# Environmental Assessment of the Alaskan Continental Shelf

## Quarterly Reports of Principal Investigators April—December 1979

## Volume I

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

# Environmental Assessment of the Alaskan Continental Shelf

## Quarterly Reports of Principal Investigators for April—December 1979

## VOLUME I

Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

March 1980

**U.S. DEPARTMENT OF COMMERCE**
National Oceanic and Atmospheric Administration

**U.S. DEPARTMENT OF INTERIOR**
Bureau of Land Management

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## MARINE BIRDS

RECEPTORS (BIOTA)

Marine Birds

Contents

Quarterly Report

Contract No. 03-5-022-68

Research Unit #108

Reporting Period: 1 July - 30 September 1979

# SIMULATION OF MARINE BIRD POPULATION ENERGETICS

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## INTRODUCTION

Seabirds are linked to the marine environments they occupy by a variety of influences, but perhaps foremost among these are energy and trophic flows. How and where colonially breeding birds obtain the energy necessary to sustain themselves and rear their offspring may be the major factor determining their sensitivity to perturbations of the marine system. In an earlier report (Wiens et al. 1979) we described a modeling approach to consider the spatial and demographic aspects of such linkages. In order to place such model exercises in perspective, however, it is necessary first to determine the overall magnitude and seasonal pattern of energy and trophic flows through the dominant breeding populations of a given system. In this report, we estimate such measures for the area on and about Kodiak Island, relying heavily upon information obtained by personnel of the U.S. Fish and Wildlife Service.

## METHODS

Preliminary analyses of the energetics and basic demography of the three dominant species of marine birds breeding on Kodiak Island were carried out using a modified version of the BIRD II computer simulation model developed by Wiens and Innis (Wiens and Innis 1974, Innis and Wiens 1977). Of the 20 pelagic bird species known to breed on Kodiak Island proper, Tufted Puffins, Black-legged Kittiwakes, and Glaucous-winged Gulls are clearly dominant, both numerically and trophically. Shearwaters, Northern Fulmars, and Common Murres are also abundant in the area surrounding Kodiak, but because they do not breed on Kodiak, we do not consider them in this analysis. Additionally, because the populations of shearwaters and fulmars in this region are entirely pelagic, there is at present no reliable method of estimating their true population sizes. The problem of transforming pelagic census data into population size estimates will be dealt with in a forthcoming report on pelagic distributions about Kodiak Island.

## INPUT VARIABLES

The BIRD II model requires as inputs a large number of species- and population-specific values in order to perform detailed simulations of the changing energy demands of each species through the course of a breeding cycle. Values for these variables were derived from data provided by RUs 341 and 342. These data were collected primarily at Chiniak Bay and Sitkalidak Strait in 1977 and 1978. Wherever data were available for more than one year of location, a weighted average was used for that variable. In many cases, however, data were available in an appropriate form for only one year. A list of input variables, their definitions, and the values we employed in the analyses reported here is provided in Table 1.

## DEMOGRAPHY

Although data supplied by field investigators provide basic phenological and reproductive parameters for populations of the three dominant species, it is useful to synthesize these values into a single unified demographic construct for each species. The demographic subroutine of BIRD II produces output that estimates temporal variations in population structure through the course of the breeding season; such output is depicted for the three dominant species in Figs. 1-3.

Table 1. Input variables: abbreviations, descriptions, units, and values. Where the value of a variable is constant for all species, the value is given below; otherwise, it is given on the foolowing page. All data are from RUs 341 and 342.

| Abbr. | Description | Units | Value |
|---|---|---|---|
| BOTT | Minimum activity elevation of metabolism | Dimensionless | 0.10 |
| DEF | (Digestive efficiency)$^{-1}$ | Dimensionless | 1.33 |
| NSP | Number of species | Dimensionless | 3 |
| SPHZ | Time that BOTT is attained | Julian date | 15 |
| TC | Lower limit to thermoneutral zone | Degrees C | 0 |
| TEND | Time of end of run | Julian date | 263 |
| TLA | Deviation from 12-hr photoperiod | Hours | 3 |
| TSTRT | Time of start of run | Julian date | 119 |
| TTOP | Maximum activity elevation of metabolism | Dimensionless | 0.25 |
| AK | Logistic growth curve constant | Dimensionless | Variable |
| AMW | Mean body weight of adults | Grams | Variable |
| CS | Mean clutch size | Eggs | Variable |
| DCI | Time of completion of last clutch | Julian date | Variable |
| DOI | Time of completion of first clutch | Julian date | Variable |
| FS | Fledging success | Dimensionless | Variable |
| FW | Mean body weight of fledglings | Grams | Variable |
| HMW | Mean body weight of hatchlings | Grams | Variable |
| HS | Hatching success | Dimensionless | Variable |
| PBD | Population size at TIN | Birds | Variable |
| PE | Population size at TEND | Birds | Variable |
| PI | Length of incubation period | Days | Variable |
| PN | Length of nesting period | Days | Variable |
| PPBF | Fraction of PBD that are breeding females | Dimensionless | Variable |
| PS | Population size at TSTRT | Birds | Variable |
| TD | Time of first departure | Julian date | Variable |
| TE | Time of last departure | Julian date | Variable |
| TIN | Time of initiation of nesting | Julian date | Variable |
| TS | Time of first arrival | Julian date | Variable |

Table 1 (cont.). Input variables.

| Abbr. | Black-legged Kittiwake | Glaucous-winged Gull | Tufted Puffin |
|---|---|---|---|
| AK | 0.225 | 0.182 | 0.111 |
| AMW | 440 | 1,298 | 815 |
| CS | 1.7 | 2.4 | 1.0 |
| DCI | 198 | 172 | 165 |
| DOI | 168 | 156 | 146 |
| FS | 0.70 | 0.75 | 0.89 |
| FW | 1,405 | 1,100 | 590 |
| HMW | 35 | 68 | 58 |
| HS | 0.72 | 0.62 | 0.65 |
| PBD | 107,440 | 34,550 | 203,700 |
| PE | 0 | 8,840 | 0 |
| PI | 29 | 30 | 12 |
| PN | 35 | 36 | 45 |
| PPBF | 0.76 | 0.63 | 0.75 |
| PS | 0 | 8,840 | 0 |
| TD | 230 | 224 | 233 |
| TE | 261 | 248 | 248 |
| TIN | 168 | 156 | 146 |
| TS | 145 | 119 | 119 |

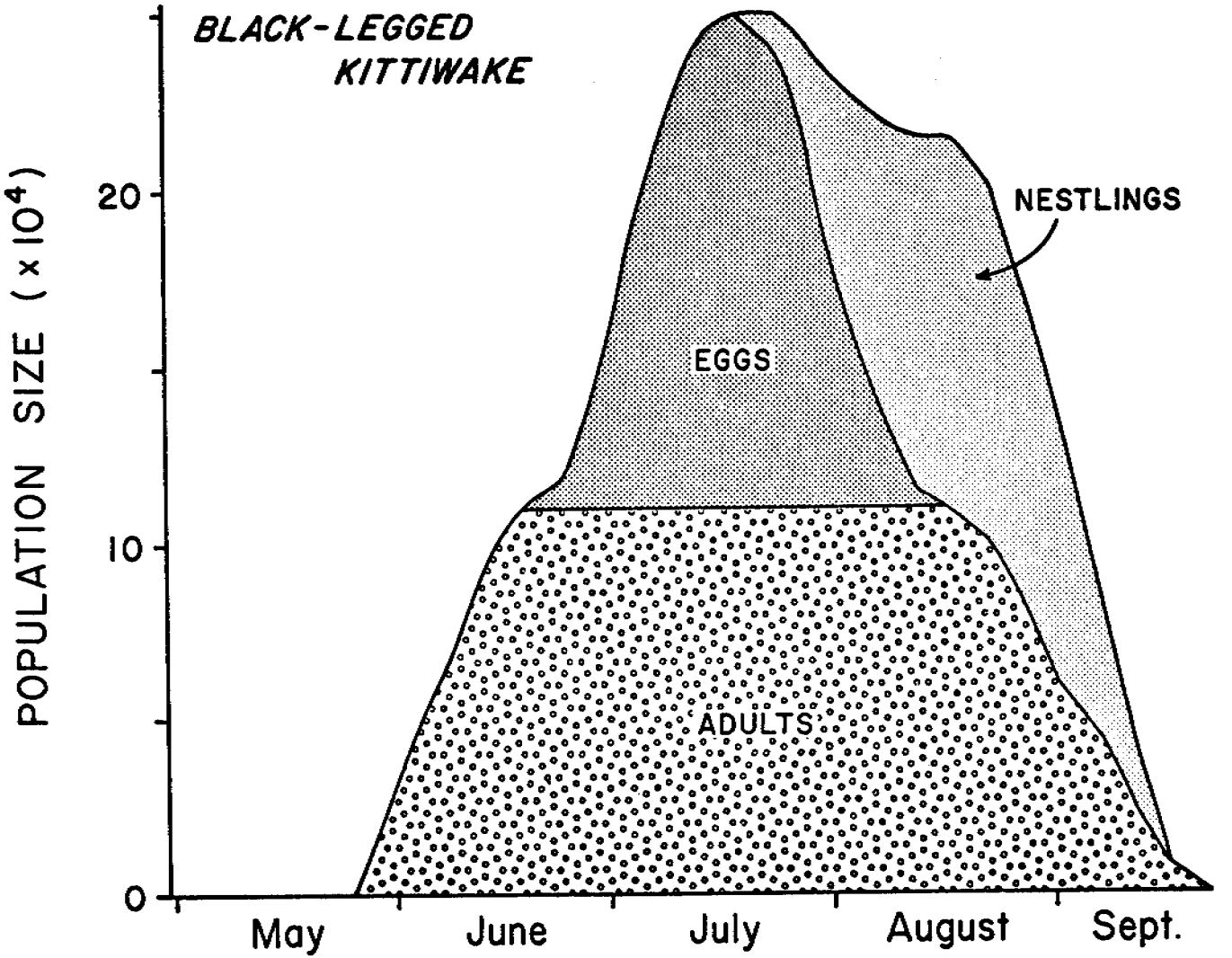


Fig. 1. Model age structure and phenology of the Kodiak Island Black-legged Kittiwake population during the breeding season. The width of each band is equal to the number of individuals in that category.

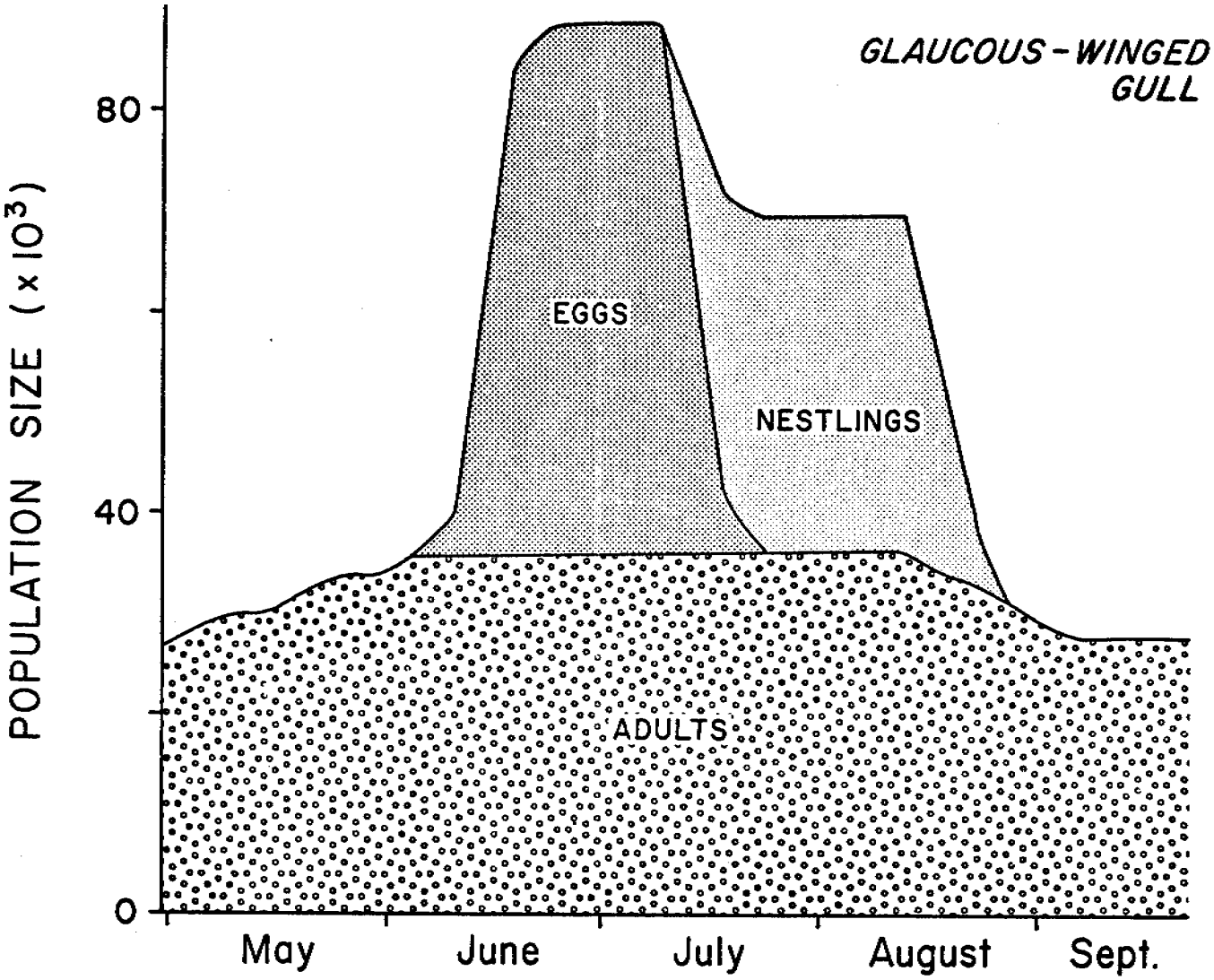


Fig. 2. Model age structure and phenology of the Kodiak Island Glaucous-winged Gull population during the breeding season. The width of each band is equal to the number of individuals in that category.

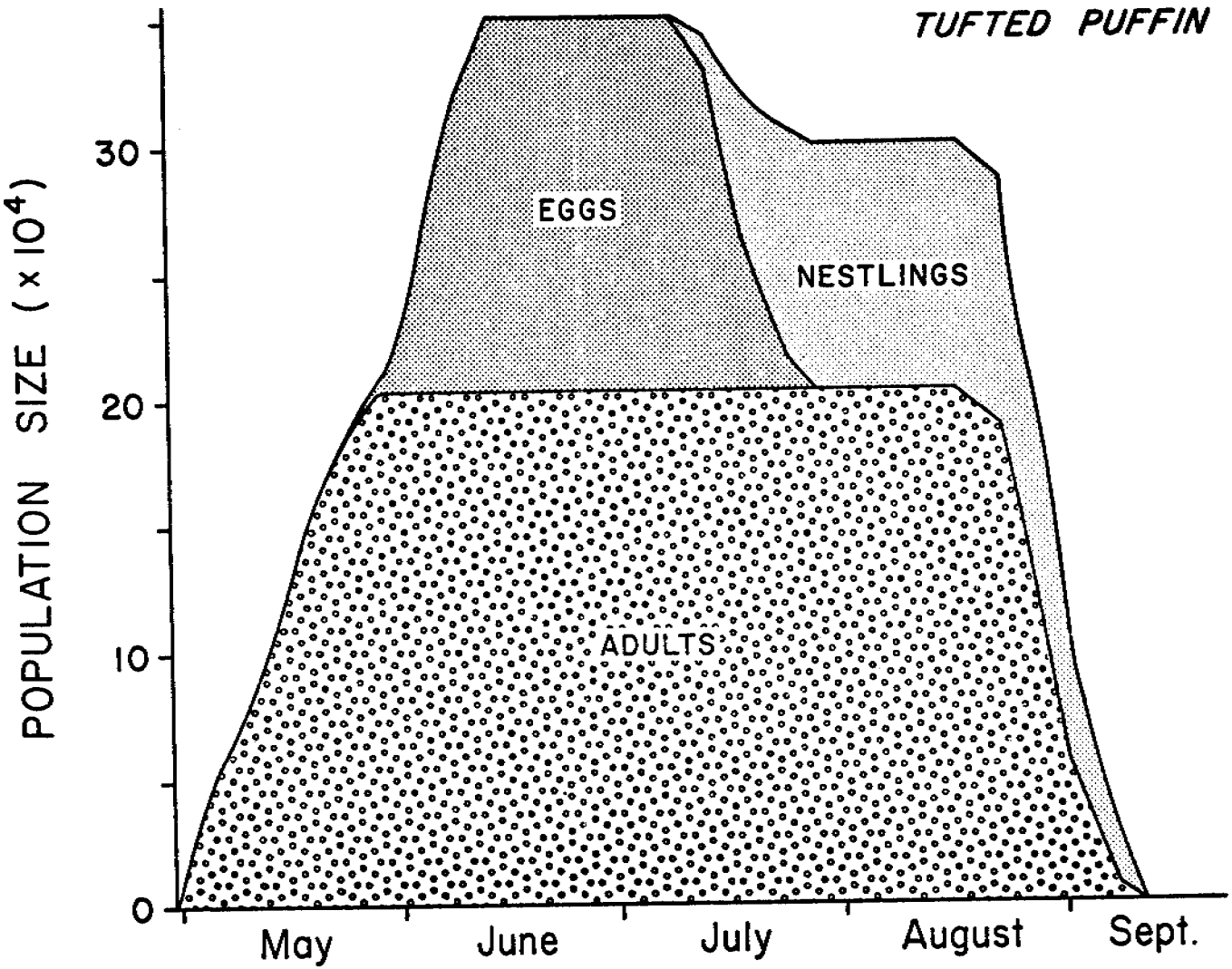


Fig. 3. Model age structure and phenology of the Kodiak Island Tufted Puffin population during the breeding season. The width of each band is equal to the number of individuals in that category.

No data are available that specify the form of the increase in adult numbers at the beginning of the breeding season. Our work with data from the Pribilof Islands seabird community, however, indicates that populations increase in an approximately linear fashion, reaching their peak at the time of the onset of egg laying. Because the chronology of egg laying was well documented for the Kodiak birds, it was necessary only to estimate the time of the onset of immigration. We approximated this date using Pribilof Islands data, assuming that the elapsed time between the onset and end of immigration was similar on Kodiak. A similar problem was encountered with the form of the emigration curve. Again, our experience with the Pribilof Islands data suggested that it is reasonable to assume that adults depart shortly after their chicks fledge. Because incubation and nestling periods are known for these species, it is relatively simple for the model to derive the form of the emigration curve.

Adult populations of Tufted Puffins and Glaucous-winged Gulls began increasing in early May. Although some puffins remain in the area throughout the year (Arneson, RU 3, Annual Report 1977), this is probably only a small fraction of the summer breeding population. A much larger proportion of the Glaucous-winged Gull population (approximately 75%) overwinters in the Kodiak area (Gould, RU 337; pers. comm.), although it is likely that summer and winter populations are comprised of different individuals. Like Tufted Puffins, Black-legged Kittiwakes are present in low numbers throughout the winter, but their numbers do not begin to increase until late May, 2-3 weeks later than the puffins.

Populations are probably most vulnerable to perturbation effects during the period when nestlings are present. While there is evidence that fouling of eggs by oil reduces hatching success (Patten, RU 96, Annual Reports 1977, 1978), nestlings are also subject to death resulting from fouling of feathers, ingestion of oil, and diminished rate of food delivery by adults. Thus the peak of population sensitivity to perturbation for all three species is most likely to occur between late July and mid-September. After this time, any birds remaining in the area would be nonbreeding birds and therefore more able to avoid the consequences of spill contact or resource depression resulting from environmental perturbation.

## ENERGY FLOW

Of the birds that breed on Kodiak Island, Tufted Puffins are undoubtedly the most important consumer species, in terms of the energy they demand of the system. During the course of the breeding season, BIRD II simulations estimate that the Tufted Puffin population consumes $5.90 \times 10^9$ kcal. This compares with an estimated $2.12 \times 10^9$ kcal consumed by the Black-legged Kittiwake population and $1.73 \times 10^9$ kcal consumed by the Glaucous-winged Gull population. Total breeding season energy demand by these three species in the Kodiak area is thus $9.75 \times 10^9$ kcal. Assuming an average energetic content of approximately 1.2 kcal/g wet weight (Wiens and Scott 1975), this corresponds to 8,100 metric tons of food. By way of comparison, breeding season energy demand of the dominant species on the Pribilof Islands (chiefly murres) was estimated by the same modeling procedure as $6.49 \times 10^{10}$ kcal or 53,600 metric tons of food, nearly an order of magnitude greater. The Kodiak values, however, do not include several major species that do not actually breed on the island; such "peripheral" species are of minor importance in the Pribilof system. Within the Kodiak area as a whole, for example, the energy uptake of the Tufted Puffin is probably

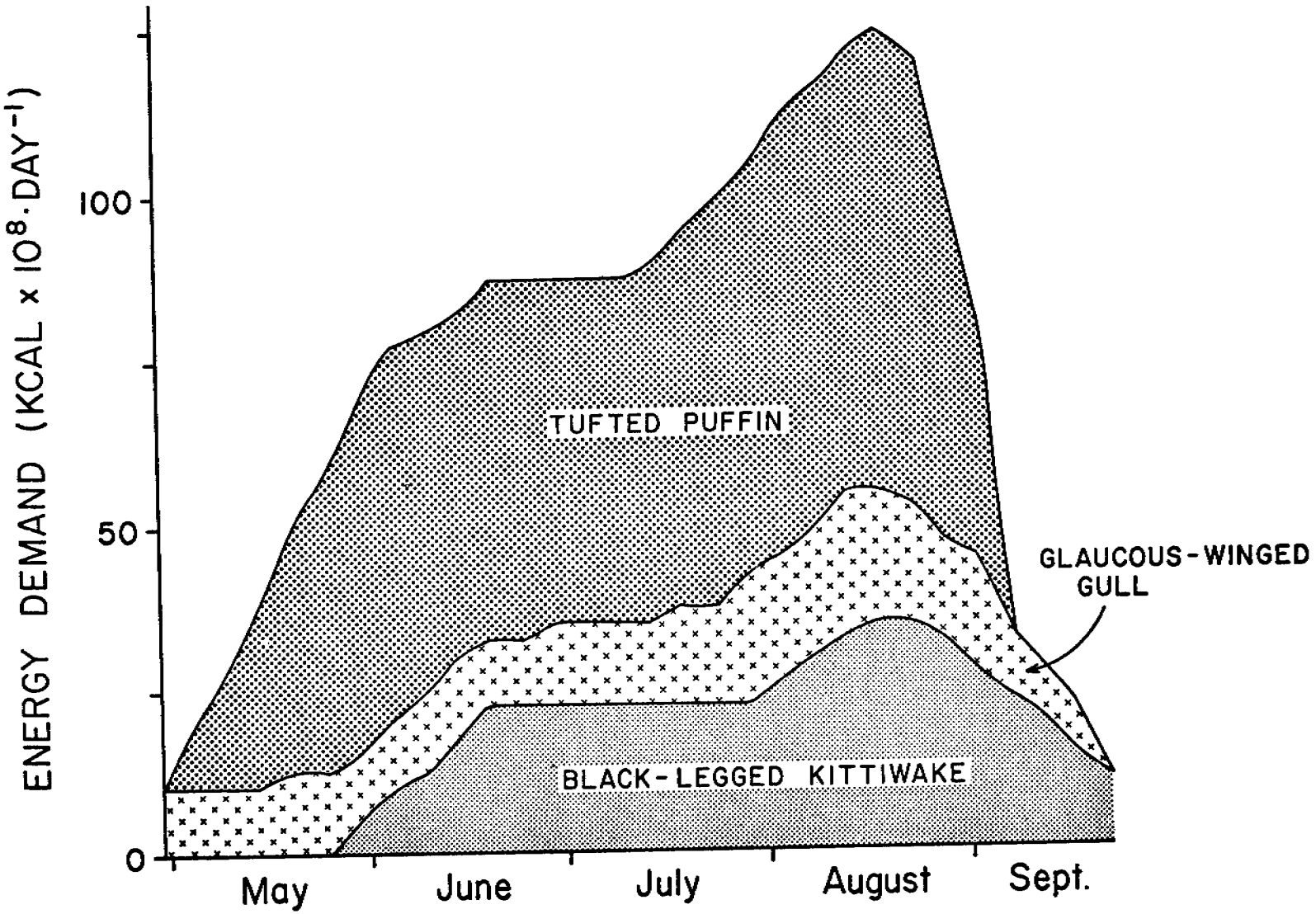


Fig. 4. Estimated daily energy demand by the three dominant species of birds nesting on Kodiak Island during the breeding season. The width of each band is equal to the daily energetic demand of the appropriate species.

exceeded by that of the Common Murre, which is abundant on the Barren Islands and the north shore of the Shelikof Strait. Although shearwaters do not breed in the area and absolute population sizes cannot be determined, their high local abundance indicates that they are also an important consumer species.

The energetic demand of the Kodiak breeding colonies begins to increase rapidly in early May with the arrival of breeding adults (Fig. 4). A plateau of community energy demand is reached during June, when most breeding adults are present and incubating. As nestlings begin to grow, energy demand once more increases, reaching a peak in mid- to late August. At the maximum, these three species together consume $1.24 \times 10^8$ kcal per day. With the onset of fledging, community energy demand falls off rapidly and reaches winter levels by the end of September.

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# RECEPTORS (BIOTA)

FISH, LITTORAL, BENTHOS, ETC.

RECEPTORS (BIOTA)

Fish, Littoral, Benthos, Etc.

Contents

QUARTERLY REPORT

Contract: #03-5-022-56
Task Order: #15
Research Unit: #5
Reporting Period: 10/1/79-
12/31/79
Number of Pages: 42

# DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF THE KODIAK SHELF, COOK INLET, AND NORTHEASTERN GULF OF ALASKA (YAKUTAT BAY TO CROSS SOUND)

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with

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December 1979

## KODIAK SHELF

See Appendix A for Interim Report of the Kodiak Shelf.

## LOWER COOK INLET

### I. TASK OBJECTIVES

A. Inventory and census of dominant species.

B. Description of spatial distribution patterns of selected species.

C. Provide preliminary observations of biological interrelationships between selected segments of benthic marine communities. Emphasis will be placed on the food webs supporting commercially harvested crustaceans.

D. Provide information on growth and mortality of infaunal bivalves.

### II. FIELD AND LABORATORY ACTIVITIES

A. Field Activities

1. All field activities have been suspended.

B. Laboratory

1. All experimental work with captive organisms was stopped in FY-78.

2. Laboratory work completed includes:

   a. Analysis of distribution and abundance of commercially harvested crab and shrimp during 1976, 1977 and 1978 cruises.

   b. Stomach analysis of adult and juvenile snow crab, king crab, dungeness crab, post-larval king crab, and *Crangon dalli*, pink shrimp, coonstripe shrimp, humpy shrimp, and six species of hermit crab are completed. This section of the Final Report is typed.

   c. Preliminary information on the importance of prey availability to recruitment success of the zoeae of snow crab, king crab, and pink shrimp is available. Data on the effect of temperature and early starvation of king crab zoeae is also available. These components of the feeding study for the Final Report are finished.

   d. Growth, growth history and mortality data is available on six species of bivalves commonly found throughout Cook Inlet. This component of the Final Report is finished.

e. Distribution and abundance of invertebrates from trawl and grab samples are in the stages of data analysis. Computer analysis complete. Section due for completion 1 February 1980.

## III. RESULTS

A. Data for parts of objectives A, B, and C appear in 1978 and 1979 Annual Reports.

B. All work on the two components (1) food study, and (2) bivalve biology, appearing on the time table for fiscal year 1979 were completed on schedule. All laboratory work is completed. The trawl and grab data will not be completed until 1 February 1980. This portion of the project was retarded because of computer tie-ups caused by the Bering Sea Symposium. The Final Report writing will be completed on or before 31 March 1980.

## IV. PRELIMINARY INTERPRETATION OF RESULTS (SEE ANNUAL REPORTS FOR 1978 AND 1979)

## NORTHEASTERN GULF OF ALASKA
## (YAKUTAT BAY TO CROSS SOUND)

### I. TASK OBJECTIVES

A. A quantitative inventory census of dominant epifaunal invertebrates by depth intervals.

B. A description of spatial distribution patterns of selected epifaunal invertebrates.

C. Where possible, assess spatial distribution and relative abundance of selected infaunal invertebrate species.

D. Observations of biological interrelationships, emphasizing trophic interactions, between selected segments of the benthic biota.

### II. FIELD AND LABORATORY ACTIVITIES

A. Field Activity

A cruise via the NOAA ship *Miller Freeman* occurred 5-26 November 1979 between Yakutat Bay and Cross Sound.

B. Laboratory Activity

Verification of trawl, grab, and pipe dredge specimens is underway.

### III. RESULTS

A total of 84 stations were surveyed; 70 offshore stations and 14 Yakutat Bay stations.

A. 400-mesh Eastern otter trawl

50 tows were made at 49 stations. The number of quantitative and qualitative tows were 45 and 2, respectively. Three tows resulted in a ripped net and no data were obtained. Only three stations (3 tows)

were obtained in Yakutat Bay. All but two of the high priority stations were surveyed.

B. Van Veen Grabs

A total of 46 grab stations were obtained; 34 in the offshore area and 12 in Yakutat Bay. Usually 5 grabs were obtained at each station.

C. Pipe Dredge

A total of 34 dredge stations were occupied; 29 in the offshore area and 5 in Yakutat Bay.

D. Temperature

Water temperature profile was obtained via XBT at 65 stations and via CTD at 3 stations.

E. Stomach Analysis

Examination of stomach contents from 20 species of fishes yielded 1403 individuals analyzed. Flatfishes dominated the analysis with 10 species totaling 1108 stomachs. Invertebrates examined or collected for stomach analysis were snow crab (264), dungeness crab (57), and the sea star, *Pycnopodia helianthoides* (40).

F. Preserved Specimens

Specimens were preserved in 26 5-gallon plastic buckets. All buckets will be shipped to the Institute of Marine Science at the University of Alaska in Fairbanks.

G. Commensal Relationships

Six (6) species of hermit crab were examined for their commensal relationship of miscellaneous invertebrates.

APPENDIX A

OCS INTERIM REPORT

# Distribution, Abundance, Community Structure and Trophic Relationships of the Benthos of the Kodiak Shelf

H. M. Feder, Principal Investigator

with

Stephen Jewett

## I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Until recently little was known about the biology of the invertebrates of the shallow, nearshore benthos of Kodiak Island. Since these invertebrates may be the ones most affected by petroleum operations in waters adjacent to Kodiak Island, baseline data on these species are essential before industrial activities begin there.

The specific objectives of this investigation of Kodiak Island addressed in this Annual Report are:

A. On a limited basis, assess distribution and relative abundance of epifaunal invertebrates in selected bays and offshore areas.

B. Determine the feeding habits of the principal inshore epifaunal invertebrate species, emphasizing king crab, and selected bottomfish.

Offshore sampling was conducted in March 1978 adjacent to Portlock Bank and in June-July 1978 and February 1979 along the entire east side of the Kodiak Island continental shelf. The most important group, in terms of biomass, collected near Portlock Bank was echinoderms, specifically sea stars and sea urchins. King and snow crab were the second-most important group from this area. Kodiak shelf sampling in June-July and February revealed king and snow crab as the dominant species.

Forty-six permanent benthic stations were established in two bays - 29 stations in Izhut Bay and 17 stations in Kiliuda Bay. These stations were sampled with a try-net and/or a 400-mesh Eastern otter trawl on seven separate cruises: April, May, June, July, August, and November 1978, and March 1979. Taxonomic analysis of the epifauna collected delineated nine phyla in each bay. The dominant invertebrate species had distinct biomass differences between the bays. Important species,

in terms of biomass, in Izhut Bay were snow crab (*Chionoecetes bairdi*) and the sunflower sea star (*Pycnopodia helianthoides*). Kiliuda Bay was dominated by king crab (*Paralithodes camtschatica*), snow crab, and pink shrimp (*Pandalus borealis*).

Stomachs of king crab collected via trawling and spring SCUBA activities, contained a wide variety of prey. Prey of crab from Izhut Bay was dominated by fishes. Crab of Kiliuda Bay mainly preyed upon molluscs, specifically clams. Food obtained from king crab from the June-July 1978 and February 1979 Kodiak Shelf sampling consisted mainly of clams and cockles, however, crustaceans and fishes were also important. King crab collected during SCUBA sampling mainly contained clams and acorn barnacles.

Food data for snow crab and pink shrimp in addition to king crab will be available for the Final Report, and these data, in conjunction with similar data from Cook Inlet and the Bering Sea, will enhance our understanding of the trophic role of these crustaceans in their respective ecosystems. Additional food data for the sea star *Pycnopodia helianthoides* and bottom-fishes, as well as an assessment of the literature, will make it possible to develop a food web for benthic and nektobenthic species of inshore and offshore waters around Kodiak Island. Comprehensions of basic food interrelationships is essential for assessment of the potential impact of oil on the crab-shrimp-dominated benthic systems of the waters adjacent to Kodiak.

The importance of deposit-feeding clam in the diet of king and snow crab in Kodiak waters has been demonstrated by preliminary feeding data collected there. It is suggested that an understanding of the

relationship between oil, sediment, deposit-feeding clam, and crab be developed in a further attempt to understand the possible impact of oil on the two commercially important species of crab in the Kodiak area.

Initial assessment of data suggests that a few unique, abundant and/or large invertebrate species (king crab, snow crab, several species of clams) are characteristic of the bays investigated and that these species may represent organisms that could be useful for monitoring purposes.

It is suggested that a complete understanding of the benthic systems of Kodiak waters can only be obtained when the infauna is also assessed in conjunction with the epifauna. Based on stomach analyses, infaunal species are important food items for king and snow crab. However, the infaunal components of the Kodiak Shelf have not been quantitatively investigated to date. A program designed to examine the infauna should be initiated in the very near future.

## II. INTRODUCTION

See Feder *et al.* (1979).

## III. CURRENT STATE OF KNOWLEDGE

See Feder *et al.* (1979).

## IV. STUDY AREA

A large number of stations were occupied on the Kodiak Continental Shelf in conjunction with the Alaska Department of Fish and Game and National Marine Fisheries Service (see Appendix A, Table 1 in Feder *et al.*, 1979). Inshore areas most extensively sampled by trawl included

Izhut Bay, located on the southeast side of Afognak Island, and Kiliuda Bay, located on the east side of Kodiak Island (see Figs. 1 and 2 in Feder *et al.*, 1979). Additional inshore areas were sampled on Kodiak Island by SCUBA: Near Island Basin; McLinn Island, and Anton Larsen Bay (see Fig. 3 in Feder *et al.*, 1979). Outer shelf stations were occupied by trawl near Portlock Bank (see Fig. 4 in Feder *et al.*, 1979), and by trawl and pipe dredge along the east side of the Kodiak Island Shelf (see Fig. 5 in Feder *et al.*, 1979; Fig. 1 present report).

## V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Data on benthic epifauna, including feeding data on crab and fish, were collected during ten cruises in 1978-79. The NOAA Ship *Miller Freeman* was used primarily for offshore sampling, and the M/V *Yankee Clipper* and the R/V *Commando* were used primarily for inshore collecting.

Sampling from the *Miller Freeman* was conducted 21-24 March 1978, 19-9 June-July 1978, and 14-24 February 1979 using a commercial-size 400-mesh Eastern otter trawl (12.2 m horizontal opening). A pipe dredge was also used from the *Freeman* in June-July 1978 and February 1979 to obtain invertebrates to aid in the identification of invertebrate and fish stomach contents.

The *Yankee Clipper* sampled 10-22 April, 7-15 May, 7-22 June, 9-21 July, and 8-23 August 1978. The *Commando* also sampled 7-15 May, 7-22 June, 9-21 July, and 8-23 August 1978, in addition to 4-17 November 1978 and 1-20 March 1979. A try-net (6.1 m horizontal opening) was used from the *Clipper*, and a try-net and Eastern otter trawl were used from the *Commando*.

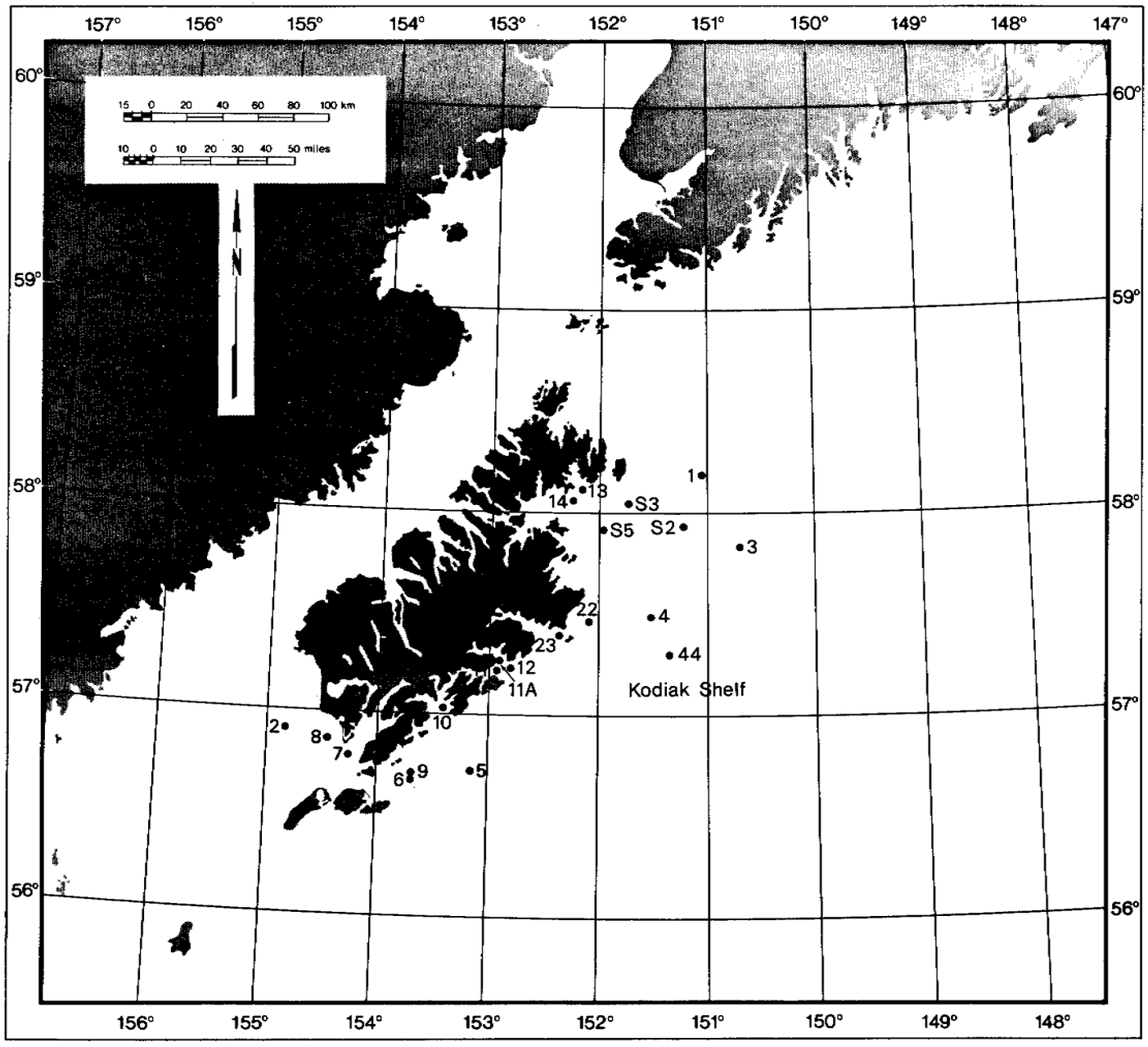


Figure 1. Benthic stations occupied on the Kodiak Continental Shelf, June-July 1978 and February 1979.

Exploratory diving for crab, via SCUBA, was conducted near the city of Kodiak in May, June and October 1978 and May 1979. SCUBA-caught king crab, obtained for stomach analysis, were caught in May 1978 at Near Island Basin (57°47.0' N, 152°3.0' W) near McLinn Island (57°46.2' N, 152°27.1' W), and in June at Near Island Basin and two locations in Anton Larsen Bay (site #1 - 57°52.0' N, 152°37.4' W and site #2 - 57°52.5' N, 152°39.0' W). Diving in October 1978 was conducted in Near Island Basin; no king crab were observed. King crab were collected in May 1979 at Near Island Basin, McLinn Island (57°46.3' N, 152°26.5' W) and Anton Larsen Bay site #2.

Invertebrates from the trawls were sorted on shipboard, given tentative identifications, counted and weighed. Aliquot samples of individual taxa were labeled and preserved for final identification at the University of Alaska, Fairbanks. Invertebrates from the pipe dredge were sorted, identified, and counted at the University of Alaska. Non-commercial invertebrates from some Izhut and Kiliuda Bay stations in June and August were inadvertently not recorded.

Biomass per unit area ($g/m^2$) is included for all trawl data and is calculated as follows:

$$\text{Biomass} = \sum_{i=i}^{k} [\text{weight}/(\text{distance fished} \times \text{trawl width})]$$

Analysis of food habits of a variety of predators taken by trawl was conducted in the laboratory at the University of Alaska. A summary of the number of stomachs examined by sampling area and collection period is included in Table I in Feder *et al.*, 1979. Feeding data collected in 1979 are summarized in this report.

On shipboard, king crab selected for stomach analysis were measured (length in millimeters) and weighed (wet weight in grams). Carapace length is defined as the distance from the posterior margin of the right orbital indentation to the mid-point of the posterior marginal identation. Crab were categorized as belonging to one of eight classes (Powell *et al.*, 1974): (1) newshell juvenile females less than 120 mm; (2) newshell adult females greater than 94 mm; (3) newshell males less than 100 mm - individuals that molted during the last molting period; (4) oldshell males less than 100 mm - individuals that failed to molt during the last molting period, often referred to as skipmolts; (5) very oldshell males less than 100 mm - individuals that failed to molt during the two or more molting periods, often referred to as double skipmolts; (6) newshell males greater than 100 mm; (7) oldshell males greater than 100 mm; and (8) very oldshell males greater than 100 mm. Stomachs[1] and intestines were removed and were placed in plastic "Whirlpak" bags and fixed in 10% buffered formalin and final identification was made at the University of Alaska, Fairbanks.

In the laboratory, stomach contents were removed, and sorted by taxon. Each taxon was blotted dry, weighed to the nearest 0.001 g, measured volumetrically by water displacement to the nearest 0.01 ml. Taxon weighing was accomplished by weighing a vial with a known quantity of water and then weighing the vial and water plus the taxon. The difference in the two weights equal the taxon weight.

Food material may never completely fill a stomach to the theoretical maximum volume. Large quantities of digestive fluids, in addition to

[1]In this study, references to crab stomachs includes that portion extending from the terminal portion of the esophagus to the beginning of the intestine.

hard and bulky food material that is not readily compressed prevents filling to capacity.

The fullness of stomach was calculated using a method adapted from Cunningham (1969) for southeast Bering Sea king crab. He delineated a curvilinear relationship between king crab length and the theoretical maximum stomach volume. To do this, he measured the maximum stomach volume of 216 crab which ranged from 80-180 mm carapace length. The regression formula was $Y = 34.25 - 0.72x + 0.0047x^2$, and the correlation coefficient was 0.899. Since king crab examined in our study were similar in size to those examined by Cunningham, we used his regression formula with our crab to calculate the theoretical maximum volumes. The percent of fullness was derived by dividing the observed volume by the theoretical maximum volume. The prey in the intestines of king crab were examined and recorded by frequency of occurrence.

Fish stomachs were examined when possible, and contents were recorded as frequency of occurrence.

## VI. RESULTS

### A. Trawl Data: Distribution - Biomass

Data collected via trawls in 1978 are reported in Feder *et al.* (1979). Trawl data for 1979 is included below.

#### 1. Kodiak Shelf - February 1979 (Figure 1; Table I and II)

Trawling activities via the NOAA ship *Miller Freeman* on the Kodiak Continental Shelf in February 1979 yielded 14 successful stations. One station, Station 3, was not considered quantitative because the net was torn, however, fish stomachs were examined from this station. The mean epifaunal

TABLE I

TRAWL STATIONS OCCUPIED ON THE KODIAK SHELF BY THE NOAA SHIP *MILLER FREEMAN*, FEBRUARY 1979

| Station | Coordinates | | Depth m |
|---|---|---|---|
| | Start | Finish | |
| 12 | 57°12'5N 152°47'5W | 57°11'3N 152°47'5W | 128-142 |
| 11A | 57°12'8N 152°58'6W | 57°13'0N 152°57'5W | 119-132 |
| 10 | 57°01'2N 153°26'4W | 57°00'5N 153°27'8W | 128 |
| 9 | 57°46'1N 153°44'2W | 57°42'7N 153°43'1W | 146 |
| 7 | 56°46'9N 154°18'1W | 56°48'0N 154°20'1W | 51-55 |
| 8 | 56°50'7N 154°26'0W | 56°49'9N 154°24'2W | 69 |
| 5 | 56°43'1N 153°10'0W | 56°41'7N 153°09'6W | 150 |
| 23 | 57°22'2N 152°25'5W | 57°20'5N 152°25'4W | 56 |
| 44 | 57°15'3N 151°16'9W | 57°16'7N 151°16'9W | 150-152 |
| 4 | 57°29'0N 151°29'7W | 57°28'8N 151°31'2W | 152 |
| 3 (qual.) | 57°47'7N 150°42'1W | 57°46'8N 150°42'7W | 84 |
| 14 | 58°05'0N 152°15'4W | 58°04'1N 152°17'0W | 162-170 |
| S2 | 57°56'9N 151°18'8W | 57°58'1N 151°18'8W | 69-71 |
| S3 | 58°02'5N 151°49'1W | 58°03'4N 151°46'6W | 163-166 |
| S5 | 57°56'5N 152°00'9W | 57°57'1N 151°58'2W | 196-199 |

TABLE II

PERCENT AND ACTUAL ($g/m^2$) BIOMASS COMPOSITION OF THE INVERTEBRATE PHYLA AND DOMINANT SPECIES COLLECTED VIA TRAWL ON THE KODIAK SHELF, FEBRUARY 1979

| Phylum | Percent | $g/m^2$ |
|---|---|---|
| Cnidaria | 0.52 | 0.016 |
| Mollusca | 14.81 | 0.466 |
| Arthropoda | 80.57 | 2.537 |
| Echinodermata | 2.96 | 0.093 |
| Urochordata | 1.14 | 0.035 |
| TOTAL | 100.00 | 3.148 |

| Species | Percent | $g/m^2$ |
|---|---|---|
| *Modiolus modiolus* | 14.05 | 0.442 |
| *Pandalus borealis* | 1.61 | 0.051 |
| *Paralithodes camtschatica* | 14.17 | 0.446 |
| *Chionoecetes bairdi* | 63.70 | 2.000 |
| *Gorgonocephalus caryi* | 2.96 | 0.093 |
| *Halocynthia aurantium* | 1.11 | 0.035 |
| TOTAL | 97.60 | 3.067 |

invertebrate biomass for all stations was 3.15 $g/m^2$. The biomass was dominated by the phylum Arthropoda (80.5% of the biomass), and followed by the phylum Mollusca (14.8%). The snow crab (*Chionoecetes bairdi*) and the king crab (*Paralithodes camtschatica*) dominated the arthropods with 63.7% and 14.2% of the total biomass, respectively. The mussel, *Modiolus modiolus*, was the most important mollusc. This bivalve comprised 14.0% of the total biomass.

Snow crab were found at 14 stations. Stations with high biomass of snow crab were 12, 11A, 10, 7, 8, 14 and S5. Station 7 yielded the greatest biomass of snow crab with 185 individuals at 139.4 kg.

Seven stations contained king crab, and the highest biomass occurred at Station 7 with 75 individuals (65 ovigerous females) at 117.1 kg. Pink shrimp were present at six stations, comprised 1.6% of the biomass, and were most abundant at Station 14.

The mussel, *Modiolus modiolus*, was found at only one station, Station S2, where 1150 individuals weighed 172.5 kg.

Fish, crab, and shrimp were collected for examination of stomach contents and are presented in the feeding section of this report.

2. Izhut Bay - March 1979 (Table III)

Benthic trawling in Izhut Bay during March 1979 was successfully accomplished via the R/V *Commando* at 13 stations; nine via a try-net trawl and 4 via a commercial otter trawl. Most station names and locations are listed in Figure 1 and Appendix A - Table I in Feder *et al.* (1979). The mean epifaunal invertebrate biomass for all stations was 9.52 $g/m^2$. Ninety percent of the biomass consisted of crustaceans with the pink shrimp (*Pandalus borealis*)

TABLE III

PERCENT AND ACTUAL ($g/m^2$) BIOMASS COMPOSITION OF THE INVERTEBRATE PHYLA AND DOMINANT SPECIES OF IZHUT AND KILIUDA BAYS, MARCH 1979

| | Izhut Bay | | Kiliuda Bay | |
|---|---|---|---|---|
| Phylum | Percent | $g/m^2$ | Percent | $g/m^2$ |
| Porifera | 0.07 | 0.007 | <0.01 | <0.001 |
| Cnidaria | 1.02 | 0.097 | 24.50 | 0.523 |
| Annelida | <0.01 | <0.001 | 0.03 | <0.001 |
| Mollusca | 0.22 | 0.021 | 0.88 | 0.019 |
| Arthropoda | 90.47 | 8.620 | 67.68 | 1.445 |
| Ectoprocta | <0.01 | <0.001 | <0.01 | <0.001 |
| Echinodermata | 8.19 | 0.780 | 6.87 | 0.146 |
| Urochordata | <0.01 | <0.001 | 0 | 0 |
| TOTALS | 100.00 | 9.525 | 100.00 | 2.133 |

| | Izhut Bay | | Kiliuda Bay | |
|---|---|---|---|---|
| Species | Percent | $g/m^2$ | Percent | $g/m^2$ |
| *Metridium senile* | 1.03 | 0.098 | 24.50 | 0.523 |
| *Pandalus borealis* | 41.21 | 3.926 | 2.02 | 0.043 |
| *Pandalus hypsinotus* | 8.33 | 0.794 | 0.16 | 0.003 |
| *Paralithodes camtschatica* | 0.34 | 0.032 | 52.44 | 1.119 |
| *Chionoecetes bairdi* | 39.86 | 3.798 | 8.70 | 0.186 |
| *Cancer magister* | 0.30 | 0.029 | 3.31 | 0.070 |
| *Dermasterias imbricata* | 0 | 0 | 2.29 | 0.049 |
| *Gephyreaster swifti* | 0 | 0 | 1.09 | 0.023 |
| *Pycnopodia helianthoides* | 7.81 | 0.744 | 0.01 | <0.001 |
| *Strongylocentrotus purpuratus* | 0 | 0 | 2.23 | 0.047 |
| TOTALS | 98.88 | 9.421 | 96.75 | 2.063 |

contributing 41.2% of the biomass and the snow crab (*Chionoecetes bairdi*) contributing 39.8% of the biomass. The largest catches of pink shrimp and snow crab came from a new station, Station 679 (58°09'5 N, 152°13'5 W). At this station 344.6 kg of shrimp and 280.0 kg of snow crab were taken in a 25 minute tow via the otter trawl.

Stomachs of snow crab and pink shrimp were preserved for laboratory examination.

3. Kiliuda Bay - March 1979 (Table III)

A total of eight stations were successfully occupied in Kiliuda Bay in March 1979; five with a try-net and 3 with a commercial otter trawl. Most station names and locations are listed in Figure 1 and Appendix A - Table I in Feder *et al.* (1979). The mean epifaunal invertebrate biomass for all stations was 2.12 $g/m^2$. The majority of the biomass consisted of arthropods (85.9%), mainly the red king crab (*Paralithodes camtschatica*; 52.4%) and the snow crab (8.7%). The largest catch of king crab occurred in a ten minute try-net tow at Station 579 where 56 crab (mainly ovigerous females) weighed 66.4 kg.

Stomach contents of king crab and snow crab were preserved for laboratory examination.

B. Pipe Dredge Data: Distribution - Relative Abundance

Pipe dredge data were collected on the Kodiak Shelf in June-July 1978 and February 1979 to aid in the identification of fish and invertebrate stomach contents. As a qualitative sampling device only relative abundances of invertebrate species were obtained. The dominant taxa by sampling period and station is included in Table IV. Bivalve molluscs, specifically *Axinopsida*

TABLE IV

DOMINANT TAXA BY STATION COLLECTED VIA PIPE DREDGE ON THE KODIAK SHELF

| June 1978 | | | February 1979 | | |
|---|---|---|---|---|---|
| Station 1 | No. | % | | | |
| *Ampelisca birulai* | 8 | 16.0 | No data obtained at Station 1 | | |
| *Echinarachnius parma* | 5 | 10.0 | | | |
| *Macoma* spp. | 4 | 8.0 | | | |
| *Ophiura sarsi* | 4 | 8.0 | | | |
| Station 22 | | | | | |
| *Glycera capitata* | 3 | 33.0 | No data obtained at Station 22 | | |
| *Elassochirus tenuimanus* | 2 | 22.0 | | | |
| Station 44 | | | | | |
| *Macoma lipara* | 24 | 29.3 | No data obtained at Station 44 | | |
| *Cucumaria* sp. | 22 | 26.8 | | | |
| *Balanus crenatus* | 8 | 9.8 | | | |
| *Nuculana fossa* | 6 | 7.3 | | | |
| Station 4 | | | Station 4 | No. | % |
| *Macoma* spp. | 17 | 19.3 | *Axinopsida serricata* | 200 | 37.5 |
| *Cucumaria* spp. | 12 | 13.6 | *Psephidia lordi* | 100 | 18.8 |
| *Onuphis iridescens* | 11 | 12.5 | *Macoma* spp. | 100 | 18.8 |
| *Glycera capitata* | 10 | 11.4 | *Nuculana fossa* | 34 | 6.4 |
| | | | *Nucula tenuis* | 24 | 4.5 |
| Station 5 | | | Station 5 | | |
| *Nuculana fossa* | 5 | 25.0 | *Eudorella emarginata* | 50 | 29.1 |
| *Pinnixa occidentalis* | 3 | 15.0 | *Myriochele heeri* | 20 | 11.6 |
| | | | *Echiurus* spp. | 20 | 11.6 |
| | | | *Pinnixa occidentalis* | 16 | 9.3 |
| | | | *Nuculana fossa* | 10 | 5.8 |
| Station 7 | | | Station 7 | | |
| *Axinopsida serricata* | 200 | 52.5 | *Axinopsida serricata* | 500 | 87.0 |
| Rhynchocoela | 20 | 5.2 | *Nucula tenuis* | 35 | 6.1 |
| *Heteromastus filiformis* | 20 | 5.2 | *Yoldia thraciaeformis* | 9 | 1.6 |
| *Macoma moesta* | 20 | 5.2 | | | |
| *Praxillella affinis* | 15 | 3.9 | | | |
| *Nucula tenuis* | 15 | 3.9 | | | |
| *Macoma calcarea* | 12 | 3.1 | | | |

TABLE IV

CONTINUED

| June 1978 | | | February 1979 | | |
|---|---|---|---|---|---|
| Station 8 | No. | % | Station 8 | No. | % |
| *Axinopsida serricata* | 100 | 38.9 | *Nucula tenuis* | 320 | 57.5 |
| *Nucula tenuis* | 50 | 19.5 | *Axinopsida serricata* | 70 | 12.6 |
| *Thysanoessa inermis* | 40 | 15.6 | *Nuculana fossa* | 70 | 12.6 |
| *Haploscoloplos panamensis* | 10 | 3.9 | *Yoldia thraciaeformis* | 45 | 8.1 |
| *Yoldia montereyensis* | 10 | 3.9 | *Macoma* spp. | 22 | 3.9 |
| Station 9 | | | Station 9 | | |
| *Axinopsida serricata* | 500 | 56.2 | *Axinopsida serricata* | 300 | 35.1 |
| *Macoma calcarea* | 100 | 11.2 | *Nucula tenuis* | 180 | 21.1 |
| *Eudorella emarginata* | 50 | 5.6 | *Myriochele heeri* | 100 | 11.7 |
| *Nucula tenuis* | 45 | 5.1 | *Macoma* spp. | 70 | 8.2 |
| *Nuculana fossa* | 45 | 5.1 | *Pinnixa occidentalis* | 60 | 7.0 |
| *Haploscoloplos panamensis* | 30 | 3.4 | *Nuculana fossa* | 50 | 5.8 |
| | | | *Travisia forbesii* | 22 | 2.6 |
| Station 10 | | | Station 10 | | |
| *Axinopsida serricata* | 15 | 50.0 | *Pinnixa occidentalis* | 250 | 69.1 |
| *Macoma* spp. | 5 | 16.7 | *Axinopsida serricata* | 50 | 13.8 |
| Echiuridae | 5 | 16.7 | *Echiurus echiurus* | 30 | 8.3 |
| | | | *Yoldia amygdalea* | 13 | 3.6 |
| Station 11 | | | Station 11A | | |
| Echiuridae | 300 | 95.2 | *Axinopsida serricata* | 35 | 70.0 |
| *Heteromastus filiformis* | 4 | 1.3 | *Pinnixa occidentalis* | 3 | 6.0 |
| *Yoldia amygdalea* | 4 | 1.3 | *Macoma* spp. | 2 | 4.0 |
| *Axinopsida serricata* | 4 | 1.3 | *Yoldia amygdalea* | 2 | 4.0 |
| Station 12 | | | Station 12 | | |
| Sarcodina Rhizopodea | 1000 | 53.9 | *Nucula tenuis* | 43 | 20.2 |
| Echiuridae | 500 | 27.0 | *Axinopsida serricata* | 40 | 18.8 |
| *Axinopsida serricata* | 200 | 10.8 | *Macoma* spp. | 35 | 16.4 |
| *Macoma* spp. | 50 | 2.7 | *Yoldia amygdalea* | 21 | 9.9 |
| *Cylichna alba* | 30 | 1.6 | *Nuculana fossa* | 10 | 4.7 |
| | | | Ophiuroidea | 10 | 4.7 |
| Station 13 | | | | | |
| *Axinopsida serricata* | 31 | 47.7 | | | |
| *Heteromastus filiformis* | 10 | 15.4 | | | |
| Sarcodina Rhizopodea | 5 | 7.7 | No data obtained at Station 13 | | |
| *Nephtys punctata* | 5 | 7.7 | | | |
| *Macoma* spp. | 5 | 7.7 | | | |

TABLE IV

CONTINUED

| June 1978 | | | February 1979 | | |
|---|---|---|---|---|---|
| Station 14 | No. | % | Station 13 | No. | % |
| *Cerebratulus* spp. | 1 | 16.7 | *Axinopsida serricata* | 10 | 37.0 |
| *Amphicteis gunneri* | 1 | 16.7 | *Nephtys punctata* | 8 | 29.6 |
| *Nuculana fossa* | 1 | 16.7 | *Yoldia thraciaeformis* | 3 | 11.1 |
| *Axinopsida serricata* | 1 | 16.7 | *Psephidia lordi* | 3 | 11.1 |
| *Clinocardium ciliatum* | 1 | 16.7 | | | |
| *Macoma calcarea* | 1 | 16.7 | | | |
| | | | Station 3 | | |
| No data obtained at Station 3 | | | *Macoma obliqua* | 6 | 28.6 |
| | | | *Ophiopholis aculeata* | 5 | 23.8 |
| | | | *Golfingia vulgaris* | 3 | 14.3 |
| | | | Station 23 | | |
| No data obtained at Station 23 | | | *Psephidia lordi* | 1800 | 86.6 |
| | | | *Olivella baetica* | 85 | 4.1 |
| | | | *Suavodrillia kennicotti* | 75 | 3.6 |
| | | | *Glycinde picta* | 30 | 1.4 |
| | | | Gammaridae | 18 | 0.9 |
| | | | Station S2 | | |
| No data obtained at Station S2 | | | *Oregonia gracilis* | 7 | 18.9 |
| | | | *Cancer oregonensis* | 7 | 18.9 |
| | | | *Ophiopholis aculeata* | 5 | 13.5 |
| | | | Station S3 | | |
| No data obtained at Station S3 | | | *Psephidia lordi* | 16 | 16.7 |
| | | | *Axinopsida serricata* | 15 | 15.6 |
| | | | *Nuculana fossa* | 13 | 13.5 |
| | | | *Myriochele heeri* | 10 | 10.4 |
| | | | Station S5 | | |
| No data obtained at Station S5 | | | *Nuculana fossa* | 13 | 15.3 |
| | | | *Myriochele heeri* | 10 | 11.8 |
| | | | *Yoldia thraciaeformis* | 10 | 11.8 |
| | | | *Psephidia lordi* | 10 | 11.8 |
| | | | *Axinopsida serricata* | 8 | 9.4 |

*serricata, Psephidia lordi, Nucula tenuis, Nuculana fossa*, and *Macoma* spp., dominated at most stations. These bivalve species are common prey to many invertebrate and fish predators on the Kodiak Shelf. Any relationship between the relative abundance of these pipe-dredge species and the species consumed by various predators will be discussed in the Food Studies section of the Final Report.

C. Food Studies

1. *Paralithodes camtschatica* (Red king crab)

a. Kodiak Shelf - February 1979

King crab examined in stomach analysis came from Stations 7, 8 and 23 (Tables V and VI). Seventeen out of 22 crab had food in their stomachs. Only males, mainly oldshell males, were examined. The mean percent fullness was 1.3 ± 3.1%. Most of the food contents were composed of unidentified animal material (62.8% by weight), although 13 other food categories were identified. Fishes comprised 9.9% by weight and occurred in 23% of the crab examined. Fishes were a most important food at Stations 7 and 8. Hermit crab (Paguridae) made up 9% of the weight of stomach contents and occurred in 9% of the crab examined. Molluscs, specifically protobranch clams, *Nuculana* spp., were important food items at all three stations, although they only contributed 2.7% by weight of the stomach contents.

b. Kiliuda Bay - March 1979

The 38 king crab collected in Kiliuda Bay in March 1979 came from five stations; 20 at Station 579, 8 at Station 580, 2 at Station 576, 3 at Station 577, and 5 at a new location - Station 676 (57°18' N, 152°25'8 W). Molluscs were the main identifiable foods (Table VII). Dominant molluscs

TABLE V

STOMACH CONTENTS OF KING CRABS COLLECTED VIA TRAWLS ON THE KODIAK SHELF, FEBRUARY 1979
MEAN DEPTH 60 ± 8.9 METERS

Number Examined: 22

Number Empty: 5

Percent Composition of Crab Classes[1]: 6 = 13.6%; 7 = 86.4%

Mean Length: 150 ± 19 mm

Mean Weight: 2745 ± 928 g

Mean Percent Fullness[2]: 1.3 ± 3.1

Number of Prey Taxa: 14

| | | Dominant Prey[2] | | |
|---|---|---|---|---|
| Phylum | Species[3] | % Frequency of Occurrence | % by Weight | % by Volume |
| Mollusca | *Nuculana* spp. (clams) | 23 | 2.7 | 2.8 |
| | *Polinices* spp. (gastropod) | 5 | 3.8 | 3.9 |
| Chordata | Pisces (fishes) | 23 | 9.9 | 10.6 |
| Arthropoda | Paguridae (hermit crabs) | 9 | 9.0 | 9.2 |
| Sediment | | 55 | 1.3 | 1.2 |
| Unidentified animal material | | 68 | 62.8 | 62.1 |

[1]see methods for description of crab classes

[2]based on all stomachs examined

[3]species or lowest level of identification

TABLE VI

STATION DATA AND STOMACH CONTENTS OF KING CRABS COLLECTED VIA TRAWLS ON THE KODIAK SHELF, FEBRUARY 1979

| Station Name | 7 | 8 | 23 |
|---|---|---|---|
| $\bar{x}$ Depth, m | 53 | 70 | 57 |
| Number Examined | 10 | 4 | 8 |
| Number Empty | 1 | 0 | 4 |
| % Crab Composition[1] | 6=10%; 7=90% | 6=25%; 7=75% | 6=12.5%; 7=87.5% |
| $\bar{x}$% Fullness | 0.9 ± 0.8% | 3.4 ± 6.7% | 1.8 ± 3.1% |
| Prey Taxa | 9 | 7 | 10 |
| Dominant Prey-% Wt. | Unid. animal=59.1<br>Pisces=34.4 | Unid. animal=64.9<br>Paguridae=14.9<br>Shrimp=14.9 | Unid. animal=63.1<br>Paguridae=9.0<br>*Polinices*=9.0<br>*Nuculana* spp.=6.5 |

[1]see methods for description of crab classes

TABLE VII

STOMACH CONTENTS OF KING CRABS COLLECTED VIA TRAWLS IN KILIUDA BAY, MARCH 1979
MEAN DEPTH 37 ± 26.5

Number Examined: 38

Number Empty: 8

Percent Composition of Crab Classes[1]: 2 = 63.2%; 6 = 36.8%

Mean Length: 109 ± 17 mm

Mean Weight: 1460 ± 649 g

Mean Percent Fullness[2]: 6.9 ± 9.9%

Number of Prey Taxa: 21

| | | Dominant Prey[2] | | |
|---|---|---|---|---|
| Phylum | Species[3] | % Frequency of Occurrence | % by Weight | % by Volume |
| Mollusca | *Macoma* spp. (clams) | 45 | 25.3 | 21.3 |
| | *Nuculana* spp. (clams) | 13 | 0.7 | 0.7 |
| Chordata | Pisces (fishes) | 10 | 23.6 | 24.8 |
| Arthropoda | Paguridae (hermit crabs) | 8 | 11.7 | 12.8 |
| Unidentified animal material | | 71 | 29.8 | 31.4 |
| Unidentified plant material | | 13 | 1.5 | 1.3 |

[1]see methods for description of crab classes

[2]based on all stomachs examined

[3]species or lowest level of identification

were the pelecypods *Macoma* spp. These clams comprised 25.3% of the stomach contents weight and occurred in 45% of the stomachs. *Macoma* spp. was an important food at Stations 579, 580, and 576. The protobranch clam *Nuculana* spp. was found in 13% of the stomachs but accounted for 0.7% of the weight. Unidentified fishes and crab were also common prey yielding 23.6% and 11.7% of the stomach biomass, respectively. A large proportion (29.8% by weight) of the stomach contents was unidentified animal material. Plant material was found in 13% of the stomachs but only accounted for 1.5% of the biomass.

c. Near Island Basin - May 1979

A total of 21 king crab were collected via SCUBA in Near Island Basin in May 1979 (Table VIII). Most were newshell males greater than 100 mm. All but one crab was observed to be actively feeding. Food species observed in the possession of crab were the clam *Spisula polynyma*, the seastar *Pycnopodia helianthoides*, the mussel *Mytilus edulis*, polychaetes and barnacles. Only one crab had an empty stomach. The mean stomach fullness was 19.4 ± 15.4%. Twenty-five prey categories were identified. The dominant prey were barnacles (*Balanus crenatus*) and tube-dwelling polychaetes (*Owenia fusiformis*) which accounted for 31.2% and 18.9% of the stomach contents weight, respectively. Molluscs also were important food items, specifically the clam *Macoma* spp. (5.1% of the weight), *Protothaca staminea* (5.2%), and *Hiatella arctica* (2.6%). Unidentifiable animal and plant material were frequently found.

d. McLinn Island - May 1979

The 16 king crab collected near McLinn Island in May 1979 came from a location approximately 450 m NW of the McLinn Island site of May 1978

TABLE VIII

STOMACH CONTENTS OF KING CRABS COLLECTED VIA SCUBA IN NEAR ISLAND BASIN, MAY 1979
MEAN DEPTH 11 METERS

Number Examined: 21

Number Empty: 1

Percent Composition of Crab Classes[1]: 1 = 4.8%; 6 = 95.2%

Mean Length: 125 ± 11 mm

Mean Weight: 1571 ± 479 g

Mean Percent Fullness[2]: 19.4 ± 15.4

Number of Prey Taxa: 25

| | | Dominant Prey[2] | | |
|---|---|---|---|---|
| Phylum | Species[3] | % Frequency of Occurrence | % by Weight | % by Volume |
| Arthropoda | *Balanus crenatus* (barnacles) | 71 | 31.2 | 30.0 |
| Annelida | *Owenia fusiformis* (tube-dwelling worm) | 62 | 18.9 | 22.7 |
| Mollusca | *Macoma* spp. (clams) | 52 | 5.1 | 5.1 |
| | *Protothaca staminea* (clams) | 43 | 5.2 | 5.4 |
| | *Hiatella arctica* (clams) | 33 | 2.6 | 2.7 |
| Unidentified animal material | | 95 | 18.3 | 18.8 |
| Unidentified plant material | | 81 | 3.4 | 2.7 |

[1]see methods for description of crab classes

[2]based on all stomachs examined

[3]species or lowest level of identification

(see Feder *et al.*, 1979). Most crabs were new, softshell gravid females. Only eight out of 16 crab contained food (Table IX). The eight empty stomachs were all from softshell females. The mean stomach fullness of the 16 crab was 2.7 ± 4.1%. Sixteen prey taxa were identified. Dominant prey species were the snow crab (*Chionoecetes bairdi*) and barnacles (*Balanus crenatus*) which comprised 34.6% and 6.7% of the stomach contents biomass, respectively. Other important prey included the bivalve molluscs, *Macoma* spp., *Protothaca staminea* and *Clinocardium* spp. which accounted for 3.7%, 0.9%, and 0.9% of the food weight, respectively. Unidentified animal and plant material made up 26.7% and 3.0% of the weight, respectively.

e. Anton Larsen Bay (Site #2) - May 1979

Diving in Anton Larsen Bay (Site #2) in May 1979 yielded 17 king crab for stomach analysis (Table X). Hardshell adult males and females dominated the catch. All crab contained food and had a mean stomach fullness of 8 ± 12.3%. Twenty-five prey taxa were identified, and bivalves and barnacles were the dominant prey. The bivalves *Hiatella arctica*, *Clinocardium* spp., and *Serripes groenlandicus* were most important yielding 3.7%, 8.1%, and 11.1% of the food biomass, respectively. The barnacle *Balanus crenatus* occurred in 65% of the crab and accounted for 16.6% of the food biomass. Unidentified animal and plant material were frequently found and made up 38.4% and 2.9% of the food biomass, respectively.

2. *Chionoecetes bairdi* (Snow crab) and *Pandalus borealis* (Pink shrimp)

Feeding data on snow crab and pink shrimp will appear in the Final Report.

TABLE IX

STOMACH CONTENTS OF KING CRABS COLLECTED VIA SCUBA NEAR MCLINN ISLAND, MAY 1979
MEAN DEPTH 15 METERS

Number Examined: 16

Number Empty: 8

Percent Composition of Crab Classes[1]: 1 = 6.3%; 2 = 81.3%; 6 = 12.5%

Mean Length: 116 ± 35 mm

Mean Weight: 1087 ± 539 g

Mean Percent Fullness[2]: 2.7 ± 4.1

Number of Prey Taxa: 16

| | Dominant Prey[2] | | | |
|---|---|---|---|---|
| Phylum | Species[3] | % Frequency of Occurrence | % by Weight | % by Volume |
| Arthropoda | *Chionoecetes bairdi* (crab) | 19 | 34.6 | 32.1 |
| | *Balanus crenatus* (barnacle) | 19 | 6.7 | 6.6 |
| Mollusca | *Macoma* spp. (clam) | 6 | 3.7 | 3.5 |
| | *Protothaca staminea* (clam) | 6 | 0.9 | 0.9 |
| | *Clinocardium* spp. (cockle) | 6 | 0.9 | 0.9 |
| Unidentified animal material | | 50 | 26.7 | 27.5 |
| Unidentified plant material | | 19 | 3.0 | 2.8 |

[1]see methods for description of crab classes

[2]based on all stomachs examined

[3]species or lowest level of identification

TABLE X

STOMACH CONTENTS OF KING CRABS COLLECTED VIA SCUBA IN
ANTON LARSEN BAY (SITE #2), MAY 1979
MEAN DEPTH 6 METERS

Number Examined: 17

Number Empty: 0

Percent Composition of Crab Classes[1]: 2 = 64.7%; 6 = 29.4%; 7 = 5.9%

Mean Length: 121 ± 15 mm

Mean Weight: 1388 ± 648

Mean Percent Fullness: 8 ± 12.3%

Number of Prey Taxa: 25

| | Dominant Prey | | | |
|---|---|---|---|---|
| Phylum | Species[2] | % Frequency of Occurrence | % by Weight | % by Volume |
| Mollusca | *Hiatella arctica* (clam) | 41 | 3.7 | 3.9 |
| | *Clinocardium* spp. (cockle) | 17 | 8.1 | 8.2 |
| | *Serripes groenlandicus* (cockle) | 12 | 11.1 | 10.8 |
| Arthropoda | *Balanus crenatus* (barnacle) | 65 | 16.6 | 15.8 |
| Unidentified animal material | | 100 | 38.4 | 39.6 |
| Unidentified plant material | | 82 | 2.9 | 2.4 |

[1]see methods for description of crab classes

[2]species or lowest level of identification

3. *Gadus macrocephalus* (Pacific cod)

a. Kodiak Shelf - February 1979

Fifty-five Pacific cod were examined during this sampling period, and 45 contained food (Table XI). The most frequently consumed prey in all cod examined was unidentified fishes (23.6% frequency of occurrence), snow crab (*Chionoecetes bairdi*; 20.0%), pink shrimp (*Pandalus borealis*; 18.2%), and crangonid shrimp (18.2%).

4. *Hemilepidotus jordani* (Yellow Irish lord)

a. Kodiak Shelf - February 1979

Among the 90 yellow Irish lord that were examined 27 had empty stomachs (Table XI). Dominant prey in terms of frequency of occurrence in the 90 fish were snow crab (24.4%) and unidentified fishes (14.4%). Pea crab (*Pinnixa occidentalis*), krill, polychaetes, and pink shrimp occurred at between 5-10% frequency of occurrence.

5. *Myoxocephalus* spp. (sculpins)

a. Kodiak Shelf - February 1979

Only 12 sculpins of the genera *Myoxocephalus* were examined during February 1979; 11 stomachs contained food (Table XI). The most important prey were snow crab (66.7% occurrence), walleye pollock (*Theragra chalcogramma*; 25%), and unidentified fishes (25%).

6. *Hippoglossoides elassodon* (Flathead sole)

a. Kodiak Shelf - February 1979

Ninety flathead sole were examined during February 1979; 45.6%

TABLE XI

STOMACH CONTENTS OF SELECTED FISHES FROM THE KODIAK ISLAND CONTINENTAL SHELF, FEBRUARY 1979

| Stomach Contents | Percent Frequency of Occurrence Based on Stomachs w/food | Total Stomachs |
|---|---|---|
| *Gadus macrocephalus* Kodiak Shelf - 13-24 February 1979 | N = 45 | N = 55 |
| Pisces (13) | 28.9 | 23.6 |
| *Chionoecetes bairdi* (snow crab) (11) | 24.4 | 20.0 |
| *Pandalus borealis* (pink shrimp) (10) | 22.2 | 18.2 |
| Crangonidae (gray shrimp) (10) | 22.2 | 18.2 |
| Empty (10) | - | 18.2 |
| Shrimp (6) | 13.3 | 10.9 |
| *Theragra chalcogramma* (walleye pollock) (5) | 11.1 | 9.1 |
| Polychaeta (segmented worm) (3) | 6.7 | 5.5 |
| *Trichotropis* sp. (2) | 4.4 | 3.6 |
| Octopoda (2) | 4.4 | 3.6 |
| *Pinnixa* sp.(pea crab) (2) | 4.4 | 3.6 |
| Stichaeidae (pricklebacks) (2) | 4.4 | 3.6 |
| *Ammodytes hexapterus* (Pacific sand lance) (2) | 4.4 | 3.6 |
| Osmeridae (smelts) (2) | 4.4 | 3.6 |
| Plant (1) | 2.2 | 1.8 |
| Hydrozoa (1) | 2.2 | 1.8 |
| *Cyclocardia* sp. (cockle) (1) | 2.2 | 1.8 |
| *Yoldia* sp. (bivalve) (1) | 2.2 | 1.8 |
| *Colus* sp. (snail) (1) | 2.2 | 1.8 |
| Gastropoda (snails) (1) | 2.2 | 1.8 |
| Crustacea (1) | 2.2 | 1.8 |
| Crab (1) | 2.2 | 1.8 |
| Euphausiacea (krill) (1) | 2.2 | 1.8 |
| *Pagurus aleuticus* (hermit crab) (1) | 2.2 | 1.8 |
| Echiuroidea (spoon worm) (1) | 2.2 | 1.8 |
| Gadidae (cods) (1) | 2.2 | 1.8 |
| Zoarcidae (eelpouts) (1) | 2.2 | 1.8 |
| Pleuronectidae (flatfish) (1) | 2.2 | 1.8 |
| *Lyconectes aleutensis* (dwarf wrymouth) (1) | 2.2 | 1.8 |
| Unidentified material (1) | 2.2 | 1.8 |
| *Hemilepidotus jordani* Kodiak Shelf - 13-24 February 1979 | N = 63 | N = 90 |
| Empty (27) | - | 30.0 |
| *Chionoecetes bairdi* (snow crab) (22) | 34.9 | 24.4 |
| Pisces (fishes) (13) | 20.6 | 14.4 |
| *Pinnixa occidentalis* (pea crab) (8) | 12.7 | 8.9 |

TABLE XI

CONTINUED

| Stomach Contents | Percent Frequency of Occurrence Based on Stomachs w/food | Total Stomachs |
|---|---|---|
| Euphausiacea (krill) (7) | 11.1 | 7.8 |
| Polychaeta (segmented worm) (6) | 9.5 | 6.7 |
| *Pandalus borealis* (pink shrimp) (6) | 9.5 | 6.7 |
| *Macoma* sp. (bivalve) (4) | 6.3 | 4.4 |
| Shrimp (3) | 4.8 | 3.3 |
| *Echiurus echiurus* (spoon worm) (3) | 4.8 | 3.3 |
| *Ammodytes hexapterus* (Pacific sand lance) (3) | 4.8 | 3.3 |
| *Yoldia* sp. (bivalve) (2) | 3.2 | 2.2 |
| Pelecypoda (bivalve) (2) | 3.2 | 2.2 |
| Crustacea (2) | 3.2 | 2.2 |
| *Pherusa plumosa* (segmented worm) (1) | 1.6 | 1.1 |
| Nudibranch (1) | 1.6 | 1.1 |
| Octopoda (1) | 1.6 | 1.1 |
| Gastropoda (snails) (1) | 1.6 | 1.1 |
| Gammaridae (sand fleas) (1) | 1.6 | 1.1 |
| *Pagurus aleuticus* (1) | 1.6 | 1.1 |
| *Triglops* sp. (sculpin) (1) | 1.6 | 1.1 |
| Sediment (1) | 1.6 | 1.1 |
| Eggs (1) | 1.6 | 1.1 |
| Unidentified material (1) | 1.6 | 1.1 |
| *Myoxocephalus* spp. | N = 11 | N = 12 |
| Kodiak Shelf - 13-24 February 1979 | | |
| *Chionoecetes bairdi* (snow crab) (8) | 72.7 | 66.7 |
| *Theragra chalcogramma* (walleye pollock) (3) | 27.3 | 25.0 |
| Pisces (fishes) (3) | 27.3 | 25.0 |
| *Pandalus goniurus* (humpy shrimp) (2) | 18.2 | 16.7 |
| Octopoda (2) | 18.2 | 16.7 |
| Hippolytidae (shrimp) (1) | 9.1 | 8.3 |
| *Eucalus* sp. (shrimp) (1) | 9.1 | 8.3 |
| *Pandalus hypsinotus* (coonstripe shrimp) (1) | 9.1 | 8.3 |
| Shrimp (1) | 9.1 | 8.3 |
| Rock (1) | 9.1 | 8.3 |
| Empty (1) | - | 8.3 |
| *Hippodlossoided elassodon* | N = 49 | N = 90 |
| Kodiak Shelf - 13-24 February 1979 | | |
| Empty (41) | - | 45.6 |
| *Pandalus borealis* (pink shrimp) (18) | 36.7 | 20.0 |
| Euphausiacea (krill) (10) | 20.7 | 11.1 |
| Shrimp (5) | 10.2 | 5.6 |
| *Macoma moesta* (4) | 8.2 | 4.4 |

TABLE XI

CONTINUED

| Stomach Contents | Percent Frequency of Occurrence Based on Stomachs w/food | Percent Frequency of Occurrence Based on Total Stomachs |
|---|---|---|
| Crangonidae (gray shrimp) (3) | 6.1 | 3.3 |
| *Chionoecetes bairdi* (snow crab) (3) | 6.1 | 3.3 |
| Polychaeta (segmented worms) (2) | 4.1 | 2.2 |
| *Pinnixa* sp (pea crab) (2) | 4.1 | 2.2 |
| Unidentified material (2) | 4.1 | 2.2 |
| *Nuculana fossa* (Fossa nut shell) (1) | 2.0 | 1.1 |
| *Yoldia amygdalea* (bivalve) (1) | 2.0 | 1.1 |
| *Theragra chalcogramma* (walleye pollock) (1) | 2.0 | 1.1 |
| Stichaeidae (pricklebacks) (1) | 2.0 | 1.1 |
| *Hippoglossoides elassodon* (flathead sole) (1) | 2.0 | 1.1 |
| Pisces (fishes) (1) | 2.0 | 1.1 |
| *Lepidopsetta bilineata* Kodiak Shelf - 13-24 February 1979 | N = 31 | N = 70 |
| Empty (39) | - | 55.7 |
| Polychaeta (segmented worms) (18) | 58.1 | 25.7 |
| *Yoldia myalis* (bivalve) (6) | 19.4 | 8.6 |
| Ophiuroidae (brittle star) (6) | 19.4 | 8.6 |
| *Macoma moesta* (bivalve) (3) | 9.7 | 4.3 |
| Shrimp (3) | 9.7 | 4.3 |
| *Ophiura sarsi* (brittle star) (3) | 9.7 | 4.3 |
| Unidentified material (3) | 9.7 | 4.3 |
| Pelecypoda (bivalves) (2) | 6.5 | 2.9 |
| *Serripes groenlandicus* (clam) (2) | 6.5 | 2.9 |
| Amphipoda (sand fleas) (2) | 6.5 | 2.9 |
| Hydrozoa (1) | 3.2 | 1.4 |
| *Travisia forbesii* (segmented worm) (1) | 3.2 | 1.4 |
| *Pherusa plumosa* (segmented worm) (1) | 3.2 | 1.4 |
| *Nuculana fossa* (Fossa nut shell) (1) | 3.2 | 1.4 |
| Crustacea (1) | 3.2 | 1.4 |
| Thoracica (barnacles) (1) | 3.2 | 1.4 |
| *Molpadia* sp. (sea cucumber) (1) | 3.2 | 1.4 |
| *Echiurus echiurus* (spoon worm) (1) | 3.2 | 1.4 |
| Sediment (1) | 3.2 | 1.4 |
| *Isopsetta isolepis* Kodiak Shelf - 13-24 February 1979 | N = 6 | N = 20 |
| Empty (14) | - | 70.0 |
| Polychaeta (segmented worm) (2) | 66.6 | 10.0 |
| *Macoma* sp. (bivalve) (1) | 33.3 | 5.0 |
| *Pandalus borealis* (pink shrimp)(1) | 33.3 | 5.0 |
| Shrimp (1) | 33.3 | 5.0 |

TABLE XI

CONTINUED

| Stomach Contents | Percent Frequency of Occurrence Based on Stomachs w/food | Total Stomachs |
|---|---|---|
| *Chionoecetes bairdi* (snow crab) (1) | 33.3 | 5.0 |
| Pisces (fish) (1) | 33.3 | 5.0 |
| Unidentified material (1) | 33.3 | 5.0 |
| *Limanda aspera* | N = 23 | N = 50 |
| Kodiak Shelf - 13-24 February 1979 | | |
| Empty (27) | - | 54.0 |
| *Echiurus echiurus* (spoon worm) (10) | 43.5 | 20.0 |
| *Pinnixa occidentalis* (pea crab) (9) | 39.1 | 18.0 |
| *Pandalus borealis* (pink shrimp) (9) | 39.1 | 18.0 |
| *Macoma* sp. (bivalve) (4) | 17.4 | 8.0 |
| Polychaeta (segmented worm) (3) | 13.0 | 6.0 |
| *Yoldia amygdalea* (bivalve) (3) | 13.0 | 6.0 |
| Hirudinea (leech) (1) | 4.3 | 2.0 |
| *Argis* sp. (gray shrimp) (1) | 4.3 | 2.0 |
| Crustacean (1) | 4.3 | 2.0 |
| Pisces (fish) (1) | 4.3 | 2.0 |
| Unidentified material (1) | 4.3 | 2.0 |

had empty stomachs (Table XI). The most frequently consumed food in 90 fish was pink shrimp (20%), and krill (11.1%).

7. *Lepidopsetta bilineata* (Rock sole)

a. Kodiak Shelf - February 1979

More than 55% of the 70 rock sole examined in February 1979 had empty stomachs (Table XI). The most important prey among all rock sole were polychaetes (25.7% occurrence). A variety of other prey were taken.

8. *Isopsetta isolepis* (Butter sole)

a. Kodiak Shelf - February 1979

A total of 20 butter sole were examined but only six contained food (Table XI). No single species dominated. Polychaetes were found in two stomachs and six other food species were each found in only one stomach.

9. *Limanda aspera* (Yellowfin sole)

a. Kodiak Shelf - February 1979

Yellowfin sole stomachs examined in February 1979 also contained little food; 23 out of 50 stomachs contained food (Table XI). The most frequently found food items among 50 stomachs were the spoon worm (*Echiurus echiurus*; 20%), pea crab (*Pinnixa occidentalis*; 18%), and pink shrimp (18%).

# VII DISCUSSION

## A. Trawl Data: Distribution - Biomass

Since the crustaceans *Paralithodes camtschatica*, *Chionoecetes bairdi*, and *Pandalus borealis* dominated the epifaunal biomass, the following discussion is limited to those species. A limited discussion of the other epifaunal species will be included in the Final Report.

### 1. Kodiak Shelf - February 1979

Data on the distribution and biomass of king crab, snow crab, and pink shrimp collected on the Kodiak Shelf in February 1979 was similar to that reported from the June-July 1978 cruise in the same area (see Results and Discussion in Feder *et al.*, 1979).

### 2. Izhut Bay - Kiliuda Bay - March 1979

The most notable trend in the invertebrate composition of these two bays was that the biomasses of king crab, snow crab, and pink shrimp were often inversely related in dominance (i.e. a high biomass of one species in one bay and a low biomass of the same species in the other bay). This was especially evident in March 1979 when pink shrimp and snow crab had high biomasses in Izhut Bay but had comparitively low biomasses in Kiliuda Bay of the same period. Conversely, the biomass of king crab was low in Izhut Bay and high in Kiliuda Bay.

The only appreciable change in the composition of invertebrates in Izhut Bay in March 1979 was the preponderance of pink shrimp. In the six previous sampling periods only May and August had high biomasses of the shrimp (i.e. 22.5% and 44.8% of the biomass, respecitvely). The previous

sampling period, November 1978, had a pink shrimp biomass less than 1%. Pink shrimp were absent from Izhut Bay in April 1978.

The pink shrimp biomass in Kiliuda Bay in March 1979 was low in comparison to the biomass during August and November 1978. The March decline is similar to the low biomass noted in the spring of 1978 (see Results and Discussion in Feder *et al.*, 1979).

B. Food Studies

1. *Paralithodes camtschatica* (King crab)

a. Kodiak Shelf - February 1979

King crab examined for stomach contents in February 1979 were in marked contrast to those examined from the same locations in June-July 1978. Fewer crab were caught and examined during the winter period. The mean crab fullness was 9.1 ± 10% in June-July whereas the mean fullness was only 1.3 ± 3.1% in February. Similar dominant prey from both periods were *Yoldia* spp. and fishes. It is probably that the low mean fullness is due to the fact that February is the beginning of the spring migration to shallower waters for molting and breeding (see Results and Discussion in Feder *et al.*, 1979).

b. Kiliuda Bay - March 1979

The stomach contents of king crab in Kiliuda Bay in March 1979 is similar to contents found in April and November 1978 (i.e. clams, crabs and fishes; see Results and Discussion in Feder *et al.*, 1979). Barnacles seem to be more important food in spring and early summer months.

c. Near Island Basin - McLinn Island - Anton Larsen Bay - May 1979

Food of king crab from the these three locations was very similar to the food taken by king crab from these areas in 1978 (see Results and Discussion in Feder *et al.*, 1979).

2. Miscellaneous Fishes

a. Kodiak Shelf - February 1979

A full discussion on the food habits of the miscellaneous fishes examined throughout the Kodiak study will be presented in the Final Report (see Results and Discussion in Feder *et al.*, 1979).

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SUMMARY OF FIELD NOTES FOR NEGOA

NOVEMBER, 1979

NOAA Ship *Miller Freeman* - Cruise 795

Trawls were made at 34 stations in the Priority I area. Twenty-three additional stations were surveyed and considered to be untrawlable. Three stations at which the net was ripped were also considered untrawlable. Thus, all but two of the Priority I stations were at least surveyed. Van Veen grab samples were taken at 26 of the previously trawled Priority I stations. In addition, five other Priority I stations were so sampled. Pipe dredge samples were taken from 15 of the previously trawled Priority I stations and 12 of the other, mostly untrawlable, stations.

Trawls were taken from four stations in the Priority II area. Van Veen grab samples were taken at one of these and a pipe dredge sample was taken at another.

In the Priority III area, trawls were made at five stations. At one of these, van Veen grab samples and a pipe dredge were also taken.

Trawls were made at three stations in Yakutat Bay. An additional 11 stations were surveyed and considered to be untrawlable. At one of the trawled stations, van Veen grab samples and a pipe dredge were also taken. In addition to this station, van Veen grab samples were taken from 11 other stations and pipe dredge samples were taken from an additional four.

The vertebrate and invertebrate faunas represented in these trawls were relatively diverse at most stations but, in many cases, only a few individuals of each species were present per station. Some species were

distributed over the entire area while others were relatively localized or were more prevalent at near-shore stations than off-shore.

Large numbers of ophiuroids, particularly *Ophiura sarsi* (Sta. 104A - 11,350), and *Ophiopholis* sp. (Sta. 95F - 500), occurred throughout the area exclusive of Yakutat Bay. Scallops, *Pecten caurinus*, occurred only at near-shore stations in the vicinities of Icy Bay (Sta. 93C - 1093), Dry Bay (Sta. 108A - 736), and Yakutat Bay (Sta. 4A - 90). Butter sole (Sta. 109A - 2100), *Isopsetta isolepis*, and starry flounder, *Platichthys stellatus*, occurred only at near-shore stations. This was also the case with Pacific tomcod, *Microgadus proximus* (Sta. 109A - 500), and dungeness crab, *Cancer magister* (Sta. 94A - 900). Arrowtooth flounder, *Atheresthes stomias* (Sta. 95F - 1150), was present at most stations but was perhaps more abundant at off-shore stations. Shrimps, particularly *Pandalus* spp. and *Pandalopsis dispar*, were more abundant in near-shore areas. Urchins, particularly *Allocentrotus* sp. and *Strongylocentrotus* sp., were abundant only at off-shore stations (Sta. 98D - 600, 900; Sta. 100E - 25, 2200).

In Yakutat Bay, dungeness crab, shrimps (including *Pandalus* spp., *Pandalopsis* sp. and *Crangon* sp.) and scallops were most abundant. Relatively few species were present in Disenchantment Bay, near Hubbard Glacier.

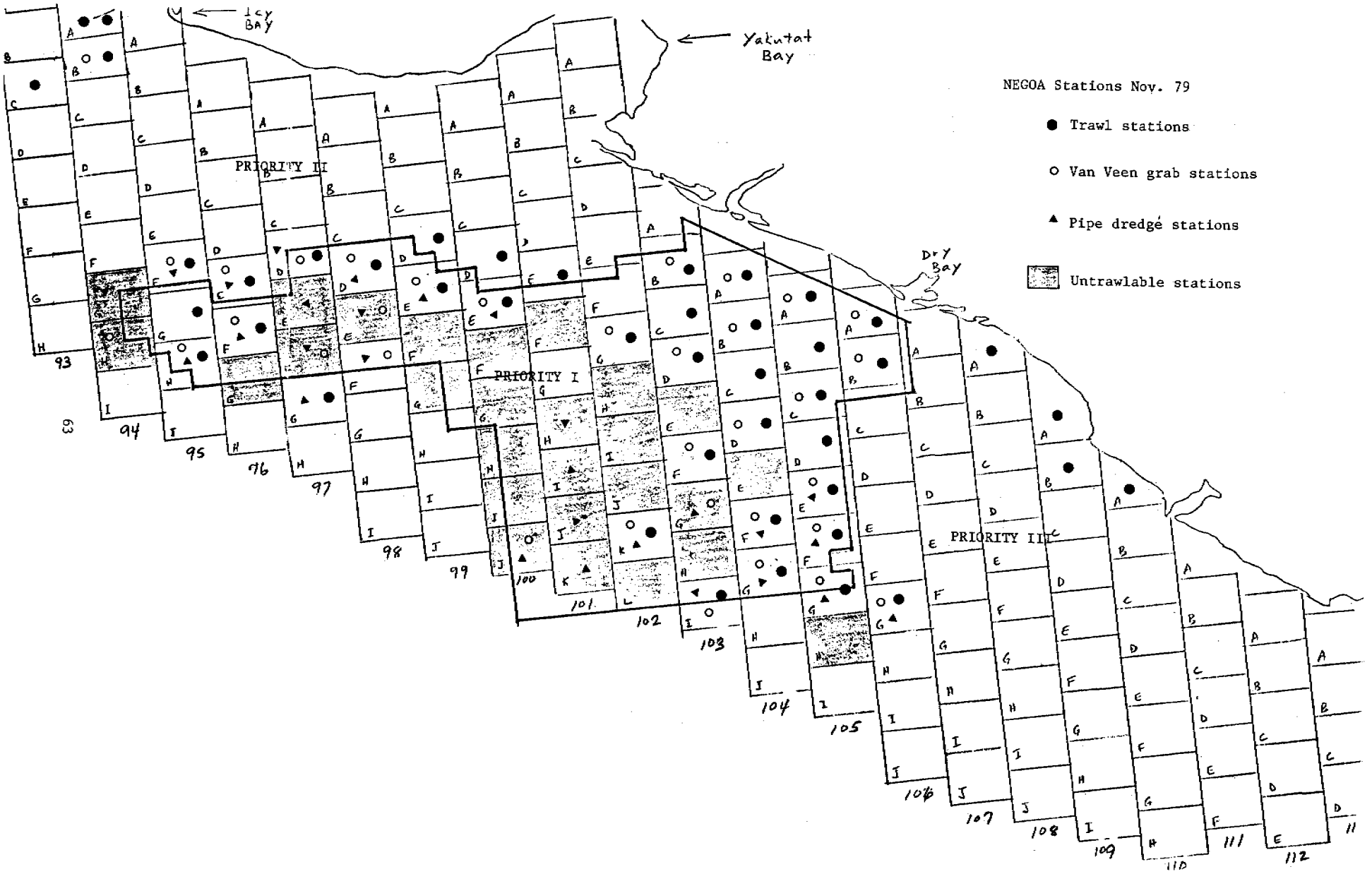
A preliminary examination of fish food habit data indicated that species such as arrowtooth flounder, sablefish (*Anaplopoma fimbria*), Pacific cod (*Gadus macrocephalus*), and halibut (*Hippoglossus stenolepis*), generally prey on small fishes and shrimp. Starry flounder and butter sole, consumed mainly ophiuroids and polychaete worms, respectively.

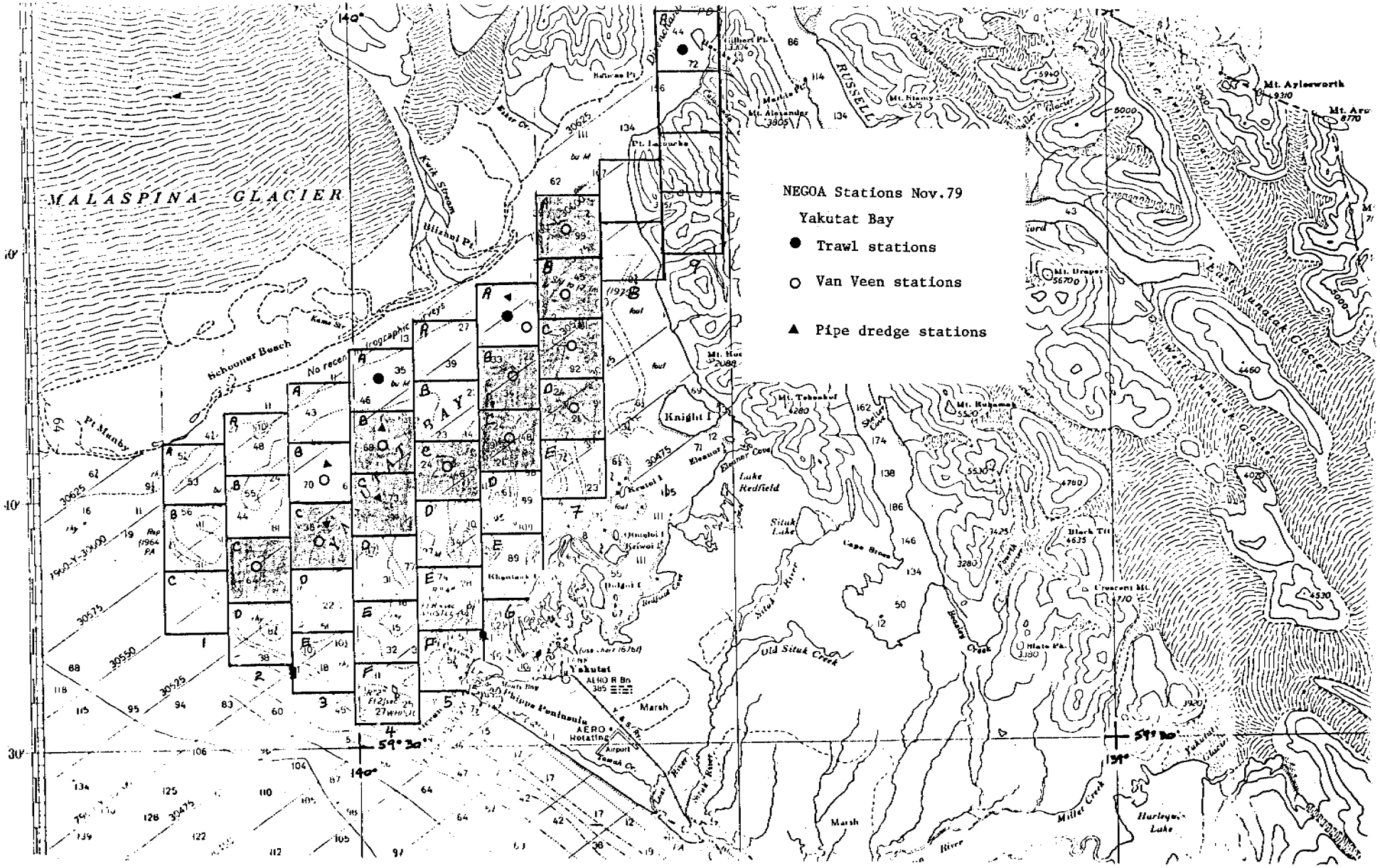
Rock sole (*Lepidopsetta bilineata*), dover sole (*Microstomus pacificus*), flathead sole (*Hippoglossoides elassodon*), and English sole (*Parophrys vetulus*), occurring at stations farther from shore, consumed mainly ophiuroids, with other prey items such as polychaetes and small clams occurring less frequently. At more near-shore stations these same species consumed fewer ophiuroids, more crustaceans (including shrimp and amphipods), and more small clams.

Rex sole (*Glyptocephalus zachirus*) from stations farther from shore, consumed mainly polychaetes with a few small crustaceans and clams occurring occasionally. At more near-shore stations this species consumed a much greater diversity of prey items, including amphipods, polychaetes, shrimps, clams, and even ophiuroids.

A preliminary examination of six species of Pagurid crabs indicated the relatively common occurrence of commensal relationships involving several different invertebrates. These included at least four species of amphipods and four species of polychaete worms.

Steven G. McGee
Research Assistant


Icy Bay
Yakutat Bay
Dry Bay
PRIORITY III
PRIORITY I
PRIORITY III
NEGOA Stations Nov. 79
Trawl stations
Van Veen grab stations
Pipe dredge stations
Untrawlable stations


NEGOA Stations Nov.79
Yakutat Bay
Trawl stations
Van Veen stations
Pipe dredge stations
MALASPINA GLACIER
Schooner Beach
Pt Manby
Knight I
Lake Redfield
Situk Lake
Old Situk Creek
Yakutat
AERO R Bn
AERO Rotating
Airport
Marsh
Ocean Cape
Cape Suckling
Mt. Arlesworth
Mt. Draper
Mt. Tebenkof
Mt. Kukenwak
Crescent Mt
Black Tit
Millet Creek
Harlequin Lake
Yakutat Glacier
Tsiu-tsuk Glacier
RUSSELL
59° 30'
140°

QUARTERLY REPORT

NOAA-OCSEAP
Contract No. 03-5-022-68
Research Unit #6
Reporting Period: 1 July-30 September 1979

The distribution, abundance, composition, and variability of the western Beaufort Sea benthos.

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28 September 1979

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Principal Investigator

## I. Abstract

During this quarter progress has been made in several areas of sample analysis in the laboratory and in data reduction and analysis. There was no scheduled fieldwork for RU #006. Polychaete worms from a series of inner shelf stations sampled during the 1976 R/V ALUMIAK cruise have been identified. A total of 99 species and 16,801 individuals are included in the collections. Bivalve and gastropod molluscs and cumacean and gammarid amphipod crustacean identifications continue.

Preliminary analyses for the ice algal community pilot project at the Stefannson Sound Boulder Patch on the interrelationships between the benthic community and the epontic community have been completed for several aspects of the subproject. Harpacticoid copepods were sampled from both substrates and were used as indicator organisms. These fauna are comprised of different species in the undersurface of the ice and sediments below. Results on the interrelationships between the benthic and epontic faunal communities can only be acquired by a detailed time series study that includes the macrofauna as well as the meiofauna.

## II. Task Objectives

### A. General nature and scope of the study.

The ecological studies of the shelf benthos include functional, process-oriented research that is built on a strong base of descriptive work on ecological patterns and their relationship to the environment. Seasonal changes in the numerical abundance and biomass of the large macro-infauna (>0.5 mm) are defined at stations across the continental shelf. The benthic food web and its relationship to bird, fish and mammalian predators are under investigation.

The species composition, distribution and abundance of the benthos are being defined in the southwestern Beaufort Sea. Species and station groupings are statistically analyzed and the relationships to the bottom environment explored. Dominant species are identified. These patterns provide an insight into the relative importance of various features of the environment in determining the distribution and abundance of the benthic invertebrate fauna.

### B. Specific Objectives

The major emphasis of the ongoing research (FY-79) is the delineation of the benthic food web and description of the coastal benthos. Efforts to characterize the composition of the Beaufort Sea fauna to the species level are continuing since this is a critical step toward understanding the dynamics of the benthic ecosystem.

1) Objective 1 - Beaufort Sea benthic food web analysis

a) The numerical density, biomass, and gross taxonomic composition of the benthic macro-infauna at selected 1977 and 1978 water column food web stations will be obtained.

b) The identification of prey species important in the benthic food web will be undertaken.

c) The gut contents of selected species of benthic invertebrates will be analyzed as far as possible to determine the food web links within the benthic communities.

2) Objective 2 - Beaufort Sea coastal benthos

The identification of coastal fauna from 5-25 meters depth from 1976 R/V ALUMIAK collections will be continued.

3) Objective 3 - Benthic macro-infaunal ecology

a) Further identifications of abundant species will be undertaken from samples collected in thesouthwestern Beaufort Sea during the WEBSEC and OCS field trips and cruises.

b) Statistical analyses of species and station groups will be run, and correlations between these and various characteristics of the benthic environment will be made.

4) Objective 4 - Summary and synthesis of benthic environment characteristics.

a) Sediment samples from OCS benthos stations will be analyzed for particle size, organic carbon, and Kjeldahl nitrogen by a subcontract to Dr. S. Naidu, University of Alaska.

b) The bottom water characteristics of the southwestern Beaufort Sea continental shelf will be summarized as far as possible with the available information.

5) Objective 5 (RU #6W) - Ice algal - benthic community interrelationships

a) Sediment and ice undersurface samples and particle trap and vertically migrating animal collections will be made during the ice algal blooms.

b) The sample will be analyzed to determine the degree of similarity between the two journal communities.

c) The particle collector and animal migration trap samples will be analyzed to determine flux rates of organic materials to the sediment surface and of animals between the two surfaces.

## III. Field and Laboratory Activities

### A. Field Activities

1) Field trip

none

2) Field Scientific Party

none

3) Field Methods

none

### B. Laboratory Analysis

1) Scientific Personnel

| | | |
|---|---|---|
| a) | Andrew G. Carey, Jr. | Principal Investigator<br>Associate Professor |
| | Responsibilities: | Coordination, evaluation, analysis, and reporting. |

| | | |
|---|---|---|
| b) | James Keniston | Research Assistant<br>(left job 30 June 1979) |
| | Responsibilities: | Data management, statistical analysis |
| c) | Keith Walters | Research Assistant Unclassified<br>(commences work 8 October 1979) |
| | Responsibilities: | Data management, statistical analysis |
| d) | Paul Montagna | Research Assistant Unclassified<br>(left job 31 July 1979) |
| | Responsibilities: | Sample processing, biomass measurements, harpacticoid copepod and crustacean systematics, and field collection |
| e) | R. Eugene Ruff | Research Assistant Unclassified |
| | Responsibilities: | species list compilation, sample processing, reference museum curation, polychaete systematics, field collection, and laboratory management |
| f) | Paul Scott | Research Assistant Unclassified |
| | Responsibilities: | Sample processing, data summary, molluscan systematics and sample collection |
| g) | Ken Golubier | Part-time Assistant |
| | Responsibilities | Sample processing, sample curation |
| h) | Gordon R. Bilyard | Research Assistant Unclassified<br>(half-time) |
| | Responsibilities: | Polychaete identification, data analysis<br>N.B. G.R. Bilyard completed work toward the Ph.D. June 1979 |

2) Methods - no changes in standard techniques

3) Sample Localities

   a) Stefannson Sound Boulder Patch
   b) Beaufort Sea Lease Area
   c) OCS Pitt Point Transect

IV. Results

1) Field work in ecology

a) Ice epontic animal community and benthic community interrelationships at the Boulder Patch, Stefannson Sound.

The meiofauna and macrofauna have been picked from the March 1979 (OCS-9) and the May 1979 (OCS-10) sediment, ice and trap samples. Identification of indicator organisms has been completed by Paul A. Montagna (Tables 1-9). Harpacticoid copepods were examined in detail and identified to species. Further analysis of samples and data analysis will be necessary before definite conclusions can be drawn. Preliminary examination of the data indicate that the harpacticoid copepod faunas associated with the two surfaces are different at the two periods in March and May 1979.

b) Infaunal densities, biomass and taxonomic composition (>1.0 mm fraction).

Further picking and sorting of quantitative Smith-McIntyre grab samples has been accomplished. Animal densities in the major animal groups are listed in Tables 10 through 13, and biomass in Table 14.

c) Small macro-infaunal densities for western Beaufort Sea bathyal stations (0.5-1.0 mm).

The infaunal numerical densities for the major animal groups are listed in Tables 15 through 17.

2) Systematics

a) Polychaete species identifications (>1.0 mm)

Species identification of polychaetous annelids collected on OCS-5 (August 1976) from the R/V ALUMIAK in water depths of 5 to 25 meters has been completed this quarter. Identifications are by R.E. Ruff with the collaboration of Gordon R. Bilyard, Ph.D. Identifications will be verified with the cooperation of Dr. Kristian Fauchald of the Smithsonian Institution.

In 1976 the coastal zone between 5-25 meters was sampled using a Smith-McIntyre grab sampler from the R/V ALUMIAK and the USCGC GLACIER. Stations were located along five transect lines between Point Barrow and Barter Island (Figure 1) Efforts were made to sample at 5 meter depth intervals along each transect, but ice conditions prevented the sampling of the 20 and 25 meter stations on the Pingok Island and Narwhal Island lines. A total of twenty-one stations were successfully occupied, however, and five biological grabs plus an additional sediment sample were collected at each station (Table 18). Temperature and salinity data were taken where possible.

The coastal region was designated at the 1978 Beaufort Sea Synthesis Meeting as a critical area in which foodweb interactions would be subject to impairment due to potential oil pollution from projected petroleum exploration and production. Large standing stocks of benthic invertebrates have been recorded from this shallow area, making it an important feeding ground for arctic fish, diving birds, and marine mammals. Few data exist, however, concerning the species composition, distribution, abundance, and environmental interactions of

the benthic fauna in this zone. For these reasons the examination of the 1976 coastal grab samples has been accorded priority as an OCS task objective.

Since the polychaetous annelids comprise from 70-85% of the total infaunal community in the inshore environment (Carey, 1978), this group was selected for detailed analysis. The grab samples were sieved through 1.0 mm mesh screen, and the polychaetes were sorted to the family level as a preliminary step. Each family was then examined, and the organisms were identified to the species level. A total of 16,801 specimens occurred in the 105 grab samples, and these have been identified to 99 species distributed between 32 families. The numerical abundance of each species at each of the stations is given in Table 19. Detailed statistical ecological analyses are planned.

b) Pelecypod mollusc species identifications

The juvenile pelecypod molluscs from the 0.5-1.0 mm size fraction of Smith-McIntyre grab samples collected from the Pitt Point Line have been identified and quantified by Paul Scott (Tables 20 through 22). These results will be used to study the life histories of the benthic infauna at the five stations.

c) Pelecypod mollusc species identifications (>1.0 mm)

Pelecypod molluscs from OCS-4 (PPB-25 and PPB-55 only) and OCS-7 have been identified to species by P.H. Scott. This material includes 35 species from 18 families for a total of 2372 specimens examined. The bivalve species data, stations of occurrence and number of specimens encountered are listed on Table 23.

d) Gastropod mollusc species identifications (>1.0 mm)

Tentative identifications of portions of the gastropod mollusc collections have been made by Paul Scott (Table 24). These species will be verified by Dr. James McClean of the Los Angeles County Natural History Museum.

e) Gammarid amphipod identifications

Additional identifications of the gammarid amphipod fauna have been accomplished by Paul Montagna. These are tentative at this time (Tables 25 and 26).

3) Lease zone preliminary sample processing

Quantitative Smith-McIntyre grab samples of benthic infauna have been picked and sorted to major taxonomic category by R. Eugene Ruff. Polychaete worms species are being identified by R.E. Ruff.

## V. Preliminary Interpretation of Results

Interpretation is deferred until further sample and statistical analyses can be undertaken. Several papers that describe the community ecology of coastal fauna are in progress.

VI. Auxiliary Material

Paper In Press: Bilyard, G.H. and A.G. Carey, Jr. Zoogeography of western Beaufort Sea Polychaeta/Annelida). (Sarsia 64:00-00).

VII. Problems Encountered/Recommended Changes

The departure of the part-time data manager/analyst (James Keniston) and of a biological research assistant (Paul Montagna) has left the research program short-handed. Adequate funding is necessary to complete the proposed tasks during FY-80. The hiring of a data manager has been accomplished, but the acquisition of a biological research a-sistant versed in crustacean systematics would make the identification of much of this fauna possible from the 1977 and 1978 summer cruises.

VIII. Milestone Chart and Data Submission Schedule

1) The up-dated 1978-79 laboratory schedule is shown in Figure 1.

2) Explanation of changes:

a) Delays in completion of some of the milestones have been projected. These are continuing projects, and more complete summaries are feasible at later dates.

b) The digital data submitted by magnetic tape has been tentatively delayed until the final report of RU #006 as mutually agreed between the P.I. and the OCS-Arctic Project Office..

MILESTONE CHART

1/78

0 - Planned Completion Date

X - Actual Completion Date

RU # 006 PI: Andrew G. Carey, Jr.

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

| | MAJOR MILESTONES | 1978 O | N | D | 1979 J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Foodweb Research | | | | | | | | | | | | | | | |
| | a. Macro-infaunal analyses | | | | | | | | | | | | | | | 0 |
| | b. Macro-epifaunal analyses | | | | | | | | | | | | | | | 0 |
| | c. Predator GI tract analyses | | | | | | | | | | | | | | | 0 |
| | d. Prey distribution summary | | | | | | | | | | | | | | | 0 |
| 2. | Ice algal-benthic communities | | | | | | | | | | | | | | | 0 |
| 3. | Seasonal variability | | | | | | | | | | | | | | | |
| | PPB macro-infaunal analyses | | | | | | | | | | | | | | | 0 |
| 4. | Quarterly Report | | | | X | | | X | | | X | | | X | | |
| 5. | Annual Report | | | | | | | X | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 6. | Data analyses | | | X | | | X | | | X | | | | 0 | | |
| | Transmittal* | | | | | | | | | | | | | 0 | | |
| | *delayed to Final Report submittal | | | | | | | | | | | | | | | |

Table 1: Organisms caught in the vertical migration trap at BP-1 during OCS-9 deployed 5 days (9-14 March 1979).

| Upper (ice facing) trap | Small trap (D=26cm) | Large trap (D=100cm) | Total |
|---|---|---|---|
| Amphipoda | | | |
| *Anonyx nugax* | 1 | 1 | 2 |
| *Atylus carinatus* | - | 1 | 1 |
| *Gammaracanthus loricatus* | - | 1 | 1 |
| *Gammarus* sp. | - | 1 | 1 |
| *Onisimus littoralis* | 1 | - | 1 |
| Total | 2 | 4 | 6 |
| Calanoida | 6 | 2 | 8 |
| Harpacticoida | | | |
| *Tisbe* sp. | 2 | - | 2 |
| *Halectinosama* sp. E | - | 1 | 1 |
| Total | 2 | 1 | 3 |
| Ostracoda (Podocopa) | - | 14 | 14 |
| Nematoda | 1 | 1 | 2 |
| Lower (bottom facing) trap | nothing | nothing | 0 |

Table 2: Organisms caught in the vertical migration traps at BP-1 during OCS-10, deployed 4 days (18-22 May 1979).

| Upper (ice facing) trap | Small trap (D=26cm) | Large trap (D=100cm) | Total |
|---|---|---|---|
| Amphipoda | | | |
| *Atylus carinatus* (juv.) | 1(1) | 5(13) | 20 |
| *Gammarus* sp. | - | 1 | 1 |
| Total | 2 | 19 | 21 |
| Calanoida | 10 | 4 | 14 |
| Harpacticoida | | | |
| *Tisbe* sp. | - | 1 | 1 |
| *Halectinosoma* sp. F | - | 1 | 1 |
| Total | 0 | 2 | 2 |
| Cyclopoida | | | |
| *Cyclopina schneideri* | - | 1 | 1 |
| *Cyclopina gracilis* | 3 | - | 3 |
| Total | 3 | 1 | 4 |
| Copepod nauplii | 4 | 1 | 5 |
| Ostrocoda (Podocopa) | 1 | - | 1 |
| Nematoda | 1 | 2 | 3 |
| Polychaeta | | | |
| *Nereis zonata* (epitokes) | - | 3 | 3 |
| Syllaidae sp. | - | 1 | 1 |
| *Autolytus primaticus* (cf.) | 1 | - | 1 |
| Total | 1 | 4 | 5 |
| Polychaete larvae | 3 | 4 | 7 |
| Lower (bottom facing) trap | 1 juv. *Atylus* | nothing | 1 |

Table 3: Densities of organisms found in Ice Cores (ICB) at BP-1 (OCS-9). Cores 1-9 collected 9 March 1979, cores 10-20 collected 14 March 1979. Numbers for each ice core are per 9.62 $cm^2$.

| ICB # | 1 | 2 | 3 | 4 | 5 | 7 | 9 | 10 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | $\bar{X}$, SE | Per $10cm^2$ | Per $1,000cm^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polychaete larvae | 5 | 17 | 16 | 9 | 5 | 1 | 2 | 3 | 1 | 2 | 5 | - | 11 | 3 | 1 | 4 | 3 | 5.2 ±1.2 | 8.4±2.0 | 840 |
| nauplii | - | - | 4 | 2 | 2 | 2 | - | 2 | - | 6 | 4 | 1 | 2 | - | - | 4 | - | 1.7 ±0.5 | 2.8±0.7 | 277 |
| Calanoida | - | - | - | 1 | - | - | - | 3 | - | 1 | 1 | - | - | - | - | - | 4 | 0.6 ±0.3 | 1.0±0.5 | 95 |
| Harpacticoida | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 0.1 ±0.08 | 0.2±0.1 | 9 |
| Rotifera | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.06±0.06 | 0.1±0.1 | 9 |
| Nematoda | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 0.06±0.06 | 0.1±0.1 | 9 |

Table 4: Comparison of two epontic community sampling devices, at BP-1 (OCS-10) collected 18-19 May 1979. Numbers for ice cores (ICB) per 9.62 $cm^2$, numbers for Ice Box Transects (IBT) are per 1,000 $cm^2$.

| ICB # | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | $\bar{X}$, SE | Per $1000cm^2$ | IBT # | 1 | 2 | 3 | 4 | 5 | 6 | $\bar{X}$,SE(Per $1,000cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polychaete larvae | - | - | - | - | - | - | - | - | - | 0 | 0 | | - | 2 | 2 | 2 | 2 | 2 | 1.7± 0.3 |
| nauplii | 1 | - | - | - | - | - | 1 | - | - | 0.22±0.15 | 36 | | - | 5 | 21 | 51 | 25 | 11 | 18.8± 7.5 |
| Cyclopoida | 2 | 1 | - | - | - | - | - | 1 | 1 | 0.56±0.24 | 90 | | - | 10 | 27 | 73 | 28 | 7 | 24.2±10.8 |
| Harpacticoida | - | - | 1 | - | - | - | 1 | - | - | 0.22±0.15 | 36 | | 2 | - | 2 | - | 2 | - | 1.0± 0.5 |
| Rotifera | - | - | - | - | - | - | - | - | - | 0 | 0 | | 1 | 16 | 9 | 2 | 7 | - | 5.8± 2.5 |
| Nematoda | 1 | 3 | 2 | 7 | 5 | 1 | 6 | 5 | - | 3.3 ±0.83 | 541 | | 16 | 58 | 102 | 119 | 249 | 110 | 109.0±32.2 |
| Amphipoda | - | - | - | - | - | - | - | - | - | 0 | 0 | | - | - | - | 1 | - | - | 0.2± 0.2 |

Table 5: Density of meiofaunal groups at BP-1 (OCS-10), collected 18 May 1979. Numbers for each Diver Sediment Core (DSC) are per 6.12 $cm^2$.

| | DSC-21 | DSC-22 | DSC-23 | DSC-24 | DSC-25 | DSC-26 | DSC-27 | DSC-28 | DSC-29 | DSC-30 | $\bar{X}$, SE | Per $10cm^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nematoda | 108 | 357 | 289 | 625 | 234 | 137 | 426 | 173 | 720 | 35 | 310±71 | 504±116 |
| Kinoryncha | - | - | 1 | 1 | 2 | - | - | - | 2 | 1 | 0.1±0.3 | 1.1±0.4 |
| Polychaeta | 2 | 14 | 10 | 17 | 9 | 4 | 27 | 1 | 18 | 2 | 10±2.7 | 17±4.4 |
| Harpacticoida | 1 | 18 | 26 | 18 | 15 | 15 | 30 | 11 | 13 | 26 | 17±2.7 | 28±4.4 |
| Tanaidacea | 1 | 1 | 10 | 13 | 2 | - | 3 | 2 | 8 | - | 4.0±1.6 | 6.5±2.6 |
| Ostracoda | - | 8 | 4 | 3 | - | 6 | 3 | - | 8 | 2 | 3.4±1.0 | 5.5±1.5 |
| Cumacea | - | 2 | - | - | - | - | 1 | - | 1 | - | 0.4±0.2 | 0.7±0.4 |
| Isopoda | - | - | - | 1 | - | - | - | - | - | - | 0.1±0.09 | 0.2±0.15 |
| nauplii | - | 3 | 4 | 1 | - | 1 | 2 | - | 5 | 8 | 2.4±1.0 | 3.9±1.5 |
| Pelecypoda | - | - | - | - | - | 1 | - | - | - | - | 0.1±0.09 | 0.2±0.15 |
| Gastropoda | - | - | - | - | - | - | - | - | 1 | - | 0.1±0.09 | 0.2±0.15 |
| Priapulida | - | - | - | - | - | 1 | - | - | - | - | 0.1±0.09 | 0.2±0.15 |
| Anthozoa | - | - | - | - | - | - | - | - | 1 | - | 0.1±0.09 | 0.2±0.15 |

Table 6: Density of meiofaunal groups at BP-1 (OCS-9), collected 14 March 1979. Numbers for each Diver Sediment Core (DSC) are per 6.12 $cm^2$.

| | DSC-1 | DSC-2 | DSC-3 | DSC-4 | DSC-5 | DSC-6 | DSC-9 | DSC-13 | DSC-14 | DSC-16 | $\bar{X}$, SE | Per $10cm^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nematoda | 129 | 33 | 145 | 452 | 429 | 280 | 670 | 545 | 371 | 288 | 334±63 | 542±102 |
| Kinoryncha | - | - | - | 1 | 2 | - | 3 | - | 1 | - | 0.7±0.3 | 1.1±0.5 |
| Nemertinea | 2 | - | - | - | - | - | - | - | - | - | 0.2±0.3 | 0.3±0.5 |
| Polychaeta | 3 | 4 | 5 | 21 | 9 | 7 | 38 | 4 | 19 | 8 | 12±3.5 | 19±5.7 |
| Amphipoda | - | - | - | - | - | - | 1 | - | - | - | 0.1±0.09 | 0.2±0.2 |
| Harpacticoida | 5 | 14 | 12 | 25 | 10 | 28 | 15 | 13 | 12 | 12 | 15±2.2 | 24±3.6 |
| Tanaidacea | - | - | 1 | - | 1 | - | - | - | - | - | 0.2±0.3 | 0.3±0.2 |
| Ostracoda | 6 | 1 | 3 | 7 | 3 | - | 7 | 2 | 3 | 5 | 4±0.6 | 6.5±1.0 |
| Acarina | - | - | - | - | - | - | - | - | 2 | - | 0.2±0.3 | 0.3±0.2 |
| nauplii | 1 | 12 | 8 | 12 | 17 | 6 | 15 | 2 | - | - | 7±1.9 | 11±3.1 |

Table 7: Copepoda found in ice samples. G - gravid ♀ , C - copepodite.

| | | |
|---|---|---|
| OCS-9 | | |
| | ICB-13 | |
| | 1 - *Halectinosoma neglectum* | (1G) |
| | ICB-14 | |
| | 1 - *Halectinosoma neglectum* | (1C) |
| OCS-10 | | |
| | ICB-21 | |
| | 2 - *Cyclopina gracilis* | (2C) |
| | ICB-22 | |
| | 1 - *Cyclopina gracilis* | (1C) |
| | ICB-23 | |
| | 1 - *Pseudobradya* sp. C | (1♀) |
| | ICB-27 | |
| | 1 - *Pseudobradya* sp. C | (1♀) |
| | ICB-28 | |
| | 1 - *Cyclopina gracilis* | (1C) |
| | ICB-29 | |
| | 1 - *Cyclopina gracilis* | (1G) |
| | IBT-1 | |
| | 2 - *Pseudobradya* sp. C | (2C) |
| | IBT-2 | |
| | 10 - *Cyclopina gracilis* | (10C) |
| | IBT-3 | |
| | 2 - *Halectinosoma* | (2C) |
| | 27 - *Cyclopina gracilis* | (2,♀,25C) |
| | IBT-4 | |
| | 73 - *Cyclopina gracilis* | (2G,2♀,69C) |
| | IBT-5 | |
| | 2 - *Halectinosoma neglectum* | (1♂,1C) |
| | 28 - *Cyclopina gracilis* | (1G,1♀,26C) |
| | IBT-6 | |
| | 7 - *Cyclopina gracilis* | (1 ♂,6G) |

Table 8: Copepoda found in sediment samples. G = gravid ♀, C = copepodite

OCS-9

DSC-1

| | | |
|---|---|---|
| 2 - | Bradya typica | (1♀,1C) |
| 3 - | Halectinosoma sp. F | (1♀,2♂) |

DSC-2

| | | |
|---|---|---|
| 4 - | Bradya typica | (1♀,3C) |
| 1 - | Halectinosoma sp. F | (1G) |
| 1 - | Halectinosoma sp. G | (1♀) |
| 1 - | Pseudobradya sp. B | (1♀) |
| 1 - | Pseudobradya sp. C | (1G) |
| 2 - | Paramphiascella fulvofasciata | (1G,1C) |
| 5 - | Ameira sp. A | (1♀,4C) |

DSC-3

| | | |
|---|---|---|
| 1 - | Bradya typica | (1♀ |
| 3 - | Halectinosoma sp. F | (1G,2C) |
| 3 - | Paramphiascella fulvofasciata | (2♂,1C) |
| 3 - | Ameira sp. A | (1G,2C) |
| 2 - | Danielssenia stefanssoni | (2♀ |

DSC-4

| | | |
|---|---|---|
| 3 - | Bradya typica | (2C,1C) |
| 4 - | Halectinosoma sp. F | (1♀, 1♂,2C) |
| 1 - | Halectinosoma sp. G | (1♀) |
| 1 - | Paramphiascella fulvofasciata | (1♀) |
| 10 - | Ameira sp. A | (1♀,1♂,8C) |
| 4 - | Cletodes tenuipes | (3♀,1♂) |

DSC-5

| | | |
|---|---|---|
| 1 - | Bradya typica | (1C) |
| 3 - | Halectinosoma sp. F | (1♀,2♂) |
| 1 - | Stenhelia sp. C | (1C) |
| 3 - | Ameira sp. A | (1G,1♀,1C) |
| 1 - | Cletodes tenuipes | (1♀) |
| 1 - | Echinolaophonte brevispinosa | (1♀) |
| 1 - | Harpacticus flexus | (1♀) |

DSC-6

| | | |
|---|---|---|
| 2 - | Bradya typica | (2C) |
| 4 - | Halectinosoma sp. F | (4♀) |
| 1 - | Cletodes tenuipes | (1♀) |
| 3 - | Danielssenia stefanssoni | (1♀,2C) |

DSC-9

| | | |
|---|---|---|
| 1 - | Bradya typica | (1C) |
| 1 - | Halectinosoma sp. E | (1♀) |
| 2 - | Halectinosoma sp. F | (1G,1♀) |
| 1 - | Halectinosoma sp. G | (1♀) |
| 1 - | Amphiasoides sp. A | (1♀) |
| 2 - | Paramphiascella fulvofasciata | (1G,1C) |
| 2 - | Stenhelia nuwukensis | (2C) |

Table 8 (continued)

OCS-9 (cont.)

