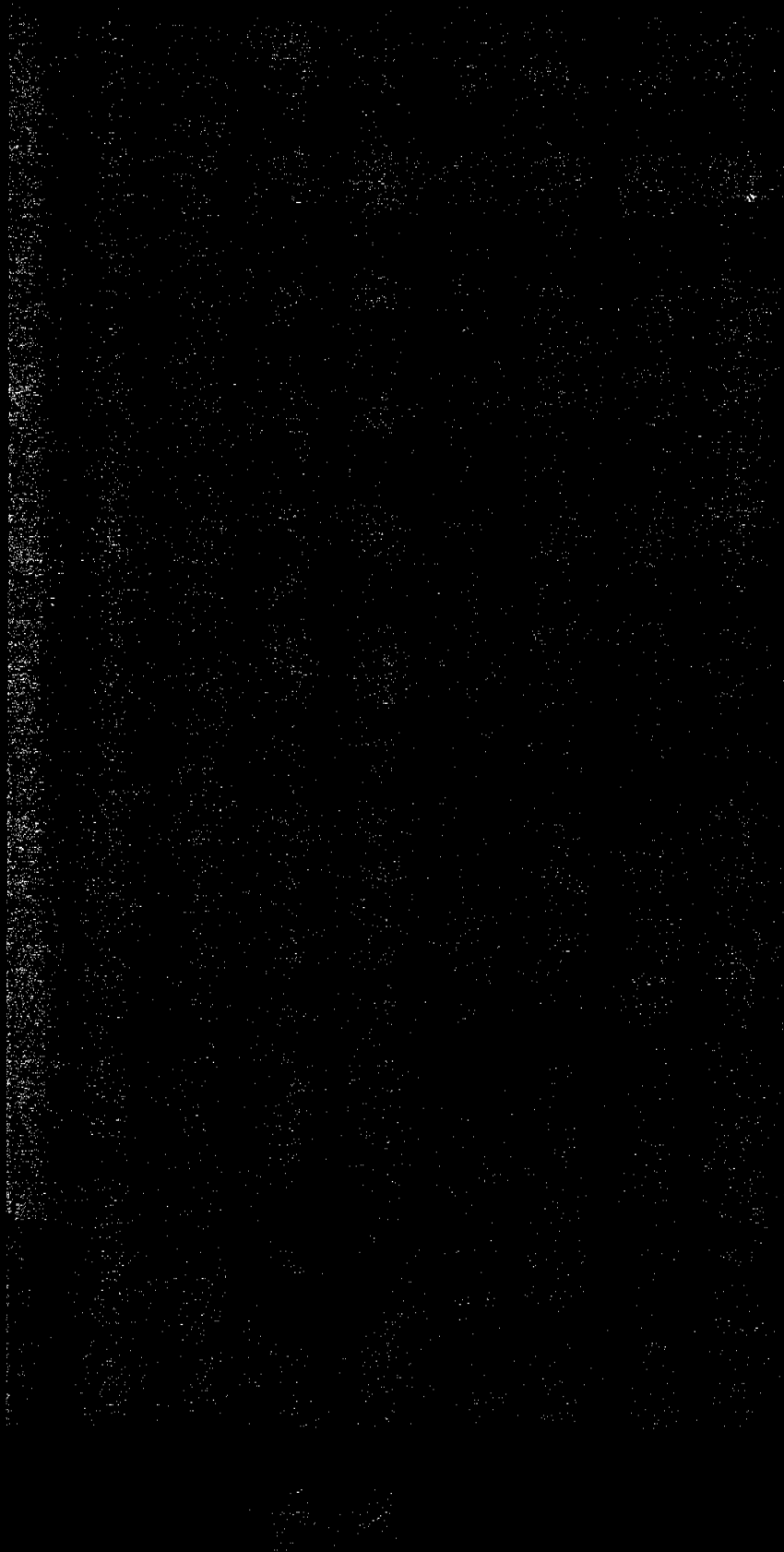

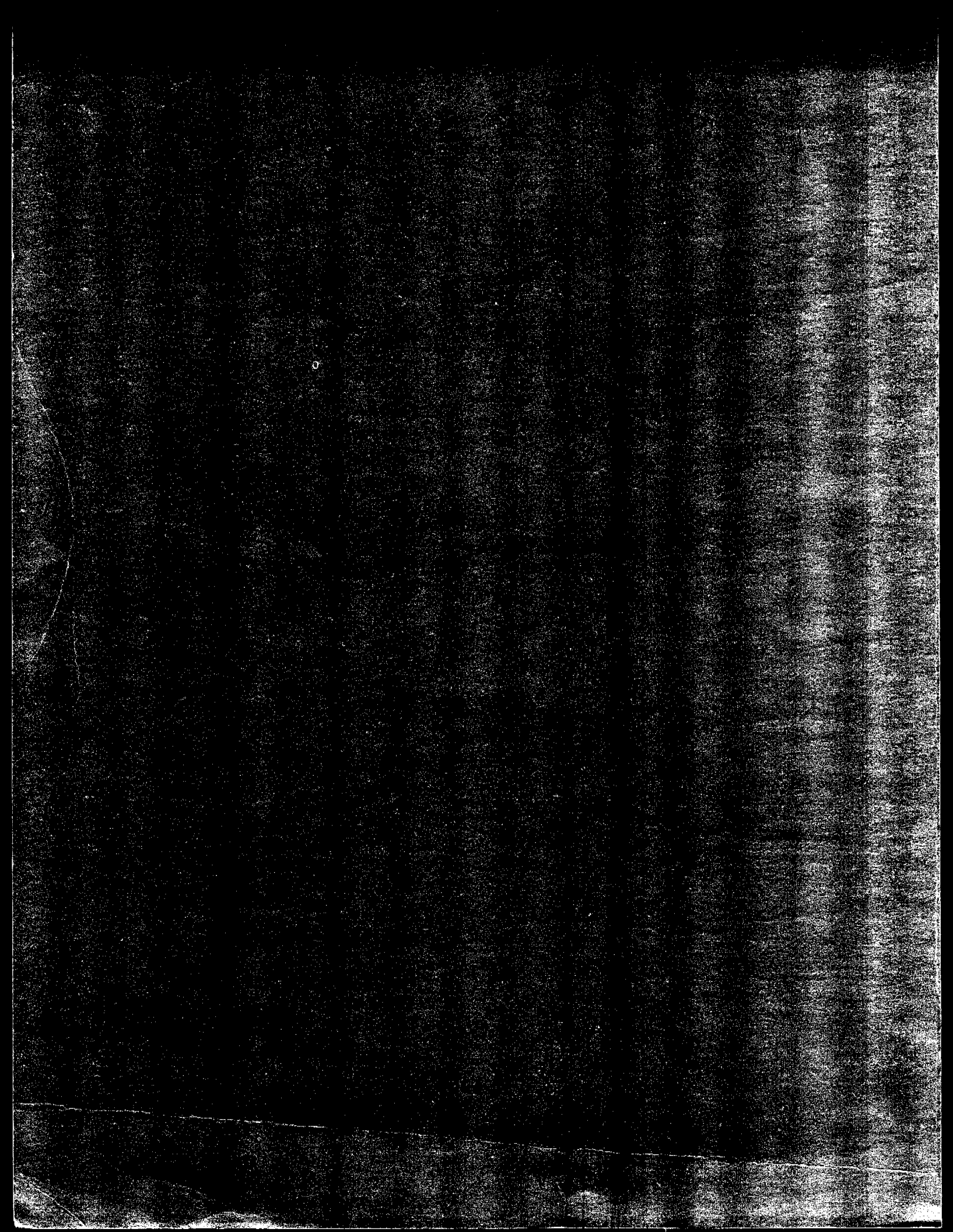

Environmental Assessment of the Alaskan Continental Shelf

Quarterly Reports of Principal Investigators for October — December 1978

VOLUME I

Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

March 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Research Laboratories

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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VOLUME I

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RECEPTORS (BIOTA)

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QUARTERLY REPORT

Contract: #03-5-022-56
Research Unit: #194
Task Order: #8
Reporting Period: 1 October-31 December 1978
Number of Pages: 10

MORBIDITY AND MORTALITY OF MARINE MAMMALS

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University of Alaska
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Institute of Arctic Biology
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Biological Technician
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

31 December 1978

I. TASK OBJECTIVES THIS QUARTER

A. To process materials collected during FY78.

B. To participate in the Vertebrate Consumer Workshop.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Trip Schedule

1. 2 - 10 November (Shults) Nome: Necropsy of collected specimens, via shore-based small boat.
2. 27 November-5 December (Fay) St. Lawrence Island: investigation of reports of unusual walrus mortality.

B. Laboratory and Other Activities

Parasitological investigations of FY78 collected specimens was continued, and one stranded cetacean from Cook Inlet was necropsied.

Fay and Shults participated in the Vertebrate Consumer Workshop, Fairbanks, 17-19 October.

C. Methods

Necropsy and parasitological investigations were by standard methods. Survey of the walrus mortality was by interview and direct observation.

III. RESULTS

The field trip to Nome, for the purpose of necropsy of specimens collected by Alaska Department of Fish and Game (ADF&G) personnel (R.U.#230,232), was unsuccessful, due to adverse weather and ice conditions. No specimens were collected.

An unscheduled field trip to St. Lawrence Island was taken in late November, in response to requests from the resident Eskimos and the ADF&G, to investigate reports of an unusually large number of dead walruses in that area. The results of that trip are presented in APPENDIX I. Briefly, more than 100 carcasses had been found, all apparently the result of natural mortality, including numerous cases of death from trauma and spontaneous abortion. Shortage of funds, as well as unfavorable weather and snow conditions prevented more detailed investigation of this die-off. Provided that funding can be obtained, a follow-up investigation could be scheduled for late spring 1979.

Necropsy of a young harbor porpoise, found dead on shore in upper Cook Inlet, disclosed severe parasitism of the middle and inner ears with associated lesions at the base of the brain.

Parasitological investigations of specimens collected in FY78 are not yet completed and cannot be reported at this time.

IV. PRELIMINARY INTERPRETATION OF RESULTS

Most of the mortality of walruses at St. Lawrence Island appears to have been normal, relative to the unusually large number of animals inhabiting that area this year. However, the large number (between 25 and 50) of spontaneous abortions does appear to be of additional significance, since it could be associated with toxicity of marine pollutants, such as hydrocarbons, organophosphates, or heavy metals.

Preliminary diagnosis of the cause of death of the porpoise from Cook Inlet is voluntary stranding, associated with severe neurological damage by the invading parasites.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

This project is not presently funded for any further work in the Bering Sea, whereas it seems that this area is likely to be the one in greatest need of attention, over the next few years. Two marine mammal populations in that area, the Pacific walrus and the California gray whale, appear to have reached their peak of abundance following a long period of re-growth. Until they have reestablished a balance with their environment, numerous instances of mass mortality from natural causes are likely to occur. Some means for monitoring these and evaluating them seems essential; at present, no such means are available.

APPENDIX I

REPORT ON NATURAL MORTALITY OF WALRUSES AT ST. LAWRENCE ISLAND, FALL 1978

By

Francis H. Fay

Institute of Marine Science
University of Alaska, Fairbanks
Fairbanks, AK 99701

INTRODUCTION

On 22 November 1978, I received a telephoned report *via* the Alaska Department of Fish and Game from the village of Savoonga, stating that an unusually large number of walruses had been dying from natural causes at St. Lawrence Island, including also a large number of aborted fetuses in one locality there, near northeast Cape. Walruses were said to be uncommonly abundant in the area during the previous two weeks and to be hauling out, exhausted, on several beaches where they were not known to haul out before. With the objective of trying to determine the causes of this mortality, I set out on 27 November for Savoonga, arriving there on 29 November (after 2 days delay by weather). In transit from Nome, I had seen 23 walruses in the open water (about 1/1.8 sq. mi) swimming toward St. Lawrence Island. Stormy weather for the next three days prevented my getting to the principal areas where the mortality had occurred. On 3 December, during a brief lull in the storms, I was taken there *via* snowmachine and back to Savoonga, a round trip of approximately 120 miles. I returned to Nome the evening of 4 December and to Fairbanks the following evening.

With the limitations imposed by foul weather, particularly heavy snowfalls, it was not feasible to obtain the kinds of materials needed for diagnosis of the causes of the mortality. However, a substantial amount of first-hand information concerning the attendant circumstances, the locations, and manner in which it occurred was obtained by interview. The following is a resumé of that information.

GENERAL CONDITIONS

The people of Savoonga spend a substantial amount of their time in summer and autumn at their camps on the northeastern and southeastern parts of St. Lawrence Island and on the Punuk Islands, where they go to fish, to hunt birds and seals, and to dig in several old village sites for "fossil" ivory. In their travels this year, they found walruses present in large numbers (at least hundreds) about the eastern end of St. Lawence and the Punuk Islands throughout the summer, a condition that had not been seen for at least the past 50 years. In October and early November, the numbers

increased drammatically to thousands — far more than had been seen at that time in the memory of anyone now living on the island (the eldest being about 80 years old). At the same time, large herds were coming ashore in three localities where they were not known ever to have hauled out before and in two where they have hauled out regularly in recent years. These are shown on the accompanying map. In addition, large groups of walruses had been seen in the water near each of those locations.

At the time when these unusual haulouts occurred, the weather was extremely stormy, with high winds and very rough seas (no ice on the area up to the time of my departure, 4 December). The animals, which had swum at least 200 miles (the nearest ice was in the Chukchi Sea), appeared to be exhausted, fell asleep soon after they hauled out, and slept so soundly that it was possible to walk right up to them and even touch them without waking them. Several observers stated repeatedly that the animals came ashore without fear of either people or their machines (3-wheeled Honda ATV's). Folklore has it that, on the Punuk Islands where they formerly hauled out annually in autumn, they sometimes climbed even onto the houses of the former inhabitants, breaking them down and crushing the people inside. In order to keep the walruses away from the houses, the people set fire to the beach grass in the area.

The number of animals hauling out in each of the five areas was not estimated or described adequately for estimation, with two exceptions. In the vicinity of Kialegak (Area #4), they covered the beach for a distance of about 2 miles and extended inland for 30 to 40 yards. Some 40,000 animals would be required to fill an area of those dimensions. At least, some tens of thousands must have been present in that group. At the old village site of Kialegak, which rises some 10 to 20 feet above the water and extends back at least 50 yards inland, the animals covered the entire site and onto the tundra behind it. They lay there long enough and in such numbers as to thaw the surface of the frozen ground and compress the massive quantity of bones (from walrus, seal, whale, and man) on its surface well into the muck; only the largest whale bones remained visible on the surface, after the animals had left.

On the northernmost island of the Punuk Islands (Area #5), there were "thousands" present in late October on the southwestern point. The area

occupied was approximately 200 x 1,000 ft, which would accommodate about 6 to 7 thousand animals (an aerial photo of this same area on 18 October 1975 by Dr. G. C. Ray showed approximately 6,000 animals). Many more (at least hundreds) were in the water around the island at that time, and the number that hauled out increased during the three-week period of observation. The animals were arriving and departing continually; some easily recognizable individuals slept in the same location for at least two days. At one point, the number of animals in the water to the southwest was so great that they resembled a peninsula of land extending in that direction to the horizon (i.e. in the direction of the Kialegak haulout area). By late November, about a week after the observers had left the island, the animals were seen (with binoculars from Apavawook Cape, about 4.5 miles away) to be covering the whole island (i.e. about six times the area covered previously, hence about 30-40,000 animals).

NATURAL MORTALITY

Dead animals were found in each of the major haulout areas, in some cases while the living animals were still there and, in others, after the living animals had left. Most of these were adult females and immature animals of either sex; a few were adult males. Except at Punuk, the number of dead individuals was not large (3 to 8 per haulout). However, at Area #3, there were also many aborted fetuses — at least 25, and perhaps as many as 50, some of which were still enclosed in the amniotic sac (regretably, by the time of my arrival there, the beach was drifted with 10 to 20 ft of new snow, and none of the fetuses were accessible).

At Punuk, several thousand animals were present continually during three weeks of observation, in which time at least 30 animals died. Twenty-five of these died in one location beneath a wave-cut terrace at the waters edge. This occurred at night, when the entire herd stampeded off the beach, into the water (for reasons not apparent to the observers camped nearby, who heard but did not see the stampede). When found the next morning, the 25 animals were all together; one or two of them were still alive but mortally injured. They apparently had been trampled and suffocated by the passage of others falling or jumping onto them from the terrace above, in

their rush for the sea. From time to time, single carcasses of animals that died *in situ* were found also on the haulout itself. The heat from the bodies of the living animals that lay alongside and on those carcasses caused them to bloat very quickly (within 12 hours), and autolysis of their skin together with the friction of animals crawling over them resulted in rapid loss of the epidermal layer and hair. Some of these were believed to have been killed by adult bulls, which were in some cases extremely belligerent, striking fiercely with their tusks at other bulls and even at some of the females and immature animals. On at least one occasion, an adult bull rushed through the resting herd for a distance of at least 100 yards to engage an arriving bull in a fight. They fought long and with extreme vigor, one dealing what appeared to be mortal wounds to the other. One old bull that had lain asleep in the same place for at least two days was found dead in the same place on the third day.

As far as anyone could determine, none of the dead had been killed by gunshot. However, the actual causes (other than, perhaps, a few cases due to aggression by the belligerent bulls and the 25 killed and maimed in the stampede) were not determined. At least two carcasses in areas other than Punuk were partly dissected and found to have broken ribs and hemorrhaged blubber, indicative of severe trauma, possibly from attack by killer whales, which are known to strike swimming walruses by ramming them from beneath. Conceivably, these individuals had been damaged at sea and were able to crawl ashore before they died. Perhaps, some of them had simply washed ashore on the storm tides, after they died. Certainly, many did wash ashore in other areas, away from the haulouts; I saw at least 7 in one $\frac{1}{4}$-mile long section of beach near Ivikhtok Camp. Most of the mortality on the haulouts was attributed to crushing or suffocating by other walruses. This seems to me probable in the case of the smaller, younger animals, which might easily be trampled underfoot, and in the case of the 25 below the wavecut terrace at Punuk.

The cause of the spontaneous abortions remains unknown. Since less than half of the gestation had been completed (implantation is in June, birth the following May), it is improbable that abortion was caused by diseases, such as leptospirosis or San Miguel Sea Lion Virus. Those would be more probable causes in the last half of the gestation (i.e. more likely

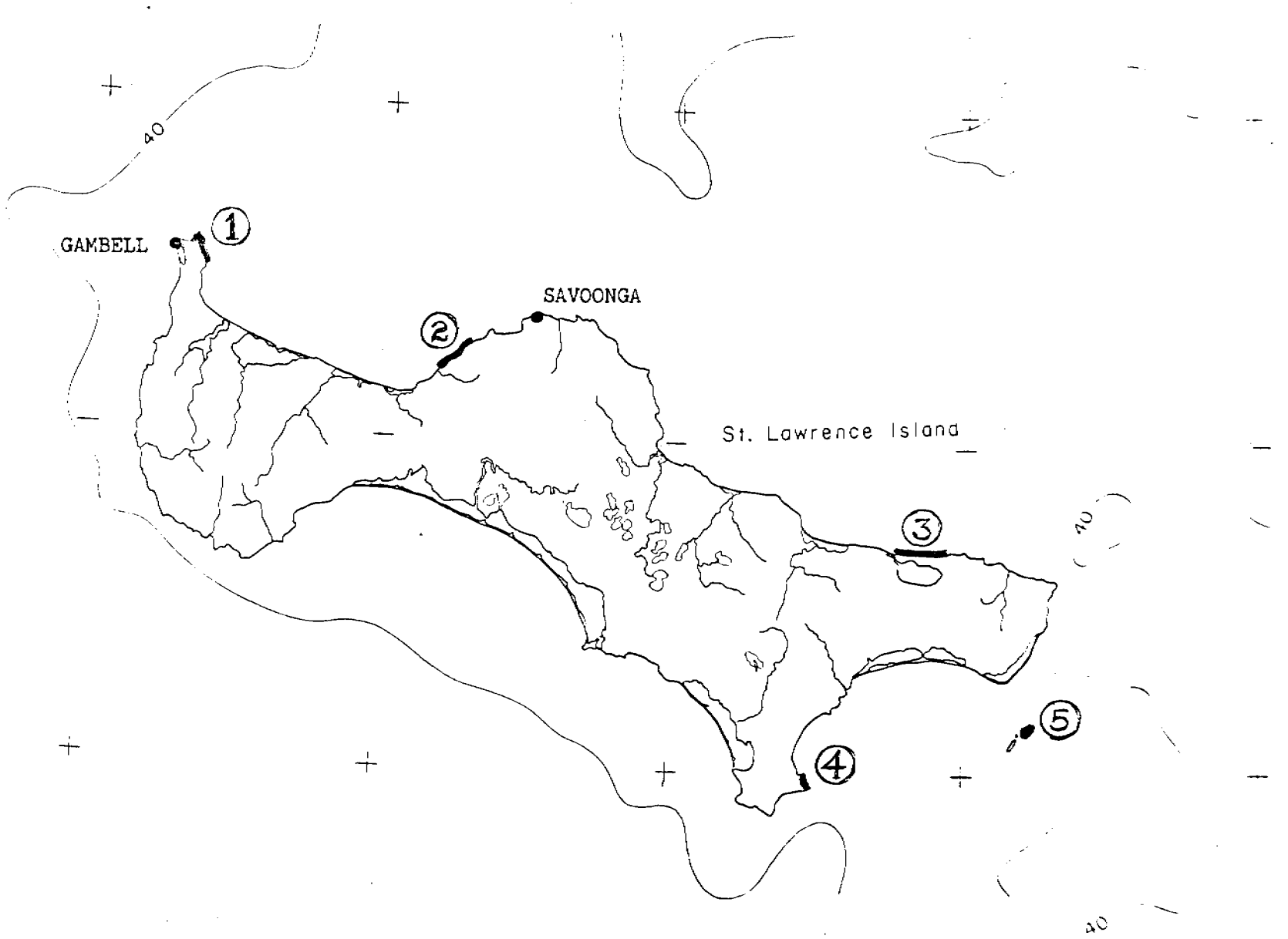
in February to April). The most probable causes at this early stage of gestation would be toxemia, malnutrition, exhaustion, or trauma or a combination of these.

CONCLUSION

The total number of dead walruses found along the northern and eastern coasts of St. Lawrence Island this fall has been larger than usual, perhaps more than 100 in all including aborted fetuses, and the number is growing daily. While this has caused some excitement and concern, especially among the islanders, I feel that it is not abnormal relative to the number of living walruses present there. I have estimated from earlier work that the normal rate of natural mortality in the walrus population is on the order of about 2 percent per year; hence, with the presence of some 50 to 60 thousand or more animals in that area for about two months, one might expect to find as many as 150-200 carcasses of animals that died from various natural causes.

The unusual aspects of the situation are (1) the presence of such large numbers and (2) their hauling out in locations not utilized previously within at least the past half-century. These are indicative of some major changes in distribution pattern, probably related to "population pressure". There have been many other such indications in recent years. At the same time, we know that the walrus population is much larger than it has been for a long time (estimated about 200,000 in the mid-1800's; 40-50,000 in the 1950's; 200,000 in 1975) and that it has some finite upper limit, which is dictated at least in part by the food supplies available to it. The recent departures from the usual distribution pattern of the 1950's and 1960's, together with the increasing number of reports of growing proportions of very thin, lean animals, suggest that the Pacific walrus population is experiencing some difficulty in finding adequate food supplies in its former haunts, which suggests further that it may have already reached or exceeded its optimal level in numbers. It is this possibility that is the main concern of the St. Lawrence Islanders, who are to a large extent dependent on the walrus resource for their existence. In the past, they have seen how an animal population (in that case, reindeer in 1948) can reach a high level in excess of the carrying capacity of its range, then

"crash" in less than a year to about 1/1000 of its former size. Their concern is that the walrus population is about to do the same. I share that concern.



St. Lawrence Island, Bering Sea, showing locations in which large herds of walruses hauled out during October-November 1978. Sites 1 and 5 are traditional hauling grounds; sites 2, 3, and 4 were used this year for the first time in the memory of the island's Eskimo residents.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: December 31, 1978

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 8 R.U. NUMBER: 194

PRINCIPAL INVESTIGATOR: Dr. F. H. Fay

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates From	To	Estimated Submission Dates[1] Batch 1
Data as yet to be submitted:			
Tugidak Is.	July 1977		12/30/78
Surveyor Leg 4	4/16 - 4/20/78		12/30/78
Surveyor Leg 7	6/19 - 7/9/78		12/30/78
Tugidak Is.	May - June 1978		12/30/78
Alaska Peninsula	May 1978		12/30/78
Priblofs	7/1 - 7/31/78		12/30/78
Alaska Peninsula	7/7 - 7/19/78		12/30/78
Lower Cook Inlet	8/14 - 8/18/78		12/30/78

Note: [1]Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer. Specimen data will be reported separately in tabular format.

All data beach survey due await keypunching and will be submitted soon.

Information on histology of animals reported by others and those collected by P.I. is currently being assembled by the P.I.

Fiscal Report

Contract: 03-5-022-56

Task Order: #8

Date: December 22, 1978

Category	Billed this Quarter	Cumulative Billed
Salaries and Wages	$12,565.14	$143,157.42
Travel	741.99	15,536.56
Equipment	-0-	-0-
Other	1,352.60	24,105.70
Staff Benefits	2,241.56	25,488.50
Overhead	6,282.57	73,808.64
Total Billed	$23,183.86	$282,096.82
Total Award		313,051.00
Total Unbilled		30.954.18

These data are taken from University of Alaska vouchers submitted in the three months prior to the above date.

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #229
1 Oct. - 31 Dec. 1978
Number of Pages - 1

Biology of the Harbor Seal, *Phoca vitulina richardsi*, in the Gulf of Alaska

Principal Investigators:

Kenneth W. Pitcher, Alaska Department of Fish and Game
Donald G. Calkins, Alaska Department of Fish and Game

23 January 1979

I. Task Objectives

A. To complete laboratory analyses of harbor seal reproductive tracts and stomach contents collected during FY1978 and to estimate ages for these animals.

B. To submit the appropriate data sets to NODC.

C. To complete analyses on data collected during the life of RU229 and to prepare a final report.

II. Activities

Laboratory procedures were completed for all specimen materials. Data from seals collected in calendar year 1978 for record types 1, 2 and 3 were submitted for keypunching.

III. Results

Not applicable.

IV. Preliminary Interpretation

Not applicable.

V. Problems Encountered

Ten skulls from collected harbor seals were lost in transit from Kodiak making it impossible to estimate ages from these animals.

VI. Estimate of Funds Expended

Salaries	$8100
Travel/Per Diem	280
Contractual Services	200
Commodities	300
Equipment	0
TOTAL	$8800

Quarterly Report

Contract #03-5-022-53
Research Unit #230
Reporting Period: 1 October-31 December 1978
Number of Pages: 3

The Natural History and Ecology of the Bearded Seal (Erignathus barbatus) and the Ringed Seal (Phoca hispida)

Principal Investigators:

John J. Burns and Kathryn J. Frost
Marine Mammals Biologists
Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

Assisted by: Lloyd Lowry, Pam Fields, Larry Miller, Dan Strickland, Richard Tremaine and Glenn Seaman

31 December 1978

I. Task Objectives

1. Summarization and evaluation of existing literature and available unpublished data on reproduction, distribution, abundance, food habits and human dependence on bearded and ringed seals in the Bering, Chukchi and Beaufort Seas.

2. Acquisition of large amounts of specimen material required for an understanding of productivity, growth rates and mortality in these two species.

3. Acquisition of baseline data on mortality (including parasitology, diseases, predation and human harvest) of ringed and bearded seals.

4. Determination of population structure of bearded and ringed seals as indicated by composition of harvest taken by Eskimo subsistence hunters.

5. Initial assessment of regional differences in density and distribution of ringed and bearded seals in relation to geographic areas and, to a lesser extent, in relation to major habitat condition.

6. Acquisition of additional information on seasonal migrations.

II. Field and Laboratory Activities

Primary emphasis of this research unit during the first quarter of FY 79 was on processing age and reproductive specimens. Personnel were engaged in sectioning, staining and "reading" seal teeth and reading seal claws to determine age structure of the populations. Analysis of reproductive tracts from seals collected during 1978 was begun. In addition, 42 seals collected in the Beaufort Sea in November were processed.

Field work was minimal during this quarter. An attempt to obtain a November collection of seals at Nome was unsuccessful due to stormy weather. Successful November collecting trips were made in the Beaufort Sea, at Prudhoe Bay and at Barrow with the aid of a chartered Bell 206 and a NOAA UH1H helicopter. These trips were part of a larger scale Beaufort Sea Winter Studies program.

Extensive data analysis was begun this quarter with the aid of a newly acquired DEC VT 78 microcomputer. Software was written for data entry, checking, transfer of data to and from the University of Alaska Honeywell computer and for analyses of male reproductive parameters and population age structure. Data management of age data consumed large blocks of time.

Project PI's spent a week in October preparing for and attending the OCSEAP Vertebrate Consumer Workshop.

Table 1 provides a complete listing of field and laboratory activities during the past quarter. Dates and personnel are included.

Table 1. Field and laboratory activities, 1 October-31 December 1978.

Activity	Dates	Personnel
Specimen collections:		
Nome	2-9 November	K. Frost
Prudhoe Bay	5-11 November	J. Burns
Barrow	13-16 November	L. Lowry
Vertebrate Consumer Workshop	17-19 October	J. Burns, K. Frost
Laboratory processing and interpretation of age material	continuous	K. Frost, J. Burns, P. Fields, D. Strickland
Laboratory processing and interpretation of reproductive material	intermittent	J. Burns, K. Frost D. Tremaine
Data management	continuous	K. Frost, P. Fields
Data analysis, software preparation	continuous	L. Lowry, L. Miller, K. Frost

Methods

For a discussion of methods, refer to RU #230 Annual Report, 1 April 1978.

Data Collected or Analyzed

A total of 42 seals was collected during our November Beaufort Sea sampling effort. Twenty-two ringed seals were obtained in the vicinity of Prudhoe Bay. Nineteen ringed seals and one bearded seal were collected east of Point Barrow. Effort in the Prudhoe Bay collection was directed specifically toward the proposed lease area.

All male reproductive tracts collected to date have been processed. All female reproductive tracts collected through 1977 have been processed, as well as part of the 1978 collections. Processing of teeth and claws from all 1978 and 1977 collections is almost complete.

Great progress has been made in setting up our DEC microcomputer and preparing software for data entry and analysis. To date software has been written for data transfer from the University of Alaska Honeywell computer, for entry and checking of physical data and age data, for analyses of male and female reproductive data and for preliminary analysis of age data. The acquisition of the DEC microcomputer and the hiring of Larry Miller as a full-time computer programmer have greatly expedited data entry and analysis.

III. and IV. Results and Preliminary Interpretation

A detailed presentation and discussion of results will be presented in the upcoming 1 April 1979 Annual Report.

V. Problems Encountered/Recommended Changes

None.

VI. Estimate of Funds Expended

As of 31 December we have expended approximately the following amounts during FY 79:

Salaries and benefits	$15,600
Travel and per diem	2,000
Contractual services	1,000
Commodities	1,500
Equipment	--
Total Expenditures	$20,100

Quarterly Report

Contract #03-5-022-53
Research Unit #232
Report Period: 1 October-31 December 1978
Number of Pages: 3

Trophic Relationships Among Ice Inhabiting Phocid Seals

Principal Investigators:

Lloyd F. Lowry, Kathryn J. Frost and John J. Burns
Marine Mammals Biologists
Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

Assisted by: Pam Fields, Richard Tremaine, Larry Miller, Dan Strickland and Glenn Seaman

31 December 1978

I. Task Objectives

The investigation of trophic relationships among ice inhabiting phocids is addressed to the following task objectives:

1. Compilation of existing literature and unpublished data on food habits of ringed seals, bearded seals, spotted seals and ribbon seals. In addition, available information on distribution, abundance and natural history of potentially important prey species is being gathered.

2. Collection of sufficient specimen material (stomachs) for determination of the spectrum of prey items utilized by the seal species being studied throughout their geographic range and during all times of year. The contents of seal stomachs are sorted, identified and quantified. This information will be analyzed for geographical and temporal variability in prey utilization patterns as well as for species, sex- and age-related dietary differences.

3. Analysis of feeding patterns in relation to distribution, abundance and other life history parameters of key prey species. This involves determination of the degree of selectivity demonstrated by each species of seal as well as the availability and suitability of primary and alternative food sources. To whatever extent possible the effect of seal foraging activities on populations of prey species will be examined in light of observed rates of food consumption and foraging behavior. The accomplishment of this objective is largely dependent on information gathered by other OCSEAP projects involving benthic and planktonic organisms.

4. Analysis of trophic interactions among these species and other potential competitors such as walruses, whales, marine birds, fishes and humans. Input from other OCSEAP studies will be critical in this phase of the project.

With the understanding thus obtained of the trophic interrelationships of ice inhabiting phocids in the Bering-Chukchi and Beaufort marine systems we will evaluate the probable kinds and magnitude of effects of OCS development on these species of seals. This will involve both direct effects such as disruption of habitat in critical feeding areas or alterations of populations of key prey species, and indirect effects such as influence on populations of competitors for food resources.

II. Field and Laboratory Activities

Primary emphasis of this project during the first quarter of FY 79 was on data compilation and analysis. Acquisition in September of a new DEC VT 78 microcomputer has greatly facilitated this compilation and analysis. Software has or is being written for data entry, data checking,

stomach contents analyses and various data sorting regimes. All 1977 seal trophics data were submitted to Michael Crane at AEIDC for submission to NODC. Most 1978 trophics data are data managed and ready for submission pending compilation of age and reproductive data.

Limited field work was undertaken during this quarter. Successful collections of ringed seals were made out of Prudhoe Bay and Barrow with the use of a Bell 206 and a NOAA UH1H helicopter. A village collection was attempted at Nome in early November but was unsuccessful due to stormy weather.

Laboratory activities during this quarter consisted of beginning to process November collections of seals from Prudhoe Bay and Barrow. In addition, several collections of prey species were examined. Preparation of a voucher collection as specified in the 23 October 1978 OCSEAP Voucher Specimen Policy was begun. Belukha whale stomach contents collected at Elephant Point in June were analyzed.

Several weeks in October were devoted to preparation for and attendance at the OCSEAP Vertebrate Consumer Workshop. Project PI's were involved in disciplinary presentations, a bowhead whale panel discussion, and workshop sessions on fish and invertebrate species accounts, trophics data and microcomputers.

Table 1 provides a complete listing of field and laboratory activities during the past quarter. Dates and personnel are included.

Table 1. Field and laboratory activities, 1 October-31 December 1978.

Activity	Dates	Personnel
Specimen collections:		
Nome	2-9 November	K. Frost
Prudhoe Bay	5-11 November	J. Burns
Barrow	13-16 November	L. Lowry
Preparation for Vertebrate Consumer Workshop	9-13 October	L. Lowry, K. Frost
Vertebrate Consumer Workshop	17-19 October	J. Burns, K. Frost, L. Lowry
Laboratory processing of specimen material	intermittent	L. Lowry, K. Frost R. Tremaine, D. Strickland
Archival of voucher specimen collection	November	R. Tremaine
Data management	continuous	K. Frost
Submission of 1977 RU 230/232 data	December	K. Frost
Microcomputer software preparation/data analysis	continuous	L. Lowry, L. Miller

Methods

Field collection procedures and methods for laboratory analyses are described in the 1978 Annual Report for RU #232.

Data Collected or Analyzed

A total of 42 seals was collected during our November work in the Beaufort Sea. Twenty-two ringed seals were collected in the Prudhoe Bay vicinity. Nineteen ringed seals and one bearded seal were collected just east of Barrow.

Stomach contents from 54 belukha whales collected at Elephant Point (Kotzebue Sound) in June were analyzed and the data tabulated and presented at the Vertebrate Consumer Workshop.

III. and IV. Results and Discussion

A detailed presentation and discussion of results will be provided in the upcoming 1979 Annual Report.

V. Problems Encountered/Recommended Changes

None.

VI. Estimate of Funds Expended

As of 31 December we have expended the following amounts during FY 79:

Salaries and benefits	$34,000
Travel and per diem	1,200
Contractual services	2,100
Commodities	700
Equipment	--
Total Expenditures	$38,000

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #243
Reporting Period-Oct. 1 - Dec. 31
Number of Pages - 4

Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska

Principal Investigators:

Donald G. Calkins, Alaska Department of Fish and Game
Kenneth W. Pitcher, Alaska Department of Fish and Game

January 1, 1979

I. Task Objectives

To determine numbers and biomass of Steller sea lions in the Gulf of Alaska. To establish sex and age composition of groups of sea lions utilizing the various rookeries and hauling grounds. To determine patterns of animal movement, population identity and population discreteness of sea lions in the Gulf. To determine changes in seasonal distribution.

To investigate population productivity and growth rates of Steller sea lions in the Gulf of Alaska with emphasis on determining; age of sexual maturity, overall birth rates, duration of reproductive activity and survival rates for various sex and age classes.

To determine food habits of Steller sea lions in the Gulf of Alaska with emphasis on variation with season and habitat type. An effort will be made to relate food habits with prey abundance and distribution. Effects of sea lion predation on prey populations will be examined.

To incidentally collect information on pathology, environmental contaminant loads, critical habitat and fishery depredations.

II. Field or Laboratory Activities

A. Laboratory activities

1. Tentative ages have been assigned to all sea lions collected in 1978.

2. All sea lion reproductive material collected in 1978 has been examined.

3. All stomach contents collected in 1978 have been examined.

4. See Table 1 for data on sea lions which has been submitted to AEIDC during the first quarter of FY79.

Table 1. Information submitted to AEIDC during first quarter, FY79, for RU 243.

File Idents.	Animals	Platform	Lease Area
478L10	SL-196-78-SL-201-78	Surveyor	LCI-KOD
678L10	SL-202-78-SL-215-78	Surveyor	LCI-KOD-NEGOA
787L10	SL-216-78-SL-225-78	Pandalus	KOD
878L10	SL-226-78-SL-230-78	Surveyor	KOD

Record Types 1, 2, 3, & 8 for all

#1 Location (lat./long/, date of coll., time of coll., habitat)

#2 Physical 1 (taxonomic code, sex, group size, measurements)

#3 Physical 2 (additional measurements, stomach condition)

#8 Text

B. Methods

1. See Annual Report

III. Results

A. None

IV. Preliminary Interpretation of Results

A. None

V. Problems encountered

A. None

VI. Estimate of funds expended:

A. Funds expended during this quarter:

1.	Salaries and benefits	$24,000
2.	Surveys	3,000
3.	Commodities (lab supplies, photo supplies, etc.)	1,000
4.	Travel, per diem and transportation of equipment and supplies	3,000

Quarterly Report

Contract #03-5-022-55
Research Unit #248
Report Period: 1 November-31 December 1978
Number of Pages: 2

The relationship of marine mammal distributions, densities and activities to sea ice conditions

Principal Investigators:

John J. Burns
Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

Francis H. Fay
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Lewis H. Shapiro
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Assisted by: Brenden Kelley

31 December 1978

I. Task Objectives

The specific project objectives are:

1. To determine the extent and distribution of regularly occurring, ice-dominated marine mammal habitats in the Bering, Chukchi and Beaufort Seas;

2. To describe and delineate those habitats;

3. To determine the physical environmental factors that produce those habitats;

4. To determine the distribution and densities of the various marine mammal species in the different ice habitats; and

5. To determine how the dynamic changes in quality, quantity and distribution of sea ice relate to major biological events in the lives of marine mammals (e.g. birth, nurture of young, mating, molt and migrations).

II. Field and Laboratory Activities

No field activities were conducted during this quarter. All effort was devoted to analysis of data and preparation of a final report.

Mr. Brenden Kelley continued the tasks of analyzing all available NOAA satellite imagery which show the extent and characteristics of ice in selected areas of the Bering, Chukchi and Beaufort Seas. Two kinds of information were coded: 1) quality of the images on a scale of 1-4, and 2) the characteristics of ice on a scale of 1-15. This scale was used to record characteristics ranging from open water to solid landfast ice. Additional information including extent of ice cover and movements (as determined from sequential images) was recorded.

At this time the data base is essentially complete. All data from the Bering and Chukchi Seas have been incorporated. Beaufort Sea data will be complete in the near future. Descriptive data on ice conditions for all days for which NOAA satellite imagery is available have been or will be processed. These include data from 20 areas in the Bering, Chukchi and Beaufort Seas from spring 1974 through June 1977.

Primary emphasis at this time is on analyses of these data. Computer programs are being developed to provide a summary of the frequency of specific ice conditions at each station over a period of time. A statistical description of patterns of ice changes is being developed which will correlate changing ice conditions with geographic location, prevailing seasonal winds (expressed as vector mean winds), etc. Some preliminary programs are being modified to incorporate information obtained from initial analyses. For example, data from cloudy days were initially excluded from data analyses. It has since become evident that ice conditions on those cloudy days are very different from patterns occurring

during clear weather, and indicate fairly substantial short-term movements of ice into areas previously thought to be ice-free throughout the winter.

In addition to the above analyses, data are also being catalogued by time, location and ice characteristics for inclusion in a catalog or key to all LANDSAT photos. This catalog will reference data from each day for which photos are available.

Project personnel are accumulating appropriate illustrative material for inclusion in the final report. Sequences of satellite pictures depicting varying ice conditions are being selected for duplication.

III. Results

The final report for RU 248 is in preparation at this time for submission in March 1979.

IV. Problems Encountered.

None.

V. Estimate of Funds Expended during this Quarter

This project is presently being conducted on the basis of a no-cost extension.

RECEPTORS (BIOTA)

Marine Birds

Contents

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #3
Reporting Period - October 1, 1978
December 31, 1978

Pages 2

Identification, Documentation and Delineation of Coastal Migratory Bird Habitat in Alaska

Paul D. Arneson

Alaska Department of Fish and Game

29 December 1978

I. Task Objectives

A. To analyze all data on the seasonal distribution and abundance of coastal marine birds.

B. To summarize this bird data in a form most useful for future decision making on oil and gas leasing in the outer continental shelf.

C. To graphically and pictorially present coastal bird information so that the relative importance of areas within lease areas are readily apparent.

II. Activities

No field or laboratory activities were conducted during this report period. Data collected during the summer field season were transcribed, keypunched, corrected and finalized for submission to NODC.

Much time was devoted to correcting all survey data collected in the three years of this study and now corrections need to be made on the flexible diskettes so that sorting and final analyses can begin. Also, several meetings were attended including an oiled bird workshop and a coordination meeting for Lower Cook Inlet principal investigators.

III. Results

Not Applicable

IV. Preliminary Interpretation

Not Applicable

V. Problems Encountered

Not Applicable

VI. Estimate of Funds Expended

Salaries	$9080
Travel/Per Diem	50
Contractual Services	500
Commodities	30
Equipment	-0-
Total	$9660

15th Quarterly Report

Contract No. 03-5-022-72
Research Unit 083
Reporting Period 1 October 1978-
31 December 1978

Reproductive Ecology of Pribilof Island Seabirds

George L. Hunt, Jr.
Department of Ecology and
Evolutionary Biology
University of California
Irvine, California 92717

1 January 1979

I ABSTRACT

During the 15th Quarter all personal returned from the field and analysis of data from the 1978 field season was begun. G. Hunt attended a Vertebrate Consumers workshop in Fairbanks.

II TASK OBJECTIVES

1) Commence analyses of data gathered during the 1978 Field Season.

2) Prepare data from the 1978 Field Season for automatic data processing.

III RESEARCH ACTIVITIES

A. Field Studies - none

B. Laboratory activity:

1) Burgeson has been rechecking work-ups of food samples from 1975 for which errors in the original work-up were found and has begun analysis of the 1978 samples.

2) Naughton has begun analysis of the 1978 at-sea survey data.

3) Squibb is engaged in analysis of the 1978 colony data.

4) Bush has completed coding the 1978 at-sea survey data which have entered on tape and sent to Hal Peterson.

5) Hunt, with the help of Hal Peterson of University of Rhode Island has completed arrangements for the purchase of ADP equipment to develop the net between PIs for field investigations and Hal Peterson's shop.

B. Scientific Personnel:

George L. Hunt, Jr.	Associate Professor, UCI, PI
Barbara Burgeson	Administrative Assistant I, UCI administrative chores, food sample work-ups
Grace Bush	Coder, UCI; data management
Maura Naughton	Laboratory Assistant II, UCI at-sea survey data analysis
Ron Squibb	Laboratory Assistant II, UCI colony data analysis

C. Methods

We are using the same methods as used in previous years. Please see the 1977 Annual Report (1 April 1978).

D. Sample Locations, Trackline

No field sampling was done.

E. Data Collected

No new data were collected in this report period.

F. Data Analyses

Data analysis is in progress. No one segment is complete.

IV, V RESULTS AND PRELIMINARY INTERPRETATION

I prefer not to speculate until analysis has progressed further. Contrary to estimates in the 14th Quarterly report, it does appear that Black-legged Kittiwakes had reduced reproductive success in 1977 although the reduction was not as severe as that for the Red-legged Kittiwakes.

VI AUXILIARY MATERIAL

None.

VII PROBLEMS ENCOUNTERED

No serious problems were encountered.

VIII ESTIMATE OF FUNDS EXPENDED (Direct Costs)

	Total Appropriated 1975 - 1978	Total Expended 1975 - 31 Oct 78	Balance as of 31 December 1978
Salaries	$157,890	$114,404	$43,486
Employee Benefits	24,877	15,366	9,511
Supplies	21,764	20,150	1,614
Equipment	16,147	8,790	7,357
Travel	44,066	28,537	15,529

VIII ESTIMATE OF FUNDS EXPENDED (Direct Costs) continued

Other	$22,682	$3,472	$19,210
Total	$287,426	$190,719	$96,707

It is anticipated that there are sufficient funds available to conduct the work contracted for.

QUARTERLY REPORT

Contract No. 03-5-022-84
Research Unit #172
Reporting Period: 1 Oct - 31 Dec 1978
Number of pages: 2

Shorebird Dependence on Arctic Littoral Habitats

Research Coordinator: Peter G. Connors
Bodega Marine Laboratory
University of California
Bodega Bay, CA 94923

Principal Investigator: R. W. Risebrough

Date of Report: December 20, 1978

I. Task Objectives

The ultimate objective of this study is the assessment of the degree and nature of dependence of each shorebird species on Arctic habitats which may be susceptible to perturbation from offshore oil development activities. The approach entails three major areas of investigation:

1. Seasonal occurrence of shorebirds by species, in a variety of arctic littoral and near-littoral habitats, both disturbed and undisturbed.
2. Foraging habitat preferences of shorebirds within the littoral zone, by species.
3. Studies of the major invertebrate prey systems used most heavily by common shorebird species in arctic littoral habitats.

II. Laboratory Activities

A. No field schedule

B. Scientific party

Research coordinator: Peter G. Connors, Univ. of California, Bodega Marine Laboratory

C. Methods

Continued organization and analysis of invertebrate samples, transect census data, and transect habitat data.

III. Results

Bird densities were compared between 3 shoreline transects having high levels of activity disturbance from people and machines, and 3 similar transects with lower activity disturbance, all within 19 km of Chukchi shoreline at Barrow. Most species were less common on disturbed shores, but not significantly so. Two species were more common on disturbed

transects: Glaucous Gulls and Ruddy Turnstones are both preferential garbage foragers, attracted by the higher levels of garbage, especially in the vicinity of Barrow dump.

IV. Preliminary Interpretation

We expect that shoreline activities associated with development will not have serious effects on shorebird densities arising solely from the noise and activity disturbance. If garbage becomes common in development areas, Glaucous Gulls and Ruddy Turnstones will be attracted.

V. Problems

None

VI. Estimate of Funds Expended

For FY79, funds expended through December 15, 1978 totalled approximately $9,200 of the allocation of $49,842.

Quarterly Report

Contract #: 03-7-022-35140
Research Unit: 196
Report Period: 1 October -
31 December 1978
Number of pages: 1

The Distribution, Abundance and Feeding Ecology of Birds Associated with Pack Ice

George J. Divoky
Principal Investigator

Assisted by:

A. Edward Good

Point Reyes Bird Observatory
4990 Shoreline Highway
Stinson Beach, California 94970

January 1, 1979

I. Task Objectives

Determine the relationship of pelagic seabirds to the ice environment on a seasonal basis.

II. Field Activities

A. Ship and field trip schedule

No field work was conducted. The principal investigator attended the fall meeting of OCSEAP bird investigators in Fairbanks in October. In December the principal investigator gave a paper at the Pacific Seabird Group meeting titled " The Breeding Biology and Population Dynamics in northern Alaska."

III. Results

At the October OCSEAP meeting at Fairbanks, William Drury presented the results of a Glaucous Gull survey of the Chukchi coast. He found a surprisingly high percentage of sub-adult birds and asked other investigators to examine their data. As a result, selected data files were examined. The results are presented on Table 1 of this report. Our Our findings support Drury's suspicions that the Glaucous Gull population may be expanding. We have sent our findings to appropriate investigators.

IV. Preliminaty interpretation of results

None

V. Problems encountered

None

VI. Estimate of funds expended

Salaries	$ 7,170
Travel	630
Equipment	0
Other direct costs	37
Overhead (39% of salaries)	2,796
Total	10,633

Table 1. Summary of Glaucous Gull age ratios from selected data of R.U. 196.

Location and dates	Number aged	Percent subadult	Percent adult
Bering Sea			
17 Mar. - 3 Apr. 1977	237	27%	73%
Bering Sea			
2-15 May 1978	514	47%	53%
2- 7 May 1978	145	16%	84%
8 May 1978	71	34%	66%
9-15 May 1978	298	65%	35%
Beaufort Sea (nearshore)			
2-25 Aug. 1977	101	41%	59%
Beaufort Sea (nearshore)			
5-29 Aug. 1978	177	47%	53%
Beaufort Sea (offshore)			
29 Aug.-15 Sept. 1978	295	26%	74%
Barrow Dump			
18-20 June 1977	327	97%	3%
1-28 July 1977	5523	22%	78%
11 Aug. 1977	642	26%	74%
4 Sept. 1977	850	44%	56%
Cooper Island			
June 1976	23	30%	70%
July 1976	54	20%	80%
Aug. 1976	294	24%	76%
Sept. 1976	740	20%	80%
July 1978	343	74%	26%
Aug. 1978	822	60%	40%
Sept. 1978	1418	62%	38%

Quarterly Report

Research Unit 237
October 1 - December 31, 1978

Birds of Coastal Habitats on the South Shore of the Seward Peninsula and the Bering Strait, Alaska

William H. Drury

College of the Atlantic
Bar Harbor, Maine

QUARTERLY REPORT

OCTOBER - DECEMBER 1978

RESEARCH UNIT #237

Contract No. 03-6-022-35208

Reporting Period: 1 October 1978 to 1 January 1979.

Title: Birds of Coastal Habitats on the South Shore of the Seward Peninsula and the Bering Strait, Alaska

Date Submitted: 5 January 1978

I. Highlights of Quarter's Accomplishments

A. Rough draft of the annual report has been completed and is being reviewed by members of the field party. This report concentrates on:
a) our studies of the breeding of Common Murres and Black-legged Kittiwakes, and
b) our aerial survey tracklines designed to establish the patterns of distribution of birds feeding at sea.

B. A lot of time and thought has been expended on solving the continuing problems related to entering data, the uniformity of entry systems, and the convenience of retrieval of data and analysis.

C. Drury and Ramsdell attended the successful meeting for post field-season reports of students of sea mammals and seabirds at Fairbanks in October.
Drury gave an invited paper for the Centennial Celebration of the Linnaean Society of New York. The topic was Coastal Surveys for Marine Birds on the Northeast and Northwest Coasts. This paper will be published in the Proceedings of the Linnaean Society and its major features included in the annual report for this research unit.

II. Task Objectives

A. To determine the numbers and distribution of seabirds in the Bering Strait region, between Saint Lawrence Island and Cape Lisburne.

B. To describe the schedule and phenology of events at Bluff Cliffs during occupation of the cliffs, the breeding period, and the period when the birds leave and return to sea.

C. To examine trophic relations by making estimates of reproductive success, by determining distributions and concentrations of birds feeding at sea, and by identifying the organisms used as food.

D. To compare these results with those in the Southern Chuckchi Sea, the Southern Bering Sea, Gulf of Alaska, and published information on the Barents Sea and North Atlantic.

III. Field or Laboratory Activities

A. No field work was done in this quarter.

B. Scientific party

William H. Drury	College of the Atlantic	Principal Investigator
Cathy Ramsdell	Processing field data, writing reports	

C. Field methods have been described.

D. Sample locations were expanded during the 1978 season to include estimates of birds on the cliffs of the Southwest Capes, Brunnell Cape area of Saint Lawrence Island, Cape Thompson and Cape Lisburne. Aerial survey tracklines were expanded to include areas within 100 nautical miles of the bird cliffs at Cape Thompson and Cape Lisburne.

IV. Results

Results were summarized in the September Quarterly Report and will be be reviewed in the annual report.
The distribution of birds feeding at sea was consistent with the patterns reported previously in the Norton Basin and in the Southern Chuckchi Sea, as reported by Swartz and Springer and Rosenau.
The breeding season at Bluff Cliffs in 1978 was outstandingly successful.

V. Preliminary Interpretation of Results

We have no new interpretations of results to report.

Quarterly Report
October-December, 1978
Research Unit: 337

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS IN ALASKAN WATERS

Calvin Lensink
Principal Investigator

Patrick Gould
Project Leader

U.S. Fish & Wildlife Service
Office of Biological Services-Coastal Ecosystems
1011 E. Tudor Road
Anchorage, Alaska 99503

January 1, 1979

QUARTERLY REPORT

I. TASK OBJECTIVES

The overall FY 79 objective of RU 337 is the analyses of shipboard and aerial survey data and the preparation of a final report. Specific tasks for the quarter included: 1) review of pertinent literature, 2) preparation of introductory sections of the final report, 3) evaluation of the status of digital data, and 4) submission of the RU 337 renewal proposal.

II. FIELD OR LABORATORY ACTIVITIES

No field or laboratory programs were conducted during this quarter.

A. Ship or Field Trip Schedule: None

B. Scientific Party: None

C. Methods: None

D. Sample Locations: None

E. Data Collected or Analyzed: None

F. Milestone Chart and Data Submission Schedules

See Table 1 for the Milestone Chart/Data Submission Schedule. Schedule changes reflect the extended deadline of July 1, 1979, as agreed in the FY 79 renewal proposal. All digital data collected under RU 337 have been submitted to Dr. Hal Petersen of RU 527. File Type 033 data collected under RU 341 are currently being processed by us.

III. RESULTS

We received the final data tapes for the Bering and Arctic Seas from RU 527 late in December. Consequently very little data analysis and report writing were accomplished this quarter. Intensive data analysis will begin in January, 1979. The FY 79 renewal proposal was submitted and accepted during this quarter. Table 2 portrays the present status of file type 033 data.

IV. PRELIMINARY INTERPRETATION OF RESULTS

Data have not yet been analyzed so interpretation of results is not possible at this time.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No new problems were encountered during this quarter and we have no recommended changes.

Table 1. Milestone Chart and Data Submission Schedule

RU 337 PI Calvin Lensink

O = Planned Completion Date
X = Actual Completion Date

MAJOR MILESTONES	1978 O	N	D	1979 J	F	M	A	M	J	J	A	S	O	N	D
Digital Data Submission						O									
Quarterly Reports				X			X								
Data Analysis:															
Arctic Seas					O										
Bering Sea						O									
Gulf of Alaska							O								
Final Report										X					

Table 2. Present Status of RU 337 Data

1. Data validation and format conversion have been completed by RU 527 for 61 field operations including:

FW5004	FW5008	FW5009	FW5010	FW5011	FW5012	FW5013	FW5014	FW5015
FW5016	FW5018	FW5020	FW5021	FW5022	FW5023	FW5024	FW5026	FW5027
FW5030	FW5032	FW5033	FW5034	FW5035	FW5036	FW5037	FW6001	FW6006
FW6009	FW6012	FW6015	FW6021	FW6025	FW6026	FW6028	FW6029	FW6057
FW6066	FW6067	FW6070	FW6074	FW6082	FW6084	FW6085	FW6086	FW6087
FW6088	FW6089	FW6093	FY6186	FW7026	FW7027	FW7028	FW7029	FW7031
FW7032	FW7033	FW7034	FW7035	FW7036	FW7042	FW7045		

2. Data validation and format conversion is currently being conducted by RU 527 for 29 field operations including:

FW5003	FW5006	FW5025	FW5029	FW5031	FW6002	FW6004	FW6005	FW6007
FW6008	FW6010	FW6011	FW6013	FW6014	FW6016	FW6018	FW6019	FW6027
FW6050	FW6051	FW6052	FW6064	FW6069	FW6077	FW6078	FW6083	FW6092
FW6094	FW6095							

3. Keypunching and initial data validation are now being conducted by the USFWS for 22 field operations including:

FW5028	FW6200	FW6300	FW6400	FW7047	FW8006	FW8007	FW8008	FW8012
FW8014	FW8015	FW8016	FE8017	FW8018	FW8019	FW8023	FW8024	FW8025
FW8026	FW8027	FW8028	FW8029					

All of the above (3) operations except FW8029 have been keypunched and only FW5028 will require format conversion by RU 527.

QUARTERLY REPORT
OCTOBER-DECEMBER, 1978
RESEARCH UNIT: 341

POPULATION DYNAMICS AND TROPHIC RELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA

Calvin Lensink
Patrick Gould
Gerald Sanger
PRINCIPAL INVESTIGATORS

U.S. Fish & Wildlife Service
Office of Biological Services-Coastal Ecosystems
1011 E. Tudor Road
Anchorage, Alaska 99503

January 1, 1979

QUARTERLY REPORT

I. TASK OBJECTIVES

A. Colony Studies

1. Prepare preliminary reports on the results of 1978 field studies and present them at the Vertebrate Consumers Workshop in Fairbanks, Alaska (17-19 October, 1978).

2. Assemble and analyze data obtained during the 1978 field season on the breeding biology of selected marine bird species at Middleton Island, Chisik Island, Chiniak Bay and Sitkalidak Strait.

3. Begin the preparation of the annual report.

4. Prepare and submit the FY 79 renewal proposal for RU 341.

B. Trophic Studies

1. Prepare preliminary reports on the results of 1978 field studies and present them at the Vertebrate Consumers Workshop in Fairbanks, Alaska (17-19 October, 1978).

2. Verify and correct previously keypunched data (File Type 031).

3. Develop translation programs for the conversion of data (File Type 031) currently entered on obsolete formats.

4. Begin the preparation of the annual report.

5. Prepare and submit the FY 79 renewal proposal for RU 341.

II. FIELD OR LABORATORY ACTIVITIES

There were no field or laboratory activities connected with this quarters work.

A. Ship or Field Trip Schedule: None

B. Scientific Party: None

C. Methods: None

D. Sample Locations: None

E. Data Collected or Analyzed

No data were collected during this quarter.

Analyses of data on the breeding biology and trophic dynamics of selected marine bird species were begun during this quarter and included:

1. Analysis of variance between years with respect to: clutch size, brood size and number of fledglings.

2. Analysis of co-variance of growth curves between years.

3. Analysis of variance of the adjusted means of the above curves (no. 2) with multiple range tests for significant differences.

4. Canonical analysis of the important habitat parameters which may influence productivity.

5. Chi-square analysis of important habitat parameters.

6. Analysis of variance of prey lengths.

7. Factor analysis and diversity indices of the principal components of each bird species' diet.

The following measures of productivity were analyzed:

1. Nests with eggs per nest built.

2. Clutch size.

3. % of breeding pairs which hatched one or more eggs.

4. Brood size at hatching.

5. Eggs hatched per eggs laid.

6. % breeding pairs fledging at least one young.

7. Brood size at fledging.

8. Chicks fledged per chicks hatched.

9. Chicks fledged per eggs laid.

10. Chicks fledged per nest with eggs.

11. Chicks fledged per nest built.

F. Milestone Chart and Data Submission Schedule

Major milestones and data submission schedules are portrayed in Table 1.

III. RESULTS

Data analyses have not been completed at this time although major headway was made in all areas.

IV. PRELIMINARY INTERPRETATION OF RESULTS

No interpretation is possible at this time.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No new problems have been encountered and we have no recommended changes at this time.

TABLE 1. Major Milestones and Data Submission Schedule.

RU: 341 PI's: Lensink, Gould, Sanger

O = planned completion date
X = actual completion date

MAJOR MILESTONES	1978 O	N	D	1979 J	F	M	A	M	J	J	A	S	O	N	D
Annual Reports (Colony & Trophics)							X								
Quarterly Reports (Colony)				X			X			X			X		
Quarterly Reports (Trophics)				X			X			X					
Chisik Island Field Work												X			
Digital Data (Colony)												O			
Digital Data (Seawatches)							O								
Digital Data (Trophics)							O								
Final Report (Colony)												O			
Final Report (Kachemak Bay Trophics)										O					
Final Report (Kodiak Island Trophics)												O			
Final Report (Gulf of Alaska Trophics)												O			

ECOLOGICAL STUDIES OF COLONIAL SEABIRDS AT CAPE THOMPSON AND CAPE LISBURNE, ALASKA

Quarterly Progress Report

31 December 1978

NOAA-OCSEAP
Contract No. 03-6-022-35210
Research Unit No. 460

Principal Investigators

Alan M. Springer
David G. Roseneau

LGL Alaska
P. O. Box 80607
Fairbanks, Alaska 99708

(907) 479-2669

Summary of Third Quarter Activities

Both investigators attended the Vertebrate Consumer Workshop which was held in Fairbanks during 17-19 October. No other work was performed on RU 460 during this quarter.

RECEPTORS (BIOTA)

Marine Fish

Contents

QUARTERLY REPORT

CONTRACT: #03-5-022-56
TASK ORDER: #15
RESEARCH UNIT: #5
REPORTING PERIOD:
NUMBER OF PAGES:

DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE, AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF THE KODIAK SHELF, COOK INLET, AND NORTHEAST GULF OF ALASKA

Principal Investigator
Dr. Howard M. Feder

with

Max Hoberg
Stephen C. Jewett
Kris McCumby
John Rose
A. J. Paul
J. McDonald
P. Shoemaker

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

December 1978

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KODIAK SHELF

BERING SEA AND GULF OF ALASKA

LOWER COOK INLET

KODIAK SHELF

I. TASK OBJECTIVES

A. On a limited basis, assess distribution and relative abundance of epifaunal invertebrates, exclusive of king and snow crabs, in selected bays and inshore areas.

B. Using available data, assess the distribution and abundance of king crabs and snow crabs in selected bays and inshore areas, and selected offshore areas.

C. Using available data, assess spatial distribution of selected, infaunal invertebrate species.

D. Determine, where possible, the feeding habits of the principal inshore epifaunal invertebrate species exclusive of king crab (see E below); the food habits of the pink shrimp and the snow crab are to be especially examined.

E. Continue studies on the feeding habits of the king crab. The following listed objectives should eventually delineate (1) what the major geographic areas are that support (in terms of food) king crab of various sizes and life stages, and (2) which food item(s) or group(s) are most important to the enhancement of the size of a particular king crab stock.

   1. Examine, to the extent that collected material permits, the percent weight and/or volume composition of prey items of king crab of different sex, length and ecdysis stage by area (depth) and time of year.
   2. Examine the feeding intensity of king crab following the same parameters as in objective (E1) above.
   3. Examine the relationship between catch number of king crab and their feeding intensity as determined by objective (E2).

F. Develop food webs integrating invertebrate, fish and bird feeding data in collaboration with the Alaska Department of Fish and Game R.U. 552.

G. Compile seasonal reproductive data, and other biological data whenever possible, on dominant benthic epifaunal invertebrates.

II. FIELD AND LABORATORY ACTIVITIES

A. Data collection *via* SCUBA, 26 and 30 October 1978.

1. Scientific party - Stephen C. Jewett, Institute of Marine Science (IMS), responsible for collection of crab feeding data.
2. Methods - Samples were obtained *via* SCUBA using a fine-mesh nylon net supported on a 30 x 90 cm steel frame. The net was dragged across the bottom catching juvenile snow crabs, other small animals, and sediment. The net penetrated the sediment approximately 7 cm.
3. Sample location - Near Island Basin, east of the city of Kodiak boat harbor between Near Island, Holiday Island and Crooked Island.
4. Data collection - Five bottom sweeps, each approximately 3 m long, yield 1.65 ℓ of fine sandy sediment. Invertebrates were dominated by 49 juvenile ($\bar{x}$ 14 mm width) snow crabs (*Chionoecetes bairdi*), approximately 200 gammarid amphipods, 124 small cockles (*Clinocardium nuttallii*), 100 tiny snails (*Lacuna variegata*), and 100 tiny nestler clams (*Hiatella arctica*). At least 18 other species of invertebrates were also present.

B. Trawl cruise - 4-17 November 1978 *via* R/V *Commando*.

1. Scientific party - John R. Rose, IMS, responsible for collection of all benthic invertebrate data.
2. Methods - Samples were obtained *via* a 20-foot try-net and a 400-mesh otter trawl.
3. Sample locality - Izhut Bay and Kiliuda Bay of Kodiak Island.
4. Data collection - Data on invertebrate distribution and abundance were taken from all stations sampled. Feeding data were taken when possible.

Izhut Bay: A total of 11 tows were made with the try-net and four tows with the otter trawl. In general, November catches of invertebrates seemed smaller in Izhut than during the summer months. Stomachs from 50 snow crabs and two king crabs (*Paralithodes camtschatica*) were collected. In addition, the stomachs of 36 sunflower sea stars (*Pycnopodia helianthoides*) were examined for food.

Kiliuda Bay: Six try-net tows and two otter trawl tows were made. One otter trawl site and one try-net site was not sampled due to large numbers of "stored" king crab pots and "working" dungeness crab pots. Invertebrate catches elsewhere in this bay did not seem to vary much from those collected during the summer months; however,

large numbers of juvenile shrimps were encountered in November in the outer portion of the bay. Fifty snow crab and 55 king crab stomachs were taken. Approximately 400 pink shrimps (*Pandalus borealis*) were collected for stomach analysis.

III. RESULTS

A. All trawl and king crab feeding data are in the final stages of key-punching.

B. During the past quarter 463 king crab stomachs were examined quantitatively. In addition, 93 snow crabs were examined quantitatively and 36 sunflower ea star stomachs were examined qualitatively. Since the initiation of the Kodiak project, the following stomachs have been collected and examined: king crabs 715 collected - 713 examined: snow crabs 1378 - 400; dungeness crabs 37 - 0; pink shrimps 2400 - 0; yellow Irish lord 228 - 228; great sculpin 94 - 94; Pacific cod 234 - 234; flathead sole 156 - 156; rock sole 117 -117; arrowtooth flounder 18 -18; sablefish 31 - 31; Atka mackerel 20 - 20; walleye pollock 20 -20; and the sunflower sea star 199 - 199.

IV. PRELIMINARY INTERPRETATION OF RESULTS

Final analysis of king crab feeding data is currently underway. Examination of the unanalyzed data shows polychaete worms, snails, and clams dominate the diet of king crabs.

Data collected on distribution, relative abundance, and feeding habits of epifaunal invertebrates should allow us to address the task objectives for the Kodiak shelf project.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Sometime between August 24 and October 30 a green trunk containing OCS gear and collection supplies was taken from its storage at the NMFS Gibson Cove Facility. Replacement supplies, not budgeted, such as calipers, a

balance, specimen bags, reference books, and other field sampling materials had to be purchased prior to the November sampling date. Although the supplies were in a locked area, many other OCS investigators also share the facility. The trunk, though well labeled, was presumably taken by mistake. The gear has not been recovered to date. Proper security must be available for OCSEAP equipment.

BERING SEA AND GULF OF ALASKA

I. TASK OBJECTIVES

A. Inventory and census of dominant species.

B. Description of spatial and seasonal distribution patterns of selected species.

C. Provide comparison of dominant species distribution with physical, chemical and geological factors.

D. Provide preliminary observations of biological interrelationships between selected segments of benthic marine communities.

II. FIELD AND LABORATORY ACTIVITIES

A. Grab Program

1. No cruises were scheduled for this quarter.
2. No data analysis was scheduled for this quarter.

B. Trawl and Pipe Dredge Program

1. No data analysis of trawl and pipe dredge material from the Bering Sea was scheduled for this quarter.
2. Preliminary analysis of trawl data from NEGOA Port Etches, Zaikof Bay and Rocky Bay has been initiated in Hinchinbrook and Montague Island.

III. RESULTS

A. Grab Programs

1. The Final Report for NEGOA is in its final draft stage, and should be submitted in the next quarter.
2. The Final Report for the Bering Sea is in the final stages of organization. A master's thesis examining the infauna is in the final stages of preparation, and will be incorporated as an appendix to the final report.

B. Trawl and Pipe Dredge Program

1. The NEGOA trawl report was completed and submitted in the last quarter.
2. The trawl data from bays adjacent to Montague and Hinchinbrook Island, has been tabulated on coding forms and should be submitted for key-punching in the next quarter.
3. The Final Report for the Bering Sea is in the final stages of organization.

IV. PRELIMINARY INTERPRETATION OF RESULTS

General interpretations of data are included in the 1976, 1977 and 1978 Annual Reports and Institute of Marine Science Technical Report R76-8. Additional comments will be included in the Final Reports.

V. PROBLEMS ENCOUNTERED

No direct problems, but see comments in previous Quarterly Reports concerning lack of food data in NEGOA and sparse data for the Bering Sea.

LOWER COOK INLET

I. TASK OBJECTIVES

A. Inventory and census of dominant species.

B. Description of spatial and seasonal distribution patterns of selected species.

C. Provide comparison of dominant species distribution with physical, chemical and geological factors.

D. Provide preliminary observations of biological interrelationships between selected segments of benthic marine communities.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Activities

All field activities have been completed.

B. Laboratory Activities

1. Data on the following subjects have been collected:

   a. Detailed stomach analysis of snow crab, king crab, dungeness crab, hermit crabs, are completed. Analysis of juvenile snow crab, king crab, adult pink, humpy, coonstripe and sidestripe and crangonid shrimps are in progress.

   b. Examinations were made of a total of 272 specimens of the pink shrimp (*Pandalus borealis*), the humpy shrimp (*Pandalus goniurus*), the coonstripe shrimp (*Pandalus hypsinotus*), and the sand shrimp (*Grangon dalli*) from three different lower Cook Inlet stations on cruises from 27 March to 2 April, 6 to 16 May, 6 to 17 June, and July 1978. Thirty speciments of juvenile *Chionoecetes bairdi* were examined from a cruise of April, 1976. The shrimps were weighed, and measured for their carapace length. Their stomachs contents were analyzed and the observations noted. The juvenile *Chionoecetes* were measured for their carapace width and length, and an analysis was done on their stomach contents.

      From the pandalid and crangonid shrimps observed and from the juvenile *C. bairdi*, a list of prey items in the stomachs was compiled. The frequency of occurrence of food items was noted, and the quantity of the prey species was determined when possible. Whole prey items were measured for their maximum length.

c. Age, growth, mortality, and productivity estimations for selected species of clams have been completed. The data are now being compiled in final form.

d. Dry tissue weights are being determined for organisms from selected grab samples to determine the relative importance of the major groups of infauna to standing stock. This component will not be completed until spring, 1979.

e. A graduate thesis concerning the feeding biology of *Crangon dalli*, an important prey species, is in progress. This study will include:

(1) Detailed microscopic (compound) evaluation of gut contents of *Crangon dalli* collected on LCI cruises in 1978. Thus far, in general terms, identified prey include benthic Foraminifera polychaetes (mostly deposit feeders), small clams, small crustacea and amphipods.

(2) Caustic alkali (KOH) and caustic acid (HCI) digestion of gut contents to determine fraction of sediment present. This work will characterize the extent of the so-called "sediment/detrital" feeding. Additional species of shrimp will be examined by this technique as time permits.

f. All trawl data is being keypunched for final submission to NODC.

2. Bacterial biomass studies

It is apparent that bacteria play an important role in the carbon cycles of ecosystems and specifically in detrital food chains in the ocean (Fenchel and Jørgensen, 1977). In order to be able to measure the association between deposit-feeding invertebrates and bacterial biomass, we have worked on techniques for measuring bacterial biomass which would be applicable to sediment and invertebrate gut contents.

The muramic acid assay was chosen as a measure of bacterial biomass because of its specificity for bacteria. Several methods of measuring muramic acid have been described by various authors (Casagrande and Park, 1977; King and White, 1977; Moriarty, 1975 and 1976).

Initially, we chose the King and White (1977) method for measuring muramic acid due to its relative simplicity. However, we were unable to obtain consistent results when analyzing our sediment samples. We then proceeded with a gas chromatographic (GC) method described by Casagrande and Park (1977). The GC method has been used by Casagrande and Park (1978) to analyze samples from the Okefenokee swamp.

The GC method has yielded reasonable and consistent results when applied to laboratory grown bacterial cultures. However, when applied to our sediment samples, there were interfering substances present which mask the muramic acid peak. Attempts to "clean-up" the sediment samples have been unsuccessful.

Clean-up procedures have involved other chromatographic techniques. Neither thin-layer or Sephadex column chromatography were successful in substantially removing the interfering compounds. It may be possible to purify the samples *via* ion-exchange chromatography. A reliable method for measuring bacterial biomass would be an invaluable tool for comprehending the relationship between deposit-feeding invertebrates and detritus-associated bacteria.

C. Work Planned

All activities for fiscal year 1978-1979 will consist of completing the above components of the project and compiling a final report that will primarily include:

(a) Distribution and abundance of the benthos.
(b) Key species and critical habitats.
(c) Feeding data for key species and major prey species.
(d) Growth and production data for clams.

III. RESULTS

A. The Cook Inlet field program is completed and collected specimens are now being examined in the laboratory. Some data on most species are now available for analysis (see Field and Laboratory Activities section of this Quarterly Report for details).

B. Dry weights of aged clams are now available. Carbon analysis is in progress. Species examined were: *Spisula polynyma, Nuculana fossa, Tellina nuculoides, Glycymeris subobsoleta, Macoma calcarea, Nucula tenuis*. Productivity calculations for these species will be initiated when carbon values are determined.

C. The limited results of the bacteriological studies are briefly discussed in the previous section. These studies will not be continued during the current research period; this phase of the project has been terminated.

D. Of the 181 pandalid shrimps examined, the major prey items were polychaetous annelid and crustacean remains. Sponge spicules and molluscan fragments were also found, but not as frequently. Diatoms were present in some specimens, and were especially prevalent in the pink shrimp (*P. borealis*) at Station 37 from the May 1978 cruise (Table I).

E. Ninety-one crangonid shrimps were examined. The major food items found were polychaete fragments and crustacean remains. Molluscs, when present, were often whole. Occasionally, the sediment found in the stomachs appeared to be the remains of polychaete worm tubes. Diatoms commonly occurred in stomachs but not in large numbers. Nematodes of at least two different species were present in many of the *Crangon dalli* stomach contents from the June cruise at Station PME1 1.

