ZOOPLANKTON ECOLOGY OF NORTON SOUND, ALASKA

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ZOOPLANKTON ECOLOGY OF NORTON SOUND, ALASKA

A

THESIS

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By

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ABSTRACT

The zooplankton distribution in Norton Sound was monitored for the Outer Continental Shelf Environmental Assessment Program. Salinity, temperature, and predation were investigated as factors controlling species composition and community structure. Sampling was concentrated along the eastern coast of Norton Sound during July and August, 1976. The copepod *Acartia clausi* and the cladocerans *Evadne sp.* and *Podon sp.* were numerically dominant in the samples. These species are able to tolerate the widely ranging salinities and temperatures of the coastal waters. The *A. clausi* population abundance was correlated with water temperature, while cladoceran and larval mollusc populations were correlated with salinity. No differences in species composition were discerned between stations along the shallow coast; however, the seaward community contained a greater diversity of organisms supporting a larger planktonic carnivore biomass.

Zooplankton was a numerically dominant item in the diets of many fish species, although the epibenthic mysid community was volumetrically most important.

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CHAPTER 1.

INTRODUCTION

What zooplanktons lack in size, they make up for in numbers. This great variety of animals, which floats in the ocean, comprises a vital food source for fish, whales, and humans. Accordingly, in our effort to exploit the food and mineral wealth of the sea, we must be critically aware of the impact our activities may have on the zooplankton community. In order to do so, we must first gather baseline data that will indicate the present abundance and distribution of the various zooplankton species. Further, we must gain insight into the natural factors, chemical, physical, and biological, which influence the zooplankton distribution.

It was not until the late eighteenth century, that strong interest began to develop in planktonic organisms. Naturalists armed with Johannes Mueller's fine-meshed net qualitatively sampled the oceans, content with describing the morphology, life history, and taxonomy of these floating forms. A hundred years elapsed before Hensen, a physiologist, pioneered a new approach to the study of plankton. Unlike the naturalists preceding him, Hensen was concerned with processes, developing methods for quantitative sampling to determine the spatial and temporal distribution and abundance of organisms (Currie, 1972).

William Scoresby (1820, cited by Currie, 1972), studying samples collected on whaling voyages, was first to recognize the vital role of plankton in the Arctic. Redburn (1974) provided a thorough review of subsequent Arctic research, and Motoda and Minoda (1972) summarized work in the Bering Sea.

In May, 1974, the Bureau of Land Management (BLM) of the Department of the Interior requested the National Oceanic and Atmospheric Administration (NOAA) to perform an environmental assessment of the Northeastern Gulf of Alaska in preparation for oil and gas lease sales scheduled for 1976. The objectives of the BLM-NOAA study were to identify critical marine habitats, and to develop methods for predicting and monitoring the impact of energy resource development. Equipped with that information, the Department of the Interior could better formulate sound management, leasing, and regulatory decisions to maximize the return of oil, while minimizing the environmental costs.

In October, 1974, eight areas were added to the study. One of these was Norton Sound, in the northern Bering Sea, scheduled for leasing in December, 1981 (U.S. Department of Commerce, 1977). Previous zooplankton investigations there had not penetrated eastward much beyond the mouth of the Sound (Johnson, 1953; Zenkevitch, 1963, pp. 828-834; Motoda and Minoda, 1972). Motoda and Minoda (1972) found a gradation of species across the oceanic regime into the Bering Sea (Figure 1). At the mouth of Norton Sound, they reported

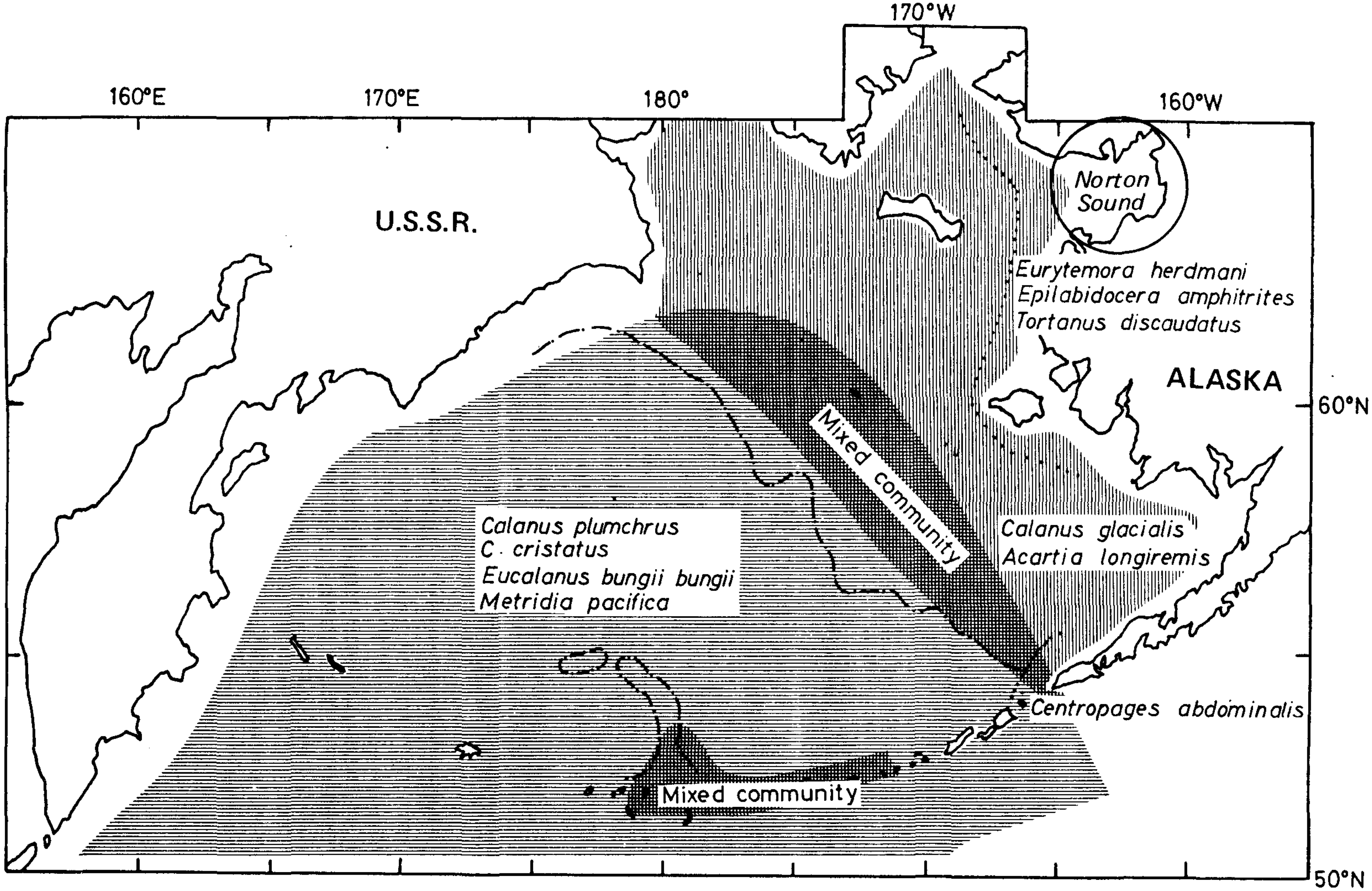


Figure 1. Regional distribution of Bering Sea copepod communities in the upper water in early to mid-summer (Motoda and Minoda, 1972). The circle surrounds Norton Sound.

a predominance of the copepods Eurytemora herdmani, Epilabidocera amphitrites, and Tortanus discaudatus. Johnson (1953) collected Centropages abdominalis, Acartia longiremis, and Acartia clausi in that area, but species in the eastern end of the sound were not known previous to the 1976 and 1977 NOAA-BLM Outer Continental Shelf Environmental Assessment Program (OCSEAP). As part of that study, I chose to sample the eastern coastal waters. It is in the coastal zone that the effects of development and resource exploitation may be especially noticeable.

Although plankton data in Norton Sound were limited, background information from a presumably analagous region, Kotzebue Sound, in the Chukchi Sea, did exist. Studies were undertaken there between 1959 and 1966, to predict the environmental impact of Project Chariot, a proposed experimental harbor excavation using nuclear devices. The project was part of the United States Atomic Energy Commission's Plowshare Program to establish peaceful uses for nuclear explosives (Wilimovsky and Wolfe, 1966).

The southeastern Chukchi Sea is influenced by a northern current flowing through the Bering Strait. The water originates in the southeastern Bering Sea and is modified by Yukon River outflow south of Norton Sound (Fleming and Heggarty, 1966). The zooplankton composition in outer Kotzebue Sound reflects the influence of Bering Sea water, while along the coast neritic species thrive in the warmer, less saline environment (English, 1966). Similarly, outer Norton Sound contains Bering Sea water, while its coastal zone and surface waters are freshened with input from rainfall, the Yukon River in the southwest, and other smaller rivers in the east (Nebert, 1974).

Would the distribution of zooplankton in Norton Sound be divided between inner continental shelf and neritic coastal species as is the case in Kotzebue Sound? The purpose of my study was to describe the composition and the spatial and temporal distribution of the summer zooplankton community along the eastern coast of Norton Sound, and to compare this community with a more seaward assemblage examined by other OCSEAP investigators. I hoped that concurrent monitoring of salinity and water temperature could provide a basis for understanding the patterns of distribution and abundance of zooplankton.

CHAPTER 2.

MATERIALS AND METHODS

2.1. Field Investigations

Coastal zooplankton collections were obtained in cooperation with the Alaska Department of Fish and Game (ADF&G), conducting an OCSEAP census of fish species between Tolstoi Point and Cape Denbigh, Norton Sound during the summer of 1976. Replicate zooplankton tows were taken at each fishing site (Figure 2). In order to determine which species were preying upon zooplankton, the foreguts of sampled fish were removed and preserved in 10% formalin. Small fish specimens were preserved intact following abdominal injections of Formalin.

The zooplankton sampling design was necessarily flexible, dependent upon weather conditions and the schedule of ADF&G. At nine of the stations, samples were obtained in both July and August. Since every sample could not be adequately examined due to limited time and resources, four samples from each of the nine stations were examined (Appendix A). The 36 samples represented 4 periods of summer study, early July (Period I), late July (Period II), early August (Period III), and late August (Period IV).

The water depth at the coastal stations was less than 10 m. Zooplankton was captured by a 2.5 m long, 0.5 m diameter, conical ring net of 0.333 mm Nitex mesh, towed

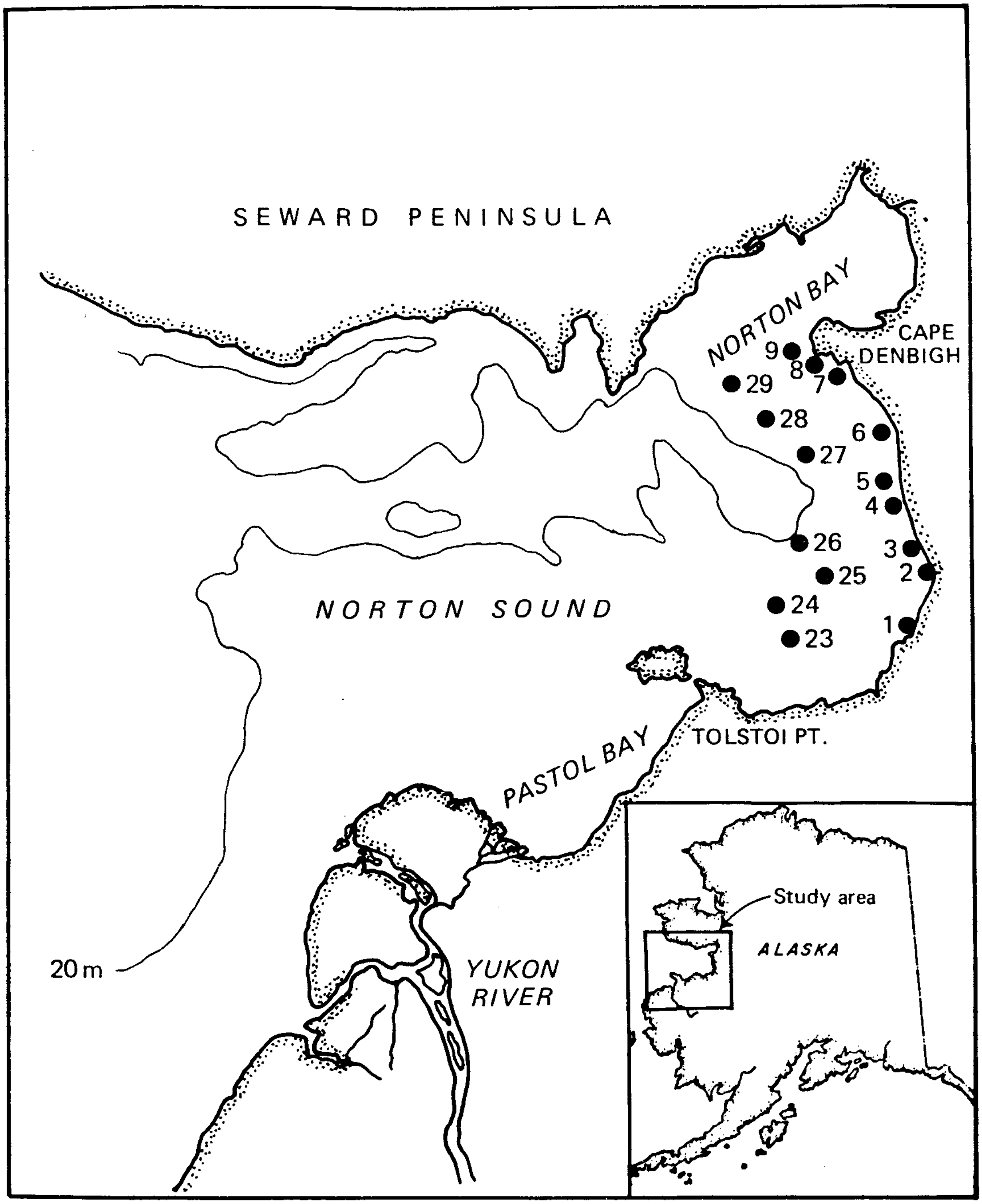


Figure 2. Locations of the coastal study area stations (1-9) and Discoverer cruise stations (23-29) in eastern Norton Sound, 1976.

behind a 7 m flat bottomed skiff. A flowmeter was hung in the mouth of the net between the center bridle bar and net ring. The cod end of the net was a plastic cup with windows of 0.333 mm mesh to allow filtration. The tows were taken horizontally, hauling the net 1 m below the surface for 5 minutes at a rate of 1 meter per second. Station positions were located by visual fixes of onshore topography. Distance from the stations to shore (typically 1 km) varied, but was sufficient to insure a depth of at least 1 to 2 m. Collections were preserved in 10% formalin. No attempt was made to include the occasionally voluminous amounts of medusae.

Salinity bottles were filled by holding them below the water's surface, and water temperature was measured with a thermometer placed in a bucket sample of surface water.

Zooplankton at offshore stations in the Bering and Chukchi Seas was collected by OCSEAP investigators aboard the NOAA oceanographic survey ships Discoverer (cruise 002, 1976) and Surveyor (cruise SU77, 1977). A 1 m diameter Nitex net, 0.333 mm mesh, was lowered to bottom (10-50 m) and then hauled vertically to the surface. A few shallow water coastal samples were obtained using boats launched from these ships. The boats towed 0.5-m ring nets horizontally, 1 m below the surface.

2.2. Laboratory Investigations

The 36 selected coastal samples were processed at the Marine Sorting Center, University of Alaska. Large, rare items including arrow worms, small medusae, larval fishes, and decapod larvae were counted and removed. The remainder of the sample was poured into a graduated beaker. Water was added to a known volume appropriate for the estimated volume of sample being diluted. From this diluted sample, 5 ml aliquot subsamples were drawn with a Hensen-Stempel pipet. Enough subsamples were enumerated under a stereomicroscope to count at least 100 members of the most dominant taxon. The common organisms, primarily copepods, were identified to species whenever possible.

Sample dry weights were obtained using the method of Lovegrove (1966). For seven of the 1977 Surveyor cruise samples, along an east-west transect across Norton Sound, the sorted large items were dried and weighed separately from the rest of the zooplankton (Figure 3; see also Appendix B). This procedural change followed observations that the 1976 samples collected from the Discoverer at offshore stations contained a proportionately greater volume of these items than samples from the coastal study area.