DSC-9 (cont.)

| | |
|---|---|
| 1 - *Stenhelia* sp. P | (1C) |
| 2 - *Ameira* sp. A | (1G,1C) |
| 1 - *Rhizothrix* sp. A | (1C) |
| 2 - *Danielssenia stefanssoni* | (2C) |

DSC-13

| | |
|---|---|
| 1 - *Halectinosoma neglectum* | (1♀) |
| 5 - *Halectinosoma* sp. F | (3G,2♀) |
| 1 - *Amphiascoides* sp. A | (1♀) |
| 1 - *Ameira* sp. A | (1G) |
| 1 - *Cletodes tenuipes* | (1♀) |
| 2 - *Danielssenia stefanssoni* | (2C) |

DSC-14

| | |
|---|---|
| 1 - *Halectinosoma* sp. G | (1♀) |
| 2 - *Paramphiascella fulvofasciata* | (2C) |
| 5 - *Ameira* sp. A | (♀,3C) |
| 1 - *Rhizothrix* sp. A | (1♂) |
| 1 - *Eurycletodes* sp. A | (1♀) |
| 2 - *Danielssenia stefanssoni* | (2C) |

DSC-16

| | |
|---|---|
| 1 - *Pseudobradya* sp. C | (1♀) |
| 1 - *Stenhelia* sp. C | (1C) |
| 4 - *Ameira* sp. A | (1♀,3C) |
| 1 - *Cletodes tenuipes* | (1♀) |
| 1 - *Cletodes* sp. A | (1G) |
| 1 - *Cletodes* sp. B | (1♂) |
| 2 - *Danielssenia stefanssoni* | (1♀,1C) |

OCS-10

DSC-21

| | |
|---|---|
| 1 - *Amphiascoides* | (1♀) |

DSC-22

| | |
|---|---|
| 10 - *Bradya typica* | (1♀,9C) |
| 1 - *Pseudobradya* sp. C | (1C) |
| 2 - *Haloschizopera* sp. A | (1G,1C) |
| 3 - *Ameira* sp. A | (1G,1♀,1C) |
| 1 - Ameiridae | (1♂) |
| 1 - *Cletodes tenuipes* | (1♀) |

DSC-23

| | |
|---|---|
| 5 - *Bradya typica* | (5C) |
| 9 - *Halectinosoma* sp. F | (6♀,3C) |
| 11 - *Haloschizopera* sp. A | (2G,3♀,1♂,5C) |
| 1 - *Zosime* sp. A | (1♀) |

OCS-10 (continued)

DSC-24

| | | |
|---|---|---|
| 11 | - *Bradya typica* | (1G,1♀,9C) |
| 2 | - *Halectinosoma* sp. F | (2C) |
| 2 | - *Haloschizopera* sp. A | (2C) |
| 1 | - *Ameira* sp. A | (1♀) |
| 1 | - *Ameiridae* | (1C) |
| 1 | - *Laophontidae* | (1♂) |

DSC-25

| | | |
|---|---|---|
| 5 | - *Bradya typica* | (5C) |
| 1 | - *Amphiascoides* sp. A | (1C) |
| 1 | - *Haloschizopera* sp. A | (1C) |
| 1 | - *Ameira* sp. A | (1♀) |

DSC-26

| | | |
|---|---|---|
| 4 | - *Bradya typica* | (1G,3C) |
| 2 | - *Amphiascoides* sp. A | (2C) |
| 4 | - *Haloschizopera* sp. A | (1G,3C) |
| 1 | - *Stenhelia nuwukensis* | (1♀) |
| 1 | - *Stenhelia* sp. E | (1♂) |
| 1 | - *Ameira* sp. A | (1♂) |
| 1 | - *Tisbe* sp. | (1♂) |

DSC-27

| | | |
|---|---|---|
| 8 | - *Bradya typica* | (1♂,7C) |
| 1 | - *Halectinosoma neglectum* | (1♀) |
| 7 | - *Halectinosoma* sp. F | (3♀,4C) |
| 4 | - *Haloschizopera* sp. A | (3♀,1C) |
| 2 | - *Stenhelia nuwukensis* | (2C) |

DSC-28

| | | |
|---|---|---|
| 1 | - *Bradya typica* | (1C) |
| 7 | - *Halectinosoma* sp. F | (4♀,3C) |
| 1 | - *Amphiascoides* sp. A | (1♂) |
| 1 | - *Ameira* sp. A | (1C) |

DSC-29

| | | |
|---|---|---|
| 5 | - *Bradya typica* | (1♀,4C) |
| 3 | - *Halectinosoma* sp. F | (1G,1♂,1C) |
| 1 | - *Stenhelia nuwukensis* | (1♀) |
| 3 | - *Ameira* sp. A | (2♀,1C) |
| 1 | - *Rhizothrix* sp. A | (1♂) |
| 1 | - *Echinolaophonte brevispinosa* | (1♀) |
| 1 | - Cylindropsyllidae | (1♂) |

DSC-30

| | | |
|---|---|---|
| 13 | - *Halectinosoma* sp. F | (8♀,2♂,3C) |
| 1 | - *Pseudobradya* sp. B | (1♀) |
| 1 | - *Haloschizopera* sp. A | (1G) |
| 1 | - *Stenhelia* sp. E | (1G) |
| 1 | - *Ameira* sp. A | (1♀) |
| 6 | - *Danielssenia stefanssoni* | (6C) |

Table 9: Synopsis of copepod data, sediment density per 10 $cm^2$ ($\bar{X}\pm SE$, N=10), ice density per 1,000 $cm^2$ ($\bar{X}\pm SE$, N=6).

| Species | OCS-9 Sediment | OCS-10 Sediment | OCS-9 ice | OCS-10 ice |
|---|---|---|---|---|
| Ectinosomatidae | | | | |
| Halectinosoma neglectum | 0.2±0.2 | 0.2±0.2 | 16±11 | 0.7±0.4 |
| Halectinosoma sp. E | 0.2±0.2 | - | - | - |
| Halectinosoma sp. F | 4.0±0.8 | 6.6±2.4 | - | - |
| Halectinosoma sp. G | 0.7±0.3 | - | - | - |
| Bradya typica | 2.3±0.7 | 10.1±2.2 | - | - |
| Pseudobradya sp. B | 0.2±0.2 | 0.2±0.2 | - | 0.3±0.3 |
| Pseudobradya sp. C | 0.2±0.2 | 0.2±0.2 | - | - |
| Tachidiidae | | | | |
| Danielssenia stefanssoni | 1.8±0.4 | 1.0±1.0 | - | - |
| Harpacticidae | | | | |
| Harpacticus flexus | 0.2±0.2 | - | - | - |
| Tisbidae | | | | |
| Tisbe sp. A | - | 0.2±0.2 | - | - |
| Zosime sp. A | - | 0.2±0.2 | - | - |
| Diosaccidae | | | | |
| Stenhelia nuwukensis | 0.3±0.3 | 0.7±0.4 | - | - |
| Stenhelia sp. C | 0.3±0.3 | - | - | - |
| Stenhelia sp. E | - | 0.3±0.3 | - | - |
| Stenhelia sp. P | 0.2±0.2 | - | - | - |
| Amphiascoides sp. A | 0.3±0.3 | 0.8±0.4 | - | - |
| Paramphiascella fulvofasciata | 1.6±0.6 | - | - | - |
| Haloschizopera sp. A | - | 3.7±1.4 | - | - |
| Ameiridae | | | | |
| Ameira sp. A | 5.4±1.5 | 1.8±0.6 | - | - |
| Ameirid B | - | 0.3±0.3 | - | - |
| Cylindropsyllidae | | | | |
| Cylindropsyllid A | - | 0.2±0.2 | - | - |
| Cletodidae | | | | |
| Cletodes tenuipes | 0.7±0.3 | 0.2±0.2 | - | - |
| Cletodes sp. A | 0.2±0.2 | - | - | - |
| Cletodes sp. B | 0.2±0.2 | - | - | - |
| Rhizothrix sp. A | 0.3±0.3 | 0.2±0.2 | - | - |
| Eurycletodes sp. A | 0.2±0.2 | - | - | - |
| Laophontidae | | | | |
| Echinolaophohte brevispinosa | 0.2±0.2 | 0.2±0.2 | - | - |
| Laophontid A | - | 0.2±0.2 | - | - |
| Cyclopoida | | | | |
| Cyclopina gracilis | - | - | - | 24±11 |

Table 10: Animal densities of Station 40 (OCS-7) collected on 26 August 1977.

| Phylum | Class | Order | Grab Number 1643 | 1644 | 1645 | 1646 | 1647 |
|---|---|---|---|---|---|---|---|
| Cnidaria: | Anthozoa | | 13 | 15 | 5 | 7 | 10 |
| Nematoda | | | 74 | 97 | 55 | 99 | 59 |
| Nemertinea | | | 2 | 2 | 3 | 5 | 3 |
| Annelida: | Polychaeta | | 198 | 190 | 203 | 199 | 212 |
| Sipuncula | | | 2 | 9 | 12 | 5 | 12 |
| Arthropoda: | Crustacea: | Amphipoda | 4 | 8 | 10 | 11 | 19 |
| | | Harpacticoida | | 20 | 4 | 5 | 8 |
| | | Isopoda | | 3 | 1 | 1 | |
| | | Ostracoda | 25 | 30 | 20 | 30 | 47 |
| | | Tanaidacea | 16 | 49 | 42 | 77 | 36 |
| | | Cumacea | 7 | 10 | 3 | 8 | 6 |
| | Pycnogonida | | | 1 | | | |
| Mollusca: | Pelecypoda | | 12 | 13 | 6 | 24 | 44 |
| | Gastropoda | | 1 | 3 | | | 1 |
| Echinodermata: | Ophiuroidea | | 3 | 6 | 1 | | 9 |
| | Holothuroidea | | 1 | 1 | 1 | | |
| | Asteroidea | | | | | | 1 |
| Hemicordata | | | 6 | 2 | 2 | | 2 |
| TOTAL | | | 364 | 459 | 368 | 471 | 469 |

Table 11: Animal densities for Station 39 (OCS-7) collected on 26 August 1977.

| Phylum | Class | Order | Grab Number 1637 | 1638 | 1639 | 1640 | 1641 |
|---|---|---|---|---|---|---|---|
| Cnidaria: | Anthozoa | | 5 | 2 | 5 | 1 | 7 |
| Nematoda | | | 108 | 139 | 160 | 101 | 174 |
| Nemertinea | | | 9 | 12 | 11 | 14 | 7 |
| Annelida: | Polychaeta | | 124 | 140 | 230 | 170 | 263 |
| Sipuncula | | | 7 | 2 | 2 | 1 | 2 |
| Arthropoda: | Crustacea: | Amphipoda | 12 | 10 | 15 | 9 | 12 |
| | | Harpacticoida | 3 | 5 | 6 | | 6 |
| | | Isopoda | 1 | 4 | | 2 | |
| | | Ostracoda | 18 | 26 | 28 | 8 | 72 |
| | | Tanaidacea | 9 | 7 | 7 | 2 | 12 |
| | | Cumacea | 18 | 26 | 22 | 9 | 26 |
| | Pycnogonida | | 1 | | | | 2 |
| Mollusca: | Pelecypoda | | 44 | 95 | 63 | 74 | 86 |
| | Gastropoda | | 2 | 2 | 13 | 3 | 6 |
| | Aplacophora | | | | 1 | | |
| Brachiopoda | | | | | 2 | | |
| Echinodermata: | Ophiurodea | | 9 | 11 | 12 | 7 | 4 |
| | Holothuroidea | | | 2 | 2 | | |
| | Asteroidea | | | | 1 | | 1 |
| Hemicordata | | | 3 | 1 | | 2 | 1 |
| TOTAL | | | 373 | 484 | 580 | 403 | 681 |

Table 12: Animal densities for Station 37 (OCS-7) collected on 25 August 1977

| Phylum | Class | Order | Grab Number 1629 | 1630 | 1631 | 1632 | 1633 |
|---|---|---|---|---|---|---|---|
| Cnidaria: | Anthozoa | | | 1 | | | 2 |
| Nematoda | | | 6 | 38 | 12 | 21 | 205 |
| Nemertinea | | | 1 | 4 | 4 | 7 | 8 |
| Annelida: | Polychaeta | | 26 | 118 | 117 | 44 | 469 |
| Sipuncula | | | | 1 | | | |
| Echiroidea | | | | | | | 1 |
| Priapulida | | | | 1 | | | 2 |
| Arthropoda: | Crustacea: | Decapoda | | | | 1 | |
| | | Amphipoda | | 7 | 5 | | 3 |
| | | Harpacticoida | | | 1 | 2 | 19 |
| | | Isopoda | | 1 | 1 | 1 | 3 |
| | | Ostracoda | | 7 | 6 | 7 | 108 |
| | | Tanaidacea | 1 | 12 | 1 | 4 | 29 |
| | | Cumacea | 7 | 2 | 6 | | 2 |
| Mollusca: | Pelecypoda | | 3 | 53 | 48 | 35 | 125 |
| | Gastropoda | | 6 | 8 | 4 | 3 | 19 |
| | Polyplacophora | | | 1 | | | |
| Echinodermata: | Ophiuroidea | | 1 | 4 | 1 | | 7 |
| | Holothuroidea | | | 3 | 2 | 4 | 1 |
| TOTAL | | | 51 | 261 | 208 | 129 | 1003 |

Table 13: Animal densities for Station 36 (OCS-7) collected on 25 August 1977.

| Phylum | Class | Order | Grab Number 1623 | 1624 | 1625 | 1626 | 1627 |
|---|---|---|---|---|---|---|---|
| Cnidaria: | Anthozoa | | 1 | 1 | -- | 1 | 1 |
| Nematoda | | | 5 | 17 | 6 | 45 | 29 |
| Nemertinea | | | 3 | 6 | 4 | 8 | 11 |
| Annelida: | Polychaeta | | 238 | 333 | 208 | 335 | 287 |
| Sipuncula | | | 52 | 62 | 57 | 69 | 70 |
| Arthropoda: | Crustacea: | Amphipoda | 3 | 5 | 3 | 5 | 1 |
| | | Harpacticoida | 2 | 2 | 1 | 5 | 6 |
| | | Isopoda | 1 | 4 | 1 | 8 | 2 |
| | | Ostracoda | 1 | 5 | 3 | 3 | 2 |
| | | Tanaidacea | 6 | 7 | 3 | 9 | 4 |
| | | Cumacea | 1 | | 2 | 5 | 2 |
| Mollusca: | Pelecypoda | | 71 | 87 | 62 | 131 | 107 |
| | Gastropoda | | 1 | 2 | | 1 | 2 |
| | Aplacophora | | | 3 | 6 | 3 | 7 |
| Echinodermata: | Ophiuroidea | | | 4 | | 2 | |
| | Holothuroidea | | | 1 | | | |
| | Asteroidea | | | | | 1 | 1 |
| Hemicordata | | | | 4 | | 6 | 3 |
| TOTAL | | | 385 | 543 | 356 | 637 | 535 |

Table 14: Biomass, preserved wet weights in grams per 0.1 $m^2$ from OCS-7 Demarcation Point stations, collected in August 1977.

| Station | Depth(m) | Grab | Anthozoa | Sipuncula | Annelida | Arthropoda | Mollusca | Echinodermata | Misc. Phyla | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 400 | 1623 | .46 | .13 | 3.59 | .08 | .53 | --- | .05 | 4.84 |
| | 403 | 1624 | .02 | .13 | 2.50 | .07 | .55 | .04 | .04 | 3.35 |
| | 401 | 1625 | --- | .12 | 3.45 | .03 | .54 | --- | .21 | 4.35 |
| | 403 | 1626 | .26 | .19 | 2.78 | .10 | .53 | .03 | .03 | 3.92 |
| | 403 | 1627 | .04 | .13 | 2.14 | .04 | .49 | .02 | .06 | 2.92 |
| 37 | 26 | 1629 | --- | --- | .57 | .05 | .26 | .01 | .02 | .91 |
| | 25 | 1630 | --- | + | 1.28 | .10 | 3.39 | .02 | .02 | 4.81 |
| | 25 | 1631 | --- | --- | .45 | .10 | .98 | .48 | .11 | 2.12 |
| | 25 | 1632 | --- | --- | .17 | .72 | .87 | --- | .08 | 1.84 |
| | 25 | 1633 | + | --- | .92 | .23 | 3.29 | .76 | .08 | 5.28 |
| 39 | 50 | 1637 | .46 | .17 | 1.51 | .93 | 9.45 | .51 | .05 | 13.08 |
| | 50 | 1638 | .01 | .04 | 1.70 | .50 | 15.24 | .84 | .15 | 18.48 |
| | 50 | 1639 | .17 | .01 | 2.19 | .28 | 2.60 | .47 | .07 | 5.79 |
| | 50 | 1640 | --- | .08 | 1.26 | .14 | 6.63 | .51 | .48 | 9.10 |
| | 50 | 1641 | 3.95 | + | 1.62 | .51 | 3.06 | 9.94 | .28 | 19.36 |
| 40 | 158 | 1643 | .05 | + | .71 | .16 | 6.14 | 1.51 | .05 | 8.62 |
| | 160 | 1644 | .01 | .04 | 1.06 | .30 | 1.03 | .27 | 1.14 | 3.85 |
| | 164 | 1645 | + | .06 | 1.50 | .09 | .07 | .01 | .46 | 2.19 |
| | 148 | 1646 | .02 | .09 | 1.37 | .26 | .34 | --- | .28 | 2.36 |
| | 136 | 1947 | .01 | .11 | 2.20 | .19 | 2.76 | .71 | .15 | 6.13 |

+ = presence, not weighable
- = absence

Table 15 : Small macroinfauna (0.50 mm fraction) densities for CG-20 (WEBSEC-71) collected on 25 August 1971, 2295 m.

| | | | Grab Number | | | | | |
|---|---|---|---|---|---|---|---|---|
| Phylum: | Class: | Order | 888s | 889s | 890s | 891s | 892s | Total |
| Nematoda | | | 16 | 8 | 4 | 28 | 26 | 82 |
| Annelida: | Polychaeta | | 22 | 19 | 7 | 12 | 32 | 92 |
| Porifera | | | - | 8 | 5 | - | 2 | 15 |
| Arthropoda: | Crustacea: | Amphipoda | 2 | 1 | 1 | - | 5 | 9 |
| | | Cirripedia | - | - | - | 2 | - | 2 |
| | | Harpacticoida | - | 2 | - | - | - | 2 |
| | | Ostracoda | 1 | - | - | - | - | 1 |
| | | Tanaidacea | - | 1 | - | - | 5 | 6 |
| Mollusca: | Pelecypoda | | 8 | 4 | 9 | 8 | 9 | 38 |
| Total | | | 49 | 43 | 26 | 50 | 79 | 247 |

Table 16 : Small macroinfauna (0.50 mm fraction) densities for CG-80 (WEBSEC-71) collected on 13 September 1971, 2204 m.

| | | | Grab Numbers | | | | |
|---|---|---|---|---|---|---|---|
| Phylum: | Class: | Order | 1023s | 1024s | 1025s | 1026s | Total |
| Cnidaria: | Anthozoa | | - | - | 1 | 2 | 3 |
| Nematoda | | | 37 | 96 | 125 | 88 | 346 |
| Nemertinea | | | - | - | - | 1 | 1 |
| Annelida: | Polychaeta | | 29 | 59 | 62 | 41 | 191 |
| Sipuncula | | | 1 | - | 1 | - | 2 |
| Arthropoda: | Crustacea: | Amphipoda | 1 | 2 | 1 | 2 | 6 |
| | | Cirripedia | 2 | 6 | - | 1 | 9 |
| | | Harpacticoida | 11 | 5 | 5 | 3 | 24 |
| | | Isopoda | 4 | - | 1 | 3 | 8 |
| | | Tanaidacea | 1 | - | 1 | - | 2 |
| | | Cumacea | 1 | 5 | - | 1 | 7 |
| Mollusca: | Pelecypoda | | 8 | 2 | 5 | 2 | 17 |
| Echinodermata: | Holothuroidea | | - | - | 1 | - | 1 |
| Total | | | 95 | 175 | 203 | 144 | 617 |

Table 17 : Small macroinfauna (0.50 mm fraction) densities for CG-85 (WEBSEC-71) collected on 12 September 1971, 1100 m.

| | | | Grab Number | | | | | |
|---|---|---|---|---|---|---|---|---|
| Phylum: | Class: | Order | 1018s | 1019s | 1020s | 1021s | 1022s | Total |
| Nematoda | | | 383 | 181 | 188 | 148 | 139 | 1,039 |
| Annelida: | Polychaeta | | 44 | 11 | 19 | 35 | 44 | 153 |
| Sipuncula | | | 4 | 1 | 2 | 1 | - | 8 |
| Priapula | | | 3 | - | 2 | - | - | 5 |
| Arthropoda: | Crustacea: | Amphipoda | - | - | 6 | 2 | 1 | 9 |
| | | Cirripedia | 2 | - | - | - | - | 2 |
| | | Harpacticoida | 1 | 5 | 2 | 1 | 2 | 11 |
| | | Isopoda | - | 1 | 2 | - | - | 3 |
| | | Ostracoda | - | - | 4 | - | 1 | 5 |
| | | Tanaidacea | 4 | 20 | 9 | 9 | 26 | 68 |
| | | Cumacea | 1 | 1 | - | - | 2 | 4 |
| Mollusca: | Pelecypoda | | 18 | 35 | 32 | 15 | 59 | 159 |
| | Gastropoda | | 1 | 1 | - | 2 | - | 4 |
| Hemicordata | | | - | - | - | - | 1 | |
| Total | | | 461 | 256 | 266 | 213 | 275 | 1,471 |

Table 18. Samples collected in Beaufort Sea coastal waters in July and August 1976.

| Transect | Date(1976) | Station | Position | Depth(m) | Cond. | Salinity ‰ | Temperature (°C) | No. Biol. Samples | No. Sed. Samples |
|---|---|---|---|---|---|---|---|---|---|
| Point Barrow | 19 Aug. | BRB-25 | 71°27.3'N 156°22.3'W | 25.9 | | | | 5 | 1 |
| | | BRB-20 | 71°28.0'N 156°18.6'W | 19.5 | | | | 5 | 1 |
| | | BRB-15 | 71°28.2'N 156°13.1'W | 15.5 | | | | 5 | 1 |
| | | BRB-10 | 71°24.9'N 156°23.8'W | 9.8 | | | | 5 | 1 |
| | | BRB-5 | 71°23.4'N 156°27.1'W | 5.2 | 25.00 | 27.00 | 3.50 | 5 | 1 |
| Pitt Point | 20 Aug. | PPB-25 | 71°09'N 152°38'W | 26.0 | | | | 5 | 1 |
| | | PPB-20 | 71°05.2'N 152°58.7'W | 19.2 | 11.10 | 12.70 | -1.60 | 5 | 1 |
| | | PPB-15 | 71°04.4'N 153°01.5'W | 14.9 | 25.50 | 31.20 | -1.30 | 5 | 1 |
| | | PPB-10 | 70°59.1'N 153°08.8'W | 9.9 | 25.10 | 27.77 | -0.80 | 5 | 1 |
| | | PPB-5 | 70°56.4'N 153°12.9'W | 5.5 | 23.20 | 25.10 | -1.90 | 5 | 1 |
| Pingok Island | 22 Aug. | PIB-15 | 70°33.2'N 149°34.6'W | 14.9 | 24.87 | 31.45 | 1.88 | 5 | 1 |
| | | PIB-10 | 70°34.8'N 149°32.3'W | 10.2 | 23.00 | 22.32 | 2.15 | 5 | 1 |
| | | PIB-5 | 70°34.9'N 149°32.0'W | 4.5 | 20.65 | 22.08 | 2.08 | 5 | 1 |
| Narshal Island | 28 Aug. | NIB-15 | 70°26.0'N 147°26.2'W | 16.2 | 24.93 | 31.76 | -1.98 | 5 | 1 |
| | | NIB-10 | 70°24.3'N 147°29.2'W | 9.8 | 24.50 | 31.02 | -1.96 | 5 | 1 |
| | 27 Aug. | NIB-5 | 70°24.9'N 147°30.5'W | 5.0 | 24.09 | 30.10 | -0.88 | 5 | 1 |
| Barter Island | 31 Aug. | BAB-25 | 70°11.3'N 143°31.5'W | 24.6 | 24.82 | 31.98 | -2.00 | 5 | 1 |
| | | BAB-20 | 70°10.8'N 143°33.7'W | 20.3 | 24.46 | 31.33 | -2.00 | 5 | 1 |
| | 3 Sept. | BAB-15 | 70°09.5'N 143°36.2'W | 15.1 | 24.24 | 30.78 | -1.93 | 5 | 1 |
| | | BAB-10 | 70°09.0'N 143°32.2'W | 10.1 | 24.28 | 30.75 | -1.86 | 5 | 1 |
| | | BAB-5 | 70°08.4'N 147°37.7'W | 5.0 | 23.47 | 28.40 | -0.98 | 5 | 1 |
| TOTALS: 5 Transects | | 21 Stations | | | | | | 105 Biol. Samples | 21 Sed. Samples |

Table 19(continued)

Polychaete species - Barrow Transect (BRB)

| BRB-5 (5 meters) (continued) | No. specimens |
|---|---|
| SPIONIDAE (continued) | |
| Pygospio elegans Claparede, 1863 | 2 |
| Spio filicornis (Muller, 1776) | 5 |
| Spio theeli (Soderstrom, 1920) | 175 |
| Spiophanes bombyx (Claparede, 1870) | 1 |

Table 19 (continued)

Polychaete species - Barrow Transect (BRB)

| BRB-10 (10 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 3 |
| *Ampharete vega* (Wiren, 1883) | 3 |
| *Neosabellides* (?) sp. | 7 |
| Genus A | 3 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 9 |
| *Parheteromastus* sp. A | 31 |
| *Heteromastus filiformis* (Claparede, 1864) | 1 |
| *Barantolla americana* Hartman, 1963 | 1 |
| Genus B | 2 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 22 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 2 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 1 |
| *Ophryotrocha* sp. | 3 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 69 |
| HESIONIDAE | |
| *Bonuania* sp. | 1 |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 4 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 1 |
| *Nephtys discors* Ehlers, 1868 | 2 |
| *Nephtys incisa* Malmgren, 1865 | 1 |
| *Nephtys longosetosa* Oersted, 1843 | 32 |
| OPHELIIDAE | |
| *Ophelina groenlandica* Støp-Bowitz, 1948 | 1 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 3 |
| *Scoloplos armiger* (Muller, 1776) | 27 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 1153 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 12 |
| *Eteone longa* (Fabricius, 1780) | 32 |
| *Mystides borealis* Theel, 1879 | 1 |

Table 19 (continued)

Polychaete species - Barrow Transect (BRB)

| BRB-10 (10 meters) (continued) | No. specimens |
|---|---|
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 2 |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 5 |
| SABELLIDAE | |
| *Chone* sp. | 8 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 1 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 7 |
| SPIONIDAE | |
| *Marenzellaria wireni* Augener, 1913 | 5 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 2 |
| *Polydora quadrilobata* Jacobi, 1883 | 1 |
| *Prionospio steenstrupi* Malmgren, 1867 | 5 |
| *Pygospio elegans* Claparede, 1863 | 19 |
| *Spio filicornis* (Muller, 1776) | 1 |
| *Spio theeli* (Soderstrom, 1920) | 3 |
| TEREBELLIDAE | |
| *Polycirrus medusa* Grube, 1855 | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 5 |

Table 19 (continued)

Polychaete species - Barrow Transect (BRB)

| BRB-15 (15 meters) | No. specimens |
|---|---|
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 3 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 2 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 2 |
| HESIONIDAE | |
| *Bonuania* sp. | 4 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 5 |
| *Nephtys ciliata* (Muller, 1776) | 1 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 1 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 176 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 5 |
| *Eteone longa* (Fabricius, 1780) | 2 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 14 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 1 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 1 |
| *Prionospio steenstrupi* Malmgren, 1867 | 7 |
| *Pygospio elegans* Claparede, 1863 | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 1 |

Table 19 (continued)

Polychaete species - Barrow Transect (BRB)

| BRB-20 (20 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Neosabellides* (?) sp. | 3 |
| Genus A | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 1 |
| *Parheteromastus* sp. A | 1 |
| *Barantolla americana* Hartman, 1963 | 4 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 6 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 3 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 1 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 2 |
| *Flabelligera* sp. | 1 |
| LUMBRINERIDAE | |
| *Lumbrineris latreilli* Audouin & Milne-Edwards, 1843 | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 150 |
| *Nephtys ciliata* (Muller, 1776) | 7 |
| *Nephtys longosetosa* Oersted, 1843 | 1 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 2 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 243 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 11 |
| *Eteone longa* (Fabricius, 1780) | 7 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 14 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 1 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 1 |
| *Polydora quadrilobata* Jacobi, 1883 | 1 |
| *Polydora socialis* (Schmarda, 1861) | 1 |
| *Prionospio steenstrupi* Malmgren, 1867 | 19 |
| *Spio filicornis* (Muller, 1776) | 1 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 4 |

Table 19(continued)

Polychaete species - Barrow Transect (BRB)

| BRB-25 (25 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 9 |
| *Neosabellides* (?) sp. | 1 |
| Genus A | 6 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 10 |
| *Parheteromastus* sp. A | 8 |
| *Heteromastus filiformis* (Claparede, 1864) | 5 |
| *Barantolla americana* Hartman, 1963 | 15 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 14 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 5 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 1 |
| *Bonuania* sp. | 3 |
| LUMBRINERIDAE | |
| *Lumbrineris fragilis* (Muller, 1776) | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 34 |
| *Nephtys ciliata* (Muller, 1776) | 8 |
| *Nephtys discors* Ehlers, 1868 | 2 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 11 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 176 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 20 |
| *Eteone flava* (Fabricius, 1780) | 1 |
| *Eteone longa* (Fabricius, 1780) | 24 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 20 |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 3 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 25 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 3 |
| *Polydora caulleryi* Mesnil, 1897 | 13 |
| *Polydora quadrilobata* Jacobi, 1883 | 5 |
| *Prionospio steenstrupi* Malmgren, 1867 | 33 |
| *Pygospio elegans* Claparede, 1863 | 2 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 2 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-5 (5 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 28 |
| *Ampharete vega* (Wiren, 1883) | 270 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 7 |
| ARENICOLIDAE | |
| *Arenicola glacialis* Murdoch, 1885 | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 42 |
| *Parheteromastus* sp. A | 6 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 44 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 18 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 1 |
| DORVILLEIDAE | |
| *Ophryotrocha* sp. | 12 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 1 |
| OPHELIIDAE | |
| *Travisia* sp. | 1 |
| ORBINIIDAE | |
| *Scoloplos armiger* (Muller, 1776) | 238 |
| PARAONIDAE | |
| *Allia* sp. C | 1 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 43 |
| *Mystides borealis* Theel, 1879 | 5 |
| SABELLIDAE | |
| *Chone* sp. | 206 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780 | 11 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster-Benedict, 1887) | 110 |
| *Sphaerodoridium* sp. B | 1 |

Table 19 (continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-5 (5 meters) (continued) | No. specimens |
|---|---|
| SPIONIDAE | |
| *Marenzellaria wireni* Augener, 1913 | 12 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 467 |
| *Spio theeli* (Soderstrom, 1920) | 530 |
| TEREBELLIDAE | |
| *Polycirrus medusa* Grube, 1855 | 1 |
| *Proclea graffii* (Langerhans, 1884) | 4 |
| Genus C | 13 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 175 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-10 (10 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 1 |
| *Ampharete arctica* Malmgren, 1866 | 1 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 7 |
| *Parheteromastus* sp. A | 7 |
| *Heteromastus filiformis* (Claparede, 1864) | 3 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 54 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 5 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 1 |
| LUMBRINERIDAE | |
| *Lumbrineris minuta* Theel, 1879 | 1 |
| MALDANIDAE | |
| *Praxillella praetermissa* (Malmgren, 1865) | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 1 |
| *Nephtys ciliata* (Muller, 1776) | 2 |
| *Nephtys longosetosa* Oersted, 1843 | 4 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 17 |
| *Scoloplos armiger* (Muller, 1776) | 6 |
| PARAONIDAE | |
| *Allia* sp. A | 8 |
| *Allia* sp. B | 1 |
| *Allia* sp. C | 4 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 17 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 2 |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 1 |
| SABELLIDAE | |
| *Chone* sp. | 138 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 8 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-10 (10 meters)(continued) | No. specimens |
|---|---|
| SPHAERODORIDAE | |
| *Sphaerodoridium* sp. B | 3 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 9 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 50 |
| *Spio theeli* (Soderstrom, 1920) | 14 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 6 |
| TEREBELLIDAE | |
| *Artacama proboscidea* Malmgren, 1866 | 1 |
| *Proclea graffii* (Langerhans, 1884) | 1 |
| Genus C | 23 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 14 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-15 (15 meters) | No. specimens |
|---|---|
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 11 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 1 |
| COSSURIDAE | |
| *Cossura Longocirrata* Webster & Benedict, 1887 | 4 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 3 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 5 |
| *Nephtys ciliata* (Muller, 1776) | 2 |
| OPHELIIDAE | |
| *Ophelina acuminata* Oersted, 1843 | 1 |
| PARAONIDAE | |
| *Allia* sp. A | 1 |
| *Allia* sp. B | 7 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 2 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 242 |
| *Spio theeli* (Soderstrom, 1920) | 1 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-20 (20 meters) | No. specimens |
|---|---|
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 33 |
| *Heteromastus filiformis* (Claparede, 1864) | 2 |
| CIRRATULIDAE | |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 18 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 8 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 4 |
| *Bonuania* sp. | 1 |
| NEPHTYIDAE | |
| *Aglaophamus malmgreni* (Theel, 1879) | 1 |
| *Micronephthys minuta* (Theel, 1879) | 8 |
| OPHELIIDAE | |
| *Ophelina acuminata* (Oersted, 1843) | 1 |
| PARAONIDAE | |
| *Allia* sp. A | 25 |
| *Allia* sp. B | 5 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 4 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843 | 2 |
| *Eteone longa* (Fabricius, 1780) | 2 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 1 |
| SABELLIDAE | |
| *Chone* sp. | 1 |
| *Euchone papillosa* (M. Sars, 1851) | 2 |
| *Jasmineira* sp. | 1 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 1 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 23 |
| *Polydora caulleryi* Mesnil, 1897 | 8 |
| *Prionospio steenstrupi* Malmgren, 1867 | 1 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-20 (20 meters) (continued) | No. specimens |
|---|---|
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 1 |
| TEREBELLIDAE | |
| *Artacama proboscidea* Malmgren, 1866 | 2 |
| Genus C | 2 |
| TROCHOCHAETIDAE | |
| *Trochochaeta carica* (Birula, 1897) | 2 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-25 (25 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 1 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 19 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 9 |
| *Heteromastus filiformis* (Claparede, 1864) | 8 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 40 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 89 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 19 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 2 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 1 |
| LUMBRINERIDAE | |
| *Lumbrineris minuta* Theel, 1879 | 3 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 94 |
| *Nephtys ciliata* (Muller, 1776) | 6 |
| OPHELIIDAE | |
| *Ophelina acuminata* Oersted, 1843 | 1 |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 2 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 4 |
| PARAONIDAE | |
| *Allia* sp. A | 69 |
| *Allia* sp. B | 34 |
| *Tauberia gracilis* (Tauber, 1879) | 4 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 4 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 2 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 2 |

Table 19(continued)

Polychaete species - Pitt Point Transect (PPB)

| PPB-25 (25 meters) (continued) | No. specimens |
|---|---|
| SABELLIDAE | |
| *Chone* sp. | 2 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 2 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 3 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis biserialis* (Berkeley & Berkeley, 1944) | 7 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 2 |
| *Polydora socialis* (Schmarda, 1861) | 1 |
| *Prionospio steenstrupi* Malmgren, 1867 | 2 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 5 |
| TEREBELLIDAE | |
| *Artacama proboscidea* Malmgren, 1866 | 18 |
| *Proclea graffii* (Langerhans, 1884) | 1 |

Table 19(continued)

Polychaete species - Pingok Island Transect (PIB)

| PIB-5 (5 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete vega* (Wiren, 1883) | 155 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 15 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 16 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 4 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 1 |
| ONUPHIDAE | |
| *Nothria conchylega* (M. Sars, 1835) | 1 |
| ORBINIIDAE | |
| *Scoloplos armiger* (Muller, 1776) | 3 |
| *Orbinia* sp. | 2 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 7 |
| SABELLIDAE | |
| *Chone* sp. | 30 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 13 |
| *Sphaerodoridium* sp. B | 3 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 55 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 262 |
| TEREBELLIDAE | |
| Genus C | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 1 |

Table 19(continued)

Polychaete species - Pingok Island Transect (PIB)

| PIB-10 (10 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete vega* (Wiren, 1883) | 9 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 24 |
| *Parheteromastus* sp. A | 3 |
| *Heteromastus filiformis* (Claparede, 1864) | 1 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 64 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 9 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 39 |
| DORVILLEIDAE | |
| *Ophryotrocha* sp. | 7 |
| MALDANIDAE | |
| *Praxillella praetermissa* (Malmgren, 1865) | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 42 |
| *Nephtys ciliata* (Muller, 1776) | 1 |
| PARAONIDAE | |
| *Allia* sp. A | 7 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 23 |
| *Mystides borealis* Theel, 1879 | 1 |
| SABELLIDAE | |
| *Chone* sp. | 206 |
| *Euchone analis* (Kroyer, 1856) | 1 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 1 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 117 |
| *Sphaerodoridium* sp. B | 9 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 5 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 2344 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 7 |

Table 19(continued)

Polychaete species - Pingok Island Transect (PIB)

| PIB-10 (10 meters (continued) | No. specimens |
|---|---|
| TEREBELLIDAE | |
| Genus C | 1 |
| TRICHOBRANCHIDAE | |
| Terebellides stroemi Sars, 1835 | 6 |

Table 19 (continued)

Polychaete species - Pingok Island Transect (PIB)

| PIB-15 (15 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 10 |
| *Amphicteis sundevalli* Malmgren, 1866 | 3 |
| *Lysippe labiata* Malmgren, 1866 | 4 |
| *Sabellides borealis* Sars, 1856 | 3 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 3 |
| *Heteromastus filiformis* (Claparede, 1864) | 2 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 38 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 17 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 3 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 7 |
| *Diplocirrus longosetosus* (Marenzeller, 1890) | 1 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 9 |
| *Bonuania* sp. | 7 |
| MALDANIDAE | |
| *Clymenura polaris* (Theel, 1879) | 19 |
| *Microclymene acirrata* Arwidsson, 1907 | 12 |
| *Praxillella praetermissa* (Malmgren, 1865) | 91 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 13 |
| *Nephtys ciliata* (Muller, 1776) | 3 |
| *Nephtys longosetosa* Oersted, 1843 | 2 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 3 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 21 |
| *Scoloplos armiger* (Muller, 1776) | 4 |
| PARAONIDAE | |
| *Allia* sp. A | 2 |
| *Allia* sp. C | 1 |
| *Tauberia gracilis* (Tauber, 1879) | 2 |

Table 19 (continued)

Polychaete species - Pingok Island Transect (PIB)

| PIB-15 (15 meters) (continued) | No. specimens |
|---|---|
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 3 |
| *Eteone longa* (Fabricius, 1780) | 6 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 3 |
| *Melaenis loveni* Malmgren, 1865 | 1 |
| SABELLIDAE | |
| *Euchone elegans* Verrill, 1873 | 1 |
| *Euchone papillosa* (M. Sars, 1851) | 4 |
| *Euchone* sp. | 1 |
| *Laonome kroyeri* Malmgren, 1866 | 5 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 5 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 28 |
| SPHAERODORIDAE | |
| *Sphaerodoridium* sp. B | 1 |
| *Sphaerodoridium* sp. C | 1 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 13 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 23 |
| *Polydora socialis* (Schmarda, 1861) | 3 |
| *Prionospio steenstrupi* Malmgren, 1867 | 1 |
| SPIRORBIDAE | |
| *Dexiospira spirillum* (Linnaeus, 1758) | 1 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 4 |
| TEREBELLIDAE | |
| *Lanassa venusta* (Malm, 1874) | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 2 |
| Unknown family affiliation | 1 |

Table 19(continued)

Polychaete species - Narwhal Island Transect (NIB)

| NIB-5 (5 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 2 |
| *Ampharete vega* (Wiren, 1883) | 29 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 32 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 29 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 5 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 5 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 126 |
| *Bonuania* sp. | 3 |
| MALDANIDAE | |
| *Praxillella praetermissa* (Malmgren, 1865) | 2 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 1 |
| PHYLLODOCIDAE | |
| *Eteone longa* (Fabricius, 1780) | 2 |
| POLYNOIDAE | |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 2 |
| SABELLIDAE | |
| *Chone* sp. | 71 |
| *Euchone papillosa* (M. Sars, 1851) | 1 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 5 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 157 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 81 |
| *Spio filicornis* (Muller, 1776) | 10 |
| TEREBELLIDAE | |
| *Polycirrus medusa* Grube, 1855 | 7 |
| Genus C | 4 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 35 |

Table 19 (continued)

Polychaete species - Narwhal Island Transect (NIB)

| NIB-10 (10 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 3 |
| *Ampharete vega* (Wiren, 1883) | 366 |
| *Amphicteis sundevalli* Malmgren, 1866 | 15 |
| *Sabellides borealis* Sars, 1856 | 1 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 5 |
| *Parheteromastus* sp. A | 1 |
| *Heteromastus filiformis* (Claparede, 1864) | 1 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 85 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 3 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 2 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 7 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 24 |
| *Bonuania* sp. | 1 |
| MALDANIDAE | |
| *Clymenura polaris* (Theel, 1879) | 1 |
| *Praxillella praetermissa* (Malmgren, 1865) | 5 |
| NEPHTYIDAE | |
| *Nephtys ciliata* (Muller, 1776) | 1 |
| *Nephtys longosetosa* Oersted, 1843 | 1 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 2 |
| *Travisia* sp. | 2 |
| ORBINIIDAE | |
| *Scoloplos armiger* (Muller, 1776) | 1 |
| *Orbinia* sp. | 1 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 4 |
| *Eteone longa* (Fabricius, 1780) | 20 |
| *Mystides borealis* Theel, 1879 | 2 |

Table 19 (continued)

Polychaete species - Narwhal Island Transect (NIB)

| NIB-10 (10 meters) (continued) | No. specimens |
|---|---|
| POLYNOIDAE | |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 3 |
| *Melaenis loveni* Malmgren, 1865 | 2 |
| SABELLIDAE | |
| *Chone* sp. | 7 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 46 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 13 |
| *Sphaerodoridium* sp. C | 1 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 175 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 570 |
| *Spio filicornis* (Muller, 1776) | 5 |
| *Spio theeli* (Soderstrom, 1920) | 2 |
| SYLLIDAE | |
| *Exogone dispar* (Webster, 1879) | 3 |
| *Exogone naidina* Oersted, 1845 | 2 |
| TEREBELLIDAE | |
| *Polycirrus medusa* Grube, 1855 | 2 |
| Genus C | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 39 |
| Unknown Family Affiliation | 1 |

Table 19 (continued)

Polychaete species - Narwhal Island Transect (NIB)

| NIB-15 (15 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 4 |
| *Ampharete vega* (Wiren, 1883) | 2 |
| *Lysippe labiata* Malmgren, 1866 | 3 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 6 |
| *Parheteromastus* sp. A | 5 |
| *Heteromastus filiformis* (Claparede, 1864) | 11 |
| CIRRTULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 74 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 13 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 19 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 6 |
| *Diplocirrus hirsutus* (Hansen, 1879) | 1 |
| *Diplocirrus longosetosus* (Marenzeller, 1890) | 1 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 11 |
| *Bonuania* sp. | 5 |
| LUMBRINERIDAE | |
| *Lumbrineris impatiens* (Claparede, 1868) | 1 |
| MALDANIDAE | |
| *Clymenura polaris* (Theel, 1879) | 2 |
| *Microclymene acirrata* Arwidsson, 1907 | 3 |
| *Praxillella praetermissa* (Malmgren, 1865) | 15 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 23 |
| *Nephtys ciliata* (Muller, 1776) | 1 |
| OPHELIIDAE | |
| *Ophelina acuminata* Oersted, 1843 | 1 |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 8 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 4 |
| *Scoloplos armiger* (Muller, 1776) | 1 |

Table 19 (continued)

Polychaete species - Narwhal Island Transect (NIB)

| NIB-15 (15 meters) (continued) | No. specimens |
|---|---|
| PARAONIDAE | |
| *Allia* sp. A | 1 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 10 |
| *Eteone longa* (Fabricius, 1780) | 13 |
| *Mystides borealis* Theel, 1879 | 4 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 3 |
| *Melaenis loveni* Malmgren, 1865 | 2 |
| SABELLIDAE | |
| *Chone* sp. | 9 |
| *Euchone* sp. | 3 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 4 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 9 |
| SPHAERODORIDAE | |
| *Sphaerodoridium* sp. B | 1 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 1 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 44 |
| *Pygospio elegans* Claparede, 1863 | 1 |
| TEREBELLIDAE | |
| *Laphania boecki* Malmgren, 1866 | 6 |
| *Proclea graffii* (Langerhans, 1884) | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 5 |
| Unknown family affiliation | 1 |

Table 19(continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-5 (5 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 1 |
| *Ampharete vega* (Wiren, 1883) | 226 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 1 |
| ARENICOLIDAE | |
| *Arenicola glacialis* Murdoch, 1885 | 1 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 28 |
| DORVILLEIDAE | |
| *Ophryotrocha* sp. | 3 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 5 |
| ORBINIIDAE | |
| *Scoloplos armiger* (Muller, 1776) | 115 |
| *Orbinia* sp. | 1 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | frag. |
| *Eteone longa* (Fabricius, 1780) | 7 |
| *Mystides borealis* Theel, 1879 | 1 |
| POLYNOIDAE | |
| *Arcteobia anticostiensis* (McIntosh, 1874) | 3 |
| SABELLIDAE | |
| *Chone* sp. | 127 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 112 |
| *Sphaerodoridium* sp. B | 22 |
| *Levidorum* sp. ? | 1 |
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 33 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 217 |
| *Spio theeli* (Soderstrom, 1920) | 1 |
| TEREBELLIDAE | |
| Genus C | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 10 |

Table 19(continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-10 (10 meters ) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 1 |
| *Ampharete vega* (Wiren, 1883) | 39 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 10 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 5 |
| *Parheteromastus* sp. A | 4 |
| *Heteromastus filiformis* (Claparede, 1864) | 3 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 32 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 1 |
| *Ophryotrocha* sp. | 2 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 3 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 1 |
| MALDANIDAE | |
| *Microclymene acirrata* Arwidsson, 1907 | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 13 |
| *Nephtys longosetosa* Oersted, 1843 | 5 |
| ORBINIIDAE | |
| *Scoloplos armiger* (Muller, 1776) | 16 |
| PARAONIDAE | |
| *Allia* sp. C | 1 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 2 |
| *Eteone longa* (Fabricius, 1780) | 14 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 7 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 4 |

Table 19 (continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-10 (10 meters) (continued) | No. specimens |
|---|---|
| SPIONIDAE | |
| *Marenzelleria wireni* Augener, 1913 | 8 |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 351 |
| *Spio theeli* (Soderstrom, 1920) | 3 |
| TEREBELLIDAE | |
| *Polycirrus medusa* Grube, 1855 | 2 |
| *Proclea graffii* (Langerhans, 1884) | 1 |
| Genus C | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 13 |

Table 19(continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-15 (15 meters) | No. Specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 7 |
| *Ampharete vega* (Wiren, 1883) | 2 |
| *Lysippe labiata* Malmgren, 1866 | 2 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 17 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 17 |
| *Parheteromastus* sp. A | 8 |
| *Heteromastus filiformis* (Claparede, 1864) | 12 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 171 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 47 |
| *Ophryotrocha* sp. | 23 |
| FLABELLIGERIDAE | |
| *Brada incrustata* (Støp-Bowitz, 1948 | 1 |
| *Brada villosa* (Rathke, 1843) | 40 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 28 |
| *Bonuania* sp. | 60 |
| LUMBRINERIDAE | |
| *Lumbrineris minuta* Theel, 1879 | 1 |
| MALDANIDAE | |
| *Microclymene acirrata* Arwidsson, 1907 | 102 |
| *Praxillella praetermissa* (Malmgren, 1865) | 19 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 133 |
| *Nephtys ciliata* (Muller, 1776) | 2 |
| *Nephtys longosetosa* Oersted, 1843 | 8 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 6 |
| *Ophelina groenlandica* Støp-Bowitz, 1948 | 1 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 2 |
| PARAONIDAE | |
| *Allia* sp. A | 16 |
| *Allia* sp. B | 1 |
| *Allia* sp. C | 9 |
| *Tauberia gracilis* (Tauber, 1879) | 1 |

Table 19 (continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-15 (15 meters) (continued) | No. specimens |
|---|---|
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 1 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 4 |
| *Eteone longa* (Fabricius, 1780) | 7 |
| *Eteone spetsbergensis* Malmgren, 1865 | 2 |
| *Mystides borealis* Theel, 1879 | 1 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 4 |
| *Melaenis loveni* Malmgren, 1865 | 2 |
| SABELLIDAE | |
| *Chone* sp. | 4 |
| *Euchone analis* (Kroyer, 1856) | 1 |
| *Euchone papillosa* (M. Sars, 1851) | 4 |
| *Euchone* sp. | 4 |
| *Laonome kroyeri* Malmgren, 1866 | 4 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 3 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 6 |
| SPHAERODORIDAE | |
| *Sphaerodoropsis minuta* (Webster & Benedict, 1887) | 1 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 162 |
| *Polydora socialis* (Schmarda, 1861) | 2 |
| *Pygospio elegans* Claparede, 1863 | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 7 |
| Unknown family affiliation | 14 |

Table 19(continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-20 (20 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Ampharete acutifrons* (Grube, 1860) | 16 |
| *Lysippe labiata* Malmgren, 1866 | 24 |
| Genus A | |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 90 |
| CAPITELLIDAE | |
| *Capitalla capitata* (Fabricuis, 1780) | 6 |
| *Parheteromastus* sp. A | 28 |
| *Heteromastus filiformis* (Claparede, 1864) | 27 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 314 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 16 |
| COSSURADAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 31 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 9 |
| *Ophryotrocha* sp. | 8 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 156 |
| *Diplocirrus longosetosus* (Marenzeller, 1890) | 1 |
| HESIONIDAE | |
| *Mereimyra aphroditoides* (Fabricius, 1780) | 10 |
| *Bonuania* sp. | 44 |
| LUMBRINERIDAE | |
| *Lumbrineris minuta* Theel, 1879 | 1 |
| MALDANIDAE | |
| *Clymenura polaris* (Theel, 1879) | 20 |
| *Microclymene acirrata* Arwidsson, 1907 | 27 |
| *Praxillella praetermissa* (Malmgren, 1865) | 4 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 144 |
| *Nephtys ciliata* (Muller, 1776) | 6 |
| *Nephtys longosetosa* Oersted, 1843 | 1 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 43 |
| *Ophelina groenlandica* Støp-Bowitz, 1948 | 5 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 13 |
| *Scoloplos armiger* (Muller, 1776) | 3 |

Table 19 (continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-20 (20 meters) (continued) | No. specimens |
|---|---|
| PARAONIDAE | |
| *Allia* sp. A | 50 |
| *Allia* sp. C | 13 |
| *Tauberia gracilis* (Tauber, 1879) | 17 |
| PECTINARIIDAE | |
| *Cistenides hyperborea* (Malmgren, 1865) | 5 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 4 |
| *Eteone longa* (Fabricius, 1780) | 3 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 4 |
| *Melaenis loveni* Malmgren, 1865 | 1 |
| SABELLIDAE | |
| *Chone* sp. | 11 |
| *Euchone* sp. | 2 |
| SCALIBREGMIDAE | |
| *Scalibregma inflatum* Rathke, 1843 | 6 |
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 25 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 21 |
| *Prionospio steenstrupi* Malmgren, 1867 | 1 |
| STERNASPIDAE | |
| *Sternaspis scutata* (Renier, 1807) | 19 |
| SYLLIDAE | |
| *Exogone dispar* (Webster, 1879) | 1 |
| TEREBELLIDAE | |
| *Artacama proboscidea* Malmgren, 1866 | 3 |
| *Proclea graffii* (Langerhans, 1884) | 1 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 19 |
| Unknown family affiliation | 6 |

Table 19 (continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-25 (25 meters) | No. specimens |
|---|---|
| AMPHARETIDAE | |
| *Amphicteis sundevalli* Malmgren, 1866 | 1 |
| APISTOBRANCHIDAE | |
| *Apistobranchus tullbergi* (Theel, 1879) | 2 |
| CAPITELLIDAE | |
| *Capitella capitata* (Fabricius, 1780) | 7 |
| *Parheteromastus* sp. A | 6 |
| *Heteromastus filiformis* (Claparede, 1864) | 30 |
| CIRRATULIDAE | |
| *Chaetozone setosa* Malmgren, 1867 | 36 |
| *Tharyx* (?) *acutus* Webster & Benedict, 1887 | 7 |
| COSSURIDAE | |
| *Cossura longocirrata* Webster & Benedict, 1887 | 6 |
| DORVILLEIDAE | |
| *Schistomeringos caecus* (Webster & Benedict, 1884) | 3 |
| FLABELLIGERIDAE | |
| *Brada villosa* (Rathke, 1843) | 5 |
| HESIONIDAE | |
| *Nereimyra aphroditoides* (Fabricius, 1780) | 4 |
| MALDANIDAE | |
| *Microclymene acirrata* Arwidsson, 1907 | 1 |
| NEPHTYIDAE | |
| *Micronephthys minuta* (Theel, 1879) | 11 |
| *Nephtys ciliata* (Muller, 1776) | 2 |
| *Nephtys incisa* Malmgren, 1865 | 1 |
| NEREIDAE | |
| *Nereis zonata* Malmgren, 1867 | 1 |
| OPHELIIDAE | |
| *Ophelina cylindricaudatus* (Hansen, 1879) | 14 |
| ORBINIIDAE | |
| *Scoloplos acutus* (Verrill, 1873) | 4 |
| PHYLLODOCIDAE | |
| *Anaitides groenlandica* (Oersted, 1843) | 4 |
| *Eteone longa* (Fabricius, 1780) | 3 |
| POLYNOIDAE | |
| *Antinoella sarsi* (Malmgren, 1865) | 4 |

Table 19(continued)

Polychaete species - Barter Island Transect (BAB)

| BAB-25 (25 meters) (continued) | No. specimens |
|---|---|
| SIGALIONIDAE | |
| *Pholoe minuta* (Fabricius, 1780) | 3 |
| SPIONIDAE | |
| *Minuspio* nr. *cirrifera* (Wiren, 1883) | 17 |
| TRICHOBRANCHIDAE | |
| *Terebellides stroemi* Sars, 1835 | 1 |

Table 20. Densities of pelecypod juveniles in the small macrofauna (0.5 mm-1.0 mm) from Pitt Point, 25 meters (PPB-25). Density reported in total per $m^2$.

| Species | Density OCS-1 Oct.'75 | OCS-2 Mar.'76 | OCS-3 May '76 | OCS-4 Aug.'76 | OCS-6 Nov.'76 |
|---|---|---|---|---|---|
| Nucula bellotii | 16 | 2 | 14 | 12 | 12 |
| Portlandia juvenile | 86 | 6 | 14 | 76 | - |
| Portlandia frigida | 2 | - | - | - | - |
| Yoldia juvenile | 2 | - | 6 | 6 | 4 |
| Nuculana juvenile | - | - | - | 4 | 2 |
| Musculus juvenile | 6 | - | 12 | 22 | 6 |
| Dacrydium vitreum | - | - | 2 | - | - |
| Thyasira gouldii | - | - | 4 | - | - |
| Thyasira juvenile | - | 2 | 10 | - | - |
| Mysella juvenile | 2 | - | - | 2 | 2 |
| Astarte juvenile | 2 | - | - | - | 2 |
| Serripes groenlandicus | 24 | - | - | 2 | 2 |
| Macoma juvenile | 46 | 10 | 8 | 22 | 2 |
| Liocyma fluctuosa | 2 | - | - | - | 2 |
| Pandora glacialis | 10 | - | - | - | - |
| Lyonsia arenosa | 20 | - | - | 2 | - |
| Thracia juvenile | - | - | - | - | 4 |
| TOTAL per $m^2$ | 218 | 20 | 70 | 148 | 38 |

Table 21. Densities of pelecypod juveniles in the small macrofauna (0.5 mm - 1.0 mm) from Pitt Point, 55 meters (PPB-55). Density reported in total per $m^2$.

| Species | Density OCS-1 Oct.'75 | OCS-2 Mar.'76 | OCS-3 May '76 | OCS-4 Aug.'76 | OCS-6 Nov.'76 |
|---|---|---|---|---|---|
| Nucula bellotii | 16 | 24 | 53 | 110 | 40 |
| Nuculana minuta | - | 8 | - | - | - |
| Nuculana juvenile | - | 16 | 37 | 5 | 25 |
| Portlandia juvenile | - | 8 | 21 | 5 | - |
| Yoldia juvenile | - | - | 5 | 5 | - |
| Musculus juvenile | 16 | 8 | 16 | - | - |
| Dacrydium vitreum | 8 | - | - | - | - |
| Arctinula greenlandicus | 64 | 24 | 63 | - | - |
| Thyasica juvenile | 32 | 8 | 5 | 16 | 10 |
| Axinopsida orbiculata | - | - | - | - | 5 |
| Mysella juvenile | - | - | - | 16 | - |
| Cyclocardia crebricostata | 8 | 40 | 5 | - | 10 |
| Astarte juvenile | 56 | 72 | 68 | 63 | 40 |
| Serripes groenlandica | 88 | 8 | 16 | - | 10 |
| Macoma juvenile | 16 | 24 | 58 | 47 | 20 |
| Liocyma fluctuosa | 8 | 16 | - | - | - |
| Hiatella arctica | 8 | - | - | - | - |
| Pandora glacialis | 8 | - | - | - | - |
| Thracia juvenile | - | - | - | 5 | - |
| TOTAL per $m^2$ | 328 | 256 | 347 | 272 | 160 |

Table 22. Densities of pelecypod juveniles in the small macrofauna (0.5 mm - 1.0 mm) from Pitt Point, 100 meters (PPB-100). Density reported in total per $m^2$.

| | Density | | | | |
|---|---|---|---|---|---|
| Species | OCS-1 Oct.'75 | OCS-2 Mar.'76 | OCS-3 May '76 | OCS-4 Aug.'76 | OCS-6 Nov.'76 |
| Nucula bellotii | 85 | 64 | 20 | 64 | 30 |
| Nuculana juvenile | - | - | 13 | 24 | 10 |
| Portlandia juvenile | - | 8 | - | 8 | 10 |
| Yoldia juvenile | - | - | - | 8 | - |
| Musculus juvenile | - | - | - | 24 | - |
| Arctinula greenlandicus | - | - | 7 | 32 | - |
| Thyasira juvenile | 20 | - | - | 24 | - |
| Mysella juvenile | 20 | 16 | - | - | - |
| Astarte juvenile | - | 16 | 13 | 32 | 30 |
| Macoma juvenile | - | 32 | 13 | 40 | 30 |
| Liocyma fluctuosa | - | - | - | 80 | - |
| TOTAL per $m^2$ | 125 | 136 | 66 | 336 | 110 |

Table 23. Species data for pelecypod molluscs from OCS-4 (August 1976) and OCS-7 (August 1977).

| Family: Species | Stations of Occurrence | Total Specimens |
|---|---|---|
| Nuculidae | | |
| *Nucula bellotii* | PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, Sta. 39 | 147 |
| Nuculanidae | | |
| *Nuculana minuta* | PPB-55, PPB-70, PPB-100 | 13 |
| *Nuculana pernula* | PPB-55, Sta. 37, Sta. 39 | 21 |
| *Nuculana radiata* | PPB-25, PPB-55, PPB-70, PPB-100, Sta. 37, Sta. 39, Sta. 40 | 173 |
| *Portlandia arctica* | PPB-25, Sta. 37 | 450 |
| *Portlandia frigida* | PPB-40, PPB-55, PPB-70, PPB-100, Sta. 36, Sta. 37, Sta. 39, Sta. 40 | 214 |
| *Portlandia lenticula* | PPB-25, Sta. 37, Sta. 39, Sta. 40 | 124 |
| *Yoldia hyperborea* | PPB-40, PPB-55 | 3 |
| Arcidae | | |
| *Bathyarca glacialis* | PPB-70, Sta. 39, Sta. 40 | 11 |
| *Bathyarca raridentata* | Sta. 39 | 1 |
| Mytilidae | | |
| *Crenella decussata* | Sta. 37 | 2 |
| *Dacrydium vitreum* | PPB-55, Sta. 36, Sta. 39, Sta. 40 | 32 |
| *Musculus discors* | PPB-55, PPB-100, Sta. 37, Sta. 39 | 16 |
| *Musculus corrugatus* | PPB-70, Sta. 37, Sta. 39 | 7 |
| Pectinidae | | |
| *Cyclopecten greenlandicus* | PPB-25, PPB-55, PPB-70, Sta. 37, Sta. 39, Sta. 40 | 64 |
| Thyasiridae | | |
| *Axinopsida orbiculata* | PPB-55, PPB-70 | 10 |
| *Thyasira gouldii* | PPB-40, PPB-55, PPB-100, Sta. 37, Sta. 40 | 71 |
| *Thyasira equalis* | Sta. 36 | 433 |
| Montacutidae | | |
| *Mysella planata* | PPB-55, PPB-100 | 7 |
| *Mysella tumida* | PPB-100 | 2 |
| Carditidae | | |
| *Cyclocardia crebricostata* | PPB-40, PPB-55, PPB-70, Sta. 39 | 76 |
| Astartidae | | |
| *Astarte crenata* | Sta. 40 | 1 |
| *Astarte borealis* | PPB-40, PPB-55, PPB-100, Sta. 39 | 10 |
| *Astarte montagui* | PPB-40, PPB-55, PPB-70, PPB-100, Sta. 39 | 333 |
| Cardiidae | | |
| *Clinocardium ciliatum* | PPB-25, PPB-55, PPB-70, Sta. 39 | 4 |
| *Serripes greenlandicus* | PPB-55, PPB-70 | 4 |

Table 23 (continued)

| Family: Species | Stations of Occurrence | Total Specimens |
|---|---|---|
| Tellinidae | | |
| *Macoma calcarea* | PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, Sta. 37, Sta. 40 | 56 |
| Veneridae | | |
| *Liocyma fluctuosa* | PPB-25, PPB-40, PPB-55, PPB-100, Sta. 39 | 25 |
| Hiatellidae | | |
| *Hiatella arctica* | PPB-25, PPB-55, PPB-70 | 6 |
| Pandoridae | | |
| *Pandora glacialis* | PPB-25, PPB-55, PPB-70, Sta. 37, Sta. 39 | 13 |
| Lyonsiidae | | |
| *Lyonsia arenosa* | PPB-55, PPB-70 | 4 |
| Periplomatidae | | |
| *Periploma aleutica* | PPB-100 | 3 |
| Thraciidae | | |
| *Thracia devexa* | PPB-55, PPB-70, PPB-100, Sta. 37, Sta. 39 | 20 |
| Cuspidariidae | | |
| *Cuspidaria glacialis* | Sta. 36 | 4 |
| *Cuspidaria subtorta* | Sta. 36 | 2 |

Table 24. Tentative species of gastropod molluscs from the OCS-1 (Fall 1975), Pitt Point transect line. * denotes presence of shells only.

| Station | Family | Species | Number/$m^2$ |
|---|---|---|---|
| PPB-25 | Trochidae | Margarites giganteus | 2 |
| | | Solariella obscura | 4 |
| | Rissoidae | Alvania cruenta | * |
| | | Alvania janmayeni | * |
| | | Cingula arenaria | 2 |
| | Buccinidae | Buccinium juvenile | 2 |
| | Cancellariidae | Admete couthouyi | * |
| | Hydrobiidae | Hydrobia minuta | * |
| | Turridae | Oenopota novajasemliensis | * |
| | | Oenopota elegans | 2 |
| | | Oenopota juvenile | 4 |
| | | Propebela gouldii | * |
| | Retusidae | Retusa sp. A | 2 |
| | Diaphanidae | Diaphana sp. A | 2 |
| | Scaphandridae | Cylichna alba | * |
| | | Cylichna sp. A | * |
| | | Haminoea sp. A | * |
| PPB-55 | Trochidae | Solariella obscura | 2 |
| | | Solariella juvenile | 2 |
| | Turitellidae | Tachyrhynchus erosus | 4 |
| | Rissoidae | Alvania cruenta | 2 |
| | | Alvania janmayeni | * |
| | Naticidae | Natica clausa | 2 |
| | | Polinices pallidus | 4 |
| | Muricidae | Boreotrophon juvenile | 2 |
| | Neptuneidae | Beringus sp. A | * |
| | Turridae | Oenopota novajasemliensis | * |
| | | Oenopota harpa | 2 |
| | | Oenopota bicarinata | * |
| | | Oenopota decussata | * |
| | | Oenopota elegans | 2 |
| | | Oenopota reticulata | 2 |
| | | Oenopota incisula | * |
| | | Oenopota sp. A | 4 |
| | | Oenopota juvenile | 2 |
| | | Propebela gouldii | 2 |
| | Retusidae | Retusa sp. A | * |
| | Lepetidae | Lepeta cacea | * |

Table 24. OCS-1 gastropods (continued)

| Station | Family | Species | Number/$m^2$ |
|---|---|---|---|
| PPB-100 | Trochidae | Margarites giganteus | * |
| | | Margarites olivaceus | * |
| | | Margarites costalis | * |
| | | Solariella obscura | * |
| | Rissoidae | Alvania cruenta | 6 |
| | Naticidae | Polinices pallidus | 2 |
| | Cancellaridae | Admete couthouyi | 4 |
| | Muricidae | Boreotrophon sp. A | * |
| | Turbinidae | Moelleria costulata | 4 |
| | | Moelleria sp. A | 2 |
| | Turridae | Oenopota elegans | * |
| | Diaphanidae | Diaphana juvenile | 6 |
| | Lepetidae | Lepeta cacea | 2 |
| | Order Nudibranchia | | |
| | Doridídae | Cadlina laevis | 2 |

Table 25 : Tentative Amphipoda identifications, OCS-4, Station PPB-25

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG-1359 | Lysianasidae | Beocksimus | platus | 1 | AA062 |
| | Oedicerotidae | (Aceroidea | latipes) | 2 | AA076 |
| | Argissidae | (Argissa | hanatipes) | 1 | AA0013 |
| | Lysianasidae | Onisimus | litoralis | 1 | AA156 |
| SMG 1284 | Gammaridae | (Gammarus | | 1 | |
| | Gammaridae | (Melita | dentata) | 1 | AA040 |
| SMG 1285 | Oedicerotidae | (Aceroida | latipes) | 1 | AA076 |
| | Oedicerotidae | Acanthostepheia | behringiensis | 1 | AA135 |
| | Oedicerotidae | Arrhis | phyllonyx | 1 | AA078 |
| SMG 1281 | Ampetiscidae | Byblis | arcticus | 2 | AA296 |
| SMG 1282 | Oedicerotidae | Arrhis | phyllonyx | 2 | AA078 |
| | Oedicerotidae | (Aceroides | latipes) | 10 | AA076 |
| | Lysianassidae | Anonyx | nugax | 1 | AA050 |
| | Halistoridae | Pontopereia | femorata | 1 | AA043 |
| SMG 1283 | Ampeliscidae | (Haploops | laevis?) | 2 | |
| | Oedicerotidae | Aceroidea | latipes | 1 | AA076 |
| | Corophiidae | | | 1 | |
| | Corophiidae | (Protomedia?) | | 2 | |

Table 26 : Tentative Amphipoda identifications, OCS-4 Station PPB-55.

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1331-06 | Ampeliscidae | Ampelisca | eschrichti | 1 | AA005 |
| | Ampeliscidae | (Haploops | | 8 | |
| | Ampeliscidae | (Byblis | arcticus) | 4 | AA296 |
| | Corophiidae | (Unciola | leucopsis) | 3 | |
| | Corophiidae | (Photis | | 8 | |
| | Corophiidae | (Podoceropsis | | 1 | |
| | Dexaminidae | (Gurnea | nordenskjoldi) | 2 | AA030 |
| | Oedicerotidae | (Aceroides | latipes) | 1 | AA076 |
| | Phoxocephalidae | (Harpinia | serrata) | 9 | AA100 |
| | Phoxocephalidae | (Paraphoxus | oculatus) | 2 | AA101 |
| | Stenthoidae | (Metopa sp.) | | 3 | |
| | Oedicerotidae | Monoculodes | borealis | 1 | AA080 |
| | Oedicerotidae | Bathymedon | obtusifrons | 1 | AA079 |
| | Oedicerotidae | Westwoodilla | megalops | 1 | AA088 |
| SMG 1333-09 | Ampeliscidae | (Ampelisca | eschrichti) | 1 | AA005 |
| | Ampeliscidae | (Byblis | arcticus) | 9 | AA296 |
| | Ampeliscidae | (Haploops | | 8 | |
| | Corophiidae | (Photis | | 9 | |
| | Corophiidae | (Unciola | | 1 | |
| | Dexaminidae | (Gurnea | nordenskjoldi) | 1 | AA030 |
| | Oedicerotidae | (Aceroides | latipes) | 6 | AA076 |
| | Oedicerotidae | (Westwoodilla | megalops) | 2 | AA088 |
| | Oedicerotidae | (Monoculodes) | latimanus | 2 | AA081 |
| | Phoxocephalidae | (Paraphoxus | oculatus) | 5 | AA101 |
| | Phoxocephalidae | (Harpinia | serrata) | 12 | AA100 |
| | | Harpinia | kobjakovae | 2 | AA097 |
| | Argissidae | Argissa | hanatipes | 1 | AA013 |
| SMG 1334-07 | Argissidae | Argissa | hanatipes | 1 | AA0013 |
| | Ampeliscidae | Byblis | arcticus | 12 | AA296 |
| | Ampeliscidae | Haploops | | 7 | |
| | Corophiidae | Unciola | leucopsis | 3 | |
| | Corophiidae | Photis | | 3 | |
| | Corophiidae | Podoceropsis | | 2 | |
| | Oedicerotidae | Aceroides | latipes | 1 | AA076 |
| | Oedicerotidae | Monoculodes | latimanus | 1 | AA081 |
| | Oedicerotidae | Perioculodes | longimanus | 2 | AA036 |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1334-07 (continued) | Dexaminidae | Guernea | nordenskjoldi | 4 | AA030 |
| | Lysianassidae | Hippomedon | abyssi | 2 | AA054 |
| | Phoxocephalidae | Harpinia | serrata | 13 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 4 | AA101 |
| | Gammaridae | Melita | dentata | 1 | AA040 |
| | Oedicerotidae | Westwoodilla | megalops | 1 | AA088 |
| | Oedicerotidae | Bathymedon | obtusifrons | 1 | AA079 |
| SMG 1337-07 | Ampeliscidae | Byblis | arcticus | 6 | AA0296 |
| | Ampeliscidae | Haploops | | 4 | |
| | Corophiidae | Unciola | | 2 | |
| | Corophiidae | Podoceropsis | | 1 | |
| | Corophiidae | Photis | | 1 | |
| | Dexaminidae | Guernea | nordenskjoldi | 2 | AA030 |
| | Lysianassidae | Anonyx | nugax | 1 | AA050 |
| | Acanthonotozomatidae | Odius | kelleri | 1 | AA190 |
| | Oedicerotidae | Aceroides | hamatipes | 1 | AA076 |
| | Oedicerotidae | Monoculodes | latimanus | 2 | AA081 |
| | Phoxocephalidae | Harpinia | serrata | 6 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 2 | AA101 |
| | Phoxocephalidae | Bathymedon | obtusifrons | 5 | AA079 |
| SMG 1338-08 | Argissidae | Argissa | hanatipes | 1 | AA013 |
| | Ampeliseidae | Byblis | arcticus | 10 | AA296 |
| | Ampeliseidae | Haploops | | 7 | |
| | Corophiidae | Photis | | 6 | |
| | Corophiidae | Unciola | | 1 | |
| | Corophiidae | Goesia | | | |
| | Dexaminidae | Guernea | nordskjoldi | 1 | AA030 |
| | Oedicerotidae | Aceroides | latipes | 4 | AA076 |
| | Oedicerotidae | Monoculodes | | 3 | |
| | Phoxocephalidae | Harpinia | serrata | 9 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 1 | AA101 |
| | Stenothoidae | Metopa | | 2 | |
| | Phoxocephalidae | Harpinia | kobjakovae | 1 | AA097 |
| | Oedicerotidae | Perioculodes | longimanus | 12 | AA036 |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1339-08 | Ampeliscidae | Ampelisca | eschrichti | 6 | AA005 |
| | Ampeliscidae | Byblis | arcticus | 10 | AA296 |
| | Ampeliscidae | Haploops | | 6 | |
| | Corophiidae | Unciola | | 5 | |
| | Corophiidae | Photis | | 6 | |
| | Corophiidae | Goesia | | 4 | |
| | Desaminidae | Guernia | nordenskjoldi | 1 | AA030 |
| | Oedicerotidae | Aceroides | latipes | 2 | AA076 |
| | Oedicerotidae | Periculodes | longimanus | 3 | AA036 |
| | Argissidae | Argissa | hanatipes | 1 | AA0013 |
| | Haustoriidae | Pontoporeia | femorata | 1 | AA043 |
| | Phoxocephalidae | Harpinia | serrata | 13 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 6 | AA101 |
| SMG 1342-08 | Ampeliscidae | Ampelisca | eschrichti | 1 | AA005 |
| | Ampeliscidae | Byblis | arcticus | 12 | AA296 |
| | Ampeliscidae | Haploops | | 3 | |
| | Corophiidae | Unciola | | 5 | |
| | Corophiidae | Protomedeia | | 4 | |
| | Oedicerotidae | Monoculodes | | 3 | |
| | Oedicerotidae | | | | |
| | Phoxocephalidae | Harpinia | serrata | 6 | AA100 |
| | Phoxocephalidae | Paraphoxus | | 4 | AA101 |
| | Stenothoidae | Metopa | | 1 | |
| SMG 1343-04 | Ampeliscidae | Byblis | arcticus | 13 | AA2096 |
| | Ampeliscidae | Haploops | | 7 | |
| | Corophiidae | Unciola | | 2 | |
| | Corophiidae | Protomedia | | 4 | |
| | Corophiidae | Photis | | 4 | |
| | Synopidae | Tipon | spiniferum | 1 | AA120 |
| | Ischyroceridae | Ischyrocerus | | 2 | |
| | Oedicerotidae | Aceroides | latipes | 2 | AA076 |
| | Oedicerotidae | Monoculodes | | 1 | |
| | Oedicerotidae | Westwoodella | megalops | 1 | AA088 |
| | Stenothoidae | Metopa | | 1 | |
| | Dexaminidae | Guernea | nordenskjoldi | 1 | AA030 |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1343-04 (continued) | Lysianasidae | Anonyx | nugax | 4 | AA050 |
| | Lysianasidae | Hippomedon | abyssi | 1 | AA054 |
| | Amphilochidae | Gitana | abyssicola | 1 | AA330 |
| | Phoxocephalidae | Harpinia | serrata | 17 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 7 | AA100 |
| SMG 1345-07 | Ampeliscidae | Byblis | arcticus | 6 | AA296 |
| | Ampeliscidae | Haploops | | 5 | |
| | Lysianasidae | Anonyx | nugax | 1 | AA050 |
| | Stenthoidae | Metopa | | 2 | |
| | Dexaminidae | Guernea | nordenskjoldi | 3 | AA030 |
| | Phoxocephalidae | Harpinia | serrata | 14 | AA100 |
| | Phoxocephalidae | Panaphoxus | oculatus | 8 | AA101 |
| | Gammaridae | Melita | dentata | 1 | AA040 |
| | Stenothaidae | Metopella | longimana | 1 | AA150 |
| | Corophiidae | Photis | | 8 | |
| | Corophiidae | Unciola | | 1 | |
| | Corophiidae | Protomedia | | 4 | |
| | Corophiidae | Podoceropsis | | 5 | |
| | Corophiidae | ? | | 2 | |
| | Ensinidae | Rhachotropis | oculata | 1 | AA331 |
| | Oedicerotidae | Perioculodes | longimanus | 5 | AA036 |
| | Oedicerotidae | Westwoodilla | megalops | 1 | AA088 |
| | Oedicerotidae | ? | | 1 | |
| | Acanthonotozomidae | Odius | kelleri | 1 | AA190 |
| SMG 1346-07 | Ampeliscidae | Byblis | arcticus | 6 | AA296 |
| | Ampeliscidae | Haploops | | 2 | |
| | Phoxocephalidae | Harpinia | serrata | 11 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 9 | AA101 |
| | Lysianassidae | Anonyx | nugax | 1 | AA050 |
| | Acanthonotozomidae | Odius | kelleri | 1 | AA190 |
| | Dexaminidae | Guernea | nordenskjoldi | 1 | AA030 |
| | Stenothaidae | Metopa | | 5 | |
| | Corophiidae | Photis | | 9 | |
| | Corophiidae | Protomedia | | 7 | |
| | Corophiidae | Goesia | | 4 | |
| | Corophiidae | Podoceropsis | | 3 | |
| | Synopidae | Tipon | spiniferum | 3 | AA120 |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1346-07 (continued | Angissidae | Argissa | hamatipes | 1 | AA0013 |
| | Oedicerotidae | Aceroides | latipes | 2 | AA076 |
| | Oedicerotidae | Perioculodes | longimanus | 11 | AA036 |
| | Oedicerotidae | Westwoodella | megalops | 3 | AA088 |
| | Oedicerotidae | Monoculodes | | 4 | |
| | Gammaridae? | Gammaridus sp. | | 2 | |
| SMG 1347-06 | Ampeliscidae | Byblis | arcticus | 11 | AA296 |
| | Ampeliscidae | Haploops | | 6 | |
| | Phoxocephalidae | Harpinia | serrata | 12 | AA100 |
| | Stenthoidae | Metopa | | 1 | |
| | Corophiidae | Unciola | | 5 | |
| | Corophiidae | Photis | | 7 | |
| | Corophiidae | Protomedia | | 2 | |
| | Corophiidae | Goesia | | 3 | |
| | Dexaminidae | Guernea | nordenskjoldi | 1 | AA030 |
| | Oedicerotidae | Aceroides | latipes | 1 | AA076 |
| | Oedicerotidae | Westwoodella | megalops | 2 | AA088 |
| | Oedicerotidae | Monoculodes | | 2 | |
| | Ampeliscidae | Ampelisca | eschrichti | 1 | AA005 |
| | Phoxocephalidae | Harpinia | Kobjakovae | 1 | AA097 |
| | Oedicerotidae | Perioculodes | longimanus | 1 | AA036 |
| SMG 1348-07 | Ampeliscidae | Ampelisca | eschrichti | 8 | AA005 |
| | Ampeliscidae | Byblis | arcticus | 7 | AA296 |
| | Ampeliscidae | Haploops | | 11 | |
| | Argissidae | Argissa | hanatipes | 1 | AA0013 |
| | Dexaminidae | Guernea | nordenskjoldi | 8 | AA030 |
| | Stenthoidae | Metopa | | 4 | |
| | Phoxocephalidae | Harpinia | serrata | 14 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 4 | AA101 |
| | Synopidae | Tipon | spiniferum | 3 | AA120 |
| | Lysanassidae | Beockosimus | plautus | 1 | AA062 |
| | Corophiidae | Unciola | | 9 | |
| | Corophiidae | Photis | | 4 | |
| | Corophiidae | Protomedia | | 6 | |
| | Corophiidae | Podoceropsis | | 3 | |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1348-07 (continued) | Oedicerotidae | Periculodes | longimanus | 5 | AA036 |
| | Oedicerotidae | Westwoodilla | Megalops | 5 | AA008 |
| | Eusiridae | Rhachotropis | oculata | 1 | AA331 |
| | Pleustidae | Pleustes | panopla | 1 | AA106 |
| SMG 1349-06 | Ampeliscidae | Ampelisca | eschrichti | 1 | AA005 |
| | Ampeliscidae | Byblis | arcticus | 6 | AA296 |
| | Ampeliscidae | Haploops | | 12 | |
| | Stenthoidae | Metopa | | 2 | |
| | Dexaminidae | Guernea | nordenskjoldi | 5 | AA030 |
| | Argissidae | Argissa | hanatipes | 2 | AA0013 |
| | Phoxocephalidae | Harpinia | serrata | 7 | AA100 |
| | Phoxocephalidae | Panaphoxus | oculatus | 5 | AA101 |
| | Lysianasidae | Boeckosimus | platus | 1 | AA062 |
| | Amphilochidae | Odius | kelleri | 1 | AA190 |
| | Corophiidae | Photis | | 1 | |
| | Corophiidae | Protomedia | | 8 | |
| | Corophiidae | Podoceropsis | | 2 | |
| | Corophiidae | Unciola | | 1 | |
| | Oedicerotidae | Aceroides | latipes | 4 | AA076 |
| | Oedicerotidae | Monoculodes | | 1 | |
| | Oedicerotidae | Westwoodilla | megalops | 1 | AA088 |
| SMG 1350-08 | Argissidae | Argissa | hanatipes | 1 | AA013 |
| | Ampeliscidae | Byblis | arcticus | 11 | AA296 |
| | Ampeliscidae | Haploops | | 7 | |
| | Dexaminidae | Guernea | nordenskjoldi | 13 | AA030 |
| | Stenthoidae | Metopa | | 4 | |
| | Phoxocephalidae | Harpinia | serrata | 24 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 6 | AA101 |
| | Corophiidae | Photis | | 13 | |
| | Corophiidae | Protomedia | | 6 | |
| | Corophiidae | Podoceropsis | | 4 | |
| | Corophiidae | Unciola | | 7 | |
| | Oedicerotidae | Aceroides | latipes | 2 | AA076 |
| | Oedicerotidae | Periculodes | longimanus | 9 | AA036 |
| | Oedicerotidae | Monoculodes | | 4 | |
| | Oedicerotidae | Westwoodilla | megalops | 2 | AA088 |
| | Lysianassidae | Anonyx | nugax | 1 | AA050 |

Table 26 (continued)

| Grab # | Family | Genus | Species | No. | Species Code |
|---|---|---|---|---|---|
| SMG 1351-06 | Ampeliscidae | Byblis | arcticus | 9 | AA296 |
| | Ampeliscidae | Haploops | | 7 | |
| | Dexaminidae | Guernea | nordenskjoldi | 1 | AA030 |
| | Phoxocephalidae | Harpinia | serrata | 2 | AA100 |
| | Phoxocephalidae | Paraphoxus | oculatus | 3 | AA101 |
| | Corophiidae | Protomedia | | 2 | |
| | Corophiidae | Unciola | | 2 | |
| | Oedicerotidae | Westwoodilla | megalops | 3 | AA088 |

QUARTERLY REPORT

NOAA-OCSEAP
Contract No. 02-5-022-68
Research Unit #6
Reporting Period: 1 October - 31 December 1979

The distribution, abundance, composition, and variability of the western Beaufort Sea benthos.

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21 December 1979

Andrew G. Carey, Jr.
Principal Investigator

## I. Abstract

During this quarter continued progress has been made in sample analysis in the laboratory and in data reduction and analysis. There was no scheduled fieldwork for RU #006. Identifications of bivalve and gastropod molluscan collections from SW Beaufort Sea continental shelf continue. Polychaete identifications from inner shelf collections taken from the 1976 R/V ALUMIAK cruise have been verified in consultation with Dr. Kristian Fauchald at the Smithsonian Institution. Initial quantitative ecological analyses of the bivalve molluscan and polychaetous annelid coastal communities indicate a general species grouping from Point Barrow to Demarcation Point in water depths of 5 to 25 meters. Weaker regional subgroups are presently under analysis and evaluation. Analysis of the spring (1979) ice algal community-benthic community interactions continue. The production of final digitized data tapes for benthic data collected from RU #006 are now underway. The data base is being transposed to a more efficient data management system and will be completed during the contract year.

## II. Task Objectives

### A. Objectives

1. Conclude synthetic analyses of benthic communities across the Beaufort Sea continental shelf with concentration on nearshore synthesis.

   a. Document zoogeographic zonation and faunal community clustering of the Beaufort lease region, so as to put into regional context both the current sale area and future proposed Beaufort Sea lease sales. Correlative studies will determine the major features of the physical, chemical and biological environment that appear to have effect on faunal distributions and abundances. When possible, the distribution of numerically dominant species, important prey species in the food web and communities on the Beaufort Sea shelf will be mapped with known distributions and with extrapolations based on known ecological relationships.

   b. The benthic food web will be documented as far as possible for the lease zone environments. The distribution, abundance and ecology of key prey species will be summarized.

   c. The temporal variation of benthic communities will be analyzed across the continental shelf on the OCS Pitt Point Station Transect. The recruitment, growth, life histories and reproductive activity of numerical dominant species will be defined as far as possible. Extrapolation from these data will be used to determine rough estimates of the rate of recovery from disturbance of characteristic benthic invertebrate species across the continental shelf.

2. The interrelationships between the epontic ice algal community and the benthic community beneath will be defined as far as possible in conjunction with RU's 359 and 537.

   a. The similarity of the fauna associated with the under-ice surface and the sediment surface will be statistically analyzed to determine if the benthos might be actively grazing on the epontic algal cells or preying on other associated fauna.

   b. The downward flux of particulate organic carbon will be measured to determine if the ice algal community provides a potential food source to the in situ benthic organisms.

   c. The mechanism of vertical migration of benthic fauna to the under-ice surface will be studied, if feasible, to determine if there is a direct association between certain vagile benthic species and the under-ice epontic community.

### B. Discussion of Objectives

Objective 1

Ecological trends give an over-view of the ecology of the benthic fauna that provides interpretations of the environmental and biological causes of the distributional and abundance patterns.

Trends in the distribution of species, species groups, station groups, and feeding types can only be determined and evaluated with the help of a computer programmer and quantitative ecological analyst. Such studies and those involving multivariate analyses of faunal-environmental correlations are dependent on the continued cooperation and effort of the appropriate specialist. Computer summary, manipulation and analysis is the only practical means of utilizing so much data.

Foodweb studies are important because these feeding links are the routes by which energy, elements and pollutants are transferred from one trophic level to another. Such studies are necessary to identify the keystone species and important feeding areas on the Beaufort Sea continental shelf.

The smaller end of the food web in the Beaufort Sea ecosystem may be very important in transferring energy from oceanic and terrestrial detritus to the macrofauna upon which benthic-feeding fish, birds and marine mammals depend. The proposed studies could assess the relative importance of the small organisms in the inner shelf benthic food web in about six environmentally important areas subject to oil and gas development. Much of these data are now lacking for the Beaufort Sea, and no such integrated studies have been attempted before.

The total and average data from the year-round benthic samples at five standard stations on the Pitt Point Transect across the Beaufort Sea continental shelf strongly indicate that the communities undergo seasonal reproductive cycles. Data on the reproductive activity and population size structure of individual species throughout the year are essential to test this hypothesis.

The year-round biological activity of the shallow coastal waters and protected lagoons should be studied to determine if the fauna may be more sensitive to oil-related pollution problems at any particular season of the year. As the free or brooded larval phase of benthic invertebrate reproductive cycles is considered a very sensitive stage, life histories of the dominant and key food web species must be considered to estimate risks involved.

Objective 2

It has come to the attention of NOAA/BLM-OCSEAP that further year-round information is needed on the oceanographic and ecological processes taking place in the coastal waters of the Beaufort Sea. As exploratory and probably production drilling will take place in lagoonal and coastal waters out to 20 meters depth, studies are planned in this region to determine if the winter-spring months are biologically quiescent or whether organisms may be active and/or vulnerable to the oil-related activities during the ice-covered months of the year.

The proposed research, to be undertaken in cooperation with other scientists, (RU's 359 and 537) is oriented toward the processes maintaining the coastal and lagoonal ecosystems in the Beaufort Sea. Of particular interest is the source of carbon that fuels the heterotrophic organisms living within the system. In lower latitude oceanic waters most of the carbon fixed by photosynthesis is ultimately derived from the phytoplankton, but in coastal

waters much of the organic material may be land-derived. Water acts as a three dimensional reservoir and transporter of living and non-living organic carbon. The carbon cycle is a complex one that involves a web of interacting organisms. The benthos as an ecological group depend to a large extent on detritus that falls down to them. In the ice-covered waters of the Arctic, the epontic diatoms on the undersurface of the sea ice is an added source of carbon to the system (Horner, 1976), and in shoal waters benthic algae add to the primary production (Matheke and Horner, 1974). In the coastal Beaufort Sea and its bordering lagoons detrital peat from the coastal erosion may also add carbon.

The underice diatom bloom is known to exist in coastal waters in the Chukchi Sea off Barrow, AK (Horner and Alexander, 1972) and in the Eskimo Lakes, an estuarine inlet from the eastern Beaufort Sea (Grainger, 1975). Though its areal extent either in coastal waters or offshore over the continental shelf is now known, it has been suggested that these epontic diatoms could be an important energy source to the southern Beaufort Sea ecosystem (Clasby, et al., 1973) and for the Chukchi Sea (Hameedi, 1978). The pennate diatoms may fall to the sea floor upon ice melt in June (Matheke and Horner, 1974). There are very few ice algae data from the Beaufort Sea and no direct measurements to determine if the epontic diatoms fall to the bottom during ice melt. It is not resolved whether the ice algae add to the phytoplankton population (Hameedi, 1978) or fall to the sea floor (Matheke and Horner, 1974).

Various organisms become associated with the ice-sea water interface as the diatom bloom progresses through the months of April, May and June (Horner, 1976). Nematode worms are most abundant but harpacticoid copepods, amphipods and polychaete larvae have been observed on the underice surface. A coastal amphipod Onisimus affinis, an important member of the demersal fish food chain, has been reported as present in the epontic community presumably for feeding (Percy, 1975).

The degree of linkage between the underice epontic community and the benthic community beneath is not known. There is no direct evidence that this "upside down benthic community" is important in the energetics of the bottom communities themselves (Horner, 1976; Hameedi, 1978). It has been hypothesized that the sinking of detritus and diatom cells from the epontic community could provide a sizeable downward organic input to the benthic communities and that the vertical migration of benthic fauna up to the ice undersurface could provide another significant and earlier source of energy-rich organics to certain faunal groups of the benthos.

The proposed research subproject on the interactions of the benthic community and the underice epontic community should prove whether direct fluxes of food materials and organisms exist between the two surfaces.

It is most pertinent to note that Schell (RU #537) recently measured substantial concentrations of chlorophyl on the undersurface of Beaufort Sea ice to distances of 100 n mi offshore (personal communication). The existence of the algal epontic community in oceanic waters in the Beaufort Sea suggests that primary production in this community is indeed energetically important to the total Beaufort Sea ecosystem. The questions of the fate of the organic particulates associated with the epontic community and the degree of interaction between the benthic and underice surfaces become that much more pressing.

III. Field and Laboratory Activities

A. Field Activities

1) Field trip

none

2) Field Scientific Party

none

3) Field Methods

none

B. Laboratory Analysis

1) Scientific Personnel

a) Andrew G. Carey, Jr. — Principal Investigator, Associate Professor

Responsibilities: Coordination, evaluation, analysis, and reporting

b) Keith Walters — Research Assistant Unclassified (commenced work 8 October 1979)

Responsibilities: Data management, statistical analysis

c) R. Eugene Ruff — Research Assistant Unclassified

Responsibilities: Species list compilation, sample processing, reference museum curation, polychaete systematics, field collection, and laboratory management

d) Paul Scott — Research Assistant Unclassified

Responsibilities: Sample processing, data summary, molluscan systematics and sample collection

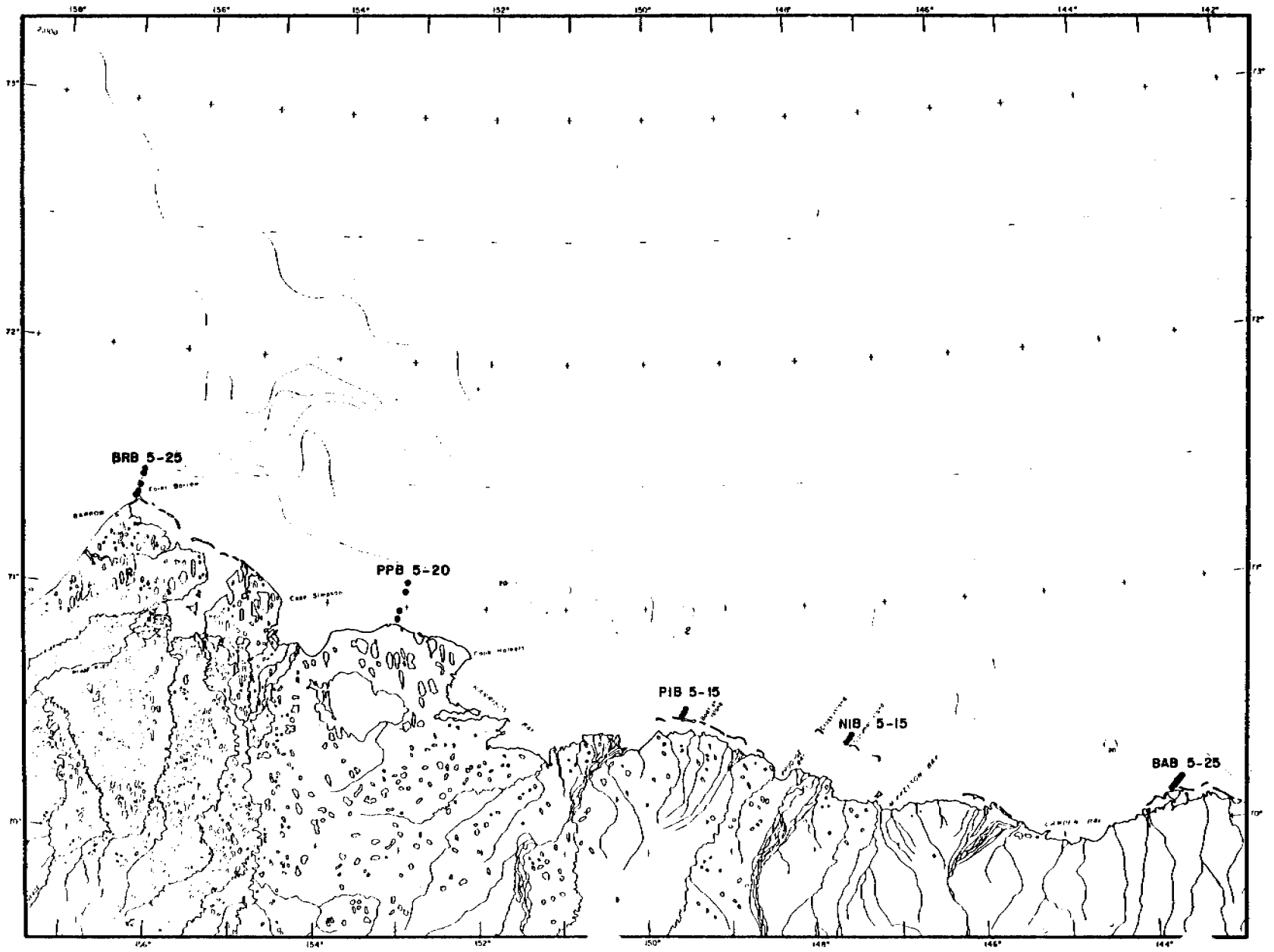
e) Ken Golubier — Part-time Assistant

Responsibilities: Sample processing, sample curation (finished part-time work December 21, 1979)

f) Gordon R. Bilyard — Research Assistant Unclassified (half-time)

Responsibilities: Polychaete identification, data analysis (Left Oregon State University December 26, 1979 to begin work at Tetra Tech, Inc.)

Figure 1: Locations of coastal stations taken aboard R/V ALUMIAK, summer 1976.



2) Methods - no changes in standard techniques

3) Sample Localities

a) Stefannson Sound Boulder Patch
b) Beaufort Sea Lease Area
c) OCS Pitt Point Transect
d) Inner Continental Shelf

## IV. Results

### A. Pelecypod mollusc species identifications and ecological analyses

Pelecypod molluscs from the Pitt Point transect line sampled during the field efforts OCS-3 and 4 have been identified by Paul Scott. A list of families and species encountered as well as their approximate densities is summarized in Tables 1 through 3.

The pelecypod species data from nearshore Beaufort Sea samples (OCS-5, R/V ALUMIAK, August, 1976) (Figure 1) is currently undergoing ecological analyses. This is a unique data set including samples from Point Barrow to Barter Island in the 5 to 25 meter depth range. These analyses should give us a better feel for coastal bivalve diversity, distribution and community similarity.

### B. Gastropod mollusc species identifications

Tentative gastropod mollusc identifications from OCS-5 have been made by Paul Scott. This material includes 39 species from 12 families and is summarized in Table 4.

### C. Quantitative ecological analyses of coastal fauna

Preliminary statistical analyses have been undertaken on the community ecology of the polychaete (Annelida:Polychaeta) and the bivalve (Mollusca: Pelecypoda) fauna from the SW Beaufort Sea inner continental shelf. The fauna come from the five station transects (5-25 m depth) collected during the 1976 cruise of the R/V ALUMIAK (Figure 1). Patterns of species and station groupings have been obtained with similarity indices and clustering techniques. The tentative conclusion drawn from these analyses is that there is a fairly homogenous inner continental shelf community that extends from Point Barrow to Demarcation Point. There are weak subgroupings indicated by these analyses; these patterns are under further investigation.

### D. Ice algal-benthic community interactions

Analyses have continued on the fauna of the sea ice undersurface and the sediments beneath at the Boulder Patch during the spring ice algal bloom. The harpacticoid copepods have been used as indicator organisms of the meiofaunal community.

E. Temporal variability of the SW Beaufort Sea benthic fauna

Samples and animal groups from the 1975-76 seasonal samples and the 1976-78 yearly samples collected on the OCS Pitt Point Station Transect continue to be processed and analyzed.

F. Megafaunal benthos of the SW Beaufort Sea

Otter trawls were collected during the 1978 USCGC NORTHWIND cruise to the SW Beaufort Sea by RU #006 (OCS 8). Preliminary sorting and enumeration of the samples of the benthic megafauna have been accomplished; these data are listed in Tables 5 through 10. No conclusions can be drawn at this time.

G. Data Management

It has been determined that the current inhouse system for benthic data storage and retrieval should be replaced by a true data base management system. The reasons for this change include the following:

| | | |
|---|---|---|
| 1. | System maintenance | The current system of interconnected FORTRAN programs requires constant programmer maintenance. |
| 2. | System flexibility | New or differing reports and data files require major new program development under the current system. |
| 3. | Online capabilities | Currently, only batch mode processing is available. To allow for hands-on researcher interfacing and ease and accessibility of data storage and retrieval conversion to a potential online system is proposed. |
| 4. | Documentation | The lead-in time and system documentation can be greatly reduced and improved by conversion. |

An OSU computer center maintained data base management system is currently available and is proposed as the new system. SIR, Scientific Information Retrieval, is a hierarchically structured system which provides for online processing of data. The system is virtually self-documenting. A pilot project has just been completed where the OSU Benthic Ecology Museum has been converted to SIR. The system is performing as expected with both a considerable saving in time and money from the inhouse system it replaced. Conversion of benthic data to the new system structure is proceeding under the direction of Keith Walters.

V. Preliminary interpretation of Results

Though no firm conclusions can be drawn from the results at this time, several interpretive comments are made in the preceding sections in Results.

VI. Auxiliary Material

A. Bibliography of References

Clasby, R.C., R. Horner and V. Alexander. 1973. An in situ method for measuring primary productivity of Arctic sea ice algae. J. Fish. Res. Board Can. 30: 835-838.

Grainger, E.H. 1975. Biological productivity of the southern Beaufort Sea: The physical-chemical environment and the plankton. Beaufort Sea Project Technical Report No. 12a. 82 pp.

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

Horner, R.A. 1976. Sea ice organisms. Oceanogr. Mar. Biol. Ann. Rev. 14: 167-182.

Horner, R.A. and V. Alexander. 1972. Algae populations in arctic sea ice: an investigation of heterotrophy. Limnol. Oceanogr. 17: 454-458.

Matheke, G.E.M. 1974. Primary productivity of the benthic microalgae in the Chukchi Sea near Barrow, Alaska. J. Fish. Res. Board Can. 31: 1779-1786.

Percy, J.A. 1975. Ecological physiology of arctic marine invertebrates. Temperature and salinity relationships of the amphipod Onisimus affinis H.J. Hansen. J. exp. mar. Biol. Ecol. 20: 99-117.

B. Papers in preparation or in print

1. Papers in preparation

a. Bilyard, G.R. and A.G. Carey, Jr. Zoogeography of western Beaufort Sea Polychaeta. Sarsia. In press.

b. Carey, A.G., Jr. and P.H. Scott. The distribution and abundance of nearshore bivalve molluscs in the Southwestern Beaufort Sea. In preparation.

c. Carey, A.G., Jr. and P.H. Scott. The distribution and abundance of nearshore bivalve molluscs in the southwestern Beaufort Sea. In preparation.

d. Carey, A.G., Jr. and R.E. Ruff. The distribution, abundance and ecology of nearshore polychaetes in the southwestern Beaufort Sea. In preparation.

e. Dickinson, J. and A.G. Carey, Jr. The distribution, abundance and ecology of gammarid amphipods across the southwestern Beaufort Sea shelf. In preparation.

2. Papers in print

a. Bilyard, G.R. and A.G. Carey, Jr. 1979. Distributional patterns of western Beaufort Sea polychaetous annelids. Marine Biology 54: 329-339.

C. Oral Presentations

None

VII. Problems encountered/recommended changes

A. Data accumulation lag.

Owing to the departure of a Biological Research Assistant (P.M. Montagna), RU #006's capability to identify a wide taxonomic range of fauna has decreased. Dependency on outside specialists for primary identifications and verification of previously identified material creates significant delays and/or complete data gaps. Supplementary funding of RU #006 for work-up of previous Chukchi Sea samples would add to our taxonomic capability and significantly increase efficiency in the laboratory by providing support for one additional research assistant with demonstrated ability with Crustacean systematics.

Table 1 . Species data for pelecypod molluscs from PPB-55, OCS-3 (May 1976).

| Family | Species | Approximate Number Per $m^2$ |
|---|---|---|
| Nuculidae | Nucula bellotii | 33 |
| Nuculanidae | Nuculana minuta | 20 |
| | Nuculana radiata | 8 |
| | Portlandia frigida | 63 |
| Arcidae | Bathyarca glacialis | 3 |
| Mytilidae | Musculus niger | 3 |
| | Musculus discors | 5 |
| Pectinidae | Arctinula greenlandica | 43 |
| Thyasiridae | Axinopsida orbiculata | 3 |
| Carditidae | Cyclocardia crebricostata | 30 |
| Astartidae | Astarte montagui | 100 |
| | Astarte crenata | 18 |
| Cardiidae | Clinocardium ciliatum | 3 |
| Tellinidae | Macoma loveni | 15 |
| Veneridae | Liocyma fluctuosa | 5 |
| Myidae | Mya truncata | 3 |
| Pandoridae | Pandora glacialis | 13 |
| Lyonsiidae | Lyonsia arenosa | 8 |
| | Total per $m^2$ | 376 |

Table 2 . Species data for pelecypod molluscs from PPB-100, OCS-3 (May 1976).

| Family | Species | Approximate Number Per $m^2$ |
|---|---|---|
| Nuculidae | Nucula bellotii | 80 |
| Nuculanidae | Nuculana minuta | 10 |
| | Nuculana radiata | 3 |
| | Portlandia frigida | 13 |
| Mytilidae | Dacrydium vitreum | 3 |
| | Musculus niger | 13 |
| | Musculus discors | 7 |
| Pectinidae | Arctinula greenlandica | 3 |
| Thyasiridae | Axinopsida orbiculata | 3 |
| | Thyasira gouldii | 20 |
| Montacutidae | Montacuta dawsoni | 3 |
| | Mysella planata | 3 |
| Cardiidae | Cyclocardia crebricostata | 36 |
| Astartidae | Astarte crenata | 30 |
| | Astarte borealis | 43 |
| | Astarte montagui | 96 |
| | Astarte juvenile | 36 |
| Tellinidae | Macoma loveni | 20 |
| Veneridae | Liocyma fluctuosa | 7 |
| Hiatellidae | Hiatella arctica | 3 |
| Lyonsiidae | Lyonsia arenosa | 3 |
| Thraciidae | Thracia myopsis | 7 |
| | Total per $m^2$ | 439 |

Table 3 . Species data for pelecypod molluscs from PPB-100, OCS-4 (August 1976).

| Family | Species | Approximate Number Per $m^2$ |
|---|---|---|
| Nuculidae | Nucula bellotii | 30 |
| Nuculanidae | Nuculana radiata | 5 |
| | Nuculana minuta | 5 |
| | Portlandia frigida | 25 |
| Mytilidae | Dacrydium vitreum | 5 |
| | Musculus discors | 40 |
| Thyasiridae | Thyasira gouldii | 10 |
| Cardiidae | Cyclocardia crebricostata | 5 |
| Astartidae | Astarte crenata | 10 |
| | Astarte borealis | 15 |
| | Astarte montagui | 85 |
| Tellinidae | Macoma loveni | 10 |
| Beneridae | Liocyma fluctuosa | 15 |
| Hiatellidae | Hiatella arctica | 5 |
| Thraciidae | Thracia devexa | 10 |
| | Thracia myopsis | 10 |
| | Total per $m^2$ | 285 |

Table 4: Tentative species list of gastropod molluscs from OCS-5 (Summer 1976, R/V ALUMIAK).

| | |
|---|---|
| **Point Barrow - 25 m** | |
| Naticidae | *Natica clausa* |
| Turridae | *Propebela gouldii* |
| Retusidae | *Retusa* sp. A |
| Philinidae | *Philine* sp. A |
| | Total gastropods - 2 per $m^2$ |
| **Point Barrow - 20 m** | |
| Cancellaridae | *Admete* sp. A |
| Retusidae | *Retusa* sp. A |
| | *Retusa* sp. 1 |
| Philinidae | *Philine pruinosa* |
| | *Philine* sp. 1 |
| | Total gastropods - 6 per $m^2$ |
| **Point Barrow - 15 m** | |
| Trochidae | *Solariella obscura* |
| Turridae | *Oenopota decussata* |
| Retusidae | *Retusa* sp. A |
| | *Retusa* sp. 1 |
| Philinidae | *Philine* sp. A |
| Scaphandridae | *Scaphander* sp. B |
| | Total gastropods - 2 per $m^2$ |
| **Point Barrow - 10 m** | |
| Retusidae | *Retusa* sp. A |
| | *Retusa* sp. 1 |
| Scaphandridae | *Cylichna* sp. 2 |
| | Total gastropods - 96 per $m^2$ |
| **Point Barrow - 5 m** | |
| Turridae | *Propebela gouldii* |
| Scaphandridae | *Cylichna alba* |
| | Total gastropods - 6 per $m^2$ |
| **Pitt Point - 25 m** | |
| Rissoidae | *Cingula castenea* |
| Turridae | *Oenopota novajasemliensis* |
| | *Propebela gouldii* |
| Retusidae | *Retusa* sp. A |
| Scaphandridae | *Cylichna alba* |
| | *Cylichna* sp. A |
| | *Scaphander* sp. A |
| | *Cephalaspidean* sp. A |
| | Total gastropods - 46 per $m^2$ |

Table 4 (continued)

| | |
|---|---|
| **Pitt Point - 20 m** | |
| Trochidae | *Margarites giganteus* |
| Turridae | *Oenopota novajasemliensis* |
| Retusidae | *Retusa* sp. A |
| Scaphandridae | *Cylichna* sp. A |
| | Total gastropods - 12 per $m^2$ |
| **Pitt Point - 15 m** | |
| Turridae | *Oenopota novajasemliensis* |
| Retusidae | *Retusa* sp. A |
| | Total gastropods - 6 per $m^2$ |
| **Pitt Point - 10 m** | |
| Turridae | *Oenopota novajasemliensis* |
| | *Oenopota* sp. D |
| Retusidae | *Retusa* sp. A |
| | *Retusa* sp. 1 |
| Scaphandridae | *Cylichna* sp. A |
| | Total gastropods - 52 per $m^2$ |
| **Pitt Point - 5 m** | |
| Naticidae | *Polinices pallidus* |
| Buccinidae | *Buccinum* juvenile |
| Neptuneidae | *Beringus* juvenile |
| Turridae | *Oenopota arctica* |
| Scaphandridae | *Cylichna* sp. A |
| | Total gastropods - 82 per $m^2$ |
| **Pingok Island - 15 m** | |
| Trochidae | *Margarites costalis* |
| | *Solariella obscura* |
| Naticidae | *Natica clausa* |
| | *Polinices pallidus* |
| Rissoidae | *Cingula castenea* |
| Cancellaridae | *Admete couthouyi* |
| Turridae | *Oenopota novajasemliensis* |
| | *Propebela gouldii* |
| Retusidae | *Retusa* sp. A |
| | *Retusa* sp. 1 |
| Diaphanidae | *Diaphana minuta* |
| Scaphandridae | *Cylichna alba* |
| | *Cylichna* sp. 1 |
| | *Scaphander* sp. A |
| | *Scaphander* sp. B |
| | *Scaphander* sp. 1 |
| Philinidae | *Philine* sp. A |
| | Total gastropods - 46 per $m^2$ |

Table 4 (continued)

Pingok Island - 10 m

| | |
|---|---|
| Naticidae | Polinices pallidus |
| Velutinidae | Velutina velutina |
| Neptuneidae | Colus juvenile |
| Turridae | Oenopota novajasemliensis |
| | Oenopota sp. D |
| | Oenopota sp. E |
| Retusidae | Retusa sp. A |
| Scaphandridae | Cylichna sp. A |
| | Scaphander sp. A |
| | Scaphander sp. B |
| | Total gastropods - 32 per $m^2$ |

Narwhal Island - 25 m

| | |
|---|---|
| Trochidae | Solariella obscura |
| Turridae | Oenopota novajasemliensis |
| Retusidae | Retusa sp. A |
| Scaphandridae | Scaphander sp. B |
| | Total gastropods - 18 per $m^2$ |

Narwhal Island - 15 m

| | |
|---|---|
| Trochidae | Margarites giganteus |
| | Margarites costalis |
| Rissoidae | Cingula castenea |
| Velutinidae | Velutina undata |
| Cancellaride | Admete sp. A |
| | Admete couthouyi |
| Turridae | Oenopota novajasemliensis |
| | Oenopota bicarnata |
| Retusidae | Retusa sp. A |
| | Retusa, sp. 1 |
| Diaphanidae | Diaphana sp. A |
| Philinidae | Philine sp. juvenile |
| Scaphandridae | Cylichna sp. A |
| | Scaphander sp. A |
| | Scaphander sp. B |
| | Scaphander sp. 1 |
| | Total gastropods - 34 per $m^2$ |

Narwhal Island - 10 m

| | |
|---|---|
| Turridae | Oenopota arctica |
| Retusidae | Retusa sp. 1 |
| Philinidae | Philine sp. juvenile |
| Scaphandridae | Scaphander sp. B |
| | Scaphander sp. 1 |
| | Total gastropods - 86 per $m^2$ |

Table 4 (continued)

Narwhal Island - 5 m

| | |
|---|---|
| Trochidae | Margarites costalis |
| Turridae | Oenopota novajasemliensis |
| Philinidae | Philine juvenile |
| Scaphandridae | Scaphander sp. B |
| | Total gastropods - 38 per $m^2$ |

Barter Island - 25

| | |
|---|---|
| Trochidae | Margarites giganteus |
| Naticidae | Polinices pallidus |
| Cancellaridae | Admete couthouyi |
| Turridae | Oenopota novajasemliensis |
| | Oenopota sp. B |
| | Oenopota sp. D |
| | Oenopota sp. E |
| Retusidae | Retusa sp. A |
| Philinidae | Philine lima |
| Scaphandridae | Cylichna sp. A |
| | Cylichna sp. 1 |
| | Scaphander sp. A |
| | Scaphander sp. B |
| | Cephalaspidean sp. |
| | Total gastropods - 42 per $m^2$ |

Barter Island - 20 m

| | |
|---|---|
| Trochidae | Margarites giganteus |
| | Solariella obscura |
| Rissoidae | Cingula castenea |
| | Alvania sp. 1 |
| Naticidae | Polinices pallidus |
| Cancellaridae | Admete couthouyi |
| Turridae | Oenopota novajasemliensis |
| | Oenopota sp. E |
| Retusidae | Retusa sp. A |
| Diaphanidae | Diaphana sp. A |
| Scaphandridae | Cylichna alba |
| | Cylichna sp. 1 |
| | Scaphander sp. A |
| | Scaphander sp. B |
| | Cephalaspidean sp. |
| Philinidae | Philine sp. |
| | Total gastropods - 56 per $m^2$ |

Barter Island - 15

| | |
|---|---|
| Trochidae | Solariella sp. 1 |
| Rissoidae | Cingula castenea |
| Naticidae | Natica clausa |
| Cancellaridae | Admeta couthouyi |
| Turridae | Oenopota novajasemliensis |
| | Oenopota sp. E |
| Retusidae | Retusa sp. A |
| | Retusa sp. 1 |

Table 4 (continued)

| | |
|---|---|
| Barter Island - 15 (continued) | |
| Scaphandridae | Cylichna sp. 2 |
| | Scaphander sp. A |
| | Scaphander sp. B |
| | Total gastropods - 156 per $m^2$ |
| Barter Island - 10 m | |
| Turridae | Oenopota novajasemliensis |
| | Oenopota sp. E |
| Retusidae | Retusa sp. A |
| | Retusa sp. 1 |
| Scaphandridae | Cylichna sp. 2 |
| | Scaphander sp. B |
| | Scaphander sp. 2 |
| | Total gastropods - 64 per $m^2$ |
| Barter Island - 5 m | |
| Scaphandridae | Scaphander sp. B |
| | Total gastropods - 2 per $m^2$ |

Table 5 . Otter trawl locations from the OCS-8, USCGC NORTHWIND cruise.

| Trawl Number | Station | Depth (meters) | Location |
|---|---|---|---|
| 711 | Demarcation 250 | 150-300 | 70°25.5'N,141°44.5'W |
| 712 | Demarcation 100 | 85 | 70°28'N,141°38'W |
| 713 | Barter Island 500 | 457-1092 | 70°31.8'N,143°08.9'W |
| 714 | Barter Island 500 | 450 | 70°41.9'N,144°04.4'W |
| 715 | Barter Island 500 | 757 | 70°49'N, 143°45'W |

Table 6. Animal identifications and relative densities from otter trawl 711 taken on 4 September 1978 during the OCS-8, USCGC NORTHWIND cruise.

| Phylum: | Class: | Order | Number |
|---|---|---|---|
| Cnidaria: | Hydrozoa | | + |
| | Anthozoa | | 25 |
| Nemertinea | | | 3 |
| Annelida: | Polychaeta | | 5 |
| Molluska: | Gastropoda | | 31 |
| | Bivalvia | | 11 |
| Arthropoda: | Pycnogonida | | 2 |
| | Crustacea: | Isopoda | 5 |
| | | Amphipoda | 2 |
| | | Decapoda | 44 |
| | | Decapoda | 1 |
| Sipuncula | | | 3 |
| Echinodermata: | Ophiuroidea | | 303 |
| | Crinoidea | | 15 |

Table 7 . Animal identifications and relative densities from otter trawl 712 taken on 4 September 1978 during the OCS-8, USCGC NORTHWIND cruise

| Phylum: | Class: | Order | Number |
|---|---|---|---|
| Cnidaria: | Anthozoa | | 1 |
| Molluska: | Bivalvia | | 1 |
| Arthropoda: | Crustacea: | Decapoda | 4 |
| | | Decapoda | 2 |
| Echinodermata: | Asteroidea | | 3 |
| | Ophiuroidea | | 63 |
| | Crinoidea | | 21 |

Table 8 . Animal identifications and relative densities from otter trawl 713 taken on 6 September 1978 during the OCS-8, USCGC NORTHWIND cruise.

| Phylum: | Class: | Order | Number |
|---|---|---|---|
| Cnidaria: | Hydrozoa | | + |
| | Anthozoa | | 46 |
| Annelida: | Polychaeta | | 44 |
| Molluska: | Gastropoda | | 22 |
| Arthropoda: | Pycongonida | | 4 |
| | Crustacea: | Isopoda | 2 |
| | | Isopoda | 1 |
| | | Decapoda | 47 |
| Echinodermata: | Asteroidea | | 196 |
| | Ophiuroidea | | 354 |

Table 9 . Animal identifications and relative densities from otter trawl 714 taken on 7 September 1978 during the OCS-8, USCGC NORTHWIND cruise.

| Phylum: | Class: | Order | Number |
|---|---|---|---|
| Cnidaria: | Anthozoa | | 71 |
| Annelida: | Polychaeta | | 46 |
| | Hirudinea | | 1 |
| Molluska: | Gastropoda | | 48 |
| | Aplacaphora | | 1 |
| Arthropoda: | Crustacea: | Cumacea | 1 |
| | | Isopoda | 3 |
| | | Decapoda | 20 |
| Echinodermata: | Asteroidea | | 524 |
| | Ophiuroidea | | 226 |
| Nemerteanea: | | | 2 |

Table 10. Animal identifications and relative densities from otter trawl 715 taken on 7 September 1978 during the OCS-8, USCGC NORTHWIND cruise.

| Phylum: | Class: | Order | Number |
|---|---|---|---|
| Cnidaria: | Anthozoa | | 20 |
| Annelids: | Polychaeta | | 258 |
| Molluska: | Gastropoda | | 22 |
| | Aplacophora | | 1 |
| | Bivalvia | | 4 |
| Arthropoda: | Crustacea: | Mysidacea | 24 |
| | | Amphipoda | 1 |
| Echinodermata: | Asteroida | | 415 |
| | Ophiuroidea | | 291 |
| Nemerteans | | | 2 |
| Sipuncula | | | 5 |

Contract 03-5-022-81
Research Unit 356
July 1 to September 30, 1979
38 pages

QUARTERLY REPORT

# Environmental Assessment of Selected Habitats in the Beaufort and Chukchi Sea Littoral Systems

September 21, 1979

A. C. Broad
Kenneth Dunton
David T. Mason
D. E. Schneider

I. TASK OBJECTIVES: The objectives of RU356 for the quarter were:

A. Continued investigation of the Stefansson Sound boulder patches including observations of growth of specific elements of the biota and of various environmental factors in the region.

B. Continued laboratory experiments designed to evaluate the responses of shallow water Beaufort Sea invertebrates to environmental conditions and the effects of these stresses on tolerance of crude oil.

C. Completion of observations of stress-strain relations in Arctic salt marshes at Prudhoe Bay and at Kotzebue.

D. Laboratory analysis of samples collected in the Beaufort Sea nearshore and inshore regions in 1978 and of samples from the Chukchi Sea nearshore taken in 1977.

II. FIELD OR LABORATORY ACTIVITIES:

A. Schedule of Field Activities

1. Messrs. Dunton, Hanes, Olson and Smith lived on and used Narwhal Island as a base of operations from mid July to August 4. Ms. Schonberg assisted them during part of that period.

a. July 10: Dive team arrives in Deadhorse.

b. July 11-15: Prepare RV ARCTIC CHAR, a 21 foot Boston Whaler, for field season. Airlift supplies to NARL camp on Narwhal Island by ERA helicopter. Clean and prepare NARL camp (with assistance from NARL) for summer habitation. Ken Dunton explores sea ice with Erk Reimnitz (RU205).

c. July 16: Launch ARCTIC CHAR at East Dock, arrive on Narwhal Island in early evening.

d. July 17-22: Conduct benthic studies at DS-11 in the Boulder Patch.

e. July 21: Sue Schonberg arrives in Deadhorse.

f. July 23: Dive team departs Narwhal Island for Deadhorse by boat. Ken Dunton departs to Fairbanks for OCSEAP synthesis meetings. Travel by ERA helicopter and Wien.

g. July 24-25: Ken Dunton in Fairbanks for OCSEAP synthesis meetings. Depart for Deadhorse on the evening of the 25th.

h. July 26: Dive team conducts a benthic sampling program at the Exxon Ice Island.

i. July 27: Sue Schonberg departs Deadhorse for Bellingham. Dive team arrives on Narwhal Island in evening.

j. July 28 - August 3: Conduct benthic studies at DS-11. Work with the RV KARLUK (Reimnitz, RU205) on July 28 and July 30 (transplant boulders in an experiment to seaward side of Narwhal and retrieve and re-deploy current meters belonging to Mathews - RU526).

k. August 4: Dive team departs Narwhal Island for summer. Airlifts by ERA helicopter (a total of ten 206 helo hours were used by this group).

l. August 5: Dive team departs Deadhorse.

m. August 6-7: Ken Dunton works with Don Schell (RU537) at the University of Alaska on studies related to the growth of the kelp Laminaria solidungla.

2. Dr. Schneider, and/or Mr. Hanes or Mr. Banner (replacement for Mr. Hanes 7/16 - 8/14) were at NARL, Barrow, continuously through the quarter.

3. A. C. Broad, D. E. Schneider, K. Dunton participated in a synthesis meeting in Fairbanks, July 24-27.

4. Dr. Mason was at Kotzebue (Arctic Circle beach) from August 7 to 16 and at Deadhorse (Prudhoe Bay marsh) from August 17 to 31.

B. Scientific Party (except for contract personnel, all of Western Washington Unviersity)

1. Principal Investigator, A. C. Broad (on salary through August 31)

2. Associate Investigators

   a. D. E. Schneider (through August 31)
   b. D. T. Mason (month of August)

3. Assistant Investigator, Ken Dunton

4. Laboratory Supervisor, Helmut Koch

5. Marine Technicians:

   a. James Hanes
   b. William D. Banner (one month)

6. Research Aides

   a. Mark Childers
   b. Susan Schonberg (hourly wages)

7. Computer Programmers

   a. Alexander Benedict (hourly wages)
   b. Evelyn Albrecht (hourly wages)

8 Laboratory Helpers (all hourly wages)

   a. James Bock
   b. Susan Burgdorff

c. Kara Cameron
d. Dawn Christman
e. Gregory Duke
f. Geoffrey Pounds
g. Neil Safrin
h. Donna Sorenson
i. Russell Thorson
j. Jonathan Zehr

9. Work-study students (no cost to contract)
   a. Sandra Bohenstiehl
10. Divers (on contracts)
   a. John Olson
   b. Gary F. Smith

C. Methods: All methods used have been reported previously or are referred to specifically in appended sections of results.

D. Sample Localities:

1. Observations in Stefansson Sound were made at our Dive Site 11 (70° 19.25'N; 147° 35.1'W).
2. Arctic salt marshes in which observations were made are located at Arctic Circle Landing Strip south of Kotzebue (about 66°27'N, 161° 52'W) and in the mouth of the Putuligayak River at Prudhoe Bay (about 70°18'N; 148°29'W).

E. Data Collected

1. The following data and/or samples were collected in Stefansson Sound.
   a. Data on the growth of Laminaria solidungla and L. saccharina since May.
   b. Quantitative benthic samples of the Boulder Patch flora and fauna.
   c. Quantitative benthic samples of the infauna associated with the Boulder Patch.
   d. Qualitative sampling and photography of the kelp community.
   e. Observations of animal behavior, including feeding and reproduction.
   f. Data on the salinity, temperature, visibility and currents at DS-11 during the field season.
   g. Quantitative estimates of the rates of sedimentation.
   h. Data on the growth and recolonization of organisms on rock substrata.

i. Quantitative data of the infauna and epifauna near the Exxon Ice Island.

In addition, new experiments were initiated in July at DS-11 to study:

j. The growth of Alaria esculenta, a large, brown kelp.

k. The effect of varying amounts of sediment (1 cm, 5 cm, and 10 cm) on the survival of various animal and plant species.

l. The influence of continuous darkness on the growth of Laminaria.

2. Data derived from laboratory experiments at NARL, Barrow, are treated separately in an appended report by D. E. Schneider.

3. Dr. Mason collected data on soil salinity, albedo, several measures of soil strength, effects of grazing by geese, and plant cover (recovery) at experimental sites exposed to oil, sand cover or vertical cutting in 1977 and 1978 at marshes near Kotzebue and Prudhoe Bay. A preliminary analysis of recovery is given below.

4. The present status (as of 9/15/79) of intertidal and shallow subtidal samples collected by RU356 is summarized in Table 1. There are 12 substrate samples yet to be analyzed and 731 biological samples other than plankton samples. Of these biological samples, 330 require sorting and all require identification of organisms and weighing. Data yet to be reported to NODC include those from two 1978 Beaufort Sea field trips (both of which should be reported in early 1980), one tape of 1977 Beaufort-Chukchi shore data (to be reported in 1979) and two sets of data from 1977 Chukchi shore samples still largely unprocessed.

   Data from plankton samples will be treated in a future report.

F. Milestone Chart. Our milestone chart for fiscal 1979 indicated that 1977 data would be reported to NODC in June, 1979, and that analysis of 1978 data would continue through December, 1979. Actually (see Table 1 below) the analysis of 1978 field data is essentially complete, although, coding, keypunching and tape generation remain to be done, but two sets of 1977 samples remain to be analyzed. That analysis probably will occupy our laboratory through July, 1980. In our milestone chart for fiscal 1980, we indicated that the remaining Chukchi samples would be analyzed by the end of 1980. That almost certainly will be completed earlier. Otherwise, the most recent milestone chart is essentially correct.

TABLE 1. Status of littoral, nearshore and inshore samples collected by RU356 as of 9/15/79.

| RU356 TEAM[1] | AREA | SAMPLES COLLECTED | | | | | SAMPLES ANALYZED | | | | | INTERTIDAL DATA FORMAT | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S | B | E | OB | P | S | B | E | OB | P[2] | C[3] | P[4] | TAPE[5] | NODC[5,6] | |
| 15 | BFT | 118 | 242 | 37 | 127 | 0 | 118 | 242 | 37 | 127 | - | yes | yes | 1976 | 770113 | Shore samples east of Canning River |
| 25 | BFT | 27 | 118 | 33 | 49 | 0 | 27 | 118 | 33 | 49 | - | yes | yes | 1976 | HØ8J24 | Shore samples between Canning & Colville Rivers |
| 35 | BFT | 13 | 128 | 16 | 34 | 0 | 13 | 128 | 16 | 34 | - | yes | yes | 1976 | M1ØP34 | Shore samples west of Colville River |
| 55 | BFT | 0 | 0 | 0 | 22 | 2 | 0 | 0 | 0 | 22 | - | yes | yes | 1976 | 761229 | Misc. shore samples |
| 16 | BFT | 41 | 169 | 20 | 29 | 21 | 41 | 169 | 20 | 29 | - | yes | yes | 1977 | 780218 | Shore samples |
| 26 | BFT | 53 | 178 | 31 | 0 | 25 | 53 | 178 | 31 | 0 | - | yes | yes | 1977 | 780219 | Lagoon samples |
| 36 | BFT | 17 | 34 | 14 | 1 | 14 | 17 | 34 | 14 | 1 | - | yes | yes | 1977 | 780214 | ALUMIAK samples |
| 46 | CHK | 39 | 119 | 21 | 49 | 18 | 39 | 119 | 21 | 49 | - | yes | yes | 1977 | 780217 | Shore samples north of Point Hope |
| 56 | CHK | 19 | 94 | 37 | 57 | 14 | 19 | 94 | 37 | 57 | - | yes | yes | 1977 | 780215 | Shore samples, Kotzebue Sound |
| 66 | CHK | 31 | 101 | 23 | 65 | 32 | 31 | 101 | 23 | 65 | - | yes | yes | 1977 | 78Ø216 | Shore samples, Seward Peninsula |
| 17 | CHK | 50 | 306 | 64 | 97 | 53 | 45 | 64 | 0 | 0 | - | no | no | (6/80) | (7/80) | Shore samples. All sorted but some ID problems |
| 27 | BFT | 42 | 125 | 41 | 0 | 41 | 42 | 125 | 41 | 0 | - | yes | yes | 1979 | 790317 | ALUMIAK samples |
| 37 | CHK | 48 | 266 | 22 | 83 | 31 | 41 | 43 | 0 | 0 | - | no | no | (8/80) | (9/80) | Shore samples |
| 47 | BFT/CHK | 30 | 187 | 13 | 6 | 14 | 30 | 187 | 13 | 6 | - | yes | yes | 11/79 | 12/79 | Shore samples |
| 57 | BFT | 44 | 346 | 56 | 29 | 46 | 44 | 346 | 56 | 29 | - | yes | yes | 1979 | 790411 | Shore samples |
| 18 | BFT | 0 | 240 | 120 | 0 | 60 | 0 | 240 | 120 | 0 | - | no | no | (12/79) | (12/79) | Shore samples |
| 38 | BFT | 0 | 77 | 18 | 19 | 18 | 0 | 77 | 18 | 19 | - | no | no | (12/79) | (12/79) | ALUMIAK samples. Some ID's require verification |
| TOTALS | | 572 | 2730 | 566 | 667 | 389 | 560 | 2265 | 480 | 468 | - | | | | | |

[1]Last digit is year of field activity

S=Substrate
B=Benthos
E=Epibenthos
OB=Other, biol.
P=Plankton

[2]Analysis of plankton not reported

C[3]=Coded
P[4]=Punched
[5]Dates in parentheses are estimates
[6]Six digit numbers are NODC file ID's.

III. RESULTS AND PRELIMINARY INTERPRETATIONS

A. Boulder Patch Biology: Up to date results of on-going *in situ* experiments will be presented in the annual report after data have been adequately analyzed and taxonomic work completed. Preliminary data analyses show a decrease in algal linear growth from the spring in both species of *Laminaria*. Differences in total net linear growth in *Laminaria solidungla* exposed to different conditions of ice cover have been documented. Water turbidity and sedimentation increased markedly since the May sampling period.

B. Trophic Relationships of the Arctic Shallow Water Marine Ecosystem - July 1 to September 30, 1979. D. E. Schneider with the assistance of D. Banner and J. Hanes.

The trophic experiments conducted during the summer of 1979 were designed to fill in some existing data gaps from our previous work and to extend our understanding of the importance of detritus and deposit feeding in the Beaufort Sea shallow water ecosystem. Only a brief outline of the experiments and some preliminary results will be presented in this Quarterly Report. A detailed report of these studies will appear in the 1979 Annual Report following complete analysis of the data.

Sediment Feeding Experiments

In 1978 *Gammarus setosus*, a common amphipod, was found to ingest fine sediments deposited in nearshore gravel during the period of ice cover. The ability of this species to assimilate organic material from these sediments was investigated. Sediment that would pass through a 63μ screen was presented to *G. setosus* held in small static volumes of seawater. The organic content of the sediment and the freshly produced fecal pellets was determined using the dichromate wet oxidation method described by Strickland and Parsons (1968). Preliminary data analysis indicates that the organic assimilation, calculated according to Conover (1966), is about 32 percent. *G. setosus* is therefore capable of deriving nutrition from the fine sediments that collect nearshore during the period of ice cover. *G. setosus* appears in large numbers as the shore lead develops in late spring and seems to be actively using this food source at that time.

In an attempt to estimate the living microbial biomass associated with the above sediments, the ATP content was measured (Holm-Hansen and Booth,

1966). A mean value of $1.65 \times 10^{-3}$ µg ATP/mg dry weight was obtained for the sediment samples analyzed. Assuming a C:ATP ratio of 285:1 (Holm-Hansen, 1973), the estimated living microbial carbon is $4.7 \times 10^{-4}$ mg C/mg dry sediment. The total carbon content of the sediment, estimated by dichromate wet oxidation, is $2.93 \times 10^{-2}$ mg C/mg dry sediment. Therefore the living microbial biomass only constitutes about 1.6% of the total carbon associated with this sediment. Presumably a large proportion of the organic matter assimilated by G. setosus when feeding on these sediments is in the form of particulate organic detritus and adsorbed organic materials. A similar attempt to measure the ATP content of fecal pellets derived from sediment feeding was unsuccessful. The ATP content of the fecal pellet extracts was too low to be reliably measured with the procedure employed.

Organic Assimilation of Peat Particle Size Fractions

The ability of G. setosus to assimilate organic matter from a series of different peat particle size fractions was investigated in 1978 and positive Conover's (1966) percent assimilations were only found with particles >425µ in diameter. This experiment was repeated twice in 1979 using two different size classes of G. setosus. The organic content of food and feces was determined by weight loss upon ignition in a muffle furnace (500°C for two hours). The experimental procedure was similar to that used in 1978 except that in some cases where the fecal material was not produced as well formed pellets, feces were collected on pre-ashed and tared Whatman GF/c glass fiber filters prior to dry weight and ash weight determinations. Tables 2 and 3 show the organic content of the peat fractions and feces as well as the organic assimilation. The assimilation efficiencies were high over a much greater range of peat particle sizes in these experiments than was found in last years experiment. The only negative assimilation occurs with the <63µ particles when fed to large G. setosus. Small individuals appear to be able to utilize organic matter even from the smallest particles investigated.

Ground Peat Organic Assimilation

To further investigate the effect of particle size on organic assimilation of peat the following experiment was set up. Coarse peat, 71050µ in particle diameter, was dried in an oven at 60°C for several days. Half of

TABLE 2. *Gammarus setosus* Peat Size Fraction Assimilation Efficiency. Large sized (>15mm body length) individuals were used in this experiment.

| Peat Size Fraction | Peat % Organic | Feces % Organic | Conover's % Assimilation |
|---|---|---|---|
| >1050μ | 66.2 | 23.4 | 84.4 |
| 425 < x < 1050μ | 65.8 | 21.8 | 85.5 |
| 202 < x < 425μ | 65.3 | 25.1 | 82.2 |
| 102 < x < 202μ | 60.6 | 25.4 | 77.9 |
| 63 < x < 102μ | 39.7 | 21.4 | 58.6 |
| <63μ | 16.3 | 21.2 | -38.2 |

TABLE 3. *Gammarus setosus* Peat Size Fraction Assimilation Efficiency. Small sized (<12mm body length) individuals were used in this experiment.

| Peat Size Fraction | Peat % Organic | Feces % Organic | Conover's % Assimilation |
|---|---|---|---|
| >1050μ | 67.1 | 34.4 | 74.3 |
| 425 < x < 1050μ | 69.2 | 25.4 | 84.8 |
| 202 < x < 425μ | 69.7 | 36.7 | 74.8 |
| 102 < x < 202μ | 65.7 | 21.0 | 86.1 |
| 63 < x < 102μ | 48.7 | 10.4 | 87.8 |
| < 63μ | 16.2 | 8.4 | 52.6 |

this material was ground in a Wiley Mill to pass an 80 mesh screen. Samples of both coarse peat and the ground peat were rehydrated in Millipore filtered sea water for three hours and then fed to small sized G. setosus. Analysis of the organic content of food and feces was by weight loss upon ignition in a muffle furnace (500°C for two hours). No significant difference was found between the organic content of the food (74.0% organic for ground peat vs. 72.2% organic for unground) or the feces (52.1% organic for feces from ground peat vs. 53.9% organic for feces from unground peat). The Conover's percent assimilations were 61.8 and 54.9 for the ground and unground peat experiments respectively. This suggests that particle size per se does not influence organic assimilation and that the organic content of the particle size class is apt to be a more important determinant of assimilation capability.

$^{14}$C-labelled Cellulose Oxidation

The high assimilation efficiencies shown by G. setosus when feeding on peat suggested that this species may have some ability to digest the resistant structural carbohydrates found in plant cell walls. Experiments were set up in collaboration with Don Schell (RU357) to determine if G. setosus is capable of oxidizing Cellulose - $^{14}$C.

Experiment number one was carried out in the dark and at a temperature of 8.5°C. Six 2ℓ erlenmeyer flasks were set up each containing one of the following combinations:

A. Seawater (15‰ salinity) only.
B. Seawater + 9 G. setosus
C. Seawater + Peat (Ca.80 mg dry weight)
D. Seawater + Peat + 9 G. setosus
E. Seawater + Peat + 9 G. setosus
F. Seawater + Peat + $HgCl_2$ (poisoned control)

At time 0 approximately 120 µg of cellulose - $^{14}$C was added to each flask. Flasks were sampled at approximately 0, 4, 8, and 18 hours. At each sampling period a water sample was removed and the labelled $CO_2$ was stripped into a $CO_2$ absorbant for scintillation counting using a nitrogen gas train. Three G. setosus were removed at each of the last three sampling periods. The guts of these animals were dissected from the bodies and these were placed in separate scintillation vials for counting. Preliminary analysis of the

amount of $^{14}CO_2$ appearing in the water samples indicates that over the 18 hour period, those flasks with G. setosus consumed and released as $CO_2$ approximately 4.6% of the added label. In contrast, the sample containing only sea water and peat consumed and released only 1.3% of the added label. The 3.3% difference is presumed to be due to ingestion and respiration of the label by G. setosus. Analysis of the label appearing in the guts and bodies of the amphipods removed from the experimental flasks indicates that there was a sequential transfer of label from the gut to the remaining body tissues during the 18 hour experimental period.

Experiment number two was carried out in the dark and at a temperature of 0°C. The experimental procedure was similar to that described for the first experiment except that the guts were not separated from the bodies of the amphipods when they were prepared for counting. Six 2ℓ erlenmeyer flasks were set up each containing one of the following combinations:

A. Seawater (25 ‰ salinity) + Peat (Ca. 1.5 mg dry weight)
B. Seawater + Peat + 24 Onisimus sp.
C. Seawater + Peat + 24 Onisimus sp.
D. Seawater + Peat + 9 Gammarus setosus
E. Seawater + Peat + 9 Gammarus setosus
F. Seawater only.

Preliminary analysis of the $^{14}CO_2$ appearing in the water samples over the 18 hour experimental period indicates that the flask containing sea water plus peat consumed and released as $^{14}CO_2$ about 2% of the added label. The two flasks containing Onisimus sp. oxidized 1.95 and 1.83% of the added label, suggesting that this species of amphipod cannot oxidize cellulose. The two flasks containing G. setosus oxidized 3.40 and 3.17% of the added label, again indicating that this species can digest cellulose. The flask containing seawater alone only oxidized 0.8% of the label.

It seems likely from these tracer experiments that G. setosus is able to assimilate a high proportion of the organic matter in peat because of its ability to oxidize cellulose. It is not known if this capability is the result of symbiotic cellulytic gut microbes or direct cellulose activity in the gut of this species. Some of the antibiotic experiments described below may shed some light on this question.

The following experiments have been run during the latter part of

August and early September, but data analysis is not complete enough to provide preliminary results at this time.

Eroding Tundra Peat Organic Assimilation

During the summer of 1978 it was found that G. setosus was not capable of assimilating organic matter from peat derived from an eroding tundra bank that had not yet entered the marine system. This result was surprising in that very high assimilation efficiencies were obtained for peat that had been in the marine system for some time. In view of this discrepancy the experiment was repeated again this summer using both fresh eroding tundra peat and some that had been soaked in raw seawater for one week. The experimental procedures were those described for the 1978 experiments. In addition the ATP content of both fresh and raw seawater soaked eroding tundra peat has been measured to estimate the microbial biomass associated with this material.

Antibiotic experiments

An effort has been made to investigate the importance of microbial populations in determining the level of assimilation of peat by G. setosus. A series of experiments have been run in which either the peat or the amphipods or both have been treated with antibiotics (neomycin - $SO_4$ and streptomycin - $SO_4$ both at 50 mg/liter) for two days prior to the determination of assimilation efficiency. The following combinations have been run:

A. Antibiotic treated peat fed to untreated amphipods in Millipore filtered seawater containing no antibiotics.
B. Untreated peat fed to antibiotic treated amphipods in Millipore filtered seawater containing no antibiotics
C. Antibiotic treated peat fed to antibiotic treated amphipods in Millipore filtered seawater containing no antibiotics.
D. Antibiotic treated peat fed to untreated amphipods in Millipore filtered seawater containing antibiotics.
E. Untreated peat fed to untreated amphipods in Millipore filtered seawater containing no antibiotics.

Laminaria Organic Assimilation

A single experiment was conducted during the summer of 1978 to determine whether G. setosus could assimilate organic matter from kelp fragments. This experiment was repeated during this summer using pieces of Laminaria saccharina.

Other experiments scheduled to be completed before September 30.

As experiments are still being run while this report is being written the above list is not complete for the entire reporting period. We anticipate running at least one experiment in which peat has been soaked in Prudhoe Bay crude oil and the effect of this treatment on assimilation of peat by G. setosus is evaluated. The ATP content of coarse peat and of G. setosus feces derived from feeding on this fraction will be measured if time permits. It is hoped that this will provide information on the utilization of microbial populations which inhabit the peat. Finally we hope to begin some experiments on the assimilation of organic material from sediments by deposit feeding polychaete worms or bivalve molluscs.

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C. Stress-strain Relationships in Arctic Salt Marshes

1. Both sites were visited and experiments were assayed for plant cover; additionally, salinity, albedo and several measures of soil strength were determined for the four communities treated in 1977 and the two treated in 1978 at each site. A detailed analysis of these results is under way. Measurements were also made to give an estimate of the effects of goose grazing, and a vehicle track made early in 1978 and monitered that season was again studied. Whole plants of the five dominant species that had grown in the experimental sand overlays were removed carefully and dissected in the laboratory to estimate the ratio of above ground to below ground live weight.

2. Using the same analytical protocols of previous summers two columns of data (1979) may be added to the table of half-effects and the following conclusions tentatively drawn:
   a. The higher altitude communities of both locations showed clear signs of recovery from applied crude oil. This was especially apparent at the southern location.
   b. When an additional stress of a marginal location with high soil salinities was present (Prudhoe, C. sub-1977 application; Kotzebue, Puccinellia-1978 application), the toxic effects of oil were enhanced and showed poor recovery the second and third growing seasons. A detailed analysis of this interaction is is progress.
   c. The ratio of half-effect levels of oil at Prudhoe to those at Kotzebue indicates the more northern community is relatively over six times more sensitive to oil toxicity than the southern community. In comparison, sand in the north showed only two to three times the effect it did in the south and the band of kill in the northern community caused by vertical cuts was about double the width found in the south. The tolerance of closely spaced cuts, however, seems to be much greater in the north (and in the relatively lush Carex subspathacea/ramenskii sward at Kotzebue).
   d. The application of sand effects a clear recovery over the years, the emergent and invading plants enlarging their cover domains

so that increasingly deeper overlays are half-covered at the end of each successive season. The salinity stresses again seem to hinder this recovery.

Carex subspathacea (and C. ramenskii) will dominate at high siltation rates because of their extensive investment in rhizome. (Above ground parts are only one-fifth of the total live plant.) These may grow some ten centimeters $yr^{-1}$ buried 5-10 centimeters in turf organically toughened by their remains.

In contrast, Puccinellia with only half of its biomass underground in a simple root system can survive more severe salinity stresses and avoid deeply anerobic conditions by its prostrate segmenting leaf/stem structure above ground. In a stable or slowly eroding marsh it characteristically lives at the lowest levels, is the most sensitive to oil of all the saltmarsh plants, and is the most pleomorphic in response to nano-climates. Again, 5-10 centimeters of extension (more to the south) may be put out by this plant in surface runners which grow in late season. These float up into high waters because of air trapped in ribbed lipophilic young surfaces. These runners detach easily and, along with the abundant pieces of both dominant marsh plants cut and lost in the sloppy feeding of brant, are the primary mode of spread of Puccinellia. It will grow only if stranded in a region of low sedimentation.

e. The recovery from vertical cutting in otherwise relatively unstressed communities again showed improvement since last year: the kill bands narrowed except in the Puccinellia at Kotzebue. However, the half-effects, based on the communities' responses to intense cutting remain mixed and difficult to interpret.

3. Preliminary analyses of the soil strength measures showed a weakening of soil integrity at several scales as plant cover is reduced in high stress situations. These results, still in analysis, offer a strong link between the vigor of the plant community and the erosibility of the saltmarsh habitat.

TABLE 4. Half effects of stresses applied to Arctic salt marshes.

| STRESSOR | APPLIED -- 1977 | | | APPLIED -- 1978 | |
|---|---|---|---|---|---|
| | 1977 | 1978 | 1979 | 1978 | 1979 |
| | Half-effect -- liters $m^{-2}$ | | | | |
| OIL | | | | | |
| Prudhoe | | | | | |
| *Carex ursina* | 1.7 | .82 | 4.3 | .48 | .63 |
| *C. subspathacea* | .4 | .07 | .16 | .68 | 3.7 |
| Kotzebue | | | | | |
| *C. sub/ram* | [high | 4.7 | high | 5.7 | 17.0 |
| *Paccinellia* | 25] | .14 | 8.3 | .88 | .23 |
| RATION OTZ/PUO | ---- | 5.5 | 2 | 6.5 | 8.0 |
| | Half-effect -- cm | | | | |
| SAND | | | | | |
| Prudhoe | | | | | |
| *C. ursina* | 3.8 | 3.7 | 5.0 | 1.6 | 2.5 |
| *C. subspathacea* | 4.7 | 5.4 | 4.1 | 1.5 | 2.1 |
| Kotzebue | | | | | |
| *C. sub/ram* | 5.3 | 7.1 | 12.1 | 6.5 | 9.0 |
| *Puccinellia* | 5.1 | 5.2 | 7.8 | 3.9 | 3.3 |
| RATIO OTZ/PUO | 1.2 | 1.4 | 2.2 | 3.4 | 2.7 |
| | cuts · $cm^{-1}$; [or] cm kill band width<br>Half-effect | | | | |
| CUTS | | | | | |
| Prudhoe | | | | | |
| *C. ursina* | -- | -- | -- | 8.2[5] | .50[3.4] |
| *C. subspathacea* | .39 | .60 | -- | .61[5] | .69[2.0] |
| Kotzebue | | | | | |
| *C. sub/ram* | -- | -- | -- | .25[2] | .92[.02] |
| *Puccinellia* | .40 | .30 | .34 | .26[2] | .18[2.8] |
| RATIO OTZ/PUO | 1.0 | .5 | | .4[.4] | .9[.5] |

D. Preliminary results of the analysis of benthic samples made from RV ALUMIAK in 1978 are given in appended tables 6-26. The majority of these samples were made in the Stefansson Sound-Lefingwell Lagoon region inside the chain of Maguire-Stockton-McLure Islands. The biomass and number of organisims per $m^2$ in these samples is markedly higher than that in samples taken elsewhere in the Beaufort Sea at comparable depths. This difference is evident in Table 5 (below). Data on which Table 5 is based have been presented in our annual report for 1979 or are those in Tables 6-26. The 1977 data from the Canning River to Prudhoe Bay area were taken largely from outside the islands. Table 5 indicates that the benthic biomass inside Stefansson Sound-Lefingwell Lagoon is about 6 times that outside the barrier islands and that benthic organisms inside the islands are 6 times as numerous as they are outside.

V. PROBLEMS ENCOUNTERED: None

[1]Includes estimates from original contract (fiscal 1975) and modifications 1-10 (through fiscal 1979)

[2]Western Washington University Controller's Office estimates allowable overhead at $142,284.

[3]Amounts in parentheses are estimates of expenditures authorized for winter process studies.

[4]Estimated September expenditures are $12,000 of which $3,000 will be expenditures for winter process addendum to contract (mod. 10).

TABLE 5. Mean of stations means of wet weight biomass ($g \cdot m^{-2}$) and number ($n \cdot m^{-2}$) of macrobenthonic animals in the Beaufort Sea nearshore/inshore region in 1977 and 1978. The data are derived from catches of $0.1 m^2$ Smith-McIntyre grab screened through 0.423 NITEX. The 1977 stations were mostly from outside the barrier island chain and those visited in 1978 were mainly inside the islands.

| YEAR | East of Canning River | | Canning River to Prudhoe Bay | | Stump Island to Cape Halkett | | Cape Halkett to Point Barrow | |
|---|---|---|---|---|---|---|---|---|
| | 8 stations | | 12 stations-1977<br>15 stations-1978 | | 11 stations-1977<br>6 stations-1978 | | 13 stations | |
| | $g \cdot m^{-2}$ | $n \cdot m^{-2}$ | $g \cdot m^{-2}$ | $n \cdot m^{-2}$ | $g \cdot m^{-2}$ | $n \cdot m^{-2}$ | $g \cdot m^{-2}$ | $n \cdot m^{-2}$ |
| 1977 | 26.07 | 2,157.62 | 18.97 | 2,045.50 | 27.86 | 4,569.48 | 43.88 | 4,090.38 |
| 1978 | - | - | 121.05 | 11,885.88 | 48.81 | 3,130.58 | - | - |

TABLE 6. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station FØE(70°11.2' N; 146°05.7' W, 2.6 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 14.55 | 29.59 | 29.54 | 26.51 | 25.05 | 54 | Prionospio cirrifera, Ampharete vega, Tharyx spp, Chaetozone setosa, Terebellides stroemi |
| OLIGOCHAETES | 0.01 | 0.06 | 0.02 | 0.01 | 0.03 | 0 | |
| GASTROPODS | 0.30 | 0.46 | 0.56 | 0.19 | 0.38 | 1 | |
| BIVALVES | 9.26 | 28.34 | 1.14 | 9.04 | 11.95 | 26 | Portlandia arctica, Cyrtodaria kurriana |
| ISOPODS | | | | | | | |
| AMPHIPODS | 2.57 | 2.18 | 3.45 | 3.68 | 2.97 | 6 | Onisimus glacialis, Pontoporeia affinis, Pontoporeia femorata |
| OTHER | 6.70 | 4.45 | 8.79 | 4.50 | 6.11 | 13 | Priapulus caudatus, Halicryptus spinulosus, Ostracods |
| Σ | 33.39 | 65.08 | 43.50 | 43.93 | 46.48 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 7,978 | 20,769 | 16,031 | 19,356 | 16,033.50 | 55 | Prionospio cirrifera, Tharyx spp., Chone sp., Ampharete vega, Sphaerodoropsis minuta, Terebellides stroemi, Chaetozone setosa, Pygospio elegans, Spio fillicornis, Eteone longa |
| OLIGOCHAETES | 50 | 320 | 70 | 70 | 127.50 | 0 | |
| GASTROPODS | 40 | 70 | 100 | 100 | 77.50 | 0 | Cylichna occulta! |
| BIVALVES | 150 | 180 | 140 | 70 | 135.00 | 0 | Portlandia arctica |
| ISOPODS | | | | | | | |
| AMPHIPODS | 460 | 750 | 460 | 600 | 567.50 | 2 | Onisimus glacialis, Pontoporeia femorata, Pontoporeia affinis |
| OTHER | 410 | 3,700 | 36,384 | 7,317 | 11,952.75 | 41 | Halicryptus spinulosus, Diastylis sulcata, Ostracods! |
| Σ | 9,088 | 25,789 | 53,185 | 27,513 | 28,893.75 | 98 | |

REMARKS: silt, peat, sand

TABLE 7. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station F1A (70°11.1' N; 146°14.3' W, 3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | $g/m^2$ | | |
| POLYCHAETES | 9.31 | 29.93 | 25.32 | 18.00 | 20.64 | 45 | Ampharete vega, Terebellides stroemi, Scolecolepides arctius |
| OLIGOCHAETES | 0.01 | 0.01 | | 0.01 | 0.01 | 0 | |
| GASTROPODS | 0.23 | 0.25 | | | 0.12 | 0 | |
| BIVALVES | 2.21 | 2.96 | 5.90 | 0.51 | 2.90 | 6 | Portlandia arctica! |
| ISOPODS | 11.77 | | 16.55 | | 7.08 | 15 | Saduria entomon! |
| AMPHIPODS | 1.16 | 1.85 | 1.89 | 2.54 | 1.86 | 4 | Pontoporeia femorata |
| OTHER | 11.08 | 25.87 | 13.64 | 4.26 | 13.71 | 30 | Corymorpha sp., Halicryptus spinulosus, Ostracods, Hydroid, unk. |
| Σ | 35.77 | 60.87 | 63.30 | 25.32 | 46.32 | 100 | |
| | | | | | $n/m^2$ | | |
| POLYCHAETES | 2,039 | 6,161 | 2,441 | 4,791 | 3,858.00 | 37 | Scolecolepides arctius, Tharyx spp, Chone sp, Ampharete vega, Prionospio cirrifera, Pygospio elegans, Sphaerodoropsis minuta, Terebellides stroemi |
| OLIGOCHAETES | 30 | 30 | | 40 | 25.00 | 0 | |
| GASTROPODS | 20 | 10 | | | 7.50 | 0 | |
| BIVALVES | 60 | 40 | 70 | 90 | 65.00 | 1 | |
| ISOPODS | 10 | | 10 | | 5.00 | 0 | |
| AMPHIPODS | 70 | 1,000 | 90 | 150 | 327.50 | 3 | Pontoporeia femorata |
| OTHER | 13,268 | 5,114 | 5,646 | 1,010 | 6,259.50 | 59 | Corymorpha sp, Ostracods! Hydroid, unk., Halicryptus spinulosus, Mysis litoralis |
| Σ | 15,497 | 12,355 | 8.257 | 6,081 | 10,547.50 | 100 | |

REMARKS: sand peat

TABLE 8. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station F2A (70°12.1' N; 146"24.3' W, 3.5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 13.69 | 15.46 | 15.07 | 7.66 | 12.97 | 67 | Anaitides groenlandica, Travisia forbesii, Scolecolepides arctius, Chone sp, Ampharete vega, Maranzelleria sp., Chaetozone setosa |
| OLIGOCHAETES | 0.27 | 0.19 | 0.17 | | 0.16 | 1 | |
| GASTROPODS | | | | 0.09 | 0.02 | 0 | |
| BIVALVES | 3.73 | 2.17 | 0.94 | 1.20 | 2.01 | 10 | Liocyma fluctuosa, Boreacola vadosa |
| ISOPODS | | | | | | | |
| AMPHIPODS | 0.74 | 0.86 | | | 0.40 | 2 | |
| OTHER | 8.80 | 2.06 | 2.74 | 1.72 | 3.83 | 20 | Nemertean, unk, Molgula sp, Ostracods |
| Σ | 27.23 | 20.74 | 18.92 | 10.67 | 19.39 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 3,963 | 3,369 | 2,774 | 3,773 | 3,469.75 | 27 | Chaetozone setosa, Spio filicornis, Chone sp, Tharyx sp, Ampharete vega |
| OLIGOCHAETES | 1,440 | 1,690 | 700 | 1,780 | 1,402.50 | 11 | Tubificidae, Enchytraeidae! |
| GASTROPODS | | | | 10 | 2.50 | 0 | |
| BIVALVES | 1,820 | 1,850 | 790 | 1,530 | 1,497.50 | 12 | Boreacola vadosa! Liocyma fluctuosa |
| ISOPODS | | | | | | | |
| AMPHIPODS | 130 | 30 | | | 40.00 | 0 | |
| OTHER | 7,320 | 7,397 | 6,496 | 4,040 | 6,313.25 | 50 | Ostracods! |
| Σ | 14,673 | 14,336 | 10,760 | 11,133 | 12,725.50 | 100 | |

REMARKS: sand, peat

TABLE 9. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station F4B (70°12.1' N; 146° 41.4' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 49.98 | 18.30 | 26.49 | 108.41 | 50.80 | 13 | Haploscoloplos elongata, Prionospio cirrifera, Melanis loveni, Terebellides stroemi, Nereimyra aphroditoides, Lumbrinereis fragilis, Chone sp, Ampharete vega, Maldanidae, unk. |
| OLIGOCHAETES | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0 | |
| GASTROPODS | 0.35 | 0.40 | 0.90 | 12.13 | 3.45 | 1 | Amauropsis purpurea! |
| BIVALVES | 239.15 | 345.15 | 297.81 | 312.32 | 298.59 | 78 | Astarte Borealis! Liocyma fluctuosa, Cyrtodaria kurriana, Astarte monteguei, Portlandia arctica, Astarte sulcata, Macoma calcarea |
| ISOPODS | | | | | | | |
| AMPHIPODS | 1.80 | 0.27 | 1.72 | 0.23 | 1.01 | 0 | Atylus carinatus, Pontoporeia femorata! |
| OTHER | 39.47 | 21.85 | 23.78 | 22.61 | 26.93 | 7 | Anemone, unk., Nemerteans, Ostracods, Priapulus caudatus, Halicryptus spinulosus, Holothoroid, unk. |
| Σ | 330.76 | 385.98 | 350.70 | 455.61 | 380.77 | 99 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 8,711 | 8,059 | 7,595 | 6,420 | 7,696.25 | 49 | Chone sp., Tharyx spp., Nereimyra aphroditoides, Prionospio cirrifera, Aricidea suecica, Lumbrinereis fragilis, Terebellides stroemi, Ampharete vega, Spio filicornis, Maldanidae, unk., Exogone naidina, (continued in remarks) |
| OLIGOCHAETES | 20 | 60 | 20 | 10 | 27.50 | 0 | |
| GASTROPODS | 200 | 180 | 270 | 100 | 187.50 | 1 | Cylichna occulta |
| BIVALVES | 260 | 270 | 310 | 190 | 257.50 | 2 | Liocyma fluctuosa, Astarte borealis |
| ISOPODS | | | | | | | |
| AMPHIPODS | 270 | 70 | 190 | 50 | 145.00 | 1 | Pontoporeia femorata! |
| OTHER | 7,912 | 5,836 | 15,410 | 160* | 7,329.50 | 47 | Halicryptus spinulosus, Ostracods! |
| Σ | 17,373 | 14,475 | 23,795 | 6,930 | 15,643.25 | 99 | |

REMARKS: silt, sand, peat
*NO OSTRACODS!

