Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 68 August 1990

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
Alaska OCS Region
OCS Study, MMS 90-0056

"Outer Continental Shelf Environmental Assessment Program Final Reports of Principal Investigators" ("OCSEAP Final Reports") continues the series entitled "Environmental Assessment of the Alaskan Continental Shelf Final Reports of Principal Investigators."

It is suggested that reports in this volume be cited as follows:

Dunton, K. H., S. V. Schonberg, and D. M. Schell. 1984. Biological reconnaissance of Boulder Island Shoal in western Camden Bay, Beaufort Sea, Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 68: 1–24.

Feder, H. M., A. S. Naidu, M. J. Hameedi, S. C. Jewett, and W. R. Johnson. 1989. The Chukchi Sea continental shelf: benthos–environmental interactions. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 68: 25–311.

Rosenthal, R. J., D. C. Lees, and T. M. Rosenthal. 1977. Ecological assessment of sublittoral plant communities in the northern Gulf of Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 68: 313–459.

Dames and Moore. 1978. Ecology of unconsolidated beaches in Lower Cook Inlet. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 68: 461–629.

OCSEAP Final Reports are published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Ocean Assessments Division, Alaska Office, Anchorage, and primarily funded by the Minerals Management Service, U.S. Department of the Interior, through interagency agreement.

Requests for receipt of OCSEAP Final Reports on a continuing basis should be addressed to:

NOAA–OMA–OAD
Alaska Office
Federal Bldg., U.S. Courthouse Room A13
222 West Eighth Ave., #56
Anchorage, AK 99513–7543

OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM

Final Reports of Principal Investigators

Volume 68

August 1990

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
Alaska OCS Region

OCS Study, MMS 90-0056

Anchorage, Alaska

The facts, conclusions, and issues appearing in these reports are based on research results of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), which is managed by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and funded (wholly or in part) by the Minerals Management Service, U.S. Department of the Interior, through an Interagency Agreement.

Mention of a commercial company or product does not constitute endorsement by the National Oceanic and Atmospheric Administration. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

The content of these reports has not been altered from that submitted by the Principal Investigators. In some instances, grammatical, spelling, and punctuation errors have been corrected to improve readability; some figures and tables have been enhanced to improve clarity in reproduction.

Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

VOLUME 68 AUGUST 1990

CONTENTS

BIOLOGICAL RECONNAISSANCE OF BOULDER ISLAND SHOAL IN WESTERN CAMDEN BAY, BEAUFORT SEA, ALASKA

by

K. H. Dunton, S. V. Schonberg, and D. M. Schell

Institute of Water Resources
Engineering Experiment Station
University of Alaska
Fairbanks, Alaska 99701

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 651

January 1984

ACKNOWLEDGMENTS

We thank Jim Hanes for his expert navigation and field assistance, particularly under adverse sea and ice conditions. We are also very grateful to Joan Forshaug for her donation of field assistance, particularly during the unforeseen 24-hour absence of Jim Hanes for medical reasons. We also thank Alan Paulson for editing, Louise Flood for typing and Steve Zimmerman, who was directly responsible for the project described in this report.

SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT

This report presents the results of a two-day geophysical and biological survey in western Camden Bay, near Boulder Island Shoal, in the Alaskan Beaufort Sea. The primary objective of this survey was to determine if a kelp bed existed in the lee (south and west) of Boulder Island Shoal. Earlier, it was hypothesized (Dunton et al., 1983) that this shoal was the source of much of the drift kelp seen on beaches in the area.

Benthic trawls and fathometer records indicate that boulders and cobbles are rare in the survey area. However, many kelp plants were collected in trawls at certain locations south and west of Boulder Island Shoal. These plants were usually attached to pea size gravel and small pebbles. Occasionally, we dredged up plants attached to small angular cobbles up to 6 cm in diameter.

The small kelp beds located near Boulder Island Shoal are not comparable to the boulder patches in Stefansson Sound. The kelp in Camden Bay live in a relatively marginal environment in respect to both rock cover and protection from ice scour by deep-draft ice. The major limiting resource is rock substrata, which kelp require for attachment to the seafloor. The rich invertebrate assemblage, common to the Boulder Patch in Stefansson Sound, is also lacking.

Despite the limited size and diversity of this community, kelp and associated fauna do occur. As such, site-specific diving surveys should be conducted prior to the construction of offshore facilities to minimize the impact on these rare communities.

TABLE OF CONTENTS

INTRODUCTION

General Nature and Scope of Study

The primary goal of the benthic survey in western Camden Bay was to provide information on the occurrence of kelp in the vicinity of Boulder Island Shoal (Figure 1). The survey area extended to the south and west of the shoal as shown in Figure 2. Severe ice conditions permitted very little work north of the shoal, even with a small boat. A Ross SL-500 recording fathometer was used in conjunction with benthic trawls to map the character of the seabed.

Specific Objectives

1. Determine the presence and location of kelp beds in the vicinity of Boulder Island Shoal in western Camden Bay.

2. As time permits, determine the areal extent of the kelp beds and their floral and faunal composition.

Relevance to Problems of Petroleum Development

In Stefansson Sound, the presence of an abundant and diverse flora and fauna associated with cobbles and boulders resulted in special protection for the Boulder Patch from industrial activity related to petroleum exploration. The kelp in the Boulder Patch contributes the largest fraction of carbon in this area, and this carbon source is utilized by many invertebrate consumers. The presence of a similar kelp community in western Camden Bay may thus require similar attention, depending on its size and composition.

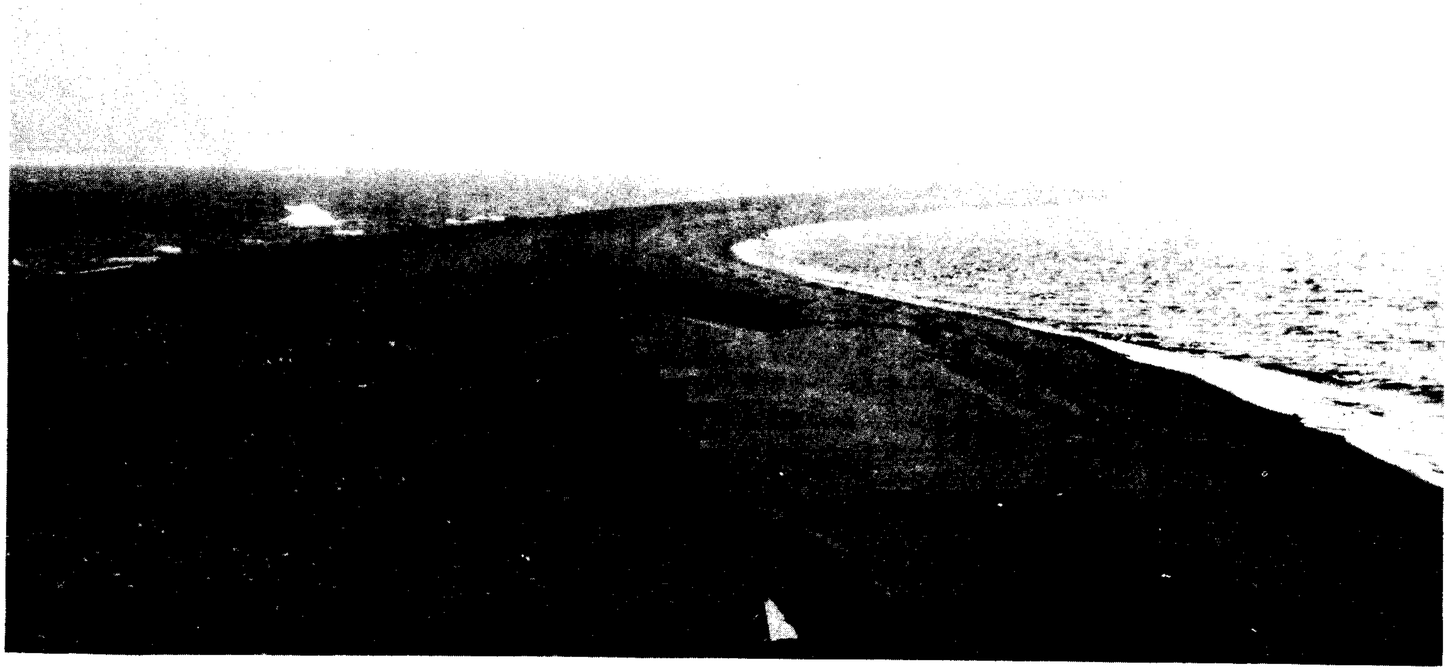

Figure 1. Boulder Island Shoal (looking east from its western tip) in western Camden Bay. The shoal made its first appearance in many years in 1983 (Reimnitz, personal communication).

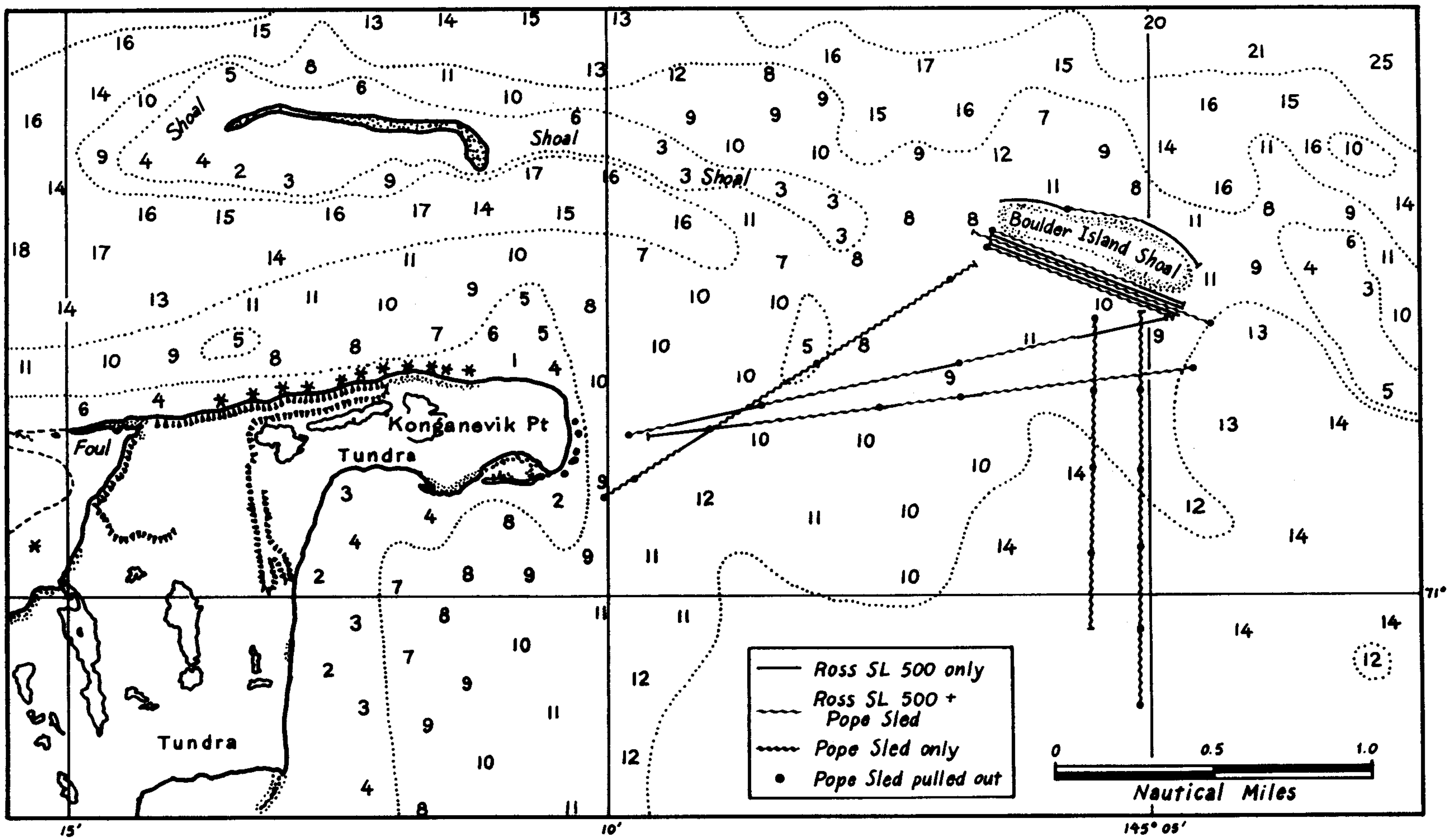

Figure 2. The study area extended from Konganevik Point to an imaginary line running south from the eastern tip of Boulder Island Shoal in water depths ranging between 3 and 5 meters (depths are listed in feet). The location of the sled and geophysical transects are shown. Solid circles along each transect line indicate places where the contents of the sled were removed and the transect restarted.

Kelp as a Carbon Source

Although the input of terrestrial peat carbon to the nearshore Alaskan Beaufort Sea is of the same magnitude as that derived from marine sources, marine primary production supplies nearly all of the carbon used in arctic marine foodwebs (Schell, 1983). Most of this carbon is supplied by phytoplankton, but benthic microalgae and ice algae also contribute carbon on a less consistent temporal and spatial scale. The discovery of the Boulder Patch and its large population of flora and fauna by E. Reimnitz in 1971 also led to the discovery of another marine carbon source of unknown magnitude -- kelp. Subsequent long-term in situ productivity studies indicated that the carbon contribution made by kelp in the Boulder Patch doubled the amount of carbon available to consumers in that region (Dunton et al., 1982). It also appears that kelp is an alternate food source for many animals that primarily rely on phytoplankton. Thus, the kelp communities found in association with "boulder patches" may not only be unusual but also supply a source of carbon that is utilized by organisms that are eaten by birds, fishes, and marine mammals (Dunton and Schell, 1982).

Cobbles and Boulders in Western Camden Bay

The presence of cobbles and boulders in western Camden Bay was first reported by Barnes and Ross (1980). Subsequent investigation of the seabed using underwater television showed that the rocks supported a diverse benthic community (Barnes, 1981). This benthic community appeared similar to the Boulder Patch (Reimnitz and Ross, 1979; Dunton et al., 1982) in the types of organisms present. In August 1981, some of the nearshore boulder ridges described by Barnes (1981) were examined by divers (Dunton and Schonberg, 1981). Their short examination revealed patchy occurrences of rocks where Barnes (1981) had indicated, but the benthic fauna and flora were not comparable in density or diversity to that of the Boulder Patch. However, only a few rock patches were examined, and these were in relatively shallow water (less than 3.5 m depth). Biological assemblages are more likely to possess a greater luxuriancy in deeper water which affords greater protection from the thick winter ice.

From sonographs, Barnes and Ross (1980) identified several locations where they postulated the existence of boulders and cobbles on the seabed in deeper water. No boulders or cobbles were found, however, when the area was thoroughly investigated using divers and a variety of benthic sampling equipment (Dunton et al., 1983). Since Barnes and Ross did not make any direct seabed observations, it appears that they may have misinterpreted certain ambiguities in their sonographs, confusing boulders with other topographical features on the seabed (Dunton et al., 1983).

STUDY AREA: BEAUFORT SEA (100 PERCENT)

The study area for this project is western Camden Bay, south of Boulder Island Shoal, between longitude 145°05' and 145°10', in water depths ranging from 3 to 5 m (Fig. 2). Calibration of geophysical instruments was conducted at OCSEAP DS-11 in Stefansson Sound.

SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Geophysical survey data and samples were collected from the *R/V Proteus*, a 25-foot Boston Whaler leased to OCSEAP by Arctic Marine Research Associates. The vessel carried a crew of three, was fully canvassed and powered by twin 140 HP outboard engines. Navigation equipment included a Furuno 16-mile radar, flasher fathometer, compass, and RDF (radio direction finder). Mast, boom and outriggers provided a means to tow and retrieve trawl equipment from the stern, port, or starboard sides.

Geophysical Survey

Geophysical coverage was obtained across the study area along the transects shown in Figure 2. The accoustical system was a Ross Model

SL-500 recording fathometer. This instrument has been used successfully in previous studies in Stefansson Sound to locate boulder patches. It uses a narrow beam 200 kHz transducer and produces a paper copy fathogram. Boulders and cobbles on the seafloor are indicated on traces by elongate return signals and by slight surface roughness. All survey transects were established using a compass and radar fixes from natural and artificial land targets. Radar targets were also placed on Boulder Island Shoal. Navigation fixes are generally accurate within ±200 m.

Biological Sampling and Seabed Observations

Biological samples were collected using our Pope sled, a small specially designed sled for sampling rocky bottoms (Dunton et al., 1983). Locations of sled transects are shown in Figure 2. Due to unforeseen medical problems suffered by one of the crew, no diving was accomplished, although underwater photographs of the seabed were taken on the south side of Boulder Island Shoal by wading.

RESULTS AND DISCUSSION

Occurrence and Location of Macroalgae

Figure 3 shows the relative density of kelp along various segments of our transect lines based on collections from the Pope sled. Although plants were found scattered throughout the survey area, the greatest number of plants were collected at two locations: the first, directly south of Boulder Island Shoal in water depths of 3 to 4 meters; and the second, southwest of the shoal at depths of 3 m.

The density of plants in this area appears relatively low compared to the Boulder Patch. Nonetheless, the abundance of kelp in such a large area would seem now to account for the drift on beaches directly south of the shoal on Soplu Spit and on barrier islands to the west (Dunton et al., 1983).

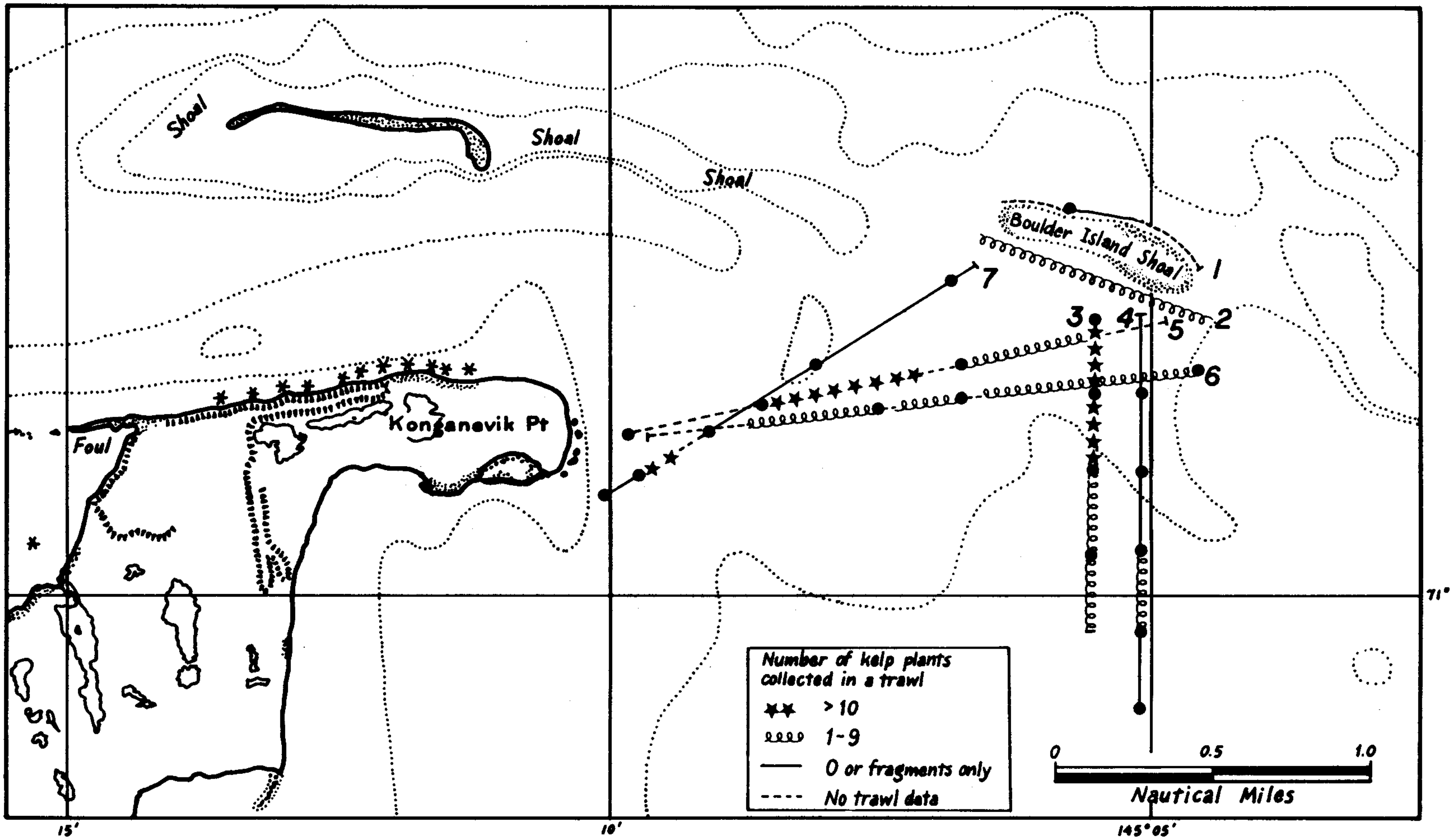

Figure 3. The numbers of plants collected along various segments of each transect in the survey area.

Surficial Bottom Features

Bottom traces from the Ross SL-500 revealed little topographical relief (Figure 4). This was also confirmed from the trawls -- rocks larger than pebble size were rare. Occasionally, we collected small angular cobbles up to 6 cm in diameter with attached kelp. The sediments in the area varied from stiff clays to soft mud. Ice gouges were evident in the area.

Direct observation of the seabed was made in shallow water (<2 m) from the southwestern shore of the shoal. We found the bottom to consist of small cobbles, gravel, and sand (Figure 5). Our trawl data indicated, however, that the frequency of the pebbles and cobbles dropped rapidly as we moved from the shore into water depths of 3 to 4 m.

Fauna and Flora Collected

The fauna and flora collected along various segments of each of the major transects are listed in Table 1. Three species of kelp (*Laminaria solidungula*, *L. saccharina*, and *Alaria esculenta*) were collected in the trawls. *L. saccharina* (Figure 6) was collected most frequently. This is likely due to substrate limitations, since this plant possesses rhizoidal holdfasts which allow it to colonize gravel, small pebbles and even detrital material (Figure 7). On the other hand, *L. solidungula* has a discoidal holdfast, which limits its occurrence to larger pebbles or preferably cobble-sized rocks, which are largely absent in the survey area. Except for drift material, all plants collected appeared healthy and reproductively mature.

Several species of red algae were collected among the kelp. These included *Rhodomela confervoides*, *Odonthalia dentata*, *Phycodrys rubens*, and *Phyllophora truncata*. We found only a few animal species associated with the kelp bed community. These included the sponge *Haliclona gracilis* (Figure 7), and a variety of hydroids and bryozoans (Table 1).

TABLE 1. Summary of material collected in trawls made in western Camden Bay. See Figure 2 for location of transects. Segments of each transect (delineated by solid circles in Figure 2) are ordered starting from Boulder Island Shoal.

Transect Number	Segment of Transect	Material Collected
1		No attached biota. Pebbles and small cobbles (up to 5 cm diameter).
2		*Laminaria saccharina* attached to pebbles; *Odonthalia dentata* (red alga); large fragments of *L. solidungula* and *L. saccharina*.
3	1st Quarter	Many *L. saccharina* and *L. solidungula* plants. Mud.
	2nd Quarter	Many *L. saccharina* (30-100 cm long) and *L. solidungula* (30-40 cm long) plants. *Rhodomela confervoides* and bryozoans attached to kelp and small cobbles.
	3rd Quarter	Several *L. saccharina*, *L. solidungula* and *Phyllophora trancata* (red alga) plants. Hydroids collected on small pebbles.
	4th Quarter	*Alaria esculenta*, *L. saccharina*, red algae (*Rhodomela confervoides* and *Phyllophora truncata*), hydroids (*Thuiaria* sp.), sponges (*Haliclona gracilis*), and bryozoans (*Flustrella* sp.) attached to small cobbles approximately 6 cm in diameter.
4	1st Fifth	One piece drift kelp. Gravel.
	2nd Fifth	Mud and silty sand. No attached biota.
	3rd Fifth	No attached biota.
	4th Fifth	Many *L. saccharina* (20-30 cm long) and *L. solidungula* plants attached to small flat cobbles (5-6 cm diameter). Also *Rhodomela confervoides* and hydroids attached to small cobbles.
	Last Fifth	Flocculent mud.
5	1st Third	Several *L. saccharina* and *Phyllophora truncata* plants.

TABLE 1. (Continued)

Transect Number	Segment of Transect	Material Collected
5	2nd Third	Many (greater than 30) L. saccharina and L. solidungula plants attached to pebbles. Also Phyllophora truncata and Odonthalia dentata.
	Last Third	No data.
6	1st Third	L. saccharina (fragments and whole plants) attached to pebbles. Hydroids growing on stipes of plants.
	2nd Third	L. saccharina (fragments and whole plants) attached to pebbles. Hydroids growing on stipes of plants.
	Last Third	Several L. saccharina (10-50 cm long) plants. Phyllophora truncata and hydroids attached to holdfast and stipe.
7	1st Fifth	Fragments of kelp and red algae.
	2nd Fifth	Fragments of kelp and red algae.
	3rd Fifth	Fragments of kelp and red algae. Sand.
	4th Fifth	Trawl filled with L. saccharina, L. solidungula, A. esculenta, and red algae (Phyllophora and Rhodomela). Plants attached to small cobbles.
	Last Fifth	No biota.

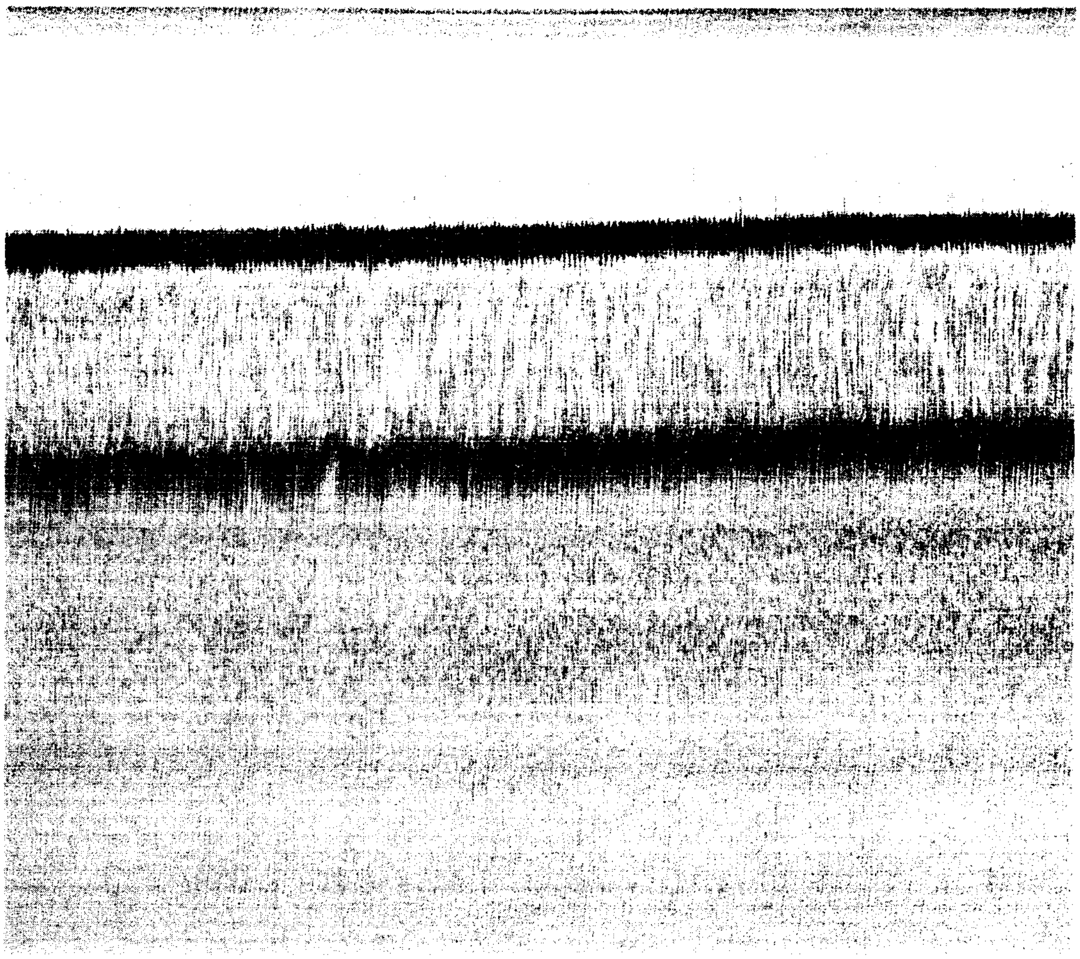

Figure 4. The Ross SL-500 depth recorder trace of the seafloor along the middle segment (asterisked portion) of transect 5. The trace shows a flat seabed surface, despite the presence of kelp along this portion of the transect (see Figure 3).

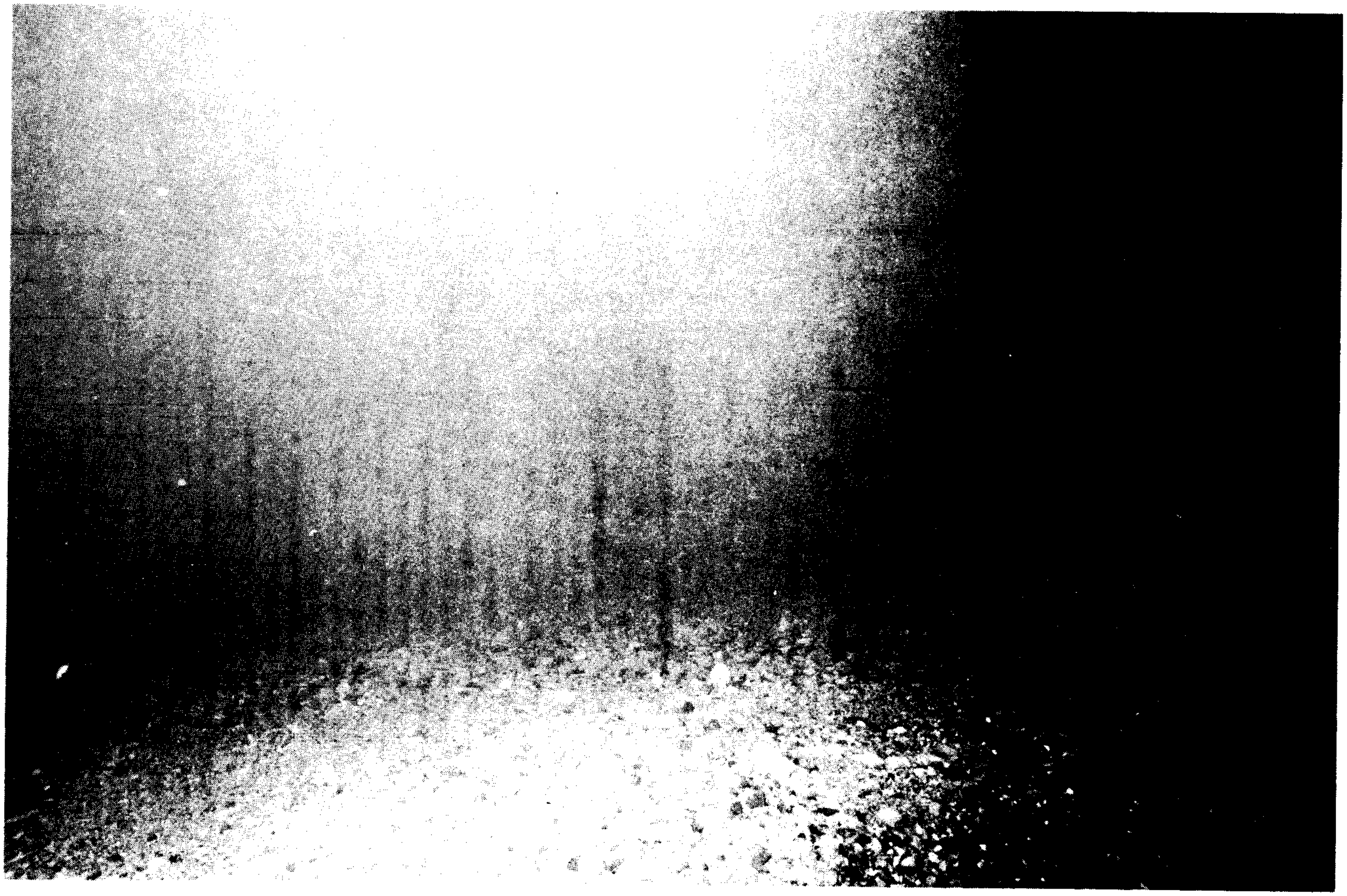

Figure 5. The seafloor at a depth of 2 m along the southwestern tip of Boulder Island Shoal consists of small cobbles, pebbles and sand.

Figure 6. Two species of kelp, Laminaria saccharina and Alaria esculenta (with midrib), were collected in the trawls. The largest plants in this photograph are nearly a meter long.

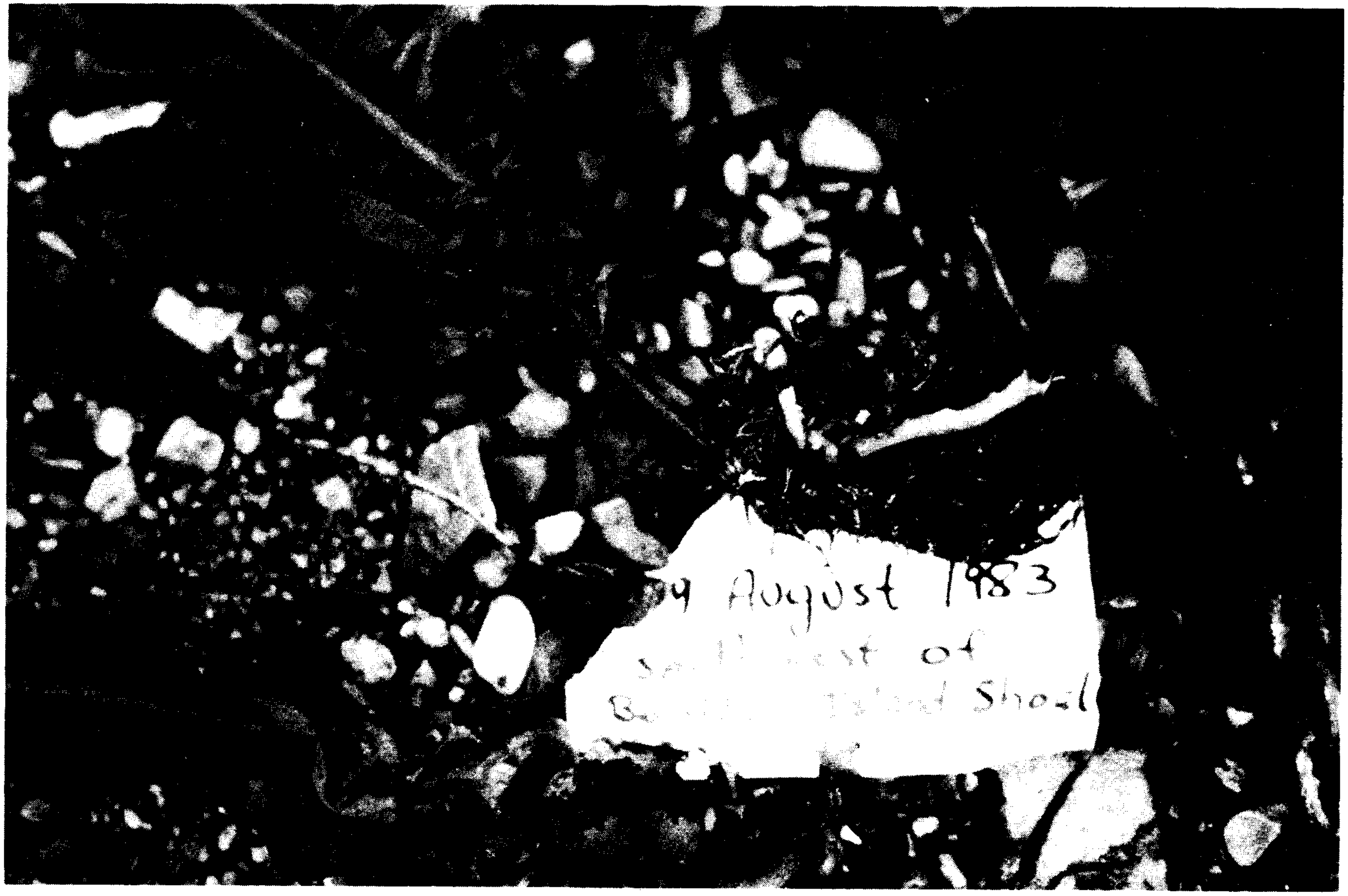

Figure 7. Only a few species of animals were found associated with the kelp. The sponge Haliclona was one species found attached to the rhizoidal holdfasts of L. saccharina and A. esculenta.

NEEDS FOR FURTHER STUDY

The source of large amounts of drift kelp on beaches east of the survey area appears to be from areas south and west of Boulder Island Shoal. Unless there is a need to investigate the composition and size of this community more thoroughly, there are no needs for further field work involving kelp beds in this area.

REFERENCES CITED

Barnes, P.W. 1981. Camden Bay "Boulder Patch." In: Barnes, P., and Reimnitz, E. Geological Processes and Hazards of the Beaufort Sea Shelf and Coastal Regions. Annual Report, 1981. Nat. Oceanic Atmos. Admin., Boulder, CO. Attachment B. 4 p.

Barnes, P.W. 1982. Marine ice-pushed boulder ridge, Beaufort Sea, Alaska. Arctic. 35(2):312-316.

Barnes, P.W., and Ross, C.R. 1980. Ice-pushed boulder pile - Camden Bay, Alaska. In: National Oceanic and Atmospheric Adm., Environmental Assessment of the Alaskan Continental Shelf; Investigators Quarterly Reports, January 1980. 11 p.

Dunton, K.H., Reimnitz, E., and Schonberg, S. 1982. An arctic kelp community in the Alaskan Beaufort Sea. Arctic. 35(4):465-484.

Dunton, K.H., and Schell, D.M. 1982. The use of $^{13}C:^{12}C$ ratios to determine the role of macrophyte carbon in an arctic kelp community. Eos. 63:54 (abstract).

Dunton, K.H., and Schonberg, S.V. 1981. The Canning River to Demarcation Bay: A preliminary survey of macrophyte communities. Cruise and summary report. NOAA Environmental Research Labs, Boulder, CO. 47 p.

Dunton, K.H., Schonberg, S.V., and Schell, D.M. 1983. Geophysical and biological reconnaissance of rock habitats in western Camden Bay, Beaufort Sea, Alaska. Institute of Water Resources, University of Alaska, Fairbanks. Report IWR-104. 30 p.

Reimnitz, E., and Ross, C.R. 1979. Lag deposits of boulders in Stefansson Sound; Beaufort Sea, Alaska. U.S. Geological Survey Open File Report 79-1205. 16 p.

Schell, D.M. 1983. Carbon-13 and carbon-14 abundances in Alaskan aquatic organisms: delayed production from peat in arctic food webs. Science. 219:1068-1071.

Schell, D.M., Ziemann, P.J., Parrish, D.M., Dunton, K.H., and Brown, E.J. 1982. Foodweb and nutrient dynamics in nearshore Alaskan Beaufort Sea waters. In: Environmental Assessment of the Alaskan Continental Shelf: Final Report. BLM/NOAA/OCSEAP, Boulder, CO. 185 p.

THE CHUKCHI SEA CONTINENTAL SHELF: BENTHOS-ENVIRONMENTAL INTERACTIONS

by

H. M. Feder and A. S. Naidu

Institute of Marine Science
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

M. J. Hameedi

Ocean Assessments Division Alaska Office
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
222 West Eighth Avenue, #56
Anchorage, Alaska 99513-7543

S. C. Jewett and W. R. Johnson

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 687

February 1989

ACKNOWLEDGMENTS

This study was funded by the Minerals Management Service, Department of the Interior, through an interagency agreement with the National Oceanic and Atmospheric Administration, Department of Commerce, as part of the Alaska Outer Continental Shelf Assessment Program, to the University of Alaska Fairbanks through a cooperative agreement (NA-ABH-00031).

We would like to thank the officers and crew of the NOAA ship *Oceanographer* involved in sampling. We would also like to thank the following Institute of Marine Science, University of Alaska Fairbanks, personnel: M. Baskaran and Wieslawa Wajda for sediment analysis, Dave Foster and Gail Gardiner for shipboard sampling assistance and sediment analysis, Tama Rucker for shipboard sampling and laboratory analysis of all biological samples, Kris McCumby for assistance with laboratory analysis of biological samples, John Smithhisler for current meter preparation, Chirk Chu for data processing and programming, and the Publications staff for aid in preparation of this report. Laboratory facilities were provided by the Institute of Marine Science, University of Alaska Fairbanks.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

I. INTRODUCTION

A. General Nature and Scope of Study

The Chukchi Sea is a shallow sea which connects the Arctic Ocean and the Bering Sea. The continental shelf of the Chukchi Sea is relatively wide, and is ice covered 7 to 8 months of the year. Since the harvest of commercially-important species north of Bering Strait has historically been low, little emphasis has been placed on acquisition of environmental data typically used to manage fisheries. However, with the emergence of possible sites for offshore oil and gas development in this region, interest in marine resources has emerged with special emphasis on the occurrence of marine mammals and on their reliance on benthic food resources. Furthermore, as the importance of the transport of nutrients and particulate organic carbon from the Bering Sea to this region becomes more evident (McRoy, 1986; Walsh and McRoy, 1986; Grebmeier *et al.*, 1988), questions have arisen concerning the importance of this advected nutrient source to the eastern Chukchi Sea benthic biota. In particular, the biology, distribution, abundance, standing stock, and carbon mineralization (carbon demand) of the benthic organisms used seasonally as food by marine mammals in the northeast Chukchi Sea (the region considered in the investigation here) must be understood when assessing potential impacts of the oil and gas industry there.

The Chukchi Sea reflects a mixture of processes and fluxes from many sources. The most important flux is the outflow of water northward through the Bering Strait (Coachman *et al.*, 1975). In summer, this water is relatively warm, causing the Chukchi Sea to be ice free earlier in the year and remain ice free longer in the autumn than bodies of water further north. This water also brings nutrients and Bering Sea organisms with it, producing important ecological effects in the Chukchi Sea (Grebmeier *et al.*, 1988). Aagaard (1964) and Coachman *et al.* (1975) identified a number of water masses in the Chukchi Sea, including Bering Sea water, Alaska Coastal water, Chukchi resident water, and indications of Siberian Coastal water and Arctic Ocean water. The movement of these water masses is closely related to the sea-floor bottom topography, with the northward flow through Bering Strait bifurcating northwest of Cape Lisburne, where part of the flow is northwestward and part northeastward along the Alaska coast (Figs. 1 and 2). The primary interest of our study was in the region of the northeastward branch of the flow over the shelf and along the Alaska coast. The flow along the coast may be characterized by high velocity currents (often more than 50 cm/s) and great variability in both speed and direction (Coachman and Aagaard, 1981; Aagaard, 1984).

The sources of energy supporting the marine biological system in the southern Chukchi Sea are suggested by the high primary productivity of water in the western Bering Strait (Sambrotto *et al.*, 1984). Nutrient-rich water from the Gulf of Anadyr moves northward across the northeastern Bering Sea shelf supporting high concentrations of phytoplankton in the water column, as well as in water moving through the Strait. This production supports a large zooplankton crop and a high benthic biomass north of the Strait (Stoker, 1978; Grebmeier, 1987; Grebmeier *et al.*, 1988). It is suggested by our study that the northward movement of the productive waters of the southern Chukchi, and its contained particulate organic carbon, provides a food resource to the benthos of the northern Chukchi Sea as well. The increased plankton volumes from inshore to offshore and from south to north from Bering Strait to Icy Cape (English, 1966) seem to support the suggestion that zooplankters are being advected northward by water currents

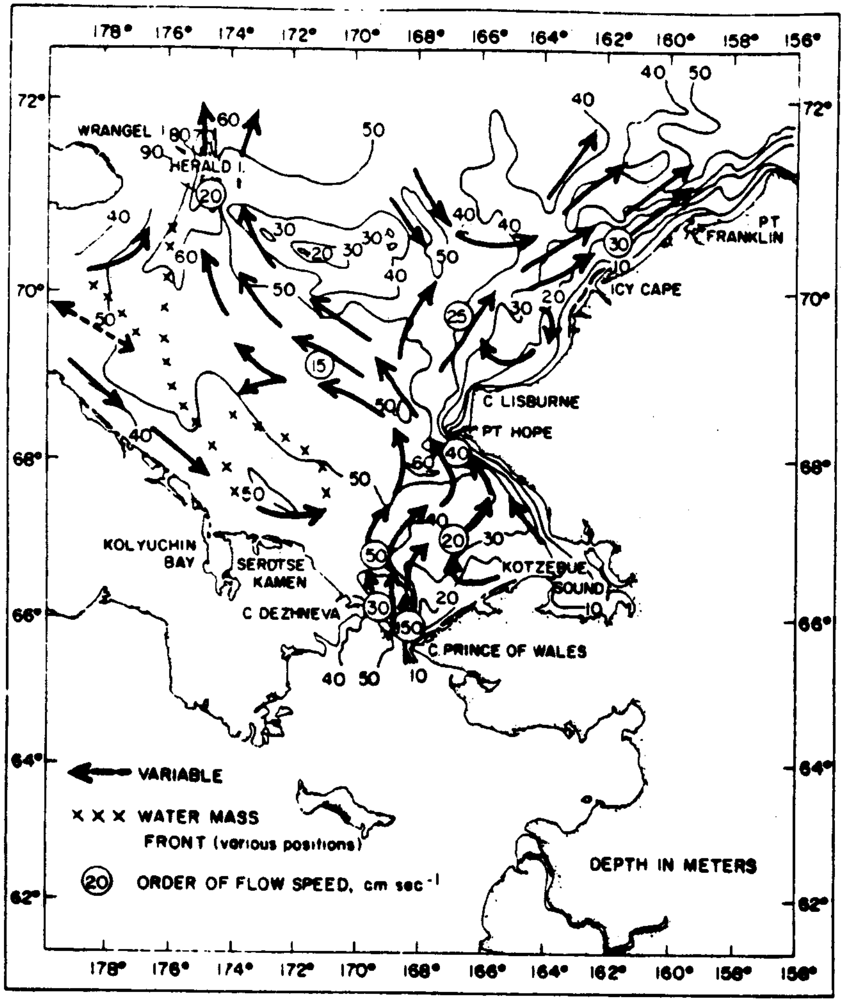

Figure 1. Schematic of upper layer flow in the Chukchi Sea. (Dotted arrows indicate variable currents. Various positions of water mass fronts are indicated and circled numbers are estimated flow speeds in cm/s.) (From Coachman *et al.*, 1975.)

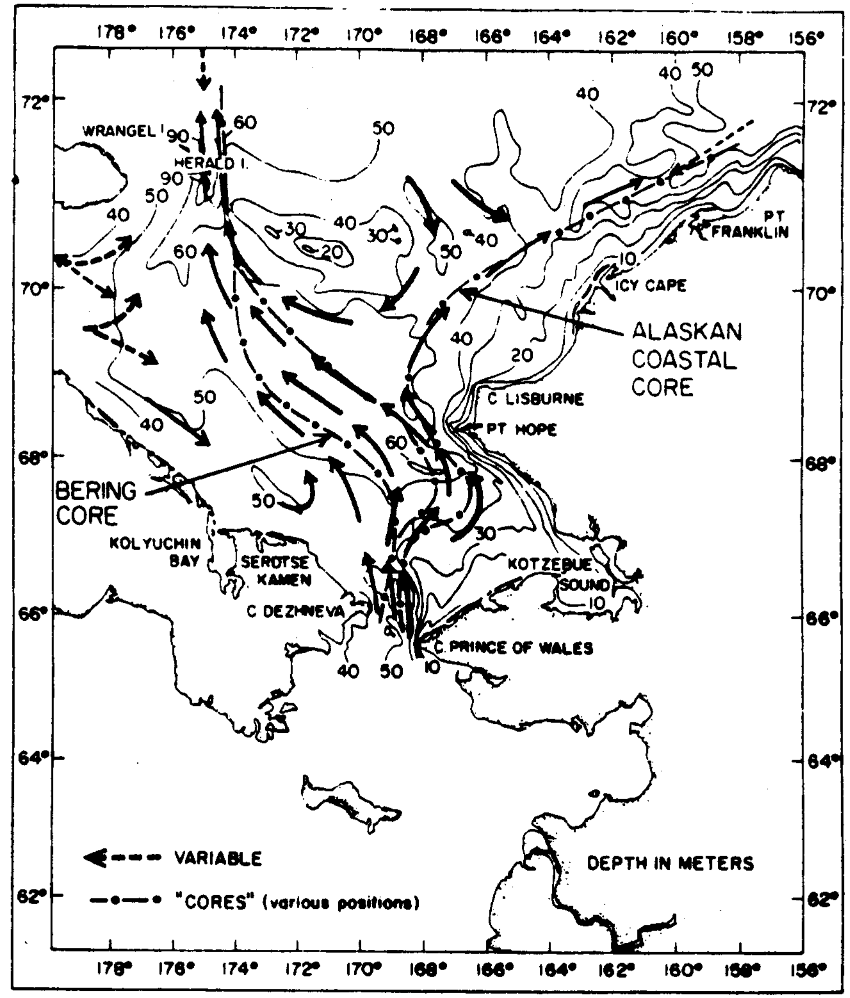

Figure 2. Schematic of lower layer flow in the Chukchi Sea. (Dotted arrows indicate variable currents. Various positions of "cores" of Bering Sea water masses are indicated.) (From Coachman *et al.*, 1975.)

and are supplementing resident stocks in the Chukchi Sea. In the northern Chukchi Sea and regions of the Beaufort Sea that do not have perennial ice cover, the annual primary production ranges from 25-150 gC/m^2 with production lowest north of Point Barrow (Parrish, 1987). Presumably much of the initial pulse of water-column primary productivity in these northern waters remains ungrazed, similar to the situation described for the shallow shelf of the southeastern Bering Sea (Cooney and Coyle, 1982; Walsh and McRoy, 1986). The flux to the bottom of these ungrazed phytoplankters, as well as dead and dying zooplankters advected from more southerly waters, might be expected to enrich the benthic environment resulting in enhanced benthic standing stocks.

As stated earlier, high standing stocks of macrofauna are reported on the sea bottom north of Bering Strait. Grebmeier (1987) demonstrated that benthic biomass was significantly higher to the west of a hydrographic front between the Bering/Anadyr and the Alaska Coastal water. Although this frontal system has not been identified within the northern Chukchi Sea, the northward flow of the mixed Anadyr/Bering water after it passes through the Bering Strait has been traced as it moves northward toward Point Barrow. Data collected in our study suggest that this water approaches the Alaska coast just north of Icy Cape at approximately $70^{o}30'$ N latitude. The highest biomass values in our study were recorded for the region north and northwest of the 32.4 $^{o}/oo$ isohaline which occurs just north of this latitude. These high benthic biomass values were associated with large numbers of surface deposit and suspension-feeding organisms. These observations suggest that the high particulate organic carbon (POC) values in the water column identified in the southeastern Chukchi Sea by Grebmeier (1987) extend into the northern Chukchi and supply a rich and persistent food supply there.

The high standing stocks of benthic species in these waters presumably also explains, at least in part, the success of summer-feeding populations of walrus and gray whales along the Alaska coast north of $70^{o}30'$ latitude (Fay, 1982; Moore and Clarke, 1986).

Sediment characteristics and sedimentary processes exert a powerful influence on the distribution and abundance of benthic organisms. One of the primary sediment factors affecting distribution of benthic organisms is the grain size of bed sediments, because this factor invariably controls benthic habitat attributes (e.g., sediment porosity, permeability, bearing strength, oxidation-reduction potential boundary, etc.). There are, of course, other important sedimentological factors that control distribution of benthic species, as for example, flux of POC to the bottom, sediment accumulation rates, sediment water content, and degree of water turbidity (McCave, 1976). In ice-stressed arctic areas such as the Chukchi Sea, the hazards posed by ice-gouging of bottom sediments can be an additional influencing factor (Phillips *et al.*, 1985). All of the above factors are directly or indirectly correlatable with the hydrodynamic conditions leading to the determination of flux of POC and sediment supply, erosion and deposition, all of which can vary significantly between regions and within any one region.

The benthic system of the northern Chukchi Sea shelf has some similarities to that of the Beaufort Sea (Carey *et al.*, 1974), but there are also some important differences between the two bodies of water. The Beaufort Sea is ice covered for longer periods of time than the Chukchi, primary production is reduced in the Beaufort, and polynyas occur along the Chukchi but not that of the Beaufort shelf.

In the northern Chukchi Sea, prior to the present study, little effort had been directed to understanding benthic organism-sediment interactions, although some preliminary data based on a local study were available (Phillips *et al.*, 1985). Therefore, in order to better comprehend the benthic environment, the present investigation examined the areal distribution and dynamics of lithological and benthic facies, and the relationship of benthos to water-mass characteristics, sediment accumulation rates and fluxes of POC to the bottom sediments of the northeastern Chukchi Sea.

B. Goals of the Study

To determine the benthic community structure of the northeastern Chukchi Sea benthic ecosystem and relate benthic biomass stock and production to: (a) ocean circulation, sediment, and sea-ice distributions; and (b) feeding requirements of major vertebrate consumers.

C. Specific Objectives

1. Determine the distribution, abundance, biomass and community structure of the infaunal benthos and estimate infaunal production.
2. Relate benthic community structure, biomass, and production to environmental factors such as water depth, temperature, current velocity, salinity, sediment properties and dynamics, and organic carbon flux.
3. Identify, wherever possible, those bottom areas of the northern Chukchi Sea that are important as sources of food for gray whales and Pacific walrus.

II. CURRENT STATE OF KNOWLEDGE

A. Physical Oceanography

The circulation in the northeast Chukchi Sea near the Alaskan coast is dominated by time variable inflow through Bering Strait and wind forcing (Aagaard, 1964; Coachman *et al.*, 1975; Coachman and Aagaard, 1981). In addition, seasonal ice production and melting greatly modifies water mass properties (Aagaard, 1964; Coachman *et al.*, 1975). The prevailing interpretation of the flow between Cape Lisburne and Point Barrow is that the flow is generally northeastward, with the center of the transport roughly 50 km offshore (Figure 1; Aagaard, 1964; Paquette and Bourke, 1974; Coachman *et al.*, 1975). Near the coast, the flow may also be northeastward, although there are indications of recirculation systems "behind" the major capes, which interrupt this flow (Wiseman *et al.*, 1974). Farther offshore, the northeastward flow produces "bays" in the marginal ice zone, because of the melting action of the warm water in the flow (Paquette and Bourke, 1981). In the extreme northern part of the Chukchi, the circulation is influenced by the Beaufort Sea (Arctic Ocean).

Wind stress forcing from the east and northeast can also produce reversals of this prevailing northeastward flow toward the southwest. Time series current measurements in this region have supported this interpretation, although they have revealed large reversals in the alongshore flow in response to the wind (Mountain *et al.*, 1976; Wilson *et al.*, 1982; Aagaard, 1984, Hachmeister and Vinelli, 1985). These reversals account for a significant amount of the variance in current meter measurements. Current measurements from near the axis of Barrow Canyon showed mean current near the bottom of 25 cm/s, with 50 cm/s speeds being common, and many periods of upcanyon flow (Mountain *et al.*, 1976). They showed that a close relationship existed between the barometric pressure gradient and the currents. Coastal currents observed by Wilson *et al.* (1982) indicated both northeastward and southwestward flow along the coast with speeds of up to 100 cm/s. The correlation between these currents and the winds were between 0.65 and 0.72. The currents along the coast between Barrow and Wainwright were highly correlated (0.90 and zero lag) (Wilson *et al.*, 1982).

The water masses which flow northeastward along the coast are the Bering Sea Water and Alaska Coastal Water, with Chukchi Resident Water found farther to the west (following the nomenclature of Coachman *et al.*, 1975). The Chukchi Resident Water is closely related to the water mass also called Chukchi Bottom Water (Paquette and Bourke, 1974). Along the northern boundary of the Chukchi Sea in summer, evidence of water from the Arctic Ocean has been observed (Garrison and Becker, 1976). Barrow Canyon has been described as a "drain" for the Chukchi Sea (Paquette and Bourke, 1974; Garrison and Becker, 1976). The Chukchi Sea water described by Garrison and Becker (1976) and others for spring conditions was nearly at the freezing point for the entire water column. It is a result of the brine rejection during the freezing process of sea ice. It can be distinguished from the Beaufort Sea water because the Beaufort water is actually warmer.

The northeast Chukchi Sea from Cape Lisburne to Icy Cape is ice covered from late October/early November until early July, with large annual variations in these dates (Wiseman and Rouse, 1980). In addition, the length of the freeze up and break up periods and concentration of ice during them also varies considerably, with most of the short term changes produced by wind forcing. The flow of warmer water from the Bering Sea through Bering Strait delays the freeze up of the Chukchi Sea and promotes the melt back in the spring (Paquette and Bourke, 1981). Ice conditions were generally lighter in the Chukchi Sea in the summer of 1986 when the data described here were acquired.

Tidal heights and tidal currents are small. The tidal amplitude at Barrow is between 5 to 10 cm (Harris, 1911; Matthews, 1970). The observed mean tidal range at Peard Bay is 14 cm, with a spring range of 18 cm and a neap range of 9 cm, and tidal currents of less than 3 cm/s (Kinney, 1985). Tidal models have shown that the tide is produced by a progressive (Poincare) wave in the Arctic Ocean (Sverdrup, 1926; Kowalik, 1981; Kowalik and Matthews, 1982). The recent results of these models have positioned an amphidromic point southwest of Point Hope (Kowalik and Matthews, 1982). The tidal ellipse velocities are between 5 and 10 cm/s throughout the northeast Chukchi Sea. For tides as small as these, the meteorological tides (storm surges) are more significant as a source of sea level variations (Hunkins, 1965; Wiseman *et al.*, 1974; Kowalik, 1984).

B. Geological/Geochemical Oceanography

The continental shelf area of the northeastern Chukchi Sea is one of the most intensively sampled shelf areas of the world for surficial sediment samples. Several maps are available to depict the spatial distribution patterns of grain sizes of surficial sediments of the northeastern Chukchi Sea shelf. The sediment granulometric data generated for the area up until 1969 were summarized by McManus *et al.* (1969). In continuation of this work, Naidu (1987) has completed a composite map showing the distribution of sediment types and their sorting values for the contiguous area of the Bering-Chukchi-Beaufort Seas; this map updates the granulometric data including information published subsequent to 1969. The sediment types in Naidu's map are based on Folk's (1954) nomenclature and the map illustrates that all sediment types occur in the northeastern Chukchi Sea shelf. However, there is considerable spatial variation in sediment types. In fact, the patchy nature of sediment distribution observed in the Chukchi Sea is considered quite typical for the Alaskan arctic shelves. The entire continental shelf region of the Chukchi Sea is non-graded, inasmuch as there is no progressive decrease in overall particle size from the coast to the shelf edge (Fig. 3). In the northeastern Chukchi Sea the sediments are generally poorly to extremely poorly sorted.

As shown in Figure 3, there are three principal sediment types in the study area. The inner shelf of the northeastern Chukchi Sea and the shoals (e.g., Herald and Hanna shoals) are carpeted by relatively coarser material (e.g., muddy gravel, gravelly muddy sand or gravelly sand). Contiguous to the inner shelf and extending up to the middle of the study area are a variety of sandy substrates. Farther seaward of the coarse sediments are muds with various proportions of gravel and sand (Fig. 3). Acoustic records obtained in 1986 for the inshore area in the vicinity of Point Barrow, northeastern Chukchi Sea, provide evidence of the presence at the shelf of highly dipping folded rock outcrops (Naidu, unpub.). Additional high resolution seismic profiles show a thin sediment cover, generally less than 6 m thick, overlying folded bedrock over much of the northeastern Chukchi Sea (Phillips *et al.*, 1985; Phillips, 1987).

Factor analysis of granulometric data has been used by McManus *et al.* (1969) to explain the evolution of the distributional pattern of sediments. McManus *et al.* (1969) identified three factors that explained 92 percent of the aerial variations of ten granulometric variables. Factor I represented contemporary deposition of silts and clays from the water column,

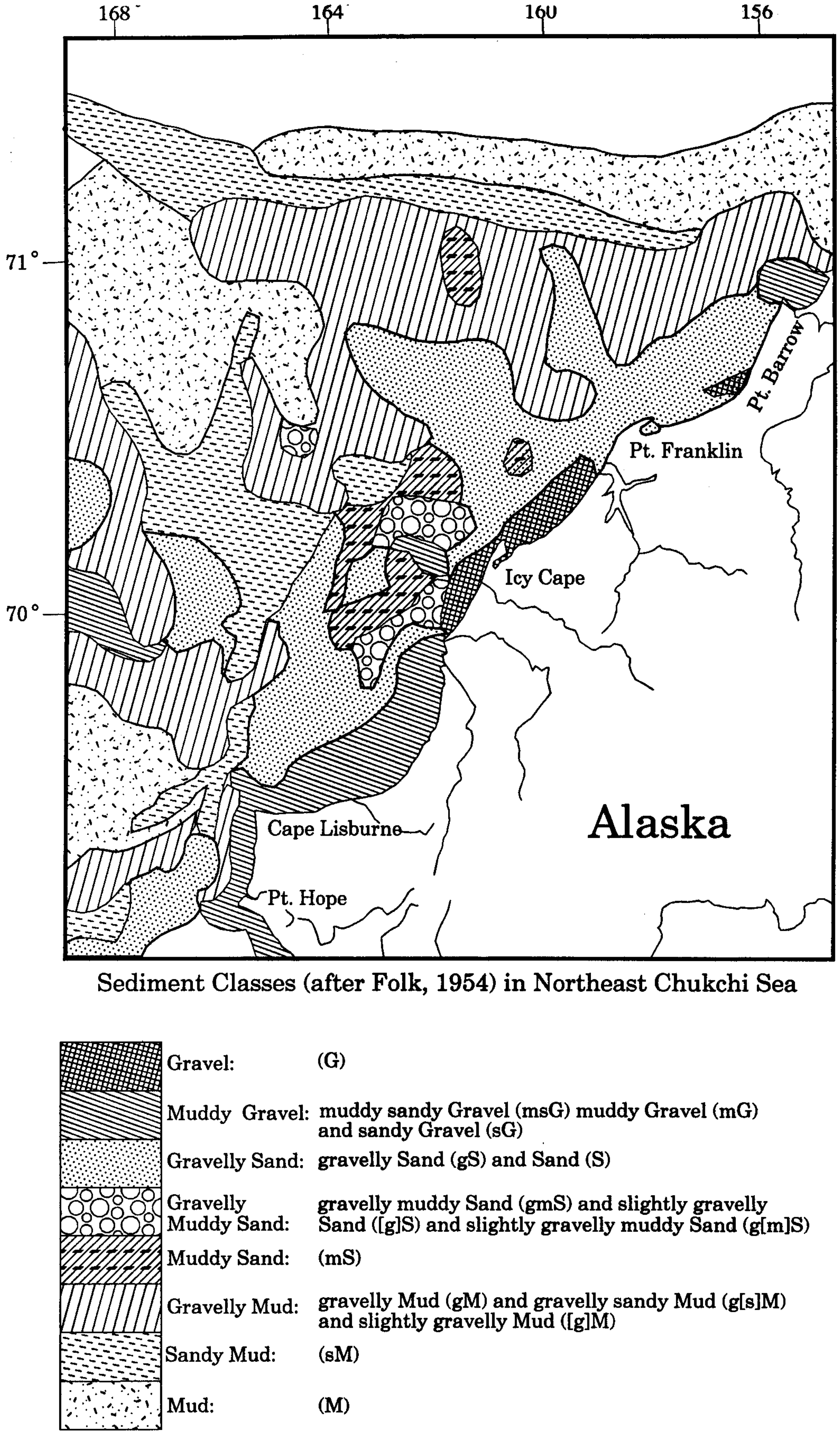

Figure 3. Distributional pattern of sediment classes in northern Chukchi Sea (after Naidu, 1987).

especially in areas of low-energy and abrupt decreases in transporting competency. Factor II represented areas of high supply and deposition of bed-load sand and/or where sands are modified under high energy hydrodynamic conditions, such as the nearshore region. Sands grouped in this factor could be either modern, relic or palimpsest deposits. Sediments classified in Factor III represented deposits resulting primarily from beach processes. It was further surmised by McManus *et al.* (1969) that, although the Chukchi Sea is covered by ice for 8 to 9 months, ice plays an insignificant role as an agent of transport and deposition of sediments.

A few investigations have addressed the chemical properties of northeastern Chukchi Sea sediments. The concentrations of organic carbon in the surface sediments are reported to be low, about 1.0 % by weight (Creager and McManus, 1966). The distributions of a few major and minor elements in sediments of the Alaskan Chukchi Sea were mapped by Sharma (1979) and shown to correlate strongly with sediment types. Variations in the alkali and alkaline-earth elements in the sediment interstitial waters at selected stations of eastern Chukchi Sea were discussed by Naidu and Sharma (1972) in the context of possible sediment diagenesis. Golan-Bac (1985) analyzed hydrocarbon gas in surface sediments of the northeastern Chukchi Sea and concluded that the light hydrocarbons which are present in low concentrations most likely result from biological and/or very early diagenetic processes.

The intricate mosaic of surficial sediment types across the northeastern Chukchi Sea continental shelf is primarily related to the unique environmental setting (relatively wide shelf, ice cover for 7 to 8 months in a year and occasional storm surges), current regime, and complex

Pleistocene transgressive-regressive history (McManus *et al.*, 1969, 1983; Sharma, 1979; Hopkins *et al.*, 1982; Phillips *et al.*, 1985; Naidu, 1987). The general sediment patchiness is presumably a result of intense but haphazard reworking of the sea bottom by ice gouging (Toimil, 1978; Phillips *et al.*, 1985) and erratic transport and deposition of mud by ice. The gravelly beds in the northeastern Chukchi Sea shelf are most likely either relic ice-rafted dropstones and/or lag deposits and reflect areas of little deposition at the present time. The outer shelf is a trap for terrigenous mud presumably derived from the Bering Sea (Naidu and Mowatt, 1983).

More recently, additional data have been gathered that provide further insight into the sources and dynamics of sediments in Chukchi Sea. Naidu and Mowatt (1983), and the numerous references therein, have elucidated the sources, transport pathways and depositional sites of fine-grained particles as reflected by the distribution patterns of clay minerals. Presently the western portion of the study area of Chukchi Sea receives the major proportion of clayey sediments of Yukon River origin. The sediment is displaced from the Bering Sea via the net northward set Alaska Coastal Current (ACC), presumably as a nepheloid layer (McManus and Smyth, 1970). Evidence was also presented by Naidu and Mowatt (1983) to show that the primary trajectory of this sediment transport pathway is bifurcated westward and northeastward off Point Hope; this correlates closely with the regional water circulation pattern. It is speculated by Eittreim *et al.* (1982) that a portion of the northeastward sediment and water transport is funneled through the Barrow Canyon (Garrison and Becker, 1976; Eittreim *et al.*, 1982). The advective processes relative to the ACC play an important role in the production of bedforms near the canyon head (Eittreim *et al.*, 1982). A study by Burbank (1974) involved mapping of the suspended sediments in the northeastern Chukchi Sea using satellite imagery. This study showed a narrow band of dense sediment plume adjacent to the coast, suggesting derivation of suspended particles locally from coastal erosion.

Barnes (1972), Phillips *et al.* (1985) and Phillips (1987), following a site-specific study in the region between Cape Lisburne and Point Franklin, delineated five lithological facies changes across the shelf in the eastern central Chukchi Sea between Cape Lisburne and Icy Cape. It was contended that these sediment changes and accompanied bed forms are influenced by contemporary processes such as intensity of ice gouging, wave/current action (especially sediment transport by the shore-parallel ACC and storm-generated currents), bioturbation and the redistribution of sediments by local eddies and gyres. Phillips (1987) has surmised that the ACC may rework the sediments of the northeast Chukchi Sea out to approximately 70 km from the shore. Further, the lag gravel deposits and northward migrating bed forms are associated with the ACC. The gravel deposits support a diverse and abundant benthic community (Phillips, 1987).

C. Biological Oceanography

1. Primary Production

The productivity levels in the eastern Chukchi Sea, in general, appear to be higher (in terms of the amount of carbon fixed annually) than those in the Beaufort, but considerably lower than in the Bering Sea (Truett, 1984). Insight into the sources of energy supporting the southern Chukchi Sea is evident from the high productivity of western Bering Strait (Sambrotto *et al.*, 1984). Upwelled nutrient-rich water from the Gulf of Anadyr moves northward across the shelf and supports high concentrations of phytoplankton as it moves through Bering Strait. Although Sambrotto *et al.* (1984) estimate as much as 324 $gC/m^2/yr$, it is evident that the data set for the estimate is limited. It has been hypothesized that if upwelling and current movements prevail throughout the winter season, providing a supply of nutrient-rich water to the southern Chukchi Sea, the spring formation of a stable surface layer coupled with the onset of ice melting and the increase of light intensity could result in a phytoplankton bloom of similar magnitude to that in the Bering Sea (Schell, 1987). No data exists to support or deny this hypothesis.

In the northern Chukchi and regions of the Beaufort Sea with perennial ice cover, the estimates of primary production are much more tenuous. Carey (1978) reviewed the literature and concluded that the primary production in the northeast Chukchi ranged from 18 to 28 $gC/m^2/yr$. However, Hameedi (1978) investigated summer production in the marginal ice zone of the Chukchi Sea and found values of 0.077-0.97 gC/m^2/half-day. Extrapolating from Hameedi's values and assuming that production in the water column occurs primarily over a two-month period, yearly production values can be estimated at approximately 9-116 $gC/m^2/yr$. More recently, Parrish (1987) described the seasonal production for the eastern Chukchi Sea and southern Beaufort Sea. He used instantaneous estimates and other rate measurements from Alexander *et al.*, (1975), Dawson (1965), Hameedi (1978), Horner (1981), and his own work to construct a synthesis of annual primary productivity in the Chukchi and Beaufort seas. Parrish estimated production from 25-150 $gC/m^2/yr$ with values lowest north and northwest of Point Barrow (Figure 4).

2. Zooplankton

Two surveys provide preliminary information of the zooplankton in the Chukchi Sea in the open-water period. Zooplankton samples were taken at a number of stations from Bering Strait to Icy Cape in 1959 and 1960 (English,

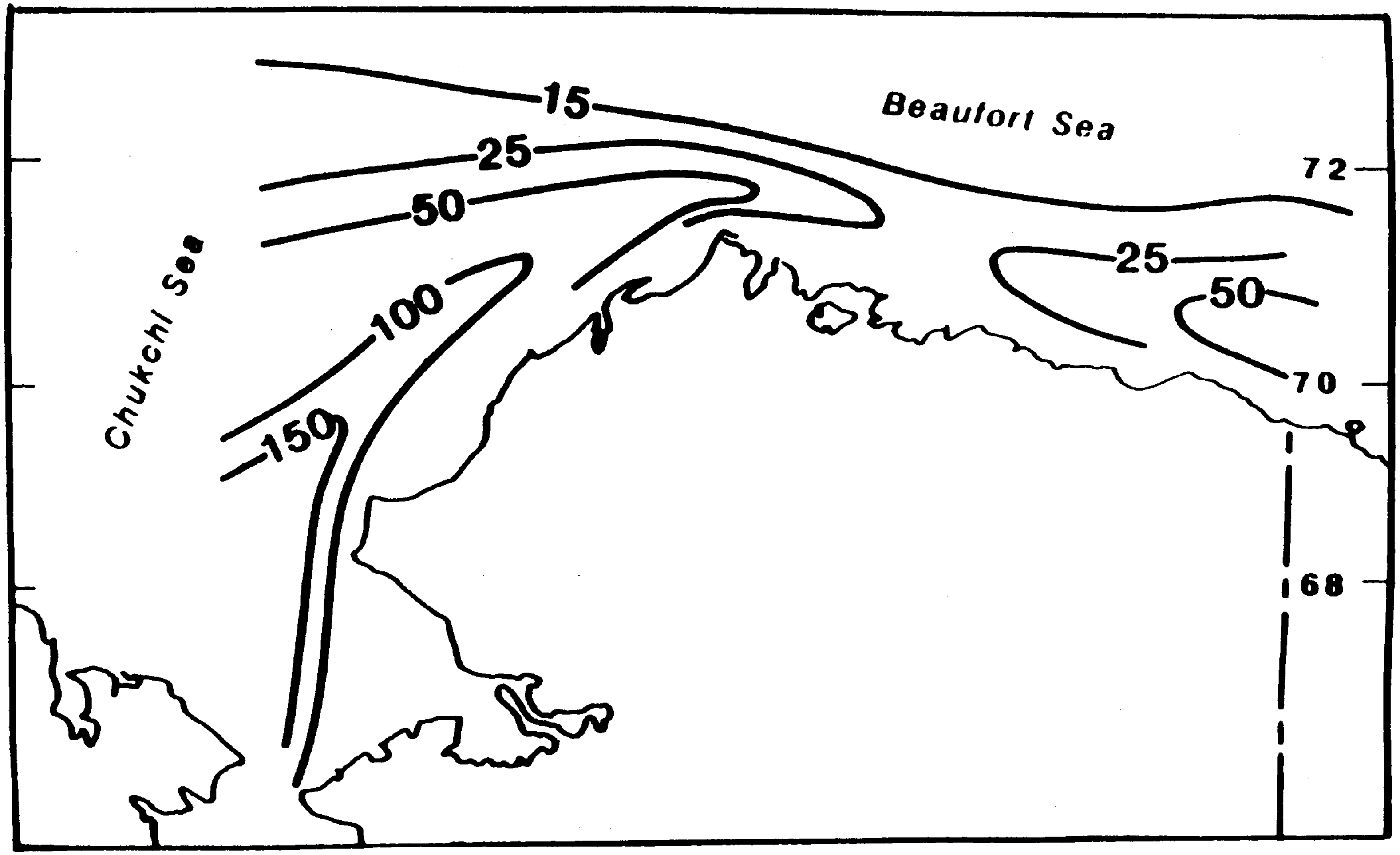

Figure 4. Projected annual primary production (gC/m²/yr) in the Chukchi and Beaufort seas (Parrish, 1987).

1966). The data revealed trends of increasing plankton volumes from inshore to offshore and from south to north. In the offshore area where waters are stratified dominant species were the calanoid copepods *Metridia lucens, Calanus plumchrus*, and *Eucalanus bungii*. The major species nearshore, where the waters are relatively well-mixed, were the calanoids *Eurytemora pacifica* and *Acartia clausii* and the cladoceran *Evadne nordmani*.

Ten years later, in 1970, zooplankton was collected at a number of locations in the Cape Lisburne-Icy Cape region (Wing, 1972; 1974). Contour plots of zooplankton abundance indicated that three environments were sampled: 1) an area of high abundance and diversity northwest of Cape Lisburne; 2) an area of low abundance and diversity between Cape Lisburne and Point Lay; and 3) an area of rapid north-south variation but generally low abundance extending west along the 70° N parallel. The hydromedusan *Aglantha digitale* was the predominant zooplankter, both in numbers and biomass. Calanoid copepods were the second most abundant zooplankter; other taxa represented included Coelenterata, Nematoda, Annelida, Mollusca, and Truncata. Abundance distributions of calanoid copepods showed greater densities ($>1000/m^3$) in the region northwest of Cape Lisburne. Conversely, calanoid densities were lowest ($<100/m^3$) in the region northeast of Cape Lisburne and west of Icy Cape.

3. Benthos

Although studies of the benthos north of Bering Strait span nearly 30 years, few of these investigations were quantitatively oriented. The most comprehensive studies accomplished were those of Stoker (1978, 1981) who examined the distributional, biomass, trophic and productivity aspects of the bottom fauna (primarily infauna) of the eastern Chukchi Sea from 1970-74.

His data and insightful conclusions serve as a framework for understanding the benthic system of these waters.

Subsequent to Stoker's investigations, an infaunal study for NOAA/OCSEAP expanded Stoker's earlier quantitative work by focusing on the area from Bering Strait to Point Hope and extending into Kotzebue Sound (Feder *et al.*, 1985).

More recently Grebmeier (Grebmeier, 1987; Grebmeier *et al.*, 1988, 1989), working with the benthic component of an NSF project (ISHTAR), studied how various environmental parameters influence benthic structure and biomass on either side of a frontal system between two water masses (the Bering Shelf/Anadyr water and the Alaska Coastal Water). Although her work was primarily conducted in the northeastern Bering Sea, she occupied stations in the southeastern Chukchi Sea as far north as Cape Lisburne. Earlier studies in the vicinity of Cape Thompson yielded a partial checklist and general discussion of the benthic fauna (mainly epifauna) there (Sparks and Pereyra, 1966). An ecological survey in the eastern Chukchi Sea (Point Hope to Point Barrow) yielded qualitative information on infaunal invertebrates, zooplankton, and fishes as well as pelagic birds and mammals (Ingham *et al.*, 1972). A trawl survey extending to Point Hope quantitatively assessed the epifaunal and fish fauna in the area (Feder and Jewett, 1978; Jewett and Feder, 1981; Wolotira *et al.*, 1977). Some semi-quantitative demersal trawling for invertebrates and fishes was conducted in 1977 in the area between Point Hope and Point Barrow known as Barrow Arch (Frost and Lowry, 1983). The biological utilization and comparison of vulnerabilities within the Peard Bay ecosystem are considered in Kinney (1985). Information on the biomass of infaunal and epifaunal invertebrates of the Bering, Chukchi, and Beaufort Seas has been summarized by Jewett (1988a,b) in a data atlas prepared under the auspices of NOAA/SAB.

The broad scale patterns of distribution, abundance, and zonation of benthic organisms across the Beaufort Sea Shelf, contiguous to the northeast Chukchi Sea, are now reasonably understood through the efforts of Carey *et al.* (1974), Carey and Ruff (1977) and Carey *et al.* (1984). Benthic community structure and diversity are related to water circulation, sediment distribution patterns, and impact of ice. Some aspects of these studies are applicable to the Chukchi Sea. However, in addition to this, data on primary production and flux of particulate organic carbon (POC) to the bottom are also essential for understanding the benthic system.

For an understanding of benthic biomass relationships in the northeastern Chukchi Sea, it is important to examine data available for other northern Alaska shelf areas. High benthic standing stocks of infaunal benthos are reported for Bering Strait, on the sea bottom north of the strait, and in the region adjacent to Kotzebue Sound (Stoker, 1978, 1981; Feder *et al.*, 1985; Grebmeier, 1987; Feder, unpub.). Further, the infauna in these regions is dominated by deposit (detrital) feeding organisms characteristic of organically-enriched areas. The source of the particulate organic carbon (POC) for the organisms north of the Strait is probably the highly productive Anadyr waters of the northeastern Bering Sea (Grebmeier *et al.*, 1988, 1989; Sambrotto *et al.*, 1984). The richness of the food benthos in the southeastern Chukchi Sea is suggested by the relatively large populations of Tanner crab (*Chionoecetes opilio*) and sea stars found in these regions (Feder and Jewett, 1981; Jewett and Feder, 1981) that feed on infaunal benthos. In years of low bottom-water temperatures, benthic-feeding fishes are excluded from the southeastern Chukchi Sea, thus reducing the predation pressure on the food benthos and contributing to the high benthic standing stocks (Neiman, 1963; Jewett and Feder, 1980). Benthic biomass values for the northeastern Chukchi Sea are presented in Stoker (1978, 1981). High biomass values for this northern region are shown in his figures but are not discussed.

4. Marine Mammals

Benthic-foraging populations of gray whales (*Eschrichtius robustus*) feed intensively in some regions of the northern Chukchi Sea. Large feeding populations of these whales are described on the inner Chukchi shelf west of Icy Cape to north off Point Franklin, although low densities of gray whales occur from Cape Prince of Wales to Point Barrow (Phillips *et al.*, 1985; Ljungblad, 1987; Moore and Clarke, 1986; Moore *et al.*, 1986a,b; Phillips and Colgan, 1987). Benthic amphipods typically dominate the diet of gray whales. A review of the marine mammals that utilize the nearshore Chukchi Sea is found in Kinney (1985).

Predation by Pacific walrus (*Odobenus rosmarus divergens*) is low in the southeastern Chukchi Sea, but once they move into the northeastern Chukchi feeding intensifies (Stoker, 1981; Fay, 1982). A close correlation occurs between the distribution of walrus populations and the extent and character of the pack ice. During August, the edge of the pack ice generally retreats northward to about 70°30' N in the Chukchi and Beaufort Seas while in September the mean position of the southern edge is about 74° N (Grantz *et al.*, 1982). Most of the walrus population along the northwestern coast of Alaska during these two months occur north of 71° N (Fay, 1982). Bivalve mollusks typically dominate their diet (Fay, 1982). See the Discussion (pp. 210-220) for additional information on gray whales and walruses.

The number of bearded seals (*Erignathus barbatus*) utilizing the waters off the coast of Alaska is presently thought to be in excess of 300,000 animals (Nelson *et al.*, 1985). In the Chukchi and Beaufort seas, winter habitat is relatively limited due to extensive unbroken heavy drifting ice. During summer the most favorable bearded seal habitat is found in the central or northern Chukchi Sea along the margin of the pack ice. Spider crabs (*Hyas*), crangonid shrimps, and clams (*Serripes*), and to a lesser extent Tanner crabs (*Chionoecetes*), make up the bulk of the bearded seal diet in the Chukchi Sea (Nelson *et al.*, 1985). Both bearded seals and walruses compete for clam resources (Lowry *et al.*, 1980).

III. STUDY AREA: LOCATION AND SETTING

The northeastern Chukchi Sea is an epicontinental sea on the continental shelf extending from Point Hope in the south to Point Barrow in the north. The study area (Fig. 5) is bounded by the Longitudes 156°W to 160°W (the U.S.-U.S.S.R. boundary line). With the exception of a few areas, all of the northeastern Chukchi Sea consists of a broad, relatively shallow (average depth of 50 m) and flat shelf with minor relief generated by ice gouging (Fig. 6). There are two prominent shoal areas: one, the Hanna Shoal/Bank, northwest of Point Franklin, which rises to within 25 m of the sea surface; and the other, the Blossom Shoals, situated off of Icy Cape, rising to within 10 m of the surface (Fig. 6; after Hill *et al.*, 1984). Another striking physiographic feature of the northeastern Chukchi Sea is the Barrow Canyon or Sea Valley, 25-50 km wide and about 100 m deep within the shelf region, trenching parallel to the coast and a head at the shelf edge off of Point Franklin at about 60 m depth (Eittreim *et al.*, 1982). The shelf edge is around 60-70 m depth. The coast is characterized

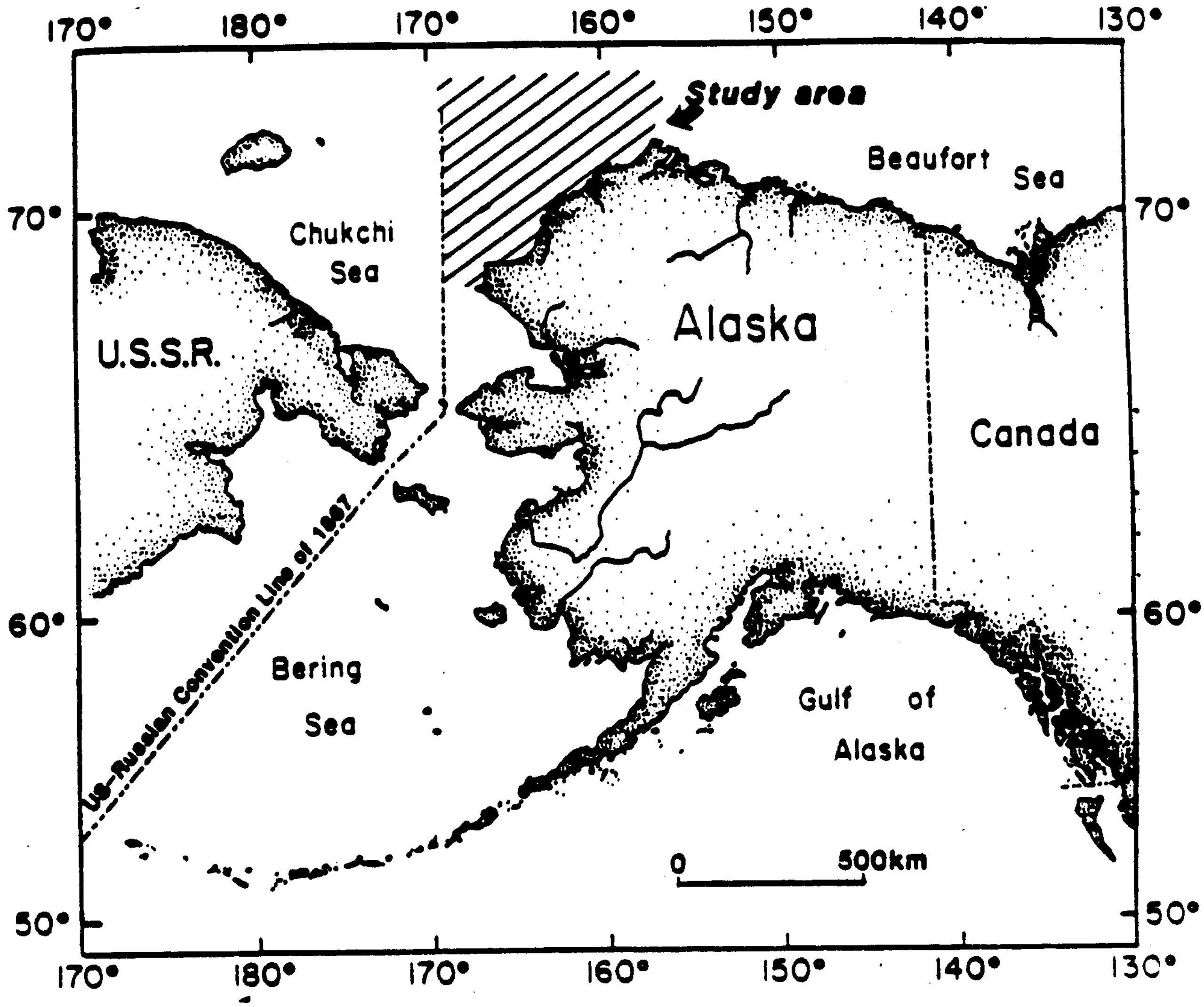

Figure 5. The study area in the northeastern Chukchi Sea as shown by the shading on the map.

by a number of promontories with embayed regions in between (Fig. 6). The coastal hinterland north of Cape Lisburne and extending up to Point Barrow is constituted of broad coastal plain while steep sea cliffs of Permian to Cretaceous age sedimentaries abut against the coast between Point Hope and Cape Lisburne.

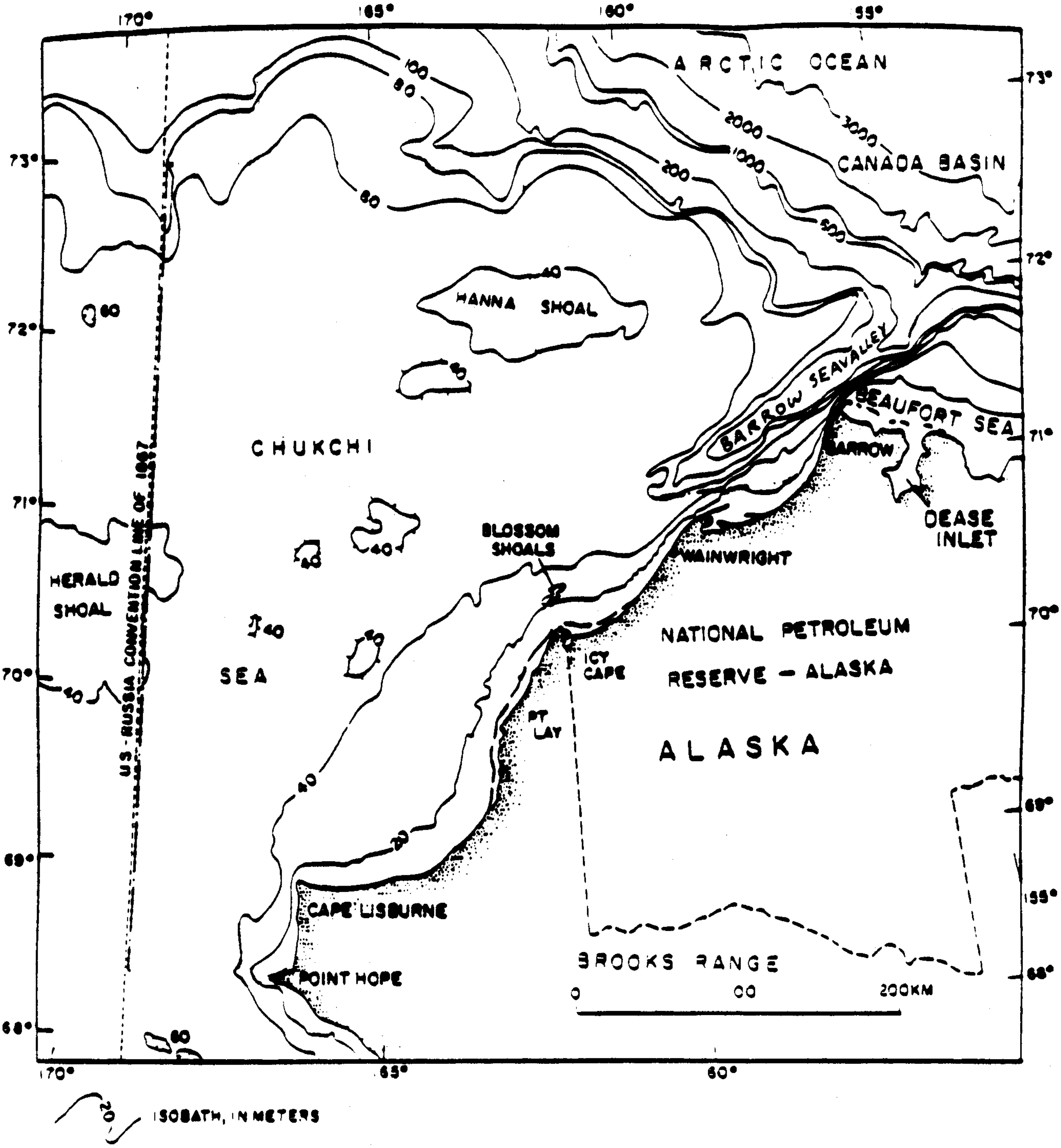

Figure 6. Map showing the bathymetry of northeast Chukchi Sea (after Hill *et al.*, 1984; Phillips *et al.*, 1985).

The most distinctive character of the climate of the study area is the presence of long, severely cold winters with ice cover for about 7 to 8 months and short, cool summers for the rest of the year. The mean annual temperature for the coastal plain hinterland is about -12°C and the mean annual precipitation is about 12 cm. The formation of sea ice begins in late September and the typical sea ice thickness is about 2 m. There appears to be a definite pattern of ice zonation. In Figure 7 are shown

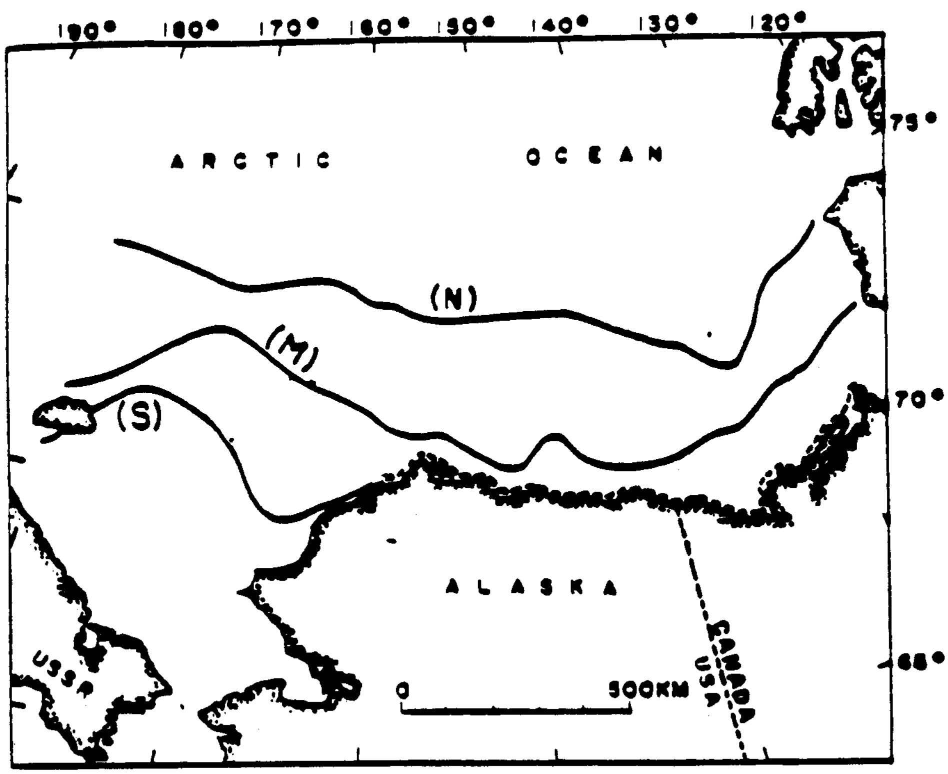

Figure 7. The northernmost (N), southernmost (S), and median (M) positions of pack ice in northeastern Chukchi Sea in September (map extracted from Grantz *et al.*, 1982).

the most southerly, northerly and median margins of the pack ice edge, based on data collected from 1954 through 1970 (Grantz *et al.*, 1982). In winter about 10-50 km of the inner shelf is dominated by the fast ice (Fig. 8; Phillips *et al.*, 1985), while farther offshore narrow, disjointed polynyas occur (Fig. 9, after Stringer, 1982). These polynyas are irregularly-shaped openings enclosed by ice which may contain brash or uniform ice which is markedly thinner ice than the surrounding ice (Stringer, 1982). The spring break is around late May and by late June almost all of the study area is free of ice.

The role of both pack and sea ice in the erosion, transport and deposition of sediments is now becoming clearer. Although ice-rafting of gravel appears insignificant in the Alaskan arctic shelves, the dispersal of silts and clays by ice is a dominant mechanism of sediment transport. Rex (1955), Toimil (1978) and Grantz *et al.* (1982) have provided comprehensive accounts of their investigations, including side-scan surveys, pertaining to ice gouge action on the northeastern Chukchi Sea floor. Toimil (1978) showed that although ice gouging is ubiquitous in the shelf, the density of ice gouges generally increased with increasing latitude, increasing slope gradients and decreasing water depth, and that the density of gouging varies widely (Fig. 10). The depth of gouge incisions ranges from 2 to 4 m. The inner shelf area between Point Lay and Point Barrow is the only area where the ice gouge azimuths are generally oriented parallel to the coastline and the Alaska Coastal Current (Grantz *et al.*, 1982). The total effect of the ice gouging is large-scale reworking and resuspension of the sea floor sediments, and possible deleterious impact on sedentary benthic organisms, resulting from bottom scoring. Additionally, bottomfast ice moves large volumes of sediments adjacent to the beach resulting in low ridges and mounds.

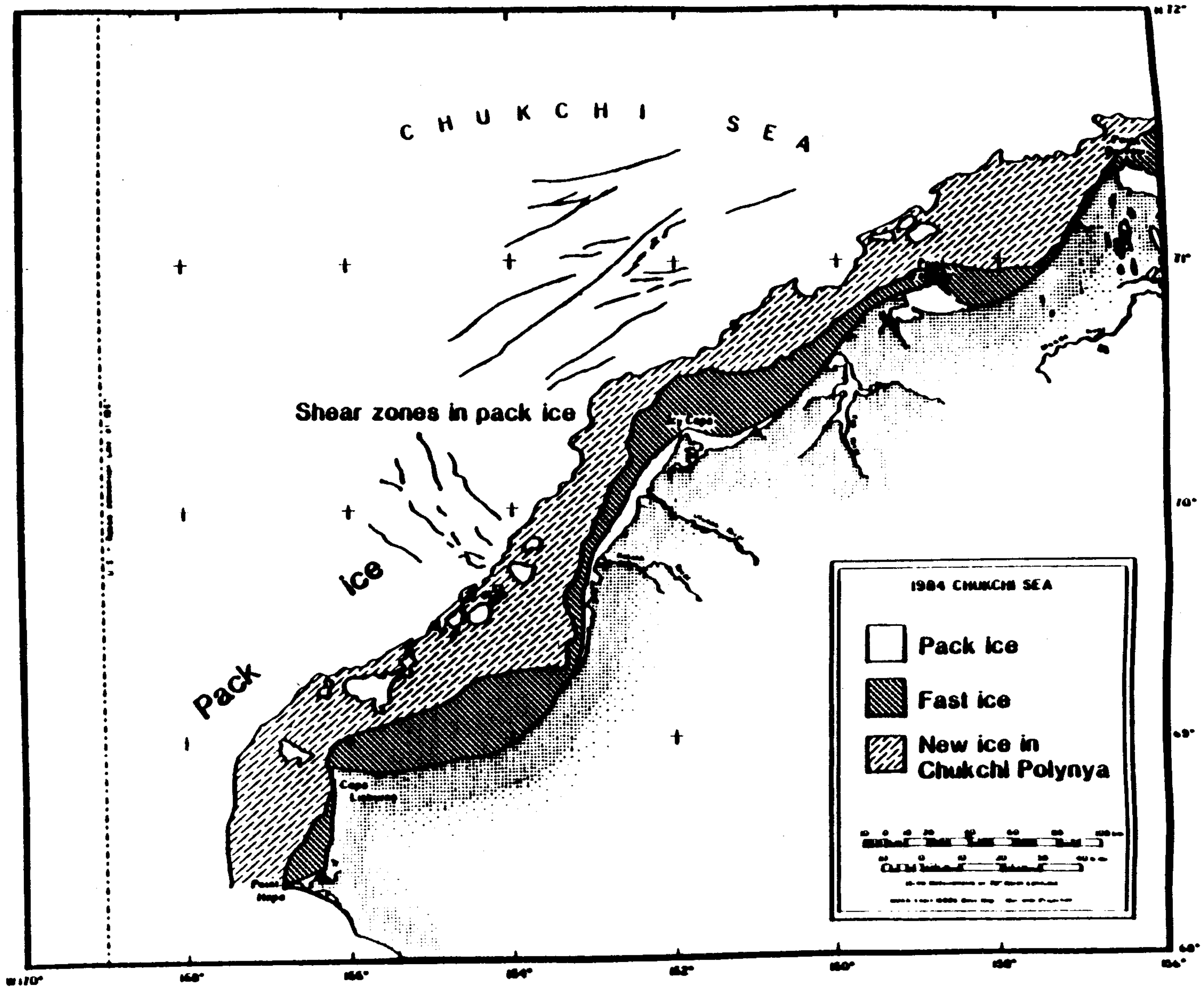

Figure 8. Zonation of pack, fast, and new ice in northeastern Chukchi Sea (after Phillips *et al.*, 1985).

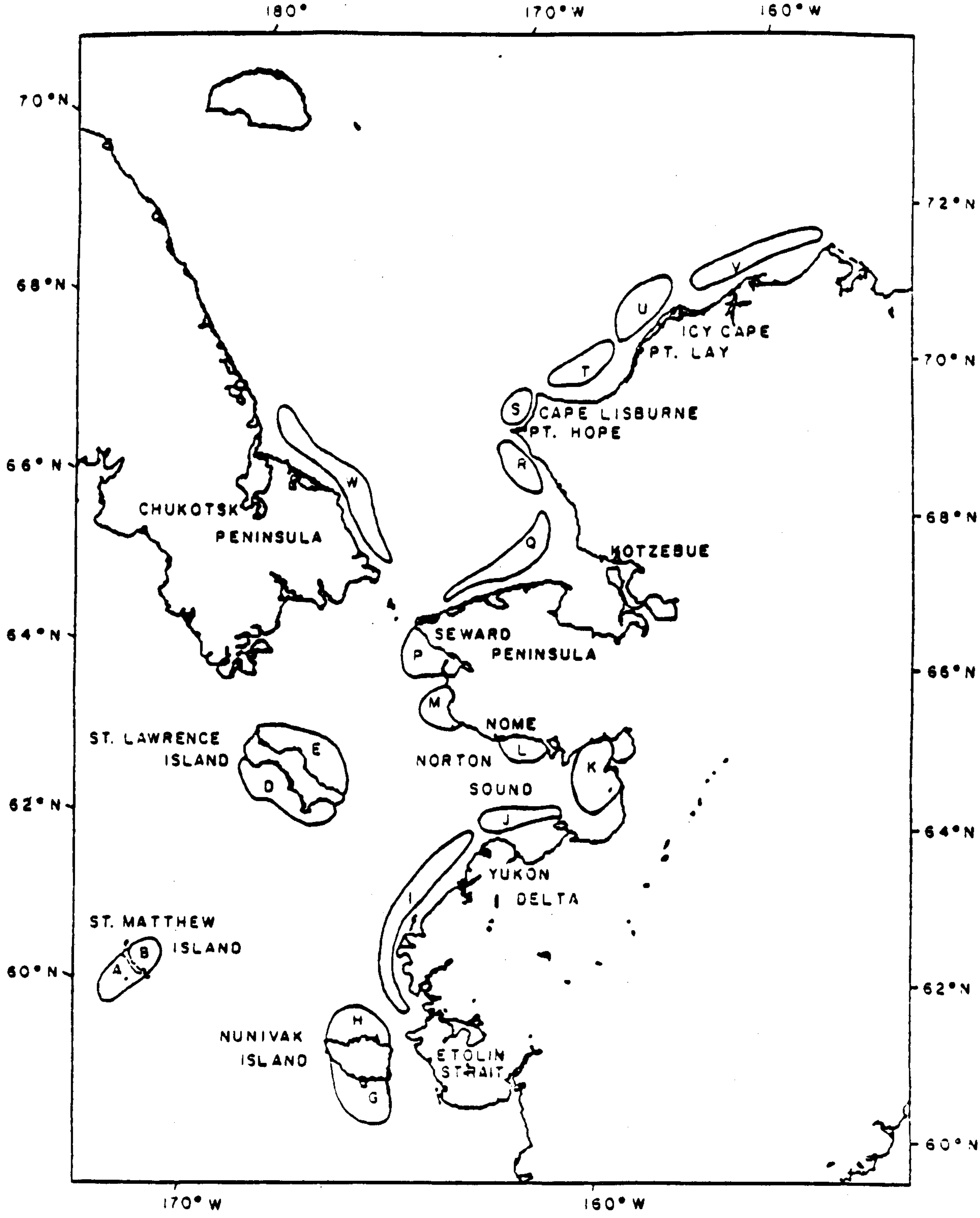

Figure 9. Distribution of polynyas in northeastern Chukchi Sea and adjacent areas (after Stringer, 1982).

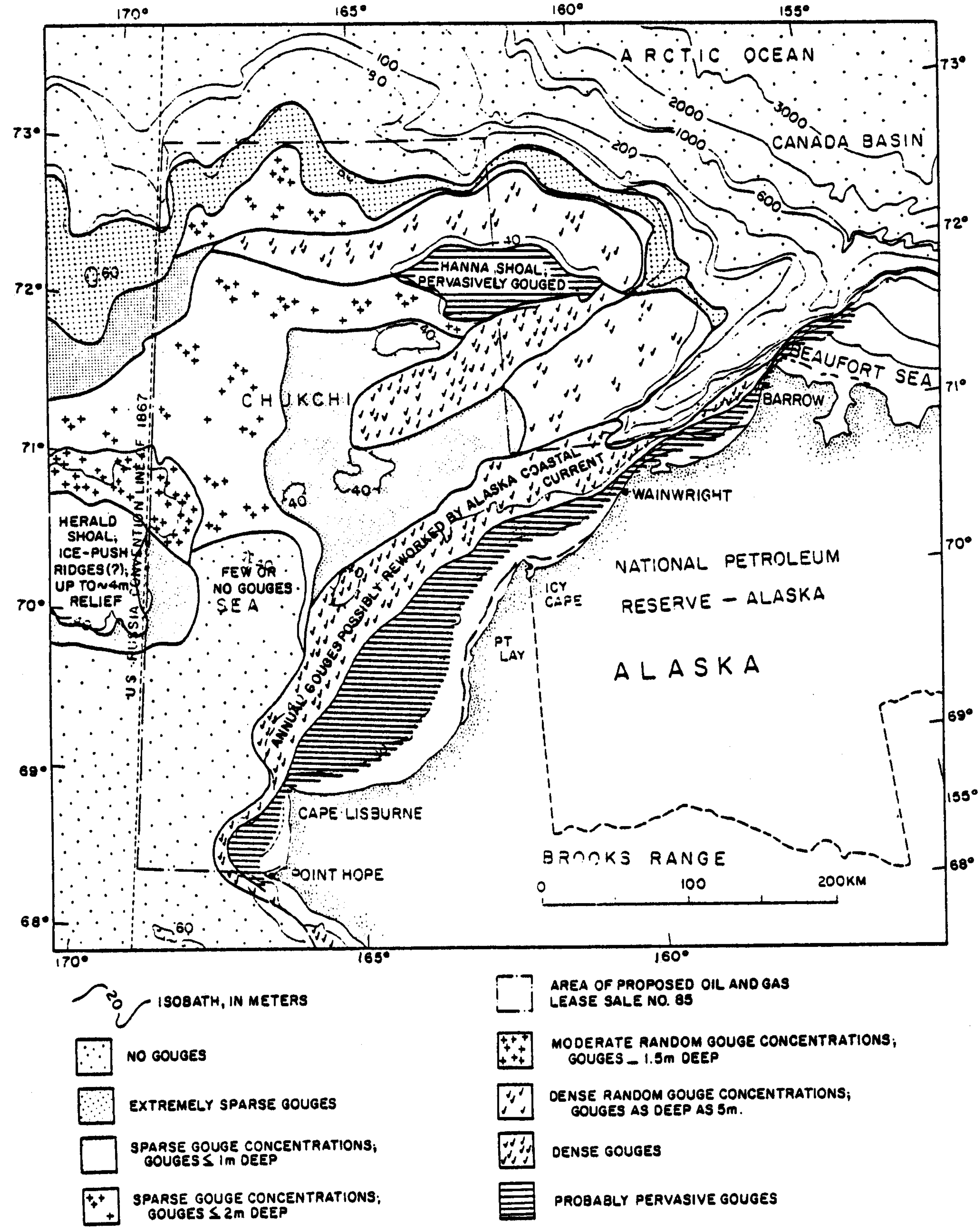

Figure 10. Map of northeastern Chukchi Sea showing the regional variation in the intensity of ice gouging (after Grantz *et al.*, 1982).

No quantitative data on an extensive scale are available on the erosional rate of the coastline of the northeastern Chukchi Sea. Harper (1978) has estimated a rate of 0.31 m/yr for Peard Bay to the Barrow coast and Grantz *et al.* (1982) have reported a 2 to 6 m/yr coastal erosion rate from Icy Cape to Point Barrow. The latter rate is similar to that observed along the adjacent Beaufort Sea coast (Naidu *et al.*, 1984; Reimnitz and Barnes, 1987) and is the highest on the earth. Gravel and sand yielded from this mass wasting is deposited as a lag along the beach and nearshore.

Astronomical tides of the northeastern Chukchi Sea are generally mixed semidiurnal with mean ranges from 10-30 cm.

The flow directions and speeds of the upper and bottom water layers in the Chukchi Sea are shown in Figures 1 and 2. A detailed description of these flows and their velocities are provided in the section on Physical Oceanography. It may suffice to mention that these flows can play an important role in the distribution of sediments, particulate organic carbon, ice and in the formation of northward migrating bedforms (especially by the Alaska Coastal Current off Icy Cape; Grantz *et al.*, 1982; Phillips *et al.*, 1985). Additionally, the presence of a net northeastward alongshore current has been a critical factor for the development of the extensive barrier island system along the northeastern Chukchi Sea coast (Short, 1979). Few estimates of the alongshore sediment transport rate by littoral currents are available. In August 1977 Nummedal (1979) estimated an average rate of 1663 m/day in the vicinity of Point Barrow, but this rate can be augmented by several factors during occasional summer storms (Hume, 1964), resulting in large-scale changes in coastal morphology and beach sediment budget.

IV. SOURCES, RATIONALE, AND METHODS OF DATA COLLECTION

A. Sources and Rationale

It is known that a number of oceanographic factors and sedimentary properties influence the density and distribution of marine benthic organisms. As succinctly stated by Webb (1976), "Most classical marine ecology implies that similar groups or species consistently occur on similar substrata." The selection of a settlement site by larvae of benthic species based on substrate character is more critical for sedentary than adult mobile species. However, the total interaction between benthic organisms and the inorganic sediment fractions is not well understood. As mentioned earlier, one of the primary sediment factors generally affecting distribution of benthic species is the grain-size of the bed sediments, in addition to flux of POC, sediment accumulation rates, water mass characteristics, degree of water turbidity, and others (McCave, 1976). In ice-stressed arctic areas such as the Chukchi Sea, ice-gouging of bottom sediments can be an additional limiting factor for distribution of benthic species (Barnes and Reimnitz, 1985; Barnes *et al.*, 1984; Phillips *et al.*, 1985; Phillips and Reiss, 1985a, b; Carey and Ruff, 1977; Carey *et al.*, 1974).

The design for sampling the benthos was tailored in such a way that an adequate number of samples was collected from various representative environments of the northeastern Chukchi Sea. The sampling sites were selected on the basis of known distribution patterns of sediment types, water mass characteristics, ice gouge densities, and the mean ice-edge position during the summer (Figure 3). The most northerly stations occupied were limited by the southern margin of pack ice during the sampling period, while the western most stations were at the U.S.-U.S.S.R.

boundary. In order to examine temporal variability of fauna in the study area, four additional benthic stations were occupied to coincide with those stations sampled for benthos by Stoker (1978). Three additional stations were selected in the vicinity of Point Franklin and Peard Bay, a region identified as an important summer feeding ground for gray whales (Phillips *et al.*, 1985).

It was assumed that all important environmental parameters (e.g., water mass characteristics, ice zonation, polynyas, suspended particulate load, etc.) could be assessed in terms of their effects on the benthic system in the framework of the station locations established as above.

Water mass characteristics were included in the sampling plan for the cruise on the NOAA ship *Oceanographer* in 1986. The sampling plan was keyed principally to the sediment type, but the close relationship between sediment type, prevalent currents and the water mass structure was recognized. Thus, while all the stations were not occupied in a sequential cross section fashion, many were, and other stations were grouped into logical cross section units for analysis. The principal water masses which were designated for analysis were the Bering Water, Alaska Coastal Water, Chukchi Resident Water (Modified Bering Water) and the Beaufort Sea Water. The precise definitions of these water masses have been described as varying interannually, so that the bounds on temperature and salinity is a function of an individual year (Coachman *et al.*, 1975). The separation of what has been defined as Chukchi Resident Water, Chukchi Bottom Water, Siberian Coastal Water, and some of the descriptions of nearshore Beaufort Sea Water adds additional complexity to the individual designation of water masses.

B. Methodology

1. Field Sampling and Measurements

a. Physical

A Grundy (Plessy; Bissett-Berman) Conductivity-Temperature-Depth (CTD) Model 9040 system was used during the *Oceanographer* cruise. This instrument was owned, maintained and operated by NOAA. The CTD was lowered at most of the stations, and the data recorded on computer tape. On three casts, stations CH1, CH12, and CH33 the data were not recorded, either due to instrument malfunction or human error. The CTD system was calibrated at the Pacific Northwest Regional Calibration Center in October, 1985. Field calibration samples for salinity and reversing thermometer measurements were collected near the bottom on most casts. The salinity samples were analyzed on the ship using an Autosal laboratory salinometer. CTD profiles were acquired after deployment of the moorings and after their recovery. The CTD tapes were processed at NOAA Pacific Marine Environmental Laboratory (PMEL) in Seattle Washington. One meter averages of the temperature and salinity were calculated and the data then sent to the University of Alaska. These one meter average data were then appended to the CTD data base on the Geophysical Institute VAX 780 computer. The data base uses the INGRES relational data management system for access and retrieval of the data.

The *Oceanographer* has an RD Instruments Acoustic Doppler Current Profiling (ADCP) system which was operated during the cruise. This system sends out a 150 kHz acoustic pulse and measures the Doppler shift of frequency of the backscattered sound received at the four beam transducer. The Doppler shifted frequency of the pulse is proportional to the relative speed of the ship over the water. The system transmits a pulse at the rate of one per second and two minutes worth of data were averaged together for each ensemble. To determine the ship's speed, a modified acoustic pulse is sent, and the directly reflected Doppler shift from the bottom reflection is measured. The ship's motion is then subtracted and the water motion over the bottom is determined in a range of bins beneath the ship, from 5 m to about 80 percent of the water depth at 2 m intervals. The data were recorded on an IBM PC on the ship. The data were processed at the Institute of Marine Science, University of Alaska. The positions of the ship for each ensemble were determined by interpolation between satellite fixes. Normally, LORAN C is used for relative positioning, but LORAN C cannot be used for navigation in the northern Chukchi Sea due to the radio propagation characteristics and the placement of the master and slave stations. Since the ship speed was determined by bottom tracking as described above, the relative error of interpolating the position of the ship does not affect the value of the current measured, and probably represents less than a mile error in position.

Cooperation with the scientists on the previous cruise (particularly Dr. James Overland of PMEL) allowed us to deploy four moorings (Table 1; Fig. 11). Each mooring consisted of a railroad wheel anchor (approximately 300 kg), an acoustic release, an Aanderaa RCM4 Current meter, sediment trap and eight plastic Viny floats (Fig. 12). Since the moorings were to be in place less than a month, the current meters were deployed primarily to obtain estimates of the current velocities that the sediment traps were experiencing during their sampling. Very little in the way of significant statistics were expected from the current records with durations between 5 and 8 days. However, as is often the case, these short time series sampled an interesting and significant wind forcing event. To determine the source of the variations in the currents, the winds from the NWS station at Barrow

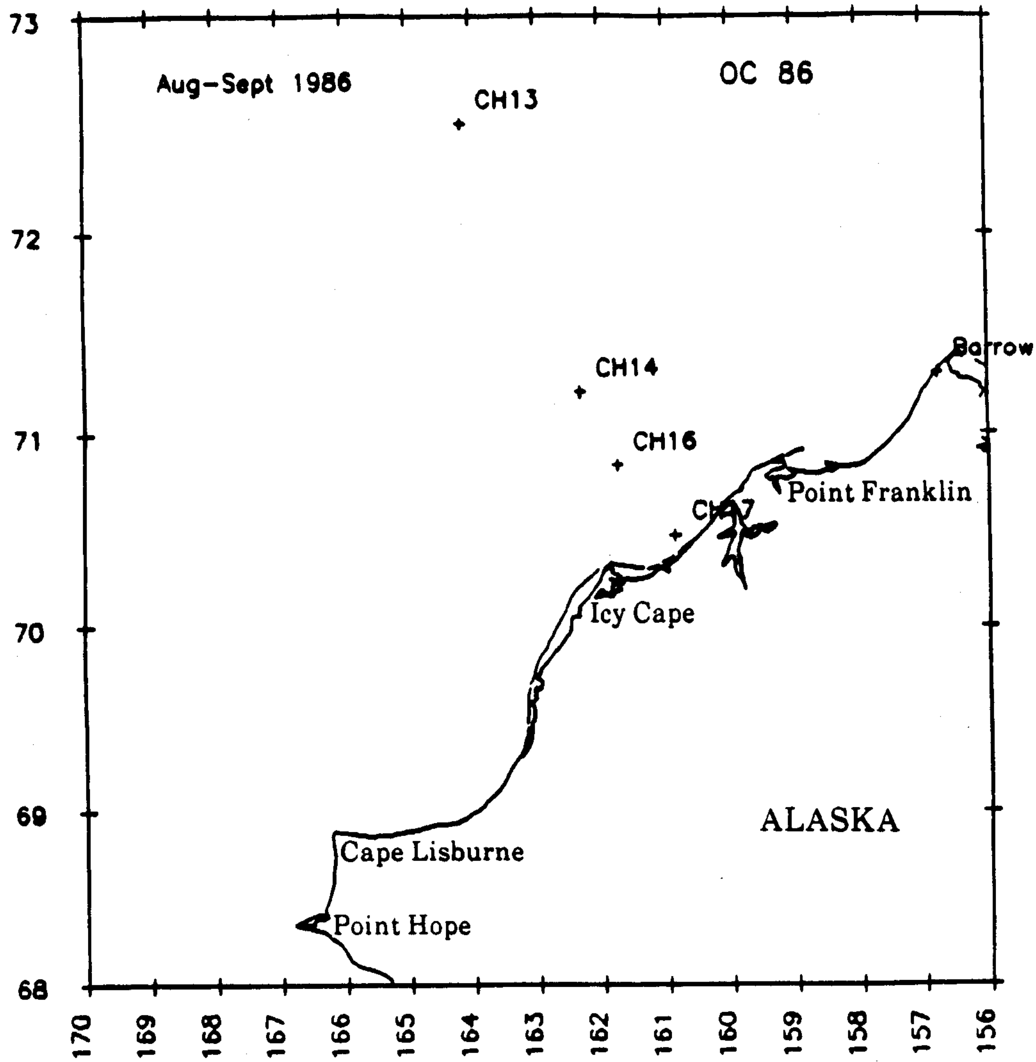

Figure 11. Locations of the current meter-sediment trap moorings, August-September 1986, in northeastern Chukchi Sea.

Table 1. *Oceanographer* 1986 UAF/NOAA Mooring Deployments

Mooring	Lat(N)	Lon(W)	Start Date	GMT Time	End Date	Depth (m)	Meter Depths	15 min Samples
CH13/1	72 30.6	164 09.0	27-Aug	0117	31-Aug	49	47	388
CH14/1	71 12.6	162 19.2	26-Aug	1815	2-Sep	44	42	616
CH16/1	70 50.4	161 45.0	26-Aug	1521	2-Sep	44	42	612
CH17/1	70 28.8	160 51.0	26-Aug	1234	1-Sep	22	20	609

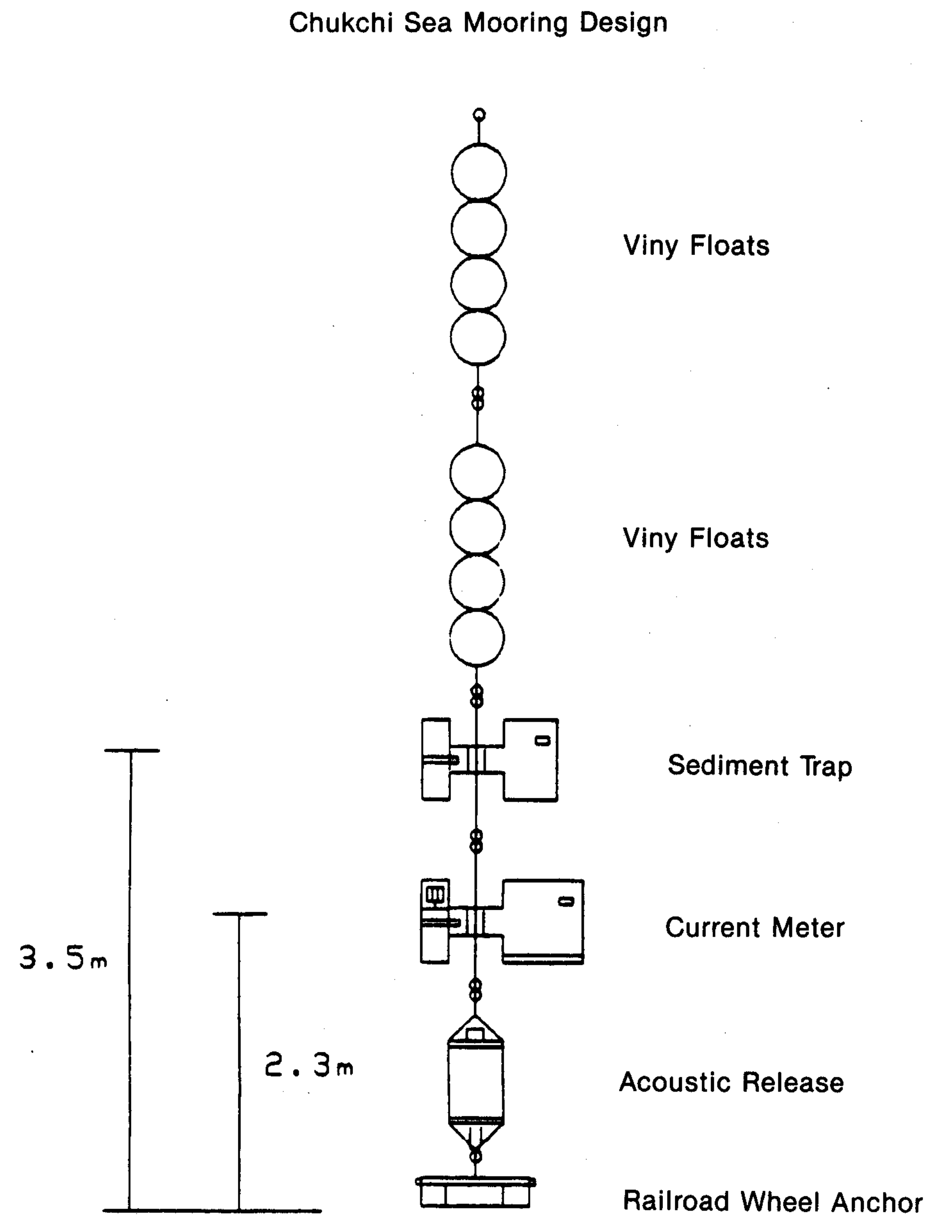

Figure 12. The vertical array of instruments and floats on a typical mooring deployed in the study area.

were obtained from the Local Climatic Summary. The tapes were read and processed at Aanderaa Instruments, Canada. To compare to the Barrow winds, a 2.86 hour half power point low pass filter was applied to the original data, the values at the whole hour were interpolated, and then the series were decimated to three hourly samples.

b. Geological and Biological

Sediment, water and benthic biological samples were collected during a cruise extending between 22 August to 1 September, 1986 on board the NOAA vessel R/V *Oceanographer*. For the purpose of characterizing the benthic substrate habitats, bottom surficial sediment samples were collected at 47 stations using a 0.1 m^2 van Veen grab sampler (Table 2, Fig. 13). Each of these samples were split into two subsamples which were then placed in two separate freezer boxes. One box of samples was to be used for analysis of granulometric composition, and the other for the analysis of organic carbon and nitrogen. The latter subsamples were maintained in a frozen state for shipment to the laboratory in Fairbanks. At the 47 stations two liter water samples were retrieved from the Niskin bottles that were attached to the CTD system that was programmed to obtain samples at selected water depths (e.g., at surface, mid depth and near bottom). Each of the water samples was split into two 1 liter subsamples, each of which in turn was filtered separately through preweighed and precombusted Gelman glass filters (pore size approximately 0.45 µm) and preweighed Nucleopore membranes (pore size 0.45 µm), using a suction device. The sediment particles trapped on the glass filter were used for organic carbon and nitrogen analysis, whereas the particles on the Nucleopore membranes were used for the purpose of estimating the vertical distribution of the suspended particulate

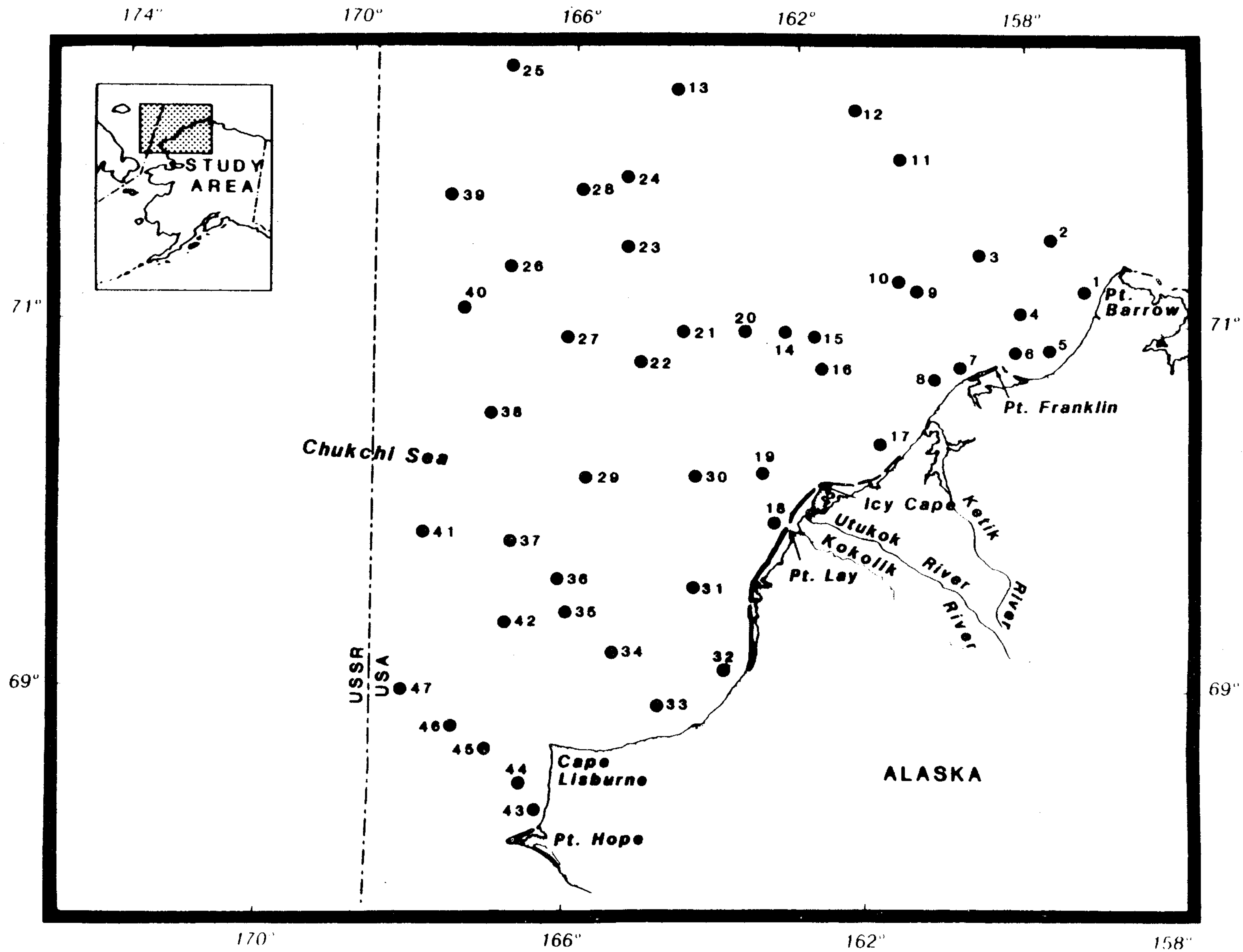

Figure 13. Map of northeastern Chukchi Sea showing station (CH) locations where physical oceanographic, geological, and biological samples were collected in August-September 1986 aboard the NOAA Ship *Oceanographer*.

Table 2. Summary of events at stations occupied in the eastern Chukchi Sea (north of Point Hope) aboard the NOAA Ship <u>Oceanographer</u>, Cruise OC862, August and September 1986.

Sta. Name	Latitude	Longitude	Depth (m)	CTD	Van Veen grab	Susp. Sediment	Benthos core	Piston core	Mooring	Nut./chyll. Prim. Prod.	Ben. Trawl	Bongo Tow
CH1	71 17.4 N	157 4.8 W	46	x	x	x	-	-	-	-	x	-
CH2	71 34.4 N	157 40.4 W	62	x	x	x	x	-	-	-	x	-
CH3	71 31.2 N	158 56.4 W	51	x	x	x	x	-	-	-	-	-
CH4	71 11.2 N	158 9.3 W	42	x	x	x	-	-	-	x	-	-
CH5	70 57.5 N	157 50.4 W	19	x	x	x	-	-	-	-	-	-
CH6	70 57.3 N	159 0.2 W	27	x	x	x	-	-	-	-	-	-
CH7	70 52.6 N	159 30.9 W	31	x	x	x	-	-	-	-	-	-
CH8	70 50.3 N	159 59.0 W	46	x	x	x	-	-	-	-	-	-
CH9	71 18.6 N	160 4.7 W	50	x	x	x	-	-	-	-	-	-
CH10	71 23.1 N	160 17.1 W	47	x	x	x	x	-	-	-	-	-
CH11	72 4.6 N	160 7.3 W	32	x	x	x	x	-	-	x	-	-
CH12	72 25.3 N	160 54.0 W	44	x	x	x	-	-	-	-	-	-
CH13	72 31.1 N	164 8.0 W	48	x	x	x	-	-	x	x	-	-
CH14	71 12.7 N	162 19.7 W	47	x	x	x	x	-	x	-	-	-
CH15	71 10.4 N	161 54.1 W	47	x	x	x	-	-	-	-	-	-
CH16	70 50.2 N	161 45.3 W	43	x	x	x	-	-	x	-	-	-
CH17	70 30.9 N	160 54.5 W	23	x	x	x	-	-	x	x	-	-
CH18	70 7.9 N	162 43.2 W	18	x	x	x	-	-	-	-	-	-
CH19	70 22.2 N	162 53.1 W	30	x	x	x	-	-	-	-	-	-
CH20	71 12.1 N	163 5.3 W	46	x	x	x	-	-	-	-	-	-
CH21	71 12.2 N	164 12.0 W	42	x	x	x	x	-	-	-	-	-
CH22	71 3.2 N	164 56.0 W	38	x	x	x	x	-	-	-	-	-
CH23	71 37.0 N	165 6.4 W	42	x	x	x	-	-	-	x	x	-
CH24	72 2.1 N	165 6.7 W	43	x	x	x	-	-	-	-	-	-
CH25	72 37.6 N	167 4.5 W	51	x	x	x	x	x	-	-	-	-
CH26	71 32.2 N	167 5.6 W	47	x	x	x	x	-	-	x	x	-
CH27	71 9.6 N	166 6.5 W	42	x	x	x	x	x	-	-	-	-
CH28	70 50.7 N	165 51.5 W	41	x	x	x		-	-	-	-	-
CH29	70 21.2 N	165 46.5 W	43	x	x	x	x	-	-	x	-	-
CH30	70 22.6 N	164 0.7 W	39	x	x	x	-	-	-	-	x	x
CH31	69 45.3 N	164 5.0 W	26	x	x	x	-	-	-	-	x	-
CH32	69 17.3 N	163 39.7 W	15	x	x	x	-	-	-	-	-	-
CH33	69 5.9 N	164 40.7 W	18	x	x	x	-	-	-	-	-	-
CH34	69 23.7 N	165 22.4 W	32	x	x	x	x	-	-	x	-	-
CH35	69 35.2 N	166 2.3 W	39	x	x	x	x	-	-	-	x	-
CH36	69 46.8 N	166 15.3 W	44	x	x	x	-	-	-	-	x	-
CH37	70 0.2 N	167 0.2 W	47	x	x	x	x	-	-	-	x	-
CH38	70 42.0 N	167 22.9 W	52	x	x	x	x	-	-	-	-	-
CH39	71 52.2 N	168 15.4 W	48	x	x	x	x	x	-	-	-	-
CH40	70 16.7 N	167 54.3 W	45	x	x	x	-	x	-	-	-	-
CH41	70 2.2 N	168 27.9 W	42	x	x	x	-	-	-	-	-	-
CH42	69 33.6 N	167 4.9 W	47	x	x	x	x	-	-	-	-	-
CH43	68 29.9 N	166 29.9 W	23	x	x	x	-	-	-	-	-	-
CH44	68 36.9 N	166 46.0 W	31	x	x	x	-	-	-	-	-	-
CH45	68 49.3 N	167 24.7 W	45	x	x	x	x	-	-	-	-	-
CH46	68 58.1 N	167 52.9 W	47	x	x	x	-	-	-	-	-	-
CH47	69 8.0 N	168 37.2 W	50	x	x	x	-	x	-	-	x	-

concentrations within the water column. Both of these filtered samples were washed with double distilled deionized water to free them of salts and stored frozen for subsequent analysis in Fairbanks.

In addition to the sediment grabs, samples of 18 Benthos gravity cores and five Benthos piston cores were collected at selected stations (Table 2; Fig. 13) for the estimation of sediment accumulation rates. These core samples were transferred to Fairbanks in plastic liners. As mentioned earlier, the sediment trap was attached to each of the four current meter moorings (for station locations see Table 1 and Fig. 11) at about five meters above the sea floor. The purpose of the sediment trap deployment was to estimate the gross fluxes of sediments, and particulate organic carbon and nitrogen to the sea bottom during the summer (August-September). The traps were deployed for 5-8 days (Table 1). Following recovery of the moorings, particulates collected in the individual traps were quickly transferred into polyethylene bottles and stored frozen.

Thirty-seven (37) stations were established (Table 2; Fig. 13) to represent variable benthic biological environments in the northeast Chukchi Sea based mainly on a range of sediment types (Fig. 3; after Naidu, 1987), bathymetric characteristics (Fig. 6), and marine mammal distributions (e.g., Fay, 1982; Phillips *et al.*, 1985). At each station, five replicate biological bottom samples were collected with a 0.1 m^2 van Veen grab. Material from each grab was washed on a 1.0 mm stainless steel screen, and the biological material preserved in 10% buffered formalin. Benthic trawling was accomplished at ten stations. A small try net (4 m net opening) was towed 10-15 minutes at 2-4 kts.

2. Laboratory Analysis

Sediments from the grab samples were analyzed for their grain sizes by the usual pipette-sieve method, and the sediment types and grain size distributions defined statistically following the conventional grain size parameters stated in Folk (1980). The Nuclepore filter membranes with filtered sediments were dried in an oven at 80^{o}C, cooled and weighed in a Cahn balance in order to estimate the suspended particulate concentrations. The Gelman glass filters were first exposed to 2N HCl acid vapors in a desiccator to dissolve carbonates, then dried in an oven and weighed in a Cahn balance. The carbonate-free sediment sample on the glass filter was analyzed for organic carbon (OC) and Nitrogen (N), using a Perkin-Elmer Model 240B CHN analyzer. Urea was used as the reference standard. The precision of analysis was 8%. The relative abundance of organic carbon and nitrogen (mg/g) thus estimated on each glass filter was then computed against the total weight of sample of dry suspended particles estimated per liter of sea water as obtained on the Nucleopore membrane corresponding to the same water depth and station as the glass filter. The OC and N estimates were prorated to the suspension weights on the Nucleopore membranes because these membranes provide more accurate suspension weight data by virtue of better precision obtained using them. This finally also provided the concentration of OC and N in suspended sediments on a carbonate weight basis. Organic carbon and nitrogen in bottom sediments were estimated on dry carbonate-free sample powders using the CHN analyzer. All OC/N ratios in this report are computed on a weight to weight basis of OC and N. The carbonate-free bottom surficial sediment powders were submitted to Coastal Science Laboratories, Inc. (Austin, Texas) for the analysis of stable carbon isotopes (e.g., ^{12}C and ^{13}C) by mass spectrometry. The stable carbon isotopic ratios received from the above laboratory were expressed as $\delta^{13}C$ and corrected to the PDB standard. The standard error of the $\delta^{13}C$ determination was 0.2 $^{o}/oo$.

The samples collected from the sediment traps were centrifuged and the solids collected, dried and accurately weighed to estimate the flux of particulates to the bottom for the duration of the time that the traps were deployed. From the above, the flux per day was calculated. The dry particulates were treated with 10% HCl to remove carbonates. The carbonate-free sample was analyzed for OC and N as per the method outlined above.

The linear sediment accumulation rates (cm/yr) were estimated by the ^{210}Pb geochronological method following the steps outlined in Nittrouer *et al.* (1979) and Naidu and Klein (1988). The mass sedimentation rate ($g/m^2/yr$) was calculated from the linear sedimentation rate and by taking into account the sediment porosity and density (2.56 gC/cm^3). The sediment porosity, in turn, was estimated on the basis of the mean fractional water content of all the sections in an individual core (see Appendix I). The core samples were extruded out of the plastic liners and quickly split into 1-cm sections. The water content was determined on these sectioned samples after drying at 90°C for 24 hrs. The dry sections were pulverized using an agate mortar and pestle. Two grams of each of these powders were taken into solution by digestion in HF, HNO_3 and HCl. Prior to the digestion, ^{208}Po spike was added to the powder. The polonium was electroplated onto silver planchets following the method of Flynn (1968), and then assayed by using an alpha spectrometer with a surface barrier detector coupled to a 4096 channel analyzer. The concentration of ^{210}Pb excess was estimated by measuring ^{226}Ra (Rn emanation method, Mathieu, 1977) in the solution left after polonium plating. The annual accumulation rates of OC and N for selected stations were estimated by multiplying the ^{210}Pb-based annual mass sediment accumulation rates ($g/m^2/yr$) with the concentrations (mg/g) of OC and N in surficial sediments at the selective stations.

In the laboratory, biological samples were rewashed and transferred to a 70% ethanol solution. All specimens were identified, counted, and weighed after excess moisture was removed.

3. Data Analysis

Cross correlation time-series analysis was performed to obtain time lag estimates for the maximum correlation between the wind at the National Weather Service station at Barrow and the currents measured at the current meter/sediment trap moorings.

All data on sediment granulometric compositions, including the sediment types and the conventional statistical grain size parameters (Folk, 1954), were digitized using standard NODC formats (073). Groupings of data on sediment grain sizes, OC, N, and OC/N were established based on cluster analysis. In this analysis the log transformed data were used. To elucidate the relationship between granulometric composition, OC, N, OC/N, and sediment water contents, correlation coefficients among the various variables were established. Additionally the correlation coefficients between the $\delta^{13}C$ and OC/N values against benthic biomass were obtained. The purpose of the latter analysis was to check if any covariance occurs between the benthic biomass and the quality of OC accumulating at the sea floor, as reflected by the $\delta^{13}C$ and OC/N values.

The data base used in the classification and ordination of stations consisted of taxon abundance at 37 stations. In many benthic biological studies, species collected by grab and subsequently used in analyses include slow-moving surface dwellers and small, sessile epifauna. These organisms are grouped with other fauna taken by grab to permit a more accurate assessment of the composition and production of the benthic fauna. This approach was used here. Highly motile epifauna such as large gastropods, shrimps, crabs, and sea stars (except the infaunal sea star *Ctenodiscus crispatus*) were excluded from analyses.

Station groups were delineated using a hierarchical cluster analysis. Data reduction prior to calculation of similarity coefficients eliminated fragments of specimens. The Czekanowski coefficient was used to calculate similarity matrices for cluster analysis routines (Bray and Curtis, 1957; Boesch, 1977). Since the latter coefficient emphasizes the effect of dominant (i.e., numerically abundant) taxa on classification, a log transformation ($Y = ln [X+1]$) of all data was applied prior to analysis. Principal coordinate analysis (Gower, 1967, 1969) was also used as an aid to interpret the cluster analysis (Stephenson and Williams, 1971; Boesch, 1973). The Czekanowski similarity coefficient was also applied to calculate the similarity matrix used in principal coordinate analysis (Probert and Wilson, 1984). Dominant taxa were determined by a ranking program (a list of all taxa is available from the Institute of Marine Science, University of Alaska). Two diversity indices, H' (Shannon and Weaver, 1963) and H (Brillouin, 1962), a dominance index, D (Simpson, 1949), and species richness, SR (Margalef, 1958) were calculated. The Shannon (H') and Brillouin (H) indices calculated were closely correlated ($r = 0.97$), indicating that either index is acceptable, as Loya (1972) and Nybakken (1978) suggest. The Shannon Index is presented here.

Wet weight biomass values were converted to carbon by applying the conversion values of Stoker (1978) determined for taxa in the same region. Benthic carbon production was calculated from these carbon values by applying conservative P/B values available for northern species (Curtis, 1977; Stoker, 1978; Walsh *et al.*, 1988; Grebmeier, 1987; and R. Highsmith, unpubl.) (Appendix II).

Programs were developed by Chirk Chu (IMS Data Management Group) for ranking taxa by abundance, wet-weight biomass, carbon biomass, and carbon production. These programs were used to determine the top-ranked taxa in stations and station groups established by cluster analysis, and to calculate the percent fidelity of these taxa to stations in each station group. An additional program calculated the percentage of higher taxa by abundance and carbon biomass present within each station and each station group.

The trophic structure of each station group was classified in two ways: (1) by grouping the taxa in each station group into five feeding classes: suspension feeders, surface deposit feeders, subsurface deposit feeders, predators, and scavengers; and (2) by grouping taxa in each station group into four feeding classes (Josefson, 1985): interface feeders (surface deposit + suspension feeders) that utilize particulate organic carbon at the sediment-water interface, subsurface deposit feeders, predators, and scavengers. Each taxon was assigned to a feeding class based on the literature and personal observations (Appendix II). All taxa were combined by station or major station group, and the percentage of individuals belonging to each feeding classification calculated for each group. Taxa were also classified into three classes of motility: sessile, discretely motile (generally sessile but capable of movement to escape unfavorable environmental conditions: Jumars and Fauchald, 1977), and motile (Appendix II). The percentage of individuals belonging to each motility class was also calculated for each station and station group.

Stepwise multiple discriminant analysis, using the BMDP7M program, was applied to the biological data to correlate (1) station group separation by cluster analysis and (2) regional separation according to biomass, with the environmental variables measured. Three separate analyses were performed using (1) sediment variables based on dry weight determinations [% gravel, % sand, % mud, mean sediment size, sorting, sediment organic carbon and nitrogen, and sediment OC/N], (2) sediment variables based on wet weight [% gravel + % sand, % mud, % water in sediment, organic carbon and nitrogen in sediment, and sediment OC/N], and (3) physical oceanographic variables [surface and bottom temperature, and current velocity]. The percentage values for sediment variables were arc sine transformed. Multiple discriminant analysis (canonical variate analysis) is a statistical method which determines functions whose application to the original data maximizes the observed variations among different groups (Cooley and Lohnes, 1971). Unlike classification and ordination, the method begins with a set of stations which have already been grouped and aims only to search for the relationships between these groups. Since the procedure starts with already defined clusters, multiple discriminant analysis is not a pattern analysis method and has not been widely employed in benthic studies. However, multiple discriminant analysis has been used by several authors to test a biological model (i.e., benthic station groups) with environmental parameters (Flint and Rabalais, 1980; Flint, 1981: Gulf of Mexico outer continental shelf benthos; Shin, 1982: Galway Bay benthos) and seems applicable to our studies.

Two grain size parameters (mean size and sorting), the percentage of sediment size classes (e.g., gravel %, sand %, etc.), suspended particle concentrations in the surface and near-bottom waters, OC, N, OC/N, and carbon isotopic ratios were first individually computer plotted on standard base maps of the study area and isopleths hand drawn to bring out the regional distributional patterns in the above parameters. These plots were made to determine if any relationships exists between stations or station groups and sediment types and fluidity. Binary plots including percentages of mud and water contents, and ternary plots including percentages of gravel + sand, mud + water contents were obtained (see Boswell, 1961, for the rationale of the ternary plots).

V. RESULTS

A. Physical Oceanography

1. Time Series

A time series plot of sticks proportional to the wind and current strength and direction demonstrates a relationship between the wind and currents (Fig. 14). The currents at the three moorings near the Alaskan coast indicate a reversal of the normal northeastward flow to southwestward. This reversal was produced by wind, which had begun to blow from the east northeast at up to 4 m/s (30 miles per hour). The nearshore mooring (CH17) had the largest amplitude variation of currents and the largest temperature variation. The amplitude of the reversal decreased offshore, from CH17 to CH14. The station farther from the coast, CH13, was near the ice-edge and on the other side of Barrow Canyon and a sub-sea bank (Hanna Shoal). The flow at CH13 was consistently toward the east, and is not related to the

Barrow wind. The alongshore component of the flow was estimated to be along the 60° axis, and this component of the flow clearly demonstrates the reversal (Fig. 15).

Cross correlation analysis was performed to obtain time lag estimates for the maximum correlation between the wind at the National Weather Service (NWS) Station at Barrow and the currents measured at the moorings (Table 3, Figs. 16-19). The calculations were performed for the component of current or wind along 60° axis, roughly the angle of the coastline orientation. The highest correlation was observed at CH17 with a value of 0.88 at 6 hours lag. The correlation decreased with distance offshore and the time lag of the highest correlation increased (Table 3).

The temperature time series from the current meters supports the hypothesis that the wind was producing upwelling (Fig. 20). The temperature

Table 3. Maximum cross correlation coefficients (at lag in hours).

Station	CH17	CH16	CH14	CH13
Barrow	0.883 (6)	0.800 (12)	0.708 (12)	0.986 (-27)†
CH17		0.985 (6)	0.935 (3)	0.925 (-21)†
CH16			0.991 (3)	
CH14				1.033 (-18)†

†Near zero at zero lag, not significant. The significance level for an effective number of degrees of freedom was estimated to be: critical $r_{0.05} = 0.755$.

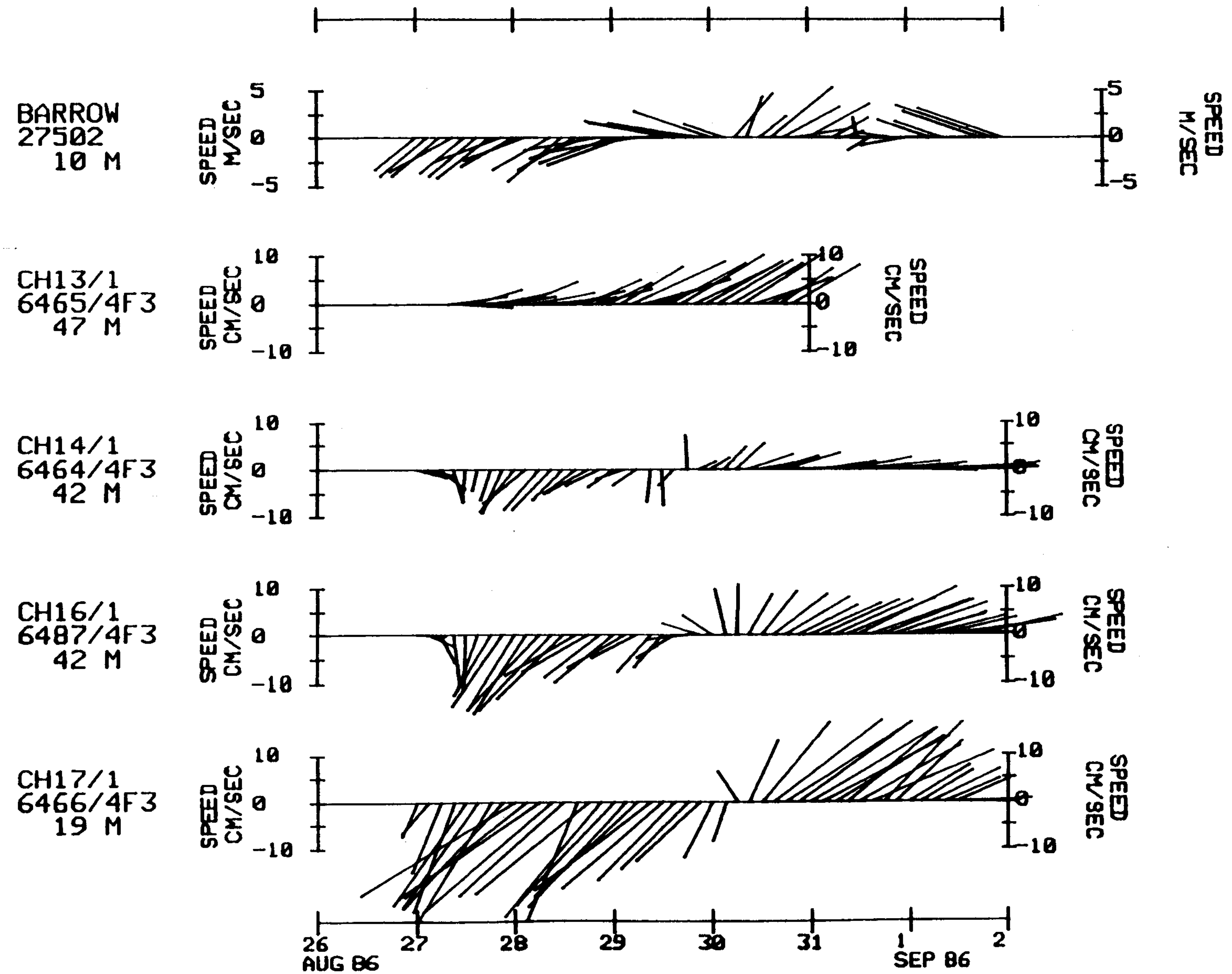

Figure 14. Vector plot of the wind measured at Barrow and the currents measured at the mooring locations.

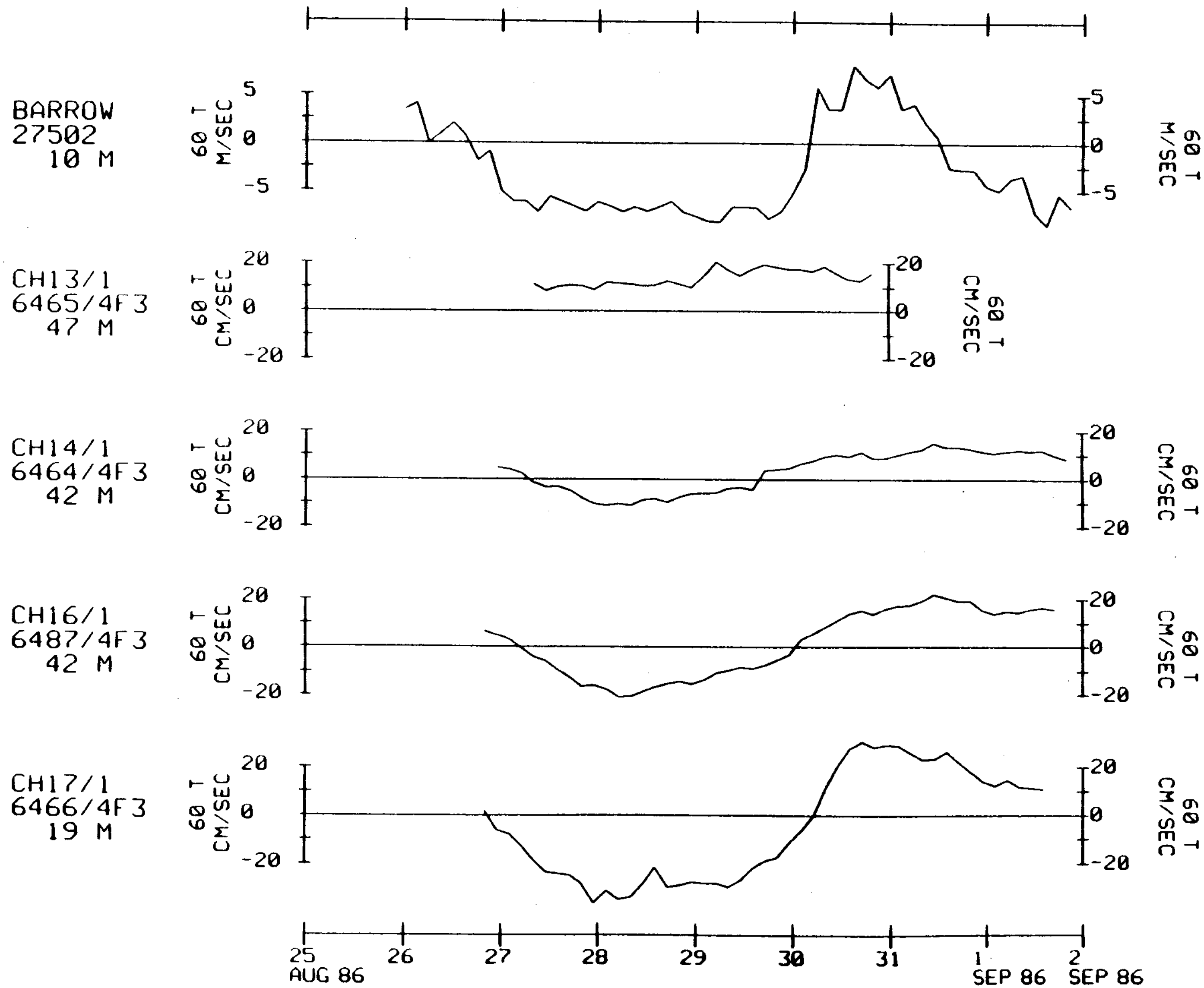

Figure 15. Time series of the wind and current along the 60°T axis, approximately alongshore at Barrow and the current meter moorings.

