

Section 4

INVERTEBRATES

by

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Section 4

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4.1 SUMMARY

1. Zooplankton biomass on the NAS during 1984 and 1985 was extremely low compared with that of offshore Bering Sea shelf waters, other arctic waters and other marine waters in general. Other Bristol Bay nearshore waters are, like the NAS, typically low in biomass.
2. Sample results show that biomass and composition of zooplankton varied among seasons; important points are as follows:
 - (a) Total biomass was highest in July samples, but may have actually been highest in June (when no samples were taken). The biomass peak on the NAS (June?/July) and other inshore areas (July/August) was later than that on the outer shelf (May) or middle shelf (early June). Biomass on the NAS was lowest in September, probably as a result of jellyfish predation.
 - (b) Chaetognaths were the dominant **taxon** in winter, but decreased in abundance through spring and summer. **Copepods** generally increased in abundance from a January low to a late spring (May) high, sometimes remaining abundant into late summer. Abundance of euphausiids showed no clear seasonal trend. Decapod larvae and fish larvae both increased in absolute biomass from a January low to a July high.
 - (c) Carnivorous zooplankton were dominant in *winter*; the abundance of herbivores began increasing in April with onset of the spring bloom, and generally increased through July.
 - (d) Timing of life cycles of Calanus marshallae (a middle shelf copepod) and of Neocalanus plumchrus (an outer shelf copepod) on the NAS

was similar to timing of their life cycles elsewhere.

3. The spatial distribution and composition of the plankton was strongly influenced by the distribution of water masses. Distributions of **copepod** and euphausiid species, and in some cases their biomasses, were strongly affected by intrusions of middle shelf water into the NAS study area. Intrusions of mid-shelf water were marked by the presence of middle shelf copepods, high biomasses of euphausiids, and, in some cases, high total biomasses.
4. Large schyphozoan jellyfish were the most **conspicuous** zooplankters present in the study area. Their biomass was higher than that of the rest of the plankton combined. Biomass of jellyfish was highest in September; predation by jellyfish may have been one factor responsible for the generally low biomass of other zooplankton in late summer and early fall.
5. Benthic infaunal biomass was very low at depths of less than 10 m. This is typical of northern shorelines exposed to ice scour and heavy wave action. Biomasses of **infauna** at depths of **20-50 m** were typical of those found in deeper parts of the Bering Sea shelf. Beyond 20 m, bivalves and echinoderms were found in approximately equal proportions and together accounted for **88%** of the total biomass. **Polychaetes** were the dominant group in terms of numbers.
6. Total infaunal biomass was highest in the western portion of the study area. Biomass was relatively high between Cape Mordvinof and Moffet Lagoon, low between Moffet Lagoon and Nelson Lagoon, and high off Port Moller. Biomass distributions of bivalves and **echinoderms** followed the same pattern; polychaetes were more uniformly distributed.
7. Surface deposit-feeding was the dominant mode of feeding of infaunal animals. This is typical of other northern areas.
8. Starfish, mysids, crangonid shrimp, and amphipods were the dominant epibenthic animals; shrimp and mysids were the dominant epibenthic animals inside the 10-m depth contour.

This and other studies show that crab populations have declined drastically in the past several years. Distributional patterns of various epifaunal groups were as follows:

- (a) Starfish were most abundant beyond the 20-m depth contour.
- (b) Crangonids were most abundant at depths of 3-10 m and off Port Moller and Cape Seniavin.
- (c) Mysids were most abundant at depths of 3-10 m and 50 m. At 3-10 m, they were abundant off Port Moller and Cape Seniavin and on Transect 5.
- (d) More amphipods were taken by the grab than by any other method, indicating that they were in or on the sediment rather than above it. They were most abundant at water depths of 10-50 m.

4.2 INTRODUCTION

Invertebrates on which this study focused are those that are important because (1) they are of commercial or subsistence value to man, and/or (2) they are major food web components of vertebrates or invertebrates important to man. Those commercially important species for which the NAS study area provides important habitat have been identified mainly from existing literature. Those that are important food web components have been identified from the literature and from current findings of this study.

4.3 CURRENT STATE OF KNOWLEDGE

4.3 .1 Substrates

Substrate (sediment) characteristics are important measures of invertebrate habitat quality. Cimberg et al. (1984), on the basis of 38 substrate samples at depths of 10 to 60 m within the NAS study area, characterized the sediments in most localities as being composed of well-sorted sands (Fig. 4.1). Gravel comprised a significant fraction of the

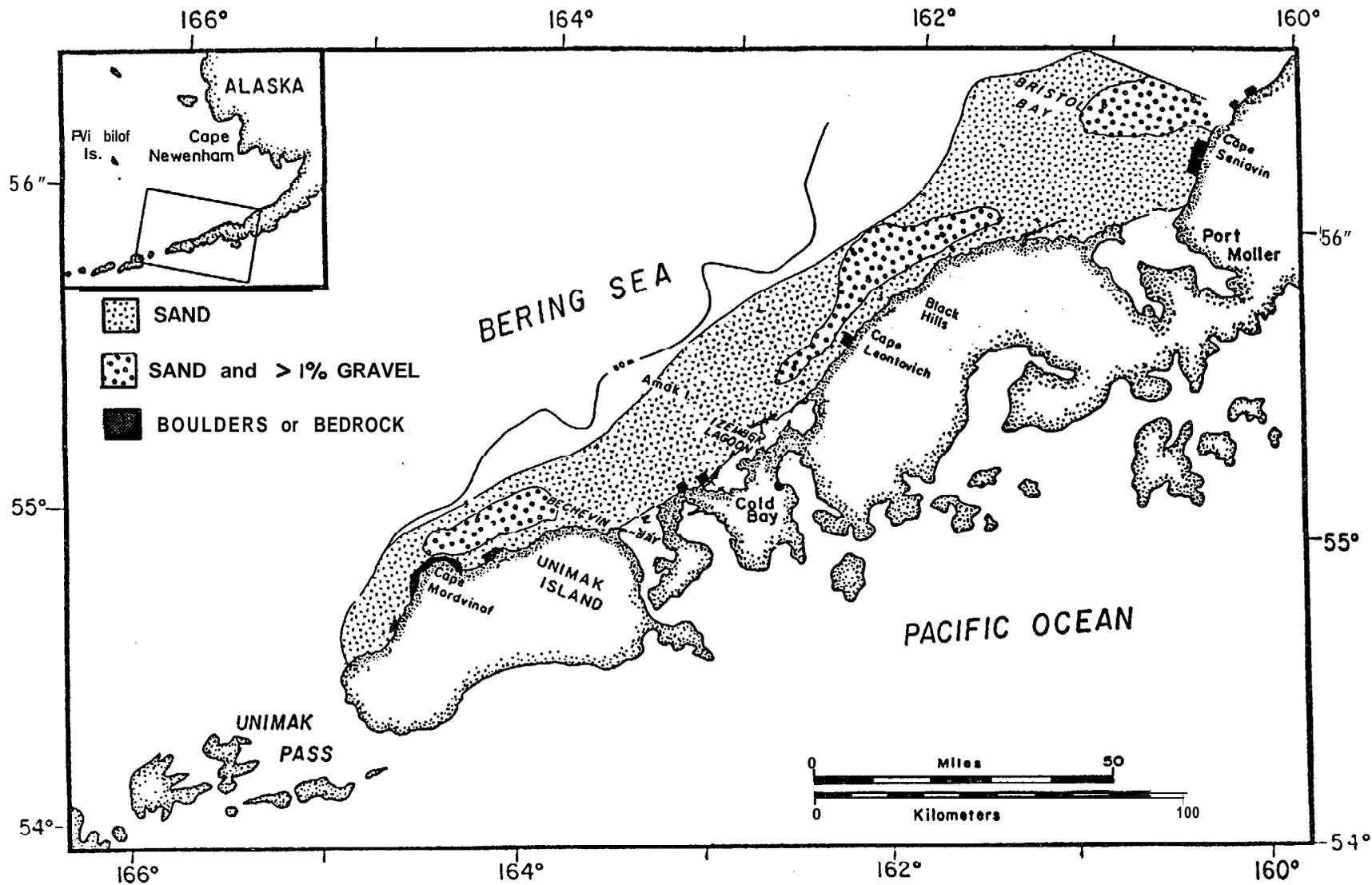


Fig. 4.1 General distribution of benthic substrate types on the North Aleutian Shelf (After Cimberg et al. 1984, Sears and Zimmerman 1977)

substrate at depths of 21 to 40 m off Unimak Island (19.2%), Black Hills (64.8%), and Cape Seniavin (11.1%). Silt comprised 7% or less of the sediments in 95% of the samples.

Shorelines are mainly sand. Boulders and bedrock are found in the vicinity of Cape Mordvinof and Cape Seniavin but in few other locations (Sears and Zimmerman 1977) (Fig. 4.1).

4.3.2 Species Important to Man

Three species have been identified that are important to man and that make significant use of the NAS study area. The red king crab (*Paralithodes camtschatica*) is undoubtedly the most important of these; it has great commercial value and its Bering Sea population is highly dependent on the shallow nearshore zone (Armstrong et al. 1983). The Tanner crab (*Chionoecetes bairdi*) is also commercially significant to the Bering Sea fishery, but its populations are less dependent on nearshore habitats (Otto 1981). Extensive concentrations of the Alaska surf clam (*Spisula polynyma*) have recently been found near the north coast of the Alaska Peninsula; these seem to have potential as a harvestable resource (Hughes and Bourne 1981). Few other invertebrate species that are currently useful to humans make appreciable use of the nearshore zone.

4.3.2.1 Red King Crab

The red king crab is **widely** distributed in the North Pacific Ocean and the Bering Sea (Armstrong et al. 1983). A major fishery is centered in the southeastern Bering Sea; over 10% of the world's red **king** crab catch in 1976 and 1977 came from this area (Otto 1981). The vast majority of red king *crabs* in the Bering Sea are found in outer Bristol Bay and the area immediately north of the Alaska Peninsula (Fig. 4.2).

Red king crabs in the Bering Sea are distributed somewhat in accord with sex and life-history stage. In summer, female and small male crabs are generally found **closer to shore than are the large** males (Fig. 4.3). During late winter and early spring, adult males apparently migrate closer to shore to join females for breeding (McMurray et al. 1984).

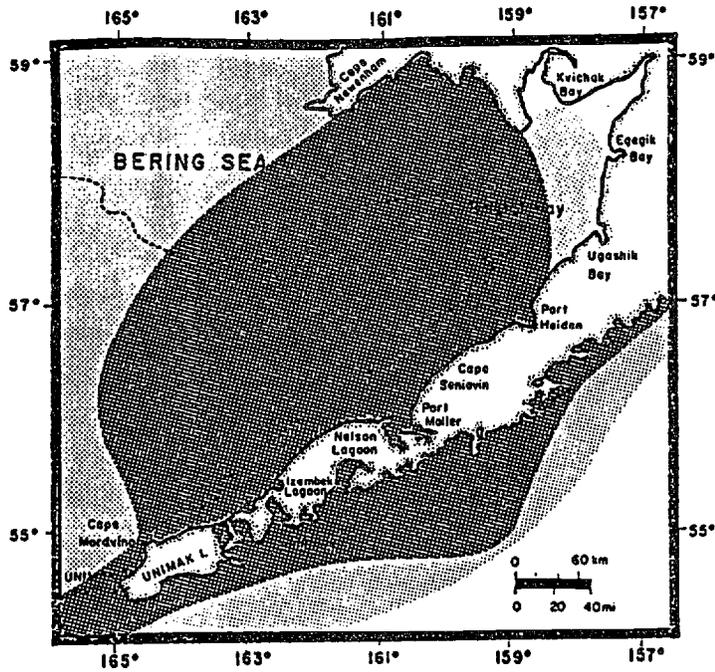


Figure 4.2. Distribution of **red** king crab in the southeastern Bering Sea. Darkly shaded portions indicate areas of consistent abundance (From Otto 1981).

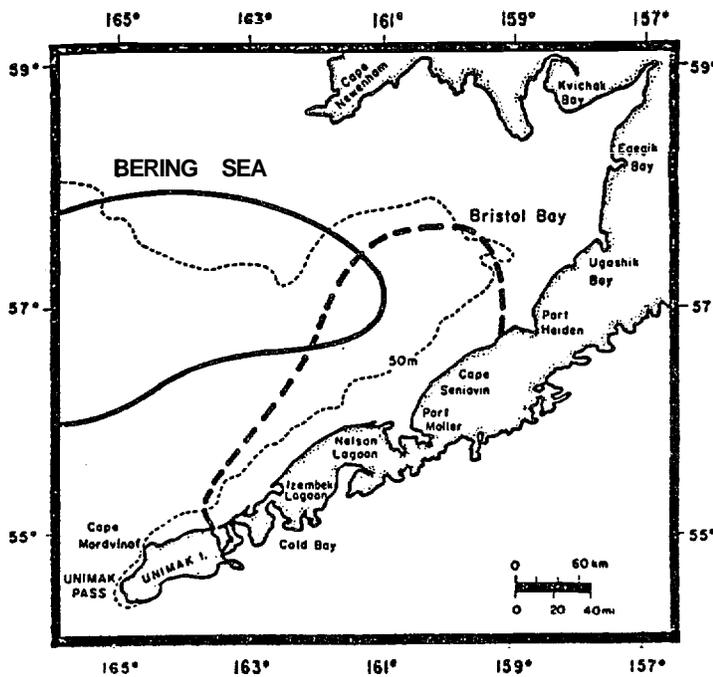


Figure 4.3 . Centers of abundance of large (>134 mm carapace length) male red king crabs (solid line) and of Female red king crabs (dotted line) in the southeastern Bering Sea, May-July 1980 (after Otto 1980).

Eggs carried from the previous year hatch about 1-20 April in this nearshore region, and the larvae drift with currents until July or August before settling to assume a benthic life mode (Armstrong et al. 1983, McMurray et al. 1984). Thus, although the majority of mating (and presumably the hatch as well) normally occurs between Unimak Island and Port Heiden (Fig. 4.3), the greatest abundance of juveniles is normally from Port Heiden to Kvichak Bay in eastern Bristol Bay, northeastward from the point of hatch, in the direction of the prevailing transport (Fig. 4.4). Very few juvenile crabs are found southwest of Port Moller.

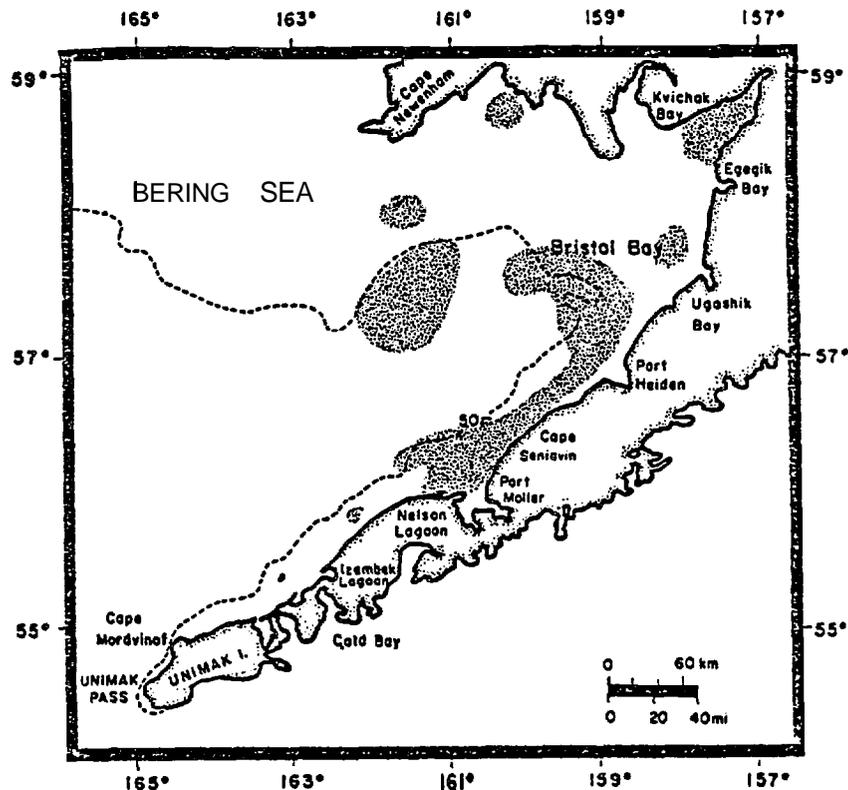


Figure 4.4. General distribution of juvenile red king crabs (age 3 and younger) in the southeastern Bering Sea as determined by sampling in April-May, June, and September, 1983 (adapted from McMurray et al. 1984).

Adult king crabs in the southeastern Bering Sea consume polychaete worms, sand dollars, gastropods, bivalves, echinoderms and other benthic invertebrates. Early post-larval crabs have been observed to feed on hydroids, copepods, ostracods, diatoms, and detritus (Feder and Jewett 1981). Crab larvae presumably feed on zooplankton.

Predators on adult king crabs include halibut, sea otters, and man. **Sculpins** (and presumably other benthic fishes) eat juvenile crabs (**Feder and Jewett 1981**), and larval crabs are probably consumed by pelagic fishes and invertebrates.

Physical habitat factors appear to strongly influence the distribution and abundance of populations of the various life stages of crabs. Water temperature in spring and summer may affect the distributional patterns of adults (**Armstrong et al. 1983**); females are generally found in warmer waters than are males. It has been postulated that the growth rates and survival of larval crabs are **temperature-dependent** (**Armstrong et al. 1983, McMurray et al. 1984**). Juvenile crab distribution on the NAS is strongly associated with substrate type--juveniles are usually found where the bottom is composed of gravel or coarser materials (**McMurray et al. 1984**).

Armstrong et al. (1983) and **McMurray et al. (1984)** have speculated that the sizes of red king crab populations are determined largely by the production of eggs and the subsequent survival of the crabs during their larval and early post-larval stages. The number of eggs produced may be relatively unimportant, but the survival of larvae and young may be more critical. Larval survival probably is strongly temperature-dependent: the higher the water temperature, the greater the rate of survival. Juvenile survival rates seem strongly related also to the availability of protective "refuge" substrates (shell, cobble, invertebrate aggregates) (**McMurray et al. 1984**). This suggests that the precipitous decline in catches by the fishery from **1966** to **1970** (**Otto 1981**) was probably not caused by fishing pressure.

4.3.2.2 Other Species

Other NAS species of actual or potential direct interest to man include Tanner crab (**Chionoectes bairdi**) and the Alaska surf clam (**Spisula polynyma**). The other species of Tanner crab abundant in the Bering Sea (**C. opilio**) occurs in relatively low numbers in the NAS study area, and will not be addressed here.

Chionoectes bairdi is widely distributed in the southern Bering Sea and the northern Gulf of Alaska; its juvenile and adult stages are most

abundant along the outer shelf from west of the Pribilof Islands to Unimak Island, and along the NAS between Unimak Island and Cape Seniavin (Otto 1981) (Fig. 4.5). Tanner crab larvae hatch about mid-April and disperse throughout the southeastern Bering Sea (Armstrong et al. 1984). High larval abundances occur over the outer and middle shelf areas in depths less than 150 m; larvae are also abundant near the Alaska Peninsula (Armstrong et al. 1983). Unlike red king crabs, neither larval abundance nor crab age-class strengths of Tanner crabs vary dramatically from year to year.

Adult Tanner crabs in the southeastern Bering Sea feed mainly on polychaetes, and young crabs feed on crustaceans, polychaetes, and molluscs, in decreasing order of importance (Feder and Jewett 1981, quoting Tarverdieva 1976). Tanner crabs are, in turn, fed upon by king crabs, several species of benthic and demersal fishes, and walrus; in the NAS they are also the target of a commercial fishery (Feder and Jewett 1981). Chionoecetes bairdi appear to distribute themselves in areas that are relatively warm in summer--the outer shelf (100-200 m depths) and the North Aleutian Shelf--and to avoid cold areas (e.g., the northern Bering Sea and most of the middle shelf environment) (Armstrong et al. 1983). In addition to cold water temperatures limiting crab distribution, fishing efforts by domestic and foreign fleets since 1975 may have caused a drastic decline in Tanner crab abundance in the eastern Bering Sea (Otto 1981).