F. The *Chionoecetes bairdi* stomachs contained predominantly polychaete and crustacean remains. There were some molluscan fragments and many diatoms in the samples. Large amounts of sediment were present in many of the stomachs (Table I).

IV. PRELIMINARY INTERPRETATION OF RESULTS

The pandalid and crangonid shrimps appear to be opportunistic in their feeding habits. The presence in shrimp stomachs of deposit-feeding polychaetes (Spionidae, Maldanidae, Terebillidae) and protobranch clams (*Nuculana* spp., *Nucula tenuis*), as well as crustaceans that feed on these polychaetes and clams, emphasizes the important role of sediment in the life of these shrimps. The large numbers of diatoms (Thalassiosiraceae) present in *Pandalus borealis* stomachs in May, appears to demonstrate the seasonal influence a phytoplankton bloom may have on an area and the possible trophic importance of diatoms as a food resource at certain times of the year.

General interpretations of all other data are included in the 1978 Lower Cook Inlet Annual Report. Additional comments on the work in progress will be included in the Final Report.

FOOD ITEMS OF *PANDALUS* SPP. AND *CRANGON DALLI*, NUMBER OF SPECIMENS EXAMINED, AND DATES OF COLLECTION OF MATERIAL FROM LOWER COOK INLET[1]

Pandalus borealis C. I. St. 37	50 specimens 78/05/16	Diatoms (especially Thalassiosiraceae)- abundant in large quantities Polychaeta - common Mollusca - not present Crustacea - abundant
Pandalus borealis C. I. St. 37	50 specimens 78/07/20	Diatoms - few Polychaeta - common Mollusca - few (Bivalvia) Crustacea - abundant
Pandalus hypsinotus C. I. St. 37	50 specimens 78/07/20	Diatoms - few Polychaeta - abundant Mollusca - few (Bivalvia) Crustacea - abundant
Pendalus goniurus C. I. St. 62 A Tr. 13	24 specimens 78/03/30	Diatoms - few Polychaeta - common Mollusca - few (Bivalvia) Crustacea - abundant
Crangon dalli PMEL 1	50 specimens 78/06/14	Diatoms - abundant - in small quantities Nematoda - abundant Polychaeta - abundant Mollusca - few (Bivalvia) Crustacea - common
Crangon dalli C. I. St. 62 A St. 13	32 specimens 78/03/30	Diatoms - common Polychaeta - common Mollusca - common (Bivalvia) Crustacea - common

[1]Food items for *Crangon dalli*, *Crangon communis*, and *Pandalus hypsinotus* from C. I. St. 37, 16 May 1978 are not recorded. Only preliminary analysis was available at this time.

V. PROBLEMS ENCOUNTERED

Basically the research program is progressing satisfactorily. The termination of all field activities this year was unexpected, and will make it difficult to complete studies on trophic interactions initiated in 1977-1978. A program seriously designed to understand food relationships in an area, cannot possibly be completed in one year; consequently, the research activities initiated in the 1977-1978 project period were designed for a minimum of two to three years. Additional limited ship time for collection of live material for the second year was essential in order to complete laboratory feeding studies initiated on crangonid (sand) shrimps, a major food resource for bottom fishes in Cook Inlet. It is hoped that some live material may be forthcoming from other investigators during the present research period.

REFERENCES

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King, J. D. and D. C. White. 1977. Muramic acid as a measure of microbial biomass in estuarine and marine samples. *Appl. Environ. Microbiol.* 33:777-783.

Moriarty, D. J. W. 1977. Improved method using muramic acid to estimate biomass of bacteria in sediments. *Oceologia* (Berl.) 26:217-323.

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OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: December 31, 1978

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 15/20[2] R.U. NUMBER: 5/303/281

PRINCIPAL INVESTIGATOR: Dr. H. M. Feder

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates From	To	Estimated Submission Dates[1] Batch 1	2	3	4[3]
			032	032	032	T.B.D.
LCI						
Surveyor	77/11/4	77/11/16	None	3/1/79	None	6/30/79
Surveyor	78/3/27	78/4/2	None	3/1/79	None	6/30/70
Surveyor	78/8/13	78/8/22	None	3/1/79	None	6/30/79
Miller Freeman	78/5/8	78/5/16	None	3/1/79	None	6/30/79
Miller Freeman	78/6/6	78/6/16	None	3/1/79	None	6/30/79
Miller Freeman	78/7/12	78/7/22	None	3/1/79	None	6/30/79
Kodiak						
Yankee Clipper/Commando	78/4/8	78/4/21	None	3/1/79	None	4/30/79
Yankee Clipper/Commando	78/5/1	78/5/22	None	3/1/79	None	4/30/79
Yankee Clipper/Commando	78/6/8	78/6/21	None	3/1/79	None	4/30/79
Yankee Clipper/Commando	78/7/9	78/7/21	None	3/1/79	None	4/30/79
Yankee Clipper/Commando	78/8/8	78/8/23	None	3/1/79	None	4/30/79
Yankee Clipper/Commando	78/11/4	78/11/17	None	3/1/79	None	4/30/79
Miller Freeman	78/6/19	78/7/9	None	3/1/79	3/1/79	4/30/79
Miller Freeman	78/3/21	78/3/24	None	3/1/79	None	4/30/79
Scuba	78/5/4	78/10/30	None	None	None	4/30/79

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4[3]
			032	032	032	T.B.D.
Scuba	78/5/4	- 78/5/19	None	None	None	4/30/79
Negoa						
Searcher	78/7/27	- 78/8/8	None	6/30/79	None	Limited data 8/1/79

Note: (1) Data Management Plan and Data Format have been approved and are considered contractual.

(2) Only data which have not been submitted are listed.

(3) Data batch 4 is feeding data, the proper format for submission is to be determined.

Data batch 1 = Grab data, File Type 032

2 = Trawl data, File Type 032

3 = Pipe dredge data, File Type 032

Fiscal Report

Contract: 03-5-022-56

Task Order: #15

Date: December 22, 1978

Category	Billed this Quarter	Cumulative Billed
Salaries and Wages	$40,155.06	$267,238.89
Travel	1,807.51	20,726.15
Equipment	195.00	7,777.40
Other	29,237.20	260,885.62
Staff Benefits	6,908.46	44,542.58
Overhead	19,924.25	132,972.52
Total Billed	$98,227.48	$734,143.16
Total Award		$831,278.00
Total Unbilled		97,134.84

These data are taken from University of Alaska vouchers submitted in the three months prior to the above date.

QUARTERLY REPORT

NOAA-OCSEAP
Contract No. 03-5-022-68
Research Unit #6
Reporting Period: 1 October - 31 December 1978

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

Andrew G. Carey, Jr., Principal Investigator
School of Oceanography
Oregon State University
Corvallis, Oregon 97331

26 December 1978

Andrew G. Carey, Jr.
Principal Investigator

I. Abstract

Laboratory research this quarter has included additional infaunal grab sample processing and the identification of large benthic macro-infauna (>1.0 mm in size). A major effort has been placed on the small fraction (0.5-1.0 mm) of the 1975-76 year-round samples from the standard OCSEAP Pitt Point Station Transect in support of further analysis of the seasonality of the continental shelf benthic communities. Food web analysis and synthesis continues. Many of the coastal (5-25 meters depth) polychaete wrom species have been identified. Identification and verification of earlier identifications of species from earlier benthic infaunal samples continue. A summary of research and preliminary conclusions is included in the report.

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 (>1.0 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-78) 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 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 numerical density, biomass, and gross taxonomic composition of the coastal benthic macro-infauna will be obtained from grab samples taken at stations on the inner continental shelf and coastal zone. These samples were collected during the summer of 1976 on the R/V ALUMIAK. This research is in large part supported by supplemental funds from NOAA/BLM in response to a letter proposal of April 5, 1977. This research will continue throughout the FY-78 contract year.

3) Objective 3 - Benthic macro-infaunal ecology

a) Further identifications of abundant species will be undertaken from samples collected in the southwestern 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.

III. Field and Laboratory Activities

A. Field activities - OCS 8

1) Ship Schedule

During the period 15 August - 15 September 1978, Research Unit #6 participated in the second integrated food web cruise to the southwestern Beaufort Sea on board the USCGC NORTHWIND. The biota through the water column to the sea floor were sampled at selected areas on the inner shelf to define trophic inter-relationships.

2) Field Scientific Party (OSU Benthos)

a) R. Eugene Ruff OSU Research Assistant (OSU Benthos Group)
b) Bruce Caldwell OSU Research Assistant (Temporary)

3) Field Methods

a) Benthic macro-infauna (> 0.05 mm) were sampled by 0.1 m^2 Smith-McIntyre bottom grab at selected stations. Five to ten quantitative samples were obtained at each station to provide adequate estimates

of quantitative variability and a sufficient number of species for description of the community composition. Several shallow stations were occupied from a hovering U.S. Coast Guard helicopter. The samples were washed on shipboard with 0.42 mm aperture screens to retain the macrofauna. The samples were temporarily preserved in 10% neutralized formalin and shipped back to Oregon for laboratory analysis. Subsamples for sedimentological analyses were taken from each grab and were stored deep-frozen.

b) Benthic meiofauna (0.064-0.5 mm in size) were subsampled by coring from the Smith-McIntyre grab and a 0.1 m^2 spade box-corer.

d) Pelagio-benthic invertebrate fauna were sampled by hauling a 0.5 m^2 zooplankton net adjacent to the sediments on the inner shelf in the lease area from a helicopter. A Hessler-Sanders epibenthic sled was also utilized.

d) Mega-epifauna were sampled at selected stations east of Barter Island by a 10-foot otter trawl.

4) Sample localities

As planned, a series of stations were occupied on the inner continental shelf in the southwestern Beaufort Sea from Point Barrow to Demarcation Point. A total of 97 grab and 4 otter trawl samples were collected (Tables 1-3). Several Hessler-Sanders epibenthic sled and 0.1 m^2 box core samples were also attempted. The inshore environment and the BLM oil lease area were most heavily sampled. The third year of samples was collected from the standard OSU Benthos stations off Pitt Point to determine the temporal variability of the benthic infaunal communities across the continental shelf.

B. Laboratory Activities

1. Laboratory personnel

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

Responsibilities: coordination, evaluation, analysis, and reporting

b. James Keniston — Research Assistant (Part-time)

Responsibilities: data management [NB: Gish resigned from the position on 9 March 1978. Mr. Keniston was hired as a part-time temporary replacement.

c. Paul Montagna — Research Assistant

Responsibilities: sample processing, biomass measurements, crustacean systematics (Harpacticoid Copepoda and Gammarid amphipoda) and field collection.

d. R. Eugene Ruff — Research Assistant

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

e. Paul Scott — Research Assistant

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

2. Laboratory Methods

No changes have been made in our standard laboratory methodology this quarter. See previous reports for our standard laboratory procedures.

3. Data Analyzed

a. Numerical density of macro-infauna.

Faunal densities for the small fraction of the macro-infauna are reported in Tables 1 through 4. These are the first results to be derived from the more detailed analyses of the NOAA-OCSEAP PPB Transect for the definition of temporal changes in community structure and in the dominant species populations present. By analyzing the relative numbers of small individuals and juveniles, we can determine if recruitment occurs at a particular time of year. Note that the small macrofauna can form a large portion of the animal densities (Table 4).

b. Systematics.

(1) Polychaete Species Identification

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 continued throughout the quarter. Identifications are by R.E. Ruff. A summarization of polychaete families and species encountered is found on Table 5. Identifications will be verified with the cooperation of Dr. Kristian Fauchald of the University of Southern California.

(2) Pelecypod Mollusc Species Identifications

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 6.

4. Milestone Chart and Data Submission Schedule

a. The up-dated 1977-78 laboratory schedule is shown in Figure 1.

b. Explanation of schedule changes

1. Milestone number 5, species identifications, has not yet been reached; this is a continuing effort. Detailed data, i.e. species, numerical density and distribution, of polychaetous annelid worms have been submitted in digital format on magnetic tape for samples from the U.S. Coast Guard icebreaker GLACIER cruise, WEBSEC-71. An up-date of pelecypod mollusc and harpacticoid copepod species is also included in this report.

2. Milestone 6, sediment analyses, have now been completed for the 1976-77 samples taken from the benthic stations.

3. Milestone 7, WEBSEC-OCS epifaunal photo survey summary, is being completed. Selection of computational techniques have delayed completion.

4. Milestone 8, WEBSEC-OCS infaunal survey summary, is underway. confirmation of species in several taxonomic groups has been delayed.

5. Milestone 10, benthic food web analysis and synthesis, is underway. A preliminary summary has been achieved.

N.B. Digital data transmittal via magnetic tape has not been completed this quarter. After discussion of this research objective with Toni Johnson of the Arctic Project Office, it was decided to defer data transmittal to the final report of the contract by RU #6. Owing to the necessary lag time in data transmittal caused by the long process of species identification and verification, RU #6 has had to continue to update past tape records. This procedure has caused a significant expenditure of time and effort by EDS. By mutual agreement it was decided to delay data transmittal until the final report at which time a complete and verified tape of all data analyzed to date will be transmitted by magnetic tape to the NOAA-OCSEAP data base.

O - Planned Completion Date

X - Actual Completion Date

RU # 6 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
Foodweb Research															
Macro-infaunal analysis										O					
Macro-epifaunal analysis													O		
Predator GI tract analysis										O					
Prey species distribution summary												O			
Yearly variability															
PPB macro-infaunal analysis							O								
Quarterly Report				X			O			O			O		
Annual Report							O								
Data - analysis			X			O			O			O			
transmittal													O		

* See explanation on following page.

IV. Preliminary Interpretation of Results

A. General Summary of Research and Conclusions to Date

ABSTRACT

Summary of Objectives, Conclusions, and Implications with Respect to OCS Oil and Gas Development.

Extensive exploration and development for oil and gas on the Alaskan and Canadian continental shelf have the potential to significantly influence the marine environment of the Beaufort Sea. It is impossible with our present knowledge to accurately predict the consequences of petroleum development on the marine benthos.

The past and continuing goal of this project has been to acquire the knowledge of the ecology of benthic invertebrate faunas of the Beaufort Sea continental shelf necessary to evaluate the consequences of offshore oil and gas development. The distribution and abundance of the fauna has been examined in detail with studies of the spatial and temporal variability of these. These data will provide a baseline against which future changes in the benthic environment and community structure can be evaluated. Of current importance are: (1) the definition of temporal changes in sublittoral community structure, (2) the determination of the life histories and secondary production estimates of dominant and ecologically important species, (3) the description of the benthic food web, and (4) the study of the ecology of benthic invertebrates important as prey organisms to the marine mammals, birds, and fishes. Now that broad ecological patterns of benthic invertebrates on the Beaufort Sea shelf are becoming fairly well known, it is imperative to define the dynamic processes maintaining temporal and spatial structure.

I. Introduction.

A. General nature and scope of the study.

The present benthic ecological studies on the continental shelf 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 (>1.0 mm) are defined at stations across the 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 and to the biological relationships 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. Abundance patterns provide data on potentially productive areas of the shelf that may support the large and important top predators. Biological and ecological information on important prey species are necessary for an understanding of the functioning of the oceanic food web.

The development of the research on the continental shelf benthic invertebrates has proceeded along a logical sequence. As very little was known about the fauna at the initiation of the exploration and developmental phases of the oil and gas fields on the Alaskan North Slope, the early research involved basic survey work on the 1971 and 1972 U.S. Coast Guard oceanographic cruises in the Beaufort Sea, WEBSEC-71 and WEBSEC-72. Initial processing and analysis of bottom grab and otter trawl samples and bottom photographs were sponsored by the Oceanographic Section of the National Science Foundation by a grant to the Principal Investigator.

When NOAA, under sponsorship of BLM, started an environmental assessment research program around the continental shelves of Alaska, Oregon State University participated in the benthic program in the Beaufort Sea. A combination NSF and NOAA/BLM research program supported several approaches and phases of research. Detailed analysis of benthic communities and identification of the total polychaete worm fauna over a wide range of depths could be accomplished uder the National Science Foundation's auspices. Further continental shelf survey sampling could be continued under the OCSEAP with the cooperation of the Coast Guard and their Beaufort Sea icebreaker program. With NOAA's interest and logistics support, seasonal sampling and study of temporal changes in the continental shelf communities could be accomplished for the first time.

During the first year of operation a major objective of Task Order #4 for RU #6 was to summarize the literature and unpublished data. The majority of this information came from the work-up of the samples and the analysis of the data already on hand at Oregon State University as a result of participation in the WEBSEC program. The objectives for Task Order #5 under the present research contract for RU #6 emphasize the delineation of the benthic food web and the description of the coastal benthos. Efforts to characterize the composition of the Beaufort Sea fauna to the species level are continuing as this is a critical step toward understanding the dynamics of the benthic ecosystem. Detailed studies on temporal changes in the continental shelf benthic communities continue.

II. Methodology

A. Sampling locations

The OSU benthos group has now occupied stations across the Beaufort Sea from Point Barrow to Demarcation Point. (Figure /). Work in the Beaufort Sea began in 1971 with the first WEBSEC cruise. During WEBSEC-71 Smith-McIntyre grab stations were occupied from Cape Halkett to Barter Island at depths ranging from 25 meters to 2500 meters. The samples gathered at these stations yielded our first look at the Beaufort Sea macro-infauna. The following year (WEBSEC-72) both otter trawl and bottom photography stations were taken in geographic and depth zones similar to WEBSEC-71. The combination of data from otter trawls and bottom photographs gives good density and species composition estimates of the larger mega-epifauna (see Gear below).

OCS sampling began in fall 1975 with the first benthic seasonal ice stations along the Pitt Point transect at depths from 25-100 meters. Ice stations were also occupied in the winter, spring and fall of 1976 along the Pitt Point and Narwhal Island transects. The samples from these stations yielded macro-infauna data which was used to formulate the hypothesis of Beaufort Sea seasonality. Two cruises in the summer of 1976 aboard the R/V ALUMIAC and the USCGC GLACIER widely expanded the previous macro-infauna coverage. Inshore stations (5-25 meters) along the Point Barrow, Pitt Point, Pingok Island, Narwhal Island and Barter Island transects were covered during the R/V ALUMIAC cruise. During the 1977 USCGC GLACIER summer cruise new macro-infauna stations were added at depths to 3700 meters and as far east as the Canadian Border (Demarcation Point).

B. Through-the-ice benthic sampling

Techniques and gear have been developed by the OSU benthic group for sampling benthic infauna at standard seasonal stations from the sea ice in the Beaufort Sea. The field strategy is based on mobile logistic support with daily field trips out on the ice via helicopter. Techniques and equipment have been oriented toward maneuverability and speed as time is critically short on these daily ice expeditions.

A benthic ice station is first located along the transect line with navigational assistance from the nearest DEW radar station. Water depth is also an important criterion for station position as most benthic organisms are distributed in depth zones. The water depth is determined with a small, insulated, electronic depth sounder (Data Marine, Model 2600).

When the desired position and depth are located actual station preparation begins with the cutting of a 4-foot square hole through the ice. A chain saw and an 8 inch power ice auger are used as the main cutting tools. The ice auger is used to drill holes in each corner of the 4-foot square and an additional hole in the center. The chain saw then cuts around the perimeter of the square and diagonally to the center auger hole. The large ice blocks made in this procedure are pushed down in the water and under surrounding ice leaving a usable sampling hole.

After the sampling hole is complete, a steel pipe (1-1/2" diameter) tripod is rigged over the hole with one block at the apex and one at the base of one leg. The wire (3/16" diameter) wire is led first through the lower block, then

through the upper one and finally is fastened to a roller bearing swivel and to the 0.1 m^2 Smith-McIntyre grab. For stability the tripod legs are placed into 2-3 inch deep holes chipped in the ice. Opposite the grab stand a guy line is attached from the upper tripod to a 1 inch aluminum pipe imbedded in the ice to counteract any lateral force exerted by deploying and retrieving the grab to and from the hole. The portable gasoline powered hydro winch (Hydro Products, Model No. HR35B) is placed on the ice to one side and positioned so the wire feeds freely to the lower block on one tripod leg. The winch is secured in place by 4 1-inch aluminum pipes sunk into predrilled 1-1/2" holes bored into the ice by a hand auger. The light weight grab stand made of a folding aluminum angle form is placed next to the hole between two tripod legs. It also is secured in place by 2 1-inch aluminum pipes.

These procedures vary from season to season as weather and ice conditions change. For example: when the temperatures are below 20°F (fall, winter) the bottom grab will ice up as soon as it comes out of the water, and it is a full-time job to keep blow torches operating to de-ice the grab. In milder spring conditions this is not a problem. The ice hardness and thickness is also seasonally different making station site selection highly variable. In the fall (October) most of the ice was freshly frozen and about two feet thick so that the right ice conditions could be found on a given site. In late winter (March) refrozen leads were reasonably abundant and 1-2 foot thick ice could be found after a thorough search. Late spring conditions (May) were found to be the most difficult of all. Because the temperatures were higher, refrozen leads tended to be only 1-6 inches thick. Pack ice which may be between 3-10 ft. thick would not be suitable for quickly cutting a large hole during the one day field trip. Left with no alternatives, stations were erected over narrow, open leads in the ice. Many special safety procedures were employed during these stations to ensure security of personnel and equipment in case of sudden ice shifting.

The OSU benthos group is now confident that a technique has been developed and refined, so that through-the-ice sampling programs can be carried out reliably and successfully in all seasons.

C. Gear

Several different pieces of equipment are necessary to adequately sample the benthic fauna in the Beaufort Sea. The Smith-McIntyre grab has been used to sample the infauna in shallow to moderate depths. For normal routine sampling, this instrument has proven both efficient and effective. For sampling in very dense sediments at great depths, a 0.25 m^2 box corer has been utilized. This sampler collects large volume, high quality samples that yield accurate estimates of infaunal population densities, and species composition.

The larger epifauna has been sampled when ice conditions permit with a four meter otter trawl. Although qualitative in nature, these trawls effectively capture the rarer organisms and greatly aid in elucidating the overall species distributions. Quantitative estimates of the larger epifauna have been accomplished through bottom photography with an EG & G model 205 deep-sea camera system. Large organisms can be easily counted from the photographs, and the otter trawl collections will aid or confirm species identifications.

The multiple screen cascading sediment siever, a new system for washing benthic infaunal samples was designed, built and field tested in the first quarter of 1976. The sieving system consists of a wash box, three tiered sieve boxes (appertures of 0.6 cm, 1.0 mm and 0.42 mm) and a built-in water supply. Each tiered sieve receives the successively screened water, animals and sediment from the larger aperture sieve above it. The water, sediment and animals cascade from one sieve box to the next and finally flow through the 0.42 mm aperture sieve. All sediment and animals smaller than 0.42 mm are discharged through the discharge spout at the bottom of the system. Field tests on the multiple screen siever have proven the system to be compact, efficient and gentle enough to maintain most of the organisms in excellent shape. The new system has cut our field washing time in half when compared to conventional sieving methods.

D. Laboratory Analysis

Sample analysis at the Oregon State University benthic laboratory follows a five step labor intensive procedure: 1) laboratory washing and sorting into large macrofauna (>1.0 mm) and small macrofauna (0.5 mm to 1.0 mm), 2) initial picking and sorting of animals into major phyla, 3) determination of wet weights for biomass estimates, 4) counting and resorting of samples into finer taxonomic groups and 5) final species identification. Over 350 quantitative samples from the Beaufort Sea have been processed through step 4 in the past two and one half years. Species identifications of dominant animal groups continues at a steady rate. Estimates of time expended to produce quantitative species data (steps 1-5) have yielded a figure of 98 total man-hours per sample.

New techniques for laboratory sample washing (step 1) were developed in the second quarter of 1976. The new sample washer was devised in order to decrease man hours spent on the process and to increase laboratory efficiency. The sample washer is a simple sprinkler system placed over a series of three sieves (apertures of 9.5 mm, 1.0 mm and 0.42 mm). Water is sprinkled over the entire sieve surface, gently washing the sample with a minimum of effort or attention from laboratory personnel. Samples processed by this method have proved to be very well washed with little or no damage to the animals.

In the third quarter of 1976 a new technique for wet-weight determination was evolved. A millipore filtering apparatus is the backbone of the new method. Animals sorted into major phyla are washed directly from the sample vial into the filter apparatus. By slowly applying a vacuum the liquid is gently drained through the apparatus leaving the animals on a tared filter. The filter, with animals, is removed from the Millipore holder and weighed to the nearest 0.1 gram on a Mettler top-loading balance. The invertebrates are then washed directly back into sample vials. Throughout the entire process the animals are never manipulated with forceps or other potentially damaging instruments. Using this technique exposure time (i.e. dessication time) in air is generally less than one minute. Total weighing time for each animal group is approximately four minutes. The advantages of the method include: (1) decreased damage to animals through dessication and manipulation, (2) faster weighing times, and (3) increased precision of results.

III. Results

A. Coastal Fauna (5-25 meters depth) Abundance Patterns

The coastal large macrofauna (>1.0 mm) are generally more abundant inshore at 5 or 10 meters depth (Figure 2). Polychaetes comprise 70-85% of the total infauna in this zone. Biomass, in contrast, does not peak with density indicating that these organisms are small in size on the average (Figure 3).

The minimum numerical abundance zone at 15-25 meters depth coincides with the sea ice shear zone between the landfast ice and the moving polar pack. However, detailed studies of the effects of ice gouging on the benthic community are necessary before causality is assigned to this physical phenomonon.

When a grab sample contains a high concentration of peat, it often has a large number of organisms associated with it. Perhaps the peat acts as a source of detritus and organic materials for the benthic food web.

The range and variability of the biomass of the large macro-infauna (>1.0 mm) across the continental shelf off Pitt Point are similar to the remainder of the southwestern Beaufort Sea observed from grab samples taken in 1971. The numerical density on the Pitt Point Transect has a much greater variability. Perhaps the observed seasonal cycles are the cause for this greater range.

B. Continental Shelf Abundance Patterns

Abundance patterns on the continental shelf have been analyzed using two measures of standing stock, numerical density (Figure 4).
In the southwestern Beaufort Sea animal numbers appear to follow a bimodal distribution with increasing depth. Densities of up to 5000 organisms/m^2 can be found near shore between 5-15 m. Numbers decrease in the ice-gouging zone (20-40 m) and then increase again reaching maxima over the shelf edge on the upper slope. However, this pattern is not true east of Barter Island where numbers do not increase past the ice-gouging zone, indicating a different ecological environment. The deep-sea environment is also very different exhibiting very low density and standing stocks.

Similar trends can defined in the biomass data for the Beaufort Sea as with numerical density, though less clearly defined. High standing stocks are encountered on the nearshore shelf between 5-15 meters. These decrease through the ice-gouging zone and increase again to the upper slope, particularly in the Cape Halkett region. But east of the Colville River the trend is less clear and seems to reverse east of Prudhoe Bay, rather than as far east as Barter Island as in numerical density. Again, deep-sea values are very low.

It appears as if the inshore communities are comprised of numerous but small organisms, which decrease as an available food source in the ice-gouging zone. The shelf slope community are large and of larger sized organisms.

The zone east of the Canning River is probably ecologically different than other inshore areas.

The deep-sea fauna is small and sparse.

C. Seasonal Abundance Patterns

Findings from grab samples taken seasonally across the Beaufort Sea continental shelf off Pitt Point in 1975-76 have revealed that the biomass and total numerical abundance of the benthic community change throughout the year. On the outer shelf, the magnitude and periodicity of the fluctuations are indicative of an annual reproductive cycle with a seasonal peak in recruitment. These fluctuations are not encountered at the shallowest shelf station.

The benthic assemblages at the 55 m, 70 m and 100 m stations on the outer portions of the continental shelf shows marked variations in numerical density (Figure 20). An average trend for these stations outlines an increase in animal abundance occurring in the spring. A maximum of 8,500/m^2 is reached in May, and a subsequent decline occurs throughout the summer and fall. This pattern suggests a seasonal recruitment to the (>1.0 mm) benthic community beginning early in the year, and a decline later in the year which might be attributed to predation or competition.

Variations in biomass at these outermost shelf stations also suggest a seasonal trend (Figure 21). The average biomass maximum for the soft-bodied organisms appears in August, however, and not in May when peak densities occur. This pattern could be caused by growth of the individuals after their spring recruitment into the benthic population. High growth rates would have to exist to account for this seasonal increase. The average biomass values decrease through the fall and winter to a minimum in March, implying limited food inputs coupled with continued predation on the benthic community.

In contrast to the outer shelf, the total yearly range in infaunal abundance and biomass at the shallowest shelf station (25 m) vary within much narrower limits and do not exhibit a seasonal pattern. This station lies within the shear zone and is subject to active ice gouging. The benthic community at this depth may be adapted to episodic destruction and could be characterized by the presence of opportunistic species with asynthronous reproductive cycles.

D. Species Distributions

Gammarid amphipods were examined in detail along the Pitt Point transect at depths of 25, 40, 55, 70, and 100 m. Over 100 species were found, including representatives of 21 families (see annual report of March 28, 1978, Table 4).

Charts of species distributions provide clear evidence of depth zonation in the amphipod fauna across the continental shelf: distinct amphipod assemblages are identifiable from inner, middle, and outer shelf depths. The number of amphipod species increases with increasing depth on the continental shelf, partly because middle shelf forms are also found on the outer shelf. The number of amphipod specimens per m^2 shows a similar increase offshore, which may be related to increased habitat stability (absence of ice gouging). As many amphipods are epibenthic and frequently swim above the bottom, the numerical densities of the amphipod fauna across the continental shelf are an indication of food resources available to marine birds and fishes in the western Beaufort Sea.

In addition to the use of amphipod species data to understand the role of the benthos in the Beaufort Sea ecosystem, species data on the polychaetous annelids is presently being analyzed. To date 125 species have been encountered (see annual report of March 28, 1978, Table 3), including 15 undescribed taxa (new to science). Completion of the sorting and identification of the polychaetes at 24 stations arranged along 5 transects in the Western Beaufort Sea has recently been completed, and species data are now available for analysis. Of the 22,399 polychaetes examined, less than 2.4% were not identified to species. Most often when identifications could not be made the specimens were damaged and key characters were missing.

The maximum number of species found along the five transects occurs on the outer continental shelf (45-135 m). Although reasons for the observed species richness maximum on the outer continental shelf remain unclear, habitat disturbance inshore by the ice keels of pressure ridges, and decreased nutrient inputs beyond the outer continental shelf - upper continental slope zone may be contributing factors.

Habitat disturbance inshore and decreasing nutrient inputs offshore may also be postulated as factors influencing the total abundance of polychaetes across the continental shelf and slope, although these hypotheses remain untested. Comparison of abundance maxima along the continental shelf and slope indicates a shift from an upper continental slope maximum in the three western transects to an outer continental shelf maximum in the two eastern transects. Note also that the abundance maximum decreases from >2100 polychaetes/0.5 m^2 in the westernmost transect to 110-1350 polychaetes/0.5 m^2 in the two easternmost transects. The inshore shift of the abundance maximum and the eastward decrease of the abundance maximum may be due to the presence of Bering Sea water in the westernmost portion of the Beaufort Sea. Particulate matter entrained with the Bering Sea water may be falling out of the water column and enriching the benthic community on the upper continental slope and outer continental shelf in the westernmost Beaufort Sea. Further analysis of the polychaete data will provide insight into these and other phenomena. Since polychaetes are often a substantial portion of the diet of bottom feeding fish, polychaete species richness and abundance data may be interpreted as an indication of prey availability for those species of fish.

E. Species Groupings

Numerical analyses have been initiated to examine in greater detail the spatial patterns exhibited by the benthic community on the continental shelf in the Beaufort Sea. Most of these analyses have been accomplished on the samples taken during the WEBSEC cruises in 1971 and 1972 since these samples have the most species data available.

A cluster analysis was performed on 30 benthic invertebrate species at 27 stations occurring across the continental shelf and upper slope. A matrix of the SIMI similarity indices (Stander, 1970) was clustered using a complete linkage algorithm (Sneath and Sokal, 1973), and phenograms were generated to visually present the results (Figure 6).

Four station groups, labeled 'A' through 'D', were generated by the clustering procedure. In general, these groups occurred in bands with east-west axes, and were situated across the continental shelf as a nearshore group ('B'), a midshelf intermediategroup ('C'), and a group of stations along the outer portion

of the shelf ('A'). The 'D' group was confined to the western portion of the study area along the outer edge of the shelf. These station groupings reveal an anomalous area off the mouth of the Colville River, and the migration inward of the outer shelf station type off Barter Island.

The phenogram of the 30 benthic invertebrate species (12 gammarid amphipods, 11 cumaceans, 7 pelecypods) resulted in five distinct groups (I-V) (Table 1). These groups could be generally correlated with the station groupings as follows:

Group I. cosmopolitan, found at station groups A, B, C and D

Group II. outer shelf organisms, found at station group A but rare at group D stations

Group III. species found east of 15°W, at station groups A, B and C

Group IV. shallow water organisms, station group B

Group V. species found west of 150°W, at station group D/

The species groupings indicate that the Beaufort Sea continental shelf can be divided into a western and eastern region with the division at ∿ 150°W. The Colville River may have a significant influence on the benthic community in the western region. The eastern portion is again divisible into inner-shelf and outer-shelf species groups. The outer-shelf organisms tend to occur in shallow water to the east off Barter Island.

Fager's recurrent group analysis (Fager, 1957) was employed to examine the station and species affinities between the large epifauna organisms captured in the otter trawls in 1971 and 1972. This analysis uses an index derived from the geometric mean of the proporation of joint occurrences of each species based on their presence or absence at each station. Thirty-four epifaunal species (17 Arthropoda, 17 Echinodermata) were selected for analysis, and the percentages of these species in common at each of 20 trawling stations were plotted and ranked on a trellis diagram (Figure 12). Recurrent groups were then determined according to criteria outlined by Fager which combines the largest number of species having mutual affinities.

Results of the epifaunal analysis reveal that the trawl stations are also situated across the continental shelf with east-west axes (Figure 13). The strongest affinities tended to occur along the depth contours in the inner- and mid-shelf regions. The deepest stations had reduced affinities with the shelf trawls. The area round Barter Island appeared to be anomalous in terms of epifaunal species in common with trawls taken further to the west.

When the epifaunal species were examined in detail, several groups could be discerned (Figure 14):

Group A - cosmopolitan, occurs all across the shelf
Group B, Group D - occur along the outer shelf
Group C - occur along the inner shelf

G. Bibliography (Papers derived from OSU Benthos Beaufort Sea research)

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Montagna, P.A. Two new bathyal species of Pseudotachidius (Copepoda, Harpacticoida) from the Beaufort Sea (Alaska, U.S.A.). (In Press, Crustaceana)

F. Trophic Interactions

Trophic interactions among the benthic organisms are complex and often unknown (Figure 22). Often many feeding types can be found in one taxon, and many species as omnivores can have multiple sources of food. Research indicates that in general the detrital food web is an important energy source. The actual details of energy transfer are unknown, however, the role of bacteria and the small invertebrate fauna (microfauna and meiofauna) are little understood. Because of the seasonal environmental changes, predator migrations and biological cycles, the food web and relative use and flow of energy in the ecosystem will change throughout the year. Major pathways of energy are probably habitat related and depend on the structure of the individual communities.

Measures of standing stocks demonstrate where food sources are potentially available, and infauna-epibenthic interactions demonstrate trophic relationships. Taxonomic information describes which organisms are dominant in the benthic ecosystem.

Preliminary foodweb data for the continental shelf invertebrate benthos have been summarized (Figure 23). The deposit feeders and omnivores are the most important feeding groups.

G. Relevance to Problems Associated with Petroleum Development.

Extensive exploratory and production drilling for petroleum on the Alaskan and Canadian continental shelf has the potential to significantly influence the marine benthic environment and its associated biota. It is impossible with the present state of our knowledge of the benthos and the Arctic environment to accurately predict either the long or short term consequences of oil and gas development on the marine invertebrate benthos and the benthic food web. Only recently has descriptive baseline data on species distribution, composition, and abundance become available with estimates of variability in space and time.

These data can be used as comparisons against which to assess the extent of major impacts on the benthic environment. These are a first step toward understanding the role of the sea floor fauna in the Beaufort Sea ecosystem and effects they might suffer from a major oil spill.

The objective of the second phase of the benthic ecological research is oriented toward the elucidation of energy pathways within the benthic food web, and the maintenance of community structure through the population dynamics of dominant species. When the major pathways of carbon flow within the benthic food web and to major marine mammal, bird and fish predators are known then critical pathways (e.g. dominant prey species) can be evaluated for their sensitivity to oil and other forms of pollution caused by man's activities off the northern Alaskan coast.

The measurement of rates and processes within the food web is ultimately a more difficult task but one that would allow more accurate estimates of environmental impacts. Changes in the metabolism, assimilation, growth and reproductive rates of species populations can be used to determine the extent of chronic effects of pollution (Widdows 1978). The partitioning of energy production and use in the benthos and ecosystem would provide a clearer understanding of the functioning of the ecological units and the degree to which they may be imparted by oil exploration and production.

Our (RU#6) benthic research on year-round reproductive activity of dominant benthic species on the continental shelf on the benthic food web, particularly in regards to marine mammals, birds, and fishes seeks to define some of the functional interactions among the community components. These must be known before the effects of environmental impacts can be predicted.

The benthic invertebrates constitute a major source of food for the top level carnivores, including birds, seals, and occasional walrus. Any decrease in benthic populations caused by oil pollution might eventually be reflected in the populations of these larger animals. Nearshore areas would be most sensitive since it would be in these regions that pollutants would be most likely to mix to the benthic boundary.

The timing of environmental disturbances in this strongly seasonal environment may be extremely critical in determining the stresses experienced by the benthic community. For example, an oil spill in the winter on top of the pack ice could be cleaned up with little or no resultant damage to the marine benthos, while a spill of the same magnitude during a summer of open water might have significant impact. It remains to be determined if the bottom-dwelling invertebrates are more or less sensitive to oil related pollution during the summer months, but the pelagic larvae and juvenile stages of the benthic organisms would be vulnerable to spills during periods of open water conditions.

It seems likely that the development of the oil and gas resources will bring about changes in the marine environment, but the extent of degradation in the benthic environment cannot be predicted. There remains a great scientific need

for long term studies on the dynamics of the benthic populations, including year-round sampling with measurements on growth, metabolism, and reproductive activity.

We conclude that future monitoring should be site specific. It is simplistic to say that the benthic fauna are distributed solely in depth zones and are correlated with distance from shore. Latitudinal (and longitudinal) trends in faunal distributions and abundances are demonstrated by our data (e.g. Bilyard and Carey, unpublished). Generalizations on the ecology of the Beaufort Sea, therefore, should be made with caution.

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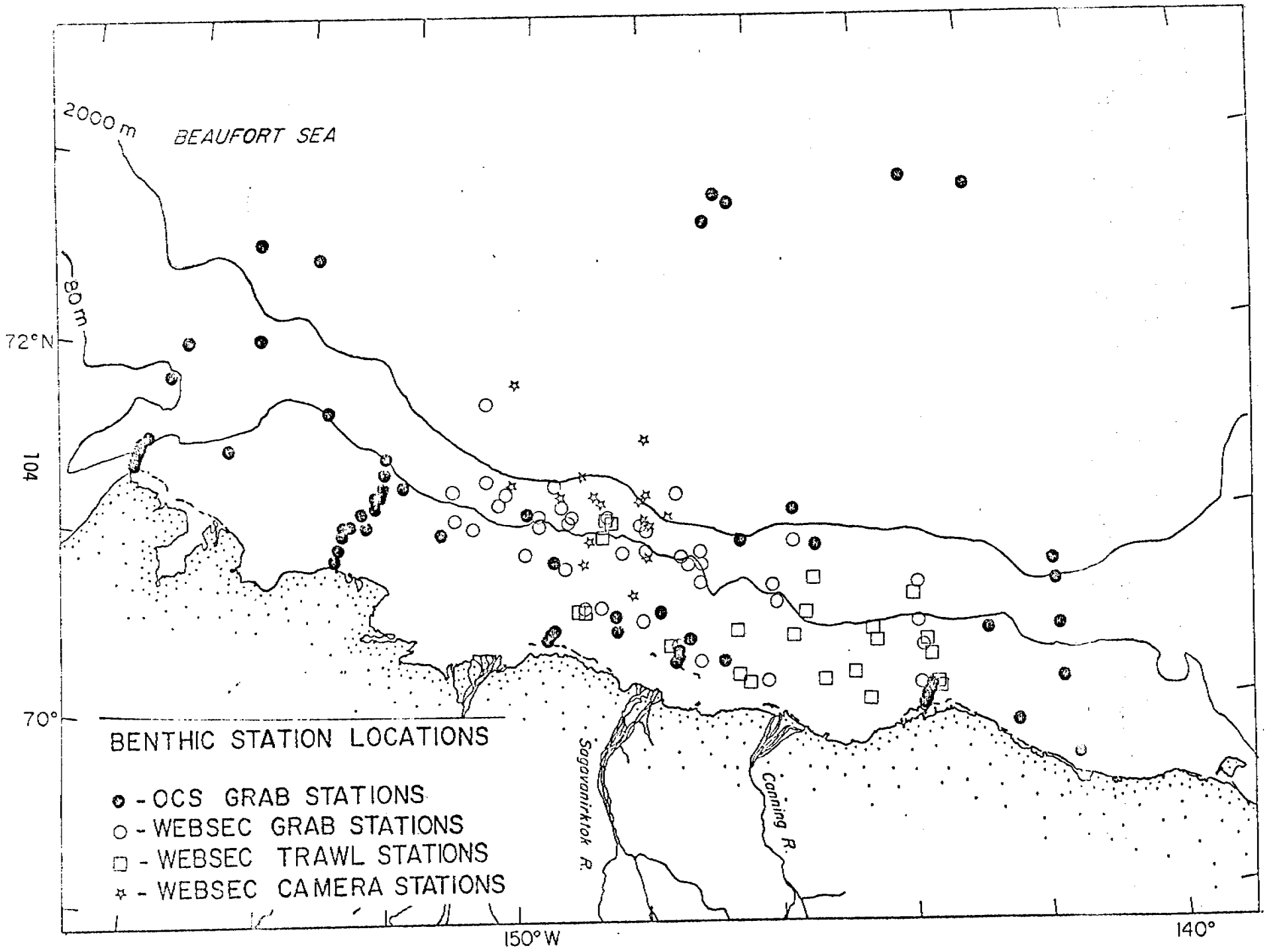


Figure 1. Station location summary, 1971 - 1978.

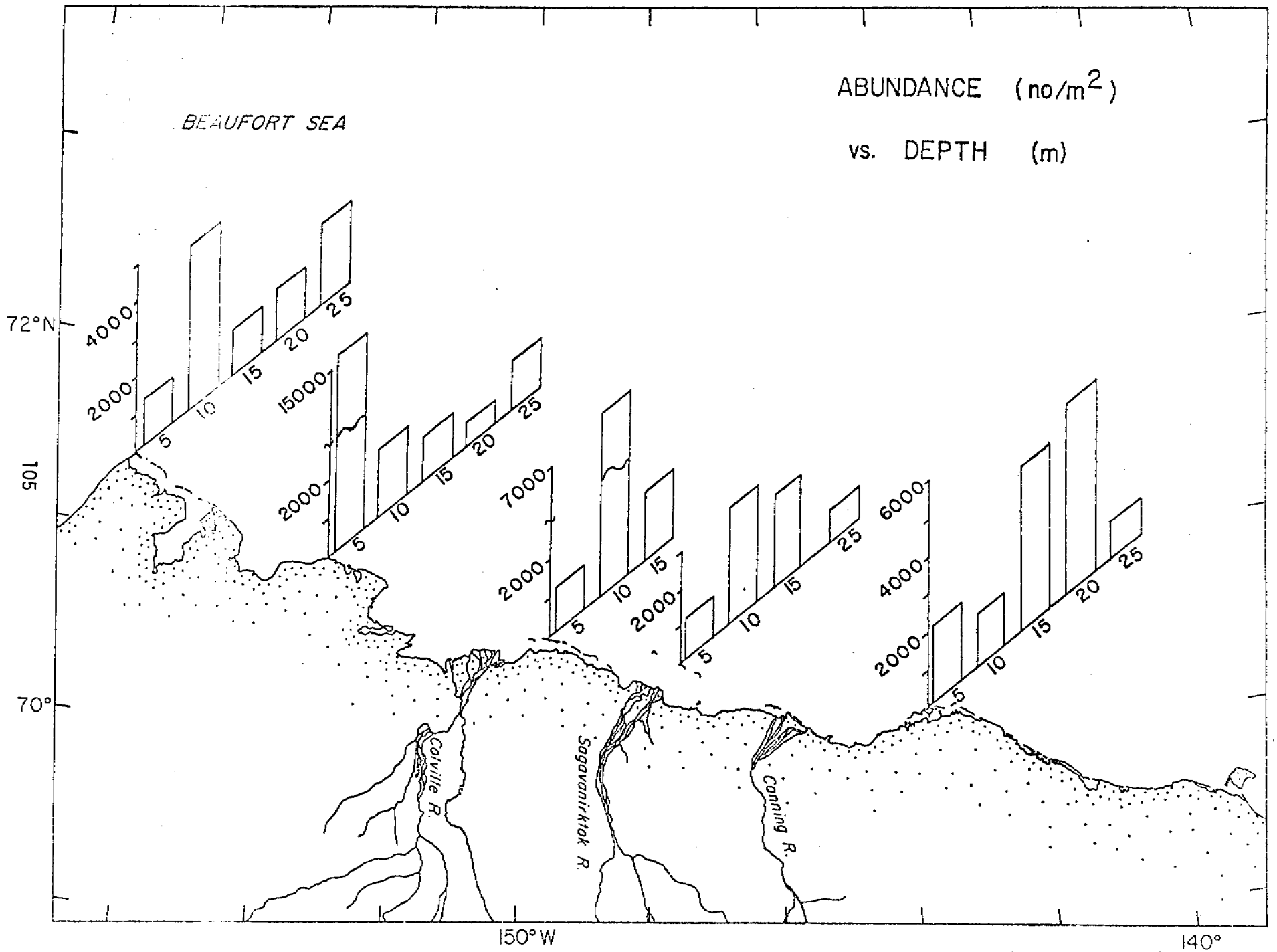


Figure 2. Numerical density of coastal infauna (> 1.0 mm) collected during 1976 R/V ALUMIAK cruise.

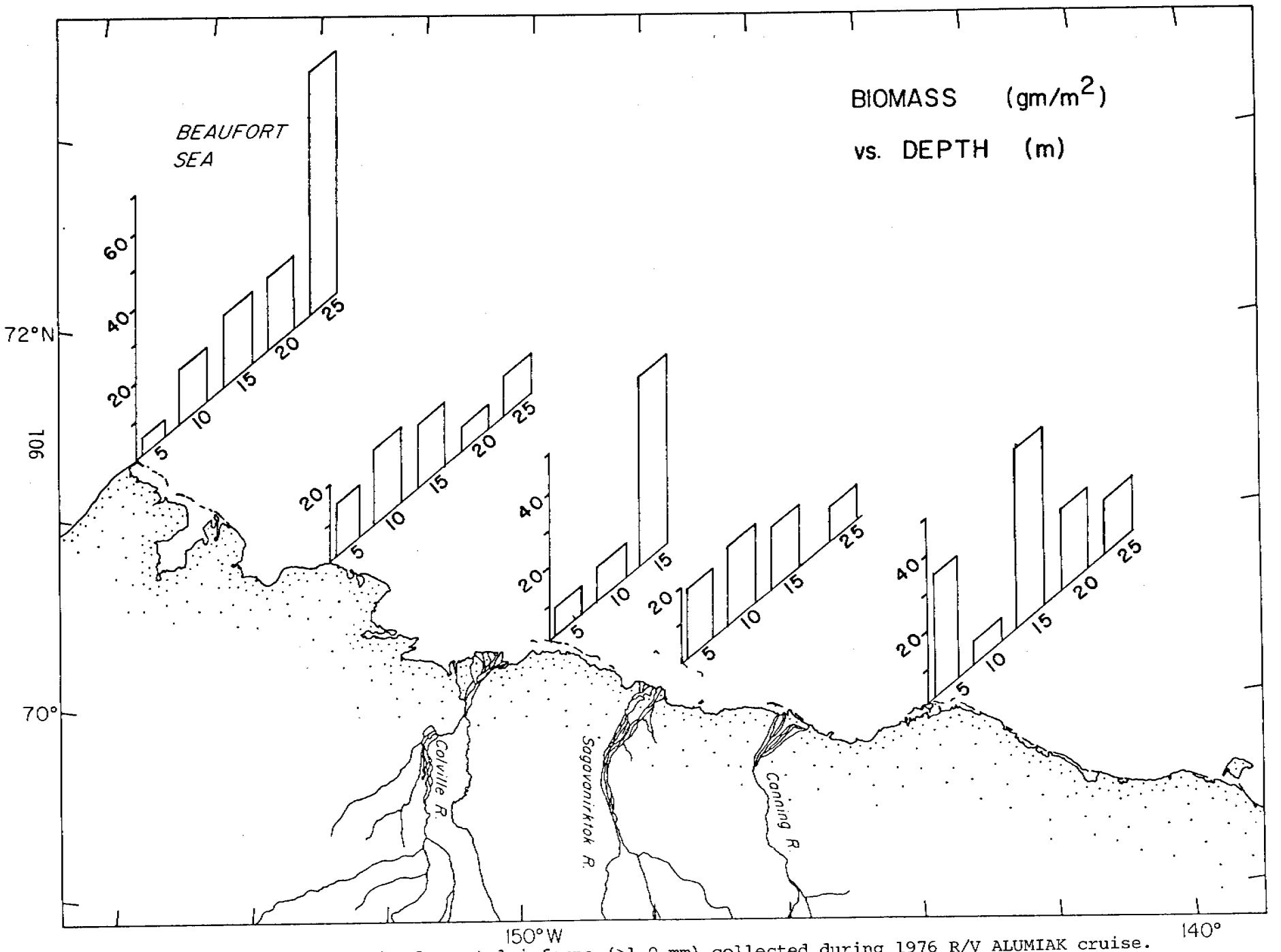


Figure 3. Biomass (g wet wt.) of coastal infauna (>1.0 mm) collected during 1976 R/V ALUMIAK cruise.

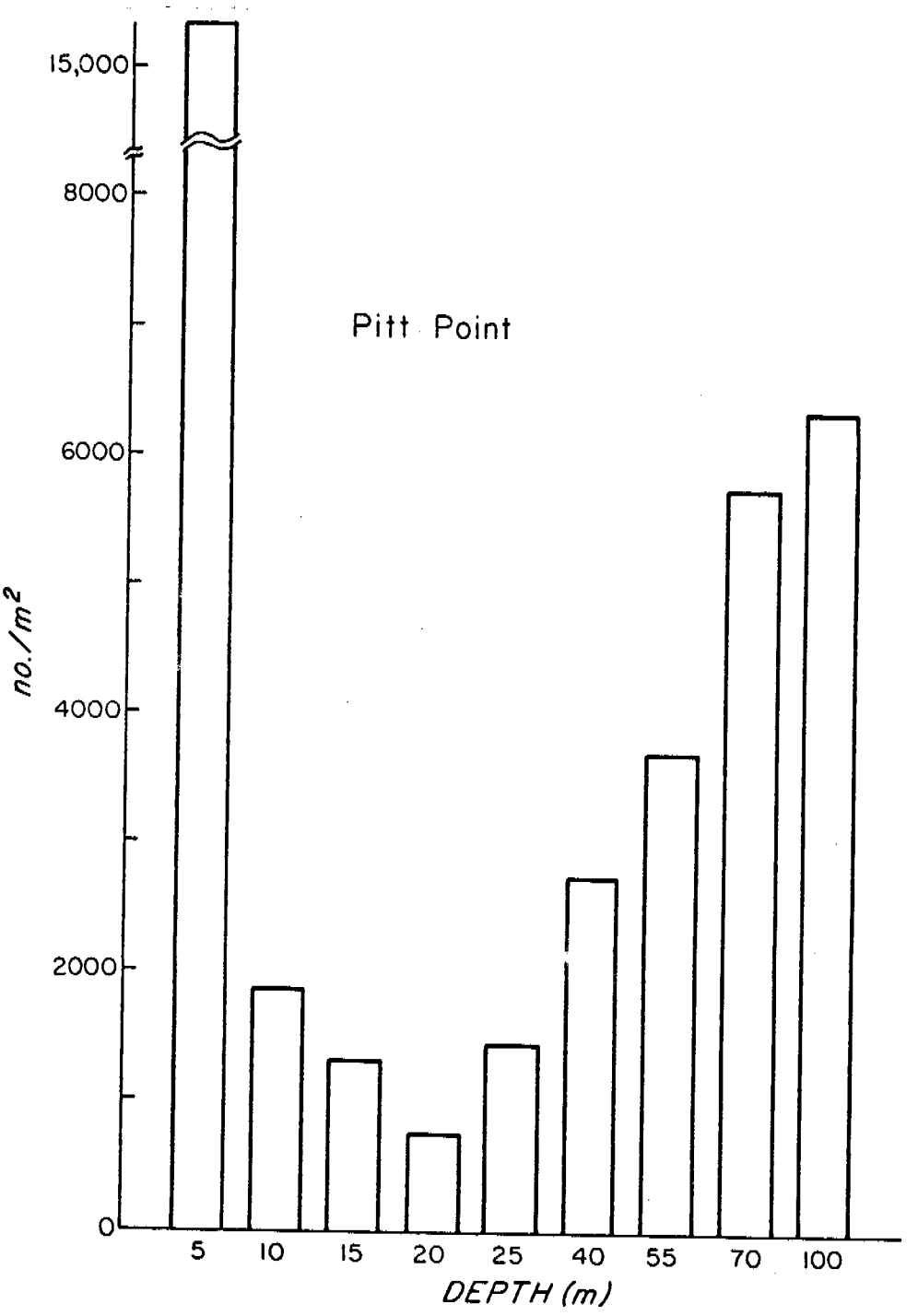


Figure 4. Numerical density of infauna (>1.[illegible] mm) during summer, 1976.

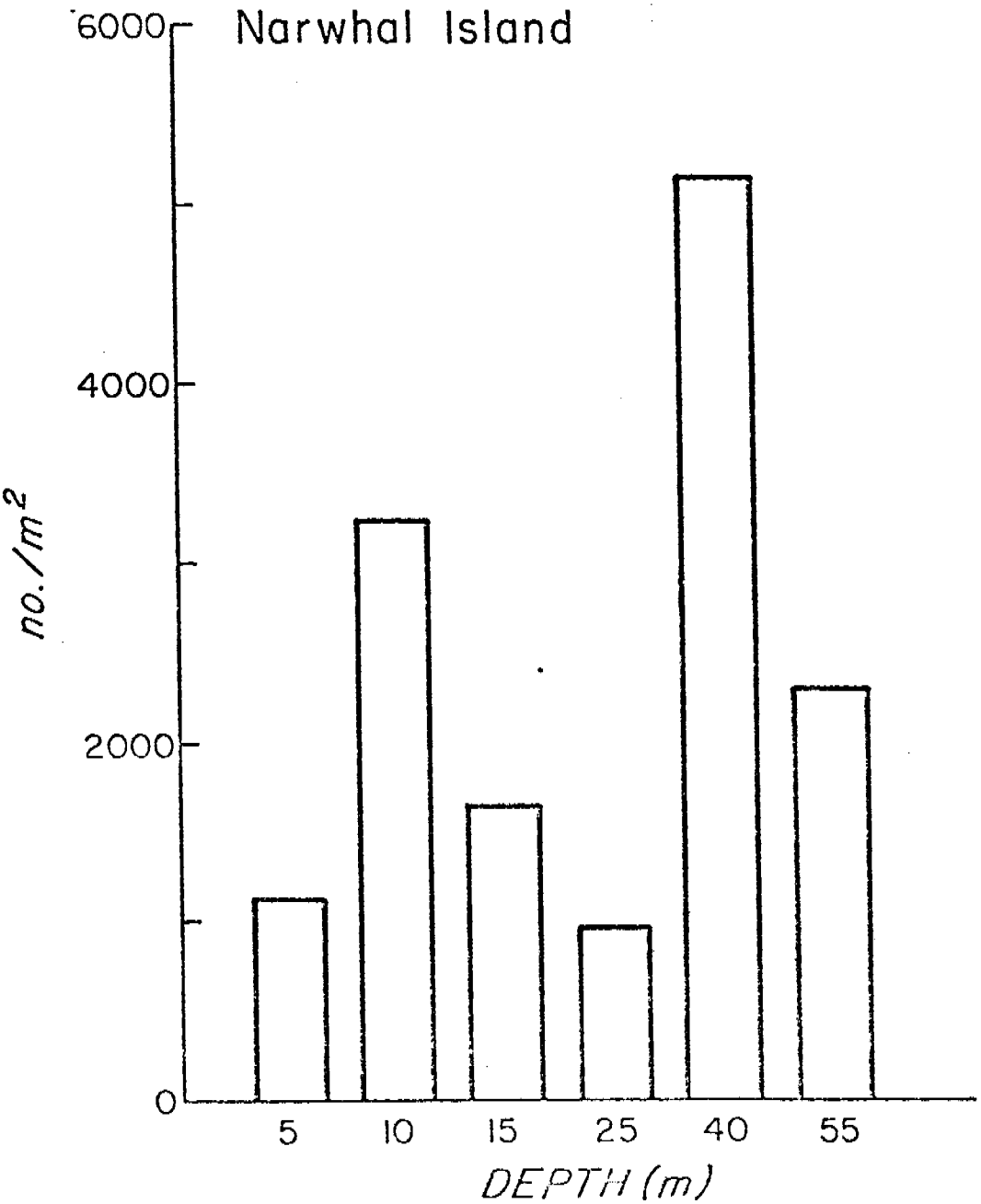


Figure 5. Numerical density of infauna (> 1.0 mm) during summer, 1976.

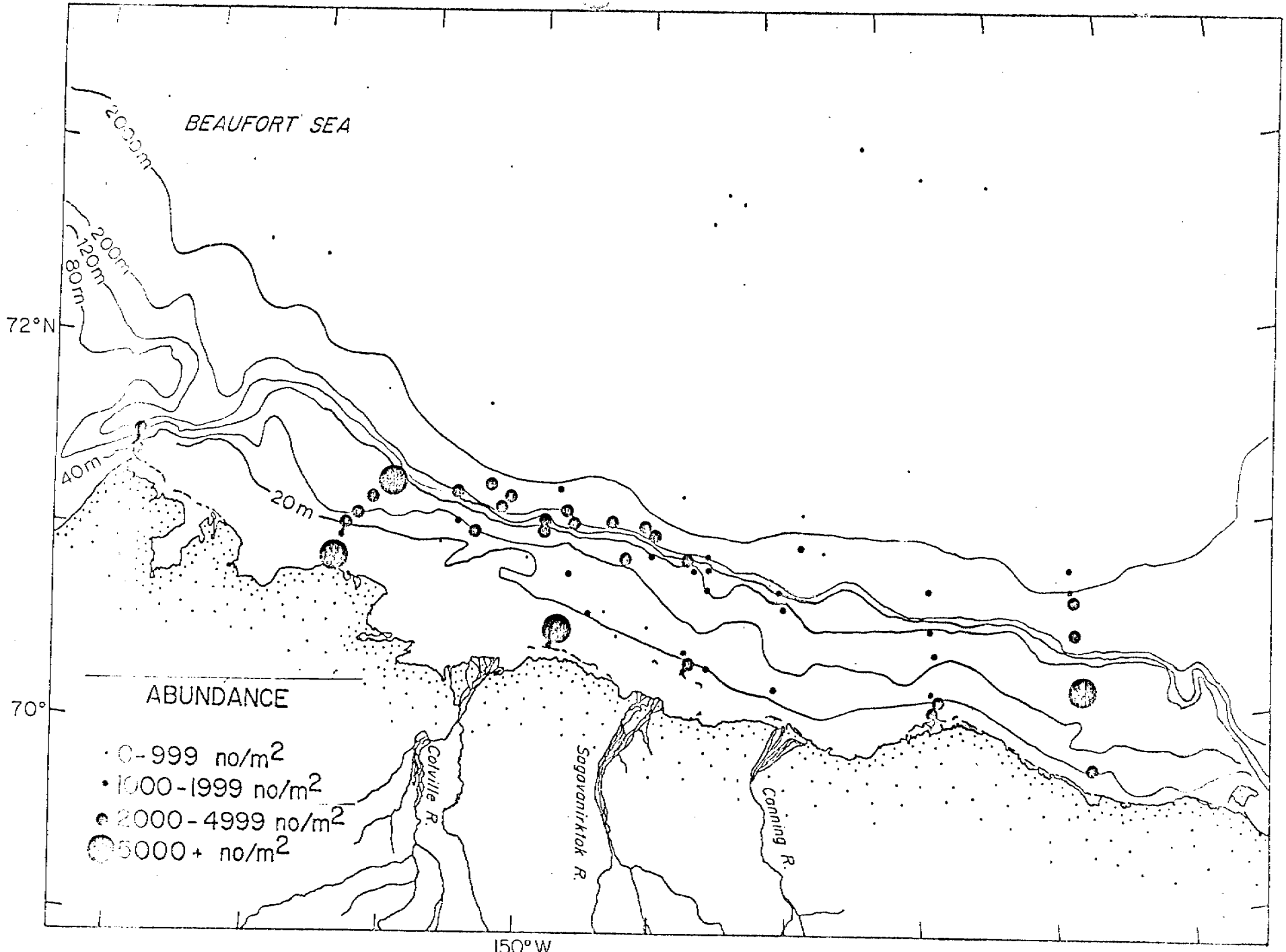


Figure 1. Total numerical density of infauna (>1.0 mm) . Summer, 1971 - 1977.

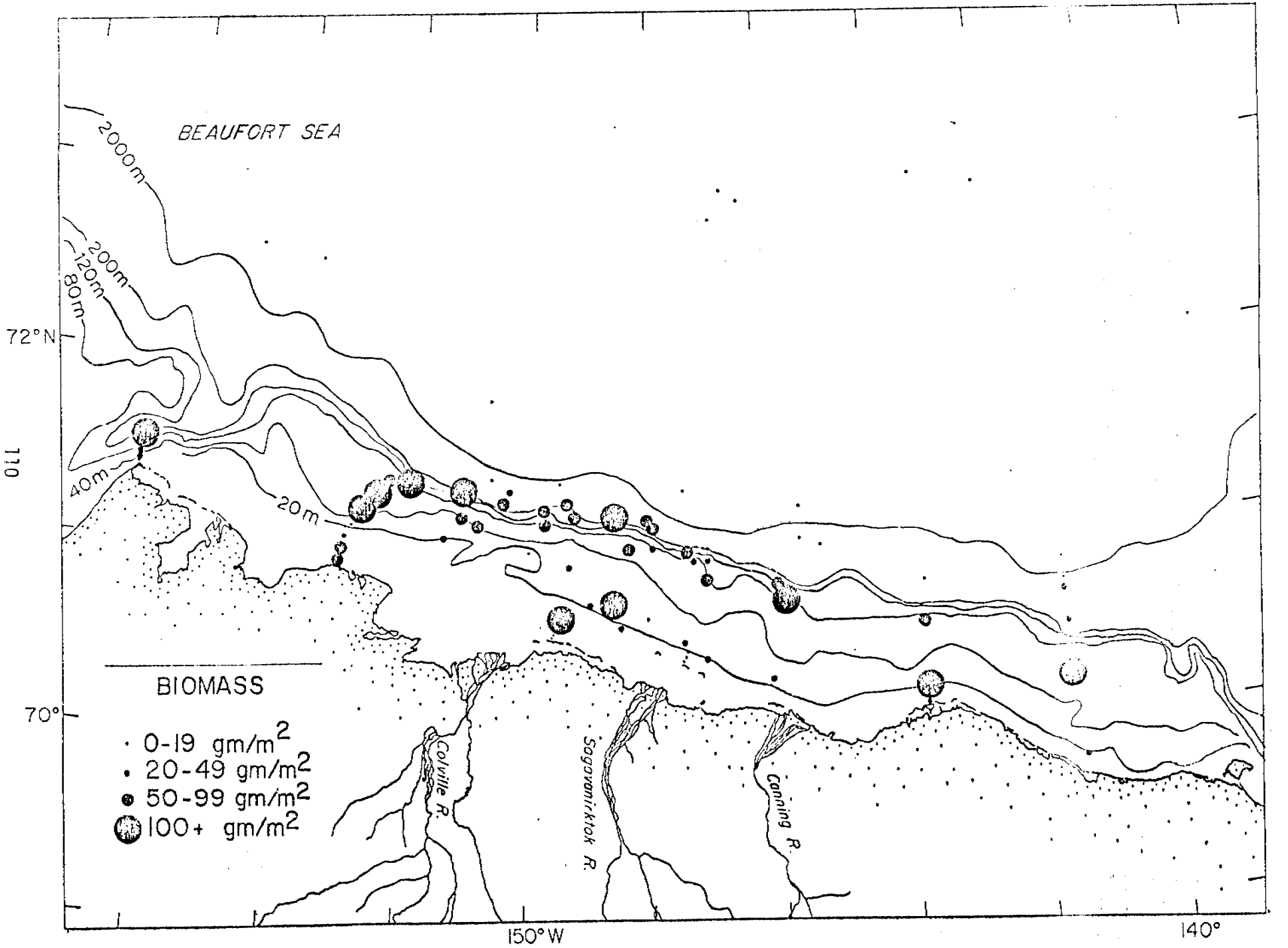


Figure 7. Total biomass (wet-preserved wt.) of infauna (>1.0 mm). Summer, 1971-1977.

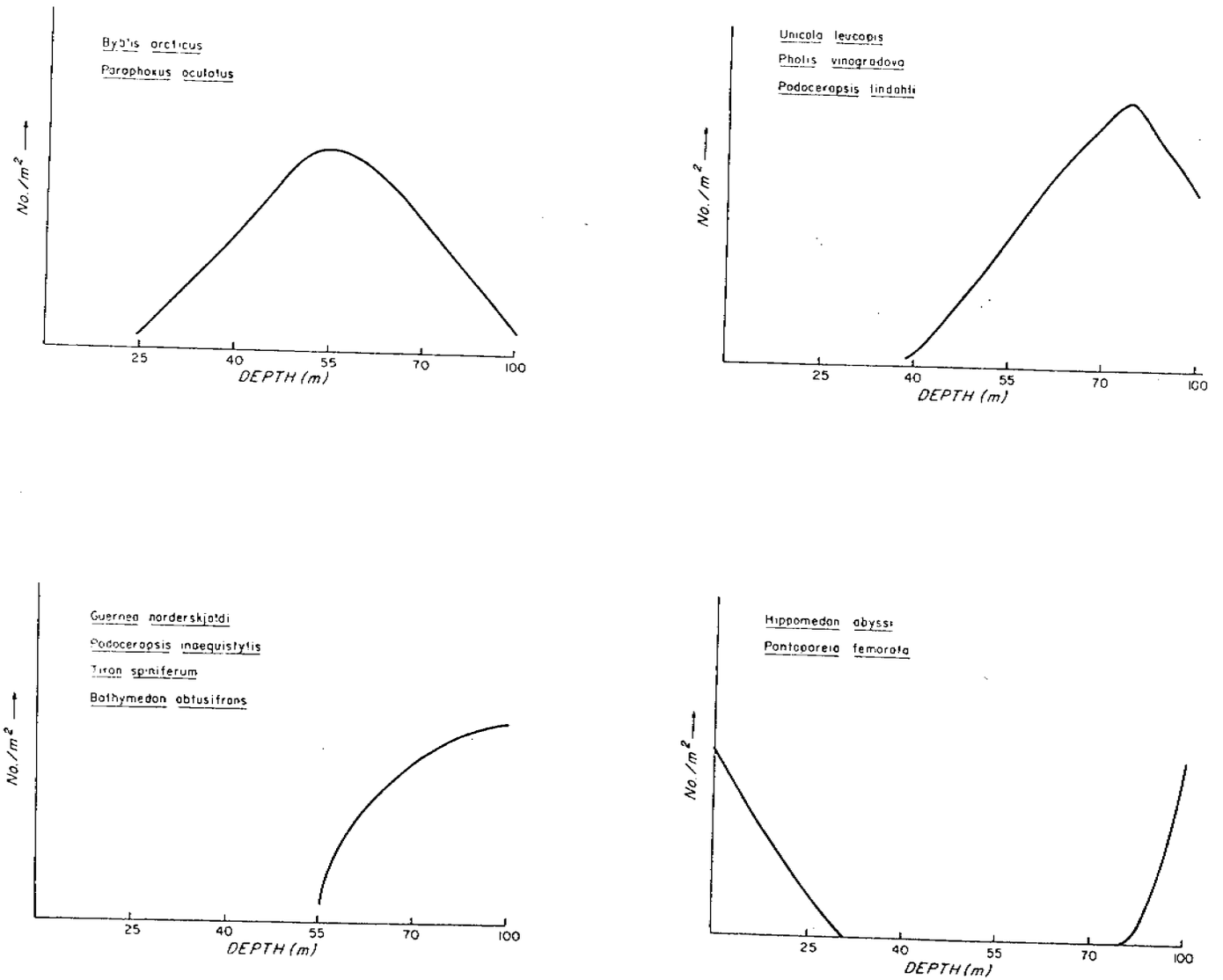


Figure 8. Characteristic patterns of distribution of gammarid amphipod species on the Pitt Point Transect.

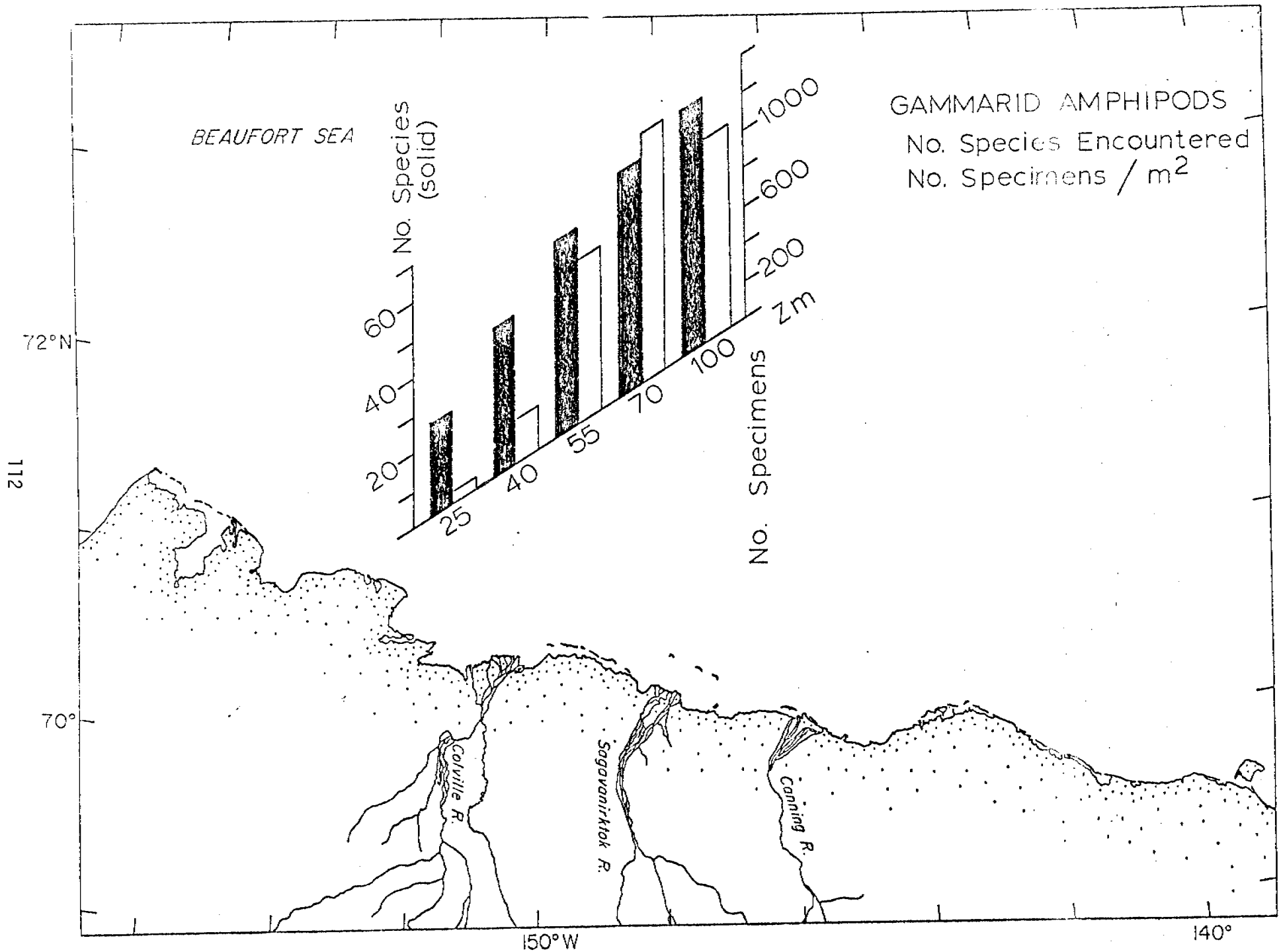


Figure 9. Number of species and numerical density of gammarid amphipods on the Pitt Point Transect.