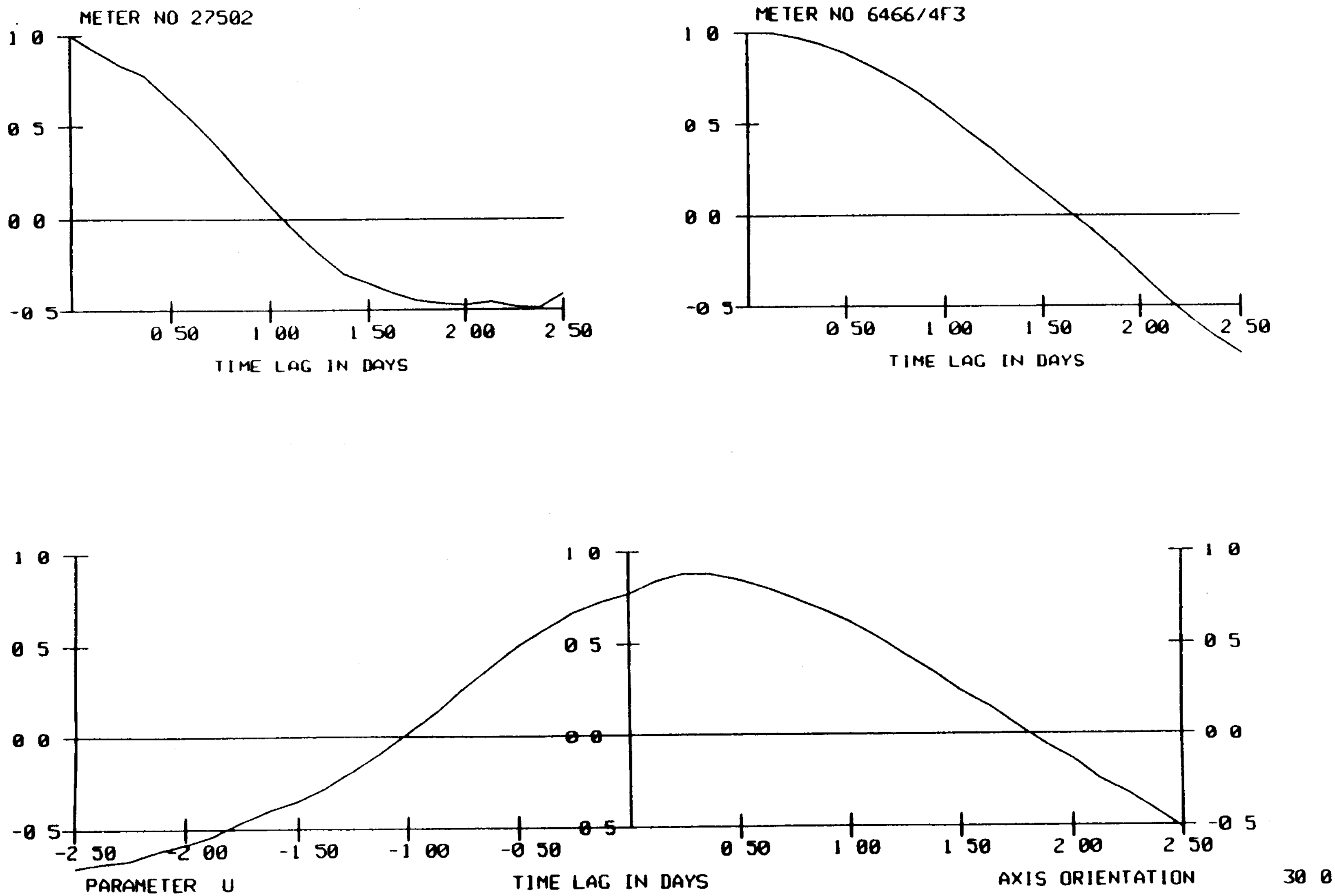

Figure 16. Lag autocorrelation and cross correlation functions for Barrow and CH17, calculated for the time series along the 60°T axis (30° rotation).

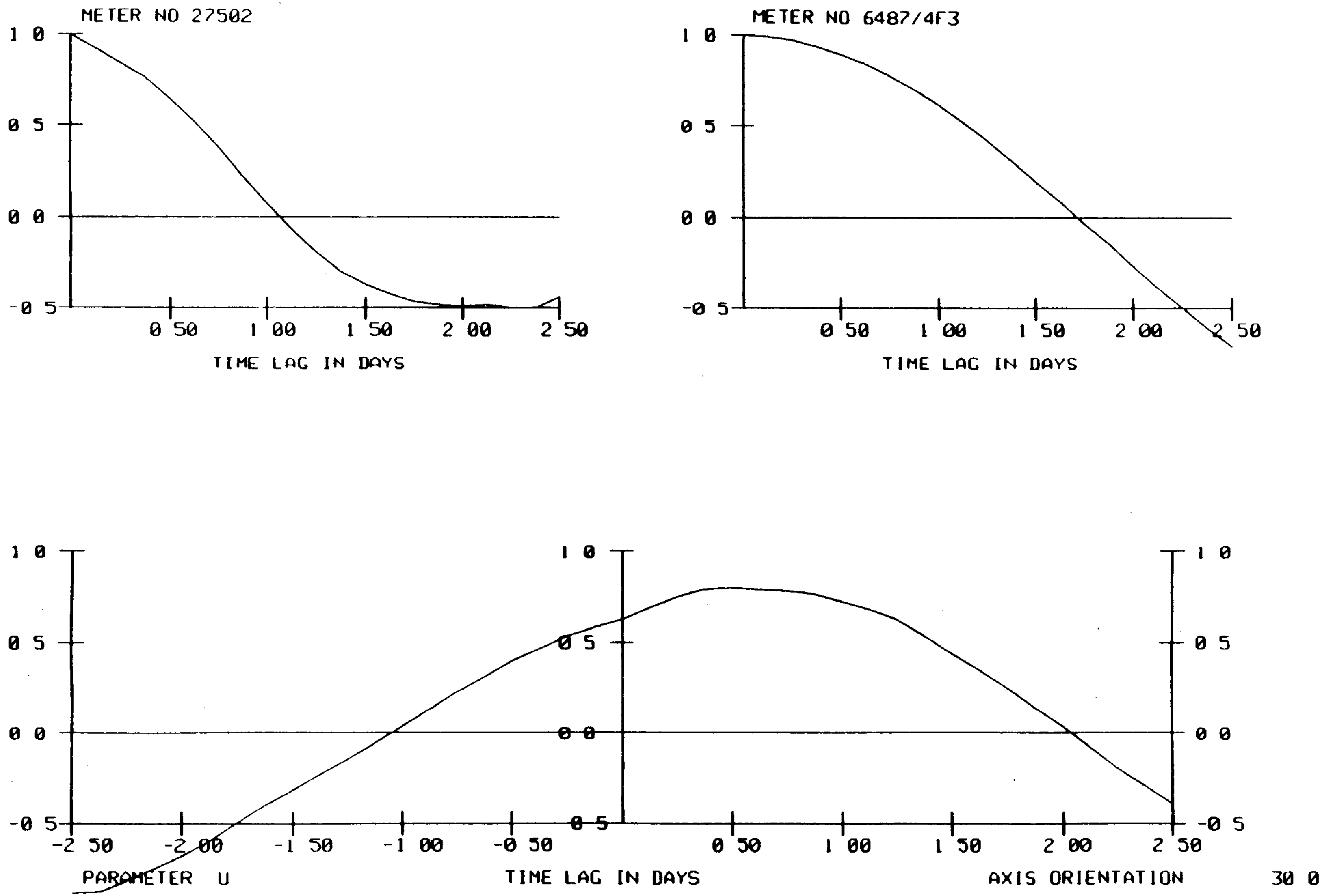

Figure 17. Lag autocorrelation and cross correlation functions for Barrow and CH16, calculated for the time series along the 60°T axis (30° rotation).

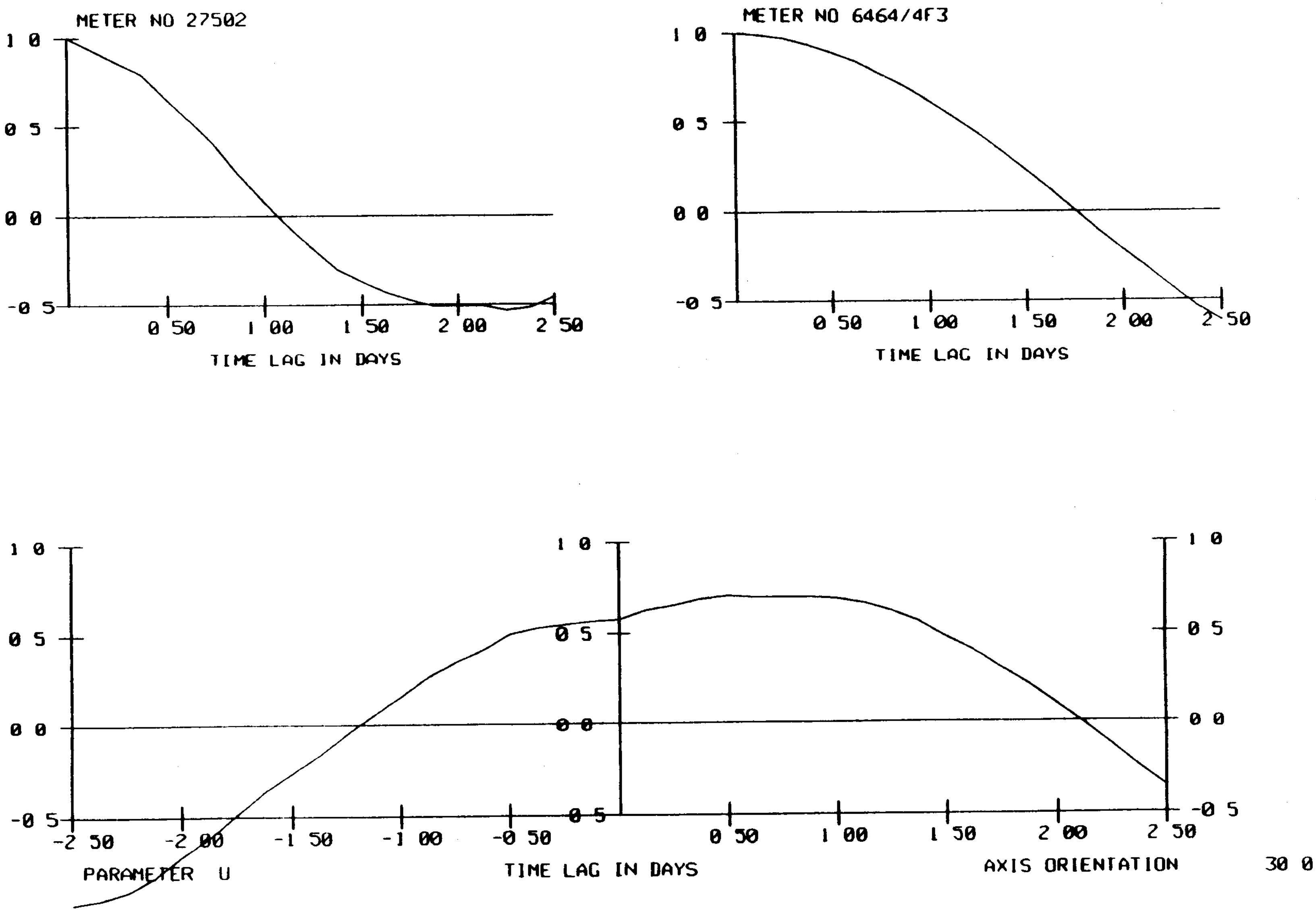

Figure 18. Lag autocorrelation and cross correlation functions for Barrow and CH14, calculated for the time series along the 60°T axis (30° rotation).

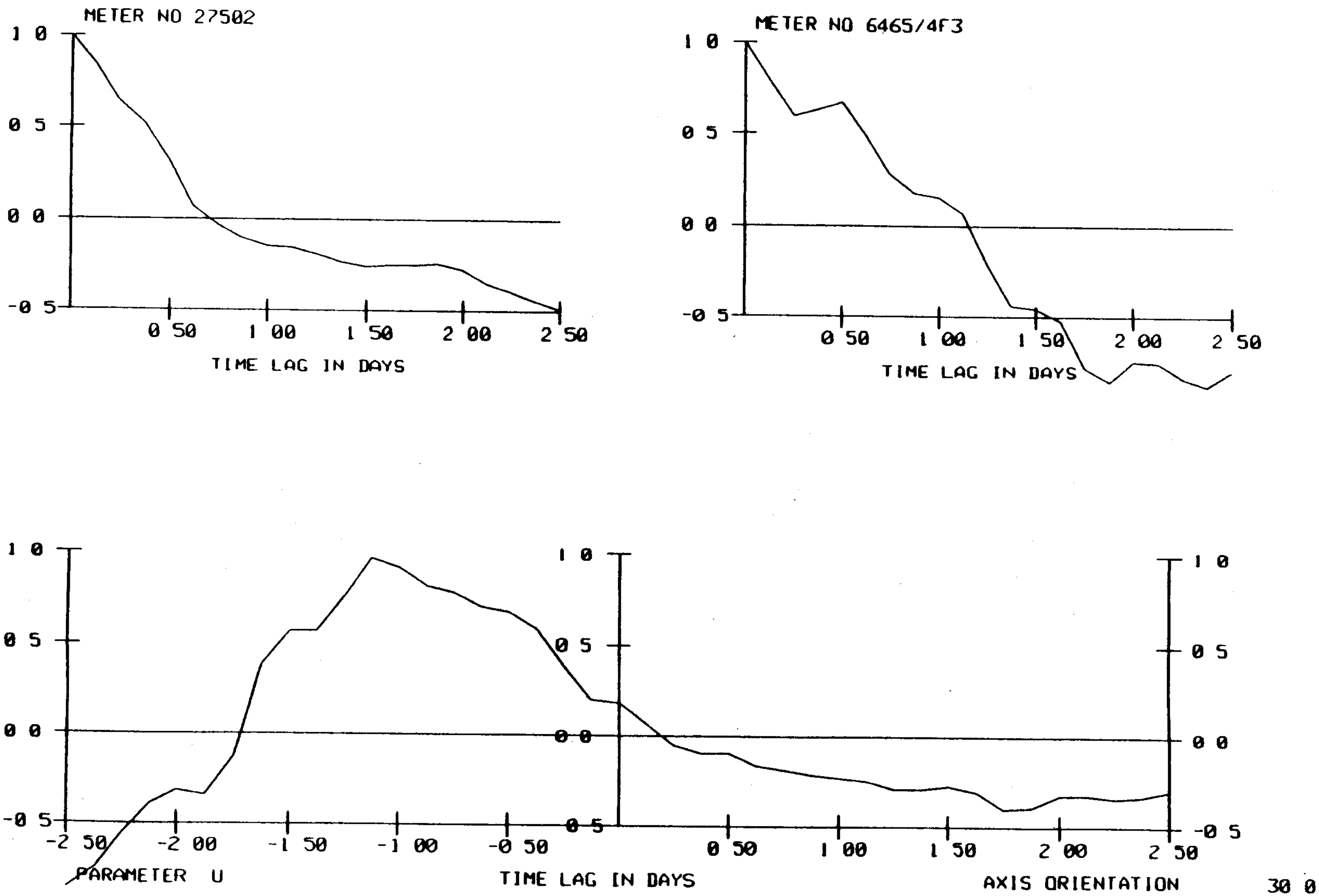

Figure 19. Lag autocorrelation and cross correlation functions for Barrow and CH13, calculated for the time series along the 60°T axis (30° rotation).

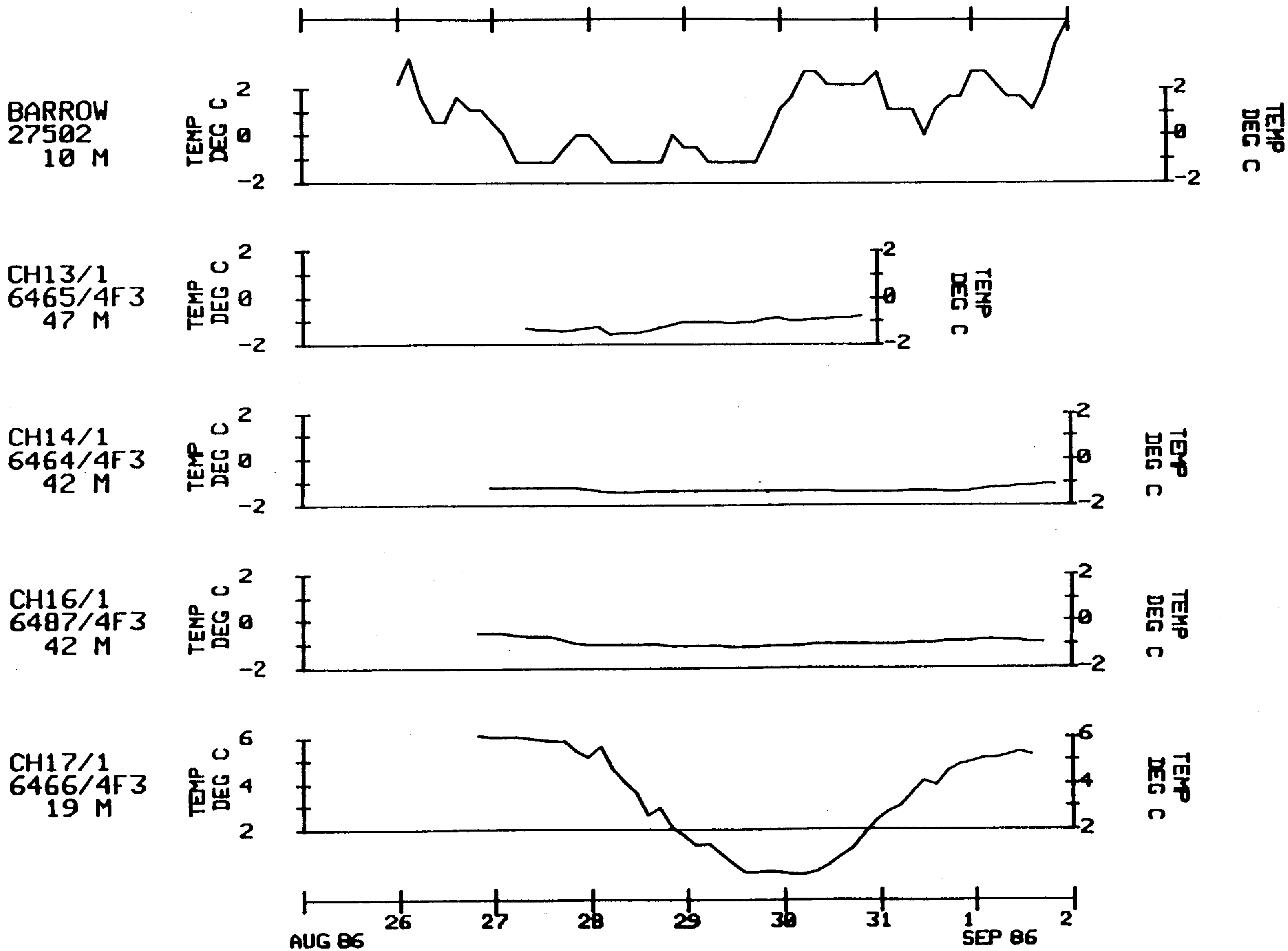

Figure 20. Time series of temperature measured at the moorings.

at CH17 decreased from warmer than 6°C before the wind reversal to less than 0° on August 30. The two current meters at CH16 and CH14 showed very slight decreases, but they were near the bottom and were measuring less than 0°C prior to the wind event. The timing of the temperature response produced the minimum temperature coincident with the reversal of the current from the anomalous southwestward flow to northeastward. From the CTD cross section, the 0° isotherm occurred at about 30 m depth following the event, when the moorings were recovered (Fig. 21). Thus, the upwelling resulted in lifting this isotherm at least 10 m to the 19 m depth of the CH17 current meter. The salinity cross section indicates that the coastal water had higher salinity than the surface water adjacent offshore (Fig. 22).

2. Acoustic Doppler Currents

The ADCP currents from the ship mounted system give an idea of the horizontal extent of the current response. The ADCP data were acquired from a point near Barrow on the cruise continuously throughout the cruise at two minute intervals. These data were smoothed with a 61 point triangular filter and then subsampled at one hour intervals. The smoothed data show strong southwestward flow near Barrow at the same time and at roughly the same distance offshore as CH17 (Fig. 23). Subsequently, as the ship proceeded offshore, the current velocities must be interpreted with both the wind event time history and the spatial current distribution. The pattern of currents measured with the system does reproduce many of the features of the earlier descriptions of the flow (Figs. 1-2; Fleming and Heggarty, 1966; Creager and McManus, 1966; Coachman *et al.*, 1975). In particular, the recirculation in the major embayment behind Point Hope is indicated, as well as the northeastward flow in the band offshore, associated with the Bering

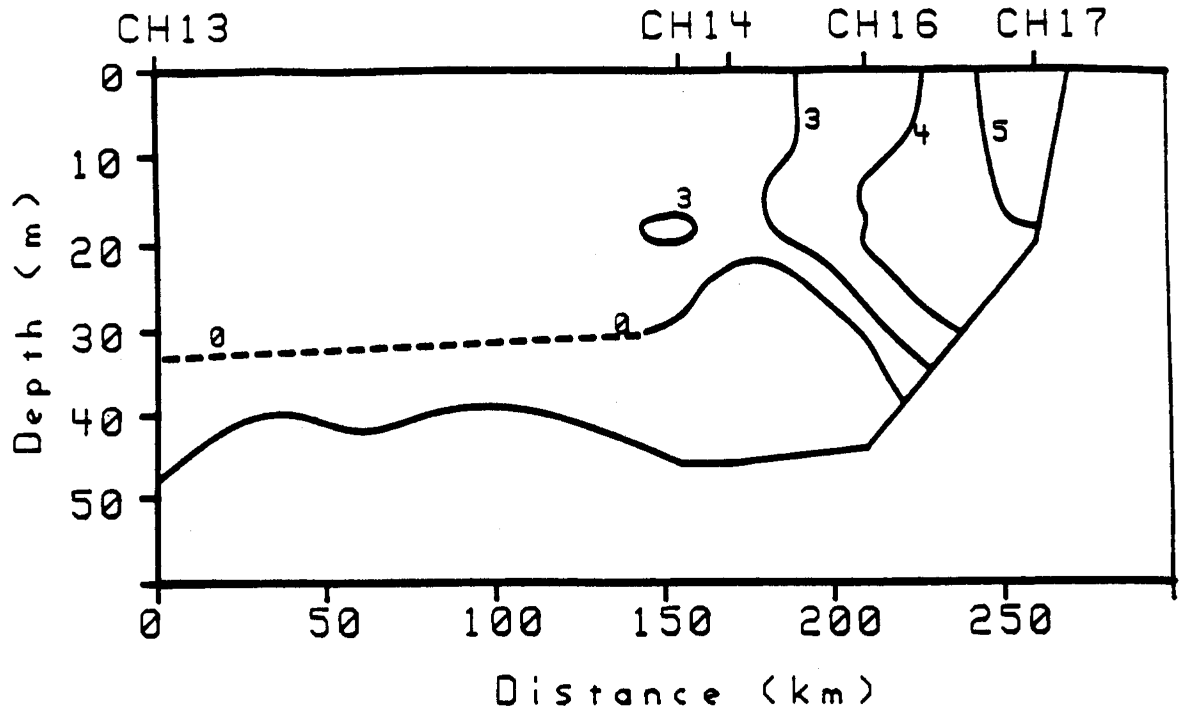

Figure 21. Cross section of temperature. Note that the contour interval is not constant.

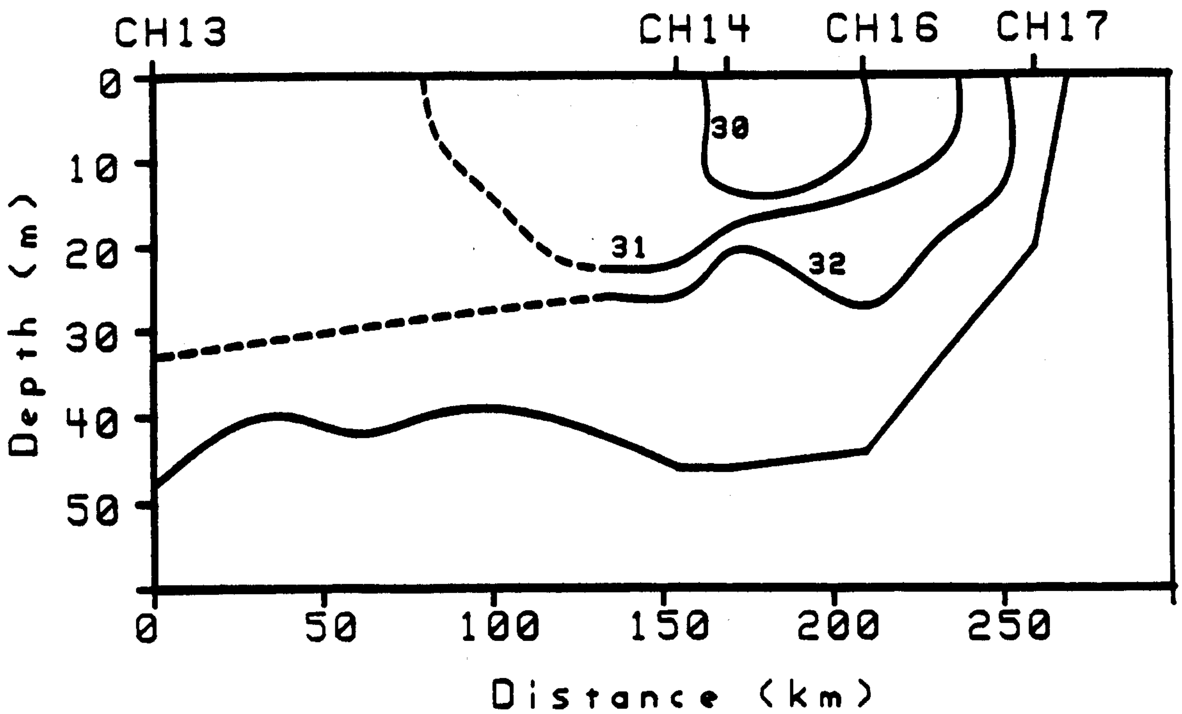

Figure 22. Cross section of salinity.

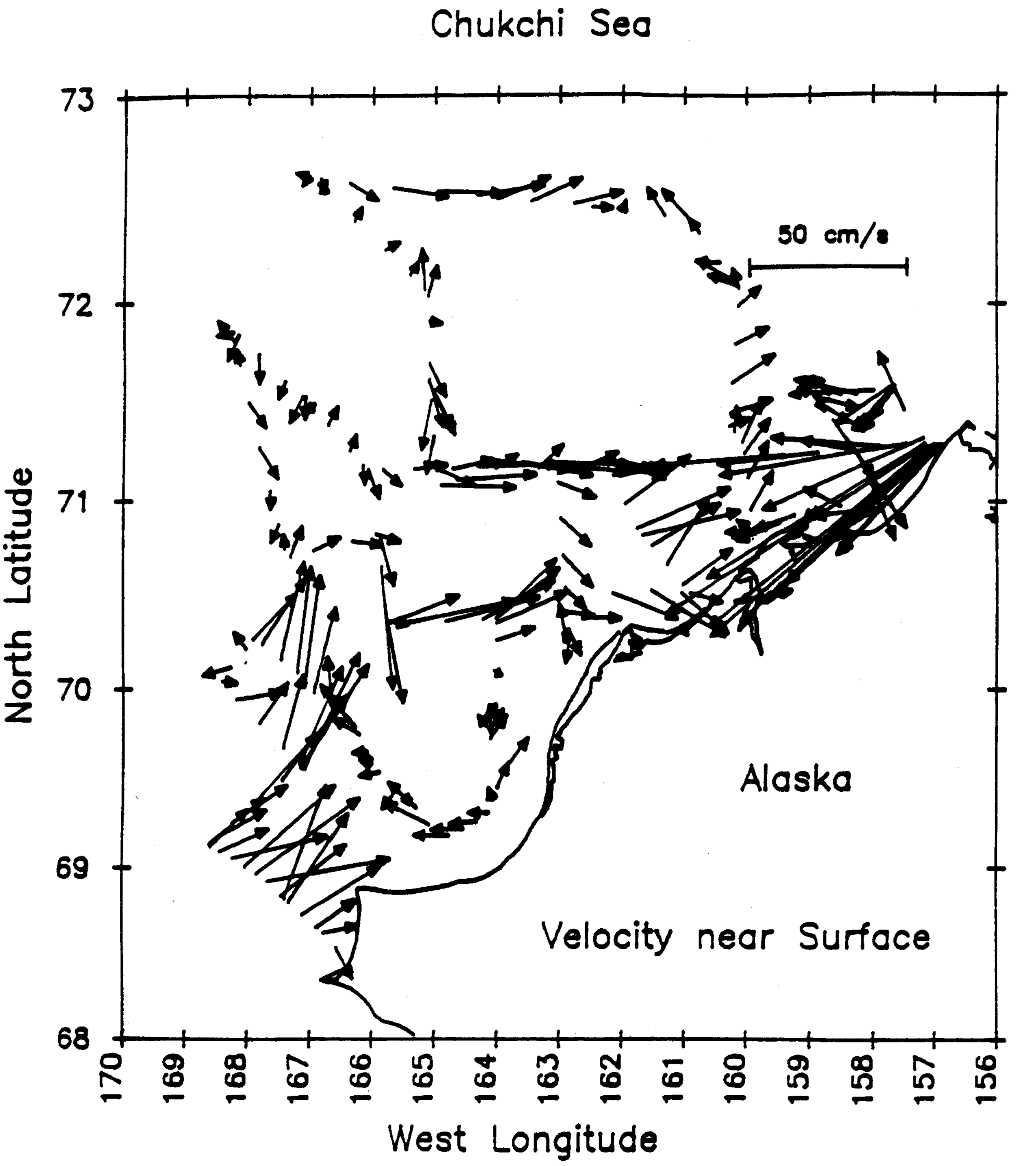

Figure 23. ADCP current estimates plotted on a chart. The estimates represent approximately one hour averages of the near surface current.

Sea Water. North of 70°30'N the currents are predominantly eastward and northeastward.

The ADCP results of a current reversal at Barrow (Fig. 24) coincident with the reversal event at CH17 is consistent with the observations made by Wilson *et al.* (1982) at Barrow and Wainwright. They found that the alongshore current within the coastal flow had a correlation coefficient of 0.90 at zero time lag. These results imply that the length scales of the alongshore flow is long compared to the distance between Barrow and Wainwright (700 km). Thus, the coastal region of the northeast Chukchi Sea responds rapidly (within 6 hours) to wind forcing nearly as a unit from Point Barrow to Point Hope.

3. Water Mass Analysis

Water mass analysis was conducted using two techniques, the first was a traditional T-S diagram method and the second was a cluster analysis on T-S pairs for the surface and near bottom waters. The cluster analysis was employed because it is less subject to bias by the analyst. A T-S diagram of all the stations indicates that the ranges of the temperatures and salinities are consistent with those observed earlier (Fig. 25; Coachman *et al.*, 1975). Stations sampled within the coastal domain often had a limited range of temperature and salinity. The separation of the Chukchi Resident Water and the Beaufort Sea Water is a subjective one near the end point (i.e., the freezing point curve). Garrison and Becker (1976) use a line across the base of the T-S diagram (from -1.6, 31.7 to -1.78, 34.0) to define the Chukchi Water. Paquette and Bourke (1981) use a similar range of T-S to define "northern water", which could be Chukchi or Beaufort derived. Garrison and Becker (1976) used "warm" differences from the Chukchi Water line to show the influence of the Beaufort Water. The late

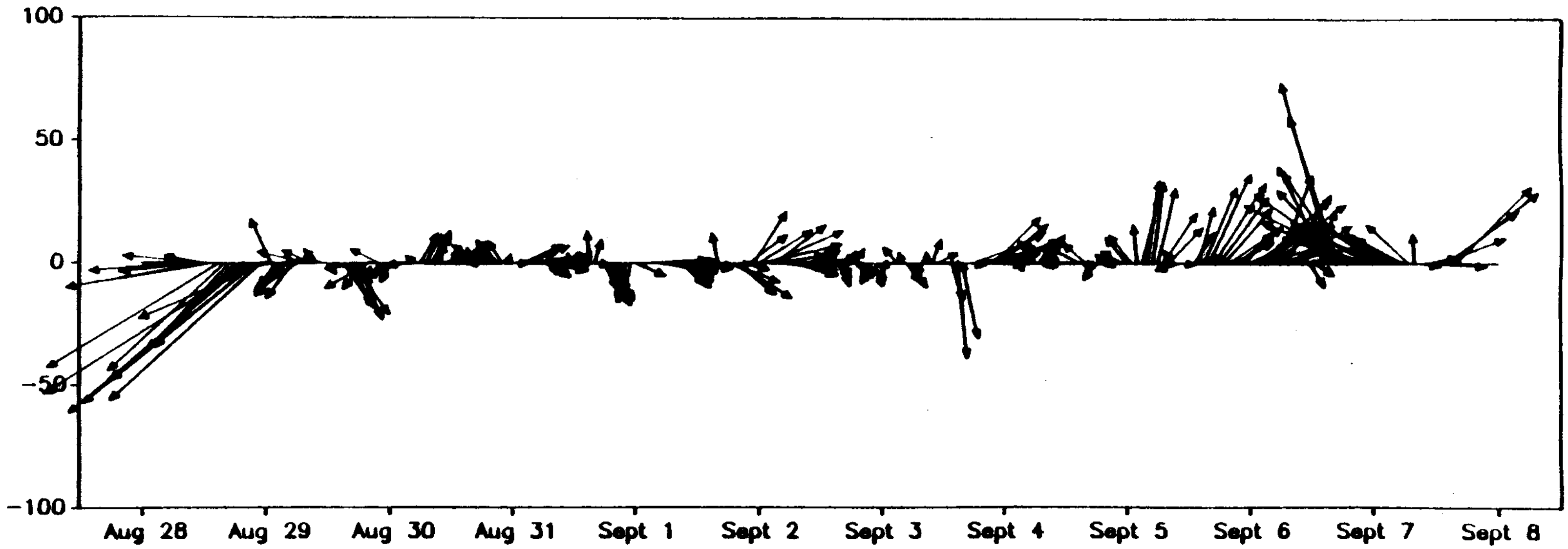

Figure 24. ADCP current estimates plotted from the ship as a time series. The vectors represent time and spatial variation since the ship was moving during most of the measurements. The estimates were averaged and then interpolated to one-hour intervals. See Figure 23 for the map showing the ADCP vectors.

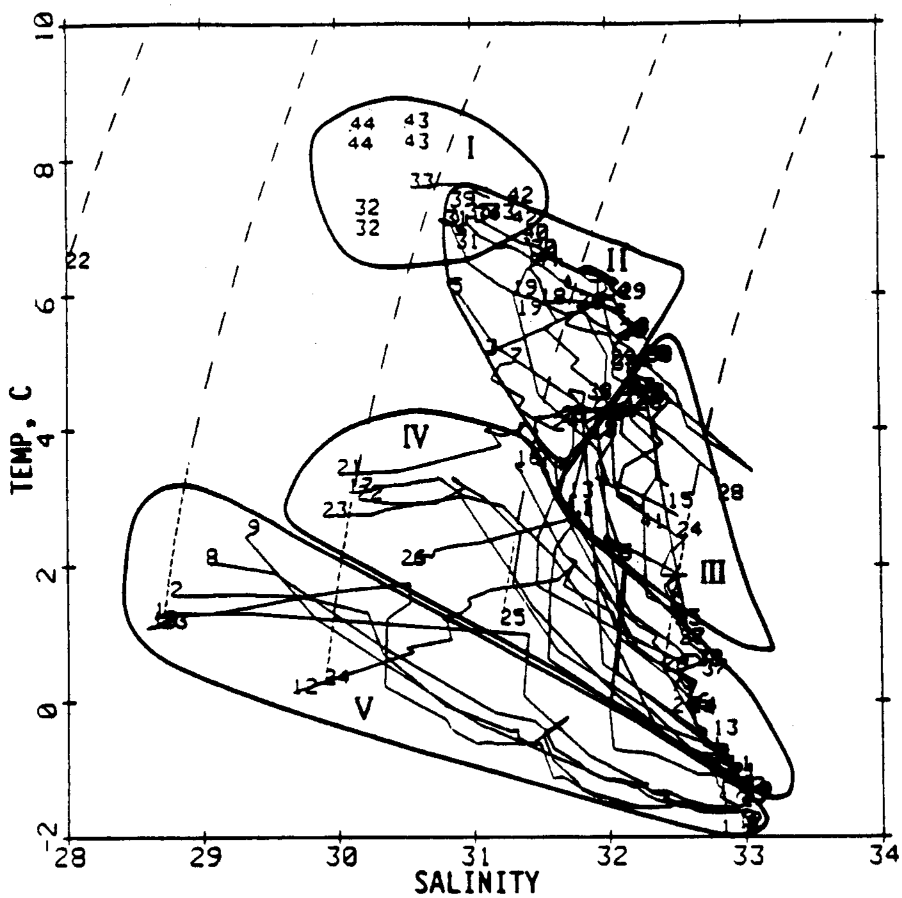

Figure 25. T-S (temperature-salinity) diagram for all of the CTD stations. The lines indicate the water mass designations in the text.

summer-autumn conditions of the *Oceanographer* cruise also meant that the definitions used for the spring (ice-edge) conditions are not always applicable. To avoid adding to a pantheon of water mass names, very general (inclusive) categories were established and the stations were assigned to them (Table 4). The major groups are shown in Figures 26-31. Based on the shapes of the T-S curves and their positions on the T-S diagrams, a map of the water masses was constructed (Fig. 32). Water masses designated I and II constitute water derived from the Alaska coast and Bering Shelf,

TABLE 4. Water mass groupings based on T-S diagram analysis

Mass I	Mass II	Mass III	Mass IV	Mass V
CH18	CH17	CH22	CH4	CH2
CH31	CH19	CH26	CH5	CH3
CH32	CH29	CH27	CH6	CH9
CH34	CH30	CH28	CH7	CH10
CH43	CH35	CH38	CH8	CH11
CH44	CH36	CH40	CH13	
CH45	CH37		CH14	
	CH42		CH15	
	CH46		CH16	
	CH47		CH20	
			CH21	
			CH23	
			CH24	
			CH25	
			CH39	

without significant modification. Mass I is Coastal Water and has warm temperatures. Mass II has warm temperatures connected to the coastal water, but has bottom salinities in the range of 32.0 to 32.2. The adjacent water mass, designated III, has generally lower temperatures and slightly higher bottom salinities. The two northernmost masses, IV and V, show significant influence of the Beaufort Sea or residence in the Chukchi Sea. These designations represent part of the mixing continuum from the Bering Sea water to the Beaufort Sea/Chukchi Sea water (Fig. 32).

As an objective approach to the problem of designating water masses, a cluster analysis was performed on the surface T-S pairs from each station and separately for the bottom T-S pairs. A similar cluster analysis with all of the T-S pairs for all the depths at each station produced results which were difficult to interpret. This was because many of the stations have temperature inversions or indications of interleaving water masses. Thus, only the results of the surface and bottom calculations will be used.

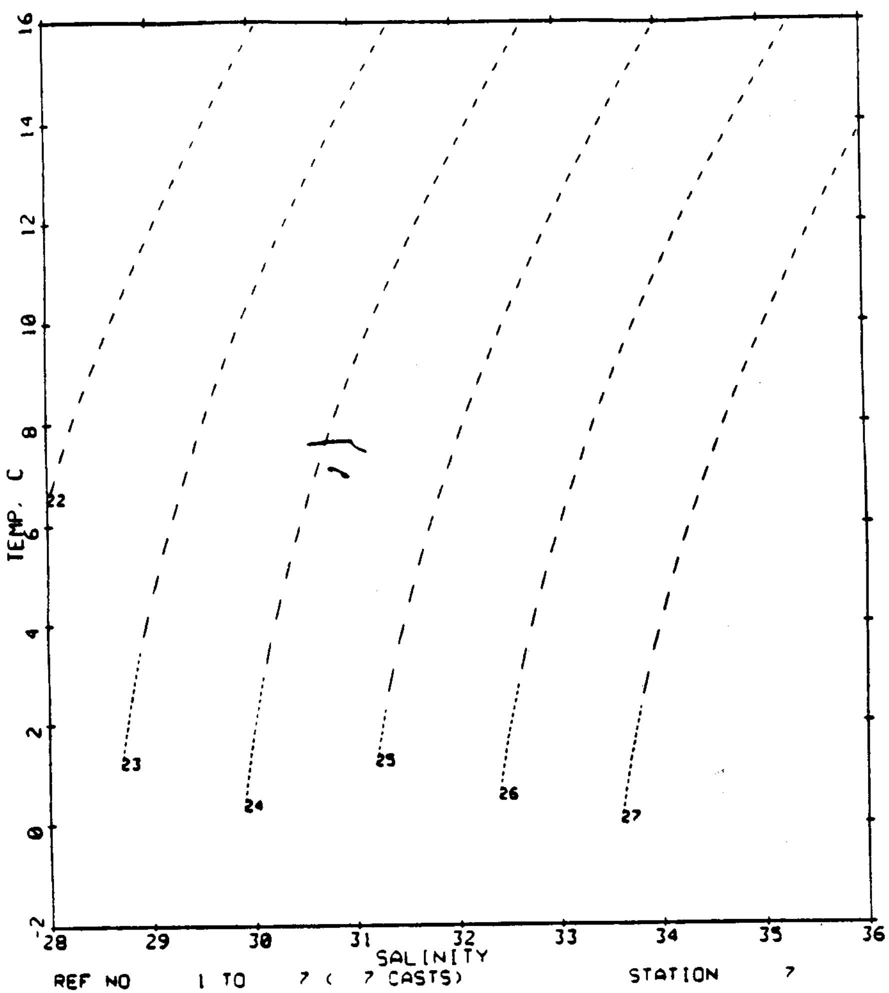

Figure 26. T-S diagram of the Coastal Water, Mass I.

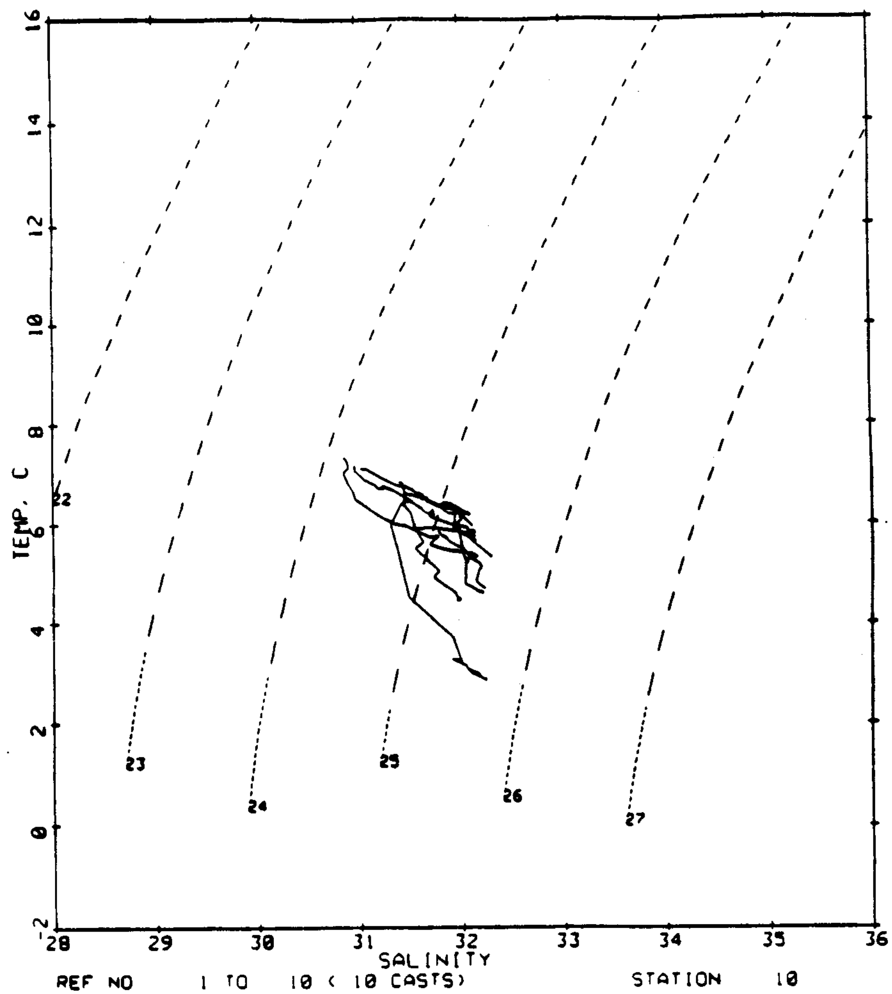

Figure 27. T-S diagram of the Bering Sea Water, Mass II.

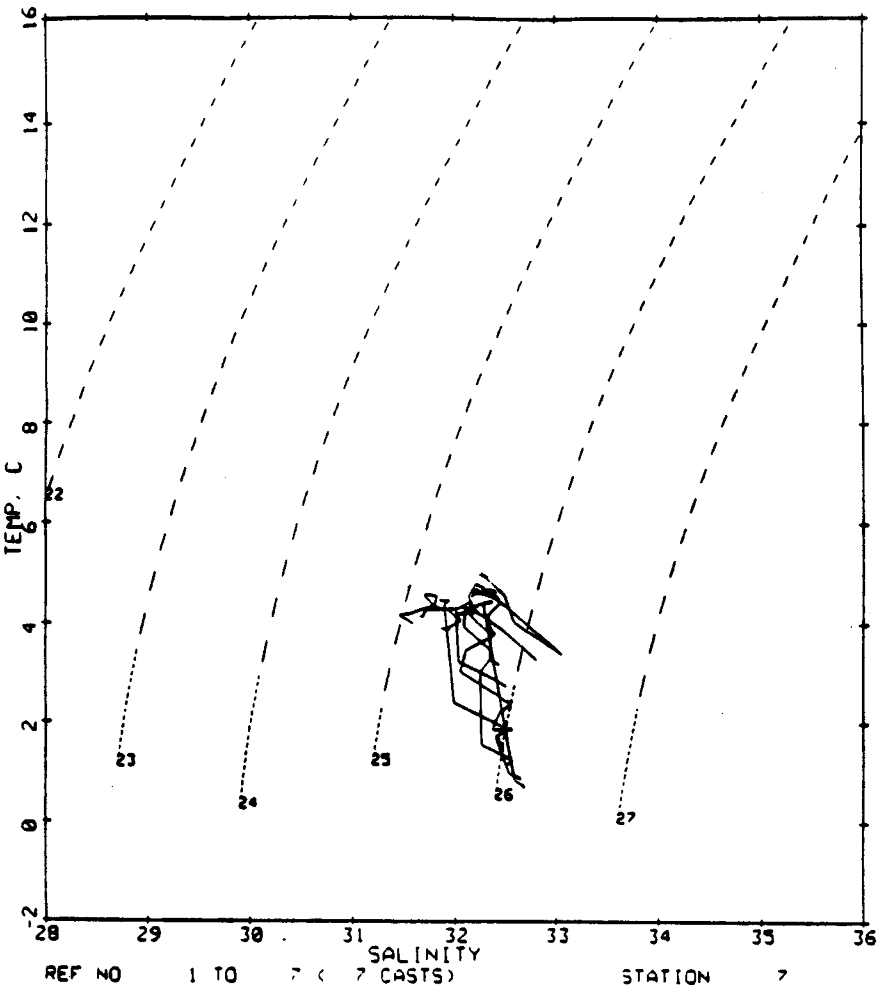

Figure 28. T-S diagram of the Chukchi Water, Mass III.

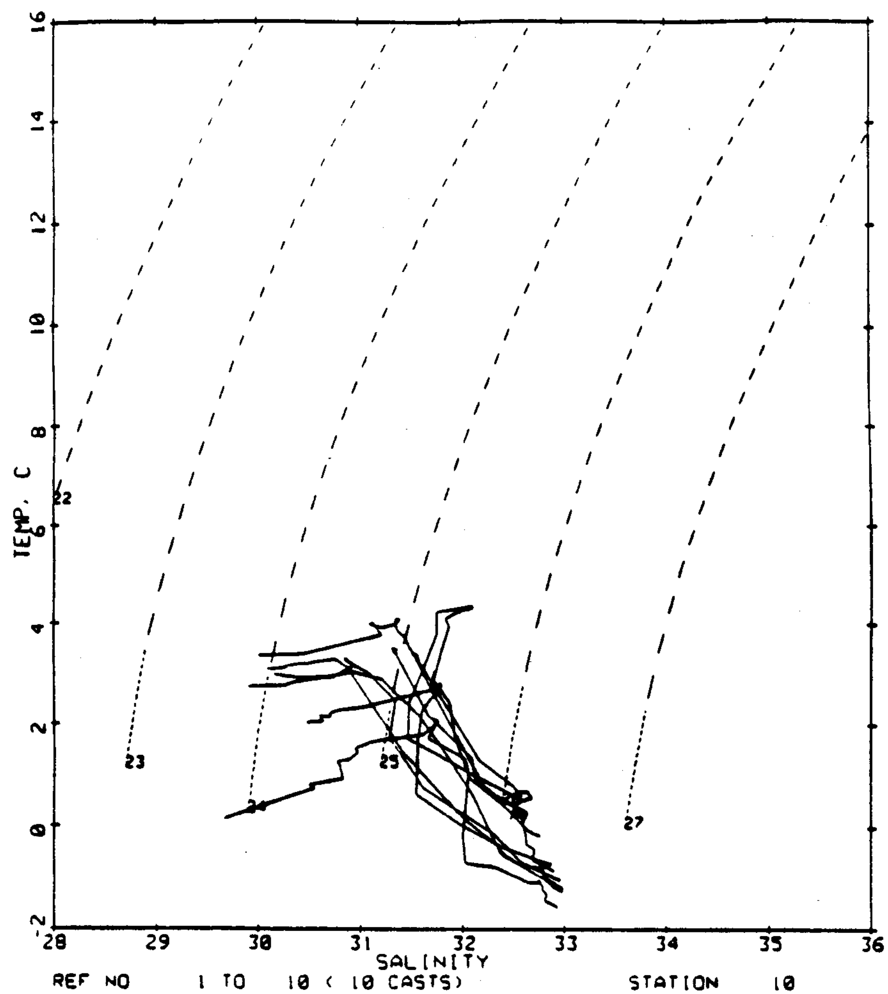

Figure 29. T-S diagram of the Chukchi Water, Mass IVa.

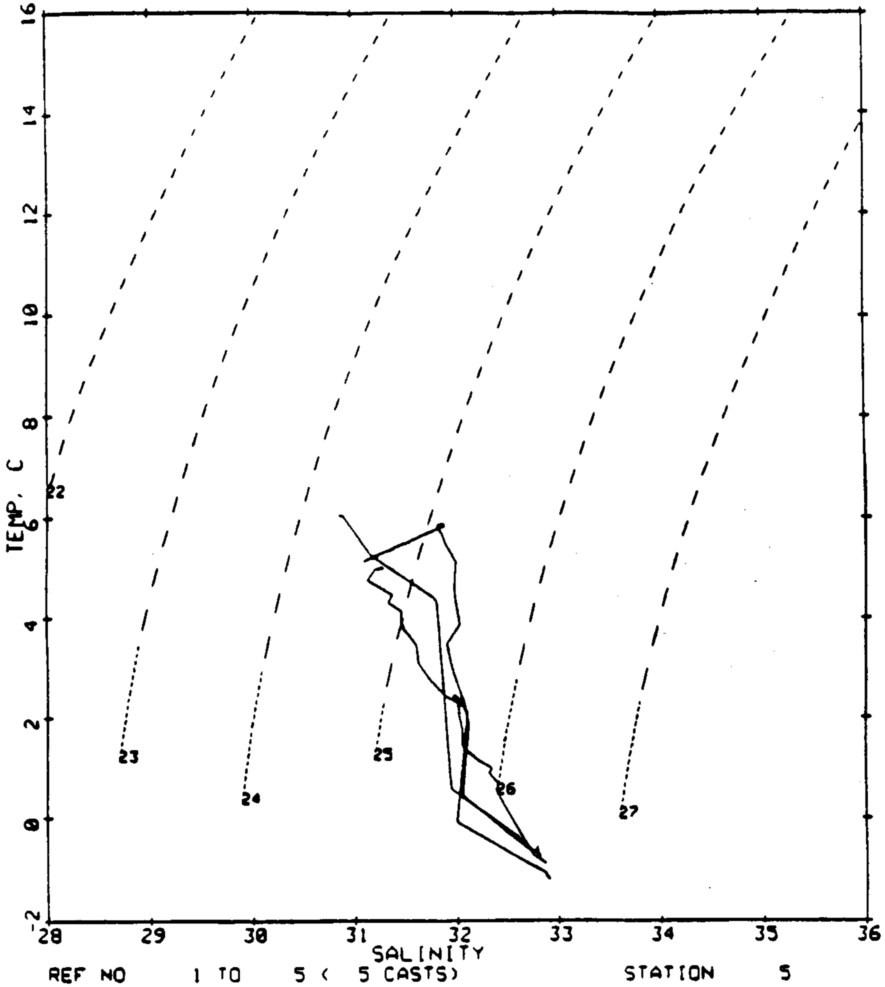

Figure 30. T-S diagram of the Chukchi Water, Mass IVb.

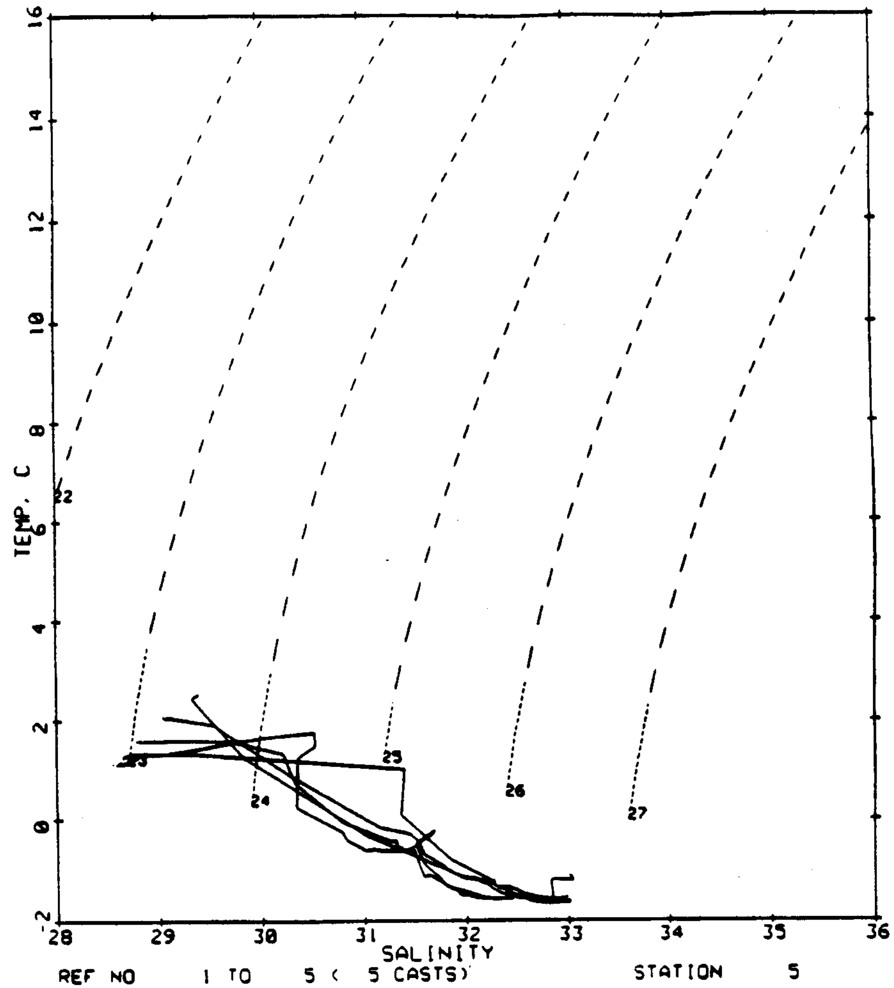

Figure 31. T-S diagram of the Beaufort Water, Mass V.

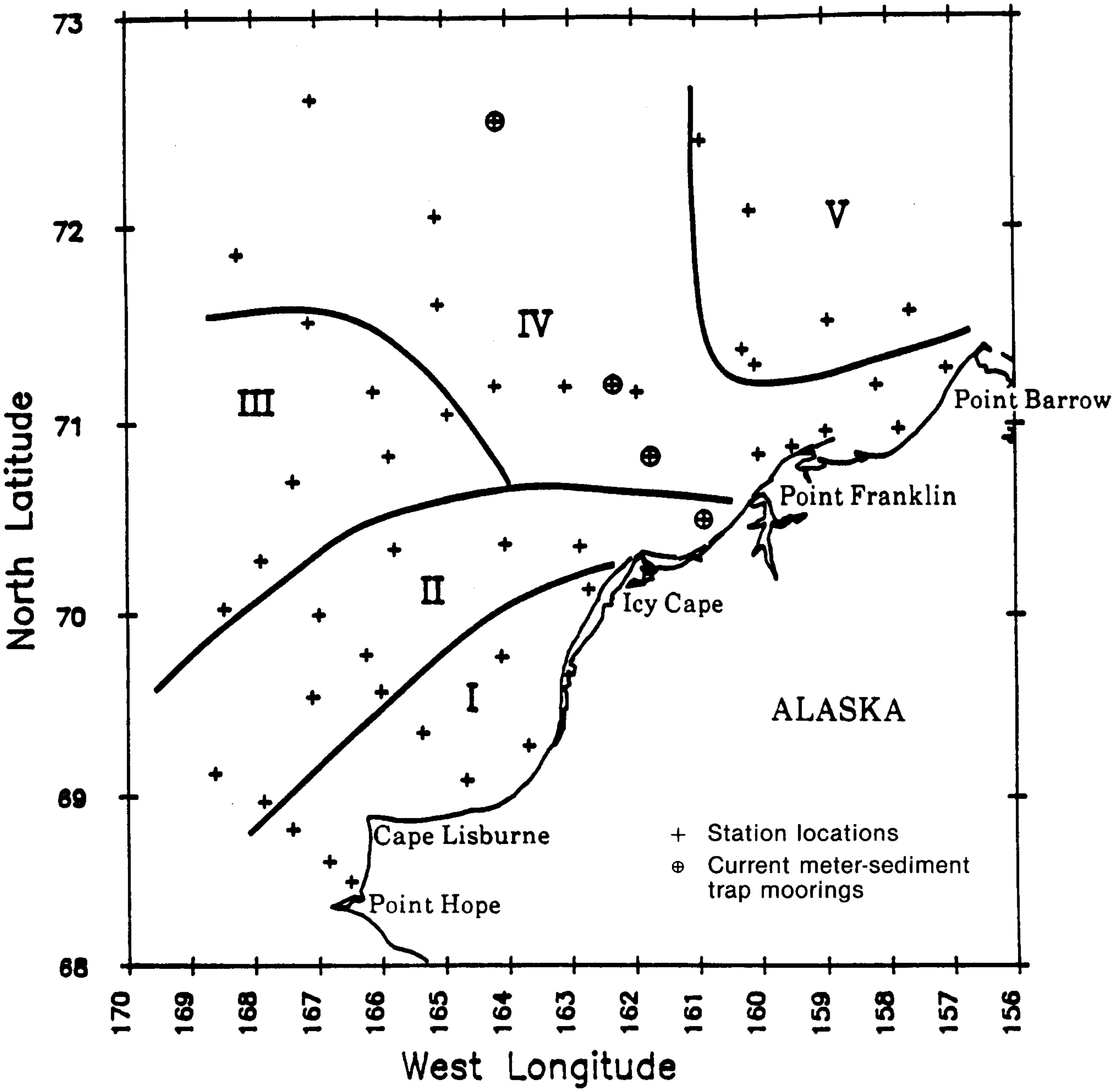

Figure 32. Chart of the water mass groupings based on the T-S diagrams.

The surface analysis (Fig. 33) yielded four groups at a 0.995 similarity index. Group I represents the Coastal-Bering Sea water, with warm temperatures and lower salinities. Group II is the Chukchi Water, with higher salinities and intermediate temperatures. Group III is the Beaufort

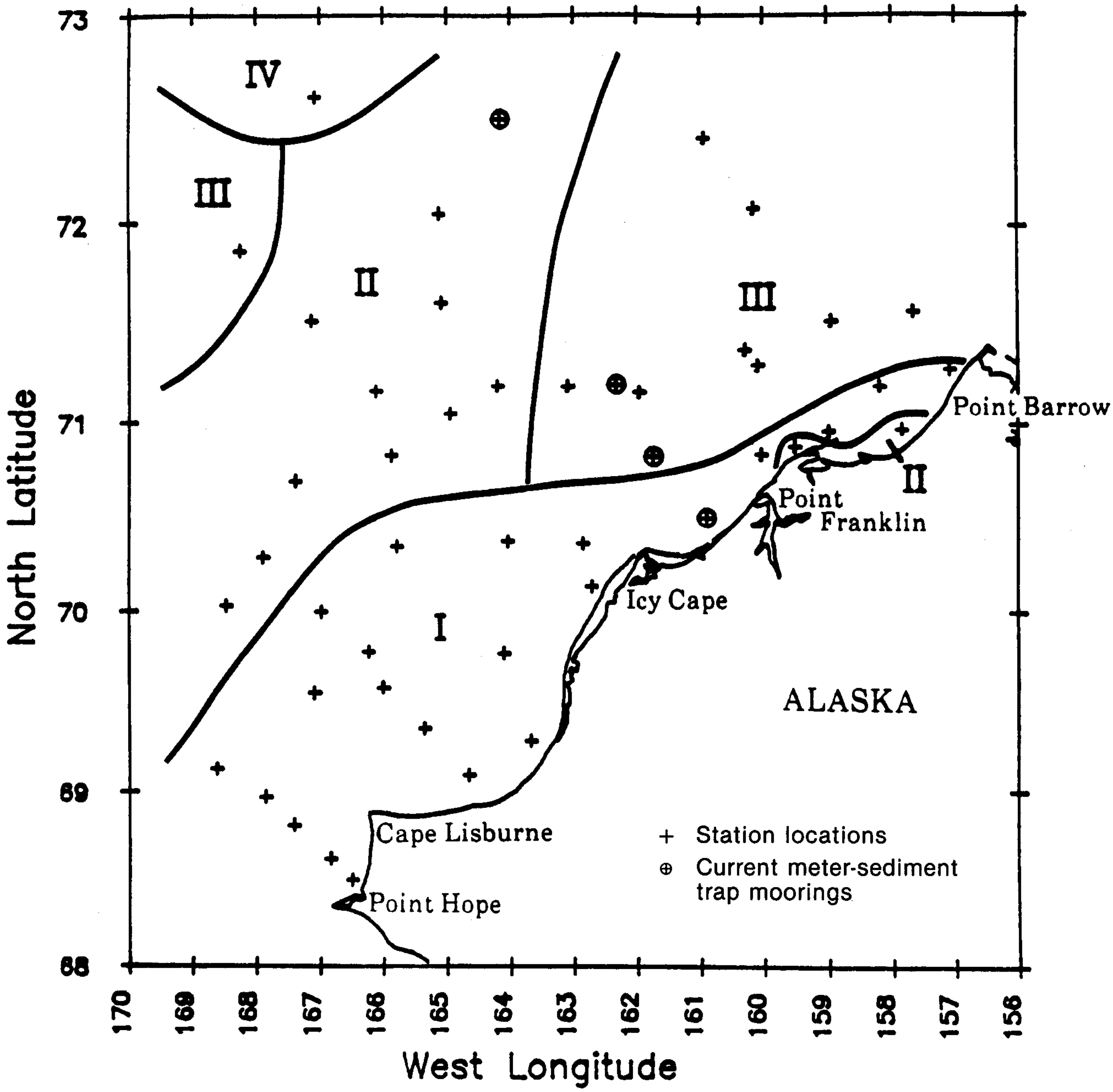

Figure 33. Chart of the water mass groupings based on the surface temperature and salinity cluster analysis.

Water, with most of the contributing stations in the northeast portion of the domain. The Group IV consists of a single station at the ice-edge, which had low temperature and salinity.

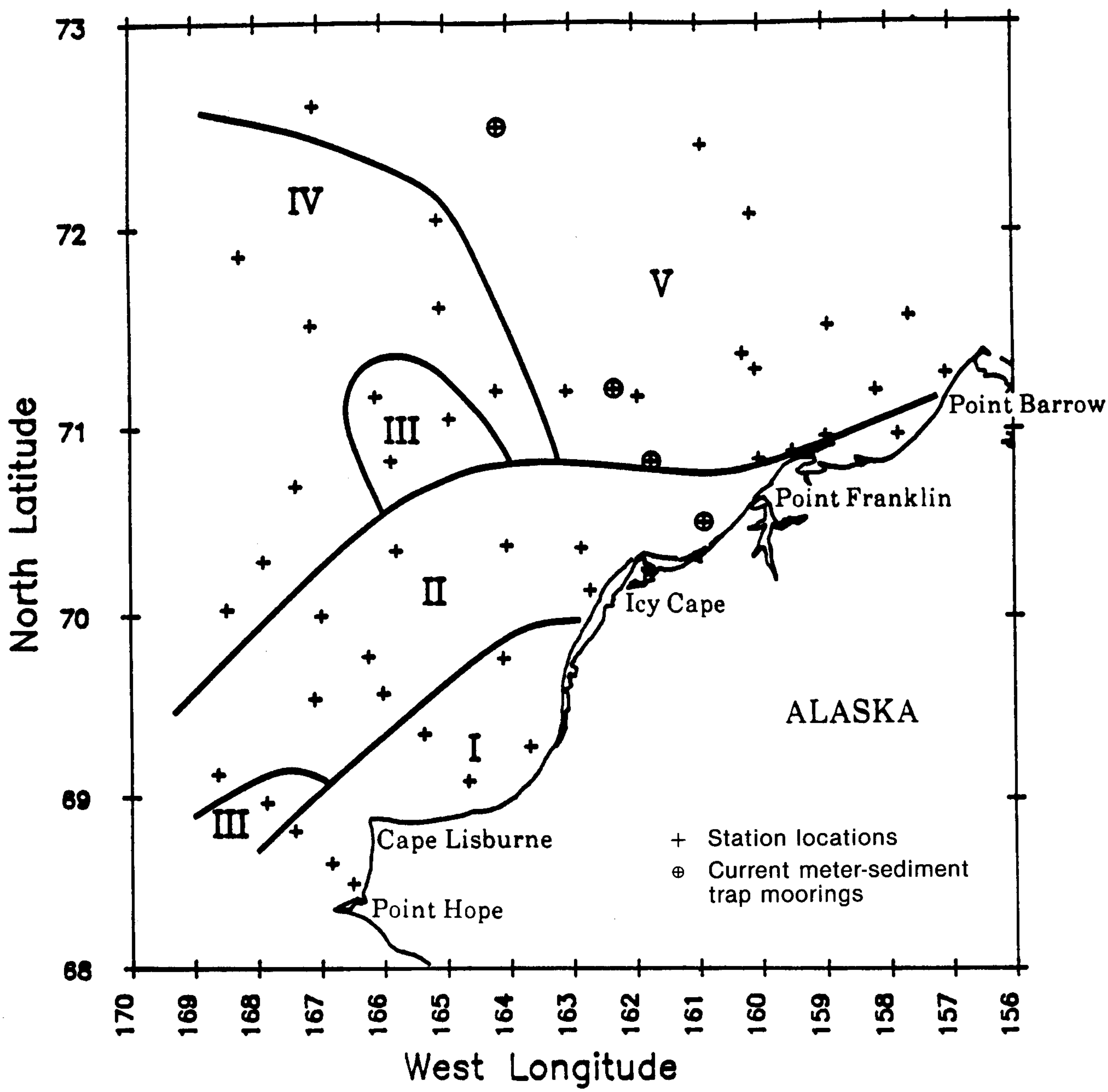

Figure 34. Chart of the water mass groupings based on the bottom temperature and salinity cluster analysis.

The bottom analysis indicated suggested five groups at the 0.97 similarity index, in a consistent pattern with the surface groups (Fig. 34). Groups I and II represent the Coastal water and Bering Sea water as before, although they can be separated based on the salinity at the bottom. Group III is a transitional group, representing a mixed water mass.

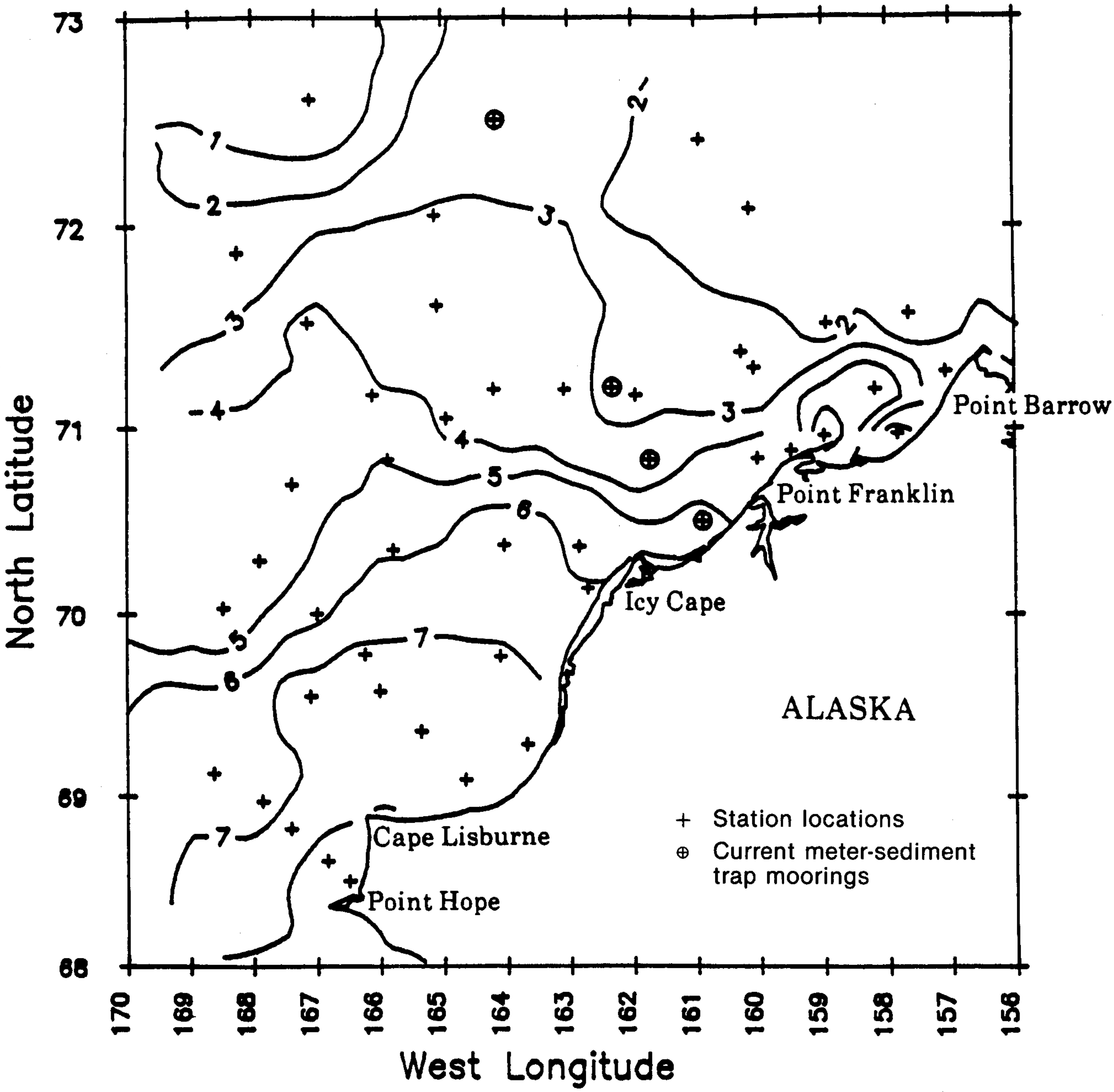

Figure 35. Chart of the surface temperature (°C) from the *Oceanographer*, 1986.

Groups IV and V are the northernmost groups, indicating the influence of the Beaufort Sea and the ice formation processes in the Chukchi Sea. The two northern groups (IV and V) merge in the next lower level of similarity, and then groups II and III merge. The coastal water remains distinct from all the other stations due to the warm temperature, low salinity conditions.

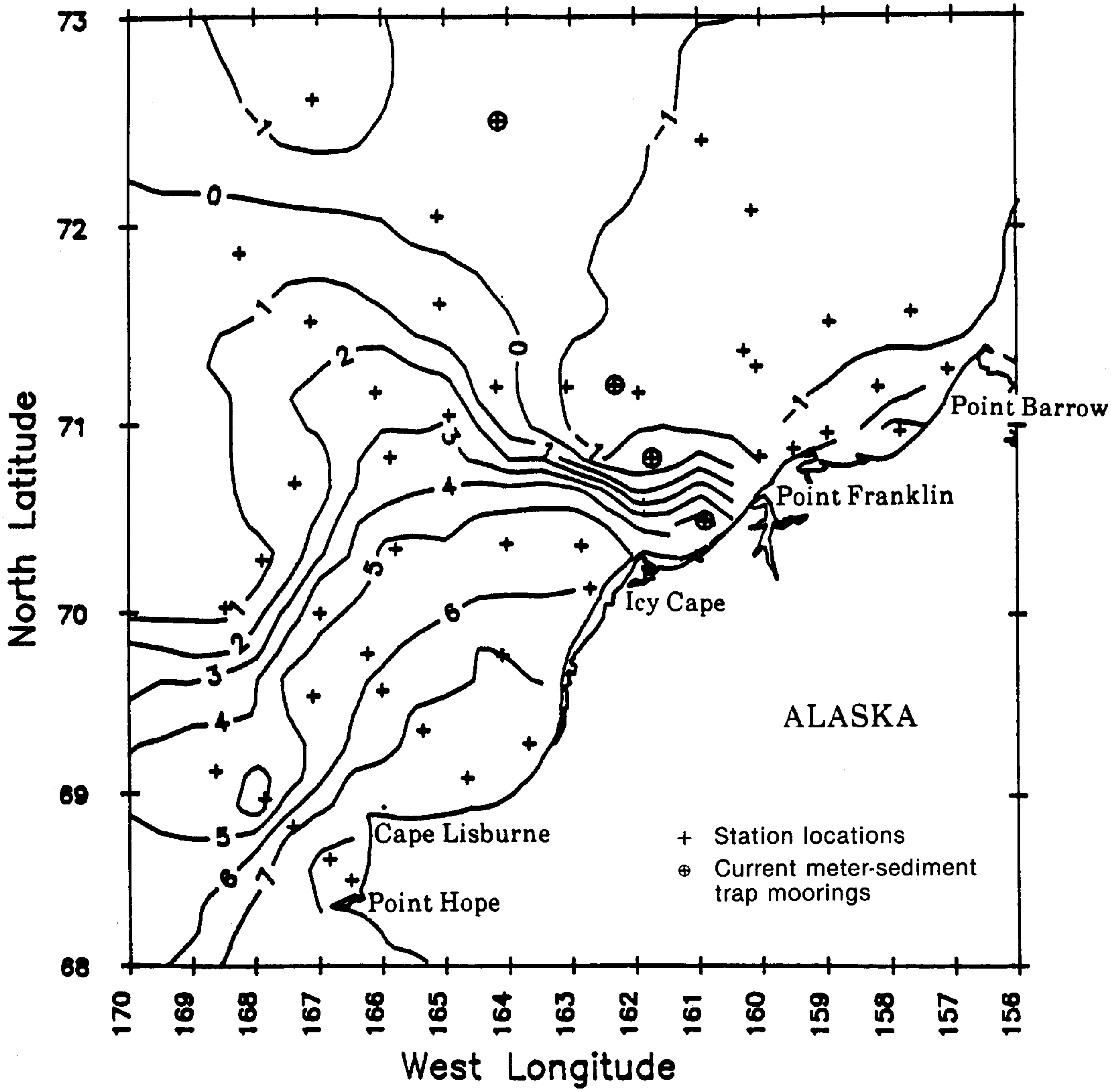

Figure 36. Chart of the bottom temperature (°C) from the *Oceanographer*, 1986.

For both of these techniques, the line separating the groupings follows the temperature contours ($5^{o}C$ at the surface, Fig. 35, and $4^{o}C$ at the bottom, Fig. 36) and the bottom salinity contours (32.5 $^{o}/oo$, Fig. 37). The surface salinity differs from the other slightly, and appears to suggest a

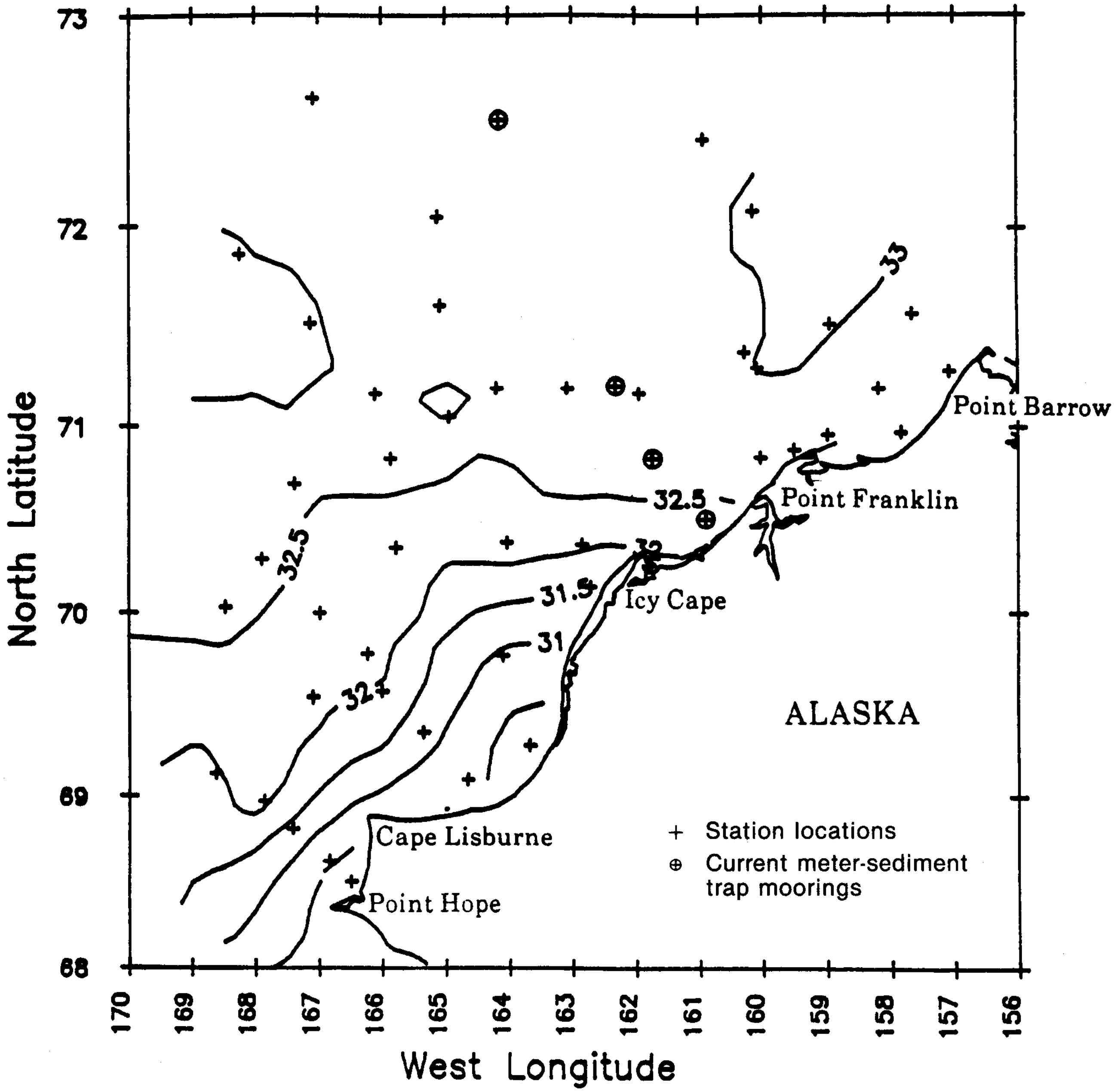

Figure 37. Chart of the bottom salinity from the *Oceanographer*, 1986.

connection of higher salinity surface waters (>32.0) to waters in the central Chukchi Sea (Fig. 38).

B. Geological Oceanography

The results of the grain size analyses of bottom sediments on a dry weight basis are listed in Table 5 and the regional distributional pattern

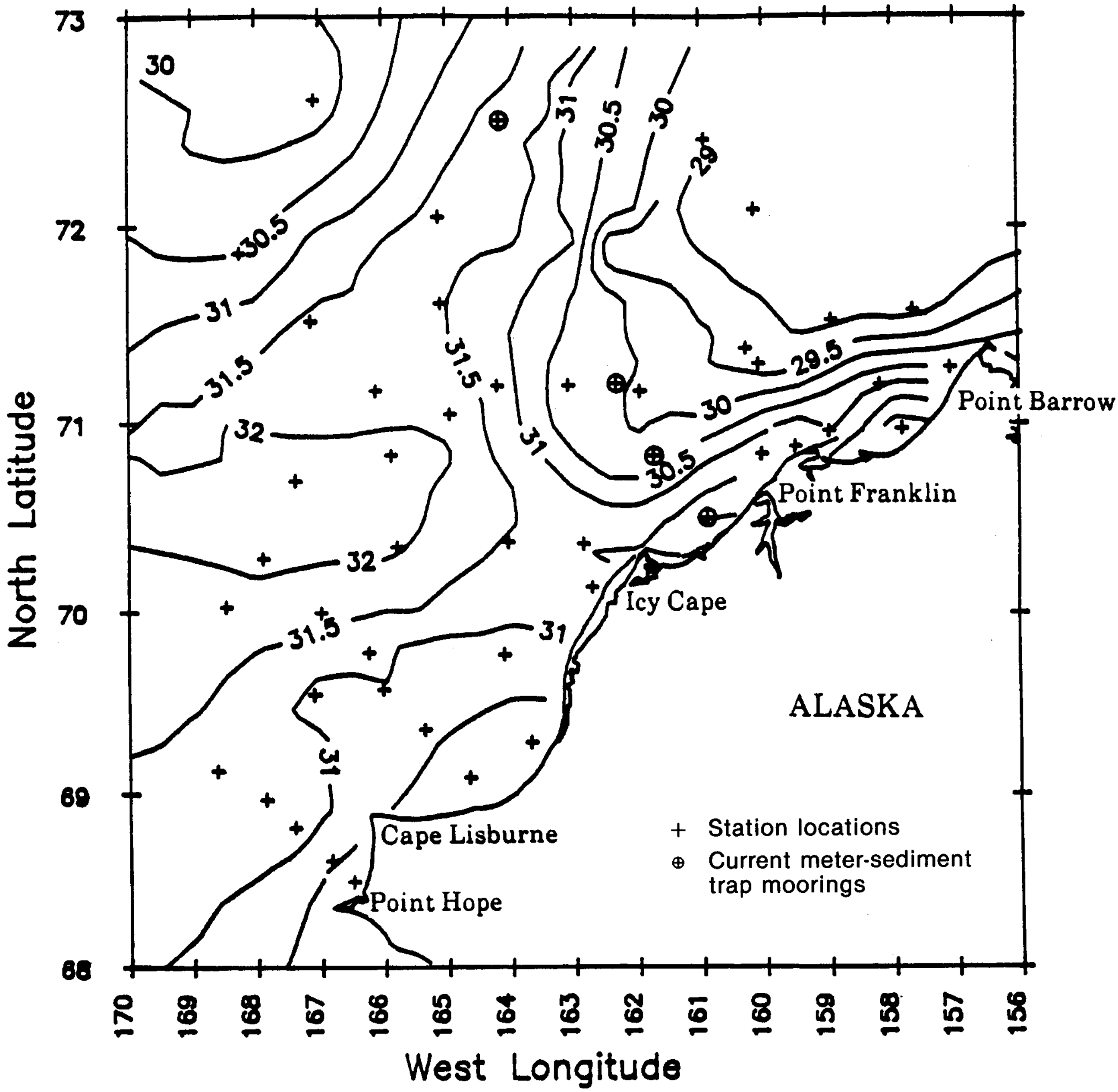

Figure 38. Chart of the surface salinity from the *Oceanographer,* 1986.

of the size parameters within the study are shown in Figures 39 to 45. It is quite clear that, with the exception of a few stations (e.g., CH18, CH19, CH22, CH30 and CH31), all stations have very-poorly- to extremely-poorly-sorted sediment size distributions (Fig. 13). Within the study area essentially three major sediment types (gravels, sands and muds) can be

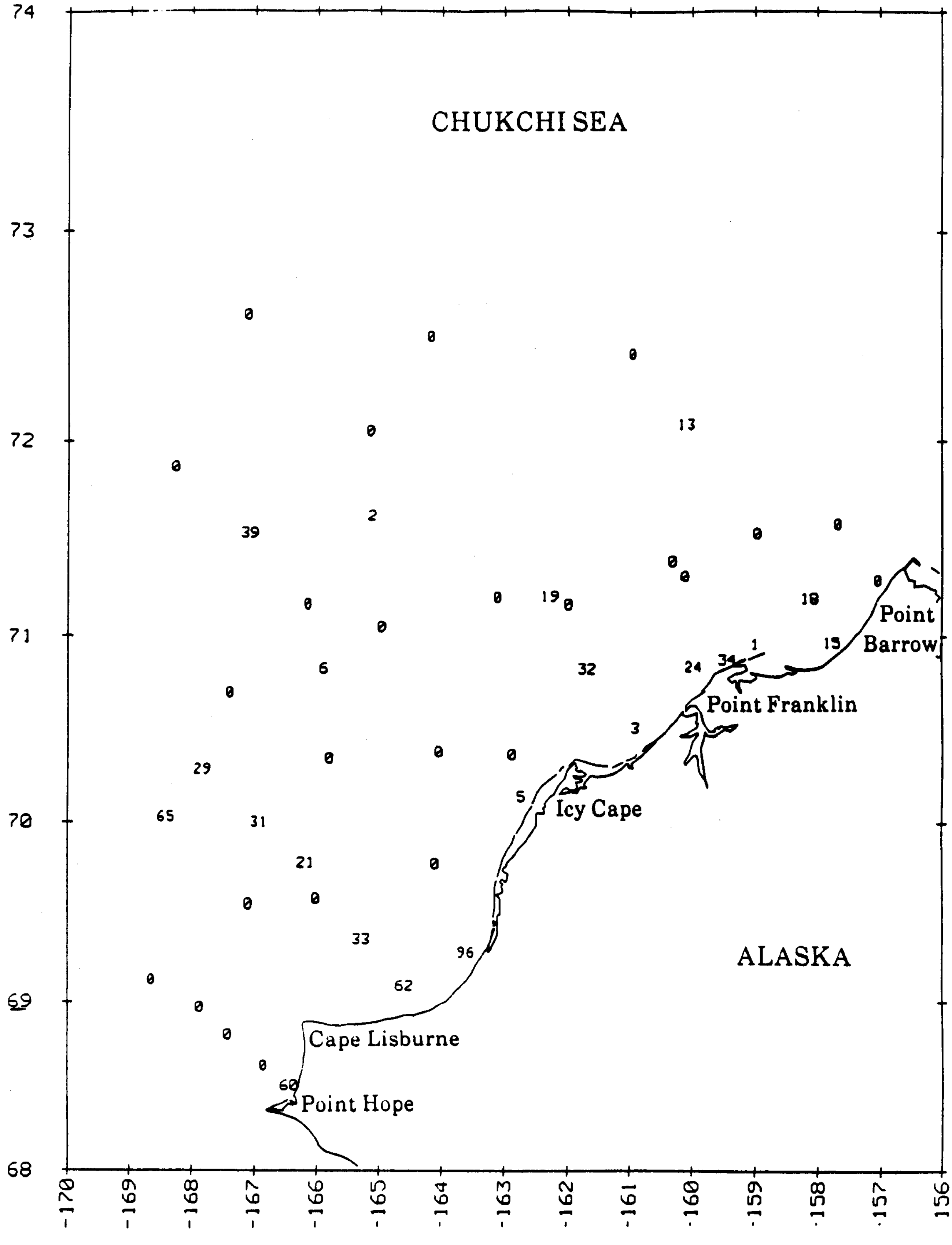

Figure 39. Gravel percentages in surficial sediments of the northeastern Chukchi Sea.

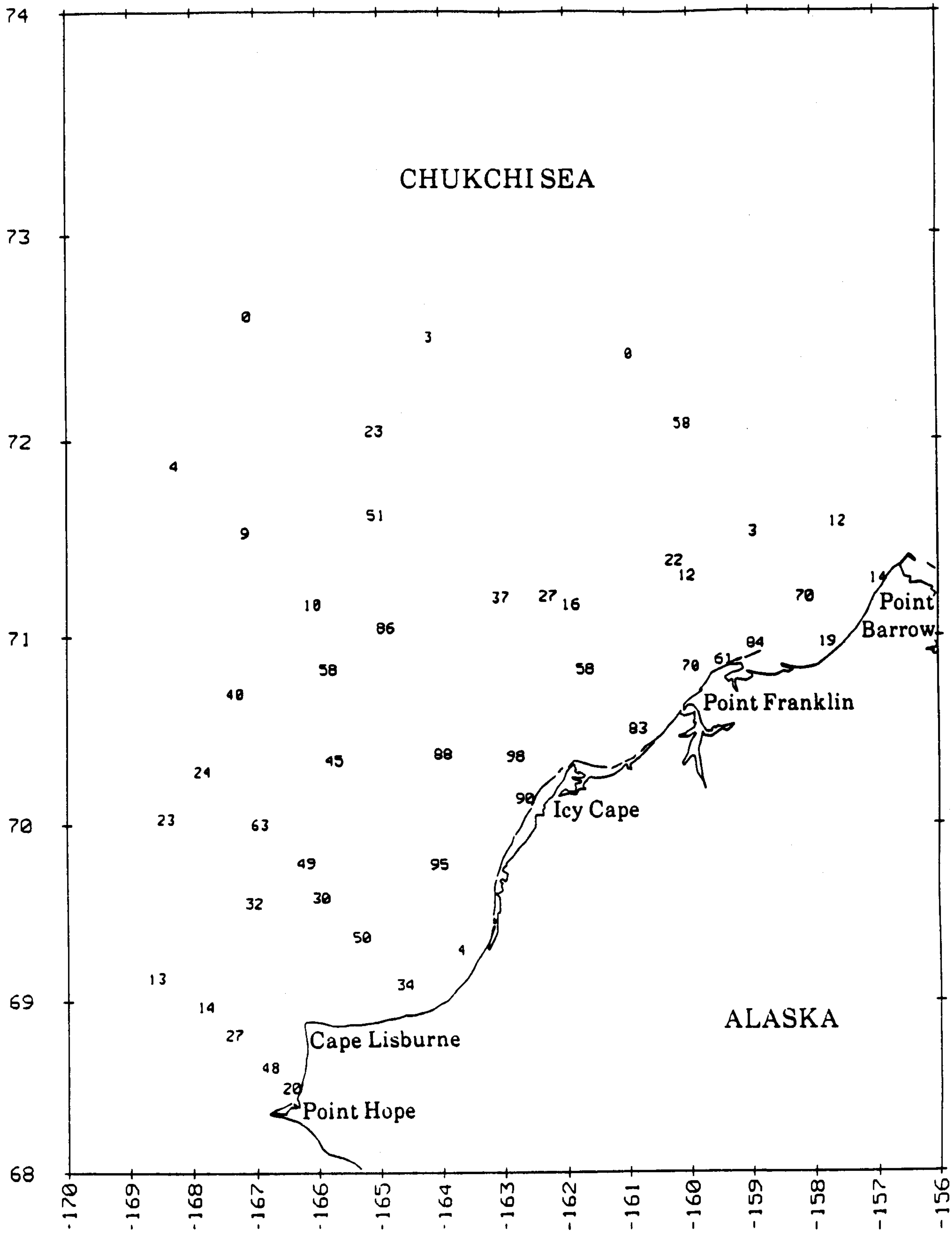

Figure 40. Sand percentages in surficial sediments of the northeastern Chukchi Sea.

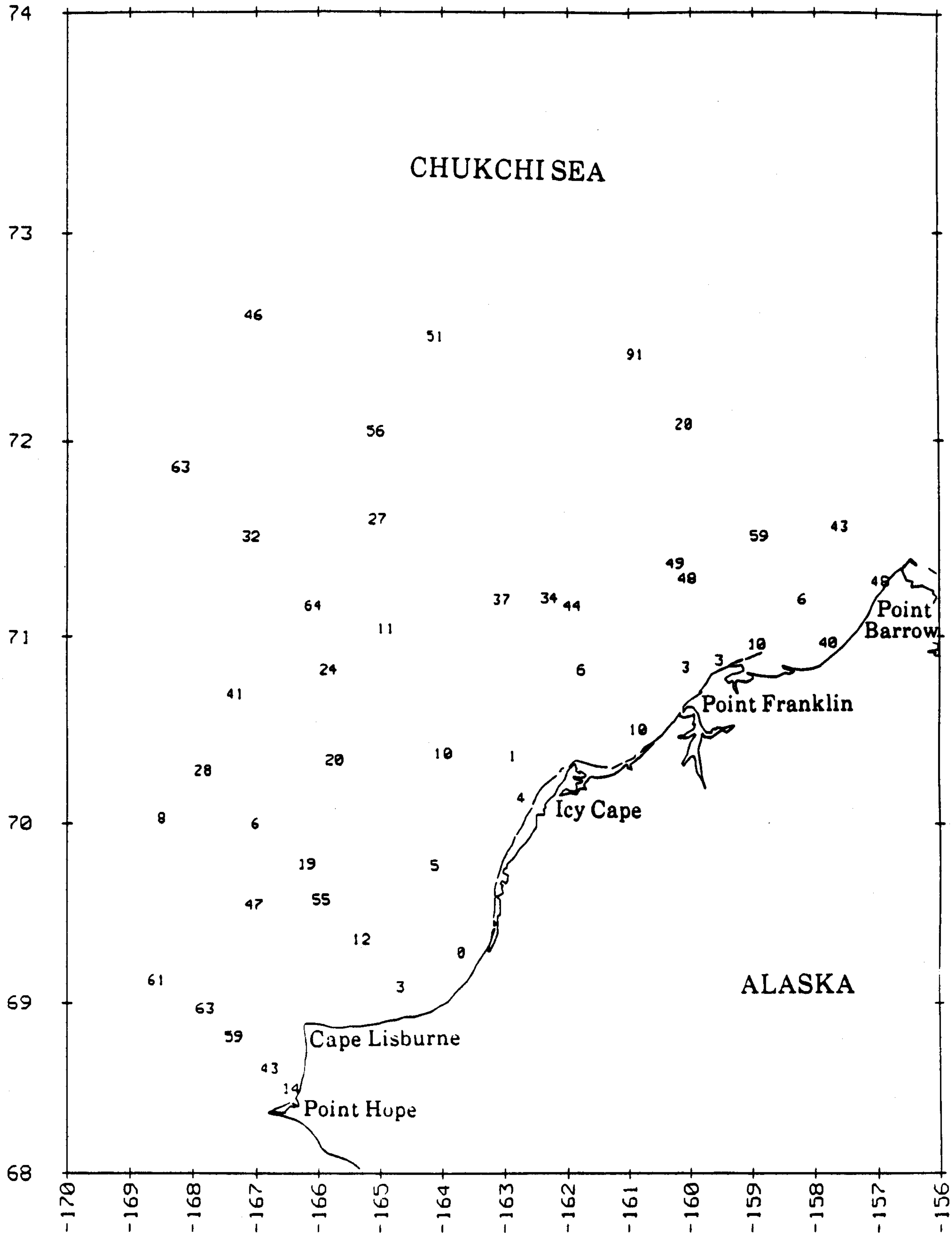

Figure 41. Silt percentages in surficial sediments of the northeastern Chukchi Sea.

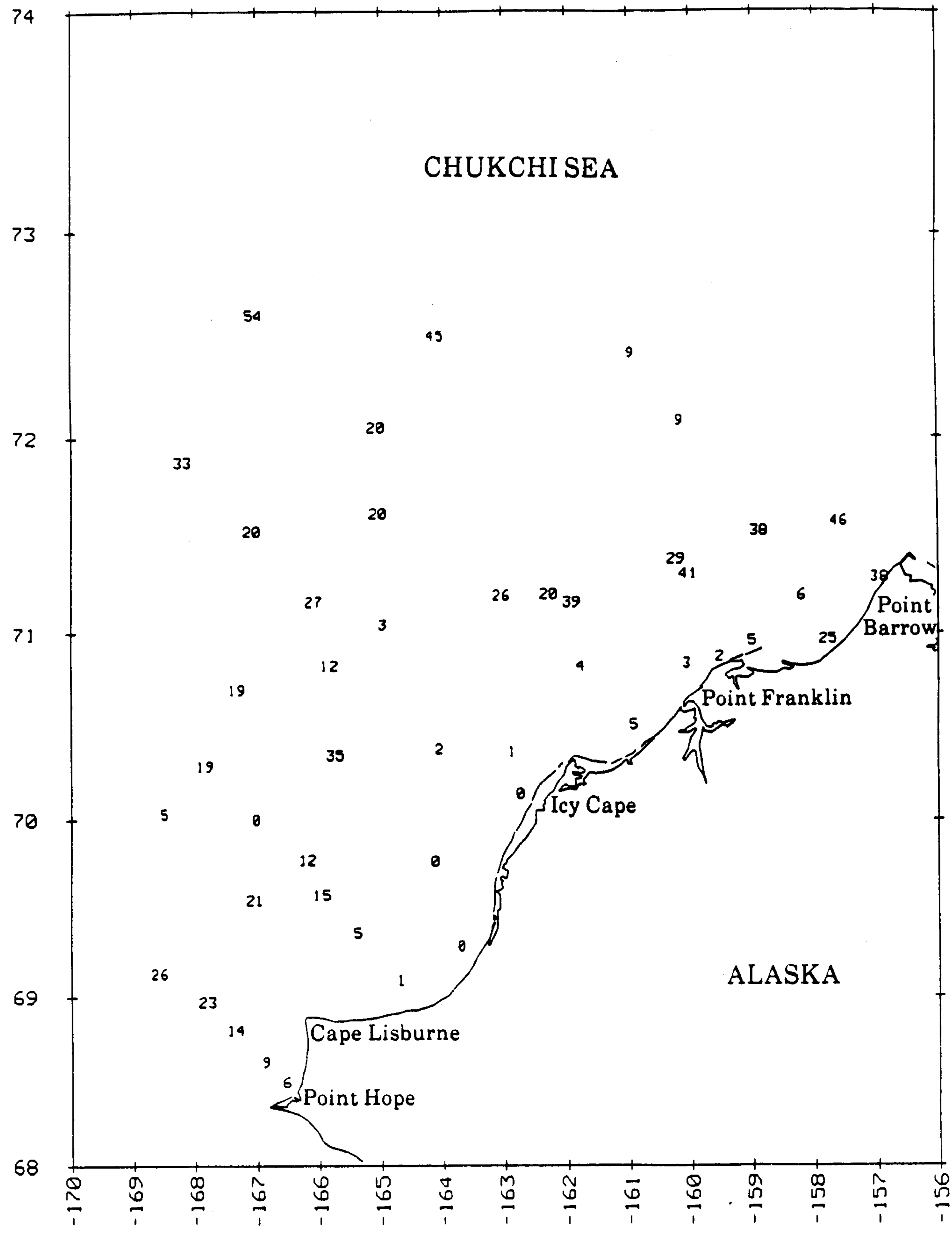

Figure 42. Clay percentages in surficial sediments of the northeastern Chukchi Sea.

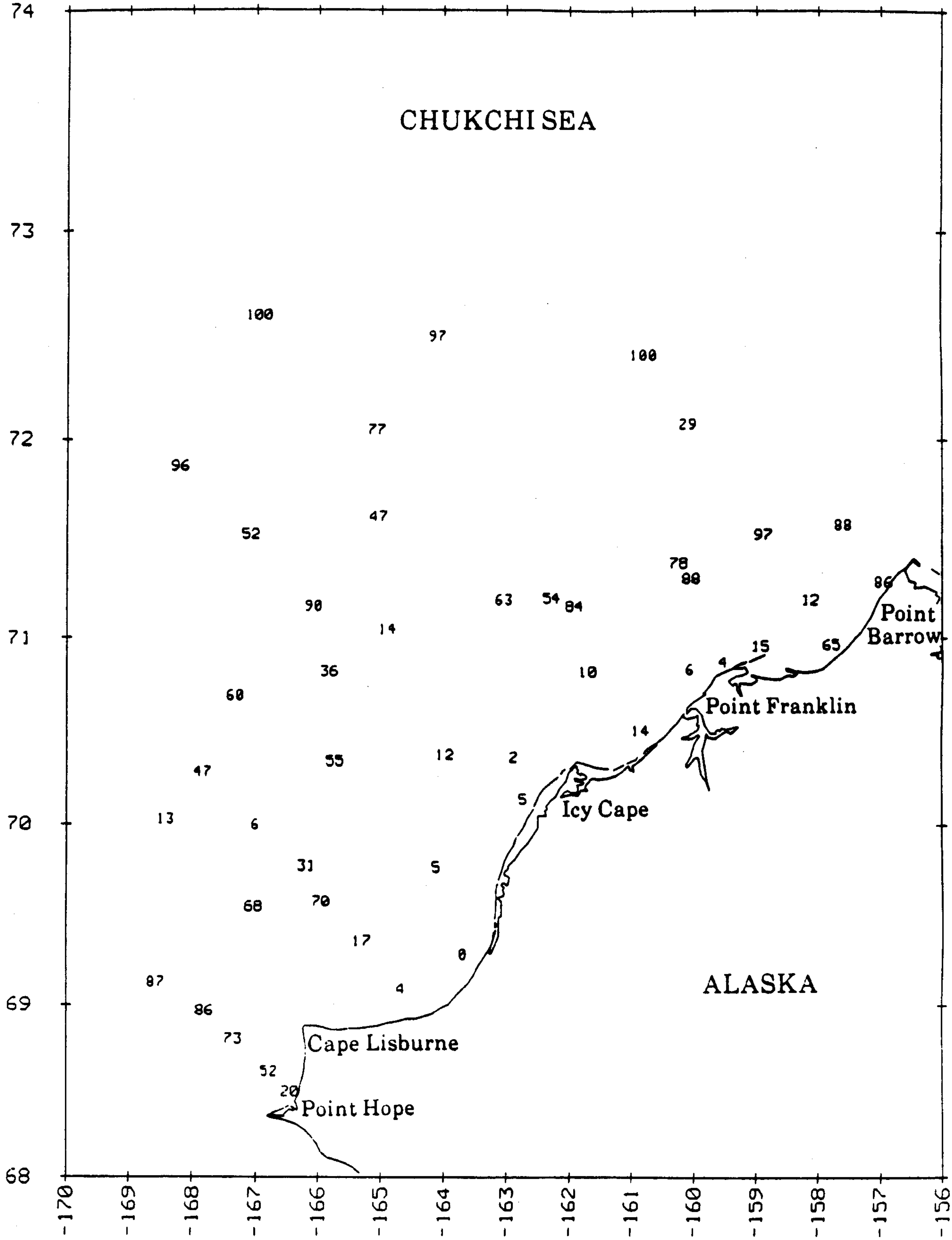

Figure 43. Mud percentages in surficial sediments of the northeastern Chukchi Sea.

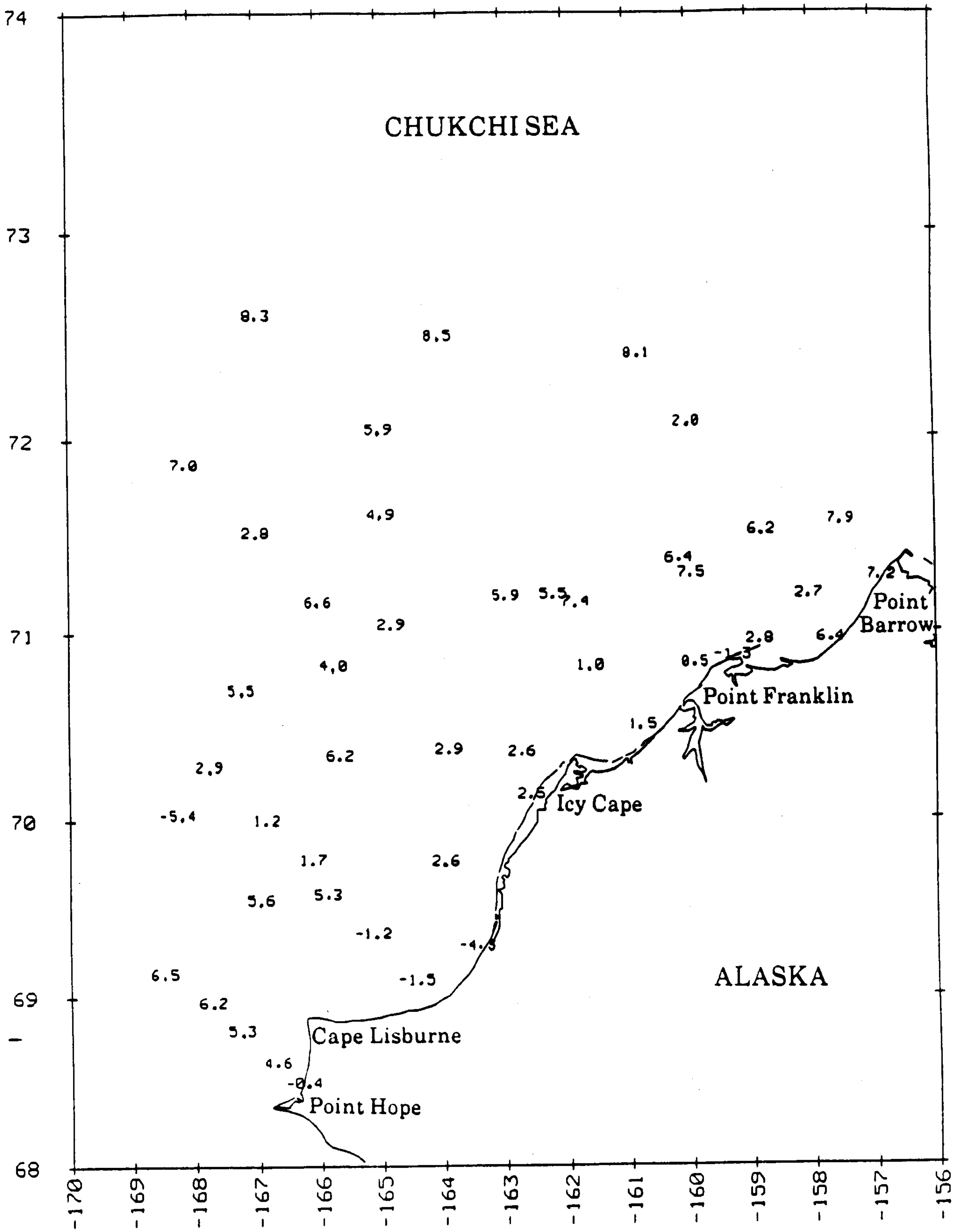

Figure 44. Mean size of surficial sediments of the northeastern Chukchi Sea.

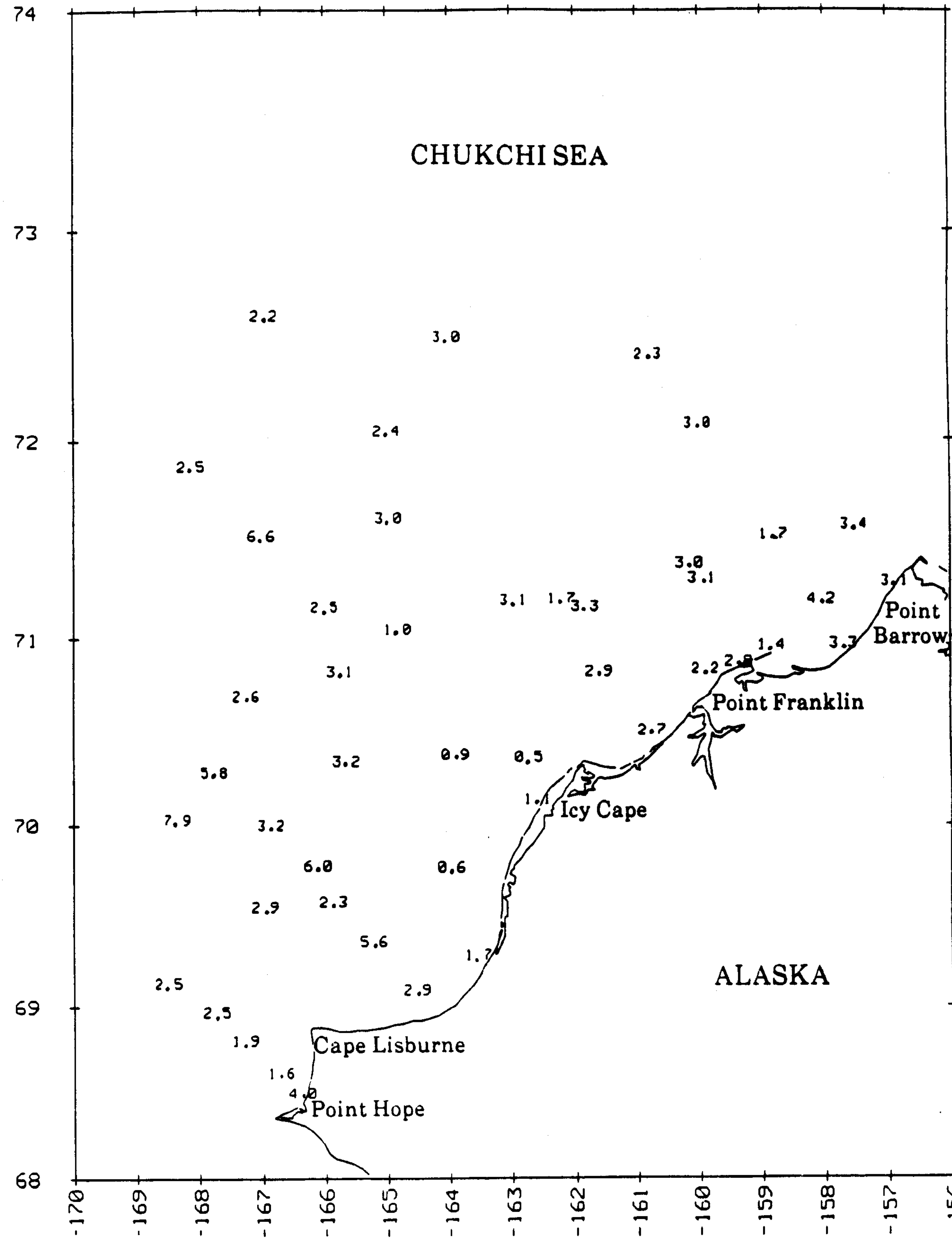

Figure 45. Grain-size sorting values (δ) of surficial sediments of the northeastern Chukchi Sea.

Table 5. Granulometric data of surficial sediments of the northeastern Chukchi Sea.

Station Name	Gravel %	Sand %	Silt %	Clay %	Mud %	Mz ϕ	Sorting δ
CH1	0.00	13.51	48.37	38.12	86.49	7.19	3.06
CH2	0.00	11.86	42.59	45.55	88.14	7.85	3.38
CH3	0.00	3.16	58.75	38.09	96.84	6.23	1.68
CH4	18.14	70.19	5.64	6.03	11.67	2.67	4.19
CH5	15.37	19.20	40.01	25.43	65.44	6.37	3.33
CH6	1.03	84.19	10.16	4.62	14.78	2.85	1.43
CH7	34.21	61.38	2.60	1.80	4.40	-1.34	2.85
CH8	23.94	70.46	2.78	2.82	5.60	0.47	2.24
CH9	0.00	11.53	47.73	40.74	88.47	7.47	3.12
CH10	0.00	22.31	49.04	28.64	77.68	6.40	2.97
CH11	12.64	58.49	20.04	8.83	28.87	1.99	2.99
CH12	0.00	0.21	90.92	8.87	99.79	8.09	2.32
CH13	0.00	3.42	51.30	45.28	96.58	8.46	2.96
CH14	18.55	27.29	34.01	20.06	54.16	5.45	1.75
CH15	0.00	16.26	44.49	39.25	83.74	7.41	3.27
CH16	32.13	57.78	6.18	3.91	10.09	1.00	2.92
CH17	2.71	82.89	9.63	4.78	14.41	1.49	2.72
CH18	4.79	90.45	4.41	0.35	4.76	2.54	1.11
CH19	0.00	97.60	1.39	1.01	2.40	2.60	0.47
CH20	0.00	37.05	37.18	25.77	62.95	5.86	3.08
CH21	----	-----	-----	-----	-----	----	----
CH22	0.00	86.22	10.89	2.88	13.77	2.89	1.00
CH23	1.52	51.49	27.28	19.71	46.99	4.93	3.00
CH24	0.00	23.21	56.48	20.31	76.79	5.92	2.40
CH25	0.00	0.45	45.78	53.77	99.55	8.28	2.23
CH26	39.01	9.48	31.79	19.71	51.51	2.80	6.61
CH27	0.00	9.82	63.52	26.66	90.18	6.57	2.49
CH28	5.80	57.85	24.42	11.94	36.36	4.02	3.06
CH29	0.00	44.53	20.40	35.07	55.47	6.17	3.24
CH30	0.00	88.07	9.70	2.22	11.92	2.90	0.86
CH31	0.00	95.35	4.65	0.00	4.65	2.58	0.56
CH32	95.69	3.91	0.39	0.00	0.39	-4.33	1.69
CH33	62.09	33.79	2.87	1.25	4.12	-1.52	2.93
CH34	32.87	50.40	11.55	5.19	16.78	-1.19	5.60
CH35	0.00	29.84	54.80	15.36	70.16	5.26	2.29
CH36	20.53	48.96	18.66	11.85	30.51	1.67	6.02
CH37	31.09	62.54	6.37	0.00	6.37	1.25	3.25
CH38	0.00	39.63	41.09	19.28	60.37	5.52	2.56
CH39	0.00	4.32	63.15	32.54	95.69	7.00	2.46
CH40	28.59	24.25	27.95	19.21	47.16	2.86	5.77
CH41	64.50	22.99	7.93	4.57	12.50	-5.36	7.89
CH42	0.00	31.76	47.29	20.95	68.24	5.57	2.90
CH43	60.33	19.65	14.23	5.79	20.02	-0.39	4.01
CH44	0.00	47.92	43.01	9.07	52.08	4.57	1.56
CH45	0.00	26.74	59.43	13.83	73.26	5.32	1.92
CH46	0.00	14.18	63.17	22.65	85.82	6.19	2.48
CH47	0.00	12.80	60.93	26.28	87.21	6.47	2.55

Table 5. (continued)

Station Name	SWSP (mg/l)	BWSP (mg/l)	OCSWSP (μg/l)	OCBWSP (μg/l)	NSWSP (μg/l)	NBWSP (μg/l)	OC/N SWSP	OC/N BWSP
CH1								
CH2	0.61	2.37						
CH3	0.34	0.95						
CH4	2.52	1.06						
CH5	3.21	3.63						
CH6	4.60	1.83	147.6	86.3	26.3	20.9	5.6	4.1
CH7	3.84	2.03	154.5	102.8	26.5	15.2	5.8	6.8
CH8	3.36	1.91	148.6	98.4	24.2	14.1	6.1	7.0
CH9	0.43	1.46	57.1	83.7	8.9	14.1	6.4	5.9
CH10	0.77	3.37	51.5	128.3	7.4	18.1	7.0	7.1
CH11	0.34	1.57	88.8	93.1	13.0	14.8	6.8	6.3
CH12	0.96	4.42	134.4	145.0	14.7	15.8	9.1	9.2
CH13	0.03	3.17	111.3	191.1	12.5	27.7	8.9	6.9
CH14	0.37	2.57	119.8	211.5	15.4	38.5	7.8	5.5
CH15	2.22	0.62	144.5	106.1	26.1	16.4	5.5	6.5
CH16	0.50	0.58	135.2	88.0	22.5	15.6	6.0	5.6
CH17	1.16	1.05	120.6	95.0	22.9	16.3	5.3	5.8
CH18	1.80	1.75		146.6		25.7		5.7
CH19	1.33	1.60		80.1		13.8		5.8
CH20		2.53						
CH21	0.96	1.76	163.7	132.6	30.1	23.1	5.4	5.7
CH22	0.85	1.40	151.2	133.6	21.5	21.3	7.0	6.3
CH23	0.71	1.21	119.1		18.6		6.4	
CH24	0.45	2.11	108.4	149.2	16.9	25.1	6.4	5.9
CH25	0.93	2.58	102.8	105.7	14.8	14.4	7.0	7.3
CH26	0.47	0.61						
CH27	0.69	2.26	843.2		137.3		6.1	
CH28	0.65	3.82						
CH29	1.13	0.78		78.5		15.4		10.2
CH30	0.85	2.35	170.6		32.6		5.2	
CH31	0.87	1.26	118.7	130.0	20.9	23.9	5.7	5.4
CH32	4.45		197.1		30.9		6.4	
CH33	3.08		196.5		36.0		5.5	
CH34	1.55	2.14	127.3	111.5	28.0	20.3	4.6	5.5
CH35	0.81	1.35	135.2	58.8	33.4	14.9	4.1	4.0
CH36	1.22	1.36						
CH37	0.80	1.26		72.9		13.3		5.5
CH38	0.35	3.52						
CH39		1.30						
CH40	0.44	0.72						
CH41	0.28	0.94						
CH42	0.03	0.72	96.0	135.5	21.9	19.9	4.4	6.8
CH43	3.72	2.47	197.4		40.1		4.9	
CH44	4.18	3.94						
CH45	4.31	3.82	106.4	185.1	16.5	26.2	6.5	7.1
CH46	0.29	0.51		220.5		32.5		6.8
CH47	1.25	0.78	248.7		28.4		8.8	

Table 5. (continued)

Station Name	OC (mg/g)	N (mg/g)	OC/N	δ13C o/oo
CH1	5.11	0.53	9.60	
CH2	6.90	0.88	7.80	
CH3	5.32	0.66	8.10	-21.9
CH4	11.86	1.55	7.70	
CH5	5.98	0.75	8.00	-24.2
CH6	4.31	0.51	8.50	
CH7	8.24	1.02	8.08	
CH8	10.02	1.25	8.00	
CH9	8.60	1.07	8.00	
CH10	3.76	0.44	8.60	
CH11	7.25	0.88	8.20	-22.2
CH12	4.43	0.57	7.80	-21.5
CH13	13.76	1.92	7.20	-21.0
CH14	9.62	0.82	11.70	-19.3
CH15	13.54	0.81	16.70	
CH16	5.71	0.51	11.20	-16.0
CH17	6.21	0.48	12.90	-23.7
CH18	7.30	0.48	15.20	
CH19	4.86	0.34	14.10	
CH20	7.25	0.84	8.60	
CH21	10.46	1.38	7.60	
CH22	2.36	0.31	7.60	
CH23	13.79	1.70	8.10	-20.5
CH24	9.79	1.08	9.10	-20.6
CH25	15.74	2.12	7.40	-20.9
CH26	10.11	0.78	13.00	-19.6
CH27	1.65	0.22	7.50	
CH28	2.19	0.28	7.80	-21.5
CH29	6.63	0.83	8.00	-21.7
CH30	1.21	0.19	6.30	
CH31	5.88	0.32	18.40	-22.6
CH32	----	----	----	
CH33	5.23	0.39	13.40	-21.6
CH34	2.59	0.30	8.60	
CH35	4.20	0.48	8.80	
CH36	1.82	0.23	7.90	-21.9
CH37	2.73	0.30	9.10	
CH38	2.25	0.29	7.80	
CH39	1.58	0.21	7.50	-21.2
CH40	10.04	1.25	8.00	-22.6
CH41	4.48	0.55	8.20	
CH42	2.40	0.40	6.00	
CH43	8.89	1.01	8.00	
CH44	7.73	0.99	7.80	-22.4
CH45	9.46	1.18	8.00	
CH46	2.29	0.28	8.20	
CH47	11.79	1.55	7.60	-21.5

delineated (Fig. 3). However, under these major sediment types are embraced a number of Folk's (1954, 1980) sediment classes (Fig. 3). As depicted in Figure 3, there is apparently a broad seaward fining of sediment types. However, further examination of the granulometric variations suggests that within the broad lithologic units mosaics of different sub-types of sediments are observed; thus, such a distributional pattern generally conforms to the lithofacies changes previously discussed for the northeastern Chukchi Sea by Naidu (1987) and shown in Figure 3.

The concentrations of suspended particles for August 27-September 17, 1986, at selected depths of the water column of the northeastern Chukchi Sea are shown in Table 6. The distributional patterns of the suspended particles in water samples collected at the sea surface and near the sea floor are depicted in Figures 46 and 47. It is clearly shown that the particulate concentrations in the surface waters progressively decrease seaward from the coast (Fig. 46) up to the northern margin of the study area where slightly increased concentrations are locally observed. In the near bottom waters the concentration gradient is apparent only within the innershore region, beyond which there appears to be a reversal in the concentration trend (Fig. 47). These trends are generally substantiated in the vertical profiles of suspensate loads along a seaward transect extending from Station CH17 through Stations CH16 and CH14 to Station CH13 (Fig. 48).

The concentrations of organic carbon (OC) and nitrogen (N), the OC/N and the stable carbon isotopic ratios ($\delta^{13}C$) in sea floor surficial sediments are shown in Table 7 and their distributional patterns depicted in Figures 49, 50, 51, and 52, respectively. The distributional patterns of OC and N in bottom sediments are very similar (Figs. 49 and 50), indicating that there are relatively large concentrations of OC and N in two areas:

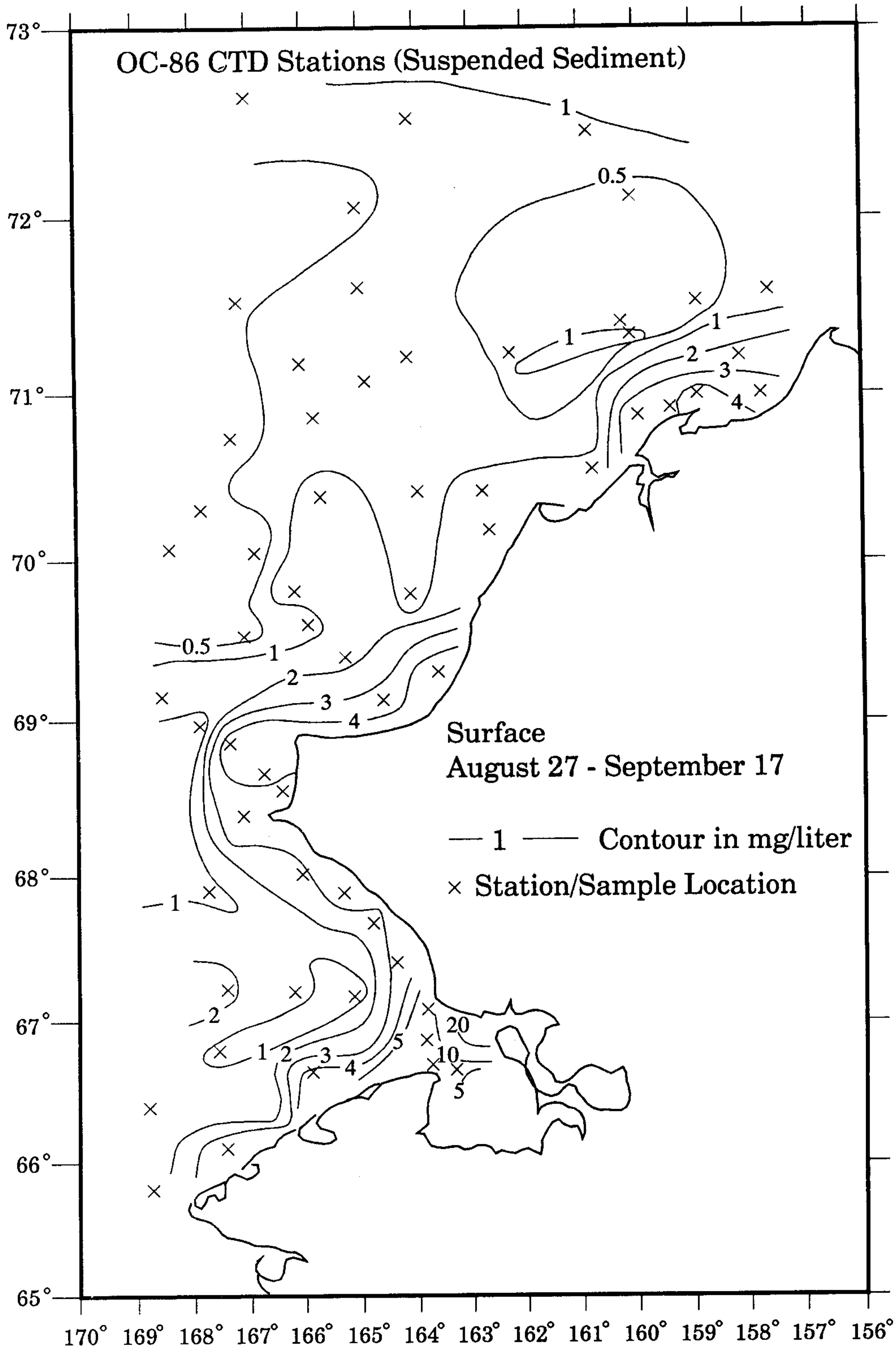

Figure 46. Surface water suspended sediment concentration.

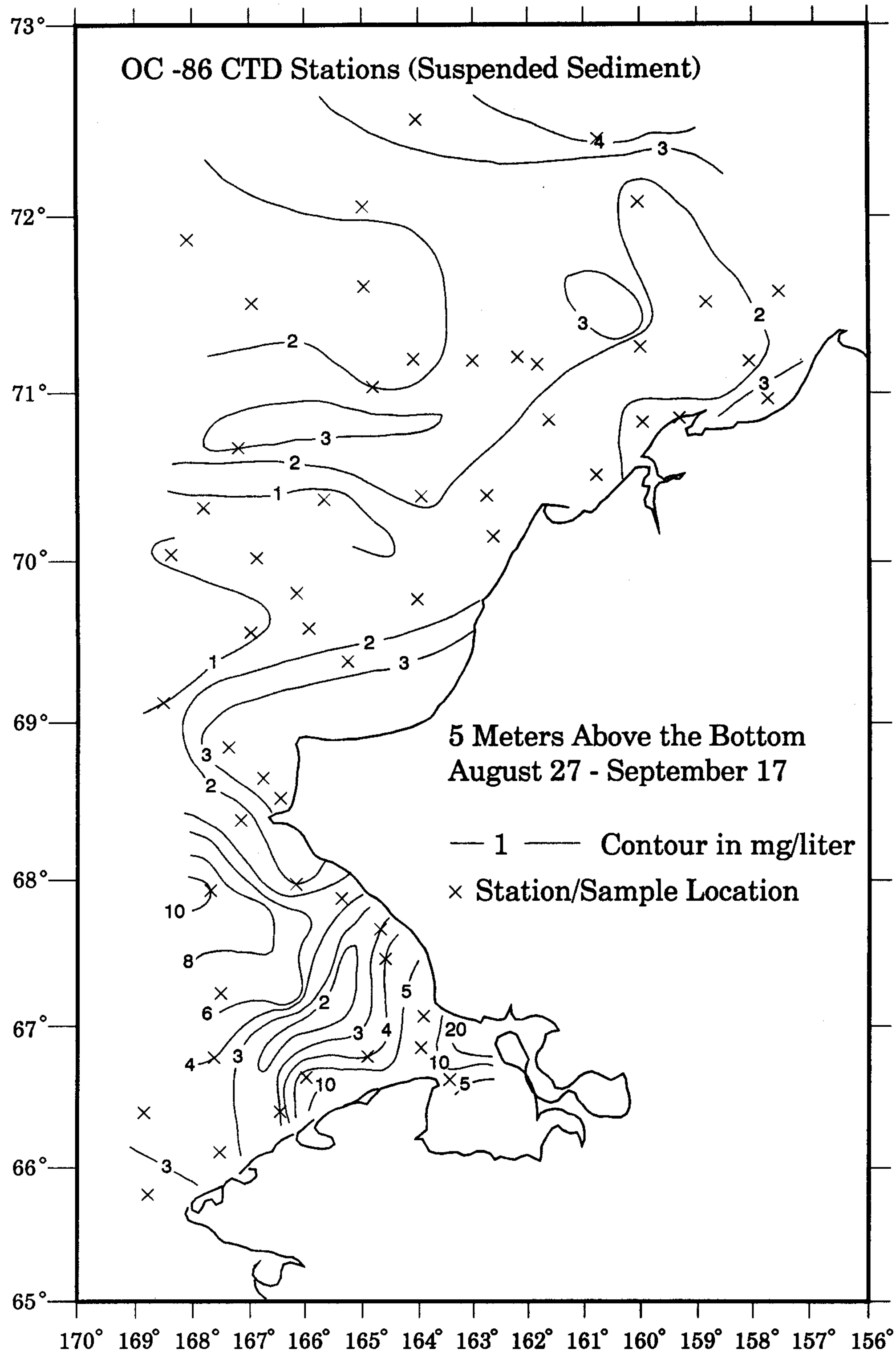

Figure 47. Suspended sediment concentration 5 m above the sea floor.

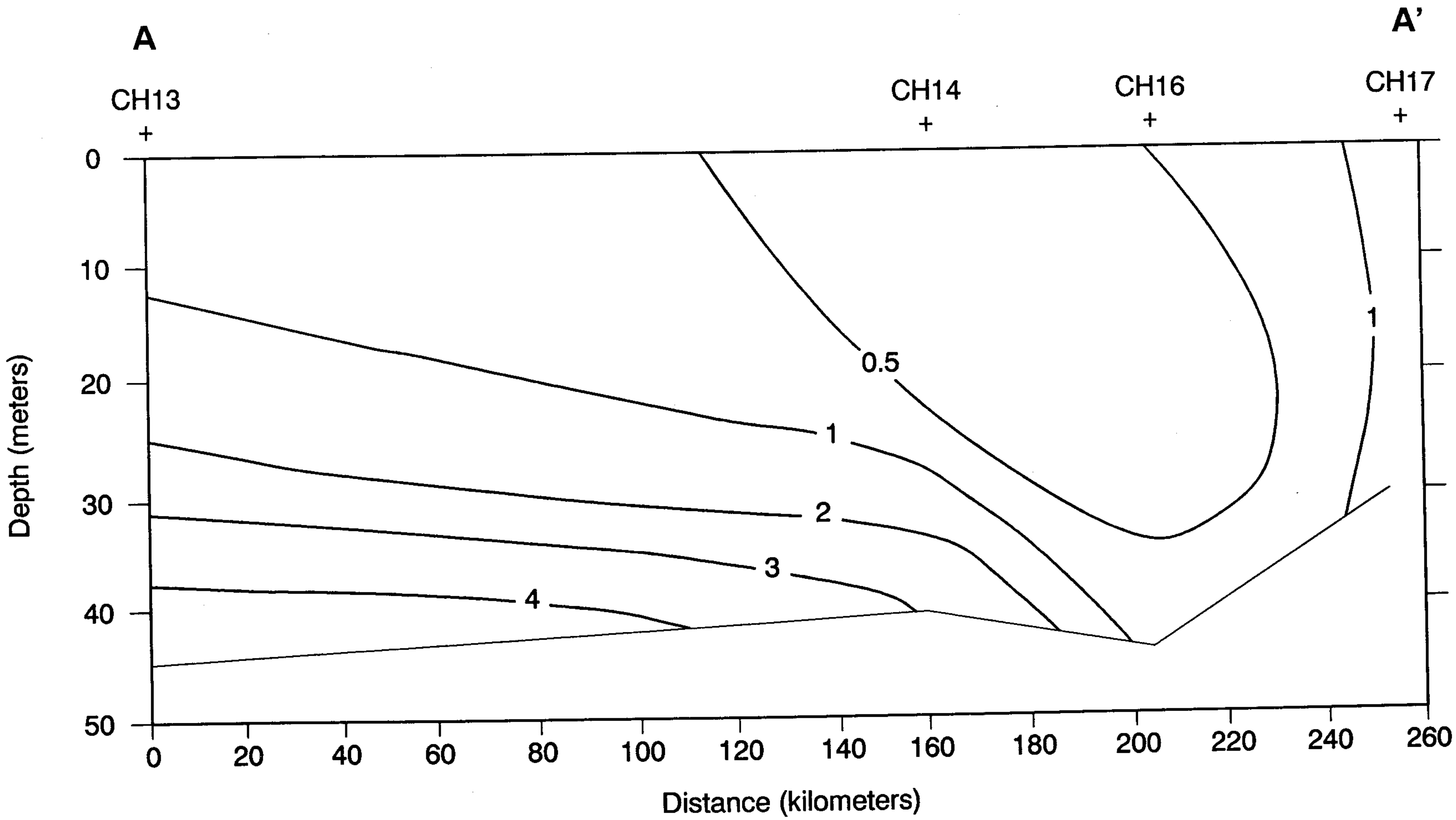

Figure 48. Chukchi Sea vertical profile of suspended sediment concentration. Contours are in mg/liter. For transect location, see Figure 11.

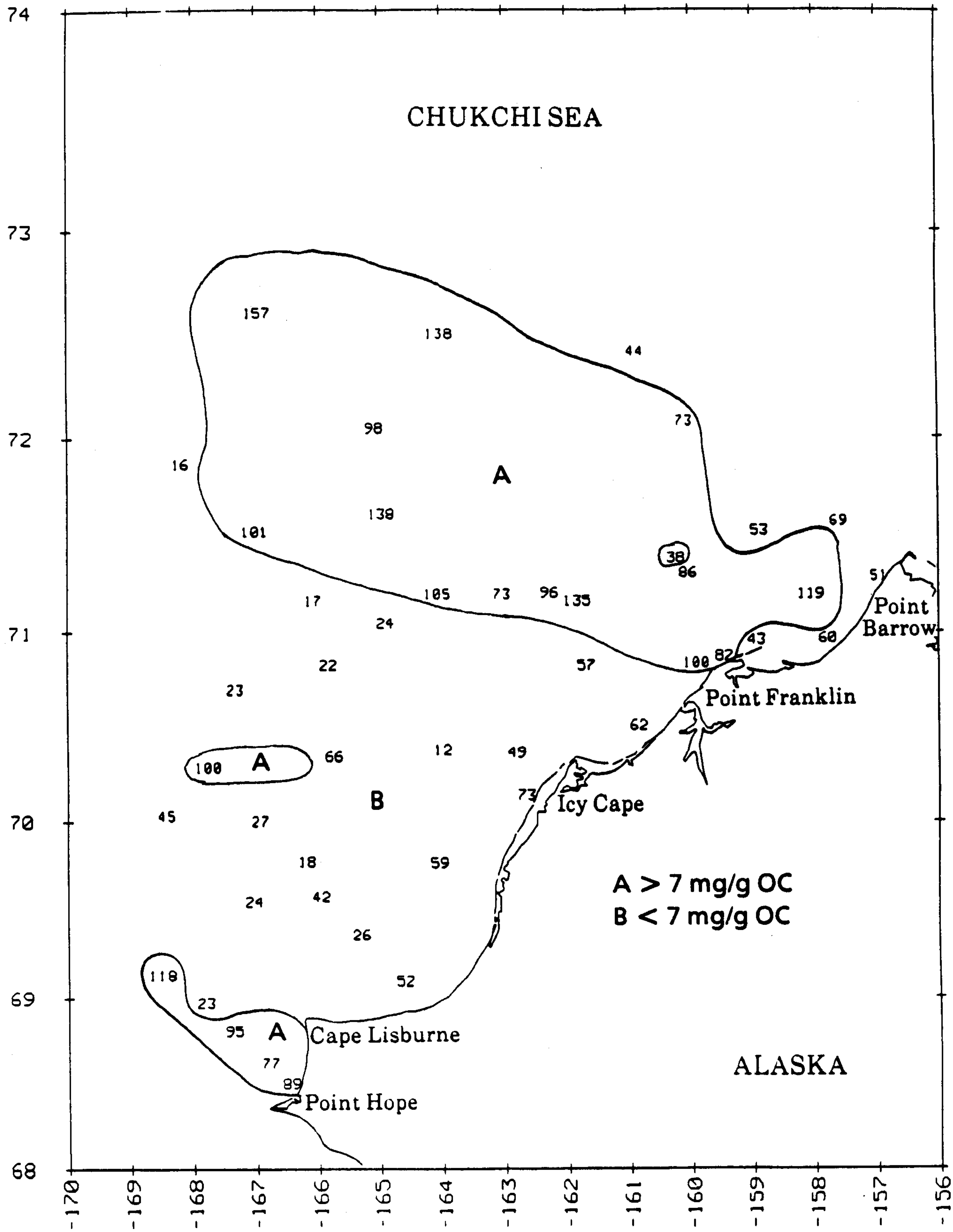

Figure 49. Organic carbon (mg/g x 10^{-1}) in bottom surficial sediments in the northeastern Chukchi Sea.

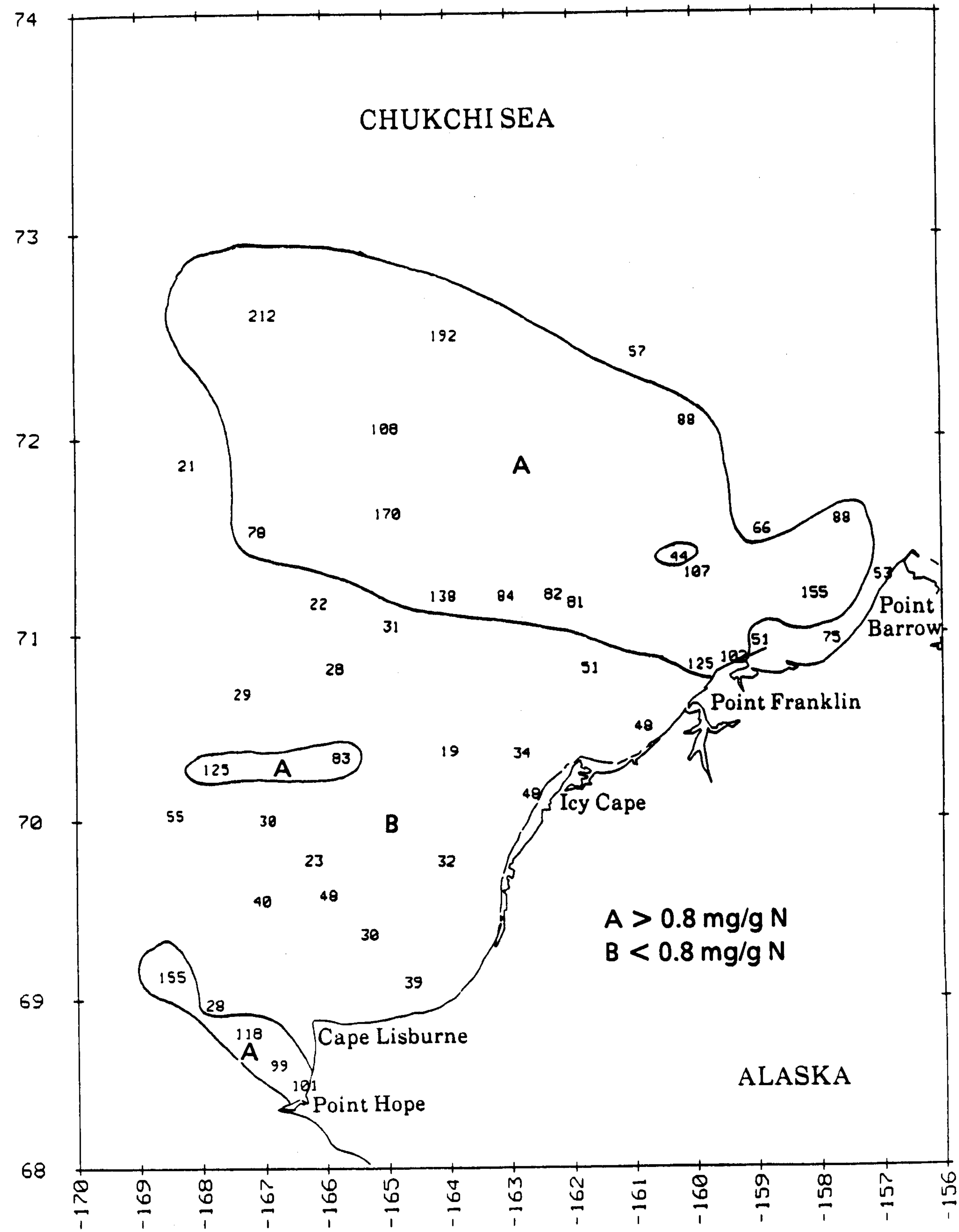

Figure 50. Nitrogen (mg/g x 10^{-2}) in bottom surficial sediments in the northeastern Chukchi Sea.

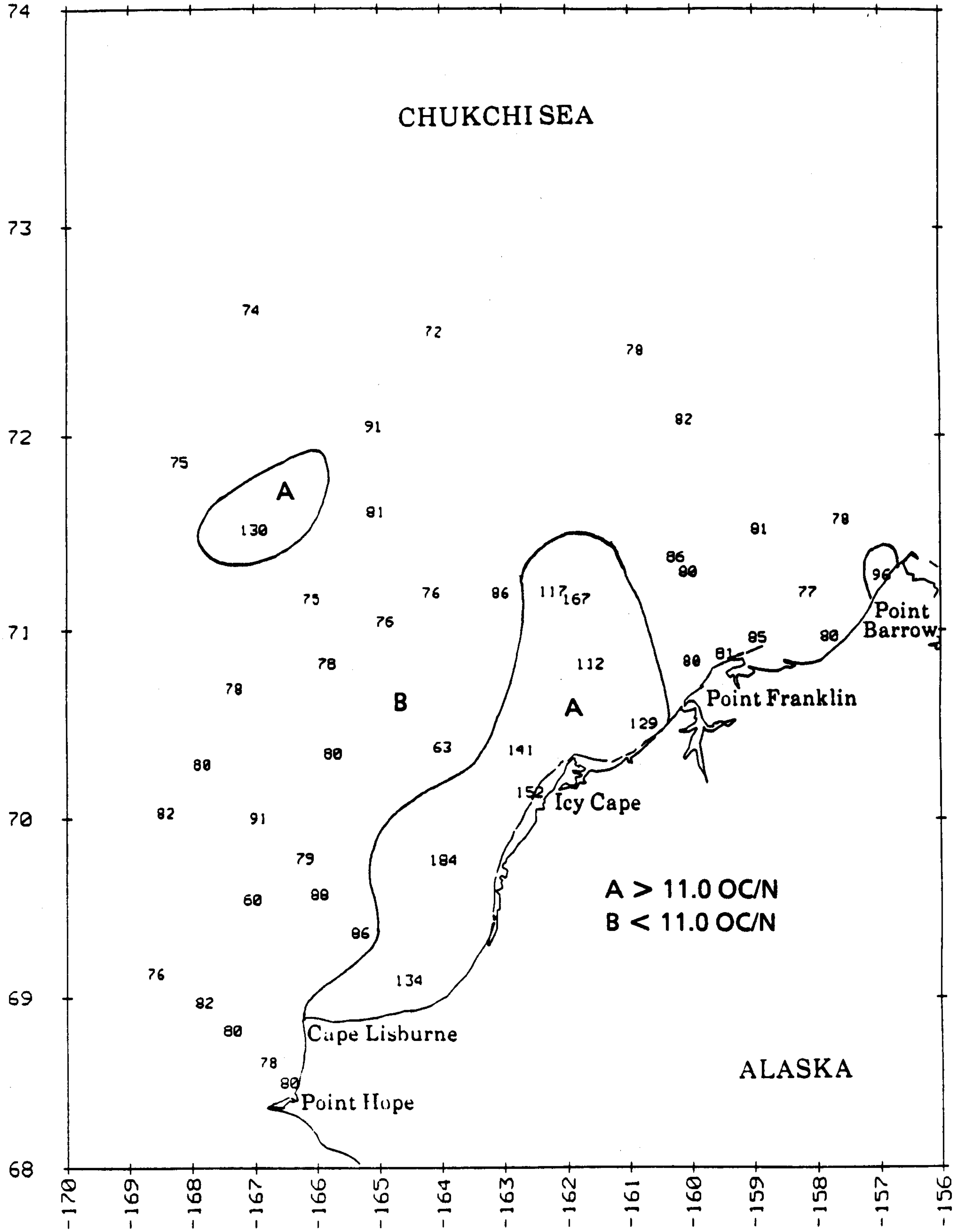

Figure 51. OC/N values (x 10^{-1}) of bottom surficial sediments in the northeastern Chukchi Sea.

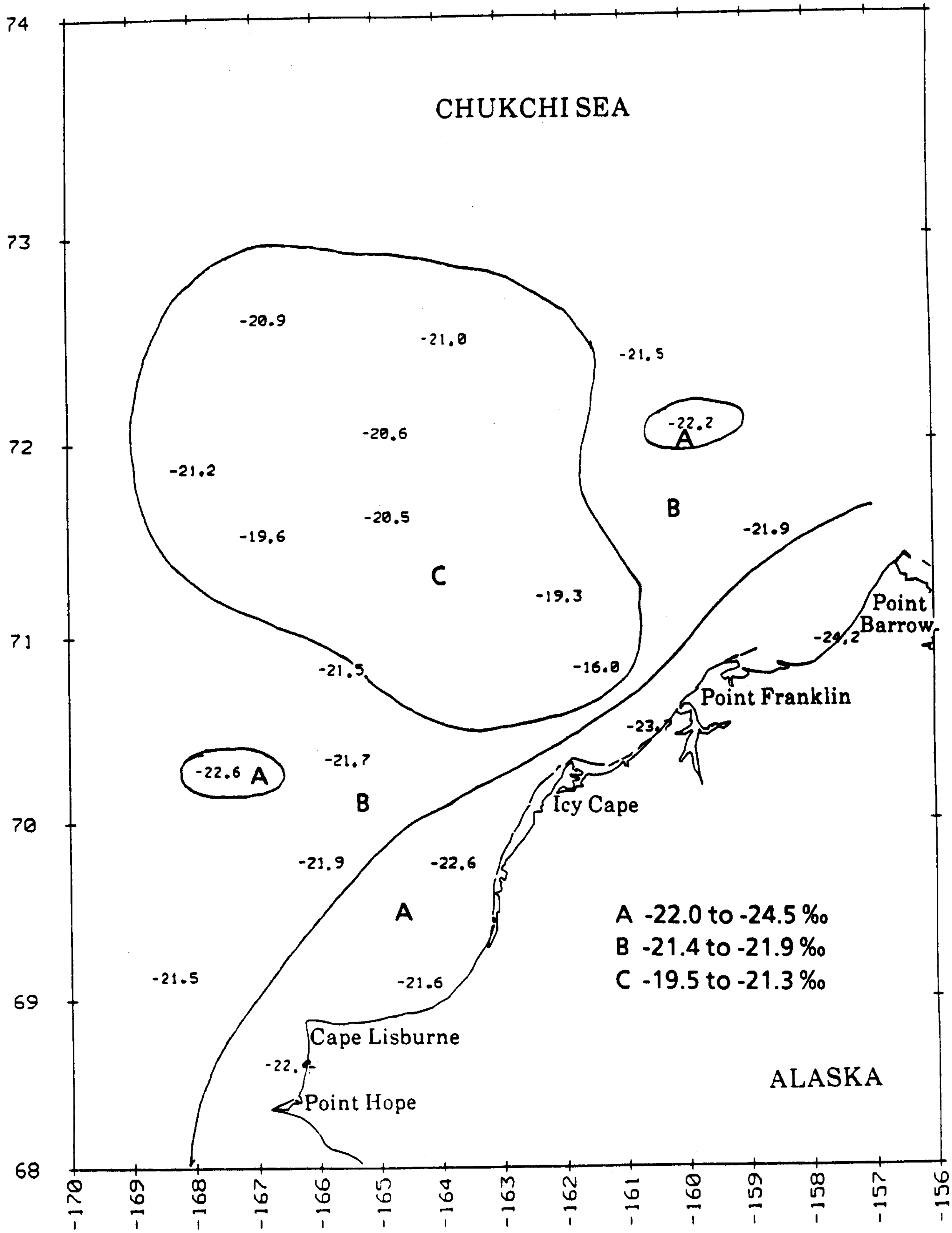

Figure 52. Stable organic carbon isotopic ratios ($\delta^{13}C^{o}/oo$) of bottom surficial sediments.

Table 6. Concentrations of suspended particulates and organic carbon (OC), nitrogen (N), OC/N ratios in the suspended particulates of surface (SWSP) and near bottom (BWSP) waters of the northeastern Chukchi Sea.