In 1977, an exploratory survey in the southeastern Bering Sea revealed extensive concentrations of Alaska surf clams along the north coast of the Alaska Peninsula (Hughes and Bourne 1981). Preliminary investigations (Fig. 4.6) suggest that these clam populations have the potential to support a viable fishery. The greatest concentrations are apparently located between Port Moller and Ugashik Bay, and at depths of 30-32 m (Hughes and Bourne 1981). Surf clams are primarily suspension feeders, consuming a variety of small plankton and detritus from the water column; in turn, they are probably eaten by crabs, sea stars, fishes and walrus (Feder and Jewett 1981). It has been speculated that unfavorably low salinities and excessive depths may limit surf clam abundance in other areas of the southeastern Bering Sea (Hughes and Bourne 1981), and that the population is currently at environmental equilibrium. It is likely,

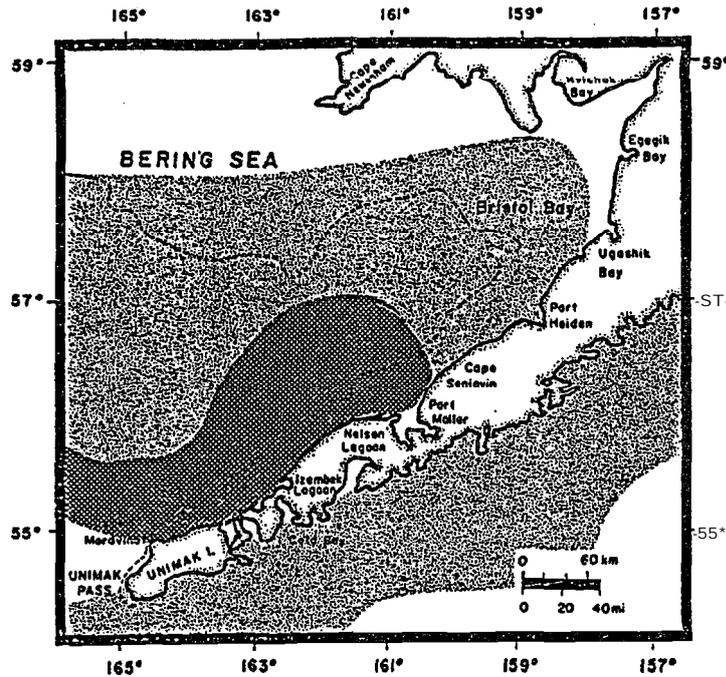


Figure 4.5. Distribution of the Tanner crab in the southeastern Bering Sea. Darkly shaded portions indicate areas of consistently high abundance (from Otto 1981).

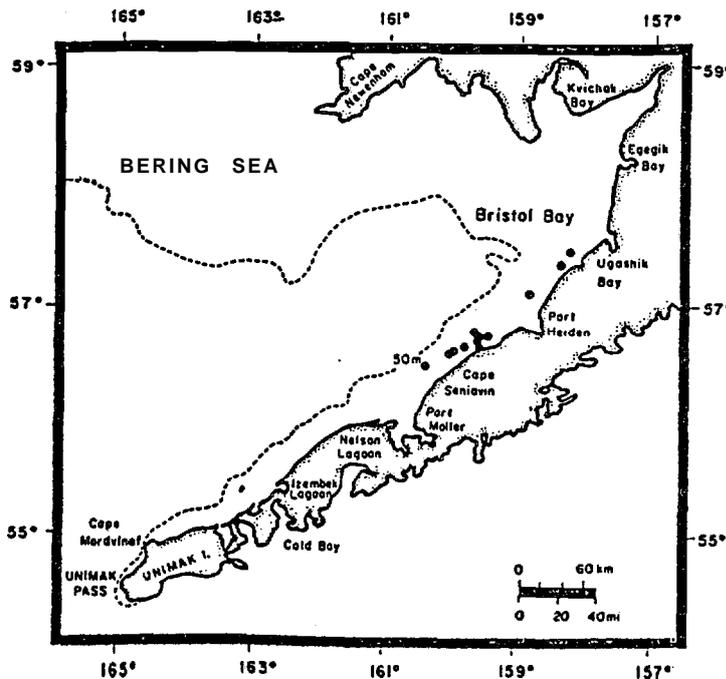


Figure 46. Locations where Production fishing studies for the Alaska surf clam were conducted on the NAS in 1978 (from Hughes and Bourne 1981).

however, that appreciable fishing pressures could quickly reduce **its** abundance because of the slow growth (about 10 years) of individuals to harvestable size (Hughes and Bourne 1981).

4.3.3 Invertebrates Important in Food Webs

Based on existing information and the findings of this study, invertebrate groups important in food webs of animals directly important to humans include copepods, euphausiids, amphipods, mysids, polychaetes, shrimps, bivalves, and echinoderms (sand dollars). The most important of these are probably copepods, euphausiids, amphipods, and bivalves. Other groups generally are less important in these food chains, even though some are extremely abundant on the **NAS** (e.g., starfish, jellyfish, and chaetognaths) .

4.3.3.1 Copepods

Copepods are extremely important in the diets of fishes in the southeastern Bering Sea. Seasonally, they constitute major proportions of the diets of adult sand lance, capelin, and herring; and young of salmon and pollock. Furthermore, they are consumed by other **invertebrates--**euphausiids, for example--that are important in vertebrate food webs. **Copepods** are the main constituent of zooplankton biomass in the Bering Sea (and elsewhere); as such, they are the principal water-column consumers of phytoplankton (Heinrich 1962).

A considerable amount is known about the **copepod** communities on the outer and middle portions of the shelf of the southeastern Bering Sea. In the outer portions of the shelf (> 100 m deep), large **copepods** (e.g., Neocalanus cristatus, N. plumchrus, and Eucalanus bungii) dominate (Fig. 4.7) and are efficient at grazing phytoplankton because they are present in large numbers at the beginning of the spring phytoplankton bloom, having overwintered in deep waters. The middle shelf (50-100 m deep) is hydrographically isolated from the deep waters beyond the shelf break; the **copepods** in the middle shelf are mainly the smaller Pseudocalanus spp., Calanus marshallae, Oithona similis, and Acartia lonniremis that enter the spring phytoplankton bloom in small numbers, having overwintered on the

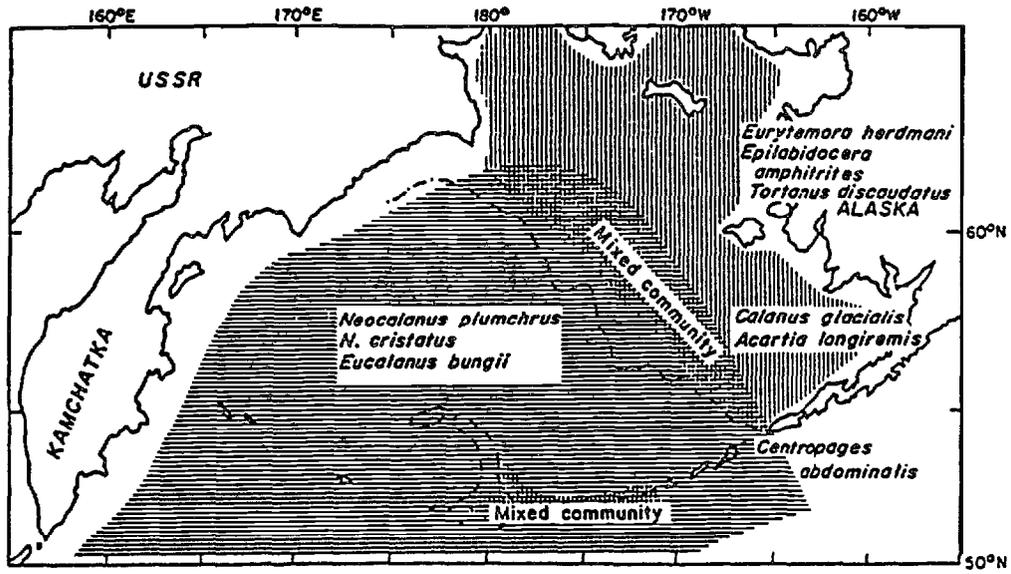


Figure 4.7. Dominant copepod species in various parts of the Bering Sea in early to mid-summer (adapted from Motoda and Minoda 1974).

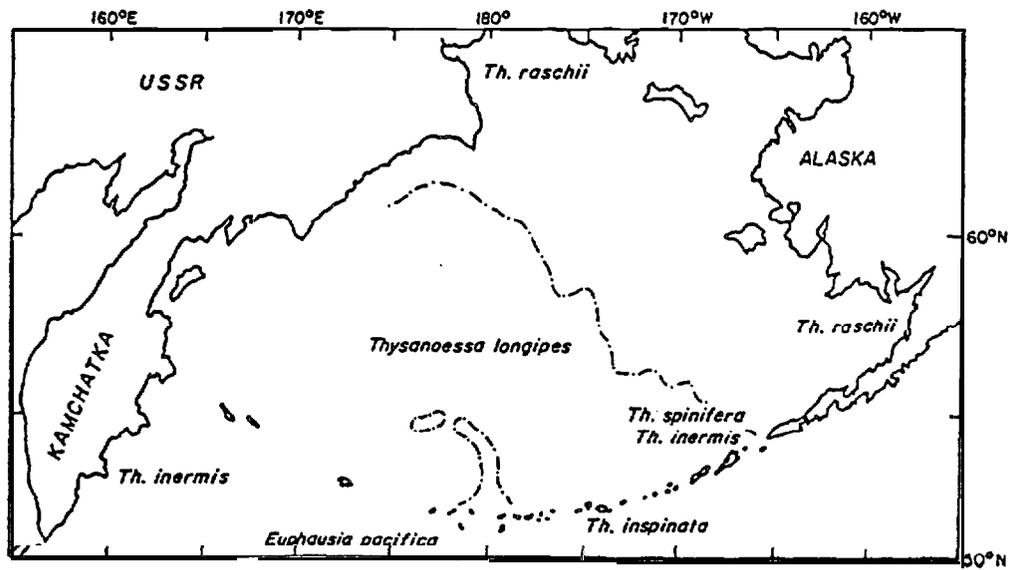


Figure 4.8. Dominant species of euphausiid in various parts of the Bering Sea (from Motoda and Minoda 1974).

shelf. Their populations are not able to grow quickly enough to graze the phytoplankton efficiently (Motoda and Minoda 1974, Dagg 1982, Cooney and Coyle 1982). As a consequence of these differences between outer shelf and middle shelf copepod communities, the outer shelf supports a mainly pelagic food web but the middle shelf supports a relatively large benthic food web fueled by the large amount of sinking phytoplankton.

Little is known about the species composition or grazing efficiency of the copepod community inside the 50-m isobath. The species composition is, at times, similar to that of the middle shelf. Further, because the waters here probably are not strongly isolated from those of the deep parts of the North Pacific and/or the Bering Sea (see Schumacher and Moen 1983), large, deep-water species that are efficient grazers also spill into the area from the middle and outer shelf.

Given the early spring population levels of copepods in various places, low temperatures, rather than food scarcity, are suspected to limit their annual productivity. Dagg (1982) found that, after the water warms in the spring and the phytoplankton bloom begins, many copepods are saturated with food until Late fall. This is particularly true of the smaller copepods such as those found in the middle shelf domain; they require a lower food concentration to obtain a maximum daily ration than do the larger, outer-shelf copepods.

4.3.3.2 Euphausiids

Euphausiids on the NAS are major components of the diets of mammals (minke whale), birds (shearwaters, black-legged kittiwakes), and fishes (salmon, herring, capelin, sand lance, pollock, yellowfin sole). The principal euphausiid in diets of nearshore consumers is probably Thysanoessa raschii, which tends to be dominant in the less saline coastal waters (Fig. 4.8) (Ponomareva 1966). Thysanoessa inermis is also sometimes important on the NAS.

Most of the abundant, high-latitude euphausiids are omnivorous to varying degrees (Mauchline and Fisher 1969). Dagg (1982) showed that, in the southeastern Bering Sea, Thysanoessa individuals eat phytoplankton at most times and places, but can derive most of their ration from phytoplankton only if phytoplankton standing crops reach bloom levels. At

sub-bloom levels, they consume relatively more copepods, crustaceans, and eggs of other organisms. Because they can switch food sources, they can persist through much of the summer despite declines in phytoplankton production (Dagg 1982).

Euphausiids in general, and Thysanoessa in the Bering Sea (Dagg 1982), tend to aggregate in large swarms, to become stratified in the water column, and to migrate vertically on a diurnal time scale. Typically, T. rasohii and T. inermis migrate toward the surface at night and to the bottom during daylight hours (Dagg 1982), except during the breeding season in late spring and early summer, when they may swarm at the surface both day and night (Ponomareva 1966).

Dagg (1982) suggests that Thysanoessa populations need relatively high densities of food (phytoplankton, copepods, etc.) to maintain themselves. Under other than bloom conditions, they may be able to find high densities only where natural phenomena (ocean currents, etc.) concentrate the food.

Euphausiids probably **figure** prominently in Bering Sea carbon budgets, and may form a significant portion of total zooplankton biomass, especially on the middle shelf and perhaps in coastal waters (Vidal and Smith 1986).

4.3.3.3 Amphipods

Amphipods important in the diets of vertebrates on the shelf of the southeastern Bering Sea include pelagic hyperiid species (Parathemisto libellula, P. pacifica) and benthic species (corophiids, gammarids and Anonyx spp.) (Feder and Jewett 1981). Parathemisto spp. are common pelagic species of the nearshore zone (Armstrong et al. 1984, Motoda and Minoda 1974) (Fig. 4.9); P. libellula appears to be the most common (Lewbel 1983, Motoda and Minoda 1974). Parathemisto libellula is important in vertebrate diets; Hunt et al. (1981) reported that **over 60%** of the fall diet of short-tailed shearwaters in the Bering Sea was P. libellula, and that murrens and black-legged kittiwakes frequently consumed large amounts of this species. Benthic amphipods are common in the diets of some fishes, especially benthic fishes such as yellowfin and rock sole.

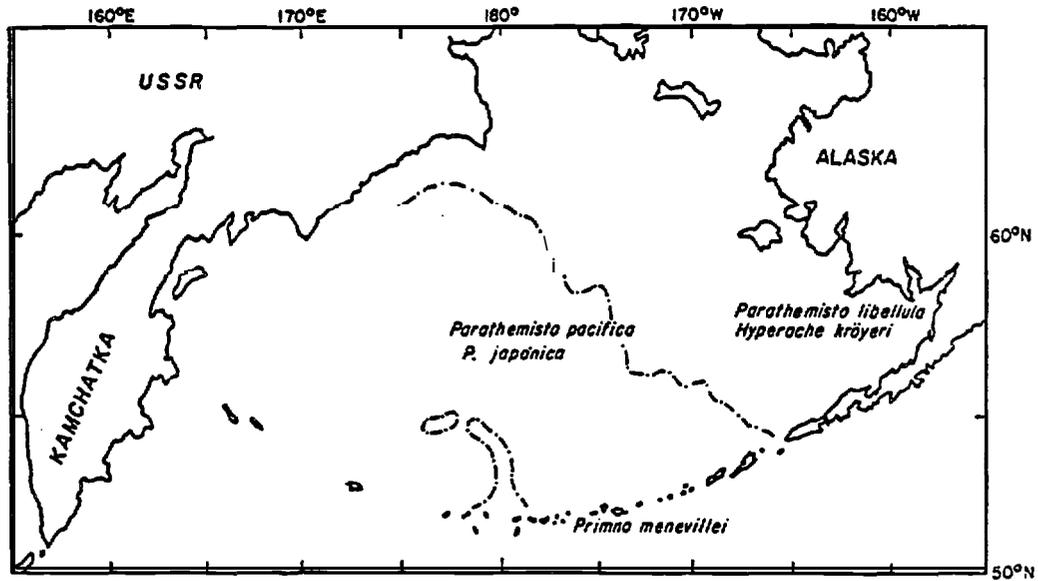


Figure 49). Regional differences in dominant species of amphipods in the Bering Sea in early to mid-summer (from Motoda and Minoda 1974).

4.3.3 .4 Bivalves

Bivalves are important in the diets of yellowfin sole, sea ducks, walrus, and sea otters; they also dominate nearshore infauna biomass (Armstrong et al. 1984). Abundant bivalve species on the NAS include Tellina lutea, Macoma calcarea, Cyclocardia crebicosata, Spisula polynyma, and Siliaua patula (Armstrong et al. 1984, Cimberg et al. 1984, McDonald et al. 1981). Bivalves are, in general, patchily distributed on the NAS. A few species (e.g., Spisula polynyma, Tellina lutea) are so highly clumped in local situations that commercially viable quantities can be harvested by clam dredge (McDonald et al. 1981). Each species tends to be distributed according to specific sediment types (McDonald et al. 1981). Sediments in the NAS nearshore zone are relatively coarse (sand size and larger) (see previous Section 4.3.1), and thus sustain bivalve populations adapted to coarse-grained substrates.

Bivalves identified as important prey for otters, yellowfin sole, and walrus on the NAS include Macoma, Cyclocardia, and Siliaua, Spisula, and Tellina, respectively (Cimberg et al. 1984, Lowry et al. 1982). Most of these bivalves are suspension feeders, though Macoma and Tellina are able to function as deposit feeders as well (Feder and Jewett 1981, McDonald et al. 1981, Stoker 1981).

4.3.3.5 Intertidal Animals

Exposed sand beaches, the predominant shoreline type in the NAS, appear to harbor very sparse populations of infaunal animals. O'Clair et al. (1981) found no *infauna* on a sand beach on Operl Island, and only a few polychaetes on Cape Glazenap. Very low densities of infaunal animals are a feature of shorelines that are exposed to ice and heavy wave action (Thomson et al. 1986).

Intertidal soft (mud) substrates within the protected confines of Port Moller, Moffet Lagoon and Izembek Lagoon support an abundance of infaunal animals, especially bivalves and polychaetes (O'Clair et al. 1981). Infaunal biomass within lagoons may reach 1000 g/m².

Exposed bedrock and boulder substrates in the NAS support substantial biomasses of seaweed and animals as documented by O'Clair et al. (1981) from samples collected at Cape Mordvinof and Cape Lapin on Unimak Island, and on Amak Island. *FUCUS*, *Alaria* and other seaweeds, and mussels, barnacles, and limpets are common on these rocky substrates. Mean density of mussels was 229 individuals/m² at the two lowest strata sampled at Cape Sapin by O'Clair et al. (1981). Distribution of these rocky shoreline substrates and their associated biota is limited to the Cape Mordvinof, Cape Seniavin, and Amak Island areas, and a few other isolated spots in the 'study area (Fig. 4.1).

4.3.3.6 Other Groups

Although copepods, euphausiids, amphipods, and bivalves appear to be the most important invertebrates in food webs of the species of immediate interest to people, other groups are sometimes important. Polychaetes, mysids, shrimps, red king crab, and sand dollars are frequently reported as important foods for species such as rock sole (polychaetes), pollock (mysids), Pacific cod and gray whale (shrimps), and sea otters (king crab, sand dollar).

4.4 METHODS

Zooplankton samples were collected at the 20-, 35- and 50-m stations on each transect (Fig. 1.2). Additional samples were collected at 75- and

100- m depths on Transects 4 and 5. At each station, oblique and horizontal tows (10 min duration) were made with paired bongo nets (0.6 m diameter with 333- and 505-micron meshes) equipped with General Oceanics 2030 flowmeters. Samples were preserved in 10% formalin on board ship.

In the laboratory, zooplankton samples were sorted to major taxonomic category and weighed on a Mettler PT 200 electronic balance (± 1 mg). When subsampling was necessary, large animals were picked out of the entire sample and the remaining portion of the sample was mixed and subsampled by weight. In some samples, copepods were identified to species.

Infaunal animals were collected with a 0.1-m² Van Veen grab operated from the ship in water depths >30 m. Animals collected in the grab were rinsed through nested 5.6-mm and 1-mm screens and preserved in 10% formalin on board ship. Epifaunal animals were collected in the trynet bottom trawl (see Section 5.0, this report), an epibenthic sled, and a drop net. The epibenthic sled consisted of a rectangular (76 x 35.5 cm) box with a 2-mm-mesh net, mounted on steel runners such that the bottom of the box was 11.5 cm off the bottom. It was towed from the Monark launch for 10 min at depths of 3, 5, 10, 20 and 50 m. A modified Clutter (1965) drop net was used to sample epibenthic invertebrates from the Zodiac launch at depths of 3, 5, and 10 m. The net was 0.5 m in diameter and 0.75 m high, with a 1.0-mm-mesh net that pursed at both ends. In most cases, starfish and crangonids were counted and weighed on board ship and then discarded. Other invertebrates were preserved in 10% formalin.

In the laboratory, benthic invertebrates were identified and weighed on a Mettler PT 200 electronic balance (± 1 mg).

Jellyfish were collected in a Marinovich midwater trawl (see Section 5.0, this report). The catch was dumped into a 800-L square container, and the volume was estimated by measuring the depth of the catch in the container.

Microprocessor-controlled LORAN C receivers on the ship and the launch were used to determine position and distance towed for the sled and trawls.

Data analysis was performed on an IBM PC-AT microcomputer equipped with a 20-MB hard disk, using programs developed by LGL, Lotus 123, and the BMDP statistical software package (IBM PC version). Zooplankton species assemblages were identified with the BMDP4M factor analysis

program (Dixon 1981). Before factoring, a logarithmic transformation was applied to density data ($\log [\text{no./m}^3 + 1]$) in order to reduce the skewness inherent in such data. The correlation matrix of transformed species abundances was calculated, principal components were extracted from this matrix, and factors were generated by Varimax rotation. Four factors were considered (nine principal components had eigenvalues >1); these four factors accounted for 79% of the variance among the 12 species variables. Each factor represents a group of species that tended to occur together. A measure of the abundance of each species assemblage in a particular sample was obtained by calculating the corresponding factor score. A factor score is a linear additive function of the original variables, with each variable weighted in proportion to its correlation with the factor. A high factor score indicates that the group of species represented by the factor is common in the sample in question, and a low or negative factor score indicates that those species are rare or absent.

