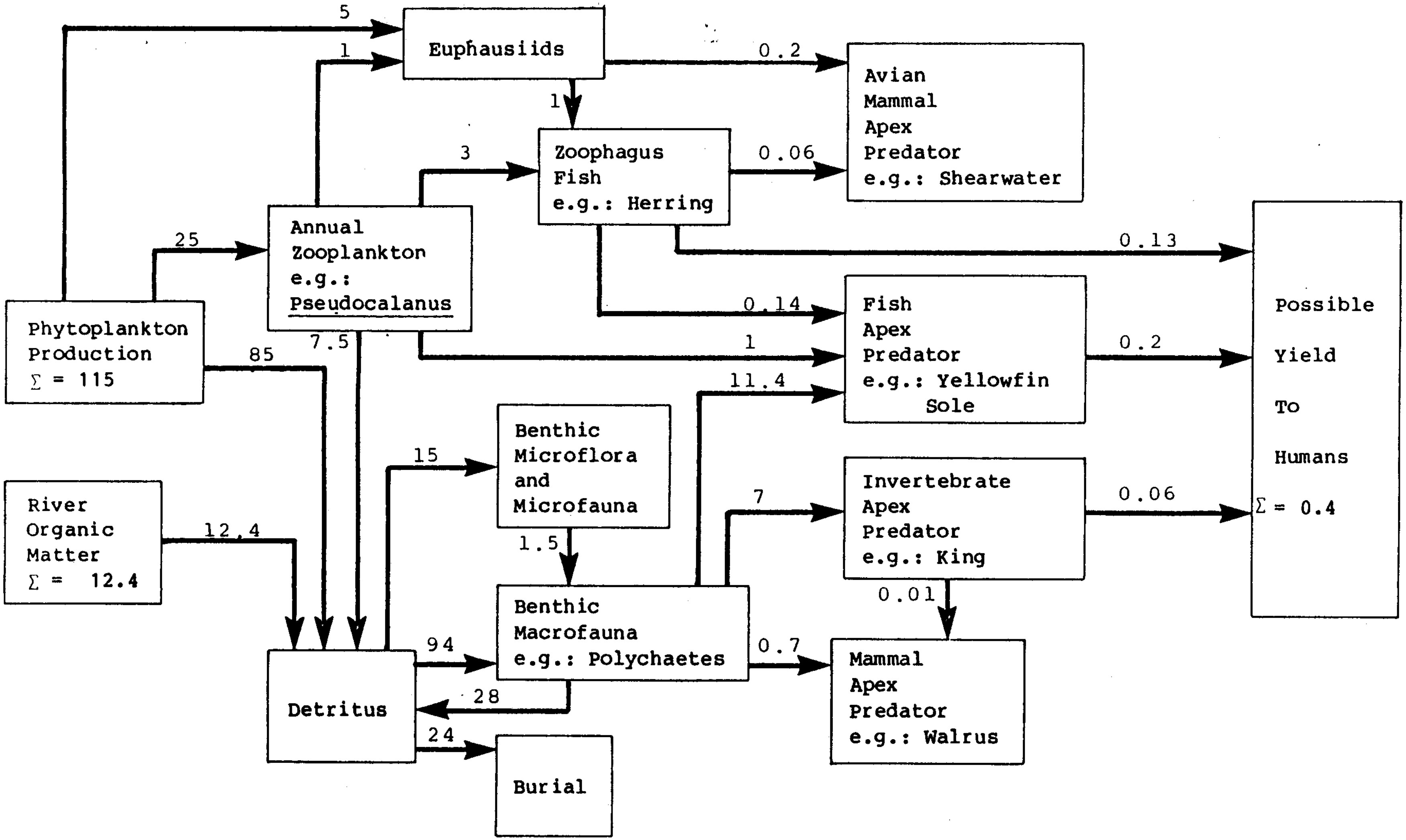


Figure 137. Conceptual endemic system model for Inner Bristol Bay. Hypothetical carbon budget in g m^{-2} yr^{-1}.

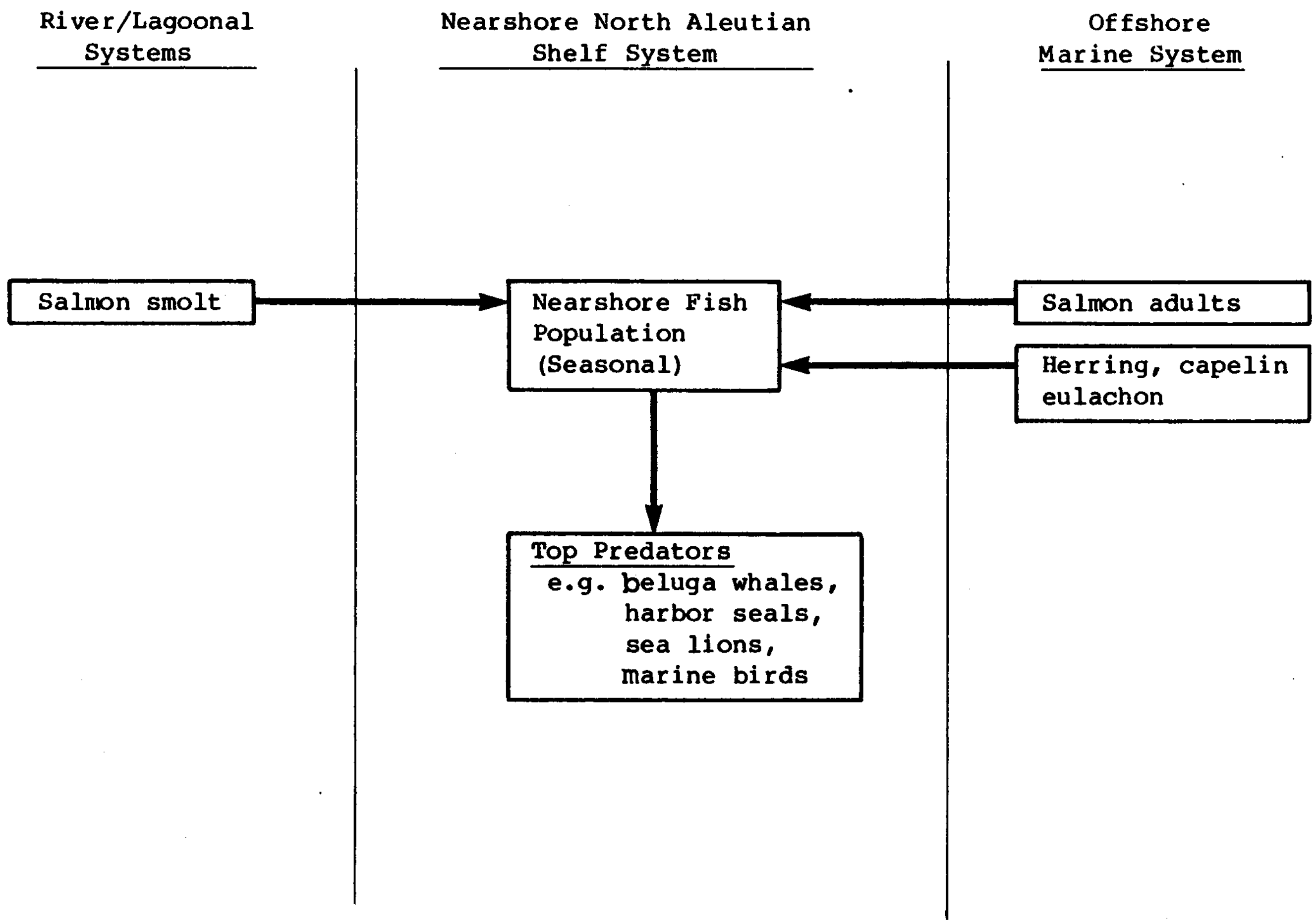


Figure 138. Conceptual "Import-Export" trophic system model for North Aleutian Shelf.

rather than being consumed in the water column. This endemic system supports most, if not all, of the zooplankton, benthic infaunal, and fish productivity of the nearshore region. Most of all of the higher trophic level marine mammal and bird species probably rely on this endemic system for nutritional maintenance to varying degrees.

b. Import-Export Trophic System

The second trophic system (Figure 138), a parallel but interacting import-export system, is seasonal and pulsating in nature, and is comprised of the huge runs of anadromous fish which utilize the area, along with their retinue of predators. The hypothesis in this regard is that these migratory populations of anadromous (and in some cases marine) fish such as salmon, smelt, herring, capelin, and eulachon statisfy most of their energy and growth requirements in other marine or freshwater environments and import this biomass in seasonal pulses into the nearshore zone.

Supportive data are lacking but are needed for this second system. Some estimate of the relative importance of such an import system to the nearshore zone can be made, however, by considering just the outmigrating salmon smolt and the inmigrating adult salmon. Data given earlier in the characterizatrion sections indicate that mean numbers of 500 million outmigrating smolt and 18 million inmigrating adult salmon pass through the inshore area each year. Converting this biomass to carbon on a year basis yields some 10^{10} gm C/yr, compared to some 10^{12} gm/yr contributed by primary productivity. Considering these migratory fish to be two to three trophic levels above primary productivity, and assuming a ten percent transfer efficiency, this amount of carbon is at least roughly equivalent to the amount at the trophic level expected to be derived from the in-situ primary productivity. Of course, much of this migratory carbon is not utilized in the inshore system, but is simply passed through.

It is conjectured, however, that these seasonal pulses of imported energy resources may be critical to the maintenance of the particularly high populations of some top predators, especially beluga whales and harbor seals; and perhaps also to Steller sea lions and marine birds which frequent the area. It is perhaps of some significance in this regard that all of these predators either disperse or depart from the area in the fall, coinciding with the departure from the area of such migratory fish species.

c. Habitat Factors

Along with food requirements, suitable habitat is an important parameter explaining the nearshore distribution of many species. As an interfacial zone between rich terrestrial and marine systems, the nearshore waters, shallow benthic areas, and shoreline features are highly utilized, especially by species who have particular needs for these specialized habitats. Often these habitats are used only during critical stages of life cyles or maybe on a seasonal basis.

Examples of such nearshore habitat usage by key species were summarized earlier in Table 15. Usage for haul-out, pupping or rookeries, feeding, or as migratory corridors apply to such key mammal species as harbor seals, Steller sea lions, Pacific walruses, grey whales, beluga whales, and sea otters. For birds, usage of the bay/lagoon systems, shoreline features, and nearshore marine areas is heavy. Usage consists of migratory staging, as a migratory corridor, nesting and breeding, and feeding for such key bird species as common murres, short-tailed shearwaters, black-legged kittiwakes, black brant, emperor geese, Steller's eider, dunlin, and western sandpiper.

The inshore zone also is heavily utilized by fishes and macroinvertebrates. Examples of such use by key species include the migration of salmon and salmon smolt between the inshore freshwater systems and the ocean, including maintenance feeding enroute. Smelt also spawn in freshwater streams and heavily utilize the inshore area feeding on amphipods, polychaete worms, small fish, and like food resources. Marine fishes such as yellowfin sole, Pacific herring, and capelin utilize the nearshore zone for spawning, nursery grounds, and feeding. Red king crab use the broad, shallow area (<50 m) along the Alaska Peninsula and northern and inner Bristol Bay for mating/spawning and juvenile development. The shallow benthic habitats, enriched by the carbon flux from marine productivity and riverine/lagoonal organic detritus, support large populations of bivalves such as the Alaska surf clam and the great Alaskan tellin.

2. Hypotheses for Testing and Approach

a. Introduction

The most obvious data gaps are those concerning a) fundamental food web relationships and b) utilization and importance of nearshore habitats.

We have hypothesized that the high biological productivity in the nearshore area is based upon two somewhat independent systems. One system, heavily dependent upon marine productivity, but with important lagoonal/river contributions, is an endemic, benthic-rich system. The second, an import/export system based primarily on migratory anadromous fishes, is probably of equal importance to higher predators. The data to verify and quantify these hypothetical food webs, and to identify critical linkages potentially vulnerable to oil impacts, are very fragmented.

For example, the inshore marine primary productivity and that contributed by lagoonal/riverine systems has been estimated from very sparse data. The critical roles of lower level consumers, and even of their locations, are not documented. Zooplankton grazing rates, potentially important roles for mysids and euphausiids, the importance of detrital material in the nearshore area, and infaunal standing stock and production estimates are all topics for which directed research is needed so that importance and potential vulnerability of food web links may be understood. Similar conditions exist with regard to good data on higher trophic level consumers, starting with almost nothing on major forage fishes (such as smelts) and proceeding with large data gaps on feeding of key marine mammal and bird species (such as otters, sea lions, harbor seals, and seabirds).

A similar situation exists with regard to utilization of nearshore habitats. It would be expected that the large lagoonal areas would be extensively utilized as nursery grounds for marine species. Yet, sampling designed to look at such broad utilization (covering only three to four weeks) has been carried out in only one lagoon (Izembek). An assessment of importance cannot be made from such limited data. The extensive shallow estuarine bays surrounding Bristol Bay have also not been studied as to their real importance as nursery or feeding grounds, though some work has been started on the open Peninsula coast regarding inshore utilization and feeding by crabs and otters. Major effort should be placed upon studies of these lagoons and embayments in order to document their suspected multifaceted importance to Bristol Bay food webs, in addition to their obvious bird habitat importance.

b. Summary of Data Gaps

A summary of identified research needs and of data gaps pertaining to the North Aleutian Shelf nearshore zone is given in Table 31. This summary identifies hypotheses for testing and associated experimental approaches.

c. Discussion of Data Gaps

Biological Processes. Carbon budgets for the North Aleutian Shelf and Inner Bristol Bay regions were developed based upon the best available data regarding primary production (both phytoplankton and seagrasses), faunal abundances, and trophic relationships. It was often necessary to extrapolate utilizing data from deeper water areas of the shelf or from other inshore areas. The general model suggests that the coastal zone supports primarily a benthic food web. Grazing of detrital material and phytoplankton by zooplankton is considered to be low. Expected low abundances of euphausiids in nearshore waters is estimated to

Table 31. Summary of research needs and data gaps

Ecosystem Component	Hypothesis for Testing	Approach
1. Primary producers/ carbon sources		
a. Marine phytoplankton	1. In-situ phytoplankton production contributes approximately 80-90% of the organic carbon available to the endemic inshore food web.	1. Determine phytoplankton standing crops, distributions, productivity, and nutrient regimes in the near-shore areas of Bristol Bay.
b. Lagoonal seagrass export	1. Eelgrass exported from lagoons contributes approximately 14% of the organic carbon available to the endemic food web in the north Peninsula inshore zone.	1. Determine standing stock and productivity of vegetation within the lagoons and bays along the Alaska Peninsula on which sufficient data do not now exist.
c. River organic matter	1. Riverborne detrital organic material contributes approximately 7 to 10% of the organic carbon available to the endemic inshore food web.	1. Measure detrital organic carbon in north Peninsula and inner Bristol Bay rivers. Estimate flows from gauging data, or from rainfall drainage area relationships.
d. Migratory fishes	1. Migratory fishes effectively import carbon equivalent to that of the 2nd or 3rd trohpic level of the endemic system and this carbon is important to seasonally high populations of top predators.	1. Determine distribution, abundance, and usage of the inshore areas, including bays and lagoons of a) migratory fishes (anadromous and marine) and b) of top predators (fish, mammals, birds). 2. Conduct food habit studies on top predators feeding in the inshore zones, including stomach analyses where appropriate.

Table 31. (Continued)

Ecosystem Component	Hypothesis for Testing	Approach
	2. A large flux of detrital material (80-90% marine origin; 10-20% river/lagoon origin) is cycled through the benthic food web, with an unknown portion being passed up to higher predators.	1. Use carbon and nitrogen isotope techniques to elucidate food web relationships and document pathways of detrital carbon from lagoonal and terrestrial origins, with emphasis on both areas of possible sources (e.g., Izembek Lagoon) and an area where phytoplankton sources would dominate.
3. Higher Level Consumers		
a. Fish	1. Forage fish are a very important link in the inshore food web and quantitatively very significant in transferring organic productivity to apex predators.	1. Conduct basic biological research on major forage fish species (osmerid smelts and herring) that utilize the nearshore areas, including life-history parameters. Determine seasonal distribution and spawning habitats, fecundity and recruitment, growth rates, age-specific mortality rates, and age-specific feeding habits (e.g. stomach analyses). Do herring spawning surveys to supplement existing data or other efforts.
	2. Yellowfin sole are benthic predators, important in transferring benthic productivity to apex predators. They also prey on and compete with other benthic predators such as crab.	1. Obtain additional data on the feeding habits of yellowfin sole in the inshore areas to supplement data existing for one subarea, include seasonal variations and size-specific data.
b. Crabs	1. The North Aleutian Shelf nearshore zone is important to the red king crab population of the southeastern Bering Sea.	1. Obtain additional information on the inshore distribution and abundance of larval and juvenile crabs, the location and function of podding activities in later stage juveniles, and on feeding relationships within the nearshore zone.

Table 31. (Continued)

Ecosystem Component	Hypothesis for Testing	Approach
2. Lower level consumers		
a. Zooplankton	1. Zooplankton grazing within the nearshore zone consumes only about 26% of the in-situ phytoplankton carbon; the remainder enters the benthic food web.	1. Obtain basic distribution and abundance data for zooplankton in nearshore areas and lagoons (Izembek, Port Heiden, Port Moller) by field surveys.
		2. Determine grazing rates for zooplankton in the nearshore zone by shipboard grazing experiments using natural populations.
	2. Euphausiids and mysids may furnish important links from phyto- and zooplankton to higher predators such as marine birds and forage fish.	1. Sample nearshore area with techniques appropriate to capture euphausiids and also mysids, and determine abundance and distributions.
		2. Do stomach analyses of forage fish and appropriate marine birds.
	3. Epibenthic crustaceans (e.g., amphipods) may provide an important link from detrital carbon to higher predators through forage fish.	1. Sample nearshore areas with techniques appropriate to sample epifauna.
		2. Do stomach analyses of forage fish.
b. Benthic	1. A rich benthic community is quantitatively a major element in the nearshore ecosystem, involving perhaps 75% of the organic carbon of the endemic trophic system.	1. Supplement presently inadequate data in the inshore areas on standing stocks and distributions of benthic organisms. Include suitable sampling (e.g., hydraulic dredge) for deeper living bivalve mollusks believed to be quantitatively very important.
		2. Estimate benthic production by sequential field sampling and measurement of life history parameters (size, sex, fecundity) of the biomass-dominant species.

Table 31. (Continued)

Ecosystem Component	Hypothesis for Testing	Approach
c. Mammals	1. The distribution of harbor seals, the most numerous marine mammal species in the nearshore area, is related to habitat and food availability; their vulnerability to development is greatest through their supporting food chain; and they compete with commercial fisheries. Similar hypotheses apply to sea lions.	1. Determine the general feeding habits (including seasonality in prey selection) and seasonal shifts in population distribution for both harbor seals and sea lions. 2. Obtain data on the population biology of Steller sea lions to document or help explain the apparent population decline, include work on breeding success and productivity, incidence and causes of natural mortality, and general condition of the population.
	2. Sea otters are an important controlling element in the structure of the inshore benthic ecosystem.	1. Obtain additional information on the feeding habits of the sea otter and distributional characteristics relative to their food resources.
	3. Sea otters utilize False Pass to migrate to the southern side of the Alaska Peninsula in the winter.	1. Determine if False Pass is a major migratory pathway.
d. Birds	1. Seabirds (including shearwaters, murres, and kittiwakes) depend upon both the endemic food web and the migratory resources in the inshore areas for their sustenance.	1. Obtain regional information in the nearshore zone on the feeding ecology of seabirds, emphasizing shearwaters, murres, and kittiwakes.
	2. Fall and winter are times of most vulnerability for overwintering species.	1. Determine fall and winter distributions and feeding habits of overwintering species such as common murres, Steller's and king eiders, oldsquaws, and black scoters.

Table 31. (Continued)

Ecosystem Component	Hypothesis for Testing	Approach
4. Circulation and transport affecting other ecosystem components	1. The NAS is on a meteorological knife-edge with large interannual variability in storm tracks, north of or along the Aleutian Chain/Alaska Peninsula (Overland and Pease, 1982) associated with large scale meteorological patterns. Nearshore flow is event dominated, with periods of wind-driven counter-flow close to shore, probably statistically very significant but variable, and important to larval distribution of inshore spawning species upwelling and inshore density structure, inshore/offshore mixing of detrital organic material, and the movements of food organisms and predators.	1. Determine the currents in the near-shore region of Bristol Bay with special emphasis on synoptic regional coverage and on/offshore variability. Utilize moorings located in eastern Unimak Pass, along the nearshore zone of the Alaska Peninsula, in the inner Bristol Bay, and along the northern bay shore, including inshore and offshore moorings. Correlate data with regional meteorological data. 2. Determine the influence of nearshore currents and density structure on dispersion and transport of carbon and nutrients; also determine the relationship between meteorological events and material fluxes across the inner front boundary of the coastal domain. Utilize hydrographic and chemical sections, including detrital organic matter, determined seasonally.
	2. Exchange between the waters of bays and lagoons with the near-shore marine waters is important to nutrient (organic matter) export, to lagoonal ecology, and to potential pollutant contamination.	1. Determine water exchange between lagoons/inner bays and the near-shore zone as well as residence times in these embayments.
	3. The addition of organic material and nutrients to the nearshore zone, along with their subsequent transport, affects the distribution of biota which depend upon the benthic rich endemic system.	1. Determine lagoonal/riverine export of organic matter and nutrients as a function of season, along with their subsequent spatial distribution. Correlate with benthic population and distributional data.

further reduce grazing pressures relative to the Middle Shelf Domain. Estimation of consumption of zooplankton by small forage fish (herring and osmerid smelts) may be inaccurate due to the very limited data regarding their distribution and abundances in this area. Further inaccuracies in the carbon budgets may result from estimates of carbon flux to the numerous benthic predators which occupy the nearshore region during all or portions of their life history.

It is evident that substantial data gaps still exist in our understanding of the biological processes occurring in the nearshore areas of the North Aleutian Shelf and Inner Bristol Bay regions. A number of questions still need resolving before the proposed carbon budget can be confirmed or refined. Further refinement of the carbon budget will greatly enhance its utility in identifying critical energy pathways through the system.

The following topics have been identified within each of the major trophic levels as components of the system which require further research to refine the proposed carbon budgets. A few of these areas have been addressed in studies conducted in 1982 for which final reports have not yet been submitted. A few may still require further research if an adequate data base was not established.

Primary Producers/Carbon Sources

1. Determine the standing stock and productivity of vegetation within the lagoons and bays along the Alaska Peninsula.

Standing stocks of the dominant vegetation in Izembek Lagoon have been estimated at about 430 g C/m^2 or about 56,000 metric tons of carbon. Similar estimates have not been established for other bays and lagoons.

Productivity data have been obtained only from Izembeck Lagoon where carbon production in the eelgrass meadows was estimated to range from 3.3 to 8.0 g C/m^2/day or 177,000 metric tons per year. Again, estimates are unavailable for other lagoons and bays.

Carbon inputs from lagoons and marshes to the entire North Aleutian Shelf were estimated in this report to be 20 g C/m^2/year with Izembeck Lagoon contributing as much as 14 g C/m^2/year and all others contributing a total of 6 g C/m^2/ year. This carbon contribution to the coastal domain is estimated to be 14 percent of the total carbon input including total organic matter from rivers and phytoplankton production. While this input comprises a significant amount of the total carbon when assumed to be distributed evenly across the entire coastal domain of the North Aleutian Shelf, it is more likely that regions in the immediate vicinity of these lagoons and marshes receive a much greater percentage of their carbon from these sources.

2. Additional data regarding phytoplankton standing crops and productivity in the nearshore zone are required.

Inshore standing crops have been estimated to range from 1×10^5 to 10^9 cells per/m^3 with an annual production of 115 to 120 g C/m^2/year. These estimates, however, are based upon few collections from the offshore oriented PROBES studies. Spatial and temporal patterns have not been well established in this zone, particularly in reference to possible nutrient point sources.

Lower Level Consumers

1. Obtain basic distribution and abundance data for zooplankton in nearshore areas and lagoons (Izembek, Port Heiden, and Port Moller).

While community structure and production of zooplankton assemblages in many areas of the Bering Sea have been well studied, little information is available from the nearshore region of the North Aleutian Shelf. Data on nearshore assemblages is primarily from the northern side of outer Bristol Bay off Cape Newenham. This region differs in both hydrography and general bathymetry from the nearshore zone of the North Aleutian Shelf. These assemblages may be similar to those of the nearshore area of inner Bristol Bay but it is unlikely that they resemble the assemblages present along the Alaska Peninsula.

The roles of both euphausiids and mysids in these region should be examined. We have estimated that euphausiids are present at standing stocks of half the level found over the mid-shelf area strictly on the basis of depth preferences. Less is known about the role of mysids in this area. Mysids are extremely important in many similar areas. Sampling methods appropriate to sampling mysids have apparently not been applied in either the lagoons or nearshore areas.

2. Establish zooplankton grazing rates in the nearshore zone.

Zooplankton grazing within the nearshore zone has been estimated to be relatively low. Approximately 22 percent of the carbon produced by phytoplankton is estimated to be consumed by annual zooplankton species. Another four percent of this carbon is estimated to be consumed by euphausiids. The remainder of the phytoplankton production is believed to enter the benthic food web as detritus. More accurate estimates of grazing rates would greatly enhance the proposed carbon budget.

3. Both standing stock and production estimates are needed for infaunal assemblages (production to biomass ratios).

Infaunal data in the nearshore zone are usually sketchy and generally based upon small sample sizes. Less than twelve stations were within the nearshore area in Haflinger's (1981) survey of benthic infaunal communities of the southeastern Bering Sea shelf. A more recent study which has not yet been submitted in final form has significantly increased the data base on the species composition of infaunal assemblages from Cape Sarichef to Cape Seniavin but did not provide production or biomass estimates.

Bivalve mollusks believed to be important in this region are undoubtedly underestimated. Sampling with a hydraulic dredge is recommended in order to effectively sample these deeper living species which may play an important role in the nearshore foodweb.

4. Benthic food web relationships within the nearshore zone need further work to evaluate the role of detrital material (both from seagrasses and phytoplankton).

It appears that detrital material originating from the coastal lagoons and from unconsumed phytoplankton provide an important carbon source for the benthos. Present data are not adequate to determine or document the pathways through which this energy source is channeled.

Carbon and nitrogen isotope work would be useful in establishing the pathways through which these different types of decrital material are made available to higher trophic levels. Work should be conducted both near major point sources of seagrass detritus (Izembek Lagoon) and in areas distant from these point sources where phytoplankton detritus would be expected to be the predominant carbon source.

Higher Level Consumers

1. Basic biological research is needed for all major forage species of fish (osmerid smelts and herring) that utilize the nearshore areas.

Osmerid smelts, including capelin and boreal smelt, have been identified as dominant forage species in this region yet information on their life histories within the study area is nearly nonexistent. Slightly more is known of the life history of herring within the nearshore areas due to their commercial importance.

Data regarding general population parameters (for example: age-specific mortality rates, growth rates, and recruitment rates), seasonal distribution, and spawning habitats are needed. Spawning surveys should be conducted for herring in order to obtain accurate estimates of the adult population which utilize the area as spawning habitat.

Osmerid smelts and herring are believed to be of major importance to birds, mammals and other fish. These trophic interactions need further study to clearly establish the role of forage fish in the carbon budget. Age specific feeding habits of forage fish should also be examined, particularly in light of the relatively low standing stocks of zooplankton which are expected in this area.

2. Information on the age/size specific feeding habits of yellowfin sole should be obtained.

The feeding habits of yellowfin sole have recently been studied in a portion of the study area. These data have been grouped to characterize the feeding habits of the species as a whole. Size-specific feeding habit data may be available from this data base. If this is true, then data may only be necessary for the inner Bristol Bay regions not included in this study.

3. Data regarding the general feeding habits (including seasonality in prey selection) and seasonal shifts in population distribution are needed for both harbor seals and sea lions.

Information on the feeding habits of harbor seals, which are the most numerous marine mammal species found in the area, is extremely scanty. A total of only 20 harbor seals has been analyzed from the region for stomach contents, 19 of which were collected between 4 and 12 October 1981 (Lowry et al, 1982). This sample size is certainly too small to provide a comprehensive view of feeding habits and prey selection of harbor seals in this area, and tells us nothing about seasonal changes in prey selection. Such dietary information is essential for assessing perturbation impacts upon this population and for assessing the predation impact of the species upon commercial fisheries of the region.

Also, data concerning seasonal shifts in harbor seal distribution within the region are almost nonexistent. All population surveys have in the past been conducted during the summer when seals were hauled on the beaches during pupping and molting. Other than surmise and anecdotal information, there is virtually nothing known about population distributions once seals leave the beaches. Again, such information is crucial to forming any assessment of perturbation impacts upon that population.

Essentially the same situation exists regarding data needs for sea lions. Though the diets of Steller sea lions have been studied extensively in other areas, only twelve have been analyzed from the Bering Sea and most of these were taken in the Pribilof vicinity (Lowry et al, 1982). Clearly, much more complete information regarding sea lion feeding behavior in this region is needed, both in order to assess perturbation impacts upon the population and to evaluate sea lion-commercial fisheries competition and interaction. This information is particularly needed in the case of sea lions in light of recent population declines, perhaps the result of depleted stocks of commercial fish species (Braham et al, 1980).

4. The population biology of Steller sea lions in the nearshore region needs further study.

In view of the recent decline in the sea lion population, it would be helpful to have information regarding breeding success and productivity of the population, incidence and causes of natural mortality, and general condition of the population.

5. Further research is needed regarding sea otter feeding habits and distributional characteristics relative to their food resources.

Present data on the feeding habits of sea otters in the nearshore zone are limited to analysis of nine scat samples collected in two days from a single location.

6. The proposed hypothesis that sea otters utilize False Pass to migrate to the southern side of the Alaska Peninsula in the winter needs to be tested.

Use of False Pass as a migratory route to the south would make this region extremely important to sea otters. An oil spill in this region during migratory periods could severely impact the population. This hypothesis should therefore be tested to determine whether this region is a major migratory pathway and, if so, to determine the timing of migrations through the area.

7. Further information is needed on the feeding ecology of seabirds (including shearwaters, murres, and kittiwakes) in the nearshore zone.

Information regarding marine bird feeding ecology, though fairly well known for adjacent areas such as the Pribilofs, is sketchy for the Bristol Bay-Alaska Peninsula coastal region. Additional information is necessary in order to assess probable impacts on seabirds resulting from environmental disturbance and in order to assess the impact of seabird populations on commercial fish stocks such as salmon, herring, and pollock. Studies are needed for major species such as common murres, short-tailed shearwaters, and black-legged kittiwakes. It is particularly important to determine the role of forage fish such as herring and osmerid smelts as well as seasonal aggregations of outmigrating juvenile salmon in the diets of these species.

8. Winter and fall distributions of seabirds and waterfowl species known to overwinter in the area need to be established. Species warranting investigation in this regard include common murres, Steller's and king eiders, oldsquaws, and black scoter.

This information is crucial in assessing the vulnerability of these species to the potential environmental disruption associated with development of the hydrocarbon resources in this area.

9. The ecological relationships between red king crab and the nearshore habitats need to be clearly established.

It is well-known that the shallow water areas are important to the red king crab population of the southeastern Bering Sea. The functional relationships of the nearshore zone to the success of this important species, however, are poorly understood. Information is needed on factors controlling the distribution and abundance of larval and juvenile crabs, the location and function of podding activities in later stage juveniles, and feeding relationships within the nearshore zone.

<u>Physical, Chemical, and Geological Processes</u>. The integration of physical and meteorological oceanographic efforts with ecological studies was an unique and successful feature of previous PROBES and OCSEAP studies in the southeastern Bering Sea. This close cooperation should be continued for the needed studies in the nearshore zone and in the lagoons and inner bays.

Physical, meteorological, geological, and chemical studies need to be done for two general purposes. One purpose is to confirm the movement of oil or other pollutants in the inshore zone or into lagoons and bays. The major purpose, however, is to understand those transport processes that control the distribution of biota and general ecology of the nearshore zone.

The following are topics which require additional research in order to address the questions of nutrient and carbon transport in the nearshore zone throughout Bristol Bay.

1. Determine the currents in the nearshore region of Bristol Bay, with special emphasis on synoptic regional coverage and on offshore variability.

It has been demonstrated that a slow mean counterclockwise flow exists in Bristol Bay. Flow through Unimak Pass and up along the Alaska Peninsula has also been demonstrated, indicating that the coastal jet flow of the Gulf of Alaska and Kenai Current may furnish more or less continous source waters to the Bristol Bay inshore flow. From stations north of the Peninsula, it has been shown that inshore flow characteristics are dominated by frequent storm events. Under such conditions, counterflow systems are possible with northeast flow seaward of a narrow, wind-driven southwest coastal jet (see Figures 27 and 29 in Schumacher and Moen, 1983). Little work has been done in the inner bay or along its northern edge, nor have simultaneous measurements been taken around the bay to see how the bay responds to storm events. Simultaneous moorings are needed in eastern Unimak Pass, along the nearshore zone of the Alaska Peninsula, in inner Bristol Bay, and along the northern bay shore in order to learn how bay waters respond to storm events.

2. Determine the influence of nearshore currents and density structure on dispersion and transport of carbon and nutrients; also determine the relationship between meteorological events and material fluxes across the inner front boundary of the coastal domain.

Hydrographic and chemical sections are needed seasonally in the inshore region of the bay in order to quantify carbon and nutrient transport assumptions of the endemic food web hypothesis. Potential sources of nutrients from the Unimak Pass and region, to the west, and flux (event dominated?) through the coastal domain boundaries need to be measured. Each seasonal effort needs to bracket some storm events, since processes on these time-scales may well be most important to transport.

3. Determine water exchange between lagoons/inner bays and the nearshore zone as well as residence times in these important embayments.

The nearshore flow regimes near the mouths of important embayments, and the exchange between inshore waters and the embayments need to be studied such that transport of pollutants into and particulate organic matter and nutrients out of these embayments can be quantified. Since meteorological events may be important to these transport processes, time-series measurements are needed.

4. Determine the spatial distribution of nutrients with export contributions from lagoons and rivers as a function of season.

In support of primary productivity measurements described earlier and augmenting the data taken for nutrient transport purposes, spatial and seasonal data sufficient to identify sources are needed. The lagoonal and riverine export of carbon is undoubtedly highly seasonal and may be more important locally than over the entire inshore region. Any sources from the west in the region of Unimak Pass also would need to be mapped.

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APPENDIX A

DESCRIPTION OF KEY SPECIES

HARBOR SEAL

Introduction

The harbor seal (Phoca vitulina) is one of several species of phocid seals which occurs at least seasonally within the waters of Bristol Bay and along the Alaska Peninsula.

Distribution. Harbor seals are found within the nearshore zone all the way from Unimak Pass around to Cape Newenham. Approximately 80 percent of the population, however, hauls during the summer for moulting and pupping on beaches at Port Moller, Port Heiden, and Cinder River. Other major hauling sites along the coast are Egegik Bay, Ugashik Bay, Seal Islands, Izembek Lagoon, and Bechevin Bay (Braham et al, 1977; Everitt and Braham, 1980). During the onset of winter ice, the population seems to disperse, probably shifting somewhat to the south or moving into the edge of the winter ice (F.H. Fay, personal communication).

Commercial Importance. Like all marine mammals, harbor seals are currently protected by federal law, with no commercial harvest allowed. Some seals are taken by Alaskan natives for subsistence use, though apparently not enough to significantly impact the population. Though quantitative data are generally lacking, harbor seals are known to feed on several commercial fish species, including salmon, pollock, and herring.

Population Status. The resident population of harbor seals in the area is estimated at 28,000 to 30,000 (Everitt and Krogman, 1979; Everitt and Braham, 1980), though this estimate may be overly conservative (F.H. Fay and J.J. Burns, personal communication). The population appears more or less stable.

Life History

Reproduction. Females normally produce a single pup every year. Pups are born on the beach in June or July. As described by Johnson (1977), this is a critical period in that disturbance, particularly from boats and low-flying aircraft, frequently results in separation of pups and mothers, and starvation of the latter. Practically the entire adult population occupies the beaches of the region at this time and would be particularly vulnerable to oil spills.

Feeding, Age and Growth. Harbor seal pups nurse for a period of from 3 to 6 weeks, during which time they normally double in weight (Lowry et al, 1982). Pups weigh about 12 kg at birth. They continue to grow after weaning, though at a reduced rate, until about 10 years of age when average weights are 85 kg for males and 76 kg for females (Lowry et al, 1982). Food requirements range from 13 percent of total body weight per day during the first year to 3 percent per day at age nine (Ashwell-Erickson et al, 1978).

Harbor seals are top predators, feeding on a wide range of fish, cephalopods and crustaceans. Major prey items from this area seem to include pollock, sandlance, smelt, greenling, sculpins and various flatfishes (Lowry et al, 1982). It is likely that they also take, during certain times of year, salmon juveniles and adults, herring, capelin, yellowfin sole, shrimp, and crabs.

STELLER SEA LION

Introduction

The Steller sea lion (Eumetopias jubatus) is the only otarid seal common in the nearshore zone of the region. The other otarid of the Bering Sea, the northern fur seal, generally remains further offshore.

Distribution. Sea lions occur throughout the Bristol Bay and northern Aleutian region. During the breeding season, approximately 80 percent of the population is concentrated at rookeries in the Fox Islands, with most of the remainder of the breeding population located at the Amak Island rookery. Minor, non-breeding rookeries have been observed on Hagemeister Island, Cape Newenham, Crooked Island, and the Twins. Sea lions are absent from the area during winter months when they probably frequent the ice edge of the central Bering Sea (Braham et al, 1977; Lowry et al, 1982).

Commercial Importance. Sea lions are protected under federal law with no commercial harvest allowed at present. They are known to feed on several species of commercially harvested fish, though their impact on these populations is unknown.

Population Status. At present, the population in the north Aleutian-Bristol Bay region is estimated to be between 15,000 and 25,000 (Braham et al, 1977, 1980; Braham and Rugh, 1978). For reasons which are uncertain, this population seems to have declined significantly (perhaps by as much as 50 percent) since the late 1950's and early 1960's (Braham et al, 1980).

Life History

Reproduction. Females normally give birth to a single pup each year at rookeries in the Fox Islands and on Amak Island. Pups are born between May and early July, and nurse for about one year.

Feeding, Age and Growth. Sea lion pups weigh about 23 kg at birth. Most females attain their average adult weight of 263 kg by age six, while males continue to grow until their eleventh year, when they weigh an average of 566 kg. Daily consumption rates probably range between six and ten percent of total body weight (Lowry et al, 1982). They are opportunistic feeders on a wide range of finfish, squid and octopus.

PACIFIC WALRUS

Introduction

The Pacific walrus (_Odobenus rosmarus divergens_) is the sole representative of the family Odobenidae in the Bering Sea.

Distribution. During winter months, large numbers of walruses of mixed sex and age composition frequent the ice edge in northern and central Bristol Bay. During summer, a population of between 12,000 and 20,000 males remains in northern Bristol Bay. The principal hauling ground for this summer population is Round Island, though animals range widely during feeding forays and are known to haul at other locations in northern Bristol Bay and along the coast of the Alaska Peninsula (Fay, 1982; Fay and Lowry, 1981).

Commercial Importance. Walruses are currently protected under federal law, with no commercial harvest allowed. Significant numbers are harvested each year by Alaskan natives for subsistence use and for ivory, though this hunting has apparently not had any adverse impact on the population.

Population Status. The present population of walrus in the Bering and Chukchi Seas is estimated at over 250,000 animals. This population has increased rapidly over the past several decades and is still growing, though at a reduced rate (Fay, 1982; Fay and Stoker, 1982a,b). The number of animals frequenting Bristol Bay during winter is highly variable, depending on ice conditions.

Life History

Reproduction. Females normally produce a single calf every other year. Calves are born on the ice from late April through early June. Recent studies (Fay and Stoker, 1982a,b) indicate that reproductive success has declined over the past few years, probably indicating population stress.

Feeding, Age and Growth. Calves weigh 45-75 kg at birth, and triple their weight during the first year when they are solely dependent on nursing. Females attain their average adult weight of 880 kg by 12 to 14 years of age, while males continue to grow until about 16, when they weigh an average of 1,200 kg (Fay, 1982). Walrus feed on a wide variety of benthic infaunal and epifaunal invertebrates, sandlance and occasionally other seals (Fay et al. 1977). In Bristol Bay walruses are known to take at least 22 general of benthic invertebrates, though the vast bulk (90%) is contributed by bivalve mollusks of the genera _Serripes_, _Tellina_, _Spisula_, _siliqua_ and _Mya_ (Fay and Lowry, 1981). There are some indications that they are stressing their food resource, at least in the northern Bering Sea (Fay and Stoker, 1982a,b).

GRAY WHALE

Introduction

The gray whale (Eschrichtius robustus) is the sole member of the family Eschrichtidae. It is one of the most common cetaceans in the region, is certainly the one most frequently encountered in the nearshore zone of the shelf, and is the most numerous baleen whale in the Bering Sea (Lowry et al, 1982).

Distribution. Gray whales are migratory, entering the Bering Sea through Unimak Pass from March until June and departing in the fall. The entire population follows around Bristol Bay close inshore during the spring migration, with some animals remaining in the area throughout the summer months (Braham et al, 1977; Gill and Hall, 1983).

Commercial Importance. Gray whales are protected by federal law, with no commercial harvest allowed. A few are taken each year for subsistence by Alaskan natives, and there is a limited subsistence harvest in Siberian waters.

Population Status. The present population of gray whales is estimated to be at least 15,000 (Rugh and Braham, 1979). This population has increased rapidly over the past few decades, and is probably still growing.

Life History

Reproduction. Females give birth, usually, to a single calf every other year. Calves are born while the population is overwintering in the lagoons of Baja California.

Feeding, Age and Growth. Calves are born between December and early February, averaging 4.75 m in length at birth. They grow to 7-8 m by the time they are weaned in August, and are about 9 m in length by the end of their first year. After the first year they continue to grow, though more slowly, attaining an average adult length of 12 m and weighing as much as 34,000 kg (Lowry et al, 1982). Gray whales feed on benthic epifauna and infauna, with most of their diet consisting of gammarid amphipods of the genera *Ampelisca*, *Lembos*, *Anonyx*, and *Pontoporeia*. Daily consumption is estimated to be about 1,200 kg per animal per day (Lowry et al, 1982).

BELUGA (BELUKHA) WHALE

Introduction

The beluga is the sole member of the family Monodontidae in the Bering Sea, and is the most common toothed whale (suborder Odontoceti) in the nearshore zone.

Distribution. Belugas are widespread in northern Alaska waters, occurring from Cook Inlet on the north Pacific coast around to the Beaufort Sea. In the Bristol Bay-Alaska Peninsula region, they occur primarily in the upper part of Bristol Bay, concentrating in the vicinity of the Nushagak and Kvichak River mouths during summer months (Brooks, 1955).

Commercial Importance. Belugas are protected under federal law with no commercial harvest allowed. Some are taken each year for subsistence use by Alaskan natives. Belugas are also known to feed on several commercial stocks of finfish, including salmon, herring, and pollock, though their impact upon these populations is unknown at present.

Population Status. The total Bering-Chukchi-Beaufort beluga population is estimated at 15-18,000 animals, 1,000 to 1,500 of which frequent Bristol Bay (Lowry et al, 1982). This Bristol Bay population varies considerably from year to year and seasonally (Brooks, 1955). So far as is known, the population is stable at this time.

Life History

Reproduction. Females normally give birth every third year. Most calves are born in July or early August, and nurse for a period of 2 years (Lowry et al, 1982).

Feeding, Age and Growth. Beluga calves average 150 cm in length at birth and weigh 80 kg. By age ten they have normally attained their maximum adult size of 3.2-4.4 meters (520-1,200 kg) for males, 3.1-3.6 meters (480-700 kg) for females (A.D.F. & G., unpublished data). Belugas consume a wide variety of fish and invertebrates, though smelt and salmon seem to comprise a major part of their diet in the Bristol Bay region from May through August (Lowry et al, 1982). During the winter months, when they move out to the edge of the winter ice, they probably rely heavily on pollock (Seaman et al, 1982). Records from captive belugas indicate a consumption rate of four to seven percent of body weight per day (Lowry et al, 1982).

SEA OTTER

Introduction

The sea otter (Enhydra lutris) is the only marine member of the family Mustelidae and, along with the polar bear, is one of only two members of the order Carnivora classified as marine mammal.

Distribution. Sea otters occur, in the Bristol Bay-Alaska Peninsula region, from Unimak Island to about Port Heiden, with the population density decreasing toward the northern part of this range. The bulk of the population is found between Cape Mordvinof on Unimak Island to about Cape Leontvich on the Alaska Peninsula (Schneider and Faro, 1975).

Commercial Importance. Once hunted intensely for their valuable fur, sea otters are now protected by federal law with no commercial harvest allowed. They feed on several commercially valuable species of invertebrates, including king and tanner crab, and may affect these populations in the nearshore zone.

Population Status. The current population estimate is from 11,700 to 17,200 sea otters residing in the Bristol Bay-Unimak Island area (Lowry et al, 1982). This population is probably still expanding slowly.

Life History

Reproduction. Normally, a single pup is born to females in the spring of every other year in the Bristol Bay region (Lowry et al, 1982).

Feeding, Age and Growth. Average weights of pups at birth are 1.75 kg for males, 1.96 kg for females. Sea otters reach sexual maturity at three or four years of age, with adult weights of 28.3 kg (mean) for males and 21.1 kg for females. The preferred prey of otters seems to be sea urchins, though they will consume practically any invertebrate species. When these are depleted, they will feed on slow-moving fish. In the Bristol Bay region, the principal prey species may be yellowfin sole, augmented by bivalve and gastropod mollusks and various crabs. Adult otters consume between 20 and 25 percent of their body weight daily (Estes and Palmisano, 1974).

COMMON MURRE

Introduction

The common murre (Uria aalge) is one of many members of the family Alcidae common to the eastern Bering Sea. Other members of the family present include the thick-billed murre (Uria lomvia), pigeon guillemot (Cepphus columba), and several species of murrelets, auklets, and puffins.

Distribution. Within the Bristol Bay-Alaska Peninsula region, the vast majority of breeding murres are confined to large cliff-rookeries at Cape Newenham, Cape Peirce, the islands of northern Bristol Bay, Amak Island, and a few minor colonies on Unimak Island and along the Alaska Peninsula. Overwintering populations of murres seem to congregate along the coast of the Alaska Peninsula from about Port Moller outward, and in Unimak Pass (Hunt et al, 1981). Summer distributions are probably controlled by the availability of both nesting habitat (sea cliffs) and food supply; winter distributions are probably dictated largely by availability of food and by weather and sea conditions.

Commercial Importance. Murres are of no direct commercial importance. Some eggs, fledglings and adult birds are taken for subsistence use, but apparently not in quantities sufficient to impact the population. Indirectly, murres feed heavily on several species of commercially important fish, though their impact on these populations is unknown.

Population Status. At least one million common murres nest in this region (Sowls et al, 1978; Bartonek and Sealy, 1979). During fall and winter the number of murres in the region is probably reduced by at least half, with the remainder moving for the winter to south of the Alaska Peninsula. So far as is known, the population is more-or-less stable in this area, though significant fluctuations have been known to occur in this and adjacent areas due to hostile weather and/or fluctuations in food resources (Bailey and Davenport, 1972; D.G. Roseneau, personal communication).

Life History

Reproduction. A single egg is laid on cliff ledges in late spring. Reproductive success is apparently dependent on weather patterns during the nesting period and on availability of prey species (often related to weather patterns) during nesting and fledging. In some colonies, predators such as foxes and gulls also affect reproductive success.

Feeding, Age and Growth. Fish probably form the mainstay of murre diets in the Bristol Bay region. Analyses from other areas (Hunt et al, 1981) indicate that walleye pollock are the most frequent species taken, followed by other available fish species, cephalopods, and crustaceans. In the Bristol Bay vicinity, it seems probable that murres also consume juvenile salmon when available.

SHORT-TAILED SHEARWATER

Introduction

The short-tailed shearwater (Puffinus tenuirostris) is one of several seabirds of the family Procellariidae which frequent the eastern Bering Sea. Other members of this family in the area include sooty shearwaters (Puffinus griseus) and fulmars (Fulmarus glacialis).

Distribution. Short-tailed shearwaters nest in the southern hemisphere, returning to the North Pacific and Bering Sea to feed during summer months (Hunt et al, 1981). While in the Bering Sea, feeding concentrations of shearwaters occur within inner Bristol Bay, along the nearshore zone of the Alaska Peninsula, and in Unimak Pass. Distribution is, presumably, determined by availability of prey.

Commercial Importance. None.

Population Status. Estimates of shearwater populations present in the region during summer vary considerably from author to author, with estimates ranging from seven million (Sanger and Baird, 1977) to a minimum of nine million (Hunt et al, 1981). This latter estimate may even be considerably low, since Hunt et al (1981) seem to feel that a more realistic estimate for normal years is probably around 20 million birds. When present, shearwaters commonly occur in huge flocks exceeding 100,000 birds, and form aggregations of a million or more. So far as is known, the population is stable.

Life History

Reproduction. Shearwaters breed on islands off southern Australia.

Feeding, Age and Growth. While in the Bering Sea, the preferred prey of shearwaters seems to be euphausiids during summer (over 70 percent; Hunt et al, 1981), and hyperiid amphipods (particularly Parathemisto libellula) during fall (Hunt et al, 1981). They also consume, in lesser proportions, fish, cephalopods, and carrion.

BLACK-LEGGED KITTIWAKE

Introduction

The black-legged kittiwake (Rissa tridactyla) is one of many species of the family Larinae which frequent the eastern Bering Sea.

Distribution. Most of the nesting population of blacklegged kittiwakes in the Bristol Bay-Alaska Peninsula region is confined, probably by habitat restrictions, to rocky islands and headlands in the vicinity of Cape Newenham, Cape Peirce, the islands of northern Bristol Bay and Amak Island. Due probably to habitat rather than to food requirements, the nesting locations of this and other seabird species, particularly murres, often coincide. Kittiwakes usually arrive in the Bering Sea between late April and mid-May, and depart in the fall.

Commercial Importance. No commercial importance is presently attached to kittiwakes, other than perhaps the fact that they seem to feed on juveniles of some commercially important fish species. Their impact upon these species is unknown. In the past, kittiwake eggs, young, and adults contributed significantly to local Eskimo and Aleut subsistence economies of the region.

Population Status. Between 300,000 and 500,000 black-legged kittiwakes probably nest and feed in Bristol Bay and along the coastal zone of the Alaska Peninsula (Sowls et al, 1978; Bartonek and Sealy, 1979). This population is probably somewhat unstable in that surface-feeding seabirds, in which category kittiwakes fall, seem in general to be more subject to recruitment failures as the result of inclement weather and/or fluctuating prey availability.

Life History

Reproduction. Kittiwakes, like murres, nest in dense rookeries on cliffs of rocky islands and headlands. Two eggs are normally produced between late June and early July, with young birds fledging by early September (Petersen and Sigman, 1977). Kittiwake reproductive success appears to be highly unstable, probably as the result of weather patterns and food availability.

Feeding, Age and Growth. The diet of kittiwakes is somewhat variable seasonally and from area to area. In the Pribilof region they feed heavily on amphipods and euphausiids prior to nesting, then switch to fish during incubation. They are known to feed heavily on pollock, sandlance, myctophids, cod, probably several other species of small fish, and on squid to some extent (Hunt et al, 1981).

BLACK BRANT

Introduction

The black brant (Branta bernicla nigricans) is one of many species of the family Anatidae (swans, geese, and ducks), which frequent the lagoons, estuaries, and nearshore zone of Bristol Bay and the Alaska Peninsula.

Distribution. During their spring and fall migrations to and from nesting grounds on the Yukon-Kuskokwim Delta, the entire world population of black brant visits Izembek and adjacent lagoons.

Commercial Importance. Brant are hunted for sport, and provide part of the subsistence diet of Alaskan natives along the coast of the Bering and Chukchi Seas.

Population Status. The black brant population is currently estimated at 150,000-200,000 birds (King and Dau, 1981; U.S. Fish and Wildlife Service, 1982). So far as is known, the population is stable.

Life History

Reproduction. About half of the brant population nests on the Yukon-Kuskokwim Delta (King and Dau, 1981), with the remainder nesting in the vegetated intertidal along the coast of the northern Bering and Chukchi Seas. The productivity of black brant is fairly low, estimated at about 25 percent annually (U.S. Fish and Wildlife Service, 1980). Jones (1970) estimates that between 31 percent and 69 percent of the adults are non-breeders.

Feeding, Age and Growth. Brant feed on eelgrass and other marine and intertidal vegetation. At Izembek Lagoon, where the entire population stages during the fall migration, brant rely almost exclusively on eelgrass to put on needed fat reserves after the breeding and moulting season (C.P. McRoy, personal communiction). Brant normally arrive at Izembek from September until early October, and remain until late October or early November (Jones, 1970).

EMPEROR GOOSE

Introduction

The emperor goose (Philacte canagica) is one of many species of the family Anatidae which frequents the nearshore zone of the Alaska Peninsula and Bristol Bay during its spring and fall migrations.

Distribution. During spring and fall migrations, emperor geese stage at various lagoons and estuaries along the Alaska Peninsula and Bristol Bay. Principal areas are Izembek Lagoon, Port Moller, Port Heiden, and Cape Peirce (U.S. Fish and Wildlife Service, 1981; Petersen and Sigman, 1977; Petersen and Gill, 1982).

Commercial Importance. Emperor geese are hunted for sport, and comprise part of the subsistence diet of Alaskan natives along the Bering Sea coast.

Population Status. The current population is estimated at about 80,000-150,000 (King and Dau, 1981; Petersen and Gill, 1982), all of which reside in the Bering Sea. So far as is known, the population is stable.

Life History

Reproduction. Emperor geese nest primarily on the Yukon-Kuskokwim Delta in the vegetated intertidal.

Feeding, Age and Growth. Emperor geese feed primarily on intertidal invertebrates. Recent studies (Petersen, 1983) indicate that they also supplement this diet with marine and intertidal vegetation, including eelgrass where available. Emperor geese winter in the Aleutian Islands.

STELLER'S EIDER

Introduction

Steller's eider, (*Polysticta stelleri*) is one of many members of the family Anatidae which frequents the coast of Bristol Bay and the Alaska Peninsula.

Distribution. During the spring and fall migrations, huge flocks of Steller's eiders stage and moult at lagoons and estuaries of Bristol Bay and along the Alaska Peninsula. During the fall migration, birds normally arrive in the area in August or early September, feed and moult in lagoons and estuaries, and depart in early October (Petersen, 1980). In some years, however, they do not arrive in the area until after the moult, sometimes as late as November (Jones, 1965). Steller's eiders winter from Kodiak Island west along the south side of the Alaska Peninsula and into the eastern Aleutians. Significant numbers also overwinter in open-water areas of the northern Alaska Peninsula and Bristol Bay coasts (Jones, 1965).

Commercial Importance. Steller's eiders are hunted for sport, and are used as a subsistence resource by Alaskan natives.

Population Status. The present population is estimated at about 400,000, all of which frequent the Bering Sea during migration (King and Dau, 1981). The population appears to be stable.

Life History

Reproduction. Most Steller's eiders nest along the Chukchi coast of Alaska and Siberia.

Feeding, Age and Growth. During their fall migration and moult, Steller's eiders are known to feed almost exclusively on 0-1 age class mussels (*Mytilus edulis*) and amphipods (*Anisogammarus pugettensis*) in the intertidal and shallow subtidal zone of lagoons and estuaries along the coast of Bristol Bay and the Alaska Peninsula (Petersen, 1980).

DUNLIN

Introduction

Dunlins (Calidris alpina) are one of many members of the family Charadriidae (plovers, turnstones, and surfbirds) which seasonally frequent the coast of Bristol Bay and the Alaska Peninsula.

Distribution. Dunlin occupy the littoral areas of Bristol Bay and the Alaska Peninsula during the spring migration (May), while on their way to the nesting grounds, and as post-nesting foraging habitat prior to the fall migration (late June-mid October). During this post-breeding period, they undergo moult and put on fat reserves in preparation for the fall migration to wintering grounds in the Pacific Northwest and California (Gill and Handel, 1981). Major dulin concentrations occur in the estuary-lagoon systems of the region such as Port Heiden, Nelson Lagoon, Port Moller, Izembek Lagoon, and so on.

Commercial Importance. None.

Population Status. No estimates of the total population are currently available. Dunlin are by far the most common and numerous shorebird in the area, comprising about 80 percent of the total shorebird population. Gill and Jorgensen (1979) estimate summer populations of 260,000 in the Nelson Lagoon area alone. So far as is known, the population is stable.

Life History

Reproduction. The major nesting area for Dunlin in the region is the Yukon Delta, though some nesting does occur along the Alaska Peninsula (Gill and Handel, 1981). No productivity estimates are available.

Feeding, Age and Growth. Dunlins feed in the region, during the summer and fall post-breeding period, on the littoral beaches and exposed flats of estuaries and lagoons along the Alaska Peninsula and Bristol Bay. Presumably, their diet consists primarily of infaunal and epifaunal crustaceans.

WESTERN SANDPIPER

Introduction

Along with dunlin, western sandpipers (*Calidris mauri*) are one of numerous members of the large Charadiidae family which frequents the Bristol Bay-Alaska Peninsula region.

Distribution. Western sandpipers occupy littoral zones of estuaries and lagoons in the region during both the spring migration, from early to mid-May, and during the postbreeding season prior to the fall migration (late June to early September).

Commercial Importance. None.

Population Status. No estimates of total population are currently available. It is, following dunlin, the most common and numerous shorebird found along the Bristol Bay-Alaska Peninsula coast during summer and early fall. It is estimated that at least 36,000 sandpiper use the Nelson Lagoon area during the post breeding period (Gill and Jorgensen, 1979). The population appears stable at present.

Life History

Reproduction. Though the major nesting grounds of the region is the Yukon Delta, large numbers of sandpiper are known to nest along the coast of the Alaska Peninsula as well (Gill and Handel, 1981). No productivity estimates are available.

Feeding, Age and Growth. Like dunlins, western sandpipers feed on intertidal beaches and exposed flats of lagoons and estuaries along the Alaska Peninsula and Bristol Bay coast. Their major prey probably consists of infaunal and epifaunal crustaceans.

SOCKEYE (RED SALMON)

Introduction

Sockeye salmon (Oncorhynchus nerka) are one of five salmon species which spawn in streams and lakes of the Alaska Peninsula-Bristol Bay region.

Distribution. Though sockeye salmon enter at least 30 streams of the Bristol Bay and Alaska Peninsula coast during their spawning migration, about 90 percent of the average total run is associated with 5 river systems of inner Bristol Bay (Nushagak, Kvichak-Naknek, Egegik, Ugashik, and Togiak). Adult salmon enter the Bering Sea from the North Pacific enroute to spawning grounds in early May, arrive in Bristol Bay starting about mid-June and peaking between the first and the tenth of July, and by late July or early August have all entered the stream systems and nursery lakes. Juvenile salmon outmigrate into Bristol Bay in late May and early June of most years, with maximum concentrations found northeast of Port Heiden from late May through early July (Straty and Jaenicke, 1980). Juveniles outmigrate close inshore along the Alaska Peninsula coast to about the vicinity of Port Moller, where they swing out to sea and, eventually, pass through Unimak Pass into the North Pacific. Adult salmon on their return migration stay well out to sea until they are within proximity of their home rivers, where they then swing inshore (Favorite et al, 1977).

Commercial Importance. Historically, the Bristol Bay sockeye salmon fishery has been the most important salmon fishery in North America (Stern et al, 1976). Since 1963, an average of 10.1 million fish have been landed annually in Bristol Bay, for an average ex-vessel value of $29.719 million. In 1983, 37.226 million sockeye were landed, for an ex-vessel value of $138.8 million (A.D.F. & G. files, Anchorage).

Population Status. Though sockeye salmon runs occur every year in Bristol Bay, they are strongly cyclical in that much higher numbers of fish seem to occur, on the average, every 5th year. Returning runs of sockeye vary greatly, from about 2.2 million to in excess of 56 million fish (A.D.F. & G. files, Anchorage). The average run of adult sockeye into Bristol Bay is about 16.5 million fish (Stern et al, 1976), while escapement of juvenile salmon is estimated to average 313.3 million fish annually (Stern et al, 1976).

Life History

Reproduction. Sockeye salmon spawn in the lakes adjacent to the Alaska Peninsula and Bristol Bay. Adults spawn on gravel beds of these lakes in late summer, after which all of them die. Alevins hatch during the winter and remain in the gravel until spring, by which time their yolk sacs are absorbed. They remain feeding in the lake systems for one to two years, then outmigrate into Bristol Bay and eventually, the Bering Sea and North Pacific, where they spend from two to three years before returning (Rogers, 1977).

Feeding, Age and Growth. The size of outmigrating sockeye smolt ranges from 89 to 149 mm (5.4-33 g) for 1.0 year old fish, and from 109 to 184 mm (8-71 g) for 2.0 year old fish (Ogi, 1973). Growth during the early part of the outmigrating, when juveniles remain close inshore, is fairly slow. Once they move offshore, into the apparently richer oceanic waters, growth rates increase significantly. Both juveniles and adults feed on zooplankton and smaller fishes. Preferred prey items seem to be euphausiids, copepods, cladocerans, and sandlance (Straty and Jaenicke,1980).

BOREAL (RAINBOW) SMELT

Introduction

Boreal or rainbow smelt (*Osmerus eperlanus*) is one of several small forage fish (including herring, capelin, sandlance, and eulachon) which inhabit the estuaries and nearshore zone of Bristol Bay.

Distribution. Little is known about the distribution of smelt other than that they are very common in the estuary and river systems of Bristol Bay.

Commercial Importance. Though there is presently no commercial smelt fishery in the region, smelt are taken for subsistence use.

Population Status. Virtually nothing is known concerning the abundance or population status of smelt in this area. Warner and Shafford (1981) estimate that it is the most common forage fish in the Meshik-Port Heiden area from late May through June.

Life History

Reproduction. In most regions, smelt overwinter in freshwater streams, spawn in tributaries soon after the ice goes out, and return to the coastal estuaries to feed for the summer (Warner and Shafford, 1981). In the Port Heiden vicinity, however, it is conjectured (Barton et al, 1977) that smelt may remain in the estuary year-round, ascending the streams to spawn during the day and returning at night to feed.

Feeding, Age and Growth. Little is known other than that smelt fed on mysids, amphipods, fish, polychaete worms, and other invertebrates. Adults spawn at age two or three, and continue to spawn for two to three years (Warner and Shafford, 1981).

RED KING CRAB

Introduction

The red king crab, *Paralithodes camtschatica*, belongs to the family Lithodidae and is one of two *Paralithodes* spp. in the eastern Bering Sea; the other is the blue king crab, *P. platypus*.

Distribution. Red king crab are distributed on both sides of the North Pacific Ocean. In Asian waters, it is found from the Sea of Japan northward into the Sea of Okhotsk and along the shores of the Kamchatka Peninsula; the northern limit on the Asiatic coast at approximately 60° N. latitude. The species occurs throughout the Aleutian Islands and the southeastern Bering Sea where large fisheries exist. On the west coast of North America, the northern limit appears to be the southeastern Chukchi Sea. Red king crab are distributed in the Gulf of Alaska from the Aleutian Islands south to Vancouver Island, British Columbia. The commercial fishery is generally confined to depths less than 200 meters. King crab migrate from offshore feeding grounds to coastal spawning areas from January to April, then stay in coastal waters through the summer before returning to greater depths offshore. Before the recent decline in stock, greatest concentrations of pre-recruit and legal-sized male crabs were located in 50-100 meters of water in the eastern Bering Sea. Red king crab are found in 0-5.5° C temperatures. Maximum concentrations of males are caught near the 1.5° C isotherm; females are found in 3-6° C. Spawning and mating occur in the shallow waters. Larvae settle out in waters less than 50 meters. Juveniles remain in the shallow waters along the North Aleutian Shelf and northern and inner Bristol Bay (Armstrong et al, 1981, 1982; Haynes, 1974; VTN Oregon, 1983 a,b,c).

After the eggs are hatched in the shallow waters along the North Aleutian shelf, the larvae mainly reside in the upper 30 meters. The larvae molt through four zoeal and one glaucothöe stages and become juveniles from mid-July to mid-August. First-year juveniles reside among coarse substrate bottom in patchy locations. Recent surveys have identified patches of juveniles in Kvichak Bay, off Port Moller and Cape Seniavin and around the Walrus Islands (VTN Oregon, 1983 a,b,c). Juveniles remain in the shallow waters for approximately three years until they begin the similar offshore migrations as adults.

Man affects the distribution and abundance of red king crab through commercial fishing, either directly upon the crab or upon their competitors, e.g., Pacific cod, yellowfin sole, and Pacific halibut. Water temperature, predators, and parasites are the natural factors which affect red king crab distribution and abundance.

Commercial Importance. King crab have been exploited in the southeastern Bering Sea since the 1940's. Until 1960, U.S., Soviet, and Japanese fisherman caught king crab with otter trawl, tangle net, and pots; thereafter only pots were used. In 1971 the Soviets ceased fishing for king crab in this region; Japan ceased operation after 1973. Only domestic fishermen now fish king crab in this region. The 1980 and 1982 seasons were historic high and low seasons, respectively. In 1980, the red king crab harvest reached 59.1 thousand mt in the southeastern Bering Sea. The catch in 1981 and 1982 plummeted to 15.4 thousand mt and 1.3 thousand mt, respectively (Powell and McCrary, 1982). In 1982 fishermen received $3.50/lb (Forrest Blau, A.D.F. & G., personal communication, 1982). The projected red king crab harvest is expected to remain low for several years.

Population Status. The 1983 red king crab population is the lowest since the onset of the commercial fishery in 1958. Recent NMFS crab surveys in the southeastern Bering Sea have revealed that in addition to finding few pre-recruit and legal-sized males, large numbers of adult females were found clutchless (Dr. Robert Otto, NMFS, personal communication, 1983). A 1983 NMFS survey of the Bristol Bay region revealed that 54.8 million males and 33.8 million females (86.6 total) were present. This estimate is almost one third of the 1982 estimate. This decline in abundance from 1982 to 1983 is reflected in both sexes (Otto, personal communication, 1983).

Life History

Reproductive Mode. Female red king crab carry their eggs beneath their abdominal flap for approximately eleven months. Once the crab has arrived in the shallow waters of the North Aleutian Shelf egg hatching begins. After egg hatching and molting, mating and spawning ensue while still in shallow water.

Feeding, Age and Growth. Adult king crab in the eastern Bering Sea are opportunistic feeders, mainly feeding on polychaete worms, pelecypods, gastropods, sand dollars, and brittle stars (Feder and Jewett, 1981). Similar prey is assumed to be taken by juveniles. An OCSEAP study is currently underway to address juvenile crab feeding.

King crab reach maturity between seven and eight years of age. Males and females have a carapace length between 99-120 mm at maturity. Male crab may live for approximately 15 years. (Guy Powell, A.D.F. & G., personnal communication, 1982).

YELLOWFIN SOLE

Introduction

Yellowfin sole, _Limanda aspera_, belongs to the family Pleuronectidae, and is one of two species of _Limanda_ found in the eastern Bering Sea.

Distribution. Yellowfin sole is limited in distribution to continental shelf and slope waters of the North Pacific Ocean, the Bering Sea and, to a limited extent, the Chukchi Sea. It ranges along the Pacific coast of North America from Barclay Sound, Vancouver Island, British Columbia, northward into the Chukchi Sea and along the Asian coast from the Gulf of Anadyr southward to the east and west coasts of Hokkaido Island, Japan, and along the Asian mainland in the Okhotsk Sea and the Sea of Japan to about 35°N off South Korea. Its bathymetric range is from about 5 to 360 meters, although in some regions (e.g., the Gulf of Alaska) it is limited to continental shelf waters of generally 100 meters or less. The deepest recorded occurrence (360 meters) is in the eastern Bering Sea (Bakkala, 1981a).

Yellowfin sole form dense concentrations on the outer continental shelf of the eastern Bering Sea in winter. The largest of these is formed in the vicinity of Unimak Island, and the second largest is west of St. Paul Island. Other lesser winter concentrations have been recognized. One may be south or east of St. George Island, and the other, consisting of small fish, in Bristol Bay. Unimak Island/St. George Island populations migrate toward shore in winter and early spring, concentrating along the North Aleutian Shelf and Bristol Bay. The large wintering concentration located west of St. Paul Island may remain relatively independent of the Unimak Island/St. George concentrations throughout the year. Spawning occurs in waters less than 100 meters in the summer. More than a million eggs may be produced by each spawning female. The young remain in shallow nearshore areas throughout their first few years of life. They begin to disperse to more offshore waters at three to five years of age. The observed age range of yellowfin sole since the early 1970's has been 2-19 years for males and 2-21 years for females; however, about 97% of the sampled population were younger than 13 (Bakkala, 1981a).

Man influences yellowfin sole through the commercial fishing activity either directly on yellowfin sole or on their competitors and/or prey.

Indices of relative abundance and biomass estimates from trawl surveys in the southeastern Bering Sea have shown that abundance continued to increase through 1978 and presumably is still increasing today. The primary reason for the increase has been the recruitment of a series of relatively strong year-classes originating in the years 1966-70. These were years of relatively warm climatic condition; year-classes produced in cold years had relatively low abundance. Evidence also suggests that extensive ice cover may delay the start of spring inshore migrations, and residual cold water in central shelf regions may alter patterns of summer migrations and distributions (Bakkala, 1981a).

Commercial Importance. This species was heavily fished by the USSR and Japan in the late 1950's and early 1960's, with peak harvests reaching approximately 500,000 mt/year. After 1962, harvests dropped drastically (Bakkala, 1981a; Haflinger and McRoy, 1983). Signs of improvement in the general yellowfin sole stock appeared in the early 1970's and have continued to present (Pereyra et al, 1976). In 1980, a joint US/USSR fishery for yellowfin sole in the eastern Bering Sea was successful. Five American catcher boats caught 8,638 mt of food-grade yellowfin sole, 1,421 mt of Pacific cod, and 3,118 mt of fishmeal-grade product for a grand total of 13,177 mt, valued a approximately $1.6 million during this period. The product was transported to the USSR and then marketed in the USSR and Africa (Fisher, 1980).

Population Status. Perhaps in response to the easing of fishing pressure, fish populations have, since the mid-1970's, steadily approached and perhaps exceeded pristine stock levels. Current biomass estimates for this species are in the two to four million mt range, making it the most common flatfish found on the shelf of the eastern Bering Sea, second only to Alaska pollock in biomass (Bakkala, 1981a; Haflinger and McRoy, 1983).

Life History

Reproductive Mode. Yellowfin sole are oviparous spawners. Little else is know about their reproductive mode.

Feeding, Age and Growth. Recent findings on the food of yellowfin sole in the southeastern Bering Sea along the Alaska Peninsula revealed that newly recruited surf clams *Spisula polynyma* (1-2 mm) were often encountered in the range of 100-500 per stomach of yellowfin caught in the deeper waters (>30 meters) off Port Moller, while various groups of polychaete worms, benthic amphipods, and the sand dollar *Echinarachnius parma* dominated the shallow water and Bristol Bay samples (Haflinger and McRoy, 1983). King crab glaucothöe larvae and Tanner crab (*Chionoecetes bairdi*) zoea were also taken as food; however, only two of 557 fish examined accounted for nearly all the crab consumption reported here. The overall incidence of king crab was 0.69/stomach. Overall incidence of Tanner crab was 0.27/stomach. Extrapolations from these rates to total numbers of crab consumed for one month in this area are 11.5×10^9 king crab and 4.5×10^9 Tanner crab.

A characterizaton of yellowfin sole food and feeding habits is presented in Bakkala (1981a) and summarized here. Yellowfin sole are capable of feeding on a variety of animals, from strictly benthic forms such as clams and polychaete worms to zooplankton (mysids and euphausiids) to pelagic fishes (capelin and smelt). About 50 different taxa have been found in stomachs of yellowfin sole in the eastern Bering Sea. The kinds of organisms consumed vary by season, area, and size of fish. Although feeding generally stops in winter, instances of fairly intense winter feeding have been recorded. During the onshore migrations in May and June 1971, 73 percent of the fish that had wintered near Unimak Island were feeding, but feeding intensities were low for fish that had wintered near St. George Island (0.05 percent), St. Paul Island (19 percent), and in Bristol Bay (zero percent). They fed more intensively as they moved onto the central shelf. Diet varies by region, apparently dependent on the availability of food organisms.

Contents of 2,357 stomachs taken over a broad area of the eastern Bering Sea showed that the primary food items, representing 65 percent of stomach contents by weight, were bivalves, amphipods, polychaete worms, and echiuroid worms. Polychaetes and amphipods were the principal food items in smaller fish (10-20 cm). Polychaetes and bivalves and then echiuroids and amphipods were the principal food in larger fish (20-30 cm), and bivalves and echiuroids in fish longer than 30 cm.

Male yellowfin sole in the southeastern Bering Sea begin to mature at a length of 10.5 cm. The length at which 50 percent of the population is mature is 12.8 cm for males and 25.2 cm for females. All males mature at 25 cm and most females at 30 cm. Yellowfin sole first become recruited to the fishery at 13 or 14 cm, which corresponds to an age of four or five years (Bakkala, 1981a).

PACIFIC HERRING

Introduction

Pacific herring, Clupea harengus pallasi, is a member of the family Clupeidae and is the only member of the genus Clupea in the North Pacific Ocean.

Distribution. In the North Pacific Ocean, herring are distributed along the Asiatic and North American continental shelves; in Asia they range from Taksi Bay, near the mouth of the Lena River, to the Yellow Sea; and in North America from Cape Bathurst in the Beaufort Sea to San Diego Bay, California. Pacific herring spawn between the intertidal zone and about 20 meters (Wespestad and Barton, 1981).

Herring wintering northwest of the Pribilof Islands migrate to the Alaska coast in spring and spawn in Bristol Bay and between the Yukon and Kuskokwim Rivers. Although some may also spawn in the eastern Aleutian Islands, Alaska Peninsula, and Norton Sound, herring in these areas may also winter inshore near spawning grounds. Herring spawn in coastal waters between late April and mid-May. Eggs hatch in two or three weeks as planktonic larvae and metamorphose to juveniles after six to ten weeks (Wespestad and Barton, 1981). Little is known of larval and juvenile stages in the eastern Bering Sea.

Commercial fishing may affect the distribution and abundance of Pacific herring. Temperature may influence seasonal distributions more than anything else. In a major wintering area northwest of the Pribilof Islands, dense schools have been found during the day a few meters off the bottom at depths of 105-137 meters and at water temperatures of 2-3.5° C. In spring they migrate to warmer coastal waters, where they remain during the summer because of heavy phytoplankton blooms (1-3 g/m^3); poor feeding conditions exist on the outer shelf (Wespestad and Barton, 1981).

Commercial Importance. Following inception of the inshore herring sac roe fisheries in the eastern Bering Sea in the mid-1960's, herring catches and fishing effort remained low until recent years. Due to favorable market conditions and high prices for sac roe herring, both catch and effort have dramatically increased since 1977. A domestic harvest of nearly 12,000 mt of herring and 200 mt of spawn-on-kelp with a combined ex-vessel value of nearly $8.5 million was landed in 1979 (Wespestad and Barton, 1981). In 1981, 28 companies paid more than 200 permit holders and their crews an estimated $4 million for over 11,000 mt of herring and another $300,000 for 172 mt of spawn-on-kelp (Fried and Skrade, 1982). The total harvest for the eastern Bering Sea for 1983 was 30.7 mt; 24.5 mt were harvested from the Togiak District (Craig Whitmore A.D.F. & G., personal communication, 1983).

Population Status. Abundance of herring in the eastern Bering Sea appears to have increased since 1978 in all major coastal areas. Total spawning biomass is estimated to have ranged from 187,210 to 334,723 mt in 1978, and from 258,079 to 637,583 mt in 1979, an indicated 27 percent increase at the lower range (Wespestad and Barton, 1983). Studies have shown that Bristol Bay contains the largest assemblage of spawning herring within the entire State of Alaska: in 1981 about 144,000 mt of herring arrived to spawn within Bristol Bay (Fried and Skrade, 1982).

Life History

Reproductive Mode. Herring liberate their eggs in the coastal environment on substrates consisting primarily of rocks covered with rockweed kelp (*Fucus* sp.). However, almost any substrate is used under conditions of dense spawning.

Feeding, Age and Growth. Herring are planktivorous. The first food of herring larvae is usually limited to small and relatively immobile plankton organisms. Microscopic eggs often make up more than half of the earliest food; other items include diatoms and nauplii of small copepods. Herring do not have a strong preference for certain food species but feed on the comparatively large organisms that predominate in the plankton of a given year. Feeding generally occurs before spawning and intensifies afterwards. During winter, feeding declines, and ceases in late winter. Fall prey is dominated by euphausiids; spring prey is dominated by pelagic amphipods and chaetognaths. After spawning, the main diet is euphausiids, *Calanus* sp., and *Sagitta* sp. (Wespestad and Barton, 1981).

Herring have been found to live as long as 15 years, and generally occur in substantial numbers from ages three to six, but when strong year-classes occur, ages seven to ten may comprise a substantial portion of the catch. Bering Sea stocks grow at about the same rate as those in the Gulf of Alaska and British Columbia until ages three to four, but growth is greater in the Bering Sea for older fish which achieve a greater maximum length and weight than the more southern stocks (Wespestad and Barton, 1981).

CAPELIN

Introduction

The capelin, Mallotus villosus, is one of six members of the family Osmeridae. Both generic and specific names of the capelin mean hairy, the appearance of the rough extruded scales on spawning males.

Distribution. The capelin occurs circumpolar in the northern hemisphere. It occurs south to approximately 42° N. The only information on where the various life stages of capelin occur concerns their spawning. Capelin typically spawn along clean, fine gravel beaches; however, spawning has been documented at depths of up to 60 meters (Barton et al, 1977).

Man may only affect their distribution and abundance by way of commercial fisheries that target on other planktivorous species. Predation, water temperatures and severe storms during spawning are presumably the natural factors that affect capelin distribution and abundance.

Commercial Importance. The capelin has no commercial importance, although it has the potential of becoming a commercially valuable resource. It is taken in some areas for subsistence purposes.

Population Status. In 1976, capelin was the most geographically widespread forage fish species encountered in the eastern Bering Sea and constituted the second-most abundant species (next to herring) captured at onshore stations between Ugashik Bay and Unimak Island (Barton et al, 1977).

Life History

Reproductive Mode. Capelin liberate their eggs in the sand in intertidal regions.