(continued from above) Haploscoloplos elongata, Schistomeringos sp., Sphaerodoropsis minuta

TABLE 10. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station F5A (70° 10.7' N; 146° 52.5' W, 3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | $g/m^2$ | | |
| POLYCHAETES | 8.36 | 6.94 | 13.53 | 7.69 | 9.13 | 47 | Scolecolepides arctius, Chaetozone setosa, Prionospio cirrifera, Tharyx sp., Chone sp., Terebellides stroemi, Arenicola marine |
| OLIGOCHAETES | 0.01 | 0.02 | 0.16 | 0.12 | 0.08 | 0 | |
| GASTROPODS | | | | 0.04 | 0.01 | 0 | |
| BIVALVES | 14.61 | 3.04 | 1.13 | 6.26 | 6.26 | 32 | Portlandia arctica! |
| ISOPODS | 2.49 | 0.91 | | | 0.85 | 4 | Saduria entomon |
| AMPHIPODS | 0.46 | 1.12 | 1.65 | 2.24 | 1.37 | 7 | Boeckosimus affinis |
| OTHER | 1.54 | 1.15 | 1.15 | 2.93 | 1.69 | 9 | Mysis relicta, Ostracods! |
| Σ | 27.47 | 13.18 | 17.62 | 19.28 | 19.39 | 99 | |
| | | | | | $n/m^2$ | | |
| POLYCHAETES | 1,148 | 808 | 3,104 | 3,225 | 2,071.25 | 74 | Tharyx spp., Chaetozone setosa, Prionospio cirrifera, Scolecolepides arctius, Ampharete vega, Chone sp. |
| OLIGOCHAETES | 10 | 30 | 360 | 260 | 165.00 | 6 | Tubificidae, unk! |
| GASTROPODS | | | | 30 | 7.50 | 0 | |
| BIVALVES | 60 | 30 | 60 | 160 | 77.50 | 3 | |
| ISOPODS | 10 | 10 | | | 5.00 | 0 | |
| AMPHIPODS | 30 | 30 | 70 | 110 | 60.00 | 2 | |
| OTHER | 70 | 140 | 400 | 1,090 | 425.00 | 15 | Nemerteans, unk, Halicryptus spinulosus, Ostracods! |
| Σ | 1,328 | 1,048 | 3,994 | 4,875 | 2,811.25 | 100 | |

REMARKS: silt, sand, peat

TABLE 11. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station GØA (70° 14.0' N; 147° 06.0' W, 6 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 17.81 | 34.81 | 22.47 | 29.28 | 26.09 | 8 | Praxillella praetermissa, Cirrophorus sp, Maldanidae, unk., Ampharete vega, Microclymene pacifica, Nephtys ciliata, Amphicteis sundevalli, Terebellides stroemi, Ampharete acutifrons, Tharyx sp., Euchone analis, Prionospio cirrifera |
| OLIGOCHAETES | 0.74 | 0.26 | 0.18 | 0.19 | 0.34 | 0 | |
| GASTROPODS | 0.22 | 7.26 | 0.22 | 0.68 | 2.10 | 1 | Plicifusus sp., Oenopida sp. |
| BIVALVES | 426.44 | 240.69 | 197.83 | 221.87 | 271.71 | 85 | Astarte borealis! Pandora glacialis, Liocyma fluctuosa, Astarte monteguei, Macoma calcarea |
| ISOPODS | 37.05 | 7.70 | | 5.93 | 12.88 | 4 | Saduria sibini, Saduria entomon! Saduria sibirica |
| AMPHIPODS | 1.08 | 1.67 | 0.43 | 0.70 | 0.97 | 0 | Atylus carinatus |
| OTHER | 8.09 | 3.29 | 1.92 | 2.32* | 3.91 | 1 | Molgula sp., Ostracods! Holothuroid unk, Priapulus caudatus |
| Σ | 491.43 | 295.68 | 223.05 | 260.97 | 318.00 | 99 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 8,041 | 10,988 | 9,190 | 7,260 | 8,869.75 | 30 | Cirrophorus sp., Exogone naidina, Tharyx spp., Lumbrinereis minuta, Prionospio cirrifera, Aricidea suecica, Microclymene pacifica, Apistobranchus tullbergi, Ampharete acutifrons, Haploscoloplos elongatus (continued in remarks) |
| OLIGOCHAETES | 1,600 | 830 | 400 | 320 | 787.50 | 3 | Tubificidae! |
| GASTROPODS | 40 | 150 | 60 | 70 | 80.00 | 0 | |
| BIVALVES | 330 | 220 | 260 | 80 | 222.50 | 1 | Astarte borealis! |
| ISOPODS | 1,190 | 160 | | 100 | 362.50 | 1 | Saduria sibini! Saduria sibirica! |
| AMPHIPODS | 60 | 230 | 140 | 370 | 200.00 | 1 | Pontoporeia femorata! |
| OTHER | 10,189 | 14,654 | 3,773 | 49,049 | 19,416.25 | 65 | Brachydiastylis resima, Leptognathia gracilis, Ostradocs! |
| Σ | 21,450 | 27,232 | 13,823 | 57,249 | 29,938.50 | 101 | |

REMARKS: silt, peat, sand

*(red algae - 42.38 g)

(continued from above) Praxillella praetermissa, Terebellides stroemi, Ampharete vega, Nereimyra aphroditoides, Brada villosa

TABLE 12. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station GØB (70° 12.6' N; 147° 00.0' W, 5.3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 24.68 | 23.52 | 19.75 | 24.03 | 23.00 | 15 | Haploscoloplos elongata, Amphicteis sunduvalli, Ampharete acutifrons, Terebellides stroemi, Prionospio cirrifera, Chone duneri, Maldanidae, unk., Tharyx sp. |
| OLIGOCHAETES | 0.08 | 0.31 | 0.31 | 0.26 | 0.24 | 0 | |
| GASTROPODS | 0.01 | 0.04 | | 0.65 | 0.18 | 0 | |
| BIVALVES | 117.38 | 122.49 | 86.41 | 116.10 | 110.60 | 72 | Astarte borealis! Portlandia arctica, Liocyma fluctuosa, Astarte sulcata, Macoma calcarea, Musculus discors |
| ISOPODS | | | | 18.24 | 4.56 | 3 | |
| AMPHIPODS | 7.45 | 4.96 | 2.05 | 8.32 | 5.70 | 4 | Haploops tubicula! |
| OTHER | 4.27 | 24.01 | 4.48 | 3.23 | 9.00 | 6 | Ostracods, Mysis sp., Halicryptus spinulosus, Nemerteans, unk., Priapulus caudatus |
| Σ | 153.87 | 175.33 | 133.00 | 170.93 | 153.28 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 5,250 | 10,714 | 10,835 | 8,800 | 8,899.75 | 61 | Prionospio cirrifera, Ampharete acutifrons, Cirrophorus sp., Aricidea suecica, Haploscoloplos elongata, Ampharete vega, Lumbrinereis fragilis, Exogone naidina, Terebellides stroemi, Allia sp., Tharyx spp., (continued in remarks) |
| OLIGOCHAETES | 410 | 1,080 | 1,250 | 750 | 872.50 | 6 | Tubificidae! |
| GASTROPODS | 10 | 60 | | 60 | 32.50 | 0 | |
| BIVALVES | 210 | 230 | 140 | 110 | 172.50 | 1 | |
| ISOPODS | | | | 10 | 2.50 | 0 | |
| AMPHIPODS | 270 | 730 | 490 | 170 | 415.00 | 3 | Haploops tubicula! |
| OTHER | 7,127 | 390 | 4,864 | 4,600 | 4,245.25 | 29 | Ostracods! Nemerteans, Brachydiastylis resima, Mysis sp. |
| Σ | 13,277 | 13,204 | 17,579 | 14,500 | 14,640.00 | 100 | |

REMARKS: silt, sand, peat

(continued from above) Chone duneri, Maldanidae, unk., Chone sp., Ophryotrocha sp., Schistomeringos sp., Sphaerodoropsis minuta, Nereimyra aphroditoides, Spio filicornis

TABLE 13. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station GØC (70° 15.5' N; 147°00.0' W, 5.3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 16.04 | 13.64 | 23.50 | 11.26 | 16.11 | 7 | Prionospio cirrifera, Aricidea suecica, Maldanidae, unk., Tharyx spp., Haploscoloplos elongata |
| OLIGOCHAETES | 2.01 | 1.15 | 1.59 | 0.41 | 1.29 | 1 | Tubificidae, unk! |
| GASTROPODS | 0.91 | 113.06 | 0.16 | 2.25 | 29.10 | 12 | Neptunea heros! Polinices sp, Natica sp. |
| BIVALVES | 77.30 | 143.01 | 354.00 | 141.25 | 178.89 | 73 | Astarte sulcata, Astarte borealis! Portlandia arctica, Macoma calcarea, Liocyma fluctuosa, (continued in remarks) |
| ISOPODS | 24.68 | 3.74 | 28.09 | | 14.13 | 6 | Saduria sibirica, Saduria sabini |
| AMPHIPODS | 1.68 | 2.78 | 4.57 | 2.79 | 2.96 | 1 | Pontoporeia femorata! |
| OTHER | 0.46 | 3.74 | 0.78 | | 1.23 | 1 | Halicryptus spinulosus, Anemone, unk. |
| Σ | 123.08 | 281.12 | 412.69 | 157.96 | 243.73 | 101 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 7,725 | 6,785 | 7,324 | 2,338 | 6,043.00 | 57 | Prionospio cirrifera, Aricidea suecica, Cirrophorus sp, Chone sp., Tharyx spp., Ophryotrocha sp., Sphaerodoropsis minuta |
| OLIGOCHAETES | 4,120 | 1,820 | 2,890 | 420 | 2,312.50 | 22 | Tubificidae, unk! |
| GASTROPODS | 60 | 20 | 90 | 10 | 45.00 | 0 | |
| BIVALVES | 530 | 570 | 710 | 430 | 560.00 | 5 | Portlandia arctica, Liocyma fluctuosa |
| ISOPODS | 40 | 40 | 50 | | 32.50 | 0 | |
| AMPHIPODS | 460 | 1,070 | 1,240 | 300 | 767.50 | 7 | Aceroides latipes, Melita formosa, Pontoporeia femorata! |
| OTHER | 110 | 60 | 3,097 | | 816.75 | 8 | Ostracods! |
| Σ | 13,045 | 10,365 | 15,401 | 3,498 | 10,577.25 | 99 | |

REMARKS: silt, sand, peat

(continued from above) Nucula belloti, Clinocardium sp, Thyasira fluctuosa, Astarte monteguei

TABLE 14. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station G2A (70° 17.5' N; 147°20.0' W, 5.3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | $g/m^2$ | | |
| POLYCHAETES | 6.50 | 6.33 | 9.62 | 9.52 | 7.99 | 11 | Marenzelleria sp., Terebellides stroemi |
| OLIGOCHAETES | 0.09 | 0.02 | 0.02 | 0.01 | 0.04 | 0 | |
| GASTROPODS | 0.18 | 0.03 | 0.46 | 2.33 | 0.75 | 1 | Polinices sp.! |
| BIVALVES | 5.64 | 123.36 | 84.41 | 22.33 | 58.94 | 83 | Liocyma fluctuosa, Thraciidae, unk., Travisia forbesi, Astarte Monteguei, Boreacola vadosa, Astarte borealis Astarte sulcata |
| ISOPODS | | | | | | | |
| AMPHIPODS | 0.17 | 2.86 | 4.30 | 0.33 | 1.92 | 3 | Acanthostepheia behringiensis! |
| OTHER | 0.82 | 0.47 | 0.60 | 2.30 | 1.05 | 1 | Mysis litoralis |
| Σ | 13.40 | 133.07 | 99.41 | 36.88 | 70.68 | 99 | |
| | | | | | $n/m^2$ | | |
| POLYCHAETES | 885 | 860 | 711 | 1,054 | 877.50 | 18 | Marenzelleria sp., Chone sp., Ampharete vega, Spio filicornis |
| OLIGOCHAETES | 1,000 | 410 | 300 | 130 | 460.00 | 10 | Enchytraeidae, unk.! |
| GASTROPODS | 20 | 10 | 30 | 20 | 20.00 | 0 | |
| BIVALVES | 1,380 | 1,670 | 2,300 | 3,710 | 2,265.00 | 47 | Boreacola vadosa! Liocyma fluctuosa, Thraciidae, unk., Astarte monteguei, Astarte borealis |
| ISOPODS | | | | | | | |
| AMPHIPODS | 210 | 160 | 320 | 210 | 225.00 | 5 | Corophium sp. |
| OTHER | 760 | 590 | 910 | 1,460 | 930.00 | 19 | Ostracods, Leptognathia gracilis |
| Σ | 4,255 | 3,700 | 4,571 | 6,584 | 4,777.50 | 99 | |

REMARKS: sand

TABLE 15. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station G3C (70° 16.0' N; 147° 38.0' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 13.29 | 16.11 | 57.24 | 18.57 | 26.30 | 18 | Anaitides groenlandica, Ampharete vega, Chaetozone setosa, Haploscoloplos elongata, Terebellides stroemi, Euchone analis, Tharyx spp., Maldanidae, unk. |
| OLIGOCHAETES | | | 0.02 | | 0.01 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 6.18 | 22.53 | 285.69 | 7.92 | 80.58 | 56 | Liocyma fluctuosa! Macoma sp., Astarte borealis! Macoma calcarea |
| ISOPODS | | 1.35 | | 121.89 | 30.81 | 21 | Saduria entomon! Saduria sp. |
| AMPHIPODS | 0.06 | 0.30 | 2.10 | 0.12 | 0.65 | 0 | Boeckosimus affinis |
| OTHER | 14.58 | 2.06 | 2.79 | 5.37 | 6.20 | 4 | Ostracods, Halicryptus spinulosus |
| Σ | 34.11 | 42.35 | 347.84 | 153.87 | 144.55 | 99 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 3,804 | 4,601 | 11,130 | 3,686 | 5,805.25 | 32 | Exogone niadina, Ampharete vega, Chone sp., Tharyx spp. Chaetozone setosa, Haploscoloplos elongatus, Prionospio cirrifera, Nereimyra aphroditoides, Lumbrinereis fragilis, Aricidea suecica, (continued in remarks) |
| OLIGOCHAETES | | | 30 | | 7.50 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 120 | 180 | 210 | 180 | 172.50 | 1 | Astarte borealis! Liocyma fluctuosa |
| ISOPODS | | * | | 60 | 15.00 | 0 | |
| AMPHIPODS | 60 | 90 | 150 | 60 | 90.00 | 0 | |
| OTHER | 26,847 | 7,737 | 631 | 13,950 | 12,291.25 | 67 | Ostracods! |
| Σ | 30,831 | 12,608 | 12,151 | 17,936 | 18,381.50 | 100 | |

REMARKS: sand, silt, peat

*fragment

(continued from above) Terebellides stroemi, Scolecolepides arctius, Maldanidae, unk., Lumbrinereis minuta, Exogone dispar

TABLE 16. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station G4A (70° 21.2' N; 147° 46.5'W, 5.6 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 18.79 | 15.15 | 8.14 | 2.17 | 11.06 | 36 | Melanis loveni, Marenzelleria sp., Scaligbregma inflatum, Ampharete acutifons, Arenicola sp. |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | 0.00 | | | | 0.00 | 0 | |
| BIVALVES | 13.43 | 0.93 | 59.49 | 0.36 | 18.55 | 60 | Astarte borealis, Liocyma fluctuosa, Cyrtodaria kurriana, Macoma loveni, Astarte monteguei |
| ISOPODS | | | | | | | |
| AMPHIPODS | 0.11 | 0.02 | 0.34 | 0.02 | 0.12 | 0 | |
| OTHER | 0.07 | 0.21 | 3.46 | 1.84* | 1.40 | 4 | Molgula sp! |
| Σ | 32.40 | 16.31 | 71.43 | 4.39 | 31.13 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 1,255 | 848 | 989 | 351 | 860.75 | 57 | Prionospio cirrifera, Chaetozone setosa, Maranzelleria sp. |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | 10 | | | | 2.50 | 0 | |
| BIVALVES | 120 | 70 | 260 | 30 | 120.00 | 8 | Astarte borealis |
| ISOPODS | | | | | | | |
| AMPHIPODS | 90 | 40 | 80 | 20 | 57.50 | 4 | |
| OTHER | 50 | 460 | 1,300 | 30 | 460.00 | 31 | Ostracods! |
| Σ | 1,525 | 1,418 | 2,629 | 431 | 1,500.75 | 100 | |

REMARKS: sand, silt (peat)

*0.27g red algae

TABLE 17. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station G5A(70° 29.8' N; 147° 53.0' W, 7 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 24.26 | 14.14 | 17.90 | 19.14 | 18.86 | 9 | Praxillella praetermissa, Travisia forbesii, Maldanidae unk., Tharyx sp., Sternaspis scutata, Maranzelleria sp. Haploscoloplos elongata |
| OLIGOCHAETES | | | 0.02 | 0.01 | 0.01 | 0 | |
| GASTROPODS | | | 1.56 | 0.04 | 0.04 | 0 | Solariella sp! |
| BIVALVES | 1.92 | 311.28 | 312.48 | 47.06 | 168.19 | 79 | Liocyma fluctuosa, Astarte borealis! Macoma moesta, Nucula bellotii, Macoma loveni |
| ISOPODS | 0.02 | | | | 0.01 | 0 | |
| AMPHIPODS | 0.04 | 0.26 | 0.12 | 0.28 | 0.18 | 0 | |
| OTHER | 40.62 | 2.40* | 33.56 | 21.06 | 24.41 | 12 | Bryozoan, Ostracods, Ascidian unk., Holothuroid unk., Diamphiodia sp., Golfingia sp. |
| Σ | 66.86 | 328.08 | 365.64 | 87.59 | 212.05 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 11,948 | 3,087 | 7,590 | 9.498 | 8,030.75 | 59 | Haploscoloplus elongatus, Aricidea suecica, Exogone naidina, Exogone dispar, Tharyx sp., Maldanidae unk., Cirrophorus sp., Ampharete vega, Lumbrinereis fragilis, Scoloplos armiger, (continued in remarks) |
| OLIGOCHAETES | | | 40 | 20 | 15.00 | 0 | |
| GASTROPODS | | | 40 | 20 | 15.00 | 0 | |
| BIVALVES | 220 | 140 | 420 | 260 | 260.00 | 2 | Astarte borealis! |
| ISOPODS | 20 | | | | 5.00 | 0 | |
| AMPHIPODS | 100 | 40 | 60 | 20 | 55.00 | 0 | |
| OTHER | 6,220 | 1,380 | 1,480 | 11,480 | 5,140.00 | 38 | Ostracods, Nemerteans, Brachydiastylis resima, Leptognathia gracilis |
| Σ | 18,508 | 4,647 | 9,630 | 21,298 | 13,520.75 | 99 | |

REMARKS: sand, gravel, silt, peat

*(Kelp - 485.52 g)

(continued from above) Schistomeringos sp., Chaetozone setosa, Ampharete acutifrons, Chone sp, Microclimene sp, Aristobranchus tullbergi, Prionospio cirrifera

TABLE 18. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station HØB (70° 24.3' N; 148° 06.6' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 15.46 | 11.04 | 13.46 | 9.64 | 12.40 | 14 | Anaitides groenlandica, Maranzelleria sp., Travisia sp. |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | 0.08 | | 0.03 | 0.11 | 0.06 | 0 | |
| BIVALVES | 0.19 | 0.85 | 0.07 | 1.30 | 0.60 | 1 | Liocyma fluctuosa |
| ISOPODS | | | | | | | |
| AMPHIPODS | 7.49 | 0.03 | 0.08 | 0.03 | 1.91 | 2 | |
| OTHER | 146.79* | 34.00 | 84.14 | 33.71 | 74.66 | 83 | Ascidian unk! Molgula sp! Holothuroid! Ostracods |
| Σ | 170.01 | 45.92 | 97.78 | 44.79 | 89.63 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 1,340 | 935 | 1,874 | 1,096 | 1,311.25 | 15 | Maranzelleria sp., Prionospio cirrifera, Spio filicornis, Ampharete vega, Tharyx sp., Chaetozone setosa, Exogone naidina, Sphaerodoropsis minuta |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | 30 | | 30 | 30 | 22.50 | 0 | |
| BIVALVES | 60 | 30 | 50 | 110 | 62.50 | 1 | |
| ISOPODS | | | | | | | |
| AMPHIPODS | 140 | 70 | 120 | 20 | 87.50 | 1 | Monoculopsis longicornis |
| OTHER | 370 | 150 | 28,612 | 430 | 7,390.50 | 83 | Molgula sp! Holothuroid, unk., Ostracods! |
| Σ | 1,940 | 1,185 | 30,686 | 1,686 | 8,874.25 | 100 | |

REMARKS: sand, silt, gravel

*algae - 13.88 g (kelp & Opuntiella)

TABLE 19. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station H3G (70° 25.7' N; 148° 32.4' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | $g/m^2$ | | |
| POLYCHAETES | 18.64 | 2.92 | 20.88 | 15.20 | 14.41 | 97 | Ampharete vega, Terebellides stroemi, Tharyx sp., Chone sp., Maldanidae, unk., Aricidea suecica, Schistomeringos sp. |
| OLIGOCHAETES | 0.01 | | | 0.03 | 0.01 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | | 0.04 | | | 0.01 | 0 | |
| ISOPODS | | | | | | | |
| AMPHIPODS | | | 0.02 | | 0.00 | | |
| OTHER | 0.01 | 0.02 | | 1.48 | 0.38 | 3 | Mysis sp. |
| Σ | 18.66 | 2.98 | 20.90 | 16.71 | 14.81 | 100 | |
| | | | | | $n/m^2$ | | |
| POLYCHAETES | 2,538 | 2,335 | 2,486 | 2,165 | 2,380.75 | 97 | Chone sp., Tharyx sp., Ampharete vega, Schistomeringos sp. |
| OLIGOCHAETES | 20 | | | 40 | 15.00 | 1 | |
| GASTROPODS | | | | | | | |
| BIVALVES | | 10 | | | 2.50 | 0 | |
| ISOPODS | | | | | | | |
| AMPHIPODS | | | 20 | | 5.00 | 0 | |
| OTHER | 140 | 10 | | 20 | 42.50 | 2 | Ostracods |
| Σ | 2,698 | 2,355 | 2,505 | 2,225 | 2,445.75 | 100 | |

REMARKS: gravel, silt, sand

TABLE 20. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station H3H(70° 30.2' N; 148° 32.4' W, 10 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 3.76 | 8.70 | 3.82 | 2.57 | 4.71 | 18 | Prionospio cirrifera, Scolecolepides arctius |
| OLIGOCHAETES | 0.07 | 0.18 | 0.09 | 0.01 | 0.09 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 13.17 | 29.36 | 24.77 | 9.49 | 19.20 | 75 | Macoma calcarea, Portlandia arctica |
| ISOPODS | | | 2.31 | 2.46 | 1.19 | 5 | Saduria sabini |
| AMPHIPODS | 0.02 | | 0.03 | | 0.01 | 0 | |
| OTHER | 0.13 | 0.03 | 1.29 | | 0.36 | 1 | Ostracods, unk! |
| Σ | 17.15 | 38.27 | 32.31 | 14.53 | 25.56 | 99 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 1,713 | 2,925 | 1,635 | 1,030 | 1,825.75 | 61 | Prionospio cirrifera, Cossura longocirrata, Tharyx sp, Chone sp., Aricidea suecica |
| OLIGOCHAETES | 330 | 420 | 190 | 40 | 245.00 | 8 | Tubificidae! |
| GASTROPODS | | | | | | | |
| BIVALVES | 290 | 320 | 350 | 30 | 247.50 | 8 | Portlandia arctica |
| ISOPODS | | | 10 | 10 | 5.00 | 0 | |
| AMPHIPODS | 20 | | 10 | | 7.50 | 0 | |
| OTHER | 120 | 30 | 2,570 | | 680.00 | 23 | Ostracods! |
| Σ | 2,473 | 3,695 | 4,765 | 1,110 | 3,010.75 | 100 | |

REMARKS:

TABLE 21. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station I3H (70° 33.8' N; 149° 30.0' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D* | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 0.02 | 3.09 | 0.01 | | 1.04 | 4 | Antionella sarsi! |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | | | | | | | |
| BIVALVES | | | | | | | |
| ISOPODS | 56.10 | 20.36 | | | 25.49 | 96 | Saduria entomon! |
| AMPHIPODS | | | 0.00 | | 0.00 | 0 | |
| OTHER | 0.03 | | 0.28 | | 0.10 | 0 | |
| Σ | 56.15 | 23.45 | 0.29 | | 26.63 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 50 | 30 | 10 | | 30.00 | 60 | |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | | | | | | | |
| BIVALVES | | | | | | | |
| ISOPODS | 10 | 10 | | | 6.67 | 13 | |
| AMPHIPODS | | | 10 | | 3.33 | 7 | |
| OTHER | 20 | | 10 | | 10.00 | 20 | |
| Σ | 80 | 40 | 30 | | 50.00 | 100 | |

REMARKS: gravel, sand, silt

*One grab sample inadvertently discarded.

TABLE 22. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station H4A(70° 27.5' N; 148° 43.3' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 9.24 | 19.50 | 10.08 | 13.32 | 13.04 | 90 | Scolecolepides arctius, Ampharete vega |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | | | | | | | |
| BIVALVES | | | | | | | |
| ISOPODS | | | | | | | |
| AMPHIPODS | 0.21 | 1.77 | 2.16 | | 1.04 | 7 | Onisimus litoralis, Boeckosimus affinis |
| OTHER | 0.06 | 1.23 | | 0.42 | 0.43 | 3 | Mysis relicta |
| Σ | 9.51 | 22.50 | 12.24 | 13.74 | 14.50 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 375 | 1,095 | 618 | 650 | 684.50 | 93 | Scolecolepides arctius, Prionospio cirrifera, Chone sp., Ampharete vega |
| OLIGOCHAETES | | | | | | | |
| GASTROPODS | | | | | | | |
| BIVALVES | | | | | | | |
| ISOPODS | | | | | | | |
| AMPHIPODS | 30 | 60 | 20 | | 27.50 | 4 | |
| OTHER | 30 | 60 | | 20 | 27.50 | 4 | |
| Σ | 435 | 1,215 | 638 | 670 | 739.50 | 101 | |

REMARKS: sand, silt

TABLE 23. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station I3G (70° 34.5' N; 149° 30.0' W, 10 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C* | D* | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | g/$m^2$ | | |
| POLYCHAETES | 4.13 | 2.02 | | | 3.08 | 5 | Prionospio cirrifera |
| OLIGOCHAETES | 0.00 | | | | 0.00 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 1.27 | 1.95 | | | 1.61 | 3 | Portlandia arctica! |
| ISOPODS | 105.17 | | | | 52.59 | 85 | Saduria entomon! |
| AMPHIPODS | | 0.13 | | | 0.07 | 0 | |
| OTHER | 0.13 | 8.80 | | | 4.47 | 7 | Nemertean, unk! |
| Σ | 110.70 | 12.90 | | | 61.82 | 100 | |
| | | | | | n/$m^2$ | | |
| POLYCHAETES | 2,110 | 1,990 | | | 2,050.00 | 76 | Prionospio cirrifera, Tharyx sp. |
| OLIGOCHAETES | 20 | | | | 10.00 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 90 | 450 | | | 270.00 | 10 | Axinopsida orbiculata |
| ISOPODS | 30 | | | | 15.00 | 1 | |
| AMPHIPODS | | 20 | | | 10.00 | 0 | |
| OTHER | 270 | 440 | | | 355.00 | 13 | Ostracods! |
| Σ | 2,520 | 2,900 | | | 2,710.00 | 100 | |

REMARKS: silt, clay, sand, peat

*Abandoned station after 2 grabs because of drifting ice.

TABLE 24. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station JØB (70° 30.9' N; 150' 01.9' W, 3 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 44.59 | 30.50 | 19.77 | 26.82 | 30.42 | 26 | Scolecolepides arctius! Arenicola glacialis, Ampharete vega, Tharyx sp., Arenicola sp. |
| OLIGOCHAETES | 0.19 | 0.22 | 0.44 | 0.46 | 0.33 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 66.31 | 74.85 | 76.99 | 93.29 | 77.86 | 66 | Cyrtodaria kurriana! Portlandia arctica |
| ISOPODS | 3.32 | | 0.24 | | 0.89 | 1 | Saduria sp. |
| AMPHIPODS | 3.45 | 3.02 | 4.69 | 5.94 | 4.28 | 4 | Pontoporeia affinis, Pontoporeia femorata |
| OTHER | 7.40 | 5.10 | 2.68 | 0.57 | 3.94 | 3 | Halicryptus spinulosus, Nemertean, unk! |
| Σ | 125.26 | 113.69 | 104.81 | 127.08 | 117.71 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 1,860 | 1,910 | 1,628 | 2,135 | 1,883.25 | 34 | Scolecolepides arctius! Tharyx spp., Chone sp., Ampharete vega |
| OLIGOCHAETES | 280 | 410 | 540 | 590 | 455.00 | 8 | Tubificidae, unk! |
| GASTROPODS | | | | | | | |
| BIVALVES | 1,090 | 1,220 | 1,060 | 930 | 1,075.00 | 19 | Cyrtodaria kurriana! Portlandia arctica |
| ISOPODS | 0.50* | | 10 | | 2.63 | 0 | Aceroides latipes |
| AMPHIPODS | 1,320 | 1,030 | 1,360 | 1,690 | 1,350.00 | 24 | Pontoporeia femorata, Pontoporeia affinis |
| OTHER | 220 | 1,867 | 250 | 989 | 831.50 | 15 | Diastylis sulcata, Ostracods |
| Σ | 4,771 | 6,437 | 4,848 | 6,334 | 5,597.50 | 100 | |

REMARKS: silt, peat

*fragments

TABLE 25. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station J1A (70° 33.1' N; 150° 14.0' W, 5 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 33.97 | 40.62 | 15.02 | 21.72 | 27.83 | 63 | Ampharete vega, Scolecolepides arctius, Prionospio cirrifera |
| OLIGOCHAETES | 0.29 | 0.03 | 0.01 | 0.02 | 0.09 | 0 | |
| GASTROPODS | | | | | | | |
| BIVALVES | 1.03 | 2.88 | 16.76 | 0.89 | 5.39 | 12 | Cyrtodaria kurriana |
| ISOPODS | | 8.79 | | 18.02 | 6.70 | 15 | Saduria entomon! |
| AMPHIPODS | 3.40 | 4.14 | 0.94 | 1.77 | 2.56 | 6 | Boeckosimus affinis, Pontoporeia femorata |
| OTHER | 1.13 | 2.43 | 2.54 | 0.46 | 1.64 | 4 | Diastylis sulcata, Nemertean, unk. |
| Σ | 39.82 | 58.89 | 35.27 | 42.88 | 44.22 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 6,934 | 3,525 | 1,123 | 1,768 | 3,337.50 | 65 | Chone sp., Tharyx spp., Prionospio cirrifera, Ampharete vega, Scolecolepides arctius, Sphaerodoropsis minuta, Capitellidae, unk., Schistomeringos sp. |
| OLIGOCHAETES | 570 | 120 | 40 | 40 | 192.50 | 4 | Tubificidae unk! |
| GASTROPODS | | | | | | | |
| BIVALVES | 30 | 150 | 100 | 30 | 77.50 | 2 | Cyrtodaria kurriana |
| ISOPODS | | 10 | | 20 | 7.50 | 0 | |
| AMPHIPODS | 260 | 270 | 60 | 140 | 182.50 | 4 | Pontoporeia femorata |
| OTHER | 270 | 4,050 | 860 | 110 | 1,322.50 | 26 | Diastylis sulcata, Halicryptus spinulosus, Ostracods! |
| Σ | 8,046 | 8,125 | 2,183 | 2,108 | 5,120.00 | 99 | |

REMARKS: silt, clay, peat

TABLE 26. 1978 ALUMIAK DATA: Wet weight biomass and number of individuals of six categories of macrobenthonic animals/$m^2$ at Station J2C (70° 35.5' N; 150° 25.0' W, 10 m depth) in August, 1978. Data are derived from catch of 0.1 $m^2$ Smith-McIntyre grab screened through 0.423 mm Nitex. Principal species are those represented in the sample by either 1.0 g of wet weight biomass or 100 individuals/$m^2$ in at least one sample. If followed by !, the species accounted for virtually all or the number of mass of that taxonomic category in at least one sample.

| TAXONOMIC CATEGORY | SAMPLE A | B | C | D | $\bar{X}$ | % OF TOTAL | PRINCIPAL SPECIES |
|---|---|---|---|---|---|---|---|
| | | | | | | $g/m^2$ | |
| POLYCHAETES | 13.02 | 15.57 | 3.37 | 3.15 | 8.78 | 38 | Nephtys ciliata, Prionospio cirrifera |
| OLIGOCHAETES | 0.00 | 0.07 | | | 0.02 | 0 | |
| GASTROPODS | 0.04 | | 0.41 | | 0.11 | 0 | |
| BIVALVES | 15.74 | 22.98 | 6.99 | 0.23 | 11.49 | 50 | Liocyma fluctuosa, Portlandia arctica, Portlandia intermedia, Astarte sulcata |
| ISOPODS | 1.43 | 3.75 | | | 1.30 | 6 | Saduria sabini! |
| AMPHIPODS | 0.25 | 1.13 | 0.23 | 0.05 | 0.42 | 2 | Boeckosimus affinis |
| OTHER | 1.62 | 1.30 | 0.53 | 0.11 | 0.89 | 4 | Mysis litoralis |
| Σ | 32.10 | 44.80 | 11.53 | 3.54 | 22.99 | 100 | |
| | | | | | | $n/m^2$ | |
| POLYCHAETES | 2,908 | 4,513 | 1,498 | 761 | 2,420.00 | 53 | Prionospio cirrifera, Tharyx spp., Chone sp., Capitella capitata |
| OLIGOCHAETES | 10 | 160 | | | 42.50 | 1 | Tubificidae! |
| GASTROPODS | 10 | | 10 | | 5.00 | 0 | |
| BIVALVES | 710 | 1,030 | 810 | 60 | 652.50 | 14 | Portlandia intermedia, Portlandia arctica, Axinopsida orbiculata |
| ISOPODS | 20 | 30 | | | 12.50 | 0 | |
| AMPHIPODS | 50 | 60 | 50 | 20 | 45.00 | 1 | |
| OTHER | 370 | 4,227 | 879 | 80 | 1,389.00 | 30 | Ostracods! Mysis litoralis |
| Σ | 4,078 | 10,020 | 3,247 | 921 | 4,566.50 | 99 | |

REMARKS: silt, clay, peat

Contract 03-5-022-81
Research Unit 356
October 1 to December 31, 1979
8 Pages

# QUARTERLY REPORT

## Environmental Assessment of Selected Habitats in Arctic Littoral Systems

December 20, 1979

A. C. Broad
Kenneth H. Dunton
D. E. Schneider

I. TASK OBJECTIVES: During the first quarter of fiscal 1980, RU356 had three task objectives:

A. Continued investigation of the Stefansson Sound boulder patches including observations of growth of specific elements of the biota and of environmental factors of the region;

B. Continued laboratory experiments designed to evaluate the responses of shallow water Beaufort Sea invertebrates to environmental conditions and to the effects of these stresses on tolerance of crude oil; and

C. Laboratory analysis of samples collected in the Beaufort Sea nearshore and inshore regions in 1978 and of samples from the Chukchi Sea nearshore taken in 1977.

II. FIELD OR LABORATORY ACTIVITIES

A. Schedule of Field Activities:

1. Messrs. Hanes and Yackley were at NARL Barrow from October 23 to the end of the quarter except as noted below. Messrs. Dunton, Cinkovich, and Olson were at Deadhorse from November 10 to 26, Mr. Hanes from November 11 to 25, Mr. Yackley from November 15 to 25, and Ms. Schonberg from November 17 to 26. Dr. Schneider was at NARL from December 8 to 12.

a. November 10: dive team arrives in Deadhorse in p.m.

b. November 11: Locate pinger at the Exxon Ice Island site and set up field camp for diving. Travel by NOAA helicopter. Hanes arrives in evening from Barrow.

c. November 12-13: Divers survey Exxon Ice Island site at two locations: at the geographic center and 467 feet west of center. Travel by NOAA helicopter.

d. November 14: Locate pingers at DS-11 with the assistance of Reimnitz and Barnes (RU-205). Divers (Reimnitz and Olson) locate DS-11 pinger, Mathew's pinger (RU-526) and tripod belonging to Larson (RU-529). Travel by NOAA helicopter.

e. November 15: A joint effort between RU-356, RU-205 and RU-529 commences to establish an ice camp (set up NARL parcoll and break down Exxon camp) and retrieve Larson's tripod and Mathew's equipment. Travel by NOAA helicopter. Yackley (RU-356/Schneider) arrives from Barrow.

f. November 16-17: No work completed. Fog and snow prohibit flying. Schonberg arrives in Deadhorse.

g. November 18: Work continues at DS-11. Parcoll installation completed. Travel by ERA 212 helicopter.

h. November 19: No work completed. High winds and low visibility prevent the ERA helicopter from landing at DS-11.

i. November 20: Tripod and Mathew's equipment retrieved by Divers. RU-356 commences benthic studies at DS-11. Travel by ERA helicopter.

j. November 21: Benthic studies continue. Divers collect a few ice samples for Osterkamp (RU-253). Travel by ERA helicopter.

k. November 22: No work completed. Poor visibility, unable to use helicopter.

l. November 23-24: Continue and complete diving operation at DS-11. Collect organisms for RU-356/Schneider. Parcoll taken down on November 24 after diving. Travel by ERA helicopter.

m. November 25: Ship parcoll to Deadhorse and pack at Mukluk camp for winter. Dive at Exxon Ice Island #3, 300 meters west of the center. Travel by ERA helicopter. Hanes and Yackley depart Deadhorse for Barrow.

n. November 26: Dive team departs Deadhorse in am.

B. Scientific Party (except for contract divers, all of Western Washington University)

1. Principal Investigator, A. C. Broad (not on salary)

2. Co-Principal Investigators:

   a. D. E. Schneider (not on salary)

   b. Ken Dunton

3. Laboratory Supervisor, Helmut Koch

4. Marine Technician, James Hanes

5. Research Aides:

   a. Mark Childers
   b. Susan Schonberg (half time)
   c. Richard Yackley (after October 15)
   d. Jonathan Zehr (hourly wages)

6. Computer Programmer, Evelyn Albrecht (hourly wages)

7. Laboratory Helpers (hourly wages)

   a. James Bock
   b. Susan Burgdorff
   c. Kara Cameron
   d. Dawn Christman
   e. Geoffrey Pounds
   f. Russell Thorson

8. Work study students (no cost to contract)
    a. Sandra Bohenstiehl
    b. Gary Smith
9. Divers (on contract)
    a. Eugene Cinkovich
    b. John Olson
10. Contract help in laboratory, Sandra Bohenstiehl

C. Methods: All methods have been reported previously or are referred to in an appended section of results.

D. Sample Localities
1. Observations at the Exxon Ice Island Site were made north of Prudhoe Bay (70°23.5'N; 148°17.2'W).
2. Observations in Stefansson Sound were made at our Dive Site 11 (70°19.25'N, 147°35.1'W).
3. Animals for experiments were collected at DS-11 and in Elson Lagoon.

E. Data Collected
1. The following data and/or samples were collected in Stefansson Sound, DS-11.
    a. Data on the growth of Laminaria solidungla since August.
    b. Quantitative benthic samples of the boulder patch infauna.
    c. Grain samples of the sea floor, under boulders and between boulders.
    d. Data on the salinity, temperature, visibility and currents during the sampling period.
    e. Data on the biomass and dry weight of L. solidungula and L. saccharina.
    f. Algal samples were collected for laminarin, mannitol and nitrate analyses.
    g. Live flora and fauna were shipped to Bellingham for taxonomic study and observation.
2. Due to the unfavorable ice conditions for collecting, most of the efforts of the group at NARL this Fall have involved construction of equipment such as amphipod traps and activity monitoring chambers, and working out experimental procedures for the upcoming experiments. Recent field activities have involved making a series

of grab samples in Elson Lagoon in order to locate a suitable site for a dive hut. No experiments have been completed, but the following are in progress or soon will be.

a. Quantitative activity monitoring of selected epibenthic species exposed to hypersaline conditions and crude oil dispersions. Collections of Anonyx nugax, Boeckosimus affinis, and Saduria entomon have been made and experiments with these are in progress. As soon as diving operations can be started, activity of Mysis litoralis will also be investigated.

b. Oxygen consumption of common benthic species from Elson Lagoon at different salinities and crude oil dispersions. Initial runs have already been made on Liocyma fluctuosa and a common orbiniid polychaete (species yet to be determined). As soon as diving operations can begin in Elson Lagoon other species will be investigated.

c. Tolerance experiments on benthic species exposed to hypersaline conditions and crude oil dispersions will be initiated as soon as diving operations in Elson Lagoon commence. These experiments should be underway before the end of December.

F. Milestone Chart. Tapes of data for our teams 47 and 18 (see Table 1 of September 21, 1979, Quarterly Report) have been sent to NODC. The data from team 38 will be sent in January, 1980 instead of December, 1979. Sorting of samples from teams 17 and 37 has been completed (except plankton) and identification of the material is ahead of schedule. These data may be sent to NODC before the July and September, 1980 predictions.

## III. RESULTS AND PRELIMINARY INTERPRETATIONS

A. Boulder Patch Biology: Up to date results of on-going in situ experiments will be presented in the annual report after the data have been analyzed and taxonomic work completed.

For the second consecutive year, both clean fast ice and extremely turbid ice characterized the ice canopy. Working in close association with Reimnitz and Barnes (RU 205), divers found the turbid ice to be associated with large-scale surface roughness. The turbid ice had a high concentration of fine-grained sediments and particulate matter that consisted of fragments of kelp and whole kelp plants and pebbles with attached marine life. Visibility measured less than 2 meters and a silt layer of 1 to 2 mm thick covered rocks and kelp fronds. The

mean linear growth of L. solidungula from August 1 to November 23 measured approximately 1.5 cm, equivalent to the increment of growth measured during the same period in 1978. Several experiments were initiated to determine the role of storage and translocation in the growth of this plant.

B. An appended report deals with benzo(a)pyrene hydroxylase activity levels in fish tissues.

V. PROBLEMS ENCOUNTERED: As noted above, weather and unusually late freeze-up hindered activities in the field. Problems in enzyme analyses are noted in the appendix.

APPENDIX 1.

# The Assay of Benzo(a)pyrene Hydroxylase in Beaufort Sea Fishes

A. C. Broad and Robert W. Carter

Payne and Penrose (1975) and Payne (1976) related levels of benzo(a)-pyrene hydroxylase activity found in gill and liver tissue of marine fish to ambient levels of petroleum hydrocarbons. We proposed the same analysis of tissues from Beaufort Sea fish to test the feasibility of the technique for our application and to establish some baseline data.

Materials and methods: Beaufort Sea fishes were collected during the R/V ALUMIAK cruise in 1978 by netting and with a hook and line. Smaller fishes (mainly arctic cod and four-horned sculpin) were frozen whole. A few large Arctic char were taken at Prudhoe Bay, and the livers and gills of these were frozen. At the end of the cruise, the fish were transferred to a freezer at the Naval Arctic Research Laboratory and, as soon thereafter as possible, to Bellingham, packed in dry ice and carried as personal baggage on a commercial flight. Despite all possible care being taken to insure against thawing, some deterioration of tissue was noted when the analysis was conducted, and it was assumed that the tissues had thawed at some time in transit or in storage.

In the winter of 1978, 38 large fish (3 species of cisco, humpback whitefish, and boreal smelt) were obtained from Jim Helmericks. The fish had been taken in the Colville River in November and frozen. They were transferred to Bellingham carried as personal baggage. Although these fish arrived in excellent condition, and no deterioration of the tissue was evident, they had been frozen for a matter of five to six months before the analysis was completed. Livers of the fish were removed without thawing, by chipping away the excess body with a hatchet.

For comparison, some fish were netted in Bellingham Bay and near the San Juan Islands (Whatcom and San Juan Counties, Washington). Livers of these fish were removed in the field and frozen in dry ice.

The enzyme isolation and assay procedures used were those of Nebert and Gelboin (1968), Holtzman and Rumack (1973), Conney, Miller and Miller (1957); and Kuntzman et al. (1966).

Results: The technique did not reveal enzyme activity in any of the Arctic fishes tested. All fish from Washington showed measurable levels of activity; those from Bellingham Bay were significantly ($P < 0.0025$, analysis of variance) higher than those from the presumably cleaner waters adjacent to the San Juan isalnds.

Discussion: The analysis for benzo(a)pyrene hydroxylase shows activity of mixed function oxidases (MFO) apparently induced by petroleum hydrocarbons and a variety of other substrates (see also Alvares, et al., 1967; Conney and Klutch, 1963; Conney, Miller and Miller, 1957; Dehlinger and Schimke, 1972; Fukami, et al., 1979; Gillette, 1963 and 1966; Kuntzman et al., 1966). The measurable levels of activity in Washington fishes may be related to petroleum, but are not necessarily so. The technique of analysis, however, as carried out in our laboratory, was adequate for the demonstration of MFO activity in fish livers, even in individuals from relatively clean water. Our failure to detect MFO activity in Arctic fish, therefore, may be attributed to extremely low levels of the enzyme or to its deterioration even though the tissues were hard frozen during the relatively long periods of time between capture and analysis. The former interpretation is consistent with the low level of development in the Beaufort, but the near impossibility of decreasing the interval between capture and analysis with our current sampling regime makes further work by RU356 and current resolution of this dilemma impractical.

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QUARTERLY REPORT

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1 April - 30 June 1979
Number of Pages: 24

# Beaufort Sea Plankton Studies

Rita A. Horner

1 July 1979

I. Abstract of Quarter's Accomplishments

Field studies were done in the Boulder Patch area of Stefansson Sound to determine the primary productivity of the ice algae and phytoplankton. Analysis of the zooplankton samples collected with the 505 μm mesh bongo net during the icebreaker cruise in August-September 1978 has been completed.

II. Task Objectives

The task objectives are to assess the winter density distribution and environmental requirements of zooplankton and phytoplankton in the nearshore areas of the Beaufort Sea in an integrated sampling effort with other RU's and to analyze data collected during the 1978 icebreaker cruise in the Beaufort Sea.

III. Field or Laboratory Activities

A. Ship or Field Trip Schedule

1. Dates: 12-20 May 1979
2. No vessel
3. Helicopter
4. NOAA, chartered ERA

B. Scientific Party

1. Rita Horner
2. Private Consultant
3. Field collection and sample analysis

C. Methods

1. Field sampling

All samples were collected by diver Jim Hanes, Western Washington University, Bellingham, WA., during two dives on each of four sampling days. The sampling site was a dive hole used by RU 526 divers and located about 100 m west of the parcoll set up at Dive Site 11 (RU 356).

Water samples were collected in 2 ℓ polyethylene bottles from just under the ice (0 m) and from 4 m. Portions of these samples were poured into 60 ml reagent bottles, two light and one dark bottle for each depth, and inoculated with 2 ml $Na_2H^{14}CO_3$ solution to determine the primary productivity of the water column. The samples were incubated *in situ* by attaching the bottles to a line suspended from the bottom of the ice. Another portion of the water sample was poured into a 250 ml jar and preserved with 5 to 10 ml 4% formaldehyde for a phytoplankton standing stock sample. The rest of the water sample, usually about 1.5 ℓ, was returned to the shore laboratory for further processing.

Experiments to determine *in situ* primary productivity of the sea ice community were done using combination incubation chamber - samplers (Clasby *et al.*, 1973; Alexander *et al.*, 1974). Two light and one dark chamber were

placed in the ice and inoculated with 2 ml $Na_2H^{14}CO_3$ solution. In order to keep the $^{14}C$ solution from freezing in the hypodermic syringes, each syringe filled with $^{14}C$ solution was placed in a plastic container partially filled with hot water which the diver then took down to the experimental site. Following inoculation, the samples were left to incubate for 3 to 4 hr.

The diver collected 3 to 5 additional ice cores using the combination samplers. These cores were placed in 250 ml darkened jars. One core was immediately preserved with 4% formaldehyde for a standing stock sample. The other cores were returned to the shore laboratory for further processing.

Following the incubation period, the diver retrieved the ice cores and water samples. The ice cores were transferred to 250 ml jars and preserved with 5 ml 4% formaldehyde to prevent further uptake of the isotope by the cells. The water samples were kept in the dark until they could be processed at the shore laboratory.

2. Laboratory

On return to the shore laboratory, 1 to 1.5 ℓ of the water samples was filtered through a 47 mm 0.45 µm HA Millipore filter. The filter was frozen for the determination of plant pigments. Some of the filtered water was put into a 250 ml polyethylene bottle for salinity determination and some was put into a 125 ml polyethylene bottle and frozen for nutrient determinations.

One of the extra ice cores was also filtered through a 47 mm, 0.45 µm Millipore filter and the filter frozen for plant pigment determinations. The remaining two or three ice cores were also filtered through 47 mm, 0.45 µm filters. This filter was also frozen for pigment determinations; the water was put into 125 ml polyethylene bottles. One bottle was frozen for nutrient determinations and one was used for salinity determinations.

The primary productivity samples were all filtered through 25 mm, 0.45 µm Millipore filters which were rinsed with 0.01 N HCl, and placed in labeled scintillation vials for determination of carbon uptake.

All samples were returned to Seattle for analysis. Water column and ice standing stock samples will be analyzed using the inverted microscope technique (Utermöhl, 1931). Nutrient samples were analyzed using autoanalyzer techniques (Strickland and Parsons, 1968). Primary productivity samples were analyzed in a Packard Tri-Carb Liquid Scintillation Spectrometer with Aquasol as the scintillation cocktail. Plant pigments were determined using fluorometric techniques (Strickland and Parsons, 1968).

D. Sample Location

All sampling was done at the Boulder Patch, 70°19'N, 147°34.4'W, in Stefansson Sound.

E. Data Collected or Analyzed

| Parameter | Number Collected | Number Analyzed * |
|---|---|---|
| Standing Stock | | |
| Water Column | 6 | 0 |
| Ice | 4 | 0 |
| Primary Producivity | | |
| Water Column | 18 | 18 |
| Ice | 12 | 12 |
| Nutrients | | |
| Water Column | 6 | 6 |
| Ice | 4 | 4 |
| Salinity | | |
| Water Column | 6 | 6 |
| Ice | 4 | 4 |
| Plant Pigments | | |
| Water Column | 6 | 6 |
| Ice | 8 | 8 |

* Samples analyzed, but values not calculated

F. Laboratory Activities - Seattle

Analysis of zooplankton samples collected with the 505 µm mesh bongo net during the 1978 icebreaker cruise has been completed (Table 1).

## IV. Results

Results from the spring sampling are not available at this time.

## VI. Preliminary Interpretation of Results

Results are not yet available.

## VI. Auxiliary Material

A. References

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Clasby, R. C., R. Horner, and V. Alexander. 1973. An in situ method for measuring primary productivity of Arctic sea ice algae. J. Fish. Res. Board Can. 30:835-838.

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Table 1. Abundance (number per 1000 $m^3$) of zooplankton taxa found in net hauls from the Beaufort Sea. All samples were collected with bongo nets, mesh size 505 µm. Where no number is present, no animals were found.

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A* | 1 | 3 | 4 | 5 | 6 | 7† | 8† |
| Coelenterata | | | | | | | | |
| Hydrozoa | | | | | | | | |
| *Aeginopsis laurentii* | | 60 | | 470 | 230 | 170 | 610 | 1000 |
| *Aglantha digitale* | 200000 | 720 | 12210 | 3510 | 2300 | 1190 | 16110 | 23700 |
| *Bougainvillia superciliaris* | | | | | | | | |
| *Calycopsis birulai* | | | | | 30 | | | |
| *Corymorpha flammea* | | | | 40 | 70 | 20 | | |
| *Coryne tubulosa* | 70 | 10 | | 20 | | 20 | | |
| *Cuspidella mertensii cf.* | | | | | | | | |
| *Cuspidella* sp. *cf.* | 40 | | | | | | | |
| *Melicertum campanula cf.* | 70 | | | | | | | |
| *Melicertum* sp. *cf.* | | | | | | | | |
| *Obelia* sp. *cf.* | 110 | | | | | | | |
| *Perigonimus vesicarius* | | 10 | | 130 | 200 | 40 | 60 | |
| *Perigonimus yoldia-arcticae* | | | | | | | | |
| *Perigonimus* spp. | | 10 | | | | 20 | 60 | 100 |
| *Plotocnide borealis cf.* | | | | 150 | 170 | 90 | | |
| *Rathkea octopunctata* | 40 | | 160 | | | | | |
| *Rathkea* sp. | 40 | | | | | | | |
| *Rathkea* sp. *cf.* | 70 | | | | | | | |
| unidentified Hydrozoa | 3460 | | | 110 | | 510 | | 50 |
| Scyphozoa - unidentified | | | | | | | | |
| Siphonophora - unidentified | | | | 20 | | | | |
| Ctenophora | | | | | | | | |
| *Beroë cucumis* | | | | | | | | |
| *Pleurobrachia pileus cf.* | 70 | 120 | | | 400 | 170 | 280 | 150 |

* First net haul taken; not at a station.
† Volume of water filtered has been estimated for these tows using ship speed x duration of tow x mouth area of the net.
§ Haul taken for George Divoky.

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A* | 1 | 3 | 4 | 5 | 6 | 7† | 8† |
| Polychaeta - unidentified larvae | 5710 | 180 | 1260 | 170 | 130 | 510 | 60 | 100 |
| Mollusca | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | |
| *Clione limacina* | 180 | 10 | | | | | 60 | 50 |
| *Spiratella helicina* | 360 | 70 | | 150 | 30 | 170 | 390 | 750 |
| unidentified Mollusca | 11430 | 60 | | | | 340 | | |
| unidentified mollusc larvae | | | | 230 | 70 | | | |
| Crustacea | | | | | | | | |
| Ostracoda | | | | | | | | |
| *Conchoecia borealis maxima* | | | | | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | 3430 | 600 | 2530 | 61020 | 12130 | 7660 | 670 | 150 |
| Calanoida - juveniles | | 14990 | 128000 | 45190 | 20130 | 103320 | 75220 | 1850 |
| Cyclopoida | 25140 | 60 | 420 | | | | | 50 |
| Harpacticoida | 40 | | | | | | | |
| unidentified nauplii | | | | | | | | |
| Cirripedia | | | | | | | | |
| Nauplii | 610 | 1430 | 2110 | | | 510 | 110 | |
| Cyprids | 140 | 120 | 840 | | | | | |
| Mysidacea | | | | | | | | |
| *Mysis litoralis* | | | | | | | | |
| *Mysis oculata* | | | | 20 | 100 | 20 | | |
| *Mysis relicta* | | | | | | | | |
| *Mysis* spp. | | | | | | 40 | | |
| Cumacea - unidentified | | | | | | 210 | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| *Apherusa glacialis* | | 160 | | 40 | | | 60 | 500 |
| *Apherusa glacialis cf.* | | | | | | | 60 | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A* | 1 | 3 | 4 | 5 | 6 | 7† | 8† |
| *Onisimus glacialis* | | 50 | | | | 40 | | |
| *Onisimus glacialis cf.* | | | | 90 | | | | |
| *Onisimus nanseni* | | | | | | | | |
| *Onisimus* sp. | | | | | | | | |
| unidentified Gammaridea | | 10 | | | | 110 | | |
| Hyperiidea | | | | | | | | |
| *Hyperia galba* | | 10 | | 40 | 100 | 20 | 170 | 50 |
| *Parathemisto abyssorum* | | 150 | | 40 | 300 | 470 | | 100 |
| *Parathemisto abyssorum cf.* | | | | | | | | |
| *Parathemisto libellula* | | 100 | 50 | 110 | 170 | 430 | | |
| *Scina* sp. | | | | | | | | |
| unidentified Hyperiidea | | 10 | | | 70 | 20 | | |
| unidentified Amphipoda | | | | | | | | |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa inermis* | | | | | | | | |
| *Thysanoëssa longipes* | | | | | | | | |
| *Thysanoëssa longipes cf.* | | | | | 30 | | | |
| *Thysanoëssa raschii* | | | | | | | | |
| unidentified furcilia | | 20 | | 20 | | 20 | 60 | |
| Decapoda | | | | | | | | |
| Anomura - unidentified zoea | | 40 | 50 | 20 | 30 | 130 | | |
| Brachyura | | | | | | | | |
| unidentified zoea | 140 | 50 | 160 | | 70 | 20 | 170 | 450 |
| Atelecyclidae | | | | | | | | |
| *Telmessus* sp. - megalopae | | | | | | | | |
| Oregoniinae | | | | | | | | |
| *Hyas* sp. - megalopae | | | | | | | | |
| Caridae | | | | | | | | |
| Crangonidae | | | | | | | | |
| Hippolytidae | | 40 | | 130 | 100 | 170 | | 100 |
| Pandalidae | | | | | | | | |
| *Pandalus borealis* IV | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers A* | 1 | 3 | 4 | 5 | 6 | 7† | 8† |
|---|---|---|---|---|---|---|---|---|
| *Pandalus goniurus* II | | | | | | 20 | | |
| *Pandalus* sp. IV | | | | | | | | |
| unidentified zoea | | | 420 | | | | | |
| Echinodermata - unidentified larvae | | | 420 | | | 20 | | |
| Appendicularia (Larvacea) | | | | | | | | |
| *Fritillaria borealis* | 524570 | 300 | 78320 | 1450 | 70 | 24000 | 16670 | 33700 |
| *Fritillaria* spp. | 14860 | 180 | 6740 | 90 | 1870 | | 560 | 950 |
| *Oikopleura labradoriensis* | | | 840 | | | | | |
| *Oikopleura vanhöffeni* | | 4900 | 2110 | 510 | | 9020 | 110 | |
| *Oikopleura* spp. | | 19040 | 420 | 1020 | 70 | 15150 | 1110 | 100 |
| Chaetognatha | | | | | | | | |
| *Eukrohnia hamata* | | | | 170 | | | | |
| *Sagitta elegans* | 9140 | 16840 | 13050 | 470 | 5030 | 8850 | 7670 | 5450 |
| unidentified Chaetognatha | 9140 | 2030 | 2110 | 90 | | | 4330 | 9600 |
| Pisces | | | | | | | | |
| Agonidae | | | | | | | | |
| *Aspidophoroides olriki* | | | 50 | | | | | |
| Cottidae | | | | | | | | |
| *Myoxocephalus quadricornis cf.* | | | | | | | | |
| Cyclopteridae | | | | | | | | |
| *Liparis koefoedi* | | | | | | | | |
| *Liparis* sp. | | 10 | | | | | | |
| Gadidae | | | | | | | | |
| *Boreogadus saida* | | | | | | | 60 | |
| unidentified Gadidae | | | | | | | | |
| Pleuronectidae | | | | | | | | |
| *Pleuronectes quadrituberculatus cf.* | 40 | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A* | 1 | 3 | 4 | 5 | 6 | 7† | 8† |
| Stichaeidae | | | | | | | | |
| *Lumpenus fabricii cf.* | | | | | | | | |
| *Lumpenus* sp. | | 10 | | | | | | |
| Other organisms | | | | | | | | |
| unidentified animals | 2290 | 190 | 8420 | 40 | | 230 | 330 | 250 |
| unidentified Foraminifera | | | | | | | | |
| unidentified invertebrate eggs | | | | | | | | |
| unidentified Nematoda | | | | 20 | | 60 | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 |
| **Coelenterata** | | | | | | | | |
| **Hydrozoa** | | | | | | | | |
| *Aeginopsis laurentii* | 190 | 100 | 1080 | 130 | 170 | 230 | 380 | 1120 |
| *Aglantha digitale* | 6570 | 4930 | 12760 | 35280 | 6960 | 2230 | 520 | 80 |
| *Bougainvillia superciliaris* | 20 | 20 | | 40 | | | | |
| *Calycopsis birulai* | | | | | 5 | | 50 | |
| *Corymorpha flammea* | | | | | | | | 80 |
| *Coryne tubulosa* | | | | | | | | 40 |
| *Cuspidella mertensii cf.* | | | | 10 | | | | |
| *Cuspidella* sp. *cf.* | | | | | 5 | | | |
| *Melicertum campanula cf.* | | | | | | | | |
| *Melicertum* sp. *cf.* | | | | | | | | |
| *Obelia* sp. *cf.* | | | | | | | | |
| *Perigonimus vesicarius* | | | | | | 90 | 290 | 230 |
| *Perigonimus yoldia-arcticae* | | | | | | | | |
| *Perigonimus* spp. | | 160 | | | | | | 80 |
| *Plotocnide borealis cf.* | | | | | | 270 | 140 | 190 |
| *Rathkea octopunctata* | | | | | | | | |
| *Rathkea* sp. | | | | | | | | |
| *Rathkea* sp. *cf.* | | | | | | | | |
| unidentified Hydrozoa | 50 | | | | 520 | 550 | 140 | 80 |
| Scyphozoa - unidentified | | 30 | | | | | | |
| **Siphonophora - unidentified** | | | | | 5 | | | |
| **Ctenophora** | | | | | | | | |
| *Beroë cucumis* | 20 | 20 | | | | | | |
| *Pleurobrachia pileus cf.* | 120 | 30 | | | | 230 | 50 | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 |
| Polychaeta - unidentified larvae | | | | 660 | 700 | 140 | | 120 |
| Mollusca | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | |
| *Clione limacina* | 140 | 100 | 50 | 140 | | 90 | 140 | 80 |
| *Spiratella helicina* | 260 | 100 | | 130 | | 140 | | 120 |
| unidentified Mollusca | | | | | | | | |
| unidentified mollusc larvae | | | | | | 180 | | 40 |
| Crustacea | | | | | | | | |
| Ostracoda | | | | | | | | |
| *Conchoecia borealis maxima* | | | | | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | 20 | 210 | 540 | 790 | 1040 | 21450 | 55240 | 19690 |
| Calanoida - juveniles | 900 | 8900 | 31890 | 16000 | 31130 | 41090 | 110860 | 208620 |
| Cyclopoida | | | | | 170 | | | |
| Harpacticoida | | | | | | | | |
| unidentified nauplii | | | | | | | | 80 |
| Cirripedia | | | | | | | | |
| Nauplii | 20 | 30 | 650 | | 350 | 320 | 330 | 310 |
| Cyprids | | | | | | | | |
| Mysidacea | | | | | | | | |
| *Mysis litoralis* | | | | | | 50 | | |
| *Mysis oculata* | | | | | | 50 | | |
| *Mysis relicta* | | | | | | | | |
| *Mysis* spp. | | | | | | | | |
| Cumacea - unidentified | | | | | | | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| *Apherusa glacialis* | | 70 | 10 | | | 50 | 50 | 80 |
| *Apherusa glacialis cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|
| *Onisimus glacialis* | | 30 | | | 10 | | | 120 |
| *Onisimus glacialis cf.* | | | | | | | | |
| *Onisimus nanseni* | | 30 | | | | | | |
| *Onisimus* sp. | | | | | | | | |
| unidentified Gammaridea | | | 10 | | | | | |
| Hyperiidea | | | | | | | | |
| *Hyperia galba* | | | 10 | | | | | |
| *Parathemisto abyssorum* | 20 | | 70 | 20 | 170 | 90 | 50 | 150 |
| *Parathemisto abyssorum cf.* | | | | | | | | |
| *Parathemisto libellula* | 50 | 190 | 40 | 30 | 80 | 270 | 330 | 230 |
| *Scina* sp. | | | | | | | | |
| unidentified Hyperiidea | | | | | | | | |
| unidentified Amphipoda | | | | | | 50 | | |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa inermis* | | | | 20 | | | 50 | |
| *Thysanoëssa longipes* | | | | 10 | | | | |
| *Thysanoëssa longipes cf.* | | | | | | | | |
| *Thysanoëssa raschii* | | | | 10 | | | | |
| unidentified furcilia | | | 40 | 20 | 5 | | | |
| Decapoda | | | | | | | | |
| Anomura - unidentified zoea | | | 30 | 20 | 50 | 90 | 50 | |
| Brachyura | | | | | | | | |
| unidentified zoea | 240 | 450 | 140 | 60 | 10 | | | |
| Atelecyclidae | | | | | | | | |
| *Telmessus* sp. - megalopae | | | 10 | | | | | |
| Oregoniinae | | | | | | | | |
| *Hyas* sp. - megalopae | | | 10 | | | | | |
| Caridae | | | | | | | | |
| Crangonidae | | | | | | | | |
| Hippolytidae | 50 | | 90 | 130 | 80 | 230 | 240 | 380 |
| Pandalidae | | | | | | | | |
| *Pandalus borealis* IV | | | | | 5 | | | |

Table 1. (continued)

| Taxon | Station Numbers 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|
| *Pandalus goniurus* II | | | | | | | | |
| *Pandalus* sp. IV | | | | | | | | |
| unidentified zoea | | | | | | | | |
| Echinodermata - unidentified larvae | | | | | | | | |
| Appendicularia (Larvacea) | | | | | | | | |
| *Fritillaria borealis* | 15900 | 4310 | 6380 | 6030 | 6090 | 3360 | 15240 | 7920 |
| *Fritillaria* spp. | 2950 | 760 | | | 520 | 2050 | 2190 | 230 |
| *Oikopleura labradoriensis* | | | | | | 500 | | |
| *Oikopleura vanhöffeni* | | | | | | 230 | 480 | 1540 |
| *Oikopleura* spp. | | | 220 | | 5390 | 410 | 1710 | 4920 |
| Chaetognatha | | | | | | | | |
| *Eukrohnia hamata* | | | | | 350 | 50 | | 80 |
| *Sagitta elegans* | 860 | 3830 | 19030 | 23480 | 19830 | 7180 | 860 | 380 |
| unidentified Chaetognatha | 4000 | 690 | | 6030 | 3130 | 50 | | 120 |
| Pisces | | | | | | | | |
| Agonidae | | | | | | | | |
| *Aspidophoroides olriki* | | 20 | | | | | | |
| Cottidae | | | | | | | | |
| *Myoxocephalus quadricornis cf.* | | | 10 | | | | | |
| Cyclopteridae | | | | | | | | |
| *Liparis koefoedi* | | | | | | | | 40 |
| *Liparis* sp. | | | | | | | | |
| Gadidae | | | | | | | | |
| *Boreogadus saida* | | | 50 | | 5 | | 50 | |
| unidentified Gadidae | | | 10 | | | | | 120 |
| Pleuronectidae | | | | | | | | |
| *Pleuronectes quadrituberculatus cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 |
| Stichaeidae | | | | | | | | |
| *Lumpenus fabricii cf.* | | | | | 5 | | | |
| *Lumpenus* sp. | | | | | | | | |
| Other organisms | | | | | | | | |
| unidentified animals | 170 | | | | | | | 190 |
| unidentified Foraminifera | | | | | | | | |
| unidentified invertebrate eggs | | | | | | | | |
| unidentified Nematoda | | | | | 170 | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B§ | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| **Coelenterata** | | | | | | | | |
| **Hydrozoa** | | | | | | | | |
| *Aeginopsis laurentii* | 330 | 930 | 820 | | 880 | 620 | 150 | 380 |
| *Aglantha digitale* | 270 | 930 | 1240 | 1210 | 6240 | 1780 | 4190 | 4060 |
| *Bougainvillia superciliaris* | | | | | | | | |
| *Calycopsis birulai* | | 20 | 60 | | | | | |
| *Corymorpha flammea* | | | 30 | | 180 | 20 | | |
| *Coryne tubulosa* | | | | | | | | |
| *Cuspidella mertensii cf.* | | | | | | | | 30 |
| *Cuspidella* sp. *cf.* | | | | 2 | | | | |
| *Melicertum campanula cf.* | | | | 4 | | | | |
| *Melicertum* sp. *cf.* | | | | | | | | |
| *Obelia* sp. *cf.* | | | | | | 50 | | |
| *Perigonimus vesicarius* | 120 | 140 | 410 | | | | | 30 |
| *Perigonimus yoldia-arcticae* | | | | | | | | |
| *Perigonimus* spp. | 180 | 50 | 60 | | | | | 30 |
| *Plotocnide borealis cf.* | | 50 | | | | | | |
| *Rathkea octopunctata* | | | | | | | | |
| *Rathkea* sp. | | | | | | | | |
| *Rathkea* sp. *cf.* | | | | | | | | |
| **unidentified Hydrozoa** | | 50 | | 20 | 180 | | | |
| **Scyphozoa - unidentified** | | | | | | | | |
| **Siphonophora - unidentified** | | | | 260 | | | | |
| **Ctenophora** | | | | | | | | |
| *Beroë cucumis* | | | | | | | | |
| *Pleurobrachia pileus cf.* | 60 | | | 30 | 120 | | 40 | 120 |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B[§] | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| Polychaeta - unidentified larvae | 30 | 50 | 90 | 10 | | | | |
| Mollusca | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | |
| *Clione limacina* | | 50 | | 4 | | | | |
| *Spiratella helicina* | 420 | 330 | 30 | 4 | 1470 | 70 | 190 | 470 |
| unidentified Mollusca | | | | 10 | | | | |
| unidentified mollusc larvae | | | | | | 20 | | |
| Crustacea | | | | | | | | |
| Ostracoda | | | | | | | | |
| *Conchoecia borealis maxima* | | | | 300 | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | 640 | 6000 | 62000 | 3930 | 5060 | 7350 | 4670 | 13440 |
| Calanoida - juveniles | 17180 | 107070 | 48000 | 19170 | 31940 | 69490 | 86960 | 137940 |
| Cyclopoida | | 190 | | | | 40 | | 60 |
| Harpacticoida | | | | | | | | |
| unidentified nauplii | 60 | 50 | 90 | | | | | |
| Cirripedia | | | | | | | | |
| Nauplii | | 50 | | | | 40 | | 30 |
| Cyprids | | | | | | | | |
| Mysidacea | | | | | | | | |
| *Mysis litoralis* | | 20 | 380 | | | | | |
| *Mysis oculata* | | | 60 | | | | | 30 |
| *Mysis relicta* | | | 150 | | | | | 30 |
| *Mysis* spp. | | 20 | 970 | | | 20 | | 220 |
| Cumacea - unidentified | | | 30 | | | | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| *Apherusa glacialis* | | 280 | 180 | | | 130 | 20 | 60 |
| *Apherusa glacialis cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B§ | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| *Onisimus glacialis* | | 20 | 60 | | 60 | 40 | | 30 |
| *Onisimus glacialis cf.* | | | | | 60 | | | |
| *Onisimus nanseni* | | | | | | | | |
| *Onisimus* sp. | | | | | | | | |
| unidentified Gammaridea | | | | | | | | |
| Hyperiidea | | | | | | | | |
| *Hyperia galba* | 30 | | 120 | | 60 | 40 | | |
| *Parathemisto abyssorum* | | 350 | 90 | 180 | | 1250 | 670 | 560 |
| *Parathemisto abyssorum cf.* | | 20 | | | | | | |
| *Parathemisto libellula* | 150 | 280 | 180 | 120 | 60 | 200 | 390 | 90 |
| *Scina* sp. | | | | 2 | | | | |
| unidentified Hyperiidea | 30 | | | | | | | |
| unidentified Amphipoda | | | | 4 | | | | |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa inermis* | | | | | | | | |
| *Thysanoëssa longipes* | | | | 2 | | | | |
| *Thysanoëssa longipes cf.* | | | | | | | | |
| *Thysanoëssa raschii* | | 20 | | | | | | |
| unidentified furcilia | | 50 | 30 | | | 40 | | |
| Decapoda | | | | | | | | |
| Anomura - unidentified zoea | 30 | | 30 | | | | | |
| Brachyura | | | | | | | | |
| unidentified zoea | | | | | | | | |
| Atelecyclidae | | | | | | | | |
| *Telmessus* sp. - megalopae | | | | | | | | |
| Oregoniinae | | | | | | | | |
| *Hyas* sp. - megalopae | | | | | | | | |
| Caridae | | | | | 60 | | | |
| Crangonidae | | | | | | | | |
| Hippolytidae | 480 | 530 | 90 | | 410 | 90 | | 90 |
| Pandalidae | | | | | | | | |
| *Pandalus borealis* IV | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B[§] | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| *Pandalus goniurus* II | | | | | | | | |
| *Pandalus* sp. IV | | | | | | | | |
| unidentified zoea | | | | | | | | |
| Echinodermata - unidentified larvae | | 20 | | | | 90 | 70 | 30 |
| Appendicularia (Larvacea) | | | | | | | | |
| *Fritillaria borealis* | 6060 | 5810 | 10940 | 10 | 820 | 4800 | 4780 | 3000 |
| *Fritillaria* spp. | 1520 | 3350 | 4760 | 10 | 60 | 950 | 3330 | 1380 |
| *Oikopleura labradoriensis* | | | | | | 40 | | |
| *Oikopleura vanhöffeni* | 1000 | 5160 | 2000 | | 7410 | 4470 | 2740 | 8000 |
| *Oikopleura* spp. | 7420 | 14090 | 15530 | 360 | 18710 | 7530 | 8670 | 16690 |
| Chaetognatha | | | | | | | | |
| *Eukrohnia hamata* | | 70 | | 1130 | | 40 | 150 | 380 |
| *Sagitta elegans* | 150 | 260 | 470 | 30 | 350 | 580 | 780 | 440 |
| unidentified Chaetognatha | 360 | 70 | | | 60 | 110 | | 190 |
| Pisces | | | | | | | | |
| Agonidae | | | | | | | | |
| *Aspidophoroides olriki* | | | | | | | | |
| Cottidae | | | | | | | | |
| *Myoxocephalus quadricornis cf.* | | | | | | | | |
| Cyclopteridae | | | | | | | | |
| *Liparis koefoedi* | | | | | | | 20 | |
| *Liparis* sp. | | | | | | | | |
| Gadidae | | | | | | | | |
| *Boreogadus saida* | | | | | | | | 30 |
| unidentified Gadidae | | | | | | | | |
| Pleuronectidae | | | | | | | | |
| *Pleuronectes quadrituberculatus cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | B[§] | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| Stichaeidae | | | | | | | | |
| *Lumpenus fabricii cf.* | | | | | | | | |
| *Lumpenus* sp. | | | | | | | | |
| Other organisms | | | | | | | | |
| unidentified animals | 30 | | | 10 | 120 | | | |
| unidentified Foraminifera | | | | | | 20 | | |
| unidentified invertebrate eggs | | | | 30 | | | | |
| unidentified Nematoda | | | | | | | | 30 |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 28 | 29 | 30 | 31 | 33 | 34 | 35 |
| **Coelenterata** | | | | | | | | |
| **Hydrozoa** | | | | | | | | |
| *Aeginopsis laurentii* | 930 | 240 | 280 | 670 | 30 | 50 | 750 | 650 |
| *Aglantha digitale* | | 320 | 81100 | 1520 | 880 | 7360 | 147250 | 309230 |
| *Bougainvillia superciliaris* | | | | | | 10 | | 40 |
| *Calycopsis birulai* | | | | | | | | |
| *Corymorpha flammea* | | | | | | | | |
| *Coryne tubulosa* | | | | | | | | |
| *Cuspidella mertensii cf.* | | | | | | | | |
| *Cuspidella* sp. *cf.* | | | | | | | | |
| *Melicertum campanula cf.* | | | | | | | | |
| *Melicertum* sp. *cf.* | | | | | | | | |
| *Obelia* sp. *cf.* | | | | | | | | |
| *Perigonimus vesicarius* | 130 | 40 | | | 30 | | | |
| *Perigonimus yoldia-arcticae* | | | | | | | | |
| *Perigonimus* spp. | 100 | | | | 60 | | 250 | |
| *Plotocnide borealis cf.* | | | | | | | | |
| *Rathkea octopunctata* | | | | | | | | |
| *Rathkea* sp. | | | | | | | | |
| *Rathkea* sp. *cf.* | | | | | | | | |
| unidentified Hydrozoa | 370 | 20 | 11590 | | | 420 | 500 | 380 |
| **Scyphozoa - unidentified** | | | | | | | | |
| **Siphonophora - unidentified** | | | | | | | | |
| **Ctenophora** | | | | | | | | |
| *Beroë cucumis* | | | | | | | | |
| *Pleurobrachia pileus cf.* | | 120 | | 210 | | | 60 | 40 |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 28 | 29 | 30 | 31 | 33 | 34 | 35 |
| Polychaeta - unidentified larvae | | | 4140 | | | 50 | 280 | 350 |
| Mollusca | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | |
| *Clione limacina* | | | 20 | | 30 | | | |
| *Spiratella helicina* | 30 | 40 | | 210 | 120 | | 310 | 120 |
| unidentified Mollusca | | | 15720 | | | | | |
| unidentified mollusc larvae | | | | | | | 60 | |
| Crustacea | | | | | | | | |
| Ostracoda | | | | | | | | |
| *Conchoecia borealis maxima* | | | | | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | 1070 | 3360 | 830 | 6180 | 3880 | 640 | 3500 | 2770 |
| Calanoida - juveniles | 28670 | 113600 | 8000 | 79030 | 78300 | 4290 | 76500 | 49850 |
| Cyclopoida | | | 27860 | | | | 190 | |
| Harpacticoida | | | | | | | 30 | |
| unidentified nauplii | | 80 | 5240 | | 240 | | | |
| Cirripedia | | | | | | | | |
| Nauplii | 170 | 20 | 830 | 30 | 210 | 110 | 90 | |
| Cyprids | | | 280 | 30 | 120 | | | |
| Mysidacea | | | | | | | | |
| *Mysis litoralis* | | | | | | | | |
| *Mysis oculata* | | | | 30 | | | | 40 |
| *Mysis relicta* | | | | | | | | |
| *Mysis* spp. | | | | 30 | | | | |
| Cumacea - unidentified | | | | | | | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| *Apherusa glacialis* | 30 | | | 60 | | 10 | 60 | |
| *Apherusa glacialis cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 28 | 29 | 30 | 31 | 33 | 34 | 35 |
| *Onisimus glacialis* | | | | | | | | |
| *Onisimus glacialis cf.* | 30 | | | | | | | |
| *Onisimus nanseni* | | | | | | | | |
| *Onisimus* sp. | | | | | 30 | | | |
| unidentified Gammaridea | | | | | | | | |
| Hyperiidea | | | | | | | | |
| *Hyperia galba* | 30 | 40 | | 120 | | | 30 | |
| *Parathemisto abyssorum* | 30 | 80 | | 120 | 420 | | 120 | 270 |
| *Parathemisto abyssorum cf.* | | 40 | | | | | | |
| *Parathemisto libellula* | 330 | 520 | 20 | 30 | 360 | 30 | 120 | 120 |
| *Scina* sp. | | | | | | | | |
| unidentified Hyperiidea | | | | | | | 30 | |
| unidentified Amphipoda | | | | | | | | 40 |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa inermis* | | | | | | | | |
| *Thysanoëssa longipes* | | | | | | | | |
| *Thysanoëssa longipes cf.* | | | | | | | | |
| *Thysanoëssa raschii* | | | | | | | | |
| unidentified furcilia | | | | 30 | | 10 | 30 | |
| Decapoda | | | | | | | | |
| Anomura - unidentified zoea | | | | 270 | | 20 | 30 | |
| Brachyura | | | | | | | | |
| unidentified zoea | | 20 | | 150 | 120 | 10 | | |
| Atelecyclidae | | | | | | | | |
| *Telmessus* sp. - megalopae | | | | | | | | |
| Oregoniinae | | | | | | | | |
| *Hyas* sp. - megalopae | | | | | | | | |
| Caridae | | | | | | | | |
| Crangonidae | | | | | | | | |
| Hippolytidae | 170 | | 70 | 360 | 480 | 10 | 30 | |
| Pandalidae | | | | | | | | |
| *Pandalus borealis* IV | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 28 | 29 | 30 | 31 | 33 | 34 | 35 |
| *Pandalus goniurus* II | | | | | | 10 | | |
| *Pandalus* sp. IV | | | | | | | | |
| unidentified zoea | | 60 | | | | | | |
| Echinodermata - unidentified larvae | | | 550 | | | | | |
| Appendicularia (Larvacea) | | | | | | | | |
| *Fritillaria borealis* | 10400 | 6000 | 52970 | 1580 | 6480 | 2490 | 10250 | 8620 |
| *Fritillaria* spp. | 2600 | | | 480 | 15580 | 260 | 750 | 620 |
| *Oikopleura labradoriensis* | | | 1660 | | | | | |
| *Oikopleura vanhöffeni* | 4200 | 280 | | 1270 | 120 | | 2250 | 920 |
| *Oikopleura* spp. | 8400 | 3120 | 550 | 2790 | 6300 | 210 | 5250 | 920 |
| Chaetognatha | | | | | | | | |
| *Eukrohnia hamata* | 30 | | | | | | | |
| *Sagitta elegans* | 800 | 640 | 100970 | 10240 | 5820 | 4720 | 38280 | 49850 |
| unidentified Chaetognatha | 330 | 2080 | 21240 | 1880 | 8480 | 3020 | 12250 | 9230 |
| Pisces | | | | | | | | |
| Agonidae | | | | | | | | |
| *Aspidophoroides olriki* | | | | | | | | |
| Cottidae | | | | | | | | |
| *Myoxocephalus quadricornis cf.* | | | | | | | | |
| Cyclopteridae | | | | | | | | |
| *Liparis koefoedi* | | 20 | | | | | | |
| *Liparis* sp. | | | | | | | | |
| Gadidae | | | | | | | | |
| *Boreogadus saida* | 30 | | | 30 | 30 | | | |
| unidentified Gadidae | | | | | | | | |
| Pleuronectidae | | | | | | | | |
| *Pleuronectes quadrituberculatus cf.* | | | | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 27 | 28 | 29 | 30 | 31 | 33 | 34 | 35 |
| Stichaeidae | | | | | | | | |
| *Lumpenus fabricii cf.* | | | | | | | | |
| *Lumpenus* sp. | | | | | | | | |
| Other organisms | | | | | | | | |
| unidentified animals | | | 1380 | 90 | | | 910 | 310 |
| unidentified Foraminifera | | | | | 30 | | | |
| unidentified invertebrate eggs | | | | | | | | |
| unidentified Nematoda | | | | | | | | |

Utermöhl, H. 1931. Neue Wege in der quantitativen Erfassung des Planktons. Verh. int. Verein. theor. angew. Limnol. 5:567-596.

B. Papers in Preparation or in Print - None

C. Oral Presentations - None

VII. Problems Encountered/Recommended Changes

Distribution of the ice algae is patchy and we had some difficulty locating an area where ice algae were present that was close to the D.S. 11 dive site. We were lucky to find it close to an already existing dive hole, even though it meant the divers and surface support personnel had to be outside and we had to carry gear and samples between the two sites. The biggest problem this caused was trying to keep the radioactive isotope solution from freezing before it could be inoculated into the samples. This problem was solved with the hot water baths, but it meant the diver had to surface three times to get the isotope (once for each incubation chamber) thus lengthening the time he was in the water. We were also lucky that the weather was relatively good, so that we could work outside. The backup diver usually got into a sleeping bag to keep warm, but his hands and feet were still cold.

The NOAA helicopter was very busy with so many projects needing time. Often the helicopter could not pick us up until several hours, often 3 to 4, after my sampling was done. In order to minimize possible and unknown damage to the samples, an ERA helicopter was chartered to pick up me and anyone else who needed to return to shore in the early afternoon. This worked out very well and I got back to the lab just about the time the ice cores had thawed and were ready to be processed.

At the shore laboratory there is a definite lack of electrical outlets, counter space, and sinks. I had the only possible place to set up and filter water samples. Fortunately, no one else was there who needed this kind of space until the day I left. Freezer space could also be a problem. Four projects were using the small amount of space available. Other arrangements will have to be made when large numbers of samples must be frozen.

IX. Acknowledgements

I would like to thank Ken Dunton and his divers, John Olson, Gary Smith, and especially Jim Hanes for their excellent help. Kate Persons did a tremendous job making sure everyone had enough helicopter time.

QUARTERLY REPORT

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1 Jul - 30 Sep 1979
Number of Pages: 43

# Beaufort Sea Plankton Studies

Rita A. Horner

30 September 1979

I. Abstract/Highlights of Quarter's Accomplishments

Analysis of phytoplankton samples collected during the icebreaker cruise in August-September 1978 has been completed. Processing of all icebreaker data is complete. Analysis of samples collected in February, March, and May 1979 in Stefansson Sound has been completed. All data will be ready for submission to NODC in October. Phytoplankton and zooplankton voucher specimens from icebreaker cruises in 1976, 1977, and 1978, and from the Stefansson Sound winter sampling program will be ready for submission to the California Academy of Sciences in October.

II. Task Objectives

The task objectives are to assess the winter density distribution and environmental requirements of zooplankton and phytoplankton in the nearshore areas of the Beaufort Sea in an integrated sampling effort with other RU's and to analyze data collected during the 1978 icebreaker cruise in the Beaufort Sea.

III. Field or Laboratory Activities

A. Ship or Field Trip Schedule

There was no field work done during this quarter.

B. Laboratory Activities - Winter Studies

1. Phytoplankton

Five (5) samples, 4 water and 1 ice core, collected during the period 12-20 May 1979 at the Boulder Patch in Stefansson Sound were analyzed.

2. Zooplankton

One (1) sample collected at the Boulder Patch as part of Project Whales sponsored by BLM, was analyzed and the results are included in Table 1.

C. Methods

1. Phytoplankton

Standing stock samples were analyzed using a Zeiss phase-contrast inverted microscope and Zeiss 5 and 10 ml counting chambers. Rare and large organisms (> 100 µm) were counted at 125 X magnification in 50 ml chambers and abundant, small organisms (< 100 µm) were counted at 312 X magnification in 5 ml chambers. One-tenth of the 5 ml chamber and one-fifth of the 50 ml chamber were counted. The ice core sample was settled in the usual way, but so many cells were present that it was impossible to count in either the 5 or 50 ml chamber. Instead, a 1 ml subsample was taken from the

Table 1. Abundance (number per 1000 $m^3$) of zooplankton taxa found in 0.75 m ring net hauls from Stefansson Sound. November 1978 samples were collected with a 308 µm mesh net; March and May 1979 samples were collected with a 216 µm mesh net.

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 Nov | 10 Nov | 14 Nov | 16 Nov* | 13 Mar | 14 Mar | 16 Mar | 16 May† |
| **Coelenterata** | | | | | | | | |
| Hydrozoa | | | | | | | | |
| *Coryne tubulosa* | | | | | 450 | | | |
| *Halitholus cirratus* | | | | | | | | 755 |
| *Perigonimus yoldia-arcticae* | | | | | 450 | | | |
| *Perigonimus* spp. | | | | | | 910 | | |
| *Sarsia* sp. | | | | | | | | 377 |
| Scyphozoa | | | | | | | | |
| *Aurelia* sp. (ephyra larvae) | | | | | | | | 377 |
| **Polychaeta** | | | | | | | | |
| Syllidae | | | | | | | | |
| *Autolytus fallax* | | | | | | | | 377 |
| Unidentified trochophores | | | | | | | | 3774 |
| Unidentified larvae | | | | | 450 | | | |
| Unidentified juveniles | | | | | | | | 83522 |
| **Crustacea** | | | | | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | 474070 | 263370 | 188240 | 242530 | 1360 | 910 | 450 | |
| Calanoida - juveniles | 6505350 | 9692180 | 3742990 | 5107690 | 74240 | 268450 | 90540 | |
| Cyclopoida | | | 1360 | 680 | 62020 | 53420 | 38930 | |
| Harpacticoida | 410 | | 450 | 230 | 2720 | 2260 | 1810 | |
| Unidentified Copepoda | | | | | | | | 347925 |
| Unidentified nauplii | | | | | 12220 | 14490 | 4980 | |
| Cirripedia | | | | | | | | |
| Unidentified cyprids | | 820 | 2710 | | | | | |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 Nov | 10 Nov | 14 Nov | 16 Nov* | 13 Mar | 14 Mar | 16 Mar | 16 May† |
| Mysidacea | | | | | | | | |
| *Mysis litoralis* | | 410 | 450 | | | | | |
| *Mysis relicta* | 820 | 410 | | | | | | |
| *Mysis* spp. | | | 1810 | | | | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| Calliopiidae *cf.* | | | | 230 | | | | |
| Eusiridae *cf.* | | | | 450 | | | | |
| Gammaridae | | | | | | | | |
| *Gammarus wilkitzkii* | | | | 230 | | | | |
| *Gammarus* sp. (juv.) | | | | | | | | 377 |
| Lysianassidae | | | | | | 450 | | |
| *Boeckosimus (Onisimus) glacialis* | | | | | 450 | 450 | | |
| *Boeckosimus (Onisimus)* spp. *cf.* | | | 1360 | | | | | |
| Unidentified Lysianassidae *cf.* | | | | | | | | |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa raschii* | | | | 230 | | | | |
| Unidentified calyptopids | 410 | | | | | | | |
| Isopoda | | | | | | | | |
| Unidentified Isopoda | | | | | 450 | 450 | | |
| Nematoda | | | | | | | | 377 |
| Chaetognatha | | | | | | | | |
| *Sagitta elegans* | 820 | 410 | 1360 | 230 | | | 910 | |
| Appendicularia (Larvacea) | | | | | | | | |
| *Oikopleura* sp. | | | | | | | | 63396 |

Table 1. (continued)

| Taxon | Station Numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 Nov | 10 Nov | 14 Nov | 16 Nov* | 13 Mar | 14 Mar | 16 Mar | 16 May† |
| Other organisms | | | | | | | | |
| Unidentified animals | 410 | 410 | 450 | | | | | 7547 |
| Unidentified invertebrate eggs | | | 7690 | 8370 | | | | |

sample jar after the sample was thoroughly shaken. The 1 ml subsample was put into a 5 ml counting chamber and 4 ml distilled water were added. After settling overnight, one-tenth of the sample was counted.

2. Zooplankton

The zooplankton sample was first sorted for large and rare organisms. The sample was then split using a Folsom plankton splitter until a subsample containing approximately 100 specimens of the most abundant remaining taxon was obtained. For the sample collected 16 May, only the copepods and polychaete larvae were split. Organisms were identified and counted using a dissecting microscope. Voucher specimens were kept for all taxa.

3. Nutrients and Salinity

Nutrient and salinity determinations for ice samples were run on ice cores collected with the combination incubator-sampler. Cores were allowed to melt and were then filtered through 0.45 µm Millipore filters. A 125 ml polyethylene bottle was partially filled with water and frozen for the nutrient sample; the remainder of the water was poured into a second 125 ml bottle and stored at room temperature for the salinity sample.

These samples were returned to the University of Washington, Department of Oceanography Chemistry Laboratory for analysis. The nutrient samples were analyzed using autoanlyzer techniques; the salinity samples were analyzed using a whetstone bridge.

D. Sample Location

All sampling was done at the Boulder Patch, 70°19'N, 147°34.4'W in Stefansson Sound.

E. Data Collected and Analyzed

Data collected and analyzed during the Winter Studies program in Stefansson Sound is given in Table 2.

## IV. Results - Winter Studies

### A. Phytoplankton and Ice Algae

Phytoplankton levels in the water column in Stefansson Sound were low during the winter period (Tables 3 and 4). In November, 1978, unidentified flagellates, mostly $< 6$ µm in diameter, were the most common organisms. A few diatoms, including spores of *Chaetoceros* spp. and cells of *Navicula* spp. and *Nitzschia* spp., were also present. Although the diatoms contained chloroplasts, they did not appear to be healthy. Chlorophyll *a* levels were low.

Phytoplankton levels remained low in February and March with unidentified

Table 2. Data collected and analyzed during the Winter Studies program, Stefansson Sound, 1978-79.

| Parameter | Nov | | Feb | | Mar | | May | |
|---|---|---|---|---|---|---|---|---|
| | Coll | Anal | Coll | Anal | Coll | Anal | Coll | Anal |
| Primary Productivity | | | | | | | 30 | 30 |
| Phytoplankton Standing Stock | 18 | 6 | 2 | 2 | 10 | 4 | 10 | 5 |
| Plant Pigments | 18 | 17 | 2 | 2 | 10 | 10 | 14 | 14 |
| Phytoplankton Net Tows | | | | | | | | |
| Vertical | 1 | | | | | | | |
| Horizontal-in water | 2 | | | | | | | |
| Horizontal-bottom of ice | 1 | | | | | | | |
| Zooplankton Net Tows | | | | | | | | |
| Vertical | 18 | 3 | | | 10 | 3 | 3 | 1* |
| Horizontal | 3 | 1 | | | 2 | 1 | | |
| Ice cores | | | | | 2 | 1 | | |
| Nutrients | | | | | | | 10 | 10 |
| Salinity | | | | | | | 10 | 10 |

* Collected as part of Project Whales sponsored by BLM

Table 3. Phytoplankton data from the Winter Studies program, Stefansson Sound, 1978-79.

| Date | Standing Stock (Total Cells /Liter) 0 m | 4 m | Chlorophyll *a* ($mg\ m^{-3}$) 0 m | 4 m | Phaeopigments ($mg\ m^{-3}$) 0 m | 4 m | Primary Productivity ($mg\ C\ m^{-3}\ hr^{-1}$) 0 m | 4 m | Ice |
|---|---|---|---|---|---|---|---|---|---|
| 08 Nov 78 | 26000 | 14000 | 0.06 | | 0.07 | | | | |
| 09 | 24000 | 18000 | 0.02 | 0.02 | 0.12 | 0.12 | | | |
| 10 | | | 0.06 | 0.06 | 0.06 | 0.08 | | | |
| 11 | | | 0.05 | 0.05 | 0.04 | 0.05 | | | |
| 12 | | | 0.06 | 0.04 | 0.07 | 0.06 | | | |
| 13 | | | 0.06 | 0.04 | 0.05 | 0.06 | | | |
| 14 | | | 0.07 | 0.04 | 0.05 | 0.05 | | | |
| 15 | | | 0.05 | 0.06 | 0.06 | 0.06 | | | |
| 16 | 46000 | 46000 | 0.06 | 0.06 | 0.05 | 0.05 | | | |
| 15 Feb 79 | 36000 | 22000 | 0.02 | 0.01 | 0.07 | 0.04 | | | |
| 12 Mar 79 | 46000 | 34000 | 0.01 | 0.00 | 0.03 | 0.02 | | | |
| 13 | | | 0.00 | 0.01 | 0.02 | 0.03 | | | |
| 14 Ice core | 38000 | | | | | | | | |
| 14 | | | 0.00 | 0.01 | 0.03 | 0.03 | | | |
| 15 | | | 0.01 | 0.01 | 0.03 | 0.07 | | | |
| 16 | 60000 | 82000 | 0.01 | 0.01 | 0.03 | 0.03 | | | |
| 15 May 79 | Ice cores (1 core) | | 168.51 | | 236.90 | | | | 38.92 |
| | (2 cores)* | | 27.29 | | 46.16 | | | | |
| 18 | 162000 | 38000 | 0.42 | 0.17 | 1.13 | 0.24 | 0.16 | 0.12 | 36.73 |
| | Ice cores (1 core) | | 84.24 | | 176.59 | | | | |
| | (2 cores)* | | 147.00 | | 64.05 | | | | |
| 19 | | | 0.67 | 0.24 | 1.05 | 0.43 | 0.16 | 0.80 | 8.13 |
| | Ice cores (1 core) | | 89.08 | | 125.44 | | | | |
| | (2 cores)* | | 111.20 | | 84.80 | | | | |
| 20 | 208000 | 36000 | 1.19 | 0.23 | 0.89 | 0.33 | 0.11 | 0.26 | 36.70 |
| | Ice 23070000 | | | | | | | | |
| | Ice cores (1 core) | | 157.86 | | 44.24 | | | | |
| | (3 cores)* | | 72.00 | | 96.00 | | | | |

* actual values, not averages

Table 4. Phytoplankton and ice core standing stock (number of cells per liter) from Winter Studies samples, Stefansson Sound, 1978-79.

| | 8 Nov 78 | | 9 Nov 78 | | 16 Nov 78 | | 15 Feb 79 | |
|---|---|---|---|---|---|---|---|---|
| Taxon | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| **Diatoms** | | | | | | | | |
| *Amphiprora* spp. | | | | | | | | |
| *Amphiprora hyperborea* | | | | | | | | |
| *Chaetoceros* spp. | 2000 | | 2000 | | | 8000 | 2000 | |
| *Chaetoceros septentrionalis* | | | | | | | | |
| *Cylindrotheca closterium* | | 2000 | | | | | | 2000 |
| *Gyrosigma* spp. | | | | | | | | |
| *Licmophora* spp. | | | | | | | | |
| *Melosira* spp. | | | | | | | | |
| *Navicula* spp. | | | | 2000 | | | | |
| *Navicula marina* | | | | | | | | |
| *Navicula pelagica* | | | | | | | | |
| *Nitzschia* spp. | | | | | | | | |
| *Nitzschia delicatissima* | | | | | | | | |
| *Nitzschia frigida* | | | | | | | | |
| *Nitzschia grunowii* | | | | | | | | |
| *Nitzschia seriata cf.* | | | | | | | | |
| *Thalassiosira* spp. | | | | | | | | |
| *Thalassiosira antarctica cf.* | | | | | | | | |
| *Thalassiosira gravida* | | | | | | | | |
| *Tropidoneis* sp. | | | | | | | | |

Table 4. (continued)

| Taxon | 8 Nov 78 | | 9 Nov 78 | | 16 Nov 78 | | 15 Feb 79 | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| **Unidentified pennate diatoms** | | | | | | | | |
| < 10 µm | | 2000 | | | | | | |
| 11 - 20 µm | | | | | | | | |
| 21 - 30 µm | | | | | | | | |
| 31 - 40 µm | | | | | | | | |
| 41 - 50 µm | | | | | | | | |
| 51 - 75 µm | | | | | | | | |
| 76 - 100 µm | | | | | | | | |
| 101 - 150 µm | | | | | | | | |
| **Unidentified flagellates** | | | | | | | | |
| < 10 µm | 20000 | 10000 | 20000 | 14000 | 44000 | 36000 | 32000 | 18000 |
| 11 - 20 µm | | | | | 2000 | | | |
| 21 - 30 µm | 2000 | | | | | | | |
| 31 - 40 µm | | | | | | | | |
| 41 - 50 µm | | | | | | | | |
| **Identified flagellates** | | | | | | | | |
| *Calycomonas gracilis* | | | | | | | | |
| **Unidentified choanoflagellates** | | | | | | | | 2000 |
| **Unidentified cryptomonads** | | | | | | | | |
| *Dinobryon petiolatum* | | | | | | | | |
| *Eutreptiella* sp. *cf.* | | | | | | | | |
| **Unidentified euglenoid** *cf.* | | | | | | | | |
| *Urceolus* sp. | | | | | | | | |
| *Platymonas* sp. *cf.* | 2000 | | 2000 | | | | | |

Table 4. (continued)

| Taxon | 8 Nov 78 | | 9 Nov 78 | | 16 Nov 78 | | 15 Feb 79 | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| **Dinoflagellates** | | | | | | | | |
| *Gonyaulax* sp. | | | | | | | | |
| *Peridinium* spp. | | | | | | | | |
| Unidentified Peridiniales | | | | | | | 2000 | |
| Unidentified dinoflagellates | | | | 2000 | | 2000 | | |

Table 4. (continued)

| Taxon | 12 Mar 79 | | 14 Mar 79 | 16 Mar 79 | | 18 May 79 | |
|---|---|---|---|---|---|---|---|
| | 0 | 4 | ice core | 0 | 4 | 0 | 4 |
| **Diatoms** | | | | | | | |
| *Amphiprora* spp. | | | | | | | |
| *Amphiprora hyperborea* | | | | | | | |
| *Chaetoceros* spp. | | 2000 | 4000 | | | | |
| *Chaetoceros septentrionalis* | | | | | | | |
| *Cylindrotheca closterium* | | | | 2000 | | 4000 | |
| *Gyrosigma* spp. | | | | | | | 2000 |
| *Licmophora* spp. | | | | | | | |
| *Melosira* spp. | | | | | | | |
| *Navicula* spp. | | | 2000 | | | | |
| *Navicula marina* | | | | | | | |
| *Navicula pelagica* | | | | | | | |
| *Nitzschia* spp. | | 4000 | 2000 | 2000 | 2000 | 8000 | |
| *Nitzschia delicatissima* | | | | | | | |
| *Nitzschia frigida* | | | | | | 6000 | |
| *Nitzschia grunowii* | | | 2000 | | | 14000 | |
| *Nitzschia seriata cf.* | | | | | | 6000 | |
| *Thalassiosira* spp. | | | 6000 | | | | |
| *Thalassiosira antarctica cf.* | | | 12000 | | | | |
| *Thalassiosira gravida* | | | | | | | |
| *Tropidoneis* sp. | | | | | | | |

Table 4. (continued)

| Taxon | 12 Mar 79 | | 14 Mar 79 | 16 Mar 79 | | 18 May 79 | |
|---|---|---|---|---|---|---|---|
| | 0 | 4 | ice core | 0 | 4 | 0 | 4 |
| Unidentified pennate diatoms | | | | | | | |
| < 10 µm | | | 2000 | | 2000 | 2000 | 2000 |
| 11 - 20 µm | | | 6000 | | | 2000 | |
| 21 - 30 µm | | | | | | | |
| 31 - 40 µm | | | | | 8000 | 4000 | |
| 41 - 50 µm | | | | | | | |
| 51 - 75 µm | | | | | | | |
| 76 - 100 µm | | | | | | | |
| 101 - 150 µm | | | | | | | |
| Unidentified flagellates | | | | | | | |
| < 10 µm | 40000 | 22000 | 2000 | 46000 | 64000 | 84000 | 34000 |
| 11 - 20 µm | 2000 | | | 2000 | | 8000 | |
| 21 - 30 µm | | | | | | | |
| 31 - 40 µm | | | | | | | |
| 41 - 50 µm | | | | | | | |
| Identified flagellates | | | | | | | |
| *Calycomonas gracilis* | | | | | | | |
| Unidentified choanoflagellates | 4000 | 6000 | | 6000 | | | |
| Unidentified cryptomonads | | | | | 2000 | | |
| *Dinobryon petiolatum* | | | | | | | |
| *Eutreptiella* sp. *cf.* | | | | | | 2000 | |
| Unidentified euglenoid *cf.* | | | | | | 2000 | |
| *Urceolus* sp. | | | | | | | |
| *Platymonas* sp. *cf.* | | | | | | 4000 | |

Table 4. (continued)

| Taxon | 12 Mar 79 | | 14 Mar 79 | 16 Mar 79 | | 18 May 79 | |
|---|---|---|---|---|---|---|---|
| | 0 | 4 | ice core | 0 | 4 | 0 | 4 |
| Dinoflagellates | | | | | | | |
| *Gonyaulax* sp. | | | | | | | |
| *Peridinium* spp. | | | | | | 14000 | |
| Unidentified Peridiniales | | | | 2000 | 4000 | 2000 | |
| Unidentified dinoflagellates | | | | | | | |

Table 4. (continued)

| Taxon | 20 May 79 ice core | 20 May 79 0 | 4 |
|---|---|---|---|
| Diatoms | | | |
| *Amphiprora* spp. | 50000 | | |
| *Amphiprora hyperborea* | 60000 | 6000 | |
| *Chaetoceros* spp. | 280000 | 4000 | |
| *Chaetoceros septentrionalis* | | 2000 | |
| *Cylindrotheca closterium* | 80000 | 12000 | 4000 |
| *Gyrosigma* spp. | 130000 | 2000 | |
| *Licmophora* spp. | 530000 | 2000 | |
| *Melosira* spp. | 40000 | | |
| *Navicula* spp. | 550000 | 2000 | |
| *Navicula marina* | 80000 | | |
| *Navicula pelagica* | 860000 | | |
| *Nitzschia* spp. | 2560000 | 10000 | |
| *Nitzschia delicatissima* | | 4000 | |
| *Nitzschia frigida* | 6080000 | 14000 | |
| *Nitzschia grunowii* | 5880000 | | |
| *Nitzschia seriata cf.* | | 12000 | |
| *Thalassiosira* spp. | | | |
| *Thalassiosira antarctica cf.* | | | |
| *Thalassiosira gravida* | | | |
| *Tropidoneis* spp. | 10000 | | |

Table 4. (continued)

| Taxon | 20 May 79 ice core | 20 May 79 0 | 20 May 79 4 |
|---|---|---|---|
| **Unidentified pennate diatoms** | | | |
| <10 µm | 190000 | 2000 | |
| 11 - 20 µm | 850000 | | |
| 21 - 30 µm | 870000 | 4000 | |
| 31 - 40 µm | 320000 | | |
| 41 - 50 µm | 200000 | 2000 | 2000 |
| 51 - 75 µm | 350000 | | |
| 76 - 100 µm | 30000 | | |
| 101 - 150 µm | 80000 | | |
| **Unidentified flagellates** | | | |
| < 10 µm | 2740000 | 98000 | 28000 |
| 11 - 20 µm | 320000 | 6000 | |
| 21 - 31 µm | 20000 | 4000 | |
| 31 - 40 µm | 10000 | 2000 | |
| 41 - 50 µm | 20000 | | |
| **Identified flagellates** | | | |
| *Calycomonas gracilis* | | | 2000 |
| **Unidentified choanoflagellates** | | | |
| **Unidentified cryptomonads** | 20000 | 2000 | |
| *Dinobryon petiolatum* | | 2000 | |
| *Eutreptiella* sp. *cf.* | 10000 | 2000 | |
| Unidentified euglenoid *cf.* *Urceolus* sp. | 30000 | | |
| *Platymonas* sp. *cf.* | 50000 | 2000 | |

Table 4. (continued)

| Taxon | 20 May 79 ice core | 20 May 79 0 | 4 |
|---|---|---|---|
| **Dinoflagellates** | | | |
| *Gonyaulax* sp. | | 2000 | |
| *Peridinium* spp. | 20000 | 8000 | |
| Unidentified Peridiniales | | | |
| Unidentified dinoflagellates | 60000 | 2000 | |

small flagellates being the most numerous organisms. A few pennate diatoms were also present. In February, there were many small detritus particles in the water sample collected from just beneath the ice (0 m) which made phytoplankton counting difficult. The detritus particles probably came from dirty brash ice that formed a thick layer on the underside of the ice (Dunton pers comm). Not as much detritus was found in the sample collected near the sea floor. Chlorophyll *a* levels were very low.

By March, the number of individual diatom cells and the number of diatom species increased with species that are common in the spring beginning to appear. Chlorophyll *a* levels were still extremely low.

One ice core collected 14 March was also analyzed. The core, about 30 cm long and 2.5 cm in diameter, was collected from the brash ice layer on the underside of the ice. *Navicula* sp., *Nitzschia* spp., and unidentified pennate diatoms were present, along with *Thalassiosira* spp. The large amount of detrital material made positive identification of the *Thalassiosira* spp. impossible.

By May, more diatom cells were present in the water column, including species of *Chaetoceros, Cylindrotheca, Navicula,* and *Nitzschia*. Unidentified flagellates, usually < 10 μm, were abundant, along with a few cryptomonad, chrysophyte, and euglenoid species. Unidentified *Peridinium* spp. and other unidentified dinoflagellates were present in low numbers. Chlorophyll *a* levels in the water column were still low, but beginning to increase.

An ice core, approximately 4.8 cm in diameter and 2 cm long, collected with the combination-incubator sampler (Clasby *et al.* 1973; Alexander *et al.* 1974) was analyzed. More than 23 x $10^6$ cells per liter were present, including diatoms and flagellates. *Nitzschia* spp. were the most abundant organisms. *Nitzschia frigida* Grunow and *N. grunowii* Hasle comprised nearly 50% of the total population. Both of these species are common in the ice in the Barrow area with *N. frigida* found in large numbers only in the ice, while *N. grunowii* is also a prominent component of the phytoplankton in spring (Alexander *et al.* 1974; Horner 1976). Other typical ice organisms found included *Eutreptiella cf. braarudii* Throndsen and *Urceolus* sp., probably *U. macromastix* Skuja. *Eutreptiella* sp. is sometimes found in the water column also, but only when ice is present (Horner unpubl obs). Neither of these species occurred in large numbers. Chytridiaceous fungi were found parasitizing some of the pennate diatoms.

Chlorophyll *a* levels in the ice cores were extremely variable and phaeopigments were high (Table 3).

Primary productivity was low in the water column, averaging about 0.15 mg C $m^{-3}$ $hr^{-1}$. In the ice, primary productivity on 15, 18, and 20 May was about the same, near 37 mg C $m^{-3}$ $hr^{-1}$, but on 19 May, productivity was only 8 mg C $m^{-3}$ $hr^{-1}$.

Nutrient and salinity data are given in Table 5.

Table 5. Nutrient and salinity data from the May 1979 winter studies program in Stefansson Sound. Where no number is present, no sample was taken.

| Date | Nutrient Concentrations (µg at/l) $NO_3$ | $NO_2$ | $NH_3$ | $PO_4$ | $SiO_4$ | Salinity (°/₀₀) |
|---|---|---|---|---|---|---|
| 15 May | | | | | | |
| 0 m | | | | | | |
| 4 m | | | | | | |
| ice | 1.35 | 0.14 | 2.68 | 1.38 | 19.90 | |
| 18 May | | | | | | |
| 0 m | 1.55 | 0.04 | 1.07 | 0.20 | 24.06 | 18.28 |
| 4 m | 4.69 | 0.17 | 0.84 | 1.42 | 13.34 | 35.20 |
| ice | 1.19 | 0.06 | 2.85 | 0.74 | 20.62 | 15.26 |
| 19 May | | | | | | |
| 0 m | 1.57 | 0.06 | 1.68 | 0.39 | 26.27 | 18.32 |
| 4 m | 4.72 | 0.16 | 0.24 | 0.95 | 13.23 | 35.19 |
| ice | 1.24 | 0.05 | 1.87 | 0.50 | 21.02 | 15.94 |
| 20 May | | | | | | |
| 0 m | 1.01 | 0.05 | 1.04 | 0.24 | 24.53 | 16.57 |
| 4 m | 4.46 | 0.16 | 0.79 | 0.91 | 13.43 | 34.76 |
| ice | 0.76 | 0.06 | 2.66 | 0.46 | 20.56 | 14.05 |

B. Zooplankton

The dominant group of animals present from November through March was juvenile calanoid copepods (Table 1). In November they comprised > 99.5% of the zooplankton. Copepods were also the dominant group in May, but were not sorted to Order or life cycle stage. Taxonomic studies on copepods from the winter sampling will be done in FY 80.

Other taxa identified during the winter include barnacle larvae, amphipods, euphausids, isopods, chaetognaths, larvaceans, polychaetes (especially juveniles), and jellyfish; unidentified animals and unidentifed invertebrate eggs were also present. Only juvenile polychaetes and larvaceans were present in large numbers and only in May.

V. Preliminary Interpretation of Results

Phytoplankton levels from November through March were low, averaging about 38 x $10^3$ cells per liter with most of the cells being unidentified flagellates < 10 μm in diameter. These cells are probably not photosynthetic judging from the low chlorophyll *a* levels. By May, diatoms were more abundant, although unidentified, small flagellates were still the most abundant group of organisms in the water column. Chlorophyll *a* levels were slightly higher in May.

An ice core collected 14 Mar 1979 contained few diatoms, but by May, a well-developed ice algae community was present in some areas. The extent of this community in Stefansson Sound is not known, although ice cores taken to determine a good sampling location indicated patchiness within a relatively small area around Dive Site 11 (RU 356).

Chlorophyll *a* levels in the ice cores were extremely variable. Reasons for this include the patchiness of the ice community, possibly within a very small area, and the difficulty in retrieving the sampling corers from the ice. A variable and unknown amount of ice could easily have been lost during the retrieval. Patchiness may also be the reason for the decrease in primary productivity on 19 May.

The fact that most of the zooplankton present during the winter were juvenile copepods probably indicates that the lagoon system is a major habitat for these organisms. More definite information can be given after the copepods are identified and sexed.

The paucity of larger animals such as amphipods and euphausids may be an artifact caused by our sampling gear. The only gear we used sampling through a hole in the ice was ring nets that were usually hauled vertically from the bottom to the surface. Larger animals are able to avoid this net, usually by swimming upwards and sideways. In November, we sampled horizontally by anchoring a line and pulley just beneath the ice, but hauling a net by hand is not fast enough to catch the larger organisms. We hope to try a downward fishing net during spring 1980.

With the exception of Horner *et al.* (1974), there is little available information concerning the plankton in the Stefansson Sound area in summer.

These authors found three phytoplankton communities in Prudhoe Bay and out to Reindeer Island. Pennate diatoms were the most abundant organisms inside Prudhoe Bay, while small flagellates were dominant in low salinity surface water in the lagoon area. Centric diatoms were more common in deeper, more saline water in the lagoon and north of Reindeer Island. Whether the same situation occurs farther east in Stefansson Sound is not known. Copepods were the most diverse (10 species) and abundant group of zooplankters in the summer (Horner *et al.* 1974) and that was the case in winter 1978-79, although species are not yet known for the winter-spring seasons. Other summer zooplankton taxa include coelenterates, a few polychaete larvae, a few amphipods, barnacle and crab larvae, mysids, chaetognaths, and fish. With the exception of the copepods, each of these groups, in general, comprised less than 1% of the population at stations where they occurred.

## III. Field or Laboratory Activities

### A. Ship or Field Trip Schedule

There was no field work done during this quarter.

### B. Laboratory Activities - CGC *Northwind*

#### 1. Phytoplankton

Enumeration of phytoplankton samples collected during the cruise of CGC *Northwind*, 15 Aug-15 Sep 1978, has been completed. Processing of the data for October submission to NODC has been completed.

#### 2. Zooplankton

This quarter has been spent preparing voucher specimens for submission to the California Academy of Sciences. Approximately 400 voucher specimens will be submitted in October. Processing of icebreaker and winter studies data for October submission to NODC has been completed.

### C. Methods

#### 1. Phytoplankton

Samples were analyzed using a Zeiss phase-contrast inverted microscope and 5 and 10 ml Zeiss counting chambers. Rare and large organisms (> 100 µm) were counted at 125 X magnification in 50 ml chambers; abundant, small organisms (< 100 µm) were counted at 312 X magnification in 5 ml chambers. Usually 1/10 of the 5 ml chamber and 1/5 of the 50 ml chamber were counted.

#### 2. Zooplankton

Individual specimens of each taxonomic category identified were separated from the sorted, identified samples. Identification of each specimen was checked and the individual organisms were placed in 2 dram vials. Abbreviated labels containing identification, collection data,

and a speciman reference number were placed in each vial. Regulation voucher specimen labels were filled out according to the voucher specimen policy and included the speciman reference number included in each vial.

## IV. Results

Two hundred nineteen (219) phytoplankton standing stock samples have been analyzed from the 1978 icebreaker cruise. Eighty-three (83) categories from five phyla, including 48 species and 35 other categories, including unidentified species and groups of species, were present. All the categories have been reported previously from the Chukchi and Beaufort seas (Horner 1978).

The phytoplankton have been grouped into four major categories based on taxonomic group or morphological similarities. The percentage of the phytoplankton population and the number of cells by major category are given in Table 6 and Fig. 1. The number of cells ranged from $< 1 \times 10^5$ to $> 4 \times 10^6$ cells per liter with the highest number occurring at station 27 located just outside the Maguire Islands. In general, the standing stock was considerably lower in 1978 than in 1976 and 1977.

Small species of the genus *Chaetoceros* were the most abundant organisms at most stations and at most depths except the surface. Other diatoms that were common included *Nitzschia delicatissima* Cleve, *N. grunowii* Hasle, *Thalassiosira antarctica* Comber, *T. gravida* Cleve, and *T. nordenskioeldii* Cleve. In the Annual Report for 1 April 1979, I reported that *T. antarctica* had not been found in the 1978 samples. This was true of samples analyzed at that time from the area east of Prudhoe Bay, but west of Prudhoe Bay, this species was common. Diatoms other than *Chaetoceros* spp. were the most abundant organisms only at a station north of Harrison Bay (station 33).

Small flagellates that were not identified were common and were usually dominant in surface samples. They were most abundant at all depths at three (3) stations along the Pitt Point transect (stations 10, 11, and 12), three (3) stations along the 20 m isobath off Harrison Bay (stations 7, 8, and 9), and at one (1) station off the mouth of the Canning River (station 4).

Dinoflagellates were more common and abundant in 1978 than in either 1976 or 1977. They were especially abundant at the two (2) outermost stations of the Pitt Point transect (stations 11 and 12), at six (6) stations off Harrison Bay (stations 7, 8, 9, 13, 33, and 34), and at one (1) station in deeper water off Prudhoe Bay (station 29). At most stations east of Prudhoe Bay, dinoflagellates generally comprised less than 1% of the population at any depth. Dinoflagellate species present included *Dinophysis acuta* Ehrb., *D. sphaerica* Stein, *Gonyaulax catenata* (Lev.) Kofoid, *G. spinifera* (Clap. *et* Lach.) Diesing, *Gymnodinium lohmanni* Paulsen, *Peridinium brevipes* Paulsen, *P. minusculum* Pav., *P. pallidum* Ostenfeld, *P. trochoideum* (Stein) Lemm., *Ceratium arcticum* (Ehrb.) Cleve, and *C. longipes* (Bailey) Gran.

Primary productivity and plant pigment concentrations were discussed in the Annual Report for 1 April 1979.

Table 6. Number of cells per liter and percentage of phytoplankton by major category by depth at each station, 15 Aug - 15 Sep 1978. Where no number is present, no cells were found.

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 05 | 2000 | 1 | 8000 | 3 | 246000 | 92 | 12000 | 4 | 268000 |
| | 15 | 44000 | 28 | 36000 | 23 | 72000 | 45 | 8000 | 5 | 160000 |
| | 25 | 200000 | 69 | 16000 | 6 | 56000 | 19 | 16000 | 6 | 396000 |
| | 35 | 334000 | 77 | 20000 | 5 | 64000 | 15 | 18000 | 4 | 436000 |
| | 45 | 230000 | 72 | 32000 | 10 | 56000 | 18 | 2000 | 1 | 320000 |
| 3 | 03 | 10000 | 3 | 4000 | 1 | 286000 | 95 | | | 300000 |
| | 10 | 184000 | 78 | | | 50000 | 21 | 2000 | 1 | 236000 |
| | 15 | 236000 | 59 | | | 154000 | 38 | 12000 | 3 | 402000 |
| | 20 | 136000 | 50 | 4000 | 1 | 120000 | 43 | 14000 | 5 | 274000 |
| | 25 | 34000 | 19 | 24000 | 14 | 110000 | 63 | 8000 | 5 | 176000 |
| | 30 | 92000 | 42 | 22000 | 10 | 100000 | 45 | 6000 | 3 | 220000 |
| | 35 | 176000 | 45 | 50000 | 13 | 156000 | 40 | 6000 | 2 | 388000 |
| 4 | 00 | | | 2000 | 1 | 272000 | 99 | | | 274000 |
| | 05 | | | 4000 | 2 | 220000 | 98 | | | 224000 |
| | 10 | | | | | 82000 | 98 | 2000 | 2 | 84000 |
| | 15 | 14000 | 5 | 6000 | 2 | 282000 | 93 | 2000 | 1 | 304000 |
| | 20 | 34000 | 25 | 12000 | 9 | 92000 | 67 | | | 138000 |
| | 25 | 60000 | 32 | 8000 | 4 | 120000 | 64 | | | 188000 |
| 5 | 00 | 34000 | 8 | 2000 | 1 | 382000 | 91 | | | 418000 |
| | 03 | 122000 | 36 | 20000 | 6 | 194000 | 56 | 6000 | 2 | 342000 |
| | 06 | 590000 | 68 | 192000 | 22 | 82000 | 9 | 4000 | 1 | 868000 |
| | 09 | 562000 | 66 | 114000 | 13 | 144000 | 17 | 32000 | 4 | 852000 |
| | 12 | 656000 | 61 | 80000 | 7 | 332000 | 31 | 10000 | 1 | 1078000 |
| | 15 | 568000 | 77 | 52000 | 7 | 112000 | 15 | 8000 | 1 | 740000 |
| | 20 | 328000 | 49 | 48000 | 7 | 290000 | 43 | 6000 | 1 | 672000 |

Table 6. (continued)

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 00 | 4000 | 1 | 10000 | 1 | 828000 | 97 | 10000 | 1 | 852000 |
| | 05 | 132000 | 49 | 70000 | 26 | 60000 | 22 | 8000 | 3 | 270000 |
| | 10 | 130000 | 53 | 70000 | 29 | 38000 | 16 | 6000 | 2 | 244000 |
| | 15 | 140000 | 74 | 4000 | 2 | 42000 | 22 | 2000 | 1 | 188000 |
| | 20 | 172000 | 65 | | | 90000 | 34 | 4000 | 2 | 266000 |
| | 25 | 170000 | 46 | | | 194000 | 53 | 2000 | 1 | 366000 |
| | 30 | 56000 | 37 | 4000 | 3 | 84000 | 56 | 6000 | 4 | 150000 |
| | 35 | 94000 | 43 | 14000 | 6 | 108000 | 50 | 2000 | 1 | 218000 |
| 7 | 00 | 2000 | 1 | 2000 | 1 | 224000 | 91 | 18000 | 7 | 246000 |
| | 05 | | | | | 242000 | 95 | 14000 | 5 | 256000 |
| | 10 | 8000 | 4 | 38000 | 18 | 142000 | 69 | 18000 | 9 | 206000 |
| | 15 | 6000 | 3 | 18000 | 9 | 140000 | 73 | 28000 | 15 | 192000 |
| | 20 | 42000 | 20 | 20000 | 10 | 128000 | 61 | 20000 | 10 | 210000 |
| 8 | 00 | 12000 | 4 | 20000 | 6 | 264000 | 84 | 20000 | 6 | 316000 |
| | 05 | 8000 | 3 | 4000 | 2 | 220000 | 89 | 14000 | 6 | 246000 |
| | 10 | 18000 | 7 | 8000 | 3 | 192000 | 74 | 42000 | 16 | 260000 |
| | 15 | 28000 | 10 | 24000 | 9 | 184000 | 67 | 38000 | 14 | 274000 |
| | 20 | 54000 | 23 | 30000 | 13 | 132000 | 56 | 18000 | 8 | 234000 |
| 9 | 00 | 8000 | 3 | 12000 | 4 | 252000 | 80 | 42000 | 13 | 314000 |
| | 05 | 4000 | 2 | 10000 | 4 | 204000 | 84 | 26000 | 11 | 244000 |
| | 10 | 6000 | 3 | | | 156000 | 83 | 26000 | 14 | 188000 |
| | 15 | 32000 | 15 | 10000 | 5 | 142000 | 66 | 30000 | 14 | 214000 |
| | 20 | 10000 | 8 | 6000 | 5 | 88000 | 70 | 22000 | 17 | 126000 |
| 10 | 00 | 6000 | 2 | 4000 | 2 | 236000 | 92 | 10000 | 4 | 256000 |
| | 05 | 26000 | 12 | 2000 | 1 | 178000 | 81 | 14000 | 6 | 220000 |
| | 10 | 164000 | 37 | 36000 | 8 | 200000 | 46 | 38000 | 9 | 438000 |

Table 6. (continued)

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 15 | 390000 | 58 | 60000 | 9 | 206000 | 31 | 16000 | 2 | 672000 |
| | 20 | 310000 | 54 | 70000 | 12 | 182000 | 32 | 12000 | 2 | 574000 |
| 11 | 00 | 28000 | 11 | 2000 | 1 | 202000 | 78 | 28000 | 11 | 260000 |
| | 05 | 2000 | 1 | 8000 | 3 | 214000 | 87 | 22000 | 9 | 246000 |
| | 10 | 18000 | 7 | 44000 | 16 | 186000 | 67 | 28000 | 10 | 276000 |
| | 15 | 34000 | 15 | 40000 | 18 | 102000 | 46 | 44000 | 20 | 220000 |
| | 20 | 22000 | 6 | 106000 | 29 | 212000 | 58 | 28000 | 8 | 368000 |
| | 30 | 88000 | 42 | 10000 | 5 | 108000 | 52 | 2000 | 1 | 208000 |
| | 40 | 46000 | 26 | 36000 | 20 | 88000 | 49 | 10000 | 6 | 180000 |
| | 50 | 28000 | 15 | 44000 | 24 | 110000 | 59 | 4000 | 2 | 186000 |
| 12 | 00 | 8000 | 4 | | | 162000 | 85 | 20000 | 11 | 190000 |
| | 05 | 4000 | 1 | 82000 | 25 | 202000 | 62 | 40000 | 12 | 328000 |
| | 10 | 16000 | 9 | 16000 | 9 | 102000 | 59 | 40000 | 23 | 174000 |
| | 15 | 20000 | 7 | 30000 | 11 | 152000 | 56 | 70000 | 26 | 272000 |
| | 20 | 8000 | 4 | 14000 | 8 | 120000 | 66 | 40000 | 22 | 182000 |
| | 30 | 10000 | 11 | | | 62000 | 70 | 16000 | 18 | 88000 |
| | 45 | 66000 | 34 | 16000 | 8 | 100000 | 51 | 16000 | 8 | 196000 |
| 13 | 00 | 2000 | 1 | 2000 | 1 | 230000 | 94 | 10000 | 4 | 244000 |
| | 05 | 2000 | 1 | | | 142000 | 86 | 22000 | 13 | 166000 |
| | 10 | 2000 | 1 | 30000 | 20 | 102000 | 69 | 14000 | 9 | 148000 |
| | 15 | 2000 | 1 | 134000 | 63 | 62000 | 29 | 14000 | 7 | 212000 |
| | 20 | | | 32000 | 33 | 64000 | 67 | | | 96000 |
| | 30 | 44000 | 39 | | | 68000 | 60 | 2000 | 2 | 114000 |
| | 45 | 56000 | 49 | 6000 | 5 | 40000 | 35 | 12000 | 11 | 114000 |
| 14 | 00 | 98000 | 28 | 14000 | 4 | 238000 | 68 | 2000 | 1 | 352000 |
| | 03 | 338000 | 77 | 12000 | 3 | 90000 | 20 | | | 440000 |

Table 6. (continued)

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 06 | 768000 | 71 | 250000 | 23 | 70000 | 6 | | | 1088000 |
| | 09 | 514000 | 57 | 296667 | 33 | 88000 | 10 | 4000 | < 1 | 902667 |
| | 12 | 494000 | 61 | 156000 | 19 | 160000 | 20 | 4000 | < 1 | 814000 |
| | 15 | 538000 | 59 | 132000 | 14 | 242000 | 26 | 4000 | < 1 | 916000 |
| | 18 | 704000 | 70 | 120000 | 12 | 182000 | 18 | 4000 | < 1 | 1010000 |
| 16 | 00 | 66000 | 28 | 4000 | 2 | 162000 | 70 | | | 232000 |
| | 03 | 270000 | 57 | 50000 | 11 | 154000 | 32 | 2000 | < 1 | 476000 |
| | 06 | 586000 | 62 | 290000 | 31 | 62000 | 7 | 4000 | < 1 | 942000 |
| | 09 | 1644000 | 65 | 692000 | 27 | 206000 | 8 | 6000 | < 1 | 2548000 |
| | 12 | 726000 | 55 | 376000 | 29 | 210000 | 16 | 4000 | < 1 | 1316000 |
| | 15 | 1108000 | 66 | 376000 | 22 | 180000 | 11 | 14000 | 1 | 1678000 |
| | 18 | 998000 | 58 | 506000 | 30 | 192000 | 11 | 10000 | 1 | 1706000 |
| | 21 | 984000 | 61 | 404000 | 25 | 210000 | 13 | 4000 | < 1 | 1602000 |
| 17 | 00 | 66000 | 35 | 6000 | 3 | 116000 | 62 | | | 188000 |
| | 03 | 336000 | 68 | 64000 | 13 | 94000 | 19 | 2000 | < 1 | 496000 |
| | 06 | 764000 | 72 | 144000 | 13 | 156000 | 15 | 4000 | < 1 | 1068000 |
| | 09 | 778000 | 66 | 258000 | 22 | 148000 | 13 | | | 1184000 |
| | 12 | 1556000 | 60 | 778600 | 30 | 248000 | 10 | 6000 | < 1 | 2588000 |
| | 15 | 1138000 | 64 | 384000 | 22 | 248000 | 14 | 6000 | < 1 | 1776000 |
| | 18 | 1216000 | 65 | 420000 | 23 | 222000 | 12 | 2000 | < 1 | 1860000 |
| 18 | 00 | 68000 | 14 | 4000 | 1 | 400000 | 84 | 4000 | 1 | 476000 |
| | 03 | 160000 | 39 | | | 250000 | 61 | | | 410000 |
| | 06 | 310000 | 54 | 20000 | 3 | 242000 | 42 | | | 572000 |
| | 09 | 588000 | 68 | 76000 | 9 | 198000 | 23 | 4000 | < 1 | 866000 |
| | 12 | 1536000 | 56 | 954000 | 35 | 256000 | 9 | 2000 | < 1 | 2748000 |
| | 15 | 1548000 | 65 | 572000 | 24 | 252000 | 11 | 4000 | < 1 | 2376000 |

Table 6. (continued)

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 00 | 152000 | 38 | 30000 | 8 | 214000 | 54 | | | 396000 |
| | 03 | 386000 | 69 | 30000 | 5 | 144000 | 26 | 2000 | < 1 | 562000 |
| | 06 | 246000 | 73 | 8000 | 2 | 80000 | 24 | 2000 | 1 | 336000 |
| | 09 | 162000 | 72 | 8000 | 3 | 54000 | 24 | 2000 | 1 | 224000 |
| | 12 | 964000 | 84 | 42000 | 4 | 146000 | 13 | | | 1152000 |
| | 15 | 1678000 | 69 | 562000 | 23 | 196000 | 8 | | | 2436000 |
| | 18 | 1322000 | 71 | 296000 | 16 | 248000 | 13 | | | 1866000 |
| 20 | 00 | 250000 | 70 | 4000 | 1 | 104000 | 29 | | | 358000 |
| | 03 | 628000 | 79 | 62000 | 8 | 110000 | 14 | | | 800000 |
| | 06 | 594000 | 81 | 20000 | 3 | 114000 | 16 | 2000 | < 1 | 730000 |
| | 09 | 1780000 | 91 | 46000 | 2 | 118000 | 6 | 2000 | < 1 | 1946000 |
| | 12 | 1818000 | 91 | 64000 | 3 | 126000 | 6 | | | 2008000 |
| | 15 | 1896000 | 81 | 250000 | 11 | 208000 | 9 | | | 2354000 |
| 22 | 00 | 360000 | 77 | 10000 | 2 | 96000 | 21 | | | 466000 |
| | 03 | 380000 | 78 | 20000 | 4 | 88000 | 18 | 2000 | < 1 | 490000 |
| | 06 | 548000 | 75 | 30600 | 4 | 144000 | 20 | 4000 | 1 | 726600 |
| | 09 | 432000 | 75 | 20000 | 3 | 120000 | 21 | 2000 | < 1 | 574000 |
| | 12 | 816000 | 85 | 18000 | 2 | 122000 | 13 | | | 956000 |
| | 15 | 782000 | 89 | 32000 | 4 | 62000 | 7 | | | 876000 |
| 23 | 00 | 82000 | 41 | 8000 | 4 | 108000 | 54 | 2000 | 1 | 200000 |
| | 05 | 320000 | 63 | 64600 | 13 | 114000 | 22 | 8000 | 2 | 506600 |
| | 10 | 306000 | 85 | 28000 | 8 | 28000 | 8 | | | 362000 |
| | 15 | 70000 | 52 | 10000 | 7 | 54000 | 40 | | | 134000 |
| | 20 | 128000 | 70 | | | 50000 | 27 | 6000 | 3 | 184000 |
| | 25 | 40000 | 27 | 10000 | 7 | 94000 | 64 | 2000 | 1 | 146000 |
| | 30 | 62000 | 37 | 14000 | 8 | 84000 | 51 | 6000 | 4 | 166000 |
| | 35 | 68000 | 27 | 66000 | 26 | 106000 | 42 | 10000 | 4 | 250000 |

Table 6. (continued)

| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 00 | 12000 | 6 | 14000 | 7 | 168000 | 85 | 4000 | 2 | 198000 |
| | 05 | 102000 | 63 | 6000 | 4 | 50000 | 31 | 4000 | 2 | 162000 |
| | 10 | 134000 | 61 | 6000 | 3 | 74000 | 34 | 6000 | 3 | 220000 |
| | 15 | 130000 | 68 | | | 56000 | 29 | 4000 | 2 | 190000 |
| | 20 | 162000 | 64 | 4000 | 2 | 82000 | 33 | 4000 | 2 | 252000 |
| | 30 | 46000 | 34 | 8000 | 6 | 78000 | 57 | 4000 | 3 | 136000 |
| | 45 | 36000 | 34 | 10000 | 9 | 54000 | 51 | 6000 | 6 | 106000 |
| 25 | 00 | 130000 | 59 | | | 92000 | 41 | | | 222000 |
| | 03 | 188000 | 67 | 18000 | 6 | 72000 | 26 | 2000 | 1 | 280000 |
| | 06 | 128000 | 55 | 12000 | 5 | 92000 | 40 | | | 232000 |
| | 09 | 184000 | 58 | 16000 | 5 | 12000 | 4 | | | 320000 |
| | 12 | 214000 | 73 | 12000 | 4 | 60000 | 21 | 6000 | 2 | 292000 |
| | 15 | 1632000 | 76 | 364000 | 17 | 146000 | 7 | 4000 | < 1 | 2146000 |
| | 20 | 2338000 | 81 | 374000 | 13 | 178000 | 6 | 2000 | < 1 | 2892000 |
| | 25 | 5215000 | 76 | 540000 | 19 | 146000 | 5 | 4000 | < 1 | 2842000 |
| 26 | 03 | 54000 | 31 | 4000 | 2 | 118000 | 67 | | | 176000 |
| | 06 | 32000 | 27 | | | 84000 | 70 | 4000 | 3 | 120000 |
| | 09 | 64000 | 64 | 4400 | 4 | 30000 | 30 | 2000 | 2 | 100400 |
| | 12 | 60000 | 25 | 90000 | 38 | 84000 | 36 | 2000 | 1 | 236000 |
| | 15 | 18000 | 10 | 112000 | 62 | 50000 | 28 | | | 180000 |
| 27 | 00 | 108000 | 38 | 6000 | 2 | 168000 | 60 | | | 282000 |
| | 03 | 208000 | 37 | 14000 | 3 | 334000 | 61 | | | 556000 |
| | 06 | 322000 | 63 | 32000 | 6 | 156000 | 31 | | | 510000 |
| | 09 | 348000 | 77 | 20000 | 4 | 84000 | 19 | | | 452000 |
| | 12 | 338000 | 81 | 22000 | 5 | 58000 | 14 | | | 418000 |
| | 15 | 1756000 | 76 | 174000 | 8 | 374000 | 16 | 4000 | < 1 | 2308000 |
| | 18 | 3702000 | 83 | 352000 | 8 | 404000 | 9 | 6000 | < 1 | 4464000 |

Table 6. (continued)

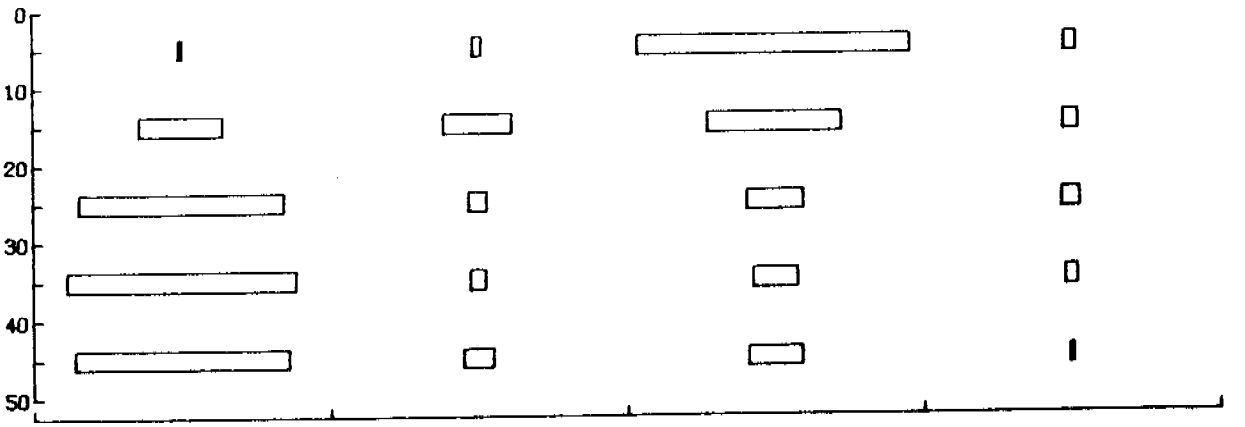
| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | 00 | 16000 | 5 | 16000 | 5 | 300000 | 88 | 8000 | 2 | 340000 |
| | 03 | 120000 | 53 | 38000 | 17 | 66000 | 29 | 2000 | 1 | 226000 |
| | 06 | 136000 | 73 | 9000 | 5 | 42000 | 22 | | | 187000 |
| | 09 | 174000 | 67 | 18000 | 7 | 66000 | 25 | 2000 | 1 | 260000 |
| | 12 | 232000 | 72 | 24000 | 7 | 66000 | 20 | 2000 | 1 | 324000 |
| | 15 | 396000 | 71 | 40000 | 7 | 118000 | 21 | 4000 | 1 | 558000 |
| | 18 | 1482000 | 87 | 95000 | 56 | 124000 | 7 | 8000 | < 1 | 1709000 |
| | 21 | 1298000 | 79 | 208000 | 13 | 136000 | 8 | 4000 | < 1 | 1646000 |
| 29 | 00 | 10000 | 6 | 36000 | 21 | 118000 | 69 | 6000 | 3 | 170000 |
| | 05 | 84000 | 29 | 86000 | 30 | 110000 | 38 | 10000 | 3 | 290000 |
| | 10 | 20000 | 17 | 38000 | 33 | 48000 | 41 | 10000 | 9 | 116000 |
| | 15 | 26000 | 8 | 178000 | 56 | 98000 | 31 | 18000 | 6 | 320000 |
| | 20 | 40000 | 16 | 56000 | 22 | 132000 | 52 | 26000 | 10 | 254000 |
| | 25 | 14000 | 8 | 56000 | 33 | 76000 | 45 | 22000 | 13 | 168000 |
| | 30 | 48000 | 31 | 30000 | 19 | 60000 | 39 | 16000 | 10 | 154000 |
| | 45 | 10000 | 1 | 4000 | 1 | 758000 | 97 | 6000 | 1 | 778000 |
| 30 | 00 | 20000 | 2 | 24000 | 2 | 1006000 | 95 | 14000 | 1 | 1064000 |
| | 03 | 380000 | 76 | 18000 | 4 | 102000 | 20 | | | 500000 |
| | 06 | 528000 | 72 | 26000 | 4 | 174000 | 24 | 2000 | < 1 | 730000 |
| | 09 | 1024000 | 88 | 38600 | 3 | 96000 | 8 | 4000 | < 1 | 1162600 |
| | 12 | 1132000 | 90 | 52000 | 4 | 70000 | 6 | 8000 | 1 | 1262000 |
| | 15 | 258000 | 55 | 20000 | 4 | 148000 | 31 | 44000 | 9 | 470000 |
| | 18 | 156000 | 41 | 80000 | 21 | 142000 | 37 | 6000 | 2 | 384000 |
| | 21 | 352000 | 50 | 194200 | 28 | 150000 | 21 | 8000 | 1 | 704200 |
| 31 | 00 | 4000 | 1 | 14000 | 3 | 526000 | 96 | 6000 | 1 | 550000 |
| | 03 | 324000 | 73 | 26000 | 6 | 92000 | 21 | | | 442000 |
| | 06 | 60000 | 39 | 24000 | 16 | 60000 | 39 | 10000 | 6 | 154000 |

Table 6. (continued)

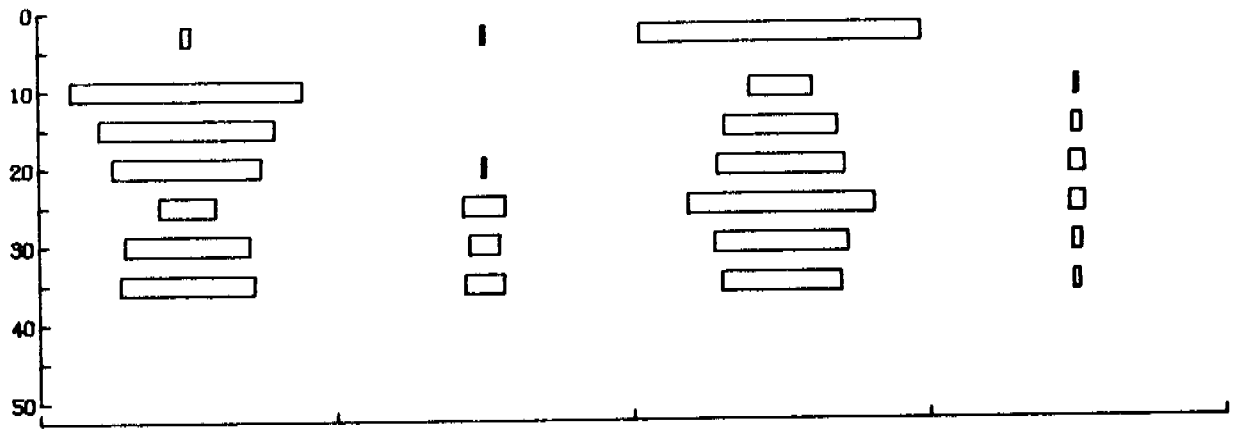
| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 09 | 116000 | 47 | 30000 | 12 | 84000 | 34 | 18000 | 7 | 248000 |
| | 12 | 404000 | 56 | 132000 | 18 | 184000 | 22 | 6000 | 1 | 726000 |
| | 15 | 676000 | 68 | 148000 | 15 | 158000 | 16 | 8000 | 1 | 990000 |
| | 18 | 708000 | 71 | 164000 | 16 | 120000 | 12 | 2000 | < 1 | 994000 |
| 32 | 00 | 18000 | 2 | 8000 | 1 | 938000 | 97 | 4000 | < 1 | 968000 |
| | 03 | 710000 | 86 | 24000 | 3 | 88000 | 11 | 4000 | < 1 | 826000 |
| | 06 | 210000 | 59 | 16000 | 5 | 122000 | 34 | 6000 | 2 | 354000 |
| | 09 | 286000 | 60 | 34000 | 7 | 138000 | 29 | 16000 | 3 | 474000 |
| | 12 | 398000 | 67 | 86000 | 15 | 96000 | 16 | 12000 | 2 | 592000 |
| | 15 | 312000 | 55 | 92000 | 16 | 146000 | 26 | 14000 | 2 | 564000 |
| | 18 | 490000 | 58 | 158000 | 19 | 186000 | 22 | 12000 | 1 | 846000 |
| 33 | 00 | 60000 | 9 | 376000 | 59 | 176000 | 28 | 22000 | 3 | 634000 |
| | 05 | 86000 | 12 | 464000 | 64 | 162000 | 22 | 18000 | 2 | 730000 |
| | 10 | 58000 | 12 | 258000 | 53 | 162000 | 33 | 10000 | 2 | 488000 |
| | 15 | 84000 | 28 | 204000 | 45 | 148000 | 33 | 14000 | 3 | 450000 |
| | 20 | 24000 | 8 | 138000 | 47 | 102000 | 34 | 32000 | 11 | 296000 |
| | 30 | 28000 | 22 | 24000 | 19 | 68000 | 53 | 8000 | 6 | 128000 |
| | 45 | 16000 | 21 | 26000 | 33 | 26000 | 33 | 10000 | 13 | 78000 |
| 34 | 00 | 326000 | 55 | 30000 | 5 | 232000 | 39 | 6000 | 1 | 594000 |
| | 03 | 346000 | 63 | 34000 | 6 | 158000 | 29 | 14000 | 3 | 552000 |
| | 06 | 406000 | 73 | 42000 | 8 | 104000 | 19 | 8000 | 1 | 560000 |
| | 09 | 448000 | 63 | 120000 | 17 | 118000 | 17 | 28000 | 4 | 714000 |
| | 12 | 148000 | 37 | 146000 | 37 | 80000 | 20 | 22000 | 6 | 396000 |
| | 17 | 84000 | 34 | 82000 | 33 | 58000 | 24 | 22000 | 9 | 246000 |
| | 22 | 176000 | 47 | 82000 | 22 | 86000 | 23 | 28000 | 8 | 372000 |
| 35 | 00 | 590000 | 74 | 28000 | 3 | 178000 | 22 | 6000 | 1 | 802000 |

Table 6. (continued)

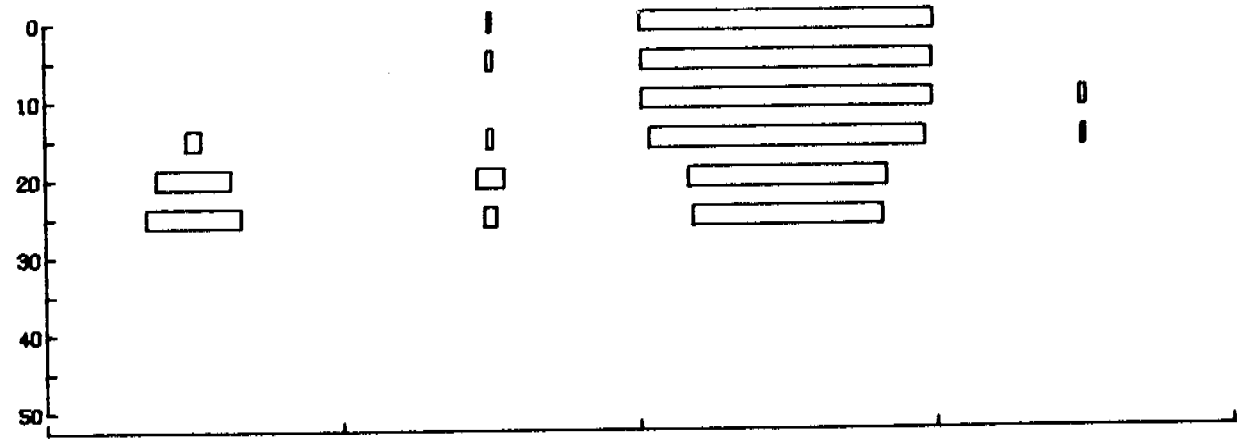
| Sta | Depth (m) | *Chaetoceros* Number | % | Other diatoms Number | % | Flagellates Number | % | Dinoflagellates Number | % | Total Number of Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 03 | 454000 | 72 | 24000 | 4 | 140000 | 22 | 10000 | 2 | 628000 |
| | 06 | 344000 | 71 | 14000 | 3 | 122000 | 25 | 2000 | < 1 | 482000 |
| | 09 | 642000 | 72 | 42000 | 5 | 190000 | 21 | 14000 | 2 | 888000 |
| | 12 | 94000 | 21 | 261000 | 58 | 78000 | 9 | 16000 | 4 | 449000 |
| | 15 | 58000 | 16 | 234000 | 65 | 46000 | 13 | 22000 | 6 | 360000 |
| | 18 | 104000 | 24 | 222000 | 51 | 90000 | 21 | 18000 | 4 | 434000 |
| | 21 | 54000 | 17 | 196000 | 63 | 40000 | 13 | 22000 | 7 | 312000 |




Station 01



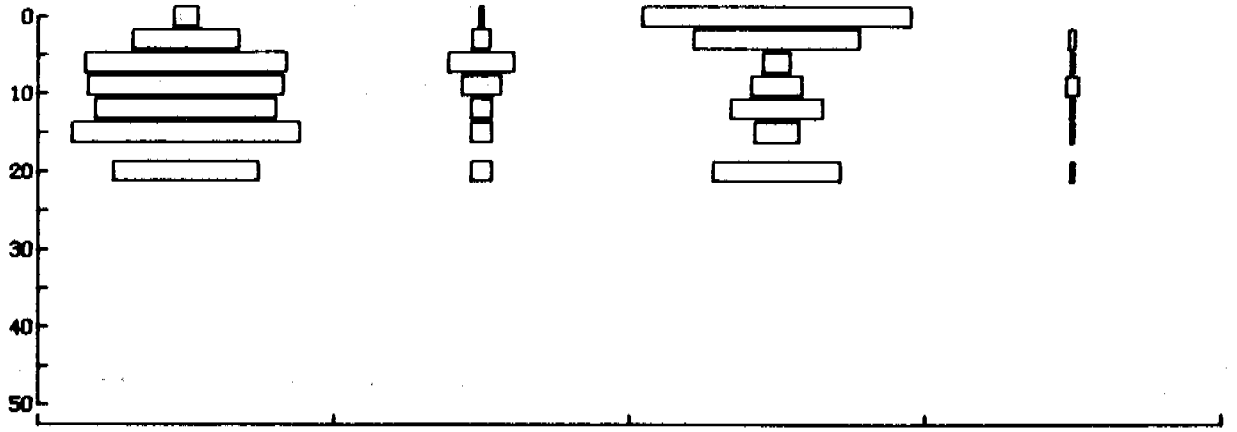

Station 03



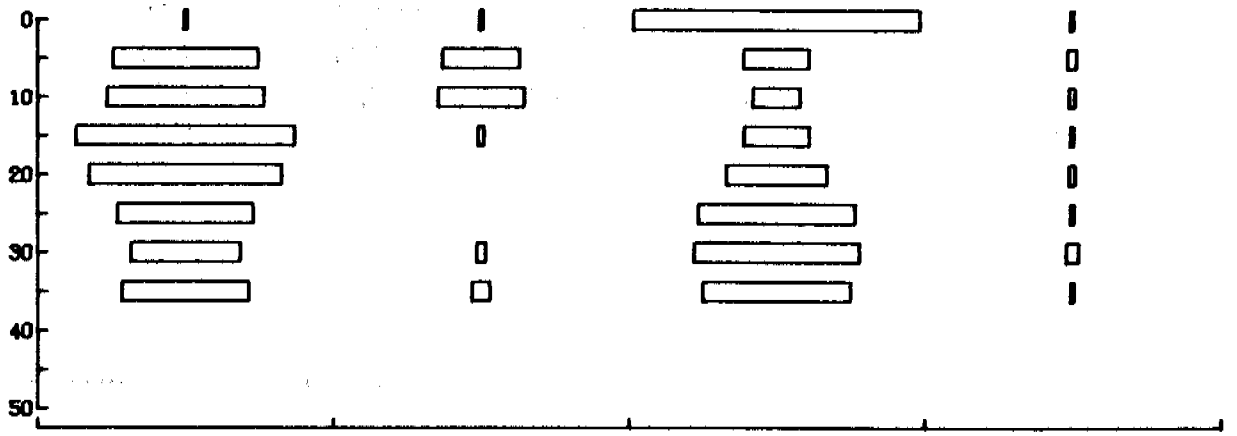

Station 04

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. Percentage of phytoplankton by major category by depth for each station. Where no number is present, no cells were found. Percentages add up to 100% running from left to right across the diagram.