Cimberg et al. (1984) collected 103 grab samples on the NAS at depths of 10 m to 60 m and presented density data for each sample. A rough estimate of the biomass contained in each of their samples was made by multiplying the mean density of each taxon in each sample by an estimate of the mean weight of an individual of that taxon. Mean weight was determined using the 29 grab samples analyzed during the present study.

A Ross Fineline 100 kHz and a Simrad EQ 39 kHz echosounder were run during plankton tows, trawls and continuous bird and marine mammal surveys. The echosounder tapes were marked at the beginning and end of trawls and plankton tows, as well as every 10 min during continuous surveys. At these times, the ship's course, speed and position, and the water depth were noted.

Forbes and Nakken (1972) noted that zooplankton abundance is proportional to the squared value of the intensity of registration on the echogram. We established a system of visually grading the echograms against 'standards' that reflected increasing densities of echo. With care, this method can provide reasonably unbiased estimates of echo abundance (Forbes and Nakken 1972).

The standard against which echograms were compared consisted of a IO-level (0-g) ordinal scale graduated by echo density. For each of the 10 levels, three examples were selected from locations where echo (zooplankton) density appeared similar (Fig. 4.9). Each segment corresponded to a IO-min time interval.

A jig was designed to restrict visual reference to one rectangle of sounder tape. This jig covered an area of approximately 1-2 m by 100 m during tows and trawls and 1-2 m by 600 m during continuous surveys. For continuous surveys, an estimate of hydroacoustic echo density was made in each 10-m depth stratum at the beginning, middle, and end of each 10-min segment. Depending on water depth, between 9 and 30 rectangles were coded for each segment. For tows, measurements were made at the depth of tow at the beginning, middle, and end of the tow.

Echosounder tapes recorded during plankton tows (100 kHz) and trawls (38 kHz) were coded by two independent observers as a check on reproductivity of coding procedures. There was close correspondence between readings made by the two observers, as shown below.

| <u>Sample Type</u> | <u>Frequency Mean Reading + SD</u> | | <u>Correlation Coefficient</u> | <u>Sample Size</u> |
|--------------------|------------------------------------|-----------------------|--------------------------------|--------------------|
| | <u>(kHz)</u> | <u>Reader 1 e r 2</u> | | |
| Trynet tows | 38 | 1.93±1.45 1.82±1.50 | 0.97 | 33 |
| Marinovich tows | 38 | 2.08±1.72 2.05±1.74 | 0.97 | 61 |
| Plankton tows | 100 | 1.99±1.38 2.08±1.46 | 0.96 | 57 |

4.5 RESULTS AND DISCUSSION

4.5.1 Zooplankton (Other Than Jellyfish)

In the following sections, zooplankton communities are characterized in terms of biomass (wet weight) distributions, taxonomic composition, and relationships to various water masses. Comparisons are made between NAS communities and those of adjacent areas. Trophic relationships of the zooplankton are discussed. Gelatinous zooplankton (jellyfish) are not included in this section, but are discussed separately in the following Section 4.5.2.

4.5.1.1 Distribution of Biomass

Total zooplankton biomass was low and relatively constant from January to May 1985, and was similar in May 1984 and 1985 (Table 4.1).

Biomass was highest in July (Table 4.1), presumably representing a delayed response to the spring phytoplankton bloom which began in April (see Section 3.0; this report). The lowest zooplankton biomass was found in September. Primary production was still high in September (see Section 3.0, this report), so it seems likely that predation on zooplankton caused the low standing crop in September (see Section 8.0, this report).

Although zooplankton biomass in samples was greatest in July, the peak in biomass could have occurred in June. (Sampling was not conducted in June.) On the outer Bering Sea shelf, zooplankton biomass is typically highest in May and declines in early June; on the middle shelf biomass is low in May but increases in late May and early June (Vidal and Smith 1986).

There was no apparent annual trend in the spatial distribution of total zooplankton biomass, but some patterns were evident within seasons (Fig. 4.10). In May 1984, biomass declined from west to east; this same trend was evident also in May 1985 (except for an anomalously high biomass on Transect 6 near the east end of the study area). In May, July, and September, total zooplankton biomass was higher at the deeper stations than at the shallow stations (Table 4.2), but in winter (January), biomass was highest in shallow water. These patterns may be a consequence of intrusions of shelf-break and middle-domain zooplankton communities into the study area at western and deeper parts, respectively. This is discussed further in Section 4.5.1.3.

The total biomass of zooplankton on the NAS was low in all seasons when compared with that occurring in offshore waters of the Bering Sea and other marine areas (Table 4.3). Even areas at appreciably higher latitudes in North America (Beaufort Sea, Lancaster Sound) have larger standing stocks of zooplankton.

4.5.1.2 Taxonomic Composition

For all 6 cruises combined, copepods accounted for 33% of the mean biomass in all oblique bongo tow samples. Euphausiids were the next most abundant group (25% of total biomass), followed by chaetognaths (22%), decapod larvae (6%), eggs (5%), fish larvae (3%), and larvaceans (3%).

There was considerable seasonal variation in both relative and absolute biomass of the various zooplankton taxa (Figs. 4.11 and 4.12).

Table 4.1. Mean biomass (mg/m^3 wet weight \pm SD) of all zooplankton except jellyfish in oblique **bongonet** tows on six cruises on the NAS.

| | Cruise | | | | | |
|----------------------|-------------|-------------|-------------|-------------|-------------|---------------|
| | 1984 | | 1985 | | | |
| | May | Sep | Jan | Apr | May | Jul |
| Total biomass | 39 \pm 44 | 15 \pm 12 | 51 \pm 71 | 32 \pm 26 | 36 \pm 35 | 143 \pm 121 |
| Sample size | 19 | 19 | 9 | 10 | 9 | 13 |

Table 4.2. Mean biomass (mg/m^3 wet weight \pm SD) of all zooplankton except jellyfish in oblique bongo net tows over two depth ranges on the NAS.

| Depth Range (m) | Cruise | | | | | |
|--------------------|-------------|-------------------|-------------|-------------|-------------|---------------|
| | 1984 | | 1985 | | | |
| | May | Sep | Jan | Apr | May | Jul |
| Biomass | | | | | | |
| 20 | 24 \pm 27 | 10 \pm 9 | 68 \pm 90 | 30 \pm 35 | 16 \pm 22 | 75 \pm 93 |
| 35-50 | 49 \pm 51 | 18 \pm 14 | 30 \pm 37 | 35 \pm 17 | 61 \pm 32 | 221 \pm 106 |
| Sample size | | | | | | |
| 20 | 8 | 7 | 5 | 5 | 5 | 7 |
| 35-50 | 11 | 12 | 4 | 5 | 4 | 6 |

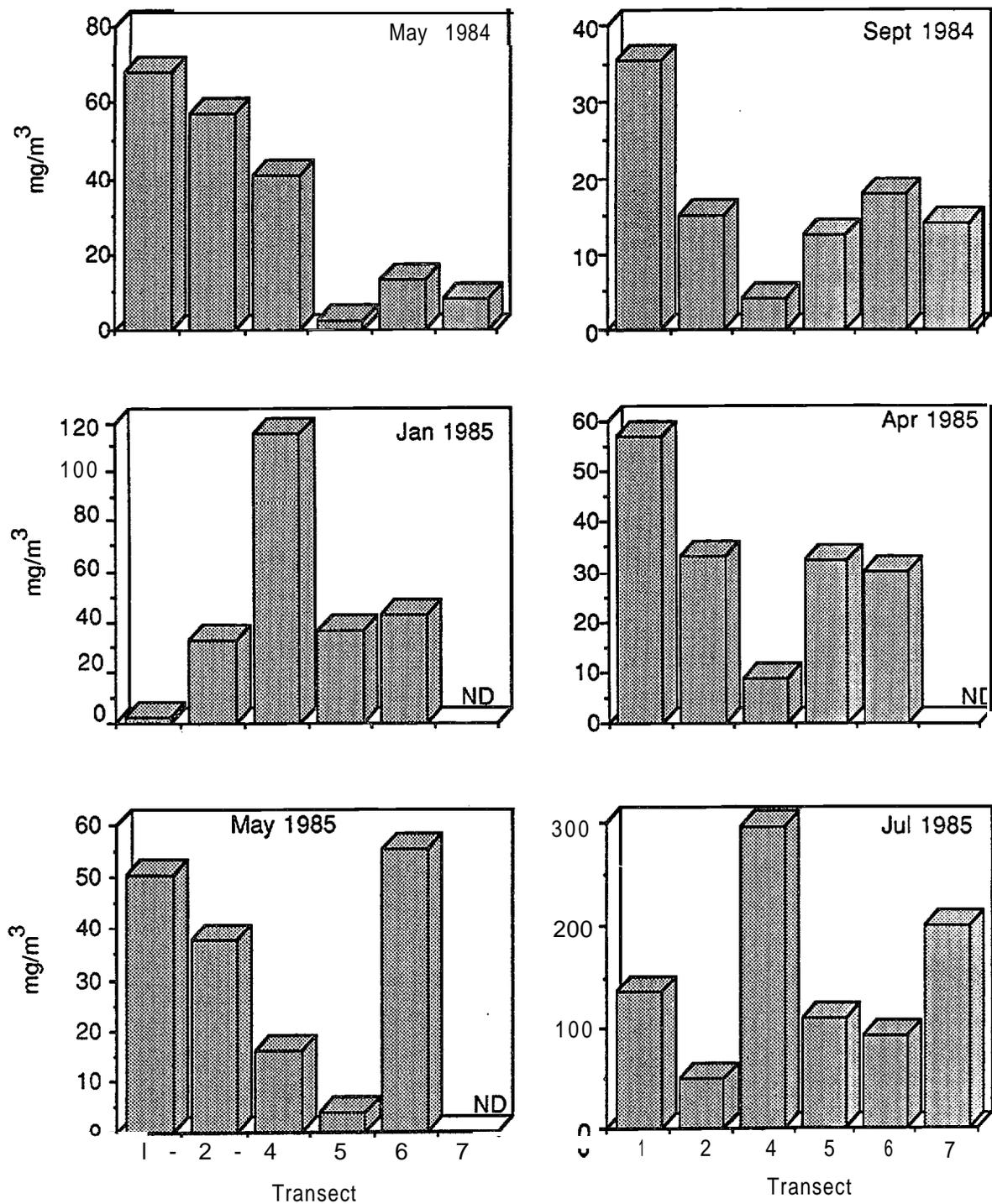


Fig. 4.10. Total biomass of zooplankton in oblique bongo net tows at water depths of 20 to 50 m at six sampling times on seven transects on the North Aleutian Shelf, Alaska. (Jellyfish and ctenophores are not included in the total. See Fig. 1.2 for transect locations.) ND means no data.

Table 4.3. Biomass of zooplankton on the NAS and in other marine areas. Based on oblique or vertical tows in the upper 50 to 150 m of the water column.

| Location | Time of Year | Biomass (mg/m ³ wet weight) | Reference |
|----------------------|--------------|----------------------------------------|-------------------------------------|
| Bering Sea | | | |
| North Aleutian Shelf | Sep-May | 15-51 (40-166) ^a | This study |
| | July | 143 (238) ^a | This study |
| Bristol Bay | Summer | 849 | Ikeda and Motoda (1978) |
| Central Water | Summer | 529 | Ikeda and Motoda (1978) |
| Northern | Summer | 1117 | Ikeda and Motoda (1978) |
| Beaufort Sea | | | |
| Alaskan | Sep | 244 | Griffiths et al. (19%) |
| Canadian | August | 150-476 | Griffiths and Buchanan (1982) |
| Canadian | August | 210 | Bradstreet and Fissel (1986) |
| Lancaster Sound | August | 400 | Sekerak et al. (1979) |
| North Atlantic | | | |
| Slope | Summer | 430-1600 | Riley and Gorgy (1948) ^b |
| Subarctic | Spring | 300-700 | Be' et al. (1971) |
| Sargasso Sea | | <25 | Be' et al. (1971) |
| North Pacific | | | |
| Northern | Summer | 244 | Ikeda and Motoda (1978) |

^a Numbers in parentheses include jellyfish.

^b In Be' et al. (1971).

For example, in May 1984, euphausiids were the dominant group, with a biomass of over 26 mg/m³. They were very rare in the plankton in September, when copepods were dominant. Chaetognaths were the dominant group in both January and April 1985, but accounted for only 11% of total biomass in July. Both copepod and euphausiid biomass (absolute and relative) fluctuated more than an order of magnitude between highs and lows.

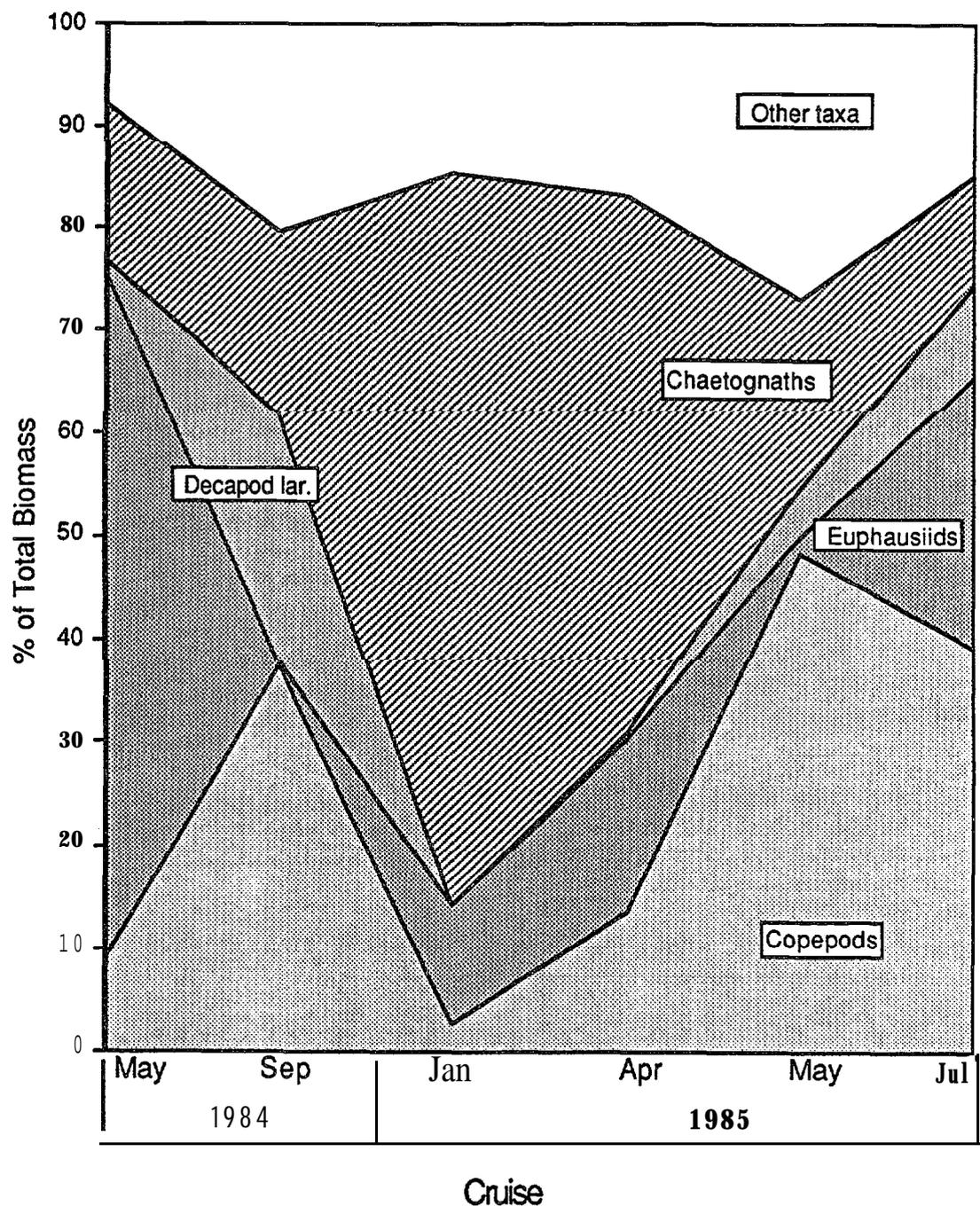


Fig. 4.11. Percent contribution of various zooplankton taxa to total biomass taken in bongo tows at water depths of 20 to 50 m during six cruises on the North Aleutian Shelf, Alaska. (Jellyfish and ctenophores are not included.)

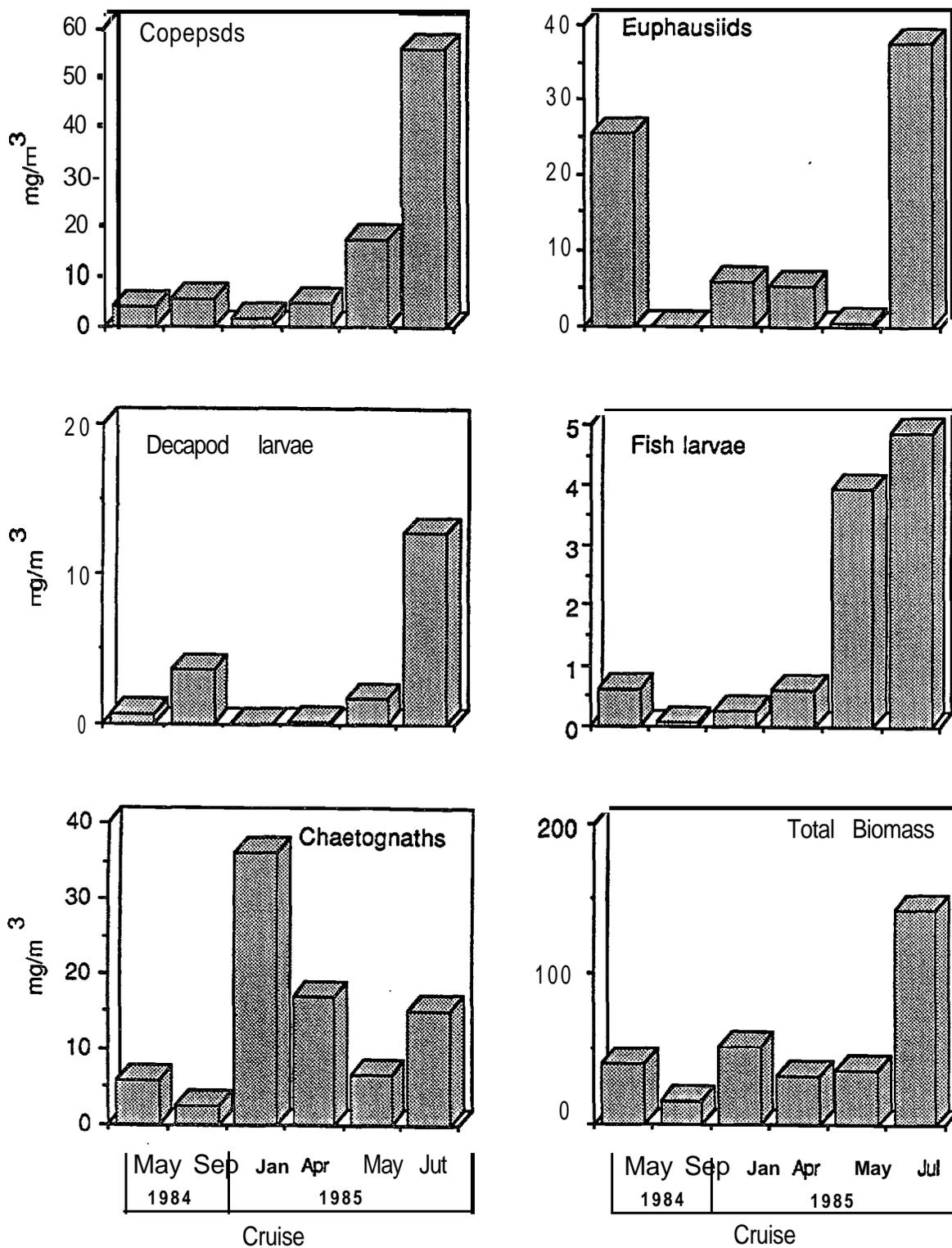


Fig. 4.12. Biomass of dominant zooplankton taxa taken in oblique bongo net tows at water depths of 20 to 50 m during six cruises on the North Aleutian Shelf, Alaska. (Jellyfish and ctenophores are not included in total biomass.)