Water sample conductivity was measured with a Hytech Induction Salinometer, and then converted to salinity using the Bennett (1976) equations.

The contents of fish foreguts were identified and

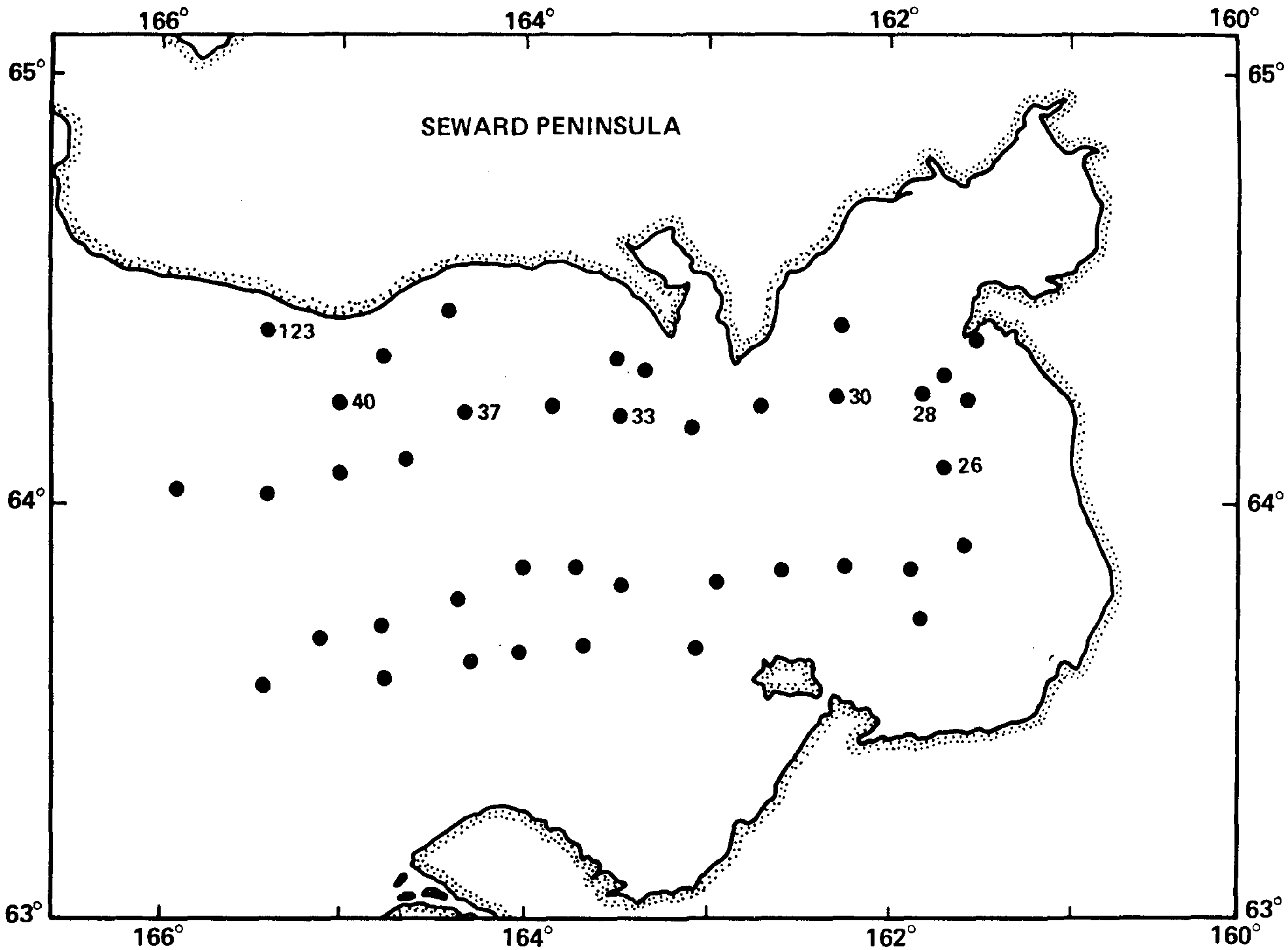


Figure 3. Locations of the Surveyor cruise stations in Norton Sound, 1977. Station numbers are indicated where planktonic herbivore and carnivore biomass were compared.

counted. For stomachs containing hundreds of prey items, a subsample was taken with the Hensen-Stemple pipet in the manner described for the zooplankton collection. Gut fullness and the percent abundance by volume of food items was judged subjectively due to the difficulty of obtaining accurate measures of small wet volumes.

2.3. Statistical Analyses

Statistical analyses were facilitated with the Universtiy of Alaska Honeywell digital computer. An analysis of variance (ANOVA) program (Ullrich and Pitz, 1977) was used to test for differences between the four periods or the nine stations, with respect to temperature, salinity, the abundance of major species (those occurring in over 30% of the samples) and total counts of all organisms. Abundance data were normalized with a base 10 logrithmic transformation (Sokal and Rohlf, 1965, pp. 382-384). Although replicate tows were taken, only one zooplankton sample per period was examined at each station; hence, only single classification, fixed treatment ANOVAS could be employed. Sample data from each station was pooled as nine "replicate" observations in each period to examine temporal differences. Data from each period was pooled as four "replicates" to examine station differences.

The null hypothesis being tested in each case was that the means of the test groups (either stations or periods) came from the same population. Sample group means were plotted with 95% confidence limits calculated using the equation:

$$x_i \pm t(MSE/n_i)^{0.5}$$

where x_i is the mean of the ith group after any data transformation, MSE is the mean square error calculated in the ANOVA (the average variance of the groups, thought to be the best estimate of the variance about each mean), n_i is the number of replicate observations in the ith group, and t is Student's t statistic for a two-tailed test at the 0.05 significance level with the number of degrees of freedom associated with the MSE (Zar, 1974, p. 139).

A Pearson product-moment correlation analysis was used to test the hypothesis that variations in the abundance of one species could be associated with changes in the abundance of other species. Linear regression analysis, with an ANOVA about the regression line (Sokal and Rohlf, 1965, p. 726) tested the supposition that any variation in species abundance was caused by changes in salinity or temperature. This statistical test was also used to determine whether the dry weight proportion of the large sorted items in the 1977 samples was a linear function of surface salinity or temperature.

Period, station, and coastal-offshore differences in copepod or total zooplankton diversity, measured with the Shannon index, were tested with the nonparametric Kruskal-

Wallis ANOVA following the example of Nybakken (1978). The index was calculated using the equation:

$$H = -\sum_{i=1}^{K} p_i \log_{10} p_i$$

where H is the Shannon index of diversity, K is the number of species, and p_i is the proportion of the community belonging to the ith category. The Shannon index was selected, as it is one of the most commonly encountered indices and has been used with copepod species (Gueredrat, 1971). It considers both components of diversity; species richness, the total number of species, and equitability, the evenness of distribution of individuals among species (Whittaker, 1972). These two factors were also calculated separately since it is sometimes preferable to investigate these components independently (Odum, 1969):

Species Richness = K and Equitability (J) = $H/\log_{10}K$

where K is the number of species, and the log of K is the theoretical maximum value for H, the Shannon diversity index with K species (Pielou, 1966).

Due to limited time and resources, zooplankton taxa other than copepods were usually not identified to the species level. The diversity indices calculated for the zooplankton community actually considered taxa rather than species richness. For this reason the index values should be considered useful only for the comparison of samples within this study. Values determined for copepod diversity have a more exact meaning and general utility since only harpacticoids and the Pseudocalanus complex could not be readily identified to the species level. Seven of the offshore samples collected on August 8, 1976, by the Discoverer along the nearest transect paralleling the eastern coast of Norton Sound were selected for a comparison of diversity with the nine coastal station samples collected during early August (Figure 2).

Selective predation on zooplankton was studied by computing Ivlev's electivity index (Ivlev, 1955, p. 45):

$$E = (r_i - p_i)/(r_i + p_i)$$

where E, electivity, varies between -1, complete avoidance, and +1, total consumption, p_i is the percentage abundance of the ith category of zooplankton in the water column, and r_i is the ration, or percentage of that category in the plankton consumed. Each zooplankton category that had a numerical abundance of at least one individual per thousand in the 36 coastal samples was included. The ration was calculated after pooling stomach contents from all species.

Differences among predators in their selection of major zooplankton prey, Acartia spp., Eurytemora spp., Podon sp., and Evadne sp. were also examined. The mean relative percentage numerical abundance of these four major prey items in the diets of the saffron cod, (*Eliginus gracilis*, n=16), the rainbow smelt (*Osmerus mordax dentex*, n=12), and 7 other species of planktivores (n=13), were compared to each other and to the relative abundance of these zooplanktons in the plankton community by using t-tests. When an F-test indicated that the variances of the samples were heterogeneous, an approximation of the t-statistic was calculated (Nie, et al., 1974, pp. 267-271).

CHAPTER 3.

RESULTS

3.1. Temperature and Salinity

In Norton Sound, a temperature and salinity gradient exists from western ocean- to eastern river-influenced waters (Figures 4 and 5). Salinity and temperature contours suggest that a portion of the Yukon plume flows eastward following the shoreline. This interpretation is supported by sediment plume tracer studies (Burbank, 1974). The highest temperatures and lowest salinities were observed in the coastal study area. Observations made during collection of the 36 coastal zooplankton samples indicated variable temperatures (8 to 21°C), and salinities (13 to 28‰, Appendix A). Period differences were statistically discernable, while station differences were not (Table 1). Melting of sea ice caused salinities and temperatures to be low in early July, but these had increased by early August. Salinities continued to rise in late August, while temperatures declined (Figure 6).

3.2. Zooplankton Species Composition and Abundance

The coastal study area was populated by 66 taxa of zooplankton (Table 2; see also Appendix C). Most striking was the distinct numerical dominance of *Acartia clausi*, followed by the cladocerans *Podon* sp. and *Evadne* sp., totaling 93% of the individuals collected (Table 3). Other

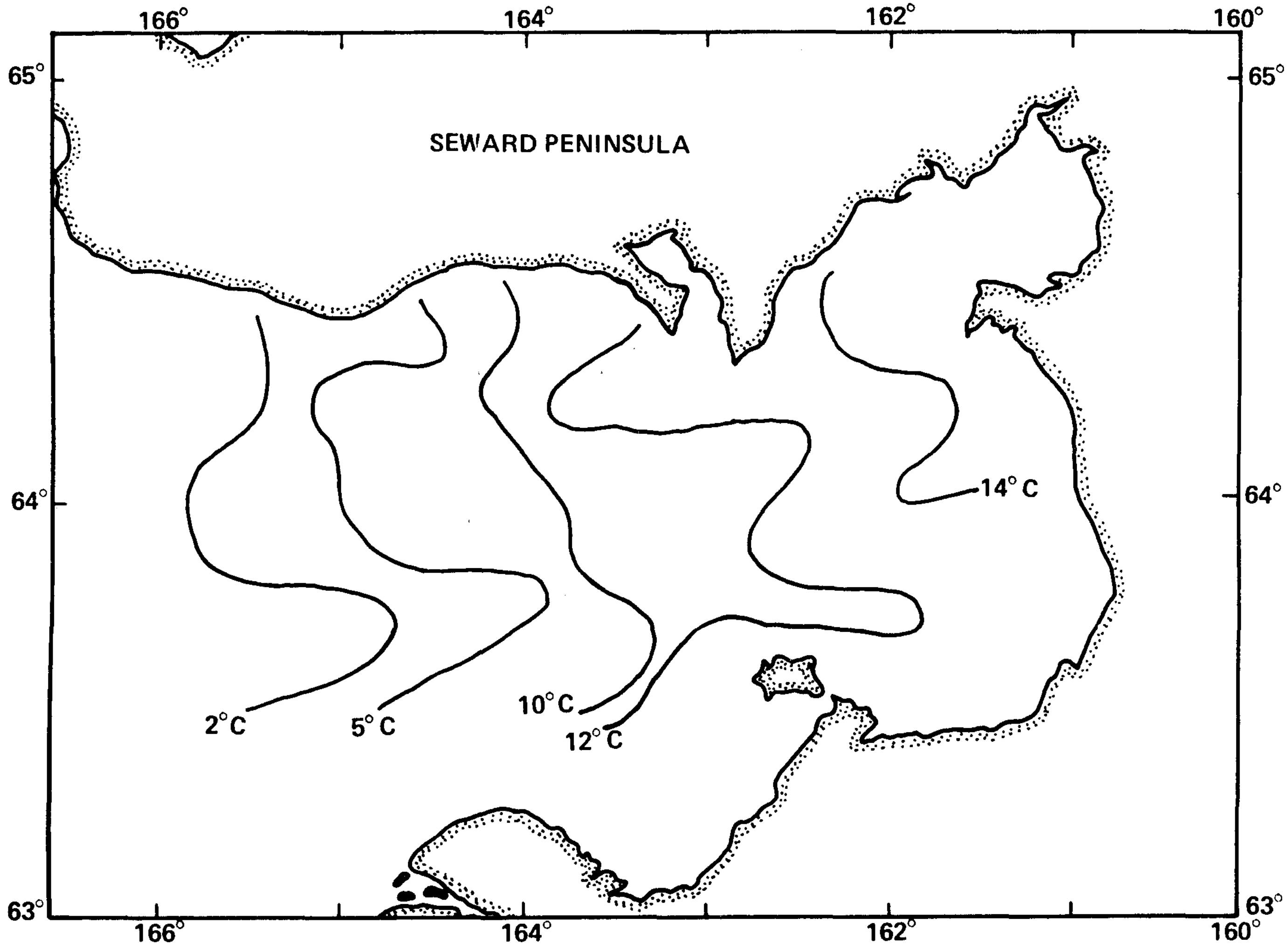


Figure 4. Sea surface temperature contours during the June to July, 1977, *Surveyor* cruise in Norton Sound.

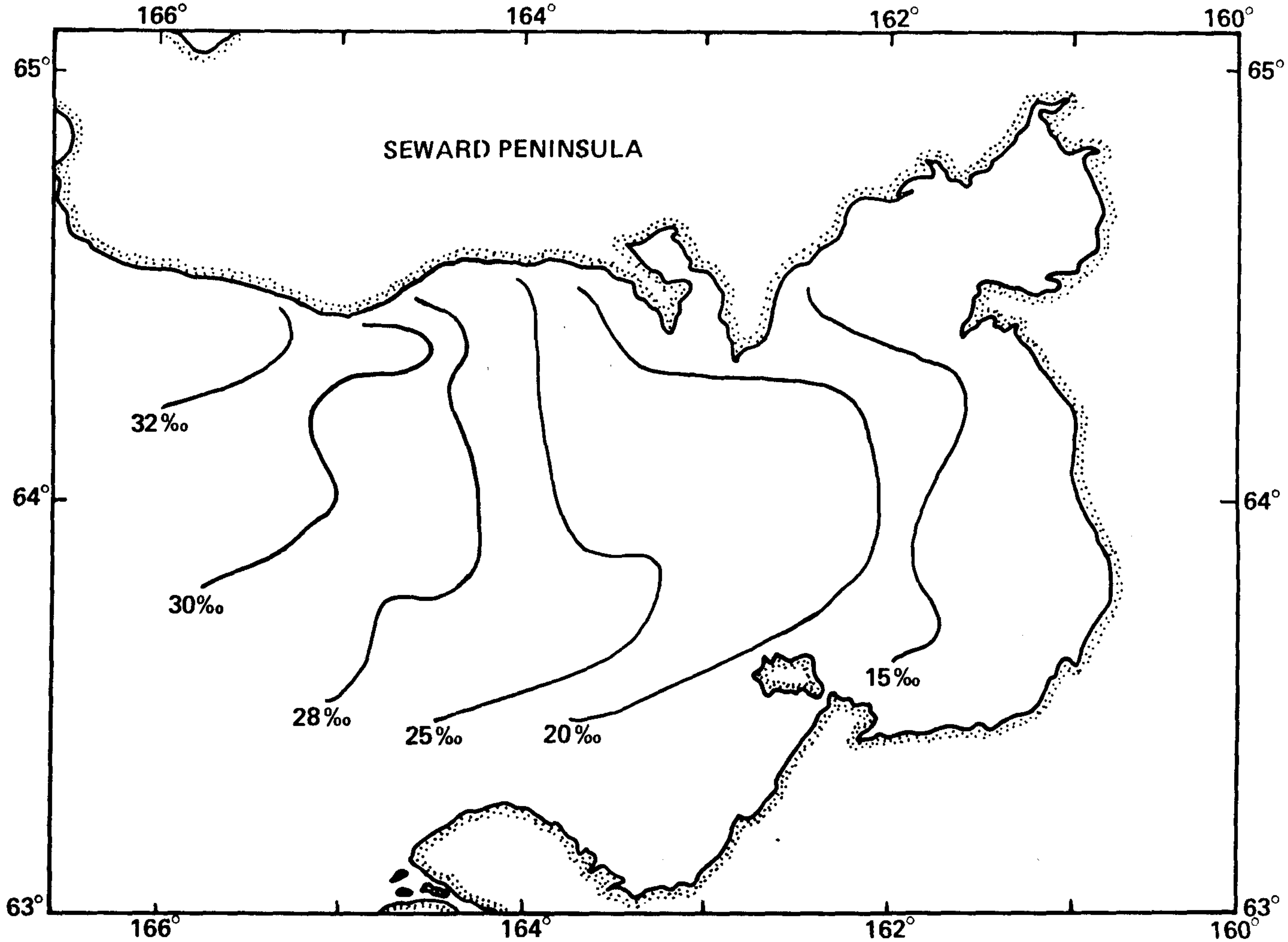


Figure 5. Sea surface salinity contours during the June to July, 1977, *Surveyor* cruise in Norton Sound.