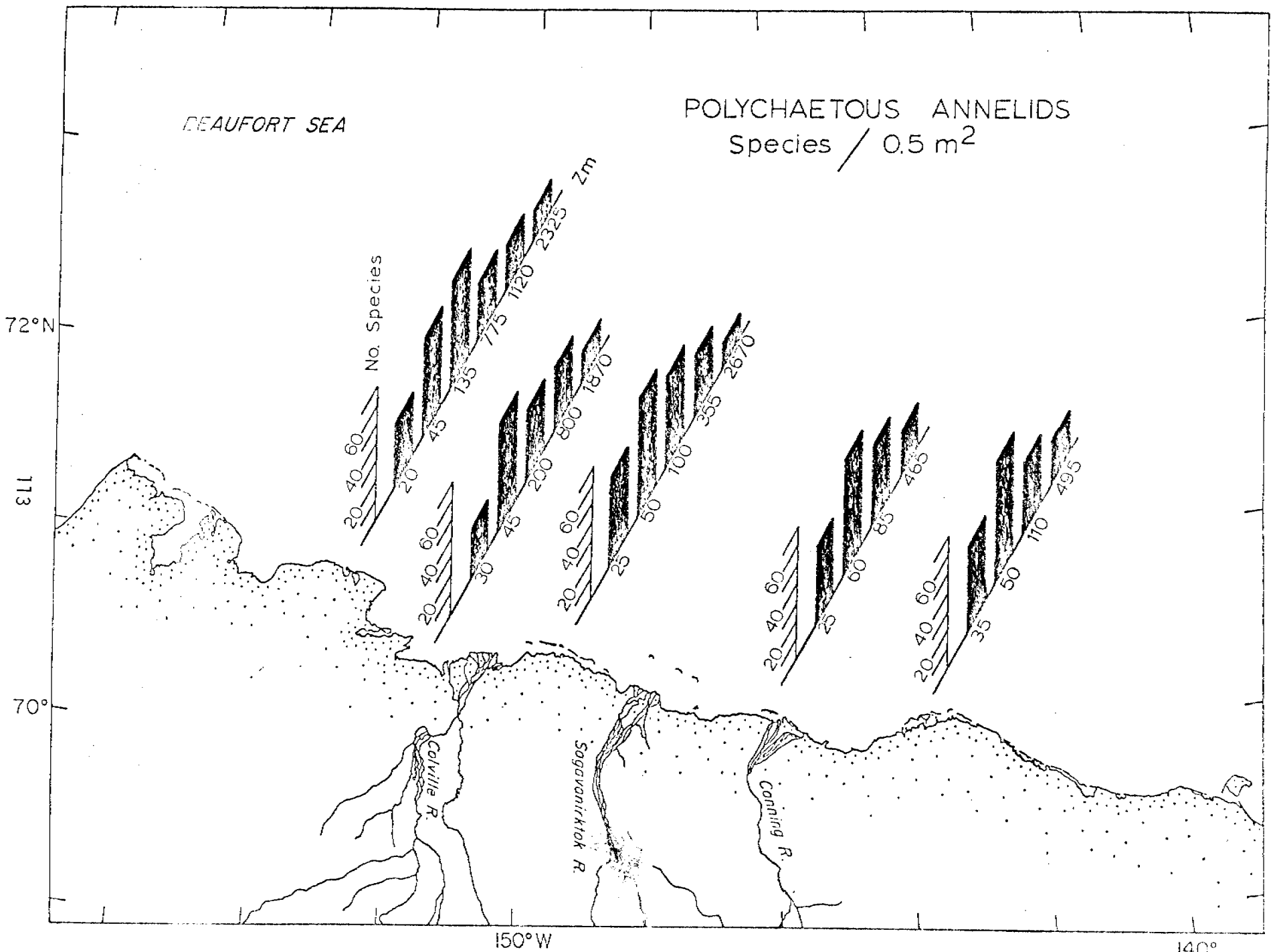


Figure 10. Numbers of polychaete species at WEBSEC stations.

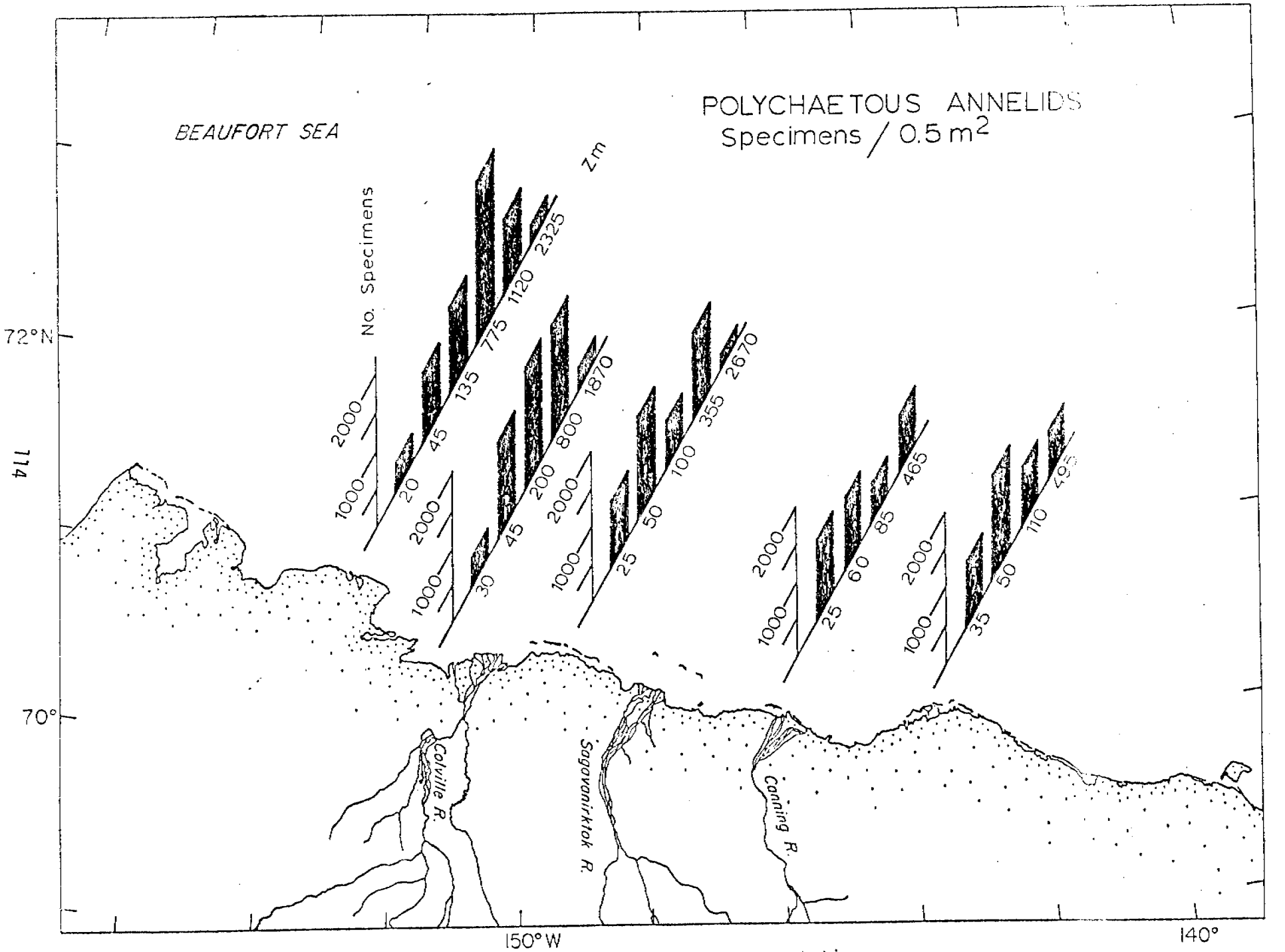


Figure 11. Numerical density of polychaetes (>1.0 mm) at WEBSEC stations.

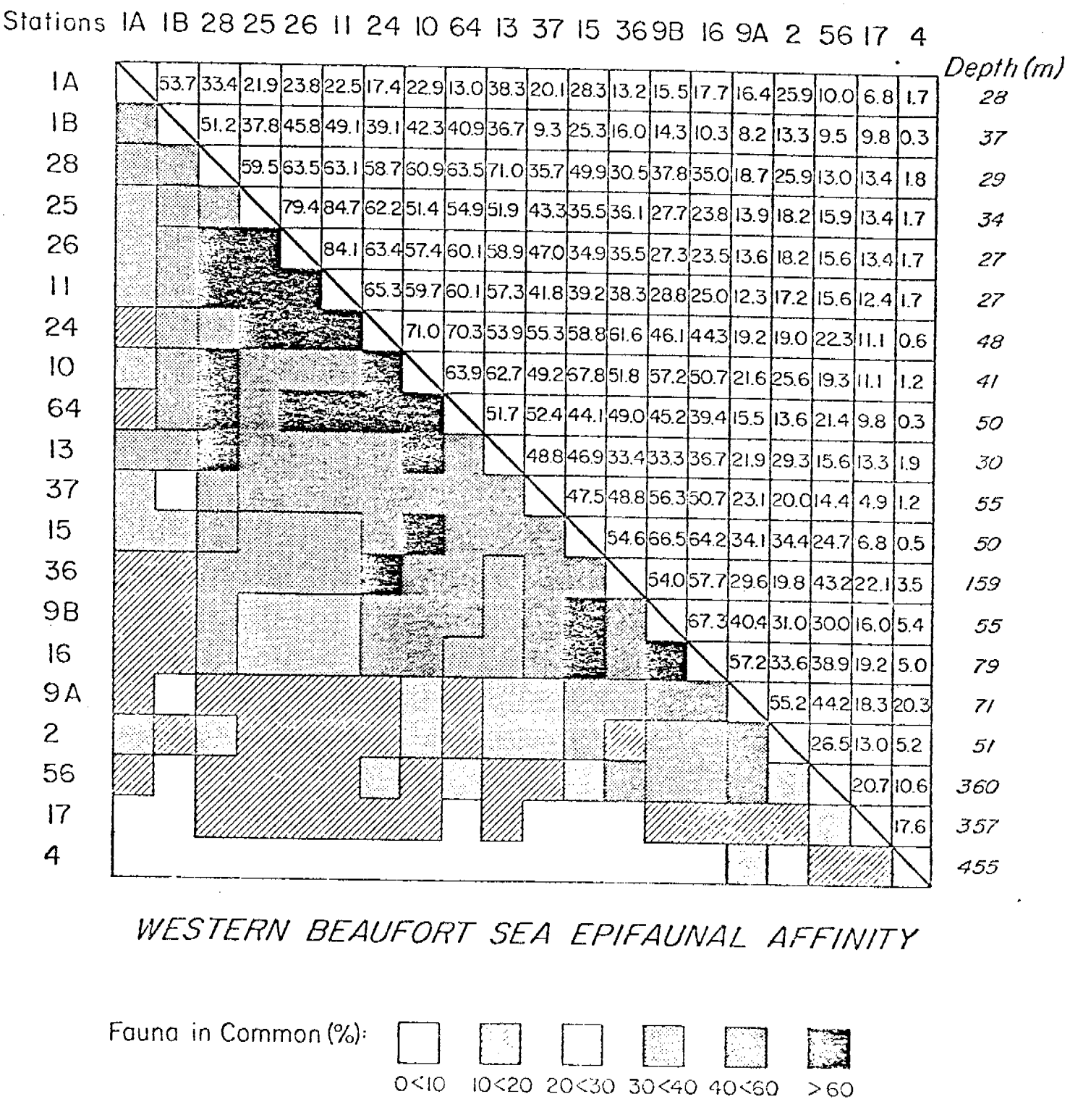


Figure 12. Trellis diagram illustrating epifaunal species affinities between WEBSEC 1972 trawling stations.

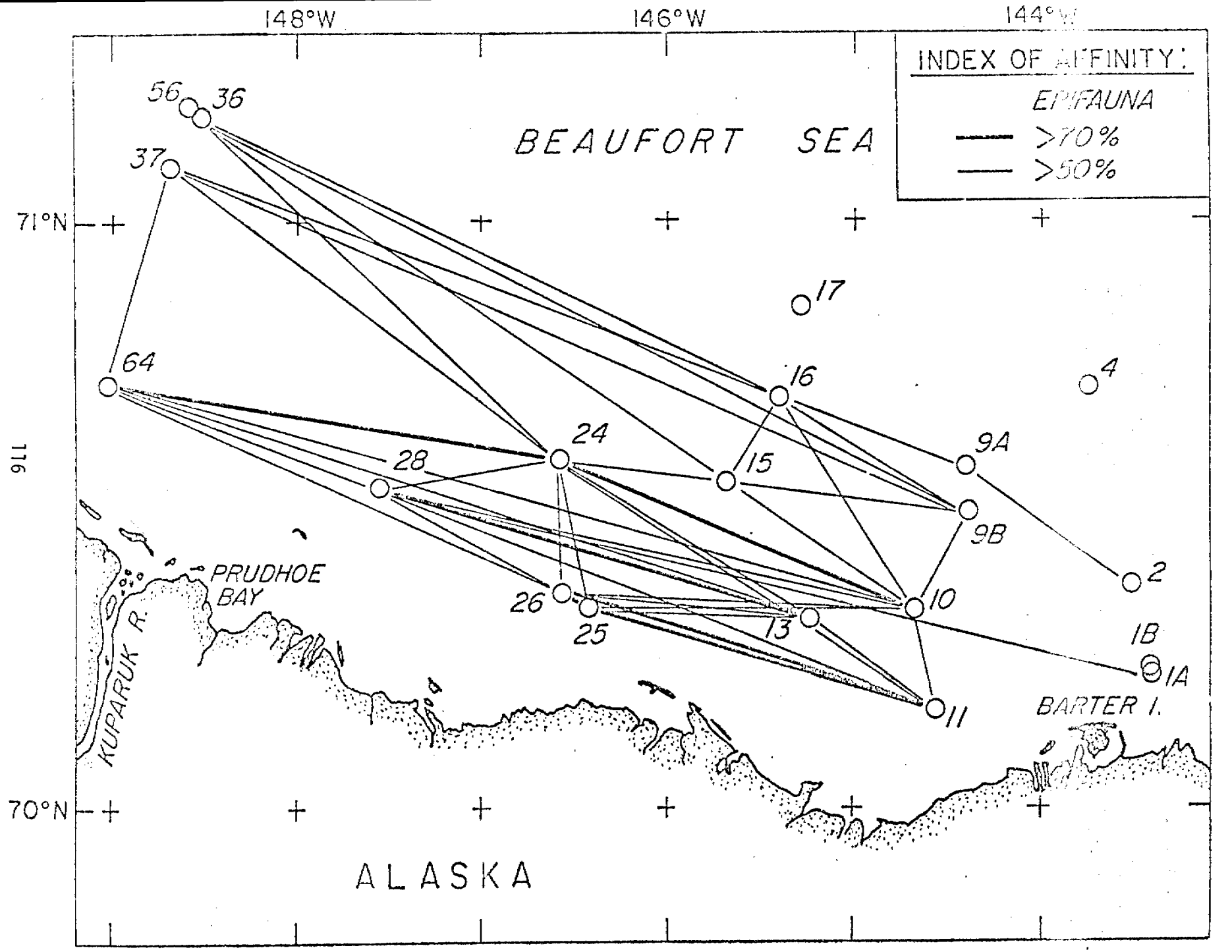


Figure 13. Diagram illustrating epifaunal species affinities between WEBSEC-73 trawling stations.

Figure 14. Relationship of species groups of representative benthic species as determined by Fager's Recurrent Group Analysis.

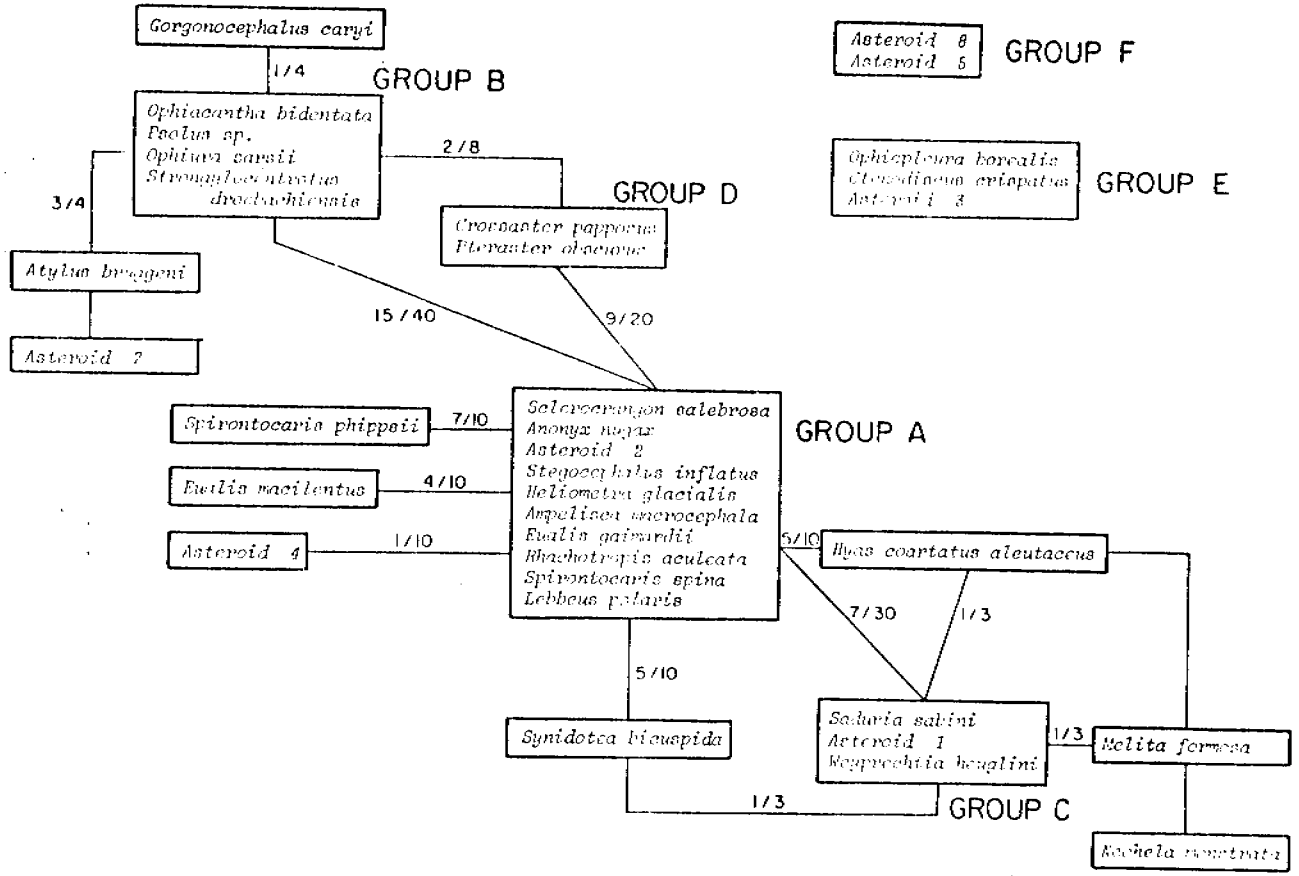


Figure 15. Stations occupied by Carey in 1971 which were examined for the cluster analysis. Open circles represent stations which were excluded from the final data matrix.

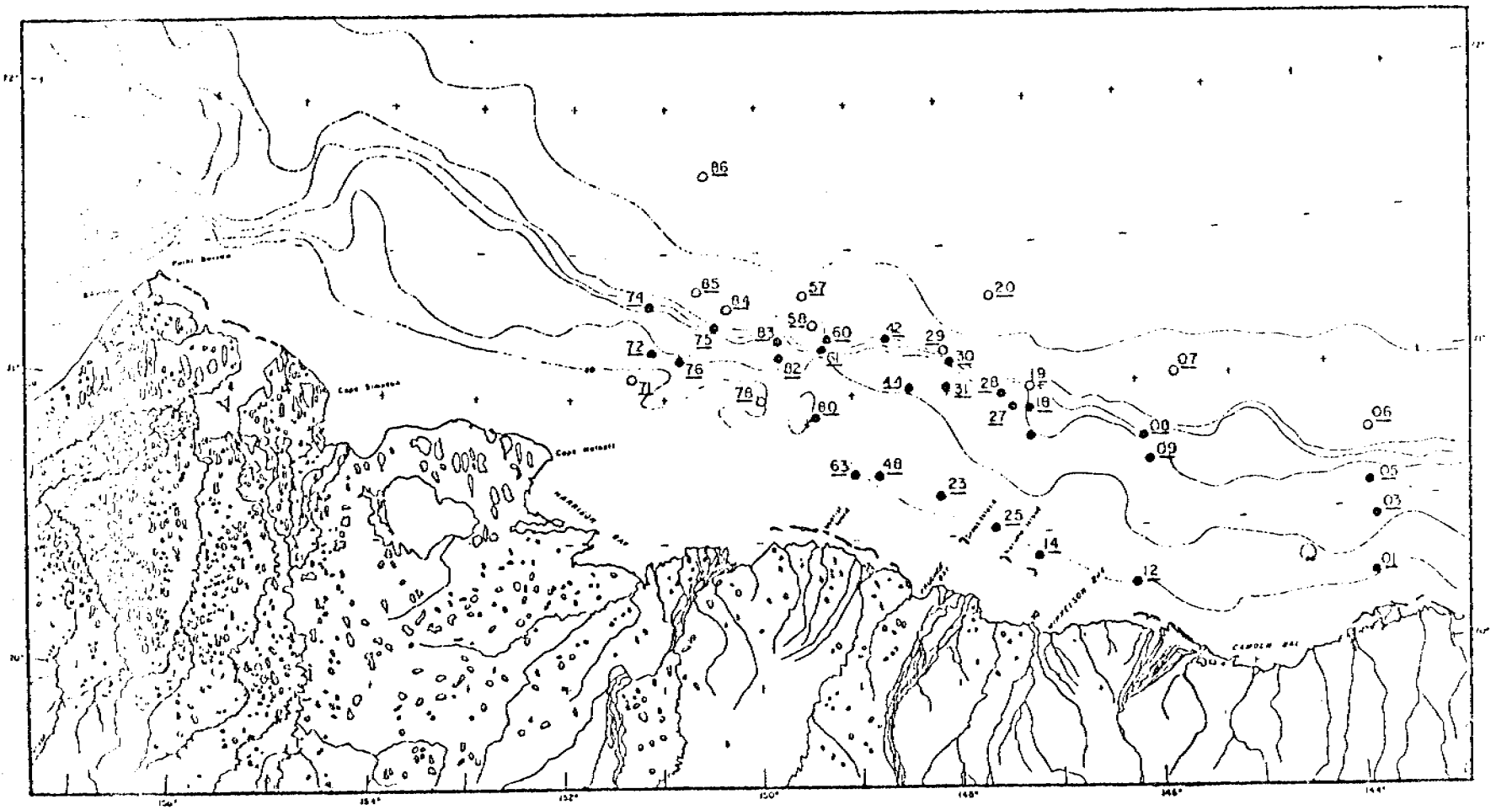


Figure 16. Species phenogram generated by a complete linkage (Farthest neighbor) classification algorithm using SIMI for the similarity matrix. Groups I through V are indicated.

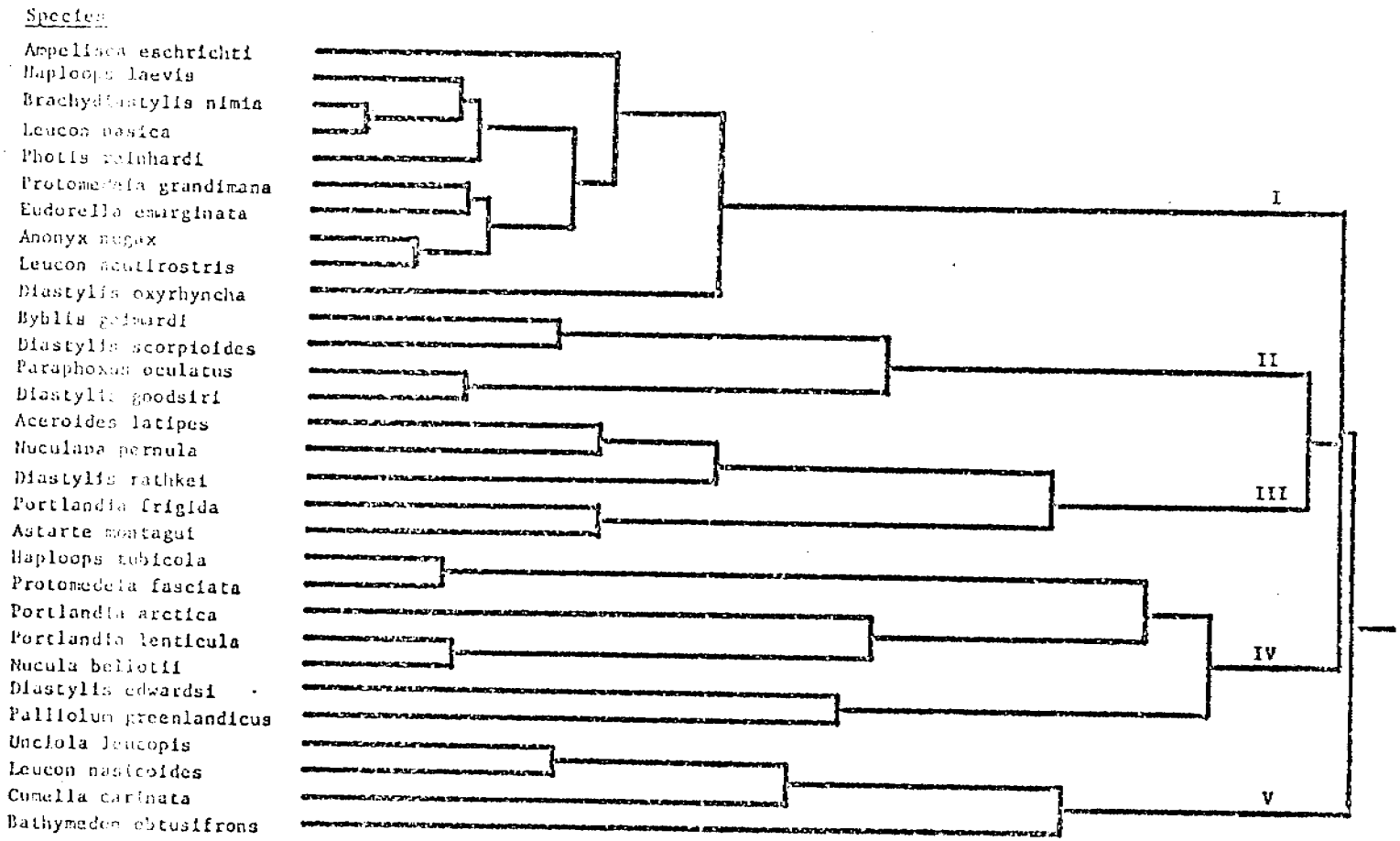
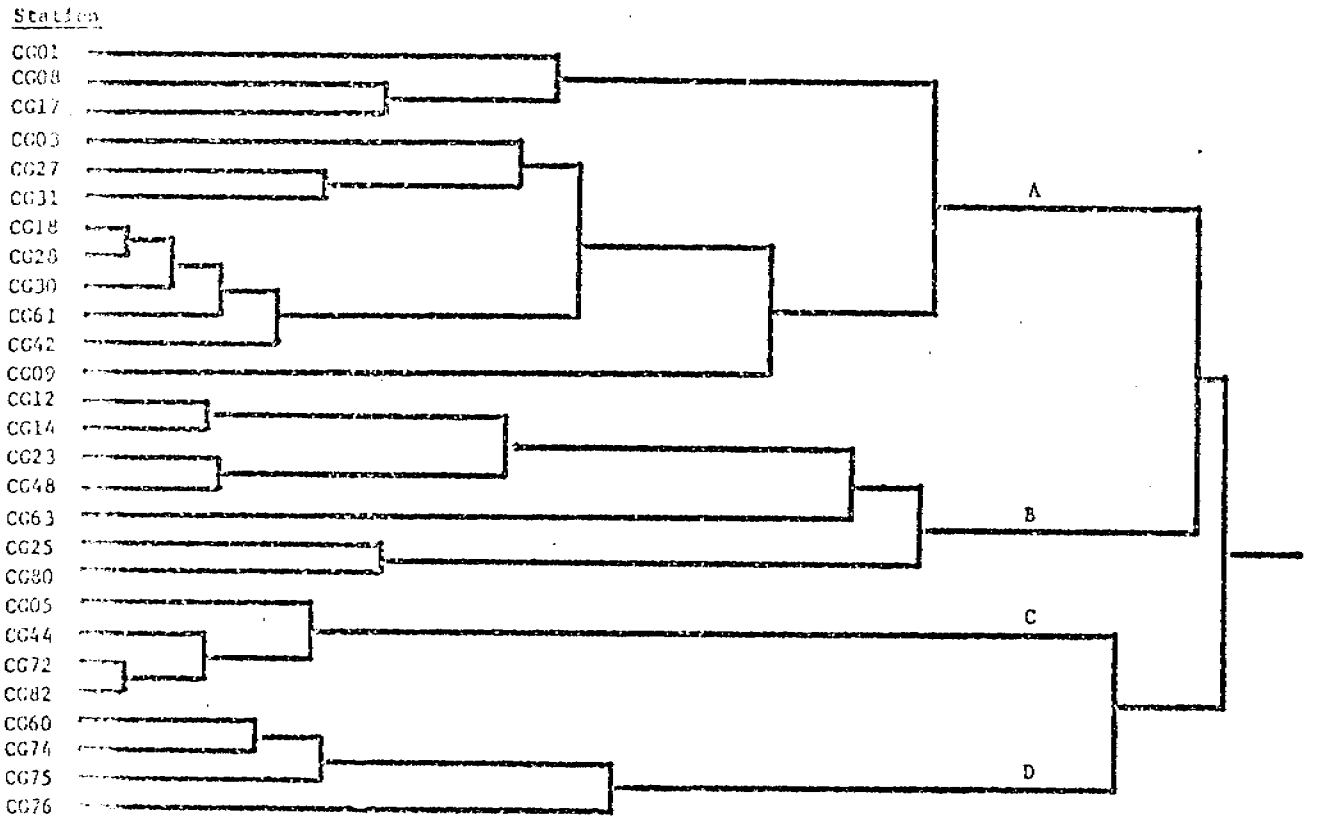


Table 1. Species groupings using SIMI for similarity matrix.

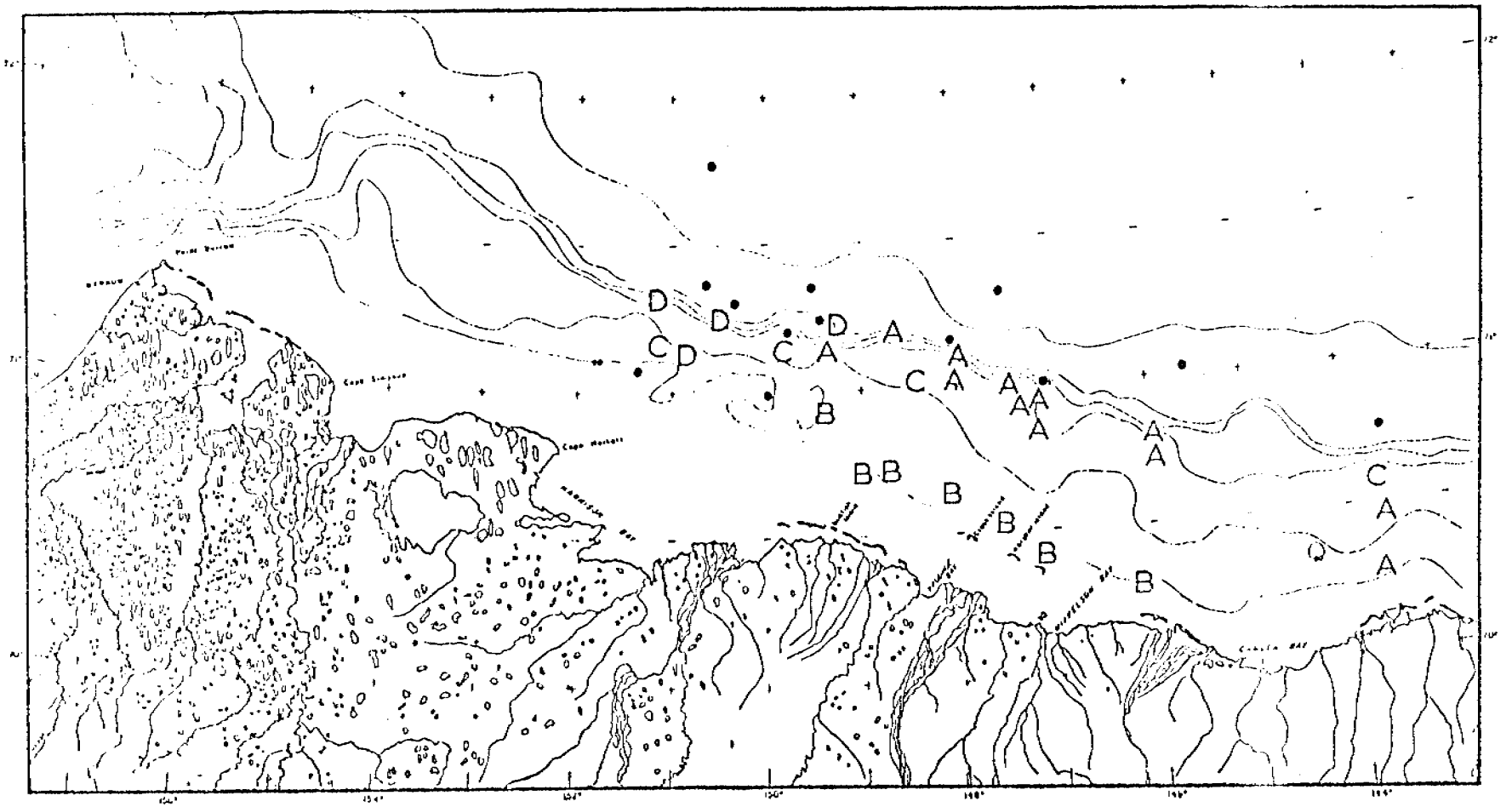
Group I -	
Ampelisca eschrichti	Cosmopolitan
Haploops laevis	
Photis reinhardi	
Protomedeia grandimana	
Anonyx nugax	Deep
Brachydiastylis nimia	Colville River
Diastylis oxyrhyncha	
Eudorella emarginata	
Leucon acutirostris	
Leucon nasica	
Group II -	
Byblis gaimardi	Deep
Paraphoxus oculatus	
Diastylis goodsiri	Rarely off Colville River
Diastylis scorpioides	
Group III -	
Aceroides latipes	East
Diastylis rathkei	
Portlandia frigida	Broad Depth
Nuculana pernula	Never off Colville River
Astarte montagui	
Group IV -	
Haploops tubicola	Shallow
Protomedeia fasciata	
Diastylis edwardsi	Rarely off Colville River
Portlandia arctica	
Portlandia lenticula	
Nucula bellotii	
Cyclopecten greenlandicus	
Group V -	
Unciola leucopis	Colville River
Bathymedon obtusifrons	
Leucon nasicoides	Never Nearshore (Sta. Grp. B)
Cumella carinata	

Figure 17. Station phenogram generated by a complete linkage (farthest neighbor) classification algorithm using SIMI for the similarity matrix. Groups 'A' through 'D' are indicated.



$$SIMI = \frac{\Sigma xi^2 + \Sigma yi^2 - \Sigma(xi - yi)^2}{2\sqrt{\Sigma xi^2}\ \sqrt{\Sigma yi^2}}$$

Figure 18. Distribution of the stations grouped in a cluster analysis across the shelf. Dots represent stations which were excluded from the analysis.



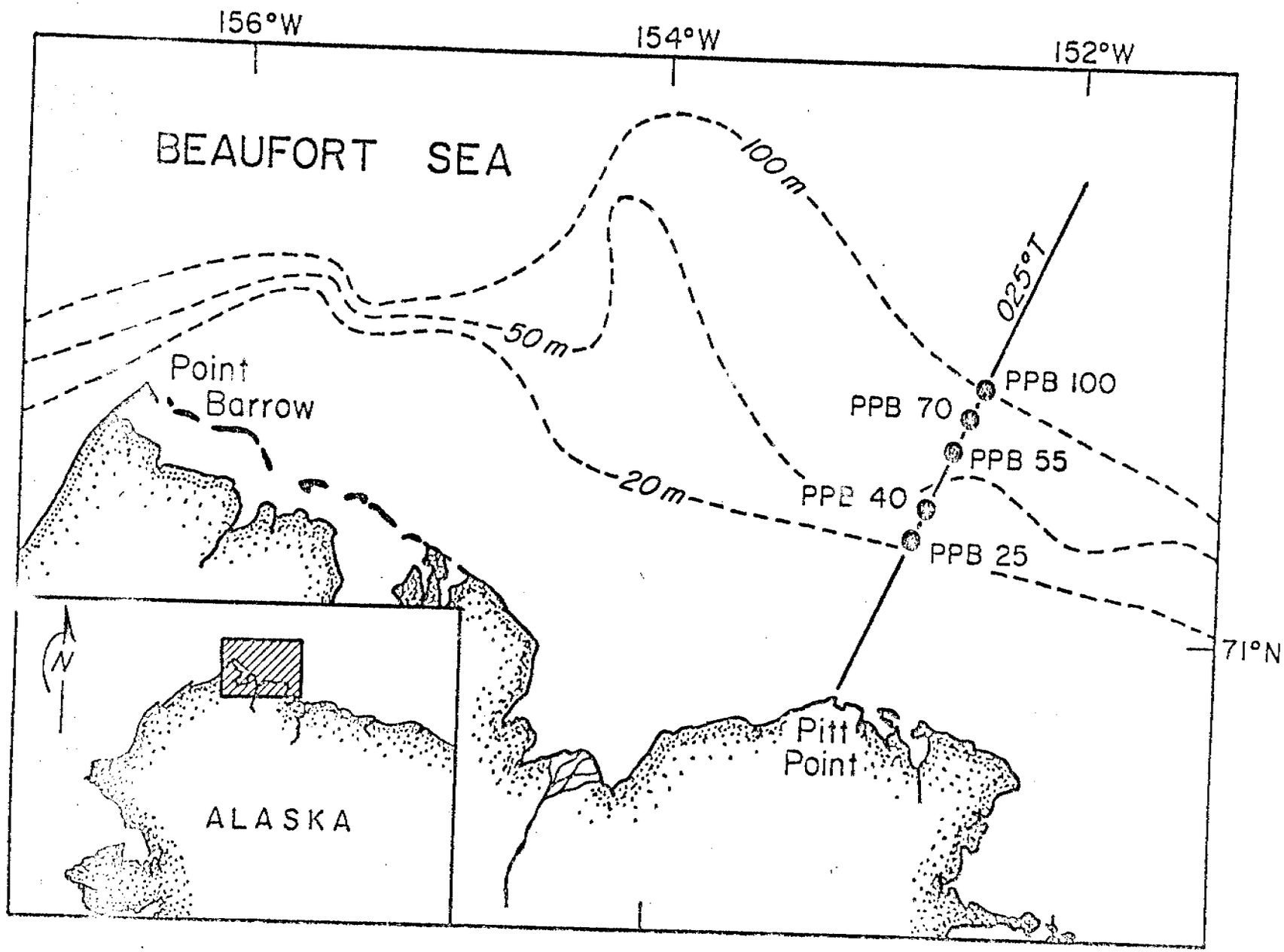


Figure 10. Location chart illustrating the five seasonal stations sampled on the Pitt Point Transect.

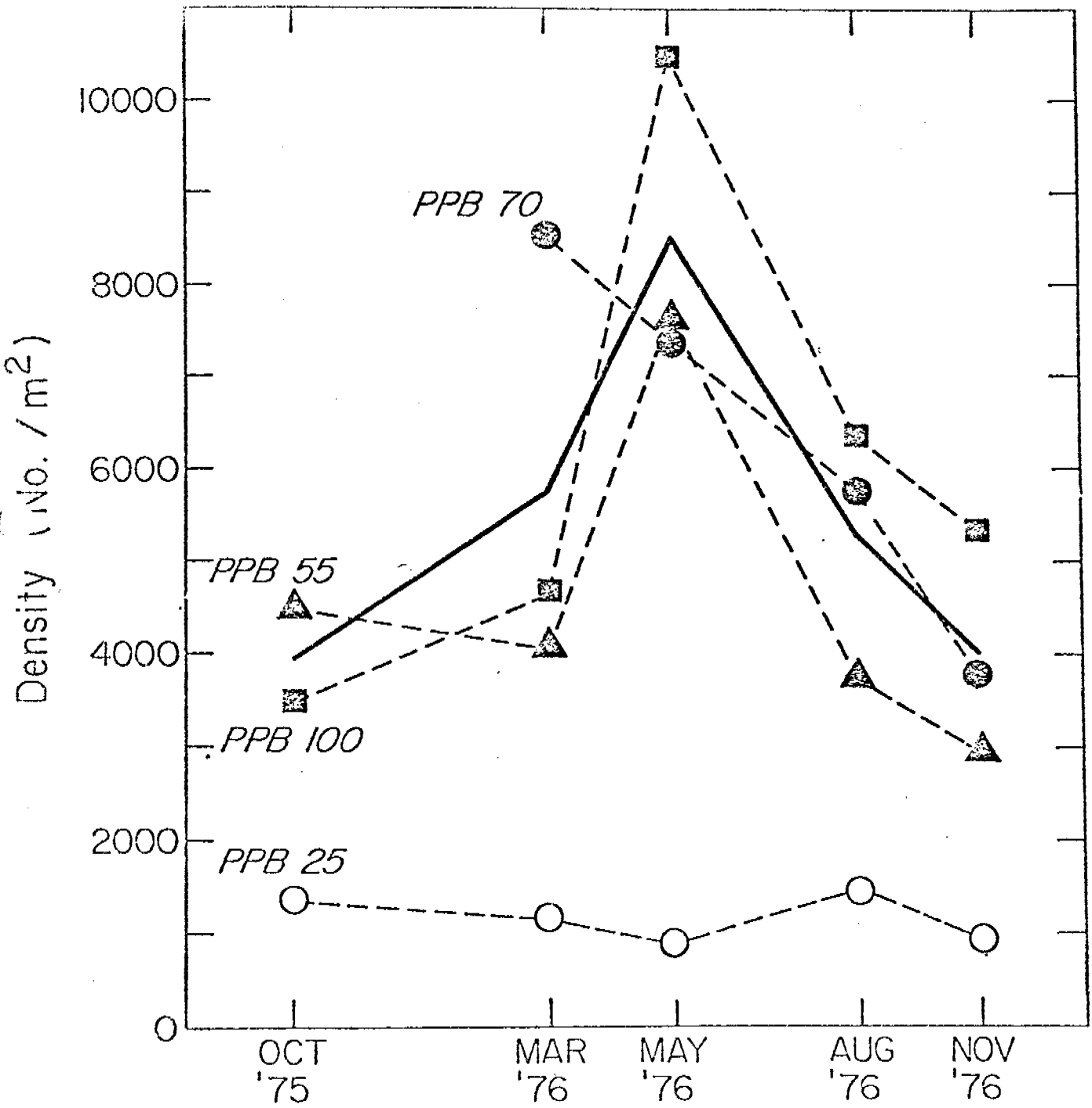


Figure 20. Means of numerical density of infauna (>1.0 mm) collected seasonally at standard stations.

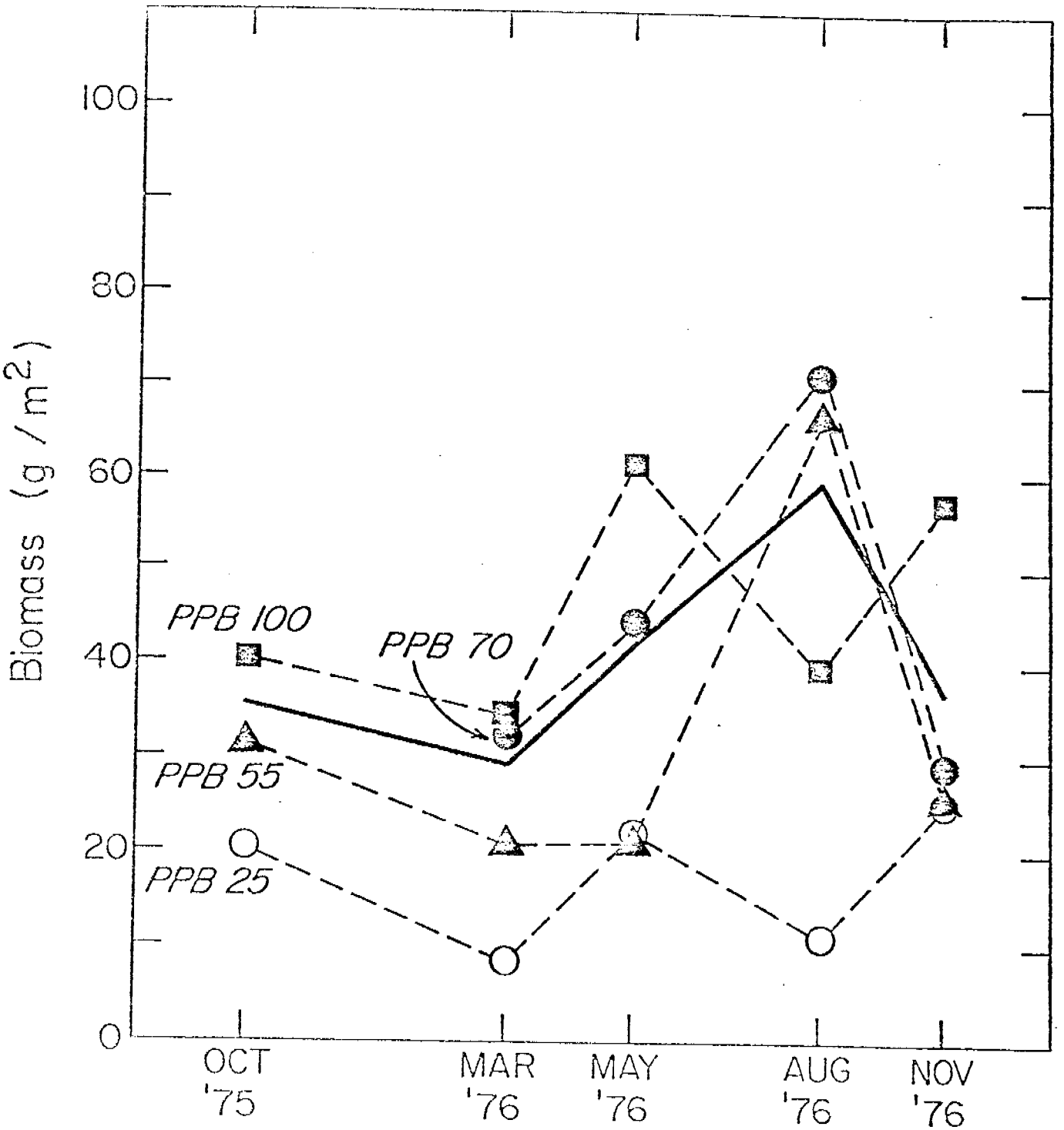


Figure 21. Biomass (wet-preserved wt. of soft-bodied infauna>1.0 mm) at standard stations.

Figure 22. Diagram of generalized marine food web in the Beaufort Sea.

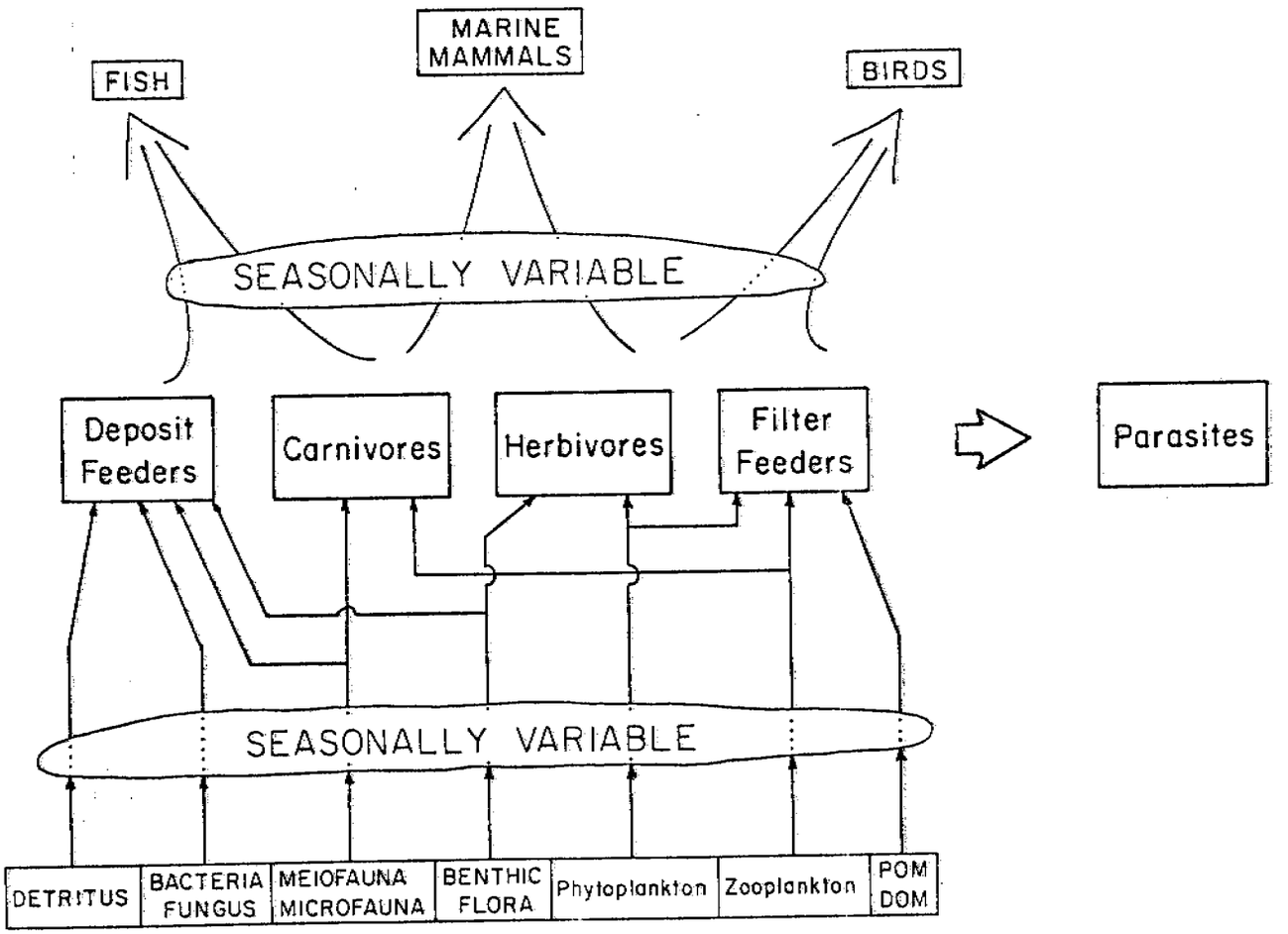
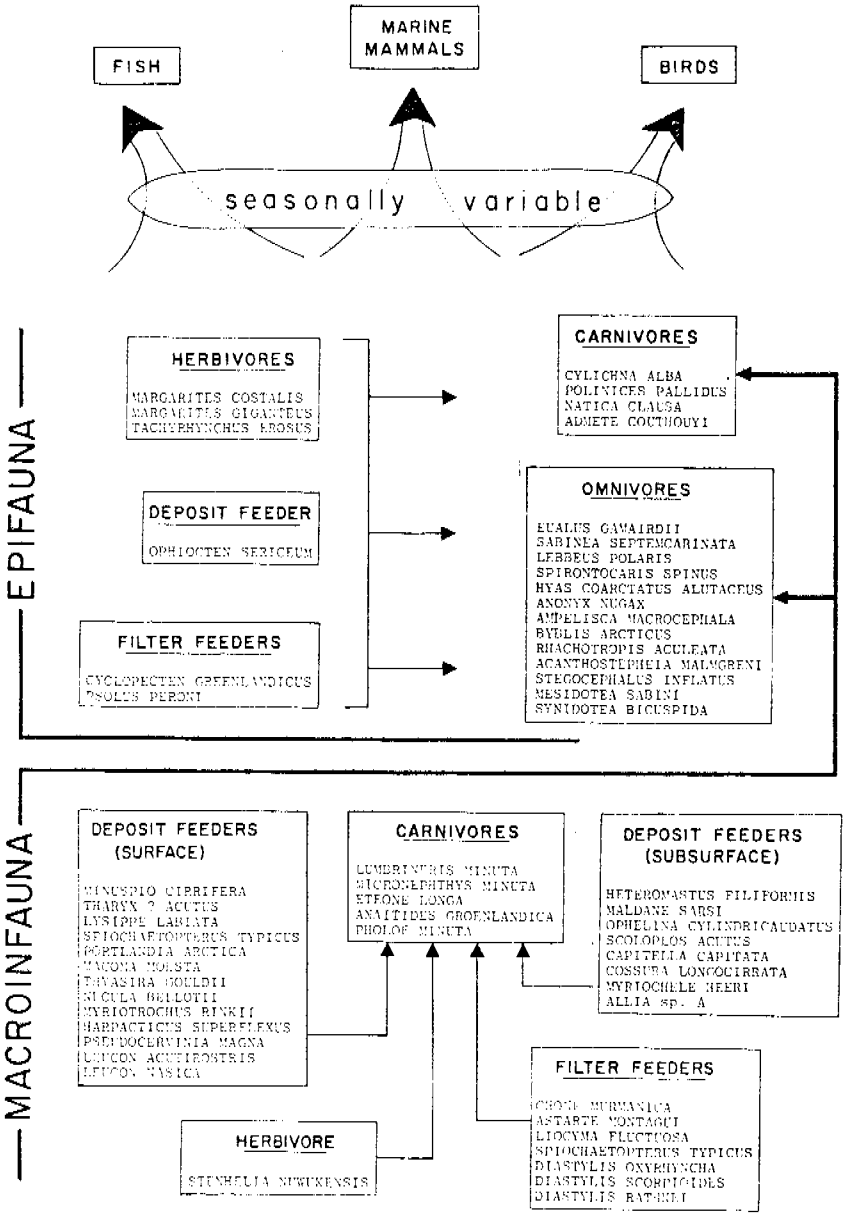


Figure 23. Diagram of benthic food web with characteristic Beaufort Sea species.



B.

DISTRIBUTIONAL PATTERNS OF WESTERN BEAUFORT SEA POLYCHAETOUS ANNELIDS*

ABSTRACT

Patterns inherent in the distributions and abundances of the polychaetous annelids of the western Beaufort Sea (Cape Halkett to Barter Island, Alaska) indicate that the benthic infauna of the western Beaufort Sea are not atypical. As in other regions, depth and depth-related processes appear to exert primary control over the distributional patterns of polychaete species. Contours of species richness and total polychaete abundance generally parallel the depth contours, and station affinities as indicated by correlation coefficients (calculated from the dominant species data subset) are strongest parallel to the depth contours. Yet not all trends in the data parallel the depth contours. A downslope shift of the abundance maximum occurs from east to west within the study area, and station clusters generated from the dominant polychaete species data are not sorted strictly by depth. A canonical analysis of discriminance was performed on the station clusters. The first and second canonical variables correlate with sediment grain size distributions, suggesting a relationship between polychaete distribution patterns and the sedimentary environment. This relationship was further substantiated when sediment grain size distributions for each station were plotted on a tertiary diagram: the stations were grouped and ordered in a pattern similar to that generated by the canonical analysis of discriminance.

*Draft manuscript of paper to be submitted to Marine Biology by G.R. Bilyard and A.G. Carey, Jr.

INTRODUCTION

Multidisciplinary oceanographic research cruises aboard the U.S. Coast Guard icebreaker "Glacier" were undertaken in the western Beaufort Sea during the summers of 1971 (WEBSEC-71) and 1972 (WEBSEC-72). The primary objective of the cruises was to further understanding of the western Beaufort Sea, including its physical, chemical, geological, and biological attributes. This paper presents some of the results of research on the marine biota of the region, in particular the polychaetous annelid component of the benthic infauna, and is part of a continuing research effort in the region by the benthic ecology group at Oregon State University (Carey et al., 1974; Carey and Ruff, 1977; Montagna, 1979).

Prior to the WEBSEC cruises, knowledge of the benthic invertebrates of the region was sketchy, contained primarily in the results of the Canadian Arctic Expedition (1913-1918) and the writings of MacGinitie (1955). [The paper on the taxonomy of the polychaetes of the Point Barrow region prepared by Pettibone (1954), a key reference work for our research, was one consequence of MacGinitie's interest in the benthos.] The WEBSEC cruises thus represent the first comprehensive effort to study the western Beaufort Sea, including the benthic invertebrates.

The purposes of this study were to delineate patterns inherent in the distributions and abundances of benthic invertebrates, and to assess the possible influences of environmental factors on those distributional patterns. The polychaetous annelids were chosen as the indicator group for this study because they represent 40-60 percent of the numbers of

individuals retained on a 1.0 mm screen, they occupy a large number of niches in the sedimentary environment, and they employ, amongst the various species, a large variety of feeding strategies (see Jumars and Fauchald, 1977). Samples collected between Cape Halkett and Barter Island during WEBSEC-71 were selected for analysis of the polychaete fauna, because the sampling gear deployed collected quantitative samples. Statistical analysis of the resultant data set was thereby facilitated.

MATERIALS AND METHODS

A Smith-McIntyre grab sampler (0.1 m^2; Smith and McIntyre, 1954) was deployed to quantitatively sample the benthic infauna of the continental shelf and slope. The depth of the continental shelf break is defined as approximately 70 m, following Carsola (1954) and Carsola et al. (1961). Of the 40 stations occupied, 24 (Table 1; Figure 1) were selected for detailed analysis of the polychaetous annelid fauna. Five grab samples were collected at each of the selected stations except station 6, where 4 were collected. For comparative purposes the selected stations have been divided into 5 transects (A to E, Figure 1) roughly perpendicular to the depth contours.

Using a modified flotation technique, the samples were carefully washed aboard ship on a sieve having a mesh aperture of 0.42 mm, and were subsequently fixed in a buffered 10% aqueous solution of formaldehyde. The samples were returned to the laboratory and

sequentially washed on sieves having mesh apertures of 1.0 mm and 0.42 mm. The samples were picked and sorted to major taxonomic categories, and the resultant faunal fractions were preserved in 70% ethanol. In this study the polychaetes in the 1.0 mm fraction were identified to species whenever possible. More than 97% of the 22,399 specimens examined were identified at the species level by the senior author; most of the remaining specimens were too damaged to permit identification.

Of the 121 polychaete species encountered, 15 are new to science and will be described in a forthcoming publication. Undescribed taxa bear letter designations in the following discussion (for example, Allia sp. A). Assistance in resolving difficult taxonomic problems was kindly provided by Dr. Kristian Fauchald at the University of Southern California. Generic assignments for polychaete species mentioned in the following discussion follow Fauchald (1977).

To facilitate some of the statistical analyses, a subset of 39 dominant species was selected (Table 2). Dominant species were defined as those species which occurred at 12 or more of the 24 stations, and/or accounted for at least 5% of the total polychaete abundance at one or more stations. Prior to statistical analysis the transformation $\ln(x+1)$ was applied to the dominant species data as a means of correcting "for departures from normality arising from the Poisson error component which causes pronounced skew when the mean count is small" (Cassie and Michael, 1968, p. 18).

Sediment samples were concurrently collected by the U.S. Geological Survey at each of the stations except stations 6 and 7. Particle size analyses were undertaken by the U.S.G.S. using standard techniques (Barnes, 1974). The resultant data have been used in some of the statistical analyses to help elucidate relationships between polychaete species and the sedimentary environment. To remove the non-linearity associated with proportional data, and to improve the normality of the data set, the transformation arcsin$\sqrt{\text{proportion}}$ was applied to the sediment grain size data prior to the statistical analysis (Cassie and Michael, 1968).

Statistical analyses were performed with the aid of a Cyber-73 series computer housed at the Milne Computer Center of Oregon State University. On the assumption that species and environmental variables are independent, possible relationships between such variables were elucidated by the computation of Pearson Product-Moment Correlation Coefficients using programs CORREL (Cooley and Lohnes, 1971) and PEARSON CORR (Vogelback Computing Center, Northwestern University). Program CLUSB generated station clusters by solving for the least sums of squares about a designated number of cluster means, after it standardized the data set such that sample means were equal to zero and standard deviations were equal to one. CLUSB was chosen because it employs a non-hierarchical clustering algorithm and thus sets no priorities on cluster separations. To test the cluster integrity, and to generate canonical variables with which the factors responsible for cluster integrity might be identified, a stepwise discriminant

analysis of station clusters was performed using program BMDO7M (Health Sciences Computing Facility, University of California, Los Angeles).

RESULTS

Depth distributions of the dominant species

A majority of the dominant species of the polychaetes are distributed over the relatively broad depth range of 20 to 1500 m or greater (Table 2), but narrower depth ranges are exhibited by species which occur in either the shallower or deeper portions of the study area. The variety of overlapping depth distributions shown in Table 2 is not unlike that encountered in other studies (Mills, 1969; Curtis, 1972), and indicates that the polychaetes of the western Beaufort Sea are not grouped into distinct assemblages along the depth gradient.

Trends in numerical abundance

Estimates of polychaete abundances are contoured in Figure 2. Abundances generally increase with increasing depth from the 20 m contour. Peak faunal densities are reached on the outer continental shelf in the eastern portion of the study area, and on the upper continental slope in the western portion of the study area. Abundances decrease with further depth increases, and very low abundances have been estimated for the deepest stations (Z>1500 m).

Trends in species richness

Species richness (number of species collected at each station) is contoured in Figure 3; trends similar to those for faunal densities are evident. Seaward of 20 m species richness increases. It is greatest along the outer continental shelf and upper continental slope (40-140 m), and decreases with increasing depth on the middle and lower continental slope. Relatively few species, as well as numbers of individuals, were collected at depths exceeding 1500 m.

Caution must be exercised when interpreting data collected at the deepest stations, however. Our standard sampling procedure of collecting five Smith-McIntyre grab samples at each station may be inadequate at these depths; better estimates of species richness would be obtained with a larger sampler (i.e., a 0.25 m^2 box corer) and replicate cores. In the Atlantic (Sanders and Hessler, 1969) and Pacific (Hessler and Jumars, 1974) Oceans the deep sea benthic fauna is very diverse, despite low numerical densities occurring there.

Station affinities

Pearson Product-Moment Correlation Coefficients for the polychaete fauna were calculated from the dominant species data subset as a measure of station affinity (Figure 4). The strongest station affinities approximately parallel the depth contours.

Cluster analysis

Stations were clustered over species using the dominant polychaete species data (Figure 5). Stations primarily clustered along depth contours, yet longitudinal trends are evident. Stations (45 m), 8 (44 m), and 9 (200 m) on the outer continental shelf and upper continental slope clustered with the shallowest stations (stations 1, 7, 12, 17, 21; 21-33 m) to form cluster A, rather than clustering with the outer continental shelf-upper continental slope stations to the east (stations 13, 14, 18, 19, 22, 23; 47-106 m). Similarly, the deepest stations (stations 6, 11, 16; 1870-2670 m) clustered with the upper continental slope stations to the east (stations 20, 24; 463-495 m) to form cluster D. The westernmost upper continental slope stations, at which some of the highest faunal densities occur, cluster separately (cluster C). Thus, in comparison with the eastern portion of the study area, the western portion is marked by the addition of a cluster and, in two other clusters (A and D), the inclusion of deeper stations than would be expected on the basis of station depths.

Discriminant analysis

A canonical analysis of discriminance was performed on the station clusters generated by CLUSB. In Figure 6 the station points are projected onto a plane described by the first and second canonical variables, which cumulatively retain more than 95% of the total sample variance. The first variable retains the greatest proportion of sample

variance, the second variable retains the second greatest proportion of sample variance, and so on, subject to the constraint that each variable is orthogonal to previously described variables. Each canonical variable is found through projection of the station points onto a linear function in which between cluster differences are best expressed. As two clusters can be separated by one linear canonical variable, all sample variance is captured in c-1 dimensions, where c equals the number of designated clusters (Cooley and Lohnes, 1971). Hence, the rank of the model in discriminant space is reduced to 3 in this analysis, and all sample variance is retained in 3 variables.

DISCUSSION AND CONCLUSIONS

Longitudinal trends

Species richness changes little from east to west along the depth contours (Figure 3), but numerical abundance of the polychaetous annelids increases from east to west on the upper continental slope (Figure 2) between 200 and 800 m. Greater abundances of certain species, particularly Lumbrineris minuta, Maldane sarsi, Minuspio cirrifera, Micronephtys minuta, Owenia fusiformis, Scoloplos acutus, Tauberia gracilis, and Tharyx ?acutus, are primarily responsible for the increased numerical densities in the western portion of the study area. The highest densities of both the polychaetous annelids (Figure 2) and the total benthic invertebrate fauna (Carey and Ruff, 1977) occur in this region. Since species richness exhibits little variation along

the depth contours, greater abundances of the species noted above result in a less equitable dominance structure within the polychaete fauna of the high density region.

Warmer water periodically intrudes into the western Beaufort Sea from the Bering and Chukchi Seas, and may be traced by its temperature characteristics (Hufford, 1973). In the summers of 1971 and 1972 these waters, which are rich in particulate organics (Johnson, 1956) intruded to approximately 148° W longitude and were characterized by temperatures above 0°C. Recent measurements by current meter and STD (Aagaard, 1978) indicate that the Bering Sea-Chukchi Sea water moves around Point Barrow in pulses that are directionally influenced by the local bathymetry of the shelf edge. The similarity between the abundance pattern of the polychaetous annelids (Figure 2) and the distributions of Bering Sea-Chukchi Sea water in 1971 and 1972 (Hufford et al., 1974) further support the hypothesis of Carey and Ruff (1977) that organic fallout from these warmer waters enriches the benthic environment on the upper continental slope to the west of 148° W longitude, and thereby fosters high standing stocks of benthic invertebrates in that region. The greater thicknesses of holocene sediments reported in this area in shallow water at the shelf edge (Barnes and Reimnitz' data, as cited in Barnes and Hopkins, 1978) indicate higher sedimentation rates at this longitude. Although the processes causing the greater sediment thicknesses are not known, higher sedimentation rates could provide a larger detrital food input to the benthos in this region.

Comparisons with other regions

Numerical abundances of the total polychaete fauna along transects A through E are plotted in Figures 7 and 8. Polychaete abundances along transects in the eastern Beaufort Sea (Wacasey et al., 1977) are also plotted in Figure 8, while abundances along the Bermuda-Gay Head transect (Sanders et al., 1965), and transects off Martha's Vineyard, Massachusetts (Wigley and McIntyre, 1964), and Newport, Oregon (Carey, unpublished data) are plotted in Figure 9. Despite the use of different collecting and sieving methods by the various researchers (Table 4), cautious comparisons of the resultant abundance data provide insight into the benthic environment of the western Beaufort Sea.

A comparison of transects A through E (Figures 7 and 8) reveals that the highest densities of polychaetes occur on the upper continental slope along transects A and B. Lower upper continental slope densities occur along transect C, while the lowest upper continental slope densities are found along transects D and E. If Bering-Chukchi Sea water is providing organic fallout to the upper continental slope environment as hypothesized, its effects decrease eastward and disappear east of transect C at approximately 148° W longitude. This was the approximate eastern margin of the water mass in 1971 and 1972 (Hufford et al., 1974).

By contrast, polychaete densities on the continental shelf vary much less than those on the upper continental slope. Hence, they are lower than upper continental slope densities along transects A and B, higher than upper continental slope densities along transects D and E,

and are a-proximately equal to upper continental slope densities along transect C. Eastern Beaufort Sea abundance data (Wacasey, 1977) suggest that the density patterns of the polychaetes in that region are similar to the patterns observed along transects D and E, the most easterly transects in this study (Figure 8).

Density patterns observed for western Beaufort Sea polychaetes are not unlike patterns observed in portions of the Atlantic and Pacific Oceans. Except for higher densities which probably result from the use of a smaller mesh aperture during sample washing (Table 4), the density pattern of the polychaetes along the Gay Head-Bermuda transect (Figure 9) is similar to that observed along transects A and B. Highest abundances were found on the continental slope, while lower abundances were observed on the continental shelf, and lowest abundances were observed on the lower continental slope.

Off Martha's Vineyard, Massachusetts and Newport, Oregon (Figure 9) highest polychaete abundances occurred on the continental shelf. Densities then decreased with increasing depth on the continental slope, a pattern similar to that observed along transects D and E. Abundances, however, seem to be generally higher in the western Beaufort Sea, despite the use of similar sampling and washing methods in the Martha's Vineyard study, and the use of a smaller mesh aperture for washing samples collected off Newport (Table 4).

Faunal trends and the sedimentary environment

Correlation coefficients for station pairs (Figure 4) and results of the cluster analysis of stations (Figure 5), both based on the

dominant polychaete species data, indicate that station affinities are strongest parallel to the depth contours. Similar results were obtained in earlier studies when indices of affinity (Renkonnen, 1944; Sanders, 1960) were determined for station pairs using megaepifaunal data (Carey et al., 1974), and when recurrent group analysis (Fager, 1957) was applied to both the megaepifaunal data and the bivalve molluscan data (Carey and Ruff, 1977).

High station affinities parallel to the depth contours appear to contradict the predominance of broad depth distributions exhibited by a majority of the dominant species (Table 2). However, since species are not uniformly distributed throughout the depth and breadth of their ranges, and since Pearson Product-Moment Correlation Coefficients are sensitive to changes in species abundances, no contradiction exists. Minuspio cirrifera, for example, was found at 22 stations throughout the entire depth range of the study area, but it was very abundant (more than 1,400/m^2) only on the continental slope in the western portion of the study area (stations 4, 5, 10).

Longitudinal trends inherent in the station clusters in Figure 5 include the addition of an upper continental slope cluster in the western portion of the study area, and the inclusion of deeper stations to the west in clusters A and D than would be expected on the basis of station depth. A general downslope extension of the dominant species occurs in the western portion of the study area, and results in the transgression of depth contours by the station clusters in that area. This transgression may be related to trends in the sedimentary environ-

ment, which have been shown to influence the distribution and abundance of benthic infaunal species (Thorson, 1957, 1966; Sanders, 1960).

When sediment grain size distributions for each of the stations occupied (except 6 and 7) are plotted (Figure 10), it is apparent that stations with similar sedimentary characteristics have been grouped by the cluster analysis. The sediments at cluster A stations are sandy muds (mud=silt+clay) which have a relatively uniform proportion of silt (36-48%). Cluster B stations are characterized by the predominance of coarser grain sizes (sand and gravel). Gravel is found only at cluster B stations, and occurs at all but one station in that group (14, underlined in Figure 10). Two stations (3, with mixed sediments; 23, with silty clay sediments) in cluster B contain much less than 50% coarse granules, but their inclusion in cluster B is logical since each contains gravel and therefore exhibits a relatively high degree of sedimentary heterogeniety. Muds with low sand content occur at cluster C and D stations, which may be distinguished by their differing silt-clay ratios.

Higher variability of the grain size proportions at cluster A and B stations, compared to cluster C and D stations (Figure 10), probably reflects the greater intensity with which geological processes affect the sediments on the continental shelf, compared to the continental slope. Ice rafting, ice gouging, waves, currents, and tides have been shown to influence the composition and morphology of the continental shelf sediments (Barnes, 1974; Barnes and Reimnitz, 1974; Reimnitz et al., 1978). The clustering of stations with similar sedimentary

characteristics indicates that the polychaetes are good discriminators of sedimentary environments, and that the longitudinal trends observed in the station clusters (Figure 5) are probably related to similar trends in the distribution of sedimentary environments across the continental shelf and slope of the western Beaufort Sea. This relationship may be explored more fully with the aid of a canonical analysis of discriminance.

Interpretations of the canonical variables in Figure 6 were facilitated by correlating the variables with species and environmental data sets. As the environmental data are not as comprehensive as desired, the possible influences of many factors (e.g., temperature, salinity and dissolved oxygen at the sediment-water interface, sediment pore water content, food input and species interactions) upon species distributions and abundances cannot be addressed. Interpretations must, therefore, be considered incomplete.

Significant positive correlations ($P<.01$) of the first canonical variable with 1) the number of polychaete species at each station, 2) the natural logarithm of the total abundance of the polychaete fauna at each station, 3) percent sand, and 4) percent gravel in the sediments were found. Species significantly correlated with the first variable predominantly demonstrated significant correlations with percent sand or percent sand and percent gravel (Table 3). Highest abundances of those species were generally found at stations in cluster B (Figure 5) on the outer continental shelf and upper continental slope (40-140 m).

The first canonical variable was negatively correlated with percent silt ($P<.05$) and percent clay ($P<.01$). Species negatively correlated

with the first variable were correlated with percent clay (Table 3), and were most abundant at the stations comprising cluster D (Figure 5).

The positive correlations ($P<.01$) of the first variable with species richness and total polychaete abundance indicate that the stations occupied may be grouped and ordered primarily by the diversity of the polychaete fauna at each station. Diversity is highest at group B stations, found along the outer continental shelf and upper continental slope. The predominantly inner shelf stations in group A exhibit somewhat decreased diversity, while lowest diversities are found at group C and D stations. The correlation of faunal diversity with sediment grain size is obvious when Figures 6 and 10 are compared: grain size and faunal diversity decrease concurrently.

The second canonical variable correlates with percent silt ($P<.01$). (Note that because program BMDO7M plotted the second variable increasingly negative, correlations were reversed in sign. For simplicity the signs have been changed in Table 3 and the text.) Significant correlations of species with the second variable were primarily exhibited by those species associated with silt (Table 3), with one exception. Anaitides groenlandica curiously correlates with both the first ($P<.01$) and second ($P<.05$) variables. As this species is predaceous (Ushakov, 1972), unmeasured factors such as prey density may influence its distribution such that correlations with both variables result. Those species associated with silt and the second canonical variable (Table 3) are generally most abundant at stations in cluster A.

In summary, two independent data sets have been used to compare stations occupied on the continental shelf and slope. Cluster and discriminant analysis of polychaete species data generated four station groups and ordered them in two-dimensional space with a minimal loss of variance (Figure 6). Sediment grain size data were also used to compare stations by plotting station points on a tertiary sediment diagram (Figure 10).

Correlations of the canonical variables in Figure 6 associated the greatest proportion of sample variance with grain size, and the second greatest proportion of sample variance with the silt content of the sediments. Examination of the station points in Figure 10 reveals an analogous pattern of sample variance: most variance is associated with grain size, and the station groups are ordered in the same sequence as they are along the first canonical variable. Additional sample variance in Figure 10 may be attributed to the group A stations, since the projection of those station points onto a line perpendicular to the silt axis would greatly reduce station point scatter.

As the stations have been similarly grouped and ordered by analyses performed on two data sets, a dependency of one data set on the other is highly probable. Hence, the distributional patterns and abundances of the dominant polychaete species probably result largely from variations in the sedimentary environment on the continental shelf and slope of the western Beaufort Sea.

The results of this study strongly indicate that the benthos of the western Beaufort Sea are not atypical. Variations in numerical abundance and overlapping depth distributions of the dominant species of polychaetes within the study area are similar to abundance and distribution patterns observed in temperate regions. The influence of variations in the sedimentary environment of the benthos cannot be clearly separated from the influence of depth and depth-related processes, as these factors are not independent. Yet results of the statistical analyses performed on the dominant species data suggest that, as in other regions of the World Ocean, considerable control over species distributions is exerted by the sedimentary environment of the western Beaufort Sea.

Most important to present and future research efforts in the western Beaufort Sea is the conclusion that longitudinal variations exist within both the benthic environment and the benthic fauna. These variations are expressed most strongly on the upper continental slope west of 148° W longitude, and may be a consequence of the intrusion of Bering-Chukchi Sea water into the western Beaufort Sea. Therefore, extrapolations of conclusions from studies conducted in one portion of the western Beaufort Sea to other portions of the western Beaufort Sea should be carefully scrutinized.