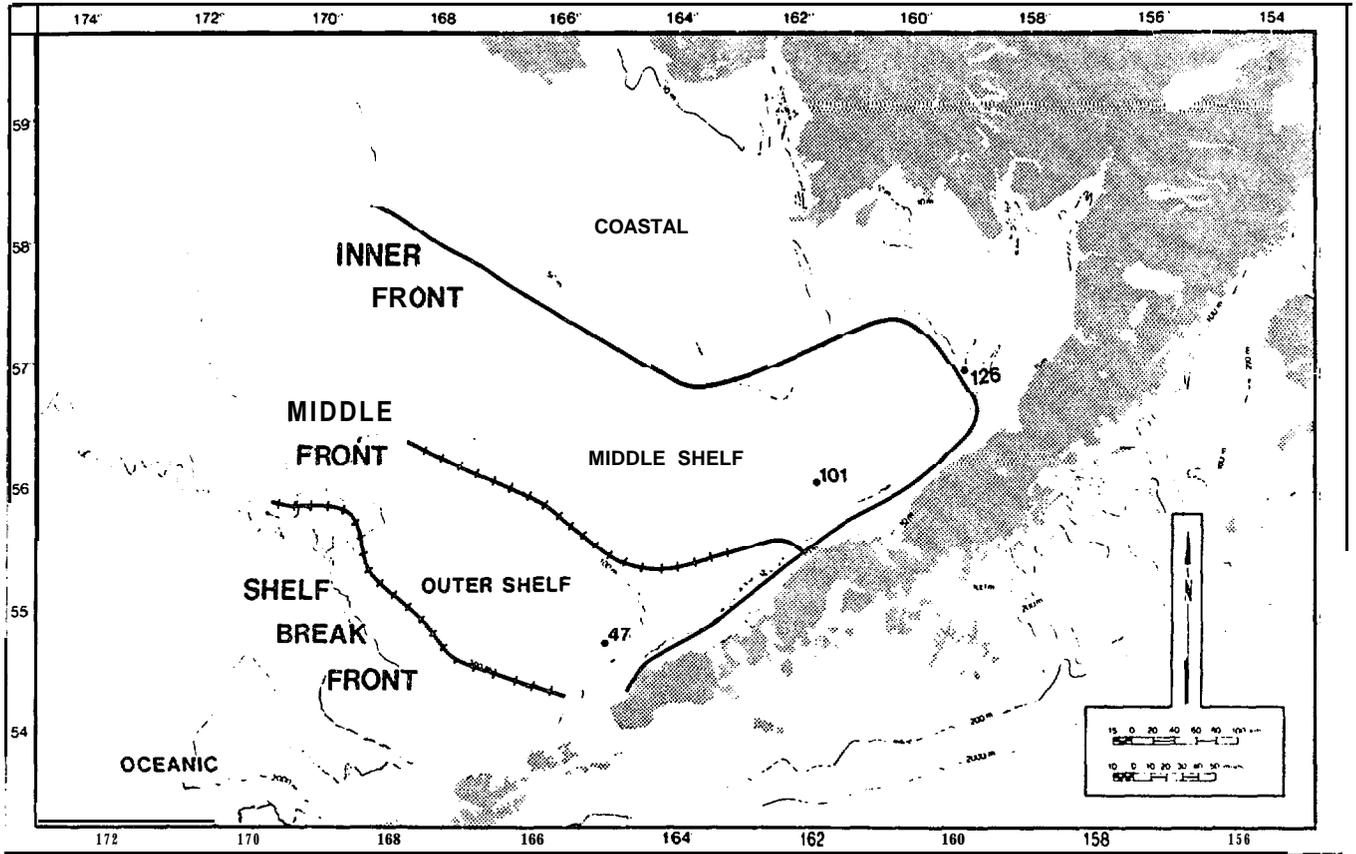
Annual variability in biomass was likewise large. Euphausiids were scarce in May 1985 in comparison with their relative and absolute abundance in **May** 1984; copepods, on the other hand, were more abundant in May 1985 (Figs. 4.11 and 4.12). Biomass of fish larvae increased continuously from September 1984 through July 1985; it was several times higher in May **1985** than in May **1984**.

Seasonal changes in relative and absolute biomasses of **taxa** are readily explainable in some cases. The dietary dependencies and life cycles of **copepods** suggest that they would increase from a winter-spring low to a midsummer high. Seasonal changes in behavior of euphausiids (breeding at the surface in late spring/early summer; descending to deep water at most other times) suggest that they would be more readily caught in the shallow waters **of** the NAS in late spring and early summer. Increased abundances of zooplankton predators (e.g., chaetognaths, fishes, birds) **in** summer would suggest a potential decline in zooplankton prey (copepods, euphausiids) by fall. The copepod-eating chaetognaths, not common as prey for other organisms, would be expected to reach highest biomasses in fall and winter.

Reasons for the observed annual changes in biomass of some **taxa** (see above) are less obvious. **However**, annual changes in total zooplankton biomass were **very** small; total biomass of spring **1984** (May) was about equal to that **of** spring (April, May) 1985. Some possible causes of variability in taxonomic composition of the zooplankton of the NAS are discussed in Section 4.5 **.1.3** below.

4.5 **.1.3** Copepods and Water Masses

There is a juxtaposition of four water masses in the vicinity of the NAS--the coastal, middle shelf, outer shelf, and oceanic domains. The study area itself has been presumed to be almost wholly within the coastal domain (Fig. **4.13**). Evidence from physical oceanography (Section 2.0, this report) and primary productivity (Section **3.0**, this report) suggest that intrusions of one or more of the other water masses into the study area are common. Because zooplankton are more or less passively transported, frequent occurrences in the study area of zooplankton assemblages not characteristic **of** the coastal domain support the idea that



Fig, 4.13. Hydrographic domains and fronts in the southeastern Bering Sea.
 (From Kinder and Schumacher 1981)

other water masses are intruding. In the following paragraphs, we evaluate the use of zooplankton as tracers of water masses and discuss zooplankton distribution as evidence for intrusions of water from the middle shelf, outer shelf, and oceanic domains into the study area.

Copepods in particular, but also euphausiids, are useful as tracers of *water masses*. Different domains have different dominant species groups, frequently with different life history patterns (see Mitoda and Minoda 1974, Cooney 1981). A brief analysis of **copepod** species assemblages and life cycles on the **NAS** and their associated habitat requirements in offshore waters will illustrate this point. This has already been addressed briefly in Section 4.3.3.1.

The oceanic community is dominated by the large **copepods** Neocalanus cristatus, N. plumchrus, Eucalanus bungii, and Metridea pacifica. These large **copepods** must overwinter at ocean depths beyond the shelf edge; they migrate upward in large numbers in spring to take advantage of phytoplankton blooms at the surface. The shelf community (including middle and, to some extent, inner shelf domains) is dominated by the small **copepods** Acartia lonniremis, Pseudocalanus spp., and Oithonia similis that overwinter on the shelf, surviving in low numbers until spring. Outer shelf waters adjacent to ocean depths contain a **mixture of** these dominants in summer. Very near the coast, another **copepod** community typically occurs; the composition of this community on the NAS is strongly influenced by the transport of Alaska Coastal Current water through Unimak Pass and into the study area (see Cooney 1981).

Calanus marshallae is the only large-sized **copepod** that reproduces in the middle shelf domain (Vidal and Smith 1986). It also appears to reproduce on the NAS, where it overwinters as adults and Stage V copepodites. Calanus marshallae may produce two cohorts per year (Smith and Vidal 1986). We found copepodites II and III on the NAS in April and May 1985. By July 1985, stage II was absent and a large proportion of stage IV were present. In September 1984 only stage IV and V were present (Fig. 4.14). The life cycle of this species on the NAS during 1984 and 1985 was similar to its life cycle on the middle shelf (see Smith and Vidal 1986, Vidal and Smith 1986).

Neocalanus plumchrus is a dominant **copepod** of the outer shelf domain; it penetrates the middle shelf only in small numbers. On the **outer** shelf

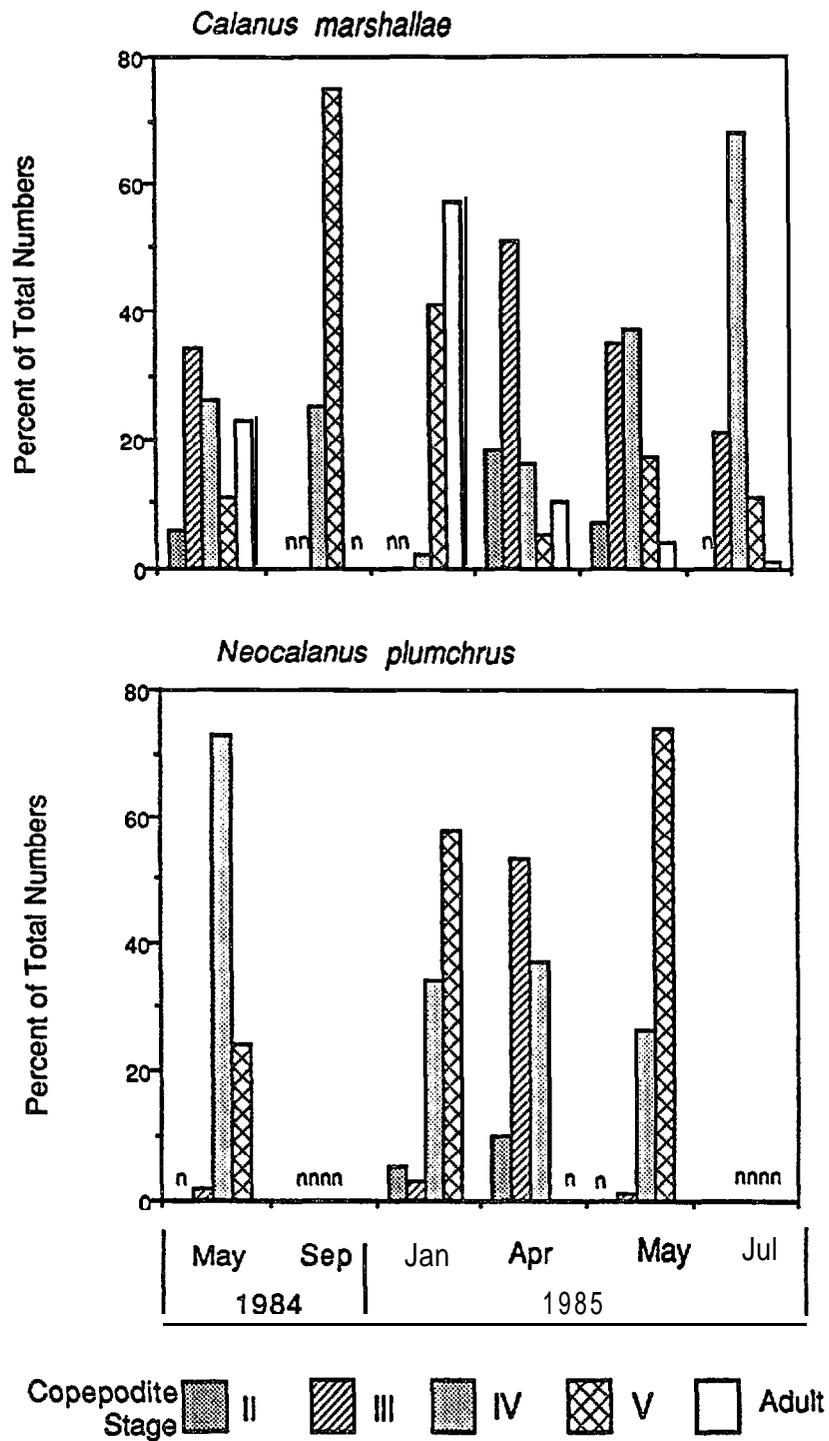


Fig. 4.14. Relative abundance of life stages of two copepod species during six cruises on the North Aleutian Shelf, Alaska, expressed as a percent of the total number of each species collected. N means none collected.

and slope, it appears to complete its life cycle by the end of May, at which time the population descends to deep (>300 m) water (Smith and Vidal 1986). On the NAS, stages II and III were common in January and April and rare in May (Fig. 4.14). By May, most individuals had matured to stages IV and V, and by July, C. plumohrus was absent from the NAS.

We analyzed zooplankton samples from the NAS in an attempt to determine their water mass affiliations. Species identifications were carried out for copepods in oblique bongo net samples taken at 20 and 50 m on Transects 2 and 6 and at one offshore (depth >50 m) station. Calanus marshallae was the most common copepod in the samples, followed by Acartia longiremis and Pseudocalanus minutus (Table 4.4).

Factor analysis was used to identify recurrent copepod assemblages (see Appendix 4A for details). Each factor shown on Table 4.5 represents an assemblage of copepod species that occur together. The community affinities (oceanic, middle shelf, etc.) for each of these species are also shown.

Factor one, representing Pseudocalanus spp., Acartia longiremis, Calanus marshallae, and two other species, is characteristic of water masses that contain a mixture of oceanic, middle shelf and coastal water. The second factor represents an assemblage of species that are characteristic of the nearshore domain. The third factor, representing Neocalanus cristatus, N. plumchrus, and one other species, is characteristic of oceanic offshore waters. The fourth factor, representing Eucalanus bungii and Calanus marshallae, is also characteristic of oceanic offshore water.

The dominant assemblage for each transect/depth/cruise combination was determined through an analysis of the factor scores (see Section 4.4, this report). The results (Table 4.6) show that different zooplankton assemblages were predominant during various time periods, and that during some time periods, the distribution of assemblages in the study area was quite heterogeneous.

Zooplankton distributions indicate that intrusion of middle shelf water onto the NAS study area occurred during most of the cruises, but was generally confined to the portion seaward of the 40-m contour. The evidence indicates that this intrusion was most pronounced in May 1984 and July 1985. In May 1984, there was oceanographic evidence that intrusion

Table 4.4. Mean density (no./100 m³) of copepod species in oblique bongo tows during six cruises on the NAS.

| Species | Cruise | | | | | | | % of Total |
|----------------------------------|--------|--------|-------|--------|--------|---------|------|------------|
| | May 84 | Sep 84 | Jan85 | Apr 85 | May 85 | Jul. 85 | Wan | |
| <u>Calanus marshallae</u> | 120 | 2 | 96 | 284 | 1604 | 7436 | 1590 | 38.3 |
| <u>Calanus sp. (small)</u> | 66 | 0 | 43 | 63 | 0 | 0 | 29 | 0.7 |
| <u>Neocalanus cristatus</u> | 4 | 0 | 0 | 3 | 18 | 0 | 4 | 0.1 |
| <u>Neocalanus plumchrus</u> | 259 | 1 | 19 | 174 | 478 | 0 | 155 | 3.7 |
| <u>Mesocalanus tenuicornis</u> | 1 | 0 | 6 | 0 | 2 | 0 | 1 | 0.0 |
| <u>Eucalanus bungii</u> | 0 | 1 | 7 | 0 | 7 | 362 | 63 | 1.5 |
| <u>Pseudocalanus spp.</u> | 117 | 3 | 0 | 647 | 2255 | 961 | 664 | 16.0 |
| <u>Metridia pacifica</u> | 4 | 2 | 3 | 69 | 77 | 891 | 174 | 4.2 |
| <u>Scolecithricella minor</u> | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0.0 |
| <u>Eurytemora herdmanni</u> | 0 | 5 | 0 | 31 | 2 | 36 | 12 | 0.3 |
| <u>Centropages abdominalis</u> | 0 | 753 | 0 | 4 | 10 | 923 | 282 | 6.8 |
| <u>Epilabidocera longipedata</u> | 0 | 60 | 9 | 0 | 0 | 2 | 12 | 0.3 |
| <u>Acartia longiremis</u> | 19 | 41 | 5 | 740 | 1164 | 3281 | 875 | 21.1 |
| <u>Acartia tumida</u> | 17 | 0 | 0 | 1 | 179 | 828 | 171 | 4.1 |
| <u>Tortanus discaudatus</u> | 0 | 481 | 1 | 3 | 2 | 185 | 112 | 2.7 |
| Unidentified Calanoid | 3 | 16 | 0 | 1 | 0 | 18 | 6 | 0.2 |
| Calanidae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| <u>Lubbockia sp.</u> | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| <u>Oithona spinirostris</u> | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 0.0 |
| <u>Oithona sp.</u> | 0 | 1 | 0 | 0 | 10 | 0 | 2 | 0.0 |
| Total | 609 | 1367 | 188 | 2020 | 5809 | 14925 | 4153 | 100 |
| Sample size | 4 | 4 | 5 | 5 | 5 | 5 | 28 | |

Table 4.5. Results of a factor analysis of the 12 most common zooplankton species in 28 oblique bongo net samples from the NAS, Alaska during six cruises in 1984 and 1985. The values shown are the correlations between the log transformed densities of various species (the original variables) and each of the four factors determined in the analysis. Species whose densities were weakly correlated with a factor ($r < 0.4$) are not shown. Also shown are the community affinities of each species according to Cooney (1981).

| Factor 1. Mixed (oceanic/shelf/coastal) | | Community affinities * |
|-------------------------------------------|-------|------------------------|
| <u>Pseudocalanus spp.</u> | 0.924 | O/M |
| <u>Acartia longiremis</u> | 0.842 | M |
| <u>Calanus marshallae</u> | 0.733 | M |
| <u>Metridia pacifica</u> | 0.659 | 0 |
| <u>Acartia tumida</u> | 0.551 | |
| <hr/> | | |
| Factor 2. Nearshore | | |
| <u>Centropages abdominalis</u> | 0.937 | N |
| <u>Totanus discaudatus</u> | 0.824 | N |
| <u>Epilabdocera longipedata</u> | 0.571 | Coastal in N. Pacific |
| <u>Eurytemora herdmani</u> | 0.424 | N |
| <hr/> | | |
| Factor 3. Oceanic 1 (oceanic/outer shelf) | | |
| <u>Neocalanus cristatus</u> | 0.902 | 0 |
| <u>Neocalanus plumchrus</u> | 0.879 | 0 |
| <u>Acartia tumida</u> | 0.415 | |
| <hr/> | | |
| Factor 4. Oceanic 2 (oceanic/outer shelf) | | |
| <u>Eucalanus bungii</u> | 0.723 | 0 |
| <u>Calanus marshallae</u> | 0.482 | M |

* 0 = Oceanic, outer shelf. M = Middle shelf, coastal. N = Nearshore.

Table 4.6. Dominant copepod assemblages at selected stations on the NAS. Assemblages were determined through a factor analysis of the density of the most common copepod species. The dominant assemblage(s) were determined through consideration of the factor scores for each sample. N = 1 for each cruise, transect depth combination.

| Transect | Depth | Cruise | | | | | |
|----------|-------|----------|-----------|----------|----------|----------|--------------------|
| | | May 1984 | Sep 1984 | Jan 1985 | Apr 1985 | May 1985 | Jul 1985 |
| 2 | 20 | Oceanic1 | Nearshore | Oceanic2 | Mixed | Mixed | Nearshore/Oceanic2 |
| | 50 | Oceanic1 | Nearshore | Oceanic2 | Oceanic2 | Oceanic1 | Oceanic2 |
| 6 | 20 | * | Nearshore | * | Mixed | Mixed | Nearshore |
| | 50 | Mixed | * | Oceanic2 | Mixed | Mixed | Mixed/Nearshore |
| land 4 | >50 | ND | No | Oceanic2 | Oceanic1 | Oceanic1 | Oceanic2 |

ND means no data.

* No score >0.

Table 4.7. Number of 10 minute segments of 38 kHz and 100 kHz echosounder tapes that were coded, total distance represented by the coded data and mean coded value for five cruises on the NAS.

| Date | 38 kHz | | | 100 kHz | | |
|-----------|---------------|-----------------|----------------------|-----------------------|-----------------|---------------------|
| | Distance (km) | No. of Segments | Mean Value \pm S D | Distance Covered (km) | No. of Segments | Mean Value \pm SD |
| May 1984 | 239 | 82 | 0.4 \pm 0.6 | 160 | 57 | 3.6 \pm 1.1 |
| Sep 1984 | 559 | 172 | 2.1 \pm 1.0 | 594 | 183 | 1.8 \pm 0.8 |
| Jun 1985 | 259 | 70 | 1.2 \pm 0.9 | 252 | 66 | 1.1 \pm 0.7 |
| May 1985 | 805 | 217 | 1.5 \pm 0.8 | 351 | 95 | 2.2 \pm 0.7 |
| July 1985 | 464 | 114 | 2.4 \pm 0.9 | 464 | 114 | 3.5 \pm 0.9 |

of offshore water occurred in the western portion of the study area to the 20-m contour (see Section 2.0, this report). At the same time, **copepods** associated with oceanic waters *were* found at 20- and 50-m depths on Transect 2 (west) but not on Transect 6 (east), and high biomasses of euphausiids were found in the western portion of the study area, but not in the east (Fig. 4.15). (Sampling evidence suggests that euphausiids are much *more* abundant in the deeper shelf waters than in NAS waters.) Total zooplankton biomass was also highest in the western part of the study area at this time.

The pronounced intrusion of offshore water into the study area in July was also associated with the presence of oceanic **copepod** assemblages and high biomasses of euphausiids and of zooplankton in general. This intrusion was very strong at the 50-m contour and weak at 20 m (see Section 2.0, this report). The highest biomass of euphausiids was found at 50 m (Fig. 4.15) and total zooplankton biomass at 35-50 m was three times as high as that at 20 m (see Table 4.2).

Water masses present on the NAS in September were typically coastal in nature. Nearshore **copepod** assemblages predominated at three of four stations sampled on Transects 2 and 6 (Table 4.6). Euphausiids *were* not found at any of the stations, either because intrusion of water from beyond the 50 m **contour** was weak or because the euphausiids had migrated to offshore **waters** (or to benthic habitats when samples were being taken).