Table 1. ANOVA of period and station effects on salinity and temperature.

Physical Factor	Statistical Significance+: Treatment: Period F‡	df#	Station F	df
Salinity	**	3,32	NS	8,27
Temperature	**	3,31	NS	8,26

+H_o: There was no period or the station effect on salinity or temperature. Reject H_o for significant treatments.

‡NS not significant, P>0.05
* significant, 0.01<P≤0.05
** significant, P≤0.01

#Degrees of freedom are one less for temperature since temperature data was not collected at one station.

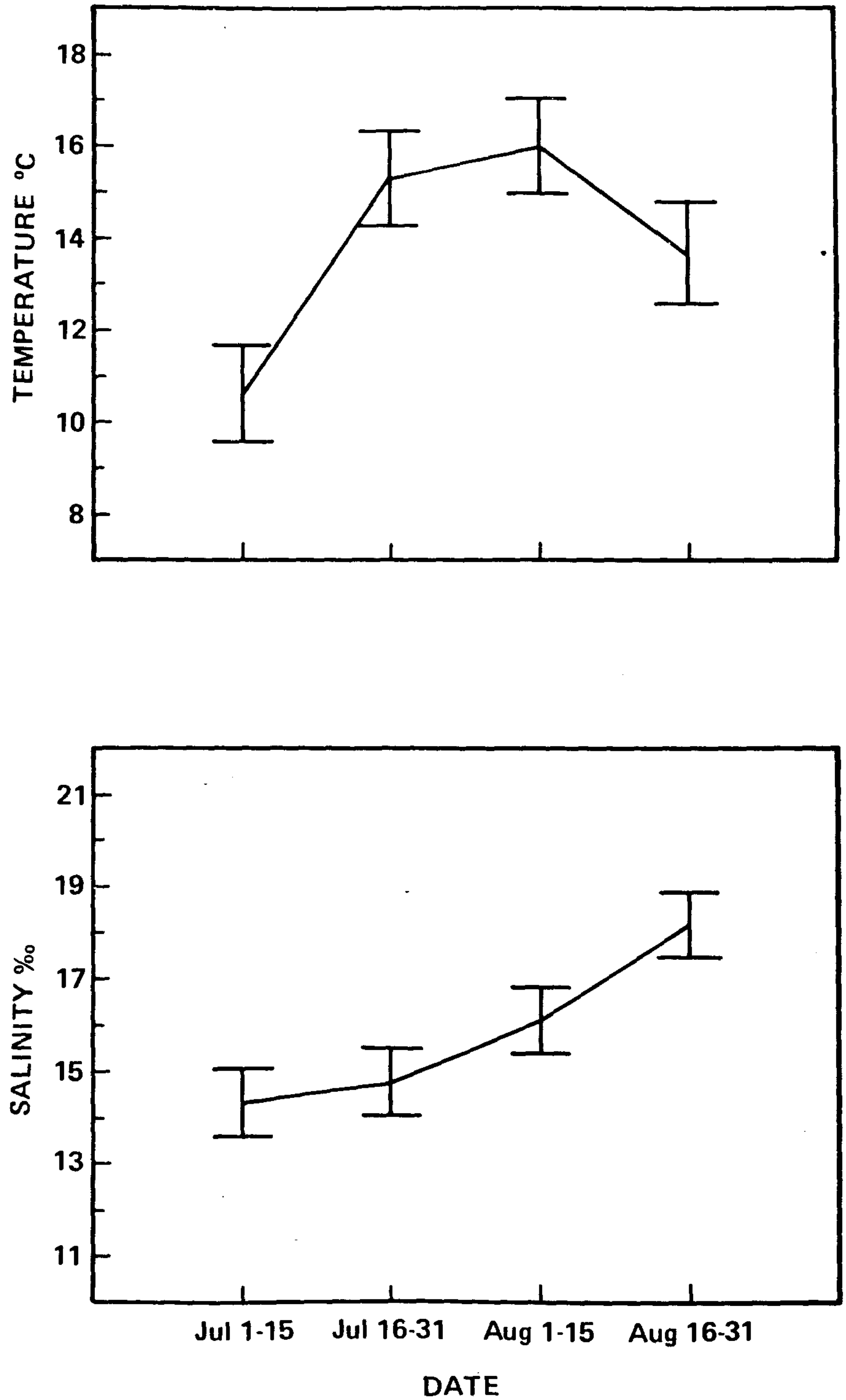


Figure 6. Temporal patterns in temperature and salinity at the Norton Sound coastal stations during July and August, 1976. Mean values of the 9 coastal stations are plotted with the 95% confidence intervals displayed.

Table 2. Zooplankton taxa collected in the Norton Sound coastal study area, July - August, 1976.

Zooplankton Taxa
Copepoda
Copepod nauplii
Acartia bifilosa
Acartia clausi
Acartia longiremis
Calanus spp.
Calanus glacialis
Centropages abdominalis
Epilabidocera amphitrites
Eurytemora spp.
Eurytemora americana
Eurytemora herdmani
Eurytemora pacifica
Pseudocalanus spp.
Tortanus discaudatus
Ectinosma sp?
Harpacticus sp?
Cladocera
Evadne sp.
Evadne nordmanni
Podon sp.
Podon leukarti
Cirripedia
Cirripedia cypris and nauplius stages
Mysidacea
Mysidae juvenile
Cumacea
Cumacea unident.
Diastylis sp.
Lamprops sp.
Atylus collingi
Calliopiidae
Calliopius laeviusculus
Hyperia galba
Decapoda
Crangonidae zoea
Hydrozoa
Hydromedusa juvenile
Obelia sp.
Obelia longissima
Perigonimus sp.
Rathkia sp.

Table 2. continued

Zooplankton Taxa

Scyphozoa
- Scyphozoa juvenile
- *Aurelia sp.*
- *Aurelia limbata*
- *Cyanea capillata*

Polychaeta
- *Autolytus sp.*
- *Eteone sp.*
- *Magelona sp.*
- Spionidae
- Syllidae?

Mollusca
- Bivalve veligers
- Gastropod veligers

Insecta
- Insecta unident.
- Diptera
- Homoptera
- Hymenoptera

Echinodermata
- Asteroidea (brachiolaria larvae)
- Echinoidea (echinopleuteus larvae)
- Holothuroidea (auricularia larvae)
- Ophiuroidea (ophiopluteus larvae)

Chaetognatha
- *Sagitta sp.*

Urochordata
- Tunicata unident.

Teleostei
- Teleostei larvae unident.
- Teleostei eggs unident.
- *Ammodytes hexapterus*
- *Clupea harengus*
- Cottidae
- *Liopsetta glacialis*
- *Osmerus sp.*
- *Platichtys stellatus*
- Pleuronectidae
- Stichaeidae

Table 3. Occurrence of zooplankton taxa in the Norton Sound coastal samples, July - August, 1976.

Taxonomic Category	Mean Numerical Abundance[1] No./m^3	Dominance % Abundance	Frequency of Occurrence[2] %
Acartia clausi	1601	61	100
Podon sp.	508	19	89
Evadne sp.	339	13	86
Pseudocalanus spp.	32	1	44
Centropages abdominalis	28	1	61
Gastropod veligers	28	1	31
Bivalve veligers	25	1	33
Eurytemora pacifica	14	1	69
Eurytemora herdmani	14	1	39
Acartia bifilosa	7	<1	14
Crangonidae zoea	3	<1	81
Cirripedia	3	<1	28
Tortanus discaudatus	2	<1	25
Obelia longissima	2	<1	8
Acartia longiremis	1	<1	8
Spionidae	1	<1	8
Obelia sp.	P	<1	17
Copepod nauplii	P	<1	6
Teleost eggs	P	<1	8
Cyanea capillata	P	<1	39
Clupea harengus	T	<1	47
Insects (unidentified)	T	<1	6
Pleuronectidae	T	<1	14
Stichaeidae	T	<1	6
Diptera	T	<1	25
Autolytus sp.	T	<1	22
Platichthys stellatus	T	<1	8
Sagitta sp.	T	<1	17
Lamprops sp.	T	<1	14
Ammodytes hexapterus	T	<1	6

[1] Present (P) implies less than one individual per cubic meter, while trace (T) means less than one individual per 10 cubic meters.

[2] Taxa which occurred in only 1 of the 36 processed samples were not included in this table.

copepods and gastropod and bivalve veligers accounted for an additional 6%, with less than 1% divided among the remaining 44 taxa. Acartia clausi, Podon sp., and Evadne sp. were also the most frequently occurring organisms, appearing in 100%, 89%, and 86% of the samples respectively; however, Crangonidae zoea (81%), the larval herring, Clupea harengus pallasi (47%), the scyphozoan, Cyanea capilata (39%) and other taxa with low mean abundances appeared in a large number of samples. Even though many of these taxa contained organisms substantially larger than copepods, the taxa were not populous enough to challenge the dominance of Acartia clausi and the cladocerans.

A total of 12 taxa occurred in over 30% of the samples. In no instance could any significant differences in species abundance be discerned between stations, but 5 of those taxa did display abundance changes between periods (Table 4 and Figure 7). A comparison of aliquots within several samples indicated that less than 0.2% of this variability could be attributed to laboratory sampling error.

The cladoceran populations had peak abundances during late July. This increased zooplankton abundance to a maximum mean value of 3,400 organisms/m^3 from an early July low of only 1,000 organisms/m^3. Biomass and total count measures of zooplankton abundance were correlated. The increase in abundance of Acartia clausi during early August prevented the total counts from decreasing significantly, as

Table 4. ANOVA of period and station effects on zooplankton abundance.

Taxonomic category	Period F‡	Period df	Station F	Station df
	Statistical Significance[+]			
	Treatment			
Scyphozoa				
Cyanea capillata	NS	3,32	NS	8,27
Mollusca				
Bivalve veligers	*	3,32	NS	8,27
Gastropod veligers	**	3,32	NS	8,27
Cladocera				
Evadne sp.	**	3,32	NS	8,27
Podon sp.	**	3,32	NS	8,27
Copepoda				
Acartia clausi	*	3,32	NS	8,27
Centropages abdominalis	NS	3,32	NS	8,27
Eurytemora herdmani	NS	3,32	NS	8,27
Eurytemora pacifica	NS	3,32	NS	8,27
Pseudocalanus spp.	NS	3,32	NS	8,27
Decapoda				
Crangonidae zoea	NS	3,32	NS	8,27
Teleostei				
Clupea harengus pallasi	NS	3,32	NS	8,27
Total abundance for all taxa	*	3,32	NS	8,27

[+] H_o: There was no period or the station effect on zooplankton. Reject H_o for significant treatments.

‡NS not significant, $P>0.05$
* significant, $0.01<P\leq 0.05$
** significant, $P\leq 0.01$

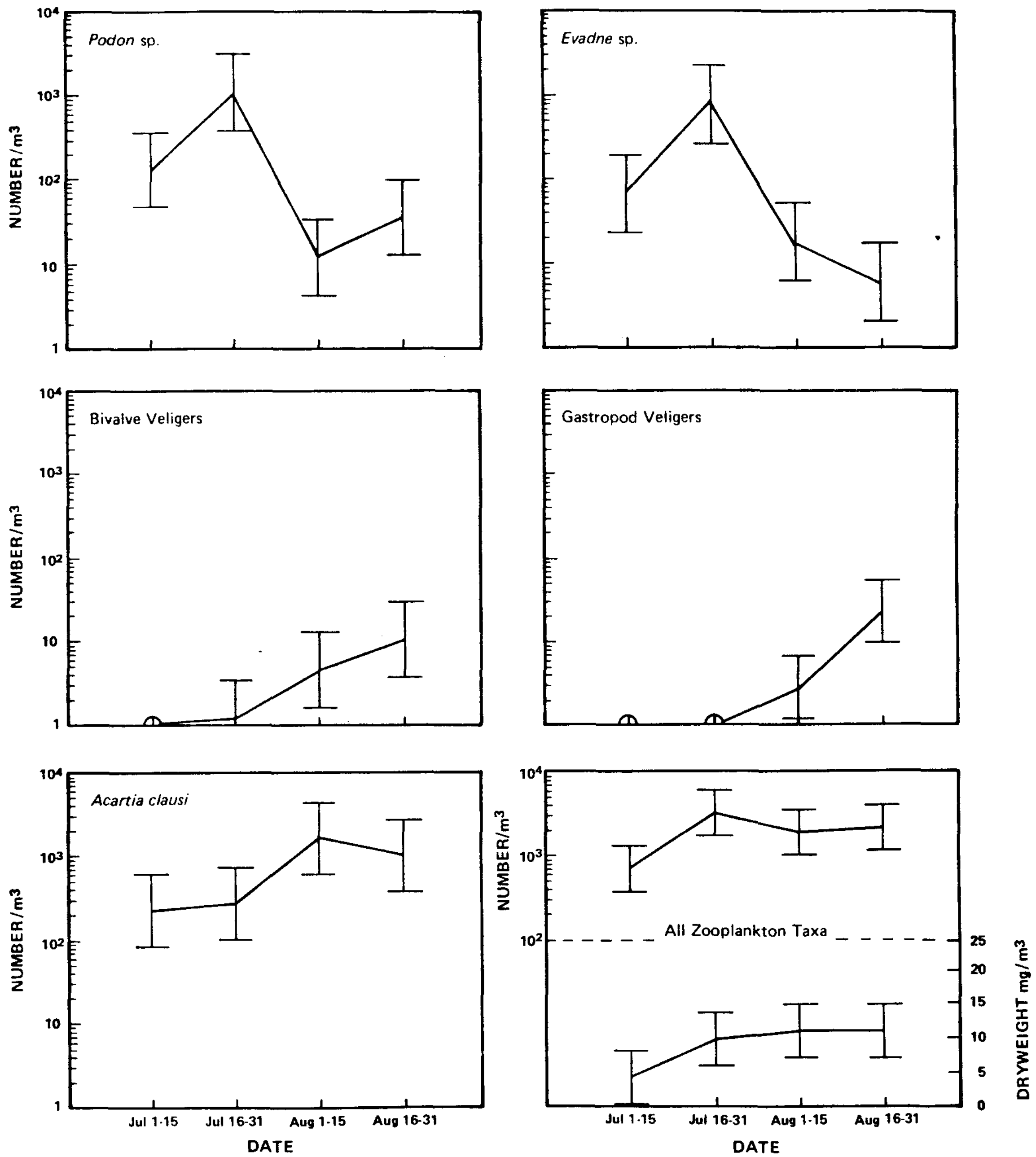


Figure 7. Temporal patterns in the abundance of zooplankton taxa at the Norton Sound coastal stations during July and August, 1976. Mean values of the 9 coastal stations are plotted with 95% confidence intervals displayed. The symbol (∩) indicates that none of the taxa were sampled in that period.

Podon sp. and *Evadne sp.* declined in number. It was during this period that molluscan veligers began to appear regularly in the zooplankton samples augmenting their numbers by late August (Figure 8).