Station Name	SWSP (mg/l)	BWSP (mg/l)	OCSWSP (µg/l)	OCBWSP (µg/l)	NSWSP (µg/l)	NBWSP (µg/l)	OC/N SWSP	OC/N BWSP
CH1								
CH2	0.61	2.37						
CH3	0.34	0.95						
CH4	2.52	1.06						
CH5	3.21	3.63						
CH6	4.60	1.83	147.6	86.3	26.3	20.9	5.6	4.1
CH7	3.84	2.03	154.5	102.8	26.5	15.2	5.8	6.8
CH8	3.36	1.91	148.6	98.4	24.2	14.1	6.1	7.0
CH9	0.43	1.46	57.1	83.7	8.9	14.1	6.4	5.9
CH10	0.77	3.37	51.5	128.3	7.4	18.1	7.0	7.1
CH11	0.34	1.57	88.8	93.1	13.0	14.8	6.8	6.3
CH12	0.96	4.42	134.4	145.0	14.7	15.8	9.1	9.2
CH13	0.03	3.17	111.3	191.1	12.5	27.7	8.9	6.9
CH14	0.37	2.57	119.8	211.5	15.4	38.5	7.8	5.5
CH15	2.22	0.62	144.5	106.1	26.1	16.4	5.5	6.5
CH16	0.50	0.58	135.2	88.0	22.5	15.6	6.0	5.6
CH17	1.16	1.05	120.6	95.0	22.9	16.3	5.3	5.8
CH18	1.80	1.75		146.6		25.7		5.7
CH19	1.33	1.60		80.1		13.8		5.8
CH20		2.53						
CH21	0.96	1.76	163.7	132.6	30.1	23.1	5.4	5.7
CH22	0.85	1.40	151.2	133.6	21.5	21.3	7.0	6.3
CH23	0.71	1.21	119.1		18.6		6.4	
CH24	0.45	2.11	108.4	149.2	16.9	25.1	6.4	5.9
CH25	0.93	2.58	102.8	105.7	14.8	14.4	7.0	7.3
CH26	0.47	0.61						
CH27	0.69	2.26	843.2		137.3		6.1	
CH28	0.65	3.82						
CH29	1.13	0.78		78.5		15.4		10.2
CH30	0.85	2.35	170.6		32.6		5.2	
CH31	0.87	1.26	118.7	130.0	20.9	23.9	5.7	5.4
CH32	4.45		197.1		30.9		6.4	
CH33	3.08		196.5		36.0		5.5	
CH34	1.55	2.14	127.3	111.5	28.0	20.3	4.6	5.5
CH35	0.81	1.35	135.2	58.8	33.4	14.9	4.1	4.0
CH36	1.22	1.36						
CH37	0.80	1.26		72.9		13.3		5.5
CH38	0.35	3.52						
CH39		1.30						
CH40	0.44	0.72						
CH41	0.28	0.94						
CH42	0.03	0.72	96.0	135.5	21.9	19.9	4.4	6.8
CH43	3.72	2.47	197.4		40.1		4.9	
CH44	4.18	3.94						
CH45	4.31	3.82	106.4	185.1	16.5	26.2	6.5	7.1
CH46	0.29	0.51		220.5		32.5		6.8
CH47	1.25	0.78	248.7		28.4		8.8	

Table 7. Organic carbon (OC), nitrogen (N), OC/N ratios and stable organic carbon isotopic ratios ($\delta^{13}C$°/₀₀) of bottom surficial sediments, northeastern Chukchi Sea.

Station Name	OC (mg/g)	N (mg/g)	OC/N	δ13C o/oo
CH1	5.11	0.53	9.60	
CH2	6.90	0.88	7.80	
CH3	5.32	0.66	8.10	-21.9
CH4	11.86	1.55	7.70	-22.5
CH5	5.98	0.75	8.00	-24.2
CH6	4.31	0.51	8.50	
CH7	8.24	1.02	8.08	-24.9
CH8	10.02	1.25	8.00	
CH9	8.60	1.07	8.00	
CH10	3.76	0.44	8.60	
CH11	7.25	0.88	8.20	-22.2
CH12	4.43	0.57	7.80	-21.5
CH13	13.76	1.92	7.20	-21.0
CH14	9.62	0.82	11.70	-19.3
CH15	13.54	0.81	16.70	
CH16	5.71	0.51	11.20	-18.0
CH17	6.21	0.48	12.90	-23.7
CH18	7.30	0.48	15.20	-24.8
CH19	4.86	0.34	14.10	
CH20	7.25	0.84	8.60	
CH21	10.46	1.38	7.60	
CH22	2.36	0.31	7.60	
CH23	13.79	1.70	8.10	-20.5
CH24	9.79	1.08	9.10	-20.6
CH25	15.74	2.12	7.40	-20.9
CH26	10.11	0.78	13.00	-19.6
CH27	1.65	0.22	7.50	-22.6
CH28	2.19	0.28	7.80	-21.5
CH29	6.63	0.83	8.00	-21.7
CH30	1.21	0.19	6.30	-22.6
CH31	5.88	0.32	18.40	-22.6
CH32	....	....	....	
CH33	5.23	0.39	13.40	-21.6
CH34	2.59	0.30	8.60	-22.4
CH35	4.20	0.48	8.80	-23.2
CH36	1.82	0.23	7.90	-21.9
CH37	2.73	0.30	9.10	-23.4
CH38	2.25	0.29	7.80	
CH39	1.58	0.21	7.50	-21.2
CH40	10.04	1.25	8.00	-22.6
CH41	4.48	0.55	8.20	
CH42	2.40	0.40	6.00	
CH43	8.89	1.01	8.00	-23.6
CH44	7.73	0.99	7.80	-22.4
CH45	9.46	1.18	8.00	-22.4
CH46	2.29	0.28	8.20	
CH47	11.79	1.55	7.60	-21.5

one due northwest of Point Franklin and the other northwest of Point Hope (Figs. 49 and 50). The OC/N plots of bottom sediments in Figure 51 show a region of relatively high OC/N (>11.0) in the inshore area extending from Cape Lisburne to Wainwright. The carbon isotopic ratios ($\delta^{13}C$) of bottom surficial sediments are included in Table 7 and their distributional pattern in the northeastern Chukchi Sea is shown in Figure 52. The nearshore region adjacent to land has significantly lower ratios (>-22.0; -22.4 to -24.5 $^{o}/oo$) than the offshore area. A significant increase in the ratios (i.e., with less negative $\delta^{13}C$ values) with increasing distance from the coast is detected (Naidu, unpub.). A large area with relatively high ratios (-19.5 to -21.3 $^{o}/oo$) is delineated locally in the outer shelf northwest of Point Franklin and Wainwright (Fig. 52).

The OC, N and OC/N values of suspended particles of surface and near bottom waters at selected stations are shown in Table 8 and their distributions in the northeastern Chukchi Sea are plotted in Figures 53 through 58. It is notable that OC is consistently higher in the nearshore suspended particulates in surface and bottom waters and N in bottom waters in the southern region of the study area. Additionally, there is a disjointed area further north where the OC concentrations are also relatively higher in the suspended particulates in both surface and bottom waters (Figs. 53 and 55). It would seem that within and in the vicinity of this northern area the N values in the surface water suspended particles are relatively lower and the OC/N values corresponding to stations in the area are slightly higher (>7.0).

In Table 9 are shown the gross fluxes of suspended particles and particulate organic carbon and nitrogen from suspensions to the sea bottom. The fluxes are represented on a per day basis ($mg/cm^2/dy$) and were

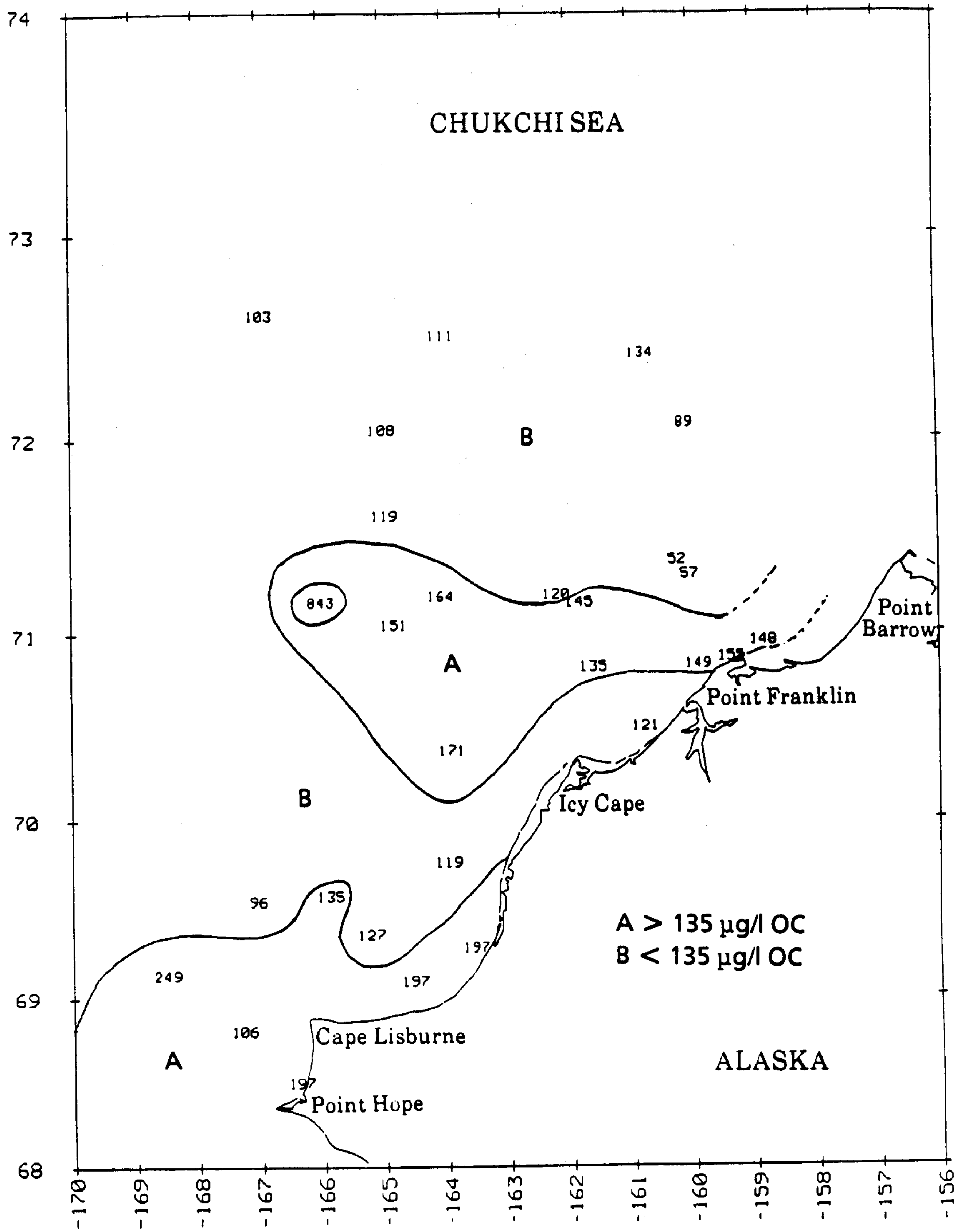

Figure 53. Organic carbon (µg/L) in suspended particles of surface waters in the northeastern Chukchi Sea.

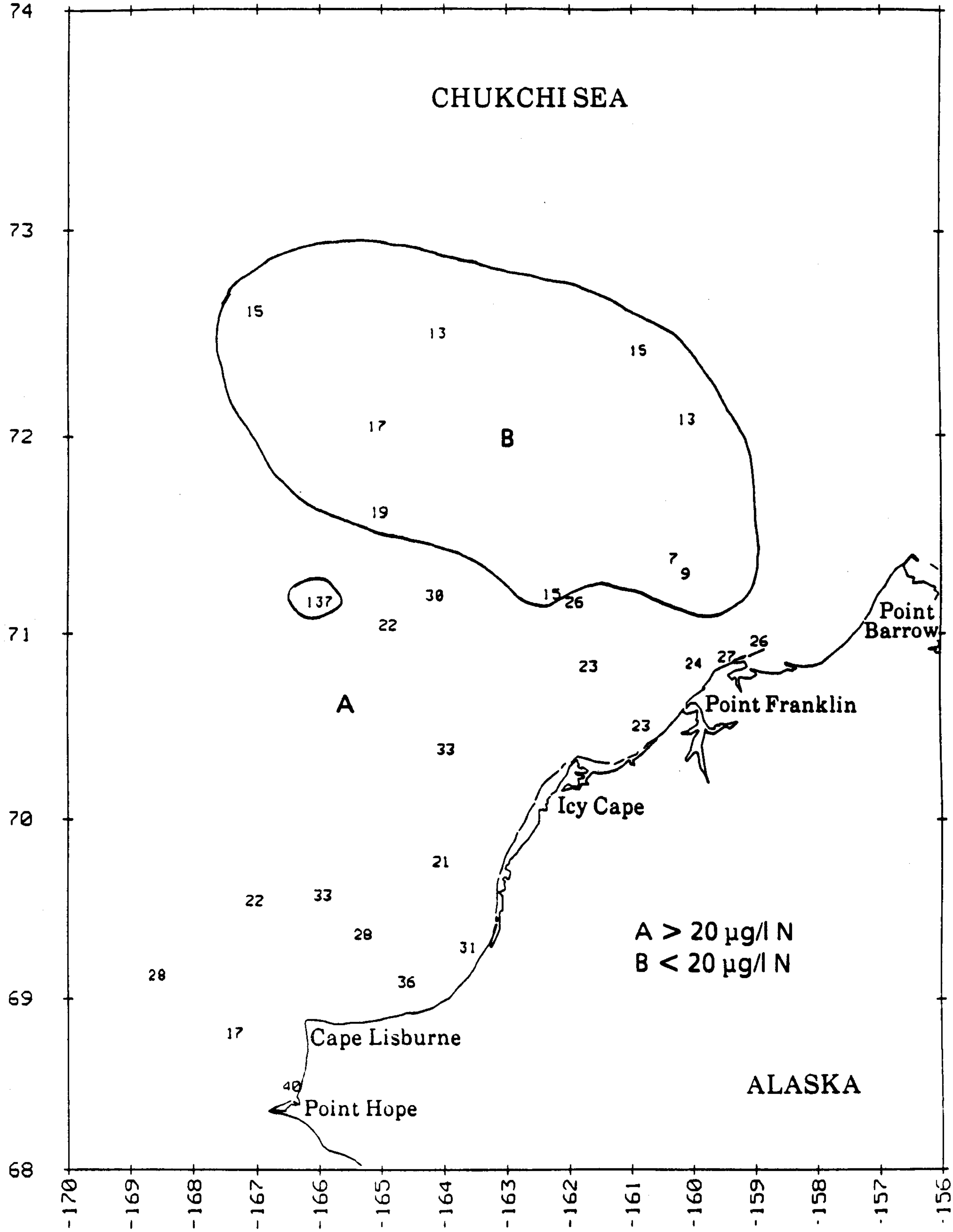

Figure 54. Nitrogen ($\mu g/L$) in suspended particles of surface waters in the northeastern Chukchi Sea.

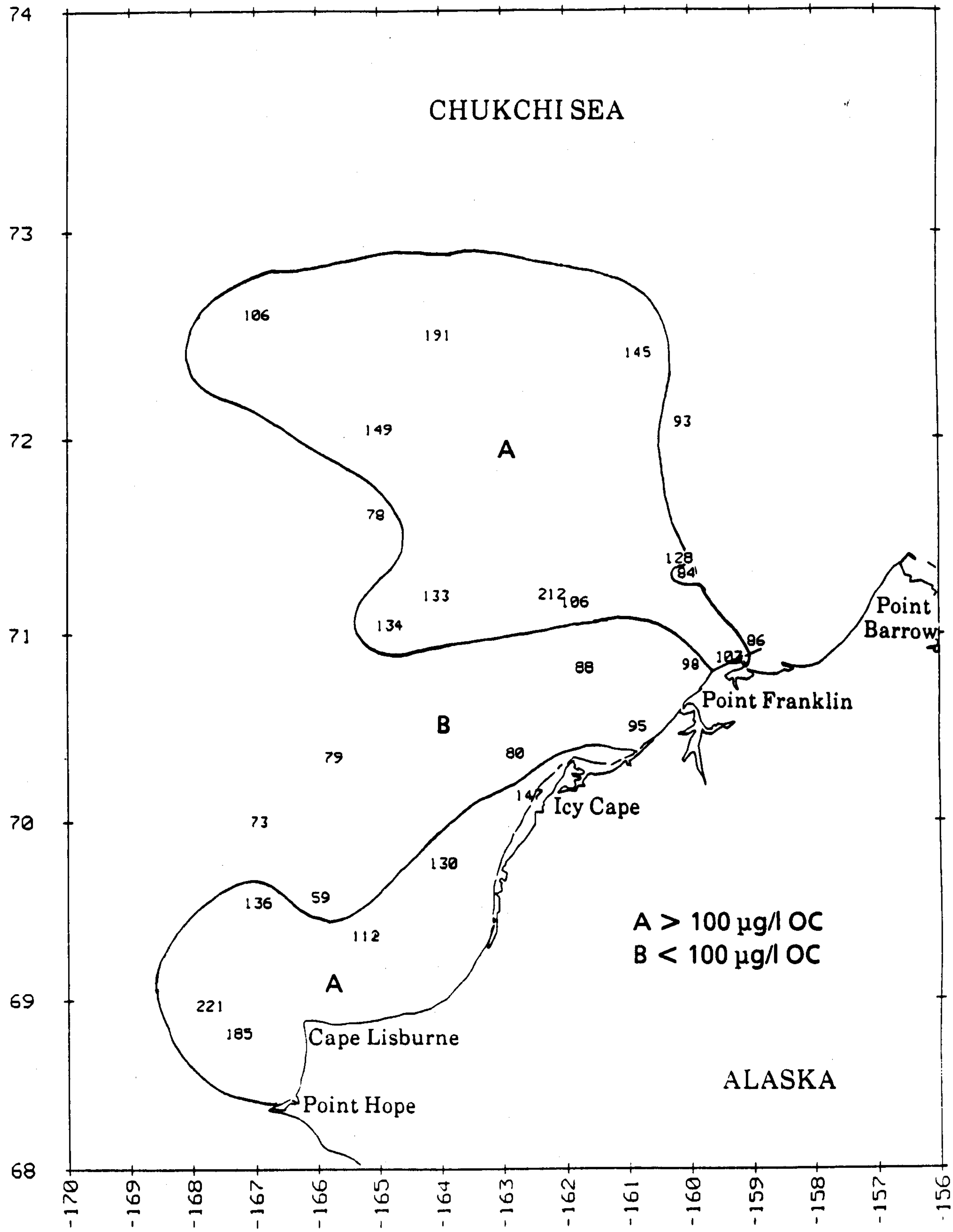

Figure 55. Organic carbon (µg/L) in suspended particles of near bottom waters in the northerneastern Chukchi Sea.

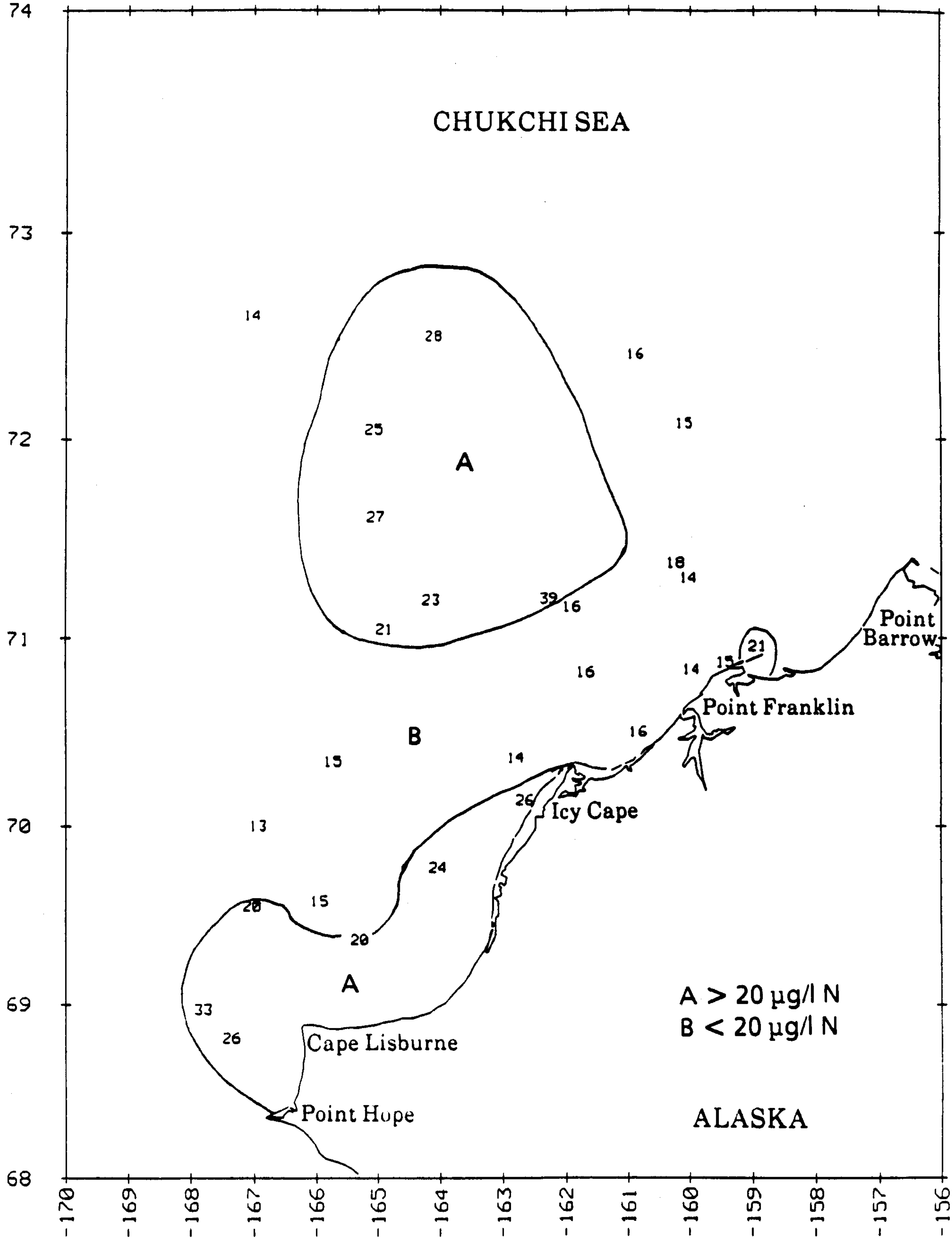

Figure 56. Nitrogen (µg/L) in suspended particles of near bottom waters in the northeastern Chukchi Sea.

Table 8. The gross flux of suspended particles (mg/L), contents of organic carbon (OC) and nitrogen (N), and OC/N ratios in carbonate-free suspended particles in the surface waters (0 m) and at selected depths from the surface in east and southeast Chukchi Sea.

Station	Depth (M)	Suspended Particle (mg/L)	OC (μg/L)	N (μg/L)	OC/N
CH 05	14	3.63	109.91	15.33	7.17
CH 07	0	3.84	154.454	26.518	5.82
	12	3.11	124.071	20.679	6.00
	26	2.03	102.83	15.20	6.76
CH 08	0	3.36	148.555	24.183	6.14
	30	2.20	88.67	14.11	6.28
	41	1.91	98.43	14.068	7.00
CH 09	0	0.43	57.11	8.85	6.45
	25	0.37	45.900	8.343	5.50
	42	1.46	83.658	14.110	5.93
CH 10	0	0.77	51.50	7.39	6.97
	20	0.54	62.419	9.803	6.37
	37	3.37	128.32	18.129	7.08
CH 11	0	0.34	88.77	12.954	6.85
	15	0.81	247.080	57.102	4.33
	30	1.57	93.10	14.84	6.27
CH 12	0	0.96	134.40	14.69	9.15
		1.13	120.236	19.219	6.26
		4.42	145.02	15.79	9.18
CH 13A	0	0.03	111.305	12.530	8.88
	20	0.16	92.075	11.015	8.39
	45	3.17	191.142	27.682	6.90
CH 13B	0	0.86	112.471	18.538	6.07
	20	1.22	106.352	16.265	6.54
	40	4.18	229.604	103.386	2.22*
CH 14	0	0.37	119.755	15.432	7.76
	20	0.34	108.974	16.265	6.70
	34	2.57	211.538	38.462	5.50
CH 15	0	2.22	144.522	26.114	5.53
	20	0.73	92.075	18.765	4.91
	40	0.62	106.061	16.417	6.46
CH 16	0	0.50	135.198	22.477	6.01
	19	0.31	108.100	17.780	6.08
	38	0.58	87.995	15.583	5.65
CH 17	0	1.16	120.629	22.932	5.26
	19	1.05	94.988	16.341	5.81
CH 18	13	1.75	146.55	25.65	5.71

Table 8. (continued)

Station	Depth (M)	Suspended Particle (mg/L)	OC (µg/L)	N (µg/L)	OC/N
CH 19	25	1.60	80.05	13.75	5.82
CH 21	39	1.76	132.57	23.05	5.75
CH 22	0	0.85	151.21	21.48	7.09
	17	0.62	157.97	27.52	5.74
	35	1.40	133.62	21.26	6.29
CH 23	0	0.71	119.056	18.562	6.41
	20	0.45	92.39	149.419	0.62*
	40	1.21	78.348	26.74	2.93*
CH 24	0	0.45	108.39	16.935	6.40
	20	0.54	100.54	14.865	6.76
	36	2.11	149.15	25.06	5.95
CH 25	0	0.93	102.83	14.84	6.93
	25	0.59	199.59	43.16	4.62
	46	2.58	105.68	14.387	7.35
CH 27	0	0.62	843.240	137.326	6.14
CH 30	0	0.85	170.61	32.58	5.24
CH 31	0	0.87	118.73	20.88	5.69
	21	1.26	129.97	23.90	5.44
CH 32	0	4.45	197.12	30.90	6.38
	0	7.56	211.53	41.29	5.12
CH 33	0	3.08	196.54	36.02	5.46
CH 34	0	1.55	127.34	28.01	4.54
	26	2.14	111.53	20.33	5.48
CH 35	0	0.81	135.16	33.43	4.04
	20	0.21	58.79	14.91	3.94*
CH 37	42	1.26	72.91	13.28	5.49
CH 42	21	0.03	96.01	21.871	4.39
	38	1.15	98.88	15.37	6.43
	38	0.72	135.457	19.898	6.81
CH 43	0	3.72	197.39	40.12	4.92
CH 45	0	4.31	106.372	16.518	6.44
	20	1.76	213.45	32.21	6.63
	39	3.82	185.08	26.170	7.07
CH 46	20	0.51	220.53	32.50	6.78
CH 47	0	1.25	248.70	28.40	8.76

Table 9. Gross fluxes ($mg/cm^2/dy$) of sediments, organic carbon, and nitrogen to the sea bottom from the water column in the northeastern Chukchi Sea (see Table 2 and Fig. 13 for station locations) during August-September 1986.

Station	Sediment	OC	N	OC/N
CH17	1.180	0.00929	0.00103	9.0
CH16	0.146	0.00129	0.00016	8.1
CH14	0.353	0.00070	0.00011	6.4
CH13	3.526	0.01282	0.00196	6.5

calculated by taking into account the amount of particulates intercepted in traps during August-September 1986 and corresponding to the four locations shown in Figure 13 (also see Table 2). By comparison to most nearshore areas, the sediment fluxes in the northeastern Chukchi Sea are generally very low. It would seem that the gross flux of suspended particulates increases seaward across the shelf from Station CH16 to CH13 through CH14, and that the gross flux is markedly higher at the northern margin of the study area (CH13, CH25). At Station CH17, which is shallow and nearer the coast, the gross sediment flux is relatively higher than at the two stations farther seaward (CH16 and CH14). The gross fluxes of OC and N are also highest at Station CH13 and both these values successively decrease from Stations CH17 to CH14 to CH16 (Table 9). The OC/N values of the trapped particulate samples are also provided in Table 9. It is shown that the OC/N values in the sediment trap samples decrease significantly from the inner shelf to the outer shelf.

The ^{210}Pb-based linear (cm/yr) and mass ($g/m^2/yr$) accumulation rates of sediments at selected offshore stations in the northeastern Chukchi Sea are shown in Table 10[1]. The linear rates vary from 0.16 cm/yr to 0.26 cm/yr whereas the mass accumulation rates range between 1,487 and 2,505 $g/m^2/yr$. Based on the mass sedimentation rates and the concentrations of organic carbon and nitrogen in surficial sediments (Table 7), the accumulation rates of organic carbon and nitrogen at the selected offshore stations were computed. These rates, corresponding to the various stations, are shown in Table 10. A lack of a net linear exponential decay in excess ^{210}Pb activity

Table 10. ^{210}Pb-based linear (cm/yr) and mass ($g/m^2/yr$) sediment accumulation rates ($g/m^2/yr$) of particulate organic carbon (OC) and nitrogen at selected stations, northeast Chukchi Sea.

Station	Linear Accum. Rate (cm/yr)	Mass Accum. Rate ($g/m^2/yr$)	OC Accum. Rate ($g/m^2/yr$)	N Accum. Rate ($g/m^2/yr$)
CH13	0.16	1660	22.8	3.2
CH21	0.23	2153	22.5	2.9
CH26	0.26	2142	21.6	1.7
CH38	0.26	2505	5.6	0.7
CH39	0.21	1487	2.3	0.3
CH40	0.16	2149	21.6	2.7

[1]The raw data on which these calculations are based, including the total and excess ^{210}Pb and ^{226}Ra activities (dpm/g) and water contents of 1-cm sections of individual cores are included in the appendix section of this report (Appendix I).

in sediment cores collected (and analyzed by us) from the inshore areas indicate extremely low or no deposition of sediments.

Figure 59 shows binary plots between surficial sediment mean size and the sediment grain size sorting (expressed as standard deviation, Folk, 1980), whereas Figure 60 displays the plots between percentages of water and mud (silt + clay) in surficial sediments. The ternary plots in Figure 61 relate to percentages of water, clay and gravel + sand in the surficial sea floor sediments at stations where benthic samples were also taken and analyzed. The plots in Figures 60 and 61 are based on data shown in Table 11, which correspond to calculations of proportional contents of water, mud and gravel plus sand on a wet sediment basis (please note that the granulometric data in Table 5 and Figure 59 are based on a dry sediment basis). Figures 59, 60, and 61 show that there are four distinct station groupings and that these groupings generally match closely with the benthic macrofaunal station groups.

C. Benthic Biological Studies

1. General

Over 425 taxa were identified from 37 stations occupied in October 1986 (Table 12; Fig. 62), with polychaetes, crustaceans (barnacles and amphipods), and mollusks (bivalves) typically dominant in abundance. Sipunculids, clams, sea cucumbers, and sand dollars were generally dominant in biomass (Appendix III; a complete list of taxa are on file at the Institute of Marine Science, University of Alaska Fairbanks).

2. Abundance, Diversity, Biomass, Carbon Production of Individual Stations

Abundance values (Table 12) for macrofauna ranged from 454 (offshore northern Station CH13) to 31,576 (inshore northern Station CH16)

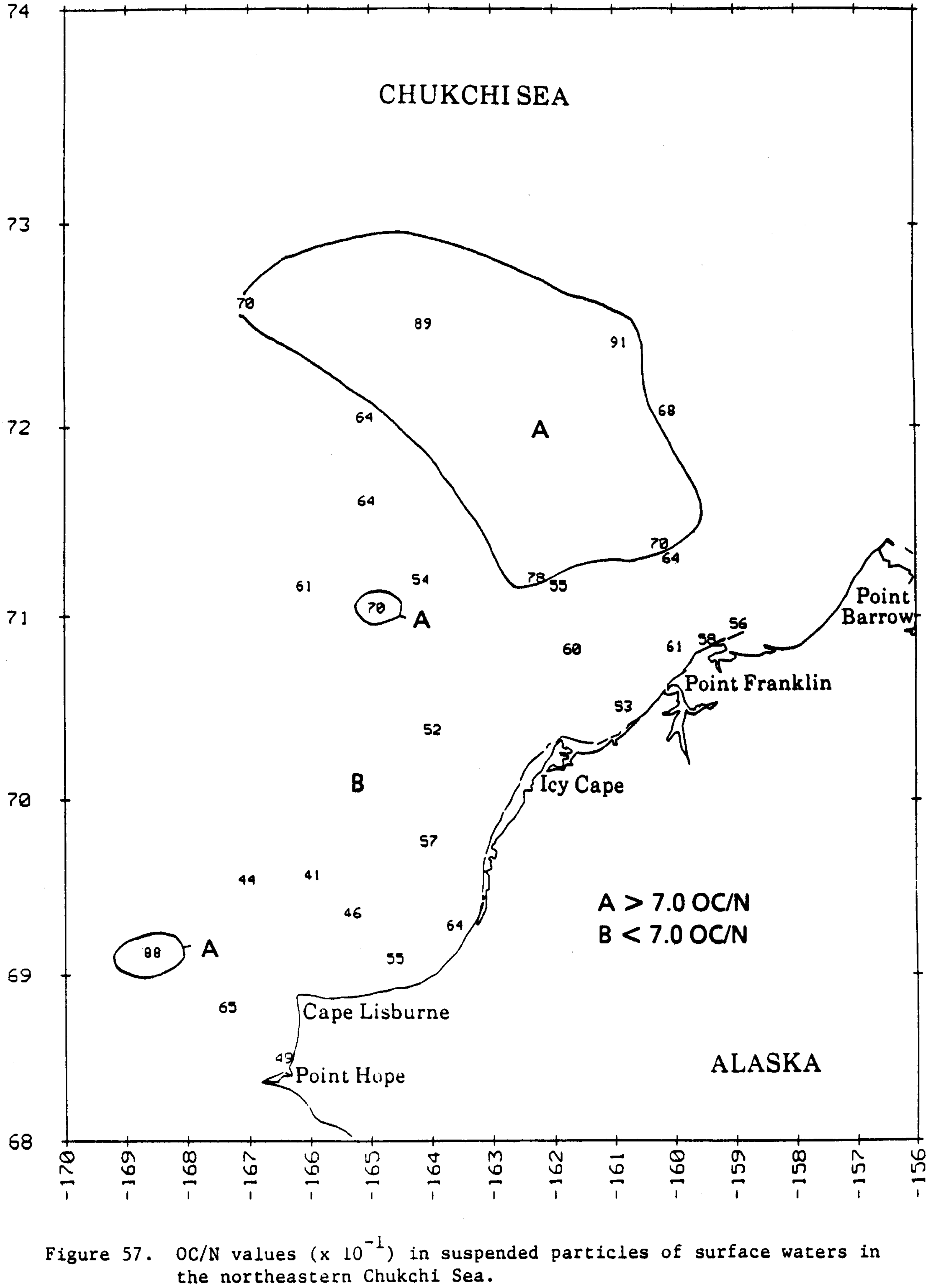

Figure 57. OC/N values (x 10^{-1}) in suspended particles of surface waters in the northeastern Chukchi Sea.

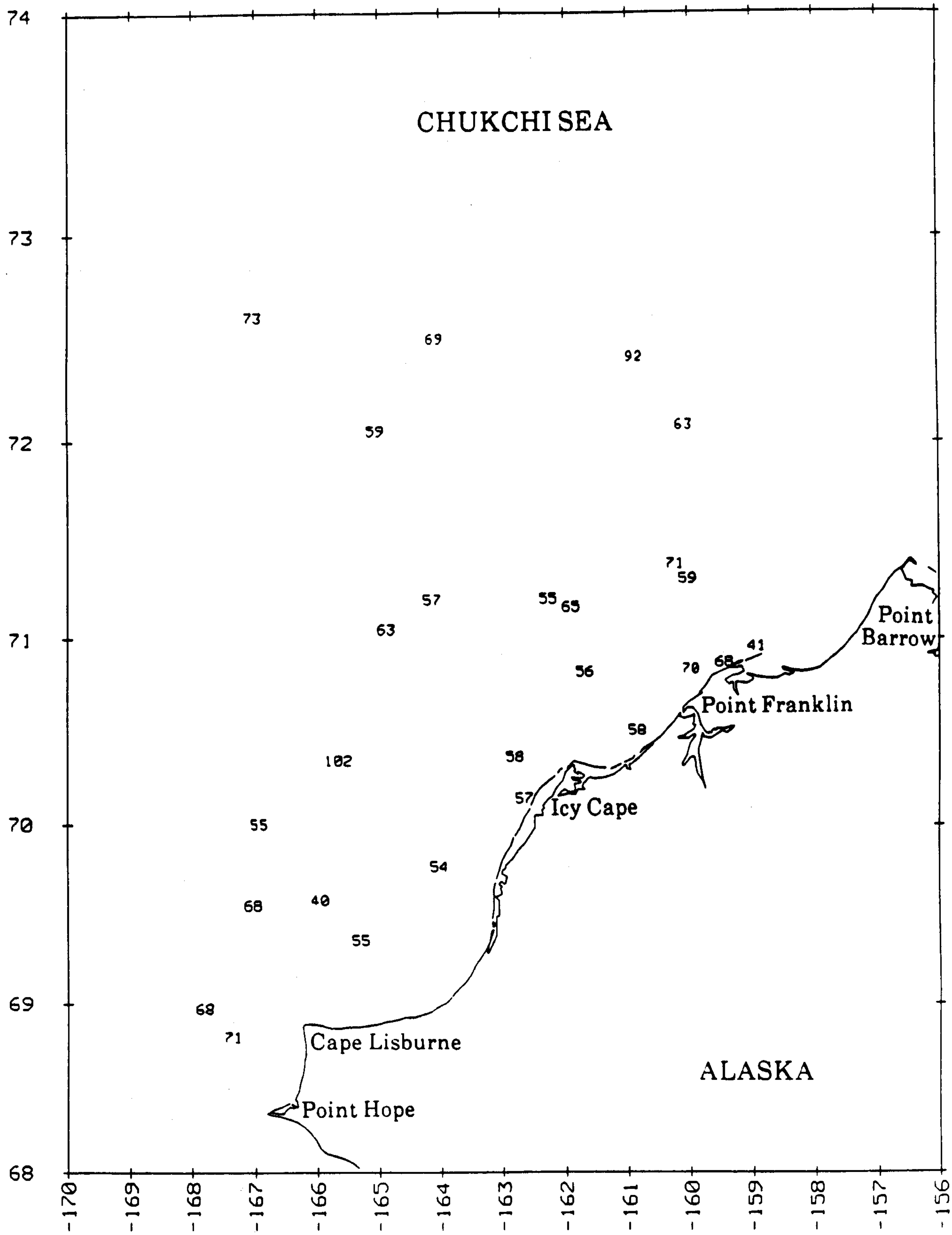

Figure 58. OC/N values (x 10^{-1}) of suspended particles of near bottom waters in the northeastern Chukchi Sea.

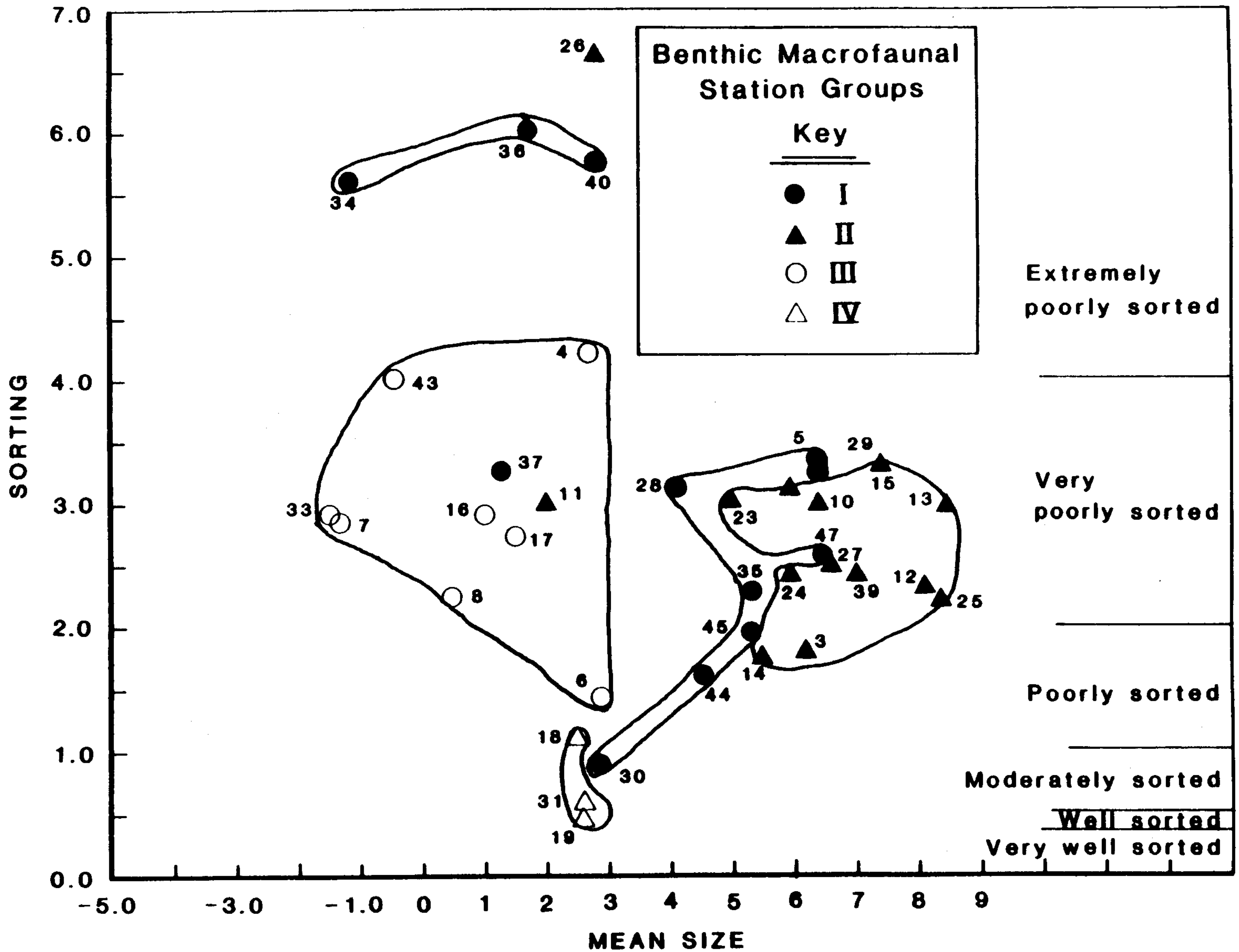

Figure 59. The relationship of the stations (CH) to station groups based on sorting and mean size of dry sediments for cluster groups (see Figs. 74 and 78).

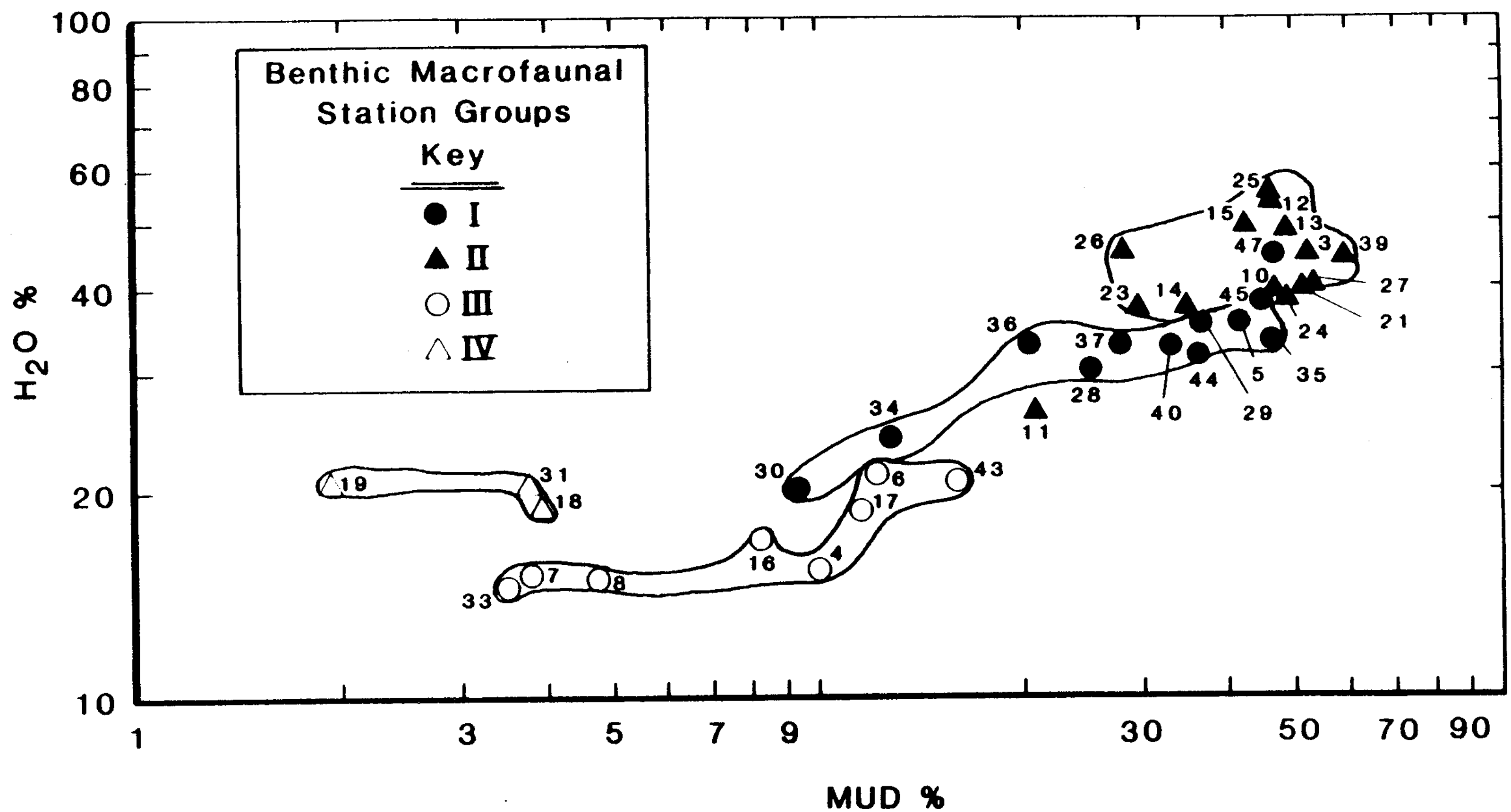

Figure 60. The relationship of the stations (CH) to station groups based on % water and % mud in sediment (see Figs. 74 and 78).

Table 11. Contents (by weight percent) of gravel and sand, mud and water in sea floor surficial wet sediments, northeast Chukchi Sea.

Sample No.	Gravel & Sand %	Mud %	Water %
CH1	11.48	73.48	15.04
CH2	6.45	47.91	45.64
CH3	1.74	5.16	45.10
CH4	73.99	9.78	16.23
CH5	22.25	42.14	35.61
CH6	67.55	11.71	20.73
CH7	81.03	3.73	15.23
CH8	80.35	4.77	14.89
CH9	6.02	46.26	47.76
CH10	13.50	47.05	39.44
CH11	52.67	21.37	25.96
CH12	0.10	46.69	53.20
CH13	1.75	49.34	48.91
CH14	28.75	33.97	37.28
CH15	8.25	42.50	49.25
CH16	74.43	8.35	17.21
CH17	69.51	11.69	18.79
CH18	77.02	3.85	19.14
CH19	77.87	1.92	20.21
CH20	22.35	37.99	39.64
CH21	10.34	50.38	39.28
CH22	66.36	10.60	23.04
CH23	33.40	29.61	36.99
CH24	14.28	47.26	38.46
CH25	0.20	45.51	54.27
CH26	26.65	28.30	45.05
CH27	5.86	53.77	40.36
CH28	44.60	25.48	29.92
CH29	28.76	35.84	35.40
CH30	70.18	9.50	20.32
CH31	76.25	3.70	20.03
CH32	99.61	0.39	0.00
CH33	81.99	3.51	14.49
CH34	63.17	12.74	24.14
CH35	19.92	46.85	33.22
CH36	46.38	20.37	33.25
CH37	40.96	25.81	33.23
CH38	25.81	39.30	34.88
CH39	2.39	52.94	44.69
CH40	35.28	31.49	33.21
CH41	61.95	8.84	29.18
CH42	20.07	43.11	36.81
CH43	63.69	15.94	20.37
CH44	32.84	35.69	31.47
CH45	16.49	45.19	38.32
CH46	8.21	49.65	42.14
CH47	6.93	47.26	45.81

Table 12. Abundance, biomass, and estimated carbon production and carbon requirements for benthic macrofauna collected by van Veen grab in the eastern Chukchi Sea aboard the NOAA R/V *Oceanographer*, August/September 1986, Cruise OC862. All taxa collected are included in the entries for this table. Fragments are not included in the abundance values, but are included in the other computations. TE = transfer efficiency.

Station Name	Abundance (indiv/m^2)	Wet Weight Biomass (g/m^2)	Carbon Biomass (gC/m^2)	Carbon Production (gC/m^2/yr)	Carbon Required (gC/m^2/yr) 10% TE	Carbon Required (gC/m^2/yr) 20% TE
CH3	838	177.24	7.53	2.8	28	14
CH4	1592	456.99	13.65	4.0	40	20
CH5	3656	138.01	6.63	3.4	34	17
CH6	8472	99.05	5.62	4.9	49	25
CH7	7482	387.33	19.64	15.6	156	78
CH8	2508	379.86	13.20	4.6	46	23
CH10	2912	306.71	13.00	7.0	70	35
CH11	1922	129.32	3.57	1.7	17	8
CH12	758	266.57	11.41	6.3	63	31
CH13	454	277.24	10.30	4.1	41	20
CH14	726	269.10	12.10	5.8	58	29
CH15	4392	272.86	11.17	9.4	94	47
CH16	31576	611.67	15.99	7.2	72	36
CH17	4998	125.50	6.64	5.4	54	27
CH18	462	136.66	3.21	2.3	23	11
CH19	1622	211.96	5.75	1.9	19	9
CH21	1146	296.60	11.79	11.5	115	58
CH23	616	246.69	9.60	5.9	59	29
CH24	1270	174.49	7.62	5.6	56	28
CH25	974	438.78	16.58	5.4	54	27
CH26	564	173.60	7.01	2.7	27	13
CH27	772	49.49	2.88	3.2	32	16
CH28	994	145.33	8.15	6.8	68	34
CH29	734	66.94	4.08	5.0	50	25
CH30	810	69.26	2.99	2.8	28	14
CH31	702	357.42	5.61	1.6	16	8
CH33	6988	168.07	3.21	1.4	14	7
CH34	2296	131.13	6.87	5.0	50	25
CH35	1328	202.87	9.67	8.0	80	40
CH36	1044	134.06	6.48	5.0	50	25
CH37	2566	140.21	7.16	5.6	56	28
CH39	1062	110.69	4.61	1.9	19	10
CH40	2014	265.34	11.50	9.9	99	50
CH43	3938	94.57	2.05	1.4	14	7
CH44	2320	141.93	6.77	2.8	28	14
CH45	828	17.96	0.96	0.7	7	3
CH47	632	87.10	4.34	1.8	18	9
Averages	2918	209.69	8.09	4.9	49	24
(±1 SD)	(5249)	(129.32)	(4.42)	(3.1)	(31)	(16)

individuals/m^2, wet weight ranged from 18 (inshore southern Station CH45) to 612 g/m^2 (inshore northern Station CH16), carbon biomass ranged from 0.96 (inshore southern Station CH45) to 19.64 gC/m^2 (northern Station CH7), and carbon production estimations varied from 0.7 (inshore southern Station CH45) to 15.6 gC/m^2/yr (inshore northern Station CH7). Mean ($\pm$ one standard deviation) values for these parameters for the 37 stations are 2,918$\pm$5,249 indiv./m^2, 210$\pm$129 g wet weight/m^2, 8.09$\pm$4.42 gC/m^2, and 4.9$\pm$3.1 gC/m^2/yr. Shannon Diversity (Table 13) ranged from 1.07 (inshore Station CH8) to 3.72 (offshore Station CH40) and species richness ranged from 3.40 (Station CH31) to 13.76 (Station CH7). Simpson Diversity varied from 0.04 (offshore Stations CH11, 14 and 40) to 0.70 (Station CH16). Shannon Evenness varied from 0.22 (Station CH16) to 0.85 (Station CH14).

In general, highest abundance values occurred close to the coast north of Icy Cape (Table 12; Figs. 62 and 63) with organisms dominated by polychaetes, barnacles and amphipods (Figs. 64-66). Benthic amphipods, a major food resource of gray whales, represented a dominant component of the fauna at coastal stations just north of Icy Cape, a region identified as a feeding area for populations of gray whales in the summer (Phillips *et al.*, 1985). Biomass, carbon production, and $\delta^{13}C$ values were significantly higher ($P<0.05$) to the north and west of a frontal zone (see Physical Oceanography section) (Table 14; Figs. 67-69). High biomass and production values were also obtained at Stations CH34, 35, 36, and 37 just north of Cape Lisburne.

3. Trophic Structure and Motility for Individual Stations

Data showing trophic structure, based on taxon abundance, at individual stations are included in Table 15 and Figures 70-73. As noted in this table and these figures the highest percentage values for suspension feeders were

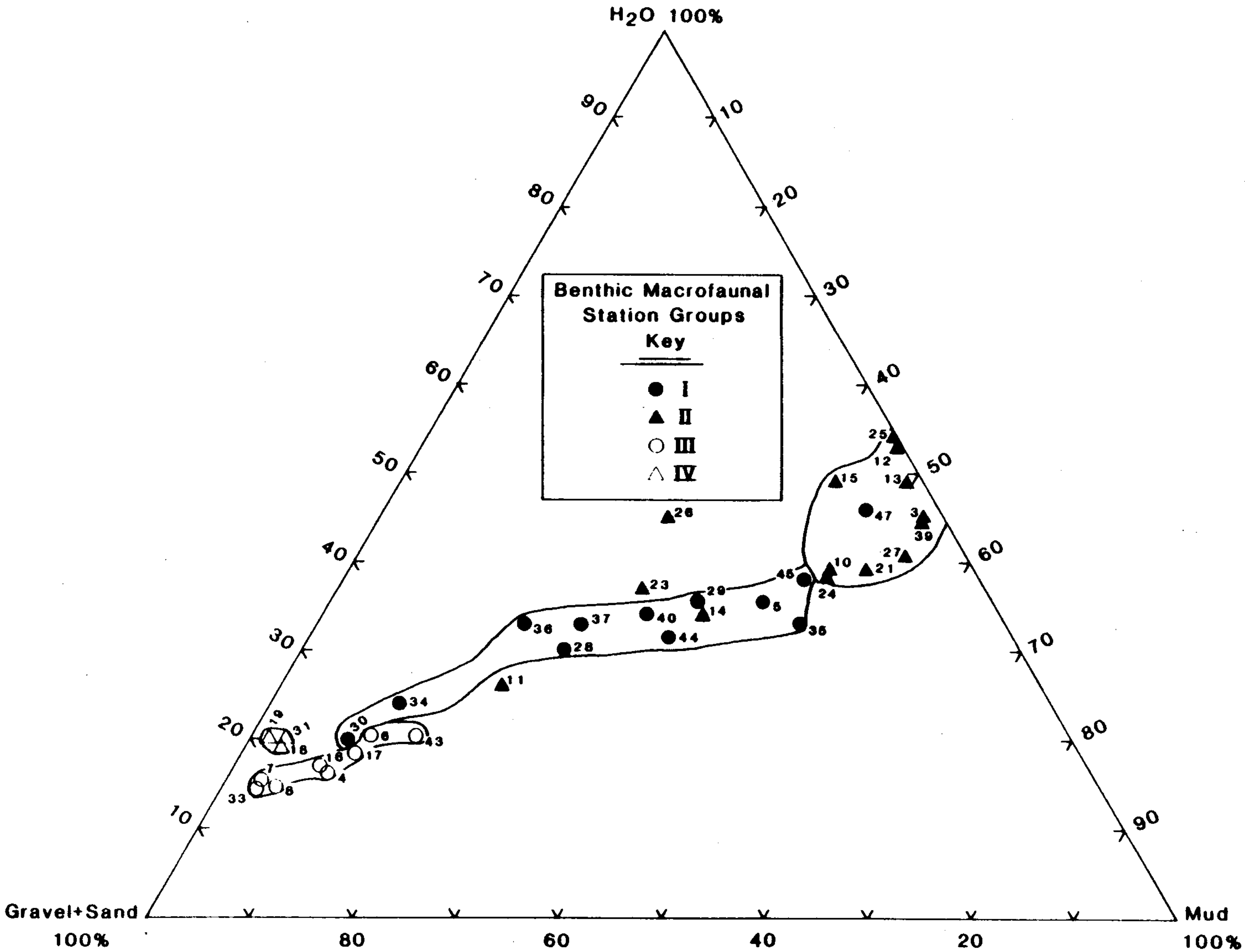

Figure 61. Ternary diagram relating stations (CH) to station groups based on % water, gravel, sand, silt, and clay (see Figs. 74 and 78).

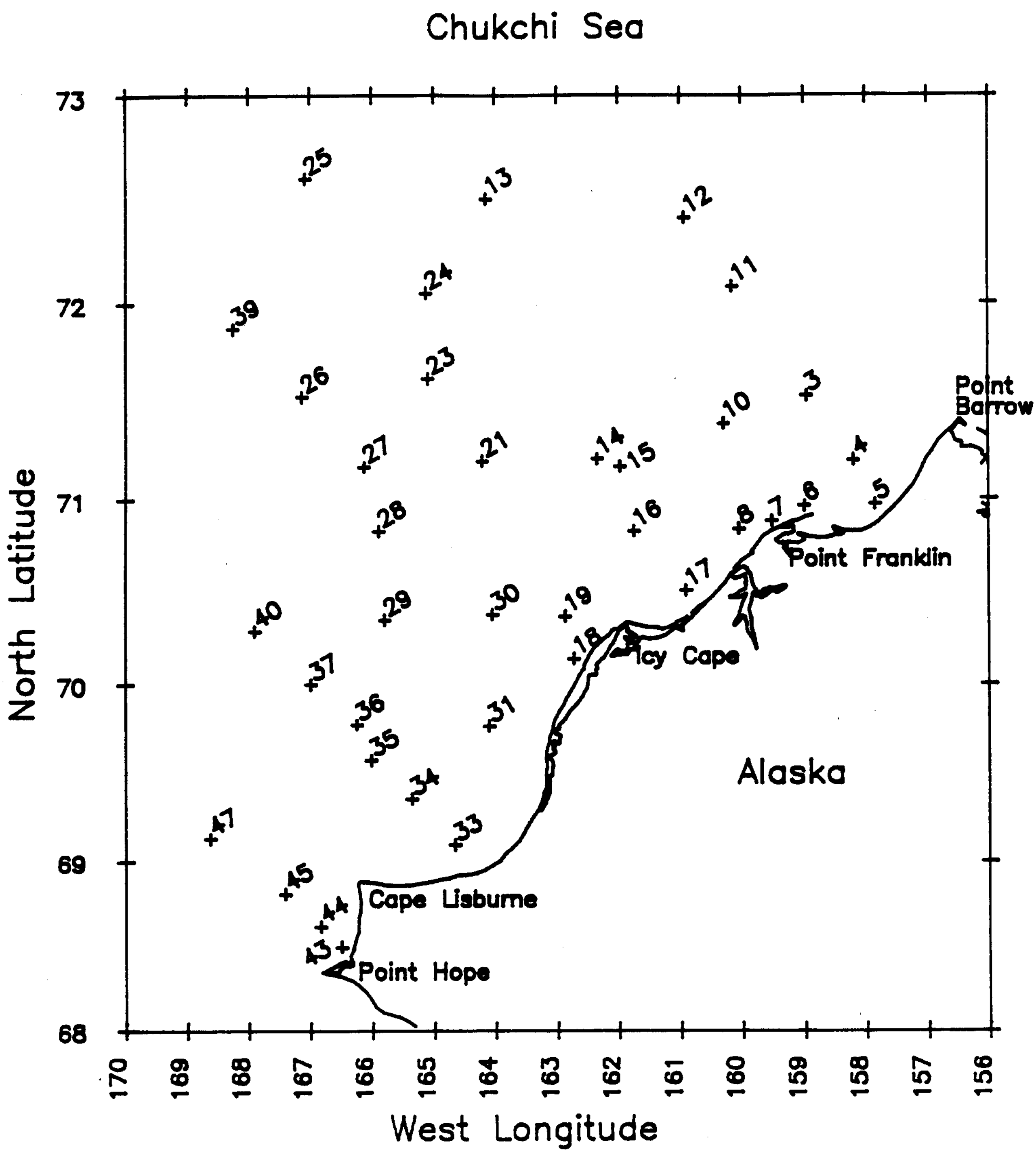

Figure 62. Stations (CH) where benthic biological (van Veen grab) samples were collected in the northeastern Chukchi Sea, August-September 1986. All station names are to be preceded by CH (e.g., CH3, CH4, CH5, etc.).

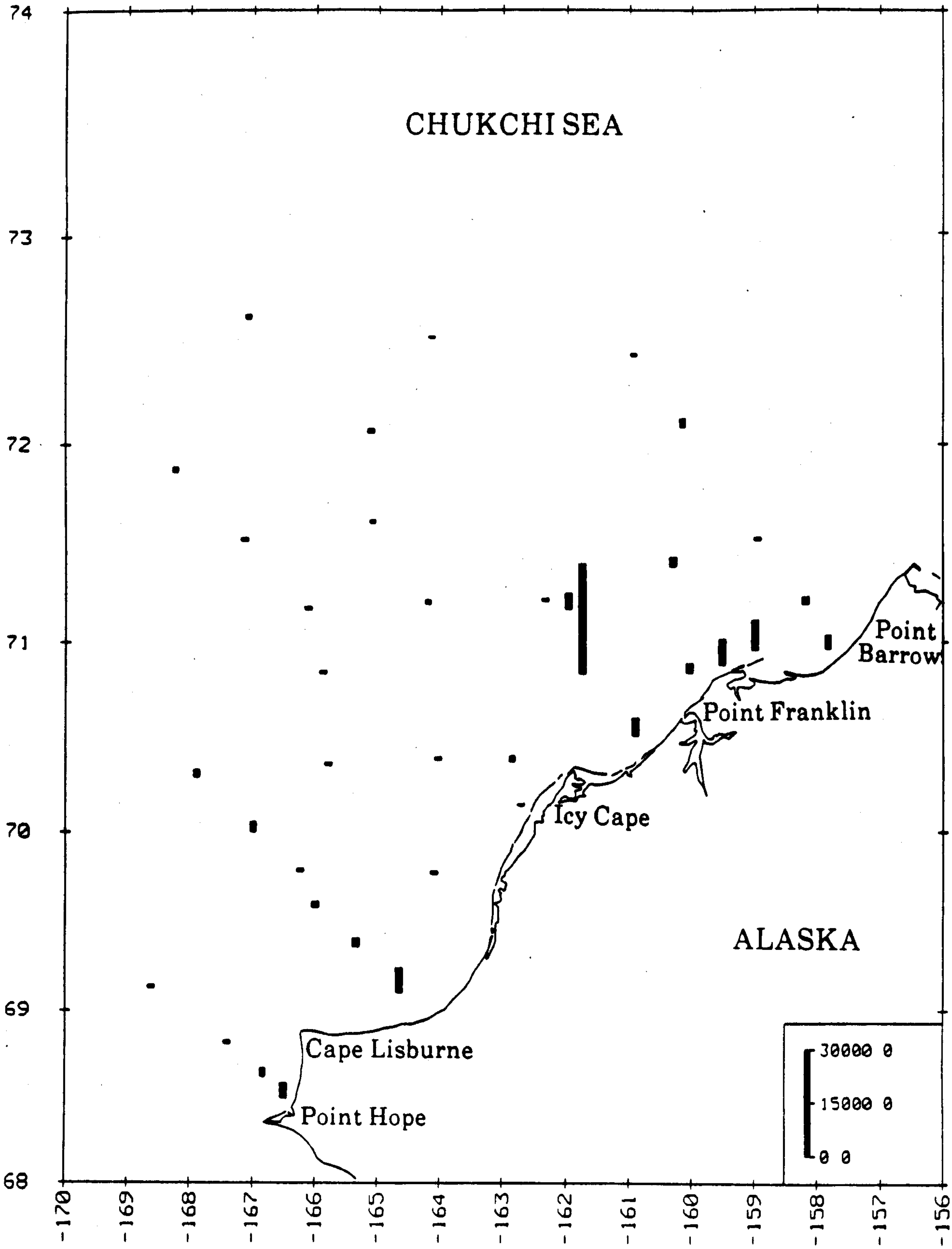

Figure 63. The abundance (indiv./m^2) of benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

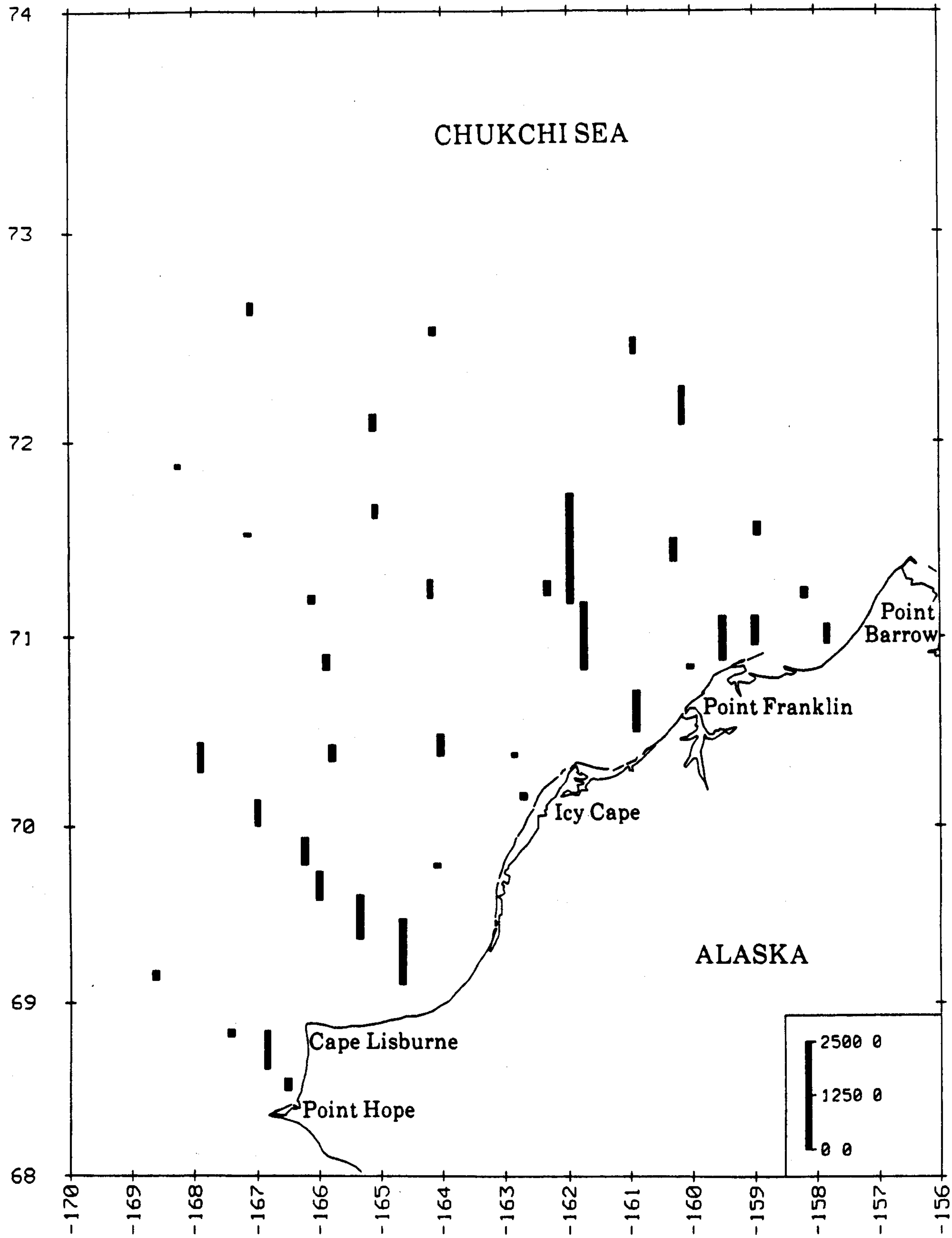

Figure 64. The abundance (indiv./m^2) of polychaetous annelids at stations occupied in the northeastern Chukchi Sea, August-September 1986.

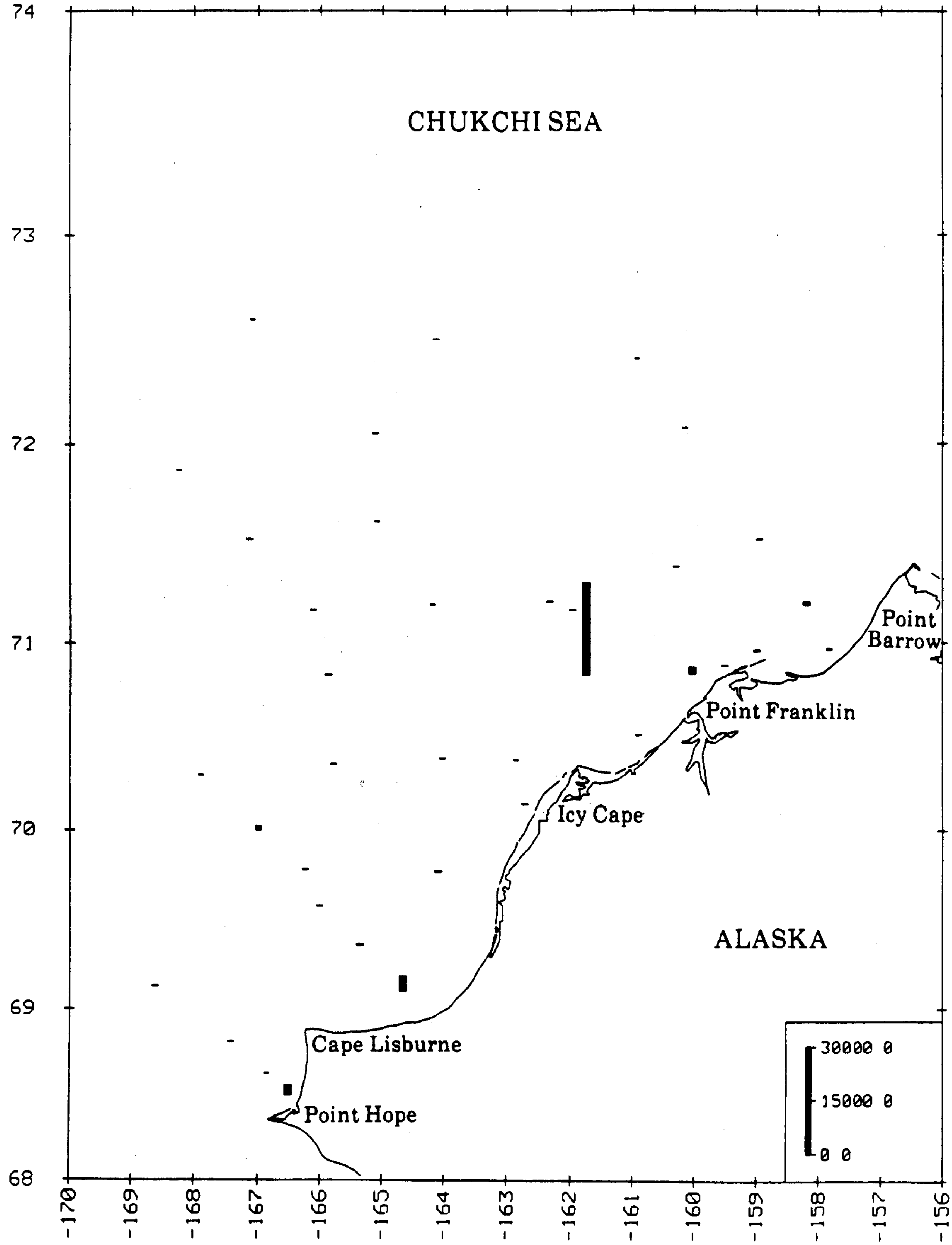

Figure 65. The abundance (indiv./m^2) of barnacles (*Balanus* sp.) at stations occupied in the northeastern Chukchi Sea, August-September 1986.

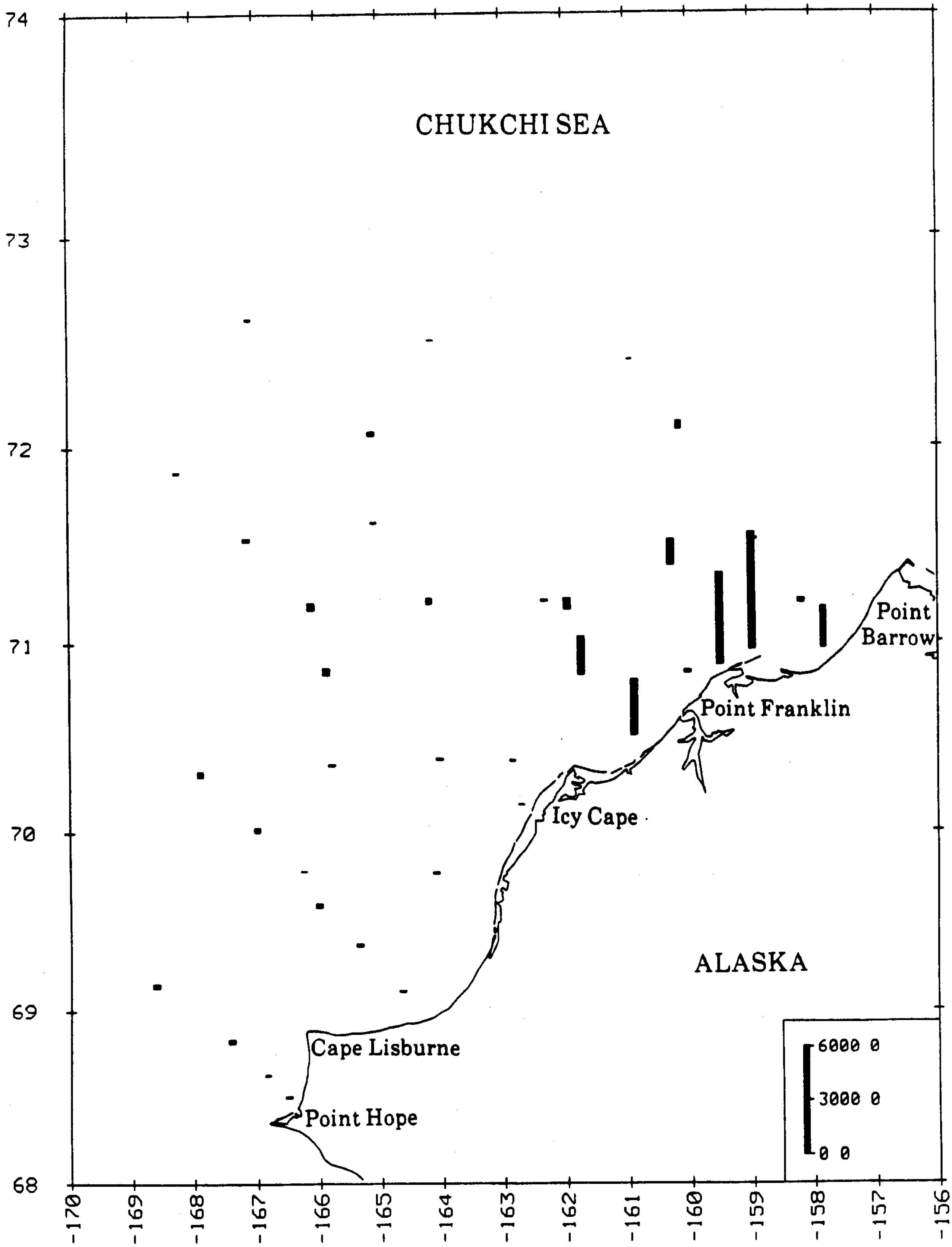

Figure 66. The number (indiv./m^2) of amphipods at stations occupied in the northeastern Chukchi Sea, August-September 1986.

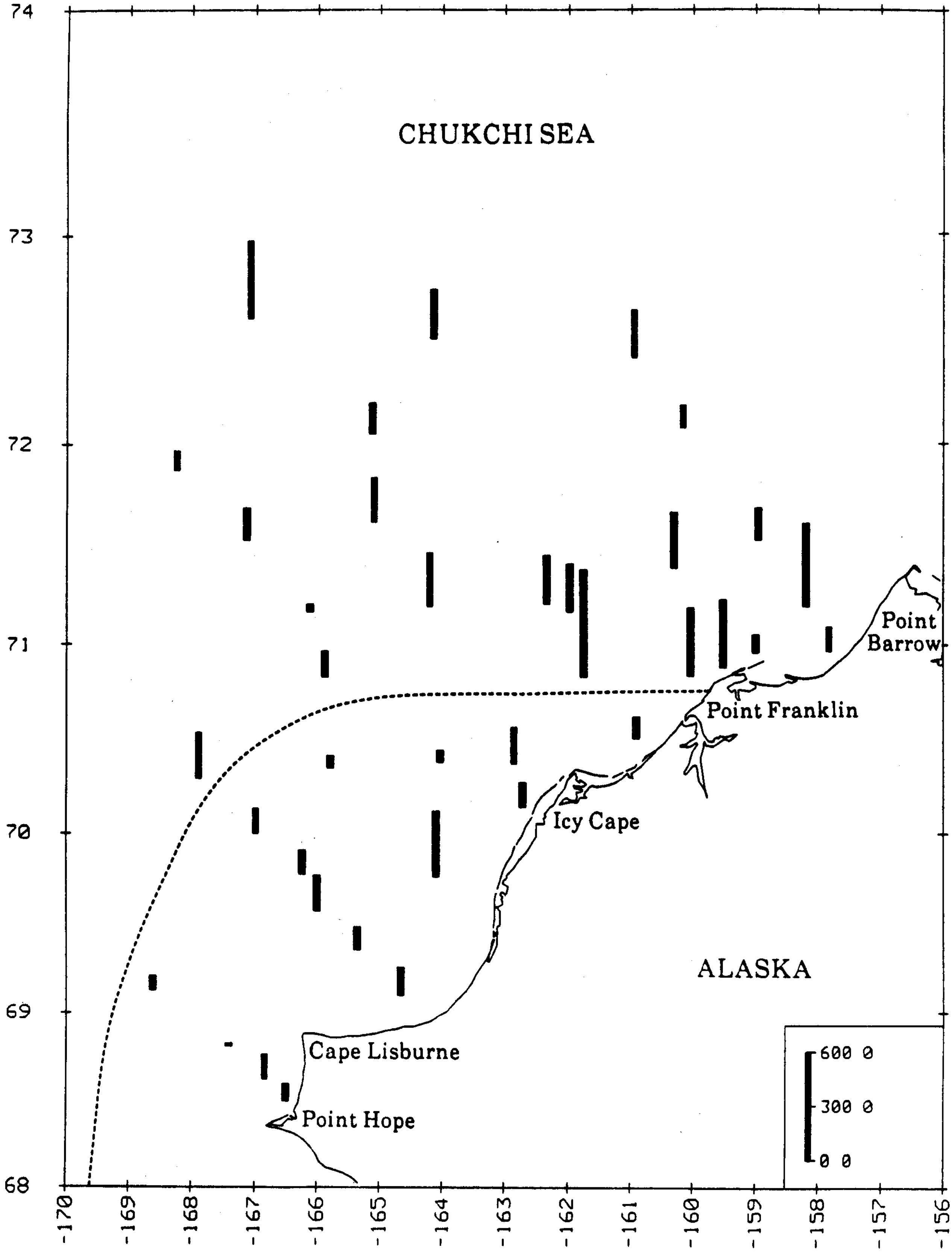

Figure 67. Distribution of wet weight biomass (g/m^2) at stations occupied in the northeastern Chukchi Sea, August-September 1986. The frontal zone (shown by the dashed line) presumably separates the mixed Bering Shelf/Anadyr Water in the west and north from the Alaska Coastal Water.

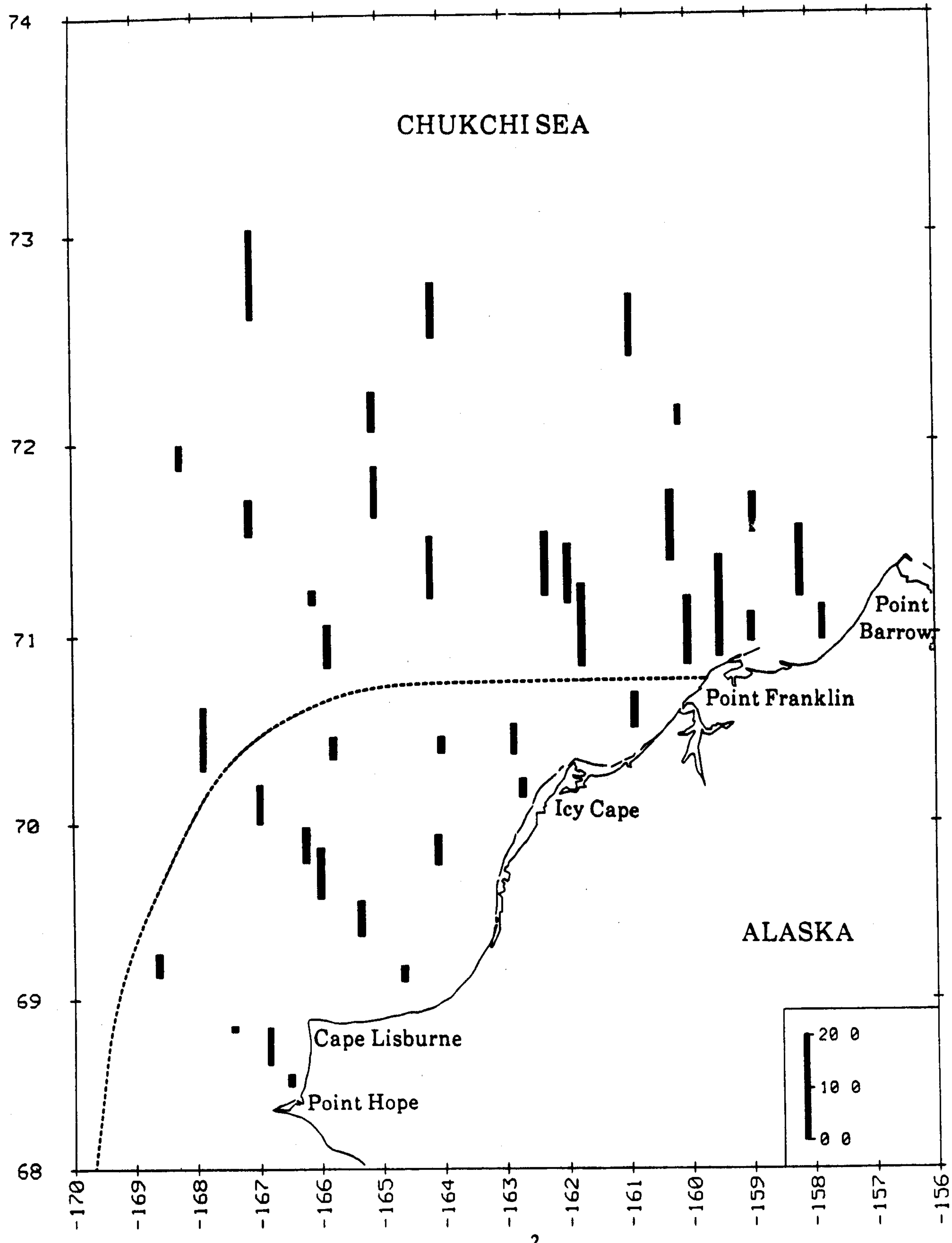

Figure 68. Distribution of biomass (gC/m^2) in the northeastern Chukchi Sea, August-September 1986. The frontal zone (shown by the dashed line) presumably separates the mixed Bering Shelf/Anadyr Water in the west and north from the Alaska Coastal Water.

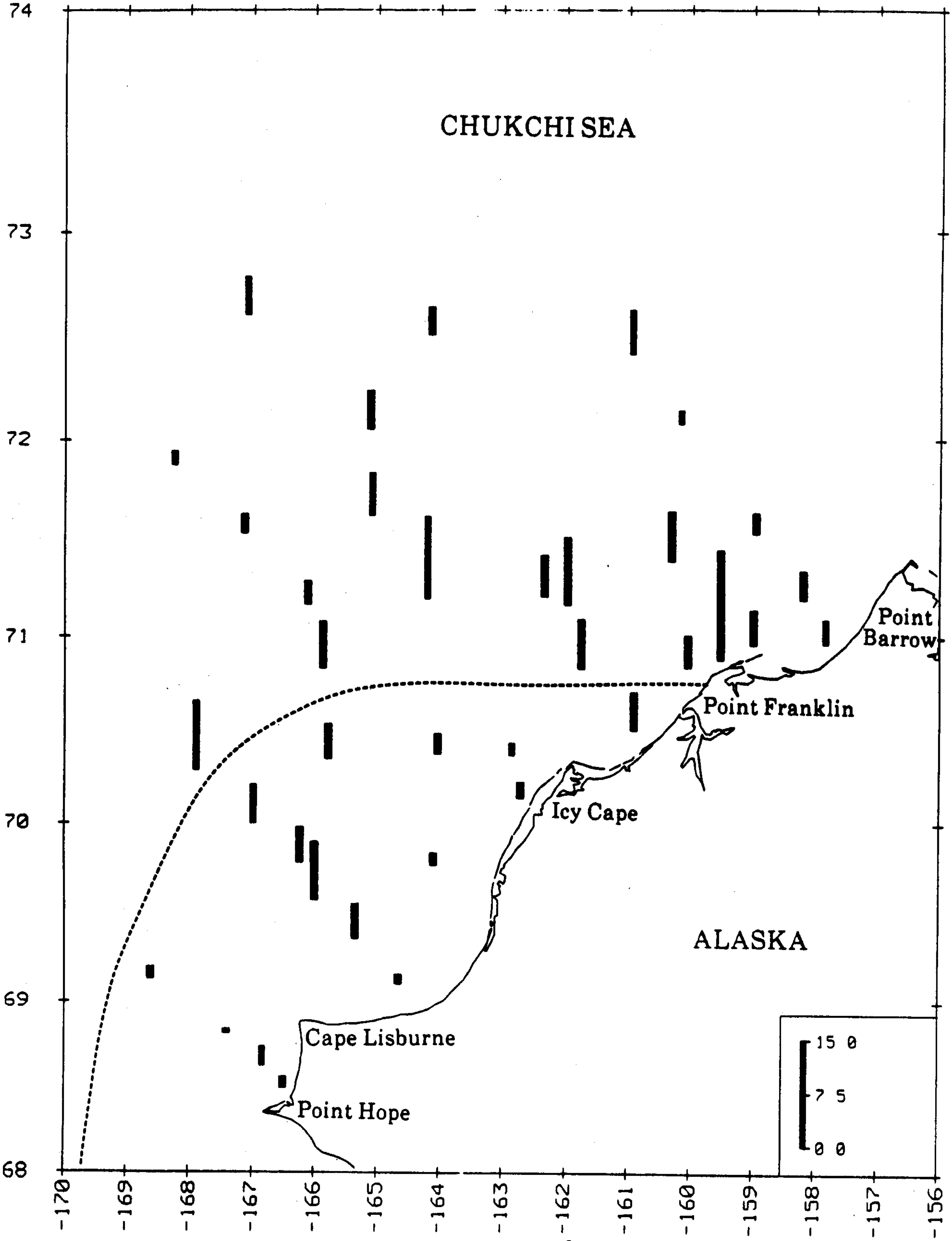

Figure 69. Carbon production estimates (gC/m^2/yr) for the 37 stations occupied in the northeastern Chukchi Sea, August-September 1986. The frontal zone (shown by the dashed line) presumably separates the mixed Bering Shelf/Anadyr Water in the west and north from the Alaska Coastal Water.

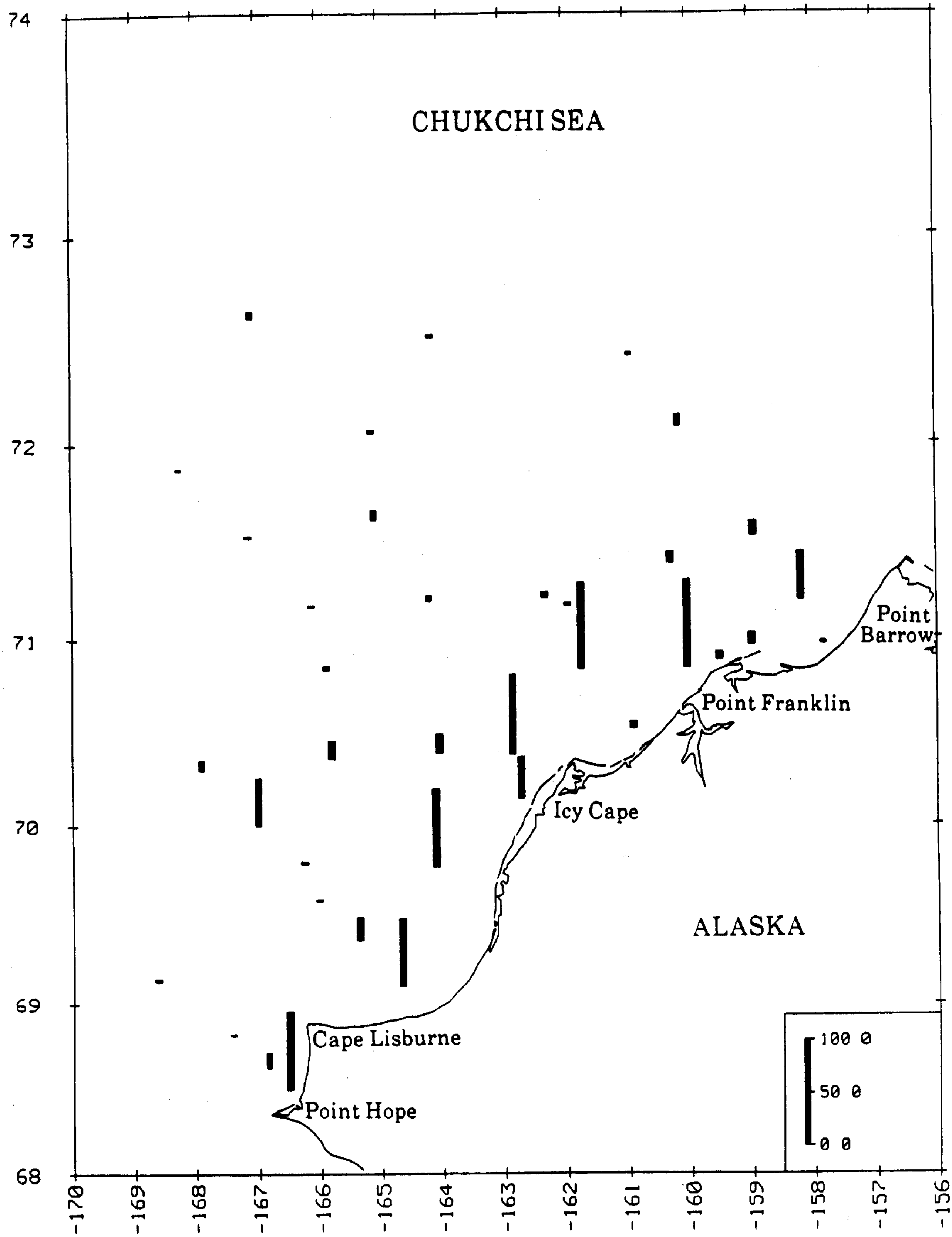

Figure 70. The percent abundance of suspension-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

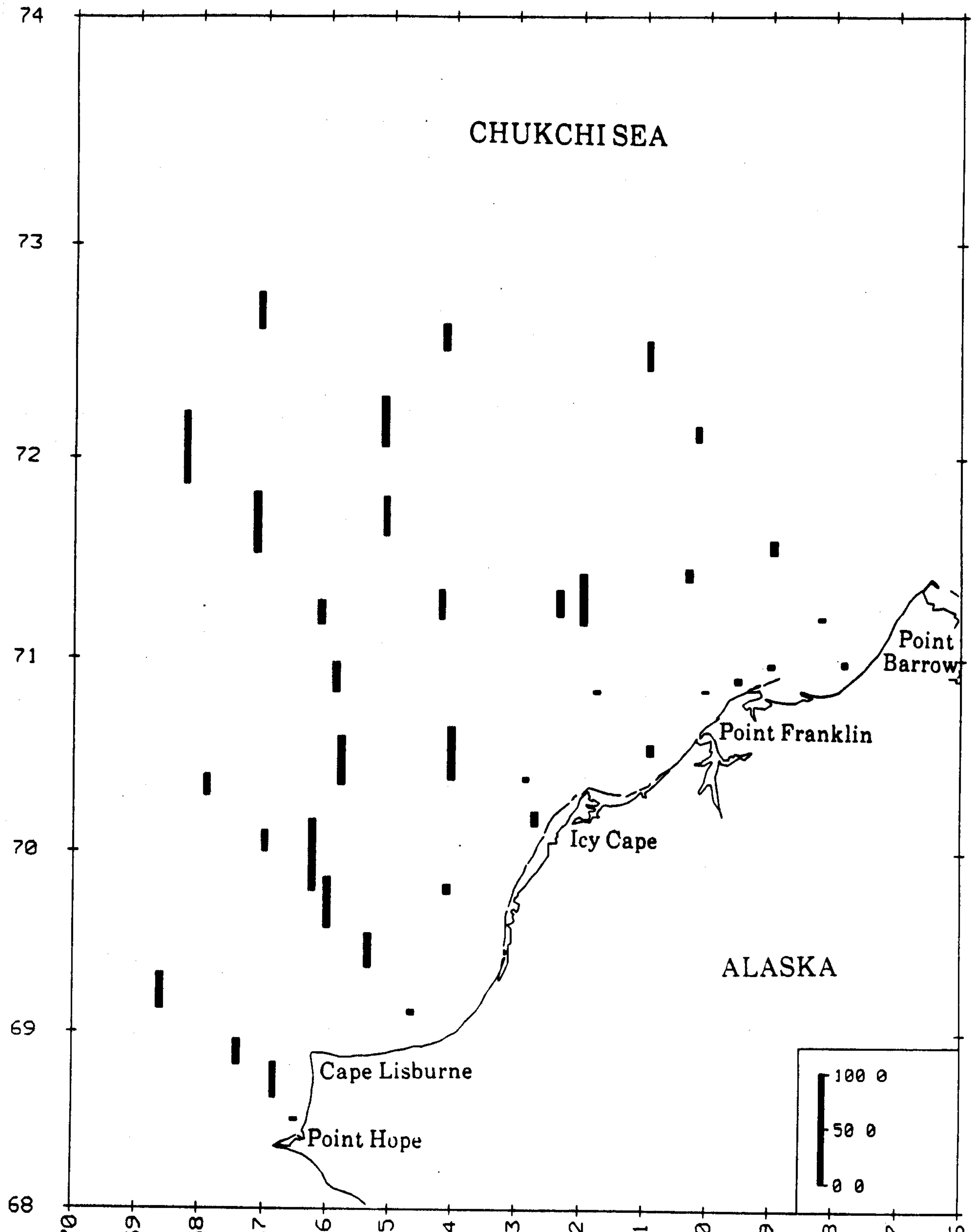

Figure 71. The percent abundance of subsurface deposit-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

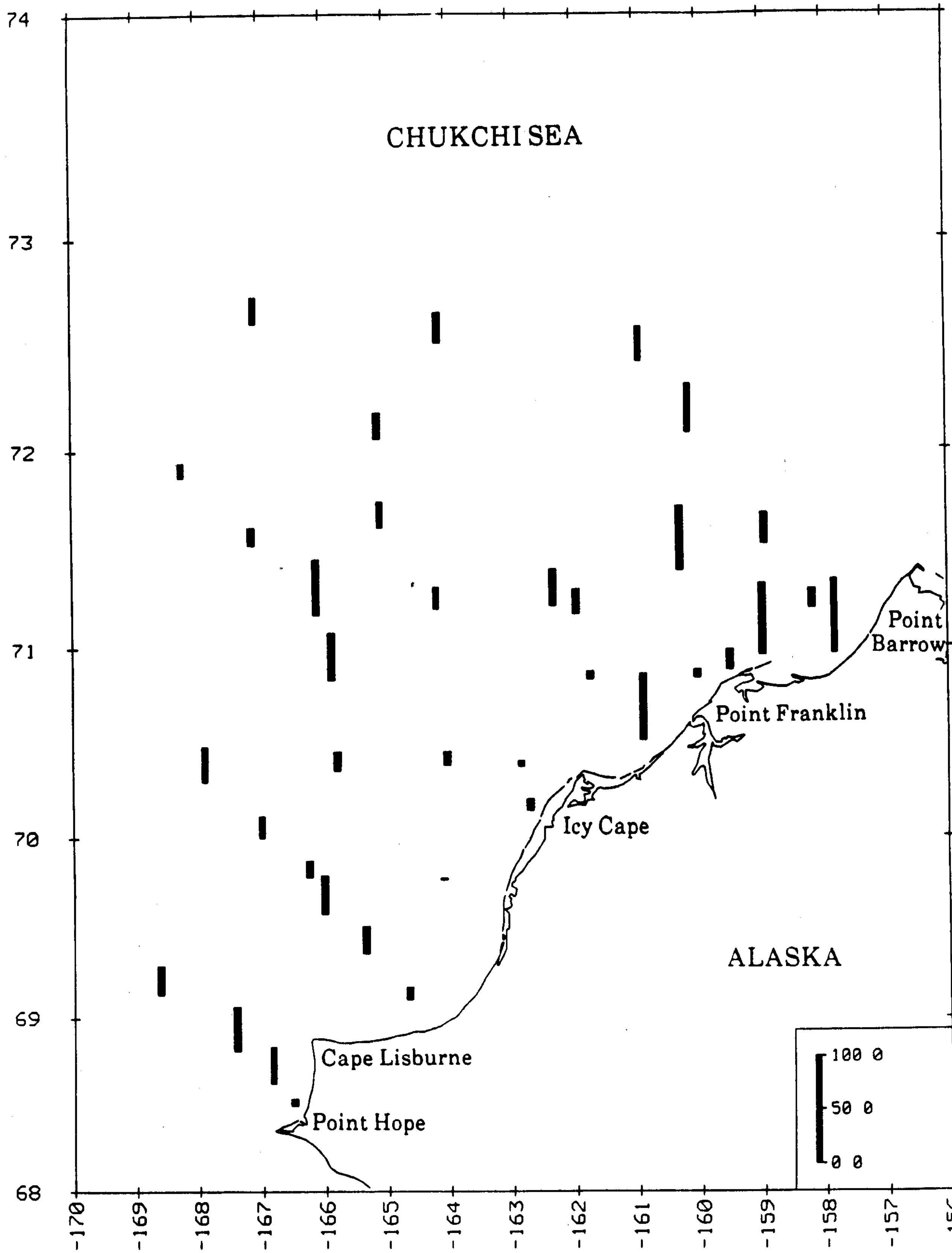

Figure 72. The percent abundance of surface deposit-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

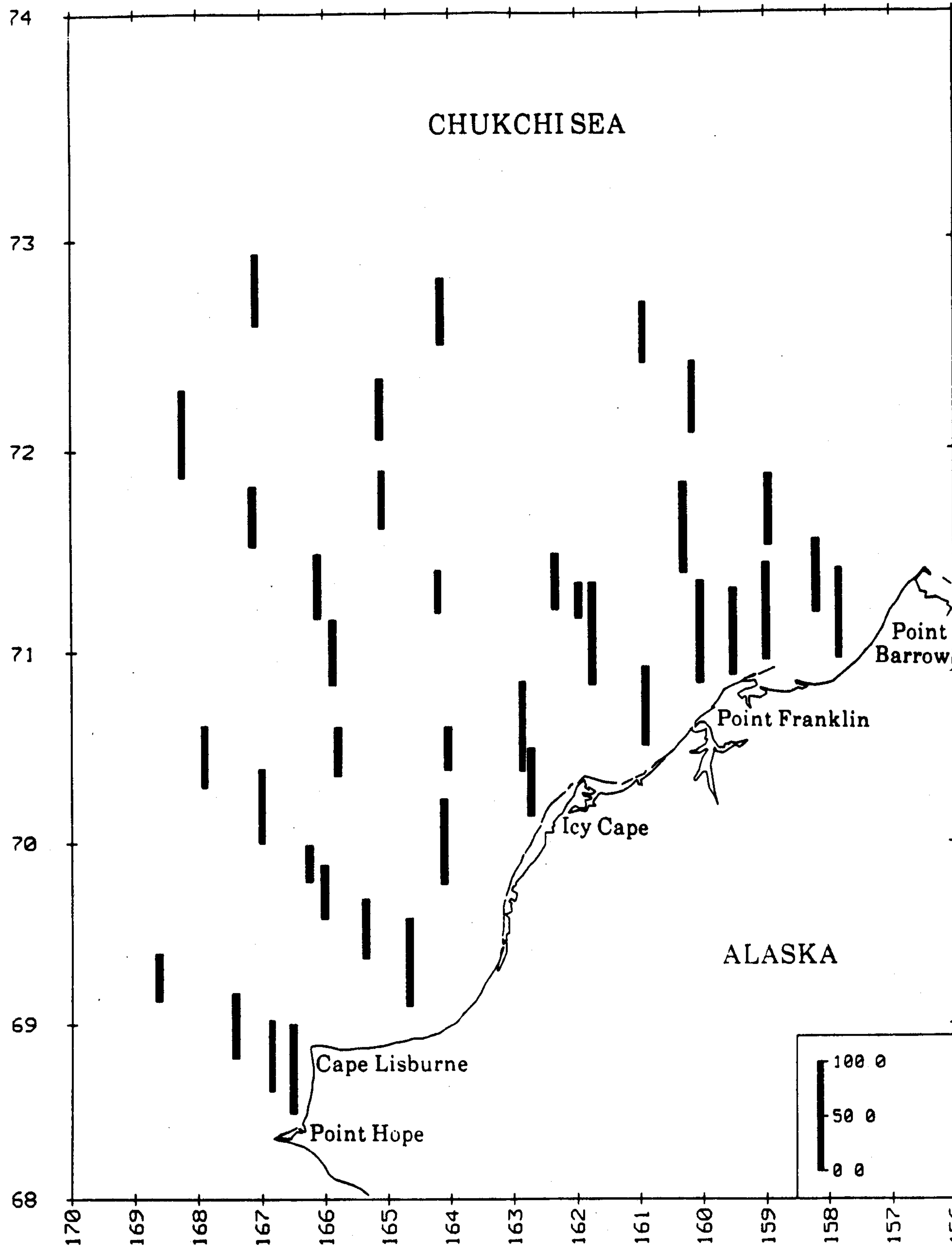

Figure 73. The percent abundance of interface-feeding (SDF+SF) benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

Table 13. Number of species (taxa), diversity indices, Shannon evenness, and species richness for benthic macrofauna collected at 37 benthic stations by van Veen grab in the eastern Chukchi Sea aboard the NOAA R/V *Oceanographer*, August/September 1986, Cruise OC862. Fragments and taxa excluded from cluster analysis (presented later) are not included in any computation.

Station Name	No. of Taxa	DIVERSITY Simpson	DIVERSITY Shannon	Shannon Evenness	Species Richness
CH3	61	0.07	3.27	0.80	8.98
CH4	68	0.19	2.57	0.61	9.21
CH5	74	0.18	2.40	0.56	9.09
CH6	101	0.22	2.52	0.55	11.42
CH7	123	0.26	2.50	0.52	13.76
CH8	40	0.65	1.07	0.29	4.99
CH10	79	0.11	2.88	0.66	9.97
CH11	87	0.04	3.71	0.83	11.47
CH12	46	0.09	2.90	0.76	6.81
CH13	35	0.14	2.52	0.71	5.57
CH14	61	0.04	3.49	0.85	9.19
CH15	107	0.19	2.73	0.58	12.68
CH16	143	0.70	1.10	0.22	13.72
CH17	91	0.22	2.61	0.58	10.63
CH18	29	0.19	2.35	0.70	4.61
CH19	43	0.28	1.94	0.52	5.70
CH21	60	0.09	2.98	0.73	8.52
CH23	52	0.06	3.30	0.84	8.04
CH24	54	0.09	3.03	0.76	7.48
CH25	45	0.12	2.64	0.69	6.40
CH26	37	0.21	2.38	0.66	5.86
CH27	48	0.09	2.99	0.77	7.14
CH28	55	0.08	3.12	0.78	7.93
CH29	52	0.06	3.25	0.82	7.82
CH30	40	0.13	2.70	0.73	5.86
CH31	23	0.28	1.73	0.55	3.40
CH33	72	0.44	1.65	0.39	8.08
CH34	53	0.11	2.73	0.69	6.79
CH35	45	0.08	2.89	0.76	6.14
CH36	45	0.14	2.65	0.70	6.37
CH37	70	0.19	2.58	0.61	8.87
CH39	31	0.44	1.62	0.47	4.36
CH40	94	0.04	3.72	0.82	12.44
CH43	37	0.39	1.52	0.42	4.40
CH44	39	0.13	2.56	0.70	4.98
CH45	35	0.12	2.69	0.76	5.21
CH47	28	0.11	2.54	0.76	4.31

Table 14. Mean (±one standard deviation) abundance, carbon biomass, carbon production, carbon requirements, $\delta^{13}C$, and OC/N of benthic organisms at station north and south of the postulated front in the eastern Chukchi Sea. Data collected by van Veen grab, August/September 1986. Fragments are not included in the abundance computations, but are included in all other computations.

	Abundance (indiv/m^2)	Wet Weight Biomass (g/m^2)	Carbon Biomass (gC/m^2)	Carbon Production (gC/m^2/yr)	Carbon Required (gC/m^2/yr) 10% TE	20% TE	$\delta^{13}C$	OC/N
Northern CH Stations								
3,4,5,6, 7,8,10,11, 12,13,14,15, 16,21,23,24, 25,26,27,28, 39,40	3486 (6635) N=22	258 (136) N=22	10.16 (4.33) N=22	5.9 (3.3) N=22	59 (33) N=22	30 (16) N=22	-20.9 (1.89) N=14	8.9 (2.3) N=22
Southern CH Stations								
17,18,19,29, 30,31,33,34, 35,36,37,43, 44,45,47	1705 (1364) N=15	139 (79) N=15	5.05 (2.32) N=15	3.4 (2.1) N=15	34 (21) N=15	17 (11) N=15	-22.2 (0.78) N=7	10.3 (3.6) N=15

Table 15. Trophic structure, based on taxon abundance, for each station in the eastern Chukchi Sea, August-September 1986. SDF=surface deposit feeder, SSDF=subsurface deposit feeder, CARN=predator, SCAV=scavenger, HERB=herbivore, SF=suspension feeder.

BASED ON ABUNDANCE

STA #	SDF Number	SDF %	SSDF Number	SSDF %	CARN Number	CARN %	SCAV Number	SCAV %	HERB Number	HERB %	SF Number	SF %	UNKNOWN Number	UNKNOWN %	TOTAL # OF IND
CH3	253.3	30.23	108.7	12.97	141.4	16.88	46.8	5.59	57.6	6.88	206.2	24.60	24.0	2.86	838.0
CH4	283.5	17.81	34.0	2,14	234.3	14.72	224.3	14.09	28.3	1.78	777.7	48.85	10.0	0.63	1592.0
CH5	2531.6	69.24	145.3	3.98	110.1	3.01	425.8	11.65	16.0	0.44	417.2	11.41	10.0	0.27	3656.0
CH6	5632.5	66.48	350 0	4.13	296.4	3.50	879.8	10.38	464.1	5.48	805.2	9.50	44.0	0.52	8472.0
CH7	1471.7	19.67	370.0	4.95	541.4	7.24	2321.0	31.02	1877.7	25.10	704.2	9.41	196.0	2.62	7482.0
CH8	193.3	7.71	28.0	1.12	85.3	3.40	51.7	2.06	13.7	0.54	2114.0	84.29	22.0	0.88	2508.0
CH10	1842.7	63.28	365.3	12.55	175.7	6.03	198.5	6.82	83.9	2.88	223.8	7.69	22.0	0.76	2912.0
CH11	857.5	44.62	263 3	13 70	251.9	13.11	185.3	9.64	31.0	1.61	299.0	15.56	34.0	1.77	1922.0
CH12	255.8	33.74	210 0	27.70	112.6	14.86	27.3	3.61	45.8	6.04	94.5	12.47	12.0	1.58	758.0
CH13	130.6	28.76	114.0	25.11	75.5	16.62	24.2	5.32	31.3	6.89	72.5	15.97	6.0	1.32	454.0
CH14	264.6	36.45	187 3	25.80	87.1	12.00	49.5	6.81	30.1	4.15	53.3	7.35	54.0	7.44	726.0
CH15	1002.8	22.83	2101.3	47.84	422.6	9.62	403.3	9.18	142.6	3.25	231.5	5.27	88.0	2.00	4392.0
CH16	2700.6	8.55	1000.0	3.17	475.3	1.51	721.0	2.28	47.3	0.15	26569.8	84.15	62.0	0.20	31576.0
CH17	3184.8	63.72	537.9	10.76	315.1	6.31	420.5	8.41	25.3	0.51	478.3	9.57	36.0	0.72	4998.0
CH18	49.4	10.68	62.0	13.42	58.3	12.62	52.3	11.33	2.0	0.43	218.0	47.18	20.0	4.33	462.0
CH19	98.7	6.08	70 7	4 36	89.7	5.53	70.3	4.34	6.0	0.37	1272.7	78.46	14.0	0.86	1622.0
CH21	241.8	21.10	309.3	26.99	175.0	15.27	146.7	12.80	57.1	4.99	74.0	6.46	142.0	12.39	1146.0
CH23	154.4	25.07	221.3	35 93	72.0	11.68	39.6	6.44	23.8	3.87	74.8	12.15	30.0	4.87	616.0
CH24	314.2	24.74	588.0	46.30	103.1	8.12	50.8	4.00	17.3	1.36	108.5	8.54	88.0	6.93	1270 0
CH25	235.5	24.18	334.0	34.29	118.3	12.14	69.3	7.12	40.0	4.10	167.0	17.15	10.0	1.03	974.0
CH26	93.4	16.55	322 0	57.09	57.3	10.16	29.0	5.14	5.3	0.95	47.0	8.33	10.0	1.77	564.0
CH27	413.1	53.51	176.0	22.80	96.0	12.43	56.6	7.34	5.3	0.69	21.0	2.72	4.0	0.52	772.0
CH28	465.2	46.80	280.7	28.24	90.5	9.10	81.1	8.16	11.8	1.19	50.7	5.10	14.0	1.41	994.0
CH29	139.5	19.01	336 0	45.78	59.5	8.10	58.2	7.92	3.3	0.45	121.5	16.55	16.0	2.18	734.0
CH30	106.4	13.13	405.3	50.04	74.0	9.13	58.3	7.20	3.7	0.45	152.3	18.81	10.0	1.23	810.0

Table 15. (continued)

BASED ON ABUNDANCE

STA	SDF		SSDF		CARN		SCAV		HERB		SF		UNKNOWN		TOTAL #
#	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	OF IND.
CH31	8.3	1.19	61.3	8.74	44.0	6.27	32.3	4.61	1.7	0.24	518.3	73.84	36.0	5.13	702.0
CH33	826.5	11.83	437.3	6.26	397.6	5.69	343.6	4.92	53.8	0.77	4769.1	68.25	160.0	2.29	6988.0
CH34	586.9	25.56	724.0	31.53	172.6	7.52	152.9	6.66	4.7	0.20	515.0	22.43	140.0	6.10	2296.0
CH35	486.0	36.60	640.0	48.19	84.0	6.32	57.0	4.29	6.0	0.45	33.0	2.48	22.0	1.66	1328.0
CH36	162.2	15.54	718.0	68.77	57.1	5.47	50.8	4.87	3.3	0.32	32.5	3.11	20.0	1.92	1044.0
CH37	485.9	18.94	490.0	19.10	196.3	7.65	210.0	8.18	12.8	0.50	1127.0	43.92	44.0	1.71	2566.0
CH39	139.0	13.09	720.0	67.80	63.7	5.99	21.3	2.01	8.0	0.75	52.0	4.90	58.0	5.46	1062.0
CH40	702.5	34.88	390.0	19.36	193.9	9.63	301.9	14.99	17.7	0.88	322.0	15.99	86.0	4.27	2014.0
CH43	245.8	6.24	78.7	2.00	333.0	8.45	323.3	8.21	6.7	0.17	2940.7	74.67	10.0	0.25	3938.0
CH44	816.5	35.20	785.9	33.88	64.3	2.77	54.7	2.36	0.7	0.03	453.9	19.57	144.0	6.21	2320.0
CH45	352.4	42.56	206.7	24.96	76.7	9.26	57.7	6.96	23.0	2.78	39.7	4.79	72.0	8.70	828.0
CH47	180.2	28.51	218.0	34.49	48.1	7.62	61.1	9.68	0.5	0.08	30.0	4.75	94.0	14.87	632.0

at the nearshore stations (see Fig. 62), while the highest values for subsurface deposit feeders generally occurred offshore. Surface deposit feeders were variably common at inshore and offshore stations. A high percentage of interface feeders (surface deposit feeders + suspension feeders) occurred at all stations (Fig. 73). Generally, a high percentage, by abundance, of sessile organisms were found nearshore with more motile individuals generally occurring offshore (Table 16; Figure 62). Details of the fauna comprising the various feeding groups and motility types are considered by Station Group in the section below entitled "Dominant Taxa, Trophic Structure and Motility of Taxa within Cluster Groups" (page 157).

4. Numerical Analysis

A cluster analysis of the abundance data from 37 stations delineated four cluster (station) groups (Fig. 74). The dominant fauna characterizing each of the cluster groups, ranked by abundance within each cluster group, is presented in Table 17. The percent occurrence (Fidelity) of each of the dominant taxa at stations comprising the cluster groups is also included in this table.

The results of the principal coordinate analysis of abundance data are shown in Figures 75-77. The stations in Cluster Groups I and IV form relatively tight groupings on the plots of the first and second, and the first and third coordinate axes. Stations in Groups II and III are best separated on the plot of the first and third coordinate axes. Stations in Cluster Groups I and II are separated on the plot of the first and second coordinate axes. Although Station CH5 is located along the coast and north of all of the other stations in Group I, it joins this group at a relatively high level of similarity in the cluster analysis. Further, Station CH5 is closely associated with Group I on the plots of the first and second and the

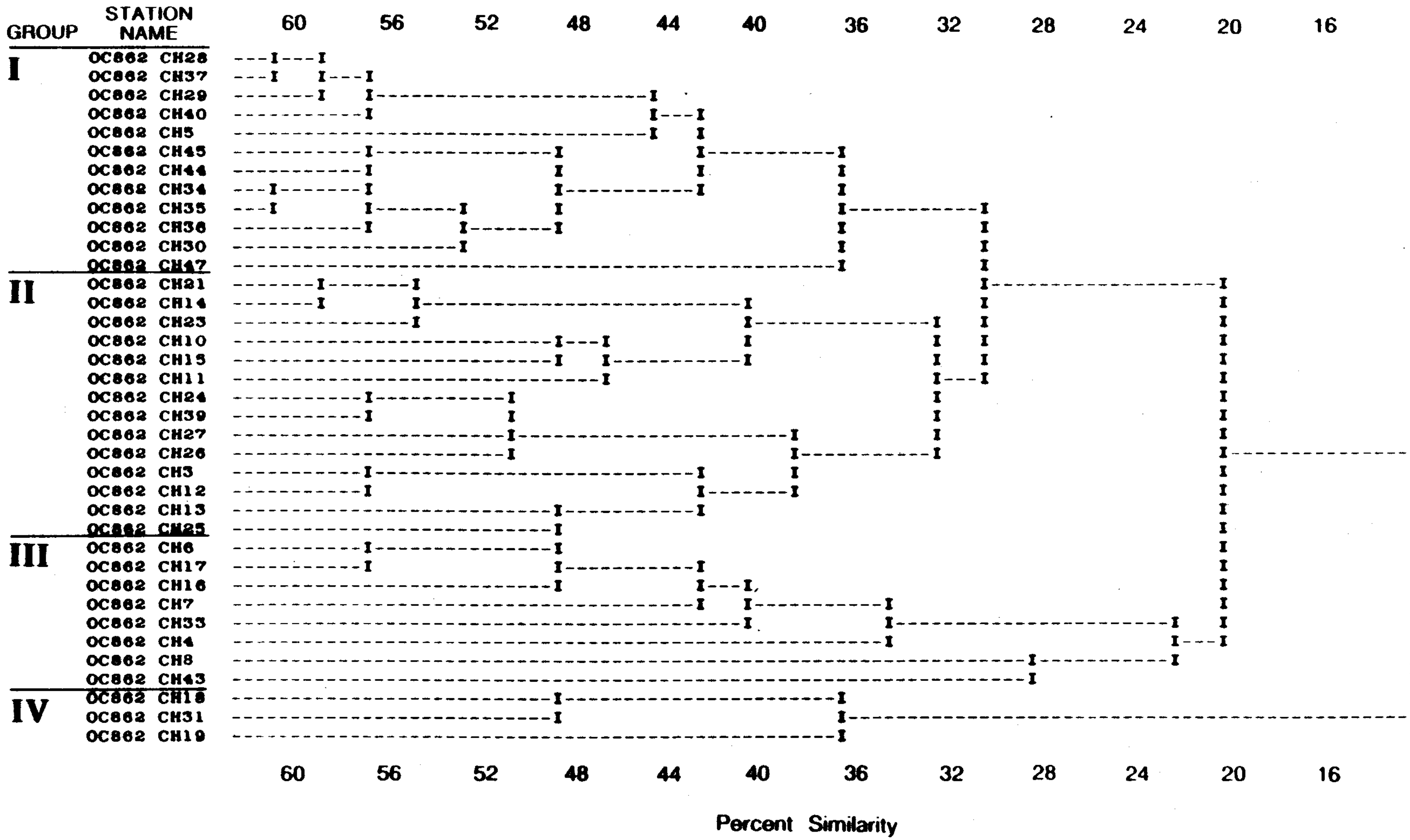

Figure 74. Dendrogram resulting from a hierarchical cluster analysis of benthic abundance data at 37 stations occupied in the northeastern Chukchi Sea, August-September 1986.

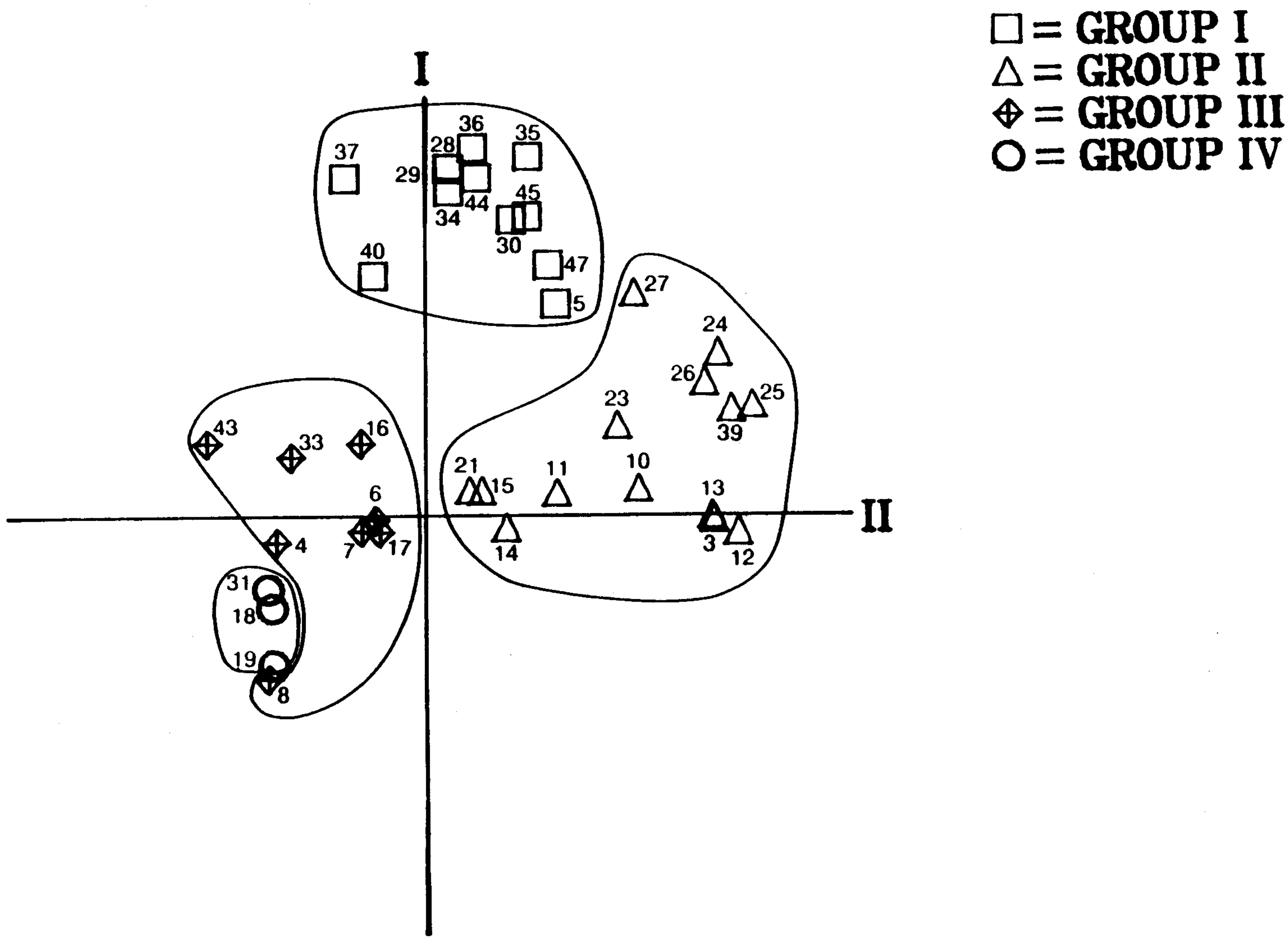

Figure 75. Plot of loadings on coordinate axes one and two of a Principal Coordinate Analysis of benthic data at stations occupied in the northeastern Chukchi Sea, August-September 1986. Station groups determined by multivariate analyses are differentiated by symbols and by lines circumscribing each group.

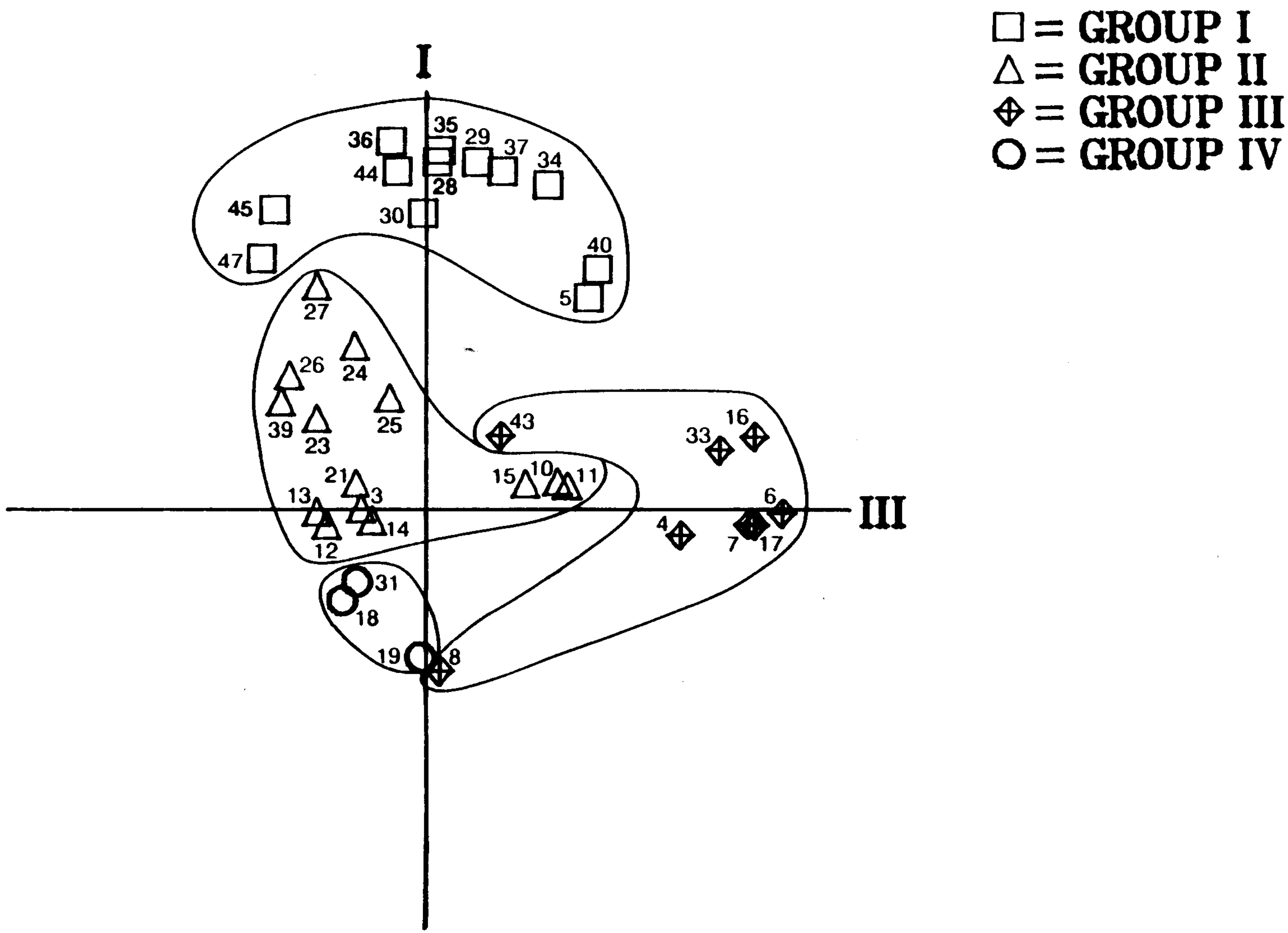

Figure 76. Plot of loadings on coordinate axes one and three of a Principal Coordinate Analysis of benthic data at stations occupied in the northeastern Chukchi Sea, August-September 1986. Station groups determined by multivariate analysis are differentiated by symbols and by lines around each group.

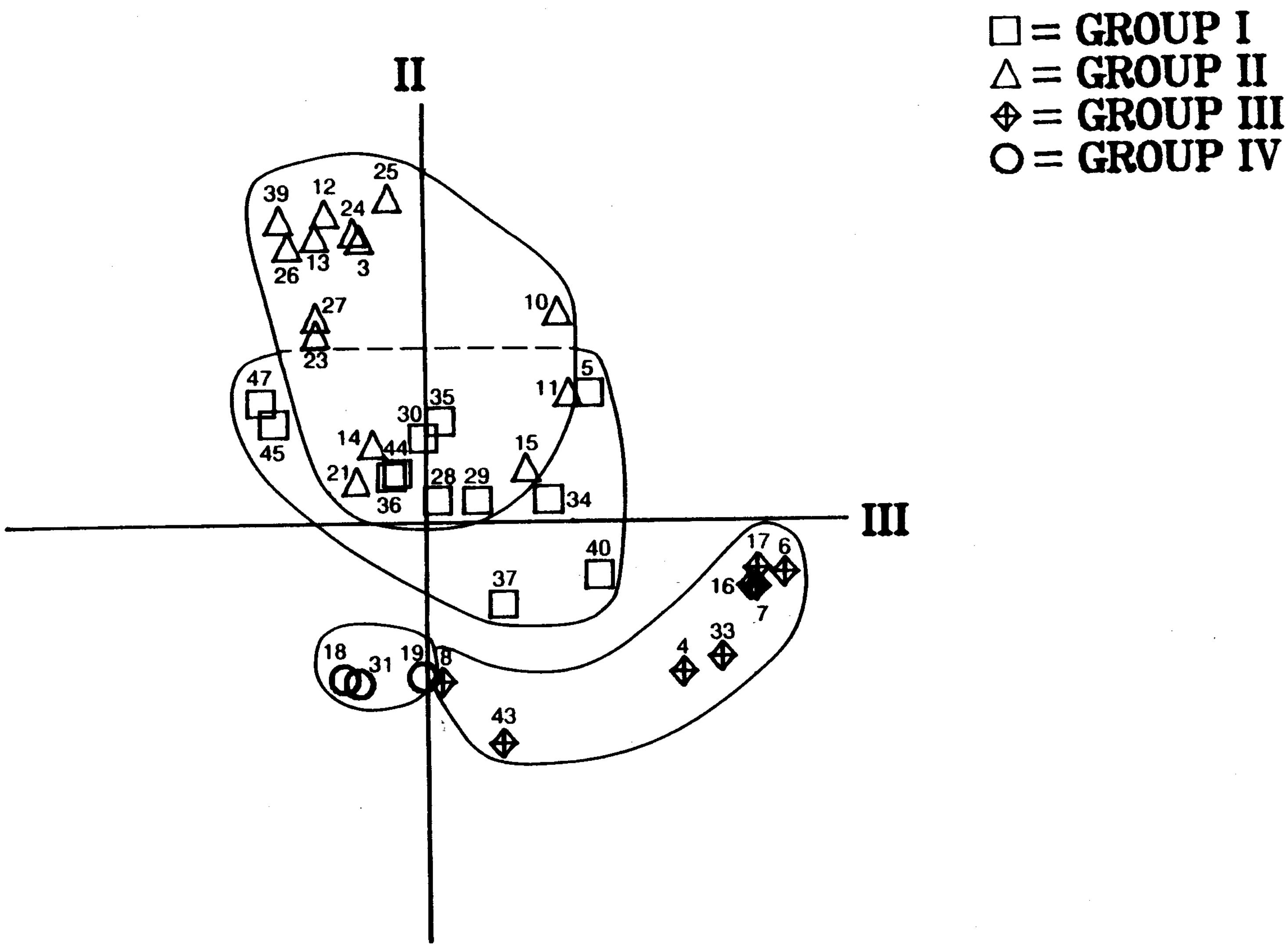

Figure 77. Plot of loadings on coordinate axes two and three of a Principal Coordinate Analysis of benthic data at stations occupied in the northeastern Chukchi Sea, August-September 1986. Station groups determined by multivariate analyses are differentiated by symbols and lines circumscribing each group.

Table 16. Motility types, based on taxon abundance for each station sampled in the eastern Chukchi Sea, August-September 1986. SESS=sessile, DM=discreetly motile, MOT=motile.

BASED ON ABUNDANCE

STAT NO	SESS Number	SESS %	DM Number	DM %	MOT Number	MOT %	MIXED Number	MIXED %	UNKNOWN Number	UNKNOWN %	TOTAL # OF INDIVIDUALS
CH3	217.7	25.98	210.7	25.14	385.7	46.02	0.0	0.00	24.0	2.86	838.0
CH4	857.5	53.86	179.2	11.26	545.2	34.25	0.0	0.00	10.0	0.63	1592.0
CH5	169.4	4.63	1868.3	51.10	1608.3	43.99	0.0	0.00	10.0	0.27	3656.0
CH6	839.5	9.91	2060.3	24.32	5528.3	65.25	0.0	0.00	44.0	0.52	8472.0
CH7	435.8	5.82	4855.6	64.90	1994.6	26.66	0.0	0.00	196.0	2.62	7482.0
CH8	2111.7	84.20	154.6	6.17	219.6	8.76	0.0	0.00	22.0	0.88	2508.0
CH10	174.1	5.98	2099.0	72.08	617.0	21.19	0.0	0.00	22.0	0.76	2912.0
CH11	499.5	25.99	485.3	25.25	903.3	47.00	0.0	0.00	34.0	1.77	1922.0
CH12	89.4	11.79	273.3	36.06	383.3	50.57	0.0	0.00	12.0	1.58	758.0
CH13	22.3	4.92	241.3	53.16	184.3	40.60	0.0	0.00	6.0	1.32	454.0
CH14	208.0	28.65	168.0	23.14	296.0	40.77	0.0	0.00	54.0	7.44	726.0
CH15	2134.4	48.60	533.3	12.14	1636.3	37.26	0.0	0.00	88.0	2.00	4392.0
CH16	26789.2	84.84	1381.9	4.38	3342.9	10.59	0.0	0.00	62.0	0.20	31576.0
CH17	524.1	10.49	2945.0	58.92	1493.0	29.87	0.0	0.00	36.0	0.72	4998.0
CH18	27.4	5.92	101.3	21.93	313.3	67.82	0.0	0.00	20.0	4.33	462.0
CH19	509.4	31.41	485.3	29.92	613.3	37.81	0.0	0.00	14.0	0.86	1622.0
CH21	262.7	22.92	169.7	14.80	571.7	49.88	0.0	0.00	142.0	12.39	1146.0
CH23	125.4	20.35	202.3	32.84	258.3	41.94	0.0	0.00	30.0	4.87	616.0
CH24	72.3	5.70	495.3	39.00	614.3	48.37	0.0	0.00	88.0	6.93	1270.0
CH25	70.7	7.26	495.7	50.89	397.7	40.83	0.0	0.00	10.0	1.03	974.0
CH26	14.7	2.60	328.7	58.27	210.7	37.35	0.0	0.00	10.0	1.77	564.0
CH27	48.7	6.31	377.7	48.92	341.7	44.26	0.0	0.00	4.0	0.52	772.0
CH28	133.7	13.45	406.6	40.91	439.6	44.23	0.0	0.00	14.0	1.41	994.0
CH29	230.7	31.43	167.7	22.84	319.7	43.55	0.0	0.00	16.0	2.18	734.0
CH30	178.4	22.02	193.3	23.87	428.3	52.88	0.0	0.00	10.0	1.23	810.0

Table 16. (continued)

BASED ON ABUNDANCE

STAT NO	SESS Number	SESS %	DM Number	DM %	MOT Number	MOT %	MIXED Number	MIXED %	UNKNOWN Number	UNKNOWN %	TOTAL # OF INDIVIDUALS
CH31	273.0	38.89	44.0	6.27	349.0	49.71	0.0	0.00	36.0	5.13	702.0
CH33	4733.5	67.74	664.3	9.51	1430.3	20.47	0.0	0.00	160.0	2.29	6988.0
CH34	617.8	26.91	424.6	18.49	1113.6	48.50	0.0	0.00	140.0	6.10	2296.0
CH35	95.4	7.18	388.3	29.24	822.3	61.92	0.0	0.00	22.0	1.66	1328.0
CH36	371.3	35.57	316.3	30.30	336.3	32.22	0.0	0.00	20.0	1.92	1044.0
CH37	1327.2	51.72	557.9	21.74	636.9	24.82	0.0	0.00	44.0	1.71	2566.0
CH39	20.7	1.95	769.7	72.47	213.7	20.12	0.0	0.00	58.0	5.46	1062.0
CH40	357.4	17.75	487.3	24.20	1083.3	53.79	0.0	0.00	86.0	4.27	2014.0
CH43	3187.1	80.93	249.4	6.33	491.5	12.48	0.0	0.00	10.0	0.25	3938.0
CH44	422.0	18.19	1018.0	43.88	736.0	31.72	0.0	0.00	144.0	6.21	2320.0
CH45	53.0	6.40	392.0	47.34	311.0	37.56	0.0	0.00	72.0	8.70	828.0
CH47	122.7	19.41	160.7	25.42	254.7	40.29	0.0	0.00	94.0	14.87	632.0

Table 17. Dominant (in terms of abundance) benthic fauna in four station cluster groups. Data collected by van Veen grab in the eastern Chukchi Sea aboard the NOAA R/V *Oceanographer*, Cruise OC862, August/September 1986.

Station Group	Stations in group	%[1] similarity	Dominant taxa	Abundance (indiv/m²)	% Occurrence[2] in group
I	28,37,29, 40,5,45, 44,34,35, 36,30,47	22	*Byblis gaimardi*	140	92
			Balanus crenatus (juv)	135	92
			Leitoscoloplos pugettensis	85	100
			Nucula bellotti	85	100
			Echiurus echiurus alaskensis	81	83
			Cirratulidae	73	100
			Brachydiastylis resima	72	50
			Barantolla americana	66	100
			Maldane glebifex	63	100
			Protomedeia spp.	56	83
			Byblis sp.	44	58
			Sternaspis scutata	42	75
			Thyasira gouldi	36	83
			Harpinia kobjakovae	23	67
			Leucon nasica	22	67
			Myriochele oculata	21	50
			Ampelisca macrocephala	21	67
II	21,14,23, 10,15,11, 24,39,27, 26,3,12, 13,25	32	*Nucula bellotti*	161	100
			Maldane glebifex	148	86
			Lumbrineris sp.	78	100
			Macoma calcarea	64	100
			Byblis breviramus	53	50
			Paraphoxus sp.	51	50
			Cirratulidae	33	93
			Ostracoda	33	57
			Barantolla americana	24	100
			Leitoscoloplos pugettensis	23	86
			Harpinia kobjakovae	21	64
			Haploops laevis	21	71
			Ophiura sarsi	19	50

(continued)

Table 17. (continued)

Station Group	Stations in group	%[1] similarity	Dominant taxa	Abundance (indiv/m^2)	% Occurrence[2] in group
III	6,17,16 7,33,4 8,43	22	*Balanus crenatus* (juv)	4159	88
			Atylus bruggeni	550	38
			Protomedeia spp.	437	88
			Balanus crenatus	345	50
			Ampelisca macrocephala	298	75
			Foraminifera	138	88
			Ischyrocerus sp.	106	75
			Leitoscoloplos pugettensis	77	88
			Cirratulidae	62	88
			Grandifoxus nasuta	59	50
			Ampelisca eschrichti	56	63
			Erichthonius tolli	56	25
			Urochordata	56	63
			Polydora quadrilobata	50	13
			Pholoe minuta	41	88
			Scoloplos armiger	40	75
IV	18,31,19	36	*Echinarachnius parma*	276	100
			Cyclocardia rjabininae	242	33
			Balanus crenatus (juv)	75	33
			Foraminifera	58	100
			Scoloplos armiger	37	100
			Spiophanes bombyx	21	67
			Mysella sp.	17	33
			Glycinde wireni	11	100
			Liocyma viridis	11	67
			Amphiophiura sp.	11	67

[1]Similarity level at which groups were selected.
[2]The value for each of the dominant taxa included in this column for multi-station groups is based on the number of stations at which the particular taxon occurs.

first and third coordinate coordinate axes. Nevertheless, the similarity of Station CH5 to northern Station Group II is indicated on the plot of the first and second coordinate axes. Stations CH8 and CH43 are included in coastal Station Group III, but join the other stations of this group at a low level of similarity. Both of these stations are also only marginally associated with other stations of Group III on the plots of principal coordinate axes. Stations in Group II separate, in the cluster analysis, into two subgroups at a higher level of similarity; these subgroups mainly comprise the northern offshore groups of stations (Stations CH3, 12, 13, 24, 25, 26, 27, and 39) and stations adjacent to Group III (Stations CH10, 11, 14, 15, 21, and 23). The separation of Group II into two subgroups is also apparent in the principal coordinate plots. The distribution of infaunal station groups based on cluster and principal coordinate analyses are shown in Figure 78. Also shown on this figure are stations making up five transects (A-E) that lie across the cluster groups. A characterization of these transects is included in Appendix IV.

A general description of the fauna comprising the four cluster (station) groups is included below (also see Tables 17-20).

Cluster Group I, the most southerly of the offshore groups identified, is composed of 12 stations. Crustaceans (primarily barnacles and amphipods) dominated in abundance (38% of the total abundance) but not carbon biomass (4% of the total carbon biomass). Annelids ranked next in abundance (34%) but highest in carbon biomass (43%). The most abundant organisms present were sessile, suspension-feeding, juvenile barnacles (*Balanus crenatus*) which occurred at 92% of the stations in the cluster group and the tube-dwelling, surface-deposit-feeding, ampeliscid amphipod *Byblis gaimardi* which also occurred at 92% of the stations. No adult *B. crenatus* occurred within this station group. This group is also characterized by the deposit-feeding polychaetes *Leitoscoloplos pugettensis* (Orbiniidae), *Barantolla americana* (Capitellidae), *Maldane glebifex* (Maldanidae), and Cirratulidae, and the deposit-feeding bivalve *Nucula bellotti*, all of which occurred at 100% of the stations. The deposit-feeding cumacean *Brachydiastylis resima*, the polychaete *Sternaspis scutata* (Sternaspidae), the echiuroid worm *Echiurus*

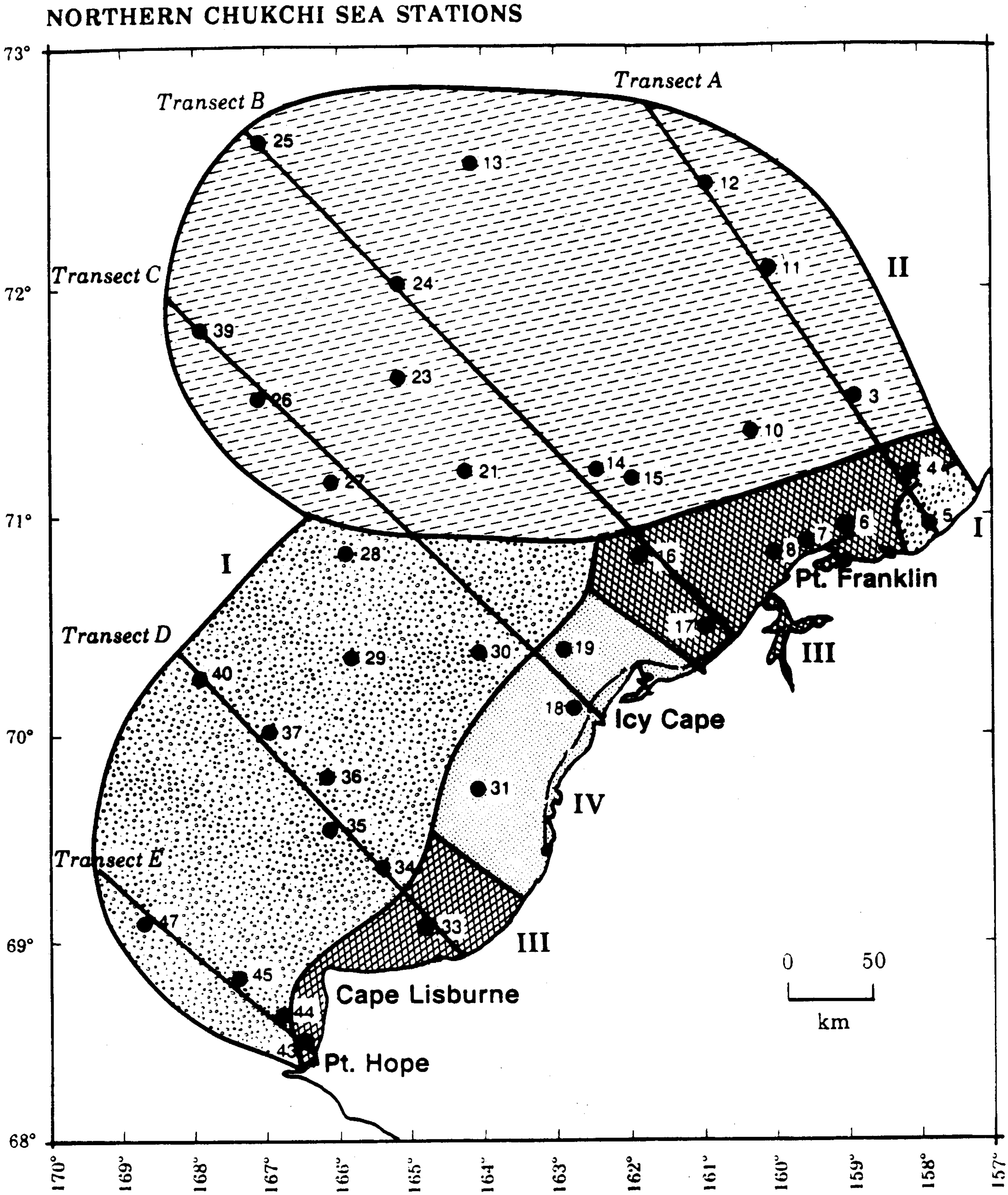

Figure 78. Distribution of macrofaunal communities in the northeastern Chukchi Sea based on cluster and principal coordinate analyses of abundance data collected August-September 1986. Transects shown on the figure are for station data included in Appendix IV.

Table 18. Dominant (in terms of carbon biomass) benthic fauna in four station cluster groups. Data collected by van Veen grab in the eastern Chukchi Sea aboard the NOAA R/V *Oceanographer*, Cruise OC862, August/September 1986.

Station Group	Stations in group	%[1] similarity	Dominant taxa	Biomass (gC/m^2)	% Occurrence[2] in group
I	28,37,29, 40,5,45, 44,34,35, 36,30,47	22	*Golfingia margaritacea*	0.93	67
			Maldane glebifex	0.75	100
			Nephtys ciliata	0.43	100
			Nucula bellotti	0.42	100
			Echiurus echiurus alaskensis	0.33	83
			Macoma calcarea	0.30	42
			Nicomache lumbricalis	0.28	50
			Nephtys paradoxa	0.24	8
			Praxillella praetermissa	0.21	83
			Psolus peroni	0.20	8
II	21,14,23, 10,15,11, 24,39,27, 26,3,12, 13,25	32	*Macoma calcarea*	2.28	100
			Golfingia margaritacea	1.75	71
			Nucula bellotti	0.67	100
			Maldane glebifex	0.67	86
			Lumbrineris fragilis	0.37	57
			Astarte borealis	0.37	57
			Nuculana radiata	0.36	36
			Nephtys paradoxa	0.25	29
			Natica clausa	0.20	36
			Yoldia hyperborea	0.17	64
III	6,17,16, 7,33,4, 8,43	22	*Atylus bruggeni*	1.82	38
			Psolus peroni	1.72	50
			Golfingia margaritacea	0.45	75
			Liocyma viridis	0.43	50
			Astarte borealis	0.39	25
			Yoldia myalis	0.34	50
			Nephtys caeca	0.28	25
			Natica clausa	0.26	63
			Polinices pallida	0.23	75
			Chelyosoma sp.	0.23	50

(continued)

Table 18. (continued)

Station Group	Stations in group	%[1] similarity	Dominant taxa	Biomass (gC/m^2)	% Occurrence[2] in group
IV	18,31,19	36	*Echinarachnius parma*	1.22	100
			Cyclocardia rjabininae	1.01	33
			Natica clausa	0.43	67
			Travesia forbesi	0.34	100
			Tellina lutea	0.33	33
			Yoldia scissurata	0.32	67
			Musculus niger	0.23	33
			Travesia pupa	0.10	33
			Liocyma viridis	0.07	67
			Macoma calcarea	0.07	67

[1]Similarity level at which groups were selected.

[2]The value for each of the dominant taxa included in this column for multi-station groups is based on the number of stations at which the particular taxon occurs.

echiurus alaskensis, and the amphipod *Protomedeia*, as well as the suspension-feeding bivalve *Thyasira gouldi*, were also common. In terms of carbon biomass, this group was dominated by the surface deposit-feeding sipunculid worm *Golfingia margaritacea* and *M. glebifex* which occurred at 67 and 100% of the stations, respectively.

Cluster Group II, north of Group I, consists of 14 stations. The top-ranked phyla, in terms of abundance, in this group were Annelida (38%), Crustacea (primarily amphipods; 26%), and bivalve mollusks (24%). Bivalves dominated the carbon biomass (47%) followed by annelids (25%) and sipunculids (13%). This group is dominated by two subsurface deposit-feeding species, the polychaete *M. glebifex* and the bivalve *N. bellotti*. Also characterizing this group were the mixed-feeding polychaete *Lumbrineris* sp. (Lumbrineridae), the deposit/suspension-feeding clam *Macoma calcarea*, the tube-dwelling amphipod *B. breviramus*, and the amphipod *Paraphoxus* sp. Also

Table 19. The percentage by abundance, biomass, carbon, and carbon production of phyla at station groups. Data collected by van Veen grab in the eastern Chukchi Sea, August-September 1986. Fragments are not included in the abundance computations.

GROUP	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2/yr	CARBON PROD %
I	PROTOZOA	19.7	1.23	0.001	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	1.8	0.11	0.233	0.18	0.002	0.03	0.000	0.00
	RHYNCHOCOELA	1.0	0.06	1.612	1.26	0.150	2.38	0.015	0.32
	NEMATODA	47.0	2.93	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA *	539.5	33.68	40.925	31.89	2.739	43.48	3.834	81.01
	GASTROPODA	31.8	1.99	6.997	5.45	0.423	6.71	0.127	2.68
	CHITON	0.2	0.01	0.001	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	217.5	13.58	34.568	26.93	1.217	19.32	0.365	7.71
	PYCNOGONIDA	0.2	0.01	0.001	0.00	0.000	0.00	0.000	0.00
	BALANUS	135.5	8.46	0.267	0.21	0.003	0.05	0.000	0.01
	AMPHIPODA	365.3	22.81	3.326	2.59	0.221	3.51	0.221	4.67
	OTHER CRUSTACEA	115.0	7.18	0.251	0.20	0.018	0.29	0.018	0.38
	SIPUNCULA	11.5	0.72	20.798	16.20	0.936	14.86	0.094	1.98
	ECHIURA	81.3	5.08	6.452	5.03	0.329	5.22	0.033	0.70
	PRIAPULIDA	6.0	0.37	0.078	0.06	0.003	0.06	0.000	0.01
	BRYOZOA	0.3	0.02	1.146	0.89	0.012	0.19	0.001	0.03
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	16.3	1.02	9.805	7.64	0.220	3.49	0.022	0.46
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	11.8	0.74	1.878	1.46	0.026	0.42	0.003	0.06
		1601.8		128.345		6.299		4.733	

GROUP	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2/yr	CARBON PROD %
II	PROTOZOA	3.4	0.26	0.006	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.002	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	8.9	0.67	3.085	1.35	0.154	1.67	0.015	0.29
	RHYNCHOCOELA	1.4	0.11	1.420	0.62	0.132	1.43	0.013	0.25
	NEMATODA	11.0	0.84	0.003	0.00	0.000	0.00	0.000	0.00
	ANNELIDA *	494.4	37.61	33.923	14.89	2.334	25.30	3.267	62.38
	GASTROPODA	34.7	2.64	4.654	2.04	0.343	3.72	0.103	1.97
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	320.1	24.35	130.825	57.43	4.307	46.68	1.292	24.67
	PYCNOGONIDA	0.1	0.01	0.000	0.00	0.000	0.00	0.000	0.00
	BALANUS	0.9	0.07	0.000	0.00	0.000	0.00	0.000	0.00
	AMPHIPODA	274.6	20.88	5.696	2.50	0.383	4.15	0.383	7.32
	OTHER CRUSTACEA	76.7	5.84	0.182	0.08	0.011	0.12	0.011	0.21
	SIPUNCULA	21.3	1.62	27.527	12.08	1.239	13.43	0.124	2.36
	ECHIURA	2.0	0.15	0.012	0.01	0.001	0.01	0.000	0.00
	PRIAPULIDA	7.7	0.59	0.417	0.18	0.019	0.20	0.002	0.04
	BRYOZOA	2.3	0.17	0.152	0.07	0.002	0.02	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	50.6	3.85	13.379	5.87	0.165	1.79	0.013	0.26
	HEMICHORDATA	0.3	0.02	0.816	0.36	0.056	0.61	0.006	0.11
	UROCHORDATA	4.3	0.33	5.711	2.51	0.080	0.87	0.008	0.15
		1314.7		227.810		9.227		5.238	

*All annelids were in the class Polychaeta.