In April 1985, the coastal domain extended to the 50-m isobath. Euphausiids were scarce and **copepod** assemblages representative of a mixed regime 'were present (Fig. 4.15; Table 4.6) (see Section 2.0, this report). In May 1985, there appears to have been an intrusion of offshore water that was similar in magnitude to that observed in May 1984. In May of both years, this intrusion extended to the 20-m isobath. Despite this similarity, there were substantial differences in the composition of the plankton (Fig. 4.11) and in the species composition of the copepods. In May 1985, Calanus marshallae, Pseudocalanus sp., and Acartia lonniremis were the dominant **copepods** (Table 4.4). In May 1984, Neocalanus plumchrus was the dominant **copepod** and the abundances of C. marshallae, Pseudocalanus sp., and A. lonniremis were much lower than in May 1984 (Table 4.4). As shown below, N. plumchrus was equally abundant in May of

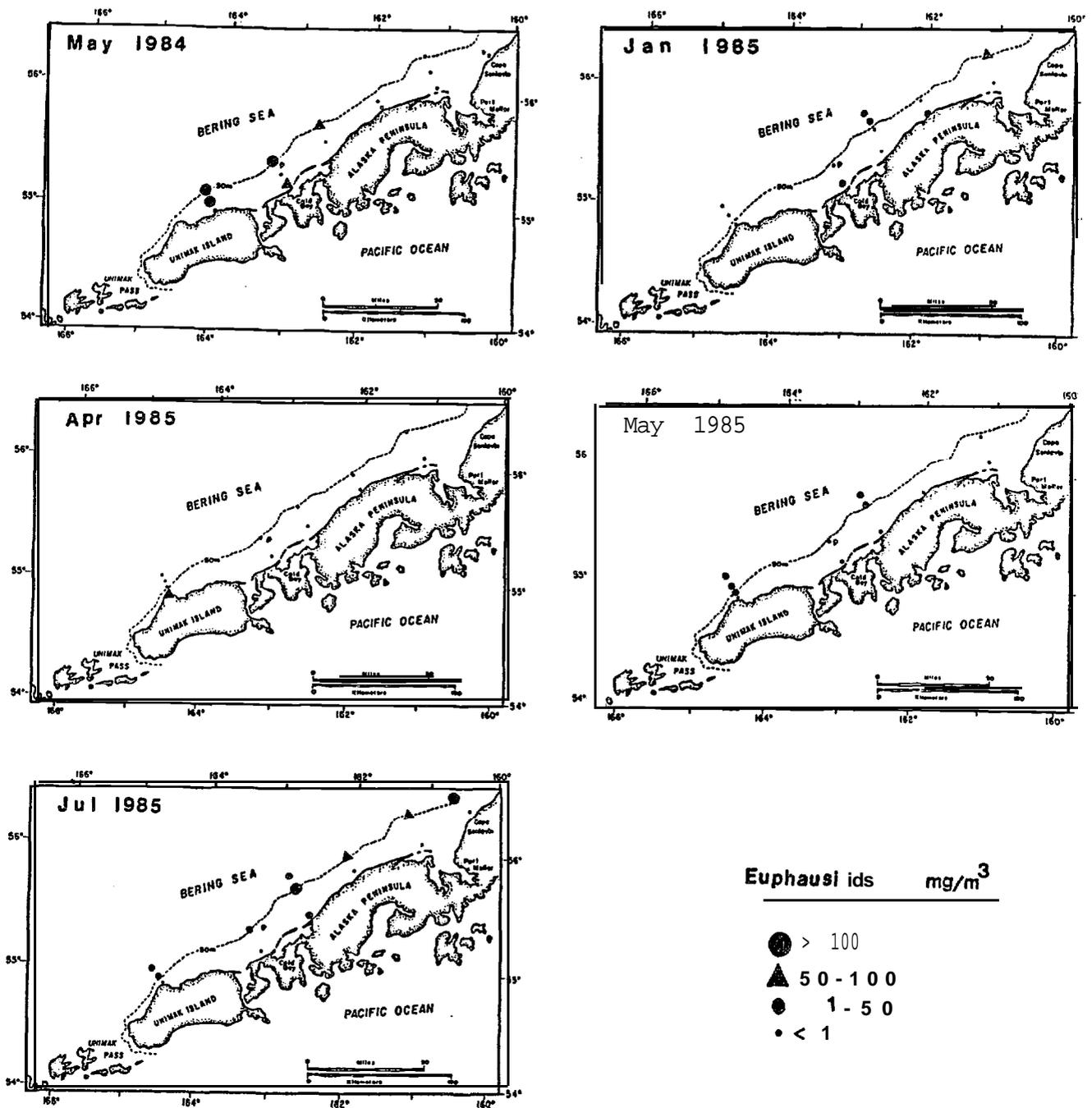


Fig. 4.15. Distribution of euphausiid biomass in oblique bongo net tows during five cruises on the North Aleutian Shelf, Alaska. (Euphausiids were absent in September 1984.)

both years on Transect 2, but the other three species were far more abundant in **1985**, especially on Transect 6.

| TRANSECT : | 2 (West) | | 6 (East) | |
|------------------------------------|----------|----------|----------|----------|
| YEAR: | May 1984 | May 1985 | May 1984 | May 1985 |
| Density (no./1000 m ³) | | | | |
| <u>Neocalanus Dlumchrus</u> | 517 | 550 | 1 | 19 |
| <u>Calanus marshallae</u> | 122 | 265 | 117 | 1886 |
| <u>Pseudocalanus sp.</u> | 83 | 309 | 152 | 3946 |
| <u>Acartia longiremis</u> | 10 | 1237 | 27 | 1071 |

Neocalanus Dlumchrus is found on the outer shelf and slope (Smith and Vidal 1986), and is thus indicative of oceanic water intrusion. The other three species are characteristic of the middle shelf, and show the influence of that water mass, especially on Transect 6. On the middle shelf, the abundance of these three species may vary from year to year, depending on thermal conditions in spring (Smith and Vidal 1986). Physically, the intrusion of offshore water appears to have been the same in both years; however, differing conditions on the middle shelf during the two years may have affected the quantities of zooplankton that were advected onto the shelf.

The species composition and abundance of zooplankton on the NAS appear to be determined by (1) the seasonal cycle, (2) the degree of advection of offshore waters, (3) the source of the offshore waters, and (4) conditions in offshore waters. As shown below, predation may also be an important factor structuring nearshore zooplankton communities.

4.5 .1.4 Hydroacoustic Sampling of Zooplankton

Hydroacoustic sampling was conducted during most zooplankton tows and during transects conducted for shipboard censusing of seabirds and marine mammals. Hydroacoustic surveys provided information on zooplankton at far more locations than could be sampled during net sampling. However, before the hydroacoustic data can be interpreted, it is necessary to understand

the relationships between the hydroacoustic data and amounts of zooplankton estimated during net sampling.

There was a significant positive correlation **between** the ordinal estimates of echo-intensity and the biomass of zooplankton (not including jellyfish) in horizontal tows ($r = 0.40$, $p < 0.01$, $df = 62$). However, correlations between ordinal estimates of echo-intensity were better for biomass of large zooplankters than for biomass of **copepods or** gelatinous zooplankton as shown below:

| | Correlation | | |
|----------------------------------------------------|------------------------------|--------------|------------|
| | <u>C o e f f i c i e n t</u> | | <u>d f</u> |
| Total | 0.40 | <0.01 | 62 |
| Euphausiids, mysids , fish larvae (grouped) | 0.45 | x0.01 | 62 |
| Copepods | 0.17 | NS | 62 |
| Chaetognaths | 0.08 | NS | 62 |
| Jellyfish | 0.19 | NS | 62 |

NS means not significant, $P > 0.05$.

Thus, the coded hydroacoustic data appears to represent mainly the biomass of large non-gelatinous zooplankters.

Using similar methods, Bradstreet and Fissel (1986) obtained a correlation coefficient of 0.77 between **coded** echo-intensity and total zooplankton biomass. However, they deleted samples taken close to the thermocline. (No samples were deleted in this study.) In addition, they used 200 kHz echosounder. The higher frequency gives a better return from small zooplankters such as copepods.

A total of 515 **10-min** segments of **100-kHz** echosounder data representing **1821** km of **ship's** track recorded during continuous surveys were coded in the present study (Table 4.7). Mean **values** of hydroacoustic echo-density were highest in May of 1984 and July 1985 (Table 4.7), months with the highest biomass of euphausiids (Fig. 4.12). Echosounder transects were not run on the three eastern **transects** in May of 1985 and, thus, mean values for that month are not directly comparable with those recorded for other cruises.

Figure 4.16 shows the distribution of mean values of echo-intensity for each 10-min transect segment (about 3.5 km). Depending on depth, between 9 and 30 values were coded for each segment. Similar mean intensity values have been enclosed by contours. This figure represents the broad-scale distribution of large zooplankters. During most cruises these large zooplankters appear to have been homogeneously distributed throughout the study area.

Figure 4.17 shows the distribution of the maximum of the 9 to 30 values of echo-intensity recorded for each 10-min transect segment. Similar maximum intensity values are enclosed by contours. This figure represents the distribution of patches of large zooplankters. It is evident from this figure that many adjoining transect segments had at least one patch of zooplankton that was similar in intensity. The presence of patches over large areas would indicate that those large areas would be good foraging areas for fish and birds. Extensive areas with patches of the highest intensity category were found in May 1984 and July 1985. These types of areas were of limited extent in September 1984 and non-existent in January 1985.

4.5.1.5 Trophic Relationships

In evaluating trophic relationships, we first categorized the zooplankton taken in the oblique bongo tows as herbivores or carnivores. The herbivores included copepods, larvaceans, mysids and euphausiids. Euphausiids apparently feed on phytoplankton when it is abundant, and become predatory when it is not (Dagg 1982). Because the availability of phytoplankton on the NAS is far in excess of its consumption by zooplankton for the period April to October (see Section 8.4, this report), we assumed euphausiids to be herbivorous. Carnivores included hyperiid amphipods and chaetognaths.

The relative abundances of herbivores and carnivores changed with the seasons. In winter, the zooplankton was dominated by carnivores (see Fig. 4.18). With the onset of the spring phytoplankton bloom, herbivores increased in abundance, and by midsummer the relative abundance of herbivores was far greater than that of the carnivores. Predation by

jellyfish in late summer (see next section) may reduce the standing crop of zooplankton in early fall to its lowest observed level of the year.

4.5.2 Gelatinous Zooplankton

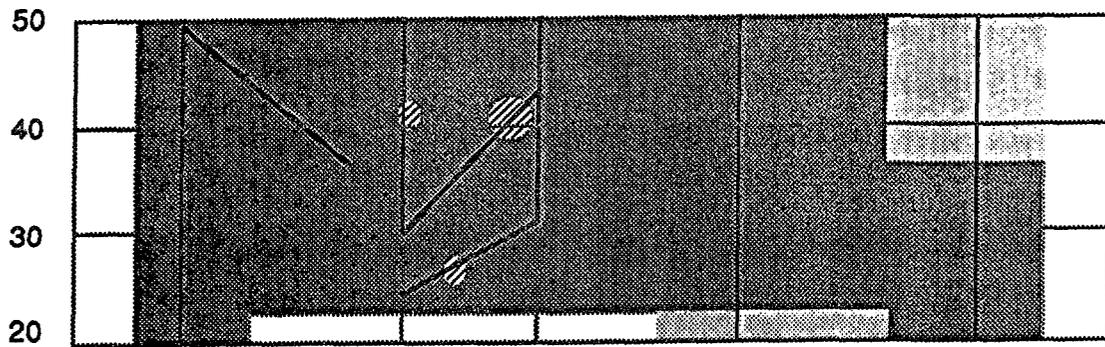
Large scyphozoans (jellyfish) were the most **conspicuous** zooplankters present during most cruises, but they were not sampled effectively by planktonnets because of their relative scarcity as individuals. Using 500 g as the biomass of an average jellyfish and a mean biomass of 1.5 g/m³ in September (as determined in Marinovich tows), jellyfish density was estimated to be 1 individual/333 m³. The mean volume sampled in oblique bongo net tows was only 110 m³, an insufficient volume to effectively sample these organisms. The Marinovich midwater trawl, on the other hand, sampled from 1000 to 250,000 m³, and thus yielded a more reliable estimate of biomass of these large jellyfish than did the bongo nets. Even the Marinovich trawl, however, underestimated actual biomass, because some individuals or fragments likely passed through the large diameter mesh of the net.

Biomass estimates of large gelatinous zooplankton taken in Marinovich tows (mainly **scyphozoans**) were *very* high relative to those of other zooplankters and of jellyfish taken in plankton nets (Table 4.8). The biomass of gelatinous zooplankton in Marinovich tows was highest in September 1984 and lowest in May 1985 (Table 4.8, Fig. 4.19). Gelatinous zooplankton can be voracious predators on zooplankton and fish larvae (Arai and Hay 1982, Moller 1984, Van der Veer 1985). The high biomass of gelatinous zooplankton in September 1984 could, through predation, have been one of the causes of the concomitant low biomass of other zooplankters (Table 4.81).

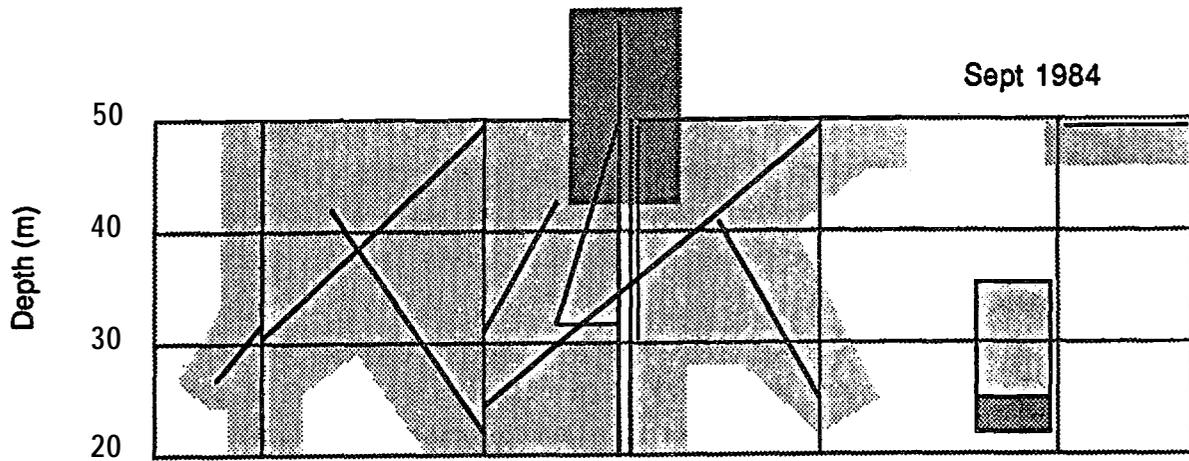
In contrast to conditions on the NAS, predation on copepods of the middle shelf appears to be **slight**, and a high biomass is maintained into October (Smith and Vidal 1986). In other areas, and apparently in the southeastern Bering Sea as well, gelatinous zooplankters are generally more abundant in nearshore than in offshore waters (Alldredge 1984). Thus, on the NAS, predation pressure by gelatinous zooplankton could be an important factor in shaping seasonal zooplankton dynamics, and could be

100 kHz Mean Values

May 1984



Sept 1984



0.5 1 2 4 5 6 7

Transect

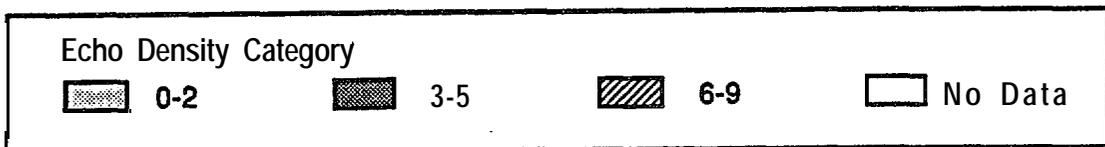
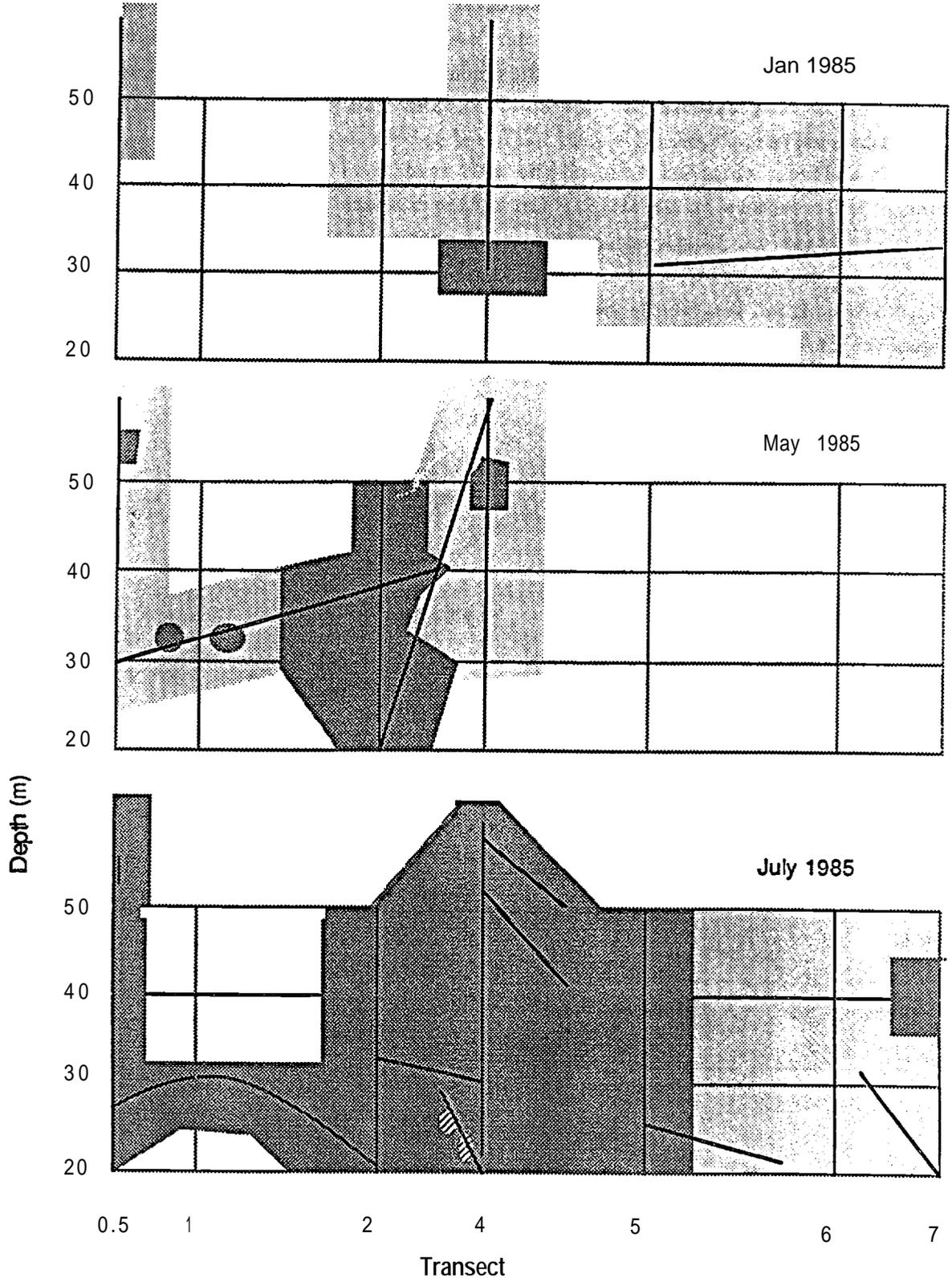


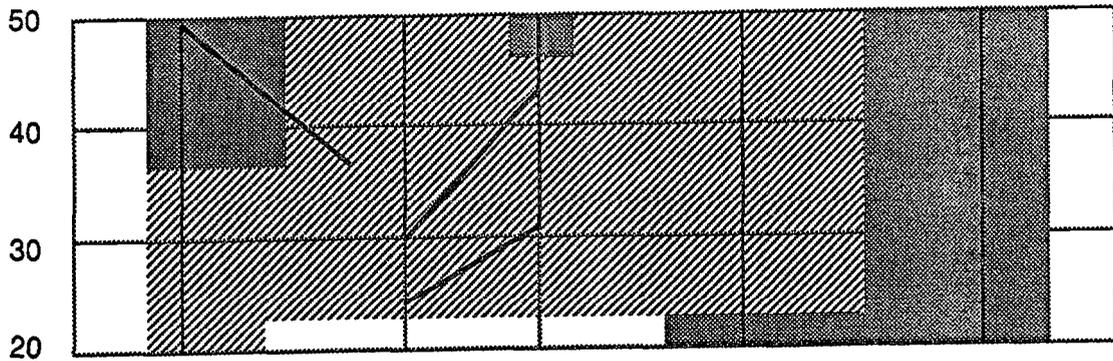
Fig. 4.16. Stylized map of the NAS, Alaska, showing the distribution of mean hydroacoustic echo-density recorded on a 100 kHz echosounder during five cruises. For each 10-min transect segment, the mean of the 9 to 30 coded values of echo-density recorded for that segment are shown. Similar mean values are enclosed by contours. Solid lines show transect locations. Echo-densities recorded during offshore sampling between 50 and 100 m water depths are also shown.