Significant positive correlations were obtained between the veliger populations suggesting response to the same set of environmental parameters (Tables 5 and 6). Veliger abundance increased with rising salinities. The two cladoceran populations were also correlated. Their numbers declined as salinities increased. Increases in the abundance of *Acartia clausi* were dependant upon rising temperatures rather than salinity. In the coastal samples, congeners of *Acartia* and *Eurytemora* did not display obvious habitat separation along the parameters of salinity or temperature (Figures 9 and 10).

In the 1977 *Surveyor* samples *Acartia clausi* was the dominant taxon at station 26 near the coastal study area. *Pseudocalanus spp.*, *Calanus glacialis*, and *Calanus sp.* copepodites were dominant westward to the mouth of Norton Sound where the influence of Bering Sea water increased. While the coastal samples were composed primarily of small herbivorous copepods and cladocerans, the offshore samples contained a greater percentage of chaetognaths, larval fish, and other zooplanktonic carnivores (Appendix D). The ratio of herbivore to carnivore biomass in *Surveyor* cruise samples was highest in eastern Norton Sound because of the decreased

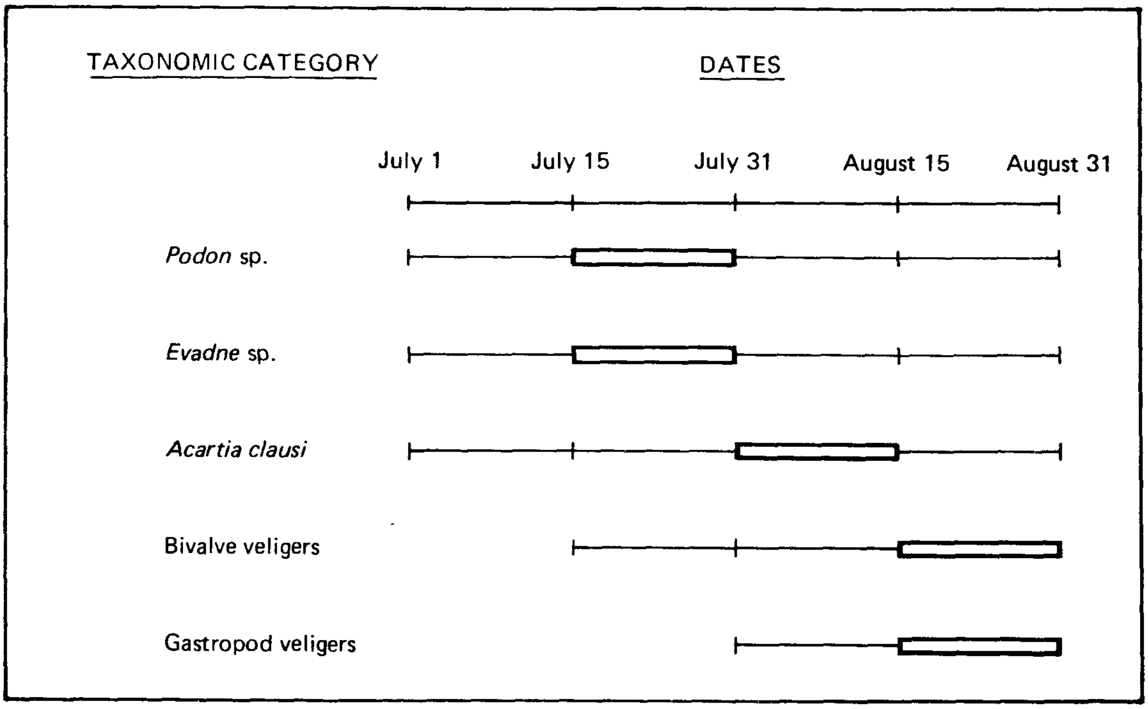


Figure 8. Temporal sequence of the appearance (├──┤) of zooplankton taxa at the Norton Sound coastal stations. Periods of maximum numerical abundance (▭) are displayed.

Table 5. Correlation analyses between selected pairs of zooplankton taxa.

Taxonomic Category	r	Significance[+,‡]	df
Bivalve with gastropod veligers	+0.45	**	1,34
Evadne sp. with *Podon* sp.	+0.76	**	1,34
Acartia clausi with *Evadne* sp.	-0.26	NS	1,34
Acartia clausi with *Podon* sp.	-0.31	NS	1,34

[+]H_o: There is no correlation between the pairs of species. Reject H_o for significant Pearson product-moment (*r*) values.

[‡]NS not significant, $P>0.05$
** highly significant, $P<0.01$

Table 6. Regression analyses of temperature and salinity on zooplankton abundance.

Taxonomic Category	Temperature r	Temperature F‡	Temperature df	Salinity r	Salinity F	Salinity df
	Correlation coefficient (*r*) and statistical significance[+] of the ANOVA about the regression line					
Mollusca						
Bivalve veligers	+0.27	NS	1,33	+0.47	*	1,34
Gastropod veligers	+0.23	NS	1,33	+0.65	**	1,34
Cladocera						
Podon sp.	+0.01	NS	1,33	-0.41	*	1,34
Evadne sp.	+0.12	NS	1,33	-0.59	**	1,34
Copepoda						
Acartia clausi	+0.45	*	1,33	+0.23	NS	1,34
Total abundance for all taxa	+0.40	*	1,33	+0.09	NS	1,34

+ H_o: Changes in salinity or temperature do not affect changes in zooplankton taxa. Reject H_o for significant F values.

‡NS not significant, $P>0.05$
* significant, $0.01<P\leq 0.05$
** significant, $P\leq 0.01$

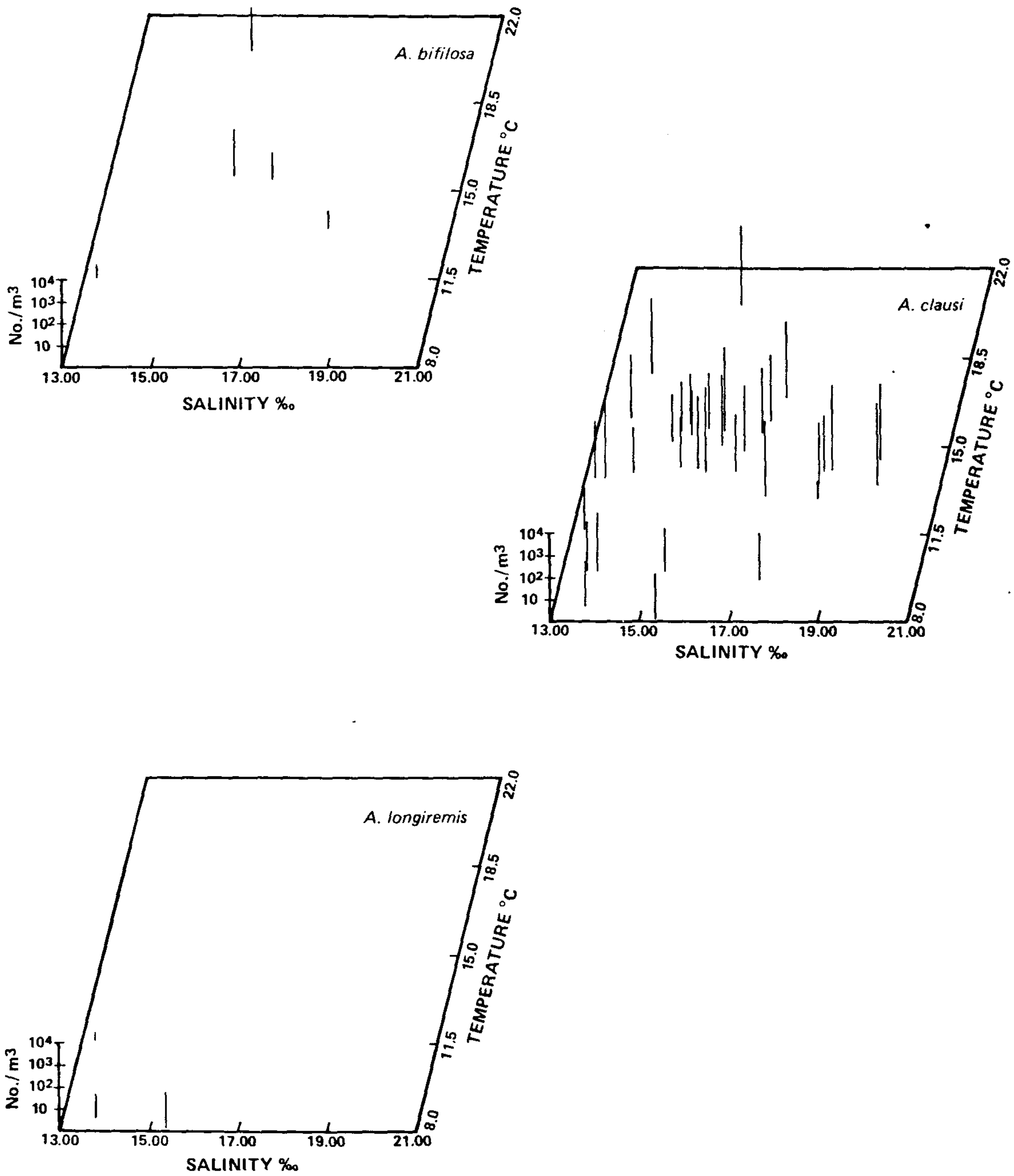
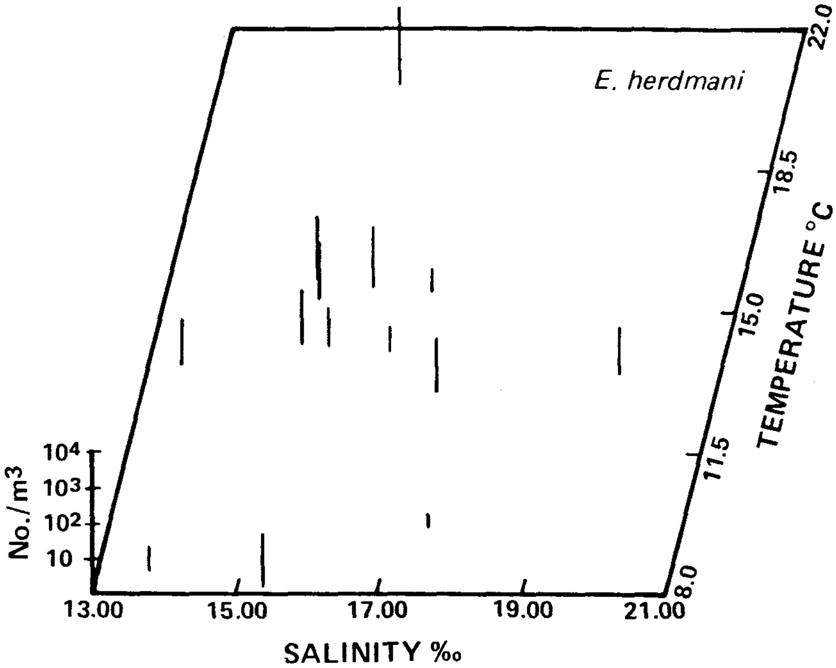


Figure 9. Abundance of Acartia congeners in coastal samples collected at the indicated salinities and temperatures.



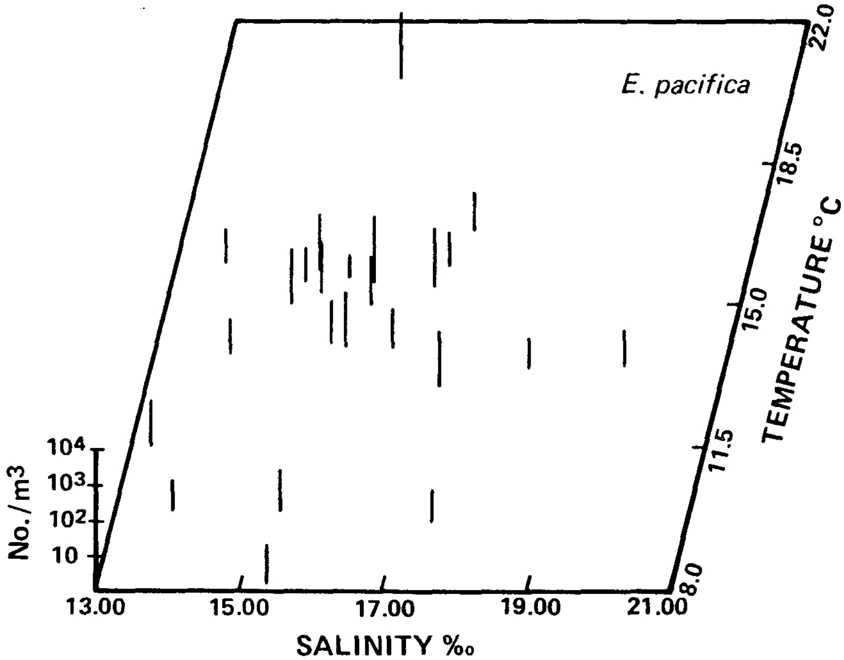


Figure 10. Abundance of Eurytemora congeners in coastal samples collected at the indicated salinities and temperatures.

salinity (r = -0.89, df = 1,5, P<0.01, Figure 11; see also Appendix B).

3.3. Zooplankton Diversity

Copepod diversity at the coastal stations was very low (Appendix C). Only a dozen calanoid copepod species were identified in the coastal study area with no more than seven occurring in a single sample. The extreme dominance of *Acartia clausi* caused Pielou's evenness index, J, to be generally low. In fact for one sample there was no diversity, *A. clausi* being the only copepod present. No significant differences in copepod diversity (Shannon's H) were detected between stations, but period effects were observed when equitability fell to low levels during early August as the *Acartia clausi* population attained its maximum abundance and dominance. When the coastal study area stations were compared to the seven closest *Discoverer* cruise stations, differences in diversity were apparent. More zooplankton taxa were present offshore, and *Acartia clausi* was less dominant (Appendix E). Copepod and zooplankton taxa diversity in each offshore sample was higher than in any of the nine, period III, coastal samples (P<0.001). Diversity was further increased, (though not to high levels), over the continental Bering and Chukchi Shelves, but declined to low values inside Kotzebue Sound at the mouth of the Kobuk River, a region where *Evadne* sp. and *A. clausi* were the predominant zooplankters (Cooney, 1977).

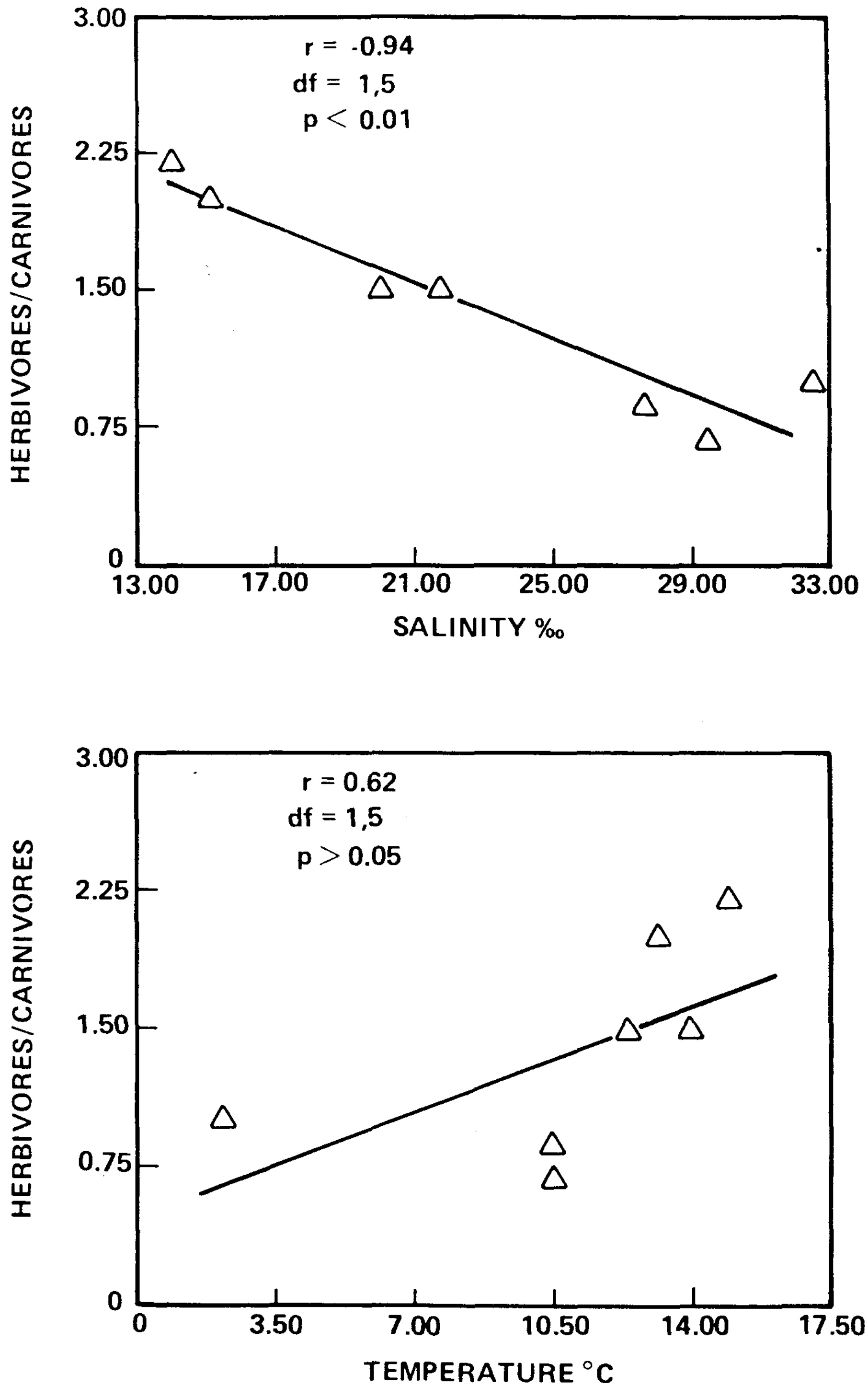


Figure 11. The effects of salinity and temperature on the ratio of planktonic herbivore to carnivore biomass.