Table 19. (continued)

GROUP	PHYLUM	ABUNDANCE #/M2	%	BIOMASS g/M2	%	CARBON BIOMASS gC/M2	%	CARBON PROD gC/M2/yr	%
III	PROTOZOA	139.8	1.65	0.020	0.01	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	6.948	2.39	0.069	0.69	0.007	0.13
	COELENTERATE	13.0	0.15	7.269	2.50	0.339	3.39	0.034	0.61
	RHYNCHOCOELA	3.3	0.04	0.359	0.12	0.033	0.33	0.003	0.06
	NEMATODA	200.0	2.37	0.016	0.01	0.000	0.00	0.000	0.00
	ANNELIDA *	792.3	9.38	19.774	6.81	1.387	13.87	1.942	34.94
	GASTROPODA	55.0	0.65	12.706	4.38	0.895	8.95	0.269	4.83
	CHITON	4.0	0.05	0.337	0.12	0.021	0.21	0.006	0.11
	BIVALVIA	157.0	1.86	64.500	22.21	1.662	16.62	0.499	8.97
	PYCNOGONIDA	10.3	0.12	0.013	0.00	0.001	0.01	0.001	0.02
	BALANUS	4505.0	53.35	9.454	3.26	0.104	1.04	0.010	0.19
	AMPHIPODA	2210.3	26.17	33.031	11.37	2.404	24.04	2.404	43.25
	OTHER CRUSTACEA	191.5	2.27	1.163	0.40	0.083	0.83	0.083	1.50
	SIPUNCULA	20.3	0.24	9.965	3.43	0.448	4.48	0.045	0.81
	ECHIURA	5.3	0.06	0.013	0.00	0.001	0.01	0.000	0.00
	PRIAPULIDA	0.3	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	12.3	0.15	3.740	1.29	0.052	0.52	0.005	0.09
	BRACHIOPODA	1.0	0.01	0.005	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	44.3	0.52	83.984	28.92	1.981	19.80	0.198	3.56
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	79.8	0.94	37.087	12.77	0.519	5.19	0.052	0.93
		8444.3		290.385		10.002		5.559	

GROUP	PHYLUM	ABUNDANCE #/M2	%	BIOMASS g/M2	%	CARBON BIOMASS gC/M2	%	CARBON PROD gC/M2/yr	%
IV	PROTOZOA	58.0	6.25	0.301	0.13	0.003	0.06	0.000	0.02
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.7	0.07	0.155	0.07	0.009	0.20	0.001	0.05
	RHYNCHOCOELA	0.0	0.00	0.096	0.04	0.009	0.18	0.001	0.05
	NEMATODA	3.3	0.36	0.001	0.00	0.000	0.00	0.000	0.00
	ANNELIDA *	113.3	12.20	8.018	3.41	0.666	13.71	0.932	48.56
	GASTROPODA	22.0	2.37	9.001	3.82	0.646	13.30	0.194	10.09
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	304.7	32.81	50.775	21.57	2.152	44.34	0.645	33.64
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BALANUS	75.3	8.11	0.018	0.01	0.000	0.00	0.000	0.00
	AMPHIPODA	34.0	3.66	0.081	0.03	0.005	0.10	0.005	0.26
	OTHER CRUSTACEA	6.7	0.72	0.065	0.03	0.005	0.10	0.005	0.25
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	302.0	32.52	159.879	67.93	1.261	25.99	0.126	6.57
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	8.7	0.93	6.955	2.96	0.097	2.01	0.010	0.51
		928.7		235.345		4.853		1.919	

*All annelids were in the class Polychaeta.

Table 20. Benthic station groups and their associated dominant taxa together with feeding types, motility, and general remarks. Taxa are ranked by abundance. SF=Suspension Feeder, IF=Interface Feeder, SSDF=Subsurface Deposit Feeder, SDF=Surface Deposit Feeder, Pred=Predator, Sc=Scavenger, S=Sessile, DM=Discretely Motile (rarely moves), M = Motile.

Grp.	Dominant Taxon	Feeding Type	Motility	Remarks
I	*Byblis* (amphipod)	SDF (IF)	DM	Sandy Mud; in tubes
	Balanus (barnacle)	SF (IF)	S	Needs gravel/shell
	Leitoscoloplos (annelid)	SSDF	M	Needs mud
	Nucula (protobranch clam)	SSDF	DM	Needs mud
	Echiurus (echiuroid)	SDF (IF)	DM	Needs mud
	Cirratulidae (annelid)	SDF (IF)	M/DM	Needs mud
	Brachydiastylis (cumacean)	SDF (IF)	M	Needs mud
	Barantolla (annelid)	SSDF	M	Needs mud
	Maldane (annelid)	SSDF	S	Needs mud; in tubes
	Protomedeia (amphipod)	SDF (IF)	M	Needs mud, gravel
	Sternaspis (annelid)	SSDF	M	Mud
	Thyasira (bivalve)	SF (IF)	S	Mud
	Harpinia (amphipod)	SDF, P, Sc	M	Mud
	Leucon (cumacean)	SDF (IF)	M	Mud
	Myriochele (annelid)	SSDF	S or DM	Mud
	Ampelisca (annelid)	SDF (IF)	DM	Sandy mud
II.	*Nucula* (protobranch clam)	SSDF	DM	Mud
	Maldane (annelid)	SSDF	S	Mud; tubes
	Lumbrineris(annelid)	Pred./SDF (IF)	M	Mud
	Macoma (bivalve)	SDF/SF (IF)	DM	Mud
	Byblis (amphipod)	SDF (IF)	DM	Muddy sand; in tubes
	Paraphoxus (amphipod)	Pred	M	Muddy sand
	Cirratulidae (annelid)	SDF (IF)	M/DM	Mud
	Ostracoda (crustacean)	SF/SDF (IF)	M	Mud
	Barantolla (annelid)	SSDF	M	Mud
	Leitoscoloplos (annelid)	SSDF	M	Mud
	Harpinia (amphipod)	Pred	M	Muddy sand
	Haploops (amphipod)	SDF (IF)	DM	Muddy sand, gravel
	Ophiura (brittle star)	SDF/Pred/SC	M	Mud
III.	*Balanus* (juv. barnacle)	SF	S	Needs gravel/shell
	Atylus (amphipod)	SDF (IF)	M	Sandy mud
	Protomedeia (amphipod)	SDF (IF)	M	Needs mud, gravel
	Balanus (adult barnacle)	SF (IF)	Sessile	Needs gravel/shell
	Ampelisca (amphipod)	SDF (IF)	DM	Sandy mud; tubes
	Foraminifera	P/Sc	DM/M	Sandy mud
	Ischyrocerus (amphipod)	Sc	M	Sandy mud
	Leitoscoloplos (annelid)	SSDF	M	Mud

Table 20. (continued)

Grp.	Dominant Taxon	Feeding Type	Motility	Remarks
	Cirratulidae (annelid)	SDF (IF)	M/DM	Sandy mud
	Grandifoxus (amphipod	SDF	M	Sand
	Ampelisca (amphipod)	SDF (IF)	DM	Sandy mud
	Erichthonius (amphipod)	SDF/SF	DM	Sandy mud
	Urochordata (tunicate)	SF (IF)	S	Sandy gravel
	Polydora (annelid)	SDF/SF (IF)	DM	Sandy gravel/shell
	Pholoe (annelid)	P/S	M	Sandy mud
	Scoloplos (annelid)	SSDF	M	Sandy to Sandy Mud
IV.	*Echinarachnius*(sand dollar)	SF (IF)	M	Sandy to Sandy Mud
	Cyclocardia (cockle)	SF (IF)	DM	Sandy to Sandy Mud
	Balanus (juv. barnacle)	SF (IF)	S	Needs gravel/shell
	Foraminifera	P/Sc	M/DM	Mud, Sand
	Scoloplos (annelid)	SSDF	M	Sandy to Sandy Mud
	Spiophanes (annelid)	SDF/SF (IF)	S	Sandy to Sandy Mud
	Mysella (bivalve)	SF (IF)	DM/M	Sandy to Sandy Mud
	(members of the general group of *Mysella* tend to be commensals with sand-dwelling echinoderms like *Echinarachnius*)			
	Glycinde (annelid)	C/S	M	Sandy to Sandy Mud
	Liocyma (bivalve)	SF (IF)	DM/S	Sandy to Sandy Mud
	Amphiophiura (brittle star)	SDF/P/SC	M	Sandy to Sandy Mud
	Golfingia (sipunculid)	SDF (IF)	DM	Sandy Mud/Gravel
	Melita (amphipod)	SDF (IF)	M	Sandy Mud
	Astarte (bivalve)	SF (IF)	DM	Sandy Mud
	Chelysoma (tunicate)	SF (IF)	Sessile	Sandy Gravel
	Tharyx (annelid)	SDF (IF)	M/DM	Sandy Gravel

included among the dominant benthic fauna present in this group are deposit-feeding cirratulid polychaetes, the polychaetes *B. americana* and *L. pugettensis*, and ostracods. In terms of carbon biomass, this group was dominated by the surface deposit/suspension feeding bivalve *Macoma calcarea* and *G. margaritacea* at 100 and 71% of the stations, respectively.

Cluster Group III, occurring along the coast, consists of eight stations, separated into a northern and southern component. This group was completely dominated in abundance by crustaceans (juvenile and adult barnacles, and amphipods) that accounted for 82% of the abundance. Juvenile *B. crenatus*, occurred at 88% of the stations. Also common within this cluster group were adult *B. crenatus*, and the amphipods *Atylus bruggeni*, *Protomedeia* spp., and *Ampelisca macrocephala*. Amphipod crustaceans dominated the carbon biomass, and comprised 24% of that biomass. Bivalve mollusks comprised 17% and annelids 14% of the carbon biomass, respectively. The suspension-feeding sea cucumber, *Psolus peroni*, made up 17%[2]. The surface deposit feeding amphipod *Atylus bruggeni* and the *P. peroni* occurred at 38 and 50% of the stations, respectively.

Cluster Group IV, adjacent to the coast but between Point Lay and Icy Cape, consists of three stations. The two abundance co-dominants in this group were Echinodermata (primarily the sand dollar *Echinarachnius parma*) and bivalve mollusks (primarily the cockle *Cyclocardia rjabininae*) each making up 33% of the total abundance within the group. Annelids and crustaceans (primarily juvenile *B. crenatus*) each comprised 12% of the total abundance. No adult *B. crenatus* were found at stations within this group. Bivalves dominated the carbon biomass, comprising 44% of the total, followed by echinoderms (primarily sand dollars) at 26%, and annelids and gastropods, with 14 and 13% of the abundance, respectively. The dominant taxa were the two suspension-feeding species *E. parma* (at 100% of the stations in the group) and *C. rjabininae* (at 33% of the stations). Also important at this station were Foraminifera, juvenile *B. crenatus*, the subsurface deposit-feeding polychaete *Scoloplos armiger* (Orbiniidae), the small deposit/suspension-feeding polychaete *Spiophanes bombyx* (Spionidae), and the clam *Mysella* sp. Most of the preceding taxa are interface feeders.

---

[2] Computed as $\frac{1.7\ \text{gC/m}^2\ (\textit{Psolus}\ \text{biomass})}{10.0\ \text{gC/m}^2\ (\bar{X}\ \text{biomass})} \times 100$.

See Results, Section H, page 209, for data table.

5. Abundance, Biomass, Production, and Diversity of Taxa within Cluster Groups

The mean abundance among cluster groups was lowest in Group IV with a value of 929 indiv./m^2 and highest in Group III with a value of 8444 indiv./m^2 (Table 21a). The mean wet weight biomass was lowest in Group I with a value of 128 g/m^2 and highest in Group III with a value of 290 g/m^2. The mean carbon biomass among cluster groups was lowest in Group IV with a value of 4.9 gC/m^2 and highest in Group III with a value of 10.0 gC/m^2. Carbon production estimates were highest within Groups II (5.3 gC/m^2/yr) and III (5.6 gC/m^2/yr) and lowest at Group IV (1.9 gC/m^2) (Table 21a). The low production value for the latter group is a reflection of the dominance by two species with low P/B values, the cockle *Cyclocardia rjabininae* (P/B = 0.1) and the sand dollar *Echinarachnius parma* (P/B = 0.1). Mean number of taxa, Shannon and Simpson Diversity indices, and Shannon Evenness for each cluster group are included in Table 21b. High Shannon and low Simpson (a dominance index) values generally occurred within Cluster Groups I and II. Evenness values were generally high within the latter groups as well. Relatively low Shannon and high Simpson values occurred at Cluster Groups III and IV where specific taxa dominated (for example, juvenile barnacles dominated within Cluster Group III, while cockles and sand dollars dominated Cluster Group IV; Table 17).

6. Dominant Taxa, Trophic Structure and Motility of Taxa within Cluster Groups

The dominant taxa present (abundance and biomass), and the feeding and motility types identified within the station groups varied according to coastal location and substrate type (Figs. 64-66; 70-73; 79-82 and Tables 17, 22-23).

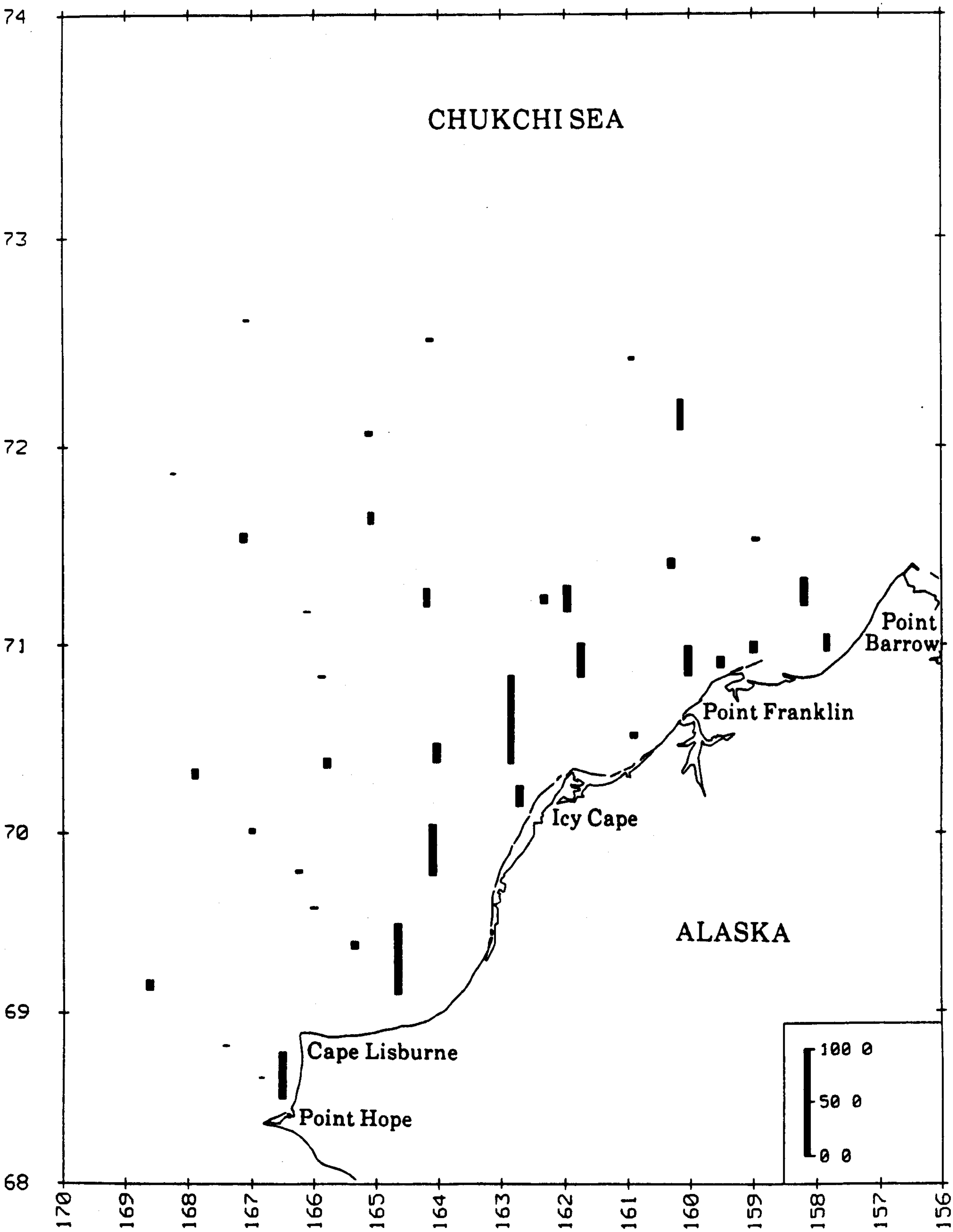

Figure 79. The percent carbon biomass of suspension-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

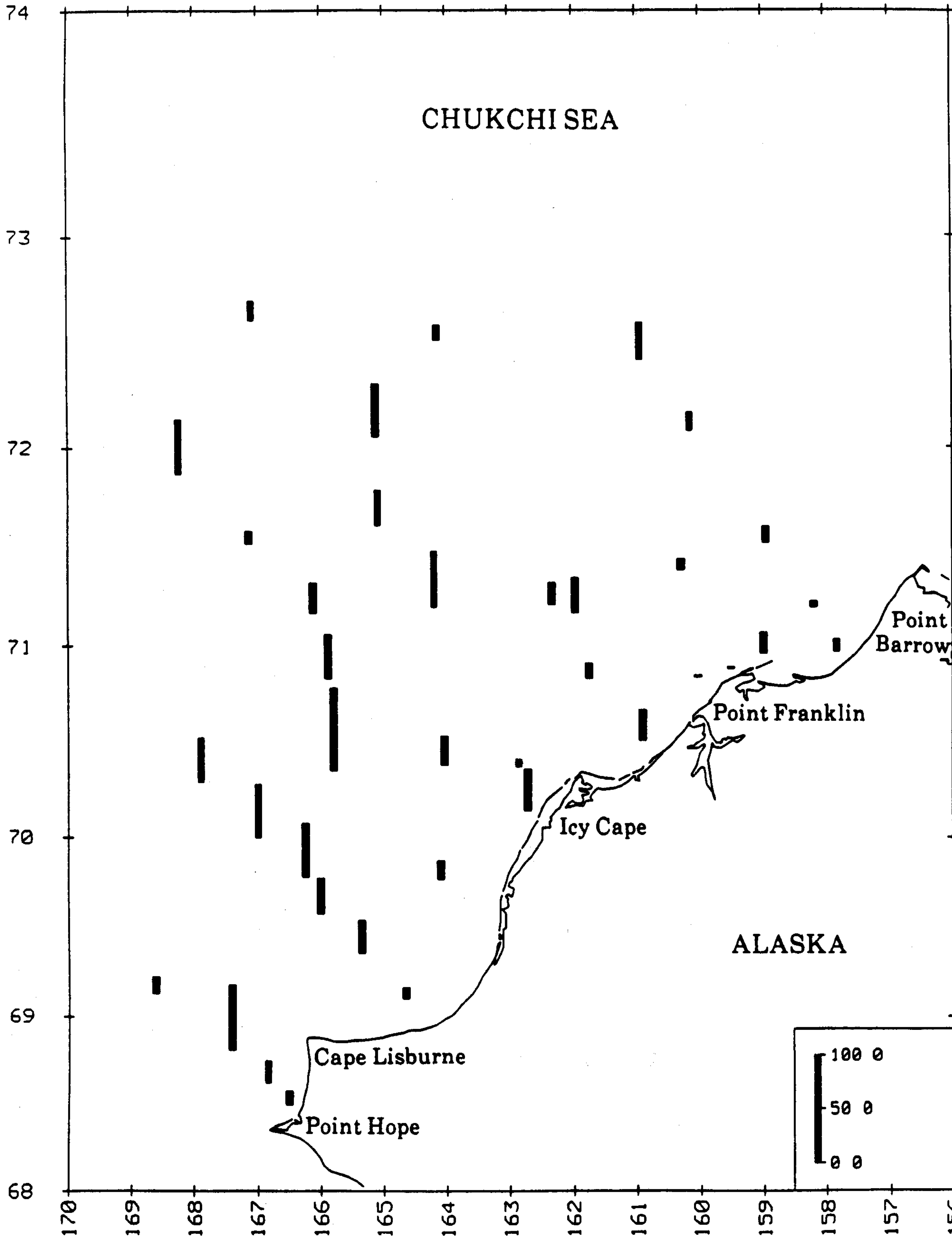

Figure 80. The percent carbon biomass of subsurface deposit-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

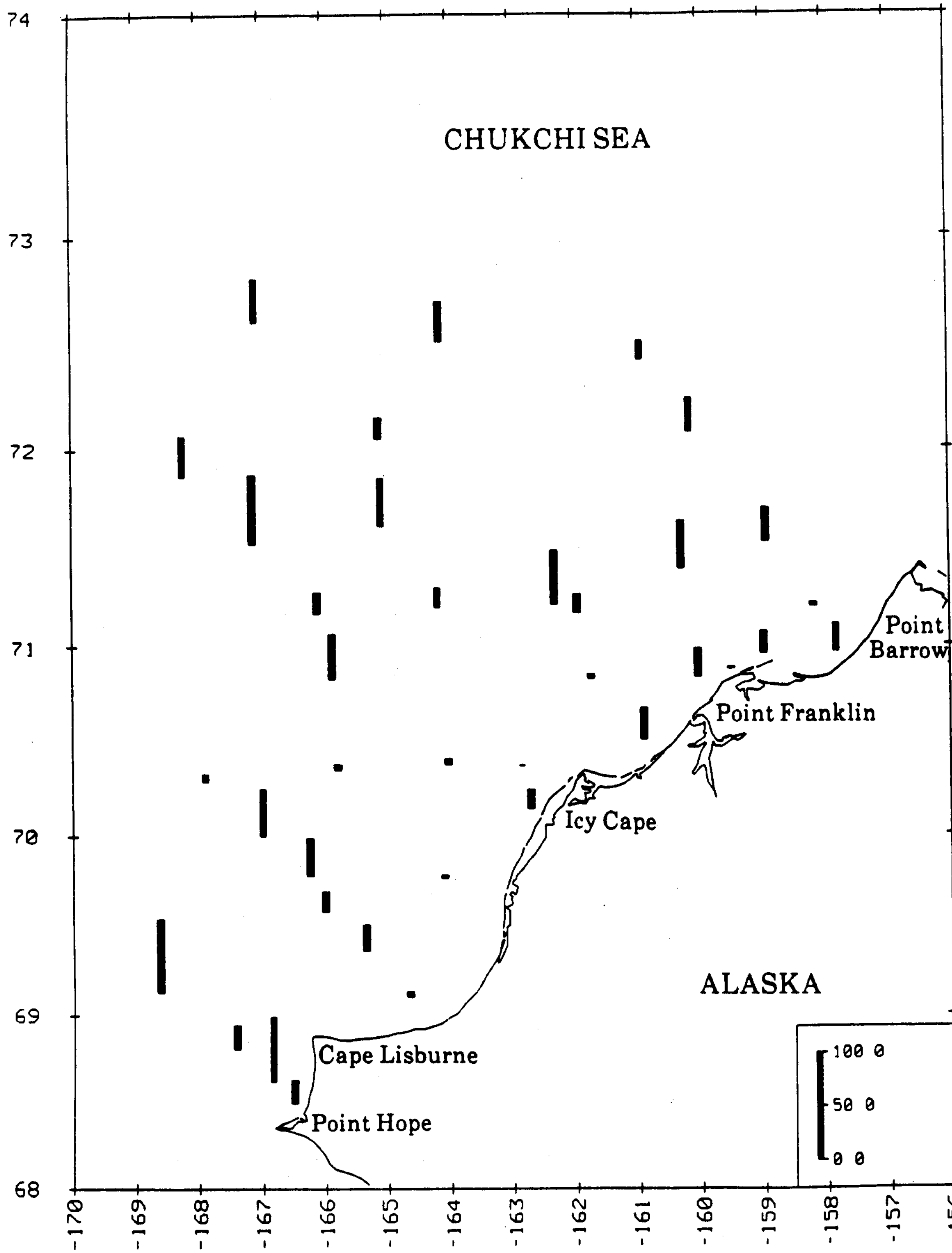

Figure 81. The percent carbon biomass of surface deposit-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

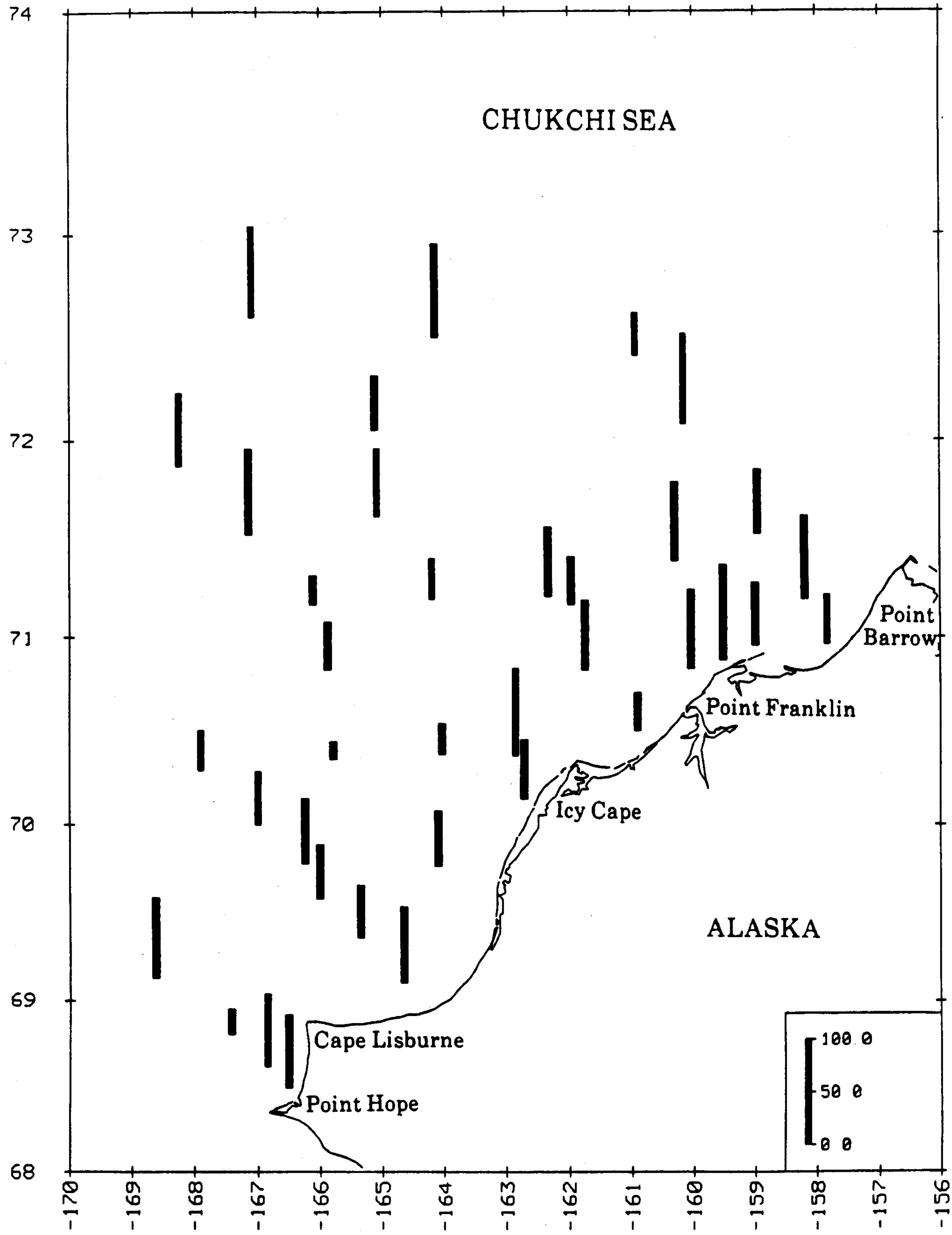

Figure 82. The percent carbon of interface-feeding benthic fauna at stations occupied in the northeastern Chukchi Sea, August-September 1986.

Table 21a. Mean abundance, wet weight biomass, carbon biomass, carbon production, and carbon requirements of benthic organisms at station groups. Data collected by van Veen grab in the eastern Chukchi Sea, August/September 1986. Fragments are not included in the abundance computations, but are included in the biomass computations. TE = transfer efficiency.

Station Group	Abundance (indiv/m²)	Wet Weight Biomass (g/m²)	Carbon Biomass (gC/m²)	Carbon Production (gC/m²/yr)	Carbon Required (gC/m²/yr) 10% TE	20% TE
I	1602	128	6.3	4.7	47	24
II	1315	228	9.2	5.2	52	26
III	8444	290	10.0	5.6	56	28
IV	929	235	4.9	1.9	19	9

Table 21b. Number of species (taxa), diversity indices, Shannon evenness, and species richness at station groups. Fragments and taxa excluded from cluster analysis are not included in these computations.

Station Group	No. of Taxa	DIVERSITY Simpson	Shannon	Shannon Evenness	Species Richness
I	172	0.04	3.65	0.71	23.51
II	204	0.05	3.84	0.72	28.55
III	248	0.29	2.47	0.45	27.51
IV	64	0.18	2.39	0.57	9.28

Table 22a. The percentage by abundance (indiv/m^2) of benthic feeding types at station groups. Data collected by van Veen grab in the eastern Chukchi Sea, August/September 1986. SDF = surface deposit feeder, SF = suspension feeder, IF = interface feeder (SDF + SF), SSDF = subsurface deposit feeder, CARN = carnivore, SCAV = scavenger. Fragments are not included in the abundance computations, but are included in the carbon and production computations. A small percentage of unknown feeding types were present, but omitted from the table.

Station Group	SDF %	SF %	IF %	SSDF %	CARN %	SCAV %	HERB %	ABUNDANCE (indiv/m^2)
I	36.50	17.14	53.64	27.78	6.38	8.17	0.54	1602
II	33.68	9.37	43.05	32.71	10.61	7.33	3.15	1315
III	21.52	57.97	79.49	4.20	3.96	7.82	3.73	8444
IV	5.61	72.11	77.72	6.96	6.89	5.56	0.35	929

Table 22b. The percentage by carbon biomass (gC/m^2) of benthic feeding types at station groups.

Station Group	SDF %	SF %	IF %	SSDF %	CARN %	SCAV %	HERB %	CARBON (gC/m^2)
I	29.73	12.73	42.47	36.30	17.88	1.89	1.47	6.3
II	34.65	22.31	56.95	26.87	12.77	1.70	1.70	9.2
III	10.83	42.76	53.60	8.87	16.04	10.72	10.78	10.0
IV	5.03	60.17	65.20	18.33	14.51	1.40	0.55	4.9

Table 22c. The percentage by carbon production (gC/m^2/yr) of benthic feeding types at station groups.

Station Group	SDF %	SF %	IF %	SSDF %	CARN %	SCAV %	HERB %	PRODUCTION (gC/m^2/yr)
I	13.81	4.51	18.32	53.72	24.28	1.52	2.16	4.7
II	24.96	11.28	36.24	38.77	18.65	2.26	4.08	5.2
III	12.81	13.87	26.68	12.49	22.61	19.39	18.82	5.6
IV	5.16	32.76	37.94	43.50	15.92	1.40	1.26	1.9

Table 23a. The percentage by abundance (indiv/m^2) of benthic motility types at station groups. Data collected by van Veen grab in the eastern Chukchi Sea, August/September 1986. Fragments are not included in the abundance computations, but are included in the carbon and production computations. A small percentage of the unknown motility types were present, but omitted from the table.

Station Group	SESSILE %	DISCRETELY MOTILE %	MOTILE %	ABUNDANCE (indiv/m^2)
I	21.22	33.20	42.09	1602
II	21.52	37.21	38.11	1315
III	58.44	18.49	22.27	8444
IV	29.07	22.63	45.79	929

Table 23b. The percentage by biomass (gC/m^2) of benthic motility types at station groups.

Station Group	SESSILE %	DISCRETELY MOTILE %	MOTILE %	CARBON (gC/m^2)
I	31.03	41.23	27.74	6.3
II	18.95	57.90	23.15	9.2
III	41.53	35.05	23.41	10.0
IV	20.05	23.62	56.33	4.9

Table 23c. The percentage by carbon production (gC/m^2/yr) of benthic motility types at station groups.

Station Group	SESSILE %	DISCRETELY MOTILE %	MOTILE %	PRODUCTION (gC/m^2/yr)
I	48.19	14.24	37.58	4.7
II	32.96	31.08	35.96	5.2
III	17.96	45.67	36.38	5.6
IV	14.87	19.47	65.67	1.9

In terms of abundance and carbon biomass, the inshore fauna at Station Group III consisted primarily of suspension feeding (58% of the total abundance; 43% of the total carbon biomass; 14% of the total carbon production), sessile (58% of the total abundance; 42% of the total carbon biomass; 18% of the total carbon production) taxa living on a sandy-gravel substrate. Surface deposit feeding taxa (primarily amphipods but also polychaetes) are also common within Group III (22% of the total abundance but only 11% of the total carbon biomass).

Relative to abundance and carbon biomass, the fauna along the coast at Station Group IV consisted of an even higher percentage of suspension feeders (72% of the total abundance; 60% of the total carbon biomass; 33% of the total carbon production). All stations in this group were dominated by the suspension-feeding sand dollar *Echinarachnius parma* living in a sandy substrate. The number of surface deposit feeders were greatly reduced in Station Group IV (6% of the total abundance; 5% of the total carbon biomass; 5% of the total carbon production); amphipods were uncommon at the stations of this group. Primarily motile taxa occurred here (46% of the total abundance; 56% of the total biomass; 66% of the total production). Sessile taxa were common here (29% by abundance; 20% by biomass; 15% by total production), but reduced relative to Group III.

The offshore mud-dwelling fauna (Cluster Groups I and II) comprised a much higher percentage of subsurface deposit feeders (28-33% of the total abundance; 27-36% of the total carbon biomass; 39-54% of the total carbon production) than occurred in Groups III and IV. Surface deposit feeders were also common in these groups (34-37% by abundance; 30-35% by carbon biomass; 14-25% by carbon production). Discretely motile and motile taxa were more abundant in Groups I and II than at the inshore station groups. Sessile organisms were still common within the two offshore station groups, although only a few taxa mainly contributed to this category: Group 1 - primarily the tube-dwelling polychaete *Maldane glebifex* and the juvenile barnacle *Balanus crenatus*; Group 2 - mainly *M. glebifex* (see Table 23 for motility values).

7. Stepwise Multiple Discriminant Analysis

The results of stepwise multiple discriminant analysis of the environmental conditions recorded in the study on station groups (based on abundance data) are shown in Table 24 and Figs. 83-85. All of the sediment data used in the first two analyses (Tables 24a and b) are based on dry weight values.

The first analysis, summarized in Table 24a, excluded percent mud which had a high covariance with percent sand. Discriminant functions 1 and 2 contribute 97.8% of the total separation among station groups. Further, 62.2% of the stations were correctly grouped by the jacknife classification into station groups by the three variables that form the discriminant functions. These variables are arc sine transformed % gravel, % sand, and sediment OC/N. Station positions along the two function axes are plotted in Figure 83. An assessment of the coefficients of discriminant functions which produce the coordinates is presented in Table 24a. The lowest negative value along the discriminant function (DF) 1 (canonical variable 1) is due to % sand. The high positive value along DF 2 is the result of the percent gravel in the sediment. A negative value along DF 2 is the result of the OC/N value of the sediment. The centroid of Station Group IV is distinct from that of Groups I, II, and III along the axis of DF I. Centroids of Groups I and II are separated from Group III on DF axes I and II. Station Group II is distinct from Group I along the first and second discriminant functions. The separation of Group IV from Groups I, II, and III is mainly the result of

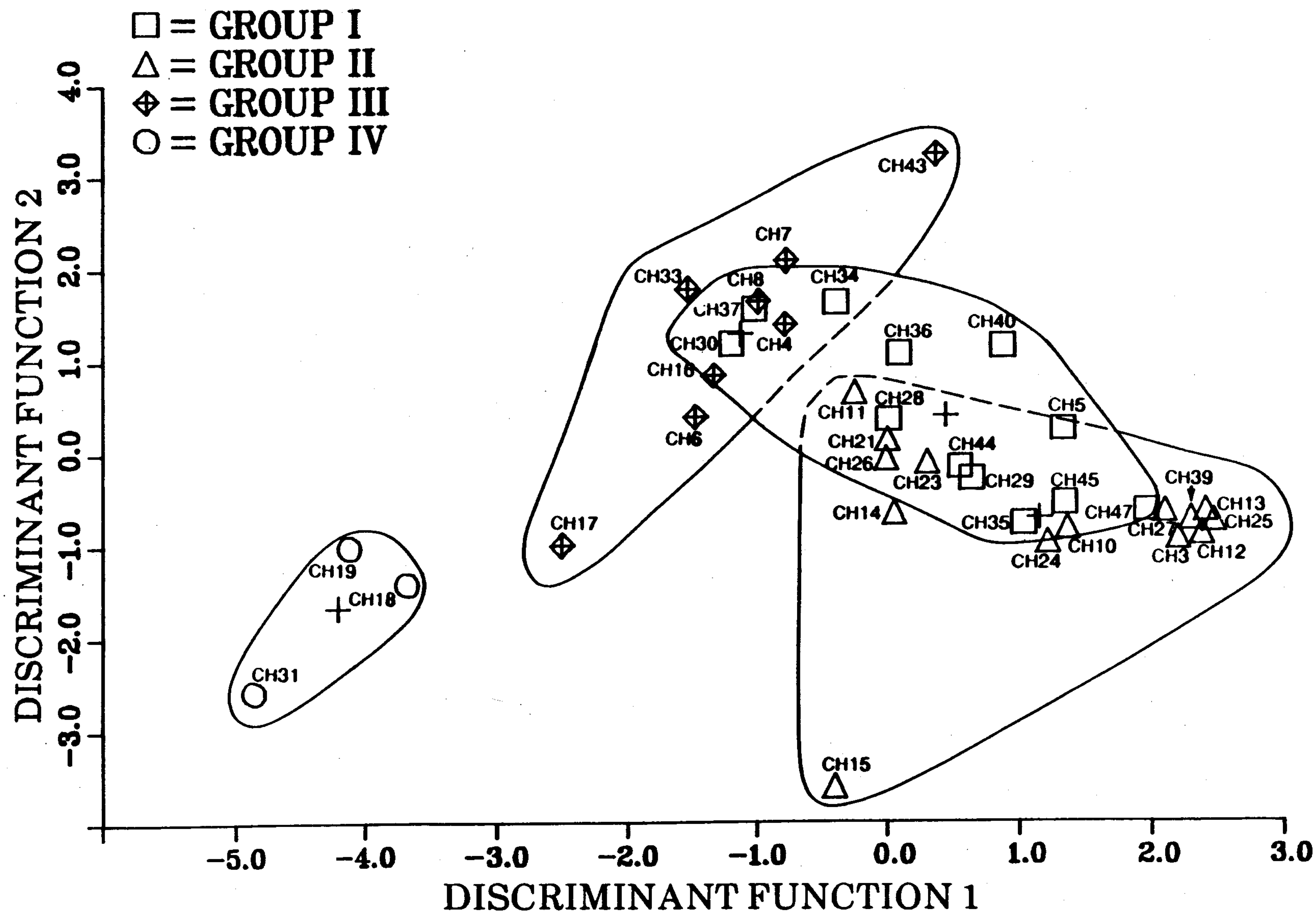

Figure 83. Station and station group plot of the results of the multiple discriminant analysis utilizing environmental conditions recorded in the study. The analysis is based on dry sediment weight values. The centroids of the four respective station groups are shown by +. Mud values are excluded (see Table 24a).

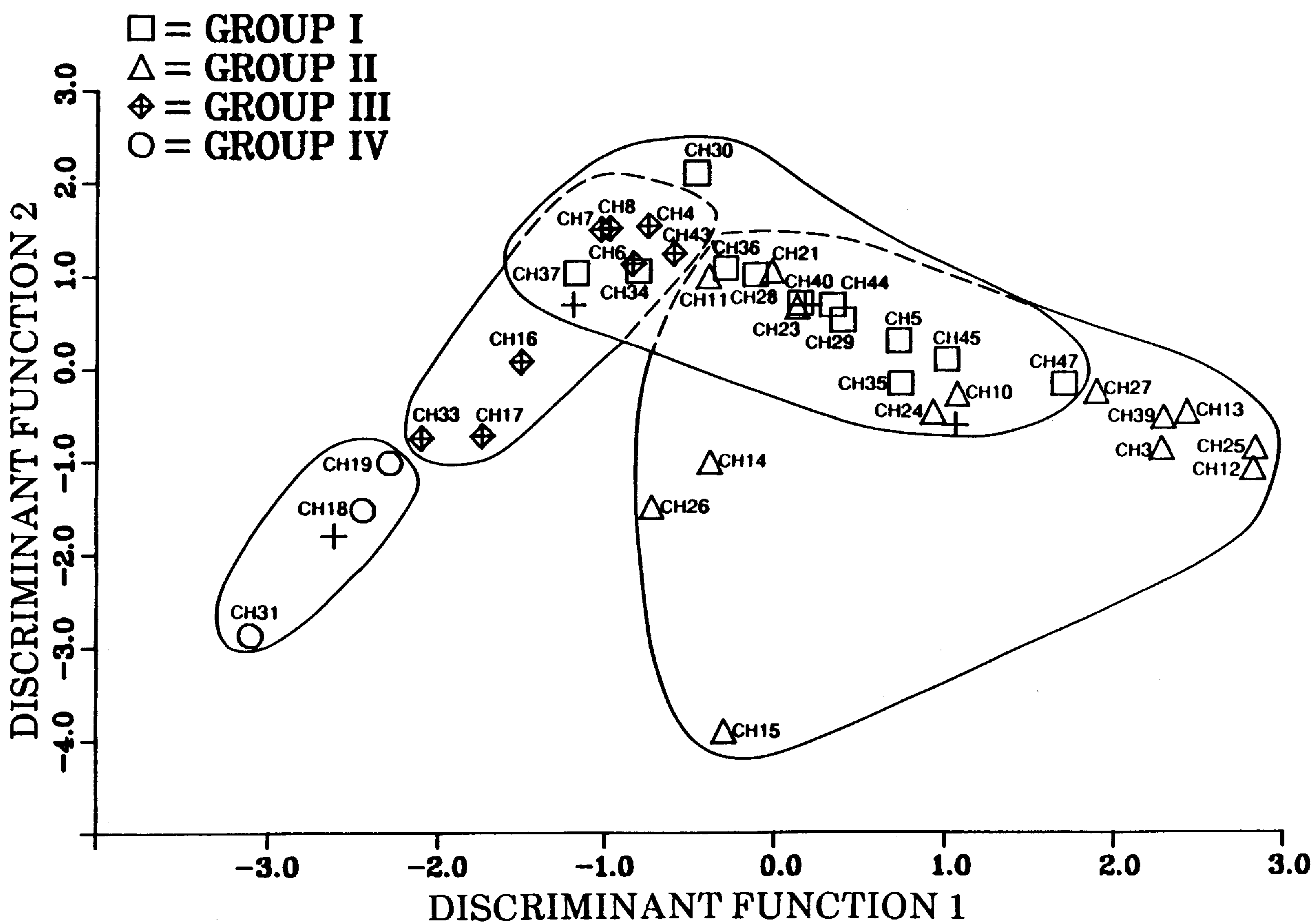

Figure 84. Station and station group plot of the results of the multiple discriminant analysis utilizing environmental conditions recorded in the study. The analysis is based on dry sediment weight values. The centroids of the four respective station groups are shown by +. Sand values are excluded (see Table 24b).

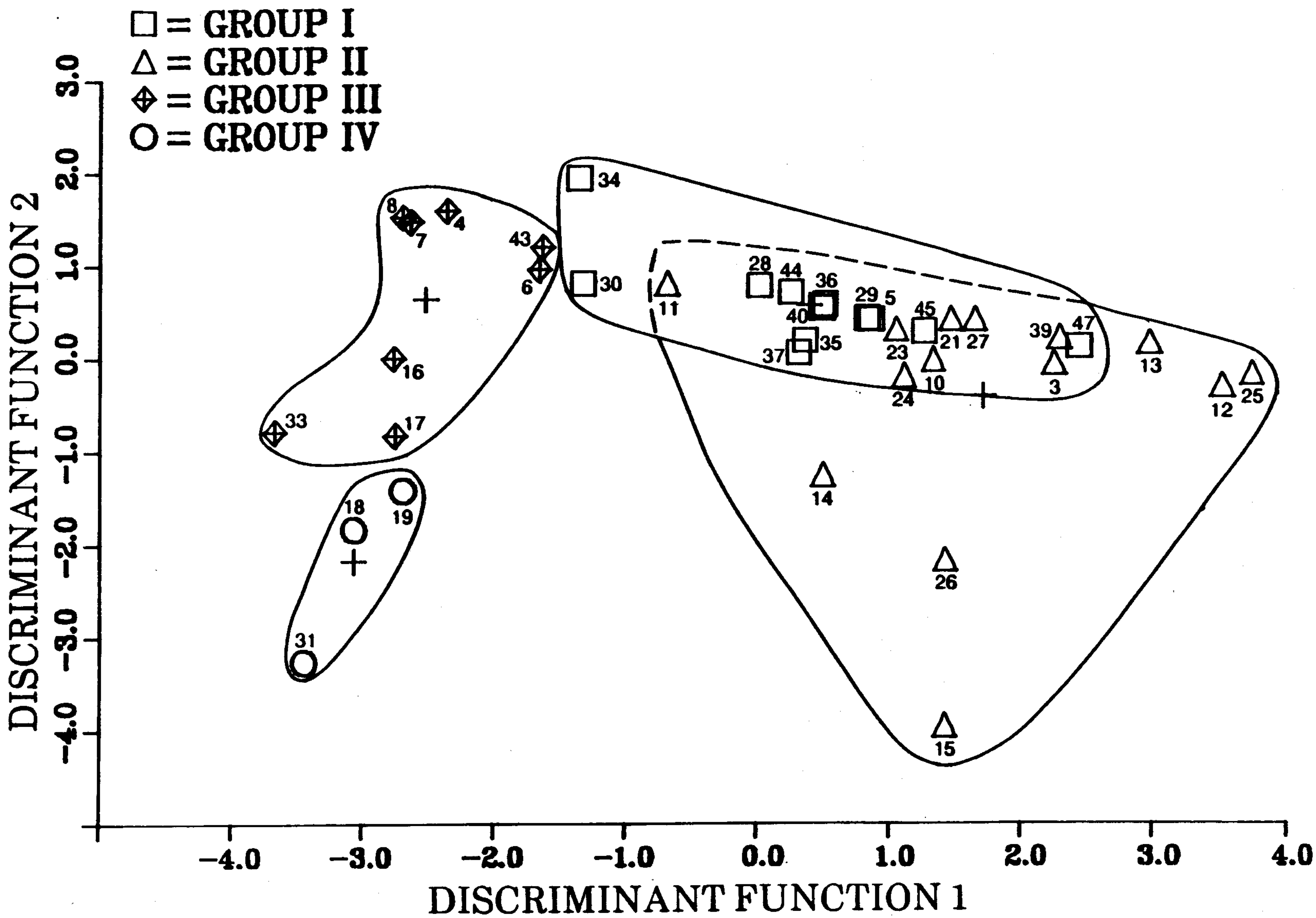

Figure 85. Station and station group plot of the results of the multiple discriminant analysis utilizing environmental conditions recorded in the study. The analysis is based on wet sediment weight values. The centroids of the four respective station groups are shown by +. All sediment data used in the analysis (see Table 24c).

Table 24a. Summary of the stepwise multiple discriminant analysis of the environmental conditions among the four station groups formed by cluster analysis of abundance data. Sediment data used in the analysis are based on dry weight values. Excludes percent mud which has a high covariance with percent sand (see Fig. 83).

Discriminant Function	1	2	3
Percent of Separation	71.61	26.19	2.20
Cumulative Percent of Separation	71.61	97.80	100.00

Variables and standardized discriminant function coefficients			
Percent Gravel	-0.30	0.95	--
Percent Sand	-0.91	0.36	--
Sediment OC/N	-0.53	-0.72	--

Table 24b. Summary of the stepwise multiple discriminant analysis of the environmental conditions among the four station groups. Sediment data used in the analysis are based on dry weight values. Excludes percent sand which has a high covariance with percent mud (see Fig. 84).

Discriminant Function	1	2
Percent of Separation	66.29	33.71
Cumulative Percent of Separation	66.29	100.80

Variables and standardized discriminant function coefficients		
Percent Mud	0.83	-0.59
Sediment OC/N	-0.44	-0.92

Table 24c. Summary of the stepwise multiple discriminant analysis of the environmental conditions among the four station groups. All sediment data used in the analysis are based on wet weight values (see Fig. 85).

Discriminant Function	1	2
Percent of Separation	83.65	16.35
Cumulative Percent of Separation	83.65	100.00

Variables and standardized discriminant function coefficients		
Percent Water in Sediment	0.96	-0.29
Sediment OC/N	-0.17	-0.94

the higher percentage of sand in the sediment at Group IV. On the other hand, the difference in the percent gravel results in the differentiation between Groups I and II as well as the separation of both of these groups from Station Group III. Group IV has a higher OC/N value than Groups I, II and III.

The second analysis, summarized in Table 24b and plotted in Figure 84, excluded percent sand which had a high covariance with percent mud. Discriminant function 1 contributes 66.3% of the total separation among station groups while function 2 only contributes 33.7% to the total separation among station groups. Nearly 65% of the stations were correctly grouped by the jacknife classification into station groups by the two variable that form the discriminate functions. These variables are arc sine transformed percent mud and sediment OC/N values. The separation of the centroids of Groups I and II along DF 1 is based on the higher percentage of mud in Group II while both of these groups have a higher percentage of mud than Groups III and IV. The higher OC/N values at Station Groups III and IV along DF 1 separates these groups from I and II.

The results of another stepwise multiple discriminant analysis of environmental conditions recorded, using wet weight of sediment samples, on cluster groups are shown in Table 24c and Figure 85. Discriminant function 1 contributed 83.7% of the total separation among station groups. Further, 75.7% of the stations were correctly grouped by the jacknife classification into station groups by the two variables that form the discriminant functions. The variables are percentage of water within the sediment and the sediment OC/N value. A high positive value along the discriminant function 1 is due to the percentage of water in the sediment. The negative value along discriminant function 1 is due to the OC/N value of the sediment. The centroids of Station Groups I and II are distinct from those of Groups III and IV along the axis DF I. The separation of Groups I and II from III and IV on DF 2 is due to the higher percentage of water and the lower OC/N value in the sediments of Station Groups I and II. Separation of Station Group III from IV, and the separation of Group I from II is also apparent along the axis of DF 2, and is due primarily to the higher sediment OC/N values at Station Groups IV and II, respectively.

Since the mean carbon biomass at the stations to the north and west of a postulated frontal zone (10.3 gC/m^2) was significantly higher ($P<0.001$) than the mean value calculated for the southern stations (5.2 gC/m^2) (Table 14), stations were separated, by carbon biomass, into a northern and a southern group. Bottom temperature and bottom salinity were highly correlated variables; thus, two analyses were run, each with either bottom temperature or bottom salinity in addition to other physical oceanographic variables. Discriminant function 1 for each analysis contributed 100% of the total separation between the two station groups. Further, 91.9-97.3% (the former for bottom salinity; the latter for bottom temperature) of the stations were correctly grouped by the jacknife classification into the two groups by the variable (either bottom salinity or bottom temperatures) that formed a single discriminant function (Fig. 86). Thus, the contributing variables were either bottom temperature or bottom salinity, and the separation of the two groups, by carbon biomass, is due to lower bottom-water temperatures and higher bottom salinities in the northern region.

8. Production and Carbon Requirements of the Benthos

Overall, estimated annual benthic production was highest within Station Groups I-III (4.7-5.6 $gC/m^2/yr$) and lowest at Group IV (1.9 $gC/m^2/yr$) where

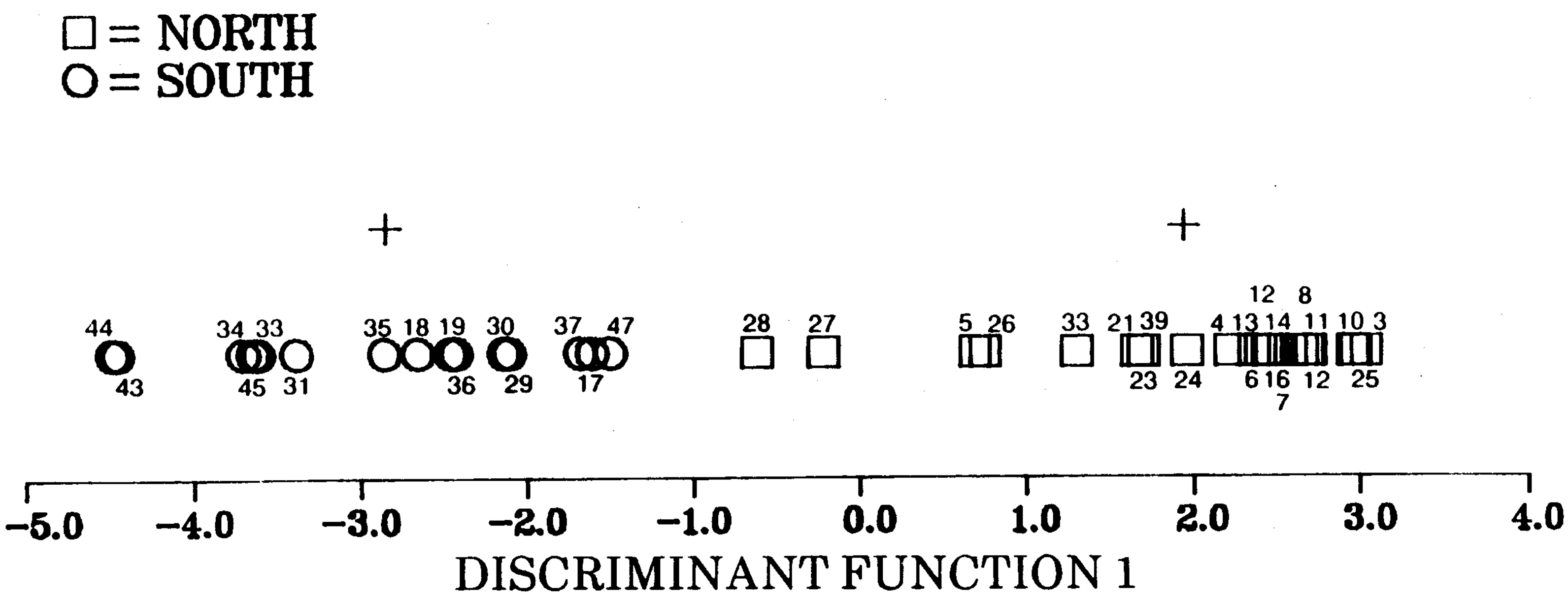

Figure 86. Station and station group plot of the results of the multiple discriminant analysis utilizing physical oceanographic conditions recorded in the study. The centroids of the two groups (north and south) separated by biomass values are shown by +.

the benthos was dominated by cockles and sand dollars (Table 21a; also see Table 12 for individual station data).

Annual production was dominated by the contribution from polychaetous annelids at Groups I (81% of the total production), II (62%), and IV (49%) (Table 19). No other groups were important at Group I. Bivalve mollusks were the next largest contribution to production within Group II (25%) and Group IV (34%). Annual production was dominated within Group III by amphipod crustaceans (43%), with polychaetes next in importance (35%).

Annual production by subsurface deposit-feeding taxa was highest at the two offshore groups (Group I: 54%; II: 39%) and at inshore Group IV (44%) (Table 22c). Production at inshore Group III was relatively evenly dispersed among all feeding groups. Assessment of interface feeders (surface deposit + suspension feeders) suggests that use of POC in the water column and on sediment surfaces was least important at offshore Group I (18%), but was important within the other three groups (II: 36%; III: 27%; IV: 38%).

Mean annual production of the northern high biomass stations (5.9 $gC/m^2/yr$; Table 14; Fig. 69) is significantly higher than that for the southern stations (3.4 $gC/m^2/yr$). Further, the annual production of interface feeders was highest at the northern stations, with suspension feeders dominating alongshore and surface-deposit feeders important offshore.

Four stations, south of the postulated front and just north of Cape Lisburne (Table 12; Figs. 62, 69: Stations CH34, 35, 36, 37), are located beneath a clockwise oceanic gyre (W. Stringer, pers. commun.), and have relatively high biomass values. Production at these stations is similar (i.e., a mean value of 5.9 $gC/m^2/yr$) to that of the stations north and west of the front. Alternatively, the other southern stations with low biomass values had a mean production value of only 2.5 $gC/m^2/yr$.

Estimates of carbon required by the benthos at Station Groups I-IV (groups delineated by cluster analysis of abundance data), and at the northern and southern station groups (the two latter groups separated according to biomass) are presented in Tables 21a and 14, respectively. Transfer efficiencies of 10 and 20% were utilized in the calculations. A transfer efficiency of carbon to the macrobenthos in northern Alaskan shelf of 20% is suggested by Walsh and McRoy (1986).

9. Demersal Fishes and Epibenthic Invertebrates

Demersal or benthic trawling was accomplished at ten stations in the northeastern Chukchi Sea between Point Hope and Point Barrow (Table 2; Figs. 13 and 62). A small demersal otter trawl or try net (4 m net opening) was towed 10-15 minutes at 2-4 knots. Because the R/V *Oceanographer* did not have adequate trawling capabilities, all material obtained in the trawls was treated as non-quantitative. However, dominant taxa were ranked in decreasing order of importance based on relative abundance or biomass, whichever was applicable. A characterization of the trawl catches is included in Table 25. Few fishes were caught, although arctic cod (*Boreoqadus saida*) and flathead sole (*Hippoglossoides elassodon*) were most numerous. The invertebrates that dominated in abundance were the brittle star *Ophiura sarsi*, the Tanner crab *Chionoecetes opilio*, and crangonid shrimps. Sea stars (*Asterias amurensis, Ctenodiscus crispatus,* and *Leptasterias* spp.) and tunicates (*Boltenia, Molqula, Styela,* and *Halocynthia*) dominated the biomass.

The brittle star *Ophiura sarsi* was most abundant at soft-bottomed Stations CH2, 23, 30, and 47 (Table 25). These were mainly large organisms

Table 25. Characterization of demersal trawl catches in the northeastern Chukchi Sea aboard the RV *Oceanographer*, August-September 1986. Dominant taxa (in terms of number and/or biomass) are ranked in order of decreasing dominance.

Station	Depth (m)	Bottom Type	Dominant Taxa[1]	Comments
CH1	48	hard	*Boltenia ovifera* - T	
			Molgula grifithsii - T	
			Sclerocrangon boreas - CS	
			Asterias amurensis - SS	
			Gorgonocephalus caryi - BAS	
			Cryptochiton stelleri - C	
			Bryozoa	
			Sponge	
CH2	66	soft	*Ctenodiscus crispatus* - SS	
			Ophiura sarsi - BS	
			Pectinariidae - P	
			Astarte spp. - CL	
			Cyclocardia sp. - CO	
			Eunephtya sp. - soft coral	
CH23	40	soft	*Ophiura sarsi* - BS	95% of biomass
			Chionoecetes opilio - SC	
			Hyas coarctatus - SPC	
CH26	46	soft	*Chionoecetes opilio* - SC	9-25 mm carapace width
			Leptasterias sp. - SS	
			Eualus sp. - HS	
			Boreogadus saida - AC	
			Argis lar - CS	
			Natica pallida - SN	
CH30	39	sand	*Ophiura sarsi* - BS	90% of biomass
			Chionoecetes opilio - SC	5% of biomass 10-30 mm carapace width
			Pagarus trigonocheirus - HC	
			Pandalus goniurus - PS	
			Pandalus tridens - PS	
			Argis lar - CS	
			Boreogadus saida - AC	
CH31	27	sand	*Echinarachnius parma* - SD	95% of biomass

Table 25. (cont'd)

Station	Depth (m)	Bottom Type	Dominant Taxa[1]	Comments
CH35	39	sand	*Leptasterias polaris acervata* - SS *Pandalus goniurus* - PS *Chionoecetes opilio* - SC *Pagurus trigonocheirus* - HC *Ophiura sarsi* - BS *Hippoglossoides elassodon* - FS	
CH36	44	soft	No organisms in two tows.	
CH37	47	hard	*Boltenia ovifera* - T *Boltenia echinata* - T *Molgula retortiformis* - T *Styela rustica* - T *Halocynthia aurantium* - T *Chionoecetes opilio* - SC *Hyas coarctatus* - SPC	
CH47	50	soft	*Chionoecetes opilio* - SC *Ophiura sarsi* - BS *Leptasterias polaris acervata* - SS	10 adult females 11 subadult females

[1]AC = Arctic cod
BAS = Basket star
BS = Brittle star
C = Chiton
CL = Clam
CO = Cockle
CS = Crangonid shrimp
FS = Flathead sole
HC = Hermit crab
HS = Hippolytid shrimp
P = Polychaete
PS = Pandalid shrimp
SC = Snow crab
SD = Sand dollar
SN = Snail
SPC = Spider crab
SS = Sea star
T = Tunicate

with disk diameters typically exceeding 20 mm. A subsample (N = 50) of *O. sarsi* from Station CH30 was examined for food items. The most frequently occurring food items were the remains of other brittle stars (100%), bivalves (92%), and gastropods (50%). All (100%) brittle stars also contained sediment in their stomachs (Table 26).

Numerous Tanner crabs were collected at 7 of 10 trawl station locations. Most adults were caught at the southern sector; juveniles mainly came from the other regions. Station CH47 yielded ten adult females with eggs and 11 subadult females with internal developing ova. The size of the adults ranged between 45 and 58 mm carapace width, within the size range of adult females caught in the vicinity of Point Hope in 1976 (Jewett, 1981).

Two stations where several hundred juveniles were caught in a ten-minute tow were CH26 and CH30. The crabs at these stations were similar in size, i.e., 10-30 mm carapace width. The sex ratio was nearly one to one. One notable difference in the crabs from these two sites was the presence of juvenile barnacles on the exoskeleton of all crabs at inshore Station CH30 and absence of barnacles on crabs at offshore Station CH26. A subsample (N = 50) of crabs from each of these stations was examined for stomach analyses (Table 27). The most frequently occurring food groups in crabs from both stations, in order of percent frequency of occurrence, were clams and cockles (61%), crustaceans (53%), and polychaetes (22%). Prey in crabs at CH26, where mud dominated the substrate, were mainly unidentified polychaetes, *Yoldia* sp. clams, and amphipods. The most frequently taken prey in crabs from Station CH30, a site where sand predominated the substrate, were foraminifera, unidentified clams, *Nucula bellotti* clams, amphipods, and barnacles. Sediment was present in all of the crabs at CH30, but absent from all crabs at CH26.

Table 26. Frequency of occurrence of items within stomachs of the brittle star, *Ophiura sarsi*, from Station CH30 in the eastern Chukchi Sea, September 1986, Cruise OC862.

Station:	CH30
Number Examined:	50
Average Disk Diameter:	22.1 mm (SD = 1.2)

Prey Group	Frequency of Occurrence Number	Percent
Foraminifera	7	14
Hydrozoa	2	4
Bivalvia	46	92
Gastropoda	25	50
Veliger larvae	1	2
Crustacea	9	18
Decapoda	1	2
Copepoda	1	2
Cyprid larvae	11	22
Ophiuroidea	50	100
Sediment	50	100

Table 27. Frequency of occurrence of items within the Tanner crab, *Chionoecetes opilio*, from Stations CH26 and CH30 in the eastern Chukchi Sea, September 1986, Cruise OC862.

Station:	CH26	CH30	CH26 + CH30
Number Examined:	50	50	100
Average Carapace width:	23.2 mm (SD = 1.3)	20.9 mm (SD = 2.1)	22.1 mm (SD = 2.1)

Prey Group	Frequency of Occurrence						
	Number	(%)	Number	(%)	Number	(%)	
Protozoa	3	(6)	1	(2)	4	(4)	
Foraminifera	1	(2)	30	(60)	31	(31)	
Polychaeta (unidentified)	15	(30)	6	(12)	21	(21)	
Myriochele oculata	0	(0)	1	(2)	1	(1)	
Nereidae	1	(2)	0	(0)	1	(1)	22
Bivalvia (unidentified)	16	(32)	18	(36)	34	(34)	
Yoldia sp.	15	(30)	0	(0)	15	(15)	
Nucula bellotti	3	(6)	9	(18)	12	(12)	
Clinocardium sp.	1	(2)	0	(0)	1	(1)	61
Gastropoda	2	(4)	5	(10)	7	(7)	
Crustacea	14	(28)	10	(20)	24	(24)	
Amphipoda	15	(30)	7	(14)	22	(22)	
Bathymedon sp.	3	(6)	0	(0)	3	(3)	
Copepoda	1	(2)	1	(2)	2	(2)	
Ostracoda	0	(0)	1	(2)	1	(1)	
Balanus sp.	0	(0)	6	(12)	6	(6)	53
Asteroidea	1	(2)	0	(0)	1	(1)	
Ophiuroidea	0	(0)	5	(10)	5	(5)	
Sediment	0	(0)	50	(100)	50	(50)	
Empty	2	(4)	3	(6)	5	(5)	

10. Gray Whale and Pacific Walrus Feeding Areas

Although no data were gathered in this study on gray whale (*Eschrichtius robustus*) and walrus (*Odobenus rosmarus divergens*) feeding habits, some benthic biological data were obtained from areas where these marine mammals are known to feed. Macrofaunal sampling occurred at 12 stations, CH4-8, 17-19, 31, 33, 43, and 44 (Fig. 62), within the region where gray whales occur between Point Hope and Point Barrow mainly within 50 km of shore (Clarke *et al.*, 1987). The average depth of these stations was 27.8±8.9 m. Only four of these stations had high concentrations of amphipods, the main prey of gray whales. Stations CH5, 6, 7, and 17 had an average amphipod abundance and carbon biomass of 4,319±1,987 individuals/m^2 and 4.7±5.9 gC/m^2, respectively (Table 28). The average amphipod abundance and carbon biomass at the other eight stations was only 87±63 amphipods/m^2 and 0.09±0.1 gC/m^2, respectively.

Three amphipod families dominated the abundance and carbon biomass at these four stations - Isaeidae, Ampeliscidae, and Atylidae (Table 29). Isaeid amphipods were dominated by small *Protomedeia* spp. and *Photis* spp.. Ampeliscids were dominated by the larger tube-dwellers *Ampelisca* spp. and *Byblis* spp.. The important atylid was *Atylus bruggeni*, a highly mobile species.

A group of stations sampled in the present study, i.e., Station Group II (14 stations) (Fig. 78), encompassed most of the summer and fall habitat of walruses (Fay, 1982; Frost *et al.*, 1983). The average organic carbon value within the sediment at Group II stations was highest (8.7 mgC/g) of the four station cluster groups. Also, the benthic macrofaunal carbon biomass at this group of stations was a high 9.2 gC/m^2. The fauna was dominated by the bivalves *Macoma* spp., *Nucula bellotti*

Table 28. Benthic stations in the northeastern Chukchi Sea between Point Hope and Point Barrow within 50 km of shore. These are within the area where gray whales occur during summer.

Station	Abundance ($indiv/m^2$) All Infauna	Abundance ($indiv/m^2$) Amphipods	% Amphipods	Biomass (gC/m^2) All Infauna	Biomass (gC/m^2) Amphipods	% Amphipods
CH5	3656	2302	63.0	6.63	0.81	12.2
CH6	8472	6644	78.4	5.62	2.90	51.6
CH7	7482	5204	69.6	19.64	13.50	68.7
CH17	4998	3128	62.6	6.64	1.82	27.4
$\overline{X}$	6152	4319	68.4	9.6	4.7	40.0
(SD)	(2215)	(1987)	(7.4)	(6.7)	(5.9)	(25.1)
CH4	1592	204	12.8	13.65	0.40	2.9
CH8	2508	128	5.1	13.20	0.11	0.8
CH18	462	6	1.3	3.21	<0.01	0.3
CH19	1622	76	4.7	5.75	0.01	0.2
CH31	702	20	2.8	5.61	<0.01	0.2
CH33	6988	118	1.7	3.21	0.06	1.9
CH43	3938	68	1.7	2.05	0.10	4.9
CH44	2320	80	3.4	6.77	0.03	0.4
$\overline{X}$	2516	87	4.2	6.68	0.09	1.4
(SD)	(2112)	(63)	(3.7)	(4.4)	(0.1)	(1.7)

(tenuis), and *Astarte* spp., the sipunculid *Golfingia margaritacea*, and polychaete worms (Table 30).

Benthic samples were also taken in the present study in the area where extensive walrus feeding traces were observed offshore between Icy Cape and Point Franklin (Phillips and Colgan, 1987). Most stations within this area

Table 29. Dominant amphipod families at stations in the northeastern Chukchi Sea where gray whales occur.

	Dominant Amphipod Families in Individuals/m²					
	Stations					
Taxa	CH5	CH6	CH7	CH17	Average	%
Isaeidae	514	4564	136	98	1328	30.7
Ampeliscidae	1644	372	16	2530	1140	26.4
Atylidae	2	874	3506	0	1095	25.4
Corophiidae	44	160	848	60	278	6.4
Ischyroceridae	0	366	342	24	183	4.2
Phoxocephalidae	24	88	6	336	113	2.6
Lysianassidae	30	112	40	32	54	1.2

	Dominant Amphipod Families in gC/m²					
	Stations					
Taxa	CH5	CH6	CH7	CH17	Average	%
Atylidae	0.001	1.687	12.836	0	3.631	75.3
Ampeliscidae	0.625	0.484	0.010	1.742	0.715	15.0
Isaeidae	0.055	0.501	0.014	0.004	0.144	3.0
Lysianassidae	0.112	0.033	0.302	0.009	0.114	2.4
Ischyroceridae	0	0.160	0.123	0.003	0.072	1.5
Corophiidae	0.003	0.016	0.158	0.018	0.049	1.0
Phoxocephalidae	0.001	0.003	0	0.041	0.011	0.2

grouped together (Group III) based on cluster analysis of the infaunal abundance data (Fig. 78). Few of the most abundant fauna were ones typically taken by walruses. However, bivalves and gastropods consisted of nearly 17% and 9% of the carbon biomass, respectively. Dominant bivalves were *Liocyma viridis*, *Astarte borealis* and *Yoldia myalis*. Dominant gastropods were *Natica clausa* and *Polinices pallida* (Table 31).

Table 30. Dominant infaunal invertebrates in Group II stations in the vicinity where Pacific walrus typically occur in the northeastern Chukchi Sea.

Number of stations: 14
Average indiv./m^2 1315 ±1094
Average gC/m^2 9.2 ± 3.9

Dominant Groups	Average Indiv./m^2	%	Dominant Groups	Average gC/m^2	%
Polychaeta	494	37.6	Bivalvia	4.3	46.7
Bivalvia	320	24.3	Polychaeta	2.3	25.0
Amphipoda	275	20.9	Sipuncula	1.2	13.0

Dominant Taxa	Average Indiv./m^2	Dominant Taxa	Average gC/m^2
Nucula bellotti	161	*Macoma* spp.	2.4
Maldane glebifex	148	*Golfingia margaritacea*	1.8
Lumbrineris sp.	78	*Nucula bellotti*	0.7
Macoma spp.	71	*Maldane glebifex*	0.7
Byblis brevirimus	53	*Lumbrineris fragilis*	0.4
Paraphoxus sp.	51	*Astarte* spp.	0.4
Cirratulidae	33	*Nuculana radiata*	0.4
Ostracoda	33	*Nephtys paradoxa*	0.3
Barantolla americana	24	*Natica clausa*	0.2
Leitoscoloplos pugettensis	23	*Yoldia hyperborea*	0.2

Table 31. Dominant infaunal invertebrates in Group III stations in the vicinity where Pacific walrus typically occur in the northeastern Chukchi Sea.

Number of stations:	8	
Average indiv./m^2	8444	±9655
Average gC/m^2	10.0	± 6.5

Dominant Groups	Average Indiv./m^2	%	Dominant Groups	Average gC/m^2	%
Thoracea	4505	53.3	Amphipoda	2.4	24.0
Amphipoda	2210	26.2	Echinodermata	2.0	19.8
Annelida	792	9.4	Bivalvia	1.7	16.6

Dominant Taxa	Average Indiv./m^2	Dominant Taxa	Average gC/m^2
Balanus crenatus (juv.)	4159	*Atylus bruggeri*	1.82
Atylus bruggeni	550	*Psolus peroni*	1.72
Protomedeia spp.	437	*Golfingia margaritacea*	0.45
Balanus crenatus (adult)	345	*Liocyma viridis*	0.43
Ampelisca macrocephala	298	*Astarte borealis*	0.39
Foraminifera	138	*Yoldia myalis*	0.34
Ischyrocerus sp.	106	*Nephtys caeca*	0.28
Leitoscoloplos pugettensis	77	*Natica clausa*	0.26
Cirratulidae	62	*Polinices pallida*	0.23
Grandifoxus nasuta	59	*Chelyosoma* sp.	0.23

VI. DISCUSSION

A. Physical Oceanography

A salient feature of the physical oceanographic data presented in this report is that wind-driven coastal upwelling occurred. The measured currents from both the moorings near the coast (CH)17) and the shipboard ADCP system (near Barrow) indicated a reversal of the flow towards the southwest over a three day interval, followed by a return to the northeastward flow. There were significant correlations between Barrow winds and the currents at the three coastal moorings during this reversal. Based on the distance between the ship and the moorings, we can estimate that the reversal occurred from Point Barrow to Icy Cape and possibly to Cape Lisburne, implying a minimum alongshore length scale of 200 to 400 km. On the northern flank of Hanna Shoal (CH13), no reversal of the eastward flow along the shelf was observed. The temperature time series from the current meters supports the upwelling hypothesis, showing a decrease of 6°C over a three-day period, followed by a return to the original conditions. The upwelling resulted in lifting this isotherm at least 10 m to the 19 m depth of the CH17 current meter.

Alternative explanations for the observed temperature at CH17 include horizontal advection and *in situ* cooling and warming. The argument for *in situ* cooling is weak on the basis that the required cooling is more than could be produced by the measured air temperature over the short period of the event. In particular, the return of warm temperatures near the end of the time series could not have been produced by local warming of a water column 19 m thick when the air temperature did not exceed approximately 4°C. The contribution of horizontal advection to the upwelling hypothesis cannot be ruled out with the present data set. Cold water was available deeper in the Barrow Canyon which could move horizontally with the velocities measured by the current meters during the reversal event. The bottom temperature map (Fig. 38) shows that below $0^{o}C$ temperatures were observed at CH8, approximately 50 km from the mooring location at the time of the minimum temperature at the mooring. The interpretation of the temperature map requires some caution, because it also represents both time and space variations. The most likely scenario is that both vertical and horizontal displacements of the water occurred as a result of the wind event. This signature was observed at CH17, even though the mooring station was more than two Rossby radii of deformation from the coast.

The temperature and salinity data from this cruise are similar to the summer conditions in the Chukchi Sea constructed by Coachman *et al.* (1975) as a composite of several cruises. The water mass analysis indicates that the warm coastal water had penetrated as far north as about $70^{o}30'$. Hydrographic data suggest that modified Bering Water (Chukchi Resident Water) approaches the Alaska coast north of Icy Cape. The Beaufort Sea water was found along the axis of the Barrow Canyon, producing a tongue of colder and higher salinity water near the bottom. For both of the traditional T-S technique and the cluster analyses, the front separating the water mass groupings follows the temperature contours ($5^{o}C$ at the surface, Fig. 35; $4^{o}C$ at the bottom, Fig. 36) and the bottom salinity contours (32.5 $^{o}/oo$, Fig. 37). The temperatures and salinities of the water masses on both sides of the front vary interannually, as well as the intensity of the front itself (Coachman *et al.*, 1975). The front is essentially maintained by the alongshore flow of the Alaska Coastal Water.

B. The Relationship of Sediment Parameters to Taxon Assemblages

It is currently accepted that benthic communities and their component organisms are distributed in a continuum along environmental gradients (Mills, 1969). However, it is still possible to recognize faunal assemblages, realizing that their separation into groups are typically not as discrete as had been suggested previously (Thorson, 1957).

As presented in the Results section (Table 17), the assemblages identified in the northeastern Chukchi Sea included four cluster (station) groups: I - a muddy-sandy-gravel assemblage dominated in abundance by the tube-dwelling ampeliscid amphipod *Byblis gaimardi* and the juvenile barnacle *Balanus crenatus*, II - a muddy assemblage dominated by the tube-dwelling polychaete *Maldane glebifex* and the protobranch clam *Nucula bellotti*, III - a sand assemblage characterized by the juvenile and adult barnacle *B. crenatus* and amphipods (including the tube-dwelling ampeliscid *Ampelisca macrocephala*), and IV - a sandy-gravel assemblage dominated by the sand dollar *Echinarachnius parma* and the cockle *Cyclocardia rjabininae*. It would appear that mean grain size *per se* is rarely the factor to which organisms respond to exclusively; benthic assemblages are typically a reflection of sediment size as well as several other sediment properties. Thus, the separation of the four station groups identified in the northeastern Chukchi Sea is best explained by the relative presence of gravel, sand, and mud in conjunction with OC/N values and percent water in the sediment, as determined by stepwise multiple discriminant analysis (Figs. 83-85). The observed benthic groupings (as defined in the context of sediment granulometric composition and fluidity) in the northeastern Chukchi Sea are not surprising because benthic assemblages have been determined in other areas on the basis of substrate type and associated water content (e.g., Boswell, 1961; Day *et al.*, 1971; Franz, 1976; McCave, 1976; Webb, 1976; Flint, 1981; Mann, 1982).

In our study area there is generally a covariance in the mud and water content in sediments (Fig. 60). The high water content in muddy sediments of our area is apparently related to the relatively higher porosity of the muds. Clayey particles which are enriched in muddy sediments, by virtue of their nonspherical shape, contribute to the higher porosity of the muds.

The presence of resident populations of the sand dollar *Echinarachnius parma* and the cockle *Cyclocardia rjabininae* (two shallow-dwelling suspension feeders) in inshore Group IV, in a low fluidity sandy-gravel deposit can simply be explained by the presence of a firm substrate with a high bearing strength in the area where these organisms occur. It is probable that the close association of these two species with a sand-gravel substrate is due to the prevalence of relatively intense currents (Alaska Coastal Water: ACW) over the above substrate type (Phillips, 1987) which would induce resuspension of sediments and associated Particulate Organic Carbon (POC) as a food source. Regional concentrations of suspended particles (Figs. 46 and 47; Table 6) indicate, as expected, that there is relatively more resuspension in the turbulent inshore region. As illustrated by the multivariate analyses of biological data (Figs. 74-77), there is a definite separation between inshore Station Groups III and IV which is presumably due to a generally higher content of gravel and lower content of sand in the substrate of Group III (Table 5; Figs. 39, 40, 61 and 83). As noted above, Group III is dominated by juvenile and adult barnacles associated with lag gravels under intense coastal currents. These coastal areas are also characterized by rocky outcrops (as shown by the high resolution seismic profiles recorded by Phillips *et al.*, 1985, and by us) which reflect high energy hydrodynamic conditions. The predominance of amphipods, especially ampeliscids, in the northern portion of Group III is most likely not primarily controlled by the nature of the substrate. As discussed later, it appears that an unusual flux of POC to the bottom in the northern segment of Group III contributes to amphipod dominance there.

The dominance of two subsurface deposit-feeding species, the tube-dwelling polychaete *Maldane* and the protobranch clam *Nucula*, in offshore Station Group II is quite consistent with the muddy and fluid nature of the sediment in which these organisms dwell. It is to be expected that the higher water content in mud which results in a fluidized sediment, would also generally impart thixotrophic properties to the mud. Presumably this fluidized mud offers a suitable substrate for the building of subsurface tubes by *Maldane*, and provides easy access by the clam *Nucula* to the surrounding sediments with their contained POC. The close association of POC with muddy sediments has been repeatedly shown by numerous investigators (see Weston, 1988, for references). The importance of muddy fluidized and POC-enriched sediments (Figs. 49, 60, and 61) as an environment for deposit-feeding organisms within offshore Groups I and II, but particularly Group II, is further demonstrated by the variety of surface and subsurface deposit-feeding species present (Tables 15 and 20; Fig. 78).

The bottom on which organisms within Station Groups I and II reside consist predominantly of muddy substrates. However, there are some subtle differences in the sediment nature at the stations comprising these two groups, as illustrated by differences in the proportions of coarse grains (gravel+sand) and water (Fig. 61). These sediment differences are reflected by the differences and abundance of dominant species between the two groups (Table 17). Thus, Group I is dominated by the surface-deposit feeding ampeliscid amphipod *Byblis gaimardi* and the suspension-feeding juvenile barnacle *B. crenatus*, whereas Group II is dominated by two subsurface deposit-feeding species, the clam *N. bellotti* and the tube-dwelling *M. glebifex* (Table 17). The presence of juvenile, but not adult, barnacles, in Group I indicates that although larvae are transported to the area, insufficient POC must be present in the water column to sustain resident adult populations in the area. The relatively low concentrations of organic carbon in the bottom sediments of stations in Groups I, as compared to Group II, suggests a net lower flux of POC to the bottom in the region of the Group I stations (Tables 7 and 8; Figs. 49, 55, and 78). In a latter section of this discussion, the relationship of the difference in flux of POC to the bottom in the above two regions is considered as it relates to regional variation in benthic biomass in our study area.

Our conclusions relative to substrate types and associated benthic macrofauna for the northeast Chukchi Sea are generally in agreement with the preliminary findings of Phillips *et al.* (1985) for selected sites extending from Icy Cape to Point Franklin. Differences in the faunal components described by Phillips *et al.* (1985) and our work are probably related to differences in sampling gear utilized by the two projects.

C. Additional Factors Determining Taxonomic Composition of Benthic Groups

There are obviously a number of other factors, in addition to the sediment properties discussed above, that determine the taxonomic composition of benthic assemblages. Some of the factors that might be important in our study area are water mass distributions, local eddies and gyres, intensified wave/current action during occasional storms, presence of and extent of polynyas, sediment accumulation rates, intensity of ice gouging on the bottom, the southern boundary of the pack ice in summer, disturbance of the sea bottom by the feeding activities of walruses and gray whales, and the quantity as well as nutritional quality of POC flux to the bottom.

At present, limited data makes it impossible to quantitatively assess the relationships between the above-cited factors and the distributional patterns, as well as biomass, of benthic species present in the northeast Chukchi Sea. Nevertheless, it is possible to speculate about the role of some of these factors on the benthos in our study area, based on a number of descriptive reports and papers (e.g., Barnes, 1972; Phillips *et al.*, 1985; Arctic Ocean Science Board, 1988; and some of the data collected in our study). In this section we discuss water mass origins, the regional variations in sediment accumulation rates, intensity of ice-gouging, and presence of polynyas on the benthic community composition. The remaining factors will be considered in the section to follow.

The origin of water masses and their temperature/salinity regimes often explain the distribution of benthic invertebrates. The temperature and salinity values characterizing a particular water mass are often associated with identifiable assemblages (groups) of benthic species (e.g., see Stewart *et al.*, 1985; Grebmeier *et al.*, 1988; also see Discussion, page 223, of this report relative to biomass distribution and its relationship to mixed Bering Sea water). The movement of water masses leads to dispersal of species by planktonic larval stages, which affects the distribution of such organisms (Thorson, 1957). The species found at our offshore Station Groups I and II are generally those characteristic of the cold, relatively high salinity, muddy bottom under the Chukchi Resident Water and the Bering Water north of Bering Strait. Alternatively, many of the benthic species of inshore Station Groups III (southern portion of the group) and IV are those generally characteristic of the somewhat warmer, lower salinity, sandy-gravel bottom under Alaska Coastal Water. Additionally, substrate typically affects small-scale distributions of species through choice of particular substrate types at the larval settlement stage (Wilson, 1953) and through adult substrate requirements. Thus, cyprid larvae of the barnacle *Balanus crenatus* were transported by ocean currents to inshore and offshore regions of our study area where they settled whenever a suitable substrate was available. However, only the inshore waters provided the requirements for adult survival and adult barnacles only occurred inshore. As another example, the tube-dwelling amphipods of the family Ampeliscidae occur in high abundance offshore on the sandy bottom of the northeastern Bering Sea under the cold, nutrient-rich Bering Shelf-Anadyr Water (Grebmeier, 1987). However, these amphipods only occur in abundance on the sandy substratum inshore in the northeastern Chukchi Sea north of 70°30', where mixed Bering Water (Bering Shelf-Anadyr Water) approaches the coast and presumably supplies POC to the crustaceans there as well (see Discussion, pages 223-224).

The influence of varying sediment accumulation rates on benthic community composition, feeding habits, and benthic motility has been widely demonstrated (refer to Feder and Jewett, 1987, 1988, for reviews emphasizing some Alaskan benthic biological systems). Based on high-resolution seismic profiles collected by Phillips *et al.* (1985) and by the present project (unpublished data), ^{210}Pb geochronology and the east-west lithological facies changes (Fig. 3; Phillips *et al.*, 1985), it appears that the northeast Chukchi Sea can be divided into two broad areas with markedly different sedimentation rates. The inshore area up to 70 km offshore, and a few shallow-water offshore areas adjacent to Hanna Shoal (Fig. 6), are presumably regions of relatively low or no deposition. This is reflected inshore by presence of rock outcrops and a thin blanket of lag gravel and sandy deposits, as shown by the sonographs, and in the lack of a net linear exponential decay in excess ^{210}Pb activities of sediment cores. Such a substratum is consistent with the high energy hydrodynamic conditions prevailing there (Phillips *et al.*, 1985). In contrast, the far offshore area is a region with a net sediment accumulation, varying from 0.16 to 0.26 cm/yr (Table 10), suggesting sediment deposition under lower energy hydrodynamic environments than inshore. These broad regional variations in sediment accumulation rates complement our earlier conclusions relating to benthic biological distributional patterns based on sediment properties. The macrobenthic inshore Groups III and IV of our studies occur in regions characterized by very low sediment accumulation. These groups, unlike offshore Groups I and II that are dominated by deposit feeders, consist primarily of suspension feeders (Tables 20 and 22a).

Ice scouring of the sea floor disrupts and modifies the sea bed over much of the ice-stressed continental shelf of the Alaskan arctic, affecting the sediments and their associated fauna (Barnes and Reimnitz, 1974; Carey *et al.*, 1974; Grantz *et al.*, 1982; Barnes *et al.*, 1984; Phillips *et al.*, 1985). In the Beaufort Sea, ice gouging results in lowered benthic abundance and biomass values in the inner to middle shelf and patchiness in benthic abundance along certain isobaths (Carey *et al.*, 1974; Feder and Schamel, 1976). A comparison of the benthic abundance and biomass values between the northeast Chukchi and Beaufort Sea shelf areas (Carey *et al.*, 1974, and data in this report) indicates regional differences. Generally speaking, in contrast to the shelf areas of the Beaufort Sea, the abundance and biomass values are higher on the northeastern Chukchi shelf, inclusive of the inner and midshelf areas (Appendix IV). Further, in the vicinity of Point Franklin in the northeastern Chukchi Sea (Figs. 63, 67, and 68; Appendix Tables IV.1-IV.3), there are high abundance and biomass values inshore. We suggest that one of the reasons for the variations of the benthos between the Beaufort and northeast Chukchi Seas may be the decreased annual ice cover in the Chukchi region (Grantz *et al.*, 1982). Consequently, it is expected that "the activity and the effects of sea ice on the Beaufort shelf to the northeast are more intense and pervasive in a general way than the Chukchi shelf" (Grantz *et al.*, 1982).

Polynyas are described for coastal shelf areas of the northeastern Chukchi Sea (Stringer, 1982), but not for the western Beaufort Sea. The local importance of the Chukchi polynyas to the marine ecosystem is not known (Arctic Ocean Science Board, 1988), but they do represent regions where ice is periodically excluded in winter. It is to be expected that ice gouging would be markedly reduced during such periods. This may explain, in part, the generally reduced affect of ice on the benthic fauna in the northeast Chukchi Sea in contrast to the marked reduction in this fauna inshore in the Beaufort Sea. As will be discussed below, increased benthic biomass values under some of the northern polynyas may also be a reflection of the increased input of POC generated locally within the polynyas (Arctic Ocean Science Board, 1988) to supplement advected sources of carbon.

D. Factors Affecting Benthic Abundance, Diversity, and Biomass

The dominant benthic organisms in the northeastern Chukchi Sea were polychaetous annelids, bivalve mollusks, and amphipods (particularly tube-dwelling ampeliscid amphipods). Mean abundance values recorded in the present study for offshore station groups were generally lower than those reported by Grebmeier *et al.* (1989) for the southeastern Chukchi Sea.

However, the mean abundance value for the northeastern inshore stations of Group III delineated in our study (Figs. 63 and 78; Table 21a) was considerably higher than that for the inshore group described by Grebmeier *et al.* (1989) for the southeastern Chukchi Sea. Some of the high abundance and biomass values noted in our study occurred close to the coast north of Icy Cape to Point Franklin, where the fauna was dominated by amphipods (inclusive of ampeliscids), a major food resource for gray whales (Nerini, 1984). Point Franklin has been identified as an area where these whales congregate and feed in summer (Phillips *et al.*, 1985; Moore *et al.*, 1986 a,b). In contrast, stations in our inshore Group IV, adjacent to Icy Cape under Alaska Coastal Water (ACW), had low macrobenthic abundance values similar to those reported by Grebmeier *et al.* (1989) for coastal stations in the southeastern Chukchi Sea. Feeding aggregates of gray whales do not occur within our Group IV area.

High Shannon diversity and low Simpson (a dominance index) indices and high evenness values generally occurred within offshore Station Groups I and II, both primarily muddy areas. These latter two groups typically consisted of stations with a diverse fauna with no particular species dominating. On the other hand, specific taxa dominated inshore Groups III and IV, both sandy-gravel areas. In particular, juvenile barnacles and amphipods dominated Group III while cockles and sand dollars dominated Group IV. Dominance by a few taxa in the latter groups was reflected by relatively low Shannon, high Simpson, and low evenness values (Tables 13 and 21b).

In the context of sediment sorting, there was an important difference between the distributional patterns of the benthos in the southeastern and northeastern Chukchi Sea and the adjacent northeastern Bering Sea shelf. Grebmeier (1987) related diversity and evenness values in the northeastern

Bering Sea to sediment heterogeneity. She reported highest diversity values at nearshore stations where sediments were poorly sorted and lowest diversity values offshore where sediments were relatively well sorted. However, in the southeastern Chukchi Sea, she indicated that diversity increased offshore where more heterogeneous sediments, as reflected by poorer sorting, occurred. Our studies demonstrate that all sediments in the northeastern Chukchi Sea, both close to shore and further offshore, are very poorly to extremely poorly sorted. Consequently, differences in benthic faunal diversity between inshore and further offshore regions in the northeastern Chukchi are probably not solely related to differences in sediment sorting. Other environmental factors that could have influenced the benthic diversity in the northeastern Chukchi Sea are assessed below.

Some of the sea bed of the outer shelf of the northeastern Chukchi Sea consists of erosional lag gravels either of contemporary (Phillips, 1987) or relict origin (McManus *et al.*, 1969). These few offshore regions, consisting of poorly sorted gravely sediments, support abundant epifauna composed of anemones, soft corals, barnacles, bryozoans, basket stars and tunicates (also see Table 25). However, adjacent to these gravel fields, the sea floor contains a blanket of mud at least 60 cm thick (Phillips, 1987), reflecting sediment deposition under relatively low energy hydrodynamic conditions. Large numbers of motile infauna (up to 75% of the total abundance) are common at stations within this mud-rich area. Intense sediment reworking by bioturbation characterizes the shallow subsurface of these muddy regions, as reflected by the numerous biological tracks covering the sea floor surface and the mottling structure depicted in box-core samples (Phillips, 1987). Thus, benthic biological processes appear to dominate over the physical processes of waves, currents, and ice-gouging in the muddy offshore areas.

As mentioned above, some of the shelf gravels are contemporary lag deposits. The northward flowing ACW intensively reworks the sea floor sediments out to approximately 70 km from the eastern shore to water depths of about 30 m (Phillips, 1987), winnowing out fine particles. The inshore sediments, underlying the ACW north of Icy Cape, consist of lag gravels and sand that support benthic communities with high abundance values. The continuous disturbance of the bottom of these inshore waters by the combined action of local eddies and gyres, ice gouging, intensified wave/current action during occasional storms, and feeding activities of gray whales and walrus (Barnes, 1972; Phillips and Reiss, 1985a, b) results in a stressful environment with benthic populations of low Shannon diversity, low evenness, and high Simpson dominance values. Thus, opportunistic species characteristic of disturbed environments, e.g., ampeliscid amphipods (Oliver and Slattery, 1985), are dominant on the bottom inshore north of Icy Cape in the northeastern Chukchi Sea. Vertical sediment reworking by the bottom-feeding gray whales and walruses transfers particulate organic carbon (POC) derived from subsurface sediments onto the sea-floor surface. Such a process is described for the adjacent northeastern Bering Sea following gray whale bottom-feeding disturbance (Oliver and Slattery, 1985). The utilizable POC, derived from sediment reworking, would supplement the primary settling POC as a food source and would, therefore, enhance the success of fast-growing, opportunistic benthic species (see Boesch and Rosenberg, 1981; Jones and Candy, 1981; Poiner and Kennedy, 1984; Thistle, 1981, for reviews on this process).

In our studies, high biomass values were particularly obvious at most coastal and offshore stations north of 70°30' latitude, as well as offshore Station 40 (Figs. 67 and 68). Previous work on the benthos in the adjacent northeastern Bering and southeastern Chukchi Seas (Grebmeier, 1987; Grebmeier *et al.*, 1988) demonstrated significantly higher benthic biomass (gC/m^2) values to the west of an oceanic front located between the nutrient-rich Bering Shelf-Anadyr Water (BSAW) and the relatively nutrient-poor Alaska Coastal Water (ACW). The BSAW has been demonstrated to be highly productive (Grebmeier *et al.*, 1988; ISHTAR, unpubl. progress reports). Grebmeier *et al.* (1988) suggest that the high primary production of this water mass produces a persistent and nutritionally adequate food supply to the benthos. This frontal system (delineated by bottom salinity varying from 32.4-32.7 $^o/oo$) has not been identified within the northern Chukchi Sea, although the northward flow of the mixed BSAW after it passes through the Bering Strait (now called Bering Water by Coachman *et al.*, 1975) has been traced as it moves toward Point Barrow (Spaulding *et al.*, 1987). Analysis of hydrographic data collected by our project suggests that modified Bering Water approaches the Alaska coast north of Icy Cape. It is hypothesized that the carbon rich waters identified in the southeastern Chukchi Sea (i.e., the mixed BSAW or Bering Water, as modified by mixing in the central Chukchi; Grebmeier *et al.*, 1988) also extend into the northern Chukchi and the Alaska coast north of $70^o30'$ latitude and supply a rich and persistent food source to the benthos that supplements resident POC. Net northward transport of water into the northeast Chukchi Sea is supported by the work of Naidu *et al.* (1981) and Naidu and Mowatt (1983) based on clay mineral distribution patterns. Their studies imply that the central and northeast Chukchi Seas are major depositional sites of the clays derived from the northeastern Bering Sea. It is assumed that all clay-sized particles, including associated bound organics and discrete POC, have similar transport pathways in the sea. The reasons for this are that both clay-sized inorganic and organic particles have similar hydraulic equivalents, and are therefore co-deposited (Trask, 1939) and that clays generally serve as a preferential binder for organics (Weston, 1988). In the present study, the highest biomass values occurred in the region approximately north and northwest of the 32.4 $^{o}/oo$ isohaline and the 0.0^{o} isotherm ($\bar{X}$ = 10.2 gC/m^2 north of the front; $\bar{X}$ = 5.0 gC/m^2 south of the front) (Table 14; Figs. 67 and 68). Similarly, an examination of Stoker's (1978) carbon values at stations in the northeastern Chukchi Sea revealed that carbon biomass was significantly greater (P=0.01) at northern stations (N=8) than at southern stations (N=4). Stepwise multiple discriminant analysis of our benthic biomass data demonstrates a separation of the north/northwestern region from the south/southeastern region by the higher bottom salinities and lower bottom-water temperatures present in the former region. Values for the latter two physical parameters in the northern region were similar to those identified offshore further south in the southeastern Chukchi Sea which suggests that modified Bering Water and the associated hydrographic front extends from south to north in the Alaskan Chukchi Sea.

Perhaps there are additional factors contributing to the high biomass north of $70^{o}30'$ latitude in our study area. Periodic upwelling in the nearshore zone from Icy Cape to Point Barrow is reported (see Physical Oceanography section and Johnson, 1989). This process could locally enhance annual primary production, and increase the POC flux (as phytoplankton and zooplankton) to the bottom in this region. However, annual primary production north of $70^{o}30'$ latitude, on a regional scale, is reported as a modest 25-100 gC/m^2 (Parrish, 1987). It is possible that the annual water-column production is locally increased inshore within polynyas (Arctic Ocean Science Board, 1988). Further, the ice-edge region, which may extend as far south as Icy Cape in the summer, may also contribute considerably to total water-column productivity (Niebauer and Alexander, unpubl.). Additionally, carbon production by under-ice (epontic) algae in late spring is estimated as 13 $gC/m^2/yr$ (Parrish, 1987). Presumably flux of phytoplankton and epontic algal debris to the bottom is enhanced by reduced grazing pressures by zooplankton in these northern waters, similar to the situation described by Cooney and Coyle (1982) and Walsh and McRoy (1986) for the shallow inner and middle shelf of the southeastern Bering Sea. Additionally, the flux to the bottom of dead and dying zooplankters advected from more southerly waters might also be expected to enrich the benthic environment, resulting in enhanced benthic standing stocks. The increased plankton volumes from inshore to offshore and from south to north from Bering Strait to Icy Cape (English, 1966) seem to support the suggestion that zooplankters are advected northward by the water currents. Particulate organic matter enrichment of the bottom must, in fact, persist on a long-term basis in the northern margin of the northeastern Chukchi Sea, for the various reasons discussed above. This contention is supported by the local presence of a relatively higher content of organic carbon and nitrogen in the sediment and the continued return in summer of gray whales (Moore and Clarke, 1986; Clarke *et al.*, 1987) and walrus (Fay, 1982; person. commun.) to regions north of 70°30' to feed.

The high benthic biomass that we observed for inshore waters north of Icy Cape is not typical of the inshore benthos under Alaska Coastal Water south of the Cape (this study; Grebmeier *et al.*, 1988). The latter point to some extent supports our hypothesis that the advection of POC, presumably from the southeastern Chukchi Sea via Bering Strait into these northern coastal regions, is important.

Throughout the entire study area, benthic interface feeders (surface deposit feeder + suspension feeders) generally dominate over subsurface deposit feeders (Figs. 71 and 73). This reflects the general importance of nutritionally adequate POC in the water column and its flux to the sediment surface where most of it is consumed by the interface feeders. Consequently, little POC apparently remains for incorporation into the bottom sediments for use by subsurface deposit feeders.

E. Biomass, Production, and Carbon Requirements of the Benthos

Thomson (1982) noted that the mean biomass (wet weight) generally decreased from Newfoundland (1455 g/m^2) through the Arctic Islands (200-438 g/m^2) to the Beaufort Sea (41 g/m^2: Carey, 1977), and he suggested that this trend appeared to parallel a trend in decreasing primary production. On the subarctic Alaska shelf, a relationship between biomass and primary productivity has also been documented. In the southeastern Bering Sea where primary productivity is 166 $gC/m^2/yr$ (Walsh and McRoy, 1986), benthic biomass in the mid-shelf region is 330 g/m^2. In the northeastern Bering Sea and Bering Strait, with primary production values of 250-300 $gC/m^2/yr$ (Sambrotto *et al.*, 1984; Springer, 1988; Walsh *et al.*, 1988), the benthic biomass offshore under Bering Shelf-Anadyr Water (BSAW) is reported as 482-1593 g/m^2 (Stoker, 1978; Feder *et al.*, 1985; Grebmeier, 1987). A wide, but lower, range of benthic biomass (55-482 g/m^2) occurs inshore under Alaska Coastal Water (ACW) in the northeastern Bering and southeastern Chukchi Seas where primary productivity is estimated at 50 $gC/m^2/yr$ (Sambrotto *et al.*, 1984; Springer, 1988; Walsh *et al.*, 1988. South of 70°30' north latitude, in the northeastern Chukchi Sea under ACW, a relatively low mean benthic biomass was determined (139 ± 79 g/m^2) (Table 14; Fig. 67). However, north of 70°30' latitude (for our offshore as well as inshore stations), relatively high values for benthic biomass were determined (258$\pm$136 g/m^2), although primary productivity values for that area are only estimated to be 50-100 gC/m^2 (Parrish, 1987). Thus, the relatively high benthic biomass in the northeastern Chukchi Sea north of 70^{o}30' appears to be an exception to the relationships referred to above, i.e., a direct relationship between benthic standing stock and primary production. Consequently, our biomass data reinforces the earlier conclusion that some source of POC, in addition to local primary production, is fluxing to the bottom in our study area. It is likely that this supplemental POC sustains the higher biomass in the northeastern Chukchi Sea in contrast to the lower values reported for the contiguous Beaufort Sea by Carey (1977).

The estimated mean benthic production value (5.9 gC/m^2/yr) for the region north of the oceanic front in the northeastern Chukchi Sea (Table 14; Fig. 69), as suggested above, is significantly greater (P=0.009) than that for the benthos south of this region (3.4 gC/m^2/yr). The higher benthic production in the northern region apparently sustains the seasonal predation by walruses and small populations of gray whales in parts of that area. Generally speaking, it would be expected that the numbers of walruses and gray whales present are related to the level of benthic production, providing of course that a large proportion of that production is utilizable as food by these marine mammals. In the case of the northeastern Chukchi Sea in the vicinity of Peard Bay, it appears that there is a disproportionate number of marine mammals present there, as compared to the northeastern Bering Sea, based on the differences in production in the two areas. Illustrating this point are the similar densities of gray whales in the central northeastern Bering Sea and coastal northeastern Chukchi Sea (Ljungblad, 1987), even though benthic production is different within the two regions. The estimated mean production value for the central northeastern Bering Sea is an estimated 13.7 $gC/m^2/yr$ (calculated from biomass data of Grebmeier, 1987), while that of the northeastern Chukchi is estimated at 5.9 $gC/m^2/yr$. The apparent discrepancy (i.e., similar gray whale densities in both areas but lower apparent production to the north) may be related to the reduced predation by bottom-feeding crabs and fishes in the northeastern Chukchi Sea (Naidu and Sharma, 1972) compared to the northeastern Bering Sea (Jewett and Feder, 1981) in conjunction with reduced feeding activities in late summer for these mammals in the northern waters (Clarke *et al.*, 1987).

Four stations (CH34-37) south of the front and just north of Cape Lisburne are located beneath a clockwise oceanic gyre (W. J. Stringer, person. commun.) and have relatively high benthic biomass values (Figs. 62, 67, and 68). Estimated production at these stations is similar (i.e., a mean value of 5.9 $gC/m^2/yr$) to that of the stations north of the front discussed above. Alternatively, all of the other stations north of Cape Lisburne and south of the front had relatively low benthic biomass values with a mean production of only 2.5 $gC/m^2/yr$. Presumably, a continued flux of carbon to the bottom under the gyre enriches the bottom and results in an enhanced carbon biomass and production at the four stations.

The short sampling time (i.e., a single cruise 22 August - 1 September 1986) makes it impossible to calculate a carbon budget for the study area. However, the multiple sources of autochthonous and allochthonous carbon available to the benthos in the northern portion of our study area and the presumed reduction in water-column grazing in this region (see comments on pages 38 and 40-41 of this report) suggests that the carbon requirements calculated for the benthos (Table 12) are reasonable. Additional sediment trap data and benthic respiration measurements are needed to substantiate our calculations and tentative conclusions.

F. The Relationship of Stable Carbon Isotopic Ratios, OC/N Values, and Macrobenthic Biomass

The distributional patterns of the stable carbon isotopic ratios ($\delta^{13}C$) clearly show that the nearshore areas, compared to offshore regions, are characterized by relatively lighter isotopic ratios (Fig. 52). This can be explained in the context of a model consisting of two-end-member sources of organic carbon to sediments, terrigenous and marine. This conclusion is substantiated by a general seaward decrease from the coast in OC/N values of bottom sediments (Fig. 51) and in the particulates collected in sediment traps (Table 8).

As discussed earlier, the abundance and biomass of macrobenthic animals in our study area can be related to a number of environmental factors. These factors include sediment characteristics, water mass origin, intensity of waves, currents, ice gouging, and feeding activities of marine mammals, as well as the amount and nutritional values of organic matter fluxing to and accumulating on the bottom. In attempting to assess the nutritional value of organic carbon in sediments, the $\delta^{13}C$ values were compared with benthic biomass and abundance values. It was assumed that carbon in sediments with relatively lighter isotopic ratios relate to terrigenous organic matter with large proportions of refractory organics, and thus, of low nutritional value. Likewise, it was assumed that carbon in sediments with heavier isotopic ratios reflect association with marine-derived organics which are generally more readily utilized by benthic organisms, and are, thus, of high nutritional value. Analyses of similar data from the southeastern Chukchi Sea have shown that no significant correlations exist between $\delta^{13}C$ or OC/N and macrobenthic abundance or biomass (Research Unit 690 data not included in this report). The lack of correlations suggests that the nature of organic matter, as reflected by $\delta^{13}C$ and OC/N of the sediments, is not the sole factor controlling macrobenthic abundance and biomass in the northeastern Chukchi Sea. As discussed earlier, apparently sediment texture, water content of sediments, and the amount of organic matter fluxing to the bottom, some of which may be highly site-specific, are the predominant factors determining benthic abundance and biomass.

G. The Importance of Epibenthic Invertebrates and Demersal Fishes

Demersal trawling for invertebrates and fishes was conducted at ten stations in the Barrow Arch in August/September 1977 (Frost and Lowry, 1983). Ten fishes representing six families were caught. The most abundant and frequently caught fishes were the arctic cod (*Boreogadus saida*). The hamecon (Cottidae:*Artediellus scaber*) and the fish doctor (Zoarcidae: *Gymnelis viridis*) followed in abundance and frequency of occurrence. A total of 166 invertebrate species or species groups were found, including 38 gastropods, 26 amphipods, 20 bivalve molluscs, 14 shrimps, and 11 echinoderms. Echinoderms were the most abundant invertebrate group. These included six species of sea stars, three sea cucumbers, one sea urchin, and one brittle star. The brittle star, *Ophiura sarsi*, was the most abundant echinoderm. The most frequently caught gastropods were *Margarites costalis, Natica clausa, Buccinum polare,* and *Polinices pallida*. These gastropods occurred in nine, eight, six and five of the ten stations, respectively.

Dominant species collected in the present study were somewhat similar to those collected by Frost and Lowry (1983). However, their collections included only a few Tanner crab (*Chionoecetes opilio*), an abundant epibenthic component of trawl catches at most of our stations. Generally, the dominant species collected in both studies reflected the type of bottom characterizing the trawled area. Further, knowing that the substrate consisted of mud, sand, or sand-gravel indicates the type of hydrodynamic conditions present on the bottom. Data available from the qualitative studies summarized above identify the need for an extensive, quantitative investigation of the epibenthos and demersal fishes of the northeastern Chukchi Sea.

The collections of brittle stars, *O. sarsi*, resulting from our trawl studies consisted primarily of large specimens (mean disc diameter = 22 mm), suggesting the presence of an abundant, nutritionally adequate source of food for these organisms. The brittle stars were feeding heavily on bivalve molluscs, gastropods, small crustaceans, and barnacle cyprid larvae. In a Danish fjord, a related species, *O. ophiura (= O. texturata*) fed mainly on juvenile bivalves and were more successful than members of the species living outside the fjord, where bivalves were rarely available as food (Feder, 1981; Feder and Pearson, 1988). *Ophiura sarsi* living in Cook Inlet, an embayment of the northern Gulf of Alaska, were smaller (mean disc diameter = 13 mm) than individuals living in the northeastern Chukchi Sea and were feeding primarily as scavengers (Feder *et al.*, 1981).

Although the northeastern Chukchi Sea approaches the northern limits of the range of the Tanner crab, *Chionoecetes opilio* (Jewett, 1981), the crab did occur at seven of the ten trawl stations occupied for our investigation. However, adult crabs were primarily found in the southern part of the study region while juveniles dominated catches in the more northern stations. Food appeared to be adequate to sustain these crabs to the adult stage in the northern portion of the study area (also see reviews on feeding habits for the Tanner crab in Alaskan waters in Feder and Jewett, 1981, 1987); thus, other factors must prevent survival of juveniles to adults. Possibly, low bottom temperatures decrease growth rates and make juveniles more vulnerable to predation. Relative to this point, the Tanner crab represents one of the most important forage species for bearded seal (*Erignathus barbatus*) in northern Alaskan waters, including the northeastern Chukchi Sea (Lowry *et al.*, 1980). Predation pressure by this mammal may be responsible for the low population levels of the Tanner crab. Consequently, as suggested previously, the Tanner crab does not appear to represent an important competitor for food used by walruses and gray whales in the northern sector of the northeastern Chukchi Sea.

H. Important Feeding Areas of Gray Whales and Pacific Walruses

1. Whales

A portion of the gray whale (*Eschrichtius robustus*) population annually migrates to the eastern Chukchi Sea in summer (Moore *et al.*, 1986a), passing through Bering Strait before mid-June (Braham, 1984). They are not typically associated with ice, and, in fact, the main movements into the Chukchi Sea occur after the pack ice has retreated northward. Approximately 1,650 gray whales were estimated to occur in the nearshore waters of the eastern Chukchi Sea in 1981 (Davis and Thomson, 1984). Few gray whales penetrate into the Beaufort Sea (Moore and Ljungblad, 1984).

The annual distribution, abundance, habitat preference and behavior of gray whales along the eastern Chukchi Sea were investigated via aerial surveys during July 1980-83 (Moore *et al.*, 1986a). Similar investigations were made in the northeastern Chukchi Sea during mid-July through late October 1982-86 (Clarke *et al.*, 1987). Gray whales were distributed from south of Point Hope to north of Point Barrow, between 0.5 and 166 km offshore (Clarke *et al.*, 1987). Most sightings in 1982-84 were made between Icy Cape and Point Barrow at an average distance from shore and depth of 14.5 ± 18.9 km and 20.5 ± 9.9 m, respectively (Moore *et al.*, 1986b).

Monthly abundance estimates were highest in July and lowest in October, with the highest estimates calculated for the area north of 70°N from July through September, and for the Point Hope area in October (Clarke *et al.*, 1987). Annual variation of whale sightings has been high. The coastal Chukchi Sea south of Point Hope to Point Barrow supported relatively high whale densities (1.48 whales/km^2) in 1982, but relatively low densities were observed there in 1980, 1981 and 1983, i.e., 0.26, 0.28 and 0.37 whales/km^2, (Moore *et al.*, 1986a).

Annual differences in the gross annual recruitment rate of calves by region reflects a partial segregation of cow-calf groups in the northeastern Chukchi Sea (Moore *et al.*, 1986a). This northern range may be a possible weaning area for cow-calf pairs (Clarke *et al.*, 1987).

Sonographs, television, and bottom photographs collected during reconnaissance surveys in the northeast Chukchi Sea in 1984 and 1985 identified scattered to dense benthic feeding traces on the sea floor from gray whales as well as walruses (Phillips and Colgan, 1987). The highest concentration of gray whale feeding traces were found at depths of 23 to 34 m on the inner shelf between Wainwright and Point Franklin where the Alaskan Coastal Current actively transports sediment and associated detrital particles.

Ljungblad (1987) noted that gray whale distribution and highest densities correspond to areas where dense prey assemblages have been documented. Both Chirikov Basin, in the north central Bering Sea, and coastal Saint Lawrence Island have been described as primary feeding areas for gray whales (Rice and Wolman, 1971; Zimushko and Ivashin, 1979; Bogoslovskaya *et al.*, 1981: all cited in Ljungblad, 1987). Dense assemblages of benthic amphipods dominate the benthic biota and the food of gray whales in these regions (Stoker, 1981; Nerini and Oliver, 1983; Thomson and Martin, 1984; Nerini, 1984; Oliver *et al.*, 1984). Analysis of stomach contents of gray whales taken by whalers along the northern Chukchi Peninsula revealed that three genera of amphipods, in particular *Ampelisca, Anonyx*, and *Pontoporeia*, were preferred prey, although there was usually a variety of prey species in the stomachs (Blokhin and Pavlyuchkov, 1983, as cited in Moore *et al.*, 1986b).

Thomson and Martin (1984) estimated that gray whales consume approximately 4% of the overall annual productivity of benthic amphipods, their principal prey in the Chirikov Basin. They further concluded that this level is sustainable by the prey populations there (Thomson and Martin, 1984). Recent investigations by Highsmith and Coyle (pers. commun.) have shown that gray whales within the Chirikov Basin are consuming amphipods at a rate approximating that of Thomson and Martin (1984).

Observations made in the northern Chukchi Sea between 1982 and 1986 revealed that most gray whale were feeding (59%), as indicated by mud plumes with whale sightings (Clarke *et al.*, 1987). Ljungblad (1987) noted that whales feeding on epibenthic animals probably do not create the mud plumes characteristic of whales foraging for infaunal species, thus their feeding may go unrecognized by aerial observers. As in other regions, benthic amphipods were assumed to be the principal prey group taken in the northern region, although Nerini (1984) also pointed out that gray whales exhibited a high degree of dietary flexibility and could be termed food "generalists."

As suggested previously, the high benthic biomass and production values north of 70°30' in the northeastern Chukchi Sea, as determined by our studies, presumably sustain seasonal predation by the small inshore population of gray whales present.

An understanding of the extent and distribution of prime feeding habitat for gray whales in the northern Chukchi Sea is strengthened through macrofaunal sampling on whale feeding grounds. The infaunal sampling conducted by Stoker (1981) occurred seaward of the coastal regions typically used by gray whales. However, our study included 12 stations (CH4-8, 17-19, 31, 33, 43, and 44: Fig. 62) between Point Hope and Point Barrow within 50 km of the shore at an average depth of 27.3±8.9 m where most sightings have occurred (Clarke *et al.*, 1987). Only four of these stations (CH5, 6, 7, and 17: Figs. 62 and 66) had high concentrations of amphipods ($\bar{X}$=4,319±1,987 amphipods/m^2), especially the families Isaeidae, Ampeliscidae, and Atylidae. Amphipod abundance values were also relatively high at stations CH10 and CH16, but both of these stations are located approximately 80 km offshore.

Amphipod abundance values at Stations CH5, 6, 7, and 17 (Table 28) were similar to those reported for the gray whale feeding grounds in the Chirikov Basin in the northern Bering Sea ($\bar{X}$=5,086±5,907 amphipods/m^2). However, the values at Stations CH5, 6, 7, and 17 were much lower than those reported for the gray whale feeding grounds off Southeast Cape, St. Lawrence Island in the northern Bering Sea ($\bar{X}$=107,873±57,192/m^2) (Thomson and Martin, 1984). Although the large ampeliscids are typically taken by gray whales, smaller amphipods (e.g., Isaeidae and Atylidae), as well as other benthic invertebrates, are also taken by these opportunistic feeders (Oliver *et al.*, 1983; Nerini, 1984). Presumably other epifaunal and infaunal prey are also taken to supplement their diet when they occur in the northern Chukchi Sea. The seemingly reduced quantity of benthic amphipods on the northern limit of the gray whales' range supports the observation made by Clarke *et al.* (1987), i.e., the northeastern Chukchi Sea is an important summering area for gray whales from July through October, principally as a peripheral feeding ground and possibly a weaning area for cow-calf pairs.

2. Walrus

Most of the Pacific walrus (*Odobenus rosmerus*) population, including adult females and calves and subadults of both sexes, summer in the Chukchi Sea mainly residing along the southern edge of the pack ice. The migrants move north with the receding ice typically reaching the Chukchi Sea by the end of June (Fay, 1982). The population mainly inhabits the northern Chukchi Sea north of Point Lay to east of Point Barrow to Wrangel Island. Their distribution is determined to a great extent by winds and ice conditions and varies from year to year. By using the moving ice, walruses are continually transported to new feeding grounds while they rest. By staying with the ice, they are able to exploit the benthic resources of nearly the entire shelf. As ice formation begins in the fall, walruses move southward, some swimming well ahead of the advancing ice. Solitary animals occasionally overwinter near Point Hope (Fay, 1982).

In September and October 1970, an area approximately 46 km northwest of Point Lay and another area north of Point Barrow had highest densities of walruses (Ingham *et al.*, 1972). A survey between Point Hope and the ice edge in September 1975 found walruses most abundant between 162^{o} and 165^{o}W longitude (Estes and Gol'tsev, 1984).

Reconnaissance surveys in the northeast Chukchi Sea in 1984 and 1985 identified scattered to dense benthic feeding traces on the sea floor from walruses in gravel and sand regions to depths of 53 m (Phillips and Colgan, 1987). Two areas of high concentrations of walrus feeding traces were identified as south of Hanna Shoal near the pack ice boundary and offshore between Icy Cape and Point Franklin.

The stomach contents of 44 walruses were examined in September 1987 from two areas approximately 50 km south of Hanna Shoal (Fig. 87; Area 1: 71°19' to 71°38' N lat., 163°20' to 163°35' W long.; Area 2: 71°12' to 71°28' N lat., 161°06' to 161°44' W long.) (F. Fay, pers. commun., 1988). These stomachs contained 36 prey taxa, with ten bivalve and nine gastropod taxa most numerous. Dominant prey, in order of decreasing biomass, were gastropod mollusks, the priapulid worm *Priapulus caudatus,* ampeliscid amphipods, the polychaete worm *Flabelligera* sp., bivalve mollusks, and the ascidian *Pelonaia corrugata* (Table 32). Stomachs of 11 males near Point Barrow in July and August 1952 and 1953 contained mainly siphons of the clam *Mya truncata* (Brooks, 1954, as cited in Fay, 1982). Also present were the holothurian *Molpadia arctica*, a priapulid worm, and three species of snails.

More than 60 genera of marine organisms, representing ten phyla, have been identified as prey of the Pacific walrus. Bivalve mollusks (clams, mussels, and cockles) have been found more often and in greater quantities than any other group of benthic invertebrates (Fay, 1982).

Information on the benthic invertebrate resources of the northeastern Chukchi Sea, in addition to what the walrus stomach analyses revealed, give insight into the relative productivity of this region. Stoker (1978, 1981) sampled the infaunal invertebrates with a van Veen grab at five stations south of Hanna Shoal during August and September 1973 and 1974 (Fig. 87). These stations were located in a region where walrus feeding is known to occur during open water in summer; the infaunal biomass at these stations

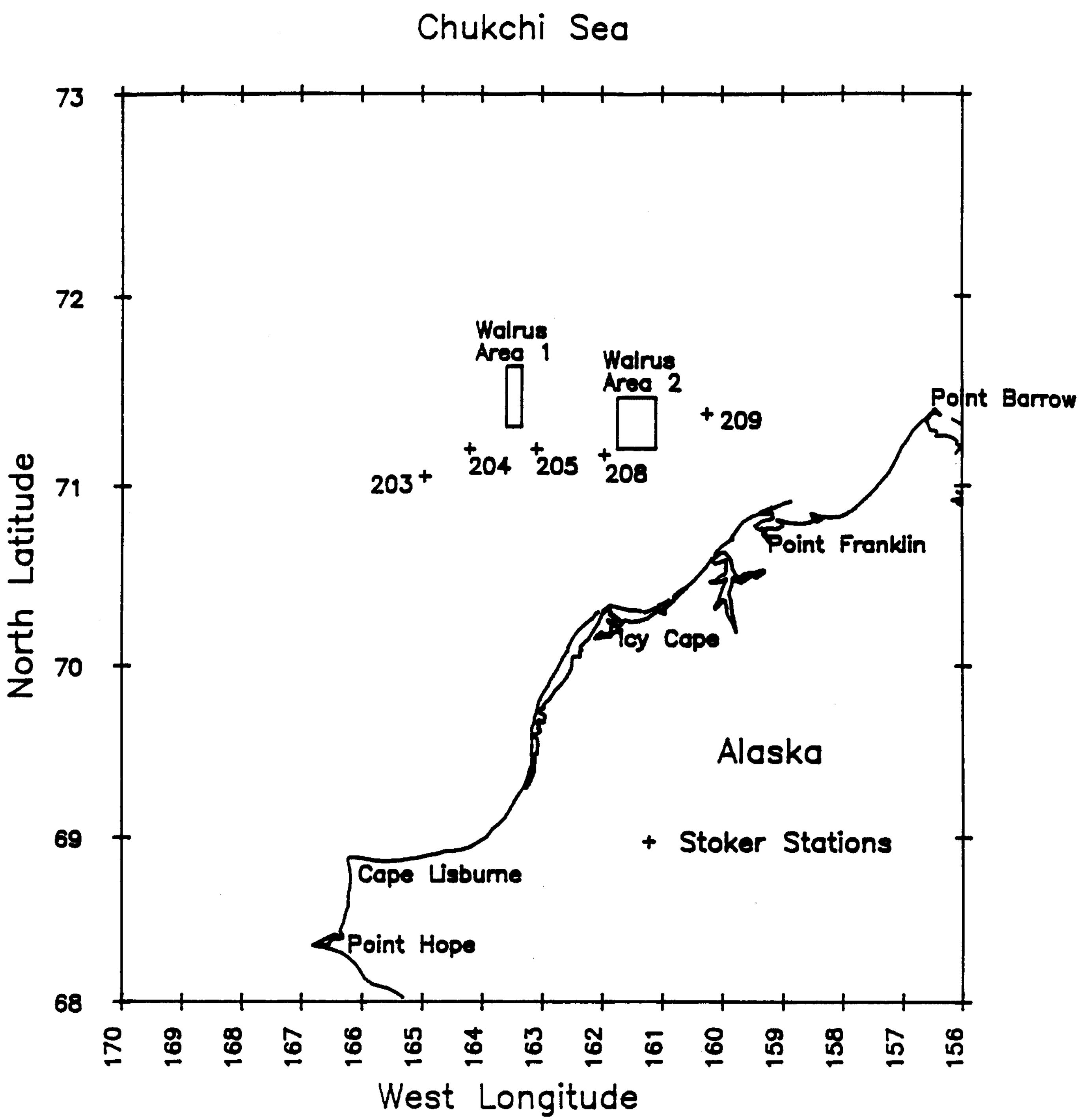

Figure 87. Locations where walruses were examined for stomach contents, September 1987 (Areas 1 and 2) (Fay, unpubl.) and where benthic sampling occurred in 1973-74 by Stoker (1978, 1981).

Table 32. Stomach contents from Pacific walrus collected in the northeastern Chukchi, September 1987 (F. Fay, pers. comm., 1988).

Area	1			2			Combined Areas		
Number of Stomachs	8			36			44		
	Percent								
	Number	Weight	Frequency	Number	Weight	Frequency	Number	Weight	Frequency
Polychaeta	12.7	16.7	63	3.2	1.6	44	5.1	3.8	48
Flabelligera sp.	12.4	16.6	50	3.2	1.6	36	5.0	3.7	39
Priapulus caudatus	6.5	7.7	100	7.1	8.9	78	8.1	8.7	82
Gastropoda	35.8	17.6	100	58.4	14.7	89	53.9	15.2	91
Naticidae	32.2	0	100	52.8	1.3	89	48.7	1.2	91
Pelecypoda	30.5	5.4	88	6.3	1.4	61	11.1	2.0	66
Tellinidae	24.0	3.0	75	4.4	0.3	42	8.3	0.7	48
Amphipoda	6.3	3.5	63	24.0	7.4	56	20.5	6.9	57
Pelonaia corrugata	7.1	6.7	50	0.1	0.1	22	1.5	1.0	27

averaged a relatively high value of 19.6 gC/m^2. The dominant macrofaunal groups in the five stations were bivalves, sipunculids, and polychaetes, making up 28, 25, and 24% of the carbon biomass, respectively (Table 33). The dominant bivalves were *Astarte* spp., *Macoma* spp., *Nucula tenuis*, and *Mya truncata*.

A group of stations sampled in the present study, i.e., the 14 stations in Station Group II (Fig. 78), encompassed most of the summer and fall habitat of walruses (Fay, 1982; Frost *et al.*, 1983). The average organic carbon value within the sediment at Group II stations was highest (8.7 mgC/g) of the four station cluster groups. Also, the benthic carbon biomass at this group of stations was a high 9.2 gC/m^2. The fauna was dominated by the bivalves *Macoma* spp., *Nucula bellotti (=tenuis)*, and *Astarte* spp., the sipunculid *Golfingia margaritacea*, and polychaete worms (Table 30).

Benthic samples were also taken in the present study in the area where extensive walrus feeding traces were observed offshore between Icy Cape and Point Franklin (Phillips and Colgan, 1987). Most stations within this area grouped together (Group III) based on cluster analysis of the infaunal abundance data (Fig. 78). Few of the most abundant fauna were ones typically taken by walruses. However, bivalves and gastropods consisted of nearly 17% and 9% of the carbon biomass, respectively. Dominant bivalves were *Liocyma viridis, Astarte borealis* and *Yoldia myalis*. Dominant gastropods were *Natica clausa* and *Polinices pallida* (Table 31).

The feeding activity of gray whales and walruses may be a significant factor contributing to the high benthic productivity of the northeastern Chukchi Sea. Both excavate into the sediment suspending fines and recycling nutrients that would otherwise be trapped in the sediment. Furthermore,

Table 33. Dominant infaunal invertebrates from stations in the vicinity where Pacific walrus typically occur in the northeastern Chukchi Sea. Data from Stoker (1978, 1981).

Number of stations:	5
Average indiv./m^2	1127 ±535
Average gC/m^2	19.6 ±3.7

Dominant Groups	Average Indiv./m^2	%	Dominant Groups	Average gC/m^2	%
Polychaeta	553	49.1	Bivalvia	5.5	28.1
Bivalvia	210	18.6	Sipuncula	4.9	25.0
Ophiuroidae	177	15.7	Polychaeta	4.6	24.0

Dominant Taxa	Average Indiv./m^2	Dominant Taxa	Average gC/m^2
Maldane sarsi	322	*Golfingia margaritacea*	4.8
Ophiura sarsi	118	*Astarte* spp.	2.5
Nucula tenuis	67	*Psolus* sp.	1.3
Macoma spp.	53	*Maldane sarsi*	1.1
Terebellides stroemi	45	*Macoma* spp.	1.0
Diamphiodia craterodmeta	42	*Nicomache lumbricalis*	0.5
Astarte spp.	38	*Flabelligera* sp.	0.4
Nicomache lumbricalis	20	*Terebellides stroemi*	0.4
Lumbrineris fragilis	18	*Nucula tenuis*	0.4
Golfingia margaritacea	17	*Mya truncata*	0.4
Yoldia hyperborea	13	*Pelonaia corrugata*	0.3

organic debris accumulates in the excavations, thereby attracting large numbers of animal colonizers (Oliver and Slattery, 1985).

Johnson and Nelson (1984) calculated that the volume of sediment injected into the water column by feeding gray whales in the northeastern Bering Sea is at least 1.2×10^9 m^3/yr, or over two times the yearly sediment load of the Yukon River. This figure may well approximate the volume of sediment liberated by both gray whales and walruses on their northern feeding grounds.

Additionally, the areas where gray whales and walruses feed in the northern Chukchi Sea are intensively gouged by ice (Grantz *et al.*, 1982). This mechanism, coupled with the the feeding activities of gray whales and walruses, which results in a tilling effect on the seabed, probably enhances benthic productivity of the region (Johnson and Nelson, 1984).

VII. CONCLUSIONS

Previous work in the northeastern Bering and southeastern Chukchi Seas identified an oceanic front between the relatively cold, nutrient-rich Bering Shelf-Anadyr Water (BSAW) or modified Bering Water and the relatively warm, nutrient-poor Alaska Coastal Water. The northward flow of the BSAW has been traced toward Point Barrow. Water mass analysis in our study indicates that generally the warm coastal water penetrates as far north as about 70°30' and that modified Bering Water approaches the coast north of Icy Cape. The Beaufort Sea water produces a tongue of colder and higher salinity water near the bottom of the Barrow Canyon. In the rest of the volume of the northeast Chukchi Sea, the Bering Sea-Anadyr water mass which flows northward through Bering Strait is the major water mass contribution. These water masses can be modified in their characteristics by winter ice formation, which tends to produce cold and salty deep and bottom waters and fresh near-surface layers. For both of the traditional T-S technique and the cluster analyses, the line separating the water mass groupings follows the temperature and bottom salinity contours. These water masses remain relatively distinct, with oceanic fronts between the masses. These fronts are maintained by the frontogenic forces of the mean currents, particularly the coastal current and the general northward flow resulting from the Bering Strait transport.

Temperature and salinity values characteristic of the water masses overlying the shelf of the northeastern Chukchi Sea were associated with identifiable assemblages of benthic species. The species collected at offshore Station Groups I and II (based on abundance values) were generally those characteristic of the cold, relatively high salinity bottom water under the modified BSAW which originates as a northward flow through Bering

Strait. Alternatively, many of the benthic species of inshore Groups III (primarily the southern portion of this region) and IV are those characteristic of the warmer, lower salinity bottom water of the Alaska Coastal Current. Previous work on the tube-dwelling amphipods of the family Ampeliscidae in the northeastern Bering Sea reported high abundance values for these crustaceans under the cold, nutrient-rich BSAW. However, in the northeastern Chukchi Sea these amphipods only occur in abundance inshore north of 70°30' (within Station Group III) where mixed Bering Water approaches the coast and apparently supplies a supplemental source of POC to the bottom where it is available to the crustaceans.

It is recognized that there are a number of other factors, in addition to water mass properties, that determine the taxonomic composition of benthic assemblages in the study area. However, because of the limited data available it is only possible at present to draw some tentative conclusions concerning the role of sedimentation rates, ice, and polynyas on benthic distribution patterns. It is suggested that the delineation (based on abundance values) of macrobenthic inshore Groups III and IV (consisting primarily of suspension feeders) from offshore Groups I and II (dominated by subsurface deposit feeders) is due to the relatively higher sediment accumulation rates in the offshore than in the inshore region. The broad regional variations in the sedimentation rates, as documented by us, are consistent with the net seaward decrease in wave energy conditions attended by greater sediment flux to the bottom during summer in the offshore region. The importance of fluidized muddy and POC-enriched sediments as an environment suitable for deposit-feeding organisms within offshore Groups I and II (but particularly Group II) is indicated by the variety of subsurface deposit-feeding species present in these groups.

The distributional patterns of the stable carbon isotopic ratios ($\delta^{13}C$ ‰) of bottom sediments clearly show that the nearshore areas, compared to offshore regions, have relatively lighter isotopic ratios. This is explained in the context of a model consisting of two-end-member sources of organic carbon to sediments, terrigenous and marine. This conclusion is substantiated by a general seaward decrease from the coast in the OC/N values of bottom sediments and in the organic particulates collected in sediment traps. A lack of correlation between $\delta^{13}C$ or OC/N and macrobenthic abundance or biomass suggests that the nature of organic matter (e.g., relatively more labile or refractory), as reflected by $\delta^{13}C$ and OC/N of the sediments, is not the sole factor controlling macrobenthic abundance or biomass in the study area. Apparently sediment texture and water content as well as the amount of organic matter fluxing to the bottom are the predominant factors determining benthic abundance and biomass.

The four macrobenthic station groups (based on abundance values) identified in the northeastern Chukchi Sea are best explained by discriminant analysis in terms of the percent gravel, sand, and mud in conjunction with OC/N values and percent water in the sediment. In general, Group I comprised a fauna associated with mud-sand-gravel with 20-40% water; dominant species consisted of the ampeliscid amphipod *Byblis gaimardi* and juveniles of the barnacle *Balanus crenatus*. Group II consisted of fauna associated with a muddy substrate with 45-60% water content dominated by the tube-dwelling polychaete *Maldane glebifex* and the protobranch clam *Nucula bellotti*. Group III consisted of an assemblage associated with a sandy substrate containing 15-20% water, and characterized by juvenile and adult *B. crenatus* and amphipods (including the large *Ampelisca macrocephala*). Group IV consisted of an assemblage associated with a sandy-gravel substrate containing about 20% water, and dominated by the sand dollar *Echinarachnius parma*.

Previous work on the benthos in the southeastern Chukchi Sea demonstrated significantly higher biomass (gC/m^2) values to the west of an oceanic front located between the modified Bering Water and the ACW. High biomass values in our study were prevalent at most coastal and offshore stations north of 70°30' latitude where modified Bering Water approaches the coast north of Icy Cape. We suggest that the carbon-rich waters identified in the southeastern Chukchi Sea (i.e., the mixed BSAW, as modified by mixing in the Chukchi Sea) also extend into the northern Chukchi and the coast north of 70°30' and supply a rich and persistent food source to the benthos. The predominance (abundance and biomass) of surface deposit-feeding amphipods (including ampeliscids) in the northeastern section of Station Group III appears to reflect a region of unusual flux of POC to the bottom. Benthic amphipods are a major food resource for gray whales, and the presence of feeding populations of these whales in the vicinity of Point Franklin in the summer apparently represents a long-term response to an abundant and reliable food source.

In general, the dominant epibenthic invertebrates and fishes collected reflected the type of bottom characterizing the trawled area (data are only qualitative assessments obtained using a small otter trawl). The brittle star, *Ophiura sarsi*, was generally common and consisted primarily of large specimens which suggests the presence of an abundant, nutritionally adequate source of food. Adult Tanner crab, *Chionoecetes opilio*, occurred primarily in the southern part of the study region while juveniles dominated catches in the more northern stations. Food appeared to be adequate for these crabs in the northern portion of the study area, thus other factors must prevent survival of juvenile to adults. Possibly low bottom temperatures decrease growth rates and make juveniles more vulnerable to predation. Thus, the Tanner crab does not appear to be an important competitor for food used by walruses and gray whales in the northeastern Chukchi Sea.

A comparison of the benthic abundance and biomass values between the northeast Chukchi and adjacent Alaskan Beaufort Sea shelf areas indicates higher abundance and biomass in the Chukchi, inclusive of the inner and midshelf areas. We suggest that one of the reasons for the observed regional variations of the benthos is the decreased annual ice cover in the northeastern Chukchi Sea. Additionally, presence of polynyas are documented for the inner shelf of the northeastern Chukchi Sea but not for the western Beaufort Sea. It is, therefore, presumed that ice-scouring of the sea floor would be relatively more intense and, thus, more devastating to the benthos, in the Beaufort Sea than in the Chukchi Sea.

A review of the gray whale (*Eschrichtius robustus*) literature reveals that these whales inhabit the northeastern Chukchi Sea primarily nearshore between Icy Cape and Point Barrow during July through October. Macrofaunal sampling in our project revealed that the greatest concentrations of benthic invertebrates, including amphipods (a preferred gray whale prey), occurs within the area where gray whales concentrate. A group of stations sampled in the present study, i.e., the 14 stations in Station Group II, encompassed most of the summer and fall habitat of Pacific walruses (*Odobenus rosmarus divergens*). Values of organic carbon within the sediment and benthic macrofaunal carbon biomass were highest within this region. The faunal biomass sampled was dominated by polychaete worms, sipunculid worms, and bivalves, all common prey groups of walruses. Stomach contents of walruses examined by Dr. F. Fay within the general area sampled in our project revealed that common infaunal organisms, as well as several epifaunal species not sampled by the van Veen grab used in our study, were important food items.

In summary, the abundance and biomass of macrobenthic animals in the northeastern Chukchi Sea are related to a number of environmental factors. The factors discussed in this report include water mass origin, storm effects, currents, local eddies and gyres, presence and extent of polynyas, southern boundary of the pack ice in summer, sediment characteristics and accumulation rates, nutritional quality of POC flux to the bottom, ice gouging, and disturbance of the sea bottom by the feeding activities of walruses and gray whales. It is suggested that the carbon rich waters identified in the southeastern Chukchi Sea (i.e., the mixed BSAW as modified by mixing in the central Chukchi Sea) extend into the northern Chukchi and the coast north of $70^{\circ}30'$ latitude and supply a rich and persistent food to the offshore and inshore benthos. Benthic biological processes appeared to dominate over physical processes in the establishment and maintenance of benthic communities in the muddy offshore areas, although the increased flux of POC to the bottom in these areas generally resulted in higher biomass values north of $70^{\circ}30'$. The disturbance of the bottom of inshore waters by the combined action of local eddies and gyres, ice gouging, storm induced turbulence, and feeding activities of gray whales and walruses (inshore north of Icy Cape) has resulted in a stressed environment where opportunistic species have become established. The success of these species has apparently been enhanced by advection of POC by mixed Bering Water (as suggested above).

VIII. REFERENCES

Aagaard, K. 1964. Features of the physical oceanography of the Chukchi Sea in the autumn. M. S. thesis. Univ. of Washington, Dept. of Oceanography, 41 pp.

Aagaard, K. 1984. Current, CTD, and pressure measurements in possible dispersal regions of the Chukchi Sea. NOAA/OCSEAP Final Report RU 91, 77 pp.

Abbott, R. T. 1974. *American Seashells*. Second edition. Van Nostrand Reinhold, New York. 663 pp.

Alexander V., C. Coulon, and J. Chang. 1975. Studies of primary productivity and phytoplankton organisms in the Colville River system, pp. 299-427. *In* Alexander et al., Environmental studies of an arctic estuarine system - final report. EPA-660/3-75-026, Environmental Protection Agency, Corvallis, OR.

Arctic Ocean Science Board. 1988. International Arctic Polynya Project (IAP^2) (A Program of the Arctic Ocean Sciences Board). University of Alaska, Fairbanks, Alaska 99775-1080. 24 pp.

Barnes, P. W. 1972. Preliminary results of geological studies in the eastern central Chukchi Sea. U.S. Coast Guard Oceanogr. Rept. Srs. 50:87-110.

Barnes, P. W. and E. Reimnitz. 1974. Sea ice as a geologi agent on the Beaufort Sea shelf of Alaska. *In* J. C. Reed and John E. Sater (eds.), *The Coast and Shelf of the Beaufort Sea*. Arctic Inst. North America, Arlington, Virginia, pp. 301-353.

Barnes, P. W. and E. Reimnitz. 1985. Sea-ice influence on arctic coastal retreat. *In* N. C. Kraus (ed.), Coastal Sediments '87. Proc. of a specialty conference on Advances in Understanding of Coastal Sediment Process, New Orleans, Louisiana. II:1578-1591.

Barnes, P. W., D. M. Schell and E. Reimnitz. 1984. The Alaskan Beaufort Sea: Ecosystems and Environments. Academic Press, Inc., Orlando, Florida, 466 pp.

Barnes, R. D. 1980. *Invertebrate Zoology*. Saunders College/Holt, Rhinehart, and Winston, Philadelphia. 1989 pp.

Bernard, F. R. 1979. *Bivalve Mollusks of the Western Beaufort Sea*. Contin. Sci. Natural History Museum of Los Angeles Co. #313 80 pp.

Boesch, D. F. 1973. Classification and community structure of macrobenthos of the Hampton Roads area, Virginia. Mar. Biol. 21:226-244.

Boesch, D. F. 1977. Application of numerical classification to ecological investigation of water pollution. EPA Ecological Research Series 600/3-77-033.

Boesch, D. F. and R. Rosenberg. 1981. Response to stress in marine benthic communities. *In* G. W. Barrett and R. Rosenberg (eds.), *Stress Effects on Natural Ecosystems*. John Wiley and Sons, Ltd., New York, pp. 179-200.

Boswell, P. G. H. 1961. *Muddy Sediments*. Heffer Co., Cambridge, Massachusetts, 140 pp.

Braham, H. W. 1984. Distribution and migration of gray whales in Alaska, pp. 249-266. *In* M. L. Jones, S. L. Swartz and J. S. Leatherwood (eds.), *The Gray Whale*, Academic Press, San Francisco, CA.

Bray, J. R. and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Mon. 27:235-249.

Brillouin, L. 1962. *Science and Information Theory*. Academic Press, New York, 169 pp.

Burbank, D. C. 1974. Suspended sediment transport and deposition in Alaskan coastal waters. M. S. Thesis. University of Alaska, Fairbanks, Alaska.

Boesch, D. F. and R. Rosenberg. 1981. Response to stress in marine benthic communities. *In* G. W. Barrett and R. Rosenberg (eds.), *Stress Effects on Natural Ecosystems*, John Wiley and Sons, Ltd, New York, pp. 179-200.

Carey, A. G., Jr. 1977. The distribution, abundance, diversity and productivity of the western Beaufort Sea benthos. *In* Environmental Assessment of the Alaska Continental Shelf. Annual report of the principal investigators, March 1977. Vol. 4. National Oceanic and Atmospheric Administration, Boulder, CO, pp. 1-53.

Carey, A. G. (ed.). 1978. Marine Biota (plankton/benthos/fish). *In* G. Weller and D. Norton (eds.), Interim synthesis: Beaufort/Chukchi, pp. 174-237. U.S. Dept. Commer., NOAA/OCSEAP, Boulder. CO.

Carey, A. G., Jr., and R. E. Ruff. 1977. Ecological studies of the benthos in the western Beaufort Sea with special reference to bivalve mollusks. *In* M. J. Dunbar (ed.), *Polar Oceans*. Arctic Institute of North America, Calgary, Alberta, Canada, pp. 505-530.

Carey, A. G., Jr., R. E. Ruff, J. G. Castillo, and J. J. Dickinson. 1974. Benthic ecology of the western Beaufort Sea continental margin: preliminary results. *In* J. C. Reed and J. F. Sater (eds.), *The Coast and Shelf of the Beaufort Sea*. Arctic Institute of North America, Arlington, VA, pp. 665-680.

Carey, A. G., Jr., M. A. Boudrias, J. C. Kern, R. E. Ruff. 1984. Selected ecological studies on continental shelf benthos and sea ice fauna in the southwestern Beaufort Sea. *In* Outer Continental Shelf Environmental Assessment Program, Final Report of Principal Investigators. 23:1-164.

Clarke, J. T. , S. E. Moore, and D. K. Ljungblad. 1987. Observations on gray whale (*Eschrichtius robustus*) utilization patterns in the northeastern Chukchi Sea, July-October 1982-86. Seventh Biennial Conf. Biol. Mar. Mammals. Abstract.

Coachman, L. K., and K. Aagaard. 1981. Reevaluation of water transport in the vicinity of Bering Strait. *In* D. W. Hood and J. A. Calder (eds.), *The Eastern Bering Sea Shelf: Oceanography and Resources*. U. S. Dept. Commerce. 1:95-110.

Coachman, L. K., K. Aagaard. and R. B. Tripp. 1975. *Bering Strait: The Regional Physical Oceanography*. Univ. of Wash. Press, Seattle, 172 pp.

Cooley, W. W. and P. R. Lohnes. 1971. *Multivariate data analysis.* Wiley, New York, 363 pp.

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.

Creager, J. S., and D. A. McManus. 1966. Geology of the southeastern Chukchi Sea. *In* N. J. Wilomovshy and J. N. Wolfe (eds.), *Environment of the Cape Thompson Region, Alaska*, U.S. Atomic Energy Commission, 1225 pp.

Curtis, M. A. 1977. Life cycles and population dynamics of marine benthic polychaetes from the Disko Bay area of West Greenland. Ophelia 16:9-58.

Davis, R. A. and D. H. Thomson. 1984. Marine mammals, pp. 47-79. *In* J. C. Truett (ed.), *The Barrow Arch Environment and Possible Consequences of Planned Offshore Oil and Gas Development*. NOAA/OCSEAP, Anchorage, AK, 229 pp.

Dawson, R. A. 1965. Phytoplankton data from the Chukchi Sea. Tech. Rept. 117, Dept. Oceanography, Univ. Washington, 123 pp.

Day, J. H. 1967. A monograph on the polychaeta of South Africa. Part 1 - Errantia; Part 2 - Sedentaria. Brit. Mus. Nat. Hist., London. 878 pp.

Day, J. H., J. G. Field and M. P. Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf off North Carolina. J. Animal Ecol. 40:93-123.

D'yakonov, A. M. 1950. Seastars of the USSR seas. Keys to the Fauns of USSR. Zoological Institute of the Academy of Sciences USSR #34. Trans. from Russian:Israel Program for Scientific Translation. 1968. 183 pp.

Eittreim, S., A. Grantz and J. Greenberg. 1982. Active geological processes in Barrow Canyon, northeast Chukchi Sea. Marine Geol. 50:61-76.

Eltringham, S. K. 1971. *Life in Mud and Sand.* English Universities Press. 218 pp.

English, T. S. 1966. Net plankton volumes in the Chukchi Sea, pp. 809-815. *In* N. J. Wilimovsky and J. N. Wolfe (eds.), *Environment of the Cape Thompson Region, Alaska*. U. S. Atomic Energy Comm., Wash., D. C.

Estes, J. A. and V. N. Gol'tsev. 1984. Abundance and distribution of the Pacific walrus: results of the first Soviet-American joint aerial survey, autumn, 1975. *In* F. H. Fay and G. A. Fedoseev (eds.), Soviet-American Cooperative Studies on Marine Mammals, Vol. 1 Pinnipeds. NOAA Technical Report NMFS 12.

Fauchald, K. and P. A. Jumars. 1979. The diet of worms: A study of polychaete feeding guilds. Oceanogr. Mar. Biol. ann. Rev. 79:193-284.

Fay, F. H. 1982. Ecology and Biology of the Pacific Walrus, *Odobenus rosmarus divergens* Illiger. U. S. Dept. Interior, Fish and Wildlife Service, North America Fauna, 74, Washington, DC, 179 pp.

Feder, H. M. 1981. Aspects of the feeding biology of the brittle star *Ophiura texturata.* Ophelia 20:215-235.

Feder, H. M. and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea, and Kotzebue Sound. Inst. Mar. Sci. Rept. R78-1, Univ. Alaska, Fairbanks, 124 pp.

Feder, H. M. and S. C. Jewett. 1981. Feeding interactions in the eastern Bering Sea with emphasis on the benthos. *In* D. W. Hood and J. A. Calder (eds.), *The Eastern Bering Sea Shelf: Oceanography and Resources*. U. S. Dept. Commerce 2:1229-1261.

Feder, H. M. and S. C. Jewett. 1987. The subtidal benthos. *In* D. W. Hood and S. T. Zimmerman (eds.), *The Gulf of Alaska: Physical Environment and Biological Resources*. U. S. Ocean Assessments Division, Alaska Office, U. S. Minerals Management Service, Alaska OCS Region, MMS86-0095, U.S. Government Printing Office, Washington, D. C. pp. 347-396.

Feder, H. M. and S. C. Jewett. 1988. The Subtidal Benthos. *In* D. G. Shaw and M. J. Hameedi (eds.), *Environmental Studies in Port Valdez, Alaska*. Springer-Verlag, Berlin, pp. 165-202.

Feder, H. M. and T. H. Pearson. 1988. The benthic ecology of Loch Linnhe and Loch Eil, a sea-loch system on the west coast of Scotland. V. Biology of the dominant soft-bottom epifauna and their interaction with the infauna. J. Exp. Mar. Biol. Ecol. 116:99-134.

Feder, H. M. and D. Schamel. 1976. *In* D. W. Hood and D. C. Burrell (eds.), Assessment of the Arctic Marine Environment: Selected Topics. Occas. Publ. No. 4. Institute of Marine Science, University of Alaska, Fairbanks, pp. 329-359.

Feder, H. M., G. J. Mueller, M. H. Dick and D. B. Hawkins. 1973. Preliminary benthos survey. *In* D. W. Hood, W. E. Shiels and E. J. Kelley (eds.), *Environmental Studies of Port Valdez*. Inst. Mar. Sci. Occas. Publ. No. 3, Univ. Alaska, Fairbanks, pp. 305-386.

Feder, H. M., A. J. Paul, M. Hoberg and S. Jewett. 1981. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of Cook Inlet. *In* Environmental Assessment of the Alaskan Continental Shelf, Final Reports, Biological Studies 14:45-676.

Feder, H. M., R. H. Day, S. C. Jewett, K. McCumby, S. McGee and S. V. Schonberg. 1985. Infauna of the northeastern Bering and southeastern Chukchi Seas. *In* Outer Continental Shelf Environmental Assessment Program. Final Reports of Principal Investigators 32:1-120.

Fleming, R. H., and D. Heggarty. 1966. Oceanography of the southeastern Chukchi Sea. *In* N. J. Wilomovshy and J. N. Wolfe (eds.), *Environment of the Cape Thompson Region, Alaska*. U.S. Atomic Energy Commission, 1225 pp.

Flint, R. W. 1981. Gulf of Mexico outer continental shelf benthos: macrofaunal-environmental relationships. Biol. Ocean. 1:135-155.

Flint, R. W. and Nancy N. Rabalais. 1980. Polychaete ecology and niche patterns: Texas Continental Shelf. Mar. Ecol. Prog. Ser. 3:193-202.

Flynn, W. W. 1968. The determination of low levels of polonium-210 in environmental materials. Analytica Chimica Acta 43:221-227.

Folk, R. L. 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. Jour. Geol. 62:344-359.

Folk, R. L. 1980. *Petrology of Sedimentary Rocks*. Hemphill Publishing Co., Austin, Texas, 182 pp.

Franz, D. 1976. Benthic molluscan assemblages in relation to sediment gradients in northeastern Long Island Sound, Connecticut. Malacologia. 15:377-399.

Fretter, V. and A. Graham. 1962. *British Prosobranch Molluscs*. Roy. Soc., London. 755 pp.

Frost, K. J. and L. F. Lowry. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort seas, 1976-77. NOAA Tech. Rept. NMFS SSRF-764, 22 pp.

Frost, K. J., L. F. Lowry, and J. J. Burnes. 1983. Distribution of marine mammals in the coastal zone of the eastern Chukchi Sea during summer and autumn. NOAA/OCSEAP, Environmental Assessment of the Alaskan Continental Shelf, Final Rep. 20:563-650.