Feeding, Age and Growth. Little is known about the food and feeding habits of the capelin from the eastern Bering Sea. Capelin are planktivorous. Smith et al (1978) examined the stomach contents of 135 feeding individuals from the southeastern Bering Sea. All specimens were captured during the period from late spring to early fall; therefore, no information is available on seasonality of feeding in Bering Sea capelin. Only two phyla were represented among the food organisms, the Arthropoda (all crustaceans) and the Chaetognatha. The most numerous prey organisms were calanoid copepods. The only identifiable genus was Calanus. Virtually all of the amphipods present were members of the pelagic Hyperiidae. Identifiable euphausiid specimens were all of the genus Thysanoessa. The smallest food item, copepods, had its greatest volumetric and relative importance in the smallest fishes. The same is true of the next smallest food item, the mysids.

Little is known about the age and growth of capelin.

GREAT ALASKA TELLIN

Introduction

The Great Alaska tellin clam, Tellina lutea, belongs to the family Tellinidae, and is the only member of the genus Tellina in the southeastern Bering Sea.

Distribution. Tellina populations in the southeastern Bering Sea occur mainly on the inner and middle continental shelf of Bristol Bay. Recent studies have shown that nearly 80 percent of all tellin clams caught came from depths less that 50 meters, although densities were greatest closer to the 50 meter depth (Hughes et al, 1977; McDonald et al, 1981). Seventy-eight percent of the clams occurred in medium to fine sand with 83 percent at sediment sorting from 39 to 44 percent (McDonald et al, 1981). Benthic and/or demersal commercial fishing operations may affect the distribution and abundance of the Great Alaska tellin clam. Alterations to their benthic habitat may result from trawling. Furthermore, removal of predator species (e.g., yellowfin sole) could also enhance their distribution and abundance. Water temperatures and predators are the two most important natural factors that may affect the distribution and abundance of this species.

Commercial Importance. This species currently is not commercially harvested, although it has been identified as a potential commercial species (Hughes et al, 1977).

Population Status. A clam survey done during 1977 in the southeastern Bering Sea estimated that the harvestable biomass inside the 50 meter contour between Port Moller and Ugashik Bay was conservatively placed at about 82,000 mt (Hughes et al, 1977).

Life History

Reproductive Mode. The sexes are separate, and gametes are liberated into the water.

Feeding, Age and Growth. Tellina lutea is a filter-feeder.

Seventy-one Tellina clams from the southeastern Bering Sea ranged from 2 to 15 years old. Seventy-two percent were between 6 and 13 years old. The mean shell length of 15 year-old clams was 72.3 mm (McDonald et al, 1981).

ASTERIAS AMURENSIS

Introduction

The sea star, Asterias amurensis, has no common name. It is one of two members of the genus Asterias that occurs in the eastern Bering Sea.

Distribution. This species is distributed on both sides of the North Pacific. In Japan it occurs from Hokkaido in the north to Kii Peninsula in the south on the Pacific side and to Toyama Bay on the Japan Sea side. In Alaska it occurs from the Alaska Peninsula north through the southeastern Chukshi Sea. It occurs mainly within depths of less than 50 meters (Jewett and Feder, 1981). Larval Asterias presumably settle near the spawning population. Once they attain post-larval existence their movement is minimal. The only human activity that may affect the distribution and abundance of this sea star is the commercial fishing that is directed at other benthic and demersal organisms. Natural factors that affect their distribution and abundance include water temperature, predators, and prey.

Commercial Importance. This species has no commercial importance.

Population Status. In 1975-76 Asterias amurensis was the most ubiquitous species in benthic trawl surveys, occurring at 69 percent of the stations in the southeastern Bering Sea. This sea star was more commonly found in shallow water (20 to 60 meters). It accounted for 84.4 percent of the biomass from the 0-40 meter stratum in the southeastern Bering Sea. The mean density of A. amurensis in these shallow waters was 157.6 sea stars/km (Jewett and Feder, 1981). These 1975-76 figures may reflect the current population status.

Life History

Reproductive Mode. The sexes are separate. Gametes are released into the sea and fertilization is external.

Feeding, Age and Growth. The sea star Asterias amurensis feeds on a variety of organisms in the southeastern Bering Sea (Feder et al, 1978). It has been estimated that food, primarily clams, consumed annually by A. amurensis in Japanese waters amounts to 8 x 10^3 mt, approximating the annual consumption of food (primarily clams) taken by bottom fishes (Hatanaka and Kosaka, 1958). Presumably, the large standing stock of A. amurensis in the shallow waters of the southeastern Bering Sea preys intensively on the bivalve resources of the region (i.e., Tellina lutea, Cyclocardia ciliatum, Macoma calcarea, Spisula polynyma, and Serripes groenlandicus). The food requirements for sea stars, crabs, and some species of bottom fishes in the coastal regions of the southeastern Bering Sea are similar; thus, the size of sea-star populations must have an important bearing on the production of useful crabs and fishes.

The only means of determining the growth of Asterias is to examine the seasonal variation in the frequency distributions of the arm lengths. This has not been done for this species in the southeastern Bering Sea.

ALASKA SURF CLAM

Introduction

The Alaska surf clam, Spisula polynyma, belongs to the family Mactridae, and is also known as the pinkneck clam because of its pink-colored siphon.

Distribution. Major concentrations of Alaska surf clams occur southwest of Nunivak Island, northeast of the Pribilof Islands, and along the southeast portion of the shelf of the Alaska Peninsula (McDonald et al, 1981). Most juveniles are found in 50-100 m of water (McDonald et al, 1981). Adults are found in greatest concentrations at 30-32 m depths (Hughes and Bourne, 1981). They are found in waters with relatively high current velocities and poorly sorted sediments (McDonald et al, 1981). Benthic and/or demersal commercial fishing operations may affect the distribution and abundance of the Alaska surf clam. Alterations to their benthic habitat may result from trawling. Furthermore, removal of predator species (e.g., yellowfin sole) could also enhance their distribution and abundance. Water temperature and predators are the two most important natural factors that may affect the distribtuion and abundance of the Alaska surf clam.

Commercial Importance. No commercial fishery currently exists for this species. However, recent studies indicate potential for a commercial fishery in the region between Port Moller and Naknek (Hughes and Bourne, 1981).

Population Status. A 1977 exploratory survey of subtidal clam resources in the southeastern Bering Sea revealed extensive concentrations of Alaska surf clams (Spisula polynyma) along the north coast of the Alaska Peninsula (Hughes and Bourne, 1981). An area of 6,800 km^2 between Port Moller and Ugashik Bay had an estimated exploitable whole clam biomass of 329,000 + or - 52,000 mt and potential annual yield of 17,800 mt of whole clams. This resource was most dense at depths of 30-32 m.

Life History

Reproductive Mode. The sexes are separate, and gametes are liberated into the water.

Feeding, Age and Growth. The Spisula polynyma clam is a filter-feeder, ingesting phytoplankton and particulate matter. This species is long-lived and slow-growing with a maximum age of 25 years. At the age of eight it is fully recruited into the spawning population (Hughes and Bourne, 1981).

APPENDIX B

TOXICITY SUMMARY TABLES

Table B-1. Toxicity of Petroleum to Marine Macrophytes

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Fucus edentatus *Fucus vesiculosus* *Fucus distichus*	Reproductive	12 days	No. 2 fuel oil JP-4 JP-5 Willamar Crude	0-2000 ppm 200 ppb critical dose	Length of Juvenile Plants Measured		112
Fucus vesiculosus	Acute and Chronic (Field Surveys)	5 yr Observation after spill	Light and heavy fuel oil	400 tons into a small bay (Sweden)	Growth (Recovery)	Resistant to light and heavy fuel oil. May relate to time of year spill occurs (fall/winter) followed by clean up effort.	86
Salicornia virginica	Acute and Chronic (Field Surveys)	2 wk 3 yr	No. 2 fuel oil spill in Bourne, Mass.	Oil in salt-marsh. Oil remaining in peat.	Growth (Recovery)	Some recovery in "high" areas after 3 years, dwarfed plants in "low" areas.	51
Spartina alterniflora	Chronic (Field Surveys) Acute	2 wk and 3 yr	No. 2 fuel oil spill in Bourne, Mass.	Oil in salt-marsh Oil remaining in peat.	Growth (Recovery)	Marsh grass not able to reestablish after 3 years.	51

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Abarenicola pacifica (lugworm)	Chronic	11 days	Prudhoe Bay Crude in Sediment	250 to 1000 ppm	Mortality and Behavior		8
Abarenicola pacifica	Chronic	60 days	Phenanthrene, Chrysene, & Benzo (a) pyrene	C^{14} labeled	Ratio of tissue conc. to sediment conc. measured.		9
Capitella capitata	Acute (TLm)	96 hr 28 days	Louisiana Crude	>19.8 ppm 17.8 ppm	Lethality		23
		96 hr 28 days	No. 2 fuel oil	>8.7 ppm 7.3 ppm			
Chenodrilus serratus	Acute (TLm)	96 hr 28 days	Louisiana Crude	>19.8 ppm 15.8 ppm	Lethality		23
		96 hr 28 days	No. 2 fuel oil	4.1 ppm 2.6 ppm			
Cirriformia spirabranchia	Acute (TLm)	96 hr 28 days	Louisiana Crude	>19.8 ppm 7.9 ppm	Lethality		23
		96 hr 28 days	No. 2 fuel oil	8.7 ppm 5.5 ppm			

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Naiselinguis (oligochaete)	Acute ($\bar{x}$ survival time)	2-6 D	WSF Crude	4.0-14.0 ppm	Lethality		59
Neanthes arenaceodentata	Acute (LC_{50})	48 hr	Crude oil	13.9 ppm	Lethality		83
		96 hr		12.5 ppm			
Neanthes arenaceodentata	Acute (TLm)	48 hr	No. 2 fuel oil	3.2 ppm	Lethality		107
		96 hr		2.7 ppm			
		48 hr	Bunker C oil	4.6 ppm			
		96 hr		3.6 ppm			
		48 hr	Crude oil (a)	13.9 ppm			
		96 hr		12.5 ppm			
		48 hr	Crude oil (b)	>10.4 ppm			
		96 hr		>10.4 ppm			
Neanthes arenaceodentata Gravid females 60 segments-54 days	Acute (TLm)	24 hr	Crude	>19.8 ppm	Lethality		106
		48 hr	Crude	18.0 ppm			
		96 hr	Crude	17.6 ppm			
Capitella capitata	Acute (TLm)	48 hr	No. 2 fuel oil	3.5 ppm	Lethality		107
		96 hr		2.3 ppm			
		48 hr	Bunker C oil	1.1 ppm			
		96 hr		0.9 ppm			
		48 hr	Crude oil (a)	16.2 ppm			
		96 hr		12.0 ppm			
		48 hr	Crude oil (b)	10.4 ppm			
		96 hr		9.8 ppm			

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Neanthes arenaceodentata	Acute (TLm)				Lethality		106
Juvenile stages							
4 segments-9 days		24 hr	No. 2 fuel oil	>8.7 ppm			
		48 hr		>8.7 ppm			
		96 hr		8.4 ppm			
18 segments-21 days		24 hr		>8.7 ppm			
		48 hr		>8.7 ppm			
		96 hr		5.7 ppm			
32 segments-30 days		24 hr		>8.7 ppm			
		48 hr		7.8 ppm			
		96 hr		5.2 ppm			
40 segments-40 days		24 hr		>8.7 ppm			
		48 hr		6.2 ppm			
		96 hr		4.0 ppm			
4 segments-9 days		24 hr	Crude	>19.8 ppm			
		48 hr		>19.8 ppm			
		96 hr		>19.8 ppm			
18 segments-21 days		24 hr		>19.8 ppm			
		48 hr		>19.8 ppm			
		96 hr		>19.8 ppm			
32 segments-30 days		24 hr		>19.8 ppm			
		48 hr		>19.8 ppm			
		96 hr		17.8 ppm			

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Neanthes arenaceodentata	Acute (TLm)				Lethality		106
Juvenile stages							
40 segments-40 days		24 hr	Crude	>19.8 ppm			
		48 hr		17.0 ppm			
		96 hr		15.2 ppm			
Adult stages							
Immature		24 hr	No. 2 fuel oil	>8.7 ppm			
48 segments-46 days		48 hr		3.2 ppm			
		96 hr		2.7 ppm			
Mature males		24 hr		>8.7 ppm			
60 segments-54 days		48 hr		3.0 ppm			
		96 hr		2.6 ppm			
Gravid females		24 hr		>8.7 ppm			
60 segments-54 days		48 hr		5.6 ppm			
		96 hr		4.2 ppm			
Immature		24 hr	Crude	18.0 ppm			
48 segments-46 days		48 hr		13.9 ppm			
		96 hr		12.5 ppm			
Mature males		24 hr		18.0 ppm			
60 segments-54 days		48 hr		13.6 ppm			
		96 hr		12.0 ppm			
Nereis branti trochophore stage	Acute	48 hr	No. 2 diesel oil	0.5% in seawater	100% Mortality		24

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Nereis diversicolor	Acute ($\bar{X}$ Survival time)	2-6 days	WSF Crude	5.0-15.0 ppm	Lethality		59
Nereis succinea	Acute (TLm)	48 hr	WSF Bunker C fuel oil	5.53 ppm	Lethality (0)		14
Nereis vexillosa	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l(gc) >10.58 >3.36	Lethality	Alaskan sp.	101
Nereis vexillosa (larva)	Acute ($\bar{X}$ Survival time)	48 hr	No. 2 fuel oil	0.5 %	Lethality		24
Ophryotrocha puerilis	Acute (TLm)	96 hr 28 days	Louisiana Crude	17.2 ppm	Lethality		23
		96 hr 28 days	No. 2 fuel oil	2.2 ppm 1.4 ppm			
Ophryotrocha sp.	Acute (TLm)	96 hr 28 days	Louisiana Crude	12.9 ppm 10.9 ppm	Lethality		23
		96 hr 28 days	No. 2 fuel oil	2.9 ppm 2.4 ppm			

Table B-2. Toxicity of Petroleum to Annelids

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Platynereis dumerilii	Acute (LC_{50})	48 hr 96 hr	WSF Crude	12.3 ppm 9.5 ppm	Lethality		83
Serpula vermicularis (larva)	Acute ($\bar{x}$ Survival time)	3 hr	No. 2 fuel oil	0.5%	Lethality		24

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Acmaea scutum Veliger stage	Acute	48 hr	No. 2 diesel oil	0.5% in seawater	100% Mortality		24
Acmaea scutum	Chronic (EC_{50})	24 hr 48 hr	No. 2 diesel oil	41.0 ppm 23.5 ppm	Behavior		39
	Acute (EC_{50})	24 hr 48 hr	WSF of No. 2 diesel oil	17.0 ppm 15.6 ppm	Lethality		22
Arenicola marina	Chronic (Field study)	4 to 150	No. 2 fuel Bunker C-a Bunker C-b SLA Crude Kuwait Crude	35-2086 µg/g oil to sediment concentration	Biochemistry (tissue con.) Chemistry (cast con.)	sediment working of sediment- bound oil	46
Argopecten irradians Adult	Acute (% mort)	 91 days 91 days 91 days 7 days	 WSF No. 2 fuel oil	ppm 0.006 0.067 0.54 10.6	Lethality 17.3% 24.6% 87.9% 100.0%		125
Argopecten irradians (bay scallop)	Acute	6 hr dosing 5 day depuration	Kuwait Crude oil & Corexit 9527 oil dispersant	Various concentrations of oil, dispersant & a mixture of the two	Mortality Behavior		87

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Cardium edule (8-15 mm)	Acute (LC_{50})	96 hr	Crude	<1,000 ppm	Lethality		116
Cardium edule	Acute (LC_{50})	48 hr	Phenol	500 ppm	Lethality		85, 94
Cerastoderma lamarcki	Acute (Survival days)	3 days 5 days	WSF Crude	4.0 14.0	Lethality		59
Chlamys lericus	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l (GC) 3.94 >3.36	Lethality	Alaskan sp.	101
Chlamys rubida			WSF	ppm (uv)	Lethality	Arctic and Subarctic Species	102
	Acute (TLm)	96 hr	Prudhoe Bay Crude	168			
		96 hr	Cook Inlet Crude	162			
		96 hr	Cook Inlet untreated Crude	146			
		96 hr	No. 2 fuel oil	199			
		96 hr	OWD of Prudhoe Bay Crude	155			
		96 hr	Cook Inlet Crude	148			

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Collisella scutum	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) 8.18	Lethality	Alaskan sp.	101
			No. 2 fuel oil	>3.36			
Colus halli	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >8.98	Lethality	Alaskan sp.	101
Crassostrea angulata (larva)	Acute (% mort)	6 hr (exposure)	Crude	1,000 ppm	Lethality 30.7%		95
			No. 2 fuel oil	1,000 ppm	Lethality 26.0%		
Crassostrea gigas (larva)	Acute (ED_{50})	48 hr		ppm	Lethality	Prudhoe Bay oil	69
			crude	523			
			extract	323,600			
			WSF:				
			pentane	46,000			
			hexane	41,000			
			heptane	11,000			
			cyclohexane	69,000			
			benzene	9.4			
			toluene	5.9			
			o-xylene	0.4			
			m-xylene	1.2			
			p-xylene	0.4			
			PH:				
			napthalene	194			
			cyclooctane	233			
			isopropyl benzene	236			
			o-xylene	338			

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Crassostrea gigas (larva) (continued)	Acute (ED_{50})	48 hr	PH (continued):	ppm	Lethality	Prudhoe Bay oil	69
			m-xylene	626			
			p-xylene	695			
			benzene	1,052			
			ethyl benzene	1,182			
			toluene	1,209			
			cyclohexane	1,701			
			cyclopentane	3,753			
Crassostrea gigas (larva) (veliger stage)	Acute (% survival)	24 hr	No. 2 diesel oil	0.5%	Lethality		24
Crassostrea gigas (larva)	Acute (% mort)	6 hr exposure	Crude	1,000 ppm	Lethality 31.4%		95
			No. 1 fuel oil	1,000 ppm	Lethality 27.0%		
Crassostrea virginica (gamete, embryo, larva)			WSF of 3 Crude oils	1 ppm		Prudhoe Bay oil	96
	Life History	1 hr			Reproduction		
	Chronic	1 hr			Growth		
	Acute	1 hr (exposure)			Lethality		
Crassostrea virginica (adult)	Acute (% survival)	13 days	Diesel	5,291 ppm	Lethality 33%		25
		13 days	Diesel + sand	5,291 ppm	Lethality 75%		
		12 days	Crude	2,000 ppm	Lethality 75%		
		12 days	Crude + sand	2,000 ppm	Lethality 75%		

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Cryptochiton stelleri	Acute (TLm)	24 hr	No. 2 fuel oil	>1.13 ppm	Lethality		103
		96 hr	No. 2 fuel oil	1.24 ppm			
Gibbula umbilicalis	Acute (% mort)	6 hr (exposure)	Crude	whole	Lethality 4%	17°C	30
			Crude (residue)	whole	0%	17°C	
Haminoea virescens veliger stage	Acute	31 hr	No. 2 Diesel oil	0.5% in seawater	100% Mortality		24
Harmothoe imbricata	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >10.58	Lethality	Alaskan sp.	101
Katharina tunicata trochophore stage	Acute	72 hr	No. 2 Diesel oil	0.5% in seawater	100% Mortality		24
Katharina tunicata	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >8.46	Lethality	Alaskan sp.	101
			No. 2 fuel oil	>3.36			
Katharina tunicata	Acute (TLm)	24 hr	No. 2 fuel oil	1.03 ppm	Lethality		103
		96 hr	No. 2 fuel oil	0.44 ppm			

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Littorina littoralis (adult)	Acute (% mort)	5 days (exposed)	Crude (various)	Whole oil % asphaltenes	Lethality	Crude oils coded	88
			CT 10	5.8	1		
			CT 18	0.4	55		
			CT 4	2.8	63		
			CT 14	5.0	57		
			CT 12	1.4	85		
			CT 6	1.4	72		
			CT 5	0.5	56		
			CT 7	0.7	48		
			CT 11	0.5	52		
			CT 9	0.7	21		
			CT 19	0.1	17		
			CT 8	0.17	32		
			CT 17	0.4	70		
			CT 16	0.0	29		
			CT 20	0.1	44		
			Ct 2	0.05	74		
			CT 1	0.05	89		
			CT 15	0.0	52		
			CT 3	0.0	83		
			CT 13	0.0	64		
Littorina littorea (adult)	Acute (% mort)	(exposure)	Crude	Whole oil	Lethality		30
		6 min			12%		
		30 min			10%		
		1 hr			20%		
		6 hr			62%		

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Littorina Littorea	Acute (% mort)				Lethality		30
		6 hr (exposure)	Crude	Whole	34%	14°C	
			Crude (residue)	Whole	0%	14°C	
Littorina littorea	Acute (TD_{50})	10 hr	Crude	11%	Lethality	4.6°C	48
		12 hr		12.5%		4.6°C	
		2 hr		11%		11.0°C	
		4 hr		12.5%		11.0°C	
Littorina obtusata	Acute (% mort)				Lethality		30
		6 hr (exposure)	Crude	Whole	44%	10°C	
			Crude (residue)	Whole	0%	10°C	
Littorina saxatilis rudis	Acute (% mort)				Lethality		30
		6 hr (exposure)	Crude	Whole	80%	18°C	
			Crude (residue)	Whole	0%	18°C	
Littorina sitkana	Acute (TLm)			(ppm)			
		24 hr	Cook Inlet	>20.97	Lethality		103
		96 hr	Crude	>20.97	Lethality		
Littorina sitkana	Acute (TLm)		Cook Inlet	mg/l (GC)		Alaskan sp.	101
		96 hr	Crude	>8.46	Lethality		

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Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Macoma balthica	Acute (ECM)	2 mo	Prudhoe Bay Crude	1.2, 2.4, 5 $\mu l/cm^2$ per day	lethality	Arctic species 8-18°C	123
	Chronic (Burrowing)	3 days	WSF static	0.436 ppm	Behavior		
		11 days		0.036 ppm	Lethality		
		3 days	WSF flow-through	0.367 ppm	Behavior		
				0.019 - 0.302 ppm	ϕ Lethality		
		1 day	Oil-contaminated sediment	0.5 μm 0.669 μm	Lethality Behavior		
Macoma balthica (linnaeus)	Acute Chronic	exposures up to 60 days	Prudhoe Bay Crude (Oil slicks, WSF, and Oil-treated sediment)		Lethality and Behavior		75
Macoma balthica	Bio-accumulation	180 days	Prudhoe Bay Crude	0.03 0.3 3.0 mg/l	Accumulation & Depuration Measured		26
	Sublethal	180 days	Prudhoe Bay Crude	0.03 0.3 3.0 mg/l	Behavior		114
Macoma calcarea	Chronic (Field Survey)	2 days to 4 years	Aged crude (experimental spill)	variable	Biochemistry (Body burdens)	Subarctic species	15

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Macoma inquinata	Chronic (Bioaccumulation)	7 days 40 days 60 days	Prudhoe Bay Crude and C^{14} polycyclic aromatic hydrocarbons	contaminated detritus at 2,000 μg/g	Biochemistry (Body burdens)	feeding type considered, deposit feeder	105
Macoma inquinata		54 days	Prodhoe Bay Crude in sediment	1237 ppm	Mortality & Morphology		10
Macoma inquinata	Chronic	60 days	phenanthrene, chrysene, & benzo(a)-pyrene	C^{14} labeled	Ratio of tissue conc. to sediment conc. measured		9
Margarites pupillus	Acute (TLm)	96 hr	Cook Inlet crude	mg/l (GC) >8.46	Lethality	Alaskan sp.	101
Melibe leonina veliger stage	Acute	15 hr	No. 2 diesel oil	0.5% in seawater	100% Mortality		24
Mercenaria mercenaria (clam)	Chronic	24 hr	phenol	0, 1, 10, 100, 1000, 10000, 25000, & 50000 ppb	Histology		41

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Mercenaria mercenaria (juvenile)	Acute (% mort)	4 mo 4 mo 4 mo 20 days	WSF of No. 2 fuel oil	0.006 ppm 0.06 ppm 0.54 ppm 10.6 ppm	0 Lethality 0 Lethality 1.6 Lethality 100.0 Lethality		125
Modiolus demissus (adult)	Acute		WSF Bunker C oil	5.53 ppm	Lethality (ϕ%)	12-18% sal.	14
Monodonta lineata	Acute (% mort)	6 hr exposure	Crude Crude (residue)	Whole Whole	Lethality ϕ/6% ϕ/ϕ%	14/17°C 14/17°C	30
Mopalia cilliata	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >8.46	Lethality	Alaska sp.	101
Mya arenaria	Chronic (Field survey)	6 yr exposure	Bunker C oil ("Arrow" spill)	Dosing over period of recovery i.e. natural	Growth (Length and Weight)	Significantly lower at oiled stations	124
Mya arenaria	6 yr and Older	Chronic (bioaccumulation, biomagnification and field survey)	4 days and 6 yr	No. 2 Fuel oil ("Arrow" spill). WSF of: Kuwait Crude & No. 2 fuel in lab study	Biochemistry (no induction of aryl hydrocarbon hydroxylase AHH)	Lack of AHH presents an opportunity for food chain transfer (unaltered)	127

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Mya arenaria (x, 25 mm)	Chronic (Bio-accumulation)	28 days	No. 2 oil	ppm 10, 50, 100 single dose	Metabolism (Respiratory Rates)	Lowest dose (10 ppm) appeared to cause most significant and long-lasting effect.	111
Mya arenaria	Chronic (Field survey)	6 yr	Bunker C oil	Sediment loads as great as 3800 g/g	Growth (Shell and Tissue) Biochemistry (Body burdens)	Population under stress 6 yr after "Arrow" spill	45
Mya arendria	Sublethal Field	Up to 4 years after exposure	No. 2 fuel oil mixed with JP5 jet fuel	Variable	Histopathological Study		11
Mya truncata	Chronic (Field study)	2 days to 4 yr	Aged Crude (experimental spill)	Variable	Biochemistry (Body burdens)	Subarctic species	15
Mytilus californianus (adult)	Acute (% mort)	48 to 56 days	Crude	10,000ppm	Lethality 0-100%		57

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Mytilus edulis	Chronic	1 wk and 5 wk	WSF of Northsea Crude	µg/l 20-35	Growth (Test for growth) Mussels Biochemistry (lysosomal latency)	Scope for growth depressed in dosed in 1 and 5 weeks. Paper presents several good studies.	12
Mytilus edulis (6 yr and older)	Chronic (Bioaccumulation, Biomagnification, & Field survey	4 days and 6 yr	No. 2 fuel oil "Arrow" spill WSF of Kuwait Crude No.2 fuel	ppm variable 4.3-24.9 2.0-1.7	Biochemistry (No Induction of aryl hydrocarbon hydroxylase AHH)	Lack of AHH presents an opportunity for food chain transfer (unaltered)	127
Mytilus edulis	Acute (TLm)	96 hr	Cooke Inlet Crude No. 2 fuel oil	mg/l (GC) >8.97 >1.25	Lethality	Alaskan sp.	101
Mytilus edulis (adult)	Acute (% mort)	6 hr exposure	Crude to Whole oil	N/A	Lethality (0%)	17°C	30
Mytilus edulis (adult)	Acute (TLm)	24 hr 96 hr 24 hr 96 hr	Crude Crude No. 2 fuel No. 2 fuel	>5.15 ppm >5.15 ppm >3.11 ppm >3.11 ppm	Lethality	Cook Inlet Crude Oil	103

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Mytilus edulis (9.8mm, $\bar{x}$)	Chronic (EC_{50})	24 hr 48 hr	No. 2 diesel oil	16.6 ppm 15.0 ppm	Behavior		39
Mytilus edulis (60-70mm)	Chronic (EC_{50})	96 hr	Crude	<1,000 ppm	Behavior		116
Mytilus edulis	Acute (TD_{50})	>10 hr	Crude	11% 12.5%	Lethality 0% Lethality 0%	Test at 4.6°C and 11°C	48
Mytilus edulis (adult)	Chronic (EC_{50})	24 hr 48 hr	WSF of No. 2 Diesel oil	17.0 ppm 15.6 ppm	Growth (Loss of Byssus Thread)		22
Mytilus edulis (blue mussel)	Chronic	7 days	Ekofish Crude oil WSF	3.5 ppm	Freezing Tolerance Measured		6
Mytilus edulis (blue mussel)	Chronic Field Observations	2 day exposure 86 day observation	No. 2 fuel oil	Exposed by oil slick	Depuration of various compounds measured		40

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Mytilus edulis (blue mussel)	Field Observations After spill	12 mo	Eleni V Oil spill	Variable	Accumulation		16
Mytilus edulis (blue mussel)	Chronic	4 wk to 5 mo	North Sea Crude oil WAF (WSF)	7 to 6% μg/l	Accumulation Patterns & Physiological Responses Measured		132
Mytilus gallo-provincialis (larva)	Acute (% mort)	6 hr exposure	Crude	1,000ppm	Lethality (28.4%)		95
			No. 1 Fuel oil	1.000ppm	Lethality (24.4%)		
Neptunea lyrata	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >10.58	Lethality	Alaskan sp.	101
Notoacmaea pelta	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >8.46	Lethality	Alaska sp.	101
Notoacmaea scutum	Acute (TLm)	96 hr	Cook Inlet Crude	3.65	Lethality		103
		24 hr	No. 2 fuel	>4.19	Lethality		
		96 hr	No.2 fuel	5.04	Lethality		

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Nucella lima	Acute (TLm)	24 hr 96 hr	Cook Inlet Crude oil	>20.97 ppm >20.97 ppm	Lethality		103
Ostrea edulis 6 yr or older	Chronic (Bioaccumulation, Biomagnification and Field survey)	4 days and 6 yr	No. 2 fuel ("Arrow" spill) WSF of Kuwait Crude No. 2 fuel	ppm variable 4.3 to 24.9 2.0 to 1.7	Biochemistry (No Induction of aryl hydrocarbon hydroxylase AHH)	Lack of AHH presents an opportunity for food chain transfer (unaltered)	127
Patella vulgata	Chronic	Exposure 6 hr 12 hr	Crude	Whole	Behavior 40-60% 30-55%	Detachment not a sign of mortality	36
Patella vulgata	Acute (Chronic)	6hr (exposure)	Crude Crude (Residue)	Whole Whole	Lethality 100% 0%	12°C 12°C	30
Pecten opercularis (45-70 mm)	Acute (LC_{50})	96 hr	Crude	<1,000 ppm	Lethality		116
Protothaca staminea	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >6.84	Lethality	Alaska sp.	101

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Protothaca staminea	Chronic (Bioaccumulation)	40 days 60 days	Prudhoe Bay Crude in Field Test	Contaminated Sediment	Biochemistry (Body burdens)	Feeding type considered, suspension feeder	105
Protothaca staminea	Acute (TLm)	96 hr 96 hr	Cook Inlet Crude No. 2 fuel oil	>14.7 ppm >2.11 ppm	Lethality		103
Protothaca staminea		54 days	Prudhoe Bay Crude in sediment	1237 ppm	Mortality & Morphology		10
Pyrgohydrodiadubia	Acute (Survival days)	12 days 6 days	WSF Crude	4.0 14.0	Lethality		59
Thais lamellosa	Chronic (EC_{50})	36 hr 48 hr	WSF of No. 2 diesel oil.	11.3 ppm 59.0 ppm	Unknown Unknown		22
Thais lima	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l (GC) >8.46 >3.36	Lethality	Alaska sp.	101

Table B-3. Toxicity of Petroleum to Mollusks

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Urosalpinx cinerea (oyster drill)	Acute	6 hr dosing 5 day depuration	Kuwait Crude oil & Corexit 9527 oil dispersant	Various concentrations of oil, dispersant and a mixture of the two	Mortality Behavior		87
	Chronic	Up to 7 weeks	Nigerian Crude oil in clay	0 to 10 mg/l	Growth and Feeding Measured.		38
Urosalpinx cinerea	Chronic (Field survey)	3 yr	No. 2 fuel oil	Results of spill	Histology (Genetic comparisons) Reproduction (Ecological reestablishment)		27
Venus mercenaria	Acute (mort)	12.5 days	Crude	Unknown	ϕ Lethality		25
			Diesel	Unknown	ϕ Lethality		
			Lubricating	Unknown	ϕ Lethality		
			Fuel	Unknown	ϕ Lethality		

Table B-4. Toxicity of Petroleum to Echinoderms

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Asterias forbesi (common starfish)	Acute	6 hr dosing 5 day depuration	Kuwait Crude oil & Corexit 9527 oil Dispersant	Various concentrations of oil, dispersants & a mixture of both	Mortality Behavior		87
Crossaster papposus (larvae)	Acute	200 hr	No. 2 Diesel oil	0.5%	Lethality		24
Cucumaria vega	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >6.84	Lethality	Alaska sp.	101
Cucumaria vega cf.	Acute	96 hr	Crude	>14.7	Lethality	4-12°C	103
Dendraster excentricus (larvae)	Acute	21 hr	No. 2 Diesel oil	0.5%	Lethality		24
Eupentacta quinquesemita	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >12.29	Lethality	Alaska sp.	101
Eupentacta quinquesemita	Acute	96 hr	No. 2 fuel & Crude oil	>6.9 ppm	Lethality	4-12°C	103
Leptasterias hexactis	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l(GC) >10.58 >3.36	Lethality	Alaskan sp.	101

Table B-4. Toxicity of Petroleum to Echinoderms

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Luidia foliata (larva)	Acute	15 hr	No. 2 Diesel oil	0.5%	Lethality		24
Patiria miniata embryos (bat starfish)	Chronic	Up to 48 hrs	Prudhoe Bay Crude WSF	100% WSF	Growth measured vs time exposed		34
	Chronic effects of embryos from parental exposure	48 hrs	Prudhoe Bay Crude vs Monterey Zone vs Rincon Zone vs Isla Vista seep.	Up to 100% WSF	Growth measured		109
Piaster ochraceous (larva)	Acute	12 hr	No. 2 Diesel oil	0.5%	Lethality		24
Strongylocentrotas drobachiensis	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) >10.58	Lethality	Alaskan sp.	101
Stongylocentrotas purpyratus (eggs)	Acute	4 hr	Jet, Diesel, heating oil and Crude	12.5%	Lethality and Growth		2

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Acanthomysis pseudomacropsis	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l (GC) >9.02 2.31	Lethality	Alaska sp.	101
Acanthomysis pseudomacropsis	Acute (TLm)	96 hr 96 hr	WSF/Cook Inlet Crude No. 2 fuel	ppm (IR) >8.99 >0.95	Lethality		103
Acartia clausi	Acute (Survival)	24 hr	Crude oil Black oil Solar oil	ppm 10-50 50-100	Lethality Little diff. Great diff. in Survival	Great variation in test results	79
Arisogammarus locustoides	Acute (mort)	96 hr 96 hr	Treated: Puget Sound ballast H_2O Valdez ballast H_2O	ppm to 33 7.4 and 5.6	Lethality None None None		133
Anisogammarus sp.	Acute (LC_{50})	48 hr	WSF of: No. 2 Diesel oil	ppm 100.0	Lethality	Only one contested	39
Anonyx nugax (amphipod)	Acute (LC_{50})	8 days	Naphthalene @ 4.8+/-0.5 6.9+/-0.4 9.6+/-0.3 $\bar{x}$=7.1+/-2.4 °C	1.95 1.20+/-0.07 1.52+/-0.07 1.56+/-0.11 ppm	Lethality	Arctic	99

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Anonyx nugax (Amphipod)	Acute (LC_{50})	8 days	Cook Inlet Crude WSF @ 3.5+/-0.3 °C	2.26+/-0.093 ppm	Lethality	Auke Bay Collected	99
Anonyx nugax (amphipod)	Acute (LC_{50})	4 days	Naphthalene @ 4.8+/-0.5 6.9+/-0.4 9.6+/-0.3 $\bar{x}$=7.1+/-2.4 °C	 2.7+/-0.10 2.06+/-0.05 1.84 2.20+/-0.13 ppm	Lethality		99
Atylus carinatus	Acute (% mort)	96 hr	Dispersion (Normal wells)	ppm 300-1000	Lethality 15%	Crude	93
Balanus cariosus (larva)	Acute ($\bar{x}$ Survival)	12 hr	No. 2 Diesel oil	0.5%	Lethality		24
Balanus crenatus	Acute (% mort)	96 hr	Crude (Normal wells)	ppm 30-1000	Lethality 73%	Arctic sp.	93
Balanus glandula	Acute (TLm)	 24 hr 96 hr	WSF of: Cook Inlet Crude	ppm(IR) >8.51 >8.51	Lethality		103

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Boeckosimus (=onisimus) alfinis	Long-term Chronic & Acute	3 days to 16 wk	Prudhoe Bay Crude WSF	1 ppm 1 p/hund thou 1 p/ten thou 1 p/thou 1 p/ten	Mortality Behavior	Arctic	19
Boeckosimus nanseni (amphipod)	Acute (LC_{50})	4 days	Cook Inlet Crude WSF @ 3.4°C	5.462+/- 0.533 ppm	Lethality	Prudhoe Bay (Arctic)	99
		8 days	"	4.879+/- 0.33 ppm	"	"	99
Boeckosimus nanseni (amphipod)	Acute (LC_{50})	4 days	Naphthalene @		Lethality	Arctic	99
			6.9+/-0.4	4.02+/-0.12			
			9.6+/-0.3	2.88+/-0.09			
			$\bar{x}$=6.6+/-2.2	3.45+/-0.57			
		8 days	Naphthalene @				
			4.8+/-0.5	5.26+/-0.12			
			5.0+/-1.8	3.36			
			6.9+/-0.4	2.49+/-0.05			
			9.6+/-0.3	2.88+/-0.09			
			$\bar{x}$=6.6+/-2.2	3.45+/-0.24			
Calanus hyperboreas	Acute (% mort)		Dispersion of:	ppm	Lethality	Crude oils	93
		96 hr	Atkinson Pt	300-1000	0		
		96 hr	Venezuelan	300-1000	0		
		96 hr	Norman Wells	300-1000	10		
		96 hr	Pembina	300-1000	37.5		

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Callinectes sapidus (blue crab)	Chronic	120 sec exposure	Prudhoe Bay Crude WSF	0.15 mg/l max.	Behavior Perception of WSF was measured		90
Calliopius laeviusculus	Acute (LT_{50})	Minutes exposure		Whole	Lethality	Temp. °C	22
		103	No. 2 Diesel			15.5+/-0.4	
		531	Mineral oil			13.3+/-0.4	
Carcinus maenas	Acute (LC_{50})	48 hr	Phenol	ppm 56.0	Lethality		84, 94
Cancer magister (larva)	Acute			ppm	Lethality	Alaskan	102
	(TLm)	48 hr	Cook Inlet	>7.1			
	(ECm)	48 hr	Crude oil	1.6			
	(TLm)	48 hr	Prudhoe Bay	>5.5			
	(ECm)	48 hr	Crude oil	2.14			
Cancer magister dana (dungeness crab) larval stages	Acute	48 hr and 96 hr	Prudhoe Bay Crude (WSF)	.0083 mg/l max.	Lethality	Alaskan	20
			Naphthalene	0.17 mg/l max.			
			Benzene	7.0 mg/l max.			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Cancer magister dana (dungeness crab) larval stages	Chronic	60 days	Prudhoe Bay Crude (WSF) Naphthalene Benzene	.0083 mg/l 0.17 mg/l .0083 mg/l	Development	Alaskan	20
Cancer magister	Acute (LC_{50})	96 hr	Ballast water treatment effluent.	ppm 1.7	Lethality		4
Cancer magister (dungeness crab) larval stages	Acute Chronic	96 hr 60 days	Cook Inlet Crude Naphthalene	0.22 ppm total hydrocarbons Lowest effective conc.	Lethality Growth	Alaskan	21
Cancer magister	Acute (TLm)	96 hr	No. 2 fuel oil	ppm 4778 +/-1071	Lethality	Alaskan	129
Cancer productus (larva)	Acute (TLm)	96 hr 96 hr 96 hr	No. 2 fuel oil Crude (a) Crude (b)	ppm 4 200 250	Lethality		129
Cancer productus	Acute (LT_{50})	min 730	No. 2 Diesel oil	Whole	Lethality	13.1°C	22

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Centropages ponticus	Acute (Survival)	24 hr	Black oil	ppm 10-50 50-100	Lethality Little diff. Great diff. in Survival	Large variation in results	79
Chionoecetes bairdi (juvenile)	Acute (TLm)		Prudhoe Bay Crude	ppm	Lethality	Subarctic Species	58
premolt		24 hr		560			
		96 hr		560			
post molt		24 hr		830			
		96 hr		560			
Chionoecetes bairdi (larva)	Acute (TLm) (ECm)	 96 hr 96 hr	Cook Inlet Crude (treated)	ppm >10.8 1.7	Lethality	Subarctic Species	102
Corophium clarencense	Acute (% mort)	96 hr	Dispersion Normal wells	ppm 300-1000	Lethality 67.5%	Crude oil	93
Crangon alaskensis	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	µg/l (GC) 0.87 0.36	Lethality	Alaskan sp.	101
Crangon crangon (brown shrimp)	Chronic	42 days	Eleni V. Oil spill oil	Up to 500 µg/l	Mortality Behavior Accumulation Growth		16
Crangon crangon	Acute (LC_{50})	48 hr	Phenol	ppm 23.4	Lethality		84, 94

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Eliminius modestus (spat)	Chronic		Crude oil surf. film	ppm			28
		4 hr		100	>50% normal cirral beat		
		48 hr		100	28% normal cirral beat		
		4 hr		100	50% normal cirral beat		
		48 hr		100	10% normal cirral beat		
Eliminius modestus (Stage II nauplius)	Chronic	24 hr	Suspension in Crude	ppm	Behavior:		28
				1000	Loss of Swimming		
				100	No change		
Eliminius modestus (larva)	Acute (LC_{50})	1 hr	Fresh Crude	ppm 100	Lethality		84, 94
Eualus fabricii (larva)	Acute		WSF of	ppm(IR)	Lethality	Subarctic sp.	102
	(TLm)	96 hr	Cook Inlet	5.89			
	(ECm)	96 hr	Crude (treated)	0.95			
	(TLm)	96 hr	Prudhoe Bay	6.36			
	(ECm)	96 hr	Crude	1.29			
Eualus fabricii	Acute (TLm)		WSF of	ppm (IR)	Lethality	Subarctic sp.	103
		24 hr	Cook Inlet	2.52			
		96 hr	Crude	1.46			
		24 hr	No. 2	0.91			
		96 hr	fuel oil	0.53			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Eualus fabricii	Acute		WSF of:	ppm(IR)	Lethality	Subarctic	102
	(TLm)	96 hr	Prudhoe Bay Crude	1.94			
		96 hr	Cook Inlet (treated)	3.17			
		96 hr	Cook Inlet Crude	4.34			
		96 hr	No. 2 fuel oil	0.53			
			OWD of:				
		96 hr	Prudhoe Bay Crude	13.91			
		96 hr	Cook Inlet (treated)	10.06			
Eulalus suckleyi	Acute		Ballast	ppm	Lethality		98
	(LC_{50})	96 hr	water	0.4		April 17	
			treatment	1.2		April 22	
			effluent				
Eualus suckleyi	Acute		Cook Inlet	mg/l (GC)	Lethality	Alaska	101
	(TLm)	96 hr	Crude	1.86		sp.	
			No. 2 fuel oil	1.10			
Gammaracanthus loricatus (amphipod)	Acute (LC_{50})	4 days	Naphthalene @ 2.05+/-0.5	2.29 ppm	Lethality	Arctic	99
		8 days	Naphthalene @ 2.05+/-0.5	2.09 ppm			

Table B-5 Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Gammaracanthus loricatus (amphipods)	Acute (LC_{50})	8 days	Cook Inlet Crude WSF @ 2.0+/-0.5 °C	>1.729	Lethality	Prudhoe Bay Collected (Arctic)	99
Gammarus macronatus	Acute (TL_{50})	48 hr	WSF of Bunker C	ppm 0.42	Lethality		14
Gammarus marino gammarus olivii	Acute (% Survival)	10 days	Crude	ppm	Lethality		77
(adult)				1000	0		
				100	100		
				10	80		
				1	100		
(juvenile)				1000	0		
				100	0		
				10	20		
				1	50		
Ghorimosphaeroma oregonesis oregonesis	Acute (LT_{50})	Minutes exposure	No. 2 Diesel oil	Whole	Lethality	Temp. °C	22
		1360				10.9+/-0.7	
		1040				13.8+/-0.7	
		403				20.2+/-0.5	
		392				25.0+/-0.4	
		119				30.0+/-0.6	
		3400	Mineral oil			12.9+/-0.7	
		2120				18.5+/-1.7	

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Hemigrapsis nudus	Acute (TLm)	96 hr	Cook Inlet crude	mg/l(GC) 8.45	Lethality	Alaskan sp.	101
Hemigrapsus nudus	Acute (LT_{50})	Min. exposure	Mineral oil	Whole	Lethality	Temp. (°C)	22
		1,770				12.8+/-0.7	
		835				20.2+/-0.3	
Hemigrapsus nudus	Acute (LT_{50})	Min. exposure	No. 2 diesel oil	Whole	Lethality	Temp. (°C)	22
		812				14.0+/-1.0	
		364				20.5+/-0.4	
		149				2.50+/-0.1	
		42				30.5+/-0.8	
Hemigrapsus oregonensis	Acute (Mortality)	96 hr	Treated Valdez ballast water	Percent	Lethality		133
				1	0		
				3	0		
				10	0		
				30	0		
				100	0		
Hemigrapsus oregonensis	Acute (LT_{50})	Min. exposure	No. 2 diesel oil	Whole	Lethality	Temp. (°C)	22
		1,795				12.0+/-0.4	
		1,305				14.5+/-1.1	
		835				17.4+/-0.7	
		295				20.3+/-0.5	
		675				20.3+/-0.5	
		235				25.0+/-0.5	
		57				30.2+/-0.5	

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Hemigrapsus oregonensis	Acute (LC_{50})	48 hr	WSF No. 2 diesel	ppm 3,000	Lethality		39
Homarus americanus (lobster)	Chronic		Crude oil	0.9 ml/ 100 liters seawater	Behavior Chemo-sensory		7
Homarus americanus	Chronic		WSF	50 ppb			7
Homarus americanus (larva)	Acute (LC_{50})		Crude (Dispersion)	ppm	Lethality		131
1st stage		96 hr		0.86			
3rd & 4th stage		96 hr		4.90			
1st stage		30 days		0.14			
Homarus americanus (larva)	Acute (LC_{50})		Crude (Emulsions)	ppm	Lethality		130
		24 hr		100	100%		
		96 hr		10	variable		
		96 hr		1	low		
		96 hr		0.1	low		
		96 LC_{50}		2-30	LC_{50}		
Idothea baltica basteri (adult)	Acute (Survival)	10 days	Crude	ppm	Lethality		77
				1,000	75%		
				100	90%		
				10	100%		
				1	100%		

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Idothea baltica	Acute		Crude	ppm	Lethality		77
basteri	(Survival)	10 days		1,000	0		
(adult)				100	25		
				10	60		
				1	75		
Idothea fewkesi	Acute		Treated	Percent	Lethality		133
	(mort.)	96 hr	Valdez	1	0		
			ballast	3	0		
			water	10	0		
				30	0		
				100	0		
Idothea tribola	Acute		WSF of	ppm	Lethality		14
	(TL_{50})	48 hr	Bunker C	5.53	No effect		
Idothea	Acute		WSF of Cook	ppm (IR)	Lethality		103
wosnesenskii	(TLm)	96 hr	Inlet Crude	>8.99			
			No. 2				
		96 hr	fuel oil	>5.59			
Leander adspersus	Acute (TL_{50})	96 hr	Oil	50 ppm	Lethality		80
Leander adspersus	Acute		Crude	ppm	Lethality		166
var. *Fabricii*	(LC_{50})	96 hr		<1,000			
Rathke	Chronic		Crude	350	Behavior (locomotion)		

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Leander terruicornis	Acute (LC_{50})		WSF of:	ppm (IR)	Lethality		83
		48 hr	S. LA	10.2			
		96 hr	Crude	6.0			
Limulus polyphemus (horseshoe crab)	Acute	Through first 3 Instar Development	No. 2 fuel oil	0 to 50% WSF	Lethality, development rate, and respiration		68
Eggs & larvae	Chronic						
Mesidatea entomon	Chronic	160 days	WSF of:	% of stock	Growth (length & molting times, includes intermolt period).	Arctic sp.	92
			Norman Wells Crude	100, 50, 10			
			Pembina Crude	100, 50, 10	Small effect on growth (length). High concentration increased intermolt period.		
			Norman Wells (weathered)	100, 50, 10			
Mesidotea entomon	Acute (LT_{50})	41 days	WSF of:	ppm	Lethality	Arctic sp.	92
			Norman Wells Crude	1.71	17 days		
			Pembina Crude	0.50	17 days		
			Norman Wells (weathered)	1.01	41 days		
Mesidotea entomon	Acute (% mort.)		Dispersion	ppm	Lethality		93
		96 hr	Norman Wells	300-1,000	0	Crude	

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Mesidotea sabini	Acute (% mort.)	96 hr	Dispersion Norman Wells	ppm 300-1,000	Lethality 0	Crude oil	93
Mesidotea sibirica	Acute (% mort.)	96 hr	Dispersion Norman Wells	ppm 300-1,000	Lethality 0	Crude	93
Mysidopsis almyra	Acute (LC_{50})		WSF of:	ppm	Lethality		83
		48 hr	S. LA	8.7			
		96 hr	Crude	-			
Mysidopsis almyra	Acute (TLm)		S. LA Crude	ppm	Lethality		5
		48 hr	OWD	37.5			
		48 hr	WSF	8.7			
			Kuwait				
		48 hr	OWD	63.0			
		48 hr	WSF	6.6			
			No. 2 fuel				
		48 hr	OWD	1.3			
		48 hr	WSF	0.9			
			Bunker C				
		48 hr	WSF	0.9			
Mysis relicia (mysid)	Acute (LC_{50})	4 days	Naphthalene @ 4.4°C	2.0 ppm	Lethality	Arctic	99
		4 days	Cook Inlet Crude WSF @ 4.4°C	2.60 +/-0.52 ppm	Lethality	Prudhoe Bay (Arctic)	99

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Neohaustorius biarticulatus	Acute (LD_{50})		No. 2 fuel	ppm	Lethality		108
		36 hr	Turbulent stirring	25			
		72 hr	Slow stirring	25			
		24 hr	Clean sand & oil	50			
Neomysis awatschensis	Acute (LC_{50})		Emulsion No. 2 diesel oil	ppm (IR)	Lethality		22
		24 hr		327			
		48 hr		112			
Neomysis sp.	Acute (LC_{50})		WSF of: No. 2 diesel oil	ppm	lethality		39
		24 hr		350.0			
		48 hr		95.0			
Neopanope texana (larva)	Acute (LC_{50})	96 hr	WSF of: Crude	ml/L 10	Lethality	(Taken from graph)	60
Oithona nana	Acute (Survival)	24 hr	Black oil	ppm	Lethality	Large variation in results	79
				10-50	Little diff.		
				50-100	Great diff. in survival		
Onisimus affinis (Boekisimus)	Chronic	96 hr	Crude oil WSF (Pembina, Atkinson Point, Norman Wells, & Venezuelan)	0 to 10,000 ppm	Respiration		91

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Onisimus affinis	Acute			ppm	Lethality	Oil and SW	93
	(% mort.)	96 hr	Norman Wells	300-1,000	95	dispersion	
		96 hr	Venezuelan	300-1,000	100	of Crudes	
		96 hr	Atkinson Pt.	300-1,000	88		
		96 hr	Pembina	300-1,000	25		
		96 hr	Venezuelan	20-200	18		
		96 hr	Norman Wells	20-200	33		
Orchestia	Acute	Min. exposure	No. 2	Whole	Lethality	temp (°C)	22
traskiana	(LT_{50})	152	diesel oil			12.2+/-0.3	
		134				13.4+/-0.4	
		104				19.7+/-0.7	
		106				24.8+/-0.5	
		2,900	Mineral oil			13.7+/-0.6	
		1,650				20.4+/-0.7	
Orchomene	Acute (TLm)		Cook Inlet	mg/l (gc)	Lethality	Alaskan sp.	101
pinguis		96 hr	Crude	>7.98			
			No.2				
			fuel oil	>1.74			
			WSF of:	ppm (IR)	Lethality		103
		24 hr	Cook Inlet	>7.40			
		96 hr	Crude	>7.40			
			No. 2				
		96 hr	fuel oil	>1.34			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Pachygrapsus	Acute	Min. exposure		ppm	Lethality		80
marmoratus	(% survival)	5	oil	100	25%		
(larva)		5	Bunker C	100	15%		
		5	Solar oil	100	10%		
		30	oil	100	10%		
		30	Bunker C	100	20%		
		30	Solar oil	100	0%		
		60	oil	100	0%		
		60	Bunker C	100	0%		
		60	Solar oil	100	0%		
Pagurus	Acute	Min. exposure	No. 2	Whole	Lethality		22
granosimanus	(LT_{50})	350	diesel oil				
Pagurus	Acute	Minutes	No. 2	Whole	Lethality	temp. (°C)	22
hirsutinsculus	(LT_{50})	159	diesel oil			10.1+/-0.1	
		49				20.3+/-1.7	
		34				24.9+/-0.5	
		1,118	Mineral oil			12.0+/-0.7	
		435				16.6+/-0.7	
	Acute		Cook Inlet	mg/l (GC)	Lethality	Alaskan sp.	101
	(TLm)	96 hr	Crude	>10.58			
			No. 2				
			fuel oil	>3.36			
	Acute		Cook Inlet	ppm	Lethality		103
	(TLm)	96 hr	Crude	3.1			
			No. 2				
		96 hr	fuel oil	>5.59			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Pagurus longicarpus	Acute		No. 2	ppm	Lethality		108
	(LD_{50})	12 hr	fuel oil	50			
			WSF of				14
	(LT_{80})	48 hr	Bunker C	0.62			
Palaemonetes pugio (grass shrimp)	Life history	72 hr	No. 2 fuel oil, naphthalene	1.44 ppm hydrocarbon	Respiration, hatching success, growth		120
	Acute		WSF No. 2	ppm (IR)	Lethality		125
	(% mort.)	control 4 mo.	fuel oil	0.006	0.8%		
		4 mo.		0.067	6.2%		
		100 days		0.54	73.8%		
		6 days		10.6	100%		
	Acute		WSF of	ppm	Lethality		83
	(LC_{50})	48 hr	S. LA	>16.8			
		96 hr	Crude	>16.8			
	Chronic	32 days (exposure) 16 days (recovery)	Dimethyl-naphthalene and Fluctuating temperature and reduced salinity	µg/g of food 0.24	Metabolism under stressed conditions (temp., reduced O_2 and salinity)	Increased resistance to hyooxia by shrimp fed contam-inated food.	37

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Palaemonetes pugio (grass shrimp)	Acute (TLm)	48 hr	WSF of:	ppm	Lethality	temp. (°C)	121
			S. LA Crude	<16.80		21	
			Kuwait	<10.20		21	
			No. 2 fuel	5.50		21	
			Bunker C	3.43		21	
			S. LA Crude	15.70		24	
			S. LA Crude	10.70		32	
			benzene	33.00		21	
			naphthalene	2.35		21	
			methylnaphthalene	1.00		21	
			dimethylnaphthalene	0.70		21	
			phenol	20.0		21	
	Acute (TLm)		S. LA Crude	ppm	Lethality		5
		48 hr	OWD	1,650			
		96 hr	OWD	200			
		48 hr	WSF	>16.8			
		96 hr	WSF	>16.8			
			Kuwait				
		48 hr	OWD	9,000			
		96 hr	OWD	6,000			
		48 hr	WSF	>10.2			
		96 hr	WSF	>10.2			
			No. 2 fuel				
		48 hr	OWD	3.4			
		96 hr	OWD	3.0			
		48 hr	WSF	4.1			
		96 hr	WSF	3.5			
			Bunker C				
		48 hr	WSF	2.8			
		96 hr	WSF	2.6			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Pandalus borealis	Acute (TLm)		WSF of:	ppm (IR)	Lethality	Arctic/	102
		96 hr	Prudhoe Bay			subarctic	
			Crude	2.11		sp.	
		96 hr	Cook Inlet				
			Crude				
			(treated)	2.43			
	Acute (TLm)		WSF of:	ppm (IR)	Lethality	Arctic/	103
		24 hr	Cook Inlet	2.89		subarctic	
		96 hr	Crude	2.43		sp.	
		24 hr	No. 2	0.38			
		96 hr	fuel oil	0.21			
	Acute (TLm)		Cook Inlet	mg/l (GC)	Lethality	Alaskan sp.	101
		96 hr	Crude	4.94			
Pandalus danae	Acute	Index	Prudhoe Bay	ppm	Lethality		4
	(Toxicity	15.7+/-5.2	Crude	2.6-5.4		winter & fall	
	Index --	3.5+/-1.8		1.5-5.9		spring & summer	
	ppm-days)						
		18.0+/-7.8	Prudhoe Bay	2.8-12.6		winter & fall	
		8.1+/-0.8	Crude with	2.3-7.6		spring & summer	
			a dispersant				
	Acute	24 hr	Filtered	ppm (IR)	Lethality	Alaskan	13
	(% mort.)		SW extract	0.6	0		
			Prudhoe	1.2	20		
			Crude	2.3	100		
				3.3	100		

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Pandalus danae	Acute	24 hr	Unfiltered	ppm (IR)	Lethality	Alaskan	13
	(% mort.)		SW extract	0.6	0		
			Prudhoe Bay	1.2	80		
			Crude	2.3	100		
				3.3	100		
			Filtered	0.6	0		
			SW extract	1.2	0		
			S. LA Crude	2.3	60		
				3.3	100		
			Unfiltered	0.6	0		
			SW extract	1.2	100		
			S. LA Crude	2.3	100		
				3.3	100		
			WSF	1.86	100		
			Prudhoe Bay	1.02	10		
			Crude oil	0.56	10		
	Acute			ppm	Lethality	Alaskan	103
	(TLm)	24 hr	Cook Inlet	0.95			
		96 hr	Crude	0.81			
		24 hr	No. 2	1.68			
		96 hr	fuel oil	1.11			
	Acute		OWD	ppm	Lethality	Alaskan sp.	126
	(LC_{50})	72 hr	No. 2	1.3			
		96 hr	fuel oil	0.8			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Pandalus	Acute		Cook Inlet		Lethality	Subarctic	102
goniurus	TLm	96 hr	Crude	1.72			
(larva)	ECm	96 hr	(treated)	1.69			
Pandalus	Acute		Cook Inlet	mg/l (GC)	Lethality	Alaskan sp.	101
goniurus	(TLm)	96 hr	Crude	1.79			
	Acute		WSF of:	ppm (IR)	Lethality	Subarctic	102
	(TLm)		Prudhoe Bay			sp.	
		96 hr	Crude	1.26			
			Cook Inlet				
			Crude				
		96 hr	(treated)	1.98			
			Cook Inlet				
		96 hr	Crude	1.85			
		96 hr	No. 2 fuel	1.69			
			OWD of:				
			Prudhoe Bay				
		96 hr	Crude	2.31			
			Cook Inlet				
			Crude				
		96 hr	(treated)	4.13			
	Acute		WSF of:	ppm (IR)	Lethality		103
	(TLm)	24 hr	Cook Inlet	2.31			
		96 hr	Crude	1.98			
			No. 2 fuel				
		96 hr	oil	1.69			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Pandalus hypsinotus (post-larval)	Bioaccumulation	144 hr exposure 48 hr depuration	Tritiated naphthalene	6ppb	Accumulation and depuration measured		71
Pandalus hypsinotus	Acute (TLm)		WSF of:	ppm (IR)	Lethality	Arctic/ subarctic sp.	102
		96 hr	Prudhoe Bay Crude	1.96			
		96 hr	Cook Inlet Crude	2.72			
Pandalus hypsinotus (coonstrip shrimp) (larvae)	Acute (LC_{50})	96 hr	Cook Inlet Crude WSF	7.94 ppm (stage 1) 4.06 (stage 2)	Lethality		75
	Chronic	144 hr			Percent molting success		75
Pandalus hypsinotus	Acute (LC_{50})	96 hr	Ballast water treatment effluent	ppm	Lethality		98
				1.8		April 22	
				2.1		April 27	
				1.9		May 23	
				1.6		May 27	
				1.5		June 2	

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Pandalus hypsinotus (larva)	Acute (TLm) (ECm)	 96 hr 96 hr	WSF of: Cook Inlet Crude (treated)	ppm (IR) 7.94 1.83	Lethality	Arctic/ subarctic sp.	102
	(TLm) (ECm)	96 hr 96 hr	Prudhoe Bay crude	8.53 0.75		test @ 3.5°C	
Pandalus hypsinotus	Acute (TLm)	24 hr 96 hr	WSF of Cook Inlet Crude	ppm (IR) 2.87 2.72	Lethality	Arctic/ subarctic sp.	42
Pandalus montagui	Acute (LC_{50})	48 hr	phenol	17.5 ppm	Lethality		84, 94
Pandalus platycerus (spot shrimp)	Bioaccumulation	7 days	Prudhoe Bay Crude (WSF)	0.11 ppm	Accumulation	Alaskan	71
Paracalanus parvus	Acute (survival)	24 hr	Black oil	ppm 10-50 50-100	Lethality little diff. Great diff. in survival	Large variation in results	79
Paralithodes camtschatica	Acute (TLm)	 24 hr 96 hr	WSF of: Cook Inlet Crude	ppm 5.16 4.21	Lethality	Arctic/ Alaskan	103
		96 hr	No. 2 fuel oil	5.10			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Paralithodes camtschatica (king crab) (larva)	Acute (LC_{50})	96 hr	Cook Inlet Crude WSF	2.00 ppm (stage I) 1.33 (molting larvae)	Lethality	Alaskan	21
	Chronic	144 hr	Cook Inlet Crude WSF	0 to 1.87 ppm	Percent molting success	Alaskan	75
	Acute		WSF of:	ppm (IR)	Lethality	Arctic Alaskan	102
	TLm	96 hr	Cook Inlet	3.0			
	ECm	96 hr	Crude (treated)	3.0			
	TLm	96 hr	Prudhoe Bay	>6.4			
	ECm	96 hr	Crude	1.4			
Paralithodes camtschatica	Acute (TLm)		WSF of:	ppm (IR)	Lethality	Arctic Alaskan	102
		96 hr	Prudhoe Bay Crude	2.35			
		96 hr	Cook Inlet Crude	4.21			
		96 hr	No. 2 fuel oil	5.10			
	Acute (TLm)	96 hr		mg/l (GC)	Lethality	Alaskan sp.	101
			Cook Inlet Crude	3.69			
			No. 2 fuel oil	1.02			
	Acute (LC_{50})	96 hr	Ballast water treatment effluent	ppm	Lethality		98
				2.4		April 17	
				1.4		April 22	
				2.5		April 27	

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Penaeus aztecus	Acute		WSF of	ppm	Lethality		83
(larva)	(LC_{50})	48 hr	S. LA	>19.8			
		96 hr	Crude	>19.8			
Penaeus aztecus	Acute		S. LA Crude	ppm	Lethality		5
	(TLm)	48 hr	OWD	>1,000			
		96 hr	OWD	>1,000			
			No. 2 fuel oil				
		48 hr	OWD	9.4			
		96 hr	OWD	9.4			
			Bunker C				
		48 hr	WSF	3.5			
		96 hr	WSF	1.9			
Penillia avirostris	Acute (survival)	24 hr	Black oil	ppm	Lethality	Large variation in results	79
				10-50	little diff.		
				50-100	Great diff. in survival		
Pilumnus hirtellus	Acute (TL_{50})	96 hr	oil	10 ppm	Lethality		80
Porcellana platycheles	Acute			ppm	Lethality		32
	(% survival)	20 days	Crude	10,000			
		20 days		1,000			
Pugettia producta (megalops)	Acute		No. 2	ppm	Lethality		70
	(TLm)	96 hr	fuel oil	>10			
		96 hr	Crude (a)	<100			
		96 hr	Crude (b)	<1,000			

Table B-5. Toxicity of Petroleum to Arthropods

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Pugettia producta (larva)	Acute (TLm)		No. 2	ppm	Lethality		129
		96 hr	fuel oil	10			
		96 hr	Crude (a)	500			
		96 hr	Crude (b)	450			
Trigriopus californicus	Acute (days to 100% mortality)		Crude	1.5 mm thick slick	Lethality		61
		3 days			100%	no aeration	
		5 days	Crude		100%	aeration	
Uca pugnax	Acute Chronic (life cycle, life history, and field survey)	7 years	Fuel oil spill in salt-marsh west of Falmouth, MA	ppm high 6,000 in sediment. >1,000 toxic to adults; 100-200 toxic to juveniles	Lethality reproduction; behavior; biochemistry	Good long term salt-marsh contamination study. Recovery not complete after 7 years.	65, 64

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Alosa sapidissima (juvenile)	Acute (TLm)	24 hr	WSF of	91 ppm	Lethality		119
		48 hr	gasoline	91 ppm			
		24 hr	Diesel	204 ppm			
		48 hr	fuel	167 ppm			
		48 hr	Bunker	2,417 ppm			
		96 hr	#6	1,952 ppm			
Alosa sapidissima (young)	Acute (LC_{50})	48 hr	Gasoline	91 ppm	Lethality		84, 44
		48 hr	Fuel oil	2,417 ppm			
		48 hr	Diesel oil	167 ppm			
Ammodytes hexapterus	Acute (TLm)	96 hr	#2 fuel oil	4,326 ppm	Lethality		129
Anoplarchus purpurescens	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l(GC) >11.72	Lethality	Alaskan sp.	101
Aulorhynchus flavidus	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l(GC) 2.55	Lethality	Alaskan sp.	101

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Aulorhynchus flavidus	Acute (TLm)	96 hr	WSF of: Cook Inlet Crude	1.34 ppm (IR)	Lethality		103
Boreogadus saida (Arctic cod)	Acute LC_{50}	4 days	Cook Inlet Crude WSF @ 2.0+/-0.5	1.569 +/- 0.040	Lethality	Prudhoe Bay collected (Arctic)	99
Borreogadus saida (Arctic cod)	Acute LC_{50}	4 days	naphthalene @ 1.5+/-0.2 2.0+/-0.5 6.4+/-1.1 8.5+/-1.3 X4.6+/-3.4 °C	 1.52+/-0.04 1.24+/-0.09 1.55 1.22+/-0.17 1.38+/-0.05 ppm		Arctic	99
Boreogadus saida (Arctic cod)	Acute LC_{50}	8 days	naphthalene @ 1.5+/-0.2 2.0+/-0.5 6.4+/-1.1 8.5+/-1.3 X4.6+/-3.4 °C	 1.46+/-0.04 1.24+/-0.09 1.46+/-0.05 1.22+/-0.17 1.35+/-0.04 ppm	Lethality	Arctic	99

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Clupea harengus (egg)	Acute (% mort)	140 days	Crude:	ppm:	Lethality	Age at start	66
			Venezuelan	100-10,000	100%	3.5 days	
			Iranian	100-10,000	100%	3.5 days	
			Libyan	100-10,000	90%	4.5 days	
			Libyan	100-10,000		5.5 days	
Clupea harengus pallasii (larva)	Acute (TLm)	96 hr	WSF of Cook Inlet Crude (treated)	3.0 ppm (IR)	Lethality	Arctic Subarctic sp.	102
Clupea harengus pallasi	Acute (LC_{50})	96 hr	Ballast water treatment effluent	1.4 ppm 2.6 ppm	Lethality	May 27 June 2	4
Clupea pallasii	Acute				Lethality		115
(egg)	(TL_{50})	96 hr	benzene	40-45 ppm			
(larva)		48 hr	benzene	20-25 ppm			
Clupea pallasii	Acute (TLm)	96 hr	#2 fuel oil	20 ppm	Lethality		129

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Clupea pallasii	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) 1.22	Lethality	Alaska sp.	101
Clupea sp. (egg)	Chronic	45 hr	"Total hydrocarbons" (North Sea oil)	240 μg/l	Growth (hatching) extended hatching period if concentration > 100 g/l		33
Coryphopterus heptacanthus (marine goby)	Sublethal Feeding	4 days			Threshold limit to appetite decline	Feeding behavior noted	117
				phenol	3 ppm		
				Suspended lamp oil	0.3 ppm		
				Suspended heavy oil	2 ppm		
				Suspended "Mobil" oil	4 ppm		
				Crude oil	0.2 ppm		
Cymatogaster aggregata	Acute (TLm)			ppm (IR)	Lethality		129
(adult)		96 hr	#2 fuel	500+/-80			
(adult)		72 hr	S.LA Crude	1,200			
(adult)		96 hr	Kuwait Crude	1,300+/-260			
(juvenile)		72 hr	S.LA Crude	840+/-80			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Cyprihodon variegatatus	Acute (TLm)		OWD of:	ppm:	Lethality		5
		48 hr	S.LA Crude	33,000			
		96 hr	S.LA Crude	29,000			
		48 hr	Kuwait Crude	80,000			
		96 hr	Kuwait Crude	80,000			
		48 hr	#2 fuel oil	200			
		96 hr	#2 fuel oil	93			
			WSF of:				
		48 hr	S.LA Crude	19.8			
		96 hr	S.LA Crude	19.8			
		48 hr	#2 fuel oil	>6.9			
		96 hr	#2 fuel oil	6.3			
		48 hr	Bunker C oil	4.4			
		96 hr	Bunker C oil	3.1			
Cyprinodon variegatus (sheepshead minnow) (eggs)	Acute Hatching success	8 days	#2 fuel oil WSF	10 ppm total hydrocarbons 2 ppm naphthalenes	Mortality Hatching		3
Cyprinodon variegatus	Acute (LC_{50})	48 hr	WSF of	>19.8 ppm	Lethality		83
		96 hr	S.LA Crude	>19.8 ppm			
Eleginus gracilis	Acute (TLm)		WSF of:	ppm (IR)	Lethality		103
		24 hr	Cook Inlet	2.48			
		96 hr	Crude	2.28			
		24 hr	#2 fuel	>4.56			
		96 hr	oil	2.93			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Engraulis mardax	Acute				Lethality		129
(egg)	(TL_{50})	48 hr	Benzene	20-25 ppm			
(larva)		48 hr	Benzene	20-25 ppm			
Esox lucius	Acute		WSF of	ppm	Lethality		50
I (eyed egg)	(TLm)	24 hr	Russian	>10,000	approx. 0	Dissolved	
		48 hr	Crude	>10,000	approx. 0	fractions	
II (yolk sac)		24 hr	oil	>10,000	approx. 0	of this	
		48 hr		>10,000	approx. 0	Crude seem	
III (free swimming)		24 hr		>10,000	approx. 0	to have	
		48 hr		>10,000	approx. 0	no effect	
IV (1 mo. old)		24 hr		>10,000	approx. 0		
		48 hr		>10,000	approx. 0		
Fundulus heteroclitus	Chronic (Field Survey)	8 yr	#2 fuel oil spill "Florida"	-	Bio-chemistry	Mixed function oxygenase activity indicates marsh not recovered after 8 years	113
Fundulus heteroclitus (mummichog) (eggs)	Acute Hatching Success	8 day	#2 fuel oil WSF	10 ppm total hydrocarbons 2 ppm naphthalenes	Mortality Hatching		3

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Fundulus similis (longnose killifish) (eggs)	Acute Hatching Success	8 days	South Louisiana Crude WSF	20 ppm total hydro- carbons 0.3 ppm naphthalenes	Mortality Hatching Success		3
Fundulus similus	Acute (LC_{50})	48 hr 96 hr	WSF of S.LA Crude	16.8 ppm 16.8 ppm	Lethality		83
Fundulus similus	Acute (TLm)		OWD of:	ppm	Lethality		5
		48 hr	S.LA Crude	6,000			
		96 hr	S.LA Crude	6,000			
		48 hr	Kuwait	14,800			
		96 hr	Crude	14,800			
		48 hr	#2	36			
		96 hr	fuel oil	33			
			WSF of:				
		48 hr	S.LA	16.8			
		96 hr	Crude	16.8			
		48 hr	Kuwait	10.4			
		96 hr	Crude	10.4			
		48 hr	#2	4.7			
		96 hr	fuel oil	3.9			
		48 hr	Bunker	2.27			
		96 hr	C. oil	1.69			
Gadus macrocephalus (cod)	Acute	2 hr		4 ppm	100% Mortality	Alaskan	35

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Gadus morhua (egg)	Acute (% mort)	100 hr	WSF of:	ppm	Lethality	10^4 ppm is approx.	67
			Venezuelan Crude	10,000	40%		
			Iranian	10,000	30%	10 ppm	
			Crude	100	10-17%	dissolved	
			Libyan Crude	2.1-10^6	approx. 0	hydrocarbon	
Gadus morhua	Chronic (Lifecycle)	Age of eggs	WSF of:	ppm	Hatching success		67
		0.5 days	Venezuelan	10,000	20%	10^4 ppm	
		0.5 days	Iranian	10,000	20%	is approx.	
		0.5 days	Libyan	10,000	40%	10 ppm dissolved hydrocarbon	
		4 days	Venezuelan	10,000	25%		
		4 days	Iranian	10,000	40%		
		4 days	Libyan	10,000	95%		
		10 days	Venezuelan	10,000	50%		
		10 days	Iranian	10,000	50%		
		10 days	Libyan	10,000	50%		
Gadus morhua	Acute (LC_{50})	96 hr	Oman Crude	ppm >1,000	Lethality		116

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Gadus morhua	Acute	N/A	WSF of:	ppm	Lethality	Age at transfer	67
(larva)	($\bar{X}$ Critical Time)		Iranian Crude	100	14 days	1 day	
				100	10 days	3 days	
				100	8.2 days	5 days	
				100	5.5 days	10 days	
			Agha Crude	1,000	8.4 days	1 day	
				1,000	7.5 days	3 days	
				1,000	5.9 days	5 days	
				1,000	4.5 days	10 days	
			Jari Crude	10,000	4.2 days	1 day	
				10,000	3.5 days	3 days	
				10,000	2.5 days	5 days	
				10,000	0.5 days	10 days	
Gadus morhua	Acute	140 days	WSF of:	ppm	Lethality	Age at start	66
(egg)	(% mort)		Venezuelan Crude	10,000	30%	0-1 days	
				10,000	40%	3.5 days	
				10,000	20%	10 days	
				1,000	40%	0-1 days	
				1,000	25%	3.5 days	
				1,000	2.5%	10 days	
				100	approx. 0	1-0 days	
				100	approx. 0	3.5 days	
				100	approx. 0	10 days	
			Libyan Crude	10,000	approx. 0		
				1,000	approx. 0		
				100	approx. 0		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Gadus morhua (continued)	Acute	140 days	WSF of:	ppm	Lethality	Age at start	66 cont.
(egg)	(% mort)		Iranian	100	60%	0-1 days	
			Crude	100	approx. 0	3.5-10 days	
				1,000	45%	0-1 days	
				1,000	35%	3.5 days	
				1,000	12%	10 days	
				10,000	70%	0-1 days	
				10,000	60%	3.5 days	
				10,000	5%	10 days	
Hypomesus pretiosus (surf smelt) (eggs & larvae)	Developmental	Through development	Prudhoe Bay Crude SWSF	Various: depending on life stage	Physiology		73
Leptocottus armatus	Acute (TLm)	96 hr	Kuwait Crude	5,600+/- 1,400 ppm	Lethality		129
Lepidopsetta bilineata (rock sole)	Chronic	2 weeks to 4 months	Prudhoe Bay Crude oil contaminated sediments	0.2 to 1.0% (v/v)	Pathology	Arctic	73

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Lepidopsetta bilineata (rock sole)	Acute	20 hr	naphthalene	4 ppm	100% Mortality	Alaskan	35
Mallotus villosus	Acute (TLm)	72 hr	S.LA Crude	150+/- 360 ppm	Lethality	Subarctic sp.	129
Menidia beryllina	Acute (TLm)	48 hr 96 hr	WSF of: S.LA Crude	8.7 ppm 5.5 ppm	Lethality		83
Menidia beryllina	Acute (TLm)		OWD of:	ppm	Lethality		5
		48 hr	S.LA	5,000			
		96 hr	Crude	3,700			
		48 hr	Kuwait	15,000			
		96 hr	Crude	9,400			
		48 hr	#2 fuel	125			
			WSF of:				
		48 hr	S.LA	8.7			
		96 hr	Crude	5.5			
		48 hr	Kuwait	6.6			
		96 hr	Crude	6.6			
		48 hr	#2	5.2			
		96 hr	fuel oil	3.9			
		48 hr	Bunker	2.7			
		96 hr	C oil	1.9			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Menidia menidia	Acute (LC_{50})	48 hr	Waste crankcase oil	2,200 ppm	Lethality		42
		96 hr		1,700 ppm			
	(% mort)	7 days		250 ppm	100%		
	(% mort)	36 days		100 ppm	0%		
	(% mort)	60 days		20 ppm	0%		
Morone saxatilis (juvenile)	Acute (LC_{50})		benzene		Lethality		78
		72 hr		10.9 ppm			
		96 hr		10.9 ppm			
Morone saxatilis (striped bass)	Sublethal	96 hr	benzene in freshwater	5 & 10 ppm	Oxygen Consumption Maxed at 24 hr for 5 ppt. No diff. in 10 ppt.		17
Myoxocephalus polyacanthocephalus	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) 3.96	Lethality	Alaskan sp.	101
		96 hr	#2 fuel oil	1.31			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Myoxocephalus verrucosus (sculpin)	Acute	20 hr	Naphthalene	4 ppm	100% Mortality	Alaskan	35
	Sublethal		Naphthalene	1 ppm	Morphology Physiology	Alaskan	35
Onocottus hexacornis (arctic sculpin)	Acute (LC_{50})	8 days	Cook Inlet Crude WSF @ 2.0+/-0.5 °C	>1.729 ppm	Lethality	Prudhoe Bay collected (Arctic)	99
		4 days	Naphthalene @				
			1.5+/-0.2	1.06 ppm	Lethality	Arctic	
			2.0+/-0.5	1.07 ppm			
			6.4+/-1.1	1.63 ppm			
			8.5+/-1.3	1.82 ppm			
			$\bar{X}$=4.6+/-3.4 °C	1.40+/-0.11			
		8 days	Naphthalene @				
			1.5+/-0.2	1.00 ppm	Lethality	Arctic	
			2.0+/-0.5	1.07 ppm			
			6.4+/-1.1	1.63 ppm			
			8.5+/-1.3	1.74 ppm			
			$\bar{X}$=4.6+/-3.4	1.36+/-0.11			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Oligocottus maculosus (tidepool sculpin)	Acute Delayed Mortality	66 hr exposure 5 day depuration	No. 2 fuel oil	0.100 to 0.398 ml/l	Delayed Mortality Measured		22
Oligocottus maculosus	Acute (LC_{50})	48 hr	No. 2 Diesel Oil	400 ppm	Lethality		39
Oncorhynchus gorbuscha	Acute (TLm)	48 hr 96 hr	Prudhoe Bay Crude	550 ppm 148 ppm	Lethality	30 ppt salinity	22
		96 hr	Cook Inlet Crude	mg/l (GC) 1.69	Lethality	Alaskan sp.	101
		96 hr	No. 2 fuel oil	0.97			
Oncorhynchus gorbuscha (fry) (pink salmon) (fry)	Acute (TLm)	96 hr 96 hr	Prudhoe Bay Crude	213 ppm 110 ppm	Lethality	7.5°C 11.5°C	97
	Acute Delayed Mortality	66 hr exposure 5 day depuration	No. 2 fuel oil	0.100 to 0.398 ml/l in seawater	Delayed Mortality Measured	Alaskan	22