3.4. Effects of Predation

Twenty-three species of fish were collected in the coastal study area (Appendix F). Two hundred and thirty-eight foreguts from the 23 species were examined and 87 taxa of prey were identified (Appendix G). The mysids, (*Neomysis rayii*, *N. czerniawskii*, and *N. mirabilis*) were the most frequently occurring prey and occupied the largest percentage by volume of stomach contents, excluding unidentifiable material and sediment. Unidentified eggs, *Acartia spp.* (almost all *A. clausi*) and *Eurytemora spp.* (mostly *E. pacifica* and some *E. herdmani*) were important food items because of their numerous and frequent occurrences. Benthic organisms (oligocheates, polychaetes, and bivalves), fish (primarily larval smelt), and insects were common in the diets of some fish species (Figure 12).

Most predators appeared to feed opportunistically. The two most frequently captured fish species, the rainbow smelt and saffron cod, consumed all food groups. Prey diversity was apparently lower in other species, but fewer foreguts were examined from those fishes. The fact that new prey items were continually identified as additional stomachs were examined suggested that prey lists were incomplete for many predators.

Acartia clausi was the most abundant zooplankter in both the plankton and foregut samples; however, *Eurytemora spp.*, harpacticoid copepods, and bivalve veligers, which

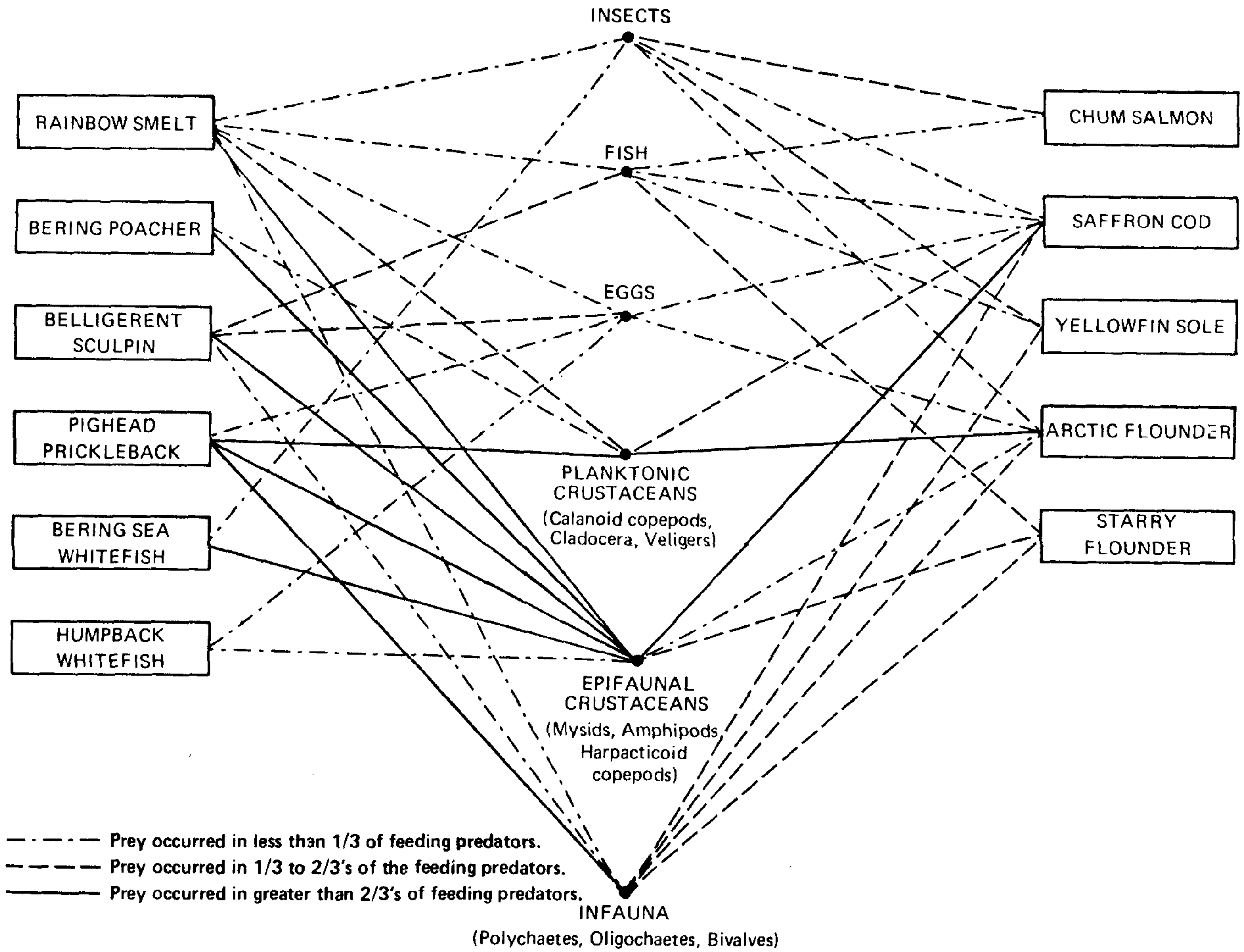


Figure 12. Strength of predation on food categories in the Norton Sound coastal study area.

were relatively scarce in the water, were numerous in the foreguts. This indictated that these items were being selectively consumed (Table 7). Despite similar trends of positive selection values for *Eurytemora spp*. and negative values for *Acartia clausi*, and *Evadne sp*., interspecific diet differences were observed between the saffron cod, rainbow smelt, and miscellaneous predators (Figure 13). All test groups had significantly different mean consumption values ($P<0.001$) for each of the zooplankton prey considered, except the saffron cod and the miscellaneous predator groups which consumed similar percentages of *Eurytemora spp*.

Table 7. Ivlev's index of electivity for zooplankton prey by teleost predators in the Norton Sound coastal study area.

Zooplankton Taxa	Percent Abundance of a Taxon in the Water $=R_i$	Percent[1] Abundance of a Taxon in the Fore-guts $=P_i$	Ivlev's Index $E_i = \frac{R_i - P_i}{R_i + P_i}$
Hydrozoa			
Obellia longissima	0.06	0.03	-0.3
Mollusca			
Bivalve veligers	0.95	10.30	+0.8
Gastropod veligers	1.06	1.10	0.0
Arthropoda			
Cladocera			
Evadne sp.	12.99	2.69	-0.7
Podon sp.	19.49	4.87	-0.6
Copepoda			
Acartia sp.	61.69	28.90	-0.4
Calanus spp.	0.01	0.07	+0.9
Centropages abdominalis	1.07	0.04	-0.9
Eurytemora spp.	1.08	26.79	+0.9
Pseudocalanus spp.	1.24	0.67	-0.3
Tortanus discaudatus	0.07	0.04	-0.3
Harpacticoids	0.01	20.07	+1.0
Decapoda			
Crangonidae zoea	0.11	3.39	+0.9
Cirripedia			
Barnacle larvae	0.11	0.11	0.0
TOTAL	100%	100%	

[1] This percentage was calculated relative to the sum total of all zooplankton (except eggs and unidentified calanoids contained in 170 foreguts from 23 species of fish (Appendix F).

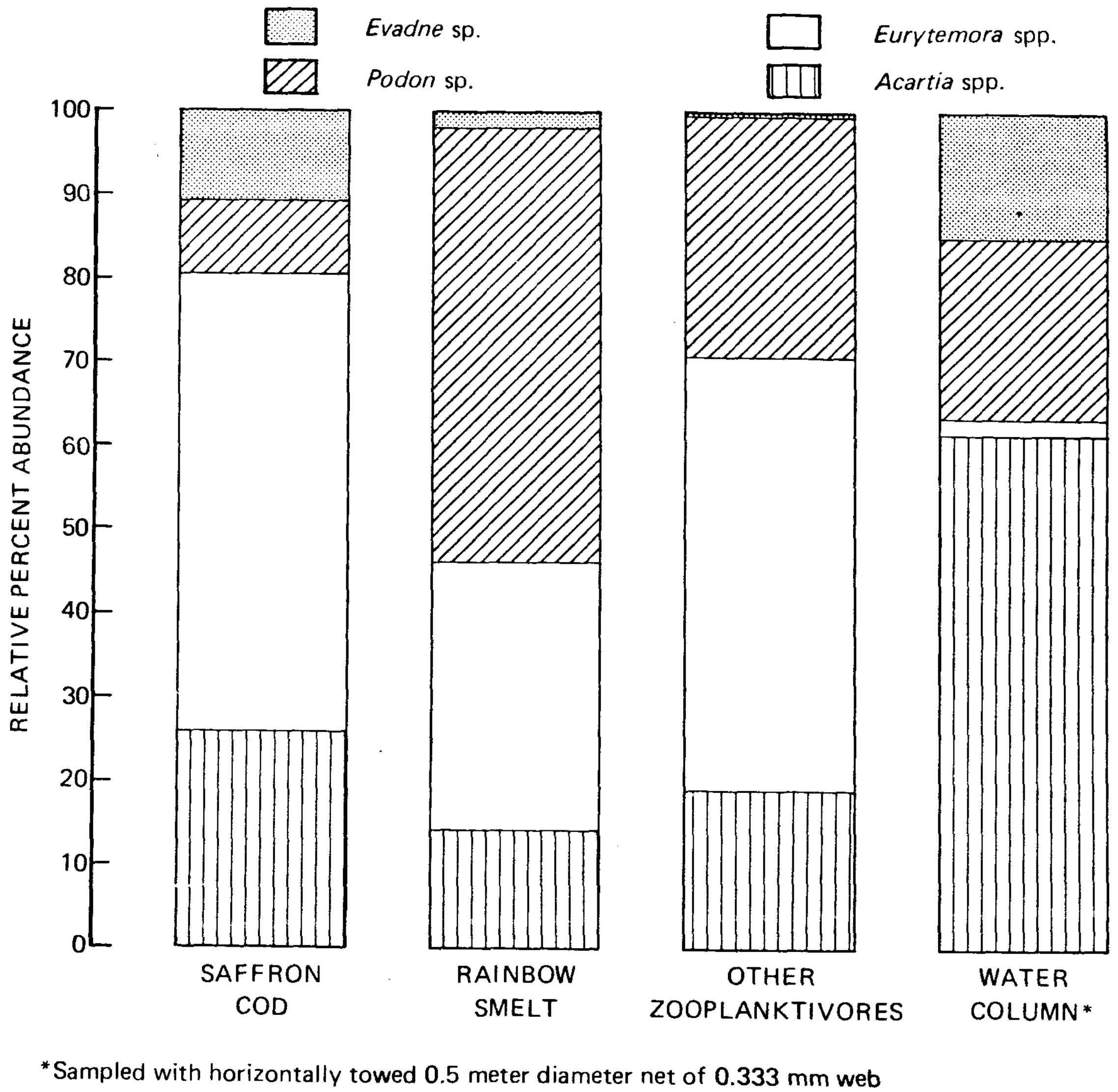


Figure 13. Differences in the diets of Norton Sound zooplanktivorous fishes. All groups select for Eurytemora spp. but to varied extents.

CHAPTER 4.

DISCUSSION

4.1. Factors Influencing the Abundance and Distribution of Zooplankton

The Norton Sound coastal zone receives considerable freshwater from the Yukon and smaller coastal rivers during the summer months which dilutes the Bering Sea water. The resulting environment is most similar to an estuary. The zooplankton inhabitants are littoral and neritic forms adapted to widely ranging temperatures and salinities. The only major groups to adapt their entire life cycles to brackish water are the cladocerans and copepods especially of the suborder calanoida (Jeffries, 1967).

The distribution of calanoid species is dependent upon water mass characteristics with temperature being the major factor that determines which species will be present in the open ocean. Patterns of salinity assist in determining which neritic species will flourish (Brodskii, 1950). Salinities and temperatures were not significantly different between coastal stations. Therefore, it followed that no significant abundance differences could be detected for the major zooplankton species between stations. On the other hand, salinity and temperature changes were observed between periods. These were reflected in abundance changes in the populations of *Acartia clausi*, the cladocerans, and the mollusc veligers.

Data from zooplankton samples collected over the continental shelf by OCSEAP investigators contained a zooplankton assemblage which differed from the coastal community. Although *Acartia clausi* was still present, its numbers had declined, as another species, *A. longiremis*, became more prevalent. *Pseudocalanus spp.* was the most abundant organism in collections from the northeastern Bering and central Chukchi Seas, relinquishing its dominance to the hydrozoan *Aglantha digitale*, and the larvacean *Oikopleura sp.* in the southeastern Chukchi (Figure 14). Other species which exhibited sporadic dominance included *Podon sp.*, the larvacean *Fritillaria borealis*, the hydrozoan *Obelia longisima*, and larval forms of polychaetes, barnacles, and echinoderms. Only in Kotzebue Sound, did *Evadne sp.* and *A. clausi* regain numerical supremacy in waters freshened by the Kobuk and Noatak Rivers.

The marine cladocerans *Evadne sp.* and *Podon sp.* are cosmopolitan in distribution. A few individuals of each genus in the samples were identified as the species *Podon leukarti* and *Evadne nordmanni*, mainly neritic forms. In the eastern Atlantic *E. nordmanni* is found both along the coast and in the open ocean (Gieskes, 1971). It is moderately eurythermal and tolerant of salinity changes from sea water to distilled water under laboratory conditions (Baker, 1938).