Station 05

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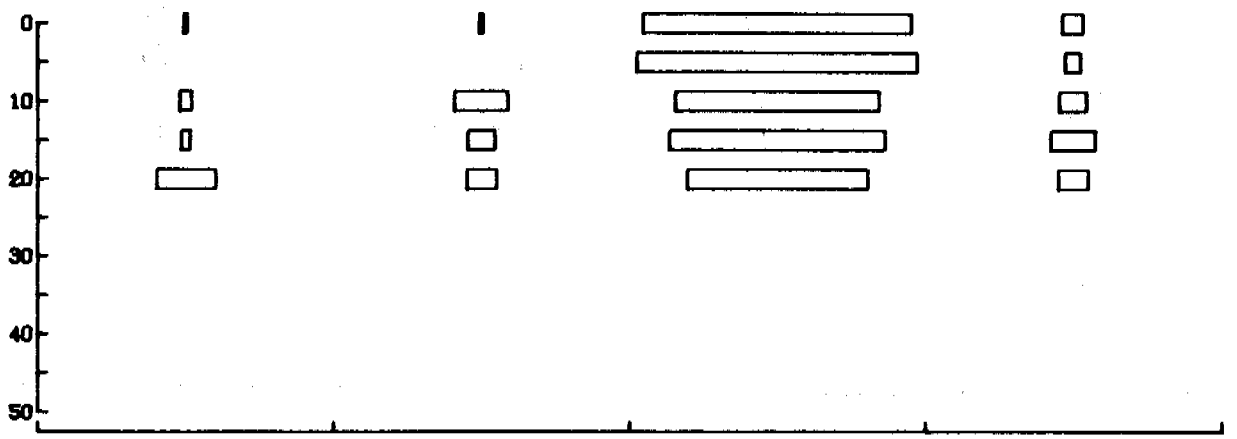
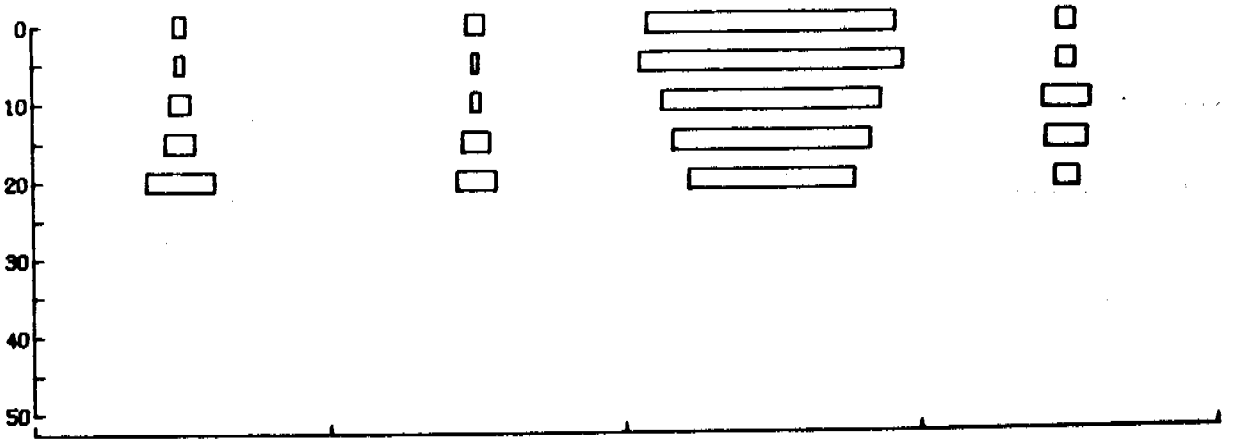



Station 07

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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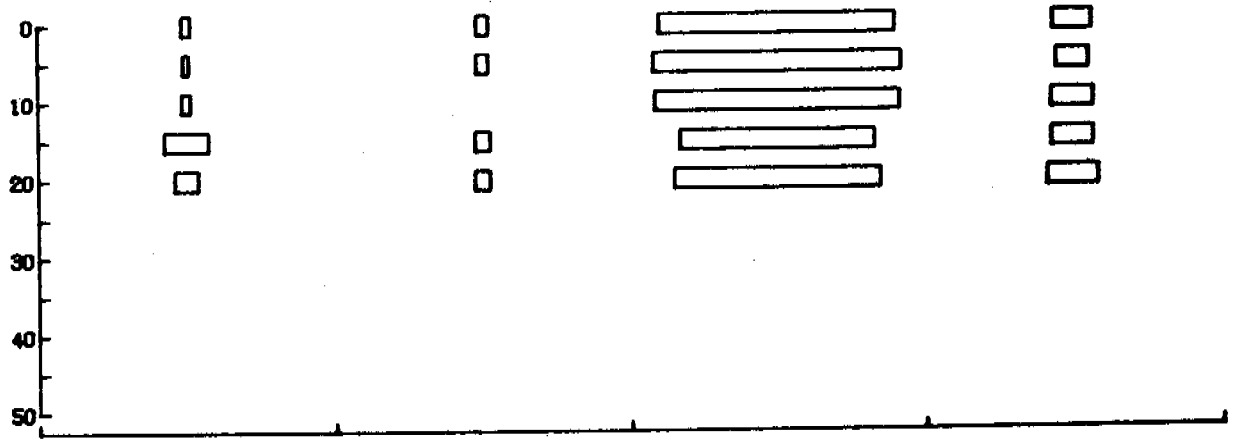


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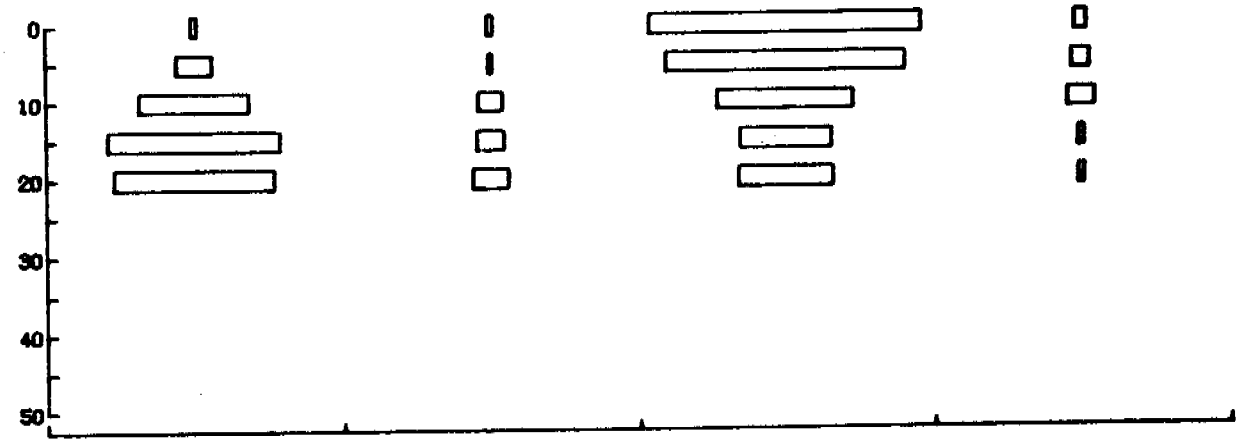
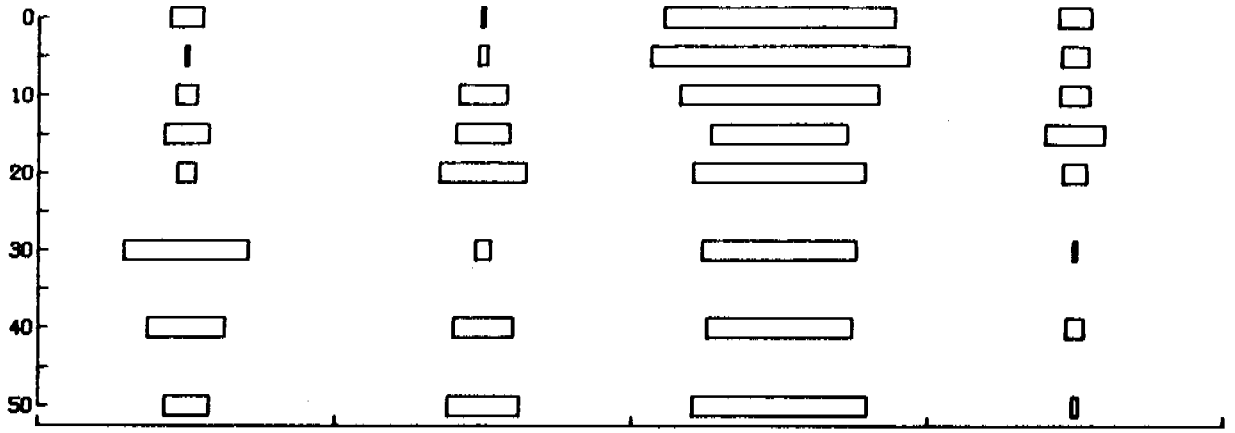



Station 10

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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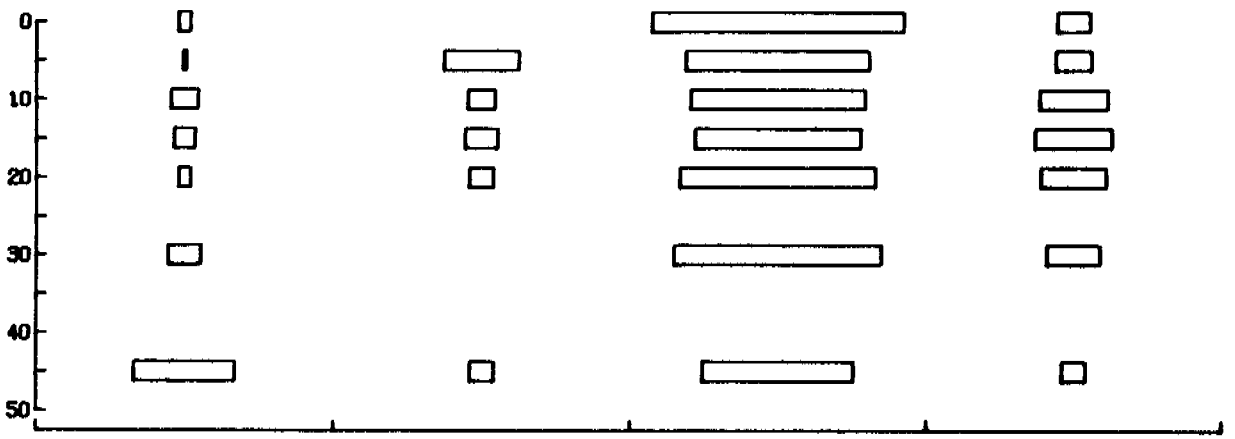


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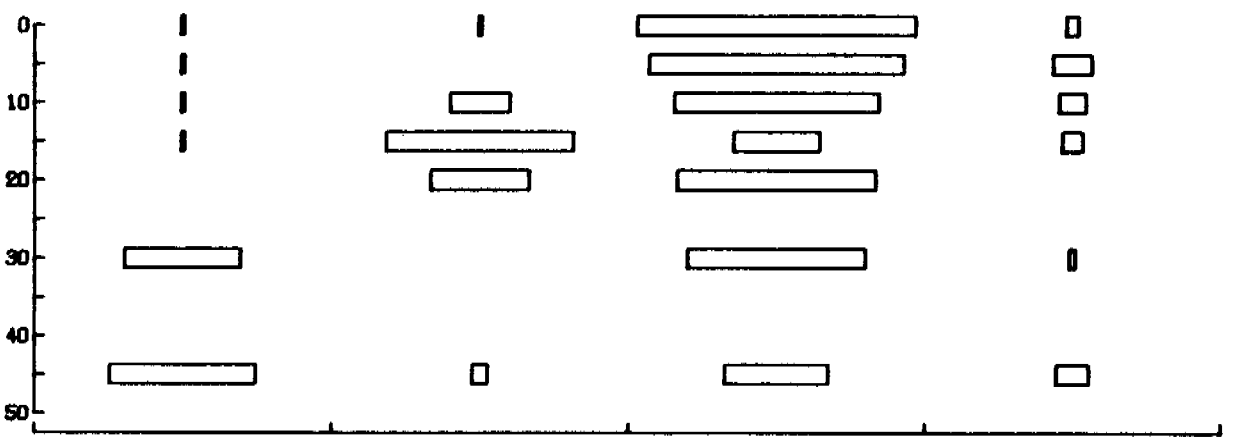
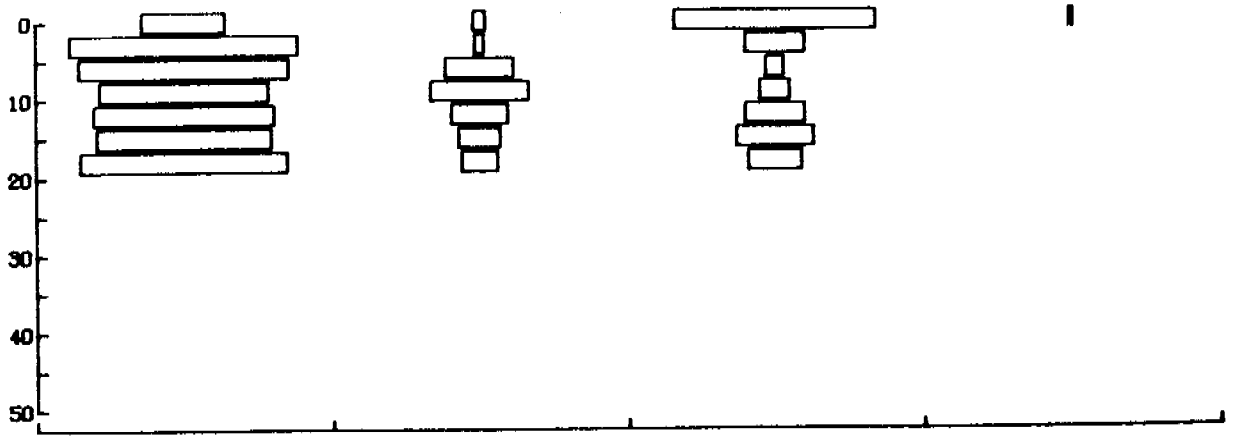



Station 13

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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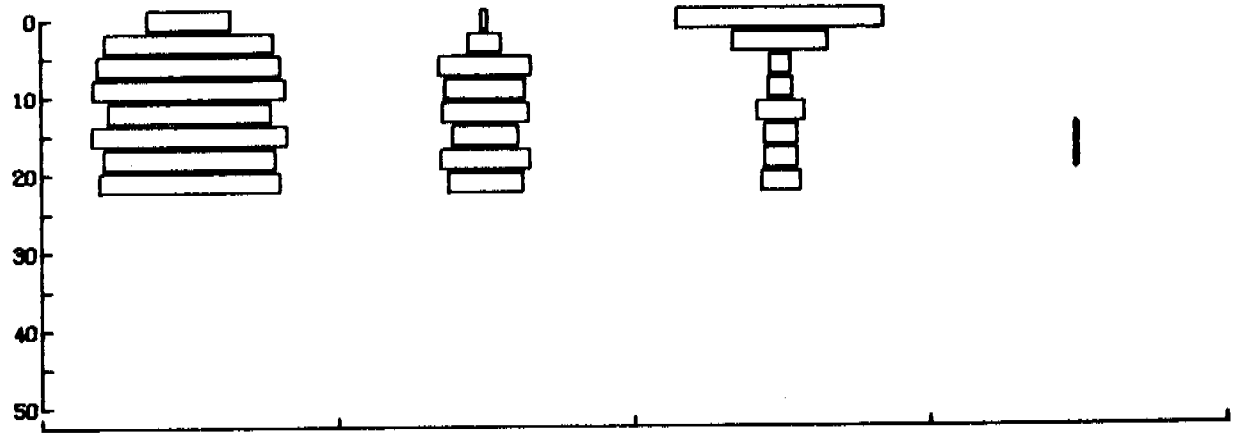


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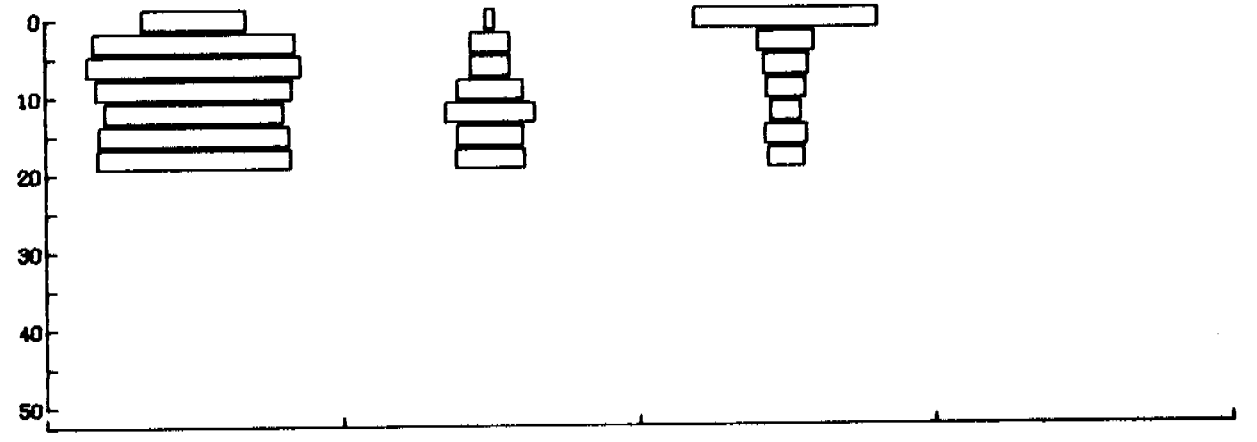
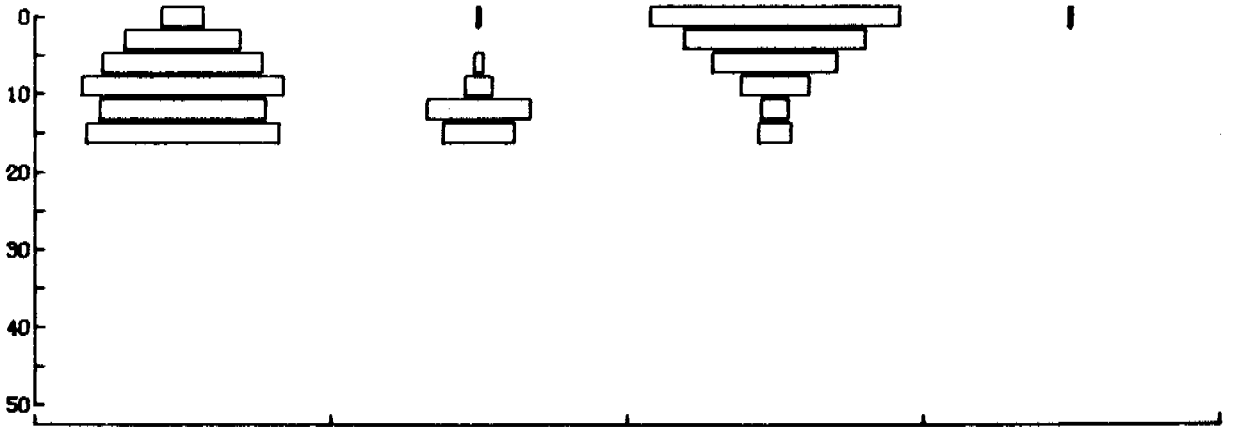



Station 17

*Chaetoceros* All Other Diatoms Flagellates **Dinoflagellates**

Fig. 1. (continued)

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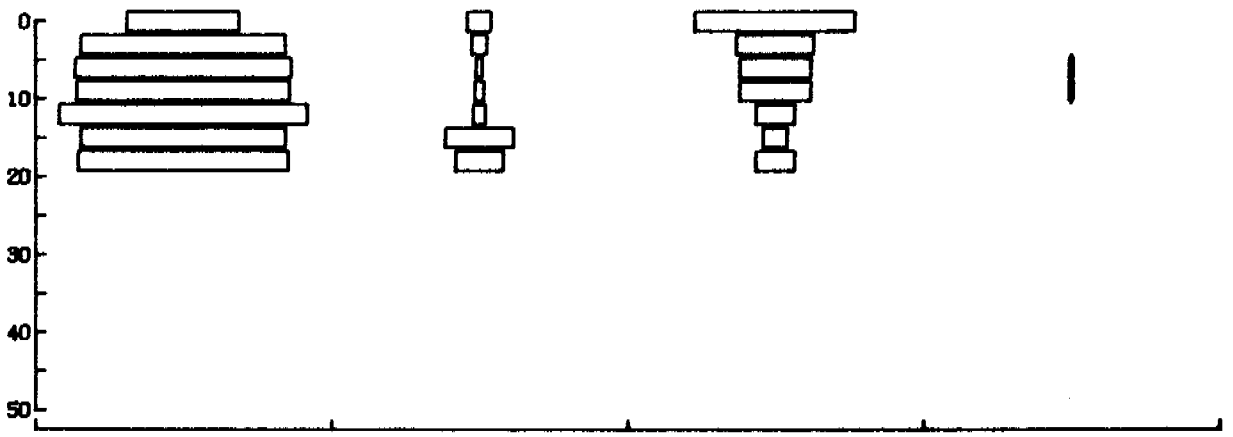


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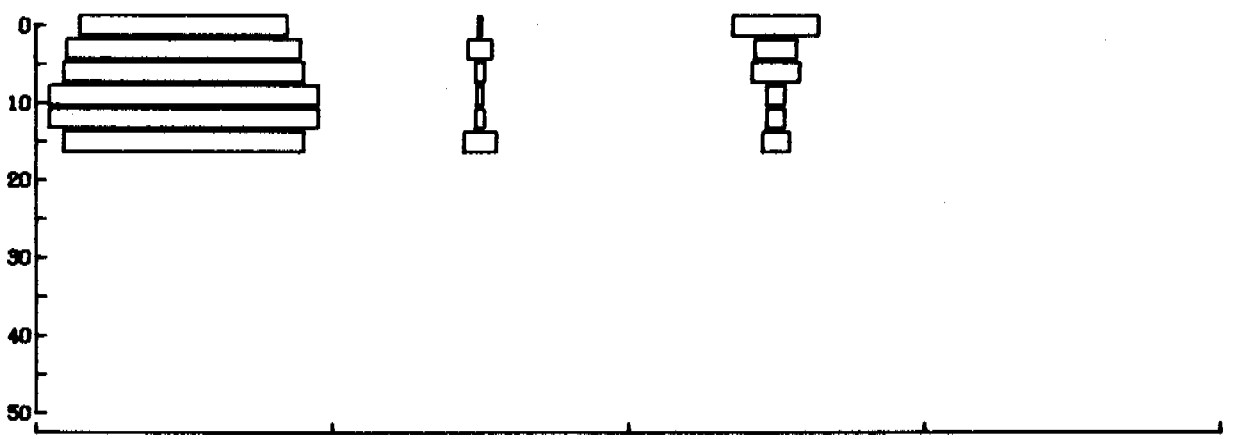
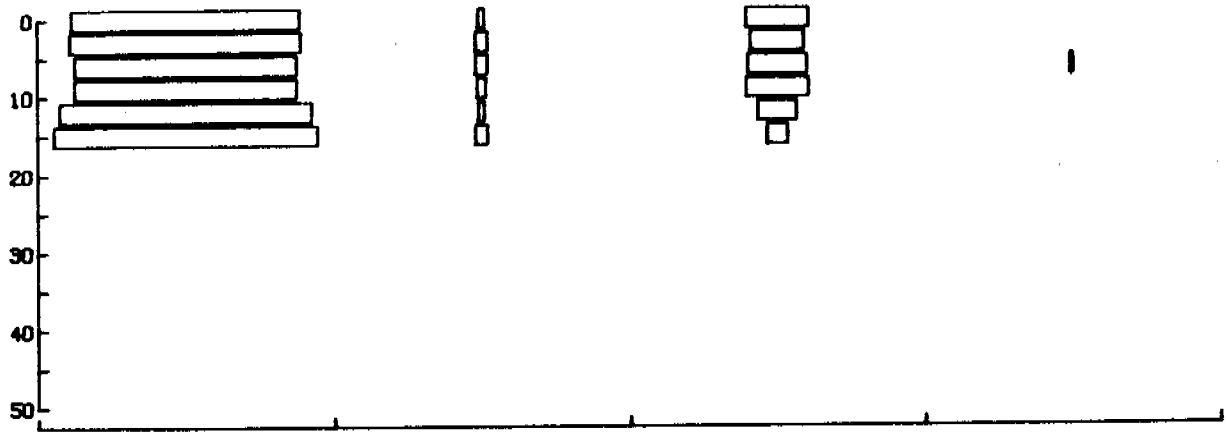



Station 20

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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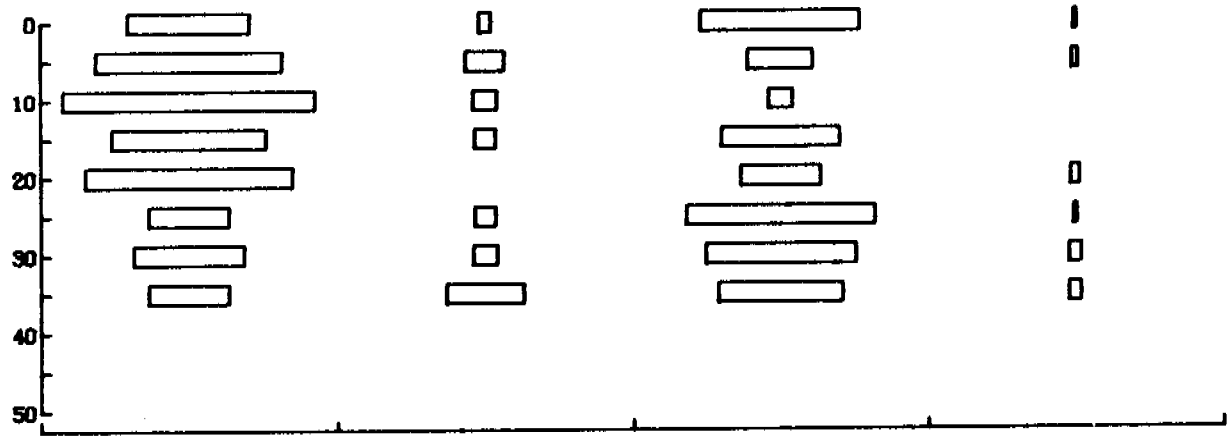


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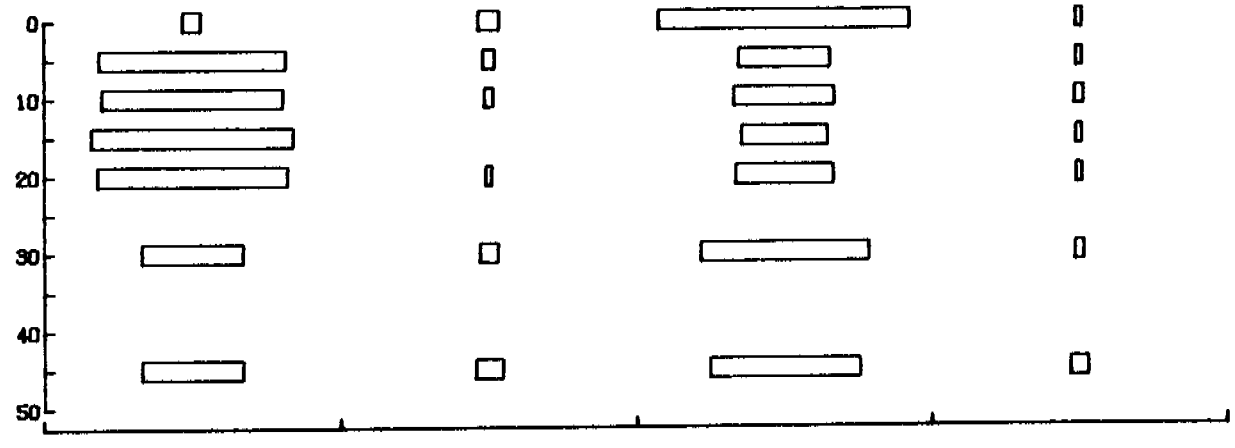
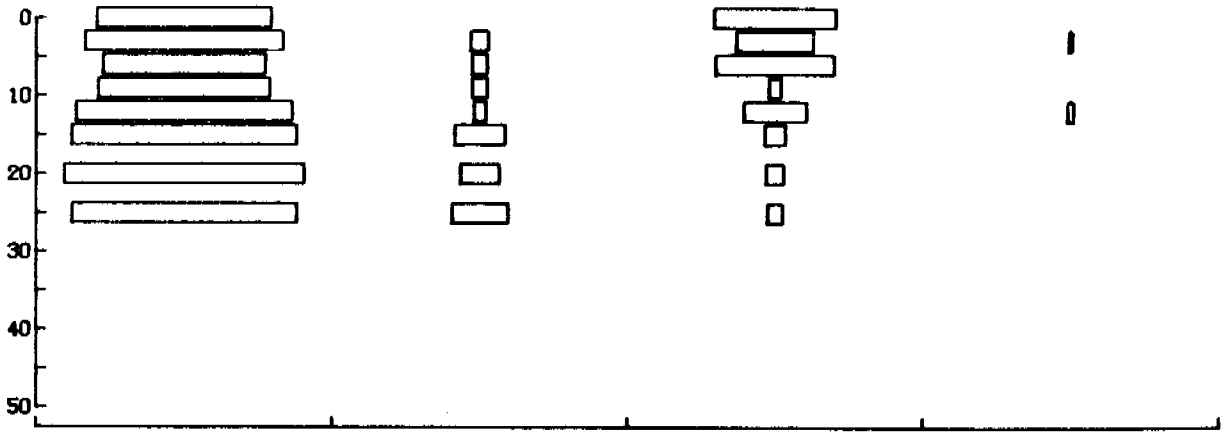



Station 24

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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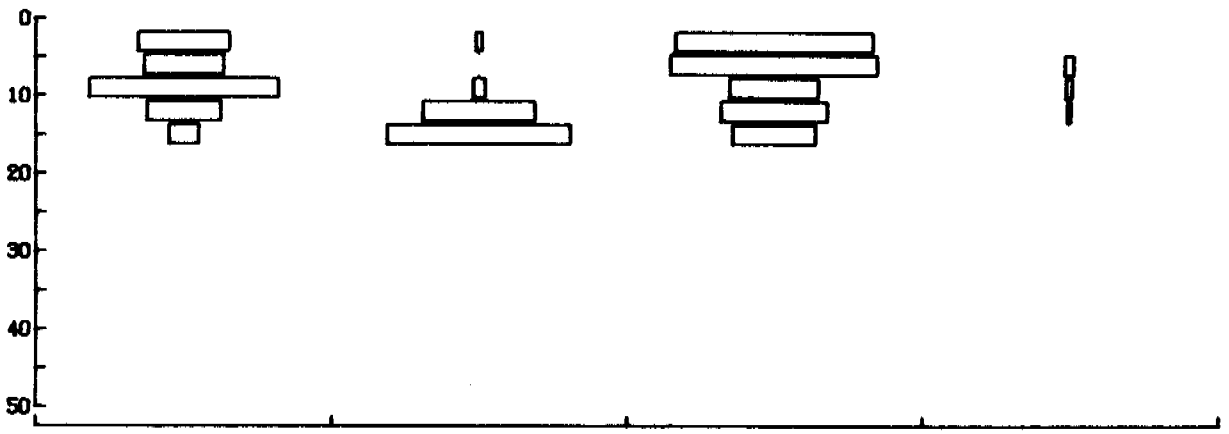


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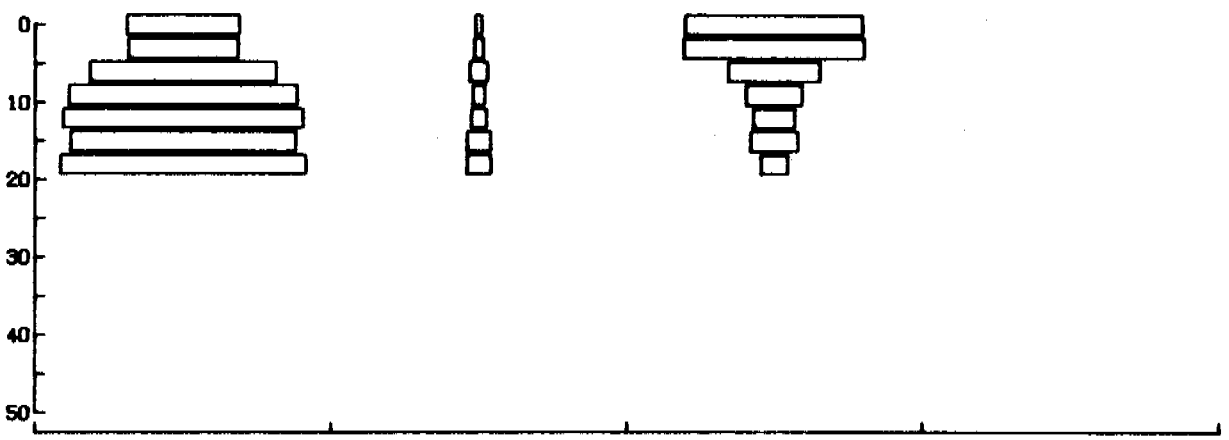
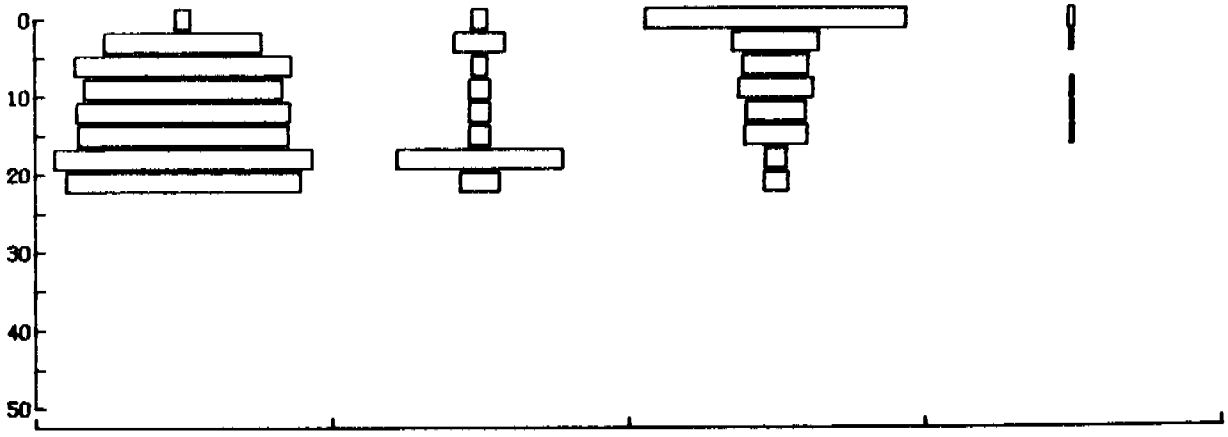



Station 27

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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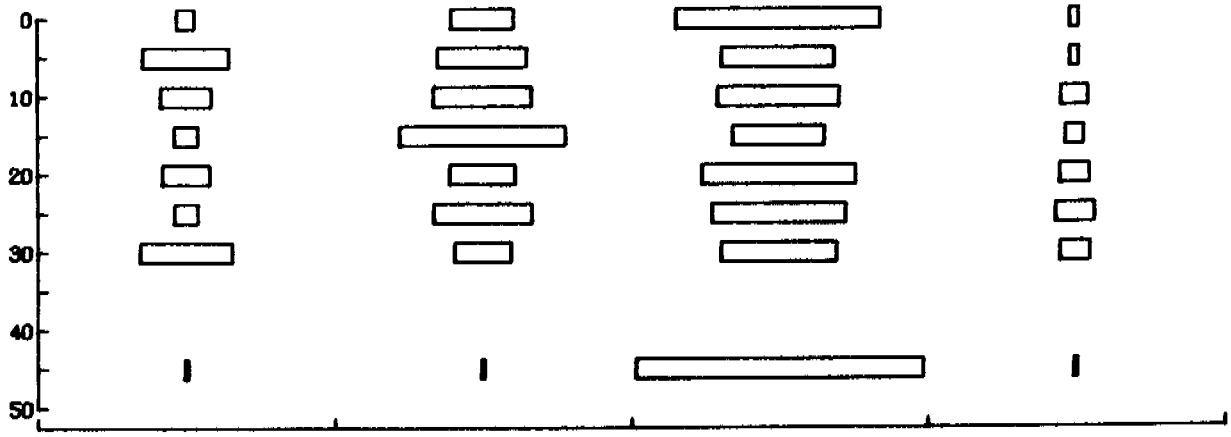


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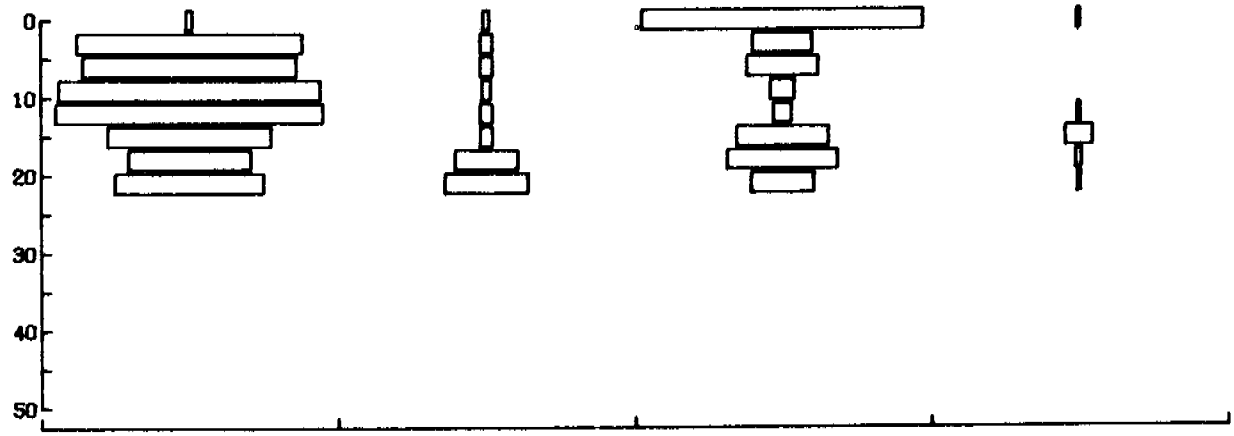
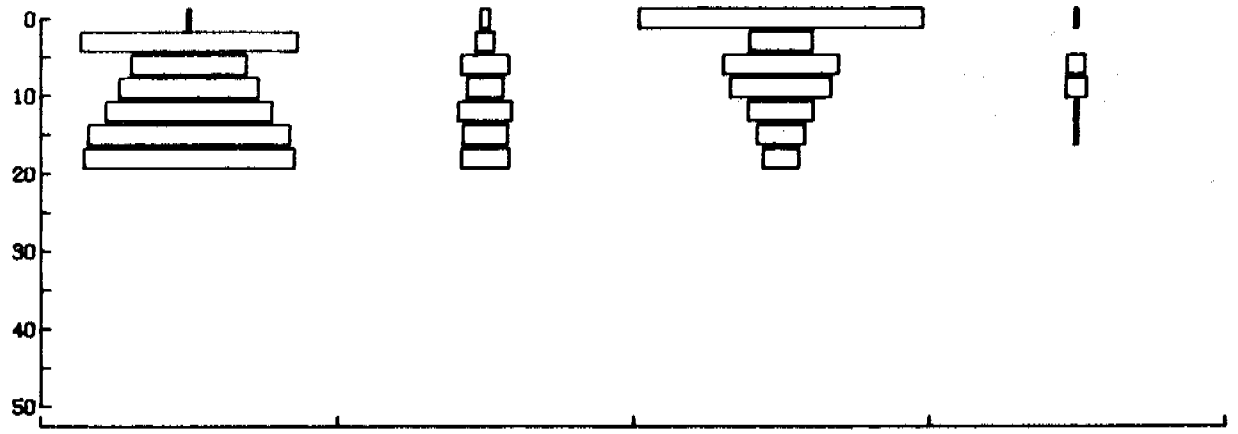


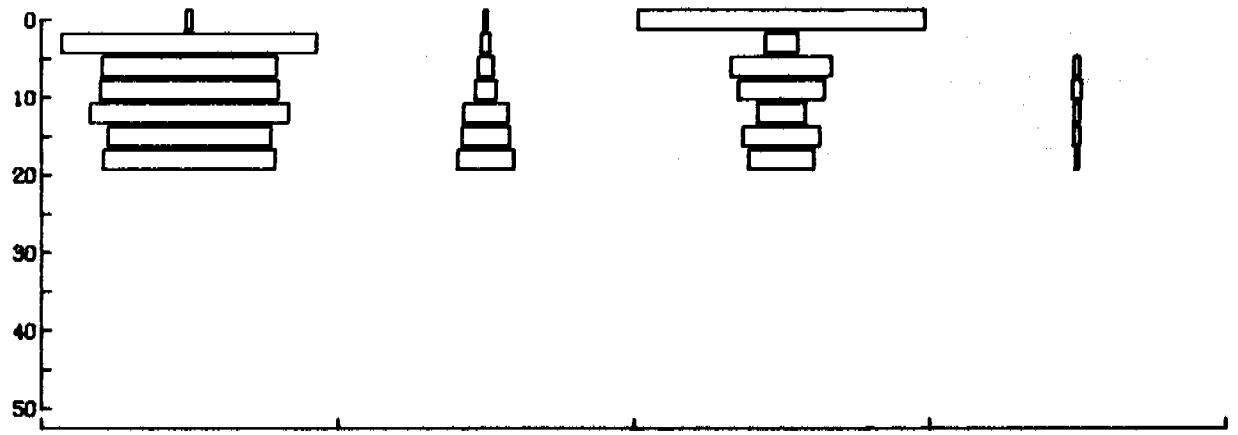

Station 30

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

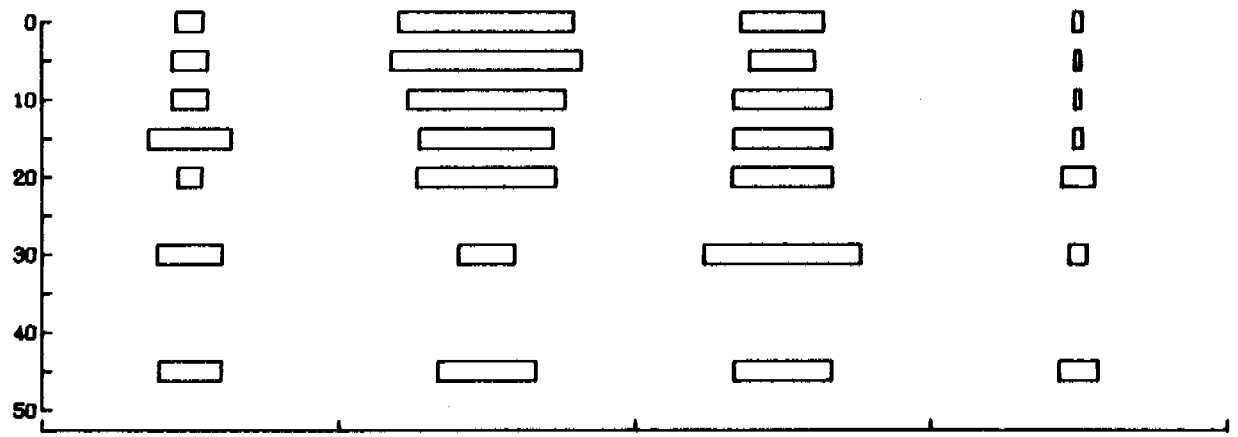
Fig. 1. (continued)




Station 31



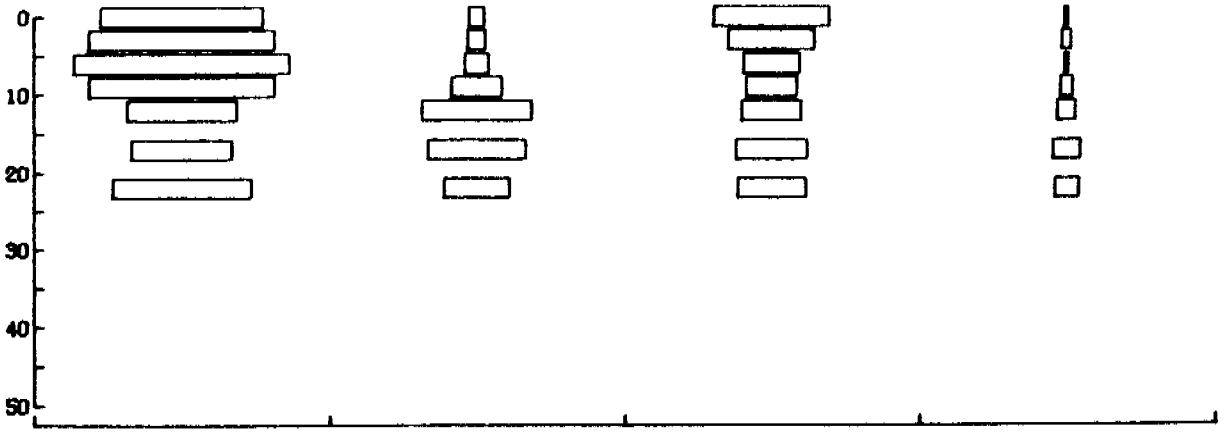

Station 32




Station 33

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

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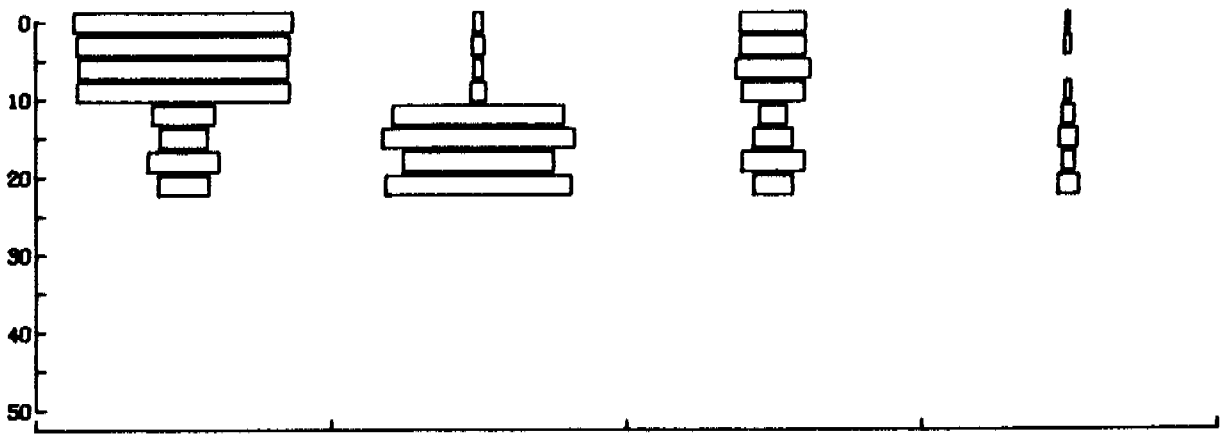



Station 35

*Chaetoceros* All Other Diatoms Flagellates Dinoflagellates

Fig. 1. (continued)

Results of zooplankton investigations were presented in the Quarterly Report for 1 July 1979.

## V. Preliminary Interpretation of Results

As in 1976 and 1977, all species found in the 1978 samples have been previously reported from the Beaufort Sea. *Chaetoceros* spp. and unidentified small flagellates were the most abundant organisms again. More dinoflagellates were present in 1978 than in previous years.

Based on sampling in August and September for three years, phytoplankton species are widely distributed throughout the Beaufort Sea. Only a few species appear to be associated with special hydrographic conditions, *i.e.*, *Leptocylindrus minimus* Gran in Bering Sea water. Standing stocks are variable and patchy throughout the Beaufort Sea. Microflagellates are often dominant in surface waters, perhaps as a result of lower salinity and higher light conditions. Small species of the diatom genus *Chaetoceros* and/or microflagellates were the most abundant organisms at nearly all stations. Primary production and chlorophyll *a* concentrations are variable and patchy throughout the sampling area, but are highest where diatoms are the most abundant organisms. Estimated annual primary production ranged from *ca.* 2 g C $m^{-2}$ $yr^{-1}$ in 1978 to 14 g C $m^{-2}$ $yr^{-1}$ in 1977.

## VI. Auxiliary Material - References Cited


Alexander, V., R. Horner, and R. C. Clasby. 1974. Metabolism of Arctic sea ice organisms. Inst. Mar. Sci., Univ. Alaska Rep. R74-4. 120 pp.

Clasby, R. C., R. Horner, and V. Alexander. 1973. An in situ method for measuring primary productivity of arctic sea ice algae. J. Fish. Res. Board Can. 30:835-838.

Horner, R. 1976. Sea ice organisms. Oceanogr. Mar. Biol. Ann. Rev. 14: 167-182.

Horner, R. 1978. Beaufort Sea plankton studies. Quarterly Report for the period 1 Apr - 30 June 1978. BLM/NOAA OCSEAP. 88 pp.

Horner, R., K. O. Coyle, and D. R. Redburn. 1974. Ecology of the plankton of Prudhoe Bay, Alaska. Inst. Mar. Sci., Univ. Alaska Rep. R74-2; Sea Grant Rep. No. 73-15.


## VII. Problems Encountered/Recommended Changes

No problems have been encountered this quarter.

# MILESTONE CHART

O - Planned Completion Date
X - Actual Completion Date
(to be used for updates)

RU # 359 PI: Rita A. Horner

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

| MAJOR MILESTONES | 1979 O | 1979 N | 1979 D | 1980 J | 1980 F | 1980 M | 1980 A | 1980 M | 1980 J | 1980 J | 1980 A | 1980 S | 1980 O | 1980 N | 1980 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field Effort | | O X | | | O X | X | | X | | | | | | | |
| Sample Analysis: Plant Pigments | | | X | | | | | O | | | | X | | | |
| Primary Productivity | | | X | | | | | O | | | | X | | | |
| Phyto Standing Stock | | | X | | | | | | | O | X | | | | |
| Zoo Standing Stock | | | | | | | | | O X | | | | | | |
| Data Processing: Plant Pigments | | | | | | O | | | | X | | | | | |
| Primary Productivity | | | | O | | | O | | | X | | | | | |
| Phyto Standing Stock | | | | | | | | | | | | O X | | | |
| Zoo Standing Stock | | | | | | | | | | | | O X | | | |
| Data Submission: All Data | | | | | | | | | | | | | O X | | |

QUARTERLY REPORT

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1 Oct - 31 Dec 1979
Number of Pages: 51

# Beaufort Sea Plankton Studies

Rita A. Horner

31 December 1979

I. Abstract - Highlights

Analysis of zooplankton samples from the Chukchi and Bering seas is nearly complete. Detailed analysis of the zooplankton, primarily copepods, collected in Stefansson Sound in November 1978 and March 1979 is nearly complete. Enumeration of phytoplankton samples from the Chukchi Sea collected in 1974 has begun.

II. Task Objectives

The objectives of RU 359 are to:

1. Complete the analysis and synthesis of samples collected on the 1978 icebreaker cruise in the Beaufort Sea;

2. Conduct field studies in conjunction with RU's 6 and 537 to assess winter distribution and environmental requirements of zooplankton, phytoplankton, ice algae, and benthic microalgae in the nearshore area of the Beaufort Sea;

3. Complete and submit a final summary report on winter results;

4. Analyze available samples from the Chukchi Sea;

5. Complete a comprehensive literature review and synthesize available data concerning phytoplankton, ice algae, and zooplankton in the Chukchi Sea.

III. Field or Laboratory Activities

A. There were no field activities this quarter.

B. Laboratory Activities

1. Personnel

a. Thomas Kaperak - Oceanographer I - sorting, identifying, counting of zooplankton samples collected in the Chukchi Sea, CGC *Glacier*, 7 Aug to 4 Sep 1976.

b. Deborah Wencker - Oceanographer I - sorting, identifying, counting of zooplankton samples collected in the Norton and Hope basins, CGC *Polar Sea*, 17 Apr to 6 May 1979.

c. David Murphy - Student Helper - sorting, identifying, counting of zooplankton samples collected in the Norton and Hope basins, CGC *Polar Sea*, 17 Apr to 6 May 1979; responsible for identifying shrimp from all samples collected by RU 359.

d. Gayle Heron - Oceanographer II - sorting, identifying, counting of copepods in samples collected by RU 359, starting with Stefansson Sound winter samples.

e. Rita Horner - Principal Investigator - enumeration of phytoplankton samples collected in the Chukchi Sea, CGC *Staten Island*, 7 to 15 Aug 1974; report writing, data management.

2. Methods

a. Zooplankton collection

1. CGC *Glacier* 1976 Chukchi Sea samples

Samples were collected with 60 cm bongo nets with mesh sizes of 333 and 500 µm and 0.75 m ring nets with a mesh size of 308 µm. A TSK flow meter was mounted in the mouth of each bongo net to determine the amount of water filtered. The bongo tows were double oblique with deployment at *ca.* 50 m/min, a 30 sec soaking time at depth, and retrieval at *ca.* 20 m/min. Sampling depth varied depending on water depth, but the net was placed as close to the bottom as possible.

The ring net was lowered to a predetermined depth, usually 10 or 20 m, soaked for 10 sec, and vertically hauled to the surface. Two or more tows were made at each station depending on water depth.

The samples were concentrated by swirling in the net collection cup to remove excess water. The bongo net samples contained large quantitites of phytoplankton and some were therefore subsampled before preservation. Subsampling was done by pouring the concentrated sample into a calibrated container which was then swirled to homogenize the sample. A subsample was poured into a 500 ml jar and the fraction retained was noted on the sample label.

All samples were preserved with 37% formaldehyde buffered with a saturated solution of sodium borate.

2. CGC *Polar Sea* 1979 Bering Sea samples

Samples were collected with 60 cm bongo nets with mesh sizes of 333 and 500 µm and 0.75 m ring nets with a mesh size of 308 µm. Sampling procedure was as described above except that ring net hauls were usually made from near the bottom to the surface instead of from 10 or 20 m to the surface. Samples were not subsampled before preservation.

All samples were preserved with 37% formaldehyde buffered with saturated solutions of sodium borate and sodium acetate.

3. Stefansson Sound 1978-79 winter samples

Samples were collected with 0.75 m ring net with a mesh size of 308 µm. Vertical tows were made by lowering the net to the bottom and retrieving by hand at a constant rate. Horizontal tows were made

by extending a line from the sampling hole to an ice piton located on the surface *ca.* 12 m away. The net was clipped to a pulley on the line, pulled backward by the ring to the ice piton and forward to the sampling hole. Tows were timed with a stopwatch to obtain an approximate speed of tow. The samples were concentrated and preserved with 37% formaldehyde buffered with saturated solutions of sodium borate and sodium acetate.

b. Zooplankton analysis

1. Chukchi and Bering seas

All samples were first sorted for large and rare organisms. The remaining samples was then split in a Folsom plankton splitter until a subsample containing *ca.* 100 specimens of the most abundant remaining taxonomic group was obtained. Some of the Bering Sea samples, containing large numbers of several taxonomic categories, were split before any sorting was done. The individual splits of the samples were then sorted and rough counted by taxonomic category until at least 100 specimens of each category or the total number of specimens for each category was counted. Twenty-six Chukchi Sea samples have been counted and identified; the Bering Sea samples have been sorted and rough counted by taxonomic category and species identification started.

Voucher specimens have been kept for all taxa.

2. Stefansson Sound

All organisms in the samples were identified and counted; the samples were not split. For copepods, sex and life cycle stages were determined where possible and the animals were measured.

c. Phytoplankton collection and analysis

Samples were collected with 5 ℓ Niskin bottles. Portions of the water samples were poured into 250 ml jars and preserved with 4% formaldehyde buffered with sodium acetate.

Standing stock samples are being analyzed using a Zeiss phase-contrast inverted microscope and Zeiss 5 and 50 ml counting chambers. Rare and large organisms (> 100 µm) are counted at 125 x magnification in 50 ml chambers and abundant, small organisms (< 100 µm) are counted at 312 x magnification in 5 ml chambers.

Water for chlorophyll *a* determinations was filtered through 47 mm, 0.45 µm Millipore filters, a few drops of a saturated solution of $MgCO_3$ were added to the last few ml of sample filtered. The filter was frozen in a dessicator until the sample could be analyzed.

Chlorophyll *a* concentrations from the 1974 cruise were determined in 1974 using spectrophotometric methods. The filters were ground in *ca.* 12 ml 90% acetone and centrifuged 3 times for a total of 30 min. The supernatant liquid was made up to 14.5 ml with 90% acetone and poured into 5 cm path-length spectrophotometric cells. The extinction was measured against a cell

containing 90% acetone at 7500, 6630, 6450, 6300, and 4800 Å using a Beckman DU-2 spectrophotometer. Chlorophyll *a* concentrations were calculated using the SCOR/UNESCO equations (Unesco 1966) where

$$\text{Chl } a = 11.64E_{6630} - 2.16E_{6450} + 0.10E_{6300}$$

after subtracting the 7500 (blank) reading from the 6630, 6450, and 6300 values.

Phaeopigment concentrations were not determined.

Chlorophyll *a* and phaeopigment concentrations from the Bering Sea samples were analyzed using fluorometric techniques (Strickland and Parsons 1968).

Primary productivity measurements were made in 60 ml reagent bottles. Two light and one dark bottle were used for each depth. Two ml of $NaH^{14}CO_3$ solution were added to each bottle, aluminum foil was wrapped around the dark bottle, and the samples were incubated in an incubator located on the fantail. Light levels were measured at the beginning and end of the incubation period with a Gossen Super Pilot photographic light meter. Low temperature was maintained by constantly running seawater from the ship's fire main system through the incubator. Following a 3 to 4 hr incubation period, the samples were filtered onto 25 mm, 0.45 µm Millipore filters, rinsed with 5 ml filtered seawater and 5 ml 0.01 N HCl, and placed in liquid scintillation vials.

Carbon uptake was determined using a Packard Tri-Carb Liquid Scintillation Spectrometer with Aquasol (New England Nuclear) as the scintillation cocktail.

3. Sample locations

See Fig. 1 for 1976 CGC *Glacier* Chukchi Sea stations; Fig. 2 for 1979 CGC *Polar Sea* Bering Sea stations; and Fig. 3 for 1974 CGC *Staten Island* Chukchi Sea stations (Fig. 3 is from Hannon, unpubl.).

## IV. Results

### A. Zooplankton

#### 1. Chukchi Sea

Copepods were the most abundant organisms at all stations (Tables 1 and 2). Barnacle and polychaete larvae were also abundant at all stations along with appendicularians in the genus *Fritillaria*. Unidentified mollusc larvae, chaetognaths, hydrozoans, and decapod zoea were present at all stations and sometimes abundant. Other organisms present at some stations were pteropods, ctenophores, amphipods, and euphausiids. Unidentified fish larvae were present at most stations, but were never abundant.

#### 2. Bering Sea

Calanoid copepods, the chaetognath *Sagitta elegans*, and amphipods were present at all stations. The hydromedusa *Aglantha digitale*

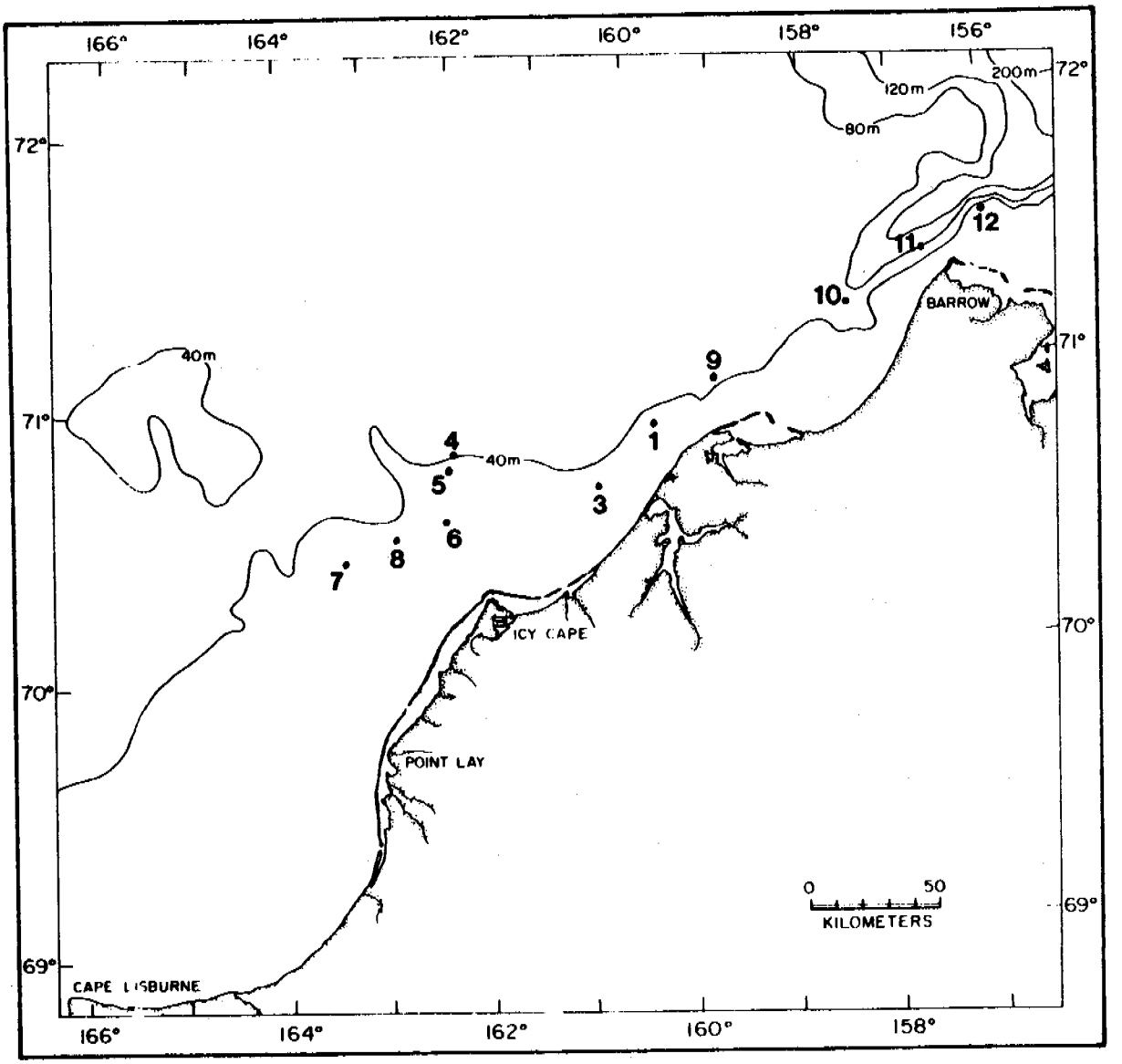



Fig. 1. Station locations, Chukchi Sea, CGC *Glacier*, 7 Aug - 4 Sep 1976.

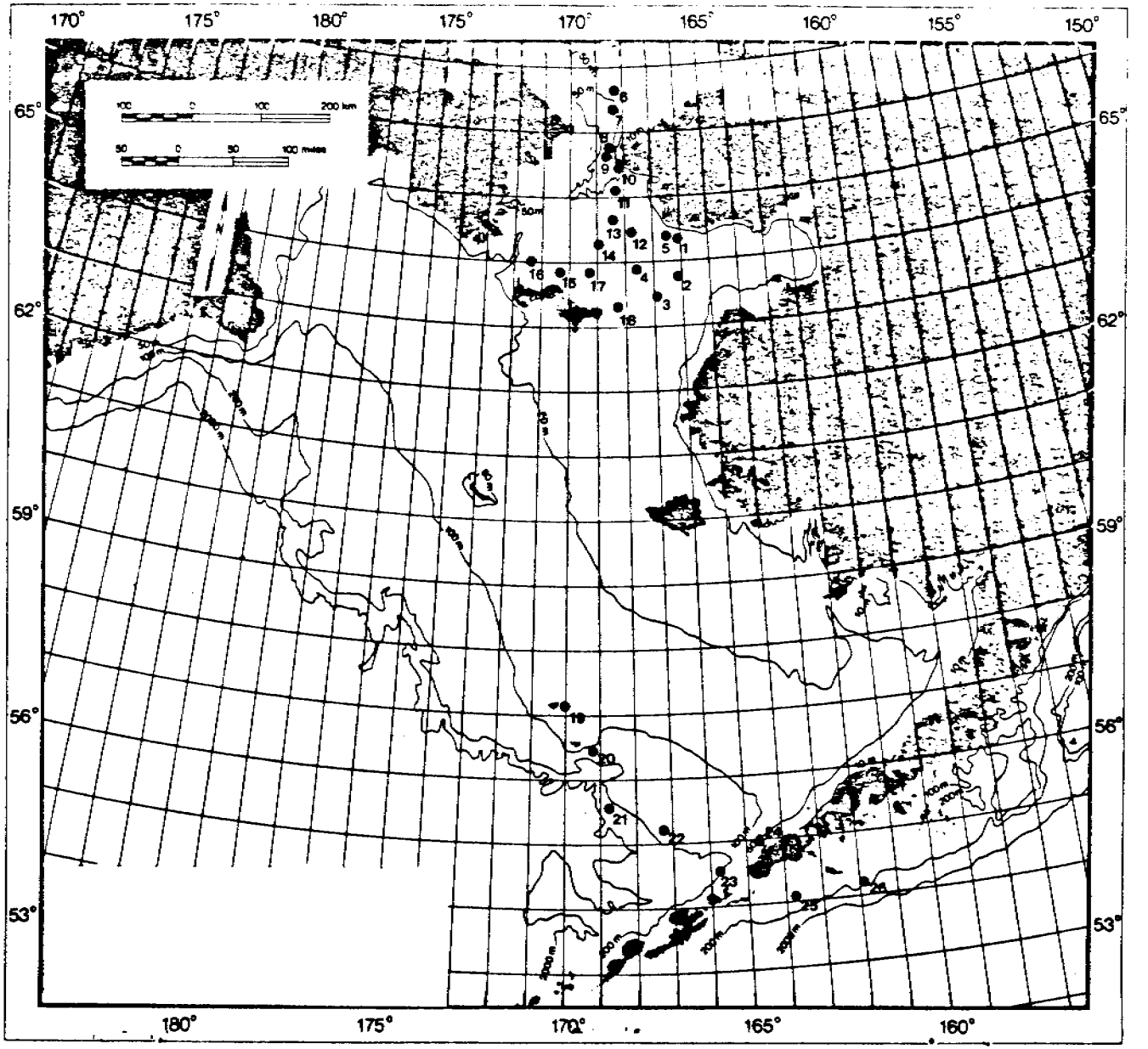



Fig. 2. Station locations, Bering and Chukchi seas, CGC *Polar Sea*, 17 Apr - 6 May 1979.

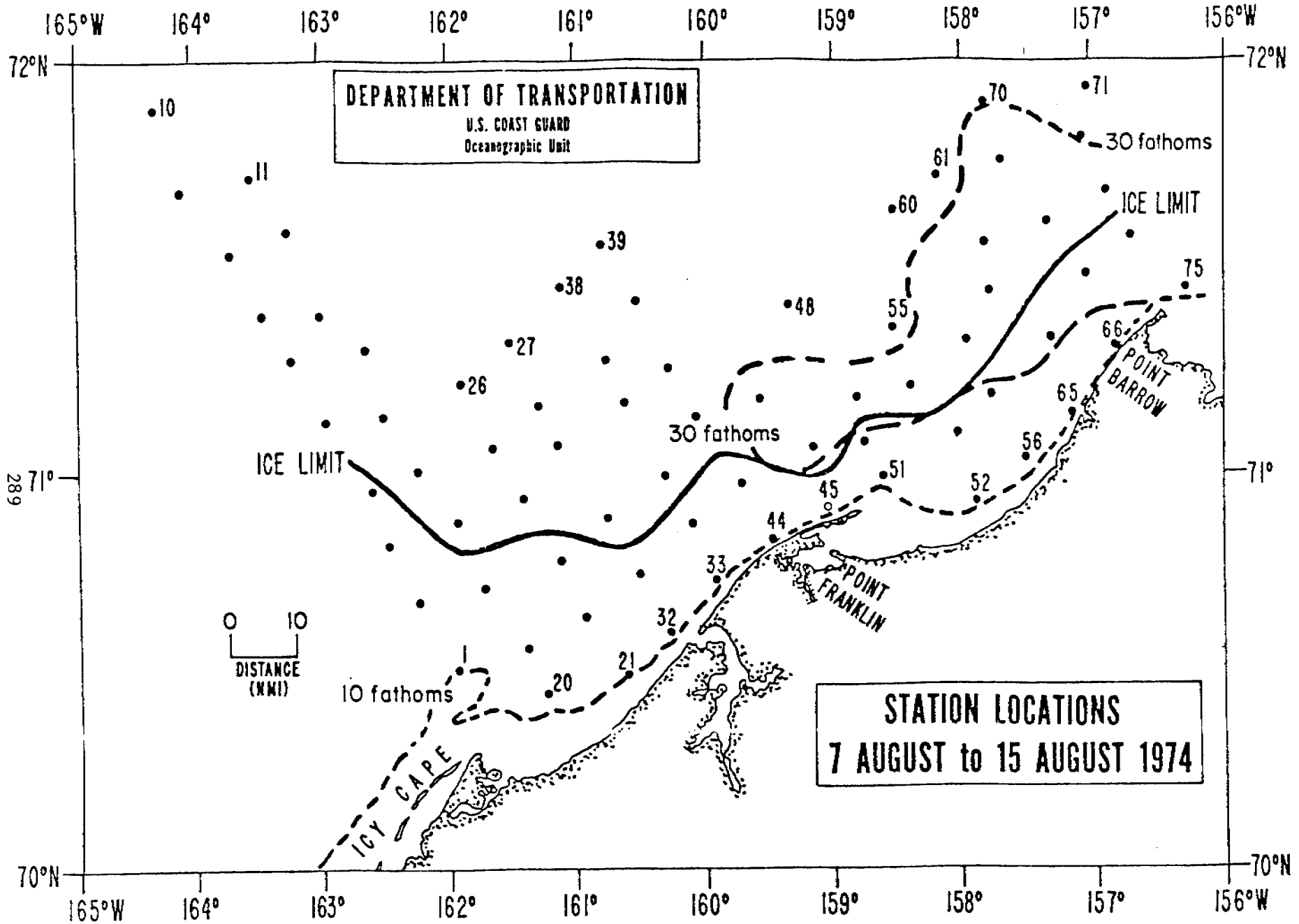



Fig. 3. Station locations, Chukchi Sea, CGC *Staten Island*, 7 - 15 Aug 1974.

Table 1. Abundance (number per 1000 $m^3$) of zooplankton taxa found in net hauls from the Chukchi Sea. All samples were collected with bongo nets. Where no number is present, no animals were found.

| | Station Number | 4 | 4* | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| Taxon | Mesh size (μm) | 333 | 500 | 333 | 500 | 333 | 500 | 333 | 500 |
| Coelenterata | | | | | | | | | |
| Hydrozoa | | | | | | | | | |
| *Aglantha digitale* | | | | | | | 20380 | 22120 | 11380 |
| *Calycopsis birulai* | | | | | | | 60 | | |
| *Corymorpha flammea* | | | | | | | 190 | | |
| *Coryne tubulosa* | | | 30 | | | | | | |
| *Obelia longissima cf.* | | | | | 90 | | 120 | | |
| *Perigonimus vesicarius* | | | | | 50 | | | | 360 |
| *Perigonimus* spp. | | | | | | | 190 | | |
| *Perigonimus* spp. *cf.* | | | 90 | 320 | 90 | | | | |
| *Rathkea octopunctata* | | 800 | 270 | 480 | 380 | 1800 | 1310 | 16590 | 3790 |
| Unidentified Hydrozoa | | 22000 | 27360 | | 27110 | 16430 | 10000 | 55290 | 49330 |
| Scyphozoa - unidentified | | | 60 | 160 | 50 | | 60 | | |
| Ctenophora | | | | | | | | | |
| *Beroë cucumis* | | | | | | | | | |
| *Pleurobrachia pileus cf.* | | | | | | | | 350 | 590 |
| Polychaeta - unidentified larvae | | 1147730 | 316580 | 1548390 | 246960 | 345080 | 262000 | 414710 | 129030 |
| Mollusca | | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | | |
| *Clione limacina* | | | | | 50 | | | | |
| *Spiratella helicina* | | 270 | 120 | 160 | 990 | | 380 | 520 | 360 |
| Unidentified mollusc larvae | | 286000 | 78200 | 495480 | 9080 | 156110 | 4000 | 453410 | 75900 |

* Volume of water filtered has been estimated for these tows using ship speed x duration of tow x mouth area of the net.

† Net hauls not subsampled in the field (see p. ).

Table 1. (continued)

| Taxon | Station Number | 4 | 4* | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| | Mesh size (μm) | 333 | 500 | 333 | 500 | 333 | 500 | 333 | 500 |
| Crustacea | | | | | | | | | |
| Copepoda | | | | | | | | | |
| Calanoida - adults | | 68270 | 7820 | 82580 | 15060 | 73950 | 26000 | 105060 | 68310 |
| Calanoida - juveniles | | 614400 | 117250 | 1114840 | 99390 | 903780 | 108000 | 724350 | 223900 |
| Cyclopoida | | 1437870 | 293130 | 2085160 | 162640 | 550490 | 76000 | 652470 | 113850 |
| Harpacticoida | | 25600 | 19540 | 41290 | 3010 | 8220 | | 11060 | |
| Unidentified nauplii | | 891730 | 300950 | 1672260 | 120470 | 451890 | 50000 | 309650 | 94870 |
| Cirripedia | | | | | | | | | |
| Unidentified nauplii | | 102400 | 31270 | 103230 | 63250 | 16430 | 22000 | 22120 | 3790 |
| Unidentified cyprids | | 315730 | 46900 | 1362580 | 24090 | 213620 | 14000 | 38710 | 7590 |
| Mysidacea | | | | | | | | | |
| *Mysis* spp. | | | | | | | 60 | | |
| Cumacea - unidentified | | | | | | | | | |
| Amphipoda | | | | | | | | | |
| Gammaridea | | | | | | | | | |
| *Apherusa glacialis* | | | | | | | | | |
| *Boeckosimus nanseni* | | | | | | | | | |
| *Onisimus (=Pseudalibrotus) glacialis* | | | | | | | | | |
| Unidentified Gammaridea | | | | | | | | | |
| Hyperiidea | | | | | | | | | |
| *Parathemisto abyssorum* | | | | | | | 60 | | |
| *Parathemisto libellula* | | 130 | 30 | | 90 | | | | |
| Unidentified Hyperiidea | | 130 | | | | 260 | | | |
| Euphausiacea | | | | | | | | | |
| *Thysanoëssa inermis* | | | 30 | | 50 | | 120 | | 120 |
| *Thysanoëssa longipes* | | | | | | | | | |
| *Thysanoëssa raschii* | | 270 | 30 | | 280 | | 60 | | 120 |
| Unidentified furcilia | | 270 | 460 | 160 | 190 | 260 | 190 | 520 | |
| Unidentified calyptopis *cf.* | | 130 | | | | | | | |
| Unidentified nauplii *cf.* | | | | | | 260 | | | |

Table 1. (continued)

| Taxon | Station Number | 4 | 4* | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| | Mesh size (μm) | 333 | 500 | 333 | 500 | 333 | 500 | 333 | 500 |
| Decapoda | | | | | | | | | |
| Anomura - unidentified zoea | | 1200 | 370 | 1290 | 1180 | 260 | 810 | 520 | 710 |
| Brachyura - unidentified zoea | | 6530 | 5220 | 160 | 240 | 1540 | 1620 | 1900 | 2490 |
| Caridea - unidentified zoea | | 530 | 240 | 160 | 240 | 260 | 120 | 520 | 710 |
| Crustacea - unidentified | | 106670 | | | | | | | |
| Appendicularia | | | | | | | | | |
| *Fritillaria borealis* | | 580270 | 410380 | 2374190 | 508990 | 410810 | 218000 | 740940 | 390870 |
| *Fritillaria* spp. | | 2530130 | 1207690 | 2972900 | 774020 | 246490 | 80000 | 1260710 | 387080 |
| *Oikopleura labradoriensis* | | | | | | | | | |
| *Oikopleura vanhöffeni* | | | | | | | | | |
| Chaetognatha | | | | | | | | | |
| *Sagitta elegans* | | 4270 | 7820 | | 27110 | | | 11060 | |
| Unidentified Chaetognatha | | 76800 | 23450 | 123870 | 45180 | 41080 | 62000 | 38710 | 26560 |
| Pisces | | | | | | | | | |
| Unidentified eggs | | | | | | | | | |
| Unidentified larvae | | 1200 | 670 | 650 | 380 | | 60 | | 120 |
| Other organisms | | | | | | | | | |
| Nematoda | | | | | | | | | 7590 |
| Unidentified invertebrate eggs | | 25600 | | | | 90380 | 12000 | 105060 | 7590 |
| Unidentified animals | | | | | 3010 | | 38000 | | |

Table 1. (continued)

| Taxon | Station Number | 9† | 9† | 10 | 10*† |
|---|---|---|---|---|---|
| | Mesh size (µm) | 333 | 500 | 333 | 500 |
| Coelenterata | | | | | |
| Hydrozoa | | | | | |
| *Aglantha digitale* | | | 120 | 810 | |
| *Calycopsis birulai* | | | | | |
| *Corymorpha flammea* | | | | | |
| *Coryne tubulosa* | | | | | |
| *Obelia longissima cf.* | | | | | 30 |
| *Perigonimus vesicarius* | | 20 | 40 | | 40 |
| *Perigonimus* spp. | | | | | |
| *Perigonimus* spp. *cf.* | | | | 200 | 10 |
| *Rathkea octopunctata* | | | | | 20 |
| Unidentified Hydrozoa | | 10 | 10 | | 100 |
| Scyphozoa - unidentified | | 110 | 40 | | |
| Ctenophora | | | | | |
| *Beroë cucumis* | | | | | |
| *Pleurobrachia pileus cf.* | | | 50 | | 30 |
| Polychaeta - unidentified larvae | | 62840 | 220 | 155730 | 31700 |
| Mollusca | | | | | |
| Gastropoda - Pteropoda | | | | | |
| *Clione limacina* | | 10 | 20 | | |
| *Spiratella helicina* | | | 220 | | 2440 |
| Unidentified mollusc larvae | | | 50 | | |

Table 1. (continued)

| Station Number | 9† | 9† | 10 | 10*† |
|---|---|---|---|---|
| Taxon / Mesh size (µm) | 333 | 500 | 333 | 500 |
| Crustacea | | | | |
| Copepoda | | | | |
| Calanoida - adults | 50040 | 6440 | 77870 | 17070 |
| Calanoida - juveniles | 269960 | 9150 | 279020 | 29260 |
| Cyclopoida | 22110 | | 227110 | 19500 |
| Harpacticoida | | | 6490 | |
| Unidentified nauplii | 9310 | | 181690 | 2440 |
| Cirripedia | | | | |
| Unidentified nauplii | 553890 | 1820 | 1297780 | 97520 |
| Unidentified cyprids | 10470 | 290 | 12980 | |
| Mysidacea | | | | |
| *Mysis* spp. | | | | 10 |
| Cumacea - unidentified | | | | |
| Amphipoda | | | | |
| Gammaridea | | | | |
| *Apherusa glacialis* | 80 | 50 | 200 | 20 |
| *Boeckosimus nanseni* | | | | 10 |
| *Onisimus (=Pseudalibrotus) glacialis* | | 10 | | 30 |
| Unidentified Gammaridea | 50 | 30 | | 30 |
| Hyperiidea | | | | |
| *Parathemisto abyssorum* | | | | |
| *Parathemisto libellula* | 50 | 10 | | 10 |
| Unidentified Hyperiidea | 10 | | | |
| Euphausiacea | | | | |
| *Thysanoëssa inermis* . | 20 | 20 | | |
| *Thysanoëssa longipes* | | 10 | | |
| *Thysanoëssa raschii* | 20 | | | |
| Unidentified furcilia | 10 | | | 10 |
| Unidentified calyptopis *cf.* | | | | |
| Unidentified nauplii *cf.* | | | | |

Table 1. (continued)

| Taxon | Station Number | 9† | 9† | 10 | 10*† |
|---|---|---|---|---|---|
| | Mesh size (μm) | 333 | 500 | 333 | 500 |
| Decapoda | | | | | |
| Anomura - unidentified zoea | | 710 | 500 | 810 | 710 |
| Brachyura - unidentified zoea | | 440 | 260 | 410 | 220 |
| Caridea - unidentified zoea | | 120 | 140 | 200 | 350 |
| Crustacea - unidentified | | | 10 | | |
| Appendicularia | | | | | |
| *Fritillaria borealis* | | 140800 | | 837070 | 297450 |
| *Fritillaria* spp. | | 80290 | | 1511910 | 292570 |
| *Oikopleura labradoriensis* | | | | | |
| *Oikopleura vanhöffeni* | | | | | |
| Chaetognatha | | | | | |
| *Sagitta elegans* | | 3490 | 5700 | 2640 | 3050 |
| Unidentified Chaetognatha | | 47710 | 530 | 51910 | 17070 |
| Pisces | | | | | |
| Unidentified eggs | | | 10 | | |
| Unidentified larvae | | 40 | 40 | | 30 |
| Other organisms | | | | | |
| Nematoda | | | | | |
| Unidentified invertebrate eggs | | 4650 | | | |
| Unidentified animals | | | 100 | | |

Table 2. Abundance (number per 1000 $m^3$) of zooplankton taxa found in vertical net hauls from the Chukchi Sea, 1976. All samples were collected with a 0.75 m ring net, mesh size 308 µm. Where no number is present, no animals were found.

| Station Number | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|
| Taxon — Max sample depth (m) | 10 | 20 | 10 | 20 | 10 | 20 | 10 | 20 |
| Coelenterata | | | | | | | | |
| Hydrozoa | | | | | | | | |
| *Aglantha digitale* | 500 | 440 | 1000 | 330 | | 220 | 12000 | |
| *Calycopsis birulai* | | | | | | | | |
| *Corymorpha flammea* | | | | | | | | |
| *Coryne tubulosa* | | | | | | | | |
| *Obelia longissima cf.* | | | | | 1250 | | | 110 |
| *Perigonimus vesicarius* | | | | | | | | |
| *Perigonimus* spp. | | | | 220 | | | | |
| *Perigonimus* spp. *cf.* | | | 250 | | | | | |
| *Rathkea octopunctata* | 750 | 670 | 500 | 440 | 7000 | 1220 | 20000 | 14220 |
| Unidentified Hydrozoa | 64000 | 1440 | 160250 | 56890 | 656000 | 99560 | 32000 | 42890 |
| Scyphozoa - unidentified | 500 | 220 | | | | | | |
| Ctenophora | | | | | | | | |
| *Beroë cucumis* | | | | | | | | |
| *Pleurobrachia pileus cf.* | | | | | | | 250 | |
| Polychaeta - unidentified larvae | 64000 | 56890 | 1632000 | 1095110 | 120000 | 277330 | 4000 | 64000 |
| Mollusca | | | | | | | | |
| Gastropoda - Pteropoda | | | | | | | | |
| *Clione limacina* | | | | | | | 750 | 330 |
| *Spiratella helicina* | 1000 | | 1750 | 1110 | 750 | 440 | 1500 | 2000 |
| Unidentified mollusc larvae | | | 32000 | 227560 | 16000 | 341330 | | 14440 |

Table 2. (continued)

| Station Number | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|
| Taxon / Max sample depth (m) | 10 | 20 | 10 | 20 | 10 | 20 | 10 | 20 |
| Crustacea | | | | | | | | |
| Copepoda | | | | | | | | |
| Calanoida - adults | | 21330 | | 14220 | | | 44000 | 35560 |
| Calanoida - juveniles | 160000 | 7110 | 128000 | 256000 | 24000 | 106670 | 80000 | 85330 |
| Cyclopoida | 160000 | 320000 | 672000 | 881780 | 344000 | 988440 | 72000 | 163560 |
| Harpacticoida | | | | | | | | |
| Unidentified nauplii | 64000 | 170670 | 384000 | 611560 | 160000 | 526220 | 16000 | 85330 |
| Cirripedia | | | | | | | | |
| Unidentified nauplii | | 49780 | 704000 | 241780 | 8000 | 78220 | | |
| Unidentified cyprids | 64000 | 99560 | 1824000 | 625780 | 80000 | 305780 | 16000 | 56890 |
| Mysidacea | | | | | | | | |
| *Mysis* spp. | | | | | | | | |
| Cumacea - unidentified | | | | | | | | |
| Amphipoda | | | | | | | | |
| Gammaridea | | | | | | | | |
| *Apherusa glacialis* | | | | | | | | |
| *Boeckosimus nanseni* | | | | | | | | |
| *Onisimus (=Pseudalibrotus) glacialis* | | | | | | | | |
| Unidentified Gammaridea | | | | | | | | |
| Hyperiidea | | | | | | | | |
| *Parathemisto abyssorum* | | | | | | | | |
| *Parthemisto libellula* | | | | | | | | |
| Unidentified Hyperiidea | | | | | | | | |
| Euphausiacea | | | | | | | | |
| *Thysanoëssa inermis* | | | | | | | | |
| *Thysanoëssa longipes* | | | | | | | | |
| *Thysanoëssa raschii* | | | | | | | | |
| Unidentified furcilia | | | 500 | 110 | | 330 | | |
| Unidentified calyptopis *cf.* | | | | 110 | | | | |
| Unidentified nauplii *cf.* | | | | | | | | |

Table 2. (continued)

| Station Number | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
|---|---|---|---|---|---|---|---|---|
| Taxon Max sample depth (m) | 10 | 20 | 10 | 20 | 10 | 20 | 10 | 20 |
| Decapoda | | | | | | | | |
| Anomura - unidentified zoea | | 560 | 2500 | 2670 | | 890 | | |
| Brachyura - unidentified zoea | 1750 | 670 | 250 | | 500 | 560 | 1000 | 1110 |
| Caridea - unidentified zoea | | | 250 | 780 | | 110 | | |
| Crustacea - unidentified | | | | | | | | |
| Appendicularia | | | | | | | | |
| *Fritillaria borealis* | 3328000 | 2232890 | 3200000 | 1678220 | 800000 | 448000 | 440000 | 995560 |
| *Fritillaria* spp. | 3264000 | 1614220 | 3232000 | 2005330 | 888000 | 632890 | 572000 | 1251560 |
| *Oikopleura labradoriensis* | | | 500 | | | | | |
| *Oikopleura vanhöffeni* | | | 750 | | | | | |
| Chaetognatha | | | | | | | | |
| *Sagitta elegans* | | 21330 | | 14220 | | | 4000 | |
| Unidentified Chaetognatha | 96000 | 92440 | 96000 | 56890 | 176000 | 163560 | 36000 | 71110 |
| Pisces | | | | | | | | |
| Unidentified eggs | | | | | | | | |
| Unidentified larvae | | 110 | | | | | | |
| Other organisms | | | | | | | | |
| Nematoda | | | | | | | | |
| Unidentified invertebrate eggs | | 42670 | 320000 | 42670 | | 135110 | | 28440 |
| Unidentified animals | | | | | | | | |

Table 2. (continued)

| Station Number | 9 | 9 | 9 | 10 | 10 | 10 |
|---|---|---|---|---|---|---|
| Taxon Max sample depth (m) | 10 | 20 | 50 | 10 | 20 | 50 |
| **Coelenterata** | | | | | | |
| **Hydrozoa** | | | | | | |
| *Aglantha digitale* | 750 | 890 | 550 | | 440 | 180 |
| *Calycopsis birulai* | | | | | | 50 |
| *Corymorpha flammea* | | | | | | 50 |
| *Coryne tubulosa* | | | | | | |
| *Obelia longissima cf.* | | 110 | | | | |
| *Perigonimus vesicarius* | | | | | | |
| *Perigonimus* spp. | | 110 | | | | 140 |
| *Perigonimus* spp. *cf.* | | | | | | |
| *Rathkea octopunctata* | 1250 | 1780 | | 500 | 110 | |
| Unidentified Hydrozoa | 72000 | 12560 | 5910 | | | 500 |
| Scyphozoa - unidentified | 2500 | 670 | 230 | 500 | 330 | 180 |
| **Ctenophora** | | | | | | |
| *Beroë cucumis* | | 110 | | | | |
| *Pleurobrachia pileus cf.* | | | 180 | | | |
| **Polychaeta - unidentified larvae** | 64000 | 55110 | 93090 | 64000 | 106670 | 81450 |
| **Mollusca** | | | | | | |
| **Gastropoda - Pteropoda** | | | | | | |
| *Clione limacina* | | | | | | |
| *Spiratella helicina* | 1000 | 220 | 90 | 2000 | | |
| Unidentified mollusc larvae | 8000 | | 140 | | | |

Table 2. (continued)

| Station Number | 9 | 9 | 9 | 10 | 10 | 10 |
|---|---|---|---|---|---|---|
| Taxon Max sample depth (m) | 10 | 20 | 50 | 10 | 20 | 50 |
| Crustacea | | | | | | |
| Copepoda | | | | | | |
| Calanoida - adults | 8000 | 21330 | 49450 | | 49780 | 104730 |
| Calanoida - juveniles | 104000 | 245330 | 365090 | 128000 | 533330 | 622550 |
| Cyclopoida | 256000 | 87110 | 27640 | 480000 | 78220 | 29090 |
| Harpacticoida | 8000 | 7110 | 2910 | | | 8730 |
| Unidentified nauplii | 72000 | 17780 | 10180 | 608000 | 120890 | 40730 |
| Cirripedia | | | | | | |
| Unidentified nauplii | 208000 | 371560 | 298180 | 64000 | 135110 | 55270 |
| Unidentified cyprids | 104000 | 115560 | 87270 | 64000 | 49780 | 55270 |
| Mysidacea | | | | | | |
| *Mysis* spp. | | | | | | 50 |
| Cumacea - unidentified | | | 90 | | | |
| Amphipoda | | | | | | |
| Gammaridea | | | | | | |
| *Apherusa glacialis* | | 220 | 410 | | 110 | |
| *Boeckosimus nanseni* | | | | | | |
| *Onisimus (=Pseudalibrotus) glacialis* | 250 | | 50 | | | |
| Unidentified Gammaridea | | | 90 | | 110 | |
| Hyperiidea | | | | | | |
| *Parathemisto abyssorum* | | | | | 110 | |
| *Parathemisto libellula* | | | 50 | | | |
| Unidentified Hyperiidea | | 220 | | | | |
| Euphausiacea | | | | | | |
| *Thysanoëssa inermis* | | | 50 | | | |
| *Thysanoëssa longipes* | | | | | | |
| *Thysanoëssa raschii* | | | | | | |
| Unidentified furcilia | | 110 | | | | |
| Unidentified calyptopis *cf.* | | | | | | |
| Unidentified nauplii *cf.* | | 1780 | 1450 | | 110 | |

Table 2. (continued)

| Station Number | 9 | 9 | 9 | 10 | 10 | 10 |
|---|---|---|---|---|---|---|
| Taxon — Max sample depth (m) | 10 | 20 | 50 | 10 | 20 | 50 |
| Decapoda | | | | | | |
| Anomura - unidentified zoea | 1500 | 1560 | 1640 | 2000 | 560 | 550 |
| Brachyura - unidentified zoea | 1000 | 440 | 90 | 3000 | 890 | 270 |
| Caridea - unidentified zoea | 750 | 330 | 680 | 250 | 110 | 140 |
| Crustacea - unidentified | | | | | | |
| Appendicularia | | | | | | |
| *Fritillaria borealis* | 904000 | 330670 | 62550 | 4224000 | 1052440 | 506180 |
| *Fritillaria* spp. | 768000 | 259560 | 75640 | 3840000 | 1230220 | 293820 |
| *Oikopleura labradoriensis* | | | | | | |
| *Oikopleura vanhöffeni* | | | | | | |
| Chaetognatha | | | | | | |
| *Sagitta elegans* | | 5330 | 20360 | | 7110 | 2910 |
| Unidentified Chaetognatha | 296000 | 158220 | 48000 | 96000 | 56890 | 20360 |
| Pisces | | | | | | |
| Unidentified eggs | | | | | | |
| Unidentified larvae | | | | | | |
| Other organisms | | | | | | |
| Nematoda | | 1780 | | | 7110 | |
| Unidentified invertebrate eggs | 24000 | 30220 | 17450 | | 92440 | 23270 |
| Unidentified animals | | 12440 | 14550 | | | |

and crustacean eggs were present in most samples. Samples from stations 21-23, 25, and 26 contained chaetognaths other than *Sagitta elegans*. *Clione limacina* was the most abundant pteropod at stations north of St. Lawrence Island (northern stations) and *Limacina helicina* was most abundant at stations south of the Pribilof Islands (southern stations). *Thysanoëssa raschii* was the only euphausiid present at northern stations, while *T. spinifera* and *Euphausia pacifica* were present only at southern stations. *Thysanoëssa inermis* and *T. longipes* occurred in both areas. Euphausiid larvae were present at stations 22-28. Crab larvae were present at all stations except 1, 5, 7, and 8, and were very abundant at station 19 near St. Paul Island.

Other organisms present at some stations were shrimp larvae, fish eggs and larvae, barnacle nauplii and cyprids, ostracods, adult and larval polychaetes, echinoderm larvae, cephalopods, mysids, cumaceans, isopods, medusae, ctenophores, foraminiferans, radiolarians, and some unidentified organisms.

Tables giving numbers of organisms will be included in the Annual Report.

3. Stefansson Sound

Copepods, which were the most abundant organisms collected during the 1978-79 winter studies project, are now being studied extensively. Other organisms are also being identified and counted. Species found in samples collected in November 1978 and March 1979 are listed in Table 3.

B. Phytoplankton

1. Chukchi Sea

Sixty-five standing stock samples from 12 stations have been analyzed. Small flagellates, < 10 μm in diameter, were the most abundant organisms in samples collected from near the surface and at all depths in samples collected near shore, stations 1-3. Diatoms, especially *Nitzschia grunowii* Hasle and *Thalassiosira* spp., were abundant in deeper water and at offshore stations.

Chlorophyll *a* (Table 4) ranged from 0.37 mg $m^{-3}$ at station 14-0 to 25.16 mg $m^{-3}$ at station 15-20. Highest chlorophyll values occurred at depth and where diatoms were most abundant.

Cell numbers ranged from $6 \times 10^4$ cells per liter at station 2-10 to $5.6 \times 10^6$ cells per liter at station 12-15. Several species of the genus *Nitzschia* and unidentified flagellates < 10 μm in diameter comprised about 80% of the total number of cells at station 12-15. A small organism, tentatively identified as *Pelagococcus subviridis* Norris comprised about 50% of the cells at station 2-10.

2. Bering Sea

Primary productivity and plant pigment concentrations are given in Table 5 and vertical profiles are shown in Fig. 4. Primary productivity ranged from 0.12 to 17.16 mg C $m^{-3}$ $hr^{-1}$ in the northern Bering Sea.

Table 3. Zooplankton species found in samples collected in Stefansson Sound in November 1978 and March 1979.

- Coelenterata
  - Anthomedusae
    - *Halitholus cirratus* Hartlaub, 1913
- Annelida
  - Polychaeta
    - Unidentified larvae
- Arthropoda
  - Cladocera
    - *Eubosmina longispina* (Leydig, 1860)
  - Ostracoda
    - Unidentified species
  - Copepoda
    - Calanoida
      - *Calanus glacialis* Jaschnov, 1955
      - *Calanus hyperboreus* Krøyer, 1938
      - *Microcalanus pygmaeus* (G. O. Sars, 1900)
      - *Pseudocalanus elongatus* (Boeck, 1864)
      - *Pseudocalanus major* G. O. Sars, 1900
      - *Derjugnia tolli* (Linko, 1913)
      - *Erytemora richingsi* Heron and Damkaer, 1976
      - *Metridia longa* (Lubbock, 1854)
      - *Limnocalanus macrurus* G. O. Sars, 1863
      - *Acartia longiremis* (Lilljeborg, 1853)
    - Cyclopoida
      - *Oithona similis* Claus, 1866
      - *Cyclopina gracilis* Claus, 1863
      - *Oncaea borealis* G. O. Sars, 1918
  - Cirripedia
    - *Balanus* sp. nauplii
  - Isopoda
    - Unidentified epicaridean parasite
  - Amphipoda
    - Lysianassidae
      - *Boeckosimus affinis* (Hansen, 1887)
      - *Onisimus litoralis* (Krøyer, 1844-45)
- Chaetognatha
  - *Sagitta elegans* Verrill, 1873

Table 4. Summary of sation locations, hydrography, and chlorophyll *a* concentrations in the Chukchi Sea between Icy Cape and Point Barrow, 7-15 August 1974.

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 01 | 000 | 7 Aug | 70°31' | 161°58' | 7.32 | 30.188 | 0.97 |
| | 007 | | | | 7.30 | 30.188 | 0.83 |
| | 010 | | | | 6.62 | 30.640 | 0.87 |
| | 014 | | | | 4.95 | 31.778 | 0.91 |
| 02 | 000 | 7 Aug | 70°40.6' | 162°17.5' | 0.60 | 28.374 | 0.87 |
| | 005 | | | | 1.44 | 28.975 | 0.69 |
| | 010 | | | | 0.00 | 30.286 | 0.62 |
| | 020 | | | | -1.21 | 32.316 | 1.32 |
| | 030 | | | | -1.42 | 32.625 | 7.42 |
| | 042 | | | | | | 7.96 |
| 03 | 000 | 7 Aug | 70°49.7' | 162°30.9' | 0.60 | 27.860 | 0.82 |
| | 005 | | | | 2.10 | 28.025 | 0.66 |
| | 010 | | | | 0.01 | 31.241 | 1.32 |
| | 020 | | | | -1.46 | 32.361 | 4.05 |
| | 030 | | | | -1.65 | 32.832 | 9.05 |
| | 038 | | | | | | 10.59 |
| 04 | 000 | 8 Aug | 70°58' | 162°39' | 0.59 | 27.372 | 0.94 |
| | 005 | | | | 0.40 | 28.591 | 1.00 |
| | 010 | | | | -0.90 | 30.191 | 1.28 |
| | 020 | | | | -1.46 | 32.403 | 2.30 |
| | 030 | | | | -1.70 | 33.083 | 7.89 |
| | 042 | | | | -1.68 | 33.126 | 4.04 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 05 | 000 | 8 Aug | 71°08.0' | 163°00.0' | 0.37 | 26.542 | 0.95 |
| | 014 | | | | -1.11 | 30.433 | 1.23 |
| | 024 | | | | -1.49 | 32.321 | 2.19 |
| | 034 | | | | -1.74 | 33.278 | 2.82 |
| | 039 | | | | -1.71 | 33.298 | 4.51 |
| 06 | 000 | 8 Aug | 71°16.9' | 163°16.4' | 0.70 | 22.574 | 0.95 |
| | 005 | | | | -0.60 | 30.547 | 1.01 |
| | 010 | | | | -1.14 | 31.61 | 2.10 |
| | 020 | | | | -1.67 | 32.92 | 7.72 |
| | 030 | | | | -1.75 | 33.32 | 4.90 |
| 07 | 000 | 8 Aug | 71°24.1' | 163°29.4' | 0.57 | 25.117 | 0.74 |
| | 005 | | | | -0.66 | 30.707 | 0.69 |
| | 010 | | | | -1.23 | 31.821 | 0.52 |
| | 020 | | | | -1.70 | 33.098 | 8.65 |
| | 030 | | | | -1.77 | 33.325 | 3.79 |
| | 039 | | | | -1.75 | 33.367 | 2.54 |
| 08 | 000 | 8 Aug | 71°32.0' | 163°44' | 0.80 | 17.499 | 1.06 |
| | 006 | | | | -1.16 | 31.382 | 1.22 |
| | 016 | | | | -1.39 | 31.974 | 3.01 |
| | 026 | | | | -1.70 | 32.810 | 15.03 |
| | 031 | | | | -1.77 | 33.255 | 3.79 |
| | 036 | | | | -1.76 | 33.324 | 4.05 |
| 09 | 000 | 8 Aug | 71°40.6' | 164°06' | 1.53 | 6.511 | 0.99 |
| | 005 | | | | -1.36 | 31.959 | 4.27 |
| | 010 | | | | -1.53 | 32.232 | 9.02 |
| | 020 | | | | -1.67 | 32.915 | 12.84 |
| | 030 | | | | -1.77 | 33.372 | 3.45 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 10 | 000 | 8 Aug | 71°53.4' | 164°18.6' | 0.83 | 6.951 | 1.06 |
| | 005 | | | | -1.15 | 30.930 | 0.74 |
| | 010 | | | | -1.30 | 31.908 | 1.19 |
| | 015 | | | | -0.60 | 32.327 | 5.97 |
| | 020 | | | | -1.65 | 32.875 | 7.10 |
| | 035 | | | | -1.72 | | 3.90 |
| 11 | 000 | 8 Aug | 71°43' | 163°33' | -0.61 | 25.787 | 1.19 |
| | 005 | | | | -1.28 | 31.870 | 3.50 |
| | 010 | | | | -1.49 | 32.209 | 8.39 |
| | 015 | | | | -1.62 | 32.499 | 14.33 |
| | 020 | | | | -1.71 | 33.228 | 12.73 |
| | 031 | | | | -1.75 | 33.390 | 3.98 |
| 12 | 000 | 8 Aug | 71°36' | 163°17.5' | -0.50 | 24.752 | 1.34 |
| | 005 | | | | -1.13 | 31.415 | 1.98 |
| | 010 | | | | -1.54 | 32.355 | 7.00 |
| | 015 | | | | -1.63 | 32.553 | 19.07 |
| | 020 | | | | -1.68 | 33.147 | 11.21 |
| | 033 | | | | -1.74 | 33.284 | 3.74 |
| 13 | 000 | 8 Aug | 71°23.7' | 163°02.2' | -0.76 | 25.535 | 0.72 |
| | 005 | | | | -1.19 | 31.611 | 0.75 |
| | 015 | | | | -1.55 | | 0.39 |
| | 025 | | | | -1.72 | 33.285 | 5.10 |
| | 039 | | | | -1.75 | 33.298 | 4.00 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl $a$ (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 14 | 000 | 8 Aug | 71°19' | 162°41' | 0.78 | 24.970 | 0.37 |
| | 005 | | | | -0.21 | 30.430 | 0.44 |
| | 010 | | | | -1.20 | 31.646 | 0.42 |
| | 015 | | | | -1.53 | 32.279 | 1.07 |
| | 020 | | | | -1.72 | 32.884 | 18.32 |
| | 038 | | | | -1.75 | 33.375 | 3.99 |
| 15 | 000 | 9 Aug | 71°09.3' | 162°31.7' | 0.51 | 25.721 | 0.42 |
| | 005 | | | | -0.67 | 29.549 | 0.82 |
| | 010 | | | | -1.14 | 30.661 | 0.97 |
| | 020 | | | | -1.63 | 32.745 | 25.16 |
| | 030 | | | | -1.72 | 33.340 | 3.97 |
| | 040 | | | | -1.74 | 33.361 | 4.47 |
| 16 | 000 | 9 Aug | 71°01.5' | 162°16.8' | -0.15 | 27.107 | 0.54 |
| | 005 | | | | -0.15 | 28.748 | 0.53 |
| | 010 | | | | -0.97 | 30.043 | 0.85 |
| | 020 | | | | -1.54 | 32.505 | 2.55 |
| | 030 | | | | -1.68 | 33.168 | 2.65 |
| | 038 | | | | -1.70 | 33.162 | 2.92 |
| 17 | 000 | 9 Aug | 70°53' | 161°59' | 2.39 | 27.763 | 0.60 |
| | 005 | | | | 0.08 | 29.380 | 0.53 |
| | 010 | | | | -0.76 | 31.334 | 1.19 |
| | 020 | | | | -1.55 | 32.583 | 3.90 |
| | 030 | | | | -1.62 | 32.866 | 10.06 |
| | 038 | | | | -1.63 | 32.880 | 10.13 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 18 | 000 | 9 Aug | 70°43' | 161°45' | 3.15 | 27.779 | 0.77 |
| | 005 | | | | 0.94 | 28.860 | 0.47 |
| | 010 | | | | -0.45 | 30.731 | 0.53 |
| | 020 | | | | -1.20 | 32.375 | 0.61 |
| | 030 | | | | -1.41 | 32.658 | 10.09 |
| | 038 | | | | -1.44 | 32.662 | 9.16 |
| 19 | 000 | 9 Aug | 70°34.2' | 161°26.3' | 6.62 | 29.929 | 0.89 |
| | 005 | | | | 7.03 | 30.113 | 0.68 |
| | 010 | | | | 4.90 | 31.494 | 0.70 |
| | 015 | | | | 1.40 | 32.150 | 1.07 |
| | 020 | | | | 1.27 | 32.19 | 0.96 |
| 20 | 000 | 9 Aug | 70°27.5' | 161°17' | 6.58 | 31.085 | 0.70 |
| | 005 | | | | 6.61 | 31.084 | 0.57 |
| | 010 | | | | 5.95 | 31.332 | 0.67 |
| | 015 | | | | 4.98 | 31.993 | 1.73 |
| 21 | 000 | 9 Aug | 70°30' | 160°39' | 6.77 | 30.106 | 0.54 |
| | 005 | | | | 6.83 | 30.106 | 0.58 |
| | 010 | | | | 6.04 | 30.388 | 0.51 |
| | 012 | | | | 6.43 | 31.226 | 0.52 |
| 22 | 000 | 9 Aug | 70°38.5' | 160°59' | 6.50 | 29.876 | 0.55 |
| | 005 | | | | 6.64 | 29.951 | 0.51 |
| | 010 | | | | 0.19 | 31.442 | 0.68 |
| | 015 | | | | 0.23 | 32.408 | 1.09 |
| | 020 | | | | 0.29 | 32.413 | 1.15 |
| | 27 | | | | 0.29 | 32.413 | 1.19 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 23 | 000 | 9 Aug | 70°46.8' | 161°10.7' | 3.75 | 28.426 | 0.72 |
| | 005 | | | | 1.71 | 28.928 | 0.44 |
| | 010 | | | | 0.46 | 30.045 | 0.47 |
| | 020 | | | | -1.08 | 32.228 | 4.07 |
| | 030 | | | | -1.47 | 32.704 | 5.08 |
| | 037 | | | | -1.50 | 32.707 | 4.93 |
| 24 | 000 | 9 Aug | 70°56.6' | 161°27.2' | 0.97 | 27.417 | 0.53 |
| | 005 | | | | 0.15 | 28.936 | 0.58 |
| | 010 | | | | -0.98 | 30.527 | 1.08 |
| | 020 | | | | -1.52 | 32.410 | 2.11 |
| | 030 | | | | -1.64 | 33.068 | 6.86 |
| | 038 | | | | -1.66 | 33.065 | 7.15 |
| 25 | 000 | 9 Aug | 71°04' | 161°42' | 0.38 | 26.909 | 0.87 |
| | 005 | | | | -0.43 | 28.639 | 0.59 |
| | 015 | | | | -1.46 | 32.222 | 1.07 |
| | 025 | | | | -1.72 | 33.226 | 3.89 |
| | 039 | | | | -1.73 | 33.252 | 3.23 |
| 26 | 000 | 9 Aug | 71°14.4' | 161°57.2' | 0.23 | 24.537 | 0.50 |
| | 003 | | | | -0.24 | 29.266 | 0.65 |
| | 008 | | | | -1.07 | 31.519 | 0.52 |
| | 018 | | | | -1.60 | 32.665 | 3.43 |
| | 028 | | | | -1.73 | 33.317 | 4.29 |
| | 041 | | | | -1.75 | 33.417 | 4.13 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 27 | 000 | 9 Aug | 71°20.2' | 161°32.9' | 0.22 | 19.772 | 0.72 |
| | 005 | | | | -0.76 | 30.803 | 0.40 |
| | 010 | | | | -1.26 | 31.593 | 0.52 |
| | 020 | | | | -1.63 | 32.820 | 18.52 |
| | 030 | | | | -1.72 | 33.287 | 3.40 |
| | 041 | | | | -1.74 | 33.285 | 3.61 |
| 28 | 000 | 10 Aug | 71°10.5' | 161°20.4' | 0.81 | 25.335 | 0.50 |
| | 005 | | | | -0.65 | 30.038 | 0.43 |
| | 010 | | | | -1.22 | 31.744 | 0.53 |
| | 020 | | | | -1.58 | 32.671 | 6.97 |
| | 030 | | | | -1.73 | 33.386 | 3.93 |
| | 043 | | | | -1.75 | 33.426 | 4.46 |
| 29 | 000 | 10 Aug | 71°04.5' | 161°11.2' | 0.55 | 25.809 | 0.64 |
| | 005 | | | | -0.37 | 29.113 | 0.46 |
| | 010 | | | | -0.94 | 31.294 | 0.52 |
| | 020 | | | | -1.55 | 32.763 | 0.86 |
| | 030 | | | | -1.73 | 33.402 | 5.51 |
| | 037 | | | | -1.75 | 33.399 | 4.30 |
| 30 | 000 | 10 Aug | 70°53.7' | 160°48.5' | 2.07 | 27.529 | 0.58 |
| | 005 | | | | 0.80 | 28.329 | 0.42 |
| | 010 | | | | -0.95 | 30.201 | 0.54 |
| | 020 | | | | -1.52 | 32.552 | 2.65 |
| | 030 | | | | -1.64 | 33.075 | 6.53 |
| | 041 | | | | -1.66 | 33.075 | 6.62 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 31 | 000 | 10 Aug | 70°45' | 160°34' | 3.07 | 28.723 | 0.54 |
| | 005 | | | | 2.78 | 28.860 | 0.38 |
| | 010 | | | | 0.00 | 30.334 | 0.39 |
| | 020 | | | | -1.03 | 32.351 | 0.74 |
| | 030 | | | | -1.09 | 32.618 | 2.90 |
| | 037 | | | | -1.09 | 32.619 | 2.61 |
| 32 | 000 | 10 Aug | 70°36.0' | 160°19.0' | 6.57 | 29.818 | 0.78 |
| | 005 | | | | 5.19 | 30.258 | 0.86 |
| | 010 | | | | 5.05 | 31.795 | 1.72 |
| | 017 | | | | 5.05 | 31.794 | 1.89 |
| 35 | 000 | 10 Aug | 71°00.5' | 160°21.8' | 0.29 | 26.704 | 0.99 |
| | 010 | | | | -0.99 | 31.488 | 0.53 |
| | 020 | | | | -1.51 | 32.404 | 3.43 |
| | 030 | | | | -1.71 | 33.232 | 8.72 |
| | 040 | | | | -1.71 | 33.236 | 7.86 |
| | 049 | | | | -1.72 | 33.234 | 9.68 |
| 36 | 000 | 10 Aug | 71°10.8' | 160°39.5' | -0.03 | 27.308 | 0.89 |
| | 005 | | | | -0.74 | 30.229 | 0.71 |
| | 010 | | | | -1.16 | 31.732 | 0.82 |
| | 020 | | | | -1.64 | 32.826 | 7.64 |
| | 030 | | | | -1.72 | 33.262 | 3.74 |
| | 040 | | | | -1.75 | 33.389 | 3.36 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 37 | 000 | 10 Aug | 71°17.4' | 160°48' | -0.56 | 29.214 | 0.91 |
| | 005 | | | | -1.04 | 31.364 | 0.77 |
| | 010 | | | | -1.18 | 31.856 | 0.78 |
| | 020 | | | | -1.59 | 32.651 | 17.76 |
| | 030 | | | | -1.72 | 33.236 | 2.63 |
| | 043 | | | | -1.74 | 33.288 | 4.33 |
| 38 | 000 | 10 Aug | 71°28' | 161°10' | -1.03 | 29.243 | 1.14 |
| | 005 | | | | -1.36 | 31.278 | 1.53 |
| | 010 | | | | -1.41 | 31.643 | 1.96 |
| | 020 | | | | -1.64 | 32.571 | 7.34 |
| | 030 | | | | -1.73 | 33.228 | 2.07 |
| | 041 | | | | -1.74 | 33.284 | 3.00 |
| 39 | 000 | 11 Aug | 71°32.9' | 160°49.8' | -0.54 | 21.280 | 1.52 |
| | 005 | | | | -1.27 | 30.539 | 1.03 |
| | 010 | | | | -1.32 | 30.809 | 1.59 |
| | 020 | | | | -1.56 | 31.772 | 7.61 |
| | 030 | | | | -1.72 | 32.700 | 5.09 |
| | 041 | | | | -1.73 | 33.163 | 2.64 |
| 40 | 000 | 11 Aug | 71°25.8' | 160°33.6' | -0.16 | 6.845 | 1.26 |
| | 005 | | | | -1.34 | 30.205 | 0.90 |
| | 010 | | | | -1.31 | 30.634 | 1.35 |
| | 020 | | | | -1.56 | 31.827 | 6.31 |
| | 030 | | | | -1.72 | 32.968 | 2.93 |
| | 039 | | | | -1.74 | 33.149 | 2.40 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 41 | 000 | 11 Aug | 71°15.8' | 160°17.9' | -1.12 | 29.263 | 0.80 |
| | 005 | | | | -1.17 | 29.741 | 0.94 |
| | 010 | | | | -1.25 | 31.137 | 0.96 |
| | 020 | | | | -1.47 | 32.000 | 2.16 |
| | 046 | | | | -1.73 | 33.245 | 4.41 |
| 42 | 000 | 11 Aug | 71°08.5' | 160°06.3' | -0.29 | 26.111 | 1.11 |
| | 010 | | | | -1.24 | 31.585 | 0.66 |
| | 020 | | | | -1.54 | 32.237 | 2.22 |
| | 030 | | | | -1.70 | 33.128 | 9.27 |
| | 040 | | | | -1.73 | 33.349 | 3.50 |
| | 052 | | | | -1.75 | 33.360 | 3.47 |
| 43 | 000 | 11 Aug | 70°58.0' | 159°44' | 2.56 | 28.166 | 0.59 |
| | 005 | | | | 2.54 | 28.166 | 0.53 |
| | 010 | | | | -0.38 | 29.707 | 0.74 |
| | 020 | | | | -0.93 | 32.344 | 1.31 |
| | 030 | | | | -0.78 | 32.371 | 1.37 |
| | 047 | | | | -0.84 | 32.387 | 1.24 |
| 46 | 000 | 11 Aug | 71°03.9' | 159°12.3' | 0.02 | 27.043 | 0.87 |
| | 010 | | | | -0.90 | 30.58 | 0.71 |
| | 020 | | | | -1.21 | 32.51 | 3.49 |
| | 030 | | | | -1.23 | 32.53 | 3.78 |
| | 050 | | | | -1.26 | 32.57 | 4.42 |
| | 076 | | | | -1.55 | 32.815 | 6.28 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 47 | 000 | 11 Aug | 71°11' | 159°36' | -1.22 | 28.908 | 1.09 |
| | 010 | | | | -1.28 | 30.789 | 1.57 |
| | 020 | | | | -1.49 | 31.646 | 3.12 |
| | 030 | | | | -1.65 | 32.355 | 5.12 |
| | 050 | | | | -1.73 | 33.212 | 3.74 |
| | 070 | | | | -1.75 | 33.334 | 4.29 |
| 48 | 000 | 11 Aug | 71°25' | 159°22' | -0.76 | 26.754 | 0.63 |
| | 010 | | | | -1.37 | 30.278 | 1.62 |
| | 020 | | | | -1.43 | 31.078 | 3.99 |
| | 030 | | | | -1.68 | 31.904 | 5.38 |
| | 040 | | | | -1.70 | 32.137 | 1.36 |
| | 045 | | | | -1.73 | 32.556 | 1.44 |
| 49 | 000 | 12 Aug | 71°11.7' | 158°49.8' | -0.49 | 25.539 | 0.70 |
| | 010 | | | | -1.16 | 29.890 | 0.75 |
| | 025 | | | | | 31.694 | 1.72 |
| | 050 | | | | -1.72 | 33.216 | 6.33 |
| | 075 | | | | -1.72 | 33.279 | 8.27 |
| | 093 | | | | -1.73 | 33.283 | 7.55 |
| 54 | 000 | 12 Aug | 71°13' | 158°24' | -0.23 | 27.281 | 0.75 |
| | 010 | | | | -0.55 | 30.199 | 0.78 |
| | 025 | | | | -1.43 | 32.459 | 2.49 |
| | 050 | | | | -1.52 | 32.727 | 6.26 |
| | 075 | | | | -1.54 | 32.801 | 6.53 |
| | 090 | | | | -1.62 | 32.959 | 7.29 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 55 | 000 | 12 Aug | 71°22' | 158°32' | -0.70 | 26.746 | 0.50 |
| | 010 | | | | -1.34 | 29.473 | 0.68 |
| | 020 | | | | -1.50 | 30.742 | 1.65 |
| | 030 | | | | -1.53 | 31.412 | 3.21 |
| | 040 | | | | -1.67 | 31.849 | 4.65 |
| | 050 | | | | -1.73 | 32.667 | 1.81 |
| 58 | 000 | 13 Aug | 71°20' | 157°58' | -0.30 | 27.157 | 0.89 |
| | 010 | | | | -0.71 | 29.684 | 0.92 |
| | 025 | | | | -1.45 | 31.918 | 3.95 |
| | 050 | | | | -1.70 | 33.164 | 5.96 |
| | 075 | | | | -1.69 | 33.182 | 6.23 |
| | 110 | | | | -1.71 | 33.195 | 8.06 |
| 59 | 000 | 13 Aug | 71°30.9' | 158°21.5' | -0.54 | 27.285 | 0.91 |
| | 010 | | | | -0.89 | 29.393 | 0.95 |
| | 020 | | | | -1.04 | 31.075 | 2.91 |
| | 030 | | | | -1.67 | 31.603 | 2.50 |
| | 040 | | | | -1.66 | 31.788 | 0.72 |
| | 054 | | | | -1.71 | 32.110 | 1.46 |
| 60 | 000 | 13 Aug | 71°37.6' | 158°31.8' | -0.47 | 27.019 | 0.69 |
| | 010 | | | | -1.53 | 30.099 | 2.89 |
| | 020 | | | | -1.59 | 30.705 | 2.85 |
| | 030 | | | | -1.65 | 31.229 | 3.73 |
| | 040 | | | | -1.64 | 31.632 | 3.94 |
| | 050 | | | | -1.72 | 32.281 | 0.85 |

Table 4. (continued)

| Sta | Depth (m) | Date | Latitude (N) | Longitude (W) | Temperature (°C) | Salinity (°/₀₀) | Chl *a* (mg $m^{-3}$) |
|---|---|---|---|---|---|---|---|
| 61 | 000 | 13 Aug | 71°43' | 158°10.9' | -0.13 | 23.780 | 1.10 |
| | 010 | | | | -1.04 | 28.45 | 0.70 |
| | 020 | | | | -1.54 | 30.943 | 6.40 |
| | 030 | | | | -1.62 | 31.253 | 2.49 |
| | 040 | | | | -1.68 | 31.835 | 5.43 |
| | 050 | | | | -1.72 | 32.121 | 1.57 |

Table 5. Summary of station locations, hydrography, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity, CGC *Polar Sea* cruise, Bering Sea, 17 Apr - 6 May 1979.

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 000 | 0644 | 19 Apr | 64°15.5' | 165°51.9' | 8 | 2 | * | 31.842 | 1.68 | | 8.23 |
| | 003 | | | | | | | -1.67 | 31.845 | 1.92 | | 7.29 |
| | 006 | | | | | | | -1.69 | 31.887 | 2.32 | | 9.82 |
| | 009 | | | | | | | -1.68 | 31.886 | 1.28 | | 7.00 |
| | 012 | | | | | | | -1.68 | 31.877 | 1.36 | | 7.25 |
| | 015 | | | | | | | -1.69 | 31.800 | 1.36 | | 8.26 |
| | 018 | | | | | | | -1.71 | 31.820 | 2.72 | | 10.31 |
| | 021 | | | | | | | -1.72 | 31.929 | 2.64 | | 11.82 |
| 02 | 000 | 1622 | 19 Apr | 63°46.1' | 166°03.2' | 0 | 4 | -1.51 | 31.675 | 4.48 | | 0.12 |
| | 003 | | | | | | | -1.52 | 31.652 | 5.76 | | 3.67 |
| | 006 | | | | | | | -1.52 | | Bottle didn't trip | | |
| | 009 | | | | | | | -1.53 | 31.653 | 5.04 | | 2.84 |
| | 012 | | | | | | | -1.53 | 31.654 | 5.76 | | 3.35 |
| | 015 | | | | | | | -1.54 | 31.665 | 7.56 | 0.36 | 3.44 |
| | 018 | | | | | | | -1.56 | 31.684 | 10.44 | 0.36 | 2.12 |
| | 021 | | | | | | | -1.54 | 31.693 | 11.16 | | 2.79 |
| 03 | 000 | 0612 | 20 Apr | 63°32.95' | 166°52.78' | 0 | 4 | -1.62 | 31.559 | 4.66 | | 9.19 |
| | 004 | | | | | | | -1.63 | 31.554 | 3.36 | 0.42 | 10.51 |
| | 008 | | | | | | | -1.64 | 31.550 | 1.34 | 1.83 | 7.88 |
| | 012 | | | | | | | -1.63 | 31.555 | 3.90 | 0.26 | 7.63 |
| | 016 | | | | | | | -1.64 | 31.557 | 3.22 | 0.40 | 6.41 |
| | 020 | | | | | | | -1.64 | 31.559 | 2.94 | 0.28 | 8.09 |
| | 024 | | | | | | | -1.65 | 31.553 | 3.80 | 0.44 | 5.32 |
| | 028 | | | | | | | -1.64 | 31.556 | 2.10 | 0.28 | 4.58 |

* Where no temperature is present, both thermometers on the bottle malfunctioned.

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04 | 000 | 1237 | 20 Apr | 63°56.7' | 167°35.9' | 5-6 | 4 | -1.62 | 31.933 | 0.91 | | 2.45 |
| | 004 | | | | | | | -1.64 | 31.927 | 1.44 | | 2.60 |
| | 008 | | | | | | | -1.63 | 31.928 | 0.81 | 0.15 | 1.71 |
| | 012 | | | | | | | -1.67 | 31.939 | 1.63 | 0.14 | 2.44 |
| | 016 | | | | | | | -1.65 | 31.935 | 1.14 | 0.09 | 1.72 |
| | 020 | | | | | | | -1.69 | 31.938 | 1.14 | 0.23 | 3.02 |
| | 024 | | | | | | | -1.73 | 31.937 | 1.29 | 0.31 | 1.85 |
| | 028 | | | | | | | -1.73 | 31.944 | 1.56 | 0.28 | 2.50 |
| 05 | 000 | 0537 | 21 Apr | 64°30.3' | 166°23.3' | 6-7 | 4 | -1.67 | 31.240 | 2.89 | | 3.10 |
| | 003 | | | | | | | -1.66 | 31.225 | 1.56 | | 7.20 |
| | 006 | | | | | | | -1.68 | 31.457 | 3.20 | 0.19 | 3.88 |
| | 009 | | | | | | | -1.66 | 31.438 | 1.28 | | 4.13 |
| | 012 | | | | | | | -1.68 | 31.490 | 1.93 | | 3.61 |
| | 015 | | | | | | | -1.72 | 31.456 | 1.68 | 0.06 | 6.16 |
| | 018 | | | | | | | -1.71 | 31.456 | 0.83 | | 5.51 |
| 06 | 000 | 0956 | 22 Apr | 66°36.26' | 168°25.40' | 7-8 | 4 | -1.29 | 31.587 | 0.25 | 0.94 | 0.97 |
| | 005 | | | | | | | | 31.689 | 0.26 | 0.99 | 1.30 |
| | 010 | | | | | | | -1.66 | 31.715 | 0.14 | 0.95 | 0.84 |
| | 015 | | | | | | | -1.70 | 31.716 | 1.17 | | 1.25 |
| | 020 | | | | | | | | 31.740 | 0.35 | 0.59 | 0.81 |
| | 025 | | | | | | | -1.69 | 31.760 | 1.07 | 0.22 | 1.19 |
| | 030 | | | | | | | -1.71 | 31.763 | 0.12 | 1.42 | 0.77 |
| | 035 | | | | | | | -1.72 | 31.760 | 1.00 | 0.40 | 1.26 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 09 | 000 | 1222 | 24 Apr | 65°36.6' | 168°35.6' | 7-8 | 2 | -1.64 | 31.684 | 0.35 | 1.40 | 1.59 |
| | 005 | | | | | | | -1.69 | 31.726 | 0.98 | 0.14 | 1.60 |
| | 010 | | | | | | | -1.70 | 31.723 | 0.94 | 0.08 | 1.33 |
| | 015 | | | | | | | -1.72 | 31.714 | 0.82 | 0.18 | 1.27 |
| | 020 | | | | | | | -1.70 | 31.723 | 0.91 | 0.27 | 1.56 |
| | 025 | | | | | | | -1.71 | 31.723 | 0.93 | 0.21 | 1.21 |
| | 035 | | | | | | | -1.73 | 31.722 | 1.16 | 0.27 | 1.01 |
| | 045 | | | | | | | -1.72 | 31.719 | 1.16 | 0.38 | 1.07 |
| 10 | 000 | | | | | | | -1.30 | 31.437 | 0.62 | 0.08 | 8.66 |
| | 005 | | | | | | | -1.39 | 31.432 | 0.52 | 0.07 | 11.24 |
| | 010 | | | | | | | -1.63 | 31.442 | 0.53 | 0.09 | 5.93 |
| | 015 | | | | | | | -1.37 | 31.444 | 0.41 | 0.03 | 10.42 |
| | 020 | | | | | | | -1.39 | 31.443 | 0.48 | 0.09 | 6.84 |
| | 025 | | | | | | | | 31.448 | 0.54 | 0.11 | 7.73 |
| | 030 | | | | | | | -1.33 | 31.458 | 0.50 | 0.09 | 6.02 |
| 11 | 000 | 0625 | 26 Apr | 65°01.8' | 168°15.7' | 7-8 | 3 | | 32.312 | 0.49 | 0.42 | 0.53 |
| | 005 | | | | | | | -1.38 | 32.308 | 0.39 | 0.27 | 0.52 |
| | 010 | | | | | | | -1.49 | 32.308 | 0.26 | 0.33 | 0.33 |
| | 015 | | | | | | | -1.44 | 32.311 | 0.26 | 0.23 | 0.42 |
| | 020 | | | | | | | | 32.306 | 0.39 | 0.20 | 0.46 |
| | 025 | | | | | | | -1.51 | 32.323 | 0.36 | 0.27 | 0.44 |
| | 030 | | | | | | | -1.42 | 32.345 | 0.46 | 0.31 | 0.62 |
| | 040 | | | | | | | | 32.359 | 0.40 | 0.40 | 0.60 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl $a$ (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 000 | 0634 | 27 Apr | 64°29'64' | 167°40.10' | 0 | 2 | -1.11 | 31.568 | 10.00 | 2.00 | 12.27 |
| | 004 | | | | | | | -1.18 | 31.569 | 8.50 | 2.00 | 15.94 |
| | 008 | | | | | | | -1.21 | 31.572 | 10.00 | 1.50 | 15.07 |
| | 012 | | | | | | | -1.21 | 31.569 | 12.00 | 0.50 | 17.05 |
| | 016 | | | | | | | -1.22 | 31.573 | 3.50 | | 13.24 |
| | 020 | | | | | | | -1.21 | 31.571 | 9.50 | 2.00 | 14.75 |
| | 024 | | | | | | | -1.23 | 31.568 | 9.00 | 2.00 | 8.63 |
| | 028 | | | | | | | -1.23 | 31.563 | 4.60 | 4.40 | 17.16 |
| 13 | 000 | 1337 | 27 Apr | 64°37.82' | 168°25.67' | < 1 | 2 | -1.49 | 32.191 | 1.00 | 0.50 | 0.94 |
| | 004 | | | | | | | -1.57 | 32.189 | 0.80 | 0.40 | 1.00 |
| | 008 | | | | | | | -1.58 | 32.191 | 0.50 | 0.30 | 1.06 |
| | 012 | | | | | | | -1.60 | 32.195 | 0.60 | 0.30 | 1.70 |
| | 016 | | | | | | | -1.60 | 32.192 | 0.70 | 0.30 | 1.15 |
| | 020 | | | | | | | -1.61 | 32.193 | 0.70 | 0.35 | 1.14 |
| | 024 | | | | | | | -1.63 | 32.196 | 0.70 | 0.40 | 1.12 |
| | 030 | | | | | | | -1.63 | 32.200 | 0.55 | 0.40 | 1.19 |
| 14 | 000 | 0602 | 28 Apr | 64°12.66' | 168°57.44' | 4-5 | 4 | -1.69 | 32.371 | 0.17 | 0.14 | 0.23 |
| | 004 | | | | | | | -1.73 | 32.376 | 0.17 | 0.14 | 0.30 |
| | 008 | | | | | | | -1.75 | 32.368 | 0.17 | 0.16 | 0.29 |
| | 012 | | | | | | | -1.76 | 32.368 | 0.16 | 0.15 | 0.28 |
| | 016 | | | | | | | -1.74 | 32.377 | 0.17 | 0.17 | 0.31 |
| | 020 | | | | | | | -1.77 | 32.406 | 0.16 | 0.14 | 0.26 |
| | 026 | | | | | | | -1.77 | 32.433 | 0.15 | 0.19 | 0.33 |
| | 032 | | | | | | | -1.78 | 32.499 | 0.14 | 0.20 | 0.21 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 000 | 0611 | 29 Apr | 63°50.91' | 170°26.03' | 0 | 3 | -1.40 | 32.029 | 0.13 | 0.11 | 0.38 |
| | 004 | | | | | | | -1.53 | 32.032 | 0.17 | 0.12 | 0.44 |
| | 008 | | | | | | | -1.54 | 32.028 | 0.18 | 0.10 | 0.36 |
| | 012 | | | | | | | -1.54 | 32.031 | 0.16 | 0.10 | 0.33 |
| | 016 | | | | | | | -1.53 | 32.025 | 0.15 | 0.10 | 0.32 |
| | 020 | | | | | | | -1.54 | 32.035 | 0.18 | 0.10 | 0.39 |
| | 024 | | | | | | | -1.54 | 32.037 | 0.14 | 0.12 | 0.33 |
| | 030 | | | | | | | -1.56 | 32.034 | 0.17 | 0.12 | 0.32 |
| 16 | 000 | 1307 | 29 Apr | 64°00.6' | 171°25.5' | 1-3 | 4 | -1.52 | 31.978 | 0.38 | 0.11 | 0.71 |
| | 004 | | | | | | | -1.64 | 31.980 | 0.30 | 0.06 | 0.54 |
| | 008 | | | | | | | -1.66 | 31.979 | 0.39 | 0.09 | 0.90 |
| | 012 | | | | | | | -1.69 | 31.980 | 0.40 | 0.06 | 0.77 |
| | 016 | | | | | | | -1.68 | 31.979 | 0.27 | 0.24 | 0.83 |
| | 020 | | | | | | | -1.68 | 31.976 | 0.38 | 0.11 | 0.63 |
| | 024 | | | | | | | -1.69 | 31.966 | 0.37 | 0.08 | 0.71 |
| | 028 | | | | | | | -1.70 | 31.980 | 0.35 | 0.10 | 0.75 |
| 17 | 000 | 0600 | 30 Apr | 63°44.83' | 169°12.32' | 0 | 5 | -1.58 | 32.261 | 0.16 | 0.10 | 0.28 |
| | 002 | | | | | | | -1.61 | 32.282 | 0.21 | | 0.21 |
| | 006 | | | | | | | -1.58 | 32.398 | 0.15 | 0.11 | 0.22 |
| | 010 | | | | | | | -1.59 | 32.299 | 0.14 | 0.09 | 0.21 |
| | 014 | | | | | | | -1.56 | 32.348 | 0.13 | 0.11 | 0.23 |
| | 018 | | | | | | | | 32.316 | 0.12 | 0.10 | 0.18 |
| | 024 | | | | | | | -1.63 | 32.346 | 0.11 | 0.11 | 0.22 |
| | 030 | | | | | | | -1.68 | 32.434 | 0.12 | 0.13 | 0.16 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl a (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 000 | 1343 | 30 Apr | 63°17.83' | 168°20.07' | 0 | 4 | -1.16 | 31.449 | 1.40 | 0.25 | 2.02 |
| | 004 | | | | | | | -1.19 | 31.450 | 1.20 | 0.30 | 2.02 |
| | 008 | | | | | | | -1.20 | 31.456 | 1.35 | 0.30 | 2.04 |
| | 012 | | | | | | | -1.23 | 31.455 | 1.30 | 0.30 | 2.70 |
| | 018 | | | | | | | -1.27 | 31.457 | 1.35 | 0.30 | 1.76 |
| | 024 | | | | | | | -1.32 | 31.461 | 1.80 | 0.35 | 2.38 |
| | 030 | | | | | | | -1.34 | 31.459 | 1.40 | 0.30 | 3.44 |
| | 036 | | | | | | | -1.33 | 31.462 | 1.80 | 0.40 | 3.67 |
| 19 | 000 | 0552 | 2 May | 57°06.89' | 170°00.7' | 0 | 3-4 | 2.68 | 32.583 | 1.05 | 0.35 | 2.13 |
| | 005 | | | | | | | 1.56 | 32.542 | 1.35 | 0.50 | 2.19 |
| | 010 | | | | | | | 2.67 | 32.540 | 1.05 | 0.35 | 2.47 |
| | 015 | | | | | | | 2.64 | 32.538 | 1.65 | 0.60 | 3.20 |
| | 020 | | | | | | | 2.67 | 32.664 | 1.05 | 0.45 | 1.69 |
| | 025 | | | | | | | 2.67 | 32.585 | 0.95 | 0.40 | 2.53 |
| | 030 | | | | | | | 2.66 | 32.583 | 1.05 | 0.25 | 2.35 |
| | 042 | | | | | | | 2.66 | 34.977 | 0.85 | 0.70 | 3.58 |
| 20 | 000 | 1255 | 3 May | 56°27.50' | 169°25.06' | 0 | 12 | 3.91 | 32.546 | 0.28 | 0.15 | 0.54 |
| | 010 | | | | | | | | 32.514 | 0.28 | 0.11 | 0.81 |
| | 020 | | | | | | | 3.55 | 32.504 | 0.29 | 0.16 | 1.08 |
| | 030 | | | | | | | 3.49 | 32.485 | 0.24 | 0.11 | 1.07 |
| | 040 | | | | | | | 3.50 | 32.468 | 0.25 | 0.17 | 0.70 |
| | 050 | | | | | | | | 32.444 | 0.25 | 0.17 | 0.85 |
| | 060 | | | | | | | 3.48 | 32.410 | 0.25 | 0.14 | 0.82 |
| | 080 | | | | | | | 3.48 | 32.379 | 0.28 | 0.14 | 0.93 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 000 | 0657 | 3 May | 54°34.07' | 165°58.64' | 0 | ~ 7 | 4.49 | 32.808 | 4.00 | 0.80 | 6.18 |
| | 010 | | | | | | | 4.57 | 32.788 | 3.30 | 0.70 | 10.42 |
| | 020 | | | | | | | 4.57 | 32.785 | 2.80 | 0.70 | 14.05 |
| | 030 | | | | | | | 4.40 | 32.785 | 1.90 | 0.30 | 7.99 |
| | 045 | | | | | | | 4.40 | 32.800 | 1.70 | 0.45 | 5.90 |
| | 060 | | | | | | | 4.35 | 32.808 | 1.55 | 0.40 | 5.55 |
| | 075 | | | | | | | 4.32 | 32.829 | 1.60 | 0.55 | 8.74 |
| | 100 | | | | | | | 4.09 | 32.977 | 0.65 | 0.40 | 2.15 |
| 24 | 000 | 1423 | 3 May | 54°58.7' | 164°36.2' | 0 | ~ 7 | 4.81 | 32.240 | 1.15 | 0.35 | 5.18 |
| | 005 | | | | | | | 4.76 | 32.235 | 0.95 | 0.25 | 5.19 |
| | 010 | | | | | | | 4.74 | 32.239 | 1.10 | 0.20 | 5.75 |
| | 015 | | | | | | | 4.70 | 32.252 | 1.10 | 0.30 | 5.60 |
| | 020 | | | | | | | 4.72 | 32.303 | 1.25 | 0.45 | 2.58 |
| | 025 | | | | | | | 4.52 | 32.318 | 0.70 | 0.35 | 4.45 |
| | 035 | | | | | | | 4.44 | 32.380 | 0.85 | 0.30 | 2.42 |
| | 045 | | | | | | | 4.41 | 32.424 | 0.55 | 0.40 | 0.98 |
| 25 | 000 | 0658 | 4 May | 54°10.36' | 163°47.78' | 0 | 8 | 4.72 | 31.704 | 0.85 | 0.20 | 2.71 |
| | 010 | | | | | | | 4.69 | 31.709 | 0.80 | 0.30 | 2.45 |
| | 020 | | | | | | | 4.70 | 31.718 | 0.90 | 0.25 | 2.74 |
| | 030 | | | | | | | 4.54 | 31.812 | 1.60 | 0.45 | 3.23 |
| | 040 | | | | | | | 4.53 | 31.875 | 1.25 | 0.35 | 3.10 |
| | 050 | | | | | | | 4.47 | 31.923 | 0.90 | 0.60 | 1.91 |
| | 060 | | | | | | | 4.21 | 31.974 | 0.55 | 0.50 | 0.71 |
| | 075 | | | | | | | 4.04 | 32.170 | 0.09 | 0.32 | 0.20 |

Table 5. (continued)

| Sta | Depth (m) | Time (Local) | Date | Latitude (N) | Longitude (W) | Ice Cover (oktas) | Secchi Depth (m) | Temp (°C) | S°/₀₀ | Chl *a* (mg $m^{-3}$) | Phaeo (mg $m^{-3}$) | Prim Prod (mg C $m^{-3}$ $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 000 | 1605 | 4 May | 54°14.7' | 161°52.5' | 0 | > 12 | 4.62 | 31.789 | 0.45 | 0.30 | 1.34 |
| | 005 | | | | | | | 4.60 | 31.798 | 0.50 | 0.20 | 1.25 |
| | 010 | | | | | | | 4.59 | 31.794 | 0.75 | 0.20 | 1.33 |
| | 020 | | | | | | | 4.47 | 31.805 | 0.55 | 0.20 | 1.43 |
| | 030 | | | | | | | | 31.822 | 0.45 | | 0.59 |
| | 040 | | | | | | | 4.15 | 31.953 | 0.13 | 0.27 | 0.15 |
| | 050 | | | | | | | 3.97 | 32.138 | 0.14 | 0.10 | 0.12 |
| | 060 | | | | | | | 4.03 | 32.250 | 0.07 | 0.22 | 0.08 |
| 27 | 000 | 1506 | 5 May | 56°21.44' | 155°30.78' | 0 | > 10 | 5.07 | 32.194 | 3.60 | 0.60 | 15.14 |
| | 005 | | | | | | | 5.00 | 32.192 | 3.40 | 0.60 | 16.23 |
| | 010 | | | | | | | 4.77 | 32.192 | 3.90 | 0.50 | 14.25 |
| | 015 | | | | | | | 4.55 | 32.205 | 3.10 | 0.40 | 7.91 |
| | 020 | | | | | | | 4.53 | 32.194 | 3.30 | | 8.94 |
| | 030 | | | | | | | 4.47 | 32.199 | 2.25 | 0.40 | 5.47 |
| | 040 | | | | | | | 4.49 | 32.230 | 1.85 | 0.50 | 3.73 |
| | 050 | | | | | | | 4.64 | 32.323 | 1.25 | 0.65 | 3.49 |
| 28 | 000 | 0659 | 6 May | 59°07.07' | 152°54.38' | 0 | > 10 | | 32.099 | 3.40 | 0.60 | 22.33 |
| | 010 | | | | | | | 4.98 | 32.044 | 3.70 | 0.60 | 19.80 |
| | 020 | | | | | | | 4.89 | 32.100 | 4.80 | 0.80 | 18.78 |
| | 030 | | | | | | | 4.71 | 32.144 | 3.10 | 0.70 | 13.47 |
| | 040 | | | | | | | 4.72 | | 2.80 | 0.80 | 10.66 |
| | 050 | | | | | | | 4.70 | 32.142 | 3.10 | 1.00 | 9.27 |
| | 060 | | | | | | | 4.69 | 32.136 | 2.30 | 0.70 | 8.53 |
| | 070 | | | | | | | 4.68 | 32.138 | 2.60 | 0.90 | 8.88 |

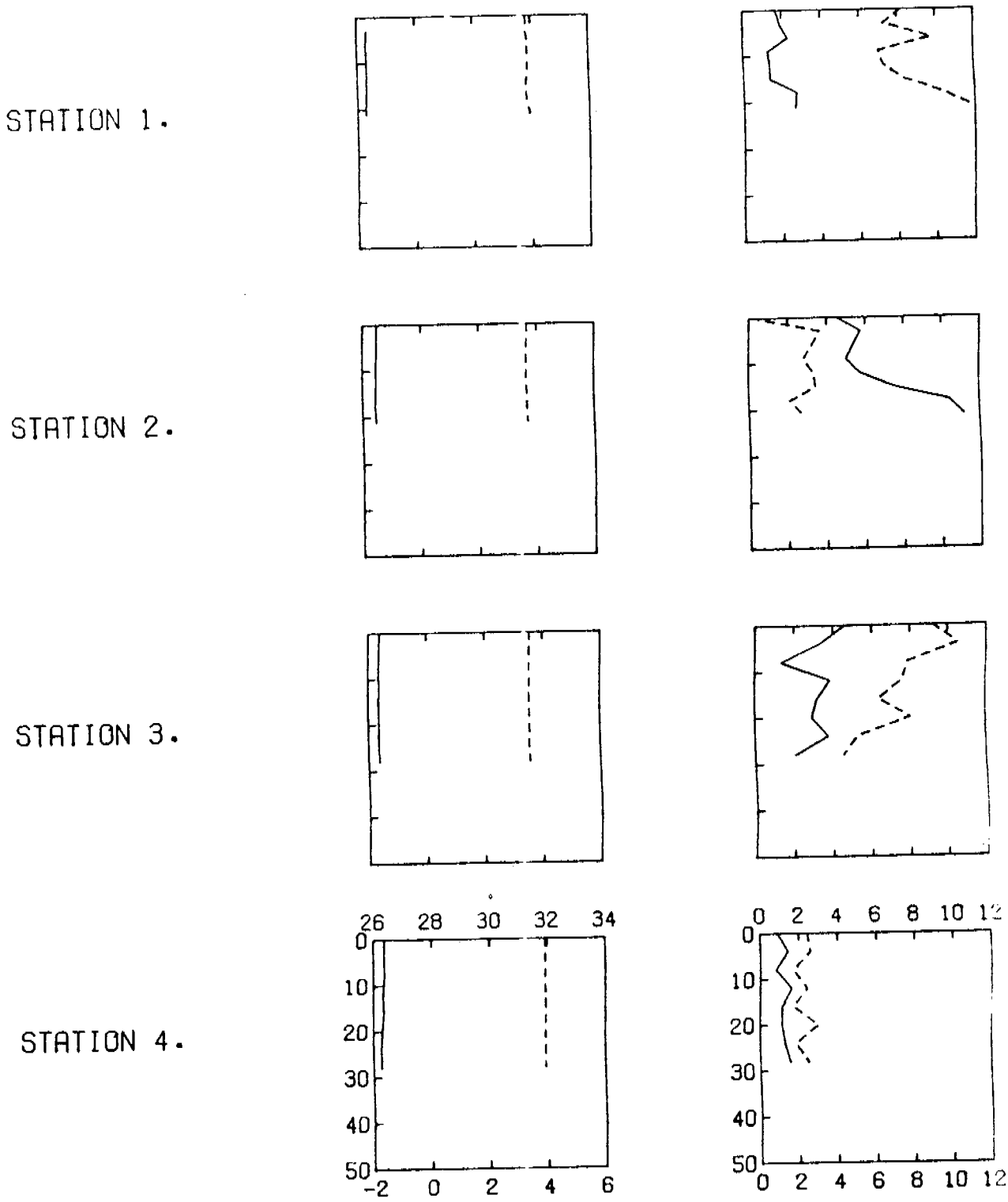
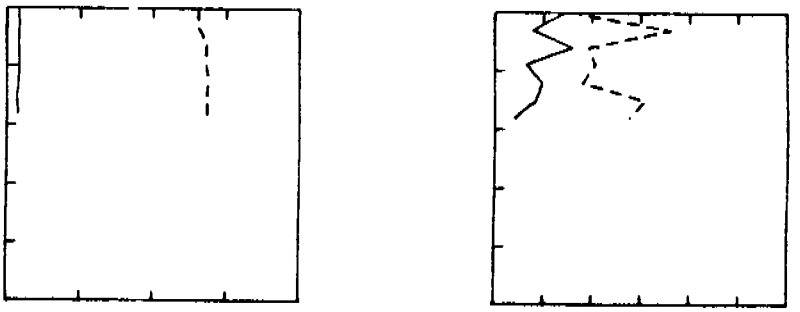



Fig. 4. Depth profiles of temperature-salinity and chlorophyll *a*-primary productivity in the Bering Sea and Shelikof Strait, 17 Apr-6 May 1979. Salinity (°/$_{oo}$) ---; temperature (°C) ___; primary productivity (mg C $m^{-3}$ $hr^{-1}$) ---; chlorophyll *a* (mg $m^{-3}$) ___.

STATION 5.



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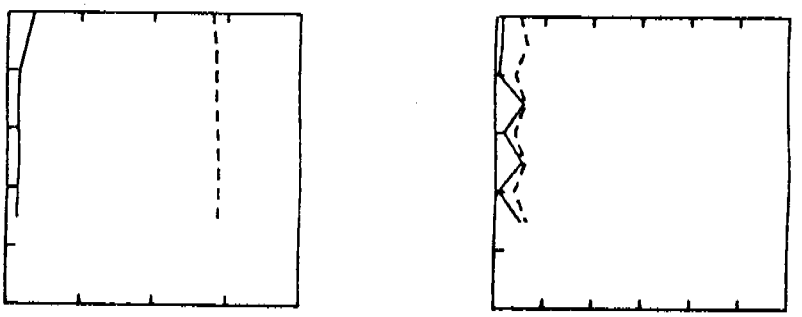
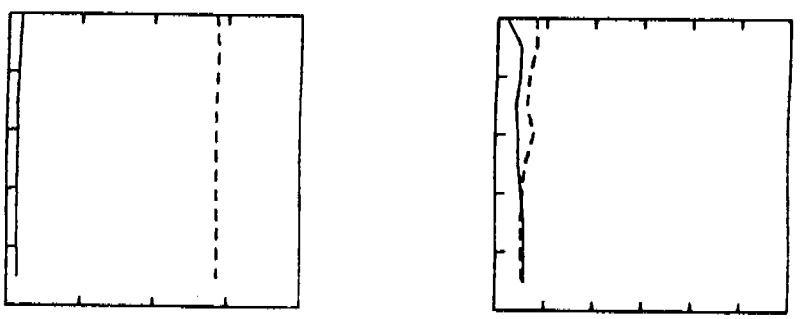


STATION 9.



STATION10.

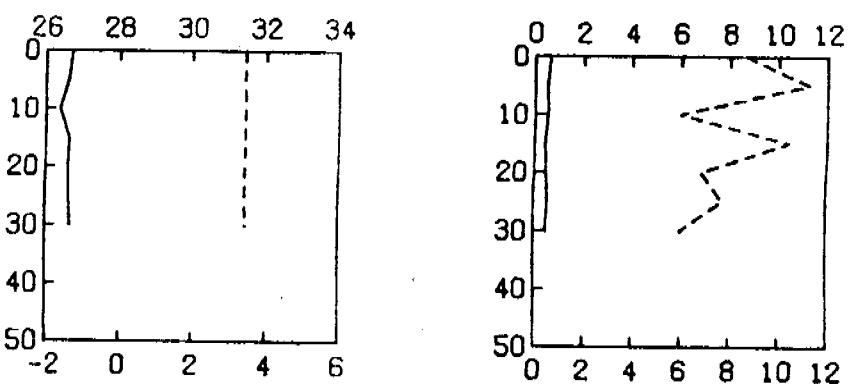
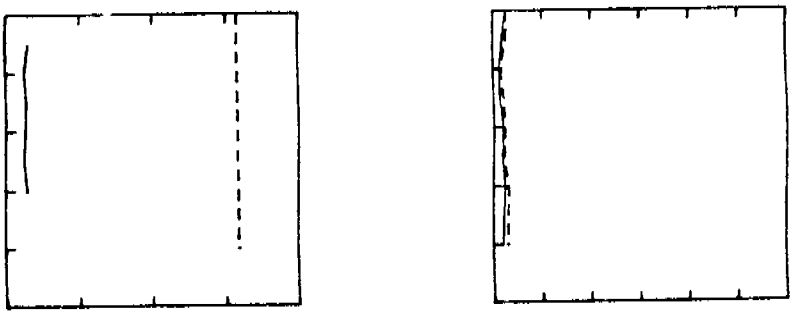



Fig. 4. (continued)

STATION11.



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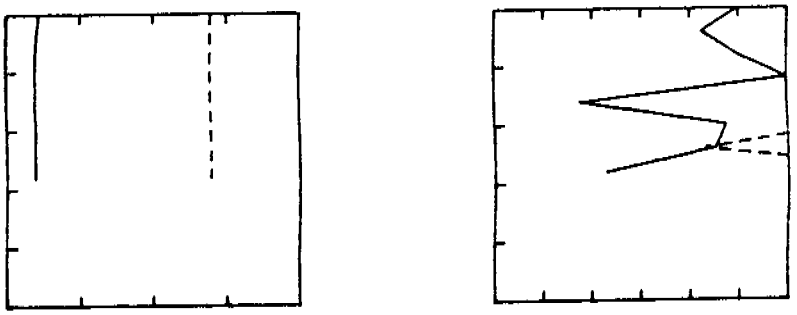

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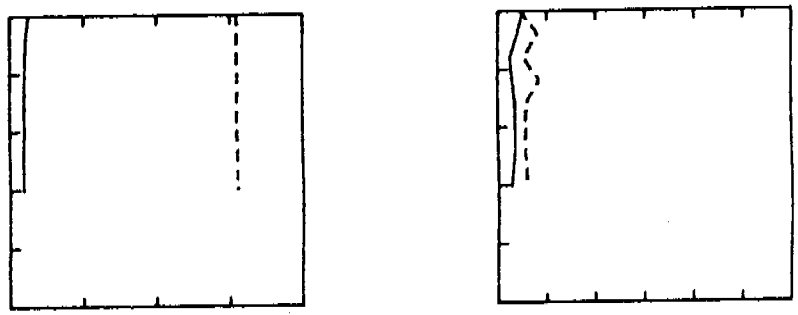

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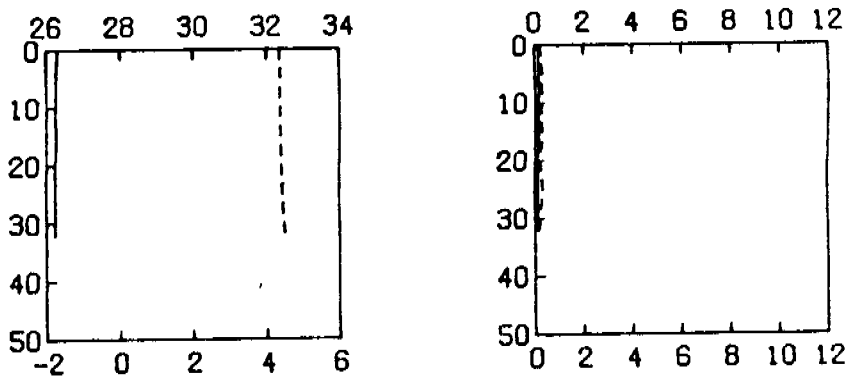
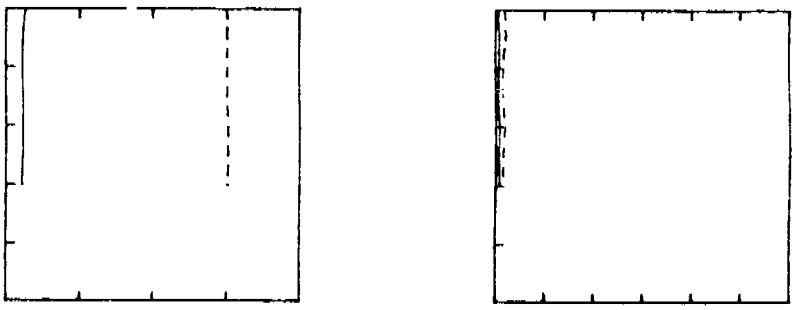



Fig. 4. (continued)

STATION15.



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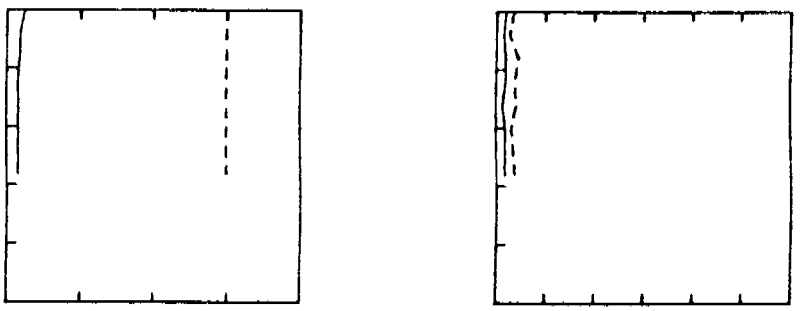

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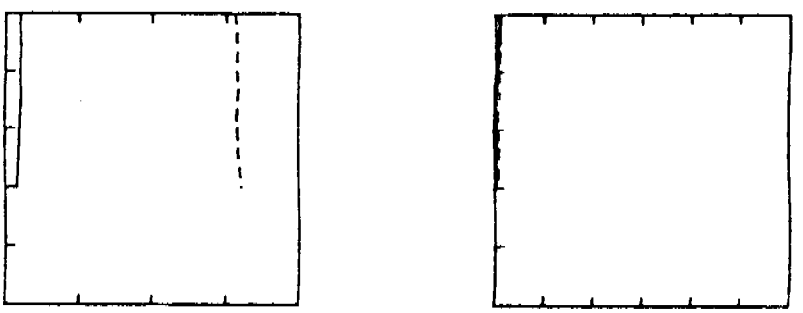

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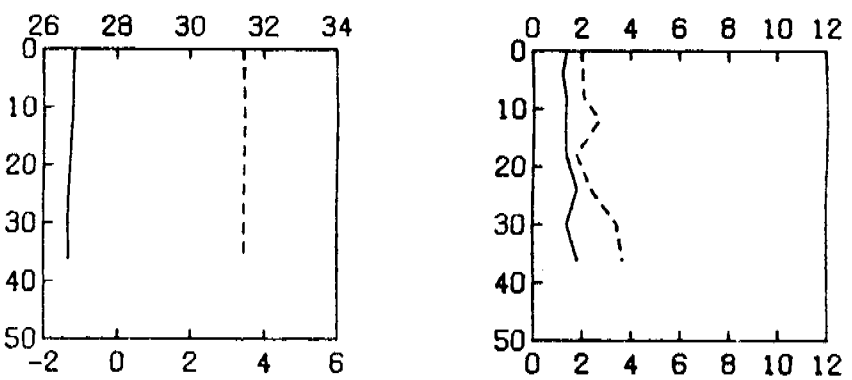
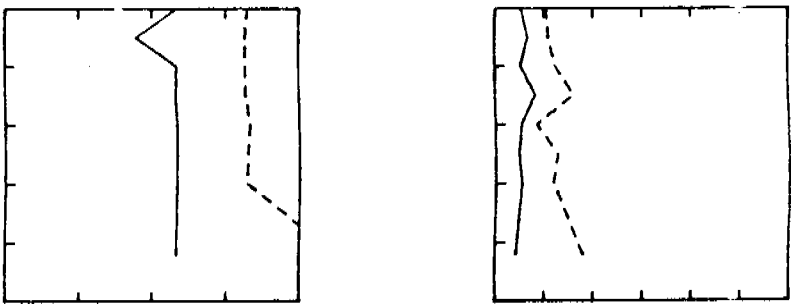



Fig. 4. (continued)

STATION19.