Garrison, G. R. and P. Becker. 1976. The Barrow submarine canyon: A drain for the Chukchi Sea. J. Geophys. Res. 81:4445-4453.

Golan-Bac, M. 1985. Hydrocarbon gas in surface sediments of the Chukchi Sea. Annual Rept. Submitted to NOAA/OCSEAP, Anchorage, Alaska, pp. B-1 to B-4.

Gower, J. C. 1967. Multivariate analysis and multidimensional geometry. Statistician 17:13-28.

Gower, J. C. 1969. A survey of numerical methods useful in taxonomy. Acarologia 11:357-375.

Grantz, A., D. A. Dinter, E. R. Hill, R. E. Hunter, S. D. May, R. H. McMullin and R. L. Phillips. 1982. Geologic framework, hydrocarbon potential, and environmental conditions for exploration and development of proposed oil and gas lease sale 85 in the central Chukchi Sea. U.S. Geol. Survey Open File Rept. 82-1053.

Grebmeier, J. M. 1987. The ecology of benthic carbon cycling in the northern Bering and Chukchi Seas. Ph. D. dissertation, Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1988. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. I. Food supply source and benthic biomass. Mar. Ecol. Prog. Ser. 48:57-67.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1989. Pelagic-benthic coupling in the northern Bering and southern Chukchi Seas II. Benthic community structure. Mar. Ecol. Prog. Ser. (in press).

Hachmeister, L. E. and J. B. Vinelli. 1985. Nearshore and coastal circulation in the Northeastern Chukchi Sea. U.S. Dept. Commerce and U.S. Dept. Interior, OCSEAP Final Report RU 646, 93 pp.

Hameedi, M. J. 1978. Aspects of water column primary productivity in the Chukchi Sea during summer. Mar. Biol. 48:37-46.

Harper, J. R. 1978. Coastal erosion rates along the Chukchi Sea coast near Barrow, Alaska. Arctic 31:428-433.

Harris, R. A. 1911. Arctic Tides. U.S. Dept. of Commerce, Labor Coast and Geodetic Survey, Washington DC, 103 pp.

Hill, E. R., A. Grantz, S. D. May and M. Smith. 1984. Bathymetric map of the Chukchi Sea. Map I-1182-D, Dept. of Interior, U.S. Geol. Survey.

Hong, G. H. 1986. Fluxes, dynamics and chemistry of particulate matter and nutrient regeneration in the central basin of Boca de Quadra, southeast Alaska. Ph.D. Thesis, Univ. Alaska, Fairbanks, Alaska, 225 pp.

Hopkins, D. M., J. V. Matthews, C. E. Schweger and S. B. Young (eds.) 1982. *Paleoecology of Beringia*. Academic Press, New York.

Horner, R. 1981. Beaufort Sea plankton studies. Final reports of Principal Investigators. NOAA/OCSEAP Vol. 13:65-314.

Hufford, G. L. 1974. On apparent upwelling in the southern Beaufort Sea, J. Geopys. Res. 9:1305-1306.

Hume, J. D. 1964. Shoreline changes near Barrow, Alaska, caused by the storm of October 3, 1963. Rept. 15th Alaska Sci. Conf., Fairbanks, Alaska.

Hunkins, K. L. 1965. Tide and storm surge observations in the Chukchi Sea, Limnol. Oceanogr. 10:29-39.

Hyman, L. H. 1967. *The Invertebrates VI: Molusca I.* McGraw-Hill, New York. 792 pp.

Ingham, M. C., B. A. Rutland, P. W. Barnes, G. E. Watson, G. J. Divoky, A. S. Naidu, G. D. Sharma, B. L. Wing and J. C. Quast. 1972. WEBSEC-70, An ecological survey in the eastern Chukchi Sea. USCG Oceanographic Rept. 50 (CG 373-50). U. S. Coast Guard Oceanogr. Unit, Washington, D. C., 206 pp.

Jewett, S. C. 1981. Variations in some reproductive aspects of female snow crabs *Chionoecetes opilio*. J. Shellfish Research 1:95-99.

Jewett, S. C. 1988a. Epifaunal invertebrate biomass, Section 2.4. *In: Bering, Chukchi, and Beaufort Seas Strategic Assessment: Data Atlas*. U. S. Dept. Commer., National Oceanic and Atmospheric Administration, Ocean Assessment Division, Washington, D.C. (in press).

Jewett, S. C. 1988b. Infaunal invertebrate biomass, Section 2.5. *In: Bering, Chukchi, and Beaufort Seas Strategic Assessment: Data Atlas.* U. S. Dept. Commer., National Oceanic and Atmospheric Administration, Ocean Assessment Division, Washington, D.C. (in press).

Jewett, S. C. and H. M. Feder. 1980. Autumn food of adult starry flounder, *Platichthys stellatus*, from the northeastern Bering Sea and the southeastern Chukchi Sea. J. Cons. Int. Explor. Mer 39:7-14.

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.* U. S. Dept. of Commerce 2:1131-1153.

Johnson, W. R. 1989. Current response to wind in the Chukchi Sea: a regional upwelling event. J. Geophy. Res. In press.

Johnson, K. R. and C. H. Nelson. 1984. Side-scan sonar assessment of gray whale feeding in the Bering Sea. Science 225:1150-1152.

Jones, G. and S. Candy. 1981. Effect of dredging on the macrobenthic infauna of Botany Bay. Australian Journal of Freshwater Research 32:379-399.

Jørgensen, C. B. 1966. *Biology of Suspension Feeding.* Pergammon Press, Oxford. 357 pp.

Josefson, A. B. 1985. Distribution of diversity and functional groups of marine benthic infauna in the Skagerrak (eastern North Sea) - can larval availability affect diversity? Sarsia 70:229-249.

Jumars, P. A. and K. Fauchald. 1977. Between-community contrasts in successful polychaete feeding strategies. *In* B. C. Coull (ed.), *Ecology of Marine Benthos.* University of South Carolina Press, Columbia, S.C., pp. 1-20.

Kinney, P. J. 1985. Environmental characterization and biological utilization of Peard Bay. *In* Outer Continental Shelf Environmental Assessment Program. Final Reports of Principal Investigators 35:97-440.

Kowalik, Z. 1981. A study of the M_2 tide in the ice-covered Arctic Ocean, Norwegian Res. Bull.-Modeling, Identification and Control 2:201-223.

Kowalik, Z. 1984. Storm surges in the Beaufort and Chukchi Seas, J. Geophys. Res. 89:10570-10578.

Kowalik, Z., and J. B. Matthews. 1982. The M_2 tide in the Beaufort and Chukchi Seas. J. Phys. Oceanogr. 12:743-746.

Loya, Y. 1972. Community structure and species diversity of hermatypic corals at Eilat, Red Sea. Mar. Biol. 13:100-123.

Lowry, L. L., 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 33:330-342.

Ljungblad, D.K. 1987. Gray whale distribution in the Chukchi and Bering Seas, pp. 101-106. *In* D. A. Hale (ed.), *Chukchi Sea Information Update*. NOAA/OCSEAP, MMS 86-0097, 106 pp.

MacGinitie, G. E. and N. MacGinitie. 1949. *Natural History of Marine Animals*. McGraw-Hill, New York. 523 pp.

Mann, K. H. 1982. Ecology of coastal waters: A systems approach. *In: Studies in Ecology, Vol. 8*. Univ. Calif. Press, Los Angeles, California, 322 pp.

Margalef, R. 1958. Information theory in ecology. General Systems 3:36-71.

Mathieu, G. 1977. ^{222}Rn and ^{226}Ra technique of analysis. *In* Lamont-Doherty Geophysical Observatory. Annual Technical Rept., Coo-2185-02ERDA, 30 pp.

Matthews, J. B. 1970. Tides at Point Barrow. North Eng. 2:12-13.

McCave, I. N. 1976. *The Benthic Boundary Layer*. Plenum Press, N. Y. 323 pp.

McManus, D. A. and C. S. Smyth. 1970. Turbid bottom water on the continental shelf of the northern Bering Sea. J. Sedimentary Petrology 40:869-873.

McManus, D. A., J. C. Kelley and J. S. Creager. 1969. Continental shelf sedimentation in an arctic environment. Geol. Soc. Amer. Bull. 80:1961-1984.

McManus, D. A., J. S. Creager, R. J. Echols and M. J. Holmes. 1983. The Holocene transgression on the Arctic flank of Beringia: Chukchi Valley to Chukchi Estuary to Chukchi Sea. *In: Quaternary Coastline*. Academic Press, New York, NY, pp. 365-388.

McRoy, C. P. 1986. ISHTAR Progress Report, Vols. I and II, submitted by the Executive Committee to the Office of Polar Programs, National Science Foundation, Washington, D. C., Inst. Mar. Sci., Univ. Alaska, Fairbanks. Vol. I, 279 pp., Vol. II, 269 pp.

Mills, E. L. 1967. The biology of an ampeliscid amphipod crustacean sibling species pair. J. Fish. Res. Bd. Canada 24:305-355.

Mills, E. I. 1969. The community concept in marine zoology, with comments on continua and instability in some marine communities: a review. J. Fish. Res. Bd. Can. 26:1415-1428.

Moore, S. E. and D. K. Ljungblad. 1984. Gray whales (*Eschrichtius robustus*) in the Beaufort, Chukchi and Bering Seas: distribution and sound production, pp. 543-559. *In* M. L. Jones, S. L. Swartz and J. S. Leatherwood (eds.), *The Gray Whale*, Academic Press, San Francisco, CA.

Moore, S. E. and J. T. Clarke. 1986. A comparison of gray whale (*Eschrichtius robustus*) and bowhead whale (*Balaena mysticetus*) distribution, abundance, habitat preference and behavior in the northeastern Chukchi Sea, 1982-84. Rep. Int. Whal. Commn. 36:273-279.

Moore, S. E., D. K. Ljungblad, and D. R. Schoik. 1986a. Annual patterns of gray whale (*Eschrichtius robustus*) distribution, abundance and behavior in the northern Bering and eastern Chukchi Seas, July 1980-83. Rep. Int. Whal. Commn. (Special issue 8), pp. 231-242.

Moore, S. E., J. T. Clarke, and D. K. Ljungblad. 1986b. A comparison of gray whale (*Eschrichtius robustus*) and bowhead whale (*Balaena mysticetus*) distribution, abundance, habitat preference and behavior in the northeastern Chukchi Sea, 1982-84. Rep. Int. Whal. Commn. 36:273-279.

Morris, P. A. 1966. *A Field Guide to Pacific Coast Shells.* Houghton Mifflin Co., Boston, 297 pp.

Morris, R. H., D. P. Abbott and E. C. Haderlie. 1980. *Invertebrates of the California Coast.* Stanford University Press, Stanford, CA, 690 pp.

Morton, J. E. 1958. *Molluscs.* Hutchinson and Co., Ltd., London, 232 pp.

Mountain, D. G., L. K. Coachman, and K. Aagaard. 1976. On the flow through Barrow Canyon. J. Phys. Oceanogr. 6:461-470.

Naidu, A. S. 1987. Marine surficial sediments, Section 1.2. *In: Bering, Chukchi and Beaufort Seas, Coastal and Ocean Zones Strategic Assessment: Data Atlas.* Pre-publication Edition, NOAA/SAB, Dept. Commerce, Rockville, Maryland.

Naidu, A. S. and L. H. Klein. 1988. Sedimentation processes. *In* D. G. Shaw and M. J. Hameedi (eds.), *Environmental Studies in Port Valdez, Alaska: A Basis for Management.* Lecture notes on coastal and Estuarine Studies, Vol. 24, Springer-Verlag, Berlin Heidelberg, West Germany, pp. 69-91.

Naidu, A. S. and T. C. Mowatt. 1983. Sources and dispersal patterns of clay minerals in surface sediments from the continental shelf areas off Alaska. Geol. Soc. Amer. Bull. 94:841-854.

Naidu, A. S. and G. D. Sharma. 1972. Geological, biological, and chemical oceanography of the eastern central Chukchi Sea. *In* M. C. Ingham et al. (eds.), *WEBSEC-70, An Ecological Survey in the Eastern Chukchi Sea.* USCG Oceanographic Rept. 50 (CG 373-50). U.S. Coast Guard Oceanogr. Unit, Washington, DC, pp. 173-195.

Naidu, A. S., J. S. Creager and T. C. Mowatt. 1981. Clay mineral dispersal patterns in the north Bering and Chukchi Seas. Marine Geology. 47:1-15.

Naidu, A. S., S. E. Rawlinson and H. V. Weiss. 1984. Sediment characteristics of the lagoons of the Alaskan Beaufort Sea coast, and evolution of Simpson Lagoon. *In* P. W. Barnes, D. M. Schell, E. Reimnitz (eds.), *The Alaskan Beaufort Sea: Ecosystems and Environments.* Academic Press, Inc. Orlando, FL, pp. 275-292.

Nelson, R. R., J. J. Burns, and K. J. Frost. 1985. The bearded seal (*Erignathus barbatus*). *In* J. J. Burns, K. J. Frost and L. F. Lowry (eds.), *Marine Mammal Species Accounts.* Alaska Department of Fish and Game Tech. Bull. No. 7. 96 pp.

Neiman, A. A. 1963. Quantitative distribution of benthos on the shelf and upper slope in the eastern part of the Bering Sea. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific* (Israel Prog. Sci. Transl., 1968).

Nerini, M. K. 1984. A review of gray whale (*Eschrichtius robustus*) feeding ecology, pp. 423-450. *In* M. L. Jones, S. L. Swartz and J. S. Leatherwood (eds.), *The Gray Whale*. Academic Press, San Francisco, CA.

Nerini, M. K. and J. S. Oliver. 1983. Gray whales and the structure of the Bering Sea benthos. Oecologia 59:224-225.

Nittrouer, C. A., R. W. Sternberg, R. W. Carpenter and J. T. Bennett. 1979. The use of Pb-210 geochronology as a sedimentological tool: Application to the Washington Continental Shelf. Marine Geology 31:297-316.

Nummedal, D. 1979. Coarse grained sediment dynamics -- Beaufort Sea, Alaska. *In* Proc. Port and Ocean Engineering Under Arctic Conditions. Norwegian Inst. Technology, Trondheim, Norway, pp. 845-858.

Nybakken, J. 1978. Abundance, diversity and temporal variability in a California intertidal nudibranch assemblage. Mar. Biol. 45:129-146.

Oliver, J. S., P. N. Slattery, M. A. Silberstein, and E. F. O'Connor. 1983. A comparison of gray whale, *Eschrichtius robustus*, feeding in the Bering Sea and Baja California. U.S. Nat'l. Mar. Fish. Serv. Fish. Bull. 81:513-522.

Oliver, J. S., P. N. Slattery, M. A. Silberstein, and E. F. O'Connor. 1984. Gray whale feeding on dense ampeliscid amphipod communities near Bamfield, British Columbia. Can. J. Zool. 63:41-49.

Oliver, J. S. and P. N. Slattery. 1985. Destruction and opportunity on the sea floor: effects of gray whale feeding. Ecology 66:1965-1975.

Paquette, R. G., and R. H. Bourke. 1974. Observation on the coastal current of Arctic Alaska. J. Marine Res. 32:195-207.

Paquette, R. G., and R. H. Bourke. 1981. Ocean circulation and fronts as related to ice melt-back in the Chukchi Sea. J. Geophys. Res. 86:4215-4230.

Parrish, D. M. 1987. An estimate of annual primary production in the Alaska Arctic Ocean. M. S. thesis, Dept. of Mar. Sci. and Ocean., Univ. of Alaska Fairbanks, Alaska, 166 pp.

Phillips, R. L. 1984. Summary of geology, processes, and potential geohazards. *In* D. A. Hale (ed.), *Chukchi Sea Information Update*. Ch. 4, pp. 21-31.

Phillips, R. L. 1987. Summary of geology, processes, and potential geohazards in the northeastern Chukchi Sea. *In* D. A. Hale (ed.), *Chukchi Sea: Information Update*. NOAA/NOS Service, Ocean Assessment Division, Anchorage, Alaska, pp. 21-31.

Phillips, R. L., P. Barnes, R. E. Hunter, D. Rearic, T. Reiss, E. Kempema, J. Chin, S. Graves and T. Scott. 1985. Geologic investigations in the Chukchi Sea, 1984, NOAA Ship Surveyor cruise. U. S. D. I., Geological Survey, Annual Report to NOAA/OCSEAP, 88 pp.

Phillips, R. L. and T. E. Reiss. 1985a. Nearshore marine geological investigations, Icy Cape to Wainwright, northeast Chukchi Sea. U.S. Geol. Survey Open File Rept. 84-828, USGS, Menlo Park, California, pp. 1-27.

Phillips, R. L. and T. E. Reiss. 1985b. Nearshore marine geologic investigations, Point Barrow to Skull Cliff, Northeast Chukchi Sea. Final Rept. submitted to NOAA-NOS, Anchorage, pp. 157-181.

Phillips, R. L. and M. W. Colgan. 1987. Sea-floor feeding traces of gray whales and walrus in the northeast Chukchi Sea, pp. 183-186. *In* J. P. Galloway and T. D. Hamilton (eds.), *Geologic Studies in Alaska by the U.S. Geological Survey during 1987*. U.S. Geological Survey Circular 1016.

Poiner, I. R. and R. Kennedy. 1984. Complex patterns of change in the macrobenthos of a large sandbank following dredging. Marine Biology 78:335-352.

Probert, P. K., and J. B. Wilson. 1984. Continental shelf benthos off Otago Peninsula, New Zealand. Estuarine, Coastal and Shelf Science 19:373-391.

Purchon, R. D. 1968. *The Biology of the Mollusca*. Pergamon Press, Oxford, U.K. 560 pp.

Reimnitz, E. and P. W. Barnes. 1987. Sea-ice influence on arctic coastal retreat. *In* C. K. Nicholar (ed.), Coastal Sediments 1987. Proc. Specialty Conf. on Advances in Understanding of Coastal Sediment Processes, New Orleans, LA. 2:1578-1591.

Rex, R. W. 1955. Microrelief produced by sea ice grounding in the Chukchi Sea near Barrow, Alaska. Arctic 8:177-186.

Sambrotto, R. N., J. J. Goering and C. P. McRoy. 1984. Large yearly production of phytoplankton in the western Bering Strait. Science 225:1147-1150.

Schell, D. M. 1987. Primary production and nutrient dynamics in the Chukchi Sea. *In* D. A. Hale (ed.), *Chukchi Sea Information Update*, Ch. 6, pp. 43-47.

Schell, D. M., P. J. Ziemann, D. M. Parrish, K. H. Dunton and E. J. Brown. 1984. Food web and nutrient dynamics in nearshore Alaska Beaufort Sea waters. *In* Outer Continental Shelf Environmental Assessment Program. Final Reports. National Oceanic and Atmospheric Administration, Boulder, Colorado 25:327-499.

Schultz, G. A. 1969. *The Marine Isopod Crustaceans*. Wm. C. Brown Co., Dubuque, IA, 359 pp.

Shannon, C. E. and W. Weaver. 1963. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, 117 pp.

Sharma, G. D. 1979. *The Alaskan Shelf: Hydrographic, Sedimentary and Geochemical Environment*. Springer-Verlag, New York, NY, 498 pp.

Shin, P. K. 1982. Multiple discriminant analysis of macrobenthic infaunal assemblages. J. Exp. Mar. Biol. Ecol. 59:39-50.

Short, A. D. 1979. Barrier island development along the Alaskan-Yukon coastal plains. Geol. Soc. Amer. Bull. 86:199-202.

Simpson, E. H. 1949. The measurement of diversity. Nature 163:688.

Smith, R. I. and J. T. Carlton (eds.) 1975. *Lights Manual: Intertidal Invertebrates of the California Coast*. Univ. Calif. Press, Berkley, CA, 716 pp.

Sparks, A. K. and W. T. Pereyra. 1966. Benthic invertebrates of the southeastern Chukchi Sea. *In* N. J. Wilimovsky and J. N. Wolfe (eds.), *Environment of the Cape Thompson Region, Alaska*. U. S. Atomic Energy Comm., Oak Ridge, Tenn. 2:817-838.

Spaulding, M., T. Isaji, D. Mendelsohn and A. C. Turner. 1987. Numerical simulation in wind-driven flow through the Bering Strait. J. Phys. Oceanogr. 17:1799-1816.

Springer, A. M. 1988. The paradox of pelagic food webs in the northern Bering Sea. Ph. D. dissertation, Inst. Mar. Sci., Univ. of Alaska, Fairbanks.

Stanley, S. M. 1970. Relation of shell form to life habits of the bivalvia (mollusca). Geol. Soc. Am., Mem. 125, 296 pp.

Stephenson, W. and W. T. Williams. 1971. A study of the benthos of soft bottoms. Sek Harbour, New Guinea, using numerical analysis. Aust. J. Mar. and Freshwater Res. 22:11-34.

Stewart, P. L., P. Pocklington and R. A. Cunjak. 1985. Distribution, abundance and diversity of benthic macroinvertebrates on the Canadian continental shelf and slope of southern Davis Strait and Ungava Bay. Arctic 38:281-291.

Stoker, S. W. 1978. Benthic invertebrate macrofauna on the eastern continental shelf of the Bering and Chukchi seas. Ph. D. Dissertation, Inst. Mar. Sci., Univ. Alaska, Fairbanks, 259 pp.

Stoker, S. W. 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*. U. S. Dept. of Commerce.

Stringer, W. J. 1982. Width and persistence of the Chukchi polynya. Rept. submitted to NOAA/OCS, Anchorage, Alaska, Geophysical Institute, Univ. Alaska Fairbanks, Alaska, not paged.

Sverdrup, H. U. 1926. Dynamic of tides on the north Siberian Shelf. Results from the Maud expedition, Geofys. Publ., 4, No. 5, 75 pp.

Thistle, D. 1981. Natural physical disturbances and communities of marine soft bottoms. Marine Ecology Progress Series 6:223-228.

Thomson, D. H. 1982. Marine benthos in the eastern Canadian high arctic: multivariate analyses of standing crop and community structure. Arctic 35:61-74.

Thomson, D. H. and L. R. Martin. 1984. Feeding ecology of gray whales in the Chirikof Basin, pp. 377-460. *In* D. H. Thomson (ed.), *Feeding Ecology of Gray Whales (Eschrichtius robustus) in the Chirikof Basin, Summer 1982*. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 43 (1986), pp. 209-460.

Thorson, G. 1957. Bottom communities (sublittoral or shallow shelf). *In* J. W. Hedgpeth (ed.), *Treatise on Marine Ecology and Paleoecology, Vol. 1: Ecology*. Memoir 67, Geological Society of America, New York, NY, pp. 461-634.

Toimil, L. J. 1978. Ice gouge microrelief on the floor of the eastern Chukchi Sea, Alaska: A reconnaissance survey. U.S. Geol. Survey Open-file Rept., 94 pp.

Trask, P. D. 1939. Organic content in recent marine sediments. *In* P. D. Trask (ed.), *Recent Marine Sediments*. Thomas Murty & Co., London, pp. 428-453.

Trueman, E. R. 1975. *The Locomotion of Soft-bodied Animals*. American Elsevier Publishing Co., Inc., New York, 200 pp.

Truett, J. C. 1984. Lower Trophic Levels, pp. 133-152. *In* J. C. Truett (ed.), *The Barrow Arch Environment and Possible Consequences of Planned Offshore Oil and Gas Development*. NOAA/OCSEAP, 229 pp.

Walsh, J. J. and C. P. McRoy. 1986. Ecosystem analysis in the southeastern Bering Sea. Continental Shelf Res. 5:259-288.

Walsh, J. J., C. P. McRoy, T. H. Blackburn, L. W. Coachman, J. J. Goering, J. J. Nihoul, P. L. Parker, A. L. Springer, R. B. Tripp, T. E. Whitledge, K. Henriksen, and P. Andersen. 1988. The role of Bering Strait in the carbon/nitrogen flux of polar marine ecosystems. *In* L. Rey and V. Alexander (eds.), *Marine Living Systems of the Far North*. E. J. Brill, Leiden (in press).

Webb, J. E. 1976. Organism-sediment relationships. *In* I. N. McCave (ed.), *The Benthic Boundary Layer*. Plenum Press, New York, New York, pp. 273-295.

Weston, D. P. 1988. Macrobenthos-sediment relationships on the continental shelf off Cape Hatteras, North Carolina. Cont. Shelf Res. 8:267-286.

Wilson, D. E., S. D. Pace, P. D. Carpenter, H. Teas, T. Goddard, P. Wilde, and P. J. Kinney. 1982. Nearshore Coastal Currents, Chukchi Sea, Summer 1981. U.S. Dept. Commerce and U.S. Dept. Interior, OCSEAP Final Report RU 531, 255 pp.

Wilson, D. P. 1953. The settlement of *Ophelia bicornis* Savigny larvae. J. Mar. Biol. Assoc. U.K. 31:413-438.

Wing, B. 1972. Preliminary report on the zooplankton collected on WEBSEC-70, pp. 196-202. *In* U.S. Coast Guard Oceanographic Report No. 50 (CG 373-50), Washington, D.C.

Wing, B. 1974. Kinds and abundance of zooplankton collected by the USCG Icebreaker Glacier in the eastern Chukchi Sea, September-October 1970. NOAA Tech. Rept. NMFS SSRF-679, U. S. Dept. Commerce, 18 pp.

Wiseman, W. J. and L. J. Rouse, Jr. 1980. A coastal jet in the Chukchi Sea. Arctic 33:21-29.

Wiseman, W. J., Jr., J. N. Suhayda, S. A. Hsu and C. D. Walters, Jr. 1974. Characteristics of nearshore oceanographic environment of arctic Alaska, *In: The Coast and Shelf of the Beaufort Sea*. Arctic Institute of North America, pp. 49-64.

Wolotira, R. J., Jr., T. M. Sample and M. Morin, Jr. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea and adjacent waters in the baseline year 1976. NWAFS Proc. Rept., 292 pp.

Yonge, C. M. and T. E. Thompson. 1976. *Living Marine Molluscs*. Wm. Collins Sons and Co., Ltd., London, 288 pp.

APPENDIX I

Table Ia. The weight percentages of water, and radioactivities (dpm g^{-1}) of ^{226}Ra, total ^{210}Pb ($^{210}Pb_T$) and excess ^{210}Pb ($^{210}Pb_{EX}$) in 1-cm sections of sediment cores taken from selected stations in northeast Chukchi Sea.

Station	Core Section (cm)	$H_2O\%$	$^{210}Pb_T$	^{226}Ra	$^{210}Pb_{EX}$
CH-13	0-1	33.7	2.05 ± 0.05	0.82 ± 0.01	1.23 ± 0.05
	1-2	36.2	1.92 ± 0.07	1.05 ± 0.02	0.87 ± 0.07
	2-3	36.8	1.72 ± 0.05	1.06 ± 0.02	0.66 ± 0.05
	3-4	36.9	1.39 ± 0.04	0.75 ± 0.02	0.64 ± 0.04
	4-5	37.3	1.42 ± 0.04	1.34 ± 0.02	0.08 ± 0.04
	5-6	37.0	1.50 ± 0.05	0.98 ± 0.02	0.52 ± 0.05
	6-7	37.0	1.37 ± 0.03	0.95 ± 0.02	0.42 ± 0.04
	7-8	36.8	1.43 ± 0.05	1.16 ± 0.02	0.27 ± 0.05
	8-9	37.0	1.24 ± 0.04	1.24 ± 0.02	0.00 ± 0.04
		$\bar{x}$ = 36.52			
CH-21	0-1	45.3	1.99 ± 0.05	1.00 ± 0.01	0.99 ± 0.05
	1-2	44.0	2.05 ± 0.05	1.15 ± 0.02	0.90 ± 0.05
	2-3	40.6	1.91 ± 0.05	1.43 ± 0.02	0.48 ± 0.05
	3-4	39.1	1.67 ± 0.05	1.10 ± 0.02	0.57 ± 0.05
	4-5	40.9	1.72 ± 0.05	1.17 ± 0.02	0.55 ± 0.05
	6-7	40.5	1.69 ± 0.05	1.19 ± 0.42	1.50 ± 0.42
	7-8	39.4	1.42 ± 0.04	1.14 ± 0.02	0.28 ± 0.05
		$\bar{x}$ = 40.39			
CH-26	0-1	59.9	2.05 ± 0.07	1.13 ± 0.02	0.92 ± 0.07
	1-2	46.9	1.87 ± 0.07	1.14 ± 0.02	0.73 ± 0.07
	2-3	36.0	1.66 ± 0.03	1.08 ± 0.02	0.58 ± 0.04
	3-4	39.8	1.48 ± 0.03	1.02 ± 0.02	0.46 ± 0.04
	4-5	41.7	1.62 ± 0.03	1.01 ± 0.02	0.61 ± 0.04
	5-6	39.8	1.57 ± 0.05	1.63 ± 0.03	-0.06 ± 0.06
	6-7	35.2	1.44 ± 0.03	1.14 ± 0.02	0.30 ± 0.04
	8-9	35.2	1.24 ± 0.03	0.84 ± 0.01	0.40 ± 0.03
		$\bar{x}$ = 40.59			

Appendix I. Continued.

Station	Core Section (cm)	$H_2O\%$	$^{210}Pb_T$	^{226}Ra	$^{210}Pb_{EX}$
CH-38	0-2	39.7	1.97 ± 0.05	1.09 ± 0.02	0.88 ± 0.05
	2-4	39.0	1.66 ± 0.05	1.06 ± 0.02	0.60 ± 0.05
	4-6	41.3	1.30 ± 0.04	1.31 ± 0.03	-0.01 ± 0.05
	6-8	42.9	1.51 ± 0.04	1.24 ± 0.03	0.27 ± 0.05
	8-10	33.5	1.27 ± 0.04	1.08 ± 0.02	0.19 ± 0.05
		$\bar{x}$ = 39.28			
CH-39	0-2	56.3	2.31 ± 0.05	1.28 ± 0.03	1.03 ± 0.06
	2-4	53.8	2.05 ± 0.05	1.29 ± 0.03	0.76 ± 0.06
	4-6	52.1	1.37 ± 0.05	0.95 ± 0.02	0.42 ± 0.05
	6-8	49.0	1.11 ± 0.05	1.07 ± 0.02	0.06 ± 0.05
	8-10	47.1	1.28 ± 0.03	1.13 ± 0.02	0.15 ± 0.04
	10-12	44.9	1.20 ± 0.03	0.74 ± 0.03	0.46 ± 0.04
		$\bar{x}$ = 50.53			
CH-40	0-1	34.4	1.47 ± 0.05	0.94 ± 0.02	0.53 ± 0.05
	1-2	32.0	1.60 ± 0.05	0.86 ± 0.02	0.74 ± 0.05
	2-3	27.7	1.58 ± 0.04	0.99 ± 0.02	0.59 ± 0.05
	3-4	29.9	1.36 ± 0.04	1.40 ± 0.02	-0.04 ± 0.05
	4-5	32.1	1.33 ± 0.04	0.91 ± 0.02	0.42 ± 0.05
	5-6	29.9	1.22 ± 0.03	1.05 ± 0.02	0.17 ± 0.04
	6-7	24.9	0.96 ± 0.03	0.98 ± 0.02	-0.02 ± 0.04
		$\bar{x}$ = 30.13			

Appendix II. Conversion values[1], feeding and motility types[2] for macrofauna of the NE Bering and SE Chukchi Seas. P/B = Production/Biomass.

KEY: Feeding Type:
H=herbivore
IF=Interface feeder
Mx=mixed
P=predator
S=scavenger
SDF=surface deposit feeder
SF=filter feeder
SSDF=subsurface deposit feeder
U=unknown

Motility Type:
S=sessile
DM=discretely motile
M=motile
Mx=mixed

Taxon Code:
P=phylum
Cl=Class
Subcl=Subclass
O=Order
F=Family

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
P. Protozoa					
(Foraminifera:*Pyrgo*)	345214	.010	0.1	P/S (Mx)	S/DM/M (Mx)
P. Porifera	36	.010	0.1	SF (IF)	S
P. Cnidaria					
Cl. Anthozoa	37	.061	0.1	SF(IF)/P	S
Cl. Hydrozoa	--	.061	0.1	P/SF(IF)	
F. Nephtheidae	374704	.040	0.1	SF	S
F. Cerianthidae	374301	.061	0.1	SF	S
P. Platyhelminthes	39	.093	0.1	P	M
P. Rhynchocoela	43	.093	0.1	P	M
F. Reineidae	430302	.093	0.1	P	M
P. Nematoda	47	.010	0.1	P/H/SDF (IF)(Mx)	M
P. Annelida	50		1.4	Mx	Mx
Cl. Polychaeta	5001	.069	1.4	Mx	Mx
F. Nereidae	500124	.069	1.4	(P/SDF/SF/IF) (Mx)	M
F. Ampharetidae	500167	.069	1.4	SDF(IF)	S
F. Chrysoptalidae	500108	.068	1.4	P	M
F. Flabelligeridae	500154	.044	1.4	SDF(IF)	M/DM
F. Magelonidae	500144	.069	1.4	SDF(IF)	DM
F. Maldanidae	500163	.070	1.4	SSDF	S
F. Nephtyidae	500125	.072	1.4	P	M

Appendix II (continued)

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
F. Ophelidae	500158	.095	1.4	SSDF	M
F. Orbiniidae	500140	.061	1.4	SSDF	M
F. Oweniidae	500164	.069	1.4	SF/SDF(IF) (Mx)	DM/M
F. Oweniidae		.069	1.4	SSDF	
F. Pectinariidae	500166	.045	1.4	SSDF	M
F. Phyllodocidae	500113	.087	1.4	P/S (Mx)	M
F. Polynoidae	500102	.073	1.4	P/S (Mx)	M
F. Sabellidae	500170	.075	1.4	SF	S
F. Spionidae	500143	.069	1.4	SF/SDF(IF) (Mx)	DM
F. Scalibregmidae	500157	.069	1.4	SSDF	M
F. Sternaspidae	500159	.041	1.4	SSDF	M
F. Syllidae	500123	.069	1.4	P/H/SDF(IF) (Mx)	M
F. Terebellida	500168	.061	1.4	SD	S
F. Capitellidae	500160	.069	1.4	SSDF	M
F. Glyceridae	500127	.069	1.4	P	M/DM (Mx)
F. Eunicidae	500130	.069	1.4	P	M/DM (Mx)
F. Cirratulidae	500150	.069	1.4	SDF(IF)	M/DM/S (Mx)
F. Goniadidae	500128	.069	1.4	P/S (Mixed)	DM
F. Sphaerodoriidae	500126	.069	1.4	SSDF	M
F. Sigalionidae	500106	.069	1.4	P/S	M
F. Trichobranchidae	500169	.069	1.4	SDF(IF)	S
F. Lumbrineridae	500131	.093	1.4	P/H/SDF(IF) (Mx)	M
F. Onuphidae	500121	.069	1.4	P/SDF(IF)/S (Mx)	S/DM (Mx)
F. Chaetopteridae	500149	.069	1.4	SDF(IF)	S
F. Hesionidae	500121	.069	1.4	P	M
F. Paraonidae	500141	.069	1.4	SDF(IF)	M
F. Trochochaetidae	500145	.069	1.4	SDF(IF)	M
F. Dorvilleidae	500136	.069	1.4	P/S(Mx)	M
F. Cossuridae	500152	.069	1.4	SSDF	M
F. Apistobranchidae	500142	.069	1.4	SDF(IF)	DM
F. Arenicolidae	500162	.069	1.4	SSDF	DM
F. Sabellaridae	500162	.069	1.4	SF(IF)	S
F. Serpulidae	500173	.069	1.4	SF(IF)	S
Polychaete fragments	500100	.069	1.4		
C. Oligochaeta		.069	1.4	SSDF	
P. Sipunculida	72	.045	0.1	SDF(IF)	S
F. Golfingiidae	720002	.045	0.1	SDF(IF)	DM

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
P. Echiurida	73	.051	0.1	SDF(IF)	DM
F. Echiuridae	730102	.051	0.1	SDF(IF)	DM
P. Priapulida	74	.045	0.1	SDF(IF)/S/P (Mx)	DM
F. Priapulidae	740001	.045	0.1	SDF(IF)/P/S (Mx)	DM
P. Mollusca		.028	0.3	Mx	Mx
Cl. Aplacophora	54	.037	0.3	SSDF/P/S (Mx)	M
F. Chaetodermatidae	540201	.037	0.3	SSDF/P/S (Mx)	M
Cl. Polyplacophora	53	.063	0.3	S/H	M
F. Ischnochitonidae	530302	.063	0.3	S/H	M
Cl. Scaphopoda	56	.063	0.3	SSDF	M
Cl. Bivalvia	55	.028	0.3	SF/SDF/SSDF (IF)(Mx)	S/M/DM (Mx)
F. Pectinidae (*Delectopecten*)	550905	.028	0.3	SF(IF)	M
F. Astartidae	551519	.015	0.3	SF(IF)	S/DM?
F. Cardiidae	551512		0.3	SF/SDF(IF)	S/DM?
(*Serripes*)	55152202	.033	0.3	SF(IF)	DM
(*Clinocardium*)	55152201	.022	0.3	SF/SDF (Mx)	DM
F. Mytilidae	550701	.028	0.3	SF(IF)	S
F. Nuculanidae	550204	.047	0.3	SSDF	DM/M (Mx)
(*Yoldia*)	55020405	.047	0.3	SSDF	M
(*Nuculana*)	55020402	.019	0.3	SSDF	DM
F. Nuculidae	550202	.039	0.3	SSDF	DM
F. Tellinidae	551531	.035	0.3	SDF/SF (IF)(Mx)	DM
(*Macoma*)	55153101	.035	0.3	SDF(IF)	DM
(*Tellina*)	55153102	.028	0.3	SF(IF)	DM
F. Veneridae	551547	.028	0.3	SF(IF)	S
F. Thyasiridae	551502	.028	0.3	SF(IF)	S
F. Montacutidae	551510	.028	0.3	SF(IF)	S
F. Myidae	551701	.028	0.3	SF(IF)	S/DM (Mx)
P. Bryozoa (encrusting)	78	.010	0.1	SF(IF)	S
F. Alcyonidiidae	780301	.021	0.1	SF(IF)	S
F. Flustridae	781506	.021	0.1	SF(IF)	S
P. Brachiopoda (*Terebratulina*)	80	.021	0.1	SF(IF)	S

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
F. Carditidae	551517	.062	0.3	SF(IF)	S/DM (Mx)
F. Cuspidaridae	552010	.028	0.3	P	DM
(*Cardiomya*)	55201001	.028	0.3	P	DM
F. Mactridae	551525	.028	0.3	SF(IF)	S
F. Pandoridae	552002	.028	0.3	SF(IF)	S
F. Kellidae	551508	.028	0.3	SF/SDF(IF) (Mx)	S/DM (Mx)
F. Ungulinidae (*Diplodonta*)	551505	.028	0.3	SF/SDF(IF) (Mx)	S
F. Hiatellidae	551706	.028	0.3	SF(IF)	S
F. Lyonsiidae	552005	.018	0.3	SF(IF)	S
F. Periplomatidae	552007	.028	0.3	SF(IF)	S?
F. Thraciidae	552008	.028	0.3	SF(IF)	S
Cl. Gastropoda	51	.062	0.3	P/S/H/SDF(IF) (Mx)	M
F. Cylichnidae	511004	.062	0.3	P/S (Mx)	M
F. Nassariidae	510508	.062	0.3	S/P/SDF(IF) (Mx)	M
F. Turridae	510602	.062	0.3	P	M
F. Olividae	510510	.062	0.3	P	M
F. Trochidae	510210	.062	0.3	H/P	M
F. Naticidae	510376	.080	0.3	P	M
F. Turitellidae	510333	.062	0.3	SF(IF)	DM
F. Muricidae	510501	.062	0.3	P	M
F. Lamellariidae	510366	.062	0.3	P	M
F. Pyramidellidae (*Odostomia*)	510801	.062	0.3	SDF(IF)	M
F. Rissoidae (*Alvinia*)	510320	.062	0.3	H	M
F. Acmaeidae	510205	.062	0.3	H	M
F. Epitoniidae	510351	.062	0.3	P	M
F. Trichotropidae	510362	.062	0.3	SF(IF)	DM
F. Calyptraeidae	510364	.062	0.3	SF(IF)	S/DM (Mx)
F. Buccinidae	510504	.057	0.3	P/S (Mixed)	M
F. Neptuneidae	510505	.048	0.3	P/S (Mixed)	M
F. Cancellariidae	510514	.062	0.3	H	M
F. Philinidae	511005	.062	0.3	P	M
F. Retusidae	511013	.062	0.3	P	M
Subcl. Opisthobranchia	5181	.037	0.3	P	M
Cl. Polyplacophora	53	.062	0.3	S/H (Mixed)	M
F. Ischnochitonidae	530302	.062	0.3	S/H (Mixed)	M
P. Arthropoda		.074	1.0		
Cl. Crustacea	61	.074	1.0		

Appendix II (continued)

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
SubCl. Cirripedia					
F. Balanoidae	613402	.011	0.1	SF(IF)	S
SubCl. Malacostraca					
O. Cumacea	6154	.074	1.0	SDF(IF)	DM
F. Nannastacidae	615408	.074	1.0	SDF(IF)	DM
F. Leuconidae	615404	.074	1.0	SDF(IF)/S	M
F. Lampropidae	615401	.074	1.0	SDF(IF)/S (Mx)	DM
F. Diastylidae	615404	.074	1.0	SF(IF)/S(Mx)	M
F. Cumidae	615402	.074	1.0	SDF(IF)	M
F. Campylaspidae	615407	.074	1.0	SDF(IF)	M
O. Amphipoda	6169	.074	1.0	Mx	Mx
F. Ampeliscidae	616902	.068	1.0	SDF(IF)	DM
F. Aoridae	616906	.063	1.0	SDF(IF)	M
F. Corophidae	616915	.066	1.0	SF/SDF(IF) (Mx)	DM
F. Gammaridae	616921	.074	2.5	SDF(IF)	
F. Lysianassidae	616934	.081	1.0	S/SF/SDF(IF)/ P(Mx)	M
F. Isaeidae (prev.F. Photidae)	616926	.068	1.0	SDF(IF)	M
F. Oedocerotidae	616937	.074	1.0	SDF(IF)	M
Subcl. Ostracoda	6110	.074	1.0	SDF(IF)	M
O. Harpacticoida	6119	.074	1.0	SDF(IF)	M
O. Cyclopoida	6120	.074	1.0	SDF(IF)	M
O. Nebaliacea	6145	.074	1.0	SF/SDF(IF) (Mx)	M
F. Phoxocephalidae (*Paraphoxus*, *Harpinia*)	616942	.074	1.0	SDF(IF)	M
F. Pleustidae	616943	.074	1.0	SDF(IF)	M
F. Haustoriidae (*Pontoporeia*)	616922	.099	1.0	SDF(IF)	DM
F. Stenothoidae	616948	.074	1.0	SDF(IF)	M
F. Eusiridae	616920	.062	1.0	U	M
F. Dexaminidae	616917	.074	1.0	SF(IF)	DM
F. Acanthonotozomatidae	616901	.074	1.0	U	M
F. Caprellidae	617101	.074	1.0	S/P/SF(IF)/H (Mx)	M
F. Argissidae	616907	.074	1.0	U	M
F. Atylidae	616909	.074	1.0	S/H (Mx)	DM
F. Calliopiidae	616912	.074	1.0	S/H (Mx)	M
F. Ischyroceridae	616927	.074	1.0	S?	DM
F. Parampithoidae	616939	.074	1.0	U	M?
F. Podocereidae	616944	.074	1.0	P?/U (Mx)	M
F. Synopiidae	616950	.074	1.0	S	M

Appendix II (continued)

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
O. Isopoda	6158	.074	1.0	SDF(IF)/S (Mx)	M
F. Anthuridae	616001	.074	1.0	S/P (Mx)	DM
F. Amphithoidae	616904	.074	1.0	S/P (Mx)	M
Cl. Ostracoda	6110	.074	1.0	P/H/S/SF/SDF (IF)(Mx)	M
O. Decapoda	6175	.057	1.0	S/P (Mx)	M
F. Pinnotheridae	618906	.057	1.0	Mx	M
Cyclopoida	6120	.074	1.0	P	M
Thoracica	6134	.011	1.0	SF(IF)	S
Nebaliacea	6145	.074	1.0	SF/SDF(IF) (Mx)	M
Pseudocumidae	615406	.074	1.0	U	M?
Tanaidacea	6155	.074	1.0	P/SF/SDF(IF) (Mx)	DM/M
Idoteidae	616202	.074	1.0	H/S/P (Mx)	M
Munnidae	616312	.074	1.0	H/S/P (Mx)	M?

F. Ampeliscidae (for additional information on species)					
A. macrocephala	6169020101			SDF/SF(IF)	DM
A. eschrichti	6169020105			SDF/SF(IF)	DM
Byblis gaimardi	6169020202			SDF(IF)	DM
A. birulai	6169020102			SDF/SF(IF)	DM
Haploops	61690203			SF(IF)	DM
P. Echinodermata	81	.018	0.1	P/S/SDF(IF)/ SSDF(Mx)	M
Cl. Echinoidea	8136	.008	0.1	SDF(IF)/S/H/ SSDF(Mx)	M
F. Echinarachniidae	815502	.008	0.1	SF(IF)	M
F. Strongylocentrotidae	814903	.011	0.1	SDF(IF)/H (Mx)	M
Cl. Holothuroidea	8170	.018	0.1	SSDF/SF(IF) (Mx)	S
F. Psolidae	817203	.024	0.1	SDF/SF(IF) (Mx)	DM
F. Cucumariidae	817206	.018	0.1	SDF/SF(IF) (Mx)	DM
F. Synaptidae	817801	.018	0.1	SDF/SF(IF) (Mx)	DM

Appendix II (continued)

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
Cl. Ophiuroidea	8120	.014	0.1	SDF(IF)/S/P (Mx)	M/DM (Mx)
F. Ophiactidae	812902	.014	0.1	SDF/SF(IF) (Mx)	DM
F. Ophiuridae	812701	.014	0.1	SDF(IF)/P/S (Mx)	M
F. Amphiuridae	812903	.014	0.1	SDF/SF(IF) (Mx)	M
Cl. Asteroidea					
F. Porcellanasteridae (*Ctenodiscus*)	810702	.018	0.01	SSDF	M

Dominant species in Families--For information only

F. Echnarachniidae - *E. parma*
F. Ophiactidae - *O. acuulata*
F. Ophiuridae - *O. maculata*

TAXON	TAXON CODE	CONV. C-ORG wet.wt.	P/B	FEEDING TYPE	MOTILITY TYPE
P. Enteropneusta	8201	.069	0.1	SDF/SF(IF) (Mx)	DM
P. Chordata					
Cl. Ascidiacea	8401	.014	0.1	SF(IF)	S
F. Styelidae (*Pelonaia corrugata*)	840601	.014	0.1	SF(IF)	S
F. Pyuridae	840602	.014	0.1	SF(IF)	S
F. Molgulidae	840603	.014	0.1	SF(IF)	S
F. Corellidae	840404	.014	0.1	SF(IF)	S

[1]Carbon conversion values from formalin wet weights are those included in Stoker (1978) or are calculated from values in Stoker (1978).

[2]Feeding and motility types are based on Abbott, 1974; Barnes, 1980; Bernard, 1979; Day, 1967; D'yakonov, 1950; Eltringham, 1971; Fauchald and Jumars, 1979; Feder *et al.*, 1973; Fretter and Graham, 1962; Hyman, 1967; Jørgensen, 1966; MacGinitie and MacGinitie, 1949; Mills, 1967; Morris, 1966; Morris *et al.*, 1980; Morton, 1958; Purchon, 1968; Schultz, 1969; Smith and Carlton, 1975; Stanley, 1970; Trueman, 1975; Yonge and Thompson, 1976.

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH3	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	42.0	5.01	24.262	13.69	1.480	19.65	0.148	5.22
	RHYNCHOCOELA	0.0	0.00	1.096	0.62	0.102	1.35	0.010	0.36
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	312.0	37.23	15.354	8.66	0.931	12.36	1.304	46.02
	GASTROPODA	36.0	4.30	7.013	3.96	0.551	7.31	0.165	5.83
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	282.0	33.65	86.813	48.98	3.199	42.48	0.960	33.88
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	120.0	14.32	2.268	1.28	0.154	2.05	0.154	5.44
	SIPUNCULA	10.0	1.19	16.416	9.26	0.739	9.81	0.074	2.61
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	2.0	0.24	0.004	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	30.0	3.58	21.950	12.38	0.347	4.61	0.015	0.54
	HEMICHORDATA	0 0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	4.0	0.48	2.062	1.16	0.029	0.38	0.003	0.10
		838.0		177.238		7.532		2.833	
CH4	PROTOZOA	224.0	14.07	0.005	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.652	0.14	0.007	0.05	0.001	0.02
	COELENTERATE	16.0	1.01	31.413	6.87	1.259	9.22	0.126	3.13
	RHYNCHOCOELA	0.0	0.00	0.198	0.04	0.018	0.13	0.002	0.05
	NEMATODA	134.0	8.42	0.009	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	220.0	13.82	17.920	3.92	1.265	9.27	1.772	44.09
	GASTROPODA	32.0	2.01	21.239	4.65	1.449	10.62	0.435	10.82
	CHITON	22.0	1.38	2.190	0.48	0.138	1.01	0.041	1.03
	BIVALVIA	20.0	1.26	36.553	8.00	1.427	10.46	0.428	10.66
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	808.0	50.75	6.081	1.33	0.454	3.33	0.451	11.22
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	4.0	0.25	2.830	0.62	0.033	0.24	0.003	0.08
	BRACHIOPODA	8.0	0.50	0.044	0.01	0.001	0.01	0.000	0.00
	ECHINODERMATA	58.0	3.64	287.354	62.88	6.892	50.49	0.689	17.15
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	46.0	2.89	50.502	11.05	0.707	5.18	0.071	1.76
		1592.0		456.990		13.651		4.019	

Appendix III (continued)

STATION	PHYLUM	-----ABUNDANCE----- #/M2	%	------BIOMASS------ g/M2	%	--CARBON BIOMASS--- gC/M2	%	----CARBON PROD---- gC/M2	%
CH5	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.05	0.346	0.25	0.014	0.22	0.001	0.04
	RHYNCHOCOELA	2.0	0.05	15.722	11.39	1.462	22.06	0.146	4.31
	NEMATODA	28.0	0.77	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	416.0	11.38	16.293	11.81	1.132	17.08	1.584	46.72
	GASTROPODA	30.0	0.82	8.630	6.25	0.458	6.91	0.137	4.05
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	106.0	2.90	56.129	40.67	1.817	27.42	0.545	16.07
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	3046.0	83.32	13.869	10.05	0.892	13.46	0.891	26.29
	SIPUNCULA	2.0	0.05	16.008	11.60	0.720	10.87	0.072	2.12
	ECHIURA	4.0	0.11	0.268	0.19	0.014	0.21	0.001	0.04
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	2.0	0.05	9.010	6.53	0.095	1.43	0.009	0.28
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	18.0	0.49	1.730	1.25	0.023	0.35	0.002	0.07
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		3656.0		138.010		6.627		3.391	
CH6	PROTOZOA	128.0	1.51	0.015	0.02	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.182	0.18	0.002	0.03	0.000	0.00
	COELENTERATE	0.0	0.00	0.688	0.69	0.042	0.75	0.004	0.09
	RHYNCHOCOELA	0.0	0.00	0.066	0.07	0.006	0.11	0.001	0.01
	NEMATODA	100.0	1.18	0.009	0.01	0.000	0.00	0.000	0.00
	ANNELIDA	656.0	7.74	15.497	15.65	1.084	19.30	1.517	30.81
	GASTROPODA	56.0	0.66	2.522	2.55	0.169	3.00	0.051	1.03
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	280.0	3.31	33.627	33.95	1.309	23.31	0.393	7.98
	PYCNOGONIDA	10.0	0.12	0.042	0.04	0.003	0.06	0.003	0.06
	CRUSTACEA	7146.0	84.35	41.640	42.04	2.952	52.57	2.950	59.92
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	2.0	0.02	0.006	0.01	0.000	0.01	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	2.0	0.02	1.291	1.30	0.013	0.24	0.001	0.03
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	26.0	0.31	1.498	1.51	0.008	0.15	0.001	0.02
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	66.0	0.78	1.968	1.99	0.028	0.49	0.003	0.06
		8472.0		99.051		5.616		4.923	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH7	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	40.886	10.56	0.409	2.08	0.041	0.26
	COELENTERATE	44.0	0.59	24.029	6.20	1.296	6.60	0.130	0.83
	RHYNCHOCOELA	2.0	0.03	0.297	0.08	0.028	0.14	0.003	0.02
	NEMATODA	462.0	6.17	0.074	0.02	0.001	0.00	0.000	0.00
	ANNELIDA	1042.0	13.93	9.578	2.47	0.602	3.07	0.843	5.42
	GASTROPODA	112.0	1.50	15.188	3.92	0.941	4.79	0.282	1.82
	CHITON	2.0	0.03	0.056	0.01	0.004	0.02	0.001	0.01
	BIVALVIA	64.0	0.86	6.649	1.72	0.236	1.20	0.071	0.45
	PYCNOGONIDA	72.0	0.96	0.058	0.01	0.004	0.02	0.004	0.03
	CRUSTACEA	5610.0	74.98	188.963	48.79	13.959	71.08	13.958	89.77
	SIPUNCULA	4.0	0.05	0.002	0.00	0.000	0.00	0.000	0.00
	ECHIURA	2.0	0.03	0.002	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	2.0	0.03	0.006	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	6.0	0.08	14.460	3.73	0.161	0.82	0.016	0.10
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	52.0	0.70	78.928	20.38	1.884	9.59	0.188	1.21
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	6.0	0.08	8.154	2.11	0.114	0.58	0.011	0.07
		7482.0		387.330		19.639		15.549	
CH8	PROTOZOA	56.0	2.23	0.003	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.028	0.01	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.08	0.153	0.04	0.009	0.07	0.001	0.02
	RHYNCHOCOELA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	86.0	3.43	23.404	6.16	1.619	12.26	2.267	49.06
	GASTROPODA	14.0	0.56	22.852	6.02	1.824	13.81	0.547	11.84
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	118.0	4.70	141.423	37.23	3.639	27.56	1.092	23.63
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	2110.0	84.13	12.022	3.16	0.229	1.73	0.125	2.70
	SIPUNCULA	86.0	3.43	76.006	20.01	3.420	25.90	0.342	7.40
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.031	0.01	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	34.0	1.36	103.940	27.36	2.463	18.65	0.246	5.33
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	2.0	0.08	0.001	0.00	0.000	0.00	0.000	0.00
		2508.0		379.863		13.204		4.620	

Appendix III (continued)

STATION	PHYLUM	--ABUNDANCE----- #/M2	%	------BIOMASS------ g/M2	%	--CARBON BIOMASS--- gC/M2	%	----CARBON PROD---- gC/M2	%
CH10	PROTOZOA	2.0	0.07	0.004	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.113	0.04	0.007	0.05	0.001	0.01
	RHYNCHOCOELA	0.0	0.00	0.350	0.11	0.033	0.25	0.003	0.05
	NEMATODA	14.0	0.48	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	574.0	19.71	15.184	4.95	0.990	7.61	1.386	19.81
	GASTROPODA	52.0	1.79	20.430	6.66	1.596	12.27	0.479	6.84
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	608.0	20.88	188.187	61.36	6.307	48.52	1.892	27.04
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	1576.0	54.12	48.565	15.83	3.144	24.18	3.144	44.93
	SIPUNCULA	54.0	1.85	15.932	5.19	0.717	5.51	0.072	1.02
	ECHIURA	2.0	0.07	0.006	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	8.0	0.27	0.400	0.13	0.018	0.14	0.002	0.03
	BRYOZOA	0.0	0.00	0.072	0.02	0.001	0.01	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	14.0	0.48	11.785	3.84	0.109	0.84	0.011	0.16
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	8.0	0.27	5.678	1.85	0.079	0.61	0.008	0.11
		2912.0		306.711		13.000		6.997	
CH11	PROTOZOA	6.0	0.31	0.003	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	52.0	2.71	1.526	1.18	0.059	1.66	0.006	0.34
	RHYNCHOCOELA	0.0	0.00	0.321	0.25	0.030	0.84	0.003	0.17
	NEMATODA	30.0	1.56	0.004	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	868.0	45.16	10.766	8.33	0.639	17.89	0.894	51.44
	GASTROPODA	64.0	3.33	0.915	0.71	0.058	1.64	0.018	1.01
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	220.0	11.45	51.511	39.83	1.681	47.09	0.504	29.01
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	600.0	31.22	3.348	2.59	0.226	6.32	0.226	12.99
	SIPUNCULA	8.0	0.42	0.070	0.05	0.003	0.09	0.000	0.02
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	28.0	1.46	1.648	1.27	0.027	0.74	0.003	0.15
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	14.0	0.73	4.503	3.48	0.081	2.27	0.008	0.47
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	32.0	1.66	54.700	42.30	0.766	21.46	0.077	4.41
		1922.0		129.316		3.569		1.738	

Appendix III (continued)

STATION	PHYLUM	----ABUNDANCE-----		------BIOMASS------		--CARBON BIOMASS---		----CARBON PROD----	
		#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH12	PROTOZOA	2.0	0.26	0.004	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	16.0	2.11	7.118	2.67	0.434	3.81	0.043	0.69
	RHYNCHOCOELA	0.0	0.00	0.252	0.09	0.023	0.21	0.002	0.04
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	360.0	47.49	41.631	15.62	2.721	23.86	3.810	60.86
	GASTROPODA	16.0	2.11	9.223	3.46	0.735	6.44	0.220	3.52
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	274.0	36.15	179.372	67.29	7.037	61.69	2.111	33.72
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	62.0	8.18	0.564	0.21	0.040	0.35	0.040	0.65
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.052	0.02	0.001	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	22.0	2.90	17.696	6.64	0.265	2.33	0.017	0.27
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	6.0	0.79	10.654	4.00	0.149	1.31	0.015	0.24
		758.0		266.566		11.406		6.260	
CH13	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	16.0	3.52	0.734	0.26	0.068	0.66	0.007	0.17
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	176.0	38.77	11.704	4.22	0.920	8.93	1.288	31.22
	GASTROPODA	12.0	2.64	2.112	0.76	0.153	1.49	0.046	1.12
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	208.0	45.81	259.664	93.66	9.018	87.55	2.705	65.60
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	22.0	4.85	1.015	0.37	0.072	0.70	0.072	1.74
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	14.0	3.08	1.546	0.56	0.070	0.68	0.007	0.17
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	6.0	1.32	0.462	0.17	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		454.0		277.237		10.301		4.124	

Appendix III (continued)

		ABUNDANCE		BIOMASS		CARBON BIOMASS		CARBON PROD	
STATION	PHYLUM	#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH14	PROTOZOA	2.0	0.28	0.001	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	6.0	0.83	3.320	1.23	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	2.0	0.28	9.850	3.66	0.916	7.57	0.092	1.59
	NEMATODA	2.0	0.28	0.001	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	352.0	48.48	40.535	15.06	2.959	24.45	4.143	71.95
	GASTROPODA	16.0	2.20	9.412	3.50	0.547	4.52	0.164	2.85
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	100.0	13.77	55.120	20.48	1.773	14.65	0.532	9.24
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	96.0	13.22	3.865	1.44	0.263	2.17	0.263	4.56
	SIPUNCULA	34.0	4.68	116.132	43.16	5.226	43.18	0.523	9.08
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	20.0	2.75	0.632	0.23	0.028	0.23	0.003	0.05
	BRYOZOA	2.0	0.28	0.066	0.02	0.001	0.01	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	90.0	12.40	23.602	8.77	0.299	2.47	0.030	0.52
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	4.0	0.55	6.560	2.44	0.092	0.76	0.009	0.16
		726.0		269.096		12.103		5.757	
CH15	PROTOZOA	22.0	0.50	0.056	0.02	0.001	0.01	0.000	0.00
	PORIFERA	0.0	0.00	0.026	0.01	0.000	0.00	0.000	0.00
	COELENTERATE	8.0	0.18	6.834	2.50	0.172	1.54	0.017	0.18
	RHYNCHOCOELA	0.0	0.00	0.413	0.15	0.038	0.34	0.004	0.04
	NEMATODA	16.0	0.36	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	2646.0	60.25	77.029	28.23	5.660	50.66	7.924	84.52
	GASTROPODA	74.0	1.68	11.406	4.18	0.882	7.89	0.265	2.82
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	196.0	4.46	122.668	44.96	2.969	26.58	0.891	9.50
	PYCNOGONIDA	2.0	0.05	0.001	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	1058.0	24.09	2.069	0.76	0.144	1.29	0.144	1.54
	SIPUNCULA	156.0	3.55	18.700	6.85	0.841	7.53	0.084	0.90
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	40.0	0.91	1.588	0.58	0.071	0.64	0.007	0.08
	BRYOZOA	2.0	0.05	0.180	0.07	0.002	0.02	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	170.0	3.87	31.580	11.57	0.388	3.47	0.039	0.41
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	2.0	0.05	0.304	0.11	0.004	0.04	0.000	0.00
		4392.0		272.859		11.173		9.375	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH16	PROTOZOA	58.0	0.18	0.002	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	13.702	2.24	0.137	0.86	0.014	0.19
	COELENTERATE	40.0	0.13	1.584	0.26	0.088	0.55	0.009	0.12
	RHYNCHOCOELA	24.0	0.08	0.569	0.09	0.053	0.33	0.005	0.07
	NEMATODA	180.0	0.57	0.009	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	1554.0	4.92	42.252	6.91	3.009	18.82	4.212	58.68
	GASTROPODA	126.0	0.40	30.957	5.06	2.144	13.41	0.643	8.96
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	310.0	0.98	245.689	40.17	4.511	28.21	1.353	18.85
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	29050.0	92.00	16.495	2.70	0.493	3.08	0.386	5.37
	SIPUNCULA	48.0	0.15	1.626	0.27	0.073	0.46	0.007	0.10
	ECHIURA	38.0	0.12	0.094	0.02	0.005	0.03	0.000	0.01
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	86.0	0.27	9.440	1.54	0.190	1.19	0.019	0.26
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	32.0	0.10	185.147	30.27	4.391	27.46	0.439	6.12
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	30.0	0.10	64.102	10.48	0.897	5.61	0.090	1.25
		31576.0		611.668		15.992		7.178	
CH17	PROTOZOA	34.0	0.68	0.104	0.08	0.001	0.02	0.000	0.00
	PORIFERA	0.0	0.00	0.130	0.10	0.001	0.02	0.000	0.00
	COELENTERATE	0.0	0.00	0.217	0.17	0.013	0.20	0.001	0.02
	RHYNCHOCOELA	0.0	0.00	1.498	1.19	0.139	2.10	0.014	0.26
	NEMATODA	72.0	1.44	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	958.0	19.17	26.334	20.98	1.916	28.84	2.683	50.17
	GASTROPODA	34.0	0.68	7.544	6.01	0.555	8.36	0.167	3.12
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	308.0	6.16	44.786	35.69	1.900	28.60	0.570	10.66
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	3444.0	68.91	27.980	22.30	1.889	28.43	1.889	35.33
	SIPUNCULA	2.0	0.04	0.001	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	1.246	0.99	0.012	0.19	0.001	0.02
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	140.0	2.80	14.872	11.85	0.205	3.09	0.021	0.38
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	6.0	0.12	0.780	0.62	0.011	0.16	0.001	0.02
		4998.0		125.497		6.644		5.347	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE		BIOMASS		CARBON BIOMASS		CARBON PROD	
		#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH18	PROTOZOA	50.0	10.82	0.262	0.19	0.003	0.08	0.000	0.01
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.43	0.466	0.34	0.028	0.89	0.003	0.13
	RHYNCHOCOELA	0.0	0.00	0.219	0.16	0.020	0.64	0.002	0.09
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	152.0	32.90	15.574	11.40	1.293	40.35	1.810	80.06
	GASTROPODA	8.0	1.73	0.632	0.46	0.046	1.45	0.014	0.62
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	28.0	6.06	35.526	26.00	1.171	36.54	0.351	15.54
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	10.0	2.16	0.245	0.18	0.018	0.57	0.018	0.80
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	212.0	45.89	83.736	61.27	0.625	19.49	0.062	2.76
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		462.0		136.660		3.205		2.261	
CH19	PROTOZOA	88.0	5.43	0.528	0.25	0.005	0.09	0.001	0.03
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.036	0.02	0.003	0.06	0.000	0.02
	NEMATODA	2.0	0.12	0.001	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	112.0	6.91	3.628	1.71	0.308	5.36	0.431	22.96
	GASTROPODA	46.0	2.84	6.526	3.08	0.418	7.28	0.125	6.68
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	844.0	52.03	83.172	39.24	4.041	70.34	1.212	64.59
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	90.0	5.55	0.131	0.06	0.012	0.20	0.012	0.62
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	426.0	26.26	113.684	53.63	0.898	15.64	0.090	4.79
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	14.0	0.86	4.254	2.01	0.060	1.04	0.006	0.32
		1622.0		211.960		5.745		1.877	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH21	PROTOZOA	4.0	0.35	0.010	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.009	0.00	0.001	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.262	0.09	0.024	0.21	0.002	0.02
	NEMATODA	2.0	0.17	0.002	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	400.0	34.90	104.832	35.34	7.490	63.52	10.486	90.92
	GASTROPODA	42.0	3.66	0.387	0.13	0.017	0.14	0.005	0.04
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	154.0	13.44	130.988	44.16	2.623	22.25	0.787	6.82
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	410.0	35.78	1.622	0.55	0.099	0.84	0.099	0.86
	SIPUNCULA	12.0	1.05	26.054	8.78	1.172	9.94	0.117	1.02
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.004	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.114	0.04	0.001	0.01	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	120.0	10.47	32.319	10.90	0.363	3.08	0.036	0.31
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	2.0	0.17	0.001	0.00	0.000	0.00	0.000	0.00
		1146.0		296.604		11.791		11.533	
CH23	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.008	0.00	0.000	0.01	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	1.094	0.44	0.102	1.06	0.010	0.17
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	288.0	46.75	50.892	20.63	3.341	34.81	4.678	78.96
	GASTROPODA	22.0	3.57	1.306	0.53	0.081	0.84	0.024	0.41
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	188.0	30.52	91.616	37.14	2.152	22.42	0.646	10.90
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	40.0	6.49	2.810	1.14	0.194	2.02	0.194	3.27
	SIPUNCULA	8.0	1.30	77.414	31.38	3.484	36.29	0.348	5.88
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	70.0	11.36	21.550	8.74	0.245	2.55	0.024	0.41
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		616.0		246.690		9.599		5.924	

Appendix III (continued)

STATION	PHYLUM	-----ABUNDANCE----- #/M2	%	------BIOMASS------ g/M2	%	--CARBON BIOMASS--- gC/M2	%	----CARBON PROD---- gC/M2	%
CH24	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	3.776	2.16	0.351	4.61	0.035	0.62
	NEMATODA	14.0	1.10	0.003	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	372.0	29.29	43.951	25.19	2.837	37.26	3.972	70.68
	GASTROPODA	52.0	4.09	0.430	0.25	0.027	0.35	0.008	0.14
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	498.0	39.21	114.010	65.34	3.989	52.38	1.197	21.30
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	238.0	18.74	5.805	3.33	0.407	5.35	0.407	7.25
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	8.0	0.63	0.072	0.04	0.004	0.05	0.000	0.01
	PRIAPULIDA	2.0	0.16	0.008	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	86.0	6.77	6.432	3.69	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		1270.0		174.487		7.615		5.619	
CH25	PROTOZOA	2.0	0.21	0.004	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	2.0	0.21	0.972	0.22	0.090	0.55	0.009	0.17
	NEMATODA	70.0	7.19	0.016	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	258.0	26.49	6.834	1.56	0.510	3.08	0.714	13.25
	GASTROPODA	20.0	2.05	0.162	0.04	0.011	0.07	0.003	0.06
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	528.0	54.21	413.475	94.23	15.015	90.56	4.505	83.59
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	60.0	6.16	0.931	0.21	0.070	0.42	0.070	1.29
	SIPUNCULA	8.0	0.82	0.760	0.17	0.034	0.21	0.003	0.06
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	2.0	0.21	0.210	0.05	0.009	0.06	0.001	0.02
	BRYOZOA	0.0	0.00	0.002	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	20.0	2.05	3.988	0.91	0.052	0.32	0.005	0.10
	HEMICHORDATA	4.0	0.41	11.428	2.60	0.789	4.76	0.079	1.46
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		974.0		438.782		16.581		5.389	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH26	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.166	0.10	0.015	0.22	0.002	0.06
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	48.0	8.51	14.947	8.61	1.019	14.54	1.427	53.20
	GASTROPODA	18.0	3.19	0.068	0.04	0.004	0.06	0.001	0.05
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	366.0	64.89	67.877	39.10	1.761	25.11	0.528	19.69
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	126.0	22.34	4.422	2.55	0.337	4.80	0.337	12.55
	SIPUNCULA	4.0	0.71	86.120	49.61	3.875	55.27	0.388	14.45
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	2.0	0.35	0.002	0.00	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		564.0		173.602		7.012		2.682	
CH27	PROTOZOA	8.0	1.04	0.001	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.306	0.62	0.028	0.99	0.003	0.09
	NEMATODA	2.0	0.26	0.001	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	176.0	22.80	29.768	60.14	1.997	69.32	2.796	87.89
	GASTROPODA	42.0	5.44	1.766	3.57	0.109	3.78	0.033	1.03
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	92.0	11.92	13.423	27.12	0.483	16.78	0.145	4.56
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	420.0	54.40	2.781	5.62	0.198	6.88	0.198	6.23
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	18.0	2.33	0.096	0.19	0.005	0.17	0.000	0.02
	PRIAPULIDA	10.0	1.30	1.336	2.70	0.060	2.09	0.006	0.19
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	2.0	0.26	0.014	0.03	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	2.0	0.26	0.002	0.00	0.000	0.00	0.000	0.00
		772.0		49.494		2.881		3.181	

Appendix III (continued)

STATION	PHYLUM	-----ABUNDANCE----- #/M2	%	------BIOMASS------ g/M2	%	--CARBON BIOMASS--- gC/M2	%	----CARBON PROD---- gC/M2	%
CH28	PROTOZOA	14.0	1.41	0.002	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.20	0.037	0.03	0.002	0.02	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	1.678	1.15	0.156	1.92	0.016	0.23
	NEMATODA	12.0	1.21	0.005	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	346.0	34.81	64.640	44.48	4.442	54.52	6.219	91.14
	GASTROPODA	26.0	2.62	0.939	0.65	0.058	0.71	0.017	0.26
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	112.0	11.27	5.563	3.83	0.182	2.24	0.055	0.80
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	446.0	44.87	3.022	2.08	0.206	2.53	0.206	3.02
	SIPUNCULA	4.0	0.40	68.590	47.20	3.087	37.89	0.309	4.52
	ECHIURA	24.0	2.41	0.070	0.05	0.004	0.04	0.000	0.01
	PRIAPULIDA	2.0	0.20	0.018	0.01	0.001	0.01	0.000	0.00
	BRYOZOA	0.0	0.00	0.178	0.12	0.002	0.02	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	2.0	0.20	0.028	0.02	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	4.0	0.40	0.562	0.39	0.008	0.10	0.001	0.01
		994.0		145.332		8.147		6.823	

STATION	PHYLUM	#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH29	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.104	0.16	0.010	0.24	0.001	0.02
	NEMATODA	16.0	2.18	0.003	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	362.0	49.32	50.774	75.85	3.386	83.03	4.740	94.60
	GASTROPODA	26.0	3.54	4.911	7.34	0.303	7.43	0.091	1.82
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	88.0	11.99	6.516	9.73	0.229	5.62	0.069	1.37
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	218.0	29.70	1.558	2.33	0.106	2.59	0.105	2.11
	SIPUNCULA	10.0	1.36	0.064	0.10	0.003	0.07	0.000	0.01
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	2.0	0.27	0.438	0.65	0.005	0.13	0.001	0.01
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	6.0	0.82	0.750	1.12	0.010	0.26	0.001	0.02
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	6.0	0.82	1.826	2.73	0.026	0.63	0.003	0.05
		734.0		66.944		4.078		5.011	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH30	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.25	2.261	3.26	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	2.0	0.25	0.863	1.25	0.080	2.68	0.008	0.29
	NEMATODA	18.0	2.22	0.003	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	492.0	60.74	24.667	35.62	1.779	59.44	2.491	88.55
	GASTROPODA	22.0	2.72	5.762	8.32	0.358	11.97	0.107	3.82
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	230.0	28.40	25.366	36.63	0.629	21.00	0.189	6.70
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	40.0	4.94	0.064	0.09	0.004	0.13	0.004	0.13
	SIPUNCULA	2.0	0.25	0.006	0.01	0.000	0.01	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.202	0.29	0.002	0.07	0.000	0.01
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	2.0	0.25	10.064	14.53	0.141	4.71	0.014	0.50
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		810.0		69.258		2.993		2.813	
CH31	PROTOZOA	36.0	5.13	0.114	0.03	0.001	0.02	0.000	0.01
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.032	0.01	0.003	0.05	0.000	0.02
	NEMATODA	8.0	1.14	0.008	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	76.0	10.83	4.854	1.36	0.396	7.05	0.554	34.23
	GASTROPODA	12.0	1.71	19.844	5.55	1.472	26.25	0.442	27.29
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	42.0	5.98	33.626	9.41	1.243	22.16	0.373	23.04
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	248.0	35.33	0.118	0.03	0.001	0.01	0.000	0.00
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	268.0	38.18	282.218	78.96	2.261	40.31	0.226	13.97
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	12.0	1.71	16.610	4.65	0.233	4.15	0.023	1.44
		702.0		357.418		5.610		1.619	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH33	PROTOZOA	64.0	0.92	0.013	0.01	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.066	0.04	0.003	0.10	0.000	0.02
	RHYNCHOCOELA	0.0	0.00	0.106	0.06	0.010	0.31	0.001	0.07
	NEMATODA	542.0	7.76	0.017	0.01	0.000	0.01	0.000	0.00
	ANNELIDA	1570.0	22.47	11.879	7.07	0.765	23.79	1.070	74.87
	GASTROPODA	66.0	0.94	1.342	0.80	0.081	2.51	0.024	1.69
	CHITON	8.0	0.11	0.452	0.27	0.028	0.89	0.009	0.60
	BIVALVIA	138.0	1.97	4.434	2.64	0.179	5.58	0.054	3.76
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	4470.0	63.97	1.692	1.01	0.071	2.22	0.064	4.46
	SIPUNCULA	14.0	0.20	0.164	0.10	0.007	0.23	0.001	0.05
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.585	0.35	0.006	0.18	0.001	0.04
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	116.0	1.66	147.316	87.65	2.062	64.18	0.206	14.43
		6988.0		168.066		3.213		1.430	
CH34	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.003	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	8.0	0.35	0.046	0.04	0.004	0.06	0.000	0.01
	NEMATODA	302.0	13.15	0.015	0.01	0.000	0.00	0.000	0.00
	ANNELIDA	1018.0	44.34	33.516	25.56	2.336	34.03	3.270	65.38
	GASTROPODA	20.0	0.87	11.314	8.63	0.874	12.74	0.262	5.24
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	324.0	14.11	63.109	48.13	2.380	34.66	0.714	14.27
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	554.0	24.13	10.481	7.99	0.700	10.19	0.698	13.96
	SIPUNCULA	2.0	0.09	11.842	9.03	0.533	7.76	0.053	1.07
	ECHIURA	48.0	2.09	0.456	0.35	0.023	0.34	0.002	0.05
	PRIAPULIDA	4.0	0.17	0.318	0.24	0.014	0.21	0.001	0.03
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	6.0	0.26	0.019	0.01	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	10.0	0.44	0.009	0.01	0.000	0.00	0.000	0.00
		2296.0		131.128		6.865		5.002	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE		BIOMASS		CARBON BIOMASS		CARBON PROD	
		#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH35	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.432	0.21	0.040	0.42	0.004	0.05
	NEMATODA	36.0	2.71	0.008	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	682.0	51.36	69.893	34.45	4.574	47.31	6.404	80.22
	GASTROPODA	22.0	1.66	2.350	1.16	0.143	1.48	0.043	0.54
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	208.0	15.66	121.541	59.91	4.432	45.84	1.330	16.65
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	248.0	18.67	2.620	1.29	0.172	1.78	0.172	2.16
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	128.0	9.64	6.000	2.96	0.306	3.16	0.031	0.38
	PRIAPULIDA	4.0	0.30	0.028	0.01	0.001	0.01	0.000	0.00
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		1328.0		202.873		9.669		7.983	
CH36	PROTOZOA	2.0	0.19	0.001	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.004	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.140	0.10	0.013	0.20	0.001	0.03
	NEMATODA	10.0	0.96	0.002	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	628.0	60.15	45.589	34.01	2.996	46.24	4.195	83.55
	GASTROPODA	12.0	1.15	2.006	1.50	0.125	1.94	0.038	0.75
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	182.0	17.43	58.060	43.31	2.162	33.36	0.649	12.92
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	100.0	9.58	2.859	2.13	0.050	0.77	0.025	0.50
	SIPUNCULA	2.0	0.19	23.942	17.86	1.077	16.63	0.108	2.15
	ECHIURA	50.0	4.79	0.798	0.60	0.041	0.63	0.004	0.08
	PRIAPULIDA	42.0	4.02	0.336	0.25	0.015	0.23	0.002	0.03
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	16.0	1.53	0.324	0.24	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		1044.0		134.061		6.480		5.020	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH37	PROTOZOA	218.0	8.50	0.002	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.002	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.048	0.03	0.004	0.06	0.000	0.01
	NEMATODA	64.0	2.49	0.008	0.01	0.000	0.00	0.000	0.00
	ANNELIDA	572.0	22.29	52.188	37.22	3.564	49.79	4.989	89.95
	GASTROPODA	42.0	1.64	1.920	1.37	0.119	1.66	0.036	0.64
	CHITON	2.0	0.08	0.006	0.00	0.000	0.01	0.000	0.00
	BIVALVIA	168.0	6.55	5.085	3.63	0.186	2.60	0.056	1.01
	PYCNOGONIDA	2.0	0.08	0.012	0.01	0.001	0.01	0.001	0.02
	CRUSTACEA	1310.0	51.05	2.723	1.94	0.157	2.19	0.152	2.74
	SIPUNCULA	74.0	2.88	65.446	46.68	2.945	41.15	0.295	5.31
	ECHIURA	18.0	0.70	0.154	0.11	0.008	0.11	0.001	0.01
	PRIAPULIDA	4.0	0.16	0.054	0.04	0.002	0.03	0.000	0.00
	BRYOZOA	0.0	0.00	0.154	0.11	0.003	0.04	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	14.0	0.55	0.423	0.30	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	78.0	3.04	11.986	8.55	0.168	2.34	0.017	0.30
		2566.0		140.211		7.157		5.546	
CH39	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.296	0.27	0.028	0.60	0.003	0.14
	NEMATODA	4.0	0.38	0.003	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	92.0	8.66	11.466	10.36	0.660	14.31	0.924	48.02
	GASTROPODA	20.0	1.88	0.546	0.49	0.034	0.73	0.010	0.53
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	768.0	72.32	56.830	51.34	2.296	49.80	0.689	35.81
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	102.0	9.60	2.243	2.03	0.171	3.71	0.171	8.89
	SIPUNCULA	4.0	0.38	27.778	25.09	1.250	27.11	0.125	6.50
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	10.0	0.94	0.110	0.10	0.005	0.11	0.000	0.03
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	62.0	5.84	11.422	10.32	0.168	3.63	0.002	0.09
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		1062.0		110.694		4.611		1.924	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH40	PROTOZOA	2.0	0.10	0.004	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	16.0	0.79	0.136	0.05	0.007	0.06	0.001	0.01
	RHYNCHOCOELA	0.0	0.00	0.282	0.11	0.026	0.23	0.003	0.03
	NEMATODA	68.0	3.38	0.009	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	696.0	34.56	90.293	34.03	6.262	54.47	8.767	88.25
	GASTROPODA	56.0	2.78	32.032	12.07	1.637	14.24	0.491	4.94
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	178.0	8.84	25.168	9.49	0.750	6.52	0.225	2.26
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	760.0	37.74	2.916	1.10	0.186	1.62	0.185	1.87
	SIPUNCULA	38.0	1.89	0.535	0.20	0.024	0.21	0.002	0.02
	ECHIURA	134.0	6.65	0.312	0.12	0.016	0.14	0.002	0.02
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	3.772	1.42	0.038	0.33	0.004	0.04
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	22.0	1.09	101.722	38.34	2.436	21.19	0.244	2.45
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	44.0	2.18	8.156	3.07	0.114	0.99	0.011	0.11
		2014.0		265.337		11.496		9.935	
CH43	PROTOZOA	554.0	14.07	0.018	0.02	0.000	0.01	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	2.0	0.05	0.002	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.138	0.15	0.013	0.63	0.001	0.09
	NEMATODA	110.0	2.79	0.006	0.01	0.000	0.00	0.000	0.00
	ANNELIDA	252.0	6.40	11.323	11.97	0.838	40.86	1.174	83.63
	GASTROPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	18.0	0.46	2.834	3.00	0.097	4.75	0.029	2.08
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	2616.0	66.43	54.282	57.40	0.681	33.20	0.157	11.19
	SIPUNCULA	8.0	0.20	1.926	2.04	0.087	4.22	0.009	0.62
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRYOZOA	0.0	0.00	0.036	0.04	0.000	0.02	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	12.0	0.30	0.124	0.13	0.000	0.02	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	366.0	9.29	23.880	25.25	0.334	16.29	0.033	2.38
		3938.0		94.569		2.052		1.404	

Appendix III (continued)

STATION	PHYLUM	-----ABUNDANCE-----		------BIOMASS------		--CARBON BIOMASS---		----CARBON PROD----	
		#/M2	%	g/M2	%	gC/M2	%	gC/M2	%
CH44	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.002	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.036	0.03	0.003	0.05	0.000	0.01
	NEMATODA	10.0	0.43	0.004	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	896.0	38.62	25.869	18.23	1.349	19.91	1.888	66.61
	GASTROPODA	8.0	0.34	6.130	4.32	0.490	7.24	0.147	5.19
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	674.0	29.05	38.685	27.26	1.398	20.63	0.419	14.79
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	94.0	4.05	0.439	0.31	0.029	0.43	0.029	1.03
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	560.0	24.14	68.224	48.07	3.479	51.36	0.348	12.27
	PRIAPULIDA	8.0	0.34	0.042	0.03	0.002	0.03	0.000	0.01
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	70.0	3.02	2.496	1.76	0.024	0.35	0.002	0.08
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		2320.0		141.928		6.774		2.835	
CH45	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.006	0.03	0.000	0.01	0.000	0.00
	COELENTERATE	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	162.0	19.57	4.847	26.99	0.296	30.90	0.415	59.88
	GASTROPODA	76.0	9.18	0.801	4.46	0.050	5.17	0.015	2.15
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	224.0	27.05	9.002	50.13	0.419	43.68	0.126	18.14
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	322.0	38.89	1.985	11.05	0.131	13.67	0.131	18.92
	SIPUNCULA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHIURA	10.0	1.21	1.142	6.36	0.058	6.07	0.006	0.84
	PRIAPULIDA	6.0	0.72	0.110	0.61	0.005	0.52	0.000	0.07
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	28.0	3.38	0.066	0.37	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		828.0		17.959		0.959		0.693	

Appendix III (continued)

STATION	PHYLUM	ABUNDANCE #/M2	ABUNDANCE %	BIOMASS g/M2	BIOMASS %	CARBON BIOMASS gC/M2	CARBON BIOMASS %	CARBON PROD gC/M2	CARBON PROD %
CH47	PROTOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PORIFERA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	COELENTERATE	0.0	0.00	0.001	0.00	0.000	0.00	0.000	0.00
	RHYNCHOCOELA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	NEMATODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ANNELIDA	204.0	32.28	12.566	14.43	0.749	17.26	1.049	60.04
	GASTROPODA	42.0	6.65	7.145	8.20	0.457	10.53	0.137	7.85
	CHITON	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BIVALVIA	116.0	18.35	0.564	0.65	0.019	0.44	0.006	0.33
	PYCNOGONIDA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	CRUSTACEA	252.0	39.87	3.627	4.16	0.271	6.24	0.271	15.50
	SIPUNCULA	4.0	0.63	63.148	72.50	2.842	65.50	0.284	16.27
	ECHIURA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	PRIAPULIDA	2.0	0.32	0.024	0.03	0.001	0.02	0.000	0.01
	BRYOZOA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	BRACHIOPODA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	ECHINODERMATA	12.0	1.90	0.027	0.03	0.000	0.00	0.000	0.00
	HEMICHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
	UROCHORDATA	0.0	0.00	0.000	0.00	0.000	0.00	0.000	0.00
		632.0		87.102		4.338		1.746	

APPENDIX IV

Distribution of Fauna Along Transects

The fauna at benthic stations along five transects (Figure 78) were examined. A comparison of the stations were made according to dominant taxa, feeding method, motility, abundance, biomass, sediment type and organic content of sediment (Tables 1-6). A presentation of the five transects (A-E) is included below.

TRANSECT A

(Stations CH5, CH4, CH3, CH11, CH12)

Station CH5

The substrate at Station CH5 was mixed, with mud predominating (65%), followed by sand (19%) and gravel (15%). The benthic infaunal invertebrate abundance here was 3,656 individuals/m^2, the highest among stations along Transect A. Most benthic organisms residing here were either discretely motile (51%) or motile (44%) forms. The interface feeding organisms (surface deposit feeders and suspension feeders) that dominated in abundance reflected a surface-detritus based system where particulate organic carbon (POC) primarily accumulates on rather than within the sediment. The surface deposit feeding amphipods of the families Ampeliscidae and Isaeidae and cumaceans of the families Diastylidae and Leuconidae predominated. These groups accounted for nearly 80% of the station abundance. The predominant organisms, *Byblis* spp., belong to the amphipod family Ampeliscidae that may also suspension feed. *Byblis* is a genus that is characteristic of muddy sediment. This station is within an area where gray whales are known to feed in the summer on benthic amphipods.

Station CH4

At Station CH4, immediately offshore from Station CH5, approximately 70% of the sediments here were sand; gravel accounted for 18%. The fauna were mainly sessile (54%) with 34% motile. The coarse substrates here was dominated by interface feeders, especially barnacles which utilize POC from the water column. Barnacles accounted for nearly 67% of the abundance. At this station the organic carbon values from the sediment, as well as the fauna, was highest among stations along the transect. Since the sediment carbon value was high and there were few subsurface deposit feeders it is implied that most of the sediment carbon was refractory. Although few in number, the sea cucumbers (Holothuroidea) dominated the carbon biomass.

Stations CH3 & CH12

The depth, substrate, and dominant benthic taxa at Stations CH3 and CH12 were similar. The sediment at these stations reflected a depositional environment with more than 97% of the substrate composed of mud. Organic carbon within the sediment and abundance values were similar. Station CH12 had a higher carbon biomass due mainly to the presence of protobranch clams of the family Nuculanidae. Polychaetes of the family Lumbrineridae (*Lumbrineris* sp.) and clams of the families Tellinidae (*Macoma calcarea*) were most numerous. Lumbrinerid worms obtain their food through a mixture of predatory and surface deposit feeding modes, while *Macoma* deposit feeds at the sediment surface. Other dominant surface deposit feeders common to Stations CH3 and CH12 were cumaceans of the family Leuconidae and polychaetes of the family Cirratulidae. Abundant subsurface deposit feeding groups common at both stations were the families Nuculanidae (clams) and Capitellidae (polychaetes). The organic carbon values in the sediment at these stations were also similar.

Station CH11

Station CH11, located between Stations CH3 and CH12, was mainly composed of the coarser fractions of sand (58%) and gravel (13%). The fauna here were primarily motile, although 26% of the abundance were sessile. Dominant organisms here mainly reflected a surface-detritus based system rather than a depositional and POC-accumulating environment. Surface deposit feeding polychaetes (Cirratulidae and Ampharetidae), amphipods (Ampeliscidae and Phoxocephalidae), and cumaceans (Diastylidae) dominated the abundance here. Since some subsurface deposit feeders were also fairly abundant (i.e., nuculid clams and maldanid polychaetes), some accumulation of POC also accumulates within the sediment.

Transect Summary

The substrate at stations along this transect passed alternately from mainly mud to sand. This patchiness of substrate types was also reflected in the fauna. In general, there was a trend of decreasing interface feeders from shore to sea and an increase of subsurface deposit feeders from shore to sea.

TRANSECT B

(Stations CH17, CH16, CH14, CH24, CH25)

Station CH17

Station CH17, located in the lee of Icy Cape in 23 m, was dominated by a sandy substrate (nearly 83%). Discretely motile and motile forms dominated the abundance with 59% and 30%, respectively. Here ampeliscid amphipods dominated the benthos in abundance and carbon biomass, therefore, the station indicated a surface-detritus based system. Ampeliscids, as well as two other numerically important amphipod families (Phoxocephalidae and Isaeidae) and a cumacean family (Diastylidae), utilize the POC deposited at the sediment surface, although the amphipods are also capable of suspension feeding. This station is within an area where gray whales are known to feed in the summer on benthic amphipods. Some accumulation of POC also occurs at this site since 11% of the abundance were subsurface deposit feeders, i.e., polychaetes (Maldanidae and Orbiniidae) and clams (Nuculanidae).

Station CH16

The next station offshore from Station CH17 was Station CH16 in 43 m. Here the benthic environment was mainly sand (58%) and gravel (32%); mud comprised only 10%. The fauna was extremely diverse with 143 taxa identified. Nearly 85% of the abundance were sessile organisms. Suspension feeders dominated with 84% of the abundance. More than 26,000 barnacles/m^2 were responsible for the high Simpson Diversity Index of 0.70. The high carbon biomass (16.2 gC/m^2) was due mainly to sea cucumbers (Holothuriodea) and astartid clams. Although this site is mainly characterized as a suspensory one, a reasonable amount of POC evidently reaches tha sediment surface as indicated by the numerous surface deposit feeders (9% of the abundance; e.g., isaeid, ampeliscid, phoxocephalid, and oedicerotid amphipods and cumaceans). Few subsurface deposit feeders were present (3% of the abundance).

Station CH14

Further offshore at Station CH14 the sediment had an increase in mud (54%), but nearly 45% was sand/gravel. Approximately 64% of the faunal abundance were motile and discretly motile; nearly 29% were sessile. The abundance of the fauna at this station (726 individuals/m^2) was less than 3% of that found at Station CH16, however, the carbon biomass was similar. The high carbon biomass was due mainly to sipunculid worms. The Simpson Diversity Index at Station CH14 was only 0.04. Because of the relatively high mud content deposit feeders dominated. Surface and subsurface deposit feeders accounted for 36 and 26% of the abundance, respectively. Only 7% of the abundance were suspension feeders. Therefore, since Station CH14 has a higher proportion of interface feeders it is characterized as mainly a surface-detritus based system. Some accumulation of POC also accumulates within the sediment as evidenced by the reasonably high abundance of subsurface deposit feeders. Although six groups were numerically important (the polychaetes - Lumbrineridae, Maldanidae and Ampharetidae; amphipods - Phoxocephalidae; brittle stars - Ophiuridae; and sipunculid worms - *Sipuncula*) at Station 14, no single group dominated.

Station CH24

Station CH24 was nearly 150 km offshore from Station CH14, but at a similar water depth. Here the substrate was predominately mud (77%) with moderate amount of sand (23%). No gravel was observed. The feeding modes of the fauna were mixed with organisms that feed at the sediment surface interface (33%) and ones that deposit feed within the substrate (46%).

Subsurface deposit feeding nuculid clams and surface deposit feeding gammarid amphipods dominated the abundance. Most of the abundance were discretely motile or motile.

Station CH25

The last station along Transect B, Station CH25, was about 380 km from shore in 51 m. Mud dominated the substrate here (99%). The organic carbon within the sediment (15.7 mg/g) and the carbon biomass (16.6 gC/m^2) here was the highest among stations along this transect. Interface feeders and subsurface deposit feeders accounted for 41 and 34% of the abundance, respectively. Tellinid clams (*Macoma* spp.) accounted for nearly 73% of the biomass. This group feeds at the sediment interface combining surface deposit feeding with suspenion feeding. Nuculid and tellinid clams accounted for nearly 44% of the abundance. As suggested by the extremely high carbon value at this station it is apparent that a high flux of POC to the bottom must occur here to sustain large numbers of both surface and subsurface deposit feeding organisms.

Transect Summary

The substrate along this transect became progressively muddier the farther from shore. As with Transect A, this transect displayed a general decrease of interface feeders and an increase of subsurface deposit feeders from shore to sea. Stations along this transect had the highest average values of sediment carbon, carbon biomass, and abundance among the five transects.

TRANSECT C

(Stations CH18, CH30, CH28, CH27, CH26, CH39)

Station CH18

Station CH18 consisted mainly of sand (90%) and organisms capable of utilizing mixed (mainly deposit and suspension feeders) feeding strategies. This station had the lowest abundance along Transect C, 462 individuals/m^2. Most of the faunal abundance were motile organisms; only about 6% were sessile. The sand dollar, *Echinarachnius parma*, dominated in abundance. This suspension-feeding echinoderm feeds at the sediment surface. Four of the numerically-important faunal groups feed at the sediment interface by suspension feeding and surface deposit feeding. These are the polychaetes Spionidae and Owenidae, sea cucumbers (Holothuroidea), and brittle stars of the family Ophiuridae. Based upon the physical composition of the sediment (i.e., 90% sand) this station represents a suspensory environment. Consequently, the POC present is available at the benthic boundary layer where it is used by the dominant suspension feeding sand dollar. The presence of subsurface deposit feeders (e.g., the polychaetes Pectinariidae, Opheliidae, and Orbiniidae) indicates that the relatively high organic content of the sediment is sufficiently nutritious to support these organisms as well.

Station CH30

Immediately offshore from Station CH18, in an area also dominated by sand (88%), was Station CH30. The fauna here did not typify that of a sand-dominated area because nearly 50% of the 10 dominant faunal groups were subsurface deposit feeders. Most were motile organisms. Sessile forms accounted for approximately 22% of the abundance. Surface deposit feeders were also present, but not as numerous as subsurface deposit feeders. Only one suspension feeding group was among the top ten abundant faunala groups, the clam family Thyasiridae (mainly *Axinopsida serricata*). Although the substrate at Stations CH18 and CH30 were similar, more resuspension of POC evidently occurs at Station CH18 than at Station CH30. Although the sediment carbon content was low (1.2 mg/g) as compared to Station CH13, the dominance of subsurface deposit feeders at Station CH30 indicates that the carbon present here is of high quality.

Station CH28

The substrate at Station CH28 was mainly sand (58%) and mud (36%). Approximately 85% of the organisms were motile or discretely motile. Nearly 52% were interface feeders and 23% were subsurface deposit feeders. Surface deposit feeding amphipods accounted for nearly 37% of the faunal abundance. The family Ampeliscidae, mainly *Byblis gaimardi*, accounted for 24% of the abundance. subsurface deposit feeders were also numerically important, in particular, polychaetes of the families Capitellidae, Maldanidae, and Orbiniidae. There were no suspension feeders among the 10 most abundant faunal groups (76% of the abundance). Abundant faunal groups present at both Stations CH28 and CH30 were Capitellidae, Maldanidae, Orbiniidae and Cirratulidae and clams of the family Nuculidae.

Station CH27

The sediment at Station CH27 consisted mainly of mud (90%). This station mainly resembles a surface-detritus based system, since the majority of the abundance were interface feeders. Approximately 51% of the faunal abundance consisted of four families of surface deposit feeding amphipods. *Haploops* and *Harpina* of the family Ampeliscidae dominated. Although surface deposit feeders were the most abundant forms, subsurface deposit feeders were also numerous, especially clams of the families Nuculanidae and Nuculidae and polychaetes of the families Sternaspidae and Orbiniidae. The presence of a high percentage of surface deposit feeders, as opposed to subsurface deposit feeders, suggest that a high flux of POC to the bottom occurs here, but that most of the carbon is utilized at the surface.

Station CH26

In contrast to Station CH27, where interface feeders dominated the muddy substrate, Station CH26 was dominated by subsurface deposit feeders in a substrate of less mud (51%) mud and more gravel (39%). Most (96%) were discretely motile and motile forms; few (3%) were sessile. Two subsurface deposit feeding clam families accounted for 55% of the faunal abundance. Nearly 20% of the abundance consisted of three families of surface deposit feeding amphipods. Abundant faunal groups in common at Stations CH26 and CH27 were the polychaetes Cirratulidae, the amphipods Ampeliscidae, Phoxocephalidae, and Lysianassidae, the clams Nuculanidae and Nuculidae, and the snails Retusidae.

Station CH39

Station CH39, the most distant from shore, had mostly a muddy substrate (96%), indicative of a depositional region. It had the highest abundance (1062 individuals/m^2) of all stations along this transect. There were few taxa here (31). Most (93%) of the faunal abundance were comprised of discretely motile and motile organisms. subsurface deposit feeders dominated, especially the nuculid clam *Nucula bellotti*, which accounted for more than 60% of the station abundance. This clam was respondible for the high Simpson Diversity Index of 0.44. Stations CH39 and CH26 were similar in that both were dominated by the clams Nuculidae, Nuculanidae, and

Tellinidae. Since most of the abundance at Station CH39 were subsurface deposit feeders one might conclude that the nutritional quality within the substrate was high, although the organic carbon value within the sediment was a low 1.6 mg/g. Furthermore, the abundant subsurface deposit feeding clams (Nuculidae and Nuculanidae) typically feed close to the sediment surface, adjacent to the newly deposit detrital zone.

Transect Summary

The substrate along this transect generally became progressively finer with increasing distance from shore. Interface feeders, as a percentage of the abundance, was generally lowest at the offshore end of the transect. Conversely, subsurface deposit feeders were most numerous farther from shore. The sediment carbon, carbon biomass, and abundance was generally low along this transect.

TRANSECT D

(Stations CH33, CH34, CH35, CH36, CH37, CH40)

Station CH33

Coarse substrate dominated Station CH33, 62% gravel and 34% sand, reflecting a suspensory environment. This station had the greatest abundance along the transect, 6,988 individuals/m^2. Approximately 67% of the faunal abundance were sessile organisms. Nearly 62% of the abundance were suspension feeding barnacles, 4,318/m^2. The preponderance of barnacles was responsible for the high Simpson Diversity Index, 0.44.

Station CH34

The sediment at Station CH34 had less gravel and more sand than at Station CH33. Here gravel, sand, and mud accounted for 33%, 50%, and 17%, respectively. Only 23% of the faunal abundance were sessile. Of the ten most abundant faunal groups surface and subsurface deposit feeders and suspension feeders were well represented. The carbon biomass at this station is primarily attributable to subsurface deposit feeding orbiniid polychaetes and nuculid clams, and surface deposit feeding/suspension feeding ampeliscid amphipods. Therefore, the environment at this station indicates that deposition of POC is sufficient to accumulate within and at the sediment surface, but not so much as to preclude the occurrence of suspension feeding organisms.

Station CH35

At Station CH35, where 70% of the sediment was mud, subsurface deposit feeders and interface feeders dominated the abundance. This reflected an environment of deposition where sufficient carbon appears to Be available to support both surface and subsurface deposit feeders. subsurface deposit feeding capitellid and sternaspid polychaetes and nuculid clams accounted for nearly 50% of the faunal abundance. Most (60%) of the abundance was comprised of motile forms.

Station CH36

Station CH36 had 49% sand, 30% mud, and 21% gravel. Approximately 35% of the faunal abundance were sessile organisms; motile and discretely motile forms made up 33% and 29% of the abundance, respectively. subsurface deposit feeders dominated the faunal abundance, as well as the carbon biomass. Important subsurface deposit feeding families, in terms of abundance, were maldanid, capitellid and orbiniid polychaetes and nuculid clams. Common surface deposit feeders, in terms of abundance, presumably associated with the increased sand fraction at this station were echiurid worms, priapulid worms, and ampeliscid amphipods.

Station CH37

Coarse sediment was found at Station CH37; sand and gravel accounted for nearly 63% and 31%, respectively. This region can be characterized as a suspensory one. Sessile organisms amounted to more than 52% of the faunal abundance. Suspension feeders, in particular juvenile barnacles, dominated the abundance.

Station CH40

Station CH40, the outermost station along the transect, had mixed sediment. Mud, sand, and gravel accounted for 47%, 24% and 29%, respectively. A total of 94 taxa were identified, the most diverse station in the transect. Station CH40 had the highest biomass of all stations along this transect. More than 53% of the abundance were motile;about 15% were sessile. No single faunal group dominated as indicated by the low Simpson

Diversity Index of 0.04. Of the ten most abundant faunal groups, most were surface deposit feeders. Although surface deposit feeders dominate this station in terms of abundance, the subsurface-deposit feeding maldanid polychaete was a dominant in carbon biomass. Consequently, it is apparent that a high flux of POC to the bottom must occur to sustain surface and subsurface deposit feeders. That such a flux does occur is suggested by the high carbon value for this station, although the OC/N value and the δ^{13} values suggest that much of this carbon is refractory.

Transect Summary

The substrate along this transect displayed no obvious trend, rather it was relatively heterogenous with high abundance and biomass values. Consequently, interface feeders generally were abundant throughout the transect.

TRANSECT E

(Stations CH43, CH44, CH45, CH47)

Station CH43

Gravel (60%) was the dominant sediment at Station CH43. In this suspensory environment, where 81% of the abundance were sessile organisms, suspension feeding barnacles dominated. This station had the highest transect abundance of 3,938 individuals/m^2. Nearly 65% of the abundance or 2,548 barnacles/m^2 were found here. This dominant group was responsible for the relatively high Simpson Diversity Index of 0.39.

Station CH44

Station CH44 was located immediately seaward of Station CH43. Gravel was absent here but sand and mud accounted for 48% and 52%, respectively, indicative of a region of greater deposition. Motile and discretely motile forms accounted for about 76% of the abundance, both in similar proportions. Approximately 55% of the abundance was interface feeders. Surface and subsurface deposit feeders were also similar in abundance. The large surface deposit feeding echiurid worm, *Echiurus echiurus alaskensis*, dominated in abundance and carbon biomass.

Station CH45

The sediment at Station CH45 contained finer fractions than Station CH44. Mud predominated here with 73%; sand accounted for 27%. Most organisms were either motile or discretely motile forms. The abundance was dominated by Interface feeders. The surface deposit feeding amphipods from the family Ampeliscidae (mainly *Byblis gaimardi*) accounted for more than 23% of the faunal abundance. This genus typically resides in muddy sediments. The other important faunal groups were nearly equally divided between surface and subsurface deposit feeders. Only 6% of the abundance were suspension feeders. The carbon biomass here was the lowest of all stations (1 gC/m^2).

Station CH47

At Station CH47, the outermost station on the transect, the coarser fraction were reduced. In fact, the trend from shore to seaward along this transect was toward increasing muds or greater deposition. Station CH47 had the lowest transect abundance, 632 individuals/m^2. The motile, discretely motile, and sessile fauna accounted for 40%, 25%, and 19%, respectively. Deposit feeders dominated the abundance. The subsurface deposit-feeding polychaete family Maldanidae dominated the abundance and carbon biomass. Three amphipod families were the most abundant surface deposit feeders.

Transect Summary

The sediment at stations along this transect became progressively muddier the farther from shore. The sediment carbon values at the stations in this transect were all high with a trend of increasing values from onshore to offshore. However, the OC/N values and the $\delta^{13}C$ values suggest that the carbon, in general, is refractory at all stations, a circumstance to be expected in a shelf region underlying the Alaska Coastal Current (Grebmeier *et al.*, 1988).

Table IV.1 Summary of faunal and sediment parameters at five benthic station transects, southeastern Chukchi Sea, August-September 1985.

Transect	Sta Name	Depth m	Sediment G %	Sediment S %	Sediment M %	Sediment Carbon mg/g	Abundance #/m^2	Carbon Biomass gC/m^2	Feeding Mode IF %	Feeding Mode SSDF %	Motility S %	Motility DM+M %
A	CH5	19	15	19	65	5.2	3656	6.6	81	4	5	95
	CH4	42	18	70	12	10.0	1592	13.7	67	2	54	45
	CH3	51	0	3	97	5.3	838	7.5	55	13	26	71
	CH11	32	13	58	29	6.4	1922	3.6	60	14	26	72
	CH12	44	0	0	100	4.4	758	11.4	46	28	12	87
B	CH17	23	3	83	14	6.1	4998	6.6	73	11	10	89
	CH16	43	32	58	10	4.3	31576	16.0	93	3	85	15
	CH14	47	18	27	54	8.1	726	12.1	44	26	29	64
	CH24	43	0	23	77	9.8	1270	7.6	32	46	6	87
	CH25	51	0	1	99	15.7	974	16.6	41	34	7	92
C	CH18	18	5	90	5	7.0	462	3.2	58	13	6	90
	CH30	39	0	88	12	1.2	810	3.0	32	50	22	77
	CH28	41	6	58	36	2.1	994	8.2	52	28	13	85
	CH27	42	0	10	90	1.6	772	2.9	56	23	6	93
	CH26	47	39	10	51	7.3	564	7.0	25	57	3	96
	CH39	48	0	4	96	1.6	1062	4.6	18	68	2	93
D	CH33	18	62	34	4	3.2	6988	3.2	80	6	68	30
	CH34	32	33	50	17	1.9	2296	6.9	48	32	27	67
	CH35	39	0	30	70	4.2	1328	9.7	39	48	7	91
	CH36	44	21	49	30	1.5	1044	6.5	19	69	36	62
	CH37	47	31	63	6	2.1	2566	7.2	63	19	52	47
	CH40	45	29	24	47	7.8	2014	11.5	51	19	18	78
E	CH43	23	60	20	20	5.5	3938	2.1	81	2	81	19
	CH44	31	0	48	52	7.7	2320	6.8	55	34	18	76
	CH45	45	0	27	73	9.5	828	1.0	47	25	6	85
	CH47	50	0	13	87	11.8	632	4.3	33	35	19	66

1/ Sediment: G = Gravel: S = Sand: M = Mud.
2/ Feeding Mode: IF = Interface Feeder: SSDF = Subsurface deposit feeder.
3/ Motility: S = Sessile: DM = Discretely Motile: M = Motile.
4/ Percent Feeding Mode and Motility is based on abundance.

Table IV.2 Station transects of dominant faunal groups as ranked by abundance--Transect A.

STATION	DOMINANT FAUNAL GROUP	ABUNDANCE #/M2	BIOMASS g/M2	CARBON gC/M2
CH5	AMPELISCIDAE	1644.0	9.186	0.625
	DIASTYLIDAE	632.0	1.002	0.074
	ISAEIDAE	514.0	0.808	0.055
	CIRRATULIDAE	160.0	0.398	0.027
	LEUCONIDAE	70.0	0.145	0.011
	SIGALIONIDAE	56.0	0.148	0.010
	MALDANIDAE	48.0	0.962	0.067
	COROPHIIDAE	44.0	0.052	0.003
	NUCULIDAE	32.0	5.454	0.213
	LYSIANASSIDAE	30.0	1.386	0.112
	OTHER	426.0	118.469	5.429
	TOTAL..............	3656.0	138.010	6.627
CH4	BALANIDAE	574.0	0.334	0.004
	FORAMINIFERA	224.0	0.005	0.000
	NEMATODA	134.0	0.009	0.000
	ISAEIDAE	74.0	0.106	0.007
	HOLOTHUROIDEA	54.0	287.298	6.892
	UROCHORDATA	46.0	50.502	0.707
	SYLLIDAE	38.0	0.083	0.006
	GAMMARIDAE	34.0	0.614	0.045
	LYSIANASSIDAE	32.0	3.692	0.299
	CIRRATULIDAE	32.0	0.524	0.036
	OTHER	350.0	113.823	5.655
	TOTAL..............	1592.0	456.990	13.651
CH3	LUMBRINERIDAE	142.0	0.470	0.044
	TELLINIDAE	86.0	61.802	2.163
	THYASIRIDAE	74.0	0.404	0.011
	NUCULIDAE	62.0	1.850	0.072
	LEUCONIDAE	44.0	0.190	0.014
	CNIDARIA	42.0	24.262	1.480
	MONTACUTIDAE	32.0	0.258	0.007
	CIRRATULIDAE	32.0	0.146	0.010
	NEPHTYIDAE	26.0	4.942	0.356
	CAPITELLIDAE	24.0	0.080	0.006
	OTHER	274.0	82.834	3.369
	TOTAL..............	838.0	177.238	7.532
CH11	CIRRATULIDAE	220.0	0.278	0.019
	AMPELISCIDAE	158.0	2.894	0.197
	DIASTYLIDAE	144.0	0.220	0.016
	PHOXOCEPHALIDAE	136.0	0.064	0.005
	AMPHARETIDAE	102.0	3.506	0.238
	NUCULIDAE	90.0	12.224	0.477
	LUMBRINERIDAE	84.0	0.438	0.041
	MALDANIDAE	72.0	0.789	0.055
	NEPHTYIDAE	72.0	1.870	0.135
	TRICHOBRANCHIDAE	62.0	0.990	0.068
	OTHER	782.0	106.043	2.318
	TOTAL..............	1922.0	129.316	3.569
CH12	LUMBRINERIDAE	124.0	0.880	0.082
	TELLINIDAE	110.0	103.532	3.624
	CIRRATULIDAE	104.0	0.480	0.033
	NUCULANIDAE	78.0	62.178	2.922
	NUCULIDAE	70.0	9.884	0.385
	NEPHTYIDAE	40.0	28.766	2.071
	LEUCONIDAE	28.0	0.125	0.009
	PECTINARIIDAE	26.0	9.854	0.443
	CAPITELLIDAE	22.0	0.138	0.010
	CNIDARIA	16.0	7.118	0.434
	OTHER	140.0	43.611	1.392
	TOTAL..............	758.0	266.566	11.406

Table IV. 3 Station transects of dominant faunal groups as ranked by abundance--Transect B.

STATION	DOMINANT FAUNAL GROUP	ABUNDANCE #/M2	BIOMASS g/M2	CARBON gC/M2
CH17	AMPELISCIDAE	2530.0	25.612	1.742
	PHOXOCEPHALIDAE	336.0	0.560	0.041
	DIASTYLIDAE	218.0	0.864	0.064
	MALDANIDAE	186.0	1.508	0.106
	ORBINIIDAE	178.0	0.496	0.030
	OWENIIDAE	156.0	0.482	0.033
	ASTARTIDAE	120.0	3.886	0.058
	OPHIURIDAE	108.0	14.632	0.205
	ISAEIDAE	98.0	0.063	0.004
	NUCULANIDAE	92.0	36.654	1.723
	OTHER	976.0	40.740	2.638
	TOTAL..............	4998.0	125.497	6.644
CH16	BALANIDAE	26134.0	10.794	0.119
	ISAEIDAE	654.0	0.691	0.047
	LEUCONIDAE	626.0	0.403	0.030
	AMPELISCIDAE	620.0	2.600	0.177
	OEDICEROTIDAE	330.0	0.316	0.023
	CAPITELLIDAE	326.0	0.150	0.010
	PHOXOCEPHALIDAE	298.0	0.318	0.024
	MALDANIDAE	280.0	17.872	1.251
	ORBINIIDAE	238.0	2.016	0.123
	NEMATODA	180.0	0.009	0.000
	OTHER	1890.0	576.499	14.188
	TOTAL..............	31576.0	611.668	15.992
CH14	LUMBRINERIDAE	86.0	8.436	0.785
	MALDANIDAE	72.0	24.560	1.719
	OPHIURIDAE	50.0	21.246	0.297
	NUCULIDAE	50.0	18.602	0.725
	AMPHARETIDAE	50.0	0.650	0.044
	PHOXOCEPHALIDAE	40.0	0.060	0.004
	AMPHIURIDAE	34.0	2.204	0.000
	SIPUNCULA	34.0	116.132	5.226
	CAPITELLIDAE	24.0	0.204	0.014
	MONTACUTIDAE	24.0	0.494	0.014
	OTHER	262.0	76.508	3.274
	TOTAL..............	726.0	269.096	12.103
CH24	NUCULIDAE	294.0	43.156	1.683
	GAMMARIDAE	118.0	0.604	0.045
	TELLINIDAE	108.0	31.010	1.085
	CAPITELLIDAE	84.0	0.672	0.046
	HOLOTHUROIDEA	82.0	5.670	0.000
	ORBINIIDAE	80.0	0.243	0.015
	STERNASPIDAE	58.0	18.308	0.751
	NUCULANIDAE	58.0	19.336	0.909
	LUMBRINERIDAE	46.0	14.726	1.370
	PHOXOCEPHALIDAE	36.0	0.027	0.002
	OTHER	306.0	40.735	1.710
	TOTAL..............	1270.0	174.487	7.615
CH25	NUCULIDAE	228.0	28.216	1.100
	TELLINIDAE	196.0	345.698	12.099
	LUMBRINERIDAE	120.0	1.450	0.135
	NEMATODA	70.0	0.016	0.000
	MONTACUTIDAE	56.0	0.530	0.015
	CAPITELLIDAE	42.0	0.102	0.007
	NUCULANIDAE	38.0	37.252	1.751
	LEUCONIDAE	26.0	0.140	0.010
	ORBINIIDAE	22.0	0.054	0.003
	GONIADIDAE	14.0	0.122	0.008
	OTHER	162.0	25.202	1.451
	TOTAL..............	974.0	438.782	16.581

Table IV.4 Station transects of dominant faunal groups as ranked by abundance--Transect C.

STATION	DOMINANT FAUNAL GROUP	ABUNDANCE #/M2	BIOMASS g/M2	CARBON gC/M2
CH18	ECHINOIDEA	174.0	74.740	0.598
	FORAMINIFERA	50.0	0.262	0.003
	SPIONIDAE	46.0	0.510	0.035
	SIGALIONIDAE	24.0	0.108	0.007
	HOLOTHUROIDEA	18.0	7.082	0.000
	OWENIIDAE	18.0	0.180	0.012
	OPHIURIDAE	18.0	1.910	0.027
	PECTINARIIDAE	16.0	2.460	0.111
	OPHELIIDAE	12.0	10.024	0.952
	ORBINIIDAE	12.0	0.442	0.027
	OTHER	74.0	38.942	1.432
	TOTAL..............	462.0	136.660	3.205
CH30	ORBINIIDAE	242.0	2.158	0.132
	THYASIRIDAE	132.0	0.576	0.016
	NUCULIDAE	68.0	3.042	0.119
	GONIADIDAE	52.0	0.080	0.006
	CAPITELLIDAE	50.0	0.032	0.002
	CIRRATULIDAE	34.0	0.050	0.003
	MALDANIDAE	30.0	4.689	0.328
	SIGALIONIDAE	26.0	0.050	0.003
	MAGELONIDAE	22.0	0.130	0.009
	NEMATODA	18.0	0.003	0.000
	OTHER	136.0	58.448	2.375
	TOTAL..............	810.0	69.258	2.993
CH28	AMPELISCIDAE	234.0	2.746	0.187
	CAPITELLIDAE	86.0	0.463	0.032
	PHOXOCEPHALIDAE	84.0	0.043	0.003
	MALDANIDAE	80.0	44.706	3.129
	NUCULIDAE	70.0	2.328	0.091
	CIRRATULIDAE	48.0	0.284	0.020
	OEDICEROTIDAE	46.0	0.035	0.003
	LEUCONIDAE	34.0	0.052	0.004
	ORBINIIDAE	28.0	0.206	0.013
	NEPHTYIDAE	28.0	10.636	0.766
	OTHER	256.0	83.833	3.901
	TOTAL..............	994.0	145.332	8.147
CH27	AMPELISCIDAE	258.0	1.644	0.112
	PHOXOCEPHALIDAE	68.0	0.050	0.004
	OEDICEROTIDAE	48.0	0.064	0.005
	NUCULANIDAE	46.0	0.964	0.045
	STERNASPIDAE	42.0	6.762	0.277
	NUCULIDAE	32.0	0.514	0.020
	ORBINIIDAE	26.0	0.092	0.006
	RETUSIDAE	24.0	0.218	0.014
	CIRRATULIDAE	24.0	0.206	0.014
	LYSIANASSIDAE	20.0	0.774	0.063
	OTHER	184.0	38.206	2.322
	TOTAL..............	772.0	49.494	2.881
CH26	NUCULIDAE	200.0	8.420	0.328
	NUCULANIDAE	112.0	8.636	0.406
	LYSIANASSIDAE	64.0	2.102	0.170
	TELLINIDAE	42.0	13.214	0.462
	PHOXOCEPHALIDAE	24.0	0.024	0.002
	AMPELISCIDAE	20.0	0.506	0.034
	RETUSIDAE	12.0	0.012	0.001
	LUMBRINERIDAE	10.0	0.480	0.045
	NEPHTYIDAE	10.0	9.414	0.678
	CIRRATULIDAE	8.0	0.116	0.008
	OTHER	62.0	130.678	4.877
	TOTAL..............	564.0	173.602	7.012
CH39	NUCULIDAE	644.0	36.326	1.417
	TELLINIDAE	72.0	6.900	0.242
	HOLOTHUROIDEA	54.0	1.910	0.000
	NUCULANIDAE	38.0	13.518	0.635
	ISAEIDAE	28.0	0.240	0.016
	NEPHTYIDAE	26.0	4.916	0.354
	PHOXOCEPHALIDAE	24.0	0.021	0.002
	STERNASPIDAE	22.0	1.950	0.080
	LUMBRINERIDAE	16.0	0.080	0.007
	HAUSTORIIDAE	14.0	0.216	0.021
	OTHER	124.0	44.617	1.837
	TOTAL..............	1062.0	110.694	4.611

Table IV.5 Station transects of dominant faunal groups as ranked by abundance--Transect D.

STATION	DOMINANT FAUNAL GROUP	ABUNDANCE #/M2	BIOMASS g/M2	CARBON gC/M2
CH33	BALANIDAE	4318.0	0.762	0.008
	NEMATODA	542.0	0.017	0.000
	SPIONIDAE	462.0	0.708	0.049
	ORBINIIDAE	168.0	0.664	0.041
	SYLLIDAE	146.0	0.224	0.015
	CAPITELLIDAE	142.0	0.037	0.003
	UROCHORDATA	116.0	147.316	2.062
	CIRRATULIDAE	114.0	0.066	0.005
	SIGALIONIDAE	94.0	0.050	0.003
	AMPHARETIDAE	90.0	0.687	0.047
	OTHER	796.0	17.535	0.980
	TOTAL	6988.0	168.066	3.213
CH34	BALANIDAE	414.0	0.157	0.002
	ORBINIIDAE	384.0	4.494	0.274
	NEMATODA	302.0	0.015	0.000
	CIRRATULIDAE	272.0	0.206	0.014
	CAPITELLIDAE	182.0	0.115	0.008
	AMPELISCIDAE	118.0	10.208	0.694
	NUCULIDAE	100.0	28.202	1.100
	ECHIURIDA	48.0	0.456	0.023
	THYASIRIDAE	42.0	0.218	0.006
	PHYLLODOCIDAE	26.0	0.055	0.005
	OTHER	408.0	87.002	4.738
	TOTAL	2296.0	131.128	6.865
CH35	CAPITELLIDAE	184.0	0.423	0.029
	STERNASPIDAE	178.0	11.998	0.492
	NUCULIDAE	154.0	47.082	1.836
	GAMMARIDAE	140.0	1.346	0.100
	ECHIURIDA	128.0	6.000	0.306
	CIRRATULIDAE	88.0	0.159	0.011
	ORBINIIDAE	68.0	0.250	0.015
	ISAEIDAE	60.0	0.108	0.007
	MALDANIDAE	48.0	9.098	0.637
	POLYNOIDAE	38.0	0.184	0.013
	OTHER	242.0	126.225	6.222
	TOTAL	1328.0	202.873	9.669
CH36	MALDANIDAE	338.0	24.762	1.733
	NUCULIDAE	162.0	34.258	1.336
	CAPITELLIDAE	118.0	0.203	0.014
	ORBINIIDAE	80.0	0.384	0.023
	ECHIURIDA	50.0	0.798	0.041
	PRIAPULIDA	42.0	0.336	0.015
	AMPELISCIDAE	26.0	0.182	0.012
	POLYNOIDAE	24.0	0.374	0.027
	LEUCONIDAE	18.0	0.034	0.003
	BALANIDAE	18.0	2.488	0.027
	OTHER	168.0	70.242	3.247
	TOTAL	1044.0	134.061	6.480
CH37	BALANIDAE	984.0	0.483	0.005
	FORAMINIFERA	218.0	0.002	0.000
	AMPELISCIDAE	190.0	0.990	0.067
	CAPITELLIDAE	182.0	0.963	0.066
	MALDANIDAE	116.0	45.668	3.197
	NUCULIDAE	104.0	2.674	0.104
	CIRRATULIDAE	94.0	0.174	0.012
	UROCHORDATA	78.0	11.986	0.168
	SIPUNCULA	74.0	65.446	2.945
	ORBINIIDAE	64.0	0.162	0.010
	OTHER	462.0	11.663	0.582
	TOTAL	2566.0	140.211	7.157
CH40	DIASTYLIDAE	190.0	0.130	0.010
	PHOXOCEPHALIDAE	158.0	0.108	0.008
	LEUCONIDAE	136.0	0.153	0.011
	CIRRATULIDAE	134.0	0.165	0.011
	ECHIURIDA	134.0	0.312	0.016
	MALDANIDAE	120.0	65.870	4.611
	CAPITELLIDAE	110.0	0.346	0.024
	AMPELISCIDAE	92.0	1.594	0.108
	NEMATODA	68.0	0.009	0.000
	POLYNOIDAE	68.0	2.118	0.155
	OTHER	804.0	194.532	6.542
	TOTAL	2014.0	265.337	11.496

Table IV.6 Station transects of dominant faunal groups as ranked by abundance--Transect E.

STATION	DOMINANT FAUNAL GROUP	ABUNDANCE #/M2	BIOMASS g/M2	CARBON gC/M2
CH43	BALANIDAE	2548.0	52.946	0.582
	FORAMINIFERA	554.0	0.018	0.000
	UROCHORDATA	366.0	23.880	0.334
	NEMATODA	110.0	0.006	0.000
	CIRRATULIDAE	96.0	0.453	0.031
	GAMMARIDAE	68.0	1.336	0.099
	ORBINIIDAE	38.0	2.104	0.128
	AMPHARETIDAE	22.0	0.130	0.009
	GONIADIDAE	14.0	0.160	0.011
	CAPITELLIDAE	14.0	0.031	0.002
	OTHER	108.0	13.505	0.855
	TOTAL...............	3938.0	94.569	2.052
CH44	ECHIURIDA	560.0	68.224	3.479
	THYASIRIDAE	314.0	1.026	0.029
	OWENIIDAE	240.0	0.314	0.022
	STERNASPIDAE	218.0	13.584	0.557
	NUCULIDAE	120.0	0.638	0.025
	NUCULANIDAE	84.0	8.795	0.413
	MALDANIDAE	76.0	4.830	0.338
	ORBINIIDAE	74.0	0.442	0.027
	TELLINIDAE	74.0	0.190	0.007
	CAPITELLIDAE	70.0	0.247	0.017
	OTHER	490.0	43.638	1.861
	TOTAL...............	2320.0	141.928	6.774
CH45	AMPELISCIDAE	194.0	1.732	0.118
	NUCULANIDAE	82.0	8.742	0.411
	LEUCONIDAE	68.0	0.148	0.011
	TELLINIDAE	60.0	0.054	0.002
	PHOXOCEPHALIDAE	44.0	0.022	0.002
	NUCULIDAE	40.0	0.090	0.004
	MALDANIDAE	38.0	1.838	0.129
	TROCHIDAE	34.0	0.656	0.041
	CIRRATULIDAE	30.0	0.176	0.012
	STERNASPIDAE	28.0	0.850	0.035
	OTHER	210.0	3.651	0.196
	TOTAL...............	828.0	17.959	0.959
CH47	MALDANIDAE	110.0	7.104	0.497
	AMPELISCIDAE	90.0	1.352	0.092
	LYSIANASSIDAE	56.0	2.094	0.170
	PHOXOCEPHALIDAE	54.0	0.040	0.003
	LEUCONIDAE	40.0	0.077	0.006
	NUCULIDAE	36.0	0.090	0.004
	CAPITELLIDAE	28.0	0.114	0.008
	CIRRATULIDAE	26.0	0.252	0.017
	STERNASPIDAE	18.0	3.448	0.141
	NUCULANIDAE	16.0	0.210	0.010
	OTHER	158.0	72.321	3.391
	TOTAL...............	632.0	87.102	4.338

ECOLOGICAL ASSESSMENT OF SUBLITTORAL PLANT COMMUNITIES IN THE NORTHERN GULF OF ALASKA

by

R. J. Rosenthal, D. C. Lees, and T. M. Rosenthal

Dames & Moore
510 L Street, Suite 310
Anchorage, Alaska 99501

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 78

September 1977

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

Table *Page*

LIST OF TABLES (Continued)

INTRODUCTION

This final report presents the results of our sublittoral baseline investigation, which was initiated in the summer of 1975 in conjunction with the National Marine Fisheries Service intertidal program for the northeastern Gulf of Alaska (NEGOA). Three rocky intertidal stations were selected by NMFS, Auke Bay Biological Laboratory, for inclusion in the NEGOA littoral program, namely: (1) Latouche Point, Latouche Island; (2) Macleod Harbor, Montague Island and (3) Zaikof Bay, Montague Island, in Hinchinbrook Entrance (Figure 1).

The National Marine Fisheries Service established intertidal baseline monitoring sites in each of the previously mentioned locations during 1974-75. The intended purpose of our participation in the program was to expand the biological data acquisition in each location into the shallow sublittoral zone adjacent to the shoreline.

The shallow rocky sublittoral zone in the north Gulf coast - Prince William Sound region is typically dominated by benthic marine plants, therefore the initial effort was directed at identifying the organisms found within these assemblages. The rocky sublittoral zone is defined as the hard or consolidated substratum which lies below MLLW (mean lower low water), or the 0.0' tide elevation on nautical charts. It is for the most part a continuation of the intertidal, for many of the organisms and life history patterns are common to and transcend both zones. Usually there is no distinct break in distributions, and a separation of the two zones is more of a sampling convenience than a reality.

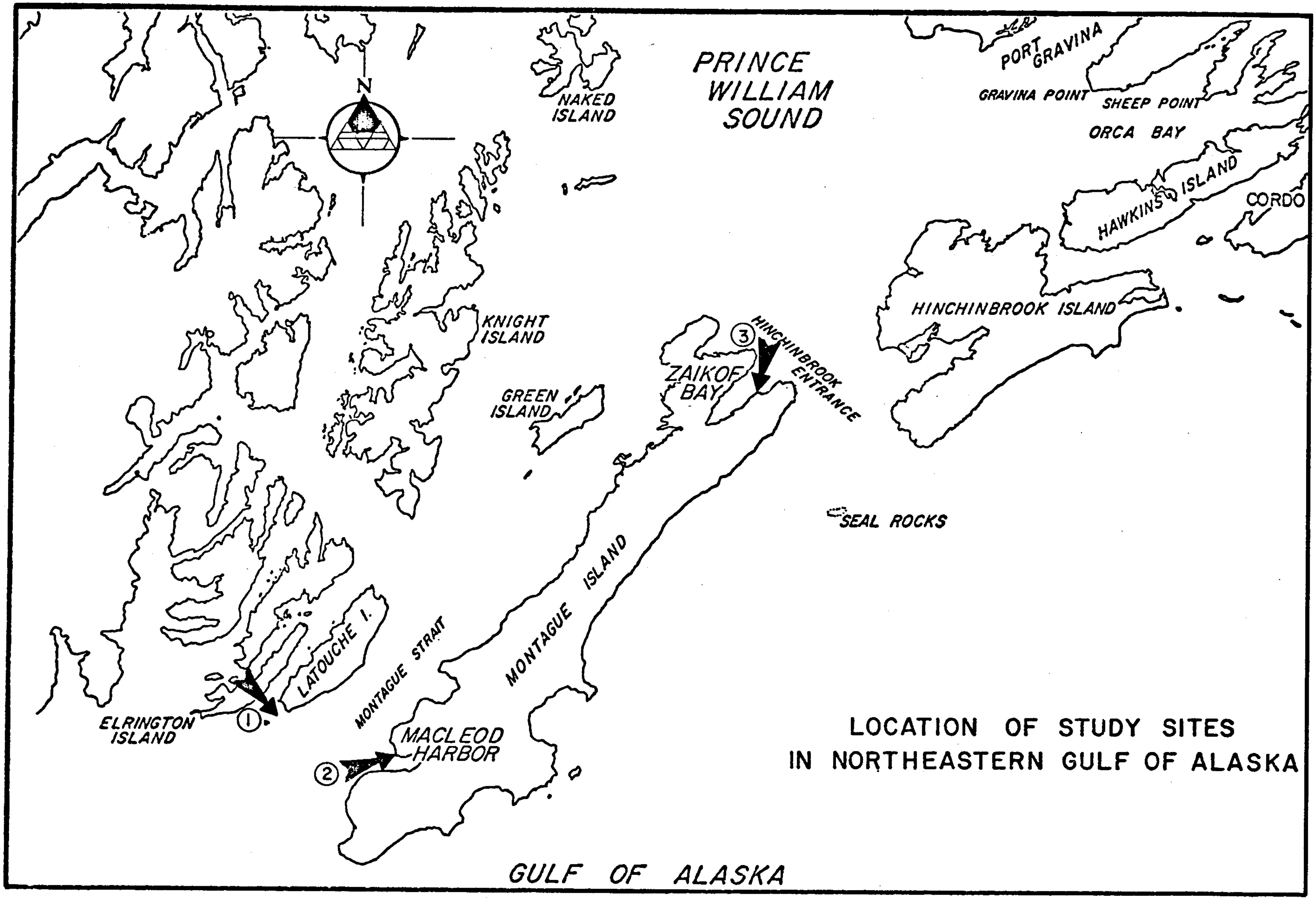

Figure 1. Location of study sites in northeastern Gulf of Alaska.

The solid substratum covers a wide range of geological facies, ranging from patches of gravel and cobbles to extensive reefs composed of exposed bedrock or pavement. Typically, the biota is attached to, or associated with the hard substrate. Because the populations inhabiting various substrata and microhabitat types are frequently different, they require different sampling and study regimes.

The present field study began on July 22, 1975, when diver-biologists associated with Dames & Moore made observations in Zaikof Bay. The nearshore stations were revisited subsequently in mid-September 1975, late November 1975, mid-March 1976 and late June 1976. These observations and sampling periods spanned five seasons from summer 1975 through early summer 1976. Each location was sampled at least three times, and one of the stations (Latouche Point) was visited on five separate occasions.

GENERAL STUDY OBJECTIVES

The purpose of this study was to provide an inventory of the biological resources and ecological composition of three rocky sublittoral sites in the northeastern Gulf of Alaska. This was accomplished by first making a reconnaissance survey of the study sites in order to make a qualitative assessment of the habitat types present. After this phase, more intensive sampling was conducted at each location.

During this baseline investigation, we attempted to provide a characterization of habitats, biotic assemblages and species composition that reflected seasonal or temporal differences. The intent was to examine the baseline parameters that would partially serve as a basis for assessment of impacts and provide the background data necessary for designing long-term monitoring studies.

METHODS

Most of the direct observations were made while scuba diving at depths from MLLW to about 30 meters below the sea surface. A total of 52 dives, representing approximately 119 man hours, were spent underwater during this phase of the project. Our normal procedure was to spend between 3 and 4 days working at each site. More casual observations dealing with usage of the inshore zone by birds and mammals were made either in route to, or while anchored on station. Movement to the OCS study sites and living accommodations while in the field were provided by the M.V. Humdinger, a 36' commercial troller that is equipped for diving and intertidal research.

Numerical information was gathered from specific locations in the subtidal zone. Except when collecting specimens, we tried not to disturb the organisms or their environment. All observations were made during daylight hours.

Because of the multitude of species present within the shallow subtidal zone, we chose to limit our sampling to the more conspicuous or characteristic species in the assemblage. Characteristic or representative important species are: (1) species of obvious numerical (biomass) importance, (2) species that are known to have important structural roles for furnishing habitat, (3) the competitive dominants or key predators which may be uncommon, but which are considered likely to have important functional roles in the maintenance of the community and (4) species of aesthetic or present-day commercial value.

Several types of quantitative data have been collected about the characteristic species present at each site. Included are estimates of density (number of specimens per meter^2), frequency (spatial distribution), and percent cover (primary and secondary space). Methods of estimating percent cover, or the amount of surface area occupied by a particular taxon or group varied. Usually this information was obtained from replicated 0.25m^2 quadrats. The quadrats were either placed in a haphazard (unbiased) manner, or stratified in such a way that a particular habitat or microhabitat was sampled in the sublittoral zone. The surface or floating seaweed canopies were estimated visually.

Random or haphazard transect bands of various dimensions were also used in each location to estimate density (abundance). The transects were usually run along a specific isobath or depth contour. However, due to physical heterogeneity, some changes in depth and substrate were frequently encountered.

Biomass estimates have been generated for selected species at the study sites as a first step toward estimating consumption rates, and to provide information on temporal variations in population structure at specific sites. Measurements of linear size (length, width, aperture width, etc.) and weight (wet or dry weight of soft tissue) have also been obtained.

In addition to the numerical information derived from the quadrats and transects, species-specific interactions or natural history phenomena involving feeding and reproduction were also recorded. These methods assisted in describing the conditions at each study site and permitted examination of the differences between seasons and locations.

THE MARINE PLANT COMMUNITY

From the high water mark or splash zone of the littoral zone down to a depth of about 30 meters below the sea surface, the rocky habitats in the northern Gulf of Alaska are visually dominated by marine vegetation. The macroscopic seaweeds and seagrasses (macrophytes) form a conspicuous belt along the seashore. However, this band is not continuous, and is occasionally broken or interrupted by conditions in the physical environment that are unfavorable or preclude plant colonization and growth. Some of the marine plants that occur either in shallow waters, or grow along the beachlines are visible at various stages of the tide. There are a few subtidal species that form floating canopies that periodically become visible to even the casual observer. However, most of the vegetative band is below the low tide level, and is therefore unseen by surface observers.

The terms community and assemblage are used freely and often times interchanged throughout this report. The question of whether a community is an organized unit (system), or simply a collection of species with similar biological requirements is unresolved at the present time. However, a definition we have been able to work with is simply "a community is a group of species which are often found living together" (Fager, 1963).

The rocky sublittoral waters generally contain the greatest number of seaweed species. Typically this habitat is dominated by the broad-leafed brown algae or kelps which display high standing crop. Frequently, the attached benthic plants form dense stands or beds that are comparable to a meadow or terrestrial forest. In some parts of the North Gulf Coast the vegetative belt is wide and extends approximately 5 to 6 kilometers from shore; in other locations where vertical relief is sharp, the width of the belt is less than a few hundred meters (Rosenthal, unpublished data). In most areas, significant development of algal assemblages is limited to the upper 25 meters of the water column.

Marine plant communities are highly productive systems (Dawson, 1966; Mann, 1973), which typically attract or contain numerous animals, many of the species are of commercial or high aesthetic value. Some of the associated species live year-round or complete their life cycle in these habitats, while others, such as the herring or king crab, have a more temporary or transitory occurrence.

Recent studies (review by Mann, 1973) have pointed out the important role of macrophytes in coastal productivity. For example, Mann (1972) estimated the primary production in the seaweed zone in St. Margaret's Bay, Nova Scotia averaged 1750 grams of carbon per square meter per year. This was about three times more than the total phyto-plankton production in the same bay. Additional studies by Westlake

(1963) indicate annual levels of production of seaweeds in northern latitudes between 1,000 to 2,000g $c/m^2/yr$. Since these figures apply only to a narrow zone adjacent to land, the estimates are even more important when evaluating the contribution of the seaweeds to the production of carbon in Prince William Sound, a marine ecosystem dominated by its lengthy, rocky shoreline and extensive macrophyte zone.

The floristic components of sublittoral algal assemblages in southern Alaska have received very little attention until the past decade. Recently, Rosenthal and Barilotti (1973), and Dayton (1975) provided descriptive information on kelp bed ecosystems off the west coast of Chichagof Island, Alexander Archipelago and Amchitka Island in the Aleutian Chain. Additional studies conducted by Rosenthal and Lees (in Dames & Moore, 1976a) in Kachemak Bay; Lees and Rosenthal (in Dames & Moore, 1977) on the Outer Kenai Peninsula, and Rosenthal (in Dames & Moore, 1976b) in northeastern Prince William Sound provide lists of species, vegetative profiles and estimates of density and percent cover for the characteristic seaweeds in these general locations.

Johansen (1971) made a relatively complete collection of the macroalgae from the Prince William Sound region. Thirty-three shoreline stations in the Sound were occupied approximately 15 months after the earthquake of March 27, 1964. However, all of the collections and observations were made in the intertidal zone, and no information was obtained from the shallow sublittoral waters adjacent to the shore.

In 1913, the U.S. Department of Agriculture conducted a survey of the kelp beds of Alaska (Cameron, 1915). This investigation was primarily designed to inventory the location, size, type and estimated yield of existing kelp beds in southern Alaska. The importance of this kind of information to present day research has been in providing historical records of the size and exact location of Alaskan kelp beds. Two of the locations in this present study, namely, Macleod Harbor and the southwest end of Latouche Island, are listed in the kelp bed inventory of western Alaska (Rigg, 1915).

RESULTS

DESCRIPTION OF THE STUDY SITE (LATOUCHE POINT)

Latouche Island is situated on the southwest edge of Prince William Sound. The primary site in this present study was off the extreme southwestern end of the island near a rocky promontory that we have appropriately named Latouche Point (Figure 1). The point is strategically situated between Latouche Passage on the north and Montague Strait to the south. Both waterways are major arteries connecting the Sound to the Gulf of Alaska. The entire island underwent dramatic land-level changes during the March 27, 1964 earthquake, resulting in the shoreline being uplifted approximately 10 feet (Plafker, 1969). The present-day shoreline is rocky and moderately wooded with spruce and hemlock. Salt grass (*Elymus*) is common above the high water mark.

The point is exposed to westerly ocean swells, and a great deal of drift accumulates along the beachline, especially during early fall and spring. Tidal currents are typically moderate to weak in the lee of the Point. However, further offshore or in Latouche passage where the water mass is not deflected by land, the tidal currents can exceed 2 nautical miles per hour.

The rocky bench that fringes the southwest end of the island projects at least 200 meters horizontally into the shallow sublittoral zone (Figure 2). These measurements were made directly seaward or southwest of the NMFS intertidal transect, from the intertidal-subtidal fringe to a point where the rock and unconsolidated sediments merge. An overall change in water depth from between 9 and 10 meters was recorded between these two ecotones. Surge channels cut through the rock bench and generally run in a perpendicular fashion with respect to the shoreline. Beyond the rockbench the seafloor becomes somewhat homogenous, and the bottom is composed mainly of coarse sands, gravel and shell debris. Ripple marks were prominent features of the unconsolidated substrate.

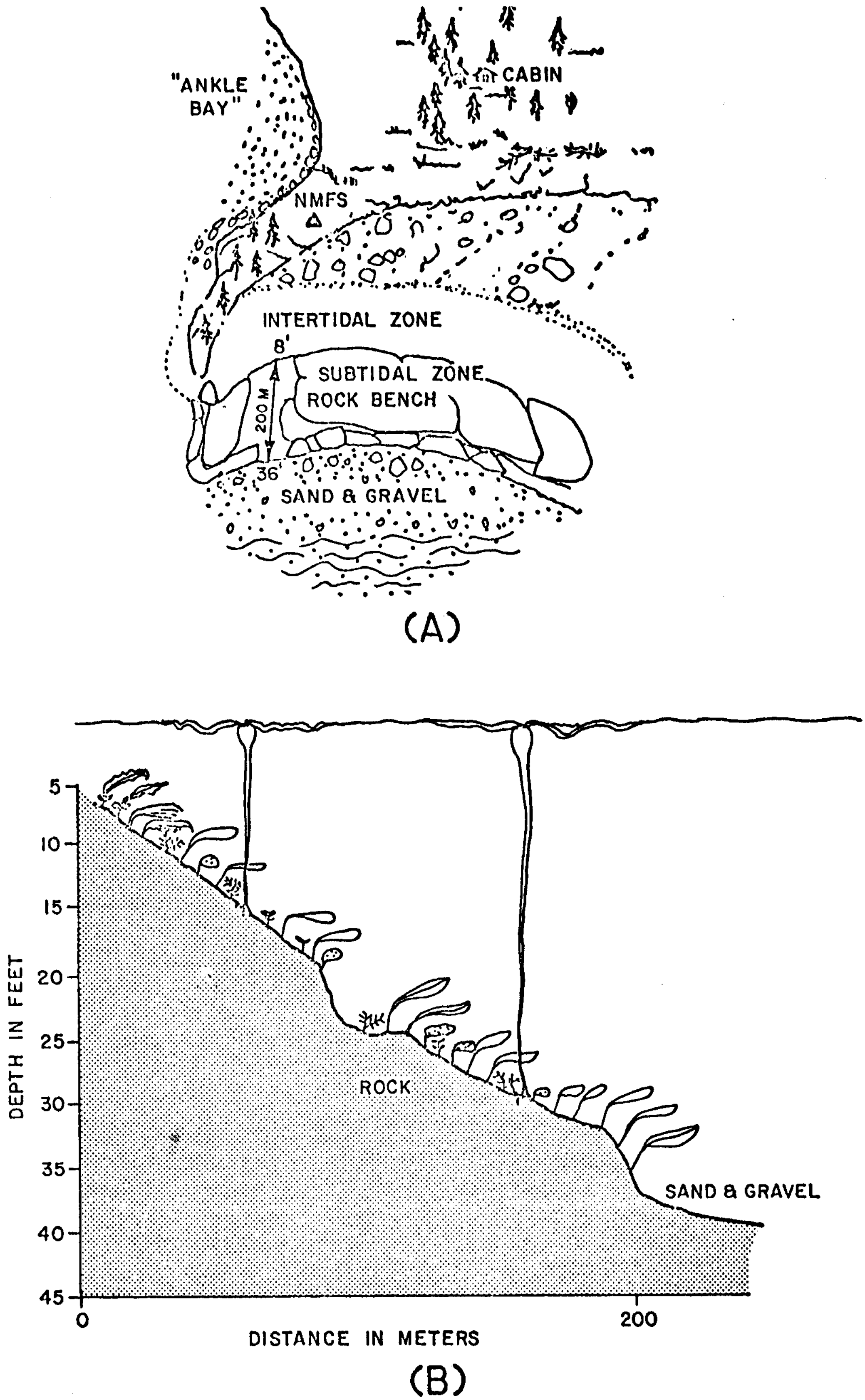

Figure 2. Study site (A) and subtidal vegetative canopies (B) at Latouche Point.

BIOLOGICAL SETTING (ALGAL ASSEMBLAGE)

Much of the subtidal study area off Latouche Point was covered by a heavy growth of macroalgae. During summer months a large bed of bull kelp (Nereocystis luetkeana) grew on the shoal area between Latouche Point and Danger Island. The floating portion of the kelp bed was highly visible at slack low tide. Most of the Nereocystis grew on either the rock pavement or boulders. Individual plants were found from the intertidal-subtidal fringe, out to depths in excess of 20 meters. The densest part of the bed was between the 3 and 15 meter depth contour. Densities ranging up to 1.40 individuals/m^2 were observed for mature bull kelp (Tables 1 and 2). The average density during all sample periods was 0.35 plants/m^2. Juvenile Nereocystis were present in the study area during spring and summer; juveniles peaked in the spring and early summer and adult plants peaked in summer and early fall.

The vegetative understory beneath this floating or surface canopy was multi-layered, or composed of a number of separate algal canopies. The second canopy level during summer was composed of the annual brown alga Cymathere triplicata. Typically, Cymathere grew on cobbles, gravel and shell debris. It was extremely common in early summer (1976), and densities during the June survey averaged 3.16 plants/m^2 (Table 2). The plants were highly aggregated with a maximum of 11.60/m^2 in the band transects. Some of these plants were 2 to 3 meters in length. The third canopy level was composed of Laminaria

TABLE 1

DENSITY ESTIMATES OF SOME DOMINANT MACROPHYTES AT LATOUCHE POINT
(estimates were derived from band transects of different lengths)

Taxon	9-17-75	9-17-75	11-26-75	11-26-75	11-26-75	11-27-75	3-18-76	3-18-76
Nereocystis luetkeana	3 $0.12/m^2$	0	0	0	1 $0.06/m^2$	14 $0.93/m^2$	0	0
Laminaria spp.	116 $4.64/m^2$	251 $10.04/m^2$	84(15)* $6.60/m^2$	74(61)* $5.60/m^2$	171(61)* $15.47/m^2$	Not counted	126 $12.6/m^2$	83 $8.30/m^2$
Agarum cribrosum	37 $1.48/m^2$	49 $1.96/m^2$	40 $2.67/m^2$	26 $1.73/m^2$	25 $1.67/m^2$	Not counted	14 $1.40/m^2$	4 $0.40/m^2$
Pleurophycus gardneri	7 $0.28/m^2$	7 $0.28/m^2$	0	0	2 $0.13/m^2$	Not counted	16 $1.60/m^2$	9 $0.90/m^2$
Constantinea spp.	Not counted	Not counted	16 $1.07/m^2$	24 $1.60/m^2$	10 $0.67/m^2$	Not counted	Not counted	Not counted
Opuntiella californica	Not counted	Not counted	8 $0.53/m^3$	16 $1.07/m^2$	34 $2.27/m^2$	Not counted	Not counted	Not counted
Ptilota filicina	Not counted	Not counted	17 $1.37/m^2$	6 $0.40/m^2$	31 $2.07/m^2$	Not counted	Not counted	Not counted
Area sampled:	25 x 1m	25 x 1m	15 x 1m	15 x 1m	15 x 1m	15 x 1m	10 x 1m	10 x 1m
Depth:	12m	12m	12m	14m	7m	7-8m	10m	8m
Substrate type:	Rock	Rock	Rock & Sand	Rock & Sand	Rock	Rock	Rock & Sand	Rock & Gravel

* Number in parenthesis indicates these plants had undergone blade renewal.