100 kHz Mean Values



100 kHz Maximum Values

May 1984



Sept 1984

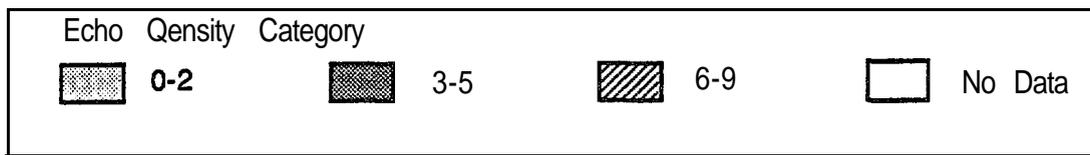
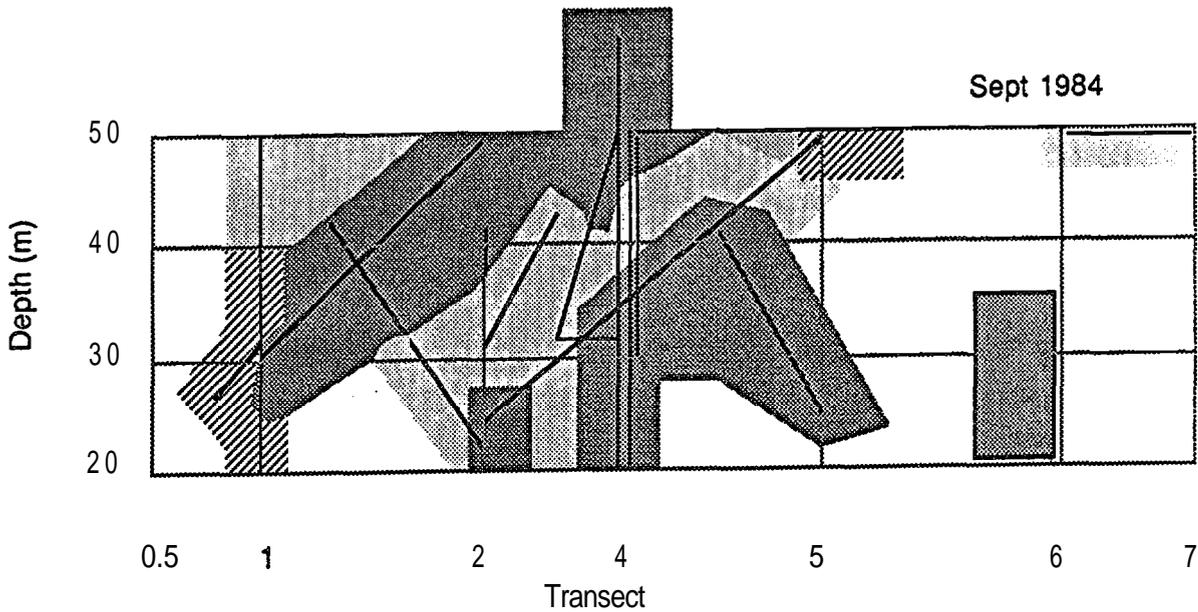
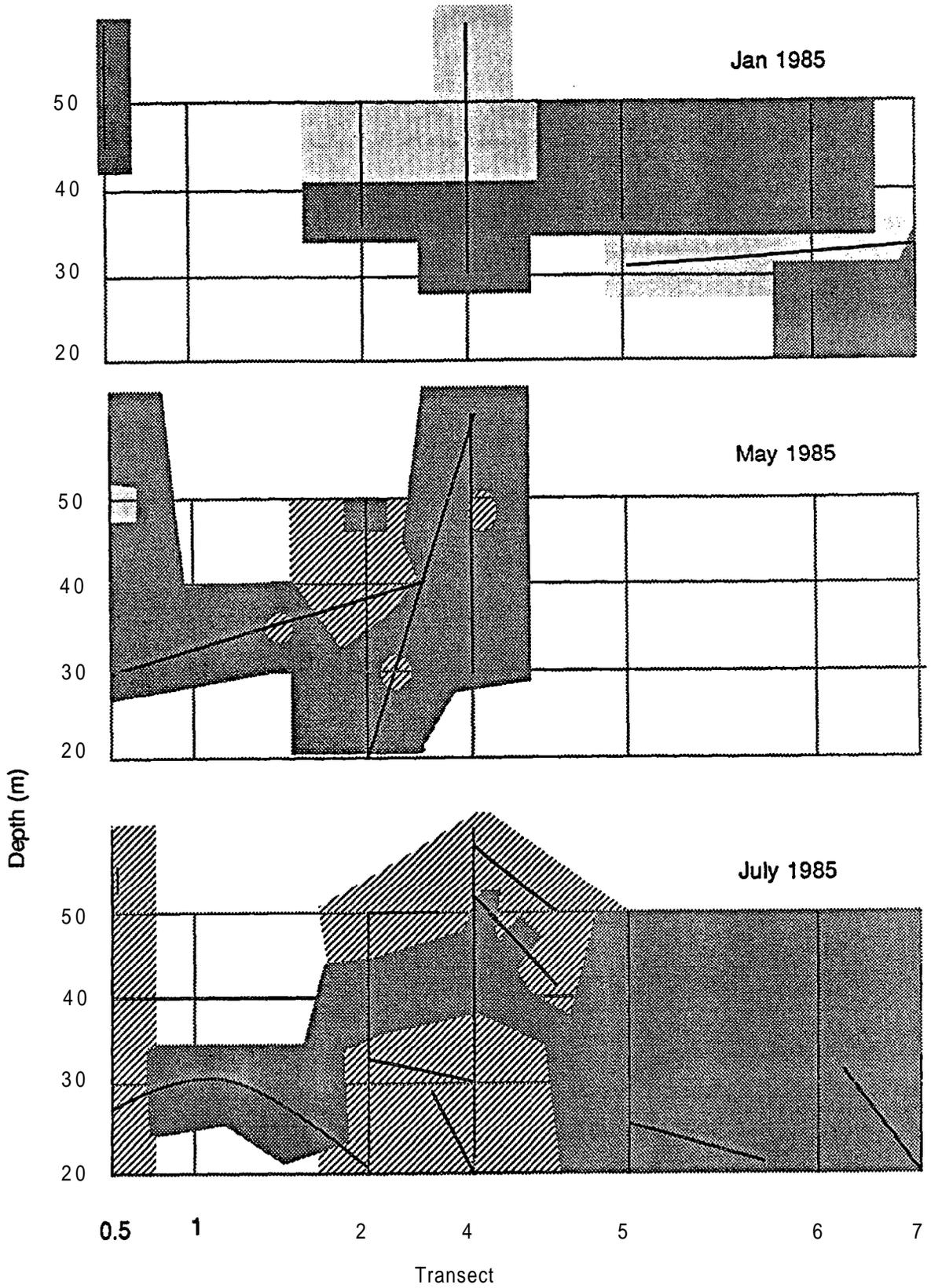


Fig. 4.17. Stylized map of the NAS, Alaska, showing the distribution of maximum hydroacoustic echo-density recorded on a 100 kHz echosounder during five cruises. For each 10-min transect segment, the maximum of the 9 to 30 coded values of echo-density recorded for that segment are shown. Similar maximum values are enclosed by contours. Solid lines show transect locations. Echo-densities recorded during offshore sampling between 50 and 100 m water depths are also shown.

100 kHz Maximum Values



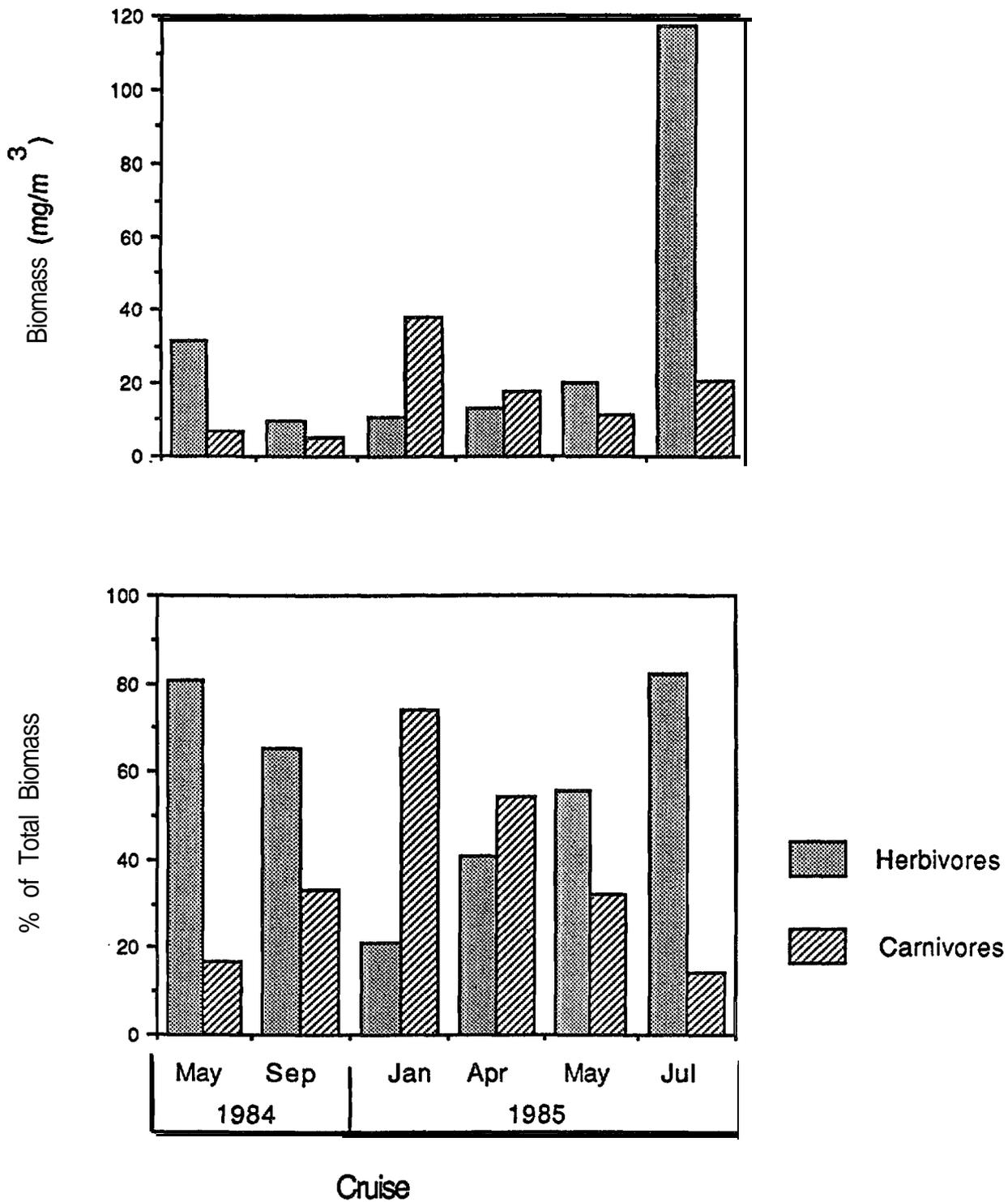


Fig. 4.18. Estimated biomasses of planktonic herbivores and carnivores (excluding jellyfish and ctenophores) in the water column at depths of 20 to 50 m during six cruises on the North Aleutian Shelf, Alaska.

Table 4.8. Mean biomass ($\text{mg}/\text{m}^3 \pm \text{SD}$ wet weight) of herbivores, carnivores and gelatinous zooplankton (jellyfish) taken in oblique bongo tows, and of gelatinous zooplankton taken in Marinovich mid-water tows on the NAS.

| | Cruise | | | | | |
|---------------------------|-----------|-----------|------------|-----------|----------|----------|
| | May 1984 | Sep 1984 | Jan 1985 | Apr 1985 | May 1985 | Jul 1985 |
| oblique bongo tows | | | | | | |
| Herbivores | 31 | 10 | 11 | 13 | 20 | 117 |
| Carnivores | 7 | 5 | 38 | 18 | 12 | 21 |
| Total biomass* | 39 | 15 | 51 | 32 | 36 | 143 |
| All jellyfish | 1 | 74 | 115 | ND | 17 | 89 |
| Marinovich trawls | | | | | | |
| All jellyfish | ND | 1522 | 195 | ND | 111 | 210 |
| Sample size | | | | | | |
| Bongo tows | 19 | 19 | 9 | 10 | 9 | 13 |
| Marinovich tows | 0 | 27 | 8 | 0 | 7 | 11 |

* not including gelatinous zooplankton.

ND means no data.

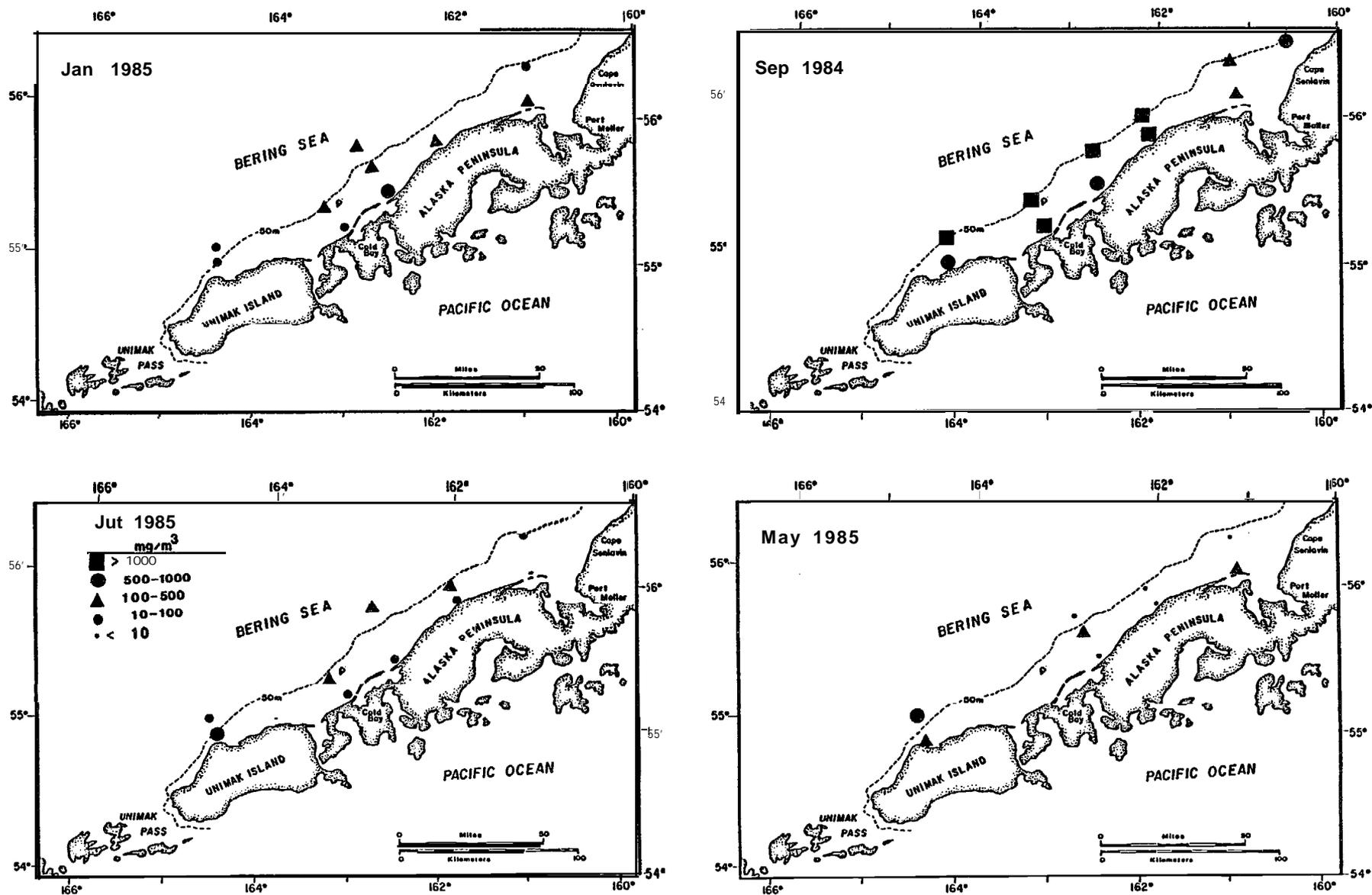


Fig. 4.19. Distribution of biomass of gelatinous zooplankton taken in Marinovich mid-water tows during four cruises on the North Aleutian Shelf, Alaska.

one cause of major differences in seasonal cycles between nearshore and off shore waters.

4.5.3 Benthic Invertebrates

4.5.3.1 Infaunal Benthos

General results of benthic grab samples taken during this study (Table 4.9) compare well with benthic grabs taken in the same area by Cimberg et al. (1984). Cimberg et al. (1984) took 63 samples with a grab similar to that used in the present study at depths of 30 to 60 m. Shown below is a comparison of their results with those of the present study; data for each taxon, as determined in this study, were applied to Cimberg et al.'s density data to estimate biomass.

| | Mean Density | | Mean Biomass | |
|-------------|--------------------------------|------------------------------------|------------------------------|------------------------------------|
| | \pm SD (no./m ²) | | \pm SD (g/m ²) | |
| | This Study (20-50 m) | Cimberg et al. (1984) (30-50 m) | This Study (20-50) | Cimberg et al. (1984) (30-50 m) |
| Bolychaetes | 606 \pm 542 | 761 \pm 816 | 16 \pm 13 | 13 \pm 10 |
| Bivalves | 515 \pm 921 | 68 \pm 85 | 85 \pm 119 | 31 \pm 53 |
| Echinoderms | 73 \pm 67 | 58 \pm 67 | 101 \pm 227 | 101 \pm 116 |
| Total | 1290 \pm 1379 | 1028 \pm 942 | 208 \pm 229 | 152 \pm 160 |

With the exception of bivalve density and biomass, there was close correspondence between the results of the two studies. Biomass and density of bivalves were about 50 g/m* and 450 individuals/m* higher, respectively, in samples collected during this study than in samples collected by Cimberg et al. (1984). The spatial distribution of sampling effort was different between the two studies and could account for these differences.

Table 4.9. Taxonomic composition of the **infauna** collected over two depth ranges during six cruises on the NAS, expressed as a percentage of mean total infaunal biomass or density.

| | % of Total Biomass | | % of total Density | |
|----------------------------------------|--------------------|---------|--------------------------------|---------|
| | 3-10 m | 20-50 m | 3-10 m | 20-50 m |
| Bivalves | 0 | 41 | 0 | 40 |
| Echinoderms | 8 | 48 | <1 | 6 |
| Polychaetes | 92 | 8 | 99 | 47 |
| Gas tropods | 0 | 2 | 0 | 2 |
| Other taxa | <1 | 1 | <1 | 6 |
| Total (g/m ²) ^a | 3 | 208 | Total (indiv./m ²) | 1029 |
| Sample size | 9 | 20 | Sample size | 9 |

^a Not including crustaceans.

Biomass. Total infaunal biomass was very low at depths less than 10 m (Table 4.10). A subtidal barren zone is a common feature of northern shorelines that are affected by ice (Thomson 1982, Thomson et al. 1986). The NAS coast is heavily invaded by ice only during some years, but **infauna** typically recolonize slowly, and even infrequent ice scour might explain the observed scarcity of **infauna**. Wave action in shallow water may also be responsible for the **faunal** break at 10 m depth (Cimberg et al. 1984).

Biomass was quite high at depths of 20 to 60 m (mean of 166 g/m²), but appeared to decrease with increasing depth beyond 60 m (Table 4.10). The relatively low biomass at 30-m depths may be related to the relatively high percentage of gravel at this depth (Fig. 4.1).

At depths of 20 to 50 m, biomass was marginally higher in the western portion of the study area than in the eastern portion (mean of 188 g/m² in the west, 134 g/m² in the east). However, 9 of 22 stations (41%) in the eastern portion of the study area contained a biomass >200 g/m², and only 3 of 23 stations (13%) in the west contained a biomass >200 g/m². Biomass was high off Cape Mordvinof and Isembek Lagoon, uniformly low between Isembek Lagoon and Port Moller and high at three stations off Port Moller, (Fig. 4.20). Mean biomass of **infauna** on the NAS was comparable to that recorded in other parts of the Bering Sea shelf, much higher than that in the Beaufort Sea, and lower than that found in the Canadian High Arctic (Table 4.11).

Bivalves accounted for 20 to 40% of total infaunal biomass at depths of 20 to 50 m (Tables 4.9 and 4.12). The density of bivalves was highest at stations off Bechevin Bay, Isembek Lagoon, and Port Moller (Fig. 4.21). Biomass of bivalves was especially high at depths of 40-50 m (Table 4.12). Bivalves of the genera Tellina, Yoldia, Macoma, and Siliqua were important biomass contributors.

Echinoderms were a co-dominant **taxon** (with bivalves) in terms of wet weight biomass (Tables 4.9 and 4.12) and were most common in the region west of Isembek Lagoon and off Port Moller (Fig. 4.22). Of these, sand dollars were the most important biomass contributors.