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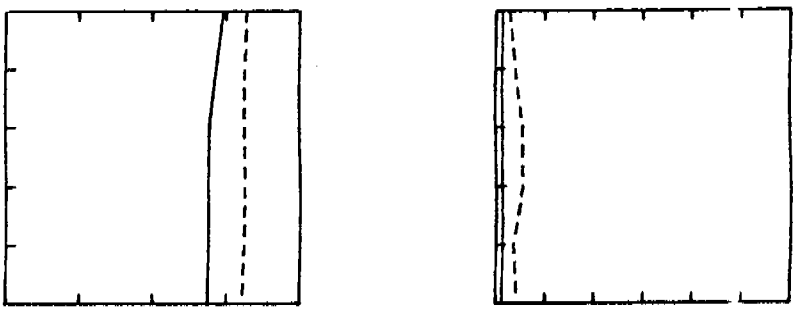

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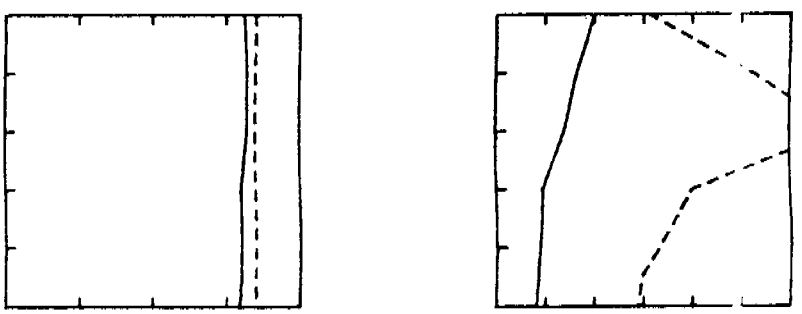

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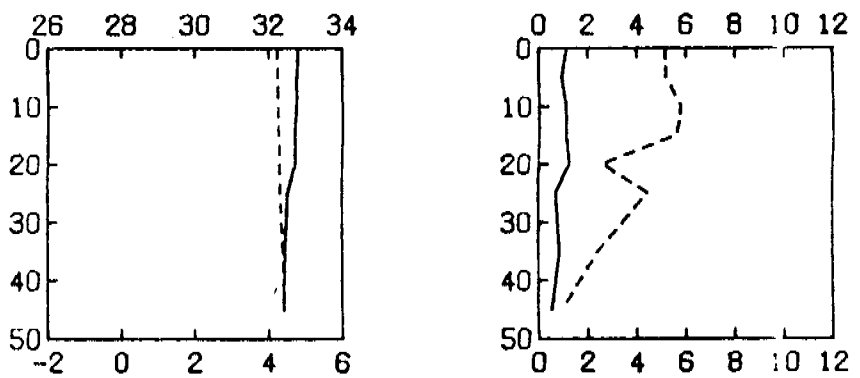


Fig. 4. (continued)

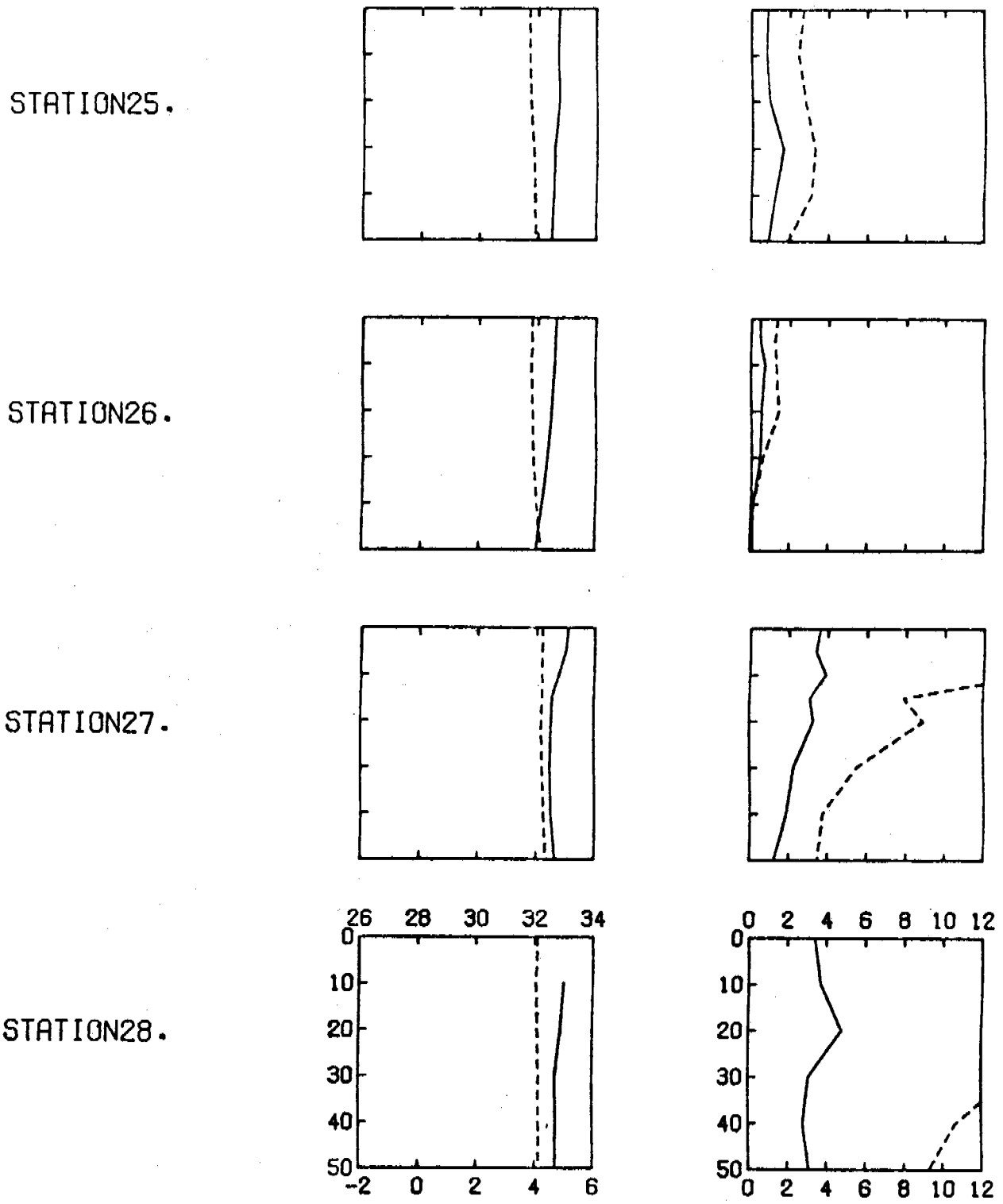


Fig. 4. (continued)

Higher productivity, to 22.33 mg C $m^{-3}$ $hr^{-1}$ occurred in Shelikof Strait (station 28). In the northern Bering Sea (stations 1-18), integrated productivity ranged from 6.25 mg C $m^{-2}$ at station 17 to 397.64 mg C $m^{-2}$ at station 12. In the southern Bering Sea, (stations 19-24), integrated productivity ranged from 69.30 mg C $m^{-2}$ at station 20 to 748.90 mg C $m^{-2}$ at station 23.

No standing stock samples have been analyzed.

## V. Preliminary Interpretation of Results

### A. Zooplankton

Interpretation of results is not possible at this time for Bering and Chukchi sea data.

Several interesting organisms have been found in the Stefansson Sound samples. *Halitholus cirratus*, an anthomedusa, has been recorded from N.E. Ellesmere Island, Point Barrow, and the southern Beaufort Sea (Shih *et al.* 1971), but has not been reported from previous RU 359 Beaufort Sea samples. It is considered to be an Arctic circumpolar species, but is also abundant in deep water in the Baltic Sea (Kramp 1959).

Records and descriptions in the literature are contradictory concerning *Bosmina* and *Eubosmina*. *Bosmina longirostris* (O. F. Muller) has been recorded near the mouth of the Colville River (Reed 1962), but the one specimen collected in Stefansson Sound on 13 March 1979 most closely resembles *Eubosmina longispina* (Leydig), a species reported to be abundant in Alaskan lakes (Carlson 1974).

### B. Phytoplankton

No previously unreported species of phytoplankton have been found in the samples analyzed to date, although *Coscinodiscus lacustris* Grunow is present in small numbers in some samples from the Chukchi Sea. This species has been reported previously from sea ice collected in the Beaufort Sea near Point Barrow (Grant and Horner 1976), but was not a conspicuous component of the ice community. In culture studies, *C. lacustris* tolerated a wide range of salinities, growing at salinities ranging from 10 to 50°/$_{oo}$. There was no lag period at salinities ranging from 20 to 35°/$_{oo}$, but above and below this range there was a lag period of about 3 days (Grant and Horner 1976).

In samples collected near shore, an organism resembling *Pelagococcus subviridis* was found, sometimes in relatively large numbers. This organism, originally described from the North Pacific, was placed in the Chrysophyceae based on organelle fine structure and pigment composition although it is somewhat atypical. The cells are solitary or aggregated into loose chains that may branch. Individual cells range in size from about 2.5 to 5.5 µm (Lewin *et al.* 1977). The cells found in the Chukchi Sea samples are similar in size and colony shape, but pigment composition is not known. Similar cells have also been seen in samples from the Beaufort Sea (Horner unpubl.) and were reported as perhaps being yeasts in samples from Port Valdez

(Horner *et al.* 1973).

Many of the diatoms are weakly silicified making identification difficult. This is probably caused by the long time in storage between collection and analysis. Although there are no nutrient data from this cruise, silica is probably never limiting in this area.

## VI. Auxiliary Material

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### B. Papers in Preparation or in Print - None

### C. Oral Presentations - None

## VII. Problems Encountered/Recommended Changes - None

## IX. Acknowledgements

Sampling during the 1974 CGC *Staten Island* cruise was done by MSTC Dennis Noble and Mr. Larry Hannon, U.S. Coast Guard Oceanographic Unit. Mr. Hannon also provided the temperature and salinity data. Funding for the phytoplankton collections was provided by Office of Naval Research Grant No. N00014-67-A-0317-003.

Quarterly Report
Period 2/21 - 2/20/79
R.U. 542

# Shallow Water Fish Communities in the Northeastern Gulf of Alaska: Habitat Evaluation, Temporal and Spatial Distribution, Relative Abundance and Trophic Interactions.

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October 6, 1979

## ABSTRACT

The marine fishes are an important component of the inshore fauna of the northeastern Gulf of Alaska. Direct Observations of fishes living in Hinchinbrook Entrance and Montague Strait were made during April, May, June, July and August 1979. The shallow water fish assemblages of this region are represented by at least 59 species which are typically found in the nearshore zone. Twenty-five percent of the fish identified to date were previously unreported in these waters and as such represent northern range extensions in the eastern Pacific.

During 1979, 5,340 square meters of sea floor were examined for fish density and vertical distribution along randomly or haphazardly placed transects. Another 3,960 square meters of underwater terrain was surveyed within fixed transect bands. The data gathered during this, and other sample periods will be used to determine relative abundance, biomass and depth distribution of fish populations in the NEGOA region. Most of the counts were replicated to account for differences in tidal height and water direction, time of day and the activity patterns of the individual fish. The nearshore areas were comprised of both solitary and schooling fish. Rockfish (Scorpaenidae), greenling (Hexagrammidae), sculpin (Cottidae), wolf-fish (Anarhichadidae), and ronquil (Bathymasteridae) dominated the exposed rocky habitats, while more protected locations were numerically dominated by sculpin (Cottidae), prickleback (Stichaeidae), righteye flounder (Pleuronectidae), greenling (Hexagrammidae) and codfish (Gadidae).

Patterns of habitat utilization were studied in relation to a few key parameters which seemingly effect spatial distribution and contribute to resource partitioning in the nearshore zone. Observations made while diving suggest that these distributions are effected by: (1) the depth of the water column, (2) type of bottom topography, and (3) degree of exposure in relation to ocean swell and net water flow. Emphasis has been placed on studying the characteristic or representative important

species in these habitats. Fish have been included in this category on the basis of their numerical importance, commercial value or functional role in the maintence of the natural system.

Samples from these fish populations have been taken for the purpose of describing their food habits, thus leading to a better understanding of trophic interaction and energy flow in the coastal zone. Most of the specimens were collected during daylight hours with spears and hand nets. The remainder were either caught in gillnets, on hook and line or taken with the aid of chemicals. The stomach contents of 186 specimens were inspected for food items during this past sample period. In all, a total of 461 specimens, comprised of 26 species, have been examined for food material. Important prey of the bottom feeders included gammaridean amphipods, brachyuran crabs, caridean shrimps, ophiuroids, caprellid amphipods, gastropods, mussels and fish eggs. Whereas, schooling fishes that feed and spend most of their time in the water column preyed heavily upon zooplankters such as calanoid copepods, pteropods, megalops crab larvae, tomopterid polychaetes, chaetognaths, amphipods and fish.

Age-length relationships derived from otolith readings for black and dusky rockfish were obtained during 1979. These data will be used as background information to determine the size and age composition of these relatively unexploited fish populations. Additional natural history information, i.e. periods of reproduction, larval release time etc., which are pertinent to a basic understanding of nearshore systems have been recorded to aid in our assessment of the vulnerability of these shallow water fish populations to both natural and man-induced perturbations in the Gulf of Alaska.

## I. Task Objectives

The goals of this study are to provide a detailed description, and an ecological analysis of fish inhabiting the shallow waters of the northeastern Gulf of Alaska. This has been accomplished by:

A) Describing the major habitats and evaluating patterns of habitat utilization by fish populations in the NEGOA region.

B) Improving the species list or inventory of fish that inhabit the inshore zone.

C) Estimating numerical density, biomass and depth distributions of these fish populations.

D) Assessing spatial and temporal distributions of these fish populations.

E) Analyzing the food habits of some of the more common inshore species.

F) Deriving age-length relationships for rockfish populations.

G) Gathering pertinent natural history information involving fish spawning, larval release time and territoriality.

## II. Field and Laboratory Activities

### A. Field Activities: F.V. Searcher

1. April 2-13, 1979 - Elrington Passage & Hinchinbrook Entrance
2. May 16-22, 1979 - Hinchinbrook Entrance
3. June 1-9, 1979 - Montague Strait & Hinchinbrook Entrance
4. June 16-24, 1979 - Hinchinbrook Entrance & Montaque Strait
5. July 1-6, 1979 - Hinchinbrook Entrance
6. July 16-21, 1979 - Montague Strait & Hinchinbrook Entrance
7. July 23-27, 1979 - Naked Islands, Montaque Strait
8. July 30 - August 6, 1979 - Montague Strait

### B. Scientific Party

1. Richard J. Rosenthal, Alaska Coastal Research
2. Dennis Lees, Dames & Moore
3. Thomas Rosenthal, Alaska Coastal Research
4. Dr. Larry Moulton, Woodward & Clyde
5. Daniel Gotshall, California Department of Fish and Game
6. Bill Driskoll, Dames & Moore

### C. Methods

Field work was conducted aboard the F.V. Searcher. Shallow subtidal observations and sampling was carried out while scuba diving in specific study locations. A total of 120 dives were made in these areas from 4/5 - 9/5/79, and this represented 150 man hours of under-

water bottom time. Numerical information on fish density and distribution was obtained from both fixed and random transect lines. Analysis of food items in the stomachs of captured specimens, and species identifications were made both in the laboratory and while aboard the Searcher.

D. Sample Localities

Direct observations were made, and samples were obtained from 12 specific locations, representing 8 general sites in the northeastern Gulf of Alaska (see Figure 1). These included:

1) Danger Island - southern shoreline
2) Elrington Passage - Bathtub Rock
3) Zaikof Bay - Zaikof Point and Middle Reef
4) Schooner Rock - north and south side of islet
5) Constantine Harbor - entrance and eastern shoreline
6) Little Smith Island - southeast end
7) Naked Island - entrance to Bass Harbor
8) Peak Island - northwest point

E. Data Collected or Analyzed

1. Types of Samples/Observations
   a. 5,340 square meters of sea floor were examined during 1979 for fish density and distribution along random transects.
   b. Fixed transects that were emplaced during August, 1978 remained in place over the winter. Replicate counts were made along these lines, and a total of 3,960 square meters of underwater terrain was surveyed.
   c. Patterns of habitat utilization were analyzed using a frequency of occurrence table. Data was obtained on 370 specimens.
   d. To date, 59 species have been collected and identified from these study sites. Fish were captured with the aid of spears, chemicals and gillnets.
   e. The stomach contents of 186 specimens were inspected for food material during 1979, and this brings the total to 461 specimens.
   f. All fish were measured (standard length), weighed and the sex was determined when possible. Size composition data will be used to determine fish biomass in each area.
   g. Age-length relationships for dusky and black rockfishes were derived from otolith readings and standard length measurements.

2. Types of Analysis

A variety of statistical procedures are being used to test for differences or similarities among data sets.
   a. The fish density information was normalized and has been tabulated according to the number of fish/square meter, and fish/hectare.
   b. The Mann-Whitney U-distribution test is being used to test for differences between the estimated densities in different

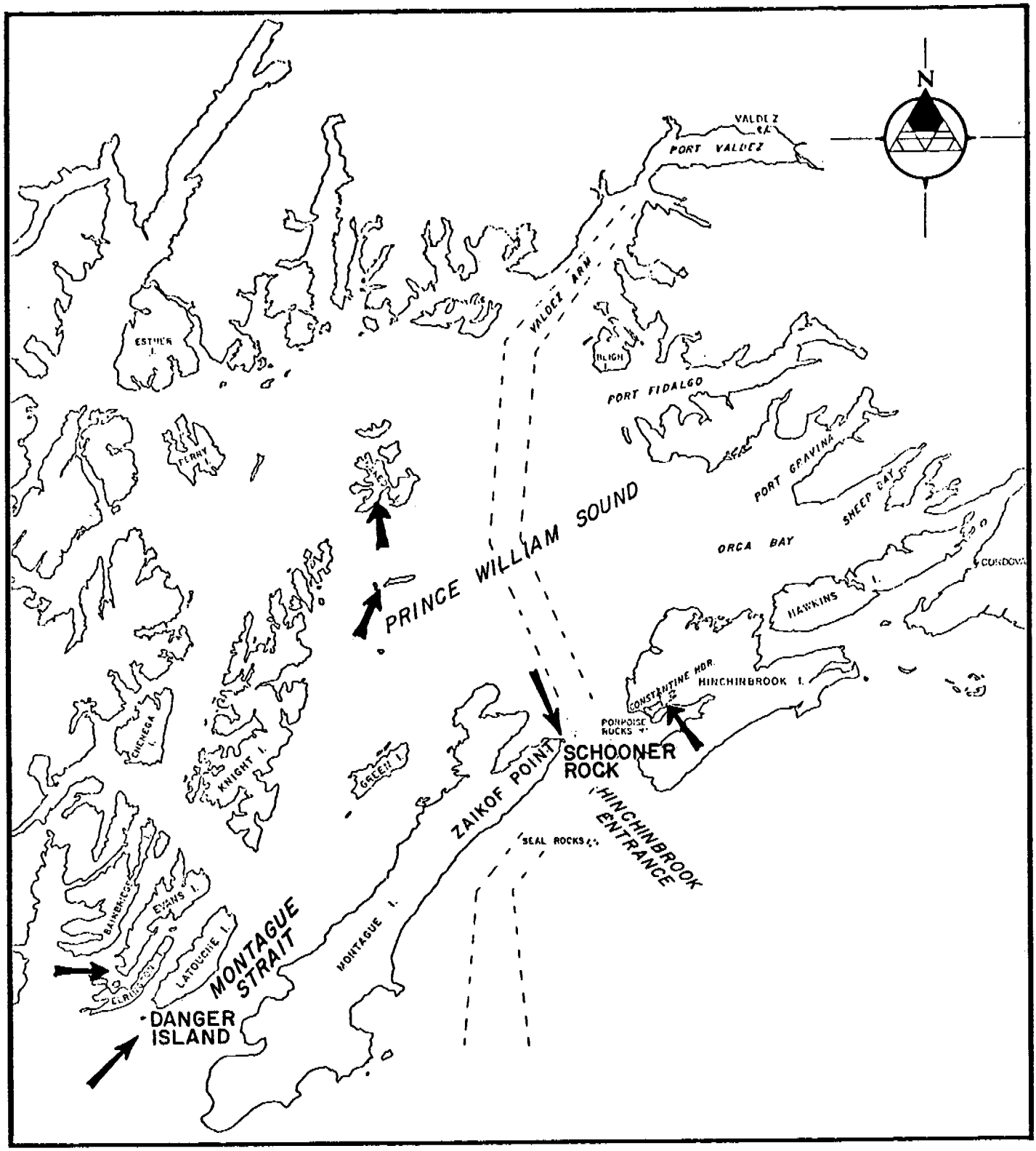


FIGURE 1

SHALLOW WATER STUDY SITES
IN
NORTHEASTERN GULF OF ALASKA

NAUTICAL MILES
0 10 20 30

study areas and between seasons.

c. Differences between transect replicates and comparisons between fixed and random transects are being examined using a Wilcoxon T-test, Mann-Whitney U-Test and the Kruskal - Wallis Analysis of Variance.

d. The Spearman-Rank Correlation Co-efficient is employed to measure association or similarity between the species composition in the different study areas.

e. Reading the otoliths of rockfishes under reflected light with the aid of a dissecting microscope. Replicate counts of the annuli were made over a 2 month period.

f. Confirmation of fish identifications for range extensions and systematic studies has been done with the assistance of experts in the field of taxonomy.

F. Milestone Chart - 1979

Field Work - April, May, June, July, August

Report Preparation - September, October, November & December

## III. Results

A. Diving surveys have been conducted at eight areas: Danger Island, Elrington Passage, Naked Island, Little Smith Island, Peak Island, Zaikof Point, Schooner Rock and Constantine Harbor. Estimates of numerical density have been obtained from transects (fixed and random) emplaced between 0 and 27 m.

B. Schooner Rock had the highest numerical density of fish, followed by Danger Island, Zaikof Point and Constantine Harbor. Mean density estimates varied substantially from early spring (oceanic winter) to late summer. Fish density and species richness increased in all areas from April - August.

C. Black rockfish (Sebastes melanops) and dusky rockfish (Sebastes ciliatus) were the most abundant schooling fish in the inshore zone, whereas the kelp greenling (Hexagrammos decagrammus) was the most abundant solitary bottom species. Red Irish Lord (Hemilepidotus hemilepidotus) and Alaskan ronquil were present at all 8 locations.

D. To date, 59 species representing 16 families have been identified from the shallow waters of the NEGOA region. At least 15 of the species, or 25 percent of the ichthyofauna had not been reported from these waters prior to the present study. These species are: tubesnout, yellowtail rockfish, Puget Sound rockfish, China rockfish, Longfin sculpin, brown rockfish, silvergrey rockfish, tiger rockfish, lingcod, scalyhead sculpin, brown irish lord, mosshead warbonnet, arctic shanny, bonyhead sculpin and penpoint gunnel. Most of the previously over looked fish were not uncommon in these waters, but instead were conspicuous in the nearshore zone.

E. In terms of species composition, Schooner Rock and Zaikof Point were most similar, while Danger Island and Constantine Harbor

were least similar. Danger Island and Schooner Rock were dominated by schooling species during all seasons of observation. Solitary bottom species such as kelp greenling and whitespotted greenling dominated the counts at Zaikof Point.

F. Vertical distributions of fish indicate that the 0-5 m depth interval was the least utilized bathymetric zone, whereas the 10-20 m depth interval was heavily populated. Seasonal patterns in vertical distribution suggest that most of the species that were found in shallow water (< 10 m) during summer, moved to deeper depths during oceanic winter and early spring. Also, there is strong evidence that some of the solitary bottom species such as the greenlings become more quiescent or cryptic in winter.

G. The subtidal boulder fields and rocky outcrops below the kelp forests typically supported the highest density of fish on a year-round basis. However, shallow eelgrass meadows and seaweed beds were important habitats during late spring and summer when there was an influx of juvenile and more transitory species into the nearshore zone.

H. Since the inception of this study, approximately 461 specimens, representing 26 species have been examined for food material. The most commonly consumed prey of the bottom species were gammaridean amphipods, gastropods, brachyuran crabs, caridean shrimps, ophuiroids, caprellid amphipods, gastropods, mussels and fish eggs. Schooling fish preyed heavily on pelagic zooplankton such as calanoid copepods, pteropods, megalops crab larvae, tomopterid polychaetes, chaetognaths, amphipods and fish.

## IV. Auxiliary Material

### A. Bibliography of References - Update

1.) Six, L.D. and H.E. Horton, 1977. Analysis of age determination methods for yellowtail rockfish, canary rockfish and black rockfish off Oregon. Fish Bull., U.S. 75: 405-514.

### B. Scientific Papers

In addition to the final report it is anticipated that 3 scientific papers will result from this OCSEAP study.

### C. Oral Presentations:

1.) A slide show of this work was given on March 17, 1979 at the "Man In The Sea Symposium", Seattle, Washington.
2.) A lecture was presented to the fisheries students at the University of Alaska on April, 1979.

## V. Problems Encountered/Recommended Changes

Weather and logistics play a major role in carrying out field research in the northern Gulf of Alaska. Fortunately, the weather and water condition were adequate during the period from 4/1/79 - 8/12/79 to allow the scheduled work to be completed.

QUARTERLY PROGRESS REPORT

Contract No.: R7120825
Research Unit No.: RU 551
Reporting Period: July 1 - Sept 30, 1979
Number of Pages: 7

# SEASONAL COMPOSITION AND FOOD WEB RELATIONSHIPS OF MARINE ORGANISMS IN THE NEARSHORE ZONE

Co-Principal Investigators

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and Robert Y. Wolotira

Northwest and Alaska Fisheries Center Seattle, Washington

September 1979

I. Highlights of Quarter's Accomplishments

Data tape for summer 1978 submitted to OCSEAP. Ichthyoplankton from winter 1979 cruise identified. Identification of decapod larvae has been completed for both inshore and offshore samples collected through summer 1978.

Analysis of fall 1978 ichthyoplankton data has begun and identification of decapod larvae collected in offshore samples in fall 1978 and spring 1979 is in process.

II. Objectives

To determine the seasonal composition, distribution and apparent abundance of marine organisms in waters contiguous to Kodiak Island, with emphasis on ichthyoplankton, meroplankton, and holoplankton.

III. Field or Laboratory Activities

A. Field activities. There were no field activities this quarter.

B. Laboratory activities.

1. Scientific group (all analyses except for those of crab and shrimp are conducted at the Seattle Laboratory):

| Name | Affiliation | Role |
|---|---|---|
| Jean Dunn | NWAFC | Co-principal investigator |
| Arthur Kendall | NWAFC | Co-principal investigator |
| Robert Wolotira | NWAFC* | Co-principal investigator |
| John Bowerman | NWAFC* | Fisheries Biologist |
| Ann Matarese | NWAFC | Fisheries Biologist |
| Beverly Vinter | NWAFC | Ichthyoplankton Specialist |
| Don Fisk | NWAFC | Physical Science Technician |
| Bernie Goiney | NWAFC | Biological Technician |
| Gale Hudkins | NWAFC* | Biological Technician |
| Eric Monk | NWAFC* | Biological Technician |

*Kodiak Laboratory

2. Methods:

Fish eggs and larvae were identified by microscopic examination using standard procedures of larval fish taxonomy. Fish eggs and

larvae were measured by means of a calibrated ocular micrometer.

Aliquots of zooplankton from the 0.333 mm mesh Bongo net were identified by the sorting contractor to phylum, class, or order, as appropriate, except for euphausiids which were identified to species. Euphausiids from the Tucker trawl were also identified by the sorting contractor.

Crab and shrimp larvae were identified to species and life history stage.

3. Sample collection localities: N/A

4. Data analyzed:

a. Miller Freeman cruise (MF-78-2) summer 1978:

The tape of the ichthyo- and zooplankton data and ancillary information from the summer 1978 cruise was forwarded to OCSEAP this quarter.

b. Wecoma cruise (WE-78-1) fall 1978:

Data are in a final audit stage for submission to OCSEAP on tape.

c. Miller Freeman cruise (MF-79-1) winter 1979:

Ichthyo- and zooplankton from this cruise have been identified and digitizing of data has begun. Identification of crab and shrimp larvae has begun.

d. Identification of crab and shrimp larvae from aliquots of samples collected from inshore sampling (Commando-RU-553) is in process (Table 1).

IV. Results

Catches of dominant fish larvae and eggs based on Bongo tows from the fall 1978 cruise (WE-78-1) are shown in Table 2. Capelin (Mallotus

villosus) larvae dominated catches in bongo nets, followed by Irish Lords (Hemilepidotus spp.) and Atka mackerel (Pleurogrammos monopterygius). Catches in the neuston nets were dominated by Irish Lords, Atka mackerel and greenling (Hexagrammos stelleri). Eggs of the bathylagid smelt, Leuroglossus schmidti, predominated in bongo and Tucker trawl catches.

V. Preliminary Interpretation of Results. None

VI. Auxiliary Material. None

VII. Problems Encountered or Recommended Changes. None

**Table 1.--** PRELIMINARY RESULTS OF SORTING FOR SHRIMP AND CRAB LARVAE
July-September, 1979

| AREA | GEAR | NO. SAMPLES SORTED | NO. NATANTIA IDENTIFIED IN SAMPLES | NO. REPTANTIA IDENTIFIED IN SAMPLES |
|---|---|---|---|---|
| OFFSHORE (Samples collected 6/78-11/78) | | | | |
| | Tucker | 33 | 97 | 123 |
| | Bongo | 97 | 215 | 1851 |
| INSHORE (Samples collected 5/78-3/79) | | | | |
| IZHUT | Tucker | 76 | 2276 | 3184 |
| | Bongo | 45 | 315 | 1121 |
| | Sled | 3 | 87 | 6 |
| CHINIAK | Tucker | -- | -- | -- |
| | Bongo | 17 | 77 | 121 |
| | Sled | 3 | 272 | 2 |
| KILIUDA | Tucker | 12 | 358 | 254 |
| | Bongo | 20 | 13 | 233 |
| | Sled | 4 | 55 | 39 |
| KIAUGNAK | Tucker | -- | -- | -- |
| | Bongo | 4 | 8 | 17 |
| | Sled | -- | -- | -- |
| TOTALS | | 314 | 3773 | 6951 |

Table 2.--Catches of most abundant fish eggs and larvae (based on bongo tows) from fall, 1978 cruise near Kodiak Island, Alaska.

| | Bongo | | Neuston | | Tucker | |
|---|---|---|---|---|---|---|
| | Number of positive hauls | Catch | Number of positive hauls | Catch | Number of positive hauls | Catch |
| Larvae | | | | | | |
| *Mallotus villosus* | 50 | 857 | 24 | 108 | 31 | 232 |
| *Hemilepidotus spp.* | 53 | 404 | 52 | 2192 | 36 | 641 |
| *Pleurogrammos monopterygius* | 7 | 145 | 37 | 1543 | 2 | 5 |
| *Hexagrammos stelleri* | 8 | 33 | 72 | 1428 | 3 | 5 |
| Eggs | | | | | | |
| *Leuroglossus schmidti* | 23 | 289 | 2 | 2 | 20 | 786 |
| Macrouridae | 8 | 18 | 0 | 0 | 8 | 36 |
| Unidentified | 5 | 5 | 0 | 0 | 1 | 3 |
| *Theragra chalcogramma* | 3 | 3 | 1 | 1 | 0 | 0 |

Table 3.--Major milestone/activity chart for
RU 551 - July-September 1979

O - Planned Completion Date

X - Actual Completion Date

RU # 551 PI: Dunn, Kendall, Wolotira

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

| MAJOR MILESTONES | 1978 O | N | D | 1979 J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Submit tape to OCSEAP (DI-78-4) | | | | | | | | X | | | | | | | |
| Ichthyoplankton data analysis (MF-78-2) | | | | | | | O | — | — | X | | | | | |
| Zooplankton data analysis (MF-78-2) | | | | | | | O | — | — | — | X | | | | |
| Crab and shrimp data analysis (MF-78-2) | | | | | | O | — | — | — | X | | | | | |
| Crab and shrimp data analysis (RU553-summer 78) | | | | | O | — | — | — | X | | | | | | |
| Miller Freeman cruise (MF-79-1) | | | | | | X | | | | | | | | | |
| Ichthyoplankton identified (WE-78-1) | | | | | | O | — | — | — | X | | | | | |
| Annual report | | | | | | | X | | | | | | | | |
| Ichthyoplankton data analysis (WE-78-1) | | | | | | | | | O | — | X | | | | |
| Submit tape to OCSEAP (MF-78-2) | | | | | | | | | X | | | | | | |
| Zooplankton data analysis (WE-78-1) | | | | | | | O | — | — | — | — | X | | | |
| Crab and shrimp data analysis (WE-1-78) | | | | | | | O | — | — | — | — | X | | | |
| Crab and shrimp data analysis (RU553-fall 1978) | | | | | | O | — | — | — | — | X | | | | |
| Submit tape to OCSEAP (WE-78-1) | | | | | | | | | | | | X | | | |

Table 3.--cont.

O - Planned Completion Date

X - Actual Completion Date

RU # 551 PI: Dunn, Kendall, Wolotira

Major Milestones: Reporting, data management and other significant contractual requirements; peripds of field work; workshops; etc.

| MAJOR MILESTONES | 1978 O | N | D | 1979 J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ichthyoplankton identification (MF-79-1) | | | | | | | | | | | ⊢ | X | | | |
| Ichthyoplankton data analysis (MF-79-1) | | | | | | | | | | | | | ⊢ | O | |
| Zooplankton data analysis (MF-79-1) | | | | | | | | | | | ⊢ | | | O | |
| Crab and shrimp data analysis (MF-79-1) | | | | | | | | | | | ⊢ | | | | O |
| Submit quarterly report | | | | | | | | | | | | X | | | |
| Crab and shrimp data analysis (RU553-winter 79) | | | | | | | | | | | | | ⊢ | | O |
| Submit tape to OCSEAP (MF-79-1) | | | | | | | | | | | | | | | O |
| Submit final report | | | | | | | | | | | | | | | O |
| | | | | | | | | | | | | | | | |
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# MICROBIOLOGY

# MICROBIOLOGY

Contents

Quarterly Report

Task Numbers A-27; B-9
Contract #03-5-022-68
Report Period 1 April, to
30 June, 1979

# Study of Microbial Activity and Crude Oil-Microbial Interactions In the Waters and Sediments of Cook Inlet and the Beaufort Sea

Research Unit 190

SUBMITTED BY:

Robert P. Griffiths
Co-Principal Investigator
Assistant Professor-Senior Research
Department of Microbiology
Oregon State University
Corvallis, OR 97331

Richard Y. Morita
Co-Principal Investigator
Professor of Microbiology and
Oceanography
Department of Microbiology
Corvallis, OR 97331

I. Task Objectives

Our main objectives are to study the natural levels of relative microbial heterotrophic activity, and respiration percentages, and nitrogen fixation rates in natural microbial populations found in the Beaufort Sea and Cook Inlet under contrasting seasonal conditions. Our other objectives are to evaluate the effects of crude oil on microbial activity and nitrogen fixation rates. These studies are interpreted in light of other data that has also been collected on the same samples. These data include inorganic nutrient data, sample temperature, salinity and location; as well as direct counts, plate counts and crude oil degradation potential data collected by Dr. Atlas, (RU #30).

II. Field and Laboratory Activities

A. Field studies

During this period, we participated in a cruise in the Cook Inlet and we conducted field studies at the NOAA laboratory at Kasitsna Bay, AK. The Cook Inlet cruise, which was conducted from May 7 to May 21, 1979, was a coordinated effort between microbiologist and hydrocarbon chemists. One of the main objectives of this cruise was to determine what changes had taken place in the Upper Cook Inlet in response to crude oil production in that area. The Kasitsna Bay work was designed to determine the long-term effects of crude oil and the dispersant Corexit 9725 on microbial function in marine sediments. This is the second field study period that we have had at that facility. The first was conducted in Feb., 1979. Our most recent field period started on April 9 and was concluded on May 8, 1979.

During the time that we were not in the field, we were either preparing for our summer field studies at Kasitsna Bay and Norton Sound or we were analyzing the data from the spring field work.

B. Scientific party

All of the personnel involved in this project are in the Department of Microbiology, Oregon State University.

C. Personnel

Dr. Robert Griffiths, Co-principal Investigator
Dr. Richard Y. Morita, Co-Principal Investigator
Mr. Thomas McNamara, Technician (Research Assistant, Unclassified)
Mr. Bruce Caldwell, " " " "
Mr. Peter Yorgey, Graduate Student
Ms. Gael Kurath, " "

D. Methods

The methods used in our field work are essentially the same as those reported in our last annual report.

III. Results

The data that were generated during the spring field trips are still in the process of being analyzed.

IV. Preliminary interpretation of results

From the data that have been collected in Elson Lagoon (Barrow, AK) and at the Kasitsna Bay laboratory, it is becoming evident that crude oil has a profound effect on marine microbial communities. Our preliminary analysis indicates that the following changes occur.

A. Acute effects

1. The most recent data substantiates observations that we have made in the past concerning the effects of crude oil on the uptake of glucose by microorganisms. The uptake rates are significantly reduced in both water and sediment samples. This effect is particularly pronounced in actively metabolizing populations. This indicates that microbial populations may be more susceptible to crude oil perturbation in the late spring and summer months than in the winter.

2. In many samples, the percent respiration (mineralization) increases in the presence of crude oil. This probably reflects an environmental stress under these conditions. This shift suggests that biosynthetic mechanisms may be impaired in microbial populations that are exposed to crude oil.

3. The dispersant Corexit 9725 greatly reduces glucose uptake in microbial populations. In many cases, the uptake rate is only 10% of that found in untreated samples. These data suggest that Corexit by itself (at a concentration of 50 ppm) may act as a significant environmental stress in microbial populations. In samples that were exposed to crude oil and Corexit, the effect was even more pronounced. If these trends continue to be observed as our study progresses then the conditions under which this dispersant is applied should be reviewed.

B. Long-term effects

1. The data that have been accumulated up to this time suggest that crude oil interferes with the normal flow of organic carbon through the sediments and into the rest of the food chain. It is currently thought that as much as 80% of the organic carbon available as a food source at all trophic levels in the inshore environment originates as organic detritus. If this carbon cannot be cycled up through the food chain, then the overall productivity of the system is going to be reduced. In the Cook Inlet, this would mean reduced yields of commercially important species such as crab and shrimp. The crude oil appears to kill the organisms that are directly consuming the detritus for food.

2. For the last two years, we have been studying the acute effects of crude oil on nitrogen fixation rates in marine sediments. From these studies we have concluded that there are no significant short-term effects of crude oil on nitrogen fixation. The situation, however, is much different when the exposure time is lengthened from hours to weeks. After approximately six weeks of exposure to crude oil, nitrogen fixation rates in marine sediments decreases dramatically so that the rate is 10% or less of the non-treated sediments. This observation has several important ramifications. If nitrogen fixation rates are reduced in the presence of crude oil then the availability of fixed nitrogen as an inorganic nutrient should also be reduced. The end result would be a reduction in the rate at which organic carbon is incorporated into the food chain. It would also result in reduced biodegradation rates of the crude oil itself. The availability of fixed nitrogen would be reduced even further, if the rate at which fixed nitrogen is converted to atmospheric nitrogen (denitrification) is increased in exposed sediments (a hypothesis proposed by Dr. Atlas [(RU #30]).

3. The presence of crude oil effects the pH and Eh of the sediments. This effect is most noticeable at the surface. In the untreated samples, both the pH and the Eh decrease markedly a few cm from the surface; this was not the case in the oiled samples where these values were essentially the same from the surface to the bottom of the containers. The major contributing factor for this is probably the accumulation of detritus material on the surface of the oiled sediment. This material forms a distinct coat on the surface which probably reduces gas exchange. The reduction of both pH and Eh should be interpreted as a significant change in the environment of the sediment surface which could interfere with normal recruitment.

4. The level of total adenylates (ATP+ADP+AMP) is lower in sediments exposed to crude oil. In this application, the total adenylates can be roughly equated with total biomass in the sediment. Since bacterial numbers do not appear to be significantly reduced by crude oil, the observed adenylate reduction is probably related to the number of higher (eucaryotic) organisms present. This observation fits in very nicely with the observation that detritus builds up in oiled sediments. Some of the organisms that normally feed on this detritus are missing.

5. There is a good correlation between the measurements made in the trays and the aquaria in the crude oil effects study at Kasitsna Bay. This means that the aquaria and the associated seawater flow system is a valid method of measuring crude oil effects under laboratory conditions.

V. Problems encountered

Due to delays in funding and delays in manufacturing, we have not received the electron capture detector for our gas chromatograph until this May. This detector is required for the sensitive measurement of nitrous oxide which in turn is a means of measuring the rate at which fixed nitrogen is converted to atmospheric nitrogen. Because of the complexity of installation, we will not have the manpower to have this operational until this fall.

Quarterly Report

Task Numbers A-27; B-9
Contract #03-5-022-68
Report Period 1 July, to
30 September

# Study of Microbial Activity and Crude Oil-Microbial Interactions In the Waters and Sediments of Cook Inlet and the Beaufort Sea

Research Unit 190

SUBMITTED BY

Robert P. Griffiths
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Department of Microbiology
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Richard Y. Morita
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Professor of Microbiology and
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I. Task Objectives

Our main objectives are to study the natural levels of relative microbial heterotrophic activity, respiration percentages, and nitrogen fixation rates in natural microbial populations found in the Beaufort Sea and Cook Inlet under contrasting seasonal conditions. Our other objectives are to evaluate the effects of crude oil on microbial activity and nitrogen fixation rates. These studies are interpreted in light of other data that have also been collected on the same samples. These data include inorganic nutrients, temperature, salinity and location; as well as direct counts, plate count and crude oil degradation potential data collected by Dr. Atlas. (RU #30)

II. Field and Laboratory Activities

A. Field studies

During this period, we participated in a cruise in the Norton Sound and we conducted field studies at the NOAA laboratory at Kasistna Bay, AK. The Norton Sound cruise, conducted from July 2 to July 23, 1979, was a coordinated effort between microbiologist and hydrocarbon chemists. One of the main objectives of this cruise was to determine what changes had taken place in the marine microorganisms near the natural hydrocarbon seeps in that area. The Kasistna Bay work was designed to determine the long-term effects of crude oil and the dispersant Corexit 9527 on microbial function in marine sediments. This was the third field study period that we had at that facility. Our most recent field period started on July 2 and was concluded on August 23, 1979.

B. Scientific party

All of the personnel involved in this project are in the Department of Microbiology, Oregon State University.

C. Personnel

Dr. Robert Griffiths, Co-principal Investigator
Dr. Richard Y. Morita, Co-Principal Investigator
Mr. Thomas McNamara, Technician (Research Assistant, Unclassified)
Mr. Bruce Caldwell, " " " "
Mr. Peter Yorgey, Graduate Student
Ms. Gael Kurath, " "

D. Methods

The methods used in our field work are essentially the same as those reported in our last annual report.

III. Results

A. Beaufort Sea (Elson Lagoon)

Three sediment samples were taken from Elson Lagoon. One was taken from a location near the oiled sediment tray site (BB803), one was taken from an oiled sediment that was exposed to crude oil for 12 months (BB801) and another that had been exposed to crude oil for 18 months (BB802). In both of the oiled samples, the relative microbial activity, as measured using both glucose and glutamic acid, was significantly lower than the control, and the respiration percentages were greater. In both of the oiled samples, there was a significant reduction in the arylsulfatase and amylase activities. In the sample that had been exposed to crude oil the longest (BB802) there was a significant increase in cellulase activity. Phosphatase activity was essentially the same in all samples.

B. Norton Sound

During the joint cruise with the hydrocarbon chemists in July, we collected and analyzed 62 water and 35 sediment samples. The analysis of relative microbial activity in the waters of this region indicates that there are two major water masses in this area. One of these water masses has characteristics similar to open ocean water that we have studied in the past. This water mass was found in a region which was within a 75 mile radius from eastern tip of St. Lawrence Island. These waters showed high salinity, low relative levels of microbial activity and high respiration percentages in the microbial populations. The waters analyzed at the other locations showed the reverse pattern. The lower salinities and higher relative levels of microbial activity show the impact of the freshwater input from the Yukon River (a major feature of the Norton Sound). A statistical analysis of the relationship between salinity and relative microbial activity indicates that there is an inverse relationship that is significant at the $p < 0.0005$ level. The highest levels of microbial activity were observed in fresh water from the Yukon River.

Within the water mass showing high microbial activity, there was another distinct water mass (near Nome, AK) which was near the seep area. This water mass was found at stations, 10, 10A, 15-19, 21-28, 39, and 40. The effect of crude oil on the uptake of glucose by the microbial populations in this water mass was less than that observed in the other areas studied. The statistical significance of that difference was $p < 0.0003$. The average percent reduction within that region was 49% vs. 64% for the other stations.

An analysis of surface vs bottom waters in the Norton Sound indicated that there was a difference between these water masses as well. The bottom waters were colder and more saline than the surface waters and the relative microbial activity was significantly higher ($p < 0.02$) than those observed on the surface. The average percent reduction in microbial

activity in the presence of crude oil was lower in the bottom waters than in the surface waters but the significance of this difference was only at the $p < 0.16$ level.

An analysis of the sediment samples revealed that the levels of nitrogen fixation were relatively low; as low or lower than the rates observed in the Beaufort Sea. We also measured the effects of crude oil on relative microbial activity in the same samples. There were a number of sediment samples collected that showed little or no depression of glucose uptake rates in the presence of crude oil but these samples were not necessarily associated with the known hydrocarbon seep site. A comparison of these data with those collected by the hydrocarbon chemists should elucidate any correlations that might exist between depresed crude oil effects on microbial function and the presence of hydrocarbons.

In the presence of crude oil, the uptake of glucose was depressed on an average of 57% in water samples and 37% in sediment samples. When the same populations were exposed to the dispersant Corexit 9527 at a concentration of 50 ppm, the average percent depression in uptake rates was 85% in water samples and 54% in sediment samples. All of these differences were significant at the $p < 0.001$ level.

C. Kasistna Bay

1. Acute effects of crude oil and Corexit 9527

When both water and sediment samples were exposed to crude oil, Corexit 9527 or crude oil with Corexit, the rate of glucose uptake was significantly reduced. The greatest impact was found in water samples that were exposed to crude oil with Corexit (the mean percent reduction was 91). In other words, on the average, the rate at which glucose was taken up and utilized by these microbial populations was reduced to only 9% of normal when they were exposed to crude oil and Corexit at 50 ppm. The least effect was observed in sediment samples exposed to crude oil which had been previously exposed to crude oil for 6 months. In this case the mean reduction was only 12% of the controls.

Short-term exposure (8 hour) to the dispersant Corexit 9527 also profoundly effected the uptake of glucose by marine microbial populations. In the 25 water samples analyzed in July-August, the mean rate of glucose uptake was reduced by 82% in presence of 50 ppm Corexit. In the 20 field sediment samples analyzed, the mean rate of glucose uptake was reduced by 60% in the presence of 50 ppm Corexit and 74% in the presence of Corexit and crude oil. A study of the effects of Corexit on the kinetics of glucose uptake indicated that the percent respiration, $V_{max}$, $K_t+S_n$, and $T_t$ values were all altered under these conditions. Nine water samples were analyzed to determine the concentration at which Corexit reduces the uptake or glucose by 50%. The mean concentration at which this occurred was 12 ppm. In most cases, there was little additional effect when the concentration was increased above 20 ppm.

2. Long term effects of crude oil on microbial function in marine sediments

During this period, we conducted another set of measurements on sediments which were treated with crude oil and/or Corexit that were contained in both aquaria and trays. As was the case in our April, 1979 observations, the aquaria seem to very closely approximate the conditions in the trays. Most of the variables measured showed smaller differences between the mean values observed in the trays vs the aquaria than in the differences observed for the same variable from tray to tray or even within the same aquarium.

The total concentration of adenylates in the oiled sediments were roughly 1/2 that in the control samples. The nitrogen fixation rates were, on the average, reduced to about 20% of normal in sediments that had been exposed to crude oil for 6 months. Changes were also seen in the levels of several enzyme activities but only one was significant at the $p < 0.05$ level. Amylase activity was significantly reduced in the oiled-tray sediments

In sediment samples that had been treated for 6 months with crude oil or crude oil and Corexit, the rate of glucose or glutamic acid uptake was decreased. When compared with the controls, the mean reduction of both glucose and glutamic acid uptake rates in the presence of crude oil was 71% and about 85% in the presence of crude oil with Corexit. The changes observed in the aquaria were somewhat less pronounced. The long term effect of crude oil on the kinetics of glutamic acid uptake was also studied in both the trays and aquaria. There was a significant change in all variables measured when comparing oiled samples with controls. The maximum potential velocity of glutamic acid uptake ($V_{max}$) and the $K_t+S_n$ values decreased while the turnover time and the percent respiration values increased. The percent respiration values for both glucose and glutamic acid increased in the presence of crude oil and crude oil with Corexit.

Similar to our April observations, there was a significant difference between the pH and Eh on the surface of oiled vs nonoiled sediments. Values for both of these variables decreased in the oiled sediments. In addition to these changes, we observed a greater rate of both $CO_2$ and methane production from the oiled sediments.

IV. Preliminary interpretation of results

A. General comments

We have confirmed our earlier observations concerning both the long-term and short-term effects of crude oil and the dispersant Corexit 9527 on microbial function (these were described in our last quarterly report). We have strong evidence that suggests that either crude oil or

the dispersant Corexit 9527 can act as a short-term environmental stress on microbial populations in both marine water and sediments. When water or sediment is exposed to crude oil with Corexit, the effect on the microbial population is greater than when it is exposed to either crude oil or Corexit alone. We also have strong evidence that suggests that the long-term presence of crude oil in marine seidments significantly alters microbial function, physical and chemical properties of the sediment and interfers with the transfer of organic carbon from the sediments into the rest of the foodchain. Similar changes appear to take place in both the Beaufort Sea (Elson Lagoon) and Cook Inlet (Kasistna Bay) sediments although they may take longer to become evident in Beaufort Sea sediments.

The study that was conducted in the Norton Sound in July, 1979 produced data which will be helpful in characterizing the major water masses present and may be useful in indicating areas of chronic hydrocarbon input.

B. Acute effects of crude oil and Corexit on marine microbial function

1. Crude oil

The depressive acute effect of crude oil on the uptake of both glucose and glutamic acid by benthic and pelagic marine microbial populations has now been well documented. Although the acute effect on this function is initially less in sediment samples than in water samples, the long-term effects seem to be more pronounced in sediments. Our data indicates that pelagic microorganisms may recover their heterotrophic activity levels within a matter of days after exposure; however, the composition of the population has most probably changed.

2. Corexit 9527

The initial effect of Corexit on both pelagic and benthic microbial function can be quite profound at relatively low levels. We have observed reductions in glucose uptake of 50% at a Corexit concentration of 7 ppm (the mean value for the 9 samples tested was 12 ppm). The observed reduction in uptake rates most probably relfects an interaction between the Corexit and the cell membrane (thus altered substrate uptake). Although this is probably the principal locus of action, it is not the only microbial function that is altered. Both significant positive and negative respiration percentage changes have also been observed which indicate that both respiratory and biosynthetic mechanisms may also be altered. As was the case with crude oil, the reduction in glucose uptake rates were greater in pelagic than in benthic microbial populations. But unlike crude oil, we have not seen significant long-term changes in benthic microbial populations that have been exposed to Corexit alone. However, we have observed that Corexit may act to intensify the long-term effects of crude oil on benthic microbial communities. We are

currently conducting studies which are designed to determine what types of population shifts occur in the presence of Corexit. It is our plan to coordinate these studies with measurements of species diversity to be conducted by Dr. Atlas and his associates (RU #30).

C. Long-term effects of crude oil and Corexit on benthic microorganisms

Visual inspection of sediments that have been exposed to crude oil for 6 months indicate that there are obvious differences between these sediments and the non-oiled controls. The oiled sediments show very few signs of living infauna (i.e., no syphon holes and no evidence of borrowing activity) and they appear more reduced from the bottom to the surface. When we terminated two of the aquaria experiments, we sifted through all of the sediment to preserve any infauna specimens present for future analysis. In approximately 30 liters of sediment, we found two small worms which were found just under the surface in a layer of detritus that had accumulated since the beginning of the experiment 6 months earlier. In the control aquaria, there were numerous syphon holes, there was extensive borrowing activity, and very little accumulation of detrital material on the surface. These differences were probably reflected in the differences we observed in the levels of total adenylates between oiled and non-oiled sediments. These data suggest that the normal utilization of organic detritus is not taking place in sediments that have been exposed to crude oil. This further suggests that the oiled sediments are acting as a nutrient carbon sink instead of a food source for utilization by higher trophic levels.

In addition to the above mentioned changes, there have also been differences observed between non-oiled and oiled sediments in essentially every variable that we have measured. At this time it is difficult to determine if these are caused by primary, secondary or tertiary effects. Although the exact mechanisms involved are of academic interest, it is not necessary at this point to define them. What is important at this stage is to determine what functions are altered and how these changes effect the total system. Most of the changes reported here took place within the first 2 months exposure and increased slightly or remained about the same in sediments exposed for 6 months. In the oiled sediments, the surface pH and Eh were lower and the release rates for $CO_2$ and methane were increased when compared to the controls. It is inferred from these observations that the surface $O_2$ concentration was also lower. These conditions may, in part, be due to the lack of borrowing activity and/or they may be due to the decomposition of killed organisms. We also observed that there was a coating over the surface of the oiled sediment. This coating appeared to consist primarily of accumulated detrital material (mostly diatoms) but we also have evidence which suggest that this coating may also consist of biogenic material associated with the decomposition of the crude oil itself. In July, we observed what appeared to be different layers of organic detritus with some layers appearing more reduced than others. Taken as a whole, these observations suggest that the oiled sediments have surface characteristics

much different than non-oiled sediments and this would most probably alter both the qualitative and quantitative characteristics of the recruitment populations.

In addition to these more obvious changes, we also have taken measurements that suggest that there were changes in the benthic microbial community as well. Perhaps the most important of these changes, as far as the benthic community is concerned, is the greatly reduced nitrogen fixation rates observed in the presence of crude oil. As we mentioned in our last quarterly report, the reduction in the influx of fixed nitrogen into the system may act to reduce crude oil biodegradation rates and general microbial heterotrophic activity. As one would anticipate from previous investigations, the concentration of hydrocarbon degrading bacteria appeared to increase in the presence of crude oil but the overall rate of heterotrophic activity as measured by both glucose and glutamic acid uptake show significant decreases under the same conditions. The increases in the respiration percentages and the change in all of the kinetic parameters that we measured suggest that changes have occurred in the microbial community in the presence of crude oil. At this time, except in the case of hydrocarbon utilizing bacteria, we cannot tell if there has been a change in the physiology of the original population or if there has been a qualitative shift in the population. It is quite possible that both types of changes have occurred. Dr. Atlas has observed that the diversity of the species present decreases in the presence of an environmental stress. It appears that crude oil is acting as an important environmental stress which is altering microbial function in at least two major ways; the reduction in nitrogen fixation rates and the reduction of heterotrophic activity.

V. Problems encountered

None of significance.

Quarterly Report

Task Numbers A-27; B-9
Contract #03-5-022-68
Report Period 1 October to
31 December, 1979

# Study of Microbial Activity and Crude Oil-Microbial Interactions In the Waters and Sediments of Cook Inlet and the Beaufort Sea

Research Unit 190

SUBMITTED BY

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I. Task Objectives

Our main objectives are to study the long term effects of crude oil on microbial function in Subarctic marine sediments. The variables to be studied are; pH, Eh, glucose and glutamic acid uptake rates, percent respiration, adenylate concentrations, energy charge determinations from the adenylate information, $CO_2$ and methane evolution rates, enzyme activities, cell concentrations, inorganic nutrient concentrations, and rates of nitrogen fixation and denitrification. In addition, we plan to compare these findings with similar observations made in Beaufort Sea sediments and sediments collected in various locations within Cook Inlet. We also plan to study carbon and nitrogen cycling in both the water column and the sediments near the NOAA Kasitsna Bay laboratory.

II. Field and Laboratory Activities

A. Field studies

During this period, we conducted a series of observations at the Kasitsna Bay facility. At that time we analyzed 12 trays and 2 aquaria, 6 sediment samples from Glacier Bay and 14 sediments and 17 water samples from our standard stations near the laboratory. Six of the twelve trays studied were the new crude oil overlay sediment trays which have not previously been analyzed.

B. Laboratory studies

During this period, we initiated our analysis of denitrification rates in marine sediments. The new electron capture detector was installed in our gas chromatograph and the techniques required for this work were tested.

C. Scientific party

All of the personnel involved in this project are in the Department of Microbiology, Oregon State University.

D. Personnel

Dr. Robert Griffiths, Co-principal Investigator
Dr. Richard Y. Morita, Co-Principal Investigator
Mr. Thomas McNamara, Technician (Research Assistant, Unclassified)
Mr. Bruce Caldwell, " " " "

E. Methods

The methods used in our field work are essentially the same as those reported in our last annual report.

III. Results

A. Summary of observations made in the crude oil effects studies to date.

Essentially every facet of microbial function that we have studied in detail has shown a change due to the presence of crude oil.

These changes suggest the crude oil greatly reduced biological productivity in marine seidments. The changes observed thus far include:

(1) Decreased microbial heterotrophic activity as measured by both glucose and glutamic acid uptake.

(2) Increased respiration percentages which indicate an environmental stress condition and/or shift in metabolism.

(3) Decreased levels of total adenylates indicating decreased total biomass.

(4) Reduced pH and Eh levels on the surface of treated sediments.

(5) Greatly reduced rates of nitrogen fixation and denitrification.

(6) Increased $CO_2$ and methane production rates.

(7) Gross visible changes in the benthic infauna. In the control trays and aquaria, there was abundant burrowing activity and indications of surface detrital utilization by the benthic infauna. This was not true of the treated samples. As a result, there was an accumulation of detrital material on the treated sediments and very little present on the control sediments.

(8) Significantly altered rates of microbially-mediated nutrient transformations involving carbon, nitrogen, and phosphorous have been observed through altered enzyme activities in sediment samples.

(9) Greatly reduced rates of organic nutrient uptake in water and sediment samples exposed to the dispersant Corexit 9527. Additive adverse effects have also been observed in sediments exposed to both crude oil and Corexit.

(10) We have also recently made some observations that suggest that the rate of crude oil degradation in marine seidments is related to the C:N ratio of the detritus present in that sediment. The presence of organic nitrogen may well hold the key to crude oil degradation because fixed nitrogen is known to be required for that process and fresh crude oil essentially eliminates nitrogen fixation.

All of the above observations have been made in sediment samples collected near the Kasitsna Bay laboratory which have been exposed to crude oil for up to 6 months. Similar observations have also been made in oiled sediments collected in the Beaufort Sea (Elson Lagoon).

B. Observations made during the October field study period in Kasitsna Bay.

At this point, not all of the data has been analyzed, however, the following statements can be made about the sediments that were exposed to crude oil for 8 months:

1. Both nitrogen fixation and denitrification rates are depressed.

2. Glucose and glutamic acid uptake rates are lower in the oiled sediments but the difference from the non-oiled controls is not statistically significant. We observed an increase percent respiration in the oiled sediments which was statistically significant. At this time we do not know if the reduced effect of oil on substrate uptake is a function of reduced crude oil effect or if this is a seasonal phenomenon. We will not be able to determine the cause until more extensive studies are conducted.

3. $CO_2$ evolution rates were higher in the oiled sediments.

4. There was still no visible signs of recruitment by borrowing infauna species.

5. There was no significant difference between the surface pH values in the oiled sediments but there was a significant reduction in the surface Eh values in the surface sediments in the oiled trays.

6. A time series experiment was conducted on oiled sediments to determine how long it would take to see measurable changes in $CO_2$ evolution rates and nitrogen fixation rates. Non-oiled sediment served as controls. Within two days, the nitrogen fixation rates were reduced to 50% of the control. In the initial phase of this experiment, the rate of $CO_2$ evoluation was reduced in the oiled sediments; perhaps in response to the initial stress caused by the crude oil perturbation. After 10 1/2 days incubation, however, the rate of $CO_2$ evolution was about 200% higher in the oiled sediments than in the non-oiled controls. This indicates to us that the crude oil was probably being degraded at this point.

7. During the same field study, samples from the Glacier Bay spill were analyzed. These included three control sediments that were not impacted by fuel oil and three that were. If these sediments are compared as two sets of three, there were no significant differences found between these two sets of samples; however, this was not the case when the sediments were compared by sediment type. When the control and oiled sediments were compared in this way we found many of the same trends that we have observed in the oiled tray experiments. These observations suggest to us that in future studies involving an actual oil spill that great care must be taken to select control sediments which closely approximate the physical characteristics of the oiled sediments. These observations also suggest that enough samples have to be taken so that a statistically significant representation is obtained.

IV. Preliminary interpretation of results

1. The crude oil treated sediments are probably acting as a nutrient sink. The detrital material that settles out of the water column is normally incorporated as biomass in benthic organisms. These organisms

(both micro and macrofauna) are consumed by other organisms on higher trophic levels and thus the organic material in detritus is incorporated into the rest of the food chain. The presence of crude oil evidently interfers with this process. We do not have enough information at this time to predict what this would mean in terms of the total productivity of an impacted area. If this block was 100% effective, it could mean a reduction in overall biological productivity of 40-80% in nearshore environments.

2. A factor that would further reduce secondary productivity and potential crude oil biodegradation rates is the reduction in nitrogen fixation rates we have observed in treated sediments. Our studies at Kasitsna Bay have shown that bacterial nitrogen fixation contributes a significant portion of fixed nitrogen available in the sediments. Seasonal trends indicate that nitrogen fixation rates are closely linked to pulses of organic carbon. It thus appears that when there is an input of detrital organic carbon, the energy for nitrogen fixation becomes available and more fixed nitrogen becomes available for the conversion of detritus into the total biomass of the benthic community.

We have conducted a series of experiments in which we have added different organic substrates to both oiled and non-oiled sediments. Our observations to date strongly suggest that fixed nitrogen is limiting for crude oil degradation and that by measuring the carbon: nitrogen ratio and/or the total nitrogen content of the sediments, crude oil biodegradation rates may be estimated. A great deal more work will have to be done before we will be able to predict actual degradation rates from chemical analyses of the sediment.

3. The chemical environment at the sediment-seawater interface is significantly different in treated sediments. The redox potential and pH are lower and the $CO_2$ and methane level is higher in these sediments than in the controls. This strongly suggests that normal recruitment patterns would be altered in sediments exposed to crude oil. These potentially adverse conditions would be in addition to any direct toxic effect that the crude oil would have by itself. For this reason, estimations of recruitment rates gained from observations of other types of perturbations may not apply in the case of crude oil. The reduction in the normal aerobic sediment layer near the surface of the sediments also reduces the normal oxidative function of both the sulfur and nitrogen cycles. This results in incomplete mineralization of detritus and loss of energy from the sediments.

4. Our studies on the acute effects of crude oil and the dispersant Corexit 9527 have shown that although these contaminants do not inhibit the growth of pelagic heterotrophic microorganisms after extended exposure (several days), there is strong evidence that suggests that these compounds are acting as a perturbing force. The uptake and respiration of organic compounds are initially inhibited by the presence of Corexit and/or crude oil. These and other observations suggest that either of these

compounds may reduce the diversity of the microbial population selecting for only those organisms that can transport nutrients into the cell in the presence of these contaminants.

5. As a result of our findings, we can make the following recommendations concerning the management of crude oil spills in Alaskan waters. Cleanup techniques which increase the likelihood of crude oil becoming incorporated into marine sediments should be avoided. The application of the dispersant Corexit 9527 to oil slicks should be avoided in restricted waters or in areas where there is little or no mixing in the water column.

6. Dennis Lees (personal communication) has recently estimated that in the soft sediments of the western side of Cook Inlet, the borrowing activity of two species of clams in itself increases the sediment surface area by 2 1/2 to 3 times. This is a very significant observation since most of the microbial metabolic activity takes place in the aerobic zone of marine sediments. This borrowing activity thus acts to greatly increase the zone of microbial activity in these marine sediments. This also acts to physically turn over the sediments to depths of up to 25 cm. If, as we have observed in our oiled sediment studies, the borrowing infauna is adversely affected by the presence of crude oil, then we would expect to find significant changes in microbial function. We have, of course, documented extensive alteration in microbial function in oiled sediments. At this point we do not know which of our observed changes can be directly related to this phenomenon.

V. Recommendations for future research, changes in research objectives and problems encountered

1. Recommendations for future research

a. The recent Bering Sea synthesis meetings conducted by NOAA have shown that very little information is available concerning the microbiology of the Bering Sea. Since several areas in the Bering Sea will be on the BLM lease schedule over the next few years, it is imperative that microbial studies be conducted in this region. Although a great deal can be learned about general microbial function during cruises on NOAA ships, virtually nothing can be learned about the long-term effects of crude oil on microbial metabolism. Through our work at Kasitsna Bay, we have proven the validity of measuring these effects in trays and aquaria located in the field. We have also shown that a well-equipped field laboratory is required to properly analyze these samples.

During our oiled sediment experiments in both the Beaufort Sea (Elson Lagoon) and the Cook Inlet (Kasitsna Bay), we have shown that there are both similarities and differences in the way in which benthic microorganisms react to crude oil perturbation. In both Beaufort and Cook Inlet exposed sediments, the relative microbial activity and the concentration of adenylates are depressed while the percent respiration (mineralization) and $CO_2$ evolution are increased. However, we have also seen basic differences between benthic microorganisms from these two regions. Different enzymes appear to react differently to crude oil

perturbation indicating different effects on the mineralization of specific organic compounds. Differences were also noted in the crude oil effects on nitrogen cycling.

These results suggest that even though there are many similarities in the way in which benthic microorganisms from various areas react to crude oil perturbation, there are also some basic differences. For this reason, we are recommending that two types of studies be conducted at the NOAA Kasitsna Bay laboratory. One approach would be to set out a minimum of 4 sets of sediment trays in representative areas of the Bering Sea. Each set would consist of 4-5 treated and the same number of non-treated sediments collected from the nearshore environment (the area most likely to be impacted by crude oil). After being left on location for approximately 6 months, subsamples would be collected for analysis at the Kasitsna Bay laboratory. Subsamples would be collected and analyzed on a periodic basis after that time. This would give us information about the basic differences and similarities observed between locations in the Bering Sea and between the Bering Sea and the Cook Inlet.

The second approach would be to continue our studies of long-term crude oil perturbation in Kachemak Bay sediments as outlined below. Since we have observed similarities between the effect of crude oil on both Beaufort and Cook Inlet sediments, we can assume that the same will hold for the Bering Sea. We feel that this is justification to continue our in-depth study of crude oil effects in the sediments near Kasitsna Bay. Such a study would not be feasible at this time in the Bering Sea.

b. The long-term exposure experiments should be continued past FY 80. This will give us a much better estimate of projected crude oil biodegradation rates. This would include monitoring existing trays and establishing new ones so that a better statistical analysis of the results can be made. In addition to providing information about potential biodegradation rates, the duration of perturbed microbial function can also more accurately be estimated. These extended observations would be particularly important in assessing long-term effects of low crude oil concentrations and long-term effects in crude oil overlays.

c. At the end of the current study, we will have accumulated a great deal of information about changes in sediments that have been exposed to a "worst case" situation; high concentrations of fresh crude oil thoroughly mixed into the sediment. This represents the theoretical maximum effect. The next step should be to study conditions that more closely approximate an actual spill situation including manipulations which might be used to control the oil; i.e., adding dispersants. This can be done using several approaches. The tray experiments could be expanded to include sediments that have been exposed to lower, more realistic concentrations of fresh and/or weathered crude oil and nontreated sediments which have been covered with a layer of treated sediments, i.e. a continuation of

our pilot study. This would provide information about the low concentration limits of crude oil effects and information aobut the effects of sediment surface contamination on microbial function in the rest of the sediment. These data would provide a better information base from which to predict crude oil effects under actual spill conditions.

During the Petroleum Effects Workshop held in San Diego in Nov., 1978, recommendations were made concerning crude oil effect studies in Cook Inlet. One of their recommendations (Group B) was to conduct a series of studies of sediments contained in tanks fitted with a seawater flow system, temperature control, and wave generator (pages 38 and 39). They also recommended a multidisciplinary research effort so that a wide range of variables could be monitored. What we are recommending is a scaled down version of their proposed experimental design. We agree with their statement that an experimental design be adapted which provides the greatest control. From our experience with both aquaria and trays, we feel that both systems are valid and should be continued. We recommended that the concept of the aquarium be expanded to larger containers and that a temperature control feature be incorporated into the system. These tanks or aquaria could be used to simulate actual spill conditions by adding oil directly onto the surface of the water rather than homogenating it into the sediments. By removing and replacing the water, tidal action could be simulated. Using this same approach, the effects of Corexit could be monitored when it is added to crude oil under simulated "normal" application instead of mixed directly into the sediments as we have done in our studies to date. By using the small tanks, chemical and biological changes in both the water column and the sediments could be tested. The conditions of the experiment could be controlled and monitored as best they can under "field" conditions

For the purposes of determining chemical and microbiological changes as well as changes in the smaller benthic infauna under "field" conditions, the trays would produce essentially all of the information that we would need. Consideration might be made of oiling small ($<100$ $m^2$) plots in the intertidal zone to obtain effects information about the larger infaunal and epifaunal groups.

d. One of the more important questions that will not be addressed in much detail by the end of this FY is the rate at which organic carbon has been transferred through the detrital food chain. This is a very difficult problem to study. We have made only modest gains in understanding the magnitude of this carbon input. At the beginning of this project we assumed that we would be measuring a large number of variables to screen for a few that might show change in crude oil perturbed systems. As the study was to progress, we planned to document these few changes and use the balance of our efforts in solving the organic carbon transfer problem. As things turned out, virtually every variable that we measured showed an effect. Documenting these changes has taken all of our research resources to date. A continuation of the project into FY 81 would give us additional time to devote to this important problem.

e. Now that the initial phase of our Kasitsna Bay work is well underway, it is becoming increasingly clear that the study must become a multi-disciplinary research effort including benthic ecologists, chemists and planktologists. In order to relate our observations to total ecosystem impact, concomitant studies by those of other disciplines must be included in this project.

2. Recommended changes in research objects

As our work progresses, we plan to discontinue certain types of observations when we feel that enough data has been collected to fully document a given event. A case in point is our studies on the acute effects of the dispersant Corexit 9527 on substrate uptake and mineralization. A mansucript summarizing this work is the final stages of preparation. Likewise, we intend to initiate other types of observations as soon as the techniques are perfected for field work. We feel that since there is so much that must be done to document crude oil effects on microbial processes, that once an altered function has been adequately documented, those results be summarized and new studies be initiated to replace them.

3. Problems encountered

None of significance.

SEVENTH QUARTERLY REPORT
(Covering the period of October 1 to December 31, 1978)

on

# ACTIVITY-DIRECTED FRACTIONATION OF PETROLEUM SAMPLES

Research Unit #500
Contract No. 03-7-022-35129

to

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

October 15, 1979

by

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## SUMMARY

Solvent partitioning of crude oil between a nonpolar solvent and a highly polar immiscible organic solvent was studied. Acetonitrile and heptane were selected as the solvent pair of choice for partitioning to separate polar components from paraffinic and intractable nonpolar components. Studies using a series of reference compounds indicated that acetonitrile behaved similarly to DMSO in partitioning with heptane. Methanol was shown to extract much more paraffinic material than acetonitrile.

*In vitro* Salmonella mutagenicity assays and mammalian-cell toxicity assays performed with some of the acetonitrile extracts indicated that the extracts were toxic but not mutagenic.

SEVENTH QUARTERLY REPORT
(Covering the period of October 1 to December 31, 1978)

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# ACTIVITY-DIRECTED FRACTIONATION OF PETROLEUM SAMPLES

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BATTELLE

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October 15, 1979

## INTRODUCTION

Studies on the biological effects of petroleum and associated chemical analyses have concentrated primarily on the hydrocarbon content that can be readily analyzed by gas chromatography. The aromatic hydrocarbons, mainly the benzenes, naphthalenes, and phenanthrenes, have been shown to have very significant toxic effects. The higher polycyclic aromatic hydrocarbons are known to be mutagenic and carcinogenic. However, little information is available concerning the biological effects of the nonhydrocarbon portions of crude oils, especially those of weathered crude oils that remain after an oil spill. The hydrocarbons that can be analyzed by gas chromatography frequently represent considerably less than half of a weathered crude oil.

This research program is an effort to determine the potential environmental hazard of the portions of weathered oil that have thus far been neglected. The program involves fractionation of both fresh and weathered Prudhoe Bay crude oil, subfractionation of primarily nonhydrocarbon fractions, biological screening of fractions to assess their toxicity and mutagenicity, and chemical characterization of any highly active fractions.

## EXPERIMENTAL

### Fractionation Studies

Studies were continued involving the solvent partitioning of oil using a nonpolar solvent such as hexane or heptane and a highly polar immiscible solvent such as dimethyl sulfoxide (DMSO) or acetonitrile. One of the main advantages of using acetonitrile instead of DMSO is the fact that the acetonitrile boils low enough (b.p. 82°C) to permit extracts to be concentrated directly using a rotating evaporator or vortex evaporator. DMSO on the other hand is not very volatile (b.p. 189°C) and the extracts must be diluted with water and back extracted with cyclopentane or methylene chloride prior to concentration. Losses of some of the more polar components may occur in the back extraction.

Methanol, like acetonitrile, is immiscible in heptane and should be capable of selectively removing polar components from oil. A study was performed to determine whether methanol would remove components from oil after most of the polar and aromatic components had been removed by acetontrile. Ten grams of fresh Prudhoe Bay crude oil was dissolved in 90 ml of heptane and centrifuged to remove heptane insolubles. The heptane solubles were then repetitively extracted five times with acetonitrile equilibrated with heptane followed by five times with methanol equilibrated with heptane. Weathered Prudhoe Bay crude oil was extracted similarly. Each fraction was concentrated to an oil in a rotating evaporator, dissolved in methylene chloride, and aliquots taken for duplicate residue weight determinations. The results are given in Table 1. The duplicate residue weights are included to give an indication of the reproducibility of residue weight determinations achieved for fractions that have had the volatile components removed in a rotating evaporator. The loss of volatiles undoubtedly accounts for the 17% loss for fresh oil. Quantitative recovery was achieved for the weathered oil. The main differences between the fresh and weathered oil were the greater amounts of heptane insolubles and remaining heptane solubles for the weathered oil.

It was of particular interest to note that the methanol extracted much greater amounts of material than acetonitrile. Gas chromatograms of the acetonitrile extracts were characterized by an aromatic hydrocarbon pattern whereas the chromatograms of the methanol extracts were characterized

TABLE 1. PARTITIONING OF PRUDHOE BAY CRUDE OIL INTO ACETONITRILE FOLLOWED BY METHANOL

| Fraction | Aliquot Weights, mg | | | | Total Amount, g | |
|---|---|---|---|---|---|---|
| | Fresh | | Weathered | | | |
| | 1 | 2 | 1 | 2 | Fresh | Weathered |
| 1. Heptane | 0.46 | 0.48 | 0.89 | 0.90 | 0.19 | 0.36 |
| 2. Acetonitrile Extract - 1 | 0.81 | 0.79 | 1.10 | 1.06 | 0.32 | 0.42 |
| 3. Acetonitrile Extract - 2 | 0.74 | 0.72 | 0.77 | 0.72 | 0.30 | 0.31 |
| 4. Acetonitrile Extract - 3 | 0.56 | 0.57 | 0.56 | 0.58 | 0.22 | 0.23 |
| 5. Acetonitrile Extract - 4 | 0.47 | 0.49 | 0.45 | 0.43 | 0.19 | 0.18 |
| 6. Acetonitrile Extract - 5 | 0.42 | 0.39 | 0.39 | 0.38 | 0.17 | 0.16 |
| 7. Methanol Extract - 1 | 1.31 | 1.27 | 1.26 | 1.22 | 0.52 | 0.50 |
| 8. Methanol Extract - 2 | 1.76 | 1.66 | 1.63 | 1.65 | 0.67 | 0.65 |
| 9. Methanol Extract - 3 | 1.57 | 1.59 | 1.56 | 1.47 | 0.63 | 0.59 |
| 10. Methanol Extract - 4 | 1.18 | 1.17 | 0.78 | 0.78 | 0.47 | 0.31 |
| 11. Methanol Extract - 5 | 1.04 | 1.04 | 1.12 | 1.02 | 0.42 | 0.45 |
| 12. Remaining Heptane Solubles | 1.05 | 1.05 | 1.47 | 1.45 | 4.21 | 5.86 |
| | | | | Total | 8.31 | 10.02 |

TABLE 2. SOLVENT PARTITIONING STUDIES

| Compound | % Extracted Into Given Solvent When Partitioned With Equal Volume of Heptane | | | |
|---|---|---|---|---|
| | Acetonitrile | DMSO | Nitromethane | Methanol |
| $C_{16}$ | 2 | 2 | 2 | 2 |
| $C_{26}$ | 2 | 2 | 2 | 2 |
| Androstane | 2 | 2 | 2 | 2 |
| Hexaethylbenzene | 17 | 16 | 20 | 20 |
| 2,3,6-Trimethylnaphthalene | 43 | 48 | 48 | 49 |
| Naphthalene | 61 | 71 | 62 | 66 |
| Phenanthrene | 71 | 90 | 69 | 73 |
| Pyrene | 71 | 92 | 66 | 72 |
| Dibenzothiophene | 68 | 91 | 69 | 74 |
| Dibenzofuran | 67 | 82 | 69 | 72 |
| Acetylnaphthalene | 94 | 98 | 96 | 98 |
| Quinoline | 98 | >98 | >98 | 98 |

by a predominantly n-paraffin pattern. Apparently the lower dielectric constant, lower dipole moment, and absence of pi bonds in methanol cause it to dissolve less-polar paraffinic materials much better than does acetonitrile. Therefore methanol was not considered further for solvent partitioning aimed at separating polar components from paraffinic and nonpolar components.

One of the concerns in using acetonitrile instead of DMSO is whether or not it will do as complete a job of extracting polar components out of a heptane solution of oil. Therefore a solution of numerous reference compounds in heptane was equilibrated by shaking for 24 hours with an equal volume of polar solvents. The partitioned amounts were determined by GC analysis. The results are given in Table 2. The very nonpolar saturated hydrocarbons stayed almost entirely in the heptane, significant or major amounts of aromatic hydrocarbons went into the polar solvents, and essentially all of the more polar compounds went into the polar solvents. All of the polar solvents, including acetonitrile and DMSO behaved very similarly with DMSO being somewhat superior for polynuclear aromatic hydrocarbons.

The above partitioning studies were performed using a 1:1 ratio of polar solvent to heptane. In order to remove polar components more completely a 5:1 ratio was studied. Ten grams of fresh Prudhoe Bay crude oil dissolved in 100-ml of heptane was extracted repetitively with 500-ml portions of acetonitrile equilibrated with heptane. The amounts extracted each time are given in Table 3. Although small amounts of material continue to be extracted out even in the eighth extraction, 90% of the total extracted in eight extracts was obtained in the first five extracts. Based on this data and also as a matter of practicality a total of five repetitive extractions using a 5:1 ratio of acetonitrile: heptane was selected for future work. Considering the partitioning data of Table 2, these conditions should be ample for practically complete extraction of aromatic and polar components.

## In Vitro Biological Screening Studies

Several of the acetonitrile and methanol extracts obtained from the solvent partitioning of Prudhoe Bay crude oil were assayed by both the Ames Salmonella mutagenicity assay with activated microsomes and by the

TABLE 3. ACETONITRILE:HEPTANE (5:1) PARTITIONING OF FRESH PB CRUDE OIL

| Extract No. | Total Amount Recovered, % |
|---|---|
| 1 | 9.9 |
| 2 | 4.8 |
| 3 | 2.2 |
| 4 | 2.0 |
| 5 | 1.3 |
| 6 | 1.0 |
| 7 | 0.8 |
| 8 | 0.6 |
| Total | 22.6 |

prescreen confluency mammalian-cell toxicity assay. The extracts that had been taken up in methylene chloride for residue weight determinations were added to DMSO, solvent exchanged with heptane to remove traces of methylene chloride, and stripped in a vortex evaporator to remove the heptane. The samples were diluted if necessary to a final concentration of 2 mg/ml in DMSO. GC analsis using a Hall electrolytic conductivity detector in the halogen-specific mode indicated that the final solutions contained less than 5 µg/ml of methylene chloride.

The mutagenicity tests were run using two dosage levels and three bacterial strians. The results are given in Table 4. No indication of mutagenicity was observed for any of the extracts. Some of the extracts exhibited significant toxicity in the separate toxicity portion of the test. However, no toxicity was observed in the mutagenicity test (run with $10^8$ cells per plate instead of the $10^3$ cells per plate used for the toxicity test) as indicated by a healthy background lawn.

The mammalian cell toxicity test was run at three concentrations. The results are given in Table 5. Toxicity was exhibited only at the highest level of 40 µg/ml. The fresh crude oil acetonitrile extracts were more toxic than those from weathered oil presumably because the toxicity is caused primarily by the aromatic hydrocarbons, many of which have been lost by the weathering process. The methanol extracts, which contain a higher proportion of paraffinic material, were not toxic.

TABLE 4. SALMONELLA MUTAGENICITY ASSAY OF CRUDE OIL FRACTIONS

| No. | Sample | Dosage, µg/plate | Revertants Per Plate Using Given Salmonella Strain | | |
|---|---|---|---|---|---|
| | | | 98 | 100 | 1537 |
| 1. | Fresh PB Crude Oil Extract AN-1[a] | 200 | 30 | 161 | 10 |
| | | 40 | 65 | 167 | 9 |
| 2. | Fresh PB Crude Oil Extract AN-3 | 200 | 57 | 166 | 11 |
| | | 40 | 32 | 156 | 8 |
| 3. | Fresh PB Crude Oil Extract AN-5 | 200 | 42 | 142 | 15 |
| | | 40 | 38 | 124 | 8 |
| 4. | Weathered PB Crude Oil Extract AN-1 | 200 | 44 | 131 | 10 |
| | | 40 | 37 | 130 | 8 |
| 5. | Weathered PB Crude Oil Extract AN-3 | 200 | 45 | 125 | 14 |
| | | 40 | 37 | 138 | 10 |
| 6. | Weathered PB Crude Oil Extract AN-5 | 200 | 39 | 158 | 11 |
| | | 40 | 40 | 150 | 12 |
| 7. | Fresh PB Crude Oil Extract M-5[b] | 200 | 39 | 118 | 10 |
| | | 40 | 43 | 127 | 8 |
| 8. | Fresh PB Crude Oil Extract M-6 | 200 | 43 | 143 | 6 |
| | | 40 | 59 | 148 | 13 |
| 9. | Corn Oil | 200 | 59 | 138 | 5 |
| | | 40 | 40 | 115 | 7 |
| 10. | Control | -- | 42 | 140 | 11 |
| 11. | 2-Aminoanthracene | 5 | 723 | 608 | 64 |

a. AN designates extraction with acetonitrile
b. M designates extraction with methanol

TABLE 5. MAMMALIAN CELL TOXICITY ASSAY OF CRUDE OIL FRACTIONS

| No. | Sample | Percent Confluency at Given Dosage, µg/ml 40 | 20 | 8 | Estimated $CD_{50}$[a] µg/ml |
|---|---|---|---|---|---|
| 1. | Fresh PB Crude Oil Extract AN-1[b] | 10 | 100 | 100 | 35 |
| 2. | Fresh PB Crude Oil Extract AN-3 | 14 | 100 | 100 | 35 |
| 3. | Fresh PB Crude Oil Extract AN-5 | 20 | 100 | 100 | 35 |
| 4. | Weathered PB Crude Oil Extract AN-1 | 95 | 100 | 100 | >40 |
| 5. | Weathered PB Crude Oil Extract AN-3 | 75 | 100 | 100 | >40 |
| 6. | Weathered PB Crude Oil Extract AN-5 | 100 | 100 | 100 | >40 |
| 7. | Fresh PB Crude Oil Extract M-5[c] | 100 | 100 | 100 | >40 |
| 8. | Fresh PB Crude Oil Extract M-6 | 100 | 100 | 100 | >40 |
| 9. | Corn Oil | 95 | 100 | 100 | >40 |

a. The dosage level that would result in only 50% confluency.
b. AN designates extraction with acetonitrile.
c. M designates extraction with methanol.

EIGHTH QUARTERLY REPORT
(Covering the period of January 1 to March 30, 1979)

on

# ACTIVITY-DIRECTED FRACTIONATION OF PETROLEUM SAMPLES

Research Unit #500
Contract No. 03-7-022-35129

to

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

October 15, 1979

by

J. S. Warner

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## SUMMARY

A fractionation scheme that entailed (1) solvent partitioning between heptane and acetonitrile, (2) gel permeation chromatography using Bio-Beads S-X8 with methylene chloride as an eluting solvent, and (3) silica gel chromatography using silica gel that has been partially deactivated by 10% methanol in ethylene dichloride was applied to fresh and weathered Prudhoe Bay crude oil.

*In vitro Salmonella* mutagenicity assays and mammalian-cell toxicity assays indicated that some of the resulting fractions were toxic but not mutagenic. Of particular interest was the fact that two of the highly polar fractions, i.e. fractions that were not comprised of aromatic hydrocarbons, were also toxic.

## EXPERIMENTAL

### Fractionation Studies

As described in the last report, repetitive solvent partitioning using 5:1 acetonitrile:heptane was chosen as the initial separation for separating the polar DMSO-soluble components of interest from paraffinic and intractable components. The second separation step chosen was gel permeation chromatography (GPC) to remove the intractable high-molecular-weight components. Sephadex LH-20 using isopropanol as the eluting solvent was investigated for this purpose but was found to be unsatisfactory because (1) isopropanol was not a good solvent for preparing concentrated solutions of the acetonitrile extractables, and (2) major amounts of dark colored remained irreversibly bound to the column. Consequently Bio-Beads S-X8 with methylene chloride as an eluting solvent was tried. This is a system that we had previously used successfully for separating polynuclear aromatic hydrocarbons from high-molecular-weight materials in sludge extracts. The system worked very well in that methylene chloride was a good solvent and very little colored material remained on the column. The column could be reused for many acetonitrile extracts.

A representative elution profile was obtained using a small amount of an acetonitrile extract of weathered oil. The amount present in each five-minute (10 ml) fraction was determined by residue weight measurements. The elution profile obtained is shown in Figure 1. For comparison the elution ranges found for various reference compounds are also indicated. Long-chain compounds eluted early and the compact aromatic compounds eluted considerably later. Polar aromatics eluted earlier than less-polar aromatics. Also shown in Figure 1 are the collection times for four fractions taken in subsequent preparative runs. Nearly all of the color appeared in A-1 even though it represented a very minor amount of the total sample weight. The bulk of the material was rather arbitrarily divided into two nearly equal fractions A-2 and A-3. Most of the aromatic hydrocarbons would be in A-3.

The third separation step chosen was silica gel chromatography to separate components on the basis of polarity. This had been studied earlier using fully activated silica gel and had given losses of irreversibly adsorbed

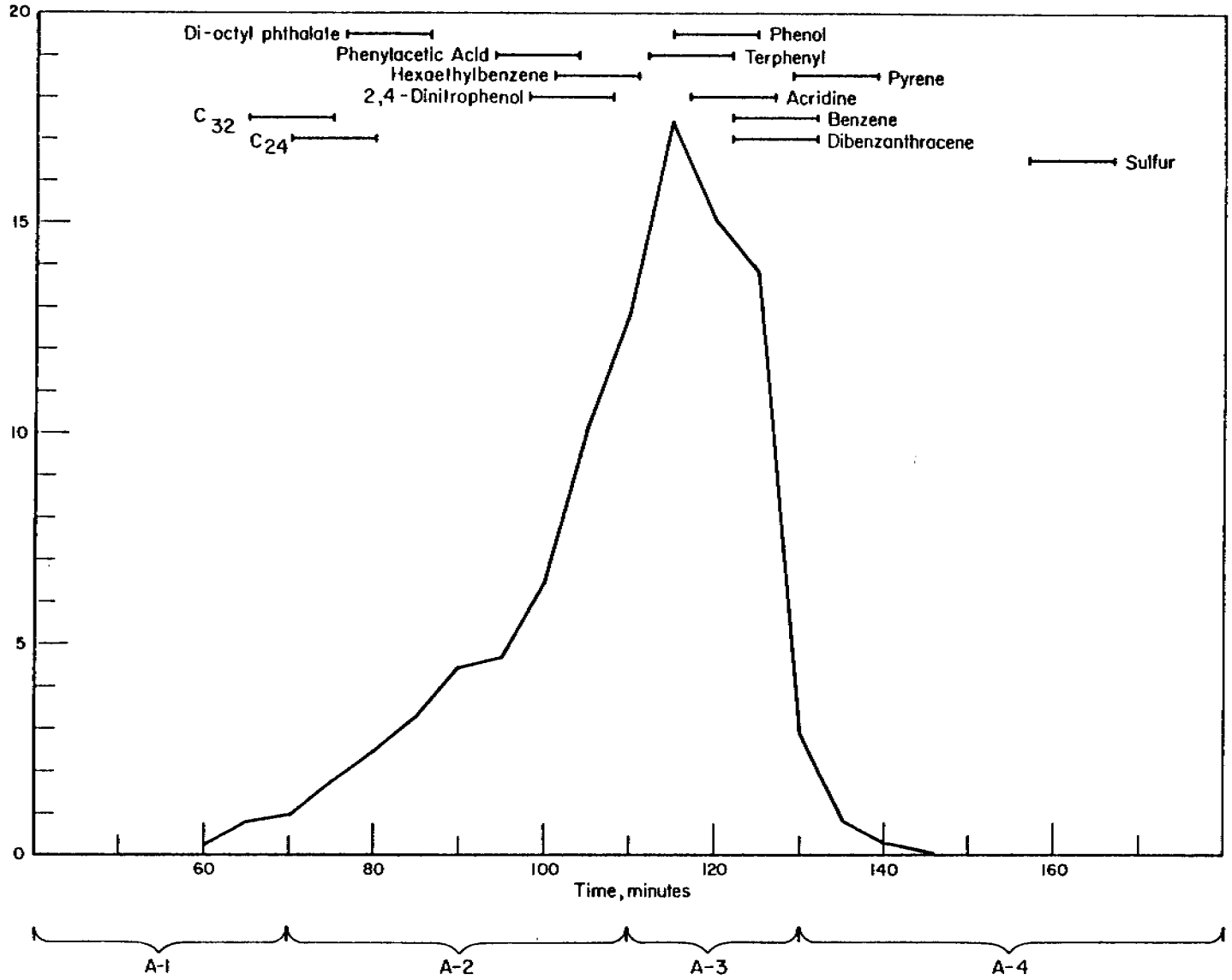


FIGURE 1. ELUTION PROFILE OF ACETONITRILE EXTRACT OF WEATHERED PB CRUDE OIL USING BIO-BEADS S-X8

material. In an effort to reduce the irreversible adsorption, the silica gel was partially deactivated by equilibration with 10% methanol in ethylene dichloride. This step also removed any polar contaminants from the column. The column was then rinsed with ethylene dichloride followed by hexane. The elution scheme used for the GPC fractions started with hexane and then went successively to 9:1 hexane:ethylene dichloride, ethylene dichloride, and 9:1 ethylene dichloride:methanol. The column could be regenerated and reused.

The final fractionation scheme that evolved from these studies is summarized in Figure 2. This scheme was applied to fresh and weathered Prudhoe Bay crude oil to obtain fractions for bioassay studies. Ten grams of oil in 100 ml of heptane was extracted five times with 500-ml portions of acetonitrile equilibrated with heptane. The acetonitrile was removed from the combined extracts using a rotating evaporator and the residual oil dissolved in methylene chloride and fractionated by GPC. The effectiveness of the GPC fractionation system is indicated by the gas chromatograms of weathered oil fractions shown in Figures 3 and 4. The main individual peaks in A-2 (Figure 3) are trace amounts of normal paraffins; most of the material does not elute from the GC column. Fraction A-3 (Figure 4) on the other hand gives the usual pattern of aromatic hydrocarbons, the methylnaphthalenes (MN), dimethylnaphthalenes (DMN), and trimethylnaphthalenes (TMN), etc. No significant overlap of the two fractions is noted.

Each A-2 and A-3 GPC fraction was concentrated to an oil, dissolved in hexane, and fractionated by silica gel chromatography using a column containing 350 g of partially deactivated silica gel (Davison Grade 923). The column was eluted at a flow rate of 10 ml/min with 1400 ml of hexane followed by 1400 ml of 1:9 ethylene dichloride:hexane, followed by 900 ml of ethylene dichloride, and finally with 1400 ml of 1:9 methanol:ethylene dichloride. Fractions were collected every 25 minutes (250 ml each). Each fraction was concentrated to an oil in a rotating evaporator at 30°C and taken up in several portions of methylene chloride to a volume of 10 ml. A 50-µl aliquot of each fraction was used for residue weight determinations.

The efficiency of the silica gel fractionation is indicated by gas chromatograms of hydrocarbon fractions shown in Figures 5 and 6. Fraction 4 from A-3 from fresh crude oil (Figure 5) gives a GC pattern indicative primarily of naphthalene and alkylnaphthalenes. The next fraction, fraction 5 (Figure 6) contains very few naphthalenes but mainly the phenanthrenes,

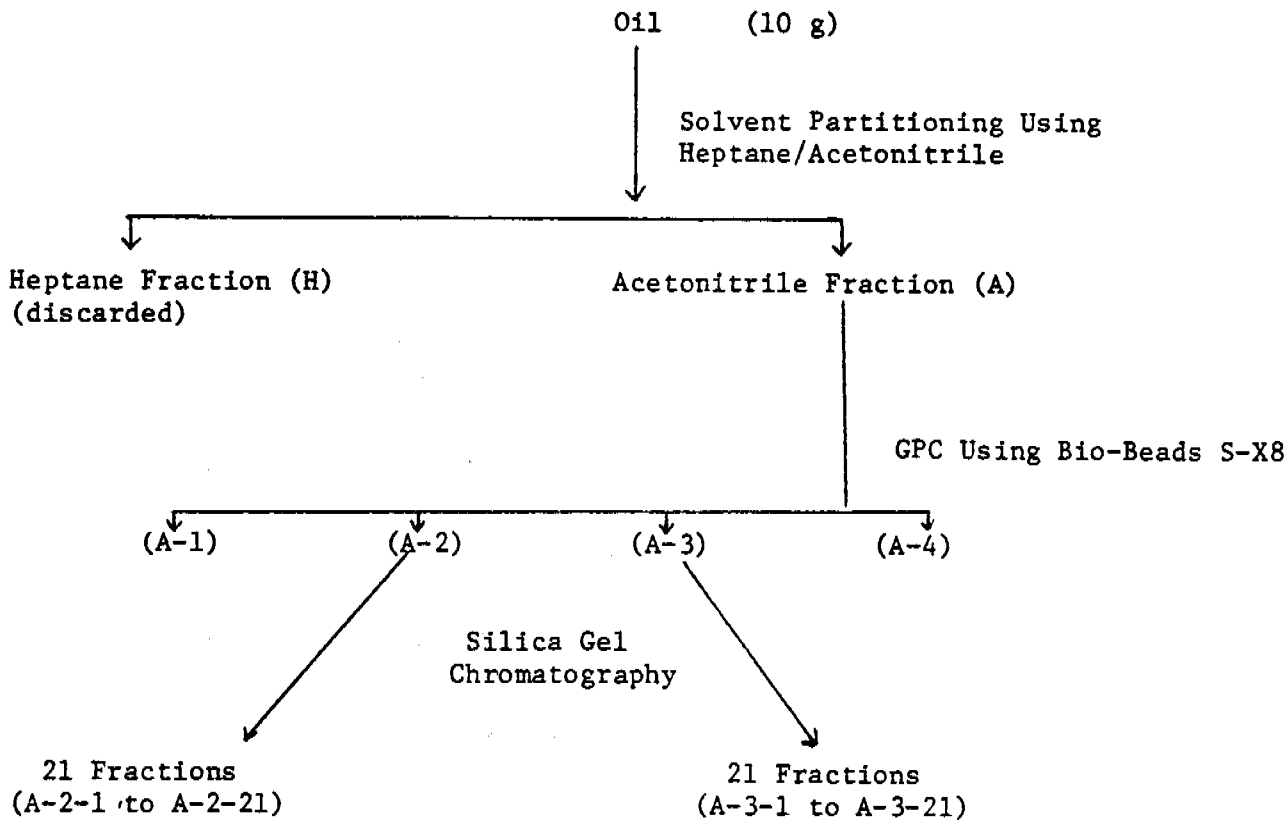


FIGURE 2. OIL FRACTIONATION SCHEME

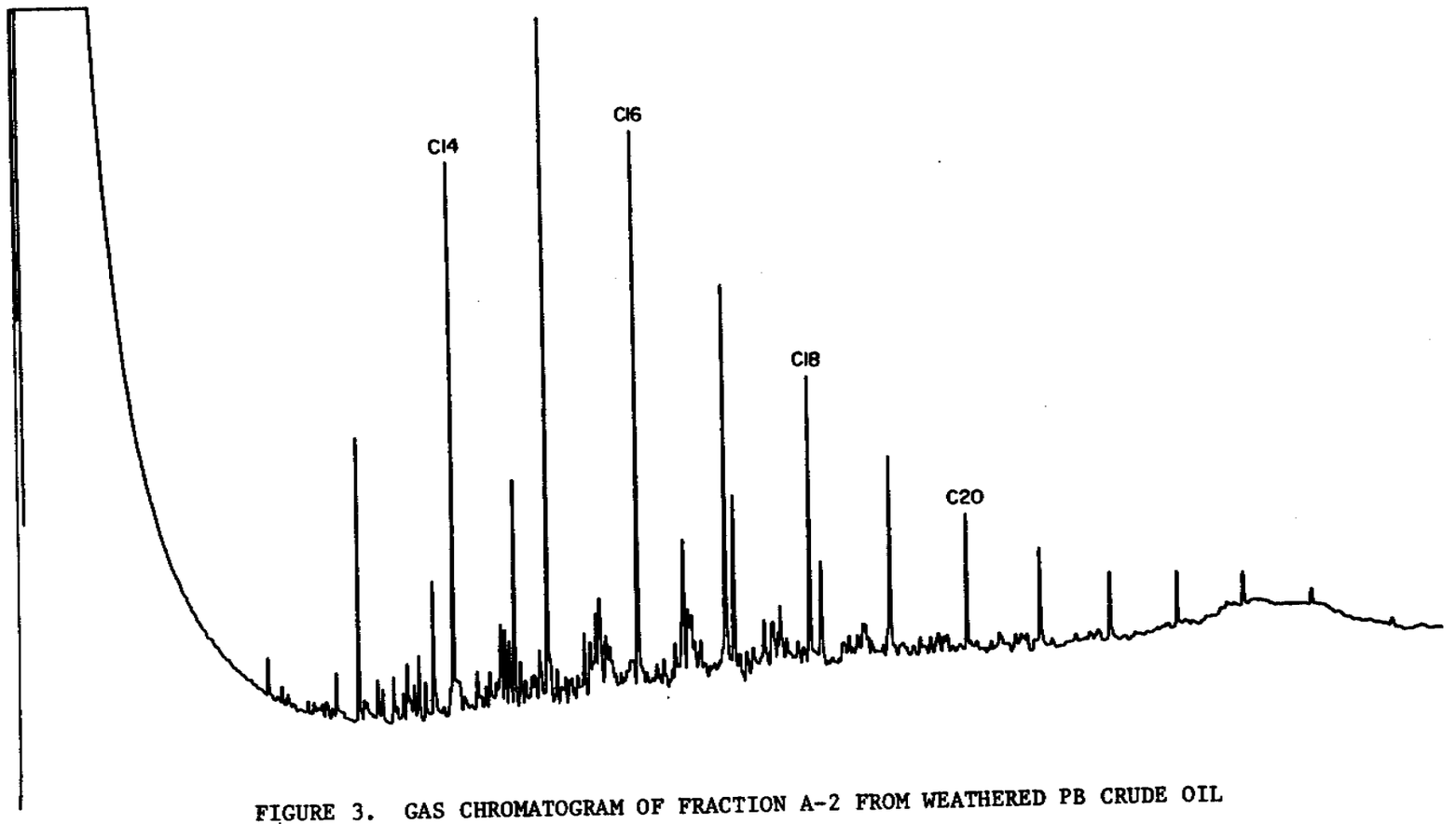


FIGURE 3. GAS CHROMATOGRAM OF FRACTION A-2 FROM WEATHERED PB CRUDE OIL

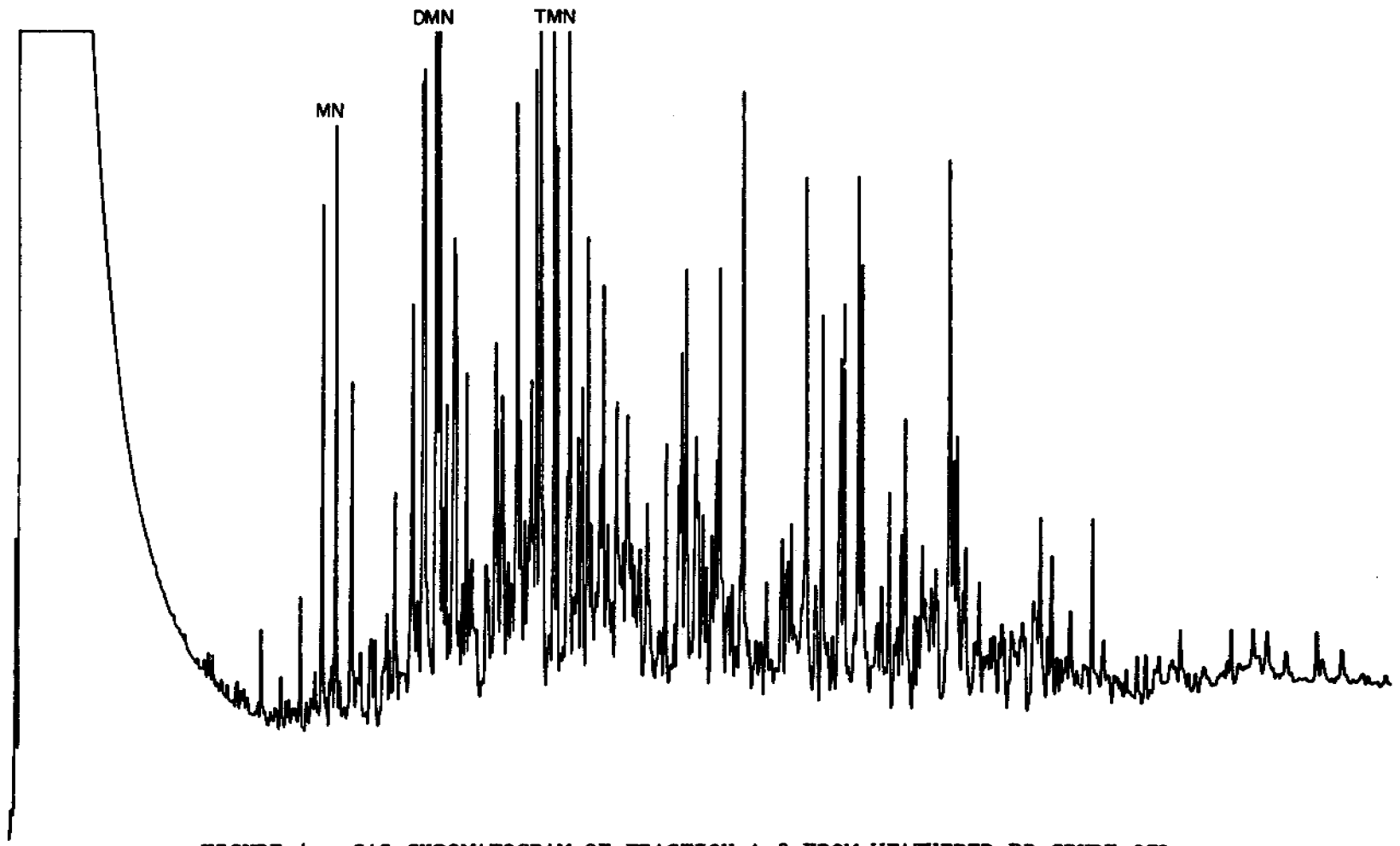


FIGURE 4. GAS CHROMATOGRAM OF FRACTION A-3 FROM WEATHERED PB CRUDE OIL

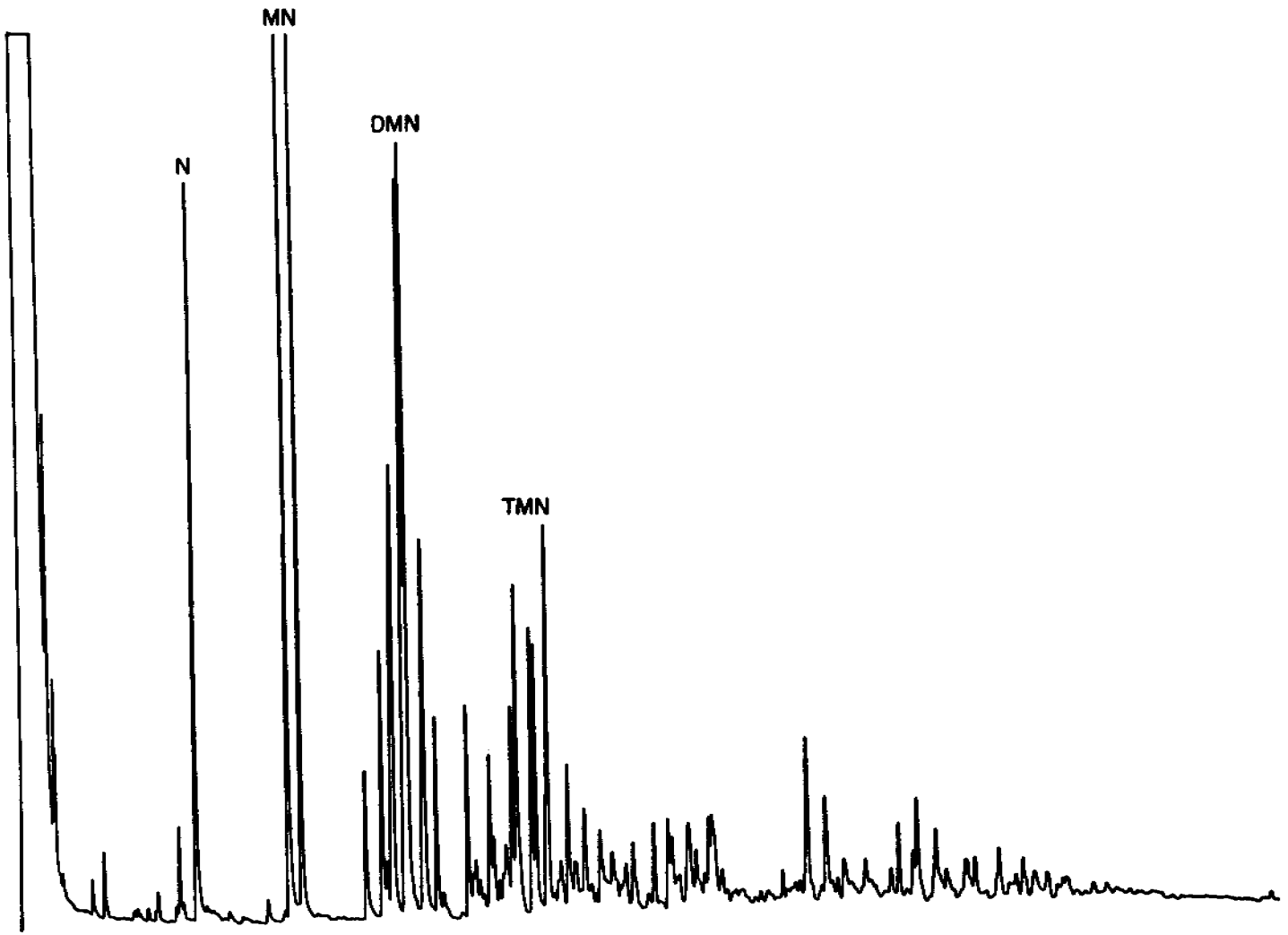


FIGURE 5. GAS CHROMATOGRAM OF FRACTION A-3-4 FROM FRESH PB CRUDE OIL

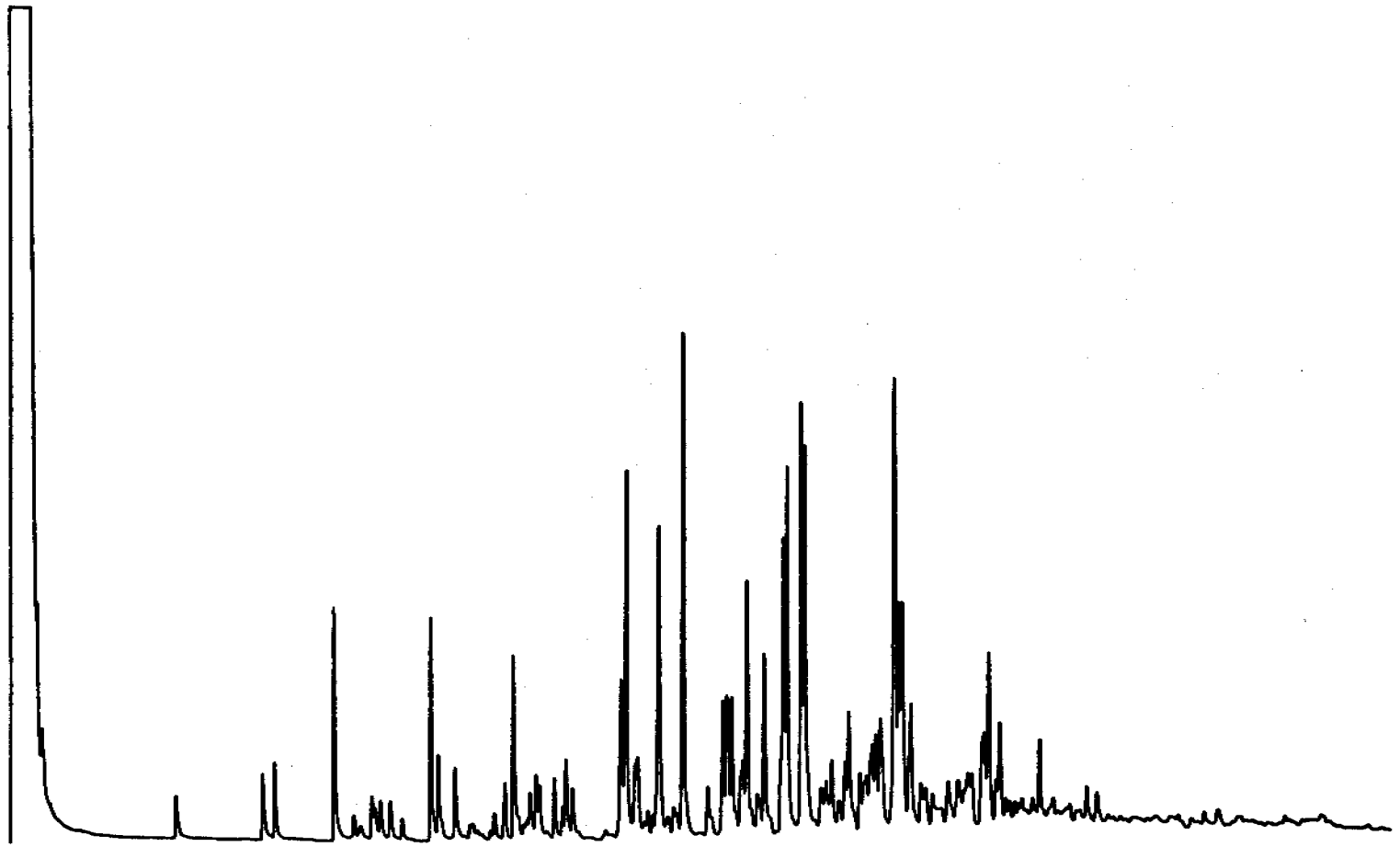

FIGURE 6. GAS CHROMATOGRAM OF FRACTION A-3-5 FROM FRESH PB CRUDE OIL

fluorenes, pyrenes, and fluoranthenes.

## In Vitro Bioassay Studies

Several of the final fractions obtained from the above fractionation process were assayed by both the Ames Salmonella mutagenicity assay and by the prescreen confluency mammalian-cell toxicity assay. The methylene chloride solvent in each fraction was exchanged with heptane and the fraction concentrated to an oil and dissolved in DMSO to give a concentration of 5 mg/ml.

The mutagenicity tests were run using two dosage levels and three bacterial strains. The results are given in Table 1. No indication of mutagenicity was observed for any of the extracts.

The mammalian cell toxicity test was run at three concentrations. The results are given in Table 2. Most of the fractions gave significant toxicity. The two fractions of greatest interest are A-2-18 and A-2-19 from weathered and fresh oil, respectively. These are highly polar fractions obtained by elution with 10% methanol in ethylene dichloride and hence do not contain any aromatic hydrocarbons. This is the first indication obtained in the program that petroleum fractions other than the aromatic hydrocarbon fractions may represent a significant biological hazard.

TABLE 1. SALMONELLA MUTAGENICITY ASSAY OF CRUDE OIL FRACTIONS

| No. | Sample | Dosage, µg/plate | Revertants Per Plate Using Given Salmonella Strain | | |
|---|---|---|---|---|---|
| | | | 98 | 100 | 1537 |
| 1. | Control | -- | 55 | 143 | 13 |
| 2. | Weathered PB Crude Oil Fraction A-2-3 | 500 | 44 | 114 | 19 |
| | | 200 | 46 | 112 | 19 |
| 3. | Weathered PB Crude Oil Fraction A-2-9 | 500 | 35 | 120 | 11 |
| | | 200 | 40 | 123 | 12 |
| 4. | Weathered PB Crude Oil Fraction A-2-13 | 500 | 53 | 129 | 17 |
| | | 200 | 55 | 141 | 20 |
| 5. | Weathered PB Crude Oil Fraction A-2-18 | 500 | 51 | 116 | 10 |
| | | 200 | 54 | 118 | 13 |
| 6. | Weathered PB Crude Oil Fraction A-3-4 | 500 | 38 | 142 | 9 |
| | | 200 | 53 | 154 | 14 |
| 7. | Weathered PB Crude Oil Fraction A-3-6 | 500 | 61 | 167 | 16 |
| | | 200 | 71 | 174 | 18 |
| 8. | Weathered PB Crude Oil Fraction A-3-8 | 500 | 63 | 164 | 14 |
| | | 200 | 52 | 194 | 17 |
| 9. | Fresh PB Crude Oil Fraction A-2-19 | 500 | 54 | 155 | 12 |
| | | 200 | 48 | 155 | 14 |
| 10. | 2-Aminoanthracene | 5 | 613 | 407 | 39 |
| 11. | Benzo(a)pyrene | 1 | 376 | 195 | 82 |

TABLE 2. MAMMALIAN CELL TOXICITY ASSAY OF CRUDE OIL FRACTIONS

| No. | Sample | Percent Confluency at Given Dosage Level, µg/ml 100 | 40 | 20 | Estimated $CD_{50}$[a], µg/ml |
|---|---|---|---|---|---|
| 1. | Weathered PB Crude Oil Fraction A-2-3 | 1 | 82 | 92 | 60 |
| 2. | Weathered PB Crude Oil Fraction A-2-9 | 95 | 100 | 99 | >100 |
| 3. | Weathered PB Crude Oil Fraction A-2-13 | 6 | 99 | 95 | 70 |
| 4. | Weathered PB Crude Oil Fraction A-2-18 | 0 | 93 | 100 | 60 |
| 5. | Weathered PB Crude Oil Fraction A-3-4 | 0 | 0 | 100 | 30 |
| 6. | Weathered PB Crude Oil Fraction A-3-6 | 0 | 20 | 98 | 35 |
| 7. | Weathered PB Crude Oil Fraction A-3-8 | 93 | 100 | 97 | >100 |
| 8. | Fresh PB Crude Oil Fraction A-2-19 | 0 | 95 | 100 | 60 |

a. The dosage level that would result in only 50% confluency.

NINTH QUARTERLY REPORT
(Covering the period of April 1 to June 30, 1979)

on

# ACTIVITY-DIRECTED FRACTIONATION OF PETROLEUM SAMPLES

Research Unit #500
Contract No. 03-7-022-35129

to

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

October 15, 1979

by

J. S. Warner

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

## SUMMARY

The fractionation scheme previously applied to Prudhoe Bay crude oil was applied to shale oil for comparison. The shale oil differed from the crude oil in that a much larger proportion of it partitioned into acetonitrile and its behavior in GPC and silica gel fractionations indicated a higher content of polar components. Also, unlike crude oil, some of the final polar fractions contained many GC-able components.

Ames Salmonella mutagenicity assays and prescreen confluency mammalian-cell toxicity assays conducted on 12 of the shale oil fractions and eight crude oil fractions showed that many of the fractions were toxic and some were slightly mutagenic. The shale oil fractions were somewhat more toxic and more mutagenic than the crude oil fractions.

In vivo toxicity tests using mysids were conducted to evaluate the suitability of using DMSO as a solvent for dispensing oil fractions and using Corexit as a dispersing agent. The $LC_{50}$s found for DMSO and Corexit were 10,000 mg/l and 94 mg/l, respectively, which are one to two orders of magnitude greater than the amounts that would be used in practice. Prudhoe Bay crude oil was not toxic enough to give an $LC_{50}$ when assayed at levels up to 10 mg/l using 250 mg/l of DMSO and 1 mg/l of Corexit.

## EXPERIMENTAL

### Fractionation Studies

The fractionation scheme that was applied to fresh and weathered Prudhoe Bay crude oil as described in the last quarterly report was applied to shale oil for comparison during the current report period. The shale oil was from a simulated *in situ* process and was kindly provided by Dr. Richard Poulson of the Laramie Energy Technology Center.

The shale oil differed from the Prudhoe Bay crude oil in that a much larger proportion of it was extracted into acetonitrile, about 45 percent instead of only 23 percent. The amounts of each of the three oils extracted into each individual acetonitrile partitioning using 5:1 acetonitrile:heptane are shown in Figure 1. The first partitioning in each case accounted for a major amount of the total extractable material.

In the second step of the fractionation scheme, GPC using Bio-Beads S-X8 with methylene chloride as the eluting solvent, the shale oil eluted somewhat earlier than the crude oils. This was probably due to the higher content of heterocyclic more polar compounds in the shale oil. The elution profiles obtained for all three oils are compared in Figure 2.

In the third step of the fractionation scheme, silica gel fractionation, the shale oil had more polar components than the crude oils. This is shown in Figure 3 which compares the elution profiles of the three oils in this last step. A major difference between shale oil and the crude oils showed up upon GC analysis of the various fractions. GC analysis of the polar A-3-13 and A-3-19 fractions from fresh crude oil showed no GC-able components. The corresponding fractions from shale oil at the same concentration level gave many GC-able components. The chromatograms are shown in Figure 4 and 5. Although it would be somewhat outside the scope of this program it would be of interest to attempt to identify these volatile polar components using GC-MS and other instrumental methods.

### *In Vitro* Biological Screening Studies



Many of the shale oil fractions were assayed along some of the

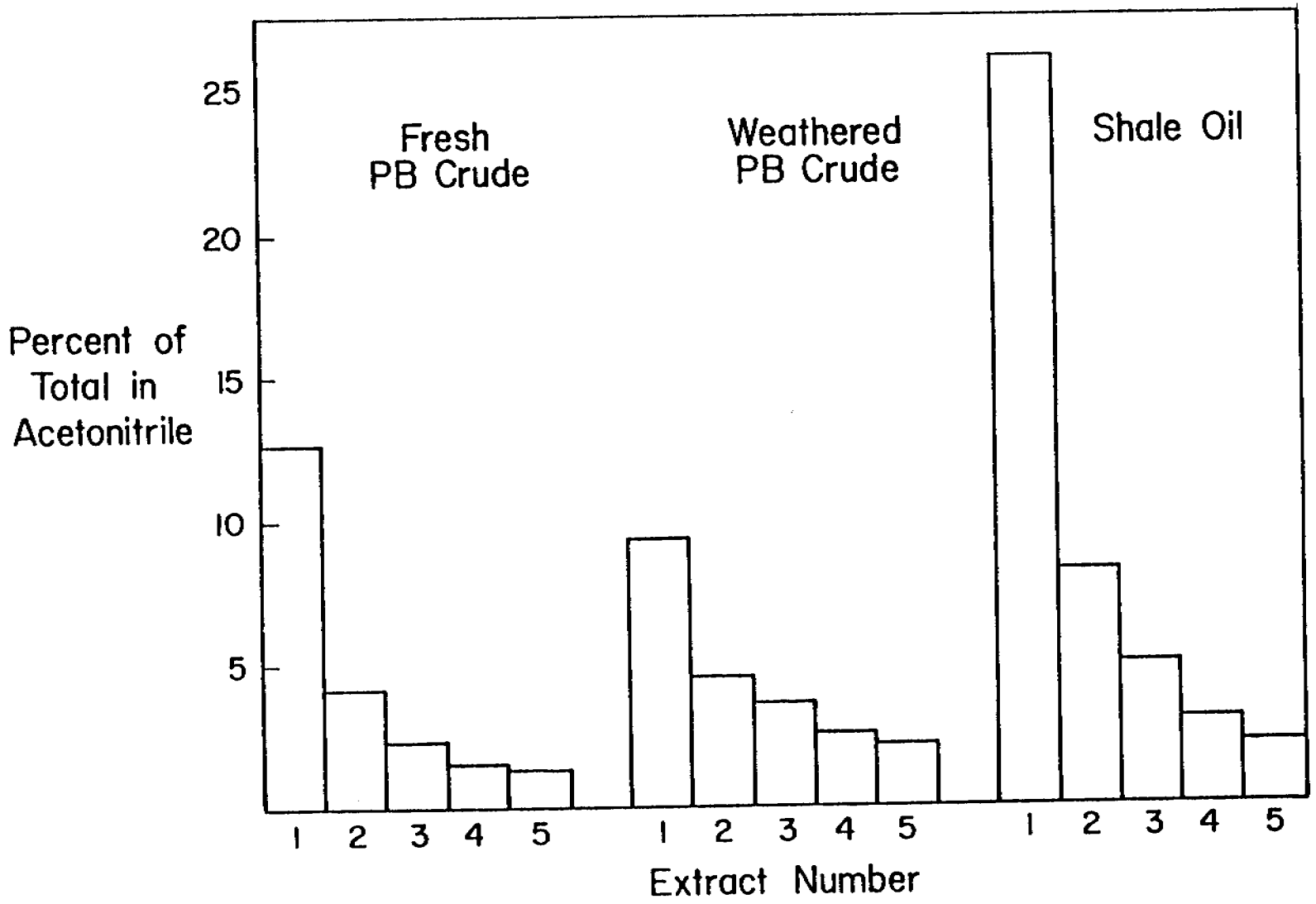


FIGURE 1. HEPTANE/ACETONITRILE PARTITIONING

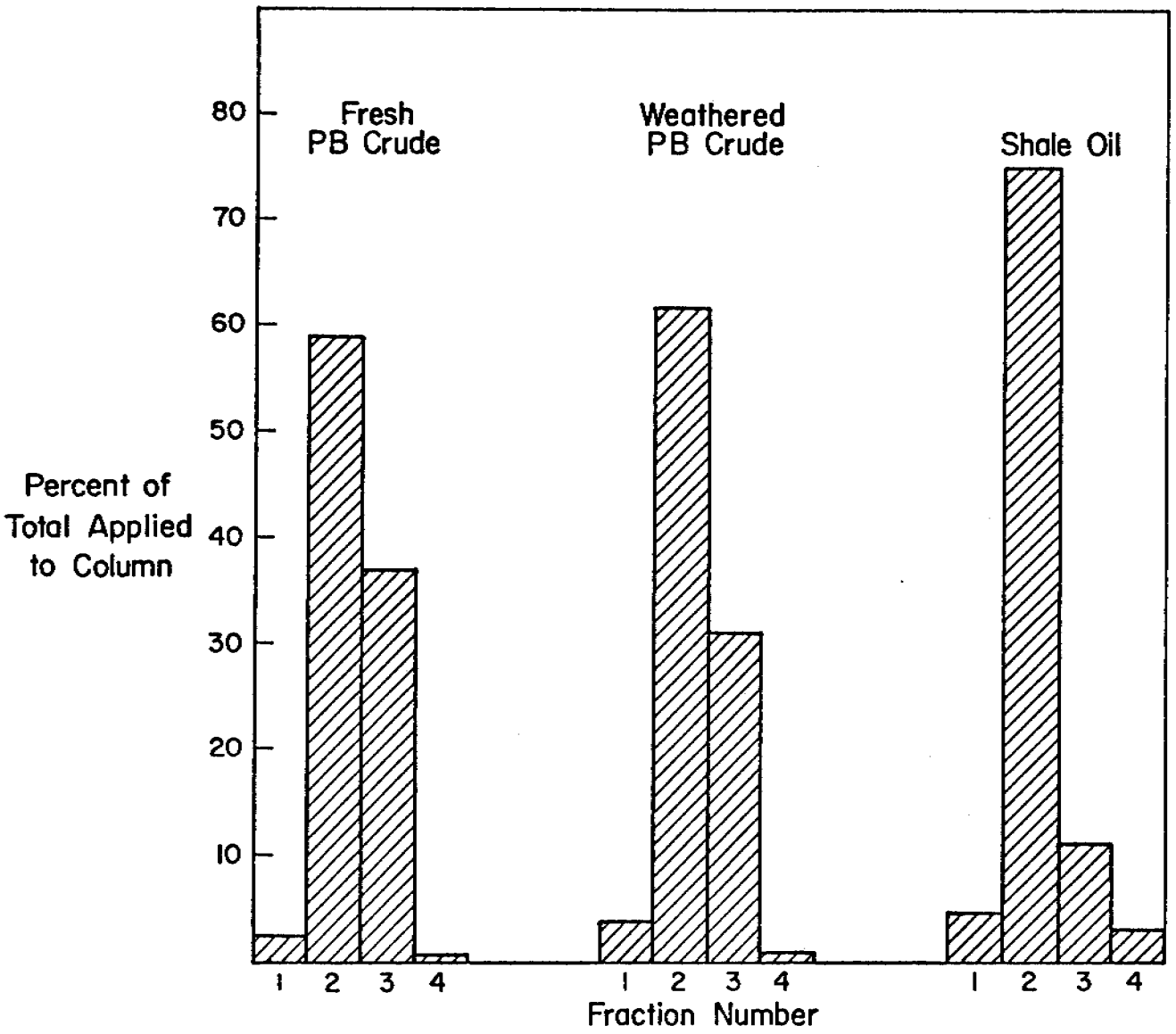


FIGURE 2. ELUTION PROFILES FROM FRACTIONATION USING BIO-BEADS S-X8

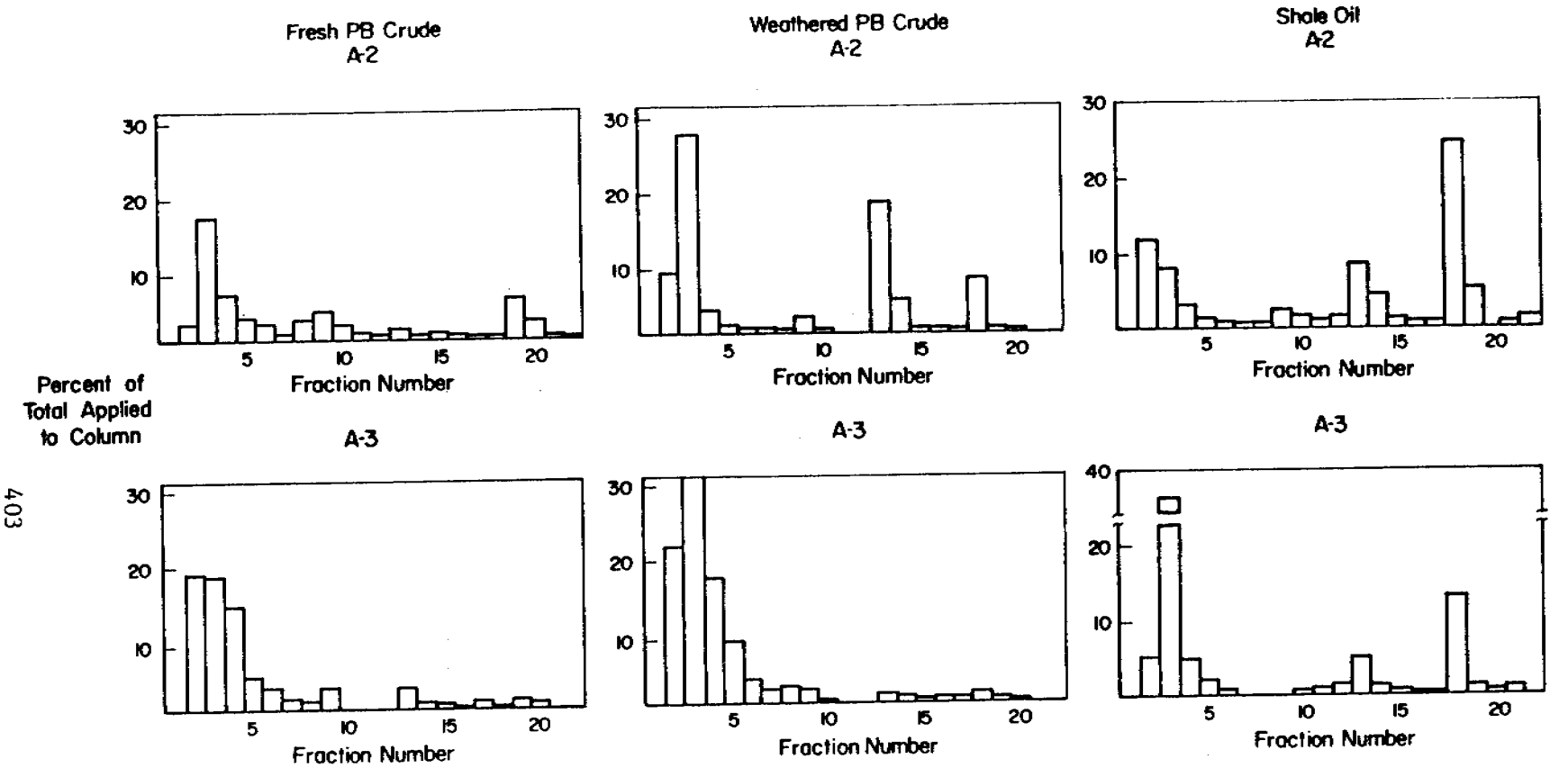


FIGURE 3. ELUTION PROFILES FROM FRACTIONATION USING SILICA GEL

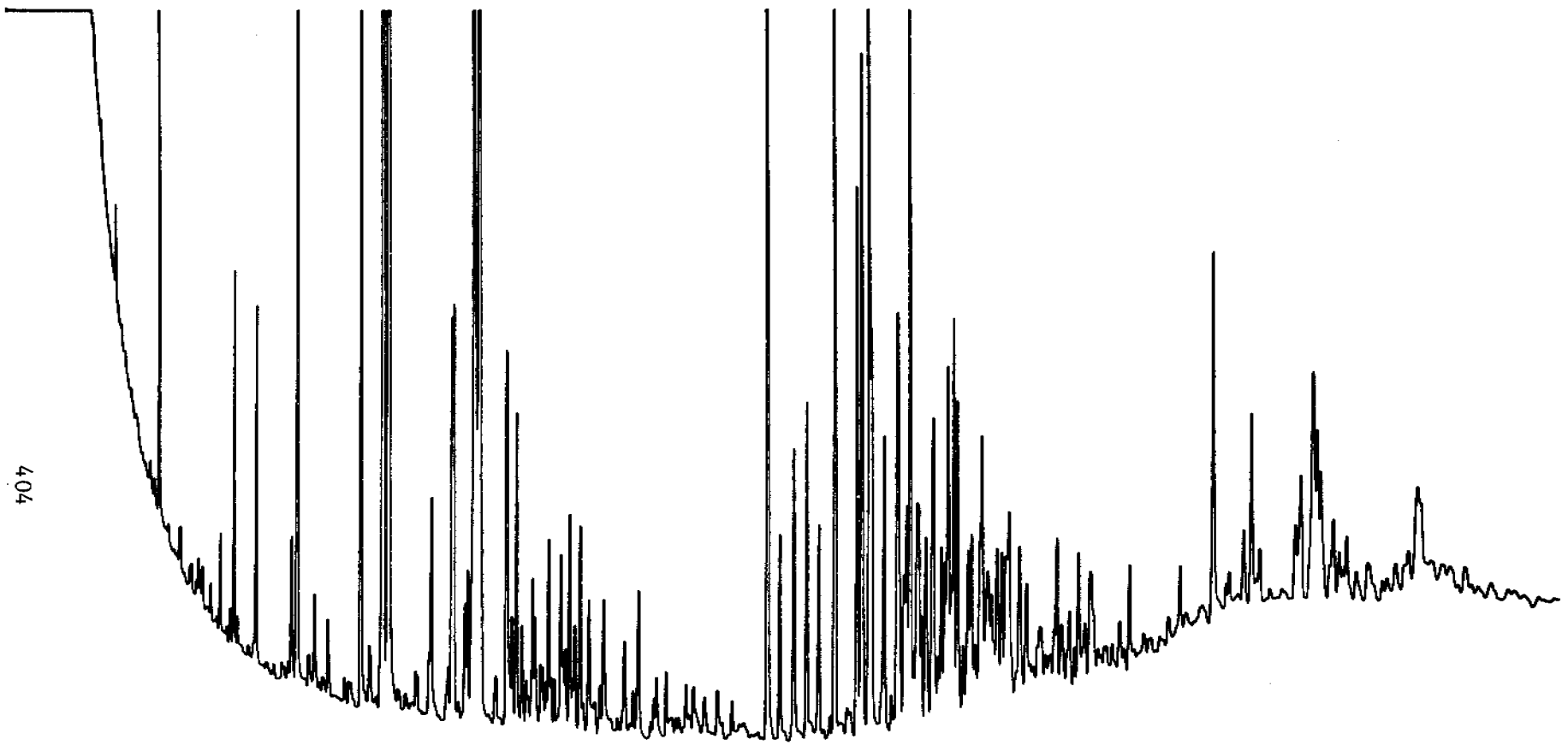

FIGURE 4. GAS CHROMATOGRAM OF FRACTION A-3-13 FROM SHALE OIL

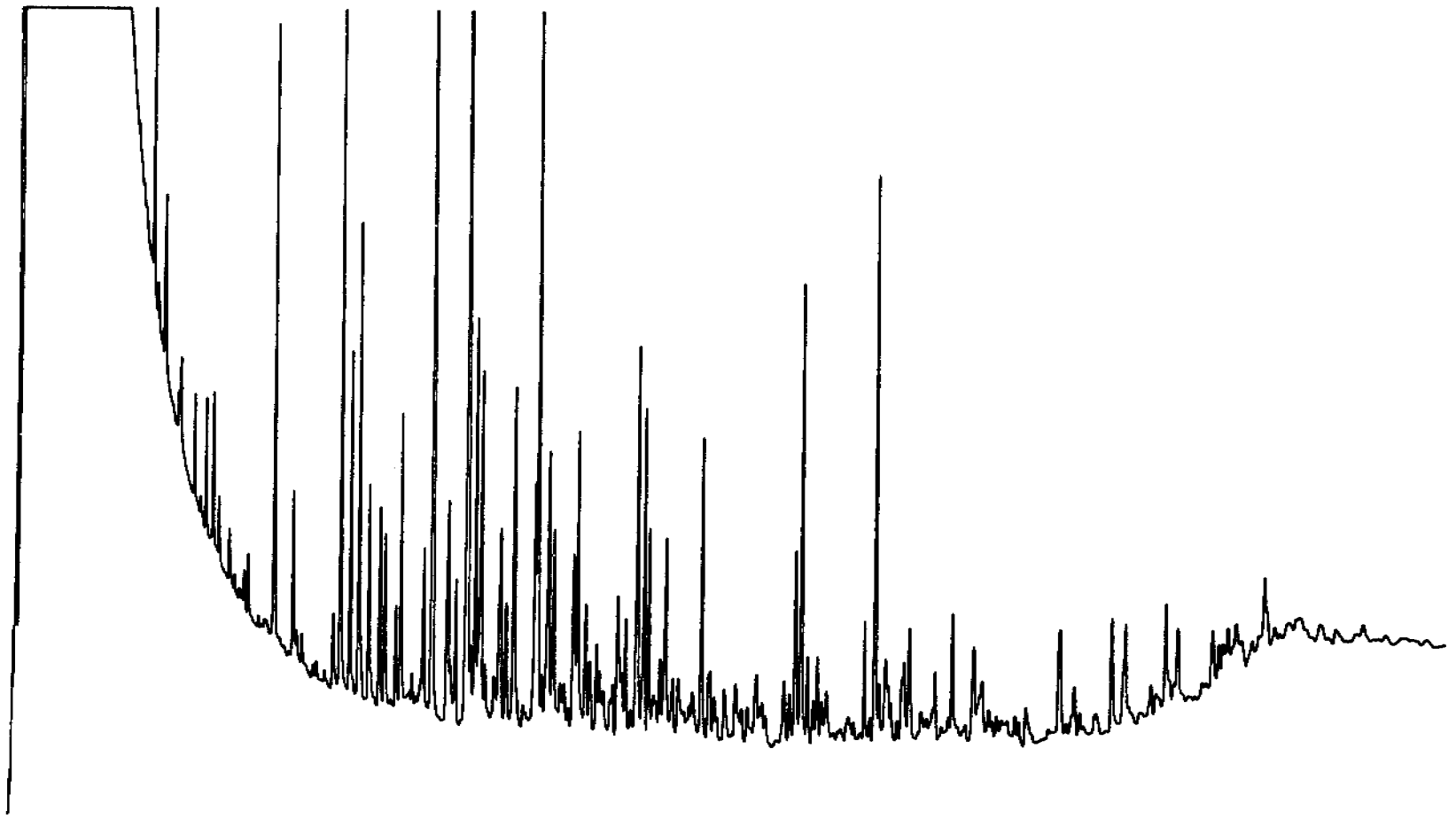

FIGURE 5. GAS CHROMATOGRAM OF FRACTION A-3-18 FROM SHALE OIL

crude oil fractions obtained previously using both the Ames Salmonella mutagenicity assay and the prescreen confluency mammalian-cell toxicity assay. The fractions were dissolved in DMSO at 12.5 mg/ml for these studies.

The mutagenicity tests were run using two dosage levels, one of which was higher than previously used, and in order to conserve material only one strain, TA-98, was used. TA-98 generally serves very well for detecting mutagenic components in petroleum-type materials. The results are given in Table 1. A slight mutagenicity was indicated in some of the fractions, especially for the more polar fractions from shale oil. It would be of interest to optimize the assay procedure for those fractions.

The mammalian-cell toxicity test was run at three concentrations. The results are given in Table 2. Most of the fractions were toxic at the 100 µg/ml level. This was true for many of the polar fractions as well as the aromatic hydrocarbon fractions. The shale oil fractions were generally more toxic than the crude oil fractions.

## In Vivo Biological Studies

### Materials and Methods

Preliminary bioassays were conducted to evaluate the toxicity of dimethyl sulfoxide and Corexit dispersant alone and in combination with Prudhoe Bay crude oil to the mysid Neomysis awatschensis.

Mysids were trawled from Sequim Bay and held at ambient temperature in large flow-through tanks. They were acclimitized for at least one day and fed a diet of Artemia nauplii.

All bioassays ran for 48 hours. Twenty animals were placed in six quart static aquaria containing two liters of seawater with gentle aeration. Mysids were tranferred from holding tanks by the use of hollow glass tubes. These tubes utilized suction to draw the animal and seawater into its chamber without direct handling. Mysids were placed in an intermediate beaker in groups of twenty and fed just prior to testing. After one hour the seawater and remaining nauplii were drained off and the beaker contents submerged in the bioassay aquarium.

Dimethyl sulfoxide and Corexit were bioassayed since future hydrocarbon fractions to be tested would contain only those components that are

TABLE 1. SALMONELLA MUTAGENICITY OF OIL FRACTIONS

| No. | Sample | Revertants Per Plate at Given Dosage, µg/plate[a] 1250 | 500 |
|---|---|---|---|
| 1. | Weathered PB Crude Oil Fraction A-2-13 | 32 | 42 |
| 2. | Weathered PB Crude Oil Fraction A-2-18 | 39 | 37 |
| 3. | Fresh PB Crude Oil Fraction A-2-6 | 41 | 40 |
| 4. | Fresh PB Crude Oil Fraction A-2-9 | 34 | 43 |
| 5. | Fresh PB Crude Oil Fraction A-2-13 | 34 | 29 |
| 6. | Fresh PB Crude Oil Fraction A-3-6 | 54 | 52 |
| 7. | Fresh PB Crude Oil Fraction A-3-9 | 72 | 72[b] |
| 8. | Fresh PB Crude Oil Fraction A-3-13 | 27 | 34 |
| 9. | Shale Oil Fraction A-2-4 | 35 | 39 |
| 10. | Shale Oil Fraction A-2-6 | 41 | 37 |
| 11. | Shale Oil Fraction A-2-9 | 24 | 39 |
| 12. | Shale Oil Fraction A-2-11 | 17 | 29 |
| 13. | Shale Oil Fraction A-2-13 | 24 | 33 |
| 14. | Shale Oil Fraction A-2-15 | 63 | 81[b] |
| 15. | Shale Oil Fraction A-2-18 | 65 | 80[b] |
| 16. | Shale Oil Fraction A-2-21 | 17 | 57 |
| 17. | Shale Oil Fraction A-3-3 | 37 | 43 |
| 18. | Shale Oil Fraction A-3-4 | 73 | 71[b] |
| 19. | Shale Oil Fraction A-3-13 | Toxic | 41 |
| 20. | Shale Oil Fraction A-3-18 | Toxic | 86[b] |
| 21. | Control | 39 | |
| 22. | 2-Aminoanthracene | 1574[c] | |

a. Salmonella strain 98 was used for all tests.

b. Slight mutagenicity indicated.

c. The dosage was 5 µg/plate.

TABLE 2. MAMMALIAN CELL TOXICITY ASSAY OF OIL FRACTIONS

| No. | Sample | Percent Confluency at Given Dosage, µg/ml 100 | 40 | 20 | Estimated $CD_{50}$,[a] µg/ml |
|---|---|---|---|---|---|
| 1. | Weathered PB Crude Oil Fraction A-2-18 | 0 | 82 | 96 | 60 |
| 2. | Fresh PB Crude Oil Fraction A-2-6 | 94 | 98 | 100 | >100 |
| 3. | Fresh PB Crude Oil Fraction A-2-9 | 89 | 94 | 96 | >100 |
| 4. | Fresh PB Crude Oil Fraction A-2-13 | 2 | 95 | 97 | 75 |
| 5. | Fresh PB Crude Oil Fraction A-3-6 | 0 | 2 | 93 | 30 |
| 6. | Fresh PB Crude Oil Fraction A-3-9 | 98 | 99 | 100 | >100 |
| 7. | Fresh PB Crude Oil Fraction A-3-13 | 0 | 68 | 97 | 50 |
| 8. | Shale Oil Fraction A-2-4 | 0 | 97 | 100 | 70 |
| 9. | Shale Oil Fraction A-2-6 | 0 | 38 | 90 | 35 |
| 10. | Shale Oil Fraction A-2-9 | 0 | 1 | 84 | 30 |
| 11. | Shale Oil Fraction A-2-11 | 0 | 3 | 88 | 30 |
| 12. | Shale Oil Fraction A-2-13 | 0 | 50 | 95 | 40 |
| 13. | Shale Oil Fraction A-2-15 | 0 | 62 | 94 | 45 |
| 14. | Shale Oil Fraction A-2-18 | 0 | 42 | 77 | 40 |
| 15. | Shale Oil Fraction A-2-21 | 0 | 20 | 49 | 20 |
| 16. | Shale Oil Fraction A-3-3 | 0 | 1 | 98 | 30 |
| 17. | Shale Oil Fraction A-3-4 | 0 | 0 | 3 | 10 |
| 18. | Shale Oil Fraction A-3-13 | 0 | 42 | 99 | 40 |
| 19. | Shale Oil Fraction A-3-18 | 78 | 73 | 92 | >100 |

a. The dosage level that would result in only 50% confluency.

soluble in DMSO, and with the added use of Corexit, should disperse in water much better than whole oil does.

A 10,000 mg/l stock solution of DMSO was prepared by adding 20 ml of DMSO (99 + %) to a 2-liter volumetric flask containing seawater and mixing ten times. Aliquots of the stock solution were measured by volumetric pipet and flasks and added to a second two-liter volumetric flask containing the diluent seawater. This was again mixed (15 times) and poured directly into the test aquaria for concentrations of 100, 500 and 1000 mg/l DMSO (see Table 3). The 5,000 and 10,000 mg/l solutions were mixed independently.

A stock solution of 10,000 mg/l Corexit was prepared by adding 5 ml of Corexit to a 500-ml volumetric flask and shaking ten times. Aliquots were delivered via volumetric pipet and flask to a 2-liter volumetric flask and seawater was added to the mark. This was mixed fifteen times and added to test aquaria for concentrations of 10, 50, 100 and 500 mg/l (see Table 3).

The Prudhoe Bay crude oil, DMSO and Corexit combination was next tested. Since the concentration for most future fractions was to be 40 mg/ml in DMSO, a 5-ml stock solution of 200 mg/5 ml Prudhoe Bay crude oil in DMSO was prepared. The mixing procedure for the bioassay solutions was as follows:

1. Seawater added to 2-liter volumetric flask.
2. Two microliters of Corexit added via microliter pipet.
3. Shaking for ten inversions of the 2-liter volumetric flask to mix the Corexit and water.
4. Twenty seconds of shaking of vial containing the oil in DMSO stock solution.
5. Addition of the oil/DMSO aliquot via microliter pipet or syringe.
6. Seawater added to the two liter mark of the volumetric flask and shaken for a total of 15 inversions.
7. Mixture poured into aquarium.

The concentrations of DMSO were 2.5, 10, 25, 100 and 250 mg/l, and the concentrations of oil in DMSO were 0.1, 0.4, 1, 4 and 10.0 mg/l, respectively. Corexit in all cases was 1.0 mg/l. Three replications were run of each concentration of DMSO/oil/Corexit (see Table 4).