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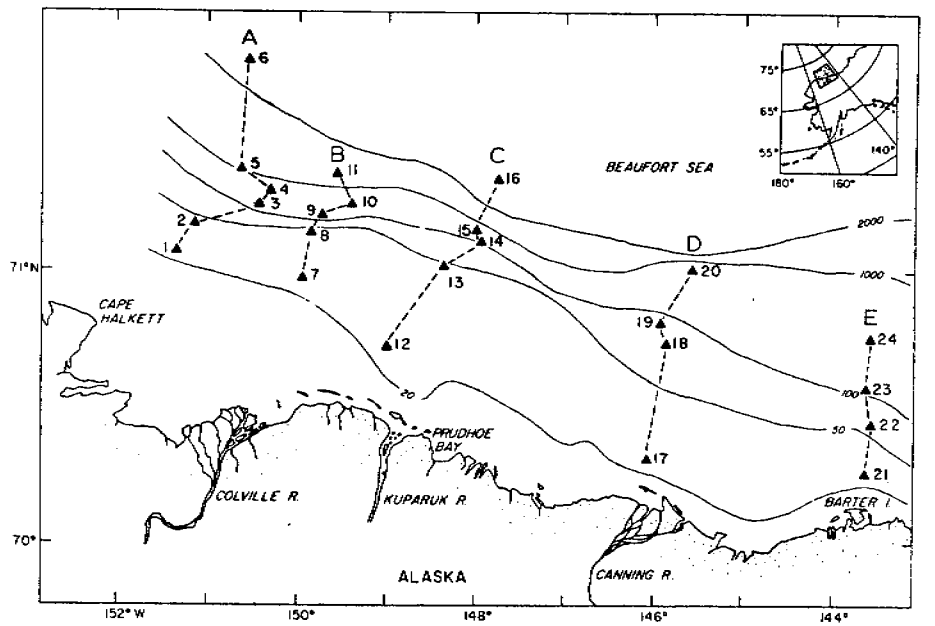

Figure 1. Stations (1-24) and transects (A-E) studied. Depth contours are in meters.

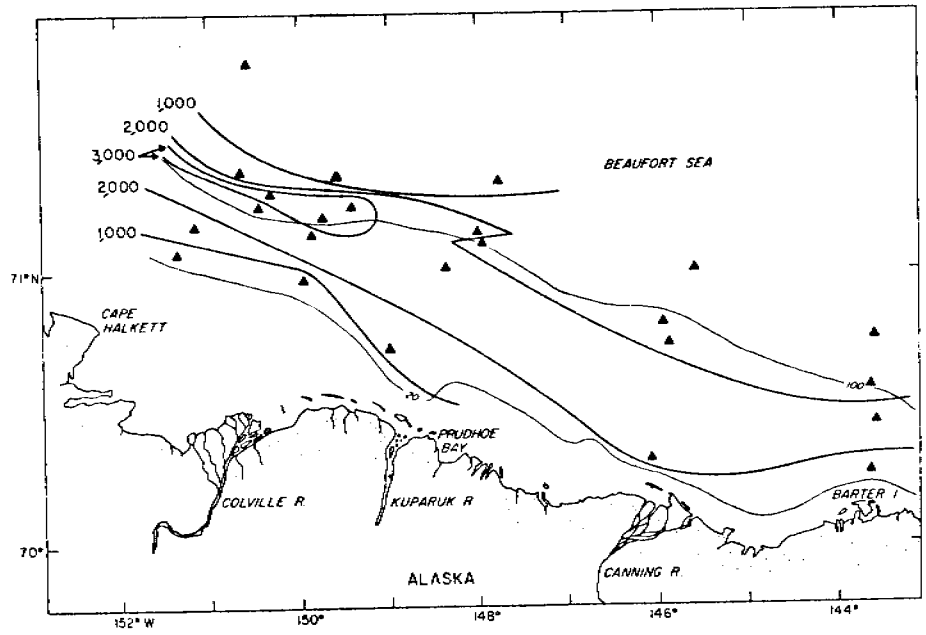

Figure 2. Polychaeta/m^2, contoured. Depth contours are in meters.

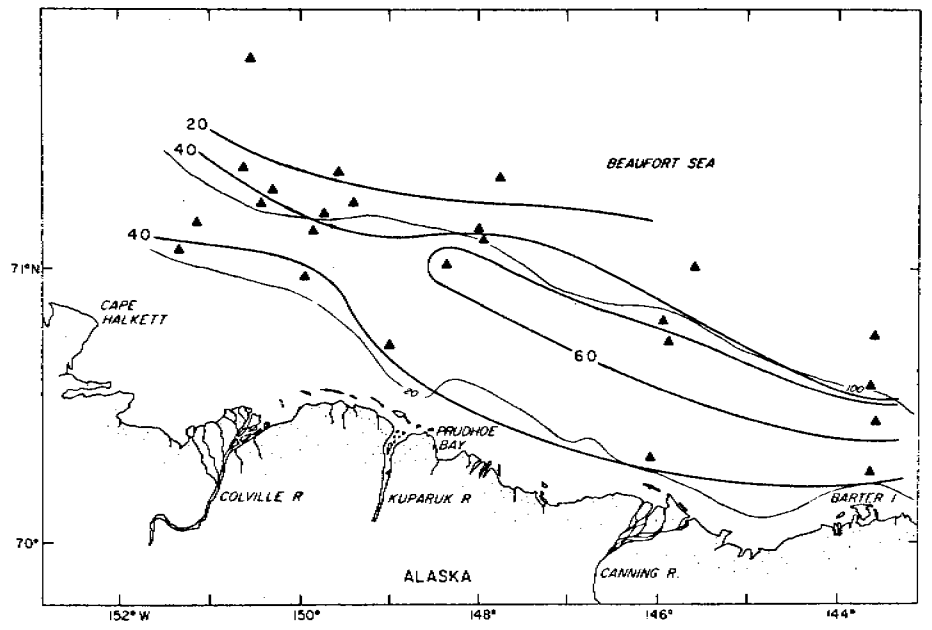

Figure 3. Number of species encountered at each station, contoured. Depth contours are in meters.

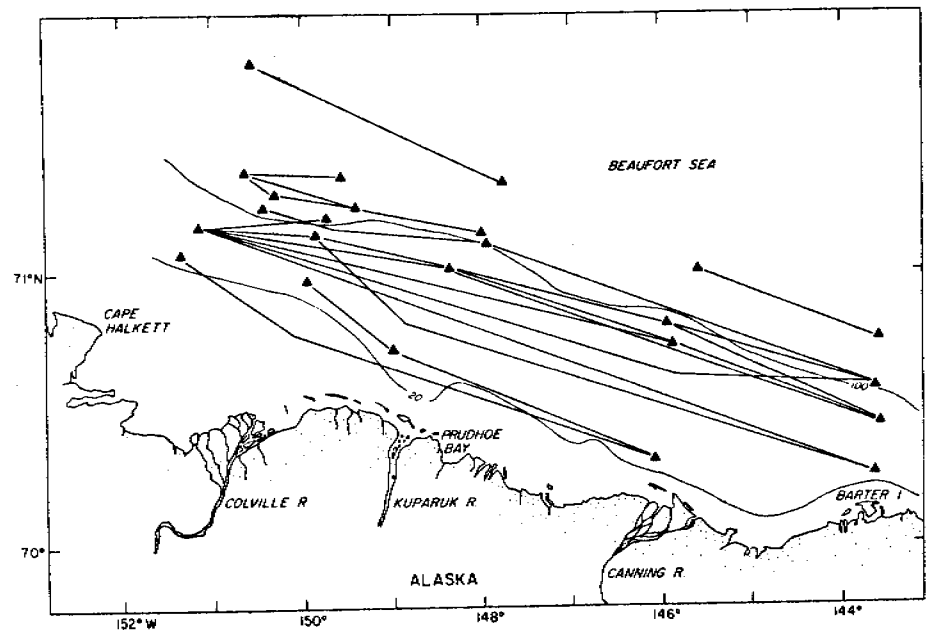

Figure 4. Station affinities estimated by Pearson Product-Moment Correlation Coefficients. All station pairings for which the correlation coefficient is > .645 ($P<.001$) are indicated. Depth contours are in meters.

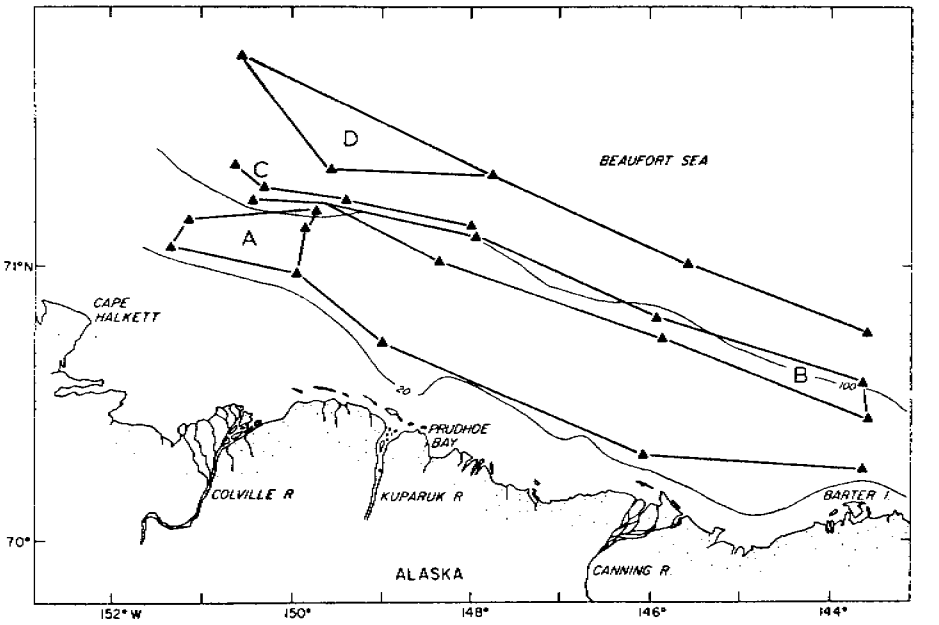

Figure 5. Four clusters of stations (A, B, C, D) in the western Beaufort Sea. Depth contours are in meters.

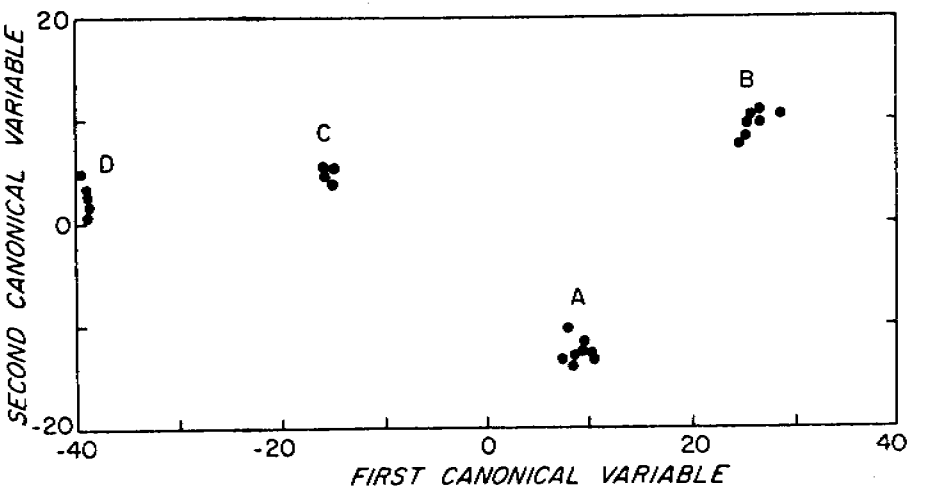

Figure 6. Station clusters plotted on the plane described by the first two canonical variables which were identified by the canonical analysis of discriminance. Station clusters correspond to those given in Figure 5; each point represents one station.

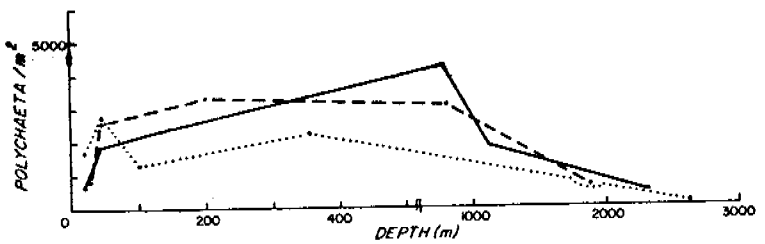

Figure 7. Polychaete abundances (as number of polychaetes/m^2) along transects A (solid line), B (dashed line), and C (dotted line) in the western Beaufort Sea. Note scale change along abscissa.

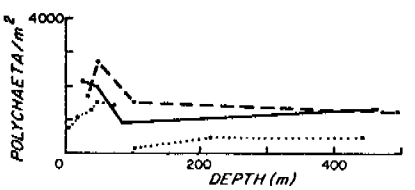

Figure 8. Polychaete abundances (as number of polychaetes/m^2) along transects D (solid line) and E (dashed line) in the western Beaufort Sea. Polychaete abundances along transects in the eastern Beaufort Sea (Wacasey et al., 1977; stations 530, 505, 545, 544, 573 and stations 554, 553, 569) are indicated by the dotted lines. Note scale change along abscissa.

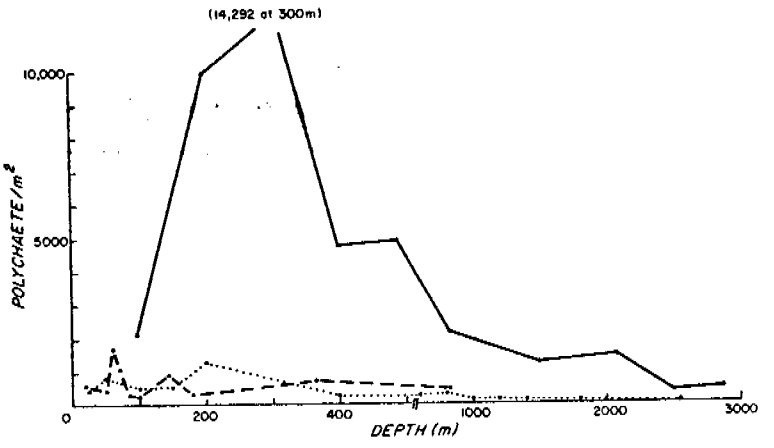

Figure 9. Polychaete abundances (as number of polychaetes/m^2 along the Gay Head-Bermuda transect (Sanders et al., 1965), a transect off Martha's Vineyard, Massachusetts (Wigley and McIntyre, 1964), and a transect off Newport, Oregon (Carey, unpublished data) are indicated by solid, dashed, and dotted lines, respectively. Note scale change along abscissa.

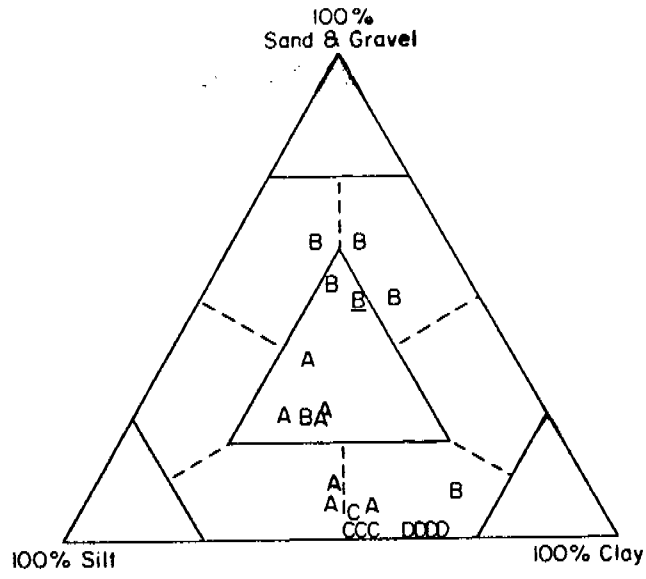

Figure 10. Sediment grain size distributions for all stations except 6 and 7 are plotted following the method outlined by Shepard (1954). Letter designations indicate the cluster (Figure 5) to which the station belongs. Gravel occurs exclusively at cluster B stations; only station 14 (underlined) in that cluster contains no gravel.

Table 1. Stations selected for detailed analysis of the polychaete fauna. Station numbers used in the following discussion are followed by the U.S. Coast Guard designations for those stations (U.S.C.G., Oceanographic Report No. CG 373-64, 1974). Zm is depth in meters.

Sta.No.	C.G. Sta.No.	Transect	Date	Latitude	Longitude	Zm
1	71	A	9/9/71	71°04.1' N	151°22.3' W	21
2	72	A	9/9/71	71°10.1' N	151°08.9' W	45
3	75	A	10/9/71	71°14.8' N	150°27.6' W	136
4	84	A	12/9/71	71°18.3' N	150°21.6' W	775
5	85	A	12.9/71	71°22.0' N	150°38.0' W	1120
6	86	A	14/9/71	71°45.1' N	150°35.0' W	2325
7	78	B	11/9/71	70°58.1' N	149°59.1' W	28
8	82	B	11/9/71	71°08.3' N	149°47.7' W	44
9	83	B	11/9/71	71°12.2' N	149°44.8' W	200
10	58	B	5/9/71	71°15.2' N	149°28.8' W	800
11	57	B	4/9/71	71°21.0' N	149°26.2' W	1870
12	63	C	7/9/71	70°43.0' N	149°00.0' W	23
13	44	C	31/8/71	71°01.0' N	148°22.7' W	47
14	30	C	30/8/71	71°06.0' N	147°57.0' W	100
15	29	C	29/8/71	71°08.5' N	148°00.0' W	355
16	20	C	25/8/71	71°13.7' N	147°22.6' W	2670
17	12	D	22/8/71	70°18.0' N	146°05.0' W	26
18	9	D	22/8/71	70°44.0' N	145°52.0' W	57
19	8	D	22/8/71	70°48.5' N	145°56.1' W	83
20	7	D	21/8/71	71°00.5' N	145°35.0' W	463
21	1	E	19/8/71	70°15.5' N	143°36.9' W	33
22	3	E	20/8/71	70°27.0' N	143°34.0' W	48
23	5	E	20/8/71	70°34.6' N	143°38.0' W	106
24	6	E	20/8/71	70°45.6' N	143°35.4' W	495

Table 2. Dominant polychaete species, including feeding type and depth range within the study area for each species. Feeding type designations are based on information given in Pettibone (1963), Day (1967), Hartmann-Schroder (1971), Ushakov (1972), and Jumars and Fauchald (1977). C, carnivore; O, omnivore; F, filter feeder; S, surface deposit feeder. Bars indicate depths of actual collection; arrows indicate scale changes.

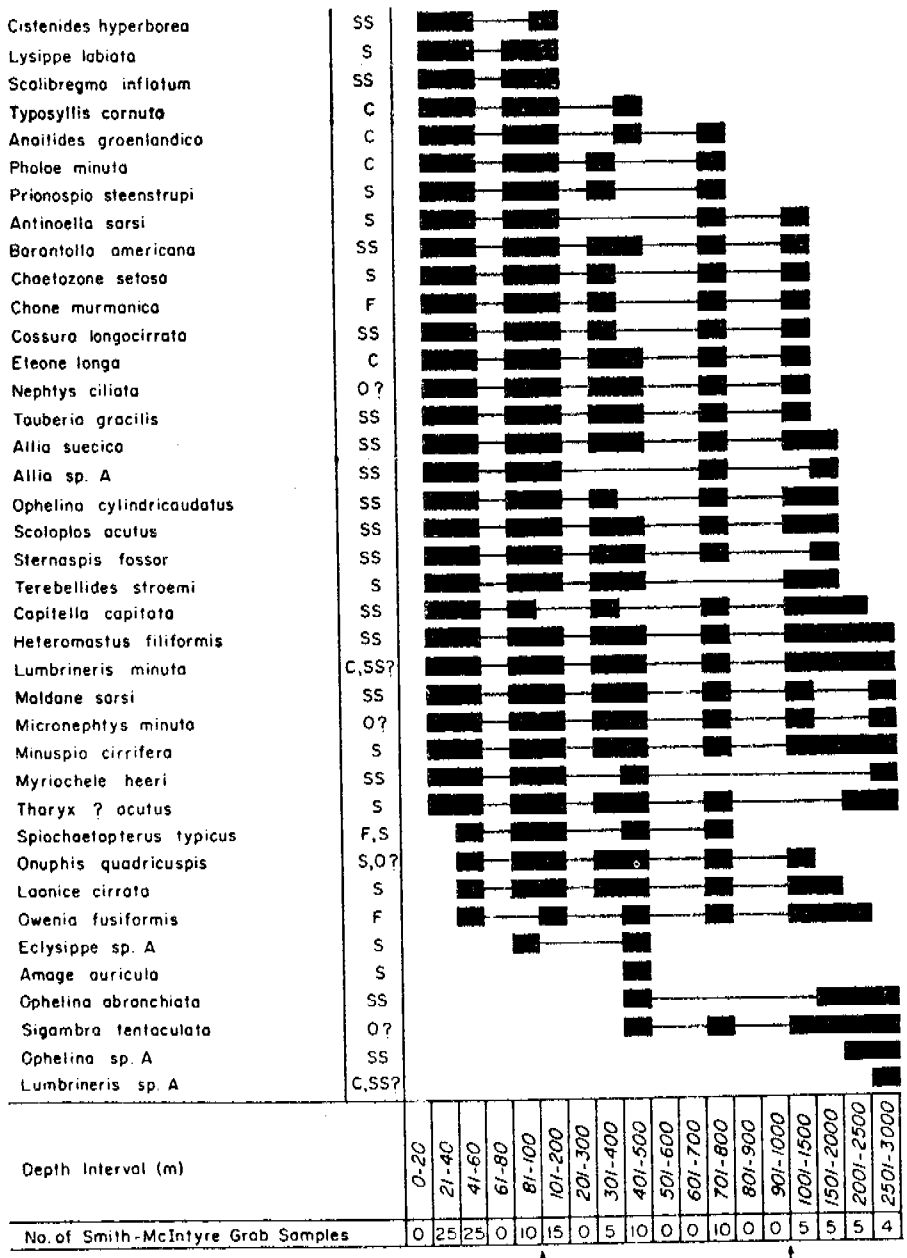

Table 3. Significant correlations ($p<.01$) of the first and second canonical variables (Figure 6) with dominant polychaete species, log transformed data ($\ln(x+1)$). Significant correlations ($P<.05$) of those species with sediment grain size, arcsin transformed data (arcsin $\sqrt{\text{proportion}}$), are also included. gr, gravel; sd, sand; st, silt; cl, clay; ns, no significant correlations with grain size.

Positive correlations, first canonical variable:

sd	Anaitides groenlandica	sd&gr	Pholoe minuta
sd&gr	Antinoella sarsi	sd	Prionospio steenstrupi
ns	Chaetozone setosa	sd&gr	Scalibregma inflatum
sd&sg	Chone murmanica	ns	Spiochaetopterus typicus
sd&gr	Heteromastus filiformis	sd&gr	Terebellides stroemi
sd	Lysippe labiata	sd	Tharyx ? acutus
sd	Micronephtys minuta	sd&gr	Typosyllis cornuta
sd&gr	Ophelina cylindricaudatus		

Negative correlations, first canonical variable:

cl	Amage auricula	cl	Sigambra tentaculata
cl	Ophelina abranchiata		

Positive correlations, second canonical variable:

sd	Anaitides groenlandica	st	Cossura longocirrata
st	Capitella capitata	st	Sternaspis fossor
st	Cistenides hyperborea		

Table 4. Samplers and mesh apertures of the sieves used for washing benthic invertebrates in the studies for which the results are compared in Figures 9, 10, and 11.

Location	Researcher(s)	Sampling Gear	Mesh Aperture (mm)
Western Beaufort Sea	this study	Smith-McIntyre Grab	1.00
Eastern Beaufort Sea	Wacasey et al., 1977	WILDCO Petersen Grab, Petterson Grab	0.50
Bermuda-Gay Head transect	Sanders et al., 1965	Deep-Sea Anchor Dredge	0.42
Martha's Vineyard, Mass.	Wigley and McIntyre, 1964	Smith-McIntyre Grab	1.00
Newport, Ore.	Carey, unpublished data	Anchor-Box Dredge	0.42

C. Distributional Notes of Harpacticoida (Crustacea: Copepoda) Collected from the Beaufort Sea (Arctic Ocean) *

ABSTRACT

Forty-one species of large-size Harpacticoida have been sorted from Smith-McIntyre grab samples sieved through 1.00 and 0.50 mm aperture screens. Fifty eight stations were occupied throughout the southwestern Beaufort Sea; ranging from Point Barrow, Alaska (USA) west, to Demarcation Point, the eastern border with Canada. The depth of the study area ranged from 5-3500 m. Harpacticus superflexus Willey and Stenhelia nuwukensis M. S. Wilson dominated the samples numerically. Though H. superflexus was ubiquitous, S. nuwukensis was restricted to a narrow range in shallow waters. The female to male ratio was 99:1. It is not known why there is such a preponderance of females, however sexually dimorphic characters may be absent or the smaller males may have passed through the sieve.

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* Draft manuscript of paper submitted to ASTARTE by P.A. Montagna and A.G. Carey, Jr. (in press)

INTRODUCTION

Currently there are only three species of Harpacticoida (Crustacea: Copepoda) with known distributions in the Beaufort Sea (Arctic Ocean). This paper adds an additional 39 species to the fauna and discusses their distribution.

The Oregon State University Marine Benthic Ecology Group has been involved in an extensive sampling program in the Beaufort Sea since 1971. Approximately 500 grab samples have been sorted from 100 stations off the northern coast of Alaska (USA). Though these samples were processed to retain the macroinfauna, 2683 harpacticoids were retrieved. The organisms found represent only the larger-sized species of the fauna; however, this preliminary subset represents the first broad range survey of harpacticoids from the Beaufort Sea.

STUDY AREA

The Beaufort Sea is a deep satellite sea adjacent to the Arctic Ocean that is bordered to the south by the northern coast of Alaska and to the southeast and east by Canada and the Canadian Archipelago. The sea has a narrow continental shelf with the shelf break at about 70 meters depth (Barnes & Reimnitz 1974). The dominant sediments on the shelf are coarse, silty sands (Carsola 1954), though the sediments are poorly sorted and are patchy in distribution (Barnes & Reimnitz 1974). The sea ice canopy is generally seasonal over the shelf and is a dominant feature of the ecology and oceanography of the region. It dampens air-sea interaction and shades the waters beneath from insolation (Coachman & Aagaard 1974, Horner 1976). On the inner shelf the keels of ice pressure ridges gouge the sea floor out to depths of 40 meters (Reimnitz

& Barnes 1974). Primary production is variable and patchy; the influence of ice shading, water column stability and low nutrient levels are thought to limit it in the Beaufort Sea to short periods in late spring and early summer (Carey 1978). Water temperatures on the shelf and seawards are always within a few degrees of 0°C throughout the water column (Coachman & Aagaard 1974).

MATERIALS AND METHODS

The harpacticoids discussed in this paper were from samples collected during eight separate field efforts from 1971-1977. The Western Ecological Beaufort Sea Cruise (WEBSEC-71) aboard the USCGC GLACIER provided the broadest coverage. Results of macroinfauna studies are reported in Carey et al. (1974) and Carey & Ruff (1977). The harpacticoids found in these samples were taken from stations 1-29 (Fig. 1).

Seven other sampling trips were sponsored by the Outer Continental Shelf Environmental Assessment Program (OCSEAP), and are labelled OCSEAP-1 through OCSEAP-7. A standard transect was established off Pitt Point, Alaska (USA) with stations at 25, 40, 55, 70 and 100 m. These stations (30-34 respectively, Fig. 1) were revisited and occupied six times from November 1976 through August 1977 by helicopter forays during ice-covered months and by ice breaker during the summer. Other cruises in the summer extended the geographical and depth ranges of the study area.

Five samples were taken at each station with a 0.1 m^2 Smith-McIntyre grab (Smith & McIntyre 1954). During helicopter trips, a portable hydro-winch and tripod were used to lower the grab through the sea-ice. All samples were treated in the following manner: in the field, samples were washed through a 0.42 mm aperture sieve and preserved with 10%

formalin and buffered sea water. In the laboratory, samples were rewashed and split into two fractions. The larger fraction was that which was retained on a 1.00 mm sieve. The smaller fraction passed through the 1.00 mm sieve but was retained on a 0.42 mm sieve. Both fractions were preserved in 70% EtOH. The larger fractions were picked and sorted. Work is now underway to pick and sort the small fractions; at present such data are available for only WEBSEC-71 stations 12 and 13, and the OCSEAP-7 deep-sea Stations 48, 49, 50, 51, 52, 54 and 58.

Though the Smith-McIntyre grab samples were quantitative for the macroinfauna, they cannot be interpreted as such for a meiofaunal group such as harpacticoids, because of our sample processing techniques. The data reported here are for large species and individuals. To our knowledge, there are no extensive reports of the Beaufort Sea meiofauna community in the literature.

RESULTS

The samples have yielded 2,683 harpactiocids of 41 species (Table I). Six species are considered to be sampled adequately because they are large and are seldom found in the small fraction. Paramphiascopsis giesbrechti (Sars), Typhlamphiascus lamellifer (Sars), Bradya typica Boeck, Pseudocervinia magna (Smirnov), Argestes mollis Sars and Paranannopus echinipes Smirnov are large species where adult body length ranges from 1.0-1.8 mm. When caudal rami and principal caudal setae are included their lengths can range up to 3 mm. Typhlamphiascus lamellifer has the most restricted range of the above group, it occurs only in the western portion of the Beaufort Sea (east of Sagavanirtok River) and along the shelf edge (approximately 100 m depth). The other five species

occurred at the shelf edge throughout the study area. Though A. mollis was found predominantly in deeper waters, the remaining four species are found only at shallow stations (1, 22, 73 and 74) in the eastern half of the region.

The two most numerically abundant species, Harpacticus superflexus Willey and Stenhelia nuwukensis M. S. Wilson, were slightly smaller in size (about 0.8-1.2 mm). Harpacticus superflexus had the widest distribution, found everywhere from east to west, and between 5-2000 m (Fig. 2), whereas S. nuwukensis was restricted to six shallow water stations (5-20 m). In fact, 95% of S. nuwukensis was found at Station 39 (5 m), an area rich in detrital peat that has probably eroded from the coastal shoreline (MacGinitie 1955).

Thalestris frigida (T. Scott) and Halectinosoma neglectum (Sars) were collected only in shallow depths (Fig. 2). Species restricted to the deep-sea (>1,000 m) were Cerviniopsis smirnov Por, three other species of Cerviniidae, and the two species of Pseudotachidius.

The discontinuity of distributions deeper than 150 m is due to the paucity of deeper sampling. Only three stations (12, 28 and 53) represent the entire zone between 150-700 m. There are two stations each at 700, 1,000 and 2,000 m. Since H. superflexus was found in practically every station (Table I), it is considered to have a continuous distribution (Fig. 2). But, P. echinipes was found in only two of the shallow shallows (<50 m) on the far eastern end of the study range, hence it's distribution is not assumed to be continuous (Fig. 2).

DISCUSSION

Reports of Harpacticoida from the Beaufort Sea are rare probably because sampling in the arctic environment is difficult and the harpacticoid fauna is small. The Canadian Arctic Expedition did find some harpacticoids at three stations in samples taken from shallow waters beneath the sea ice. Willey (1920) reported three species: Halectinosoma finmarchicum (T. Scott), Danielssenia fusiformis Brady, and H. superflexus.

The only other reports of harpacticoids from the region covered by the study area, is a study of Nuwuk Lake; a halocline lake at the end of Point Barrow, Alaska (USA), Nuwuk Lake is often inundated by ocean waters during storms. From this study Wilson (1965) described S. nuwukensis, which we found in great abundances in coastal waters extending to the Canadian border. Also from the Nuwuk Lake study, Mohr et al. (1961) report finding Danielssenia stefanssoni Willey, Microarthridion littorale (Poppe) and Proameira hiddensoensis (Schaffer).

From the adjacent Arctic Ocean to the north, Paul & Menzies (1974) reported on five species that they collected from the Alpha Cordillera ridge while stationed on "Fletcher's Ice Island, T-3." Canuella furcigera Sars, Longipedia cornuta Claus, Sarsocletodes typicus (Sars) and B. typica were taken from deep waters (1060 to 2530 m) near the North Pole.

We have found 4 of the 12 species mentioned in the above studies: the ubiquitous H. superflexus; the coastal S. nuwukensis; the widely distributed B. typica; and D. fusiformis at a single station.

In comparison with known distributions given by Lang (1948) we find zone extensions for 12 species (Table I). Of the species reported here 24 are arctic, 5 are arctic-subarctic, 8 are subarctic, and 4 occur in

unrelated regions and may be cosmopolitans. The fauna shows Atlantic affinities. Though no Pacific forms are found, this may be due to the paucity of sampling in the north Pacific Ocean.

The samples were disproportionately dominated by females. Only 28 males were found giving a female/male ratio of 98.85:1. Coull (1973) discusses the phenomenon of high female to male ratios for harpacticoids, and suggests that incompletely developed juvenile males could be misidentified as females. Since our samples yielded only large harpacticoids, very few copepodites were found, and this explanation is not likely. Most puzzling is that no males were found for the five most abundant species; M. superflexus, S. nuwukensis, P. magna, P. echinipes and Cervinia sp. L; these comprise 82% of the entire collection. Of the males found, 14 (50%) were from the family Diosaccidae; there was at least one male found from every genus represented in this family.

Coull (1973) suggests high female/male ratios may be explained by two other hypotheses: (1) a new evolutionary line within the Harpacticoida where antennule and fifth pediger sexual dimorphism are absent; (2) intersexuality, where an animal is neither male nor female, but intermediate with female characteristics dominating.

Though the males of S. nuwukensis, P. echinipes and Cervinia sp. L. are unknown, those for P. magna and H. superflexus are known. It is possible that males were missed if they do not exhibit well developed characters. However, the male of H. superflexus does have a haplocer antennule and would be easily identified. Therefore, neither hypothesis is adequate to explain why 886 H. superflexus females were found, but no males. Our present data cannot help clarify this controversy, and it is possible the Arctic environment may add another variable.

We do believe, however, that weak secondary sexual characters in males could have led to misidentification of some males. Since males are generally smaller than females they also could have been lost more easily in the sample processing. However, both of these explanations would still not account for the female/male ratio of almost 100:1 that was found in the Beaufort Sea.

ACKNOWLEDGMENTS

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Table I: Occurrence of Harpacticoida in the Beaufort Sea. Z = zoogeographic zones: A = arctic, S = subarctic, I = Indian Ocean, M = Mediterranean Sea, N = northern Atlantic Ocean. Total is the number of specimens collected from all stations.

SPECIES	Z	STATIONS	TOTAL
Ameiridae			
Parameira dubia (Sars)	S	34	1
Sarameira sp.		32	1
S. elongata (Sars)	A	33	1
Cerviniidae			
Cervinia sp. L*	A	2,3,6,7,11,13,19,24,33,34,35,51,52, 53,56	110
Cervinia sp. B		29,58	6
Cervinia sp. A		49,50	3
Cervinopsis smirnovi Por	I	48,49	3
Pseudocervinia magna (Smirnov)	A	1,2,4,7,9,10,11,12,13,15,16,18,19, 22,23,24,27,30,32,33,34,35,36,54,55	231
Stratiopontes sp.		58	1
Cletodidae			
Argestes mollis Sars	AS	13,15,18,19,32,51,52,56,57,58	23
Eurycletodes arcticus Lang	A	32,34,39	5
E. serratus Sars	S	32	1
Mesocletodes brevifurca Lang	A	48	1
M. katherinae Soyer	M	56	1
M. monensis Thompson	S	35	1
Parmannopus echinipes Smirnov	A	12,13,15,19,23,24,27,32,34,47,54	171
Diosaccidae			
Amphiascus propinquus Sars	S	15	1
Paramphiascella fulvofasciata Rosenfield & Coull	N	14,16,32	4
Paramphiascopsis diesbrechti (Sars)	S	2,8,13,15,19,30,31,32,33,34,54,55	61
Pseudomesochra longifurcata (T. Scott)	Z	32	1
Stenhelia sp. B		39	21
Stenhelia sp. C		39	14
S. bocqueti (aff.) Soyer	M	47	3
S. nunukensis M.S. Wilson	A	39,40,41,46,47,54	809
S. proxima Sars	S	39,47	5
Typhlamphiascus lamellifer (Sars	AS	12,28,31,32,33,34	17
Ectinosomidae			
Bradya confluens Lang	A	3,13,52,56,57	12
B. typica Boeck	AS	12,13,16,19,24,31,32,33,34,37,39, 44,46,47,54	76
Halectinosoma sp.		2,5,13,18,24,31,32,33,34,39,47,54	32
H. neglectum (Sars)	A	32,34,38,39,47	25
Harpacticidae			
Harpacticus superflexus Willey	A	1-6,9-21,24-27,30-35,37-40,42-47, 51-58	386
Zaus sp.		32	2
Laophontidae			
Echinolaophonte brevispinosa (Sars)	S	32	7
Tachidiidae			
Danielssenia fusiformis (Brady & Robertson)	A	34	4
Thompsonula hyaenae (Thompson)	SN	39	7
Thalestridae			
Parathalestris jacksoni (T. Scott)	AS	34,37	2
Pseudotachidius sp. A*		52,53,58	60
Pseudotachidius sp. B*		52,58	6
Thalestris frigida (T. Scott)	A	5,32,34,37,38,39,41,46,47	34
Tisbidae			
Tisbe sp.		32,34,47,55	32
Zosime sp.		32,47	2

*Indicates species descriptions in press

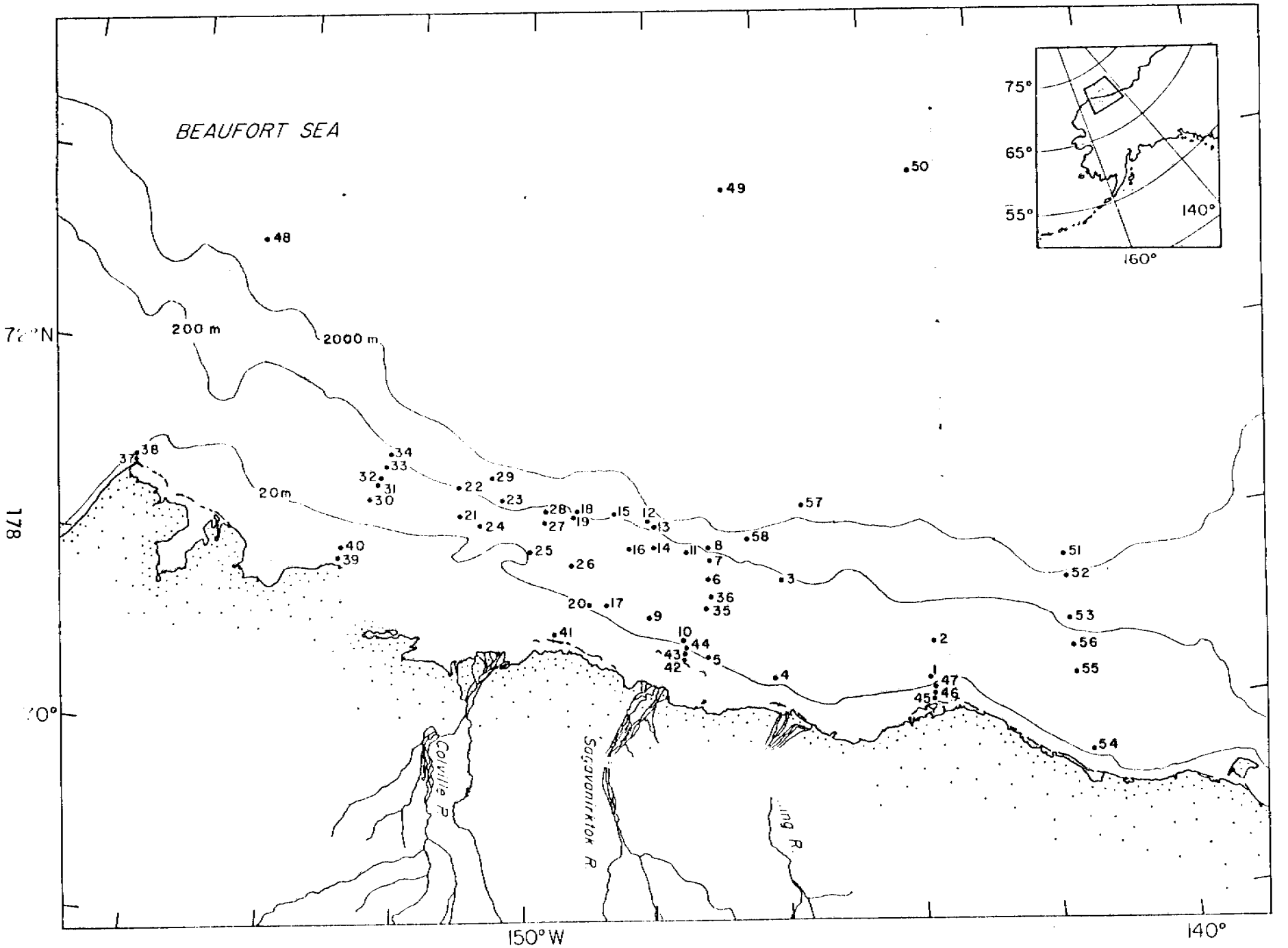


Figure 1: Station Location Chart. Five Smith-McIntyre grab samples were collected at each station.

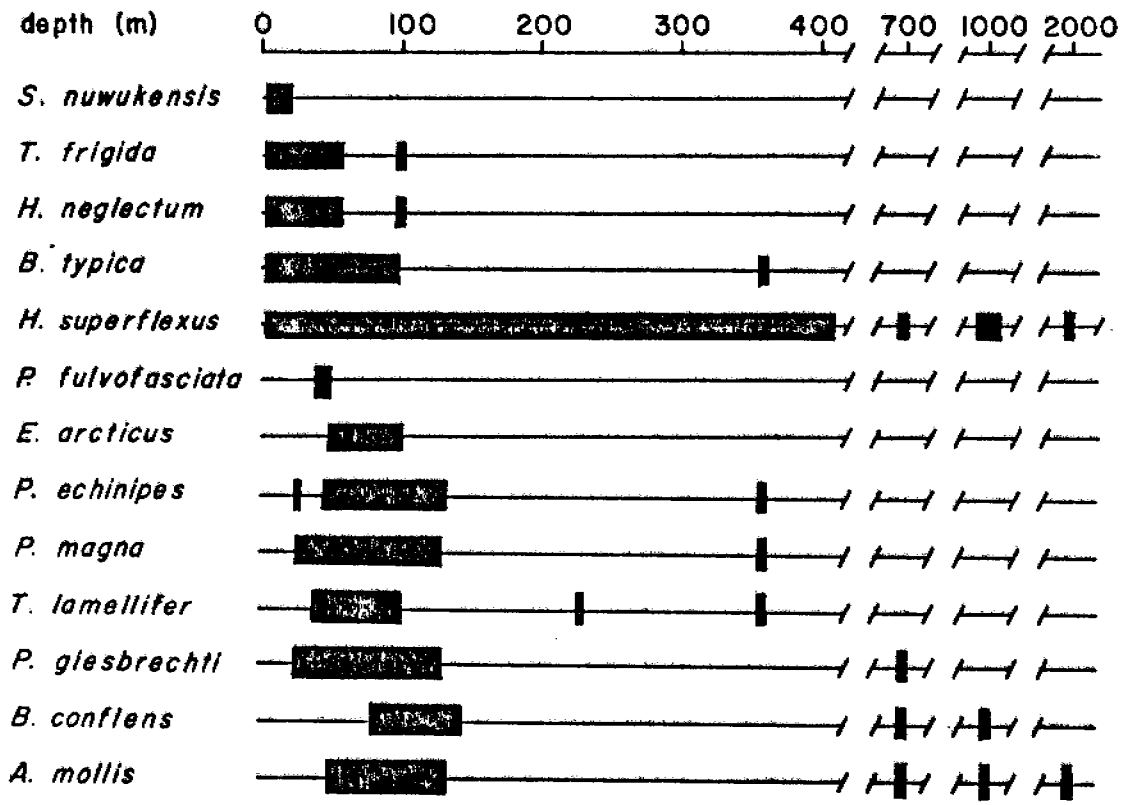


Figure 2: Depth distributions of 15 most abundant species. Lack of occurrences between 150-350 m may be caused by inadequate sampling at those depths.

V. Problems Encountered and Recommended Changes.

The perpetual problem of the lagtime involved in the complete taxonomic work-up of a sample has created problems in data transmittal via magnetic tape on a quarterly schedule. Upon discussion with Toni Johnson and EDS, the most feasible solution is the plan to submit a final up-dated and as complete a tape as possible at the end of the RU #6 contract. This procedure will reduce the load on EDS in the up-dating of tapes. Previously we up-dated our tapes each quarter as more animal identifications were made and confirmed.

VI. Estimate of Funds Expended (12/26/78).

	Budget	Spent	Spent This Quarter
Salaries & Wages	$166,965	$172,109	$15,294
Materials & Supplies	31,235	35,010	1,590
Travel	13,350	15,628	1,385
Equipment	47,617	47,431	------
Payroll Assessment	26,291	26,574	2,496
Overhead	85,367	82,947	6,784
TOTAL	$370,825	$379,699	$27,549

APPENDIX

1. Animal densities for PPB stations (0.5-1.0 mm fraction of SMG grab samples).

2. Costal Polychaeta identifications. Depth 5-25 meters. R/V ALUMIAK 1976 cruise.

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

Table 1. Animal Densities for PPB-25 (OCS-3) 0.50 mm fraction, collected on 17 May 1976. Each sample is a 0.1 m^2 Smith-McIntyre grab.

Phylum:	Class:	Order	Grab Number 1141	1142	1143	1146	1150	Total m^2	% of Fauna
Nematoda			103	61	23	78	12	554	14.5
Nemertinea			2	1	1	1	--	10	0.3
Annelida:	Polychaeta		83	65	22	88	36	10	0.3
Sipuncula			1	2	--	--	--	6	0.2
Arthropoda:	Crustacea:	Amphipoda	1	36	1	--	2	80	2.1
		Cirripedia	--	2	--	--	--	4	0.1
		Harpacticoida	79	38	15	66	7	410	10.7
		Isopoda	3	4	2	4	--	26	0.7
		Ostracoda	192	193	143	268	165	1922	50.3
		Tanaidacea	9	11	10	26	5	122	3.2
		Cumacea	--	2	--	1	--	6	0.2
Mollusca:	Pelecypoda		17	9	4	6	5	82	2.1
	Gastropoda		--	2	--	--	1	6	0.2
Echinodermata:	Ophiuroidea		1	--	--	--	--	2	0.1
	Holothuroidea		--	--	1	--	--	2	0.1
TOTAL			491	426	222	538	233	3820	100.0

Table 2. Animal Densities for PPB-55 (OCS-3) 0.50 mm fraction, collected on 20 May 1976. Each sample is 1/4 of a 0.1 m^2 Smith-McIntyre grab.

Phylum:	Class:	Order	Grab Number 1156A	1156B	1156C	1156D	1158A	1159A	1160A	Total m^2	% of Fauna
Cnidaria:	Anthozoa		--	--	--	--	--	2	--	5	.1
Porifera			1	--	1	1	--	--	--	3	.1
Nematoda			162	203	191	204	96	160	56	1290	21.1
Nemertinea			1	2	4	4	3	3	3	33	.5
Annelida:	Polychaeta		54	74	73	74	30	36	25	413	6.8
Sipuncula			--	3	3	3	--	3	--	15	.2
Kinoryncha			--	--	1	2	--	--	--	5	.1
Arthropoda:	Crustacea:	Amphipoda	108	89	113	112	63	90	71	840	13.8
		Cirripedia	1	4	2	--	5	2	1	20	.3
		Harpacticoida	24	19	16	19	6	6	6	93	1.5
		Isopoda	7	8	7	5	--	12	5	55	.9
		Ostracoda	338	341	323	335	184	356	246	2803	45.9
		Tanaidacea	36	41	41	46	22	23	12	258	4.2
		Cumacea	10	5	7	19	6	8	8	103	1.7
	Acarina		4	2	4	2	7	2	2	33	.5
Mollusca:	Pelecypoda		8	13	13	9	11	10	10	100	1.6
	Gastropoda		--	9	7	5	--	1	5	28	.5
Echinodermata:	Ophiuroidea		--	--	1	--	1	--	--	3	.1
	Holothuroidea		--	--	--	1	--	1	--	5	.1
Hemichordata			2	--	--	--	--	1	1	8	.1
Chordata:	Ascidacea		--	--	--	1	--	--	--	3	.1
TOTAL			756	813	807	842	434	716	451	6108	100.0

Table 3. Animal Densities for PPB-100 (OCS-3) 0.50 mm fraction, collected on 21 May 1976. Each sample is 1/4 of a 0.1 m^2 Smith-McIntyre grab.

Phylum:	Class:	Order	Grab Number 1161A	1161B	1162A	1166A	1168A	1169A	Total m^2	% of Fauna
Cnidaria:	Anthozoa		--	--	1	--	--	1	16	0.2
Nematoda			26	30	79	118	114	44	3080	38.0
Nemertinea			--	--	1	4	1	1	56	0.7
Annelida:	Polychaeta		4	18	25	25	43	20	1048	12.9
Sipuncula			--	--	--	--	2	1	24	0.3
Arthropoda:	Crustacea:	Amphipoda	14	16	28	26	15	17	816	10.1
		Cirripedia	--	--	2	--	1	--	24	0.3
		Harpacticoida	--	--	1	2	1	--	32	0.4
		Isopoda	--	2	8	10	6	3	232	2.9
		Ostracoda	35	30	99	77	47	34	2296	28.3
		Tanaidacea	4	3	14	16	5	7	360	4.4
		Cumacea	1	1	3	9	2	1	128	1.6
Mollusca:	Pelecypoda		1	3	4	1	1	--	72	0.9
	Gastropoda		--	2	3	--	--	--	40	0.5
Brachiopoda			--	1	--	--	--	--	8	0.1
TOTAL			84	105	265	279	236	128	8104	100.0

Table 4. Total infaunal densities per 1 m^2 for OCS-3. Stations are on the seasonal Pitt Point Transect line.

Station	Size Fraction 1.0 mm	Size Fraction 0.5 < 1.0 mm	Total
PPB-25	600	3,820	4,420
PPB-55	9,535	6,108	15,643
PPB-100	16,014	8,104	24,118

Table 5. Coastal Polychaeta identifications. Depths 5-25 meters. R/V ALUMIAK 1976 cruise.

Polychaete species- Barrow Transect (BRB)

BRB-5 (5 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	2
Ampharete vega (Wiren, 1883)	2
Neosabellides (?) sp.	2
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	11
Tharyx (?) acutus Webster & Benedict, 1887	3
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	1
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	28
Genus B	24
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	1
Nephtys longosetosa Oersted, 1843	80
ORBINIIDAE	
Scoloplos armiger (Muller, 1776)	17
PECTINARIIDAE	
Cistenides hyperborea (Malmgren, 1865)	6
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	5
Eteone longa (Fabricius, 1780)	12
Mysta barbata Malmgren, 1865	1

Table 5 (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.	6
Genus A	3
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	22
Tharyx (?) *acutus* Webster & Benedict, 1887	2
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	69
HESIONIDAE	
Genus B	1
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
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	1
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	7

Table 5 (continued)

BRB-10 (con't)	No. specimens
TEREBELLIDAE	
Polycirrus medusa Grube, 1855	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	5

Polychaete species- Barrow Transect (BRB)

BRB-15 (15 meters)	No. specimens
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	2
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	2
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	5
Nephtys ciliata (Müller, 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
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	1

Table 5 (continued)

Polychaete species- Barrow Transect (BRB)

BRB-20 (20 meters)	No. specimens
AMPHARETIDAE	
Neosabellides (?) sp.	3
Genus A	
CIRRATULIDAE	
Chaetozone setosa Malmgren, [illegible]67	6
Tharyx (?) acutus Webster & [illegible]edict, 1887	3
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	2
Flabelligera sp.	1
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	150
Nephtys ciliata (Müller, 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
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	1
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	4

Table 5 (continued)

Polychaete species- Barrow Transect (BRB)

BRB-25 (25 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	9
Neosabellides (?) sp.	1
Genus A	6
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	14
Tharyx (?) *acutus* Webster & Benedict, 1887	5
HESIONIDAE	
Nereimyra aphroditoides Fabricius, 1780	1
Genus B	3
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
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	25
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	2

Table 5 (continued)

Polychaete species- Pitt Point Transect (PPB)

PPB-5 (5 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	24
Ampharete vega (Wiren, 1883)	191
APISTOBRANCHIDAE	
Apistobranchus tullbergi (Theel, 1879)	4
ARENICOLIDAE	
Arenicola glacialis Murdoch, 1885	1
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	25
Tharyx (?) acutus Webster & Benedict, 1887	7
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	1
OPHELIIDAE	
Travisia sp.	1
ORBINIIDAE	
Scoloplos armiger (Muller, 1776)	191
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	31
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	10
TEREBELLIDAE	
Polycirrus medusa Grube, 1855	1
Proclea graffii (Langerhans, 1884)	2
Genus C	13
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	130

Table 5 (continued)

Polychaete species- Pitt Point Transect (PPB)

PPB-10 (10 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	1
Ampharete arctica Malmgren, 1866	
APISTOBRANCHIDAE	
Apistobranchus tullbergi (Theel, 1879)	1
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	54
Tharyx (?) acutus Webster & Benedict, 1887	5
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	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
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	17
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	6
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 5 (continued)

Polychaete species- Pitt Point Transect (PPB)

PPB-15 (15 meters)	No. specimens
APISTOBRANCHIDAE	
Apistobranchus tullbergi (Theel, 1879)	1
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	2
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	2
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	5
Nephtys ciliata (Muller, 1776)	2
OPHELIIDAE	
Ophelina acuminata Oersted, 1843	1
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	2

Table 5 (continued)

Polychaete species- Pitt Point Transect (PPB)

PPB-20 (20 meters)	No. specimens
CIRRATULIDAE	
Tharyx (?) *acutus* Webster & Benedict, 1887	18
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	4
NEPHTYIDAE	
Aglaophamus malmgreni (Theel, 1879)	1
Micronephthys minuta (Theel, 1879)	8
OPHELIIDAE	
Ophelina acuminata Oersted, 1843	1
PECTINARIIDAE	
Cistenides hyperborea (Malmgren, 1865)	4
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	2
Eteone longa (Fabricius, 1780)	2
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	1
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	1
TEREBELLIDAE	
Artacama proboscidea Malmgren, 1866	2
Genus C	2
TROCHOCHAETIDAE	
Trochochaeta carica (Birula, 1897)	2

Table 5 (continued)

Polychaete species- Pingok Island Transect (PIB)

PIB-5 (5 meters)	No. specimens
AMPHARETIDAE	
Ampharete vega (Wiren, 1883)	155
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	16
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	4
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	1
ORBINIIDAE	
Scoloplos armiger (Muller, 1776)	2
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	7
TEREBELLIDAE	
Genus C	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	1

Table 5 (continued)

Polychaete species- Pingok Island Transect (PIB)

PIB-10 (10 meters)	No. specimens
AMPHARETIDAE	
Ampharete vega (Wiren, 1883)	9
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	64
Tharyx (?) acutus Webster & Benedict, 1887	9
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	42
Nephtys ciliata (Müller, 1776)	1
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	23
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	1
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	7
TEREBELLIDAE	
Genus C	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	6

Table 5 (continued)

Polychaete species- Pingok Island Transect (PIB)

PPB-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
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	38
Tharyx (?) acutus Webster & Benedict, 1887	17
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	7
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	9
Genus B	7
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
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	3
Eteone longa (Fabricius, 1780)	6
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	5
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	27

Table 5 (continued)

PIB-15 (con't)	No. specimens
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	4
TEREBELLIDAE	
Lanassa venusta (Malm, 1874)	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	2

Table 5 (continued)

Polychaete species- Narwhal Island Transect (NIB)

NIB-5 (5 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	2
Ampharete vega (Wiren, 1883)	29
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	29
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	5
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	126
Genus B	3
PHYLLODOCIDAE	
Eteone longa (Fabricius, 1780)	2
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	5
TEREBELLIDAE	
Polycirrus medusa Grube, 1855	7
Genus C	4
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	34

Table 5 (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
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	85
Tharyx (?) acutus Webster & Benedict, 1887	3
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	7
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	24
Genus B	1
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
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	4
Eteone longa (Fabricius, 1780)	19
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	45
TEREBELLIDAE	
Polycirrus medusa Grube, 1855	2
Genus C	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	39

Table 5 (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
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	74
Tharyx (?) acutus Webster & Benedict, 1887	13
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	7
Diplocirrus hirsutus (Hansen, 1879)	1
Diplocirrus longosetosus (Marenzeller, 1890)	2
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	11
Genus B	5
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
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	10
Eteone longa (Fabricius, 1780)	13
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	4

Table 5 (continued)

NIB-15 (con't)	No. specimens
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	10
TEREBELLIDAE	
Laphania boecki Malmgren, 1866	4
Proclea graffii (Langerhans, 1884)	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	5

Table 5 (continued)

Polychaete species- Barter Island Transect (BAB)

BAB-5 (5 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	1
Ampharete vega (Wiren, 1883)	226
ARENICOLIDAE	
Arenicola glacialis Murdoch, 1885	1
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	28
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	5
ORBINIIDAE	
Scoloplos armiger (Muller, 1776)	115
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	frag.
Eteone longa (Fabricius, 1780)	7
TEREBELLIDAE	
Genus C	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	10

Table 5 (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
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	32
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	3
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	1
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	13
Nephtys longosetosa Oersted, 1843	5
ORBINIIDAE	
Scoloplos armiger (Muller, 1776)	16
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	2
Eteone longa (Fabricius, 1780)	14
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	7
TEREBELLIDAE	
Polycirrus medusa Grube, 1855	2
Proclea graffii (Langerhans, 1884)	1
Genus C	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	18

Table 5 (continued)

Polychaete species- Barter Island Transect (BAB)

BAB-15 (15 meters)	No. species
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	7
Ampharete vega (Wiren, 1883)	2
Lysippe labiata Malmgren, 1866	2
APISTOBRANCHIDAE	
Apistobranchus tullbergi (Theel, 1879)	16
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	169
FLABELLIGERIDAE	
Brada incrustata Støp-Bowitz, 1948	1
Brada villosa (Rathke, 1843)	40
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	28
Genus B	60
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
PECTINARIIDAE	
Cistenides hyperborea (Malmgren, 1865)	1
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	4
Eteone longa (Fabricius, 1780)	7
Eteone spetsbergensis Malmgren, 1865	2
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	3

Table 5 (continued)

BAB-15 (con't)	No. specimens
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	6
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	7

Table 5 (continued)

Polychaete species- Barter Island Transect (BAB)

BAB-20 (20 meters)	No. specimens
AMPHARETIDAE	
Ampharete acutifrons (Grube, 1860)	16
Lysippe labiata Malmgren, 1866	4
Genus A	24
APISTOBRANCHIDAE	
Apistobranchus tullbergi (Theel, 1879)	89
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	313
Tharyx (?) acutus Webster & Benedict, 1887	16
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	156
Diplocirrus longosetosus (Marenzeller, 1890)	1
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	10
Genus B	44
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	144
Nephtys ciliata (Müller, 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 (Müller, 1776)	3
PECTINARIIDAE	
Cistenides hyperborea (Malmgren, 1865)	5
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	4
Eteone longa (Fabricius, 1780)	3
SCALIBREGMIDAE	
Scalibregma inflatum Rathke, 1843	6

Table 5 (continued)

BAB-20 (con't)	No. specimens
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	25
STERNASPIDAE	
Sternaspis scutata (Renier, 1807)	20
TEREBELLIDAE	
Artacama proboscidea Malmgren, 1866	3
Proclea graffii (Langerhans, 1884)	1
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	19

Table 5 (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
CIRRATULIDAE	
Chaetozone setosa Malmgren, 1867	36
Tharyx (?) acutus Webster & Benedict, 1887	7
FLABELLIGERIDAE	
Brada villosa (Rathke, 1843)	5
HESIONIDAE	
Nereimyra aphroditoides (Fabricius, 1780)	4
NEPHTYIDAE	
Micronephthys minuta (Theel, 1879)	11
Nephtys ciliata (Müller, 1776)	2
Nephtys incisa Malmgren, 1865	1
OPHELIIDAE	
Ophelina cylindricaudatus (Hansen, 1879)	14
ORBINIIDAE	
Scoloplos acutus (Verrill, 1873)	4
PHYLLODOCIDAE	
Anaitides groenlandica (Oersted, 1843)	4
Eteone longa (Fabricius, 1780)	3
SIGALIONIDAE	
Pholoe minuta (Fabricius, 1780)	3
TRICHOBRANCHIDAE	
Terebellides stroemi Sars, 1835	1

Table 6. 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 6 (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

Contract 03-5-022-81
Research Unit 356
October 1 to December 31, 1978
8 pages

QUARTERLY REPORT

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

A.C. Broad

West Washington University
Bellingham, Washington

December 28, 1978

I. TASK OBJECTIVES: During the quarter, work on the following objectives continued:

A. Laboratory analysis of material collected during the 1977 and 1978 field seasons;

B. Investigation of metabolic activities of selected nearshore Arctic marine invertebrates during the period of ice cover;

C. Measurement of physiological responses of these species to high salinity and to freezing;

D. Assessment of the diet of selected Arctic marine invertebrates during the winter;

E. Continuation of the survey of the Stefansson Sound boulder patch;

F. Investigation of the growth rate of Laminaria and other Arctic, sessile macroalgae and invertebrates; and

G. Investigation of sedimentation, turbidity, salinity and temperature, ice conditions and other ecological factors in the Stefansson Sound boulder patch.

II. FIELD AND LABORATORY ACTIVITIES

A. Schedule of field activities.

1. Dr. Schneider and Mr. Hanes were at NARL, Barrow, from October 23 through the end of the quarter.

2. Messrs. Dunton, Olsen, Plesha and Smith were at Deadhorse from October 31 through November 20. The activities of this group were:

a. October 31: Dive team arrives in Deadhorse. Unload equipment and supplies for OCSEAP and Western Washington University.

b. November 1: Preparation of equipment and supplies for sampling. NOAA helicopter arrives in afternoon.

c. November 2-7: Search initiated for pinger at DS-11 on November 2 with the assistance of John Bitters (NARL) and Ted Flesher (OCSEAP). Pinger located on November 4. NARL airlift of parcoll and field supplies on November 5. Bad weather on November 6. Parcoll installation completed on November 7. Travel by NOAA and ERA (206) helicopter.

d. November 7-10: Divers collect data on sedimentation, recolonization, and growth experiments. Hydrographic data collected, substrates scraped clear and marked, and qualitative observations made. Plankton net pulled for Rita Horner (RU-359); deployed sampling bottles for Don Schell (RU-537). Travel by NOAA helicopter.

e. November 11-12: Divers collect mysids, amphipods and polychaetes for Dave Schneider (RU-356) for physiological and trophic studies. Travel by NOAA helicopter.

f. November 13-14: Photograph kelp community and under ice surfaces. Collect organisms, install sediment plate, tag, measure, and punch 40 additional algae for growth experiments. Assist in horizontal plankton tows (RU-359). Divers terminate sampling work at DS-11. Travel by NOAA helicopter.

g. November 15: Remove sampling equipment and supplies from parcoll. Travel by NOAA helicopter

h. November 16: Locate and retrieve hydrographic equipment belonging to Brian Mathews (RU-526) in the Egg Island channel. Travel by NOAA helicopter.

i. November 17: set up field ice camp at proposed Exxon Ice Island Site with the assistance of Dave Norton (OCSEAP). Travel by ERA (206) helicopter.

j. November 18-20: Divers survey Exxon Ice Island site at two locations: 100 feet north of the center and 500 feet north of the center. Travel by NOAA and ERA (206) helicopter.

k. November 20: Dive team departs Deadhorse for Bellingham, Washington.

B. Scientific Party (all of Western Washington University)

1. Principal Investigator
   A. C. Broad, half time

2. Associate Investigator
   D. E. Schneider

3. Assistant Investigator
   Ken Dunton

4. Laboratory Supervisor
   Helmut Koch

5. Computer Programmer
   Alexander Benedict, hourly wages

6. Divers and Field Assistants
   James Hanes, hourly wages
   John R. Olsen, on contract
   Paul D. Plesha, on contract
   Gary F. Smith, on contract

7. Laboratory Assistants (all hourly wages)
   Mark Childers
   Dawn Christman
   Wendy Pounds
   Neil Safrin
   Jon Zehr

8. Work Study Students (no cost to contract)
   Ron Adams
   Phillip Denny
   Gary C. Smith
   Tim Tucker

C. Methods:

1. Methods of laboratory analysis are those used and reported previously.

2. Physiological studies methods are dealt with below (see item III).

3. Dive Strategy: Underwater sampling was done by one or two divers at a time with a back-up diver acting as standby. Divers were tethered to the surface and dive lines were tended by surface personnel. An underwater communications system was used to maintain voice contact with the divers who worked in perpetual darkness and used a descending line and underwater lights to orient themselves underwater. Divers made two dives a day, each averaging 45 minutes.

4. Sampling Strategy: Divers worked from within a heated parcoll located directly over the dive hole at DS-11 in Stefansson Sound. In preliminary work, divers familiarized themselves with the position of the transect lines on the bottom and learned to swim in darkness without stirring up bottom sediments. The transect lines were installed in August and intersect the various in situ growth, recolonization, and sediment experiments.

   The experimental plots used in recolonization studies were visually analyzed by divers, photographed and in some cases, denuded again. Sediment depth was recorded on sediment trays and tagged kelp were measured for growth determinations. A meter stick was used by divers to measure ice thickness in a number of areas. Organisms were collected on the bottom and under the ice either by hand or with small nets. Divers made independent observations on depth, visibility, currents and overall community structure. Salinity and temperature measurements were taken using an SCT meter (YSI model 33).

D. Sample localities: The winter sampling was done at our dive site 11 (70°19.5'N; 147°34.5'W). Other work was done in the laboratories at Barrow, Alaska (NARL) and in Bellingham.

E. Data collected or analyzed: During the quarter analysis of all Beaufort Sea shore station samples made prior to 1978 was completed as was analysis of the samples from the 1977 ALUMIAK cruise, and these data are being prepared for computer print outs. Work was begun on sorting and analysis of the samples from the 1978 field season. Progress reported by Ken Dunton and analyses by David E. Schneider are dealt with below.

F. Milestone chart update: none required.

III. RESULTS

The results of laboratory analyses of Beaufort Sea shore stations and of the 1977 ALUMIAK cruise will not be available until after the first of January, and will be submitted in the NODC data format (030) early in 1979.

Preliminary analysis of benthic grab samples, taken from five lagoons bordering the Beaufort Sea during the summer of 1976, shows an increase in the standing crop biomass of macroinvertebrates (>0.5mm) with increasing water depth. More significant, perhaps, is the finding that at comparable depths between two and five meters, lagoons appear to support a greater benthic biomass per square meter than most non-lagoon systems.

TABLE 1: Mean benthic macroinvertebrate biomass at several depths in lagoon and non-lagoon environments of the Beaufort Sea nearshore system. Biomass data in grams of wet weight per square meter.

Depth (m)	Lagoons	Non-Lagoon Systems
2	18	14
$2<D\leq3$	38	-
$3<D\leq4$	48	-
$3<D\leq5$	-	34

This analysis suggests that at depths from two to five meters, lagoons may support from 4 to 14g/m^2 more macroinvertebrate biomass than non-lagoon environments. The statistical significance of these differences has not yet been determined, but it appears that these trends may be supported, in part, by more favorable sediment regimes in the lagoons. Sediment analysis showed that the proportion of fine sand, silt and clay was higher in lagoon sediments than in non-lagoon sediments at comparable depths. There appears to be a fairly high correlation between the proportion of finer grain sizes and the development of stable benthic communities in both lagoon and non-lagoon ecosystems in the nearshore environment of the western Beaufort Sea.

Livers of some fish collected from ALUMIAK during the 1978 cruise were analyzed for benzopyrene hydroxylase activity. Initial results are negative, which could be consistent with a clean environment, but there was evidence that the tissues may have thawed in transit. If this happened, the enzyme would probably have been destroyed. Our present results, therefore, are both disappointing and inconclusive. Fresh livers will be collected this winter and further analyses made.

Physiological and Trophic Studies

D. E. Schneider

The objectives of the physiological investigations are to determine the tolerance and metabolic response to winter environmental extremes for the dominant benthic and epibenthic species of the proposed oil lease area. In addition to low temperatures, winter environmental conditions include extreme high salinities that occur in the deeper regions of lagoons due to brine exclusion during ice formation.

Live specimens were collected at the Stefansson Sound boulder patch on November 11 and 12, 1978 and were transported to the Naval Arctic Research Laboratory at Barrow for experimental work. Animals were maintained in temperature controlled incubators at -1.0° C at a salinity of 30 to 32°/oo and in the dark.

Preliminary acute salinity tolerance tests run at -1.0° C have been completed for the two dominant amphipods found in Stefansson Sound, Anonyx nugax and Boeckosimus affinis, and the mysid Mysis litoralis. The results of these experiments are shown in Table 1. When transferred from 30 - 32°/oo directly to the experimental salinity, A. nugax shows 100% survival after 7 days over the range 20 to 40°/oo. Survival is lower and survivors are sluggish at 15 and 50°/oo. Similar results were obtained with B. affinis at elevated salinities, but at diluted salinities survival was complete down to 15°/oo and complete mortality did not occur at 10°/oo. Experiments with Mysis litoralis were only run at elevated salinities and survival declined at 40 and 50°/oo to 60% and 1% respectively. Parallel acute salinity tolerance tests are in progress with A. nugax and B. affinis collected in the vicinity of Barrow where they are also the dominant amphipods at this season. Experiments are also in progress with A. nugax and B. affinis as well as the isopod Saduria entomon to determine the salinity tolerance of these species when faced with a gradual change in salinity. In these experiments salinities are raised or lowered in 5°/oo increments every two days, presumably allowing the animals to osmoregulate more fully than is possible with an acute salinity challenge.

Survival of B. affinis in these salinity tolerance experiments was notably higher than that reported by Percy (J. Exp. Mar. Biol. Ecol., 20:99-117), whose amphipods were collected from a brackish empoundment. Conditioning to a salinity of 34°/oo resulted in increased survival at higher salinity, but Percy's results still differed from those reported here.

Freezing tolerance experiments have been initiated with A. nugax and B. affinis. Preliminary results indicate that when frozen at -2.8° C in 32°/oo seawater, both species show 100% survival for 1 hour but with an 8 hour exposure A. nugax reaches 0% survival while 75% of the B. affinis are still alive. Further experiments are in progress to substantiate these results.

TABLE 1: Salinity tolerance of two amphipods and a mysiid from Stefansson Sound. Animals collected in November and held in the laboratory at -1° C and 30-32°/oo salinity. Survival after 7 days exposure at -1° C at several salinities is indicated by symbols: +++ = 100% survival; ++ = 50% or greater survival; + = less than 50% survival; - = zero survival.

Salinity °/oo	Anonyx nugax	Boeckosimus affinis	Mysis litoralis
10	-	++	
15	+	+++	
20	+++	+++	
30	+++	+++	+++
40	+++	+++	++
50	++	+++	+
60	-	-	
70	-	-	

Measurement of the rate of metabolism of a number of common animals by Gilson differential respirometry has been initiated. At present, determinations have been made on A. nugax, B. affinis, Mysis litoralis, Terebellides stroemi (a polychaete), and Macoma sp. (a clam). All of these have been run at a temperature of -1.0° C and 32°/oo salinity. Future determinations will be made at elevated salinities that approximate those found during late winter conditions. Preliminary results indicate that metabolism of these species is not depressed under the above conditions.

As trophic studies are of secondary importance for the winter portion of this contract, no major experiments have been set up yet. However, fresh fecal pellets have been collected from a number of species from the Stefansson Sound boulder patch and preserved in formalin for future analysis. A few of these from Mysis litoralis have been analyzed and the results indicate a decreased importance of diatoms in the diet when compared with summer conditions, but the proportion of peat in the diet appears to remain about the same. The pellets usually contained a very high proportion of mineral grains suggesting that mysids may ingest large quantities of sediments. Fecal pellets from Anonyx nugax contain diatom frustules, arthropod fragments and few polychaete setae. The presence of some mineral grains in the pellets indicate that sediment may also be ingested by this species.

Stefansson Sound Kelp Community

Ken Dunton

Summary:

Winter studies on a kelp community were initiated in November by a team of divers working in the "boulder patch" in Stefansson Sound. Dive Site 11 (DS-11), located in the center of a large kelp community and marked in August by a pinger, was successfully located by radio direction finding equipment and divers. A parcoll was installed over the diving hole for a shelter. The task objectives of the winter sampling effort were: (1) a continuation of the overall community survey; (2) a study of the growth rates of Laminaria; (3) a study of the rate of recolonization and sedimentation on denuded rock surfaces; (4) the collection of physical data on currents, turbidity, salinity, temperature, and ice conditions; and (5) continued qualitative analysis and exploration of the kelp community to reveal changes in community structure and natural history. In addition to these tasks, the dive team collected organisms for Schneider (RU-356) and assisted Schell (Ru-537) and Horner (RU-359) in deploying equipment and collecting organisms. This team also retrieved hydrographic equipment for Mathews (RU-526) and completed a biological survey of the proposed Exxon Ice Island site under additional OCS contract funding.

Preliminary Interpretation of Results

A marked increase in water turbidity and sediment accumulation was observed at DS-11 this November. Sediment accumulation on kelp, rocks, and on our experimental trays ranged between 2.5mm and 5.0mm. Underwater visibility decreased by about 1.5 meters from August and was between 2.0 and 2.5 meters. Sediments were noticeably lighter and were easily thrown into suspension by the slightest disturbance which caused further decreases

in visibility. During the summer, such localized disturbances were usually inconsequential. Only a small amount of silt was present and turbid water was almost immediately swept away by currents. In the absence of water currents in November, however, sediment clouded the water for 20 to 30 minutes after even minor disturbances and hours after major perturbation by the divers working on or near the bottom. Visibility was reduced to between 0 and one meter in such cases. The absence of water currents over eight consecutive days this November despite a variety of weather conditions is in contrast to the fluctuating but evident currents characteristic of this area last summer.

It is too early to assess the significance of data collected on our growth and recolonization experiments. After three months a heavy cover of silt was the only addition to denuded rocks, although a definite increase in length of Laminaria blades had occurred. Community structure remained essentially unchanged, but there were three notable exceptions; (1) we noted and collected several new species of fish and observed a high abundance of Liparis juveniles; (2) I found several plants of various red algal species in various stages of apparent decomposition, i.e., blades were becoming tattered and discolored, and (3) Laminaria fronds no longer appeared in reproductive condition.

Surface ice cover at DS-11 was rough and this was reflected on the underside of the ice as well. Beneath two feet of hard ice was an uneven layer of slush--loosely bound ice crystals which formed a rolling lower surface of mounds, hollows, and long pinnacles which sometimes extended to within two meters of the sea floor. Other than two large gammarid amphipods, very few organisms (visible to the eye) were seen in association with the ice. About 30 meters south of DS-11 on a re-frozen lead the ice surface was smooth and we suspect the undersurface was smooth and without a thick layer of slush. This view is supported by discussions with the LGL field team who easily used an ice jigger board beneath this lead and our own diving observations in other localities of smooth surface ice (Exxon Ice Island site and in the Egg Island Channel).