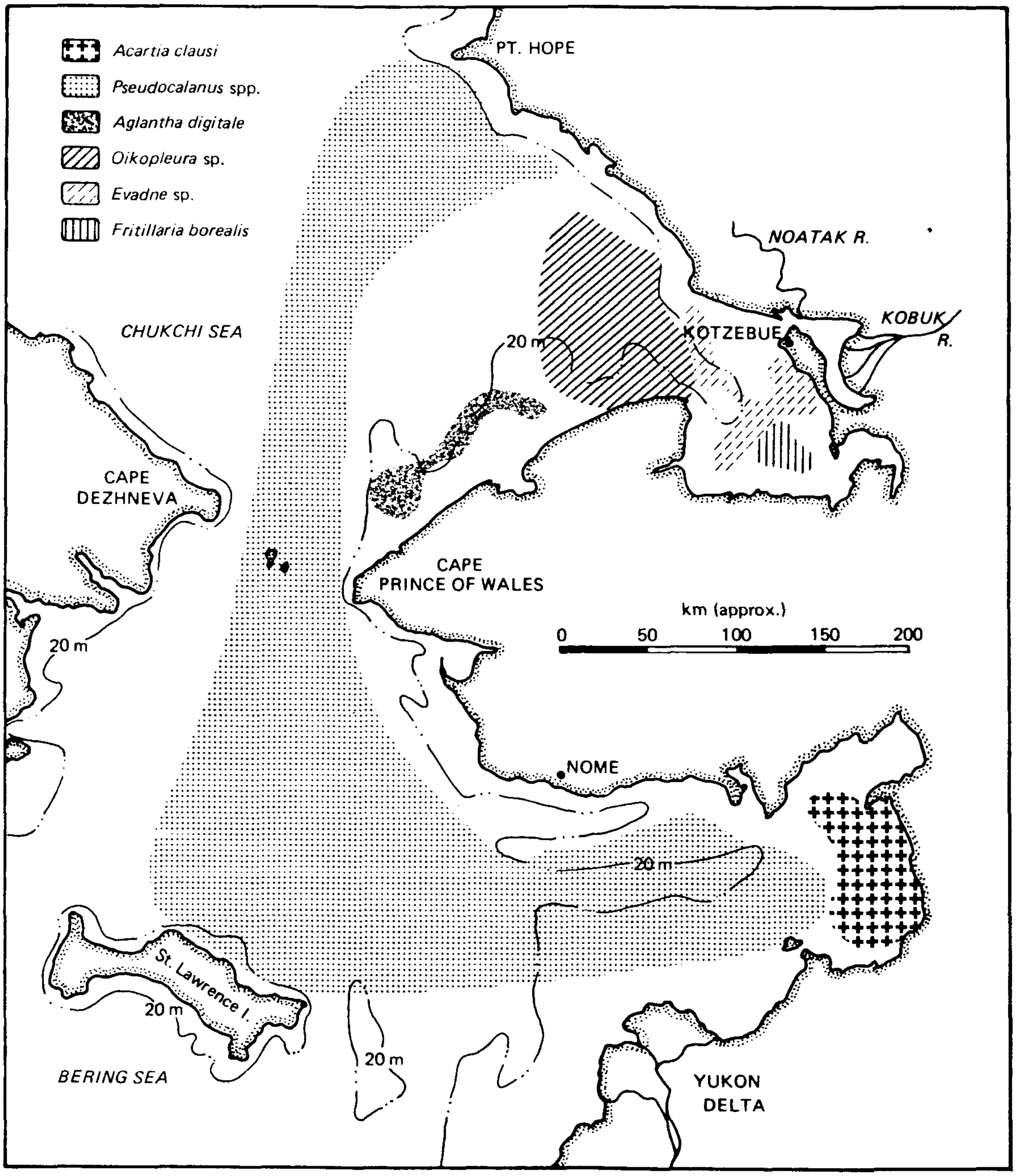


Figure 14. Summer distributions of the numerically dominant zooplankton species in regions of the Bering and Chukchi Seas, 1976. Refer to Figure 15 for station locations.

In the North Sea, temperature was shown to be a major factor controlling the abundance and distribution of marine cladocera. There *Evadne nordamanni* and *Podon leukarti* appeared in neritic waters which had warmed to 6°C; although, their presence in the open ocean was delayed beyond warming until a thermocline was established preventing the cladocerans from being advected into deeper, colder waters. Both species attained maximum abundance in early spring as water temperatures reached 10 to 13°C (Gieskes, 1971). When those optimal temperatures occurred in the coastal study area in late July, both cladoceran species attained their maximum abundances. At Point Barrow, Alaska, *E. nordmanni* and *P. leukarti* first appeared along the Chukchi coast in August when surface temperatures rose from near zero to a summer maximum of 8°C (Redburn, 1974). Seasonal succession of cladoceran species was predicted from temperature alone in a freshwater system (Allan, 1977). However, in Norton Sound, where salinities vary throughout a wide range, cladoceran abundance was found to vary as an inverse linear function of salinity during the two month study period. Conversely, bivalve and gastropod veliger abundance was positively correlated with salinity. These main components of the meroplankton began to appear in considerable numbers during late August.

Acartia clausi abundance in the coastal study area was positively correlated with temperature rather than salinity.

Conover (1956), after discovering that the abundance of *A. clausi* in Long Island Sound was correlated with the temperature distribution, performed laboratory experiments which indicated the profound effect of temperature on the metabolism and activity of *Acartia*.

Temperature was a factor that separated the distributions of species of *Acartia* in Long Island Sound (Conover, 1956). No such clear distinctions of congener distribution based on salinity and temperature patterns could be discerned in the Norton Sound coastal zone. Physical parameters change rapidly in the coastal zone, probably at a rate which is faster than the response time of the populations. But patterns which are well established are reflected in community differences. *Acartia clausi* was dominant along the coast, while *A. longiremis* was more prevalent at the mouth of Norton Sound. *A. longiremis* has a more oceanic and northern-cold water distribution than *A. clausi* (Brodskii, 1950). Therefore, during autumn, *A. longiremis* should be expected to succeed *A. clausi* in the coastal zone following an established pattern of seasonal changes in that environment. Shifts in dominance of the congeners in response to fluctuating environmental conditions insures that maximum secondary productivity may be maintained despite the physical instability (Jeffries, 1967).

Few species seem well equipped to tolerate wide ranging salinities and temperatures as evidenced by the low diversity of species in the coastal study area and in the freshened coastal waters of Kotzebue Sound. At the interface of fresh and marine waters in the Columbia River estuary, specific diversity was near zero, Eurytemora hirundoides being virtually the only zooplankter present (Haertl and Osterberg, 1967). Diminished diversity in brackish water communities is not limited to planktonic species. In the Sea of Azov, very low salinities combined with marked seasonal fluctuations in temperature, a long winter, and shallow water result in the selection of benthic animals from the richer Black Sea fauna, which is in turn a subset of the Mediterranean Sea community (Zenkevitch, 1963, pp. 495-496).

A general trend toward decreased zooplankton diversity exists at higher latitudes (Zenkevitch, 1963, p. 49). Dunbar (1968, p. 70) reasoned that the phenomenon was a selective response to increased environmental instability and seasonal oscillation. In harsh climates large populations are required to insure that a species will survive winter mortalities. Since total energy input is limited to a short production season, it follows that if specific populations are to be large, then the number of species must be small. Unstable environmental conditions are not restricted to polar climates. Instability in an equitorial Pacific upwelling system was one reason for reduced diversity in that region (Gueredrat, 1971). Unstable conditions may also occur in coastal regions where fluctuations in freshwater input and mixing and advective processess lead to high variability in the salinity and temperature regime. Because the Norton Sound coastal zone experiences both long-term seasonal and short term physical oscillations, the specific diversity of the local zooplankton community is very low.

Some caution should be exercised when comparing the diversity values of coastal and offshore Norton Sound samples since these were obtained by different methods. The larger net diameter employed offshore may have increased sample diversity by reducing net avoidance (McGowan and Fraundorf, 1966). It was assumed that horizontal hauls would adequately sample the coastal species since the water was only a few meters deep and thoroughly wave mixed. Offshore, vertical hauls integrated any species assemblages which occurred at separate depths corresponding to vertical gradients of physical conditions in the water column. This, however, should not be considered a bias since the gradients are a real source of increased diversity providing a variety of habitats in waters of greater depths.

Certainly, the effects of temperature and salinity are not independent. Temperature tolerances are modified by salinity and salinity tolerances are affected by temperature. (Kinne, 1963, 1964, 1970, 1971). Nor should the abundance (or log abundance) of a population necessarily be a linear function of either of these factors. Rather, various environmental parameters define a suitable habitat for the viable existence of a population whose abundance may then be a function of food availability, competition, predation, reproduction, and mortality rates.

4.2. Zooplankton Community Structure

In an environment with highly variable physical parameters, unpredictable changes (*r* selection) are often more important than competition (*K* selection) in controlling survivorship (MacArthur and Wilson, 1967). Under those circumstances the best reproductive strategy is to allocate maximal amounts of energy for reproduction, producing as many offspring possible as soon as possible (Pianka, 1974, p. 89). Life spans are typically less than a year with single reproduction at an early age and small body size. In more stable environments, competition becomes increasingly important in determining which individuals survive. More energy is spent on maintenance and defense mechanisms. Fewer but better developed, more competitive, offspring are produced. A larger body size is attained during their longer lives. This results in a more stable energy efficient population (Pianka, 1970).

While it is unlikely that any community will completely express either of these extremes, the opposing tendencies of *r* and *K* selection may be witnessed in Norton Sound. Along the physically unstable coast, the zooplankton consist primarily of small bodied copepods including *Acartia spp.* and *Eurytemora spp.*, about 1 mm in length, contrasting with outer shelf populations of the larger bodied *Calanus spp.*, 2 to 8 mm in length (Cooney, 1977). Conover (1956) suggested that in offshore waters *Calanus* which posseses a more highly developed feeding mechanism may have a competitive edge over *Acartia*. Yet outer continental shelf populations of the small bodied copepods, *Pseudocalanus spp.* and *Metridia pacifica* attest to the fact that physical conditions in the relatively less variable offshore environment are far from stable.

Several studies suggest that many of the coastal copepod species, including *Centropages abdominalis* and *Acartia clausi* have the ability to form dormant eggs to resist the extreme winter conditions. The eggs will develop during spring when temperatures and salinities become appropriate (Zillioux and Gonzalez, 1972; Kasahara, et al., 1974, 1975a, 1975b). The coastal cladocerans may also overwinter as a sexually produced resting egg, though most reproduction is parthenogenic, with young developed in brood pouches. This allows a single female that has encountered suitable environmental conditions to begin a population (Geiskes, 1971).

It was not possible from the data gathered in this study to determine if production was higher and efficiency lower along the coast as theory would predict. Standing stock biomass and numerical counts were lower in Kotzebue Sound and in the Norton Sound coastal study area (Figure 15). Potentially, the coastal community had the ability to be more productive if the small bodied copepods reproduced more often than the larger *Calanus spp*. This occurs in Plymouth, England, where *Acartia clausi* produces between five and seven generations per year (Digby, 1950; Evans, 1977), compared with only two or three generations of *Calanus helgolandicus*. In cooler arctic and subarctic waters, *Calanus* produces only one generation each year, overwintering as a late copepodite stage (Marshall and Orr, 1972, pp. 64-80).

The herbivore to carnivore ratio in Norton Sound decreased linearly with increasing salinity. At offshore stations carnivore biomass even exceeded the measured herbivore biomass. Pearcy (1976), observing a relatively large herbivore to carnivore ratio along the coast of Oregon, suggested that high variability in the coastal-upwelling ecosystem might lower ecological efficiency reducing trophic development. However, he also noted that many of the smaller herbivorous copepods may have passed through his coarse mesh nets. Conceivably more microzooplankters may have escaped being sampled in offshore waters biasing the herbivore-carnivore ratio. While the 0.333 mm mesh employed in this study should not have permitted adult copepods to have escaped the nets, juvenile stages and protozoans would

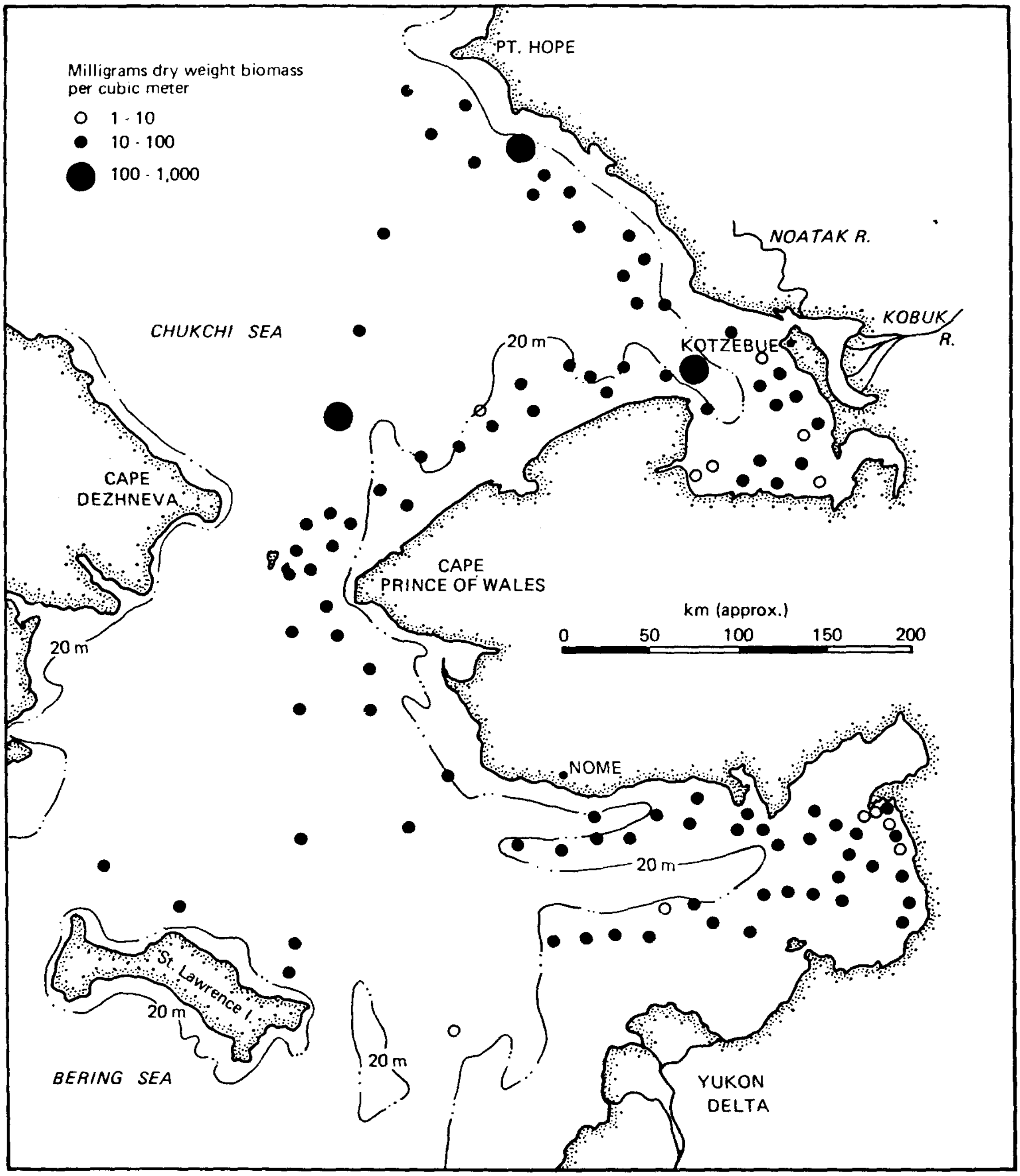


Figure 15. Zooplankton biomass at stations in the Bering and Chukchi Seas during summer, 1976.

surely have been missed.

LeBrasseur and Kennedy (1972) compared the biomass abundance of Pacific subarctic zooplankton retained in a 0.350 mm mesh net with the additional fraction of microzooplankton biomass which was retained by straining seawater through a 0.044 mm filter. The standing stock of microzooplankton was greater at mid-ocean than at coastal stations, increasing biomass estimates made with the net tows by approximately 5% and 14% in the respective areas. Production of generally smaller phytoplankton in oceanic waters may account for the higher offshore abundance of microzooplankton resulting in longer food chains (Ryther, 1969). Ryther (1969) provided the example of the euphausid, Euphausia pacifica, which may feed upon phytoplankton along the Pacific subarctic coast, but must consume microzooplankton offshore where phytoplankton are too small to be captured.

In Norton Sound, the main offshore predator is the chaetognath, Sagitta sp. Its biomass is relatively large when compared with the standing stock of herbivores collected in the net tows. The abundant predator population may have been sustained by microzooplankton, herbivores from the coastal zone, or previous pulse production of southern Bering, bathypelagic copepods swept onto the shelf in spring. In this manner chaetognaths may serve as a food reserve which would otherwise be unavailable to fishes feeding offshore during the summer months (see Lebrasseur, 1972).

4.3. Coastal Fish Feeding Behavior

Due to reduced salinities, the coastal waters of Norton Sound are inhabited by an assortment of marine, brackish water, and anadromous fish species. Their diets in Norton Sound were usually opportunistic, comparable to their diets in other areas where they have been studied (Hart, 1973; Kendel et al., 1975). Bendock (1977) found that this was the common life style of fishes in Prudhoe Bay, Arctic Ocean. The coastal zone experiences marked short term variations in salinity and temperature imposed upon a highly variable seasonal pattern which includes winter freezing. Resources in such an environment reflect that physical instability. Under these circumstances, generalists would be expected to out-compete specialists which must depend on a constant food source (Valentine, 1973, pp. 257-263). The premise is not, however, without exception. Isakson (et al., 1971) compared "rock-algae" and "sand-gravel" coastal fish communities at Amchitka, Alaska, and found generalization to be the rule in the former but specializtion in the later community.