TABLE 3. MYSIDS TOXICITY OF DIMETHYL SOLFOXIDE AND COREXIT

| Concentration, mg/l | % Mortality of Test Animals After 24 hrs | 24 hr LC50, mg/l | % Mortality of Test Animals After 48 hrs | 48 hr LC50 mg/l |
|---|---|---|---|---|
| | | Dimethyl sulfoxide | | |
| Control | 0 | | 5 | |
| 100 | 0 | | 0 | |
| 500 | 5 | | 10 | |
| 1000 | 5 | | 20 | |
| 5000 | 5 | | 15 | |
| 10,000 | 25 | >10,000 | 50 | 10,000 |
| | | Corexit | | |
| Control | 5 | | 5 | |
| 10 | 0 | | 5 | |
| 50 | 5 | | 11 | |
| 100 | 15 | | 55 | |
| 500 | 45 | >500 | 90 | 94 |

TABLE 4. MYSIDS TOXICITY OF PRUDHOE BAY CRUDE OIL IN DMSO AND COREXIT

| Concentration, mg/l | Test Set | % Mortality Of Test Animals After 24 Hrs | % Mortality Of Test Animals After 24 Hrs |
|---|---|---|---|
| Control | 1 | 10 | 10 |
| | 2 | 5 | 15 |
| | 3 | 0 | 0 |
| 0.1 PBC Oil | 1 | 10 | 10 |
| 2.5 DMSO, | 2 | 15 | 30 |
| 1.0 Corexit | 3 | 10 | 25 |
| 0.4 PBC Oil, | 1 | 5 | 20 |
| 10.1 DMSO, | 2 | 0 | 5 |
| 1.0 Corexit | 3 | 5 | 10 |
| 1.0 PBC Oil, | 1 | 5 | 10 |
| 25.0 DMSO, | 2 | 0 | 0 |
| 1.0 Corexit | 3 | 0 | 10 |
| 4.0 PBC Oil, | 1 | 25 | 30 |
| 100.0 DMSO, | 2 | 15 | 30 |
| 1.0 Corexit | 3 | 0 | 25 |
| 10.0 PBC Oil, | 1 | 10 | 25 |
| 250.0 DMSO | 2 | 5 | 10 |
| 1.0 Corexit | 3 | 25 | 35 |

The final set of bioassays was with DMSO and Corexit alone. A 10,000 mg/l stock solution of DMSO was again prepared and aliquots measured in volumetric flasks. The bioassay solution mixing procedure was as follows:

1. Seawater added to 2-liter volumetric flask.
2. Two microliters of Corexit added.
3. Shaking for ten inversions of the 2-liter volumetric flask to mix.
4. Addition of DMSO.
5. Seawater added to the 2-liter mark.
6. Shaking for 15 inversions of the 2-liter volumetric flask to mix.

Concentrations for DMSO in seawater were 25, 250, and 2500 mg/l with 1 mg/l Corexit. Two replications were run at each concentration (see Table 5).

Results

A 48-hr LC50 of 10,000 mg/l was obtained for dimethyl sulfoxide and a 48 hr LC50 of 94 mg/l for Corexit. With these toxicity thresholds in mind, the second series of bioassays containing a mixture of oil, DMSO and Corexit used maximal levels of 250 mg/l DMSO and 1 mg/l Corexit. It is interesting to note that no LC50 was reached using 10.0 mg/l whole oil (see Table 4).

The last set of bioassays to measure the combined effect of Corexit and DMSO did not reach an LC50, even at 2500 mg/l DMSO, an order of magnitude above that expected for use in future bioassay samples (see Table 5).

TABLE 5. MYSIDS TOXICITY OF DMSO AND COREXIT COMBINED

| Concentration, mg/l | Test Set | % Mortality Of Test Animals After 24 Hrs | % Mortality Of Test Animals After 48 Hrs |
|---|---|---|---|
| Control | 1 | 15[a] | 25 |
| 25 DMSO, | 1 | 10 | 25 |
| 1 Corexit | 2 | 10 | 25 |
| 250 DMSO, | 1 | 15 | 30 |
| 1 Corexit | 2 | 5 | 20 |
| 2500 DMSO, | 1 | 10 | 40 |
| 1 Corexit | 2 | 25 | 40 |

a. Air hose broke during the first 24 hrs of bioassay.

QUARTERLY REPORT

Contract # 3-5-022-56
Research Unit 537
Task Order 32
Report Period 1 July - 30 September, 1979
Number of pages: 6

# NUTRIENT DYNAMICS AND TROPHIC SYSTEM ENERGETICS IN NEARSHORE BEAUFORT SEA WATERS

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## I. TASK OBJECTIVES

The past quarter has been spent in completing laboratory analyses of samples collected in the past field season and conducting radiotracer experiments testing the ability of Beaufort Sea amphipods to digest cellulose in detrital peat. The individual task objectives undertaken may be summarized as follows.

1) Determine the extent to which the cellulose fraction present in eroded peat may serve as a direct energy source for Beaufort Sea amphipods.
2) Complete ice algae and phytoplankton standing stock estimates on ice cores and water samples obtained in the Beaufort Sea during Spring 1979.
3) Conduct laboratory investigations relating chlorophyll-a fluorescence to algal cell biomass and the variation in chlorophyll content during growth and senescence in algae.
4) Continue routine analyses of salinities and nutrient concentrations in water and ice samples obtained during the past field seasons.
5) Prepare samples of river-borne organic detritus for radiocarbon and $^{12}C/^{13}C$ isotope ratio analyses.
6) Develop techniques for measuring primary production and translocation of photosynthate in *Laminaria*.

## II. FIELD ACTIVITIES

Field Trips. Two field trips were conducted during the last quarter. The first, during 18-20 July, was to the Naval Arctic Research Laboratory at Barrow where experiments were conducted to measure the ability of amphipods to use peat as a direct carbon source for growth and energy requirements. This work was performed in cooperation with Dr. David Schneider of RU 356 and was designed to expand upon preliminary experiments conducted previously at Barrow. Amphipod sample collection involved obtaining animals amphipods from the nearshore zone by

nets along the shoreline. Amphipods were separated as to species and detritus utilization experiments were then conducted using the freshly collected specimens.

The second field trip was a cooperative effort with Ken Dunton (RU 356) and involved testing experimental designs to enable the measurement of carbon fixation and translocation of photosynthates within *Laminaria* blades. This work was accomplished at Point Migley, Lummi Island, Washington where a study site in *Laminaria* beds is available. The techniques employed are being refined for use in Stefansson Sound during the Spring 1980 field season. Field logistic sypport was provided by RU 356 personnel and Western Washington University.

Methods. The biological utilization of detrital peat by amphipods and microflora was measured in a series of tracer experiments using C-14 labeled cellulose. To test if the amphipod *Gammarus setosus* could directly utilize peat (cellulose) the following experiment was employed. To each of six flasks containing 2 liters of Beaufort Sea water (8°C) was added:

Flask A - 120 ug cellulose-C-14.

Flask B - *Gammarus* amphipods (9) + 120 ug cellulose-C-14

Flask C - Peat (80 mg dry weight) + 120 ug cellulose-C-14

Flasks D, E - Peat (∿80 mg dry weight) + *Gammarus* (9/flask) + 120 ug cellulose-C-14/flask

Flask F - Control - Peat (∿80 ug dry weight) + $Hg^{+2}(10^{-5}M)$ + 120 ug cellulose-C-14

The oxidation of the cellulose in each flask was followed by taking 300 ml subsamples of water and measuring the quantity of $^{14}CO_2$ produced by biological oxidation. After an initial "zero-time" sampling, the flasks were sampled at approximately 5, 8 and 20 hours. Each subsample of water was acidified and the carbon dioxide stripped by a stream of nitrogen and, after drying over sulfuric acid, collected in a vial containing phenethylamine liquid scintillation cocktail. The radioactivity was then measured by routine liquid scintillation counting.

Digestion and assimilation of cellulose by the gammarus amphipods was measured by sacrificing three of the animals at the time of each

water subsample. Animals were dissected and the entire intestinal tract separated from the remainder of the body. These samples were burned in a Harvey Biological Oxidizer and the resulting $^{14}CO_2$ captured in phenethylamine cocktail and counted. By comparing the rates of $^{14}CO_2$ production in flasks with and without amphipods, the relative oxidation rates by amphipods, microflora and the assimilation efficiences of the amphipods could be determined.

A comparison of cellulose oxidation by *Gammarus* and *Onisimus* amphipods was undertaken in a similar experiment except that whole body counts were used instead of dissections prior to counting. To offset the smaller size of the *Onisimus* amphipods, four animals were counted at each sampling interval.

Techniques for measuring uptake and translocation of carbon during carbon fixation and heterotrophic assimilation by *Laminaria* were tested at a study site off Point Migley, Lummi Island, Washington. Selected plants were either placed in clear or black plastic bags or fitted with small incubation chambers glued to the blades above the meristematic region of the blade.

Into the bags (or chambers) was added a known volume of seawater and either 5 microcuries of $^{14}C$ - bicarbonate or one microcurie of $^{14}C$-labeled glycine or acetate. At intervals of 24 hours thereafter, disks were cut from the blades at locations along the blade axis above and below the chamber or from the plants in the plastic bags. The disks were rinsed and wiped dry and then burned and the $CO_2$ counted for $^{14}C$ activity as described above.

## PRELIMINARY RESULTS

Cellulose Biooxidation Experiments. The data processed to date indicate that *Gammarus setosus* has the ability to digest and assimilate cellulose and by inference, the peat detritus found in the nearshore Beaufort Sea. During the 18 hour experiment, samples with amphipods present consumed and released as carbon dioxide approximately 4.6 percent of the labeled cellulose offered in contrast to 1.3 percent in

the peat and water alone (which measures the microbial contribution). The observed rates can be translated into a specific oxidation rate of approximately 17 ug peat/hr consumed and released as $CO_2$ by each amphipod under the 8°C conditions. If the body radioactivity is added to this, the total uptake increases by approximately 2.5 ug/hr-amphipod, which implies an assimilation efficiency during the course of the experiment of 12.5 percent. This rate of assimilation is sufficient to account for the growth rates observed by RU 467 and RU 356 investigators in natural systems although it is unlikely that *G. setosus* utilizes detrital food chains as its sole source of energy. These data show, however, that *G. setosus* is a direct link between detritus and macrofauna in a detrital based foodweb and capable of obtaining a large fraction of its energy requirements from cellulosic material eroded or fluvially transported into the nearshore zone.

The significance of the rapid cellulose utilization rates of *G. setosus* becomes apparent when compared with data obtained in similar experiments in which the test organisms were *Boeckisimus sp* and *Onisimus sp*. In both cases, no evidence of either carbon dioxide evolution or assimilation of carbon from $^{14}C$-labeled cellulose due to amphipods was apparent. These amphipods may not possess the intestinal microflora or the intrinsic enzymatic systems required for cellulose degradation and would require indirect sources such as meiofauna associated with detritus to enter detritus based foodwebs. Natural radiocarbon abundances in *Onisimus* amphipods collected in Simpson Lagoon support the conclusion that little peat carbon is transferred to these organisms. At this time, the conclusions described must be considered as tentative until the experiments have been verified by repetition and the cellulosic content of eroded peat detritus has been determined. It is reasonable to expect that the pathways utilizing lignin and hemicelluloses may be somewhat different and that weathered peats may be depleted in cellulose relative to the fresh vegetative material.

*Laminaria* Uptake Experiments. Photosynthetic fixation of $^{14}C$-bicarbonate was successfully measured in plastic bag enclosures of whole *Laminaria* plants. However, the amount of labeled bicarbonate added in the small chamber experiments (5μCi) was insufficient to measure uptake

and translocation of photosynthate along the blade except in the immediate vicinity of the chamber. However, by increasing the incubation times and the amount of label by 2-5 fold, these problems are expected to disappear. It is anticipated that the techniques developed will be of use in measuring both primary production rates and the translocation of photosynthate in *Laminaria* over the course of the arctic winter in experimental plants in Stefansson Sound. These experiments will be conducted during the Spring 1980 field season.

## PROBLEMS ENCOUNTERED

No problems of unexpected nature were evident during research efforts in the past quarter. The research goals set forth were all met on schedule.

QUARTERLY REPORT

Contract # 3-5-022-56
Research Unit 537
Task Order 32
Report Period 1 October - 31 December 1979
Number of pages: 4

# NUTRIENT DYNAMICS AND TROPHIC SYSTEM ENERGETICS IN NEARSHORE BEAUFORT SEA WATERS

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## I. TASK OBJECTIVES

The overall objectives of RU 537 are to describe the principal processes supplying energy (i.e. fixed carbon) to the biota of the Beaufort Sea coastal zone and to relate the various nutrient chemistry regimes observed to this production of energy. Both terrestrially derived and in situ energy production mechanisms are considered in relation to their support of marine foodwebs. We seek to describe the significance of various energy sources to key invertebrates and higher fauna considered important to the ecosystem and for human utilization.

The past quarter has been spent in the collection of additional water samples and light measurements in Stefansson Sound and on analytical work in the laboratory. Specific objectives for these efforts include:

1. Determine November 1979 under-ice nutrient concentrations in nearshore Beaufort Sea waters.
2. Determine light attenuation by sea ice during the fall season.
3. Obtain samples of nearshore fauna for carbon isotope determina tion.
4. Complete nutrient analyses on samples obtained from the Stefansson Sound-Simpson Lagoon area during summer 1979.

## II. FIELD ACTIVITIES

Field trips. One field trip to Prudhoe Bay was undertaken during the past quarter, from 9-12 November. Personnel participating were Don Schell and Robert Harris. Weather conditions for flying were generally bad but one day provided good flying and 12 of 14 planned stations were occupied. Aircraft support was a chartered Bell 206 helicopter. The weather on following day deteriorated drastically and because demand was high from other investigators for helicopter time, it was decided to conclude the sampling effort. The stations that had been sampled were chosen to provide good areal coverage and it is not felt that the failure to sample the remaining stations detracts much from the data gathered.

Methods. Sampling holes were bored using a Hoffco ice auger. The thinness of the ice and relatively warm air temperatures resulted in rapid penetration which aided quick completion of each station. Water samples were collected with a 2-liter VanDorn bottle. Light measurements were taken with a Protomatic light meter which had the sensor mounted on a flexible arm to enable light measurements to be read beneath the ice 1 m away from the borehole. Light measurements were taken on the north, south, east, and west sides of the borehole both looking up at the ice and down into the water with the sensor.

Upon returning to Prudhoe, the water samples were halved with the whole water frozen for subsequent chlorophyll fluorescence analysis and the remainder filtered and frozen for nutrient analysis in Fairbanks. The nutrient concentrations and chlorophyll fluorescence were determined as soon as feasible upon return to the Institute of Water Resources.

## III. PRELIMINARY RESULTS

Light measurements in the Stefansson Sound area confirmed that turbidity in even thin ice ($\sim$ 35 cm) reduces light penetration to almost undetectable levels. Turbidity, which is due to the inclusion of organic particulate matter in the ice, is highly localized within a particular area but a common phenomenon both inside and outside of the barrier islands where stratification of the water column is not pronounced. At one station (Foggy Island Bay) there were large quantities of loose slush ice beneath the surface ice sheet, which may indicate anchor ice formation at depth and subsequent floating of the crystals to the underside of the ice sheet. These data would indicate that the presence or absence of spring epontic algal blooms on the underice surface is determined early in the winter season at many Beaufort Sea locations. The required light intensity to initiate and sustain the ice algae bloom would not be present due to ice turbidity at many of the stations occupied, assuming the present ice cover remains shorefast. Furthermore, in areas of heavy particulate inclusion in the ice, the water-column algal bloom would not occur until well into the following summer when the ice melts.

This prevention of algal growth effectively shortens the primary production season and could result in high year-to-year variability in annual primary production. It is reasonable to assume that the effects of this variation are felt up the nearshore food chains. Further investigation into the spatial distribution of turbid ice and the effects on under-ice productivity will be undertaken by this research unit and others during 1980.

## IV. PROBLEMS ENCOUNTERED

Poor flying weather during November limited the area sampled but most of the planned stations were occupied. All laboratory work is proceeding on schedule.

# EFFECTS

EFFECTS

Contents

Quarterly Report
April-June 1979
Research Unit #73

# SUBLETHAL EFFECTS OF PETROLEUM HYDROCARBONS AND TRACE METALS, INCLUDING BIOTRANSFORMATIONS, AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, PATHOLOGICAL, AND BEHAVIORAL INDICES

by

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June 26, 1979

## I. ABSTRACT

The responses of marine organisms to environmental contaminants are reflected in numerous changes that are detectable at population and organismic levels, as well as at cellular and molecular levels. The general scope of this study is to evaluate effects caused by behavioral, physiological, pathological, morphological, and chemical changes in subarctic and arctic marine animals exposed to petroleum.

The report for this quarter will highlight the developmental biology studies (see Physiology) concerning the effects of slightly weathered Prudhoe Bay crude oil (PBCO) on the development of chum salmon (Oncorhynchus keta) embryos and alevins. Brief reviews will be included of the status of studies of pathological effects of exposing flatfish to oil-contaminated sediment, and of tests for binding of hydrocarbon/metabolites to DNA in tissues of flatfish exposed to petroleum-contaminated sediment.

*Physiology*

The effect of slightly weathered PBCO on the development and survival of chum salmon embryos and alevins was evaluated in laboratory studies. The embryos were relatively resistant to oil, although a substantial number (42%) of the group of fish exposed throughout embryonic development died. The effect of oil exposure was more manifest following hatching, with alevin mortality observed (as high as 82%) that was generally reflective of the duration of exposure to oil.

Exposure of newly hatched alevins to slightly weathered PBCO increased the mortality of fish at this developmental stage by more than 100%, compared to unexposed controls.

There were no detected gross abnormalities clearly resulting from oil exposure.

*Chemistry*

The metabolic activation and subsequent binding of benzo[a]pyrene (BP) to salmon sperm DNA were catalyzed by liver extracts of starry flounder (Platichthys stellatus) and English sole (Parophrys vetulus). Specific activity (S.A.) of binding (pmoles bound/mg DNA/mg protein) for fish liver extract at 25°C was comparable to S.A. obtained with rat liver extract at 37°C. Moreover, the pattern of nonconjugated metabolites accumulated in fish liver extracts was similar to that obtained for rat liver supernatant; with BP 7,8-, 9,10-dihydrodiol and 3-hydroxy BP constituting the major metabolites.

*Pathology*

An experiment which involved exposure of juvenile English sole to sediment contaminated with 1.0% (v/v) PBCO was terminated after 4 months. No grossly visible differences were observed between test and control fish. Tissue specimens are currently being subjected to histopathological and chemical analyses. A similar experiment using pre-juvenile (less than 6 months old) English sole is now being initiated.

## II. OBJECTIVES

*Physiology*

To evaluate the effects of weathered PBCO on chum salmon embryo and alevin development.

*Chemistry*

To investigate the metabolism and disposition of petroleum hydrocarbons in demersal fish. Specifically, in the present studies to test the binding of hydrocarbon/metabolites to DNA in tissues of flatfish exposed to petroleum-contaminated sediment.

*Pathology*

To determine the frequency and nature of pathological changes occurring in flatfish as a result of exposure to oil-contaminated sediments.

## III. FIELD OR LABORATORY ACTIVITIES

### A. SHIP OR FIELD TRIP SCHEDULE - N/A

### B. SCIENTIFIC PARTY

The following persons affiliated with the Environmental Conservation Division of the Northwest and Alaska Fisheries Center participated in the planning, development, and performance of experiments presented in this report.

| Name | Role |
|---|---|
| D. Malins, PhD, DSc | Principal investigator; hydrocarbon metabolism |
| H. Hodgins, PhD | Principal investigator; physiology and pathology studies |
| D. Weber | Principal investigator; physiology studies |
| D. Misitano | Fishery research biologist; physiology studies |
| U. Varanasi, PhD | Research chemist; hydrocarbon studies |
| D. Gmur | Chemist; hydrocarbon studies |
| K. Gleim | Chemist; hydrocarbon studies |
| T. Scherman | Physical science technician; assistant in hydrocarbon analyses |
| B. McCain, PhD | Microbiologist; pathology studies |
| W. Gronlund | Fishery research biologist; pathology studies |

| | |
|---|---|
| W. Ames | Fishery research biologist; pathology studies |
| J. Hawkes, PhD | Fishery research biologist; cell biology studies and electron microscopy |
| C. Stehr | Fishery research biologist; cell biology studies |
| E. Gruger, Jr., PhD | Research chemist; coordinator of chemical analyses. |

## C. METHODS

### *Physiology*

The method of generating weathered PBCO and exposure of chum salmon eggs and alevins to weathered oil is described in detail in the OCSEAP RU-73 Annual Report, April, 1979. Briefly, the experimental design consisted of layering fresh PBCO on the water surface of a flow-through wave generator at an initial concentration of 4,000 ppm (v/v). After outdoor "weathering" of the oil for 30 hr, water was drawn off through a 25 cm deep gravel beach located at one end of the generator and distributed to gravel-lined glass troughs at a flow rate of 400 ml/min per trough. For 3 hr each day, 4 days per week, the troughs with salmon eggs or alevins were exposed to brackish water containing weathered oil. At the same time, troughs containing control eggs and alevins received brackish water without added oil; for the other 21 hr/day all troughs received dechlorinated fresh water. The 30 hr weathering process and exposure regime were repeated each week from late December, 1978, to button-up stage mid-April, 1979, when the fry were transferred to saltwater (Fig. 1). The fry were then held and fed for another 15 days before the experiment was terminated. During oil-exposure the brackish water temperature ranged from 4.5° to 10.2°C (salinity range 16-24 °/oo), and the freshwater temperature ranged from 5.5° to 10.5°C.

Analytical chemistry is in progress which is designed to depict changes that occurred in the PBCO, and products formed, as a result of the 30 hr weathering process, but the analyses have not been completed. These results will be presented in a subsequent report.

Egg mortality and rate of embryo development were determined from samples of 40 or more eggs; mortality was determined also by counts of dead eggs collected at time of hatching compared with the initial number of eggs placed in each trough. Alevin mortality was calculated from the number of survivors at termination of the experiment and the number of dead alevins recovered. The latter calculations are minimal estimates of mortality.

In addition to alevin exposure to weathered oil in troughs, some alevins were held in inverted glass one-gallon jugs with the bottoms removed for evaluation of effects of oil on alevin emergence from gravel. The jugs were filled with coarse gravel to a depth of 20 cm, and supplied with water upwelling from the bottom (neck).

Replicate water samples for gas chromatographic (GC) analysis were taken daily from lines leading into the egg-holding troughs. Extraction procedures for removal of petroleum hydrocarbons are described in the OCSEAP RU-73 Annual Report, April, 1979.

Data were treated statistically using chi-square analysis.

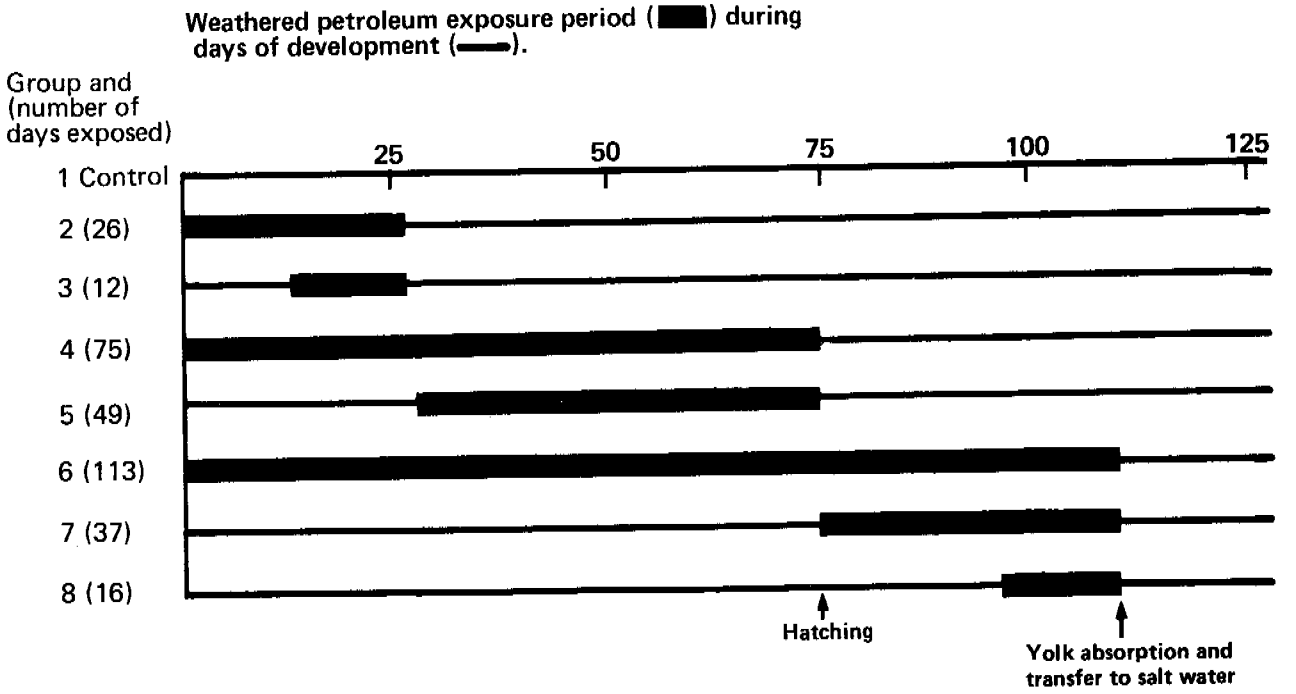


FIG. 1. Days of development of chum salmon eggs and alevins, and time and duration of exposure to weathered PBCO.

*Chemistry*

Livers of English sole exposed to petroleum-contaminated sediments (see Pathology) were taken at 24, 61, and 91 days after the initiation of exposure. Livers of control fish were also taken at each of these time periods. Liver supernatants (10,000 x g) were prepared and stored at -60°C for future analyses.

Using liver supernatants from control starry flounder and English sole, metabolism of benzo[a]pyrene was studied in vitro to determine optimum conditions of temperature, pH, substrate concentration, and NADPH concentration. Moreover, optimization studies were carried out for determining specific activity of binding (pmoles bound/mg DNA/mg protein) to DNA using liver supernatants from control fish. Profiles of organic-soluble metabolites were obtained using thin-layer chromatography (Burke et al. 1978).

*Pathology*

Two groups of 44 English sole each (test and control) were exposed to high-silt sediment (silt content of 47.4%) either with or without added PBCO (1.0% v/v). At 0-time, and at 24, 61, 91, and 126 days, 6 fish from each group were sacrificed and samples of tissue were taken for histological, hematological, and chemical analyses. At these same intervals all the fish were examined for external abnormalities and measured for length, and surface sediment samples were collected and frozen for chemical analyses.

D. SAMPLE LOCATIONS

Flatfish were collected from Puget Sound or the estuary of the Columbia River.

Chum salmon eggs were collected at the Quilcene National Fish Hatchery, Quilcene, Washington on the day of artificial spawning. All eggs were from a single female to minimize variability.

E. DATA COLLECTED OR ANALYZED

1. Number and Types of Samples/Observations

At approximately one month intervals after fertilization, 10 g samples of chum salmon eggs or alevins were collected for determination of petroleum hydrocarbon uptake. Over 190 control and weathered oil water samples were collected along with 28 samples of weathered "mousse."

As part of the chum salmon development studies, tissues from 28 oil-exposed alevins were sampled. Ten were processed for scanning electron microscopy and 6 have been examined; 8 were processed for light microscopy and transmission electron microscopy, and 3 have been examined by light microscopy.

As part of the pathology research, 240 tissue samples were taken for histology, 24 blood samples were collected for hematology, 8 sediment samples were taken for hydrocarbon analysis, and 3 tissue samples were collected for hydrocarbon analysis.

2. Number and Types of Analyses

136 oil-in-water samples have been extracted, and 36 have been analyzed for hydrocarbon composition by GC.

24 hematological analyses have been completed.
135 flatfish tissue specimens have been examined histologically.

3. Miles of Trackline - N/A

IV. RESULTS

*Physiology*

A. EMBRYOS

Chum salmon eggs were exposed to weathered PBCO starting 1, 14, or 26 days after fertilization (see Fig. 1). There was no consistent pattern of differential mortality between embryos exposed to weathered oil and non-oil-exposed embryos in samples collected at 26 or 75 days of development (Table 1). Of the dead embryos examined at 75 days, those exposed to oil within the first 26 days (Groups 2, 3, 4, and 6) showed an average of only 38% attaining the eyed stage of development, compared to 65% for controls. (All the data were adjusted for 2.6% of the eggs which were unfertilized.)

Table 1. Percent mortality of embryos after 26 days of development and at time of hatching (75 days), percent of dead embryos on day 75 attaining eyed stage of development, and percent of viable eggs hatched on days 76 and 82.

| Group[a] | Days oil exposure | Cumulative % mortality on day of development | | % of dead embryos attaining eyed stage[b] | Cumulative % hatch of viable eggs on days | |
|---|---|---|---|---|---|---|
| | | 26 | 75 | | 76 | 82 |
| 1 | Control | 2 | 27 | 65 | 15 | 70 |
| 2 | 1-26 | 16 | 25 | 14 | 95 | 99 |
| 3 | 14-26 | 11 | 28 | 31 | 60 | 95 |
| 4,6 | 1-75 | 7 | 42 | 47 | 50 | 96 |
| 5 | 26-75 | 2 | 9 | 70 | 80 | 98 |

[a] See Figure 1.
[b] Occurs at approximately 45 days of development.

Though there were no obvious differences in growth of oil-exposed versus control embryos (Fig. 2), time of hatching was consistently earlier for all oil-exposed embryos. Within 10 days from initiation of hatching over 99% of all viable eggs had hatched and there were no marked differences in hatching success between oil-exposed and control groups.

B. ALEVINS

After hatching, exposure to weathered oil was continued in one group (Group 6) and one of the control groups was switched to oil exposure (Group 7). The cumulative mortality for controls and the 6 oil-exposed groups is shown in Figure 3. Generally, the longer the duration of exposure to weathered

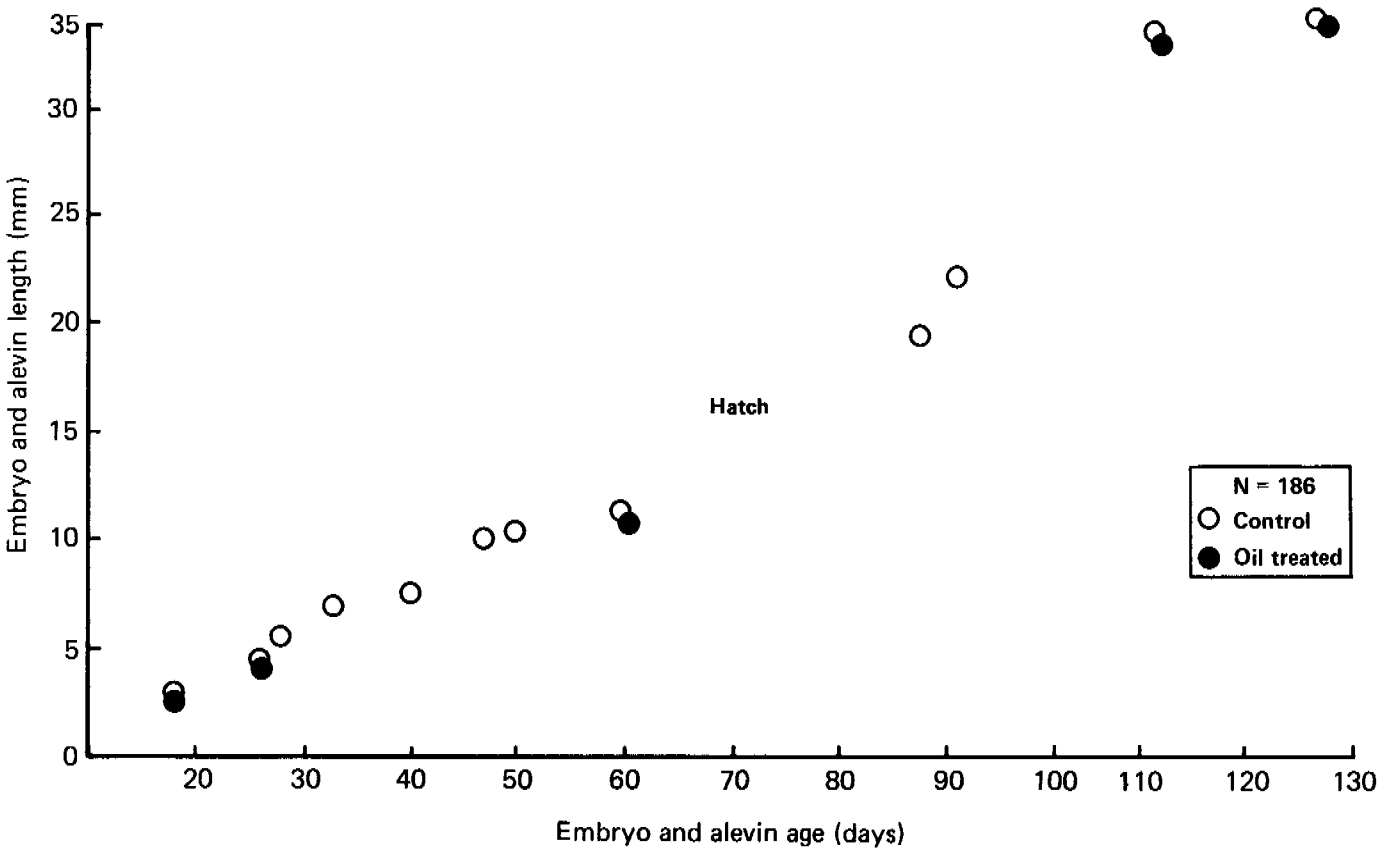


FIG. 2. Growth of chum salmon control embryos and alevins (open circles) and embryos and alevins exposed continuously to weathered PBCO (solid circles).

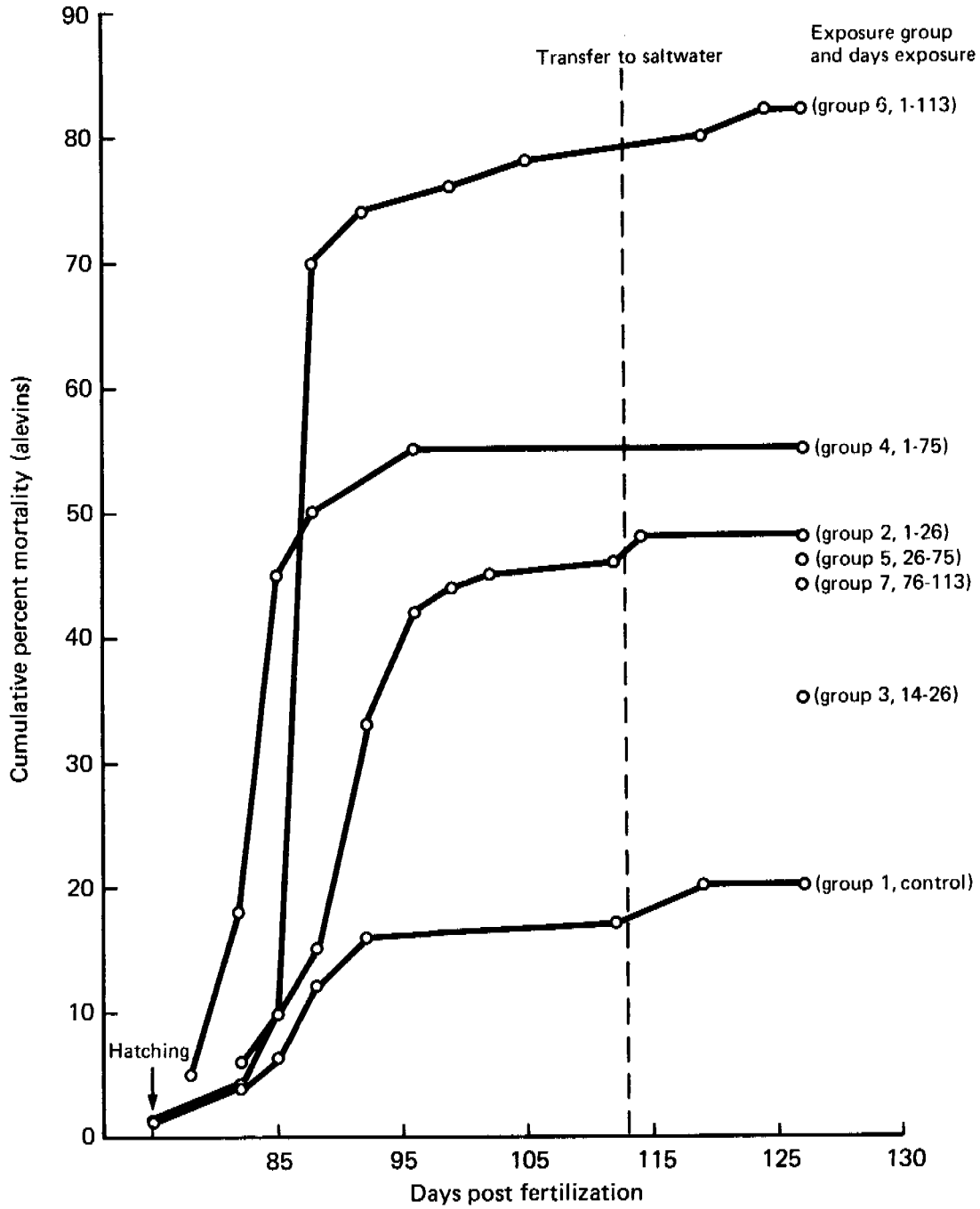


FIG. 3. Cumulative percent mortality for alevin chum salmon exposed to weathered PBCO for periods of 1 to 113 days after fertilization. Transfer to saltwater occurred at completion of yolk absorption.

oil the lower the survival, with 85% of the mortality occurring within 20 days after hatching. There was no appreciable increase in mortality in any groups following the termination of oil exposure and transfer to salt water.

Twenty-two days after hatching, one of the two remaining control groups was divided and half of the alevins were exposed (on day 97 post fertilization) to weathered oil for the following 16 days (Group 8, Fig. 1). There were no mortalities in this oil-exposed group; however, it was observed that during the 3 hr exposure periods 50% or more the alevins were swimming near the water surface at a 45 to 80 degree angle to horizontal. This posturing at the surface appears typical of fry and juvenile salmon during exposure to petroleum hydrocarbons (Morrow 1975, Cardwell 1973; Bean et al. 1974). To determine if this behavioral response to weathered oil was sufficient to force the alevins out of the gravel prior to natural emergence, 20 control fish were placed in each of two gravel filled gallon jugs. For the following 10 days (days 103-113 post fertilization) the fish in one container were exposed for 3 hr/day to weathered oil and alevins in the other container served as controls. There was no detectable differences in behavior of alevins in either jug, with 5 to 10% of both control and oil-exposed alevins appearing on the gravel surface. During the 10-day experiment there was a 10% mortality in each container.

Gross abnormality in alevins (i.e., severe spinal curvature) was observed in all oil-exposed and control groups at a frequency of 1 to 3%. At the termination of the experiment all survivors were feeding, and the average length of control and oil-exposed alevins was similar (Fig. 2).

Hydrocarbon concentrations in the water during the overall exposure period averaged 526 ppb.

### *Chemistry*

Results show that, as with mammals, benzo[a]pyrene (BP) is metabolically activated and becomes bound to DNA in the presence of liver extracts from English sole and starry flounder. Specific activity (S.A.) of binding for fish liver enzymes at 25°C (optimum temperature for *in vitro* studies) was comparable to S.A. of binding for rat liver extract at 37°C. No appreciable binding occurred in the absence of NADPH indicating a strong requirement for NADPH for binding of BP to DNA when fish liver enzymes were used. The pattern of nonconjugated metabolites (determined by thin-layer chromatography) accumulated in liver extracts was similar to that reported for rat liver extracts, with 7,8-, and 9,10-dihydrodiol and 3-hydroxy BP constituting the major metabolites. Studies are in progress to assess if exposure to petroleum-contaminated sediments caused differences in the pattern of metabolites of BP or in the extent of binding of metabolically activated BP to DNA in the liver of English sole.

### *Pathology*

During the 126 days in which the English sole were exposed to PBCO-contaminated sediments, no significant differences in the gross appearance or weight and length of the test and control groups were observed. Examination of histological and hematological specimens is continuing; no conclusions can be made at this time. A similar experiment using recently metamorphosed, less than 6 month old, English sole is being initiated.

## V. PRELIMINARY INTERPRETATION OF RESULTS

### *Physiology*

Survival of chum salmon eggs was not decreased at hatching (day 75, Table 1) following exposure to slightly weathered PBCO for either the first third or the last two-thirds of their development period. Continuous exposure to the weathered oil throughout embryonic development, however, did significantly ($P=0.01$) reduce survival, compared with controls. The primary effect of oil exposure during embryonic development appeared in the first 10 to 15 days after hatching (Fig. 3). For embryos and alevins exposed continuously during development only 20% of those hatching survived through yolk sac absorption. There were no gross teratogenic effects of oil exposure observed, and some short-term oil-exposure during embryonic development may accelerate hatching.

The experimental design of the present study on chum salmon and those conducted by Rice et al. (1975) and Moles et al. (1979) on pink and coho salmon are quite different and thus not directly comparable. The major differences between this study with chum salmon and that report by Rice et al. (1975) is the weathering of PBCO prior to egg and alevin exposure (chum), and the duration of exposure which was limited to 4 days for eggs and 10 days for alevins by Rice et al. In the study with pink salmon the eggs were found to be extremely resistant to acute doses of oil, and sensitivity to oil generally increased as the alevins matured. This same trend of increased sensitivity to PBCO as development proceeded was also evident in studies by Moles et al. (1979) with coho salmon (O. kisutch) eggs and alevins. The results of the present chum salmon studies suggest in addition that there was a latent effect from oil-exposure prior to hatching that contributed to reduced survival of the alevins, i.e., after hatching. This may be an effect directly on the developing embryo or an effect related to an accumulation of hydrocarbons in the yolk, and may reflect metabolic processes resulting in alteration of hydrocarbons and production of toxic products.

### *Chemistry*

The results show for the first time that liver enzymes of a marine fish: (a) catalyze the binding of benzo[a]pyrene to fish DNA *in vitro*, and (b) that the 7,8-dihydrodiol of benzo[a]pyrene, which is thought to be the ultimate carcinogen in mammals, was one of the major metabolites of this compound present in liver extracts of starry flounder and English sole. The implications are, therefore, that this constituent of petroleum can be biotransformed to mutagens and carcinogens by fish liver enzymes.

### *Pathology*

Because all the necessary analyses have not been completed for the most recent 4-month experiment, definitive interpretations cannot be made. The indications are, however, that the oil exposure had no grossly or microscopically detectable pathological effect on the juvenile English sole.

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VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES - None.

QUARTERLY REPORT
JULY-SEPT. 1979
RESEARCH UNIT #73

# SUBLETHAL EFFECTS OF PETROLEUM HYDROCARBONS AND TRACE METALS, INCLUDING BIOTRANSFORMATIONS, AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, PATHOLOGICAL, AND BEHAVIORAL INDICES

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I. ABSTRACT

The general scope of this study is to evaluate behavioral, physiological, pathological, morphological, and chemical changes in subarctic and arctic animals exposed to petroleum.

The report for this quarter will highlight the completed studies (see Physiology) on the effects of fresh and slightly weathered crude oil on the development of flatfish eggs, embryos, and larvae. Abstracts will be included concerning the status of pathological effects of exposing flatfish to oil-contaminated sediment, and of the metabolism and binding of hydrocarbon/metabolites to DNA of tissues of hydrocarbon-exposed and control salmon and flatfish. The latter studies will be presented in greater detail in subsequent reports.

## Physiology

Flatfish (Pleuronectidae) eggs may be particularly vulnerable to floating oil and the saltwater-soluble fraction (SWSF) of oil associated with an oil slick since eggs of many pleuronectid species incubate at or near the surface of the water column. To evaluate this potential susceptibility two species of flatfish eggs, embryos, and larvae were exposed to fresh Prudhoe Bay crude oil (PBCO), weathered PBCO, and the weathered SWSF of PBCO. Fresh PBCO and the weathered "mousse" of PBCO layered on the water surface generally induced high egg and embryo mortality. Eggs exposed to the weathered SWSF of PBCO did not undergo extremely high mortality nor was embryonic development inhibited, but most hatched larvae exhibited morphological abnormalities.

## Chemistry

The covalent binding of metabolically activated benzo[a]pyrene (BP) to salmon DNA by liver enzymes of untreated starry flounder (Platichthys stellatus) was respectively 7.5 and 2.5 times greater than the corresponding values for coho salmon (Oncorhynchus kisutch) and rat. Prior intraperitoneal injection of both fish species with polynuclear aromatic hydrocarbons (PAH), such as 3-methylcholanthrene (MC) or BP, resulted in a marked (10-53-fold) increase in the binding.

Benzo[a]pyrene metabolites formed by fish liver supernatants consisted of BP dihydrodiols (4,5-, 7,8-, and 9,10-dihydrodiols), phenols (3-OH, 9-OH, 7OH), quinones (3,6-, 1,6-, and 6,12-Q), and BP 4,5-oxide. In both salmon and flatfish, BP 9,10-dihydrodiol and BP 7,8-dihydrodiol were the major metabolites comprising 48-72% of the total ethyl acetate-extractable metabolites. The ratio of the dihydrodiols to phenols was significantly greater for both fish species compared to rat.

## Pathology

English sole (Parophrys vetulus) exposed to high-silt sediment contaminated with 1.0% (v/v) PBCO for 126 days did not consistently differ from controls in any of the parameters examined. Both groups had abnormalities in livers and olfactory organs which were not correlated with exposure to petroleum. Hematocrit values and hemoglobin levels for oil-exposed fish were higher than controls, but the differences were not always statistically significant.

II. OBJECTIVES

## Physiology

To evaluate the effect of PBCO on the development of eggs, embryos, and larvae of two species of flatfish.

## Chemistry

To investigate the metabolism and disposition of petroleum hydrocarbons in marine fish. Specifically, in studies this quarter 1) to investigate the metabolism of BP by liver enzymes of coho salmon and starry flounder exposed to PAH, and 2) to investigate the binding of BP to salmon DNA in the presence of liver enzymes from PAH-exposed or control flatfish and salmon.

## Pathology

To determine the frequency and nature of pathological changes occurring in flatfish as a result of exposure to oil-contaminated sediments.

III. FIELD OR LABORATORY ACTIVITIES

A. SHIP OR FIELD TRIP SCHEDULE - N/A.

B. SCIENTIFIC PARTY

The following persons affiliated with the Environmental Conservation Division of the Northwest and Alaska Fisheries Center participated in the planning, development, and performance of experiments presented in this report.

| Name | Role |
|---|---|
| D. Malins, PhD, DSc | Principal investigator (P.I.); hydrocarbon metabolism |
| H. Hodgins, PhD | P.I.; physiology and pathology studies |
| D. Weber | P.I.; physiology studies |
| D. Misitano | Fishery research biologist; physiology studies |
| U. Varanasi, PhD | Research chemist; hydrocarbon studies |
| D. Gmur | Chemist; hydrocarbon studies |
| K. Gleim | Chemist; hydrocarbon studies |
| T. Scherman | Physical science technician; assistant in hydrocarbon analyses |
| B. McCain, PhD | Microbiologist; pathology studies |
| W. Gronlund | Fishery research biologist; pathology studies |

| | |
|---|---|
| W. Ames | Fishery research biologist; pathology studies |
| J. Hawkes, PhD | Fishery research biologist; cell biology studies and electron microscopy |
| C. Stehr | Fishery research biologist; cell biology studies |
| E. Gruger, Jr., PhD | Research chemist; coordinator of chemical analyses |

C. METHODS

Physiology

Fresh, weathered, and the weathered SWSF of PBCO were used in the flatfish egg experiments. The method of weathering PBCO is described in OCSEAP R.U. #73, Annual Report, April 1979. Briefly, the weathering of oil consisted of layering fresh PBCO on the water surface of a flow-through wave generator at an initial concentration of 4,000 ppm (v/v). After outdoor agitation of the oil for 28 to 30 hr, "mousse" from the water surface was collected, and "weathered" SWSF was drawn off from the bottom of the wave generator. During weathering the saltwater temperature was 7.8 to 9°C and the salinity was 27 to 30 ppt.

Two species of flatfish eggs were tested, English sole and sand sole (Psettichthys melanostictus). Gravid fish were taken by trawl from Puget Sound, and stripped and fertilized immediately on board. All eggs used in each test were from a single female to reduce variations in viability of eggs between females. Fertilization success rates and subsequent viability were very high, approximately 90% as indicated by cell cap formation.

Twenty-four hours after fertilization (early cell cap stages), the eggs were introduced into 1,000 and 2,000 ml separatory funnels containing either fresh or weathered PBCO layered on the water surface, or the SWSF of weathered PBCO obtained from the wave generator. The funnels were attached to an air supply through the bottom and air was bubbled slowly through the mixture; this created a gentle current in the funnel keeping the eggs in suspension. Funnels were immersed during the incubation period in a water bath at 10°C.

Water samples for chemical analysis were taken after 3 days and again after hatching (8 days). Samples were taken by transferring the contents of the funnel, except for the oil on the water surface, into a beaker. The water was then siphoned from the beakers through a screened cylinder to prevent the passage of eggs and larvae. For samples taken in mid-incubation, the eggs were then poured back into the funnels and topped off with non-oil-contaminated seawater. Layered oil was not renewed so hydrocarbon concentrations were essentially reduced after the first water change. The weathered SWSF was renewed with an aliquot of the original SWSF which had been refrigerated in a sealed glass bottle with a teflon-lined lid.

The water samples were analyzed by gas chromatography and total hydrocarbons detected by this method were determined. Extraction procedures for removal of petroleum hydrocarbons are described in the OCSEAP R.U. #73, Annual Report, April, 1979, with the exception that n-decylcyclohexane was added as an additional recovery standard. The concentration of total hydrocarbons presented are not adjusted for percents recovery which were 60.5 and 90.8% for triisopropylbenzene and n-decylcyclohexane, respectively.

Some hydrocarbons were extracted from control water samples taken after incubation with flatfish eggs for 3 days. The concentration of hydrocarbons in

control water (10 to 32 ppb) was not subtracted from the total hydrocarbon concentration found in water samples from oil-exposed groups.

Samples of sand sole larvae collected on the day of hatching were processed for scanning electron microscopy. Also on the day of hatching in both experiments the eggs and larvae were examined and categorized using the following nomenclature:

NONDEVELOPED EGGS - Two types of eggs that did not develop and which were indistinguishable as to the cause. (A) Nonviable eggs which were not successfully fertilized (approximately 10% in these experiments). (B) Eggs which died in early cell division as a result of oil exposure or natural failure (embryo not formed).

RUPTURED EGGS - Whole egg cases and fragments of chorion. Only detected in tests with sand sole (and not associated with remnants of hatching).

NORMAL EMBRYO - Embryo transparent, with a visible heartbeat.

ABNORMAL OR DEAD EMBRYO - Opaque, often scoliosis evident, and no heartbeat.

NORMAL LARVAE - Alive, notochord straight, finfold continuous, digestive tract complete, pigmentation complete.

ABNORMAL LARVAE - Alive, slight curvature of the notochord and entire body, generally a lateral curvature of up to 45°.

GROSSLY ABNORMAL LARVAE - Alive, with body curvature exceeding 45°. (Some with notochord curvature of 180° and double 180° curvatures.) Finfold deformed, digestive tract incomplete, pigmentation not in patches but scattered, lying motionless on bottom.

DEAD LARVAE - No heartbeat, generally opaque and usually contorted.

D. SAMPLE LOCATIONS

Flatfish were collected from Puget Sound or the estuary of the Columbia River. Coho salmon were from local hatchery stocks.

E. DATA COLLECTED OR ANALYZED

For physiology studies see text and tables in Methods and Results sections.

In chemistry studies aliquots of liver and bile were taken from six English sole which had been injected 24 hr earlier with an aromatic hydrocarbon fraction of PBCO. Parallel control samples were taken from six fish injected with peanut oil. The samples were frozen (-80°C) and subsequently shipped to Dr. Richard Pelroy, Battelle Biology Laboratory, Richland, Washington, for the Ames mutagenicity test.

In pathology studies, 240 flatfish tissue samples were examined by light microscopy.

## IV. RESULTS

### Physiology

### A. ENGLISH SOLE

Exposure of English sole eggs to fresh and weathered PBCO layered on the surface at a concentration of 4,000 ppm (v/v) and the SWSF of weathered PBCO all produced high percentages of deformed larvae or dead eggs and larvae, while in the control group 75% of the larvae were normal (Table 1). Almost all (97%) of the eggs exposed to fresh PBCO were killed. Weathered PBCO layered on the surface produced about equal amounts of dead eggs and grossly abnormal larvae, and exposure to the weathered SWSF allowed eggs to hatch but resulted in 75% grossly abnormal and dead larvae.

### B. SAND SOLE

In the earlier experiments with English sole eggs the concentrations of oil used produced a high percentage of dead eggs and deformed larvae; thus, in follow-up experiments with sand sole eggs, both similar and lower concentrations of oil were employed. In an additional test, mineral oil was layered on the surface at a concentration of 2,000 ppm (v/v) to evaluate the effect of an oil film which did not produce water-soluble components.

Effects of oil-exposure on eggs of sand sole are summarized in Table 2. In all tests, counts of eggs and larvae were taken on the day of hatching; however, in four tests using either fresh or weathered PBCO layered on the surface, the oil apparently caused rupture of the egg membrane with resultant disintegration of the yolk and fragmentation of the chorion. In these tests a total count was not possible and the number of eggs initially introduced was based on the average stocking density of control eggs in either the 1,000 or 2,000 ml incubation funnels.

Replicate control tests show that an average of 90 $\pm$ 2% of the eggs hatched into normal larvae (Fig. 1). Mineral oil had no apparent effect on development and is comparable with controls. Fresh PBCO layered on the surface at concentrations of either 4,000 or 2,000 ppm (50%) had a devastating effect with over 90% of the eggs being killed prior to development of a recognizable embryo (Fig. 2). Weathered PBCO layered on the surface at the same concentrations produced effects similar to that caused by fresh oil with an estimated 67 to 88% being killed as non-developed eggs. The weathered SWSF of PBCO at an initial concentration of 500 ppb produced an entirely different effect; eggs developed and hatched, however, two-thirds were deformed. The most comon abnormality was scoliosis in varying degrees of severity (Fig. 3). Severe secondary abnormalities were observed in some larvae: absence of yolk, shortened length, pigment scattered rather than in patches, fin-fold deformed, and incomplete digestive tract. Weathered SWSF at an initial concentration of approximately 250 ppb (50%) produced 80 $\pm$ 2% normal larvae and only 10 $\pm$ 1% deformed larvae. The percent of normal embryos and larvae at termination of each test in shown in Figure 4.

Figures 5 and 6 are scanning electron micrographs of the olfactory epithelial area of larval sand sole collected one day after hatching. The olfactory sensory surfaces of sand sole were damaged by the petroleum exposure and epithelial cells surrounding the organ appear hypertrophied.

TABLE 1. Test conditions and results of English sole (Parophrys vetulus) eggs exposed to PBCO. Data were collected at time of hatching (end of 8-day exposure) and reported in percent of total eggs introduced.

| Test conditions & total hydrocarbon conc. (ppb) in water after 3 days | EGGS | | | EMBRYO | | LARVAE | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total initially introduced (N) | Non-developed (%) | Ruptured & fragmented (%) | Normal (%) | Abnormal or dead (%) | Normal (%) | Abnormal (%) | Grossly abnormal (%) | Dead (%) |
| Control (32) | 348 | 13.5 | 0 | 0.9 | 0 | 74.7 | 5.2 | 0 | 5.7 |
| Fresh PBCO (2,978) | 285 | 96.8 | 0 | 0 | 0 | 0 | 0 | 1.4 | 1.8 |
| Weathered PBCO (317) | 195 | 39.0 | 0 | 0 | 2.0 | 0 | 0 | 36.9 | 22.1 |
| Weathered SWSF of PBCO (87)[a] | 372 | 22.0 | 0 | 0 | 3.0 | 0 | 0 | 64.5 | 10.5 |

[a]Hydrocarbon concentration in the SWSF of weathered PBCO at start of test was 262 ppb.

TABLE 2. Test conditions and results of sand sole (Psettichthys melanostictus) eggs exposed to PBCO and mineral oil. Data were collected at time of hatching (end of 8-day exposure) and reported in percent of total eggs introduced.

| Test conditions & total hydrocarbon conc. (ppb) in water after 3 days | EGGS | | | EMBRYO | | LARVAE | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total initially introduced (N) | Non-developed (%) | Ruptured & fragmented[b] (%) | Normal (%) | Abnormal or dead (%) | Normal (%) | Abnormal (%) | Grossly abnormal (%) | Dead (%) |
| Control replicates pooled (10) | 1,469 | 7.4 | 0 | 0.1 | 0 | 89.7 | 1.8 | 0 | 1.0 |
| Mineral oil (33) | 679 | 1.6 | 0 | 0 | 0 | 92.6 | 3.1 | 0.9 | 1.8 |
| Fresh PBCO (2,841) | 980[b] | 9.5 | 83.0 | 0 | 7.5 | 0 | 0 | 0 | 0 |
| Fresh PBCO (50%, 1,420 est.) | 490[b] | 4.8 | 89.0 | 0 | 1.0 | 0 | 0 | 0 | 5.2 |
| Weathered PBCO (324) | 980[b] | 3.9 | 84.1 | 0 | 0.9 | 0 | 0 | 0 | 11.1 |
| Weathered PBCO (50%, 160 est.) | 490[b] | 8.4 | 58.8 | 1.6 | 1.2 | 2.0 | 3.5 | 4.1 | 20.4 |
| Weathered SWSF of PBCO (64)[a] | 365 | 15.6 | 0 | 4.9 | 0 | 0 | 43.6 | 22.2 | 13.7 |
| Weathered SWSF of PBCO replicates pooled (50% = 27 by GC) | 968 | 5.5 | 0 | 0.4 | 0.2 | 78.9 | 8.9 | 1.6 | 4.5 |

[a] Hydrocarbon concentration in the SWSF of weathered PBCO at start of test was 527 ppb.
[b] Estimate based on the average number of eggs stocked in the control funnels.

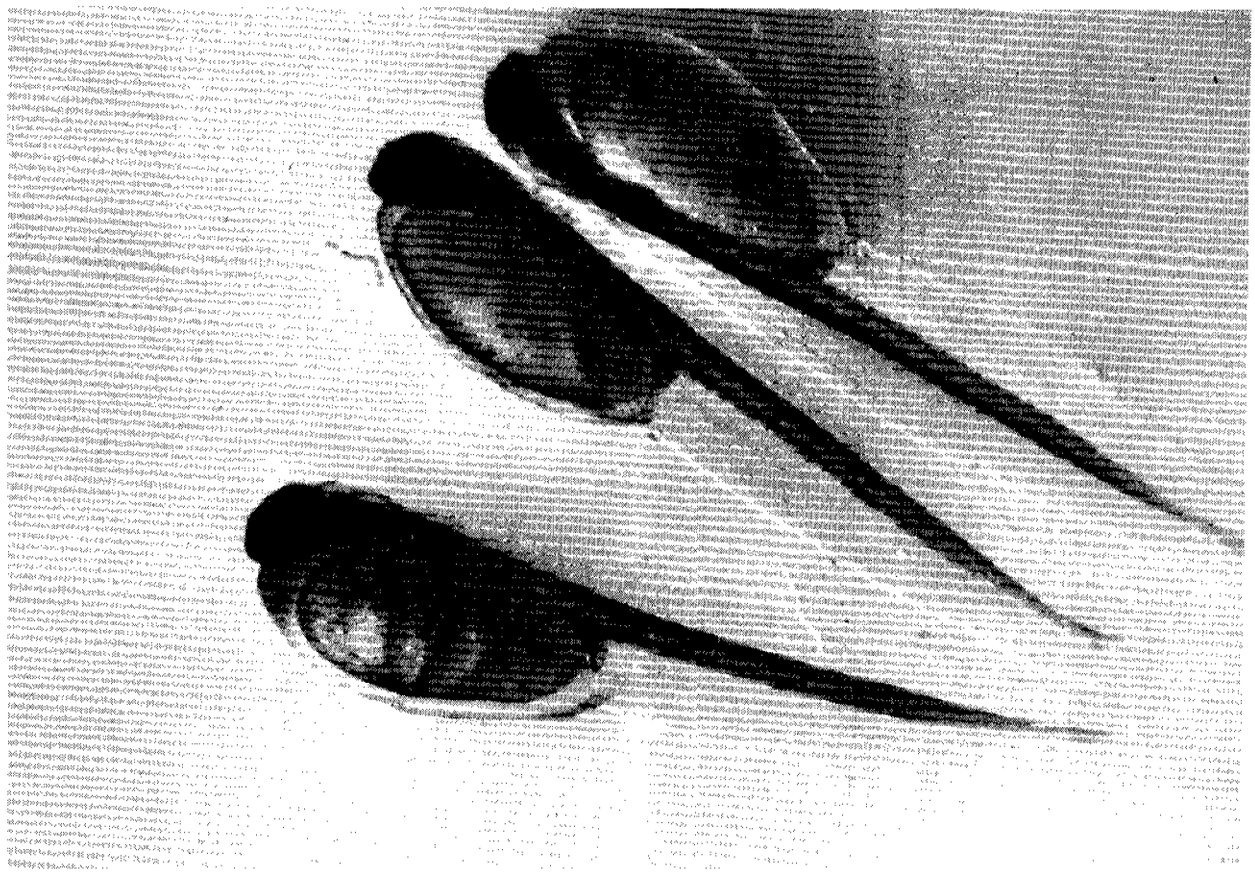

FIG. 1. Normal sand sole larvae, 3.0 mm standard length.

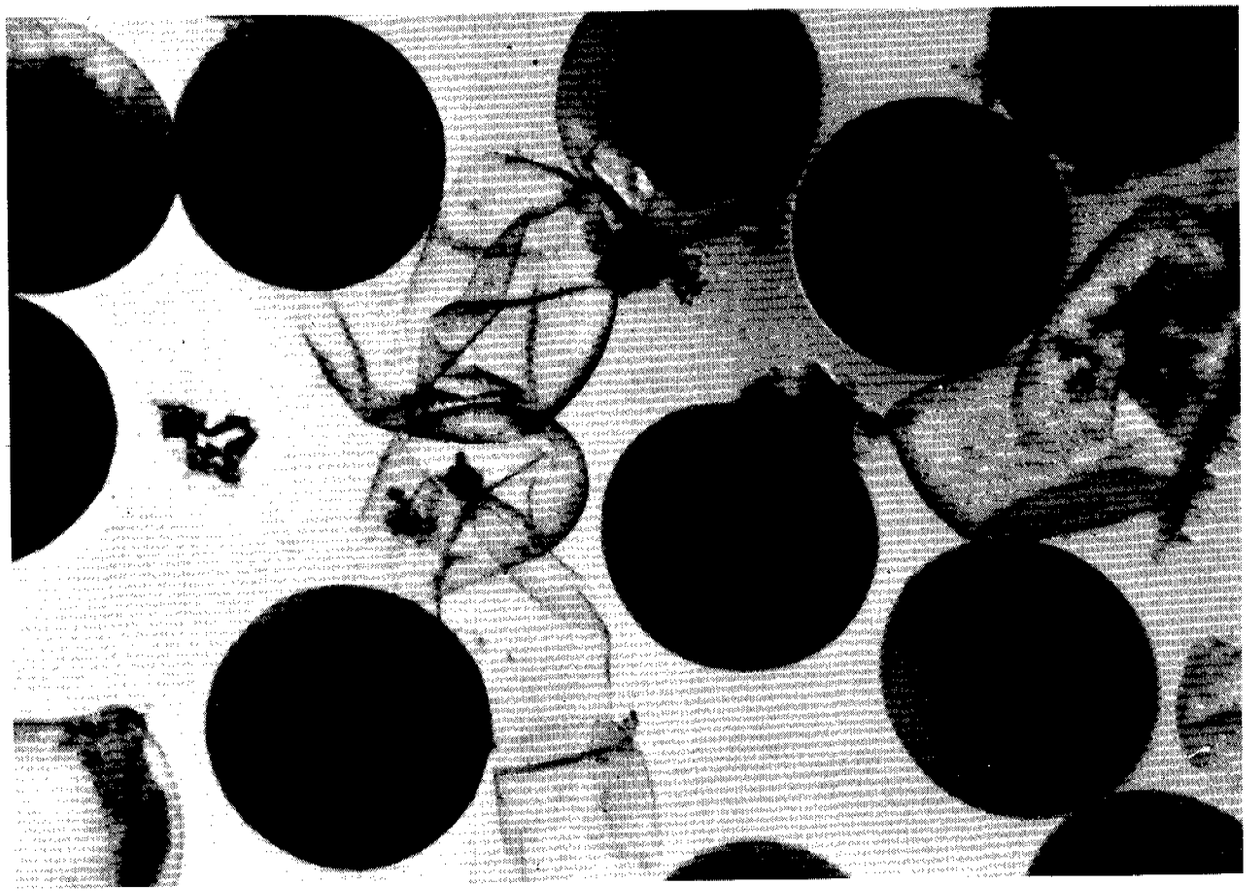

FIG. 2. Dead sand sole eggs, 1.0 mm diameter and fragmented chorions.

FIG. 3. Abnormal sand sole larvae, 2.3 mm standard length showing scoliosis.

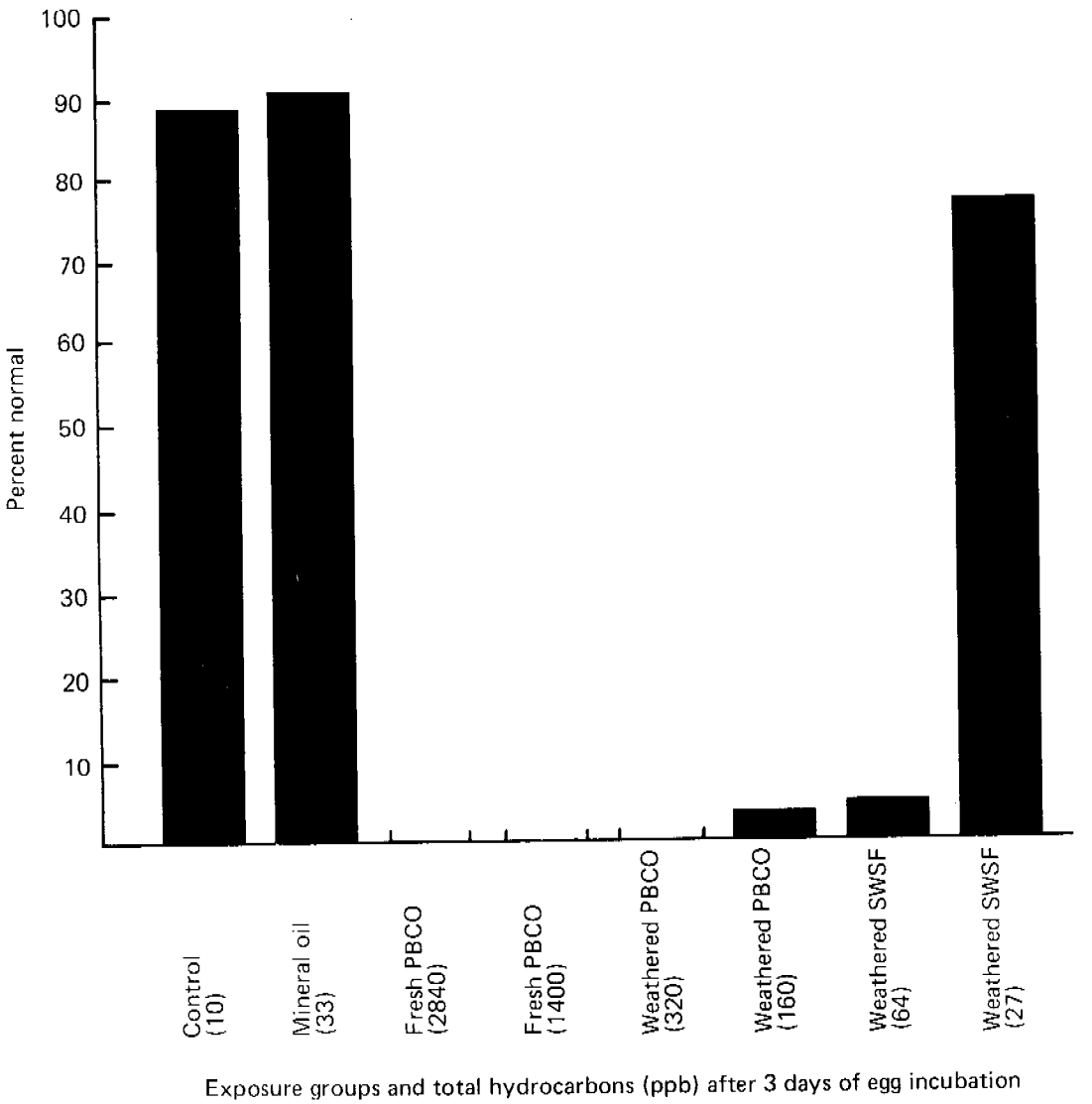


FIG. 4. Test conditions and percent of sand sole eggs that developed into normal embryos and larvae.

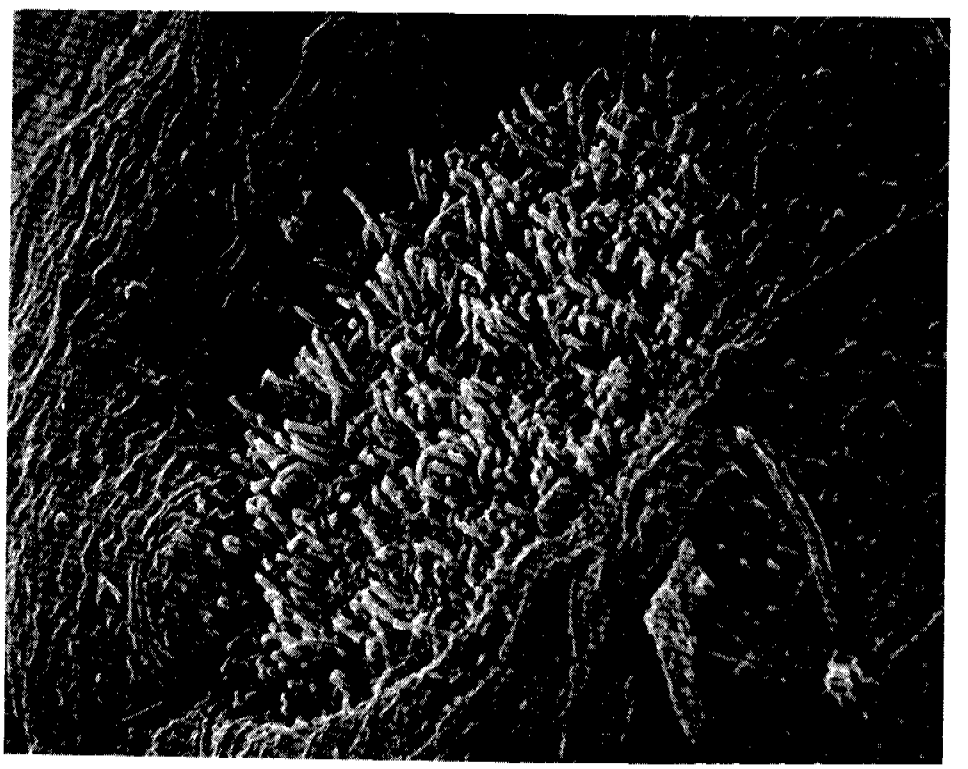

FIG. 5. Olfactory surface of control sand sole larvae (2,000 X).

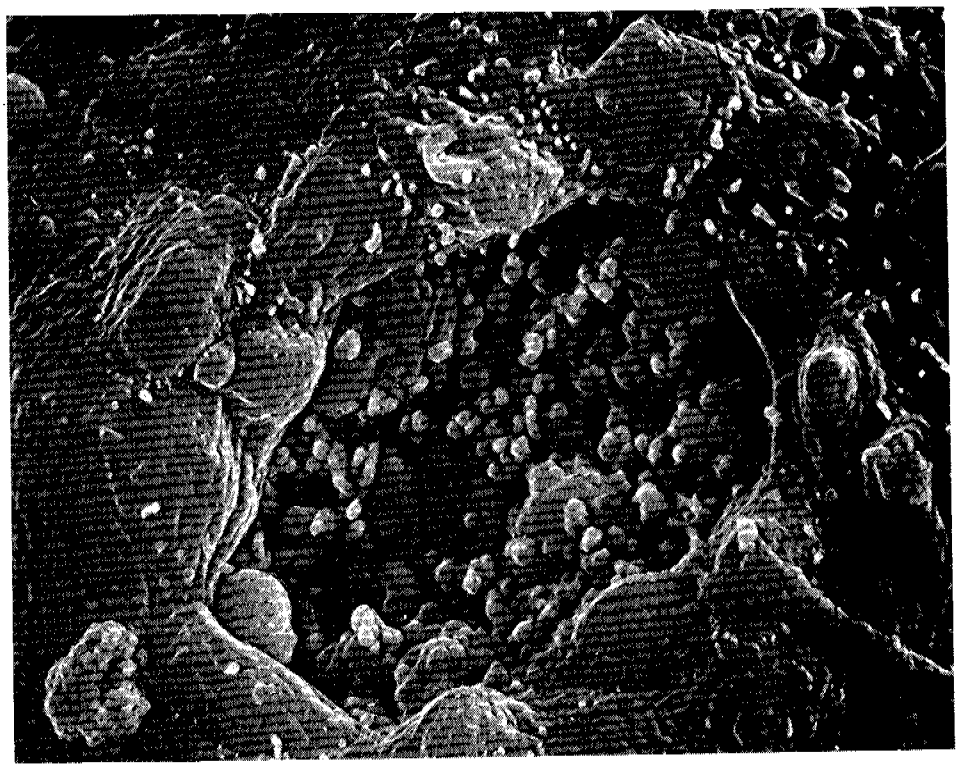

FIG. 6. Olfactory surface of oil-exposed sand sole larvae exposed to the SWSF of weathered PBCO, 527 ppb initial concentration (1,650 X).

V. PRELIMINARY INTERPRETATION OF RESULTS

## Physiology

Fresh PBCO and weathered PBCO layered on the water surface generally resulted in mortality of flatfish eggs prior to development of a recognizable embryo. High concentrations of the SWSF of weathered PBCO had a different effect, with high embryo survival, but few normal larvae. The results of these experiments indicate that the release of oil in an area where flatfish are spawning may potentially be very detrimental to egg and larval survival.

The rupture of sand sole eggs exposed to fresh and weathered PBCO was unexpected and made evaluation of precise numbers lost difficult. This effect may be of importance in application to field sampling of pelagic eggs in the vicinity of an oil-contaminated area. Ruptured eggs would likely sink out of the water column with the resultant assessment of pollutant effect being underestimated.

VI. AUXILIARY MATERIAL

A. BIBLIOGRAPHY OR REFERENCES - None.

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C. ORAL PRESENTATIONS

HAWKES, J.W. "The effects of xenobiotics on fish tissues: Ultrastructural studies." Presented at the American Society for Pharmacology and Experimental Therapeutics as part of a symposium on "Pharmacology of Marine Species," in Portland, Oregon, August, 1979.

MALINS, D.C. "The analysis of petroleum products in marine environments." Presented at the 14th European Marine Biology Symposium, Island of Helgoland, Germany, September, 1979.

VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES - None.

Quarterly Report
Oct.-Dec. 1979
Research Unit #73

# SUBLETHAL EFFECTS OF PETROLEUM HYDROCARBONS AND TRACE METALS, INCLUDING BIOTRANSFORMATIONS, AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, PATHOLOGICAL, AND BEHAVIORAL INDICES

by

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December 31, 1979

I. ABSTRACT

The responses of marine organisms to environmental contaminants are reflected in numerous changes that are detectable at population and organismic levels, as well as at cellular and molecular levels. The general scope of this study is to evaluate effects caused by behavioral, physiological, pathological, morphological, and chemical changes in subarctic and arctic marine animals exposed to petroleum.

The report for this quarter will highlight the biochemical studies concerning the metabolism of benzo[a]pyrene (BP) and covalent binding of BP derivatives to DNA using liver enzymes of the benthic starry flounder (Platichthys stellatus) and English sole (Parophrys velutus), and the pelagic coho salmon (Oncorhynchus kisutch).

Physiology

Surf smelt (Hypomesus pretiosus) eggs were exposed to three different concentrations of the seawater soluble fraction (SWSF) of weathered Cook Inlet crude oil (CICO) for 3 h/day during 23 days of embryonic development. At the highest concentration (qualitative and quantitative chemical determinations yet to be made), less than 10% of the exposed eggs developed into normal embryos or larvae. At a SWSF concentration of approximately 50% of the highest concentration, 55% of the eggs developed normally. At the lowest concentration (approximately 25% of the highest SWSF concentration) 90% of exposed eggs and larvae were normal--a percentage identical with that of the controls.

Chemistry

Metabolism of BP and covalent binding of BP derivatives to DNA were further investigated (for preliminary report see OSCEAP Quarterly Report

June-September 1979) using liver enzymes of pleuronectids (starry flounder and English sole) and a salmonid (coho salmon). Extensive (80-90%) metabolism of BP was accompanied by the production of large proportions (>40% of metabolites) of 9,10 dihydro- 9,10 dihydroxy benzo[a]pyrene (BP 9,10 dihydrodiol) in preparations containing liver enzymes of fish pretreated with the polynuclear aromatic hydrocarbons, BP and 3-methylcholanthrene (MC), or Prudhoe Bay crude oil (PBCO). Because BP 9,10 dihydrodiol is released rapidly from cells, the present results showing the formation of large proportion of BP 9,10 dihydrodiol by liver enzymes may have important implications in the efficient removal of BP from fish liver and its transport to other tissues (e.g., muscle, skin) via the circulatory system.

To assess the bioavailability of polynuclear aromatic hydrocarbons (PAH) from sediment, English sole were exposed to radioactively labeled BP and naphthalene mixed in sediment. Various tissues of the fish were sampled and the samples stored for future analyses of hydrocarbons and their metabolites.

## Pathology

An experiment in which 90 juvenile English sole were exposed to high-sand sediment contaminated with 1.0% (v/v) PBCO was terminated after 48 days due to a disruption in the flow of seawater. The same number of English sole were exposed to uncontaminated sediment. Samples of fish tissue and sediment were collected at 0-time and at 38 days. Light microscopic examination of liver tissues demonstrated no detectable petroleum-related abnormalities.

II. OBJECTIVES

Physiology

To evaluate the effect of CICO on the development of eggs and larvae of surf smelt.

Chemistry

To elucidate the metabolism and disposition of petroleum hydrocarbons in marine fish.

Pathology

To determine the frequency and nature of pathological changes occurring in flatfish as a result of exposure to oil-contaminated sediments.

III. FIELD OR LABORATORY ACTIVITIES

A. SHIP OR FIELD TRIP SCHEDULE - N/A.

B. SCIENTIFIC PARTY

The following persons affiliated with the Environmental Conservation Division of the Northwest and Alaska Fisheries Center participated in the planning, development, and performance of experiments presented in this report.

| Name | Role |
|---|---|
| D. C. Malins, PhD, DSc | Principal Investigator, hydrocarbon metabolism |
| H. O. Hodgins, PhD | P.I.; physiology and pathology studies |
| B. B. McCain, PhD | P.I.; pathology studies |
| D. D. Weber | P.I.; physiology studies |
| U. Varanasi, PhD | P.I.; hydrocarbon metabolism |
| D. W. Brown | P.I.; analytical chemistry |
| S-L. Chan, PhD | Assistant Director, EC Division |
| W. T. Roubal, PhD | Research chemist; hydrocarbon and metabolite analyses and effects |

| | |
|---|---|
| W. E. Ames | Research biologist; works with Dr. McCain on pathology |
| W. D. Gronlund | Research biologist; works with Dr. McCain on pathology |
| D. A. Misitano | Research biologist; works with D. Weber on eggs and larvae |
| J. W. Hawkes, PhD | Cell biologist; electron microscopy, developmental biology |
| C. Stehr | Research biologist; assistant to Dr. Hawkes in electron microscopy |
| D. Gmur | Chemist; assistant to Dr. Varanasi on hydrocarbon and metabolite analyses and effects |
| M. M. Krahn, PhD | Chemist; hydrocarbon and metabolite analyses |
| L. S. Ramos | Chemist; hydrocarbon and metabolite analyses |
| V. Henry | Chemist; hydrocarbon and metabolite analyses |
| P. G. Prohaska | Chemist; hydrocarbon and metabolite analyses |
| D. G. Gennero | Technician; hydrocarbon and metabolite analyses |
| M. S. Myers | Research biologist; assistant to Dr. McCain in histopathology |
| P. S. Fraser, PhD | Chemist; petroleum hydrocarbon metabolite preparation |
| K. Gleim | Technician; assistant to Dr. Roubal in hydrocarbon and metabolite analyses and effects |
| G. Sergneri | Administrative Assistant |
| E. Gruger, Jr., PhD | Research chemist; coordinator of chemical analyses |

C. METHODS

## Chemistry

Sexually immature starry flounder from the estuary of the Columbia River, English sole from Point Pulley, Washington, and coho salmon from Manchester, Washington were acclimatized to flowing unfiltered seawater for a minimum of two weeks. Some of the fish were injected intraperitoneally with 10 mg/kg of BP, MC, or PBCO dissolved in corn oil. There was no detectable difference

in the binding of $^{3}$H-BP to DNA when liver enzymes from untreated or corn oil-injected fish were used. Accordingly, most of the data in these studies were obtained from the untreated fish. The fish were killed 24 h after the injection and supernatants of liver homogenates were prepared according to previously described procedures [Pedersen et al. 1976]. The standard reaction mixture for in vitro binding of BP to DNA contained 2 mg of DNA in 2.5 ml of 0.02 M phosphate buffer (pH 7.4), 0.75 mg NADPH in 0.1 ml of 0.1 M EDTA (pH 7.4), and 0.2 ml of the supernatant (5 mg protein). The reaction was started by adding 5 nmoles of BP in 50 µl of ethanol. The mixtures were incubated in the dark for 15 min at 25°C for the fish liver supernatant and at 37°C for the rat liver supernatant. The reaction mixture was then treated according to the procedure previously described [Buty et al. 1976]. Data for the rat liver were obtained for comparison.

Benzo[a]pyrene metabolites were formed in the liver supernatant mixture containing $^{3}$H-BP without the addition of DNA. The mixture was extracted twice with 6 ml of ethyl acetate to remove unreacted BP and ethyl acetate-extractable metabolites from the aqueous phase. Radioactivity was determined in both aqueous and organic phases. Ethyl acetate extracts were spotted on silica gel plates and developed in benzene:ethanol (9:1, v/v) as described previously [Varanasi and Gmur 1979]; the extracts were cochromatographed with known standards of BP and its metabolites. Separation and quantification of the metabolites were carried out according to previously described procedures [Cohen and Moore 1976; Varanasi and Gmur 1979]. Metabolites were also separated by high pressure liquid chromatograph (HPLC) as described previously [Selkirk et al. 1974]. All operations were carried out under dim light to prevent photo-oxidation.

D. SAMPLE LOCATIONS

Eggs of surf smelt were collected in Puget Sound. (Physiology)

Flatfish were collected from Puget Sound or the estuary of the Columbia River. Coho salmon were from local hatchery stocks. (Chemistry)

E. DATA COLLECTED OR ANALYZED

Thirty water samples of the SWSF of CICO were collected for chemical analysis.

Over 200 embryos and hatched larvae were sampled for scanning and transmission electron microscopy.

In chemistry, 120 fish were used for BP metabolism and in vitro binding of BP derivatives to DNA; for exposure of flatfish to hydrocarbons in sediment a total of 24 fish were used.

In pathology studies, 160 flatfish tissue samples were examined by light microscopy.

IV. RESULTS

## Chemistry

### Influence of PAH-pretreatment of fish on in vitro Binding of BP to DNA

The binding values for the untreated English sole and starry flounder were 3 and 8 times, respectively, greater than the corresponding value for coho salmon (Table 1). Moreover, pretreatment of English sole with PBCO resulted in an 18-fold increase in the binding value compared to the corresponding value for untreated English sole; the increase in the binding for the PBCO-pretreated starry flounder was only 5-fold.

Pretreatment of coho salmon, starry flounder, and rat with MC resulted in a substantial increase in the in vitro binding of $^{3}$H-BP to DNA compared to the corresponding values obtained with liver extracts of untreated animals. The value for binding obtained with liver extracts from MC-pretreated starry flounder was about ten times greater than that obtained with the untreated fish; the corresponding increase in the value of binding was, respectively, 48- and 12-fold for coho salmon and rat. For both coho salmon and starry flounder, the binding of BP to DNA was slightly greater when fish were pretreated with BP than when they were pretreated with MC.

Metabolism of Benzo[a]pyrene

Figure 1 depicts thin-layer chromatograms of ethyl acetate-extractable metabolites formed by liver extracts of MC-pretreated fish species and rat. The data revealed that for all three fish species BP 9,10-dihydrodiol and 7,8-dihydro 7,8-dihydroxy benzo[a]pyrene (BP 7,8-diohydrodiol) were the major metabolites. The metabolite profile for the MC-treated rat revealed the presence of a high proportion of phenols and quinones, together with significant amounts of BP 7,8-dihydrodiol and BP 9,10-dihydrodiol. Profiles of BP metabolites obtained after incubation of liver extracts with $^{14}$C-BP were similar to those obtained with $^{3}$H-BP.

Pretreatment of starry flounder and coho salmon with MC resulted in a considerable increase in BP metabolism catalyzed by the liver supernatants (Table 2). Liver extracts from MC-pretreated starry flounder produced a larger proportion (52%) of ethyl acetate-extractable metabolites than liver extracts from both coho salmon (40%) and rat (38%). Ratios of the concentrations of non-K region dihydrodiols (BP 9,10 dihydrodiol and BP 7,8 dihydrodiol) to monohydroxybenzo[a]pyrenes (3-hydroxy BP and

9-hydroxy BP) were significantly (P  0.05) greater in all four fish liver extracts than that in the rat liver extract. Pretreatment of both coho salmon and starry flounder with MC resulted in increases in proportions of BP 9,10-dihydrodiol and the "prediol" components eluted before BP 9,10-dihydrodiol, and a marked decrease in the proportion of BP 7,8-dihydrodiol formed by the liver extracts. For example, BP 7,8-dihydrodiol comprised 32% and 17%, respectively, of the ethyl acetate-extractable metabolites in incubations containing liver extracts from untreated and MC-pretreated starry flounder; the corresponding values for BP 9,10-dihydrodiol were 44% and 52%, respectively.

TABLE 1

THE IN VITRO BINDING OF ACTIVATED BP to DNA

CATALYZED BY LIVER SUPERNATANTS FROM FISH AND RAT

| Species | System[a] (supernatant) | pmole of BP equivalent/mg DNA/mg protein[b] | % of control value |
|---|---|---|---|
| Starry flounder | Control | 0.15 | 100 |
| | MC | 1.62 | 1,000 |
| | BP | 1.70 | 1,100 |
| | PBCO | 0.74 | 500 |
| | MC[c] | 0.53 | --[d] |
| English sole | Control | 0.06 | 100 |
| | PBCO | 1.05 | 1,800 |
| | MC | 0.16 | --[d] |
| Coho salmon | Control | 0.02 | 100 |
| | MC | 0.97 | 4,900 |
| | BP | 1.06 | 5,300 |
| | MC[c] | 0.30 | --[d] |
| Rat | Control | 0.06 | 100 |
| | MC | 0.69 | 1,200 |

[a] Liver supernatants (10,000 x g) were obtained from either untreated (control) animals or those injected with 10 mg/kg of 3-methylcholanthrene (MC); benzo[a]pyrene (BP); or Prudhoe Bay crude oil (PBCO) when the water temperature for fish was 13°C.

[b] Liver supernatants (≈ 5 mg protein) from different animals were incubated in the dark with 5 nmole BP, 2 mg salmon sperm DNA and cofactors for 15 min at 25°C (for fish) and 37°C (for rat). Each value is an average of two experiments and three replicate measurements using pooled liver extracts from 5 animals. Binding values for incubation without NADPH were less than 0.001 and were subtracted from the values reported.

[c] Liver supernatants were obtained from MC-treated fish when the water temperature was 8°C.

[d] No control fish were sampled at 8°C.

[Taken from Varanasi and Gmur 1979.]

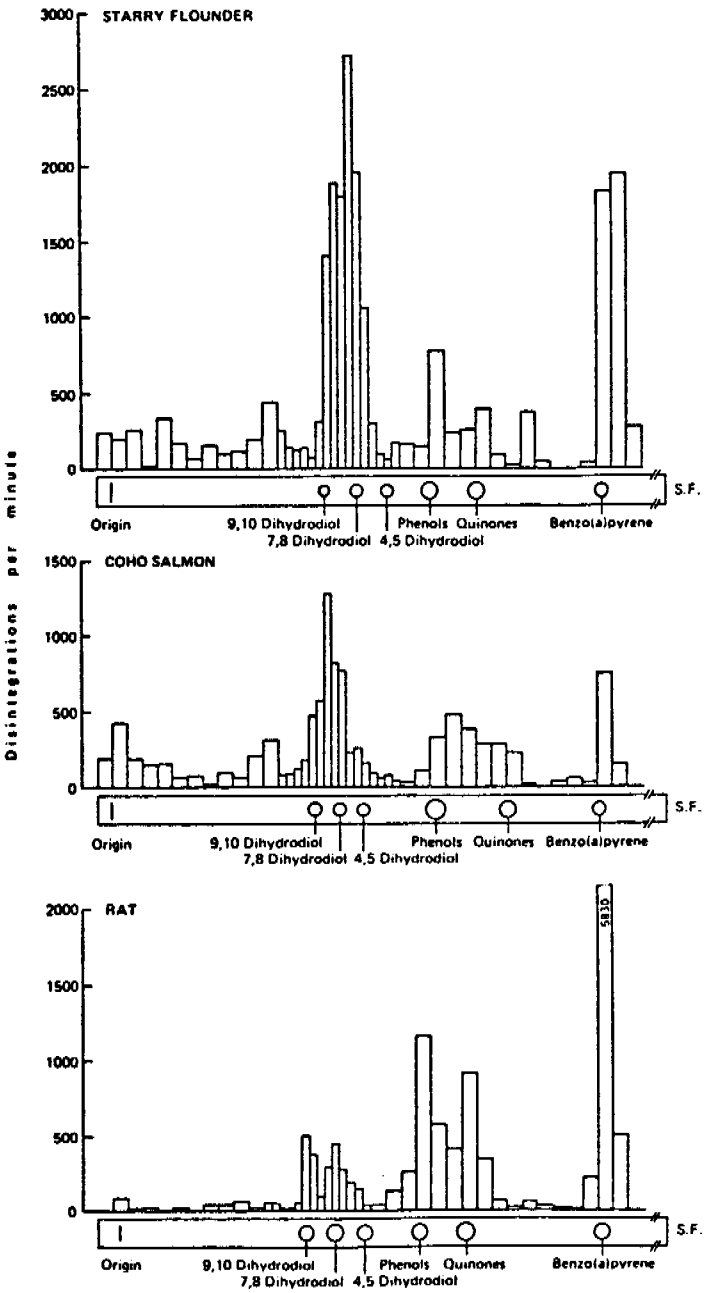


FIGURE 1. Ethyl acetate-extractable metabolites of [$^3$H]BP produced by liver supernatants from MC-treated (a) starry flounder, (b) coho salmon, and (c) rat were separated by TLC. The radioactive metabolites were cochromatographed with the reference unlabeled metabolites (adapted from Varanasi and Gmur 1979). S.F. indicates solvent front.

TABLE 2

METABOLISM OF BENZO[a]PYRENE BY LIVER EXTRACTS FROM FISH AND RAT

| | STARRY FLOUNDER | | COHO SALMON | | RAT |
|---|---|---|---|---|---|
| | Control | MC-pretreated | Control | MC-pretreated | MC-pretreated |
| | % of total radioactivity[a] | | | | |
| Unreacted BP | 40 | 13 | 59 | 5 | 35 |
| Ethyl acetate-extractable metabolites | 39 | 52 | 20 | 40 | 38 |
| Aqueous phase | 21 | 35 | 21 | 55 | 27 |
| | Ethyl acetate-extractable metabolites (nmol of BP equivalent/incubation) | | | | |
| "Prediol" | 0.07 | 0.34 | 0.01 | 0.30 | 0.15 |
| BP 9,10-dihydrodiol | 0.64 | 1.23 | 0.22 | 0.67 | 0.34 |
| BP 7,8-dihydrodiol | 0.46 | 0.40 | 0.28 | 0.18 | 0.19 |
| BP 3,6-quinone | tr[c] | 0.09 | 0.07 | 0.07 | 0.21 |
| 3-Hydroxy BP | 0.27 | 0.27 | 0.10 | 0.21 | 0.27 |
| 9-Hydroxy BP | tr | 0.05 | 0.04 | 0.10 | 0.24 |

[a] Incubation conditions are given in the text; 5 nmol of BP was used per each incubation. Metabolite extracts were from fish held at 13°C.

[b] Components eluted before BP 9,10-dihydrodiol.

[c] tr, trace.

[Taken from Varanasi et al. 1979.]

## V. PRELIMINARY INTERPRETATION OF RESULTS

The *in vitro* binding of BP derivatives to DNA using liver enzymes from both benthic fish species--English sole and starry flounder--was greater than that for coho salmon, a pelagic fish. Benthic fishes are probably constantly exposed to a multitude of xenobiotics [some of which are known inducers of mixed-function oxidases, MFO] present in sediments (McCain et al. 1978); therefore, it is not unexpected that liver preparations from these fish should yield higher values for the *in vitro* binding of BP to DNA than do coho salmon. However, many environmental factors and species-specific differences influence the xenobiotic metabolizing capability of aquatic organisms (Varanasi and Malins 1977); thus, the above explanation of the differences in binding values between pleuronectids and salmonids should be considered as tentative.

It has been proposed that the induction of hepatic aryl hydrocarbon monooxygeneses (AHM) in fish can indicate the presence of toxic chemicals in the environment (Payne 1976). Our results (Varanasi et al. 1979) and those of others (Ahokes et al. 1979) show that the magnitude of increase in *in vitro* binding of BP to DNA on pre-exposure of fish or rat to PAH (MC or BP) was relatively greater than the increase in AHM activity. Covalent binding of BP to DNA may prove to be more sensitive than AHM activity as an index of pre-exposure of fish to certain toxic chemicals. Moreover, the binding value serves as a useful index for correlating metabolism with the carcinogenicity of a PAH (Buty et al. 1976; Pelkonen et al. 1978). The carcinogenic potential of a compound to mammals is roughly correlated with the extent of covalent binding to DNA (Buty et al. 1976; Pelkonen et al. 1978). Accordingly, studies to assess the extent of covalent binding of a variety of pollutants to cellular

DNA in various target tissues of marine organisms may give useful information.

The hepatic MFO, together with conjugating enzymes, are responsible for both activation and detoxification of PAH. Therefore, treatment of animals with chemicals that alter these enzyme systems can result in either increased or decreased toxicity of the PAH. Studies show that pretreatment of rats (Ahokas et al. 1979) or mice (Wang et al. 1976) with either MC or BP resulted in a considerable increase in the *in vitro* metabolism of BP catalyzed by liver microsomes, together with increases in the proportions of both BP 7,8-dihydrodiol and BP 9,10-dihydrodiol. Although pretreatment of fish with MC in the present study resulted in a similar increase in BP metabolism, there was a marked decrease in the proportion of BP 7,8-dihydrodiol and a considerable increase in the proportion of "prediol" components (Table 2). Moreover, preliminary data show that pretreatment of these fish with either BP or PBCO resulted in similar alterations in the metabolite profiles. The decrease in BP 7,8-dihydrodiol can be explained on the basis that BP 7,8-dihydrodiol is further metabolized (Jones et al. 1978) to an ethyl acetate-extractable metabolite, 7,8,9,10-tetrahydro-7,8,9,10-tetrahydroxy BP which is formed via BP 7,8-dihydrodiol 9,10-epoxide, the postulated ultimate carcinogen of BP (Sims et al. 1974).

In rat hepatocytes (Burke et al. 1977; Jones et al. 1978) BP 9,10-dihydrodiol easily egressed into the extracellular fluid, whereas BP 7,8-dihydrodiol was equally divided between the cell and extracellular medium. Thus, extensive metabolism of BP and the production of large proportions of BP 9,10-dihydrodiol by liver enzymes of these fish, especially PAH-pretreated fish, may have important consequences in the efficient removal of

BP from the liver and its transport to other tissues (e.g., muscle or skin) via the circulatory system.

VI. AUXILIARY MATERIAL

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B. PAPERS IN PREPARATION OR IN PRINT

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VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Studies on disease resistance have not been initiated as early as anticipated because a needed technician has not been hired due to the delay in transfer of funds from OCSEAP.

# RESEARCH TO DETERMINE THE ACCUMULATION OF ORGANIC CONSTITUENTS AND HEAVY METALS FROM PETROLEUM-IMPACTED SEDIMENTS BY MARINE DETRITIVORES OF THE ALASKAN OUTER CONTINENTAL SHELF

by

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QUARTERLY REPORT
to the
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
OCSEAP Office
P. O. Box 1808
Juneau, Alaska

Contract No. 2311102778

July, 1979

# RESEARCH TO DETERMINE THE ACCUMULATION OF ORGANIC CONSTITUENTS AND HEAVY METALS FROM PETROLEUM-IMPACTED SEDIMENTS BY MARINE DETRITIVORES OF THE ALASKAN OUTER CONTINENTAL SHELF

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In a previous quarterly report (January, 1979) analytical schemes were described for studies of 1) the fate and distributions of $^{14}$C-benzo(a)pyrene in moderately coarse sandy sediments contaminated with oil and 2) the uptake and fate of these components in the intertidal detritivorous clam, Macoma inquinata, exposed to these sediments.

During this quarter, we have initiated similar studies to include exposure of the detritivorous worm, Abarenicola pacifica to an oiled fine mud substrate containing these same $^{14}$C-aromatic hydrocarbons. This report includes results for $^{14}$C-phenanthrene only.

## METHODS

Forty-eight Abarenicola pacifica and fine-grained sediment were collected from the high intertidal zone in an almost enclosed lagoon usually well protected from wave action. Six hundred microcuries (9.45 mg) of 9-$^{14}$C-phenanthrene was dissolved in 12 ml ether, together with 2.2 g Prudhoe Bay crude oil. The oil-phenanthrene-ether mixture was poured over 450 g of sediment, the ether was allowed to evaporate 20 minutes, and the oil-phenanthrene-sediment mixture was shaken by hand two minutes. It was then poured over 55

kg sediment in a fiberglass lined cement mixer and mixed one hour. This sediment was poured into 48 600 ml beakers whose bottoms had been replaced with 0.8 mm mesh Nitex. The beakers were placed on racks in tanks in a sea table and flushed with running sea water for 18 hours. At this time 89% of the calculated amount of labelled phenanthrene originally added was recovered in the sediment.

Two specimens of A. pacifica were placed in each of 8 beakers, one each in 32 beakers, and none in 8 beakers. The water level in the tanks was continuously raised and lowered by a clockwork mechanism to produce a simulated "tide" which left the surface of the beakers uncovered for about 6 hours per day. This is similar to the tidal regimen which this population encounters in their natural habitat.

Beakers containing two worms were removed after one and three days, and those containing one worm after 7, 15, 30, and 60 days. Beakers containing only sediment were removed after 30 and 60 days. Sediment cores were taken from each beaker and frozen, and the remaining sediment was centrifuged for 30 minutes at 7500 g. The supernatant water was frozen for subsequent filtration to separate true interstitial water from small particles. The worms were rinsed and frozen immediately after removal from the sediment. They were later thawed and rinsed with hexane, and their intestinal tracts were removed and slit open. The sediment within their guts was removed, the interior of the guts were rinsed with hexane, and the body wall and intestinal tracts were frozen together.

The methods used for extraction and analysis of the tissue and sediment were the same as those described in the quarterly report of January 1979, with one exception. Due to the very fine grain size of the sediment, it was necessary to continue Soxhlet extraction for two days instead of one.

## RESULTS AND DISCUSSION

Figure 1 shows the uptake in tissue and retention in sediment of $^{14}C$-activity from the described exposure system. Uptake of $^{14}C$-activity in the tissue of Abarenicola pacifica increased during the first 15 days and then decreased at a decreasing rate falling to 52% of the 15 day value at 60 days. More $^{14}C$-activity was retained in sediment, with 73% of the total activity present at day 1 still present at day 60. The numerical data are shown in Table 1.

The ability of the worms to turn over the sediment and thereby effect the removal of $^{14}C$-phenanthrene was also investigated. Table 2 shows the total $^{14}C$-activity in 30 and 60 day sediment samples in the presence and absence of worms. No significant differences were observed in the activities in the 60 day samples. A difference was observed in the mean values of the 30 day samples. However, the probability of this difference being significant was low ($P \cong 0.4$).

The distribution of phenanthrene between interstitial water and associated sediment was next examined (Table 3). At all time intervals over 99.8% of the $^{14}C$-activity was associated with sediment. It therefore seems likely that the uptake exhibited by these polychaetes was from ingestion of sediment rather than accumulation from interstitial water.

## CONCLUSIONS

Greater persistence of $^{14}C$-phenanthrene was observed in oil contaminated fine mud substrate than was observed in an oiled coarser sediment, in which only 8% of the activity present on day 1 remained after 2 months (see Annual Report, April, 1979). Uptake of $^{14}C$ phenanthrene in Abarenicola pacifica

occurred during the first 15 days of exposure with over half of the activity still remaining in the organisms after 60 days. These higher levels of retained activity probably result from the greater retention of $^{14}C$-phenanthrene in the sediment resulting in greater availability of this compound to the organism. Data on the the effect of burrowing activity on the retention of $^{14}C$-phenanthrene in the mud substrate proved inconclusive. Large statistical variability would require greater sample replication in order to differentiate at these activity levels.

At the time of the next quarterly report it will be possible to state the relative contribution of degradation products to the $^{14}C$-activity described in the various compartments of these experiments. The work with chrysene is nearly completed and exposure to benzo(a)pyrene was recently initiated. A field exposure to fresh and weathered oil will be conducted in this month.

Table 1. $^{14}C$-Activity extracted from tissue and sediment (N = 3).

| Day | $^{14}C$-Activity in Tissue (DPM/gram, wet wt.) | $^{14}C$-Activity in Sediment (DPM/gram, wet wt.) |
|---|---|---|
| Initial | - | 21,046 ± 4,621 |
| 1 | 15,196 ± 2,184 | 20,146 ± 2,074 |
| 3 | 27,246 ± 5,619 | 20,986 ± 39 |
| 7 | 55,496 ± 5,534 | 16,580 ± 960 |
| 15 | 63,912 ± 13,136 | 15,870 ± 982 |
| 30 | 43,466 ± 13,678 | 13,883 ± 2,322 |
| 60 | 33,275 ± 3,363 | 14,650 ± 2,559 |

Table 2. $^{14}C$-Activity in 30 and 60 day sediments containing $^{14}C$-phenanthrene with and without the presence of Abarenicola pacifica (N = 3).

| Day | With Abarenicola pacifica | Without Abarenicola pacifica |
|---|---|---|
| 30[1] | 13,883 ± 2,322 | 20,957 ± 5,166 |
| 60[2] | 14,650 ± 2,559 | 16,913 ± 3,345 |

[1] $^{14}C$-Activity in 30 day sediments with and without worms significantly different at the 0.4 level.

[2] $^{14}C$-Activity in 60 day sediments with and without worms not significantly different.

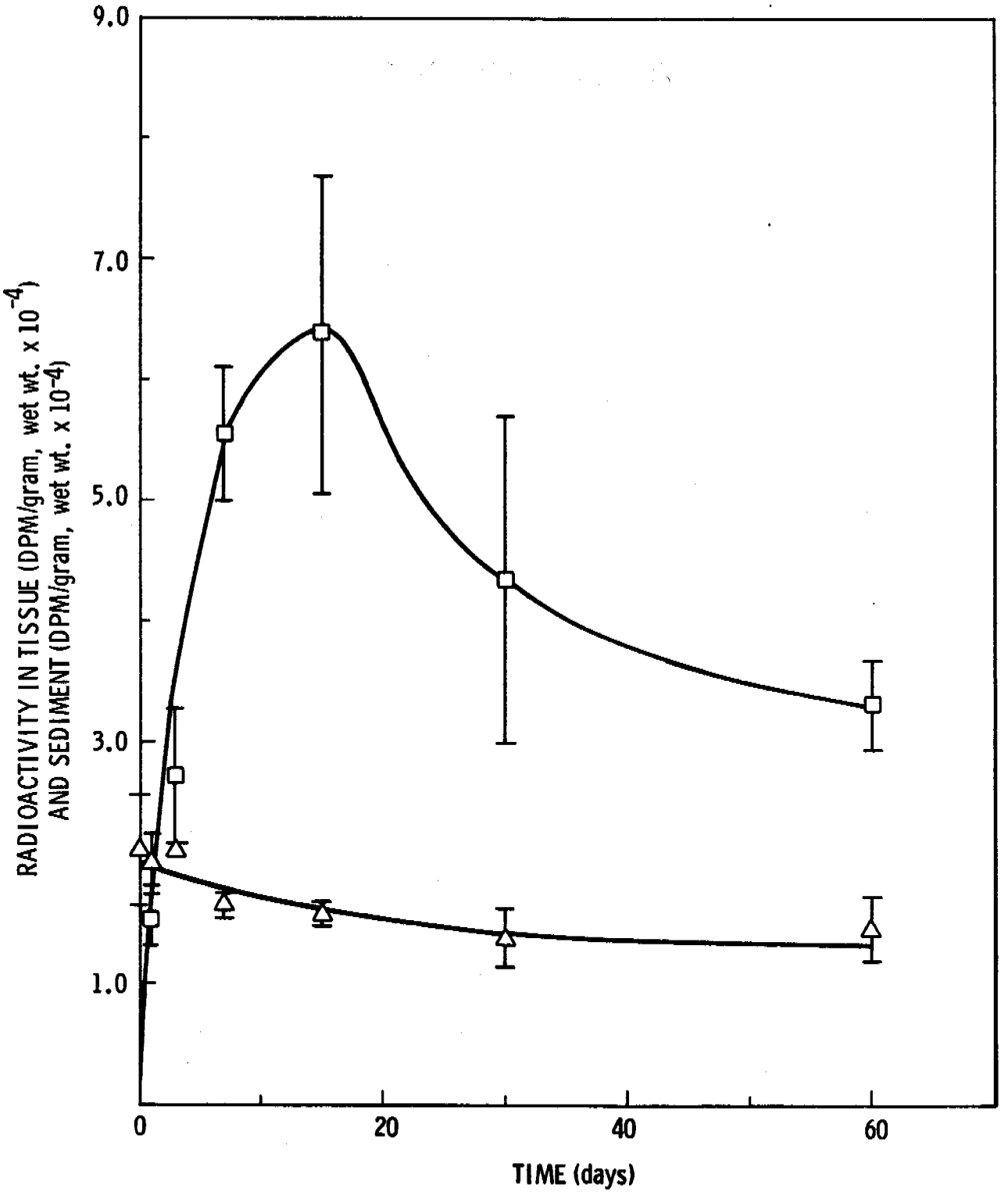
Table 3. $^{14}C$-Phenanthrene interstitial water - sediment distributions. % water in experimental sediments = 29.4 ± 1.0%.

| Compound | Day | $^{14}C$-Activity in Interstitial Water (DPM/ml) | $^{14}C$-Activity (DPM/ml) from 1 gram of Sediment (wet wt.) | $^{14}C$-Activity in Sediment (DPM/gram wet wt.) | [1]% Distribution of $^{14}C$-Activity in Interstitial Water From 1 gram Sediment (wet wt.) |
|---|---|---|---|---|---|
| Phenanthrene | 1 | 112 | 33 | 20,146 | < 0.16 |
| | 3 | 112 | 33 | 20,986 | < 0.16 |
| | 7 | 110 | 32 | 16,580 | < 0.19 |
| | 15 | 73 | 21 | 15,870 | < 0.13 |
| | 30 | 72 | 21 | 13,883 | < 0.15 |
| | 60 | 67 | 20 | 14,650 | < 0.14 |

[1] Calculation of distribution ratio assumes that the trace levels of $^{14}C$-activity in the interstitial water samples are present as parent substrate.

$$\% \ ^{14}C\text{-Activity} = \frac{^{14}C\text{-Activity in Water}}{^{14}C\text{-Activity in sediment} - ^{14}C\text{-Activity in Water}} \times 100$$

Figure 1. $^{14}C$-radioactivity in sediment and tissue exposed to radiolabelled phenanthrene (N = 3). Squares indicate levels in the sediment and triangles represent tissue samples. Bars are standard deviation.



# CONTAMINANT BASELINES

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## Contents

QUARTERLY REPORT

Research Unit: 153

Reporting Period: 1 April - June 30, 1979

Number of Pages: 21

# Identification of Natural and Anthropogenic Petroleum Sources in the Alaskan Shelf Area Utilizing Low Molecular Weight Hydrocarbons

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## I Task Objectives

During the past year, site specific studies were carried out in Cook Inlet relative to the sources of low molecular weight hydrocarbons. The research has focused on the biological production of LMWH in Kachemak Bay and the apparent sources of anthropogenic hydrocarbons in upper Cook Inlet, specifically in Trading Bay. In the past our effort was devoted to the characterization and distributions of the low molecular weight aliphatic fration ($C_1$ - $C_4$), but this year the program was upgraded to include LMW aromatics, including $C_2$ - benzenes using a GC-MS system. The objective was to identify unique LMW aromatics associated with production activities in upper Cook Inlet as a part of a longer term monitoring strategy. Because of low biological input levels and high solubility, these components are strong candidates for unique identifiers.

The characterization of biologically produced hydrocarbons is being emphasized in Lower Cook Inlet where primary productivity is much greater. This effort is focusing on the ratios of saturates to unsaturates being produced during biological activity. Without this knowledge, it is not known how the LMWH present in crude oil will differ from the ambient condition.

## II Field Schedule

### A. Ship Schedule

The distribution and abundances of LMW aliphatics and aromatics were assessed in Cook Inlet during May of this year. With the exception of the field program in upper Cook Inlet, all observations were conducted aboard the R/V DISCOVERER. The "Miss VICKI ANN" was used for shallow water work in

Trading Bay.

| Date | Cruise No. |
|---|---|
| 7 - 20 May 1979 | RP-4-DI-79A-II |

B. Scientific Compliment

The scientific party during the May cruise was:

Dr. Joel Cline, Project Leader, NOAA/PMEL

Dr. Herb Curl, Supervisory Oceanographer, NOAA/PMEL

Mr. Anthony Young, Oceanographer, NOAA/PMEL

Mr. Timothy Bates, Chemist, NOAA/PMEL

Mr. Charles Katz, Graduate Student, University of Washington

C. Methods

1. LMW Aliphatics

LMWHs are stripped from a 1 liter volume of seawater using modified procedure recommended by Swinnerton and Linnenbom (1967). A diagram of the hydrocarbon extractor is shown in Figure 1. Although the system actually used by us is somewhat simpler in detail than that reflected in Figure 1, the principle remains the same.

Chromatography of the components is effected on a column of activated alumina (6' x 3/16"), 60-80 mesh, temperature programmed from 100°C to 170°C at 8°/min. Retention times of the unsaturated hydrocarbons are controlled by the water content of the solid support. Chromatography of LMWH components through $C_4$ is accomplished in approximately 6 minutes. Detection of the component hydrocarbons as they emerge from the column is performed with a flame ionization detector.

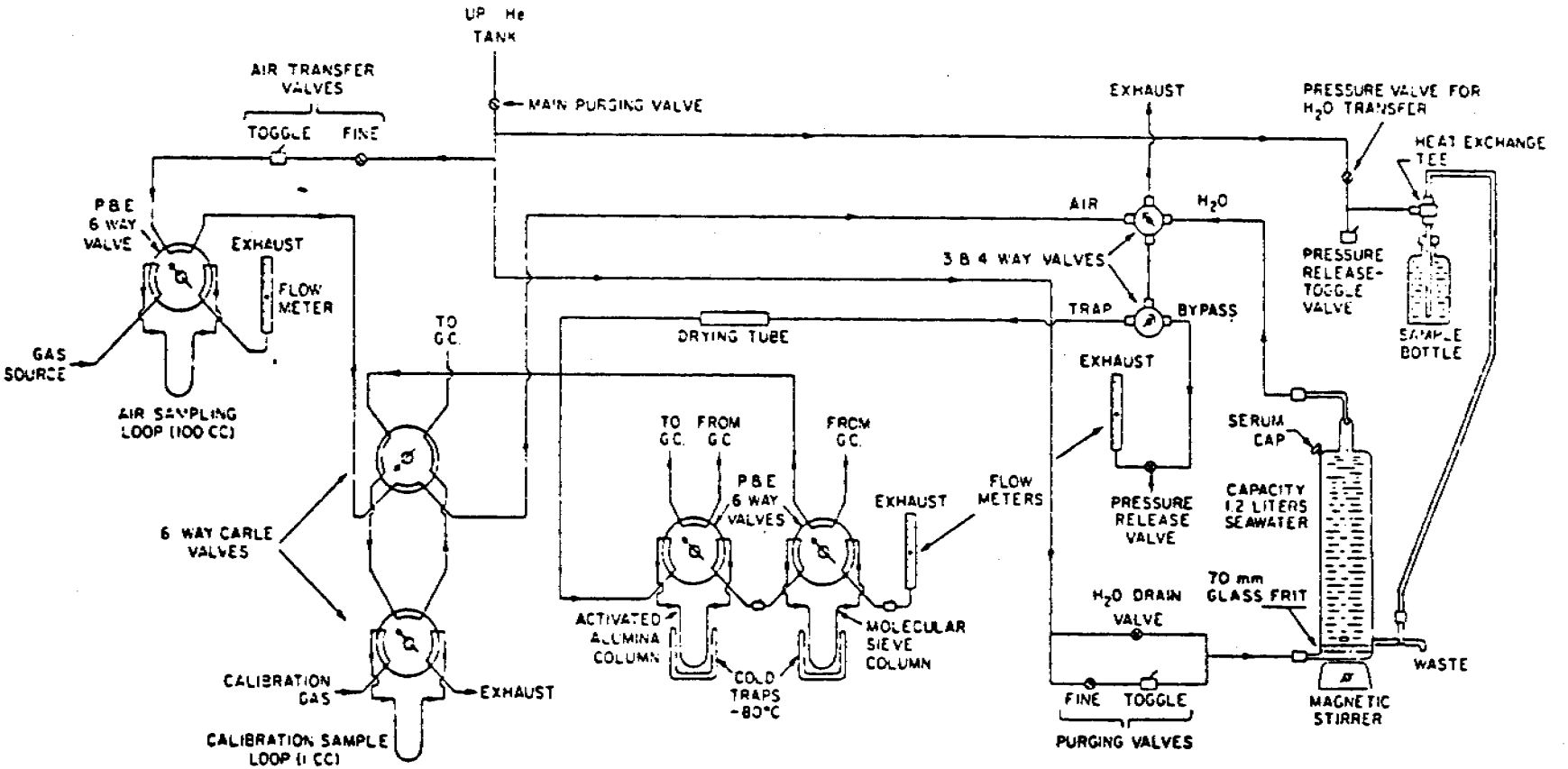


Figure 1. Low molecular weight hydrocarbon extraction system (Swinnerton and Linnenbom, 1967; Swinnerton et al., 1968). The extraction system shown is a recent modification given to us by Mr. R. Lamontagne of the Naval Research Laboratories, Washington, D. C.

2. LMW Aromatics

Collection of Water Samples: Seawater samples were collected by several procedures, including 5 liter NISKIN GO-FLO® bottles, biological seawater system, and glass bottles (500 ml) lowered through the sea surface. The purpose of the study was to determine which method, if any, was reliable for the collection of volatile organic compounds (Sauer et al., 1978).

The GO-FLO® samplers were carefully cleaned in a strong detergent, rinsed with copious quantities of clean seawater, and finally soaked in clean seawater (changed every several hours) for a minimum of 24 hours. Samplers were attached to a Kelvar® line spooled on a small gasoline-powered winch. Sampling for HC in upper Cook Inlet was conducted in this fashion.

Two seawater pumping systems on the R/V DISCOVERER were tried. The first is the "so called" biological system in which the pump is located in the bow and collects water from approximately 6 m depth. Both this system and the normal seachest pump were flushed for several days before use.

The glass bottles used in the collection of surface samples (down to one meter) were cleaned in a strong detergent, rinsed thoroughly, and oven dried before tightly sealing with Teflon® lined screw caps. These bottles were attached to a modified lake sampler in which the bottle could be lowered through the interface closed to prevent contamination from the surface layer. All water samples were stored at $3^{o}C$ in the dark with 0.5 g $NaN_3$ to reduce biological and photochemical effects.

Removal of LMW Aromatics from Seawater: Water samples (approximately 500 ml) were transferred to a modified gas dispersion bottle, heated to $40^{o}C$ in a water bath and stripped for 30 minutes with prepurified Helium. Flow rate was set at 100 ml/min. The carrier stream was passed through a condensor

cooled to near $0^{o}C$ and finally through a Tenax GC® trap (1/4" o.d. x 3") cooled to approximately $6^{o}C$. Prior to sample collection, each Tenax® tube was purged with Helium at $275^{o}C$ for several hours. Excess water vapor was removed from the Tenax® with dry Helium for 15 minutes at 100 ml/min. At the conclusion of the drying step, the Tenax® traps were immediately placed in the Bendix Flasher for thermal elution.

Analysis of LMW Organics: A Bendix Flasher (Applied Science Laboratories Inc.) was attached directly above the gas lined injector of a Hewlett Packard gas chromatograph-mass spectrometer (5992A). The Tenax GC® tubes were heated in the flasher to $250^{o}C$ and purged for 8 minutes at 4 ml/min onto the head of a 30 m wall coated (SE-54) open tubular glass capillary column held at an oven temperature of $-50^{o}C$. The oven was then quickly heated to an initial temperature of $0^{o}C$ and programmed from there at $2^{o}$/min to a final temperature of $100^{o}C$. The column was baked out at $250^{o}C$ between samples. Mass spectral data was collected and synthesized using two separate software packages. The first program provided a total ion scan from 45 to 350 AMU at each peak. The second program (Selected Ion Monitoring) allowed 20 preselected ions to be monitored for area response. This program was used for quantitation of the selected LMW aromatics compounds such as benzene, toluene, ethylbenzene, and xylenes.

Standardization Procedures: Five $\mu$l aliquots of individual aliphatic, cycloalkane, and aromatic hydrocarbons were vaporized in a heated 3000 ml flask to produce a gaseous HC standard of approximately 1.4 ng/$\mu$l for each component. This standard, which could be injected directly into the g.c., was used to assess g.c. operating conditions and detector sensitivity (m.s.).

Aqueous standards were prepared by mixing known amounts of pure solvents in methanol, which were diluted in purged distilled water and used as secondary

standards (EPA, 1977). Stripping efficiencies were assessed by comparing the response of the m.s. to each of the above standards. Aqueous standards were used to determine area response factors for individual compound quantitation.

### D. Sampling Locations

The station locations are reflected in Figures 2 and 3 , the latter figure shows the detailed sampling performed in upper Cook Inlet aboard the R/V MISS VICKI ANN. Sampling in Lower Cook Inlet was confined to subsampling several box cores taken by Dr. Kaplan's representative and conducting a general seasonal survey of the distributions of LMW aliphatics. Several stations in Lower Cook Inlet were sampled for dissolved aromatics to establish ambient background levels. These will be compared to similar observations conducted in the open North Pacific during Leg I.

Because of the general absence of fine grained sediments in Lower Cook Inlet, harpoon and gravity core samples for pore water hydrocarbons were limited to 3 stations in Shelikof Strait (see Figure 2).

## III Data Collected and/or Analyzed

1. Lower Cook Inlet

| Sample Type | Collected | Analyzed |
|---|---|---|
| Aliphatics--water | 66 | 66 |
| Biological Production | 60 | 60 |
| Aromatics--water | 14 | 14 |
| Aliphatics--sediments (cores) | 3(28)* | 2(15)* |
| Bottom Sediments (Box Core) | 8 | 0 |

Stations Occupied: 18

Trackline Miles: 500

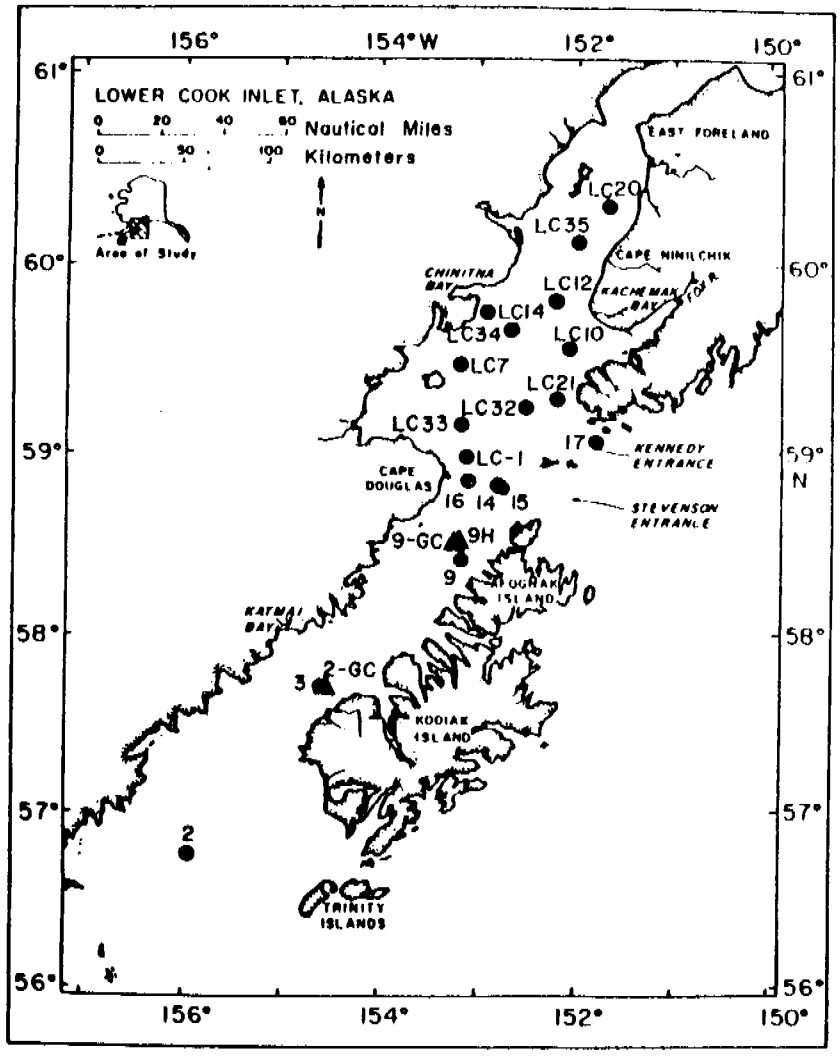


Figure 2. Station locations in Shelikof Strait and Cook Inlet. Harpoon and gravity cores were taken at Stations 2 and 9 in Shelikof Strait. Water samples were taken at the other stations.

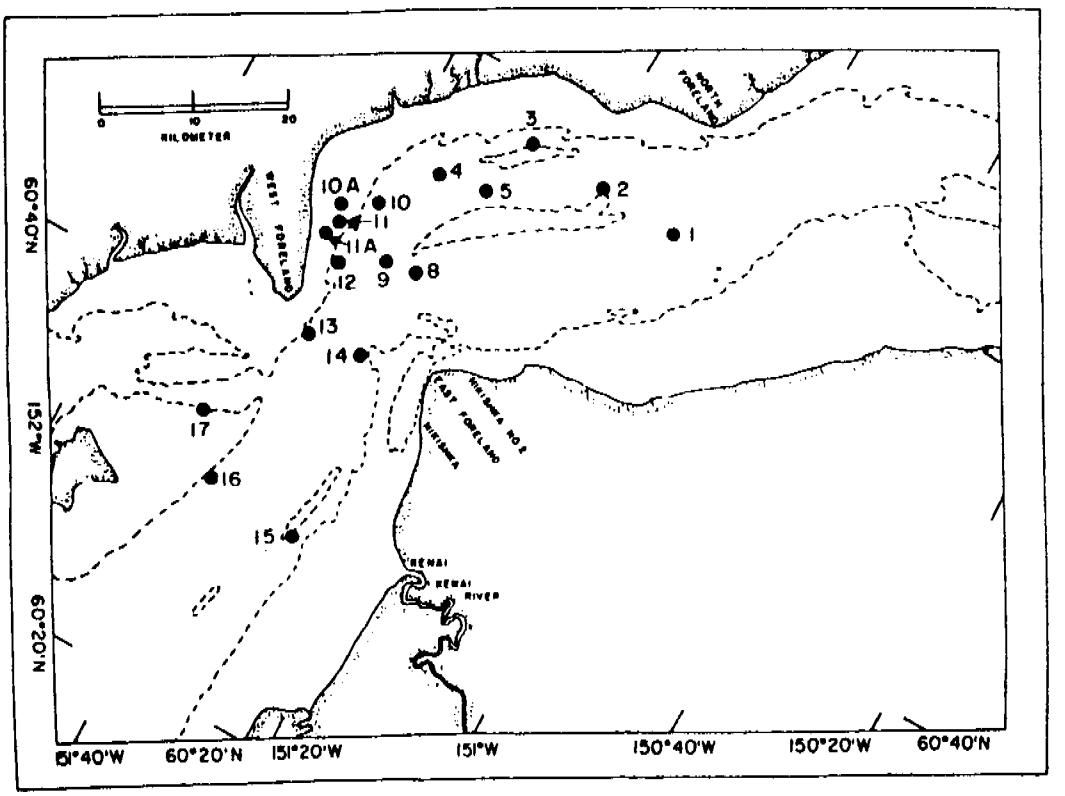


Figure 3. Station locations in upper Cook Inlet.

2. Upper Cook Inlet

| Sample Type | Collected | Analyzed |
|---|---|---|
| Aliphatics--water | 28 | 28 |
| Biological Production | 0 | 0 |
| Aromatics--water | 24 | 24 |
| Aliphatics--sediments (cores) | 0 | 0 |
| Bottom Sediments (Box Core) | 0 | 0 |

Stations Occupied: 18

Trackline Miles: 100

* Number of samples actually collected and analyzed.

## IV Results and Discussion

Because of the timing of this report, not all the data collected and analyzed during the last cruise will be available for presentation at this time. However, the salient features of our findings in upper Cook Inlet will be presented, particularily in reference to the distributions and abundances of LMW aliphatic and aromatic hydrocarbons in upper Cook Inlet.

### A. Aliphatic Hydrocarbons--Upper Cook Inlet

The surface distributions of ethane and propane are shown in Figures 4 and 5. Our experience has shown that little vertical structure is apparent in the water column, thus surface samples represent "typical" concentrations that would be found at depth.

High density sampling was conducted near the previously defined locus of the gas seep. The highest concentrations of dissolved ethane were found near the West Foreland and again off the McArthur River. Concentrations of 19 nl/L of ethane are the highest we've measured in Cook Inlet or anywhere else in Alaska. Based on previous surveys, the highest concentrations observed were near 10 nl/L. However, detailed sampling near shore during this cruise revealed even higher concentrations.

The structure of the plume shows an efflux of hydrocarbon-rich water down the west side of the inlet, whereas water deficient in hydrocarbons moves up the eastern side. Notwithstanding the presence of two or more gas vents, the bifurcated plume is probably the result of unequal tidal velocities and flow trajectories.

The highest concentrations of propane were observed at stations 11A and 4 (see Figure 3), the same locations where maximum ethane concentrations were

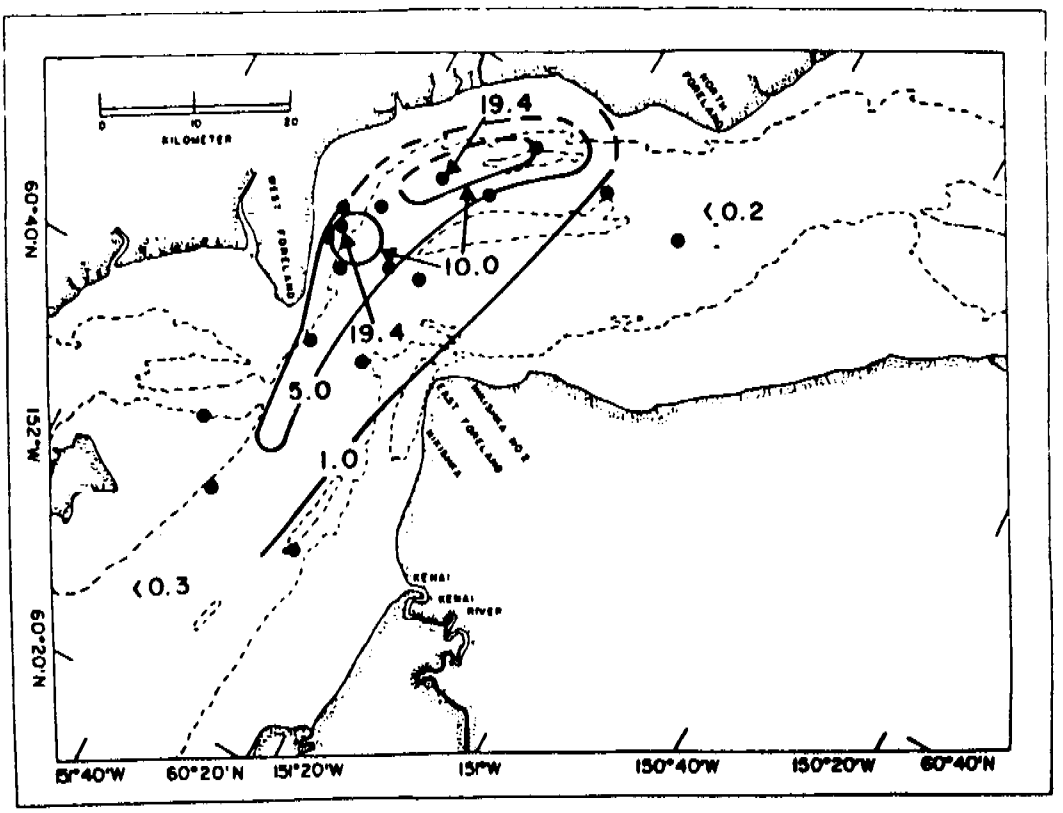


Figure 4. Surface distribution of ethane in nl/L (STP). The seep location is believed to be between the North Foreland and Middleground Shoal. Measurements were taken over a span of 3 days.

seen. The plume structure is similar, although differences are probably due to choice of station locations and contouring strategy. Table 1 summarizes the aliphatic concentrations and diagnostic ratios observed at stations 4 and 11A.

As shown in Table 1, the $C_2/C_3$ ratio is 2.2, whereas the $C_1/C_2+C_3$ ratio is near 100. The relatively high $C_1/C_2+C_3$ ratio indicates that the thermogenic gas may be appreciably diluted with biogenic methane. The strength of the source and its temporal stability suggests that the gas pool is large and

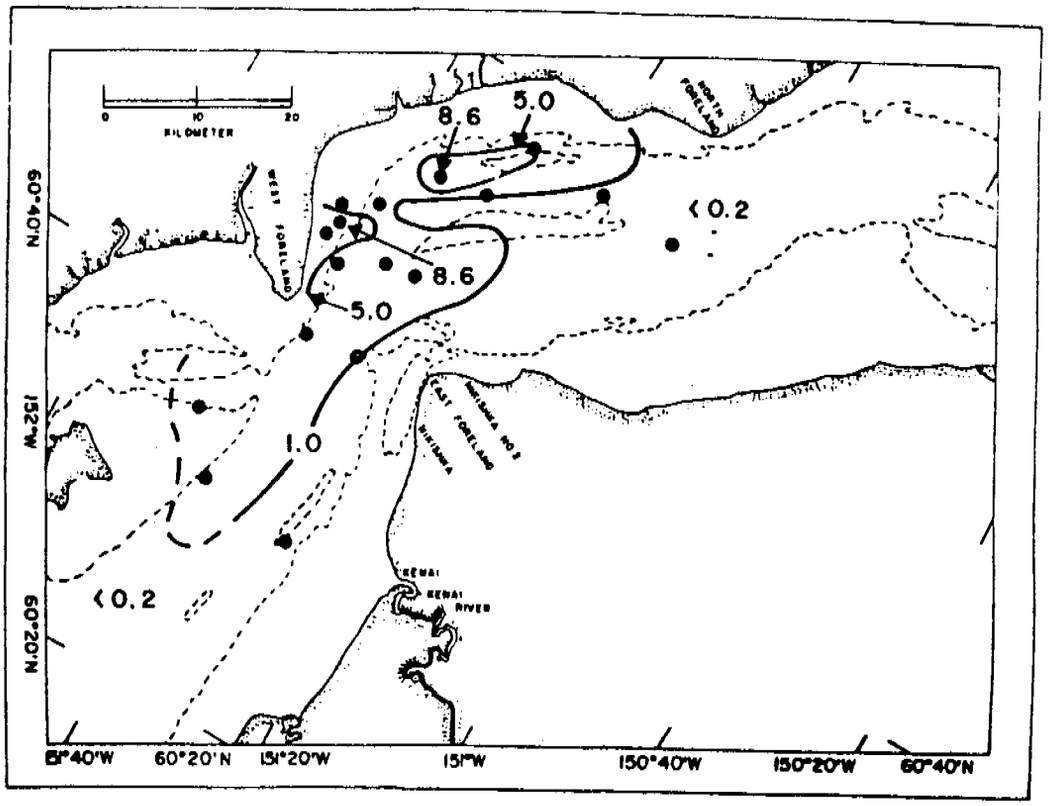


Figure 5. Surface distribution of propane in nl/L (STP). Multiple plume structures are presumably the result of tides. Measurements were taken over a span of 3 days.

Table 1. Concentrations of alkane hydrocarbons and diagnostic ratios at stations 4 and 11A in Trading Bay

| Station | $CH_4$ | $C_2H_6$ | $C_3H_8$ | $C_3/C_1$ | $C_1/C_2+C_3$ |
|---|---|---|---|---|---|
| | nl/L (STP) | | | | |
| 4 | 4080 | 19.4 | 3.6 | 0.002 | 145 |
| 11A | 2380 | 19.0 | 8.6 | 0.003 | 86 |

probably deep-seated. Vertical migration of thermogenic gas through the sediment column may have entrained biogenic hydrocarbons. Another explanation is that the source is a "dry" gas, representative of numerous gas wells in upper Cook Inlet.

Observations taken during this cruise confirm our previous findings, namely that the gas seep appears to emanate from one or two major sources, which are located near shore. In the next section is described the aromatic signature of the gas seep.

## B. Aromatic Hydrocarbons--Upper Cook Inlet

Introduction: Volatile organics is an operational definition which in this study includes those compounds in the boiling point range of 40-150$^{o}$C which can be recovered from seawater by gas phase stripping and trapped on a suitable absorbent (Bertsch et al., 1975). This group of compounds includes the potentially toxic low molecular weight aromatic compounds known to be present in petroleum (Blumer, 1969), the chlorinated and brominated cleaning solvents and industrial cleaners (Dowty and Laseter, 1975; EPA, 1977; Grob and Grob, 1974), and several naturally occurring biological compounds such as methyl sulfides (Maroulin and Bandy, 1977). The amount of data available on the naturally occurring concentrations of these compounds in seawater is extremely limited (Sauer et al., 1978; Schwarzenbach et al., 1978).

This report summarizes our use of a shipboard glass capillary gas chromatograph-mass spectrometer to identify and quantitate the concentrations of volatile organic compounds in Shelikof Strait and Cook Inlet, Alaska.

Observations were conducted in Shelikof Strait, Lower Cook Inlet and upper Cook Inlet, with emphasis on the region of Trading Bay. This is the

principle site of offshore oil and gas production in upper Cook Inlet and was chosen for intensive study on the basis of elevated concentrations of low molecular weight hydrocarbons.

Results: On previous occasions, attempts were made to characterize the dissolved aromatic hydrocarbons in Cook Inlet using conventional packed columns and flame ionization detection. Because of the chromatographic complexity generated by the presumed presence of both anthropogenic hydrocarbons and natural products, the effort this year focused on the application of a glass capillary gas chromatograph coupled to a mass spectrometer. The formal intent was to identify and quantify the aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylenes and also to identify other petroleum-derived volatile compounds that might be present. To achieve high resolution, particularly with the low molecular weight compounds, cryogenic temperature programming was employed.

A typical selected ion chromatogram, shown in Figure 6, illustrates the advantages of using glass capillary columns. The group of compounds eluting in the vicinity of the $C_2$-benzenes (I, J, K) would be rather difficult to resolve using conventional packed columns.

The mass spectrometer is an excellent detector for locating the compounds of interest in the chromatograph as well as identifying unknown compounds. The $C_2$ benzenes (I, J, K) are quite easy to separate from the other compounds by monitoring ion 106 (Figure 7). The mass spectrometer enabled us to identify several laboratory contaminants (B, C, D, F) as well as two natural products (A, G). The mass spectrometer can also be used quantitatively (Figure 8) to integrate the areas under the peaks and then compare these areas to the response of standards. The precision of the analytical method based

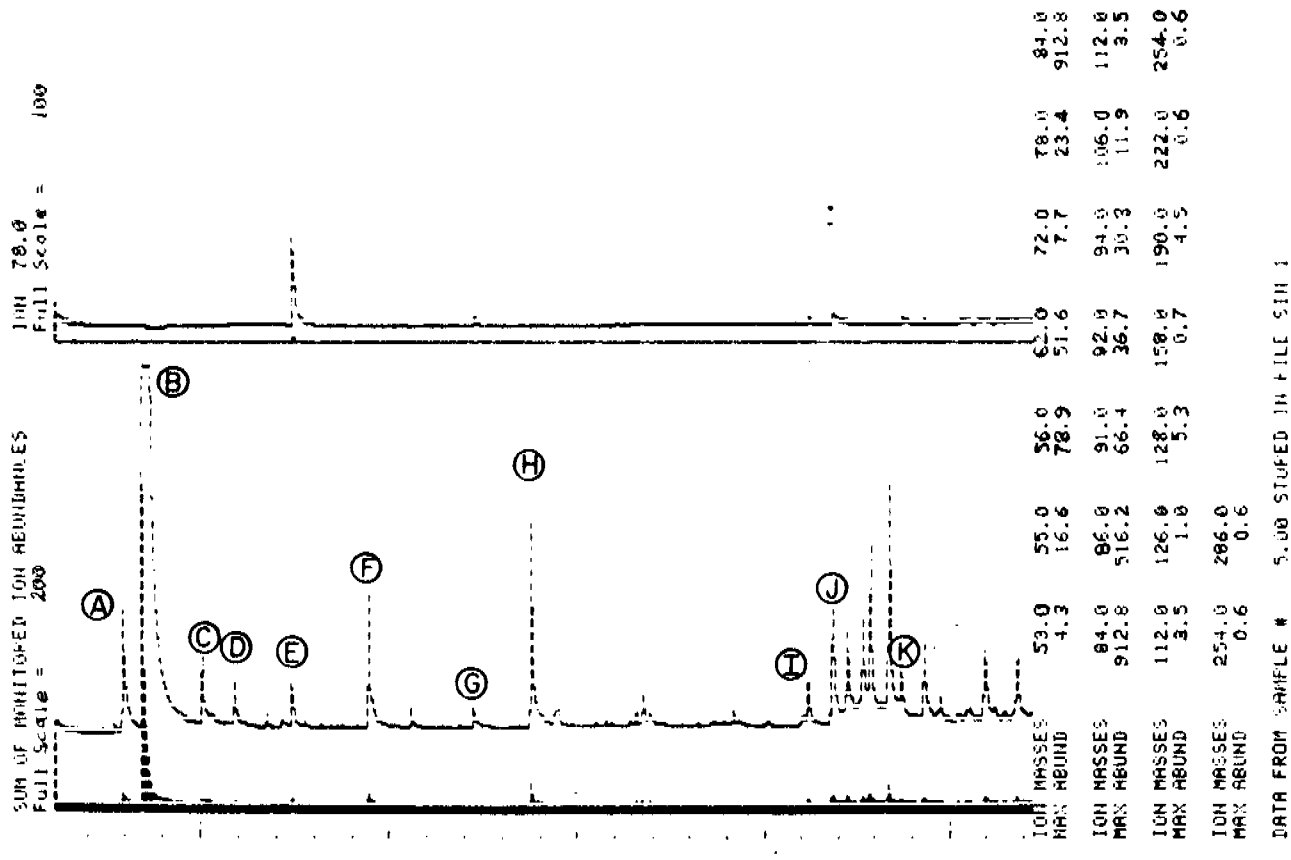


Figure 6. Selected ion chromatogram of a seawater sample collected in Shelikof Strait. A: dimethyl sulfide, B: dichloromethane, C: hexane, D: trichloromethane, E: benzene, F: trichloroethylene, G: dimethyldisulfide, H: toluene, I: ethyl benzene, J: m- and p-xylene, K: o-xylene.

on three analyses of a standard added to the stripping apparatus is ±10% (one standard deviation expressed as a percentage of the mean). The precision of the entire experimental procedure based on three samples collected at station UC-3 in upper Cook Inlet is ±35%. The limit of detection (signal:noise ratio 2) is 3 ng/L.

Sample contamination was a significant problem aboard ship. The concentration of volatile organic compounds in the atmosphere aboard the ship

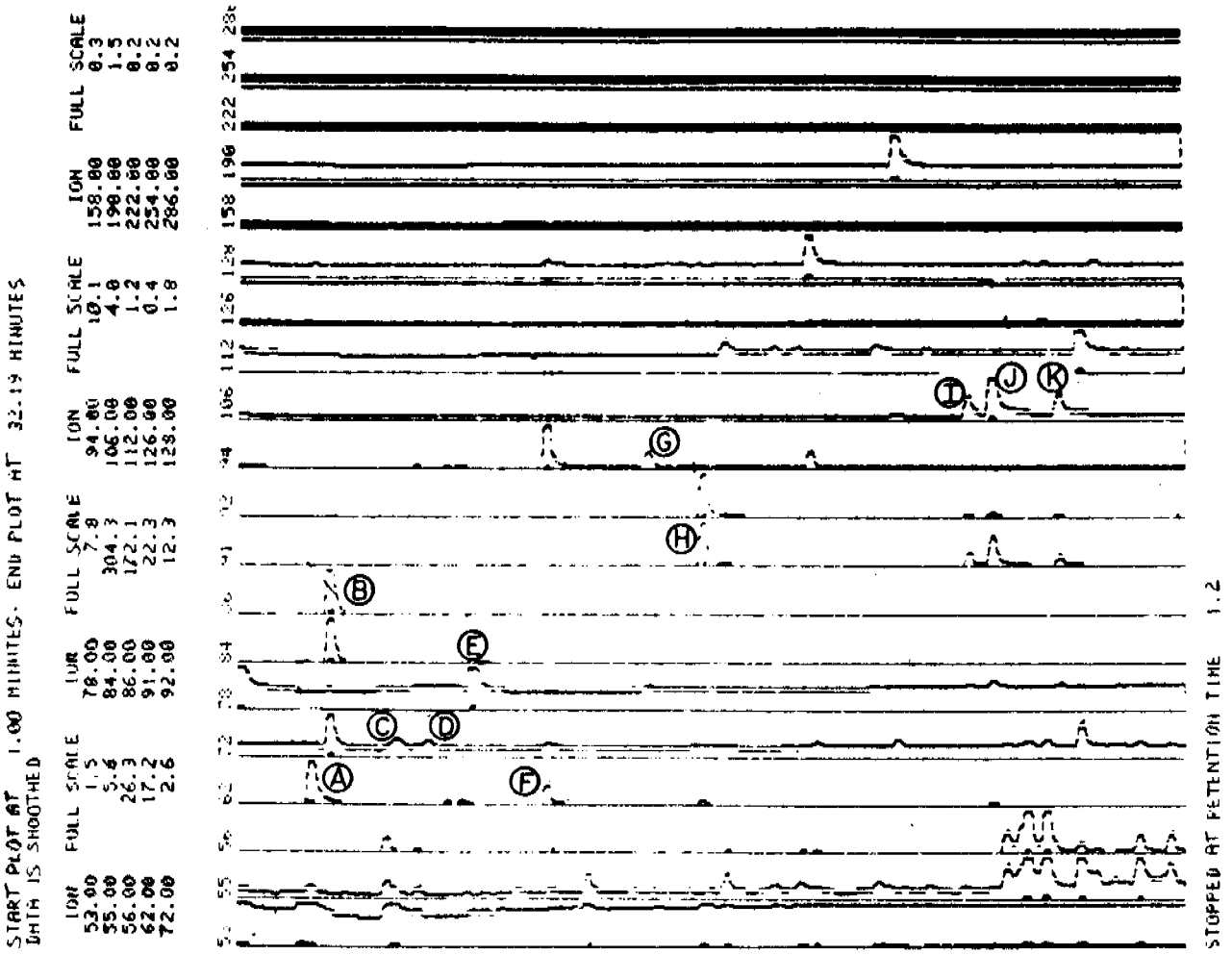


Figure 7. Individual ion chromatogram. See Figure 6 for sample and compound identification.

from cleaning solvents, laboratory solvents, ship fuel and exhaust were erratic and often high compared to ambient seawater concentrations. It is important therefore, that sample handling and storage be kept to a minimum. Careful cleaning, soaking, and storage of sampling gear can substantially minimize contamination. The concentration of volatile organics in samples collected with GO-FLO® bottles, the ship's seawater pump, and a glass bottle interface

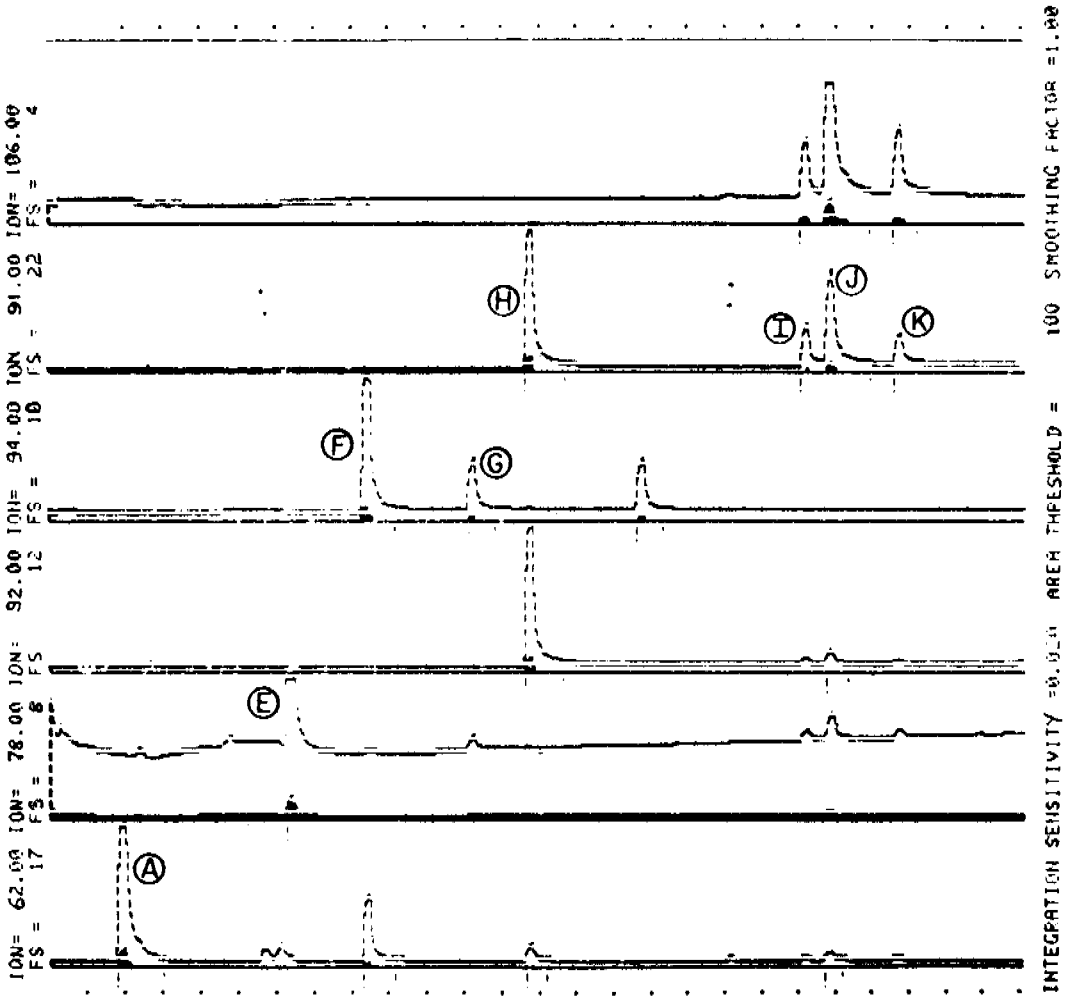


Figure 8. Selected ion integration. See Figure 6 for sample and compound identification.

sampler were not significantly different. Several samples were collected in Shelikof Strait with the interface sampler and stored for 24 hours with and without sodium azide, in the dark and in direct sunlight. The only volatile organic compound that appeared to be affected was dimethyl disulfide, which increased by a factor of 20 in the bottle stored without azide in the light. The use of sodium azide in sample storage appears to effectively inhibit biological activity without altering the original sample composition.