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Oncorhynchus gorbuscha (0.22g, $\bar{X}$) (0.47g, $\bar{X}$)	Acute (% mort)	48 hr	100% Treated	4.5 ppm	Lethality	Simulated Valdez Ballast water	133
		96 hr	30% Treated	<1.0			
	Acute (TLm)	96 hr	OWD of Prudhoe Bay Crude	ppm (IR) 4.50	Lethality	Arctic/ Subarctic sp.	102
		96 hr	Cook Inlet Crude, treated	3.41			
Oncorhynchus gorbuscha (pink salmon)	Sublethal	22 hr	Prudhoe Bay Crude WSF	0.35 to 2.22 ppm total Hydro- carbons	Coughing Response- Peaked within 3 hr	Alaskan	104
			Cook Inlet Crude WSF	"	"		
			No. 2 fuel oil	"	"		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Oncorhynchus gorbuscha	Acute (TLm)		WSF of	ppm(IR)	Lethality	Arctic/ Subarctic sp.	102
		96 hr	Prudhoe Bay Crude	1.41			
		96 hr	Cook Inlet Crude	2.92			
		96 hr	Cook Inlet Crude, treated	1.47			
		96 hr	No. 2 fuel oil	0.81			
		24 hr	Cook Inlet	4.13	Lethality	Arctic/ Subarctic sp.	103
		96 hr	Crude	2.92			
		24 hr	No. 2	0.89			
		96 hr	fuel oil	0.81			
			Prudhoe Crude	ml/l	Lethality	Arctic/ Subarctic spp.	100
Egg		96 hr		3.20	no deaths	mechanically mixed fresh- water	
Early-alevin		96 hr		0.62			
Mid-alevin		96 hr		0.55			
Late-alevin		96 hr		0.70			
Emergent fry		96 hr		0.40			
Migrant fry		96 hr		0.042		Mechanically mixed seawater	

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Oncorhynchus gorbuscha							100
Egg		96 hr		3.20	no deaths	Water	
Early-alevin		96 hr		3.20	(<50%	agitation	
Mid-alevin		96 hr		3.20	mort)	fresh-	
Late-alevin		96 hr		1.85		water	
Emergent fry		96 hr		1.25			
Migrant fry		96 hr		0.075		Water agitation seawater	
Oncorhynchus keta fry (chum salmon)	Behavior	1 wk	Cook Inlet Crude oil SWSF	0.4 ppm	Altered Behavior	Arctic	73
	Acute (LC_{50})		Emulsion No. 2 Diesel fuel	ppm	Lethality	25 ppt salinity	22
		48 hr		538			
		96 hr		312			
	Acute (TLm)	96 hr	No. 2 fuel oil	1040+/-260 ppm	Lethality		129

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Oncorhynchus keta							
Unstressed (0.9, $\bar{X}$) (Simulated ballast water)	Acute (% mort)	7 days	50% treated	3.4 ppm	Lethality 75%		133
		14 days	30% treated	2.0 ppm	63%		
Unstressed (.35g, $\bar{X}$)	Acute (% mort)	<16 hr	100% treated	6.4	100%	Simulated Valdez ballast water made from Prudhoe Crude	
		<48 hr	100% treated	4.6	100%		
Unstressed (1.83g, $\bar{X}$)		16 hr	100% untreated	7.9	100%		
		70 hr	10% untreated	1.0	100%		
Stressed (0.38g, $\bar{X}$) real ballast water		78 hr	50% untreated	<1.0 to 3.5	98%		
Unstressed (5.36g, $\bar{X}$) simulated ballast water		7.5 hr	Puget Sound water and 100% treated	13.3	100%		
		7.5 hr					
Unstressed (5.36g, $\bar{X}$)		7.5 hr	Valdez water and treated	12.8	100%		
Unstressed (1.90g, $\bar{X}$)		96 hr	Valdez water and 20%, 30%, 50% treated	<1.0 to 1.2	0		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Oncorhynchus kisutch (coho salmon)	Physiology	2 to 6 weeks	Prudhoe Bay Crude WSF	0.8 ppm	Accumulation Depuration	Alaskan	71
	Chronic	40 days	Toluene in freshwater	0.4, 0.8, 1.6, 3.2, 5.8 µl/l	Growth	Alaskan	81
			Naphthalene in freshwater	0.2, 0.4, 0.7, 1.4, 3.0 mg/l			
Oncorhynchus kisutch (coho salmon) _Oncorhynchus tschawytscha_ (chinook salmon)	Behavior	24 to 28 hr	Prudhoe Bay Crude WSF	600 ppb	Homing Behavior	Alaskan	71
Oncorhynchus kisutch (advanced parr/ 11 mo. old)	Acute (% mort)	96 hr exposure	Prudhoe Bay Crude poured on surface	ppm	Lethality	Temp.°C	82
				control	10%	8	
				3,500	50%	8	
				control	0%	13	
				3,500	62.5%	13	
				control	9.1%	8	
				3,500	80.5%	8	

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Oncorhynchus nerka (advanced parr/10 mo. old)	Acute (% mort)	96 hr	Prudhoe Bay A rude poured on surface	ppm	Lethality	Temp. C	82
				control	10%	8	
				500	39.3%	8	
				1,000	44.8%	8	
				1,750	6.7%	8	
				3,500	40.0%	8	
				control	0%	3-5	
				500	55%	3-4	
				1,750	100%	3	
				3,500	90%	4-5	
				control	0%	13	
				500	0%	13	
				1,000	6.9%	13	
				1,750	5%	13	
				3,500	20%	13	
Oncorhynchus tschawytscha (chinook salmon)	Sublethal	96 hr	Benzene in freshwater	5 and 10 ppm	Oxygen consumption maxed at 48 hr then decreased to 96 hr	Alaskan	17
Oncorhychus tschawytscha (fingerling)	Acute (% mort)	24 hr	WSF of: Prudhoe Bay Crude	ppm (IR)	Lethality		109
				1.86	100%		
				1.02	70%		
				0.56	0%		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Oncorhynchus tschawytscha	Acute (LC_{50})		Emulsion No. 2 diesel oil	ppm	Lethality	Arctic/ Subarctic sp.	22
		48 hr		1,190			
		96 hr		349			
Opsanus tau (larvae)	Acute (% survival)		Crude oil and carbon-ized sand	ppm	Lethality		25
		48 hr		5,000	100%		
				12,500	100%		
				25,000	40%		
				50,000	0%		
				100,000	0%		
		52 hr	Diesel oil and carbon-ized sand	ppm			
				approx. 25,000	100%		
				approx. 50,000	40%		
				approx. 100,000	0%		
		50 hr	Lubricating oil (SAE 20) and carbon-ized sand	approx. 25,000	80%		
				approx. 50,000	100%		
				approx. 100,000	80%		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen- tration	Test End-Point	Remarks	Reference
Parophrys vetulus (English sole) eggs and larvae	Develop- mental	Through development	Prudhoe Bay Crude SWSF	various, depending on life stage	Physiology		73
	Chronic	2 weeks to 4 months	Prudhoe Bay crude oil contaminated sediments	0.2 to 1.0% (v/v)	Pathology	Arctic	73
	Biochemical	24 hr to 160 hr ex- posure	$[^{3}H]$benzo[d]- pyrene and $[^{14}C]$naphtha- lene in sedi- ment with 1% Prudhoe Bay Crude	$[^{14}C]$NPH 0.83 mCi/mmol $[^{3}H]$B[a]P 167 mCi/mmol	Metabolism accumulation	Alaskan	128
Pholis laeta	Acute (TLm)	96 hr	Cook Inlet Crude No. 2 fuel oil	mg/l (ac) >11.72 >0.97	Lethality	Alaskan sp.	101
Platichthys stellatus	Chronic (bioaccum- ulation)	9 days	2,6 dimethyl- naphthalene	0.3-0.4 mg/kg body wt per day force feed	metabolism	Pre-expo- sure to chemicals may alter the metabolism of different chemicals & affect their toxicity.	49

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Platichtys stellatus	Acute (TLm)	96 hr	Cook Inlet Crude #2 fuel oil	mg/l (GC) >5.34 >0.97	Lethality	Alaskan sp.	101
Platichthys stellatus (starry flounder)	Physiology	2 to 6 weeks	Prudhoe Bay Crude WSF	0.8 ppm	Accumulation Depuration	Alaskan	71
Platichthys stellatus	Acute (TLm)	72 hr	S.LA Crude	1,400+/- 110 ppm	Lethality		129
Platichthys stellatus (starry flounder)	Chronic	2 weeks to 4 months	Prudhoe Bay Crude contaminated sediments	0.2 to 1.0 % (V/V)	Pathology	Arctic	73
Prophrys vetulus (145-242 mm)	Chronic (bio-accumulation)	4 months	North Slope Crude in sediment	700 ppm	Histology (severe hepato-cellular lipid vacuo-lization) Growth (weight loss)	Induction of aryl hydrocarbon hydroxylase may be occurring with this fish.	74

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Psettichthys melanosticus (sand sole) (eggs and larva)	Development	Through development	Prudhoe Bay Crude SWSF	Various depending on life stage	Physiology	Arctic	73
Psettichthys melanostictus (eggs and larva)	Acute (% mort)			ppm	Lethality		129
		6 days	S. LA Crude	10	100		
				30	100		
				50	100		
				100	100		
				500	100		
		4 days	No. 2 fuel oil	1	0		
				5	0		
				10	0		
				25	0		
				50	20		
		5 days	Kuwait Crude	10	50		
				30	20		
				50	10		
				100	60		
				500	90		
Pseudopleuronectes americanus	Acute (LC_{50})		Bunker C fuel oil	ppm	Lethality	Temp °C	110
		96 hr		>10,000		15	
		96 hr		>10,000		5	

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Pseudopleuro-nectus sp. (larva 8 hr)	Acute (% mort)	24 hr	Bunker C oil	% oil	Lethality		56
				0	0%		
				0.1	6.8%		
Psychrolutes paradoxus (tadpole sculpin)	Acute delayed mortality	66 hr exposure 5 day depuration	#2 fuel oil	0.100 to 0.398 ml/l	Delayed mortalities measured		22
Psychrolutes paradoxus	Acute (LC_{50})	48 hr	#2 diesel oil	400 ppm	Lethality		39
Rhombus maeoticus (larva)	Chronic (life cycle)			ppm	% hatch	% abnormal	78
		5 days	Bunker C fuel oil	0.1	100	100	
				0.01	100	37	
			Solar oil	1.0	100	all dead	
				0.1	100	all dead	
				0.01	100	23	
			Malgobeck oil	1.0	0	-	
				0.1	100	100	
				0.01	100	40	
				0.0	100	7	
Rhombus maeoticus	Acute (% mort)	2 days	WSF of: Bunker C	1.0	Lethality 100%		78

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Rhombus maeoticus (egg)	Acute (% viable eggs)	1 day	Bunker C	ppm	Lethality	Concludes that 0.01-1 ppm may be toxic to flat fish eggs	78
				100	82		
				10	84		
				1	76		
				0.1	87		
				0.01	89		
				0.0	83		
		2 days		100	0		
				10	0		
				1	71		
				0.1	81		
				0.01	89		
				0.0	83		
		3 days		100	-		
				10	-		
				1	0		
				0.1	81		
				0.01	89		
				0.0	83		
		1 day	Solar oil	100	81		
				10	82		
				1	89		
				0.1	87		
				0.01	94		
				0.0	83		
		2 days		100	0		
				10	10		
				1	78		
				0.1	87		
				0.01	81		
				0.0	83		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Rhombus maeoticus (egg)	Acute (% viable eggs)	3 days	Solar oil	ppm	Lethality		78
				100	-		
				10	0		
				1	78		
				0.1	67		
				0.01	81		
				0.0	83		
		1 day	Malgobeck oil	100	80		
				10	87		
				1	81		
				0.1	72		
				0.01	67		
				0.0	83		
		2 days		100	0		
				10	74		
				1	81		
				0.1	67		
				0.01	67		
				0.0	83		
		3 days		100	-		
				10	0		
				1	81		
				0.1	55		
				0.01	67		
				0.0	83		

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Salmo clarki (cutthroat trout)	Chronic	90 days	Wyoming Crude oil	up to 520 μg/liter	Growth and Morphology		134
Salmo gairdneri (yearling)	Acute (LC_{50})	48 hr	Phenol	ppm 5.25 7.25 7.90 8.00 9.3	Lethality	% SW 60 40 30 15 0	18
Salmo gairdneri (rainbow trout)	Sublethal reproductive capability	6 to 7 months	Prudhoe Bay Crude incorporated into food	2 gm oil/ 2 kg Oregon moist pellets - 2% body wt. fed per day	Reproductive Success measured no significant difference		53
Salmo gairdneri (rainbow trout)	Morphological	>1 year fed oil treated food	Prudhoe Bay Crude	1 gm oil/ 1 kg pellet food	Lens Morphology investigated	Alaskan	71, 72
Salmo salar (parr)	Acute (LC_{50})	 96 hr 96 hr	Bunker C fuel oil	ppm >10,000 >10,000	Lethality	Temp °C 15 5	110

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Salvelinus malma (smolt)	Acute (TLm)		WSF of:	ppm (IR)		Alaskan sp.	103
		24 hr	Cook Inlet	3.25			
		96 hr	Crude	2.94			
		96 hr	#2 fuel	2.29			
Salvelinus malma	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) 1.55	Lethality	Alaskan sp.	101
			#2 fuel oil	0.15			
Salvelinus malma	Acute (TLm)		WSF of:	ppm (IR)	Lethality	Alaskan sp.	102
		96 hr	Prudhoe Bay Crude	1.10			
		96 hr	Cook Inlet Crude treated	2.94			
		96 hr	Cook Inlet Crude untreated	1.54			
		96 hr	#2 fuel oil	2.29			
			OWD of:				
		96 hr	Prudhoe Bay Crude	16.41			
		96 hr	Cook Inlet Crude treated	7.30			
Scorpaenichthys marmoratus (larva)	Acute (TLm)		OWD of:	ppm	Lethality		70
		approx. 96 hr	#2 fuel oil	<10			
		approx. 96 hr	L.A. Crude	>100			

Table B-6. Toxicity of Petroleum to Fish

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Syngnathus griseolineatus	Acute (TLm)	96 hr	Kuwait Crude	ppm <675	Lethality		129
Tautogolabrus adsperus	Chronic	6 months	Venezuelan Crude oil	not measured	Growth (differences in: testis somatic index, lens diameter and plasma chloride. No histopathological changes were observed.)	Mixed function oxygenase present	89
Theragra chalcogramma (pollack)	Acute	2 hrs		4 ppm	100% Mortality	Alaskan	35
Theragra chalcogrammus	Acute (TLm)	96 hr	Cook Inlet Crude	mg/l (GC) 1.73	Lethality	Alaskan sp.	101

Table B-7. Toxicity of Petroleum to Birds

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concen-tration	Test End-Point	Remarks	Reference
Anas platyrhynchos (mallard duck) eggs	Reproduction	Until hatched	Mineral oil	Total shell coverage	Hatching success		52
Anas platyrhynchos (mallard duck) eggs	Reproduction	Until hatched	No. 2 fuel oil	Portion of shell coverage	Hatching success Sig. mortal. with 1 /l oil applied to 2% of shell		1
Anas platyrhynchos (mallard duck) Adult	Acute	100 days	Kuwait and South Louisiana Crude	Mixed with dry poultry food - 3.0 and 2.4 ml oil/kg body weight	Lethality after cold stress.		55
Anas platyrhynchos (mallard duck) Adults	Chronic	90 days	Santa Barbara Crude Kuwait Crude No. 2 fuel oil	5 ml one time daily doses ingested	Pathological effects observed		54
Anas platyrhynchos (mallard duck) Juvenile	Chronic	Single oral dose	Santa Barbara Crude	0.2 ml	Rates of mucosal transfer in small intestine measured.		31

Table B-7. Toxicity of Petroleum to Birds

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Anas platyrhynchos (mallard duck) juvenile	Acute	6 days	South Louisiana Crude oil in food	5, 10 and 20% (v/w)	Lethality		54
Coturnix coturnix Japanese quail Adult	Reproductive	Single dose	Mineral and Safflower oil Bunker C fuel oil Kuwait Crude Prudhoe Bay Crude Cook Inlet Crude	 100, 200 & 500 mg 800 mg 800 mg 800 mg	Egg Production and Hatchability Measured		47
Somateria mollissima (eider duck) eggs	Reproductive	Until Hatched	No. 2 fuel oil	Portion of shell coverage			118

Table B-8. Toxicity of Petroleum to Marine Mammals

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Callorhinus ursinus (fur seal)	Pelt Conductance	N/A	Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt			62, 63
Callorhinus ursinus (fur seal)	Physiology	12 hours	Prudhoe Bay Crude	100 ml Brushed into Pelt	Physiological Measurements		62, 63
Enhydra lutris (sea otter)	Pelt Conductance	N/A	Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt			62, 63
Enhydra lutris (sea otter)	Physiology	8 days	Prudhoe Bay Crude	60 ml Brushed into Pelt	Physiological Measurements		29
Erignathus barbatus (bearded seal)	Pelt Conductance	N/A	Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt			62, 63
Leptonychotes weddelli (weddell seal)	Pelt Conductance	N/A	Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt			62, 63
Odobenus rosmarus (walrus)	Pelt Conductance	N/A	Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt			62, 63

Table B-8. Toxicity of Petroleum to Marine Mammals

Organism	Type of Toxicity Test	Test Duration	Material Tested	Concentration	Test End-Point	Remarks	Reference
Phoca groenlandica (harp seals)	Chronic	4 days	Norman Wells Crude	Pelt Totally Coated	Behavior, Physiology, Pathology		43
Phoca hispida (ringed seals)	Acute	24 hours	Crude oil	1 cm Surface Thickness in Enclosed Pen	Lethality, Behavior, Physiology, Pathology		43
Zalophus californicus	Pelt Conductance		Prudhoe Bay Crude	.02 ml/cm^2 Brushed into Pelt	Thermal Conductance Measured		62

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ENVIRONMENTAL CHARACTERIZATION OF THE NORTH ALEUTIAN SHELF NEARSHORE REGION: ANNOTATED BIBLIOGRAPHY AND KEY WORD INDEX

by

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Kinnetic Laboratories, Inc.

Final Report
Outer Continental Shelf Environmental Assessment Program
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Introduction

The annotated bibliography and the associated Author and Key-word indices are intended to function as a stand-alone system, allowing the user to reference material according to discipline and subject matter. The Author Index is complete, second authors are listed and referenced along with primary authors in alphabetical order. Key-words also are alphabetically ordered, and entries are listed by access number. Access numbers are followed by abbreviations that denote the source of the reference material. The following is a list of sources and their abbreviations;

ADF&G......................Alaska Department of Fish and Game
ARL.......................Alaska Resources Library, Anchorage
EPA.......................Environmental Protection Agency
IMS-UAF...................Institute Marine Science-University of Alaska, Fairbanks
INPFC.....................International North Pacific Fisheries Commission
LGL.......................Lewis, Gunn, Livingston, Ltd.
NMFS......................National Marine Fisheries Service
OCSEAP-NOAA...............Outer Continental Shelf Environmental Assessment Program-National Oceanic and Atmospheric Administration
NPFMC.....................North Pacific Fisheries Management Council
NW&AFC....................Northwest and Alaska Fisheries Center
PMEL......................Pacific Marine Environmental Laboratory
RAS-UAF...................Rasmuson Library-University of Alaska, Fairbanks
UAA.......................University of Alaska, Anchorage
USF&WS....................U.S. Fish and Wildlife Service
UW........................University of Washington, Seattle
Wild. Dept.-UAF...........Wildlife Department, University of Alaska, Fairbanks
MMS.......................Minerals Management Service

Two annotations are printed to a page and are listed sequentially according to access number. To use either index, find the Author or Key-word in the appropriate index, and refer to the citation with the access number listed. To obtain a copy of the material, consult the source listed.

The material listed in this bibliography was culled from larger bodies of literature available on the Bering Sea environ and toxicity studies, and was assembled to address the specific concerns of impact of oil and gas field development as expressed in the RFP of this project. As such, much of the collected literature extensively covers the region of the nearshore area of the North Aleutian Shelf bounded by the intertidal zone and the 50 meter depth contour. The toxicity information is not as geographically bound, and is more regional in extent.

North Aleutian Shelf Author Index

North Aleutian Shelf Key Word Index

ACCESS # : 001, IMS-UAF

CITATION : Armstrong, D., G. Oliver, and C. Manen. 1982. Coastal species and habitats. In: Draft North Aleutian Shelf Synthesis Report, Chapter 3. OCSEAP/ NOAA. Juneau, Ak.

KEY-WORDS: Coastal habitats; Coastal species; Oil pollution; North Aleutian Shelf.

SYNOPSIS : This document is the product of the OCSEAP-sponsored North Aleutian Shelf Synthesis Meeting held in Anchorage, Alaska March 9-11, 1982. It considers the North Aleutian Shelf (NAS) region from Unimak Pass to Cape Newenham. Segments addressed in this document include 1) animal groups, including general biology and unique relationships to the NAS: 2) critical habitats, such as Izembek and Nelson lagoons and the area likely affected by mishaps near Cold Bay; 3) oil toxicity to selected animals and plants; 4) oil spill scenarios and their likely impact including perturbations other than oil; and 5) recommendations and research priorities.

ACCESS # : 002, ADF&G

CITATION : Alaska Department of Fish and Game. 1978. Alaska Fisheries Atlas - Volume I. ADF&G, Juneau, Ak.

KEY-WORDS: Fisheries; Life history; Management; Distribution.

SYNOPSIS : This document includes fish species accounts, management area accounts, and fish distribution maps. Fish species accounts are general life history accounts of each fish species considered and stress distribution in Alaska and the general habitat requirements of each species. Management area accounts include general discriptions of each regulatory area and specific information regarding distribution, timing and the human uses of each species within the area. Further emphasis is placed on land and water use considerations. Fish distribution maps are marked to show distribution of each species (or in some cases, group of species) throughout Alaska. Where knowledge is available, the maps show seasonal changes in distribution, spawning areas, rearing areas, and major commercial fishing areas.

ACCESS # : 003, WILDL. DEPT.-UAF

CITATION : Anon. 1979. Proposed Alaska Peninsula National Wildlife Refuge. United States Dept. of the Interior. Environmental Impact Statement. Draft, 277 pp.

KEY-WORDS: Proposal options; Wildlife habitat; Commercial fisheries; Geology.

SYNOPSIS : The importance of the Alaska Peninsula to local wildlife is stressed. Various management options are reviewed and impact of inclusion and exclusion of several areas is discussed. There is a fairly detailed presentation of the geology, vegetation, and wildlife found on the peninsula. Maps and data depicting proposal options, oil and gas potential, mining claims, minerals, vegetation, wildlife, marine mammals, fish, and birds are included. There are some data concerning human populations and commercial fish and shellfish catch.

ACCESS # : 004, RAS-UAF

CITATION : Anon. 1970. Izembek Wilderness Proposal. United States Fish and Wildlife Service. 21 pp.

KEY-WORDS: Wilderness study; Wildlife habitat; Development; History; Eelgrass; Izembek Lagoon.

SYNOPSIS : A summary of the Izembek wilderness study, this publication is intended to determine the suitability of including all or part of the refuge in the National Wilderness Preservation System. The history of the area is described along with some data on current weather patterns and general physical characteristics. Animal populations are described with particular emphasis on birds and large mammals. The major value of the area lies in the food resources associated with the eelgrass beds of the lagoon. Proposed development includes a marine lab, two shelters and a trail system. The tidal area is inseperable ecologically from the terrestrial and oil or gas development is predicted to have serious consequences on the food base for the area and offshore fisheries.

ACCESS # : 005, RAS-UAF

CITATION : Anon. 1969. Izembek National Wildlife Range. United States Dept. of the Interior. Fish and Wildlife Service. 25 pp.

KEY-WORDS: Refuge programs; Wildlife habitat; History; Development; Waterfowl; eelgrass; Izembek Lagoon.

SYNOPSIS : This report is designed to promote public understanding of the Izembek Refuge program. It includes a brief history of the area, including anthropological and geological information. The extensive eelgrass beds of the lagoon are cited as the primary food base for a diversity of wildlife. The area is thought to be a refuge for the endangered Aleutian Canada Goose. A limited trail system is proposed along with two rustic shelters for wildlife observation.

ACCESS # : 006, IMS-UAF

CITATION : Baxter, R. 1976. Inshore Marine Resources, Bristol Bay, Alaska. Unpublished report. Alaska Department of Fish & Game, Box 96, Bethel, Ak. 99559.

KEY-WORDS: Resource assessment; Longline; Fisheries; Marine mammals; Seabirds; Invertebrates; Trawl surveys.

SYNOPSIS : This document provides information on the potential commercial fisheries within the 12-mile contiguous fishery zone of Bristol Bay and lower Kuskokwim Bay. Sampling was conducted during 1974-75 by trawling, longlining, clam surveys, and beach surveys. There were only two organisms noted that would support a major commercial fishery; the herring and the capelin. In addition to information presented on these two potential commercial species, data are presented on marine mammals, seabirds, marine fishes, mollusks, crustaceans, and echinoderms.

ACCESS # : 007, WILDL. DEPT.-UAF

CITATION : Ainley, D.G., and G.A. Sanger. 1979. Trophic relations of seabirds in the northeastern Pacific Ocean and Bering Sea. USF&WS, Wildl. Res. Rep. 11: 95-112.

KEY-WORDS: Seabirds; Trophic interactions; Ecology.

SYNOPSIS : A review of literature on the diets and feeding habits of seabirds of the northeastern Pacific Ocean and Bering Sea, with broad characterizations of the diets of major species.

ACCESS # : 008, IMS-UAF

CITATION : Ashwell-Erickson, S., R. Elsner, and D. Wartzok. 1978. Metabolism and nutrition of Bering Sea harbor and spotted seals. Cont. No. 30. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 22 pp.

KEY-WORDS: Harbor seal; Spotted seal; Nutrition; Feeding; Metabolism; Marine mammals.

SYNOPSIS : A report and discussion of the results of laboratory observations of captive harbor and spotted seals is presented here. Metabolic rates and nutritional requirements are described by age group. Food requirements of spotted seals seems to decline from 13% of body weight per day during the first year to 3% per day at age nine.

ACCESS # : 009, ADF&G

CITATION : ADF&G. 1983. Annual management report, 1982, Bristol Bay area. ADF&G, Div. Comm. Fish. Ann. Rep. 213 pp.

KEY-WORDS: Salmon; Fisheries management.

SYNOPSIS : This is the latest of 23 such reports detailing management activities of the ADF&G, Div. of Comm. Fish. in the Bristol Bay area. Extensive data are presented relating to fisheries effort, catch, escapement, and return. Data are presented by area and by year, including 1982 results. Though the 1982 sockeye run of 22.2 million fish was lower than the predicted 34.6 million, it was considerably higher than runs of recent years, with a harvest of 15.1 million fish, or triple the average cycle year since 1956.

ACCESS # : 010, RAS-UAF

CITATION : Arneson, P.D., 1980. Identification, documentation and delineation of coastal migratory bird habitat in Alaska. Final Report of Principal Investigators. 350 pp. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Seabirds; Waterfowl; Shorebirds; Avifauna; Habitat; Distribution.

SYNOPSIS : This report is based primarily on the results of 33 coastal surveys flown between October, 1975 and August, 1978. Areas assessed were the northeast Gulf of Alaska, Kodiak Island, Lower Cook Inlet, the northern Alaska Peninsula, northern Bristol Bay, and the Aleutian Shelf. For each area information is presented as to species abundance, spatial and temporal distributions, habitat preference, critical habitats, migratory routes and breeding locales, and vulnerability to oil spills. Estuaries on the north side of the Alaska Peninsula had the greatest bird densities of any region surveyed. In spring, geese, sea ducks, gulls, and dabbling ducks were found in abundance. In fall, these same species were in abundance in addition to large shorebird populations. Several unique bird species use these estuaries exclusively for migration staging, and would be particularly vulnerable to oil spills. Shearwaters were particularly abundant at the southern end of the peninsula in summer, while in winter sea ducks were found in both lagoon and exposed inshore habitats.

ACCESS # : 011, ADF&G

CITATION : Arneson, P.D. 1978. Indentification, documentation and delineation of coastal migratory bird habitat in Alaska. ADF&G. Annual Report. 51pp. Anchorage.

KEY-WORDS: Avifauna; Population density; Waterfowl; Shorebirds.

SYNOPSIS : This report summarizes results of aerial surveys of Bristol Bay and Cook Inlet during May, 1977, and the winter of 1977-78, respectively. Along the Alaska Peninsula and within northern Bristol Bay, all protected waters (bays, lagoons, and estuaries) were densely populated by a wide variety of staging birds during the spring migration. However, each locale seemed to offer slightly different types of habitat and to support different species compositions. Near-shore subtidal, littoral, and supralittoral zones were all very important foraging and roosting areas. Brant were the most numerous bird recorded. This species was found in eelgrass beds of Izembek Lagoon and adjacent estuaries. The next most abundant species, Emperor Geese, preferred sandspits and mud/sand flats with associated intertidal area from Cinder River to Izembek. Shorebirds, though not as abundant as during the fall migration, were recorded in large numbers in several of the estuaries.

ACCESS # : 012, IMS-UAF

CITATION : Armstrong, D.A., L.S. Incze, J.L. Armstrong, D.L. Wencker, and B.R. Dumbauld. 1981. Distribution and abundance of decapod crustacean larvae in the S.E. Bering Sea with emphasis on commercial species. Principal Investigators' Reports for the Year Ending March 1981. Vol. II. pp. 365-596. OCSEAP/NOAA, Boulder, Colo.
KEY-WORDS: Decopod larvae; Distribution; Abundance; King Crab; Tanner crab; Crabs; Shrimps; St. George Basin; Crustacea.

SYNOPSIS : This document presents data on distribution and abundance of the larvae of king crab, Tanner crab, other brachyuran crabs, and hermit crabs, and shrimps with emphasis on pandalid species. Zooplankton data presented were collected during the years 1976 thru 1980. Results are considered in a general discussion on oil impact, with emphasis given to pollution originating in the St. George Basin.

ACCESS # : 013, IMS-UAF

CITATION : Bakkala, R.G. 1981a. Population characteristics and ecology of yellowfin sole. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 553-574. NOAA, Distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Population ecology; Yellowfin sole.

SYNOPSIS : This document presents information on the population structure, ecology, and environmental influences of the yellowfin sole in the eastern Bering Sea. Population structure information includes stock biomass and structure, size and age composition, size and age at maturity and recruitment to the fishery, length-weight relationships, growth, and mortality. Population ecology examines species interactions and distribution and seasonal movements. Climatic variations examines year-class strength in conjunction with warm or cold years and ice cover.

ACCESS # : 014, IMS-UAF

CITATION : Barsdate, R.J., M. Nebert and C.P. McRoy. 1974. Lagoon contributions to sediments and water of the Bering Sea. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 553-576.

KEY-WORDS: Izembek Lagoon; Eelgrass; Carbon budget; Nitrogen budget; Bering Sea.

SYNOPSIS : The eelgrass (Zostera marina L.) meadows of Izembek Lagoon annually produce 166,000 mt of carbon, 7400 mt of nitrogen, 1660 mt of phosphorus, 386 mt of silica and 3.45 mt of copper. Only a small fraction of the total production appears to be recycled within the lagoon. Avian herbivory accounts for no more than 3% of the total annual production, while decomposition leaching of beached grass is perhaps less than 0.1%. Detached, floating eelgrass appears to gain rather than lose nitrogen, phosphorus, copper and silica in transit from the lagoon, but the overall quantities involved are negligible. In addition to elements incorporated in detached, floating eelgrass, the lagoon exports substantial quantities of dissolved carbon, nitrogen and phosphorus. Dissolved copper and silica, on the other hand are lost to the lagoon from the Bering Sea at annual rates which may exceed 200 mt of copper and 600 mt of silica. Lead is also removed from the Bering Sea but in somewhat smaller quantities. The fixed carbon and elements of seagrasses that are eventually incorporated in the detrital organics of Bering Sea sediments may form an important component of Bering Sea food webs.

ACCESS # : 015, IMS-UAF

CITATION : Biebl, R. and C.P. McRoy. 1971. Plasmatic resistance and rate of respiration and photosynthesis of Zostera marina at different salinities and temperatures. Marine Biol. 8(1): 48-56.

KEY-WORDS: Salinity; Temperature; Stress; Zostera; Eelgrass; Photosynthesis.

SYNOPSIS : Two different forms of Zostera from tidal and subtidal habitats are exposed to various salinities and temperature. Experiments are performed using leaf pieces and respiration and photosynthesis are measured through changes in water column oxygen concentrations. Daily maximum temperatures from Izembeck are reported. Intertidal plants experience summer fluctuations from 10-30 degrees C. Zostera survived well in 0-3x normal sea water concentrations. Plants died in 4x sea water. Respiration was depressed in distilled water. There was no difference between subtidal and intertidal plants. Maximum rates of photosynthesis were observed in 1x sea water, and decreased to near zero levels at both higher and lower salinities. Respiration increased when temperatures were increased from 0 degrees C. Tidal plants showed a slightly better tolerance for high temperatures. Ranges of temperature tolerance are reported, along with positive net production.

ACCESS # : 016, IMS-UAF

CITATION : Beer, S. and R.G. Wetzel. 1982. Photosynthetic carbon fixation pathways in Zostera marina and three Florida seagrasses. Aquat. Bot. 13: 141-146.

KEY-WORDS: Photosynthesis; Carbon uptake; Eelgrass; Zostera.

SYNOPSIS : Zostera from Izembek Lagoon is compared with Thalassia, Syringodium, and Halodule from the Gulf of Mexico. Plants are exposed to short term (5 us) pulses of 14C and initial fixation products assessed as per cent of total label. Little label is incorporated into malate, suggesting that the seagrasses are using the C3 pathway for carbon fixation. A table of labeled sugars from all plants is presented.

ACCESS # : 017, ARL

CITATION : Berg, R.J. 1977. An updated assessment of biological resources and their commercial importance in the St. George Basin of the eastern Bering Sea. Principal Investigators' Reports for the Year Ending March 1977. Vol. 1. pp. 555-680. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Fishery resources; Fisheries; Environmental legislation; Walleye pollock; St. George Basin.

SYNOPSIS : The Bering Sea, in general, is one of the richest fish producers in the world, second only to the North Sea in terms of demersal fish yields. The present target species of fish in the eastern Bering Sea fishery is the Pacific (walleye) pollock (Theragra chalcogramma). Pollock undergo termperature-related seasonal migrations concentrating in shallower waters of the shelf in warm seasons, but moving to deeper waters of the shelf and slope in cold seasons. Spawning by pollock occurs northwest of Unimak Island in May. Eggs are pelagic and concentrated along the continental shelf in the upper waters layers. The St. George Basin is an important pupping and rearing area for many seasonal and resident marine mammal species. The largest northern fur seal herd in the world reproduces on the Pribilof islands. Considering the importance of the southeastern Bering Sea, including the St. George Basin area, as a protein producer, the primary recommendation of the National Marine Fisheries Service is: establishment of a marine sanctuary in the southeastern Bering Sea, including Bristol Bay and the St. George Basin area, bounded on the west generally by the 100-fm contour, under the provisions of Title III of the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532).

ACCESS # : 018, NMFS

CITATION : Bakkala, R.G. and G.B. Smith. 1978. Demersal fish resources of the eastern Bering Sea: Spring 1976. Northwest and Alaska Fisheries Center, NOAA. 234 pp.

KEY-WORDS: Demersal fish; Distribution; Abundance; Fisheries resources.

SYNOPSIS : During the spring months of 1976, a large-scale and multi-vessel demersal trawl survey was conducted in the eastern Bering Sea. A total of 683 otter trawl samples was collected within a study area of 337,930 km . This was the second of two baseline surveys designed to describe characteristics of Bering Sea demersal fish and shellfish populations. The first large-scale survey had been conducted during August-October 1975. Little information is included pertaining to waters inside the 50 m contour of the eastern Bering Sea.

ACCESS # : 019, NMFS

CITATION : Bakkala, R. 1981b. Pacific cod of the eastern Bering Sea. (Document submitted to the annual meeting of the International North Pacific Fisheries Commission, Vancouver, Canada, Oct. 1981) Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA. 49 pp.

KEY-WORDS: Pacific cod; Distribution; Abundance; Fisheries resources.

SYNOPSIS : This document examines the history of biological studies and commercial fishery on Pacific cod in the eastern Bering Sea. Little information is included pertaining to waters inside the 50 m contour of the eastern Bering Sea.

ACCESS # : 020, IMS-UAF

CITATION : Barton L.H., I.M. Warner, and P. Shafford. 1977. Herring spawning surveys - southeastern Bering Sea. Final Reports of Principal Investigators. Vol. VII. pp. 1-112. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Herring; Spawning; Fisheries.

SYNOPSIS : This report presents data from surveys conducted from Unimak Pass to the Yukon River Delta. The spatial and temporal distribution of Pacific herring and other forage fishes are presented, including the major spawning areas. The importance of herring to domestic users is also documented. Regarding oil exploration and leasing activities, the document maintains that the geological and climatological characteristics associated with most herring spawning habitats encountered in the study area may preclude effective cleanup and containment activities associated with oil spills.

ACCESS # : 021, IMS-UAF

CITATION : Barsdate, R.J., M. Nebert, and C.P. McRoy. 1972. Lagoon contributions to sediments and water of the Bering Sea. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 553-576.

KEY-WORDS: Eelgrass, Phosphorus; Elemental export; Lagoons; Izembek Lagoon; Nitrogen; Organic carbon; Heavy metals.

SYNOPSIS : Data presented here give rates of export of reactive phosphorus to the Bering Sea (495 mt/yr). The amounts of various elements incorporated into eelgrass in Izembek Lagoon are given.

ACCESS # : 022, IMS-UAF

CITATION : Barsdate, R. 1971. Distribution of copper and lead in the southeast Bering Sea and adjacent areas. In: Oceanography of the Bering Sea, Phase I. Turbulent upwelling and biological productivity mechanisms in the Southeastern Bering Sea and Aleutian Islands. D.W. Hood et al. Report No. R-71-9. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 64-71.
KEY-WORDS: Copper; Lead; Heavy metals; Izembek Lagoon; Upwelling.

SYNOPSIS : Concentration of 0.5 to 0.6 ug/l of dissolved copper and 0.1 to 0.2 ug/l of dissolved lead were found in Izembek Lagoon whereas concentrations of 1.8 to 3.3 ug/l of copper and 0.3 to 1.0 ug/l of lead were found in near shore Bering Sea samples. A plume of low values for both elements was observed west of Izembek Lagoon just off Unimak Island indicate a net loss of these elements to the Izembek Lagoon. Probably 1 metric ton of copper is lost each day.

ACCESS # : 023, ARL

CITATION : Burrell, D.C., K. Tommos, A.S. Naidu, and C.M. Hoskin. 1981. Some geochemical characteristics of Bering Sea sediments. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 305-319. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Sediments; Grain size distribution; Biota/sediment relationship; Heavy metals; Clay mineralogy.

SYNOPSIS : In the nearshore region north of the Alaska Peninsula the sediments are 50 to 90% sand-sized with occasional gravel spots extending to as much as 40% of the surficial sediments. Clay-sized sediments are usually less than 10%. The presence of macrobenthos individuals showed a maximum in a grain size mode of between 125 and 150 um (fine sand). Trace metal content of particulate matter show highly significant correlations for structural alumina-silicate elements: Al, Fe, Ca, Co. Some data for mean elemental particulate and soluble contents of Bering Sea water are given.

ACCESS # : 024, PMEL

CITATION : Baker, E.T. 1981. North Aleutian Shelf Transport Experiment. Annual report of Pacific Marine Environmental Laboratory/NOAA, Seattle. Contract No. R7120897. 61 pp.

KEY-WORDS: Suspended particulate matter (SPM); Sediments; Hydrography/suspended sediments; Eddy diffusivity; Resuspension; Coastal domain.

SYNOPSIS : Data from both the North Aleutian Shelf (NAS) area and the St. George Basin area showed a close relationship between suspended particulate matter distributions and hydrographic properties such as temperature and salinity. SPM landward of the 50 m isobath (the coastal domain) was generally well mixed throughout the water column. SPM profiles seaward of the 50 m isobath always consisted of surface and near bottom maxima seperated by a uniform, low concentration zone. Frontal regions were characterized by relatively low values of SPM concentration in the near bottom layer. Particle size distributions indicated that surface and near bottom SPM populations were distinct seaward of the coastal domain. Estimates of the vertical eddy diffusion coefficient made from the SPM profiles showed that the bottom layer is a zone of energetic turbulent mixing capped by a thinner layer of much lower eddy diffusivity. The coastal domain north of the Alaskan Peninsula was found to have a sigma T of usually less than 24 in the summer and was well mixed from top to bottom. The coastal domain is characterized by uniform vertical SPM profiles and similar particle size distribution throughout the water column, both features resulting from a well mixed water column where the primary particle source is bottom resuspension. The light attenuation values (method for measuring SPM) were highest near shore (1.4 to 2.8/m) decreasing to < 1.0 beyond the 50 m isobath.

ACCESS # : 025, ARL

CITATION : Caldwell, R.S. 1976. Acute and chronic toxicity of seawater extracts of Alaskan crude oil to zoeae of the Dungeness crab, Cancer magister Dana. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. pp. 345-375. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Environmental effects; Oil pollution; Toxicity; Aromatic compounds; Crabs; Crustacea.

SYNOPSIS : The full strength seawater soluable fraction of Cook Inlet crude oil is acutely toxic to first instar C. magister larvae but no lethalor sublethal effects were found of an continuous exposure period. In similar long-term exposures, 0.16 ppm naphthalene, the highest concentration tested, is also without effect on the larvae but 7.2 ppm benzene and possible also 1.4 ppm benzene result in reduced larval survival. The effects of benzene appear to be manifested at the time of the first zoeal molt in these long-term exposures. A comparison of the lethal concentration of benzene with the estimated concentration of this aromatic compound in the full strength seawater soluble fraction of crude oil suggests that benzene may account for a major portion of the toxicity of this fraction. Since the concentrations of many of the seawater extractable components of crude oil may be expected to decline rapidly under natural environmental conditions as a result of dilution, evaporation, and metabolism by microorganisms, these studies suggest that crude oil contaminations of seawater may not seriously affect decapod larvae as long as the larvae do not contact the oil/water interface.

ACCESS # : 026, RAS-UAF

CITATION : Bellrose, F. 1976. Ducks, Geese, and Swans of North America. Stackpole Books. Harrisburg, Pa., 544 pp.

KEY-WORDS: Ducks; Swans; Geese; Waterfowl; Ecology.

SYNOPSIS : Species accounts are presented by chapter, which include distribution, population status, migration routes and timing, habitats, feeding behavior, breeding biology, mortality and disease, and management.

ACCESS # : 027, RAS-UAF

CITATION : Bartonek, J.C., and D.D. Gibson. 1972. Summer distribution of pelagic birds in Bristol Bay, Alaska. Condor 74: 416-422.

KEY-WORDS: Distribution; Seabirds.

SYNOPSIS : Authors relate marine bird distributions as observed in Bristol Bay during the summer of 1969. The most common species observed were shearwaters, Black-legged Kittiwakes, and Common Murres.

ACCESS # : 028, RAS-UAF

CITATION : Bailey, E.P., and G.H. Davenport. 1972. Die-off of Common Murres on the Alaska Peninsula and Unimak Island. Condor 74: 215-219.

KEY-WORDS: Murres; Seabirds; Mortality; Ecology.

SYNOPSIS : Authors describe a mass die-off of some 68,000 to 100,000 Common Murres along the coast of the Alaska Peninsula and Unimak Island in April of 1970. First attributed to an unknown oil spill, mortality was later attributed to starvation due to adverse weather conditions.

ACCESS # : 029, ARL

CITATION : Bureau of Land Management. 1981. Marine mammals. In: Draft EIS for the proposed OCS oil and gas lease sale, St. George Basin. pp. 53-66. U.S. Dept. Int. Washington, D.C.

KEY-WORDS: Marine mammals; Populations; Distribution.

SYNOPSIS : The general biology and population status are reviewed from available literature sources, for northern fur seal, Steller sea lion, harbor seal, and sea otter. Spotted seals, ribbon seals, and 16 species of cetaceans are also described as occurring within the lease area.

ACCESS # : 030, ADF&G

CITATION : Brooks, J.W. 1955. Beluga investigations. ADF&G Ann. Rep. for 1955. pp. 98-106. ADF&G, Juneau.

KEY-WORDS: Beluga whale; Distribution; Feeding; Fisheries management; Marine mammals.

SYNOPSIS : From May to August, 1954 and 1955, 116 belugas were collected in Kvichak and Nushagak Bays for stomach analysis. An average of 685 red salmon fingerlings were found per stomach during the seaward smolt migration in May and June. Although beluga do eat some adult salmon, the predation loss of juveniles is considered more substantial and serious.

ACCESS # : 031, ADF&G

CITATION : Brooks, J.W. 1954. Beluga. ADF&G Annual Rep. for 1954. ADF&G, Juneau. pp. 51-57.

KEY-WORDS: Beluga whale; Salmon; Fisheries management; Marine mammals.

SYNOPSIS : The author describes beluga as common in Nushagak Bay and the mouth of the Kvichak River during red salmon migrations. After 30 May when the salmon smolt migration began, an average of 390 fingerlings were found per stomach from 68 belugas collected.

ACCESS # : 032, ARL

CITATION : Braham, H.W., and M.E. Dahlheim. 1981. Marine mammal resource assessment for the St. George Basin, Bering Sea, Alaska: an overview. Draft rep. NMML. NWAFC. NMFS/NOAA.

KEY-WORDS: Marine mammals; Distribution; Abundance; St. George Basin.

SYNOPSIS : Estimates of population size in the southeastern Bering Sea and the North Pacific are given for 15 cetacean species, for northern sea lion, for walrus, and for fur, harbor, spotted, ringed, bearded, and ribbon seals. Migration and distribution patterns in the southeastern Bering Sea, as indicated from published reports and unpublished sightings, are described and mapped for each species.

ACCESS # : 033, NW&AFC

CITATION : Braham, H.W., R.D. Everitt, B.D. Krogman, D.J. Rugh, and D.E. Withrow. 1977. Marine mammals of the Bering Sea: a preliminary report on distribution and abundance. 1975-76. U.S.D.C., NOAA/NMFS., NW & Ak. Fish. Cent., Mar. Mammal Div., Seattle, Wash. Processed Rep. 90 pp.

KEY-WORDS: Marine mammals; Population dynamics; Distribution.

SYNOPSIS : Based on aerial surveys conducted between June, 1975 and October, 1976, information is presented on distribution and abundance of ringed seals, bearded seals, spotted (largha) seals, ribbon seals, walrus, Steller seal lions, and cetaceans. During winter, spotted were the most numerous species in Bristol Bay, followed by bearded, ringed, and ribbon seals. Cetaceans sighted included gray whales, fin, minke, sei, killer and goosebeaked whales, and harbor and Dall porpoises.

ACCESS # : 034, RAS-UAF

CITATION : Burns, J.J., L.H. Shapiro and F.H. Fay. 1977. The relationships of marine mammal distributions, densities and activities to sea ice conditions. Principal Investigators' Reports for the Year Ending March 1977. Vol. 1. pp. 503-554. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Marine mammals; Sea ice; Ecology.

SYNOPSIS : Based on satellite imagery, aerial surveys, and ship surveys, authors describe occurrence, duration and interrelationships of ice conditions in 20 areas of the winter pack, define location and structure of the spring ice front, and describe seasonal and spatial distribution of marine mammals in relation to ice conditions. Bearded seals, ringed seals, ribbon seals, spotted seals and walrus are seasonally present in the Bristol Bay vicinity, with densities and distributions governed by the extent of winter ice. Ringed seals are sparse south of Norton Sound; ribbon seals are generally west of the Pribilof Islands; bearded seals are uniformly distributed throughout the ice front; walrus are clumped within the ice front, particularly in northern Bristol Bay; spotted seals are broadly distributed in the ice front, with highest concentrations near Bristol Bay. As ice retreats, many spotted seals remain in Bristol Bay, moving into the ice-free coastal zone. Spotted seals, bearded seals and ribbon seals all pup in the ice front from February until May, depending on species.

ACCESS # : 035, RAS-UAF

CITATION : Burns, J.J., and T.J. Eley. 1977. The natural history and ecology of the bearded seal (Erignathus barbatus) and the ringed seal (Phoca (pusa) hispida). Principal Investigators' Reports for the Year Ending March 1977. Vol. 1. 226-302. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Bearded seal; Ringed seal; Population dynamics; Ecology; Marine mammals.

SYNOPSIS : The bulk of this report concerns ringed seals. The report presents data on the distribution and abundance of ringed and bearded seals based on aerial surveys of March and April, 1977 and June, 1977 and discusses ringed seal taxonomy, pelage, dentition, growth rates, productivity, predation, sex and age composition, and density. The report also presents data on subsistence harvests of ice-associated marine mammals. The authors state that both ringed and bearded seals are seasonally present in northern Bristol Bay, with numbers and distributions dependent on extent of winter ice.

ACCESS # : 036, RAS-UAF

CITATION : Burns, J.J., and S.J. Harbo, Jr. 1977. An aerial census of spotted seal, Phoca vitulina largha, and walruses, Odobenus rosmarus, in the ice front of the Bering Sea. Quarterly Reports of Principal Investigators. Vol. 1. pp. 58-132. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Seals; Walrus; Marine Mammals; Population; Distribution; Ice front.

SYNOPSIS : Based on 24 aerial surveys conducted during March and April, 1976 and 1977, spotted seals and walrus are described as occurring throughout the front, with large concentrations of both species in central and western Bristol Bay.

ACCESS # : 037, RAS-UAF

CITATION : Baker, R.C., F. Wilke, and C.H. Baltzo. 1970. The northern fur seal. U.S. Fish & Wildl. Serv. Circ. #336. 20 pp.

KEY-WORDS: Fur seal; Marine mammals; Population dynamics; Ecology.

SYNOPSIS : Author's abstract: "The early history of worldwide fur sealing; the distribution and movement of northern fur seals; and their food, physical characteristics, reproduction, and mortality and disease are discussed. Information is also given on fur seal population, management, and research; sealing on the Pribilof Islands; and processing and sale of fur seal skins." Authors state that when away from the rookery seals remain at sea, generally 10 to 90 miles offshore.

ACCESS # : 038, RAS-UAF

CITATION : Braham, H.W., R.D. Everitt, and D.J. Rugh. 1980. Northern Sea lion population decline in the eastern Aleutian Islands. J. Wildlife Management. 44: 25-33.

KEY-WORDS: Mammals; Sea lions; Aleutian Islands; Population densities.

SYNOPSIS : Authors estimate based on the results of 6 aerial surveys from June, 1975 to June, 1977, that the sea lion population of the Unimak Island-Amak Island vicinity is currently (as of 1977) less than 25,000 down from over 50,000 in the late 1950's and early 1960's. Though no conclusions are drawn as to the cause of this decline, possibilities offered are increased disease (Leptospira pomona), increased competition from commerical fisheries in the area, and commercial harvesting of pelts from 1970 through 1972.

ACCESS # : 039, ARL

CITATION : Braham, H.W., and D. Rugh. 1978. Baseline characterization of marine mammals in the Bering Sea: distribution and abundance. Principal Investigators' Reports for the Year Ending March 1978. Vol. 1. pp. 1-14. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Marine mammals; Population dynamics; Distribution.

SYNOPSIS : This is a quarterly report which updates results of the authors' earlier study concerning a population decline of northern sea lions in the eastern Aleutian Islands. They report that the decline occurred prior to exploration of the Saint George, Aleutian Shelf, and Bristol Bay oil lease tracts. These areas are identified as highly important because of their proximity to the sea lions' breeding grounds. Gray whale movements through Unimak Pass are also described.

ACCESS # : 040, RAS-UAF

CITATION : Braham, H.W., C. Fiscus, and D. Rugh. 1977. Marine mammals of the Bering and southern Chukchi Seas. Principal Investigators' Reports for the Year Ending March 1977. Vol. 1. pp. 1-99. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Marine mammals; Distribution; Population status.

SYNOPSIS : Population estimates and spatial and temporal distribution patterns are described, based on the results of aerial surveys, for bearded seals, spotted (largha) seals, harbor seals, ribbon seals, ringed seals, Steller sea lions, and various cetaceans in the Bering and southern Chukchi Seas. Results indicate that the distribution, both spatial and temporal, of bearded seals, ribbon seals, spotted seals and ringed seals is primarily dependent on seasonal ice conditions. All of the above species, in addition to walrus, frequent northern Bristol Bay during the winter, with numbers and distribution governed by the extent of sea ice. The population of Steller sea lions in the northeast Aleutian-Bristol Bay area is estimated at 23,000, down approximately 50% from the late 1950's. About 80% of this population frequents rookeries in the Fox Islands, 20% utilizes Amak Island. The harbor seal population is estimated at around 30,000 for the northeast Aleutian-Bristol Bay area, with 80% frequenting 5 hauling areas. The most common cetaceans observed, excepting beluga and bowhead whales, were Dall porpoise and Minke whales. Other common species were gray whales, killer whales, and fin whales.

ACCESS # : 041, IMS-UAF

CITATION : Braham, H.W., and B.D. Krogman. 1977. Population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whale in the Bering, Chukchi, and Beaufort Seas. U.S. Dept. Comm., NOAA/NMFS. NW & Alaska Fish. Center, Seattle. 29 pp.

KEY-WORDS: Bowhead whale; Beluga whale; Population ecology; Cetacean; Ecology; Marine mammals.

SYNOPSIS : A review of the current state of knowledge (as of 1977) concerning the population status, migration patterns, reproductive timing, and food habits of bowhead and beluga whales in the Bering, Chukchi and Beaufort Seas. The population of beluga whales in Bristol Bay is estimated at 1,000 to 1,500 resident animals.

ACCESS # : 042, IMS-UAF

CITATION : Burns, J.J., and K.J. Frost. 1979. The natural history and ecology of the bearded seal, Erignathus barbatus. ADF&G, Fairbanks. 77 pp.

KEY-WORDS: Bearded seal; Marine mammals; Ecology; Trophic dynamics.

SYNOPSIS : A comprehensive account of bearded seal population status, distribution, migration patterns, life history, productivity, mortality, and food requirements. Bristol Bay appears to be the southern limit of the species' winter range, with distribution and numbers dependent on ice conditions from one year to the next. Bearded seal food preferences are as described by Kosygin (1976).

ACCESS # : 043, IMS-UAF

CITATION : Cooney, R.T., C.P. McRoy, T. Nishiyama, and H.J. Niebauer. 1979. An example of possible weather influence on marine ecosystem processes. In: Alaska fisheries: 200 years and 200 miles of change. Proc. of the 29th Alaska Science Conference, B.R. Melteff (ed.). Ak. Science Conference, Fairbanks, Ak.

KEY-WORDS: Bering Sea; Ecosystems; Gadidae; Pisces; Weather.

SYNOPSIS : The notion that the timing of certain events is critical in mediating processes of organic matter synthesis and transfer in marine pelagic systems is explored with observations recently acquired from the southeast Bering Sea. A hypothesis is advanced relating the apparent survival of a major cohort of the 1977 year-class of walleye pollock (Theragra chalcogramma) to weather patterns monitored during the month of April, the time of egg incubation and hatching. An extrapolation of relative growth measures to the size at yolk-sac absorption predicts that first feeding larvae may have encountered an unusually favorable growth environment during the last week of that month, a period coincident with the only high pressure weather cell to move through the region. It is proposed that the temporarily stabilized wind mixed layer promoted the rapid growth or local concentration of microplankton required by the first-feeding larvae present at that time, and that these fishes enjoyed a significantly higher rate of survival than did larvae prior to or following this event. A generally unimodel distribution of sizes among the surviving post-larvae sampled later supports this notion.

ACCESS # : 044, IMS-UAF

CITATION : Cooney, R.T. and K.O. Coyle. 1982. Trophic implications of cross-shelf copepod distributions in the southeastern Bering Sea. Mar. Biol. 70: 187-196.

KEY-WORDS: Copepod; Distribution; Grazing; Oceanic fronts; Zooplankton; Trophic interactions.

SYNOPSIS : Spring distributions of some numerically dominant copepods reflect the two distinct water masses separated along the 80 to 100 m isobaths. Seaward of this middle shelf front, the oceanic Bering Sea hosts populations of Calanus cristatus, C. plumchrus, and Eucalanus bungii bungii; Metridia pacifica. Oithona similis, and Pseudocalanus spp. are also present. The large oceanic species are much less abundant in waters shallower than 80 m where the community is seasonally dominated by smaller copepods, O. similis, Acartia longiremis, and Pseudocalanus spp. Experimental and field-derived estimates of carbon ingestion indicate that the oceanic/outer shelf copepods can occasionally graze the equivalent of the daily plant production and probably routinely remove 20-30% of the primary productivity. Conversely, stocks of middle shelf copepods rarely ingest more than 5% of the plant carbon productivity. During 45 d between mid to late May, 1979, approximately three times more organic matter was ingested by the outer shelf/oceanic copepod community than by middle shelf species. This imbalance in cross-shelf grazing permits middle shelf phytoplankton stocks to grow rapidly to bloom proportions, and to sink ungrazed to the seabed. Over the outer shelf and particularly along the shelf break, a much closer coupling to phytoplankton supports a large biomass of oceanic grazers. Here, copepod stocks approaching 45 g dry wt m^2 occur in late spring as a narrow band at the shelf break.

ACCESS # : 045, ARL

CITATION : Cooney, R.T. 1978. Environmental assessment of the southeastern Bering Sea: zooplankton and micronekton. Principal Investigators' Reports for the Year Ending March 1978. Vol. I. pp. 238-337. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Zooplankton; Micronekton; Copepods; Euphausiids; Walleye pollock.

SYNOPSIS : The distributional data obtained in this study, coupled with an understanding of the biology of the dominant species, is used to assess the relationship between the adjacent oceanic watermasses and that overlying the shelf and slope. Evidence is presented that suggests water shallower than 80 m is isolated biologically from the rest of the shelf environment. Recent physical oceanographic information is discussed as it relates to this observation. The results of this investigation complement the extensive work of Japanese and Soviet scientists by presenting data on the slope and shelf regimes. The influence of the seasonal ice pack is discussed and notions concerning the overall productivity of the region are developed.

ACCESS # : 046, IMS-UAF

CITATION : Cline, J.D., K. Kelly-Hansen and C.N. Katz. 1982. The production and dispersion of dissolved methane in southeastern Bering Sea. Contribution No. 558 from Pacific Marine Environmental Laboratory. NOAA/OMPA/OCSEAP final report. 98 pp.

KEY-WORDS: Methane; models; Current velocities; Port Moller; Salinity; Temperature.

SYNOPSIS : The goal of the study was to use methane as a tracer of mean circulation and to define vertical and horizontal mixing scales in local regions of the southeastern Bering Sea. Subregional studies concentrated on St. George Basin fault line and Port Moller. Methane generation lags carbon fixation by 3-4 months. The North Aleutian study occupied stations from the shore to beyond the 50 m front on several transects from east of Unimak Pass to east of Ugashik Bay in Aug. 1980, Feb. 1981, and May 1981. Evidence for fresh water input from Knichak River and numerous small sources is evident even in February. Considerable detail of T, S, and density is given for the coastal zone region indicating a cyclonic circulation. Concentration of methane near the river front were 500 nl/l in August 1980 decreasing toward the northeast. Maximum concentrations were 22,000 nl/l found in Port Moller decreasing to 1200 nl/l at the entrance. Lower concentrations were found in February 1981 (300 nl/l) and May 1981 (100-200 nl/l). Mixing of methane, once it enters the coastal zone, is rapid in both the vertical and horizontal direction. The inner zone decreases systematically beyond the coastal zone seaward. The Csanady model was applied to the methane data to describe the dispersion of the plume originating in Port Moller.

ACCESS # : 047, RAS-UAF

CITATION : Codispoti, L.A., G.E. Frederich, R.L. Iverson, and D.W. Hood. 1982. Temporal changes in the inorganic carbon system of the southeastern Bering Sea during spring 1980. Nature 296: 242-245.

KEY-WORDS: Total carbon dioxide; Partial pressure of CO_2 (pCO_2); Primary production; Alkalinity; Dissolved oxygen; Chlorophyll a.

SYNOPSIS : Previous studies of the inorganic carbon system in southeastern Bering Sea demonstrated the occurrence of extremely low partial pressures of carbon dioxide (pCO_2) and depressed total carbon dioxide concentrations during late spring. To test the hypothesis that these conditions develop during the spring phytoplankton bloom, and to provide biological production data that would be independent of the carbon-14 technique, we monitored the inorganic system in this region intensively during spring 1980. We demonstrate here that there is a clear relationship between the changes in the inorganic carbon system and the spring phytoplankton bloom.

ACCESS # : 048, IMS-UAF

CITATION : Anon. 1970. Public Hearing, Izembek National Wildlife Range. Bureau of Sport Fisheries and Wildlife. 126 pp.

KEY-WORDS: Wildlife evaluation; Izembek Lagoon; Cold Bay; Zostera; Eelgrass; Waterfowl.

SYNOPSIS : This is a transcription of a review of the existing wildlife range and proposed changes. Public testimony is included from Anchorage and Cold Bay.

ACCESS # : 049, IMS-UAF

CITATION : Phillips, R.C., W.S. Grant and C.P. McRoy. 1983. Reproductive strategies of eelgrass (Zostera marina L.). Aquat. Bot. 16: 1-20.

KEY-WORDS: Zostera; Flowering; Germination; Pacific coast; Salinity; Temperature; Eelgrass.

SYNOPSIS : Zostera on the Pacific coast of North America exhibits a range of reproductive traits, from an entirely annual population in Baja to infrequently flowering plants in northern subtidal areas. A table is presented listing vegetative, reproductive shoots, seed number and spathes for the coastal United States. High salinities generally were shown to inhibit germination - with the exception of the Gulf of Mexico where temperature was important. Flowering increased at both extremes of geographic range. Intertidal, or tidally influenced plants flowered more frequently than plants from deep water. Theories pertaining to stress and disturbance derived for terrestrial plants are applied to Zostera.

ACCESS # : 050, IMS-UAF

CITATION : Phillips, R.C. 1976. Preliminary observations on transplanting and a phenological index of seagrasses. Aquat. Bot. 2: 93-101.

KEY-WORDS: Seagrasses; Alaska; Puget Sound; Transplanting; Survival; Izembek Lagoon; Eelgrass.

SYNOPSIS : Zostera was transplanted both across geographic and tidal lines. Plants transplanted within Puget Sound survived well. Morphological variations with respect to tidal zone were shown to be plastic. Plants transplanted from Izembek Lagoon to Puget Sound did not survive. Various methods were used and evaluated. Late winter and spring are the most successful periods for transplant.

ACCESS # : 051, NMFS

CITATION : Pereyra, W.T., J.E. Reeves, R.G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Northwest Fisheries Center Processed Report. National Marine Fisheries Service, NOAA, 619 pp + Data Appendices.

KEY-WORDS: Demersal fish; Shellfish; Commercially-important species; Fishery resources.

SYNOPSIS : This reports contains (1) findings from a multi-vessel demersal trawl survey of the fauna in the eastern Bering Sea (August-October, 1975): (2) a review of data from historical research vessel surveys and commercial catch statistics; and (3) a summerization of information from the literature pertaining to commercially-important species of demersal fish and shellfish. These studies were directed toward a description and assessment of the demersal fish and shellfish populations of the eastern Bering Sea with which the Bureau of Land Management can evaluate the real and potential impact of petroleum exploration and developement. The results of these studies also provide a data base for assessment of stock conditions that will be used in the development policies for domestic and international fisheries, and in planning future research.

ACCESS # : 052, IMS-UAF

CITATION : Park, P.K., L.I. Gordon, and S. Alvarez-Borrego. The carbon dioxide system of the Bering Sea. In: Oceanography of the Bering Sea, D.W. Hood and E.J. Kelley (eds). OCC. Pub. No. 2 . Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 107-147.

KEY-WORDS: Alkalinity; pH; Total carbon dioxide; Partial pressure of Co_2 (pCo_2); Carbonate minerals; Biochemical oxidation

SYNOPSIS : This paper reviews Co_2 data from all workers that have published on the Bering Sea including that of Alvarey-Borrego et al. 1971. (J. Oceanogr. Soc. Japan 28: 71-93) which has data on distribution of Co_2 system with depth at a line of stations across the southern Bering Sea. One station was taken in 200 fathoms of water west of Unimak Pass.

ACCESS # : 053, PMEL

CITATION : Pearson, C.A., E. Baker, and J.D. Schumacher. 1980. Hydrographic, suspended particulate matter, wind and current observations during re-establishment of a structural front: Bristol Bay, Alaska. Pacific Marine Environmental Laboratory/NOAA, Seattle. Preprint AGU 1980. 27 pp.

KEY-WORDS: Hydrography; Wind; Currents; Storm effects; Stratification; Ekman flux; Coastal domain.

SYNOPSIS : This paper is particularly valuable in showing the effect of storms on the conservative as well as non-conservative property distribution in the near shore areas of Bristol Bay.

ACCESS # : 054, RAS-UAF

CITATION : Petersen, M.R. 1980. Observations of wing-feathered molt and summer feeding ecology of Steller's Eiders at Nelson Lagoon, Alaska. Wildfowl. 31: 99-106.

KEY-WORDS: Eiders; Waterfowl; Feeding; Ecology; Trophic interactions; Molting.

SYNOPSIS : The author discusses the population size of Steller's Eiders in Nelson Lagoon, the molt chronology, feeding behavior and food habits throughout the summer.

ACCESS # : 055, RAS-UAF

CITATION : Petersen, M.R., and M.J. Sigman. 1977. Field studies at Cape Peirce, Alaska - 1976. Annual Reports of Principal Investigators. Vol. 4. pp. 633-693. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Seabirds; Cape Peirce; Waterfowl; Distribution; Breeding ecology.

SYNOPSIS : This report presents information on distribution, abundance, breeding biology, and predation of cliff-nesting marine birds in the Cape Peirce-Shaiak Island vicinity, with a discussion of the spring migration, molt, and foraging areas of loons and waterfowl in 1976. The two numerically dominant species are Common Murres, with a population of between 500,000 and a million, and Black-legged Kittiwakes, with a population between 200,000 and 400,000.

ACCESS # : 056, UW

CITATION : Poe, P.H., G.D. Cortner, and O.A. Mathison. 1976. Monitoring of the Kvichak spawning and nursery areas in 1975. ADF&G Final Rep. #2131

KEY-WORDS: Salmon; Kvichak Bay; Fisheries management.

SYNOPSIS : A description of previous research conducted on the Kvichak Bay salmon run, a presentation of data collected during the 1975 field season, and comparison of 1975 data with records from previous years is presented here. The data includes; 1) the distribution of escapement on the spawning beds, 2) the relative abundance, growth, and distribution of juvenile salmon, 3) rates of primary and secondary production, and 4) the thermodynamics and climatic conditions.

ACCESS # : 057, IMS-UAF

CITATION : VTN Oregon. 1983d. Ecological characterization of shallow subtidal habitats in the northern Aleutian Shelf. Personal communication with Dr. Robert Cimberg of VTN Oregon to Stephen Pace of Kinnetic Laboratories, Inc., September 1983. RE: Food of sea otters.

KEY-WORDS: Trophic interactions; Sea otter; Food; Prey items; Marine mammals.

SYNOPSIS : Although the report from this project is not yet available, information of sea otter food, based on scat examination, revealed that four identifiable prey items were taken by sea otters. These items were razor clams, king crab, yellowfin sole, and flathead sole. Importance and/or quantities of these items are not yet available.

ACCESS # : 058, IMS-UAF

CITATION : Schandelmeier, L., and V. Alexander. 1981. An analysis of the influence of ice on spring phytoplankton population in the southeast Bering Sea. Limnol. Oceangr. 26(5): 935-943.

KEY-WORDS: Phytoplankton; Population structure; Ice; Algal blooms; Bering Sea.

SYNOPSIS : Phytoplankton populations in the southeast Bering Sea were examined with respect to the influence of ice on population structure. Techniques of numerical analysis were applied to the data collected from 109 stations over a 3-year period. Two major groups were present in spring ice-edge groups and a shelf-break group. Results suggest that the ice-edge spring bloom is a distinct but short-lived community, and that ice flora may act as an inoculum early in the spring bloom.

ACCESS # : 059, IMS-UAF

CITATION : Goering, J.J., and C.P. McRoy. 1981. A synopsis of PROBES. Eos Trans. Am. Geophys. Union. 62(44): 730-731.

KEY-WORDS: Research programs; Ecosystems; Productivity; Oceanic fronts; Trophic interactions; Food web.

SYNOPSIS : PROBES is a multi-institutional, interdisciplinary study of the marine ecosystem of the southeastern Bering Sea. The major effort of the program is to understand the processes that contribute to the large production of animals in various trophic levels. The waters over this shelf are highly structured and consist of discrete domains divided by three distinct oceanic fronts. PROBES is examining the importance of these fronts in regulating production of plants and animals and has discovered that these fronts are zones of enhanced biological activity and that the patterns of phytoplankton and zooplankton growth, biomass, and species composition are organized in relation to the fronts. The middle front, in particular, is a zone of enhanced biological activity, and it seperates the middle shelf benthic dominated food web region from the outer shelf pelagic food web dominated region.

ACCESS # : 060, IMS-UAF

CITATION : Niebauer, H.J., C.P. McRoy, J.J. Goering, and R. Iverson. 1982. Productivity data: R/V T.G. Thompson Cruises TT131, TT138, TT149 and TT159. PROBES: Processes and Resources of the Bering Sea Shelf. Unpubl. Data Rept. #82-009. Inst. Mar. Sci., Univ. Ak., Fairbanks. 225 pp.

KEY-WORDS: Primary production; Nutrients; Hydrography.

SYNOPSIS : This report contains all PROBES primary productivity and ancillary data from the Bering Sea shelf. There were a total of 4 carbon or nitrogen productivity stations taken in 1978 and 1979 in the waters close to the north side of the Alaska Peninsula, most in the vicinity of Unimak Island. No stations were actually taken within the 5 km nearshore zone. During late April and early May promary productivity was about 2 $gCm^{-2}d^{-1}$. These rates are typical of the spring bloom in the middle and outer shelf of this region but they are not necessarily applicable to the 5 km zone.

ACCESS # : 061, IMS-UAF

CITATION : McBride, D.N., J.H. Clark and L.S. Buklis. 1982. Assessment of intertidal aquatic plant abundance in the Togiak area of Bristol Bay, Alaska, 1978 through 1979 with emphasis on Fucus sp. ADF&G Data Rept. No. 74. 16 pp.

KEY-WORDS: Seaweeds; Fucus; Herring.

SYNOPSIS : This report includes quantitative assessments of seaweed abundance on the northern shore of inner Bristol Bay. In this area seaweed is a substrate for herring spawn and it is the basis of a commercial harvest.

ACCESS # : 062, IMS-UAF

CITATION : Iverson, R.L., L.K. Coachman, R.T. Cooney, T.S. English, J.J. Goering, G.L. Hunt, Jr., M.C. Maccauley, C.P. McRoy, W.S. Reeburgh and T.E. Whitledge. 1979. Ecological significance of fronts in the southeastern Bering Sea. Pgs. 437-466 in: R.J. Livingston (ed.), Ecological Processess in Coastal and Marine Systems. Plenum Publ. Corp., NY.
KEY-WORDS: Plankton; Productivity; Oceanography; Nutrients; Ecology; Fishes; Benthos.

SYNOPSIS : Three fronts; inner, middle, and outer, divide the continental shelf of the southeastern Bering Sea into three interfrontal zones which contain different food webs. The outer shelf zone contains primarily a pelagic food web while the middle and inner shelf have a predominantly benthic food web.

ACCESS # : 063, IMS-UAF

CITATION : Hood, D.W. 1983. The Bering Sea. Pgs. 337-373 in: B.H. Ketchum, ed., Estuaries and Enclosed Seas. Elsevier Sci. Publ. Co., Amsterdam.

KEY-WORDS: Bering Sea; Oceanography; Chemistry; Biology.

SYNOPSIS : This paper is a general overview of the oceanography, chemistry, and biology of the Bering Sea.

ACCESS # : 064, IMS-UAF

CITATION : VTN Oregon. 1983b. Cruise Report: Cruise 21833 (RP-MF-83A, Leg III), 2-17 June 1983, OCSEAP Red King Crab Distribution. VTN Oregon, Inc. Wilsonville, OR. 5 pp.

KEY-WORDS: King crab; Distribution; Juveniles; Larvae.

SYNOPSIS : Stations in Bristol Bay were sampled for water column parameters, zooplankton and epibenthic invertebrates. Observed densities of larval red king crab were low throughout the study area, with an apparent concentration in north-central Bristol Bay over deep water. The smallest juvenile red king crabs (<10 mm) were collected primarily in Port Moller-Port Heiden area at moderate depths; larger juveniles (10-60 mm) were collected primarily in the northeast end of Bristol Bay, especially Kvichak Bay. The majority of adult crabs collected, including bearing females, were from deeper waters of northern Bristol Bay. Water column chemical/physical data and epibenthic fauna data were recorded for each station.

ACCESS # : 065, NMFS

CITATION : Sears H.S. and S.T. Zimmerman. 1977. Alaska intertidal survey atlas. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Auke Bay Laboratory, P.O. Box 155, Auke Bay, Ak.

KEY-WORDS: Intertidal habitats; Aerial survey; Stratum composition; Beach slope; Biological cover.

SYNOPSIS : Aerial observations were made primarily to classify and provide information on three general littoral parameters: stratum composition, beach slope, and biological cover. Most observations were made from an amphibious aircraft flown at an elevation of approximately 200 ft. Four hundred and two plates were used to describe the coastline from Yakutat to Cape Prince of Wales. In order to facilitate regional usage, the plates were divided into eight geographical areas. The plates present data in the form of: five categories of strata; four categories of biological cover; four categories of beach slope; and other biological phenomena which are divided into categories for wildlife or vegetation.

ACCESS # : 066, OCSEAP/NOAA

CITATION : Michel, J., D.D. Domeracki, L.C. Thebeau, C.D. Getter, and M.O. Hayes. 1982. Sensitivity of coastal environments and wildlife to spilled oil of the Bristol Bay area of the Bering Sea, Alaska. Research Planning Institute, Inc. RPI/R/82/1/15-1, 117 pp + 106 maps. Prepared for NOAA, OCSEAP, Juneau, Ak.

KEY-WORDS: Oil spill; Coastal habitats.

SYNOPSIS : This report is an explanatory text for a series of maps delineating the sensitivity of coastal environments of Bristol Bay, Alaska, to oil spill impact. The study area extended from Unimak Island to Cape Vancouver, including Nunivak Island. The classification used, the Environmental Sensitivity Index (ESI), ranks coastal environments on a scale of 1 to 10 in order of increasing sensitivity to oil (i.e., 1 is least sensitive and 10 is most sensitive). Oil-sensitive wildlife and fisheries, such as the location of bird colonies, seal haulouts, and shellfish areas, are also indicated on the maps. Field surveys were conducted between 24 July and 28 August, 1981. A shoreline assessment technique, called the integrated zonal method, was used to describe and classify the coastal environments of Bristol Bay. The technique included aerial reconnaissance of the entire shoreline, detailed ground studies and sampling at 36 profile stations, 16 rapid-survey sites, and an extensive review of available literature. The physical and biological components of each ESI shoreline type is described, along with the predicted oil behavior and damage, and habitats are discussed in terms of the major species present, their distribution, the effects of oil, and recommended response measures. Areas of socioeconomic importance are also indicated on the maps and discussed in the text. Finally, general protection strategies are proposed for different regions.

ACCESS # : 067, Shell Oil Company, Houston, TX.

CITATION : Gusey, W.F. 1979. The fish and wildlife resources of the southeastern Bering Sea region. Environmental Affairs, Shell Oil Company, Houston, TX. 370 pp.

KEY-WORDS: Fisheries; Distribution; Crab; Shrimp; Fishes; Crustacea.

SYNOPSIS : This publication describes the more conspicuous, esthetically important and commercially valuable fish and wildlife resources of the southern Bering Sea region -- those species that permanently or seasonally occupy the waters over the Bering Sea Continental Shelf from the Aleutian Islands to the Pribilof Islands, and eastward to the Alaska mainland. Little data are available that pertains to the nearshore zone (<50 m) of the north Aleutian Basin.

ACCESS # : 068, IMS-UAF

CITATION : Sarvis, J. 1982. Annual narrative report: Izembek National Wildlife Refuge. Unpubl. Rept., U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service. 137 pp.

KEY-WORDS: Izembek Lagoon, Waterfowl; Marine mammals; Fish.

SYNOPSIS : This report covers observations and activities on Izembek and associated refuges for 1982. A summary of monthly weather data at Cold Bay is included. The report contains a summary of Whistling Swan surveys in the region and includes some production data. The continuing counts of Brant production show 9.5% juveniles for the year and 24.4% for the average for 1963-82; family composition data and mid-winter population data are also given. The report contains a table summarizing productivity and family composition data for Emperor Geese; the average for 1966-82 is 27% juveniles, while for 1982 it was 7.8%. A map presents population data for Emperor Geese on the coast of the Peninsula and Bristol Bay for late April. The winter bird list is also included. Another figure shows the distribution and abundance throughout the year of Steller's Eiders in Izembek Lagoon. From an aerial survey the refuge personnel counted 2208 sea otters and 1971 harbor seals in Izembek Lagoon. A former estimate from 1975 indicated 4500 to 5000 harbor seals in the lagoon. Four walrus were seen at Pt. Divide and in Port Moller.

ACCESS # : 069, IMS-UAF

CITATION : Sarvis, J. 1981. Annual narrative report: Izembek National Wildlife Refuge. Unpubl. Rept., U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service. 119 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Marine mammals; Fish; Unimak Island.