TABLE 2

DENSITY ESTIMATES OF SOME DOMINANT MACROPHYTES
AT LATOUCHE POINT

(Estimates Were Derived from Band Transects of Different Lengths)

Taxon	6-25-76	6-25-76	6-25-76	6-25-76	6-25-76	6-25-76	6-25-76	6-26-76	6-26-76	6-26-76	6-26-76	6-26-76
Nereocystis luetkeana	6 1.20/m^2	1 0.20/m^2	3 0.60/m^2	2 0.40/m^2	1 0.20/m^2	1 0.20/m^2	7 1.40/m^2	4 0.13/m^2	0	3 0.60/m^2	0	7 0.23/m^2
*Laminaria groenlandica**	27 5.40/m^2	21 4.20/m^2	48 9.60/m^2	0	0	0	0	Not counted	19* 3.80/m^2	20* 4.00/m^2	29* 5.80/m^2	Not counted
Laminaria yezoensis	11 2.20/m^2	13 2.60/m^2	19 3.80/m^2	28 5.60/m^2	1 0.20/m^2	0	0	Not counted	5 1.00/m^2	0	2 0.40/m^2	Not counted
Laminaria dentigera	-	-	-	22 4.40/m^2	37 7.40/m^2	44 8.80/m^2	32 6.40/m^2	Not counted	-	-	-	Not counted
Agarum cribrosum	10 2.00/m^2	4 0.80/m^2	1 0.20/m^2	5 1.00/m^2	1 0.20/m^2	0	0	Not counted	7 1.40/m^2	3 0.60/m^2	8 1.60/m^2	Not counted
Pleurophycus gardneri	1 0.20/m^2	0	0	2 0.40/m^2	5 1.00/m^2	24 4.80/m^2	30 6.00/m^2	Not counted	0	2 0.40/m^2	4 0.80/m^2	Not counted
Cymathere triplicata	1 0.20/m^2	7 1.40/m^2	8 1.60/m^2	10 2.00/m^2	53 10.60/m^2	0	0	Not counted	0	58 11.60/m^2	21 4.20/m^2	Not counted
Alaria sp.	1 0.20/m^2	3 0.60/m^2	3 0.60/m^2	0	0	4 0.80/m^2	13 2.60/m^2	Not counted	0	1 0.20/m^2	0	Not counted
Area sampled:	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	30x1 m	5x1 m	5x1 m	5x1 m	30x1 m
Depth:	15 m	13.5 m	13.5 m	6 m	5 m	3.5 m	3.5 m	9 m	9 m	9 m	9 m	9 m
Substrate type:	Sand, gravel & cobble	Gravel, cobble & rock	Gravel, sand & rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock

TABLE 3

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
SEPTEMBER 17, 1975

Taxon	No. 1	No. 2	No. 3
Laminaria spp.	50%(6)	70%	16%
Pleurophycus		20%	
Agarum			40%(1)
Constantinea	20%(7)		20%(4)
Ptilota	P		
Membranoptera	15%		
Foliose, reds, unid.		10%	1%
Encrusting coralline	50%	P	60%
Articulated coralline	5%		20%
Hildenbrandia sp.	2%	5%	
Synoicum	1%		
Musculus vernicosus	P		P
Acmaea mitra	(1)		
? *Scrupocellaria*			1%
Pagurids	(3)		(2)
Tonicella spp.			(1)
Chelyosoma sp.			(1)
Balanus nubilus			(1)
Depth (meters):	11.0	11.0	11.0
Substrate type:	Boulder & Gravel	Gravel	Boulder & Gravel

TABLE 4

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 26, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Agarum	0	0	40%(2)	0	0
Laminaria spp.	50%(2)(5)*	10%(2)*	5%(2)*	60%(2)	95%(5)(1)*
Ptilota	2%(1)	10%(1)	0	1%(1)	0
Encrusting coralline	80%	25%	90%	95%	40%
Constantinea	0	1%(1)	0	0	2%(2)
Articulated coralline	20%(8)	0	15%(9)	15%(6)	0
Opuntiella	5%(3)	0	5%(1)	0	5%(2)
Foliose reds, unid.	5%	5%	2%	0	0
Rhynchozoon	5%	1%	0	0	0
Styela	(1)	0	0	0	0
Yellow spatter sponge	3%	0	2%	0	0
Cancer oregonensis	0	(1)	0	0	0
Trichotropis	5%	0	0	0	0
Encrusting sponge	0	1%	2%	0	0
Synoicum	0	5%	2%	1%	0
Pagurids	(1)	0	0	0	0
Serpulidae	(2)	0	(1)	(1)	0
Syconid sponge	(1)	0	0	0	0
Tonicella	(1)	0	0	0	0
Orange globular sponge	0	0	1%	1%	0
White globular sponge	0	0	1%	0	0

Depth (meters): 7.0-8.0
Substrate type: rock bench

* Plants undergoing blade renewal

TABLE 5

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 26, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Agarum	30%(2)	25%(2)	30%(1)	20%(1)
Laminaria spp.	40%(7)	20%(2)	30%(2)	15%(1)
Ptilota	2%(1)	1%(1)	15%(1)	0
Encrusting coralline	45%	60%	80%	95%
Constantinea	8%(2)	0	0	5%(1)
Articulated coralline	5%(3)	30%(10)	40%(13)	15%(7)
Opuntiella	0	5%(1)	5%(1)	0
Foliose reds, unid.	5%	2%	0	0
Musculus vernicosus	(2)	(1)	(1)	0
Microporina	1%	5%	5%	0
Synoicum	1%	2%	5%	1%
Pagurids	(7)	(4)	(7)	(3)
Cryptolithodes	0	(1)	0	0
Abietinaria	0	0	1%(1)	0
Lichenopora	0	0	1%	1%
Tricellaria	0	0	2%	1%
Orange globular sponge	(1)	0	0	0
Tonicella	0	0	0	(1)
Encrusting sponge	0	0	(1)	0

Depth (meters): 10.0
Substrate type: Rock bench

TABLE 6

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 26, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Agarum	15%	50%(2)	60%(4)	15%(2)
Laminaria spp.	10%(3)	70%(2)	25%(1)	40%(2)
Ptilota	20%(4)	4%(2)	25%(1)	5%(1)
Encrusting coralline	90%	65%	50%	50%
Constantinea	0	2%(3)	0	0
Articulated coralline	10%(5)	25%(8)	2%(4)	15%(8)
Opuntiella	0	0	2%(1)	0
Hildenbrandia	0	0	1%	0
Membranoptera	0	0	0	2%
Foliose reds, unid.	0	2%	1%	0
Musculus vernicosus	0	(3)	(7)	0
Synoicum	1%	1%	0	0
Rhynchozoon	1%	1%	0	0
Tricellaria	2%	2%	3%	5%
Fusitriton	(1)	0	0	0
Strongylocentrotus	0	(1)	0	0
Orthasterias	0	0	0	(1)
Boltenia	0	0	0	(1)
Microporina	0	0	0	1%
Dendrobeania	0	2%	0	4%
Amphissa	0	0	0	(3)
Pagurids	(2)	(2)	(2)	(4)
Yellow spatter sponge	0	0	0	2%

Depth (meters): 12.0
Substrate type: Rock bench

TABLE 7

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 26, 1975

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Agarum	15%	0	10%(1)	0
Laminaria yezoensis	40%(2)	5%	30%(2)	0
Laminaria spp.	40%(2)	0	30%(3)*	40%(3)(3)*
Bossiella	8%(4)	0	0	0
Corallina	5%(4)	5%(1)	1%(1)	8%(5)
Ptilota	1%(1)	1%(1)	1%(1)	1%(1)
Constantinea	2%(1)	0	0	0
Foliose reds, unid.	0	2%	2%	3%
Encrusting coralline	80%	80%	75%	90%
Hildenbrandia	0	0	10%	0
Microporina	40%	10%	30%	30%
Syconid sponge	0	0	0	(1)
Musculus vernicosus	(8)	0	0	(8)
Triopha carpenteri	0	(1)	0	0
Serpulidae	0	0	(1)	0
Synoicum	1%	1%	1%	0
Tricellaria	1%	1%	1%	0
Dendrobeania	0	0	1%	1%
Pagurids	0	(3)	0	(1)
Heteropora	0	0	0	1%
Diodora	0	0	(1)	0
Calliostoma	0	0	0	(1)
Yellow spatter sponge	0	0	2%	1%

Depth (meters): 12.0-14.9
Substrate type: Rock bench

* Plants undergoing blade renewal

TABLE 8

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 27, 1975

Taxon	Percent Cover (number of individuals)				
	No. 1	No. 2	No. 3	No. 4	No. 5
Agarum	40%(3)	25%(0)	0	25%(1)	15%
Laminaria yezoensis	0	0	0	20%(1)	30%(2)
Laminaria spp.	10%	40%(3)(1)*	40%(4)	20%	30%(3)(2)*
Laminaria (holdfast)	30%	35%	40%	40%	40%
Hildenbrandia	30%	10%	2%	10%	5%
Bossiella	10%(4)	5%(2)	0	2%(1)	1%(1)
Corallina	0	2%(1)	0	0	15%(4)
Foliose reds, unid.	2%	1%	2%	6%	2%
Ptilota	0	0	0	2%	0
Rhodymenia spp.	0	0	0	0	1%(2)
Microporina	5%	5%	3%	35%	40%
Yellow spatter sponge	3%	0	0	3%	1%
White globular sponge	0	0	0	(1)	0
Dendrobeania	0	0	1%	1%	2%
Rhynchozoon	5%	0	0	0	0
Eudendrium	1%(3)	1%(1)	1%(3)	0	0
Synoicum	1%	0	2%	2%	1%
Serpulidae	0	0	0	(1)	0
Syconid sponge	0	0	0	0	1%
Acmaea mitra	(1)	0	0	0	0
Lichenopora	0	0	1%(2)	2%(1)	0

TABLE 8 (Cont.)

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 27, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Abietinaria	2%(1)	1%(1)	0	1%(1)	2%(2)
Chiton (unid.)	0	(1)	0	0	0
Gravel	25%	50%	80%	25%	20%
Tricellaria	1%	0	0	3%	5%
Balanus ? *alaskensis*	(1)	0	0	0	0
Musculus vericosus	(1)	0	0	0	(10)
Crossaster	0	0	(1)	0	0
Fusitriton	0	0	(1)	0	0
Trichotropis	0	0	0	(1)	0
Pagurids	0	0	0	0	(1)
Heteropora	0	0	0	(1)	0
Styela	0	0	0	0	(1)
White spatter sponge	0	0	0	1%	0

Depth (meters): 10-12m
Substrate type: boulders, gravel and rock pavement

* Plants undergoing blade renewal

TABLE 9

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
NOVEMBER 27, 1975

Taxon		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
Laminaria groenlandica		(2)	(2)		(1)			(3)		(1)		(2)	(1)	(1)	
Laminaria spp.				(2)		(2)			(4)		(1)			(1)	
Agarum cribrosum	(2)	(2)	(2)	(1)				(2)		(1)	(1)	(2)	(4)		
Opuntiella	P			P				P		P			P		
Constantinea			P	P				P			P	P			
Ralfsia								10%							
Ptilota		P	P					P		10%		P			5%
Odonthalia						5%									
Foliose red, unid.							10%		P						
Encrusting coralline	60%	70%	50%					75%					50%		
Articulated coralline				7%				2%				15%	4%		
Hildenbrandia				25%				15%		20%			40%	20%	
Styela													(1)		
Henricia		(2)						(1)					(2)		
Tonicella			(2)												
Trophonopsis			(1)												
Microporina		20%													
Fusitriton															(1)
Depth (meters):		11.5	11.5	11.5	12.0	12.5	12.5	12.0	12.5	12.5	12.5	12.5	12.0	12.5	12.5
Substrate type:		Rock pave-ment	Rock pave-ment	Rock	Rock	Gravel	Gravel	Rock	Gravel	Sand-rock	Sand-rock	Rock-gravel	Rock	Rock	Sand-rock

TABLE 10

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
March 16, 1976

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Laminaria yezoensis	50%(1)**	40%**	20%**	50%**
Laminaria groenlandica	0	(2)	(1)	(3)
Laminaria (juveniles)	(3)	0	(10)	0
Agarum	20%(2)	25%(2)	25%	25%(2)
Pleurophycus	0	0	20%(1)	10%(1)
Encrusting coralline	80%	80%	95%	90%
Ptilota	0	20%(1)	10%(1)	0
Constantinea	0	15%(3)	2%(1)	0
Rhodymenia	6%	5%	0	2%
Corallina	4%	20%	20%	25%
Bossiella	2%	2%	5%	0
Hildenbrandia	0	2%	0	2%
Ralfsia	0	5%	0	0
Microporina	5%	10%	0	0
Lichenopora	2%	0	0	0
Distaplia	2%	0	0	0
Synoicum	1%	10%	2%	2%
Gray colonial ascidian	1%	2%	1%	0
Orange encrusting sponge	1%	1%	0	0
Tricellaria	0	0	0	1%

TABLE 10 (Cont.)

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
MARCH 16, 1976

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Eudendrium	0	0	0	1%
Amphissa	0	(1)	(1)	0
Velutina sp.	0	(1)	0	(1)
Acmaea mitra	0	0	(2)	0
? Rhynchozoon	0	0	0	1%
Pagurids	0	(4)	(1)	(1)
Henricia spp.	0	(1)	0	0
Ophiopholis	0	0	present	0

Depth (meters): 9.0
Substrate type: Rock pavement and boulders

* Total Laminaria cover in quadrat

TABLE 11

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
MARCH 16, 1977

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Laminaria groenlandica		(3)	(2)	(3)	(1)	(1)	(2)	(1)				(3)
Laminaria yezoensis				(1)	(1)	(3)						(2)
Laminaria spp.			(3)	(2)		(1)	(6)					(3)
Agarum cribrosum						(2)	(1)		(1)		(1)	
Pleurophycus gardneri		(1)						(4)				
Ralfsia spp.		5%		5%							5%	
Rhodymenia		10%				15%	5%	2%	10%		5%	5%
Delesseria		10%				10%	10%	15%	2%	5%		
Callophyllis								10%				
Constantinea		10%	10%	10%	10%	2%				5%	10%	
Membranoptera		10%								20%		
Ptilota		5%		5%		5%	20%	10%		10%	5%	5%
Filamentous brown			10%									
Opuntiella					2%							
Monostroma											2%	
Articulated coralline		5%		3%			15%		10%		2%	
Encrusting coralline		50%	20%	60%		70%	85%	70%	20%	25%	25%	50%
Calliostoma		(1)				(1)						(1)
Acmaea mitra			(1)							(1)		(1)
Tonicella												(1)
Depth (meters):	10.0	10.0	10.0	10.0	10.0	10.0	9.0	9.0	9.0	9.0	9.0	9.0
Substrate type:	Gravel	Rock-Gravel	Rock-Gravel	Rock	Gravel	Gravel-Sand	Rock	Rock	Rock	Rock-Gravel	Rock-Sand	Rock

TABLE 12

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
MARCH 17, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Laminaria yezoensis	50%(1)**	80%(8)**	35%**	20%(1)**
Laminaria groenlandica	(1)	0	(3)	0
Laminaria (juveniles)	0	(2)	0	0
Pleurophycus	0	0	25%(3)	20%
Encrusting coralline	40%	50%	30%	50%
Ptilota	1%	2%	5%	2%
Constantinea	5%(1)	0	2%(1)	0
Rhodymenia	0	0	0	5%
Corallina	15%	15%	8%	15%
Bossiella	1%	4%	0	0
Ralfsia	2	0	10%	0
Opuntiella	20%	0	0	12%
Delesseria	1%	0	1%	5%
Microporina	5%	2%	2%	1%
Lichenopora	0	1%	1%	0
Synoicum	5%	2%	15%	10%
Gray colonial ascidian	15%	2%	10%	2%
Orange encrusting sponge	2%	0	0	1%
Tricellaria	0	0	0	1%
Orange colonial ascidian	0	0	0	1%
Green colonial ascidian	0	2%	2%	0
Velutina	0	0	0	(1)

TABLE 12 (Cont.)

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
MARCH 17, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Serpulidae	0	(1)	(5)	0
Pagurids	0	0	(2)	(5)
Henricia	0	0	(1)	0
Ophiopholis	0	present	present	present
Yellow globose sponge	0	0	0	1%
Lacuna	0	present	present	0
Styela	0	0	(2)	0
Searlesia	0	0	0	(1)
Margarites	0	0	0	(1)
Trophon	0	0	(2)	0
Placiphorella	(1)	0	0	0
Cancer oregonensis	0	(1)	0	0
Oregonia	0	0	0	(1)

Depth (meters): 8.0-9.0
Substrate type: Rock pavement and boulders

** Total *Laminaria* cover in quadrat

TABLE 13

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
MARCH 17, 1976

Taxon	Percent Cover (number of individuals)		
	No. 1	No. 2	No. 3
Laminaria yezoensis	40%(2)*	50%(2)	60%
Laminaria groenlandica	(1)	(1)	0
Laminaria (juveniles)	(3)	(2)	(13)
Pleurophycus	10%(2)	20%(1)	0
Encrusting coralline	40%	70%	50%
Ptilota	2%	10%	0
Constantinea	0	0	2%
Rhodymenia	2%	5%	0
Corallina	2%	15%	4%
Bossiella	0	0	3%
Hildenbrandia	2%	0	0
Opuntiella	10%	20%	5%
Delesseria	2%	2%	0
Microporina	15%	0	4%
Lichenopora	1%	1%	1%
Synoicum	6%	8%	6%
Gray colonial ascidian	15%	8%	30%
Orange encrusting sponge	1%	1%	2%
Abietinaria	0	0	2%
Green colonial ascidian	0	4%	1%
Tonicella	0	(2)	(2)

TABLE 13 (Cont.)

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
MARCH 17, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Pagurids	(2)	(12)	(6)
? *Rhynchozoon*	0	0	1%
Searlesia	(1)	0	0
Heteropora	1%	0	0
Trophon	0	0	(1)
Entodesma	(1)	0	0

Depth (meters): 7.0-8.0
Substrate type: Rock pavement and boulders

* Total *Laminaria* cover in quadrat

TABLE 14

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
MARCH 18, 1976

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Laminaria yezoensis	70%**	50%**	75%(1)**	60%(1)**
Laminaria groenlandica	(2)	(0)	(5)	(2)
Laminaria (juvenile)	0	(2)	0	0
Pleurophycus	0	25%(1)	0	30%(2)
Agarum	0	25%(1)	10%(2)	0
Encrusting coralline	60%	50%	80%	45%
Ptilota	25%	0	5%	20%
Constantinea	30%	0	0	8%
Rhodymenia	0	0	0	2%
Corallina	40%	20%	25%	8%
Bossiella	10%	5%	0	2%
Opuntiella	0	5%	5%	0
Delesseria	0	8%	1%	1%
Membranoptera	0	0	0	2%
Lichenopora	0	1%	1%	1%
Synoicum	2%	0	5%	5%
Distaplia	10%	5%	2%	0
Orange encrusting sponge	3%	0	0	1%
Tricellaria	0	1%	1%	1%
Didemnum or Trididemnum	1%	3%	0	0
Chelyosoma productum	0	0	1%(1)	0

TABLE 14 (Cont.)

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
MARCH 18, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Lacuna	0	0	0	0
Acmaea mitra	0	(2)	(2)	(1)
Searlesia	(1)	(1)	0	0
Tonicella	0	(3)	(1)	0
Serpulidae	0	0	0	0
Ophiopholis	0	0	0	0
Pagurids	0	(4)	(2)	(2)
Margarites	0	(2)	0	0

Depth (meters): 6.0-10.0
Substrate type: Rock bench and boulders

** Total *Laminaria* cover in quadrat

TABLE 15

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
MARCH 18, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Laminaria yezoensis	25%(1)**	40%(1)**	60%**	5%**
Laminaria groenlandica	0	(1)	(1)	0
Laminaria (juvenile)	0	0	(8)	(4)
Pleurophycus	0	10%(2)	0	15%
Agarum	10%	0	0	0
Encrusting coralline	40%	60%	50%	70%
Ptilota	40%	15%	20%	15%
Constantinea	16%(2)	0	0	5%
Corallina	40%	30%	40%	40%
Bossiella	1%	0	0	1%
Hildenbrandia	1%	0	0	0
Ralfsia	0	5%	0	0
Delesseria	0	0	0	1%
Alaria sp.	0	15%	0	20%(1)
Lichenopora	0	1%	0	0
Synoicum	20%	5%	5%	1%
Distaplia	5%	5%	0	0
Orange encrusting sponge	2%	1%	0	8%
Tricellaria	1%	0	1%	0
? *Leucosolenia*	0	0	1%	0

TABLE 15 (Cont.)

QUADRAT DATA (0.25m^2) FROM LATOUCHE POINT, SUBTIDAL
March 18, 1976

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Yellow encrusting sponge	0	0	2%	0
Acmaea mitra	(1)	0	0	(3)
Searlesia	0	0	0	(2)
Tonicella	0	0	0	(2)
Serpulidae	0	0	0	present

Depth (meters): 5.0-6.0
Substrate type: Rock bench

** Total *Laminaria* cover in quadrat

TABLE 16

QUADRAT DATA ($0.25m^2$) FROM LATOUCHE POINT, SUBTIDAL
JUNE 25 and 26, 1976

Percent Cover (Number of Individuals)

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16
Laminaria yezoensis	5%(1)	5%(1)				5%(1)		65%(4)		40%(3)	75%(2)					10%(1)
Laminaria groenlandica/ dentigera	0	60%	5%(1)		60%(4)	40%(3)	90%(7)								10%	40%(1)
Laminaria saccharina	0			50%(1)												
Laminaria spp.	5%(10)	2%(3)			2%(2)	5%(10)		8%(5)	2%(3)		10%(2)		30%(20)	2%(5)		
Pleurophycus	30%(3)					25%(2)	10%(1)			10%(1)						
Agarum	20%(3)	25%		5%	25%(1)					2%(1)	10%				15%	
Cymathere			50%	15%				25%(4)			15%					
Alaria sp.													5%(1)			
Nereocystis													15%(2)			
Opuntiella	10%					10%	15%									
Rhodymenia		5%							15%		8%		10%			8%
Constantinea	10%(3)									10%	15%				10%	15%
Microcladia	5%								2%							
Ptilota	5%			2%	5%	10%	20%			10%	2%			2%		15%
Pterosiphonia			5%		2%		5%									
Membranoptera				5%						10%	5%					
foliose reds, unid.		5%	10%	20%				5%	5%		5%		15%	10%		
Delesseria					2%	5%	2%			15%						
Callophyllis							5%			15%					15%	15%
filamentous reds, unid.							15%			5%						
encrusting coralline	60%	10%			50%	70%	80%	15%		60%	25%	2%	20%	5%		40%
articulated coralline	10%				5%	5%	2%									20%
Ralfsia sp.	2%					2%				2%						2%
Odonthalia kamtschatica													15%			
Bossiella sp.	15%					2%				10%	10%					
Hildenbrandia sp.	15%															
Desmarestia viridis									2%	5%						
Microporina					60%	2%	8%									2%
Heteropora	5%					2%				2%						
Distaplia					30%	15%	10%			5%						5%
Synoicum	2%				5%	15%	30%								5%	
Dendrobeania murrayi	2%															
Musculus vernicosus	P	P	P	P	P	P	P	P	P	P			P	P	P	P
Musculus discors																(1)
Calliostoma						(5)				P						
Searlesia						(1)	(1)									
Acmaea mitra										(1)			P			
Crossaster										(1)	(1)				(1)	
Henricia																(1)
? Leptasterias sp.										(1)						
pagurids							(1)							(1)		
Strongylocentrotus spp.		(1)														(1)
Trichotropis sp.							(1)									
Olivella														(1)		
Tonicella spp.	(1)					(1)	(1)			(2)						(2)
Pycnopodia												(1)				
Depth (meters):	14.5	14.5	12.0	12.0	10.5	5.5	5.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	10.5	10.5
Substrate type:	Rock & gravel	Gravel	Sand, shell and gravel	Sand, shell and gravel	Rock	Rock	Rock	Gravel and shell	Gravel and shell	Gravel and rock	Gravel and rock	Gravel	Gravel and rock	Gravel	Rock & gravel	Rock & gravel

generally lies prostrate on the substratum. Density estimates ranged from 0-2.67/m^2 in the transect bands, however densities up to 16.00/m^2 were recorded for Agarum in the quadrats.

Beneath the brown algal undergrowth was another layer of foliose and peltate reds, comprised of Constantinea spp., Opuntiella californica, Ptilota filicina, ? Schizymenia epiphytica and ? Kallymenia oblongifructa. Other ephemeral seaweeds in this red algal guild were Rhodymenia spp.; Delesseria decipiens; Odonthalia kamtschatica; Callophyllis spp.; Membranoptera sp. and Pterosiphonia bipinnata. Crustose and articulated corallines such as Lithothamnion, Bossiella and Corallina, and encrusting layers of Hildenbrandia and Ralfsia formed the final vegetative veneer on the rock substrate.

During summer months the hair-like brown algae Desmarestia aculeata and D. viridis, and a ligulate member of this group, Desmarestia ligulata var. ligulata were scattered around the study area. Typically this genus was found on cobbles, shells and gravel. Both Desmarestia aculeata and D. viridis are perennials, while D. ligulata is reputed to be an annual (Chapman, 1972).

To date, a total of 54 species of macroalgae have been identified from the shallow sublittoral zone off Latouche Point (Table 17). Of these, more are undoubtedly present in this location, however only the more conspicuous species were collected or included in the species inventory. The coralline algae still need to be properly identified since they are such a difficult group taxonomically.

TABLE 17

LIST OF MACROALGAE COLLECTED AT OCS STUDY SITES
IN THE NORTHEASTERN GULF OF ALASKA

	Latouche Point	Macleod Harbor	Zaikof Bay
CHLOROPHYTA (greens)			
Codium fragile	X		
Enteromorpha ? linza		X	X
Enteromorpha intestinalis			X
Halicystis ovalis	X		
Monostroma ? fuscum	X	X	X
Monostroma sp.	X	X	X
Spongomorpha sp.		X	
Ulva spp.		X	X
PHAEOPHYTA (browns)			
Agarum cribrosum	X	X	X
Alaria fistulosa	X drift		
Alaria ? pylaii	X	X	X
Alaria ? marginata		X	
Chordaria flagelliformis		X	
Costaria costata	X	X	X
Cymathere triplicata	X	X	X
Desmarestia aculeata	X	X	
Desmarestia ligulata var. ligulata	X	X	X
Desmarestia viridis	X	X	X
Fucus distichus	X	X	X
Laminaria groenlandica	X	X	X
Laminaria saccharina	X	X	X
Laminaria dentigera	X		
Laminaria yezoensis	X	X	X
Melanosiphon intestinalis		X	X
Nereocystis luetkeana	X	X	X
Pleurophycus gardneri	X	X	X
Pylaiella ? littoralis		X	X
Ralfsia fungiformis	X	X	X
Ralfsia pacifica	X	X	X
Scytosiphon lomentaria			X
Sphacelaria sp.		X	
RHODOPHYTA (reds)			
Antithamnion sp.			X
Bossiella orbigniana	X	X	X
Bosiella sp.	X	X	
Callophyllis edentata	X	X	X
Callophyllis flabellulata	X	X	X
Callophyllis cristata		X	
Callophyllis ? crenulata	X	X	X
? Clathromorphum circumscriptum	X		
Constantinea simplex	X	X	X
Constantinea subulifera	X	X	X

TABLE 17 (Cont.)

LIST OF MACROALGAE COLLECTED AT OCS STUDY SITES
IN THE NORTHEASTERN GULF OF ALASKA

	Latouche Point	Macleod Harbor	Zaikof Bay
Corallina frondescens	X	X	X
Corallina vancouveriensis	X	X	X
Cryptopleura sp.	X		
? *Cryptonemia* sp.	X		
Delesseria decipiens	X	X	
Erythrophyllum delesserioides		X	
Gigartina spp.	X	X	X
Halosaccion glandiforme	X	X	X
Hildenbrandia ? *occidentalis*	X	X	X
Iridea sp.			
? *Kallymenia oblongifructa*	X	X	X
Lithothamnion sp.	X	X	X
Lithothrix aspergillum	X		X
Membranoptera dimorpha	X	X	X
Membranoptera ? *multiramosa*	X		
Microcladia borealis	X	X	X
Odonthalia floccosa		X	X
Odonthalia kamtschatica	X	X	X
Opuntiella californica	X	X	X
Phycodrys sp.	X	X	X
Platythamnion sp.			X
? *Peyssonelia pacifica*	X	X	
Polyneura latissima	X		
Polysiphonia pacifica			X
Polysiphonia sp.	X	X	X
Porphyra spp.	X	X	X
Pterosiphonia bipinnata			X
Ptilota filicina	X	X	X
Ptilota tenuis	X	X	
Rhodoglossum affine		X	
Rhodymenia palmata	X	X	X
Rhodymenia pertusae	X	X	X
Schizymenia spp.	X	X	X
Stenogramme interrupta			X

No. taxa or species = 75

EPIFAUNA AND TROPHIC INTERACTION

Within the three study areas about 211 different taxa of macroinvertebrates (Table 18), and 30 species of inshore fishes (Table 19) were either identified or categorized for future taxonomic verification. Of all groups seen in the seaweed zone, the mollusks were represented by the greatest number of species, and accounted for 36 percent (n=76) of the total macroinvertebrate inventory. Despite this expression of diversity, the molluscan members of the seaweed community appeared to be only a moderate component of the overall biomass. Based on the information obtained from the quadrats ($0.25 m^2$), the attached or sessile fauna such as sea anemones, hydroids, sponges, bryozoans and ascidians were dominants in terms of percent cover and biomass.

The seaweed canopy at Latouche Point provided both food and cover for the animal components of the nearshore system; it also served as living substrate for other plants and animals. For example, some serpulid worms such as Spirorbis spp. and encrusting bryozoans spend the entire life cycle following the initial settling stage attached to seaweeds. Other species such as a tiny mussel Musculus vernicosus covered extensive portions of the shallow sublittoral zone during the summers of 1974, 1975 and 1976. Musculus was most often attached to living marine plants, however it was also found on sedentary animals and solid inorganic substrate. Many of the seaweeds off Latouche Point were almost entirely covered by M. vernicosus, which typically attaches with the foot and byssal threads. It occurred in 26 of 86 quadrats, for

TABLE 18

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

	Latouche Point	Macleod Harbor	Zaikof Bay
Porifera (sponges)			
Cliona celata	X	X	X
Halichondria ? panicea		X	X
Esperiopsis spp.	X		
Suberites fiscus		X	X
? Mycale adhaerens		X	X
White globose, unid.	X		X
Yellow spatter, unid.	X	X	X
Red globose, unid.	X	X	
Cnidaria			
Abietinaria spp.			
Sertularella turgita		X	
Anthopleura xanthogrammica	X		
Cribinopsis ? assimilis	X	X	X
Peachia ? parasitica	X		
Telia crassicornis	X	X	X
Tealia spp.	X	X	X
Ptilosarcus gurneyi		X	X
? Stomphia sp.	X		
Metridium senile	X	X	X
Campanularia verticellata	X		X
Hydractinia sp.	X		X
Obelia sp.			X
Grammaria sp.			X
Eudendrium sp.	X		
Gersemia rubiformis	X		
Lafoea sp.		X	X
Haliclystus ? auricula	X	X	X
Cyanea capillata	X	X	X
? Epizoanthus scotinus	X		
Halcampa sp.			X
Nemertea (ribbon worms)			
Unid. species A (orange)			X
Unid. species B (white bands)	X		
Mollusca (mollusks)			
Cryptochiton stelleri	X	X	X
Katharina tunicata	X	X	X

TABLE 18 (Cont.)

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

Mollusca (mollusks)	Latouche Point	Macleod Harbor	Zaikof Bay
Tonicella lineata	X	X	X
Tonicella insignis	X	X	X
Placiphorella spp.	X	X	X
Mopalia muscosa		X	X
? Ischnochiton mertensii	X	X	X
Mopalia spp.	X	X	X
Puncturella multistriata	X	X	X
Diadora aspera	X	X	X
Crepipatella lingulata	X	X	X
Crepidula nummaria		X	
Cryptobranchia concentrica		X	X
Collisella instabilis	X	X	X
Acmaea mitra	X	X	X
Fusitriton oregonensis	X	X	X
Trichotropis cancellata	X	X	X
Trichotropis insignis			X
Margarites ? pupillus	X	X	X
Calliostoma annulatum	X		
Calliostoma ligatum	X	X	X
Velutina rubens	X		
Natica spp.	X	X	X
Lacuna carinata	X	X	X
Olivella baetica	X		
Nassarius mendicus		X	
Ceratostoma nuttallii		X	
Trophon multicostatus	X	X	
Amphissa columbiana	X	X	X
Trophonopsis insignis			X
Searleisa dira	X	X	X
Volutharpa ampullacea			X
Thais ? canaliculata			
Thais lamellosa	X	X	X
Neptunea lirata			X
Turridae, unid.		X	
Trophonopsis lasius			X
Beringinus kenneycotti			X
Aglaja ocelligera		X	
Gastropteron pacificum	X	X	X
Dirona aurantia	X		
Tochuina tetraguetra	X		
Melibe leonina			X
Dendronotus dalli	X		X
Dendronotus spp.		X	
Aeolidia papillosa		X	
Hermissenda crassicornis	X	X	X

TABLE 18 (Cont.)

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

Mollusca (mollusks)	Latouche Point	Macleod Harbor	Zaikof Bay
Coryphella sp.			X
Triopha carpenteri	X	X	
Diaululu sandiegensis	X		
Anisodoris nobilis	X		
Archidoris odneri	X	X	
Cadlina luteomarginata	X	X	
Cadlina sp.	X		
Pododesmus macroschisma	X	X	X
Pecten caurinus		X	
Chlamus spp.	X	X	X
Glycymeris ? subobsoleta		X	
Hiatella arctica	X	X	X
Mytilus edulis	X	X	X
Modiolus modiolus	X	X	
Musculus vernicosus			
Musculus discors	X	X	X
Musculus ? niger			X
Tellina sp.		X	
Clinocardium nuttalli		X	X
Clinocardium ciliatum			X
Thracia trapezoides			X
Lyonsia californica	X	X	X
Prototchaca staminea		X	X
Mya truncata			X
Astarte sp.		X	X
Saxidomus giganteus		X	X
Humilaria kennerlyi	X	X	X
Macoma spp.		X	X
Octopus sp.	X		X
Annelida (segmented worms)			
Onuphis iridescens		X	
Phyllodoce ? groenlandica		X	
Lumbrineris ? similabris		X	
Scoloplos ? acmeceps		X	
Chone ? mollis		X	
Flabelligera infundibularis		X	
Nereis ? pelagica		X	
Phyllodoce sp.		X	
? Sigalion sp.		X	

TABLE 18 (Cont.)

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

Annelida (segmented worms)	Latouche Point	Macleod Harbor	Zaikof Bay
Axiothella rubrocincta		X	
Haploscolops elongatus		X	
Maldanidae, unid.		X	X
Pectinaria (Cistenides) sp.		X	X
Eudistylia vancouveri	X	X	X
Myxicola sp.	X	X	
Spirorbis spp.	X	X	X
Abarenicola sp.		X	
Serpula vermicularis	X	X	X
? Schizobranchia insignis			X
Sipincula (peanut worms)			
Eubonellia valida			X
Arthropoda (jointed foot)			
Balanus cariosus		X	
Balanus crenatus		X	X
Balanus nubilus	X	X	
Balanus ? rostrotus alaskensis		X	
Cancer magister			X
Cancer oregonensis	X		
Cryptolithodes sitchensis	X		X
Phyllolithodes papillosus			
Hapalogaster mertensii	X		
Rhinolithodes wosnesenskii			X
Placetron wosnesenskii			X
Pagurus ochotensis	X	X	
Pagurus ? beringanus			X
Pagurus stenuensae			X
Elassochirus tenuimanus	X	X	
Elassochirus gilli	X	X	X
Oregonia gracilis	X	X	X
Chionoecetes bairdi			X
Pugettia gracilis	X	X	X
Pugettia ? richii		X	
Hyas lyratus		X	
Telmessus cheiragonus		X	X
Pandalus danae	X	X	X
Pandalus sp.		X	X
Sclerocrangon sp.			X
Eualus spp.		X	X
Heptacarpus spp.	X	X	X

TABLE 18 (Cont.)

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

Arthropoda	Latouche Point	Macleod Harbor	Zaikof Bay
Idotea sp.	X		
Caprella sp.	X	X	X
Gammaridea	X	X	X
Mysidacea	X	X	X
? Discorsopagurus schmitti			X
Echinodermata (spiny skin)			
Ophiopholis aculeata	X	X	X
Ophiura ? sarsii		X	
Leptasterias spp.	X	X	X
Pteraster tesselatus			
Dermasterias imbricata	X	X	X
Henricia leviuscula	X	X	X
Henricia tumida	X		
Orthasterias koehleri	X	X	X
Pisaster ochraceus	X	X	X
Evasterias troschelii	X	X	X
Pycnopodia helianthoides	X	X	X
Crossaster papposus	X	X	X
Solaster stimpsoni	X	X	X
Solaster dawsoni	X	X	X
Tosiaster acticus	X	X	
Strongylocentrotus droebachiensis	X	X	X
Strongylocentrotus ? pallidus	X	X	
Strongylocentrotus franciscanus	X		
Parastichopus californicus		X	X
Psolus chitonoides	X	X	X
Cucumaria miniata	X	X	X
Bryozoa (moss animals)			
Flustrella ? gigantea			X
Heteropora spp.	X	X	X
? Lichenopora sp.	X	X	X
Disporella sp.		X	X
Microporina borealis	X	X	X
Tricellaria gracilis	X	X	X
Dendrobeania murryana	X	X	X
Hippodiplosia insculpta	X	X	X

TABLE 18 (Cont.)

LIST OF BENTHIC MACROINVERTEBRATES COLLECTED AT THE THREE STUDY SITES IN NORTHEASTERN GULF OF ALASKA (1975-76)

Bryozoa	Latouche Point	Macleod Harbor	Zaikof Bay
Membranipora sp.		X	
? Phidolopora pacifica	X	X	X
Costazia sp.	X	X	X
? Myriozoum coarctatum		X	
Crisia sp.	X	X	
Alcyonidium pedunculatum		X	X
Carbasea carbasea			X
Gromia oviformis	X	X	X
Brachiopoda			
Terebratalia transversa	X	X	X
Terebratulina unguicula		X	X
Urochordata			
Styela montereyensis	X		X
Chelyosoma productum	X		X
Corella willmeriana			X
Ascidia paratropa			X
Boltenia villosa	X	X	X
Halocythia igaboja			
Halocynthia aurantium	X		X
Cnemidocarpa finmarkiensis	X	X	
Metandrocarpa taylori	X	X	X
Clauelina sp.	X		
Distaplia occidentalis	X	X	X
? Synoicum sp.	X		
Didemnum or Trididemnum	X	X	X

TABLE 19

FISHES OBSERVED IN THE THREE STUDY SITES DURING 1975-76

COMMON NAME	SCIENTIFIC NAME	LOCATION
Rock greenling	Hexagrammos lagocephalus	L;M;Z
White spotted greenling	Hexagrammos stelleri	M;Z
Kelp greenling	Hexagrammos decagrammus	L;M;Z
Masked greenling ?	Hexagrammos octogrammus	L;M
Lingcod	Ophiodon elongatus	L
Great sculpin	Myoxocephalus polyacanthocephalus	M;Z
Buffalo scuplin	Enophrys bison	M
Blackfin sculpin ?	Malacottus kincaidi	M
Red irish lord	Hemilepidotus hemilepidotus	L;M
Yellow irish lord	Hemilepidotus jordani	L
Northern sculpin ?	Icelinus borealis	L
Grunt sculpin	Rhamphocottus richardsoni	L
Silverspotted scuplin	Blespsias cirrhosus	M
Pacific staghorn sculpin	Leptocottus garmatus	M
Antlered sculpin	Enophrys diceraus	L;M;Z
Sturgeon poacher	Agonus acipenserinus	Z
Pacific spiny lumpsucker	Eumicrotremus orbis	Z
Black rockfish	Sebastes melanops	L;M;Z
Copper rockfish	Sebastes caurinus	L;M
Yellowtail rockfish	Sebastes flavidus	L
Rockfishes, unid. juv.	f: scorpaenidae	L;M;Z
Searcher	Bathymaster signatus	L
Northern ronquil	Ronquilus jordani	L;M;Z
Starry flounder	Platichthys stellatus	M
Yellowfin sole	Limanda aspera	M;Z
Pacific halibut	Hippoglossus stenolepis	L
Snake prickleback	Lumpenus sagitta	M
Prickleback, unid.	f; stichaeidae	L;M;Z
Crescent gunnel	Pholis laeta	L;M;Z
Artic shanny	Stichaeus punctatus	L;M;Z
Pacific tomcod	Microgadus proximus	L;M;Z
Sand lance	Ammodytes hexapterus	L;M;Z
Pink salmon	Oncorhynchus gorbuscha	L

Location Symbols:

L = Latouche Point
M = Macleod Harbor
Z = Zaikof Bay

which density ranged up to about 2,084 individuals/m^2. From one 0.25m^2 quadrat we removed 521 M. vernicosus that were attached to two elephant-ear kelps (Laminaria groenlandica), each approximately one meter in blade length. Individual Musculus ranged in shell length from 4 to 13mm (Figure 3), however smaller Musculus (<3mm) were also present in the sample, but were not included in the size-frequency histogram. Musculus is a suspension or filter feeder that appears to thrive either in exposed locations of the northern Gulf, or in ocean entrances that are exposed to rapid water exchange. No doubt, Musculus contributes appreciable amounts of energy to secondary consumers. Major predators of Musculus in this location were sea stars, fin fishes and sea otters. Other probable predators are diving sea ducks such as the harlequin and surf scoter, which frequency raft or roost along the rocky shoreline during late spring and summer.

A number of other species utilize the seaweed resource not only for concealment and sites of attachment, but also as a source of food. For example, the limpet Collisella instabilis has only been seen attached to the taller statured understory kelps off Latouche Point. In this case the kelp provides the limpet with both food and cover. One known predator of C. instabilis is the sun star (Pycnopodia helianthoides) which frequently climbs the attached kelps in search of food or potential prey. The limpet seeks refuge from bottom dwelling invertebrates by living on the vegetation suspended above the seafloor.

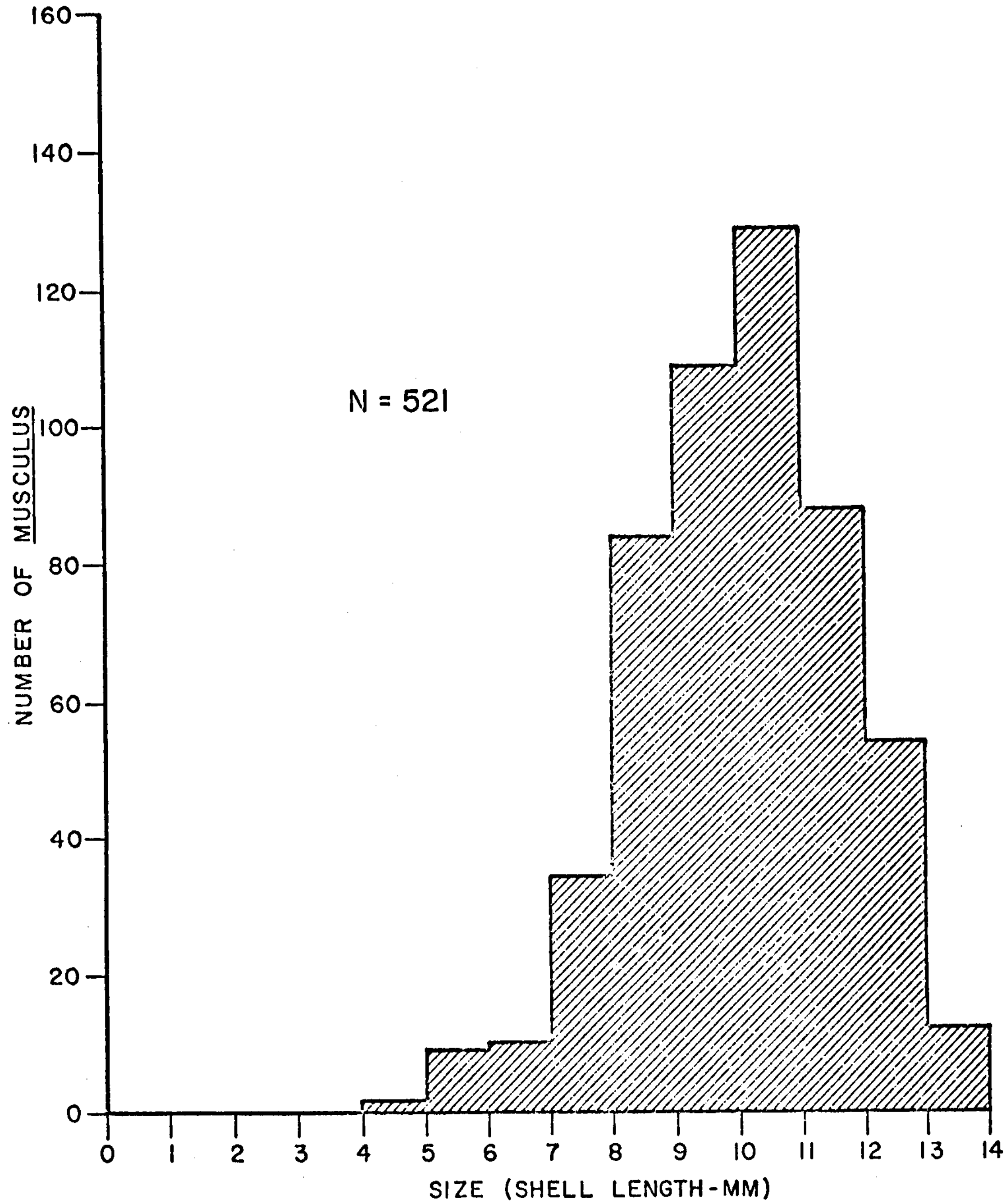

Figure 3. Size class distribution of *Musculus vernicosus* from a subtidal 0.25m² quadrat off Latouche Point.

There are a number of herbivores which feed directly on living marine vegetation, and others that feed on the plants only after they have died. However, before the seaweeds and seagrasses are available to most consumers they must be broken down by bacterial action. Some of the conspicuous herbivores are listed in Table 20. Of these five genera, the most abundant and frequently encountered were the chitons, particularly Tonicella spp. and Mopalia spp. During four of the field surveys Tonicella occurred in 14 of 86 haphazardly placed quadrats (Tables 3 through 16). Densities ranged from 0 to 9.00/m^2; the average density was 0.98/m^2. Tonicella was represented in this location by at least two species: T. lineata and T. insignis. It is a microherbivore that reputedly grazes on algal sporelings, and the diatom film that coats the rock surfaces. Other microherbivores were also common; the limpet Acmaea mitra occurred in 11 of 86 quadrats (.025m^2), and density estimates ranged from 0 to 9.00/m^2. The snail Calliostoma ligatum had a frequency of occurrence of 8/86, and an average density of 0.60/m^2. Acmaea mitra was most frequently seen on the algal turf, while Calliostoma was seen equally on rock and vegetative substrates. Asteroids or sea stars were the most important identifiable group of predators on the microherbivore guild at Latouche Point.

Probably the most important macroherbivore in the seaweed assemblages of the north Pacific is the sea urchin. At least two species have been found in this location, the green sea urchin (Strongylocentrotus drobachiensis) and the giant red urchin (Strongylocentrotus franciscanus). Despite their occurrence off Latouche Point, they were

TABLE 20

CHARACTERISTIC OR REPRESENTATIVE IMPORTANT SPECIES
(RIS) OFF LATOUCHE POINT, SUBTIDAL

Species	Occurrence	Major Taxon	Trophic Category
Agarum cribrosum (P)	A	Brown alga	Producer
Laminaria groenlandica (P)	A	Brown alga	Producer
Laminaria yezoensis (P)	A	Brown alga	Producer
Pleurophycus gardneri (P)	A	Brown alga	Producer
Nereocystis luetkeana (A)	A	Brown alga	Producer
Cymathere triplicata (A)	C	Brown alga	Producer
Constantinea spp. (P)	C	Red alga	Producer
Ptilota filicina (?)	C	Red alga	Producer
Opuntiella californica (?)	C	Red alga	Producer
Microporina borealis (?)	C	Bryozoan	Suspension feeder
Encrusting coralline algae (P)	A	Red Alga	Producer
Crossaster papposus (P)	C	Sea star	Predator
Pycnopodia helianthoides (P)	C	Sea star	Predator
Musculus vernicosus (A)	A	Mussel	Suspension feeder
Acmaea mitra (P)	C	Snail	Herbivore
Tonicella spp. (P)	C	Snail	Herbivore
Enhydra lutris (P)	C	Sea otter	Predator
Henricia spp. (P)	C	Sea star	? Suspension feeder
Orthasterias koehleri (P)	C	Sea otter	Predator
Calliostoma ligatum (P)	C	Snail	Herbivore
Ophiopholis aculeata (P)	C	Brittle star	Predator
? Distaplia occidentalis (P)	C	Ascidian	Suspension feeder
Strongylocentrotus spp. (P)	U	Sea urchin	Herbivore
Dermasterias imbricata (P)	C	Sea star	Predator
Searlesia dira (P)	C	Snail	Predator
Pargurus spp. (P)	A	Hermit crab	Scavenger/Herbivore

Key: (P) = perennial
(A) = annual
A = abundant
C = common
U = uncommon

typically cryptic in behavior and relatively uncommon. Most of the sea urchins were small individuals, and densities for both species combined ranged up to about $4.00/m^2$; however, sea urchins occurred in only 3 of 86 quadrats. These data are in agreement with the findings of the transect sampling; densities ranged from 0 to $0.12/m^2$ with an average of $0.03/m^2$ in 470 square meters of seafloor that was examined during 1975-76 (Table 21).

Grazers of lesser numerical importance were the limpets (Diadora aspera), gumboot chiton (Cryptochiton stelleri), chink shell (Lacuna variegata) and the snail (Margarites spp.). There are numerous other obligatory herbivores that know doubt play key roles in the macrophyte system, i.e. isopods, gammarid amphipods, etc., however no information is available at this time on their distribution or abundance. Most of the crustaceans seem to be highly seasonal in appearance, with peak influx into the inshore zone during spring and summer. Included in the herbivore guild are the facultative consumers which are more catholic in their diet, and as such either browse on marine plants or ingest vegetation incidental to the uptake of animal material. Some of the common members of this group are the hermit crabs, decorator crabs (Oregonia gracilis and Pugettia gracilis) and the leather star (Dermasterias imbricata).

A great percentage of the epibenthic fauna in this area are suspension or filter feeding types. This group of consumers probably represents the bulk of the biomass off Latouche Point. A few of these species are listed in the characteristic of representative important species category, and numerous others are probably noteworthy of this ranking. The articulated bryozoan (Microporina borealis) covered considerable portions of the rock substrate; percent cover estimates ranged from 0 to 60 percent during this period of time. Microporina appeared to be either an annual species or somewhat ephemeral in abundance and frequency of occurrence. Two predators of Microporina that have been identified to date, are the leather star Dermasterias and the nudibranch Triopha carpenteri. The compound ascidian Distaplia sp. and the blood star (Henricia spp.) are both listed as suspension feeders. Both animals are common off Latouche Point, for example, Henricia spp. ranged up to $0.36/m^2$, with an average density in the band transects of $0.11/m^2$ (Table 21). Distaplia is exquisite in both form and color; it covered between 0 and 30 percent of the rock substratum that was examined during 1975-76.

Seven predators are listed in Table 20. Other important secondary consumers at this location were crustaceans, gastropods, sea anemones, fishes and marine mammals. The sea stars are visual dominants in the shallow waters of the northern Gulf of Alaska. Feeding behavior of some common species off the coast of Washington has been adequately described by Mauzey, Birkeland and Dayton (1968). Since this group has such an important functional role in the rocky sublittoral zone, a great deal of time and energy has been devoted to estimating relative abundance, population size structure and gathering information on the

TABLE 21

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS FROM LATOUCHE POINT

Taxon	9-17-75						
Pycnopodia helianthoides	4 0.16/m^2	5 0.33/m^2	9 0.36/m^2	1 0.04/m^2	0	3 0.12/m^2	5 0.20/m^2
Dermasterias imbricata	0	0	1 0.04/m^2	1 0.04/m^2	0	2 0.08/m^2	0
Orthasterias koehleri	1 0.04/m^2	0	2 0.08/m^2	0	0	0	3 0.12/m^2
Crossaster papposus	2 0.08/m^2	0	1 0.04/m^2	0	0	0	1 0.04/m^2
Solaster spp.	1 0.04/m^2	0	0	0	0	0	0
Henricia spp.	9 0.36/m^2	3 0.20/m^2	0	1 0.04/m^2	0	3 0.12/m^2	6 0.24/m^2
Strongylocentrotus spp.	1 0.04/m^2	0	1 0.04/m^2	0	1 0.04/m^2	0	3 0.12/m^2
Area sampled:	25 x 1m	15 x 1m	25 x 1m	25 x 1m	15 x 1m	25 x 1m	25 x 1m
Depth:	12m	9-11m	9-11m	9m	9m	9m	12m

TABLE 21 (Cont.)

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS FROM LATOUCHE POINT

Taxon	11-26-75	11-26-75	11-26-75	3-17-76	3-17-76	6-26-76	6-26-76
Pycnopodia helianthoides	1 0.06/m^2	1 0.06/m^2	0	2 0.02/m^2	11 0.11/m^2	2 0.66/m^2	1 0.20/m^2
Dermasterias imbricata	0	0	1 0.02/m^2	1 0.01/m^2	5 0.05/m^2	1 0.03/m^2	0
Orthasterias koehleri	1 0.06/m^2	1 0.06/m^2	0	3 0.03/m^2	2 0.02/m^2	5 0.17/m^2	0
Crossaster papposus	1 0.06/m^2	2 0.13/m^2	4 0.08/m^2	0	1 0.01/m^2	0	0
Solaster spp.	0	0	0	0	0	0	0
Henricia spp.	2 0.13/m^2	1 0.06/m^2	1 0.02/m^2	0	16 0.16/m^2	0	1 0.20/m^2
Strongylocentrotus spp.	1 0.06/m^2	0	0	0	1 0.01/m^2	0	0
Area sampled: Depth:	15 x 1m 12m	15 x 1m 12m	25 x 2m 13-14m	50 x 2m 8-11m	50 x 2m 3-8m	30 x 1m 9m	5 x 1m 9m

foraging behavior of some of the common species. Four conspicuous species off Latouche Point were the sun star (Pycnopodia helianthoides); leather star (Dermasterias imbricata); Crossaster papposus and Orthasterias koehleri. Pycnopodia ranged in density from 0 to $0.66/m^2$, with an average of $0.17/m^2$ (Table 21). Individual sun stars varied in size (radius) from 27 to 185 mm. Hundreds of Pyncopodia were examined for food items; of those feeding 15 were found eating Musculus vernicosus; 3 sea urchin (Strongylocentrotus drobachiensis); 2 Musculus discors; 2 snail (Calliostoma spp.); 3 brittle star (Ophiopholis aculeata; 3 crab (Pugettia gracilis); 2 hermit crab (Pagurus spp.); 2 butter clam (Saxidomus gigantea); 1 snail (Trophonopsis sp.); 1 chiton (Placiphorella sp.); 2 crab (Cancer oregonensis); 1 chiton (Mopalia sp.); and 1 blood star (Henricia sp.).

Orthasterias koehleri is one of the most colorful stars on the reef complex; density estimates ranged from 0 to $0.17/m^2$, with an average density of $0.04/m^2$ in the band transects (Table 21). Individual Orthasterias ranged in size from 30 to 191 mm; most preyed on mussels (Musculus vernicosus and M. discors; clam (Humilaria kenneryli); rock jingle (Pododesmus macroschisma) and barnacle (Balanus spp.).

The leather star (Dermasterias imbricata) was somewhat less common; density estimates ranged from 0 to $0.08/m^2$, and the average was $0.02/m^2$. Individual Dermasterias ranged in size from 18 to 180 mm. Dermasterias frequently preyed upon Musculus vernicosus; sea anemone

(Tealia spp.); the clavate ascidian (Synoicum); bryozoa (Microporina borealis); compound ascidians (several species) and red algae.

Another conspicuous sea star in this location was Crossaster papposus. Crossaster is one of the smaller stars in this water, individuals are typically less than 50 mm in radius. Frequently it was found on rock and seaweed substrates, and repeatedly it was attached to understory kelps. Density estimates ranged from 0 to $0.13/m^2$, with an average of $0.03/m^2$. Identifiable prey included Musculus and the serpulid (Spirorbis).

There is sufficient evidence of trophic interaction to present a very qualitative food web for the conspicuous organisms at Latouche Point (Figure 4). The suspected major pathways were from the macrophytes to herbivores such as snails and sea urchins. Organic debris flowed to clams, mussels and bryozoans, and phytoplankton was ingested by clams, mussels and sponges. Linkages from all categories to tertiary consumers such as predators and scavengers are included in the food web.

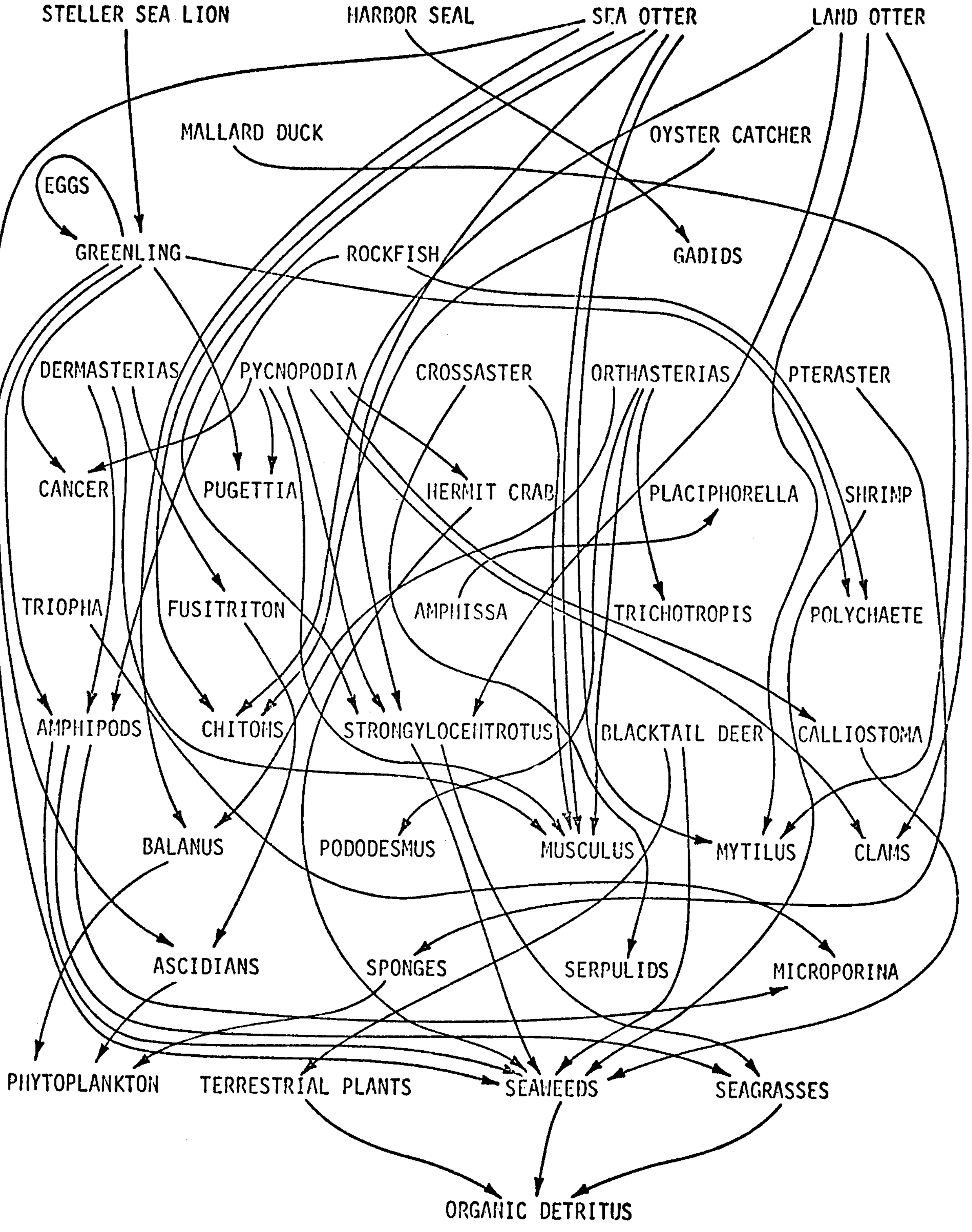

Figure 4. Food web for the rocky sublittoral zone at Latouche Point, Gulf of Alaska.

SEASONAL PATTERNS

The seaweed zone at Latouche Point underwent a marked alteration in appearance with the change of season. One seasonal change that was obvious to even the casual observer was the oscillation in areal cover of the floating portion of the kelp bed. The surface canopy, consisting of bull kelp (Nereocystis), reached peak development and covered considerable areas of the underlying seafloor during the summers of 1974, 1975 and 1976 (Rosenthal, unpublished data). Nereocystis is reputed to be an annual plant, that reaches great size in a single season (Vadas, 1972; Markham, 1969). Most of the growth takes place during the spring and early summer. Fertile plants were observed as early as March, 1976. When bull kelp is mature, zoosporangial sori fall out of the blade and drift to the bottom. Release of zoospores apparently follows soon after. Young sporelings have been observed during early spring, most reached the surface in about 2 to 3 months, and the growth phenology seems to be correlated closely with periods of maximum available light (Vadas, 1972).

During summer, the bull kelp canopy at Latouche Point covered an estimated 50 percent of the underlying seafloor in the central part of the kelp bed (Figures 5 and 6). This same part of the kelp bed was revisited in late November 1975, and at this time the floating canopy was reduced to an estimated 20 percent coverage. Not only was there a reduction in areal cover, but also a heavy attrition of attached plants. Cohorts of adult Nereocystis growing adjacent to one another frequently

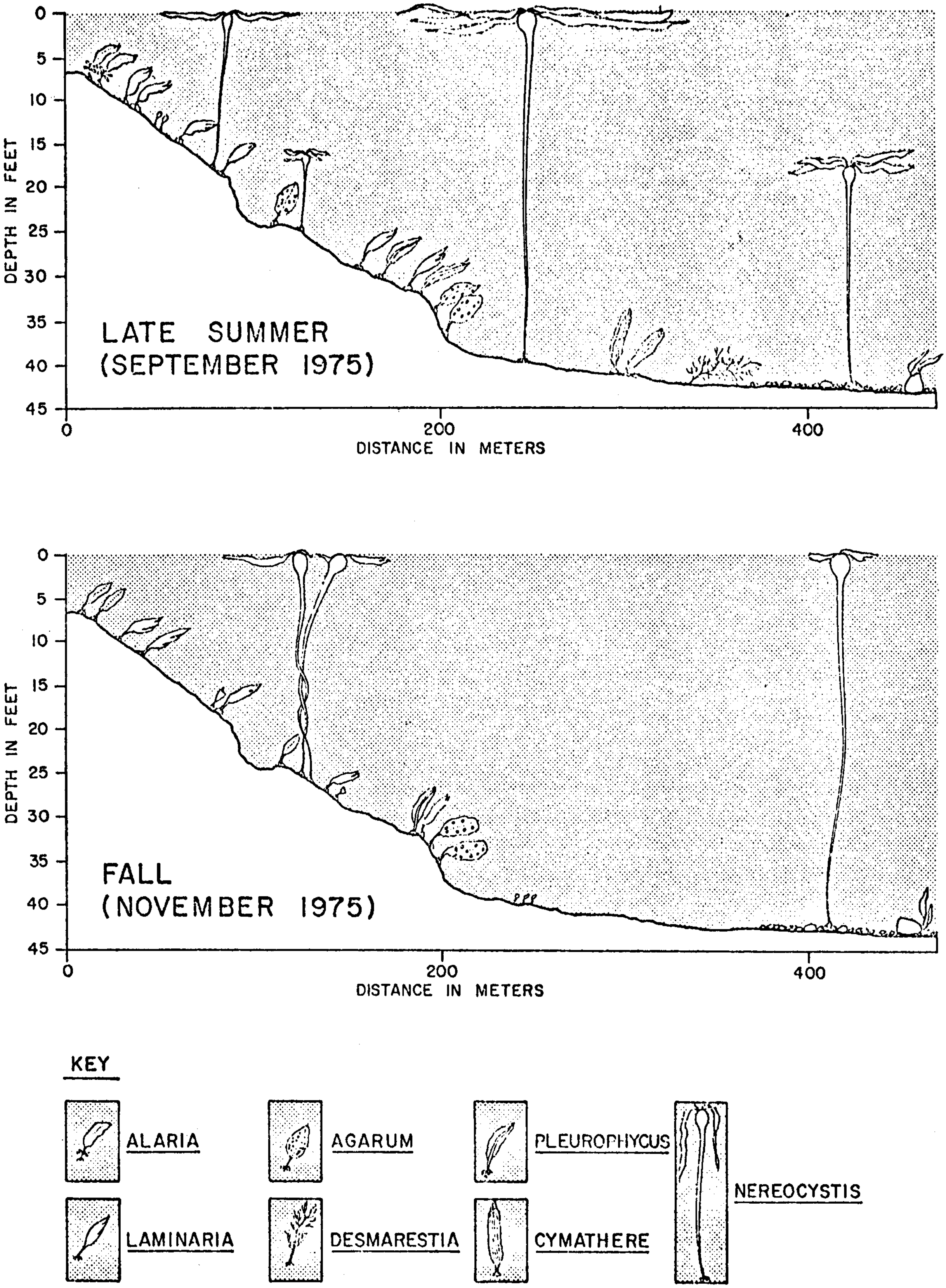

Figure 5. Subtidal vegetative profiles, Latouche Point.

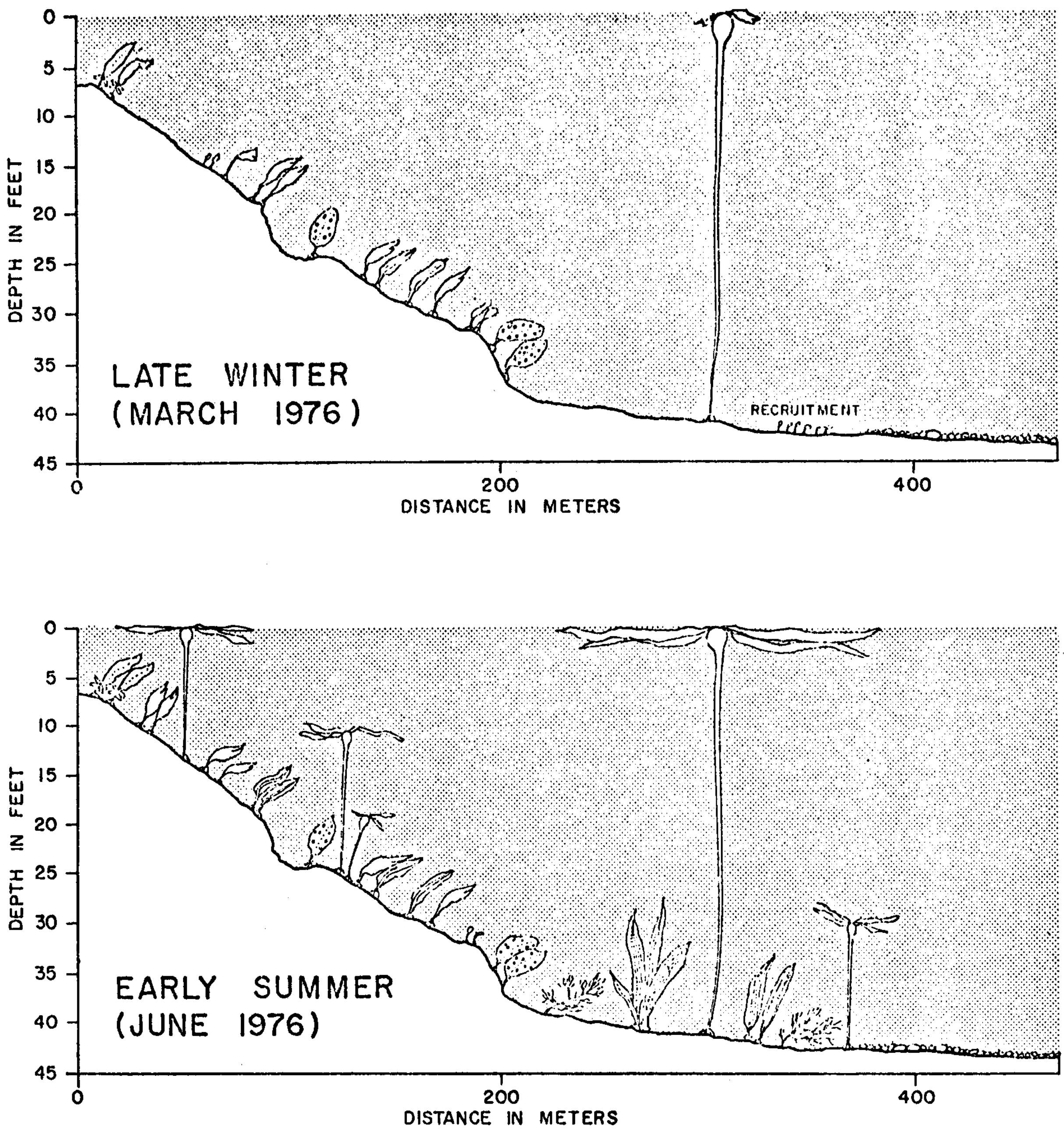

Figure 6. Subtidal vegetative profiles, Latouche Point.

become entangled (Figure 5). Other bull kelp plants that have been detached by storms, substrate dislodgment, and/or grazing, frequently drift through the beds and become entangled with the attached kelps. Mutual entanglement results, thereby leading to further plant mortality. This same source of kelp mortality was described by Rosenthal, Clarke and Dayton (1974) in the stands of giant kelp (Macrocystis) off the coast of southern California.

Dives were made off Latouche Point during oceanic winter (March 1976); at this time the surface canopy covered less than 5 percent of the seafloor. Attached Nereocystis was still present in this location; however, the blades of most had either eroded away or were reduced in surface area. Since grazing by macroherbivores is of minor importance at this site, the major cause of bull kelp mortality was probably physical detachment and/or old age (senility). No distinguishable juvenile plants were seen in the area during the March visit, however, by late June 1976 the annual cycle had been renewed, and once again the bull kelp bed was fully developed and supported a heavy surface canopy.

The understory complex or vegetative undergrowth beneath the floating canopy underwent similar change in areal cover and standing crop. The algal understory was typically composed of perennial species such as Laminaria groenlandica; L. yezoensis; L. saccharina; Agarum cribrosum and Pleurophycus gardneri. Annual or more ephemeral algae such as Cymathere triplicata and Desmarestia ligulata var. ligulata were highly seasonal in appearance; typically these species occurred in the shallow subtidal zone during the summer and disappeared during winter

(Figures 7 and 8). Other fleshy reds, i.e. Delesseria decipiens; Pterosiphonia bipinnata; Rhodymenia spp.; Membranoptera spp.; and browns Desmarestia viridis and D. aculeata were short-lived (ephemeral) or perennated (died-back) following the growing season.

In contrast to the growth strategies of the annual species, the perennials such as Agarum, Laminaria and Pleurophycus grow rapidly in the winter and early spring. Whereas, most annuals usually appear during late spring and grow rapidly reaching peak development during the summer. Another seasonal phenomena that is typical of the understory canopy is the shedding of fronds by many of the kelp species. Mann (1973) found that Laminaria and Agarum from eastern Canada completely renewed the tissue of the frond (blade) between one and five times a year. Of the 329 Laminaria spp. examined off Latouche Point during late November 1975, 25 percent (n = 86) had lost or shed a major part of the blade. Only the holdfast, stipe and meristematic growth zone remained of the kelps that were regenerating the blade prior to the active winter growth phase. During the fall when the plants lose their blades a great deal of drift material is present at this site. The surge channels or bathymetric lows in the rocky substrate served as collection points of a great deal of the drift plant material. The process of blade renewal had a significant change in the understory canopy, permitting more available light to reach the seafloor. Kelp germination was apparent during the later winter and spring of 1976.

Seasonal changes in the epifauna were also conspicuous at this location. For example, the mytilid Musculus vernicosus displayed strong

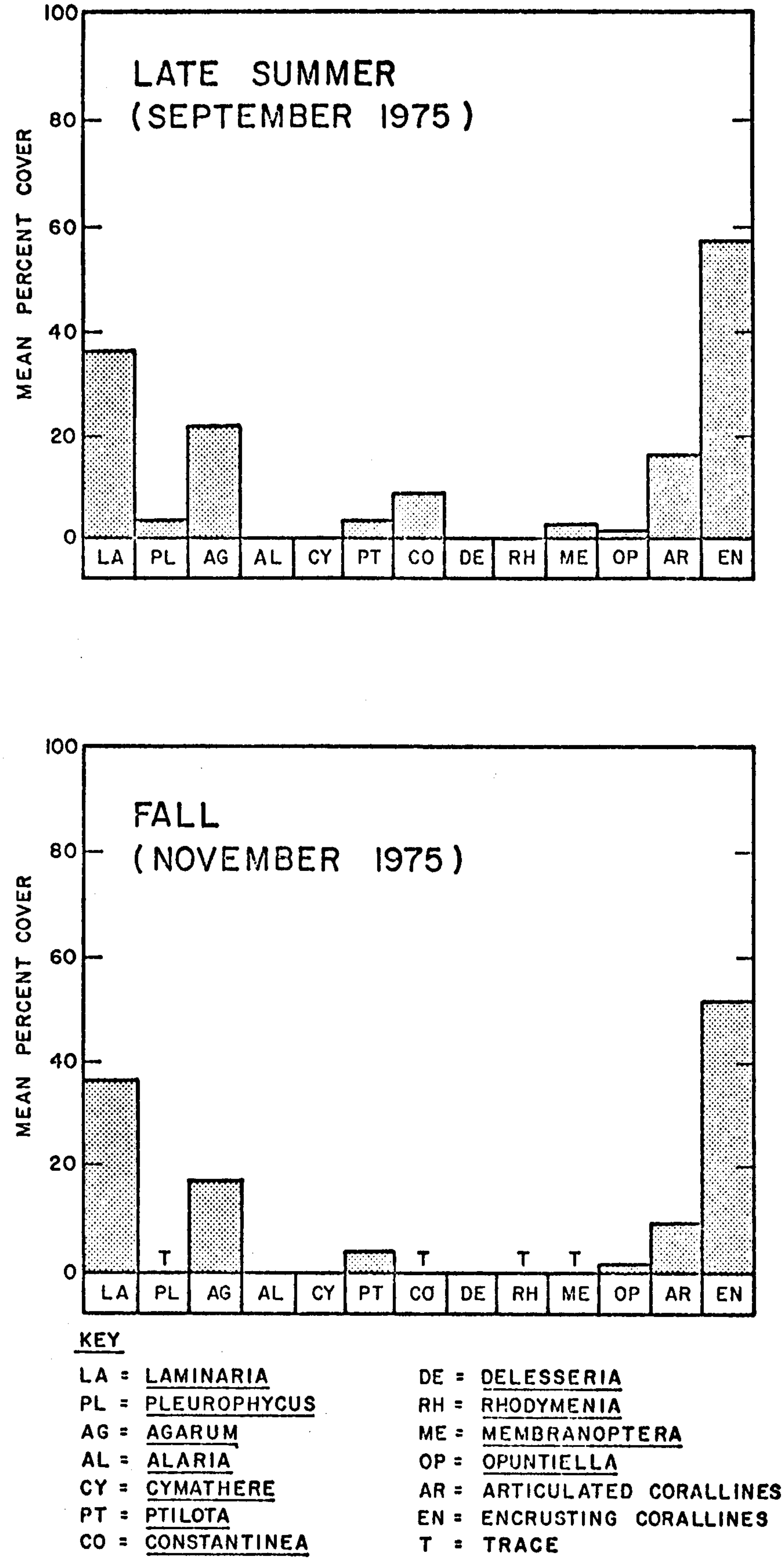

Figure 7. Algal cover at Latouche Point.

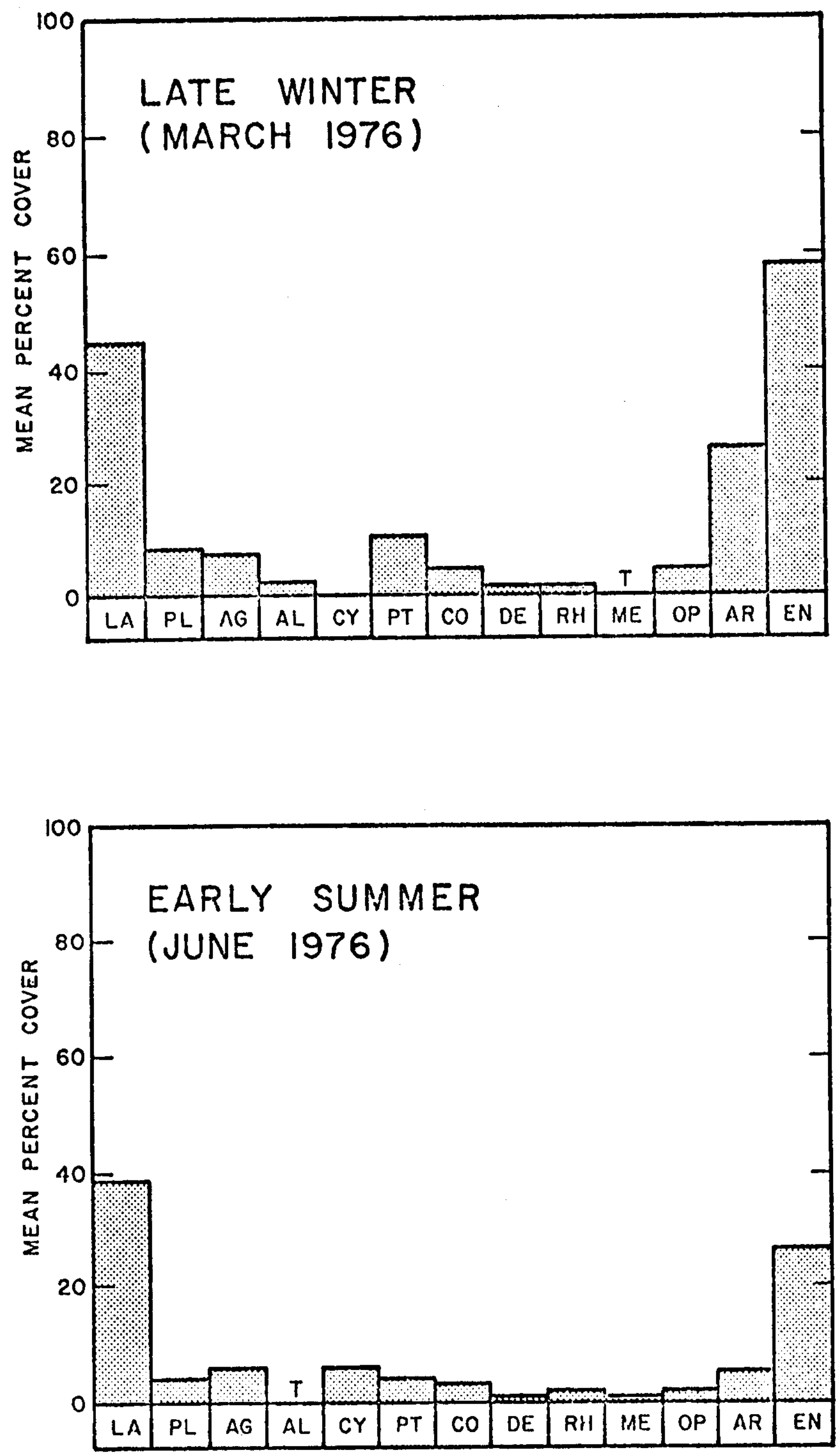

Figure 8. Algal cover at Latouche Point.

seasonal variation in cover and abundance. Since Musculus encrusts large portions of the blades of seaweeds in the lower canopies it is strongly affected by changes in the condition of the marine vegetation. Musculus vernicosus is either annual or bi-annual in terms of life history pattern, most disappeared by winter or early spring. The life history pattern agrees with the recorded longevity of the algal substrates, since the blades of most are continually being removed, and only those mussels that adhere to either the stipes or holdfast portions remain. Possibly because of predation pressures, adult Musculus are rarely successful on the bottom and so decline sharply after fall shedding of the plants. Spring and early summer marked the arrival of the juvenile spat which initially covered the understory seaweeds in such high densities that the bottom had a snow-like appearance. Juveniles were present at each sample period, however, their growth during winter is probably slow, and rapid growth commences concurrently with spring plankton blooms.

Other seasonal patterns were evident in the shallow water zone. For example, the inshore fishes, i.e. rockfish, greenling, flatfish and tomcod etc., which were prominent members of the seaweed assemblages during summer and early fall, tend to either move offshore, or become more secretive in habit. Solitary fishes were common under rock ledges and overhangs, however, schools of fish were not seen in this location until late spring. Even larger vertebrates, such as the ubiquitous sea otter, moved into more protected regions of the Sound; most could be seen either resting or feeding in the embayments and waterways of Elrington, Evans and Latouche Islands.

DESCRIPTION OF THE STUDY SITE (ZAIKOF BAY)

Zaikof Bay is located on the northeast end of Montague Island. The mouth of the bay is 2.5 miles wide and is situated on the west side of Hinchinbrook Entrance (Figure 1). The shoreline is heavily wooded with Sitka Spruce and Hemlock; the beach is narrow and rocky. The inner confines of the bay are generally protected from ocean swell; however, at times the surface waters are exposed to storm force winds. The winds generally blow from a southeasterly direction during spring and fall. Local jet stream winds or "williwaws" are known to move through these mountain canyons in excess of 120 mph. For example, during the September (1975) survey we were literally driven from Zaikof Bay by rain and storm force winds in excess of 80 mph.

The NMFS intertidal site is located on a rocky promontory on the south side of the bay. An Alaska Department of Fish & Game stream marker served as a reference point for the sublittoral work. Below the tree line the beach is composed of cobbles and large boulders. The shallow sublittoral zone appears to be a continuum of the exposed portion of the beach. At the intertidal-subtidal fringe the substratum is pavement rock; below this point is a boulder field interspersed with sand and shell material (Figure 9). A fine layer of silt covered most of the solid substratum and marine vegatation during the four seasons of observation. At a depth of approximately 10 to 12m below the sea surface the band of exposed rock stopped and was replaced by sand and silty clay. Shell debris, particularly those of the clams Saxidomus, Mya and Humilaria were common in this location.

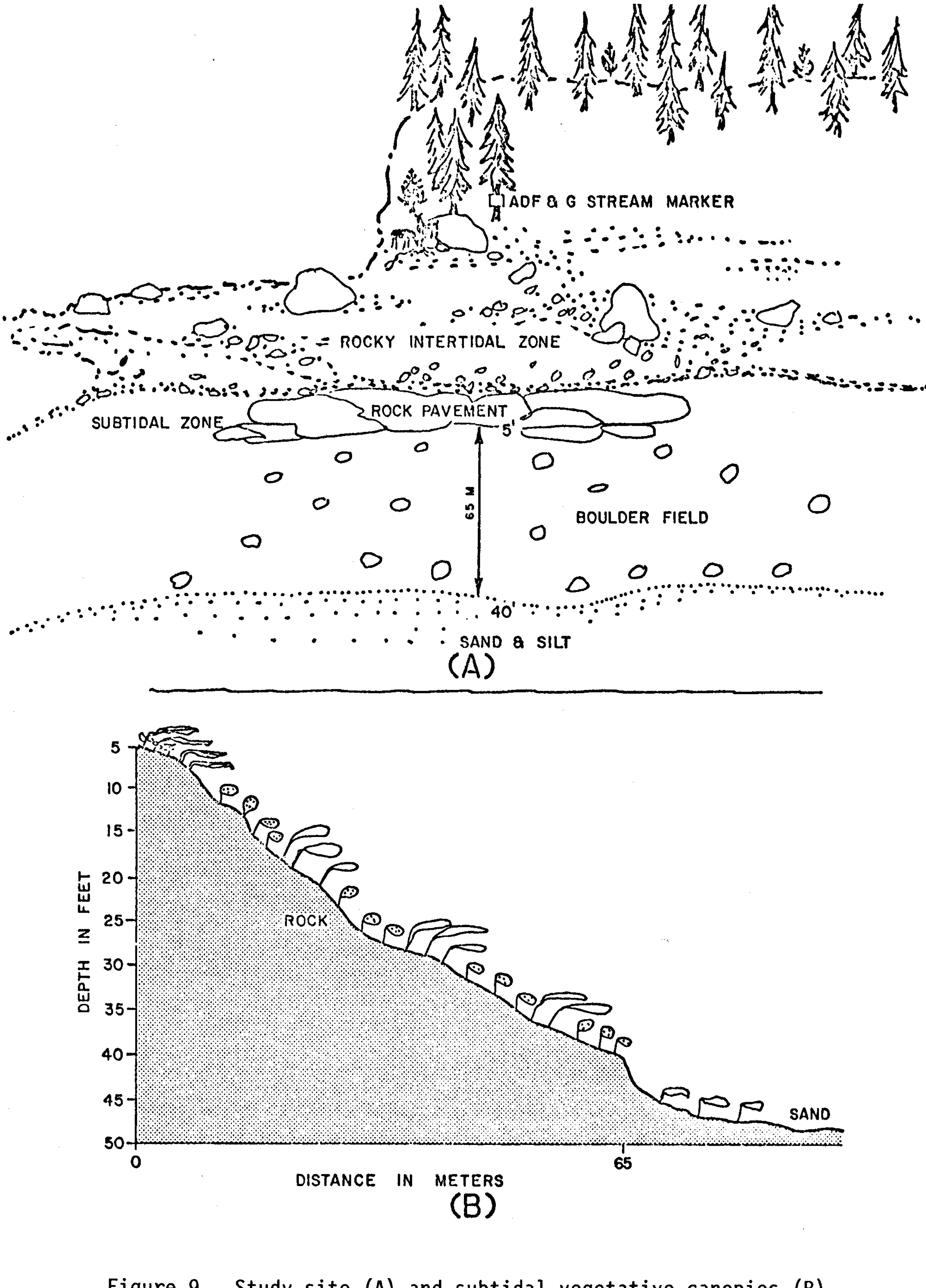

Figure 9. Study site (A) and subtidal vegetative canopies (B) at Zaikof Bay.

BIOLOGICAL SETTING (ALGAL ASSEMBLAGE)

Rockweed (Fucus distichus), formed the most conspicuous algal belt in the high intertidal zone during 1975-76. The brown alga, Alaria ? marginata was common at the MLLW mark, a major break point between the intertidal and shallow subtidal zones. The sublittoral macrophyte band was approximately 65 meters wide in the vicinity of the NMFS station (Figure 9). Most of the macroalgae was confined to the rock pavement or shallow water terrace, and the boulder field that borders the shoreline. However, a few kelp plants were found growing on the soft or unconsolidated substratum. Most of these plants were attached to empty clam shells and/or small stones.

Sieve kelp (Agarum cribrosum) was the numerical dominant in the seaweed zone. Density estimates during three of the sample periods ranged from $2.12/m^2$ to $8.20/m^2$ in the band transects (Tables 22 and 23); the average density in all transects combined was $4.62/m^2$. In 52 quadrats ($0.25/m^2$) the density ranged from 0 to $28.00/m^2$; with an average of $7.77/m^2$. Elephant-ear kelp (Laminaria groenlandica) was also abundant in this location; density estimates ranged from $0.20/m^2$ to $4.80/m^2$ with an average density of $2.48/m^2$ in the transect bands. These data agree well with the quadrat counts; the range in 41 haphazard casts ($0.25/m^2$) was 0 to $16.00/m^2$, and the mean density was $2.83/m^2$ (Tables 24 through 31). Laminaria yezoensis was also present, although relatively uncommon except in the shallow (9.0m) part of the seaweed band. The average density in the belt transects was $0.74/m^2$, compared with $1.07/m^2$ in the

TABLE 22

DENSITY ESTIMATES OF SOME DOMINANT MACROPHYTES FROM ZAIKOF BAY
(estimates were derived from band transects of different lengths)

Taxon	11-23-75	11-24-75	3-20-76	3-20-76	3-20-76
Nereocystis leutkeana	0	0	0	0	0
Laminaria groenlandica	/	/	23 2.30/m^2	33 3.30/m^2	14 1.40/m^2
Laminaria yeozoensis	/	/	0	0	12 1.20/m^2
Laminaria spp.	39 .78/m^2	43 1.72/m^2	0	0	0
Agarum cribrosum	172 3.44/m^2	53 2.12/m^2	52 5.20/m^2	59 5.90/m^2	82 8.20/m^2
Pleurophycus gardneri	0	0	0	0	0
Area sampled:	25 x 2m	25 x 1m	10 x 1m	10 x 1m	10 x 1m
Depth:	11.0-12.0	12.0-13.0	10.5m	7.5m	4.5m
Substrate Type:	Rock	Rock & Sand	Boulders	Boulders	Boulders & rock pavement

/ = placed under the category of *Laminaria* spp.

TABLE 23

DENSITY ESTIMATES OF SOME DOMINANT MACROPHYTES FROM ZAIKOF BAY

(Estimates Were Derived from Band Transects of Different Lengths)

Taxon	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76
Nereocystis luetkeana	0	0	0	0	0	0	0	0	0	0	2 0.40/m^2
Laminaria groenlandica	3 0.60/m^2	1 0.20/m^2	5 1.00/m^2	2 0.40/m^2	19 3.80/m^2	23 4.60/m^2	22 4.40/m^2	16 3.20/m^2	24 4.80/m^2	11 2.20/m^2	Not counted
Laminaria yezoensis	0	0	0	0	0	0	3 0.60/m^2	1 0.20/m^2	2 0.40/m^2	0	Not counted
Agarum cribrosum	11 2.20/m^2	19 3.80/m^2	15 3.00/m^2	22 4.40/m^2	24 4.80/m^2	35 7.00/m^2	28 5.60/m^2	29 5.80/m^2	27 5.40/m^2	12 2.40/m^2	Not counted
Pleurophycus gardneri	0	0	0	0	1 0.20/m^2	0	2 0.40/m^2	4 0.80/m^2	3 0.60/m^2	34 6.80/m^2	Not counted
Area sampled:	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m
Depth:	13.5 m	13.5 m	12.0 m	12.0 m	10.5 m	10.5 m	9.0 m	9.0 m	7.6 m	6.1 m	4.6 m
Substrate type:	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Boulders	Rock	Rock	Rock	Boulders	Boulders

TABLE 24

QUADRAT DATA ($0.25m^2$) FROM ZAIKOF BAY, SUBTIDAL
NOVEMBER 23, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Laminaria spp.	0	5%	30%(2)	5%	25%(1)
Agarum	20%(1)	0	20%(1)	5%(1)	40%(2)
Constantinea	1%(1)	0	0	0	0
Ralfsia	15%	20%	10%	20%	15%
encrusting coralline	80%	60%	90%	80%	80%
Hildenbrandia	0	0	1%	0	1%
Microcladia spp.	0	0	0	1%	0
Microporina borealis	40%	20%	25%	15%	50%
Didemnum/Trididemnum	1%	1%	1%	5%	1%
pagurids	(2)	(2)	(5)	(1)	(1)
Heteropora sp.	1%	5%	1%	1%	5%
Phidolopora pacifica	1%	1%	1%	1%	5%
Cryptobranchia concentrica	(1)	0	0	0	0
? Rhynchozoon	1%	0	0	0	0
Trichotropis cancellata	0	(1)	0	(1)	0
Crossaster papposus	0	(1)	0	0	0
serpulidae	0	(4)	(2)	(1)	(1)
Crepipatella lingulata	0	(1)	(0)	(1)	0
Acmaea mitra	0	0	(1)	0	0
Flustrella	0	0	2%	35%	0
Pycnopodia helianthoides	0	0	(1)	0	0
Hydroida (unid.)	1%	1%	0	5%	1%
Dendrobeania	0	0	0	1%	0
Thais lamellosa	0	0	0	0	(2)
globular red sponge	(1)	0	(1)	0	0

Location: 100m offshore of NMFS Transect
Depth (meters): 10.0-16.0M
Substrate type: rock outcrop

TABLE 25

QUADRAT DATA ($0.25m^2$) FROM ZAIKOF BAY, SUBTIDAL ZONE
NOVEMBER 24, 1975

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Laminaria spp.	30%(5)	40%(4)	20%(2)	10%(1)
Agarum	40%(2)	10%(2)	20%(2)	40%(1)
Microcladia spp.	1%	1%	3%	2%
Encrusting coralline	30%	40%	15%	40%
Ralfsia spp.	0	10%	0	0
Hildenbrandia	5%	0	15%	5%
Microporina borealis	5%	10%	2%	2%
Flustrella sp.	5%	5%	5%	0
Distaplia	5%(1)	0	0	0
Pagurids	(5)	(3)	(1)	(1)
Didemnum/Trididemnum	1%	0	0	0
Dendrobeania	1%	0	0	0
Puncturella multistriata	0	0	0	(1)
Tonicella spp.	(2)	(2)	(1)	(2)
Calliostoma ligatum	(1)	0	0	0
Cancer oregonensis	0	0	0	(1)
Heteropora sp.	0	2%	0	0
Crepipatella lingulata	(1)	0	0	0
Globose red sponge	(2)	0	(3)	0
Colonial ascidian (convoluted)	0	2%	2%	0

Depth (meters): 7.0-8.0

Substrate type: Boulders, cobbles and shell debris

Location: 100m off NMFS transect

TABLE 26

QUADRAT DATA ($0.25m^2$) FROM ZAIKOF BAY, SUBTIDAL ZONE
MARCH 19, 1976

Taxon	Percent Cover (number of individuals)				
	No. 1	No. 2	No. 3	No. 4	No. 5
Laminaria yezoensis	0	25%(3)	0	15%	20%
Laminaria groenlandica	0	0	0	0	0
Laminaria spp.	0	(2)	0	0	(2)
Agarum	90%(6)	15%(7)	80%(5)	50%(2)	25%(7)
Constantinea	0	6%	0	0	1%
Ralfsia	5%	0	10%	15%	10%
encrusting coralline	30%	5%	15%	10%	20%
Hildenbrandia	0	0	0	25%	0
Corallina	0	0	0	1%	2%
filamentous reds	6%	4%	5%	2%	10%
Microporina	0	1%	10%	20%	15%
Didemnum/Trididemnum	1%	0	0	0	1%
pagurids	(6)	(3)	(1)	(2)	(2)
Heteropora	0	0	0	0	2%
Trichotropis	(1)	(1)	(1)	0	0
serpulidae	(2)	(5)	(1)	(2)	(7)
Flustrella	5%	2%	10%	5%	2%
yellow sponge	2%	0	0	0	0
Distaplia	1%	0	5%	0	1%
Margarites	(1)	0	0	(1)	0

TABLE 26 (Cont.)

QUADRAT DATA (0.25m^2) FROM ZAIKOF BAY, SUBTIDAL ZONE
MARCH 19, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Abietinaria	5%	0	0	0	0
Lacuna	present	0	0	0	0
Cancer oregonensis	(1)	0	0	0	0
? *Distaplia*	2%	0	0	8%	5%
Halocynthia aurantium	(1)	0	0		
Tonicella spp.				(2)	0
Phyllolithodes	0	0	0	0	(1)
Balanus spp.	15%	8%	40%	10%	20%

Location: off NMFS Site

Depth (meters): 6.0-7.0

Substrate type: boulders

TABLE 27

QUADRAT DATA ($0.25m^2$) FROM ZAIKOF BAY, SUBTIDAL ZONE
MARCH 20, 1976

	Percent Cover (number of individuals)			
Taxon	No. 1	No. 2	No. 3	No. 4
Laminaria yezoensis	4	0	0	0
Laminaria groenlandica	10%	25%	25%(1)	40%(1)
Laminaria spp.	0	0	(2)	(2)
Agarum	60%(4)	0	25%(2)	50%(5)
Constantinea	10%	20%	10%	1%
Ralfsia	40%	40%	10%	25%
encrusting coralline	40%	40%	10%	65%
Corallina	15%	15%	10%	15%
Bossiella	0	2%	0	2%
Ptilota	0	0	20%	20%
Rhodymenia	0	0	0	5%
Microporina	40%	15%	20%	10%
Flustrella	5%	0	0	0
orange globular ascidian	0	0	2%	0
Didemnum/Trididemnum	0	0	0	1%
Metandrocarpa	0	0	1%	0
pagurids	0	(3)	(3)	(3)
Balanus sp.	0	1%	1%	0
Ophiopholis	present	present	0	0
Tonicella	(1)	0	0	0

TABLE 27 (Cont.)

QUADRAT DATA ($0.25m^2$) FROM ZAIKOF BAY, SUBTIDAL ZONE
MARCH 20, 1976

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Pododesmus	0	0	0	(2)
Amphissa	0	(2)	0	0
Lacuna	present	0	present	present
Searlesia	0	(3)	0	0
Volutharpa ampullacea	0	(1)	0	0
Myxicola	(3)	0	0	0
serpulidae	(9)	(16)	(2)	(3)

Location: off NMFS Transect

Depth (meters): 4.0-5.0

Substrate type: rock pavement

QUADRAT DATA (0.25m^2) FROM ZAIKOF BAY, SUBTIDAL ZONE
MARCH 20, 1976

Cover and Composition:

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Laminaria yezoensis	0	0	(1)	0	0
Laminaria groenlandica	25%(3)	0	25%(1)	25%(2)	15%
Laminaria (juveniles)	0	0	0	0	(1)
Agarum	70%(1)	25%	15%(2)	10%	75%(3)
Constantinea	2%	1%	0	0	0
Ralfsia	30%	10%	0	5%	0
encrusting coralline	30%	20%	15%	30%	20%
Hildenbrandia	5%	5%	0	20%	25%
filamentous reds	1%	1%	0	3%	0
Microporina	3%	2%	5%	5%	(3)
pagurids	(2)	0	(4)	(2)	(3)
Heteropora	0	0	0	1%	0
Trichotropis	0	0	(1)	(2)	0
serpulidae	0	10%	0	(1)	0
Flustrella	1%	2%	1%	15%	5%
Distaplia	2%	0	0	0	1%
Margarites	0	0	0	(1)	(1)
? Archidistoma	0	2%	1%	1%	0
orange globular ascidian	0	0	0	8%	7%
Halocynthia aurantium	(1)	0	0	0	0
Tonicella	(2)	(2)	(1)	(2)	(1)
Musculus discors	(2)	0	0	0	0
Cryptobranchia	present	present	0	present	present
Trichotropis	0	0	(1)	(2)	0
Puncturella	(1)	0	0	0	0
Fusitriton	0	0	(1)	0	0
Trophon	(1)	0	(3)	(1)	0
Ophiopholis	present	0	0	0	0
Strongylocentrotus	0	0	(1)	0	0
Balanus sp.	5%	12%	10%	15%	2%

Location: NMFS Site
Depth: 9-10m
Substratum: Boulder Field

TABLE 29

HAPHAZARD QUADRAT CASTS (0.25m^2)
FROM THE SUBLITTORAL ZONE IN ZAIKOF BAY
MARCH 20, 1976

(No. 1) Depth 10.5m; Sand, Shell Debris & Silt

Taxon	Percent Cover (number of individuals)
Laminaria (juvenile)	(1)
Rhodymenia	2%(2)
diatom scum	80%

(No. 2) Depth 10.5m; Sand & Silt

Taxon	Percent Cover (number of individuals)
Laminaria (juveniles)	(3)
unid. foliose red	(1)
diatom scum	90%
Orthasterias	(1)

(No. 3) Depth 10.5m; Sand & Silt

Taxon	Percent Cover (number of individuals)
diatom scum	80%
shell debris	20%

(No. 4) Depth 10m; Rock & Shell Debris

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(1)
Rhodymenia	(1)
Desmarestia	(1)
Unid. filamentous reds	2%

(No. 5) Depth 9m; Rock

Taxon	Percent Cover (number of individuals)
Agarum	(1)
Constantinea	5%(1)
Callophyllis	10%
Flustrella	5%
Microporina	30%
Evasterias	(1)

TABLE 29 (Cont.)

HAPHAZARD QUADRAT CASTS (0.25m2)
FROM THE SUBLITTORAL ZONE IN ZAIKOF BAY
MARCH 20, 1976

(No. 5) Cont.

Taxon	Percent Cover (number of individuals)
Ischnochiton	(1)
pagurids	(1)
unid. cottid	(1)

(No. 6) Depth 8.5m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(1)
Agarum	(3)
Callophyllis	2%
encrusting corallines	30%
Microporina	25%
Pycnopodia	(2)

(No. 7) Depth 8.5m; Rock

Taxon	Percent Cover (number of individuals)
Agarum	(5)
Callophyllis	2%
encrusting corallines	25%
Microporina	30%
Balanus	40%
Calliostoma	(2)

(No. 8) Depth 8.5m; Rock

Taxon	Percent Cover (number of individuals)
Agarum	(1)
Callophyllis	2%
Microporina	15%
Balanus	60%
Heteropora	5%

TABLE 29 (Cont.)

HAPHAZARD QUADRAT CASTS (0.25m^2)
FROM THE SUBLITTORAL ZONE IN ZAIKOF BAY
MARCH 20, 1976

(No. 9) Depth 7.5m; Rock

Taxon	Percent Cover (number of individuals)
Agarum	(1)
Callophyllis	5%
encrusting corallines	15%
Flustrella	5%
Microporina	5%
Balanus	25%
Calliostoma	(1)
Ischnochiton	(1)
Puncturella	(1)

(No. 10) Depth 8m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(2)
Laminaria (juveniles)	(2)
Agarum	(2)
Callophyllis	5%
encrusting corallines	60%
Microporina	10%
Flustrella	2%
Evasterias	(1)
Trichotropis	present

(No. 11) Depth 8m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(1)
Agarum	(1)
Callophyllis	5%
encrusting corallines	40%
Flustrella	5%
Balanus	2%
Trichotropis	(4)

TABLE 29 (Cont.)

HAPHAZARD QUADRAT CASTS (0.25m^2)
FROM THE SUBLITTORAL ZONE IN ZAIKOF BAY
MARCH 20, 1976

(No. 12) Depth 6.5m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(4)
Agarum	(3)
Callophyllis	2%
encrusting corallines	75%
Microporina	10%
Dendrobeania	2%
Flustrella	5%
Pycnopodia	(1)
Musculus discors	present

(No. 13) Depth 7m; Rock & Shell Debris

Taxon	Percent Cover (number of individuals)
Agarum	(4)
Callophyllis	5%
Microporina	10%
Balanus	20%

(No. 14) Depth 4.5m; Rock & Shell Debris

Taxon	Percent Cover (number of individuals)
Laminaria yezoensis	(1)
Laminaria groenlandica	(4)
Laminaria (juveniles)	(3)
Agarum	(5)
Rhodymenia	2%(1)
Odonthalia	5%
encrusting corallines	60%
Dendrobeania	2%
Balanus	30%

(No. 15) Depth 5m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(1)
Agarum	(6)

TABLE 29 (Cont.)

HAPHAZARD QUADRAT CASTS ($0.25m^2$)
FROM THE SUBLITTORAL ZONE IN ZAIKOF BAY
MARCH 20 1976

(No. 15) Cont.

Taxon	Percent Cover (number of individuals)
Rhodymenia	5%
Constantinea	(2)
unid. filamentous reds	20%
Hildenbrandia	5%
encrusting corallines	80%

(No. 16) Depth 5m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria groenlandica	(1)
Agarum	(6)
Rhodymenia	5%
Constantinea	1%(2)
unid. filamentous reds	20%
Hildenbrandia	5%
encrusting coralline	80%

(No. 17) Depth 3m; Rock

Taxon	Percent Cover (number of individuals)
Laminaria yezoensis	(2)
Agarum	(2)
Rhodymenia	15%
Ptilota	30%
Corallina	5%
encrusting corallines	85%

TABLE 30 & 31

QUADRAT DATA (0.25 m^2) FROM
ZAIKOF BAY, SUBTIDAL ZONE
JUNE 22 and 23, 1976

Percent Cover (Number of Individuals)

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Laminaria yezoensis	0	0	0	0	0	0	0	0	0	0	0	0
Laminaria groenlandica	0	0	0	0	20%(1)	0	0	0	0	0	80%(4)	30%(1)
Laminaria spp.	0	5%(6)	2%(5)	2%(2)	0	1%(1)	5%(6)	0	0	5%(10)	2%(15)	2%(4)
Agarum	0	0	0	0	50%(1)	30%(1)	35%	65%(1)	50%	0	15%	50%(2)
Pleurophycus	0	0	0	0	0	0	0	25%(1)	30%(1)	5%	0	0
Desmarestia viridis	25%	2%	15%	0	15%	35%	0	5%	0	20%	5%	0
Desmarestia ligulata var. ligulata	0	0	0	5%	0	0	0	0	0	2%	0	0
Ralfsia	P	0	0	0	0	0	0	0	0	P	0	0
encrusting coralline	0	0	25%	2%	5%	0	0	60%	60%	0	50%	30%
Hildenbrandia	0	0	0	0	0	0	0	0	20%	0	0	0
filamentous reds	0	2%	0	2%	15%	10%	0	0	5%	0	0	0
Callophyllis	0	0	0	0	0	0	0	0	5%	0	0	0
Microcladia	0	0	0	2%	0	0	2%	2%	0	0	20%	0
Phycodrys	0	0	0	0	0	0	0	0	2%	0	0	5%
Bossiella	0	0	0	0	0	0	0	0	0	0	0	2%
Microporina	0	0	5%	5%	25%	10%	25%	25%	60%	25%	20%	0
pagurids	0	(4)	0	(1)	0	(1)	0	0	0	0	(2)	(3)
Trichotropis	0	0	0	0	0	0	0	0	0	0	0	0
serpulidae	0	0	0	0	0	0	0	0	0	0	0	0
Flustrella	0	0	0	0	0	0	0	0	0	0	5%	5%
Balanus sp.	30%	15%	10%	0	0	0	5%	30%	0	0	0	0
Didemnum	0	0	0	0	5%	5%	5%	5%	10%	5%	5%	0
Dendrobeania	0	2%	0	0	0	15%	0	0	0	10%	10%	10%
foliose reds, unid.	0	0	0	0	0	0	10%	0	0	0	0	0
Abietinaria	5%	0	5%	0	0	2%	0	0	0	0	0	0
Heteropora	2%	0	0	0	0	0	0	0	0	0	0	0
Distaplia	2%	0	0	0	0	0	0	0	0	0	0	0
Tricellaria	0	0	2%	0	0	0	0	0	0	0	2%	2%
Grammaria sp.	30%	5%	10%	5%	25%	15%	10%	0	0	0	0	0
Hippodiplosia	2%	0	0	0	0	0	2%	0	0	0	0	0
Alcyonidium	0	0	0	0	5%	5%	2%	0	5%	0	0	2%
Hydractinea	P	0	0	0	0	0	0	0	0	0	0	0
Fusitriton	(1)	0	0	0	0	0	0	0	0	0	0	0
Ishnochiton spp.	(1)	0	0	0	0	0	0	(1)	0	0	0	0
Tonicella spp.	(2)	0	0	0	0	0	0	(1)	0	(1)	0	(1)
Corella	0	0	(1)	0	0	0	0	0	0	0	0	0
Henricia spp.	0	0	0	0	0	(1)	0	(1)	0	0	0	0
Orthasterias	0	0	0	0	0	0	(1)	0	0	0	0	(1)
Musculus ? discors	0	0	0	0	P	0	0	0	0	0	0	0
Pycnopodia	0	0	0	0	(1)	0	0	0	0	0	0	0
Solaster stimpsoni	0	0	0	(1)	0	0	0	0	0	0	0	0
Phidolopora	0	0	0	0	0	0	0	2%	0	0	0	0
Diadora	0	0	0	0	0	0	0	0	(1)	0	0	0
Trichotropis	0	0	0	0	0	0	0	0	(1)	0	0	(1)
Acmaea mitra	0	0	0	0	0	0	0	0	0	(1)	0	0
fan bryozoan	0	0	0	2%	5%	0	0	0	0	0	0	0
Depth:	15.5m	15.5m	13.5m	13.5m	12.0m	12.0m	12.0m	10.5m	10.5m	9.0m	9.0m	7.5m
Substrata:	Sand, rock & shell debris	Rock, sand & shell debris	Rock, sand & shell debris	Rock, sand & shell debris	Rock & shell debris	Rock	Rock	Rock	Rock	Rock & coarse sand	Rock & sand	Rock

quadrat counts. The third important member of this understory kelp guild was Pleurophycus gardneri. During the first three visits we did not record this species. Despite our oversight, Pleurophycus was obviously present since mature individuals were seen in the shallow regions of the reef complex during the June (1976) survey. The greatest number of Pleurophycus were attached to boulders in the 5-7 meter depth contour. For example, in June (1976) densities ranged from 0 to 6.80/m^2; the average in 10 band transects was 0.88/m^2 (Table 23) compared with an average density of 0.67/m^2 in the quadrat counts for the same sample period (Table 31).

The other conspicuous or characteristic macroalgae in this location were the reds: Callophyllis spp., Constantinea, Microcladia borealis and Rhodymenia spp. Crustose and articulated coralline algae were typically shallow in distribution and abundance. Drift or detached bull kelp (Nereocystis) was seen along the southern shores of Zaikof Bay, however it was not until June of 1976 that we actually observed attached bull kelp in the study site. Young Nereocystis or juvenile sporophytes grew on the rock substrate within the boulder field; densities averaged 0.14/m^2 during the summer survey (1976).

EPIFAUNA AND TROPHIC INTERACTION

A variety of epifaunal forms were observed in the relatively narrow macrophyte belt below MLLW. Suspension or filter feeders were abundant in this location. Most of these animals occurred along a narrow portion of the shoreline that was dominated by rock pavement and large rocks or boulders. The suspension feeders, along with the macrophyte species flourished from MLLW down to approximately 10 meters below the "0" elevation of the tide. The vertical faces of the rock substrates generally supported the greatest number of organisms. The dominant sessile forms were the bryozoans *Microporina borealis*, *Flustrella gigantea*, *Heteropora* spp. and *Dendrobeania murryani*; barnacles *Balanus* spp., serpulid worms; a nestling mytilid *Musculus discors* and the ascidians *Distaplia ? occidentalis*, *Halocynthia aurantium*, and *Didemnum* or *Trididemnum*. Hydroids were also common on rock substrata; the genera *Abietinaria* and *Grammaria* were particularly common during the June (1976) survey. For example, the tall statured *Grammaria* was recorded in 7/12 quadrats (.25m^2), with estimates of percent cover ranging between 0 and 30 percent, with an average coverage of 8.3 percent during this summer sample period.

Microherbivores were common on these same rock substrates. A few of the common species are listed in Table 32. Of the three genera, the most abundant and frequently encountered in the vegetative undergrowth was hermit crabs of the genus *Pagurus*. Hermit crabs occurred in 26/52 quadrats, with maximum densities of 24.0/m^2. The average density

TABLE 32

CHARACTERISTIC OR REPRESENTATIVE IMPORTANT SPECIES
AT ZAIKOF BAY, ROCKY SUBLITTORAL

Species	Occurrence	Major Taxon	Trophic Category
Agarum cribrosum (P)	A	Brown alga	Producer
Laminaria groenlandica (P)	C	Brown alga	Producer
Laminaria yezoensis (P)	C	Brown alga	Producer
Pleurophycus gardneri (P)	C	Brown alga	Producer
Desmarestia viridis (A)	C	Brown alga	Producer
Encrusting coralline (P)	A	Red alga	Producer
Microcladia borealis (?)	C	Red alga	Producer
Constantinea spp. (P)	C	Red alga	Producer
Callophyllis spp. (?)	C	Red alga	Producer
Ralfsia spp. (P)	C	Brown alga	Producer
Microporina borealis (A)	C	Bryozoan	Suspension feeder
Flustrella gigantea (P)	C	Bryozoan	Suspension feeder
Balanus spp. (P)	A	Barnacle	Suspension feeder
Grammaria sp.	C	Hydroid	Suspension feeder
Heteropora sp. (P)	C	Bryozoan	Suspension feeder
Pycnopodia helianthoides (P)	C	Sea star	Predator
Orthasterias koehleri (P)	C	Sea star	Predator
Dermasterias imbricata (P)	C	Sea star	Predator
Crossaster papposus (P)	C	Sea star	Predator
Henricia spp. (P)	C	Sea star	Suspension feeder/predator
Evasterias troschelii (P)	C	Sea star	Predator
Fusitriton oregonensis (P)	C	Snail	Predator/scavenger
Musculus discors (A)	C	Mussel	Suspension feeder
Tonicella spp. (P)	C	Chiton	Herbivore
Pagurus spp. (P)	A	Hermit crab	Herbivore/Scavenger
Margarites pupillus	C	Snail	Herbivore
Enhydra lutris (P)	C	Sea otter	Predator

Key: (P) = perennial
(A) = Annual
A = abundant
C = common
U = uncommon

was 5.1/m^2 in all quadrats combined. Members of this genus are reputed to be opportunistic consumers, and some species are known to consume both plant and animal matter. Herbivory was observed on attached macroalgae, particularly along the erroded edges of older blades where bacterial decomposition and tissue breakdown was no doubt great.

Several chitons (Tonicella insignis, T. lineata; Mopalia spp. and Ishnochiton spp.) and snails (Margarites pupillus, Calliostoma ligatum, Cryptobranchia spp., Puncturella spp., and Acmaea mitra) were also common in this location. The most common genera was Tonicella, and densities ranged as high as 8.0/m^2. Tonicella spp. occurred in 15 of 52 quadrats (.25m^2). Margarites and Calliostoma both reached densities of 4.0/m^2, and most often were seen on either rock or algal substrates. Most of these mollusks are microherbivores, and as such feed on the diatom film or algal turf that is generally composed of gametophytes and algal sporelings.

Macroherbivores, such as sea urchins were uncommon in this location, although a few relatively small individuals were encountered during the quadrat sampling efforts. Most of the green sea urchins (Strongylocentrotus drobachiensis) were less than 30 cm in diameter and were typically cryptic in habit. Densities of S. drobachiensis ranged from 0 to 4.00/m^2, and averaged 0.04/m^2 in the 52 haphazardly placed quadrats. Frequency of occurrence was 1/52 in this same quadrats.

These data are comparable to the transect sampling, for only 1 green sea urchin was encountered during this phase of the field work, and densities ranged from 0 to $0.02/m^2$ in the 292 square meters of seafloor that was sampled by band transects (Tables 33 and 34).

There are a number of other herbivores in the inshore system; i.e. amphipods, isopods, fishes etc.; however, no information has been generated from these groups of organisms since their occurrence at Zaikof Bay was more transient or ephemeral over the 1-year (1975-76) sample period. Other invertebrate species which utilized the seaweed resource in the bay were Lacuna carinata (snail); Diadora aspera (limpet); Mopalia spp. (chitons); Pugettia gracilis (decorator crab); Punturella spp. (snail) and Dermasterias imbricata (sea star).

As stated earlier, the sedentary or attached organisms were common on the solid substratum, and most of these species because of restrictions of mobility gather or collect food items that have either fallen or drifted to them in the water column. Most of the detritus that reaches the seafloor probably needs to be reworked further or broken down by bacterial action before it can be assimilated by the macroinvertebrates of the reef. Conspicuous members of this trophic guild included the articulated bryozoan Microporina borealis, which occurred in 40 of 52 quadrats, and covered between 0 and 60 percent of solid substrate. The average coverage over the 1-year period was 12.56 percent (Tables 24-31). Microporina longevity is unknown, although in some locations of the Northern Gulf the colonies appeared to be short-lived. Another

TABLE 33

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS AT ZAIKOF BAY
(estimates were derived from band transects)

Taxon	11-23-75	11-23-75	11-23-75	11-24-75	11-24-75	03-19-76	03-20-76	03-20-76	03-20-76
Pyncopodia helianthoides	19 0.38/m^2	5 0.25/m^2	12 0.48/m^2	16 0.64/m^2	4 0.18/m^2	11 0.22/m^2	8 0.80/m^2	3 0.30/m^2	9 0.90/m^2
Dermasterias imbricata	2 0.04/m^2	0	1 0.04/m^2	0	0	0	0	0	0
Orthasterias koehleri	3 0.06/m^2	1 0.05/m^2	1 0.04/m^2	0	1 0.05/m^2	5 0.10/m^2	1 0.10/m^2	1 0.10/m^2	0
Crossaster papposus	2 0.04/m^2	2 0.05/m^2	1 0.04/m^2	0	4 0.18/m^2	4 0.08/m^2	1 0.10/m^2	1 0.10/m^2	0
Solaster spp.	1 0.02/m^2	1 0.03/m^2	0	0	1 0.05/m^2	0	0	0	0
Henricia spp.	1 0.02/m^2	3 0.07	4 0.16/m^2	1 0.04/m^2	2 0.09/m^2	5 0.10/m^2	1 0.10/m^2	0	1 0.10/m^2
Evasterias troschelii	3 0.06/m^2	1 0.03/m^2	2 0.08/m^2	2 0.08/m^2	0	7 0.14/m^2	0	2 0.20/m^2	0
Strongylocentrotus spp.	0	0	0	0	0	1 0.02/m^2	0	0	0
Area sampled:	25 x 2m	20 x 2m	25 x 1m	25 x 1m	22 x 1m	50 x 1m	10 x 1m	10 x 1m	10 x 1m
Depth:	11-12m	10-11m	6-7m	12-13m	7-8m	7-12m	10.5m	8m	4.5m
Substrate type:	Rock	Rock & Sand	Rock	Rock & Sand	Rock	Rock	Rock & Sand	Rock	Rock

TABLE 34

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS
AT ZAIKOF BAY

(Estimates Were Derived from Band Transects)

Taxon	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	6-22-76	Combined $\bar{x}/m^2$
Pycnopodia helianthoides	2 $0.40/m^2$	1 $0.20/m^2$	0	1 $0.20/m^2$	4 $0.80/m^2$	0	1 $0.20/m^2$	3 $0.60/m^2$	1 $0.20/m^2$	3 $0.60/m^2$	0.39
Dermasterias imbricata	0	1 $0.20/m^2$	0	0	0	0	0	0	0	3 $0.60/m^2$	0.01
Orthasterias koehleri	0	1 $0.20/m^2$	2 $0.40/m^2$	0	1 $0.20/m^2$	0	1 $0.20/m^2$	0	1 $0.20/m^2$	0	0.09
Crossaster papposus	1 $0.20/m^2$	0	0	0	0	0	0	0	0	0	0.04
Solaster spp.	0	0	0	0	0	0	0	0	0	0	0.01
Henricia spp.	0	0	0	0	1 $0.20/m^2$	0	1 $0.20/m^2$	0	2 $0.40/m^2$	0	0.08
Evasterias troschelii	0	0	0	0	0	0	0	0	0	0	0.03
Strongylocentrotus spp.	0	0	0	0	0	0	0	0	0	0	
Area sampled:	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	5x1 m	
Depth:	13.5 m	13.5 m	12.0 m	12.0 m	10.5 m	10.5 m	9.0 m	9.0 m	7.6 m	6.1 m	
Substrate type:	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Boulders	Boulders	Rock	Rock	Boulders	Boulders	

common bryozoan in this area was Flustrella gigantea, which frequently grew in either mat-like encrustations between boulders or attached to the shell of Fusitriton oregonensis (snail). Estimated coverage of Flustrella ranged between 0 and 35 percent, with an average in all quadrats combined of 2.83 percent. The frequency of occurrence in the shallow water zone was 23/52. Based on observations made in Kachemak Bay (ADF&G, 1977), the canopy produced by Flustrella colonies are important habitats or nursery areas for juvenile crabs and shrimps. The colonies appeared to be perennial, and the only predator known to feed upon Flustrella in Prince William Sound is the white dorid nudibranch (Archidoris odhneri).

A third bryozoan, Heteropora spp. formed calcareous, branched colonies that are frequently referred to as coral by the fishermen of the Sound. Heteropora occurred in 10/52 quadrats, with maximum coverage of 5 percent in the haphazardly placed quadrats. Duration of life is unknown, however, judging from the size of some colonies it appeared to be long-lived. Few predators of Heteropora are known from this site, however, one occasional predator is the sun star, Pycnopodia helianthoides (Figure 10), and another known predator from the Northern Gulf is the China rockfish, Sebastes nebulosus, which probably ingests the colonies incidental to eating the brittle star (Ophiopholis aculeata) (Rosenthal, unpublished data).

Balanoid barnacles: Balanus nubilus, B. ? crenatus and B. glandula encrusted substantial portions of the rock substrate beneath

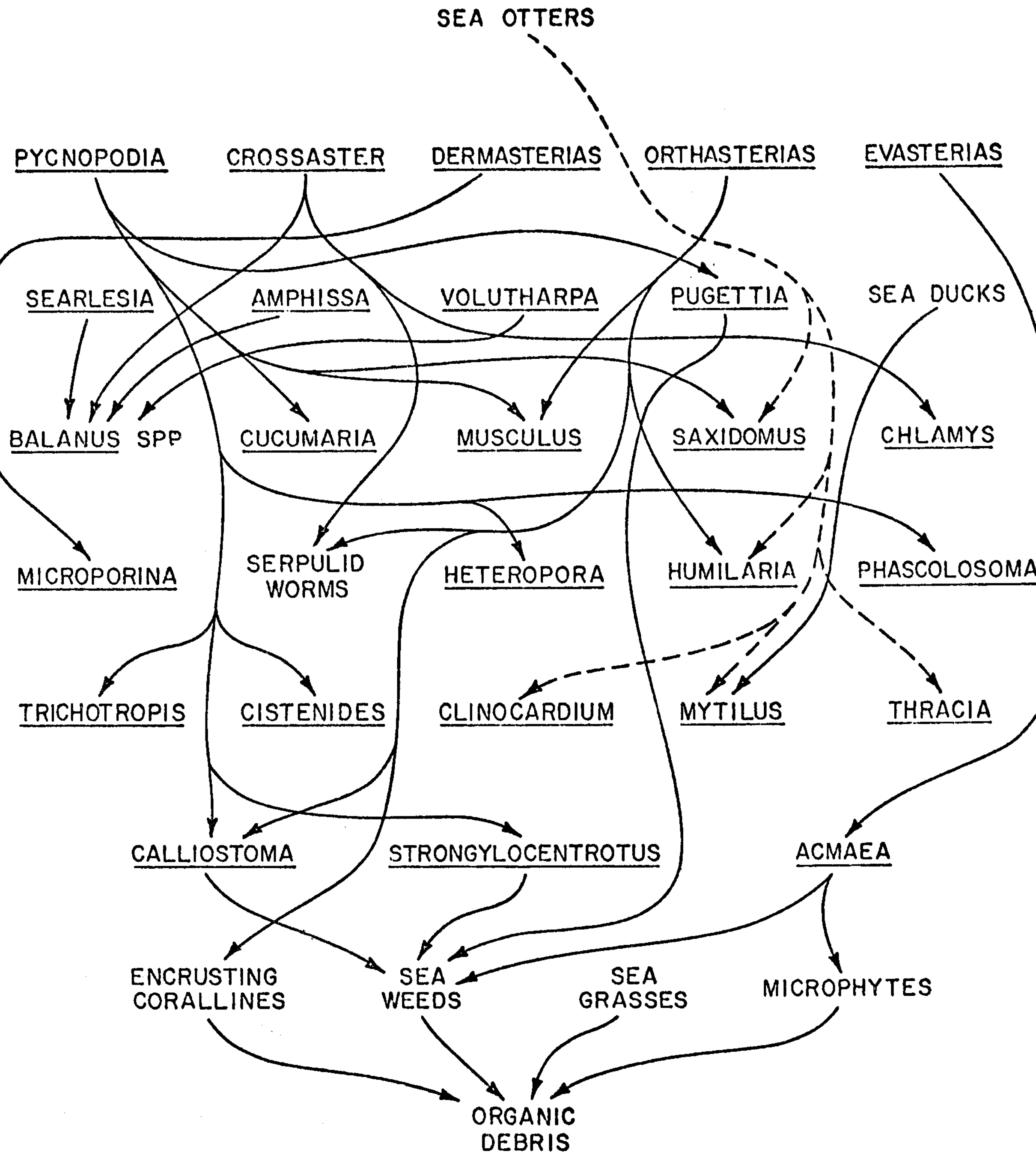

Figure 10. Food web for the conspicuous species in the shallow sublittoral zone at Zaikof Bay, Montague Island.

the vegetative undergrowth. Estimates of barnacle coverage ranged between 0 and 60 percent, with an average of 7.8 percent in all of the quadrats (.25m^2). Barnacles occurred in 23 of 52 quadrats. Some of the predators of Balanus spp. in this location included the snails: Searlesia dira, Amphissa columbiana and Volutharpa ampullacea; the sea stars Crossaster papposus and Orthasterias koehleri.

The mytilid, Musculus discors is another member of the suspension feeding guild. It occupies a considerably different niche than it's congener M. vernicosus, and has adopted a substantially different pattern of life history. Most live in byssus nests attached to the vertical faces of rocks, or the holdfast portion of kelps. The population at Zaikof Bay contained a large proportion of adults (Figure 11), which brood tremendous numbers of eggs within the byssal nests until the juveniles are at least 0.5 mm in shell length. A length-weight regression for the winter population is presented in Figure 12. Shell debris at the base of the reef indicate that Musculus populations have been successful in this location during the past few years.

Some of the major predators at Zaikof Bay are listed in Table 32, and of these 6 species are sea stars, 1 is a snail and 1 a sea mammal. Other important tertiary consumers in the bay include crabs, shrimps, gastropods, sea anemones, fishes, marine mammals and sea ducks. Sea stars were the visual dominants in this trophic level. The sun star Pycnopodia was the numerical dominant in the 292 square meters of seafloor that was quantitatively sampled by band transects (Tables 33 and

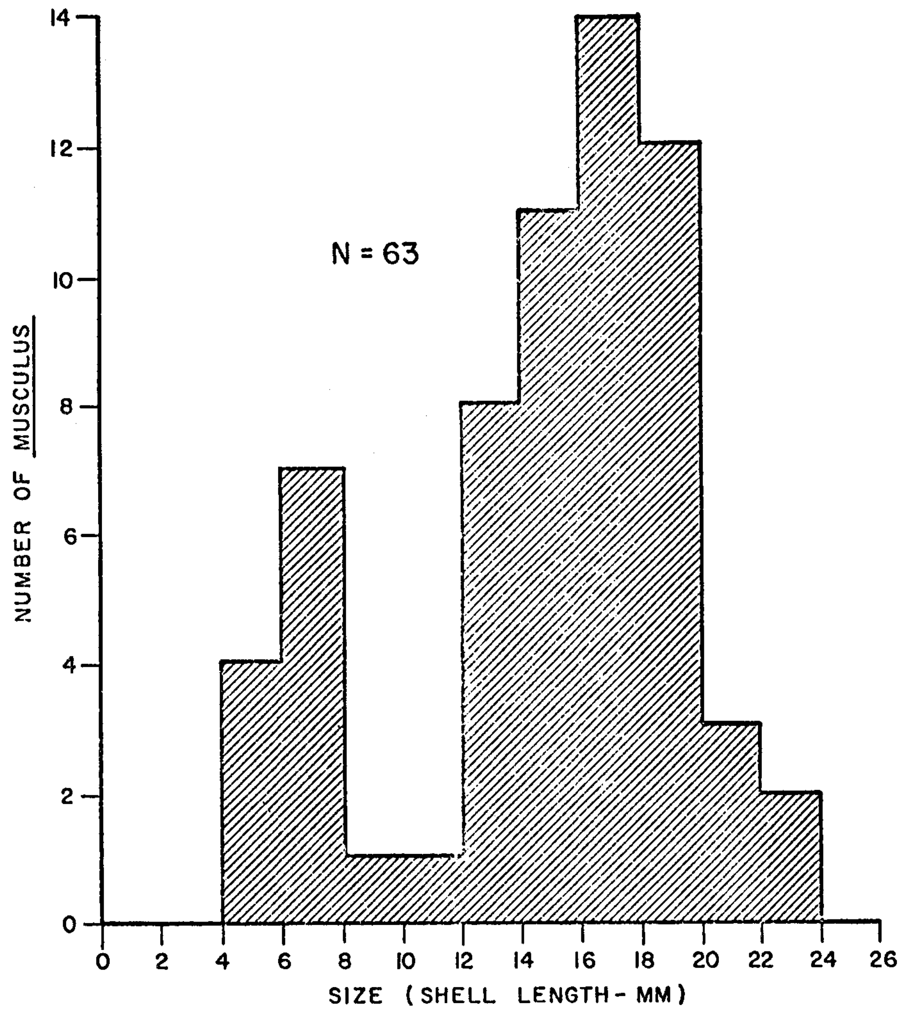

Figure 11. Size frequency histogram for *Musculus discors* collected from the subtidal zone in Zaikof Bay, 20 March 1976.

34). Density estimates ranged between 0 and 0.90 individuals/m^2; average density in all of the combined transects was 0.39/m^2. Pycnopodia is an opportunistic predator, and was observed to prey on a wide variety of species and trophic levels such as: Trichotropis spp. (snail); Calliostoma ligatum (snail); Musculus spp. (mussel); Saxidomus gigantea (clam); Cucumaria spp. (sea cucumber); Strongylocentrotus drobachiensis (sea urchin); Cistenides (polychaete); Heteropora spp. (bryozoan); Phascolosoma (sipunculid), and Pugettia gracilis (crab).

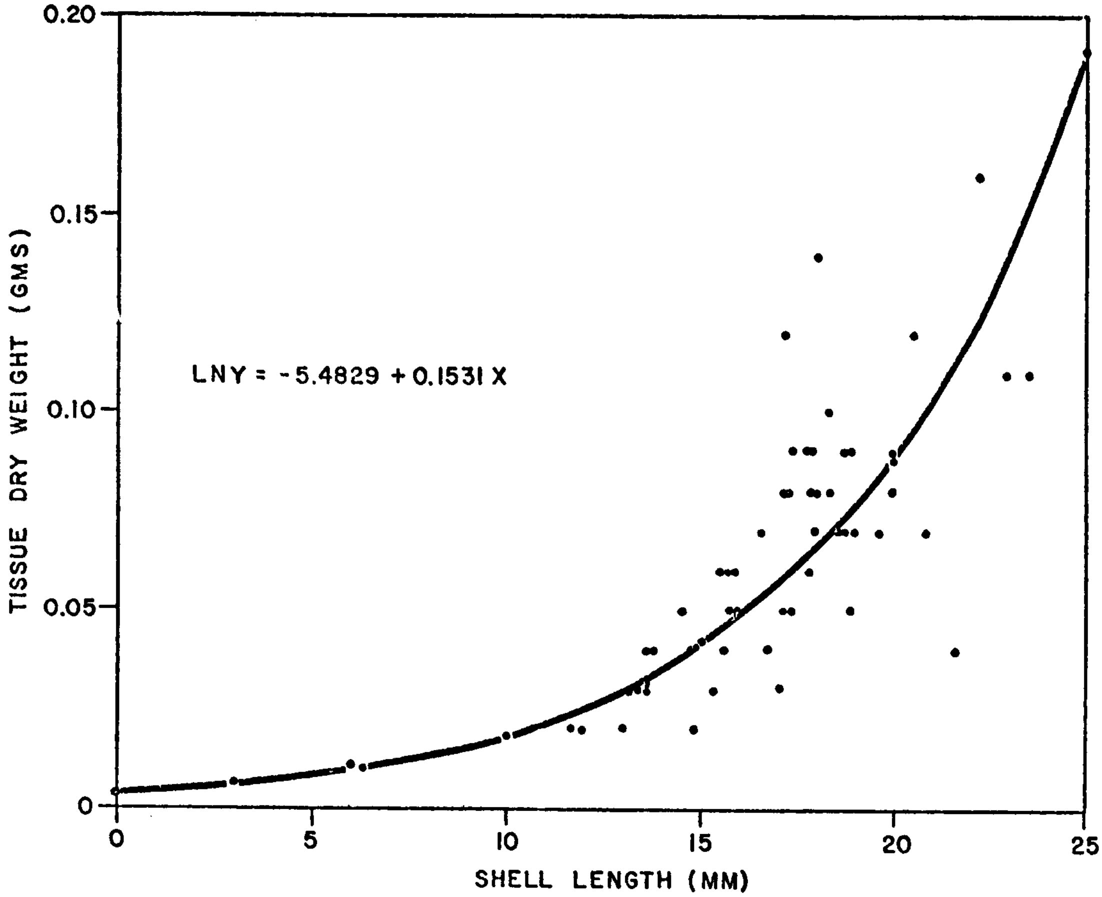

Figure 12. Relationship between shell length and dry tissue weight for *Musculus discors* from Zaikof Bay, 20 March 1976.

The second most abundant sea star was Orthasterias koehleri; density estimates ranged from 0 to 0.20/m^2, with an average of 0.09/m^2 in the band transects. Typically, it preyed on bivalve mollusks such as Musculus discors, Humilaria kennerlyi (clams) and barnacles Balanus spp.

The blood star Henricia spp. was the third most abundant genus in the shallow sublittoral zone. Since individuals were not identified to species, feeding type cannot be identified. However, one of the species present in this location H. leviuscula, is reputed to be a suspension feeder. Mode of feeding in the other species (H.

tumida) is unknown. Densities of Henricia ranged from 0 to $0.40/m^2$ with the average density of $0.08/m^2$.

Another common sea star was the multi-rayed star Crossaster papposus; estimates of density ranged from 0 to $0.20/m^2$, and the average density in all band transects was $0.04/m^2$. Individuals were seen eating serpulid worms, balanoid barnacles and a scallop Chlamys ? rubida. Most were seen either on rock substrate, or were attached to taller statured kelps in the algal understory.

Two other genera, the mottled star (Evasterias troschelli), and the genus Solaster are listed in Tables 33 and 34. Estimates of Evasterias ranged from 0 to $0.20/m^2$, with an average density of $0/03/m^2$. Solaster stimpsoni and S. dawsoni are presented under the one genus, and as such ranged from 0 to $0.05/m^2$. The mean density in all transects during 1975-76 was $0.01/m^2$.

Numerous predators and scavengers were seen in Zaikof Bay, and these included several species of fish, namely rock, whitespotted and kelp greenling, great sculpin, antlered sculpin, irish lord, rockfish, northern ronquil and flounder (Table 31). Although marine birds and mammals were not surveyed, several species of sea duck, i.e. white-winged scoter, barrow's goldeneye, and great scaup (Table 35), were seen feeding in the shallow waters of the bay. Scoters were seen diving for bay mussels (Mytilus edulis) during the March and June (1976) surveys.

Sea otters are common in Zaikof Bay, with some of the feeding directed at the clams Humilaria, Saxidomus, Clinocardium, Thracia and

TABLE 35

A LIST OF AQUATIC BIRDS AND MAMMALS OBSERVED AT THE OCS STUDY SITES DURING 1975-76

COMMON NAME	SCIENTIFIC NAME	LOCATION
	WATER BIRDS	
Harlequin duck	*Histrionicus histrionicus*	L;Z
White-winged scoter	*Melanitta deglandi*	L;M;Z
Oldsquaw	*Clangula hyemalis*	M;Z
Mallard duck	*Anas platyrhynchos*	L
Greater scaup	*Aythya marila*	M;Z
Barrow's goldeneye	*Bucephala islandica*	M;Z
Cormorant	*Phalacrocorax* sp.	L
Black-legged kittiwake	*Rissa tridactyla*	L
Glaucous-winged gull	*Larus glaucescens*	L;M;Z
Grebe	*Podiceps* sp.	M
Common murre	*Uria aalge*	L
Murrelet	*Brachyramphus* sp.	L;M;Z
Pigeon guillemot	*Cepphus columba*	L
Black oyster catcher	*Haematopus bachmani*	L;M
	MAMMALS	
Sea otter	*Enhydra lutris*	L;M;Z
Land otter	*Lutra canadensis*	L
Harbor seal	*Phoca vitulina*	L;M;Z
Steller sea lion	*Eumetopias jubata*	L;M;Z
Harbor porpoise	*Phocoena phocoena*	L;M;Z
Killer whale	*Orcinus orca*	L;Z
Dall porpoise	*Phocoenoides dalli*	Z
Minke whale	*Balaenoptera acutorostrata*	L

Location Symbols:

L = Latouche Point
M = Macleod Harbor
Z = Zaikof Bay

bay mussel (M. edulis). Shell debris was moderately abundant on the sandy slope below the boulder field.

SEASONAL PATTERNS

The macrophyte assemblage in the shallow waters of Zaikof Bay exhibited changes in both algal cover, and number of species present with the movement of time from July, 1975, until June, 1976. The most pronounced change was in the algal undergrowth, particularly the brown algae or phaerophytes. For example, during the November (1975) survey most of the laminarian kelps had either shed or lost most of the blade material above the meristematic growth region. Drift and/or detached pieces of plants, particularly sieve kelp (Agarum); elephant-ear kelp (Laminaria groenlandica) and leaves or turions of eelgrass (Zostera marina) were prominent on the bottom, particularly on soft substratra below the boulder field. Even leaves of terrestrial origin, such as alder were conspicuous in the shallow subtidal.

One of the seaweeds in the brown algal guild that oscillated in areal cover with the change of seasons was hair-kelp (Desmarestia viridis). Desmarestia viridis was rare in the study area during November, however, by late June, it occurred in 8/12 quadrats, and covered between 0 and 35 percent of the area contained in these .25m^2 quadrats. Average coverage for this same time period was 10 percent (Figure 13). Desmasteria viridis is reputed to be perennial alga (Champan 1974), however, it does undergo a perennation (die back) process during fall, with renewed growth during late winter and early spring. Many of the foliose (leaf-like), and filamentous varieties of red algae are also highly seasonal in occurrence and physical appearance. Some of these like the filamentous reds Pterosiphonia bipinnata and Polysiphonia pacifica are summer plants, while others such as the peltate red Constantinea subulifera apparently persist for a number of years provided the plant remains attached to the seafloor.

Several changes in the epifauna were also evident in this location. For instance, during 1975-76, the hydroids Grammaria sp. and Lafoea varied in abundance (coverage) in a similar fashion as the macroalgae; both hydroids covered up to 30 percent of the available surface area in the .25m^2 quadrats. However, prior to the summer survey both genera were rare or absent in this location. Grammaria and Lafoea both appear to be either annuals or exhibit substantial variation in cover and relative abundance during a year's time.

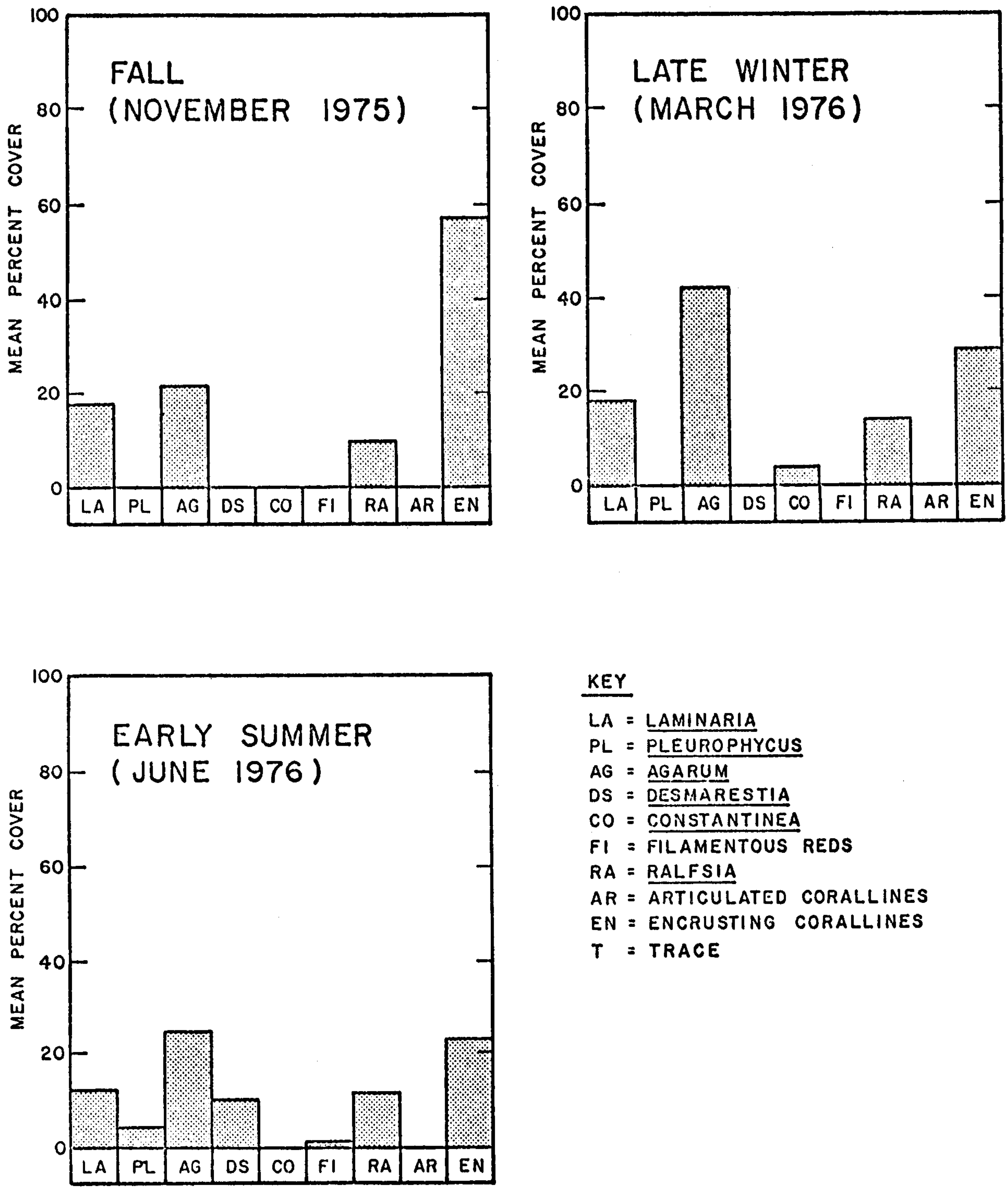

Figure 13. Algal cover at Zaikof Bay.

DESCRIPTION OF THE STUDY SITE (MACLEOD HARBOR)

Macleod Harbor, located on the southwest end of Montague Island (Figure 1) is generally protected from the Gulf of Alaska; however, it does receive some ocean swell and storm surf from Montague Strait. The northern shoreline from the entrance at Point Woodcock to about midway into the harbor is rocky and irregular. The head of the bay is shallow and fed by a large freshwater stream. Fresh water is a prominent feature of the upper part of the water column. The southwest coast of Montague Island was raised by as much as 30 feet during the Good Friday Earthquake of 1964 (Plafker, 1969). One effect of the quake was to separate the pre-earthquake littoral zone from the post earthquake shoreline.

At present, the shoreline is characterized by a band of solid substratum composed of boulders and cobbles (Figure 14). Steeply sloping rocky cliffs overlook the NMFS intertidal station on the northern shores of Macleod Harbor. Sitka spruce and hemlock grow above the rocky buttress. A number of exposed low profile ridges, extend from shore into the shallow subtidal zone. Between these ridges or fingers of rock are broad surge channels. The sublittoral zone in this part of Macleod Harbor is composed of a narrow band of bedrock approximately 40 to 70m wide. Seaward of the exposed bedrock, at depths ranging between 6 and 9m below the sea surface, the seafloor was comprised of sand, silt and moderate amounts of shell material. The surface of the sand was usually covered by a thin layer of benthic diatoms, and sulfur bacteria spotted numerous areas of the bottom.

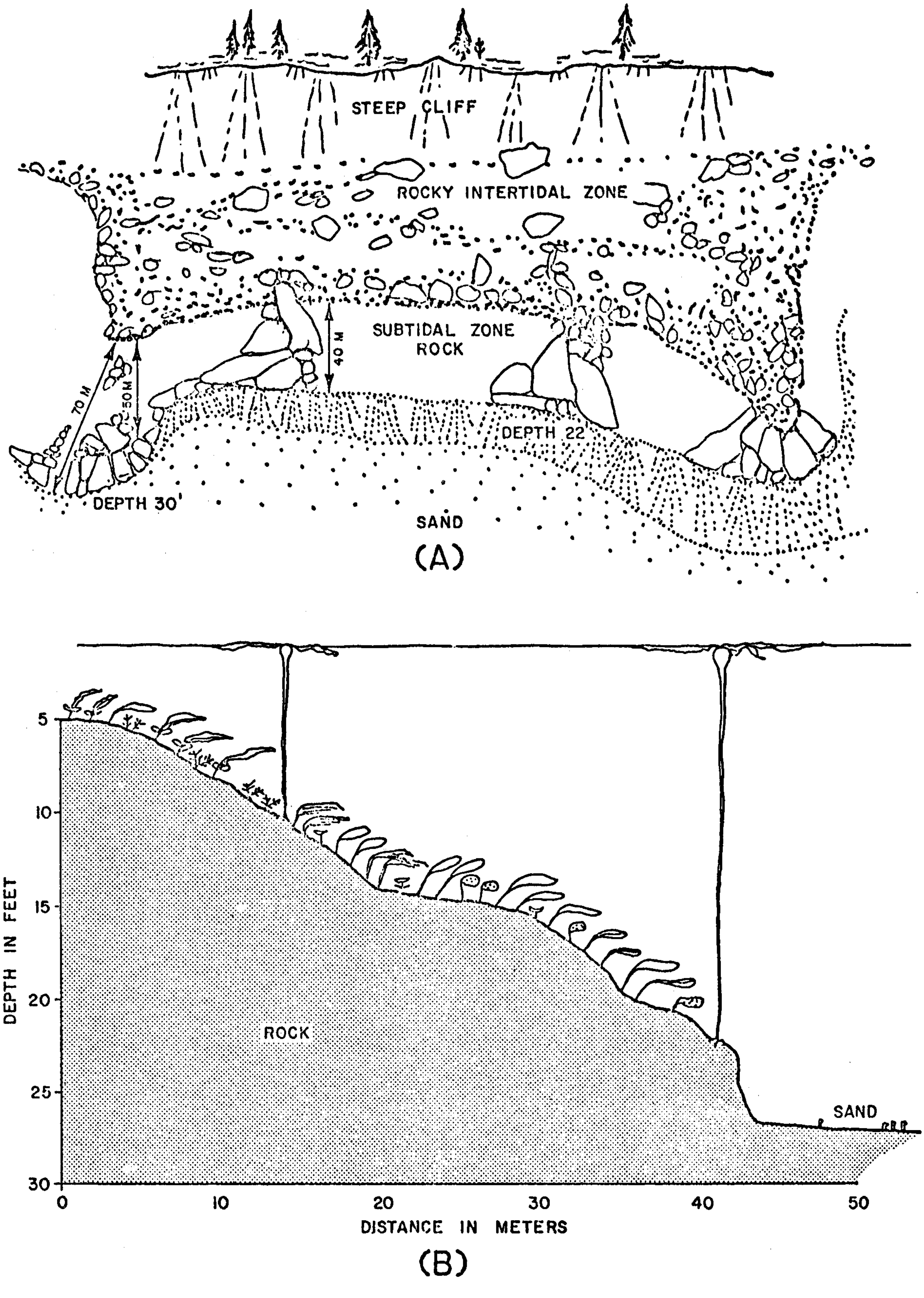

Figure 14. Study site (A) and subtidal vegetative canopies (B) at Macleod Harbor.

BIOLOGICAL SETTING (ALGAL ASSEMBLAGE)

A prominent feature of this location was the fringing bed of bull kelp (*Nereocystis luetkeana*) that occurred along the northern shoreline. During summer, the bed extended from the rocky promontory midway into the bay to approximately .25 nautical miles beyond Pt. Woodcock. Most of the bull kelp was scattered along the rocky reefs and in only a few locations was the surface canopy moderately heavy. Plants grew from MLLW to approximately 12 meters below the sea surface. Density estimates ranged from 0 to $0.46/m^2$, with an average density of $0.07/m^2$ (Table 36).

A thin band of rockweed (*Fucus distichus*) grew on the rock substrate above MLLW. Below the *Fucus* zone around the intertidal-subtidal fringe was a narrow girdle of *Alaria ? tenuifolia*. The brown alga, *Costaria costata* also occurred in the shallow water. *Costaria* is an annual species, and during March (1976) juvenile sporophytes were common in this location. Along most the rocky shoreline the seaweed belt was 40 to 70 meters wide; the width was largely determined by the availability of the hard or rock substrate. The sublittoral algal association was comprised of several layers or canopy levels. *Laminaria groenlandica* was the most abundant brown alga in the understory complex (Tables 37-50). Density estimates ranged from 0 to $64.00/m^2$, the average density during March 1976 was $14.80/m^2$ (Tables 44 to 50). Another congener, *L. yezoensis* was also common; densities ranged between

TABLE 36

DENSITY ESTIMATES OF SOME DOMINANT MACROPHYTES AT MACLEOD HARBOR
(estimates were derived from band transects of different lengths)

Taxon	9-15-75	9-15-75	9-15-75	3-13-76	3-13-76	3-15-76
Nereocystis luetkeana	0	0	23 $0.46/m^2$	0	0	0
Laminaria spp.	83 $16.6/m^2$	71 $14.2/m^2$	Not counted	42 $2.80/m^2$	31 $3.10/m^2$	36 $5.14/m^2$
Agarum cribrosum	35 $7.0/m^2$	13 $2.6/m^2$	Not counted	28 $1.87/m^2$	30 $3.00/m^2$	12 $1.71/m^2$
Pleurophycus gardneri	5 $1.0/m^2$	14 $2.8/m^2$	Not counted	0	18 $1.80/m^2$	2 $0.28/m^2$
Area sampled:	10 x 5m	10 x 5m	25 x 2m	15 x 1m	10 x 1m	7 x 1m
Depth:	7-8m	7-8m	5m	10m	4.5m	7.5-8.5m
Substrate type:	Rock & Kelp	Rock & Kelp	Rock	Rock & Sand	Rock	Rock & Sand

TABLE 37

QUADRAT DATA (0.25m^2) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13
Laminaria spp.	(3)	(2)	(3)	(3)	(1)	(9)		(13)	(7)	(6)	(3)	(1)	(1)
Agarum cribrosum	(2)				(1)						(1)	(1)	(1)
Constantinea						P							
Opuntiella						P	P	10%					
Encrusting coralline			15%			30%	80%	80%	50%				
Microporina	45%	20%		5%	2%		60%	25%		15%	10%	15%	30%
Dendrobeania	5%				2%				2%			2%	
Tricellaria							2%						
Heteropora							5%						
Didemnum/Trididemnum	2%					5%	5%						
Hippodiplosia				P									
Halocynthia aurantium												(2)	
Musculus									P				
Pycnopodia			(1)	(1)	(1)					(1)			
Dermasterias							(1)						
Thais lamellosa						(1)							
Tonicella						(1)							
Halocynthia igaboja						(1)							
Trophonopsis			(1)										
Depth (meters)	9.0	9.0	9.0	9.0	10.0	5.0	3.0	3.0	5.0	10.0	10.0	10.0	13.0
Substrate type:	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock	Rock	Rock	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock & sand

TABLE 38

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Agarum	50%	15%(1)	25%(3)
Laminaria spp.	0	10%(2)	50%(3)
Alaria sp.	0	10%	0
Encrusting coralline	70%	50%	40%
Hildenbrandia	20%	30%	20%
Didemnum/Trididemnum	3%	5%	2%
Yellow spatter sponge	15%	5%	5%
Sertularella	1%	0	2%
? Scrupocellaria	1%	0	Present
Microporina	50%	50%	30%
? Rhynchozoon	5%	1%	2%
Musculus discors	(1)	(1)	0
Tonicella	(3)	(1)	(1)
Serpulidae	(1)	0	0
Trichotropis	(3)	(1)	(1)
Metandrocarpa	0	Present	0
Synoicum	Present	0	Present
Crepipatella	(1)	(1)	(1)

Depth (meters): 10.0
Substrate type: Rock pavement
Location: Rock projection off NMFS station

TABLE 39

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2
Laminaria groenlandica	90%(3)(1)*	100%(13)(4)
Laminaria yezoensis	(2 holdfasts)	5%(2)
Agarum	0	10%(1)
Corallina	2%(1)	0
Encrusting coralline	80%	80%
Foliose reds, unid.	2%	0
Musculus vernicosus	1%	0
Tonicella	(3)	0
Acmaea mitra	(3)	(2)
Dendrobeania	0	3%
Sertularella	0	3%
Microporina	15%	15%
Pycnopodia	(1)	(2)
Pagurids	0	(5)
Cryptobranchia concentrica	0	(5)
Synoicum	0	1%
? Rhynchozoon sp.	1%	3%
Crepipatella lingulata	6%	5%
Yellow spatter sponge	1%	1%

Depth (meters): 6.0-7.0
Substrate type: Rock and boulders
Location: 200m S.E. NMFS station

* Plants undergoing blade renewal

TABLE 40

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	Percent Cover (number of individuals)			
	No. 1	No. 2	No. 3	No. 4
Laminaria groenlandica	4%(25)	15%	50%(6)	90%(3)
Laminaria yezoensis	5%(25)	15%(5)	10%(3)	0
Laminaria spp.	4%(25)	0	0	0
Cymathere triplicata	0	30%(7)	0	0
Desmarestia viridis	0	20%	0	0
Ptilota	0	0	0	5%(1)
Opuntiella californica	0	0	0	5%(1)
Constantinea	0	1%(1)	2%(3)	0
Hildenbrandia sp.	1%	0	0	0
Bossiella	0	0	0	2%
Corallina	0	0	5%	2%
Foliose reds, unid.	1%	1%	2%	5%
Ralfsia	0	0	0	0
Encrusting coralline	70%	5%	40%	20%
Musculus vernicosus	25%	20%	40%	10%
Tonicella	(3)	0	0	0
Acmaea mitra	(4)	0	0	0
Dendrobeania	1%	0	1%	1%
Sertularella	1%	0	0	0
Plumularia sp.	1%	0	0	0
Microporina borealis	0	0	5%	15%

TABLE 40 (Cont.)