Furniss (1974) emphasized the importance of amphipods, isopods, and mysids to coastal fishes of Prudhoe Bay, Alaska. Benthic production in the coastal zone is encouraged by a particularly large input of organic material

(Mann, 1976) especially during the pulsed production peaks characteristic of high latitudes. Furthermore, the time material must spend sinking through the water column where it may enter the pelagic food web is less in shallow water (Mann, 1976); even digested material will proceed to the bottom with 90% of its original energy value in the form of fecal pellets (Bogdanov, 1965). The Yukon River serves as another major source of particulates in Norton Sound. A fraction of this material may be converted by the benthic and epibenthic communities into available fish food.

It may be energetically more efficient, or at least easier for predators to consume large epibenthic crustaceans concentrated along the bottom, than to find, pursue, capture, and consume many small planktonic crustaceans in the water column (see Brooks and Dodson, 1965; Eggers, 1976). This could well explain the high electivity values observed for the bottom dwelling harpacticoid copepods. Bivalve veligers may also have begun to settle on the bottom and could have been more readily consumed. Crangonidae zoea and the copepod, Calanus spp., may have been selected for on the basis of their relatively large size, though, a high electivity value for Calanus is suspect since in absolute numbers only a few were consumed. These could have been taken by fish feeding offshore in the Calanus abundant waters thereby biasing the electivity value.

It is difficult to understand why similarly sized pelagic crustaceans should be differentially selected. Relatively many more Eurytemora spp. were consumed than Acartia spp., which did not vary noticeably in those characteristics that often result in differential predation rates, such as body shape (Kerfoot, 1977) and visibility (Zaret and Kerfoot, 1975). Perhaps their swimming rates or burst speeds, which influence predator encounter and escape probabilities, differed (Gerritsen and Strickler, 1977). This would not explain why selectivity values varied between predators. The saffron cod consumed proportionately more Evadne, while the rainbow smelt fed more heavily on Podon, even though both prey were of similar size and appearance. While the role of predation in maintaining diversity by falling most heavily on the dominant prey organism has been established (Dayton and Hessler, 1972), in this instance selective predation on Eurytemora may actually reduce the already low equitability of the coastal zone by increasing the relative dominance of Acartia.

Assuming that the observed selectivity was not an experimental artifact of non-random prey distributions or unequal rates of digestability (Gannon, 1976), then its function may have been to reduce food competition since species cannot continue to coexist while utilizing the same limiting resource (Volterra, 1926). Larval flounder species feeding on plankton in the English Channel avoid rivalry by possessing distinctive diets (Last, 1978). Along the Norton

Sound coast, the opposing selective pressures to generalize in response to fluctuating food resources, and to specialize to reduce competition, are met with compromise, expressed in a fish community whose member species consume a wide variety of prey groups while choosing particular diets within those food groups.

Since species select different diets, any perturbation causing a restructuring of the crustacean communities should also result in a reformation of the predatory fish community, although this need not always be detrimental. During the 1950's, changes in the North Sea plankton from a neritic community of small bodied species (typical of the Norton Sound coastal zone) to a more oceanic community (including the larger bodied Calanus) resulted in increased herring production (Cushing, 1975, p. 210). Nonetheless, any impact generally harmful to the crustacean populations would drastically reduce the viability of the fish community of the Bering Sea coast.

CHAPTER 5.

FUTURE STUDIES

The adaptive strategies employed by animals in the Norton Sound coastal zone to insure survival of their species in a rigorous and often unpredictable environment provide exciting opportunities for further research. A sound understanding of the adaptations of organisms to their changing environment is a prerequisite to predicting the effects of any human perturbations.

In the coastal study area, fish obtain most of their energy from the benthic food web, which in shallow water is a more constant and dependable energy bank than the pelagic system. Nonetheless, most species do not restrict themselves to solely benthic prey groups, and in this manner hedge their bets in the unstable environment. The role of species-specific selectivity as a mechanism to reduce competition might lend itself to productive laboratory study if feeding by different combinations of predators in the presence of mixed populations of zooplankton was monitored. This could also yield useful information on the mechanisms of selection, the energetics of predators, and the quantitative effect of predation on zooplankton in the sound.

In deeper waters, where the benthic detritus system becomes less important to pelagic fish species, the chaetognath may function as an energy storehouse. At times, its biomass exceeds that of the copepods which it consumes. To understand this apparent paradox would necessitate an examination of the food chain efficiency of this predator and the producton rates of the chaetognath and its prey. Zooplankton sampling throughout the ice free season would be required, for it is likely that the high summer biomass of chaetognaths was aquired during a spring pulse production in the open Bering Sea of Calanus spp. copepods which are carried by currents into Norton Sound.

This longer term study would illuminate the patterns of congener succession which insure maximum secondary production throughout changing seasonal conditions. Zooplankton sampling could even be usefully extended into the winter season. Vertical hauls through leads or holes drilled into the ice would provide data on the stage of maturity, metabolic condition, and size of populations of zooplankton which must maintain a viable breeding stock until spring when primary production resumes with a burst of activity. Sediment samples obtained through these same ice holes should be examined for the presence of overwintering zooplankton eggs.

Since the coastal study area was shown to be a relatively homogeneous biological region, future sampling should be conducted along transects perpendicular to the coast, across the physical gradients of salinity and temperature. This may provide insight into the establishment and maintenance of distinctive biological communities and the effects of weather and seasons altering the physical environment. Though, a study of this nature may be more conveniently undertaken in an area like Prince William Sound, Gulf of Alaska, where rapidly changing physical gradients compress zooplankton communities into narrower bands paralleling the coast.

No study of zooplankton ecology is complete without mention of feeding behavior and available food resources. Unfortunately, attempts to use a Coulter Counter to quantify the size distribution of phytoplankton and relate this to the ecology of zooplankton failed when microscopic examination of water samples indicated that the Coulter Counter was actually counting the much more numerous suspended particles that are loaded into the coastal zone by the Yukon and Unalakleet Rivers. If some of these particles contain a useful carbon source, then this suggests the intriguing possibility that much of the energy entering the coastal food web may originate in freshwater and terrestrial ecosystems.

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APPENDICES

APPENDIX A.

Catalogue of the coastal zooplankton collection in Norton Sound, 1976.

Station [1]	Period	Date	Local Time	Salinity ‰	Temperature °C	Biomass mg dry/m^3
1	1	10/07/76	12:25	13.45	13.7	25
2	1	10/07/76	16:23	13.21	13.7	5
3	1	10/07/76	00:55	13.27	11.6	3
4	1	06/07/76	07:10	15.34	8.2	9
5	1	05/07/76	22:00	13.55	10.0	2
6	1	05/07/76	17:12	13.79	10.0	6
7	1	05/07/76	13:26	13.71	8.6	10
8	1	02/07/76	19:56	15.29	10.0	6
9	1	02/07/76	17:48	17.45	9.7	16
1	2	28/07/76	10:01	16.31	14.0	8
2	2	26/07/76	14:57	13.91	17.8	35
3	2	16/07/76	15:27	13.68	16.1	11
4	2	18/07/76	10:08	14.05	13.9	9
5	2	18/07/76	16:34	14.87	15.6	15
6	2	18/07/76	20:47	14.75	15.1	8
7	2	21/07/76	08:49	15.05	14.2	25
8	2	21/07/76	11:56	15.06	15.8	14
9	2	21/07/76	15:08	15.14	15.3	17
1	3	13/08/76	16:39	17.04	16.9	14
2	3	13/08/76	20:28	16.82	16.0	12
3	3	05/08/76	16:37	15.52	20.6	22
4	3	05/08/76	12:10	15.87	15.0	8
5	3	04/08/76	15:30	15.85	15.6	36
6	3	04/08/76	12:44	15.48	15.7	2
7	3	04/08/76	09:58	15.44	14.1	11
8	3	01/08/76	11:11	16.40	14.8	6
9	3	01/08/76	14:58	16.69	15.5	6
1	4	28/08/76	17:53	19.48	14.5	12
2	4	24/08/76	15:32	19.55	13.5	14
3	4	24/08/76	11:48	18.91	no data	12
4	4	28/08/76	13:16	15.65	14.0	25
5	4	28/08/76	14:38	18.47	14.0	31
6	4	28/08/76	15:11	18.29	14.0	2
7	4	29/08/76	11:08	17.11	13.0	21
8	4	29/08/76	17:10	18.26	13.5	5
9	4	29/08/76	14:48	18.29	13.0	4

[1] Refer to Figure 2 for station locations.

APPENDIX B.

Catalogue of selected zooplankton samples from the 1977 *Surveyor* cruise in Norton Sound.

Station[1]	Date	Local Time	Salinity ‰	Temperature °C	Herbivore Biomass mg dry/m^3	Carnivore Biomass mg dry/m^3
40	28/06/77	20:43	29.51	10.5	3	4
37	29/06/77	00:45	27.70	10.5	5	6
33	29/06/77	07:20	21.81	12.4	14	9
30	29/06/77	13:19	20.10	14.0	9	6
28	29/06/77	22:15	15.18	13.2	22	11
26	29/06/77	23:25	14.09	15.0	24	11
123	04/07/77	07:49	32.55	2.2	10	10

[1] Refer to Figure 3 for station locations.

APPENDIX C.

Zooplankton abundance and diversity by station and period in the Norton Sound coastal study area, 1976. Present (P) implies less than one individual per cubic meter, while trace (T) means less than one individual per 10 cubic meters.

STATION NO. 1

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia clausi	2683	376	3802	2783
Centropages abdominalis	0	105	84	15
Eurytemora herdmani	16	5	0	0
Eurytemora pacifica	0	9	10	0
Pseudocalanus spp.	0	0	10	20
Tortanus discaudatus	0	9	0	0
Total number of copepod taxa (K)	2	5	4	3
Shannon's diversity index (H)	0.02	0.32	0.06	0.03
Pielou's equitability index (J)	0.05	0.46	0.10	0.07
Other taxa				
Evadne sp.	205	294	73	2
Podon sp.	742	514	63	82
Cirripedia	0	18	0	0
Hyperia galba	0	0	0	T
Crangonidae zoea	2	0	P	P
Scyphozoa	0	0	0	P
Aurelia limbata	0	0	0	T
Cyanea capillata	0	T	T	T
Autolytus sp.	0	0	0	T
Bivalve veligers	0	5	10	2
Gastropod veligers	0	0	0	155
Diptera	0	T	T	T
Asteroidea (brachiolaria larvae)	0	0	0	4
Echinoidea (echinopleuteus larvae)	0	0	0	2
Sagitta sp.	0	0	0	T
Clupea harengus	T	0	0	0
Platicthys stellatus	T	0	0	0
Total number of all taxa (K)	7	11	10	17
Shannon's diversity index (H)	0.32	0.62	0.14	0.18
Pielou's equitability index (J)	0.38	0.59	0.14	0.15

Appendix C. continued

STATION NO. 2

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m³			
Copepoda				
Acartia clausi	437	2473	1144	4396
Centropages abdominalis	10	16	3	44
Eurytemora herdmani	0	0	0	18
Eurytemora pacifica	0	0	7	9
Pseudocalanus spp.	0	0	0	9
Tortanus discaudatus	0	0	0	9
Total number of copepod taxa (K)	2	2	3	6
Shannon's diversity index (H)	0.05	0.02	0.02	0.05
Pielou's equitability index (J)	0.15	0.06	0.05	0.07
Other taxa				
Evadne sp.	166	58	20	9
Podon sp.	253	297	43	0
Cirripedia	0	0	3	0
Crangonidae zoea	10	0	0	P
Obelia sp.	2	0	0	0
Cyanea capillata	0	0	7	0
Autolytus sp.	0	0	0	T
Bivalve veligers	0	0	3	0
Gastropod veligers	0	0	7	35
Diptera	0	T	0	0
Hymenoptera	0	T	0	0
Sagitta sp.	0	0	0	T
Urochordata	0	T	0	0
Clupea harengus	T	T	0	0
Total number of all taxa (K)	7	8	9	11
Shannon's diversity index (H)	0.49	0.20	0.17	0.08
Pielou's equitability index (J)	0.58	0.22	0.18	0.08

Appendix C. continued

STATION NO. 3

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Copepod nauplii	0	7	0	3
Acartia bifilosa	2	0	100	0
Acartia clausi	125	659	3208	462
Acartia longiremis	1	0	0	0
Centropages abdominalis	0	0	0	144
Epilabidocera amphitrites	0	0	0	3
Eurytemora herdmani	0	0	184	0
Eurytemora pacifica	18	7	67	3
Pseudocalanus spp.	69	21	0	214
Tortanus discaudatus	11	0	0	7
Ectinosoma sp.?	1	0	0	0
Total number of copepod taxa (K)	7	4	4	7
Shannon's diversity index (H)	0.50	0.11	0.18	0.47
Pielou's equitability index (J)	0.59	0.18	0.30	0.56
Other taxa				
Evadne sp.	47	940	150	0
Podon sp.	40	491	134	21
Cirripedia	1	0	0	0
Mysidae juvenile	0	0	0	T
Diastylis sp.	T	0	0	0
Lamprops sp.	0	T	0	0
Crangonidae zoea	1	P	17	P
Cyanea capillata	0	0	0	T
Autolytus sp.	T	0	0	T
Bivalve veligers	0	0	267	17
Gastropod veligers	0	0	50	602
Insecta unident.	0	0	P	0
Sagitta sp.	0	0	0	T
Teleostei eggs unident.	0	0	0	3
Ammodytes hexapterus	0	0	0	T
Clupea harengus	P	T	T	0
Total number of all taxa (K)	14	9	11	17
Shannon's diversity index (H)	0.72	0.50	0.42	0.62
Pielou's equitability index (J)	0.63	0.52	0.41	0.51

Appendix C. continued

STATION NO. 4

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia clausi	95	109	1575	7085
Acartia longiremis	35	0	0	0
Centropages abdominalis	11	44	8	0
Eurytemora herdmani	35	0	0	0
Eurytemora pacifica	11	7	24	35
Pseudocalanus spp.	422	15	0	0
Tortanus discaudatus	7	7	0	0
Total number of copepod taxa (K)	7	5	3	2
Shannon's diversity index (H)	0.46	0.48	0.05	0.01
Pielou's equitability index (J)	0.55	0.69	0.10	0.04
Other taxa				
Evadne sp.	7	2285	24	0
Podon sp.	225	1825	0	35
Crangonidae zoea	7	0	P	P
Rathkia sp.	3	0	0	0
Cyanea capillata	0	0	T	T
Autolytus sp.	0	0	0	T
Gastropod veligers	0	0	0	35
Diptera	T	T	0	0
Clupea harengus	0	T	0	0
Liopsetta glacialis	T	0	0	0
Total number of all taxa (K)	13	9	6	7
Shannon's diversity index (H)	0.63	0.38	0.08	0.04
Pielou's equitability index (J)	0.57	0.40	0.10	0.05

Appendix C. continued

STATION NO. 5

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia bifilosa	0	0	144	0
Acartia clausi	185	169	6819	8877
Centropages abdominalis	0	8	263	0
Eurytemora herdmani	0	0	48	0
Eurytemora pacifica	0	8	72	0
Pseudocalanus spp.	0	0	0	19
Total number of copepod taxa (K)	1	3	5	2
Shannon's diversity index (H)	0.00	0.16	0.15	0.01
Pielou's equitability index (J)	1.00	0.33	0.21	0.02
Other taxa				
Evadne sp.	68	1867	0	0
Podon sp.	51	2154	0	19
Cirripedia	2	0	48	0
Calliopiidae	0	0	0	T
Crangonidae zoea	T	8	P	T
Obelia sp.	2	8	0	0
Aurelia sp.	0	0	T	0
Cyanea capillata	T	0	0	T
Autolytus sp.	0	0	0	T
Gastropod veligers	0	0	0	67
Holothuroidea (auricularia larvae)	0	0	0	10
Sagitta sp.	0	0	0	T
Clupea harengus	T	0	T	0
Pleuronectidae	T	0	0	0
Total number of all taxa (K)	9	7	9	10
Shannon's diversity index (H)	0.44	0.38	0.17	0.04
Pielou's equitability index (J)	0.46	0.45	0.17	0.04