SYNOPSIS : This report covers observations and activities on Izembek and associated refuges for 1981. A summary of monthly weather data at Cold Bay is included. The report contains a summary of Whistling Swan surveys in the region and includes some production data. The continuing counts of brant production show 18.6% juveniles for the year and 25.2% for the average for 1963-81; family composition data and mid-winter population data are also given. The report contains a table summarizing productivity and family composition data for Emperor Geese; the average for 1966-81 is 28.4% juveniles, while for 1981 it was 31.7%. A map presents population data for Emperor Geese on the coast of the Peninsula and Bristol Bay for late April. The winter bird list is also included. Two surveys of beached marine mammals were conducted resulting in 26 sea otter, 2 sea lion and 2 walrus carcasses. A group of 250 walrus were seen in their usual haunts near Cape Seniavin, 110 miles NE of Izembek. A table of salmon catch and escapement for the area streams is included. On Unimak Island, NOAA observers counted 14,346 gray whales (including 167 calves) and 26 killer whales over 87 days.

ACCESS # : 070, IMS-UAF

CITATION : Sarvis, J. 1980. Annual narrative report: Izembek National Wildlife Refuge. Unpubl. Rept., U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Marine mammals; Fish; Unimak Island.

SYNOPSIS : This report covers observations and activities on Izembek and associated refuges for 1980. A summary of monthly weather data at Cold Bay is included. The report contains a summary of Whistling Swan surveys in the region and includes some production data. The continuing counts of Brant production show 25.8% juveniles for the year and 25.5% for the average for 1963-80; family composition data are also given. The report contains a table summarizing productivity and family composition data for Emperor Geese; the average for 1966-80 is 28.2% juveniles. Another table gives the results for aerial surveys in Izembek Lagoon for fall 1980 and spring 1981. A winter bird list for the Cold Bay region is also included. A beaked whale carcass was found on a Bering Sea beach and a herd of about 1000 walrus was seen NE of Izembek. The report again has data on salmon catch and escapement. Data collected from Unimak Island include beached mammal and bird surveys, estimates of murres passing Cape Sarichef and complete bird list for the cape area. A beaked whale carcass was again found on the island.

ACCESS # : 071, IMS-UAF

CITATION : Sarvis, J. 1979. Annual narrative report: Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service. 67 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Marine mammals; Fish; Unimak Island; Amak Island.

SYNOPSIS : This report is a summary of natural history observations in the Izembek and Unimak Island region by refuge personnel. A brief summary of weather averages and extremes for the year is included. Data tables show the % of juvenile Brant for 1971-79 and the family group composition for 1966-79. Refuge personnel considered the numbers of gray whale, sea otter and harbor seal carcasses on Bering Sea beaches to be usual but they report a large increase (about 100 vs. 2 in 1978) in the numbers of headless walrus and attribute this to native subsistence hunting. A transient herd of about 500 hauled out on Amak prior to the appearance of the corpses. Another beaked whale was also found. The report includes tables showing catch and escapement of all salmon species in the streams of Cold Bay, Morzhovoi Bay, Izembek Lagoon and Moffett Lagoon for 1969-79. A winter bird list for Unimak Island is included.

ACCESS # : 072, IMS-UAF

CITATION : Sarvis, J. 1978. Annual narrative report: Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service. 55 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Marine mammals; Fish.

SYNOPSIS : This report is a summary of natural history observations in the Izembek and Unimak Island region by refuge personnel. A brief summary of weather averages and extremes for the year is included. Data tables show the % of juvenile Brant for 1971-78 and the family group composition for 1966-78. The range of mean family size is 2.28 to 3.22. A list of winter birds is included. A summary of sightings of marine mammal carcasses on the Bering Sea beaches includes: 2 sea otters, 2 walrus, 1 sea lion, 2 gray whales and 1 beaked whale (Mesoplodon stejnegeri).

ACCESS # : 073, IMS-UAF

CITATION : Sarvis, J. 1977. Annual narrative report: Izembek National Wildlife Range. U.S. Dept. Interior, Natl. Wildl. Refuge System, Fish Wildl. Service.

KEY-WORDS: Izembek Lagoon; Waterfowl; Marine mammals; Amak Island; Unimak Island.

SYNOPSIS : The report contains a record of birds banded around Izembek Lagoon for 1970 through 1977 and natural history observations on waterfowl and wildlife in the region. A summary of % juveniles of the Brant population is given for 1971 through 1977; in all years the % young averaged 30 to 38 with the exception of 1974 when it was only 5. Detail of population structure is also given for 1966 through 1977 and a table of total population estimates of Brant on the Pacific coast is presented for 1964 through 1978. The 24 year (54-77) average population is 140,888. Population data for the Emperor Goose for 1974-77 are also given. The author reports observations from aerial surveys of gray whale movements on the north side of Unimak Island and the Peninsula. Counts of seabirds present on Amak Island and Sea Lion Rock are given along with an estimate of the Steller's Sea Lion population on the islands (Amak=2000; Sea Lion Rock=3000).

ACCESS # : 074, IMS-UAF

CITATION : McRoy, C.P., J.J. Goering and W.E. Shiels. 1972. Studies of primary production in the Eastern Bering Sea. Pp. 199-216 In: A.Y. Takenouti, ed. Biological Oceanography of the Northern North Pacific Ocean. Idemitsu Shoten, Tokyo.

KEY-WORDS: Primary production; Unimak Pass; Izembek Lagoon.

SYNOPSIS : Data are presented for phytoplankton productivity and biomass (chlorophyll a) in the surface waters of Izembek Lagoon and Unimak Pass. Daily rates from 30 Jun to 1 Aug 68 averaged 78.7 mgC/m^3-day with a biomass of 1.24 mg chlor a/m^3. In Unimak Pass productivity averaged 243 mgC/m^3-day and biomass was 76.0 mg chlor a/m^3. All measurements were in June in 1968 and 1970. Nitrate and ammonia uptake were also measured at one station in Unimak Pass; the ratio of carbon uptake to nitrogen uptake at this station was 6.7.

ACCESS # : 075, IMS-UAF

CITATION : McRoy, C.P. and J.J. Goering. 1976. Annual budget of primary production in the Bering Sea. Mar. Sci. Comm. 2(5): 255-267.

KEY-WORDS: Primary production; Rivers; Lagoons.

SYNOPSIS : The authors construct an annual budget of primary production for the Bering Sea. The primary production of the shelf is estimated to be 141,000,000 m.t. carbon/yr which is 51% of the estimated total production. Rivers contribute 1 to 6,000,000 m.t. carbon, 75% of which is from the Alaska coast. The lagoons of the Alaska Peninsula contribute an estimated 105 m.t. carbon/yr as eelgrass detritus.

ACCESS # : 076, IMS-UAF

CITATION : McRoy, C.P. and J.J. Goering. 1974. The influence of ice on the primary productivity of the Bering Sea. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2., Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 403-421.

KEY-WORDS: Primary production; Unimak Pass; Hydrography.

SYNOPSIS : This paper reports phytoplankton productivity, biomass (chlorophyll a), temperature and salinity on a transect from Unimak Pass to the ice edge in April, 1971. Surface chlorophyll a was less than 1 mg/m^3.

ACCESS # : 077, IMS-UAF

CITATION : McRoy, C.P. and C. McMillan. 1977. Production ecology and physiology of seagrasses. Pp. 53-87 In: C.P. McRoy and C. Helfferich, eds. Seagrass Ecosystems. Marcel Dekker, Inc. New York.

KEY-WORDS: Primary production; Seagrasses; Nutrient cycling; Culture methods; Eelgrass.

SYNOPSIS : This paper presents comparisons of productivity and biomass for temperate and tropical seagrasses. A nitrogen budget for eelgrass in Izembek Lagoon is included.

ACCESS # : 078, IMS-UAF

CITATION : McRoy, C.P. 1977. Seagrass ecosystem studies at Izembek Lagoon: Report of field activities for 1977. Unpubl. Rept., Inst. Mar. Sci., Univ. Alaska, Fairbanks. 33 pp.

KEY-WORDS: Izembek Lagoon; Food-web; Invertebrates; Fish; Nutrient cycling; Phenology; Eelgrass.

SYNOPSIS : This is a progress report of research studies of the eelgrass communities of Izembek Lagoon. A quantitative description of the plant community is included along with some data on sediment nitrogen concentrations. A phenological index comparing eelgrass in Izembek Lagoon to other locations in North America is presented. A species list of invertebrates and fishes occurring in the lagoon is also presented along with a diagram of food web relationships.

ACCESS # : 079, IMS-UAF

CITATION : McConnaughey, T. and C.P. McRoy. 1979. Food web structure and the fractionation of carbon isotopes in the Bering Sea. Mar. Biol. 53: 257-262.

KEY-WORDS: Carbon isotopes; Food web; Plankton; Benthos.

SYNOPSIS : ^{13}C undergoes modest biomagnification in the food web, apparently as a result of being respired at a slower rate than ^{12}C. Using carbon isotope ratio data from pelagic and benthic invertebrates, and fishes, birds, and mammals from the Bering Sea, a model was constructed suggesting that the food web contains 5 or 6 trophic levels. The pelagic system includes about 3 and the benthos 5. Most phytoplankton carbon passes through zooplankton before reaching other consumers. Most carbon remains in the pelagic system and does not reach the benthos. Few benthic filter-feeders rely entirely on phytoplankton for food. Detritus entering the benthic system passes through 1 or 2 trophic steps before reaching the macrofauna. Predatory benthic fishes rely less on benthic macrofauna for food than on pelagic animals.

ACCESS # : 080, IMS-UAF

CITATION : Jones, R.D., Jr. 1971. Refuge narrative report: Aleutian Islands National Wildlife Refuge, Simeonof NWR, Semidi NWR, Bogoslof NWR and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 28 pp.

KEY-WORDS: Aleutian Islands; Izembek Lagoon; Wildlife; Waterfowl; Nelson Lagoon.

SYNOPSIS : This report contains average precipitation, temperature and wind data for Cold Bay, Adak and Shemya for 1971. Notes on waterfowl in the area are included. Data are given for family group counts for Black Brant in Izembek Lagoon. There are also data for the % juveniles in Emperor Goose families at several locations on the Peninsula. A table is included of the commercial catch and escapement for 1963 through 1971 of the five salmon species that spawn in streams in Izembek Lagoon and Moffett Bay. The author conducted an aerial survey of Nelson Lagoon in late August and includes a list of waterfowl observed with population estimates of some species.

ACCESS # : 081, IMS-UAF

CITATION : Jones, R.D., Jr. 1967. Refuge narrative report: Aleutian Islands National Wildlife Refuge and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 44 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Eelgrass; Wildlife.

SYNOPSIS : The report is a narrative of natural history observations at Izembek and in the western Aleutian Islands. Average monthly weather data are included for Cold Bay, Adak and Shemya. An analysis of the population structure of Brant in Izembek is presented.

ACCESS # : 082, IMS-UAF

CITATION : Jones, R.D., Jr. 1966. Refuge narrative report: Aleutian Islands National Wildlife Refuge and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 37 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Eelgrass; Wildlife.

SYNOPSIS : The report is a narrative of natural history observations at Izembek and in the western Aleutian Islands. Average monthly weather data are included for Cold Bay, Adak and Shemya. An analysis of the population structure of Brant in Izembek is presented.

ACCESS # : 083, IMS-UAF

CITATION : Jones, R.D., Jr. 1965. Refuge narrative report: Aleutian Islands National Wildlife Refuge and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 44 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Eelgrass; Wildlife.

SYNOPSIS : The report contains the monthly weather data summaries for Cold Bay and Adak. The author presents his annual natural history observations on the wildlife and waterfowl. Brant population structure data are included.

ACCESS # : 084, IMS-UAF

CITATION : Jones, R.D., Jr. 1964. Refuge narrative report: Aleutian Islands National Wildlife Refuge and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 54 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Eelgrass; Fish; Wildlife.

SYNOPSIS : The narrative report includes the averages of standard weather data for each month at Cold Bay and Adak. Natural history notes on wildlife and waterfowl are included. Presents additional counts of the Brant population in Izembek. A list of 26 fish species caught in Izembek is included.

ACCESS # : 085, IMS-UAF

CITATION : Jones, R.D., Jr. 1963. Refuge narrative report: Aleutian Islands National Wildlife Refuge and Izembek National Wildlife Range. Unpubl. Rept., U.S. Dept. Interior, Bur. Sport Fish. Wildl., Fish Wildl. Serv., Cold Bay, Ak. 21 pp.

KEY-WORDS: Izembek Lagoon; Waterfowl; Weather; Eelgrass; Wildlife.

SYNOPSIS : This is essentially a narrative of natural history observations and activities on the Izembek Range for September through December. Some weather data for the period is included. Family counts of Black Brant to determine % juveniles were begun this year. Biomass data are given for few waterfowl species collected by hunters. The report includes a figure showing the chlorophyll a content of eelgrass leaves.

ACCESS # : 086, IMS-UAF

CITATION : Williams, S.L. and C.P. McRoy. 1982. Seagrass productivity: the effects of light on carbon uptake. Aquat. Bot. 12: 321-344.

KEY-WORDS: Seagrasses; Geographic variation; Productivity; Light; Eelgrass; Carbon uptake; Population ecology.

SYNOPSIS : 14C uptake is used to document the effects of light levels on six genera of North American seagrasses. Productivity increased on a north-south gradient. Where species co-occur ecological status determines response to light stress. Two different responses are predicted for the different forms (tidal and subtidal) of Zostera in Izembek Lagoon.

ACCESS # : 087, IMS-UAF

CITATION : Smith, R. and A.C. Paulson. 1978. Izembek Lagoon. Sea Frontiers. 24: 30-38.

KEY-WORDS: Izembek Lagoon; History; Habitat; Wildlife; Eelgrass; Waterfowl.

SYNOPSIS : This article is a general survey of the Izembek Wildlife Range environment. The history of the area is briefly presented. Izembek is a critical habitat for marine birds. The seagrass beds of the lagoon are thought to be the basis of the high productivity of the area.

ACCESS # : 088, IMS-UAF

CITATION : Short, F.T. 1983. The response of interstitial ammonia in eelgrass (Zostera marina L.) beds to environmental perturbations. J. Exp. Mar. Biol. Ecol. 68: 195-208.

KEY-WORDS: Zostera; Izembek Lagoon; Perturbation; Nutrients; Eelgrass; Sediments.

SYNOPSIS : Ammonia pools are related to observed biomass of Zostera. Colonization of eelgrass is documented after ice scour on natural and introduced substrata. Ammonia levels decrease as colonization procedes. Ammonia-nitrogen is postulated to be limiting in shallow environments and possibly during the height of the growing season at high organic (deep water) stations. Sediments are capped and leaves clipped to elucidate nitrogen turnover and uptake.

ACCESS # : 089, IMS-UAF

CITATION : Short, F.T. 1981. Nitrogen resource analysis and modeling of an eelgrass (Zostera marina L.) meadow in Izembek Lagoon, Alaska. Ph.D. Dissertation. Univ. of Alaska. 173 pp.

KEY-WORDS: Zostera; Izembek Lagoon; Nitrogen uptake; Sediments; Perturbation; Models; Eelgrass; Nutrients.

SYNOPSIS : This study attempts to correlate sediment nitrogen concentrations with observed plant biomass. Uptake experiments using 15N demonstrate the importance of the water column and leaf uptake as well as root uptake. High values of sediment nitrogen were found in beds with high plant biomass. Perturbation experiments examined the effects of ice scouring and subsequent recolonization. Nitrogen levels were monitored in natural and introduced substrata. Leaves were removed and sediments in two experiments designed to document ammonia turnover and uptake rates. A computer model was developed to predict biomass, leaf length and effects of fertilization.

ACCESS # : 090, IMS-UAF

CITATION : Reardon, J. 1975. Izembek spells tops in waterfowling. Outdoor Life. 155(5): 78-81, 141-142, 145.

KEY-WORDS: Izembek Lagoon; Geese; Hunting; Eelgrass.

SYNOPSIS : An account of goose hunting at Izembek. Some information on goose population and conditions for migration south.

ACCESS # : 091, IMS-UAF

CITATION : Merritt, L.B. C.P. McRoy. 1972. Simulation of the annual ecological cycle of shallow marine plants - Eelgrass of Izembek Lagoon, Alaska. Unpublished manuscript. Int. Sympos. Math. Mode. Tech. in Water Resources Systems. 13 pp.

KEY-WORDS: Zostera; Models; Izembek Lagoon; Eelgrass; Productivity.

SYNOPSIS : Description of a mathamatical model that depicts biomass changes in Izembek Lagoon of Zostera. The model is based upon data from 1967, and generates an hourly growth rate. Biomass and physical parameters may be adjusted to test effects on the ecosystem. Light was shown to be an important variable; assumptions made in the model include a homogenous grass bed and a non-limiting nutrient supply. Simulations showed measured rates of photosynthesis to be too low to account for observed growth.

ACCESS # : 092, IMS-UAF

CITATION : McRoy, C.P. and S.L. Williams. 1977. Sublethal effects on seagrass photosynthesis. OCSEAP/NOAA. Final report. 36 pp.

KEY-WORDS: Seagrasses; Photosynthesis; Hydrocarbons; Light requirements; Izembek Lagoon; Eelgrass.

SYNOPSIS : This report contains a review of seagrass ecosystem biology. The importance of viewing eelgrass meadows as ecosystems in light of potential perturbation is stressed. Light requirements were investigated for three genera from Alaska (Zostera - Izembek Lagoon, Ruppia - Izembek Lagoon, Phyllospadix - southeastern). A 14C technique was developed for work on seagrasses. The effects of toluene and kerosene were assessed in the laboratory and in situ. Kerosene depressed plant growth but toluene had no effect. Electron microscopy showed plant cell deformation after exposure to hydrocarbons.

ACCESS # : 093, RAS-UAF

CITATION : McRoy, C.P. and N. McRoy. 1965. Field observations on the summer birds of the Izembek Lagoon region of the Alaska Peninsula. Bull. Alaska Ornithol. Soc. 5: 1-7.

KEY-WORDS: Birds; Izembek Lagoon; Waterfowl.

SYNOPSIS : This report is an annotated list of 54 birds observed around Izembek Lagoon during the summer of 1964.

ACCESS # : 094, IMS-UAF

CITATION : McRoy, C.P., D.C. Burrell, J. Goering and R.J. Barsdate. 1974. Heavy metal dynamics in seagrass ecosystems: processes and oceanic interactions. Unpublished Report. NSF/IDOE Pollutant Transfer Meeting. 20 pp.

KEY-WORDS: Trace metals; Cycling; Zostera; Izembek Lagoon; Eelgrass.

SYNOPSIS : Trace metal cycling is complicated by plant interactions with the sediments and food chain transfers. This report presents objectives for study of uptake of Zn, Cu, Cd, Hg, As, and Si. Preliminary results indicate that roots are enriched in Zn and Cu, but depleted in Cd with respect to leaves. A table with trace metal concentrations of various plant parts is included.

ACCESS # : 095, IMS-UAF

CITATION : McRoy, C.P., R.J. Barsdate and M. Nebert. 1972. Phosphorus cycling in an eelgrass (Zostera marina L.) ecosystem. Limnol. and Oceanography. 17(1): 58-67.

KEY-WORDS: Zostera; Izembek Lagoon; Phosphorus uptake; Nutrients; Eelgrass.

SYNOPSIS : Zostera is postulated as mechanism for transfer of phosphorus from sediments to water column. Phosphorus requirements and transfer rates are calculated and a box model is created. Resupply of phosphorus to the lagoon is suspected to occur through remineralization of detritus and mobilization from volcanic sands.

ACCESS # : 096, IMS-UAF

CITATION : McRoy, C.P. and R.J. Barsdate. 1970. Phosphate absorbtion in eelgrass. Limnol. and Oceanography. 15: 6-13.

KEY-WORDS: Phosphorus uptake; Zostera; Izembek Lagoon; Nutrients; Eelgrass.

SYNOPSIS : Plants were seperated into roots, rhizomes, and various leaf parts and exposed to ^{32}P tracer. Incubations were performed in the light and dark in an effort to document the role of light in uptake. $^{32}PO_4$ was also injected directly into sediments in the lagoon to measure in situ. Phosphate uptake increased with increasing light and was demonstrated to appear in the leaf tissue within 24 hours in the lagoon experiments. Significant transfer was shown from roots into the water column but the reverse was not observable.

ACCESS # : 097, IMS-UAF

CITATION : McRoy, C.P. 1974. Seagrass productivity: Carbon uptake experiments in eelgrass, Zostera marina. Aquaculture. 4: 131-137.

KEY-WORDS: Zostera; Izembek Lagoon; Carbon; Productivity; Eelgrass.

SYNOPSIS : ^{14}C was used to correlate light intensity with primary productivity in Izembek Lagoon. Five light levels were tested using various filters. Water, temperature, and solar radiation were recorded. Productivity in eelgrass is complicated by an unknown degree of internal recycling of gases and loss of organics. A relationship between light and productivity was derived, kinetic constants were variable. Inhibition was seen at high light intensities. Leaf turnover was estimated at twice per year.

ACCESS # : 098, IMS-UAF

CITATION : McRoy, C.P. 1974. Seagrass ecosystems of the Pacific coast of North America. Unpublished manuscript. AAAS Meetings. San Fransisco, Calif. 5 p.

KEY-WORDS: Seagrasses; Eelgrass; Izembek Lagoon; Decomposition; Human use.

SYNOPSIS : This paper presents a review of seagrass distribution along the Pacific coast. Izembek Lagoon is discussed and detrital loss estimated at 500,000 metric tons dry weight each year. Microbial decomposers are an important food source to eelgrass detritus grazers; direct grazing is limited. Seri Indians were reported to use eelgrass seeds as a food source.

ACCESS # : 099, IMS-UAF

CITATION : McRoy, C.P. 1970. Standing stocks and other features of eelgrass (*Zostera marina*) populations on the coast of Alaska. J. Fish. Res. Brd. Can. 27: 1811-1821.

KEY-WORDS: Zostera; Standing stock; Benthic algae; Coastal Alaska; Eelgrass; Izembek Lagoon.

SYNOPSIS : This study compares eelgrass beds in ten sites on the Alaskan coast from southeastern to the Seward Peninsula. Standing stocks and densities were highest at Izembek and Kinzarof Lagoons on the Alaska Peninsula. Differences were attributed to local environmental conditions and not latitude. Occurrence of benthic algae was correlated with sediment type. Caloric value and chlorophyl concentrations are reported for all sites.

ACCESS # : 100, IMS-UAF

CITATION : McRoy, C.P. 1970. On the biology of eelgrass in Alaska. Ph.D. Dissertation. Univ. Alaska. 156 pp.

KEY-WORDS: Izembek Lagoon; Coastal Alaska; Productivity; Elemental composition; Zostera; Eelgrass.

SYNOPSIS : Review of eelgrass biology. The chemical composition of Zostera is presented in tabular form. Because eelgrass is a rooted plant it is important in recycling nutrients that would otherwise likely be lost to the sediments. Protein content, lipids, ash, carbohydrate, and vitamin composition is reported. These values are compared with several terrestrial species. The biogeography of eelgrass in Alaska is discussed, including a survey of biomass, density, chlorophyll concentration, and caloric content. Highest standing stocks are reported for Izembek Lagoon. Standing stock is shown to correlate well with leaf length. The discovery of Zostera growing under ice on the Seward Peninsula is documented. ^{32}P is used to assess the uptake mechanisms of roots and leaves. Phosphate was shown to be transported rapidly through the plant, rates were highest in the light. Metabolic experiments using oxygen concentration as an indicator were performed. Water temperatures at various sites within the lagoon are correlated with growth patterns.

ACCESS # : 101, IMS-UAF

CITATION : McRoy, C.P. 1968. A Eurasian alga in Alaska. Pacif. Sci. 22(1): 138.

KEY-WORDS: Fucus; Distribution; Algae; Waterfowl.

SYNOPSIS : The author reports collecting Fucus inflatus at Izembek Lagoon. The species had not previously been reported on the west coast of North America. The alga may have been introduced by migrating Steller's Eiders.

ACCESS # : 102, IMS-UAF

CITATION : McRoy, C.P. 1968. The distribution and biogeography of Zostera marina (Eelgrass) in Alaska. Pacif. Sci. 22(4): 507-513.

KEY-WORDS: Zostera; Coastal Alaska; Biogeography; Eelgrass; Izembek Lagoon.

SYNOPSIS : The occurrence of Zostera is documented and mapped for coastal Alaska. Distribution is more a function of suitability of habitat than dispersal. Izembek Lagoon is sited as the largest known stand of eelgrass. Plants were discovered as far north as the Seward Peninsula. Biogeography is discussed and similarities with invertebrate distributions through the Arctic are presented.

ACCESS # : 103, IMS-UAF

CITATION : McRoy, C.P. 1966. The standing stock and ecology of eelgrass (Zostera marina L.) in Izembek Lagoon, Alaska. M.S. Thesis. Univ. Washington. 138 pp.

KEY-WORDS: Zostera; Standing stock; Izembek Lagoon; Meterology; Hydrography; Ecology; Eelgrass; Sediments.

SYNOPSIS : Eelgrass biology, distribution and literature is reviewed. The lagoon area is described and climatological data presented. A survey of eelgrass biology in Izembek includes standing stock and productivity measurements. All results are analized for statistical differences among sites. A sampling program for eelgrass is presented. Patterns within different grass beds are discussed and differences attributed to temperature. Eelgrass detritus is postulated to support the extensive diversity of mammals, birds, and invertebrates.

ACCESS # : 104, IMS-UAF

CITATION : McConnaughey, T. and C.P. McRoy. 1979. C label identifies eelgrass (Zostera marina) carbon in an Alaskan estuarine food web. Mar. Biol. 53: 263-269.

KEY-WORDS: Carbon uptake; Izembek Lagoon; Food web; Detritus; Eelgrass; Zostera.

SYNOPSIS : Naturally occurring ^{13}C is used to trace the Izembek food web. ^{12}C is respired more readily than 13C and therefore successive links in the food chain become more isotopically heavy. Lipids however are isotopically light and have been corrected for in this study using C/N. Quantitative sampling of plants, phytoplankton, invertebrates, birds, and mammals is reported in a table which includes corrected $^{13}C/^{12}C$, C/N, and observed diets. The herbivores are closest isotopically to eelgrass while detritus food chains are several times longer. Still the "reasonably short food webs" are capable of supporting the high productivity documented for the lagoon.

ACCESS # : 105, IMS-UAF

CITATION : McConnaughey, T. 1978. Ecosystems naturally labeled with Carbon-13: applications to the study of consumer food-webs. M.S. Thesis. Univ. Alaska. 127 pp.

KEY-WORDS: Food web; Eelgrass; Izembek Lagoon; Tracers; Trophic interactions.

SYNOPSIS : Natural abundance $^{13}C/^{12}C$ ratios provide a tracer for the origin of organic carbon in complex coastal marine food webs and also appear to be useful for examining trophic organization and food transfer efficiencies in more strictly oceanic environments. The tracer approach proved useful for analyzing the role of eelgrass (Zostera marina) in the food web of Izembek Lagoon, Alaska. Both eelgrass and phytoplankton contribute to the productivity of that community. The analysis was complicated by non-ideal tracer behavior, however. Animal $^{13}C/^{12}C$ ratios appeared to depend on biochemical composition, and ways to deal with this were investigated. Furthermore, animal metabolism tended to retain ^{13}C relative to ^{12}C, resulting in progressive elevation of $^{13}C/^{12}C$ ratios in the higher trophic levels. By assuming a uniform relation between ^{13}C enrichment and metabolic stoichiometry, it was possible to deduce animal "trophic positions" and food transfer efficiencies from $^{13}C/^{12}C$ data taken from the Bering Sea.

ACCESS # : 106, IMS-UAF

CITATION : McCartney, A.P. 1973. Prehistoric cultural integration along the Alaska Peninsula. M.S. Thesis. Univ. Arkansas. 49 pp.

KEY-WORDS: Applegate Cove; Stone tools; Aleuts; Anthropology; Archaeology; Comparative cultures; Izembek Lagoon.

SYNOPSIS : The Alaska Peninsula is important anthropologically because it is the juncture of four important spheres of influence. Excavations at Applegate Cove (Izembek Lagoon) are compared with sites at the base of the Alaska Peninsula. Descriptions of temporary dwellings and one permanent bone house at Izembek along with radio carbon data and artifact information are used to support the hypothesis that the tip of the peninsula represents an integration of cultural types.

ACCESS # : 107, RAS-UAF

CITATION : Jones, R.D., Jr. and D.M. Jones. 1966. The process of family disintegration on Black Brant. Wildfowl Trust. 17th Annual Report. pp 75-78.

KEY-WORDS: Black Brant; Social behavior; Family composition; Izembek Lagoon. Waterfowl.

SYNOPSIS : 34,000 observations were made in the fall of 1965. The Brant arrive in family groups that flock together, seperate from flocks of non-breeding birds. Behavior of these groups is described. A table of populations of adults and juveniles is presented. As birds prepared to continue south family groups began to break up and flocks of families and non-breeders merged.

ACCESS # : 108, RAS-UAF

CITATION : Jones, R.D., Jr. 1970. Reproductive success and age distribution of Black Brant. J. Wildlife Manage. 34(2): 328-333.

KEY-WORDS: Black Brant; Juvenile population; Family compostition; Izembek Lagoon; Waterfowl.

SYNOPSIS : Data on reproductive success for the years 1963-1969 is presented. The proportion of juveniles in the population is based on over 140,000 observations. The number of juveniles per family group ranges from 2.6-2.9. The birds' ages were determined through plumage observations. Non-breeding populations are large even when reproductive success is good. A sample calculation for reproductive success using 1966 data is reported.

ACCESS # : 109, RAS-UAF

CITATION : Jones, R.D., Jr. 1965. Returns from Steller's Elders banded In Izembek Bay, Alaska. Wildfowl Trust. 16th Annual Report. pp 83-85.

KEY-WORDS: Steller's Elders; Izembek Lagoon; Migration; Nesting; Waterfowl.

SYNOPSIS : Over 200,000 birds migrate through Izembek and Nelson Lagoons and Bechevin Bay. The population peaks in April for the spring migration, the fall arrival is much more variable depending on where the birds molt. Males and females segregate during molting. Birds banded in 1961 and 1962 at Izembek were recovered on the Arctic coast of Siberia. A table of recovered birds with recovery sites is included.

ACCESS # : 110, RAS-UAF

CITATION : Jones, R.D., Jr. 1963. An overland migration of fur seals. J. Mammal. 44(1): p 122.

KEY-WORDS: Izembek Lagoon; Cold Bay; Fur seals; Marine mammals.

SYNOPSIS : Two female fur seals (one in 1960 and one in 1962) were observed by the author migrating three miles overland from Izembek Lagoon to Cold Bay.

ACCESS # : 111, IMS-UAF

CITATION : Iizumi, H., A. Hattori and C.P. McRoy. 1982. Ammonium regeneration and assimilation in eelgrass (Zostera marina) beds. Mar. Biol. 66: 59-65.

KEY-WORDS: Nitrogen regeneration; Izembek Lagoon; Crane Cove; Nitrogen; Eelgrass; Sediments; Nutrients.

SYNOPSIS : Nitrogen regeneration in sediments is crucial to supporting high productivity in seagrass beds. Expressions are derived for total ammonia, regeneration rates, and assimilation rates in interstitial sediment pools. ^{15}N is used as an experimental tracer. High assimilation versus regeneration rates measured in Japan imply allocthonous nutrient supplies. Data from Izembek indicates that most of the nitrogen required for eelgrass growth is regenerated within the lagoon, while Crane Cove in southeastern Alaska is apparently a sink for external NO_3.

ACCESS # : 112, IMS-UAF

CITATION : Iizumi, H., A. Hattori and C.P. McRoy. 1980. Nitrate and nitrite in interstitial waters of eelgrass beds in relation to the rhyzosphere. J. Exp. Mar. Biol. Ecol. 47: 191-201.

KEY-WORDS: Izembek Lagoon; Denitrification; Sediments; Zostera; Eelgrass; Sediments; Nutrients.

SYNOPSIS : The distribution of NO_3-NO_2 and denitrification in deep anaerobic in Izembek Lagoon in 1977 is discussed. A transect through the lagoon is described in terms of changing plant and sediment characteristics. Plants are larger and less dense at the deep end of the transect compared to the shallower evironment. Sediment organics and nutrients also increase with depth. $K^{15}NO_3$ is added to sediment slurries to determine denitrification rates. Ambient NO_3 concentrations are anomylously high for reducing sediments. Chamber experiments designed to document oxygen evolution from roots support the hypothesis that light-coupled oxygen exudation into the sediments results in nitrification. The sediments from high organic areas demonstrate the greatest calculated denitrification rates.

ACCESS # : 113, IMS-UAF

CITATION : Iizumi, H. 1979. The nitrogen cycling in eelgrass (Zostera marina L.) beds. Ph.D. Dissertation. Univ. Tokyo. 120 pp.

KEY-WORDS: Izembek Lagoon; Crane Cove; Nitrogen uptake; Ammonia regeneration; Sediments; Nitrogen requirements; Zostera; Eelgrass; Nutrients.

SYNOPSIS : ^{15}N tracer experiments were performed to determine kinetics of nitrogen uptake. Leaf uptake was found to be proportional to concentration. Tanslocation to leaves from roots was higher in the light. Nitrogen was translocated from both old leaves and roots to young leaves. NH_4 repressed uptake of NO_3-NO_2. Phytoplankton and epiphyte productivity is also reported. Growth rates determined from ^{15}C and ^{14}C compared favorably. Derivation of mathematical expressions used to calculate NH_4 regeneration and assimilation are presented. Rates for three lagoon sites from different depths are reported and nitrogen requirements calculated. NO_3-NO_2 is measured in anoxic sediments and suggested to be a result of oxygen pumping from roots.

ACCESS # : 114, IMS-UAF

CITATION : Goering, J.J. and C.P. McRoy. 1969. Ecology and nitrogen cycle in a marine plant community. Unpublished Annual Progress Report to Federal Water Pollution Control Administration. 11 pp.

KEY-WORDS: Izembek Lagoon; Zostera; Algae; Nitrogen uptake; Oceanography; Eelgrass; Nutrients.

SYNOPSIS : This report is essentially a summary of on-going research with comparatively little data. Objectives of the study include quality and character of eelgrass, benthic algae, standing stock and productivity of phytoplankton, and physiological ecology of Zostera. Preliminary results suggests that NH4 uptake is light dependent. Solar radiation and temperature are designated key physical influences. Planned experiments are reported which include measurement of nitrogen fixation and oceanographic characteristics of the lagoon and near-by offshore waters. Inorganic nutrients are reported for the lagoon and offshore, preliminary data.

ACCESS # : 115, RAS-UAF

CITATION : Petersen, M.R. 1978. The feeding ecology of Steller's Eiders. Pac. Seabird Group Bull. 5(1): 33 (Abstract).

KEY-WORDS: Eiders; Waterfowl; Feeding; Trophic interactions; Ecology; Nelson Lagoon.

SYNOPSIS : A report of the foods and feeding behavior of Steller's Eiders at Nelson Lagoon. The primary food of eiders seems to be the mussel, Mytilus edulis, supplemented by amphipods, polychaete worms, isopods, clams of the genera Mya and Macoma, shrimps, and snails.

ACCESS # : 116, NMFS

CITATION : Weber, D.D. 1974. Observations of growth of southeastern Bering Sea king crab, Paralithodes camtschatica, from a tag-recovery study, 1955-65. National Marine Fisheries Service, Seattle, WA. Northwest Fisheries Center. Report No. NOAA-NMFS-DR-86; NOAA-74103102. 126 pp.

KEY-WORDS: King crab; Growth; Tagging studies.

SYNOPSIS : Growth data from a ten year tag-recovery study of southeastern Bering Sea king crab, Paralithodes camtschatica, were evaluted for sources of error and the usable growth information documented. For simplified analysis of growth data the adult male crab growth increments may be combined since the increase in carapace length, the crab's migratory pattern, molting stage at time of tagging, area of recapture, and selectivity of the fishery can influence interpretation of the growth data. The interaction of these parameters are considered in data application.

ACCESS # : 117, IMS-UAF

CITATION : Warner, I.M. and P. Shafford. 1977. Forage fish spawning surveys - southeastern Bering Sea. Principal Investigators' Reports for the Year Ending March 1977. Vol. 10. pp. 1-64. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Fishes; Spawning; Eulachon; Capelin; Smelt; Herring.

SYNOPSIS : This document presents information on the nearshore spawning stocks of forage fish along the east coast of the Bering Sea with respect to relative abundance, spatial distribution, and basic life history. Aerial surveillance and actual collection of specimens were the approaches employed in conducting the survey.

ACCESS # : 118, NMFS

CITATION : Walters, G.E. 1983. An atlas of demersal fish and invertebrate community structure in the eastern Bering Sea: Part 2, 1971-77. NOAA Technical Memorandum NMFS F/NWC-40. 152 pp.

KEY-WORDS: Demersal fish; Benthic invertebrates; Cluster analysis.

SYNOPSIS : This report presents the results from the second of two studies using numerical classification, i.e., "cluster analysis," techniques to investigate the community structure of demersal fish and invertebrates in the eastern Bering Sea. Annual summer trawl survey data for the years 1971-77 were used to describe apparent habitat areas and species associations, and to examine interannual variability.

ACCESS # : 119, NMFS

CITATION : Walters, G.E. and M.J. McPhail. 1982. An atlas of demersal fish and invertebrates community structure in the eastern Bering Sea: Part 1, 1978-81. NOAA Technical Memorandum NMFS F/NWC - 35. 122 pp.

KEY-WORDS: Demersal fish; Benthic invertebrates; Cluster analysis.

SYNOPSIS : This report presents the results of using numerical classification, i.e., "cluster analysis," techniques to investigate some of the qualitative characteristics of demersal fish and invertebrate community structure in the eastern Bering Sea. Summer trawl survey data from the 4 years, 1978-81, were used to examine relationships between species, describe apparent habitat areas, and measure the extent of interannual variability.

ACCESS # : 120, IMS-UAF

CITATION : Waldron, K.D. 1981. Ichthyoplankton. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 471-493, NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Ichthyoplankton; Larvae; Plankton; Walleye pollock.

SYNOPSIS : Ichthyoplankton studies in the Bering Sea have been conducted since 1955 by Japanese, Soviet, and United States biologists. Comparison and integration of the results of the various surveys is difficult because surveys were conducted during different seasons, different nets and types of tows were used to collect the samples, and different areas were surveyed. Sampling effort was unevenly distributed seasonally with only 1 percent expanded during winter, about 9 percent during fall, 35 percent during spring, and 55 percent during summer. Of the approximately 300 species of fish that occur as adults in the Bering Sea, eggs and/or larvae of about 270 species, divided among 137 genera in 34 families, might be expected to be present in plankton samples. Plankton collections made since 1955 contained 60 species divided among 55 genera in 24 families. Families that occurred most frequently in the 26 collections studied were Cottidae (26), Gadidae (23), Hexagrammidae (23), and Stichaeideae (23). Because of differences in seasonal and areal coverage, it is difficult to determine which larvae were most abundant. For collections made during spring between the Aleutian Islands and about 60 degrees N and centered over the continental slope, larvae of pollock (Theragra chalcogramma) were much more abundant than other species or genus. An adequate knowledge of the ichthyoplankton of the Bering Sea can be gained only by a comprehensive survey, possibly a cooperative effort by Japanese, Soviet, and U.S. vessels and scientists, of at least a year's duration.

ACCESS # : 121, IMS-UAF

CITATION : Waldron, K.D. and B.V. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Principal Investigators' Reports for the Year Ending March 1978. Vol. 1. pp. 236-237. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Ichthyoplankton; Walleye pollock; Spawning periods; Vertical distribution; Horizontal distribution; Fishes.

SYNOPSIS : This study mainly focused on walleye pollock, although other ichthyoplankton were also examined. Data were collected with bongo and neuston nets between mid April and mid May 1977. Most of the eggs and larvae collected were pollock. The report concludes that no marked differences in distribution and abundance of pollock eggs and larvae occurred between 1976 and 1977. Almost all pollock larvae and a majority of pollock eggs were more than 0.25 m below the sea surface.

ACCESS # : 122, IMS-UAF

CITATION : Waldron, K.D. and F. Favorite. 1977. Ichthyoplankton of the eastern Bering Sea. Annual Reports of Principal Investigators for the Year Ending March 1977. Vol. IX. pp. 628-682. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Ichthyoplankton; Walleye pollock; Spawning periods; Vertical distribution; Horizontal distribution; Fishes.

SYNOPSIS : Although this study addressed ichthyoplankton in general, it primarily focused on walleye pollock. Samples of ichthyoplankton were collected with bongo and neuston nets in the eastern Bering Sea between mid April and mid May 1976. Pollock accounted for most of the eggs and larvae collected. The study revealed that pollock eggs were much more abundant in the upper one meter of the water than below that depth and larvae were more abundant below the one meter depth. The study concluded with the supposition that environmental changes limited to the surface layer would be most damaging to pollock eggs, and changes extending to deeper layers would have a greater effect on pollock larvae.

ACCESS # : 123, IMS-UAF

CITATION : VTN Oregon. 1983a. Cruise Report: Cruise MF 83-1 (RP-MF-83A, Leg I), 18 April - 7 May 1983, OCSEAP Red King Crab Distribution. VTN Oregon, Inc. Wilsonville, OR. 5 pp.

KEY-WORDS: King crab; Distribution; Juveniles; Larvae.

SYNOPSIS : Plankton and epibenthic samples were collected in the North Aleutian Basin to determine the apparent distribution of larval and early juvenile red king crab (Paralithodes camtschatica). Ancillary physical and chemical data for subsequent correlations to the apparent distribution pattern(s) were also gathered. No larval red king crabs were collected before 1 May 1983. Release of larvae was apparently late this year compared to 1982 sampling; half of the adult females examined had layed eggs as of 30 April. Larvae were found at the 50 m stations between Black Hills (on Alaska Peninsula) and Cape Seniavin. A maximum density of approximately 200 Stage I zoeae per 1,000 m^3 was observed at station 17. The available data indicated that the larvae vertically migrated over the period studied. Juveniles were collected solely in nearshore rocky areas where colonial tube-forming polychaetes were present. Their apparent distribution was patchy due to the uneven distribution of these regions within Bristol Bay and the low sampling efficiency of the rock dredge. The greatest single catch of these juveniles was in Kvichak Bay. Other "successful" areas included off Port Moller and Cape Seniavin and around the Walrus Islands.

ACCESS # : 124, WILDL. DEPT.-UAF

CITATION : Tack, S.L. 1970. The summer distribution and standing stock of the fishes of Izembek Lagoon, Alaska. M.S. Thesis, University of Alaska, 111 pp.

KEY-WORDS: Fishes; Standing stocks; Izembek Lagoon; Eelgrass.

SYNOPSIS : A small otter trawl and a pushnet were used to quantitatively sample the fishes of Izembek Lagoon, Alaska, during July and August 1968. Twenty-five species of fish belonging to 11 families were taken in Izembek Lagoon during this study. Most were in juvenile stages. Three distinct communities were identified: (1) the eelgrass community dominated by the tubenose poacher (Pallasina barbata) and the masked greenling (Hexagrammus octogrammus); (2) the channel community dominated by whitespotted greenling (H. stelleri); and (3) the sand flat community dominated by the Pacific staghorn sculpin (Leptocottus armatus). The tubenose poacher was the only species that spawned during the summer, but both the masked and whitespotted greenlings were gravid at the time sampling was concluded in early August. The standing stock of fishes was estimated at 119.6 kg/ha in eelgrass, 73.4 kg/ha in channel, and 21.3 kg/ha on sand flats.

ACCESS # : 125, IMS-UAF

CITATION : Stoker, S. 1981. Benthic invertebrate macrofauna of the eastern Bering/Chukchi continental shelf. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1069-1090. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Benthos; Invertebrates; Macrofauna; Communities; Standing stock; Biomass.

SYNOPSIS : This study presents a view of a closely interrelated Bering/Chukchi benthic community system that extends unbroken over the entire continental shelf, with the Chukchi Sea benthos probably relying heavily on Bering Sea for both food supply and recruiment. Indications are that this is a highly productive and relatively stable benthic system composed of at least eight major faunal assemblages of considerable complexity. The environmental factor correlating most strongly with the distribution of these faunal assemblages and with distribution of individual major species appears to be sediment type, but summer bottom temperature and water mass distribution may also be critical. The distribution of standing stock biomass in relation to diversity suggests predation pressure on the southern and northern extremes of the study area, presumably the result of benthic-feeding marine mammal populations and possibly, in the southern region, demersal fish. In general, it appears to be a strongly detritus-based trophic system, with a high standing-stock biomass observed in the Bering Strait and southern Chukchi Sea region, probably the combined result of high near-surface primary productivity distributions and current structure. The benthic fauna over this region appears to be dominated by boreal Pacific forms, probably also a result of the current structure, with high-arctic forms frequent only in the northern waters.

ACCESS # : 126, IMS-UAF

CITATION : Smith, G.B. 1981. The biology of walleye pollock. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 1: 527-55. NOAA, distrib. by Univ. Washington Press, Seattle, WA

KEY-WORDS: Walleye pollock; Population ecology; Food web.

SYNOPSIS : This document presents biological information on the walleye pollock from the eastern Bering Sea. Population characteristics that are presented include nomenclature, genetic structure, description of habitat, stock size, size and age composition, growth, and reproduction. Within the food web pollock are an important food resource for a wide variety of other fish species, marine mammals, and avifauna. Pollock also represents a major source of predation directed toward zooplankton and cannibalistic behavior. In additionl trawl fisheries harvest approximately 950,000 mt of pollock annually.

ACCESS # : 127, IMS-UAF

CITATION : Smith, R.L., T. McConnaughey, and A.C. Paulson. Fish diets in a subarctic eelgrass (Zostera marina) ecosystem. Unpublished manuscript. 19 pp.

KEY-WORDS: Trophic interactions; Eelgrass; Fishes; Zostera.

SYNOPSIS : Dietary information on 20 fish species inhabiting the eelgrass beds of Izembek Lagoon, Alaska is reported. Fish fed primarily of benthic and epibenthic amphipods, especially caprellids, while predation on infauna and abundant epiphytic mollusks was relatively minor. Piscivory and planktivory were secondary in importance, and no detritivorous or herbivorous fish were captured. Comparison of the Izembek fish fauna with that of Japanese eelgrass beds reveals marked dissimilarity, while the fish of temperate eastern Pacific eelgrass beds are more similar. Despite differences in species composition and reduced diversity, trophic relations on this subarctic eelgrass bed are analagous to those in more temperate regions.

ACCESS # : 128, IMS-UAF

CITATION : Smith, R.L., A.C. Paulson, and J.R. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Final Reports of Principal Investigators. Vol. 1. pp. 33-107. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Trophic interactions; Demersal fishes; Predation.

SYNOPSIS : This document presents food and feeding interactions for twelve benthic and demersal fishes. Data were collected on nine species (pollock, rex sole, dover sole, flathead sole, arrowtooth flounder, Greenland flounder, capelin, and shortfin eelpout). A summary of previously existing information on three species (Pacific cod, yellowfin sole, and Pacific halibut) is also presented. Information presented includes analyses of predator size vs. prey composition; bottom type, temperature and location vs. prey composition; prey composition in diets vs. prey abundance; and prey composition vs. season.

ACCESS # : 129, INPFC

CITATION : Simpson, R.R. and H.H. Shippen. 1968. Movement and recovery of tagged king crabs in the eastern Bering Sea, 1955-63. International North Pacific Fisheries Commission Bulletin No. 24. pp 111-123.

KEY-WORDS: King crab; Tagging studies; Migration; Growth.

SYNOPSIS : More than 32,000 adult male king crabs, Paralithodes camtschatica, were tagged and released in the eastern Bering Sea in 1955-61. Carapace lengths ranged from 4 to 20 cm. Tagged crabs were recaptured in commercial king crab fisheries of Japan, the U.S.S.R, and the United States; by the end of the 1963 fishing season 14 percent of the tagged crabs had been returned. Tagging and recovery suggests that king crabs of the eastern Bering Sea constitute a single population, in which individuals move and mix randomly. Growth in length of male crabs averaged about 1 cm per year. Half of the tags returned were from crabs caught within 50 nautical miles of the locality of release. The longest distance traveled by a crab in a single year was 230 nautical miles.

ACCESS # : 130, NMFS

CITATION : Shimada A. and J. June. 1982. Eastern Bering Sea Pacific cod food habits. Personal memorandum to staff of the Northwest and Alaska Fisheries Center, Resource Assessment and Conservation Engineering Division. 35 pp.

KEY-WORDS: Pacific cod; Food habits; Trophic interactions.

SYNOPSIS : This document presents preliminary analysis of pacific cod stomachs that were examined from the southeastern Bering Sea. Approxomately half of the stomachs collected have been analyzed and are presented here. For 1980 data, a shift in diet by region was observed. Moving from shallow western waters to deeper waters in the western half of the Bering Sea, it was observed that a diet of crab, euphausiids, and fish changed to a diet chiefly composed of pollock and shrimp. Stomachs from the central region showed neither an extreme of northwestern or southeastern diets but rather a balance between each of the major prey items. In the central region, Tanner crab occurred in 27%, shrimps and euphausiids occurred in 28.1%, and pollock occurred in 27.6% of the stomachs examined. The 1981 results substantiated what was observed in 1980. Of particular interest was the proportion of red king crab in the diet of Pacific cod, 11.2% by weight. Although red king crab represented a significant percentage by weight, the actual frequency of cod predation on red king crab was at a lower percentage (7.3%) as compared to other prey items found in the total sample. The 1981 study was the first to document consumption of red king crab by Pacific cod in the southeastern Bering Sea.

ACCESS # : 131, NMFS

CITATION : Sanger, G.A. 1971. Pelagic amphipod crustaceans from the southeastern Bering Sea. Special scientific report - Fisheries series, NMFS. Report No. NOAA-TR-NMFS-SSRF-680; NOAA-74111805, 13 pp.

KEY-WORDS: Crustacea; Bering Sea; Pelagic zone; Abundance; Animal migrations; Diurnal variation; Zooplankton.

SYNOPSIS : Fourteen species of pelagic amphipods were present in zooplankton samples collected from the southeastern Bering Sea in June 1971. Parathemisto pacifica strongly dominated relative abundance. Primno macropa was the only other species present in all hauls. Cyphocaris challengeri and Hyperia medusarum were present. A presumed diurnal vertical migration was evidenced for Primno macropa, Cyphocaris challengeri and possibly for Scina rattrayi, Hyperoche medusarum, and Hyperia medusarum. The occurrence of Scina stebbingi, S. rattrayi, Vibilia caeca, Paraphronima crassipes, Phronima sedentaria, and Primno macropa extended their known range in the Bering Sea eastward, and the occurrence of Cyphocaris anonyx represents a new record for the Bering Sea.

ACCESS # : 132, NMFS

CITATION : Otto, R.S., R.A. MacIntosh, T.M. Armetta, W.S. Meyers, and K.L. Stahl. 1981. United States crab research in the eastern Bering Sea during 1981. (Document submitted to the annual meeting of the International North Pacific Fisheries Commission, Vancouver, British Columbia, October 1981). 61 pp. NWAFC, NMFS/NOAA, Seattle.

KEY-WORDS: King crab; Tanner crab; Korean hair crab; Population parameters; Tagging studies.

SYNOPSIS : This document contains research conducted during 1981. Included are the results of continued annual trawl surveys and tagging experiments. Populations of red king crabs (Paralithodes camtschatica), blue king crabs (P. platypus), two species of Tanner crabs (Chionoecetes bairdi and C. opilio) and Korean hair crab (Erimacrus isenbeckii) were the subjects of research.

ACCESS # : 133, IMS-UAF

CITATION : O'Clair, C.E., J.L. Hanson, R.T. Myron, J.A. Gharrett, T.R. Merrell, Jr., J.S. MacKinnon, and N.I. Calvin. 1979. Reconnaissance of intertidal communities in the eastern Bering Sea and the effects of ice-scour on community structure. Final Reports of Principal Investigators. Vol. X. pp. 109-415. OCSEAP/NOAA, Boulder, Colo.
KEY-WORDS: Intertidal invertebrates; Community structure; Ice-scour; Algae.

SYNOPSIS : This document examines intertidal communities that have and have not recently been exposed to ice scouring. Species richness and dominance is discussed. The report maintains that the most important characteristic of ice-stressed coasts that allows species to remain in the system is the availability of refuges from ice scouring. Spatial zones and temporal periods are the implications of oil and gas development on these intertidal communities.

ACCESS # : 134, NPFMC

CITATION : North Pacific Fishery Management Council (NPFMC). 1983. Summary of Bering Sea/Aleutian Islands groundfish fishery management plan. Anchorage, Ak. 26 pp.

KEY-WORDS: Demersal fish; Management.

SYNOPSIS : The Bering Sea/Aleutian Islands groundfish fishery management plan was implemented on January 1, 1982. The council has proposed nine amendments to become effective on July 4, 1983. The rest are in the review process. All amendments are incorporated in this summary to reflect the North Pacific Fishery Management Council's most current management of the extensive foreign and domestic groundfish fisheries in the Bering Sea and Aleutian Islands. A history of amendments is included in this summary.

ACCESS # : 137, NMFS

CITATION : Northwest and Alaska Fisheries Center. 1979-82. Trawl survey data printouts from the southeastern Bering Sea.

KEY-WORDS: Trawl surveys; Demersal fish; Benthic invertebrates.

SYNOPSIS : Trawl survey data printouts from waters inside the 50 m contour of the southeastern Bering Sea were examined for the years 1979 through 1982. All data were collected during May through August. In all years yellowfin sole and unidentified starfish (presumably Asterias amurensis) dominated the fish and invertebrate biomasses, respectively. Other dominant fishes were rock sole, walleye pollock and Pacific cod; other dominant invertebrates were king crabs.

ACCESS # : 138, NMFS

CITATION : Northwest and Alaska Fisheries Center. 1982. Cruise results - Cruise No. CH-82-03 NOAA R/V CHAPMAN and Cruise No. PSM-82-01 Chartered Vessel PAT SAN MARIE. Northwest and Alaska Fisheries Center, National Marine Fisheries Center, Seattle, WA. 18 pp.

KEY-WORDS: Crabs; Demersal fish; Resource assessment; Crustacea.

SYNOPSIS : The survey area included eastern Bering Sea continental shelf waters extending from Unimak Pass north along the 100-fathom contour to a latitude of approximately St. Matthews Island and east to the Alaska mainland. This survey examined the crab and groundfish resources by demersal trawling. Biological information and water temperature data were recorded at each station. It was determined that the dominant species within Bristol Bay were yellowfin sole, red king and Tanner crab (Chionoecetes bairdi).

ACCESS # : 137, NMFS

CITATION : Northwest and Alaska Fisheries Center. 1979-82. Trawl survey data printouts from the southeastern Bering Sea.

KEY-WORDS: Trawl surveys; Demersal fish; Benthic invertebrates.

SYNOPSIS : Trawl survey data printouts from waters inside the 50 m contour of the southeastern Bering Sea were examined for the years 1979 through 1982. All data were collected during May through August. In all years yellowfin sole and unidentified starfish (presumably Asterias amurensis) dominated the fish and invertebrate biomasses, respectively. Other dominant fishes were rock sole, walleye pollock and Pacific cod; other dominant invertebrates were king crabs.

ACCESS # : 138, NMFS

CITATION : Northwest and Alaska Fisheries Center. 1982. Cruise results - Cruise No. CH-82-03 NOAA R/V CHAPMAN and Cruise No. PSM-82-01 Chartered Vessel PAT SAN MARIE. Northwest and Alaska Fisheries Center, National Marine Fisheries Center, Seattle, WA. 18 pp.

KEY-WORDS: Crabs; Groundfish; Resource assessment.

SYNOPSIS : The survey area included eastern Bering Sea continental shelf waters extending from Unimak Pass north along the 100-fathom contour to a latitude of approximately St. Matthews Island and east to the Alaska mainland. This survey examined the crab and groundfish resources by demersal trawling. Biological information and water temperature data were recorded at each station. It was determined that the dominant species within Bristol Bay were yellowfin sole, red king and Tanner crab (Chionoecetes bairdi).

ACCESS # : 139, IMS-UAF

CITATION : McDonald, J., H.M. Feder, and M. Hoberg. 1981. Bivalve mollusks of the southeastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1155-1204. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Bivalves; Distribution; Age composition; Sediments.

SYNOPSIS : Bivalve mollusks and other infaunal species of the southeastern Bering Sea shelf have patchy distributions. The distribution of the bivalves Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Cyclocardia crebricostata, and Spisula polynyma is associated with specific sediment size, sorting ranges, percentage of mud, and depth. There is little difference in the growth rates of Nucula tenuis, Nuculana fossa, Yoldia amygdalea, Spisula polynyma, Tellina lutea, and Macoma calcarea over the southeastern Bering Sea shelf. Mortality between year-classes for each species of clam varies significantly at specific ages. The variation in year-class composition of specific stations indicates variable annual recruitment success of different areas on the shelf. The data presented here supports Neiman's age-composition hypothesis, which suggests that the prevalence of older bivalve mollusks in the middle zone of the eastern Bering Sea results from the exclusion of predatory bottom fishes by the low winter water temperatures.

ACCESS # : 140, IMS-UAF

CITATION : MacIntosh R.A. and D.A. Somerton. 1981. Large marine gastropods of the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1215-1228. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Gastropods; Snails; Environmental variables.

SYNOPSIS : Gastropods make up to 6-9% by weight of the invertebrates caught on the continental shelf and upper slope of the eastern Bering Sea by research trawl surveys. Five species of the genus Neptunea - N. lyrata, N. pribiloffensis, N. heros, N. ventricosa, and N. borealis - make up 87% of the snail biomass and 69% of the snail numbers. Fifteen of the most common large gastropods were grouped according to the similarity of environmental variables measured at the sampling sites at which each species was found. The variables used were annual maximum bottom temperature and maximum rate of warming. The analysis identified three thermal regions in the eastern Bering Sea in late summer, each region having a distinct assemblage of large gastropod mollusks. Neptunea spawn over a protracted period and capsular life of embryos is probably more than six months. Female N. heros, N. lyrata, N. pribiloffensis, and N. ventricosa mature at shell lengths of 110, 110, 105, and 102 mm, respectively; males mature at shell lengths of 95, 100, 90, and 87 mm, respectively. Recent studies of Neptunea food habits show that a variety of organisms are consumed, including polychaetes, bivalves, barnacles, fishes, and crustaceans. Japan has reported gastropods in the eastern Bering Sea since at least 1971. Reported catch rates range from 0.9 to 4.0 kg/pot and total Japanese catch has varied from 404 to 3,574 mt of edible meat per year.

ACCESS # : 141, IMS-UAF

CITATION : Jewett, S.C. and H.M. Feder. 1981. Epifaunal invertebrates of the continental shelf of the eastern Bering and Chukchi Seas. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1131-1153. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Epifauna; Invertebrates; Benthos; Biomass.

SYNOPSIS : Epifaunal invertebrates were surveyed over much of the eastern Bering and Chukchi seas continental shelf. Information on the distribution, abundance, and biomass of the dominant species is discussed by area and depth strata. Four commercially important crabs (Paralithodes camtschatica, P. platypus, Chionoecetes opilio, and C. bairdi) and four sea-star species (Asterias amurensis, Evasterias echinosoma, Leptasterias polaris acervata, and Lethasterias nanimensis) account for nearly 70% of the epifaunal biomass of the entire eastern shelf region. Commercially-important crabs dominate the southeastern portion of the shelf; echinoderms, in particular sea stars, abound in the northeastern Bering Sea and southeastern Chukchi Sea. The 20-40 m depth stratum of the SEBS was dominated (biomass) by echinoderms, particularly the sea star Asterias amurensis.

ACCESS # : 142, IMS-UAF

CITATION : Incze, L.S., D.A. Armstrong, and D.L. Wencker. 1982. Rates of development and growth of larvae of Chionoecetes bairdi and C. opilio in the southeastern Bering Sea. In: Proc. of the Int. Symp. on the Genus Chionoecetes. Lowell Wakefield Fish. Symp. Ser., Ak. Sea Grant Rep. No. 82-10. pp 191-218.

KEY-WORDS: Crabs; Chionoecetes; Zooplankton; Development; Growth; Larvae; Crustacea.

SYNOPSIS : Several aspects to the biology of larvae of Chionoecetes bairdi and C. opilio were investigated using zooplankton samples collected in the southeastern Bering Sea from 1978-1981. Large numbers of first stage zoeae of C. bairdi appeared in the plankton during late April and early May in the years sampled. The larvae of C. opilio appeared in significant numbers in the plankton at least two weeks prior to the major hatch-out of C. bairdi during two years and limited data from two other years indicates that this regularly occurs. Data on the timing of appearance of larvae in the plankton and on frequency of molting in larval populations of the two species indicate an approximate 30-day minimum to the duration of each zoeal stage and a 30 to 40-day hatch-out period. The duration of the megalops stage may be longer than 30 days for a significant proportion of the larvae of both species. A method for examining growth of zoeae in the field is described and a growth rate of approximately 5% dry weight zoea-1 day-1 calculated. The predicted ingestion rates necessary to satisfy growth requirements are briefly discussed.

ACCESS # : 143, IMS-UAF

CITATION : Hughes, S.E. and N. Bourne. 1981. Stock assessment and life history of a newly discovered Alaska surf clam (Spisula polynyma) resource in the southeastern Bering Sea. Can. J. Fish. Aquat. Sci. 38: 1173-1181.

KEY-WORDS: Population assessment; Sustainable yield; Surf clams.

SYNOPSIS : A 1977 exploratory survey of subtidal clam resources in the southeastern Bering Sea revealed extensive concentrations of Alaska surf clams (Spisula polynyma Stimpson) along the north coast of Alaska Peninsula. Using east coast hydraulic clam harvesters, subsequent 1977 and 1978 stock assessment surveys delineated a geographically isolated stock with an estimated exploitable biomass of 329,000 + or - 52,000 mt and conservatively calculated potential annual yield of 25,017 mt (maximum sustainable yield) of whole clams. Production fishing trials at 13 sites in 1978 produced an average catch per unit effort of 815 kg/h with a 1.84-m-wide clam harvester. Life history studies indicated the species is long-lived (25 yr), slow growing (k=0.135), fully recruited to the spawning population at 8 yr of age, subject to low natural mortality (conservatively calculated as M=0.19), and attains maximum cohort biomass at ages between 9.4 and 13.0 yrs. Biological rationale for management measures is presented.

ACCESS # : 144, IMS-UAF

CITATION : Haynes, E., J.F. Karinen, J. Watson, and D.J. Hopson. 1976. Relation of number of eggs and egg length to carapace width in the brachyuran crabs Chionoecetes bairdi and C. opilio from the southeastern Bering Sea and C. opilio from the Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 33: 2592-2595.

KEY-WORDS: Crabs; Chionoecetes; Fecundity; Crustacea.

SYNOPSIS : The number of eggs attatched to pleopods of Chionoecetes bairdi and C. opilio from the southeastern Bering Sea increased at a rate proportional to about 3.4 and 2.7 power of the carapace width, respectively, but for C. opilio from the Gulf of St. Lawrence it increased to the 4.2 power. The range in carapace width and number of eggs for crabs from the Bering Sea of a given carapace width were considerably greater for C. bairdi than for C. opilio. In the southeastern Bering Sea, the reproductive potential for adult females of C. bairdi with mixed spawning history is approximately 4 times greater than that of C. opilio spawning for the first time. Chionoecetes opilio females with mixed spawning history in the Gulf of St. Lawrence carry more eggs for a given carapace width than first-time spawners from the southeastern Bering Sea. Gravid C. bairdi occur within the nearshore region of the southeastern Bering Sea, as well as in deeper waters of the shelf.

ACCESS # : 145, IMS-UAF

CITATION : Haynes, E.B. 1974. Distribution and relative abundance of larvae of king crab, Paralithodes camtschatica, in the southeastern Bering Sea, 1969-70. Fish. Bull. 72: 804-812.

KEY-WORDS: King crab; Paralithodes camtschatica; Larvae; Distribution; Abundance; Marine biology; Shellfish; Plankton; Crustacea; Animal migrations.

SYNOPSIS : During the spring and summer of 1969 and 1970, larvae of king crab, Paralithodes camtschatica, were abundant in plankton samples from the southeastern Bering Sea. Abundance was highest near shore and generally lowest in the central and western parts of the study ares. As the season progressed, the center of abundance moved northwestward along the Alaska Peninsula toward the head of Bristol Bay. This change in distribution was apparently related to water current patterns.

ACCESS # : 146, IMS-UAF

CITATION : Haflinger, K. 1981. A survey of benthic infaunal communities of the southeastern Bering Sea shelf. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1091-1103. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Benthos; Infauna; Invertebrates; Standing stock; Communities; Frontal zones.

SYNOPSIS : The continental shelf of the Bering Sea south of St. Matthew Island was surveyed by taking at least five van Veen grabs at each of 96 stations and sieving organisms with a 1-mm mesh screen. Multivariate statistical methods were used to define communities organized in roughly contiguous bands paralleling local bathymetry. Community boundaries coincide with frontal zones identified in the area, suggesting a community response to water-mass characteristics or differing between-front depositional environments. Large between-station variations within the same sedimentary and temperature regimes were noted, but cannot be interpreted with the existing data. Standing stocks appeared uniformly low away from areas with a coastal influx of detritus, with the exception of an area southeast of the Pribilof Islands that seems to underlie an intensely productive water column.

ACCESS # : 147, IMS-UAF

CITATION : Golia, A. 1981. Bristol Bay: A regional fisheries development plan. Unpublished manuscript. Fisheries Program, Bristol Bay Native Association, Dillingham, Ak. pp. 53-65.

KEY-WORDS: Bristol Bay; Fisheries resources.

SYNOPSIS : Included in this document are abbreviated development plans for bottomfish and surf clam fisheries for the Bristol Bay region.

ACCESS # : 148, INPFC

CITATION : Forrester, C.R., A.J. Beardsley, and Y. Takahashi. 1978. Groundfish, shrimp, and herring fisheries in the Bering Sea and northeast Pacific - historical catch statistics through 1970. International North Pacific Fisheries Commission Bulletin No. 37. 147 pp.

KEY-WORDS: Commercial fisheries; Demersal fish; Shrimp; Herring.

SYNOPSIS : In this document the history of the fishery in the North Pacific Ocean and statistics of total catch are discussed in a general chronological order, i.e., from aboriginal times, through the periods of peak production (by some nations) associated with World Wars I and II, to and including the fisheries of the 1960's. A general summary of the fishing activities of each nation and nations combined is presented. Some historical figures of fisheries on particular species of interest to one or more nations have also been discussed. General observations of fishing vessels and gear used by various nations in particular fisheries are presented.

ACCESS # : 149, IMS-UAF

CITATION : Feder, H.M. and S.C. Jewett. 1981. Feeding interactions in the eastern Bering Sea with emphasis of the benthos. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II: 1229-1261. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Trophic interactions; Predation; Benthos; Fishes.

SYNOPSIS : The benthos of the northeastern Bering Sea, which accounts for 86% of the total benthos on the eastern shelf, supports reduced numbers of demersal fishes, presumably due to low-temperature barriers normally present. In the southeastern Bering Sea, where 23% of the food benthos of the eastern shelf is found, bottom fishes have year-round access to food resources. Major fisheries for crabs and bottom fishes occur in the southeastern portion of the Bering Sea. Most predators feed on the upper continental slope in winter, but move to shallower and warmer waters of the shelf in late spring and summer. Slow growth is characteristic of benthic invertebrates used as food on the Bering Sea shelf. However, bottom-feeding species on the slope and shelf edge probably also eat zooplankters, as these organisms accumulate on the bottom after death. Periodic organic carbon enrichment of the shelf, resulting from a poorly coupled organic carbon system, also enhances food resources on the bottom and may result in a more frequent recruitment successes for infaunal species. Organic carbon enrichment of the southeastern Bering Sea shelf is indicated by dense populations of deposit-feeding bivalve mollusks, a general increase in other infauna and high densities and biomass of epifauna.

ACCESS # : 150, IMS-UAF

CITATION : Feder, H.M., A.J. Paul, and J.M. Paul. 1978b. The pinkneck clam Spisula polynyma in the eastern Bering Sea - growth, mortality, recruitment and size at maturity. Sea Grant Report No. 78-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. Rep. No. R-78-2. 26 pp.

KEY-WORDS: Pinkneck clam; Surf clam; Spisula polynyma; Growth; Mortality; Recruitment; Maturity.

SYNOPSIS : Specimens for this study were collected in the summer of 1977. Growth histories of 15 year classes were determined by measuring the lengths of every annulus. Annual increases in shell length were typically 7 to 16 mm. The majority, 77%, of the clams were 9 years of age or older. The preponderance of older clams in samples was due to gear bias. The oldest clams were 16 years old. Two methods were used to calculate mortality rates for age classes 12 through 16. The estimated rates of natural mortality for these year classes were 9%, 27%, 40%, 67%, and 100%, respectively.

ACCESS # : 151, IMS-UAF

CITATION : Feder, H.M., J. Hilsinger, M. Hoberg, S.C. Jewett, and J. Rose. 1978a Survey of the epifaunal invertebrates of the southeastern Bering Sea. Principal Investigators' Reports for the Year Ending March 1978. Vol. IV. pp. 1-126. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Epifauna; Trophic interactions.

SYNOPSIS : The 1975-76 trawl study considered in this report delineates the major epifaunal species on the eastern Bering Sea shelf in regions of offshore oil and gas concentrations. Data were obtained on faunal composition and abundance which now are baselines to which future changes can be compared. Long-term studies on life histories and trophic interactions should define functional aspects of communities and ecosystems that are vulnerable to damage, and should help to determine the rates at which damaged environments can recover. Assessment of all data suggests that: sufficient station uniqueness exists to permit development of monitoring programs based on species composition at selected stations utilizing trawl techniques. Adequate numbers of biologically well-known, unique and/or large species are available to permit nomination of likely monitoring candidates once industrial activity is initiated.

ACCESS # : 152, IMS-UAF

CITATION : Wencker, D.L., L.S. Incze, and D.A. Armstrong. 1982. Distinguishing between Chionoecetes bairdi and C. opilio zoeae collected in the southeast Bering Sea. In: Proceedings of the Int. Sym. of the Genus Chionoecetes. Lowell Wakefield Fisheries Symposia Series, Ak. Sea Grant Rep. No. 82-10, pp 219-230.

KEY-WORDS: Crabs; Larvae; Taxonomy; Chionoecetes; Crustacea.

SYNOPSIS : Three morphological characteristics which enable separation of zoeae larvae of Chionoecetes bairdi and C. opilio are discussed; two are described here for the first time. Use of all three characteristics enables species identification of most Chionoecetes zoeae found in plankton samples from the southeastern Bering Sea.

ACCESS # : 153, PMEL

CITATION : Feely, R.A., G.J. Massoth, A.J. Paulson, M.F. Lamb and E.A. Martin. 1981. Distribution and elemental composition of suspended matter in Alaskan coastal waters. NOAA Technical Memo ERL-PMEL-27. Pacific Marine Environmental Laboratory, Seattle. 119 pp.

KEY-WORDS: Particulate matter; Elemental composition; Organic matter; C/N ratio; Unimak Pass; Kuskokwim Bay.

SYNOPSIS : This is a comprehensive study of the distribution and chemical composition of suspended material on the continental shelves of Alaska. The purpose of the study was to determine the chemical nature and transport pathways of particulate matter which would act as effective scavengers of petroleum compounds in the shelf waters. The report summarizes studies of northeast Gulf of Alaska, lower Cook Inlet, southeastern Bering Sea Shelf, and Norton Sound. Southeastern Bering Sea data were obtained September-October, 1975 and June-July 1976. Surface water particulate matter was found to be dominated by input from northern rivers notably the Kuskokwim, Togiak, Igushik, Kvichak, and Nushagak rivers. The material originating from these rivers is over 76% inorganic and of terrestrial origin: high concentrations of particulate matter (> 6 mg/l) were found near shore along the Alaska Peninsula 5 m from the bottom in September-October with much less at the surface (> 2 mg/l) in June-July. High surface values (> 6 mg/l were found near Unimak Pass and along the coast beginning up near Port Moller and extending eastward. In the high concentration areas the organic matter is thought to be primarily of marine origin because of its C/N ratio. Total particulate carbon in the near shore region in Bristol Bay is in excess of 300 Ug/l.

ACCESS # : 154, IMS-UAF

CITATION : Griffiths, R.P., B.A. Caldwell, W.A. Broich, and R.Y. Morita. 1983. Microbiological processes relating to carbon cycling in southeastern Bering Sea sediments. Mar. Ecol., Prog. Ser. 10: 265-275.

KEY-WORDS: St. George Basin; Port Moller; Microbiological activity; Respiration; Carbon dioxide; Carbon cycling; Methane production; Nitrogen fixation; Carbon dioxide production; Laminarinase.

SYNOPSIS : Carbon dioxide production rates in St. George Basin sediments ranged from 0.1 to 6.2 nmol/g/hr as compared to Port Moller which ranged from 5 to 48 nmol/g/hr. Respiration in salt marsh soils have been observed from 11 to 567 nmol/g/hr. Methane production rates in SGB were 0.00028-0.019 nmol C/g/hr and 0.0011-2.5 nmol C/g/hr in Port Moller. Laminarinase activities were lower in SGB than Port Moller. The data indicate an insignificant impact of laminarinase to SGB. Mean nitrogen fixation rates in sediments were 360 ug N/m /hr in SGB and 540 ug N/m /hr in Port Moller.

ACCESS # : 155, IMS-UAF

CITATION : Griffiths, R.P., B.A. Caldwell, J.D. Cline, W.A. Broich and R.Y. Morita. 1982. Field observations of methane concentrations and oxidation rates on the southeastern Bering Sea. Appl. Environ. Microb. 44: 435-446.

KEY-WORDS: Methane; Methane oxidation; Port Moller; Microbiological activity.

SYNOPSIS : Paper stressed the lack of information of the effect of environmental factors on methane oxidation in the marine environment. Highest rates are to be expected in areas of high suspended particulate matter.

ACCESS # : 156, IMS-UAF

CITATION : Koike, I, K. Furuya, H. Otobe, T. Nakai, T. Memoto and A. Hattori. 1982. Horizontal distributions of surface chlorophyll a and nitrogenous nutrients near Bering Strait and Unimak Pass. Deep Sea Res. 29: 149-152.

KEY-WORDS: Nitrate; Unimak Pass; Chlorophyll a; Vertical mixing; Alaska stream; Primary production.

SYNOPSIS : Data on chlorophyll a, nitrogenous nutrients, temperature, and salinity in the surface waters of Unimak Pass show some vertical mixing in the pass with an inverse relationship between nitrate and chlorophyll. In the southern Bering Sea west of the pass chlorophyll a exceeds 3 ug/l and nitrate was near zero indicating rapid utilization of pass provided nutrients in nutrient primary production.

ACCESS # : 157, IMS-UAF

CITATION : Hood, D.W. and W.S. Reeburgh. 1972. Chemistry of the Bering Sea: an overview. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 191-204.

KEY-WORDS: Chemistry; Sediment water interaction; Isotopes; Sea ice chemistry; Radon/radium exchange studies.

SYNOPSIS : In this overview paper much of the chemical work completed on the Being Sea at the time of writing is reviewed and suggestions are made to its importance and to future needs for further investigation. Sediment water interaction is thought to be of particular importance in the interstitial waters. The effect of ice or sea water chemistry is discussed. The use of Rn-222 and Ra-226 in studying mixing in the ocean is discussed as is the use of stable isotopes.

ACCESS # : 158, IMS-UAF

CITATION : Loder, T.C. 1971. Distribution of dissolved and particulate organic carbon in Alaskan polar, sub-polar and estuarine waters. Ph.D. Dissertation, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 236 pp. Section V3 on Unimak Pass. pp. 147-159.

KEY-WORDS: Dissolved organic carbon; Particulate organic carbon; Unimak Pass; Transmissivity; Absorbance.

SYNOPSIS : Data on dissolved organic carbon (DOC) and particulate organic carbon (POC) in Unimak Pass area were collected on R/V Acona cruise 027 July 27 to August 9, 1966. Five stations were reoccupied several times during the cruise. Sixteen stations in all were visited. DOC values ranged from o.60 to 1.90 mg C/l with an average of 1.20 mg C/l for depths less than 100m. POC values varied only 1.2 percent from a mean value of 741 ug C/l in the top 16 m of the water column. Transmissivity of suface waters was measured at seven stations. The calculated absorbance correlated well with the POC content of the water.

ACCESS # : 159, IMS-UAF

CITATION : Holmes, R.W. 1958. Surface chlorophyll a, surface primary production, and zooplankton volumes in the Eastern Pacific Ocean. Rapp. Proces. Verb. Reunions. Cons. Perm. Int. Explor. Mar. 144: 109-116.

KEY-WORDS: Unimak Pass; Primary production; Chlorophyll a.

SYNOPSIS : Limited data on productivity in Unimak Pass indicates Unimak Pass to have the highest level of productivity in North Pacific.

ACCESS # : 160, IMS-UAF

CITATION : Kelley, J.J., L.L. Longerich and D.W. Hood. 1971. Effect of upwelling, mixing and high primary productivity on CO_2 concentrations in surface waters of Bering Sea. J. Geophys. Res. 76: 8687-8693.

KEY-WORDS: Partial pressure of CO_2 (pCO_2); Upwelling; Samalga Pass; Amutka Pass; Primary production.

SYNOPSIS : Late spring and early fall measurements of pCO_2 were made in Bering Sea surface waters north of Amutka and Samalga Passess in the eastern Aleutian Islands. High values of CO_2, NO_3^-, and salinity were accompanied by low oxygen and temperature values. All the isopleths of these parameters give evidence of vertically mixed water. Seasonal low values of CO_2 in surface waters were observed in areas of low vertical mixing and high primary productivity.

ACCESS # : 161, IMS-UAF

CITATION : Hood, D.W. Unpublished. Cruise 261-5 of RV Acona to Unimak Pass and North Alaskan Peninsula. Inst. Mar. Sci., Univ. Alaska, Fairbanks.

KEY-WORDS: Partial pressure of CO_2 (pCO_2); Upwelling; Unimak Pass; Amak Island.

SYNOPSIS : Limited salinity, temperature, and carbon dioxide data were obtained in the Unimak Pass area in June 1978. Severe storms limited station occupation on the ten day cruise, however 10 stations were occupied in a long shore transect from west of Unimak Pass to Amak Island north of Izembek Lagoon. At all stations pCO_2 of the surface water was found to be near or less than air values indicating no evidence of upwelling in the region on this occasion.

ACCESS # : 162, IMS-UAF

CITATION : Hood, D.W. and L.A. Codispoti. 1980. Carbon budgets and transfer in the southeast Bering Sea. In: PROBES Progress Report, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 163-189.

KEY-WORDS: Inorganic carbon; Total carbon dioxide; Community production; Alkalinity; pH.