The concentration levels of the low molecular weight aromtic compounds in Shelikof Strait and Cook Inlet are on the order of 10 ng/L for benzene, ethylbenzene, and the xylenes. The concentration of toluene was approximately 20 ng/L. Because of relatively high, erratic, contamination levels, no significant differences in concentration levels were seen between samples taken in Lower Cook Inlet and those taken in Trading Bay. In two of the three samples showing the highest levels of alkanes, the aromatics were also elevated, but given the large uncertainties, these higher concentration levels were probably not significant.

Based on these few data, our conclusion is that the aromatic signature in the gas seep is not large, suggesting that only small amounts of volatile aromatics are actually present in the seep. Inspection of chromatographic measurements made by Sauer et al., (1978), show that benzene and toluene concentrations, determined at three offshore stations (30, 38, 39) in the Gulf of Mexico, are roughly 14 ng/L and 11 ng/L respectively. These values are similar to our surface values, although we would expect Alaskan waters to be cleaner, if these compounds are actually the result of subsurface injection. It is likely that both sets of measurements are influenced by random errors associated with sampling and handling. It is highly likely that aromatic hydrocarbons are present in the gas seep, but contamination problems associated with the ship must be overcome before their significance can be assessed.

The concentrations of the volatile sulfur compounds varied greatly among the samples analyzed. Dimethyl sulfide was present in the surface waters of Shelikof Strait, but not in the bottom waters nor the more turbid waters of Cook Inlet. Dimethyl disulfide was produced in water samples from Shelikof Strait stored without $NaN_3$. Unfortunately standards were not

available during the cruise to quantitate the concentration levels of these sulfur compounds. The total ion response of dimethyl sulfide in the surface waters of Shelikof Strait was roughly 25 times the total ion response of benzene.

The value of real time mass spectroscopy is further advanced by comparing our results with those of Sauer et al. (1978). At their station 32, located near the Mississippi River Delta, they report high concentrations of methane, ethane, ethene, and toluene, as well as heavier aliphatic hydrocarbons ($C_{11}$+). As the result of gc-ms analysis this year in Cook Inlet, we showed that a compound previously labled as toluene, on the basis of its retention time, was actually dimethyl disulfide, which co-elutes on a packed column. The close proximity of the peaks can be seen in Figure 6 (G-dimethyl disulfide, H-toluene). Because of the high concentration of ethene reported ($C_2H_4$ = 250 nl/L) by Sauer et al. (1978), we suspect that dimethyl disulfide was interpreted as toluene. The ethane/ethene ratio they reported was 0.36, a value typical for pristane Alaskan coastal waters and the more productive waters of Puget Sound. The high concentrations of methane is also indicative of a highly productive water mass, not necessarily the result of petroleum pollution. Of course, this argument does not negate the conclusion that the water at station 32 was polluted, only that the conclusion should not be based on the occurrance and abundance of LMW aromatics identified only by retention time.

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Swinnerton, S.W. and V.J. Linnenbom. 1967. Determination of $C_1$-$C_4$ Hydrocarbons in Seawater by Gas Chromatography. J. Gas Chromat., 5, 570-573.

## VI Problems Encountered

The complexities of measuring low molecular weight aromatic hydrocarbons in the low ng/L range at sea are enormous. The gc-ms system worked reasonably well, although several problems were encountered and partially solved. The major instrumental problems dealt with adsorption of aromatics on cold surfaces, mainly in the injector and external tubing, and with poor elution efficiency from Tenax®. The latter problem is believed to be related to the low flow rates (approximately 4 ml/min.) across the Tenax® trap during the sample transfer operation. This difficulty will be rectified during the next cruise by inserting a small cold finger between the flasher and the head of the glass capillary column.

Contamination of water samples during collection and transfer operations was the most serious problem encountered. High and variable levels of volatile organics in the ship's atmosphere contributed to relatively large uncertainties in the actual analysis. Solution of this problem is more difficult and will require the construction of a separate clean space, provided with its own clean air supply. This could be handled with either a specially constructed lab van or a clean room constructed within the present laboratory facilities.

Contamination of samples also occurs during sampling. To minimize this effect, sampling for LMW aromatics will be conducted forward of the ship's discharges, using clean samplers attached to Kelvar® line. If NOAA vessels are to be used for sensitive, low level, hydrocarbon sampling, a great deal of attention must be given to the cleanliness of the platform, including the air supply.

QUARTERLY REPORT

Research Unit: 153

Reporting Period: July 1 - Sept. 30, 1979

Number of Pages: 20

# Identification of Natural and Anthropogenic Petroleum Sources on the Alaska Shelf Area Utilizing Low Molecular Weight Hydrocarbons

## I. Norton Sound

Prepared by

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Seattle, Washington 98115

# I Task Objectives

During the past year, site specific studies were carried out in Cook Inlet and Norton Sound relative to sources of low molecular weight hydrocarbons. The research focused on biological production of LMWH in Kachemak Bay, apparent sources of thermogenic hydrocarbons in upper Cook Inlet, and a study of the gas seep in Norton Sound. Our past effort was devoted to the characterization, sources and distributions of the LMW aliphatic fraction ($C_1$ - $C_4$), but this year the program was expanded to include LMW aromatics, including $c_2$ - benzenes using a GC-MS system. The objective was to identify LMW aromatic compounds that might be associated with production activities in Trading Bay and the natural gas seep in Norton Sound. Because of low biological production of LMW aromatic compounds, coupled to their high solubility, these components represent a unique petroleum tracer.

The characterization of biologically produced hydrocarbons is being emphasized in Lower Cook Inlet where primary productivity is high, at least during spring and early summer. This effort is focusing on the ratios of saturates to unsaturates being produced during biological activity. Without this knowledge, it is not known how the LMWH present in crude oil will differ from the ambient condition.

This report will summarize our observations taken in July in Norton Sound. Detailed measurements were made of dissolved LMW aliphatics and aromatics. Attempts were made to characterize the aliphatic hydrocarbons present in the sedimentary pore waters, but the results are not considered reliable due to excessive hydrocarbon production after retrieval of the sediment samples.

Suspended matter samples were taken near the locus of the seep and at a control station located "upstream" from the seep. These samples will be analyzed for adsorbed hydrocarbons in an attempt to identify the petroleum

fraction present. These data will not be presented at this time because the analysis are incomplete.

## II Field Schedule

### A. Ship Schedule

The hydrocarbon sampling program was conducted in Norton Sound aboard the NOAA ship DISCOVERER. Shallow water sampling (z = 1m) was conducted from a small boat deployed from the R/V DISCOVERER. These observations were made at 3 stations near the Yukon River delta.

| Cruise Date | Cruise No. |
|---|---|
| 2-25 July, 1979 | RP-4-DI-79A-6 |

### B. Scientific Compliment

Participating in the hydrocarbon program during the Norton Sound cruise were:

Dr. Joel Cline, Project Leader, NOAA/PMEL

Dr. John Calder, Chief Scientist, NOAA/PMEL

Mr. Timothy Bates, Chemist, NOAA/PMEL

Mr. Anthony Young, Oceanographer, NOAA/PMEL

Ms. Joyce Quan, Physical Science Technician, NOAA/PMEL

### C. Methods

1. LMW Apliphatics

LMWHs are stripped from a 1 liter volume of seawater using modified procedure recommended by Swinnerton and Linnenbom (1967).

Chromatography of the components is effected on a column of activated alumina (6' x 3/16"), 60-80 mesh, temperature programmed from 100°C to 170°C at 8°/min. Retention times of the unsaturated hydrocarbons are controlled by the water content of the solid support. Chromatography of LMWH components through $C_4$ is accomplished in approximately 6 minutes. Detection of the com-

ponent hydrocarbons as they emerge from the column is made with a flame ionization detector.

2. LMW Aromatics

Collection of Water Samples: Seawater was obtained for analysis in several different ways. Routine sampling was made using 5 liter NISKIN® GO-FLO bottles, which were precleaned as described below. To assess contamination levels, water samples also were taken periodically from the biological pumping system, which was allowed to run continuously to reduce contamination and from a hand-held surface bottle sampler, which allowed a clean, 500 ml bottle to be lowered through the interface.

The GO-FLO® samplers were carefully cleaned in a strong detergent, rinsed with copious quantities of clean seawater, and finally soaked in clean seawater (changed every several hours) for a minimum of 24 hours. Samplers were attached to a clean, stainless steel line spooled on a small hand powered winch. The winch was mounted forward of the ship's bridge on the starboard side to reduce contamination from the ship's stack gases and surface discharges.

Two seawater pumping systems on the R/V DISCOVERER were tried during the Cook Inlet cruise. The first is the biological pumping system in which the pump is located in the bow and collects water from approximately 6m depth. Both this system and the normal seachest pump were flushed for several days before use.

The glass bottles used in the collection of surface samples (down to 1m) were cleaned in a strong detergent, rinsed thoroughly, and oven dried before tightly sealing with Teflon® lined screw caps. These bottles were attached to a modified lake sampler in which the bottle could be lowered through the interface closed to prevent contamination from the surface layer. All water samples were stored at $3^{o}C$ in the dark with 0.5 g $NaN_3$ to reduce biological

and photochemical effects.

Removal of LMW Aromatics from Seawater: Water samples (approximately 500 ml) were transferred to a modified gas dispersion bottle, heated to 40°C in a water bath and stripped for 30 minutes with prepurified Helium. Flow rate was set at 100 ml/min. The carrier stream was passed through a condensor cooled to near 0°C and finally through a Tenax GC® trap (1/4" o.d. x 3") cooled to approximately 6°C. Prior to sample collection, each Tenax® tube was purged with Helium at 275°C for several hours. Excess water vapor was removed from the Tenax® with dry Helium for 15 minutes at 100 ml/min. At the conclusion of the drying step, the Tenax® traps were placed immediately in the Bendix Flasher and the hydrocarbons transferred to a cold finger (-196°C) located physically near the injector.

Analysis of LMW Organics: During the previous Cook Inlet cruise, the Bendix Flasher (Applied Science Laboratories, Inc.) was attached directly above the gas lined injector of the GC-MS system (HP 5992A). However, because of poor hydrocarbon elution efficiencies from Tenax® at low flow rates (4 ml/min), we decided to place in series with the Bendix Flasher a small cold finger (1.6 mm o.d. x 12 cm glass lined stainless steel U-tube) cooled to -196°C with $LN_2$. The larger diameter cold finger allowed the hydrocarbons to be purged from the Tenax® at higher flow rates (30 ml/min) and trapped in a small plug near the injector. A heat gun was used to transfer the hydrocarbons from the cold finger to the head of a 30m wall coated (SE-54) open tubular glass capillary column held at -50°C. The oven was then quickly heated to an initial temperature of 0°C and programmed from there at 2°/min to a final temperature of 100°C. The column was baked out at 250°C between samples. Mass spectral data was collected and synthesized using two separate software packages. The first program provided a total ion scan from 45 to 350 AMU at each peak. The

second program (Selected Ion Monitoring) allowed 20 preselected ions to be monitored for area response. This program was used for quantitation of the selected LMW aromatic compounds such as benzene, toluene, ethylbenzene, and xylenes.

Standardization Procedures: Five µl aliquots of individual aliphatic, cycloalkane, and aromatic hydrocarbons were vaporized in a heated 3000 ml flask to produce a gaseous HC standard of approximately 1.4 ng/µl for each component. This standard, which could be injected directly into the gc, was used to assess gc operating conditions and detector sensitivity (m.s.)

Aqueous standards were prepared by mixing known amounts of pure solvents in methanol, which were diluted in purged distilled water and used as secondary standards (EPA, 1977). Stripping efficiencies were assessed by comparing the response of the m.s. to each of the above standards. Aqueous standards were used to determine area response factors for individual compound quantitation.

## D. Station Locations

The station grid, as shown in Figure 1, was occupied by hydrocarbon (Cline) and suspended matter programs (Feely). The total number of stations sampled by us was 57; stations 17A and 21B were time series stations at which vertical water column sampling was conducted every 4 hours. Total trackline distance was 990 n. mi. (1833 km), not including the small boat sampling near the Yukon River delta (see Figure 1).

## E. Data Collected

The number of samples taken are shown below.

Of all the samples taken, only the sediment and nutrient samples remain to be analyzed.

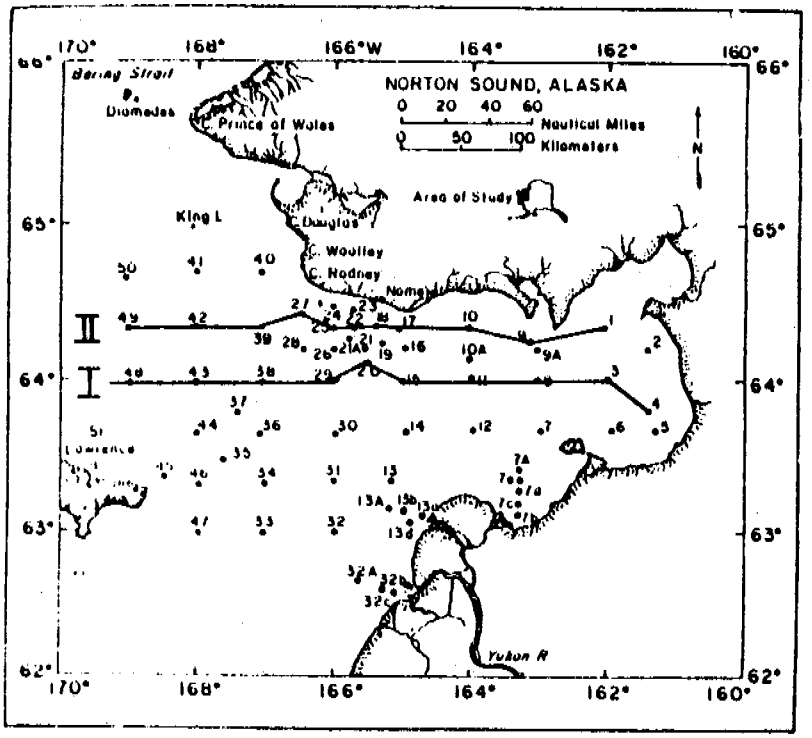


Figure 1. Station locations in July 1979. Water column properties along sections I and II are discussed in the text.

## Data Collected

| | Aliphatics | Aromatics |
|---|---|---|
| LMW Hydrocarbons (dissolved) | 253 | 36 |
| Suspended PHC | 2 | 2 |
| Pore water hydrocarbons | 12 | 0 |
| Sedimentary hydrocarbons | 4 | 4 |
| Oxygen--approximately 60 | | |
| Nutrients--approximately 60 | | |

## III Results and Discussion

In July, a survey of the distributions of dissolved and pore water LMW

hydrocarbons was carried out in Norton Sound. The sampling grid was similar to that occupied in September 1976, except more detailed observations were conducted near the Yukon River, St. Lawrence Island, and the actual seep location. Station density was increased near the northeast tip of St. Lawrence Island for the purpose of identifying submarine hydrocarbon gas seeps, which were suspected on the basis of seismic profiling conducted by U.S.G.S. In the region of the gas seep, additional analyses were incorporated. These included analyses for dissolved LMW aromatics and the acquisition of suspended solids for analysis of heavy petroleum-like hydrocarbons.

The cruise tract is shown in Figure 1. To aid in the description of the hydrography and to identify hydrocarbon sources, two east-west vertical sections will be described. The first of these (Figure 1; I) nearly bisects the Norton Basin; the second (II) passes through or near the seep.

## A. Hydrography

The surface distribution of salinity and temperature is shown in Figures 2 and 3. Offshore coastal water is identified approximately by surface salinity greater than $30^{o}/_{oo}$ and surface temperatures less than $7.5^{o}C$. At the eastern extremity, salinities as low as $19^{o}/_{oo}$ were observed along with warm temperatures ($T>11^{o}C$). It is noteworthy that the freshwater influence from the Yukon was not strongly observable except near shore. Surface salinity at station 13 (Figure 1), only 50 km from the Yukon River, was $29.3^{o}/_{oo}$, representing a maximum dilution of only 8%. Most of the fresh water appears confined to the coastal regime, where numerous diverse sources of freshwater exist. Shape of the isohaline contours would suggest a weak cyclonic circulation nearshore.

The vertical distribution of density is reflected in two zonal section (Figures 4 and 5). Distribution of mass along section I (Figure 3) shows a

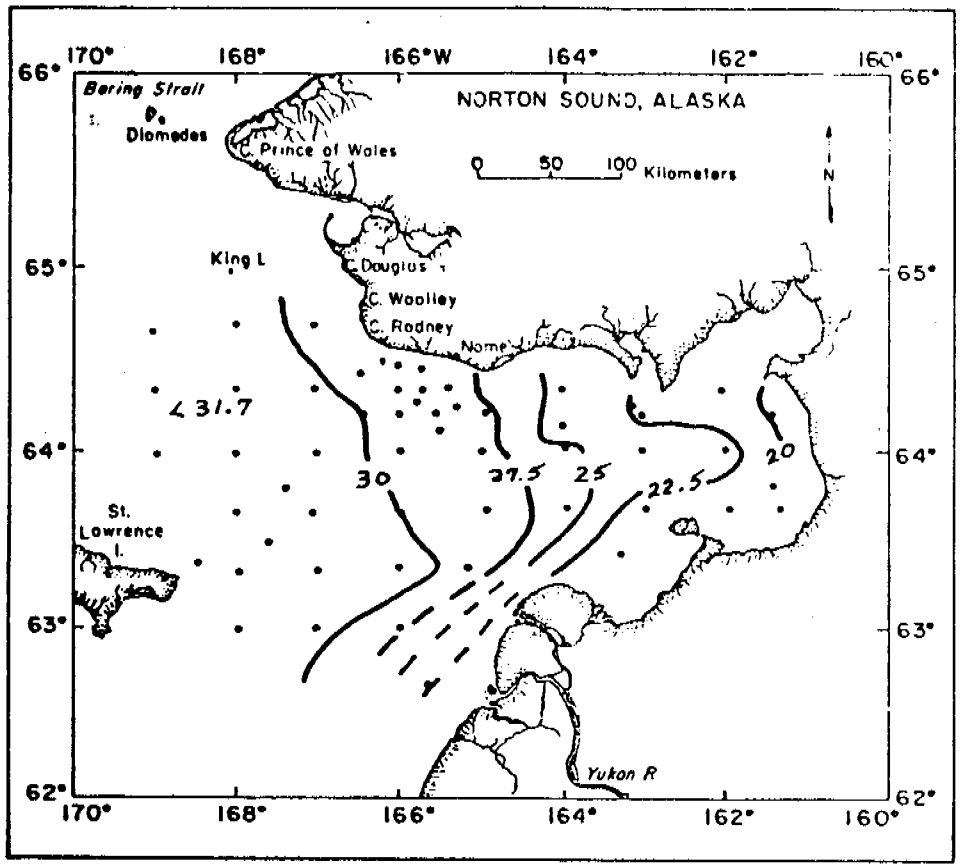


Figure 2. Surface salinity in July 1979.

moderate degree of stratification within the inner sound, with a complete breakdown of stratification between stations 15 to 29. Offshore, stratification is only weakly developed. The breakdown of the salinity-induced stratification is due to a frontal-like system along the 20 m isobath.

Section II passes north of section I and crosses near the locus of the seep. Again, we see a disintegration of the density structure near stations 18 through 25, close to the probable location of the seep. The doming of the isopycnoes at station 22 (Figure 5) is interesting. The feature might be indicative of a near bottom current (flowing northerly) or the injection of brine associated with the seep. To test the latter hypothesis, a statistical

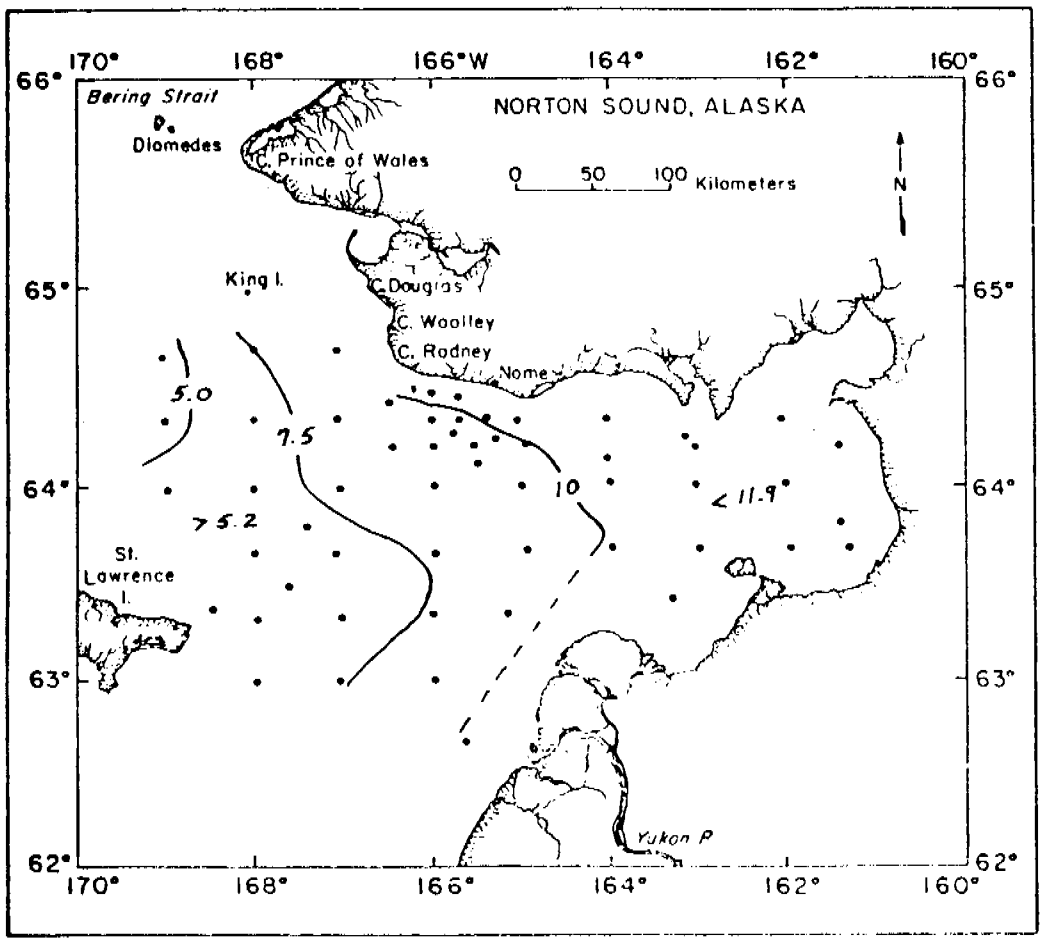


Figure 3. Surface temperature in July 1979.

survey was made of the salinity and temperature distributions at stations 18, 20, 21, 21B, 22, 25, and 26 (see Figure 1) and compared to stations east and west of the seep locus. If brine were being injected, we might suspect higher salinities and higher temperatures in the area of the seep. Unfortunately, salinity and temperature gradients across the area are large, which imposes a significant temporal uncertainty in the mass field. The picture is further confused by intense vertical mixing over the seep, which is integrating at least three separate water masses. At the time of the observations, three distinct water masses could be identified on the basis of salinity and tem-

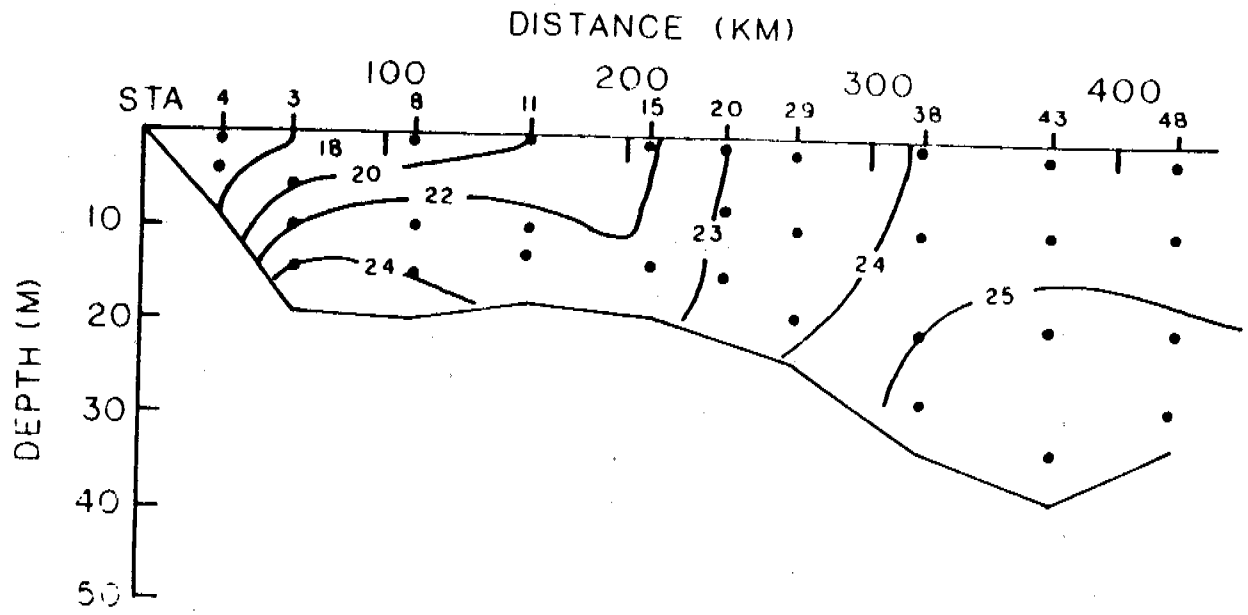


Figure 4. Vertical distribution of mass ($\sigma_t$) along section I in July 1979.

perature. They were: 1) cold, high salinity water offshore, 2) relatively warm, saline water from subsurface depths in the basin interior, and 3) warm, low salinity water along the north coast of Norton Sound. These water masses were being mixed in unknown proportions along the previously described frontal system. The non-steady behavior of the water masses in the region of the seep were further elucidated by time series measurements taken at station N21B. Here, the near bottom (14-16 m) density ($\sigma_t$) changed from 22.95 to 23.13 over a period of 36 hours. The increase in density was largely due to temperature which monotonically decreased during the period. Again, salinity induced stratification was well developed between stations 1 and 17.

In summary, hydrographic conditions during July suggest a strong interaction between the warm water of the inner sound with the cold, high salinity water found offshore. This interaction occurred along or near the 20 m isobath and resulted in a nearly neutrally bouyant water column.

## B. Distribution of Aliphatics

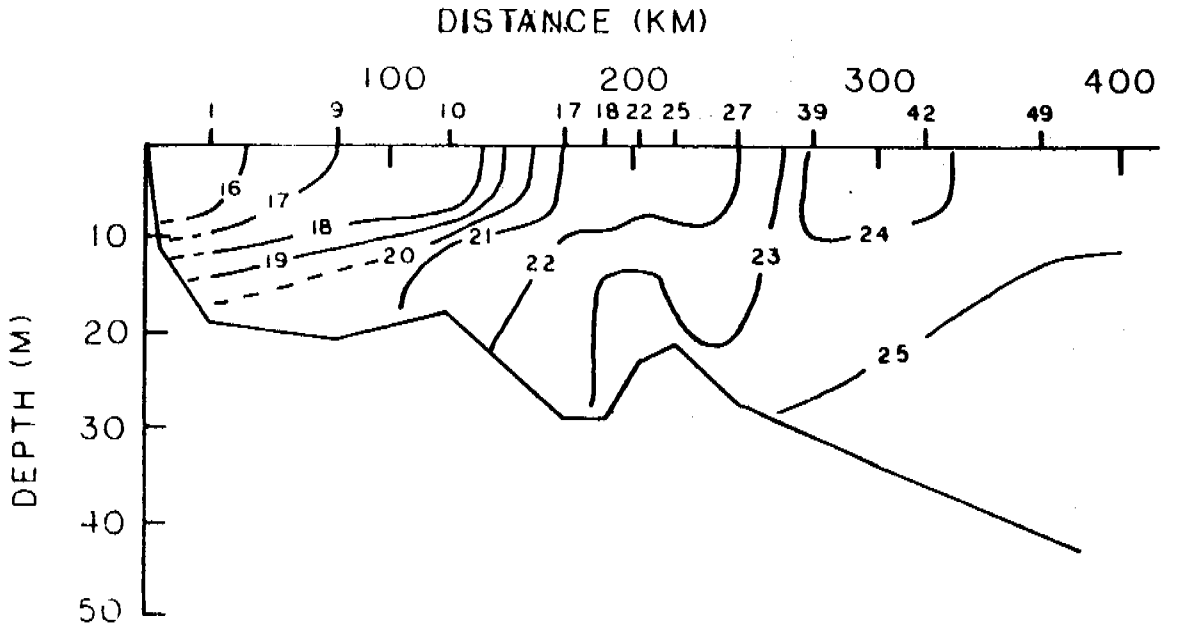


Figure 5. Vertical distribution of mass ($\sigma_t$) along section II in July 1979.

The horizontal distribution of methane at the surface and 10m is shown in Figures 6 and 7. As observed in September 1976, a strong source of methane was again identified in the southeastern corner of Norton Sound. This area is characterized by organic rich fine-grained sediments, which apparently supports methane production within the upper layers of the sediment column. In contrast to conditions in September of 1976, stratification near shore was minimal (see Figure 4), allowing a prominant methane signature to be seen at the surface. The highest concentration of methane was 1020 nl/L at station 3. Since the concentration decreased near the bottom, we assume that the source actually exists inshore of that station. Diffusion of methane to the west is evident in Figure 7.

Also apparent in Figures 6 and 7 is the prominant source of methane associated with the Yukon River. The highest concentration of methane (>2000 nl/L) was found in association with the low salinity water near the Yukon

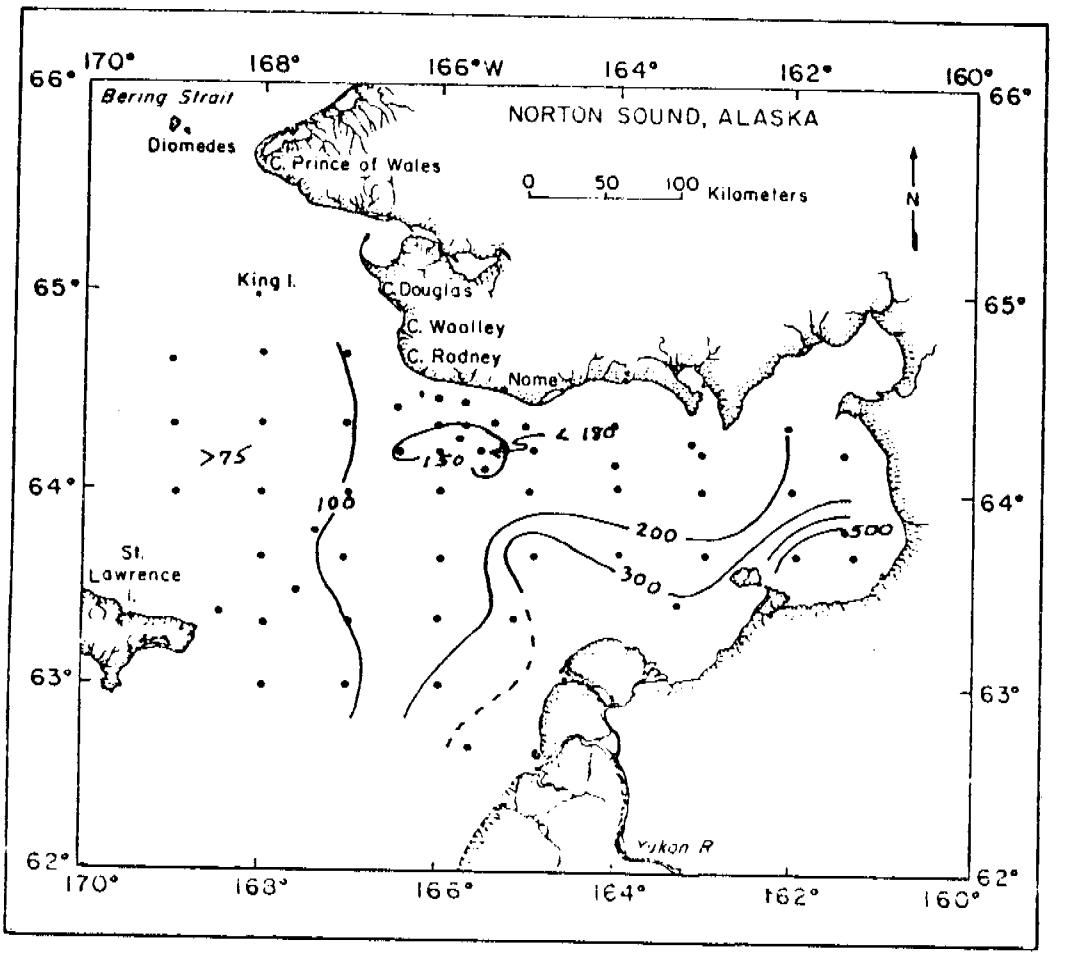


Figure 6. Surface distribution of dissolved methane (Nl/L, STP) in July, 1979.

delta. Although the isoconcentration contours suggest the plume extends northwest (Figure 6), the salinity distribution reveals that brackish water is largely confined to the immediate coast (Figure 2). High concentration of methane in the surface waters at station 14 was the result of strong vertical mixing from below (see Figure 4) and does not necessarily reflect the actual trajectory of the Yukon River plume.

Distribution of methane near the seep also is shown in Figures 6 and 7. In contrast to conditions obtained in September 1976, methane, arising from the seep was observed in the surface layers. The distinction from background was marginal and is shown by the 150 nl/L contour. Again, a breakdown in vertical

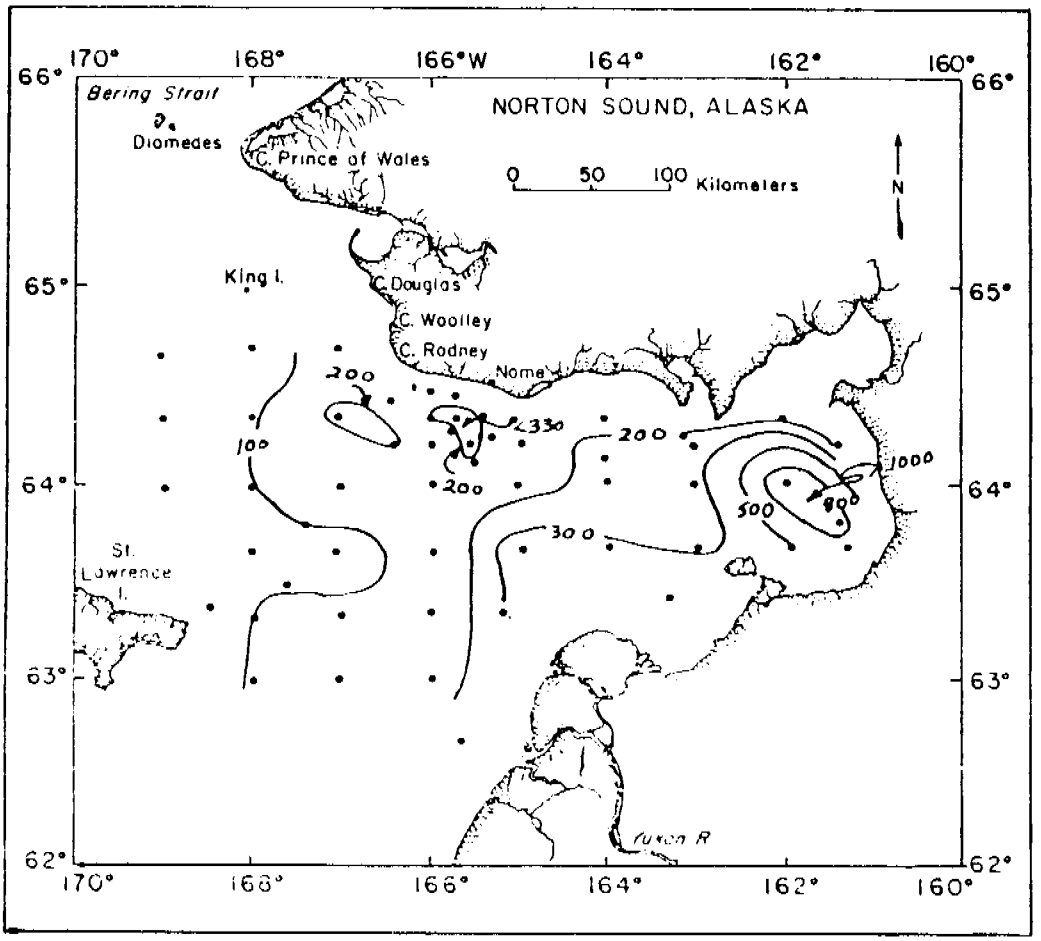


Figure 7. Distribution of dissolved methane (nl/L, STP) at 10m in July, 1979.

stratification allowed methane to be enriched in the surface layers. Concentrations at 10 m (Figure 7) reached 330 nl/L (STP), approximately a factor of two higher than the surrounding waters.

The actual source of the methane in the seep area is, of course, uncertain. Box coring and gravity coring in this region revealed surface sediments rich in LMW hydrocarbons, although reliable analyses were not realized. Headspace stripping of surface sediments revealed a preponderance (qualitatively) of saturated alkanes, indicating that 1) the surface sediments (0-5 cm) were reducing or 2) thermogenic hydrocarbons were actually present in the surface sediments at station N21A. Our inclination is to favor the former rather

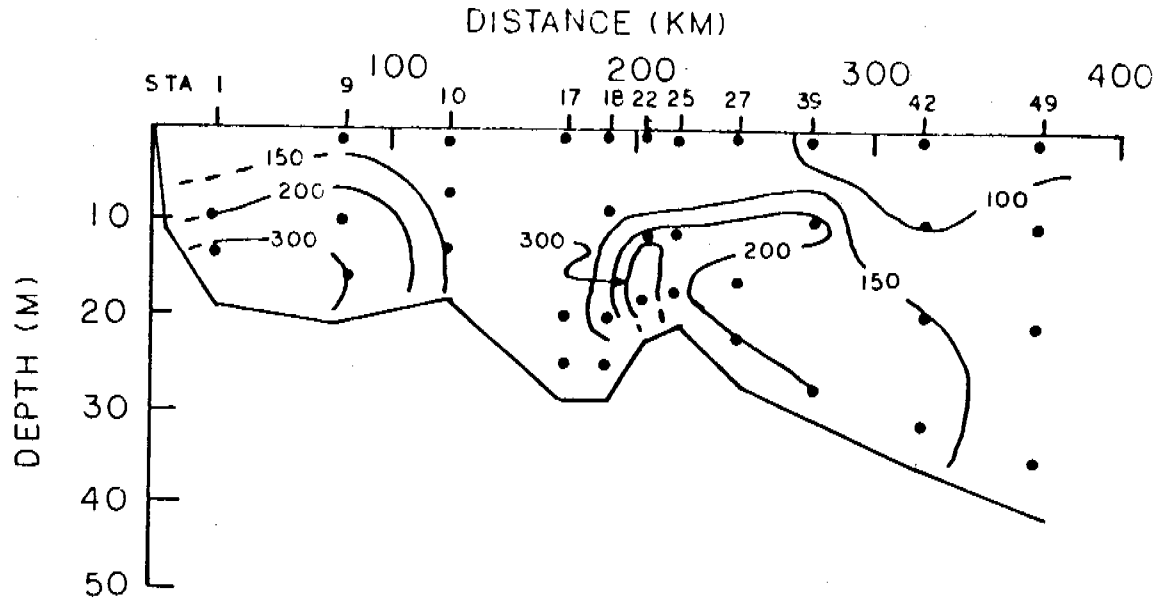


Figure 8. Vertical distribution of methane (nl/L, STP) along section II in July 1979.

than the latter explanation.

We have already shown that the region near the seep was hydrodynamically unstable, thus resuspension of methane-rich muds could be a source. Of course, the methane could be of biogenic or thermogenic origin; in all likelihood, it represents a mixture of both.

A summary of the sources of methane is shown in Figure 8. This section (II) shows the bottom methane source emanating from the southeastern corner as well as the vertical plume structure near station 22. In all likelihood, excess concentrations of saturated hydrocarbons are caused by venting gas (biogenic or thermogenic) from the previously identified gas seep or associated vents. Subsequent measurements by Kvenvolden et al., (1979) have shown that the bulk of the gas is probably carbon dioxide, with only trace amounts of aliphatic hydrocarbons. Because the methane plume is located near a small topographic high, in a region characterized by strong vertical mixing, we can not rule out resuspension or erosion of methane-rich muds from the bottom.

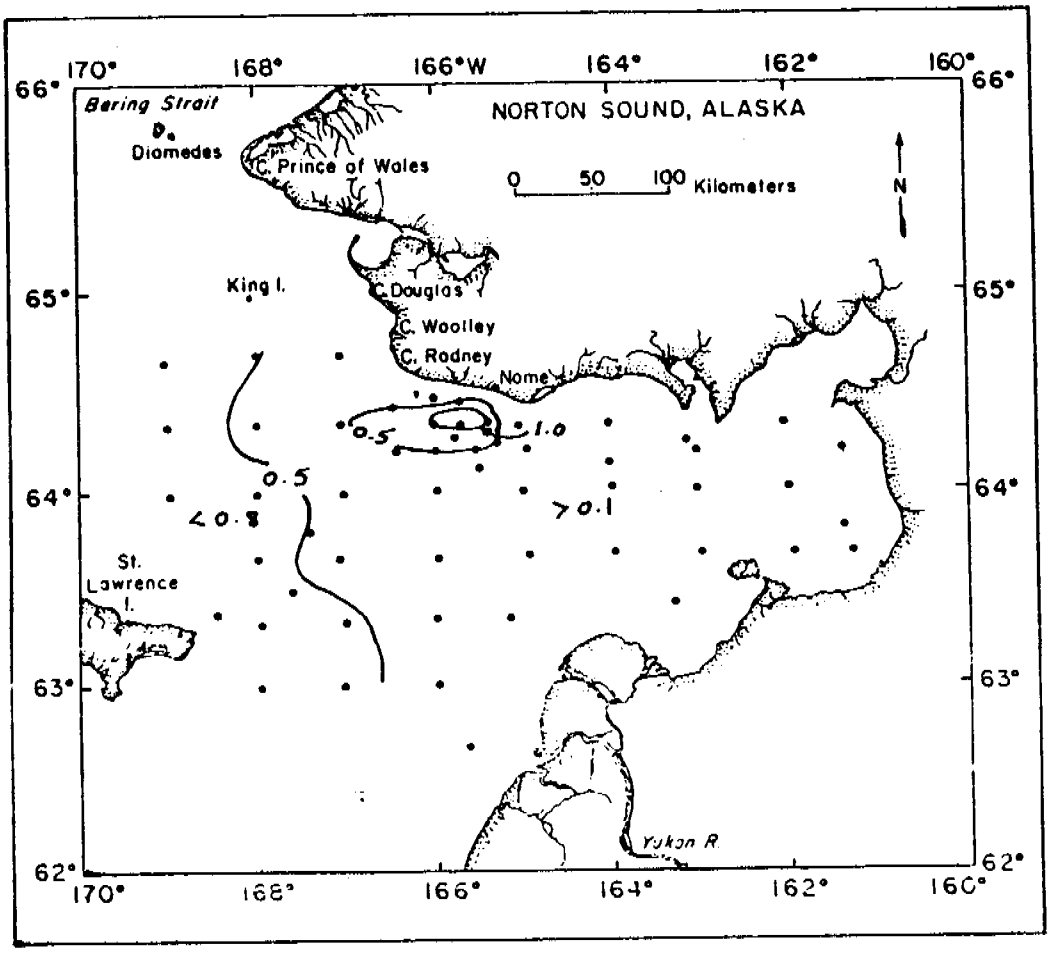


Figure 9. Distribution of ethane (nl/L, STP) at 10 m during July, 1979.

In September 1976, the seep was clearly identifiable on the basis of the ethene and propane distributions. This year, as evidenced in Figure 9, the ethane signature was much smaller. The highest concentration of ethane observed was 4 nl/L (10m depth) at a site a few kilometers west and north of the previously defined seep locus. Although the hydrocarbon plume was restricted to a defineable area of approximately 2500 $km^2$ (Figure 9), the subsurface concentration of ethane was 0.1 to 0.3 nl/L (STP) throughout the eastern extremity of the bay.

Higher concentrations of ethane were observed offshore (0.5 to 0.8 nl/L STP) and correlated with higher concentrations of ethene. Presumably, this

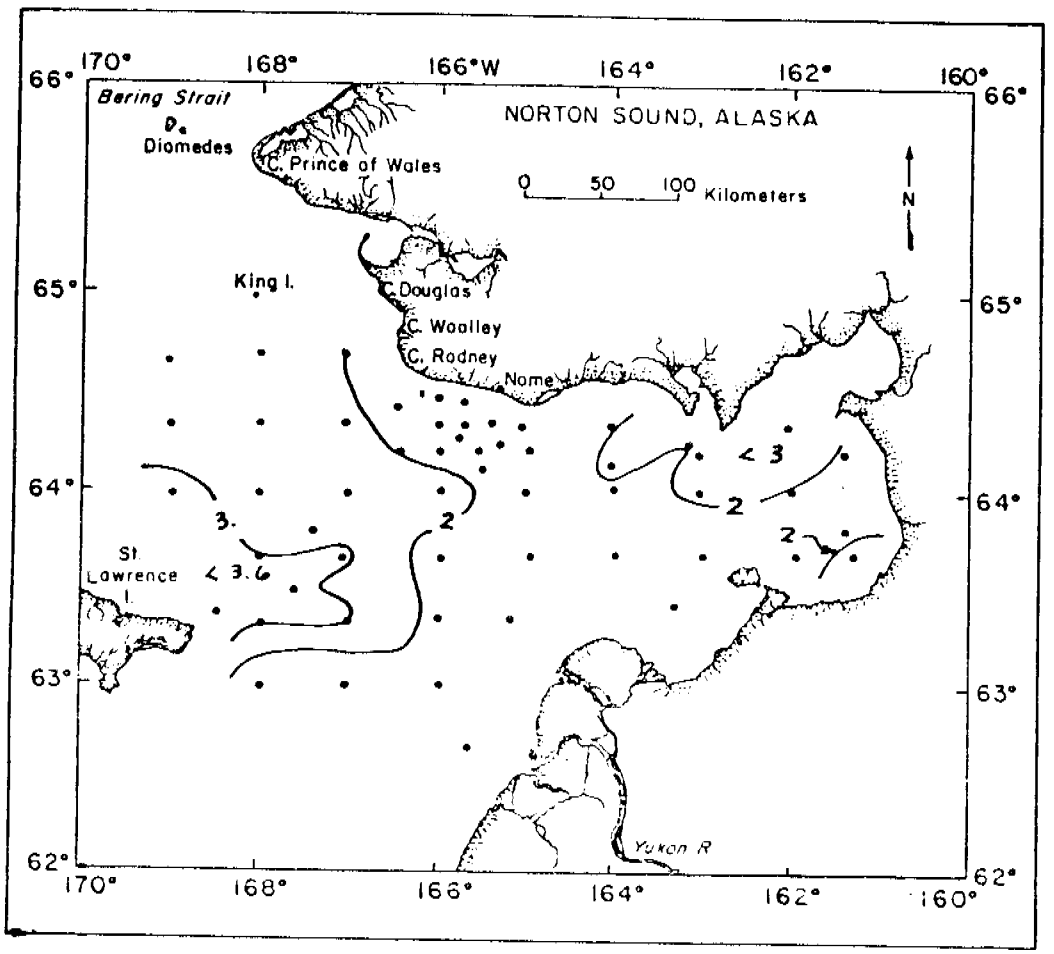


Figure 10. Surface distribution of ethene (nl/L, STP) in July, 1979.

phenomenon was related to biological processes in the colder, more productive offshore waters.

Regions of active biological activity are usually denoted by high levels of dissolved ethene. Surface distribution of ethene is shown in Figure 10. The Bering Sea coastal water is characterized by concentration of ethene ranging between 2 and 4 nl/L. In the region of the seep, the surface concentrations average 1.5 nl/L. Somewhat higher values were observed in the vicinity of Norton Bay (~2 nl/L).

During the recovery of suspended matter at station N21B (seep) and at a control station (N17A) located northeast of the seep, water samples were ana-

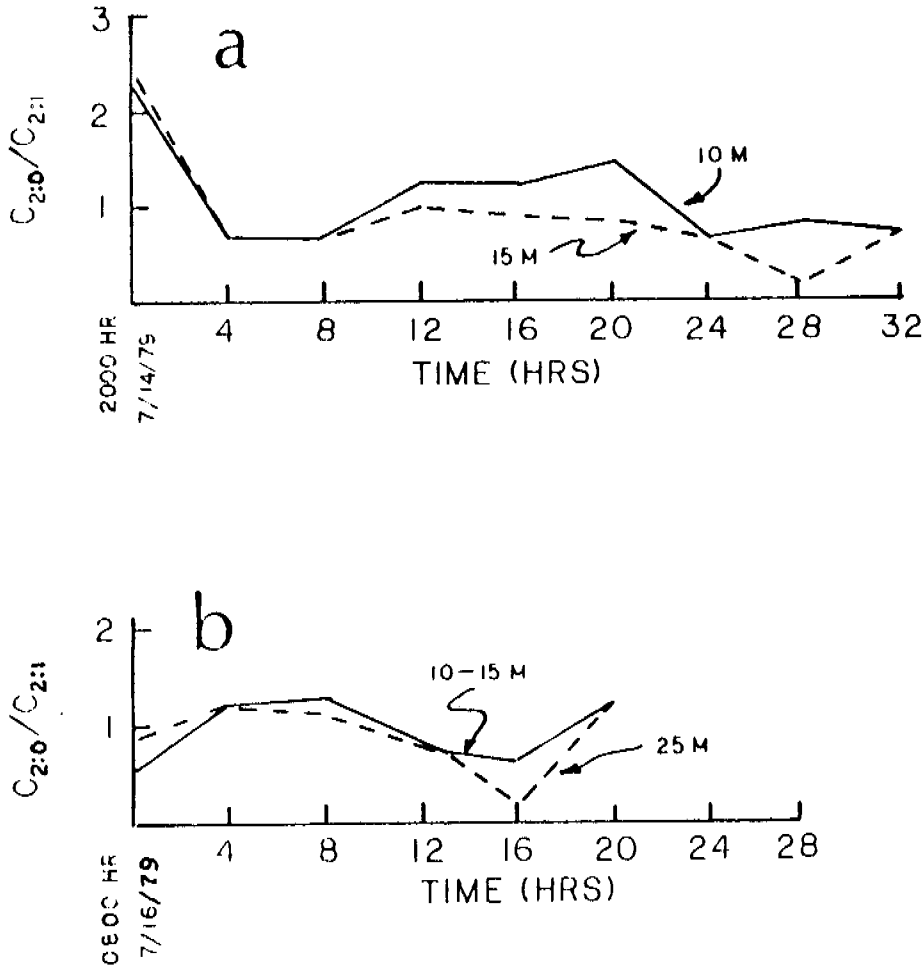


Figure 11. Temporal variation in the ethane/ethene ratio ($C_{2:0}/C_{2:1}$) at stations N21B (a) and N17A (b).

lyzed every four hours for LMW hydrocarbons. The ethane/ethene ratio ($C_{2:0}/C_{2:1}$) at these two stations is shown in Figure 11 (a, b). At station N21B, the ethane/ethene ratio varied from 0.2 to 2.4. Values of this ratio in excess of 0.5 strongly suggest an anomalous source of ethane. The control station (b) generally reflected lower ratios, but elevated levels of ethane were also evident at his station as well.

Compared to observations in and near the seep in September 1976, ethane and propane were found at significantly lower concentrations this year. We postulate two mechanisms lead to a reduced plume signature. Increased mixing

in and near the seep together with a much reduced injection rate of hydrocarbons resulted in a poorly defined hydrocarbon plume. This explanation is also supported by the near absence of dissolved LMW aromatic hydrocarbons near the seep. In fact, during our attempt to identify the locus of the seep, numerous patches and lenses of hydrocarbon-rich water were identified. This suggests that the seep was episodically active.

The sustained high $C_{2:0}/C_{2:1}$ ratio at the control station (N17A) may be due to contamination from the seep, or due to the release of biogenic ethane from near surface reducing sediments. As mentioned earlier, the bottom sediments in this area appeared to be reducing, based on the high concentrations of alkanes relative to alkenes. If current velocities were sufficiently high to erode surficial sediments, the normal $C_{2:0}/C_{2:1}$ ratio in the water column (<0.5) would be increased. Typical $C_{2:0}/C_{2:1}$ ratios for stations N1 through N16 averaged $0.12 \pm 0.05$ ($n = 48$). Offshore (stations 30-50) the ratio averaged $0.23 \pm 0.13$ ($n = 61$). The higher $C_{2:0}/C_{2:1}$ ratio found offshore is due to a systematic increase in the concentration of ethane at depth, presumably due to a bottom or near bottom biogenic source.

In summary, it appears that the activity of the seep was minimal and probably episodic. Strong vertical mixing near the seep locus further attenuated the hydrocarbon signature.

### C. Low Molecular Weight Aromatics

One of the stated objectives of this cruise was to identify aromatic hydrocarbons arising from the gas seep. Approximately 11 stations were sampled in the region of the seep and compared to six control stations located throughout the remainder of Norton Sound. Because of relatively poor sensitivity and low concentration levels, concentrations of benzene, toluene, ethylbenzene, and

and xylenes were everywhere less than 10 ng/L. It was not possible to identify the location of the gas seep on the basis of dissolved LMW aromatic compounds. This is in agreement with our previous statement that the seep was minimally active.

### D. Suspended Petroleum Hydrocarbons

During the cruise, two time series stations were occupied for the purpose of collecting suspended matter. A continuous flow centrifuge and submersible pump were used to collect suspended matter from a depth of 15m. Two integrated samples were collected at station N21B (32 hours) and at station N17A (20 hours). These samples are currently being analyzed for sorbed aliphatic and aromatic hydrocarbons.

## IV Problems Encountered

During this cruise, problems similar to those encountered in Cook Inlet were experienced. Apart from the instrumental and analytical difficulties, which we and Hewlett-Packard are attempting to resolve, the remaining problems involved the suitability of the R/V DISCOVERER for marine organic geochemistry.

The most serious problem is the continual contamination of the air space with volatile organic compounds (e.g. chlorinated aliphatics, xylenes, volatile components of diesel fuel, etc.). If this type of work or similar activities are to continue aboard the DISCOVERER, a separate clean lab must be constructed with a separate air supply.

The remaining major difficulty is one of sampling. To avert contamination of sampling gear, we must work forward of the stacks and waste discharges. The DISCOVERER should be equipped with a davit and a small electric-hydraulic winch forward of the bridge (starboard side). The winch should be spooled with Kevlar cable. With these modifications, the ship would possess greater utility as a sampling program for integrated research activities involving physics, chemistry, and biology.

QUARTERLY REPORT

Contract: #03-5-022-56
Research Unit: 162
Task Order: 12
Reporting Period: 4/1/79-6/30/79
Number of Pages: 68

# DISTRIBUTION AND DYNAMICS OF HEAVY METALS IN ALASKAN SHELF ENVIRONMENTS SUBJECT TO OIL DEVELOPMENT

Dr. David C. Burrell
Principal Investigator
Professor of Marine Science

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 1979

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## I. TASK OBJECTIVES

The primary objective of this program is to research natural pathways of potentially toxic heavy metals to and through Alaskan Shelf and coastal marine biota (with emphasis on commercially important benthic species) and hence to determine and predict changes likely to result from oil industry activity in this marine zone. Ancillary components of this work include: (1) characterizing the heavy metal inventories of the water, sediment and indigenous biota in those geographical areas for which no background data exist; (2) determining non-biological pathways (rates and routes under both natural and stressed conditions) of the heavy metals as these affect the availability of metals to the organisms; (3) toxicity effects of selected heavy metals to animals which are of major commercial importance under Alaskan environmental conditions.

## II. FIELD AND LABORATORY ACTIVITIES

### A. Field Work

1. Resurrection Bay

   R/V *Acona* No. 275, 18 April 1979

   Personnel: D. C. Burrell

   Full survey of hydrography and nutrient distributions.

2. Resurrection Bay

   R/V *Acona* 276, May 1979

   Personnel: D. C. Burrell

   T. Owens

   Operations as above

3. Lower Cook Inlet - Homer

June 1979

Personnel: D. Weihs

C. Cremo

Collection of intertidal clam samples for laboratory aquaria experiments on heavy metal uptake.

B. Scientific Parties

As noted above

C. Field Collection Methods

As discussed in 1978-79 Annual Report

D. Laboratory Analysis Program

No new techniques employed this quarter. Methods as given in previous reports.

III. RESULTS

A. Beaufort Sea

These data are complete and analysed. A final report is being prepared.

B. NEGOA Specific Study Sites

Detailed hydrographic data obtained for Yakutat Bay in April 1979 has been processed. Preliminary data are given in Appendix I.

Figures 1-4 give particulate manganese vertical profile data for RES 2.5 for October 1978 and March 1978 (R/V *Acona* Nos. 267 and 272).

Figures 5-12 give interstitial water and water column data for Resurrection Bay obtained on R/V *Acona* cruise No. 272, March 1979. Hydrographic data for

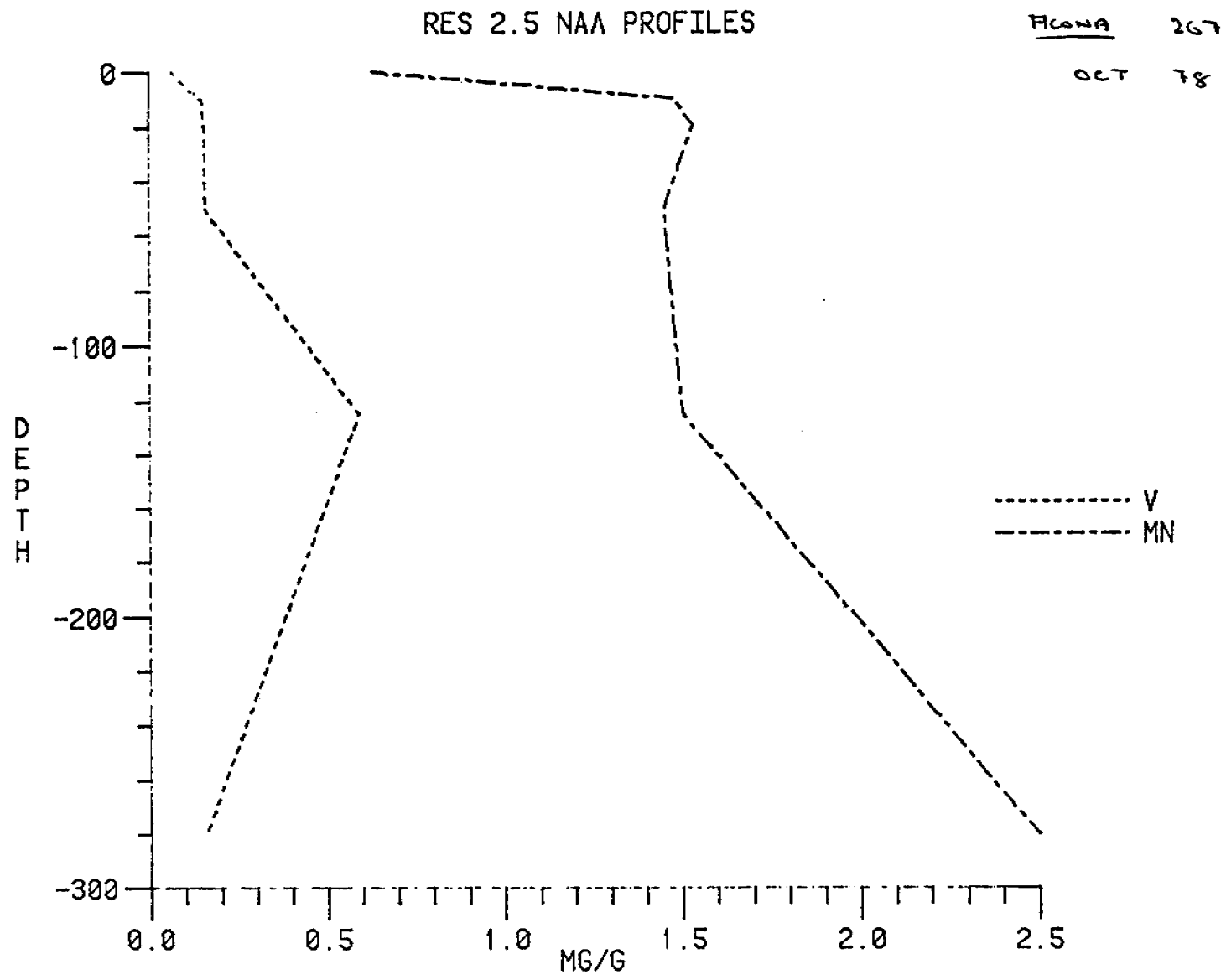
this estuary obtained in October 1978, March 1979, April 1979 and May 1979 (R/V *Acona* cruise Nos. 267, 272, 275 and 276) are given in Appendix II.

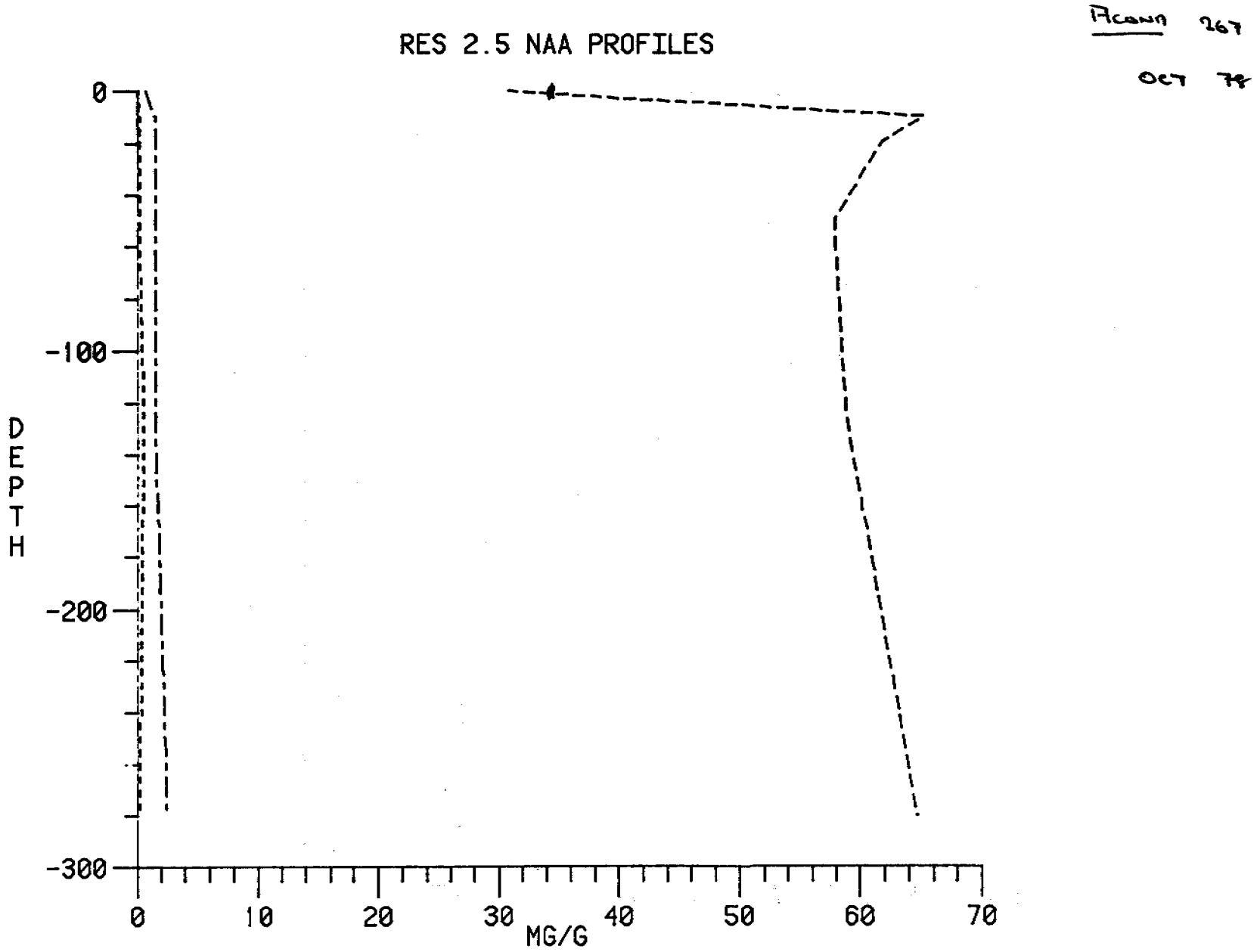
## IV. PRELIMINARY INTERPRETATION

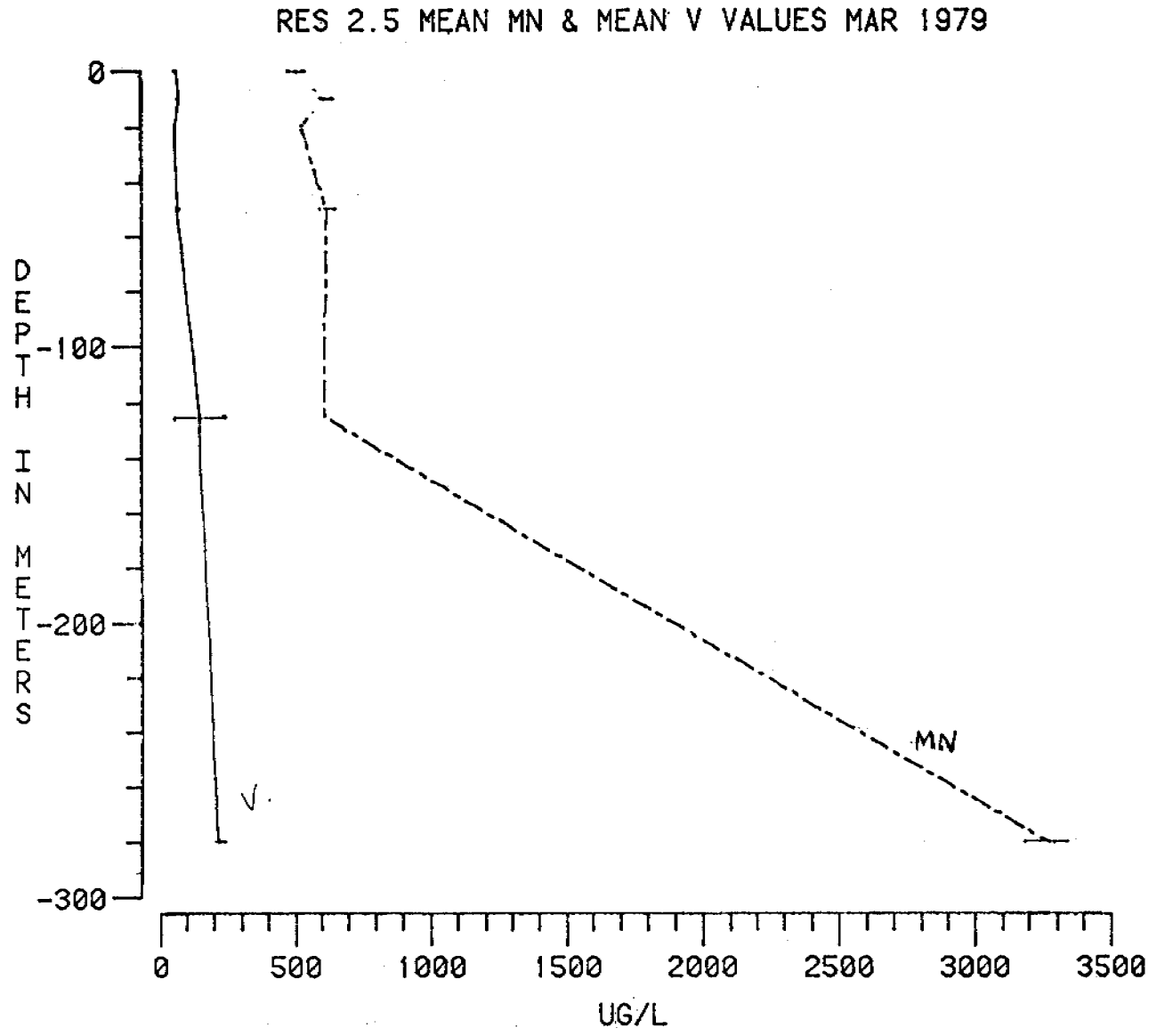
After a number of years detailed observation in several estuaries which have been designated as NEGOA specific study sites we are beginning to understand benthic processes and interfacial fluxes. This work is of paramount importance to offshore oil development because of the need to understand induced geochemical processes induced *via* hydrocarbon impact on the bottom of these physically confined environments. We have recently published two pertinent papers on work particularly sponsored by this contract. One concerns nutrient fluxes across the interface of a fjord basin and the other the closed cycling of manganese within the surface sediment-bottom basin waters. Both are samples of natural processes which would be sensitive to oil impingement. These papers are included in this report as Appendices III and IV.

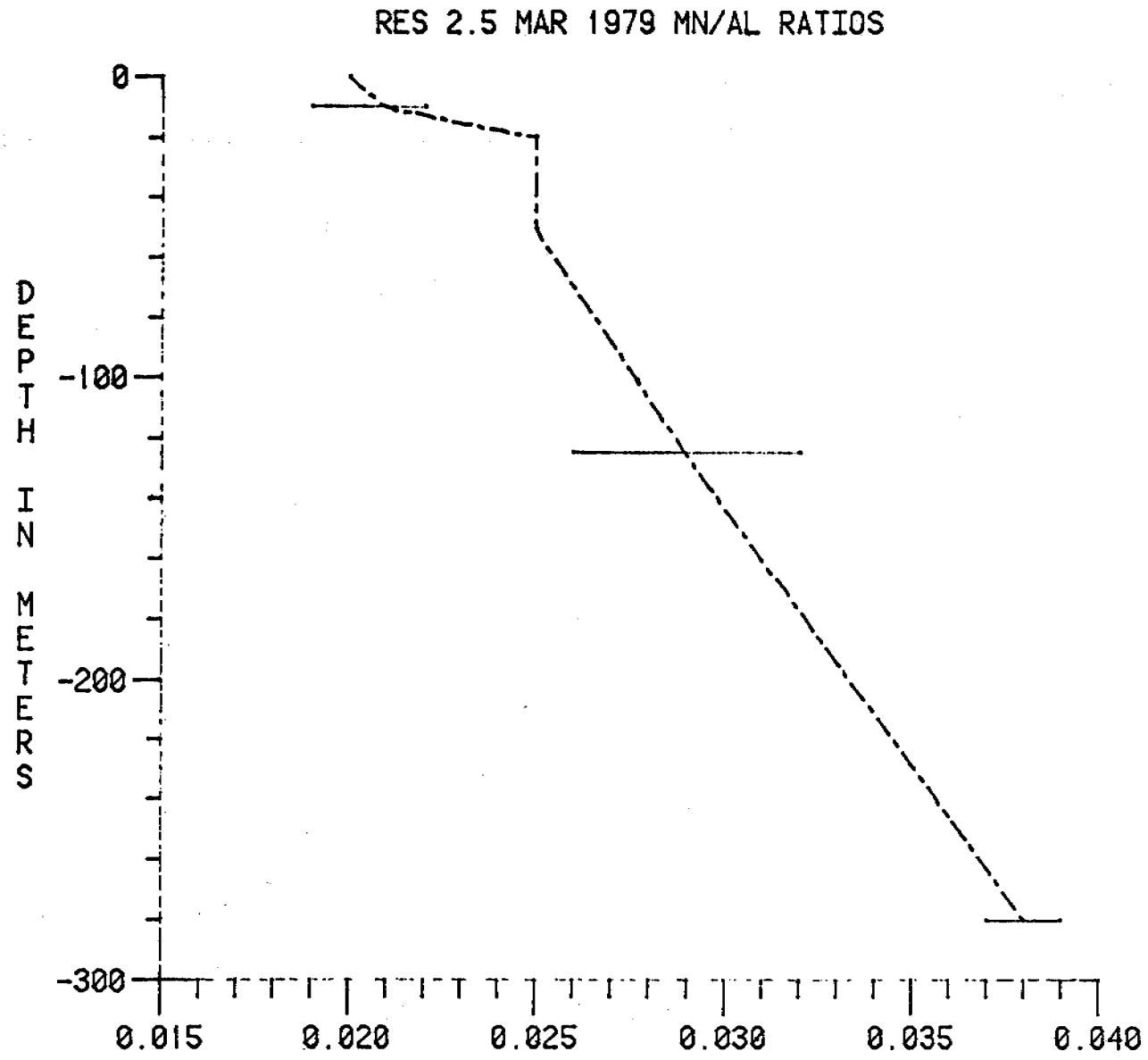
## V. PROBLEMS ENCOUNTERED

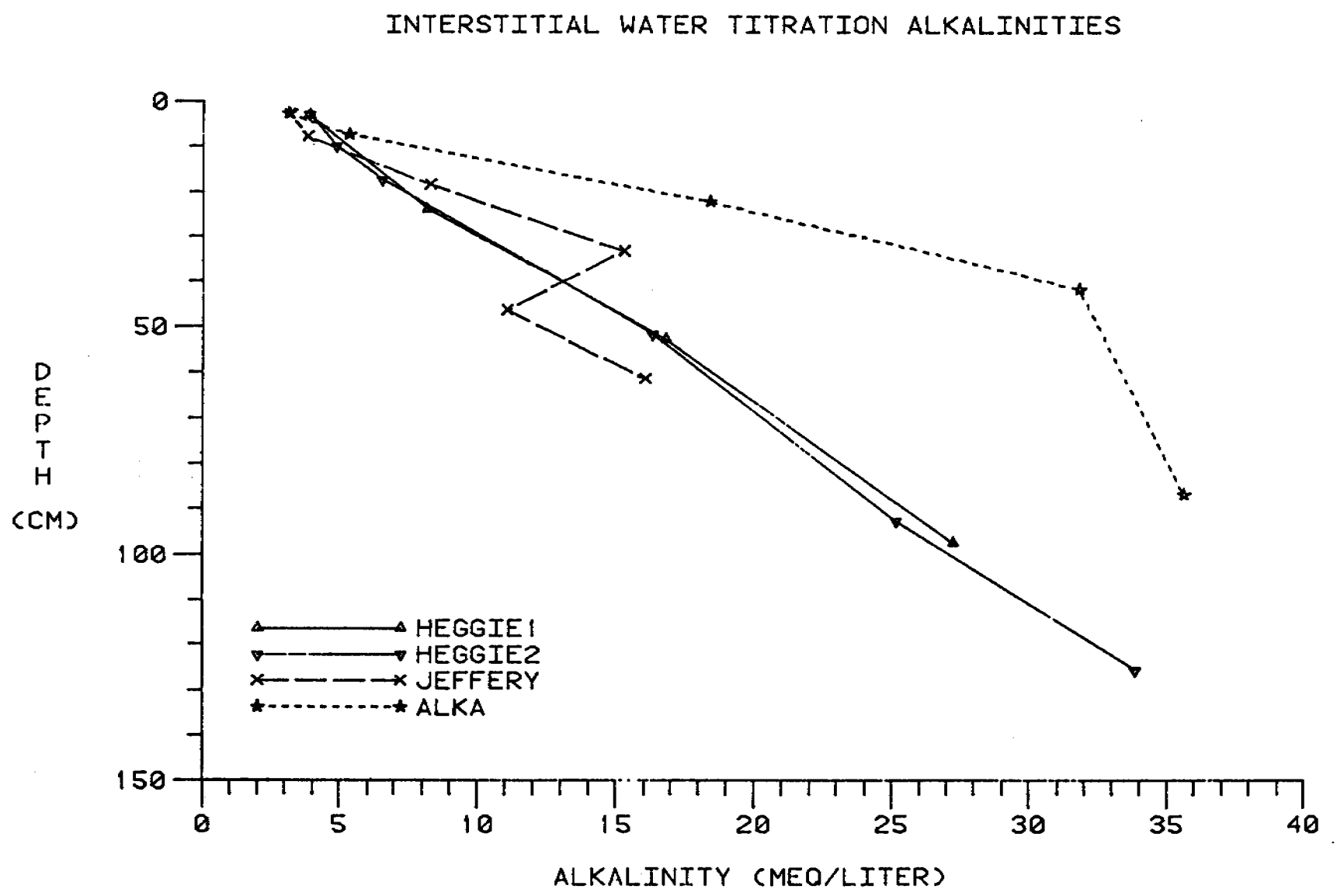
No major problems this quarter.

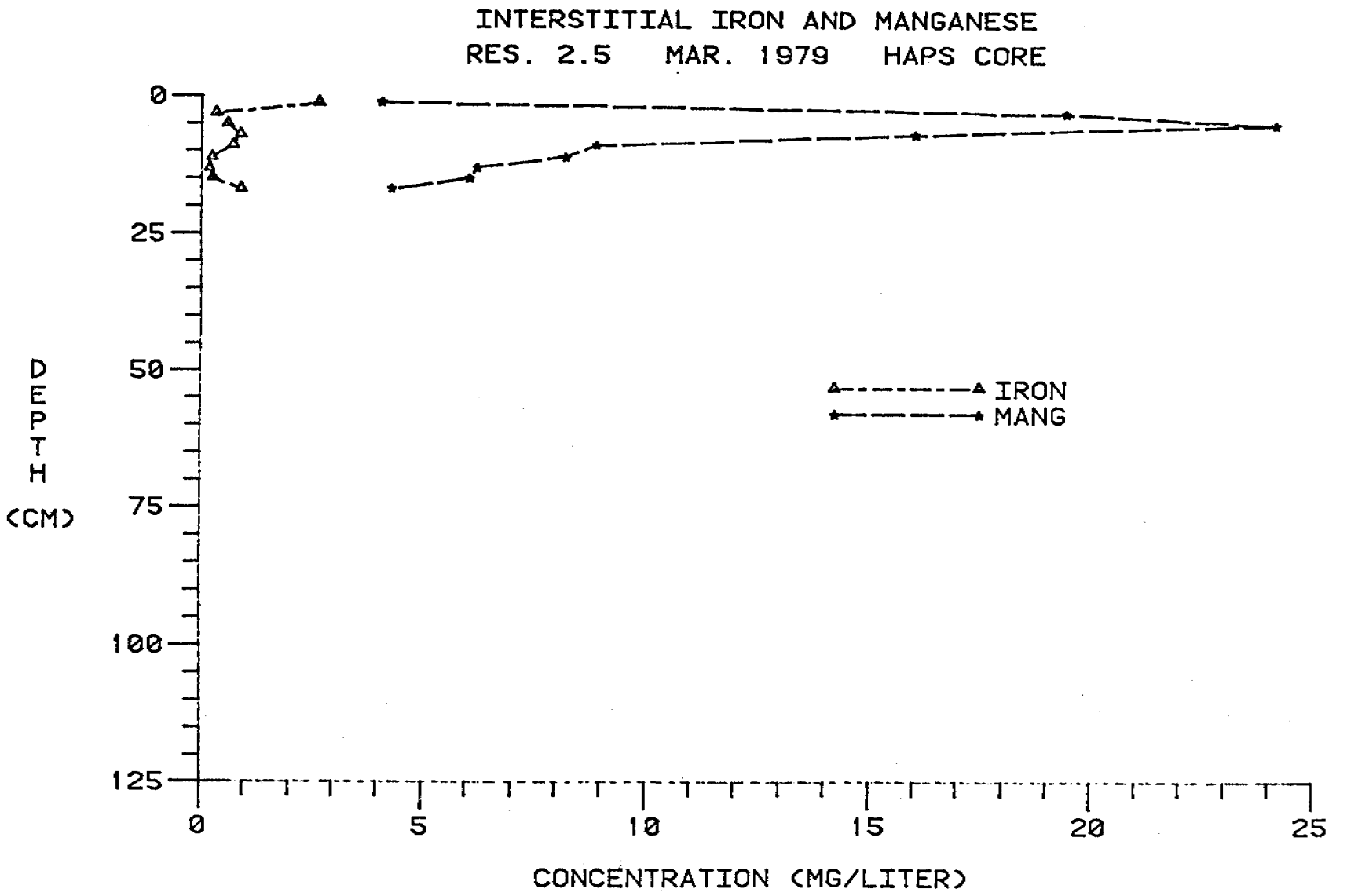

RES 2.5 NAA PROFILES
Acona 267
OCT 78
0
-100
-200
-300
DEPTH
0.0
0.5
1.0
1.5
2.0
2.5
MG/G
V
MN

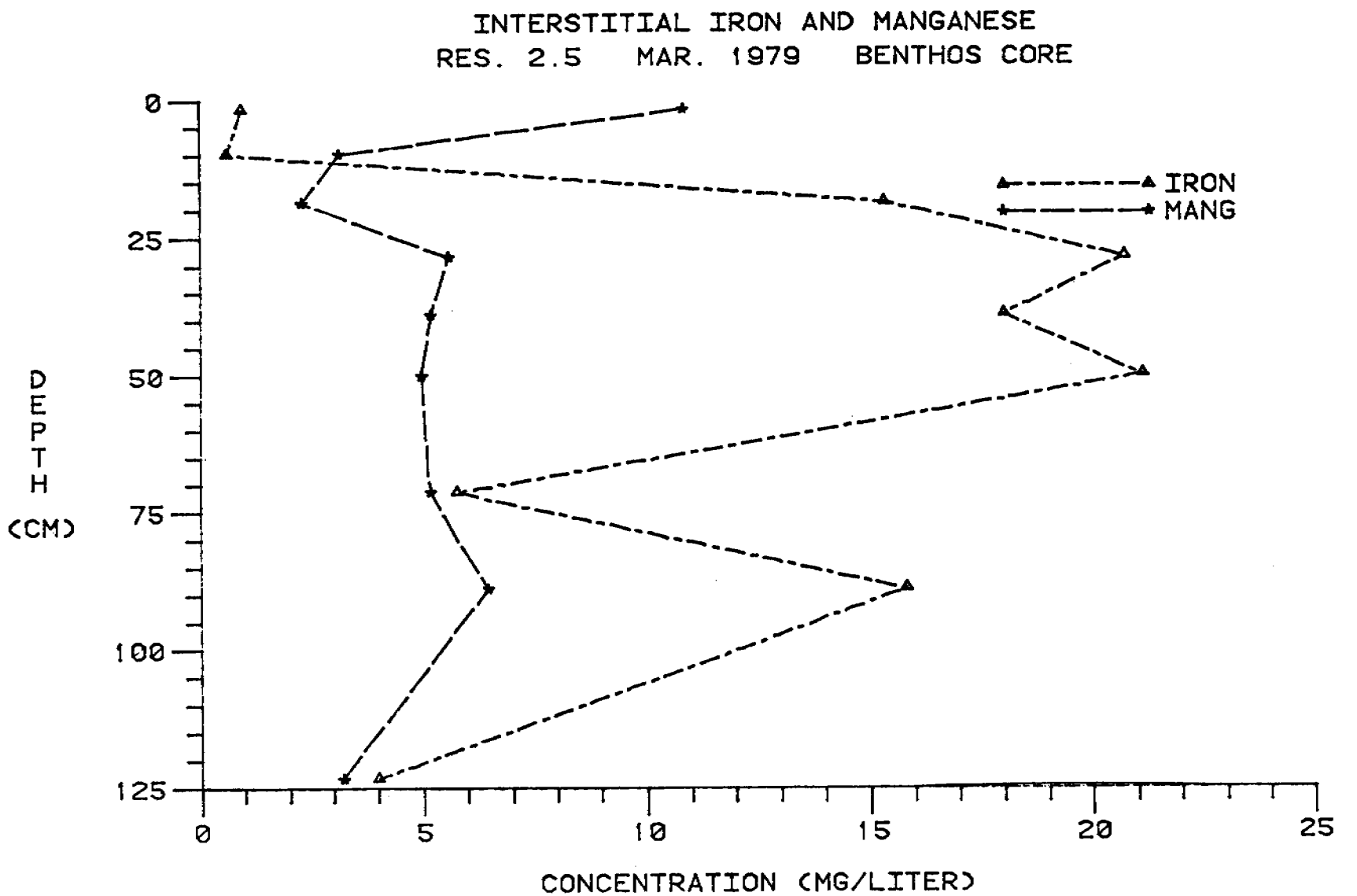

RES 2.5 NAA PROFILES
Acana 267
Oct 78
0
-100
-200
-300
DEPTH
0
10
20
30
40
50
60
70
MG/G

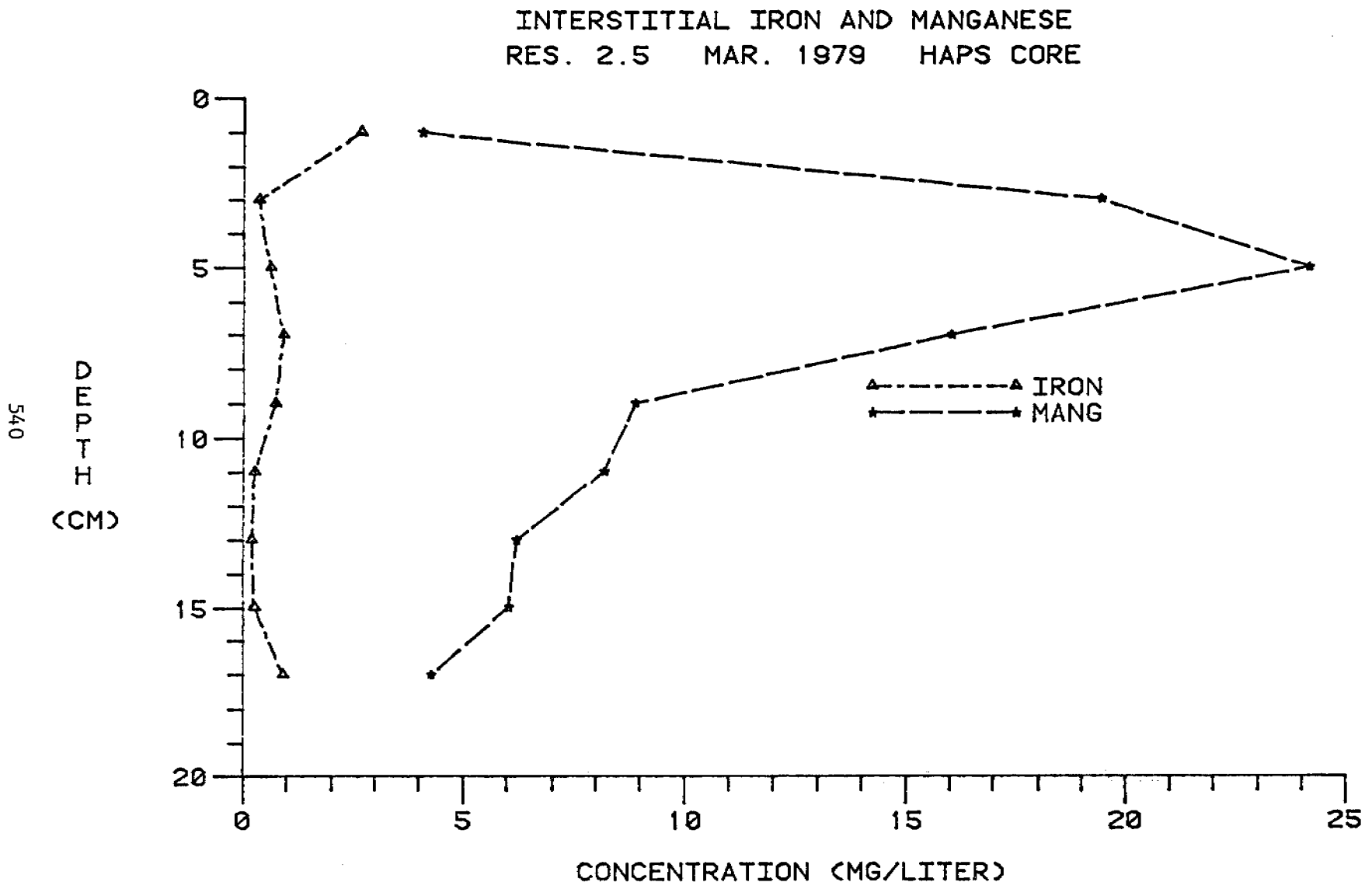

RES 2.5 MEAN MN & MEAN V VALUES MAR 1979
0
-100
-200
-300
DEPTH IN METERS
MN
V
0
500
1000
1500
2000
2500
3000
3500
UG/L

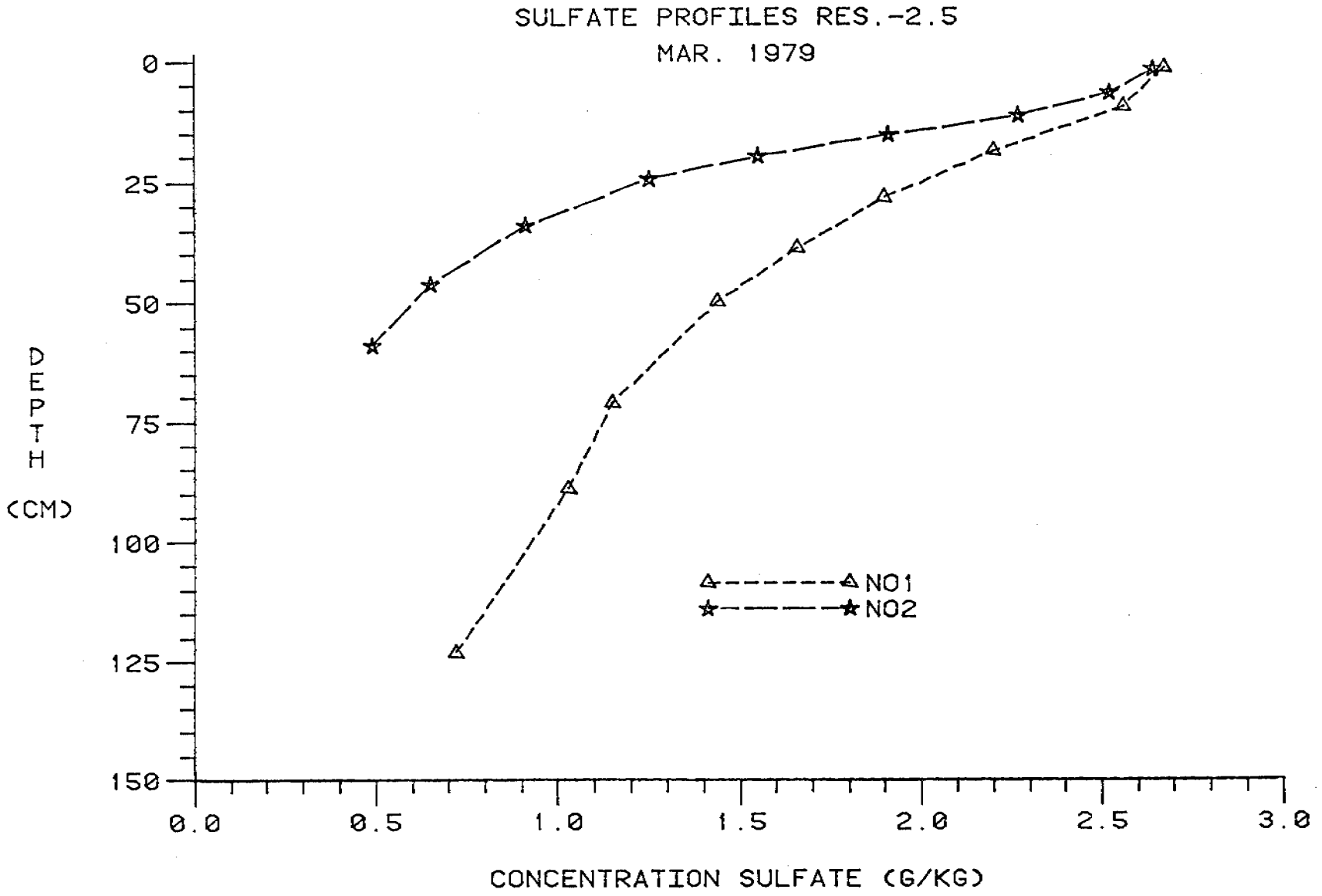

RES 2.5 MAR 1979 MN/AL RATIOS
DEPTH IN METERS
0
-100
-200
-300
0.015
0.020
0.025
0.030
0.035
0.040

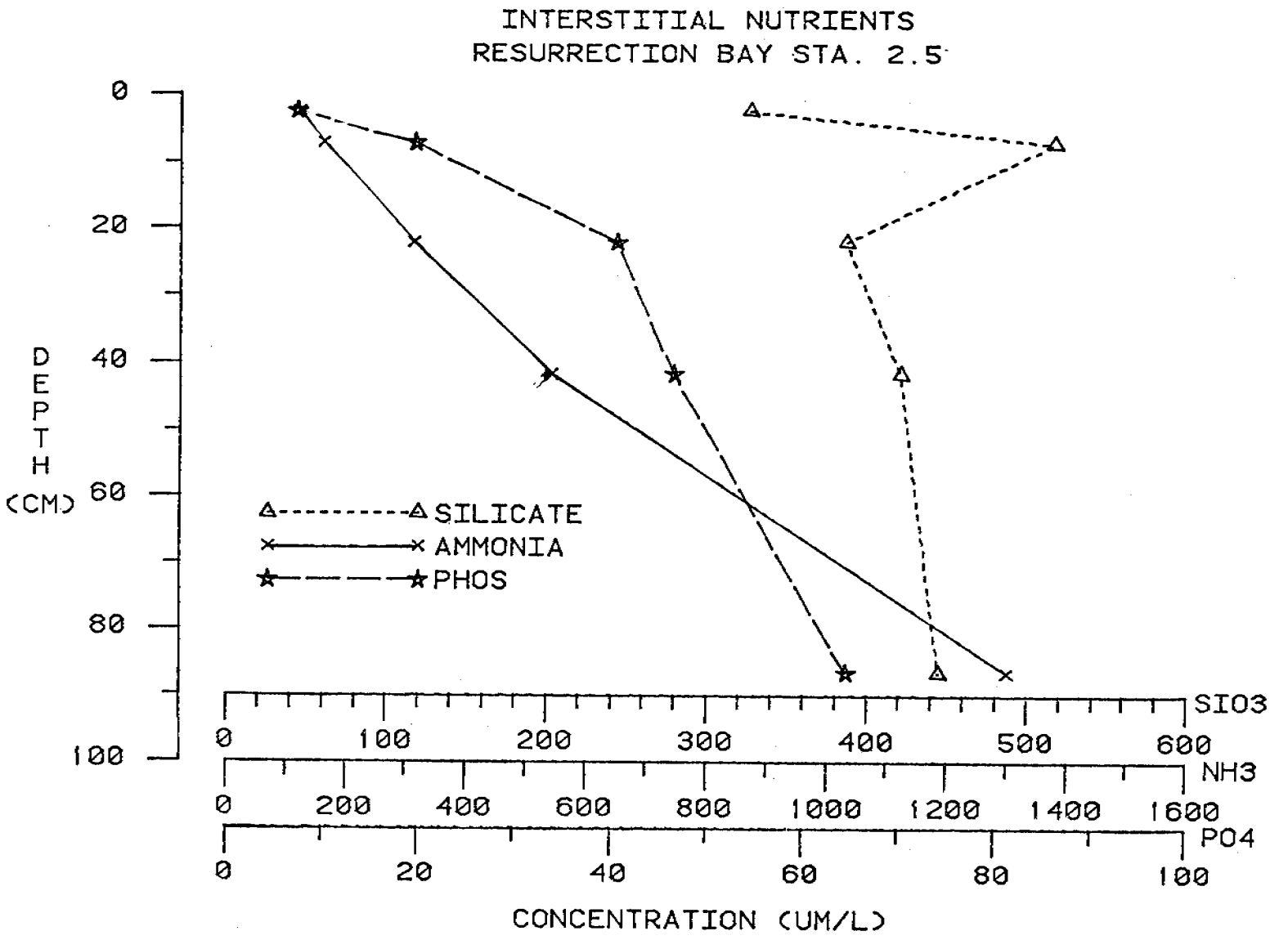

INTERSTITIAL WATER TITRATION ALKALINITIES
DEPTH (CM)
0
50
100
150
0
5
10
15
20
25
30
35
40
ALKALINITY (MEQ/LITER)
HEGGIE1
HEGGIE2
JEFFERY
ALKA

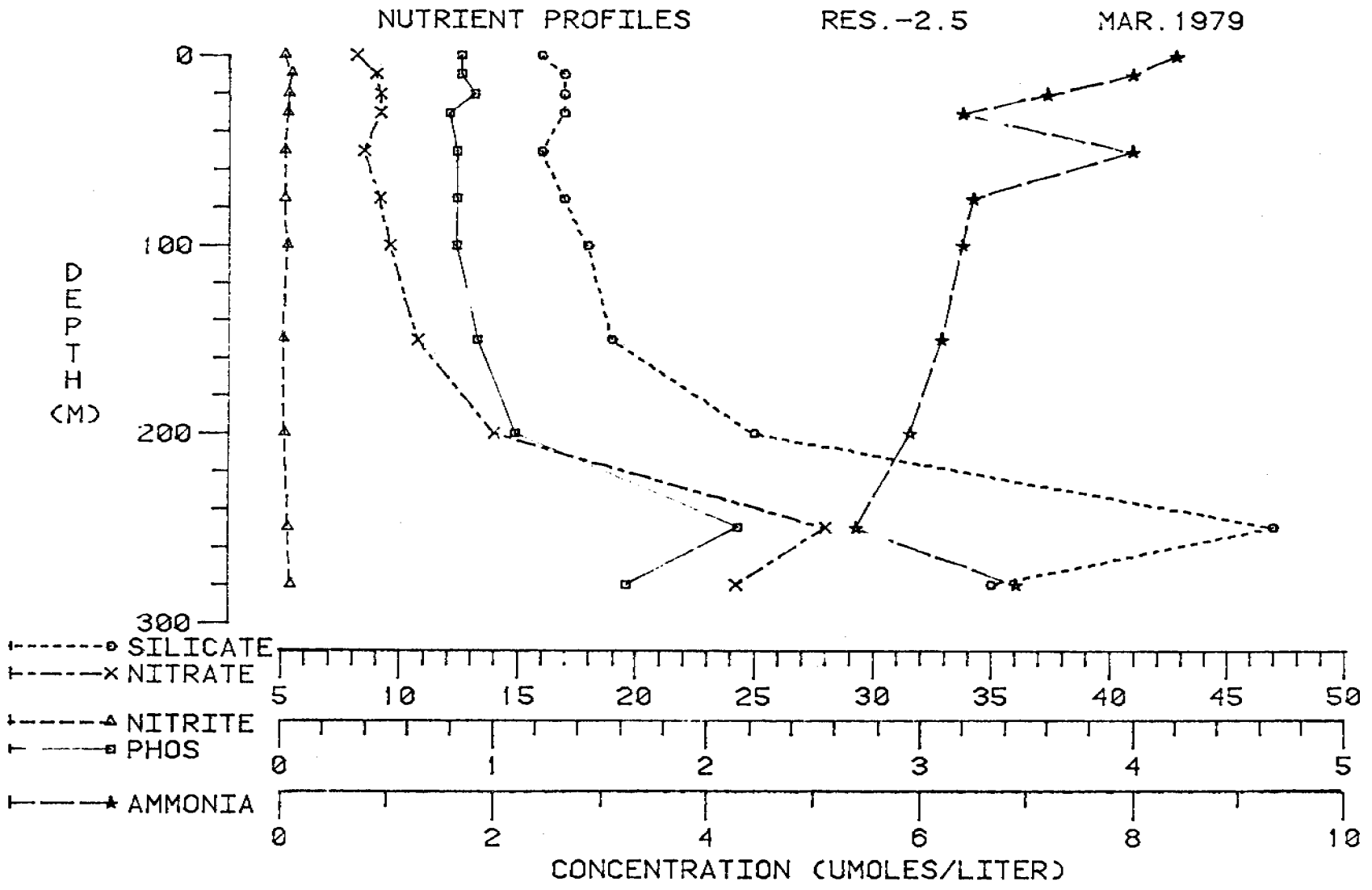

INTERSTITIAL IRON AND MANGANESE
RES. 2.5 MAR. 1979 HAPS CORE
0
25
50
75
100
125
DEPTH (CM)
IRON
MANG
0
5
10
15
20
25
CONCENTRATION (MG/LITER)

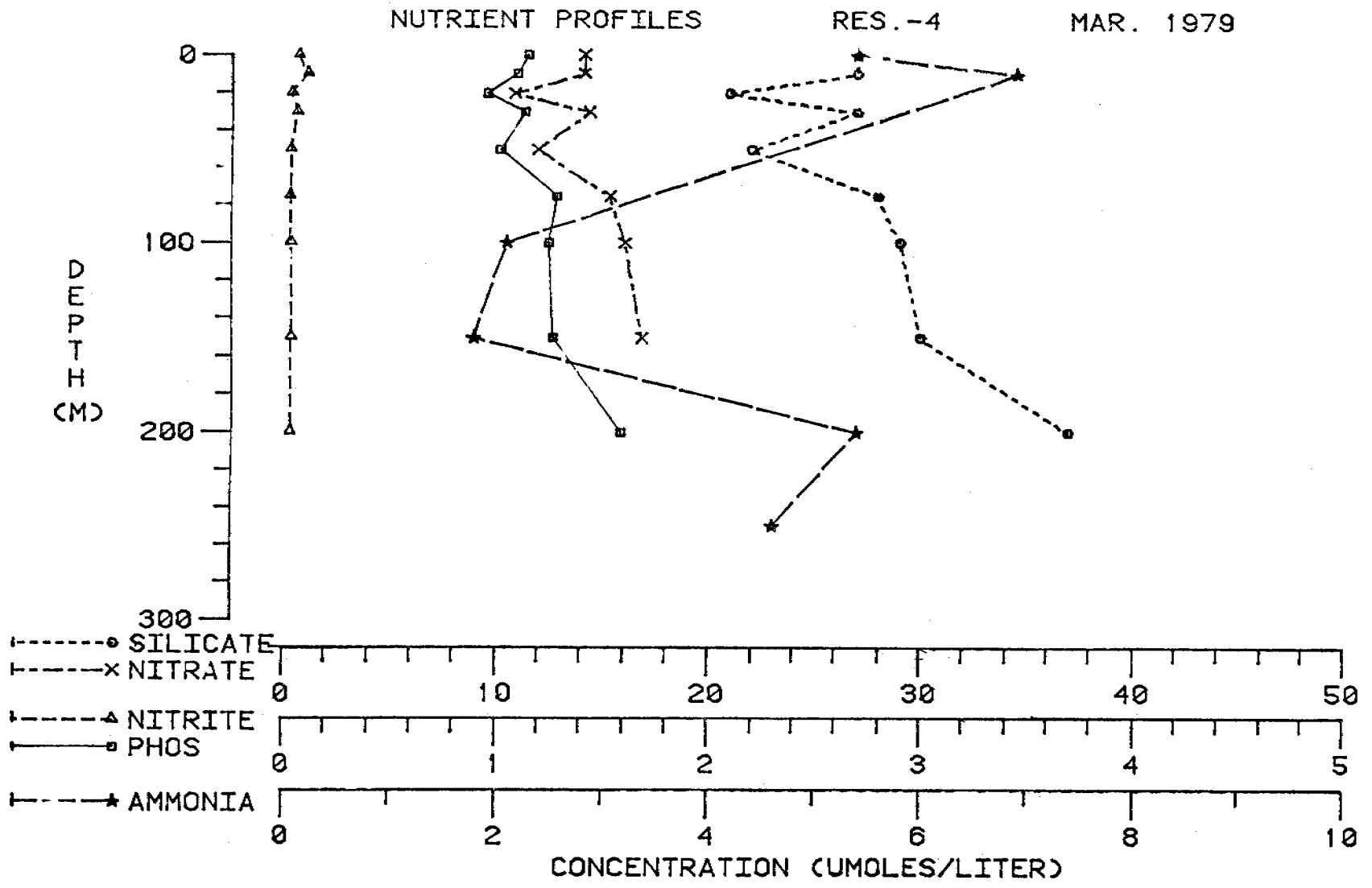

INTERSTITIAL IRON AND MANGANESE
RES. 2.5 MAR. 1979 BENTHOS CORE
IRON
MANG
DEPTH (CM)
0
25
50
75
100
125
0
5
10
15
20
25
CONCENTRATION (MG/LITER)


INTERSTITIAL IRON AND MANGANESE
RES. 2.5 MAR. 1979 HAPS CORE
DEPTH (CM)
0
5
10
15
20
IRON
MANG
0
5
10
15
20
25
CONCENTRATION (MG/LITER)


SULFATE PROFILES RES.-2.5
MAR. 1979
DEPTH
(CM)
0
25
50
75
100
125
150
0.0
0.5
1.0
1.5
2.0
2.5
3.0
NO1
NO2
CONCENTRATION SULFATE (G/KG)


INTERSTITIAL NUTRIENTS
RESURRECTION BAY STA. 2.5
DEPTH (CM)
0
20
40
60
80
100
SILICATE
AMMONIA
PHOS
SIO3
0
100
200
300
400
500
600
NH3
0
200
400
600
800
1000
1200
1400
1600
PO4
0
20
40
60
80
100
CONCENTRATION (UM/L)


NUTRIENT PROFILES
RES.-2.5
MAR.1979
DEPTH (M)
0
100
200
300
SILICATE
NITRATE
NITRITE
PHOS
AMMONIA
5 10 15 20 25 30 35 40 45 50
0 1 2 3 4 5
0 2 4 6 8 10
CONCENTRATION (UMOLES/LITER)


NUTRIENT PROFILES
RES.-4
MAR. 1979
DEPTH (M)
0
100
200
300
SILICATE
NITRATE
NITRITE
PHOS
AMMONIA
0
10
20
30
40
50
0
1
2
3
4
5
0
2
4
6
8
10
CONCENTRATION (UMOLES/LITER)

Appendix I

Yakutat Bay Hydrographic Data

R/V *Acona* No. 275

April 1979

AC CRUISE 275 CONSECUTIVE STATION NO. 3, YAK012 20/ 4/79
4.1 HOURS GMT

LATITUDE = 59 27.5N LONGITUDE = 140 23.0W SONIC DEPTH = 236 M

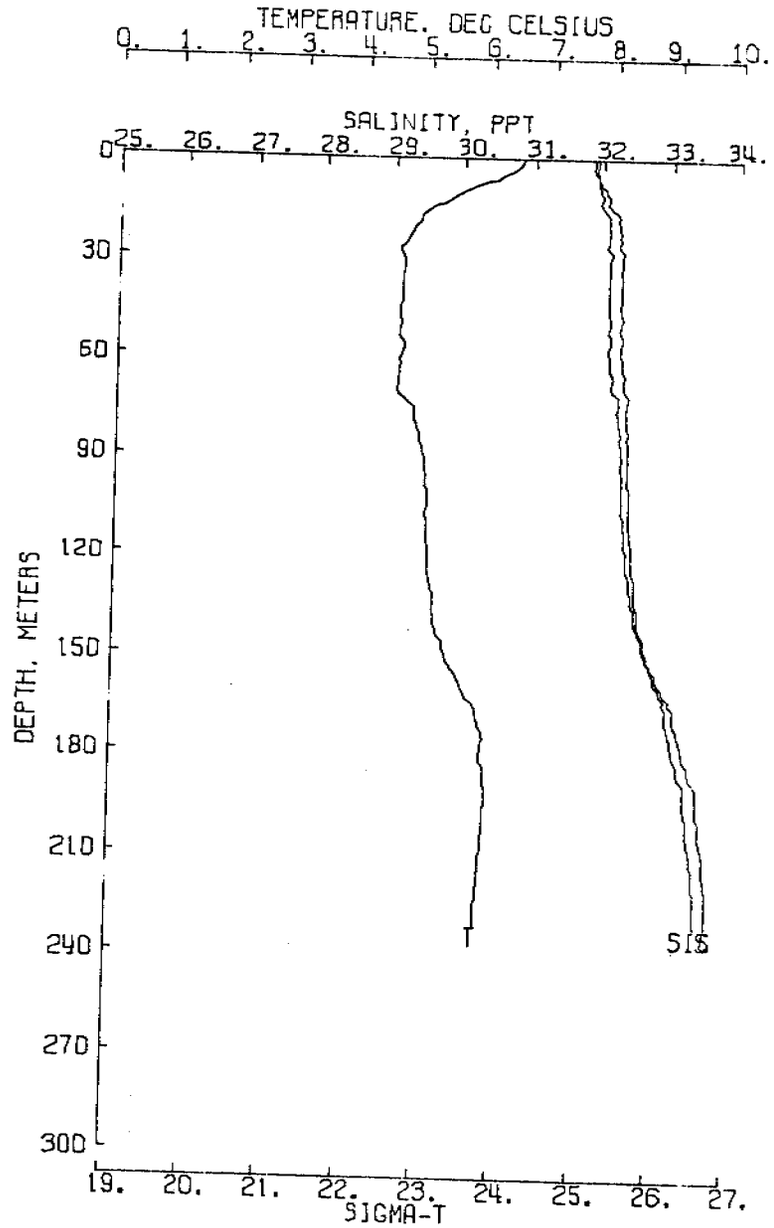
1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (3) ---ALTOCUMULUS
CLOUD AMOUNT --- (2) ---2/8
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 265 - 274 DEGR | 5 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 265 - 274 DEGR | 0.6 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |

TEMPERATURES -DRY = 13.9 DEGR C. BAROMETRIC PR. =1024.9 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 6.46 | 31.925 | 25.11 | 0. |
| 1.0 | 6.47 | 31.928 | 25.11 | 0.003 |
| 5.0 | 6.16 | 31.919 | 25.14 | 0.014 |
| 10.0 | 5.50 | 31.942 | 25.24 | 0.028 |
| 15.0 | 5.00 | 31.986 | 25.33 | 0.042 |
| 20.0 | 4.77 | 32.069 | 25.42 | 0.055 |
| 25.0 | 4.63 | 32.066 | 25.43 | 0.068 |
| 30.0 | 4.60 | 32.110 | 25.47 | 0.080 |
| 35.0 | 4.58 | 32.102 | 25.47 | 0.093 |
| 40.0 | 4.57 | 32.102 | 25.47 | 0.106 |
| 45.0 | 4.54 | 32.095 | 25.46 | 0.118 |
| 50.0 | 4.56 | 32.120 | 25.48 | 0.131 |
| 60.0 | 4.57 | 32.129 | 25.49 | 0.156 |
| 70.0 | 4.52 | 32.182 | 25.53 | 0.181 |
| 75.0 | 4.80 | 32.249 | 25.56 | 0.193 |
| 80.0 | 4.83 | 32.268 | 25.57 | 0.206 |
| 90.0 | 4.98 | 32.321 | 25.60 | 0.230 |
| 100.0 | 5.03 | 32.335 | 25.60 | 0.254 |
| 125.0 | 5.06 | 32.437 | 25.68 | 0.314 |
| 150.0 | 5.37 | 32.712 | 25.86 | 0.370 |
| 175.0 | 6.00 | 33.253 | 26.21 | 0.420 |
| 200.0 | 6.03 | 33.547 | 26.44 | 0.463 |






CRUISE 275 STATION 3

AC CRUISE 275 CONSECUTIVE STATION NO. 4. YAK010 20/ 4/79
5.5 HOURS GMT

LATITUDE = 59 34.5N LONGITUDE = 140 5.6W SONIC DEPTH = 75 M

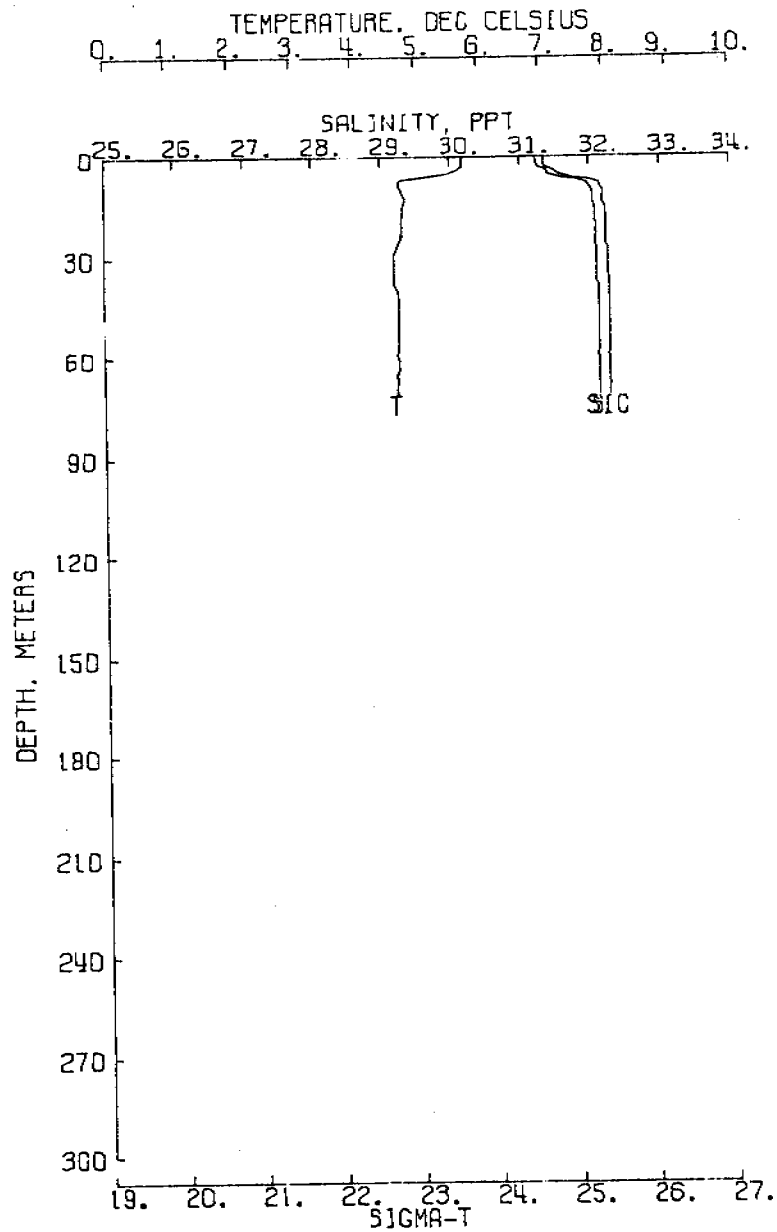
1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- (0) ---NO CLOUDS
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 265 - 274 DEGR | 5 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 265 - 274 DEGR | 0.4 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |

TEMPERATURES -DRY = 6.7 DEGR C. BAROMETRIC PR. =1024.0 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.75 | 31.220 | 24.64 | 0. |
| 1.0 | 5.76 | 31.235 | 24.65 | 0.003 |
| 5.0 | 5.51 | 31.410 | 24.82 | 0.016 |
| 10.0 | 4.79 | 32.061 | 25.41 | 0.030 |
| 15.0 | 4.82 | 32.077 | 25.42 | 0.043 |
| 20.0 | 4.76 | 32.089 | 25.44 | 0.056 |
| 25.0 | 4.75 | 32.092 | 25.43 | 0.069 |
| 30.0 | 4.65 | 32.093 | 25.45 | 0.082 |
| 35.0 | 4.65 | 32.103 | 25.46 | 0.094 |
| 40.0 | 4.69 | 32.133 | 25.48 | 0.107 |
| 45.0 | 4.72 | 32.117 | 25.46 | 0.120 |
| 50.0 | 4.71 | 32.118 | 25.46 | 0.132 |
| 60.0 | 4.70 | 32.121 | 25.47 | 0.158 |
| 70.0 | 4.70 | 32.117 | 25.46 | 0.183 |






CRUISE 275 STATION 4

AC CRUISE 275 CONSECUTIVE STATION NO. 5. YAK 9B 20/ 4/79
6.2 HOURS GMT

LATITUDE = 59 36.5N LONGITUDE = 140 3.2W SONIC DEPTH = 148 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- (0) ---NO CLOUDS
VISIBILITY --- (8) ---20-50 KM

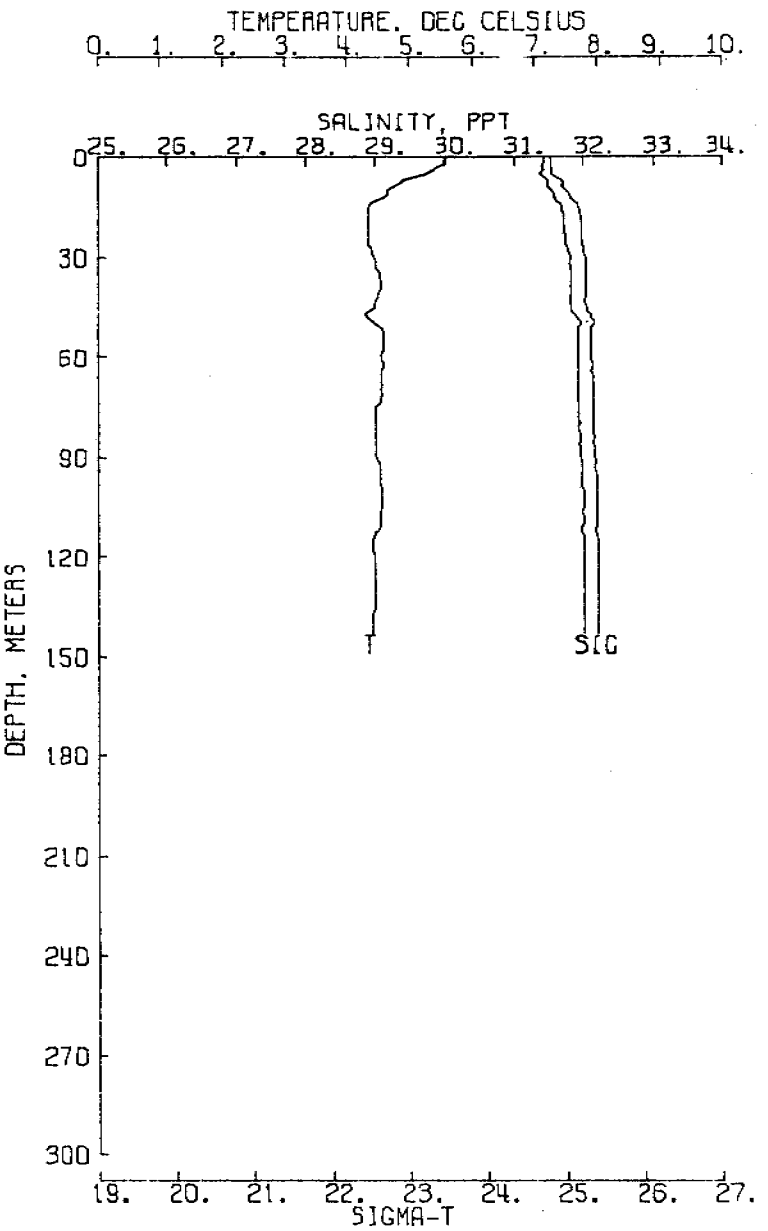
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 265 - 274 DEGR | 0.2 M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.0 DEGR C. BAROMETRIC PR. =1025.0 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.59 | 31.417 | 24.81 | 0. |
| 1.0 | 5.59 | 31.414 | 24.81 | 0.003 |
| 5.0 | 5.25 | 31.370 | 24.81 | 0.016 |
| 10.0 | 4.64 | 31.546 | 25.02 | 0.031 |
| 15.0 | 4.34 | 31.678 | 25.15 | 0.045 |
| 20.0 | 4.34 | 31.720 | 25.19 | 0.059 |
| 25.0 | 4.33 | 31.733 | 25.20 | 0.073 |
| 30.0 | 4.44 | 31.809 | 25.25 | 0.087 |
| 35.0 | 4.51 | 31.817 | 25.25 | 0.101 |
| 40.0 | 4.51 | 31.783 | 25.22 | 0.115 |
| 45.0 | 4.49 | 31.827 | 25.26 | 0.128 |
| 50.0 | 4.46 | 31.961 | 25.37 | 0.142 |
| 60.0 | 4.55 | 31.919 | 25.32 | 0.169 |
| 70.0 | 4.53 | 31.926 | 25.33 | 0.195 |
| 75.0 | 4.47 | 31.927 | 25.34 | 0.209 |
| 80.0 | 4.46 | 31.934 | 25.34 | 0.222 |
| 90.0 | 4.47 | 31.942 | 25.35 | 0.248 |
| 100.0 | 4.54 | 31.991 | 25.38 | 0.275 |
| 125.0 | 4.42 | 31.999 | 25.40 | 0.340 |






CRUISE 275 STATION 5

AC CRUISE 275 CONSECUTIVE STATION NO. 6. YAK9BA 20/ 4/79
6.8 HOURS GMT

LATITUDE = 59 37.2N LONGITUDE = 139 55.6W SONIC DEPTH = 137 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED ,
CLOUD AMOUNT --- (0) ---NO CLOUDS ,
VISIBILITY --- (8) ---20-50 KM

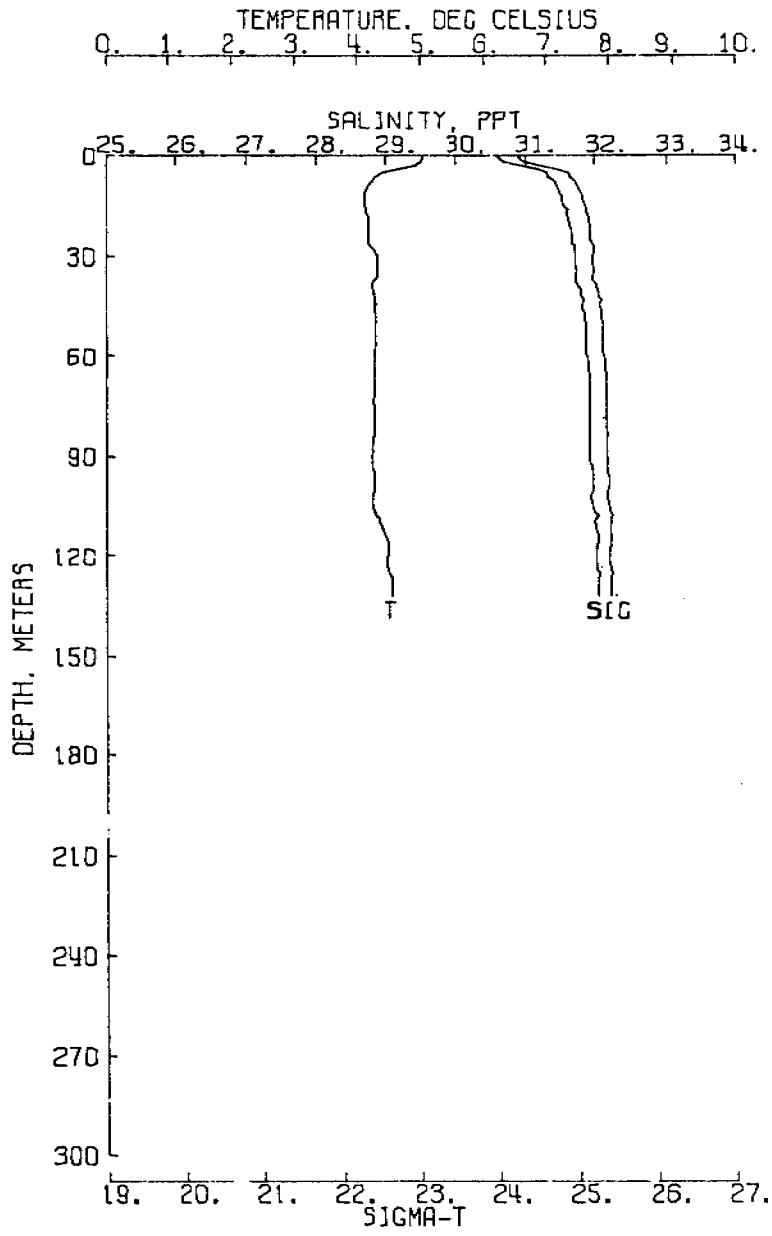
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 265 - 274 DEGR | 0.1 M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.0 DEGR C. BAROMETRIC PR. =1025.0 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.03 | 30.617 | 24.24 | 0. |
| 1.0 | 5.03 | 30.630 | 24.25 | 0.004 |
| 5.0 | 4.41 | 31.331 | 24.87 | 0.017 |
| 10.0 | 4.14 | 31.483 | 25.02 | 0.033 |
| 15.0 | 4.12 | 31.563 | 25.08 | 0.047 |
| 20.0 | 4.16 | 31.629 | 25.13 | 0.062 |
| 25.0 | 4.18 | 31.663 | 25.16 | 0.076 |
| 30.0 | 4.30 | 31.712 | 25.18 | 0.090 |
| 35.0 | 4.31 | 31.734 | 25.20 | 0.104 |
| 40.0 | 4.24 | 31.784 | 25.25 | 0.118 |
| 45.0 | 4.27 | 31.818 | 25.27 | 0.131 |
| 50.0 | 4.28 | 31.859 | 25.30 | 0.145 |
| 60.0 | 4.27 | 31.877 | 25.32 | 0.172 |
| 70.0 | 4.25 | 31.914 | 25.35 | 0.198 |
| 75.0 | 4.24 | 31.930 | 25.36 | 0.211 |
| 80.0 | 4.25 | 31.925 | 25.36 | 0.225 |
| 90.0 | 4.23 | 31.929 | 25.36 | 0.251 |
| 100.0 | 4.26 | 31.938 | 25.37 | 0.277 |
| 125.0 | 4.50 | 32.057 | 25.44 | 0.342 |






CRUISE 275 STATION 6

AC CRUISE 275 CONSECUTIVE STATION NO. 7. YAK 8 20/ 4/79
7.1 HOURS GMT

LATITUDE = 59 37.1N LONGITUDE = 139 51.5W SONIC DEPTH = 90 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED .
CLOUD AMOUNT --- (0) ---NO CLOUDS .
VISIBILITY --- (8) ---20-50 KM

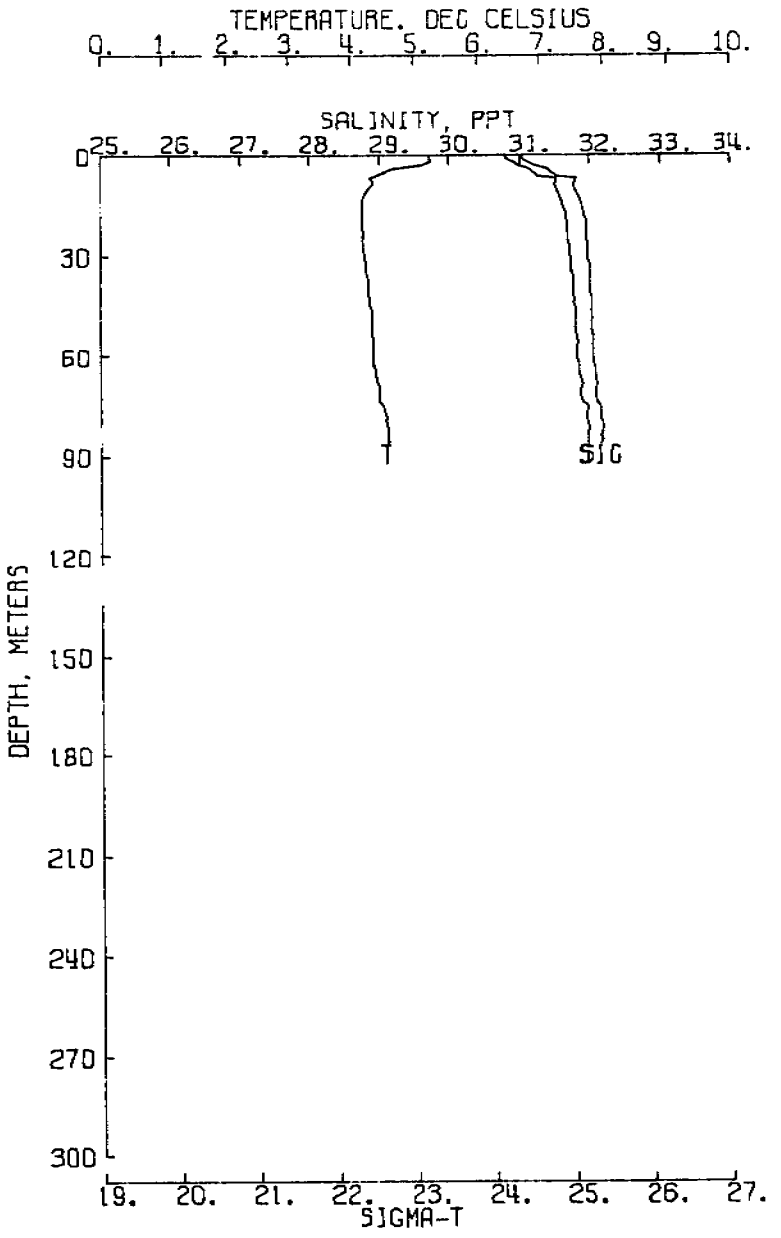
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 235 - 244 DEGR | 5 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | 0. M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES -DRY = | 5.6 DEGR C. | BAROMETRIC PR. | =1025.0 MB |
| -WET = | DEGR C. | TRANSPARENCY = | M |

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.23 | 30.809 | 24.37 | 0. |
| 1.0 | 5.23 | 30.809 | 24.37 | 0.004 |
| 5.0 | 4.51 | 31.182 | 24.74 | 0.017 |
| 10.0 | 4.27 | 31.534 | 25.05 | 0.032 |
| 15.0 | 4.16 | 31.620 | 25.12 | 0.047 |
| 20.0 | 4.16 | 31.675 | 25.17 | 0.061 |
| 25.0 | 4.18 | 31.697 | 25.18 | 0.075 |
| 30.0 | 4.19 | 31.716 | 25.20 | 0.089 |
| 35.0 | 4.24 | 31.741 | 25.21 | 0.103 |
| 40.0 | 4.26 | 31.760 | 25.23 | 0.117 |
| 45.0 | 4.29 | 31.790 | 25.25 | 0.130 |
| 50.0 | 4.31 | 31.783 | 25.24 | 0.144 |
| 60.0 | 4.35 | 31.825 | 25.27 | 0.171 |
| 70.0 | 4.43 | 31.871 | 25.30 | 0.198 |
| 75.0 | 4.47 | 31.964 | 25.37 | 0.212 |
| 80.0 | 4.54 | 31.978 | 25.37 | 0.225 |






CRUISE 275 STATION 7

AC CRUISE 275 CONSECUTIVE STATION NO. 8. YAK 7B 20/ 4/79
7.4 HOURS GMT

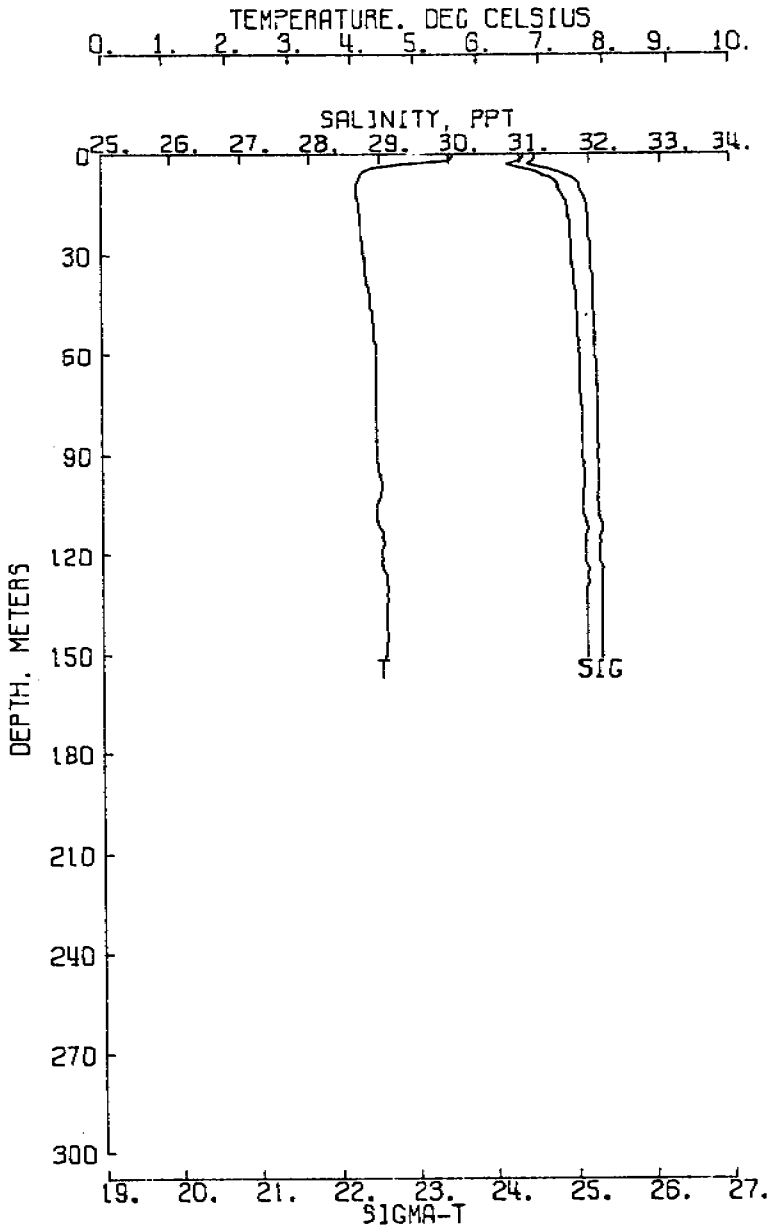
LATITUDE = 59 37.4N LONGITUDE = 139 48.8W SONIC DEPTH = 155 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED ,
CLOUD AMOUNT --- (0) ---NO CLOUDS ,
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 235 - 244 DEGR | 5 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 0 - 0 DEGR | 0. M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES -DRY = | 5.6 DEGR C. | BAROMETRIC PR. = | 1025.0 MB | |
| -WET = | DEGR C. | TRANSPARENCY = | M | |

551

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.61 | 31.056 | 24.53 | 0. |
| 1.0 | 5.61 | 31.058 | 24.53 | 0.003 |
| 5.0 | 4.20 | 31.232 | 24.81 | 0.017 |
| 10.0 | 4.07 | 31.568 | 25.09 | 0.032 |
| 15.0 | 4.10 | 31.661 | 25.16 | 0.046 |
| 20.0 | 4.14 | 31.699 | 25.19 | 0.060 |
| 25.0 | 4.15 | 31.723 | 25.21 | 0.074 |
| 30.0 | 4.19 | 31.738 | 25.22 | 0.088 |
| 35.0 | 4.19 | 31.755 | 25.23 | 0.102 |
| 40.0 | 4.25 | 31.776 | 25.24 | 0.116 |
| 45.0 | 4.29 | 31.782 | 25.24 | 0.129 |
| 50.0 | 4.32 | 31.810 | 25.26 | 0.143 |
| 60.0 | 4.38 | 31.833 | 25.27 | 0.170 |
| 70.0 | 4.36 | 31.841 | 25.28 | 0.197 |
| 75.0 | 4.36 | 31.853 | 25.29 | 0.211 |
| 80.0 | 4.36 | 31.856 | 25.29 | 0.224 |
| 90.0 | 4.38 | 31.851 | 25.29 | 0.251 |
| 100.0 | 4.45 | 31.873 | 25.30 | 0.278 |
| 125.0 | 4.48 | 31.934 | 25.34 | 0.345 |
| 150.0 | 4.51 | 31.922 | 25.33 | 0.412 |




CRUISE 275 STATION 8

AC CRUISE 275 CONSECUTIVE STATION NO. 9. YAK 7 20/ 4/79
7.9 HOURS GMT

LATITUDE = 59 39.5N LONGITUDE = 139 46.0W SONIC DEPTH = 174 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- (0) ---NO CLOUDS
VISIBILITY --- (8) ---20-50 KM

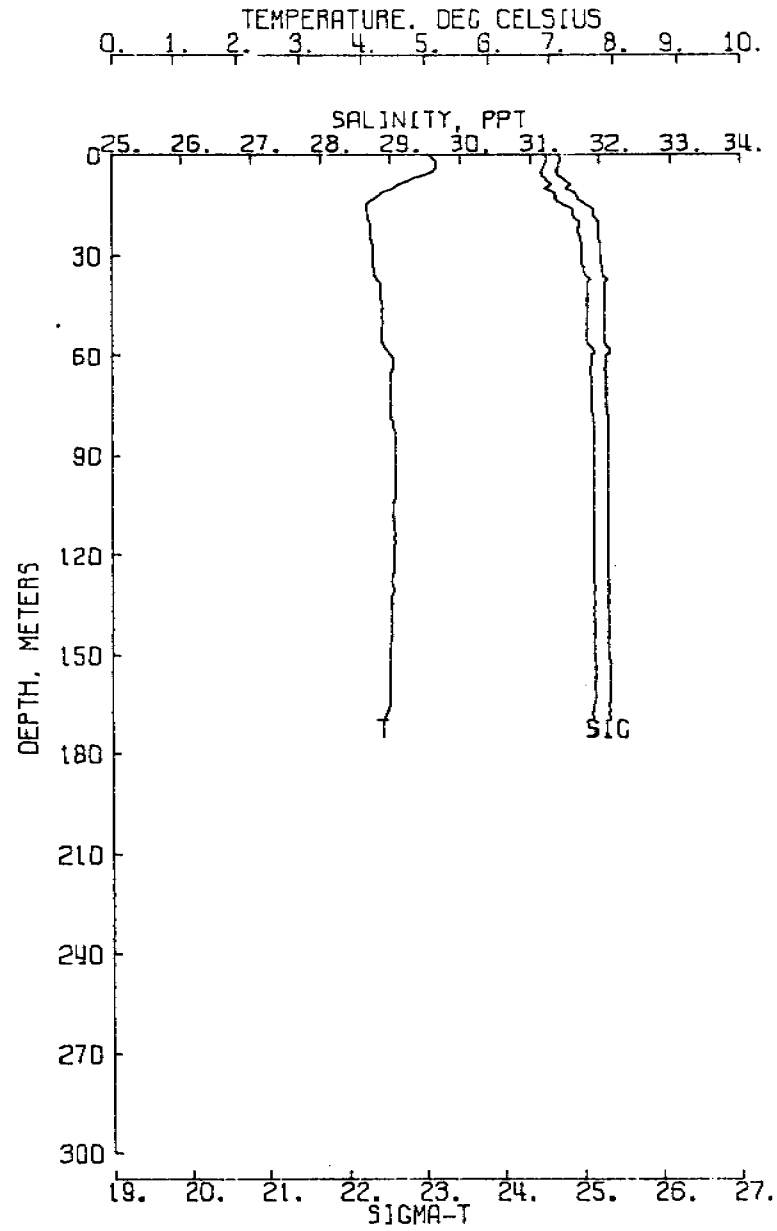
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 235 - 244 DEGR | 5 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | 0. M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.6 DEGR C. BAROMETRIC PR. =1025.0 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.02 | 31.198 | 24.70 | 0. |
| 1.0 | 5.11 | 31.232 | 24.72 | 0.003 |
| 5.0 | 5.13 | 31.157 | 24.66 | 0.016 |
| 10.0 | 4.50 | 31.216 | 24.77 | 0.032 |
| 15.0 | 4.06 | 31.513 | 25.05 | 0.048 |
| 20.0 | 4.12 | 31.716 | 25.20 | 0.062 |
| 25.0 | 4.15 | 31.712 | 25.20 | 0.076 |
| 30.0 | 4.16 | 31.741 | 25.22 | 0.090 |
| 35.0 | 4.19 | 31.774 | 25.24 | 0.103 |
| 40.0 | 4.29 | 31.807 | 25.26 | 0.117 |
| 45.0 | 4.30 | 31.808 | 25.26 | 0.131 |
| 50.0 | 4.30 | 31.819 | 25.27 | 0.144 |
| 60.0 | 4.47 | 31.875 | 25.30 | 0.171 |
| 70.0 | 4.45 | 31.870 | 25.29 | 0.198 |
| 75.0 | 4.45 | 31.873 | 25.30 | 0.212 |
| 80.0 | 4.49 | 31.888 | 25.31 | 0.225 |
| 90.0 | 4.51 | 31.892 | 25.31 | 0.252 |
| 100.0 | 4.51 | 31.895 | 25.31 | 0.279 |
| 125.0 | 4.48 | 31.891 | 25.31 | 0.346 |
| 150.0 | 4.44 | 31.903 | 25.32 | 0.413 |






CRUISE 275 STATION 9

AC CRUISE 275 CONSECUTIVE STATION NO. 10. YAK 8A 20/ 4/79
8.3 HOURS GMT

LATITUDE = 59 42.0N LONGITUDE = 139 50.4W SONIC DEPTH = 60 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- (0) ---NO CLOUDS
VISIBILITY --- (8) ---20-50 KM

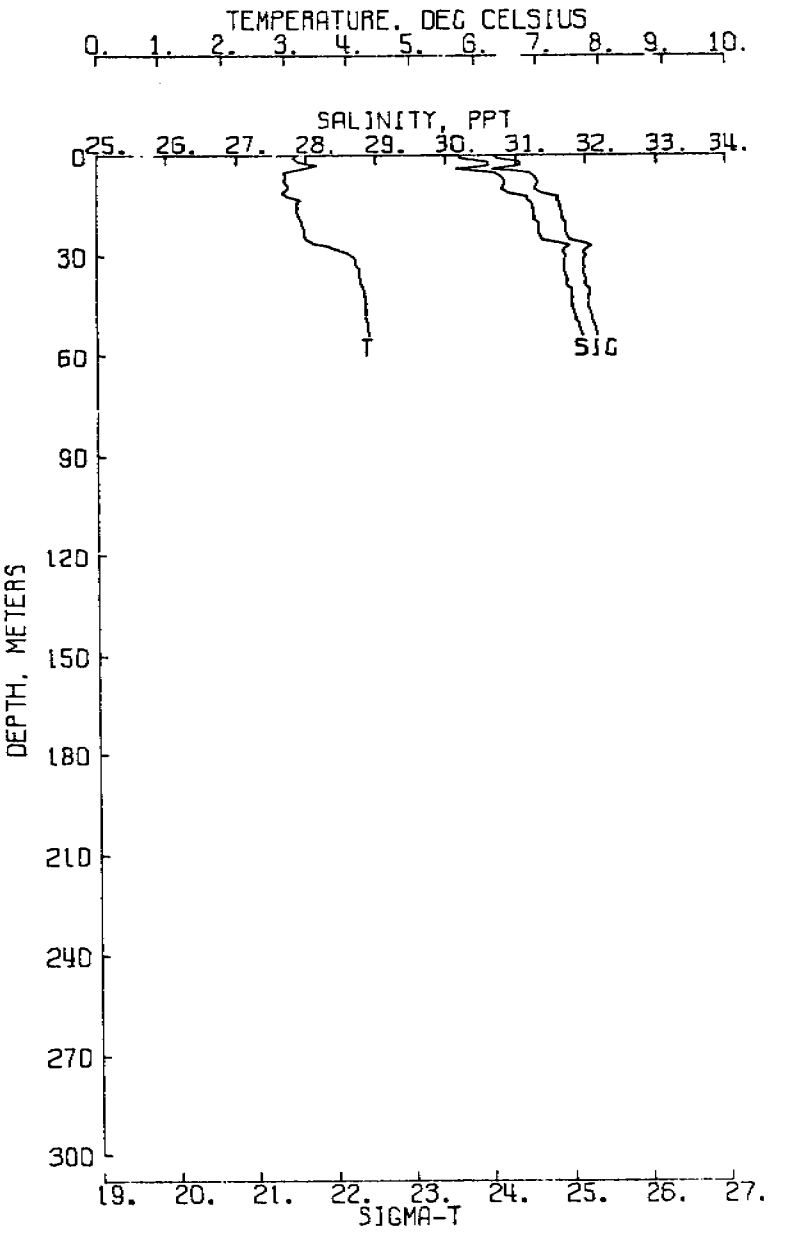
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | 0. M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 4.4 DEGR C. BAROMETRIC PR. =1025.0 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 3.22 | 30.175 | 24.06 | 0. |
| 1.0 | 3.14 | 30.215 | 24.10 | 0.004 |
| 5.0 | 2.99 | 30.711 | 24.50 | 0.018 |
| 10.0 | 3.05 | 30.808 | 24.58 | 0.035 |
| 15.0 | 3.19 | 31.236 | 24.91 | 0.051 |
| 20.0 | 3.24 | 31.314 | 24.96 | 0.066 |
| 25.0 | 3.34 | 31.380 | 25.01 | 0.081 |
| 30.0 | 4.06 | 31.721 | 25.21 | 0.095 |
| 35.0 | 4.16 | 31.695 | 25.18 | 0.109 |
| 40.0 | 4.23 | 31.793 | 25.26 | 0.123 |
| 45.0 | 4.28 | 31.791 | 25.25 | 0.137 |
| 50.0 | 4.30 | 31.887 | 25.32 | 0.151 |






CRUISE 275 STATION 10

AC CRUISE 275 CONSECUTIVE STATION NO. 11. YAK 9A 20/ 4/79
8.8 HOURS GMT

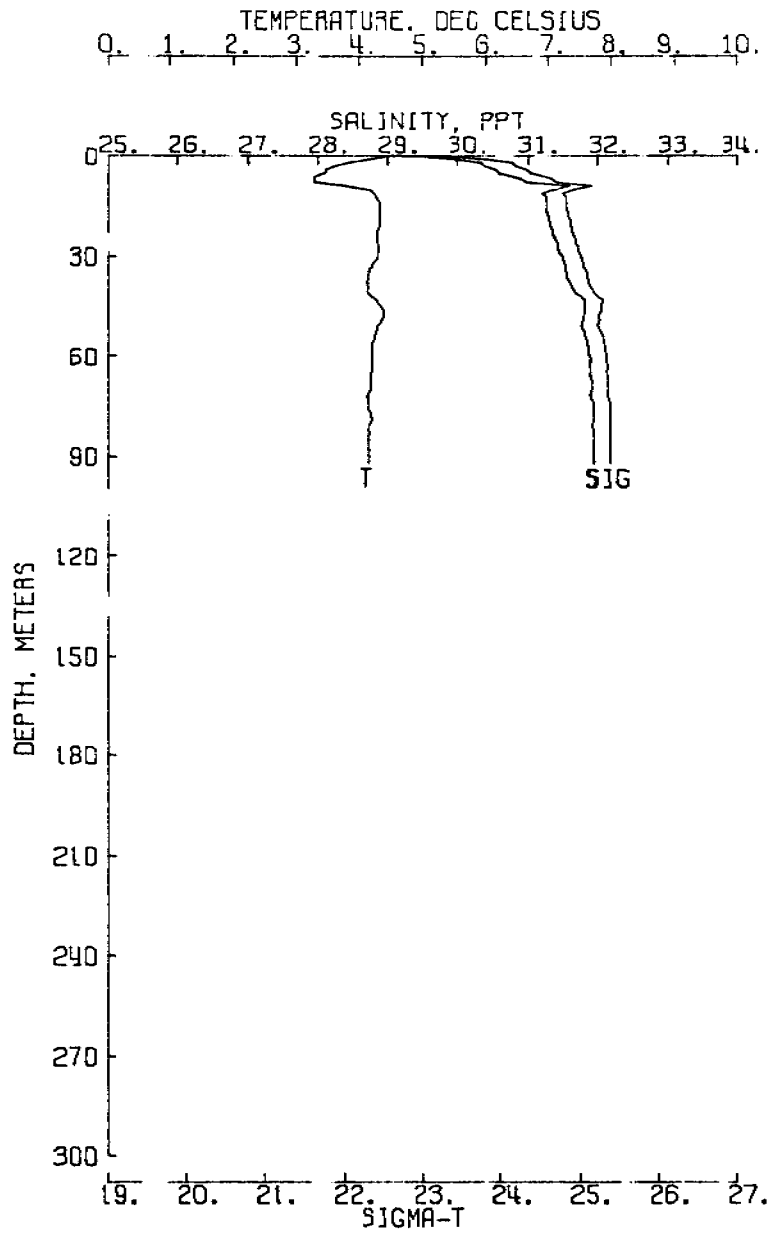
LATITUDE = 59 43.4N LONGITUDE = 139 54.5W SONIC DEPTH = 97 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED .
CLOUD AMOUNT --- (0) ---NO CLOUDS .
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS | | |
| | **DIRECTION** | **HEIGHT** | **PERIOD** | |
| SEA | 0 - 0 DEGR | 0. M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES | -DRY = 4.4 DEGR C. | BAROMETRIC PR. | =1025.0 MB | |
| | -WET = DEGR C. | TRANSPARENCY | = M | |