Polychaetes dominated infaunal numbers (Tables 4.9 and 4.12). They were relatively abundant in the western and eastern portions of the study area (most stations) and at the 60-m depth contour in the

Table 4.10. Mean biomass (wet weight) of infaunal benthos in relation to depth on the NAS and offshore waters. Data are from this study and Cimberg et al. (1984) for depths 3 to 60 m and from Hafllnger 1981 for depths 65 to 121 m.

| Depth (m) | Biomass (g/m ²) | Sample Size |
|-----------|-----------------------------|----------------|
| 3 | <1 | 3 |
| 5 | 1 | 3 |
| 10 | 43 | 24 |
| 20 | 340 | 6 |
| 30 | 107 | 42 |
| 50 | 207 | 35 |
| 60 | 181 | 19 |
| 65-121 | 92 | 7 ^a |

^a From Hafllnger (1981) : five grabs at each of seven stations off the NAS to a distance of 150 km offshore.

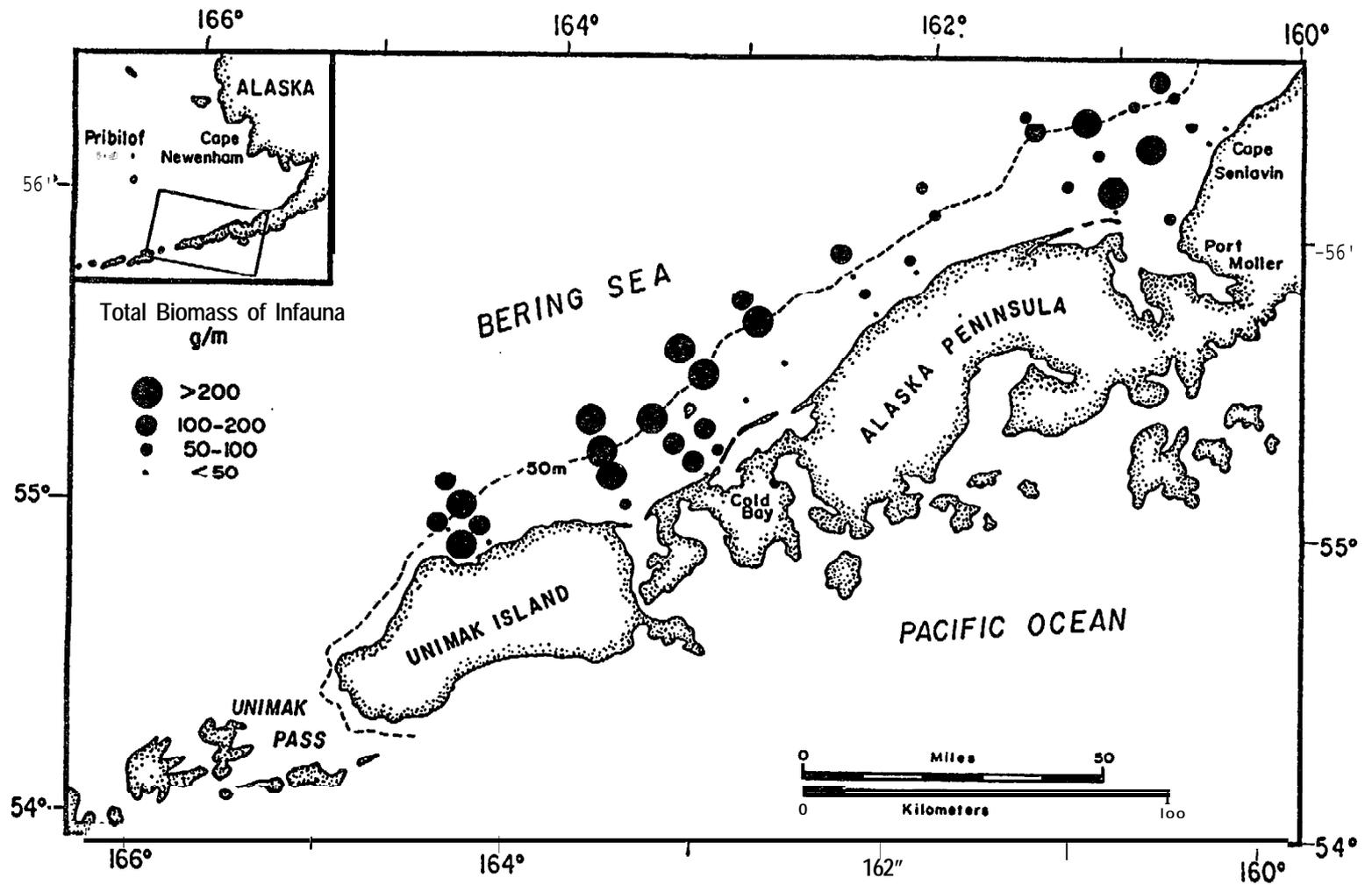


Fig. 4.20. Total infaunal biomass (wet weight) estimated from benthic grab samples taken at stations on the North Aleutian Shelf, Alaska.

Table 4.11. Biomass of infaunal benthos on the NAS, Alaska, and in other marine areas.

| Location | Depth Range (m) | Biomass (mg/m ³ wet weight) | Reference |
|-------------------------------|--------------------|-------------------------------------------|-----------------------|
| Bering Sea | | | |
| North Aleutian Shelf | 20-50 | 208 | This study |
| Offshore of N. Aleutian Shelf | 54-121 | 95 | Haflinger (1981) |
| Chirikof Basin | 20-50 | 210 | Thomson (1984) |
| st. Lawrence Island | 11-23 | 284-353 | Thomson (1984) |
| Bering Chukchi Shelf | | 301 | Stoker (1981) |
| Canadian Arctic | | | |
| Lancaster Sound | 5-50 | 520 | Thomson (1981) |
| NW Baffin Bay | 5-50 | 297 | Thomson (1981) |
| N Baffin Island | 6-20 | 933-2267 | Thomson et al. (1986) |
| NW Passage | 6-20 | 13-689 | Thomson et al. (1986) |
| Alaska Beaufort Sea | 5-50 | 41 | Carey (1977) |

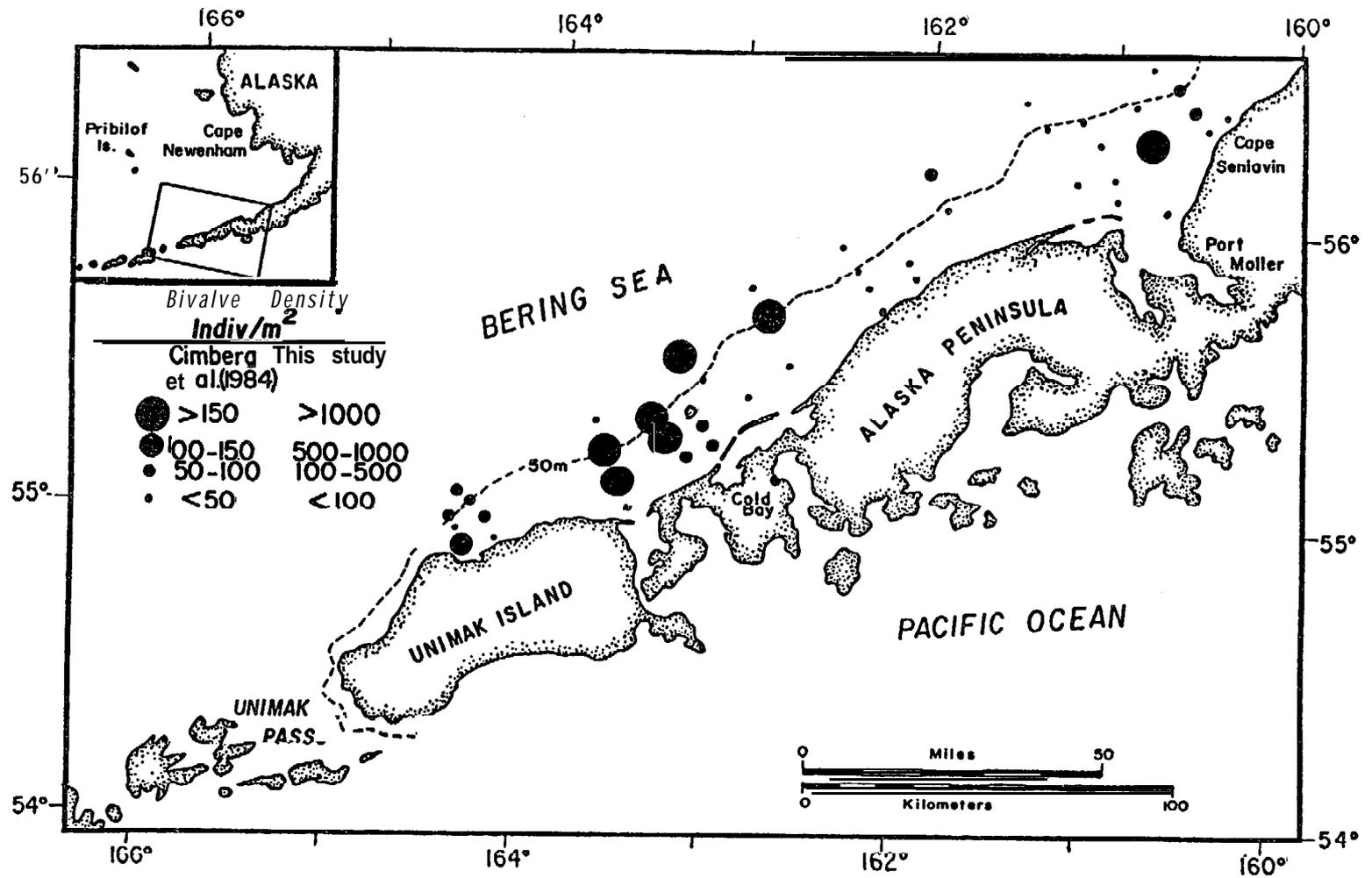


Fig. 4.21. Bivalve densities estimated from benthic grab samples taken at stations on the North Aleutian Shelf, Alaska. Data are from Cimberg et al. (1984) and from this study. **Two different** scales were used because of differences in density recorded during the two studies.

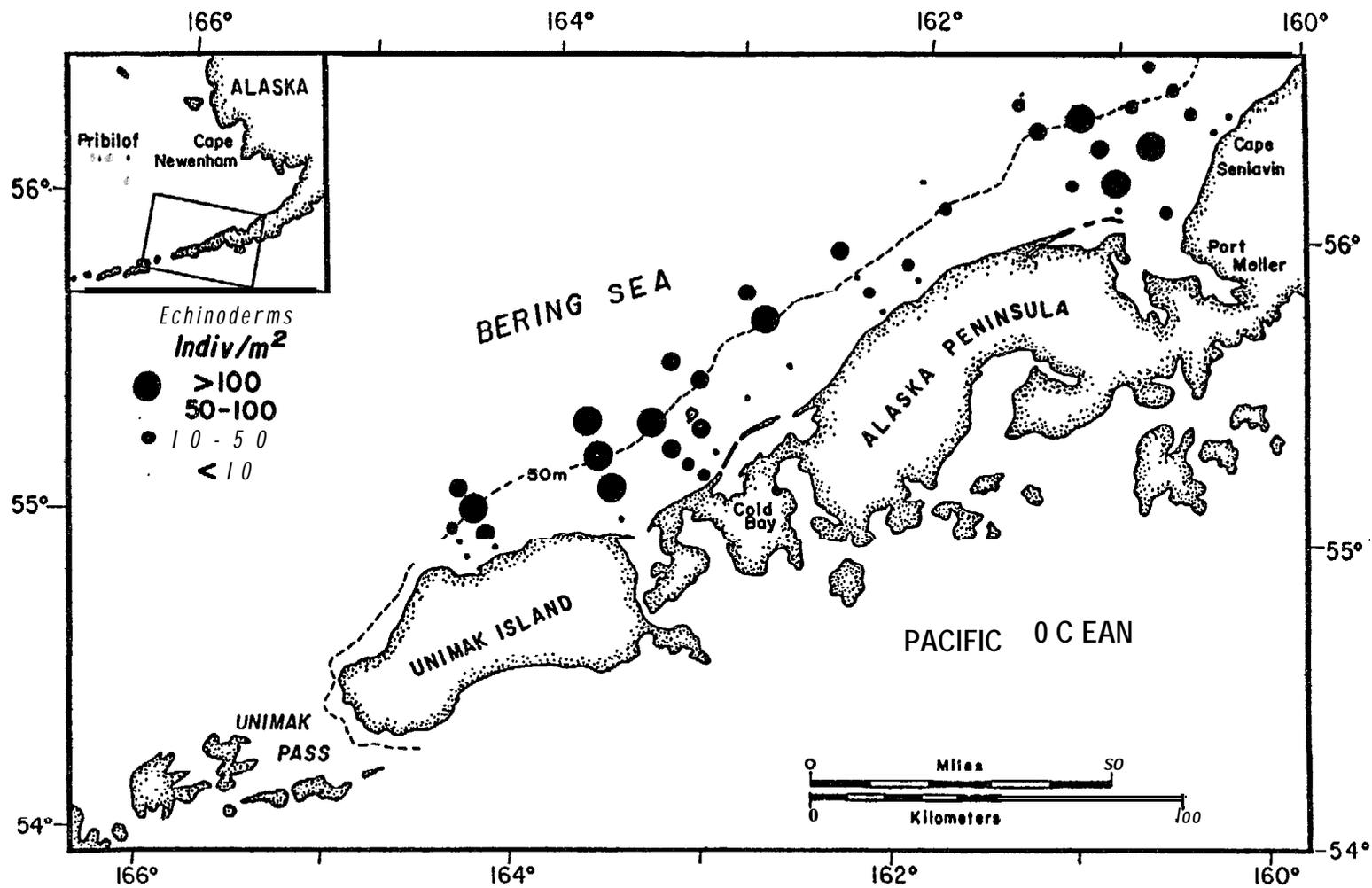


Fig. 4.22. Echinoderm densities estimated from benthic grab samples taken at stations on the North Aleutian Shelf, Alaska. Data are from Cimberg et al. (1984) and this study.

Table 4.12. Depth distribution of total infaunal biomass and biomass of dominant infaunal **taxa (g/m² ± SD wet weight)** collected during this study on the NAS, and by Haflinger (1981) in adjacent offshore waters.

| | Depth (m) | | | | | |
|---------------|-----------|-------|-------|-----------|-----------|---------------------|
| | 3 | 5 | 10 | 20-35 | 43-52 | 54-121 ^a |
| Total Biomass | <1 | 1 ± 1 | 8 ± 5 | 179 ± 263 | 278 ± 104 | 95 ± 86 |
| Bivalves | 0 | 0 | 0 | 45 ± 87 | 178 ± 139 | 26 ± 35 |
| Echinoderms | 0 | 0 | 1 ± 1 | 112 ± 270 | 74 ± 72 | ND |
| Polychaetes | 0 | 1 ± 1 | 7 ± 5 | 13 ± 10 | 24 ± 16 | ND |
| Sample Size | 3 | 3 | 3 | 14 | 6 | 41 |

^a From Haflinger (1981): 11 stations sampled off the NAS to a distance of 150 km offshore.
 ND means no data.

central portion (Fig. 4.23). At depths of 10 to 50 m they were least abundant between Port Moller and Izenbek Lagoon.

Trophic Relationships. Animals collected in grabs were assigned to one of four feeding guilds (surface deposit feeder, deposit feeder, filter feeder, carnivore), using published information. Surface deposit feeders glean food from sediment surfaces by means of tentacles or palps; included are spionid and cirratulid polychaetes; bivalves of the genera Macoma, Nucula, and Yoklaj; ophiuroids; and sand dollars. burrow through the substrate and extract whatever nutritive value they can from it, usually in the form of bacteria. These include opheliid, maldanid, and ocapitellid polychaetes and sipunculids. Filter feeders extend tentacles or siphons above the sediment surface and filter the water. Filter feeders include sabellid polychaetes, mussels, bivalves of the genera Mya and Astarte, and tunicates. Carnivores consume living organisms, typically invertebrates in the benthic community.

At depths of 20 to 60 m, surface deposit feeding was the dominant mode of feeding on the MAS (Table 4.13). Filter feeders were dominant at the 10 m depth, but their biomass was not higher than it was in deeper water. Carnivores and deposit feeders showed no obvious depth preferences. Biomass of surface deposit feeders was highest in the western portion of the study area and off Port Moller (Fig. 4.24).

The prevalence of surface deposit feeding at depths of 20 to 50 m has been noted in the northern Bering Sea and throughout the Canadian Arctic. This mode of feeding appears to be an adaptation to a pulsed primary production that is underutilized by zooplankton (Thomson 1984, Thomson and Martin 1984).

4.5.3.2 Epibenthic Animals

Biomass. Biomass dominants among the epibenthos of the NAS included starfish, crangonid shrimp, mysids, and amphipods. Biomass estimates for the epibenthos were based on several sampling methods, and estimates frequently varied widely among methods. Results from all appropriate methods are presented in the following discussions.

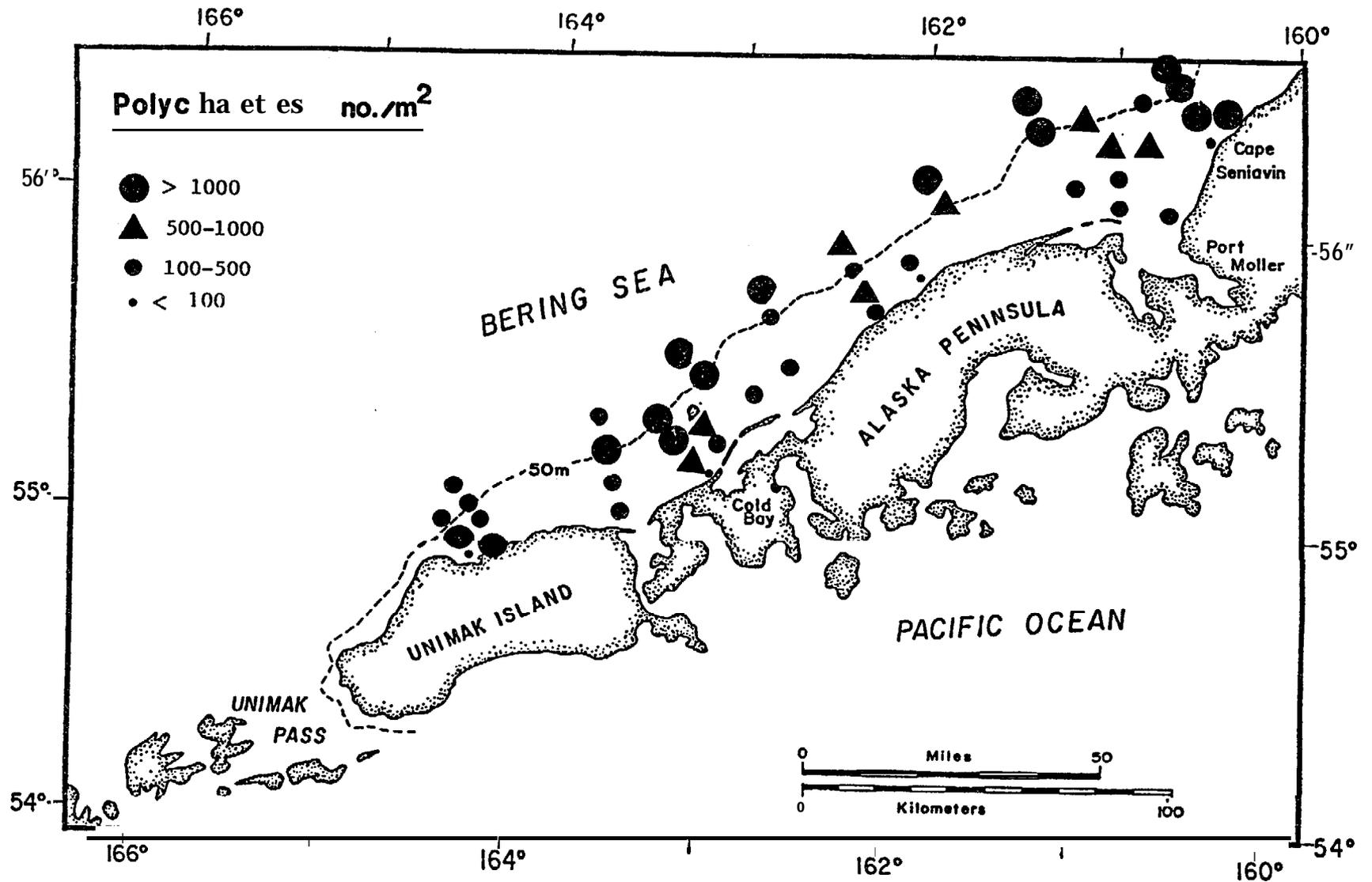


Fig. 4.23. Polychaete densities estimated from benthic grab samples taken at stations on the North Aleutian Shelf, Alaska. Data are from Cimberg et al. (1984) and this study.