SYNOPSIS : Data on the inorganic carbon system were obtained on the Southeast Bering Sea PROBES cruises aboard the R/V TG Thompson from 23 March to 4 June, 1980. Net community organic carbon production computations gave an average value of 2.5 gm2/day for the period 12 April to 23 May. Corrections of net total carbon losses by 33% to allow for estimated calcium carbonate precipitation were included in the net community organic carbon production value but no allowance was made for atmospheric transfer or convective inputs. Surface oxygen values were obtained at all stations.

ACCESS # : 163, IMS-UAF

CITATION : Hood, D.W. and L.A. Codispoti. 1981. Carbon budgets and transfer in the Southeast Bering Sea. In: PROBES Progress Report for 1981. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 131-157.

KEY-WORDS: Inorganic carbon; Carbon dioxide; C/N ratio; Regeneration; Community production; Dissolved oxygen; Primary production.

SYNOPSIS : Data on the inorganic carbon system was obtained in the southeast Bering Sea on all PROBES stations taken aboard the R/V TG Thompson in 1981. The loss of total inorganic carbon dioxide to the biota was studied in detail during the spring bloom and for about one month into the post bloom period. A decrease in inorganic carbon coincided with a decrease in nitrate during the spring bloom at a ratio of about 17 atoms to 1. In the post bloom period inorganic carbon showed rapid recovery for a short period in late June at some stations but was interrupted by major oceanographic events in mid July. This brought in a new supply of nutrients to most stations resulting in a minor secondary bloom. Because the cruise ended soon after, it was not possible to collect data for the complete recovery (regeneration) period. Surface oxygen concentrations are given for all stations occupied.

ACCESS # : 164, IMS-UAF

CITATION : Hood, D.W. and L. A. Codispoti. 1983. The effect of primary production on the carbon dioxide components of the Bering Sea shelf. In: The potential effects of carbon dioxide induced climatic change in Alaska, Jenifer H. McBeath (ed). School of Agriculture, Univ. Alaska, Fairbanks. In press.

KEY-WORDS: Inorganic carbon; Carbon dioxide; Primary production; Nitrate/carbon dioxide relations; Oxygen; Partial pressure of Co_2; Total carbon dioxide.

SYNOPSIS : Processes associated with primary production in the surface waters of the eastern Bering Sea shelf reduce the partial pressure of gaseous carbon dioxide (pCo_2) in the surface water from equilibrium with air winter time values of about 340 uA to as low as 150 uA at the end of spring bloom in June. The total inorganic carbon content in the surface water at one station reduced from 2.05 mM/l in early April to 1.70 mM/l at the beginning of June. Nitrate concentration reduced from 20 ugA/l in April to about 0 ugA/l in June. The carbon to nitrate uptake ratio for this period was 17 to 1. By June first on the Bering Sea Shelf 100-200 gC/M^2 of inorganic carbon is tied up as organic carbon in the average year. Some of this carbon will be replaced by atmospheric carbon by exchange of Co_2 through the sea surface and part from respiration by biota. The opportunity exists for some of the organic carbon to be lost to the deep ocean basin to be replaced in the shelf water column by atmospheric carbon dioxide. If all high latitude shelves behave in a similar way to the Bering Sea shelf as there is evidence they do, then the potential for biological fixation of organic carbon and subsequent transfer of part of this organic carbon to the deep sea possibly provides a useful mechanism for helping balance the global carbon budget, however, much consideration must still be given to the demands of the biota of the shelf region for fixed carbon before excesses over that required can be shown to be available for ocean transport.

ACCESS # : 165, IMS-UAF

CITATION : Kelley, J.J. and D.W. Hood. 1971. Carbon dioxide in the Pacific Ocean and Bering Sea: upwelling and mixing. J. of Geophy. Res. 76: 745-752.

KEY-WORDS: Inorganic carbon; Carbon dioxide; Partial pressure of CO_2 (pCO_2); Upwelling; Primary production.

SYNOPSIS : This a good descriptive paper comparing pCO_2 between air and water over vast areas of the North Pacific Bering Sea and southeast Pacific. Unimak Pass data for late July and early September show between 15 and 30 ppm greater pCo_2 in water than air for both sampling periods.

ACCESS # : 166, IMS-UAF

CITATION : Longerich, L.L., J.J. Kelley, and D.W. Hood. 1971. Carbon dioxide in the surface waters near the coast of southern Alaska and eastern Aleutian Islands. In: Oceanography of the Bering Sea. Phase I. D.W. Hood et al. Inst. of Mar. Sci., Univ. of Alaska Report No. R-71-9. pp. 3-58.

KEY-WORDS: Partial pressure of CO_2 (pCO_2); Carbon dioxide; pCO_2/nitrate; Upwelling; Primary production; Izembek Lagoon; Eelgrass; Phytoplankton.

SYNOPSIS : This report describes in detail the methodology used in measuring the partial pressure of carbon dioxide (pCO_2) in air and surface sea water. Extensive data are presented on pCO_2 values for the Alaska Peninsula and eastern Aleutian passes. In June pCO_2 was found deficient (-) with respect to air in excess of 100 ppm at all locations except near Samalga and Amukta Passes where it was greater (+) than air by over 100 ppm because of upwelling. In September upwelling was still found at Samalga Pass and small positive values were found in Unimak Pass (+ 10 to 100 ppm). Amukta Pass was not revisited. All other stations showed near equilibrium or negative (-10 to -100) pCO_2 (w) values. Seasonal data in Izembek Lagoon are reported. Strong correlations between pCO_2 (w) and nitrate was observed in upwelled waters.

ACCESS # : 167, IMS-UAF

CITATION : Hood, D.W. 1981. Preliminary observations of the carbon budget of the eastern Bering Sea shelf. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 1: 347-358. NOAA, Distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Partial pressure of CO_2 (pCO_2); Carbon budget; pCO_2/NO_3- correlation; Diurnal changes; Upwelling; Total carbon dioxide.

SYNOPSIS : This paper shows pCO_2 distribution near Unimak Pass as well as the shelf region north to the Pribilof Islands for the outer domain (seaward of 100 m) and for the middle and outer domain in 1978. This type of information has particular value in observing regions of vertical mixing, fresh water input and primary productivity. Some diurnal and pH data are also given.

ACCESS # : 168, IMS-UAF

CITATION : Venkatesan, M.I., M. Sandstrom, S. Brenner, E. Ruth, J. Bonilla, I.R. Kaplan and W.E. Reed. 1981. Organic geochemistry of surficial sediments from the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 1: 389-409. NOAA, distrib. by Univ. Washington Press, Seattle, WA.
KEY-WORDS: Hydrocarbons; Organic carbon; Sediments; Lipids; Humic acid; Lagoons; Organic geochemistry.

SYNOPSIS : Stations in the North Aleutian region were some distance offshore, however some implications can be drawn regarding origin of humis material.

ACCESS # : 169, RAS-UAF

CITATION : Venkatesan, M.I. and I.R. Kaplan. 1982. Distribution and transport of hydrocarbons in surface sediments of the Alaskan Outer Continental Shelf. Geochem. Cosmochem. Acta 46: 2135-2149.

KEY-WORDS: Hydrocarbons; Oil seep; Polynuclear aromatic hydrocarbons; Alkenes; Terrigenous lipids.

SYNOPSIS : This paper summerizes the hydrocarbon data for all the outer continental shelves of Alaska obtained by these authors and others. Little evidence of petroleum hydrocarbons was found but the presence of n-alkenes implies slow oxidation conditions in some of the depositional areas. In southeast Bering Sea, unlike other regions, hydrocarbons are low in the coarse grained near shore sediments and higher in fine grained sediments near the shelf edge. In general, the area is pristine with few abiological components. One station near the shelf break of the southeast Bering Sea showed some evidence of an oil seep.

ACCESS # : 170, IMS-UAF

CITATION : Sharma, G.D. 1971. Bristol Bay: model contemporary graded shelf In: Oceanography of the Bering Sea. Phase I. Turbulent upwelling and biological productivity mechanisms in the southeastern Bering Sea and Aleutian Islands. D.W. Hood et al. Rep. No. R-71-9. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 107-137.

KEY-WORDS: Sediments; Graded shelf; Sediment sources; Clay mineralogy; Feldspars; Organic carbon content; Storm waves.

SYNOPSIS : Much of the sedimentation distribution observed is explained on the basis of a strong, central, core countercurrent in Bristol Bay which was believed to be the case at the time but has since, with greater evidence, been found not to exist.

ACCESS # : 171, IMS-UAF

CITATION : Handa, N. and E. Tanoue. 1981. Organic matter in the Bering Sea and adjacent areas in the Bering Sea shelf. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 359-381. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Particulate matter; Organic nitrogen; Clorophyll a; Amino acids; Monosaccharides; Fatty acids; Biological degradation; Dissolved organic matter.

SYNOPSIS : This paper is of particular value in relating composition of particulate material especially with respect to composition of organic matter. Of particular value is Fig. 23.9 which relates the POC/chlorophyll a,PON salinity, and temperature at stations east and south of the Pribilof Islands. Unfortunately, no stations were in the near shore region of the North Aleutian Shelf.

ACCESS # : 172, IMS-UAF

CITATION : McConnaughey, T. and C.P. McRoy. 1976. Food-web structure and the fractionation of carbon isotopes in the Bering Sea. Pp. 296-316 in: Science in Alaska. Proc. 27th Alaska Sci. Conf., Fairbanks, Alaska. Resource Development - Processes and Problems. Vol. 2. Alaska Div. AAAS.

KEY-WORDS: Carbon isotopes; Food web; Plankton; Benthos; Fishes; Marine mammals; Seabirds.

SYNOPSIS : This paper provides $^{13}C/^{12}C$ ratios for 21 species of invertebrates, 7 species of fishes, 2 marine mammals, 1 seabird and mixed phytoplankton and zooplankton. A trophic structure model is constructed based on the fractionation of carbon isotope ratios by the biota. Gives more details than the 1979 paper by the same authors but the conclusions are the same.

ACCESS # : 173, IMS-UAF

CITATION : Dennison, W. 1979. Light adaptations of plants: a model based on the seagrass Zostera marina L. Ms. Thesis, Univ. of Alaska, Fairbanks. 70 pp.

KEY-WORDS: Chlorophyll ratios; Izembek Lagoon; Light limitation; Leaf area index; Eelgrass.

SYNOPSIS : Options available to plants for low light environments are presented. Sun reflectors and shades were used to document light adaptations in Zostera along a depth gradient in Izembek Lagoon. Chlorophyl a and b ratios are assessed and found to be close to optimal for maximum efficiency energy gain. Ratios were higher in deeper plants. Light manipulations had little effect on shallow eelgrass suggesting other limits on plant growth than light. Change in leaf area was determined to be the major light adaptation mechanism. Increased leaf area also increased habitat complexity.

ACCESS # : 174, IMS-UAF

CITATION : Smith, R.L. and A.C. Paulson. 1977. Osmoregulatory seasonality and freezing avoidance in some fishes from a subarctic eelgrass community. Copeia (2): 362-369.

KEY-WORDS: Izembek Lagoon; Fish; Osmoregulation; Migration; Eelgrass.

SYNOPSIS : Of 23 species examined, 7 were determined to be year round residents. A table of species and dates sampled is presented. Serum electrolytes, measured as Na^+ concentration, decreased with increasing osmolarity. It was assumed that other compounds were used to osmoregulate because considerable adjustment was documented. Fish that could not tolerate freezing conditions migrated either out of the lagoon into deeper water, or into fresh water streams.

ACCESS # : 175, WILDL. DEPT.-UAF

CITATION : Morehouse, K.A. 1974. Development, energetics, and nutrition of captive Pacific Brant (Branta bernicla orientalis, Tongarinov). Ph.D. Dissertation. Univ. of Alaska, Fairbanks. 104 pp.

KEY-WORDS: Brant; Growth rates; Growth requirements; Metabolism; Alaska. Eelgrass; Waterfowl.

SYNOPSIS : This work explores the energy relationships of young and adult Brant along with nutrition and growth and development of juveniles. Eggs collected on the Yukon-Kuskokwim delta were hatched in Fairbanks. Data on growth rates, metabolic rates, response to temperature, heart rate, and activity patterns are presented and compared. Several diets were tested containing various proportions of Zostera. Captive birds developed faster than wild birds, but eelgrass was shown to be a poor food source. The author suggests that early removal from the nest may have precluded the development of important microbial flora and hence made digestion inefficient in captive birds.

ACCESS # : 176, IMS-UAF

CITATION : Haflinger, K. 1978. A numerical analysis of the distribution of the benthic infauna of the southeastern Bering Sea shelf. Ms. Thesis, Univ. Alaska, Fairbanks. 139 pp.

KEY-WORDS: Benthos; Infauna; Invertebrates; Communities; Frontal zones.

SYNOPSIS : The continental shelf region of the southeastern Bering Sea may be classified into five provinces (station groups) based on infaunal distribution. Three large station groups lie in adjacent bands extending from the Alaskan coast to the shelf break, roughly paralleling bathymetry. Two small groups occupying positions at the head of Bristol Bay and off Nunivak Island were identified. Stations in the northeastern section of the study area (near the Pribilof Islands) show no strong affinity to the major station groups. Fourteen major biocoenoses identified on the basis of species distribution show strong correlation with the spatial positioning of station groups. Spatial patterning of these species groups is described on the basis of their representation at station groups. Characteristic differences in trophic structure between station groups are attributed to the effects of storm-induced turbulence in nearshore environments and periodic intensive input of organic carbon in the midshelf region.

ACCESS # : 177, IMS-UAF

CITATION : Wespestad V,G. and L.H. Barton. 1981. Distribution, migration, and status of Pacific herring. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 509-525. NOAA, distrib. by Univ. Washington Press, Seattle, Wa.

KEY-WORDS: Distribution; Migration; Herring; Spawning; Fecundity.

SYNOPSIS : Pacific herring are an important part of the Bering Sea food web and form the basis of a major commercial fishery. Most herring are harvested in coastal waters during the spawning period, which begins in late April/mid-May along the Alaska Penisula and Bristol Bay and progressively later north. Sexual maturity begins at age two, but most herring mature at ages three and four, the ages of recruitment to the fishery. Three major stocks occur in the Bering Sea: northwest of the Pribilof Islands, the Gulf of Olyutorski, and Cape Navarin. Although assessment of eastern Bering Sea herring have ranged from 374 thousand mt to 2.75 million mt. the current estimate of spawning biomass is 432-864 thousand mt. Fisheries data indicate that herring declined rapidly after peak harvests in the early 1970's and that peak catches were supported by a few strong year classes. Weak year-classes occurred through the early 1970's and recruitment appears to be normalized in recent years.

ACCESS # : 178, ARL

CITATION : Lensink, C.J, and J.C. Bartonek. 1976. Seasonal distribution and abundance of marine birds: Part 1, shipboard surveys. Annual Reports of Principal Investigators. Vol. 3: 107-644. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Seabirds; Distribution.

SYNOPSIS : A summary of marine bird observations collected on 21 cruises in Alaskan marine waters in 1975. Authors present information relating to regional and seasonal distribution and density by species. High densities are described for the nearshore Bristol Bay and Alaska Peninsula region for June through October, and for Unimak Pass at all seasons.

ACCESS # : 179, IMS-UAF

CITATION : Short, F.T., C.P. McRoy and W. Dennison. In Prep. Model simulation of nitrogen utilization, biomass, and production in a seagrass (Zostera marina L.) meadow. Unpubl. manuscript.

KEY-WORDS: Zostera; Izembek Lagoon; Simulation; Nitrogen; Eelgrass.

SYNOPSIS : Data from a transect at Izembek Lagoon along a depth gradient are used to create a computer model. The model reasonably predicts changes in plant biomass and growth rates. The model predicts, from a nitrogen enrichment simulation, nitrogen and light limitation. Shallow water stations are generally limited by nitrogen depletion except in spring when light may be limiting. Deeper plants, in sediments of high organic content are limited by light during most of the year, with the possible exception of periods of rapid growth.

ACCESS # : 180, IMS-UAF

CITATION : Sharma, G.D. 1974. Contemporary depositional environment of the eastern Bering Sea. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 517-552.

KEY-WORDS: Sediments; Volcanic ash; Ice/sediment relationship; Clay minerology; Heavy minerals.

SYNOPSIS : Deposition and transport of sediments in the Eastern Bering Sea is discussed in this paper. The water movement is the major control for the sediment transport and deposition in the eastern Bering Sea.

ACCESS # : 181, IMS-UAF

CITATION : Nelson, C.H., D.M. Hopkins, and D.W. Scholl. 1974. Cenozoic sedimentary and techtonic history of the Bering Sea. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea. Occ. Pub. No. 2. Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 485-516.

KEY-WORDS: Sediments; Tectonic history; River diversions; Submarine canyons; Abyssal basins.

SYNOPSIS : The Bering Sea consists of an abyssal basin that became isolated from the Pacific Ocean by the development of the Aleutian Ridge near the end of Cretaceous time and by formation of a large epicontinental shelf area that first became submerged near the middle of the Tertiary Period. We postulate that the sediment eroded from Alaska and from Siberia during Cenozoic time has been trapped in subsiding basins on the Bering shelf and abyssal basins during the Tertiary, collected in continental rise and abyssal plain deposits of the Bering Sea during Pleistocene periods of low sea level, and has been transported generally northward from the Bering shelf through the Bering Strait into the Arctic Ocean during periods of high sea level in the Pleistocene and Holocene. Filling of subsiding basins on the shelf was dominated by continental sedimentation on the early Tertiary and by marine deposition in the later Tertiary. River diversions caused by Miocene uplift of the Alaska Range increased the drainage area of the Yukon River two-fold or more. This change established the Yukon as the dominant source of river sediments (90 percent) reaching the Bering Sea and greatly accelerated sedimentation in the basins.

ACCESS # : 182, ADF&G

CITATION : Seaman, G.A., L.F. Lowry, and K.J. Frost. 1982. Foods of belukha whales (Delphinapterus leucas) in western Alaska. Cetology 44: 1-19.

KEY-WORDS: Beluga whale; Feeding; Trophic interactions; Marine mammals.

SYNOPSIS : Based on stomach observations from whales landed by subsistence hunters along the Bering and Chukchi coast, authors conclude that belugas feed on a wide variety of finfish, with diet primarily related to seasonal and areal distribution and abundance. During autumn and winter months pollock are probably the major prey in the southeastern and southcentral Bering Sea, while arctic and saffron cod are probably more important further north.

ACCESS # : 183, IMS-UAF

CITATION : Rugh, D. 1981. Fall gray whale census at Unimak Pass, Alaska, 1977-79. Abstr., 4th Biennial Conf. Biol. Mar. Mammals, 14-18 Dec., 1981, San Francisco.

KEY-WORDS: Gray whale; Population; Migration; Marine mammals.

SYNOPSIS : Author concludes that almost the entire population of gray whales migrates through Unimak Pass between late October to early January, most within 1.4 km of shore. The population summering in the Bering and Chukchi Seas is estimated at 17,000.

ACCESS # : 184, RAS-UAF

CITATION : Ridgway, S.H., and R.J. Harrison (eds.),. 1981. Handbook of marine mammals, Vol. 1 and 2. Academic Press, London and New York. 235 and 359 pp.

KEY-WORDS: Marine mammals; Biology; Distribution; Population; Ecology.

SYNOPSIS : Current information on taxonomy, anatomy, distribution, life history, behavior, food, reproduction, and mortality are included for 23 species of pinnipeds, including the 8 that occur in the Bering Sea.

ACCESS # : 185, IMS-UAF

CITATION : King, J.G., and C.P. Dau. 1981. Waterfowl and their habits in the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2: 739-753. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Waterfowl; Ducks; Geese; Migration; Nesting.

SYNOPSIS : The authors discuss in this paper the various habitat types present along the coast of the eastern Bering Sea with estimates of the extent of each type of habitat within geographic regions. A general description of migration patterns and nesting habits is reviewed, and species accounts are given for major species, which includes migration routes and dates, and preferred foraging and nesting habitat. Bristol Bay is described as primarily staging habitat during migration with the largest concentration of nesting geese in America occurring to the north on the Yukon-Kuskokwim Delta.

ACCESS # : 186, IMS-UAF

CITATION : Gill, R.E., Jr., and C.M. Handel. 1981. Shorebirds of the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol.2: 719-738. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Shorebirds; Migration; Habitat; Oil; Distribution.

SYNOPSIS : This paper describes and discusses the distributions and migratory habits of shorebird species utilizing the eastern Bering Sea. A general account of migration and habitat utilization is presented, followed by accounts by individual species. This region is used by 30 species of shorebirds, and is considered by the authors to be the most extensive and diverse expanse of intertidal habitat on the American coast of the Pacific. The intertidal of the Alaska Peninsula and Bristol Bay is used by migrating species in the spring as forage grounds in route to their breeding grounds. During the nesting period of late May through June there is little use of the littoral by shorebirds. After breeding, large numbers move back to the intertidal to feed, particularly in the Yukon Delta region. Though the lagoons of the Alaska Peninsula are important foraging habitat during this period, the extensive intertidal of northern Bristol Bay is little utilized for unknown reasons. A build-up of Western Sandpipers occurs in the Bristol Bay region in July and August, followed by an even larger buildup of Dunlin in September. The fall migration lasts into October for some species. Species are also ranked according to oil spill susceptibility. Within the Bristol Bay area, Western Sandpipers and Dunlin are considered particularly vulnerable.

ACCESS # : 187, IMS-UAF

CITATION : Hunt, G.L., Jr., P.J. Gould, K.J. Forsell, and H. Peterson, Jr. 1981. Pelagic distribution of marine birds in the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources Vol. 2: 689-718. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Seabirds; Distribution; Habitat.

SYNOPSIS : This chapter presents, by species, the seasonal and spatial distributions of seabirds over the eastern Bering Sea, with discussions of nesting habitat, locations of rookeries, diet, and population size. Distributional patterns, according to the authors, are the result of complex interactions between biotic and abiotic factors, including sea ice, food availability, habitat availability, and oceanographic frontal systems. Murres seem to be the most common bird on the eastern Bering during winter and spring, with shearwaters the most common summer bird. They believe that previous estimates of marine bird populations of the region are unduly conservative, and that at least 40 million seabirds occupy the region, comprised by 45 species.

ACCESS # : 188, IMS-UAF

CITATION : Hunt, G.L., Jr., Z. Eppley, and W.H. Drury. 1981. Breeding distribution and reproductive biology of marine birds on the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2: 649-687. NOAA, distrib. by Univ. Washington Press Seattle, WA.
KEY-WORDS: Seabirds; Distribution; Breeding ecology; Ecology.

SYNOPSIS : In this paper the authors give the locations and population estimates for all seabird colonies of the eastern Bering Sea and discuss, by species, breeding behavior, reproductive success, productivity, and stability. In general, most of the breeding marine birds of the eastern Bering Sea are concentrated in a few large colonies. Cliff-nesting species seem to be habitat limited, while non cliff-nesters are more likely limited by availability of food resources. The level of productivity of various species and colonies, and the stability of productivity, seems to depend primarily on the stability and diversity of food utilized. This is often, in turn, related to weather. In the north Bering Sea, diving birds (alcids) seem to maintain relatively stable levels of productivity by comparison with surface feeders such as kittiwakes, which undergo wide fluctuations in response to variable food supplies.

ACCESS # : 189, IMS-UAF

CITATION : Hunt, G.L., Jr., B. Bergeson, and G.A. Sanger. 1981. Feeding ecology of seabirds of the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2: 629-647. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Seabirds; Feeding ecology; Trophic interactions.

SYNOPSIS : A discussion, based on analyses of stomach samples, of the diet and feeding habits of major seabird species of the eastern Bering Sea. Composition of prey items are presented by species, area, and season. Authors conclude that, within a given area, only a very few prey species make up the bulk of foods consumed by seabirds, though prey items vary seasonally and from area to area. The total food consumption of seabirds in the eastern Bering Sea is estimated to be between 580,000 and 1,150,000 metric tons per year, including about 50% the tonnage of walleye pollock taken, in the form of adult fish, by commercial fisheries each year.

ACCESS # : 190, USF&WS

CITATION : Straty, R.R., and R.E. Haight. 1979. Interactions among marine birds and commercial fish in the eastern Bering Sea. USF&WS Res. Rep. 11: 201- 219.

KEY-WORDS: Seabirds; Trophic interactions; Feeding; Fisheries management.

SYNOPSIS : A discussion of the interactions of marine birds and commercial fish species of the eastern Bering Sea, with recommendations for further research.

ACCESS # : 191, IMS-UAF

CITATION : Sanger, G.A. 1972. Preliminary standing stock and biomass estimates of seabirds on the subarctic Pacific region. In: A.Y. Takenouti (ed.), Biological Oceanography of the Northern Pacific Ocean. Idemitsu Shoten, Tokyo, pp. 581-611.

KEY-WORDS: Seabirds; Abundance; Distribution; Trophic dynamics; Ecology.

SYNOPSIS : Based on shipboard observations, the standing stock and biomass of marine birds are calculated and summarized by season and region for each ecological group. Annual food consumption and nutrient transfer are estimated, and a hypothetical food chain is discussed.

ACCESS # : 192, RAS-UAF

CITATION : Ogi, H., and T. Tsujita. 1973. Preliminary examination of stomach contents of murres (Uria spp.) from the eastern Bering Sea and Bristol Bay, June-August, 1970 and 1971. Jap. J. Ecol. 23: 201-209.

KEY-WORDS: Murres; Seabirds; Feeding; Fishes; Plankton.

SYNOPSIS : Based on examination of 163 stomachs, authors describe principal food as consisting of larval and juvenile fishes (pollock, sandlance, capelin, sockeye salmon), euphausiids, amphipods, and squid.

ACCESS # : 193, RAS-UAF

CITATION : Lensink, C.J., J.C. Bartonek, and G.A. Sanger. 1976. Feeding ecology and trophic relationships of Alaskan marine birds. Annual Reports of Principal Investigators. Vol. 4. pp. 321-344. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Feeding; Ecology; Trophic interactions.

SYNOPSIS : A presentation of data from preliminary analyses of 83 stomachs collected from 14 species of seabirds. Prey items are described, for each species, in terms of frequency of occurrence and weight. Data are primarily from beyond the continental shelf in the Bering Sea.

ACCESS # : 194, RAS-UAF

CITATION : Lensink, C.J., J.C. Bartonek, and C.S. Harrison. 1976. Seasonal distribution and abundance of marine birds: Part 2, aerial surveys. Annual Reports of Principal Investigators. Vol. 4. pp. 1-98. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Distribution.

SYNOPSIS : A summary of marine bird census data from 11 offshore aerial surveys conducted in 1972, 1973, and 1975. Distributional data are presented by species, region, and season. Inshore Bristol Bay is described as probable key winter habitat for Oldsquaws, and key spring habitat for Short-tailed Shearwaters.

ACCESS # : 195, RAS-UAF

CITATION : Lensink, C.J., and J.C. Bartonek. 1976. Population dynamics of marine birds. Annual Reports of Principal Investigators. Vol. 4. pp. 345-361. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Population dynamics; Distribution.

SYNOPSIS : A review of existing information on marine bird distribution with research results from 1975 and 1976.

ACCESS # : 196, RAS-UAF

CITATION : Hunt, G., Z. Eppley, and W. Drury. 1979. Breeding distribution and reproductive biology of marine birds of the eastern Bering Sea. Pacific Seabird Group Bull. 6(2): 40. (abstract)

KEY-WORDS: Seabirds; Breeding distribution; Colony size; Productivity; Stability; Trophic interactions.

SYNOPSIS : A summary of available data pertaining to distribution and breeding biology of seabirds of the region with broad conclusions concerning distributions, colony size, and productivity and stability of populations. Authors postulate cliff-nesting species are habitat limited, while other species are primarily food limited. Differences in productivity and stability between colonies is related to food availability, reliability, and diversity.

ACCESS # : 197, RAS-UAF

CITATION : Harrison, C.S. 1977. Aerial surveys of marine birds. Annual Reports of Principal Investigators. Vol. 3. pp. 285-593. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Distribution; Abundance.

SYNOPSIS : Report analyzes results of aerial surveys between January and October, 1976. Distribution and abundance data are presented by species and region for the Beaufort, Chukchi, and Bering Seas, and areas of probable critical habitat are assessed.

ACCESS # : 198, RAS-UAF

CITATION : Divoky, G.J., and A.E. Good. 1979. The distribution, abundance and feeding ecology of birds associated with pack ice. Annual Reports for Principal Investigators. Vol. 1. pp. 330-599. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Sea ice; Distribution; Abundance; Ecology.

SYNOPSIS : Pelagic distribution and abundance are mapped by species for the Beaufort Sea, Chukchi and Bering Seas based on results of marine surveys. Densities are analyzed in relation to distance from land. Seasonal habitat use is also described from ground surveys at 12 coastal sites. Study deals primarily with the Beaufort and Chukchi Seas.

ACCESS # : 199, IMS-UAF

CITATION : Sowls, A.L., S.A. Hatch, and C.J. Lensink. 1978. Catalog of Alaskan seabird colonies. USF&WS. Biol Serv. Prog. Anchorage, Ak. 32 pp. + atlas.

KEY-WORDS: Seabirds; Colonies; Distribution; Abundance.

SYNOPSIS : A brief narrative description of the distribution, biology, and population status of seabird species common to Alaskan waters. The accompanying atlas illustrates the location of all known seabird colonies in Alaska with estimates of the number of birds of each species at each colony.

ACCESS # : 200, ARL

CITATION : Sanger, G.A., and P.A. Baird. 1977. Aspects of the feeding ecology of Bering Sea avifauna. Annual Reports of Principal Investigators. Vol. 12. pp. 372-417. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Feeding ecology; Trophic interactions.

SYNOPSIS : A review of published and unpublished information pertinent to the feeding ecology of Bering Sea birds, with a discussion of possible commercial fisheries/seabird interactions. Shearwaters and murres are described as eating large quantities of schooling pelagic and demersal fish, and euphausiids. Shearwaters (mostly short-tailed) are described as the most abundant bird in the Bering Bay area in summer, but are absent in winter. Locations are noted for known nesting colonies of murres, Black-legged Kittiwakes, and Parakeet Auklets.

ACCESS # : 201, ARL

CITATION : Sanger, G.A., and P.A. Baird. 1977. The trophic relationships of marine birds on the Gulf of Alaska and the southern Bering Sea. Annual Report of Principal Investigators for 1976/1977. Vol. 4. pp. 694-757. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Seabirds; Trophic interactions; Ecology.

SYNOPSIS : In this report the authors present results of analyses of seabird stomachs from the Gulf of Alaska and the southern Bering Sea. Data indicate that, though there is considerable overlap, closely related species in the same area pursue slightly different feeding strategies. Sooty Shearwaters, for instance, feed primarily on fish and secondarily on squid, while the reverse is true for Short-tailed Shearwaters. Common Murres feed almost exclusively in fish, while Thick-billed Murres feed predominately on squid. General dietary composition of 14 major species is presented, and total populations are estimated.

ACCESS # : 202, RAS-UAF

CITATION : Rice, D.W., and A.A. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). Am. Soc. Mammal. Spec.Publ. No. 3. 142 pp.

KEY-WORDS: Gray whale; Biology; Feeding; Population dynamics; Marine mammals.

SYNOPSIS : A comprehensive review of available information relating to gray whale population status, migration, age structure, growth, reproduction, predators, exploitation, and feeding habits. In the Bering and Chukchi Seas, at least 17 species of gammarid amphipods are consumed, especially Ampelisca macrocephala.

ACCESS # : 203, ARL

CITATION : Reilly, S., D. Rice, and A. Wolman. 1980. Preliminary population estimate for the California gray whale based upon Monterey shore censuses, 1967/68 to 1978/79. Rep. Int. Whaling Comm. 30: 359-368.

KEY-WORDS: Gray whale; Population; Marine mammals.

SYNOPSIS : Based on shore counts over the past 12 years, the current population estimate for the gray whale is 16,500 plus or minus 2,900 animals, virtually all of which summer in the Bering and Chukchi Seas.

ACCESS # : 204, RAS-UAF

CITATION : McAlister, W.B., and M.A. Perez. 1976. Ecosystem dynamics of birds and marine mammals, Part 1: Preliminary estimates of pinniped-finfish relationships in the Bering Sea. Proc. Rep. RU-77. 29 pp. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Marine mammals; Fish; Feeding; Trophic interactions.

SYNOPSIS : Based on available data concerning populations, residence times, and average consumption rates, estimates are derived by season and area of finfish consumption by major pinniped species. For the eastern Bering Sea shelf, annual total consumption is estimated at 4,223 metric tons, including 2,117 metric tons of finfish. This is equivalent to or slightly in excess of the present commercial take, though different species may by impacted.

ACCESS # : 205, RAS-UAF

CITATION : Harrison, C.S., and J.D. Hall. 1978. Alaskan distribution of the beluga whale, Delphinapterus leucas. Can. Field Nat. 92: 235-241.

KEY-WORDS: Beluga whale; Population; Distribution; Marine mammals.

SYNOPSIS : Based on extensive aerial surveys, the authors describe observed distribution and abundance patterns of belugas in Alaskan coastal waters.

ACCESS # : 206, RAS-UAF

CITATION : Gurevich, V.S. 1980. Worldwide distribution and migration patterns of the white whale (beluga), Delphinapterus leucas. Rep. Int. Whaling Comm. 30: 465-480.

KEY-WORDS: Beluga whale; Feeding; Abundance; Biology; Marine mammals; Fishes.

SYNOPSIS : An extensive review of information on belugas, including geographical races, behavior, herd structure, habitat, food, migration, and abundance. In the North Pacific, foods eaten include salmonids, herring, flatfish, navaga, and smelt.

ACCESS # : 207, ADF&G

CITATION : Fried, S.M., J.J. Laner, and S.C. Weston. 1979. Investigation of white whale (Delphinapterus leucas) predation upon sockeye salmon (Oncorhynchus nerka) smolts in Nushagak Bay and associated rivers: 1979 aerial reconnaissance surveys. Unpub. Rep., ADF&G, Dillingham. 15 pp.

KEY-WORDS: Beluga whale; Salmon; Feeding; Fisheries; Marine mammals.

SYNOPSIS : During aerial surveys, a total of 280 beluga were seen during flood tide, mostly moving upriver. No correlation was drawn between number of belugas seen and seaward movements of salmon smolts.

ACCESS # : 208, RAS-UAF

CITATION : Fiscus, C.H., and G.A. Baines. 1966. Food and feeding behavior of Steller and California sea lions. J. Mammal. 47: 195-200.

KEY-WORDS: Sea lions; Feeding; Trophic dynamics; Marine mammals; Fishes.

SYNOPSIS : From examinations of 34 Steller sea lion stomachs, authors conclude that predation on commercial fish species is probably minimal. Major prey items included capelin, sand lance, rockfish, sculpins, and flatfish. Only one had fed on salmon.

ACCESS # : 209, RAS-UAF

CITATION : Fiscus, C. H. 1980. Marine mammal-salmonid interactions: a review, In: McNeil, W.J., and D.C. Himsworth (eds.). Salmonid ecosystems of the North Pacific. Oregon State Univ., Corvallis. pp. 121-132.

KEY-WORDS: Marine mammals; Fisheries; Salmon.

SYNOPSIS : From an assessment of available information, the authors conclude that, although 8 species of marine mammals of the Bering Sea feed in salmon to some degree, only beluga whales consistently consume significant numbers of mature fish.

ACCESS # : 210, RAS-UAF

CITATION : FAO. 1978. Mammals in the Seas. Rep. of the FAO Advisory Comm. on Mar. Resources Research; working party on marine mammals. FAO Fish. Ser. 5. 1: 1-275.

KEY-WORDS: Marine mammals; Populations; Distribution; Biology; Ecology.

SYNOPSIS : This book includes chapters on species distributions, population status, ecological relationships, human interactions, and biology. Eight area case studies are described, including the Bering Sea.

ACCESS # : 211, UW

CITATION : Favorite, F., T. Laevastu, and R.R. Straty. 1977. Oceanography of the northeastern Pacific Ocean and eastern Bering Sea, and relations to various living marine resources. U.S. Dept. Comm. NOAA/NMSF. NW&Ak. Fish. Cent. Process Rep. 280 pp.

KEY-WORDS: Salmon; Oceanography; Ecology; Fisheries management.

SYNOPSIS : This report relates faunal population distributions to physical parameters such as temperature and salinity. In regard to Bristol Bay salmon resources, the authors describe the timing and migration routes of juvenile and adult sockeye salmon and relate such events and patterns to salinity and temperature distributions. The results and conclusions are essentially the same as those described above for the report by Straty and Jaenicke, 1980.

ACCESS # : 212, RAS-UAF

CITATION : Ogi, H. 1973. Ecological Studies on juvenile sockeye salmon, Oncorhynchus nerka (Walbaum) in Bristol Bay with special reference to its distribution and population. Hokkaido Univ. Bull. Fac. Fish. 24: 14-41.

KEY-WORDS: Distribution; Temperature; Salinity; Population; Salmon.

SYNOPSIS : An assessment of the distribution of juvenile sockeye salmon in Bristol Bay in relation to temperature and salinity, based on trawl samples taken during the summers of 1969 and 1970, is given here. The author also discusses distribution by age group and size within Bristol Bay.

ACCESS # : 213, RAS-UAF

CITATION : Straty, R.R., and H.W. Jaenicke. 1980. Estuarine influence of salinity, temperature, and food on the behavior, growth, and dynamics of Bristol Bay sockeye salmon. In: McNeil, W.J., and D.C. Himsworth (eds.). Salmonid Ecosystems of the North Pacific. Oregon State Univ. Press. Corvallis, OR. 331 pp.

KEY-WORDS: Salmon; Salmonids; Population dynamics; Fisheries management; Ecosystem analysis.

SYNOPSIS : A comprehensive assessment of the timing and migratory routes of adult and juvenile sockeye salmon in Bristol Bay, with evaluation of environmental factors (temperature, salinity, and food) on growth and migration is presented here. Sockeye smolt begin their seaward migration around the middle of May, reach Bristol Bay by the middle of July, and reach the North Pacific about six months later. This seaward migration remains nearshore, in the upper 10 meters of the water column, until it reaches the Port Moller area, after which it swings offshore and out to sea. The migration route appears to be in response to salinity gradients, with the speed of the migration at least partly determined by near-surface water temperatures. The food of juveniles consists primarily of zooplankton and smaller fishes. The adults return to Bristol Bay in mid-June and early July, entering the river systems by late July or early August. Cannibalism of the young does not occur, because the adults stay well out to sea until they reach the vicinity of their home rivers.

ACCESS # : 214, ADF&G

CITATION : Munday, P.R. 1977. Bristol Bay Data Base. Contract Rep. #3253, ADF&G, Anchorage, AK.

KEY-WORDS: Escapement; Salmon; Fisheries.

SYNOPSIS : This is a presentation of historical data, by year and statistical area of escapement, catch, and total run estimates for Bristol Bay salmon fisheries.

ACCESS # : 215, UW

CITATION : Harris, C.K., and D.E. Rogers. 1978. Forecast of the sockeye salmon run to Bristol Bay in 1978. University of Washington. Fish. Res. Inst. Circular No. 78-1.

KEY-WORDS: Salmon; Bristol Bay; Fisheries management; Forecast

SYNOPSIS : This report predicts the sockeye salmon run to major fishing districts within Bristol Bay (Naknek-Kvichak, Egegik, Nushagak) for 1978 and compares this forecast with previous runs (1950 through 1977).

ACCESS # : 216, ARL

CITATION : Stern, L.J., D.E. Rogers, and A.C. Hartt. 1976. Determination and description of knowledge of the distribution, abundance, and timing of salmonids in the Gulf of Alaska and Bering Sea. Final Report of Principal Investigators. Vol. 2. pp. 691-748. OCSEAP/NOAA, Boulder, CO.

KEY-WORDS: Salmon; Bristol Bay; Fisheries Management; Population dynamics Population ecology.

SYNOPSIS : A comprehensive review and synthesis of available data pertaining to the salmon fishery of the southeastern Bering Sea are presented. Authors present historical data back to 1925 with catch, escapement, and population estimates and means for each species by statistical area. Information is presented relative to timing of spawning runs of various species and to timing of downstream smolt migrations. Migration pathways of juveniles and spawning adults is also discussed, and nursery streams are delineated for each of the species occuring in the Bristol Bay-Alaska Peninsula area. Historically, inner Bristol Bay has been the most important salmon fishery in North America, with an average annual catch of over 10 million fish. The total Bristol Bay spawning run averages 18.3 million fish, ranging as high as 32.4 million. Sockeye salmon comprize 86% of the catch, followed by pinks and chum. About 80% of the Bristol Bay catch comes from Kvichak and Nushagak Bays.

ACCESS # : 217, ADF&G

CITATION : Frost, K.J., L.F. Lowry, and J.J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. OCSEAP/NOAA. RU# 613. OCSEAP Contract Report #NA 81 RAC 000 50. 188 pp.

KEY-WORDS: Marine mammals; Distribution; Coastal zone.

SYNOPSIS : A compilation of available sighting and information of marine mammal distributions and hauling areas in the coastal zone of the Bering Sea during ice-free months is presented here. Hauling areas and rookeries are delineated for Steller sea lions, harbor seals, spotted seals, and walrus.

ACCESS # : 218, IMS-UAF

CITATION : Harry, G.Y., and J.R. Hartley. 1981. Northern fur seals in the Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2: 847-867. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Fur seals; Trophic dynamics; Population dynamics; Marine mammals; Fisheries.

SYNOPSIS : An account of the history of fur sealing and the fur seal population is given, with discussion of present population status, seasonal/spatial distribution, food preference and metabolic requirements, mortality, and competition/interaction with other marine mammals and commercial fisheries.

ACCESS # : 219, IMS-UAF

CITATION : Frost, K.J., and L.F. Lowry. 1981. Foods and trophic relationships of cetaceans in the Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 2. pp. 825-836. NOAA, distrib. by Univ. Washington Press. Seattle, Washington.

KEY-WORDS: Cetaceans; Whales; Trophic dynamics; Ecology; Marine mammals.

SYNOPSIS : Authors present available information on the food habits of 13 cetacean species in the Bering Sea. With exception of gray whales, which are benthic feeders, all cetaceans are supported by a pelagic food web and all compete to some degree among themselves and with fishes, pinnipeds, seabirds, and humans.

ACCESS # : 220, NPFMC

CITATION : Lowry, L.F., K.J. Frost, D.G. Calkins, G.L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. N. Pac. Fish. Manag. Coun. Doc. No. 19, 291 pp. plus annotated bibliography.

KEY-WORDS: Marine mammals; Trophic dynamics; Population dynamics; Fisheries management.

SYNOPSIS : This report is a compilation, summary and evaluation of all currently available data and information concerning population status, seasonal and spatial distribution, feeding habits and food requirements of 26 species of marine mammals occuring in the Bering Sea and Aleutian Islands region, with particular attention to possible interactions with and impact on commerical fisheries of the area. A high probability of such interactions is suggested for northern fur seal, Steller sea lion, harbor seal, spotted seal, beluga whale, harbor porpoise, sea otter, gray whale, walrus, Dall's porpoise, ribbon seal, and bearded seal. Predictive assessments of interactions based on ecosystems models and simulations are not presently possible.

ACCESS # : 221, ARL

CITATION : Fay, F.H. 1982. Ecology and biology of the Pacific Walrus, Odobenus rosmarus divergens (Illiger). U.S.F. & W.S., N. Amer. Fauna. No. 74, 279 pp.

KEY-WORDS: Walrus; Ecology; Marine mammals.

SYNOPSIS : A thorough and comprehensive account of present and historical walrus population, seasonal and spacial distribution patterns, migration patterns, behavior, diseases, mortality, reproduction, taxonomy, feeding behavior, and general biology is presented.

ACCESS # : 222, RAS-UAF

CITATION : Fay, F.H. 1981. Belukha Whale. In: pp. 133-137, D.Haley (ed.), Marine Mamals of Eastern North Pacific and Arctic Waters. Pacific Search Press.

KEY-WORDS: Beluga Whale; Trophic dynamics; Marine mammals; Fishes.

SYNOPSIS : The food of beluga whales includes some 100 kinds of marine organisms, including small schooling fish, squid, octopuses, crabs, shrimp, snails, and worms. Fishes such as capelin, cod, herring, smelt, and flounder make up most of the diet in spring, summer, and autumn; polar cod is the main winter food.

ACCESS # : 223, ARL

CITATION : Laevastu, T., P. Livingston, and K. Niggol. 1980. Marine mammals in fisheries ecosystem in the eastern Bering Sea and in the northeastern Pacific Ocean. Part.1: Inputs of marine mammal data for ecosystem models PRUBUB 80-1 and 80-2, U.S. Dept. Comm. NOAA/NMFS, NW&Ak. Fish. Cent. Proc. Rep. 80-9, 13 pp.

KEY-WORDS: Marine mammals; Trophic dynamics; Fisheries management.

SYNOPSIS : Authors summarize population and distribution information concerning all marine mammal species of the area, discuss food preferences of the various species, and estimate total consumption of commercial species by marine mammals.

ACCESS # : 224, RAS-UAF

CITATION : Everitt, R.D., and H.W. Braham. 1980. Aerial Survey of Pacific harbor seals in the southeastern Bering Sea. Northwest Science 54(4): 281-288.

KEY-WORDS: Harbor Seal; Population dynamics; Population distribution; Marine mammals.

SYNOPSIS : Based on 5 aerial surveys conducted between June, 1975 and June, 1977 along the eastern Aleutians and throughout Bristol Bay, a minimum number of 29,000 harbor seals was estimated for the area. Three locations on the north side of the Alaska Peninsula - Port Moller, Port Heiden, and Cinder River accounted for 78% of the study area population count.

ACCESS # : 225, RAS-UAF

CITATION : Rugh, D.J., and H.W. Braham. 1979. California Gray Whale (Eschrichtius robustus) fall migration through Unimak Pass, Alaska. 1979. Rep. Int. Whaling Comm. 29, 20 pp.

KEY-WORDS: Gray Whale; Migration; Marine mammals.

SYNOPSIS : Based on shore observations from Cape Sarichef, Unimak Island, from 20 November to 9 December, 1977, authors estimate that approximately 15,099+/-2,341 gray whales left the Bering Sea via Unimak Pass.

ACCESS # : 226, RAS-UAF

CITATION : Hall, J.D., C.S. Harrison, J. Nelson, and A. Taber. 1977. The Migration of California Gray Whales into the Bering Sea. IN: Proc. (absracts), Second Conf. Biol. Mar. Mammals, San Diego, CA., 12-15 December 1977. 8 pp.

KEY-WORDS: Migration; Marine mammals; Gray Whale.

SYNOPSIS : Shore observations from Cape Sarichef (Unimak Island) during the spring of 1977 indicate that approximately 9,000 gray whales entered the Bering Sea via Unimak Pass between 7 April and 26 May, 1977.

ACCESS # : 227, RAS-UAF

CITATION : Everitt, R.D. and B.D. Krogman. 1979. Harbor seal distribution and abundance in the Bering Sea: Alaska Peninsula and Fox Islands. Science in Alaska, Proc. 29th Alaska Sci. Conf., Fairbanks, Ak. 21 pp.

KEY-WORDS: Harbor seal; Population dynamics; Marine mammals.

SYNOPSIS : Estimates of harbor seal populations in Bristol Bay, along the north side of the Alaska Peninsula, and in the eastern Aleutians as far west as Samalga Island, based on 6 aerial surveys between June, 1975, and July, 1976. A minimum estimate of 28,000 to 30,000 animals is arrived at for the area, with 80% of the population concentrated at 8 hauling areas along the north side of the Alaska Peninsula.

ACCESS # : 228, RAS-UAF

CITATION : Taylor, F.H.C., M. Fujinaga, and F. Wilke. 1955. Distribution and food habits of the fur seals of the North Pacific Ocean. U.S. Dept. Inter., F&WS, Wash., D.C. 86 pp.

KEY-WORDS: Fur seals; Trophic dynamics; Marine mammals; Distribution; Population.

SYNOPSIS : Pelagic distribution of fur seals is discussed based on shipboard surveys, winter concentrations are noted, sex and age ratios noted, and results of stomach content analysis is presented by region.

ACCESS # : 229, RAS-UAF

CITATION : Lander, R.H. and H. Kajimura. 1978. Status of northern fur seals. In: Mammals in the seas. FAO Fish. Ser. No. 5., Vol. 2., 50 pp.

KEY-WORDS: Fur seals; Pribilof Islands; Population dynamics; Ecology; Marine mammals.

SYNOPSIS : Discusses current fur seal population, birth rates, mortality, harvesting, range, and feeding habits. The current Pribilof Islands population is estimated at 1,300,000. Principal prey items are capelin, pollock, mackerel, sand lance, and squid.

ACCESS # : 230, NW&AFC

CITATION : Kooyman, G.L., R.L. Gentry, and B.W. McAlister. 1976. Physiological impact of oil on pinnipeds. 23 pp. NOAA/NMFS. NWAFC, Marine Mammal Division, Seattle, WA.

KEY-WORDS: Marine mammals; Pinnipeds; Seals; Physiology; Oil pollution.

SYNOPSIS : Authors discuss the physiology effects of various types of oil on several species of pinnepeds. Results indicate that even small amounts of oil have very adverse effects on fur-bearing seals (sea lions and fur seals) but negligible effects on non fur-bearing (Phocid) seals.

ACCESS # : 231, RAS-UAF

CITATION : Kenyon, K.W. and D.W. Rice. 1961. Abundance and distribution of the Steller sea lion. J. Mammal. 42: 223-234.

KEY-WORDS: Sea lion; Population dynamics; Distribution; Marine mammals.

SYNOPSIS : Discusses population estimates and distribution of sea lions in the Bering Sea from Bering Strait to and including the Aleutian Islands. The author also presents information on seasonal movements, hauling and rooking locations, and hauling-out behavior.

ACCESS # : 232, RAS-UAF

CITATION : Lowry, L.F., K.J. Frost, and J.J. Burns. 1980. Feeding of bearded seals in the Bering and Chukchi Seas and trophic interaction with Pacific walruses. Arctic 33(2): 330-342.

KEY-WORDS: Bearded seal; Walrus; Trophic dynamics; Marine mammals.

SYNOPSIS : Discusses feeding habits and prey preference of bearded seals and walrus, based on analysis of stomach samples, in the Bering and Chukchi Seas. Though the diets of the two species overlap in that both feed on clams when they are available, walrus are apparently very dependent on bivalves as the mainstay of their diet whereas bearded seals are more euryphagous and flexible. The walrus population appears to be exhibiting some signs of stress, possibly due to a recent population increase and predation pressure on these bivalve food resources. Bearded seals, on the other hand, show no indications of such stress.

ACCESS # : 233, ARL

CITATION : Lowry, L.F., K.J. Frost, and J.J. Burns. 1979. Trophic relationships among ice-inhabiting phocid seals. Principal Investigators' Reports for the Year Ending March 1977. Vol. I. pp. 303-390. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Marine mammals; Phocid seals; Trophic dynamics; Sea ice.

SYNOPSIS : Based primarily on stomach analysis of samples obtained from coastal seal-hunting subsistence villages, the food preferences of each species of seal is discussed by geographic area. Potential effects of petroleum development in the area are also discussed.

ACCESS # : 234, ADF&G

CITATION : Seaman, G.A. and J.J. Burns. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. Rep. Int. Whal. Comm. 31: 567-573

KEY-WORDS: Beluga whale; Ecology; Population dynamics; Subsistence; Marine mammals.

SYNOPSIS : Presents data on beluga subsistence harvest by Alaskan Natives, killed and lost ratios, reproductive biology, and feeding behavior.

ACCESS # : 235, ADF&G

CITATION : Klinkhart, E. 1966. The beluga whale in Alaska. ADF&G. Fed. Aid Wildl. Rest. Proj. Rep., Vol. 7. 11 pp.

KEY-WORDS: Beluga whale; Ecology; Population dynamics; Marine mammals.

SYNOPSIS : Presents general information on the population status, distribtion and life history of belugas. The Bristol Bay population, considered to be resident year-round, is estimated at 1,000 to 1,500.

ACCESS # : 236, RAS-UAF

CITATION : Johnson, B.W. 1977. The effect of human disturbance on a population of harbor seals. Principal Investigators' Reports for the Year Ending March 1977. Vol. I. pp. 422-432. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Harbor seal; Disturbance; Ecology; Marine mammals.

SYNOPSIS : Based on observations of harbor seals on Tugidak Island, the author describes effects of natural disturbance (eagles, rockslides) and human disturbance (low-flying aircraft, hikers, all-terrain vehicles) on a harbor seal rookery. It is estimated that human disturbance, particularly low-flying aircraft, caused more than 10% pup mortality.

ACCESS # : 237, IMS-UAF

CITATION : Sergeant, D.W., and P.F. Brodie. 1975. Identity, abundance and present status of populations of white whales, Delphinapterus leucus, in North America. J. Fish. Res. Bd. Can. 32: 1047-1054.

KEY-WORDS: Beluga whale; Population dynamics; Distribution; Marine mammals.

SYNOPSIS : Identifies and characterizes various geographic populations of belugas, presents size data by population and sex, and estimates abundance for each population. Evidence indicates that more southerly populations of beluga attain larger body size, which perhaps correlates to increased primary and secondary marine productivity in these areas. Authors propose that the southern limits of beluga range may be defined by competition with other delphinids or by predation by killer whales.

ACCESS # : 238, RAS-UAF

CITATION : U.S. Interagency Task Group. 1976. Draft environmental impact statement in consideration of a waiver of the moratorium and return of management of certain marine mammals to the state of Alaska. U.S. Dept. Comm. NOAA/NMFS. Wash., D.C.

KEY-WORDS: Marine mammals; Population dynamics; Sustainable yield; Game management.

SYNOPSIS : A presentation, based on best available data (as of 1976) of the population status, distribution, productivity, subsistence harvest level, and sustainable yield harvest level for 9 species of marine mammals occurring in Alaskan waters. For Bristol Bay, the Steller Sea lion population (1976) is estimated at 2,700 (excluding Unimak Island), with 6 known rookeries. The harbor seal population of Bristol Bay is estimated (conservatively) at 30,000, the beluga whale population at 1,500.

ACCESS # : 239, RAS-UAF

CITATION : Haley, D. (ed.). 1978. Marine Mammals of Eastern North Pacific and Arctic Waters, Pacific Search Press. Seattle, Wash. 256 pp.

KEY-WORDS: Marine mammals; Distribution; Biology.

SYNOPSIS : A compilation of works by 21 authors presenting current information on abundance, distribution, natural history, research methods, human impacts, and other facets of over 40 marine mammal species occurring in the area.

ACCESS # : 240, RAS-UAF

CITATION : Schneider, K., and J.B. Faro. 1975. Effects of sea ice on sea otters (Enhydra lutris). J. Mammal. 56(1): 91-101.

KEY-WORDS: Sea ice; Marine mammals; Sea otter.

SYNOPSIS : A discussion of the effects of ice on the otter population of southern Bristol Bay during the winters of 1971 and 1972. During the unusually extensive and sudden penetration of sea ice along the Alaska Peninsula in 1971, otter mortality was estimated to be at least 200. During 1972, when the onset of ice was less sudden, mortality appeared to be negligible. Authors also note the expansion of known otter range northeastward to Port Heiden by 1970.

ACCESS # : 241, RAS-UAF

CITATION : Schneider, K. 1976. Distribution and abundance of sea otters in southwestern Bristol Bay. Quarterly Report Ending December 1976. pp. 469-526. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Sea otter; Population dynamics; Marine mammals.

SYNOPSIS : A good account of the population status and distribution of otters in Bristol Bay as of 1976. Author estimates that the total population may be 8,000 to 10,000 animals based on what data was available at that time. High population densities are found from Cape Mordvinof (Unimak Island) to roughly 30 miles northeast of Izembek Lagoon, with lesser densities occurring northeast along the Alaska Peninsula to about Ugashik. In years of heavy and extensive winter sea ice, the population shifts to the southwest, often suffering significant mortality. Sea otters have been observed to range out to the 40 fathom isobath in Bristol Bay, as much as 30 miles offshore. They are estimated to consume approximately 20 to 25% of their body weight daily in food.

ACCESS # : 242, ADF&G

CITATION : Kosygin, G.M. 1976. Feeding of the bearded seal Erignathus barbatus nauticus (Pallas) in the Bering Sea during the spring-summer period. Fisheries and Marine Science Translation No. 3747. 14 pp. Dept. of the Environment, Fish. and Mar. Serv. Arctic Biol. Station. Ste. Anne de Bellevue, P.Q., Canada.

KEY-WORDS: Bearded seal; Marine mammals; Trophic dynamics.

SYNOPSIS : A description of bearded seal feeding behavior from analysis of 565 stomach samples collected over a three year period (1963-1965) is given. Items identified include 30 species of crustaceans, several species of mollusks, sponges, annelids, and 15 fish species. Primary prey species were Chionoecetes opilio (53-76% by weight), crangonid shrimps, panalid shrimps, Hyas coarctatus, octopods, and various species of fish.

ACCESS # : 243, NPFMC

CITATION : Fay, F.H., and L.F. Lowry. 1981. Seasonal use and feeding habits of walruses in the proposed Bristol Bay clam fishery area. Final Rep., N. Pac. Fish. Manag. Council. Contract No. 80-3.

KEY-WORDS: Walrus; Marine mammals; Distribution; Fisheries management; Trophic dynamics.

SYNOPSIS : An account of the population distribution, hauling areas, migration patterns, feeding behavior and food requirements of walruses within Bristol Bay. Total numbers of walrus censused ranged from 280 (Jan., 1981) to 63,800 (May, 1980). During years of extensive sea ice walrus are numerous in Bristol Bay in winter, with significantly lower populations during years of light sea ice. A resident population of about 20,000 animals, mostly males, resides in the area from May through August. The primary hauling ground is Round Island, though in recent years irregular haulouts have been observed on Amak Island, Walrus Island, Deer Island, Cape Seniavin, Cape Constantine, and Cape Newenham. At least 22 genera of benthic invertebrates are eaten by walruses within the area, though 90% of the diet is comprised by 5 genera of bivalve mollusks.

ACCESS # : 244, RAS-UAF

CITATION : Estes, J.A., and J.F. Palmisano. 1974. Sea otters: their role in structuring nearshore communities. Science 185: 1058-1060.

KEY-WORDS: Sea otter; Marine mammals; Community structure; Ecology; Trophic dynamics.

SYNOPSIS : A descriptive comparison of nearshore communities which support substantial populations of sea otters (Amchitka Island) and communities which do not (Shemya Island), is given. Results indicate that otter predation on grazers, especially sea urchins, leads to greatly increased macroalgal standing stocks and consequently altered habitat and community structure from intertidal to 60 m.

ACCESS # : 245, ARL

CITATION : Kenyon, K.W.. 1975. The Sea Otter in the Eastern Pacific Ocean. Dover Publications, Inc. New York, N.Y. 352 pp.

KEY-WORDS: Sea otter; Marine mammals; Distribution; Life history; Abundance; Trophic dynamics.

SYNOPSIS : A comprehensive account of the distribution, abundance, habitat, behavior, feeding, and life history of sea otters in the eastern Pacific Ocean and Bering Sea. As of 1965, the sea otter population of the Unimak-Amak Island vicinity was estimated at 3,856. The Port Moller vicinity appears to be the northeastern limit of the sea otter's range in the Bering Sea, probably due to adverse seasonal ice conditions further north.

ACCESS # : 246, ARL

CITATION : Dept. Interior, USF&WS, Bur. Sport Fish & Wildl. 1972. River basin studies. Southeast Alaska, Bristol Bay waterbird survey. USF&WS, Anchorage. 8 pp.

KEY-WORDS: Seabirds; Waterfowl; Avifauna; Migration; Distribution.

SYNOPSIS : Based on preliminary aerial surveys, this report presents data on bird densities and distributions along the Alaska Peninsula and within Bristol Bay Bristol Bay is described as a crossroads for waterfowl coming from wintering areas as divergent as Japan and Mexico and headed for breeding grounds as far east as Melville Island in Northern Canada and as far west as the delta of the Lena River in Central Siberia. It is considered critical staging habitat, very vulnerable to petroleum development.

ACCESS # : 247, RAS-UAF

CITATION : Hunt, G.L. Jr., J. Kaiwi, and D. Schneider. 1982. Pelagic distribution of marine birds and analysis of encounter probability for the southeastern Bering Sea. Final Reports of Principal Investigators. Vol. 16. pp. 1-160. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Seabirds; Oil Spills; Species Distribution; Distribution.

SYNOPSIS : This report estimates spatial and temporal distributions of seabirds over the southeastern continental shelf of the Bering Sea, and assesses the vulnerability, temporally and spatially, of seabird populations to possible oil spills in the area. The Bering Strait, the Pribilof and St. Lawrence Island vicinities, the shelf-edge, and Bristol Bay inside the 50 m curve are all considered sensitive areas. Shearwaters predominate in inner Bristol Bay, particularly in summer.

ACCESS # : 248, ARL

CITATION : Schneider, D. 1982. Fronts and seabird aggregations in the southeastern Bering Sea. Mar. Ecol. Prog. Ser. 10: 101-103.

KEY-WORDS: Seabirds; Trophic Dynamics; Ecology; Oceanography.

SYNOPSIS : This paper presents evidence that oceanic fronts, with associated enhancement of biological activity at the primary and subsequent levels, probably play a significant role in the feeding strategy of marine birds of the Bering Sea. Results indicate that birds frequenting the outer front (at the shelf break) are primarily surface feeders (fulmars and petrels), while those utilizing the inner (50m) front were primarily subsurface feeders (shearwaters and murres).

ACCESS # : 249, RAS-UAF

CITATION : Gill, R., M. Petersen, C. Handel, J. Nelson, A. DeGange, A. Fukuyama, and G. Sanger. 1978. Avifaunal assessment of Nelson Lagoon, Port Moller, and Herendeen Bay, Alaska 1977. U.S. Fish and Wildlife Service. Office of Biological Services, Coastal Ecosystems, Anchorage, AK., 131 pp.

KEY-WORDS: Waterfowl; Shorebirds; Avifauna; Nelson Lagoon; Port Moller; Herendeen Bay; Population dynamics; Habitat ecology; Alaska Peninsula.

SYNOPSIS : This report describes results of field efforts conducted between 18 April and 15 October, 1977 in the Nelson Lagoon vicinity. Authors present information on abundance, habitat selection, breeding success, molting, roosting, nesting, and foraging areas for major species. Arrival and departure dates of major species are described, and seasonal variation in populations assessed. In addition, migration strategies of Dunlin and Western Sandpipers are analyzed and an assessment made of Steller's Eider feeding habits within the areas. Study deals primarily with waterfowl and shorebirds. Authors caution that other lagoon systems of the Alaska Peninsula support somewhat different avifaunal communities, so that results from the Nelson Lagoon study should not be extrapolated to other locales.

ACCESS # : 250, ARL

CITATION : Livingston, P. 1980. Marine bird information synthesis. NWAFC, NMFS/NOAA Process. Rep., 25 pp.

KEY-WORDS: Seabirds; Distribution; Trophic dynamics; Ecology.

SYNOPSIS : This is a synthesis by subregions of the eastern Bering Sea and western Gulf of Alaska of available information concerning marine bird population densities, distributions, and feeding behavior and food resources. Information is also presented on seasonal population fluctuations, by subregion for various species. Though not as specific for the northeast Aleutian-Bristol Bay area, the report does provide general information as to species distribution, abundance, and feeding behavior.

ACCESS # : 251, NMFS

CITATION : Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (Gadus macrocephalus) in the eastern Bering Sea and expected abundance in 1982-86. NOAA Technical Memorandum NMFS F/NWC-25, 26 pp.

KEY-WORDS: Pacific cod; Abundance; Population dynamics; Fisheries.

SYNOPSIS : Resource assessment surveys by the Northwest and Alaska Fisheries Center (NWAFC) have shown a substantial increase in abundance of Pacific cod in the eastern Bering Sea since 1977. This increase is primarily due to the emergence of the strong 1977 year-class. Because the life span of cod is relatively short and the current abundance of the population is mainly the result of a single year-class, stock abundance may soon return to lower levels. Abundance of cod population was projected through 1986 using a numeric population simulator so that the fishing industry can anticipate the future harvest potential of the resource. The simulation indicates that the contribution of the strong 1977 year-class will diminish substantially when it reaches age 7 in 1984. Catches will then be reduced to a more historical level.

ACCESS # : 252, ARL

CITATION : Waldron, K.D. and B.V. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Final Reports of Principal Investigators. Vol. I. pp. 236-237. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Ichthyoplankton; Walleye pollock; Spawning periods; Vertical distribution; Horizontal distribution.

SYNOPSIS : This study mainly focused on walleye pollock, although other ichthyoplankton were also examined. Data were collected with bongo and neuston nets between mid April and mid May 1977. Most of the eggs and larvae collected were pollock. The report concludes that no marked differences in distribution and abundance of pollock eggs and larvae occured between 1976 and 1977.

ACCESS # : 253, IMS-UAF

CITATION : Takeuchi, I. 1962. On the distribution of zoae larvae of king crab, Paralithodes camtschatica, in the southeastern Bering Sea in 1960. Bulletin of Hokkaido Regional Fisheries Research Laboratory 24: 163-170.

KEY-WORDS: Crabs; Paralithodes camtschatica; Plankton; Larvae; Distribution; Crustacea.

SYNOPSIS : In 1960, for the purpose of surveying the distribution of king crab zoae in the free-swimming stage at the king crab fishing grounds in southeastern Bering Sea, a series of samplings as carried out using standard North Pacific plankton nets and fish larvae nets. Also, in parallel with this, the egg-carrying state of the female crabs caught in commercial nets was examined. This study was mainly carried out in the Black Hills - Port Moller area.

ACCESS # : 254, IMS-UAF

CITATION : Somerton, D.A. 1982. Effects of sea ice of the distribution and population fluctuations of Chionoecetes opilio in the eastern Bering Sea. IN: Proceedings of the International Symposium of the Genus Chionoecetes. Lowell Wakefield Fisheries Symposia Series, Alaska Sea Grant Rep. 82-10, pp. 157-172.

KEY-WORDS: Sea ice; Chionoecetes; Distribution; Phytoplankton bloom.

SYNOPSIS : Evidence is examined which suggests that, in the eastern Bering Sea, Chionoecetes opilio may synchronize the release of its larvae with a spring phytoplankton bloom which is initialized by sea ice. When this ice edge bloom does not occur, either because ice is not present or because other conditions are not appropriate for initiation of a bloom, larval survival decreases. The distribution of C. opilio is therefore limited by the maximum extent of sea ice in April when C. opilio larvae enter the plankton.

ACCESS # : 255, ARL

CITATION : Feder, H. M., K. Haflinger, M. Hoberg and J. McDonald. 1981. The infaunal invertebrates of the southeastern Bering Sea. Final Reports of Principal Investigators. Vol 9. pp. 257-670. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Infaunal distribution; Bivalves; Benthos; Sediment structure; Biomass; Pinkneck clam.

SYNOPSIS : This document contains (1) a quantitative inventory of dominant benthic infaunal species within and adjacent to identified oil-lease sites in the southeastern Bering Sea, (2) species assemblages on the basis of distribution and abundance of infaunal species on the southeastern Bering Sea shelf, and (3) a preliminary comparison of dominant species with selected physical and geological features. The distribution of eight dominant bivalve mollusks is presented with respect to sediment.

ACCESS # : 256, IMS-UAF

CITATION : K.E. Haflinger, and C.P. McRoy. 1983. Yellowfin sole (Limanda aspera) predation on three commercial crab species (Chionoecetes opilio, C. bairdi, and Paralithodes camtschatica) in the southeast Bering Sea. Unpublished report.

KEY-WORDS: Yellowfin sole; Tanner crab; King crab; Predation; Trophic interactions.

SYNOPSIS : This document examined yellowfin sole prey, in particular commercially important crabs, from two areas in the southeastern Bering Sea. The only crab taken by fish from the mid-shelf area was the Tanner crab Chionoecetes opilio. An extrapolation to the total number of first instar crab consumed by 682 fish in the mid-shelf area over the time period of September-November (90 days) was 23,700,000,000. A similar extrapolation of crab in the 10-13 mm size class was 18,500,000. No difference in crab consumption by size group of fish was apparent, while a difference was apparent for mean number of crab between different sampling locations. Other important prey items in fish from the mid-shelf area were the polychaete Myriochele sp., the bivalve Clinocardium ciliatum, and the holothuroid Cucumaria calcigera. Yellowfin sole (n=557) from the Alaska Peninsula region contained king crab (Paralithodes camtschatica) and Tanner crab (C. bairdi), but only two fish accounted for nearly all of the consumption reported here. The overall incidence of king crab glocothoe larvae was 0.69/stomach. Extrapolations from these rates to total numbers of crab consumed for one month in this area were 11,500,000,000 king crab and 4,500,000,000 Tanner crab. Non-crab stomach contents were considerably more diverse among the Alaska Peninsula samples.

ACCESS # : 257, ADF&G

CITATION : Powell G., and G. McCrary. 1982. Is the gold rush over? Alaska Fish Tales & Game Trails, Summer 1982. 17-19 pp.

KEY-WORDS: Red king crab; Commercial fisheries.

SYNOPSIS : The document examines the recent "crash" of the red king crab fishery of the southeastern Bering Sea. In 1980 the commercial harvest was the historic high of 59.1 thousand mt. The 1981 harvest declined to 15.4 thousand mt, and in 1982 the harvest was the historic low of only 1.3 thousand mt. A possible factor in this decline is heavy predation pressure by bottomfish (e.g., Pacific cod, yellowfin sole, Pacific halibut).

ACCESS # : 258, IMS-UAF

CITATION : Thorsteinson, F.V., and L.K. Thorsteinson. 1982. Finfish resources. pp. 111-139 In: M.J. Hammedi (ed.), Proceedings of a synthesis meeting: the St. George Basin environment and possible consequences of planned offshore oil and gas development; Anchorage, Alaska, April 28-30, 1981. NOAA, OMPA, OCSEAP.

KEY-WORDS: Fisheries resources; North Aleutian Shelf; St. George Basin.

SYNOPSIS : Species considered in this document included red king crab, Tanner crab, yellowfin sole, rock sole, flathead sole, Greenland turbot, Pacific halibut, Pacific herring, sablefish, and walleye pollock. These fish, with the possible exceptions of sablefish and turbot, occupy the waters of the North Aleutian Shelf seasonally as adults or during early developmental stages. Because of this, the North Aleutian Shelf fisheries workshop concentrated mainly on salmon of Bristol Bay and the north side of the Alaska Peninsula, and the potential impacts of OCS development on these stocks.

ACCESS # : 259, IMS-UAF

CITATION : VTN Oregon. 1983c. Cruise Report: Cruise MF 83-5 (RP-MF-83B, Leg II), 9-23 September 1983, OCSEAP Red King Crab Distribution. VTN Oregon, Inc. Wilsonville, OR. 6 pp.

KEY-WORDS: King crab; Distribution; Juveniles; Larvae.

SYNOPSIS : Plankton and epibenthic samples were collected in the North Aleutian Basin to determine the apparent distribution of larvae and early juvenile red king crabs (Paralithodes camtschatica). Ancillary physical, chemical and biological data for subsequent correlations to the apparent distribution pattern (s) were also gathered.

ACCESS # : 260, IMS-UAF

CITATION : Weber D.D., and T. Miyahara. 1962. Growth of the adult male king crab Paralithodes camtschatica (Tilesius). USF&WS Fish. Bull. 200, 62: 53-75

KEY-WORDS: King crab; Growth.

SYNOPSIS : Estimates of the average growth rates of the eastern Bering Sea male king crab, Paralithodes camtschatica, are presented. Through examining the advancement of modal groups in size-frequency distributions collected in 5 successive years, the growth rate of the smaller adult male crabs is described. For the larger sizes the growth per molt observed in tagged individuals and the proportion of molting crabs observed in each year are combined in a theoretical model which represents the progression of a year class through time. The resulting growth curves calculated from the 1956, 1958, and 1959 data are strikingly similar and show that male crabs 80 mm in carapace length will attain an average length of 168 mm after 8 years of growth. Crabs growing at the rate depicted for 1957 would be 153 mm in length at the end of an equal period.

ACCESS # : 261, ADF&G

CITATION : Barton, L.H., and D.L. Steinhoff. 1980. Assessment of spawning herring (Clupea harengus pallasii) stocks at selected coastal areas in the eastern Bering Sea. Alaska Department of Fish and Game Informational Leaflet No. 187. 60 pp.

KEY-WORDS: Stock assessment; Herring; Spawning.

SYNOPSIS : A 2-year study of Pacific herring, Clupea harengus pallasii, was conducted by the Alaska Department of Fish and Game along the eastern Bering Sea coast from Bristol Bay to Bering Strait to assess biomass and distribution of spawning populations as well as to collect other biological baseline data. Aerial surveys were used as the primary tool for gathering information on timing, distribution, and abundance, while ground crews deployed to selected areas along the coast obtained data on age, sex, size, and maturity composition using variable mesh gill nets to sample within major spawning areas. Major herring spawning concentrations occurred in the Togiak District of Bristol Bay, Security Cove, Goodnews Bay, Nelson Island, and Cape Romanzof in the Yukon-Kuskokwim area, and at Klikitarik and Cape Denbigh in Norton Sound. Herring are known to spawn in the Shishmaref and Kotzebue areas, but occurrence of spawning and assessment of spawning biomass have not been documented north of Bering Strait.

ACCESS # : 262, ARL

CITATION : Fisher, R.B. 1980. The joint venture for Yellowfin Sole, Bering Sea, Summer 1980; A case study in fishery development. Sponsored by The Alaska Fisheries Development Foundation and North Pacific Fishery Management Council. 89 pp.

KEY-WORDS: Yellowfin sole; Fishery development; Joint venture.

SYNOPSIS : Marine Resources Company Inc. of Seattle, Washington conducted a joint venture fishery involving three USSR processing ships and five small to medium-sized American trawlers in the southeastern Bering Sea in the summer of 1980 (June 3 to September 18, 1980). The five American catcher boats caught 8,638 mt of food-grade yellowfin sole (Limanda aspera), 1,142 mt of Pacific cod (Gadus macrocphalus), and 3,118 mt of fishmeal-grade product for a grand total of 13,177 mt, valued at approximately $1,588,000 (ex-vessel value) during this period. The catches were immediately transferred via detachable cod ends to three Soviet processing ships for processing and freezing. The yellowfin sole (and smaller amounts of rock sole, Alaska plaice and lemon sole) were four to a carton. The Pacific cod was headed and gutted and frozen in similar blocks. Small fish, damaged fish, cod offal, and "trash" species were processed into meal. The product was transported to the USSR and then marketed in the USSR and Africa. The subsequent sale of the product resulted in "export dollars" coming home to the United States. The fishery was an economic success for the participating American trawlers, Soviet processing ships, and Marine Resources Co. Inc. The fishery was the first commercial penetration by American vessels in the Bering Sea yellowfin sole fishery, a species previously exploited only by foreign nations. Careful and detailed planning for the fishery began in October of 1978. It is felt that the planning and execution of this fishery may serve as a case study in groundfish development in Alaskan waters.

ACCESS # : 263, ADF&G

CITATION : Fried, S., and J. Skrade. 1982. Bering herring: it's more than just bait. Alaska Fish Tails and Game Trails, Summer 1982, 10-11 & 16 pp.

KEY-WORDS: Herring; Commercial fisheries; Kelp.

SYNOPSIS : This document assesses the recent "sac roe" and "roe-on-kelp" herring fishery in the eastern Bering Sea.

ACCESS # : 264, U. Minnesota, Minn, MN

CITATION : Garshelis, D.L. 1983. Ecology of sea otters in Prince William Sound. PH.D. Dissertation, University of Minnesota, Minneapolis, MN. 321 pp.

KEY-WORDS: Sea otter; Population dynamics; Trophic interactions; Marine mammals.

SYNOPSIS : This document examines five aspects of the sea otter ecolgy in Prince William Sound: 1) social organization; 2) foraging strategies and prey consumption in areas with differing food resources; 3) activity; 4) movements with implications for management; and 5) examination of a sea otter-shellfishery conflict.

ACCESS # : 265, NMFS

CITATION : Hughes, S.E., R.W. Nelson, and R. Nelson. 1977. Initial assessments of the distribution, abundance, and quality of subtidal clams in the S.E. Bering Sea. NOAA/NMFS, NWAFC, Seattle, WA. 43 pp. + Appendix.

KEY-WORDS: Bivalves; Distribution; Abundance; Resource assessment.

SYNOPSIS : Results of the phase I survey indicated low clam abundance in the offshore southeastern Bering Sea survey area where survey depths were primarily 20-30 fms, while the possible surf clam resource detected along the Alaska Peninsula was at depths of 10-20 fms. The more detailed phase II survey of the Peninsula area indicated the surf clam resource to occur over a 1,600 square mile area, primarily at depths of 13-18 fms.

ACCESS # : 266, ADF&G

CITATION : McBride, D., and C. Whitmore. 1981. Age composition of Pacific herring, Clupea harengus pallasi (Valenciennes) in the Togiak District of Bristol Bay during the 1979 and 1980 spawning seasons. ADF&G Informational Leaflet No. 191, 27 pp.

KEY-WORDS: Age composition; Herring; Spawning; Fisheries.

SYNOPSIS : Age composition of Pacific herring (Clupea harengus pallasi) in the Togiak District of Bristol Bay was examined for the 1979 and 1980 spawning seasons. Samples from both the commercial harvest and catches obtained by test fishing with variable mesh gillnets were examined for both years. This study reports on an analysis of: (1) age composition of the commercial harvests during 1979 and 1980, and (2) age composition estimates of the total spawning migrations calculated from commercial purse seine and test fishing data. Herring samples from the commercial catch were collected to determine difference in age composition by gear, area, and time periods. Temporal differences in age composition were apparent between weekly time periods during 1979 as the proportion of younger fish in the commercial harvest steadily increased during the later portion of the fishery. The 1973 and 1974 year classes represented approximately 80% of the total commercial harvest during both 1979 and 1980. Test fish samples for all areas within weekly time periods were combined as a result of the lack of variation in the commercial harvest estimates. Due to consistent differences in age composition and gonad condition, samples collected from the Nushagak Peninsula area were not included with the rest of the test fishing samples. It was concluded that these data supported the hypothesis that the majority of herring in the Nushagak Peninsula area were spent fish that were exiting the inshore spawning areas. Temporal differences in age composition were apparent in test fishing catches during both 1979 and 1980.

ACCESS # : 267, RAS-UAF

CITATION : Gill, R.E., Jr., M.R. Petersen, and P.L.D. Jorgensen. 1981. Birds of the northcentral Alaska Peninsula, 1976-1980. Arctic 34: 286-306.

KEY-WORDS: Seabirds; Waterfowl; Shorebirds; Habitat; Distribution; Food habits; Port Moller.