The slush or soft layer of ice which characterizes the underice surface at DS-11 appears to be ladden with a combination of silt and other heavier organic debris. When divers penetrated or broke apart this thick layer of slush, they were literally enveloped with clouds of silt and rained with debris. We first noticed such "dirty ice" after drilling pilot holes in Stefansson Sound and watching a brown, slushy mixture fill the hole. In other locations drilled holes would fill with a "clear" slush mixture. The incorporation of silt and other debris into such thick and uneven layers of unconsolidated ice is suspected to be a result of anchor ice formation. Anchor ice has not been recorded in the Alaskan Arctic and its suggested existence is worth noting here.

A bottom composed of mud and sand at the Exxon Ice Island Site provided us with the opportunity to compare the physical characteristics and fauna of two apparently different communities this November. Several differences were noted, and some of these have added further definition to our understanding of the Stefansson Sound kelp community. Among the major differences was the high abundance of isopods and mysids at the Exxon site as compared with DS-11. At DS-11 we noticed isopods and mysids to be much fewer in number, and also found them concentrated over areas devoid of kelp or rock cover, i.e., areas of soft bottom. Other significant differences included (1) the greater amount of light present underwater at the Exxon

Site; (2) a flatter under-ice surface and a thinner under-ice slush layer at the Exxon Site; and (3) substantially less silt and lower turbidity resulting in higher visitility at the Exxon Site. The greater amount of light present underwater at the Exxon Site is probably due to thicker snow and slush layers at DS-11. In common between the two sites are numberous juveniles of Liparis and -2°C water temperatures. Salinities were slightly different, recorded as 22°/oo at the Exxon Site and 29°/oo at DS-11. None of the attached biota present at DS-11 (with the exception of a couple of Laminaria plants) were seen at the Exxon Site. Water depth at the Exxon site was 12 feet compared to a water depth of 20 feet at DS-11.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES: None this quarter.

VI. ESTIMATE OF FUNDS EXPENDED (as of November 30, 1978)

	Amount budgeted[1]	Amount Spent[2]	Amount remaining
Salary, PI	$ 58,558	$ 46,881	$ 11,677
Salaries, Associates	72,707	88,047 (8,610)	-15,340
Salaries, other	169,892	143,524	26,368
Fringe	45,182	35,216 (2,153)	9,966
Travel & Freight	40,825	42,999 (3,455)	-2,174
PI Logistics	92,451	37,045	55,406
Supplies & Contracts	9,000	27,620 (8,950)	-18,620
Equipment	17,265	19,220	-1,955
Computer Costs	7,800	5,441	2,359
Overhead	138,633	100,151 (4,761)	38,482
Totals	$652,313[1]	$546,144[2] (27,929)	$106,169

[1]includes basic contract for fiscal 1979 ($105,500) plus a Western Washington University contribution ($15,000). Does not include funds for winter process studies requested in supplemental proposal for fiscal 1979.

[2]Includes $27,929 (amounts shown in parentheses) spent for winter process studies.

QUARTERLY REPORT

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1 Oct - 31 Dec 1978
Number of Pages: 20

Beaufort Sea Plankton Studies

Rita A. Horner

1 January 1979

I. Abstract - Highlights

This quarter has been spent analyzing samples collected during the USCGC *Northwind* cruise, 15 August to 15 September 1978. Primary productivity and plant pigment samples have been analyzed; enumeration and identification of zooplankton and phytoplankton samples have begun. Winter samples were collected from Steffanson Sound in November.

II. Task Objectives

The primary objective of FY 79 is to assess the winter (November and February) density distribution of zooplankton and phytoplankton in the nearshore areas of the Beaufort Sea, especially Steffanson Sound. The secondary objective is to analyze zooplankton and phytoplankton samples collected during the FY 78 icebreaker cruise in the Beaufort Sea.

III. Field and Laboratory Activities

A. Field Activities

1. Field trip schedule

a. Dates: 8 to 16 November 1978

b. Transportation

Seven and one-half trips between Mukluk Trucking camp and the sampling site were made in a NOAA Bell 205 helicopter. One return trip was made in a chartered ERA Bell 206 helicopter; one trip was by chartered Seair Bell 206 helicopter.

2. Scientific Party: Thomas Kaperak, Assistant Oceanographer

3. Methods

Surface water temperature was taken by suspending a laboratory thermometer vertically at the water surface in the hydrohole for about five minutes.

Phytoplankton samples were taken immediately under the ice (0 m) and about 1 m above the bottom (about 4 m) with a 5 ℓ PVC water sampling bottle. A 250 ml subsample was preserved with approximately 10 ml of 4% formalin buffered with sodium acetate for a standing stock sample. Another subsample for plant pigment determinations, usually 3 ℓ, was drained into a 4 ℓ polyethylene bottle and kept in a cool place until returned to the shore laboratory for further processing.

In the laboratory, water collected for plant pigment determination was filtered through 47 mm Millipore HA (0.45 μm) filters. Near the end of the filtration process, three drops of a saturated solution of magnesium carbonate were added and the filter tower was rinsed with filtered seawater. The filters were folded into quarters, placed in labeled coin envelopes in a dessicator and frozen.

Zooplankton samples were taken using a 0.75 m ring net with a mesh size of 308 µm and an open area ratio of 2:1. Vertical tows were taken by lowering the net to the bottom and retrieving by hand at a constant rate. Horizontal zooplankton sampling was done by extending a stationary line from the sampling hole to an ice piton located on the surface approximately 12 m away. The net was clipped to a pulley on this line, pulled backward by the ring to the ice piton and then forward to the sampling hole. Slack in the stationary line caused an unknown amount of deviation from a constant depth of tow, but the deviation was assumed to be minimal and was ignored. Net tows were timed with a stopwatch to obtain an approximate speed of tow.

The net was washed by dipping it several times in the hydrohole. The collection cup was then placed in a plastic bucket and removed from the net. Samples were warmed slowly when ice occurred in the collection cup. Samples were concentrated by swirling gently in the collection cup and poured into 250 ml jars. A label with collection data was placed in the jar. The sample was preserved with 13 ml of concentrated formalin and buffered with 5 ml each of saturated sodium acetate and saturated sodium borate solutions. The jar was then tightly capped for storage.

A 0.25 m ring net, mesh size *ca.* 46 µm was used to scrape the underside of the ice for epontic organisms. In the first attempt, with the net towed behind a diver swimming immediately under the ice, swimming speed was not fast enough to keep the net horizontal and against the underside of the ice, so only a water sample was collected. On the second try, 250 ml jars, partially filled with water, were taped one to one leg of the towing bridle and one to the collecting jar to provide flotation, but the diver still could not keep the net against the ice. An ice sample was collected by leaving the flotation jars empty and increasing the towing speed by pulling the diver in by his safety line. All samples were poured into 250 ml jars and preserved with 20 ml of 4% formalin buffered with sodium acetate.

One vertical haul was made with the 0.25 m ring net. The net was allowed to fall toward the bottom and was then raised and lowered slowly for about five minutes. The sample was poured into a 250 ml sample jar and preserved with 20 ml of 4% formalin buffered with sodium acetate.

4. Sample location

All samples were taken from one location in Steffanson Sound, 70°19 N, 147°34.4 W.

5. Data collected

Parameter	Number Collected	Number Analyzed
Temperature	9	
Phytoplankton Standing Stock	18	6
Plant Pigments	18	17
Phytoplankton Net Tows		
Vertical	1	
Horizontal - water samples	2	
Horizontal - ice	1	
Zooplankton Net Tows		
Vertical	18	
Horizontal	3	

B. Laboratory Activities: Methods

Primary productivity samples collected during the *Northwind* cruise were analyzed using a Packard Tri-Carb Liquid Scintillation Spectrometer with Aquasol® (New England Nuclear, Boston, MA.) as the scintillation cocktail. Primary productivity was calculated using the equation

$$Ps\ (mg\ C\ m^{-3}\ hr^{-1}) = \frac{(L - D) \times W \times 1.05}{R \times T}$$

where (L - D) is light - dark bottle disintegrations per minute; W is carbonate carbon; 1.05 is the ^{14}C isotope factor; R is the activity of the ^{14}C used; and T is the incubation time.

Plant pigment analyses were done using a Turner Model 111 fluorometer following the method and calculations of Lorenzen (1966) except that discrete samples were analyzed, not continuous ones.

Phytoplankton 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. Usually 1/5 of the 50 ml chamber and 1/10 of the 5 ml chamber is counted.

Zooplankton samples are first sorted for large and rare organisms. Each sample is then split using a Folsom plankton splitter until a subsample containing approximately 100 specimens of the most abundant remaining taxon is obtained. Organisms are identified and counted using a dissecting microscope. Voucher specimens are being kept for all species.

C. Milestone Chart and Data Submission Schedule: see pages 5-6.

IV. Results

A. Icebreaker

Results from temperature measurements, salinity, primary productivity, and plant pigment determinations are given in Table 1. Results from the zooplankton samples analyzed as of 1 December 1978 are given in Table 2. Phytoplankton standing stock samples have been counted only for station 5. Small, unidentified *Chaetoceros* species are the most abundant organisms at this station.

B. Winter sampling

Table 3 lists plant pigment determinations from the November sampling effort.

Three phytoplankton standing stock samples have been counted. The number of cells per liter averaged about 21,000 and consisted primarily of small, < 10 μm diameter flagellates. Few diatoms cells were seen although some empty diatom frustules were present.

V. Preliminary Interpretation of Results

A. Icebreaker

It is too early for any interpretation of results except that plant pigment concentrations and primary productivity appear to be fairly low throughout the sampling area except for a few stations mostly east of Prudhoe Bay.

B. Winter sampling

Plant pigments and cell counts are extremely low indicating no photosynthetic activity. While no zooplankton samples have been completely analyzed yet, calanoid copepods appear to be the most abundant organisms, comprising perhaps more than 90% of the animals present. Copepods are not being identified to species, but counted only as adults and juveniles.

VI. Auxiliary Materials - Literature Cited

Lorenzen, C. J. 1966. A method for the continuous measurement of *in vivo* chlorophyll concentration. Deep-Sea Res. 13:223-227.

VII. Problems: None

MILESTONE CHART

RU #: 359 PI: Rita A. Horner

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

MAJOR MILESTONES	1978			1979															
	O	N	D	J	F	M	A	M	J	J	A	S	O						
Reports: Quarterly				X						O									
Annual							O												
Final													O						
Field Effort		X			O														
Sample Analysis: Pigments: icebreaker	X	X																	
winter (Nov.)		X																	
Prim. Prod.: icebreaker	X	X																	
Phytoplankton Standing Stock: icebreaker									O										
winter (Nov.)			X																
Zooplankton Standing Stock: icebreaker									O										
winter (Nov.)				O															
Data Processing: Pigments: icebreaker, winter				O															
Prim. Prod.: icebreaker				O															
Phytoplankton Standing Stock: icebreaker									O	O	O								
winter (Nov.)				O															
Zooplankton Standing Stock: icebreaker									O	O	O								

O Planned Completion Date X Actual Completion Date

MILESTONE CHART (continued)

RU #: 359 PI: Rita A. Horner

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					
winter (Nov.)							0													
Data Submission: icebreaker															0					
winter (Nov.)							0													

0 Planned Completion Date X Actual Completion Date

Table 1. Summary of station locations, hydrography, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity, USCGC *Northwind*, 15 Aug to 15 Sep 1978.

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
01	17 Aug	71°11'	150°14'	8	~ 1	005	-0.01*	24.16	0.13	0.05	
						015	2.55*	30.19	0.23	0.05	0.02
						025	1.95†	31.16	0.56	0.30	0.22
						035	2.39†	31.55	0.40	0.17	0.17
						045	1.57†	32.08	0.21	0.20	0.05
03	18 Aug	70°58.5'	149°17'	7	4-5	003	-0.27	15.93	0.18	0.06	0.01
						010	-1.03*	29.11	0.27	0.07	0.01
						015	-0.45*	29.88	0.40	0.05	0.06
						020	-0.71	30.73	0.34	0.05	0.07
						025	2.80	31.52	0.26	0.18	0.11
						030	2.40	31.68	0.38	0.20	0.17
						035	2.17	31.68	0.32	0.19	0.18
04	19 Aug	70°19.8'	146°05'	5	1	000	-0.36	28.86	0.17	0.16	0.04
						005	-0.42	29.30	0.21	0.16	0.08
						010		31.82	0.24	0.30	0.11
						015	-1.16	32.15	0.24	0.31	0.05
						020	-1.64	32.17	0.31	0.20	0.09
						025	-1.64	32.22	0.33	0.34	0.06
05	21 Aug	70°36.2'	148°20.2'	5	3-4	000	-0.08	22.36	0.16	0.10	0.03
						003	-0.20	26.20	0.17	0.07	
						006	-0.84	31.31	1.30	0.05	0.27
						009	-1.52*	32.06	0.70	0.24	0.27
						012	-1.45*	32.09	0.81	0.36	0.23
						015	-1.52	32.10	0.49	0.91	0.21
						020	-1.53	32.08	1.05	0.68	0.24

* Temperature based on only one thermometer
† Temperature values questionable
Where no value is present, no data are available

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
06	22 Aug	70°55'	148°11'	5	∿ 5	000	0.56*	9.46	0.33	0.02	
						005	-1.13*	28.38	0.38	0.10	0.04
						010	-1.42	29.80	0.27	0.07	0.04
						015	-1.39	30.12	0.36	0.04	0.07
						020	-0.17*	31.05	0.34	0.08	0.12
						025	-0.64*	31.32	0.24	0.08	0.06
						030	-0.64*	31.60	0.14	0.08	0.01
						035	0.18*	31.87	0.29	0.30	0.07
07	23 Aug	70°05.9'	149°54'	8	0	000	0.56	24.90	0.15	0.08	
						005	0.49	25.16	0.16	0.08	0.03
						010	0.79	27.93	0.26	0.12	0.05
						015	3.46	29.97	0.57	0.20	0.08
						020	2.12	30.58	0.38	0.26	0.21
08	23 Aug	71°03.6'	150°52.9'	9	0	000	0.89	25.33	0.25	0.08	0.01
						005	0.92	25.65	0.23	0.07	0.03
						010	3.34	28.87	0.48	0.16	0.08
						015	3.60	29.69	0.54	0.20	0.13
						020	3.54	29.77	0.55	0.37	0.13
09	24 Aug	71°11.1'	151°51.3'	10	0	000	1.77*	25.76	0.21	0.19	0.02
						005	1.84*	26.31	0.29	0.05	0.08
						010	1.73	28.73	0.29	0.22	0.05
						015	4.81	29.30	0.28	0.42	0.17
						020	3.51	29.93	0.27	0.40	0.05

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
10	24 Aug	71°05'	152°51'	7	0	000	1.76*	25.46	0.14	0.07	0.02
						005	2.22	27.94	0.25	0.09	0.11
						010	2.68	30.24	0.96	0.27	0.23
						015	2.33	31.09	1.78	0.67	0.45
						020	2.38	31.13	1.69	0.72	0.60
11	24 Aug	71°19.8'	152°47.7'	10	0	000	1.96*	26.02	0.25	0.08	
						005	1.75	26.06	0.32	0.08	
						010	5.12	28.64	0.53	0.17	0.18
						015	4.91	29.23	0.32	0.08	0.09
						020	3.91*	29.72	0.44	0.16	0.16
						030	2.12	31.26	0.52	0.20	0.15
						040	2.07*	31.34	0.47	0.21	0.17
						050	1.27	31.52	0.33	0.18	0.13
12	24 Aug	71°21.6'	152°41.1'	10		000	2.88*	26.11	0.29	0.08	0.02
						005	3.31	26.83	0.41	0.12	0.04
						010	4.59	28.90	0.72	0.25	0.15
						015	5.74	29.19	1.03	0.29	0.09
						020	5.88	29.22	0.69	0.17	0.09
						030	5.44	29.65	0.23	0.12	0.05
						045	2.07*	31.21	0.43	0.16	0.49
						060	0.72	31.60	0.30	0.11	0.05
						075	-1.03	31.88	0.12	0.10	0.04
						090	-1.24	32.47	0.15	0.18	

Table 1. (continued

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
13	26 Aug	71°33.5'	150°27.0'	10	2	000	0.08*	23.40	0.09	0.04	0.23
						005	0.21	24.14	0.11	0.07	0.06
						010	0.30	27.54	0.22	0.05	0.05
						015	0.62	28.80	0.27	0.05	0.06
						020	0.87	30.61	0.22	0.05	0.02
						030	-0.45	31.13	0.26	0.08	0.07
						045	-1.01*	31.72	0.14	0.09	0.04
						060	-1.43	31.98	0.06	0.06	
						075	-1.20*	32.16	0.04	0.08	0.03
						100	-1.16	32.41	0.02	0.08	
						125	-1.30	32.67	0.03	0.09	
						150	-1.12*	32.98	0.02	0.10	
						175	-0.96	33.62	0.03	0.08	
						200	-0.30	34.09	0.01	0.03	
						1800	-0.36	34.52	0.02	0.03	
14	28 Aug	70°36'	147°38.7'	7	~ 4	000	-0.69*	21.29	0.23	0.10	0.02
						003	-0.79	27.81	1.31	0.23	0.07
						006	-1.20	29.92	2.86	0.49	0.29
						009	-1.26	30.55			0.47
						012	-1.43	31.76	1.40	1.01	0.32
						015	-1.44	31.81	1.11	0.62	0.30
						018	-1.48	31.84	0.94	0.50	0.35
16	29 Aug	70°29'	147°23'	7	~ 4	000	-0.33*	21.11	0.18	0.09	
						003	-0.80	26.37	0.65	0.16	
						006	-1.10	29.88	2.37	0.39	0.32
						009	-1.15	34.37	1.76	0.46	0.89
						012	-1.45	31.75	1.92	0.72	0.90
						015	-1.36*	31.79	1.76	0.57	0.78
						018	-1.46*	31.79	2.86	1.11	0.72
						021	-1.49	31.80	2.08	0.54	0.85

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
17	30 Aug	70°21.9'	146°51.7'	7		000	-0.15	22.47	0.25	0.12	0.01
						003	-0.73	26.01	0.49	0.15	0.03
						006	-0.94*	29.05	1.76	0.23	0.18
						009	-1.28	30.60	1.51	0.32	0.39
						012	-1.38†	31.45	3.12	0.59	0.88
						015	-0.99*	31.66	2.68	0.80	1.05
						018	-1.16	31.63	3.45	0.98	1.02
18	31 Aug	70°34'	145°51.7'	5	1-2	000	0.44	23.65	0.24	0.13	0.01
						003	-0.20	27.14	0.29	0.18	0.03
						006	-0.63*	29.37	0.36	0.19	0.10
						009	-0.99†	30.73	1.01	0.35	0.20
						012	-0.87*	31.74	4.03	1.04	1.93
						015	-1.37†	31.75	3.53	1.01	1.75
						018	-1.04	31.75	4.42	1.30	1.63
19	01 Sep	70°12.7'	143°22.6'	11	0	000	2.63	26.28	0.16	0.05	
						003	-0.12	30.10	0.21	0.05	0.05
						006	-0.54*	30.59	0.12	0.05	0.04
						009	-0.42	31.06	0.28	0.20	0.16
						012	-0.90†	31.62	0.08	0.44	0.50
						015	-0.41	32.05	2.65	0.66	1.52
						018	-1.21	32.07	2.41	1.01	1.32
20	02 Sep	69°58.5'	142°15'	5	0	000	4.07	28.51	0.20	0.07	0.06
						003	1.97†	30.09	0.16	0.44	0.04
						006	1.88	31.00	0.53	0.12	0.44
						009	0.43†	31.02	0.60	0.81	0.25
						012	0.32	31.05	1.58	0.36	0.49
						015	0.28	31.08	2.03	0.84	0.90

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
21	03 Sep	70°57.8'	142°20.8'		0	000	-1.38	27.69	0.19	0.05	0.03
						005	-1.29	30.27	0.14	0.05	0.07
						010	-1.19	30.26	0.21	0.11	0.03
						015	-1.12	30.88	0.17	0.14	0.09
						020	-1.28	31.12	0.18	0.14	0.05
						025	-1.33	31.32	0.20	0.21	
						030	-1.33	31.59	0.26	0.14	0.11
						045	-1.53	31.83	0.25	0.23	0.11
						2400	-0.39	35.01			
22'	05 Sep	69°45'	141°17.5'	10	0	000	3.44	29.42	0.20	0.08	
						003	2.12	30.96	0.22	0.08	0.07
						006	1.79	31.30	0.21	0.08	
						009	0.93	31.79	0.29	0.08	0.11
						012	0.12*	31.85	0.55	0.06	0.15
						015	0.10	31.85	0.47	0.08	0.28
23	06 Sep	70°28.0'	143°33.0'		0	000	4.36	25.60	0.12	0.06	0.01
						005	3.34	28.03	0.18	0.07	
						010	0.13	30.22	0.12	0.07	0.03
						015	-1.03*	31.41	0.08	0.03	0.02
						020	-1.28*	31.87	0.14	0.05	0.12
						025	-1.24*	32.26	0.11	0.14	
						030	-1.45	32.32	0.21	0.14	0.07
						035	-1.61	32.34	0.27	0.15	0.14

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
24	06 Sep	70°28.6'	143°42.3'	15	0	000	4.18*	26.25	0.13	0.09	0.05
						005	3.02*	30.33	0.18	0.05	0.10
						010	1.75*	31.08	0.16	0.05	0.01
						015	-1.11	31.34	0.13	0.05	0.02
						020	-1.26*	31.52	0.15	0.06	0.01
						030	-1.48*	31.81	0.23	0.13	0.16
						045	-1.56	32.11	0.12	0.15	0.06
						055	-1.33	32.42	0.10	0.21	0.04
25	07 Sep	70°15.1'	143°40.0'			000	2.93*	27.35	0.09	0.06	0.02
						003	2.18*	27.94	0.12	0.05	0.03
						006	-0.18	30.43	0.21	0.16	0.11
						009	-0.54	31.27	0.37	0.16	0.11
						012	-1.14*	31.85	0.26	0.07	0.17
						015	-1.43*	32.21	3.78	0.66	1.63
						020	-1.47*	32.23	5.46	0.23	2.18
						025	-1.51	32.23	4.16	1.11	2.16
26	08 Sep	70°07.7'	144°48.4'		0	000	2.33	25.13	0.28	0.07	0.02
						003	1.13	26.36	0.16	0.07	0.07
						006	0.23	28.09	0.18	0.10	0.06
						009	-0.37	30.32	0.10	0.07	
						012	-1.24*	31.63	0.53	0.53	0.17
						015	-1.33*	31.82	0.92	0.92	0.28

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
27	08 Sep	70°17.8'	146°30.8'	8	~ 6	000	-1.01	26.08	0.21	0.08	0.07
						003	-0.97	27.40	0.24	0.12	0.04
						006	-0.92	28.93	0.34	0.11	0.10
						009	-1.12	30.03	0.47	0.08	0.22
						012	-1.27	30.39	0.56	0.08	0.29
						015	-1.38*	31.28	3.90	0.72	1.49
						018	-1.40	31.32	6.11	1.64	2.56
28	09 Sep	70°28.0'	147°25.7'	8	2	000	-0.24*	15.93	0.43	0.09	0.07
						003	-0.77	25.60	0.22	0.08	0.09
						006	-1.01	28.30	0.42	0.06	0.10
						009	-1.06*	29.44			0.21
						012	-0.74*	29.84	0.69	0.03	0.30
						015	-0.65	30.37	1.01	0.18	0.35
						018	-1.16*	30.82	2.55	0.63	1.04
						021	-1.09	30.85	3.35	0.72	1.50
29	09 Sep	71°01'	147°56.5'	10	2-3	000	-0.05	24.40	0.22	0.06	0.01
						005	0.21	27.28	0.49	0.16	0.12
						010	4.88	29.16	0.54	0.16	0.04
						015	4.86	29.80	0.94	0.27	0.34
						020	4.22	30.19	0.31	0.75	0.60
						025	4.48	30.58	0.74	0.20	0.31
						030	2.63*	30.83	0.70	0.17	0.30
						045	0.42	31.54	0.25	0.10	2.93

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
30	10 Sep	70°44.9'	148°34'		2-3	000	0.12	10.35	0.31	0.07	0.08
						003	-0.89	25.92	0.25	0.08	0.11
						006	-0.98	28.33	0.38	0.11	0.13
						009	-1.17*	29.65	0.65	0.09	0.19
						012	-0.91*	29.93	0.75	0.22	0.28
						015	1.89*	31.16	0.82	0.20	0.32
						018	1.28*	31.39	1.27	0.37	0.62
						021	1.11	31.39	2.34	0.27	1.08
31	11 Sep	70°35.5'	148°00.0'	10	3-4	000	-0.49*	16.94	0.33	0.07	0.06
						003	-0.68	27.98	0.46	0.11	0.16
						006	0.02	30.35	0.64	0.14	0.26
						009	0.07	30.58	0.31	0.92	0.46
						012	-0.41*	31.20	2.10	0.51	0.76
						015	-0.27	31.42			1.09
						018	-0.84	31.49	2.28	0.59	1.04
32	12 Sep	70°46.6'	149°30.4'	5	6-7	000	-0.55	10.48	0.53	0.14	0.08
						003	-0.82	28.54	0.44	0.16	0.15
						006	-0.82	29.61	0.37	0.08	0.10
						009	-0.56†	30.31	0.70	0.14	0.24
						012	0.45†	31.00	1.30	0.30	0.66
						015	0.26†	31.10	1.76	0.43	0.79
						018	0.79†	31.10	1.68	0.62	0.98

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
33	13 Sep	71°12.6'	149°38.4'	7	0-1	000	1.44*	27.26	0.47	0.13	0.03
						005	1.43*	27.26	0.47	0.11	0.08
						010	1.54	27.35	0.46	0.13	0.09
						015	1.72†	27.50	0.47	0.09	0.08
						020	2.59*	30.48	0.51	0.59	0.24
						030	1.68*	31.61	0.21	0.19	0.07
						045	1.27*	31.47	0.13	0.18	0.07
						060	1.08	31.64	0.14	0.20	0.11
34	13 Sep	70°52'	150°16'	8	< 1	000	-0.63	25.66	0.40	0.15	0.09
						003	-0.59	26.17	0.43	0.16	0.15
						006	-0.17	28.58	0.47	0.18	0.16
						009	0.41†	29.60	0.70	0.10	0.18
						012	2.29†	30.51	0.88	0.31	0.36
						017	1.66†	30.53	1.17	0.34	0.32
						022	1.66	30.53			0.68
35	14 Sep	71°01'	150°25'	7	1-2	000	-0.98*	26.57	0.33	0.17	0.09
						003	-0.92*	27.35	0.39	0.14	0.10
						006	-0.95	27.39	0.44	0.13	0.15
						009	-0.53	28.11	0.59	0.26	0.15
						012	2.37*	29.98			0.44
						015	3.62	30.17	0.89	0.34	0.40
						018	3.59*	30.18	0.98	0.34	0.49
						021	3.58	30.17	0.95	0.45	0.48

Table 2. 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 Number			
	N-5	N-16	N-28	N-31
Coelenterata				
Aeginopsis laurentii *	230	230	240	
Aeginopsis laurentii cf.				30
Aglantha digitale *	2280	2230	240	
Aglantha digitale cf.			80	870
Calycopsis birulai	30			
Corymorpha flammea	70			
Perigonimus vesicarius	200	90	40	30
Perigonimus spp.				60
Plotocnide borealis cf.	170	270		
unidentified medusae		540	20	
Ctenophora				
Pleurobrachia pileus cf. *	400	230	120	
Polychaeta - unidentified larvae	130	140		
Mollusca				
Gastropoda - Pteropoda				
Clione limacina		90		30
Spiratella helicina	30	140	40	120
Unidentified larvae	70	180		
Crustacea				
Copepoda				
Calanoida				
Adults	12050	21450	3330	3830
Juveniles	20000	41090	112480	77370
Unidentified nauplii			80	240
Cirripedia				
Nauplii		320	20	210
Cyprids				120
Mysidacea				
Mysis litoralis		40		
Mysis oculata	100	40		
Amphipoda				
Gammaridea				
Apherusa glacialis		40		
Onisimus spp.				30

* indicates damaged specimens, probably these species

Table 2. (continued)

Taxon	Station Number N-5	N-16	N-28	N-31
Hyperiidea				
Hyperia galba	100		40	
Parathemisto abyssorum	300	90	80	420
Parathemisto abyssorum cf. *			40	
Parathemisto libellula	170	270	510	240
Parathemisto libellula cf. *				120
unidentified Hyperiidea	70			810
Unidentified Amphipoda		40		
Euphausiacea				
Thysanoëssa longipes cf. *	30			
Decapoda				
Anomura - larvae	30	90		
Brachyura - larvae	70		20	120
Caridea - larvae	100	270	60	480
Appendicularia (Larvacea)				
Fritillaria borealis	70	3360		6410
Fritillaria spp.	1850	2040	5940	15390
Oikopleura labradoriensis		500		
Oikopleura vanhoffeni		230	280	120
Oikopleura spp.	70	410	3090	6230
Chaetognatha				
Eukrohnia hamata		40		
Sagitta elegans	5000	7180	630	5750
unidentified chaetognaths		40	2060	8380
Pisces				
unidentified larvae			20	30
Other organisms				
Foraminifera				30

Table 3. Chlorophyll *a* and phaeopigment concentrations, Steffanson Sound, 8-11 Nov 1978.

Date (Nov 1978)	Depth (m)	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})
08	0	0.06	0.07
09	0	0.02	0.12
	4.5	0.02	0.12
10	0	0.06	0.06
	4.5	0.06	0.08
11	0	0.05	0.04
	4.5	0.05	0.05
12	0	0.06	0.07
	4	0.04	0.06
13	0	0.06	0.05
	4	0.04	0.06
14	0	0.07	0.05
	4	0.04	0.05
15	0	0.05	0.06
	4	0.06	0.06
16	0	0.06	0.05
	4	0.06	0.05

VIII. Estimate of Funds Expended

It is estimated that about one-third of the funds will have been spent by 31 December 1978.

Contract # 03 -5-022-69
Research Unit 512
Reporting Period October 1, 1978
December 31. 1978

Quarterly Report

Pelagic and Demersal Fish Assessment in the lower Cook Inlet Estuary System

James E. Blackburn
Peter B. Jackson
Alaska Department of Fish & Game
P.O. Box 686
Kodiak, Alaska 99615

December 31, 1978

I. Highlights of Quarters Accomplishments

Field sampling continued from the previous quarter until the end of October but was moved to Kasitsna Bay at the beginning of the quarter, as planned. Food habits analyses were continued throughout the quarter and completed at the end of it. The processing of field samples was completed, data sheets were proofed and data keypunched, including the food habits data. A programmer has been hired and the necessary programs are being written so that the analyses will probably be completed by the late February schedule. Collection of information on the fisheries of lower Cook Inlet and Shelikof Strait has been underway.

A coordination meeting was attended in Anchorage on November 21, 1978 and several items were accomplished, notably, the tentative outline for the final report was established.

II. Specific Objectives:

1. Determine the feeding habits of principal life stages of dominant pelagic and demersal fish and provide an initial description of their role in the food web.

2. Describe the distribution and relative abundance of pelagic and demersal fish and their seasonal changes.

3. Identify areas of unusual abundance or of apparent importance to fish, especially commercially important species.

4. Review all past information on the fisheries in Lower Cook Inlet including commercial and sports catch statistics in order to determine the past and future trends in the importance of these species and to define the geographical and seasonal locations of fishing areas.

5. Define the geographical locations and seasonal use of spawning areas to the highest resolution possible.

6. Identify the geographical and seasonal locations of important prey.

7. Describe and evaluate the potential for impact on commercial, potentially commercial, and sports fisheries by OCS oil and gas exploration , development, and production based on the findings of the above six objectives plus existing information on the sensitivity of various life stages of these species, and geographical areas of potential risk.

III. Field Activities

A. Field Schedule

A 17' skiff and 21' skiff were used during the field sampling in October. The M/V HUMDINGER was used 2 days per week and as weather permitted. The HUMDINGER is an OCSEAP chartered vessel.

B. Scientific Party - All are Alaska Department of Fish & Game Personnel.

1. James Blackburn - Principal Investigator
2. Robert Sanderlin - Crew Leader
3. Jim Sicina - crew member
4. Harry Dodge - crew member
5. Claudia Mauro - crew member
6. Tom Bledsoe - crew member
7. Karen Anderson - Food habits analysis
8. William Johnson - Programmer
9. Tabea Goosen - Keypuncher

C. Methods

1. Sampling Methods:
   a. Beach seine - require skiff.
   b. Trammel net - require skiff.
   c. Gill net - require skiff.
   d. Surface tow net - require chartered vessel & skiff.
   e. Try net (20' bottom trawl) - require chartered vessel.
2. Fish Collections:

   Fish catches were sorted by species; the number and weight were recorded by species and life history stage when possible; length frequencies were taken and virtually all species were being preserved for food habits analysis. Large catches were subsampled. The stomachs of large specimens were removed, but small specimens were preserved intact. Stomachs were not taken from gill net or trammel net catches.

3. Food Habits Analysis

The data cheets and samples were sent to the Kodiak lab where the catches were tallied by species within each cruise (one cruise in October). The following priority list is used to select fish for analysis until all available analysis time for a cruise had been expended (Table 1).

Table 1. Priority list for selection of specimens for food habits analysis.

PRIORITY		
1	Sandlance	25
2	Herring	25
3	Dolly Varden	25
4	Chum Salmon Fry	25
5	Chinook Salmon Fry	15
6	Red Salmon Fry	15
7	Coho Salmon Fry	15
8	Pink Salmon Fry	15
9	Whitespotted Greenling Juvenile	15
10	Whitespotted Greenling Adult	10
11	Masked Greenling Juvenile	15
12	Masked Greenling Adult	10
13	Capelin	20
14	Eulachon	5
15	Longfin Smelt	10
16	Great Sculpin	20
17	Yellow Fin Fole	10
18	Starry Flounder	10
19	Rock Sole	10
20	Staghorn Sculpin	10
21	Pollock	10
22	Pacific Cod	10

D. Sample Locations

Figure 1 depicts locations sampled.

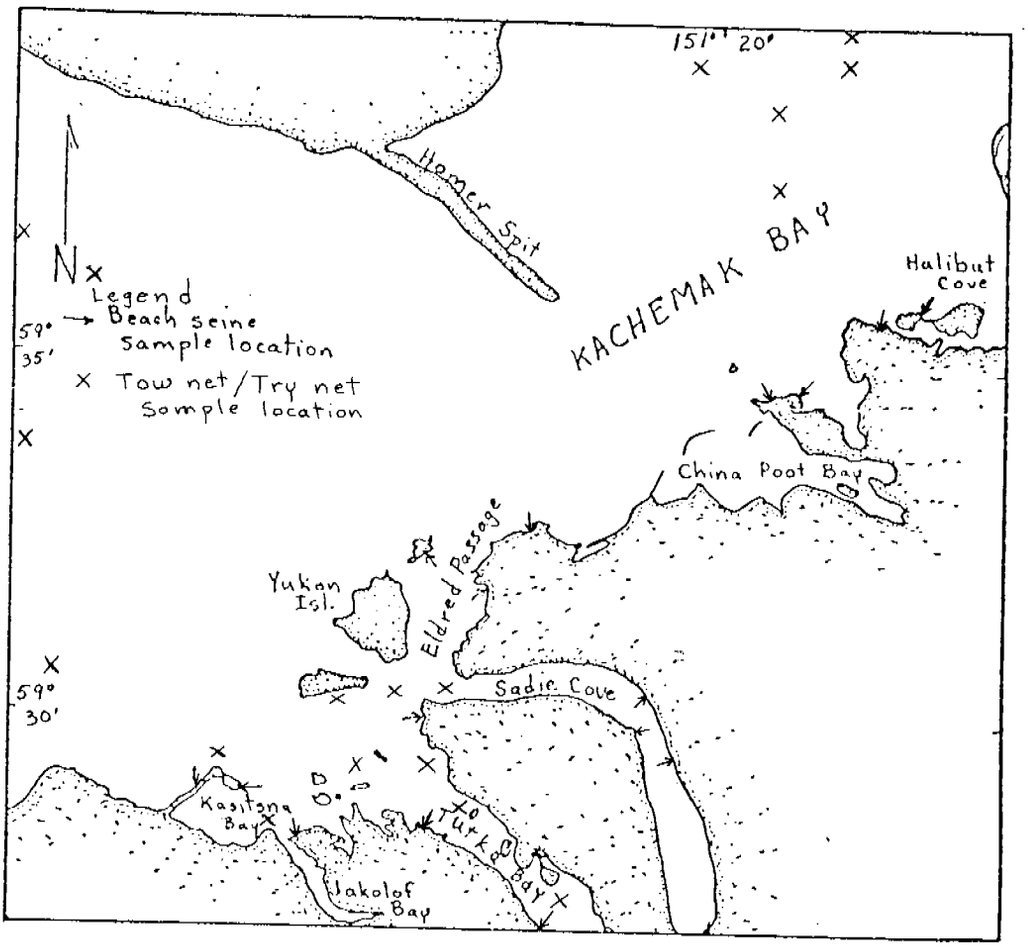


Figure 1. Locations sampled in Kachemak Bay during October 1978 by gear type.

E. Data Collected

Table 2 lists the number of Samples collected by gear type and cruise.

Table 2. Number of hauls by gear and date, FY 78, RU 512.

Date	Cruise Number	Gear Type				
		Beach Seine	Tow Net	Gill Net	Trammel Net	Try Net
April 10-30[1]	1	10	0	0	0	1
May 1-15	2	6	0	0	1	0
16-31	3	32	4	2	7	1
June 1-15	4	16	17	3	6	5
16-30	5	32	12	0	3	5
July 1-15	6	19	20	4	2	0
16-31	7	24	13	4	1	4
August 1-15	8	31	20	1	6	11
16-31	9	21	20	1	5	9
Sept. 1-15	10	33	0	2	2	0
16-30	11	29	0	2	4	0
Oct. 1-31	12	28	10	0	1	18
Total		281	116	19	38	54

[1]All samples in April and October were in Kachemak Bay and othere were in Kamishak Bay.

Table 3 lists the number of fish stomachs analyzed for food content by species and time period. An additional 100 sandlance and 99 longfin smelt stomachs have been examined from collections in 1976. Thus, a total of 1,226 stomaches have been examined.

Table 3. Number of fish stomachs analyzed for food content by species and time period.

Species	Cruise 1 & 2	3	4	5	6	7	8	9	10	11	12
Sandlance	9	25	25	16	25	25	10	11	15	15	15
Herring		24	3	25	25	20	2	4	15	15	1
Dolly Varden	1	24	25	25	25	25	10	10	15	15	10
Chum salmon - Juv	25	25	17	25	26	26	10	10	15		
Chinook salmon - Juv					11	14	8	10	1		
Red salmon - Juv			1	15	16						
Coho salmon - Juv				1	2	4					1
Pink salmon - Juv	35		3	15	1	15	9	5	1		
Whitespot Greenling - Juv	4	3	13	11							
Whitespot Greenling - Adult			2								
Capelin		10									
Longfin smelt		15	10								
Great sculpin	13	20	8								
Yellowfin sole		9	10								
Starry flounder		11									
Rock sole	1	9									
Staghorn sculpin	3	5									
Pollock		10									
Sand sole		1									
Surf smelt		1									
Bering cisco				1							
TOTAL	91	192	117	134	131	129	49	50	62	45	27

IV. Analyses

The first analyses of data will be produced late in the next quarter and presentation of the results will begin then.

V. Anticipated Problems

We have received example copies of the base maps for presentation of mapped information. Production of mapped data presentations cannot begin until more copies of the base maps are received. Since the study area extends from the Forelands in Cook Inlet to the southern extremity of Kodiak Island (for Shelikof Strait) coverage of this entire area on one figure would be efficient. Alternately the area may be covered by use of 2 maps, the Kodiak and Cook Inlet base maps. Additional maps of Kamishak and Kachemak Bays would be very useful. These requests have previously been communicated to the Project Office.

The data analysis will most likely be incomplete at the time for annual reports, in 3 months. It is quite possible that presentation of results will not be possible at that time.

VI. Estimate of Funds Expended

During this fiscal year, approximately $29,500 has been spent.

VII. Milestone chart

Attached.

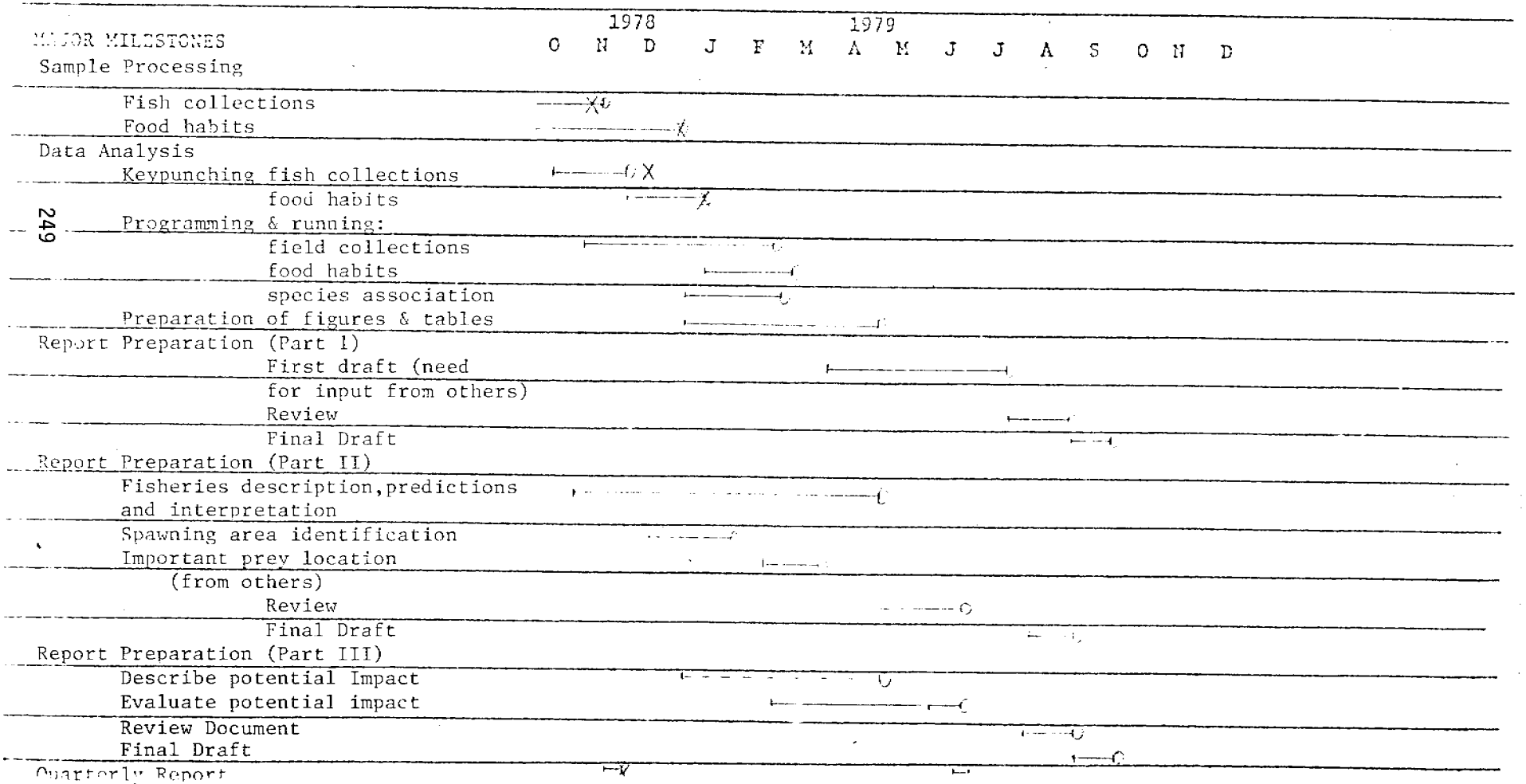
MILESTONE CHART

O - Planned Completion Date

X - Actual Completion Date
(to be used on quarterly updates)

RU # 512 PI: JAMES E. BLACKBURN

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



QUARTERLY REPORT

Contract No.: 03-5-022-67
Research Unit: 533
Reporting Period: 1 October - 31 December 1978

Seasonal Composition and Food Web Relationships of Marine Organisms in the Nearshore Zone of Kodiak Island - Including Ichthyoplankton, Meroplankton (Shellfish), Zooplankton and Fish. Part A: A Report on the Ichthyoplankton Component of the Study

Douglas Rabin and Donald E. Rogers
Fisheries Research Institute
University of Washington
Seattle, Washington 98195

Approved:

Submitted: 31 December 1978

R. L. Burgner, Director

I. Highlights of quarter's accomplishments

Zooplankton research was conducted in the Kodiak Archipelago in November, 1978. Samples were shipped to the sorting center for separation of specified taxonomic groups.

Samples from the spring and summer, 1978,cruises were sorted and the fish larvae presentin March, April, May and June samples were identified.

II. Task objectives

1. Describe seasonal composition, distribution, and relative abundance of larval stages of fishes in selected bay areas of the Kodiak Archipelago.

2. Determine seasonal development and succession of selected commercially and ecologically important fish species.

3. Correlate observed biological distributions with local hydrographic regimes and bathymetry.

III. Field and laboratory activities

A. Field trip schedule

1. Dates: 11/4/78 - 11/13/78
2. Vessel name: Commando

B. Scientific party

1. Names: Doug Rabin, Project Leader, FRI
Biff Bermingham, Assistant to Project Leader, FRI

C. Methods

Field sampling: Zooplankton was sampled in four bay areas of the Kodiak Archipelago. Gear types included a neuston sampler, bongo arrayed plankton nets, and an opening-closing mechanical Tucker trawl. Sampling methodology was identical to that of the spring and summer 1978 cruises and is described in the previous two quarterly reports.

C. Methods cont'd

Laboratory analysis: Laboratory activities included the ongoing identification of fish eggs and larvae and the processing of data for computer analysis. Laboratory activities also included the further differentiation of larval fish types into specific generic groups.

D. Sample locations

See Table 1 and Figures 1A and 1B.

E. Data Collected and Analyzed

1. Number and types of samples: See Tables 2 and 3.

2. Number and types of analyses: See Results section.

IV. Results

A preliminary characterization of the larval fish community may be made based upon the identification of ichthyoplankton found in samples taken from March through June, 1978 (Table 4). At this time just occurrence of the larvae is reported. Relative abundances will be examined in subsequent reports.

Occurring most often were larvae of the family Hexagrammidae (greenlings). They appeared during each cruise, in all four bays, and were primarily neustonic. Ammodytes hexapterus (sand lance) larvae ranked second in frequency of occurrence and were found both at and beneath the surface.

Lepidopsetta bilineata (rock sole), cyclopterid (snailfish), Lumpenus/ Lumpenella (prickleback) types, Myoxocephalus (sculpin) types A and B, Cottid type I and Lyconectes aleutensis (dwarf wrymouth) larvae ranked third in frequency of occurrence and appeared in 75% or more of the

20 bay-cruise combinations. Of these groups, only Myoxocephalus types A and B and L. aleutensis were neustonic in ≥ 50% of their occurrences.

Lepidopsetta bilineata, Gadids (cod), Myoxocephalus spp. and Gymnocanthus spp. (sculpin) appeared as newly hatched larvae primarily in the early spring zooplankton samples. In contradistinction, several larval fish groups were not first seen until the late spring cruises. These included Scorpaenids (rockfish), Hippoglossoides elassodon (flathead sole), Psettichthys melanostictus (sand sole) and Radulinus asprellus (slim sculpin).

Further characterization of the larval fish communities will be made once the results from remaining cruises and number of larvae/unit volume of water are examined.

V. Preliminary Interpretation of Results

None at this time.

VI. Auxiliary Material

None at this time.

VII. Problems Encountered/Recommended Changes

None at this time.

Table 1. Station locations for Kodiak Island nearshore zooplankton research, 1978.

Bay	Station	Latitude	Longitude	Gear used*
Izhut	Z1	58 13	152 17	N,B
	Z2 (diel)	58 10	152 14	N,B,T
	Z3	58 06	152 10	N,B,
	Z4	58 08	152 03	N,B
	Z5	58 05	152 18	N,B
	Z6**	58 15	152 16	N,B
	Z7**	58 13	152 18	N,B
	Z8**	58 11	152 20	N,B
Kalsin-Chiniak	C1	57 37	152 25	N,B
	C2	57 41	152 19	N,B
	C3	57 44	152 14	N,B
	C4	57 42	152 04	N,B
	C5	57 38	151 55	N,B
Kiliuda	L1	57 19	153 02	N,B
	L2 (diel)	57 16	152 55	N,B,T
	L3	57 12	152 45	N,B
	L4	57 16	152 37	N,B
	L5	57 36	152 54	N,B
	L6**	57 20	153 09	N,B
	L7**	57 18	153 06	N,B
	L8**	57 20	152 55	N,B
Kaiugnak	G1	57 04	153 36	N,B
	G2	57 01	153 29	N,B
	G3	56 56	153 27	N,B
	G4	56 58	153 14	N,B
	G5	56 52	153 35	N,B

*N = neuston, B = bongo, T = Tucker

**Stations added 5/78.

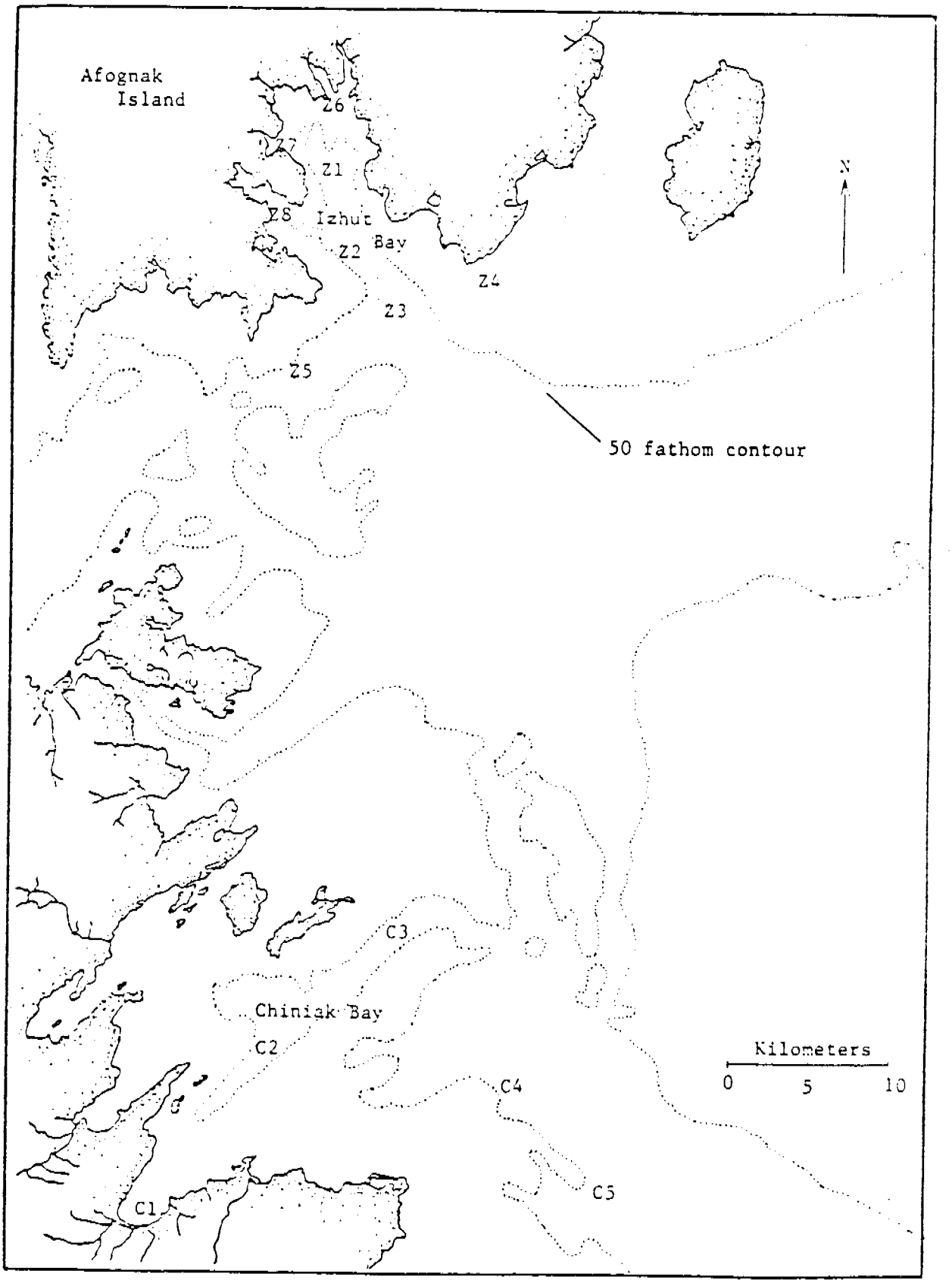


Fig. 1A. Station locations for Kodiak Island nearshore zooplankton research, 1978.

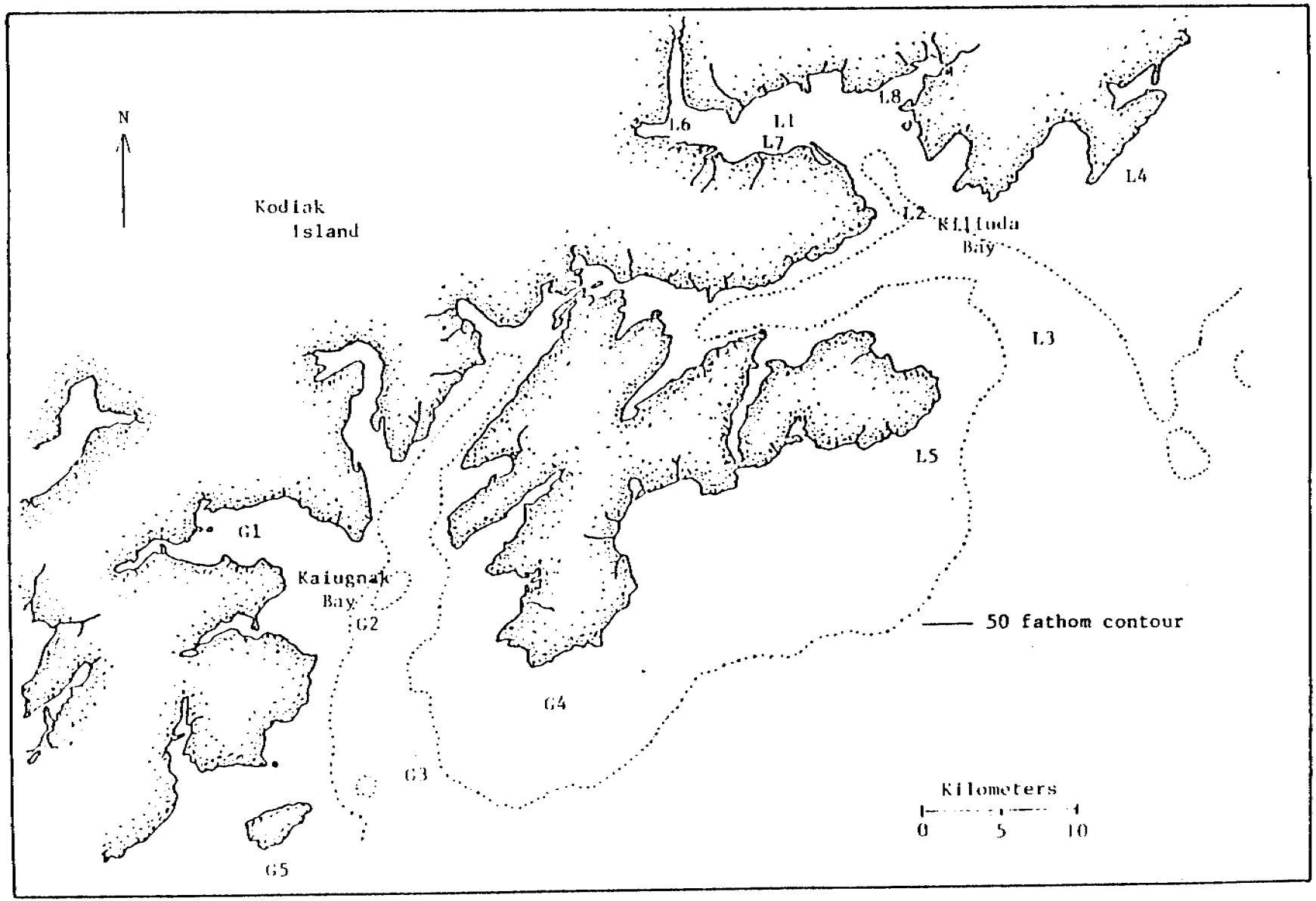


Fig. 1B. Station locations for Kodiak Island nearshore zooplankton research, 1978.

Table 2. Number of zooplankton samples collected by bay and gear type, Kodiak Island, Alaska, 1978

Cruise 11** - Commando 11/ 4/78 - 11/13/78 RU 553

Bay	Neuston	Bongo		Tucker				Epibenthic sled
		505µ	333µ	505µ		3mm		
				Day	Night	Day	Night	
Izhut	8	8	8	6	6	-	-	-
Kalsin-Chiniak	4	4	4	-	-	-	-	-
Kiliuda	8	8	8	6	6	-	-	-
Kaiugnak	5	5	5	-	-	-	-	-
Total	25	25	25	12	12			

Cruise Total 99

Scientific party: Doug Rabin, Project Leader, FRI
Biff Bermingham, FRI

**Cruise 11 for inshore plankton work only

Table 3. Cruise dates, number of samples collected, and total number of fish eggs and larvae caught by gear type, from March through September, 1978, from Kodiak Island nearshore zooplankton research.

Cruise	Date	Total Number of Samples						Number of Fish Larvae						Number of Eggs					
		N	B (333)	B (505)	T (505)	T (3 mm)	Sled	N	B (505)	T (505)	T (3 mm)	S	Σ	N	B (505)	T (505)	T (3 mm)	S	Σ
1	3/27-4/9	21	20	20	12	2	3	863	861	782	2	1	2509	805	194	228	0	0	1227
2	4/10-4/20	22	20	20	24	4	8	478	912	1585	4	10	2989	843	364	434	0	16	1657
3	4/21-5/2	22	20	20	24	4	8	835	1517	3714	7	27	6100	363	677	150	0	164	1354
4	5/3-5/30	28	26	26	24	4	8	653	1354	2673	26	43	4749	1141	2012	1184	0	237	4574
5	5/31-6/13	28	26	26	24	4	8	548	1118	2217	21	20	3924	1895	3998	1486	0	53	7432
6	6/13-6/27	28	26	26	24	4	5	229	4923	9927	77	153	15309	19947	9048	1644	0	19	30658
7	6/28-7/20	28	26	26	24	4	4	2620	96069	122729	22	68	221508	43464	13322	5387	0	50	62223
8	7/21-7/31	28	26	26	24	4	4	1745	7333	21658	14	191	30941	32632	6496	3707	0	41	42876
9	8/1-8/14	28	26	26	24	4	4	180	20348	10493	162	48	31231	29895	7818	4758	0	75	42546
10	8/15-8/25	28	26	26	24	4	4	1089	40435	71050	13	64	112651	25889	3713	3347	0	25	32974
	Σ	261	242	242	228	38	56	9240	174870	246828	348	625	431911	156874	47642	22325	0	680	227521

Gear code: N = neuston
B = bongo
T = Tucker trawl
S = Epibenthic sled

Table 4. Occurrence of fish larvae, by bay, cruise, and gear type, in the Kodiak Archipelago, March-June, 1978.

Species/Taxon	Bay:	IZHUT					KALSIN-CHINIAK					KILIUDA					KAIUGNAK				
	Time scale:	March			June		April			June		April			June		April			June	
	Cruise:	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Oncorhynchus gorbuscha				N						N						N					
Osmeridae					S						B										
Mallotus villosus		B			S							B	N								
Myctophidae																					
Gadidae																B					B
Gadus macrocephalus			B		B	B			B		B	B		NB		B	B		BN	N	B
Microgadus proximus					B									N					BS		
Theragra chalcogramma								B										B			
Zoarcidae			B	B	B		B	B	B		B	B	NB	NB			B	B	B		
Bathymasteridae					B				3										BS		
Stichaeidae				NB	NB	NB					B	N	N	SBN		B			BN	N	B
Anoplarchus spp.												N	N						N		
Chirolophus spp.				B	B	B			B		B				N	NB					B
Lumpenella/Lumpenus types		B	B	N								N	B				B				
Lumpenus sagitta		B	B	B	B	B	B	B	B		B	B	SB	SB		B	B	B	SB		B
Pholidae												B	B				B	B	B		
				B		B		B				B	N								B
Lycodes aleutensis		B	N	NB	N	N			B		B	N	NB	NS	N	N	NB	B	N		B
Ammodytes hexapterus		NB	B	NB	B	B	B	B	BS		B	NB	NB	NB	N	NB	B	SB	B	N	B
Scorpaenidae						B					B					B					B
Hexagrammidae		N	NB	NB	N	N	NB	N	N	N	N	N	NB	NB	N	N	NB	N	N	N	N
Ophiodon elongatus											B										
Cottidae			N						B												
Artedius type																N					
Blepsias spp.													N						N		
Clinocottus spp.									B		B					NB					
Dasycottus setiger					B	B					B	B						B	B		B
Enophrys bison																B					
Gymnocanthus spp.		B	B	NB	B	B	B	B	B			B	B	B			B	B	B		B
Hemilepidotus hemilepidotus			B				B														B
H. jordani													B	B	N						
Hemilepidotus spp.												B	N						B		
Icelinus borealis					B	B					B		B			B	B		B		B
Leptocottus armatus					B						B					M					
Malacocottus spp.			B	B		B	B														B
Myoxocephalus type A		B	NB	B	B	N	B	B	B			NB	NB	NB	N	B	NB	NB	NB		B
Myoxocephalus type B			B	NB	B	B	B	B	B	N	B	NB	NB	NBS	N		NB	B	NBS		
Psychrolutes type														B							
Radulinus asprellus						B					B					B					B
Triglops pingeli														S							
Triglops spp.							B				B						B				
Cottidae type I		B	NBS	B	B	B		B	B		B	B	BS	BS		B	B	SB	B		B
Cottidae type L			B	B		B		B	B		B	B			N	NB		B			B
Agonidae				B	B	B			SB		B	NB	SB	SB				B	B		
Cyclopteridae			NB	B	B	B	B	B	B		B	NB	B	B	N	B	B	B	B		B
Hippoglossoides elassodon					B	B				B		N				B			B		B
Hippoglossus stenolepis																			B		
Lepidopsetta bilineata			B	B	B	B	B	B	B		B	B	NB	NE	N	B	B	B	NB		B
Psettichthys melanostictus						B					B				B						B

Code for gear types: N = Neuston (505μ)
B = Bongo (505μ)
S = Epibenthic sled (505μ)

QUARTERLY REPORT

Contract No: R7120825
Research Unit No: RU551
Reporting Period: Oct. 1 - Dec. 31, 1978
Number of Pages: 12

SEASONAL COMPOSITION AND FOOD WEB RELATIONSHIPS OF MARINE ORGANISMS IN THE NEARSHORE ZONE

Co-Principal Investigators

Jean R. Dunn, Arthur W. Kendall

and Robert Y. Wolitira

Northwest and Alaska Fisheries Center

Seattle, Washington

December 1978

PI QUARTERLY PROGRESS REPORT

Reporting Period: October 1 - December 31, 1978

Project Title: Seasonal composition and food web relationships of marine organisms in the nearshore zone - Element I (RU 551).

I. Highlights of Quarter's Accomplishments

The fourth quarterly cruise in waters near Kodiak Island was conducted from October 26 to November 13, 1978. A total of 94 biological stations was occupied, including 85 grid stations, 1 diel station, and 8 bay stations. A total of 397 plankton samples was collected. CTD measurements totaled 93 and 768 seabed drifters were released at 16 stations.

Identification of ichthyoplankton from the spring 1978 cruise was completed and analysis of the ichthyo- and zooplankton data from that cruise begun.

Ichthyoplankton samples from the summer cruise (2MF78) are presently being identified. Crab and shrimp larvae from samples collected by RU551 and RU553 are currently being analyzed.

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

1. Ship schedules

a. The fourth quarterly offshore cruise was conducted aboard R/V Wecoma October 26 - November 13, 1978.

(1) Field Party:

Name	Affiliation	Role
Kenneth Waldron	NWAFC	Chief Scientist
Ann Matarese	NWAFC	Biologist
Donald M. Fisk	NWAFC	Physical Science Technician
Jennifer Sassano	NWAFC	Biological Technician
John Sconce	NWAFC	Biological Technician
Gary Shigenaka	NWAFC	Biological Technician
Kevin Li	Univ. Wash.	Biological Technician
Douglas Lieberg	PMC	Electronics Technician

(2) Methods:

At each grid station a surface neuston tow was made for 10 minutes to sample ichthyoneuston, followed by a double-oblique Bongo tow from near bottom to the surface to sample zoo- and ichthyoplankton. At selected stations a Tucker Trawl was used to sample discrete strata. A CTD cast was made at each station.

One station was sampled over a 24 hour period using a neuston net and a Tucker Trawl to assess diel variation in catches. Seabed drifters were released at 16 locations.

(3) Sample collection localities:

The station plan is illustrated in Figure 1. A total of 85 regular grid stations was occupied (three stations were not sampled due to weather). Eight stations were sampled in Kaiugnak and Kiliuda Bays during period of inclement weather and one diel station was occupied for 24 hours.

(4) Data collected and analyzed:

(a) Number of samples collected

101	Neuston samples
196	Bongo samples (98 each 0.505 and 0.333 mm mesh)
100	Tucker Trawl samples
Total 397	

A total of 97 CTD measurements was taken and 768 seabed drifters were released.

(b) Number and types of analyses:

Samples collected during the Wecoma cruise have been sent to the contractor for sorting.

b. The 11th cruise of the R/V Commando was conducted by RU553 from November 4 through November 13, 1978.

(1) Field Party:

Field operations were handled by personnel from RU553 and support activities were performed by personnel from RU551. The scientific party for both RU's included:

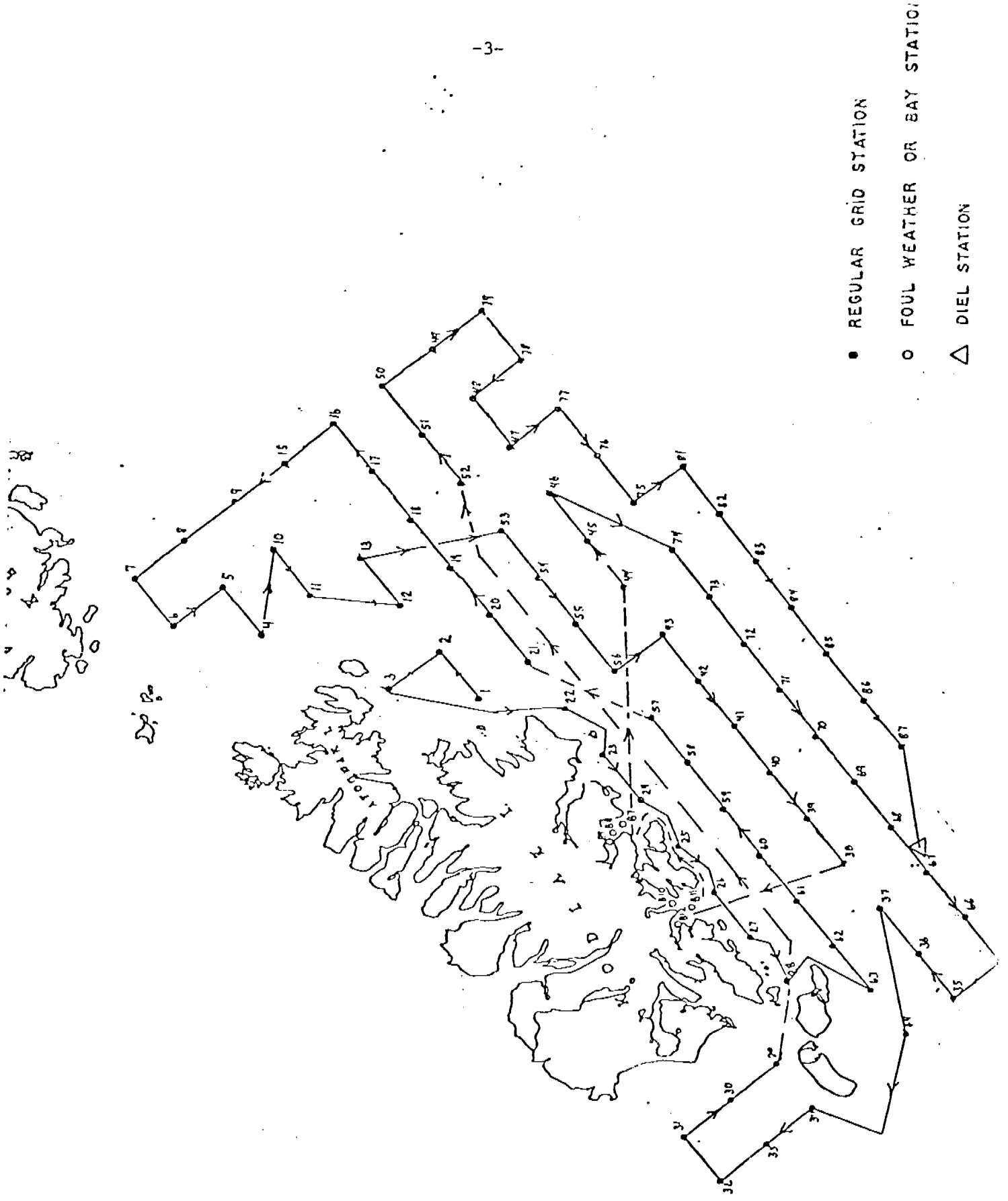


Figure 1.--Sampling plan. Cruise 1-WE-78.

Name	Affiliation	Role
D. Rabin	FRI	Biologist
B. Birmingham	FRI	Biologist
J. Bowerman	NMFS	Biologist
D. Hicks	NMFS	Technician

(2) Methods:

Zooplankton was sampled at stations located in the central and outer areas of Izhut, Kalsin, Kiliuda and Kiaugnak Bays. Each station was sampled with a surface neuston sampler, bongo arrayed plankton nets and an opening-closing Tucker trawl. Samples were preserved in buffered formalin solution and stored until shipment to the sorting contractor. Following sorting of a 500 organism aliquot into major taxa at the sorting center, the unsorted portion of each sample and the decapod crustacea portion from the aliquot will be shipped to the Kodiak facility for more detailed sorts and analyses.

(3) Sample collection localities:

Samples were obtained from eight stations each in the Izhut-Marmot, and Kiliuda Bay systems. Five stations each were sampled in Kalsin-Chiniak and Kiaugnak Bays (Table 1).

(4) Data collected and/or analyzed:

During this cruise, 99 plankton samples were collected and shipped to the sorting center. Numbers of samples collected were:

25 Neuston samples
50 Bongo samples (25 each 0.505 and 0.333 mesh)
24 Tucker Trawl samples

Total 99

In addition to the plankton samples, environmental data were also collected at each station. These observations consisted of temperature and salinity profiles and recording weather conditions.

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 Wolitira	NWAFC*	Co-principal investigator
John Bowerman	NWAFC*	Fisheries Biologist
Ann Matarese	NWAFC	Fisheries Biologist
Beverly Vinter	NWAFC	Ichthyoplankton Specialist
Jay Clark	NWAFC	Biological Technician
Don Fisk	NWAFC	Physical Science Technician
David Hicks	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:

Ichthyoplankton samples presently being identified were collected during the summer 1978 cruise (Miller Freeman 78-2). The station grid used in that cruise is identical to the one shown in Figure 1. Zooplankton data from this cruise have been received from the sorting contractor.

4. Data analyzed

a. Miller Freeman cruise (4MF77) - Fall 1977:

The tape of the ichthyo- and zooplankton data and ancillary information from the fall 1977 cruise was forwarded to OCSEAP this quarter, on schedule for the ichthyoplankton data, ahead of schedule for the zooplankton data.

b. Discoverer Cruise (4DI78) - Spring 1978:

Identification of ichthyoplankton samples was completed. Station, ichthyo- and zooplankton data were entered into our data management system, and preliminary audits were performed.

c. Miller Freeman Cruise (MF78-2) - Summer 1978:

To date, fish eggs and larvae obtained during this cruise have been identified from the following samples:

Type of sample	No. Identified	No. Collected
Neuston	112	112
Bongo (0.505 mm mesh)	65	89
Tucker Trawl	0	176
Total	177	377

Zooplankton have been sorted from aliquots from 89 Bongo (0.333 mm mesh) samples and aliquots of euphausiids from 176 Tucker Trawl samples have been identified.

d. Aliquots of crab and shrimp larvae from 667 samples have been received from Texas Instruments, Inc. (460 from RU553 and 207 from RU551).

During this quarter 305 aliquots of crab and shrimp larvae from samples collected by RU551 have been identified to lowest taxa; these data are being prepared for computer analyses. Identification of samples collected by RU553 is in progress.

IV. Results

A. Catches of the ten most abundant fish larvae and three most abundant fish eggs (based on bongo tows) from the spring cruise (4DI78) are listed in Table 2. The sand lance was the most dominant fish larvae captured in the bongo gear, followed by pollock and rock sole larvae. The most abundant fish eggs were those of pollock.

B. All previously received aliquot subsamples of crab and shrimp larvae from the nearshore and offshore surveys have been sorted to lowest taxanomic classification and several species of pandalid shrimps and brachyuran and lithodid crabs have been identified and counted. Detailed analysis awaits the arrival of all remaining aliquot subsamples and their identification.

C. Recovery locations of 17 seabed drifters released during offshore cruises are shown in Figure 2.

V. Preliminary Interpretation of Results

None

VI. Auxiliary Material

None

VII. Problems Encountered and Recommended Changes

None

VIII. Estimate of Funds Expended

Approximately $48.7K was expended this quarter, not including sorting costs.

Table 1.--Station locations for samples from RU553 in 1978.