Table 4.13. Distribution of infaunal benthic feeding guilds over six depth ranges on the NAS. Biomass was measured in samples taken during this study, and was estimated from density data presented by **Cimberg** et al. (1984).

| | Depth (m) | | | | | |
|----------------------------------------|------------|-------------|-------|-------|-------|-------|
| | 3-5 | 10 | 20 | 30 | 50 | 60 |
| Biomass (g/m²) | | | | | | |
| Surface deposit feeders | 0.0 | 10.3 | 313.8 | 73.8 | 164.9 | 148.5 |
| Deposit feeders | 0.4 | 2.1 | 3.8 | 4.2 | 5.8 | 7.1 |
| Filter feeders | 0.0 | 20.4 | 4.2 | 18.6 | 22.9 | 9.8 |
| Carnivores | 0.0 | 9.0 | 4.9 | 7.2 | 7.7 | 10.5 |
| Not classified | 0.0 | 1.4 | 12.8 | 3.0 | 5.2 | 4.8 |
| As % of total biomass | | | | | | |
| Surface deposit feeders | 0.0 | 23.8 | 92.4 | 69.1 | 79.8 | 82.2 |
| Deposit feeders | 97.6 | 4.9 | 1.1 | 4.0 | 2.8 | 3.9 |
| Filter feeders | 0.0 | 47.3 | 1.2 | 17.4 | 11.1 | 5.4 |
| Carnivores | 2.4 | 20.8 | 1.4 | 6.7 | 3.7 | 5.8 |
| Not classified | 0.0 | 3.2 | 3.8 | 2.8 | 2.5 | 2.6 |
| Total biomass (g/m²) | | | | | | |
| Sample size | 0.4 | 43.1 | 339.5 | 106.7 | 206.5 | 180.7 |
| | 6 | 24 | 6 | 42 | 35 | 19 |

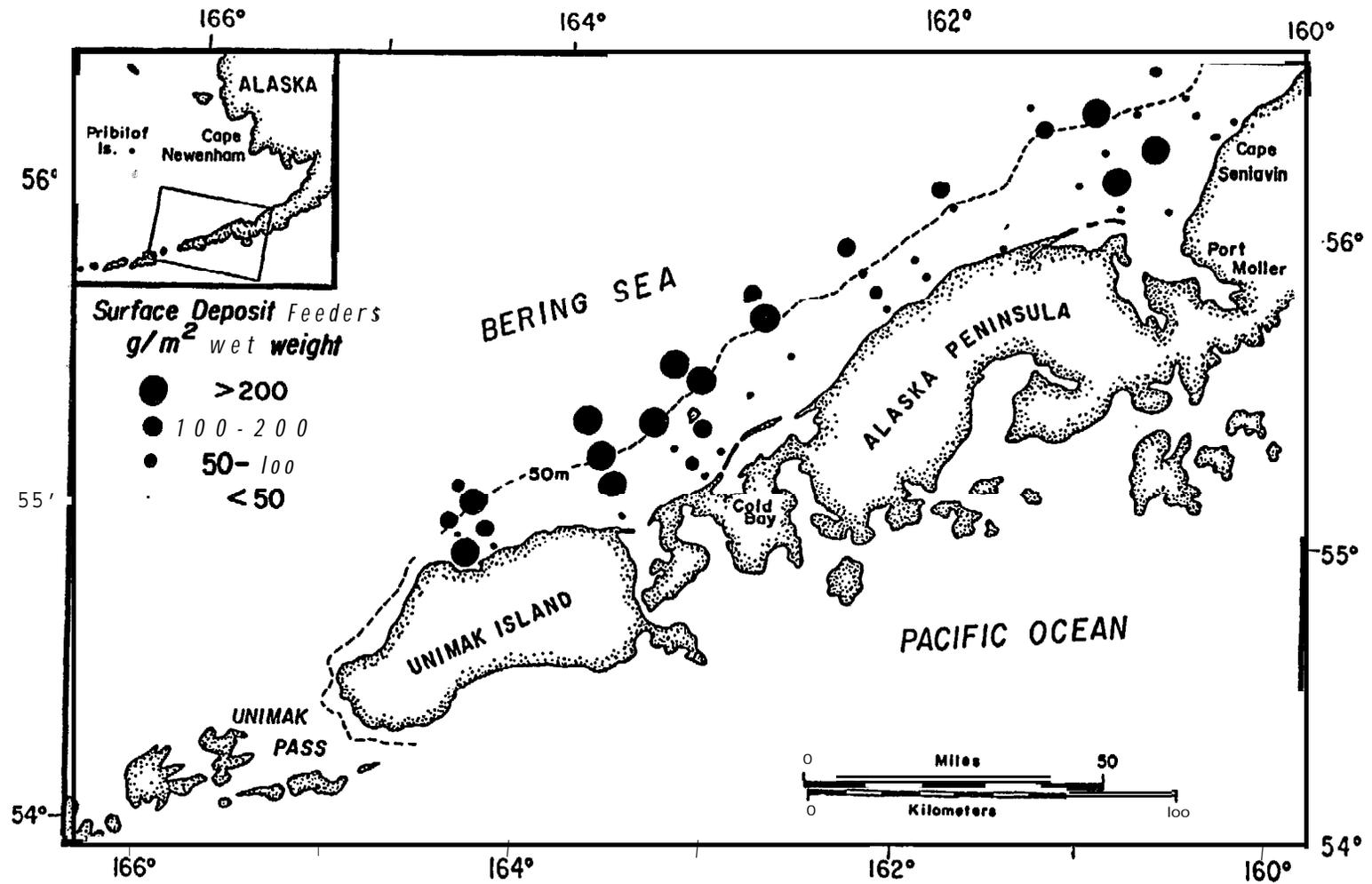


Fig. 4.24. Biomass of surface-deposit feeding invertebrates, estimated from benthic grab samples taken at stations on the NAS, Alaska.

Starfish, top-level predators on the NAS, were collected by **trynet** bottom trawl. Starfish biomass was highest at depths of **30** to **50 m**; no starfish were collected in the 73 trawls taken at depths of 3 to 10 m, as shown below.

| | Depth (m) | | | |
|---------------------------|-----------|---------|---------|---------|
| | 3-10 | 20 | 30-53 | 67-100 |
| Starfish g/m ² | 0 | 0.6±0.9 | 1.2±1.4 | 0.7±1.2 |
| Sample size | 73 | 11 | 16 | 11 |

Crangonid shrimp were the most conspicuous epibenthic animal collected in shallow water, and were the most common decapod collected. They were collected in the **trynet** bottom trawl, epibenthic sled, and drop net. In most cases, the drop net and **trynet** yielded higher estimates than did the sled (Tables 4.14 and 4.15), this indicates that the crangonids were not above the sediment surface, because the drop net and **trynet** sampled on the sediment surface, whereas the sled sampled 11.5 cm off the bottom. All three methods show that biomass of crangonids were highest in shallow water and lowest in deep water, and that in shallow water biomass was highest off Cape Seniavin (Transect 7) and Port Moller (Transect 6) at the eastern end of the study area (Tables 4.14 and 4.15).

Shrimp other than crangonids accounted for only 4% of the total biomass of shrimp collected in sled tows at depths of 3 to 50 m, and were rare in **trynet** tows (only 2 of 261 shrimp collected at seven tows in July 1985 were not crangonids). In shallow (3-10 m) drop net samples, however, shrimp other than crangonids accounted for 42% of shrimp biomass.

Feder and Jewett (1980) did not mention crangonids as being one of the common species collected in a trawl survey of Bristol Bay. Cimberg et al. (1984) found that hippolytid shrimp were the most common decapod shrimp collected in **trynet** tows, and did not find crangonids in any tows on the NAS in 1982. Hippolytid shrimp were relatively rare in the **trynet** tows and sled tows carried out during the present study.

Table 4.14. Mean biomass of crangonid shrimp ($\text{ng}/\text{m}^2 \pm \text{SD}$ wet weight) over six depth ranges sampled by three methods on the NAS. Sample sizes are shown in parentheses. ND means no data.

| Method | Depth (m) | | | | | |
|----------------|---------------------|----------------------|--------------------|--------------------|------------------|------------------|
| | 3 | 5 | 10 | 20 | 30-50 | 54-100 |
| Trinet tow | 307 \pm 511 (22) | 286 \pm 623 (26) | 183 \pm 302 (25) | 154 \pm 263 (11) | 10 \pm 14 (16) | 11 \pm 13 (11) |
| Epibentic sled | 101 \pm 279 (12) | 47 \pm 103 (30) | 39 \pm 103 (35) | 36 \pm 104 (54) | 13 \pm 24 (12) | ND |
| Drop net | 364 \pm 1038 (29) | 1341 \pm 3259 (27) | 0 (3) | ND | ND | ND |

Table 4.15. Mean biomass of crangonid shrimp ($\text{ng}/\text{m}^2 \pm \text{SD}$ wet weight) sampled by three methods at depths of 3 to 10 m on six transects on the NAS. Sample sizes are shown in parentheses.

| Method | Transect | | | | | |
|----------------|-------------------|------------------|--------------------|--------------------|----------------------|---------------------|
| | 0.5 or 1 | 2 | 4 | 5 | 6 | 7 |
| Trinet tow | 82 \pm 198 (14) | 55 \pm 98 (16) | 122 \pm 256 (15) | 15 \pm 10 (5) | 758 \pm 844 (15) | 423 \pm 225 (9) |
| Epibentic sled | 24 \pm 53 (13) | 10 \pm 22 (13) | 38 \pm 111 (20) | 23 \pm 48 (9) | 88 \pm 154 (14) | 48 \pm 76 (7) |
| Drop net | 48 \pm 158 (15) | 0 \pm 0 (5) | 121 \pm 364 (9) | 286 \pm 494 (12) | 1672 \pm 4142 (11) | 3018 \pm 3783 (6) |

Mysids were sampled by drop net, epibenthic sled, and plankton net tows. The first two methods yielded biomass estimates by unit area; the latter provided a mean biomass estimate for the water column. Only the latter method was used **consistently** among sampling periods, so seasonal comparisons of abundance rely mainly on the plankton net results. Tables 4.16 and 4.17 show that biomass estimates based on drop net and sled samples varied widely among water depths and *transects*. The extreme variability obscured any strong patterns, although there was a tendency for the highest biomass to be found in the shallows and at the easternmost stations, as was observed **for** crangonid shrimp. Table **4.18** indicates that the water-column biomass of mysids also varied widely among sampling times; no clear seasonal patterns are evident.

Amphipod biomass estimates are based on results of three different sampling techniques--benthic grab, epibenthic sled, and drop net. Benthic grab results provided the highest estimates (Tables **4.19** and 4.20). Infaunal amphipods (the families Haustoriidae, Corophiidae, and Oedicerotidae) **accounted** for over **90%** of the biomass of amphipods collected in the grab. Most of these amphipods would have been within the substrate, and not effectlvely sampled by the drop net or the epibenthic sled. As with mysids, estimates were highly variable among depths and transects. The highest **biomasses occurred** at the deeper (**10-50 m**) stations. No among-transect (alongshore) pattern was evident.

King crabs (***Paralithodes* sp.**) and Tanner crabs (***Chionoecetes* sp.**) were rare in the study area. Only 29 specimens were collected in 111 bottom trawls taken at depths of **3** to **105 m** during **six** cruises (Table **4.21**). During the July **1985** cruise, virtually no red king crabs were caught **within** the study area even though a specific effort to survey newly settled larvae was conducted by the University of Washington (P. **Denhall, pers. comm.**). The University of Washington effort did collect some juvenile Tanner crabs.

In **1975** and **1976**, Feder and Jewett (**1980**) collected king and/or Tanner crabs at all seven of their stations that *were* within our study area. They collected up to **867** individuals at one station. In **1982**, Cimberg et al. (**1984**) collected insignificant quantities of crabs (**0.4%** of total epifaunal biomass) within our study area. The general decline in crab populations of the entire Bering Sea is reflected in the low

Table 4.16. Mean biomass of mysids ($\text{mg}/\text{m}^2 \pm \text{SD}$ wet weight) sampled by two methods over five depth ranges on the NAS. Sample sizes are shown in parentheses. ND means no data.

| Method | Depth (m) | | | | |
|-----------------|------------------|---------------------|------------------|-----------------|-------------------|
| | 3 | 5 | 10 | 20 | so |
| Epibenthic sled | 101 \pm 25 (8) | 109 \pm 193 (24) | 22 \pm 60 (28) | 6 \pm 24 (46) | 95 \pm 166 (12) |
| Drop net | 23 \pm 69 (29) | 687 \pm 1166 (27) | 79 \pm 98 (3) | ND | ND |

Table 4.17. Mean biomass of mysids ($\text{mg}/\text{m}^2 \pm \text{SD}$ wet weight) sampled by two methods at depths of 3 to 10 m on six transects on the NAS. Sample sizes are shown in parentheses.

| Method | Transect | | | | | |
|-----------------|------------------|-----------------|----------------|--------------------|-------------------|--------------------|
| | 0.5 or 1 | 2 | 4 | 5 | 6 | 7 |
| Epibenthic sled | 9 \pm 24 (8) | 32 \pm 64 (9) | 1 \pm 5 (15) | 33 \pm 54 (9) | 91 \pm 12s (11) | 238 \pm 298 (7) |
| Drop net | 39 \pm 55 (15) | 4 \pm 9 (5) | o (9) | 206 \pm 316 (12) | 14 \pm 20 (11) | 2702 \pm 742 (6) |

Table 4.18. Mean biomass ($\text{mg}/\text{m}^3 \pm \text{SD}$ for bongo nets; $\text{mg}/\text{m}^2 \pm \text{SD}$ for sled tows) of mysids collected in oblique bongo net tows and epiknthic sled tows during six cruises on the NAS. Sample sizes are shown in parentheses.

| | Cruise | | | | | |
|----------------------|-------------------|------------------|-------------|----------------|-----------|------------------|
| | May 1984 | Sept 1984 | Jan 1985 | April 1985 | May 1985 | July 1985 |
| <u>Depth 30-50 m</u> | | | | | | |
| Oblique tows | 0.2 ± 0.5 (11) | 0 ± 0 (11) | 0.1 ± 2 (4) | 0.9 ± 1.2 (5) | 0 ± 0 (4) | 0 ± 0 (6) |
| Sled tows | 95.1 ± 165.8 (12) | ND | ND | ND | ND | |
| <u>Depth 20 m</u> | | | | | | |
| oblique tows | 0 ± 0 (8) | 0.2 ± 0.3 (7) | 5.8 ± 7 (5) | 4.7 ± 10.6 (5) | 0 ± 0 (5) | 0.4 ± 1.1 (7) |
| Sled tows | 1.4 ± 3.2 (18) | 13.9 ± 37.2 (18) | ND | ND | ND | 0.3 ± 0.6 (10) |
| <u>Depth 3-10 m</u> | | | | | | |
| Sled tows | 32.7 ± 71.7 (19) | 104 ± 195 (23) | ND | ND | No | 19.2 ± 55.7 (17) |

ND means no data.

Table 4.19. Mean biomass of **amphipods** ($\text{mg}/\text{m}^2 \pm \text{SD}$ wet weight) sampled by three methods over five depth ranges on the NAS. Sample sizes are shown in parentheses.

| Method | Depth (m) | | | | |
|-----------------|-----------------------|------------------------|---------------------------|----------------------|---------------------|
| | 3 | 5 | 10 | 20 | 50 |
| Grab | 500 \pm 870 (3) | 40 \pm 70 (3) | 1040 \pm 660 (3) | 3830 \pm 3600 (14) | 1190 \pm 1370 (6) |
| Epfbenthic sled | 6 \pm 14 (8) | <1 (24) | <1 (28) | <1 (46) | 4 \pm 10 (12) |
| Drop net | 72 \pm 223 (29) | 7 \pm 17 (27) | 1 \pm 2 (3) | ND | ND |

ND means no data.

Table 4.20. Mean biomass of amphipods ($\text{mg}/\text{m}^2 \pm \text{SD}$ wet weight) collected by three methods on **six** transects and two depth ranges on the NAS. Sample sizes are shown in parentheses.

| Method | Transect | | | | | |
|------------------------|-----------------------|---------------------|------------------------|-----------------------|---------------------------|----------------------|
| | 1 | 2 | 4 | 5 | 6 | 7 |
| <u>Depth 3-10 m</u> | | | | | | |
| Grab | ND | 380 \pm 660 (3) | ND | ND | 1090 \pm 840 (3) | 110 \pm 200 (3) |
| Epibenthic sled | 1 \pm 1 (8) | <1 (9) | 3 \pm 10 (15) | <1 (9) | <1 (11) | 1 \pm 1 (7) |
| Drop net | 34 \pm 109 (15) | 239 \pm 507 (5) | 39 \pm 61 (9) | 6 \pm 8 (12) | 10 \pm 25 (11) | 5 \pm 4 (6) |
| <u>Depth 20-50 m</u> | | | | | | |
| Grab | 1400 \pm 1440 (5) | 3560 \pm 2980 (6) | ND | 6090 \pm 5540 (3) | 3350 \pm 3150 (6) | ND |
| Epibenthic sled | 7 \pm 14 (6) | <1 (8) | <1 (11) | 1 \pm 1 (11) | <1 (14) | <1 (8) |

ND means no data.

Table 4.21. Total number of red king and Tanner crabs collected in bottom trawls on all NAS cruises, 1984 and 1985.

| Transect | Depth (m) | Date | No. Caught | |
|----------|-----------|---------------------|------------|--------|
| | | | Red King | Tanner |
| 4 | 72-74 | Jan/Feb 1985 | 2 | 2 |
| 4 | 50 | Jan/Feb 1985 | 1 | 2 |
| 6 | 22 | Jan/Feb 1985 | 1 | 0 |
| 5 | 50 | Jan/Feb 1985 | 4 | 0 |
| 5 | 105 | Jan/Feb 1985 | 0 | 9 |
| 4 | 75 | May 1985 | 3 | 0 |
| 6 | 50 | May 1984 | 2 | 0 |

abundance of crabs on the NAS during 1982, 1984, and 1985. In samples collected in 1975 and 1976 by Feder and Jewett (1980), crabs were the dominant epifaunal animals at depths of less than 80 m in Bristol Bay (1.8 g/m²; 54% of total biomass), and asteroids were second ranked (0.6 g/m²; 19% of total biomass). Mean biomass of asteroids in 1982 on the NAS at depths of 15 to 60 m (1.2 g/m²; Cimberg et al. 1984) and in 1984-85 at depths of 20 to 105 m (0.9 g/m²; this study) was higher than that found in 1975-76. It could be argued that the modest increase in starfish biomass resulted from the decline in crab populations. However, Feder and Jewett (1980) showed that there appears to be little overlap between the diets of these crabs (bivalves and polychaetes) and that of the asteroids (a wide variety of other invertebrates; see below). The flatfish, primarily yellowfin and rock sole, do feed extensively on bivalves and polychaetes (see 5.0, this report) and could possibly have benefited from declines in crab populations.

Trophic Relationships. With the exception of starfish, which are predatory, the benthic epifauna is supported by a detrital food chain. Starfish consume a wide variety of benthic animals. Asterias amurensis, the dominant starfish on the NAS (Cimberg et al. 1984), is classified as a feeding generalist by Feder and Jewett (1980); dominant food items in Bristol Bay included shrimp, hydrozoans and sand dollars, sponges, barnacles, and fish. Crangonids in Cook Inlet fed on small crustaceans, polychaetes, diatoms and sediment (Feder et al. 1980); they were opportunistic generalist feeders that relied heavily on the sediment detrital food chain. Crangonids are also active predators, but their prey are most often detritivores themselves. Infaunal amphipods in the northern Bering Sea are also mainly detritivores, feeding on sediment and diatoms (Thomson 1984). Mysids may be raptorial predators or filter-feeding herbivores, or they may feed on organic detritus, diatoms and meiofauna at or near the sediment surface; the same species can exhibit different feeding modes (Johnston and Lasenby 1982).

Summary. In summary, epibenthic biomass on the NAS was dominated by starfish, crangonid shrimp, mysids, and amphipods. Starfish, which are top-level predators, were most abundant in waters deeper than 20 m. Shrimp and mysids, which probably feed on phytoplankton and detritus,

tended to be most abundant in waters less than 20 m deep and in the eastern parts of the study area. Amphipods, Pike starfish, were more abundant in deeper areas. It is perhaps noteworthy that the groups preferring shallow water (shrimp, **mysids**) are probably more mobile as individuals than the starfish and amphipods that are more abundant in deeper water; thus, they could rapidly recolonize shallow areas that are periodically disturbed by ice and wave action.

4.5.3.3 Comparison with Previous Studies

There appear to be two differences between the **benthic** community sampled in this study and that of previous (1982) studies on the NAS. First, populations of bivalves seem to have been substantially higher in this study than in 1982. Second, there may have been an increase in populations of crangonid shrimp. These changes could be related to observed declines in crab populations over the last several years. King and Tanner crabs feed extensively on bivalves (Feder et al. 1980, Feder and Jewett 1980), and the decline in crab populations could have reduced predation pressure on the bivalves. (Rock sole and yellowfin sole also feed on bivalves; however, commercial fishing could have kept flatfish populations from increasing in response to this increased food supply.) Snow crabs (*Chionoecetes bairdi*) feed on crangonids in Cook Inlet, and apparently take prey in proportion to abundance (Feder et al. 1980); thus declines in crab populations on the NAS could also have allowed the crangonid populations to increase.

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Section 5

FISH RESOURCES

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