Appendix C. continued

STATION NO. 6

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia clausi	442	143	308	412
Centropages abdominalis	7	0	0	0
Eurytemora pacifica	7	31	3	0
Pseudocalanus spp.	0	0	0	6
Total number of copepod taxa (K)	3	2	2	2
Shannon's diversity index (H)	0.07	0.20	0.02	0.03
Pielou's equitability index (J)	0.14	0.67	0.07	0.12
Other taxa				
Evadne sp.	804	1961	3	13
Podon sp.	521	286	0	72
Podon leukarti	0	0	3	0
Cirripedia	7	0	3	0
Crangonidae zoea	T	19	0	0
Hydromedusa juvenile	0	0	0	3
Obelia longissima	13	0	0	3
Cyanea capillata	0	0	0	T
Autolytus sp.	0	0	0	T
Magelona sp.	0	0	0	T
Spionidae	0	10	0	0
Bivalve veligers	0	0	0	3
Diptera	0	T	0	0
Ammodytes hexapterus	0	0	T	0
Clupea harengus	P	T	P	0
Cottidae	0	0	0	T
Osmerus sp.	2	0	0	0
Pleuronectidae	T	0	0	0
Total number of all taxa (K)	11	8	7	10
Shannon's diversity index (H)	0.51	0.31	0.09	0.29
Pielou's equitability index (J)	0.49	0.34	0.11	0.29

Appendix C. continued

STATION NO. 7

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia clausi	123	197	1956	3286
Acartia longiremis	9	0	0	0
Centropages abdominalis	4	0	126	0
Eurytemora sp.	P	0	0	0
Eurytemora americana	P	0	0	0
Eurytemora herdmani	3	31	11	34
Eurytemora pacifica	0	0	15	34
Pseudocalanus spp.	P	0	0	0
Total number of copepod taxa (K)	7	2	4	3
Shannon's diversity index (H)	0.25	0.17	0.13	0.05
Pielou's equitability index (J)	0.29	0.58	0.22	0.10
Other taxa				
Evadne sp.	75	970	19	102
Podon sp.	60	2704	30	271
Cirripedia	0	8	0	0
Lamprops sp.	0	0	T	0
Atylus collingi	0	0	0	T
Calliopius laeviusculus	0	T	0	0
Crangonidae zoea	P	16	T	P
Obelia sp.	2	16	0	0
Autolytus sp.	T	0	0	0
Bivalve veligers	0	0	0	254
Gastropod veligers	0	0	0	17
Diptera	0	T	0	0
Ophiuroidea (ophiopluteus larvae)	0	0	0	17
Sagitta sp.	0	0	T	0
Clupea harengus	0	P	0	0
Pleuronectidae	P	0	0	0
Stichaeidae	P	0	0	0
Total number of all taxa (K)	14	10	9	10
Shannon's diversity index (H)	0.60	0.37	0.18	0.32
Pielou's equitability index (J)	0.52	0.37	0.19	0.32

Appendix C. continued

STATION NO. 8

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia bifilosa	0	0	0	5
Acartia clausi	90	219	994	628
Calanus sp.	17	0	0	0
Centropages abdominalis	11	0	52	5
Eurytemora herdmani	0	58	0	0
Eurytemora pacifica	14	44	0	5
Pseudocalanus spp.	222	15	0	0
Tortanus discaudatus	6	0	0	0

	I	II	III	IV
Total number of copepod taxa (K)	6	4	2	4
Shannon's diversity index (H)	0.47	0.43	0.09	0.06
Pielou's equitability index (J)	0.61	0.71	0.29	0.10

Other taxa	I	II	III	IV
Evadne sp.	76	1140	30	174
Podon sp.	135	2908	15	280
Cumacea unident.	0	15	0	0
Lamprops sp.	T	T	0	T
Crangonidae zoea	P	5	0	P
Obelia sp.	T	0	0	0
Obelia longissima	31	0	0	0
Perigonimus sp.	T	0	0	0
Cyanea capillata	0	T	0	T
Syllidae?	3	0	0	0
Bivalve veligers	0	0	15	132
Gastropod veligers	0	0	7	0
Insecta unident.	0	T	0	0
Diptera	0	0	0	T
Teleostei larvae unident.	T	0	0	0
Teleostei eggs unident.	3	0	0	0
Clupea harengus	T	P	T	0
Platicthys stellatus	0	0	T	0
Pleuronectidae	P	0	0	0

	I	II	III	IV
Total number of all taxa (K)	18	12	8	11
Shannon's diversity index (H)	0.77	0.40	0.21	0.55
Pielou's equitability index (J)	0.61	0.37	0.24	0.53

Appendix C. continued

STATION NO. 9

TAXA	PERIOD I	II	III	IV
	Number of Organisms/m^3			
Copepoda				
Acartia bifilosa	0	0	16	0
Acartia clausi	146	150	1087	4
Calanus glacialis	34	0	0	0
Centropages abdominalis	1	17	28	0
Eurytemora herdmani	1	50	3	0
Eurytemora pacifica	5	33	41	0
Pseudocalanus spp.	98	17	0	9
Tortanus discaudatus	3	0	3	0
Harpacticus sp?	4	0	0	0
Total number of copepod taxa (K)	8	5	6	2
Shannon's diversity index (H)	0.52	0.54	0.16	0.27
Pielou's equitability index (J)	0.57	0.77	0.21	0.88
Other taxa				
Evadne sp.	4	602	12	0
Evadne nordmanni	0	0	0	7
Podon sp.	35	3947	31	18
Cirripedia	1	17	0	0
Crangonidae zoea	P	17	P	P
Obelia longissima	16	0	0	0
Cyanea capillata	0	0	T	T
Eteone sp.	T	0	0	0
Spionidae	P	33	0	0
Bivalve veligers	0	0	3	182
Gastropod veligers	0	0	3	15
Homoptera	0	T	0	0
Sagitta sp.	0	0	T	0
Teleostei eggs unident.	3	0	0	0
Clupea harengus	0	T	0	0
Platicthys stellatus	T	0	0	0
Pleuronectidae	P	0	0	0
Stichaeidae	P	0	0	0
Total number of all taxa (K)	19	12	13	8
Shannon's diversity index (H)	0.71	0.32	0.25	0.38
Pielou's equitability index (J)	0.56	0.29	0.22	0.42

APPENDIX D.

Zooplankton abundance at selected *Surveyor* stations in Norton Sound, June - July, 1977. Present (P) implies less than one individual per cubic meter, while trace (T) means less than one individual per 10 cubic meters.

TAXA	40	37	33	30	28	26	123
	STATION[1]						
	Number of Organisms/m^3						
Copepoda							
Copepod nauplii	0	P	0	0	0	0	0
Acartia clausi	9	1	17	75	258	385	0
Acartia longiremis	0	0	20	43	29	18	1
Calanus sp.	12	34	17	39	245	297	29
Calanus glacialis	13	8	47	16	16	47	8
Centropages abdominalis	0	1	P	4	19	0	0
Eurytemora herdmani	0	0	0	3	9	0	0
Eurytemora pacifica	2	0	P	P	3	7	0
Pseudocalanus spp.	21	13	28	96	534	76	146
Tortanus discaudatus	2	0	0	2	3	7	0
Harpacticoid (unident.)	0	P	0	P	3	0	0
Ectinosoma sp?	0	P	0	0	0	0	0
Other Crustacea							
Crustacean eggs	28	12	1	8	0	4	15
Crustacean zoea	2	2	5	4	3	2	P
Cladocera							
Evadne sp.	0	P	0	7	3	54	0
Podon sp.	0	3	6	7	51	101	1
Cirripedia	2	20	15	8	9	7	4
Cumacea	0	0	0	0	0	T	0
Amphipoda	P	P	0	0	3	0	0
Hydrozoa	8	12	19	26	5	9	5
Polychaeta							
Spionidae larvae	0	1	0	2	6	7	0
Unidentified larvae	26	4	P	25	44	106	31
Insecta	P	T	0	0	0	0	0
Chaetognatha	23	8	14	50	3	52	9
Teleost larvae	1	P	3	P	P	P	T

[1] Refer to Figure 3 for station locations.

APPENDIX E.

Zooplankton abundance and diversity at selected *Discoverer* stations in eastern Norton Sound, August, 1976. Present (P) implies less than one individual per cubic meter, while trace (T) means less than one individual per 10 cubic meters.

TAXA	STATION[1] 23	24	25	26	27	28	29
	Number of Organisms/m^3						
Copepoda							
Acartia clausi	360	1123	3361	2406	3603	2534	2974
Acartia longiremis	20	36	178	76	51	51	59
Calanus sp.	0	0	0	0	0	0	12
Calanus glacialis	47	72	13	10	0	0	12
Centropages abdominalis	55	63	76	248	331	306	329
Derjuginia tolli	0	9	0	38	38	51	129
Eurytemora herdmani	27	36	0	86	102	115	235
Eurytemora pacifica	4	18	38	134	76	89	165
Pseudocalanus spp.	615	773	1146	649	1006	866	1023
Tortanus discaudatus	0	0	13	0	13	0	0
Total number of copepod taxa (K)	7	8	7	8	8	7	9
Shannon's index of diversity (H)	0.50	0.49	0.37	0.49	0.43	0.48	0.54
Pielou's index of equitability (J)	0.59	0.54	0.44	0.54	0.47	0.57	0.57

[1]Refer to Figure 2 for station locations.

Appendix E. continued

TAXA	STATION 23	24	25	26	27	28	29
	Number of Organisms/m^3						
Other Crustacea							
Cladocera							
Evadne sp.	231	998	255	859	828	789	1046
Podon sp.	106	503	497	363	166	102	294
Cirriped nauplii	0	9	13	0	0	0	0
Mysidacea							
Mysis sp.	P	0	0	0	0	0	0
Cumacea							
Leucon sp.	0	0	0	0	0	P	0
Amphipoda							
Argissa hamatipes	0	0	0	0	P	0	0
Monoculodes sp.	4	0	0	0	0	0	0
Decapoda							
Paguridae juvenile	T	P	P	0	0	P	0
Paguridae zoea	P	P	0	0	0	0	P
Cnidaria							
Hydrozoa							
Aglantha digitale	0	18	13	10	P	P	12
Cuspidella mertensii	T	0	0	0	0	0	0
Scyphozoa							
Cyanea capillata	T	0	P	0	P	0	0
Ctenophora	0	0	0	P	0	0	0
Rhynchocoela							
Pilidia larvae	0	9	0	0	0	0	0
Polychaeta							
Magelonidae larvae	8	27	183	68	26	1	P
Polynoidae larvae	4	0	0	0	0	13	0
Spionidae larvae	0	0	26	0	0	0	4
Unidentified larvae	12	19	13	0	13	13	12

Appendix E. continued

TAXA	23	24	25	26	27	28	29
	STATION						
	Number of Organisms/m^3						
Mollusca							
Bivalve juvenile	8	27	115	153	140	217	576
Gastropod juvenile	0	0	38	19	26	26	24
Echinodermata							
Asteroidea							
Bipinnaria larvae	35	0	0	19	0	0	0
Brachiolaria larvae	0	162	13	0	0	0	24
Ophiurodea							
Ophiopluteus larvae	8	27	0	0	38	0	24
Chaetognatha							
Sagitta elegans	32	40	122	22	24	11	18
Unidentified juveniles	4	0	0	10	13	0	0
Teleostei							
Eleginus gracilis larv.	0	0	P	0	0	0	0
Unidentified fish eggs	35	36	102	48	51	0	12
Other unidentified eggs	8	0	0	0	0	0	0
Total number of all taxa (K)	25	22	22	19	21	18	22
Shannon's index of diversity (H)	0.84	0.84	0.70	0.78	0.68	0.71	0.81
Pielou's index of equitability (J)	0.60	0.63	0.52	0.61	0.51	0.56	0.60

APPENDIX F.

Fish species inhabiting the Norton Sound coastal study area.

	Scientific Name	Common Name	No. Examined	No. with Food in Foregut
A.	Clupea harengus pallasi	Pacific herring	4	3
B.	Coregonus laurettae	Bering cisco	8	7
C.	Coregonus pidschian	Humpback whitefish	6	5
D.	Coregonus sardinella	Least cisco	8	3
E.	Oncorhynchus gorbuscha	Pink salmon	3	1
F.	Oncorhynchus keta	Chum salmon	6	5
G.	Oncorhynchus kisutch	Silver salmon	2	1
H.	Salvelinus alpinus	Arctic char	4	0
I.	Hypomesus olidus	Pond smelt	4	4
J.	Osmerus mordax dentex	Rainbow smelt	78	30
K.	Eliginus gracilis	Saffron cod	39	39
L.	Pungitius pungitius	Ninespine stickleback	4	4
M.	Hexagrammus lagocephalus	Rock greenling	2	2
N.	Megalocottus platycephalus	Belligerent sculpin	5	5
O.	Myoxocephalus jaok	Sculpin	1	1
P.	Myoxocephalus cf: scorpiodes	Sculpin	4	3
Q.	Ocella dodecaedron	Bering poacher	19	19
R.	Pallasina barbata	Tubenose poacher	3	3

Appendix F. continued

	Scientific Name	Common Name	No. Examined	No. with Food in Foregut
S.	Acantholumpenus mackayi	Pighead prickleback	8	8
T.	Limanda aspera	Yellowfin sole	5	5
U.	Liopsetta glacialis	Arctic flounder	13	12
V.	Platichthys stellatus	Starry flounder	11	9
W.	Pleuronectes quadrituberculatus	Alaskan plaice	1	1

APPENDIX G.

Prey items consumed by fish inhabiting the Norton Sound coastal study area.

Prey Items	Predators[1]
Holoplankton prey	
Copepoda	
Acartia clausi	A D IJK Q
Calanoida unident.	A IJKL
Calanus sp.	J
Calanus cristatus	J
Calanus glacialis	A
Centropages abdominalis	J
Eurytemora sp.	A IJKL Q U
Eurytemora herdmani	JK
Eurytemora pacifica	A D IJK
Pseudocalanus sp.	J
Tortanus discaudatus	J
Cladocera	
Evadne sp.	A JK
Podon sp.	A IJK
Podon leuckarti	K S
Other prey	
Protozoa	
Foraminiferida	S
Hydrozoa	
Hydrozoa unident.	E R
Abietinaria sp.	S
Sertularia sp.	M U
Annelida	
Polychaeta	K S U
Polynoidae	J
Phloe minuta	S
Phyllodocidae	J
Eteone longa	JK UV
Nereis sp.	K M
Nephtys sp.	S W
Nephtys cornuta	S
Goniadidae	A
Glycinde sp.	S
Myriochele heeri	S
Pectinairiidae	S
Cistinides sp.	UV
Sabellidae	T
Oligochaeta	K N TU

[1]Refer to Appendix F for predator codes.

Appendix G. continued

Prey Items	Predators
Mollusca	
Bivalvia	A IJK STUV
Macoma sp.	S V
Siliqua sp.	V
Gastropoda	IJ U
Lacuna sp.	U
Arachnida	
Acarina	K S
Crustacea	
Ostracoda	JK S U
Harpacticoida	JKL S U
Ectinosomidae?	A JK S U
Harpacticidae?	I KL S
Cirripedia (larvae)	I L
Mysidae	B JK M Q
Neomysis sp.	J N
Neomysis czerniawskii	B JK N P R V
Neomysis mirabilis	B J
Neomysis rayii	BC JK PQR
Cumacea	A JK Q S U
Lamprops sp.	JK QRS U W
Tanaidacea	S
Isopoda	K N
Saduria entomon	K P
Gammaridea	JKL N P S UV
Calliopius laeviusculus	K
Gammaridae	JK
Gammarus sp.	JK N
Caprellidea	K
Caridea	K Q V
Crangonidae	B JK Q U
Crangon sp.	JK
Crangon septemspinosa	K V
Telmessus cheiragonus	M

Appendix G. continued

Prey Items	Predators
Insecta	
Insecta unident.	B I K T
Auchenorryncha	D I K T
Diptera	D M
Chironomidae	B F JKL U
Empididae	D
Hymenoptera	D
Tenthredinoidea	D I
Ichneumonoidea	D
Sipuncula	
Sipuncula unident.	V
Echinodermata	
Ophiuroidea	S
Tunicata	
Ascidiacea	E U
Teleostei	
Teleostei unident.	G JK NO UV
Osmeridae	K
Osmerus mordax dentex	JK N T V
Eliginus gracilis	V
Pungitius pungitius	G
Cottidae	F
Occella dodecaedron	K
Acantholumpenus mackayi	K
Miscellaneous	
Fish scales	A JK S
Eggs	C IJK MN S U
Organic material	ABC EF JKLMN PQRS U
Inorganic material	BC FG JK M STUVW