SYNOPSIS : Year-round observations on 125 species of birds at Port Moller, Herendeen Bay, and Nelson Lagoon are presented. Breeding, migration, and roosting habits are discussed for 104 species. Twenty species of marine birds visit the area as non-breeders. Glaucous-winged gull colonies of the vicinity are some of the largest in the state. Seventeen species of waterfowl visit the area as non-breeders, another 16 as known or probable breeders. The lagoon complex is especially important as migration and wintering habitat for 7 species of waterfowl. Eighteen species of shorebirds visit the area as non-breeders, another 9 as known or probable breeders. The lagoon complex is an important migration habitat for at least 6 species of shorebirds. Information on food habitats of major species is presented.

ACCESS # : 268, ADF&G

CITATION : Krogman, B.D., H.W. Braham, R.M. Sonntag, and R.G. Punsly. 1979. Early spring distribution, density, and abundance of the Pacific walrus (Odobenus rosmarus) in 1976. Unpublished Final, Subcontract R 7120804, RU 14. 47 pp. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Walrus; Distribution; Marine mammals; Sea ice.

SYNOPSIS : This report summarizes results of a cooperative aerial survey (NMFS, ADF&G, USSR) flown over the ice-covered portion of the Bering Sea from March to June, 1976. Walrus concentrations were noted west of St. Lawrence Island and at the ice edge in Bristol Bay.

ACCESS # : 269, ADF&G

CITATION : Burns, J.J.. 1967. The Pacific Bearded Seal. ADF&G, Juneau. 66 pp.

KEY-WORDS: Bearded Seal; Marine mammals; Distribution; Trophic dynamics; Feeding habits.

SYNOPSIS : This report presents information on beared seal distribution and feeding habits. Bearded seal are described as benthic predators on a wide variety of benthic infauna, epifauna, and fish.

ACCESS # : 270, ADF&G

CITATION : Popov, L.A.. 1976. Status of main ice forms of seals inhabiting waters of the USSR and adjacent to the country's marine areas. Report to FAO Advisory Comm. Mar. Resource Res., ACMRR/MM/SC/51. 17 pp.

KEY-WORDS: Ringed seals; Bearded seals; Largha seals; Ribbon seals; Distribution; Reproduction; Feeding; Mortality; Marine mammals; Sea ice.

SYNOPSIS : A summary of information of distributions, migration, reproduction, feeding, mortality, exploitation, and trophic interactions of ice-inhabiting seals of the Bering Sea and Sea of Okhotsk.

ACCESS # : 271, RAS-UAF

CITATION : Kenyon, K.W.. 1969. The sea otter in the eastern Pacific Ocean. USF&WS. North America Fauna Number 68. 352 pp.

KEY-WORDS: Sea otter; Marine mammals; Population ecology; Trophic dynamics; Feeding behavior.

SYNOPSIS : A major and comprehensive study of sea otters, with descriptions of food requirements and feeding habits, population distribution and habitat requirements, systematics, general biology and behavior, and reproduction.

ACCESS # : 272, IMS-UAF

CITATION : Fay, F.H., H.M. Feder, and S.W. Stoker. 1977. An estimation of the impact of the Pacific walrus population on its food resources in the Bering Sea. Final Rep. to the Marine Mammal Commission. Contracts MM4AC-006 and MM5AC-024. 38 pp. US Marine Mammal Commission, Washington, D.C.

KEY-WORDS: Walrus; Feeding; Trophic dynamics; Predation; Marine mammals.

SYNOPSIS : This paper compares benthic standing stocks as assessed by grab stations over the eastern Bering and Chukchi Seas with walrus predation as evidenced from stomach samples collected in the northern Bering Sea in spring. An estimated 11,000,000 tons of benthos are consumed annually by the walrus population of the Bering-Chukchi shelf, which probably about equals or exceeds the annual net productivity of preferred prey species.

ACCESS # : 273, IMS-UAF

CITATION : Fay, F.H., and S.W. Stoker. 1982. Analysis of reproductive organs and stomach contents from walruses taken in the Alaskan Native harvest, Spring 1980. USF&WS Final rep. 14-16-0007-81-5216. Ammended, 86 pp.

KEY-WORDS: Walrus; Trophic dynamics; Feeding habits; Food Reqirements; Reproduction; Marine mammals.

SYNOPSIS : This report discusses the results of analyses of reproductive tracts and stomachs taken by native hunters during the spring of 1980. Results indicate that reproductive success has declined in recent years, perhaps as a result of increasing predation pressure on food resources of the region.

ACCESS # : 274, IMS-UAF

CITATION : Fay, F.H. and S.W. Stoker. 1982. Reproductive success and feeding habits of walruses taken in the 1982 spring harvest, with comparisons from previous years. Contract Rep. to the Eskimo Walrus Commission. Kawerak, Inc. P.O. Box 948, Nome, AK. 91 pp.

KEY-WORDS: Walrus; Trophic dynamics; Feeding habits; Reproduction; Marine mammals.

SYNOPSIS : This report discusses the results of reproductive tracts and stomachs of walrus taken by native hunters during the spring of 1982. Results indicate declining reproductive success, perhaps due to a depleted food supply.

ACCESS # : 275, RAS-UAF

CITATION : Outram, D.N. 1958. The magnitude of herring spawn losses due to bird predation on the west coast of Vancouver Island. Progr. Reports of the Pacific Coast Stations of the Fish. Res. Board of Can. 111: 9-13.

KEY-WORDS: Seabirds; Gulls; Trophic dynamics; Waterfowl; Herring.

SYNOPSIS : Preliminary work indicated that gulls and ducks were responsible for 50% of total herring egg loss. Study indicated that the decrease in egg numbers attributed to bird predation ranged 30-55% and averaged 39% overall. Most loss was in the first 3 days, when birds congregated to feed on both spawning fish and eggs. Later-spawned eggs had better survival. Most predation was by Glauous-winged and Herring gulls, especially the former species. Glaucous-winged Gulls averaged 13,800 eggs/stomach.

ACCESS # : 276, RAS-UAF

CITATION : Busdosh, M. and R.M. Atlas. 1977. Toxicity of oil slicks to Arctic amphipods. Arctic 30(1): 85-92.

KEY-WORDS: Amphipods; Mortality; Oil spill; Invertebrates.

SYNOPSIS : A study was conducted to measure the toxicity of oil spills to Arctic amphipods. Exposure to oil resulted in death, especially if animals physically entered the slicks. Arctic diesel was more toxic than Prudhoe crude oil. Toxicity of Prudhoe crude oil was associated with the paraffinic and aromatic components. Exposure to the tarry asphaltic fraction of crude oil did not result in amphipod mortality.

ACCESS # : 277, ADF&G

CITATION : Kenyon, K.W. 1972. Aerial surveys of marine mammals in the Bering Sea, 6-16 April, 1972. Unpublished Report, Bureau of Sport Fishery and Wildlife, USF&WS, Seattle, 79 pp.

KEY-WORDS: Marine Mammals; Walrus; Distribution.

SYNOPSIS : This report presents the results of an aerial survey conducted over the Bering Sea. For walrus, the main population concentrations were found west of St. Lawrence Island and in central Bristol Bay.

ACCESS # : 278, RAS-UAF

CITATION : Harrison, C.S. 1979. The association of marine birds and feeding gray whales. Condor 81: 93-95.

KEY-WORDS: Seabirds; Marine mammals; Trophic dynamics; Ecology; Behavior.

SYNOPSIS : Author presents information on marine birds feeding in mud patches kicked up by feeding gray whales in inner-shelf areas of the upper Bering and southern Chukchi seas. Thirteen species were recorded in association with gray whales, and the associations occurred 69% of the time. Glaucous Gulls were the most common, with the other species being recorded much less commonly. The author suggests that gray whales provide an important supplemental source of food to several seabird species in the area.

ACCESS # : 279, ARL

CITATION : Ohlendorf, H.M., J.C. Bartonek, G.J. Divoky, E.E. Klass, and A.J. Koynitsky. 1982. Organochlorine residues in eggs of Alaskan seabirds. U.S. Fish & Wildl. Serv, Spec. Sci. Rept. - Wildl. No. 245: 1-41.

KEY-WORDS: Seabirds; Organochlorine contamination; Aleutian Islands; Pribilof Islands; Seward Peninsula.

SYNOPSIS : Information on 13 organochlorine residues in seabird eggs collected at 18 sites in Alaska from 1973 to 1976 is presented. Data include samples from eggs collected at Cape Peirce and Round Island. The mean frequencies of occurrence were the lowest in Bristol Bay of five geographic areas for DDD, DDT, and Toxaphene and were the highest for mirex and Cis-nonachlor; intermediate values were recorded for the other eight compounds. Eggs from Bristol Bay had the lowest overall mean frequency of occurrence of all five geographic areas for all 13 comppunds. A discussion of the role of foods, migration, and wintering distribution in introducing these contaminants to the species examined, follows.

ACCESS # : 280, RAS-UAF

CITATION : Ogi, H., T Kubodera, and K. Nakamura. 1980. The pelagic feeding ecology of the Short-tailed Shearwater Puffinus tenuirostris in the Subarctic Pacific region. J. Yamashina Inst. Ornithol. 12: 157-182

KEY-WORDS: Seabirds; Trophic dynamics; Trophic interactions; Ecology.

SYNOPSIS : Information on the food habits of 439 Short-tailed Shearwaters collected in the Sea of Ohilofsk, North Pacific, and Bering Sea between 1970 and 1978 is presented. Birds from Bristol Bay had the highest mean amount of food per bird of all sampling areas. Birds there contained large quantities of euphausiids (T. raschii) and trace amounts of juvenile fishes (Ammodytes). In the Bering Sea overall, prey items were ranked: euphausiids, squid, amphipods, and fishes (in decreasing order of importance). They conclude that consumption of euphausiids in Bristol Bay (based on a population estimate of 5-7 million birds) would be over 30,000 mt during a 2-month period, or equal to the consumption of euphausiids in the same area by sockeye salmon on their way to spawn.

ACCESS # : 281, RAS-UAF

CITATION : Threlfall, W., E. Eveleigh, and J.E. Maunder. 1974. Seabird mortality in a storm. Auk 91: 846-849.

KEY-WORDS: Seabirds; Gulls; Mortality; Storm effects.

SYNOPSIS : A severe storm hitting a seabird colony at Gull Island, Newfoundland, on 16-18 June 1973 caused severe damage to seabird reproduction there. Mortality was estimated at 90-91% of the Herring Gull reproductive effort for that year. The storm also caused massive reproductive failures in Herring Gulls and Ring-billed Gulls elsewhere in Newfoundland. Examples of the effects of storms on reproduction in other species are also given.

ACCESS # : 282, ARL

CITATION : Schneider, D., and G.L. Hunt. 1982. Carbon flux to seabirds in waters with different mixing regimes in the southeastern Bering Sea. Mar. Biol. 67: 337-344.

KEY-WORDS: Seabirds; Distribution; Trophic dynamics; Biomass.

SYNOPSIS : This paper presents information on food requirements and energy flux to seabirds in the middle and outer shelf domains and the continental slope waters of the extreme southeastern Bering Sea. Biomasses of surface feeders were greatest over slope waters; of diving feeders, over outer-shelf waters. Consumption of juvenile pollock for the area was estimated at 150,000 metric tons/year. Energy flow to surface feeders was 3 times higher in outer-shelf and slope waters than in middle-shelf waters. Energy flow to diving feeders was relatively uniform across all water masses.

ACCESS # : 283, RAS-UAF

CITATION : Kessel, B., and D.D. Gibson. 1978. Status and distribution of Alaska birds. Stud. Avian Biol. 1: 1-100.

KEY-WORDS: Seabirds; Alaska; Bristol Bay; Distributions; Waterfowl; Shorebirds.

SYNOPSIS : Besides publishing updated distributional information on 202 species of birds from Alaska, good information on nesting colonies of Aleutian Terns in the area of concern is presented.

ACCESS # : 284, ARL

CITATION : Sanger, G. A. 1983. Diets and food web relationships of seabirds in the Gulf of Alaska and adjacent marine regions. Final report to OCSEAP, U.S. Fish & Wildlife Service, Anchorage, Ak. 130 pp.

KEY-WORDS: Seabirds; Sea ducks; Waterfowl; Trophic dynamics; Trophic interactions; Ecology.

SYNOPSIS : Information on the food habits of 42 species of seabirds and six species of sea ducks in the Gulf of Alaska and southeastern Bering Sea is presented. Two of the sampling areas (Cape Peirce and Nelson Lagoon) are in the area of concern. In Bristol Bay, euphausiids and hyperiid amphipods are the most important foods of Short-tailed Shearwaters; squid are also fairly important. Fish, especially pollock, were the most important foods of Black-legged Kittiwakes in Bristol Bay. Fishes (especially capelin and gadids) and euphausiids were the most important foods of Common Murres in Bristol Bay. Food webs, competition, and ingestion of commercially valuable species are discussed. This is an extensive summary of food habits.

ACCESS # : 285, RAS-UAF

CITATION : Bradstreet, M.S.W. 1982. Occurrence, habitat use, and behavior of seabirds, marine mammals, and arctic cod at the Pond Inlet ice edge. Arctic 35: 28-40.

KEY-WORDS: Seabirds; Marine mammals; Sea ice; Trophic interactions; Habitat ecology; Fishes.

SYNOPSIS : Results of surveys at Pond Inlet ice edge, in Canadian high arctic, to determine occurrence, distribution, and habitat use of birds, mammals, and fish. A total of twelve species of seabirds, four of waterfowl, and two other species of birds were seen using the ice edge. Murres, Northern Fulmars, and Black-legged Kittiwakes were the most abundant species. Birds were most common when there was < 50% ice cover; overall densities ranged 38-46 birds/km of ice edge. Seven species of marine mammals occurred at the ice edge; the most common species were narwhals and white whales. Densities ranged between 0.5-1.5 marine mammals/km of ice edge. Arctic cod tended to congregate in crevices under the ice edge. The importance of the ice edge for feeding, reproduction, and open-water for breathing, are discussed. Primary foods of the birds and mammals were arctic cod and hyperiid amphipods.

ACCESS # : 286, RAS-UAF

CITATION : Hurley, J.B. 1931. Birds observed in the Bristol Bay region, Alaska (Part II). Murrelet 12: 34-42.

KEY-WORDS: Seabirds; Gulls; Distribution.

SYNOPSIS : Mew Gulls were the most abundant gull in Bristol Bay. Bonaparte's Gulls were fairly common and nested in scattered spruce trees. Sabine's Gulls were found to nest this far south, an extension of the nesting range from the Kuskokwim River delta. Arctic Terns occurred in low numbers throughout the bay. Author claimed that there was a bounty on this species, for it eats many salmon fry. (See response by Flock, 1932, Murrelet 13: 26).

ACCESS # : 287, RAS-UAF

CITATION : Ryder, R.A. 1957. Avian - pinniped feeding associations. Condor 59: 68-69.

KEY-WORDS: Seabirds; Pinnipeds; Petrels; Gulls; Phalaropes; Terns; Trophic interactions; Marine mammals.

SYNOPSIS : Several seabird - pinniped associations are discussed from icebreaker work in the North Pacific and Arctic Oceans. Ivory and Glaucous gulls feed on walrus feces; Red Phalaropes fed in water in the midst of swimming walruses. Black-legged Kittiwakes and Glaucous and Ivory gulls feed on ringed seal remains. Northern Fulmars, Sabine's Gulls, Arctic Terns, Red Phalaropes, and Herring Gulls feed near feeding ringed seals, taking food scraps left over. Pomarine and Parasitic Jaegers work nearby, stealing food from these other species. Short-tailed Shearwaters feed on food scraps left by feeding Steller sea lions, with up to 30 birds around each sea lion. Fork-tailed Storm-Petrels and Northern Fulmars feed around foraging northern fur seals. The birds gain food and the pinnipeds may at times locate food through looking for feeding frenzies of birds.

ACCESS # : 288, RAS-UAF

CITATION : Mossman, A.S. 1958. Selective predation of Glaucous-winged Gulls upon adult red salmon. Ecology 39: 482-486.

KEY-WORDS: Gulls; Salmon; Seabirds; Trophic interactions.

SYNOPSIS : Study was done at Wood River Lakes system of Bristol Bay. A total of 81 salmon was killed over a few-day period in late July. 65 of these were females, indicating that the gulls actively selected for females. Of 15 salmon killed by gulls on a nearby creek, 12 were females, again indicating selective predation on female salmon. The gulls also open the abdominal cavity of female salmon much more frequently, and eat the viscera and (especially) the eggs. The gulls apparently use the sexual dimorphism characters of the salmon to selectively take females.

ACCESS # : 289, RAS-UAF

CITATION : Osgood, W.H. 1904. A biological reconnaissance of the base of the Alaska Peninsula. N. Am. Fauna 24: 1-86.

KEY-WORDS: Marine mammals; Seabirds; Shorebirds; Waterfowl; Distribution.

SYNOPSIS : This report summarizes data gathered in 1902 in the Alaska Peninsula area, and on a canoe trip from Nushagak to Cold Bay. An annotated species list for all birds and mammals in the area is presented, and vegetation, climate, topography, and ecology of the area are discussed.

ACCESS # : 290, WILDL. DEPT. -UAF

CITATION : Bartonek, J.C., and S.G. Sealy. 1979. Distribution and status of marine birds breeding along the coasts of the Chukchi and Bering seas. USF&WS Wildl. Res. Rept. 11: 21-31.

KEY-WORDS: Seabirds; Waterfowl; Distribution.

SYNOPSIS : A summary of seabird colony locations and sizes in the Bering and Chukchi, exclusive of the Aleutian Islands. From preliminary surveys, it appears that nearshore Bristol Bay contains one colony > 1 million birds, three colonies > 100,000 birds, and many smaller colonies. At least 11 species of seabirds nest in nearshore Bristol Bay (NOTE: several other seabird species were not considered in this analysis). Authors recommend more thorough censusing, and initiation of long-term studies.

ACCESS # : 291, USF&WS

CITATION : Trapp, J.L. 1979. Concept plan for the preservation of migratory bird habitat, Part 2: Seabirds. Unpubl. manuscript on file at U.S. Fish & Wildlife Service, Anchorage, Ak. 59 pp.

KEY-WORDS: Seabirds; Aleutian Islands; Management; Distribution.

SYNOPSIS : This manuscript presents a method for objectively ranking the 70 most important seabird colonies in Alaska. Using information on species composition and total colony size from The Catalog of Alaskan Seabird Colonies (Sowls et al., 1978), Trapp arrives at "composite species scores" for each colony. Trapp then ranks these colonies on decreasing order of importance by "composite species score". Of the 70 largest seabird colonies in Alaska, three are found in the Bristol Bay area. The Cape Newenham/Cape Peirce complex is the eleventh most important colony in the state, the Walrus Islands complex is ranked as the fifteenth most important, and Amak Island is the sixtieth most important. Nearby, the Pribilof Islands complex is ranked as the most important seabird colony in Alaska. A discussion of the proposed U.S. Fish and Wildlife Service preservation program follows.

ACCESS # : 292, USF&WS

CITATION : Gould, P.J., D.J. Forsell, and C.J. Lensink. 1982. Pelagic distribution and abundance of seabirds in the Gulf of Alaska and eastern Bering Sea. FWS/OBS - 82/48: 294 pp. USF&WS, Biological Services Program, Anchorage, Ak.

KEY-WORDS: Seabirds; Distribution; Ecology; Aleutian Islands.

SYNOPSIS : An analysis of thousands of pelagic bird transects in the Gulf of Alaska and southeastern Bering Sea is presented. Survey techniques, biases, and accuracies are discussed. Annotated species lists for birds in the Gulf and in the Bering are presented separately. Few transects have been conducted in the nearshore waters of Bristol Bay, although large numbers have been conducted in Bristol Bay as a whole. Greastest overall densities in nearshore Bristol Bay were recorded near Unimak Pass, offshore from Izembek Lagoon and Port Moller, and in upper Bristol Bay from Cape Newenham to the mouth of the Egegik River. Density maps for individual species are presented, by season, as 20' latitude x 30' longitude blocks.

ACCESS # : 293, RAS-UAF

CITATION : Flock, C. 1932. Notes on the Arctic Tern in Bristol Bay region, Alaska. Murrelet 13: 26.

KEY-WORDS: Seabirds; Arctic Tern; Salmon; Gulls; Trophic interactions; Mortality.

SYNOPSIS : No bounty paid on terns in Bristol Bay, but fishermen regularly shot them and destroyed nests. Claims were that they are "extremely destructive" to young salmon. As many as 72 young salmon were found in one bird stomach. The author considered only trout to be worse predators on young salmon. He also states that most terns nest by the thousands near lakes where salmon spawn, and that this is where most young salmon are caught. Unlike gulls (Glaucous-winged Gulls), which can only take young salmon in shallow, quiet water, the terns can catch them in both flowing and quiet waters. This paper is a response to comments in a paper by Hurley (Murrelet 12: 34-42, 1931).

ACCESS # : 294, ARL

CITATION : Gill, R., Jr., C. Handel, and M. Petersen. 1979. Migration of birds in Alaska marine habitats. Annual Reports of Principal Investigators. Vol. 5. pp. 245-288. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Seabirds; Waterfowl; Shorebirds; Migration; Distribution.

SYNOPSIS : Summaries are presented for 19 species of seabirds, shorebirds, and waterfowl in Alaska. Large movements of shearwaters 2-5 Km offshore from the Alaska Penninsula occur in May-August; large concentrations are also found in Umiak Pass in spring and fall. Cormorants migrate coastally in nearshore Bristol Bay, with the largest flock seen of about 10,000 pelagics in late April near Hagemeister Straight; most or all cormorants leaving the Bering Sea do so through Umiak Pass in September-October. Almost all of the world's Black Brant stage in spring and fall in the shallow lagoons of the Alaska Penninsula. Emperor Geese winter along the lagoons and coast of the Alaska Penninsula and Aleutian Islands. The entire world's population of Steller's Eiders stages in lagoons along the north side of the Alaska Peninsula. Major wintering areas of Common Eiders occur in the southern Bering Sea and Bristol Bay. King Eiders congregate to winter in the lagoons of the Alaska Peninsula and eastern Aleutians. Three species of scoters stage in waters off the Alaska Peninsula. many shorebirds breeding in western Alaska migrate across the base of the Alaska Peninsula and upper Bristol Bay. Black-legged Kittiwakes tend to concentrate in late fall in Bristol Bay, and later leave the Bering Sea through Umiak Pass. Murres breeding in the Bering Sea migrate primarily through Umiak Pass. A discussion of migration patterns and data gaps follows.

ACCESS # : 295, IMS-UAF

CITATION : Bartonek, J.C., R. Elsner, and F.H. Fay. 1974. Mammals and birds, p. 23-28. IN: PROBES: A prospectus on Processes and Resources of the Bering Sea Shelf, Inst. Mar. Sci., University of Alaska, Fairbanks.

KEY-WORDS: Seabirds; Waterfowl; Shorebirds; Marine mammals; Oceanography.

SYNOPSIS : This report is one section generated at an NSF sponsored workshop for generating a national/international study of the oceanography of the Bering Sea. The Bering Sea has the greastest diversity of pagophilic marine mammals in the world, and one of the largest concentrations of seabirds in the Western Hemisphere. Most activity is concentrated over the shelf. The 25 species of marine mammals consume an estimated 9-10 million mt of food annually. The 40 species of seabirds consume at least 1 million mt of food annually. The Bering Sea contains many endemic species of marine mammals, seabirds, shorebirds and waterfowl. International implications, potential conflicts, and research opportunities are discussed, and recommended research goals are presented.

ACCESS # : 296, RAS-UAF

CITATION : Gill, R.E., and G.A. Sanger. 1979. Tufted Puffins nesting in estuarine habitat. Auk 96:792-794.

KEY-WORDS: Seabirds; Tufted Puffin; Nelson Lagoon; Distribution.

SYNOPSIS : Most Tufted Puffins nest on high rocky islands and cliffs. This paper reports on a small nesting colony at Nelson Lagoon, Alaska Peninsula, where the birds nested in burrows among vegetation on 1-2 meter high islands. Storm tides flooded burrows and killed some chicks. Adults walked to the beach and took flight. Authors speculate that presence of relatively little seabird breeding habitat in Bristol Bay leads to intense inter and intraspecific competition for nest sites, leading to colonization of abnormal habitat.

ACCESS # : 297, RAS-UAF

CITATION : Murie, O.J.. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. North American Fauna. No. 61: 1-364.

KEY-WORDS: Seabirds; Waterfowl; Shorebirds; Marine mammals; Alaska Peninsula; Aleutian Islands; Biology; Distribution; Migration; Trophic dynamics.

SYNOPSIS : This monograph summarizes all information on the birds and mammals of this area up to early to mid 1950's, including Murie's extensive field work in the area of the 1920's and 1930's. Climate, vegetation, environment, and zoogeographic aspects of the area are discussed. An annotated bibliography of distribution and abundance, habitat use, and seabird and pinniped breeding colonies is presented. There is an extensive discussion of food habits and feeding ecology of several species. This is the authoritative work on this area.

ACCESS # : 298, USF&WS

CITATION : Kenyon, K.W., and J.G. King, Jr.. 1965. Aerial survey of sea otters and other marine mammals, Alaska Peninsula and Aleutian Islands, 19 April to 9 May 1965, and bird observations, Aleutian Islands survey, April-May 1965. Unpublished Manuscript on file at USF&WS, Anchorage, Alaska. 61 pp.

KEY-WORDS: Marine mammals; Distribution; Waterfowl; Aleutian Islands.

SYNOPSIS : This report summarizes results of aerial surveys flown for marine mammals and birds between Anchorage and the western Aleutian Islands in spring 1965. Approximately 17,000 adult and large juvenile otters were estimated in the area; approximately 4,000 were estimated between Unimak Pass and Port Moller. The greatest concentration of otters in the area of concern was seen from Bechevin Bay to east of Izembek lagoon. Counts of Steller sea lions and harbor seals are also presented. Information on waterfowl indicated 33,000 Emperor Geese in lagoons on the north side of the Alaska Peninsula, and "huge flocks" of Common Eiders were noted off the Alaska Peninsula at this time.

ACCESS # : 299, RAS-UAF

CITATION : Wahl, T.R.. 1978. Seabirds in the northwestern Pacific Ocean and south central Bering Sea in June 1975. Western Birds. 9: 45-66.

KEY-WORDS: Seabirds; Distribution; Behavior.

SYNOPSIS : This paper summarizes information on the distribution of seabirds on an oceanographic cruise from Japan to the Bering Sea. Birds were observed in the southeastern Bering Sea/outer Bristol Bay area over a period of 5 days. Greatest densities were seen in the Unimak Pass area, consisting primarily of Northern Fulmars, Short-tailed Shearwaters, Fork-tailed Storm Petrels, Black-legged Kittiwakes, Thick-billed Murres, and Tufted Puffins. An annotated list discusses the distribution and behavior of all species seen, and bird densities in various water masses are discussed.

ACCESS # : 300, ARL

CITATION : Royer, T.C. 1979. On the effect of precipitation and runoff on coastal circulation in the Gulf of Alaska. J. of Phys. Oceanogr. 9: 555-563.

KEY-WORDS: Gulf of Alaska; Coastal circulation; Freshwater runoff; Oceanography.

SYNOPSIS : Surface waters in the Gulf of Alaska undergo a net dilution throughout most of the year since the regional precipitation exceeds evaporation. Recent hydrographic data give evidence that seasonal dynamic height fluctuations in the upper layers (<100 m) are well-correlated with the seasonal changes in precipitation and runoff. The precipitation effect is magnified by coastal mountain ranges which enhance the rainfall at or near the coast, contributing fresh water at the coast through runoff. Previous estimates of the offshore precipitation gradient appear to be smaller than those measured recently. Precipitation and runoff alter the dynamic height through salinity changes. This dependence of dynamic height on salinity is possible here because of the high precipitation (>130 cm year-1), runoff, longshore accumulation of fresh water around the gyre, and the low water tempertures. The coastal sea level is in phase and has nearly the same amplitude as the local dynamic height, though not in phase with heating and cooling.

ACCESS # : 301, IMS-UAF

CITATION : Kelley, J.J., and D.W. Hood. 1974. Upwelling in the Bering Sea near the Aleutian Islands. Tethys 6 (1-2): 149-156.

KEY-WORDS: Upwelling; Aleutian Islands; Carbon dioxide; Nutrients; Oceanography.

SYNOPSIS : Continuous measurement of equilibrium partial pressures of carbon dioxide on the surface seawater was used to delineate the spatial extent of upwelling near the eastern Aleutian Islands. Near-surface water in the vicinity of Amukta and Samalga Passes had carbon dioxide partial pressures of 500 ppm, nutrient concentrations of over 15 ug-atoms NO_3-N/liter, 2.5 ug-atoms PO_3-P/liter and 70 ug-atoms SiO_2-S/liter. Associated with the upwelled areas were low surface-water temperature, low oxygen concentration and high salinity anomalies. Subsurface sampling revealed a complicated distribution of chemical parameters suggestive of turbulence and mixing effects. These anomalies were most intense in the vicinity of subsurface valleys and ridges.

ACCESS # : 302, RAS-UAF

CITATION : Swift, J.H., and K. Aagaard. 1976. Upwelling near Samalga Pass. Limnol. Oceanog. 21(3): 399-408.

KEY-WORDS: Upwelling; Aleutian Islands; Samalga Pass; Oceanography.

SYNOPSIS : Recent summer hydrographic data from the vicinity of Samalga Pass in the eastern Aleutians show upwelling of relatively saline water, poor in oxygen and rich in nutrients. A steady state oxygen model in which the photosynthetic production of oxygen in the euphotic zone is balanced by an upwelling of low-oxygen water yields an upper bound on the vertical velocity of 7,000 cm/s. Examination of various possible driving mechanisms for the upwelling, including winds and entrainment, suggests that the upwelling is driven by subsurface convergence.

ACCESS # : 303, ARL

CITATION : Coachman, L.K., and J.J. Walsh. 1981. A diffusion model of cross-shelf exchange of nutrients in the southeastern Bering Sea. Deep Sea Res. 28A(8): 819-846.

KEY-WORDS: Models; Nutrient cycling; Transport; Cross-shelf; Primary production Oceanography.

SYNOPSIS : A diffusion model has been used to estimate the spring cross-shelf flux of nitrate and its rate of biological uptake in the southeastern Bering Sea during 1976 to 1979. Vertical fine structure of temperature and salinity and a cross-shelf salt balance were used to estimate eddy coefficients in the diffusive fluxes of nitrate. A combination of the computed physical resupply of nitrate and its observed local time rate of change was then used to predict the rate of nitrate utilization by phytoplankton. Agreement of this model with independent N estimates of formation of phytoplankton particulate nitrogen allowed further analysis of the possible fate of the spring bloom in the outer shelf of the Bering Sea. A comparison of the utilization of spring phytoplankton production is made at the same isobath and similar latitude of the Bering and North seas.

ACCESS # : 304, ARL

CITATION : Schumacher, J.D., T.H. Kinder, D.J. Pashinski, and R.L. Charnell. 1979. A structural front over the continental shelf of the eastern Bering Sea. J. Phys. Oceanogr. 9: 79-87.

KEY-WORDS: Oceanography; Temperature; Salinity; Structural front.

SYNOPSIS : Conductivity and temperature versus depth (CTD) and expendable bathythermograph (XBT) data taken during the ice-free seasons of 1975-77 define a structural front paralleling the 50 m isobath. This front forms a narrow transition separating a well-mixed coastal domain from a two-layered central shelf domain. In early spring, prior to frontogenesis, we believe that temperature and salinity are continuous across the 50 m isobath. Thus, the front does not result from the confluence of water masses; rather the front permits the evolution of different water masses following frontogenesis. The changing balance between buoyant energy input and tidal stirring determines the frontal location and the frontal width correlates with bottom slope. The front is similar to those reported around the British Isles, but we find that in the Bering Sea the salinity distribution is important, that the ice cover influences the seasonal evolution of the hydrographic structure, and that the geostrophic (baroclinic) speed differences across the front are small (< 2 cm/s). We hypothesize that frontogenesis depends critically on positive feedback between stratification and mixing.

ACCESS # : 305, RAS-UAF

CITATION : Schumacher, J.D., C.A. Pearson, and J.E. Overland. 1982. On exchange of water between the Gulf of Alaska and the Bering Sea through Unimak Pass. J. of Geophys. Res. 87(C8): 5785-5795.

KEY-WORDS: Water exchange; Unimak Pass; Currents; Pressure (bottom) measurements; Oceanography.

SYNOPSIS : We present the first long-term current and bottom pressure observations from Unimak Pass, Alaska, and adjacent locations on the Gulf of Alaska and Bering Sea shelves. Vector mean current recorded between March and August 1980 was 12 cm/s toward 284 degrees T or onto the Bering Sea shelf, however, magnitude decreased from 20 cm/s to 6 cm/s between the first and second halves of the record. At shorter periods (3-10 days), current fluctuations in the pass were strongly coherent (K squared was greater than or equal to 0.7) with the pressure difference measured along the axis of the pass, and this was coherent with geostrophic wind estimates. The results indicated that wind-induced sea level perturbation was the dominant forcing mechanism for fluctuations. Relations among current, bottom pressure, pressure difference, and geostrophic wind time series also showed that dynamic variation on the Gulf of Alaska shelf was primarily responsible for current flucutations in the pass. Hydrographic data indicated that a baroclinic current existed along the Gulf of Alaska coast, and this flow became the long-term flow through the pass. We suggest that this feature was the extension of the Kenai Current. The historic supposition that water is transported from the Gulf of Alaska into the Bering Sea was verified; however, the waters are of coastal origin rather than from the Alaskan Stream.

ACCESS # : 306, RAS-UAF

CITATION : Kinder, T.H., and L.K. Coachman. 1978. The front overlaying the continental slope in the eastern Bering Sea. J. Geophys. Res. 83(C9): 4551-4559.

KEY-WORDS: Mixing; Continental slope; Structural front; Oceanography.

SYNOPSIS : We use hydrographic data to delineate a diffuse, large (nearly 1000 km long), and persistent (years) haline front which overlies the continental slope in the eastern Bering Sea. The front marks a transition between the waters above the deep basin, where the horizontal salinity gradient is almost zero and the flow is geostrophic, and the waters above the broad shelf, where salinity gradients are large and flow is tidally dominated. We suggest that the change in mixing from the oceanic regime above the deep basin to the tidal regime over the shelf is responsible for the front. Because our arguments do not depend upon features unique to the Bering Sea slope, similar fronts should be found where freshwater runoff can dominate the density gradient and where strong boundary currents are absent.

ACCESS # : 307, ARL

CITATION : Muench, R.D. 1976. A note on eastern Bering Sea shelf hydrographic structure; August, 1974. Deep Sea Res. 23: 245-247.

KEY-WORDS: Oceanography; Hydrographic structure; Baroclinic transport; Currents.

SYNOPSIS : Temperature, salinity, and density structures along a north-south transect across the eastern Bering Sea are characterized. Of particular interest is the detection of a subsurface current core along the 50 m isobath in northwestern Bristol Bay. Some possible relationships between this feature and regional dynamics are discussed applying the vorticity conservation theory qualitatively.

ACCESS # : 308, ARL

CITATION : Coachman, L.K., and R.L. Charnell. 1979. On lateral water mass interaction - A case study, Bristol Bay, Alaska. J. Phys. Oceanogr. 9: 278-297.

KEY-WORDS: Water mass; Mixing; Lateral interaction; Continental shelf.

SYNOPSIS : Salinity-temperature-depth data obtained on several spring and summer cruises during 1976 and 1977 from outer Bristol Bay in the southeast Bering Sea indicate the existence of a zone, between two well-defined water masses, where details of the interaction process are observable. This interaction zone is approximately 100-150 km wide and is characterized by a plethora of mid-water-column finestructure, in both temperature and salinity, that exhibit a hierarchy of vertical scale sizes. Vertical mixing energy within the zone appears low, which results in persistance of interleaving signatures induced by horizontal interaction of two adjacent water masses. Such interaction probably occurs between all laterally juxtaposed water masses of nearly the same density; outer Bristol Bay allows enhanced examination of the process because of the broad lateral extent of the transition zone.

ACCESS # : 309, RAS-UAF

CITATION : Allen, J.S., R.C. Beardsley, J.O. Blanton, W.C. Boicourt, B. Butman, L.K. Coachman, A. Huyer, T.H. Kinder, T.C. Royer, J.D. Schumacher, R.L. Smith, W. Sturges, and C.D. Winant. 1983. Physical oceanography of continental shelves. Rev. Geophys. Space Phys. 21(5): 1149-1181.

KEY-WORDS: Oceanography; Continental shelf; Hydrographic structure; Currents; Climatology; Ice; Physical/biological interactions.

SYNOPSIS : Review of the physical oceanography of continental shelves, including that of the eastern Bering Sea. Includes information on hydrographic features, currents, climatology, ice, and physical/biological interactions.

ACCESS # : 310, ARL

CITATION : Kinder, T.H., J.D. Schumacher, and D.V. Hansen. 1980. Observation of a baroclinic eddy: An example of mesoscale variability in the Bering Sea. J. Phys. Oceanogr. 10: 1228-1245.

KEY-WORDS: Baroclinic transport; Mesoscale variability; Oceanography.

SYNOPSIS : Drift buoys with shallow (17 m) drogues, released during May 1977 and tracked by satellite, delineated an eddy in the southeastern Bering Sea. Located above complex topography having a depth range of 200 to 3000 m, the eddy had a diameter of about 150 km. Mean rotational speeds 50 km from the eddy's center were 20 cm/s, but speeds up to 50 cm/s were measured. A CTD survey during July defined the eddy from 200 to 1500 m depth in temperature and salinity distributions, but no hydrographic evidence for the eddy existed at the surface. A geostrophic calculation relative to 1500 m agreed qualitatively with drifter data, but was 5 cm/s less than mean drifter speeds. Examination of the T-S correlation showed that water masses at the eddy's core were the same as those at its periphery, in contrast with a cyclonic ring observed nearby in July 1974. The last drifter left the eddy in October, and a second CTD survey in February 1978 showed that the eddy had either dissipated or moved. An earlier STD survey of the region in summer 1971 had shown neither an eddy like that seen in 1977 nor a ring like that seen in 1974.

ACCESS # : 311, RAS-UAF

CITATION : Reed, R.K., and W.P. Elliott. 1979. New precipitation maps for the North Atlantic and North Pacific Oceans. J. Geophys. Oceanogr. 84(C12): 7839-7846.

KEY-WORDS: Precipitation; North Pacific; North Atlantic; Shemya Island; St. Paul Island; Cold Bay; King Salmon.

SYNOPSIS : Oceanic precipitation intensity values derived in a previous study were combined with precipitation frequency data in the recently revised marine climatic atlases to prepare new annual and seasonal precipitation maps for the North Atlantic and North Pacific oceans. The greatest precipitation over both oceans occurs in the eastern and central tropical regions. A distinct minimum is present across both oceans in the subtropical regions, being most marked along the eastern margins. Secondary maxima are present over the northern regions, where considerable snow falls in winter. The principal seasonal changes are an increase in size and northward migration of the subtropical dry zone from winter to summer as well as reduced magnitude and gradients of precipitation to the north in summer. The tropical Pacific shows a remarkably stable distribution during the year, but the zone of maximum rainfall in the tropical Atlantic undergoes considerable variation in location. The new maps show generally less precipitation in extra-tropical regions than earlier ones, although in the tropics they give values between those of the widely varying previous maps.

ACCESS # : 312, ARL

CITATION : Coachman, L.K., and R.L. Charnell. 1977. Finestructure in outer Bristol Bay, Alaska. Deep Sea Res. 24: 869-889.

KEY-WORDS: Oceanography; Finestructure; Salinity-temperature distribution.

SYNOPSIS : A salinity-temperature-depth (STD) cruise in Bristol Bay in the Bering Sea during March, 1976 showed the existence of a subsurface layer with large density inversions. This finestructure layer, which covered a horizontal distance of some 100 km, showed a maximum negative density gradient of .000055 kg/m^4. Stations showing these inversions were in the zone of interaction between Bering Sea water and the shelf water of Bristol Bay, which had been displaced 100 km south of its usual location by strong northerly winds. The layer persisted for nearly one week. Hypotheses are advanced to account for its formation and persistences.

ACCESS # : 313, RAS-UAF

CITATION : Roden, G.I. 1967. On river discharge into the northeastern Pacific Ocean and the Bering Sea. J. Geophys. Res. 72(22): 5613-5629.

KEY-WORDS: Oceanography; River discharge.

SYNOPSIS : The information obtained from monthly mean and extreme river discharge records and the joint variation of salinity and river discharge at coastal stations are analyzed. The average annual fresh water discharge into the Pacific between California and the Aleutian Islands amounts to approximately 21,000 m^3/sec. The fresh water discharge into the Bering Sea by Alaskan and Siberian rivers occurs at an average annual rate of at least 10,000 m^3/sec. There have been no significant trends in natural streamflow during the past half century. Prolonged droughts in the Far West, as those between 1928 and 1931, are caused by a persistent cold, dry anticyclone over the plateau states. Extreme flooding, as in 1861-1862 and 1964-1965, is related to strong polar outbreaks and subsequent invasion of warm moist air from the sub-tropical Pacific. The spectra of river discharge show peaks of meteorological origin at annual and semiannual frequencies and suggest nonlinear interaction.

ACCESS # : 314, ARL

CITATION : Royer, T.C. 1981. Baroclinic transport in the Gulf of Alaska. Part II: A fresh water driven coastal current. J. Mar. Res. 39(2): 251-266.

KEY-WORDS: Oceanography; Coastal current; Baroclinic transport; Freshwater.

SYNOPSIS : A coastal geostrophic, baroclinic jet in the Gulf of Alaska is driven seasonally by fresh water discharge and winds. The narrow current (<20 km) has a mean transport of 240,000 m^3/s (relative to 100 db) and velocities in excess of 66 cm/s. The jet reaches a maximum in autumn, coincident with maximum fresh water discharge along the coast. The wind, whose maximum is in January-February, affects this current to a lesser degree than fresh water. The linear response of the baroclinic transport anomalies to wind and fresh water anomalies is used to support cause and effect relationships. The fresh, coastal current extends from Southeast Alaska into the western Gulf of Alaska and is the consequence of the accumulation of runoff beginning along the British Columbia coast. The Alaska Coastal Current and the Alaska Current are generally distinct from each other for the region sampled, with one notable exception near Kayak Island. The Alaska Coastal Current could be an important source of fresh water for the North Pacific Ocean.

ACCESS # : 315, RAS-UAF

CITATION : Schumacher, J.D., and R.K. Reed. 1980. Coastal flow in the northwest Gulf of Alaska: The Kenai Current. J. Geophys. Res. 85(C11): 6680-6688.

KEY-WORDS: Oceanography; Kenai Current; Coastal flow.

SYNOPSIS : Recent data from the northwest Gulf of Alaska reveal a coastal current which flows westward along the Kenai Peninsual (mainly within 30 km of shore), enters Shelikof Strait, and exits to the southwest of Kodiak Island. This flow, which we call the Kenai Current, has a large seasonal variation in baroclinic transport and maximum surface speed; transport is typically about 300,000 m^3/s but exceeds 1,000,000 m^3/s in fall, with concurrent speed increases from 15-30 cm/s to over 100 cm/s. The coastal flow is clearly distinct from the offshore Alaskan Stream; its seasonal signal is mainly related to a cross-shelf pressure gradient, which responds to an annual hydrological cycle. Current records from Shelikof Strait substantiate the presence of an annual signal and indicate that wind forcing has maximum effect from December through February, but it does not appear to augment flow at other times.

ACCESS # : 316, ARL

CITATION : Royer, T.C. 1981. Baroclinic transport in the Gulf of Alaska. Part I: Seasonal variations of the Alaska Current. 1981. J. Mar. Res. 32(2): 239-249.

KEY-WORDS: Oceanography; Baroclinic transport; Freshwater runoff; Alaska Current; Seasonal variations.

SYNOPSIS : Temperature and salinity sections which intersect the Alaska Current are used to determine the baroclinic, geostrophic current on 21 occasions from 1975 to 1977. A sinusoidal curve-fitting technique is applied to these Alaska Current estimates and others available in the literature to statistically test the flow for an annual signal. The mean baroclinic transport relative to 1500 db is estimated to be 9,200,000 m^3/s with seasonal signal of 1,200,000 m^3/s. The maximum is in March and minimum in September. Maximum speeds in excess of 100 cm/s are estimated and, typically, more than 80% of the transport is within 60 km of the shelf break. Thus, near Kodiak Island, the Alaska Current can be considered as a narrow, high speed jet. A distinctive characteristic of this and many other high-latitude baroclinic flows is that the horizontal density gradient is primarily a function of the horizontal salinity gradient, with the thermal gradient contributing to a lesser degree. For the Gulf of Alaska this salinity gradient could be created through runoff and coastal wind convergence.

ACCESS # : 317, ARL

CITATION : Schumacher, J.D., and T.H. Kinder. 1983. Low-frequency current regimes over the Bering Sea shelf. J. Phys. Oceanogr. 13(4): 607-623.

KEY-WORDS: Currents; Low frequency currents; Oceanography.

SYNOPSIS : Using direct current measurements made during the period 1975-81, we describe the general circulation over the southeastern Bering Sea and differentiate it by regimes related to depth and forcing mechanisms. Three regimes are present, delineated by water depth (z): the coastal (z less than or equal to 50 m), the middle shelf (50 < z < 100 m), and the outer shelf (z greater than or equal to 100 m). These are nearly coincident with previously described hydrographic domains. Statistically significant mean flow (1 to 100 cm/s) exists over the outer shelf, generally directed toward the northwest, but with a cross-isobath component. Flow of similar magnitude (1-6 cm/s) occurs in the coastal regime, paralleling the 50 m isobath in a counterclockwise sense around the shelf. Mean flow in the middle shelf is insignificant. Kinetic energy at frequencies < 0.5 cycle per day (cpd) is greater over the outer shelf than in the other two regimes, suggesting that oceanic forcing is important there but does not affect the remainder of the shelf. Kinetic energy in the band from 0.5 to 0.1 cpd follows a similar spatial pattern, reflecting the greater number of storms over the outer shelf. Mean flow paralleling the 100 and 50 m isobaths appears to be related to a combination of baroclinic pressure gradients (associated with frontal systems which separated the regimes) and interactions of tidal currents with bottom slopes located beneath the fronts.

ACCESS # : 318, NMFS

CITATION : Straty, R.R. 1977. Current patterns and distribution of river waters in inner Bristol Bay, Alaska. NOAA Tech. Rep. NMFS, SSRF - 713. pp. 1-13.

KEY-WORDS: Current patterns; River water distribution; Drift cards; Dye studies; Salinity-temperature distributions; Oceanography.

SYNOPSIS : Hydrographic studies to determine the distribution of the waters of the major sockeye-salmon-producing river systems in inner Bristol Bay show the net seaward flow of river water is along the northwest (right) side of inner Bristol Bay. The net motions of seawater toward the head of Bristol Bay transports with it the waters of Ugashik and Egegik rivers, which enter the bay on the southeast side. Near Egegik Bay to Middle Bluff, the mixed sea and river waters join the seaward flow of Kvichak and Naknek river waters, which enter at the head of Bristol Bay. Waters of these four rivers, along with the large volume of water from the rivers entering Nushagak Bay, are eventually transported to, and move seaward on, the northwest side of Bristol Bay. Waters of Naknek, Egegik, and Ugashik rivers are similar to each other in the courses followed during ebb and flood tides. Flood tide currents, along with the nontidal current, transport water from Egegik and Ugashik rivers above or north of the entrnace to Egegik and Ugashik bays.

ACCESS # : 319, IMS-UAF

CITATION : Takenouti, A.Y., and K. Ohtani. 1974. Currents and water masses in the Bering Sea: A review of Japanese work. In: D.W. Hood and E.J. Kelley (eds.), Oceanography of the Bering Sea, Occ. No. 2., Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp 39-57.

KEY-WORDS: Currents; Water masses; Oceanography.

SYNOPSIS : About half of the volume transport of the Alaskan Stream enters the Bering Sea through Aleutian Island passes and the rest from west of Attu Island. The highly stratified Alaskan Stream water loses its characteristic structure upon entering the Bering Sea during its first step of transformation from Eastern to Western Subarctic water. A general counterclockwise circulation and small eddies prevail in the Bering Sea. Dispersion of low-salinity shelf water in the surface layer and upwelling of deeper water associated with eddies reconstruct a stratified vertical pattern in the Bering Sea basin. This water then flows out as the East Kamchatka Current, mixing horizontally with cold low-salinity water from the Okhotsk Sea, and gradually becomes Western Subarctic in nature. The continental shelf of the eastern Bering Sea is characterized by various types of vertical temperature and salinity structures. Freshwater dilution of the surface layer, the intrusion of warm saline water near the bottom, and strong vertical mixing associated with winter cooling cause formation of dichothermal water. In regions where a conspicuous halocline is present as a barrier to winter convection activity, cold bottom water is absent.

ACCESS # : 320, ARL

CITATION : Dodimead, A.J., F.Favorite, and T. Hirano. 1963. Review of the oceanography of the Subarctic Pacific Region. International North Pacific Fisheries Commission, Vancouver, Canada. Bulletin No. 13. 195 pp.

KEY-WORDS: Oceanography; Fisheries.

SYNOPSIS : The oceanography of the Subarctic Pacific Region is reviewed with emphasis on the extensive new work accomplished since 1955 by the research organizations of the members of the International North Pacific Fisheries Commission - Canada, Japan, and the United States. Portions of the Bering Sea are included and a special appendix on the oceanography of Bristol Bay is enclosed.

ACCESS # : 321, ARL

CITATION : Cline, J., S. Katz, and H. Curl, Jr. 1981. Circulation processes in Bristol Bay, Alaska using dissolved methane as a tracer. Annual Reports of Principal Investigators for the Year Ending March 1981. pp 29-85. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Circulation; Methane tracer; Oceanography.

SYNOPSIS : The goal of this study is to utilize dissolved methane as a Lagrangian tracer of petroleum introduced from point sources in Bristol Bay, Alaska. Previous baseline studies in this area revealed the presence of localized sources of methane in Port Moller, an estuary along the North Aleutian Shelf (NAS), and in the bottom waters of St. George Basin (SGB).

ACCESS # : 322, ARL

CITATION : Baker, E.T. 1981. North Aleutian Shelf transport experiment. Annual Reports of Principal Investigators for the Year Ending March 1981. Vol. VI. pp. 329-389. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Transport; Suspended particulate matter; Oceanography.

SYNOPSIS : During the present reporting period, the NASTE project was organized and two field programs (August - September, 1980, and January - February, 1981) in the southeastern Bering Sea were carried out. Only data and results from the first cruise are discussed in this report since information is not yet available from the second cruise. Data from the North Aleutian Shelf (NAS) and the St. George Basin (SGB) area showed a close relationship between SPM (suspended particulate matter) distributions and hydrographic properties such as temperature and salinity. SPM landward of the 50 m isobath (the coastal domain) was generally well mixed throughout the water column. SPM profiles seaward of the 50 m isobath always consisted of surface and near bottom concentration maxima separated by a uniform, low concentration zone. Frontal regions were characterized by relatively low values of SPM concentration in the near bottom layer. Particle size distributions indicated that surface and near bottom SPM populations were distinct seaward of the coastal domain. Estimates of the vertical eddy diffusion coefficient made from the SPM profiles show that the bottom layer is a zone of energenic turbulent mixing capped by a thinner layer of much lower eddy diffusivity.

ACCESS # : 323, ARL

CITATION : Kinder, T.H. 1981. A perspective of physical oceanography in the Bering Sea, 1979. In: The Eastern Bering Sea Shelf: Oceanography and Resources. D.W. Hood and J.A. Calder (eds.). Vol. I: 5-12. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Oceanography.

SYNOPSIS : Until recently, physical oceanographic research in the Bering Sea concentrated on broad spatial and long temporal scales, and much of the field work occurred off the shelf in water overlying the deep basins. Research concentrated on basin-wide phenomena of long duration, and this work determined the oceanic climate of physical geography of the Bering Sea. Since about 1975, the focus of research has shifted toward shorter spatial and temporal scales, and also from the deep basins onto the shelf. Deviations from the large-scale mean state, such as interannual variability, fronts, eddies, tides, and vertical finestructure, are important biologically as well as physically, and this trend in research will probably continue through the next decade.

ACCESS # : 324, ARL

CITATION : Overland, J.E. 1981. Marine climatology of the Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 15-22. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Sea ice; Climatology; Oceanography.

SYNOPSIS : The climate of the Bering Sea is strongly related to the presence and movement of marginal sea ice. In winter, weather elements are continental and arctic in character, being replaced by maritime influences from the south in summer. In winter this results in north to easterly winds, a tendency for clear skies, and substantial diurnal temperature range. Summer is characterized by a progression of storms through the Bering Sea rather than fixed weather types, producing increased cloudiness, reduced diurnal temperature range, and winds rotating through the compass with a slight tendency for southwest.

ACCESS # : 325, ARL

CITATION : Niebauer, H.J. 1981. Recent short-period wintertime climatic fluctuations and their effect on sea-surface temperatures in the eastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 23-30. NOAA, distrib. by Univ. Washington, Press, Seattle, WA.
KEY-WORDS: Temperatures; Climatology.

SYNOPSIS : Upper air (700 mb) winter pressure patterns have shown sharp fluctuations over the period 1963-78. Mean annual sea-surface temperature (SST) fluctuations appear to be an effect of these short-term climatic fluctuations. The mid-1960's were a time of southerly flow of air leading to above-normal SST. A rather sharp reversal in atmospheric conditions led to a sharp drop in SST in the early to middle 1970's. Since 1977, the upper air flow has become southerly, leading to a sharp rise in SST. Autocorrelation analysis of the SST suggests that these trends persist for least two years.

ACCESS # : 326, ARL

CITATION : Kinder, T.H., and J.D. Schumacher. 1981. Hydrographic structure over the continental shelf of the southeastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol I: 31-52. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Hydrographic structure; Domains; Oceanography.

SYNOPSIS : We synthesize recent work conducted over this exceptionally broad (500 km) shelf which generally has only slow mean flow (less than or equal to 2 cm/s). Hydrographic structure is little influenced by this flow, but rather is formed primarily by boundary processes: tidal and wind stirring; buoyancy input from insolation, surface cooling, melting, freezing, and river runoff; and lateral exchange with the bordering oceanic water mass. Three distinct hydrographic domains can be defined using vertical structure to supplement temperature and salinity criteria. Inshore of the 50 m isobath, the coastal domain is vertically homogeneous and separated from the adjacent middle domain by a narrow (10 km) front. Between the 50 m and 100 m isobaths, the middle domain tends toward a strongly stratified two-layered structure, and is separated from the adjacent outer domain by a weak front. Between the 100 m isobath and the shelf break (170 m depth), the outer domain has surface and bottom mixed layers above and below a stratified interior. This interior has pronounced finestructure, as oceanic water intrudes shoreward from the weak haline front over the slope, and shelf water (middle domain) intrudes seaward across the 100 m isobath. These domains and their bordering fronts tend to persist through winter, although the absence of positive buoyancy often makes the middle shelf vertically homogeneous.

ACCESS # : 327, ARL

CITATION : Kinder, T.H., and J.D. Schumacher. 1981. Circulation over the continental shelf of the southeastern Bering Sea. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I: 53-75. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Current data; Circulation; Oceanography.

SYNOPSIS : Using extensive direct current measurements made during the period 1975-78, we describe flow over the southeastern Bering Sea shelf. Characteristics of the flow permit us to define three distinct regimes, nearly coincident with the hydrographic domains defined in the previous chapter. The coastal regime, inshore of the 50 m isobath, had a slow (1-5 cm/sec) counterclockwise mean current and occasional wind-driven pulses of a few days' duration. The middle regime, bounded by the 50 and 100 m isobaths, had insignificant (<1 cm/sec) mean flow but relatively stronger wind-driven pulses. The outer regime, between the 100 m isobath and shelf break (170 m), had a 1-5 cm/sec westward mean and low-frequency events unrelated to local winds. Over the entire shelf most of the horizontal kinetic energy was tidal, varying from 60 percent in the outer regime to 90 percent in the coastal regime. About 80 percent of the tidal energy was semidiurnal. Mean flow over the shelf is well described qualitatively by dynamic topographies, and shallow current data from coastal and outer regimes agree quantitatively as well. Two meterological conditions that force the observed current pulses have been identified. In summer eastward-traveling low atmospheric pressure centers caused low-frequency pulses in the middle regime, and weaker pulses in the coastal regime. In winter, outbreaks of cold and dry continental air forced pulses within the coastal and middle regimes.

ACCESS # : 328, ARL

CITATION : Pearson, C.A., H.O. Mofjeld, and R.B. Tripp. 1981. Tides of the eastern Bering Sea shelf. In: The Eastern Bering Sea Shelf: Oceanography and Resources. D.W. Hood and J.A. Calder (eds.). Vol. I: 111-130. NOAA, distrib. by Univ. Washington Press, Seattle, WA.

KEY-WORDS: Tides; Oceanography; Models.

SYNOPSIS : The acquisition of a substantial amount of pressure-gauge and current-meter data on the Bering Sea shelf has permitted a much more accurate description of the tides than has previously been possible. Cotidal charts are presented for the M two and, for the first time, the N two, K one, and O one constituents, and tidal current ellipse charts for M two and K one. S one, normally the second largest semidiurnal constituent, has not been included because it is anomalously small in the Bering Sea. The tide enters the Bering Sea through the central and western Aleutian Island passes and progresses as a free wave to the shelf. Largest tidal amplitudes are found over the southeastern shelf region, especially along the Alaska Peninsula and interior Bristol Bay. Each semidiurnal tide propagates as a Kelvin wave along the Alaska Peninsula but appears to be converted on reflection in interior Bristol Bay to a Sverdrup wave. A standing Sverdrup (Poincare) wave resulting from cooscillation in Kuskokwim Bay is evident on the outer shelf. Tidal models by Sunderman (1977) (a vertically integrated M two model of the entire Bering Sea) and by Lie and Leendertse (1978, 1979) (a three-dimensional model of the southeastern shelf incorporating the diurnal and semidiurnal tides) are discusses. Good qualitative agreement is found between the models and observation.

ACCESS # : 329, UAF

CITATION : Busdosh, M. 1981. Long-term effects of the water soluable fraction of Prudhoe Bay crude oil on survival, movement and food search success of the arctic amphipod Boeckosimus (Onisimus) affinis. Mar. Envirn. Res. 5(3): 167-180.

KEY-WORDS: Oil pollution; Mortality; Sublethal effects; Amphipod; Invertebrates.

SYNOPSIS : The arctic amphipod Boeckosimus (Onisimus) affinis was exposed to the water soluble fraction (WSF) of Prudhoe Bay crude oil. Animals were constantly exposed or one-time exposed for 3 or 10 days and then removed to clean water. In constant exposure experiments mortality was correlated to the strength of the solution and for 6 weeks afterwards animals in all solutions experienced similar mortality. Food search success lessened for 2 weeks, then gradually increased. Distance moved and time spent moving decreased as the concentration of the WSF increased. Animals one-time exposed to the WSF showed initial mortality rates of 15-20%, with little further mortality. Food search success was lessened relative to the strength of the WSF and duration of exposure, with general recovery within two weeks. Distance moved was decreased, but time spent moving was not. The overall period of testing was four months.

ACCESS # : 330, ARL

CITATION : Burrell, D.C. 1979. Distribution and dynamics of heavy metals in Alaskan shelf environments subject to oil development. Annual Reports of Principal Investigators for the Year Ending March 1979. Vol. 5. pp. 26-546. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Heavy metals; Oil pollution; Estuaries; Toxicity.

SYNOPSIS : The baseline work was completed in the Beaufort Sea and in Cook Inlet during the current 1978-79 contract period. The primary objective of this program is to research natural pathways of potentially toxic heavy metals to and through Alaskan shelf and coastal biota (with emphasis on commercially important benthic species), and hence to determine and predict changes likely to result from oil industry activity. Ancillary components include; (1) characterizing the heavy metal inventories of the water, sediment and indigenous biota in those geographical areas for which no background data exist, (2) determining non-biological pathways (rates and routes under both natural and stressed conditions) of the heavy metals as these affect the availability of metals to the organisms, and(3) toxicity effects of selected heavy metals to animals which are of major commercial importance under Alaskan environmental conditions. Apart from some continuing baseline survey work, this program addresses basic problems in heavy metal cycling in estuarine and nearshore areas. The work is an essential prerequisite to an understanding of the changes likely to be induced in the natural system by thorough, large scale energy development impingements.

ACCESS # : 331, ARL

CITATION : Burrell, D.C. 1977. Natural distribution of trace heavy metals and environmental background in Alaskan shelf and estuarine areas. Principal Investigators' Reports for the Year Ending March 1977. Vol. 13. pp. 290-506. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Heavy metals; Toxicity; Benthos; Sediments.

SYNOPSIS : The scope of this project included lower Cook Inlet, Norton Sound and the southern part of the Chukchi Sea in addition to the three shelf areas (Gulf of Alaska, Bering, and Beaufort Seas). Baseline collection and analysis of water column samples is now considered to be complete. For the soluble contents analysed to date, Cd, Pb, Cu, Ni, Hg, and V concentrations in filtered seawater from all shelf regions of Alaska are generally lower than commonly accepted oceanic means. As expected for such open ocean areas, distributions are quite uniform. Surficial sediment samples, collected in a uniform, contamination-free fashion in all these areas, show a number of heavy metals have been determined both as concentrations in extractable fractions from the sediment surface and as "whole rock" totals. In all cases the heavy metal contents are a function of the sediment grain size fractionation and the lithology. The concentrations of particulate heavy metals in the water are related to the particulate sediment load with enhanced concentrations adjacent to the sediment interface and in coastal waters. The clay minerology of all the fine grained fractions have also been determined. A fairly representative spread of two intertidal benthic species have been analysed. Data show heavy metal contents as low or lower than other regions. It is noted that the Alaskan shelf regions could well serve as a type example of pristine coastal environments.

ACCESS # : 332, ARL

CITATION : Barton, L.H. 1979. Finfish resource surveys in Norton Sound and Kotzebue Sound. Final Reports of Principal Investigators. Vol. 4. pp. 75- 313. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Fishes; Oil pollution; Petroleum development; Fisheries; Yukon Delta.

SYNOPSIS : An evalution of the subsistence use of Pacific herring and other fishery resources to coastal residents in Norton Sound and Kotzebue Sound is given. Contamination of important spawning, rearing, and/or overwintering areas from petroleum related activities could destroy one or more year classes, resulting in either a general weakening and decline in populations or possible elimination of an entire population, depending upon the severity and extent of pollution. Some concerns related to petroleum exploration and development and the potential impact of oil spills on the fishery resources throughout the study area are discussed. A major concern is the absence of data on distribution, relative abundance, range, age structure, etc. of fishery resources during the ice covered months. A second concern is the lack of information available on fishery resources which utilize the Yukon River Delta. This is considered as possibly the single most important ecosystem in the area and potentially the most vulnerable to disruption from either acute or chronic pollution problems. The deep water harbor of Port Clarence is also discussed as an area where further studies are needed to ensure proper planning and development of petroleum related activities in this area.

ACCESS # : 333, ARL

CITATION : Craddock, D.R. 1977. Acute toxic effects of petroleum on arctic and subartic marine organisms. In: D.C. Malins (ed.), Effects of petroleum on arctic and subarctic marine environments and organisms. Vol. 2. Academic Press, New York, NY. pp. 1-93

KEY-WORDS: Toxicity tests; Oil pollution.

SYNOPSIS : The objectives of this chapter are to review the literature on acute toxicity bioassay techniques using aquatic (mainly marine) organisms and to review the results of bioassays of petroleum relative to the toxicity of the various products tested and the sensitivity of the various marine organisms used (mainly arctic and subarctic species).

ACCESS # : 334, ARL

CITATION : Busdosh, M., K.R. Dobra, A. Horowitz, and S.E. Neff et al. 1978. Potential long-term effects of Prudhoe Bay crude oil in arctic sediments on indigenous benthic invertebrate communities. Proc. Conf. Assess. Ecol. Impacts Oil Spills, 14-17 June 1978. Am. Inst. Biol. Sci. pp. 856-874.

KEY-WORDS: Sediment; Benthos; Oil pollution; Toxicity.

SYNOPSIS : Laboratory and field experiments were performed to determine the potential toxicity of Prudhoe Bay crude oil to indigenous arctic benthic invertebrates. Toxicity was measured as mortality and as sublethal behavioral changes in feeding, movement and burrowing activities. When sediment was contaminated with fresh Prudhoe Bay crude oil, burrowing activity of the amphipod Boeckosimus (Onisimus) affinis was significantly reduced. Weathering of the oil was monitored by gas-liquid chromatography. Given a choice, in laboratory studies with oil contaminated or uncontaminated sediment, the amphipods selectively burrowed into the uncontaminated sediment. The preference for burrowing in unoiled substrate appears to be reflected in the avoidance of oil contaminated sediment in benthic community studies.

ACCESS # : 335, ARL

CITATION : Dunn, J.R., A.W. Kendall Jr., R.W. Wolotira, L. Quetin, and J.H. Bowerman. 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone. Principal Investigators' Reports for the Year Ending March 1979. Vol. VI. pp. 456-528. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Zooplankton; Food web; Fish; Oil pollution; Petroleum development.

SYNOPSIS : A field program was designed to elucidate the distribution in time and space of the zooplankton (both holo- and meroplankton) of continental shelf waters contiguous to Kodiak Island. These planktonic forms are of vital importance to the marine food web of the area, not only as food for higher trophic levels, but because most finfish and shellfish of the area spend critical early parts of their life histories as members of the plankton community. Prior to this study, virtually nothing was known about the specific composition and abundance of the zooplankton community, nor was the seasonal occurrence and areal distribution of larval forms of species contributing to the fisheries of the area known. With the knowledge of these distributions, the effects of chronic or catastrophic impacts of petroleum development can be evalutated. Certain areas and seasons may be more critical than others to the success of year classes as they pass through their planktonic phase.

ACCESS # : 336, ARL

CITATION : Drury, W.H., and J.O. Biderman. 1978. Ecological studies in the northern Bering Sea: studies of seabirds in the Bering Strait. Principal Investigators' Reports for the Year Ending March 1978. Vol. II. pp. 751-838. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Disturbance; Ecology; Bering Strait; Petroleum transport; Seabirds.

SYNOPSIS : In the area between Cape Lisburne and Saint Lawrence Island there are 3,725,000 to 4,000,000 seabirds. Little Diomede Island, the subject of this study, is a major seabird colony and the northern-most nesting colony of Parakeet, Crested and Least Auklets. Drastic population reduction or steady declines are possible results of development. It has been suggested that populations be reduced at experimental colonies in order to establish the rate of recovery. It is generally believed that arctic birds are subjected to stress by the extra effort required for breeding. Any further stress introduced by the impacts of development upon their food sources are likely to cause some degree of reproductive failure. An important aspect of OCSEAP is defining differences in biological oceanographic structures of the Bering Sea. Disturbance by the chronic effects of through traffic, by secondary effects such as helicopter operations and coastal development, by direct damage from oil spills or by indirect effects on the food of the seabirds will affect an area that is comparable to the plains of East Africa among the major natural wonders of the world.

ACCESS # : 337, ARL

CITATION : Devries, A.L. 1977. The physiological effects of acute and chronic exposure to hydrocarbons on near-shore fishes of the Bering Sea. Principal Investigators' Reports for the Year Ending March 1977. Vol. 12. pp. 1-22. OCSEAP/NOAA, Boulder, CO .

KEY-WORDS: Hydrocarbons; Oil pollution; Fishes.

SYNOPSIS : The main objective was to establish the effect of selected petroleum hydrocarbons on the physiology of certain cold-water fishes that are year round residents of the Bering Sea. Sculpins from the Bering Sea were shown to take up naphthalene from their environment, however it appeared to have little effect on the biosynthesis of either the plasma protein or of the peptide antifreeze. Morphological studies demonstrated that naphthalene exposure caused deterioration of the liver, however it was not determined whether this was a direct effect of naphthalene metabolism or resulted indirectly from anemia and reduced food intake. The normal rate of protein synthesis in the naphthalene exposed fishes suggests that compensatory mechanisms exist to maintain a constant synthetic rate of liver proteins.

ACCESS # : 338, ARL

CITATION : Devries, A.L. 1976. The physiological effect of acute and chronic exposure to hydrocarbons of petroleum on the near-shore fishes of the Bering Sea. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. pp. 1-14. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Toxicity; Oil pollution; Sculpins; Fishes; Physiology.

SYNOPSIS : Toxicity data for exposure to water soluble hydrocarbons on a few Bering Sea fishes are presented. The temperature of exposure appears to have profound effects. At low temperatures the hydrocarbons appear to be less toxic. Baseline measurements of oxygen consumption both at the organismal and tissue level reveal that the Bering Sea fishes are similar to other cold water fishes in regards to their physiology. Studies of the levels of freezing resistance in sculpin indicated that it is a seasonal phenomonen. The time course of the appearance and disappearance of freezing resistance indicate that this system will be a good model for studying the effect of naphthalene on antifreeze synthesis.

ACCESS # : 339, ARL

CITATION : Dames and Moore. 1979. Ecological studies of intertidal and shallow subtidal habitats in Lower Cook Inlet. Principal Investigators' Reports for the Year Ending March 1979. Vol. IV. pp. 1-275. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Littoral habitats; Oil pollution; Petroleum development; Cook Inlet; Ecology.

SYNOPSIS : Field studies were initiated in intertidal and shallow subtidal habitats in Lower Cook Inlet to examine species composition, zonation and seasonal patterns, trophic structure, rates of production and energy pathways. Habitats examined included rocky intertidal and subtidal areas, sand beaches and mudflats. The two major potential types of oil pollution of concern in Lower Cook Inlet are catastrophic spills of crude oil and chronic pollution by refined petroleum or refinery effluents. Chronic pollution is a concern chiefly on the eastern shore of the inlet since most onshore facilities are planned for that side. A regional assessment of coastal morphology has been used to predict behavior of oil spills in Lower Cook Inlet and to develop a classification of the susceptibility of local coastal environments to oil spills. This classification is based primarily on geological features and sediment characteristics as they relate to interactions with crude oil. It provides a useful starting point in assessing potential impacts from oil pollution, but it is necessary to temper the assessments with the idea that the major incentive for investigating potential effects of oil pollution is protection of biological assemblages. A point sometimes overlooked is that a ranking of biological assemblages by either importance or susceptibility to oil pollution does not always agree closely with the classification based on geological characteristics. Several factors must be integrated to develop a satisfactory assessment of susceptibility.

ACCESS # : 340, ARL

CITATION : Costa, D.P. and G.L. Kooyman. 1981. Effects of oil contamination in the sea otter, _Enhydra lutris_. Final Reports of Principal Investigators. Vol. 10. pp. 65-108. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Sea otter; Oil pollution; Physiology; Metabolism; Marine mammals.

SYNOPSIS : The objective of this study was to measure effects of crude oil contamination on sea otters through studies on the changes in the animal's physiology and behavior before and after contact with oil. A second objective was to attempt to rehabilitate the otters after crude oil contamination. The study has shown that small amounts of crude oil contamination have large effects on the metabolic rate of sea otters. Light oiling of approximately 25% of the animal's pelt surface area resulted in a 1.4X increase in metabolic rate while immersed in water at 15 degrees C. Furthermore, when the oil was removed by detergent, the animal's metabolic rate increase 2.1X while immersed in water at 15 degrees C. Of the three animals studied, two contracted pneumonia and one died. Studies upon free ranging sea otters have established that under certain conditions, sea otters can sustain low levels of oil contamination when 20% or less of the body surface is oiled.

ACCESS # : 341, ARL

CITATION : Cline, J., C. Katz and A. Young. 1979. Distribution and abundance of low molecular weight hydrocarbons and suspended hydrocarbons in Cook Inlet, Alaska. Annual Reports for the Year Ending March 1979. Vol. V. pp. 264-325. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Aromatic compounds; Toxicity; Oil pollution; Cook Inlet; Hydrocarbons; Petroleum development.

SYNOPSIS : During the past two years, emphasis has shifted toward sources of low molecular weight (LMW) hydrocarbons in Cook Inlet, including both natural and anthropogenic sources. Special attention has been devoted to sources of LMW aromatics in upper Cook Inlet and the fate of these compounds. Specialized studies in Cook Inlet have continued on the air-sea exchange of LMWH and in-situ production of gases in both the water column and from the underlying sediments. These data provide necessary information for the identification and sources of petroleum-like hydrocarbons in the waters of Cook Inlet. These studies were enacted to characterize the dissolved LMW natural hydrocarbons in Cook Inlet, Alaska. The purpose was to establish concentration levels and temporal and spatial variability of hydrocarbon components common to petroleum or natural gases resources prior to actual production. These measurements were felt to be an invaluable precursor to future monitoring efforts. The principal concern surrounding the distributions, sources, and sinks of LMWH is not their direct impact on biota, but rather their role as tracers of more toxic hydrocarbon fractions commonly found in crude oils. The principal goal is to provide the criteria for an early warning detection of petroleum-derived hydrocarbons and to establish the feasibility of using light hydrocarbons as tracers, particularly in reference to near-bottom mixing and resuspension processes.

ACCESS # : 342, PMEL

CITATION : Cline, J., T. Bates and C. Katz. 1980. Distribution and abundance of low molecular weight hydrocarbons and suspended hydrocarbons in Cook Inlet, Shelikof Strait, and Norton Sound, Alaska. Annual Reports of Principal Investigators for the Year Ending March 1980. Vol. 3. pp. 192-272. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Petroleum; Suspended organic matter; Dissolved organic matter.

SYNOPSIS : These studies were enacted to characterize the dissolved low molecular weight (LMW) natural hydrocarbons in Cook Inlet, Shelikof Strait, and Norton Sound, Alaska. The purpose was to establish concentration levels and temporal and spatial variability of hydrocarbon components common to petroleum or natural gas resources prior to actual production. Examination of data indicates that the LMWH will be excellent tracers of petroleum or natural gas input in all of the Alaska OCS areas. Studies to date also have revealed useful compositional parameters for distinguishing hydrocarbon sources. The most valuable of these is the ethane: ethene and propane: propene ratios. The low abundance of the aliphatic unsaturates in crude oil coupled with low production of alkanes by biological systems gives an unequivocal indicator of fossil gas and oil sources. Investigation in upper Cook Inlet have shown that dissolved LMW aromatics may be useful indicators of petroleum and refined products. These compounds are unique to crude oil and apparently are not produced by marine biological systems. Because of the low ambient levels found in pristine marine environments, such as Alaska, these compounds should provide a sensitive and reliable measure of chronic spillage.

ACCESS # : 343, PMEL

CITATION : Cline. J. 1977. Distribution of light hydrocarbons, C1-C4, in the northeast Gulf of Alaska, lower Cook Inlet, southeastern Bering Shelf, Norton Sound and southeastern Chukchi Sea. Annual Reports of Principal Investigators. Vol. 13. pp. 180-268. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Hydrocarbons; Marine biology; Oil pollution.

SYNOPSIS : The development of petroleum resources in the Gulf of Alaska may result in the release of toxic hydrocrabons to the marine environment with possible deleterious effects on the pelagic, benthic, and intertidal biota. It is of environmental significance that baseline levels of both naturally occurring and petroleum-derived hydrocarbons be established prior to the development of fossil fuel resources in the area. Low molecular weight hydrocarbon (LMWH) studies were carried out in the northeast Gulf of Alaska and the southeastern Bering Sea to determine the distributions and natural sources of methane, ethane, ethylene, propane, propylene, isobutane and n-butane. Known offshore seeps were investigated to ascertain the composition of natural gas seeps and to evaluate the merits of naturally injected LMWH as tracers of petroleum input. Baseline surveys have been completed in the northeast Gulf of Alaska, southeastern Bering Sea, Norton Sound, and southeastern Chukchi Sea. The data obtained to date is probably sufficient to delineate the background levels of the low molecular weight aliphatic hydrocarbons to be expected in a future monitoring activity.

ACCESS # : 344, ARL

CITATION : Clark, R.C. Jr. 1979. Levels and sources of critical trace metals in the marine environment. Final Reports of Principal Investigators. Vol. 5. pp. 5-51. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Water pollution; Petroleum; Trace metals.

SYNOPSIS : Some of the elements in petroleum are also found in seawater where they range in concentration from a few percent to parts per trillion. The ecological aspects, or effects, of these elements may range from beneficial (essential) to detrimental (toxic). Any assessment of the biological effects of trace metals from petroleum on the marine environment must consider the levels of these elements in petroleum, drilling chemicals and production (brine) waters the levels naturally present in seawater, the chemical form of the metals, and the reactivity and toxicity of the chemical forms of the metals. There are six trace metals, namely, chromium, nickel, copper, cadmium, mercury, and lead which occur in petroleum at trace levels and are toxic to at least some marine organisms at such levels. In view of their potential impact on the arctic and subarctic marine environments, these metals are considered in this report.

ACCESS # : 345, ARL

CITATION : Becker, P.R. 1979. Contaminants and environmental disturbances that may accompany petroleum exploration and development. Lower Cook Inlet Interim Synthesis Report. pp. 27-47. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Oil pollution; Oil spills; Petroleum development; Disturbance; Cook Inlet.

SYNOPSIS : Oil and gas production has occurred in the upper portion of Cook Inlet (above the Forelands) for about the last ten years, and onshore development has occurred just below the Forelands at Nikiski and Drift River. Information resulting from Cook Inlet's history of OCS development and applied engineering operations can provide more accurate projections of the effects of future OCS development in Lower Cook Inlet. Potential sources of hydrocarbons and associated contaminants are the off-shore platforms, pipelines, shore facilities including tanker terminals, tankers and chemicals that might be employed in the cleanup if an oil spill occurred. Considering the history of oil spills in other geographical areas and the locations of the leased blocks in Lower Cook Inlet,it is probable that the most damaging effect of platforms would come from large-volume acute spills from fires or blow-outs. It is believed that low-volume spills would be dispersed fairly rapidly by the strong currents in the central lower inlet. An important potential result of construction or expansion of onshore facilities is permanent habitat destruction through filling of subtidal areas and maintenance dredging. This could be catastrophic to biological populations both locally and regionally. A potential result of petroleum exploitation in Lower Cook Inlet is an increase in tanker traffic.

ACCESS # : 346, ARL

CITATION : Burrell, D.C. 1978. Distribution and dynamics of heavy metals in Alaskan shelf environments subject to oil development. Quarterly Report for April-June 1978. pp. 170-200. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Heavy metals; Benthos; Pollution effects.