Bay	Station	Latitude	Longitude	Gear used* remarks
Izhut	Z1	58 13	152 17	N,B
	Z2 (diel)	58 10	152 14	N,B,T,S
	Z3	58 06	152 10	N,B,S
	Z4	58 08	152 03	N,B
	Z5	58 05	152 18	N,B
	Z6**	58 15	152 16	N,B
	Z7**	58 13	152 18	N,B
	Z8**	58 11	152 20	N,B
Kalsin-Chiniak	C1	57 37	152 25	N,B
	C2	57 41	152 19	N,B,S
	C3	57 44	152 14	N,B,S
	C4	57 42	152 04	N,B
	C5	57 38	151 55	N,B
Kiliuda	L1	57 19	153 02	N,B
	L2 (diel)	57 16	152 55	N,B,T,S
	L3	57 12	152 45	N,B,S
	L4	57 16	152 37	N,B
	L5	57 36	152 54	N,B
	L6**	57 20	153 09	N,B
	L7**	57 18	153 06	N,B
	L8**	57 20	152 55	N,B
Kaiugnak	G1	57 04	153 36	N,B
	G2	57 01	153 29	N,B,S
	G3	56 56	153 27	N,B,S
	G4	56 58	153 14	N,B
	G5	56 52	153 35	N,B

*N = neuston, B = bongo, T = Tucker, S = sled.

**Stations added 5/78.

Table 2.--Catches of ten most abundant fish larvae and three most abundant fish eggs (based on bongo tows) from spring 1978 cruise near Kodiak Island.

	Bongo		Neuston		Tucker	
Larvae	Number of Positive Hauls	Catch	Number of Positive Hauls	Catch	Number of Positive Hauls	Catch
Ammodytes hexapterus	55	986	7	19	92	1303
Theragra chalcogramma	17	165	3	13	41	200
Lepidopsetta bilineata	29	108	1	1	50	164
Gymnocanthus sp.	17	47	1	1	1	2
Hemilepidotus sp.	26	42	40	1266	23	58
Stichaeidae (unid.)	15	41	2	2	47	236
Myoxocephalus sp.	7	26	2	4	13	42
Cottidae (unid.)	20	24	4	21	43	90
Cyclopteridae (unid.)	9	21	1	3	8	14
Lumpenus sagitta	7	14	-	-	13	33
Eggs						
Theragra chalcogramma	28	4414	33	501	72	6829
Pleuronectidae (unid.)	26	160	14	97	14	54
Hippoglossoides elassodon	9	93	7	15	20	129

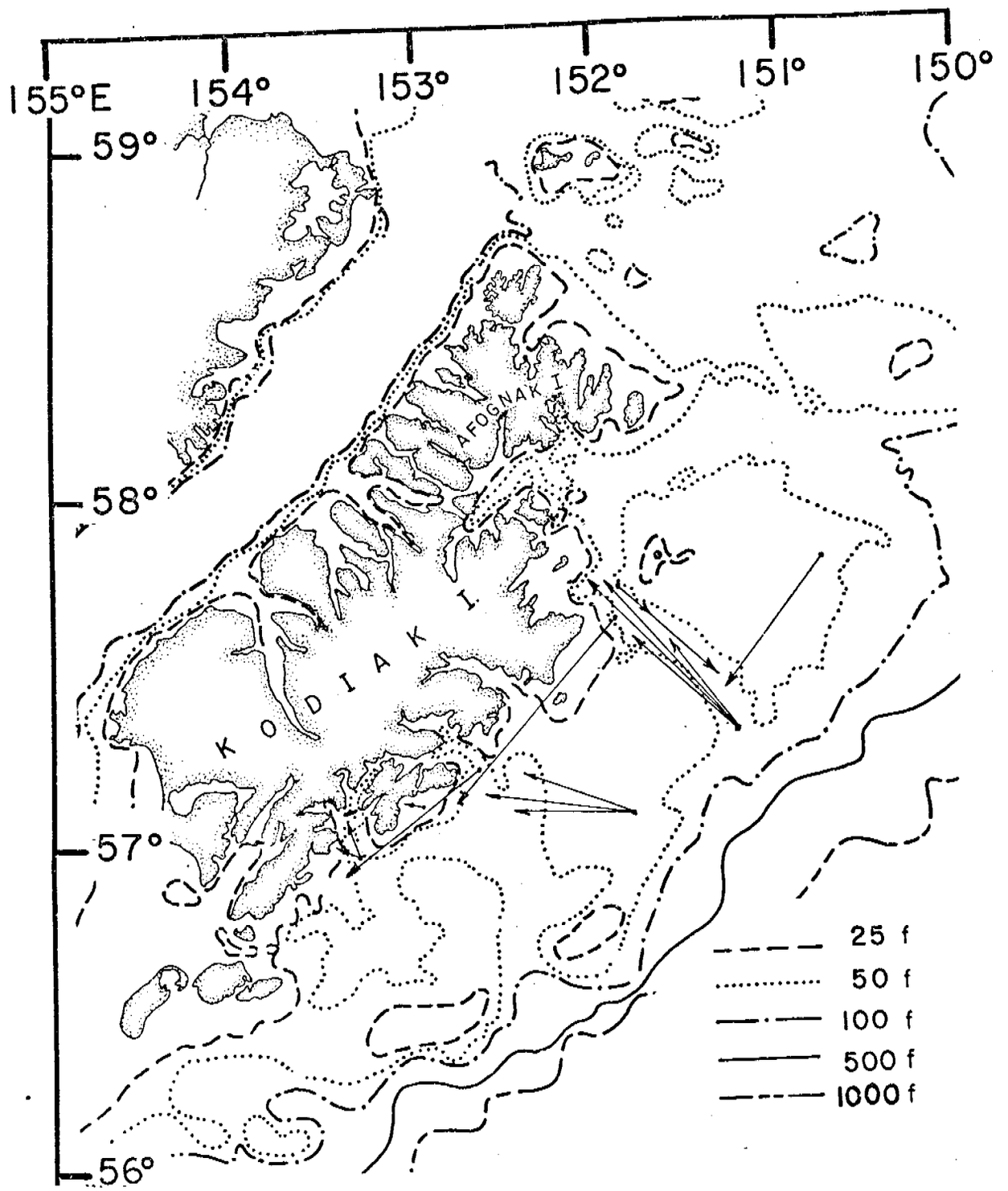


Figure 2.--Sea-bed drifter recovery locations.

MILESTONE CHART

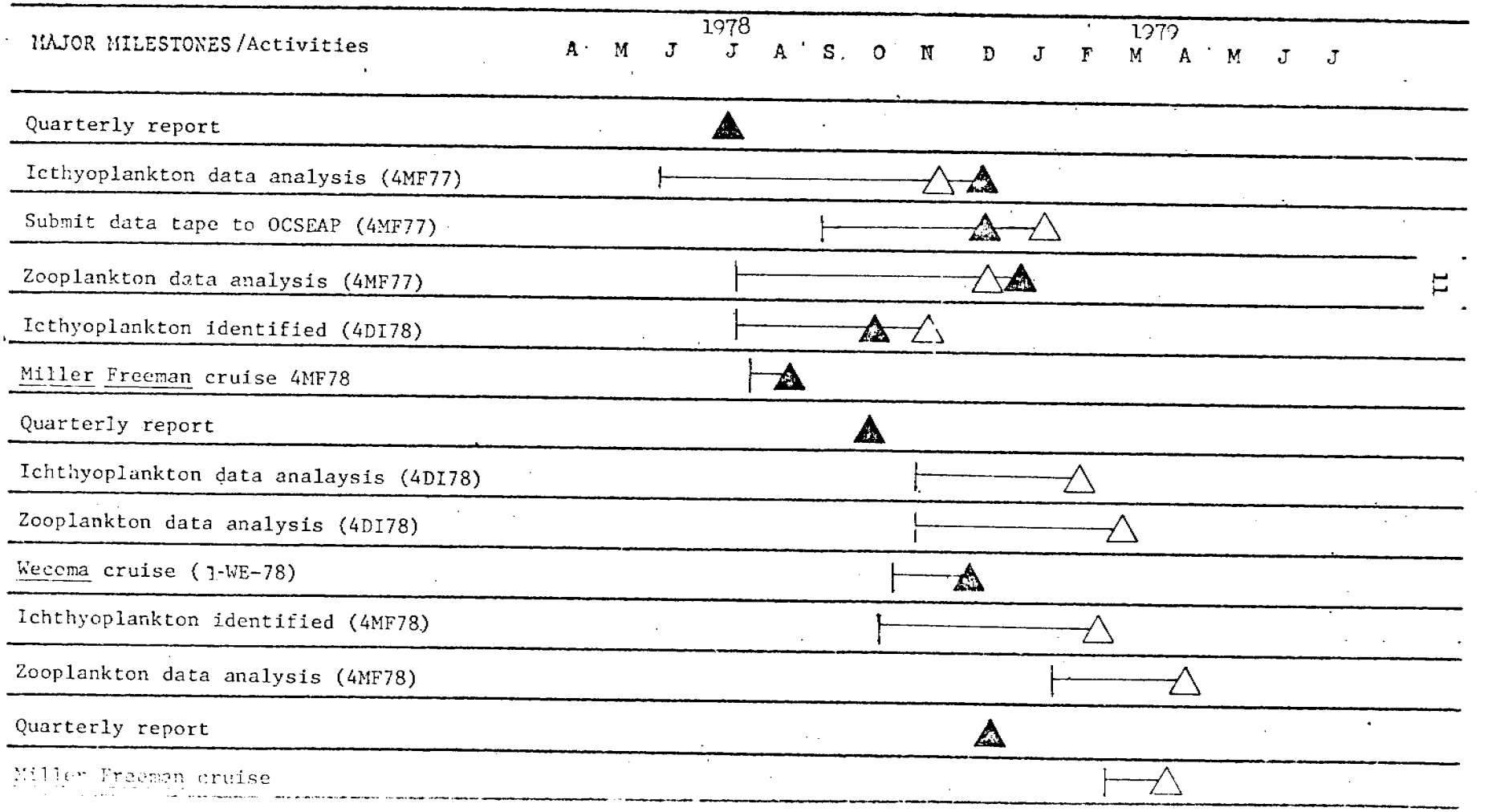
| - Start

△ - Planned Completion Date

▲ - Actual Completion Date
(to be used on quarterly updates)

RU # 551 PI: Dunn, Kendall, and Wolitira

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



MILESTONE CHART

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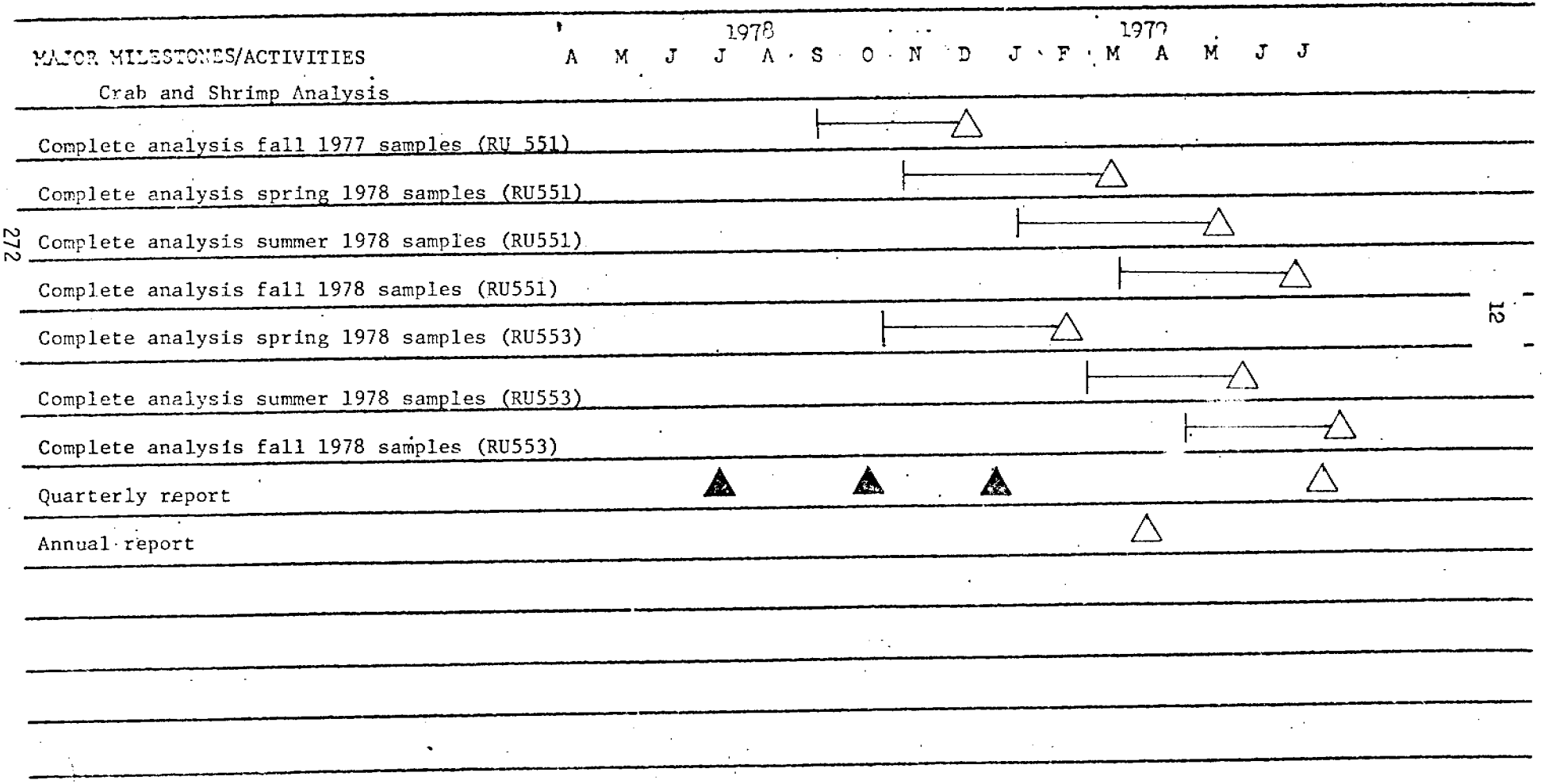
RU # 551 PI: Dunn, Kendall, Wolitira

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



Contract # 03-5-022-69
Research Unit 552
Reporting Period October 1, 1978-
December 31, 1978

Quarterly Report

Seasonal Composition, Abundance and Food Web Relationship of Principal Juvenile and Adult Marine Finfish Species Inhabiting the Nearshore Zone of Kodiak Island's Eastside

James E. Blackburn
Peter B. Jackson
Alaska Department of Fish & Game
P.O. Box 686
Kodiak, Alaska 99615

December 31, 1978

I. Highlights of Quarters Accomplishments

Field sampling was conducted during November from the R/V COMMANDO in Izhuit, Kalsin, Kiliuda and Kaiugnak bays, as had been done during the summer cruises. The processing of field samples was completed, data proofed and key punching has been initiated. A programmer has been hired and the necessary programs are being written so that the analyses will probably be completed shortly after the March cruise.

II. Task Objectives

Objectives of this study are to develop an understanding of the seasonal changes in species composition, distribution and abundance of selected marine fish occurring in nearshore waters of the Kodiak area.

III. Field or Laboratory Activities

A. Ship or Field Trip Schedule.

Table 1. Number of Hauls by gear and area completed in October through November 1978.

		Gear Type				
Bay	Date	Beach Seine	Trammel Net	Try Net	Tow Net	Otter Trawl
Kalsin	Oct.31-Nov.1	12	4	8	11	-
Izhuit	Nov. 4-8	21	5	12	16	4
Kiliuda	Nov.11, 14-16	22	7	6	18	2
Kaiugnak	Nov.12 - 14	10	3	2	8	-

B. Scientific Party.

Peter B. Jackson, Principal Investigator.	A.D.F.& G.
James E. Blackburn, Principal Investigator.	A.D.F.& G.
Leslie J. Watson, Fishery Biologist	A.D.F.& G.
Tom Bledsoe, Fishery Biologist	A.D.F.& G.
Chris Wilson, Fishery Biologist	Fishery Research Institute
Michael Gross, Fishery Biologist	Fishery Research Institute
John Rose, Fishery Biologist.	Institute of Marine Science
Bill Johnson, Programmer	A.D.F.& G.

C. Methods.

1. Four study areas were surveyed as follows:
   a. Izhut Bay - inside of a line between Pillar Cape and Peril Cape.
   b. Kalsin Bay - inside of a line between Broad Point and Isthmus Point.
   c. Kiliuda Bay - inside of a line between Pivot Point and Shearwater Point.
   d. Kaiugnak Bay - inside of a line between Cape Kiavak and Cape Kasiak.
2. Surveys utilized the charter vessel R/V COMMANDO, for primary logistical support as well as for certain fishing operations (i.e. try net and tow net operations).
3. Nearshore fishing operations and tow net operation required use of a 17-20 foot skiff equipped with a 70 h.p. engine.
4. Each study area was separated into regions which were sampled as systematically as possible. The following suite of gear types, selected on the basis of their combined ability to catch fish species throughout the nearshore zone, were used:
   a. Beach seine: 155' - tapered from wings to 12' at center, ¼" mesh throughout.
   b. Trammel net: 150' X 6' (3 panel).
   c. Tow net: 10' X 20' X 43'.
   d. 20' Standard try net with 15" x 30" trawl doors.
   e. Standard 400 mesh Eastern Otter Trawl.
5. Studies were conducted by four scientific personnel (two from FRI and two from ADF&G) in addition to a three person vessel crew. A person from R.U. 5 was on the vessel and obtained his samples incidentally to primary fishing operations as well as from specific hauls for his sampling.
6. The four person scientific crew was divided into 2 two person crews; one handled beach seines, trammel nets, and tow nets from the open skiff and the other remained on board the COMMANDO to handle the tow net and try net. In most cases these two crews were able to operate simultaneously.
7. Catch processing (i.e. species identification, enumeration, subsampling, measuring, weighing, foregut removal) was done immediately following fishing operations.

8. All trawling is done at depths from 30 to 50 fathoms. Exact trawl locations were identified during the April 1978 survey and have since remained consistant.

D. Sample locations/ship or aircraft tracklines (Figures 1a,b,c and d).

E. Data collected. (Table 1).

A total of 171 hauls of all gear types were completed by the near-shore fish survey during the cruise (Table 1).

IV. Results:

For all gear types excluding otter trawls, the catches in November were drastically smaller than the summer cruises. Some beach seine and most surface tow net samples yielded no catch at all. Small numbers of capelin larvae and greenling larvae and a few juvenile sandlance were caught in the tow net. Trammel net catches were pretty much confined to adults of rock greenling, masked greenling and *Myoxocephalus sp.* Beach seines yielded mostly juvenile *Myoxocephalus sp.*, adult tubenose poacher, rock sole, masked greenling and on a few occasions spawning sandlance and Dolly Varden. Try net catches consisted primarily of rock sole, yellowfin sole, flathead sole and *Cymnocanthus pistilliger* and *C. galeatus* with smaller numbers of butter sole, sand sole, arrowtooth flounder, English sole, whitespotted greenling and juvenile Pacific cod. In the Izhuit otter trawls the primary species were Pacific tom cod adults, yellowfin sole, rock sole, arrowtooth flounder, flathead sole and *Myoxocephalus sp.* Secondary species were staghorn sculpin and juvenile halibut and tertiary species included walleye pollock, starry flounder, butter sole, English sole, dover sole and searchers.

The Kiliuda Bay otter trawls yielded a substantially different species composition. Primary species were Pacific cod juveniles, walleye pollock juveniles, yellow Irish Lords, yellowfin sole, flathead sole and in one haul 45 juvenile halibut. Secondary species were Pacific cod adults, juvenile sablefish, *Myoxocephalus sp.*, staghorn sculpin and arrowtooth flounder. Small numbers were captured of walleye pollock adults, butter sole, rock sole, sand sole, starry flounder and adult Pacific sandfish.

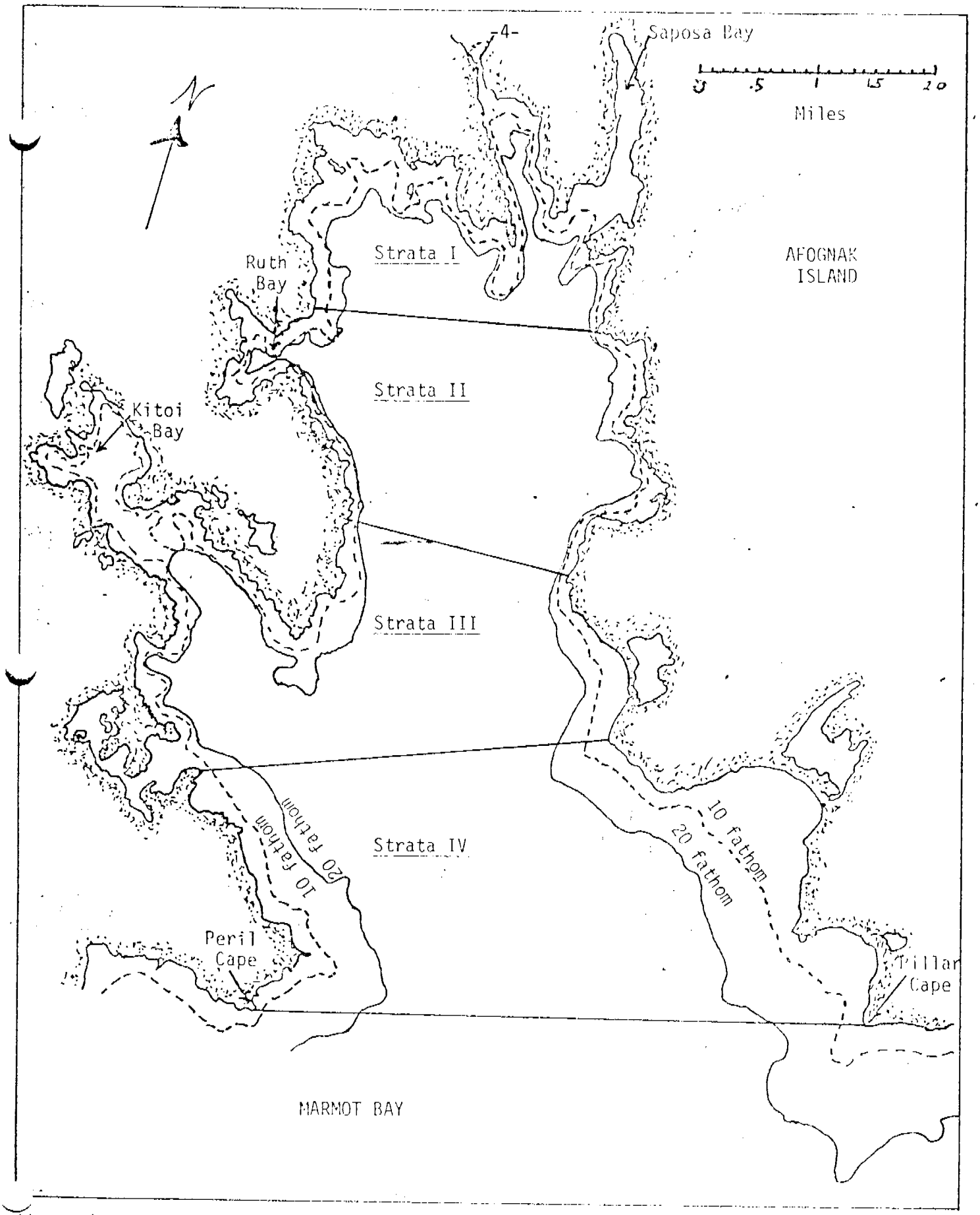


Figure 1A - Izhut Bay sampling region with 10 fathom (18.29 M) and 20 fathom (36.58 M contours and sampling strata as utilized by R.U. 552 & 553 on Kodiak Nearshore Fish Assessment Study, 1978.

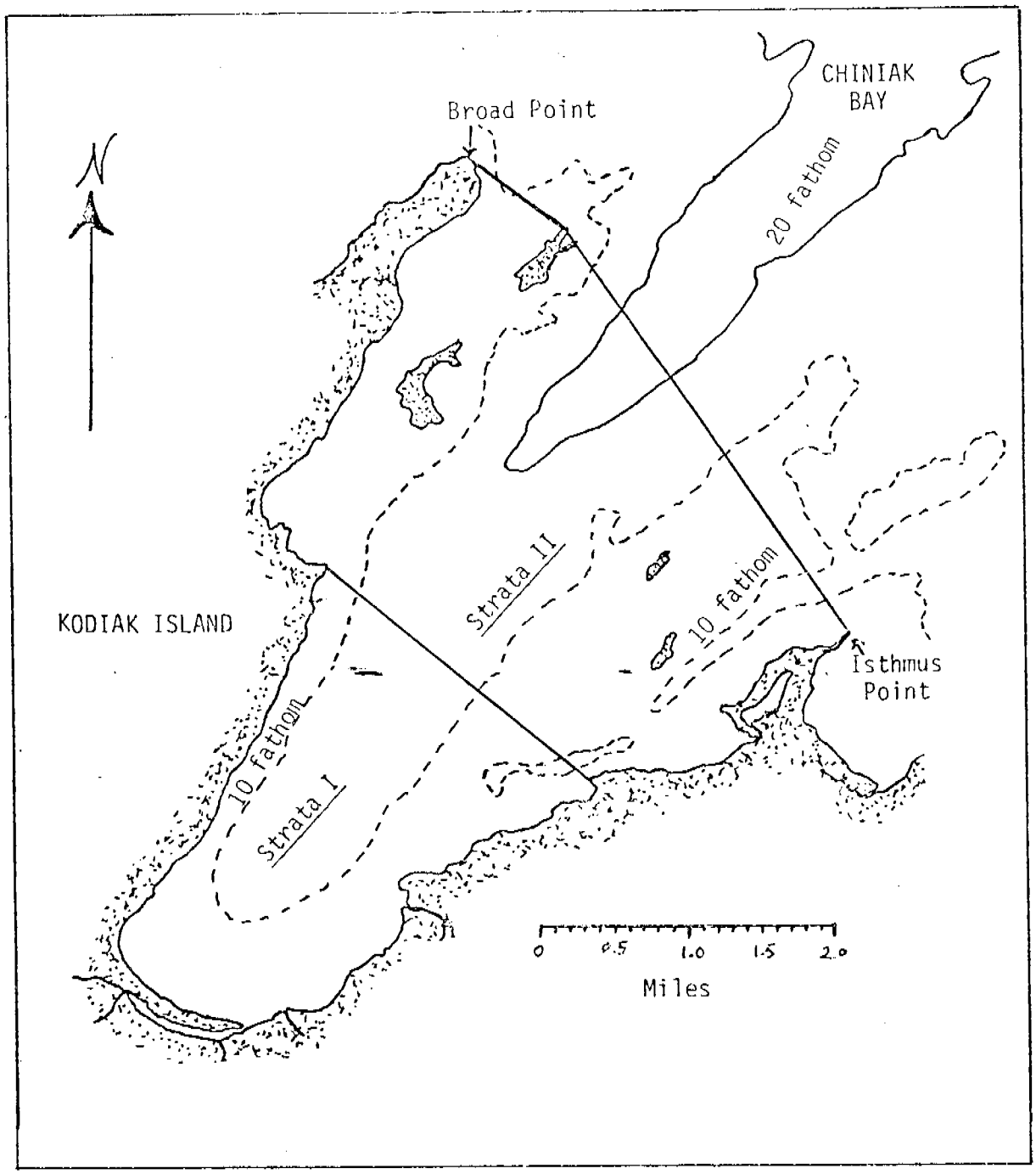


Figure 1B - Kalsin Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U.552 and 553 on Kodiak Nearshore Fish Assessment Study, 1978.

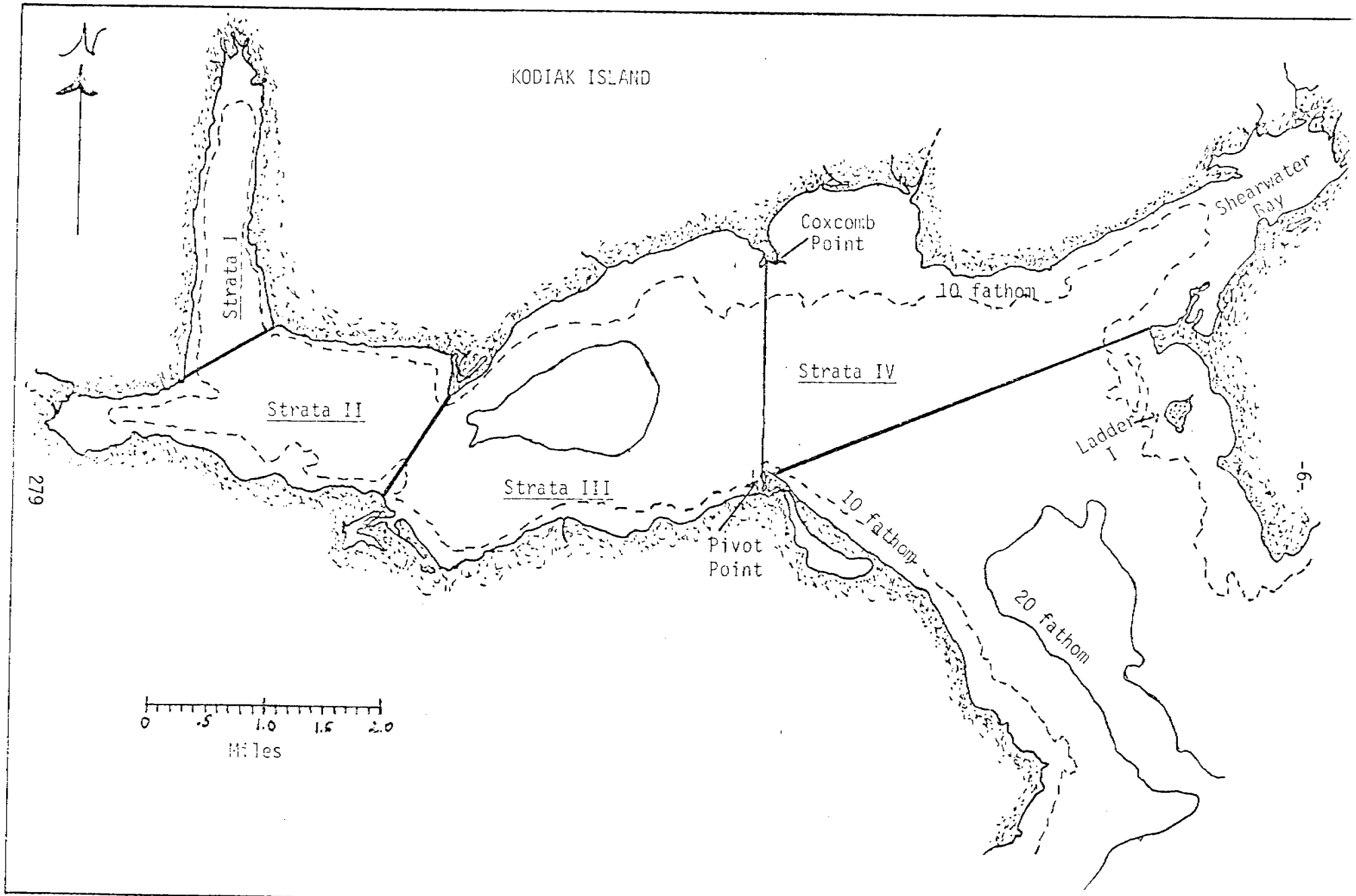


Figure 10 - Kiliuda Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U.552 and 553 on Kodiak Island Nearshore Fish Assessment Study, 1978.

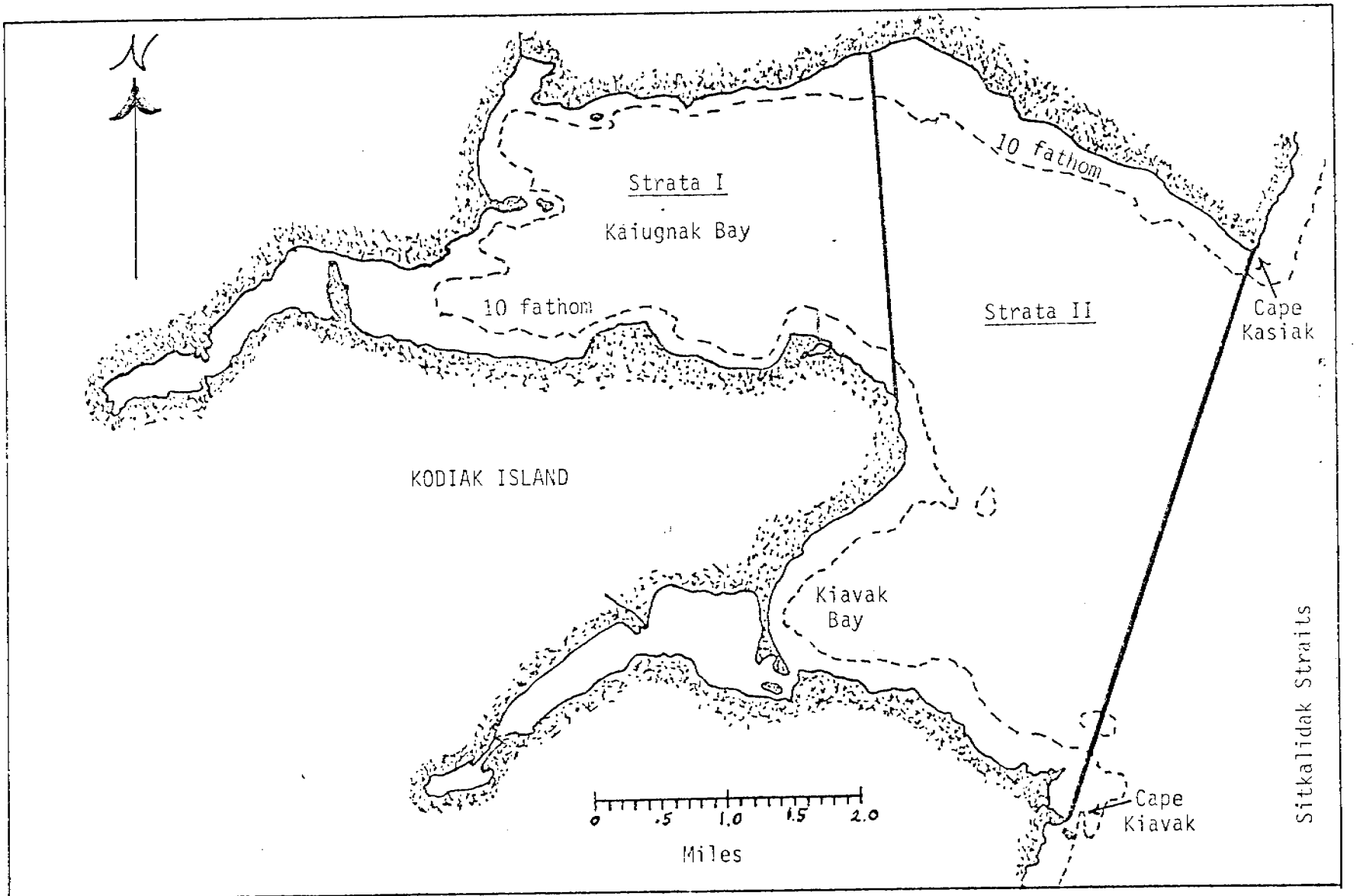


Figure 1D - Kaiugnak Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U. 552 & 553 on Kodiak Nearshore Fish Assessment Study, 1978.

V. Anticipated Problems

We have received example copies of the base maps for presentation of mapped information. Production of mapped data presentations cannot begin until more copies of the base maps are received. These requests have previously been communicated to the Project Office.

The data analysis will most likely be incomplete at the time for annual reports, in 3 months. It is quite possible that presentation of results will not be possible at that time.

VI. Estimate of Funds Expended

During this fiscal year, approximately $27,300 has been spent.

VII. Milestone Chart

Attached.

Table 7 MILESTONE CHART

0 - Planned Completion Date

X - Actual Completion Date
(to be used on quarterly updates)

RU # 552 PI: J. F. Blackburn and P. B. Jackson

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

MAJOR MILESTONES	1978 O	N	D	J	F	M	1979 A	M	J	J	A	S	O	N	D
Finalize sampling plan for FY 79	X														
Purchase equipment and supplies	X				0		0								
Hire and train survey personnel	X				0		0								
Conduct nearshore fish survey	1---X				1---0										
Conduct forage fish spawning survey							0----------						0		
Data compilation and verification for nearshore fish survey FY 79	1-------0				1---------0										
Digital data submission (File Type 023	1--0 (FY 78 data)/--0 (FY 79)								1---0 (FY 79)						
Data compilation and verification for forage fish spawning surveys										1-------0					
Digital data submission (File Type 057)											1--0				
Data analysis for comprehensive report							1----------						0		
Data product development			1---------0							1---------0					
Submission of quarterly reports		X									X		X		
Submission of Annual report (main spring and summer FY 78 data)							X								
Submit preliminary draft of comprehensive report (FY 78 and 79 data											1----0				
Final comprehensive report															0

QUARTERLY REPORT

Contract No.: 03-5-022-67
Research Unit: 553
Reporting Period: 1 October - 29 December 1978

Seasonal Composition and Food Web Relationships of Marine Organisms in the Nearshore Zone of Kodiak Island - Including Ichthyoplankton, Meroplankton (Shellfish), Zooplankton and Fish. Part B: A Report on the Fish Component of the Study

Brenda J. Rogers and Donald E. Rogers
Fisheries Research Institute
University of Washington
Seattle, Washington 98195

Approved:

Submitted: 31 December 1978

R. L. Burgner, Director

I. ABSTRACT

Sampling was conducted during this quarter from October 31 until November 16 and a total of 1,706 stomachs was collected. From the initiation of sampling in April until the most recent cruise in November, a total of 13,021 stomachs was collected. By the end of December, 8,600 stomachs had been analyzed in the lab. Stomach content data from the first three cruise months, April through June, have been keypunched and data from April and May are included in this report.

II. TASK OBJECTIVES

To determine the food habits of several nearshore pelagic and demersal fish species and the changes in food habits with respect to location, season, habitat, and life history stage.

III. FIELD OR LABORATORY ACTIVITIES

A. Ship or Field Trip Schedule

Sampling was conducted from October 31 until November 16 aboard the R/V Commando, which was chartered from the University of Washington.

B. Scientific Party

Two scientists from the Fisheries Research Institute were sent to sample fish stomachs: Michael Gross and Chris Wilson.

C. Methods

1. Field sampling: The field sampling followed that planned by RU #552. Field techniques were essentially the same as in RU #485, FY '76. As the fish were landed, they were first sorted to species. The field crew next selected specimens according to species and size (life history stage). Lengths were taken on the larger fish and recorded. The stomachs were then removed and placed in a Whirlpak bag along with 10% formalin. Smaller fish were preserved whole.

2. Laboratory analysis: The stomach contents of each large fish was blotted dry and then the total contents were weighed to the nearest .01 gm. The contents were next sorted into the lowest possible taxonomic categories. Each group was then counted and weighed to the nearest .001 gm.

If the fish were small, lengths were taken on a group of fish and an average length was recorded. Stomach contents were pooled and the contents from the pooled stomachs were treated as above. Average numbers and weights of prey items were then calculated.

D. Sample Locations

See RU #552.

E. Data Collected or Analyzed

1. Number and types of samples: The numbers of stomachs that were collected are listed by species and month in Table 1. Rock sole were the most abundant species sampled in November (417 stomachs), followed by yellowfin sole (267), flathead sole (184) and masked greenling (180).

2. Number and types of analyses: All the stomach data for April and May have been initially grouped by predator species, life history stage and month for the purpose of obtaining preliminary statistics on the predators (e.g., mean fullness of stomachs, percent empty stomachs, and mean length) and prey items by major taxa (e.g., mean numbers per stomach, mean biomass, and mean percent occurrence).

IV. RESULTS

The stomachs of 26 species of fish contained food in April and May. Summaries of the feeding habits of these fish are given by species, life history stage and month in Tables 2-19. Food items are reported by family or higher taxa.

Salmonids

Most of the pink and chum stomachs were taken in May (Table 2). Both species fed upon zooplankton (especially calanoid and harpacticoid copepods), gammarid amphipods and insects, but chum fry consumed more insects than did the pink fry. Primary foods of the silver salmon juveniles were also calanoids, harpacticoids and insects (Table 3); however, only 15 stomachs were sampled.

The adult Dolly Varden fed primarily upon polychaetes, amphipods and calanoid copepods (Table 3).

Gadids

In comparison with salmonid fry, Pacific cod juveniles consumed a wide range of prey types (Table 4). Gammarid amphipods, shrimp (Carides), and fish were important components of their diet. The adults ate very few gammarids, but shrimp and fish remained important to the diet.

Walleye pollock adults relied much more heavily on fish for food than did the juveniles but shrimp were important to both (Table 5). Euphausids were relatively important to the adults but not the juveniles, whereas chaetognaths were consumed in fairly large numbers by the juveniles but not the adults. In addition, the juveniles ate several forms of small crustaceans which, for the most part, the adults ignored.

Hexagrammids

Only 12 rock greenling juveniles were sampled and these had fed upon algae, snails (Prosobranchia), clam (pelecypod) siphons, polychaetes, small crustaceans, shrimp, crabs and fish (Table 6). The adults ate a very wide range of foods which spanned 10 phyla and 69 lower taxa. Most items occurred in trace amounts but the predominant categories by weight were echiuroids, polychaetes, gammarid amphipods, brachyuran crabs, fish and fish eggs.

The masked greenling also had a very diverse diet which included 74 categories of food (Table 7). Juveniles fed most heavily on polychaetes and gammarids which were also important to the adults. Also important by weight to the adults were pelecypods, gastropods (family Lacunidae), and hippolytid shrimp.

The list of food types for whitespotted greenling is much shorter (25 items) than for rock or masked greenling (Table 8); however, fewer whitespotted greenling were examined than the other two species. Important foods by weight, were gammarid amphipods, decapods (especially shrimp) and fish.

Three Hexagrammos sp. were sampled and their stomachs contained gastropods (Lacunidae), gammarids, shrimp, crabs and fish (Table 8). Those five items were important to the diet of six kelp greenling which also contained large numbers of fish eggs (Table 9).

Cottids

The stomachs of seven silverspotted sculpins contained only crustaceans, except for one clam siphon which was eaten by the juvenile (Table 9). Most important in the diet were gammarid amphipods.

Myoxocephalus sp. 1 fed more heavily on fish than on any other food source (Table 10). Brachyuran crabs were also utilized extensively and shrimp formed a third prominent component of the diet of the adults. Many other foods were used, but to a much lesser degree.

Only ten Myoxocephalus sp. 2 stomachs were taken in April and May and two of those were from juveniles (Table 11). The juveniles fed on gammarid amphipods and fish whereas the adult stomachs contained decapod legs, shrimp, crabs, fish and fish bones.

One Pacific staghorn sculpin, one Oligocottus sp. and eight Gymnocanthus sp. were sampled and the stomach contents of each species are listed in Table 12. The most important foods for the seven Gymnocanthus juveniles were polychaetes, gammarids and decapod megalops.

Even though the number of yellow Irish lord adults that were sampled was relatively high (66), the diversity of food in their stomachs was very low (Table 13) compared with similar numbers of great sculpins. The 35 juvenile stomachs contained more food types than did the adult stomachs. Shrimp were an important food to both adults and juveniles.

Trichodontidae

Thirteen Pacific sandfish were sampled and their diet was limited primarily to euphausids and fish (Table 14).

Pleuronectidae

The arrowtooth flounder juveniles and adults utilized the same food types. Most important by weight to both age groups were fish and fish bones and the second most important food category was shrimp (Table 14).

The arrowtooth flounder appeared to consume far more fish than did the flathead sole (Table 15). Instead, shrimp were the most important component in the diet of both juvenile and adult flathead sole.

More food types (94) were eaten by the rock sole than by any other species; however, this may in part be due to the very large samples of rock sole (Table 16). Most of the foods of both juveniles and adults were present in only trace amounts. The predominant food items for both juveniles and adults were polychaetes, clam siphons and fish.

The yellowfin sole diet was also quite diverse, with no one item occurring in large quantities (Table 17). Pelecypod siphons, polychaetes and majid crabs were the most important food items to the juveniles whereas pelecypod siphons, polychaetes, shrimp, lithodid crab legs and fish were the most important food items to the adults.

Stichaedae

Only one snake prickleback was sampled and its stomach contained polychaetes, gammarid amphipods and pelecypod siphons (Table 18).

Pholidae

The most important foods, by weight, to the ten crescent gunnel juveniles were polychaetes and gammarid amphipods and the most important to the ten adults were polychaetes, gammarids and cancrid crabs (Figure 18).

Ammodytidae

Sand lance juveniles and adults consumed more calanoid copepods than any other food item (Table 19). In general, other small crustaceans such as crustacea nauplii and gammarid amphipods made up the remainder of the diet.

V. INTERPRETATION OF RESULTS

None at this time.

VI. AUXILIARY MATERIAL

None

VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

None

Table 1. The number of fish stomachs sampled by species and month, April-November, 1978.

	April	May	June	July	August	November	Total
Rock sole	229	530	673	384	285	417	2518
Yellowfin sole	25	381	601	249	297	267	1820
Flathead sole	18	209	366	183	179	184	1139
Starry flounder	3					4	7
Arrowtooth flounder	1	41					42
Butter sole		12					12
Alaska plaice	1					2	3
Pacific halibut	4		26	20			50
Rock greenling	6	78	240	177	169	105	775
Masked greenling	69	108	124	258	254	180	993
Whitespotted greenling		49	112	176	284	68	689
Kelp greenling		6	4	2	7	6	25
Unidentified greenling		3	4	6	5		18
Myoxocephalus sp. 1	12	75	81	97	153	101	519
Myoxocephalus sp. 2	1	9					10
Myoxocephalus spp.						57	57
Oligocottus sp.	1						1
Staghorn sculpin		1					1
Gymnocanthus sp.	1	7					8
Buffalo sculpin		2					2
Silverspotted sculpin	7						7
Yellow Irish lord	1	100	155	99	113	41	509
Red Irish lord			3	10	9	2	24
Pink salmon	22	220	414	150	42		848
Chum salmon	4	200	337	74		1	616
Silver salmon		15	4				19
Dolly Varden	13						13
Sand lance	26	197	217	155	291	80	966
Eulachon						4	4
Capelin		1	31			1	33
Sandfish		13	1	28	42	2	86
Snake prickleback		2	17	40	11		70
Crescent gunnel		20	16	17	64	1	118
Penpoint gunnel					2		2
Blennioids	2						2
Daubed shanny		1					1
Shortfin eelpout							1
Pacific cod	21	84	97	159	121	80	562
Walleye pollock		81	55	47	78	62	323
Tomcod					9	23	32
Sablefish			25		35	13	73
Searcher		1					1
Prowfish				1			1
Black rockfish					4		4
Lingcod					12	5	17
Total	467	2446	3603	2332	2467	1706	13,021

Table 2. The average number and weight (mg) of prey items per pink and chum salmon stomach.
(T = trace, J = juvenile)

	Pink salmon (J) (Oncorhynchus gorbuscha)				Chum salmon (J) (Oncorhynchus keta)			
	April		May		April		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Mollusca								
Gastropoda			T	T				
Acmaeidae					0.3	T		
Annelida								
Polychaeta							T	T
Arthropoda								
Crustacea								
Copepoda								
Calanoida	0.2	T	1.3	T	2.5	T	6.1	T
Harpacticoida	6.0	T	23.7	T	6.5	T	30.7	T
Cirrepeda			T	T			0.5	T
Mysidacea			T	T			T	T
Cumacea			0.1	T				
Amphipoda								
Hyperiidea							T	T
Gammaridea	0.4	T	7.6	T			2.9	T
Decapoda			T	T				
Insecta			0.1	T			0.7	T
Collembola					5.8	T		
Diptera			T	T	3.0	T	4.3	T
Chordata								
Osteichthyes			0.1	T			T	T
Ammodytidae			T	T				
Unid. eggs					75.0	T		
Total no. stomachs	22		220		4		200	
No. empty stomachs	0		0		0		1	

Table 3. The average number and weight (mg) of prey items per silver salmon and Dolly Varden stomach.
(T = trace, J = juvenile)

	Silver salmon (J) (*Oncorhynchus kisutch*) May		Dolly Varden (*Salvelinus malma*) April	
	No.	Wt.	No.	Wt.
Annelida				
Polychaeta			3.0	130
Nereidae			3.5	121
Arthropoda				
Copepoda				
Calanoida	4.7	1	162.3	61
Harpacticoida	3.3	1		
Cirrepeda	0.1	T		
Mysidacea			0.2	1
Amphipoda				
Gammaridea			50.1	51
Calliopiidae			102.4	110
Insecta	2.7	T		
Chordata				
Hexagrammidae			0.3	3
Total no. stomachs	15		13	
No. empty stomachs	0		0	

Table 4. The average number and weight (mg) of prey items per Pacific cod stomach.

(T = trace, J = juvenile)

	Pacific cod (Gadus macrocephalus)					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta	T	T				
Rhodophyta					T	T
Mollusca						
Pelecypoda	T	T	0.1	T		
Annelida						
Polychaeta	0.5	T	0.4	T		
Nereidae	T	3				
Arthropoda						
Crustacea	0.1	1	T	3		
Crustacea legs	0.3	T				
Calanoida	0.3	T	0.4	T		
Harpacticoida			1.3	T		
Cirrepeda	0.2	T	0.2	T		
Nebaliacea						
Mysidacea	T	T	0.5	1		
Cumacea	2.1	1	0.1	T		
Amphipoda						
Gammaridea	36.1	14	54.2	43	0.1	1
Euphausiacea			0.3	1		
Isopoda						
Sphaeromatidae			0.1	T		
Decapoda						
Carides	1.2	12	1.0	27	0.3	70
Hippolytidae	1.2	11			0.1	14
Crangonidae					T	3
Pandalidae			0.6	188	12.7	5044
Brachyura			T	1	T	4
Oxrhyncha	0.1	T				
Majidae			0	22	0.3	141
Chordata						
Osteichthyes			0.1	63		
Osteichthyes bones			T	T	0.1	40
Agonidae					T	11
Ammodytidae			0.1	17		
Clupeidae					T	25
Gadidae	T	67			0.1	149
Unidentified	0.1	T				
Total no. stomachs	21		25		59	
No. empty stomachs	0		2		0	

Table 5. The average number and weight (mg) of prey items per walleye pollock stomach.
(T = trace, J = juvenile)

	Walleye pollock (*Theragra chalcogramma*)			
	May (J)		May	
	No.	Wt.	No.	Wt.
Annelida				
Polychaeta	T	T		
Arthropoda				
Crustacea	T	T	0.9	9
Calanoida	31.2	4	1.0	T
Cirrepeda	0.5	T		
Mysidacea	2.6	5		
Cumacea	0.3	T		
Amphipoda				
Gammaridea	0.7	T		
Euphausiacea	0.1	T	8.3	76
Decapod larvae	T	T		
Pandalidae	0.1	12	1.8	463
Chaetognatha	7.5	13		
Chordata				
Osteichthyes			T	55
Osteichthyes bones			0.3	94
Ammodytidae	T	T		
Gadidae			0.6	856
Unidentified	T	T	T	9
Total no. stomachs	59		22	
No. empty stomachs	3		2	

Table 6. The average number and weight (mg) of prey items per rock greenling stomach.
(T = trace, J = juvenile)

	Rock greenling (Hexagrammos lagocephalus)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta								
Ulotrichales							T	T
Cladophorales								
Cladophoraceae			0.3	3				
Rhodophyta			1.0	28			T	T
Corallinaceae							T	T
Delesseriaceae							T	T
Kallymeniaceae			12.0	17				
Phyllophoraceae							T	T
Rhodomelaceae							T	T
Phaeophyta					0.1	T	0.2	18
Chlordariaceae							T	T
Fucales							T	0.1
Laminariales							0.1	5
Cnidarea								
Anthozoa							T	2
Ectoprocta							T	T
Mollusca								
Gastropoda							0.1	1
Prosobranchia								
Acmaeidae							T	T
Lacunidae			0.7	3	0.2	T	5.3	22
Muricidae							T	T
Trochidae							T	T
Pterobranchia								
Bullidae							T	T
Pelecypoda							T	T
Pelecypod siphons	1.7	1	2.3	19	5.0	113	0.6	9
Mytilidae							T	T
Cephalopoda								
Octopoda							T	8
Echiuroidea							0.1	49
Annelida								
Polychaeta	7.0	12	1.7	70	0.1	9	4.2	52
Glyceridae							T	3
Lambrineridae							T	T
Maldanidae							T	T
Nereidae							T	4
Opheliidae	2.7	6			8.3	8	T	T
Serpulidae					0.3	T	0.1	1
Arthropoda								
Crustacea							T	3
Crustacea legs							T	T
Copepoda								
Calanoida	1.7	T						
Harpacticoida	9.7	T						

Table 6. The average number and weight (mg) of prey items per rock greenling stomach. (T = trace, J = juvenile) continued.

	Rock greenling (Hexagrammos lagocephalus)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Nebaliacea							T	T
Mysidacea							0.1	T
Cumacea							T	T
Isopoda								
Flabellifera							1.1	2
Idoteidae					0.1	1	0.2	3
Sphaeromatidae							0.6	2
Amphipoda								
Caprellidea							0.3	T
Gammaridea	19.0	6	8.7	16	13.1	16	50.1	68
Euphausiacea							T	T
Decapod							0.1	4
Decapod megalops					1.1	6	0.2	3
Carides					0.1	1	T	1
Hippolytidae			0.7	12	0.8	23	1.8	28
Anomura							T	4
Albuneidae							T	1
Paguridae							0.1	10
Brachyura								
Atelecyclidae			3.3	307	0.1	12	0.3	148
Cancridae					0.2	3	0.2	22
Oxrhyncha							0.1	4
Majidae					0.7	6	1.4	81
Chordata								
Urochordata			0.7	63				
Ascidacea							T	1
Vertebrata								
Osteichthyes			18.3	4	0.4	77	0.5	94
Osteichthyes bones							0.3	4
Osteichthyes eggs			1275.3	128			41.7	13
Ammodytidae							T	3
Cottidae							T	13
Gadiformes							T	1
Hexagrammidae							T	30
Pholidae							T	15
Scorpaenidae							T	T
Stichaeidae							T	1
Unidentified	2.0	1	0.3	65	4.0	5	578.0	54
Total no. stomachs	3		3		9		69	
No. empty stomachs	0		0		0		2	

Table 7. The average number and weight (mg) of prey items per masked greenling stomach.
(T = trace, J = juvenile)

	Masked greenling (Hexagrammos octogrammos)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta			T	T				
Ulotrichales			T	T			0.1	T
Rhodophyta	T	T					T	T
Bangiaceae			T	T				
Gigartinaceae			0.2	1				
Phaeophyta			T	T			T	T
Laminariales			0.2	3				
Angiosperma								
Potamogetonaceae			0.1	T				
Cnidarea								
Anthozoa							T	T
Hydrozoa			T	T				
Nemertinea			T	T				
Ectoprocta	T	T	T	T				
Mollusca								
Polyplacophora							T	T
Pterobranchia								
Bullidae			0.1	T			T	T
Haminoeidae					T	T		
Pelecypoda			4.8	26	T	T		
Pelecyod siphons	0.6	T	1.4	5	0.3	T	T	T
Gastropoda	0.2	T	0.2	T	0.2	T		
Acmaeidae							T	T
Lacunidae	0.9	1	9.0	13	0.2	T	0.9	1
Littorinidae	T	T	0.3	T				
Trochidae			T	T	T	T		
Cephalopoda								
Octopoda							T	1
Annelida								
Polychaeta	4.7	13	2.2	6	4.4	8	2.7	34
Ampharetidae							T	T
Glyceridae							T	T
Maldanidae							0.2	1
Nereidae	T	1					0.1	1
Opheliidae	1.7	2	0.4	T	4.2	5	0.7	1
Pectinariidae	T	T			T	T	T	T
Phyllodocidae							T	T
Serpulidae	0.9	T	0.2	T	T	T	0.1	T
Arthropoda								
Crustacea					T	T	0.1	T
Crustacea legs	0.1	T						
Crustacea megalops	T	T						
Copepoda								

Table 7. The average number and weight (mg) of prey items per masked greenling stomach. (T = trace, J = juvenile) continued.

	Masked greenling (Hexagrammos octagrammos)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Calanoida	1.9	T	T	T				
Harpacticoida	16.0	T	4.1	T	5.6	T	T	T
Cirrepeda			T	T				
Nebaliacea	T	T					T	T
Mysidacea							T	T
Cumacea	T	T	T	T	0.1	T	T	R
Tanaidacea					T	T		
Isopoda	0.4	T			T	T		
Valvifera			T	T				
Idoteidae	T	T			0.1	1	T	2
Asellota					T	T		
Munnidae					0.2	T	T	T
Flabellifera					1.0	3		
Sphaeromatidae	T	T			0.1	1	0.6	2
Amphipoda								
Caprellidea	T	T	2.1	4	0.5	T	0.9	1
Gammaridea	9.8	3	30.9	16	41.1	22	71.5	41
Amphithoidae	0.1	T						
Calliopiidae			0.5	T				
Corophiidae			0.1	T	0.3	3		
Eusiridae			0.1	1				
Gammaridae					T	T	1.5	1
Ischyroceridae			15.0	4				
Euphausiacea					0.7	5	0.1	1
Decapoda			T	2	0.1	6	0.2	5
Decapod legs			0.1	1			0.1	T
Decapod megalops			T	T	0.1	2	T	T
Carides			T	T	0.2	2	0.4	1
Crangonidae			T	T				
Hippolytidae	T	1	0.2	5	T	1	1.7	23
Anomura								
Paguridae			T	T	T	1	T	3
Brachyura							0.1	1
Oxrhyncha			T	1				
Brachyrhyncha								
Atelecyclidae			0.2	11			0.2	3
Cancridae			T	1			T	T
Chordata								
Osteichthyes					0.4	2	0.2	T
Osteichthyes bones	0.1	T	0.1	T				
Osteichthyes eggs	0.5	T	15.5	5			0.9	T
Unidentified	0.1	T	1.4	3	0.6	3	2.1	3
Unidentified eggs	0.3	T	13.1	T	9.4	T		
Total no. stomachs	36		33		56		52	
No. empty stomachs	1		0		3		1	

Table 8. The average number and weight (mg) of prey items per whitespotted greenling and unidentified greenling stomach.
(T = trace, J = juvenile)

	Whitespotted greenling (Hexagrammos stelleri)				Unidentified greenling (Hexagrammos sp.)			
	May (J)		May		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Rhodophyta	0.1	T						
Mollusca								
Gastropoda			0.9	3				
Lacunidae			T	T			8.0	30
Annelida								
Polychaeta	0.6	5	1.2	3				
Polynoidae	0.6	T						
Arthropoda								
Crustacea	0.3	7	1.1	20				
Harpacticoida	0.4	T						
Mysidacea	0.2	2						
Isopoda								
Flabelliferidae			T	T				
Amphipoda								
Caprellidea	0.1	T	0.1	T				
Gammaridea	1.4	2	3.8	40			27.0	11
Euphausiacea	0.3	2	0.6	2				
Decapoda	0.7	52			1.0	2		
Decapod legs			0.1	9				
Carides	0.1	18	1.3	170			1.0	3
Crangonidae			0.1	26				
Pandalidae	0.1	48	0.3	49				
Anomura	0.1	T						
Paguridae			0.1	3				
Brachyura			0.1	1				
Atelecyclidae			T	13			1.0	160
Cancridae			T	T				
Chordata								
Osteichthyes	0.7	3	0.3	10			3.0	41
Gadidae			T	28				
Scorpaenidae			T	15				
Unidentified	0.3	T	1.2	4				
Total no. stomachs	14		35		2		1	
No. empty stomachs	2		1		1		0	

Table 9. The average number and weight (mg) of prey items per kelp greenling and silverspotted sculpin stomach.

(T = trace, J = juvenile)

	Kelp greenling (*Hexagrammos decagrammus*)		Silverspotted sculpin (*Blepsias cirrhosus*)			
	May		April (J)			
	No.	Wt.	No.	Wt.	No.	Wt.
Rhodophyta	0.2	T				
Phaeophyta	0.2	6				
Mollusca						
Gastropoda						
Lacunidae	4.4	24				
Pelecypoda						
Pelecypod siphons			1.0	T		
Annelida						
Polychaeta	7.5	14				
Arthropoda						
Pyncnogonida	0.2	T				
Crustacea						
Copepoda						
Harpacticoida			16.0	T	0.5	T
Cumacea					0.2	T
Isopoda						
Idoteidae			4.0	1	0.2	T
Sphaeromatidae			1.0	2	0.2	T
Amphipoda						
Caprellidea			1.0	1		
Gammaridea	45.5	36	24.0	33	16.3	15
Decapoda	0.2	11				
Carides	1.2	105				
Hippolytidae	4.6	61			0.3	3
Brachyura						
Atelecyclidae	0.8	57				
Cancridae	0.2	1				
Chordata						
Osteichthyes	3.2	41				
Osteichthyes bones	0.2	T				
Osteichthyes eggs	125.0	100				
Cottidae	0.5	3				
Unidentified	5.0	75				
Total no. stomachs	6		1		6	
No. empty stomachs	0		0		0	

Table 10. The average number and weight (mg) of prey items per Myoxocephalus sp. 1 stomach.
(T = trace, J = juvenile)

	Myoxocephalus sp. 1					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta						
Ulotrichales					T	T
Phaeophyta					T	T
Laminariales					T	4
Nemertinea					0.2	1
Mollusca						
Gastropoda					0.5	5
Acmaeidae					T	T
Lacunidae					0.1	T
Naticidae					T	2
Pelecypoda						
Pelecypod siphons					0.1	4
Cardiidae	0.1	5				
Annelida						
Polychaeta	1.7	5			T	5
Arthropoda						
Crustacea					T	40
Amphipoda						
Caprellidea	0.7	1			0.2	1
Gammaridea	9.6	4	4.9	19	0.8	1
Eusiridae	8.2	6				
Euphausiacea			0.2	T		
Decapoda	0.1	1			T	3
Carides					0.7	154
Hippolytidae					T	T
Pandalidae					0.4	171
Anomura						
Lithodidae					T	17
Brachyura					T	34
Atelecyclidae					0.2	199
Canceridae	0.1	5	0.1	137	T	59
Oxrhyncha					T	82
Majidae			0.1	40	0.4	1165
Tanaidacea	0.1	T			T	T
Isopoda						
Idoteidae			0.3	13		
Sphaeromatidae					0.1	T
Chordata						
Osteichthyes			0.6	136	0.7	1202
Osteichtyes bones					0.1	74
Ammodytidae					0.2	99
Clupeidae					T	21
Cottidae			0.4	22	T	902
Gadidae					T	1371
Pholidae	0.2	38				

Table 10. The average number and weight (mg) of prey items per Myoxocephalus sp. 1 stomach. (T = trace, J = juvenile) continued

	Myoxocephalus sp. 1					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Scorpaenidae					T	309
Pleuronectidae					T	845
Stichaeidae					T	35
Unidentified			0.8	9	0.3	17
Total no. stomachs	12		14		61	
No. empty stomachs	0		2		13	

Table 11. The average number and weight (mg) of prey items per Myoxocephalus sp. 2 stomach. (J = juvenile)

	Myoxocephalus sp. 2					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Arthropoda						
Amphipoda						
Gammaridea			7.0	18		
Calliopiidae	1.0	1				
Gammaridae	9.0	28				
Decapoda						
Decapod legs					0.2	288
Carides						
Crangonidae					0.2	9
Pandalidae					1.0	381
Brachyura						
Cancridae					0.2	778
Chordata						
Osteichthyes	1.0	48			0.2	320
Osteichthyes bones					0.6	3363
Total no. stomachs	1		1		8	
No. empty stomachs	0		0		3	

Table 12. The average number and weight (mg) of prey items per Pacific staghorn sculpin, Gymnocanthus sp., and Oligocottus sp. stomach.

(T = trace, J = juvenile)

	Pacific staghorn sculpin (Leptocottus armatus)		Gymnocanthus sp.				Oligocottus sp.	
	May (J)		April		May (J)		April (J)	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Mollusca								
Pelecypoda					0.4	1		
Pterobranchia								
Bullidae					0.2	T		
Annelida	1.0	40						
Polychaeta			4.0	2	1.2	3		
Arthropoda								
Crustacea								
Copepoda								
Harpacticoida	1.0	T						
Cumacea					0.2	T		
Amphipoda								
Gammaridea	1.0	T	2.0	10	2.6	3	4.0	5
Decapoda								
Decapod megalops					1.0	2		
Total no. stomachs	1		1		7		1	
No. empty stomachs	0		0		2		0	

Table 13. The average number and weight (mg) of prey items per yellow Irish lord stomach.
(T = trace, J = juvenile)

	Yellow Irish lord (Hemilepidotus jordani)					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Phaeophyta			T	T		
Mollusca						
Pelecypoda (inorganic)			T	T	T	1
Annelida						
Polychaeta			0.1	2		
Arthropoda						
Crustacea			0.1	2	0.2	18
Crustacea legs			T	T		
Cumacea			T	T		
Amphipoda						
Gammaridea	3.0	1	0.7	1		
Lysianassidae			0.1	T		
Mysidacea					T	T
Decapoda			0.5	4	T	3
Decapod legs			T	1		
Decapod megalops						
Caridea	1.0	4	0.1	38	1.2	379
Crangonidae			T	T		
Hippolytidae			0.3	3		
Pandalidae			0.1	51	0.8	392
Anomura						
Paguridae			0.2	10		
Brachyura			0.1	3		
Brachyura legs			0.1	1		
Oxrhyncha			T	T		
Majidae			0.5	1	0.1	18
Ectoprocta			0.1	T		
Chordata						
Osteichthyes					0.2	71
Osteichthyes bones					T	T
Cottidae			T	10		
Unidentified			0.6	T	0.1	11
Total no. stomachs	1		34		66	
No. empty stomachs	0		5		7	

Table 14. The average number and weight (mg) of prey items per Pacific sandfish and arrowtooth flounder stomach. (T = trace, J = juvenile)

	Pacific sandfish (Trichodon trichodon)				Arrowtooth flounder (Atheresthes stomias)			
	May		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Arthropoda								
Crustacea								
Amphipoda								
Gammaridea	0.1	T						
Euphausiacea	6.4	50						
Decapoda								
Decapod megalops	2.1	1						
Carides					0.2	42	0.3	35
Carides legs					0.1	4	0.1	10
Pandalidae					0.1	13		
Chordata								
Osteichthyes	1.3	356	1.0	140	0.4	76	0.5	222
Osteichthyes bones					0.3	50	0.4	98
Cottidae							0.1	12
Total no. stomachs	13		1		27		14	
No. empty stomachs	2		0		9		4	

Table 15. The average number and weight (mg) of prey items per flathead sole stomach.
(T = trace, J = juvenile)

	Flathead sole (Hippoglossoides elassodon)					
	April (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Nemertinea	0.2	T				
Mollusca						
Prosobranchia						
Littorinidae	0.1	T				
Pelecypoda						
Pelecypod siphons	0.1	T	0.2	T		
Cardiidae			T	T		
Nuculoida					T	T
Annelida						
Polychaeta	0.3	T	0.2	T	0.1	2
Ampharetidae			T	T		
Arthropoda						
Crustacea			T	T		
Nebaliacea			T	T		
Mysidacea			0.4	2		
Cumacea	0.1	T	T	T		
Amphipoda						
Gammaridea			0.1	T		
Gammarid legs	0.1	T				
Euphausiacea			0.3	2		
Decapoda						
Carides			0.3	35	1.0	222
Pandalidae			0.3	58	1.9	737
Brachyura						
Majidae					T	28
Echinodermata						
Ophiuroidea			T	T		
Chordata						
Osteichthyes					T	6
Clupeidae					T	17
Stichaedae					T	4
Unidentified	0.1	T	0.1	T	0.1	2
Total no. stomachs	18		162		47	
No. empty stomachs	2		34		7	

Table 16. The average number and weight (mg) of prey items per rock sole stomach.
(T = trace, J = juvenile)

	Rock sole (Lepidopsetta bilineata)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta			T	T			0.2	4
Ulotrichales			0.1	2	T	T	0.1	7
Rhodophyta					T	T		
Bangiaceae							T	5
Phaeophyta	T	T			T	T		
Angiosperma								
Potamogetonaceae			T	T				
Protozoa								
Foraminifera	T	T						
Cnidarea								
Anthozoa							T	T
Hydrozoa			T	T			T	T
Nemertinea	0.1	T	T	T				
Priapulida					T	T		
Ectoprocta			T	T				
Mollusca								
Polyplacophora								
Ischnochitonidae					T	T	T	T
Prosobranchia					T	T	T	1
Acmaeidae			T	T	T	T	T	T
Pterobranchia					T	1		
Bullidae			T	T	0.3	T	T	T
Haminoeidae			0.1	T				
Pelecypoda	2.3	T	0.5	6	0.2	T	T	T
Pelecopod siphons	13.2	3	2.0	17	1.7	2	1.6	18
Cardiidae	T	T	0.1	2				
Mactridae					T	T		
Montaculidae							T	T
Myidae			T	T				
Nuculanidae			T	T			T	2
Pectinidae							T	T
Tellinidae			T	T	T	T	0.1	T
Veneroida			T	T	T	T		
Veneridae			T	T				
Annelida								
Polychaeta	2.8	0.2	8.0	37	2.3	8	8.7	67
Ampharetidae					0.3	T		
Flabelliferidae			T	T				
Glyceridae	T	T	0.1	3	0.1	1	T	T
Goniadidae	0.1	T	T	T			T	1
Lumbrineridae			0.3	T	0.2	T	T	T
Maldanidae			0.4	T	T	T	T	T
Nephtyidae			0.5	3				
Nereidae	T	T	0.2	8				

Table 16. The average number and weight (mg) of prey items per rock sole stomach. (T = trace, J = juvenile) continued.

	Rock sole (Lepidopsetta bilineata)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Ophiliidae	0.2	T	0.5	3	0.1	T	0.7	2
Orbiniidae			T	T				
Oweniidae							1.3	4
Pectinariidae	T	T	0.2	T	T	T	T	T
Phyllodocidae	T	T	T	T	T	T	T	T
Sabellidae			T	T	T	T		
Serpulidae	0.1	T			T	T		
Spionidae	0.1	T	2.0	6				
Terebellidae					0.1	T		
Arthropoda								
Crustacea	T	T	T	T	0.1	T		
Crustacea legs			T	T				
Ostracoda	T	T						
Copepoda					T	T		
Calanoida					0.1	T		
Caligoida							T	T
Harpacticoida					T	T		
Cirrepeda							T	T
Mysidacea	0.1	T	T	T				
Cumacea	0.1	T	0.1	T	0.1	T	0.1	T
Tanaidacea	T	T			T	T	0.1	T
Isopoda								
Sphaeromatidae							0.1	T
Amphipoda			T	T				
Caprellidea			T	T			0.1	T
Gammaridea	1.4	1	1.6	2	2.1	1	4.1	4
Gammarid legs	T	T	0.4	1				
Ampeliscidae			T	T	T	T	T	T
Eusiridae			T	T				
Gammaridae			0.2	T			T	T
Ischyroceridae			T	T				
Lysianassidae							0.6	2
Phoxocephalidae			T	T				
Euphausiacea							T	T
Decapoda					T	T	T	T
Decapod legs	T	T						
Decapod megalops	0.1	T	T	T	0.2	T	0.3	1
Carides			T	T	T	T	T	2
Carides legs			T	T				
Crangonidae							T	T
Pandalidae							T	2
Anomura								
Lithodidae			T	2				
Paguridae					T	T		
Brachyura								
Oxyrhyncha							T	T
Majidae					T	T	0.1	4

Table 16. The average number and weight (mg) of prey items per rock sole stomach. (T = trace, J = juvenile) continued.

	Rock sole (Lepidopsetta bilineata)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Brachyrhyncha								
Pinnotheridae			T	1				
Echinodermata								
Asteroidea								
Dendrasteridae							T	T
Holothuroidea							T	1
Echinoidea	T	T	T	T	T	T		
Ophiuroidea			T	2	T	T	T	T
Chordata								
Ascidacea			T	T				
Osteichthyes	T	0.1	0.1	8	T	2	0.1	27
Osteichthyes bones	T	T	0.3	1	T	T	T	T
Osteichthyes eggs	T	T						
Ammodytidae			0.9	95	T	T	T	2
Cottidae	0.3	T	0.1	T			T	T
Hexagrammidae					T	T		
Pleuronectidae							T	4
Stichaeidae							T	14
Unidentified	0.3	T	0.8	6	0.1	1	0.6	10
Unidentified egg			4.7	T	0.9	T		
Total no. stomachs	92		137		321		209	
No. empty stomachs	5		30		51		48	

Table 17. The average number and weight (mg) of prey items per yellowfin sole stomach. (T = trace, J = juvenile)

	Yellowfin sole (*Limanda aspera*)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Chlorophyta					T	T	0.1	2
Ulotrichales					T	T	T	2
Rhodophyta					T	T	T	T
Bangiaceae							T	1
Rhodymeniaceae							T	1
Phaeophyta	0.1	T			T	T	T	3
Protozoa								
Foraminifera							T	T
Cnidarea								
Anthozoa	0.1	T						
Hydrozoa			0.8	T			T	T
Nemertinea	1.3	T						
Ectoprocta					T	T	T	T
Sipunculida							T	T
Mollusca								
Gastropoda	0.1	T			T	T	T	T
Lacunidae	0.2	T						
Pterobranchia					0.2	2	T	1
Bullidae					T	T	T	T
Pelecypoda	0.9	T	3.4	2	0.3	T	0.1	T
Pelecypod siphons	25.5	3	0.6	T	3.9	2	1.2	19
Cardiidae	0.5	2	0.4	2			T	3
Nuculoida					T	T		
Nuculanidae					T	T		
Mactridae					T	T	T	T
Pectinidae							T	T
Tellinidae							T	T
Veneroida							0.3	T
Annelida								
Polychaeta	4.8	3	4.2	10	1.2	4	2.7	12
Amphaeretidae					0.2	T	0.9	1
Glyceridae							T	T
Lumbrineridae							0.1	T
Maldanidae					T	T		
Opheliidae					T	T	T	T
Oweniidae					T	T	0.1	1
Pectinariidae							T	T
Serpulidae					T	T		
Spionidae	0.1	2					0.3	2
Arthropoda								
Crustacea							T	1
Crustacea legs					T	T		
Ostracoda	0.5	T			T	T		
Copepoda								

Table 17. The average number and weight (mg) of prey items per yellowfin sole stomach. (T = trace, J = juvenile) continued,

	Yellowfin sole (Limanda aspera)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Harpacticoida	0.1	T			T	T		
Cirrepeda					T	T	T	T
Mysidacea							T	T
Cumacea					T	T		
Isopoda								
Valvifera					T	T		
Amphipoda								
Caprellidea	0.1	T	2.4	T			T	T
Gammaridea	7.3	1			0.4	T	2.0	2
Euphausiacea					T	T		
Decapoda					T	T	T	1
Decapod megalops					T	T	0.1	T
Carides					T	1	0.1	20
Crangonidae							T	1
Pandalidae							0.1	44
Hippolytidae							T	1
Anomura								
Lithodidae legs							T	26
Paguridae							T	T
Brachyura					0.1	T		
Oxrhyncha					T	T	T	T
Majidae					0.1	18	T	T
Echinodermata								
Holothuroidea			0.2	T				
Ophiuroidea					T	T	T	1
Asteroidea								
Dendrasteridae					T	T		
Chordata								
Osteichthyes					T	T	T	16
Osteichthyes eggs							T	T
Osteichthyes bones			0.2	T			T	1
Cottidae	0.1	5					T	1
Gadidae							T	20
Unidentified	0.1	T			0.2	9	0.7	4
Unidentified egg	31.3	T			2.2	T		
Total no. stomachs	19		6		194		187	
No. empty stomachs	3		1		28		47	

Table 18. The average number and weight (mg) of prey items per snake prickleback and crescent gunnel stomach. (T = trace, J = juvenile)

	Snake prickleback (Lumpenus sagitta)		Crescent gunnel (Pholis laeta)			
	May (J)		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.
Rhodophyta			0.3	T	0.1	T
Mollusca						
Gastropoda			0.1	T		
Pelecypoda						
Pelecypod siphons	3.0	1				
Annelida						
Polychaeta	2.0	0	0.3	1	1.3	8
Opheliidae	14.0	20				
Arthropoda						
Crustacea						
Crustacea legs			0.1	T		
Copepoda						
Harpacticoida			0.1	T	0.3	T
Isopoda						
Munnidae			1.7	T		
Amphipoda						
Gammaridea	10.0	4	2.6	T	8.3	7
Gammaridae			3.1	1		
Decapoda					0.1	T
Carides					0.4	T
Brachyura						
Cancridae					0.3	4
Unidentified			2.4	1	1.9	T
Total no. stomachs	2		10		10	
No. empty stomachs	1		3		2	

Table 19. The average number and weight (mg) of prey items per sand lance stomach.
(T = trace, J = juvenile)

	Sand lance (Ammodytes hexapterus)							
	April (J)		April		May (J)		May	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Mollusca								
Gastropoda							1.0	T
Gastropod veliger					0.5	T	1.0	T
Arthropoda								
Crustacea								
Crustacea nauplii							11.9	T
Capepoda								
Calanoida	50.3	2	580.0	56	78.6	16	70.8	4
Harpacticoida	0.1	T					2.5	T
Cirrepeda			1.6	T	0.2	T	24.9	T
Mysidacea	1.2	1			0.9	2	0.6	1
Tanaidacea	0.5	T					T	T
Amphipoda	0.3	T						
Caprellidea							T	T
Hyperiidea	0.3	T			T	T		
Gammaridea	2.3	3	0.2	T	0.1	T	0.3	T
Isopoda								
Flabellifera	0.3	T					T	T
Euphausiacea							0.1	T
Decapoda								
Decapod megalops			75.4	2			1.1	T
Carides							0.1	T
Pandalidae					21.3	8		
Chordata								
Osteichthyes			2.8	5	T	T	0.2	1
Total no. stomachs	20		6		96		101	
No. empty stomachs	4		1		6		0	

MICROBIOLOGY

Contents

Quarterly Report

Contract # 03-5-022-85
Research Unit 29
Period 10/1 - 12/31

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development

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January 1, 1979

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community characteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Activities

No field sampling activities were performed during this period.