QUADRAT DATA (0.25m^2) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4
Serpulidae	10%	0	0	0
Orange encrusting sponge	1%	0	2%	0
Yellow spatter sponge	0	0	5%	2%
Tricellaria sp.	0	0	0	2%
Pycnopodia	(1)	0	(1)	0
Didemnum/Trididemnum	0	0	0	1%
? *Ritterella*	0	0	0	1%(1)
Distaplia sp.	0	0	0	2%(1)
Pagurids	0	0	0	0
Balanus ? *alaskiensis*	0	0	0	(1)
Sand	25%	50%	0	25%

Depth (meters): 5.0
Substrate type: Rock outcrop
Location: 200m S.E. NMFS station

* Plants undergoing blade renewal

TABLE 41

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 29, 1975

Taxon	Percent Cover (number of individuals) No. 1	No. 2
Laminaria groenlandica	40%(4)	20%(4)
Laminaria yezoensis	20%(5)	20%(5)
Cymathere triplicata	5%(2)	0
Constantinea	2%(3)	0
Corallina	5%(2)	0
Foliose reds, unid.	10%	1%
Ralfsia spp.	1%	0
Encrusting coralline	20%	10%
Musculus vernicosus	20%	25%
Tonicella	0	(1)
Dendrobeania	1%	0
Microporina borealis	5%	1%
Yellow spatter sponge	5%	0
Pycnopodia	(1)	0
Pagurids	(3)	0
Distaplia	0	0
White colonial ascidian	1%(1)	0

Depth (meters): 5.0
Substrate type: Rock outcrop
Location: 200m S.E. NMFS station

TABLE 42

QUADRAT DATA (0.25m^2) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 30, 1975

Taxon	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20
Laminaria groenlandica	(2)		(1)	(3)	(2)	(5)	(3)		(8)	(5)
Laminaria yezoensis		(1)	(1)							
Laminaria spp.	(3)	(3)		(2)	(8)	(6)	(13)	(1)	(7)	(19)
Agarum cribrosum	(3)		(2)	(1)						
Ralfsia spp.										
Opuntiella	10%		P	P		P	P	P		P
Constantinea				P						
Hildenbrandia		20%	10%	20%	5%		10%	10%	15%	10%
Microporina	20%	60%	25%	25%	30%	20%	20%	20%	5%	10%
Tricellaria					5%				5%	
Abietinaria										10%
Heteropora	5%									
Encrusting coralline	70%	80%	70%	60%	70%	70%	60%	70%	60%	70%
Dendrobeania		5%								5%
Distaplia sp.			5%							
? *Ritterella*					2%			2%		
Pycnopodia								(1)		
Tonicella										(1)
Dermasterias						(1)				
Amphissa					(3)					
Calliostoma			(1)	(2)						
Evasterias										
Henricia							(1)			
Algal debris										
Acmaea mitra							(1)			
Depth (meters):	6.0	6.0	6.0	6.0	5.0	5.0	5.0	5.0	3.5	3.5
Substrate type:	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock

TABLE 43

QUADRAT DATA ($0.25 m^2$) FROM MACLEOD HARBOR, SUBTIDAL
NOVEMBER 30, 1975

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Laminaria groenlandica	(1)	(4)	(2)	(2)	(2)	(2)		(1)		
Laminaria yezoensis										(1)
Laminaria spp.		(1)								(2)
Agarum cribrosum		(1)	(1)			(4)	(4)	(1)		
Ralfsia spp.						P				2%
Opuntiella						P				
Constantinea										
Hildenbrandia						5%			15%	
Microporina	5%	25%	30%	10%		60%	50%	15%	20%	
Tricellaria		2%								20%
Abietinaria										2%
Heteropora									2%	
Encrusting coralline		25%	20%		10%	85%	75%	60%	30%	60%
Dendrobeania										
Distaplia										
? *Ritterella*			2%							
Pycnopodia										
Tonicella										(1)
Dermasterias										
Amphissa								(1)		
Calliostoma										
? *Lichenopora*						2%				
Evasterias						(1)				
Henricia							(1)			
Algal debris	50%		5%	5%	15%					
Acmaea mitra										
Depth (meters):	11.0	11.0	11.0	11.0	11.0	7.0	7.0	7.5	7.5	7.5
Substrate type:	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock & sand	Rock	Rock	Rock	Rock

TABLE 44

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 13, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3	No. 4	No. 5
Laminaria groenlandica	40%(13)	50%(16)	90%(6)	40%(12)	60%(7)
Agarum	(1)	(1)	0	25%(2)	0
Encrusting coralline	60%	70%	70%	60%	60%
Corallina	0	0	0	10%	0
Bossiella	0	15%	0	0	10%
Hildenbrandia	Present	Present	30%	20%	0
Opuntiella	0	(2)	0	0	0
Microporina	0	15%	0	1%	0
Distaplia	0	5%	0	0	0
Serpulidae	(2)	0	0	0	0
Tonicella	0	(1)	0	0	0
Musculus vernicosus	Present	Present	Present	Present	Present
Pagurids	0	(2)	0	0	0

Depth (meters): 3.0-5.0
Substrate type: Survey channel with rock bedrock

TABLE 45

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 14, 1976

Taxon	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Laminaria groenlandica		(1)	(2)	(4)	(3)	(5)		(5)	(3)	(3)	(4)
Laminaria yezoensis			(2)							(11)	(1)
Laminaria spp. (juv.)	(14)	(2)	(5)	(8)	(3)				(10)	(4)	(4)
Agarum cribrosum	(1)	(4)	(8)	(2)	(5)	(1)					(1)
Pleurophycus gardneri	(1)		(2)		(3)				(2)		
Ralfsia spp.			5%			5%					
Costaria costata									(3) juv.		
Nereocystis luetkeana											
Opuntiella		10%	2%		10%	10%					
Rhodymenia spp.						5%				2%	
Delesseria		2%			5%	15%	15%	10%	5%		
Callophyllis			2%		10%						
Hildenbrandia	10%	20%	15%			10%					
Microcladia	2%										
Encrusting coralline	60%	80%	80%	80%	85%	70%		75%	70%	10%	15%
Articulated coralline	5%	2%		15%	10%	5%		10%		10%	
Constantinea	2%								5%		
Tonicella	(1)	(1)	(2)		(1)					(1)	
Acmaea mitra					(1)	(1)					
Pycnopodia	(1)		(1)								
Musculus		P	P	P	P	P			P	P	P
Depth (meters):	8.0	8.0	6.0	6.0	.50	5.0	3.0	3.0	4.0	7.0	7.0
Substrate type:	Rock & sand	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock & sand	Rock & sand

TABLE 46

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 14, 1976

Taxon	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21	No. 22
Laminaria groenlandica	(1)	(2)	(1)	(6)	(15)	(5)	(8)	(2)	(1)	(2)	(3)
Laminaria yezoensis	(8)	(1)	(5)		(6)				(1)		(1)
Laminaria spp. (juv.)	(2)	(8)	(10)	(10)	(20)	(10)	(10)	(9)	(25)	(4)	(12)
Agarum cribrosum			(2)	(1)						(2)	
Pleurophycus gardneri											
Ralfsia spp.			5%	2%							
Costaria costata											
Nereocystis luetkeana											(3)
Opuntiella	5%		2%	5%		5%	15%	10%		2%	2%
Rhodymenia spp.	5%	2%				2%				5%	
Delesseria		2%	2%		2%	5%		5%			
Callophyllis											
Hildenbrandia				2%	10%	50%		10%			
Microcladia			5%	2%			20%				
Encrusting coralline	80%	50%	80%		50%	60%		65%	15%	20%	30%
Articulated coralline	5%					10%					
Constantinea		2%									
Tonicella	(1)										
Acmaea mitra	(1)		(1)								
Pycnopodia								(1)		(1)	
Musculus	P	P	P	P	P			P	P	P	P
Depth (meters):	7.0	7.0	6.0	6.0	6.0	5.0	4.0	6.0	5.0	5.0	6.0
Substrate type:	Rock	Rock	Rock	Rock & sand	Rock	Rock	Rock	Rock	Rock & sand	Rock & sand	Rock & sand

TABLE 47

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 14, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Laminaria spp.	5%(1)	60%(5)	80%(14)
Costaria (juveniles)	2%(3)	5%(3)	0
Alaria ? *marginata*	80%(1)	0	0
Constantinea	10%(6)	2%(1)	0
Rhodymenia	20%	5%	2%
Corallina	20%	1%	0
Bossiella	20%	0	0
Encrusting coralline	30%	40%	60%
Membranoptera spp.	0	0	0
Phycodrys sp.	0	5%	10%
Distaplia	0	1%	0
Yellow sponge	0	1%	0
Orange encrusting sponge	0	0	2%
Dendrobeania	0	0	1%
Diatom film	0	50%	50%
Musculus spp.	Present	Present	Present
Tonicella	0	(2)	0

Depth (meters): 3.0-5.0
Substrate type: Rock
Location: Off NMFS transect

TABLE 48

QUADRAT DATA (0.25m^2) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 14, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Laminaria spp.	0	25%(4)	50%(3)
Costaria (juveniles)	5%(1)	5%(1)	0
Alaria ? *Marginata*	50%(3)	60%(1)	10%
Constantinea	0	15%(3)	0
Rhodymenia	15%	5%	15%
Corallina	1%	40%	0
Bossiella	0	40%	2%
Encrusting coralline	80%	30%	60%
Membranoptera sp.	0	60%	0
Phycodrys sp.	10%	0	10%
Thais canaliculata	0	(1)	(4)
Distaplia	0	1%	1%
Yellow sponge	0	0	2%
Serpulidae	0	0	(1)
Pagurids	0	0	(5)
Orange encrusting sponge	1%	0	0
Dendrobeania	0	0	0
Diatom film	25%	0	25%
Musculus vernicosus	Present	Present	Present
Tonicella	0	0	(3)

Depth (meters): 3.5-5.0
Substrate type: Rock pavement

TABLE 49

QUADRAT DATA (0.25m^2) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 15, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Laminaria yezoensis	(5)	(2)	(2)
Laminaria groenlandica	50%(6)**	25%(3)**	25%(1)**
Agarum	5%	0	5%
Rhodymenia	0	1%	1%
Encrusting coralline	60%	30%	50%
Corallina	8%	1%	2%
Bossiella	8%	0	1%
Delesseria	0	0	0
Opuntiella	0	0	0
Hildenbrandia	0	2%	0
Ralfsia	1%	0	0
Distaplia sp.	7%	0	1%
Microporina	0	0	0
Tonicella	(1)	0	(2)
Searlesia	0	(1)	(1)
Pagurids	(6)	(4)	0
Musculus vernicosus	Present	Present	Present
Dendrobeania	0	0	0
Serpulidae	(2)	0	0
Acmaea mitra	0	(1)	0
Crepipatella	Present	0	0
Cryptobranchia	0	Present	Present
Puncturella	(1)	0	0
Pycnopodia	0	0	(1)

Depth (meters): 6.0-8.0
Substrate type: Rock

** Total Laminaria cover in the quadrat

TABLE 50

QUADRAT DATA ($0.25m^2$) FROM MACLEOD HARBOR, SUBTIDAL
MARCH 15, 1976

Taxon	Percent Cover (number of individuals) No. 1	No. 2	No. 3
Laminaria yezoensis	0	(1)	0
Laminaria groenlandica	10%(3)**	60%(6)**	75%(8)**
Agarum	60%(5)	15%	15%
Rhodymenia	1%	0	2%
Encrusting coralline	75%	60%	50%
Corallina	3%	1%	2%
Bossiella	8%	3%	3%
Delesseria	0	5%(1)	15
Opuntiella	0	5%	10%
Hildenbrandia	0	10%	1%
Ralfsia spp.	0	10%	0
Distaplia	3%	3%	15%
Microporina	0	1%	0
Tonicella	0	(2)	0
Metandrocarpa	0	5%	0
Pagurids	(2)	(10)	(5)
Musculus	Present	Present	Present
Dendrobeania	1%	1%	2%
Serpulidae	(1)	0	0
Acmaea mitra	0	(2)	(1)
Crepipatella	Present	0	0
Cryptobranchia	0	Present	Present
Lichenopora	0	1%	0
Puncturella	0	0	(1)

Depth (meters): 6.0
Substrate type: Rock
Location: Off NMFS transect

** Total Laminaria cover in quadrat

0 to $44.00/m^2$ and averaged $4.97/m^2$ during this same sample period. Another conspicuous species in this assemblage was sieve kelp (Agarum), the average density in 37 quadrats ($0.25m^2$) during March 1976 was $3.68/m^2$. These estimates are in good agreement with the average estimate of $3.24/m^2$ that was obtained from the band transects (Table 36). Pleurophycus gardneri was an important member of this brown algal understory; density estimates ranged from 0 to $2.80/m^2$ in the band transects, the average density in all of the transects was $1.05/m^2$. Density estimates from the $0.25m^2$ quadrats averaged $0.86/m^2$.

The other conspicuous brown algae in this location were Cymathere triplicata and Desmarestia viridis. Both species were somewhat ephemeral in occurrence, and were uncommon except during the summer and fall seasons of the year (Figure 15). Below the kelp canopies were the fleshy, erect reds such as Opuntiella californica, Callophyllis spp., Membranoptera spp., Rhodymenia palmata and R. pertusa, Constantinea and Ptilota filicina. The final vegetative layer in Macleod Harbor included the rock encrusting forms: Corallina spp., Lithothamnium spp., Ralfsia spp., and Hildenbrandia sp.

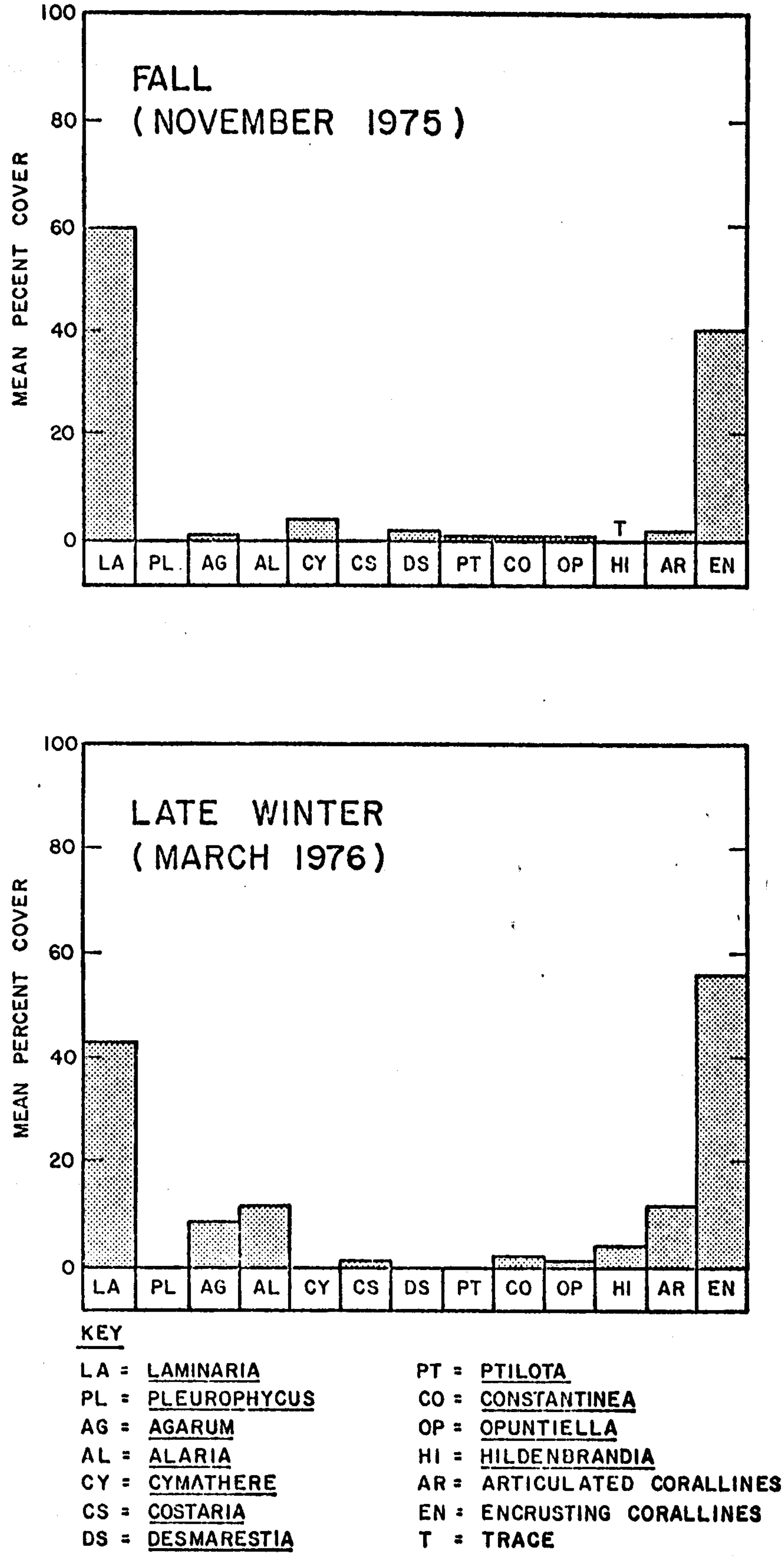

Figure 15. Algal cover at Macleod Harbor.

EPIFAUNA AND TROPHIC INTERACTION

The major rock habitats examined in Macleod Harbor were the (1) rock fingers which extended from shore, (2) surge channels between the rock-like appendages, and the (3) rock/sand interface at the base of the shoreline. The fingers are deeply fissured, with numerous over-handing ledges and shelves. Many large blocks and boulders were located around the base of the steeply sloped platform. Typically, the larger boulders were interspersed with sandy channels and patches of gravel and cobble.

The epifauna was dominated by suspension feeders and species composition was relatively diverse. The suspension feeding assemblage was dominated by the bryozoan *Microporina borealis*; it occurred in 37 of 71 quadrats (Tables 37-50). Estimates of percent cover ranged from 0 to 60 percent; however, the average coverage was 9.37 percent during the one year sample period.

Other common suspension feeders in this location were the filibranch mussels *Musculus discors* and *M. vernicosus*. During the late fall (1975) and winter (1976) surveys heavy sets of juveniles were observed in the shallow subtidal waters; most samples were collected on macrophytes and larger attached macroinvertebrates such as ascidians. Size structures of the population at this time is virtually indistinguishable.

It appeared as though there was little or no growth during the winter months, and this is probably due to the fact that as suspension or filter feeders the food source, i.e. phytoplankton, was extremely scarce during this time of year. Musculus species were encountered in 41 of 71 quadrats during two observation periods. Estimates of percent cover ranged between 0 and 40 percent. An important predator of this age group of Musculus was the muricid snail Thais canaliculata, many of which were observed feeding on dense populations of juvenile Musculus. Maximum densitiies of 16.0/m^2 were observed for Thais in this location during the March (1976) survey.

Hydroids and bryozoans such as Dendrobeania murryani, Sertularella; Tricellaria and Heteropora spp. were moderately common in this site. Other common suspension feeding forms were the ascidians Halocynthia aurantium; Distaplia sp; Synoicum sp.; ? Ritterella rubra and Didemnum or Trididemnum.

Few herbivores were seen at Macleod Harbor, however, others species were no doubt present, but because of their size and/or behavioral traits were not recorded, or listed in the generalized food web (Figure 16). As previously noted for the other two locations, the sea urchins were relatively small and cryptic in behavior. Most were seen beneath rocks, or were found crawling on the undersides of the leaf-like brown algae. Maximum densities of 0.10/m^2 of S. droebachiensis were recorded in the band transects (Tables 51 and 52).

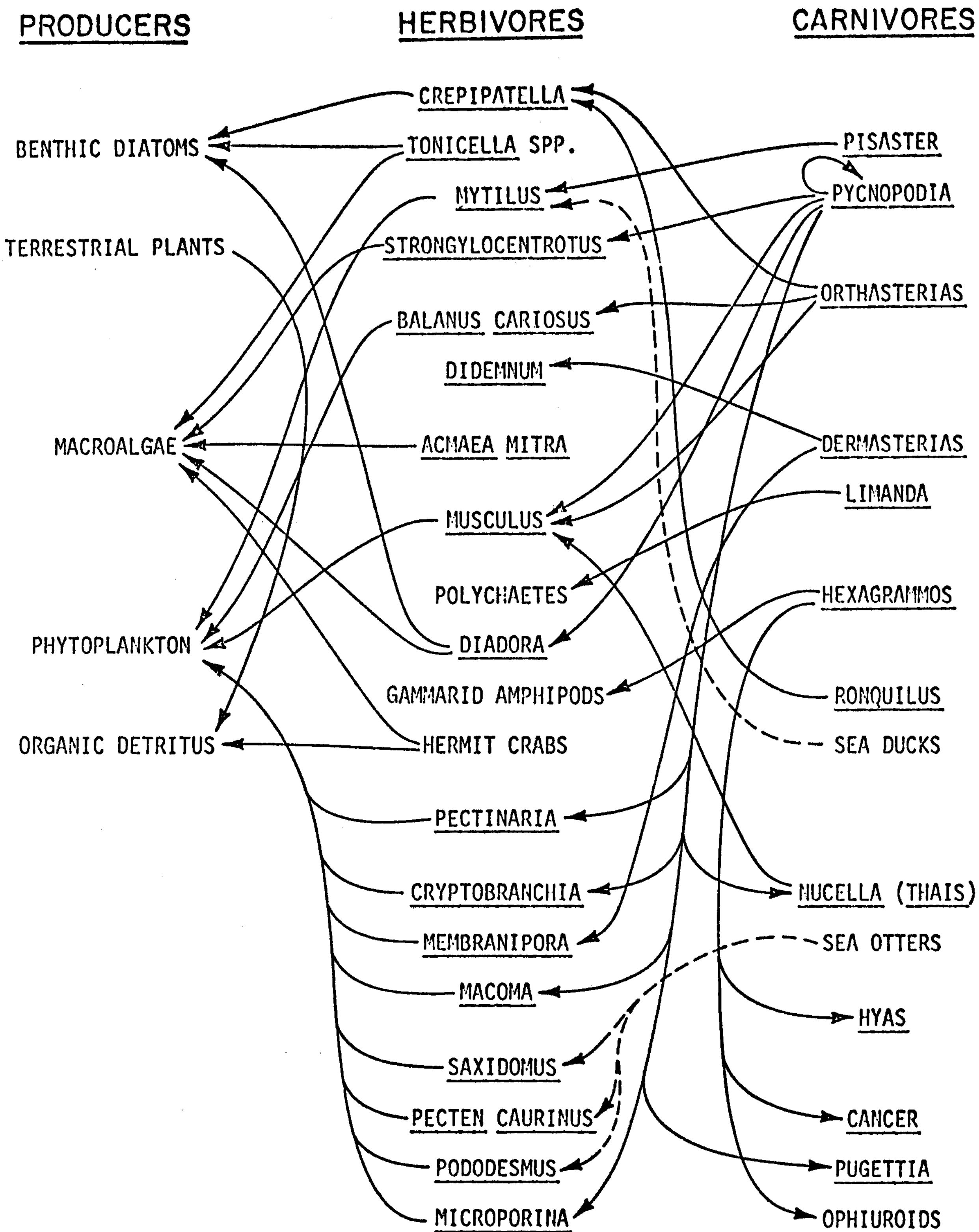

Figure 16. Food web of a sublittoral reef at Macleod Harbor, Montague Island.

TABLE 51

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS AT MACLEOD HARBOR

Taxon	9-14-75	9-14-75	9-14-75	9-14-75	9-15-75	9-15-75	9-15-75	9-15-75	9-15-75
Pycnopodia helianthoides	7 $0.14/m^2$	3 $0.12/m^2$	5 $0.33/m^2$	1 $0.06/m^2$	1 $0.04/m^2$	0	13 $0.26/m^2$	6 $0.24/m^2$	4 $0.16/m^2$
Dermasterias imbricata	0	1 $0.04/m^2$	1 $0.06/m^2$	0	1 $0.04/m^2$	0	2 $0.04/m^2$	0	0
Orthasterias koehleri	0	0	1 $0.06/m^2$	0	0	0	0	0	0
Crossaster papposus	0	0	0	0	0	0	0	0	0
Henricia spp.	0	0	1 $0.06/m^2$	0	0	0	1 $0.02/m^2$	0	0
Pisaster ochraceus	0	0	0	0	0	0	0	0	0
Evasterias troschelii	0	0	0	0	0	0	0	0	0
Strongylocentrotus spp.	0	0	0	0	0	1 $0.02/m^2$	0	0	0
Area sampled:	25 x 2m	25 x 1m	15 x 1m	15 x 1m	25 x 1m	10 x .5m	50 x 1m	25 x 1m	25 x 1m
Depth:	6-7m	12m	8m	5m	12m	7-8m	7-11m	6m	3-5m
Substate type:	Rock & sand	Sand & rock	Rock out-crop	Rock	Sand & rock	Rock & kelp	Rock & sand	Rock & kelp	Rock & kelp

TABLE 52

DENSITY ESTIMATES OF SOME COMMON ECHINODERMS AT MACLEOD HARBOR

Taxon	11-29-75	11-29-75	11-30-75	11-30-75	11-30-75	3-13-76	3-13-76	3-14-76	3-14-76	3-15-76
Pyncopodia helianthoides	18 0.72/m^2	8 0.80/m^2	15 0.38/m^2	4 0.40/m^2	0	12 0.80/m^2	1 0.10/m^2	10 0.20/m^2	5 0.33/m^2	10 0.20/m^2
Dermasterias imbricata	1 0.04/m^2	2 0.20/m^2	2 0.05/m^2	1 0.10/m^2	0	0	0	4 0.08/m^2	1 0.06/m^2	0
Orthasterias koehleri	0	3 0.30/m^2	3 0.08/m^2	0	0	0	1 0.10/m^2	1 0.02/m^2	0	1 0.02/m^2
Crossaster papposus	0	0	0	0	0	1 0.06/m^2	0	0	0	0
Henricia spp.	0	1 0.10/m^2	2 0.05/m^2	3 0.30/m^2	0	1 0.60/m^2	0	1 0.02/m^2	0	1 0.02/m^2
Pisaster ochraceus	0	0	0	0	12 1.2/m^2	0	0	0	0	0
Evasterias troschelii	0	0	1 0.03/m^2	1 0.10/m^2	0	0	0	0	0	0
Strongylocentrotus spp.	0	0	0	1 0.10/m^2	0	0	0	0	0	0
Area sampled:	25 x 1m	10 x 1m	40 x 1m	10 x 1m	10 x 1m	15 x 1m	10 x 1m	50 x 1m	15 x 1m	50 x 1m
Depth:	6-7m	3-4m	9m	6-7m	1-2m	10m	5m	2-7m	10m	3-9m
Substrate type:	Rock & sand	Rock	Rock & sand	Rock	Rock	Rock & sand	Rock	Rock	Rock & sand	Rock

Some of the other conspicuous herbivores are listed in Table 53 of Representative Important Species (RIS). These are the limpet Acmaea mitra, chitons Tonicella lineata and T. insignis, and the occasional herbivore Dermasterias imbricata (sea star). The snail Calliostoma ligatum, Diadora aspera (limpet), Puncturella spp. (snail), Crepipatella spp. (snail), Lacuna carinata (snail) and hermit crabs of the genus Pagurus were also common in this location. Most of these are microherbivores, and none were sufficiently abundant to influence the flora appreciably.

The most numerous predators in the rock habitat were the sea stars. Eight species of predatory starfish were observed in the study area, and of these the sun star Pycnopodia helianthoides was the most abundant species (Tables 51 and 52). Density estimates ranged from 0 to $0.80/m^2$, and averaged 0.28 individuals/m^2 in the 470 square meters of seafloor that was quantitatively sampled during 1975-76. Pycnopodia was observed to feed on Musculus spp.; Diadora aspera; Cryptochiton stelleri (chiton); Thais spp. (snail); Macoma spp. (clam); Microporina (bryozoan); Pectinaria (polychaete worm) and Strongylocentrotus droebachiensis (Figure 16).

The second most common species in this location was the leather star Dermasterias imbricata; density estimates ranged from 0 to $0.20/m^2$, and averaged $0.04/m^2$ in all of the combined transects. Demasterias preyed on Didemnum (ascidian); Membranipora spp. (bryozoan) and the clavate ascidian Synoicum sp. and macroalgae.

TABLE 53

CHARACTERISTIC OR REPRESENTATIVE IMPORTANT SPECIES
FROM THE SHALLOW SUBLITTORAL ZONE AT MACLEOD HARBOR

Species	Occurrence	Major Taxon	Trophic Category
Agarum cribrosum (P)	A	Brown alga	Producer
Laminaria groenlandica (P)	A	Brown alga	Producer
Laminaria yezoensis (P)	C	Brown alga	Producer
Pleurophycus gardneri (P)	C	Brown alga	Producer
Nereocystis luetkeana (A)	C	Brown alga	Producer
Costaria costata (A)	C	Brown alga	Producer
Opuntiella californica (?)	C	Red alga	Producer
Constantinea spp. (P)	C	Red alga	Producer
Callophyllis spp. (?)	C	Red alga	Producer
Rhodymenia spp. (?)	C	Red alga	Producer
Ralfsia spp. (P)	C	Brown alga	Producer
Hildenbrandia ? occidentalis (P)	C	Red alga	Producer
Delesseria decipiens (A)	C	Red alga	Producer
Encrusting coralline (P)	A	Red alga	Producer
Strongylocentrotus spp. (P)	U	Sea urchin	Herbivore
Tonicella spp. (P)	C	Snail	Herbivore
Acmaea mitra (P)	C	Snail	Herbivore
Orthasterias koehleri (P)	C	Sea star	Predator
Pycnopodia helianthoides (P)	C	Sea star	Predator
Dermasterias imbricata (P)	C	Sea star	Predator/Herbivore
Henricia spp. (P)	C	Sea star	Suspension feeder
Fusitriton oregonensis (P)	C	Snail	Predator/Scavenger
Thais canaliculata (P)	C	Snail	Predator
Halocynthia aurantium (P)	C	Ascidian	Suspension feeder
Musculus spp. (A)	C	Mussel	Suspension feeder
Enhydra lutris (P)	C	Sea otter	Predator
Microporina borealis	C	Bryozoan	Suspension feeder

Key: (P) = perennial
(A) = annual
A = abundant
C = common
U = uncommon

The star Orthasterias koehleri was next in abundance; densities of up to $0.03/m^2$ were recorded for Orthasterias, however the average of $0.03/m^2$ is probably a more realistic estimate of density. Orthasterias was seen eating Balanus cariosus (barnacle), Crepipatella (snail), and the mussels Musculus vernicosus and M. discors.

Another common asteroid was the blood star Henricia spp. The predominant blood star in this area was H. leviuscula, although two other species, H. tumida and H. sanquinolenta, occurred in the same shallow water habitat. Because of taxonomic difficulities inherent in field identifications the numerical data are presented as combined counts. Estimates of density ranged from 0 to $0.60/m^2$, with a mean density of $0.06/m^2$.

One of the other common sea stars in the littoral zone was the ochre star, Pisaster ochraceus. Pisaster was relatively rare in the rocky subtidal regions of Macleod Harbor, however, around the MLLW mark it was more common. For example, within one 10 x 1m transect we counted 12 P. Ochracens for a mean density of $1.2/m^2$ (Table 52). The only feeding observations that involved P. ochraceus during this time period were with the bay mussel, Mytilus edulis.

A number of other secondary and tertiary consumers were observed in Macleod Harbor, notably sea otters, diving ducks, harbor seals and fin fishes. Density estimates of these species were not made at this time; however, in some cases feeding observations were recorded or the occurrence of a particular species present in a certain habitat was noted. A total of 31 species of fishes are listed in Table 19; of these the most conspicuous families in the kelp habitat were the greenlings (Hexagrammidae), sculpins (Cottidae), ronquils (Bathymasteridae) and righteye flounders (Pleuronectidae). Other fishes such as pricklebacks (Stichaeidae) and gunnels (Pholididae) were seen, but because of their small size and secretive nature could not be counted properly by our sampling methodology.

SOFT BOTTOM AND FAUNAL COMPONENTS

The soft bottom directly seaward of the NMFS intertidal station consisted of fine silty sand, with ripple marks and large amounts of shell debris. The upper layer of the shell debris was composed heavily of empty Musculus spp. and clam shells. Organic debris of marine and terrestrial origin was moderate, i.e. alder leaves were common on the seafloor during the November (1975) survey. At slightly deeper depths, beyond the rock/sand interface the sand was siltier, and contained low fecal mounds that were produced by tubicolous polychaetes. A dense layer or film comprised of sessile diatoms covered the surface of the sand during March 1976. Dominant invertebrates observed on the sand were tubicolous polychaetes, the most conspicuous of which was a large maldanid or bamboo worm with a slightly branched, thick walled sandy tube. The estimated density of the maldanid ranged between 0 and 64.0 individual/m^2; the average density in 48 quadrats (.25m^2) was 25.6/m^2. The maldanid bed was best developed at depths of between 5 and 7 meters on a sandy bench west of the shoreline. A less conspicuous, but possibly larger worm was also common in this habitat; the tube did not extend very far above the sand surface. This species was identified as Onuphis iridescens. Non-tubicolous species of worms were common about 15 cm below the surface of the unconsolidated sediment.

There were a number of species observed in this soft bottom habitat including: Pycnopodia helianthoides (sea star); Crangon sp. (shrimp); Ophuira ? sarsii (brittle star); Olivella baetica (snail); Tellina sp. (bivalve); Chone ? mollis (sabellid worm); Margarites sp. (snail); Nassarius mendicus (snail); Pagurus ochotensis (hermit crab); unid. hermit crabs; Clinocardium spp. (bivalve); Halcampa sp. (sea anemone); unid. nemertean worm;and Aglaja ocelligera (opisthobranch snail). A few fishes were also common on the softer substrates, notably the yellow fin sole, Limanda aspera; starry flounder, Platichthys stellatus; whitespotted greenling, Hexagrammos stelleri; and pacific tomcod, Microgadus proximus.

DISCUSSION

Seaweeds and their associated microflora are important sources of energy in the coastal ecosystems of the northern Gulf of Alaska. Much of the carbon production in the Gulf is undoubtedly derived from within a narrow band of the shoreline where the marine plant life flourishes. Other forms of organic carbon are pumped into the system from terrestrial sources such as freshwater streams, island meadows, forests, and shallow bays or estuaries. Despite the seaward flow of energy, usually in the form of detritus, there is a positive feedback to the terrestrial system. Many of the terrestrial life forms, i.e. waterfowl, deer and land otter, utilize the resources of both major environments. One example of this feedback is the foraging behavior of the blacktail deer (Odocoileus columbianus), which utilize seaweed resources of the Prince William Sound Archipelago on a fairly regular, yet seasonal basis. This is especially evident during winter months, when heavy snows push the deer from the high country down to the beaches where they browse on both attached and drift seaweeds. For example, during the March survey (1976) four blacktail deer were sighted in the rocky intertidal zone at Latouche Point, and an equal number were seen browsing at the NMFS intertidal station in Zaikof Bay. Even higher consumer species such as the land otter, Lutra canadensis derive a great deal of energy from the sea by foraging in the shallow subtidal waters of the Sound for clams, mussels, chitons and sea urchins. Undoubtedly, however, considerably more energy flows from terrestrial to estuarine and marine systems than is returned through such pathways as described above.

Many commercially valuable species like Pacific salmon pass through the waters of Zaikof Bay, Macleod Harbor and Latouche Point on their way to and from the spawning streams of Prince William Sound. The major species in these areas are pink and chum salmon. Recently Sibert, Brown, Healey and Kask (1977) described a detritus-based food web that involved juvenile chum salmon from coastal waters of southern British Columbia and it appears that they also use some resource associated with kelp beds during their development. Additionally, schools of juvenile salmon were observed in the seaweed beds off Latouche Point during

August, 1974, and early September, 1976. Usage of these habitats by salmon has been poorly documented in Alaska.

During the 12 months of this study (1975-76), there was a pronounced oscillation in the appearance and areal dimensions of the subtidal vegetative canopies. Concurrent with these subsurface changes was a physical alteration in the size of the floating canopies of bull kelp (Nereocystis luetkeana) that typically grew above the shorter statured species. These pronounced seasonal changes have been interpreted as characteristic for this part of the Gulf of Alaska. Annual brown algae such as Nereocystis, Cymathere triplicata and Costaria costata germinated in early spring and formed dense canopies by mid to late summer. However, most of these same plants were lost by late fall of the same year. Conversely, the perennial kelps, such as Agarum cribrosum, Laminaria spp. and Pleurophycus gardneri persisted year round, and exhibited maximum growth during late winter and early spring. The rapid growth period usually follows a period of tissue shedding or blade loss. One hypothesis to account for the winter growth strategies of these perennial species is that it results from competition with both understory and taller statured annuals such as bull kelp (Nereocystis). The alternation in peak growth and development between different canopy levels would possibly negate some competitive interactions between kelps (Dames & Moore, 1976a). These factors would lead to the creation of more free space, and light penetration in the rocky subtidal zone. All of these factors could contribute to the high plant diversity and high standing crop and plant production exhibited by the seaweeds of the Gulf.

Many of the same parameters that influenced the seaweed populations in the NEGOA study sites also affected the associated invertebrate fauna. The species composition of the epifauna was reasonably constant throughout the year, however patterns of distribution, frequency of occurrence and relative abundance was effected or altered with variations of the calendar year. The variations in distribution, density and size for the mussel (Musculus vernicosus) population at Latouche Point can be used as an example. This small filibranch is a conspicuous member of the seaweed assemblages of the northeastern Gulf. Shell debris at the base of some rocky reefs and previous field observations by Rosenthal (unpublished data) indicate that these populations have thrived in the vicinity of Latouche Point and Danger Island for the past 3 years. Heavy sets of juvenile Musculus or spat were attached to algal substrates during the spring and summers of 1974-76. However, by late November, most of the population was drastically reduced in number, and this is probably due in part to algal shedding and fall storms which periodically remove the mussels along with their attachment sites. Several other epifaunal species exhibited substantial seasonal variations in abundance and coverage of the underlying substrate. Among these were the hydroids Campanularia, Grammaria and Abietinaria, which covered substantial portions of the rocky substrate in Zaikof Bay during spring and summer, but typically were reduced in coverage by late fall leading to the conclusion that annual variations in abundance are part of the life history patterns of these hydroids.

The physical oceanographic conditions in the shallow waters of Zaikof Bay, Macleod Harbor and Latouche Point differ somewhat in terms of exposure to ocean swell, velocity of tidal currents and transparency of the sea water. Two of the stations (Macleod Harbor and Zaikof Bay) are generally protected from the power of deep sea swells so conspicuous in the Gulf of Alaska. However, the southwest end of Latouche Island does receive moderate wave activity when storm surf breaks over the reef complex between the Point and Danger Island. The second major difference between stations seemed to be in the degree and/or velocity of the tidal currents. Although no measurements were made in conjunction with the biological surveys, strongest currents observed during this study were at the Latouche Point. The third physical parameter which was measured in the field was water transparency or visibility in sea water. Transparency was determined by making either visual observations while submerged, or estimating water transparency with the aid of a standard white secchi disc. Again, the Latouche Point station generally had the clearest water with a maximum secchi disc reading of 13 meters during the March (1976) survey. Latouche Point was typically bathed in an oceanic environment characteristic of exposed outer coast habitats, whereas the other 2 stations were more typical of embayment or fiord systems in Prince William Sound. At Latouche Point the bottom was usually free of silt, and the subtidal plant life formed a lush submarine forest which covered several square kilometers of the reef complex. Whereas in more protected areas such as Zaikof Bay and Macleod Harbor the hard substrate and bottom vegetation were usually dusted with a thin veneer of silt, and the seaweeds were generally restricted to a narrow girdle along the rocky shoreline.

For the most part, the composition of the subtidal algal assemblage was rather similar in all 3 areas, however, in terms of species composition, frequency and abundance the areas were dissimilar. At all three stations the benthos was dominated by marine plants, with the kelps being visual, numerical and biomass dominants. Recent subtidal surveys in the vicinity of Danger Island have shown algal biomass (wet weight) at between 1,468 and 5,676 grams/m^2 during late summer (Rosenthal, unpublished data). However, these estimates are conservative, and would be much higher if the floating canopies were included.

The underlying invertebrate fauna was dominated by suspension or filter feeders; macroherbivores appeared to be somewhat unimportant on a year-round basis. Tertiary consumers were visually conspicuous with the asteroids appearing to be the most important group in this level of the food chain. However, the importance of finfish, diving birds and marine mammals has not been assessed. For the most part, energy pathways appeared to be basically similar in each of the 3 sites, with the inshore food chain dependent upon a regular flow of plant and animal detritus.

Because circulation appeared to be somewhat restricted in Macleod Harbor and Zaikof Bay, they appear to have a higher probability of prolonged exposure to contaminants drifting on the sea surface than Latouche Point. However, since the latter is strategically situated between two major arteries of Prince William Sound, biological processes are definitely susceptible to man-induced contaminants that would affect species of aesthetic and commercial importance.

LITERATURE CITED

Fager, E. W., 1963. Communities of Organisms. The Sea, Vol. 2, Interscience Publishers, New York, 415-437

Mann, K. H., 1973. Seaweeds: Their Productivity and Strategy for Growth. Science, Vol. 182 (4116): 975-981

Westlake, D. F., 1963. Comparisons of Plant Productivity. Bio. Review, Vol. 38: 385-425

Mann, K. H., 1972. Ecological Energetics of the Seaweed Zone in a Marine Bay on the Atlantic Coast of Canada. II. Productivity of the Seaweeds. Mar. Biol. 14: 199-209

Dawson, E. Y., 1966. Marine Botany. Holt, Rienhart and Winston, Inc., 371 p.

Rosenthal, R. J. and D. C. Barilotti, 1973. Feeding Behavior or Transplanted Sea Otters and Community Interactions off Chichagof Island, Southeast Alaska, p. 74-88. In W. J. North (ed.), Calif. Inst. Tech., Kelp Habitat Improv. Proj., Ann. Rept., July 1, 1972-June 30, 1973

Dayton, P. K., 1975. Experimental Studies of Algal Canopy Interactions in a Sea Otter-Dominated Kelp Community at Amchitka Island, Alaska. U. S. Fishery Bull. 73(2): 230-237

Dames & Moore, 1976a. Marine Plant Community Studies, Kachemak Bay, Alaska. Final Report, Alaska Department of Fish and Game: 288 pp.

Dames & Moore, 1976b. Herring Spawn on Kelp Fishery of Prince William Sound. Final Report, Alaska Department of Fish and Game: 63 pp.

Dames & Moore, 1977. An Ecological Assessment of the Littoral Zone along the Outer Coast of the Kenai Peninsula. Final Report, Alaska Department of Fish and Game: 101 pp.

Rigg, G. B., 1915. Potash from Kelp V. The Kelp Beds of Western Alaska. U. S. Department of Agriculture Report 100: 105-122

Rosenthal, R. J., W. D. Clarke and P. K. Dayton, 1974. Ecology and Natural History of a Stand of Giant Kelp, *Macrocystis pyrifera* off Del Mar, California. Fishery Bull.: Vol. 72(3): 670-684

Johansen, H. W., 1971. Effects of Elevation Changes on Benthic Algae in Prince William Sound. (In). The Great Alaska Earthquake of 1964: Bilogy, NAS. Public 1604, Washington: 35-68

LITERATURE CITED (Continued)

Plafker, G., 1969. Tectonics of the March 27, 1964, Alaska Earthquake. U. S. Geological Survey Professional Paper 543-I. Washington Government Printing Office: 122 pp.

Cameron, F. K., 1915. Potash from Kelp. U. S. Department of Agriculture, Report No. 100, Washington Government Printing Office: 122 pp.

Chapman, A. R. O., 1972. Morphological Variaion and its Taxonomic Implications in the Ligulate Members of the Genus Desmarestia Occurring on the West Coast of North America. Syesis, 5: 1-20

Mauzey, K. P., C. Birkeland, and P. K. Dayton, 1968. Feeding Behavior of Asteroids and Escape Responses of their Prey in the Puget Sound Region. Ecology 49: 603-619

Vadas, R. L., 1972. Ecological Implications of Culture Studies on Nereocystis luetkeana, J. Phycol. 8: 196-203

Markham, J. W., 1969. Vertical Distribution of Epiphytes on the Stipe of Nereocystis luetkeana (Merteus) Postels and Ruprecht. Syesis 2: 277-340

Chapman, A. R. O., 1974. The Ecology of Macroscopic Marine Algae. Annual Sev. of Ecol. and Syst., Vol. 5: 65-80

ECOLOGY OF UNCONSOLIDATED BEACHES IN LOWER COOK INLET

by

Dames & Moore

510 L Street, Suite 310
Anchorage, Alaska 99501

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 78

December 1978

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

LIST OF APPENDIXES (continued)

1. INTRODUCTION

Potential development of oil and gas reserves in Lower Cook Inlet is accompanied by the prospect that the intertidal and shallow subtidal habitats of that estuary may be subjected to large scale chronic or acute contamination. The magnitude of this potential problem is based primarily on the overall importance of this littoral zone and its component habitats to the Inlet and associated systems, and secondarily, on the sensitivity of these habitats to the potential perturbations. Man tends to rank the importance of a resource according to his own observable utilization of the resource. Clamming is the most important human use of intertidal resources in Lower Cook Inlet directly perceived by most individuals, and, since only small segments of the coastline are used, the importance of intertidal habitats is often considered to be low. However, the importance and sensitivity of the zone cannot be evaluated until it has been adequately described and its relationships to other systems are at least generally defined. It is clear from experience in other parts of the world that the greatest observable impacts of oil-related problems occur in the intertidal and nearshore zones.

Intertidal habitats and assemblages in Lower Cook Inlet were generally undescribed until Dames & Moore biologists commenced rocky intertidal studies in Kachemak Bay in 1974 (Dames & Moore, 1976). Soft intertidal habitats (sand and mud) were not studied until spring and summer of 1976, when the Bureau of Land Management (BLM) initiated a reconnaissance of the physical, chemical and biological systems in Lower Cook Inlet through its Outer Continental Shelf Environmental Assessment Program (OCSEAP). These studies were initially designed to collect the information necessary to permit BLM to write the Environmental Impact Statement for the OCS oil and gas lease sale. As part of the reconnaissance, the first phase of this study (R.U. #417) was designed to examine beaches representative of the major intertidal and shallow subtidal habitats in Lower Cook Inlet (Dames & Moore, 1977).

The intertidal reconnaissance indicated that most of the rocky intertidal habitats in Lower Cook Inlet are located in Kachemak Bay and Kennedy Entrance, on the east, and in Kamishak Bay, on the west. In contrast, the intertidal areas north of Kachemak and Kamishak Bays are mainly soft, with the lower beaches in exposed areas being sand and in protected areas, mud. At lower tidal levels, approximately 50 percent of the shoreline on the west side is mud flats, largely as a consequence of the number of bays that deeply indent into the coastline. North of Kachemak Bay on the east side of the Inlet, the smooth shoreline is interrupted by just a few rivers and streams, and the lower tidal levels are almost exclusively sandy. The upper beaches (above MLLW) for a large proportion of the shoreline in the Lower Inlet are characterized by a steeper slope of coarse gravel and cobbles. Based on the slope, grain size, and impoverished fauna, this habitat appears to be the least stable of the soft, or unconsolidated, intertidal substrates in Lower Cook Inlet.

The reconnaissance study further indicated sharp differences between the biotic assemblages of the sand and mud habitats. Although both habitats are characterized by detritus-based assemblages, and depend to varying degrees upon organic debris produced in other areas, the sand beaches support a rather impoverished assemblage with low biomass whereas the mud beaches support a more diverse assemblage with moderate biomass. The sand beach faunas are dominated by polychaete worms and gammarid amphipods whereas the mud flat faunas are heavily dominated by clams. The lower level of the gravel upper beach appears to be dominated by a gammarid amphipod and an isopod, both of which form dense aggregations under large cobbles (Dames & Moore, 1977).

It became suspected through the reconnaissance study that intertidal resources are important to several other organisms and systems. For instance, shorebirds, gulls and sea ducks feed heavily on soft intertidal substrates. At least one group is feeding there during each stage of the tide. Fish and crustaceans move into the intertidal zone during high tides to feed and some species remain there during low tide (Green 1968). Several investigators have reported that mud flats are important feeding areas for juvenile salmon (Sibert et al. 1977; Kaczynski et al. 1973).

However, only preliminary descriptions of the various systems examined were provided. The major objective of the research described in this report was to more fully describe the systems at specific sites, and identify the more important relationships and processes operating in these assemblages. This necessitated a fairly detailed examination of seasonal changes in species composition and structure. Trophic relationships were not emphasized because the most important predators (birds and fish) are the object of other research units.

2. SUMMARY

2.1 STUDY SITES

The beaches selected for study in Lower Cook Inlet included two of sand and one of mud. The sandy beaches are located on the east side of Lower Cook Inlet (Figure 1). Both are accessible by vehicle. The Deep Creek site is fairly representative of beach conditions between Anchor Point and Clam Gulch. We selected the Homer Spit site because it appeared to support a richer fauna and higher standing stock than Deep Creek. The mud flat site is at Glacier Spit, Chinitna Bay, on the west side of the Inlet (Figure 1). It was chosen because it is typical of mud flats on the west side, has a year-round resident, and has shelter.

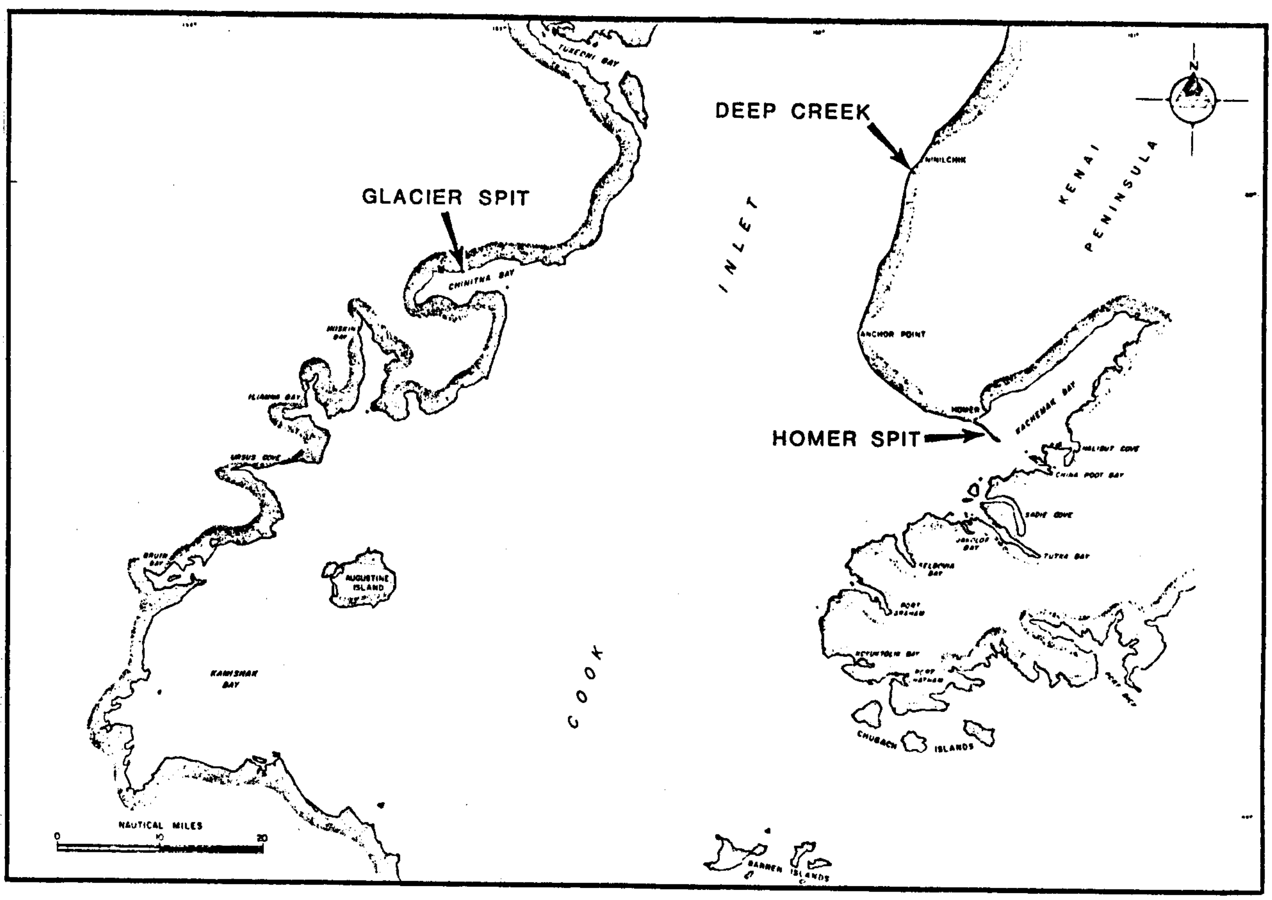

FIGURE 1 - SAMPLING LOCATIONS IN LOWER COOK INLET

2.2 SAMPLING PROCEDURES

The field studies initiated at these sites were designed to determine species composition, zonation, and seasonal changes, and to develop preliminary estimates of secondary productivity. The nucleus of the experimental design was seasonal collection of replicate core samples of the sediment and associated infauna at several lower intertidal levels on each beach. These samples provided the basic data describing the assemblages on sand and mud beaches. Relationships between these and other assemblages have been determined through examination of the literature, discussions with other investigators, and direct observation.

2.3 GENERAL RESULTS AND PRELIMINARY CONCLUSIONS

At the two sand beaches and the mud flat studied the respective faunas were distinctly different. Sampling efforts were essentially equal in each survey. Twenty-two species were identified from the sand beach at Deep Creek (Table 1), where the fauna was dominated by the gammarid amphipod *Eohaustorius eous*. Thirty species were identified from the sand beach at Homer Spit (Table 1), where the fauna was dominated by the polychaete *Scolelepis* sp. A. Forty species were identified from the mud flat at Chinitna Bay (Table 2), where the fauna was dominated by the clams *Macoma balthica*, *Mya arenaria*, *M. truncata* and *Mya priapus*. *Mya* spp. are possibly present at commercially harvestable densities. Although unmeasured, the mud flat also supported appreciable standing crops of benthic diatoms and filamentous brown and green algae in the summer. These differences reflect considerable differences in physical conditions and productivity.

Zonation of the biological assemblages was readily apparent in the distribution of species abundance but gener-

TABLE 1. FREQUENCY OF OCCURRENCE OF TAXA FROM SANDY INTERTIDAL SITES ON THE EAST SIDE OF LOWER COOK INLET IN 1977

Taxa	Deep Creek	Homer Spit
PLATYHELMINTHES		
Turbellaria, unid.	0	1
ANNELIDA - Polychaeta		
Abarenicola sp.	1	0
Capitella capitata	3	1
Chaetozone setosa	1	0
Eteone nr. *longa*	3	2
Magelona pitelkae	0	1
Nephtys ?*ciliata*	2	3
Nephtys sp. (juv.)	0	1
Paraonella platybranchia	3	3
Sabellidae, unid.	0	1
Scolelepis p. A	3	3
Scoloplos armiger	3	1
Spionidae, unid.	0	1
Spiophanes ?*bombyx*	0	1
Typosyllis sp.	0	1
ARTHROPODA - Crustacea		
Anisogammarus cf. *confervicolus*	2	0
Archaeomysis grebnitzkii	2	1

Taxa	Deep Creek	Homer Spit
Atylidae, sp.A	1	0
Crangon ?*alaskensis* *elongatus*	0	1
Eohaustorius *eous*	3	3
Gammaridae sp.A	1	0
Gammaridea, red striped	0	1
Lamprops *carinata*	0	1
Lamprops *quadriplicata*	1	1
Lamprops sp.	0	1
Lysianassidae, unid.	1	2
Oedocerotidae, unid.	1	0
Paraphoxus *milleri*	1	2
Paraphoxus sp.	2	1
Synchelidium sp.	1	0
MOLLUSCA - Gastropoda		
Littorina *sitkana*	0	1
MOLLUSCA - Pelecypoda		
Mytilus *edulis*	0	1
Protothaca *staminea*	0	1
Spisula *polynyma*	0	3
CHORDATA - Pisces		
Ammodytes *hexapterus*	0	3
Total Number of Species	22	30

TABLE 2. PERIOD OF OCCURRENCE OF TAXA FROM MUD FLAT SITE AT GLACIER SPIT, CHINITNA BAY IN 1977

TAXON		TAXON	
NEMERTEA, unid.	7[a]	ARTHROPODA	
ANNELIDA		Acarina, unid.	7
Abarenicola pacifica	4	Cyclopoida, unid.	7
Ampharete acutifrons	4,7	*Crangon* sp	7
Aphroditoidea, unid	4	Harpacticoida, unid.	7
Axiothella rubricincta	7	Insecta (larva)	7
Capitella capitata	4,7	Ischyrocerodidae, unid.	7
Eteone nr. *longa*	4,7	*Pontoporeia femorata*	7
E. nr. *pacifica*	7	*Saduria entomon*	4
Glycinde polygnatha	4	*Tritella* ?*pilimana*	4,7
Harmothoe imbricata	4,7	MOLLUSCA	
Malacoceros sp	4,7	*Aglaja diomedea*	7
Maldanidae, unid.	7	*Clinocardium nuttallii*	4,7
Nephtys sp	4,7	*Cylichna* sp	7
Nephtys sp (juvenile)	4,7	*Macoma balthica*	4,7
Oligochaeta, unid.	7	*Macoma* sp	4
Paraonella platybranchia	7	*Mya arenaria*	4,7
Paraonidae, unid.	4	*M. priapus*	4,7
Phyllodoce groenlandica	4,7	*M. truncata*	4,7
Polydora caulleryi	4,7	*Mya* spp. (juveniles)	4,7
Polygordius sp	7	*Pseudopythina* sp	4,7
Potamilla sp	4,7		
Scoloplos armiger	4,7		
Spio ?*filicornis*	7		
?*Spio* sp	4		
Spionidae, unid.	7		
ECHIURA			
Echiurus echiurus alaskensis	4,7		

[a] Number refers to month of sampling period; 4 = April, 7 = July

ally not apparent in species composition. Many of the species were more abundant at the lower tidal levels.

Most of the species exhibited considerable seasonal changes in abundance. Generally, polychaete worms and amphipods were more abundant in summer, but clams were most abundant in spring. Juveniles of several species appeared in the samples only in the summer, a relatively mild period.

In addition to the strong differences in faunal composition noted above, appreciable differences were observed in species richness, biomass, and age structure. The mud flat assemblage had appreciably higher species richness and diversity, higher biomass (about 3000 g/m^2 compared to about 20 g/m^2 on sand), and most species in the mud fauna are perennials living over five years, in contrast to the predominance by annual species on sand beaches. These characteristics indicate that the mud flat assemblage is somewhat more complex and highly developed than the sand beach assemblages.

Evaluation of the trophic structures of these assemblages indicates that all are based on detritus. The great majority of the organisms are deposit feeders or suspension feeders. Resident predators are uncommon. Feeding observations suggest that a large proportion of the animals living in these habitats are eaten by transient predators from other assemblages and geographic areas. Some of the important groups that forage heavily in these habitats include crabs, fish (e.g., flatfish, cottids and juvenile salmon), shorebirds, and diving and dabbling ducks. Qualitative impressions of exploitation levels suggest that the mud flat assemblage is utilized much more heavily than the sand beaches. A comparision of abundance, biomass and growth data seems to support this hypothesis. Several bird species (e.g., Western Sandpipers and Danlins) seem particularly dependent on mud flat assemblages during spring migration. Greater Scaup, Oldsquaw, Surf Scoters and Black Scoters feed extensively on mud flats in the winter.

These biological descriptions are crucial in arriving at several useful preliminary conclusions. First, combining the biological attributes and contributions of the various assemblages with predicted ranking of various substrates to hydrocarbon uptake, storage and retention characteristics (based on geomorphological considerations and field observations at major oil spill sites, as described by Hayes et al., 1977), it appears that mud flats are the most sensitive of the substrates examined in this study to contamination by crude oil. Furthermore, based on the high probability that: a) Much of the seemingly high productivity of mud flats is used by animals from other systems, and b) that mud flats are very important to a number of marine and terrestrial animals (some commercially important and others migrating across broad geographic ranges), the importance of protecting this habitat from pollution is quite obvious. Second, because of the concentration of sand beaches in the northeastern quadrant of Lower Cook Inlet, and of mud flats in Kachemak Bay and on the west side of the Inlet, the most acceptable location for development of onshore facilities, in biological terms, is between Anchor Point and Nikiski.

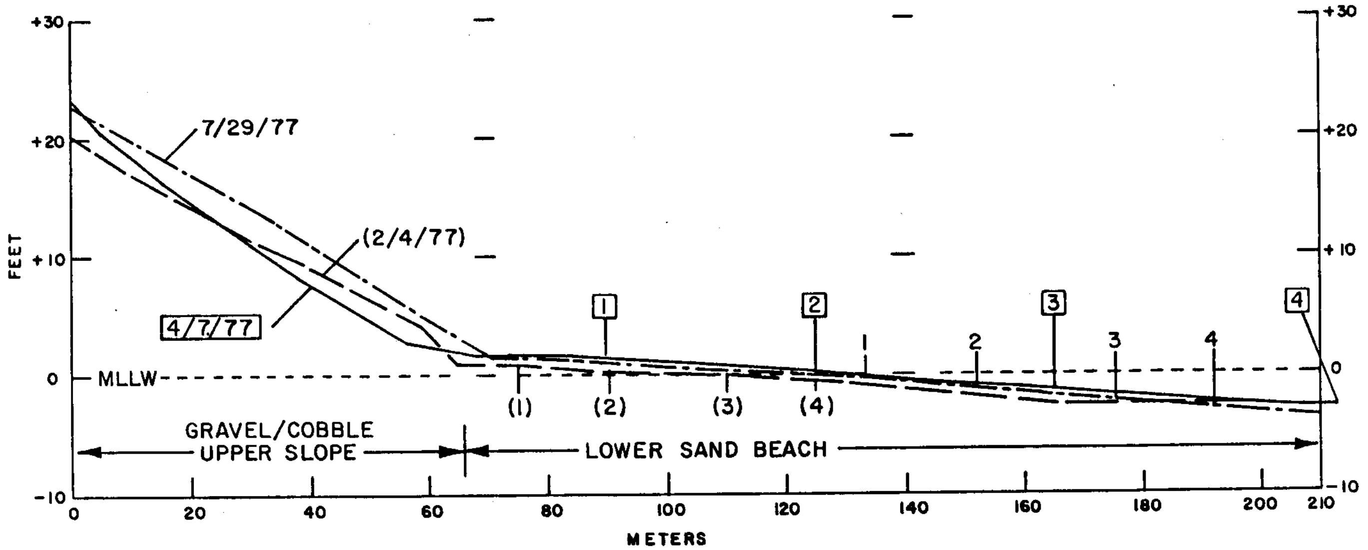

FIGURE 2A - BEACH PROFILES FOR DEEP CREEK

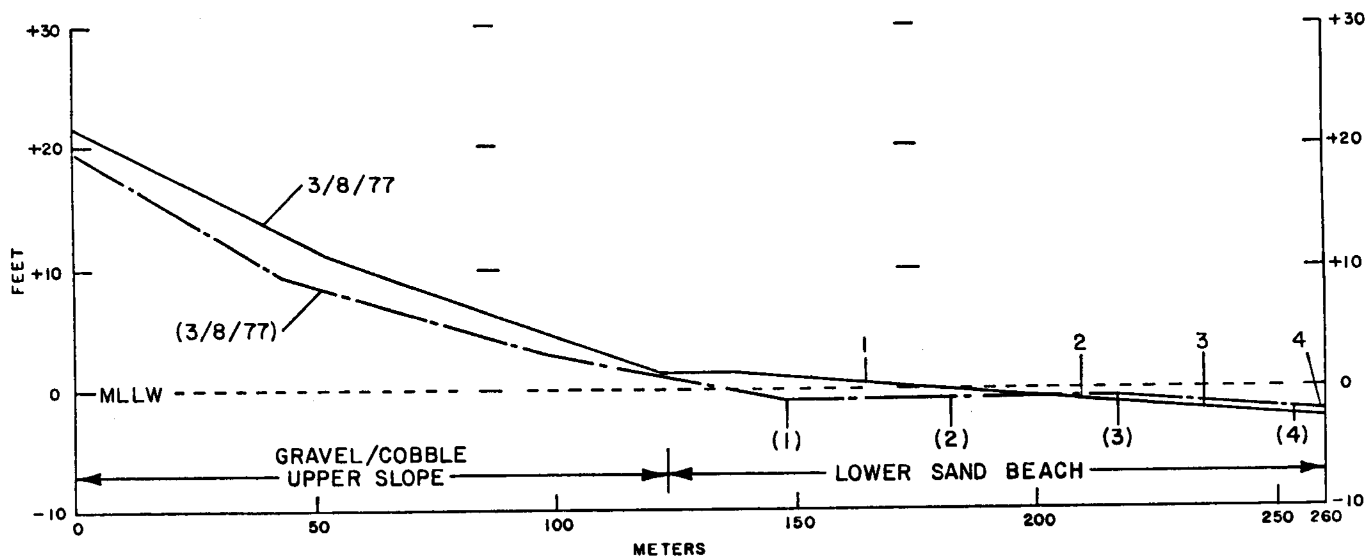

FIGURE 2B - BEACH PROFILES FOR HOMER SPIT

3. PHYSICAL DESCRIPTION OF THE STUDY SITES

3.1 GENERAL

Hayes et al. (1977) provides useful characterizations of numerous beaches on both sides of Lower Cook Inlet. Most of the beaches from Kachemak Bay north, on the east side of the Inlet, are characterized by a narrow, fairly steep, unstable, gravel beach face extending down to an elevation of from about two feet to MLLW and a broad, flat, more consolidated fine sand low-tide terrace extending out into the subtidal zone (Figure 2). The boundary between the gravel and sand facies is generally sharply demarcated by changes both in slope and substrate. However, in some locations, it is interrupted by a narrow band of small boulders. In many instances, a small water-filled trough also occurs at the boundary, apparently as a consequence of the water draining out of the gravel slope above. This trough produces small drainage channels running perpendicularly to the shoreline at intervals along the beach (Figure 3).

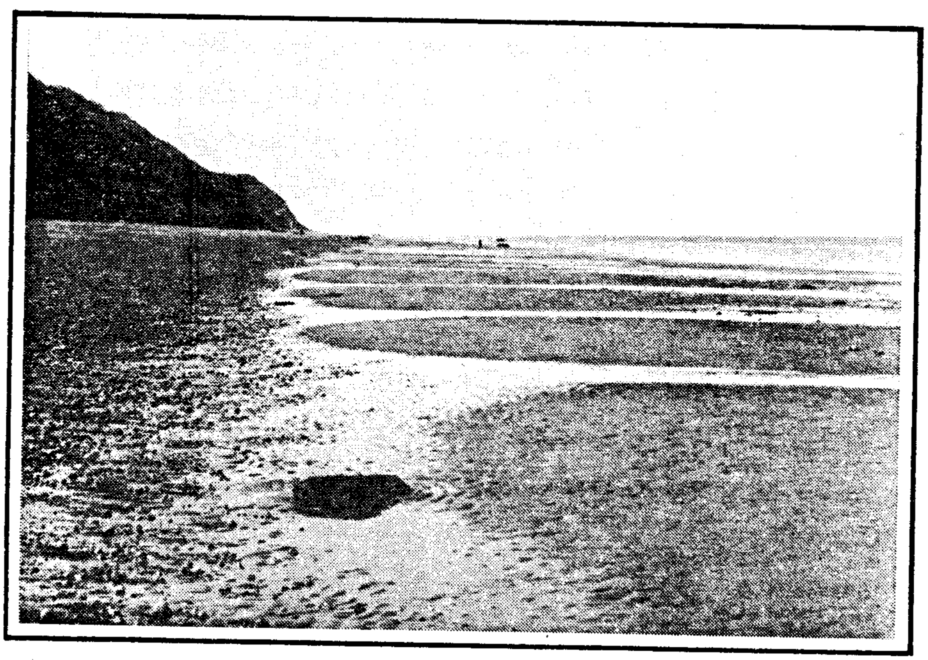

FIGURE 3 - VIEW OF BEACH AT DEEP CREEK, SHOWING STRUCTURE OF THE FORESHORE IN 1977

3.2 SAND BEACHES - HOMER SPIT AND DEEP CREEK

The sandy beaches are located on the east side of Lower Cook Inlet (Figure 1). Both were selected for accessibility. Based on his razor clam surveys, Mr. David Nelson, ADF&G (personal communication), indicated that the Deep Creek site, 1.5 miles south of the beach park, is fairly representative of beach conditions between Anchor Point and Clam Gulch. The base point for the transect is a room-sized triangular boulder at the base of the bluff (an erosional scarp). We selected the Homer Spit site, 2.5 miles south of the Kachemak Drive, because it appeared to support a richer fauna and higher standing stock than the Deep Creek site.

Corrected beach profiles for the Deep Creek and Homer Spit sites (Figure 2) provide two important pieces of information. First, it appears that the shape of the beaches change very little seasonally compared to beaches exposed to the open ocean (Bascom, 1964).

However, because of large inaccuracies in the original profile data, the accuracy of the corrected profiles is undetermined. Our notes and recollections of fixed features on the beach lead us to accept the general shape of the profiles, but to question the changes recorded for the gravel upper slopes at both sites.

Second, the gravel upper beach is considerably steeper at Deep Creek than at Homer Spit. According to Bascom (1964) this indicates that the beach at Homer is somewhat less exposed than at Deep Creek. Shepard (1963) also points out that the beach at Homer should be coarser and more porous.

Based on sediment samples collected at two levels from both lower beaches, sediment conditions are quite similar (Table 3). The sand may be slightly coarser at Homer Spit than at Deep Creek. The sediment in both areas is a moderate to well-sorted fine to medium sand with a significant quantity of small gravel; fine sand was mainly found at the lower levels. Also, thin strata of pulverized coal were common at both beaches. Evidence of anoxic conditions (blackened sand or sulfide odor) was lacking at both sites.

3.3 MUD FLAT AT GLACIER SPIT, CHINITNA BAY

The mud beach study site is adjacent to the Byer homestead, on Glacier Spit, Chinitna Bay, on the west side of the Inlet. It was chosen because it is a typical mud flat, and has a year-round resident and shelter. The base point for the transect is a solitary group of large boulders at the border between the gravel upper slope and the mud low-tide terrace.

The basic structure of the beach at the Chinitna site is similar to that described for the two sand beaches (Figure 4). An important difference is the flatter slope of the mud flat. However, the slope of the gravel upper beach at Glacier Spit is steeper than at either sand beach site.

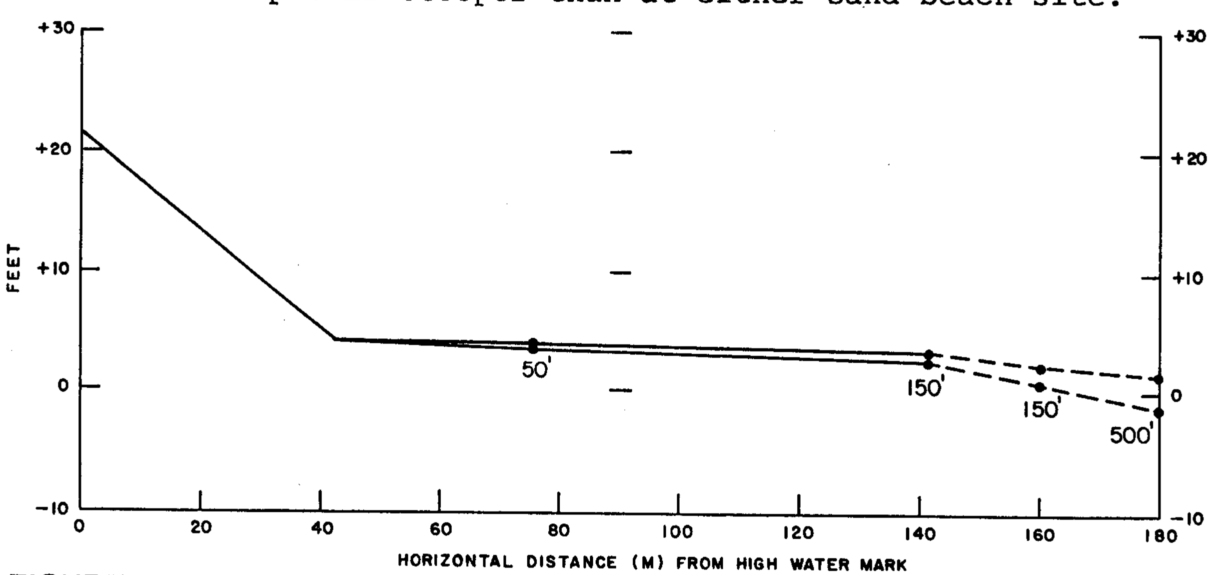

FIGURE 4 - ESTIMATED BEACH PROFILE FOR GLACIER SPIT, CHINITNA BAY

TABLE 3. SEDIMENT PARAMETERS FOR SAND BEACH SAMPLING SITES IN LOWER COOK INLET, MAY 1978

Location	Grain Size M_d (mm)	M (mm)	Dispersion $\sigma\phi$	$\alpha\phi$
Homer Spit - 30m level				
Replicate 1	0.24	0.24	0.39	0.06
2	0.28	0.28	0.54	0.04
3	0.35	0.41	0.70	-0.31
$\bar{x}$	0.29	0.31	0.54	-0.07
s	0.06	0.09	0.16	0.20
Homer Spit - 135m level				
Replicate 1	0.21	0.22	0.45	-0.14
2	0.25	0.25	0.56	-0.01
3	0.22	0.24	0.57	-0.19
$\bar{x}$	0.23	0.24	0.53	-0.11
s	0.02	0.02	0.07	0.09
Deep Creek - Level 1				
Replicate 1	0.26	0.27	0.50	-0.10
2	0.28	0.28	0.45	0.01
3	0.24	0.25	0.56	-0.17
$\bar{x}$	0.26	0.27	0.50	-0.09
s	0.02	0.01	0.06	0.09
Deep Creek - Level 3				
Replicate 1	0.22	0.21	0.40	0.06
2	0.21	0.20	0.48	0.05
3	0.21	0.20	0.42	0.06
$\bar{x}$	0.21	0.20	0.43	0.06
s	0.01	0.01	0.04	0.01

Sediment samples from Glacier Spit have not yet been processed. However, the sediment is basically a sandy silt with appreciable clay. It appears to be moderately well consolidated. Evidence of anoxic conditions (blackened sediment and shells, odor of sulfides) occur within 10 cm of the surface.

3.4 SAMPLING LEVELS

At the Homer Spit and Chinitna Bay sites, the sampling levels were established at predetermined distances from the gravel-sand interface. The location of these levels and their approximate elevations are indicated in Table 4.

At the Deep Creek site, we attempted to locate the levels according to predetermined elevations, specifically, MLLW, -1, -2 and -3 feet below MLLW. This was not successful because of the various sources of error inherent to the surveying method used and the unreliable or incomplete nature of the tidal information upon which we operated. The approximate elevations sampled at Deep Creek are indicated in Table 5.

On the sand beaches, neither of these methods of relocating sampling levels was completely satisfactory but the method used on the mud flat was satisfactory. A major technical problem on sand beaches is that the movement of the sand associated with changes in profile or elevation will cause some animals (e.g., amphipods) to relocate quickly to a suitable elevation but others such as deep-burrowing polychaetes cannot respond rapidly. Therefore, sampling at a set distance from a known point permits reasonable samples of polychaete populations, but any seasonal changes in elevation may cause problems for sampling amphipods. On the other hand, sampling at pre-determined elevations appears

TABLE 4. LOCATION AND APPROXIMATE ELEVATION OF SAMPLING LEVELS AT HOMER SPIT AND GLACIER SPIT, CHINITNA BAY, 1977.

	Homer Spit			Glacier Spit, Chinitna Bay	
Sampling Level	Distance from Interface (meters)	Approximate Elevation (feet) 3/8/77	7/28/77	Distance from Interface (meters)	Approximate Elevation (feet)
1 (Upper)	30	+0.75	-1.0	50	3.8 to 3.6
2	75	-0.75	-0.75	150	3.25 to 2.5
3	100	-1.75	-0.5	350	2.1 to 0.9
4 (Lower)	135	-2.5	-1.5	500	1.3 to -1.2

TABLE 5. VARIATION IN APPROXIMATE ELEVATION (FEET) OF SAMPLING LEVELS AT DEEP CREEK IN 1977.

Sampling Level	2/4/77	4/7/77	7/29/77
1 (Upper)	+1.0	+1.5	0.0
2	+0.5	+0.5	-1.0
3	0.0	-1.25	-2.0
4 (Lower)	-0.5	-2.75	-2.75

difficult to accomplish and also can result in large differences in the horizontal position of sequential sample sets at the same level. This would preclude sampling the same polychaete populations.

A completely satisfactory solution to this problem seems unlikely. However, based on the preliminary information that seasonal changes in the beach profiles are small, it seems most acceptable to sample at given distances from a fixed feature on the beach.

3.5 GENERAL ENVIRONMENTAL CONDITIONS

A comparison of environmental conditions at the three sites reveals some distinct differences. The factors considered are sediment temperature, ice cover and scour, salinity, turbidity, wave action and tidal currents. The comparisons are qualitative and frequently based on inference.

Severe winter air temperatures are somewhat lower at Chinitna Bay and Deep Creek than at Homer Spit. Surface sediment temperatures at the Spit are probably less severe during night low tides than at the other two sites. Chinitna Bay may also experience stronger winds than the other sites, causing greater wind chill effects. The surface layer of sediment freezes at all three sites during low tides in late fall and winter, but our impression is that it freezes deeper at Chinitna.

The scouring effects of sea ice range from substantial at Chinitna to low at both Deep Creek and Homer Spit. Wayne Byer, a resident on Glacier Spit, reports that during winter low tides, thickness of stranded ice approaches 2 m opposite his homestead (personal communication). In contrast, stranded ice blocks are not common at either of the sand beaches, but can occur during harsh winters. Floe ice at Glacier Spit may protect the sediment from extremely low temperatures in many cases, but can scour extensively.

Based on location, it would appear that salinity would be highest, and least variable, at Homer Spit, and lowest and most variable at Glacier Spit, which is essentially estuarine and situated in a bay near a number of streams. This inference is supported by the salinity patterns described by Kinney et al. (1970).

Our observations indicate that turbidity (suspended solids) is lowest, but highly variable, at Homer Spit, and highest and least variable at Glacier Spit. This agrees with the basic pattern reported by Sharma et al. (1974).

Wave action is a powerful influence at both Homer Spit and Deep Creek. Homer Spit has a maximum fetch for direct wind waves of 100 miles, and is only slightly protected from waves generated in Skelikof Straits. Breakers up to 2.5 m high have been observed there, and Hayes et al. (1977) predicts 3 m. However, Homer Spit is generally protected from northerly storms. Although Deep Creek is exposed to waves from south, west and north, and so is probably disturbed by wave action more regularly, the maximum fetch for direct waves is only about 30 miles. Because the stronger north and south waves will approach at an oblique angle, their force will be greatly reduced. Glacier Spit is generally protected from all but waves from the southeast, and surf over 1 m high is probably rare.

The influence of tidal currents varies greatly among the three sites. Exposure is greatest at Deep Creek, as it is located directly on the shoreline of the Inlet. The Homer Spit site is only slightly affected by tidal currents because of the protection provided by the Spit, particularly during outgoing tides. Glacier Spit, located near the head of Chinitna Bay, is subjected to only minimal tidal currents.

The differences in exposure to wave action and tidal currents are clearly reflected in the contrasting sediment regimes at Homer Spit and Deep Creek, on one hand, and Glacier Spit, on the other. Furthermore, slope of the upper beach indicates that Homer Spit is exposed to heavier surf; fall storms are particularly strong. However, tidal currents are stronger at Deep Creek and occur four times daily, so their overall effect may be greater.

4. METHODS

4.1 FIELD PROCEDURES

A stratified random sampling design was employed to examine the infauna of sand beaches at Homer Spit and Deep Creek, and the mud flat at Glacier Spit, Chinitna Bay. A transect extending across the beach from a specified point was established on each beach. Samples were collected at four specified levels or distances from the base of each transect. At each level, a measured line was laid out parallel to the shoreline and a set of vertical core samples was collected at random points along that line. All sample sets included ten replicate cores per level, except that only five per level were collected at Homer Spit in February 1977. The core sample collected was 10 cm in diameter (78.5 cm^2) by 30 cm in length (2356.2 cm^3). Each core sample was placed in a separate polyethylene bag and labelled. Subsequently, the core samples were sieved through a 1.0 mm screen to reduce the amount of inorganic material and the sample rebagged and preserved with a 10 percent formaldehyde-sea water solution.

Approximate beach profiles were determined using a measured PVC stadia rod, an expedient monopod and a telescopic level. Starting at the drift line of the previous high tide (estimated from the litter line and sediment dampness) a measured line was extended across the intertidal zone to the lower water line at low slack tide. Profile data were acquired by determining elevation changes over a measured horizontal ground distance with the level and stadia rod. Profile data were collected from high water to low water and back to high water; plotted profiles were averages of the two.

This method is subject to several inaccuracies. It is based on the accuracy of the published tide information on time and changes. Therefore, meteorological phenomena and correction factors are important sources of error.

4.2 LABORATORY ANALYSIS

In the laboratory each core was rough sorted under a dissecting microscope to separate the animals from the remaining sediment and to divide them by major taxa, mainly polychaete worms and crustaceans. At this time they were placed in a 30 percent isopropyl alcohol preservative. Subsequently, the samples were examined to identify the species and count the individuals. Initially, all specimens were also sent to taxonomic specialists to verify or obtain identifications. Subsequently, only difficult species have been sent out. The specialists consulted were: Bruce Benedict, formerly of Marine Biological Consultants, Inc., for gammarid amphipods, and Rick Rowe, Allan Hancock Foundation, University of Southern California, for polychaetes.

Following identification, the samples were re-examined to obtain length and weight data. Lengths of gammarid amphipods and small clams were measured on a dissecting microscope equipped with an ocular micrometer. Whole wet weights of animals were obtained by draining the specimens for about 15 seconds on damp paper towels and weighing them on a Torsion DWM2 balance accurate to ± 5 mg.

4.3 NUMERICAL ANALYSES

Quantitative samples (cores) produced several numerical parameters useful in describing and comparing faunal assemblages. Used to describe abundance were 1) the total number of specimens per level (N), 2) the average number of specimens per core sample (± one standard deviation), and 3) the number of organisms per m^2. Species richness was described with 1) the total number of species per level (S), 2) the average (± s) number of species per core, and 3) the Brillouin diversity index [$H = 1/N \left(\log_2 \frac{N!}{n_1!n_2!\ldots n_j!}\right)$, where n_1, $n_2 \ldots n_j$ are the number of individuals in species 1 through j]. The equitability, or evenness of the distribution of specimens among species was described by N/S and E, which was defined as $2^{H/S}$. Standard deviations are included to provide an indication of variability among the samples.

In addition, species-area curves were constructed to demonstrate the rate at which species were accrued within the assemblage observed at each level. This technique provided additional insight into the adequacy with which a level, or the area, was sampled.

To assist in describing zonation on the sand beaches, the abundance of each species was compared among levels to determine distribution patterns and composition at each elevation. Species that occurred at a given level in all three surveys and had a density exceeding $100/m^2$ at least once were categorized as "Dominants". "Subdominants" also occurred in each survey but their density never exceeded $100/m^2$. Species that occurred in only two surveys were categorized as "Frequent", regardless of density, and those that appeared only once, but at a density exceeding $100/m^2$, were considered "Seasonal". The categories for the mud beach, where data for only two surveys are included, are somewhat different. Species that occurred at a given level in both surveys and for which density exceeded $100/m^2$ at least once were categorized as "Dominant". "Subdominants" also occurred in both surveys but ranged between $100/m^2$ and $10/m^2$ in both surveys. Those which occurred in both surveys with densities ranging between $5/m^2$ and $10/m^2$ at least once were classified as "Frequent". Finally, species that occurred only once at densities of greater than $20/m^2$ were designated as "Seasonal".

5. RESULTS

5.1 BIOLOGICAL ASSEMBLAGE OF THE SAND BEACH AT DEEP CREEK

The infaunal assemblage at the Deep Creek site was sampled three times during the period covered by this report, namely on 4 February, 7 April and 29 July 1977. A total of 17 taxa, including eight polychaete and nine crustacean taxa, was identified during the sampling period (Table 1).

Quantitatively, the infauna was dominated heavily by gammarid amphipods, especially the haustoriid *Eohaustorius eous* (Table 6). Relative abundance was remarkably uniform seasonally. An unidentified member of the amphipod family Gammaridae (Gammaridae sp. A) was quite abundant in the July survey. The remaining species were only of marginal numerical importance. Most notable among these were the polychaetes *Eteone* nr. *longa* and *Scolelepis* sp. A, and the gammarid *Paraphoxus milleri*. The raw data for these samples, by core, level and survey, are presented in Appendix I and species summaries in Appendix II.

5.1.1 Zonation

To examine zonation, the species at each level were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, the upper level was dominated by *Eteone* and *Eohaustorius*, the middle

TABLE 6. OVERALL DENSITY (NO./M^2) OF COMMON SPECIES AT DEEP CREEK SITE

Taxa	2/77 Density	%	4/77 Density	%	7/77 Density	%
Polychaeta		(17.6)[a]		(12.9)		(13.4)
Capitella ?capitata	9.6	1.8	-	-	9.6	0.8
Eteone nr. *longa*[b]	44.6	8.6	9.6	1.6	9.6	0.8
Nephtys ?ciliata[b]	-	-	9.6	1.6	9.6	0.8
Paraonella platybranchia	15.9	3.0	9.6	1.6	12.7	1.0
Scolelepis sp. A[b]	15.9	3.0	35.0	5.4	92.3	7.4
Scoloplos armiger[b]	6.4	1.2	15.9	2.7	31.8	2.6
Gammaridea		(81.3)		(84.7)		(84.6)
Anisogammarus cf. *confervicolus*	6.4	1.2	6.4	1.0	-	-
Eohaustorius eous	404.2	78.3	461.5	78.8	648.4	51.9
Gammaridae, sp. A	-	-	-	-	388.3	31.2
Paraphoxus milleri[b]	9.6	1.8	28.6	4.9	19.1	1.5
Mysidacea						
Archaeomysis grebnitzkii	3.2	0.6	-	-	3.2	0.2

[a] Parenthetic number are total percentages in major taxa

[b] Also common in sandy infaunal samples collected at 200 ft. depths in the middle of Lower Cook Inlet and at Homer Spit

[c] Also found at Homer Spit

two levels by Eohaustorius and the lower level by Scolelepis and Eohaustorius (Table 7). Only the latter species was important at all levels.

The relationship between elevation and density was examined, but only the increase of Eohaustorius at lower elevations departed significantly from random ($P < 0.02$). In contrast, Eteone was more abundant at the upper levels than below, but the pattern was not statistically significant. In addition, densities in July appeared to be quite variable for several species. It appears that the middle level is near the upper limit for Scolelepis and Paraphoxus at this beach. The paucity of statistically significant elevation-related density differences among the species observed is probably mostly a consequence of too few samples, or a high degree of patchiness, as well as the changes in the beach shape and the corresponding movement of the animal populations in relation to the sampling levels.

Field observations indicate patterns of vertical distribution in the sediment for some of the species. All of the gammarid amphipods appear to live within 5 cm of the water-sand interface. On the other hand, the polychaetes Scolelepis and Nephtys are generally encountered at least 15 cm below the interface during low tides.

5.1.2 Seasonal Patterns

Several seasonal patterns were apparent. Overall density increased from February to July (Table 6). Within this general pattern, two trends were discerned. Gammaridae

TABLE 7. IMPORTANT SPECIES AT EACH LEVEL AT DEEP CREEK

Species	Sampling Level 1	2	3	4
Polychaetes				
Capitella capitata		Frequent		
Eteone nr *longa*	Dominant	Frequent		
Paraonella platybranchia		Frequent	Sub-dominant	Frequent
Scolelepis sp. A		Seasonal	Sub-dominant	Dominant
Scoloplos armiger			Sub-dominant	Frequent
Crustaceans				
Anisogammarus cf *confervicolus*	Frequent			Frequent
Eohaustorius eous	Dominant	Dominant	Dominant	Dominant
Gammaridae sp. A		Seasonal	Seasonal	Seasonal
Paraphoxus milleri		Frequent	Sub-dominant	Sub-dominant

sp. A increased strongly in abundance during the summer. Several other species, i.e., Eohaustorius and the polychaetes Scolelepis and Scoloplos, increased during the survey, but not significantly (respectively, P >0.65, >0.05 and >0.20, based on a Friedman X_r^2 analysis of variance computed with pooled data for each level and tested among surveys). In contrast, Eteone nr. longa decreased in abundance but not significantly (P >0.05). These trends appear strong and the lack of significance appears to be mainly a consequence of too few samples.

5.1.3 Biomass

In terms of biomass, the fauna at Deep Creek was generally dominated by polychaetes in April but by gammarid amphipods in July (Table 8). Specifically, in order of importance, the dominant polychaetes were Scoloplos, Eteone, Nephtys and Scolelepis in April, and Scoloplos, Scolelepis, Nephtys and Abarenicola in July. Dominant gammarids were Eohaustorius in April, and in July, Gammaridae sp. A and Eohaustorius. Overall, Eohaustorius dominated in terms of biomass in April and Gammaridae sp. A in July; Eohaustorius was next most important in July.

Generally, biomass levels were relatively low and consequently strongly affected by large, uncommon species such as Nephtys, or spatially and temporally patchy species such as Gammaridae sp. A. However, two general trends appeared real. During both surveys, there was a tendency for biomass to be greater at lower levels, mainly reflecting the patterns of the dominant species. Furthermore, there

TABLE 8. DISTRIBUTION OF WHOLE WET AND ESTIMATED DRY WEIGHTS IN SAMPLE SETS AT DEEP CREEK IN 1977 (WEIGHTS IN GRAMS)

Level	April 1	April 2	April 3	April 4	Survey Total Wet Weight	Survey Total Dry Weight[a]	July 1	July 2	July 3	July 4	Survey Total Wet Weight	Survey Total Dry Weight
Polychaeta	(0.360)[b]	(0.010)	(0.120)	(0.444)	(0.934)	(0.155)	(0.064)	(0.641)	(0.324)	(0.388)	(1.417)	(0.221)
Abarenicola pacifica	0	0	0	0	0	-	0	0.127	0	0	0.127	0.027
Capitella capitata	0	0	0	0	0	-	0	0.027	0	0.005	0.032	0.006
Cirratulidae, unid.	0	0	0	0	0	-	0	0	0.008	0	0.008	0.001
Eteone nr *longa*	0.260	0	0	0	0.260	0.051	0.020	0.008	0	0	0.028	0.006
Nephtys caeca	0	T	0	0.183	0.183	0.035	0	0	0.070	0.080	0.150	0.029
Paraonella platybranchia	0	T	T	0	T	T	0.001	-	-	0.001	0.002	T
Polychaeta, unid.	0	T	0	0	T	T	-	-	-	-	-	-
Scolelepis sp A	0	0	0.010	0.163	0.173	0.025	0.043	0.032[c]	0.01	0.140	0.226	0.032
Scoloplos armiger	0.100	0	0.110	0.098	0.308	0.044	0	0.447	0.235	0.162	0.844	0.120
Gammaridea[d]	(0.106)	(0.095)	(0.125)	(0.324)	(0.650)	(0.128)	(0.246)	(3.094)	(0.725)	(0.659)	(4.724)	(0.922)
Eohaustorius eous	0.033	0.095	0.125	0.291	0.544	0.107	0.126	0.234	0.315	0.239	0.914	0.179
Paraphoxus milleri	0.033	T	0	0.013	0.046	0.009	0	0.010	0.020	0.030	0.060	0.012
misc. gammarids	0.040	0	0	0.020	0.060	0.012	0.120	2.850	0.390	0.390	3.750	0.731
Total	0.466	0.105	0.245	0.768	1.584	0.283	0.310	3.825	1.049	1.047	6.231	1.143
Biomass (g/m^2)	5.93	1.34	3.12	9.78			3.95	48.70	13.36	13.33		
Average biomass (g/m^2)					5.04	0.901					19.84	3.638

[a] Based on conversion factors indicated in Thorson (1957)

[b] Parenthetic values are total wet whole weight for major taxa

[c] Only data for 9 cores

[d] Gammarid weights for July are estimates based on July abundance and wet weight/number ratio in April; samples were lost in the mails before weighing

was a strong increase in biomass between April and July. This reflected an increase in biomass in the dominant species, particularly Eohaustorius and Scoloplos, as well as the appearance of several additional species during this period (Table 8).

5.1.4 Size Structures

Observations on size structure were attempted for the gammarid Eohaustorius eous and the polychaete Scolelepis to provide insight into growth rates, life cycle and eventually permit estimation of secondary production.

It was possible to examine the size structure of Eohaustorius by measuring its length (from the tip of the rostrum to the base of the telson) with an ocular micrometer (Appendix IIIa). The length-frequency histograms represent pooled samples for all four levels (Figure 5). Based on these data, it appears that at least two age classes occurred in the population. The younger class appeared less abundant than the older one, but this may be an artifact of the mesh size of the sieve used to screen the samples. However, reproductive potential of haustoriids is reported to be fairly low (Sameoto 1969a and b).

A comparison of the April and July modes for the young age class suggests that growth was rather slow. The modal size of the older age class appears to have decreased during the same period, perhaps due to size specific predation or post spawning mortality of larger individuals. The difference in size structure is highly significant ($P < 0.005$, Kolmogorov-Smirnov two-sample test).

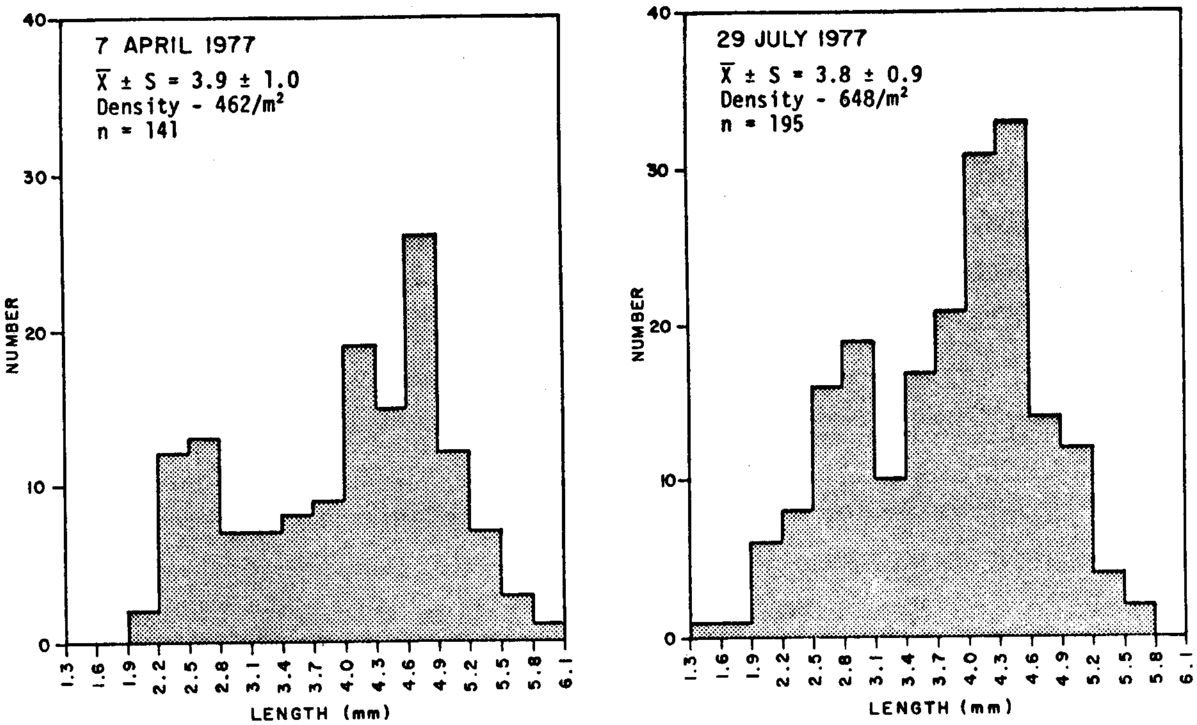

FIGURE 5 - LENGTH FREQUENCY HISTOGRAMS FOR <u>EOHAUSTORIUS EOUS</u> FROM DEEP CREEK, 1977

Size data were collected for two other gammarid amphipods but are unsatisfactory for one of several reasons. Average lengths for *Paraphoxus milleri* were 4.4 ± 1.7 mm in April (n = 8) and 7.7 ± 3.6 mm in July (n = 6) but the sample sizes were very small. Gammaridae sp A, very common in July, had an average length of 2.5 ± 0.7 mm (Appendix IIIb), but no comparative data were available from April.

Generally, useful measurements were not obtainable for *Scolelepis* because of its fragility and absence of hard parts useful in size measurements. To date, we have been unable to obtain a single whole worm. However, it is our impression based on visual examination of the samples that, on the average, worms were small in winter or spring, and large in the summer.

5.1.5 Numerical Parameters

Patterns in the numerical parameters were rather straight forward and consistent during the study. Generally, abundance, species richness and species diversity increased during the period of the survey (Table 9). Also, the first two parameters were generally higher at the lower elevations.

The significance of the observed increase in abundance from February to July was tested separately for each level on unpooled data (Appendix I) by means of the Kruskal-Wallis one-way analysis of variance. The differences were found to be highly significant ($P < 0.01$) at levels 1, 2 and 3, but did not depart from random at level 4 ($P > 0.3$).

When abundance was tested in the same manner for differences among levels, highly significant differences ($P < 0.01$) were found for all sample sets. In February and April, abundances were higher at lower elevations. In contrast, the two intermediate elevations (levels 2 and 3) had the higher densities in July.

The other abundance parameters presented (total number of organisms collected per level and number per m^2) are both derived directly from the raw data. Thus, the patterns are identical, i.e., exhibiting general increases with season and, during each survey, with lower elevation.

Species richness was evaluated statistically by comparing the number of species in each core (unpooled data) among levels and surveys; again the Kruskal-Wallis one-way

TABLE 9. SUMMARY OF NUMERICAL PARAMETERS FOR THE SANDY INTERTIDAL ASSEMBLAGE AT DEEP CREEK

	Abundance			Species Richness		Species Diversity	Evenness		
Elevation (ft)	Total per Level	$\bar{x} \pm s$ per Core	per m^2	Total per Level	$\bar{x} \pm s$ per Core	H	N/S	E	Grams Wet Weight per m^2
				4 February 1977					
0	18	1.8 ± 1.9	229.2	4	1.3 ± 0.7	1.32	4.5	0.62	-
-1	21	2.1 ± 1.6	267.4	3	1.2 ± 0.4	0.70	7.0	0.54	-
-2	39	3.9 ± 1.7	496.6	6	1.7 ± 0.8	1.05	6.5	0.35	-
-3	84	8.4 ± 4.3	1069.5	7	2.0 ± 0.7	0.69	12.0	0.23	-
Overall	162			9			18.0		
$\bar{x} \pm s$		4.1	515.7		1.6	0.9 ± 0.30		0.44 ± 0.18	-
				7 April 1977					
0	10	1.0 ± 0.9	127.3	5	0.8 ± 0.6	1.50	2.0	0.57	5.93
-1	31	3.1 ± 3.2	394.7	5	1.2 ± 0.8	0.64	6.2	0.31	1.34
-2	35	3.5 ± 2.8	445.6	6	1.3 ± 0.9	0.96	5.8	0.32	3.12
-3	108	10.8 ± 4.8	1375.1	7	2.6 ± 1.3	0.95	15.4	0.28	9.78
Overall	184			10			18.4		
$\bar{x} \pm s$		4.6	585.7		1.5	1.01 ± 0.36		0.37 ± 0.13	5.04
				29 July 1977					
0	39	3.9 ± 2.3	496.6	5	2.0 ± 0.9	1.15	7.8	0.44	3.95*
-1	173	17.3 ± 16.3	2202.7	12	3.9 ± 1.4	1.72	14.4	0.27	48.70
-2	101	10.1 ± 4.9	1286.0	11	3.4 ± 1.3	1.56	9.2	0.27	13.36
-3	84	8.4 ± 6.2	1069.5	9	2.7 ± 1.3	1.61	9.3	0.34	13.33
Overall	391			16			24.4		19.84
$\bar{x} \pm s$		9.9	1263.7		3.0	1.51 ± 0.25		0.33 ± 0.08	

* Biomass for gammarids in July based on average weight/specimen in April; animals lost in mails.

analysis of variance was used. The differences observed among surveys at a given level were significant at level 1, highly significant at levels 2 and 3, but not significant ($P > 0.5$) at level 4. At levels 1 and 3, fewest species per core were encountered in April, but at all levels, greatest species richness occurred in July. The total number of species encountered in each survey also increased during the study (Table 9). In February and April, there was a fairly well-defined increase in species richness at the lower sampling levels, but this pattern was not apparent in July.

Species diversity (H) generally increased from February to July, but was quite variable among the levels within each period. However, neither the patterns of variation with season nor with elevation were significant.

Evenness parameters generally indicated that species were less equitably distributed at lower elevations and in the later surveys. This is mainly a reflection of large increases in the density of populations of a rather limited number of species at lower elevations and through time. However, in all surveys, over 50 percent of the species were represented by three or fewer specimens. None of the patterns was statistically significant.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. In most cases, the curves for specific levels show signs of becoming asymptotic (Figure 6). Only at levels 2, 3 and 4 in July does it appear that a substantial number of additional species might have been obtained by further sampling. Such patterns emphasize the low species richness and high N/S ratios reported above.

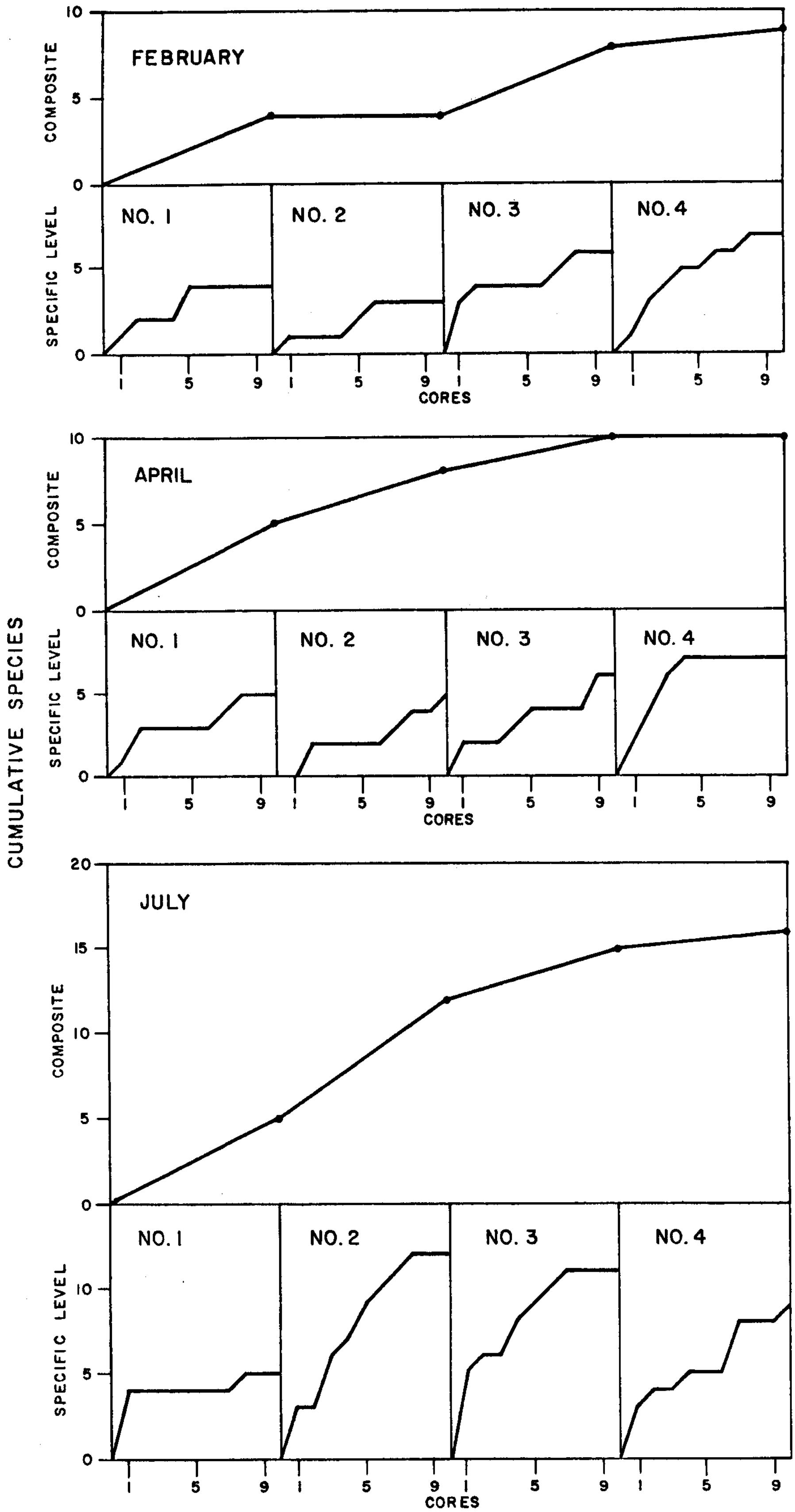

FIGURE 6 - SPECIES/AREA CURVES FOR DEEP CREEK

Composite species-area curves were constructed for each survey by tabulating, by level, the cumulative number of species identified. In all cases, the rate of "accrual" was fairly slow and uniform. This is probably a reflection of the intensity of the physical gradients. It is not surprising, however, that July, the mildest period sampled, initially produced the most rapid rate of "accrual" (the steepest slope). During that period, many less tolerant species were able to expand their local distribution to shallower levels.

5.2 BIOLOGICAL ASSEMBLAGE OF THE SAND BEACH AT HOMER SPIT

The infaunal assemblage at the Homer Spit station was sampled three times during the period covered by this report, namely on 17 February, 7 March and 28 July 1977. A total of 25 taxa, including 11 polychaete, 8 crustacean, and two molluscan (Table 1), was identified from the core samples.

Quantitatively, the infauna was dominated heavily by polychaetes, especially *Paraonella platybranchia* and *Scolelepis* sp. A (Table 10). Relative abundance of all groups was fairly uniform. Gammarid amphipods were substantially less important, with *Eohaustorius* and *Paraphoxus* the most abundant. The redneck clam (*Spisula*) and a fish (sand lance, *Ammodytes*) were encountered in low numbers in each survey. The raw data for these samples, by core, level and survey, are presented in Appendix IV and species summaries in Appendix V.

5.2.1 Zonation

To examine zonation, the species at each level

TABLE 10. OVERALL DENSITY (NO./M^2) OF COMMON SPECIES AT HOMER SPIT SITE

Taxa	2/77 Density	%	3/77 Density	%	7/77 Density	%
Polychaeta		(75.8)[a]		(84.8)		(78.1)
Eteone nr. *longa*[b,c]	6.4	1.0	0	0	3.2	0.3
Nephtys ?ciliata	6.4	1.0	9.5	1.0	3.2	0.3
Paraonella platybranchia	146.4	24.2	38.2	7.3	213.3	20.4
Scolelepis Sp. A[b,c]	273.7	45.2	385.2	73.3	547.5	52.3
Gammaridea		(16.8)		(12.7)		(5.8)
Eohaustorius eous	19.1	3.1	12.7	2.4	28.7	2.7
Paraphoxus milleri[b,c]	44.6	7.3	50.9	9.7	19.1	1.8
Pelecypoda						
Spisula polynyma[b]	12.7	2.1	3.2	0.6	6.4	0.6
Pisces						
Ammodytes hexapterus[b]	12.7	2.1	6.4	1.2	3.2	0.3

[a] Parenthetic values are percent of the overall total individuals within the major taxon indicated

[b] These species were also common in sandy infaunal samples collected at 200' depths in the middle of Lower Cook Inlet

[c] Also found at Deep Creek

were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, the upper two levels were dominated by Scolelepis, level 3 by Scolelepis, Paraonella and Paraphoxus and the lower level by Scolelepis (Table 11). Paraonella and Scolelepis were important at all levels, and the latter dominated throughout.

The relationship between elevation and density was examined, with the Kruskal-Wallis analysis of variance. Scolelepis was significantly more dense at lower elevations ($P < 0.001$). The density pattern of Paraonella, high toward the middle of the beach and lower at the upper and lower levels, was also highly significant ($P < 0.01$).

5.2.2 Seasonal Patterns

The seasonal patterns apparent in Table 10 are not statistically significant even though the differences are large in some cases. The density of the polychaete Scolelepis, for example, increased two-fold from February to July. The cumaceans Lamprops spp. became abundant in July.

Samples were collected in March immediately following a large storm to attempt to examine the effects of that disturbance. Generally, it appeared that the storm had little effect. However, a comparison of density of species between the February and March surveys provides some insight on vertical distribution within the sediment. Density reductions were noted for several species (e.g., Eteone, Eohaustorius, Spisula and Ammodytes) but only Paraonella was reduced significantly ($P < 0.05$; Table 10) and only at the 100 m level. That reduction following storm surf suggests

TABLE 11. IMPORTANT SPECIES AT EACH LEVEL AT HOMER SPIT

Species	Sampling Level (m) 30	75	100	135
Polychaetes				
Nephtys ?ciliata		Frequent		
Paraonella platybranchia	Frequent	Frequent	Dominant	Frequent
Scolelepis Sp. A	Dominant	Dominant	Dominant	Dominant
Crustaceans				
Eohaustorius eous		Sub-dominant	Sub-dominant	Frequent
Lamprops carinata				Seasonal
L. quadriplicata	Seasonal			
Paraphoxus milleri	Frequent		dominant	Sub-dominant
Pelecypods				
Spisula polynyma (juv.)				Sub-dominant
Fishes				
Ammodytes hexapterus			Frequent	

TABLE 12. DISTRIBUTION OF WHOLE WET AND ESTIMATED DRY WEIGHTS IN SAMPLE SETS AT HOMER SPIT IN 1977 (WEIGHTS IN GRAMS)

	March				Survey Total		July				Survey Total	
Sampling Level:	30m	75m	100m	135m	Wet Weight	Dry Weight[a]	30m	75m	100m	135m	Wet Weight	Dry Weight
Polychaeta	(0.080)[b]	(0.810)	(2.571)	(2.350)	(5.811)	(0.831)	(0.247)	(1.529)	(1.657)	(6.224)	(9.657)	(1.448)
Abarenicola pacifica	0	0	0	0	0	-	0	0.015	0	0	0.015	0.003
Capitella capitata	0	0	0	0	0	-	0	0	0.010	0.060	0.070	0.013
Magelona pitelkai	0	0	0	0.030	0.030	0.006	0	0	0	0	0	-
Nephtys sp.	0	0.020	0.005	0	0.025	0.005	0.184	1.140	-	0	1.324	0.255
Paraonella platybranchia	0	-	0.005	0	0.005	0.001	0.012	0.010	0.023	0.015	0.060	0.011
Sabellidae, unid.	0	0	0.005	0	0.005	0.001	0	0	0	0	0	-
Scolelepis sp A	0.080	0.790	2.556	2.240	5.666	0.807	0.048	0.364	1.624	6.149	8.185	1.166
Spio sp	0	0	0	0.080	0.080	0.011	0	0	0	0	0	-
Spiophanes bombyx	0	0	0	0	0	-	0.003	0	0	0	0.003	T
Gammaridea	(0.010)	(0.085)	(0.039)	(0.075)	(0.209)	(0.041)	(0.029)	(0.035)	(0.098)	(0.029)	(0.191)	(0.038)
Eohaustorius eous	0	0.005	0.009	0.005	0.019	0.004	0.009	0.005	0.018	0.009	0.041	0.008
Paraphoxus milleri	0.010	0.050	0.030	0.070	0.160	0.031	0.020	0	0.020	0.020	0.060	0.012
misc. gammarids	0	0.030	0	0	0.030	0.006	T	0.030	0.060	0	0.090	0.018
Total	0.090	0.895	2.610	2.425	6.020	0.872	0.276	1.564	1.755	6.253	9.848	1.486
Biomass (g/m^2)	1.15	11.40	33.23	30.88			3.51	19.91	22.35	79.62		
Average biomass (g/m^2)					19.17	2.78					31.35	4.73

[a] Based on conversion factors indicated in Thorson 1957

[b] Parenthetic values are total wet whole weight for large taxa

that these species live near the surface of the sediment. In contrast, the density of Scolelepis, which usually lives at least 15 cm below the surface, increased from February to March.

5.2.3 Biomass

In terms of biomass, the fauna at Homer Spit was strongly dominated by polychaetes in both March and July (Table 12). Scolelepis was by far the most important species at every level and in both surveys. Paraphoxus was the most important gammarid.

Biomass was relatively low but appeared only slightly affected by large, uncommon species. Two trends were fairly clear. Spatially, biomass increased markedly at lower elevation. Temporally, biomass increased sharply from April to July. Both patterns are mainly reflections of increases in Scolelepis. Gammarids showed little change by location or between periods.

5.2.4 Size Structures

Size data were collected for the gammarid amphipods Paraphoxus milleri and Eohaustorius eous, but the sample sizes were too small to provide satisfactory comparisons. The average size of Paraphoxus was 6.2 ± 1.1 mm in March (n = 7) and 6.1 ± 1.5 mm in July (n = 5). Data are not available for Eohaustorius in March, but average length was 3.8 ± 0.5 mm in July (n = 5).

5.2.5 Numerical Parameters

Patterns in the numerical parameters were fairly straight-forward and consistent during the survey. Basically, abundance, species richness and species diversity increased during the survey and, except for species diversity, at lower elevations (Table 13). Among the evenness parameters, N/S also increased during the study and at lower elevations, whereas E declined during the study and at lower elevations.

The significance of the observed increases from February to July was tested separately for each level on unpooled data (Appendix IV) using the Kruskal-Wallis analysis of variance. The seasonal increases in abundance were significant ($P < 0.05$) at the 30 m, 75 m and 135 m levels, but did not depart from random at the 100 m level. Similar analysis of abundance patterns among levels during a survey indicated that the increase in density at lower elevations observed in each survey were highly significant ($P < 0.01$).

Species richness was examined similarly by comparing the number of species per core among levels and surveys with the Kruskal-Wallis test. The seasonal changes observed at specific levels were significant at the 30 m ($P < 0.01$), 75 m and 135 m levels (for both, $P < 0.05$). Generally, there was a decline from February to March, and an increase by July at each level. Only in March were the observed differences among levels significantly different from random ($P < 0.01$). In both February and March, the average number of species per core was highest at the 100 m level. These patterns were fairly well reflected by the total number of

TABLE 13. SUMMARY OF NUMERICAL PARAMETERS FOR THE SANDY INTERTIDAL ASSEMBLAGE AT HOMER SPIT

	Abundance			Species Richness		Species Diversity	Evenness		
Sampling Level (m)	Total per Level	$\bar{x} \pm s$ per Core	per m^2	Total per Level	$\bar{x} \pm s$ per Core	H	N/S	E	Grams Wet Weight per m^2
				17 February 1977					
∿30	12	2.4 ± 1.7	305.6	4	2.0 ± 1.2	1.25	3.0	0.60	
∿75	8	1.6 ± 1.5	203.7	5	1.4 ± 1.5	1.52	1.6	0.57	
100	33	6.6 ± 2.1	840.4	7	3.8 ± 1.3	1.89	4.7	0.53	
135	42	8.4 ± 3.2	1069.6	7	3.0 ± 1.6	1.77	6.0	0.49	
Overall	95			14			6.79		
$\bar{x} \pm s$		4.8	604.8		2.6	1.61 ± 0.28		0.55 ± 0.05	
				7 March 1977					
30	9	0.9 ± 1.1	114.6	3	0.6 ± 0.7	0.71	3.0	0.55	
75	25	2.5 ± 1.6	318.3	6	1.7 ± 0.8	1.60	4.2	0.51	
100	48	4.8 ± 3.0	611.2	8	2.3 ± 1.2	1.58	6.0	0.37	
135	83	8.3 ± 6.3	1056.9	6	2.0 ± 0.8	0.75	13.8	0.28	
Overall	165			12			13.8		
$\bar{x} \pm s$		4.1	525.3		1.7	1.16 ± 0.50		0.43 ± 0.13	
				28 July 1977					
30	64	6.4 ± 5.1	814.9	12	3.3 ± 2.2	2.25	5.8	0.43	
75	47	4.7 ± 2.2	585.7	9	2.9 ± 1.2	2.16	5.1	0.50	
100	75	7.5 ± 2.9	955.0	9	3.0 ± 0.7	1.69	8.3	0.36	
135	144	14.4 ± 5.2	1833.6	10	3.3 ± 1.4	1.26	16.0	0.27	
Overall	330			16			20.6		
$\bar{x} \pm s$		8.3	1047.3		3.1	1.84 ± 0.46		0.39 ± 0.10	

species per level and the overall number of species per survey (Table 13). However, the pattern for species richness was rather confused in July.

Species diversity was, on the average, highest at each level, and overall, in July. However, the relationships among levels in a specific survey were confused.

Evenness patterns generally indicated that the species were less equitably distributed at the lower levels and in the later surveys. The decrease in evenness with lower elevation is a reflection of the relatively moderate increase in species richness in comparison with the increase in density. The average decrease in evenness during the study is a reflection of substantial density increases among a fairly stable suite of species.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. Generally, the curves for specific levels showed signs of becoming asymptotic (Figure 7). However, it appears that a substantial number of species could have been added by additional sampling at the 30 m and 135 m levels in July. This pattern accentuates the finding of low species diversity and high N/S ratios.

Composite species-area curves were constructed for each survey by tabulating by level the cumulative number of species identified. In February and March, the rate of "accrual" was fairly slow and uniform at each level. This seems to indicate a strong gradient for physical factors.

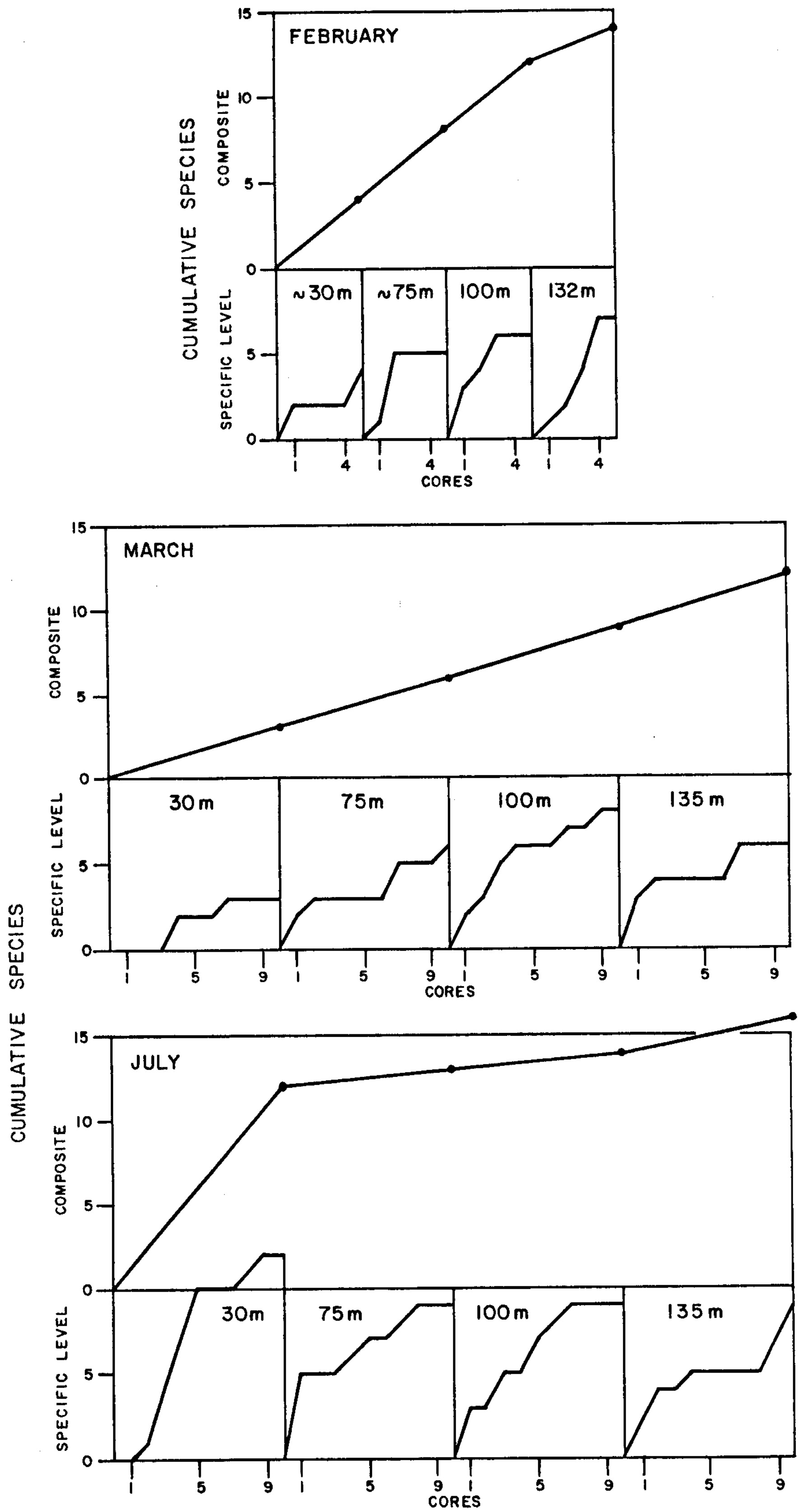

FIGURE 7 - SPECIES/AREA CURVES FOR HOMER SPIT

This interpretation is amplified by the composite curve for July, when conditions were comparatively very mild. In this case, the rate of "accrual" is initially rapid, i.e., most of the species observed were identified at the upper level, and the subsequent rate is quite slow. Although this suggests that the mild conditions have allowed a number of species previously restricted to lower levels to expand into higher elevations, examination of the species lists from the intertidal levels does not support this hypothesis.

5.3 BIOLOGICAL ASSEMBLAGE OF THE MUD FLATS AT GLACIER SPIT, CHINITNA BAY

The infaunal assemblage at Glacier Spit, Chinitna Bay, (Figure 1) was sampled twice during the period covered by this report, namely on 6 April, and 30 July, 1977. A total of 45 taxa, including 22 annelids, nine arthropods, and nine molluscs, was identified in the core samples (Table 2). Twenty of these taxa, including 67 percent of the molluscs and 50 percent of the annelids, were observed in both sample sets. Only one arthropod taxon occurred in both surveys; in fact, that species, a caprellid amphipod, *Tritella pilimana*, was the only crustacean of any importance.

In terms of abundance and biomass, the fauna was dominated heavily by pelecypods, especially *Macoma balthica* and *Mya* spp., (Table 14). Relative abundance was uniform between surveys. Furthermore, these clam species comprised at least 90 percent of the whole wet weight in the samples, while the remaining taxa contributed little. Several other species, especially the polychaete worms *Nephtys*, *Potamilla*, and *Spio*, and the clams *Clinocardium* and *Pseudopythina*, contributed at least marginally to density. Raw abundance data by core are presented in Appendix VI, and biomass data by

TABLE 14. OVERALL DENSITY (NO./M^2) AND BIOMASS[a] OF COMMON TAXA AT THE GLACIER SPIT, CHINITNA BAY SITE

	4/6/77				7/30/77			
	Density (no./m^2)	%	Biomass (g/m^2)	%	Density	%	Biomass	%
Echiurida								
Echiurus echiurus	38.2	0.6	22.82	1.0	41.4	0.8	31.80	0.8
Polychaeta		(9.5)[b]		(1.6)		(31.0)		(2.0)
Ampharete acutifrons	12.8	0.2	0.05	T	28.7	0.6	-	-
Capitella capitata	15.9	0.2	0.07	T	111.4	2.2	-	-
Eteone nr *longa*	38.2	0.6	0.55	T	121.0	2.4	0.73	T
Harmothoe imbricata	9.5	0.1	0.77	T	63.7	1.3	8.13	0.2
Malacoceros sp	15.9	0.2	0.04	T	38.2	0.8	0.05	T
Nephtys sp (adults & (juvenile)	331.0	5.0	27.92	1.2	324.7	6.5	59.94	1.5
Phyllodoce groenlandica	15.9	0.2	1.58	0.1	28.7	0.6	4.07	0.1
Polydora caulleryi	15.9	0.2	0.03	T	54.1	1.1	0.05	T
Potamilla sp	117.8	1.8	2.13	0.1	245.1	4.9	4.86	0.1
Scoloplos armiger	3.2	T	0.01	T	38.2	0.8	0.04	T
Spio filicornis	0	0	0	0	448.8	9.0	0.98	T
Crustacea		(0.1)		(T)		(4.9)		(T)
Tritella ?pilimana	3.2	T	T	T	187.8	3.8	T	T
Pelecypoda		(88.8)		(97.6)		(62.8)		(97.3)
Clinocardium nuttallii (juv. & adults)	213.3	3.2	1.53	0.1	105.0	2.1	201.8	5.0
Macoma balthica	4672.8	71.0	502.93	21.7	2654.7	53.4	461.55	11.4
Mya sp	804.8	12.2	1755.53	75.7	213.3	4.3	3257.53	80.7
Pseudopythina sp	144.7	2.2	1.94	0.1	140.1	2.8	6.6	0.2

[a] Based on whole preserved weights
[b] Parenthetic numbers are total percentages in major taxa

core in Appendix VII. These types of data are summarized, by species, in Appendices VIII and IX. Size and weight data for several species are in Appendix X.

5.3.1 Seasonal Patterns

Several seasonal patterns are apparent in the Chinitna Bay samples. The average number of specimens per core, and thus the other abundance parameters, decreased from April to July (Table 15; P <<0.001, with Student's T-test). However, within this general pattern, two strong trends were discerned. Density of polychaetes and the caprellid increased dramatically between surveys (P <<0.005, Wilcoxin matched-pairs signed ranks T-test). In contrast, most of the clams became substantially less abundant (P >0.05) during the same period.

5.3.2 Zonation

To examine zonation, the species at each level were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, all levels were numerically dominated by a small pink clam *Macoma balthica*, and a polychaete *Nephtys* was subdominant at each (Table 16). Additionally, the polychaete *Eteone* occurred frequently at all levels. Other species that were important at all levels sampled were a tubicolous polychaete *Potamilla* and the clams *Clinocardium*, *Mya* spp. (unidentified juvenile specimens) and a commensal clam *Pseudopythina*. The eastern soft shell clam, *Mya arenaria*, was only important at the two upper levels and *M. priapus* at the lower two levels. Several

TABLE 15. SUMMARY OF NUMERICAL PARAMETERS FOR THE MUDDY INTERTIDAL ASSEMBLAGE AT GLACIER SPIT, CHINITNA BAY

Elevation (ft)	Abundance: Total per Level	Abundance: $\bar{x} \pm s$ per Core	Abundance: per m^2	Species Richness: Total per Level	Species Richness: $\bar{x} \pm s$ per Core	Species Diversity: H	Evenness: N/S	Evenness: E	Grams We Weight per m^2
6 April 1977									
+3.6	428	42.8 ± 16.7	5450	16	4.7 ± 2.6	0.85	26.8	0.16	4163.66
+2.5	435	43.5 ± 8.4	5539	16	6.6 ± 1.6	1.12	27.2	0.22	2975.03
+0.9	642	64.2 ± 18.7	8175	15	7.0 ± 1.3	1.41	42.8	0.22	1144.08
-1.2	563	56.3 ± 17.3	7156	20	6.7 ± 2.0	1.40	28.2	0.22	996.46
Overall	2068			25			82.7		
$\bar{x} \pm s$		51.7	6580		6.3	1.20 ± 0.27		0.21 ± 0.03	2319.81
30 July 1977									
+3.6	250	25.0 ± 6.2	3183	20	6.4 ± 2.4	1.81	12.5	0.17	3743.89
+2.5	395	39.5 ± 13.7	5030	24	9.8 ± 2.5	2.82	16.5	0.27	3974.22
+0.9	441	44.1 ± 14.9	5615	25	10.1 ± 3.1	2.88	17.6	0.28	4858.09
-1.2	475	47.5 ± 13.9	6048	25	10.2 ± 3.3	2.54	19.0	0.22	3576.88
Overall	1561			36			43.4		
$\bar{x} \pm s$		39.0	4969		9.1	2.51 ± 0.49		0.24 ± 0.05	4038.27

TABLE 16. IMPORTANT SPECIES AT EACH LEVEL AT GLACIER SPIT, CHINITNA BAY

	Elevation (ft)			
Species	+3.6	+2.5	+0.9	-1.2
Echiurus echiurus		Frequent	Frequent	
Polychaetes				
Capitella capitata		Frequent	Frequent	Frequent
Eteone nr *longa*	Frequent	Frequent	Frequent	Frequent
Harmothoe imbricata			Frequent	
Nephtys sp	Sub-dominant	Sub-dominant	Sub-dominant	Sub-dominant
Phyllodoce groenlandica				Frequent
Polydora caulleryi		Frequent		
Potamilla sp	Frequent	Frequent	Sub-dominant	Frequent
Spio ?filicornis		Seasonal	Seasonal	Frequent
Caprellidea				
Tritella ?		Seasonal	Seasonal	Frequent
Pelecypods				
Clinocardium nuttallii	Frequent	Frequent	Sub-dominant	Sub-dominant
Macoma balthica	Dominant	Dominant	Dominant	Dominant
Mya arenaria	Frequent	Frequent		
M. priapus			Frequent	Frequent
Mya spp (juv)	Frequent	Frequent	Sub-dominant	Dominant
Pseudopythina sp	Frequent	Frequent	Sub-dominant	Frequent

other species became more important at lower levels, including the worm *Spio*, the caprellid *Tritella*, and the clams *Clinocardium* and *Mya* spp. (juveniles).

Consistent patterns of vertical distribution in the sediment were evident from field observations for several species (Figure 8). The caprellid lives on filamentous algae at the water-mud interface, (Benedict, personal communication), whereas most of the other species live in the sediments. Most of the polychaetes live near the sediment surface. However, *Potamilla* constructs tubes extending well into the sediment, and *Nephtys* adults live in burrows with at least two openings that extend to a depth of at least 15 cm into the sediment. *Echiurus* (Figures 8 and 9) constructs U-shaped burrows that may extend down into the sediment at least 30 cm. *Pseudopythina* appears to live in these burrows as a commensal, sometimes occurring attached to the spoonworm by byssus threads. The scaleworm *Harmothoe* is a commensal and appears in burrows with *Nephtys*, *Echiurus* and *Mya*. Juveniles of *Macoma*, *Mya* and *Clinocardium* live in the surface sediments. Adult *Clinocardium* live with the anterior margin of the shell right at the water-mud interface. *Macoma* and *Mya* burrow deeper as they grow larger, a trait which provides considerable protection from predators, physical stress and disruption. Adult *Macoma balthica* (Figures 8 and 9) generally live within 5 cm of the sediment surface. Adults of *Mya* spp. burrow down to at least 30 cm into the sediment and form semi-permanent burrows communicating vertically with the surface (Figures 8 and 9).

These patterns result in a substantial vertical distribution of the biomass in the upper 30 cm of the sediment. Furthermore, the burrowing habit of *Mya* spp. and

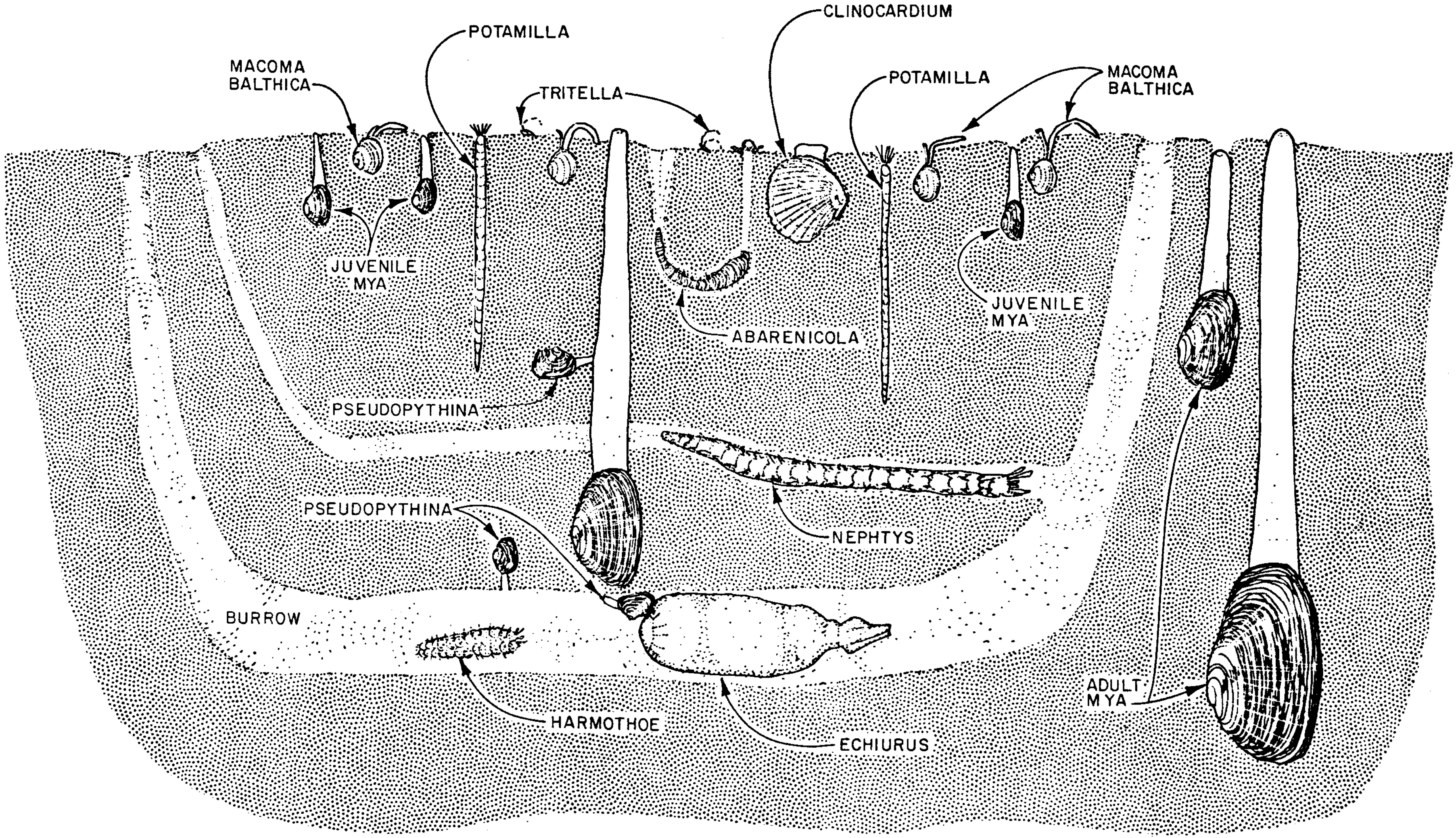

FIGURE 8 - DISTRIBUTION OF MAJOR ORGANISMS IN THE FAUNAL ASSEMBLAGE ON THE MUD FLAT AT GLACIER SPIT, CHINITNA BAY

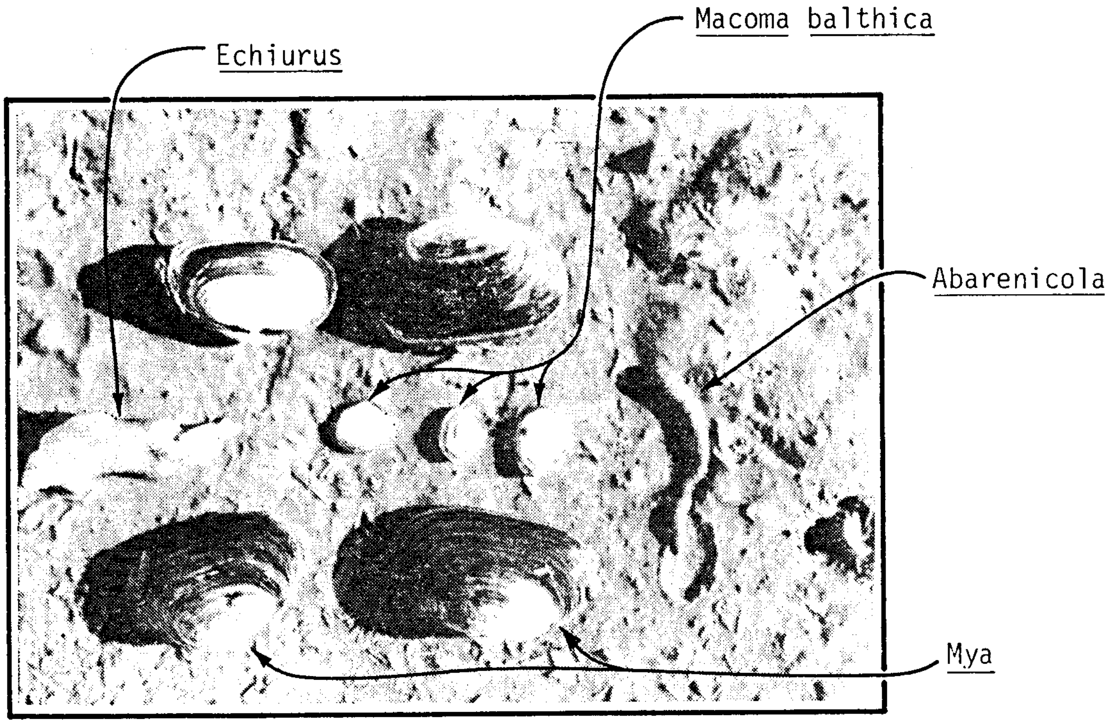

FIGURE 9 - SEVERAL DOMINANT SPECIES IN THE MUD FLAT ASSEMBLAGE AT GLACIER SPIT, CHINITNA BAY

Echiurus results in a fair degree of porosity in the upper 30 cm of the mud flats (Figures 8, 9 and 10). In Figure 10, the large holes were formed by adult Mya spp., and the smaller holes by Macoma balthica, polychaetes and Echiurus.

5.3.3 Biomass

During the survey, biomass (compared in Tables 15 and 17), generally increased significantly on the average and for most species examined (P = 0.005; Wilcoxin T-test). Among the major species, only Macoma exhibited a decline in biomass. Clam species contributed over 90 percent to both the wet and dry weight estimates for the mud flat examined.

TABLE 17. SUMMARY OF BIOMASS DATA FOR THE MUDFLAT ASSEMBLAGE, GLACIER SPIT, CHINITNA BAY IN 1977

	Average Whole Wet Weight (g/m^2)		Conversion Factor	Estimated Dry Tissue Weight (g/m^2)	
	April	July		April	July
Echiurus	22.82	31.80	14%[a]	3.19	4.45
Polychaetes	35.06	78.99	14%[b]	4.91	11.06
Clams					
Clinocardium	1.53	201.8	5%[a]	0.08	10.09
Macoma balthica	502.93	461.55	5.75%[b]	28.92	26.54
Mya spp	1755.53	3257.53	6.6%[b]	115.86	215.00
Pseudopythina	1.94	6.6	5.4%[c]	0.10	0.36
Total	2319.81	4038.27		153.06	267.5

[a] Estimates based on examination of Thorson (1957)

[b] Based on conversions published in Thorson

[c] Average for pelecypods in Thorson

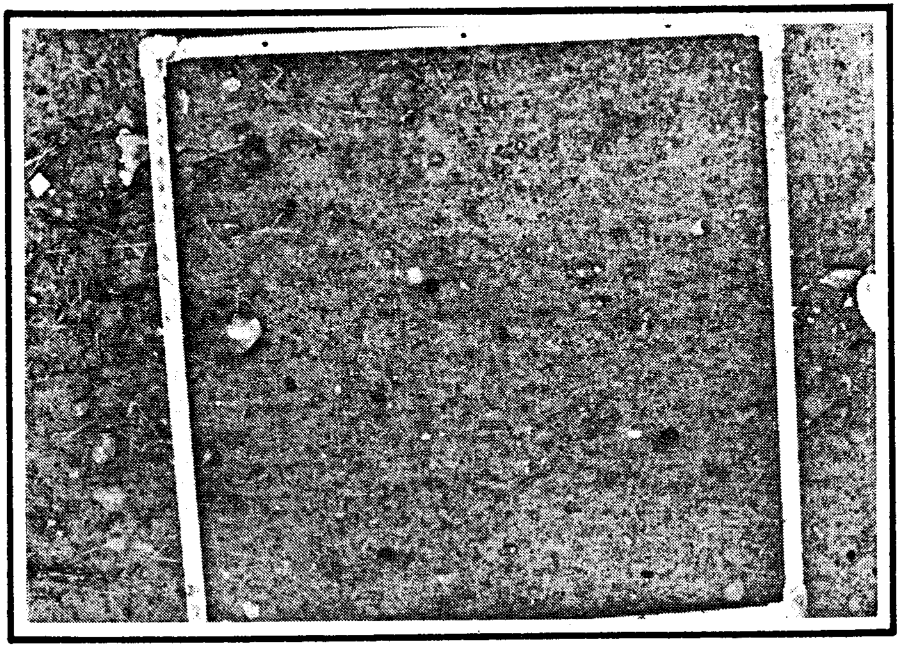

FIGURE 10 - SURFACE OF THE MUD FLAT AT BRUIN BAY IN KAMISHAK BAY, LOWER COOK INLET, SHOWING THE POROSITY AS A CONSEQUENCE OF BIOLOGICAL ACTIVITY

Data in Appendix VII indicate that adult Mya arenaria and M. priapus are particularly important. Echiurus and polychaetes contribute less than two percent each to standing stocks. Among the polychaetes, Nephtys contributes most. Clinocardium displayed the highest rate of increase in biomass, and the magnitude of change was probably due mainly to growth.

5.3.4 Biology Of Macoma balthica

Observations on size structure were made for all of the clams collected to provide insight into growth rates and life cycles as well as to assist in estimation of secondary production (Appendix X). The most useful data were for Macoma balthica and Mya spp. In all cases, the measurement used was shell length.

Length-frequency histograms for Macoma balthica from a 1976 collection and for both 1977 sampling periods covered by this report are included in Figure 11. These histograms also indicate the mean size of the distribution, its standard deviation, and estimates for density and whole wet weight per m^2, where available. This comparison reveals several important features about the population structure of Macoma. Generally, all levels exhibited similar size structures during the same sampling period. In April 1977, members of the 0-year class were considerably more numerous than those in the older mode. By July, the difference was substantially reduced, particularly at the +3.6 foot and +2.5 foot levels, where the two modes were nearly equal in abundance. The 0-year class remained more numerous at the two lower levels in July. Except at the lowest level, the older mode was also reduced substantially between April and July. The decline of both modes resulted in the large reduction in overall density observed at all levels by July. These density reductions ranged from 22 percent at the -1.2 foot level to 49 percent at the +3.6 and +0.9 foot levels and averaged 39 percent. All reductions were significant ($P < 0.01$ in all cases; Kruskal-Wallis analysis of variance).

Growth was apparent in both modes (Figure 11). The 0-year class increased from between 3 and 4 mm in April to between 6 and 7 mm in July. The larger mode probably includes several year classes, so changes in the modal mean do not accurately reflect age-specific growth rates.

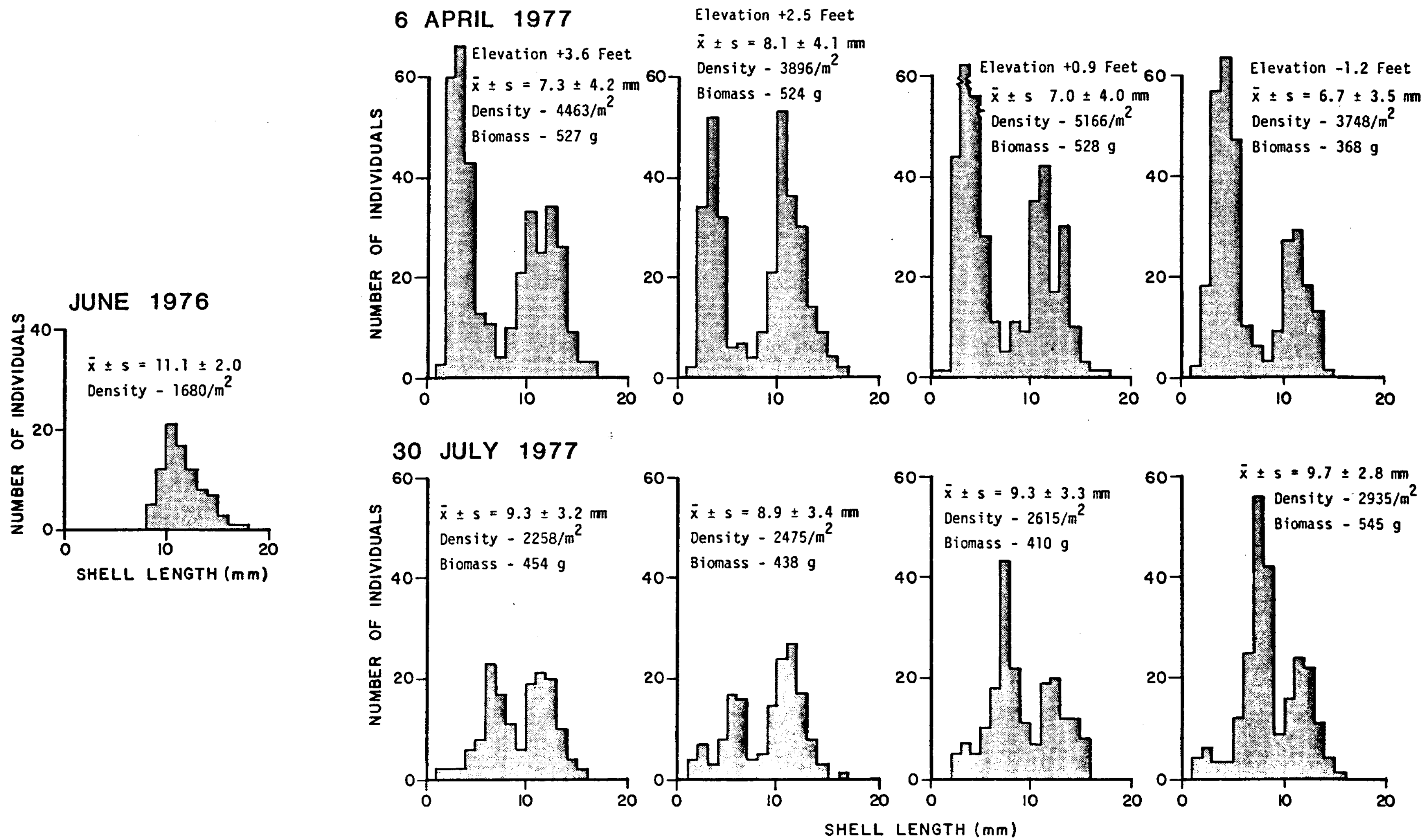

FIGURE 11 - PATTERNS IN SIZE, ABUNDANCE AND BIOMASS FOR MACOMA BALTHICA

CHINITNA BAY

Above MLLW, biomass (wet whole weight) decreased between April and July. However, a substantial increase was observed at the -1.2 foot level. This was apparently a consequence of growth, combined with a relatively limited reduction in density.

The comparison of these histograms to the one for 1976 is quite revealing. The conspicuous absence of a 0-year class in 1976 is very probably a consequence of the relative harshness of the previous winter. Notable also was the substantially lower density in early summer.

5.3.5 Biology Of *Mya* spp.

Size structures for *Mya* spp. are not clearly definable because of the relatively low density of the adults and the confusion caused by the 0-year classes (juveniles) of three species. Specimens smaller than about 20 mm are very difficult to assign to species and have therefore been tabulated separately (Appendix X). As a consequence, the number of specimens in the 0-year class for each species is unknown. However, the juvenile/adult ratio for *Mya* spp. averaged 28.7 and ranged from 1.4 to 88.0 in April, in contrast to July, when it averaged 0.7 and ranged from 0.1 to 1.3 (Table 18). Basically, the reduction in this ratio is a result of a considerable decrease in the abundance of juvenile *Mya*. Most of the loss appears to be a consequence of mortality; the slight increase in density of adults clearly doesn't account for the total reduction in juveniles. It appears, however, that growth of the juveniles was fairly rapid between April and July. Average shell length for the juvenile mode increased from 4.2 ± 1.0 mm in April to 11.9 ± 6.5 mm in July (Appendix Xc). Contrasting the virtual absence of specimens larger than

TABLE 18. DISTRIBUTION OF ADULT AND JUVENILE *MYA* SPP. IN THE INTERTIDAL ZONE AT GLACIER SPIT, CHINITNA BAY IN 1977

	Average Number per Core							
	April				July			
Tidal Elevation (ft)	+3.6	+2.5	+0.9	-1.2	+3.6	+2.5	+0.9	-1.2
Adults								
Mya arenaria	0.7	0.5	0	0.3	0.5	0.5	0.4	0.1
M. priapus	0	0.2	0.1	0.1	0.2	0.1	0.6	0.5
M. truncata	0	0	0	0.1	0	0	0.3	0.2
Total adults	0.7	0.7	0.1	0.5	0.7	0.6	1.3	0.8
Juvenile *Mya* spp	1.2	1.0	8.8	11.9	0.1	0.4	0.6	1.0
Juvenile/adult ratio	1.7	1.4	88.0	23.8	0.1	0.7	0.5	1.3

6.5 mm in April to the fact that 78 percent of the juveniles in July were larger than 6.5 mm (Figure 12) supports a hypothesis that the increase in size was due to growth and not solely differential mortality, at least initially.

Average shell length of adult _Mya_ _arenaria_ and _M_. _priapus_ increased between April and July, but the sample sizes were small (Appendix Xd and Xe). Using Students' t-test, the increase from 67.0 mm to 73.7 mm for _M_. _arenaria_ was not significant (P >0.10), but for _M_. _priapus_, the increase from 26.9 mm to 46.5 mm was significant (P <0.05). It seems imprudent to assume, without more direct evidence, that the latter increase is due solely to growth.