SYNOPSIS : Natural pathways of potentially toxic heavy metals to and through Alaskan Shelf and coastal marine biota (with emphasis on commercially important benthic species) are researched to determine and predict changes likely to result from oil industry activity in this marine zone. Ancillary components of this work include; (1) characterizing the heavy metal inventories of the water, sediment, and indigenous biota in those geographic areas for which no background data exist, (2) determining non-biological pathways (rates and routes under both natural and stressed conditions) of heavy metals as these affect the availability of metals to the organisms, and (3) toxicity effects of selected heavy metals to animals which are of major commercial importance under Alaskan environmental conditions.

ACCESS # : 347, IMS-UAF

CITATION : Brocksen, R.W. and H.T. Bailey. 1973. Respiratory response of juvenile chinook salmon and striped bass exposed to benzene, a water-soluble component of crude oil. In: Proceedings of Joint Conference on Prevention and Control of Oil Spills. March 13-15, 1973. Washington, D.C.

KEY-WORDS: Oil spills; Fish; Aromatic hydrocarbons; Salmon.

SYNOPSIS : Interest surrounding the potential effects of crude oil on aquatic organisms has increased in recent years due to the incidence of accidental oil spills. There are few experimental results reported, however, dealing with the effect on aquatic species of water-soluble aromatic hydrocarbons contained in crude oil. Such compounds are highly toxic to mammals. Experiments were conducted using juvenile chinook salmon, Oncorhynchus tshawytscha, and striped bass, Morone saxatilis. The fish were exposed to sub-lethal concentrations of the aromatic hydrcarbon benene, for periods ranging from 1-96 hours. Prior to exposure and after exposure to the benzene, respiration rates of individual fish were measured. Results show increases in respiratory rate up to 115 percent above that of control fish after exposure periods of 24 hours for striped bass and 48 hours for chinook salmon. Fish exposed to benzene concentrations of 10 ppm for periods longer than those listed exhibited a narcosis that caused a decrease in respiratory rate. The narcotic state induced by exposure to benzene was shown to be reversible when the fish were placed in fresh water and kept for periods longer than 6 days. Possible biochemical mechanisms leading to this response are hypothesized.

ATTACHMENT :

ACCESS # : 348, ARL

CITATION : Atlas, R.M. 1979. Fate and effects of oil pollutants in extremely cold marine environments. Final Report, Contract No. N00014-76-C-0400, Task No. Nr 205-013. Office of Naval Research. pp. 80.

KEY-WORDS: Oil pollution; Ecosystems; Weathering; Oil spills; Marine pollution; Hydrocarbons; Benthos.

SYNOPSIS : Studies were conducted on the fate and effects of crude and refined oils in arctic ecosystems. Major conclusions of the study were: (1) microbial populations respond rapidly to an introduction of hydrocarbons into the environment by an increase of the number of hydrcarbons utilizing bacteria and a decrease in species diversity (2) hydrocarbons will remain in arctic ecosystems for prolonged periods following contamination. Following initial abiotic weathering, biodegradation occurs slowly. The fate depends on the particular ecosystem that is contaminated. Refined oil spillages may contaminate drinking water supplies for long periods of time (3) hydrocarbon biodegradation in the arctic is limited mainly by low temperatures. Hydrocarbon utilizing microorganisms are widely distributed (4) when crude oil is exposed on water, biodegradation reduces absolute amounts of petroleum hydrocarbons, but does not appear to alter the relative percentages of oil components. This appears to be major difference between petroleum biodegradation in the arctic and in temperate regions and (5) petroleum contamination of arctic sediments will result in alterations of the benthic community. Petroleum exhibits differential toxicity to benthic invertebrates.

ACCESS # : 349, ARL

CITATION : Environmental Research Laboratories. 1976. Environmental Assessment of the Alaskan Continental Shelf. Quarterly Report of Principal Investigators. pp. 898. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Pollution effects; Oil pollution; Toxicity; Chemistry; Microbiology; Sea ice; Oceanography.

SYNOPSIS : This volume contains the quarterly reports of baseline studies on the environmental effects of the development of resources on the Alaska continental shelf. Baseline studies encompass pollution effects, chemistry and microbiology, physical oceanography geology, ice and data management.

ACCESS # : 350, ARL

CITATION : Environmental Research Laboratories. 1976. Environmental Assessment of the Alaskan Continental Shelf. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. Effects of Contaminants. pp. 392. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Toxicity; Oil pollution; Photosynthesis; Ecology; Distributions; Ecosystems; Fishes; Marine mammals; Eelgrass; Crabs; Crustacea.

SYNOPSIS : This is the 8th volume of a set of 14 which present baseline studies of the natural resources of the Alaska Continental Shelf as well as studies of the environemntal effects of the development of the resources in that area with effects of the development of the resources in that area with particular emphasis on oil pollution. This volume contains the following studies: The Physiological effect of acute and chronic exposure to hydrocarbons and of petroleum on the near-shore fishes of the Bering Sea; Physiological impact of oil on Pinnipeds; Acute and chronic toxicity, uptake, and depuration and sublethal metabolic response of Alaskan marine organisms to petroleum hydrocarbons; Sublethal effects as reflected by morphological, chemical physiological, and behavioral indices; Indentification of major processes in biotransformations of petroleum hydrocarbons and trace metals on biota in arctic and subarctic waters; Acute effects-Pacific Herring Roe in Gulf of Alaska; Acute and chronic toxicity of sea-water extracts of Alaskan crude oil to zoeae of the dungeness crab, Cancer magister Dana; And sublethal effects - effects on seagrass photosynthesis.

ACCESS # : 351, ARL

CITATION : Environmental Research Laboratories. 1977. Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1977. Vol. XII. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Heavy metals; Ecology; Ecosystems; Petroleum development.

SYNOPSIS : Reports containing baseline studies are compiled in this annual report. They are intended to serve as markers or as points of departure from which to assess the potential environmental impact that might result from resources development on the Alaskan Continental Shelf. This compilation contains the following studies: The physiological effects of acute and chronic exposure to hydrocarbons on near shore fishes of the Bering Sea; Lethal and sublethal effects on selected Alaskan Maine species after acute and long-term exposure to oil and oil components; Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, ecosystem dynamics, Eastern Bering Sea; ecosystem dynamics birds and marine mammals, Part I and Part II.; Effects of petroleum exposure on hatching success and incubation behavior of Glaucous-winged Gulls; Evolution, pathobiology and breeding ecology of the Gulf of Alaska Herring Gull group; Acute effects - Pacific Herring Roe in the Gulf of Alaska; Sublethal effects on seagrass photosynthesis; transport, retention, and effects of the water-soluble fraction of Cook Inlet crude oil; And research to determine the accumulation of organic constituents and heavy metals from petroleum-impacted sediments.

ACCESS # : 352, ARL

CITATION : Environmental Research Laboratories. 1978. Environmental Assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators. Vol. 1. Biological Studies. pp. 490. OCSEAP/NOAA.

KEY-WORDS: Oil pollution; Water pollution; Hydrocarbons; Plankton; Fish; Invertebrates; Birds.

SYNOPSIS : Seven final reports on baseline studies of the aquatic fauna and ecology of the Alaskan Continental Shelf which assess the environmental effects of petroleum developments in that area are compiled in this volume. Titles are: Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components; Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea; A review of the literature and a selected bibliography of published and unpublished literature on marine birds of Alaska; Determination and description of knowledge of the distribution, abundance, and timing of salmonids in the Gulf of Alaska and Bering Sea; Ichtyoplankton of the Eastern Bering Sea; Zooplankton and Micronektona; And Trawl survey of the epifaunal invertebrates of Norton Sound, Southeastern Chuckchi Sea, and Kotzebue Sound.

ACCESS # : 353, ARL

CITATION : Alaska Sea Grant Program. 1978. Ocean Pollution Research Program. Alaska Regional Workshop, Final Report. Anchorage, Ak. pp. 103.

KEY-WORDS: Marine biology; Sea ice; Oil pollution.

SYNOPSIS : Participants at the conference emphasized the need for long-term work onthe effects of low-level,chronic pollution,multi-disciplinary process oriented research at the community-ecosystem level and innovative approaches to the detection of subtle changes in the biological condition of species and major deleterious impacts on the indigenous biota. Other high priorities were concerned with transportation (mainly oil pollution), and fish processing and urban liquid wastes. The immense size of Alaska means that a wide spectrum of climatic and physical coastal and shelf environments are represented, each with a range of dominant pollution activities. The format of the conference recognized this by designating a series of "ecosystem" working groups such as: ice-covered waters Arctic coastal lagoons (and shallow embayments) major river deltas and plume impact areas, high-productivity shelf areas (major benthic and pelagic fishing grounds) and fjords, estuaries and confined coastal waters. Each group considered impact and associated information needs by geographical regions as follows: Gulf of Alaska, Bering Sea, and Arctic (i.e. Chukchi and Beaufort Seas).

ACCESS # : 354, RAS-UAF

CITATION : Aarset, A.V. and K.E. Zachariassen. 1982. Effects of oil pollution on the freezing tolerance and solute concentration of the blue mussel Mytilus edulis. Mar. Biol. 72: 45-51.

KEY-WORDS: Bivalves; Oil pollution; Temperature

SYNOPSIS : The purpose of the present study has been to investigate to what extent oil affects the intracellular concentrations of free amino acids in Mytilus edulis, and thus the ability of these mussels to tolerate cold exposure at low tide in winter. The study was carried out in the laboratory by exposing M. edulis mussels to oil-mixed sea water and observing the effects on their cold-hardiness and the concentrations of free amino acids in the body fluid compartments. The values for oil-polluted mussels have been compared with corresponding values of controls kept in oil-free sea water.

ACCESS # : 355, RAS-UAF

CITATION : Anderson, J.W., E.A. Crecelius, D.L. Woodruff and J.M. Augenfeld. 1980. Uptake of trace metals by the clam Macoma inquinata from clean and oil-contaminated detritus. Bull. of Environ. Contamin. and Toxicol. 25, No.3. pp. 337-344.

KEY-WORDS: Hydrocarbons; Sediments toxicity; Heavy metals; Oil pollution. Bivalves; Feeding behavior.

SYNOPSIS : A detritivorous clam, Macoma inquinata, was exposed to clean and Prudhoe Bay crude oil-contaminated detritus to determine the effect of oil on radiolabelled metal accumulation (Cr, Co, Eu, Fe, Sc, Zn) There was no evidence to suggest that exposure to 1000 ppm petroleum hydrocarbon either increased or decreased the rate at which the clam absorbs the metals, other than through a decrease in the rate of food intake. Crude oil in sediment might affect the condition of the clams through an effect on feeding behaviour, but an increased risk of heavy metal toxicity to the clam population was unlikely. Nevertheless, oil contamination could alter patterns of metal transfer in the marine benthic community and change the food web, owing to changes in the feeding behaviour.

ACCESS # : 356, ARL

CITATION : Anderson, J.W., S.L. Kiesser and J.W. Blaylock. 1979. Comparative uptake of Naphthalenes from water and oiled sediment by benthic amphipods. In: Proceedings 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup). March 19-22, 1979. Los Angeles, Ca.

KEY-WORDS: Amphipods; Oil pollution; Sediments; Aromatic hydrocarbons; Benthos.

SYNOPSIS : The benthic amphipod, Anonyx laticoxae, was exposed to whole oil on sediments or water extracts of Prudhoe Bay crude oil under both static and flowing conditions. Time periods of exposure ranged from 4 to 27 days and, while a range of compounds was present, the only class measured in water, tissues, and sediments was naphthalenes. Sediment exposures demonstrated relatively low bioavailability of naphthalenes and the route of entry appeared to be via interstitial and water column contamination. It appears that release of naphthalenes from both oiled sediment and tissues is largely controlled by water solubilities of the components, but metabolic processes may supplement this activity.

ACCESS # : 357, RAS-UAF

CITATION : Albers, P.H. 1979. Effects of Corexit 9527 on the hatchability of mallard eggs. Bull. Environ. Contam. Toxicol. 23: 661-668.

KEY-WORDS: Toxicity; Mortality; Oil pollution; Waterfowl.

SYNOPSIS : The paper reports the results of a study of the effects of Corexit 9527 dispersant, crude oil, and crude oil/Corexit 9527 mixtures on mallard duck (Anas platyrhynchos) embryos. Groups of eggs were treated with either 1,5, or 20 ul of Prudhoe Bay (Alaska) crude oil, Corexit 9527, a 30:1 oil/Corexit mixture or 5:1 oil/Corexit mixture. Mallard eggs treated with 20 ul of crude oil, Corexit 9527, 30:1 oil/Corexit 9527, 5:1 9527 had significantly lower hatching success than the untreated control eggs. The comparisons between treated groups and the control and among treated groups were used to create a general toxicity ranking: (Corexit 9527=5:1 oil/Corexit 9527) Prudhoe Bay crude oil 30:1/Corexit 9527. Corexit 9527 appeared to penetrate egg shells and shell membranes as readily as crude oil. No gross external malformations or behavioral abnormalities were observed.

ACCESS # : 358, RAS-UAF

CITATION : Anon. 1971. Water pollution as a world problem: the legal, scientific and political aspects. Europa Publications, London. pp. 248.

KEY-WORDS: Wetlands; Toxicity; Nutrients; Pollution effects.

SYNOPSIS : Papers presented at a conference convened by the David Davies Memorial Institute of International Studies and the Dept. of International Politics of the Univ. College of Wales in July 1970, considered the nature and control of pollution arising from discharges to sea and inland waters of radioactive materials, oil, organic effluents, plant nutrients, toxic substances including pesticides, sewage, and trade waste waters. The value of international control measures, where applicable, was stressed. The book includes the discussion which followed each session, and texts are appended of the Canadian Arctic Waters Pollution Bill and the Convention on Wetlands of International Importance.

ACCESS # : 359, ARL

CITATION : Caldwell, R.S., E.M. Caldarone and M.H. Mallon. 1976. Effects of a seawater-soluble fraction of Alaskan crude oil and its major aromatic components on larval stages of the dungeness crab, Cancer magister (Dana). Principal Investigator Reports for October-December 1976. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Crustacea; Crabs; Petroleum; Oil Pollution; Toxicity.

SYNOPSIS : Larval stages of the Dungeness crab, Cancer magister (Dana), were exposed continuously to dilutions of Alaskan crude oil water-soluble fraction (WSF) or seawater solutions of napthalene or benzene for periods lasting up to 60 days. Effects on survival, duration of larval development and size were employed as indicators of toxic effects. By these criteria the toxic threshold for exposure to the WSF was estimated as 4.0% of the full strength WSF (0.0049 mg/l as naphthalene or 0.22 mg/l as total dissolved aromatics). The lowest concentration at which toxic effects were observed with naphthalene was 0.13 mg/l and with benzene was 1.1 mg/l. The concentrations of aromatic hydrocarbons in the WSF were inversely related to the degree of alkylation in each of the benzene and naphthalene families, but the acute toxicity of the 12 compounds was directly related to the degree of alkyl-benzene and its derivatives. Because of these relationship, the individual aromatic compounds, contributed approximately equally to the acute toxicity of the WSF. The collective toxicity of these compounds tested individually accounted for only 8.45% of the WSF acute toxicity. Since benzene contributed a greater fraction of the WSF of this compound may involve a different mechanism in long term exposures than in acute tests.

ACCESS # : 360, IMS-UAF

CITATION : Blaylock, J.W., S.E. Miller, B.L. Olla, and W. H. Pearson. 1981. Detection of the water-soluble fraction of crude oil by the blue crab, Callinectes sapidus. Mar. Environ. Res. 5(1): 3-11.

KEY-WORDS: Crabs; Hydrocarbons; Oil pollution; Temperature.

SYNOPSIS : Blue crabs exposed to a water-soluble fraction of Prudhoe Bay crude oil abruptly changed antennular orientation, began rhythmic beating of the maxillipedal flangellae, and increased antennular flicking rate. They were more sensitive than the Dungeness crab, Cancer magister, but this may be temperature dependent. The blue crab can readily detect petroleum hydrocarbons at concentrations found in chronically polluted areas, as well as oil spills.

ACCESS # : 361, ARL

CITATION : Cheatham, D.L., R.S. McMahon, S.J. Way, and J.W. Short. 1977. The relative importance of evaporation and biodegradation and the effect of lower temperature on the loss of some mononuclear and dinuclear aromatic hydrocarbons from seawater. Principal Investigators Reports for the Year Ending March 1977. Vol. 12. pp. 44-65. OCSEAP/NOAA, Boulder, CO
KEY-WORDS: Toxicity; Oil pollution; Temperature; Cook Inlet; Hydrocarbons.

SYNOPSIS : A Cook Inlet crude oil water-soluble fraction, incubated at 5 degrees, 8 degrees, and 12 degrees C. was analyzed by gas chromatography during a 96-h period to determine the effect of temperature on evaporation and biodegradation of individual mononuclear and dinuclear aromatic hydrocarbons in seawater. The relative importance of evaporation and biodegradation on the loss of these hydrocarbons was assessed at each temperature using combinations of aeration and poison as experimental conditions. Lower temperature reduced the loss of mononuclear and dinuclear aromatic hydrocarbons from seawater. Evaporation was an especially significant factor in the loss of mononuclear aromatics, but had a significant effect on dinuclear aromatics, particularly naphthalene. Natural means exist for eliminating toxicity for longer periods of time at lower temperatures, because aromatic hydrocarbons would persist in seawater longer.

ACCESS # : 362, ARL

CITATION : Craddock, D.A. 1979. Acute toxicity of heavy metals. Final Reports of Principal Investigators. Vol. 5. pp. 52-81. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Toxicity; Heavy metals; Pollution effects; Petroleum development.

SYNOPSIS : The toxic effects of heavy metals on marine species and more specifically of the effect on arctic and subarctic species were studied. The metals that were considered are four important metals associated with the production of petroleum: cadmium, chromium, nickel, and lead. Heavy metals in solution in seawater affect marine organisms mainly by adsorption. Adsorption may occur across the general body surfaces and through special structures such as gills, and in teleosts, which ingest seawater; absorption also takes place across the walls of the gut. Of the four metals under consideration, cadmium may remain in aerated seawater in the greatest concentrations, followed by nickel, lead and chromium. The concentration of a metal lethal to a marine organism depends on the metal and the organism. The toxicity of each of the four metals is treated briefly, and a tabulation of reported toxicity phyla for each is included.

ACCESS # : 363, ARL

CITATION : Davies, W.P., G.I. Scott, C.D. Getter, M.O. Hayes and E.R. Gundlach. 1979. Methodology for environ. assess. of oil and hazardous substance spills. In: European Marine Biological Symposium on Protection of Life in the Sea. Vol. 33. pp. 246-256.

KEY-WORDS: Oil spills; Pollution effects.

SYNOPSIS : Ecological assessment of oil and hazardous material spills has been divided into three distinct phases: (1) first-order response studies-conducted at the time of the initial spill event, (2) second-order response studies-conducted 2 months to one year post-spill, which document any delayed mortality & attempt to identify potential sublethal impacts in sensitive species, and (3) third-order response studies-conducted one to three years post-spill, to document chronic impacts (both lethal and sublethal) to specific indicator species. First- and second-order response studies of the "Peck Slip" oil spill in Puerto Rico illustrate the usefulness of this method. The need for contingency planning before a spill is discussed along with the use of the vulnerability to oiling. A study of the lower Cook Inlet section of the Alaskan coast illustrates the practical application of this method.

ACCESS # : 364, RAS-UAF

CITATION: Donahue, W.H., R.T. Wang, M. Welch, and J.A.C. Nicol. 1977. Effects of water-soluble components of petroleum oils and aromatic hydrocarbons on barnacle larvae. Environ. Pollut. 13:187-202.

KEY-WORDS: Toxicity; Barnacle larvae; Oil Pollution; Hydrocarbons.

SYNOPSIS : The effects of the water-soluble fractions (WSF) of petroleum oils and of solutions of aromatics on embryos and nauplii of barnacles Chthamalus fragilis and Balanus amphitrite (niveus) were investigated. The oils tested were S. Louisiana, Alaska, Kuwait, Venezuela crudes, Diesel fuel, Bunker C, No. 2 fuel and crankcase oils. Eighteen aromatic hydrocarbons occurring in petroleum oils were also tested. Observations were made on development and hatching of embryos, and the activity, phototaxis and survival of larvae. Acute experiments (1 h duration) were carried out in glass tubes illuminated above, and larvae remaining on the bottom were separated from those actively swimming. Concentrations at which half the larvae occurred in the bottom fraction w ere determined. Oils were toxic in the series used: Crankcase No.2 fuel oil Bunker C Diesel Venezuela Kuwait Alaska S. Louisiana (in terms of percentages of saturated solutions) are given. Embryonic development and larval activity were adversely affected by No.2 fuel oil at a concentration of 3 ppm and larval activity by naphthalene at the same level.

ACCESS # : 365, RAS-UAF

CITATION : Eatin, W.C. and B.A. Rattner. 1982. Effects of dispersant and crude oil ingestion on mallard ducklings (Anas platyrhnchos). Bull. Environ. Contam. Toxicol. 29. pp. 273-278.

KEY-WORDS: Growth; Food; Transport; Oil Pollution; Toxicity; Waterfowl.

SYNOPSIS : Experiments were carried out to study what effects a diet containing the dispersant, Corexit 9527, Prudhoe Bay crude oil, or both, has on the growth and blood chemistries of mallard ducklings (Anas platyrhynchos). The results are reported with tables, and it is concluded that the ducklings could ingest low levels of dispersant, or the dispersant combined with crude oil, for 9 weeks without showing any obvious signs of toxicity.

ACCESS # : 366, RAS-UAF

CITATION : Farrington, I.W., A.C. Davies, N.M. Frew and K.S. Rabin. 1982. Fuel oil compounds in Mytilus edulis. Retention and release after an oil spill. Mar. Biol. 66: 15-26.

KEY-WORDS: Hydrocarbons; Oil spill; Bivalves.

SYNOPSIS : Mytilus edulis contaminated by a brief 2-d exposure to a No.2. fuel oil spill in the Cape Cod Canal, Mass., USA were sampled six times during an end post-spill period to study the rate of release of fuel and compounds under field conditions. Detailed measurements of compounds by high resolution glass capillary gas chromatography and quantitative glass capillary gas chromatrography-mass spectrometry-computer systems analyses provided a more comprehensive examination of release rates of different types of coumpounds. Biological half-lives were calculated for selected compounds for the first 21 d during which the release rates were exponential. Typical half-lives were n-alkanes, 0.2-0.8 d; pristane, 0.5 d; C-2 (dimethyl or ethyl) napthalenes, 0.9 d; methyl phenanthrenes, 1.7 d. Changes in relative rations of C-2 phenanthrenes during the release period were observed. The evidence available to date strongly support the role of molecular weight and accompanying properties of water solubility as the main controlling factors in the rate of release of fuel oil compounds by M. edulis. However, the data for the rapid release of n-alkanes and C-2 phenanthrenes also indicate molecular configuration as additional key factors. The data from this study are compared and contrasted to data from short term experimental studies in the laboratory, data from longer term studies from chronic exposure conditions, and data from two other oil spills with longer term exposure.

ACCESS # : 367, ARL

CITATION : Fay, F.H. 1976. Morbidity and mortality of marine mammals. Principal Investigator Reports for the Quarter Ending September. Vol. 1. pp. 43-47. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Mortality; Oil pollution; Ecology; Distribution; Marine mammals.

SYNOPSIS : The coast of Kotzebue Sound from Bering Strait to Point Hope was surveyed for dead or moribund marine mammals. A total of 166 dead marine mammals was sighted, 92 of which were old weathered remains from previous years. The findings thus far suggest that two pathologic conditions, namely dermatomycosis and streptococcosis, occur frequently enough to merit further investigation of their rate of occurrence, present impact, and potential aggravation by the stresses of oil development activities and environmental pollution. Low level infections by agents of both conditions appear to be common to all or most of the pinnipeds inhabiting the Bering and Chukchi Seas, and acute infections occur frequently enough to have been conceivable that a variety of stresses potentially imposed by oil development could have a synergistic effect on both of these conditions.

ACCESS # : 368, EPA

CITATION : Feder, H.M., M. Cheek, P. Flanagan, S.C. Jewett, and M.H. Johnston. 1976. The sediment environment of Port Valdez, Alaska:The effect of oil on this ecosystem. Environmental Protection Agency. Ecological Research Series. Report EPA 600/3-76-086. pp. 322.

KEY-WORDS: Oil pollution; Benthos; Bivalves; Sediments; Pollution; Zooplankton; Crustacean; Mortality.

SYNOPSIS : The Port Valdez intertidal sediment system was studied for three years. Physical, geological, geochemical, hydrocarbon, and biological features were examined. Sediments were poorly sorted gravels to plastic clays, and had low amounts of organic matter. Bacterial numbers varied from site to site, and decreased in numbers with depth. Meiofauna consisted primarily of nematodes and harpacticoid copepods. Most meiofaunal species were restricted to the upper three centimeters thoughout the year. Meiofaunal densities were typically highest in summer and lowest in winter. Reproductive activities of copepods tended to be seasonal with only one species reproducing throughout the year. Bacterial populations were unaffected by single applications. It is concluded that oil is removed rapidly by tidal action. Three species of copepods exposed to oil in the field significantly increased in density in experimentally oiled plots. Uptake and release of added oil by intertidal sediments and the clam (Macoma balthica) were examined in the field. Petroleum was not detectable two months after application to sediments.

ACCESS # : 369, RAS-UAF

CITATION : Federle, T.W., J.R. Vestal, G.R. Hater and M.C. Miller. 1979. Effects of Prudhoe Bay crude oil on primary production and zooplankton in Arctic tundra thaw ponds. Mar. Environ. Res. 2(1): pp. 3-18.

KEY-WORDS: Pollution effects; Petroleum; Primary production; Zooplankton.

SYNOPSIS : The effects of Prudhoe Bay, Alaska, crude oil on the indigenous phytoplankton and zooplankton of tundra thaw ponds were studied under controlled conditions in situ during the summer of 1976. These effects were compared with uncontrolled oil spills on Pond Omega (a year previously) and Pond E (six years previously). In the uncontrolled spills, the phytoplankton species composition of both ponds remained appreciably different compared with control Pond C, although phytoplankton biomass did not differ greatly. Primary production remained low in Pond Omega, but had recovered to control levels in Pond E. In controlled subpond experiments, oil caused a decrease of about 90-100% in primary production in five days, but recovered to 40-50% of the control level within fifteen days. During that time, phytoplankton biomass decreased initially, but recovered within fifteen days. Oil caused a shift in phytoplankton species composition from a predominance of cryptophytes to chrysophytes.

ACCESS # : 370, ARL

CITATION : Feely, R.A., J.D. Cline, G. Massoth, A.J. Paulson and M.F. Lamb. 1979. Composition, transport and deposition of suspended matter in Lower Cook Inlet Shelikof Strait, Alaska. Annual Reports of Principal Investigators for the Year Ending March 1979. Vol. V. pp. 195-263. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Circulation; Oil pollution; Water pollution; Heavy metals; Gulf of Alaska; Petroleum development; Oil.

SYNOPSIS : Of particular concern are the major accidents which cause massive oil spills, however, chronic release of oil through minor spills and localized transfer operations may be more important over the long term. Since crude oil is sparingly soluble in seawater, it tends to form emulsions when introduced into marine waters, especially under intense wave action. The emulsions have a high affinity for particles and tend to be adsorbed rapidly. Recent studies of oil spills in coastal waters containing high suspended loads have indicated rapid dispersal and removal of the oil by sorption onto particles along frontal zones. These zones are regions where turbid brackish water contracts seawater. The seasonal distributions, elemental composition, and fluxes of suspended particulate matter in lower Cook Inlet were studied and compared with current patterns and bottom sediment distributions. In general, the suspended matter distributions appear to follow the pattern of circulation in lower Cook Inlet and Shelikof Strait. The inflowing clear saline Gulf of Alaska water, which is enriched in biogenic particles of marine origin, flows northward along the eastern coast until it reaches the region near Cape Ninilchik where it mixes with the outflowing brackish water. Comparison of suspended matter and sediment characteristics as well as regional sedimentation rates indicates that net sedimentation of suspended matter in the central basin of lower Cook Inlet is minimal. However, net sedimentation is occurring in the embayments along the coast.

ACCESS # : 371, LGL-TORONTO

CITATION : Foy, M.G. 1982. Acute lethal toxicity of Prudhoe Bay crude oil and Corexit 9527 to arctic marine fish and invertebrates. Technology Development Report EPS (CANADA) 4-EC-82-3. pp. 62.

KEY-WORDS: Crustacea; Toxicity; Fishes; Hydrocarbons; Invertebrates; Oil; Copepod; Amphipods; Zooplankton.

SYNOPSIS : The toxicities of Prudhoe Bay crude oil, the dispersant Corexit 9527 and mixtures of the two to several arctic marine amphipods, one arctic marine copepod and one arctic marine fish, collected from Resolute Bay or Frobisher Bay, NWT, were investigated. Toxicities were assessed by semi-static 96 h bioassays in which the concentrations of hydrocarbons were measured by fluorescense spectroscopy. The sensitivities of all species to a given toxicant were of the same order, with LC_{50} values ranging from 50 to 200 ppm. However, mortality in oil-Corexit-water mixtures was much higher than in oil-water mixtures of the same nominal oil concentration, the actual oil content in the water column being much higher in the presence of the dispersant than when the two phases were mechanically mixed. Hence the higher mortality of the chemically dispersed oil-water mixtures is attributed to the higher concentration of oil encountered by the test organisms. When compared on the basis of measured oil concentrations, the dispersant appeared to diminish the toxicity of the mixtures, possibly by lowering the level of soluble aromatics in the aqueous phase.

ATTACHMENT :

ACCESS # : 372, RAS-UAF

CITATION : Foy, M.G., S.I.C. Hsiao and D.W. Kittle. 1978. Effects of crude oils and the oil dispersant Corexit on primary production of arctic marine phytoplankton and seaweed. Environ. Pollut. 15 (3): 209-221.

KEY-WORDS: Oil pollution; Algae; Phytoplankton; Seaweeds; Primary production.

SYNOPSIS : The authors have carried out an in-situ study which showed that mixtures of crude oil and Corexit were more toxic than crude oil or Corexit alone. In water samples with the same algal species composition, inhibition of production of phytoplankton generally increased with increasing oil concentration; primary production of two seaweeds was significantly inhibited by all types and concentrations of oil tested. This information may provide a greater awareness of potential indirect effects of oil pollution upon higher trophic levels and fish stocks.

ACCESS # : 373, RAS-UAF

CITATION : Gray, R.H., R.W. Hanf, D.D. Dauble and J.R. Skalski. 1982. Chronic effects of a coal liquid on a freshwater alga, Selenastrum capricornutum. Environ. Sci. & Tech. 16(4): 225-229.

KEY-WORDS: Algae; Population; Toxicity; Petroleum; Coal liquid.

SYNOPSIS : The authors have used a modification of the standard EPA Bottle toxicity test to evaluate the effects of water-soluble fractions of a solvent-refined coal liquid on the unicellular freshwater green alga, Selensatrum capricornutum. Relative toxicities of fractions of a Prudhoe Bay crude oil and No.6 fuel oil were also evaluated. Population response was measured during and after exposure to fractions prepared by sequentially extracting a blend of solvent refined coal middle heavy distillates with Columbia river water. The Prudhoe Bay crude and No.6 fuel oil were less toxic than coal liquid. Evidence was found of enhancement of algal populations at low concentrations of the water soluble fractions of the coal liquid.

ACCESS # : 374, IMS-UAF

CITATION: Green, F. 1976. EPA's view of projected oil drilling on the continental shelf. Sea Technol. 17(10): 10-13.

KEY-WORDS: Oil pollution; Coastal habitats.

SYNOPSIS : Offshore oil and gas development should allow for the husbanding of the living resources of the sea and the safeguarding of onshore values such as, recreational land, salt marshes, and human health. Since potential pollution from development of the OCS would directly threaten the coastal zone, guidelines are offered to oil drillers to prevent ecological disasters. More research is needed before the full effects of seabed oil extraction, toxicity of petroleum compounds in the food chain, and oil leaks among marine organisms can be determined. Present OCS policies are inadequate and must be reworked to include operating orders for new sites on the Atlantic Coast, Alaska, or Southern California. Coordination and planning among responsible federal and state agencies must improve. Sophisticated detection equipment is recommended to track major oil spills. A glaring omission in the overall spill prevention program is that regulations for transportation activities such as pipelines, railroads, and trucks have not yet been formulated. Safety measures could also be bolstered by additional funding for the Coast Guard patrol and clean-up activities.

ACCESS # : 375, RAS-UAF

CITATION : Griffiths, R.P., T.M. McNamara, B.A. Caldwell and R.Y. Morita. 1981. Field observations on the acute effect of crude oil on glucose and glutamate uptake in samples collected from arctic and subarctic waters. Appl. Environ. Microbiol. 41(6): 1400-1406.

KEY-WORDS: Oil pollution; Micro organisms; Sediments.

SYNOPSIS : The acute effects of crude oil on glucose uptake rates by marine microorganisms were studied in 215 water and 162 sediment samples collected from both arctic and subarctic marine waters. The mean percentage reduction of glucose uptake rates ranged from 37 to 58 in the water samples exposed to crude oil and from 14 to 36 in the sediment samples. Substrate uptake kinetic studies indicated that the observed reductions by microbial populations exposed to crude oil were caused by metabolic inhibition. The effect of crude oil was less in sediments than in the water samples, with the difference being significant at the P 0.0002 level. With the exception of one sediment study, all of the differences observed in the uptake rates between treated and nontreated samples were statistically significant. A high degree of variability was observed in the degree which glucose and glutamate uptake rates were altered in water samples exposed to crude oil. In some cases, uptake rates were greater in the samples exsposed to crude oil. Data on samples collected in Cook Inlet probably chronically exposed to crude oil are also the areas where the effects of crude oil on glucose uptake are the lowest. Two studies indicated that after pelagic populations are exposed to crude oil for several days, the heterotrophic population adjusts to the presence of crude oil.

ACCESS # : 376, RAS-UAF

CITATION : Griffiths, R.P., T.M. McNamara, B.A. Caldwell and R.Y. Morita. 1981. Field study on the acute effects of the dispersant Corexit 9527 on glucose uptake by marine microorganisms. Mar. Environ. Res. 5(2): 83-91.

KEY-WORDS: Oil pollution; Microorganisms; Monosaccarides; Sediments; Glucose; Water column.

SYNOPSIS : The effects of the dispersant Corexit 9527 and Corexit with crude oil on the rate of glucose uptake and mineralization were studied in Arctic and subarctic marine waters and sediments. Essentially all of the 149 water and 95 sediment samples tested displayed decreased glucose uptake reates in the presence of either 15 or 50 ppm Corexit. Depressed uptake rates were observed at concentrations as low as 1 pm. The mean concentration at which Corexit depressed glucose uptake by 50% was 12 ppm. The effect of Corexit was more pronounced on pelagic than on benthic microbial populations.

ACCESS # : 377, ARL

CITATION : Griffiths, R.P., and R. Y. Morita. 1978. Study of microbial activity and crude oil-microbial interactions in the waters and sediments of Cook Inlet and the Beaufort Sea. Quarterly Reports of Principal Investigators for April-June. pp. 204-246. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil spills; Biological degredation; Micro organisms; Sediments; Water column; Nitrogen fixation.

SYNOPSIS : Studies of relative microbial activity and respiration (mineralization) ratios of natural microbial populations found in water and sediment found in water and sediment samples are continued. Areas which are shown to have particularly high activity should be those in which crude oil will be degraded at higher rates. These areas probably support the highest overall biological activity and as such may be the areas which will be most affected by the presence of crude oil. These data may also be used in the future to estimate the degree of perturbation caused by chronic crude oil input. The studies include crude oil effects on microbial functions as measured by uptake and respiration characteristics using several labeled compounds. They also include the study of nitrogen fixation and the effects of crude oil on this process.

ACCESS # : 378, RAS-UAF

CITATION : Hanna, B.M., J.A. Hellebust and T.C. Hutchinson. 1975. Field studies on the phytotoxicity of crude oil to subarctic aquatic vegetation. Vereinigung Limnologie. 19: 2165-2171.

KEY-WORDS: Primary production; Chlorophyll a; Oil pollution; Aquatic plants.

SYNOPSIS : To determine the effect of an oil pipeline spill on lakes and ponds in the arctic, oiled and control test cylinders were established in a small lake. Algal species showed reduced productivity after introduction of crude oil into the system. Moss also showed a reduction in productivity that was not statistically significant in terms of control productivity. Chlorophyll A and B concentrations for sedge and horsetails showed significant reductions from surface contamination with oil. Baseline data on several growth parameters of a vegetative subarctic aquatic community were established.

ACCESS # : 379, NMFS

CITATION : Hawkes, J.W. 1978. Morphology. In: NOAA Tech. Memorandum ERL OCSEAP-1 Marine Biological Effects of OCS Petroleum Development. pp. 87-92.

KEY-WORDS: Oil pollution; Salmonids; Fish; Physiology.

SYNOPSIS : The two major objectives are to identify the effects of petroleum on fish at the cellular level and to establish which tissues show that most obvious and repeatable structural alterations. A series of experimental designs have been followed to assess the effects of Prudhoe Bay crude oil or its water-soluble fraction on both pelagic and demersal species and on adult and young. The findings are reported by considering each major target organ and describing the alterations observed for each type of experiment and variation. The common theme is the type of cellular response of selected organs or tissues to toxic substances; namely, petroleum hydrocarbons. The observed liver changes parallel hepatic alterations known for other animals to be pre-neoplastic. The changes indicate that the ability of fish to survive additional routine environmental stress may be reduced, because of depletion of energy reserves or reduced liver functions.

ACCESS # : 380, EPA

CITATION : Hayes, M.O., G.I. Scott, W. P. Davies, C. D. Getter and E. R. Gundlach. 1980. Methodology for environmental assessment of oil and hazardous substance spills. Helgolander Meeresuntersuchungen. 33: 246-256.

KEY-WORDS: Geology; Oil spills; Ecology.

SYNOPSIS : An integrated zonal method for assessment of the ecological impact of oil spills is proposed which utilizes a team of 3-4 people (geologists and biologists) who undertake geological mapping and quantitative biological surveys within the affected area defining the nature of the ecosystem and the extent of penetration of the oil. The immediate survey is followed by regular monitoring at prescribed intervals to evaluate chronic effects. The scope of the method and its application in practice are described with reference to the Peck Slip oil spill off the northeast coast of Puerto Rico and the attendant pollution of mangrove forests along the coast. In addition the concept of a vulnerability index is developed as an aid to pre-spill contingency planning and some examples of its appication are given, especially in the Cook Inlet portion of the southern Alaskan coastline.

ACCESS # : 381, NMFS

CITATION : Hodgins, H.O. 1978. Physiological and behavioral effects. In: NOAA Tech. Memorandum ERL OCSEAP-1. Marine Biological Effects of OCS Petroleum Development. pp. 72-86.

KEY-WORDS: Oil pollution; Physiology; Salmonids; Hydrocarbons; Fishes; Invertebrates; Behavior.

SYNOPSIS : Physiological and behavioral studies were designed as laboratory experiments--with the notable exception of field studies of salmon homing--to evaluate effects of sublethal petroleum exposure on species indigenous to the North Pacific Ocean tested under natural water quality and temperature conditions. The studies have provided clear implications that in certain instances heavy exposures of fish to the petroleum have little effect on physiology; whereas, in other instances, severe effects may result from light to moderate exposures to petroleum. In the category of severe exposure--little effect are the studies of oil in the diet on trout reproduction, and the disease resistance research with salmon and trout. In both of these studies high doses of crude oil in diets induced little or no detectable physiological impairment. Conversely, exposure of spot shrimp and dorid nudibranchs to ppb levels of petroleum in seawater resulted in potentially disastrous effects on feeding behavior, reproductive behavior, or embryogenesis. Other studies such as effects of petroleum on salmon migration, may fall somewhere between the above two extremes.

ACCESS # : 382, RAS-UAF

CITATION : Hsiao, S.I. 1978. Effect of crude oil on the growth of arctic marine phytoplankton. Environ. Poll. 17(2): 93-107.

KEY-WORDS: Oil pollution; Phytoplankton; Growth.

SYNOPSIS : Growth responses of arctic marine phytoplankton to crude oils were determined at various temperatures and exposures in a defined medium at constant light energy. The growth of diatoms Chaetoceros spetentrionalis, Navicula bahusiensis, and Nitzachia delicatissima was inhibited by Atkinson Point, Norman Wells, Pembina, and Venezuela crude oils after 10 d exposure at a concentration of 10 ppm at 0 deg, 5 deg, and 10 deg, C. Growth of both diatoms and the green flagellate was markedly inhibited by oil concentrations K100 ppm, but diatoms were more severely impaired than the green flagellate. Greater inhibition generally occurred with longer exposure at temperatures between 5 deg and 10 deg C than at 0 deg. C. Chlamydomonas was not killed by any of the crude oils at the concentrations, temperatures, and lengths of exposure tested. Lethal effects among diatoms varied with species, types of oil, temperatures, and lengths of exposure tested. Lethal effects among diatoms varied with species, species sensitivity of the phytoplankton to the oils was determined based on percentage survival, exponential growth rate, and generation time. Chlamydomonas was the most tolerant species and had a greater ability to resume growth, while diatoms were sensitive and had little or no ability to resume growth. Possible ecological consequences of such species sensitivity and differential growth are discussed.

ACCESS # : 383, RAS-UAF

CITATION : Hsiao, S.I.C., D.W. Kittle and M. G. Foy. 1978. Effects of crude oils and the oil dispersant Corexit on primary production of arctic marine phytoplankton and seaweed. Environ. Poll. 15(3): 209-221.

KEY-WORDS: Oil pollution; Primary production; Phytoplankton; Seaweeds.

SYNOPSIS : Effects were studied in-situ. The production rate varied with types and concentrations of crude oil, method of preparation of oil-seawater mixtures, environmental conditions, and species composition of each sample tested. In samples with the same species composition, inhibition of production generally increased with increasing oil concentration. The crude oil-Corexit mixtures were more toxic than crude oil or Corexit alone. In-situ primary production of the seaweeds Laminaria saccharina and Phyllophora truncata was significantly inhibited by all types and concentrations of oil tested.

ACCESS # : 384, ARL

CITATION : Jones, M.M. 1980. Environmental permitting for drilling in offshore areas: comments on the selection process for drilling fluids. Proceedings of Twelfth Annual Offshore Technology Conference. Houston, TX. May 5-8, 1980. Vol. 1. pp. 255-262.

KEY-WORDS: Toxicity; Water pollution; Petroleum development; Drilling mud.

SYNOPSIS : The decision-making process is examined with regard to the selection of drilling fluids in obtaining environmental permits for offshore drilling. Increased exploration and production in offshore areas has been linked to heightened environmental concerns for the impact of drilling fluids on the existing biota. As an example of the decision-making process, a case study of toxicity testing on two mud additives (a defoamant and a lubricant) for use in the Alaskan Outer Continental Shelf (OCS) is presented. Acute toxicity test results with brine shrimp nauplii (Artemia salina) are presented and compared to recommended application rates. The ensuing decision-making process is briefly described and the final regulatory and corporate decisions to accept one and reject the other are discussed. Existing hierarchical toxicity testing protocols (developed primarily for pesticides) are reviewed for their sensitivity to many biological, chemcial logistical, and economic constraints specific to drilling fluids. A modified toxicity testing protocol is presented which considers the factors and can be expanded for additional consideration of site-specific factors.

ACCESS # : 385, NMFS

CITATION : Karrick, N.L., and E.H. Gruger, Jr. 1976. Pollution in the northeast Pacific Ocean. Mar. Fish. Rev. 38(11): 2-19.

KEY-WORDS: Pacific Ocean; Water pollution; Sublethal effects; Industrial development.

SYNOPSIS : The relative freedom from pollution in the northwest Pacific Ocean has been an accident of geography and timing, especially a lower rate of industrialization and settlement than on other US coasts. Other important factors are the prevalence of on-shore winds and currents and the relatively narrow continental shelf with sharp dropoff. Emphasis in this report is directed toward use of coastal waters of northwestern North America for disposal of wastes from domestic, industrial, and agricultural activities, and toward criteria for evaluating effects on marine life. The following topics are addressed: (1) environmental factors, including physical environment, oxygen levels, temperature, and salinity; (2) contaminants, including physical transport, distribution, and toxicology (acute lethal and chronic sublethal effects); (3) short- and long-term effects of pollutants on marine life; and (4) contaminants discharged into the northeast Pacific, including domestic wastes (timber industry, logging, forest products, agriculture, food processing, aluminum production, metals, chloralkali plants, petroleum refining and drilling, nuclear plants). A table shows sources and characteristics of contaminants to the area. The existence of pollution is evidenced by contaminated estuaries and levels of chlorinated hydrocarbons, such as DDT and PCBs, in the fat of marine mammals.

ACCESS # : 386, ARL

CITATION : Kooyman, G., R. Davies and M. Castellini. 1977. Conductance of immersed Pinniped and sea otter pelts before and after oiling with Prudhoe Bay Oil. In: D.A. Wolfe (ed), Fate and Effects of Petroleum Hydrocarbons in Marine systems and Organisms. Pergammon Press, NY. pp. 151-157.

KEY-WORDS: Fur seals; Sea lion; Walrus; Sea Otter; Thermoregulation; Oil pollution; Marine mammals.

SYNOPSIS: Thermal conductance (C) of the sea otter and several species of pinniped pelts was determined during immersion, after oiling, and after cleaning. A (C) of 7 Watts/(m^2 x ^oC) for the sea otter pup was the lowest measured in all controls. The highest was 58 W /(m^2 x ^oC) for the California sea lion. Most affected by oiling was the sea otter pup in which (C) doubled. Least affected was the sea lion in which no change in (C) occurred. Washing slightly reduced (C) of the adult otter and fur seal. The results indicate that even a light oiling would have marked detrimental effects on thermoregulatory abilities of otters and fur seals at sea. The thermal effects of oil on other adult pinnipeds while at sea would be slight.

ACCESS # : 387, ARL

CITATION : Korn, S., D.A. Moles, and S.D. Rice. 1977. Effects of low temperature on the survival of pink salmon and shrimp exposed to toluene, naphthalene, and the water-soluble fraction of Cook Inlet crude oil. Principal Investigator Reports for Year Ending March 1977. Vol.12. pp. 66-84. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Shrimp; Temperature; Salmon; Cook Inlet.

SYNOPSIS : Toxicity tests were conducted at different temperatures to determine the effects of temperature on survival of shrimp and fish exposed to oil & oil component solutions. Exposure concentrations declined with time, and at differnt rates for each temperature, simulating a point source spill in the environment. Shrimp (Pandalus goniurus and Eualus spp.) and pink salmon (Oncorhynchus gorbuscha) were tested (96 h bioassays) with toluene, naphthalene, and the water-soluble fraction (WSF) of Cook Inlet crude oil at 4 degrees, 8 degrees and 12 degrees C. Median tolerance limits (96-h TLM) were computed by probit statistics. Oil concentrations were measured by ultraviolet spectrophotometry. The effect of different temperatures on the toxicity of toluene, naphthalene, and the WSF of Cook Inlet crude oil solutions depended on species and toxicant. Survival of shrimp exposed to toluene and naphthalene was significantly less at higher temperatures. In contrast, survival of pink salmon exposed to toluene was significantly less at lower temperatures. Other tests did not yield significant temperature effects.

ACCESS # : 388, ARL

CITATION : Larrance, J.D. 1978. Composition and Source Identification of Organic Detritus in lower Cook Inlet. Annual Reports of Principal Investigators for the Year Ending March 1978. Vol. VII. pp. 334-349. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Fisheries; Plankton; Detritus; Cook Inlet; Benthos; Petroleum development; Food web.

SYNOPSIS : Offshore petroleum development in lower Cook Inlet will provide a potential source of contamination of the environment by accidental large spills and chronic low-level oil pollution. Such pollution would undoubtedly have a harmful effect on important commercial fisheries in lower Cook Inlet. Benthic species harvested include snow, king, and Dungeness crab, shrimp, razor clams, and scallops. These are commercially harvested primarily within the rectangle bordered by Anchor Point, Kachemak Bay, the Barren Island, and Kamishak Bay. Some primary king crab recruitment grounds are within this area in the Bluff Point-Kachemak Bay region. The larval stages of these and other benthic species are planktonic and rely on phytoplankton as food. Adults in the benthic community ultimately depend on organic production from phytoplankton and other plants. Phytoplankton grazed by zooplankton enters the detrital food web via fecal pellet deposition. Other cells enter the benthos by sinking directly. As small sinking particles, the cells and pellets may act to transport oil from the surface to the bottom. Studies have indicated rapid removal and dispersal of surface oil by suspended particles. When oil enters seawater, emulsion of very tiny droplets can form. Some of the droplets become bound to particles by absorption and adsorption; they subsequently sink directly or are sedimented in fecal pellets after being ingested by zooplankton. Thus, ingestion and sorption act as precipitated mechanisms to transfer otherwise buoyant oil particles to the detrital food web.

ACCESS # : 389, ARL

CITATION : Larrance, J.D., D.A. Tennant, A.J. Chester and P.A. Rufio. 1977. Phytoplankton and primary productivity in the northeast Gulf of Alaska and lower Cook Inlet. Annual Reports of Principal Investigators for the Year Ending March 1977. Vol. 10. pp. 1-136. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Primary production; Phytoplankton; Oil pollution; Chlorophyll a; Nutrients; Hydrography.

SYNOPSIS : The phytoplankton and primary productivity studies in the northeastern Gulf of Alaska and lower Cook Inlet were designed to provide a baseline of phytoplankton standing stocks and rates of primary production in those areas. Measurements were made within the upper 50m of water of chlorophyll a, primary production, inorganic nutrient concentrations, temperature, salinity, and incident and underwater ambient irradiance. The several dominant phytoplankton species and their population densities were determined. The data have been examined for relationships to productivity and standing stocks in order to gain insights into the major forces which drive primary production. Although phytoplankton are likely to repopulate an area shortly following an oil spill, the species composition may be very different after prolonged contamination. The new dominant species may be inadequate to nourish grazers, and thus significant changes may occur in the food web. In addition to large spills, continuous or intermittent low-level contamination is almost certain to exist in the area around and downstream of an oil field. The resultant chronic effects on phytoplankton production are virtually unknown.

ACCESS # : 390, ARL

CITATION : Lee, R.F. 1975. Fate of petroleum hydrocarbons in marine zooplankton. Proceedings 1975 Conference on Prevention and Control of Oil Pollution. pp. 549-553.

KEY-WORDS: Oil pollution; Zooplankton; Copepods; Metabolism; Physiology; Toxicity; Amphipods.

SYNOPSIS : The uptake, metabolism, storage and discharge of petroleum hydrocarbons by marine zooplankton were discussed in light of the marine food web. Both paraffinic and polycyclic aromatic hydrocarbons were added to seawater containing various species of zooplankton-copepods, euphausiids, amphipods, crab zoea, ctenophores and jellyfish - collected off California, British Columbia and in the arctic. Hydrocarbons found included ^{3}H-Benzpyrene, ^{14}C-Benzyprene, ^{3}H-Methylcholanthrene, and ^{14}C-Napthalene.

ACCESS # : 391, ARL

CITATION : Lees, D.D., and W.B. Drldkell. 1981. Investigations on shallow subtidal habitats and assemblages in lower Cook Inlet. Final Reports of Principal Investigators. pp. 417-610. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Benthos; Oil pollution; Cook Inlet; Seaweeds; Invertebrates.

SYNOPSIS : The main objectives were to expand the available information base on shallow subtidal habitats in Kachemak and Kamishak Bays, to describe the large horse mussel (Modiolus) assemblage in more detail, and to examine the trophic structure of shallow subtidal assemblages. Major emphasis was given to rocky substrates. Three important types of assemblages were observed on shallow subtidal rocky habitats. The southern Kachemak Bay assemblage, strongly resembling shallow subtidal rocky assemblages in the northeastern Pacific, was strongly dominated by kelps and is probably least vulnerable to impingement of oil contamination and least sensitive to the effects of an acute oil spill. The northern Kachemak Bay assemblage included an important kelp component but was strongly dominated by suspension feeders. Standing stocks of suspension feeders were very high. This assemblage is probably moderately vulnerable to impingement, but highly sensitive to the effects of an acute oil spill. The Western Cook Inlet assemblage, strongly resembling epifaunal assemblages in the Bering and Beaufort Seas, was strongly dominated by suspension feeders. Except in the intertidal and very shallow subtidal zones, kelps were absent. The area is probably highly vulnerable to impingement of oil contamination and highly sensitive to the effects of acute oil spills.

ACCESS # : 392, ARL

CITATION : Malins, D.C. 1977. Biotransformation of petroleum hydrocarbons in marine organisms indigenous to the arctic and subarctic. In: D.A. Wolfe (ed.), Fate and Effects of Petroleum Hydrocarbons in Marine Organisms and Ecosystems. Pergammon Press. New York, NY. pp. 47-59.

KEY-WORDS: Metabolism; Toxicity; Invertebrates; Plankton; Fish; Oil pollution.

SYNOPSIS : The metabolism of the aromatic hydrocarbon fraction of petroleum by marine organisms was evaluated. It was pointed out that studies on the effects of petroleum on marine organisms have centered on the parent hydrocarbons rather than the potentially toxic metabolites. The biochemical pathways used by various plankton, invertebrates and fish to metabolize aromatic hydrocarbons were discussed. Particular emphasis was directed toward metabolite alterations of enzyme systems, tissue locations of various metabolites, and possible mutagenic activity.

ACCESS # : 393, ARL

CITATION : Malins, D.C., E.H. Gruger, Jr., H.O. Hodgins & N. Karrick. 1978. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformation as reflected by morphological, chemical, physiological, pathological & behavioral indices. Annual Reports of Principal Investigators for the Year Ending March 1978. Vol. VII. pp. 12-146. OCSEAP/NOAA, Boulder, CO
KEY-WORDS: Metabolism; Oil pollution; Hydrocarbons; Trace metals; Vertebrates; Invertebrates; Sublethal effects.

SYNOPSIS : Primary objectives of this research were to define and evaluate: (1) the alterations in structure of eggs, larvae, livers, and tissues of fish after petroleum exposure; (2) the importance of skin and epidermal mucus in metabolism and disposition of petroleum hydrocarbons in salmonids and flatfish; (3) the uptake, metabolism, and elimination of petroleum aromatic hydrocarbons by salmonids and flatfish; (5) the enzymes (aryl hydrocarbon monooxygenases) that metabolize and detoxify or activate aromatic hydrocarbons in a variety of aquatic species; (6) the physiological and embryological effects of aromatic hydrocarbons on early life forms of invertebrates; (7) the pathological effects of exposure of flatfish to crude petroleum-contaminated sediment; (8) the effects of exposure to petroleum on diseased vertebrate and invertebrate species exposed to petroleum hydrocarbons. The conclusions of this program are summarized according to disciplinary areas of study.

ACCESS # : 394, ARL

CITATION : Malins, D.C., E.H. Gruger, Jr., H.O. Hodgins and D.D. Weber. 1977. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, as reflected by morphological, chemical, physiological, pathological, and behavioral indices. Annual Reports of Principal Investigators for the Year Ending March 1977. Vol. 12. pp. 125-298. OCSEAP/NOAA, Boulder, CO
KEY-WORDS: Oil pollution; Petroleum development; Shrimp; Salmon; Fishes; Physiology; Behavior.

SYNOPSIS : Several findings have implications with respect to petroleum effects on aquatic species and consequently to OCS oil and gas development. Most of the studies were designed laboratory experiments and the degree to which laboratory results can be directly applied to natural events remains a considerable problem. The observed susceptibility of postlarval and adult shrimp to very low levels of naphthalene in seawater strongly suggest that petroleum introduced into the environment of these and related animals would have substantial deleterious effects. Similarly, the observed structural changes in salmonid fish after hydrocarbon exposure, and the uptake and retention of toxic trace metals by salmon and flatfish imply that the presence of petroleum and trace metals at some concentrations in diet, water, or sediment would be harmful to these species. Controlled field studies on salmon homing indicated that low concentrations of hydrocarbons do not affect salmon homing behavior or ability and thus imply that petroleum hydrocarbons in the path of migrating salmon would not completely disrupt their migration. The fact that greater accumulations of hydrocarbons were found in exposed fish at 4 degrees C, as compared to 10 degrees C, suggests that cold water environments may substantially increase hydrocarbon burden under arctic conditions in comparison to temperate regions.

ACCESS # : 395, NMFS

CITATION : Malins, D.C., E.H. Gruger, H.O. Hodgins, N.L. Karrick and D.D. Weber. 1978. Sublethal effects of petroleum hydrocarbons and trace metals including biotransformations, as reflected by morphological, physiological, pathological, and behavioral indices. In: Marine biological effects of OCS petroleum development. D.A. Wolfe (ed), NOAA/ERL. Boulder, Colo. pp. 25-40.
KEY-WORDS: Trace metals; Oil pollution; Behavior; Physiology; Fishes; Invertebrates.

SYNOPSIS : A significant body of evidence has been accumulated to indicate that aromatic hydrocarbons are rapidly and progressively converted to metabolites in the pelagic and demersal fish and in invertebrate larval forms. The literature on animal systems in general affirms the concept that extremely low levels of arene oxides are damaging to biological systems in many ways, which includes their strong mutagenic and carcinogenic potential. The tendency of starry flounder to accumulate high proportions of metabolites in skin is of interest with respect ot their known susceptibility to lesion formation in this tissue. Evidence presented for the role of mucus in the excretion of naphthalene and metabolites in fish suggests that such exudates must be considered along with other routes of elimination which lead to the recycling of petroleum and metabolic products in the marine environment. The findings to date imply that the pelagic species may be less susceptible to accumulating aromatic hydrocarbons from the environment than the demersal species, although a wider variety of different organisms must be studied in each class to verify this hypothesis.

ACCESS # : 396, ARL

CITATION : Malins, D.C., H.O. Hodgins, B.B. McCain, D.D. Weber, U. Varanasi and D.W. Brown. 1980. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, as reflected by morpological, chemical, physiological, pathological, and behavioral indices. Annual Reports of Principal Investigators. Vol. 3. pp. 13-79. OCSEAP/NOAA, Boulder, Colo.
KEY-WORDS: Oil pollution; Physiology; Salmonids; Fishes; Trace metals; Food web; Chemistry.

SYNOPSIS : Results of this program have implications with respect to petroleum effects on aquatic species and consequently to OCS oil and gas development. The studies were designed as laboratory experiments on oil exposures of marine organisms in flowing-seawater tanks. Pink and chum salmon fry spend several months in coastal estuaries before going to sea, and at this life stage they are extremely vulnerable to predation by other salmonid fishes. Predator-prey studies are in progress to determine if fry are affected by petroleum differentially from adult predators so that they suffer substantially increased predation. Pleuronectid fish were able to take up BP from oiled sediment and diet and convert it extensively into mutagenic and carcinogenic metabolites. The results show that metabolites of BP were retained in tissues of flatfish over a much longer period than napthalene and its metabolites. The presence of PAH and their metabolites in edible tissues can also have a serious impact on consumer acceptability of fish. Fresh and weathered oil exposure would result in high mortality of flatfish embryos and larvae. Also, flatfish eggs exposed to fresh and weathered PBCO were frequently ruptured. Exposure to chum salmon and surf smelt eggs to the SWSF of weathered crude oil also resulted in reduced survival.

ACCESS # : 397, ARL

CITATION : Malins D.C., H.O. Hodgins, N.L. Karrick, D.D. Weber. 1979. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformation, as reflected by morphological, chemical, physiolocial, pathological, and behavioral indices. Annual Reports of Principal Investigators for the Year Ending March 1979. Vol. 6. pp. 60-71. OCSEAP/NOAA, Boulder, CO
KEY-WORDS: Oil pollution; Fishes; Behavior; Sediments; Physiology.

SYNOPSIS : The overall objective of this program was to assess potential effects of petroelum and petroleum-related operations on marine organisms indigenous to Alaskan waters. Several principal objectives addressed by this research were: (1) to evaluate the effect ofpetroleum onsensory systems and behavior of marine species (2) to investigate the metabolism and disposition of petroleum hydrocarbons in demersal fish (3) to develop and refine ultrastructural criteria for assessing cellular damage in marine organisms resulting from exposure to petroleum (4) to detect and characterize pathological changes resulting from the exposure of flatfish to sediments contaminated with crude oil (5) to determine if petroleum-exposed eggs and larvae of salmon and flatfish develop abnormally, and to evaluate the effect of any detected abnormalities on survival. The conclusions of this program are summarized according to disciplinary areas of study.

ACCESS # : 398, ARL

CITATION : Malins, D.C., E.H. Gruger,Jr., H.O. Hodgins, N.L. Karrick and D.D. Weber. 1978. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, as reflected by morphological, chemical, physiological, pathological, and behavioral indices. Reports of Principal Investigators for April-June 1978. pp. 82-99. OCSEAP/NOAA, Boulder, CO
KEY-WORDS: Trace metals; Oil pollution.

SYNOPSIS : The responses of marine organisms to environmental contaminants are reflected in numerous changes that are detectable at population and organismic levels, as well as at cellular and molecular levels. The general scope of this study is to evaluate effects caused by behavioral, physiological, pathological, morphological, and chemical changes in subarctic and arctic marine animals exposed to petroleum hydrocarbons and trace metals.

ACCESS # : 399, ARL

CITATION : Malins, D.C., H.O. Hodgins and D.D. Weber. 1976. Sublethal effects as reflected by morphological, chemical, physiological and behavioral indices. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. OCSEAP/ NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Ecology; Salmon; Physiology; Fishes.

SYNOPSIS : Preliminary experiments in cell biology indicated that the liver of trout (Salmo gairdneri) is a primary site of alteration in biochemical activity when the fish ingest crude oil. The liver showed two major changes: a depletion of energy storage products, glycogen and lipid, and an increase in the endoplasmic reticulum, a component of cells that is instrumental in protein synthesis. When Coho salmon, (Oncorhynchus kisutch) and English sole (Paraphrys vetulus) were immersed in a sublethal concentration of water-soluble fraction of crude oil there appeared to be a depletion of mucus from the producing cells at the skin surface. These cellular changes are considered to be symptomatic of deleterious effects of petroleum oil on all three species of fish. In contrast, in related experiments, the feeding of intentionally high levels (one part/1000 oil in food) of crude oil to sexually maturing trout for six months did not result in mortality or grossly detectable damage prior to spawning: nor did it appear to impair the viability of their eggs and sperm.

ACCESS # : 400, IMS-UAF

CITATION : Mann, K.H. 1978. A biologist looks at oil in the sea. Shore and Beach 46 (4): 27-29.

KEY-WORDS: Ecosystems; Stress; Oil pollution; Decomposition; Ecology.

SYNOPSIS : Long and short-term effects of oil pollution in the sea are studied. Precise predictions of the harmful effects of such pollution from a biological standpoint are virtually impossible because of the variability and adaptability of marine animal and plant life. Dynamic modeling of this natural ecosystem has never been successful because of these variances. Oil spills that occur in the open sea have a less harmful effect than those occurring in nearshore waters. Organisms that die and decompose in the open ocean tend to sink to deeper waters where they release N and P compounds needed for plant growth; ocean currents subsequently transport these nutrients to marine communities that thrive in nearshore waters. When oil pollutes the coastal waters damage is felt in differing degrees depending upon the type of oil spilled and the type of life existing there. Following cleanup, it usually takes 10 yr for plant and animal life to repopulate in temperate waters. Because of cold temperatures, a short growing season, and long periods under ice, there is less species diversity in the arctic. Since this marine life naturally abides under stressed conditions, the further stress of an oil spill could be catastrophic for these ecosystems. The effects of potential oil spills in arctic waters are examined. The subject of sublethal effects of oil on individual organisms is not fully understood; more time and money should be allocated to the study of both basic and applied aspects of ecology.

ACCESS # : 401, RAS-UAF

CITATION : Mann, K.H., and R.B. Clark. 1978. Long-term effects of oil spills on marine intertidal communities. J. Fish. Res. Bd. of Can. 35(5): 791-795.

KEY-WORDS: Oil pollution; Sediments; Toxicity; Ecosystems; Hydrocarbon; intertidal habitats.

SYNOPSIS : The title of this symposium is "Recovery Potential of Oiled Marine Northern Environments". It is clear from the case histories of oil spills reported here that the potential for recovery is indeed present. In most cases, within 10 years of a single incident the community structure has returned to something approaching its normal state. The rate of recovery depends on many factors. One is the toxicity and quantity of oil involved; light fuel oil is much more toxic than crude oil or bunker oil and causes much greater environmental damage. Another is the nature of the shoreline on which the oil is stranded; on a high-energy, rocky shore, the oil is dispersed and removed by wave action much more quickly than on a sheltered, sedimented site, where the oil may become incorporated in sediments, persist for many years, and cause chronic perturbations to the ecosystem. A third is the biology of the organisms that have been affected. Organisms with little or no mobility and slow rates of reproduction will take much longer to recolonize a damaged area than species that produce large numbers of young that are widely dispersed. Since the former is a characteristic reproductive pattern for many organisms living in high latitudes, recovery of damaged arctic environments may be much slower than that of the temperate and subboreal environments that were the subjects of these investigations.

ACCESS # : 402, ARL

CITATION : Mecklenburg, T.A., and S.D. Rice. 1977. Effects of Cook Inlet crude oil, benzene, and naphthalene on heart rates of the Alaskan king crab (Paralithodes camtschatica). Principal Investigators' Reports for the Year Ending 1977. Vol. 12. pp. 85-125. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Crabs; Oil pollution; Sublethal effects; Naphthalene; Physiology; Paralithodes camtschatica; Crustacea.

SYNOPSIS : Continuous monitoring of heart rates during exposure to toxicants was found to be a sensitive indicator of sublethal responses in the King crab, Paralithodes camtschatica. In exposures to water-soluble fractions of Cook Inlet crude oil, benzene, and naphthalene, the heart rate response was consistently one of depression, followed by return to normal as the crude oil or aromatic concentrations in the seawater declined. In one of the experiments with crude oil, respiration was also monitored; it closely paralleled the changes in heart rate. In another, using periodically replenished crude oil water-soluble fractions, the heart rate remained depressed until the oil concentration was allowed to drop. Benzene produced more severe and longer-lasting heart rate depressions than did naphthalene or crude oil; the response of benzene also occurred much sooner after initial exposure. The long-lasting sublethal effect of benzene was evident even though the benzene degraded more rapidly in the water than either crude oil or naphthalene. All of the experiments substantiated a strong relationship between oil or aromatic fraction degradation and heart rate recovery.

ACCESS # : 403, ARL

CITATION : Mecklenburg, T.A., S.D. Rice and J.F. Karinen. 1977. In: D.A. Wolfe (ed.), Fate and Effects of Petroleum Hydrocarbons in Marine Organisms and Ecosystems. Pergammon Press, New York, NY. pp. 221-228.

KEY-WORDS: Oil pollution; Mortality; Toxicity; Shrimp; Crabs; Larvae; Crustacea.

SYNOPSIS : Larvae of the Coonstripe shrimp and King crab were exposed to solutions of the water-soluble fraction (WFS) of Cook Inlet crude oil in a series of bioassays on intermolt stages I and II and the molt period from stage I to stage II. Molting larvae were more sensitive than intermolt larvae to the WSF, and molting King crab larvae. When molting larvae were exposed to high concentrations of the WSF for as little as 6 hr, molting success was reduced by 10-30% and some deaths occurred. When larvae were exposed to these high concentrations for 24 hr or longer, molting declined 90-110% and the larvae usually died. The lowest concentrations tested did not inhibit molting at any length of exposure, but many larvae died after molting. Median lethal concentrations (LC_{50}'s) based on 144 hr of observation for molting Coonstripe shrimp and 120 hr for molting King crab were much lower than the 96-hr LC_{50}'s showing that the standard 96-hr LC_{50} is not always sufficient for determining acute oil toxicity.

ACCESS # : 404, ARL

CITATION : Mickelson, P.G., W. Lehnhausen, S.E. Quinlan. 1978. Community structure of seabirds of Wooded Island, Alaska. Principal Investigators' Reports for the Year Ending March 1978. Vol. III. pp. 680-772. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Seabirds; Oil pollution; Gulf of Alaska; Wooded Islands; Community structure.

SYNOPSIS : Information was obtained about the breeding distribution, abundance, phenology, and productivity of seabirds using Wooded Island in the Gulf of Alaska. Major seabird species on Wooded Islands, and those discussed in this report are: Tufted Puffins, Fork-tailed Storm Petrels, Glaucous-winged Gulls, Cormorants (Double-crested, Pelagic, and Red-faced), Pigeon Guillemots, Common Murres, Parakeet Auklets, and Horned Puffins. Wooded Islands may become an attraction to tourists and residents of Alaska because of their accessible location and the variety of breeding seabirds and marine mammals they harbor. Wooded Islands and the surrounding waters are threatened with oil pollution in the near future. Outer Continental Shelf oil and gas exploration has already begun in the northern Gulf of Alaska. Oil tankers are carrying crude oil south by Wooded Islands from the Valdez terminal of the Trans-Alaska oil pipeline. The effects of oil spills on Wooded Islands seabirds and other birds using the area depends largely upon the amount of oil spilled, the time of year of the spill, the stage of tides, wind velocity when oil reaches Wooded Islands area, and the success of clean-up measures. In summary, oil spills can produce a variety of direct and indirect effects which reduce the survival of birds. All possible caution should be used to minimize the probability of a large oil spill. Chronic low level oil pollution especially should be minimized. It is potentially more dangerous to the ecosystem than catastrophic spills since food organisms may concentrate hydrocarbons and remain contaminated for several years

ACCESS # : 405, NW&AFC

CITATION : Moles, A. 1980. Sensitivity of parasitized coho salmon fry to crude oil, toluene, and naphthalene. Trans. Amer. Fish. Soc. 109(3): 293-297.

KEY-WORDS: Fish; Larvae; Oil; Salmon; Toxicity; Bivalves; Naphtalene; Toluene; Parasitism.

SYNOPSIS : Coho salmon fry (Oncorhynchus kisutch) infested with Anodonta oregonensis derived glochidia and exposed to naphthalene had a 96-hour LC_{50} value of 0.77 mg per litre, compared to the control fish LC_{50} value of 3.22 mg per litre; the respective LC_{50} values after exposure to toluene were 3.08 ul per litre and 9.36 ul per litre. The effect of the extent of parasitism and toxicant on the fry was nearly additive. The tolerance limit for the three toxicants was 30-40 per cent below that for fish without parasitic infections. Glochidia, although not toxic to fish per se, decrease the energy resources available to the fish, increasing their sensitivity to all the toxicants.

ACCESS # : 406, NW&AFC

CITATION : Moles, A, A. Bates, D. Rice, and S. Korn. 1981. Reduced growth of coho salmon fry exposed to two petroleum components, toluene and naphthalene, in fresh water. Trans. Amer. Fish. Soc. 110: 430-436.

KEY-WORDS: Salmonids; Naphthalene; Toluene; Sublethal effects; Physiology.

SYNOPSIS : Coho salmon, Oncorhynchus kisutch, fry were exposed for 40 days to stable, sublethal concentrations of toluene (0.4, 0.8, 1.6, 3.2, 5.8 ul/liter) and naphthalene (0.2, 0.4, 0.7, 1.4 mg/liter) in fresh water. All fry were fed equal rations of Oregon Moist Pellet Formula II. Dry weights, wet weights, and lengths of fry exposed to the two highest concentrations of each toxicants for 40 days were significantly less than controls ($P < 0.01$). Growth per day, determined from weights and lengths, decreased linearly with increased concentrations. Fry exposed to naphthalene had a slower growth rate than fry exposed to equivalent concentrations (percentage of the 96-hour median lethal concentration or LC_{50}) of toluene. Concentrations 18% of the LC_{50} of naphthalene and 26% of the LC_{50} of toluene had no effect on dry weight, wet weight, or length of exposed fry.

ACCESS # : 407, NW&AFC

CITATION : Moles, A., S.D. Rice, and S. Korn. 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. Trans. Amer. Fish. Soc. 108(4): 408-414.

KEY-WORDS: Salmon; Toxicity; Petroleum; Hydrocarbons; Prudhoe Bay; Sculpins. Fishes.

SYNOPSIS : Freshwater juveniles of the 6 salmonid species tested had similar sensitivities in the 96-hour toxicity tests. Median tolerance limits (TLm's) of these salmonids for crude oil ranged from 2.7 to 4.4 mg/L; TLm's of benzene ranged from 11.7 to 14.7 muL/L. Threespine sticklebacks Gasterosteus aculeatus and, to a lesser extent, slimy sculpins Cottus cognatus were more tolerant than salmonids and had larger TLm's: threespine sticklebacks had a crude-oil TLm of 10.4 mg/L and a benzene TLm of 24.8 muL/L; slimy sculpins had a crude-oil TLm of 6.44 mg/L and a benzene TLm of 15.4 muL/L. Eggs of pink salmon Oncorhynchus gorbuscha and coho salmon O. kisutch were quite tolerant to crude oil (TLm > 12 mg/L) and benzene (TLm=339-542 muL/L). Emergent fry were the most sensitive freshwater stage (crude-oil TLm=8.0 mg/L; benzene TLm=12.3-17.1 muL/L). Out-migrant salmonids, tested in seawater, were twice as sensitive as out migrant salmonids tested in freshwater, probably due to the additional stress of entering seawater and the physiological changes associated with this transition. Freshwater TLm's were 2.3-8.0 mg/L for crude oil and 10.8-17.1 muL/L for benzene. Corresponding seawater sensitivities were 1.1-3.6 mg/L for crude oil and 5.5-8.5 muL/L for benzene.

ACCESS # : 408, IMS-UAF

CITATION : Morita, R.Y., B.A. Caldwell, R.P. Griffiths, and T.M. McNamara. 1981. A field study on the acute effects of the dispersant Corexit 9527 on glucose uptake by marine micro-organisms. Mar. Environ. Res. 5(2): 83-91.

KEY-WORDS: Oil pollution; Sediments; Glucose; Microbiology.

SYNOPSIS : Samples of water and sediment were collected from four areas along the Alaskan coast and used to study the effects of the oil dispersant Corexit 9527, and Corexit with crude oil, on microbial function in the marine environment. The results, reported with maps and tables, show that Corexit depresses glucose uptake rates, and it was found to affect the pelagic microbial populations more than the benthic microbial populations.

ACCESS # : 409, ARL

CITATION : Morita, R.Y., and R.P. Griffiths. 1976. Baseline study of microbial activity in the Beaufort Sea and Gulf of Alaska and analysis of crude oil degradation by psychrophilic bacteria. Principal Investigators' Reports for the year ending March 1976. Vol 10. pp. 147-191. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Micro-organisms; Water pollution; Sediments; Bacteria; Biological degradation.

SYNOPSIS : The levels of potential glutamic acid uptake observed in water samples taken from the Beaufort Sea were as high as those observed in other relatively productive marine waters. In both Barrow and Prudhoe Bay there were locations which consistently showed higher levels of potential microbial activity. When the effects of incubation temperature on the maximum potential velocity of glutamic acid uptake were studied, it was found that there was a marked increase with increasing incubation temperature. Studies on the effects of melted ice water on heterotrophic potential data suggest that when melting ice water is released into the surrounding seawater, there is little effect on the observed microbial activity or the percent respiration. The acute effects of crude oil on the uptake and respiration of glutamic acid were studied by adding an aqueous crude oil extract to the reaction bottles used to determine heterotrophic potential. No consistent alteration in function was observed when the extract was added. Changes in the heterotrophic potential with time were studied in a natural microbial population exposed to crude oil using both labeled glutamic acid and acetate. In the initial stages of incubation, the levels of activity were lower in the crude oil enrichment but as incubation progressed, the levels of activity increased. Sulfate reducing bacteria appear to be very common in the inshore sediments of the Beaufort Sea. Psychrophilic crude oil degrading bacteria are probably quite rare in the waters of the Beaufort Sea.

ACCESS # : 410, IMS-UAF

CITATION : Morrow, J.E. 1973. Oil-induced mortalities in juvenile coho and sockeye salmon. J. Mar. Res. 31: 135-143.

KEY-WORDS: Fish; Oil pollution; Transport; Toxicity; Salmon; Temperature.

SYNOPSIS : Laboratory experiments were carried out, under conditions simulating those of the Alaskan fisheries areas, to investigate the possible effects of oil pollution on juvenile coho and sockeye salmon, with reference to the proposed Trans-Alaska oil pipeline. The results are tabulated and show that there were significant increases in mortality rates of fish, for all the tested oil concentrations, ranging from 500 to 3500 ppm and for all tested water temperatures; 3, 8, and 13 C. Mortality rates were found to be directly related to oil concentration, and inversely to temperature, and crude oil was found to lose its toxicity to salmon after exposure to air, possibly through loss of volatile toxic components.

ACCESS # : 411, RAS-UAF

CITATION : Mozley, S.C., and M.G. Butler. 1978. Effects of crude oil on aquatic insects of tundra ponds. Arctic 31(3): 239-241.

KEY-WORDS: Insects; Aquatic animals; Ponds; Oil pollution.

SYNOPSIS : Aquatic insects comprise most of the biomass and production of tundra thaw ponds. Field experiments on two ponds with application rates of about 10 l/m.SUP-2 (Pond E 1970) and 0.24 l/m.SUP-2 (Pond . 1975) resulted in the selective elimination of Asynarchus (Trich., Limnephilidae) and Nemoura (Plec., Nemouridae). Chironomidae in Pond . displayed much lower rates of adult emergence in 1976 and 1977 than in 1975, immediately before and after oil treatment, with several species in the tribe Tanytarsini most reduced. Pond E did not show low emergence rates, but the proportion of Orthocladiinae was much higher than in reference ponds. Trichotanypus was severely reduced in Pond . but unusually abundant in Pond E in 1976 and 1977. Effects of oil seem to be different for different species, and occur at some point during the late larval stages of insects or at metamorphosis, but toxicity experiments did not confirm this. Oil may also interfere with reproduction in insect species which remain mainly on or near the pond surface as adults. There is no indication of recovery of Nemoura, Asynarchus, or Tanytarsini in Pond E seven years after the spill, but biomass and abundance of the other aquatic insects remain high. It is recommended that clean-up measures avoid introducing solvents or dispersants, which might be toxic to insects in the ponds.

ACCESS # : 412, IMS-UAF

CITATION : Mozley, S.C. 1978. Effects of experimental oil spills on Chironomidae in Alaskan tundra ponds. Verhandlungen Internationale Vereinigung fur Theoretische und Ungewandte Limnologie. 20(3): 1941-1945.

KEY-WORDS: Oil pollution; Benthos; Insects; Toxicity; Mortality; Reproduction.

SYNOPSIS : A study was made of the effects of Prudhoe Bay crude oil spilled on four tundra ponds near Point Barrow, Alaska. Initially oil killed macro-invertebrates only in peripheral areas when they could contact it on plants and at the surface. In one treated pond one species Trichotonypus was virtually eliminated but in another pond an unusually large population became re-established. The residual slick interfered with mating oviposition of chiromonids among the plants. Major oil spills could eliminate a major food resource for breeding birds.