B. Laboratory Activities

During this period laboratory tests were conducted for numerical taxonomy on 800 isolates from the Beaufort Sea. All laboratory testing of isolates for numerical taxonomy for both the Beaufort Sea and Cook Inlet have been completed. The data for isolates from the Summer 1978 Beaufort Sea cruise are being keypunched for transmission to NIH for data banking and analysis.

Cluster analyses are being performed on isolates from the Spring cruise in Lower Cook Inlet. Feature frequency and diversity calculations were accomplished during this period for isolates collected in Lower Cook Inlet during Spring and Fall 1977.

Gas chromatographic-mass spectral analyses were performed

during this period on oil recovered from the sediment-tray experiments in Elson Lagoon. Glass capillary columns were used for separation of hydrocarbons. The NIH-EPA library search was used for identification of residual hydrocarbons.

Denitrification potentials were determined, by gas chromatographic analyses, for sediment samples collected during Summer 1978 in the Beaufort Sea. All denitrification analyses have been completed.

Hydrocarbon degradation potentials were determined, by measuring CO_2 production from radiolabelled hydrocarbons, for water and sediment samples collected during Summer 1978 in the Beaufort Sea. Hydrocarbon degradation potential measurements were also completed for samples collected in Lower Cook Inlet during Spring 1978.

Hydrocarbon degrading microorganisms were enumerated, using a Most Probable Number Procedure, from water and sediment samples collected in the Beaufort Sea during Summer 1978.

All methods for the above procedures have been described in previous proposals and reports. No alterations were made in methodology during this period.

III. Results

Nitrogen Cycling

All sediment samples collected in the Beaufort Sea, during Summer 1978, exhibited rates of nitrogen fixation,

measured by the acetylene reduction method, of less than 0.02 μmoles ethylene produced per gram sediment per day. This was the limit of detection for acetylene reduction, i.e., no sediment sample exhibited measureable rates of nitrogen fixation.

Sediment samples did not exhibit denitrification activities unless nitrate was added. The acetylene blockage technique for measurement of denitrification failed to completely stop denitrification at nitrous oxide. Both nitrous and nitric oxides were detected as denitrification products from sediment samples amended with nitrate. The acetylene did block formation of N_2. Figures 1 and 2 show the production of nitrous oxide and nitric oxide, respectively, from sediment amended with nitrate. The combined results of these two denitrification products indicate that virtually all sediment samples tested were denitrifying, i.e, fixed forms of nitrogen that entered these sediments would be converted to nitrogen gases and lost from the marine ecosystem. Four areas had particularly high denitrification activities. These areas were near Barter Island in an area of presumed upwelling, near the Canning River, in the vicinity of the Kuparuk River, and in Demarcation Bay. Addition of a readily useable carbon source to nitrate amended sediments enhanced denitrification activities (Figs. 3 and 4). In these carbon-rich tests denitrification activities were especially high

near Barter Island in the area presumed upwelling, near the Canning River, and in the vicinity of the Kuparuk River. High denitrification activities were found well offshore along the transect from the Kuparuk River.

Diversity of Microbial Populations

Diversities of bacterial populations were calculated using the Shannon-Weaver index for samples collected within Cook Inlet during Spring 1977. Diversities less than 3 are indicative of stress on the microbial community. High diversities were found in all sediment samples. Only a limited number of sediment samples, however, were collected and analysed (Fig. 5). Diversities in surface waters were much lower outside the entrances of Cook Inlet and within Cook Inlet (Fig. 6). Diversities were also lower in the center of Cook Inlet than on either the eastern, western, or northern sides of Lower Cook Inlet. The lower diversities in the center of Cook Inlet occur within the area shown by physical oceanographers to be an area of low current exchange. The diversity in surface water at the northern most station samples, within Upper Cook Inlet, was relatively low. This may be due to hydrocarbon input detected by chemists from samples collected in this region.

Most Probable Numbers of Hydrocarbon Utilizers

Distributions of hydrocarbon utilizing microorganisms within Cook Inlet and in the Beaufort Sea were quite patchy during the sampling periods. In each area there were samples with extremely high and very low numbers of hydrocarbon utilizing microorganisms.

During April, 1978 in Cook Inlet high numbers of oil degraders were enumerated in surface waters collected above Kalgin Island, outside of the eastern entrance to the Inlet, and along a transcent from within Kachemak Bay to within Kamishak Bay (Fig. 7). High numbers of oil utilizers were also found within the small bays just north of Kamishak Bay. Sediment samples showed especially high numbers of oil utilizers in these small bays at the northern end of Kamishak Bay (Fig. 8).

In the Beaufort Sea high numbers of hydrocarbon utilizers were found in surface waters (Fig. 9) and/or sediment (Fig. 10) near Demarcation Bay, in the vicinity of the Sagavanirktok River, west of the Canning River, and at an offshore station north of the Kuparuk River.

Hydrocarbon Biodegradation Potentials

Hydrocarbon biodegradation potentials in the Beaufort Sea were typically low at many stations in both water and sediment for all hydrocarbons tested. The highest biodegradation activities were found in sediment near the mouth of the Canning River. Relatively high biodegradation potentials for non-aromatic hydrocarbons were also found in the sediment near the mouth of the Sagavanirktok River. Hydrocarbon biodegradation activities tended to be higher near shore, particularly at the mouths of rivers, than offshore in the Beaufort Sea (Figs. 11-18).

In Cook Inlet high biodegradation potentials were found above Kalgin Island, within Kamishak Bay, within the three small bays

north of Kamishak Bay, and at scattered sites through the Inlet. The three small bays north of Kamishak Bay exhibited the highest activities for all hydrocarbon substrates. The biodegradation potentials for complex polynuclear aromatics were lower than for less complex structures, however, the three bays north of Kamishak exhibited relatively high biodegradation potentials for benzanthracene (Figs. 19-26).

Mass-Spectral Analyses

The mass-spectral analyses of oil recovered from the *in situ* experiments in Elson Lagoon showed that identical compounds were present in the residual oil four weeks after spillage that were present a few days after spillage (Tables 1 and 2). The concentrations of hydrocarbons in the sediment were reduced by 40-70% one month after spillage depending on the particular hydrocarbon. Light hydrocarbons including substituted benzenes and naphthalenes, and alkanes (C_8-C_{10}) were still present in the sediment one month after spillage. Complex polynuclear aromatic compounds have not yet been isolated and identified. Dimethylnaphthalenes which have been reported by Anderson to be especially toxic were present 1 month after spillage.

IV. Interpretation of Results

The enumeration of hydrocarbon degrading microorganisms and the hydrocarbon biodegradation potential measurements indicate that there is a high probability that certain sites have been exposed to hydrocarbons. These hydrocarbons may be of biogenic

origin or may be petroleum hydrocarbons. Chemical analyses for hydrocarbons in sediments should be carried out to confirm the presence of hydrocarbons at these sites and to elucidate the origin of these hydrocarbons. Counts of hydrocarbon degraders and hydrocarbon degradation activities found at some sites indicate the possible presence of petroleum hydrocarbons in the area. This may indicate the presence of oil reserves and point to likely future sites of petroleum exploration and development. Particular concern should be given to the three bays just north of Kamishak Bay within Cook Inlet, to the site just east of the entrance to Cook Inlet which has repeatedly shown evidence of high numbers of hydrocarbon utilizers, to Demarcation Bay and the area just west of Demarcation Bay in the Beaufort Sea, to the offshore site north of the Kuparuk River that showed high numbers of hydrocarbon utilizers, and to an area north of the mouth of the Canning River. The data suggests a high probability of future petroleum development in these regions or of naturally occurring seepages of hydrocarbons into these areas. The very low biodegradation potentials in some other areas of Cook Inlet and the Beaufort Sea indicate that contaminating hydrocarbons will be degraded only very slowly by the microorganisms in those areas. Complex aromatic hydrocarbons will probably persist in such areas.

The diversity measurements in Cook Inlet suggest that high diversities are found in regions of high current flow along the east and west sides of the Inlet. Lower diversities are found

within the area of low current flow in the center of the Inlet. Diversities outside the entrances to Cook Inlet are significantly lower than diversities within the Inlet suggesting some environmental stress on populations outside of the Inlet. It is not known whether this stress reflects current movements, sources of available nutrients, or other factors. The measurement of diversity in microbial communities appears to be a sensitive index of stress on the ecosystem. We are continuing to examine diversity measurements in light of other measures of environmental parameters in both Cook Inlet and the Beaufort Sea.

The denitrification potential measurements indicate that fixed forms of nitrogen are readily converted to nitrogen gases in sediment and lost from the marine ecosystem at sites in the Beaufort Sea. The stimulation of denitrifying activities by adding an available carbon source suggests that carbon pollution of these sediments will enhance losses of fixed forms of nitrogen and may decrease the fertility of the area. It is not known whether petroleum hydrocarbons that may be released as chronic pollutants from oil development activities will support denitrification activities. Enhancement of denitrification activities by petroleum hydrocarbons would be a serious ecological effect that could reduce the carrying capacity of the nearshore regions of the Beaufort Sea for higher organisms. Several regions in the Beaufort Sea were found to have very high denitrifying potential activities. Such high activities may be indicative of events such as upwelling in those regions.

The *in situ* oil in sediment experiments indicate conclusively that toxic light hydrocarbons remain in the sediment at least 1 month after contamination with Prudhoe Bay crude oil. Although hydrocarbon concentrations declined during 1 month the residual hydrocarbons were still present in concentrations that are toxic to many benthic organisms.

V. Problems Encountered

Funding uncertainties have caused some problems in ordering supplies and employing personnel for this project.

VI. Estimate of Funds

Full funding for this fiscal year has not yet been made by OCSEAP. All funds that have been assured the University of Louisville have been committed.

TABLE 1. 2 days exposure - ether extract

Spectrum #	Retention Time	Compound
1	2.3	Toluene + Octane-derivative
2	2.6	Octane
3	3.1	Octane derivative
4	3.3	C_2 substituted benzene
5	3.4	C_2 substituted benzene
6	3.8	C_2 substituted benzene + nonane derivative
7	4.0	Nonane
8	4.4	Nonane derivative
9	4.6	Nonane derivative
10	4.7	Nonane derivative
11	4.9	Decane derivative
12	4.9	C_3 substituted benzene
13	5.1	C_3 substituted benzene
14	5.3	C_3 substituted benzene
15	5.5	C_3 substituted benzene
16	5.9	C_3 substituted benzene
17	6.2	Decane
18	6.5	C_3 substituted benzene
19	6.8	-
20	6.9	-
21	7.2	undecane derivative
22	7.3	C_4 substituted benzene
23	7.4	C_4 substituted benzene
24	7.5	C_4 substituted benzene
25	7.7	C_4 substituted benzene
26	7.9	-
27	8.0	C_4 substituted benzene
28	8.2	C_4 substituted benzene
29	8.4	Undecane derivative
30	8.7	C_5 substituted benzene
31	8.9	Undecane
32	9.5	-
33	9.6	-
34	9.8	Dodecane derivative
35	10.4	C_5 substituted benzene
36	10.7	-
37	10.8	Naphthalene
38	11.3	-
39	11.7	Dodecane
40	12.2	-
41	13.2	-
42	13.9	-
43	14.0	Methyl naphthalene
44	14.6	Tridecane
45	16.8	-
46	17.3	Tetradecane
47	15.3	-
48	15.6	-

TABLE 1. 2 days exposure - ether extract (continued)

Spectrum	Retention Time	Compound
49	15.7	-
50	15.9	-
51	16.1	-
52	16.3	-
53	16.4	-
54	16.7	-
55	17.0	Dimethyl naphthalene
56	17.3	Tetradecane
57	17.4	Dimethyl naphthalene
58	17.9	Dimethyl naphthalene
59	18.2	-
60	18.4	Tetradecane derivative
61	18.8	-
62	19.0	-
63	19.6	-
64	19.8	-
65	19.9	Pentadecane
66	20.2	-
67	20.7	-
68	21.1	-
69	22.1	-
70	22.4	Hexadecane
71	23.7	-
72	23.7	-
73	24.1	-
74	24.3	Octadecane derivative
75	24.7	-
76	24.8	-
77	25.0	-
78	25.8	-
79	26.3	-
80	26.8	-
81	27.0	-
82	27.3	-
83	27.5	Nonadecane
84	28.4	-
85	29.2	-
86	30.2	Eiconane
87	31.2	-
88	32.6	Uncosane
89	33.1	-
90	34.6	Docosane
91	36.6	-
92	38.4	-
93	40.1	-
94	41.8	-

TABLE 2. 4 weeks exposure - ether extract

Spectrum #	Retention Time	Compound
40	2.4	Octane derivative + C_1 substituted benzene
41	2.6	Octane derivative + C_1 substituted benzene
42	3.0	Octane derivative
43	3.2	Octane derivative + C_1 substituted benzene
44	3.4	C_2 substituted benzene
45	3.8	C_2 substituted benzene + nonane derivative
46	3.9	Nonane
47	4.3	Ethyl benzene + nonane
48	4.4	Nonane derivative
49	4.9	C_3 substituted benzene + alkane
50	5.1	C_3 substituted benzene
51	5.3	C_3 substituted benzene
52	5.4	C_3 substituted benzene
53	5.8	C_3 substituted benzene
54	6.1	Decane
55	6.4	C_3 substituted benzene
56	6.7	-
57	6.9	Decane derivative
58	7.1	C_4 substituted benzene + Undecane derivative
59	7.2	C_4 substituted benzene
60	7.3	C_4 substituted benzene
61	7.4	C_4 substituted benzene
62	7.6	C_4 substituted benzene
63	7.8	-
64	8.0	C_4 substituted benzene
65	8.1	C_4 substituted benzene
66	8.3	Undecane derivative
67	8.6	C_5 substituted benzene
68	8.8	Undecane
69	9.4	$C_{10}N_1$
70	9.6	-
71	9.7	-
72	9.8	C_5 substituted benzene
73	9.9	C_5 substituted benzene
74	10.1	C_5 substituted benzene
75	10.4	C_5 substituted benzene
76	10.6	-
77	10.8	Naphthalene
78	11.0	-
79	11.2	-
80	11.5	-
81	11.6	Dodecane
82	12.1	-
83	12.3	-
84	12.6	Dodecane derivative
85	13.1	Tetrahydronaphthalene
86	13.3	-
87	13.4	Tridecane derivative
88	13.5	-
89	13.7	-
90	13.8	-
91	13.9	Methyl naphthalene

TABLE 2. 4 weeks exposure - ether extract (continued)

Spectrum #	Retention Time	Compound
92	14.2	Tridecane derivative
93	14.4	Methyl naphthalene
94	14.5	Tridecane derivative
95	14.7	Dimethyl dihydronaphthalene
96	14.9	Dimethyl dihydronaphthalene
97	15.1	Tridecane derivative
98	15.6	Tridecane derivative
99	15.9	-
1	14.2	Tridecane derivative
2	14.4	Methyl naphthalene
3	14.6	Tridecane
4	14.7	Dimethyl dehydronaphthalene
5	14.9	-
6	15.1	-
7	15.7	-
8	16.0	Phenyl heptane
9	16.2	-
10	16.4	-
11	16.6	-
12	16.8	-
13	17.1	Dimethyl naphthalene
14	17.4	Tetradecane
15	17.4	Dimethyl naphthalene
16	18.0	Dimethyl naphthalene
17	18.5	Tetradecane derivative
18	18.7	-
19	19.1	-
20	19.8	Pentadecane derivative
21	20.0	Pentadecane
22	20.4	Trimethyl naphthalene
23	20.8	C_3 substituted naphthalene
24	21.2	C_{15} isomer
25	21.4	-
26	21.6	-
27	22.3	C_{16} derivative
28	22.5	Hexadecane
29	23.7	-
30	24.2	-
31	24.6	-
32	24.9	Heptadecane
33	25.1	Pristane
34	26.1	-
35	26.3	Anthracene
36	27.1	Octadecane
37	27.4	Phytane
38	28.0	-
39	28.3	-
40	29.2	Nonadecane
41	30.1	-
42	30.6	-
43	31.3	Eicosane
44	32.0	-
45	33.2	Uncosane
46	33.9	-
47	34.3	-

TABLE 2. 4 weeks exposure - ether extract (continued)

Spectrum #	Retention Time	Compound
48	35.1	Docosane
49	35.8	-
50	36.4	-
51	36.8	Tricosane
52	37.9	-
53	38.3	-
54	38.6	Tetracosane
55	40.0	-
56	40.3	Pentacosane
57	40.8	-
58	41.7	-
59	41.9	Hexacosane
60	43.7	-
61	45.9	-
62	48.5	-
63	51.9	-

FIGURE LEGENDS

Figure 1. Denitrification potential, nitrous oxide production (μmoles per gram) from sediment amended with nitrate.

Figure 2. Denitrification potential, nitric oxide production (μmoles per gram) from sediment amended with nitrate.

Figure 3. Denitrification potential, nitrous oxide production (μmoles per gram) from sediment amended with nitrate and available carbon source.

Figure 4. Denitrification potential, nitric oxide production (μmoles per gram) from sediment amended with nitrate and available carbon source.

Figure 5. Diversity of microbial populations in Cook Inlet sediment - Spring 1977.

Figure 6. Diversity of microbial populations in Cook Inlet surface waters - Spring 1977.

Figure 7. Most Probable Numbers (number per ml) of hydrocarbon utilizers in Cook Inlet water - Spring 1978.

Figure 8. Most Probable Numbers (times 100 per gram) of hydrocarbon utilizers in Cook Inlet - Spring 1978.

Figure 9. Most Probable Numbers (number per ml) of hydrocarbon utilizers in Beaufort Sea water - Summer 1978.

Figure 10. Most Probable Numbers (times 1000 per gram) of hydrocarbon utilizers in Beaufort Sea sediment - Summer 1978.

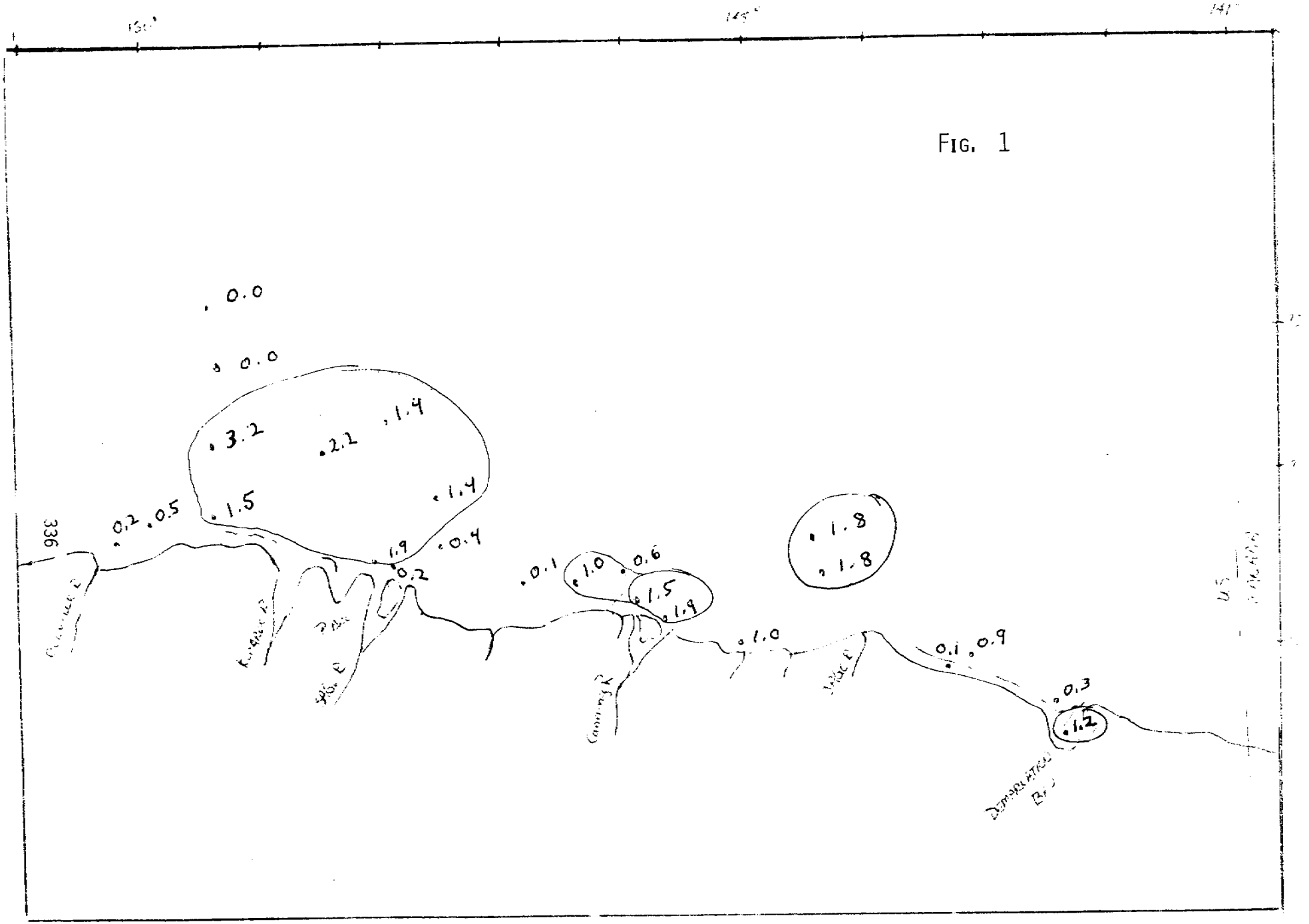
Figure 11. Hydrocarbon biodegradation potential - percent mineralization - Beaufort Sea surface water - hexadecane - Summer 1978.

Figure 12. Hydrocarbon biodegradation potential - percent mineralization - Beaufort Sea sediment - hexadecane - Summer 1978.

Figure 13. Hydrocarbon biodegradation potential - percent mineralization - Beaufort Sea surface water - pristane - Summer 1978.

Figure 14. Hydrocarbon biodegradation potential - percent mineralization - Beaufort Sea sediment - pristane - Summer 1978.

FIG. 1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0.1
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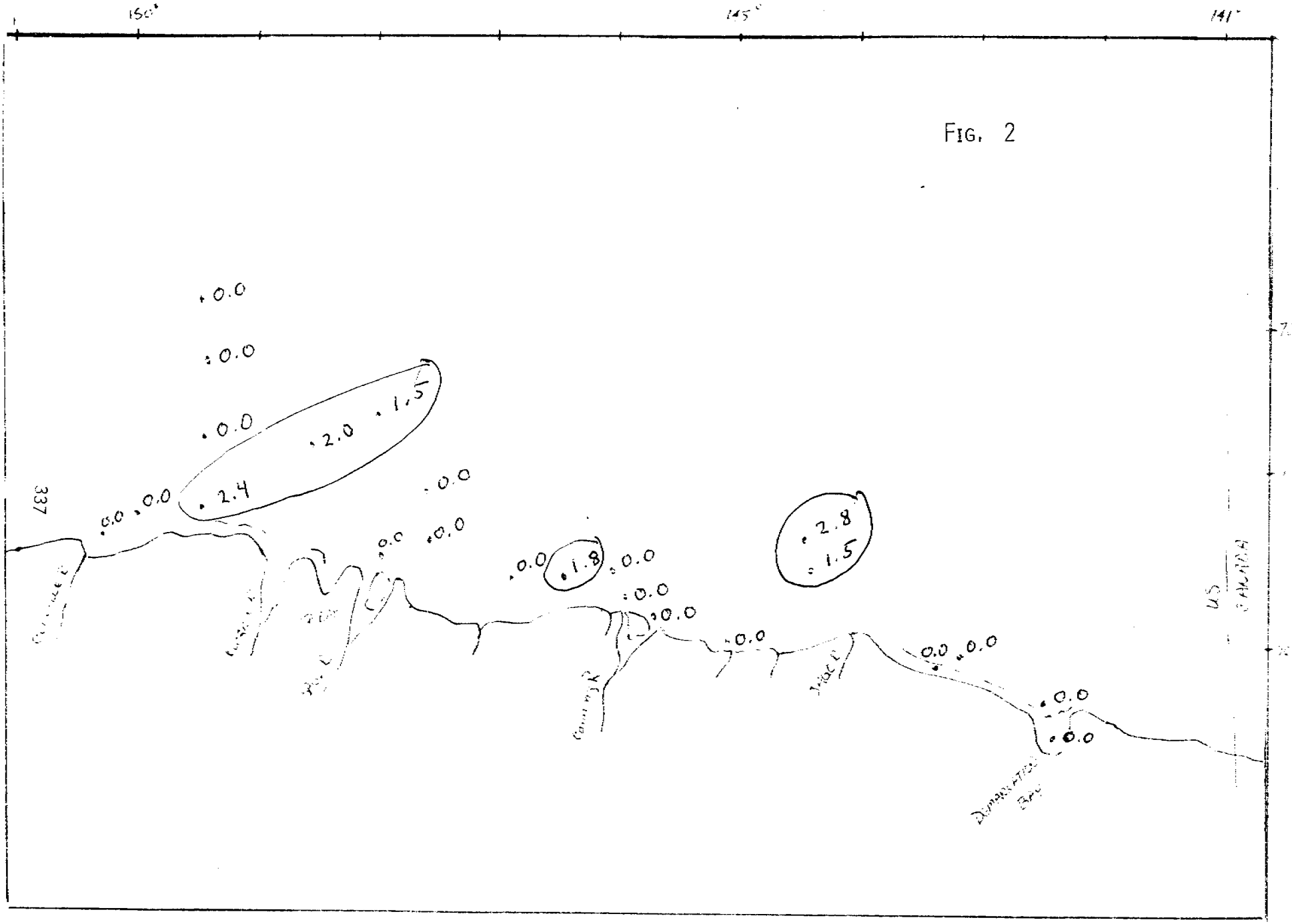
FIG. 2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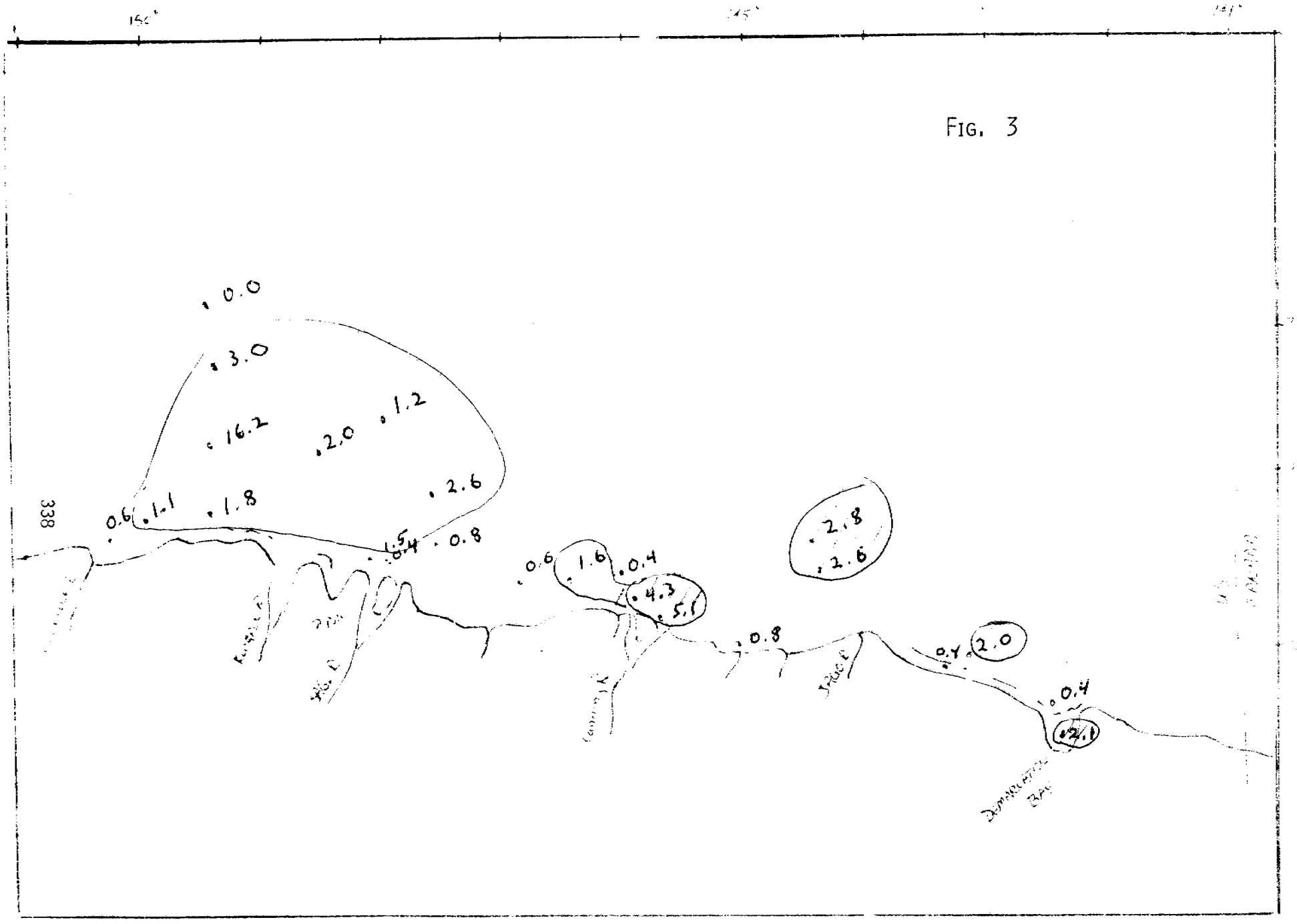
US
CANADA

FIG. 3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0.4
0.8
0.6
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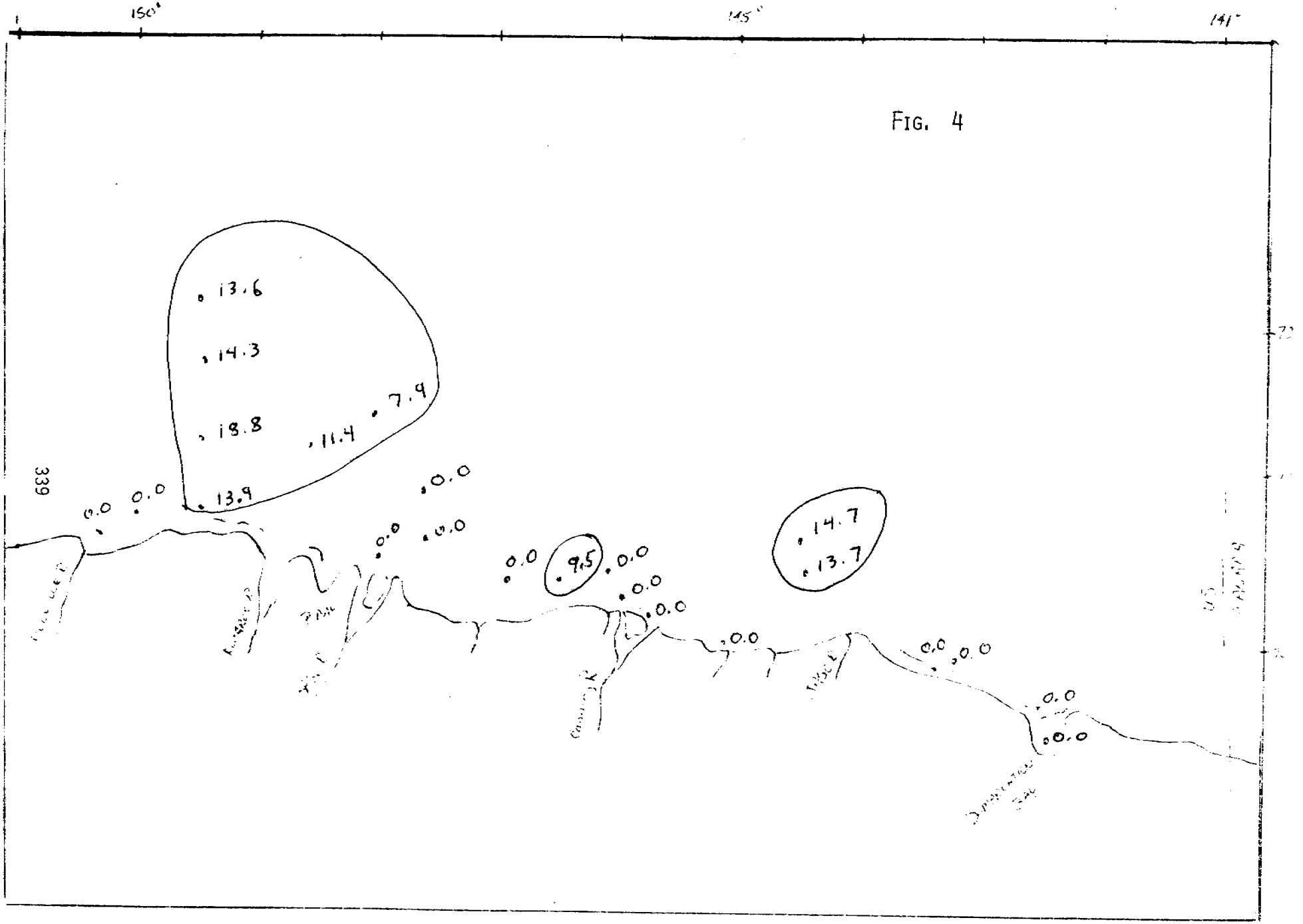
13.1

FIG. 4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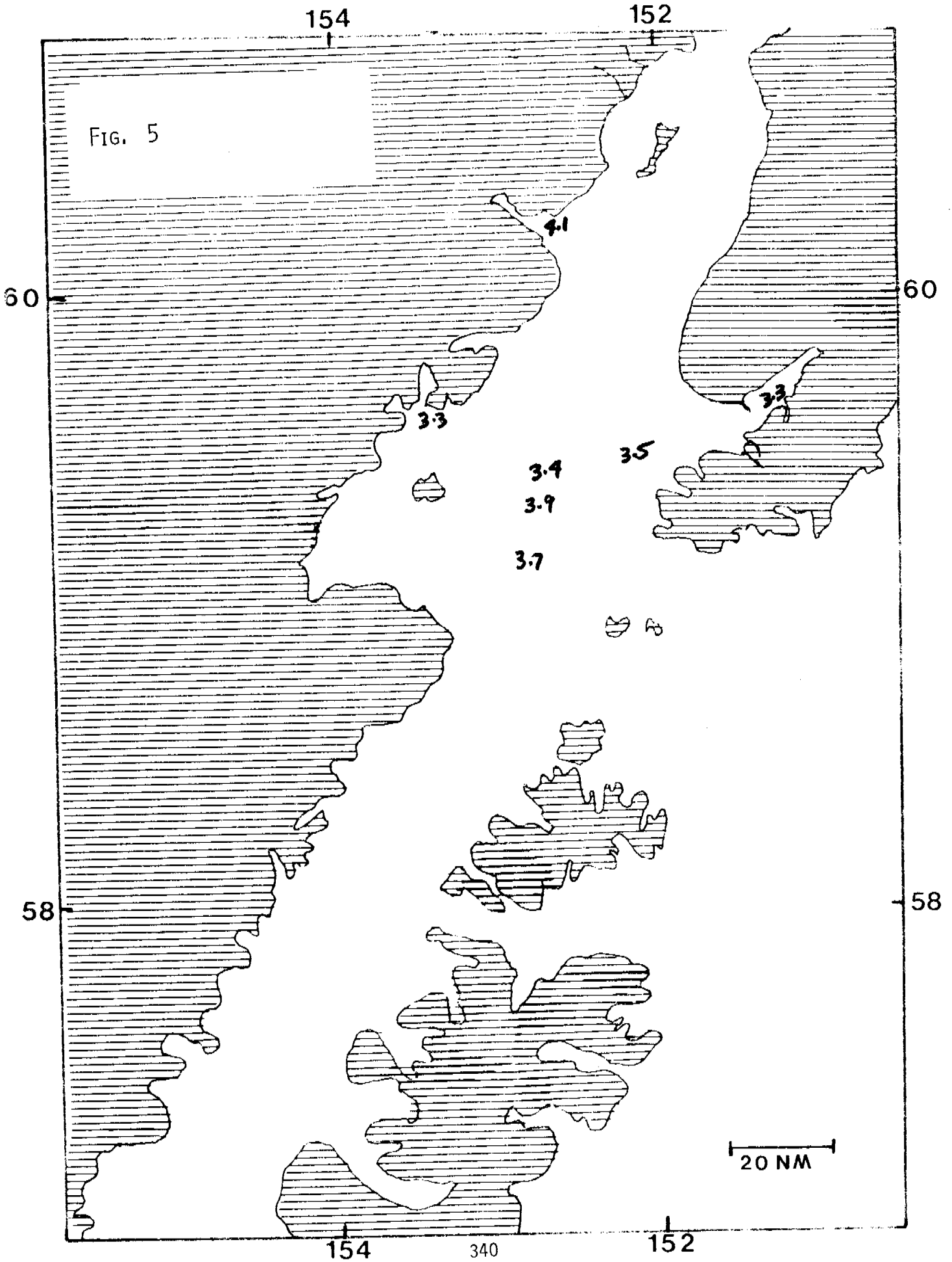


FIG. 5

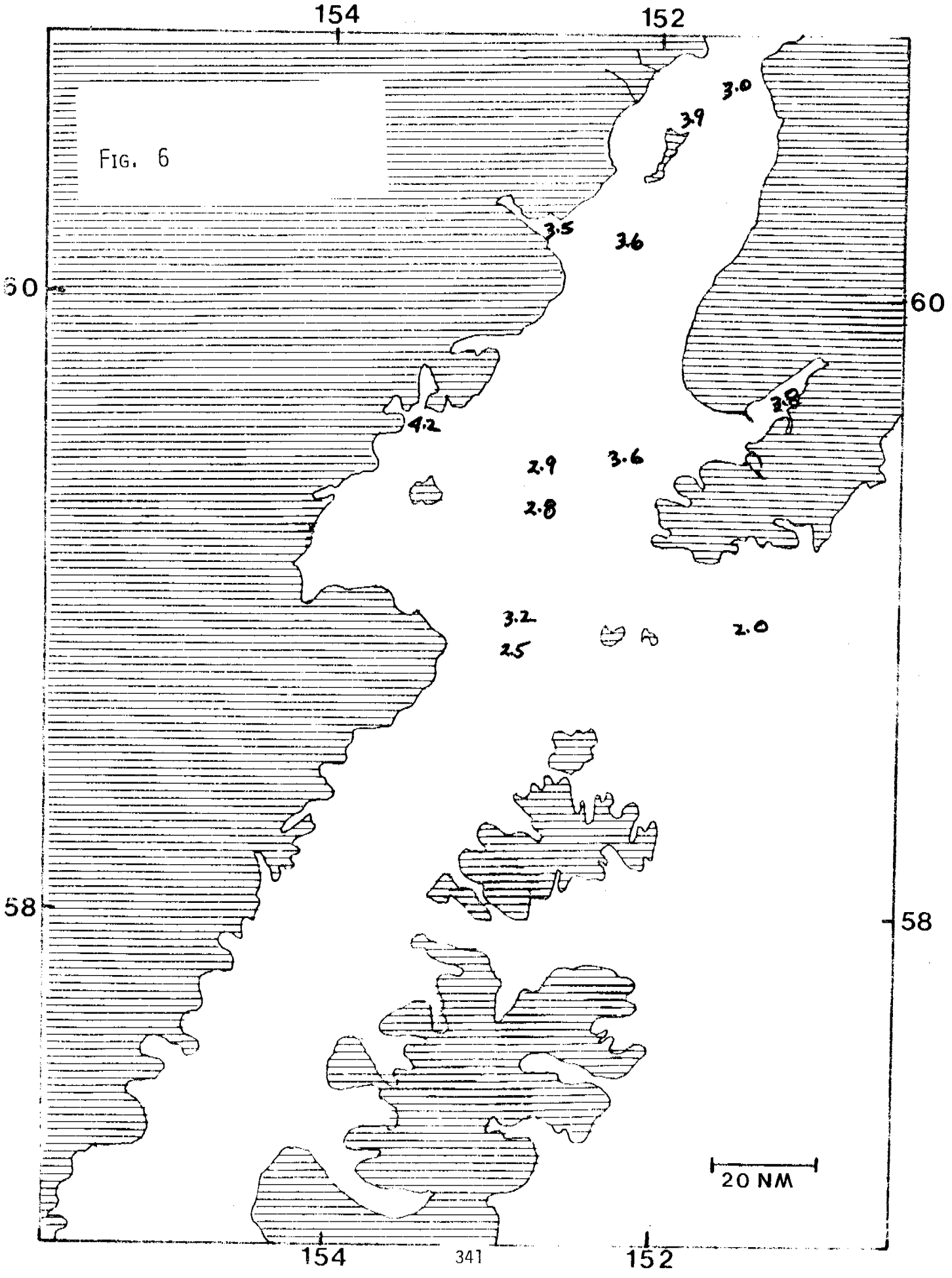


FIG. 6

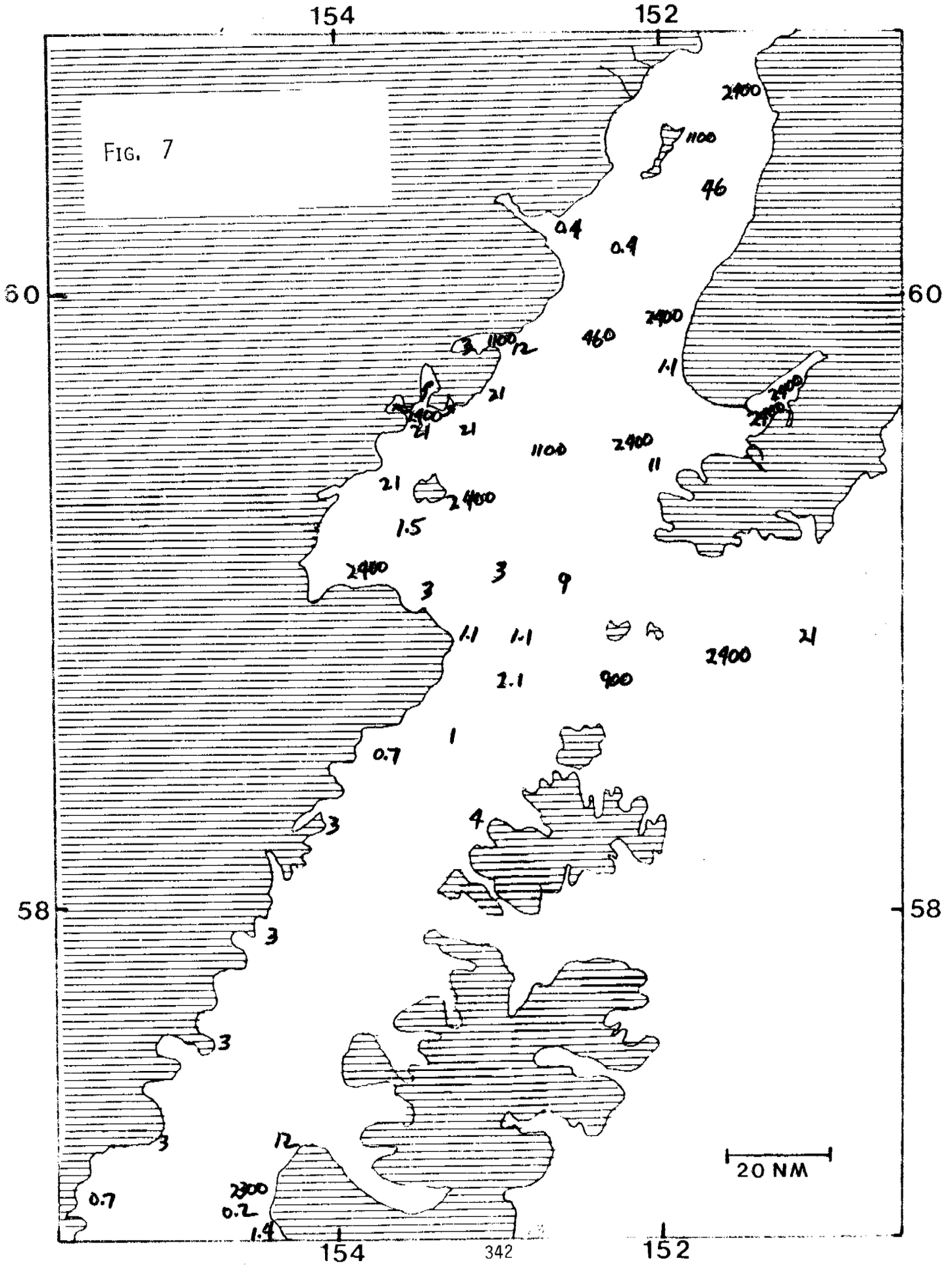
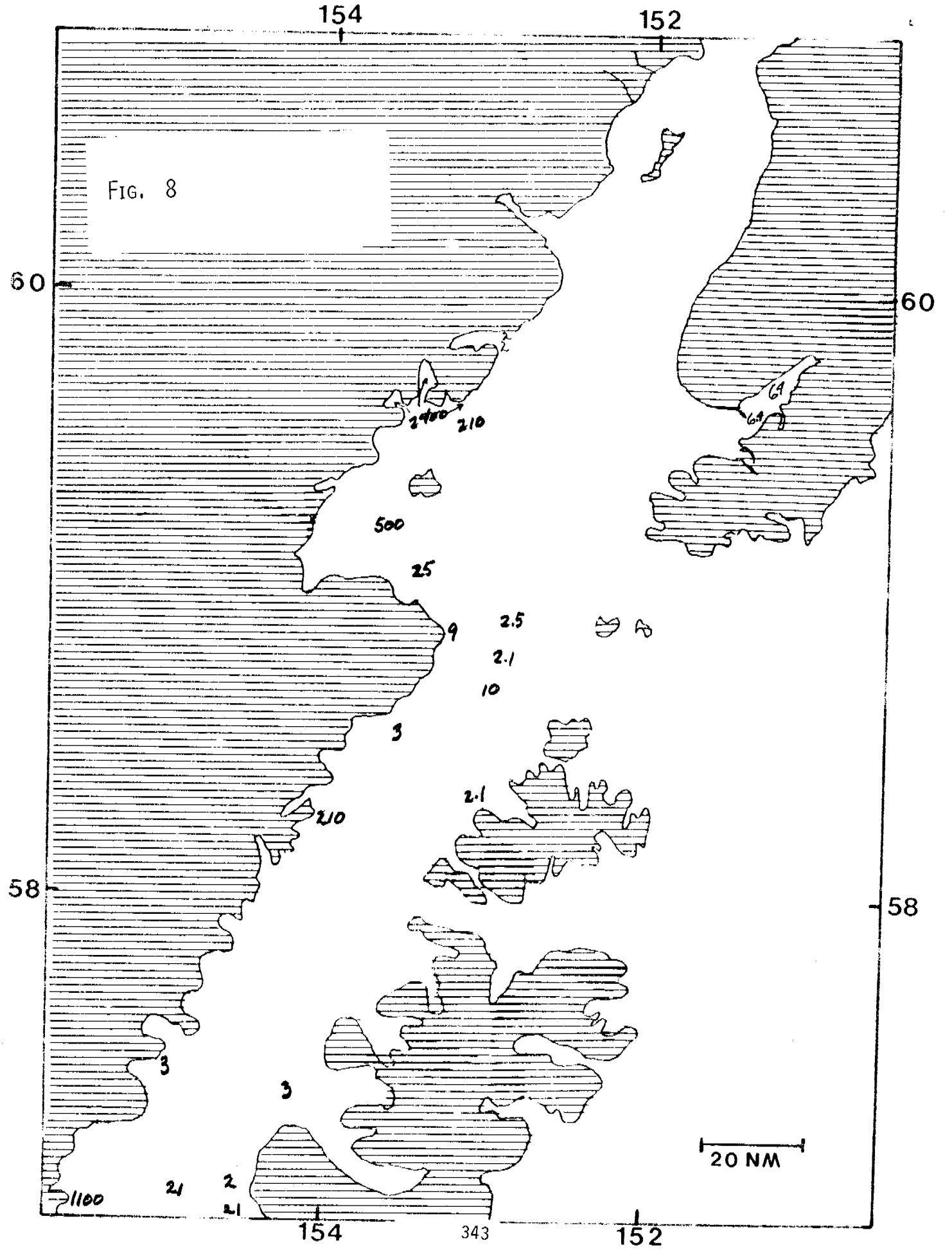


FIG. 7


154
152
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58
58
FIG. 8
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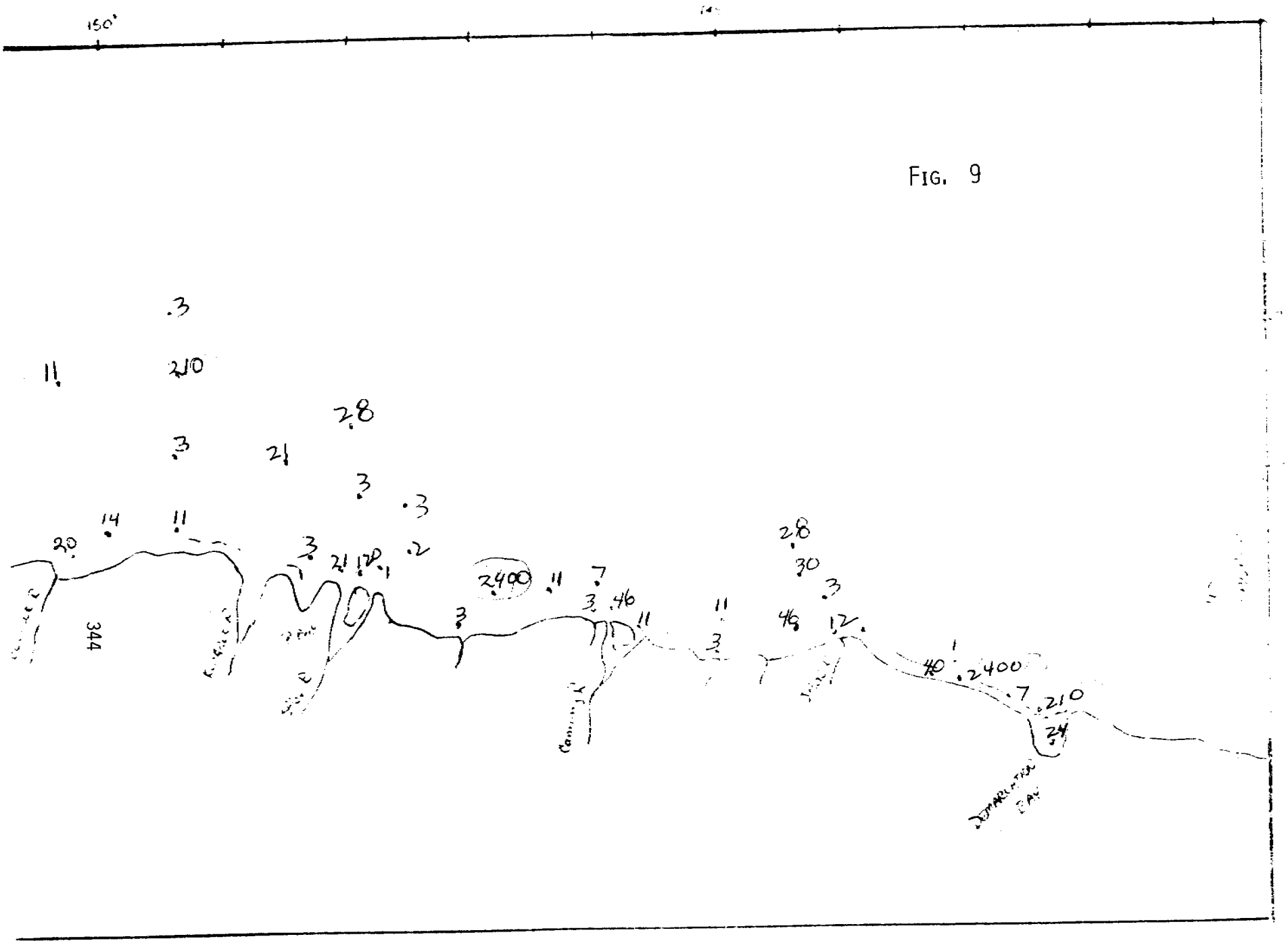
1100
21
2
21
20 NM
154
152

FIG. 9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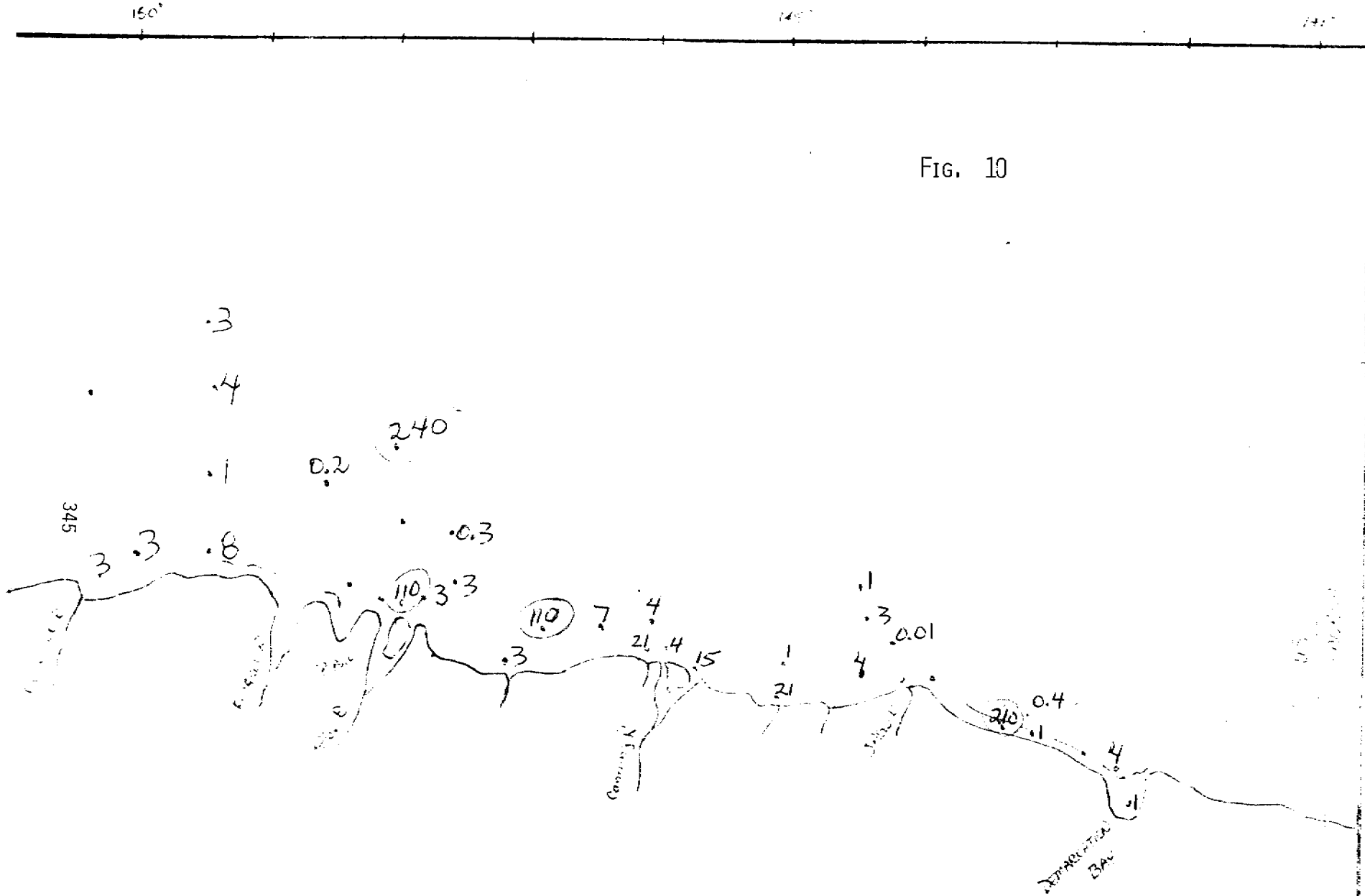
210
24

FIG. 10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DEPARTURE BAY

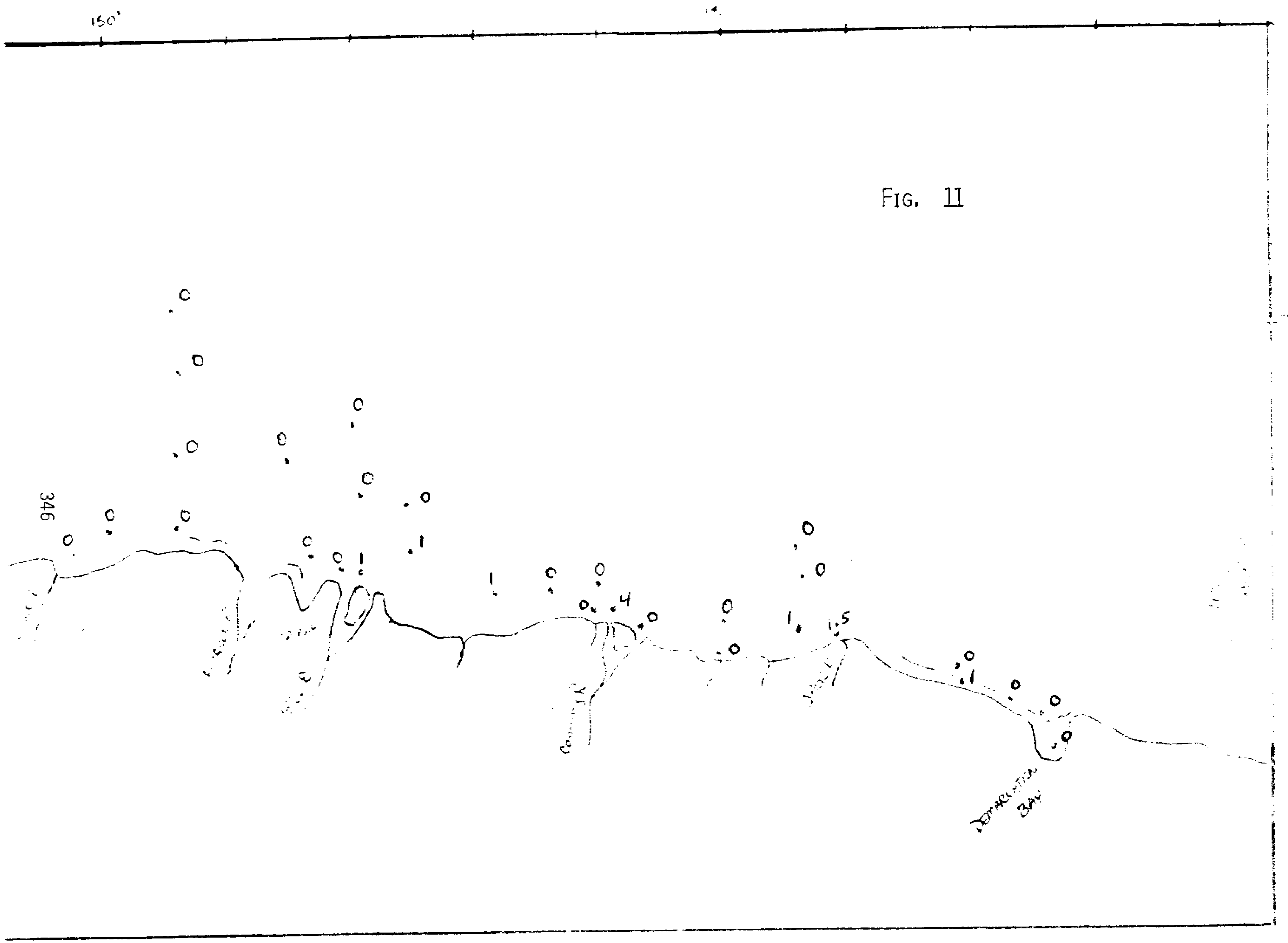


FIG. 11

FIG. 12

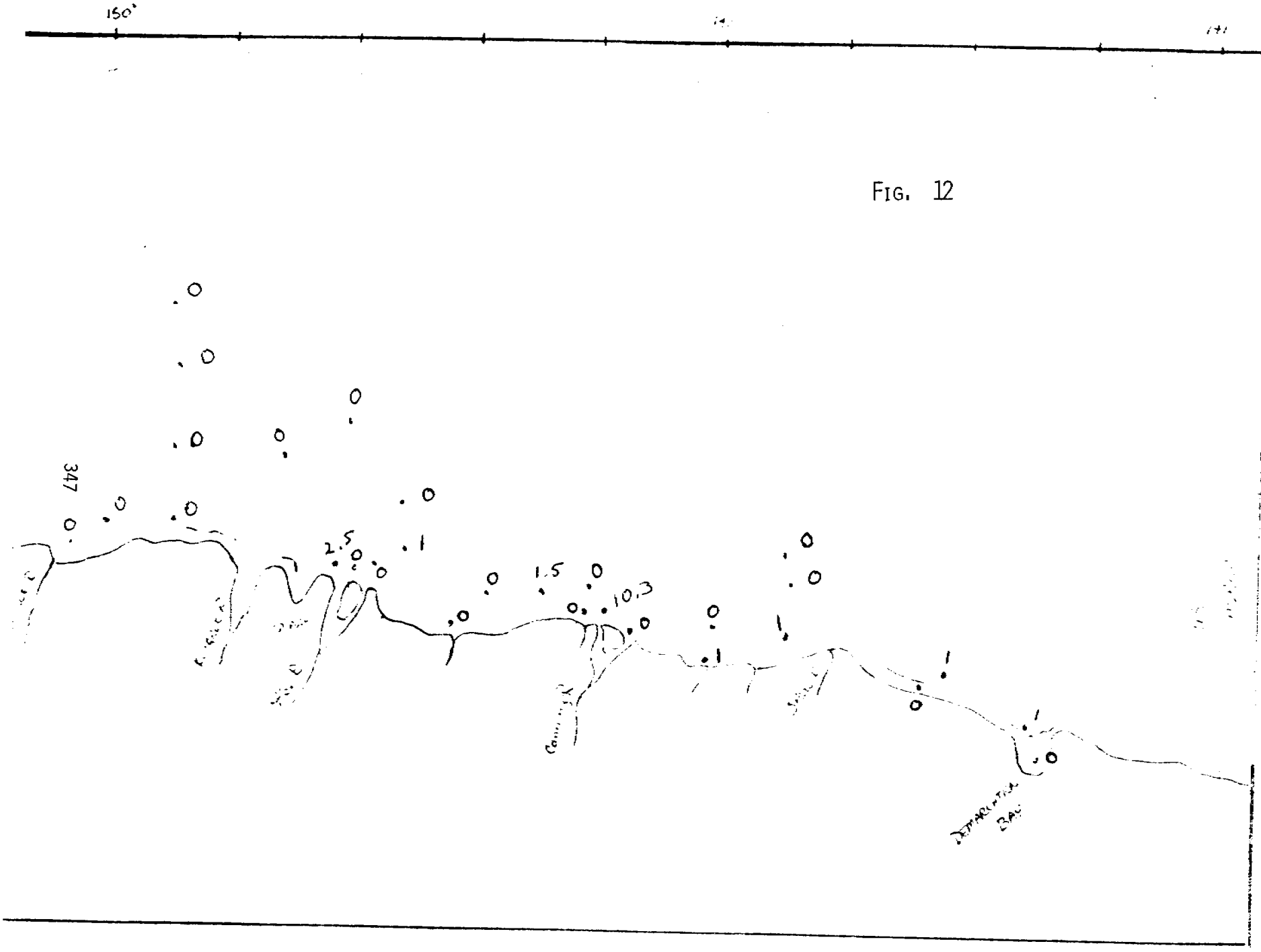


FIG. 13

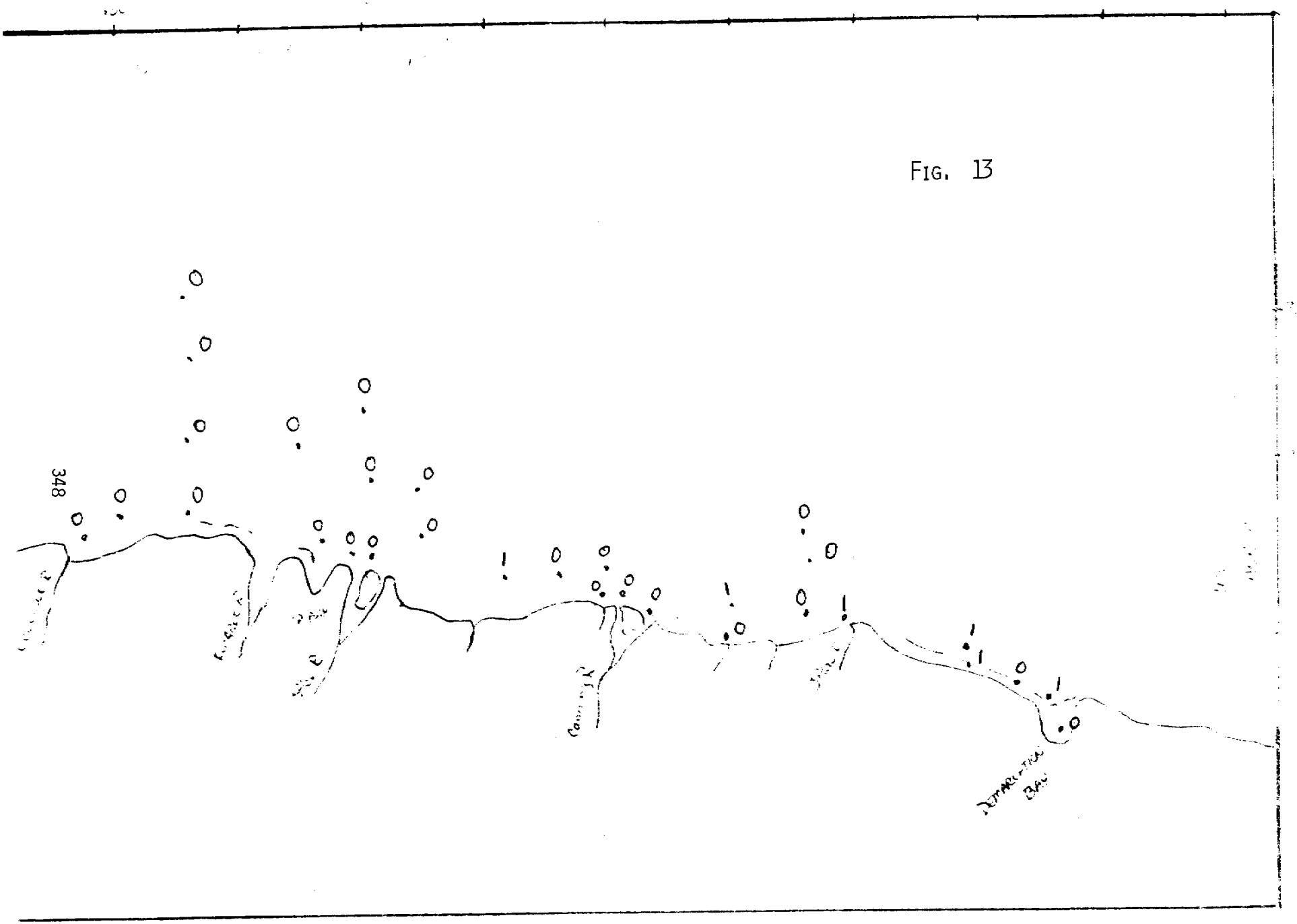
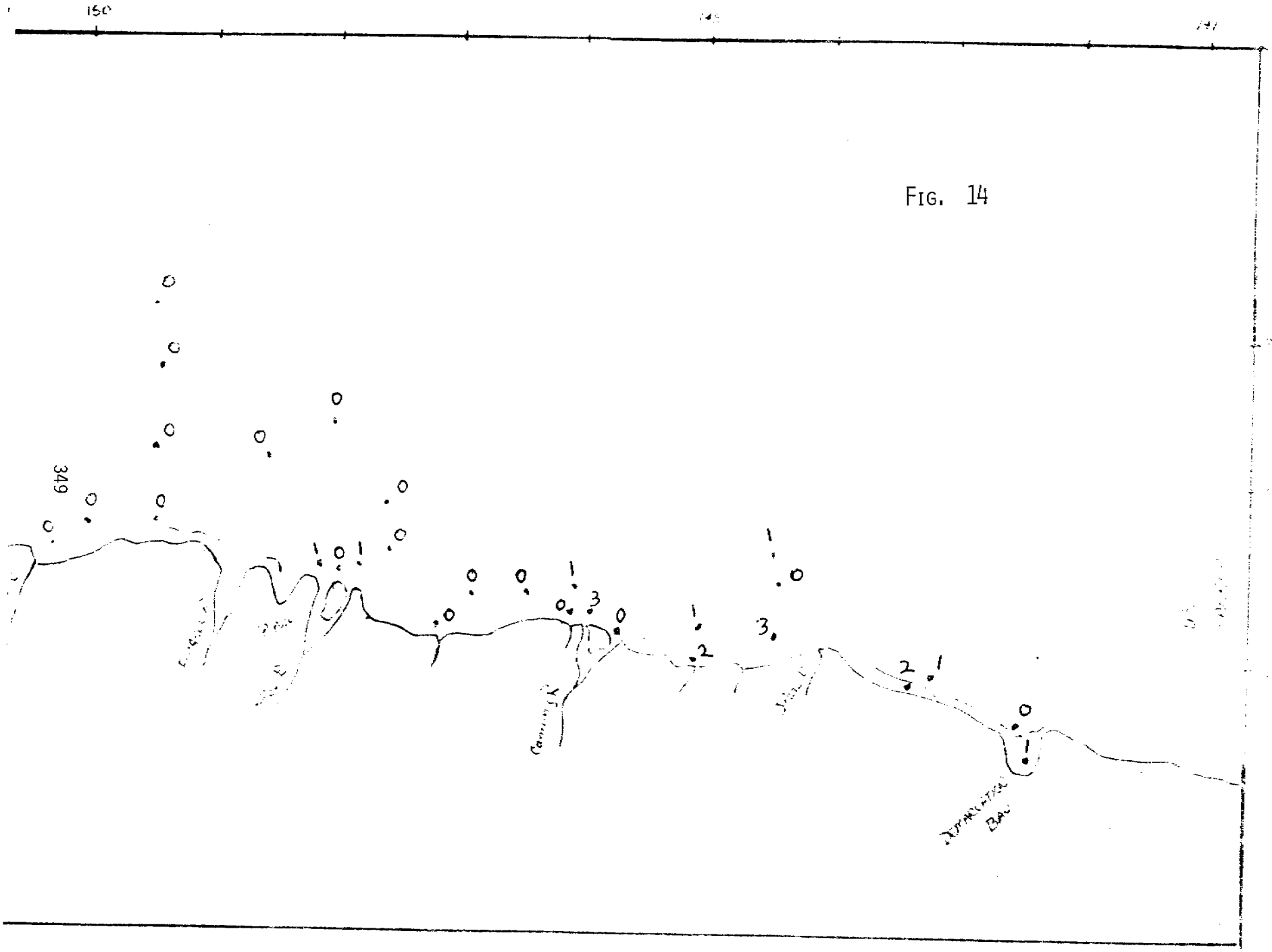