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 4.53 | 29.139 | 23.12 | 0. |
| 1.0 | 4.21 | 29.951 | 23.80 | 0.004 |
| 5.0 | 3.44 | 30.596 | 24.38 | 0.019 |
| 10.0 | 4.17 | 31.341 | 24.90 | 0.036 |
| 15.0 | 4.30 | 31.264 | 24.83 | 0.051 |
| 20.0 | 4.31 | 31.326 | 24.88 | 0.067 |
| 25.0 | 4.26 | 31.389 | 24.93 | 0.082 |
| 30.0 | 4.27 | 31.496 | 25.02 | 0.097 |
| 35.0 | 4.13 | 31.560 | 25.08 | 0.112 |
| 40.0 | 4.12 | 31.645 | 25.15 | 0.126 |
| 45.0 | 4.33 | 31.815 | 25.26 | 0.140 |
| 50.0 | 4.32 | 31.764 | 25.22 | 0.154 |
| 60.0 | 4.20 | 31.890 | 25.34 | 0.181 |
| 70.0 | 4.17 | 31.908 | 25.35 | 0.207 |
| 75.0 | 4.15 | 31.937 | 25.38 | 0.221 |
| 80.0 | 4.17 | 31.914 | 25.36 | 0.234 |
| 90.0 | 4.15 | 31.942 | 25.38 | 0.260 |






CRUISE 275 STATION 11

AC CRUISE 275 CONSECUTIVE STATION NO. 12. YAK 6B 20/ 4/79
9.3 HOURS GMT

LATITUDE = 59 45.2N LONGITUDE = 139 49.1W SONIC DEPTH = 60 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED ,
CLOUD AMOUNT --- (0) ---NO CLOUDS ,
VISIBILITY --- (8) ---20-50 KM

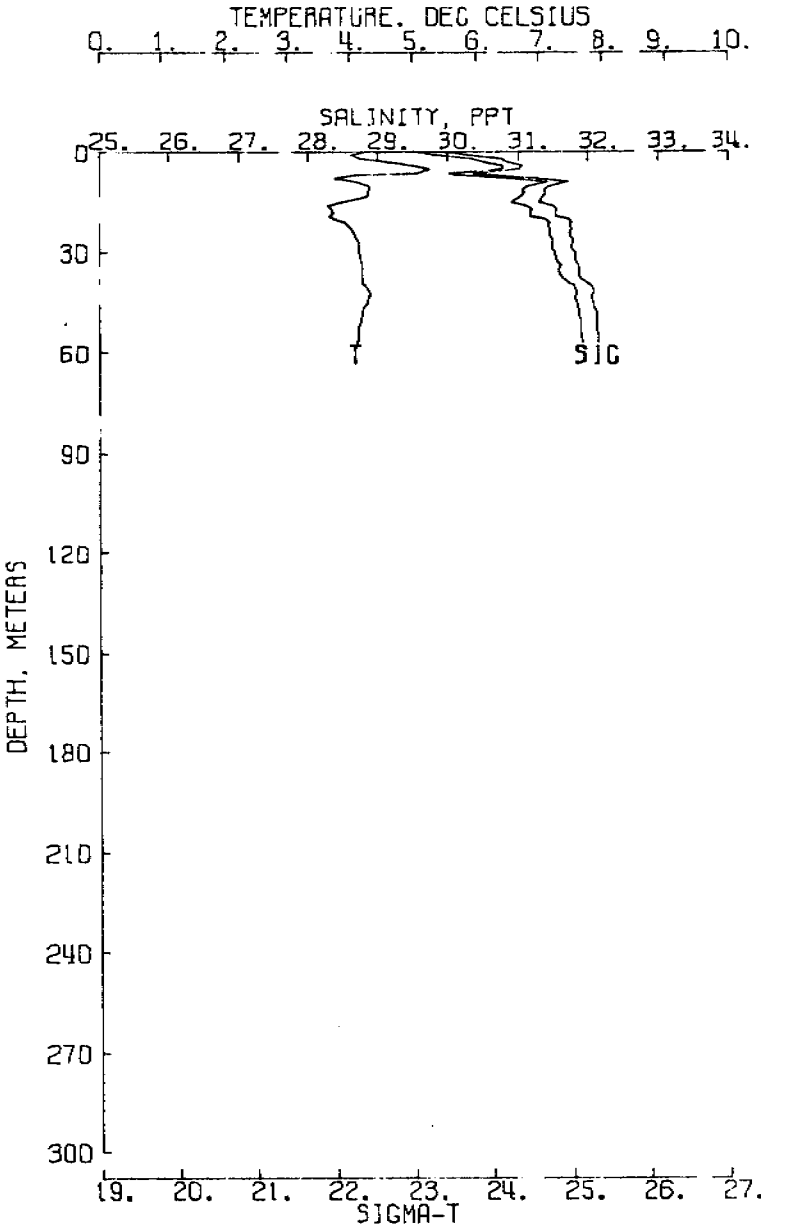
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | 0. M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 4.4 DEGR C. BAROMETRIC PR. =1025.1 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPEPATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 4.32 | 29.495 | 23.42 | 0. |
| 1.0 | 4.02 | 29.812 | 23.70 | 0.004 |
| 5.0 | 5.28 | 30.770 | 24.34 | 0.019 |
| 10.0 | 4.31 | 31.147 | 24.74 | 0.037 |
| 15.0 | 3.86 | 30.913 | 24.59 | 0.054 |
| 20.0 | 3.73 | 31.365 | 24.96 | 0.070 |
| 25.0 | 4.08 | 31.444 | 24.99 | 0.085 |
| 30.0 | 4.14 | 31.521 | 25.05 | 0.099 |
| 35.0 | 4.21 | 31.587 | 25.09 | 0.114 |
| 40.0 | 4.23 | 31.788 | 25.25 | 0.128 |
| 45.0 | 4.27 | 31.841 | 25.29 | 0.142 |
| 50.0 | 4.16 | 31.889 | 25.34 | 0.155 |






CRUISE 275 STATION 12

AC CRUISE 275 CONSECUTIVE STATION NO. 13. YAK 7A 20/ 4/79
9.7 HOURS GMT

LATITUDE = 59 43.0N LONGITUDE = 139 45.5W SONIC DEPTH = 104 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- (0) ---CIRRUS
CLOUD AMOUNT --- (0) ---NO CLOUDS
VISIBILITY --- (8) ---20-50 KM

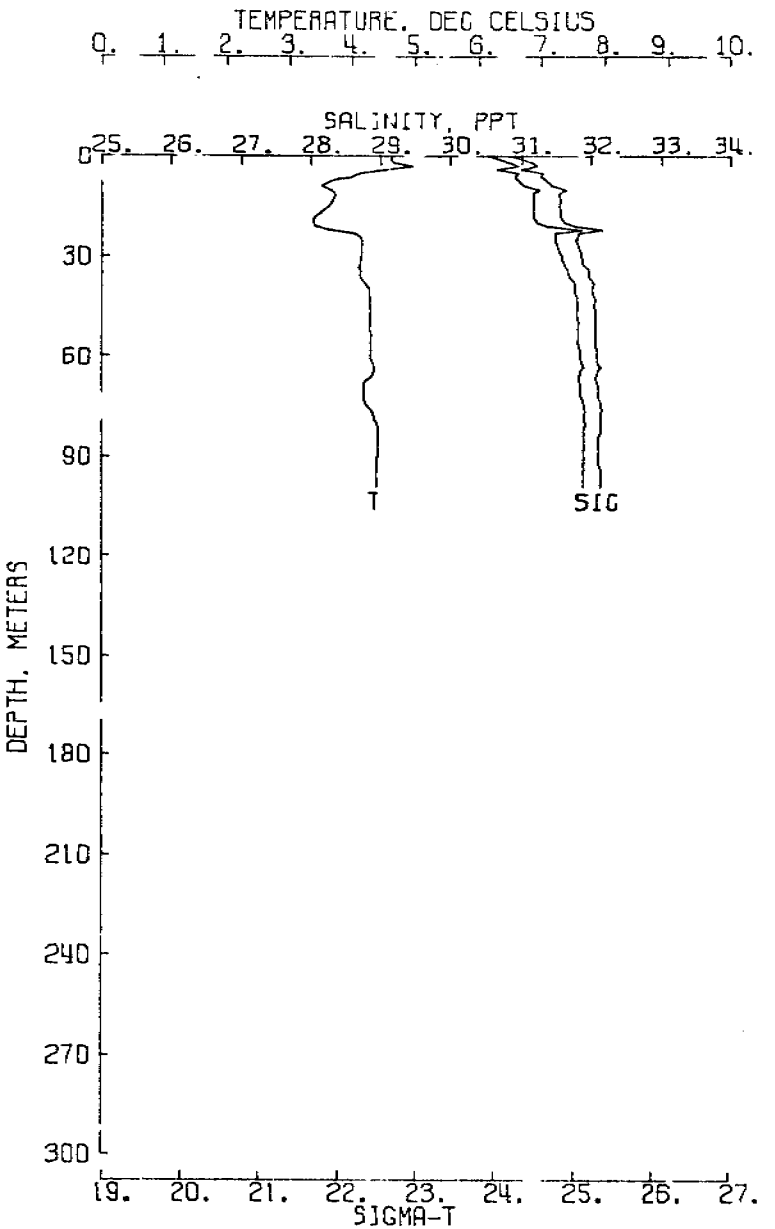
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | 0. M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 4.4 DEGR C. BAROMETRIC PR. =1025.1 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 4.67 | 30.505 | 24.19 | 0. |
| 1.0 | 4.60 | 30.665 | 24.33 | 0.004 |
| 5.0 | 4.12 | 30.954 | 24.60 | 0.018 |
| 10.0 | 3.64 | 31.260 | 24.89 | 0.034 |
| 15.0 | 3.62 | 31.164 | 24.81 | 0.050 |
| 20.0 | 3.36 | 31.217 | 24.88 | 0.066 |
| 25.0 | 4.13 | 31.482 | 25.02 | 0.080 |
| 30.0 | 4.13 | 31.575 | 25.09 | 0.095 |
| 35.0 | 4.11 | 31.669 | 25.17 | 0.109 |
| 40.0 | 4.25 | 31.764 | 25.23 | 0.123 |
| 45.0 | 4.27 | 31.796 | 25.25 | 0.137 |
| 50.0 | 4.26 | 31.809 | 25.26 | 0.150 |
| 60.0 | 4.29 | 31.840 | 25.29 | 0.177 |
| 70.0 | 4.16 | 31.848 | 25.31 | 0.204 |
| 75.0 | 4.23 | 31.889 | 25.33 | 0.218 |
| 80.0 | 4.38 | 31.920 | 25.34 | 0.231 |
| 90.0 | 4.39 | 31.892 | 25.32 | 0.258 |
| 100.0 | 4.37 | 31.896 | 25.32 | 0.285 |






CRUISE 275 STATION 13

AC CRUISE 275 CONSECUTIVE STATION NO. 14. YAK 6 20/ 4/79
10.1 HOURS GMT

LATITUDE = 59 43.5N LONGITUDE = 139 43.2W SONIC DEPTH = 95 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED.
VISIBILITY --- ( ) ---NOT RECORDED

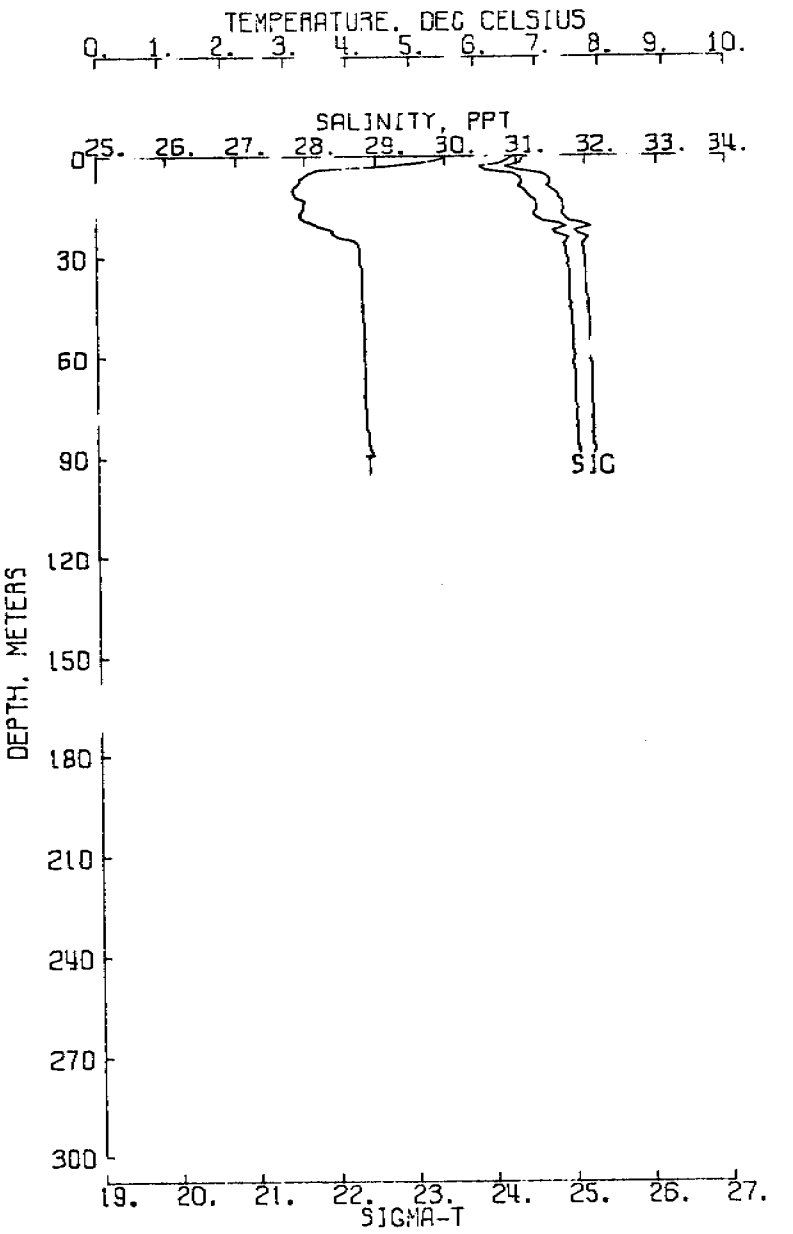
| | DIRECTION | SPEED |
|---|---|---|
| WIND | - DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 4.4 DEGR C. BAROMETRIC PR. =1025.1 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.53 | 30.992 | 24.48 | 0. |
| 1.0 | 5.50 | 30.903 | 24.42 | 0.003 |
| 5.0 | 3.40 | 30.949 | 24.66 | 0.018 |
| 10.0 | 3.13 | 31.141 | 24.84 | 0.034 |
| 15.0 | 3.31 | 31.296 | 24.94 | 0.049 |
| 20.0 | 3.43 | 31.608 | 25.18 | 0.064 |
| 25.0 | 4.11 | 31.745 | 25.23 | 0.078 |
| 30.0 | 4.20 | 31.736 | 25.21 | 0.092 |
| 35.0 | 4.22 | 31.755 | 25.23 | 0.106 |
| 40.0 | 4.22 | 31.760 | 25.23 | 0.120 |
| 45.0 | 4.23 | 31.774 | 25.24 | 0.133 |
| 50.0 | 4.24 | 31.800 | 25.26 | 0.147 |
| 60.0 | 4.26 | 31.827 | 25.28 | 0.174 |
| 70.0 | 4.25 | 31.840 | 25.29 | 0.201 |
| 75.0 | 4.26 | 31.863 | 25.31 | 0.215 |
| 80.0 | 4.28 | 31.858 | 25.30 | 0.228 |






CRUISE 275 STATION 14

AC CRUISE 275 CONSECUTIVE STATION NO. 15, YAK 5 20/ 4/79
10.3 HOURS GMT

LATITUDE = 59 44.0N LONGITUDE = 139 40.5W SONIC DEPTH = 172 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED.
VISIBILITY --- ( ) ---NOT RECORDED

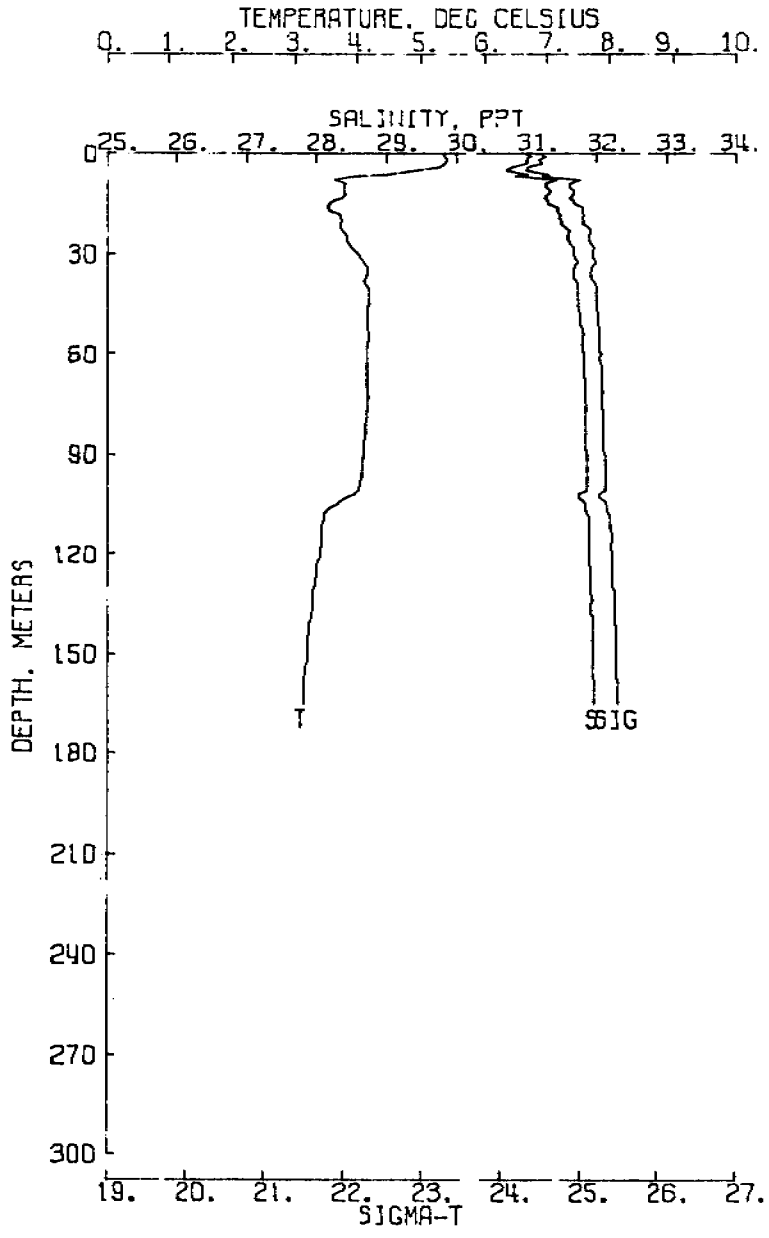
| | DIRECTION | SPEED |
|---|---|---|
| WIND | - DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.6 DEGR C. BAROMETRIC PR. =1025.3 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.38 | 30.944 | 24.46 | 0. |
| 1.0 | 5.36 | 31.070 | 24.57 | 0.003 |
| 5.0 | 4.88 | 30.708 | 24.33 | 0.017 |
| 10.0 | 3.77 | 31.268 | 24.88 | 0.034 |
| 15.0 | 3.52 | 31.307 | 24.93 | 0.049 |
| 20.0 | 3.73 | 31.499 | 25.07 | 0.064 |
| 25.0 | 3.81 | 31.572 | 25.12 | 0.078 |
| 30.0 | 3.98 | 31.652 | 25.17 | 0.092 |
| 35.0 | 4.14 | 31.663 | 25.16 | 0.106 |
| 40.0 | 4.15 | 31.744 | 25.22 | 0.120 |
| 45.0 | 4.16 | 31.735 | 25.22 | 0.134 |
| 50.0 | 4.13 | 31.767 | 25.24 | 0.148 |
| 60.0 | 4.15 | 31.815 | 25.28 | 0.175 |
| 70.0 | 4.14 | 31.831 | 25.29 | 0.202 |
| 75.0 | 4.14 | 31.832 | 25.29 | 0.216 |
| 80.0 | 4.13 | 31.846 | 25.31 | 0.229 |
| 90.0 | 4.07 | 31.860 | 25.32 | 0.256 |
| 100.0 | 4.01 | 31.859 | 25.33 | 0.283 |
| 125.0 | 3.33 | 31.917 | 25.44 | 0.348 |
| 150.0 | 3.18 | 31.951 | 25.48 | 0.412 |






CRUISE 275 STATION 15

AC CRUISE 275 CONSECUTIVE STATION NO. 16, YAK 5A 20/ 4/79
10.7 HOURS GMT

LATITUDE = 59 46.7N LONGITUDE = 139 41.7W SONIC DEPTH = 164 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED.
VISIBILITY --- ( ) ---NOT RECORDED

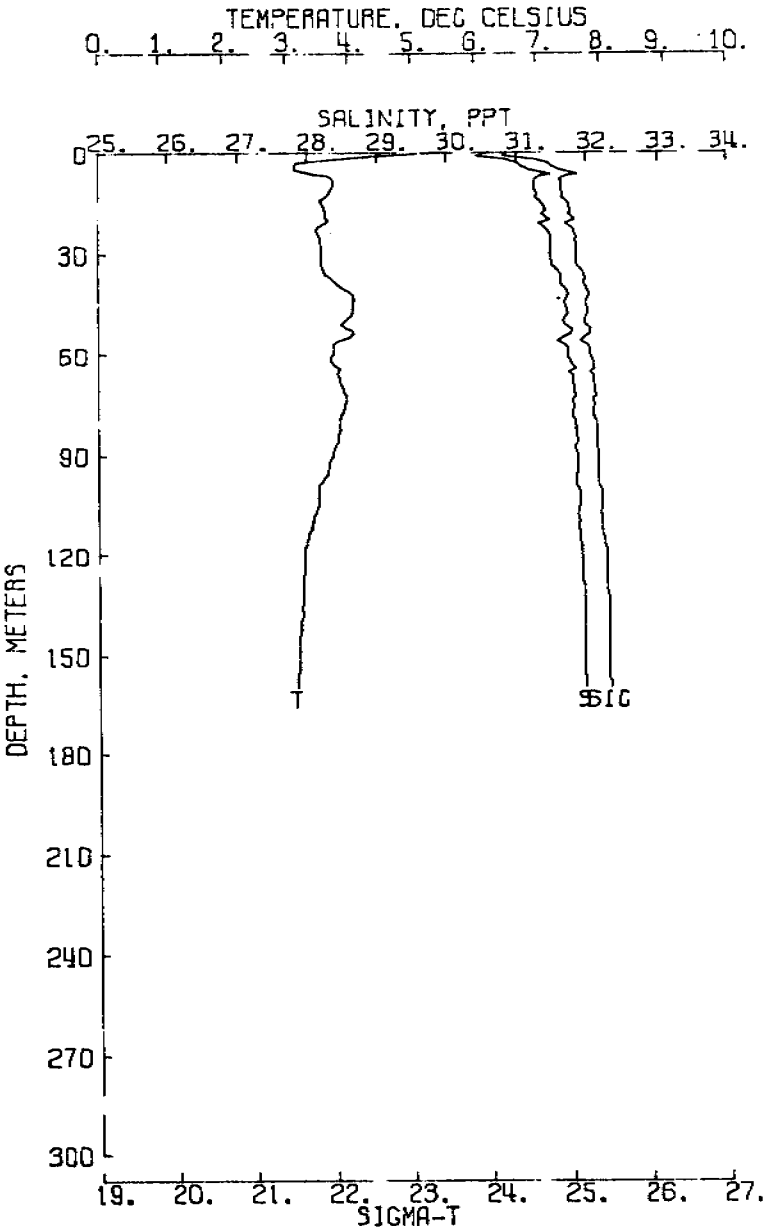
| | DIRECTION | SPEED |
|---|---|---|
| WIND | - DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.6 DEGR C. BAROMETRIC PR. =1025.4 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.45 | 30.627 | 24.21 | 0. |
| 1.0 | 4.50 | 30.451 | 24.17 | 0.004 |
| 5.0 | 3.12 | 31.193 | 24.88 | 0.017 |
| 10.0 | 3.74 | 31.274 | 24.89 | 0.032 |
| 15.0 | 3.55 | 31.372 | 24.98 | 0.047 |
| 20.0 | 3.69 | 31.478 | 25.06 | 0.062 |
| 25.0 | 3.53 | 31.490 | 25.08 | 0.077 |
| 30.0 | 3.58 | 31.488 | 25.07 | 0.091 |
| 35.0 | 3.59 | 31.585 | 25.15 | 0.106 |
| 40.0 | 3.86 | 31.665 | 25.19 | 0.120 |
| 45.0 | 4.06 | 31.691 | 25.19 | 0.134 |
| 50.0 | 3.94 | 31.664 | 25.18 | 0.148 |
| 60.0 | 3.72 | 31.726 | 25.25 | 0.175 |
| 70.0 | 3.90 | 31.814 | 25.30 | 0.202 |
| 75.0 | 3.95 | 31.818 | 25.30 | 0.216 |
| 80.0 | 3.86 | 31.840 | 25.33 | 0.229 |
| 90.0 | 3.73 | 31.855 | 25.35 | 0.256 |
| 100.0 | 3.50 | 31.878 | 25.39 | 0.282 |
| 125.0 | 3.26 | 31.929 | 25.45 | 0.347 |
| 150.0 | 3.19 | 31.954 | 25.48 | 0.410 |






CRUISE 275 STATION 16

AC CRUISE 275 CONSECUTIVE STATION NO. 17. YAK 4 20/ 4/79
11.7 HOURS GMT

LATITUDE = 59 48.0N LONGITUDE = 139 42.2W SONIC DEPTH = 142 M

1-DIGIT WEATHER CODE IS (X0) AND INDICATES CLEAR
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED,
VISIBILITY --- ( ) ---NOT RECORDED

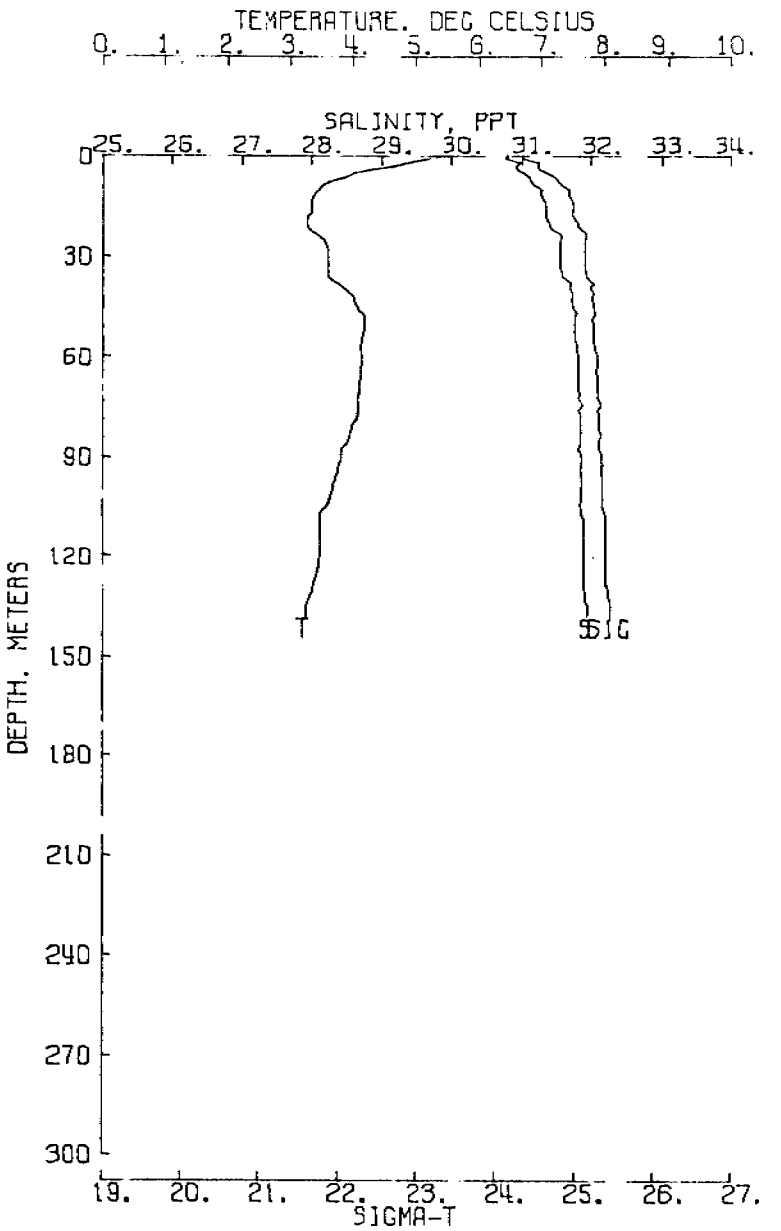
| | DIRECTION | SPEED |
|---|---|---|
| WIND | - DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.6 DEGR C. BAROMETRIC PR. =1025.4 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.50 | 30.800 | 24.34 | 0. |
| 1.0 | 5.16 | 30.764 | 24.35 | 0.004 |
| 5.0 | 4.01 | 31.030 | 24.67 | 0.017 |
| 10.0 | 3.46 | 31.299 | 24.93 | 0.033 |
| 15.0 | 3.34 | 31.347 | 24.98 | 0.048 |
| 20.0 | 3.27 | 31.400 | 25.03 | 0.063 |
| 25.0 | 3.53 | 31.557 | 25.13 | 0.078 |
| 30.0 | 3.59 | 31.554 | 25.12 | 0.092 |
| 35.0 | 3.60 | 31.573 | 25.14 | 0.106 |
| 40.0 | 3.96 | 31.680 | 25.20 | 0.120 |
| 45.0 | 4.06 | 31.750 | 25.24 | 0.134 |
| 50.0 | 4.17 | 31.762 | 25.24 | 0.148 |
| 60.0 | 4.13 | 31.818 | 25.29 | 0.175 |
| 70.0 | 4.08 | 31.826 | 25.30 | 0.202 |
| 75.0 | 4.09 | 31.864 | 25.32 | 0.215 |
| 80.0 | 4.00 | 31.821 | 25.30 | 0.229 |
| 90.0 | 3.80 | 31.876 | 25.36 | 0.256 |
| 100.0 | 3.66 | 31.851 | 25.35 | 0.282 |
| 125.0 | 3.42 | 31.889 | 25.41 | 0.347 |






CRUISE 275 STATION 17

AC CRUISE 275 CONSECUTIVE STATION NO. 18. YAK 3 20/ 4/79
13.8 HOURS GMT

LATITUDE = 59 52.5N LONGITUDE = 139 40.5W SONIC DEPTH = 247 M

1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (2) ---CIRROSTRATUS ,
CLOUD AMOUNT --- (2) ---2/8 ,
VISIBILITY --- (8) ---20-50 KM

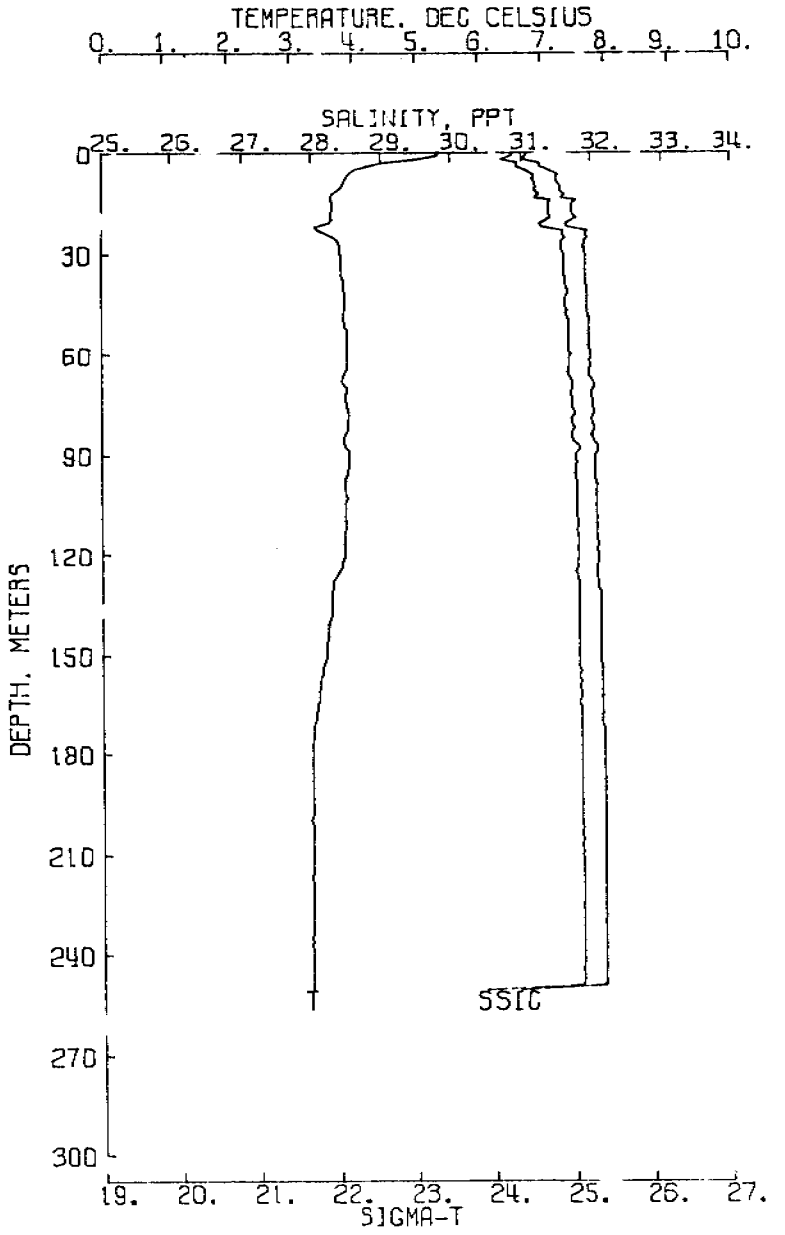
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 15 - 24 DEGR | 5 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 6.1 DEGR C. BAROMETRIC PR. =1025.8 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.39 | 30.891 | 24.42 | 0. |
| 1.0 | 5.36 | 30.868 | 24.41 | 0.004 |
| 5.0 | 4.01 | 31.057 | 24.69 | 0.017 |
| 10.0 | 3.82 | 31.220 | 24.84 | 0.033 |
| 15.0 | 3.69 | 31.406 | 25.00 | 0.049 |
| 20.0 | 3.67 | 31.435 | 25.02 | 0.063 |
| 25.0 | 3.70 | 31.624 | 25.17 | 0.078 |
| 30.0 | 3.80 | 31.606 | 25.15 | 0.092 |
| 35.0 | 3.83 | 31.616 | 25.15 | 0.106 |
| 40.0 | 3.84 | 31.630 | 25.16 | 0.121 |
| 45.0 | 3.87 | 31.644 | 25.17 | 0.135 |
| 50.0 | 3.86 | 31.673 | 25.19 | 0.149 |
| 60.0 | 3.91 | 31.700 | 25.21 | 0.177 |
| 70.0 | 3.90 | 31.734 | 25.24 | 0.204 |
| 75.0 | 3.90 | 31.749 | 25.25 | 0.218 |
| 80.0 | 3.91 | 31.723 | 25.23 | 0.232 |
| 90.0 | 3.95 | 31.776 | 25.27 | 0.259 |
| 100.0 | 3.89 | 31.784 | 25.28 | 0.286 |
| 125.0 | 3.76 | 31.776 | 25.29 | 0.354 |
| 150.0 | 3.56 | 31.824 | 25.34 | 0.420 |
| 175.0 | 3.35 | 31.840 | 25.37 | 0.486 |
| 200.0 | 3.32 | 31.852 | 25.39 | 0.552 |
| 250.0 | 3.34 | 30.478 | 24.29 | 0.683 |






CRUISE 275 STATION 18

AC CRUISE 275 CONSECUTIVE STATION NO. 19. YAK 3A 20/ 4/79
14.4 HOURS GMT

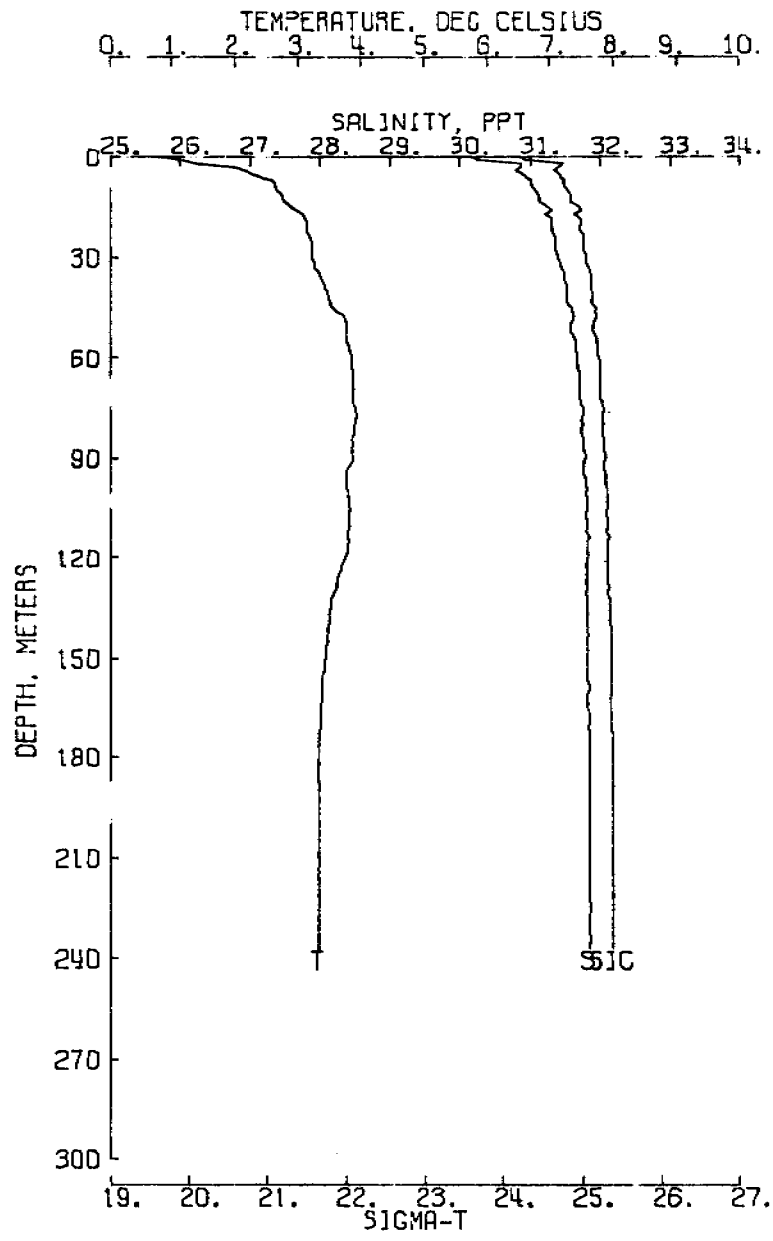
LATITUDE = 59 55.1N LONGITUDE = 139 38.8W SONIC DEPTH = 245 M

1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (2) ---CIRROSTRATUS
CLOUD AMOUNT --- (2) ---2/8
VISIBILITY --- (8) ---20-50 KM

| | | | | |
|---|---|---|---|---|
| I | DIRECTION | SPEED | | I |
| I WIND | - DEGR | KNOTS | | I |
| I | DIRECTION | HEIGHT | PERIOD | I |
| I SEA | 0 - 0 DEGR | M. | SECS | I |
| I SWELL | - DEGR | M. | SECS | I |
| I TEMPERATURES -DRY = | 6.1 DEGR C. | BAROMETRIC PR. | =1025.9 MB | I |
| I -WET = | DEGR C. | TRANSPARENCY = | M | I |

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 0.80 | 30.155 | 24.20 | 0. |
| 1.0 | 1.13 | 30.263 | 24.27 | 0.004 |
| 5.0 | 2.28 | 30.909 | 24.71 | 0.017 |
| 10.0 | 2.67 | 31.085 | 24.83 | 0.033 |
| 15.0 | 2.89 | 31.274 | 24.96 | 0.048 |
| 20.0 | 3.13 | 31.297 | 24.96 | 0.064 |
| 25.0 | 3.21 | 31.374 | 25.01 | 0.078 |
| 30.0 | 3.22 | 31.395 | 25.03 | 0.093 |
| 35.0 | 3.33 | 31.493 | 25.10 | 0.108 |
| 40.0 | 3.45 | 31.525 | 25.11 | 0.122 |
| 45.0 | 3.57 | 31.615 | 25.18 | 0.136 |
| 50.0 | 3.78 | 31.591 | 25.14 | 0.151 |
| 60.0 | 3.85 | 31.684 | 25.20 | 0.179 |
| 70.0 | 3.87 | 31.712 | 25.23 | 0.206 |
| 75.0 | 3.90 | 31.773 | 25.27 | 0.220 |
| 80.0 | 3.89 | 31.758 | 25.26 | 0.234 |
| 90.0 | 3.87 | 31.788 | 25.29 | 0.261 |
| 100.0 | 3.79 | 31.803 | 25.30 | 0.288 |
| 125.0 | 3.63 | 31.800 | 25.32 | 0.355 |
| 150.0 | 3.41 | 31.821 | 25.35 | 0.422 |
| 175.0 | 3.31 | 31.835 | 25.37 | 0.488 |
| 200.0 | 3.30 | 31.843 | 25.38 | 0.553 |






CRUISE 275 STATION 19

AC CRUISE 275 CONSECUTIVE STATION NO. 20. YAK 9 20/ 4/79
17.8 HOURS GMT

LATITUDE = 59 40.0N LONGITUDE = 139 59.5W SONIC DEPTH = 155 M

1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (7) ---7/8
VISIBILITY --- (8) ---20-50 KM

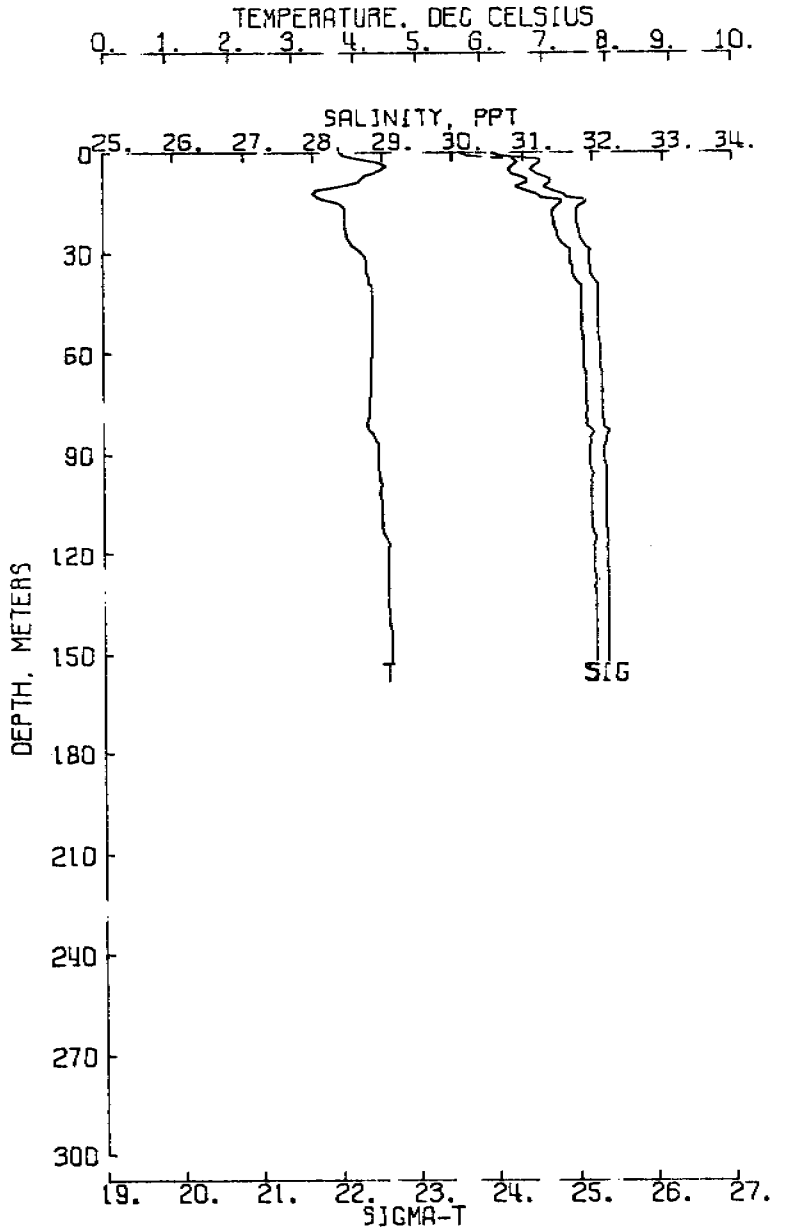
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 0 - 0 DEGR | 0 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 225 - 234 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 5.0 DEGR C. BAROMETRIC PR. =1026.5 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 3.78 | 30.097 | 23.95 | 0. |
| 1.0 | 3.82 | 30.207 | 24.04 | 0.004 |
| 5.0 | 4.42 | 30.790 | 24.44 | 0.018 |
| 10.0 | 3.73 | 30.916 | 24.61 | 0.035 |
| 15.0 | 3.74 | 31.562 | 25.12 | 0.050 |
| 20.0 | 3.85 | 31.440 | 25.01 | 0.065 |
| 25.0 | 3.89 | 31.512 | 25.06 | 0.080 |
| 30.0 | 4.11 | 31.681 | 25.18 | 0.094 |
| 35.0 | 4.21 | 31.710 | 25.19 | 0.108 |
| 40.0 | 4.28 | 31.833 | 25.28 | 0.122 |
| 45.0 | 4.29 | 31.844 | 25.29 | 0.135 |
| 50.0 | 4.29 | 31.845 | 25.29 | 0.149 |
| 60.0 | 4.27 | 31.868 | 25.31 | 0.176 |
| 70.0 | 4.25 | 31.890 | 25.33 | 0.202 |
| 75.0 | 4.23 | 31.904 | 25.34 | 0.216 |
| 80.0 | 4.21 | 31.910 | 25.35 | 0.229 |
| 90.0 | 4.37 | 31.950 | 25.37 | 0.255 |
| 100.0 | 4.42 | 31.965 | 25.37 | 0.281 |
| 125.0 | 4.52 | 32.006 | 25.39 | 0.347 |
| 150.0 | 4.56 | 32.022 | 25.40 | 0.412 |






CRUISE 275 STATION 20

Appendix II

Datalist

R/V *Acona* 267, 272,

275 and 276

October 1978, March 1979,

April 1979, May 1979

AC CRUISE 267 CONSECUTIVE STATION NO. 1. RES2.5 10/10/78
21.5 HOURS

LATITUDE = 60 1.2N LONGITUDE = 149 21.5W SONIC DEPTH = 287

1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED.
VISIBILITY --- (7) ---10-20 KM

| | DIRECTION | SPEED |
|---|---|---|
| WIND | 345 - 354 DEGR | 3 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 175 - 184 DEGR | 1.0 M. | 8 SECS |
| SWELL | - DEGR | M. | SECS |

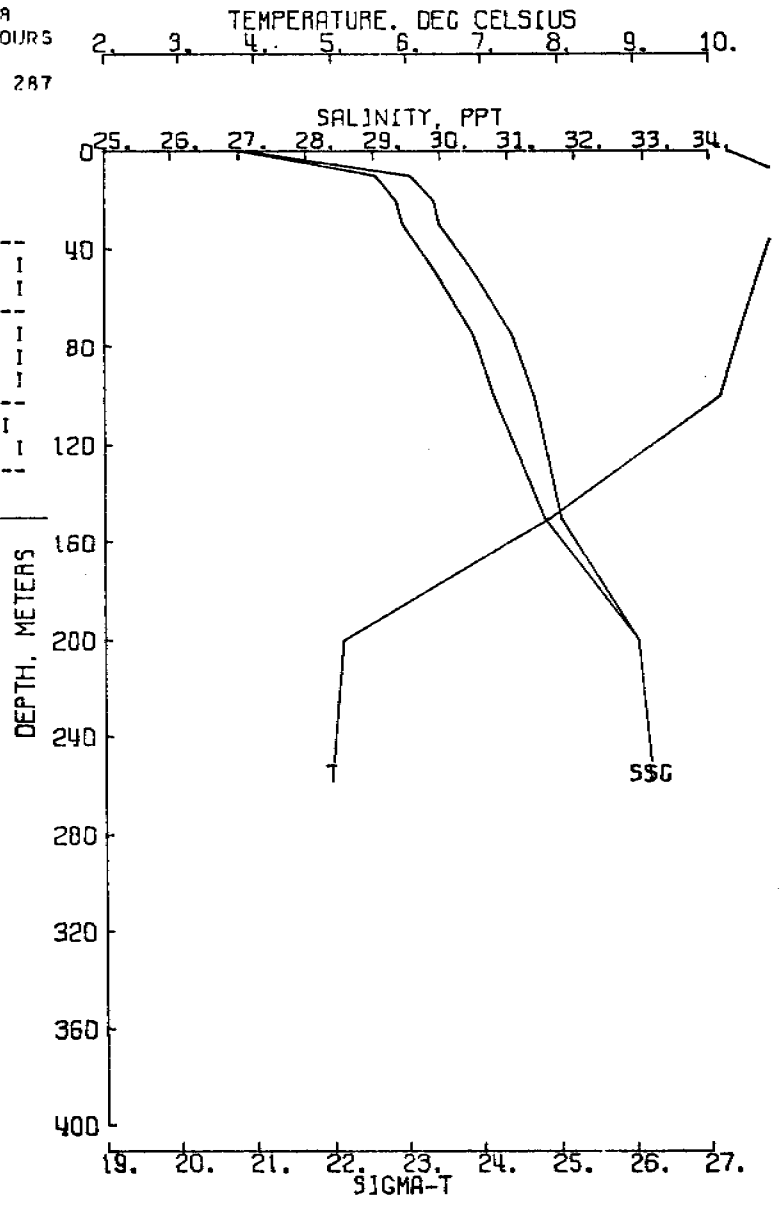
TEMPERATURES -DRY = 7.8 DEGR C. BAROMETRIC PR. = 981.9MB
-WET = DEGR C. TRANSPARENCY = M

STANDARD DEPTHS

| DEPTH | TEMP | SALIN | SIG-T | SPVOL | DEL-D |
|---|---|---|---|---|---|
| 0. | 10.24 | 27.067 | 20.78 | 700.2 | 0. |
| 10. | 11.07 | 29.563 | 22.58 | 527.9 | 0.061 |
| 20. | 10.97 | 29.917 | 22.87 | 500.1 | 0.113 |
| 30. | 10.86 | 29.986 | 22.95 | 493.4 | 0.162 |
| 50. | 10.65 | 30.526 | 23.40 | 450.3 | 0.257 |
| 75. | 10.39 | 31.070 | 23.87 | 406.2 | 0.364 |
| 100. | 10.13 | 31.389 | 24.16 | 378.8 | 0.462 |
| 150. | 7.87 | 31.797 | 24.82 | 315.7 | 0.636 |
| 200. | 5.16 | 32.919 | 26.05 | 198.9 | 0.764 |
| 250. | 5.01 | 33.120 | 26.22 | 182.7 | 0.860 |

OBSERVED DEPTHS

| | | | |
|---|---|---|---|
| 0. | 10.24 | 27.067 | 20.78 |
| 10. | 11.07 | 29.563 | 22.58 |
| 20. | 0. | 29.917 | 0. |
| 30. | 0. | 29.986 | 0. |
| 50. | 0. | 30.526 | 0. |
| 75. | 0. | 31.070 | 0. |
| 100. | 10.13 | 31.389 | 24.16 |
| 150. | 7.87 | 31.797 | 24.82 |
| 180. | 5.80 | 32.309 | 25.49 |
| 200. | 5.16 | 32.919 | 26.05 |
| 220. | 5.02 | 33.058 | 26.18 |
| 240. | 5.00 | 33.110 | 26.22 |
| 260. | 5.02 | 33.125 | 26.23 |
| 280. | 4.98 | 33.144 | 26.25 |




CRUISE 267 STATION 1

AC CRUISE 267 CONSECUTIVE STATION NO. 2. RES 4 10/10/78
0.8 HOURS GMT

LATITUDE = 59 54.7N LONGITUDE = 149 24.5W SONIC DEPTH = 261 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS .
CLOUD AMOUNT --- (8) ---8/8 TOTAL .
VISIBILITY --- (7) ---10-20 KM

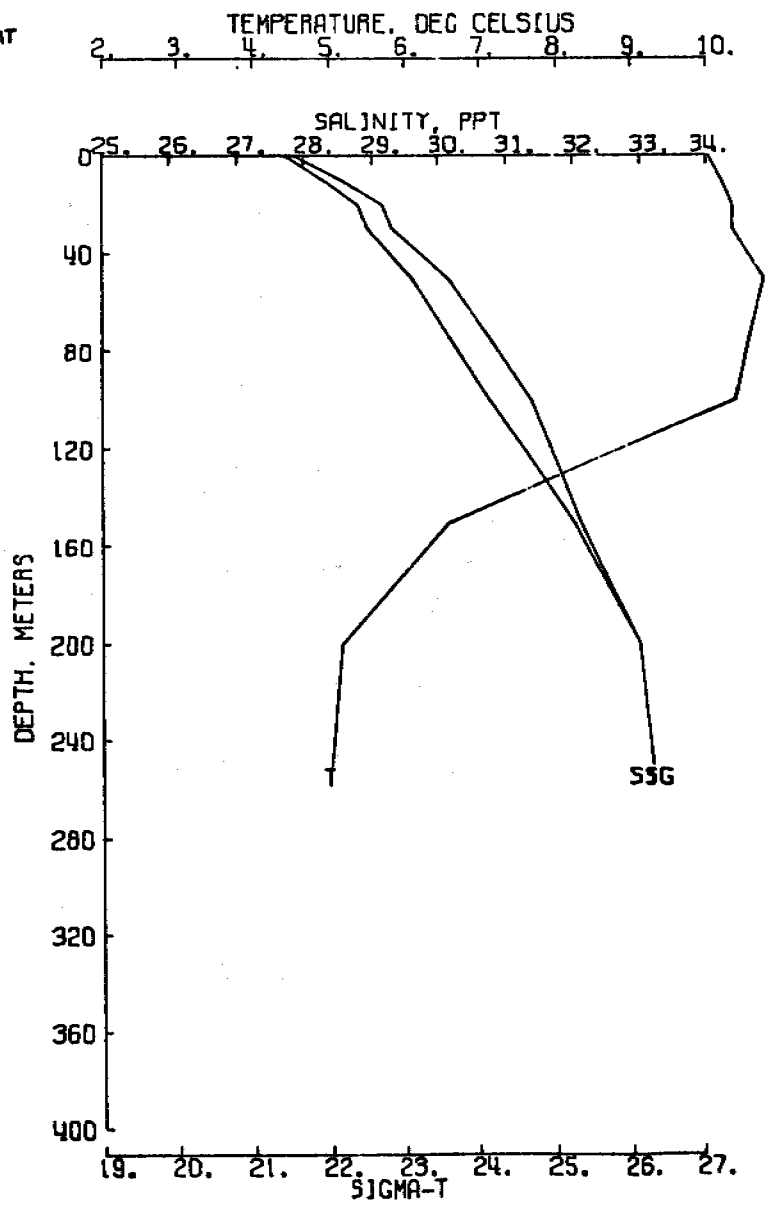
| | | | | |
|---|---|---|---|---|
| WIND | DIRECTION 5 - 14 DEGR | SPEED KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 0 - 0 DEGR | 1.0 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES | -DRY = 9.4 DEGR C. | BAROMETRIC PR. = 981.6MB | | |
| | -WET = DEGR C. | TRANSPARENCY = M | | |

STANDARD DEPTHS

| | DEPTH | TEMP | SALIN | SIG-T | SPVOL | DEL-D |
|---|---|---|---|---|---|---|
| 995 | 0. | 10.03 | 27.836 | 21.41 | 639.8 | 0. |
| | 10. | 10.21 | 28.533 | 21.92 | 590.7 | 0.062 |
| | 20. | 10.34 | 29.154 | 22.39 | 546.7 | 0.118 |
| | 30. | 10.34 | 29.327 | 22.52 | 534.0 | 0.172 |
| | 50. | 10.76 | 30.151 | 23.09 | 479.8 | 0.274 |
| | 75. | 10.58 | 30.779 | 23.61 | 155.7 | 0.353 |
| | 100. | 10.39 | 31.406 | 24.13 | 381.7 | 0.420 |
| | 150. | 6.59 | 32.140 | 25.26 | 273.4 | 0.584 |
| | 200. | 5.14 | 32.998 | 26.11 | 192.8 | 0.701 |
| | 250. | 5.01 | 33.192 | 26.28 | 177.3 | 0.793 |

OBSERVED DEPTHS

| DEPTH | TEMP | SALIN | SIG-T |
|---|---|---|---|
| 0. | 10.03 | 27.836 | 21.41 |
| 10. | 10.21 | 28.533 | 21.92 |
| 20. | 10.34 | 29.154 | 22.39 |
| 30. | 10.34 | 29.327 | 22.52 |
| 50. | 10.76 | 30.151 | 23.09 |
| 75. | 0. | 34.501 | 0. |
| 100. | 10.39 | 31.406 | 24.13 |
| 150. | 6.59 | 32.140 | 25.26 |
| 200. | 5.14 | 32.998 | 26.11 |
| 250. | 5.01 | 33.192 | 26.28 |




CRUISE 267 STATION 2

AC CRUISE 267 CONSECUTIVE STATION NO. 1, RES2.5 10/10/78
21.5 HOURS GMT

LATITUDE = 60 1.2N LONGITUDE = 149 21.5W SONIC DEPTH = 287 M

1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED.
VISIBILITY --- (7) ---10-20 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 345 - 354 DEGR | 3 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 175 - 184 DEGR | 1.0 M. | 8 SECS | |
| SWELL | - DEGR | M. | SECS | |

TEMPERATURES -DRY = 7.8 DEGR C. BAROMETRIC PR. = 981.9MB
-WET = DEGR C. TRANSPARENCY = M

OBSERVED

| TIME | DEP | TEMP | SAL | SIG-T | OXY | PO4 | NH3 | NO2 | NO3 | NO | SIO3 | PH | TALK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .0 | 0 | 10.24B | 27.067 | 20.78 | 6.11 | . | 00.7 | 0.09 | 01.6 | 559.9 | 6. | . | . |
| .0 | 10 | 11.07A | 29.563 | 22.58 | 6.18 | 0.50 | 00.4 | 0.41 | 03.2 | 580.6 | 12. | . | . |
| .0 | 20 | . | 29.917 | . | 6.22 | 0.37 | 00.4 | 0.18 | 03.1 | 583.2 | 10. | . | . |
| .0 | 30 | . | 29.986 | . | 6.29 | 0.52 | 00.3 | 0.17 | 03.7 | 594.9 | 13. | . | . |
| .0 | 50 | . | 30.526 | . | 6.54 | 0.68 | 00.4 | 0.21 | 04.1 | 620.8 | 14. | . | . |
| .0 | 75 | . | 31.070 | . | 5.96 | 0.57 | 00.5 | 0.69 | 05.0 | 577.1 | 14. | . | . |
| .0 | 100 | 10.13A | 31.389 | 24.16 | 5.92 | 0.81 | 00.5 | 0.51 | 07.9 | 599.6 | 20. | . | . |
| .0 | 150 | 7.87A | 31.797 | 24.82 | 6.14 | 0.96 | 00.2 | 0.20 | 13.5 | 669.7 | 25. | . | . |
| .0 | 180 | 5.80A | 32.309 | 25.49 | 6.09 | 1.20 | 00.0 | 0.00 | 15.3 | 681.4 | 27. | . | . |
| .0 | 200T | 5.16A | 32.919 | 26.05 | 5.14 | 1.38 | 00.0 | 0.00 | 18.3 | 623.6 | 34. | . | . |
| .0 | 220T | 5.02B | 33.058 | 26.18 | 5.07 | 1.46 | 00.1 | 0.00 | 15.6 | 593.0 | 29. | . | . |
| .0 | 240T | 5.00A | 33.110 | 26.22 | 4.40 | 1.75 | 00.4 | 0.12 | 22.4 | 594.4 | 42. | . | . |
| .0 | 260 | 5.02F | 33.125 | 26.23 | 3.20 | 1.75 | 00.0 | 0.00 | 21.3 | 477.4 | 41. | . | . |
| .0 | 280 | 4.98B | 33.144 | 26.25 | 4.78 | 2.10 | 00.1 | 0.12 | 24.3 | 645.5 | 45. | . | . |

STANDARD

| DEP | TEMP | SAL | SIG-T | OXY | SP VOL | DEL D |
|---|---|---|---|---|---|---|
| 0 | 10.24 | 27.067 | 20.78 | 6.11 | 700.23 | .000 |
| 10 | 11.07 | 29.563 | 22.58 | 6.18 | 527.91 | .061 |
| 20 | 10.97 | 29.917 | 22.87 | 6.22 | 500.10 | .113 |
| 30 | 10.86 | 29.986 | 22.95 | 6.29 | 493.42 | .162 |
| 50 | 10.65 | 30.526 | 23.40 | 6.54 | 450.30 | .257 |
| 75 | 10.39 | 31.070 | 23.87 | 5.96 | 406.17 | .364 |
| 100 | 10.13 | 31.389 | 24.16 | 5.92 | 378.76 | .462 |
| 150 | 7.87 | 31.797 | 24.82 | 6.14 | 315.65 | .636 |
| 200 | 5.16 | 32.919 | 26.05 | 5.14 | 198.89 | .764 |
| 250 | 5.01 | 33.118 | 26.22 | 3.80 | 182.88 | .860 |

AC CRUISE 267 CONSECUTIVE STATION NO. 2, RES 4 10/10/78
0.8 HOURS GMT

LATITUDE = 59 54.7N LONGITUDE = 149 24.5W SONIC DEPTH = 261 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (7) ---10-20 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 5 - 14 DEGR | 8 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 0 - 0 DEGR | 1.0 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES -DRY = | 9.4 DEGR C. | BAROMETRIC PR. = | 981.6MB | |
| -WET = | DEGR C. | TRANSPARENCY = | M | |

OBSERVED

| TIME | DEP | TEMP | SAL | SIG-T | OXY | PO4 | NH3 | NO2 | NO3 | NO | SIO3 | PH | TALK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21.5 | 0 | 10.03A | 27.836 | 21.41 | 6.61 | . | . | . | . | | . | . | . |
| 21.5 | 10 | 10.21A | 28.533 | 21.92 | . | . | . | . | . | | . | . | . |
| 21.5 | 20 | 10.34A | 29.154 | 22.39 | 6.29 | . | . | . | . | | . | . | . |
| 21.5 | 30 | 10.34A | 29.327 | 22.52 | 6.53 | . | . | . | . | | . | . | . |
| 21.5 | 50 | 10.76A | 30.151 | 23.09 | 6.14 | . | . | . | . | | . | . | . |
| 21.5 | 75 | . | 34.501 | . | 6.40 | . | . | . | . | | . | . | . |
| 21.5 | 100 | 10.39A | 31.406 | 24.13 | 6.36 | . | . | . | . | | . | . | . |
| 21.5 | 150 | 6.59A | 32.140 | 25.26 | 6.07 | . | . | . | . | | . | . | . |
| 21.5 | 200T | 5.14A | 32.998 | 26.11 | 5.08 | . | . | . | . | | . | . | . |
| 21.5 | 250T | 5.01A | 33.192 | 26.28 | 4.42 | . | . | . | . | | . | . | . |

STANDARD

| DEP | TEMP | SAL | SIG-T | OXY | SP VOL | DEL D |
|---|---|---|---|---|---|---|
| 0 | 10.03 | 27.836 | 21.41 | 6.61 | 639.79 | .000 |
| 10 | 10.21 | 28.533 | 21.92 | . | 590.74 | .062 |
| 20 | 10.34 | 29.154 | 22.39 | 6.29 | 546.70 | .118 |
| 30 | 10.34 | 29.327 | 22.52 | 6.53 | 533.98 | .172 |
| 50 | 10.76 | 30.151 | 23.09 | 6.14 | 479.84 | .274 |
| 75 | 10.58 | 34.501 | 26.50 | 6.40 | 155.70 | .353 |
| 100 | 10.39 | 31.406 | 24.13 | 6.36 | 381.69 | .420 |
| 150 | 6.59 | 32.140 | 25.26 | 6.07 | 273.37 | .584 |
| 200 | 5.14 | 32.998 | 26.11 | 5.08 | 192.76 | .701 |
| 250 | 5.01 | 33.192 | 26.28 | 4.42 | 177.31 | .793 |

AC CRUISE 272 CONSECUTIVE STATION NO. 1. RES2.5 7/ 3/79
0.7 HOURS GMT

LATITUDE = 60 1.2N LONGITUDE = 149 21.5W SONIC DEPTH = 288 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS
CLOUD AMOUNT --- (6) ---6/8
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED |
|---|---|---|
| WIND | 175 - 184 DEGR | 7 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 0 - 0 DEGR | M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES | -DRY = 5.5 DEGR C. | BAROMETRIC PR. = 997.5MB | |
| | -WET = 4.8 DEGR C. | TRANSPARENCY = M | |

OBSERVED

| TIME | DEP | TEMP | SAL | SIG-T | OXY | PO4 | NH3 | NO2 | NO3 | NO | SIO3 | PH | TALK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .0 | 0 | 3.47A | 31.439 | 25.04 | 7.37 | 0.85 | 08.4 | 0.02 | 08.2 | 731.8 | 16. | . | . |
| .0 | 10 | 3.45B | 31.577 | 25.16 | 7.33 | 0.85 | 08.0 | 0.05 | 09.0 | 735.4 | 17. | . | . |
| .0 | 20 | 3.38C | 31.619 | 25.20 | 7.04 | 0.91 | 07.2 | 0.04 | 09.2 | 711.3 | 17. | . | . |
| .0 | 30 | 3.37B | 31.625 | 25.20 | 6.90 | 0.79 | 06.4 | 0.03 | 09.2 | 698.8 | 17. | . | . |
| .0 | 50 | 3.41B | 31.670 | 25.23 | 7.58 | 0.82 | 08.0 | 0.02 | 08.5 | 753.2 | 16. | . | . |
| .0 | 75 | 3.40E | 31.670 | 25.23 | . | 0.82 | 06.5 | 0.02 | 09.2 | | 17. | . | . |
| .0 | 100 | 3.23A | 31.670 | 25.25 | 6.99 | 0.82 | 06.4 | 0.03 | 09.6 | 710.5 | 18. | . | . |
| .0 | 150 | 4.50A | 31.993 | 25.39 | 7.00 | 0.92 | 06.2 | 0.01 | 10.8 | 722.2 | 19. | . | . |
| .0 | 200 | 5.26A | 32.466 | 25.68 | 6.16 | 1.10 | 05.9 | 0.02 | 14.0 | 676.0 | 25. | . | . |
| .0 | 250T | 5.86A | 32.970 | 26.01 | 4.23 | 2.14 | 05.4 | 0.04 | 28.0 | 629.7 | 47. | . | . |
| .0 | 280T | 5.86B | 33.027 | 26.05 | 3.67 | 1.62 | 06.9 | 0.05 | 24.2 | 545.5 | 35. | . | . |

STANDARD

| DEP | TEMP | SAL | SIG-T | OXY | SP VOL | DEL D |
|---|---|---|---|---|---|---|
| 0 | 3.47 | 31.439 | 25.04 | 7.37 | 292.84 | .000 |
| 10 | 3.45 | 31.577 | 25.16 | 7.33 | 282.25 | .029 |
| 20 | 3.38 | 31.619 | 25.19 | 7.04 | 278.50 | .057 |
| 30 | 3.37 | 31.625 | 25.20 | 6.90 | 277.98 | .085 |
| 50 | 3.41 | 31.670 | 25.23 | 7.58 | 274.94 | .140 |
| 75 | 3.40 | 31.670 | 25.23 | 7.29 | 274.90 | .209 |
| 100 | 3.23 | 31.670 | 25.25 | 6.99 | 273.53 | .277 |
| 150 | 4.50 | 31.993 | 25.39 | 7.00 | 260.98 | .411 |
| 200 | 5.26 | 32.466 | 25.68 | 6.16 | 233.90 | .534 |
| 250 | 5.86 | 32.970 | 26.01 | 4.23 | 203.69 | .644 |

AC CRUISE 272 CONSECUTIVE STATION NO. 2, RES 4 7/ 3/79
21.4 HOURS GMT

LATITUDE = 59 54.7N LONGITUDE = 149 24.6W SONIC DEPTH = 262 M

1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- (2) ---CIRROSTRATUS ,
CLOUD AMOUNT --- (1) ---1/8 OR LESS ,
VISIBILITY --- (8) ---20-50 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 175 - 184 DEGR | 14 KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 175 - 184 DEGR | 0.3 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES | -DRY = 4.5 DEGR C. | BAROMETRIC PR. | =1009.0MB | |
| | -WET = 2.5 DEGR C. | TRANSPARENCY | = M | |

OBSERVED

| TIME | DEP | TEMP | SAL | SIG-T | OXY | PO4 | NH3 | NO2 | NO3 | NO | SIO3 | PH | TALK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .7 | 0 | 3.40D | 31.509 | 25.11 | 7.20 | 1.15 | 02.1 | 0.05 | 14.2 | 770.6 | 27. | . | . |
| .7 | 10 | 3.43A | 31.555 | 25.14 | 7.34 | 1.10 | 01.8 | 0.11 | 14.2 | 783.1 | 27. | . | . |
| .7 | 20 | 3.45B | 31.589 | 25.16 | 7.71 | . | . | . | . | | . | . | . |
| .7 | 30 | 1.75Q | 31.606 | 25.31 | 7.24 | 0.96 | . | 0.04 | 10.9 | 744.5 | 21. | . | . |
| .7 | 50 | 3.50D | 31.639 | 25.20 | 7.42 | 1.14 | . | 0.06 | 14.4 | 792.1 | 27. | . | . |
| .7 | 75 | 3.60R | 31.686 | 25.23 | 7.13 | 1.02 | . | 0.03 | 12.0 | 744.6 | 22. | . | . |
| .7 | 100 | 3.97A | 31.802 | 25.29 | 7.18 | 1.29 | 05.4 | 0.03 | 15.4 | 779.6 | 28. | . | . |
| .7 | 150 | 4.14B | 32.024 | 25.45 | 6.90 | 1.25 | 04.6 | 0.04 | 16.1 | 760.9 | 29. | . | . |
| .7 | 200 | 4.32A | 32.125 | 25.51 | 6.97 | 1.27 | 03.7 | 0.04 | 16.9 | 774.4 | 30. | . | . |
| .7 | 250T | 5.33A | 32.522 | 25.72 | 6.10 | 1.59 | 02.7 | 0.03 | . | | 37. | . | . |

STANDARD

| DEP | TEMP | SAL | SIG-T | OXY | SP VOL | DEL D |
|---|---|---|---|---|---|---|
| 0 | 3.40 | 31.509 | 25.11 | 7.20 | 286.97 | .000 |
| 10 | 3.43 | 31.555 | 25.14 | 7.34 | 283.75 | .029 |
| 20 | 3.45 | 31.589 | 25.16 | 7.71 | 281.35 | .057 |
| 30 | 1.75 | 31.606 | 25.31 | 7.24 | 267.67 | .084 |
| 50 | 3.50 | 31.639 | 25.20 | 7.42 | 278.03 | .139 |
| 75 | 3.60 | 31.686 | 25.23 | 7.13 | 275.40 | .208 |
| 100 | 3.97 | 31.802 | 25.29 | 7.18 | 270.03 | .276 |
| 150 | 4.14 | 32.024 | 25.45 | 6.90 | 255.14 | .407 |
| 200 | 4.32 | 32.125 | 25.51 | 6.97 | 249.60 | .534 |
| 250 | 5.33 | 32.522 | 25.72 | 6.10 | 230.98 | .654 |

AC CRUISE 275 CONSECUTIVE STATION NO. 1. RES2.5 18/ 4/79
16.9 HOURS GMT

LATITUDE = 60 1.2N LONGITUDE = 149 21.5W SONIC DEPTH = 287 M

1-DIGIT WEATHER CODE IS (X5) AND INDICATES DRIZZLE
CLOUD TYPE --- (5) ---NIMBOSTRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (7) ---10-20 KM

| | DIRECTION | SPEED |
|---|---|---|
| WIND | 175 - 184 DEGR | 15 KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 175 - 184 DEGR | 0.3 M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES -DRY = | 4.4 DEGR C. | BAROMETRIC PR. | =1013.2 MB |
| -WET = | DEGR C. | TRANSPARENCY = | M |

SCALE USED = 1

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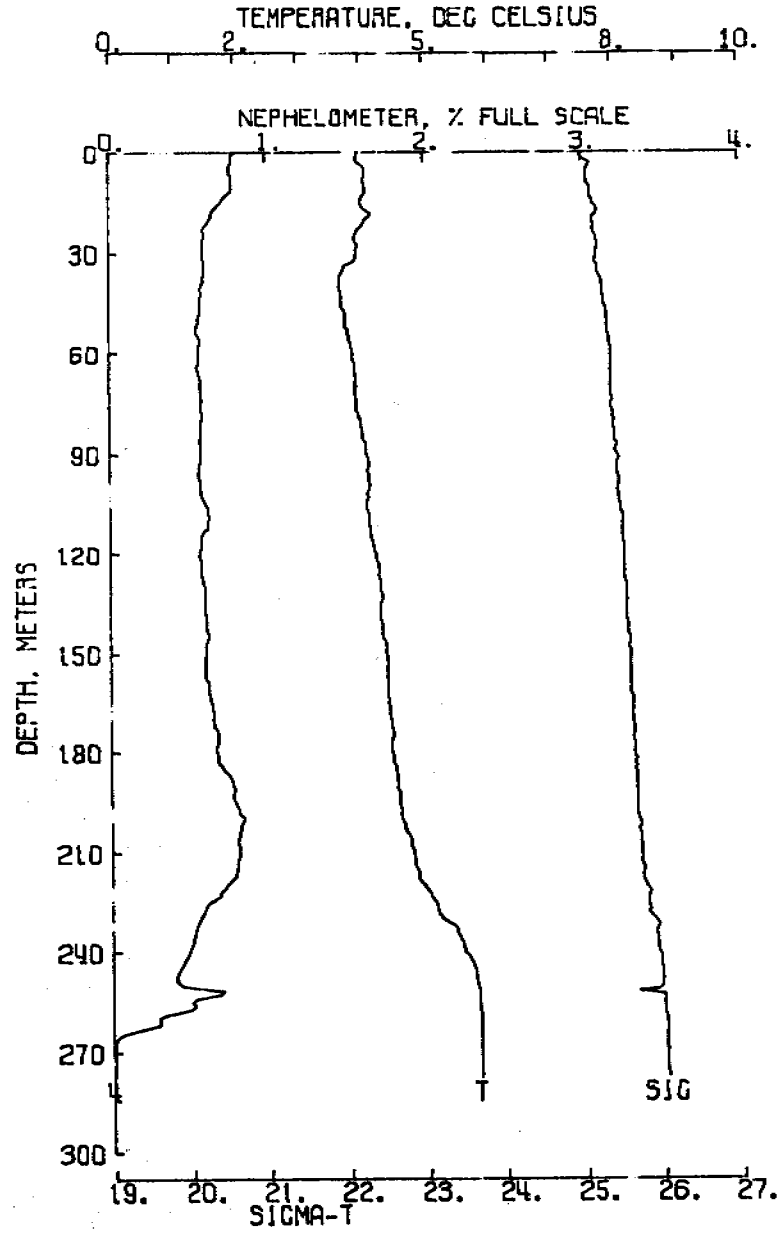
| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | NEPHELOMETER % FULL SCALE |
|---|---|---|---|---|
| 0. | 3.97 | 31.467 | 25.02 | 0.799 |
| 1.0 | 3.96 | 31.438 | 25.00 | 0.781 |
| 5.0 | 4.08 | 31.538 | 25.07 | 0.769 |
| 10.0 | 4.07 | 31.577 | 25.10 | 0.783 |
| 15.0 | 4.01 | 31.619 | 25.14 | 0.713 |
| 20.0 | 4.09 | 31.623 | 25.13 | 0.635 |
| 25.0 | 3.91 | 31.644 | 25.17 | 0.605 |
| 30.0 | 3.93 | 31.660 | 25.18 | 0.591 |
| 35.0 | 3.73 | 31.673 | 25.21 | 0.605 |
| 40.0 | 3.69 | 31.712 | 25.24 | 0.576 |
| 45.0 | 3.71 | 31.745 | 25.27 | 0.570 |
| 50.0 | 3.77 | 31.802 | 25.31 | 0.558 |
| 60.0 | 3.88 | 31.868 | 25.35 | 0.560 |
| 70.0 | 3.92 | 31.889 | 25.36 | 0.574 |
| 75.0 | 3.94 | 31.902 | 25.37 | 0.574 |
| 80.0 | 3.99 | 31.939 | 25.39 | 0.574 |
| 90.0 | 4.08 | 31.978 | 25.42 | 0.566 |
| 100.0 | 4.13 | 32.018 | 25.44 | 0.576 |
| 125.0 | 4.25 | 32.133 | 25.52 | 0.571 |
| 150.0 | 4.38 | 32.225 | 25.58 | 0.605 |
| 175.0 | 4.48 | 32.277 | 25.61 | 0.674 |
| 200.0 | 4.60 | 32.364 | 25.67 | 0.832 |
| 250.0 | 5.79 | 32.934 | 25.99 | 0.436 |




CRUISE 275 STATION 1

AC CRUISE 275 CONSECUTIVE STATION NO. 2. RES004 18/ 4/79
18.6 HOURS GMT

LATITUDE = 59 54.7N LONGITUDE = 149 24.6W SONIC DEPTH = 262 M

1-DIGIT WEATHER CODE IS (X4) AND INDICATES FOG, THICK DUST, OR HAZE
CLOUD TYPE --- (5) ---NIMBOSTRATUS ,
CLOUD AMOUNT --- (8) ---8/8 TOTAL ,
VISIBILITY --- (5) ---2-4 KM

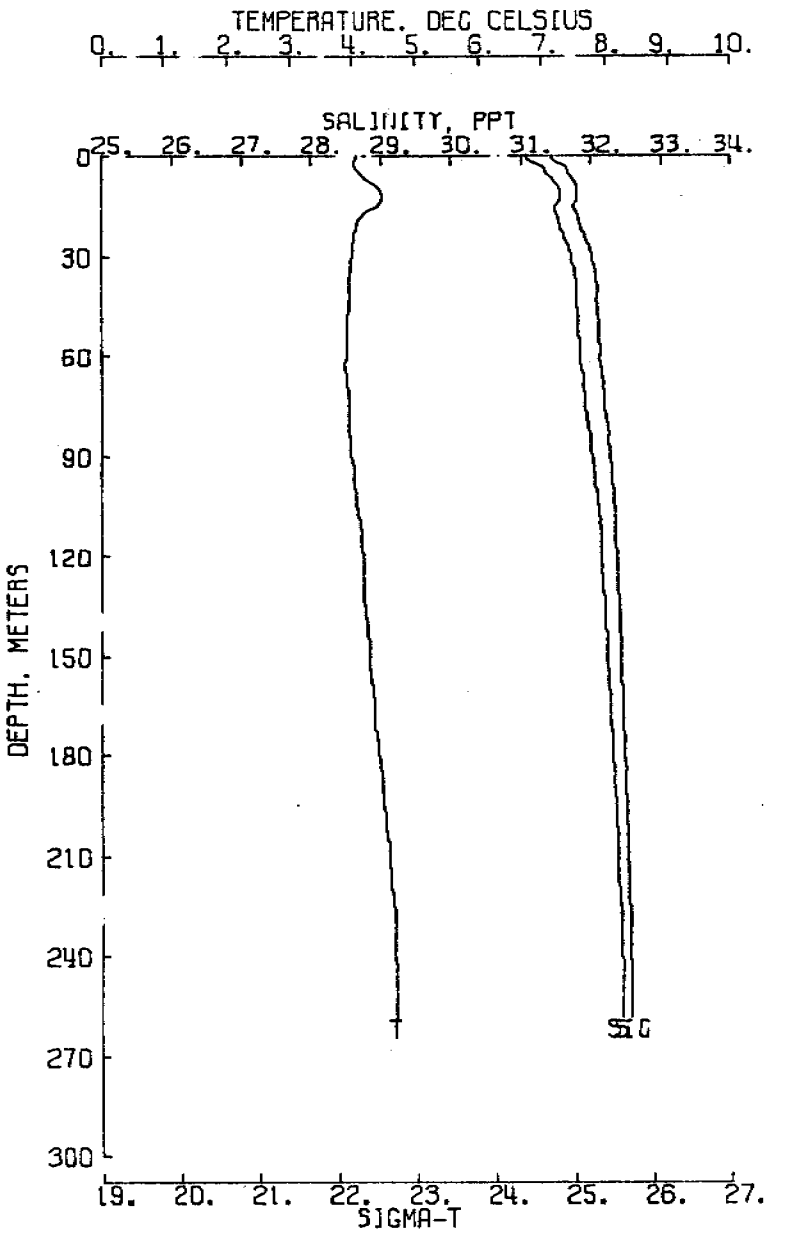
| | DIRECTION | SPEED |
|---|---|---|
| WIND | - DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 175 - 184 DEGR | 0.2 M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES -DRY = | 6.7 DEGR C. | BAROMETRIC PR. | =1012.0 MB |
| -WET = | DEGR C. | TRANSPARENCY = | M |

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 4.06 | 31.086 | 24.71 | 0. |
| 1.0 | 4.06 | 31.099 | 24.72 | 0.003 |
| 5.0 | 4.10 | 31.358 | 24.92 | 0.016 |
| 10.0 | 4.44 | 31.554 | 25.05 | 0.031 |
| 15.0 | 4.39 | 31.479 | 24.99 | 0.045 |
| 20.0 | 4.07 | 31.535 | 25.07 | 0.060 |
| 25.0 | 4.02 | 31.624 | 25.14 | 0.074 |
| 30.0 | 3.98 | 31.710 | 25.21 | 0.088 |
| 35.0 | 3.95 | 31.764 | 25.26 | 0.102 |
| 40.0 | 3.95 | 31.794 | 25.28 | 0.116 |
| 45.0 | 3.93 | 31.798 | 25.29 | 0.129 |
| 50.0 | 3.91 | 31.814 | 25.30 | 0.143 |
| 60.0 | 3.91 | 31.837 | 25.32 | 0.170 |
| 70.0 | 3.93 | 31.904 | 25.37 | 0.196 |
| 75.0 | 3.95 | 31.929 | 25.39 | 0.209 |
| 80.0 | 3.92 | 31.964 | 25.42 | 0.222 |
| 90.0 | 3.98 | 32.014 | 25.45 | 0.248 |
| 100.0 | 4.03 | 32.066 | 25.49 | 0.273 |
| 125.0 | 4.16 | 32.136 | 25.53 | 0.335 |
| 150.0 | 4.26 | 32.211 | 25.58 | 0.396 |
| 175.0 | 4.38 | 32.292 | 25.64 | 0.456 |
| 200.0 | 4.51 | 32.332 | 25.65 | 0.516 |
| 250.0 | 4.69 | 32.441 | 25.72 | 0.633 |






CRUISE 275 STATION 2

AC CRUISE 276 CONSECUTIVE STATION NO. 1. RES2.5 10/ 5/79
20.9 HOURS GMT

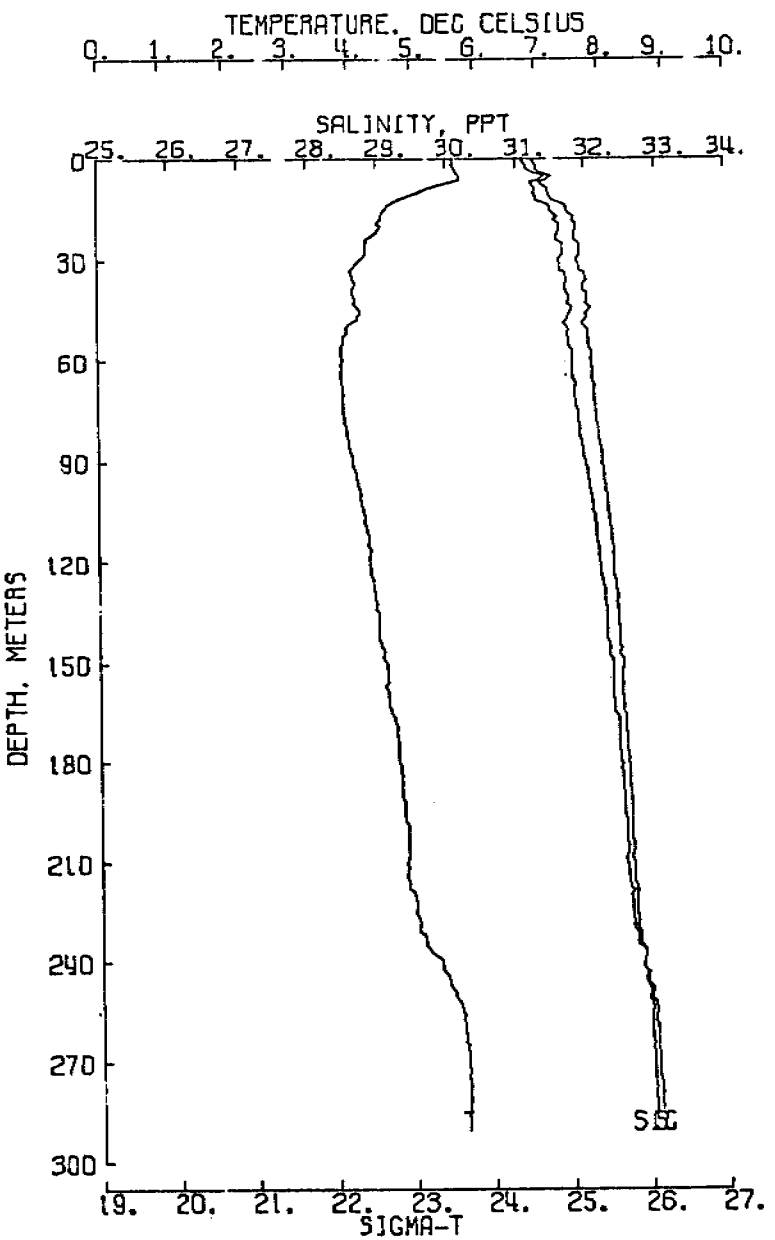
LATITUDE = 60 1.6N LONGITUDE = 149 21.5W SONIC DEPTH = 288 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS ,
CLOUD AMOUNT --- (8) ---8/8 TOTAL ,
VISIBILITY --- (6) ---4-10 KM

| | DIRECTION | SPEED | | |
|---|---|---|---|---|
| WIND | 345 - 354 DEGR | KNOTS | | |
| | DIRECTION | HEIGHT | PERIOD | |
| SEA | 345 - 354 DEGR | 0.2 M. | SECS | |
| SWELL | - DEGR | M. | SECS | |
| TEMPERATURES -DRY = | 12.2 DEGR C. | BAROMETRIC PR. = | 1003.2 MB | |
| -WET = | DEGR C. | TRANSPARENCY = | M | |

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.67 | 31.123 | 24.57 | 0. |
| 1.0 | 5.67 | 31.123 | 24.57 | 0.003 |
| 5.0 | 5.77 | 31.420 | 24.80 | 0.017 |
| 10.0 | 5.12 | 31.280 | 24.76 | 0.033 |
| 15.0 | 4.59 | 31.498 | 24.99 | 0.048 |
| 20.0 | 4.50 | 31.639 | 25.11 | 0.063 |
| 25.0 | 4.26 | 31.673 | 25.15 | 0.077 |
| 30.0 | 4.20 | 31.603 | 25.11 | 0.092 |
| 35.0 | 4.04 | 31.714 | 25.21 | 0.106 |
| 40.0 | 4.06 | 31.747 | 25.23 | 0.120 |
| 45.0 | 4.19 | 31.794 | 25.26 | 0.133 |
| 50.0 | 3.97 | 31.729 | 25.23 | 0.147 |
| 60.0 | 3.90 | 31.808 | 25.30 | 0.174 |
| 70.0 | 3.91 | 31.847 | 25.33 | 0.201 |
| 75.0 | 3.92 | 31.882 | 25.36 | 0.214 |
| 80.0 | 3.97 | 31.910 | 25.37 | 0.227 |
| 90.0 | 4.06 | 31.986 | 25.42 | 0.253 |
| 100.0 | 4.19 | 32.080 | 25.49 | 0.279 |
| 125.0 | 4.36 | 32.220 | 25.58 | 0.341 |
| 150.0 | 4.56 | 32.359 | 25.67 | 0.401 |
| 175.0 | 4.74 | 32.451 | 25.72 | 0.459 |
| 200.0 | 4.88 | 32.539 | 25.78 | 0.516 |
| 250.0 | 5.60 | 32.805 | 25.97 | 0.625 |






CRUISE 276 STATION 1

AC CRUISE 276 CONSECUTIVE STATION NO. 1. RES2.5 10/ 5/79
20.9 HOURS GMT

LATITUDE = 60 1.6N LONGITUDE = 149 21.5W SONIC DEPTH = 288 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (6) ---4-10 KM

| | DIRECTION | SPEED |
|---|---|---|
| WIND | 345 - 354 DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 345 - 354 DEGR | 0.7 M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES -DRY = | 12.2 DEGR C. | BAROMETRIC PR. = | 1003.2 MB |
| -WET = | DEGR C. | TRANSPARENCY = | M |

SCALE USED = 1

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | NEPHELOMETER % FULL SCALE |
|---|---|---|---|---|
| 0. | 5.67 | 31.123 | 24.57 | -0.013 |
| 1.0 | 5.67 | 31.123 | 24.57 | -0.013 |
| 5.0 | 5.77 | 31.420 | 24.80 | 0.000 |
| 10.0 | 5.12 | 31.280 | 24.76 | 0.036 |
| 15.0 | 4.50 | 31.498 | 24.99 | 0.056 |
| 20.0 | 4.50 | 31.639 | 25.11 | 0.120 |
| 25.0 | 4.28 | 31.673 | 25.15 | 0.203 |
| 30.0 | 4.20 | 31.603 | 25.11 | 0.429 |
| 35.0 | 4.04 | 31.714 | 25.21 | 0.507 |
| 40.0 | 4.06 | 31.747 | 25.23 | 0.507 |
| 45.0 | 4.19 | 31.794 | 25.26 | 0.497 |
| 50.0 | 3.97 | 31.729 | 25.23 | 0.489 |
| 60.0 | 3.90 | 31.809 | 25.30 | 0.512 |
| 70.0 | 3.91 | 31.847 | 25.33 | 0.525 |
| 75.0 | 3.92 | 31.882 | 25.36 | 0.539 |
| 80.0 | 3.97 | 31.910 | 25.37 | 0.544 |
| 90.0 | 4.06 | 31.986 | 25.42 | 0.529 |
| 100.0 | 4.19 | 32.080 | 25.49 | 0.539 |
| 125.0 | 4.36 | 32.220 | 25.58 | 0.558 |
| 150.0 | 4.56 | 32.359 | 25.67 | 0.582 |
| 175.0 | 4.74 | 32.451 | 25.72 | 0.651 |
| 200.0 | 4.88 | 32.539 | 25.78 | 0.647 |
| 250.0 | 5.60 | 32.885 | 25.97 | 0.679 |

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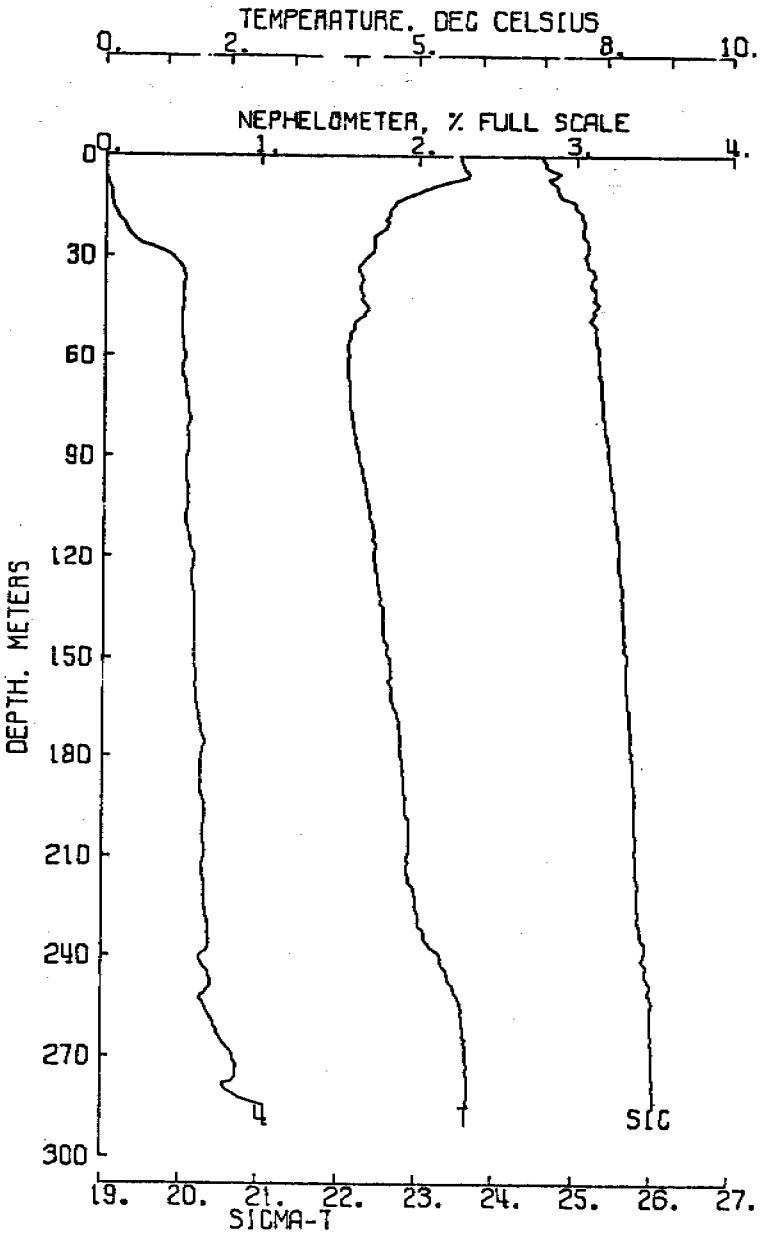



CRUISE 276 STATION 1

AC. CRUISE 276 CONSECUTIVE STATION NO. 1. RES2.5 10/ 5/79
20.9 HOURS GMT

LATITUDE = 60 1.6N LONGITUDE = 149 21.5W SONIC DEPTH = 288 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (6) ---4-10 KM

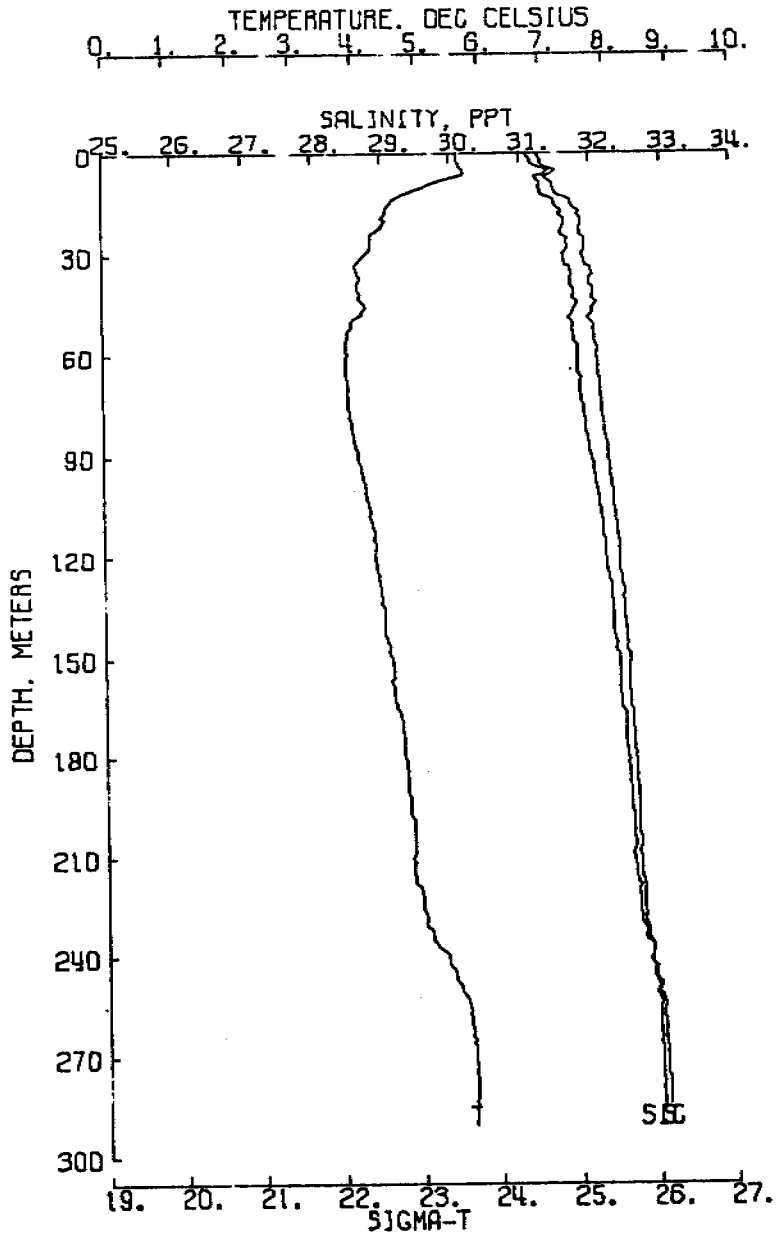
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 345 - 354 DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 345 - 354 DEGR | 0.2 M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 12.2 DEGR C. BAROMETRIC PR. =1003.2 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 5.67 | 31.123 | 24.57 | 0. |
| 1.0 | 5.67 | 31.123 | 24.57 | 0.003 |
| 5.0 | 5.77 | 31.420 | 24.80 | 0.017 |
| 10.0 | 5.12 | 31.280 | 24.76 | 0.033 |
| 15.0 | 4.59 | 31.498 | 24.99 | 0.048 |
| 20.0 | 4.50 | 31.639 | 25.11 | 0.063 |
| 25.0 | 4.28 | 31.673 | 25.15 | 0.077 |
| 30.0 | 4.20 | 31.603 | 25.11 | 0.092 |
| 35.0 | 4.04 | 31.714 | 25.21 | 0.106 |
| 40.0 | 4.06 | 31.747 | 25.23 | 0.120 |
| 45.0 | 4.19 | 31.794 | 25.26 | 0.133 |
| 50.0 | 3.97 | 31.729 | 25.23 | 0.147 |
| 60.0 | 3.90 | 31.808 | 25.30 | 0.174 |
| 70.0 | 3.91 | 31.847 | 25.33 | 0.201 |
| 75.0 | 3.92 | 31.882 | 25.36 | 0.214 |
| 80.0 | 3.97 | 31.910 | 25.37 | 0.227 |
| 90.0 | 4.06 | 31.986 | 25.42 | 0.253 |
| 100.0 | 4.19 | 32.080 | 25.49 | 0.279 |
| 125.0 | 4.36 | 32.220 | 25.58 | 0.341 |
| 150.0 | 4.56 | 32.359 | 25.67 | 0.401 |
| 175.0 | 4.74 | 32.451 | 25.72 | 0.459 |
| 200.0 | 4.88 | 32.539 | 25.78 | 0.516 |
| 250.0 | 5.60 | 32.885 | 25.97 | 0.625 |






CRUISE 276 STATION 1

AC CRUISE 276 CONSECUTIVE STATION NO. 1. RES2.5 10/ 5/79
20.9 HOURS GMT

LATITUDE = 60 1.6N LONGITUDE = 149 21.5W SONIC DEPTH = 288 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (6) ---4-10 KM

| | DIRECTION | SPEED |
|---|---|---|
| WIND | 345 - 354 DEGR | KNOTS |

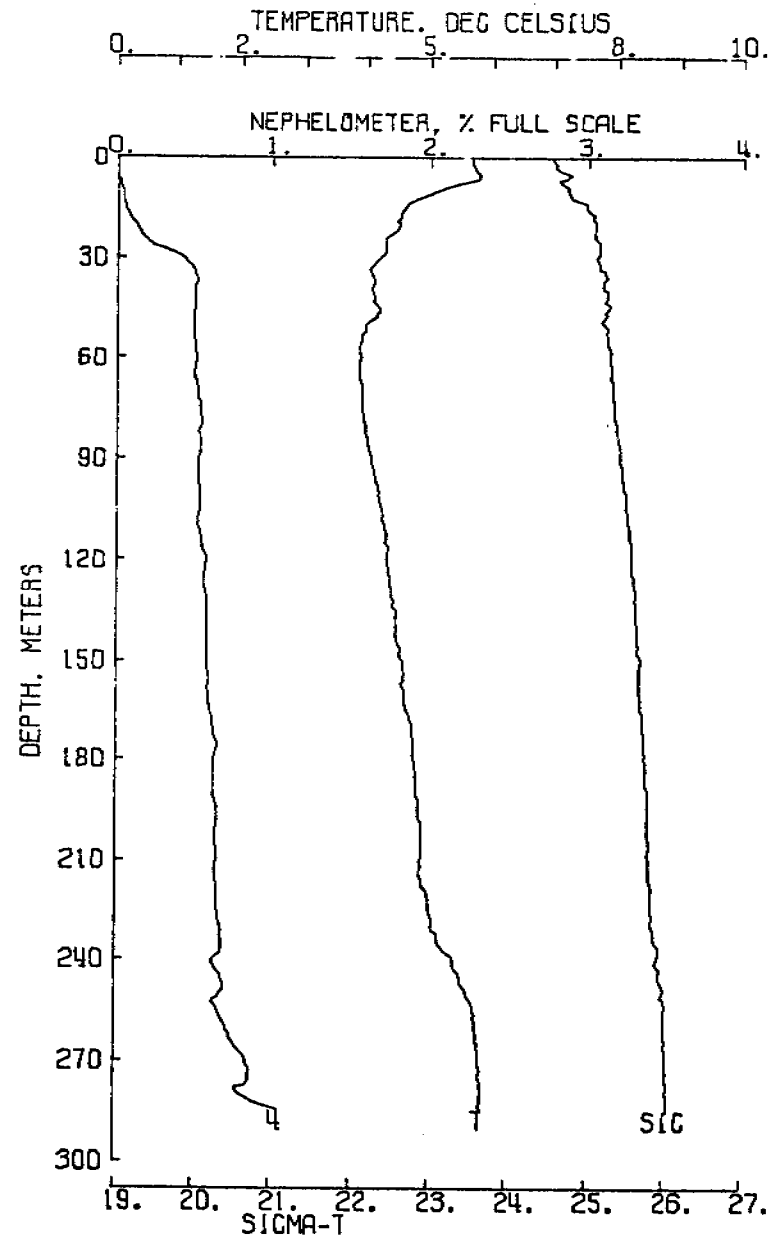
| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 345 - 354 DEGR | 0.7 M. | SECS |
| SWELL | - DEGR | M. | SECS |

| | | | |
|---|---|---|---|
| TEMPERATURES -DRY = | 12.2 DEGR C. | BAROMETRIC PR. = | 1003.2 MB |
| -WET = | DEGR C. | TRANSPARENCY = | M |

SCALE USED = 1

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | NEPHELOMETER % FULL SCALE |
|---|---|---|---|---|
| 0. | 5.67 | 31.123 | 24.57 | -0.013 |
| 1.0 | 5.67 | 31.123 | 24.57 | -0.013 |
| 5.0 | 5.77 | 31.420 | 24.80 | 0.000 |
| 10.0 | 5.12 | 31.280 | 24.76 | 0.036 |
| 15.0 | 4.50 | 31.498 | 24.99 | 0.056 |
| 20.0 | 4.50 | 31.639 | 25.11 | 0.120 |
| 25.0 | 4.28 | 31.673 | 25.15 | 0.203 |
| 30.0 | 4.20 | 31.603 | 25.11 | 0.429 |
| 35.0 | 4.04 | 31.714 | 25.21 | 0.507 |
| 40.0 | 4.06 | 31.747 | 25.23 | 0.507 |
| 45.0 | 4.19 | 31.794 | 25.26 | 0.497 |
| 50.0 | 3.97 | 31.729 | 25.23 | 0.489 |
| 60.0 | 3.90 | 31.808 | 25.30 | 0.512 |
| 70.0 | 3.91 | 31.847 | 25.33 | 0.525 |
| 75.0 | 3.92 | 31.882 | 25.36 | 0.539 |
| 80.0 | 3.97 | 31.910 | 25.37 | 0.544 |
| 90.0 | 4.06 | 31.986 | 25.42 | 0.529 |
| 100.0 | 4.10 | 32.080 | 25.49 | 0.539 |
| 125.0 | 4.36 | 32.220 | 25.58 | 0.558 |
| 150.0 | 4.54 | 32.359 | 25.67 | 0.582 |
| 175.0 | 4.74 | 32.451 | 25.72 | 0.651 |
| 200.0 | 4.88 | 32.539 | 25.78 | 0.647 |
| 250.0 | 5.60 | 32.805 | 25.97 | 0.679 |






CRUISE 276 STATION 1

AC CRUISE 276 CONSECUTIVE STATION NO. 2. RES2.5 10/ 5/79
21.0 HOURS GMT

LATITUDE = 60 1.6N LONGITUDE = 149 21.5W SONIC DEPTH = 289 M

1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (6) ---4-10 KM

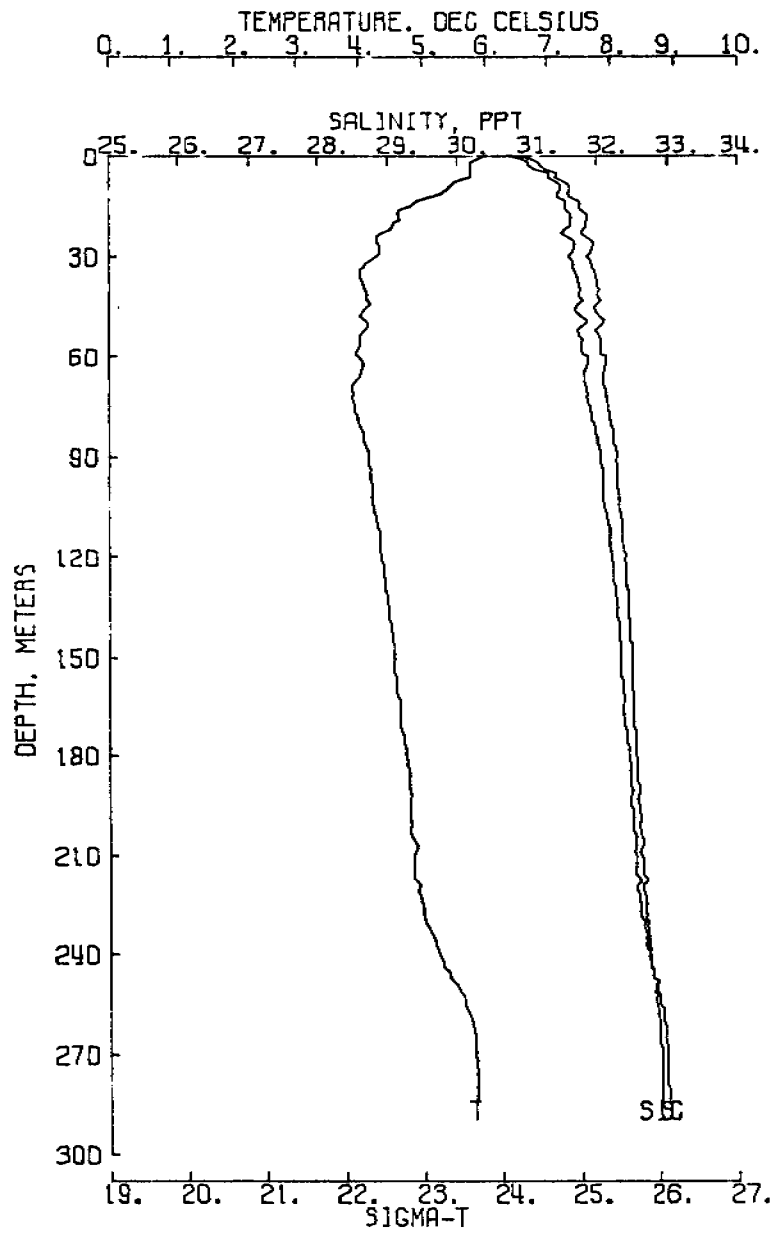
| | DIRECTION | SPEED |
|---|---|---|
| WIND | 345 - 354 DEGR | KNOTS |

| | DIRECTION | HEIGHT | PERIOD |
|---|---|---|---|
| SEA | 345 - 354 DEGR | 0.2 M. | SECS |
| SWELL | - DEGR | M. | SECS |

TEMPERATURES -DRY = 12.2 DEGR C. BAROMETRIC PR. =1003.2 MB
-WET = DEGR C. TRANSPARENCY = M

| DEPTH METERS | TEMPERATURE DEG C | SALINITY PPT | SIGMA-T | DELTA-D DYN M |
|---|---|---|---|---|
| 0. | 6.03 | 30.758 | 24.24 | 0. |
| 1.0 | 5.86 | 30.930 | 24.40 | 0.004 |
| 5.0 | 5.76 | 31.326 | 24.72 | 0.017 |
| 10.0 | 5.37 | 31.469 | 24.88 | 0.033 |
| 15.0 | 4.80 | 31.525 | 24.99 | 0.048 |
| 20.0 | 4.55 | 31.575 | 25.05 | 0.063 |
| 25.0 | 4.26 | 31.653 | 25.14 | 0.078 |
| 30.0 | 4.27 | 31.573 | 25.08 | 0.092 |
| 35.0 | 3.99 | 31.676 | 25.19 | 0.106 |
| 40.0 | 4.09 | 31.760 | 25.24 | 0.120 |
| 45.0 | 4.11 | 31.673 | 25.17 | 0.134 |
| 50.0 | 4.14 | 31.832 | 25.30 | 0.147 |
| 60.0 | 3.97 | 31.868 | 25.34 | 0.175 |
| 70.0 | 3.80 | 31.841 | 25.33 | 0.202 |
| 75.0 | 3.91 | 31.884 | 25.36 | 0.215 |
| 80.0 | 3.96 | 31.939 | 25.40 | 0.228 |
| 90.0 | 4.14 | 32.046 | 25.46 | 0.254 |
| 100.0 | 4.19 | 32.074 | 25.48 | 0.279 |
| 125.0 | 4.37 | 32.226 | 25.58 | 0.341 |
| 150.0 | 4.53 | 32.327 | 25.65 | 0.400 |
| 175.0 | 4.68 | 32.420 | 25.71 | 0.459 |
| 200.0 | 4.80 | 32.502 | 25.76 | 0.516 |
| 250.0 | 5.56 | 32.851 | 25.95 | 0.626 |






CRUISE 276 STATION 2

Appendix III

# Sediment-seawater exchanges of nutrients and transition metals in an Alaskan fjord.

Preprint of paper presented
at NATO Fjord Workshop
Victoria, Canada. June 1979

# SEDIMENT-SEAWATER EXCHANGES OF NUTRIENTS AND TRANSITION METALS IN AN ALASKAN FJORD[1]

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Resurrection Bay (southcentral Alaska) is a single silled fjord-estuary having a basin depth of 290 m (at Station RES 2.5) and a sill at approximately 185 m. The inner basin waters are renewed annually during May-October, but during the oceanographic winter period the basin waters remain relatively isolated from a downwelling flushing of bottom waters that occurs in the outer fjord as a result of a coastal convergence. The seasonal hydrography and dissolved oxygen distributions within this basin have been described by Heggie *et al.* (1977).

Figures 1 and 2 show pore water profiles for $NO_3$-N, $NH_3$-N, $SiO_4$-Si, $PO_4$-P, titration alkalinity and solid phase and soluble concentrations of the transition metals Fe, Mn, and Cu within the surface sediments of the fjord basin (Station RES 2.5; May 1975). There is no evidence for significant advective transport in these sediments so that the profile inflexions indicate zones of chemical reaction and transport of species in the pore water is predominantly *via* ionic diffusion. Table I gives species concentrations at the base of the water column and for interstitial water extracted from approximately the upper 5.5 cm of the sediment. The computed fluxes across the sediment-seawater interface are for ionic diffusion coefficients ($D_a$) assuming that the bottom water concentrations listed approximate those at the interface. In view of the large concentration differences involved this assumption is not believed to be a major source of error.

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[1]Institute of Marine Science, Contribution No. 374.

Maximum nitrate (plus nitrite) concentrations over this period within the oxygenated sediment layer were in excess of 90 μ mole $\ell^{-1}$ (Fig. 1). In the absence of regeneration, surface porewater concentrations should approximate those measured in bottom waters following renewal periods (∿ 30 μ mole $\ell^{-1}$). Nitrate produced by aerobic decomposition of biogenic material (C:N::106:15) can raise surface sediment porewaters only up to approximately 50 μ mole $NO_3$-N $\ell^{-1}$. Since the measured nitrate concentration of the surface interstitial water cannot be accounted for by standard regeneration stoichiometry it is suggested that the "excess" nitrate is due to nitrification at the boundary. Added evidence for such an ammonia oxidation hypothesis is supplied by the indicated gradients and computed benthic flux of this species. The ammonia concentration difference across the benthic boundary is in excess of two orders of magnitude (Table I; Fig. 1) and during 1973-75 ammonia concentrations at the bottom of the fjord basin at no time exceeded 1 μ mole $\ell^{-1}$ (although values > 2 μ mole $\ell^{-1}$ were found 25 m above the boundary in January and April 1975; Heggie *et al.*, 1977). The computed benthic flux of 17.7 μ mole $cm^{-2}$ $yr^{-1}$ is capable of supporting a minimum gradient in ammonia of $1.6 \times 10^{-7}$ μ mole $cm^{-4}$ (from a mean turbulent diffusion coefficient of 3.5 $cm^2$ $sec^{-1}$ computed for sill height). This would be equivalent to a concentration difference between the sediment interface and the top of the basin at sill height (approximately 100 m) of 1.6 μ mole $\ell^{-1}$; this latter has not been observed. Interstitial water ammonia increases linearly with depth to around 50 cm (Fig. 1). Diffusive transport along this gradient was computed at not less than 2.7 μ mole $cm^{-2}$ $yr^{-1}$; a flux which, at steady state, would be insufficient to maintain the estimated benthic boundary flux (17.7 μ mole $cm^{-2}$ $yr^{-1}$) discussed above. It is concluded that these several observations require additional production of ammonia at the interface, part of which is oxidized to nitrate.

Dissolved oxygen concentrations in basin waters during 1973-75 decreased from around 180 μ mole $\ell^{-1}$ after replacement (October) to less than 50 μ mole $\ell^{-1}$ by the end of the winter (May). Mean annual consumption rates for the inner basin have been estimated at 165 μ mole $\ell^{-1}$ $yr^{-1}$, with consumption rates some 5 m above the sediment at approximately 250 μ mole $\ell^{-1}$ $yr^{-1}$. Assuming that interfacial oxygen concentrations approximate those measured at the base of the water column, the minimum (molecular) diffusive flux of oxygen into the sediment is calculated to vary seasonally between 22 and 5 μ mole $cm^{-2}$ $yr^{-1}$. A mass balance for $NO_3$-N and $NH_3$-N estimates that 50 percent of the oxygen consumed in the bottom water (5 m above the sediments) during the winter of 1974-75 may be due to ammonia oxidation. Annual net productivity over this period in Resurrection Bay has been estimated at 19 mole C $m^{-2}$ $yr^{-1}$ (Heggie *et al.*, 1977) some 30 percent of which (∿ 6 mole C $m^{-2}$ $yr^{-1}$) may be accounted for using conventional organic matter oxidation stoichiometry by oxidation in deep and bottom waters, with less than an additional 1 percent oxidized in the surface oxic sediments.

Maximum pore water concentrations of manganese (305 μ mole $kg^{-1}$) were found in the top 5.5 cm of sediments, decreasing to 50 μ mole $kg^{-1}$ at 14-22 cm depth, and thereafter remain relatively constant to the maximum depth sampled (130 cm; Fig. 2). Maximum solid phase concentrations (Fig. 2) occurred in the top 0.5 cm of sediment. These distributions are attributable to diagenetic reduction and mobilization below the redox boundary, with upward diffusion and reprecipitation in the oxic zone. Pore water contents of iron increase with depth to a maximum of around 390 μ mole $kg^{-1}$ over the 42-47 cm depth zone (Fig. 2). From this surface sediment gradient, an ionic diffusion flux of approximately 1.8 μ mole $cm^{-2}$ $yr^{-1}$ was computed, considerably larger than the estimated flux of 0.08 μ mole $cm^{-2}$ $yr^{-1}$ across the benthic boundary

(Table 1). It would appear that remobilized reduced iron is efficiently trapped in the surface sediments and that, unlike manganese in this environment, little escapes into the water column.

The depth distributions of the redox species $O_2$, $NO_3$-N, Mn and Fe are consistent with a model of organic matter degradation in the sediments by oxidants in order of free energies made available to the organism. These oxidants are consumed in the top 5.5 cm of this fjord basin. The depth distribution of copper in Resurrection Bay sediments is shown in Figure 2. Heggie and Burrell (1979) have presented a model which incorporates remobilization in the surface sediments with a flux into the water column and a removal reaction in sub-surface sediments.

A relative measure of the remobility of these transition metals is given by normalizing the computed sediment-seawater flux to the apparent equilibrium solid phase concentration of each metal as shown in Table II. The relative remobilities are Mn > Cu > Fe. Table III summarizes the computed interface fluxes together with approximate standing stocks in the overlying water. The sub-sill basin water of Resurrection Bay is renewed annually (Heggie *et al.*, 1977): approximately 60 percent of the fjord water volume. If the time required to double the concentration of a species in the water column *via* input across the benthic boundary were of the same order as the residence time of the water then this transport could be an important component of the estuarine geochemical balance: this appears to be the case only for manganese in this environment. It is inferred that, for the other species considered here, riverine influx and regeneration in the water column are quantitatively more important processes.

References:

Heggie, D. T. and D. C. Burrell. 1979. Depth distributions of copper in the water column and interstitial waters of an Alaskan fjord. *In* K. A. Fanning and F. T. Manhein (eds.), *The Dynamic Environment of the Ocean Floor*. D. C. Heath and Co., Lexington. In press.

Heggie, D. T., D. W. Boisseau and D. C. Burrell. 1977. Hydrography, nutrient chemistry and primary productivity of Resurrection Bay, Alaska 1972-75. IMS Report R77-2, Inst. Mar. Sci., Univ. of Alaska. 111 pp.

Li, Y. H. and S. Gregory. 1974. Diffusion of ions in sea-water and in deep-sea sediments. *Geochim. Cosmochim. Acta* 38:703-714.

Table I

Benthic boundary species concentrations and fluxes

| Species | C ($\mu$ mole $\ell^{-1}$) B.W. | I.W. | *$D_a \times 10^{-6}$ ($cm^2$ $sec^{-1}$) | F ($\mu$ mole $cm^{-2}$ $yr^{-1}$) |
|---|---|---|---|---|
| $NO_3$-N | 36.5 | 91.7 | 11.6 | 7.0 |
| $NH_3$-N | < 1.0 | 137.5 | 11.6 | 17.3 |
| $PO_4^{\equiv}$-P | 2.6 | 17.2 | 8.0 | 1.3 |
| $SiO_4$-Si | 54.8 | 295.5 | 3.0 | 7.9 |
| Mn | 0.06 | 304.9 | 3.8 | 12.6 |
| Fe | 0.01 | 1.7 | 4.2 | 0.08 |
| Cu | 0.03 | 0.16 | 4.2 | 0.006 |

B.W. = bottom water

I.W. = surface ($\sim$ 0 - 5 cm) interstitial water

* Diffusion coefficients from Li and Gregory (1974) interpolated to 5°C.

Table II

Sediment - seawater flux of Mn, Fe, Cu normalized to apparent equilibrium contents of solid phases

| Element | Flux (F) mg $cm^{-2}$ $yr^{-1}$ | Equil. solid phase conc. (C) mg $cm^{-2}$ | C/F yrs |
|---|---|---|---|
| Mn | 0.69 | 3.3 | 4.7 |
| Cu | $4 \times 10^{-4}$ | 0.2 | 500 |
| Fe | $4.5 \times 10^{-3}$ | 190 | 42,222 |

* Sediment density $2 \times 10^{-3}$ kg $cm^{-3}$; 5 cm sediment depth.

Table III

Benthic flux, standing crop estimates and doubling time. Resurrection Bay 1974-75

| Species | Annual Mean water column concs. $\mu$ mole $\ell^{-1}$ | Annual Mean Standing crop (C) $\mu$ mole $cm^{-2}$ | Flux (F) $\mu$ mole $cm^{-2}$ $yr^{-1}$ | Doubling time (C/F) yrs |
|---|---|---|---|---|
| $NO_3 + NH_3$ | 20. | 600 | 24. | 25 |
| $SiO_4^{\equiv}$ | 36.7 | 1100 | 7.9 | 139 |
| $PO_4^{\equiv}$ | 1.9 | 56 | 1.3 | 43 |
| Mn | 0.013 | 0.37 | 12.6 | 0.03 |
| Cu | 0.008 | 0.23 | 0.006 | 38 |

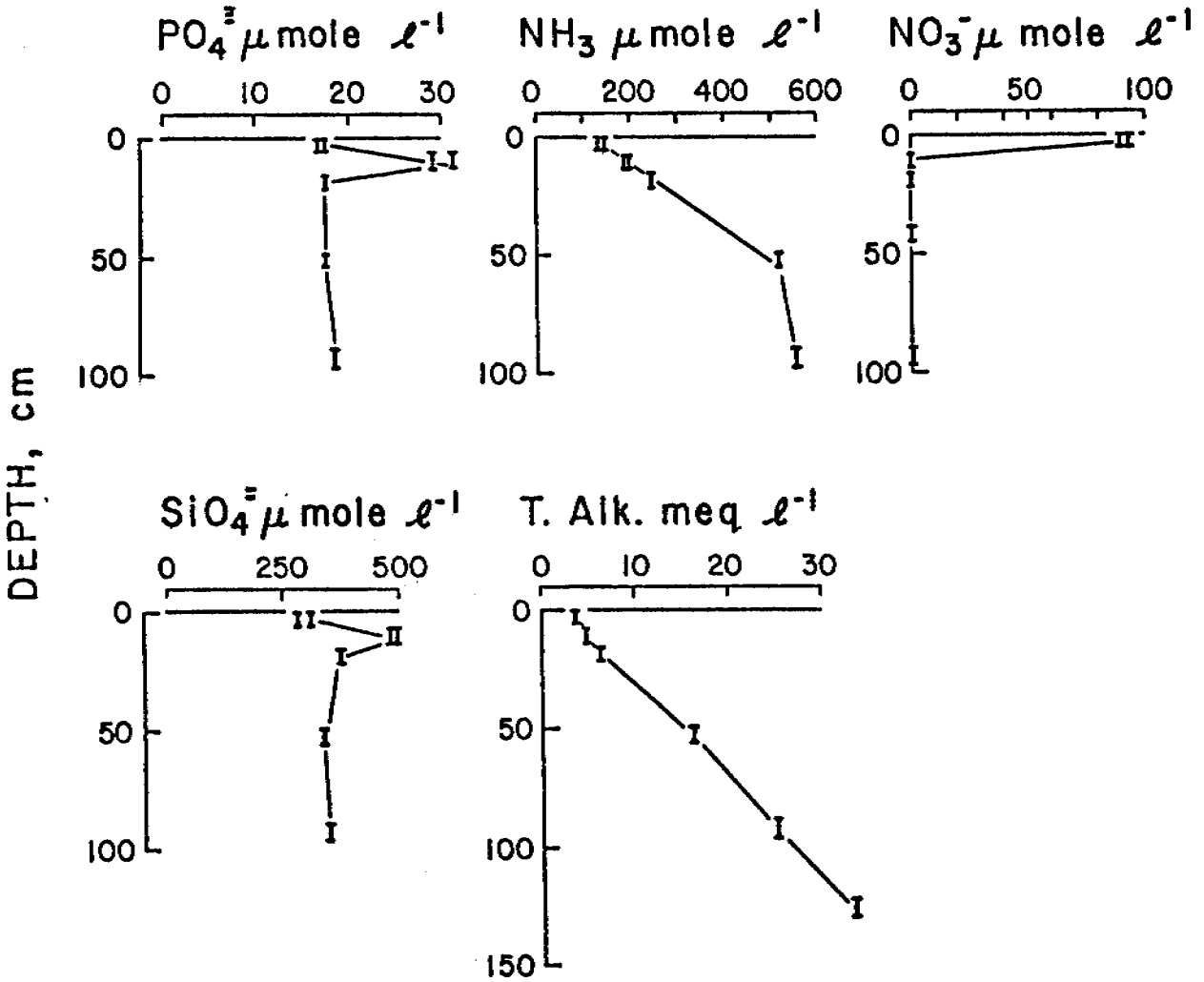


Figure 1. Resurrection Bay pore water nutrient data May 1975.

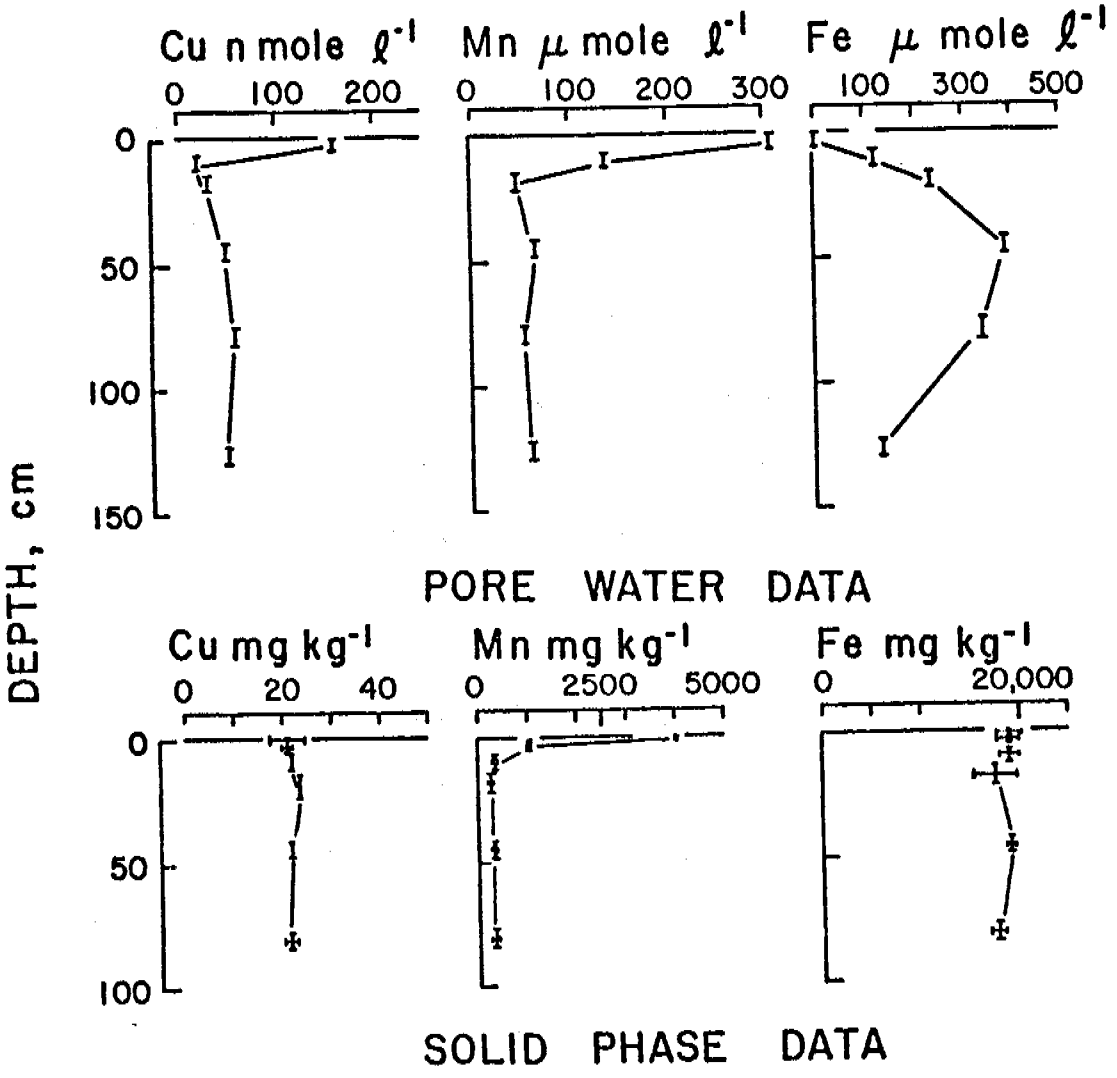


Figure 2. Resurrection Bay pore water and solid phase transition metal data, May 1975.

Appendix IV

# Reaction and flux of manganese within the oxic sediment and basin water of an Alaskan fjord

Preprint of paper presented
at NATO Fjord Workshop
Victoria, Canada. June 1979

# REACTION AND FLUX OF MANGANESE WITHIN THE OXIC SEDIMENT AND BASIN WATER OF AN ALASKAN FJORD[1]

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Manganese occurs in two oxidation states - one insoluble, one mobile - over the redox potential range found in near surface estuarine sediments. This geochemical character leads to partial remobilization of deposited manganese in the sediments below the redox boundary and a flux into the oxic marine environment where oxidation and reprecipitation occur. Such closed sub-cycle behavior is of considerable interest; not least because of potential control on the distribution of many other trace elements.

Using neutron activation analysis, we have determined the distribution of soluble and particulate manganese within the basin and near surface sediments of an Alaskan fjord (Table I, Figs. 1 and 2). Resurrection Bay has a basin (station depth 287 m) separated from the Gulf of Alaska shelf by a sill at approximately 185 m. This basin is flushed annually during the summer-fall but, because of seasonal circulation patterns developed in the Gulf, thereafter remains effectively isolated (Heggie *et al.*, 1977). The data of Table I was collected near the end of the oceanographic winter period (March). At this time, Heggie and Burrell (1979) have shown that the distribution (C) of a non-conservative species within the basin may be closely approximated by a vertical diffusion-reaction model:

$$-\frac{dC}{dt} = \frac{\delta}{\delta z}\left(K_z \frac{\delta C}{\delta z}\right) + J \qquad (1)$$

[1]Institute of Marine Science, Contribution No. 375

TABLE I

MANGANESE CONCENTRATIONS IN BASIN WATER COLUMN AND SEDIMENT
Resurrection Bay, Station RES 2.5, March

| | Water Column | | Sediment | | | |
|---|---|---|---|---|---|---|
| | | | Pore Water | | Sediment | |
| Depth[a] (m) | Dissolved $\mu M \times 10^{-2}$ | Particulate $\mu M \times 10^{-2}$ | Depth[b] (cm) | $\mu M$ | Depth[c] (cm) | mg/g |
| 3 | 5.04 | 10.60 | 2 | 65.9 | 0 | 2.92 |
| 8 | 2.62 | 9.37 | 0 | 288.0 | 7.5 | 0.92 |
| 18 | - | 5.66 | - 2 | 922.4 | 27.5 | 0.94 |
| 28 | 1.64 | 3.82 | - 4 | 194.0 | 52.5 | 0.86 |
| 38 | 1.57 | 3.39 | - 6 | 121.6 | 97.5 | 0.95 |
| 58 | 1.79 | 2.29 | - 8 | 107.0 | | |
| 78 | 1.20 | 1.78 | -10 | 82.6 | | |
| 98 | 1.04 | 1.62 | -12 | 96.3 | | |
| | | | -14 | 63.0 | | |

[a] = Positive upwards from interface

[b] = Positive upwards from reaction zone

[c] = Positive down from interface

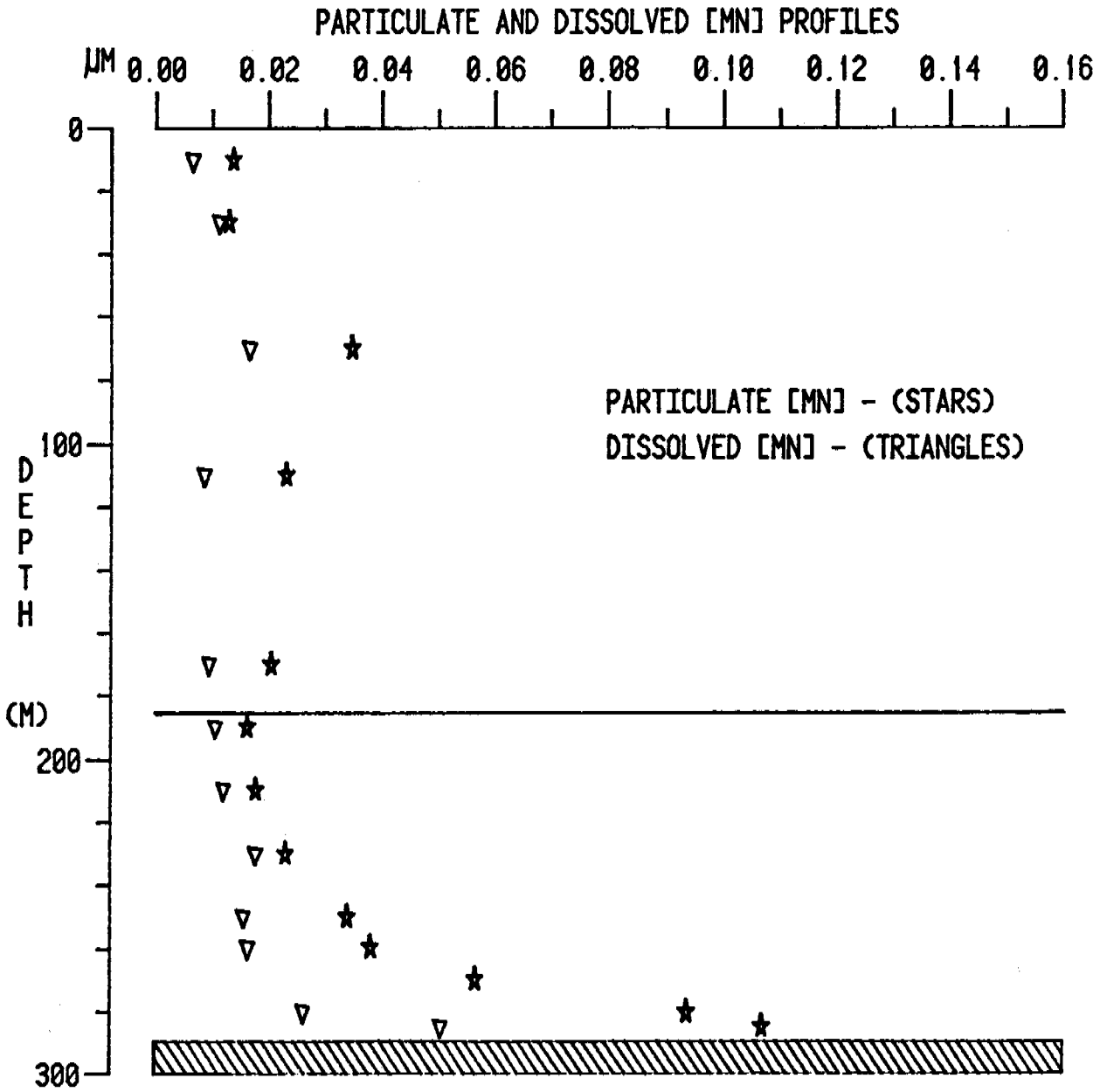


Figure 1. Data point profiles showing exponential increases with depth in both particulate and dissolved manganese in the water column (Resurrection Bay, March).

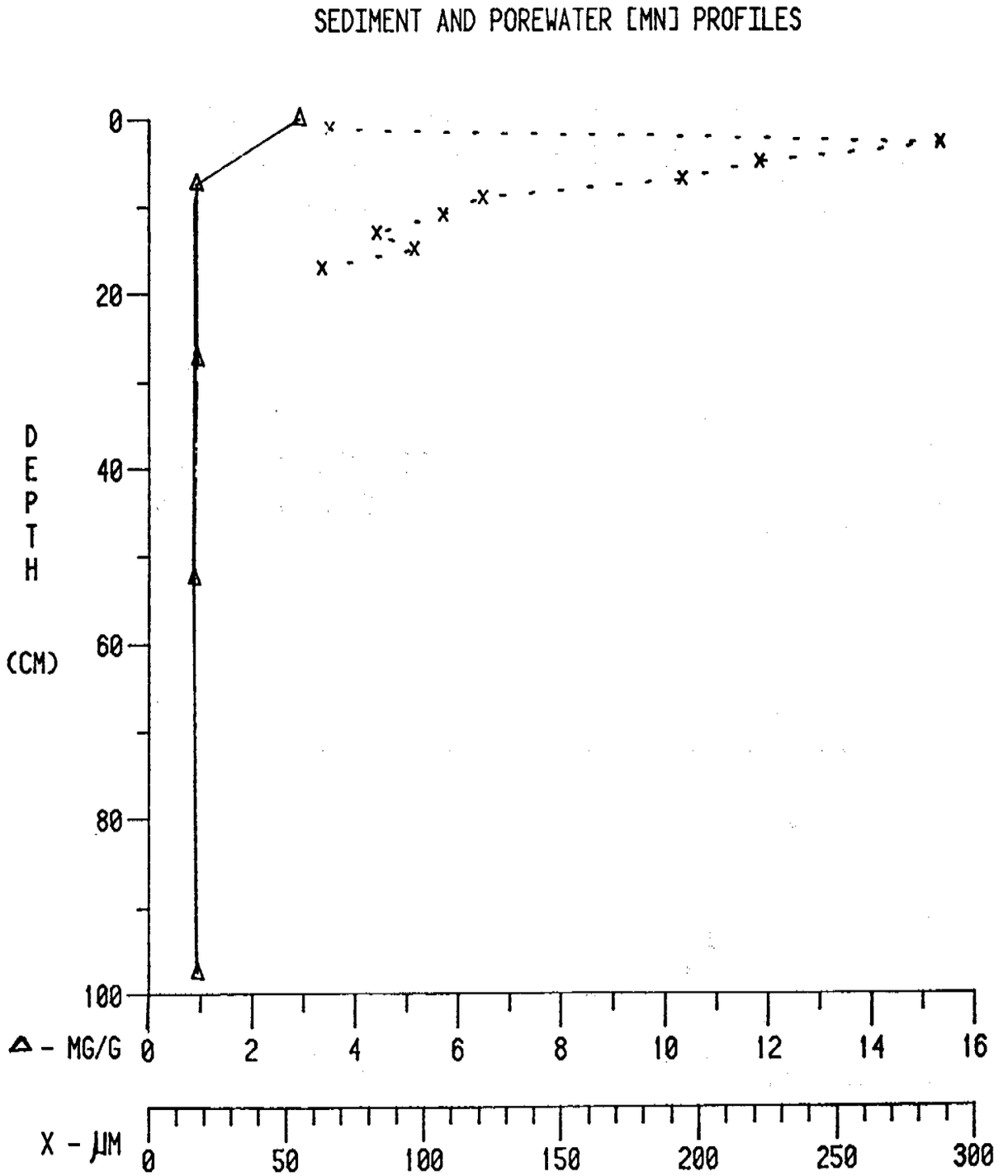


Figure 2. Data point profiles showing surface enrichment of solid phase manganese and negative gradient of interstitial water manganese in the sediment (Resurrection Bay, March).

From profiles of a number of chemical species in the sediment pore waters at this locality, it appears that advective mixing of the surface sediments is undetectable and that equation (1) may generally apply to this environment also.

In the case of dissolved manganese, the major reaction (J) term is oxidation. Following Hemm (1964) and Morgan (1967), we may define an apparent first order oxidation rate constant k:

$$-\frac{d[Mn(II)]}{dt} = k\,[Mn(II)] \qquad (2)$$

We assume that oxidized manganese sorbs onto indigenous particles in the basin column (*via* reactions that are rapid compared with the oxidation kinetics) and that subsequent transport is largely due to gravitational settling ($W_s$). Then the distribution of particulate manganese (P) shown in Figure 1 is given by:

$$\frac{dP}{dt} = -W_s \frac{\delta P}{\delta Z} + k_w C_w \qquad (3)$$

and the concentrations of dissolved water column and pore water Mn(II) ($C_w$ and $C_s$; Figs. 1 and 2) may be modeled by:

$$\frac{dC_w}{dt} = \frac{\delta}{\delta Z}\left(K_z \frac{\delta C_w}{\delta Z}\right) - k_w C_w \qquad (4)$$

$$\frac{dC_s}{dt} = \frac{\delta}{\delta Z}\left(\phi D \frac{\delta C_s}{\delta Z}\right) - k_s C_s \qquad (5)$$

The distribution of manganese at the time of year sampled is expected to approximate steady state. Assuming also constant turbulent ($K_z$) and effective ionic (D; constant porosity $\phi$) ionic diffusion coefficients to the interface. The solution to equations (3) - (5) for particulate, dissolved and pore-water manganese respectively are:

$$P-P_{\infty} = (k_w K_z)^{\frac{1}{2}} \cdot \left(\frac{C_o-C_{\infty}}{W_s}\right) \exp\left[-\left(\frac{k_w}{K_z}\right)^{\frac{1}{2}} \cdot Z\right] \quad (6)$$

$$C_w-C_{\infty} = (C_o-C_{\infty}) \exp\left[-\left(\frac{k_w}{K_z}\right)^{\frac{1}{2}} \cdot Z\right] \quad (7)$$

$$C_s-C_{s\infty} = (C_{so}-C_{s\infty}) \exp\left[-\left(\frac{k_s}{D}\right)^{\frac{1}{2}} \cdot Z\right] \quad (8)$$

The interfacial concentration ($C_o$) of dissolved Mn(II) may be determined *via* a reiterative best fit ($r = 0.895$) of equation (7) to the data of Table I, setting $C_{\infty}$ equal to the mean soluble concentration of manganese above sill height ($1.04 \times 10^{-2}$ μM) and using $K_z = 3.5$ $cm^2 sec^{-1}$ (Heggie *et al.*, 1977). We obtain $C_o = 5.71 \times 10^{-2}$ μM and an oxidation rate constant for the column ($k_w$) of $1.12 \times 10^{-6}$ $sec^{-1}$. Applying the same reiterative fit technique ($r = 0.995$), and substituting computed values for $C_o$ and $k_w$, allows solution of equation (6): $P_{\infty} = 1.60$ μM and $W_s = 1.03 \times 10^{-3}$ cm $sec^{-1}$. This latter corresponds to particulate manganese settling *via* particles of 20 μM mean diameter.

Similar treatment of the distribution of manganese in the oxic sediment zone using equation (8) is a considerably less satisfactory approach. Table I shows two relevant data points only, each of which is the mean of an approximately 2 cm sediment slice. Assumption of the steady state mode permits a second approach: $C_s$ must equal $C_o$ ($5.71 \times 10^{-3}$ μM) at the interface and the benthic flux of Mn(II) equals the rate of oxidation in the column. The latter relationships may be expressed as:

$$F_w = k_w \int C_w \, dZ \quad (9)$$

$$F_s = -D \frac{dCs}{dt} = (C_{so}-C_{s\infty})(k_s D)^{\frac{1}{2}} \cdot \exp\left[-\left(\frac{k_s}{D}\right)^{\frac{1}{2}} \cdot Z\right] \quad (10)$$

Values computed for the constants and relevant boundary conditions using these two approaches are summarized in Table II.

TABLE II

MODELING OF PORE WATER MANGANESE IN THE OXIC SEDIMENT ZONE
(Z positive up from reaction zone; see Table I)

| Equation (see text) | $C_{s\infty} \times 10^{-2}$ (μM) | $C_s$ (μM) Z = 0 | z = 2cm | z = 3cm | $k_s \times 10^{-6}$ ($sec^{-1}$) | $D \times 10^{-6}$ ($cm^2 sec^{-1}$) | $F \times 10^{-7}$ (μ mole $cm^{-2}$ $sec^{-1}$) |
|---|---|---|---|---|---|---|---|
| 8 | 1.04 | 288 | 65.9 | 31.5* | 0.82* | 1.5[a] | 2.84* |
| 8 | 1.04 | 288 | 65.9 | 31.5* | 1.1 * | 2.1[b] | 4.33* |
| 8 | 1.04 | 288 | 65.9 | 31.5* | 1.6 * | 3.1[b] | 5.71* |
| 8 | 1.04 | 288 | 65.9 | 31.5* | 2.1 * | 3.8[c] | 7.25* |
| 9&10 | 1.04 | 288 | 0.99* | 0.057 | 1.12* | 0.14* | 1.14 |



* Values computed from model

[a] Bender (1971)

[b] Elderfield *et al.* (unpublished MS)

[c] Li and Gregory (1974)

Application of the combined fjord basin sediment-water column model has yielded an apparent first order oxidation rate in both sediments and water in the order of $1 \times 10^{-6}$ $sec^{-1}$: this gives a mean lifetime of Mn(II) under these conditions of around 10.3 days. The mean settling velocity of the particulate manganese phase is approximately $1 \times 10^{-3}$ cm $sec^{-1}$. If the flux of remobilized manganese into the basin is taken as $1.14 \times 10^{-7}$ μ moles $cm^{-2}$ $sec^{-1}$, then the standing stock of "excess" manganese (ie., manganese transported from the sediment) may be computed at 0.27 μ moles $cm^{-2}$. Compared with a "natural" standing stock estimated at 0.76 μ moles $cm^{-2}$, the recycled fraction constitutes some 25% of the total water column manganese. These are lower limit estimates resulting from use of constant diffusion coefficients to the interface. Applying literature values of D (Table II) to the pore water data of Table I results in 50-90% of the benthic flux being oxidized in the zone between the interface and some 10 cm above. The major need now is for precise, very close interval sampling across the benthic boundary.

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