ACCESS # : 413, ARL

CITATION : Muench, R.D., J.D. Schumacher, and R. Sillcox. 1979. Northwest Gulf of Alaska shelf circulation. Principal Investigators' Reports for the Year Ending March 1979. Vol. VII. pp. 232-248. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Currents; Oil pollution; Sediments; Transport; Oceanography; Petroleum development.

SYNOPSIS : The objective of this work is to relate oceanic advective and diffusive processes to potential pollution problems due to OCS petroleum development. This is accomplished through field activities including moored current measurements and water mass analysis using temperature and salinity observations. The regions being considered include the northwest Gulf of Alaska continental shelf west from about the longitude of Seward, Alaska to Unimak Pass and extend offshore to the outer boundary of the Alaskan Stream some 100 km off Kodiak Island. This study provides estimates of the fields of water motion which exert primary control over trajectories of spilled oil and over diffusion processes along the trajectories. Oil introduced into the environment via long-term or chronic leakage is more likely to be dispersed throughout the water column and, possibly scavenged by suspended particulate matter. The problem then becomes one of understanding net transport of suspended matter, a process related to advective and diffusive fields within the water column. Understanding of these processes requires an analysis of the velocity field and its driving mechanisms.

ACCESS # : 414, ARL

CITATION : Muench, R.D., J.D. Schumacher, and R.B. Tripp. 1979. Norton Sound/ Chukchi Sea oceangraphic processes (N-COP). Principal Investigators' Reports for the Year Ending March 1979. Vol. VIII. pp. 288-309. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Sediments; Tides; Transport; Oil pollution; Water pollution; Petroleum development; Oceanography.

SYNOPSIS : Continuing analysis of field data obtained during prior years is enhancing understanding of flow in the northern Bering Sea, particularly with regard to subtidal fluctuations. Five current meter moorings deployed during summer 1978 yielded data which will help clarify both the regional tides and some aspects of subtidal circulation in the region between Norton Sound and St. Lawrence Island. These data are being provided as necessary input to the tidal modelling effort. Further analysis of the existing field data will address regional tidal behavior and propagation/forcing of subtidal flow events through the system. This study will provide estimates of the trajectories likely to be followed by spilled oil and will furnish an indication of dispersion rates for such oil. Oil introduced into the environment via long-term or chronic leakage is more likely to dispersed throughout the water column and, possibly scavenged by suspended particulate matter. The problem then becomes one of understanding net transport of suspended matter, a process related to the advective and diffusive fields within the water column. An understanding of these processes requires, in turn, analysis of the velocity field and its driving mechanisms.

ACCESS # : 415, RAS-UAF

CITATION : Nunes, P., and P.E. Benville, Jr. 1979. Uptake and depuration of petroleum hydrocarbons in the Manila clam Tapes semidecussata Reeve. Bull. Environ. Contam. Toxicol. 21(6): 719-726.

KEY-WORDS: Clams; Petroleum; Hydrocarbons; Cook Inlet; Toxicity; Absorbance.

SYNOPSIS : The extent to which 6 monocyclic aromatics: benzene, toluene, ethylbenzene, p-xylene, m-sylene, and o-xylene of the WSF of Cook Inlet, Alaska, crude oil were accumulated and retained by the Manila calm (Tapes semidecussata) was investigated. The clams were exposed to a mean concentration of 3.1 ppm of the 6 monocyclics for 8 d. Subsamples were analyzed every 48 hr for their aromatic content, and after 8 d the remaining clams were transferred to uncontaminated holding tanks and allowed to depurate. Five of the monocyclics were detected in the water, 4 accumulated in the clam tissue, and none were detected in the control samples. Since the concentration of p-xylene was below the detectability level of the method used, it was not found in the water or the clams. Benzene had the highest concentration in the water but it was not detected in the clam tissue samples. A constant increase in the hydrocarbon content of the clam tissues was not observed; microbial action on the hydrocarbons may have been responsible for the variations.

ACCESS # : 416, RAS-UAF

CITATION : Naidu, A.S., H.M. Feder, and S.A. Norrell. 1978. The effect of Prudhoe Bay crude oil on a tidal-flat ecosystem in Port Valdez, Alaska. In: Proceedings Tenth Annual Offshore Technology Conference, Houston, TX. May 8-11. Vol. 1. pp. 97-104.

KEY-WORDS: Oil pollution; Sediments; Ecosystems; Tidal flats; Heavy metals; Copepod.

SYNOPSIS : The tidal flat sediments of Port Valdez display significant lateral variations in lithological, chemical, and biological subfacies. The glacially derived deposits are organically low, poorly sorted gravels to clays, with admixtures of sand and silt. Summer bacterial counts are relatively low with 243 aerobic colony forming units (CFU) and 30 anaerobic CFU per gram times 10 of sediment. Meiofaunal species are restricted to the upper 3-cm oxygenated sediment layers, and consist primarily of nematodes and harpacticoid copepods. Simulated crude oil spills in an oxic muddy site resulted in no changes in sediment organic carbon and in the dissolved oxygen contents. Bacterial populations were also not significantly affected by application of up to 2000 ppm of crude oil for several days at a series of low tides. The general lack of organic carbon and bacterial change in oiled sediments may by attributed to the rapid removal of oil from tidal flat surfaces. Harpacticoid copepods were not adversely affected by crude oil; on the other hand, a significant increase in density of one species (Halectinosoma gothiceps) was noted at chronic oil dosages. Nonetheless, a significant decrease in the concentrations of Cu, Zn, Ni, and V has been observed in the tidal deposits, subsequent to the oiling of the sediments.

ACCESS # : 417, RAS-UAF

CITATION : O'Brien, W.J. 1978. Toxicity of Prudhoe Bay crude oil to Alaskan arctic zooplankton. Arctic 31: 219-228.

KEY-WORDS: Oil pollution; Oil spill; Toxicity; Zooplankton; Arctic; Crustacea; Copepod; Prudhoe Bay.

SYNOPSIS : Bioassay experiments were conducted to determine the relative susceptibilities of three arctic zooplankton species to oil pollution, and the results were compared with the effects of an actual oil spill on a pond near Barrow. In both the bioassays and the pond, the addition of Prudhoe Bay crude oil was toxic to fairy shrimp (Branchionecta paladosa), which seemed most sensitive, Daphnia middendorffiana, which was next most susceptible, and Heterocope septentrionalis which appeared somewhat resistant to the effects of oil. Cyclopoid copepods were the only common zooplankters able to survive the pond oil spill, and these were still present two and one half weeks after the spill. The rapid deaths of the other species, especially the branchiopods, suggest that zooplankton may be the most susceptible of all arctic freshwater organisms to oil pollution.

ACCESS # : 418, PMEL

CITATION : Schumacher, J.D. and R.K. Reed. 1983. Interannual variability in the abiotic environment of the Bering Sea and Gulf of Alaska. W. Woster (ed.). Univ. Washington Sea Grant Contrib. #647. PMEL. (In press)

KEY-WORDS: Interannual variability; Oceanography.

SYNOPSIS : Connections between the abiotic and biotic environments are hypothesized for the Bering Sea and for the Gulf of Alaska. Key features of the abiotic environment are first described. After establishing mean or typical conditions, interannual signals which may indicate year-to-year survival of organisms are emphasized. Further research and strategies are identified which may enhance an understanding of the abiotic environment and its relation to biota.

ACCESS # : 419, ARL

CITATION : Patten, B.G. 1977. Sublethal biologcal effects of petroleum hydrocarbon exposures: fish. In: D.C. Malins (ed.), Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Vol. 2: Biological Effects. Academic Press, New York, NY. pp. 319-335.

KEY-WORDS: Fish; Oil pollution; Hydrocarbons.

SYNOPSIS : Information is presented on the behavioral and physiological responses of marine fishes to petroleum hydrocarbons at sublethal concentrations. Of major concern are marine species indigenous to arctic and subarctic waters since this information is meager, data on organisms from other geographic environments are included to demonstrate effects that may generally relate to a variety of species.

ACCESS # : 420, ARL

CITATION : Pearson, J.D. 1976. Sublethal Effects - Effects on Sea Grass. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. pp. 377-389. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Toxicity; Food web; Eelgrass; Ice; Photosynthesis; Primary production.

SYNOPSIS : This study is directed at evaluating the effects of selected petroleum hydrocarbons (dodecane, toluene, and napthalene) on rates of photosynthesis in Zostera marina. Since Z. marina is a major contributor to primary production in many ecological niches along the Alaskan coastline, it is imperative to understand the possible effects of exposing it to low-levels of the more water soluble and toxic components of petroleum. Deleterious effects on sea-grass could disrupt whole food chains.

ACCESS # : 421, ARL

CITATION : Percy, J.A. 1977. Effects of dispersed crude oil upon the respiratory metabolism of an Arctic marine amphipod, Onisimus (Boekisimus) affinis. In: D.A. Wolfe (ed.), Fate and effects of petroluem hydrocarbons in marine ecosystems and organisms. Pergammon Press. New York, N.Y. pp. 192-200.

KEY-WORDS: Respiration; Amphipods; Oil pollution.

SYNOPSIS : Short-term lethality is an unsuitable criterion for assessing the ecological effects of pollutants. A variety of sublethal physiological effects may impair an organism's ability to function normally and lead to a reduction or elimination of sensitive populations in a polluted area. The effects of exposure to sublethal concentrations of dispersed crude oil upon the respiratory metabolism of a marine amphipod have been examined. At low oil concentrations metabolism is significantly depressed, but with increasing concentration a reversal of the response occurs. A possible explanation for this complex response is presented. The effects of other factors, such as oil type, presence of dispersants, nutritional state of the animals and weathering of the oil upon the metabolic response are also considered.

ACCESS # : 422, PMEL

CITATION : Schumacher, J.D., and P.D. Moen. 1983. Circulation and hydrography of Unimak Pass and the shelf waters north of the Alaska Peninsula. NOAA Technical Memorandum ERL PMEL-47. Pacific Marine Environmental Laboratory, Seattle, WA. 75 pp.

KEY-WORDS: Circulation; Hydrography; Unimak Pass; Alaska Peninsula; Currents; Oceanography.

SYNOPSIS : Wind, current, bottom pressure, and hydrographic observations from Unimak Pass and the adjacent shelf are presented. Mean flow was from the Gulf of Alaska into the Bering Sea and resulted from the Kenai Current. Shorter period fluctuations were bi-directional and coherent with divergence along the coast. Observations along the northern side of the Alaska Peninsula indicated Kenai Current water had an impact on the local salt content in the coastal domain, and together with freshwater discharge maintained a stronger horizontal density gradient in the vicinity of the 50-m isobath. Wind forcing, manifested both as coastal divergence and as a source of strong mixing, was evident at shorter periods. Results substantiated previous studies, but they also revealed subtle features including impact of freshwater discharge not associated with gaged rivers, importance of gaps in the mountains to the generation of pressure gradient winds, and the nature of processes which destroy and establish the inner front and the typically two-layered middle shelf domain structure.

ACCESS # : 423, ARL

CITATION : Percy, J.A. 1978. Effects of chronic exposure to petroleum upon the growth and molting of juveniles of the arctic marine isopod crustacean Mesidotea entomon. J. Fish. Res. Bd. Can. 35: 650-656.

KEY-WORDS: Oil pollution; Growth; Molting; Arctic; Isopod; Invertebrates.

SYNOPSIS : Juveniles of the benthic marine isopod Mesidotea entomon were chronically exposed to different concentrations of water-soluble fractions of fresh and weathered Norman Wells crude oil and of fresh Pembina crude for 160 d. The 100% extracts contained 1.72, 1.12, and 0.56 ppm of oil (determined flurimetrically), respectively. Most of the animals completed five or six molts before the end of the experiment. Long-term mortality was high in the 100% extracts of the oils (LT_{50}=17, 17, 41 d, for Normal Wells, Pembina, and weathered Norman Wells, respectively) but most of the animals molted at least once before dying. None of the deaths occurred in conjunction with the molt. Stimulation of the onset of the subsequent molt occurred in some exposure groups. A significant increase in the duration of the intermolt period only occurred at the highest oil concentrations. Effects on growth were slight at concentrations lower than that which is lethal during chronic exposure. Exposure to fresh Norman Wells crude depressed growth slightly, while Pembina crude slightly stimulated growth. Weathered Norman Wells severely inhibited growth at the highest concentration but stimulated growth slightly at lower concentrations.

ACCESS # : 424, RAS-UAF

CITATION : Percy, J.A. 1977. Effects of crude oil on the locomotory activity of arctic marine invertebrates. Mar. Poll. Bull. 8(2): 35-40.

KEY-WORDS: Oil pollution; Invertebrates; Amphipods; Arctic; Crustacea; Toxicity.

SYNOPSIS : The effects of exposure to seawater dispersions of northern crude oils on the locomotory activity of two Arctic marine invertebrates, the amphipod Onisimus affinis and the coelenterate Halitholus cirratus have been examined. Low concentrations of the oils significantly impair activity in both species. Exposure to light dispersions of oil, containing 50 microliters of oil per liter seawater for 24 hours reduced activity for both organisms by about 45%; exposure to a dispersion of 500 microliters per liter seawater resulted in activity depressions of 78 to 96% in Onisimus and 55% in Halitholus; exposure to 2000 microliters oil per liter seawater resulted in 98% and 100% reduction in activity, respectively. The manner in which oil interferes with locomotory activity is not known.

ACCESS # : 425, RAS-UAF

CITATION : Rattner, B.A. W.C. Eastin, Jr. 1981. Plasma corticosterone and thyroxine concentrations during chronic ingestion of crude oil in mallard ducks (Anas platyrhynchos) Comp. Biochem. Physiol. C: Comp. Pharmacol. 68(2): 103-107.

KEY-WORDS: Oil pollution; Waterfowl; Physiology.

SYNOPSIS : The morphological responses and alterations in tolerance which accompany oil exposure in ducks have been attributed to activation of the hypophyseal-adrenal axis by nonspecific stress. A preliminary assessment of adrenal and thyroid function was conducted in 150 mallard ducklings chronically exposed to various dietary quantities of crude oil. The diets consisted of untreated mash, mash mixed with 0.150 percent South Louisiana crude oil, and mash mixed with 0.015, 0.150, and 1.500 percent Alaska Prudhoe Bay crude oil. Blood samples were collected from the ducks after 6, 12, and 18 weeks of the dietary treatments. At week 6, the plasma corticosterone values from birds in the 0.150 percent South Louisiana crude oil and the 0.015 percent Prudhoe Bay crude oil treatment groups were similar to control group levels; however, at weeks 12 and 18 mean plasma corticosterone concentrations in these treatment groups appeared to be somewhat reduced. Dietary exposure to the higher levels of Prudhoe Bay crude oil exposure uniformly reduced mean corticosterone values values at all sampling times. Plasma thyroxine concentrations were not significantly altered in ducks in any of the treatment groups. Although the aliphatic components quantified in the crude oils were relatively similar in concentration, the concentrations of aromatics which were analyzed were generally greater in the Prudhoe Bay samples than in the South Louisiana crude oil perhaps accounting for the differences in the effects of equal concentrations of the two crude oils on corticosterone levels.

ACCESS # : 426, ARL

CITATION : Reichert, W.L. 1979. Behavioral and physiological effects induced by sublethal levels of heavy metals. Final Reports of Principal Investigators. Vol. 5. pp. 225-240. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Heavy metals; Water pollution; Physiology; Sublethal efects; Cadmium; Lead; Behavior.

SYNOPSIS : The physiological and behavioral effects of cadmium, chromium, lead, and nickel on marine organisms under saline conditions are reviewed. The effects of metals on physiological responses of marine organisms are dependent on the temperature and salinity of the marine environment. In general, physiological effects of heavy metals increase with increasing temperature and decreasing salinity. The sparse literature on the physiological and behavioral effects of lead, cadmium, nickel, and chromium presently provides insufficient background for balanced judgments relating to acceptable levels of these metals in the marine environment.

ACCESS # : 427, ARL

CITATION : Rice, S.D., and J.F. Karinen. 1976. Acute and chronic toxicity, uptake and depuration, and sublethal metabolic response of Alaskan marine organisms to petroleum hydrocarbons. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. pp. 25-47. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Ecology; Metabolism; Toxicity; Fishes; Crabs; Crustacea.

SYNOPSIS : This study was designed to determine the acute and chronic toxicity of crude oil and its component fractions on physiological and behavioral mechanisms of selected arctic and subarctic organisms in laboratory and field studies. Temperature has little effect on toxicity, so that data generated at 12 degrees C can be extrapolated to colder climates. Oil exposures stimulate metabolism in fish, rather than depress metabolism as in crabs.

ACCESS # : 428, ARL

CITATION : Rice, S.D., and J.F. Karinen. 1979. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Principal Investigators' Reports for the Year Ending March 1979. Vol. VI. pp. 27-59. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Toxicity; Petroleum development; Physiology; Temperature; Salinity.

SYNOPSIS : The FY 1797 program involves physiological and bioassay tests of applied research on species indigenous to the Gulf of Alaska, Bering Sea, and Beaufort Sea. The major emphasis of research has shifted from strictly descriptive acute toxicity determinations to mechanistic studies, sublethal tests, and long-term exposures that will eventually allow prediction of oil impact on the biota. Because low temperature appears to be such an important factor in governing the sensitivity of some subarctic species to oil it is necessary to determine whether this relationship holds for similar arctic species in general. A base of information has now been accumulated on acute toxicity, sublethal effects, relative toxicity of oil aromatics, effects of various environmental factors on these parameters, and effects on larvae; but this is only a small part of the information needed to predict and evaluate the major impacts of hydrocarbons in the marine environment. This study has given more knowledge about the effects of temperature and salinity on the ability of subarctic organisms to metabolize, eliminate or recover from petroleum exposure.

ACCESS # : 429, ARL

CITATION : Rice, S.D., J.F. Karinen, and S. Korn. 1978. Acute and chronic toxicity, uptake and depuration, and sublethal response of Alaska marine organisms to petroleum hydrocarbons. NOAA Technical Memorandum ERL OCSEAP-1. Marine Biological Effects of OCS Petroleum Development. pp. 11-24.

KEY-WORDS: Oil pollution; Physiology; Toxicity; Fish; Sublethal effects.

SYNOPSIS : Oil effects studies at the Auke Bay Laboratory began in late 1971, yet this report describes progress associated with OCSEAP funding which began in the last 2 months of FY 75, and draws primarily from published or drafted manuscripts. The studies can be broken down into two basic themes: (1) Toxicity challenge experiments, where an attempt is made to identify sensitive species, life stages, factors that affect toxicity, or components that are most responsible for toxicity; and (2) sublethal physiological response, where an attempt is made to identify, measure, and characterize physiological responses that are indicative of oil stress. Results from the series of sublethal effects studies may have application to monitoring effects of oil and defining the mode of action of toxicants.

ACCESS # : 430, PMEL

CITATION : Baker, E.T. 1983. Suspended particulate matter distribution, transport, and physical characteristics in the North Aleutian Shelf and St. George Basin lease areas. Draft Final Report. 134 pp. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Sediments; North Aleutian Shelf; St. George Basin; Resuspension; Oil pollution; Particulate matter.

SYNOPSIS : The principle objective of this research unit was to describe the distribution, transport, and physical characteristics of suspended particulate matter (SPM) in the area of the North Aleutian Shelf (NAS) and St. George Basin (SGB). The oceanographic conditions which result in the creation of hydrographic structural domains and frontal regions also creates characteristic SPM distributions in each of these domains. A high turbidity surface layer resulted from phytoplankton growth and river derived particles and a bottom layer of increased turbidity due to resuspension of bottom sediments were typical, with frontal zones being sites of increased horizontal particle concentration gradients. The offshore gradient of mean particle concentration fell rapidly from shore to about the 50-m isobath, and then varied little with increasing water depth. Areal distribution maps depict an SPM distribution in which particles from point sources along the coast are largely retained in the nearshore zone and dispersed parallel to the coast. Maximum concentrations of particulate-associated oil resulting from an oil spill in NAS waters was estimated to be 0.7-7 ppb in the water column of the nearshore zone (10-20 m deep) and 0.06-1.1 ppb in the offshore zone (40-90 m deep). Sedimentation of this oil to the benthos, calculated on the basis of sediment trap data, could be expected to be in the range of 1-10 mg oil m^2/day.

ACCESS # : 431, ARL

CITATION : Rice, S.D., S. Korn, C.C. Brodersen, S.A. Lindsay, and S.A. Andrews. 1981. Toxicity of ballast-water treatment effluent to marine organisms at Port Valdez, Alaska. Proceedings: 1981 Oil Spill Conference (Prevention, Behavior, Control, Cleanup). March 2-5, 1981, Atlanta, Georgia.

KEY-WORDS: Toxicity; Oil pollution; Aromatic hydrocarbons; Salmon; Shrimp.

SYNOPSIS : Approximately 12 million gallons of oily ballast water is taken ashore and treated daily at the Alyeska treatment plant, where tankers take on crude oil at the terminus of the Trans-Alaska pipeline near Valdez, Alaska. Most oil is removed, but some light aromatic hydrocarbons (1 to 16 parts per million) remain in the large volume of discharged effluent. Between May and July, the concentration of aromatic hydrocarbons in the treated effluent (measured by gas chromatography) generally declined as the seasonal temperatures increased. We measured the toxicity of the effluent on site at Valdez. For the larvae of crustaceans and of fish the median lethal concentration LC_{50} was between 10 and 20 percent of treated effluent in 96-h static tests. For salmon fry and shrimp in repeated acute flow-through assays, the LC_{50} was quite consistent, between 20 and 40 percent of treated effluent. Because the concentration of aromatic hydrocarbons was much lower in the later tests, but the toxicity of the effluent was not lower, toxicants other than aromatic hydrocarbons must contribute significantly to the toxicity of the effluent from the ballast-water treatment plant.

ACCESS # : 432, ARL

CITATION : Rice, S.D., S. Korn, and J.F. Karinen. 1977. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Annual Reports of Principal Investigators for the Year Ending March 1977. Vol. 12. pp. 23-43. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Shellfish; Physiology.

SYNOPSIS : Laboratory and field studies were conducted to determine recovery rates of selected organisms and ecosystems from perturbations resulting from either contamination or other disturbances associated with petroleum development. The research involved physiological and bioassay tests of applied research on species indigenous to the Gulf of Alaska, Bering Sea, and Beaufort Sea. The major emphasis of research has shifted from strictly descriptive acute toxicity determinations to mechanistic studies and sublethal tests that will eventually allow prediction of oil impact on the biota. Studies to determine the acute toxicity of the water-soluble fraction (WSF) of crude oil continue with experiments with species not tested previously. Methodology and apparatus of flow-through tests have been designed and three systems are in use. Experiments also continue with larvae of species not tested previously. Emphasis is on intertidal species, such as mussels, barnacles, snails, and sea urchins.

ACCESS # : 433, ARL

CITATION : Rice, S.D., S. Korn, and J.F. Karinen. 1978. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Final Reports of Principal Investigators for the Year Ending March 1978. Vol. 1. pp. 1-32. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Toxicity; Sublethal effects; Physiology.

SYNOPSIS : The research involves physiological and bioassay tests of applied research on species indigenous to the Gulf of Alaska, Bering Sea, and Beaufort Sea. The major emphasis has shifted from strictly descriptive acute toxicity determinations to mechanistic studies and sublethal tests that will eventaully allow prediction of oil impacts on the biota. The studies have two basic themes. Toxicity challenge experiments, where sensitive species, live stages, factors that affect toxicity, or components that are most responsible for toxicity are identified; and sublethal physiological response, where physiological responses that are indicative of oil stress are identified, measured, and characterized.

ACCESS # : 434, ARL

CITATION : Rice, S.D., S. Korn, and J.F. Karinen. 1980. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Annual Reports of Principal Investigators for the Year Ending March 1980. pp. 1-12. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Benthos; Food Web; Biological degredation; Sea ice.

SYNOPSIS : Although direct comparisons of arctic and subarctic animal sensitivity are difficult due to different bioassay methods used, arctic animals appear to be equal in sensitivity to oil as subarctic animals. The fish were more sensitive than the invertebrates and were comparable to pink salmon (subarctic species). Arctic animals were highly adaptable to temperature changes, although there were no effects of temperature on sensitivity of arctic animals to oil. Results indicate little difference in sensitivity of arctic and subarctic animals to oil. Lower environmental temperatures in the arctic would result in oil persisting longer after a spill due to lower volatility and biodegradation of oil components and because oil would become trapped or immobolized in ice. There are fewer species in the arctic and food chains are very short. If a species is affected, there would be few replacement species. The arctic habitat is more vulnerable, and once changed, less able to adjust. Even though individual species are generally very hardy and tolerant of natural environmental extremes and limited amounts of pollution.

ACCESS # : 435, ARL

CITATION : Rice, S.D., S. Korn, and J.F. Karinen. 1979. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Annual Reports of Principal Investigators for the Year Ending March 1979. Vol. 6. pp. 27-59. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Larvae.

SYNOPSIS : The FY 1979 program involves physiological and bioassay tests of applied research on species indigenous to the Gulf of Alaska, Bering Sea, and Beaufort Sea. The major emphasis of research has shifted from strictly descriptive acute toxicity determinations to mechanistic studies, sublethal tests, and long-term exposures that will eventually allow prediction of oil impact on the biota. Because low temperature appears to be such an important factor in governing the sensitivity of some subarctic species to oil it is necessary to determine whether this relationship holds for similar arctic species or arctic species in general. A base of information has now been accumulated on acute toxicity, sublethal effects, relative toxicity of oil aromatics, effects of various environmental factors on these parameters, and effect on larvae, but this is only a small part of the information needed to predict and evaluate the major impacts of hydrocarbons in the marine environment. This study has given more knowledge about the effects of temperature and salinity on the ability of subarctic organisms to metabolize eliminate or recover from petroleum exposure.

ACCESS # : 436, ARL

CITATION : Rice, S.D., A. Moles, T.L. Taylor, and J.F. Karinen. 1979. Sensitivity of 39 Alaskan marine species to Cook Inlet crude oil and No. 2 fuel oil. Proceedings: 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup). March 19-22, 1979. Los Angeles, Ca. pp. 549-554.

KEY-WORDS: Toxicity; Fishes; Bivalves; Bioassay; Invertebrates.

SYNOPSIS : The sensitivities of 39 subarctic Alaskan species of marine fish and invertebrates to water-soluble fractions of Cook Inlet crude oil and No. 2. fuel oil were determined. This is the largest group of animals ever tested under similar test conditions with the same petroleum oils and analytical methods. Organisms bioassayed represent several habitats, six phyla, and 39 species including fish (9), arthropods (9), mollusks (13), echinoderms (4), annelids (2), and nemerteans (2). Sensitivities were determined by 96-h static bioassays. Concentrations of selected aromatic hydrocarbons were determined by gas chromatography; concentrations of paraffins were determined by infrared spectrophotometry. Although sensitivity generally increased from lower invertebrates to higher invertebrates, and from higher invertebrates to fish, sensitivity was better correlated to habitat. Pelagic fish and shrimp were the most sensitive animals to Cook Inlet crude oil. Sensitive pelagic animals are not necessarily more vulnerable to oil spills than tolerant intertidal forms--oil may damage intertidal environments more easily and adverse effects may persist longer than in damaged pelagic environments.

ACCESS # : 437, ARL

CITATION : Rice, S.D., R.E. Romas, and J.W. Short. 1976. Effect of petroleum hydrocarbons on breathing and coughing rate and hydrocarbon uptake-depuration in pink salmon fry. Principal Investigators' Reports for the Year Ending March 1976 Vol. 8. pp. 88-118. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Toxicity; Salmon; Aromatic hydrocarbons; Physiology.

SYNOPSIS : Pink salmon fry, Oncorhynchus gorbuscha, were exposed to the water-soluble fraction of Cook Inlet and Prudhoe Bay crude oils, and No. 2 fuel oil. During 22 h exposures, breathing and coughing rates initially increased as the dose increased but then decreased after several hours. Breathing and coughing rates increased significantly during exposures to oil concentrations as low as 30% of the 96 h median tolerance limit as determined by ultraviolet spectroscopy. It is speculated that the increased respiration rate reflects an increased energy demand for enzyme synthesis. Chronic exposure requiring elevated energy demands may be detrimental to the survival of a population.

ACCESS # : 438, ARL

CITATION : Schneider, D.E. 1980. Physiological responses of arctic epibenthic invertebrates to winter stresses and exposure to Prudhoe Bay crude oil dispersions. Annual Reports of Principal Investigators for the Year Ending March 1980. Vol. 1. pp. 413-475. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Toxicity; Invertebrates.

SYNOPSIS : One of the most serious environmental challenges faced by arctic shallow-water animals is the seasonal variation in salinity. Many of the arctic shallow water epibenthic invertebrates are euryhaline. However, the upper salinity limits for survival and spontaneous locomotion for many species are approached in the deeper waters of lagoons during late winter and spring. To avoid these stressfull conditions it is predicted that many of the species will migrate from lagoons during the winter. This prediction is supported by the seasonal distribution data by mysids (Mysis littoralis, Anonyx nugax and Boeckosimus affinis). Exposure of epibenthic invertebrates to Prudhoe Bay crude oil dispersion has shown that three of the most common species are sensitive to oil, particularly at elevated salinities where the animals may already be experiencing stress from that factor. An oil spill during the winter months may have more serious impact than one during a season with less stressful salinity regime.

ACCESS # : 439, ARL

CITATION : Schneider, K.B. 1976. Assessment of the distribution and abundance of sea otters along the Kenai Peninsula, Kamishak Bay and the Kodiak Archipelago. Principal Investigators' Reports for the Year Ending March 1976. Vol. 1. pp. 333-358. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Marine mammals; Oil pollution; Sea otter; Distribution.

SYNOPSIS : Aerial and boat surveys were conducted around the Kenai Peninsula and the Kodiak Archipelago to determine the present distribution and relative abundance of sea otters. Sea otter populations in these areas are relatively small but are expanding their range. The potential for adverse impacts of OCS activities on sea otters appears high. Sea otters are more vulnerable to direct oiling than any other species of marine mammal and they may be indirectly affected by chronic low levels of pollution through the food chain. Where populations are expanding their range, a localized influence could retard repopulation of large areas. Sea otters exert a significant impact on nearshore marine communities. It is necessary to consider the history of sea otter occupation of an area when studies of these communities are conducted. Information being gathered under this project will be used to trace the patterns of range expansion, predict future trends, identify those areas where OCS activities would have greatest impact on the population and provide a basis for evaluating the sea otter's role in changes in marine communities.

ACCESS # : 440, ARL

CITATION : Smith, D.D., and G.H. Holliday. 1979. API/SC-PCO Southern California 1978 oil spill test program. Proc. Oil Spill Conference. 19 March 1979. American Petroleum Institute-Washington, DC. pp. 475-482.

KEY-WORDS: Oil pollution.

SYNOPSIS : Using Alaskan crude in a special offshore test zone authorized by an EPA Research Ocean Dumping Permit, API/SC-PCO generated a series of small oil slicks for testing dispersant application methods and mechnical cleanup equipment in late September 1978. Seven test slicks ranging from 5 to 20 bbl were sprayed with low-toxicity dispersants using a helicopter, a crop-dusting monoplane, and two types of boat-mounted spray systems. A Cyclonet 100 centrifugal skimmer was tested on an eighth slick. In addition, a capsule demonstration in which four one-barrel slicks were generated and dispersed provided agencies, media, and the public the opportunity to witness the use of dispersant at close range. The technical operational testing was supplemented by detailed chemical and biological monitoring studies and by extensive motion picture and air photographic coverage. Field observations and photographic documentation indicate that: the two dispersant application techniques tested are all viable methods for applying dispersant to oil spills at sea and the Cyclonet recovered oil, but the test slick was too small to assess probable performance in a major spill situation.

ACCESS # : 441, ARL

CITATION : Smith, R.L., and J.A. Cameron. 1977. Acute effects - Pacific herring roe in the Gulf of Alaska. Principal Investigators' Reports for the Year Ending March 1977. Vol. 12. pp. 596-635. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Fishes; Pacific herring roe; Hydrocarbons; Herring.

SYNOPSIS : The potential impact of OCS oil development activities on a single species of Alaskan marine fish, the Pacific herring (Clupea harengus pallasi) was evaluated. This project sought to simulate conditions of a crude oil spill to test the effects of low boiling point, water-soluable hydrocarbon components of Prudhoe Bay crude on developing herring larvae. Exposure for as little as 48 hrs. led to a significantly higher incidence of gross morpholgical abnormalities. Exposure for six days resulted in 100% mortality in the fertilized embryos. The following conclusions were reached: the herring reproductive cycle is vulnerable to oil pollution for at least two months, possibly more; very low hydrocarbon levels produced significant effects in terms of hatching success, gross morphological abnormalities, total larval length, and presence of hydrocarbons in hatched larvae and unhatched embryos; and deleterious effects produced by oil contamination reduce the fitness of larvae which, at best, had little chance to survive to adulthood.

ACCESS # : 442, ARL

CITATION : Smith, R.L., and J.A. Cameron. 1979. Effect of water-soluble fraction of Prudhoe Bay crude oil on embryonic development of Pacific Herring. Trans. Amer. Fish. Soc. 108: 70-75.

KEY-WORDS: Oil pollution; Fishes; Toxicity; Mortality; Juveniles; Herring; Reproduction.

SYNOPSIS : This project sought to simulate conditions of a crude oil spill to test the effects of low boiling point, water-soluble hydrocarbon components of Prudhoe Bay crude oil on developing Pacific herring embryos. Initial hydrocarbon concentrations in the experimental containers were less than 1 microgram/g H_2O. Exposure for 48 hours led to a significantly higher incidence of gross morphological abnormalities. Exposure for 6 days resulted in 100% mortality of the fertilized embryos. Gross abnormalities usually consisted of flexures in the body which reduced or prevented locomotion. Results of scanning electron microscopy reveal other defects, such as improperly formed mouths, which adversely affect biological fitness yet are difficult to detect. Exposure for 12 h or longer led to reduced size of newly hatched larvae, suggesting hydrocarbon exposure adversely affects embryonic metabolism.

ACCESS # : 443, ARL

CITATION : Smith, R.L., J.G. Pearson, and J.A. Cameron. 1976. Acute effects - Pacific herring roe in the Gulf of Alaska. Principal Investigators' Reports for the Year Ending March 1976. Vol. 8. pp. 325-343. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Pacific herring roe; Fisheries; Mortality; Larvae; Infertility.

SYNOPSIS : The objective of this study is to delineate the toxicity of soluble components of crude oil under simulated natural conditions. Toxicity is measured in terms of hatching success and gross morphological abnormalities. Herring spawn in a habitat which is particularly susceptible to the influence of crude oil. Many of the roe are deposited in the intertidal, the larger usually being deposited highest on the beach. Since the larger eggs normally produce the larvae with the greatest chance of reaching adulthood, the presence of oil on the water and on the beach will select against the highest quality of eggs in particular and will cause an increased mortality in general. Spills or seepage during the three to four week reproductive period could have significant impact on egg and larval mortality. These mortality rates are already high in nature. Development activities could have a major impact on the herring fishery in Alaska.

ACCESS # : 444, ARL

CITATION : Smith, R.L., A.C. Paulson, and J.R. Rose. 1976. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. Principal Investigators' Reports for the Year Ending March 1976. Vol. 7. pp. 471-508. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Benthos; Demersal fish; Food habits; Commercial fisheries.

SYNOPSIS : The ultimate goal is to construct a detailed picture of the food and feeding relationships of the fishes in the Gulf of Alaska and Bering Sea. This will include analyses of predator size vs. prey composition; bottom type, temperature and location vs. prey composition; prey composition in diets vs. prey abundance; prey composition vs. season. The rationale behind this study is to develop an ability to predict the impact of oil development activities on the fishes. This study, coupled with others designed to study acute and chronic toxic effects on the fish populations, will establish the predictive base necessary to make managment decisions.

ACCESS # : 445, ARL

CITATION : Smith, R.L., A.C. Paulson, and J.R. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. 1978. Principal Investigators' Reports for the Year Ending March 1978. Vol. 1. pp. 33-107. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Fishes; Feeding behavior; Oil pollution; Commercially important species.

SYNOPSIS : The rationale behind this study was to develop an ability predict the impact of oil development activities on the fishes in these two areas. The study, coupled with others designed to study acute and chronic toxic effects on the fish populations, will help establish the predictive base necessary to make management decisions. The research findings on pollock, rex sole, rock sole, dover sole, flathead sole, arrowtooth flounder, Greenland halibut, capelin and shortfin eelpout are discussed. Existing information on Pacific cod, yellowfin sole and Pacific halibut is summarized.

ACCESS # : 446, IMS-UAF

CITATION : Stekoll, M.S., L.E. Clement, and D.G. Shaw. 1977. Sublethal effects of petroleum on Macoma balthica. In: Program Review Proc. of: Environmental effects of energy related activities on marine/estuarine ecosystems. Report No. EPA-600/7-77-111 and OEMI-77-025. pp. 1-17.

KEY-WORDS: Oil pollution; Intertidal; Sublethal effects; Waterfowl; Bivalves.

SYNOPSIS : The bivalve mollusk Macoma balthica has previously been proposed as an indicator of oil pollution. This small clam was selected for study because of its wide distribution and abundance in Alaskan intertidal environments. Macoma balthica is a surface deposit feeder and suspension feeder, which would make it likely to concentrate both suspended and stranded oil that might occur following a spill. Such concentrated oil in the clams might be further distributed throughout the ecosystem via migrating birds that feed on M. balthica. It was the purpose of this investigation to show that M. balthica is able to concentrate oil from an oil-sea water dispersion and to ascertain what effects the oil might have on membrane-bound enzymes and other physical and chemcial parameters of the clams.

ACCESS # : 447, RAS-UAF

CITATION : Straughan, D. and D. Hadley. 1978. Experiments with Littorina species to determine the relevancy of oil spill data from southern California to the Gulf of Alaska. Mar. Environ. Res. 1(2): 135-163.

KEY-WORDS: Pollution effects; Temperature; Oil pollution; Invertebrates.

SYNOPSIS : L. scutulata were collected from Alaska, Canada and southern California and L. sitkana were collected from Alaska and Canada. These animals were exposed to a range of petroleums at a range of temperatures. Gasoline was the most toxic of all compounds tested. 6 (degree) C and 29 (degree) C temperatures both during and prior to experiments had a greater influence on survival and attachment rates a week after exposure to petroleum than did the different tpes of petroleum. The temperature influence can be related to both zoogeographical distribution and seasonal temperatures. Data obtained in the Santa Barbara Channel can be extrapolated to the Gulf of Alaska when differences such as temperature tolerance and type of oil are considered for the same and closely related species. Attachment rates and mortality rates changed after the animals were removed from petroleum. This suggests a weakness in standard toxicity testing procedures when mortality rates are compared immediately after removal from test solutions.

ACCESS # : 448, ARL

CITATION : Taylor, T.L., and J.F. Karinen. 1977. Response of the clam, Macoma balthica (Linnaeus) exposed to Prudhoe Bay crude oil as unmixed oil, water-soluble fraction, and oil-contaminated sediment in the laboratory. In: D.A. Wolfe (ed.), Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems. Pergammon Press, New York, NY. pp. 229-237.
KEY-WORDS: Oil pollution; Sediments; Toxicity; Mortality; Predation; Bivalves.

SYNOPSIS : This clam will likely be subjected to oil slicks layered on the mud and to water-soluble fractions (WSF) of crude oil or oil-contaminated sediment. Gentle settling of crude oil over clam beds had neglible effects on clams observed for 2 months. Water-soluble and oil-treated sediment (OTS) fractions of Prudhoe Bay crude oil inhibited burrowing and caused clams to move to the sediment surface. Although short-term exposures of clams to the WSF of crude oil and OTS caused few deaths, behavorial responses of clams to oil may be of great importance to their survival in the natural environment.

ACCESS # : 449, SC UNIVERSITY, COLUMBIA, SC

CITATION : Thomas, R.E. and S.D. Rice. 1977. The effect of exposure temperatures on oxygen consumption and opercular breathing rates of pink salmon fry exopsed to Inlet crude oil and No. 2 fuel oil. In: Marine Pollution: Functional Responses. Proc. Symp. Poll. Physiol. Mar. Organ. pp. 39-52.

KEY-WORDS: Salmonid; Aromatic hydrocarbons; Toxicity; Oil pollution; Physiology.

SYNOPSIS : The primary objective of this study was to measure breathing rates in pink salmon fry exposed to equivalent concentrations of aromatic hydrocarbon toxicants at 4 and 12 C to determine if the response at the lower temperature differs from that at the higher temperature. This experiment was of interest because spills in Alaskan waters will probably occur at lower temperatures than have been studied elsewhere, and little is known about the effects of aromatic hydrocarbons at these lower temperatures. There is general agreement that the mononuclear and dinuclear aromatic hydrocarbons are responsible for the toxic effects of water-soluble fractions from crude and refined oils. The toxicity of different oils is influenced by kinds and relative abundance of aromatic hydrocarbons present, and results suggest that those oils with relatively high concentrations of mononuclear aromatic hydrocarbons may be particularly damaging to coldwater fishes in arctic and subarctic environments.

ACCESS # : 450, RAS-UAF

CITATION : Vanderhorst, J.R., C.I. Gibson, and L.J. Moore. 1976. Toxicity of No. 2 fuel oil to Coon Stripe Shrimp. Mar. Poll. Bull. 7(6): 106-108.

KEY-WORDS: Shrimp; Oil pollution; Toxicity; Bioasssay.

SYNOPSIS : The objective in this study was to measure short-term (96 h) lethal toxicity of a No. 2 fuel oil-in-seawater dispersion to coon stripe shrimp (Pandalus danae) under continuous flow conditions. A useful starting point in assessing the effects of contaminating materials is by determining short-term lethal concentrations. The bioassay of petroleum and refined oils has resulted in highly divergent and apparently contradictory findings with respect to short-term lethal effects. Bioassay of a No. 2 fuel oil dispersion with shrimp in a continuous flow system using measured waterborne oil as the indicator of oil concentrations reveals a treatment more definable than those previously described in terms of volume ratios and produces lower lethal concentrations. Shrimp 96-h LC_{50} was 0.8 mg/l in this study as compared to values from 1.5 to 50mg/l reported for other methods. Mean concentrations in tests do not give significant differences in concentration with respect to day of the test or spatial distribution in the exposure tanks.

ACCESS # : 451, NMFS

CITATION : Varanasi, U. 1978. Biological Fate of Metals in Fish. NOAA Technical Memorandum ERL OCSEAP-1. Marine Biological Effects of OCS Petroleum Development pp. 41-53.

KEY-WORDS: Oil pollution; Toxicity; Fishes; Lead; Cadmium; Heavy metals; Salmon.

SYNOPSIS : To obtain the most comprehensive and in-depth evaluation of the impact of trace metals on arctic and subarctic organisms; the investigation was carried out in three separate phases; (1) Biochemcial interactions of trace metals in fish which dealt with patterns of uptake, accumulation, and retention of lead and cadmium in key tissues of fish exposed to low levels of water-borne metals at 4 degree and 10 degrees C (Subcellular distribution of metals as well as mechanisms of excretion were also studied); (2) evaluation of importance of skin and epidermal mucus in metabolism and excretion of metals which defines uptake, accumulation and discharge of trace metals from epidermal mucus, skin, and scales of fish; and (3) influence of metal exposure on hydrocarbon metabolism in fish. This study was initiated to assess alterations in the profiles of metabolites of hydrocarbons (e.g. naphthalene) in tissues of fish exposed to lead and cadmium.

ACCESS # : 452, ARL

CITATION : Varanasi, U., and D.C. Malins. 1977. Metabolism of petroleum hydrocarbons: accumulation and biotransformation in marine organisms. In: D.C. Malins (ed.), Effects of petroleum on arctic and subarctic marine environments and organisms. Vol. 2. Academic Press, New York, NY. pp. 175-270.

KEY-WORDS: Metabolism; Oil pollution; Hydrocarbons; Food web.

SYNOPSIS : This chapter covers studies conducted primarily on indigenous species and includes wherever possible, the relatively small amount of data which relate to the influence of environmental conditions (e.g. low temperatures). The review includes discussion of the uptake, metabolism, and discharge of petroleum hydrocarbons in marine organisms exposed to sublethal levels of petroleum. Resultant biochemical alterations in challenged organisms to ascertain overall effects of long-term exposure to sublethal concentrations of petroleum hydrocarbons is discussed. Major emphasis is on laboratory bioassay studies or simulated field experiments. In addition, certain relevant information about concentrations of petroleum hydrocarbons in animals obtained from known areas of petroleum contamination are included. Furthermore, an attempt is made to evaluate the status of knowledge on these subjects and pinpoint areas where information is lacking. It also delineates areas where more work is required to form a cohesive understanding of the biochemical consequences of exposing arctic and subarctic marine species and ecosystems to petroleum.

ACCESS # : 453, ARL

CITATION : Widdows, J., T. Bakke, B.L. Bayne, P. Donkin, D.R. Livingstone, D.M. Lowe, M.N. Moore, S.V. Evans, and S.L. Moore. 1982. Responses of Mytilus edulis on exposure to the water-accommodated fraction of North Sea oil. Mar. Biol. 67: 15-31.

KEY-WORDS: Bivalves; Toxicity; Oil pollution; Aromatic hydrocarbons; Physiology; Growth.

SYNOPSIS : Individuals of Mytilus edulis L. collected from the Erme Estuary (S.W. England) in 1978, were exposed to low concentrations (7 to 68 ug/l) of the water-accommodated fraction (WAF) of North Sea crude oil. The pattern of accumulation of petroleum hydrocarbons in the body tissue was affected by the presence of algal food cells, the period of exposure, the hydrocarbon concentration in the water, the type of body tissue, and the nature of the hydrocarbon. Many physiological responses (e.g. rates of oxygen consumption, feeding, excretion, and scope for growth), cellular responses (e.g. lysosomal latency and digestive cell size) and biochemical responses (e.g. specific activities of several enzymes) were significantly altered by short-term (4 wk) and/or long-term (5 mo) exposure to WAF. Stress indices such as scope for growth and lysosomal latency were negatively correlated with tissue aromatic hydrocarbons.

ACCESS # : 454, ARL

CITATION : Wiens, J.A., G. Ford, D. Heinemann, and C. Fieber. 1979. Simulation modeling of marine bird population energetics, food consumption, and sensitivity to perturbation. Principal Investigators' Reports for the Year Ending March 1979 Vol. I. pp. 217-270. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Petroleum development; Seabirds; Models; Murres; Pribilof Islands.

SYNOPSIS : In the development of models to explore the effects of oil perturbations on breeding seabird colonies, as depicted by the Pribilof Islands' colonies, major attention was given to short-term (within-year) and to long-term (multiyear) effects. This report describes the model structures, analyses, and results for each level of modeling, and discusses the relevance of these exercises for oil-related impacts on colonially-breeding marine birds. Analysis shows that the chronic effects of oil development may be much more damaging than the short-term effects of an oil spill because of the extreme sensitivity of these populations to light changes in annual survival (especially of adults) and in fecundity. In general, the populations should be able to recover from oil spills, although in some cases it may take decades, but a permanent decrease in annual survival or fecundity may push a species over the edge, making it unable to persist on the Pribilofs. This argument is especially germaine to Red-legged Kittiwakes, since over 95% of the world population of this species breeds on St. George. In addition, several other seabirds that breed on the Pribilofs are near the edges of their species ranges, increasing the probability that small environmental changes may push them to local extinction on the Pribilofs.

ACCESS # : 455, ARL

CITATION : Holmes, W.N., and J. Cronshaw. 1977. Biological effects of petroleum on marine birds. In: D.C. Malins (ed.), Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Vol. II. Biological Effects. Academic Press, Inc. New York. NY. pp. 359-398.

KEY-WORDS: Toxicity; Oil spill; Seabirds; Mortality.

SYNOPSIS : Although the very high levels of contamination which occur immediately after a catastrophic spillage may be short-lived, the effects of the petroleum on birds may persist long after the environment has returned to a relatively pristine state. For instance, the estimates of mortality recorded during the first few days after a spill will be derived mainly by counting beached carcasses. No estimate can be made of the number of carcasses that sank or were devoured. During subsequent weeks birds that have been collected into cleansing centers will die and this number must be added to the initial estimates. Since some of the cleansed birds may survive several weeks, data from all sources may not be collected and included in the final estimate. Thus, quite apart from the fact that not all casualties are found, serious inaccuracies may occur during the collection of mortality data from these sources.

ACCESS # : 456, ARL

CITATION : Zimmerman, S.J., and R.R. Merrell, Jr. 1976. Baseline characterization, littoral biota, Gulf of Alaska and Bering Sea. Principal Investigators' Reports for the Year Ending March 1976. Vol. 6. pp. 75-484. OCSEAP/NOAA, Boulder, CO

KEY-WORDS: Oil pollution; Distribution; Fishes; Toxicity; Littoral habitats.

SYNOPSIS : A general characterization and survey of the intertidal and shallow subtidal biota in the region from Yakutat in the eastern Gulf of Alaska to Cape Newenham in northern Bristol Bay is provided. Two objectives in the study were: to determine the distribution of the major habitat types (sandy, muddy,rocky, etc.) along the coastline; and to determine the densities and distribution of biotic populations within these habitat types. The distribution of organisms within habitat types is being determined by field parties from the Auke Bay Fisheries Laboratory (ABFL), with logistical assistance from the Pacific Marine Center. Additional projects include an extensive literature survey, a study of the accumulation of biotic debris in the 'drift' zone, the estimation of variability between sampling areas, and more intensive studies at sites which may recieve major impact from oil exploration in the eastern Gulf of Alaska. The intertidal and shallow subtidal areas provide one of the major points of contact between floating or dissoved pollutants and the marine substrate. The majority of biota in these areas are non-motile and are unable to avoid repeated exposure as oil or similar compounds come ashore. In addition to the obvious problems of suffocation or acute toxicity, other effects may occur. For instance, removal of littoral populations may cause changes in the feeding patterns of marine birds and mammals. It may also change the reproductive potential of certain marine fishes.

ACCESS # : 457, ARL

CITATION : Malins, D.C. and H.O. Hodgins. 1976. Sublethal effects as reflected by morpholgical, chemical, physiological, and behavioral indices. Principle Investigators' Reports for July-September 1976. pp. 23-60. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Fishes; Toxicity; Trace metals; Physiology; Feeding behavior; Oil pollution.

SYNOPSIS : The objective of these studies is to identify and evaluate in selected marine organisms the effects of chronic exposure to petroleum hydrocarbons and trace metals. Under the general task objective, physiological, morphological, chemical, and behavioral parameters are being investigated. (1) physiologcal: effect of ingestion of whole crude oil on reproductive success in slamonids. (2) morphological: effect of ingestion of whole crude oil on structure and ultrastructure of internal tissues of salmonids. (b) changes in skin and gill epithelium of flatfish and salmon following exposure to the water-soluble fraction (WSF) of crude oil. (3) chemical: evaluate uptake, accumulation, and discharge of trace metals from mucus, epidermis, and scales of salmonids. (4) behavioral: effects of water-soluble fraction of crude oil on feeding behavior of shrimp.

ACCESS # : 458, ARL

CITATION : Kooyman, G.L., R.L. Gentry, and W.B. McAlister. 1976. Physiological impact of oil on pinnipeds. Principle Investigators' Reports for October-December 1976. pp. 3-26. OCSEAP/NOAA, Boulder, Colo.

KEY-WORDS: Fur seals; Oil pollution; Metabolism; Temperature; Marine mammals.

SYNOPSIS : The objective of this study was to measure the effects of oil contamination on the northern fur seal through studies on the thermal conductance of pelts, dive performance, and alterations in the metabolic rate before and after contact with oil. A second objective was to compare thermal conductance in pelts of fur-bearing marine mammals with that of nonfur-bearing species to determine whether surface fouling might be a major route of impact for all species. The study has shown that small amounts of crude oil have large effects on thermal conductance of fur-bearing pelts, and no effect on nonfur-bearing pelts. In living animals light oiling of approximately 30% of the pelt surface area resulted in a 1.5-fold increase in metabolic rate while immersed in water of various tempertures. Furthermore, this effect lasted at least 2 weeks. Although normal diving was measured, we did not obtain post-oiling data to show the effect of oil contact on dive performance.

ACCESS # : 459, ARL

CITATION : Geraci, J.R., and T.G. Smith. 1977. Consequences of oil fouling on marine mammals. In: D.C. Malins (ed.), Effects of Petroleum on Arctic and Subarctic marine Environments and Organisms. Vol. II. Biological Effects. Academic Press, Inc. New York. NY. pp. 399-410.

KEY-WORDS: Marine mammals; Oil pollution; Seals; Toxicity.

SYNOPSIS : This study showed that up to 75 ml of ingested crude oil is not irreversibly harmful to seals. The liver is generally regarded as a prime target organ for hydrocarbon damage in mammals. The effects of such damage have been well documented. If sufficient quantities of these hepatotoxic substances are administered, liver enzymes are released into plasma and are detectable. The degree and duration of enzyme release is generally a function of the quantity and toxicity of the substance(s). Measurable liver damage in grey seals was induced, using 5 and 10 ml quantities of carbon tetrachloride, a rather potent fraction. In this study there was only transient liver enzyme release. If there was liver damage, it was negligible.

ACCESS # : 460, ARL

CITATION : Szaro, R.C., and P.H. Albers. 1976. Effects of external applications of No. 2 fuel oil on Common Eider eggs. In: D.A. Wolfe (ed.), Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. Pergammon Press, New York. NY. pp. 164-167.

KEY-WORDS: Toxicity; Oil pollution; Waterfowl.

SYNOPSIS : Because eggs of marine birds may be exposed to oil adhering to the feathers of adult birds, a study was undertaken to determine the effects of oil contamination. Two hundred Common Eider eggs (Somateria mollissima) were divided into four experimental sets of 50 each. Two sets were treated with No. 2 fuel oil in amounts of 5 ul and 20 ul; a third with 20 ul of propylene glycol, a neutral blocking agent. The fourth set served as a control. Hatching success was 96 percent for the eggs treated with 5 ul propylene glycol, 96 percent for the controls, and 92 percent for the eggs treated with 5 ul oil hatched. Only 69 percent of the eggs treated with 20 ul of oil survived: a significant reduction in hatchability (P less than or equal to 0.05). Mean hatching weights for all sets were statistically equal. Thus, oil pollution may significantly increase embryonic mortality in marine birds.

ACCESS # : 461, ARL

CITATION : Caldwell, R.S., E.M. Caldrone, and M.H. Mallon. 1976. Effects of a seawater-soluble fraction of Cook Inlet crude oil and its major aromatic components on larval stages of the Dungeness crab, Cancer magister Dana. In: D.A. Wolfe (ed.), Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. Pergamon Press, New York, NY. pp. 210-220.
KEY-WORDS: Crustacea; Petroleum; Aromatic hydrocarbons; Naphthalene; Toxicity; Crabs.

SYNOPSIS : Larval stages of the Dungeness crab, Cancer magister Dana, were exposed continuously to dilutions of Cook Inlet crude oil water-soluble fraction (WSF) of seawater solutions of naphthalene or benzene for periods lasting up to 60 days. Effects on survival, duration of larval development, and size were employed as indicators of toxic effects. The lowest concentration of the WSF at which toxic effects were seen was 4.0% of the full strength WSF (0.0049 mg/l as naphthalene or 0.22 mg/l as total dissolved aromatics). The lowest concentration at which toxic effects were observed with naphthalene was 0.13 mg/l and with benzene was 1.1 mg/l. The concentration of aromatic hydrocarbons in the WSF were inversely related to the degree of alkylation in each of the benzene and naphthalene families, but the acute toxicity of the 12 compounds was directly related to the degree of alkyl substitution. In addition, naphthalene and its derivatives were more toxic than benzene and its derivatives, but less concentrated in the WSF.

ACCESS # : 462, ARL

CITATION : Mecklenburg, T.A., S.D. Rice, and J.F. Karinen. 1976. Molting and survival of king crab (Paralithodes camtschatica) and coonstripe shrimp (Pandalus hypsinotus) larvae exposed to Cook Inlet crude oil water-soluble fraction. In: D.A. Wolfe (ed.), Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. Pergamon Press, New York, NY. pp. 221-228.
KEY-WORDS: Molting; Crustacea; Larvae; Paralithodes camtschatica; Crabs; Oil pollution.

SYNOPSIS : Larvae of coonstripe shrimp and king crab were exposed to solutions of the water-soluble fraction (WSF) of Cook Inlet crude oil in a series of bioassays on intermolt stages I and II and the molt period from stage I to II. Molting larvae were more sensitive than intermolt larvae to the WSF, and molting coonstripe shrimp larvae were more sensitive than molting king crab larvae. When molting larvae were exposed to high concentrations of the WSF (1.15-1.87% ppm total hydrocarbons) for as little as 6 hr, molting success was reduced by 1-30% and some deaths occurred. When larvae were exposed to these high concentrations for 24 hr or longer, molting declined 90-100% and the larvae usually died. The lowest concentrations tested (0.15-0.55 ppm total hydrocarbons) did not inhibit molting at any length of exposure, but many larvae died after molting. Median lethal concentrations (LC50's) based on 144 hr of observation for molting coonstripe shrimp and 120 hr for molting king crab were much lower than the 96-hr LC50's showing that the standard 96-hr LC50 is not always sufficient for determining acute oil toxicity. Although our LC50's for intermolt larvae are higher than levels of petroleum hydrocarbons reported for chronic and spill situations, some of our LC50's for molting larvae exposed 24 hr and longer are similar to or below these environmental levels. Comparisons of sensitivity to oil between different crustacean species or life stages should be based on animals tested in the same stage of the molt cycle, such as intermolt.

ACCESS # : 463, ARL

CITATION : Karinen, J.F., and S.D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting Tanner crabs, Chionoecetes bairdi. Mar. Fish. Rev. 36(2): 31-37.

KEY-WORDS: Crabs; Molting; Toxicity; Chionoecetes bairdi; Oil pollution; Crustacea.

SYNOPSIS : Premolt and postmolt juvenile male Tanner crabs, Chionoecetes bairdi, from Alaska waters were exposed to Prudhoe Bay crude oil in static bioassays in laboratories. Crabs in both stages were similarly susceptible to crude oil; the estimated 48-hour TLm (medium tolerance limits) values were 0.56 ml oil/liter. Molting success decreased with increasing exposure of crabs to oil, and newly molted crabs autotomized limbs during exposure to oil. Relating the results of our study to the known behavior of crabs and the documented behavior of oil spills in the ocean suggest than oil spilled in Alaska waters would harm the Tanner crab resources. The impact on all crab resources of chronic low-level oil pollution from the ballast water discharged into Prince William Sound is unknown. This study further illustrates our present state of ignorance concerning the biological effects of oil in the marine environment.

ACCESS # : 464, ARL

CITATION : Neff, J.M., and J.W. Anderson. 1981. Response of marine animals to pertroleum and specific petroleum hydrocarbons. Applied Science Publishers LTD, London. 177 pp.

KEY-WORDS: Marine mammals; Hydrocarbons; Pollution effects.

SYNOPSIS : A major research effort has been initiated in this country and abroad to assess the impacts of hydrocarbon inputs on marine organisms and ecosystems Much laboratory research to date has concentrated on acute toxicity bioassays with one or a few oils, or petrochemicals, and selected species of marine organisms. Such bioassays, while important, are of limited value in judging the potential impact of long term, low level petroleum contamination of marine ecosystems. The laboratory at Texas A&M University, under contract to the American Petroleum Institute since 1972, has conducted extensive laboratory and field research concerning the effects of petroleum and specific petroleum hydrocarbons on marine organisms and ecosystems. The purpose of this volume is to summarize and review lethal and sublethal effects of oil on marine organisms, based on results of laboratory studies completed since the publication of an earlier report (Anderson, 1975).

ACCESS # : 465, USF&WS

CITATION : King, J.G., and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. In: J.C. Bartonek and D.N. Nettleship, Conservation of Marine Birds of Northern North America. U.S. Dept. Int., Fish Wildl. Serv. Wildl. Res. Rep. 11. 319 pp.

KEY-WORDS: Seabirds; Oil pollution; Waterfowl; Survival factors; Management; Shorebirds.

SYNOPSIS : The 176 species of birds using marine habitats of the Northeast Pacific are graded on the basis of 20 factors that affect their survival. A score of 0, 1, 3, or 5, respectively, representing no, low, medium, or high significance is assigned for each factor. The total score is the Oil Vulnerability Index (OVI). The OVI's range from 1 to 100; an index of 100 indicating the greatest vulnerability. Using this system, one can rank the avifauna of different areas according to their vulnerability to environmental hazards as an aid in making management decisions.

ACCESS # : 466, USF&WS

CITATION : King, J.G., C.P. Dau, R.E. Gill, Jr, and L.M. Dresch. 1980. A quantitative catalogue of intertidal and near shore bird habitats of eastern Bering Sea. U.S. Fish Wildl. Serv., Juneau, Alaska. Unpublished report.

KEY-WORDS: Seabirds; Intertidal habitats; Shorebirds; Waterfowl.

SYNOPSIS : Bering Sea waterbird habitats include four types; the shallow usually near shore waters where diving birds can feed on the bottom, the sheltered waters of lagoons and confined bays, unvegetated tidal mud flats and beaches, and vegetated flats to the upper limit of normal storm surges. Each of these extends for hundreds of thousands of acres within the Bering Sea area. Waterfowl and shorebirds reposnd to this wealth of habitats by utilizing them in great numbers. The region is important for nesting, migrational staging, and wintering birds. The entire population of many species depends on this habitat resource and some species manage to survive year round within this region.

ACCESS # : 467, MMS

CITATION : Science Applications, Inc. 1980. Major References, North Aleutian Shelf Lease Area. For NOAA, Office of Marine Pollution Assessment, Alaska Office.

KEY-WORDS: Bibliography; North Aleutian Shelf; Biology; Oceanography.

SYNOPSIS : This bibliography contains 147 citations in physical oceanography and over 200 citations in biological oceanography. The sources are from the published literature and unpublished agency reports.

ACCESS # : 468, MMS

CITATION : Science Applications, Inc. 1981. North Aleutian Lease Area, Summary. 21 Plates. For NOAA, Office of Marine Pollution Assessment, Alaska Office.

KEY-WORDS: Biogeography; Climatology; North Aleutian Shelf; Sea ice; Food web; Geology; Habitat; Human use; Oceanography.

SYNOPSIS : Plates (21) are presented in this report which includes text summarizing conditions and resources of the North Aleutian Shelf Lease area, Sale 92.

ACCESS # : 469, NOAA

CITATION : Thorsteinson, L. (ed.). 1983. Proceedings of a Synthesis Meeting: North Aleutian Shelf and Possible consequences of Oil and Gas Development, Anchorage, Alaska. 9-11 March 1982. OCSEAP/NOAA. Unpubl. Manuscript.

KEY-WORDS: Northern Aleutian Shelf; Petroleum development; Biology; Crustacea; Bivalves; Circulation; Distribution; Ecology; Habitat; Invertebrates; Larvae; Marine mammals; Oceanography; Oil pollution; Productivity; Resource assessment; Salmon; Sublethal effects.

SYNOPSIS : Proceedings of a synthesis meeting are presented for the North Aleutian Shelf regions. Available knowledge is summarized and interpreted in light of planned oil and gas development of the region. Proposed development and environmental implications are reviewed. Topics included are the transport and fate of spilled oil, the coastal habitats and species of the North Aleutian Shelf, and fisheries resources of the area.

ACCESS # : 470, MMS

CITATION : Rice, S.D., D.A. Moles, J.F. Karinen, S. Korn, M.G. Carls, C.C. Brodersen, J.A. Gharrett, M.M. Babcock. 1983. A Comprehensive Review of all Oil-Effects Research on Alaskan Fish and Invertebrates Conducted by the Auke Bay Laboratories, 1970-1981. RU # 72. Final Report. OCSEAP/NOAA. (in press). 145 pp.

KEY-WORDS: Petroleum; Hydrocarbons; Fish; Invertebrates; Toxicity; Sublethal effects; Habitat; Port Valdez.

SYNOPSIS : This report reviews and summarizes all of the oil-effects research conducted by the Auke Bay Laboratory from the beginning in 1970 through 1981. Both published and unpublished results from 63 studies are included, regardless of funding source. Research is reviewed according to subject (e.g., toxicity, sublethal effects, studies at Port Valdez) and includes a bibliography and abstracts. The results from different studies should be compared with caution because of differences in methods used. The toxic nature of water-soluble fractions and classes of compounds was examined in several studies. A variety of biological and environmental variables affect sensitivity of Alaskan species. The rate and quantities of hydrocarbon uptake vary considerably between different compounds, tissues, life stages, and species. Oil and its components have a variety of sublethal effects that can ultimately affect population numbers. The toxicity of treated ballast water effluent at Port Valdez is rapidly diluted, and direct short-term toxic effects in the natural environment are not apparent. Because of rapid dilution and low toxicity, there appears to be little evidence that drilling muds can be an environment concern to sensitive larvae. Sensitivity of an organism in a laboratory study is different from vulnerability after an oil spill. Laboratory tests isolate one variable at a time; whereas oil spills have many variables operating at one time, and each spill is different and unique.

ACCESS # : 471, ARL

CITATION : Hameedi, M.J.(ed.). 1981. Proceedings of a synthesis meeting: The St. George Basin environment and possible consequences of planned offshore oil and gas development. Anchorage, Ak. April 28-30. U.S. Dept. of Commerce, NOAA, OMPA, OCSEAP, Juneau.

KEY-WORDS: St. George Basin; Resource assessment; Petroleum development. Environmental legislation.

SYNOPSIS : The Outer Continental Shelf Environmental Assessment Program (OCSEAP) investigators, other scientists conducting research in the southeastern Bering Sea, and managers of resources of the region met in Anchorage, Alaska, 28-30 April 1981. OCSEAP's and other data were used to: (1) describe the marine and coastal environments of the St. George Basin Lease Area; and (2) discuss and record environmental issues of concern and environmental consequences of the proposed oil and gas development, including effects of hypothetical cases of oil spills and other pollution incidents. These topics were also presented to help BLM in the preparation of the Draft Environmental Impact Statement for OCS Sale 70. The following topics were discussed in workshops and plenary sessions at the St. George Synthesis Meeting: 1) Pollutant transport mechanisms and the fate of spilled oil. 2) Environmental hazards and restrictions to petroleum technology and facilities. 3) Potential effects of oil and gas development on marine mammals, especially endangered species, with emphasis on key habitats such as Unimak Pass and the Pribilof Islands. 4) Potential effects of development on the finfish resources and pelagic ecosystems, with emphasis on salmon, halibut, pollock, and yellowfish sole fisheries. 5) Potential effects of development on marine and coastal birds, with emphasis on major colonies and foraging areas such as the Pribilof Islands region. 6) Potential effects of development on the shellfish resources and benthic ecosystem, with emphasis on king and Tanner Crab fisheries.

ACCESS # : 472, USF&WS

CITATION : Petersen, M.R., and R.E. Gill, Jr. 1982. Population and status of Emperor Geese along the north side of Alaska Peninsula. Wildfowl 33: 31-38.

KEY-WORDS: Emperor geese; Distribution; Age composition; Waterfowl.

SYNOPSIS : In conjunction with studies of waterfowl and shorebirds in the eastern Bering Sea region information was gathered on Emperor Geese. Here, the researchers (1) report the number and temporal occurrence of geese observed in Nelson lagoon; (2) evaluate the relative importance to geese of the major estuaries on the north side of the Alaska Peninsula; (3) assess age ratios and average brood sizes of geese during autumn migration along the Bering Sea coast and Alaska Peninsula; and (4) compare changes in numbers of geese estimated during censuses in spring and autumn from 1963 to 1981.

ACCESS # : 473, ARL

CITATION : Gill, R.E., Jr., and J.D. Hall. 1983. Use of nearshore and estuarine areas of the southeastern Bering Sea by gray whales (Eschrichtius robustus). Arctic 36(3): 275-281.

KEY-WORDS: Gray whale; Feeding behavior; Estuaries; Marine mammals.

SYNOPSIS : During spring aerial surveys of the coast of the southeastern Bering Sea significant numbers of gray whales were seen in nearshore waters along the north side of the Alaska Peninsula. Many (50-80%) of these animals were observed surfacing with trailing mud or lying on their sides when surfacing, characteristics both associated with feeding. A migration route close to shore (within 1-2 km) was used until whales neared Egegik Bay, where they began to head west 5-8 km offshore, across northern Bristol Bay. Smaller numbers of gray whales were present throughout summer in nearshore waters and estuaries along the north side of the Alaska Peninsula. At Nelson Lagoon, gray whales normally used the lagoon in spring, were absent during early summer, returned in mid-summer, and then were present until late November when they departed for the wintering grounds. Gray whales were present in the lagoon most often during periods of peak tidal flow; those that appeared to be feeding were oriented into the current. Three behaviors that appeared to be associated with feeding were observed: side-feeding from a stationary position within shallow waters of lagoon channels, diving within the lagoon and in nearshore waters, and elliptical side-feeding in the surf zone along the outer coast. Large crustaceans of the genus Crangon were available to them and probably eaten by gray whales at Nelson Lagoon.

ACCESS # : 474, ARL.

CITATION : North Pacific Fishery Management Council, 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. Annotated Bibliography. Council Document #19a. Anchorage, Alaska.

KEY-WORDS: Marine mammals; Bibliography; Gray whale; Bowhead whale; Whales; Fur seal; Sea Lion; Walrus; Harbor seal; Spotted seal; Ribbon seal; Ringed seal; Bearded seal; Sea otter; Beluga whale.

SYNOPSIS : Seven hundred twenty documents are annotated in this reference list. Most references deal directly with foods, distribution, density, and population status of Bering Sea marine mammals. For some species, little or no work has been done in the Bering Sea, and references to work done in other areas are included for analogy and comparison. Much of the work on food requirements and metabolic and reproductive physiology has been done with captive animals. For some species (e.g., northern fur seal), there is a great deal of literature; the papers included for these species summarize current understanding of pertinent information.

ACCESS # : 475, ARL.

CITATION : Bakkala, R., W. Hirschberger, K. King, 1979. The groundfish resources of the Eastern Bering Sea and Aleutian Islands regions. Marine Fisheries Review. 44:11(1-24).

KEY-WORDS: Commercial fisheries; Pacific cod; Demersal fish; Walleye pollock; Fisheries; Fisheries resources.

SYNOPSIS : This paper recounts the history of the major fisheries in the areas, and delimites the resources that will be available to the developing U.S. fishery. It reviews the history of past fisheries for groundfish in the Eastern Bering Sea and Aleutian Islands regions to illustrate methods and areas of fishing, species taken and the magnitude of catches, and the current conditions of the resource.

ACCESS # : 476, NMFS, Anchorage.

CITATION : Higgins, B.E., 1978. An assessment of certain living resources and potential resource-use conflicts between commercial fisheries and petroleum development activities in outer Bristol Basin and Bristol Bay, Southeastern Bering Sea. Environmental Assessment Division. NMFS. Juneau, Alaska.

KEY-WORDS: Commerical fisheries; Development; Productivity; Herring; Red King crab; Tanner crab; Salmon; Pollock; Seals; Sea Lion; Whales; Shrimp; Snails; Fisheries resources; Pollution effects; Petroleum development; St.George Basin.

SYNOPSIS : This report evaluates certain commercial and biological uses of outer Bristol Basin and Bristol Bay that may conflict with petroleum development, documents the national and international importance of the area's renewable living resources, and proposes recommendations to minimize or avoid potential resource-use conflicts. Potential resource conflicts between petroleum development and commercial fishing include loss of fishing space, interference with fishing operations, loss of or damage to fishing gear, fouling of fishing gear by oil, and contamination of fish and shellfish of commercial importance. Potential biological impacts include habitat alteration or destruction, noise and human disturbance, and pollution by oil and other contaminants. Impacts could be most severe in spring-summer, particularly June-July, the significant reproductive and developmental period for many species, especially fish and shellfish with pelagic early life history stages. The primary recommendation is to establish a marine sanctuary in the Bristol Bay/ St.George Basin area, including the Pribilof Islands and Unimak Pass, bounded on the west by the 300-fathom contour. Other recommendations propose to prohibit oil and gas leasing forever, continue to defer leasing, restrict the timing of oil and gas activities to late fall and winter, and conduct futher studies prior to making decisions on developing the area's petroleum resources.

ACCESS # : 477, ARL.

CITATION : Otto, R.S., 1981. Eastern Bering Sea crab fisheries. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf:Oceanography and Resources. Vol. II. 1037-1066. NOAA, distrib. by Univ. of Washington Press. Seattle, WA.

KEY-WORDS: Commercial fisheries; Commercially important species; Crabs; King crab; Paralithodes camtschatica; Tanner crab; Chionoecetes; Crustacea.

SYNOPSIS : Eastern Bering Sea fisheries for red king crab, blue king crab and Tanner crabs are among the most important sources of crab in the world.
Eastern Bering Sea crab fisheries currently provide about 12% of world crab landings, and some 38% of domestic crab landings. Fully 50% of the landed value of the U.S. crab catch came from the eastern Bering Sea in 1978.
The history of eastern Bering Sea crab fisheries extends back to 1930, but substantial commercial efforts were not undertaken until the 1950's, when the king crab fisheries were developed. Tanner crab fisheries were developed during the 1960's. Japan and the Soviet Union had large crab fisheries in the eastern Bering Sea before the United States mounted a substantial effort. Foreign fisheries for king crabs ceased in 1974 and are now prohibited. Japan continues to fish Tanner crab in the eastern Bering Sea, but the Soviet Union left the fishery in 1971.
Record landings of crabs in the eastern Bering Sea over the past five years have prompted the development of one of the newest and most efficient U.S. fishing fleets. The economic future of eastern Bering Sea crab fisheries is clouded by forecast declines in the abundance of red king crab and continued low abundance of Chionoecetes bairdi. Development of new markets will be necessary if the Chioniecetes opilio stock is to be fully exploited. Without the further development of the C. opilio fishery, the importance of the eastern Bering Sea as a source of crab is likely to decline.

ACCESS # : 478, ARL.

CITATION : Bakkala, R., K. King, and W. Hirschberger, 1981. Commercial use and management of demersal fish. In: D.W. Hood and J.A. Calder (eds.), The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II. 1015-1036. NOAA, distrib. by Univ. Washington Press. Seattle, WA.

KEY-WORDS: Commercial fisheries; Fisheries; Fisheries management; Fisheries resources; Fisheries development; Demersal fish; History.

SYNOPSIS : This article traces the history of various demersal fisheries in the eastern Bering Sea through the pre-management peak harvest years to the recent establishment of the management of the resources. At their peak, landings of foreign fisheries in the eastern Bering Sea were among the world's largest, supplying more than 2 million mt of groundfish annually. As declines in abundance of the resources became evident in the 1970's, catch restrictions were placed on foreign fleets. Foreign catches in 1977 and 1978 ranged from 1.0 to 1.3 million mt.
Under the U.S. Fishery Conservation and Management Act of 1976, all fishery resources within 200 miles of the Alaskan coast were placed under U.S. jurisdiction. The objectives of the management plan developed for the region were four fold. The rebuilding of the Pacific Halibut resource was continued. The rebuilding of the groundfish resources to healthy levels capable of producing maximum sustainable yields was initiated. The promotion of the participation of the U.S. fisheries in the use of the resources was started. And the harvest of the resources by foreign fleets was allowed to continue when it was consistent with the first three objectives.

ACCESS # : 479, ARL.

CITATION : Ashwell-Erickson, S. and J.R. Elsner, 1981. The energy cost of free existance for Bering Sea harbor and spotted seals. In: D.W. Hood and J.A. Calder (eds.), Eastern Bering Sea Shelf: Oceanography and Resources. Vol. II. 869-900. NOAA, distrib. by Univ. Washington Press. Seattle, WA.

KEY-WORDS: Physiology; Feeding; Food requirements; Models; Harbor seal; Spotted seal; Prey items; Herring; Caplin; Pollock; Invertebrates;

SYNOPSIS : Energy flow models based on single-prey diets were developed to assess the net energy requirements of Bering Sea harbor and spotted seal populations from long-term studies of food intake and composition, food energy content and digestiblity, and metabolic effects of temperature, feeding, exercise, molt and reproduction in several captives of each species. Caloric values of diets were directly proportional to fat content, ranging from 0.6 to 1% in pollock and from 5.1 to 18.5% in herring. The mean digestible energy of pollock and herring was 96.7% of gross ingested energy, respectively, and the net mean energy flow available from both diets was 80.3% of gross energy. Air and water temperatures comparable to those in the natural environment fell within the thermoneutral zone of the seals. Basal metabolism of both seal species declined with age. Maximum metabolic effort in water was achieved with harbor seals carrying a weight load of 8 kg at an oxygen consumption rate of 32.8ml/kg min, a value approximately four times basal rate. Metabolism during molt in harbor seals was 83% of pre-molt levels. Reproductive energy costs were estimated at 240,000 and 220,000 Kcal/yr for individual harbor and spotted seals, respectively. The mean annual gross energy required by both populations combined was estimated at 560,000,000,000 Kcal, corresponding to an annual consumption of 81,000 mt of pollock, 51,700 mt of caplin, 37,300 mt of herring and 46,100 mt of invertebrates, four important prey groups in the diets of these seals.

ACCESS # : 480, NMFS, Anchorage.

CITATION : National Marine Fisheries Service, 1980. Living marine resources and commercial fisheries relative to potential oil and gas development in the northern Aleutian shelf area (Tentative Sale No. 75). Northwest and Alaska Fisheries Center, Seattle, Washington. Inter-agency report.

KEY-WORDS: Fisheries; Productivity; Cetacean; Commercial fisheries; Crabs; Fisheries resources; Habitat; Oil pollution; Petroleum development; Pollution effects; Sea ice; Models; Unimak Pass; Crustacea.

SYNOPSIS : This report supplements the biological, oceanographic, and commercial fisheries information contained in earlier NMFS reports (Haggins, 1980), but does not provide as detailed a discusssion of these topics as is contained in the other reports. Though previous reports discuss the anticipated problems of conflict between existing fisheries and oil and gas lease sale development, this report explores the fate of spilled oil in this area as a series of complex interations between pack ice, wind events and local currents through the use of models. It also examines the important role of protected tidal flats and salt marshes in maintaining the high productivity of the Bristol Bay region and their vulnerability to spills. Similarly, the North Aleutian shelf area provides an important habitat for many species, some of which form the basis of existing or potential commercial fisheries (e.g., crabs, salmon, clams, pollock, cod). The area also provides important habitat for four species of endangered whales (e.g., gray, fin, right, and humpback), especially in the Unimak Pass area. This report urges that petroleum exploration and development be deferred until the risks to the marine resources and their habitats are more accurately assessed relative to the area's petroleum potential, and until safer technologies are available to reduce the presummed risks involved.

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