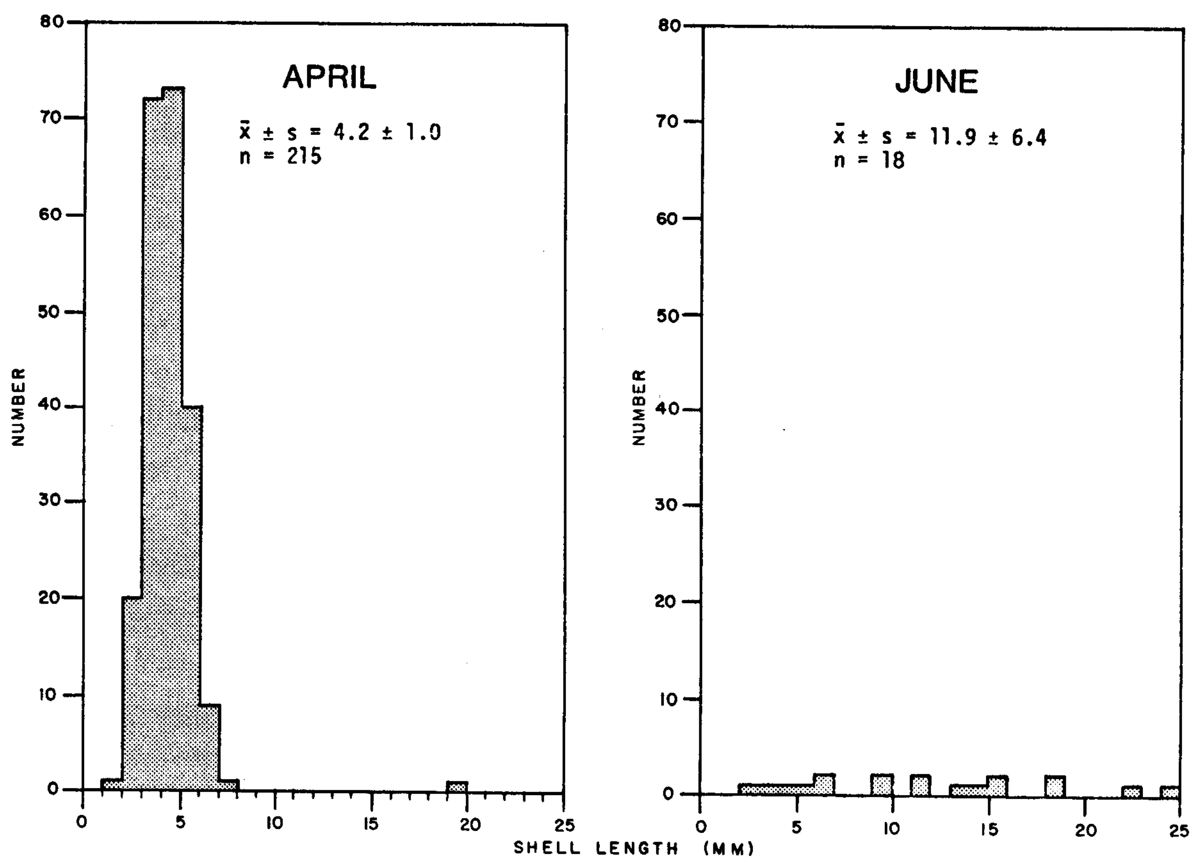

FIGURE 12 - SHELL LENGTH FREQUENCY HISTOGRAMS FOR JUVENILES OF _MYA_ SPP. FROM GLACIER SPIT, CHINITNA BAY IN 1977

Additional information on the distribution and density of adult *Mya* spp. was obtained by counting siphon holes in a series of haphazard 1/16 m^2 quadrats at each sampling level (Table 19). Generally, this method produced more conservative density estimates than the core method, probably because the clams become distinguishable to species somewhat before they are large enough to produce a readily distinctive siphon hole. In fact, the quadrat data are probably more reliable than the core data for large clams because of the larger sampling area involved (0.0625 m^2 vs. 0.0078 m^2), the larger number of samples collected (25 vs. 10 at each level) respectively, and the possibility that the corer may not satisfactorily sample large *Mya*. This interpretation is supported by a comparison of the means ($\bar{x}$) and standard deviations (s) of the two types of data. Examination of Appendix VI and Table 19 shows that, in all cases for adult *Mya* spp., s was larger than $\bar{x}$ for core data and smaller than $\bar{x}$ for quadrat data. This indicates that quadrat data were less variable.

A comparison of *Mya* densities among sampling levels based on quadrat data from April indicates that the 0.9 foot level had significantly higher density than +3.6 and -1.2 foot levels ($P < 0.05$ in all cases with the Mann-Whitney U test). However, the pattern of density is at odds with that estimated from core data (Table 19). In July, the only significant difference in density was between the +2.5 and the -1.2 foot levels ($P < 0.05$ in both cases). Density of adults appeared to be evenly reduced from the upper to the lower levels. Again, however, a curious discrepancy exists between the quadrat and the core data.

Based on the quadrat data, only the density increase from April to July at the +3.6 foot level was significant (P <0.01). The overall difference in adult density between April and July (Table 19) was not significant (P >0.10). The discrepancy between this finding and that based on core data is probably attributable to the great reduction in small clams, as discussed above.

It appears that *M. arenaria* is more successful at higher intertidal levels, whereas *M. priapus* and *M. truncata* are more successful at lower levels (Table 18). *Mya truncata* is a common subtidal species in several habitats. In April and July, juveniles were more dense at the lower levels than at upper levels. However, as indicated above, density of juveniles decreased considerably at all levels (in fact by an order of magnitude) between April and July (Table 18). This decrease was significant only at the lower two levels (P <0.05 in both cases; Kruskal-Wallis analysis of variance). No such change was apparent in adult density. This is highlighted by the changes in juvenile/adult ratio.

5.3.6 Other Size And Density Data

Size data for the basket cockle (Appendix Xg) indicate that average size increased markedly from April to July (P <0.001; Kolmogorov-Smirnov two sample test). As in the case of *Mya*, a sharp reduction in density occurred over the same period (Table 20). It appears that the intertidal population is dominated by young specimens.

TABLE 19. DISTRIBUTION AND DENSITY OF ADULT *MYA* SPP. BASED ON HAPHAZARD CASTS OF A 1/16m^2 QUADRAT

	Elevation (ft)							
	6 April 77				30 July 77			
Number per 1/16m^2 quadrat	+3.6	+2.5	+0.9	-1.2	+3.6	+2.5	+0.9	-1.2
0	1	1	0	3	0	0	0	2
1	2	2	0	4	2	4	2	4
2	6	3	3	5	2	2	4	1
3	5	6	3	3	3	1	3	5
4	8	5	4	4	4	2	6	6
5	1	2	3	3	4	6	1	0
6	1	1	3	2	1	3	2	5
7	0	2	3	1	2	1	2	1
8	0	1	1	0	2	2	2	1
9	0	0	1	0	1	2	2	0
10	0	1	0	0	3	1	0	0
11	0	0	2	0	1	0	1	0
12	1	1	0	0	0	1	0	0
13	0	0	2	0	0	0	0	0
$\bar{x}$	3.4	4.2	6.0	2.9	5.5	5.2	4.8	3.6
s	2.3	2.8	3.3	2.0	3.0	3.0	2.7	2.2
No./m^2	53.8	67.8	96.0	46.7	87.7	83.2	76.2	57.6
Overall mean				66.0/m^2				76.4/m^2
Estimated number of adults/m^2 based on core data	101.8	101.8	38.2	63.6	114.8	127.4	216.4	114.7
Overall mean				76.4/m^2				143.3/m^2

TABLE 20

DENSITY OF THE BASKET COCKLE _CLINOCARDIUM NUTTALLI_

IN THE INTERTIDAL ZONE AT CLACIER SPIT, CHINITNA BAY

Elevation (ft.)	April	July
+3.6	63.7	38.2
+2.5	50.9	76.4
+0.9	432.9	165.5
-1.2	345.8	178.2
$\bar{x} \pm s$	223.3 ± 195.0	114.6 ± 68.1

Similarly, size data for the small commensal clam _Pseudopythina_ sp. (Appendix Xi) indicate a weak increase in average size (P <0.10) from 3.2 mm to 5.0 mm. Average density was remarkably constant during this period (Table 21). This is probably a consequence of its apparent commensalism with burrowing species such as _Echiurus_, a behavior pattern that affords it considerable protection from severe predation pressures at the water-sediment interface. Highest densities appeared to occur at about MLLW.

TABLE 21

DENSITY OF THE COMMENSAL CLAM _PSEUDOPYTHINA SP._

IN THE INTERTIDAL ZONE AT GLACIER SPIT, CHINITNA BAY

Elevation (ft.)	April	July
+3.6	89.1	89.1
+2.5	203.7	114.6
+0.9	229.2	216.5
-1.2	56.6	140.1
$\bar{x} \pm s$	144.7 ± 84.6	140.1 ± 55.0

5.3.7 Numerical Parameters

Numerical parameters used to describe the assemblage exhibited few strongly consistent patterns. Abundance, species richness and species diversity generally increased from upper to lower elevations in each survey (Table 15). However, abundance decreased at all levels between April and July ($P \ll 0.001$). Species richness and species diversity all increased markedly during the same period. These patterns in abundance and species richness corresponded in a reduction in the average number of specimens per species (N/S). In spite of a seasonal decline in abundance, biomass increased substantially at all but the highest level. The seasonal change in biomass progressed from a 10 percent reduction at the +3.6 foot level, through a 34 percent increase at +2.5 feet, to 325 percent and 259 percent increases at the +0.8 foot and -1.2 foot levels.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. Generally, the curves for specific levels appeared to be leveling off, but none was asymptotic after 10 samples (Figure 13). This pattern was more apparent in July. However, it seems obvious that additional sampling effort only would have added a number of uncommon species to the lists compiled at each level during the respective sampling periods. This pattern accentuates the finding of high N/S ratios and low species diversity.

The composite species-area curves also generally tended to level off, but definitely were not asymptotic. This is to be expected because the sampling levels extend

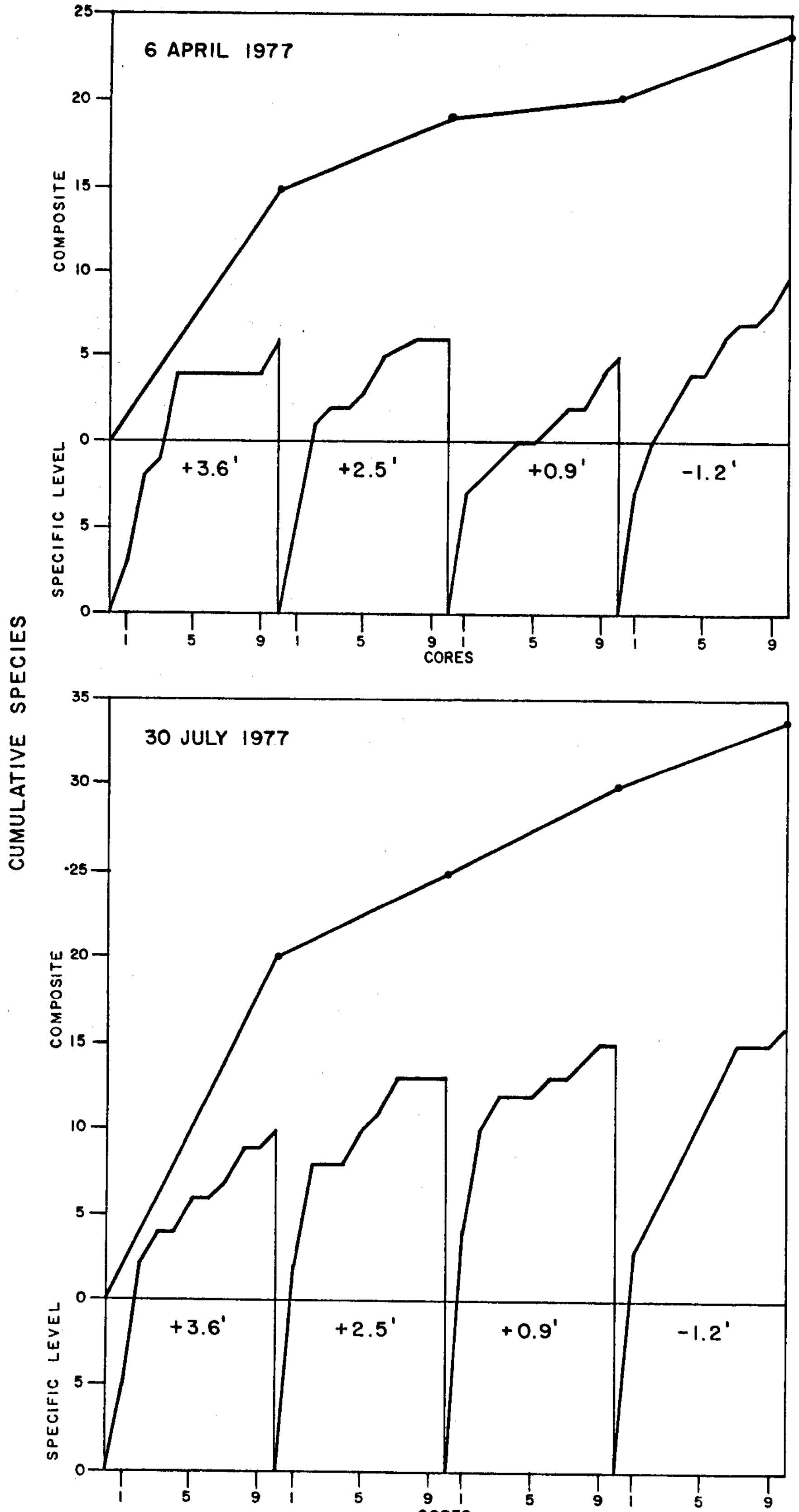

FIGURE 13 - SPECIES/AREA CURVES FOR GLACIER SPIT, CHINITNA BAY

across an elevation gradient and new species are expected to be encountered at the lower levels. In fact, the number of new species appearing below the upper level was greater in July, but seems rather modest for both sampling periods. This suggests a relative homogeneity in composition of the mud flat assemblage in the area examined.

6. DISCUSSION

6.1 SAND BEACH ASSEMBLAGES

The biological assemblages observed on the sand beaches exhibited many fundamental similarities in composition and structure. Many of the species were important at both sites, including the polychaetes *Eteone* nr. *longa*, *Nephtys ?ciliata*, *Paraonella platybranchia* and *Scolelepis* sp. A, and the gammarid amphipods *Eohaustorius eous* and *Paraphoxus milleri* (Table 1). Age structure data are not available for any for these species, but most appear to live for two years or less. Reporting on five species of haustoriids, Sameoto (1969a, 1969b) indicates ranges in longevity of 12 to 17 months; most were annuals. Hedgpeth (1957) reported that most sand beach organisms are annuals.

Many of the families, genera, and in some cases, the species, are characteristic components of unconsolidated intertidal assemblages in the Pacific and Atlantic Oceans (e.g., Withers 1977).

Many of the seasonal and elevational patterns observed for numerical parameters were similar for the two beaches (Tables 9 and 13). Levels of density, average number of species, species diversity, evenness and biomass were uniformly rather low at both locations. Sand beaches are generally characterized by low values for these parameters (Dexter 1969, 1972). At both beaches abundance, species diversity and biomass parameters generally increased from winter to summer, agreeing with the pattern described by Hedgpeth (1957), and from higher to lower elevations as reported by Johnson (1970). In addition, the average number of specimens per species increased from winter to summer, which was accurately reflected by decreases in the evenness index (E) over the same period. Keith and Hulings (1965) found similar patterns on sand beaches on the Texas Gulf Coast.

In spite of the basic similarities, some faunal dissimilarities imply important differences between the areas. Specifically, the fauna at Deep Creek was dominated numerically by gammarid amphipods, viz. *Eohaustorius*, Gammaridae sp. A and *Paraphoxus* (Table 6). In contrast, the fauna at Homer Spit was dominated by polychaetes such as *Scolelepis*, and gammarids were only of marginal importance (Table 10). In terms of biomass, the fauna at Deep Creek was again dominated by *Eohaustorius* in both surveys whereas at Homer Spit, it was dominated by *Scolelepis*. Furthermore, the fauna at Homer Spit was somewhat richer than that examined at Deep Creek, biomass was appreciably greater, and the range of organisms, including a clam and a fish, was broader. Withers (1977) reported that the polychaete fauna on Welsh beaches was better developed in sheltered areas. Furthermore, he noted that, on exposed beaches, "only a very reduced fauna of crustaceans and small polychaetes was found." These facts lead to the impression that the fauna at Deep Creek was responding to a more rigorous environment and was more typical of exposed intertidal beaches. This impression was amplified by the strong dominance at Deep Creek by a haustoriid amphipod, a family often characteristic of exposed sandy beaches (Barnard 1969), the importance of another amphipod, *Anisogammarus*, and a mysid *Archaeomysis*, both typically intertidal species (Kozloff 1973). In contrast, the fauna at Homer Spit was characterized by increased importance of polychaetes, and the consistent appearance of characteristically subtidal forms such as the redneck clam (*Spisula*) and the sand lance (*Ammodytes*).

Pronounced annual variations in the abundance of organisms are characteristic of sand beaches (Hedgpeth 1957). The increases in abundance, species richness, species diversity and biomass observed in this study in spring and summer are a consequence of a combination of reduced environmental stress, growth, and recruitment. Higher species richness indicates that several species are attempting to colonize the intertidal zone during this relatively mild period. Size structures, when available, indicated that many juvenile specimens were present, and growth was also apparent for at least one species (Eohaustorius).

It is probable that several factors are responsible for lower levels of abundance, species richness and biomass in the winter. Increased wave action undoubtedly raises mortality rates for species living near the water-sand interface. March samples from Homer Spit taken immediately after a storm suggested that density of some polychaetes was reduced. However, densities of Eohaustorius and Paraphoxus were not appreciably affected, and Scolelepis, which lives buried deeply in the sand, increased substantially during this period. Keith and Hulings (1965) reported that sand faunas on the Texas Gulf Coast were not appreciably affected by the waves of Hurricane Cindy, in 1963. Low winter temperatures undoubtedly reduce metabolic rates and feeding activities, thus slowing growth and reproductive activities. Woodin (1974) states that many polychaetes die after spawning and this may account in part for the seasonal variations in density observed at both beaches. Increased sediment instability associated with storms is likely to reduce success rate in recruitment, but this may be of little importance in winter.

The precise role of predation in the sand beach assemblages is, at present, still unclear. Predation pressure appears low, but has not been assessed in detail. The only infaunal predator recognized so far is the polychaete Nephtys (Kozloff 1973, Green 1968), which probably feeds on Scolelepis. Pressure from shorebirds appears minimal, even during the peaks of migration. Several species are known to feed on amphipods on sandy beaches (Sameoto 1969a; Dave Erikson, personal communication). Species observed on local sandy beaches include Semipalmated Plovers (Calidris pusilla), Rock Sandpipers (C. ptilacnemis), Dunlin (C. alpina), Western Sandpipers (C. mauri) and Sanderlings (C. alba). However, most prefer other habitats. Glaucous-winged Gulls (Larus glaucesens) and Mew Gulls (L. canus) are commonly observed foraging on the exposed low-tide terrace; they appear to capture the large polychaete Nephtys, amphipods, the helmet crab Telmessus, the sand lance Ammodytes, and also occasionally larger clams. When the low-tide terrace is underwater, several species of diving ducks (e.g., Greater Scaup (Aythya marila), Oldsquaw (Clangula hyemalis), White-winged Scoter (Melanitta deglandi), Surf Scoters (M. perspicillata) and Black Scoters (M. nigra) move in to feed. Apparently spring is the period of greatest utilization by sea ducks, but even then usage is minor. Predation pressure from birds is somewhat reduced in the winter.

Several demersal fishes and epifaunal invertebrates, all potential predators, have been collected on the low-tide terrace during periods of submergence. The fish included Pacific staghorn sculpin (Leptocottus armatus), brown Irish lord (Hemilepidotus spinosus), starry flounder (Platichthys stellatus), butter (Isopsetta isolepis) and English sole (Parophrys vetulus), Dolly Varden trout (Salvelinus malma), steelhead trout (Salmo gairdneri), sand lance and sandfish (Trichodon trichodon) (personal observation). The epifaunal invertebrates were mainly crustaceans, such as Dungeness, tanner, and helmet crabs and gray shrimp (Crangon sp.). Our subtidal observations indicate most of the fish and infaunal invertebrates move into deeper water during the winter months. Virnstein (1977) has shown that crabs and fish can exert strong control on infaunal population of polychaetes and clams on soft substrates. He further points out that the importance of predation cannot be determined without experimental manipulation.

The importance of competition as a factor influencing composition of the sand beach faunas and the distribution and abundance of their component species is difficult to assess based on the existing data. Sand beaches are strongly influenced by various physical stresses and thus are typical of physically controlled habitats as defined by Sanders (1968), wherein biological interactions such as competition and predation are thought to be relatively unimportant. Slow moving or juvenile organisms that live near the water-sand interface may be strongly influenced by storm surf or temperature extremes during low tides. The large decrease in the density of Paraonella noted after a winter storm may be evidence of this. Furthermore, Hedgpeth (1957) suggests that food supplies are not limiting on sand beaches. Combining these possibilities with observed low species richness and densities, it therefore seems plausible to consider interspecific competition inconsequential.

However, both Virnstein (1977) and Woodin (1974) point out the danger of ignoring biological interactions in physically controlled habitats. Interspecific competition in protected intertidal soft substrates has been shown for several species (e.g., Woodin 1974, Fenchel 1975, and Ronan 1975), but not on exposed sand beaches. The dominance of environmental stress in these habitats must be examined from the viewpoint of juveniles as well as adults of each species, as most adults live in more protected circumstances on soft substrates. For instance, recruiting juveniles of the polychaete Scolelepis face a much more rigorous environment near the water-sand interface than the deeply buried adults. It appears that the adults migrate vertically in the sand, moving upward to richer food concentrations during calm weather and downward in response to physical stresses and disturbances. Under such circumstances, it is possible that intraspecific competition for food and space could occur at the deeper, more protected levels, especially during the winter. However, as Scolelepis appears to be the only deep burrowing deposit feeder found on exposed sand beaches, interspecific competition seems unlikely.

The trophic structure of the sand beaches is not well understood, but a tentative food web is indicated in Figure 14. The main source of energy for the assemblage appears to be detritus, which the primary consumers ingest mainly for the adhering bacteria. The two major categories of detritivores recognized in the sand beach assemblages are suspension feeders and deposit feeders. The former, including a mysid Archaeomysis and the clams Spisula, Siliqua, and Tellina lutea, feed on organic particles in suspension or at the water-sand interface. However, a greater proportion of the energy appears to pass through polychaetes and gammarid amphipods. The gammarid amphipods Eohaustorius and Paraphoxus are probably selective deposit feeders, burrowing to feed on sand grains and organic particles of specific sizes. The polychaete Scolelepis, which ingests large quantities of sand, is probably a non-selective deposit feeder.

The primary consumer groups appear to contribute to both marine and terrestrial systems by serving as forage items for birds and fish. The most important linkages seem to go to fish and shorebirds. Based on the low standing stocks, low levels of observed bird predation (even during spring migration), and the relative inaccessibility of a major biomass component (the deep burrowing polychaete Scolelepis) to the major shorebirds (which feed chiefly at or near the sediment surface), it appears that the sand beach habitat contributes only minimally to bird productivity of Lower Cook Inlet. Its importance to the subtidal forms (fish, crabs, and shrimp) is unclear at present. However,

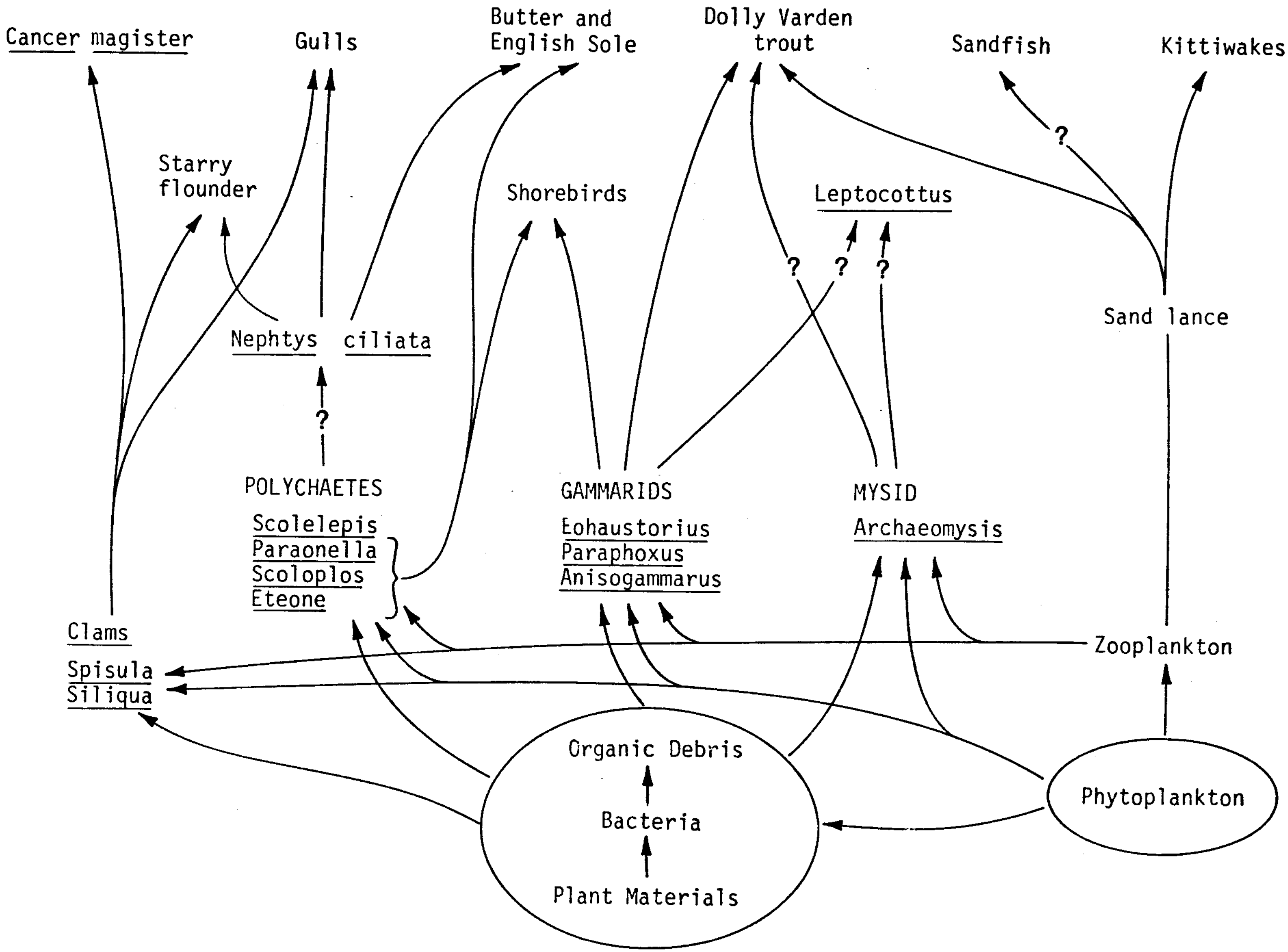

FIGURE 14 - GENERALIZED FOOD WEB FOR SAND BEACHES AT HOMER SPIT AND DEEP CREEK

productivity appears to be low in comparison with mud beaches.

A comparison of infaunal data from several sand beaches on the east side of Lower Cook Inlet suggests that the sand beach assemblages are quite variable spatially and possibly temporally (Table 22). Only 17 percent of the species were found at more than three of the stations. Only *Eohaustorius* and *Paraphoxus* were found on all occasions. Temporal patchiness cannot be examined because of differences in sampling areas and methods at Homer Spit and Deep Creek. Samples for 1976 were collected with a much smaller, shorter core tube than in 1977, and fewer samples were collected in 1976, so deep burrowing forms such as *Scolelepis*, and uncommon or patchy species were not sampled adequately in that survey.

Two patterns seem rather well-defined. Overall, polychaetes decrease and crustaceans increase in importance on the beaches moving from Homer to Deep Creek. As noted above, this seems to reflect a gradient in physical energy, with Deep Creek being subjected to stronger, more consistent current action, as well as higher turbidity, colder temperatures, lower salinities and more ice.

Further insight into this physical stress gradient is provided by comparing the species composition of Homer Spit and Deep Creek with that of a subtidal sand habitat at the A.R.Co. C.O.S.T. well site in the middle of Lower Cook Inlet (∿60 m deep). There is a surprising but definite resemblance between the intertidal sand assemblages and that described for unstable subtidal sand substrates (Table 23; Dames & Moore 1978). Forty-five percent of the species considered important at Deep Creek and eighty percent of those at Homer Spit were also common at the C.O.S.T. well site. The polychaete *Scolelepis* and a gammarid amphipod

TABLE 22. SPECIES COMPOSITION AND DENSITY (NO./M^2) AT SAND BEACHES ON THE EAST SIDE OF LOWER COOK INLET. BEACHES ARE ARRANGED FROM SOUTH TO NORTH.

TAXA	Homer Spit 1977	Homer Spit 1976	Bishops Beach 1976	Whiskey Gulch 1976	Deep Creek 1977	Deep Creek 1976	Clam Gulch 1976
Polychaeta	(78%)	(29%)	(38%)	(16%)	(13%)	(16%)	(10%)
Abarenicola sp	0	0	0	0	6.4	0	0
Capitella capitata	25.5	0	0	0	9.6	0	0
Chaetozone setosa	0	0	0	0	6.4	0	0
Eteone nr longa	3.2	0	0	0	9.6	37.8	0
Magelona ?sacculata	0	0	113.6	0	0	0	0
Nephtys ?ciliata	22.3	37.9	37.9	21.6	9.6	0	0
Paraonella platybranchia	213.3	0	0	0	12.7	75.8	75.8
Scolelepis sp A	547.5	0	0	32.5	92.3	0	12.6
Scoloplos armiger	0	75.8	0	0	31.8	75.8	0
Spio filicornis	0	0	0	0	0	75.8	25.3
Spiophanes bombyx	3.2	75.8	75.8	0	0	0	0
Crustacea	(6%)	(59%)	(63%)	(84%)	(85%)	(84%)	(90%)
Anisogammarus confervicolus	0	0	0	10.8	0	0	0
Anonyx sp	0	0	0	10.8	0	0	0
Archaeomysis grebnitzkii	0	0	0	0	3.2	0	0
Atylidae, unid.	0	0	0	0	3.2	0	0
Crangon alaskensis elongata	12.7	0	0	0	0	0	0
Cumacea, unid.	0	151.5	0	10.8	0	0	0
Eohaustorius eous	28.7	37.9	75.8	151.5	648.4	1363.6	947.0
Gammariidae, unid.	0	0	0	0	388.3	0	12.6
Hippomedon sp	0	151.5	227.3	0	0	0	0
Lamprops carinata	60.5	0	0	0	0	0	0

TAXA	Homer Spit 1977	Homer Spit 1976	Bishops Beach 1976	Whiskey Gulch 1976	Deep Creek 1977	Deep Creek 1976	Clam Gulch 1976
Crustacea, cont.							
Lamprops quadriplicata	79.6	0	0	0	19.1	0	0
Lamprops sp	3.2	0	0	0	0	0	0
Paraphoxus milleri	19.1	37.9	75.8	108.2	19.1	37.8	25.3
Synchelidium sp	12.7	0	0	0	6.4	0	0
Pelecypoda	(0.6%)	(18%)					
?Macoma sp	0	37.9	0	0	0	0	0
?psephidia lordii	0	37.9	0	0	0	0	0
Spisula polynyma	6.4	0	0	0	0	0	0
Pisces	(0.3%)						
Ammodytes hexapterus	3.2	0	0	0	0	0	0

TABLE 23. COMPARISON OF DENSITIES (NUMBER/M^2) FOR IMPORTANT SPECIES AT VARIOUS SITES ON UNSTABLE SAND HABITATS IN LOWER COOK INLET

	Deep Creek	Homer Spit	ARCO site Ocean Ranger	ARCO site Control
Polychaetes				
Capitella capitata	6.4	0	0	0
Chaetozone setosa	0	0	5.0	5.4
Eteone nr longa	21.3	3.2	0.6	92.9
Nephtys ?ciliata	6.4	6.4	12.2	35.7
Ophelia limacina	0	0	45.0	125.0
Paraonella platybranchia	12.7	132.6	0	0
Polygordius sp	0	0	7.8	407.1
Scolelepis sp A	47.7	402.1	423.9	160.7
Scoloplos armiger	18.0	2.1	61.7	33.9
Sphaerosyllis pirifera	0	0	0	25.0
Spiophanes bombyx	0	1.1	185.6	2410.7
Streptosyllis nr latipalpa	0	0	7.2	12.5
Crustaceans				
Anisogammarus confervicolus	4.3	0	0	0
Archaeomysis grebnitzkii	1.1	0	0	0
Eohaustorius eous	504.7	20.2	0	0
Gammaridae sp A	129.4	0	-	-
Orchomene cf pacifica	0	0	3.9	17.9
Paraphoxus milleri	19.1	38.2	56.1	14.3
Clams				
Astarte sp	0	0	0.6	25.0
Glycymeris subobsoleta	0	0	2.2	50.0
Liocyma fluctuosa	0	0	31.7	58.9
Spisula polynyma	0	7.4	0.6	3.6
Tellina nuculoides	0	0	19.4	44.6
Gastropods				
Propebela spp	0	0	16.1	7.1
Sand dollars				
Echinarachnius parma	0	0	22.2	17.9
Fish				
Ammodytes hexapterus	0	7.4	C	C
Overall Average Density	788	726	1017	3852

Paraphoxus were frequently considered dominants at all locations. Other species that were common at all locations include the polychaetes Eteone nr. longa, Nephtys ?ciliata, and Scoloplos armiger. It is tempting to speculate, in view of the physical gradient, that the faunal differences observed between the various sites represent sequences in the successional development of a sandy substrate, as suggested by Johnson (1970). This could not be shown without experimental manipulation, however.

6.2 MUD FLAT ASSEMBLAGES

Our studies so far have indicated that, in contrast to sand beaches, the mud flat off Glacier Spit, Chinitna Bay, supports a large standing crop of suspension and deposit feeders, has higher species richness, and appears to be highly productive. However, spatial, seasonal and annual variability were considerable, being influenced strongly by weather conditions and predation. Species richness, species diversity and biomass were greatest in the summer, whereas abundance was lowest in summer (Table 15). This apparent paradox is attributable to the large reduction in the abundance of juveniles of the clams Macoma balthica and Mya spp. between April and July; most other species increased in abundance during the same period (Table 14).

The fauna was dominated heavily by the clams Mya spp. and Macoma balthica, which comprised more than 50 percent of the individuals and 90 percent of the wet biomass and dry tissue weight in both surveys (Tables 14 and 17). Macoma was by far the most abundant, but contributed only 10 to 15 percent of the biomass. Three other visually conspicuous species of marginal importance were an echiurid Echiurus echiurus alaskanus, a large polychaete Nephtys sp., and the basket cockle Clinocardium nuttallii, all of which also contributed marginally to biomass.

Ten species exhibited densities exceeding 100 individuals/m^2 in at least one survey. These included, in order of importance, Macoma, Mya spp., Nephtys, Spio, Potamilla, Clinocardium, Pseudopythina, Tritella, Eteone and Capitella (Table 14). All of the worms except Nephtys increased in abundance substantially from April to July, whereas that worm and all of the clams became less abundant. All of the species exhibiting increased abundance are thought to be annuals, at least in this habitat. In contrast, all of the species that declined, including Nephtys, appear to be perennials (Thorson 1957).

The species that appear to represent the mature stage, or highest level of development, of this mud flat assemblage are the clams Mya, Macoma, Pseudopythina, the polychaete Nephtys and the echiurid Echiurus. The present rarity of adult Clinocardium in the intertidal zone suggests that it does not survive harsh winters at these elevations in this location. However, long-time resident Wayne Byers indicated that adult cockles were abundant on these flats prior to the uplift resulting from the 1964 earthquake (personal communication). Mya spp. and Echiurus construct semi-permanent burrows which impart a characteristic appearance to the mud flats on the west side of Lower Cook Inlet (Figure 10).

The richness of this mud flat assemblage is indicated by the density and biomass of its constituent species, particularly the dominants. For instance, in April, when the population was dominated by the 0-year class, Macoma densities ranged from 4250/m^2 to 5350/m^2 (Appendix VI) and whole wet weight ranged from 340 g/m^2 to 550 g/m^2 (Appendix VII). Such densities are among the highest recorded for Macoma (Green 1968, Tunnicliffe and Risk 1977), and this is particularly notable in view of the high percentage of animals at least one year old during the summer (Figure 11).

The contrasting seasonal patterns of abundance for the major clams and the polychaetes seem to indicate differences in reproductive cycles. Density of the three main clam taxa decreased markedly from April to July. Moreover, the 0-year class strongly dominated the age structures for Macoma, Mya spp. and Clinocardium in the April samples but was strongly reduced in all cases by July. The implication is that recruitment occurs in late summer, fall or winter. This hypothesis is partially supported for Macoma by data from the Irish Sea for reproductive condition from Chambers and Milne (1975), and for Mya truncata by Thorson (1957). Surprisingly, however, Chambers and Milne (1975) observed heavy recruitment in July, four months after the local adult population was spawned out.

Myren and Pella (1977) found no seasonal changes in density for larger specimens of M. balthica at Valdez. The data for large specimens of Macoma and Mya spp. from Glacier Spit generally support that finding, and suggested that the adult size classes are much more stable than the 0-year class.

Density of the polychaete populations increased considerably from April to July. The July samples were strongly dominated by newly settled specimens, as was the case on the sand beaches. This pattern suggests late spring or early summer spawning.

It seems probable that both physical and biological factors are important in determining the density of the organisms living in the mud flats at Glacier Spit. Physical conditions are severe, especially near the water-sediment interface where temperature and salinity fluctuate widely and ice scouring and crushing can be substantial. In addition, predation pressures and intra- and interspecific competition for food and space are probably intense, especially in the spring, when maximum densities of young clams are concentrated in the upper few centimeters of sediment and high numbers of migratory birds exploit the mud flats. In addition, predation by adult clams on larval, metamorphosing and settling juvenile clams is probably intense during major periods of recruitment.

Predation seems to exert a strong influence on the density of several species, such as *Macoma balthica*, *Mya* spp. and *Echiurus*. A broad variety of predators exploit the mud flats (Figure 15). Diving ducks (scoters, scaup and Oldsquaw), gulls and shorebirds appear to be major predators on clams and polychaetes. Diving ducks and shorebirds are most abundant during spring migration and seem to concentrate on *Macoma* and *Mya*. Judging from the reductions of nearly 50 percent and 70 percent in the densities of *Macoma* and *Mya*, respectively, these predators are fairly effective. The changes in size structure indicate that juveniles, located near the sediment surface, are most frequently utilized. Gulls were observed foraging on the mud flats during both day and night low tides, and their egesta and shell debris indicate that they feed mainly on barnacles, *Clinocardium*, and crabs; large worms such as *Nephtys* are probably also taken frequently.

The only resident predator of any importance observed in the study area was the polychaete *Nephtys* sp. The population of this perennial included specimens up to 10 cm in length, but was strongly dominated by the small, younger animals. The importance of this species is poorly understood. The few feeding observations made were for adults, and most had empty alimentary canals. The small number of feeders had all fed on adult *Echiurus*; one specimen contained two prey. Based on available prey and habits, it seems probable that juvenile *Nephtys* feeds on juvenile *Echiurus* and small polychaetes.

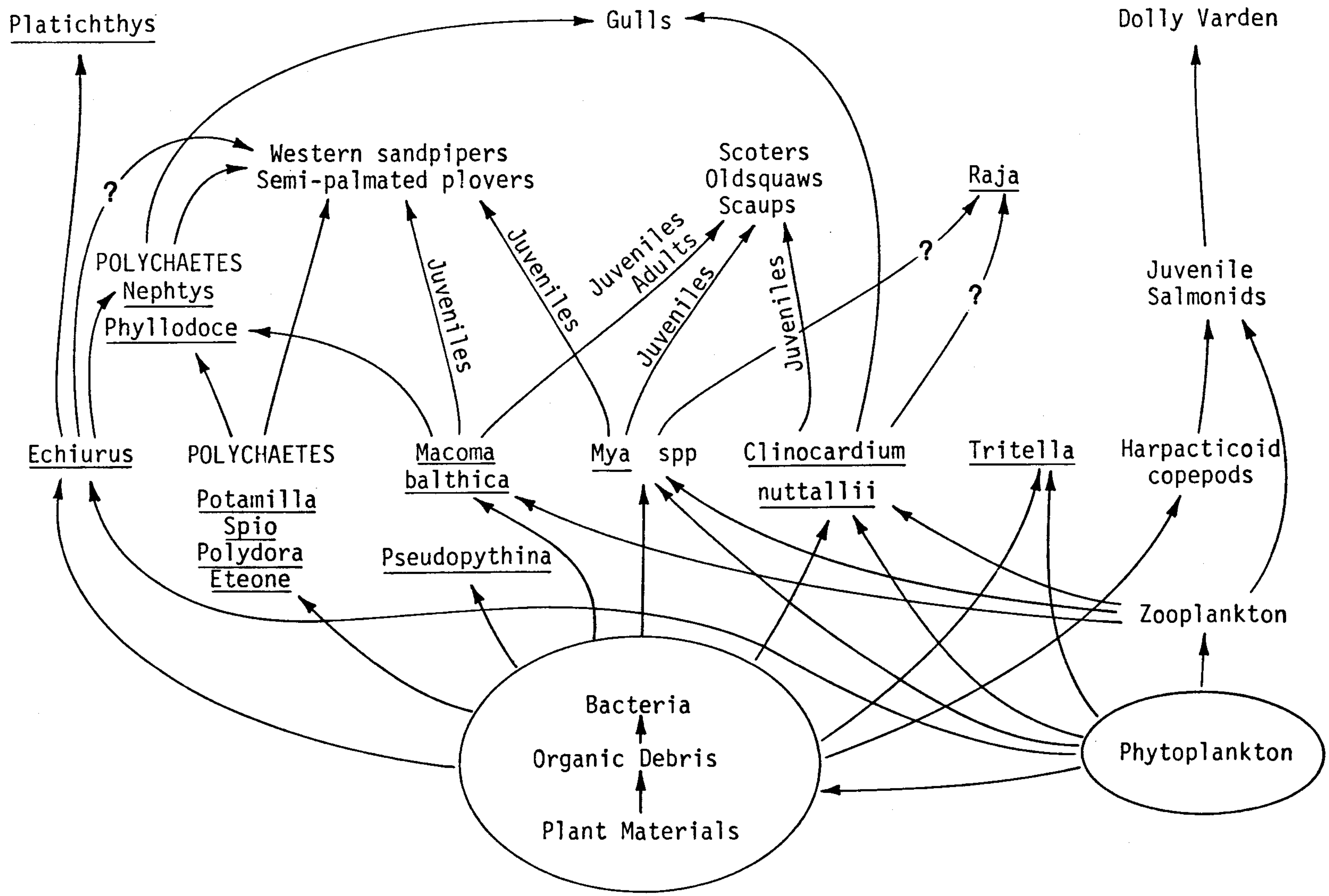

FIGURE 15 - GENERALIZED FOOD WEB FOR MUD FLAT AT GLACIER SPIT

Gastropod predators, particularly small opisthobranchs, are frequently common locally on mud substrates and on more temperate mud flats. However, they were very uncommon during this survey.

Data are presently not available to describe the function of several predators, but some speculation is permissible based on other studies or observations. Excavations and shell remains observed while diving in Cottonwood Bay suggest that skates (Raja) may move into shallow bays and feed on Clinocardium. Starry flounder are reported to feed on Echiurus in the Bering Sea (Feder, personal communication). Other potential predators important to macrofaunal forms include Dungeness (Cancer magister) and tanner crab, rock sole (Lepidopsetta bilineata), and Pacific staghorn sculpin.

As indicated above, competition for food and space may be important in determining densities and growth rates of several species, particularly the clams Macoma and Mya spp. The feeding activities of dense adult clams may strongly reduce success of recruits attempting to settle, so that suitable space is limiting for larvae. Furthermore, food and space are somewhat synonymous for Mya and Macoma and, at high densities, available food may become limiting.

Several types of mud flats have been observed in southcentral Alaska; all are dominated by clams and generally they differ sharply from those described or observed in Washington (Kozloff 1973) or California (Ricketts and Calvin 1962). Species richness is rather lower, reflecting the absence or paucity of a number of higher taxa. Southcentral Alaskan mud flats generally lack burrowing shrimp (e.g., Callianassa and Upogebia), gammarid amphipods and isopods, deposit feeding or predatory gastropods (e.g., Hydrobia or Aglaja) and commensal fish (e.g., Clevelandia).

Southcentral Alaskan mud flats appear to have greater affinity to similar habitats on the Atlantic Ocean, which also support high densities of *Macoma balthica* and/or *Mya* spp. These species dominate on many mud flats in Lower Cook Inlet, and the burrow building *Echiurus* is frequently an important structural component. On some mud flats, such as the Dayville flats in Valdez (Feder, personal communication) and Mud Bay in Homer (personal observation), *Mya* and *Echiurus* are uncommon, reducing the permeability of the sediments.

A number of mud flats support beds of eelgrass (*Zostera marina*), but intertidal stands are frequently limited by winter ice.

The generalized trophic structure proposed for the mud flat (Figure 15) appears to be based on detrital material from marine and terrestrial systems. It is considerably more diverse than that for sand beaches. Griffiths (personal communications) indicates that the bacterial flora observed in the water column on the west side of the inlet suggests that terrestrial plants may be a major source of organic debris. The detritus, associated inorganic particles, bacteria and protozoans are ingested by suspension and deposit feeders (Jorgenson, 1966), but mainly the bacteria and protozoans are digested and assimilated (Johannes and Satomi 1966). Nearly all of the infaunal animals collected at Glacier Spit were detritivores; both suspension and deposit feeders were common but suspension feeders seem to dominate. Non-selective deposit feeders such as *Abarenicola* were uncommon.

Nearly all the predators observed were transients representing other systems, and were mainly effective only in spring and summer. However, several overwintering duck species are heavily dependent on mud flats. The fish, crabs and ducks move onto the intertidal flats during high tides, and the shorebirds move in during low tides. Commercially, the most important of these interactions appears to be that of juvenile salmon and harpacticoid copepods (Sibert et al. 1977, Kaczynski et al. 1973). The consequence of this concept is that a very large proportion of the tissue produced on the flats is exploited by predators from other systems. This is a particularly important concept on the west side of the Inlet because of 1) the richness of the mud flats, 2) the large proportion of mud flat habitat in the intertidal zone and, 3) the potential susceptibility of this assemblage to oil pollution.

A preliminary assessment of secondary production can be made using data for density, growth and biomass data and the predation hypotheses. Nearly all species exhibited sizeable changes in density between April and July. With the notable exception of *Macoma*, most species exhibited relatively large increases in standing crops. For *Macoma*, density decreased nearly 50 percent concurrent with a small decrease in standing crop. Average size of all the populations appeared to increase during this period. During this same period, it is probable that predation pressures were intense. Despite predation, whole wet weight increased during this four month period from 2.3 kg/m^2 to 4.0 kg/m^2. The 74 percent increase in biomass during a period of intense predation indicated moderately high net production.

6.3 FAUNAL COMPOSITION OF GRAVEL UPPER BEACHES AND SCOURED BOULDER FIELDS

Gravel/cobble upper beaches and scoured boulder fields were frequently associated with the soft substrates and so were examined qualitatively to develop a general idea of their faunal composition and structure. These areas were quite impoverished, a condition which Kozloff (1973) reports is normal. However, particularly during summer, the lower levels of gravel and cobble substrate characteristic of upper beach areas throughout much of Lower Cook Inlet appear to support moderate densities of two scavengers, namely, the gammarid amphipod Anisogammarus confervicolus and the isopod Gnorimosphaeroma oregonensis. These organisms are most abundant in areas where ground water from the upper beach seeps onto the beach. There, they aggregate mainly under large cobbles that rest in a manner allowing water to stand or pass gently under them. Generally, these species should be considered as cryptic rather than infaunal as they do not appear to live interstitially in the gravel. Nematodes appear to be the common infaunal form.

These species are also characteristic of the scoured boulder/cobble fields occurring at about MLLW. However, these areas are not subject to the continuous grinding that occurs in the gravel beach, and therefore are capable of supporting young populations of pioneer species such as barnacles (Balanus spp.) and mussels (Mytilus edulis). Generally, these populations do not survive a harsh winter, but annual replacement appears to be fairly reliable. The last two winters have been quite mild, however, so many such areas in Lower Cook Inlet support two year classes of barnacles and mussels.

These species appear to occupy positions low in the food web, and are probably mainly dependent upon phytoplankton (barnacles and mussels), or plant and animal debris (isopods and amphipods). However, casual observations suggest that a number of invertebrate, bird and fish species heavily utilize these resources for food. The nudibranch Onchidoris bilamellata and the snail Nucella emarginata compete for the barnacle and mussel resources. Onchidoris appears to be more successful in the less stable areas.

Shorebirds, mainly sandpipers, turnstones and plovers, put considerable predation pressure on these habitats, particularly during spring migration, when utilization is intense. The Rock Sandpiper, a winter resident, appears to be particularly important. Our observations during the winter suggest that this species is using these resources during both day and night low tides. The occurrence of night feeding by shorebirds in winter does not appear well known. However, the energetics argument appears strong, considering the combination of short day length, available low (feeding) tides, the possibility of reduced prey density and higher metabolic rates for resident birds during winter months.

Several invertebrate and fish species have been collected in beach seine hauls just below these habitats and it can be assumed that many of these probably feed there. The main invertebrates are adult and juvenile Dungeness crabs (*Cancer magister*), adult helmet crabs (*Telmessus cheiragonus*) and gray shrimp (*Crangon alaskensis*). Juvenile Dungeness crabs are fairly common in the boulder/cobble field during the summer. The main fish species observed include the sand lance (*Ammodytes hexapterus*), Pacific staghorn sculpin (*Leptocottus armatus*), starry flounder (*Platichthys stellatus*), and flathead sole (*Hippoglossoides elassodon*). Specific food habits have not been investigated in this area.

6.4 PRELIMINARY DISCUSSION OF THE POTENTIAL EFFECTS OF OIL POLLUTION

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 (Warren, 1978). This would result from increased boat traffic to supply and support facilities and, in the event of development and production, from the operation of various onshore facilities related to treatment and transfer of oil and gas. During the exploration phase, chronic pollution from boat activities should be minimal, but during development and production, it could become significant. General sites being considered for construction of onshore facilities include the western tip of the southern Kenai Peninsula, between Port Graham and Port Chatham, and Anchor Point, just north of Kachemak Bay. Facilities could include crude oil terminals, production treatment facilities, and liquification and terminal facilities for natural gas. Suitable sites on the southern Kenai are located on or near very productive embayments and estuaries. The Anchor Point site would include an important river mouth and wetland.

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 (Hayes, Brown and Michel, 1977). 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 proposed by Hayes et al. (1977).

For the purposes of their assessment, Hayes et al. (1977) divided the 1216 km of examined shoreline into erosional, neutral and depositional categories (45, 38 and 17 percent, respectively). Because of the complex structure of the beaches, it is difficult to subdivide these categories into bedrock, boulder fields, gravel, sand or mud. The upper beach face in Lower Cook Inlet (Figures 2 and 3) is most commonly composed of gravel, or a mixture of gravel, sand, cobbles, and boulders. However, adjacent low-tide terraces are usually mud, sand, boulders or bedrock. The distinct difference in substrate between upper beach face and low-tide terrace on most beaches in Lower Cook Inlet makes it somewhat difficult to apply the Hayes assessment of environmental susceptibility locally. For instance, most flat fine-grained sandy beaches [given a susceptibility ranking of 3 on a scale of 1 (low) to 10 (high)], are bordered by a beach front of gravel or mixed sand and gravel (susceptibility rankings of 7 and 6, respectively). This problem is further complicated by assessment of biological susceptibility. Gravel or mixed sand and gravel beaches generally support only impoverished assemblages of small crustaceans and are therefore probably of lower importance than sand beaches which often support important populations of razor clams. Furthermore, it is important to consider the levels of tolerance or susceptibility to contamination of the organisms in an assemblage, and the importance of the assemblage to other assemblages or systems. Clearly then, several factors must be integrated to develop a satisfactory assessment of susceptibility.

6.4.1 Sand Beaches

Beaches with sandy low-tide terraces border about 50 percent of Lower Cook Inlet. They are concentrated on exposed portions of the Inlet, especially in its northeastern quadrant. Hayes et al. (1977) indicated that since these beaches are generally flat and hard-packed, they are relatively impenetrable to oil and thus have a fairly low susceptibility ranking. However, oil stranding during a falling tide may penetrate into the sediment (especially the water-soluble, toxic fractions) and come into contact with the infaunal forms (Anon. 1975). Furthermore, extensive burial of stranded oil can occur, increasing the residence time on polluted beaches. Such burial can induce anaerobic conditions, delaying microbial degradation.

The biological assemblages most commonly observed on sand beaches in Lower Cook Inlet are dominated by burrowing polychaetes, small crustaceans (gammarid amphipods and mysids) and razor clams. All are known to be somewhat sensitive to crude and petroleum products. Generally, standing stocks are low and the contribution of sand beaches to other systems appears low. However, beaches supporting dense clam populations are important to sport and commercial clamming enterprises. Recovery of the worm and crustacean populations would be rapid following contamination, but for clam populations, recovery would be very slow, possibly requiring decades.

6.4.2 Gravel And Sand Upper Beaches

As pointed out above, gravel or mixed sand and gravel upper beaches border a large proportion of the shoreline in Lower Cook Inlet. Hayes et al. (1977) indicate that oil arriving on such beaches can penetrate to considerable depths, especially on gravel, or can be buried, and thus residence periods can be great. Clean-up would be difficult without large-scale removal of sediments. Such beaches are therefore highly susceptible (ranking of 7 and 6, respectively) to oil pollution. In the Straits of Magellan, oil from the *Metula* spill formed thick asphalt pavement on low-tide terraces of mixed sand and gravel (Hayes et al. 1977); this formation was highly resistant to degradation.

The biological assemblage most frequently observed is impoverished, mainly including nematodes, one gammarid amphipod and one isopod species. The sensitivity of these species to crude oil is unknown, but, as they are all short lived, they probably could recovery fairly rapidly. However, widespread contamination could lead to a lengthy recovery period since both the gammarid and the isopod are brooders, having no pelagic larvae. Recolonization would depend upon migration rates. Our observations so far suggest that this assemblage supports limited secondary production and contributes little to other systems.

6.4.3 Scoured Boulder Fields

The extent of scoured boulder fields on the low-tide terrace is unclear, but they may be located primarily on spits and below eroding scarps. Hayes et al. (1977) do not specifically rank this type of habitat, and the basic sediment is often mixed sand and gravel. Therefore, many of the same considerations apply.

These boulder fields support a more diverse biotic assemblage, however, because of the high proportion of solid substate. Nevertheless, most of the animals are pioneer species and the populations are largely dominated by young organisms. These conditions are a consequence of scouring and abrasion. Juvenile barnacles and mussels are often dominant species and although production may be moderate, biomass is low. The contribution of this assemblage is not great, although overwintering Rock Sandpipers appear to feed in such areas. Because of their small size, many of the animals in this habitat would be susceptible to smothering by crude oil. However, natural scouring could be expected to facilitate clean-up and recovery would probably be rapid (perhaps within two years).

6.4.4 Mud Flats

Mud flats, variously referred to by Hayes et al. (1977), as muddy tidal flats, protected estuarine tidal flats and *rias*, border about 35 percent of the total shoreline of Lower Cook Inlet and nearly half of its western shoreline. The two types of mud flats described are 1) exposed muddy tidal flats, such as are observed in association with the wavecut sandstone platforms in southern Kamishak Bay, and 2) protected estuarine flats, which are "primarily drowned glaciated river valleys (*rias*)" such as Chinitna Bay (Hayes et al. 1977). Because of the difference in exposure and probable residence time, exposed flats were considered to be moderately susceptible to oil pollution (rank of 5) and protected flats to be highly susceptible (rank of 9; Hayes et al. 1977). These investigators described the flats as impermeable to oil. In fact, we believe that permeability may vary considerably, depending on the faunal components. Where the flats are dominated by *Macoma balthica*, but *Mya* spp. and *Echiurus* are absent, the flats indeed appear impermeable. Mud Bay, at Homer, and Dayville Flats, at Valdez, are examples of this type of flat. Shaw et al. (1977), in fact, reported low uptake and rapid loss of crude oil on Dayville Flats. Griffiths (personal communication) suggests that Shaw's findings may have been influenced by low densities of bacteria and organic debris, which have a direct relationship to uptake rates. However, where *Mya* and *Echiurus* are common their burrows, with densities of up to $100/m^2$ and extending up to 45 cm into the sediment, may increase the rate of oil penetration into the sediment, and allow oil to be stored at deep, anoxic levels. All mud flats observed to date on the west side of Cook Inlet are of this type.

Because of anoxic conditions near the sediment surface, and the low energy regime of the protected estuaries, residence time could extend up to 10 years in some of these areas (Hayes et al. 1977).

The fauna, dominated by longevous clam and polychaete species, includes several species that have been shown to be sensitive to oil contamination. For instance, Shaw et al. (1976) reported significant mortality in *Macoma balthica* in response to low dosages of Prudhoe Bay crude oil in elegant field experiments on Dayville Flats. Hampson and Sanders (1969) reported considerable mortality of *M. arenaria* and many polychaete species in West Falmouth, Mass., after exposure to high doses of fuel oil. Feder et al. (1976) observed anomalous increases in the density of harpacticoid copepods on Dayville Flats, but the causes and ramifications are not clear.

Because it appears that most of the tissue produced on the mud flats is utilized by transient predators from other systems, the condition of the mud flats is of considerable concern and importance. Animals particularly reliant on continued high productivity of the mud flats include 1) smolts of at least two species of salmon in spring (Sibert et al. 1977), 2) Western Sandpipers on spring migration, and 3) ducks, especially scoters, scaup and Oldsquaw, all year long. Only ducks and gulls appear to depend on adult or long-lived animals.

Recovery rates following contamination are subject to several conditions. Obviously, local conditions (orientation of estuary, time of year, tidal phase, porosity of the flat) are of importance. If appreciable quantities of oil penetrate deeply into the sediment, however, it is probable that full recovery will require at least 10 years. The dominant clam species all live at least 6-10 years (Chambers and Milne 1975, Feder and Paul 1974). Ducks appear to feed mainly on adult *Macoma*. Shorebirds, in contrast, feed mainly on young-of-year *Macoma*, *Mya*, annual polychaetes and harpacticoid copepods, which could recover fairly quickly if the sediments were uncontaminated. Based on the predictions of Hayes et al. (1977), it is probable that the exposed flats would recover in several years, but that the estuaries could require at least a decade.

7. LITERATURE CITED

Anonymous, 1975. Petroleum in the Marine Environment. National Academy of Sciences. Washington, D.C. 107 pp.

Barnard, J. L., 1969. The families and genera of marine gammaridean Amphipoda. Bull. U.S. Nat. Mus. 271, 535 pp.

Bascom, W., 1964. Waves and Beaches. Doubleday and Co., Inc. Garden City, New York. 267 pp.

Chambers, M. R. and H. Milne, 1975. The production of *Macoma balthica* (L.) in Ythan Estuary. Estuarine and Coastal Mar. Sci. 3:443-455.

Dames & Moore, 1976. Marine plant community studies, Kachemak Bay. Final Report for Alaska Department of Fish and Game. 288 pp.

__________, 1977. Reconnaissance of the intertidal and shallow subtidal biotic assemblages in Lower Cook Inlet. Final Report for Department of Commerce, NOAA, OCSEAP. 315 pp.

__________, 1978. Drilling fluid dispersion and biological effects study for the Lower Cook Inlet C.O.S.T. well. For Atlantic Richfield Co. 309 pp.

Dexter, D. M., 1969. Structure of an intertidal sandy-beach community in North Carolina. Chesapeake Sci. 10:93-98.

__________, 1972. Comparison of the community structures in a Pacific and an Atlantic Panamanian sandy-beach. Bull. Mar. Sci. 22:449-462.

Feder, H. M., and A. J. Paul, 1974. Age, growth and size-weight relationships of the soft-shell clam, *Mya arenaria*, in Prince William Sound, Alaska. Proc. Nat'l. Shellfish Assoc. 64:45-52.

Feder, H. M., L. M. Cheek, P. Flanagan, S. C. Jewett, M. H. Johnson, A. S. Naidu, S. A. Norrell, A. J. Paul, A. Scarborough and D. G. Shaw, 1976. The sediment environment of Port Valdez, Alaska and the effect of oil on this ecosystem. Final Report on project R800944, Environmental Protection Agency.

Fenchel, T., 1975. Factors determining the distribution patterns of mud snails (Hydrobiidae). Oecologia 20:1-7.

Green, J., 1968. The Biology of Estuarine Animals. University of Washington, Seattle. 401 pp.

Hampson, G. R., and H. L. Sanders, 1969. Local oil spill. Oceanus 15-8-11.

Hayes, M. O., P. J. Brown and J. Michel, 1977. Coastal morphology and sedimentation, Lower Cook Inlet, Alaska. 107 pp. Volume II, Environmental studies of Kachemak Bay and Lower Cook Inlet (L. L. Trasky, L. B. Flagg and D. C. Burbank, eds.). Alaska Department of Fish and Game.

Hedgpeth, J. W., 1957. Sandy beaches, pp. 587-608. In: Treatise on Marine Ecology and Paleoecology (J. W. Hedgpeth, ed.) Geol. Soc. Amer., Memoir 67. Washington D. C.

Johannes, R. E., and M. Satomi, 1966. Composition and nutritive value of fecial pellets of a marine crustacean. Limnol. Oceangr. 11:191-197.

Johnson, R. G., 1970. Variations in diversity within benthic marine communities. Amer. Natur. 104:285-300.

Jorgenson, C. B., 1966. Biology of Suspension Feeding. Pergamon Press. New York. 357.

Kaczynski, V. W., R. J. Feller, J. Clayton and R. G. Gerke, 1973. Trophic analysis of juvenile pink and chum salmon (Oncorhynchus gorbuscha and O. Keta) in Puget Sound. J. Fish. Res. Bd. Canada 30:1003-1008.

Keith, D. E., and N. C. Huling, 1965. A quantitative study of selected nearshore infauna between Sabine Pass and Bolivar Point, Texas. Publ. Inst. Mar. Sci. Texas 10:33-40.

Kinney, P. J., J. Groves and D. K. Button, 1970. Cook Inlet environmental data, R/V Acona cruise 065-May 21-28, 1968. Inst. Mar. Sci., Univ. Alaska, Report No. R-70-2.

Kozloff, E. N., 1973. Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago. J. J. Douglas Ltd., Vancouver, B.C. 282 pp.

Myren, R. T., and J. J. Pella, 1977. Natural variability in distribution of an intertidal population of Macoma balthica subject to potential oil pollution at Port Valdez, Alaska. Marine Biology 41:371-382.

Ricketts, E. F., and J. Calvin, 1962. Between Pacific Tides. 3rd Edition (J. W. Hedgpeth, ed.) Stanford Univ. Press, Stanford, California. 516 pp.

Ronan, T. E., Jr., 1975. Structural and paleoecological aspects of a modern marine soft-sediment community: an experimental field study. Ph.D. Thesis, Univ. California, Davis. 220 pp.

Sameoto, D. D., 1969a. Comparative ecology, life histories, and behavior of intertidal sand-burrowing amphipods (Crustacea: Haustoriidae) at Cape Cod. J. Fish. Res. Bd. Canada 26:361-388.

__________, 1969b. Physiological tolerances and behavior responses of five species of Haustoriidae (Amphipoda: Crustacea) to five environmental factors. J. Fish. Res. Bd. Canada 26:2283-2298.

Sanders, A. L., 1969. Benthic marine diversity and the stability-time hypothesis, pp. 71-81. In: Diversity and Stability in Ecological Systems (G. M. Woodwell and H. H. Smith, eds.). Brookhaven Symposia in Biology, No. 22. NTIS, Springfield, Va.

Sharma, G. D., F. F. Wright, J. J. Burns and D. C. Burbank, 1974. Sea surface circulation, sediment transport, and marine mammal distribution, Alaska continental shelf. Final Report of ERTS Project 110-1d, Univ. of Alaska, 77 pp.

Shaw, D. G., A. J. Paul, L. M. Cheek and H. M. Feder, 1976. Macoma balthica: An indicator of oil pollution. Mar. Poll. Bull. 7:29-31.

Shaw, D. G., L. M. Cheek and A. J. Paul, 1977. Uptake and release of petroleum by intertidal sediments at Port Valdez, Alaska. Estuarine and Coastal Mar. Sci. 5:429-436.

Shepard, F. P., 1963. Submarine Geology. Harper and Rowe, New York. 557 pp.

Sibert, J., T. J. Brown, M. C. Healey, B. A. Kask and R. J. Naiman, 1977. Detritus-based food webs: Exploitation by juvenile chum salmon (Oncorhynchus keta). Science 196:649-650.

Thorson, G., 1957. Bottom communities (Sublittoral or shallow shelf), pp. 461-534. In: Treatise on Marine Ecology and Paleoecology (J. W. Hedgpeth, ed.) Geol. Soc. Amer., Memoir 67. Washington, D. C.

Tunnicliffe, V., and M. J. Risk, 1977. Relationships between the bivalve Macoma balthica and bacteria in intertidal sediments: Minas Basin, Bay of Fundy. Jour. Mar. Res. 35:499-507.

Virnstein, R. W., 1977. The importance of predation by crabs and fishes on benthic infauna in Chesapeake Bay. Ecology 58:1199-1217.

Warren, T. C., 1978. Lower Cook Inlet OCS: Results of sale and scenario of development, 19 pp. In: Environmental Assessment of the Alaskan Continental Shelf, proceedings of the Lower Cook Inlet syntheses meeting, January 1978. U.S. Dept. of Commerce, NOAA, Boulder, Colorado.

Withers, R. G., 1977. Soft-shore macrobenthos along the southwest coast of Wales. Estuarine and Coastal Mar. Sci. 5:467-484.

Woodin, S. A., 1974. Polychaete abundance patterns in a marine soft-sediment environment: the importance of biological interactions. Ecol. Monogr. 44:171-187.

APPENDIX Ia. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 4 FEBRUARY 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Level 1 (Upper)												
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	1	0	1	0	0	0	0.2 ± 0.4	2
Eteone nr. *longa*	1	0	1	2	0	0	0	1	2	2	0.9 ± 0.9	9
ARTHROPODA - Gammaridae												
Anisogammarus cf *confervicolus*	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	0	2	1	0	2	1	0	0	0	0	0.6 ± 0.8	6
S	1	1	2	1	3	1	1	1	1	1		
N	1	2	2	2	4	1	1	1	2	2		

Extralimital Species: *Halichondria panicea* on Sabellid tube, *Mytilus edulis* on boulder

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Level 2												
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Eteone nr. *longa*	0	0	0	0	1	0	1	1	0	0	0.3 ± 0.5	3
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	1	2	1	0	0	1	2	6	1	1.7 ± 1.8	17
S	1	1	1	1	1	1	2	2	1	1		
N	3	1	2	1	1	1	2	3	6	1		

TAXA	1	2	3	4	5	6	7	8	9	10	x̄	± s	Total
					Level 3								
ANNELIDA - Polychaeta													
Eteone nr. longa	0	1	0	0	0	0	0	0	0	0	0.1	0.3	1
Paraonella platybranchia	0	0	0	0	0	0	1	1	2	0	0.4	0.7	4
Scolelepis Sp. A	0	0	0	0	0	0	0	1	0	0	0.1	0.3	1
Scoloplos armiger	1	0	0	0	0	0	0	0	0	1	0.2	0.4	2
ARTHROPODA - Gammaridae													
Eohaustorius eous	1	4	2	5	5	1	6	2	1	3	3.0	1.9	30
Paraphoxus milleri	1	0	0	0	0	0	0	0	0	0	0.1	0.3	1
S	3	2	1	1	1	1	1	3	2	2			
N	3	5	2	5	5	2	7	4	3	4			
					Level 4 (lower)								
ANNELIDA - Polychaeta													
Eteone nr. longa	0	0	1	0	0	0	0	0	0	0	0.1	0.3	1
Paraonella platybranchia	0	0	0	0	0	1	0	0	0	0	0.1	0.3	1
Scolelepis Sp. A	0	1	0	0	1	0	1	0	1	0	0.4	0.5	4
ARTHROPODA - Gammaridea													
Anisogammarus cf confervicolus	0	0	0	0	0	0	0	1	0	0	0.1	0.3	1
Eohaustorius eous	4	5	10	16	11	6	9	1	6	6	7.4	4.2	74
Paraphoxus milleri	0	1	0	0	0	0	0	0	1	0	0.2	0.4	2
ARTHORPODA - mysidacea													
Archaeomysis grebnitzkii	0	0	0	1	0	0	0	0	0	0	0.1	0.3	1
S	1	3	2	2	2	2	2	2	3	1			
N	4	7	11	17	12	6	10	3	8	6			

APPENDIX Ib. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 7 APRIL 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Level 1 (Upper)							
ANNELIDA - Polychaeta												
Eteone nr. *longa*	1	0	1	0	0	0	0	0	1	0	0.3 ± 0.5	3
Scoloplos armiger	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Anisogammarus cf *confervicolus*	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	2	0	0	2	0	0	0	0	0	0.4 ± 0.8	4
S	1	2	1	0	1	0	1	1	1	0		
N	1	3	1	0	2	0	1	1	1	0		
					Level 2							
ANNELIDA - Polychaeta												
Capitella capitata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Nephtys ?*ciliata*	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	1	2	0	1	4	10	4	4	1	2.7 ± 3.0	27
Paraphoxus milleri	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
S	0	2	1	0	1	1	2	2	1	2		
N	0	2	2	0	1	4	11	5	4	2		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Level 3							
ANNELIDA - Polychaeta												
Paraonella platybranchia	0	0	0	1	0	0	0	1	0	0	0.2 ± 0.4	2
Scoloplos armiger	0	0	0	0	0	0	0	0	2	0	0.2 ± 0.6	2
Scolelepis Sp. A	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	7	2	3	0	0	0	3	2	8	2.8 ± 2.8	28
?Ischyroceridae, unid.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
S	2	1	1	2	1	0	0	2	3	1		
N	4	7	2	4	1	0	0	4	5	8		
					Level 4 (Lower)							
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	2	0	0	0	0	0	0	0	0.2 ± 0.6	2
Scoloplos armiger	0	1	1	0	0	0	0	0	0	0	0.2 ± 0.4	2
Scolelepis Sp. A	1	1	1	1	0	0	0	2	2	1	0.9 ± 0.7	9
ARTHROPODA - Gammaridea												
Anisogammarus cf. confervicolus	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	15	7	3	8	13	4	3	16	13	7	8.9 ± 5.0	89
Gammaridea, unid.	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Lysianassidae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	1	0	1	0	0	0	0	0	1	0.3 ± 0.5	3
S	2	4	5	4	1	2	1	2	2	3		
N	16	10	8	11	13	5	3	18	15	9		

APPENDIX Ic. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 29 JULY 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Level 1 (Upper)							
ANNELIDA - Polychaeta												
Eteone nr. *longa*	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Paraonella platybranchia	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	1	1	0	1	0	1	0	0	0	1	0.5 ± 0.5	5
ARTHROPODA - Gammaridea												
Eohaustorius eous	2	7	0	4	1	3	1	4	2	4	2.8 ± 2.0	28
Gammaridae, Sp. A	1	0	1	1	1	0	0	0	0	0	0.4 ± 0.5	4
S	4	2	1	3	2	2	1	2	1	2	2.0 ± 0.9	
N	5	8	1	6	2	4	1	5	2	5	3.9 ± 2.3	
					Level 2							
ANNELIDA - Polychaeta												
Abarenicola Sp.	0	0	1	0	0	0	1	0	0	0	0.2 ± 0.4	2
Capitella capitata	0	0	0	0	0	0	0	1	0	1	0.2 ± 0.4	2
Eteone nr. *longa*	0	0	0	2	0	0	0	0	0	0	0.2 ± 0.6	2
Paraonella platybranchia	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	1	0	1	1	2	1	1	2	1	1	1.1 ± 0.6	11
Scoloplos armiger	0	0	1*	1*	1	1	0	0	0	0	0.4 ± 0.5	4
ARTHROPODA - Gammaridea												
Eohaustorius eous	4	8	6	2	11	6	9	3	2	1	5.2 ± 3.4	52
Gammaridae Sp. A	46	0	0	0	1	0	30	14	0	3	9.4 ± 16.1	94

TAXA	1	2	3	4	5	6	7	8	9	10	x̄ ± s	Total
					Level 2 Cont.							
Lamprops quadriplicata	0	0	0	0	0	0	1	0	1	0	0.2 ± 0.4	2
Oedocerotidae Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Synchelidium Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Mysidacea												
Archaeomysis grebnitzkii	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
S	3	1	5	4	6	4	5	4	3	4	3.9 ± 1.4	
N	51	8	10	6	17	9	42	20	4	6	17.3 ± 16.3	
					Level 3							
ANNELIDA - Polychaeta												
Chaetozone setosa	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Nephtys ?ciliata	0	0	0	0	0	0	1*	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	1*	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	0	1	0	2	0	0	0.4 ± 0.7	4
Scoloplos armiger	1	1*	0	0	0	0	1*	1	1*	0	0.5 ± 0.5	5
ARTHROPODA - Gammaridea												
Atylidae Sp. A	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	12	9	2	6	15	6	5	7	4	4	7.0 ± 4.0	70
Gammaridae Sp. A	3	0	1	2	0	2	3	0	0	0	1.1 ± 1.3	11
Lamprops quadriplicata	1	0	0	1	1	0	0	0	1	0	0.4 ± 0.5	4
Paraphoxus milleri	1	0	0	0	0	0	0	1	0	0	0.2 ± 0.4	2
Synchelidium Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	
S	5	3	2	5	3	4	4	4	3	1	3.4 ± 1.3	
N	18	11	3	11	17	10	10	11	6	4	10.1 ± 4.9	

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
						Level 4 (Lower)						
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Nephtys ?ciliata	0	1*	0	0	1	0	0	0	0	0	0.2 ± 0.4	2
Paraonella platybranchia	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	2	2	2	0	0	2	0.9 ± 1.0	9
Scoloplos armiger	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	7	9	6	1	0	19	2	2	4	5.3 ± 5.6	53
Gammaridae Sp. A	1	0	0	0	2	3	0	2	0	5	1.3 ± 1.7	13
Paraphoxus milleri	1	0	0	2	0	0	0	0	0	0	0.3 ± 0.7	3
S	3	2	1	3	4	2	4	2	1	4	3.3 ± 2.4	
N	5	8	9	9	6	5	23	4	2	12	7.8 ± 6.4	

* Fragment

APPENDIX IIa. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 4 FEBRUARY 1977

	Density (No./m^2)			
TAXA Station No.:	1	2	3	4*
ANNELIDA - Polychaeta				
Capitella capitata	25.5	12.7	0	0
Eteone nr. longa	114.6	38.2	12.7	12.7
Paraonella platybranchia	0	0	50.9	12.7
Scolelepis Sp. A	0	0	12.7	50.9
Scoloplos armiger	0	0	25.5	0
ARTHROPODA - Gammaridea				
Anisogammarus cf. confervicolus	12.7	0	0	12.7
Eohaustorius eous	76.4	216.4	381.9	942.2
Paraphoxus milleri	0	0	12.7	25.5
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	0	0	0	12.7
Total Number of Specimens:	18	21	39	84

* Lowest level on beach

APPENDIX IIb. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 7 APRIL 1977

TAXA Station No.:	Density (No./m^2) 1	2	3	4*
ANNELIDA - Polychaeta				
Capitella capitata	0	12.7	0	0
Eteone nr. *longa*	38.2	0	0	0
Nephtys ?*ciliata*	0	12.7	0	25.5
Paraonella platybranchia	0	12.7	25.5	0
?*Scolelepis* Sp. A	0	0	12.7	114.6
Scoloplos armiger	12.7	0	25.5	25.5
ARTHROPODA - Gammaridea				
Anisogammarus cf. *confervicolus*	12.7	0	0	12.7
Eohaustorius Sp.	12.7	343.7	356.4	1133.0
Gammaridea, unid.	0	0	12.7	25.5
Paraphoxus Sp.	50.9	12.7	12.7	38.2
Total Number of Specimens:	10	31	35	108

* Lowest level on beach

APPENDIX IIc. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 29 JULY 1977

	Density (No./m^2)			
TAXA Station No.:	1	2	3	4*
ANNELIDA - Polychaeta				
Abarenicola Sp.	0	25.5	0	0
Capitella capitata	0	25.5	0	12.7
Chaetozone setosa	0	0	12.7	0
Eteone nr. *longa*	12.7	25.5	0	0
Nephtys ?*ciliata*	0	0	12.7	25.5
Paraonella platybranchia	12.7	12.7	12.7	12.7
Scolelepis Sp. A	63.7	140.1	50.9	114.6
Scoloplos armiger	0	50.9	63.7	12.7
ARTHROPODA - Gammaridea				
Atylidae Sp. A	0	0	12.7	0
Eohaustorius eous	356.6	662.1	891.3	674.8
Gammaridae Sp. A	50.9	1196.8	140.1	165.5
Lamprops quadriplicata	0	25.5	50.9	0
Paraphoxus milleri	0	12.7	25.5	38.2
Synchelidium Sp.	0	12.7	12.7	0
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	0	12.7	0	0
Total Number of Specimens:	39	173	101	83

* Lowest level on beach

APPENDIX IIIa. POOLED SIZE DATA FOR *EOHAUSTORIUS EOUS* AT DEEP CREEK IN 1977

Size Class (mm)	4/7/77	7/29/77
1.3 - 1.5		1
1.6 - 1.8		1
1.9 - 2.1	2	6
2.2 - 2.4	12	8
2.5 - 2.7	13	16
2.8 - 3.0	7	19
3.1 - 3.3	7	10
3.4 - 3.6	8	17
3.7 - 3.9	9	21
4.0 - 4.2	19	31
4.3 - 4.5	15	33
4.6 - 4.8	26	14
4.9 - 5.1	12	12
5.2 - 5.4	7	4
5.5 - 5.7	3	2
5.8 - 6.0	1	
Mean length (mm)	3.9	3.8
s	1.0	0.9

APPENDIX IIIb. LENGTH DATA FOR UNID. GAMMARIDAE WITH DARK EYE AND COARSE ANTENNAE, DEEP CREEK, 29 JULY 77

	1	2	3	4	Total
1.5		3			3
1.6		2			2
1.7		1	1	1	3
1.8		2			2
1.9	1	3			4
2.0	1	3		3	7
2.1		3			3
2.2		9	3	2	14
2.3		8	1	1	10
2.4		1	1	2	4
2.5	1	8	2	1	12
2.6		2	1		3
2.7		5		1	6
2.8		7			7
2.9		4			4
3.0		1		1	2
3.1		1			1
3.2		3		1	4
3.3		3			3
3.4		3			3
3.5		1	1		2
3.6		1			1
3.7		2			2
7.0		1			1

$n = 103$

$\bar{x} = 2.52$

$s = 0.69$

APPENDIX IVa. SAMPLE DATA FOR HOMER SPIT BEACH; 17 February 1977.

TAXA	1	2	3	4	5	$\bar{x} \pm s$	Total
			Cores* near 30m level				
ANNELIDA - Polychaeta							
Eteone nr. *longa*	0	0	0	0	1	0.2 ± 0.4	1
Paraonella platybranchia	2	1	0	0	1	0.8 ± 0.8	4
Scolelepis Sp. A	1	1	1	1	2	1.2 ± 0.4	6
ARTHROPODA - Mysidacea							
Archaeomysis grebnitzkii	0	0	0	0	1	0.2 ± 0.4	1
Total	3	2	1	1	5		
			Cores* near 75m level				
ANNELIDA - Polychaeta							
Nephtys ?*ciliata*	0	1	0	0	0	0.2 ± 0.4	1
Scolelepis Sp. A	1	0	0	2	0	0.6 ± 0.9	3
Spionidae, unid.	0	1	0	0	0	0.2 ± 0.4	1
Typosyllis Sp.	0	1	0	0	0	0.2 ± 0.4	1
ARTHROPODA - Gammaridea							
Eohaustorius eous	0	1	0	0	1	0.4 ± 0.5	2
Total	1	4	0	2	1		

TAXA	1	2	3	4	5	x ± s	Total
		Cores* from 100m level					
ANNELIDA - Polychaeta							
Magelona pitelkai	0	1	0	0	0	0.2 ± 0.4	1
Paraonella platybranchia	1	4	3	0	4	2.4 ± 1.8	12
Scolelepis Sp. A	1	2	1	5	2	2.2 ± 1.6	11
ARTHROPODA - Gammaridea							
Eohaustorius eous	0	0	1	0	0	0.2 ± 0.4	1
Gammaridae, unid. (red-striped)	0	0	1	0	1	0.4 ± 0.5	2
Paraphoxus milleri	1	0	1	1	1	0.8 ± 0.4	4
PISCES							
Ammodytes hexapterus	0	0	1	1	0	0.4 ± 0.5	2
Total	3	7	8	7	8		
		Cores* from 132m level					
ANNELIDA - Polychaeta							
Magelona pitelkai	0	0	0	1	0	0.2 ± 0.4	1
Paraonella platybranchia	0	0	2	2	3	1.4 ± 1.3	7
Scolelepis Sp. A	8	2	5	6	2	4.6 ± 2.6	23
ARTHROPODA - Gammaridea							
Gammaridae, unid. (red-striped)	0	2	2	0	0	0.8 ± 1.1	4
Paraphoxus milleri	0	0	0	1	2	0.6 ± 0.9	3
MOLLUSCA - Gastropoda							
Littorina sitkana	0	0	2	0	0	0.4 ± 0.9	2
MOLLUSCA - Pelecypoda							
Spisula polynyma	0	0	0	2	0	0.4 ± 0.9	2
Total	8	4	11	12	7		

APPENDIX IVb. SAMPLE DATA FOR HOMER SPIT BEACH; 7 MARCH 1977

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Cores* from 30m level												
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	2	0	0	3	1	0	0.7 ± 1.1	7
ARTHROPODA - Gammaridea												
Paraphoxus milleri	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Total	0	0	0	2	2	0	1	3	1	0		
Cores* from 75m level												
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	0	0	0	0	0	1	1	0	2	0.4 ± 0.7	4
Scolelepis Sp. A	0	1	1	0	1	4	1	3	2	0	1.3 ± 1.3	13
ARTHROPODA - Gammaridea												
Anonyx Sp.	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Eohaustorius eous	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	0	0	1	1	0	0	2	0	0.5 ± 0.7	5
Total	2	1	1	0	2	5	3	4	4	3		

TAXA	1	2	3	4	5	6	7	8	9	10	x̄ ± s	Total
					Cores* from 100m level							
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
Paraonella platybranchia	0	1	0	2	1	1	2	0	1	0	0.8 ± 0.8	8
Sabellidae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	2	1	1	4	4	1	5	0	7	5	3.0 ± 2.3	30
Scoloplos armiger	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	2
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	0	0	1	1	0	0	0	0	0	0.2 ± 0.4	2
Paraphoxus milleri	1	0	2	0	0	0	0	0	0	0	0.3 ± 0.7	3
MOLLUSCA - Pelecypoda												
Mytilus edulis (juv.)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Total	3	2	5	7	6	2	9	0	9	5		
					Cores* from 135m level							
ANNELIDA - Polychaeta												
Magelona pitelkai	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	19	1	6	16	4	12	3	5	1	4	7.1 ± 6.3	71
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	1	0	1	0	0	1	0	3	0.7 ± 0.9	7
MOLLUSCA - Pelecypoda												
Spisula polynyma (juv.)	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
CHORDATA - Pisces												
Ammodytes hexapterus	0	0	0	0	0	0	1	1	0	0	0.2 0.4	2
Total	21	2	7	16	5	12	5	7	1	7		

APPENDIX IVc. SAMPLE DATA FOR HOMER SPIT BEACH; 28 July 1977

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Cores* from 30m level							
PLATYHELMINTHES												
Turbellaria, unid.	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
ANNELIDA - Polychaeta												
Nephtys Sp. (juv.)	0	0	0	1	1	1	0	1	0	0	0.4 ± 0.5	4
Paraonella platybranchia	0	0	0	3	3	4	5	0	0	0	1.5 ± 2.0	15
Scolelepis Sp. A	0	0	2	0	2	4	1	1	4	1	1.5 ± 1.5	15
Spiophanes ?*bombyx*	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Crustacea												
Crangon ?*alaskensis elongata* (juv.)	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Lamprops carinata	0	0	0	0	1	1	0	2	1	0	0.5 ± 0.7	5
L. quadriplicata	0	0	0	0	6	2	2	5	1	0	1.6 ± 2.2	16
Eohaustorius eous	0	0	1	0	1	0	0	0	0	0	0.2 ± 0.4	2
Gammaridae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	1	0	0	0	0	0	0	1	0	0.2 ± 0.4	2
MOLLUSCA - Pelecypoda												
Protothaca staminea	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
Total	0	1	4	5	15	12	8	10	8	1		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Cores* from 75m level							
ANNELIDA - polychaeta												
Capitella capitata	0	0	0	0	0	0	1	4	0	0	0.5 ± 1.3	5
Nephtys ?ciliata	1	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Nephtys Sp. (juv.)	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	2	4	2	1	3	1	0	0	0	0	1.3 ± 1.4	13
Scolelepis Sp. A	1	4	1	2	0	3	1	0	1	2	1.5 ± 1.3	15
ARTHROPODA - Crustacea												
Crangon ?alaskensis elongata (juv.)	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	2
Eohaustorius eous	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Lamprops carinata	1	0	0	1	0	0	0	0	0	0	0.2 ± 0.4	2
L. quadriplicata	0	0	0	0	2	1	1	0	0	0	0.4 ± 0.7	4
Lamprops Sp.	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Synchelidium Sp.	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Total	6	9	3	5	6	6	3	5	2	2		
					Cores* from 100m level							
ANNELIDA - Polychaeta												
Capitella capitata	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Nephtys Sp. (juv.)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	3	4	3	4	0	4	3	1	1	6	2.9 ± 1.8	29
Scolelepis Sp. A	6	2	2	3	3	2	3	1	5	7	3.4 ± 2.0	34

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Cores* from 100m level Cont.												
ARTHROPODA - Crustacea												
Eohaustorius eous	1	0	0	1	0	0	1	1	0	0	0.4 ± 0.5	4
Lamprops carinata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	0	0	0	0	1	0	0	0	1	0.2 ± 0.4	2
Synchelidium Sp.	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	2
PISCES												
Ammodytes hexapterus	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Total	10	6	7	8	6	7	8	3	6	14		
Cores* from 135m level												
ANNELIDA - Polychaeta												
Capitella capitata	0	2	0	0	0	0	0	0	0	0	0.2 ± 0.6	2
Eteone nr. longa	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Paraonella platybranchia	0	1	0	2	2	0	4	1	0	0	1.0 ± 1.3	10
Scolèlepis Sp. A	14	3	8	9	12	7	11	16	8	20	10.8 ± 4.9	108
ARTHROPODA - Crustacea												
Crangon ?alaskensis elongata	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Eohaustorius eous	0	0	0	0	0	0	0	0	1	1	0.2 ± 0.4	2
Lamprops carinata	1	1	0	0	0	1	2	0	4	2	1.1 ± 1.3	11
L. quadriplicata	0	2	0	0	0	0	1	1	1	0	0.5 ± 0.7	5
Paraphoxus milleri	0	0	0	1	0	1	0	0	0	0	0.2 ± 0.4	2
MOLLUSCA - Pelecypoda												
Spisula polynyma	0	0	0	0	0	0	0	0	2	0	0.2 ± 0.6	2
Total	15	9	8	12	14	9	18	18	16	25		

APPENDIX Va. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 17 FEBRUARY 1977

TAXA	Density (No./m^2)			
	30m	75m	100m	132m*
ANNELIDA - Polychaeta				
Eteone nr. *longa*	25.5	0	0	0
Magelona pitelkai	0	0	25.5	25.5
Nephtys ?*ciliata*	0	25.5	0	0
Paraonella platybranchia	101.9	0	305.6	178.3
Scolelepis Sp. A	152.8	76.4	280.1	585.7
Spionidae, unid.	0	25.5	0	0
Typosyllis Sp.	0	25.5	0	0
ARTHROPODA - Gammaridae				
Eohaustorius eous	0	50.9	25.5	0
Gammaridae, unid. (red-striped)	0	0	50.9	101.8
Paraphoxus milleri	0	0	101.8	76.4
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	25.5	0	0	0
MOLLUSCA - Gastropoda				
Littorina sitkana	0	0	0	50.9
MOLLUSCA - Pelecypoda				
Spisula polynyma	0	0	0	50.9
PISCES				
Ammodytes hexapterus	0	0	50.9	0

* lowest level on beach

APPENDIX Vb. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 7 MARCH 1977

TAXA	Density (No.m^2) 30m	75m	100m	135m*
ANNELIDA - Polychaeta				
Magelona pitelkai	0	0	0	12.7
Nephtys ?ciliata	12.7	12.7	12.7	0
Paraonella platybranchia	0	50.9	101.9	0
?Sabellidae, unid.	0	0	12.7	0
Scolelepis Sp. A	89.1	165.5	382.0	904.0
Scoloplos armiger	0	0	25.5	0
ARTHROPODA - Gammaridea				
Anonyx Sp.	0	12.7	0	0
Eohaustorius eous	0	12.7	25.5	12.7
Paraphoxus milleri	12.7	63.7	38.2	89.1
MOLLUSCA - Pelecypoda				
Mytilus edulis (juv.)	0	0	12.7	0
Spisula polynyma	0	0	0	12.7
PISCES				
Ammodytes hexapterus	0	0	0	25.5

* lowest level on beach

APPENDIX Vc. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 28 JULY 1977

TAXA	Density (No./m^2) 30m	75m	100m	135m*
PLATYHELMINTHES				
Turbellaria, unid.	12.7	0	0	0
ANNELIDA - Polychaeta				
Capitella capitata	0	63.7	12.7	25.5
Eteone nr. *longa*	0	0	0	12.7
Nephtys ?*ciliata*	0	12.7	0	0
Nephtys Sp. (juv.)	50.9	12.7	12.7	0
Paraonella platybranchia	191.0	165.5	369.2	127.3
Scolelepis Sp. A	191.0	191.0	432.9	1375.1
Spiophanes ?*bombyx*	12.7	0	0	0
ARTHROPODA - Crustacea				
Crangon ?*alaskensis elongata*	12.7	25.5	0	12.7
Eohaustorius eous	25.5	12.7	50.9	25.5
Lamprops carinata	63.7	25.5	12.7	140.1
L. quadriplicata	203.7	50.9	0	63.7
Lamprops Sp.	0	12.7	0	0
Paraphoxus milleri	25.5	0	25.5	25.5
Synchelidium Sp.	12.7	12.7	25.5	0

TAXA	Density (No./m^2) 30m	75m	100m	135m*
MOLLUSCA - Pelecypoda				
Protothaca staminea	12.7	0	0	0
Spisula polynyma	0	0	0	25.5
PISCES				
Ammodytes hexapterus	0	0	12.7	0

* lowest level on beach

APPENDIX VIa. ABUNDANCE DATA FOR CORE SAMPLES FROM THE +3.6 FOOT LEVEL AT GLACIER SPIT, CHININTA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m²
ECHIURIDAE												
Echiurus echiurus	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Abarenicola pacifica	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Capitella capitata	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr *longa*	0	0	1	0	0	0	0	0	2	0	0.3 ± 0.7	38.2
Glycinde polygnatha	0	0	0	0	1	0	0	0	0	1	0.2 ± 0.4	25.5
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Malacoceros sp	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	25.5
Nephtys sp	1	0	2	0	0	0	1	1	0	0	0.5 ± 0.7	63.7
Nephtys sp (juv.)	0	1	1	0	3	1	1	0	0	0	0.7 ± 0.9	89.1
Paraonidae, unid.	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Phyllodoce groenlandica	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	25.5
Potamilla sp	0	1	4	0	0	0	0	0	0	0	0.5 ± 1.3	63.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	1	0	1	2	0	0	0	0	1	0.5 ± 0.7	63.7
Macoma balthica	25	31	26	46	45	32	41	22	32	65	36.5 ± 13.0	4647.3
Mya arenaria	0	0	0	0	2	1	1	2	0	1	0.7 ± 0.8	89.1
Mya sp	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Mya spp (juv.)	0	0	0	1	8	0	2	0	0	1	1.2 ± 2.5	152.8
Pseudopythina sp	0	1	1	0	1	0	0	0	0	4	0.7 ± 1.3	89.1
No. of Individuals	27	36	35	48	67	34	47	25	34	75		
No. of Species	3	6	5	3	10	3	4	3	2	8		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +2.5 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										$\bar{x} \pm s$	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	1	1	0	1	1	1	2	0	0.8 ± 0.6	101.9
ANNELIDA - Polychaeta												
Aphroditoididae	1	0	0	0	0	0	1	0	0	1	0.3 ± 0.5	38.2
Capitella capitata	0	2	0	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Eteone nr longa	0	1	0	0	1	1	0	1	0	0	0.4 ± 0.5	50.9
Glycinde polygnatha	0	0	1	1	0	0	0	1	0	0	0.3 ± 0.5	38.2
Harmothoe imbricata	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Nephtys sp	2	1	1	0	0	1	0	0	1	1	0.7 ± 0.7	89.1
Nephtys sp (juv.)	2	2	2	0	0	0	2	1	1	1	1.1 ± 0.9	140.1
Polydora caulleryi	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	25.5
Potamilla sp	0	2	1	1	0	0	1	0	0	1	0.6 ± 0.7	76.4
ARTHROPODA - Isopoda												
Saduria entomon	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	1	1	0	0	0	1	0	1	0	0.4 ± 0.5	50.9
Macoma balthica	40	33	29	32	35	35	32	53	22	38	34.9 ± 8.1	4443.6
Mya arenaria	0	1	0	1	0	0	0	1	1	1	0.5 ± 0.5	63.6
M. priapus	0	0	0	0	0	1	0	0	1	0	0.2 ± 0.4	25.5
Mya sp fragment	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Mya spp (juv.)	1	3	0	0	3	0	0	2	0	1	1.0 ± 1.2	127.3
Pseudopythina sp	0	6	4	2	0	0	0	1	3	0	1.6 ± 2.1	203.7
No. of Individuals	47	52	40	38	40	40	38	62	33	45		
No. of Species	5	9	7	6	4	6	6	9	8	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +0.9 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										$\bar{x} \pm s$	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Ampharete acutifrons	1	0	0	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Capitella capitata	1	0	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Eteone nr longa	0	0	0	1	0	1	0	0	1	0	0.3 ± 0.5	38.2
Harmothoe imbricata	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
Malococeros sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Nephtys sp	1	0	1	1	2	2	3	1	1	1	1.3 ± 0.8	165.5
Nephtys sp (juv.)	2	3	3	6	0	2	2	3	3	5	2.9 ± 1.7	211.7
Phyllodoce groenlandica	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Polydora caulleryi	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Potamilla sp	1	2	2	6	2	1	6	2	2	1	2.5 ± 1.9	318.3
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	1	3	3	3	8	3	4	3	4	2	3.4 ± 1.8	432.9
Macoma balthica	37	37	38	37	50	38	57	29	64	33	42.0 ± 11.2	5347.6
Mya priapus	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Mya sp	1	0	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Mya spp (juv.)	1	1	4	9	13	7	13	6	13	21	8.8 ± 6.3	1120.5
Pseudopythina sp	0	1	0	0	0	0	6	1	4	6	1.8 ± 2.5	229.2
No. of Individuals	46	47	54	63	75	54	93	45	94	72		
No. of Species	8	6	7	6	5	7	7	6	9	9		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE -1.2 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										$\bar{x} \pm s$	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	0	0	0	0	1	0	0.2 ± 0.4	25.5
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Capitella capitata	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr *longa*	0	1	0	0	0	1	0	0	0	0	0.2 ± 0.4	25.5
Glycinde polygnatha	0	0	0	0	0	1	1	0	1	0	0.3 ± 0.5	38.2
Malacoceros sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Nephtys sp	3	1	1	1	1	0	2	0	0	0	1.0 ± 1.0	127.3
Nephtys sp (juv.)	5	1	0	0	5	4	3	0	0	1	2.1 ± 2.1	267.4
Phyllodoce groenlandica	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Polydora caulleryi	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Potamilla sp	0	0	0	1	0	1	0	0	0	0	0.2 ± 0.4	38.2
Scoloplos armiger	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
?*Spio* sp	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	38.2
ARTHROPODA - Amphipoda												
Tritella pilimana	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	1	2	8	4	0	3	4	4	5	1	2.7 ± 1.7	343.8
Macoma balthica	31	32	52	33	28	44	39	40	23	31	33.4 ± 6.5	4252.6
Macoma sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Mya arenaria	1	0	0	0	0	1	1	0	0	0	0.3 ± 0.5	38.2
Mya priapus	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	12.7
Mya truncata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Mya spp (juv.)	13	12	13	6	5	35	9	17	2	8	11.9 ± 9.8	1515.2
Pseudopythina sp	0	1	0	0	0	0	1	1	1	1	0.5 ± 0.5	63.6
No. of Individuals	57	51	76	46	39	91	61	62	34	46		
No. of Species	8	7	6	6	3	9	8	4	7	9		

APPENDIX VIb. ABUNDANCE DATA FOR CORE SAMPLES FROM THE +3.6 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	0	1	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	1	1	0	0	0	0	1	0	0.4 ± 0.5	51.0
Capitella capitata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr longa	1	1	1	0	1	0	1	0	0	0	0.5 ± 0.5	63.8
Eteone nr pacifica	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Harmothoe imbricata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Malococeros sp	0	0	0	0	0	0	1	0	0	1	0.2 ± 0.4	25.5
Nephtys sp	0	2	0	1	3	1	0	1	2	1	1.1 ± 1.0	140.1
Nephtys sp (juv)	1	0	2	1	0	0	1	1	1	1	0.8 ± 0.6	102.0
Polydora caulleryi	0	0	1	0	0	0	0	0	1	0	0.2 ± 0.4	25.5
Potamilla sp	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
Scoloplos armiger	0	1	0	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Spio filicornis	1	3	1	1	0	0	1	3	0	0	1.0 ± 1.2	127.6
ANNELIDA - Oligochaeta	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
ARTHROPODA - Crustacea												
Crangon sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Tritella ?pilimana	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	25.5
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
(juv)	0	0	0	0	0	0	0	1	1	0	0.2 ± 0.4	25.5
Macoma balthica	14	20	22	14	21	18	15	21	17	15	17.7 ± 3.1	2253.6
Mya arenaria	1	0	0	0	2	0	0	1	1	0	0.5 ± 0.7	63.8
M. priapus	0	0	0	0	1	0	1	0	0	0	0.2 ± 0.4	25.5
Mya sp (frag & juv.)	0	0	1	0	1	0	1	0	0	0	0.3 ± 0.5	38.2
Pseudopythina sp	0	2	3	0	0	0	1	1	0	0	0.7 ± 1.1	89.1
No. of Individuals	18	33	33	18	30	19	22	31	25	21		
No. of Species	5	10	9	4	6	2	7	8	7	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +2.5 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	2	0	1	1	0	0	0.5 ± 0.7	63.8
ANNELIDA - Polychaeta												
Capitella capitata	1	8	0	0	6	0	0	0	0	0	1.5 ± 3.0	191.3
Eteone nr longa	1	4	3	2	3	0	0	1	0	0	1.4 ± 1.5	178.6
Eteone nr pacifica	2	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	25.5
Harmothoe imbricata	1	0	1	0	1	0	0	1	0	0	0.4 ± 0.5	50.9
Malococeros sp	0	3	0	0	0	0	0	0	0	0	0.3 ± 0.9	38.3
Maldanidae (juv.)	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Nephtys sp (adults)	4	0	0	0	2	1	0	0	3	1	1.1 ± 1.4	140.3
(juv.)	1	8	2	4	0	1	0	1	1	2	2.0 ± 2.4	255.1
Phyllodoce groenlandica	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Polydora caulleryi	3	0	1	1	0	1	0	3	0	1	1.0 ± 1.2	127.5
Potamilla sp	4	1	0	4	0	1	2	0	0	0	1.2 ± 1.6	153.1
Scoloplos armiger	0	0	0	0	0	1	0	1	0	0	0.2 ± 0.4	25.5
Spio filicornis	6	4	4	5	3	1	1	9	3	2	3.8 ± 2.4	484.7
Spionidae, unid.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
ARTHROPODA - Crustacea												
Crangon sp	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Cyclopoida	0	0	0	0	0	0	0	1	0	1	0.2 ± 0.4	25.5
Harpacticoida	0	4	0	0	0	0	0	0	0	0	0.4 ± 1.3	50.9
Ischyroceridae	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	0	6	0	3	0	2	0	0	3	7	2.1 ± 2.6	267.9
Insecta (larvae)	0	1	0	0	1	0	0	0	0	1	0.3 ± 0.5	38.3

+2.5 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m²
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	1	0	0	1	1	0	1	0.4 ± 0.7	50.9
(juv.)	0	1	0	0	0	0	0	1	0	0	0.2 ± 0.4	25.5
Macoma balthica	10	28	29	20	22	17	18	21	15	14	19.4 ± 6.0	2470.1
Mya arenaria	1	1	0	1	0	0	1	1	0	0	0.5 ± 0.5	63.8
M. priapus	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Mya spp (frag. & juv.)	1	0	0	1	0	2	0	0	1	1	0.6 ± 0.7	76.5
Pseudopythina sp	3	1	3	0	0	0	0	2	0	0	0.9 ± 1.2	114.6
No. of Individuals	39	72	43	42	42	27	27	46	26	31		
No. of Species	12	15	7	9	10	8	8	12	5	9		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +0.9 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	0	1	1	0	0	1	0	0	2	0	0.5 ± 0.7	63.8
ANNELIDA												
Ampharete acutifrons	1	0	1	1	0	0	0	0	0	0	0.3 ± 0.5	38.3
Capitella capitata	1	0	1	0	0	11	0	0	0	0	1.3 ± 3.4	165.8
Eteone nr *longa*	0	2	1	1	0	4	0	0	2	0	1.0 ± 1.3	127.6
Harmothoe imbricata	2	1	0	2	0	1	1	2	1	0	1.0 ± 0.8	127.6
Malacoceros sp	1	2	0	0	0	0	0	0	0	0	0.3 ± 0.7	38.3
Nephtys sp (adult)	2	1	1	1	0	2	2	2	1	4	1.2 ± 0.8	153.1
(juv.)	2	1	0	0	0	1	1	1	0	0	0.6 ± 0.7	76.5
Oligochaeta, unid.	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Phyllodoce groenlandica	0	0	0	0	0	0	0	0	1	1	0.2 ± 0.4	25.5
Polydora caulleryi	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Polygordius sp	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Potamilla sp	6	2	6	8	4	2	5	2	0	1	3.6 ± 2.6	459.2
Scoloplos armiger	2	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	25.5
Spio filicornis	14	2	6	2	1	5	12	0	1	1	4.4 ± 4.9	560.2
ARTHROPODA												
Acarina	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Cyclopoida	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Pontoporeia femorata	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	10	0	0	0	0	4	3	0	9	0	2.6 ± 3.9	331.6

+0.9 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m²
MOLLUSCA												
Clinocardium nuttallii (adult)	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
(juv.)	1	0	2	5	0	0	3	0	1	0	1.2 ± 1.7	152.8
Cylichna sp	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Macoma balthica	31	22	15	14	23	22	19	24	9	26	20.5 ± 6.4	2610.3
Mya arenaria	0	1	0	1	1	0	1	0	0	0	0.4 ± 0.5	50.9
M. priapus	0	2	1	0	0	0	2	1	0	0	0.6 ± 0.8	76.4
M. truncata	0	0	2	1	0	0	0	0	0	0	0.3 ± 0.7	38.2
Mya spp (frag. & juv.)	1	0	1	2	1	1	2	1	0	1	1.0 ± 0.7	127.6
Pseudopythina sp	0	1	2	2	0	7	1	2	2	0	1.7 ± 2.0	216.5
No. of Individuals	76	40	41	40	31	62	52	36	29	34		
No. of Species	14	13	13	11	5	12	10	7	10	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE -1.2 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										$\bar{x} \pm s$	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	0	0	0	1	0	0	1	0	0.2 ± 0.4	25.5
Axiothella rubrocincta	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Capitella capitata	1	0	1	0	0	0	3	0	0	1	0.6 ± 1.0	76.5
Eteone nr *longa*	2	0	0	1	1	0	3	1	0	1	0.9 ± 1.0	114.8
Harmothoe imbricata	1	0	1	0	0	0	1	1	0	1	0.5 ± 0.5	63.8
Malacoceros sp	0	0	0	0	0	1	2	0	0	1	0.4 ± 0.7	51.0
Nephtys sp	0	1	0	2	0	2	1	2	2	1	1.1 ± 1.1	140.3
Nephtys sp (juv.)	2	6	2	3	0	6	3	0	2	1	2.5 ± 2.1	318.9
Paraonella platybranchia	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Phyllodoce groenlandica	0	2	0	1	0	0	0	0	1	1	0.5 ± 0.7	63.8
Polydora caulleryi	1	1	0	0	0	1	1	0	0	0	0.4 ± 0.5	50.9
Potamilla sp	3	5	4	3	0	1	2	5	3	4	3.0 ± 1.6	382.0
Scoloplos armiger	1	0	0	0	0	1	0	0	0	0	0.2 ± 0.4	25.5
Spio filicornis	4	13	10	3	0	5	4	3	6	3	5.1 ± 3.8	650.5
NEMERTEA, unid.	0	0	0	1	0	0	0	1	0	0	0.2 ± 0.4	25.5
ARTHROPODA												
Acarina	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Pontoporeia femorata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	7	1	0	0	0	0	1	0	0	1	1.0 ± 2.2	127.6

-1.2 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m²
MOLLUSCA												
Aglaja diomadea	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Clinocardium nuttallii (adult)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
(juv.)	2	2	1	0	1	3	2	1	0	1	1.3 ± 0.9	165.5
Macoma balthica	50	19	30	21	28	27	23	20	18	22	25.8 ± 9.4	3285.0
Mya arenaria	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
M. priapus	0	0	0	2	0	2	0	0	0	1	0.5 ± 0.8	63.8
M. truncata	0	0	0	0	1	1	0	0	0	0	0.2 ± 0.4	25.5
Mya spp (frag. & juv.)	2	1	1	0	1	2	3	0	0	1	1.1 ± 0.1	140.1
Pseudopythina sp	0	0	1	0	0	2	4	2	0	2	1.1 ± 1.3	140.1
No. of Individuals	77	52	53	37	33	55	56	36	33	43		
No. of Species	13	10	10	8	5	12	15	9	6	14		

APPENDIX VIIa. BIOMASS DATA (GRAMS WHOLE WET WEIGHT) FOR CORE SAMPLES FROM GLACIER SPIT, CHINITNA BAY, 6 APRIL 1977

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
					+3.6 Level							
ECHIURA												
Echiurus echiurus	0	0.377	0	0	0	0	0	0	0	0	0.038 ± 0.119	4.838
ANNELIDA - Polychaeta												
Abarenicola pacifica	0	0	0	0	0	0	0	0	0	0.024	0.002 ± 0.008	0.255
Capitella capitata	0	0	0	0	0.007	0	0	0	0	0	0.001 ± 0.002	0.127
Eteone nr *longa*	0	0	T	0	0	0	0	0	0.090	0	0.009 ± 0.028	1.146
Glycinde sp	0	0	0	0	0.001	0	0	0	0	0.047	0.005 ± 0.015	0.637
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0.007	0.001 ± 0.002	0.127
Malacocerus sp	0	0	0	0	0.001	0	0	0	0	0	T	T
Nephtys sp	0.005	0	0	0.14	0.726	0.054	0.139	0.10	0.005	0	0.017 ± 0.222	2.165
Nephtys sp (juv.)	0	0	T	0	T	T	T	0	0	0	T	0.026
Paraonidae, unid.	T	0	0	0	0	0	0	0	0	0	T	T
Phyllodoce groenlandica	0	0	0	0	0.017	0	0	0	0	0	0.002 ± 0.005	0.255
Potamilla sp	0	0.001	0	0	0.063	0	0	0	0	-	0.006 ± 0.020	0.764
ARTHROPODA - Crustacea												
Arthropod frag.	0	0	0	0.002	0	0	0	0	0	0	T	0.025

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m^2
+3.6' Level Cont.												
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	0.005	0	0.005	0.02	0	0	0	0	0.005	0.004 ± 0.006	0.509
Macoma balthica	4.32	4.69	2.31	4.59	4.00	3.48	3.33	2.55	5.50	7.88	4.3 ± 1.6	547.5
Mya arenaria	0	0	0	0	24.11	71.07	62.84	107.77	0	14.22	28.0 ± 38.8	3565.1
Mya spp (juv.)	0	0	0	0.005	0.05	0	0.01	0	0	0.01	0.008 ± 0.016	1.02
Mya sp (frag.)	0	0	0	0	0	0	3.03	0	0	0	0.3 ± 1.0	38.2
Pseudopythina sp	0	0.006	0.005	0	0.03	0	0	0	0	0.02	0.006 ± 0.011	0.76
Total	4.33	5.08	2.32	4.74	29.03	74.60	69.35	110.42	5.60	22.21	32.75 ± 38.35	4169.5
+2.5' Level												
ECHIURA												
Echiurus echiurus	0.135	0	0.690	1.24	0	0.90	0.025	0.360	0.291	0	0.364 ± 0.439	46.35
ANNELIDA - Polychaeta												
Aphroditoidae, unid.	0.002	0	0	0	0	0.126	0	0	0.095	0	0.022 ± 0.047	2.801
Capitella capitata	0	0.001	0	0	0	0	0	0	0	0	T	T
Eteone nr *longa*	0	0.022	0	0	0.012	0.010	0	0.004	0	0	0.005 ± 0.008	0.637
Glycinde sp	0	0	0.075	0.006	0	0	0	0.030	0	0	0.011 ± 0.024	1.401
Harmothoe imbricata	0	0	0	0	0	0.029	0	0	0	0	0.003 ± 0.009	0.382

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m^2
					+2.5' Level Cont.							
Nephtys caeca	0.42	0.890	0.146	0	0.322	0.494	0	0	0.177	0.09	0.254 ± 0.285	32.34
Nephtys sp (juv.)	0.038	0.007	0.0[illegible]3	0	0	0	0.002	0.005	0.003	0.005	0.007 ± 0.011	0.891
Polydora caulleryi	0	0	0	0	0.003	0	0	0	0.002	0	T	0.06
Potamilla sp	0	0.017	0.040	0.008	0.022	0	0.003	0	0	0.034	0.012 ± 0.015	1.528
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	0.005	0.01	0	0	0	0.01	0	0.01	0	0.004 ± 0.005	0.509
Macoma balthica	5.12	4.91	3.28	2.49	6.45	3.93	3.67	4.20	3.55	4.90	4.2 ± 1.1	534.7
Mya arenaria	0	51.61	0	7.17	0	0	0	62.62	39.20	9.86	17.0 ± 24.4	2164.5
M. priapus	0	0	0	0	0	7.05	0	0	6.10	0	1.3 ± 2.8	165.5
Mya sp (frag.)	0	0	0	0	0	0	0	0	0	0.84	0.08 ± 0.27	10.19
Mya spp (juv.)	0.01	0.02	0	0	0.02	0	0	0.005	0	0.6	0.07 ± 0.19	8.91
Pseudopythina sp	0	0.07	0.02	0.22	0	0	0	0.01	0.02	0	0.034 ± 0.07	4.33
Total	5.73	57.55	4.27	11.13	6.83	12.54	3.71	67.23	49.45	16.33	23.48 ± 24.55	2989.33

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
					+0.9' Level							
ECHIURA												
Echiurus echiurus	0	0	0	0	0	0	0	0	1.099	0	0.110 ± 0.348	14.006
ANNELIDA - Polychaeta												
Ampharete acutifrons	0.010	0	0	0	0	0	0	0	0	0.001	0.001 ± 0.003	0.127
Capitella capitata	0.001	0	0	0	0	0	0	0	T	0	0.0001 ± 0.0003	0.013
Eteone nr *longa*	0	0	0	0.004	0	0.003	0	0	0.001	0	0.001 ± 0.001	0.127
Glycinde sp	0.020	0.005	0	0	0	0	0	0	0.050	0.070	0.015 ± 0.025	1.910
Harmothoe imbricata	0	0	0	0	0	0	0	0	0.195	0	0.020 ± 0.062	2.546
Malacocerus sp	0	0	0	0	0	0	0	0	0	0.001	0.0001 ± 0.0003	0.013
Nephtys sp	0.040	0	0.575	0.450	0.35	0.238	-	-	0.245	0.093	0.288 ± 0.189	29.03
Nephtys sp (juv.)	0.001	0.006	0.006	0.012	0	0.004	0.239	0.051	0.040	0.020	0.009 ± 0.013	1.146
Phyllodoce groenlandica	0	0.409	0.007	0	0	0	0	0.011	0	0.035	0.046 ± 0.128	5.857
Polydora caulleryi	0	0	0	0	0	0	0.004	0	0	0	0.0004 ± 0.001	0.051
Potamilla sp	0.046	0.012	0.020	0.182	0.030	0.005	0.032	0.011	0.061	0.012	0.041 ± 0.053	5.220
Spionidae, unid.	0	0	0	0	0	0	0	0	0	0.002	T	0.025
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0.1	0.01	-	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02 ± 0.03	2.55
Macoma balthica	3.58	4.89	4.16	5.19	3.82	3.94	6.64	1.70	5.01	3.92	4.3 ± 1.3	547.5

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
+0.9' Level Cont.												
Mya priapus	0	0	0	0	0	2.37	0	0	0	0	0.2 ± 0.7	25.5
Mya sp (frag.)	4.29	0	33.83	0.96	0	0	0	0	0	0	3.91 ± 10.6	497.8
Mya spp (juv.)	0.005	0.01	0.03	0.07	0.14	0.075	0.10	0.06	0.10	0.17	0.07 ± 0.06	8.9
Pseudopythina sp	0	0.01	0	0	0	0	0.03	0.02	0.02	0.06	0.014 ± 0.02	1.78
Total	8.09	5.35	38.63	6.89	4.36	6.65	7.06	1.86	6.83	4.39	9.01 ± 10.56	1147.37
-1.2' Level												
ECHIURA												
Echiurus Echiurus	0.001	0	0	0	0	0	0	0	2.05	0	0.205 ± 0.648	26.101
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	0.002	0	0	0	0	0	0	0.003	0.0005 ± 0.001	0.064
Capitella capitata	0	0	0	0	0	0	T	0	0	0	T	T
Eteone nr longa	0	0.001	0	0	0	0.006	0	0.009	0	0	0.002 ± 0.003	0.255
Glycinde sp	0.001	0	0	0	0	0.004	0.055	0	0.005	0	0.007 ± 0.017	0.891
Malacocerus sp	0	0	0	0	0	0	0	0	0	T	T	T
Nephtys caeca	0.419	-	0.506	0.682	0.178	0	0.496	0.270	0.095	0	0.356 ± 0.302	45.327
Nephtys sp (juv.)	0.012	0.910	0	0	0.005	0.011	0.006	0	0	0.001	0.004 ± 0.005	0.509
Phyllodoce groenlandica	0.015	0	0	0	0	0	0	0	0	0	0.002 ± 0.005	0.191

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
-1.2 Level Cont.												
Polydora caulleryi	0	0.001	0	0	0	0	0	0	0	0	0.0001 ± 0.0003	0.013
Potamilla sp	0	0	0	0.028	0.001	0.012	0.043	0	0	0	0.008 ± 0.015	1.019
Scoloplos armiger	0	0	0	0	0	0	0	0	0.004	0	0.0004 ± 0.001	0.051
?Spio sp	0	0	0.004	0	0	0	0	0	0	0	0.0004 ± 0.001	0.051
ARTHROPODA - Crustacea												
Tritella pilimana	0	0	0	0	0	0.005	0	0	0	0	0.0005 ± 0.002	0.064
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0.005	0.01	0	0.01	0	0.1	0.01	0.02	0.02	0.05	0.02 ± 0.03	2.55
Macoma balthica	2.55	3.54	0	4.48	1.19	2.30	3.67	5.21	1.40	2.54	2.7 ± 1.6	342.3
Mya arenaria	0.99	0	0	0	0	11.15	0.68	0	0	0	1.3 ± 3.5	163.2
M. priapus	0	0	0	0.03	0	0	0	0	0	0	0.003 ± 0.01	0.382
M. truncata	0	0	0	0	0	0	24.34	0	0	0	2.4 ± 7.7	309.9
Mya spp (juv.)	0.13	0.14	0	0.13	0.07	0.32	0.05	0.13	0.02	0.07	0.11 ± 0.09	13.5
Pseudopythina sp	0	0	0	0	0	0	0.02	0.01	0.01	0.02	0.006 ± 0.009	0.76
Total	4.12	4.60	0.51	5.36	1.44	13.91	29.37	5.65	3.60	2.68	7.12 ± 8.63	906.9

APPENDIX VIIb. BIOMASS DATA (GRAMS WHOLE WET WEIGHT) FOR CORE SAMPLES FROM GLACIER SPIT, CHINITNA BAY, 30 JULY 1977

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
					+3.6' Level							
ECHIURA												
Echiurus echiurus	0	1.52	0.65	0.01	0	0	0	0	0	0	0.22 ± 0.05	27.76
ANNELIDA												
Ampharete acutifrons	0.01	0	T	T	0	0	0	0	0.01	0	T	T
Capitella capitata	0	T	0	0	0	0	0	0	0	0	T	T
Eteone nr longa	0.014	0.007	T	0	T	0	T	0	0	0	0.002 ± 0.005	0.267
Eteone nr pacifica	0	0.008	0	0	0	0	0	0	0	0	0.001 ± 0.003	0.102
Harmothoe imbricata	0	0.17	0	0	0	0	0	0	0	0	0.017 ± 0.054	2.165
Hirudinea, unid.	0	0.015	0	0	0	0	0	0	0	0	0.002 ± 0.005	0.19
?Malacocerus sp	0	0	0	0	0	0	T	0	0	T	T	T
Nephtys sp	0	0.49	0	0.20	0.52	0.35	0	0.31	0.65	1.39	0.39 ± 0.42	49.78
Nephtys sp (juv.)	T	0	0.005	T	0	0	0.265	T	-	0.003	0.027 ± 0.084	3.48
Oligochaeta, unid.	0	0	0	0	0	0	0	0	0	T	T	T
Polydora caulleryi	0	0	T	0	0	0	0	0	T	0	T	T
Potamilla sp	0	0	0	0	0.0	0	0	T	0.002	0	0.001 ± 0.003	0.153
Scoloplos armiger	0	T	0	0	0	0	0	0	0	0.005	0.001 ± 0.002	0.064
Spio filicornis	0.004	T	T	T	0	0	T	T	0	0	0.001 ± 0.002	0.122

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
					+3.6' Level Cont.							
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii	0	0	0	0	0	0	0	3.70	0	0	0.37 ± 1.17	47.1
C. nuttallii (juv.)	0	0	0	0	0	0	0	0.18	0.01	0	0.02 ± 0.05	2.4
Macoma balthica	2.90	4.65	3.45	4.64	3.25	3.80	2.70	4.34	2.98	2.97	3.6 ± 0.70	454.6
Mya arenaria	67.95	0	0	0	78.77	0	0	54.77	9.00	0	21.0 ± 32.4	2680.2
M. priapus	0	0	0	0	7.27	0	1.94	0	0	0	0.9 ± 2.3	117.3
Mya spp (juv.)	0	0	0.19	0	0	0	0	0	0	0	0.02 ± 0.06	2.4
Mya sp (frag.)	0	0	0	0	8.11	0	2.03	0	0	0	1.0 ± 2.6	127.3
Pseudopythina sp	0	0.39	0.02	0	0	0	0.005	0.005	0	0	0.0 ± 0.12	5.3
Total	70.88	7.25	4.32	4.85	97.93	4.15	6.94	63.31	12.65	4.37	27.67 ± 35.45	3522.6
					+2.5' Level							
ECHIURA												
Echiurus echiurus	1.27	0	0.38	0	1.60	0	0.1	0.795	0	0	0.415 ± 0.600	52.776
ANNELIDA												
Capitella capitata	T	0.007	0	0	0.005	0	0	0	0	0	0.001 ± 0.003	0.166
Eteone nr longa	0.007	0.014	0.05	T	0.02	0	0	0.01	0	0	0.010 ± 0.016	1.30
Eteone nr pacifica	T	0	0	0	0	0	0	0	0	0	T	T

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m^2
+2.5' Level Cont.												
Harmothoe imbricata	0.24	0	0.34	0	0.326	0	0	0.08	0	0	0.099 ± 0.145	12.55
?Maldanidae (juv.)	0	T	0	0	T	0	0	0	0	0	T	T
Malococerus sp	0	T	0	0	0	0	0	0	0	0	T	T
Nephtys sp	0.404	0	0	0	0.394	0.84	0	0	0.84	0.14	0.26 ± 0.34	33.33
Nephtys sp (juv.)	-	0.012	0.02	0.02	T	0.02	0	T	0.014	-	0.009 ± 0.009	1.12
Phyllodoce groenlandica	0	0	0	0	0	0	0.384	0	0	0.08	0.046 ± 0.121	5.908
Polydora caulleryi	T	0	T	T	0	T	0	T	0	T	T	T
Potamilla sp	0.055	0.026	0	0.11	0	T	0.02	0	0	0	0.021 ± 0.036	2.687
Scoloplos armiger	0	0	0	0	0	T	0	T	0	0	T	T
Spio filicornis	0.018	T	0.01	0.01	0.016	T	T	0.03	0.007	T	0.009 ± 0.010	1.21
?Spionidae, unid.	0	0	0	0	T	0	0	0	0	0	T	T
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	7.79	0	0	3.32	9.83	0	7.01	2.8 ± 3.9	355.9
C. nuttallii (juv.)	0	0.005	0	0	0	0	0	0.34	0	0	0.04 ± 0.11	4.4
Macoma balthica	1.85	5.15	4.76	3.93	4.28	1.95	2.89	2.86	2.27	4.46	3.4 ± 1.2	438.0
Mya arenaria	81.07	19.35	0	68.66	0	0	8.05	13.06	0	0	19.0 ± 30.3	2421.7
M. priapus	0	9.39	0	0	0	0	0	0	0	0	0.9 ± 3.0	119.6
Mya spp. (juv.)	T	0	0	0	0	0.14	0	0	0.36	0	0.05 ± 0.12	6.4

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
						+2.5' Level Cont.						
Mya sp (frag.)	0	0	0	4.50	0	0	0	5.75	0	49.21	5.9 ± 15.3	757.1
Pseudopythina sp	0.27	0.02	0.06	0	0	0	0	0.24	0	0	0.06 ± 0.11	7.5
Total	85.18	33.97	5.62	85.02	6.64	2.95	14.76	33.00	3.49	60.90	33.16 ± 32.93	4221.7
						+0.9' Level						
ECHIURA												
Echiurus echiurus	0	1.09	0.23	0	0	0.950	0	0	1.65	0	0.314 ± 0.590	40.036
ANNELIDA												
Ampharete acutifrons	T	0	T	T	0	0	0	0	0	0	T	T
Capitella capitata	0.015	0	T	0	0	0.015	0	0	0	0	0.003 ± 0.006	0.382
Eteone nr *longa*	0	0.007	T	0.005	0	0.033	0	0	0.023	0	0.007 ± 0.012	0.866
Harmothoe imbricata	0.030	0.285	0	0.03	0	0.05	0.022	0.40	0.03	0	0.083 ± 0.141	10.530
Malacocerus sp	T	0.002	0	0	0	0	0	0	0	0	T	0.032
Nephtys sp	0.986	0.383	0.065	0.930	0	1.614	0.844	0.36	1.75	0.35	0.728 ± 0.607	92.717
Nephtys sp (juv.)	0.006	–	0	0	0	–	–	–	0	0	0.001 ± 0.002	0.076
Oligochaeta, unid.	0	0.07	0	0	0	0	0	0	0	0	0.007 ± 0.022	0.891
Phyllodoce groenlandica	0	0	0	0	0	0	0	0	0.645	T	0.072 ± 0.215	9.125
Polydora caulleryi	0	0	0.007	0	0	0	0	0	0	0	0.001 ± 0.002	0.089

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
					+0.9' Level Cont.							
Polygordius sp	T	0	0	0	0	0	0	0	0	0	T	T
Potamilla sp	0.155	0.07	0.10	0.21	0.105	0.018	0.06	0.09	0	0.002	0.081 ± 0.067	10.313
Scoloplos armiger	T	0	0	0	0	0	0	0	0	0	T	T
Spio filicornis	0.037	0.008	0.009	0.01	T	0.010	0.017	0	0.004	0.014	0.011 ± 0.011	1.389
Spionidae, unid.	0	0.008	0	0	0	0	0	0	0	0	0.001 ± 0.003	0.102
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	0	25.50	0	0	0	0	0	2.6 ± 8.1	324.6
C. nuttallii (juv.)	0.15	0	0.007	4.00	0	0	0.01	0	0.005	0	0.02 ± 0.05	3.1
Macoma balthica	4.79	4.35	1.57	2.23	3.68	2.81	4.38	4.50	0.28	3.59	3.2 ± 1.5	409.6
Mya arenaria	0	39.16	0	23.00	20.80	0	11.29	0	0	0	9.4 ± 13.9	1199.8
M. priapus	0	41.22	17.78	0	0	0	5.35	19.89	0	0	8.4 ± 10.0	1072.5
M. truncata	0	0	24.54	14.75	0	0	0	0	0	0	3.9 ± 8.6	501.1
Mya spp (juv.)	0	0	0.04	0.14	0	0.54	0	0	0	0	0.2 ± 0.3	30.8
Mya sp (frag.)	28.34	0.79	0	40.97	0.65	0	10.87	9.67	0	0	9.1 ± 14.4	1162.4
Pseudopythina sp	0	0.005	0.03	0.005	0	0.17	0.005	0.59	0.01	0	0.08 ± 0.19	10.4
Total	34.51	87.38	44.38	86.28	50.74	6.21	32.83	35.50	4.40	3.96	38.62 ± 30.39	4917.36

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m²
						-1.2' Level						
ECHIURA												
Echiurus echiurus	0.520	0	0	0	0	0	0	0	0	0	0.052 ± 0.164	6.621
ANNELIDA												
Ampharete acutifrons	0	0	0	0	0	T	0	0	T	0	T	T
Axiothella rubrocincta	0	T	0	0	0	0	0	0	0	0	T	T
Capitella capitata	0.001	0	0.001	0	0	0	0.001	0	0	-	0.0003 ± 0.0004	0.038
Eteone nr longa	0.012	0	0	0.002	0	0.01	0.009	0.001	0	0.003	0.004 ± 0.005	0.471
Harmothoe imbricata	0.003	0	0.046	0	0	0	0.507	0.008	0	0.007	0.057 ± 0.159	7.270
Malococerus sp	0	0	0	0	0	-	T	0	0	T	T	T
Nephtys sp	0.597	0.345	0.170	0.675	0	0.61	0.060	1.263	0.070	1.38	0.462 ± 0.510	58.836
Nephtys sp (juv.)	-	0.014	-	-	0	0.018	-	0	-	-	0.003 ± 0.007	0.407
Paraonalla platybranchia	0	0	0	0	0	0	T	0	0	0	T	T
Phyllodoce groenlandica	0	0.015	0	0.003	0	0	0	0	0.074	0.003	0.010 ± 0.023	1.210
Polydora ?caulleryi	0.002	T	0	0	0	T	T	0	0	0	0.0002 ± 0.001	0.045
Potamilla sp	0.104	0.196	0.012	0.053	0	0.043	0.014	0.028	0.010	0.034	0.049 ± 0.060	6.290
Scoloplos armiger	0.002	0	0	0	0	0.003	0	0	0	0	0.001 ± 0.001	0.064
Spio filicornis	0.022	0.020	0.02	T	0	0.011	0.005	0.007	0.007	0.004	0.010 ± 0.008	1.229

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m^2
-1.2' Level Cont.												
ARTHROPODA - Crustacea												
Tritella ?pilimana	T	T	0	0	0	0	0	0	0	T	T	T
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	2.10	0	0	0	0	0	0	0	0.2 ± 0.7	26.7
C. nuttallii (juv.)	0.25	0.04	0.005	0	0.44	1.20	1.15	0.005	0	0.005	0.3 ± 0.5	39.4
Macoma balthica	6.52	3.03	6.88	3.93	4.89	5.04	2.86	3.49	2.33	3.80	4.3 ± 1.5	544.5
Mya arenaria	0	0	0	0	85.56	0	0	0	0	0	8.6 ± 27.1	1089.2
M. priapus	0	0	0	25.47	0	34.08	0	0	0	23.70	8.3 ± 13.7	1059.8
M. truncata	0	0	0	0	34.58	17.47	0	0	0	0	5.2 ± 11.7	662.6
Mya spp (juv.)	0.01	0.04	1.40	0	0.81	0.25	0.43	0	0	0.19	0.3 ± 0.5	39.8
Mya sp (frag.)	2.29	0	0	0	0	0	0	0	0	0	0.2 ± 0.7	29.2
Pseudopythina sp	0	0	T	0	0	0.01	0.07	0.01	0	0.15	0.03 ± 0.05	3.2
Total	10.33	3.70	10.63	30.13	126.28	58.75	5.11	4.81	2.49	29.28	28.15 ± 38.77	3584.5

APPENDIX VIIIa. SUMMARY OF DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT GLACIER SPIT, CHINITNA BAY, 6 APRIL 77

TAXA	Number per m^2 +3.6'	+2.5'	+0.9'	-1.2'
ECHIURA				
Echiurus echiurus	12.7	101.9	12.7	25.5
ANNELIDA - Polychaeta				
Abarenicola pacifica	12.7	0	0	0
Ampharete acutifrons	0	0	25.5	25.5
Aphroditoididae, unid. (?*Peisidice*)	0	38.2	0	0
Capitella capitata	12.7	25.5	25.5	12.7
Eteone nr *longa*	38.2	50.9	38.2	25.5
Glycinde polygnatha	25.5	38.2	0	38.2
Harmothoe imbricata	12.7	12.7	12.7	0
Malacoceros sp	38.2	0	12.7	12.7
Nephtys sp	63.7	89.1	165.5	127.3
Nephtys sp (juv)	89.1	140.1	211.7	267.4
Paraonidae, unid.	12.7	0	0	0
Phyllodoce groenlandica	25.5	0	25.5	12.7
Polydora caulleryi	0	25.5	25.5	12.7
Potamilla sp	63.7	76.4	318.3	38.2
Scoloplos armiger	0	0	0	12.7
?*Spio filicornis*	0	0	0	38.2
MOLLUSCA - Pelecypoda				
Clinocardium nuttallii	63.7	50.9	432.9	345.8
Macoma balthica	4647.3	4443.6	5347.6	4252.6
Macoma sp	0	0	0	12.7
Mya arenaria	89.1	63.6	0	38.2
M. priapus	0	25.5	12.7	12.7
M. truncata	0	0	0	12.7
Mya spp. (juv)	152.8	127.3	1120.5	1515.2
Pseudopythina sp	89.1	203.7	229.2	56.6
ARTHROPODA - Crustacea				
Saduria entomon	0	12.7	0	0
Tritella pilimana	0	0	0	12.7

APPENDIX VIIIb. SUMMARY OF DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT GLACIER SPIT, CHINITNA BAY, 30 JULY 77

	Number per m^2			
TAXA	+3.6'	+2.5'	+1.9'	-1.2'
ECHIURA				
Echiurus echiurus	25.5	63.8	63.8	12.7
NEMERTEA, unid	0	0	0	25.5
ANNELIDA - Oligochaeta, unid.	12.7	0	12.7	0
ANNELIDA - Polychaeta				
Ampharete acutifrons	51.0	0	38.3	25.5
Axiothella rubrocincta	0	0	0	12.7
Capitella capitata	12.7	191.3	165.8	76.5
Eteone nr *longa*	63.8	178.6	127.6	114.8
E. nr *pacifica*	12.7	25.5	0	0
Harmothoe imbricata	12.7	50.9	127.6	63.8
Malacoceros sp	25.5	38.3	38.3	51.0
Maldanidae, unid.	0	12.7	0	0
Nephtys sp	140.1	140.3	153.1	140.3
Nephtys sp (juv.)	102.0	255.1	76.5	318.9
Paraonella platybranchia	0	0	0	25.5
Phyllodoce groenlandica	0	25.5	25.5	63.8
Polydora caulleryi	25.5	127.5	12.7	50.9
Polygordius sp	0	0	12.7	0
Potamilla sp	12.7	153.1	459.2	382.0
Scoloplos armiger	25.5	25.5	25.5	25.5
Spio filicornis	127.6	484.7	560.2	650.5
Spionidae, unid.	0	12.7	0	0
ARTHROPODA				
Acarina, unid.	0	0	12.7	12.7
Crangon sp	12.7	12.7	0	0
Harpacticoidea, unid.	0	25.5	0	0
Ischyroceridae, unid.	0	50.9	0	0
Pontoporeia femorata	0	12.7	12.7	12.7
Tritella ?*pilimana*	25.5	267.9	331.6	127.6

TAXA	Number per m^2 +3.6'	+2.5'	+0.9'	-1.2'
MOLLUSCA				
Aglaja diomedea	0	0	0	12.7
Clinocardium nuttallii (adult)	12.7	50.9	12.7	12.7
C. nuttallii (juv)	25.5	25.5	152.8	165.5
Cylichna sp	0	0	12.7	0
Macoma balthica	2253.6	2470.1	2610.3	3285.0
Mya arenaria	63.8	63.8	50.9	12.7
M. priapus	25.5	12.7	76.4	63.8
M. truncatus	0	0	38.2	25.5
Mya spp (juv)	12.7	50.9	76.4	127.3
Pseudopythina sp	89.1	114.6	216.5	140.1

APPENDIX IX. SUMMARY OF BIOMASS DISTRIBUTION AMONG ORGANISMS AND LEVELS AT GLACIER SPIT, CHINITNA BAY IN 1977

Grams wet weight per m^2

	6 April				30 July			
TAXA	+3.6'	+2.5'	+0.9'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'
ECHIURA	(0.1%)	(1.6%)	(1.2%)	(2.9%)	(0.8%)	(1.3%)	(0.8%)	(0.1%)
Echiurus echiurus	4.84	46.35	14.01	26.10	27.76	52.78	40.04	6.62
ANNELIDA - Polychaeta	(0.1%)	(1.2%)	(4.0%)	(5.3%)	(1.6%)	(1.4%)	(2.5%)	(2.1%)
Ampharete acutifrons	0	0	0.13	0.06	T	0	T	T
Capitella capitata	0.13	T	0.01	T	T	0.17	0.38	0.04
Eteone nr *longa*	1.15	0.64	0.13	0.26	0.27	1.30	0.87	0.47
Glycinde polygnatha	0.64	1.40	1.91	0.89	0	0	0	
Harmothoe imbricata	0.13	0.38	2.55	0	2.17	12.55	10.53	7.27
Malacoceros sp	T	0	0.01	T	T	T	0.03	T
Nephtys sp	2.17	32.34	29.03	45.33	49.78	33.33	92.72	58.84
Nephtys sp. (juv)	0.26	0.89	1.15	0.51	3.48	1.12	0.08	0.41
Phyllodoce groenlandica	0.26	0	5.86	0.19	0	5.91	9.13	1.21
Polydora caulleryi	0	0.06	0.05	0.01	T	T	0.09	0.05
Potamilla sp	0.76	1.53	5.22	1.02	0.15	2.69	10.31	6.29
Scoloplos armiger	0	0	0	0.05	0.06	T	T	0.06
?*Spio filicornis*	0	0	0	0.05	0.12	1.21	1.39	1.23
ARTHROPODA - Crustacea	(0)	(T)	(0)	(T)	(T)	(T)	(T)	(T)
Pontoporeia femorata	0	0	0	0	0	0	T	T
Tritella ?*pilimana*	0	0	0	0.06	T	T	T	T
MOLLUSCA - Pelecypoda	(99.6%)	(96.6%)	(94.5%)	(91.8%)	(97.6%)	(97.4%)	(95.8%)	(97.5%)
Clinocardium nuttallii (adult)	0	0	0	0	47.1	355.9	324.6	26.7
C. nuttallii (juv)	0.51	0.51	2.55	2.55	2.4	4.4	3.1	39.4
Macoma balthica	547.5	534.7	547.5	382.0	454.6	438.0	409.6	544.5

TAXA	6 April +3.6'	6 April +2,5'	6 April +0.9'	6 April -1.2'	30 July +3.6'	30 July +2.5'	30 July +0.9'	30 July -1.2'
	Grams wet weight per m^2							
Mya arenaria	3565.1	2164.5	0	178.3	2680.2	2421.7	1199.8	1089.2
M. priapus	0	165.5	25.5	0.38	117.3	119.6	1072.5	1059.8
M. truncatus	0	0	0	343.8	0	0	501.1	662.6
Mya spp. (juv.)	1.02	8.91	8.9	14.01	2.4	6.4	30.8	39.8
Mya spp. (frags)	38.2	10.19	497.8	0	127.3	757.1	1162.4	29.2
Pseudopythina sp	0.76	4.33	1.78	0.89	5.3	7.5	10.4	3.2

APPENDIX Xa. SHELL LENGTH (MM) DATA FOR MACOMA BALTHICA FROM GLACIER SPIT, CHINITNA BAY ON 6 APRIL 1977

	Frequency				Overall	
Size Class	+3.6'	+2.5'	+0.9'	-1.2'	f	%
0.0 - 0.9			1		1	0.07
1.0 - 1.9	3	2	1	1	7	0.5
2.0 - 2.9	60	34	44	19	157	11.2
3.0 - 3.9	66	52	97	57	272	19.4
4.0 - 4.9	43	32	73	64	212	15.1
5.0 - 5.9	13	6	28	47	94	6.7
6.0 - 6.9	11	7	11	10	39	2.8
7.0 - 7.9	4	4	5	6	19	1.4
8.0 - 8.9	10	9	11	3	33	2.4
9.0 - 9.9	21	21	9	9	60	4.3
10.0 - 10.9	33	53	35	27	148	10.6
11.0 - 11.9	25	36	42	29	132	9.4
12.0 - 12.9	34	30	17	18	99	7.1
13.0 - 13.9	24	14	30	13	81	5.8
14.0 - 14.9	9	9	10	1	29	2.1
15.0 - 15.9	3	4	3		10	0.7
16.0 - 16.9	3	2	1		6	0.4
17.0 - 17.9			1		1	0.07
n	362	315	419	304	1400	
$\bar{x}$	7.31	8.10	6.96	6.74	7.26	
s	4.23	4.09	4.03	3.51	4.02	

APPENDIX Xb. SHELL LENGTH (MM) DATA FOR <u>MACOMA BALTHICA</u> FROM GLACIER SPIT, CHINITNA BAY ON 30 JULY 1977

	Frequency				Overall	
Size Class	+3.6'	+2.5'	+0.9'	-1.2'	f	%
2.0 - 2.9	2	4	5	4	15	1.9
3.0 - 3.9	2	8	7	6	23	2.9
4.0 - 4.9	2	4	5	3	14	1.8
5.0 - 5.9	7	11	10	3	31	3.9
6.0 - 6.9	10	20	18	12	60	7.5
7.0 - 7.9	27	18	43	25	113	14.2
8.0 - 8.9	19	12	22	56	109	13.7
9.0 - 9.9	12	6	11	42	71	8.9
10.0 - 10.9	6	15	7	9	37	4.7
11.0 - 11.9	19	32	19	16	86	10.8
12.0 - 12.9	22	29	20	24	95	11.9
13.0 - 13.9	22	17	12	22	73	9.2
14.0 - 14.9	11	9	12	11	43	5.4
15.0 - 15.9	5	3	8	4	20	2.5
16.0 - 16.9	3			1	4	0.5
17.0 - 17.9		1			1	0.1
n	169	189	199	238	795	
$\bar{x}$	9.28	8.92	9.33	9.73	9.76	
s	3.19	3.37	3.25	2.83	3.16	

APPENDIX Xc. SHELL LENGTH (MM) DATA FOR <u>MYA</u> SPP. (JUVENILES) FROM GLACIER SPIT, CHINITNA BAY

6 April 1977							30 July 1977			
+3.6'	+2.5'	+0.9'	+0.9'	-1.2'	-1.2'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'
2.6	3.9	2.2	2.5	6.4	3.4	3.8	13.8	3.8	9.0	5.0
5.1	3.3	4.1	5.4	5.2	3.8	1.9		2.9	11.4	9.9
4.3	4.0	3.2	5.0	6.0	3.3	2.0		11.6	18.1	22.9
3.2	3.6	4.6	3.6	4.2	2.6	3.5		18.2		24.1
2.5	4.9	4.5	4.0	5.2	4.3	3.5				15.3
3.9	3.7	3.8	5.3	3.9	6.4	4.9				6.6
4.1	3.1	3.6	3.2	4.4	5.9	2.2				15.7
4.3	3.1	3.7	4.0	3.7	6.5	4.7				6.8
3.5	2.4	3.8	3.8	5.1	4.0	3.3				4.6
3.6		3.3	2.5	4.7	5.8	3.1				14.3
3.4		3.5	2.7	3.0	5.7	4.3				
3.8		4.0	4.3	3.9	5.2	4.6				
		3.4	6.0	2.2	4.3	4.5				
		4.9	4.3	5.4	5.6	3.0				
		5.2	5.4	3.9	5.7	3.9				
		2.5	4.5	4.7	4.9	4.4				
		5.5	3.9	5.8	4.8	4.8				
		4.9	5.0	5.8	4.3	4.6				
		2.3	4.3	5.7	4.9	5.0				
		4.5	3.4	4.4	5.2	5.9				
		6.2	4.1	6.0	5.6	2.5				
		3.5	4.0	3.4	5.0	3.5				
		2.4	5.0	3.6	4.5	5.0				
		6.2	4.2	4.8	5.0	3.2				
		4.2	4.6	3.2	3.4	4.1				
		5.4	4.1	5.2	4.1	3.6				
		3.6	3.6	4.1	3.6	2.5				
		4.0	3.9	5.2	4.7	5.7				
		3.4	3.8	5.7	3.9	4.6				
		4.5	3.6	4.3	3.6	3.9				
		3.0	4.0	4.5	2.2	19.3				
		5.8	4.8	3.3	4.3					
		5.6	3.3	4.0	5.0					
		3.5	3.9	4.4	3.8					
		4.8	3.7	4.6	5.0					
		4.1	4.7	3.6	3.3					
		3.7	4.0	4.3	4.5					
		3.2	4.0	4.0	6.2					
		5.3								
		3.2								
		2.5								
		4.7								
		5.1								
		2.4								
		4.3								
		3.8								
		4.8								
		2.7								
		3.9								
		4.7								

6 April 1977: $\bar{x} = 4.17$, $s = 0.99$, $n = 215$

30 July 1977: $\bar{x} = 11.89$, $s = 6.41$, $n = 18$

APPENDIX Xd. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR *MYA ARENARIA* AT GLACIER SPIT, CHINITNA BAY

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
6 April 1977											
90.5	55.00	21.31	56.9	9.86	4.19	-	-	-	27.0	0.99	0.51
93.3	62.84	25.54	-	39.20	14.23				-	11.15	5.66
58.7	12.25	6.02	49.3	7.17	3.63				24.3	0.68	0.35
56.6	11.86	5.97	97.7	51.61	20.41						
91.3	52.77	19.56									
97.8	71.07	25.43									
60.4	14.22	6.50									

Average shell length ($\bar{x} \pm s$) = 67.0 ± 26.6
Wet tissue weight: whole wet weight ratio = 0.40

30 July 1977											
107.2	67.95	25.81	60.5	13.06	5.87	64.0	20.80	9.83	100.8	85.56	32.41
59.6	9.0	6.78	-	19.35	6.15	80.0	39.16	17.99			
88.8	54.77	21.61	47.9	8.05	4.00	56.9	23.00	6.82			
-	60.60	23.73	95.7	81.07	27.80	57.0	11.29	5.08			
65.8	18.17	9.91	-	68.66	28.0						

Average shell length ($\bar{x} \pm s$) = 73.7 ± 19.9
Wet Tissue weight:whole wet weight ratio = 0.40

APPENDIX Xe. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR *MYA PRIAPUS* AT GLACIER SPIT, CHINITNA BAY

6 April 1977

+3.6' Shell Length (mm)	+3.6' Whole Wet Weight (g)	+3.6' Wet Tissue Weight (g)	+2.5' Shell Length (mm)	+2.5' Whole Wet Weight (g)	+2.5' Wet Tissue Weight (g)	+0.9' Shell Length (mm)	+0.9' Whole Wet Weight (g)	+0.9' Wet Tissue Weight (g)	-1.2' Shell Length (mm)	-1.2' Whole Wet Weight (g)	-1.2' Wet Tissue Weight (g)
-	-	-	-	7.05	2.85	31.2	2.37	1.07	7.3	0.03	-
			42.2	6.10	2.69						

Average shell length ($\bar{x} \pm s$) = 26.9 ± 17.8
Wet tissue weight:whole wet weight ratio = 0.43

30 July 1977

+3.6' Shell Length (mm)	+3.6' Whole Wet Weight (g)	+3.6' Wet Tissue Weight (g)	+2.5' Shell Length (mm)	+2.5' Whole Wet Weight (g)	+2.5' Wet Tissue Weight (g)	+0.9' Shell Length (mm)	+0.9' Whole Wet Weight (g)	+0.9' Wet Tissue Weight (g)	-1.2' Shell Length (mm)	-1.2' Whole Wet Weight (g)	-1.2' Wet Tissue Weight (g)
22.1	1.94	0.91	46.0	9.39	3.66	62.8	19.89	11.41	59.1	23.70	9.16
42.3	7.27	3.44				-	23.44	7.44	60.4	24.38	9.92
						53.9	17.77	7.42	25.0	1.09	0.57
						54.8	17.78	7.65	61.3	19.48	8.12
						35.7	3.91	1.64	53.9	14.60	5.36
						27.5	1.44	0.71			

Average shell length ($\bar{x} \pm s$) = 46.5 ± 14.6
Wet tissue weight:whole wet weight ratio = 0.42

APPENDIX Xf. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR <u>MYA TRUNCATA</u> AT GLACIER SPIT, CHINITNA BAY

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
6 April 1977											
-	-	-	19.6	0.60	-	-	-	-	63.3	24.34	8.57
30 July 1977											
-	-	-	-	-	-	-	14.75	8.16	-	17.47	13.70
						-	13.87	7.82	54.6	34.58	16.39
						-	10.74	4.91			

Wet tissue weight:whole wet weight ratio = 0.44

APPENDIX Xg. SHELL LENGTH (MM) DATA FOR *CLINOCARDIUM NUTTALLII* FROM GLACIER SPIT, CHINITNA BAY

6 April 1977				30 July 1977					Frequency	
+3.6'	+2.5'	+0.9'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'	Size Class	4/6/77	7/30/77
2.0	1.6	9.2	1.9	9.6	1.8	8.7	9.6	1-3	62	16
1.5	2.1	2.5	2.6	2.3	11.5	2.3	3.4	4-6	0	2
2.0	2.4	10.8	2.1	27.1	39.9	2.3	7.4	7-9	1	4
1.9	2.8	2.0	2.0		27.9	5.8	3.4	10-12	1	5
1.7		2.1	2.1		31.3	1.6	2.2	13-15	0	1
		1.8	2.2		33.6	2.2	11.8	16-18	0	0
		1.9	1.9			4.0	12.6	19-21	0	0
		2.0	1.9			2.1	12.7	22-24	0	0
		2.0	2.0			1.9	14.0	25-27	0	2
		2.0	1.5			2.2	10.9	28-30	0	0
		1.8	1.6			2.0	1.9	31-33	0	2
		2.0	2.2			2.0	2.3	34-36	0	0
		1.8	2.2			47.2		37-39	0	1
		1.6	2.4					40-42	0	0
		1.8	1.8					43-45	0	0
		1.9	2.2					46-48	0	1
		1.8	2.5							
		2.2	1.8							
		2.3	3.0							
		2.1	2.2							
		1.8	2.4							
		1.6	2.5							
		2.0	1.9							
		1.9	1.9							
		1.7								
		2.2								
		2.1								
		1.8								
		1.7								
		2.4								
		2.3								

	6 April 1977	30 July 1977
$\bar{x}$	2.25	10.63
s	1.46	12.25
n	64	34

APPENDIX Xh. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR <u>CLINOCARDIUM NUTTALLII</u> AT GLACIER SPIT, CHINITNA BAY

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
6 April 1977											
2.0	0.005	-	1.6	0.002	-	9.2	0.1	-	1.9	0.004	-
			2.1	0.01	-				1.9	0.004	-
			2.4	0.01	-						
			2.8	0.01	-						
30 July 1977											
9.6	0.18	-	1.8	0.005	-	8.7	0.15	-	2.2	0.005	-
2.3	0.01	-	11.5	0.34	-	2.0	0.005	-	11.8	0.44	-
27.1	3.70	0.96	39.9	9.83	3.0	47.2	25.50	9.73	1.9	0.005	-
			27.9	3.32	1.30				2.3	0.005	-
			31.3	7.01	2.23				-	2.10	-
			33.6	7.79	2.49						

Wet tissue weight:whole wet weight ratio = 0.34

APPENDIX Xi. SHELL LENGTH (MM) DATA FOR <u>PSEUDOPYTHINA</u> SP. FROM GLACIER SPIT, CHINITNA BAY

6 April 1977						30 July 1977					
+3.6'	+2.5'	+0.9'	-1.2'	Size Class	Number	+3.6'	+2.5'	+0.9'	-1.2'	Size Class	Number
1.5	3.6	1.9	3.8	1.0-1.9	8	12.9	11.9	2.5	3.3	1.0-1.9	0
1.7	1.9	2.1	4.9	2.0-2.9	16	11.2	2.7	2.3	3.5	2.0-2.9	11
2.5	3.4	2.1	2.0	3.0-3.9	13	2.7	3.0	4.2	3.8	3.0-3.9	12
2.4	4.7	2.0	3.3	4.0-4.9	10	4.4	4.3	3.3	4.4	4.0-4.9	10
4.1	3.7	2.9	4.0	5.0-5.9	0	2.9	4.2	2.4	4.6	5.0-5.9	1
3.5	4.2	3.4		6.0-6.9	0	2.9	6.1	4.3	3.9	6.0-6.9	2
3.4	2.6	2.7		7.0-7.9	0	3.3	3.6	4.0	5.4	7.0-7.9	0
2.9	3.7	4.7		8.0-8.9	0		11.7	4.0	3.7	8.0-8.9	1
1.8	2.4	3.8		9.0-9.9	0		6.7	3.8	2.0	9.0-9.9	1
	2.7	3.0		10.0-10.9	0			9.2	10.0	10.0-10.9	1
	11.9	1.7		11.0-11.9	1			4.5	2.1	11.0-11.9	3
	1.8	2.0		12.0-12.9	0			2.1		12.0-12.9	1
	4.1	2.0		13.0-13.9	0			3.1		13.0-13.9	0
	4.2	2.8		14.0-14.9	0			16.2		14.0-14.9	0
	2.2	4.3						2.0		15.0-15.9	0
	1.6	3.4						3.7		16.0-16.9	1
		3.2						8.9			
		4.4									

	6 April 1977	30 July 1977
$\bar{x}$	3.18	5.04
s	1.60	3.37
n	48	44

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Alaska Office
Federal Bldg., U.S. Courthouse, Room A13
222 W. Eighth Ave., #56
Anchorage, Alaska 99513-7543

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FOURTH-CLASS MAIL
POSTAGE AND FEES PAID
U.S. Department of Commerce
Permit Number G-19

SPECIAL FOURTH CLASS

CLASS OF POSTAL SERVICE

UNIV OF ALASKA/INFO SERVICES
ARCTIC ENV INFO AND DATA CTR
707 A STREET
ANCHORAGE, AK 99501