FIG. 14



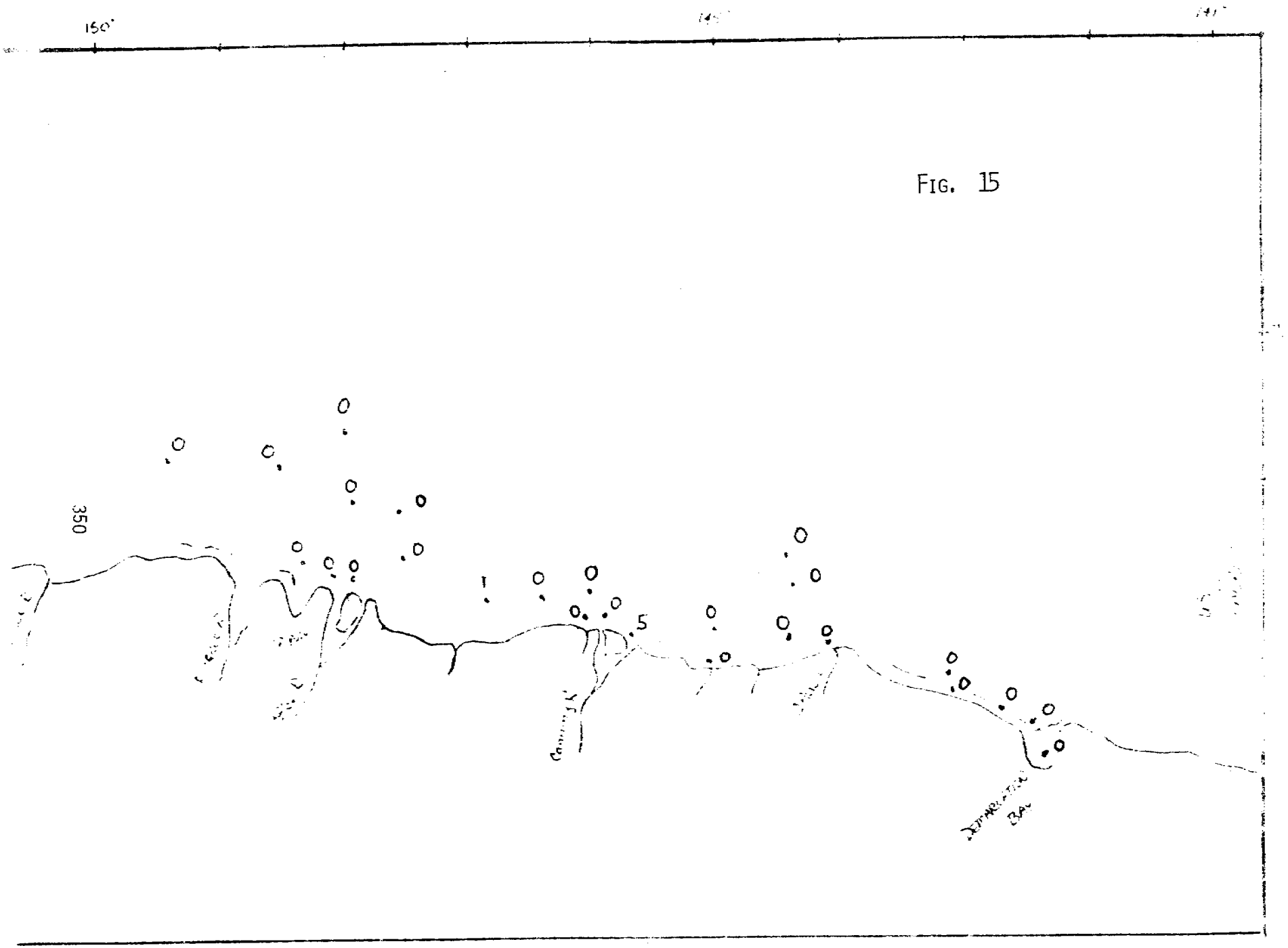


FIG. 15

FIG. 16

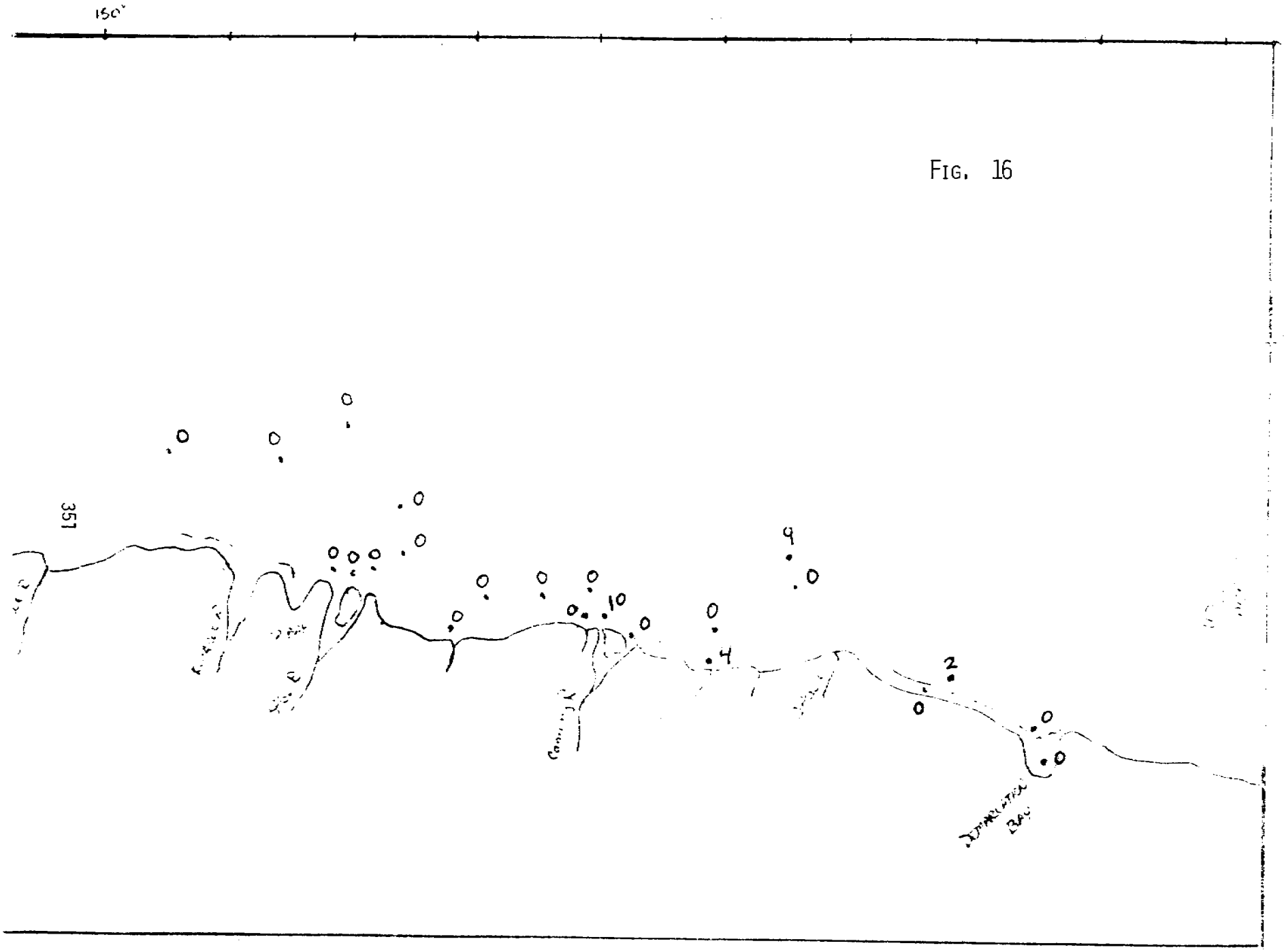


FIG. 17

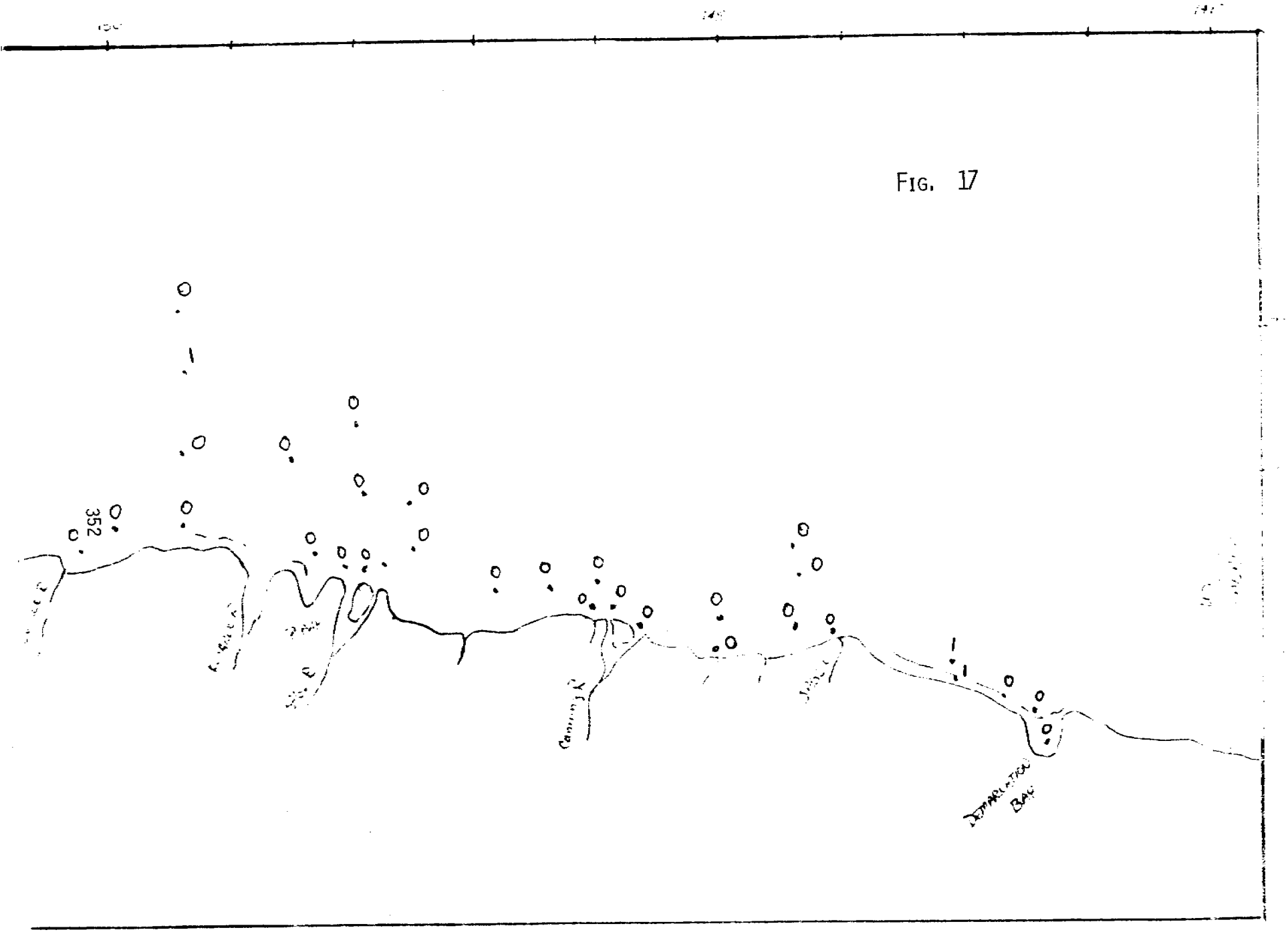
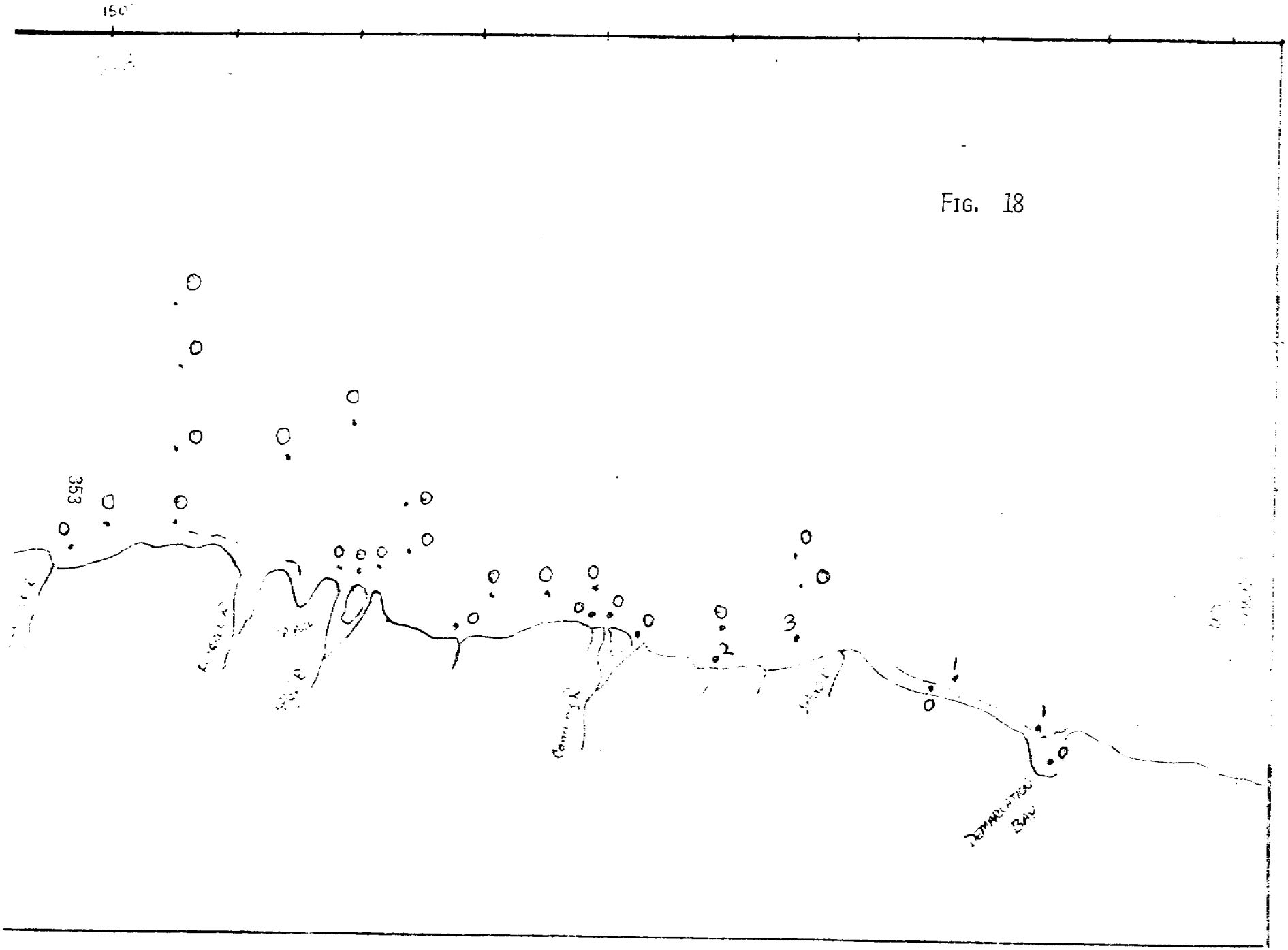


FIG. 18



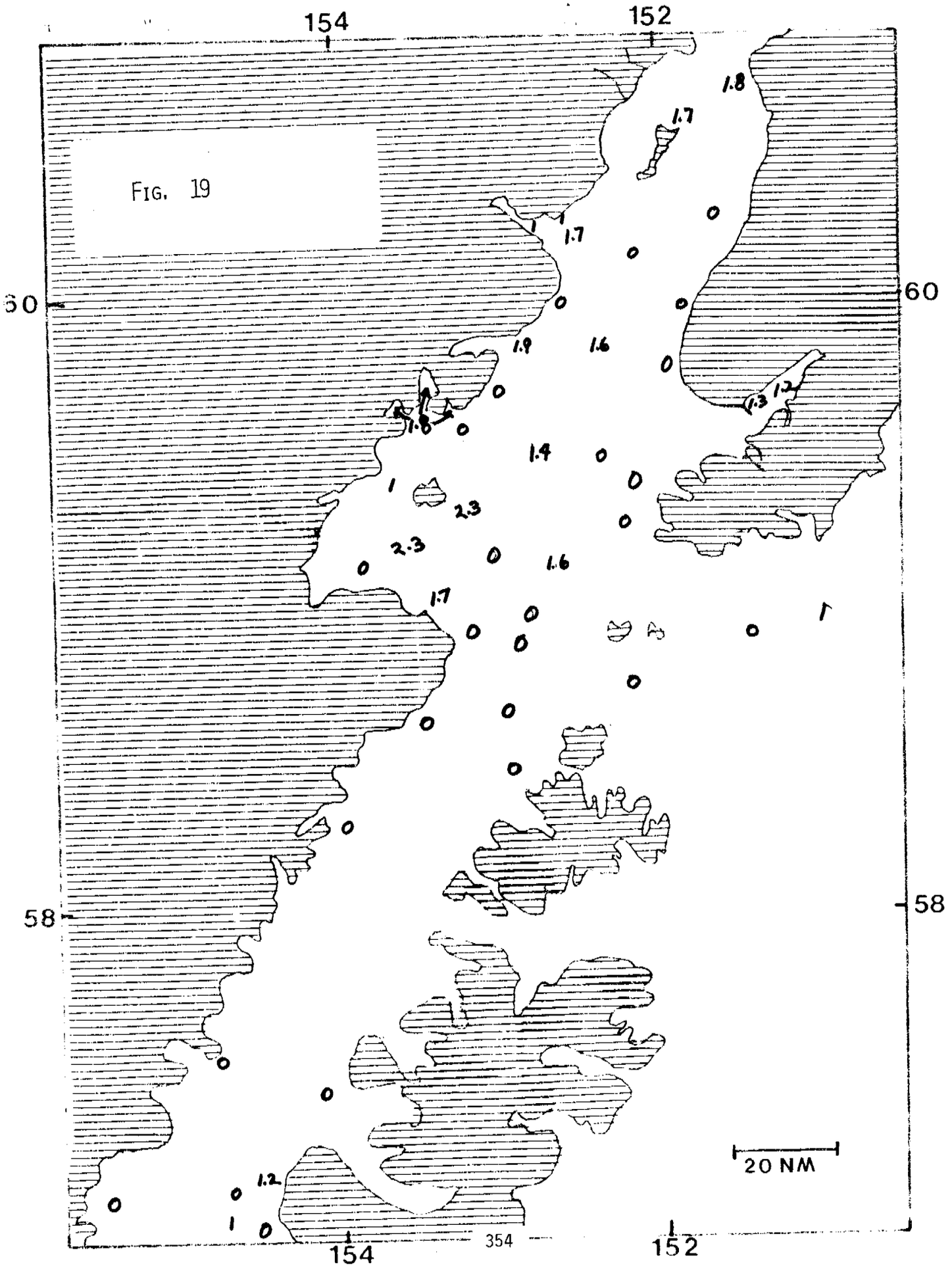


FIG. 19

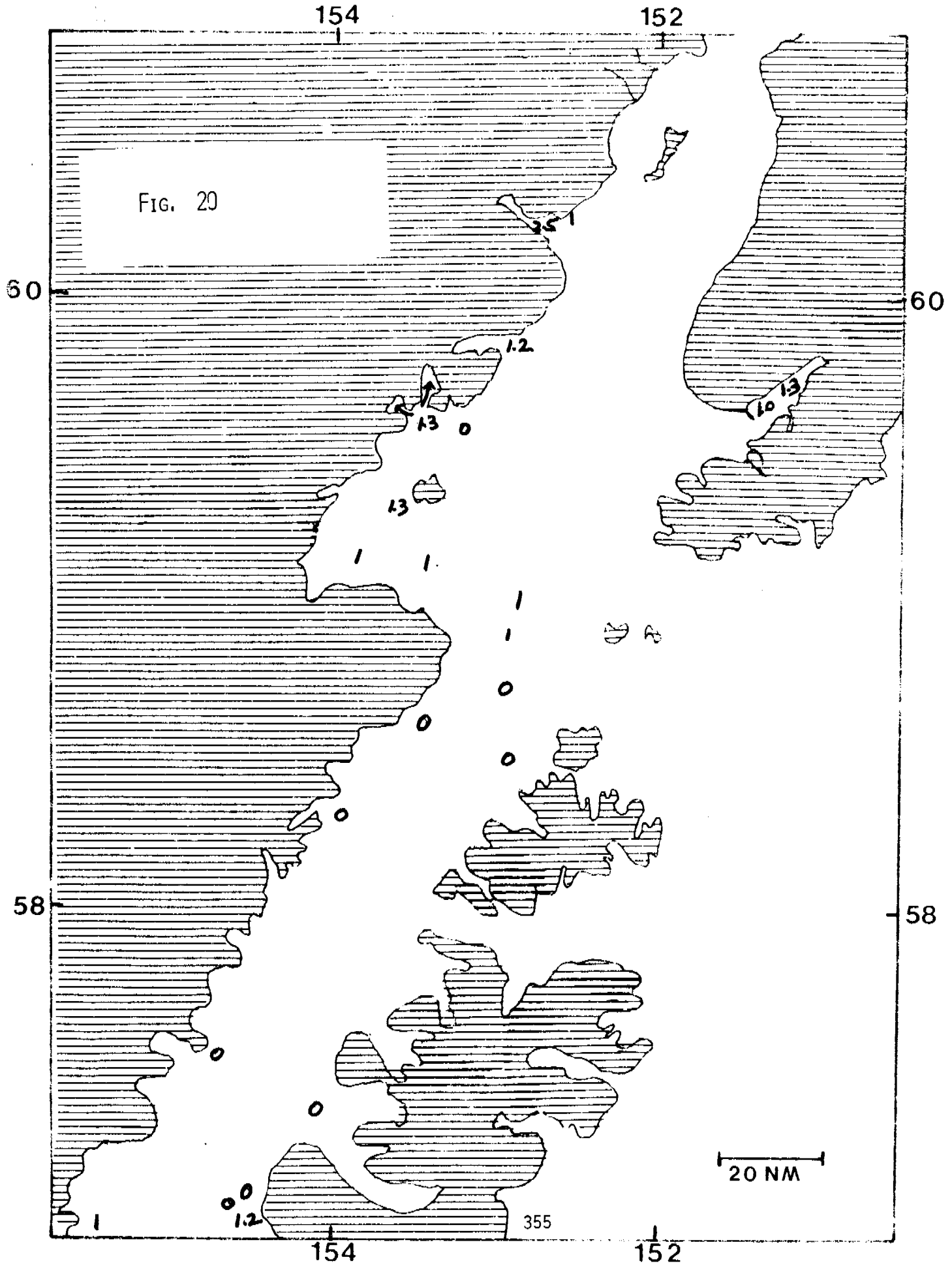
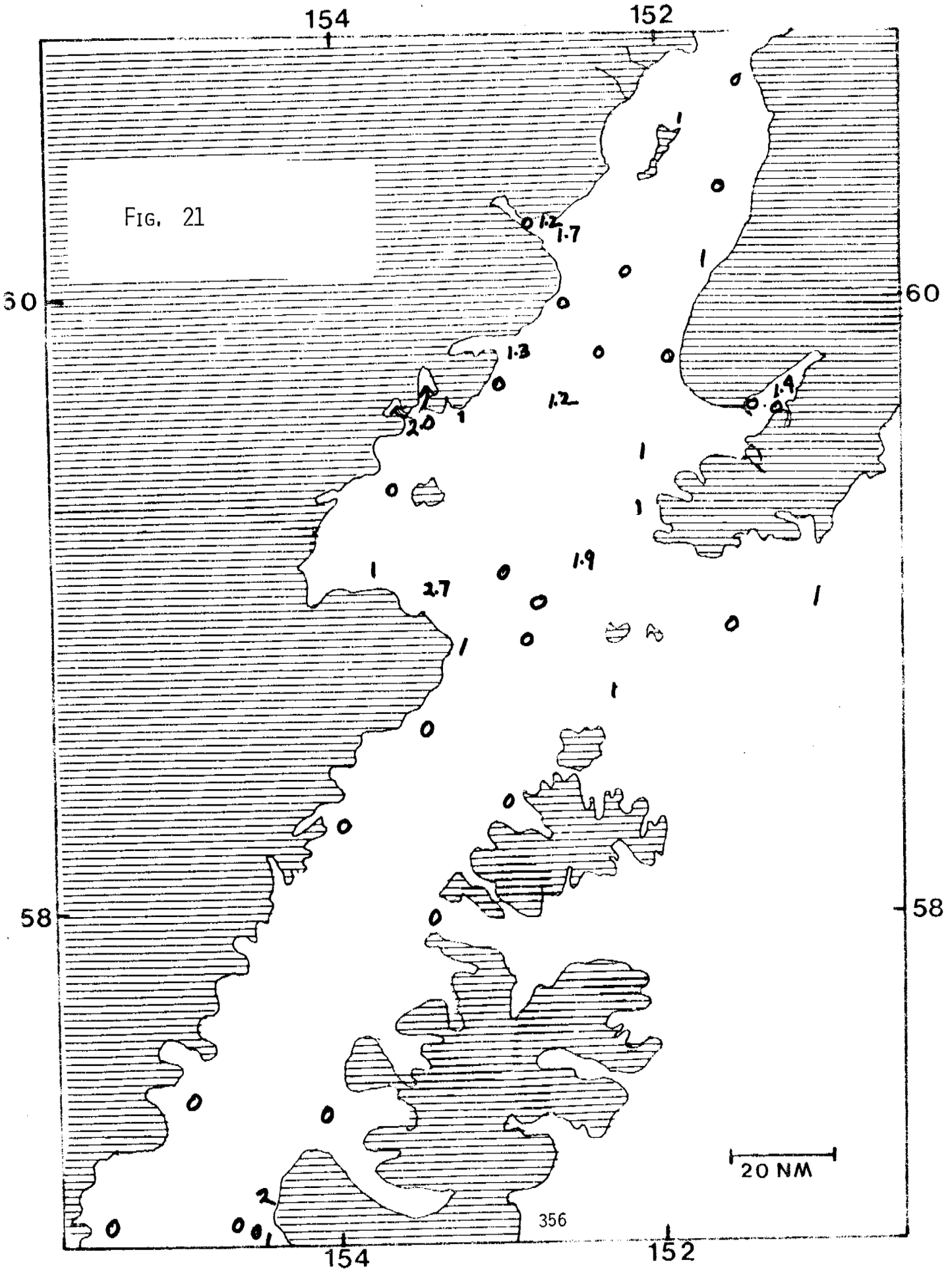


FIG. 20


154
152
60
58
FIG. 21
20 NM
356

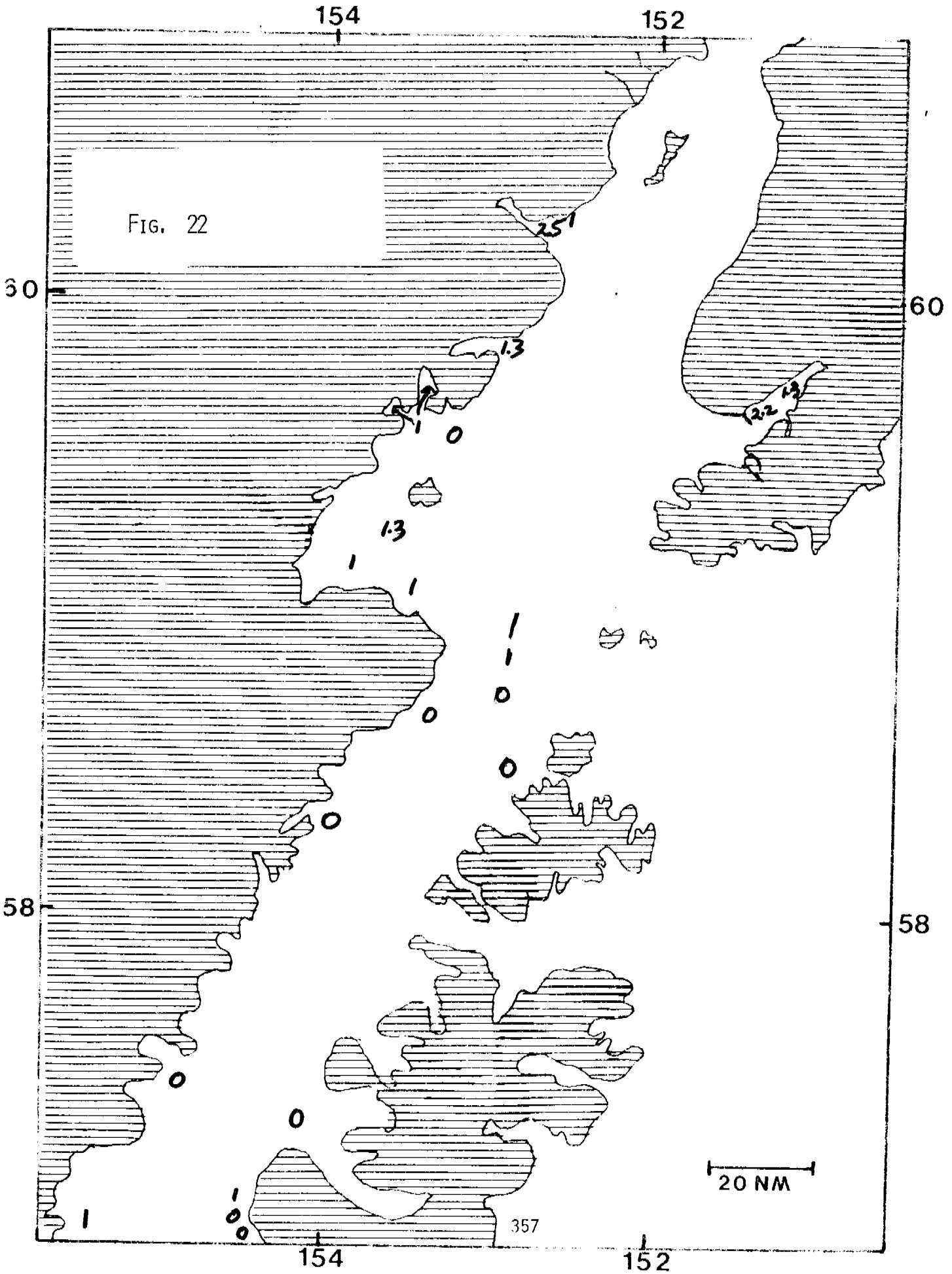
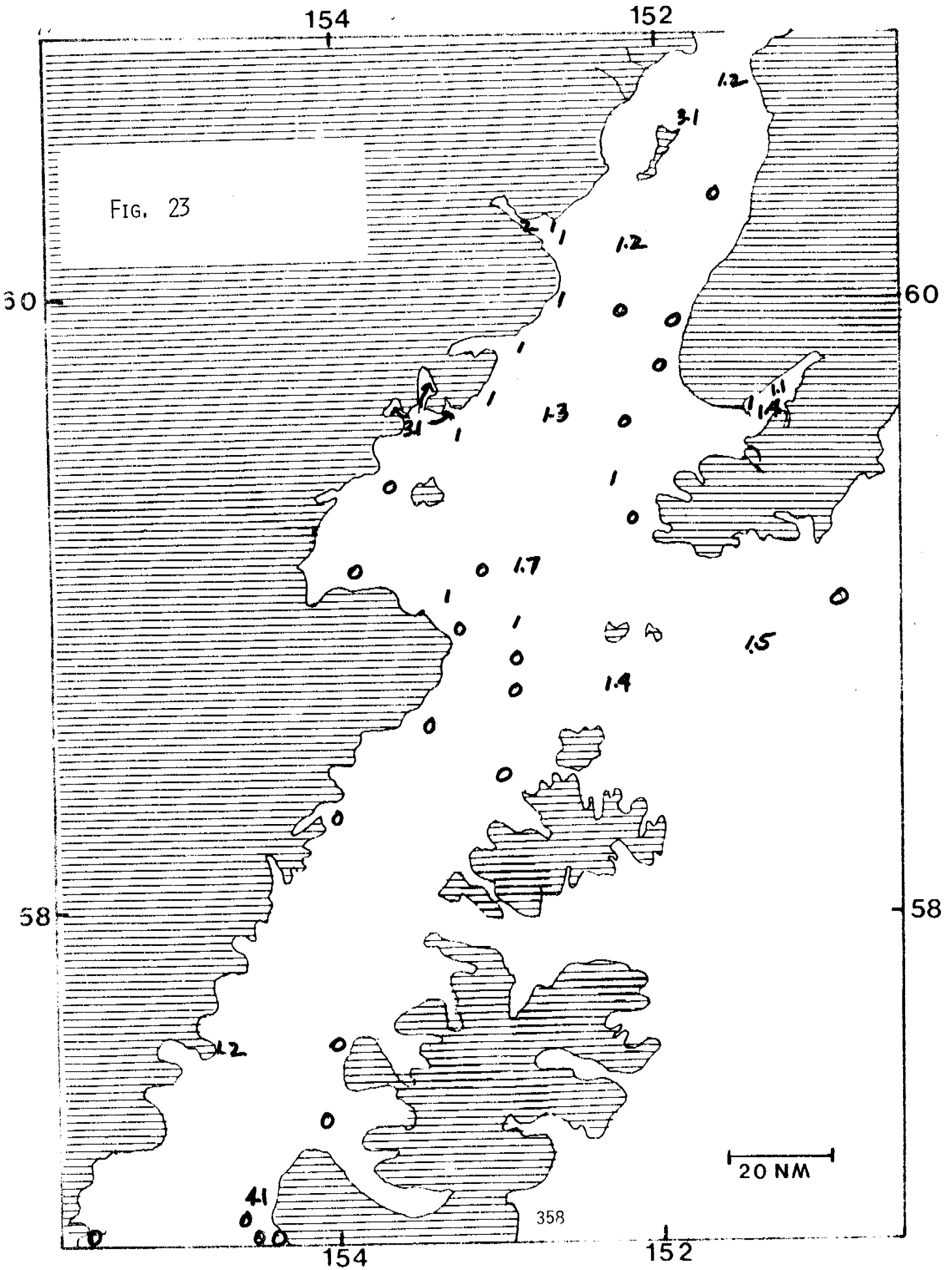


FIG. 22


154
152
60
58
FIG. 23
20 NM

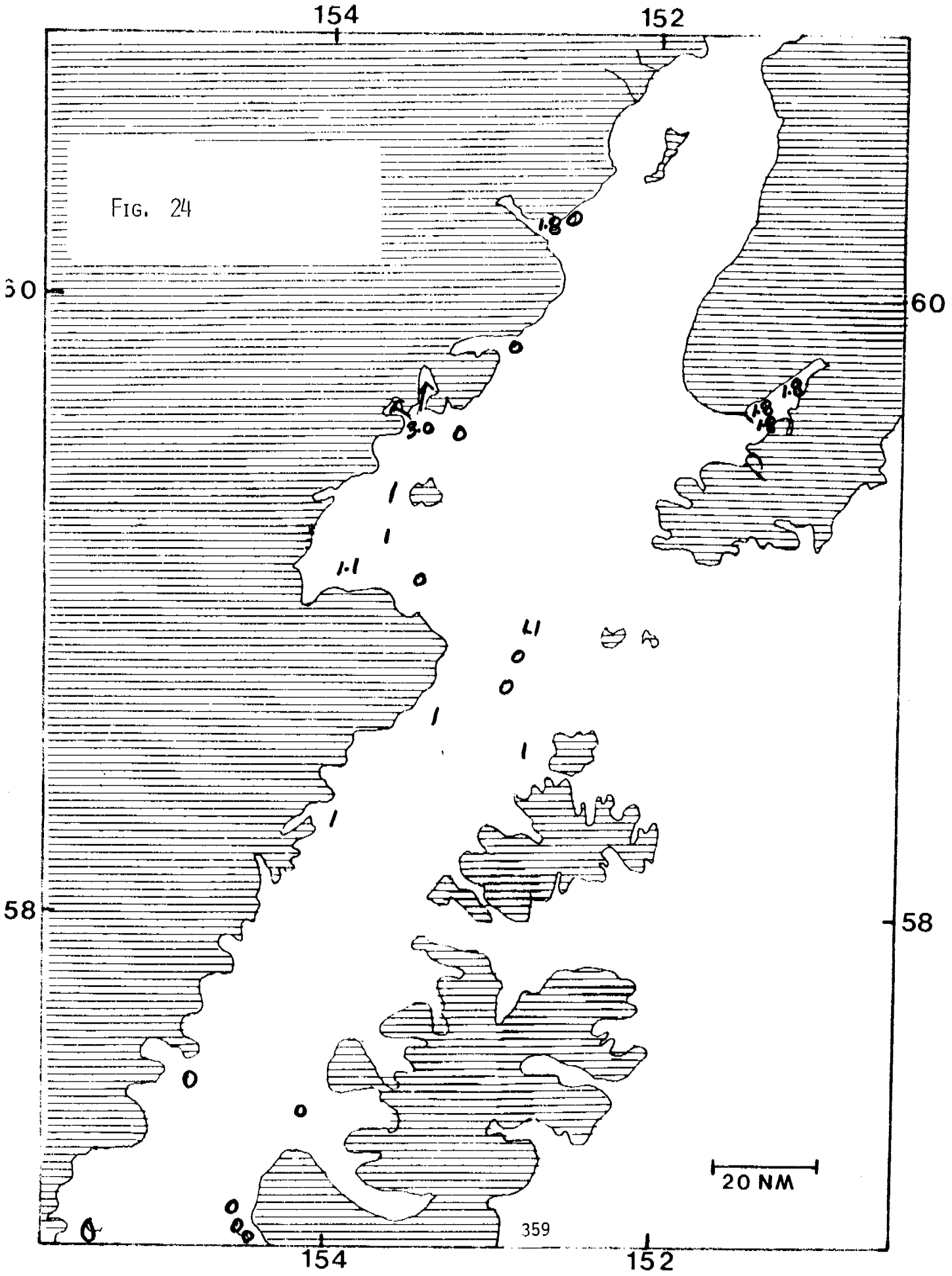


FIG. 24

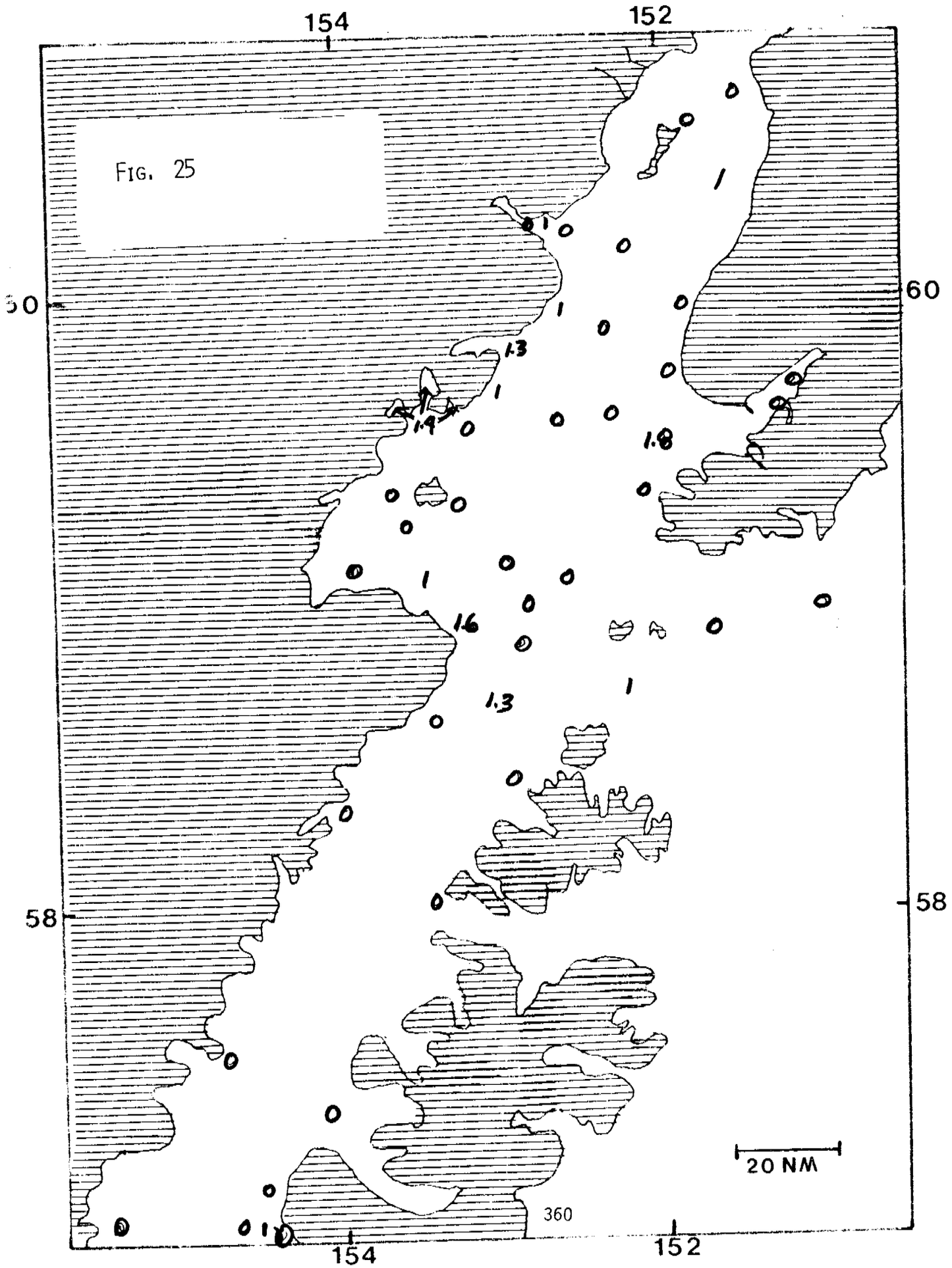


FIG. 25

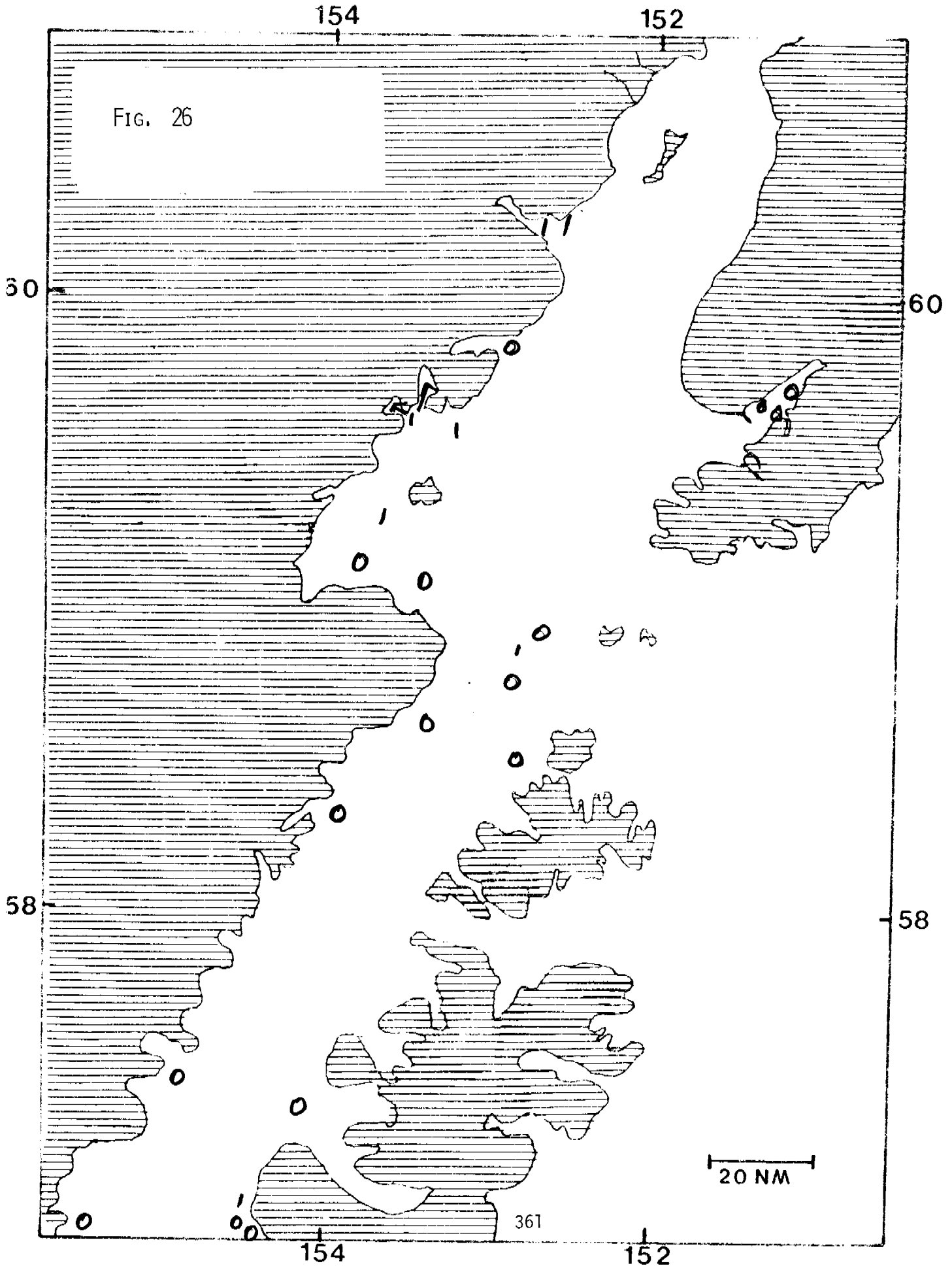


FIG. 26

Quarterly Report

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Study of Microbial Activity and Crude Oil-Microbial Interactions In the Waters and Sediments of Cook Inlet and the Beaufort Sea

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I. Task Objectives

A. Cook Inlet

1. To continue our studies of microbial activity and the effects of crude oil on that activity in the waters and sediments of Cook Inlet. These studies will be made in conjunction with the marine chemists in the OCSEAP program as well as with Dr. Atlas and his associates.

2. To initiate a study on the effects of crude oil on the detrital food web in sediments of the Lower Cook Inlet. These studies are to include long term effects on the chemical and physical characteristics of the sediments as well as effects on microbial function and predation of bacteria by other organisms.

3. To provide nutrient data on all water and sediment samples taken by both microbiological groups. These data are important in evaluating other data collected by us, especially data on N_2 fixation and denitrification.

B. Beaufort Sea

1. To obtain information concerning the effects of added crude oil on the natural microflora of the sediments. These studies will include crude oil effects on microbial function as measured by uptake and respiration characteristics using several labeled compounds.

2. To provide nutrient data on all water and sediment samples collected by both Dr. Atlas and ourselves.

C. General

1. To coordinate our sampling efforts and experimentation with that of Dr. Atlas and his associates at the University of Louisville. This will minimize duplication of effort and maximize the usefulness of the resulting data.

2. To continue our laboratory studies at Oregon State University on the effects of crude oil on predation of bacteria by protozoa and microbial activity in marine sediments.

II. Field and Laboratory Activities

A. Field trip schedule

There were no field studies conducted during this time. Most of our efforts were directed towards analyzing samples and raw data collected during the August, 1978 Beaufort Sea icebreaker cruise and working out techniques to be used during the detrital food chain studies to be conducted at Kasistna Bay.

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, Technican (Research Assistant, Unclassified)
Mr. Bruce Caldwell, " " " "

D. Methods

The methods used in our field work are essentially the same as those reported in our last quarterly and annual reports.

III. Results

A. Field Studies

The location of the samples collected during the summer, 1978 Beaufort Sea cruise is given in Figure 1. The exact locations of all stations, the station numbers used by Dr. Rita Horner, and the water column depth in meters are all given in Table 1.

1. Relative microbial activity in nonoiled samples

a. Water samples

The relative levels of microbial activity in water samples collected during the summer, 1978 Beaufort Sea Cruise showed some interesting trends (Table 2). Some of the highest values in both glucose and glutamic acid uptake were found in the regions near the Colville and Sagavanirktok Rivers (Figs. 2 and 3). Although we have not as yet received the salinity data for these stations, it would appear that this high microbial activity is associated with the effluent from these rivers.

The average rate of glucose uptake in all water samples was 7.5 ng/liter/h. at a glucose concentration of 3.8 µg/liter (Table 2). This is slightly higher than the average of 5.1 ng/liter h observed in water samples collected during the summer, 1976 Beaufort Sea cruise when the same substrate concentration was used. The average rate of glutamate acid uptake observed in water samples collected during the summer, 1978 Beaufort Sea cruise was 14.0 ng/liter/h at a substrate concentration of 5.4 µg/liter. During the summer, 1976 cruise the average value was 7.9 ng/liter/h; however, the substrate concentration used was exactly 1/2 that used in the 1978 study thus the rate a comparable concentrations would be roughly equal in the two studies. The average ratio of glucose to glutamic acid uptake (2.3) was also similar to what we have observed in past studies both in the Beaufort Sea and the Cook Inlet.

The average percent respiration in water samples exposed to glucose was 36. This is higher than the average of 27% observed in these waters in 1976 but lower than that observed in water samples collected during the April, 1978 cruise in the Cook Inlet (45%). The average percent respiration in water samples exposed to glutamic acid was 62. This is also higher than that observed in the Beaufort Sea in the summer of 1976 when the average was 46%. This is also lower than the average percent respiration observed during the April, 1978 Cook Inlet cruise. The percent respiration when either glutamic acid or glucose was used as the substrate showed similar patterns near the mouths of the Colville and Sagavaniroktok Rivers (Figs. 4 and 5). In each case, the percent respiration observed in these water samples was lower than that observed in the surrounding water masses. These are the same waters in which the relative microbial activities were higher than in the surrounding waters (Figs. 2 and 3).

b. Sediment samples

The patterns of glutamic acid uptake in the marine sediments of the Beaufort Sea are similar to those found in the water column (Fig. 6). In addition to the high microbial activity found near the mouths of the Colville and Sagavanirktok Rivers there was high activity observed in the sediment samples collected at stations 622 and 624. When glucose was used as the substrate, the highest value for microbial activity was also found at station 622 (Fig. 7). It is curious that this is also the only station where we found unusually high nitrogen fixation rates in the sediments.

The average rate of glutamate uptake in the sediments was 91 ng/g dry wt./h (Table 3). During our summer, 1976 cruise in the Beaufort Sea, we observed an average uptake of 150 ng/g dry wt./h. There was one value observed during that cruise that we feel was very atypical of these sediments. If this value is removed from the average value, the resulting mean would be 80 ng/g dry wt./h which is very close to the value observed during the summer, 1978 cruise. The average value observed in sediments returned to us from the 1977 Glacier, Beaufort Sea cruise was 420 ng/g dry wt./h. Since these sediments were stored for up to six weeks before they were assayed, it is quite possible that this is an erroneously high value (all other measurements were made on fresh samples taken in the field). The average glucose uptake in the sediment samples was 8.5 ng/g dry wt./h which is higher than the average value of 4.2 ng/g dry wt./h observed in sediment samples collected during the summer, 1976 cruise and is slightly lower than that observed in the sediment samples collected during the 1977 Beaufort Sea cruise (10.1 ng/g dry wt./h).

The average percent respiration observed in sediments exposed to glutamic acid was 53 which is higher than that observed in 1976 (28%) and that observed in 1977 (38%). The average percent respiration observed in sediments exposed to glucose was 32 which is higher than that observed in 1976 (20%) and higher than that observed in 1977 (25%).

2. Studies on the effects of crude oil and/or Corexit 9527 on the uptake of glucose.

a. Water samples:

A series of experiments were completed which were designed to determine the effects of crude oil and/or the dispersant Corexit 9527 on the uptake of glucose in both water and sediment samples collected during the 1978 Beaufort Sea cruise. As can be seen on Table 4, the average reduction in glucose uptake in the water samples exposed to fresh Prudhoe Bay crude oil was 52%. The average reduction observed in water samples exposed to 15 ppm Corexit 9527 was 58% and the average reduction in samples exposed to both crude oil and Corexit was 76%. If the levels of uptake under these conditions are compared with the nontreated samples, all differences here are statistically significant.

During these studies, we wanted to determine how crude oil and Corexit affected the uptake of glucose. To do this, we studied the kinetics of glucose uptake under the appropriate conditions (Table 5). The average maximum potential uptake of glucose (Vmax) in the water samples studied was 14.6 ng/liter/h. When exposed to crude oil, another set of subsamples gave an average of 3.7 ng/liter/h. Samples exposed to Corexit and Corexit with crude oil had averages of 2.7 and 1.5 ng/liter/h respectively. The Vmax values observed in the presence of crude oil, Corexit, and Corexit with crude oil were all significantly lower than in the nontreated samples.

The time required for the natural microbial population to utilize all of the naturally occurring glucose (T_t) was also measured in these same samples (Table 5). The average turnover time for the non-oiled samples was 177 hours. The average turnover time for samples exposed to crude oil, Corexit, and Corexit and crude oil was 492, 1145, and 1662 hours respectively. These values were all significantly higher than that observed in nontreated samples.

The transport constant plus the natural substrate concentration (K_t+S_n) was also measured in these samples (Table 5). In this case, there were differences noted but they were not statistically significant. Thus both the Vmax and the T_t values were altered by the presence of crude oil but the K_t+S_n values were not. In classical enzyme kinetics, this pattern would be attributed to noncompetitive inhibition.

The percent reduction in the rate of glucose taken up by microbial populations in the water samples exposed to crude oil showed an interesting trend (Figure 8). The waters that were most greatly effected by the presence of crude oil were found in an area near the mouth of the Colville River.

B. Sediment samples

The effects of crude oil, Corexit 9527, and a combination of the two on glucose uptake by microbial populations in sediment samples collected in the Beaufort Sea during the summer, 1978 cruise were

also measured (Table 6). The average percent reduction in glucose uptake rate was 30, 15, and 40 respectively for samples exposed to crude oil, Corexit, and crude oil plus Corexit. The reductions caused by Corexit and crude oil plus Corexit are statistically significant; the reduction caused by crude oil was not significant at the 95% confidence level.

In several of these samples, the effect of these compounds on the kinetics of glucose uptake in sedimentes was studied (Table 7). There were some differences in the Vmax values in the treated samples but they were not significantly different from the nontreated samples. Likewise, there were no significant differences observed in the T_t and K_t+S_n values in treated vs. nontreated sediment samples.

Figure 9 shows the percent reduction of glucose uptake in crude oil treated sediment samples collected in various locations during the Beaufort Sea cruise. The sediment samples that were collected off the Sagavanirktok River showed a relatively high susceptibility to the effects of crude oil whereas the sediment samples collected to the east of the Canning River and offshore from Prudhoe Bay showed relatively low susceptibility to the effects of crude oil.

3. Nitrogen fixation studies in sediment samples

The average nitrogen fixation rate observed in all samples was 0.3 ng nitrogen fixed/g dry wt./h (Table 8). This is very close to the value of 0.4 observed in all sediment samples collected during the April, 1978 Cook Inlet cruise. It was however, lower than that observed in the Elson Lagoon near Barrow, AK during the study conducted in April, 1978; a value of 1.3 ng/g dry wt./h was observed in these samples. As has been the case in the past, there was no significant alteration in nitrogen fixation rates in sediments exposed to crude oil. There did not appear to be any significant geographical trends in relative rates of nitrogen fixation. The sediment from only one location (station 622) showed an unusually high rate of nitrogen fixation.

4. ATP level and energy charge

Studies on adenylate pools were conducted in four sediment samples taken from Elson Lagoon near Barrow and four samples taken during the Northwind cruise. The results of these studies are given in Table 9.

IV. Preliminary interpretation of results:

1. The rates of glucose and glutamic acid uptake in both the water and sediment samples were similar to those that we have observed before in Beaufort Sea offshore areas at this time of year. This implies a relatively consistent overall microbial activity in this region when the samples are collected at the same time of year; however, we have observed significant variations with time of year and sample location. In the past, we have observed that water samples taken offshore generally have lower activities than those

observed nearshore. In this study, we have observed that higher levels of activity are associated with what appears to be water from major rivers. There is also evidence to indicate that the sediments close to the outflow of major rivers have elevated microbial rates as well (Figs. 6 and 7).

2. The percent respiration observed in both water and sediment samples during this sampling season was higher than that observed in the past even though the actual levels of activity were comparable. What this indicates is that proportionately less of the organic carbon that is taken up by the bacteria is being converted to bacterial biomass. For reasons unknown, during this season, the microbial populations were less efficient in producing microbial biomass than in previous years.

3. In the past, we have observed that the waters of the Upper Cook Inlet have a relatively low salinity when compared to open seawater and that they contain a very high particulate load. We have also observed that these same waters show very high rates of microbial activity (see our last annual report) and that the percent respiration is unusually low. This indicates to us that these waters contain a very active and growing population of bacteria. The same type of pattern was observed in Beaufort Sea waters near the mouths of both the Colville and Sagavanirktok Rivers (Figures 2-5). Although we have not as yet received the salinity data on these samples, it seems reasonable to assume these waters contain fresh water from these two sources. The terrestrial imput of organic carbon from these two sources could be a very important factor in the carbon budget in this region. This assumption is further substantiated by the high levels of microbial activity observed in the sediments in the same areas (Figure 6 and 7). Since there are elevated levels of microbial activity in the sediments, it is quite likely that these areas are important to the imput of organic carbon into the entire food chain through the detrital food web. If crude oil is present, it is quite likely that the transfer of this energy source to higher trophic levels will be impared. A recent study of the effects of crude oil in marine sediments and the associated water column in an actual oil spill off the coast of Sweden has shown that crude oil may change the environment near the sediment-water interface. This change could very well effect the detrital food web.

In Dr. Atlas' quarterly report, it has been suggested that denitrification rates may be increased in the presence of organic carbon. It is also known that the denitrification processes itself is enhanced by anaerobic conditions. In areas where there is an unsuually high level of organic carbon being transferred into the system, it is quite likely that the presence of crude oil may increased the metabolic activity to the point where denitrification rates are increased. If fixed nitrogen is limiting to energy transfer, then increased denitrification rates could alter this process.

4. We have also examined the effects of crude oil on the uptake of glucose by bacteria associated with sediment samples. There is very little effect of crude oil on the uptake of glucose in sediments collected to the east of the Canning River (Fig. 9). These data suggest that these sediments may have been exposed to elevated levels of hydrocarbons for an extended period of time. We cannot tell at this time whether these hydrocarbons originated from natural crude oil seeps or from hydrocarbons produced by living organisms. Dr. Atlas (RU 29) measured the concentration of hydrocarbon utilizing bacteria in the same sediment samples that we studied. Although the correlation is far from perfect, four out of the five sediment samples that he found to contain an unusually high concentration of hydrocarbon utilizing bacteria were in the areas where we found the least effect of crude oil on glucose uptake. If there is a chronic input of hydrocarbons into these sediments, we would expect to find both a decrease in the effect of crude oil on the metabolism of these organisms and we would expect to find elevated concentrations of hydrocarbon utilizing bacteria in these sediments. We concur with Dr. Atlas' conclusion that more must be learned about the presence of hydrocarbons in these sediments.

5. The effects of crude oil, Corexit 9527 and a combination of the two on glucose uptake.

a. Water samples

This is the fourth study in which we have studied the effects of crude oil on the uptake and respiration of organic substrates by microbial populations found in seawater. Except for the few samples that were studied in April, 1978, all studies have shown significant decreases of glucose uptake in samples exposed to crude oil (Table 10). During the present study, we also measured the effects of Corexit and Corexit with crude oil on glucose uptake. We found that Corexit 9527 at 15 ppm had about the same effect on the microbial population as did Prudhoe Bay crude oil (Table 4). When both crude oil and Corexit were added to the water samples, the total effect was greater than when either one was used alone. These data suggest that if the dispersant Corexit 9527 was used on a crude oil spill, the combination could act as a significant environmental stress on the pelagic microbial community. This effect could be particularly important in waters where there is very little net flow and/or mixing.

We were concerned that the effects that we were seeing were the result of competitive inhibition; i.e., that the crude oil and/or the Corexit contained some compound that was taken up by the microorganisms in the same way that glucose is utilized. This would have the same effect as adding nonlabeled glucose to our reaction vessels. In order to determine this, we conducted uptake kinetic studies (Table 5). When crude oil or Corexit were added

to the reaction mixture, the Vmax value decreased and the turnover time increased but the transport constant did not change significantly. These data suggest that what is taking place is not competitive inhibition but noncompetitive inhibition. The effect that we are seeing is therefore not caused by an artifact of the experimental design.

As was the case when uptake at one concentration was measured, both crude oil and Corexit and a combination of the two reduced the maximum potential rate of glucose uptake and they also increased the time required to utilize all of the naturally occurring glucose by the natural population.

These same trends have also been observed in seawater samples analyzed from the Cook Inlet (Table 11).

B. Sediment samples

There also appears to be an effect of crude oil and/or Corexit 9527 on the uptake of glucose in marine sediment microorganisms (Tables 6, 10, and 11). The effect is not as pronounced as that found in the pelagic microorganisms. The reason for this is not known but a least two factors may be involved: (1) the attachment of the bacteria to sediment particles may in itself help protect the organisms, (2) hydrocarbons are more commonly found in this environment thus the microbial populations are more likely to be adapted to the presence of hydrocarbons. There are some data that suggest that the second factor is probably more important than the first. Although there were no significant differences observed in the kinetics of glucose uptake in samples exposed to crude oil and Corexit, there were individual samples in which large effects were observed. In these cases, the changes in the kinetics were the same as that observed in water samples. Also of importance is the clustering of samples which showed little effect (Fig. 9). As has been discussed these areas were the same ones in which the levels of hydrocarbon utilizing bacteria were the highest. These are the types of observations we would expect if the microbial populations had adjusted to the presence of hydrocarbons.

7. The adenylate pools in 8 Beaufort Sea sediment samples were measured as indicated in Table 9. The first four samples listed were taken from the area where the oiled tray experiment in Elson Lagoon is being conducted. Two of the sediment samples were controls which were collected near the oiled trays (BB601 and BB607). The two other samples were taken from a tray that was exposed to crude oil for 4 months (BB602) and from a tray that was exposed for 7 months (BB605). The concentration of total adenylates was two orders of magnitude higher in the controls than in the oiled trays. The total adenylates in this case includes those extracted from all biological sources within the sediments. These data suggest one of two things; either the crude oil has greatly reduced the total biomass in the sediments or that the crude oil in some way interfers with either the extraction of adenylates from the sediments or it interfers with the assay itself. We have plans to determine if

crude oil effects the assay procedure itself during our first field study at Kasistna Bay. If our future work confirms these initial observations, then the effects of crude oil on infauna may be much greater than we have previously thought.

8. Both our data and that reported by Dr. Atlas for the summer, 1978 Beaufort Sea field study indicate that some very different microbial processes are taking place near Demarcation Point and near the mouths of the major rivers. It is difficult to speculate at this time what these differences mean but it is very likely that both crude oil fate and effects will be different in these areas than in most areas along the coast.

V. Problems encountered

Funding uncertanties and delays in obtaining the equipment required to conduct pilot experiments for the detrital food web studies have hampered our efforts to prepare for the detrital food web study which we will initiate in February, 1979 at the Kasistna Bay laboratory.

Table 1. Station locations and the water column depth at each station.

Station Number	Horner Station Number	Sample Number	Water Depth (Meters)	Lat. North	Long. West
3		BW601	3	71 22	156 21
3		BW602	3	"	"
3		BW603	3	"	"
3		BW604	3	"	"
3		BW605	3	"	"
3		BW606	3	"	"
3		BW607	3	"	"
3		BW608	3	"	"
609		BW609	21	70 36	147 38.7
610	16	BW610	25	70 29.6	147 23
611		BW611	5	70 28	147 58
612		BW612	5	70 22	148 08
613	17	BW613		70 21.9	146 51.7
614		BW614	3	70 19	147 35
615		BW615	3	70 13	147 17
616	18	BW616	23	70 14.5	145 51.5
617		BW617	1	70 10.5	145 55
618		BW618	2	70 05	145 29
619		BW619	2.5	69 59	144 54
620	19	BW620	24	70 13	143 20
621		BW621	3	70 09	143 21
622	20	BW622	3	69 59	142 16
623		BW623	5	69 56	142 19
624		BW624	9	69 57	142 20
625	21	BW625	2200	71 08	142 03
626	22	BW626	21	69 47	141 26
627		BW627	4	69 41	141 16
628		BW628	5	69 49	141 51
629		BW629	19	70 08	142 49
630	23	BW630	54	70 26	143 42
631	24	BW631	60	70 28	143 42
632	25	BW632	31	70 15	143 48
633		BW633	20	70 09	144 47.5
634	27	BW634	17	70 19	146 30
635	29	BW635	60	71 01	147 55
636	30	BW636	24	70 46	148 34
637	31	BW637		70 35.8	148 04
638		BW638	4	70 26	148 24
639		BW639	1	70 20.5	148 19.0
640	32	BW640	24	70 47.0	149 36.4

Table 1 (continued).

Station Number	Horner Station Number	Sample Number	Water Depth (Meters)	Lat. North	Long. West
641	33	BW641	290	71 14.3	149 33.5
642	34	BW642	24	70 52	150 16
643		BW643	2	70 31.5	149 34
644		BW644	4	70 31	150 00
645		BW645	2	70 30	150 14
646	35	BW646	18	71 01.0	150 25.0

Table 2. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all water samples collected during the summer, 1978 Beaufort Sea field studies.

	Glucose		Glutamic Acid	
Sample Number	*Uptake	Percent Respiration	*Uptake	Percent Respiration
BW601	15.6	27	34.3	54
BW604	2.3	36	4.6	59
BW606	43.9	18	21.6	56
BW608	12.1	31	10.9	59
BW609	3.4	29	44.1	53
BW610	10.9	25	12.2	57
BW611	4.3	31	20.3	51
BW612	11.3	29	36.4	62
BW613	14.8	30	11.6	56
BW614	6.9	33	6.9	60
BW615	3.4	38	12.7	71
BW616	4.3	41	19.0	66
BW617	4.8	34	9.7	61
BW618	3.5	37	3.9	66
BW619	3.5	41	3.2	62
BW620	3.0	34	18.6	48
BW621	14.9	27	9.8	63
BW622	6.9	33	9.6	51
BW623	4.5	30	8.2	59
BW624	5.6	38	14.1	59
BW625	6.0	24	3.6	77
BW626	¢26.5		20.6	
BW627	¢13.0		0.7	
BW628	¢ 4.0		11.3	
BW629	3.3	42	1.5	59
BW630	0.9	19	5.4	69
BW631	2.1	29	6.3	71
BW632	3.5	47	4.8	81
BW634	3.1	54	4.8	65
BW635	0.6	51	3.0	73
BW636	4.2	26	11.4	64
BW638	1.7	57	3.2	73
BW638	3.1	57	3.2	73
BW639	4.0	48	8.1	60
BW640	7.7	45	16.4	69
BW641	2.4	42	9.6	64
BW642	5.3	44	15.6	66
BW643	4.3	26	38.7	44
BW644	26.2	29	40.9	53
BW645	18.1	22	38.7	44
BW646	9.9	40	13.2	67

* These values are reported as ng/liter/h.
¢ These are estimates of total uptake using cell data and average percent respiration.

Table 3. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all sediment samples collected during the summer, 1978 Beaufort Sea Field studies.

	Glucose		Glutamic Acid	
Sample Number	*Uptake	Percent Respiration	*Uptake	Percent Respiration
BB601	2.7	29	19	54
BB602	1.5	57	9	54
BB603	1.3	32	8	59
BB604	9.9	22	251	59
BB605	6.9	23	96	
BB606	9.5	24	84	46
BB607	13.2		161	46
BB608	8.4	26	187	45
BB609	6.7	24	58	49
BB610	0.2		19	49
BB611	7.5	36	129	52
BB612	7.4	31	113	47
BB613	4.6	29	35	59
BB614	4.2	33	75	49
BB615	23.4	23	113	46
BB616	3.2	28	32	60
BB617	14.1	27	20	75
BB618	4.7	40	65	67
BB619	4.6	29	197	49
BB622	49.2	35	188	64
BB624	31.8	41	155	62
BB626	¢ 6.5		45	
BB627	¢17.0		88	
BB630	7.7	25	143	56
BB631	1.3	24	86	56
BB632	1.6	32	16	46
BB633	18.0	36	104	64
BB634	1.5	40	17	48
BB635	2.2	35	45	48
BB636	0.7	30	7	34
BB638	2.8	27	38	40
BB640	13.8	36	139	50
BB641	3.7	26	161	46
BB642	18.1	39	99	53
BB643	9.7	21	262	52
BB644	23.8	28	179	47
BB645	3.7	28	54	50
BB641	3.7	26	161	46

* These values are reported at ng/g dry wt./h.
¢ These are estimates of total uptake using cell data and the average percent respiration.

Table 4. The percent reduction in glucose uptake in water samples collected in the Beaufort Sea during the summer, 1978 sampling season. The reductions were in response to the addition of Prudhoe Bay crude oil, Corexit 9527 at 15ppm or a combination of the two.

Sample Number	Crude Oil	Corexit 9527	Crude Oil + Corexit
BW601	58		
BW606	65	46	86
BW608	72	62	90
BW609	40		
BW610	28	54	88
BW611	39	38	69
BW612	50		
BW613	45		
BW614	59	78	91
BW615	51		
BW616	61	74	89
BW617	49		
BW618	55		
BW619	42		
BW620	38		
BW621	69	59	82
BW622	51		
BW623	68		
BW624	59	79	89
BW625	75		
BW626	61	65	72
BW627	71		
BW628	78	92	95
BW629	49		
BW630	41		
BW631	40	53	69
BW632	52		
BW633	-8		
BW634	60		
BW635	42	58	54
BW636	66		
BW637	31	48	71
BW638	61	59	80
BW640	86		
BW641	53		
BW642	40		
BW644	72		
BW645	88		
BW646	55		
	$\bar{X}$ = 52 s = 20 n = 40	$\bar{X}$ = 58 s = 22 n = 14	$\bar{X}$ = 76 s = 20 n = 14

Table 5. The effects of crude oil, Corexit 9527, and a combination of the two on the kinetics of glucose uptake in water samples collected during the summer, 1978 Beaufort Sea field studies.

(1) Maximum Potential Uptake Rate (V_{max})

Sample Number	No Oil	Crude Oil	Corexit	Corexit + Oil
BW611	12.4	4.3	3.8	2.5
BW614	10.8	3.7	3.1	1.2
BW616	5.7	2.1	1.2	0.9
BW619	8.1	2.7		
BW632	8.6	1.5		
BW644	38.7	6.6		
BW645	17.8	5.0		
$\bar{x}$	14.6	3.7	2.7	1.5

(2) Turnover Time (T_t)

BW611	306	597	1046	1337
BW614	286	480	1693	2000
BW616	429	689	697	1650
BW619	246	384		
BW644	58	35		
BW645	42	767		
$\bar{x}$	177	492	1145	1662

(3) Transport Constant + Natural Substrate Concentration ($K_t + S_n$)

BW611	3.8	2.6	4.0	3.4
BW614	3.1	1.8	5.2	2.5
BW616	2.5	1.5	0.9	1.5
BW619	2.0	1.1		
BW644	2.2	0.2		
BW645	0.8	3.9		
$\bar{x}$	1.9	1.9	3.4	2.5

(1) = Values in ng/liter/h
(2) = Values in hours
(3) = Values in µg/liter

Table 6. The percent reduction in the amount of glucose taken up in sediment samples collected in the Beaufort Sea during the summer, 1978 sampling season. The reductions were in response to the addition of Prudhoe Bay crude oil, Corexit 9527 at 15 ppm or a combination of the two.

Sample Number	Crude Oil	Corexit 9527	Crude Oil + Corexit
BB601	28	28	23
BB602	3	18	9
BB603	0	26	0
BB604	18	21	20
BB605	9	20	34
BB606	15	19	21
BB607	11	33	37
BB608	21	9	9
BB611	58	5	60
BB612	43		
BB613	15		
BB614	14	27	48
BB615	83		
BB616	38	17	45
BB617	35		
BB618	48		
BB619	9		
BB622	6		
BB624	0	10	19
BB626	0	26	27
BB627	34		
BB630	52	21	36
BB631	46	6	49
BB632	9		
BB633	8		
BB634	36	38	45
BB635	12	4	13
BB636	53	20	60
BB638	68	0	62
BB640	2		
BB642	35		
BB643	25		
BB644	36		
BB645	33		
$\overline{X}$	32 ± 22	15 ± 11	40 ± 17
	n = 34	n = 12	n = 12

Table 7. The effects of crude oil, Corexit 9527, and a combination of the two on the kinetics of glucose uptake in sediment samples collected during the summer, 1978 Beaufort Sea field studies.

(1) Maximum Potential Uptake Rate (V_{max})

Sample Number	No Oil	Crude Oil	Corexit	Corexit + Oil
BB601	7.9	4.6	5.1	5.1
BB602	6.1	3.7	4.2	4.2
BB605	31.2	36.0	26.8	17.6
BB607	59.9	42.6	41.3	42.4
BB611	21.1	10.0	19.8	11.8
BB614	15.1	12.8	9.6	5.5
BB616	7.4	3.5	11.1	4.3
BB632	4.3	3.4		
BB640	31.0	34.9		
BB645	8.6	3.0		
$\bar{X}$	22.8	16.3	16.8	13.0

(2) Turnover Time (T_t)

BB601	2490	2798	3552	3839
BB602	4598	3672	5149	4043
BB605	822	954	1025	1162
BB607	532	628	782	801
BB611	589	1132	582	1193
BB614	1589	1062	1869	2157
BB616	1033	1318	1987	1363
BB619	541	682		
BB632	2913	2337		
BB640	465	560		
BB644	224	264		
BB645	826	530		
$\bar{X}$	1385	1064	1666	1337

(3) Transport Constant + Natural Substrate Concentration

BB601	11.3	7.3	10.5	11.2
BB602	17.6	8.6	13.6	10.8
BB605	19.4	26.1	20.9	15.5
BB607	19.7	16.5	19.8	26.0
BB611	10.1	9.2	9.1	11.3
BB614	14.6	15.1	10.9	7.2
BB616	6.2	3.7	17.6	4.5
BB619	2.3	7.5		
BB632	7.3	4.8		
BB640	8.0	10.9		
BB644	12.2	7.2		
BB645	5.6	1.3		
$\bar{X}$	11.2	10.0	14.6	11.6

Table 8. Nitrogen fixation rates observed in sediment samples collected during the summer, 1978 Beaufort Sea cruise.

Sample Number	*No Oil	Oil
BB601	1.1	
BB602	0.4	
BB603	0.5	
BB604	0.4	
BB605	0.4	
BB606	0.3	
BB607	0.3	
BB608	0.5	0.6
BB609	0	
BB610	0	0
BB612	0.1	0.1
BB613	0.4	
BB615	0.1	
BB616	0.1	0
BB617	0.1	
BB619	0	0
BB622	1.4	
BB624	0.3	
BB626	0.1	0.1
BB627	0.1	0.1
BB630	0.3	
BB631	0.2	0.2
BB632	0.2	0.3
BB633	0.2	
BB634	0.1	
BB635	0.2	0.2
BB636	0.1	
BB640	0.2	0.2
BB641	0.1	0.1
BB642	0	
BB644	0.2	
BB645	0.1	0.1
Wood	4.9	4.2
$\bar{X}$	0.3 w/o wood	

* All values reported as ng nitrogen fixed per g dry wt. per h.

Table 9. Adenylate measurements made on sediment samples collected during the summer, 1978 Beaufort Sea study.

Sample Number	*ATP	*ADP	*AMP	Total Adenylate	Energy Charge
BB601	245	6	7	263	0.95
BB602	3.2	0	0	3.2	1.00
BB605	3.6	0.2	0	3.7	0.98
BB607	211	19	0	227	0.96
BB619	337	7	10	352	0.96
BB624	13.7	1.3	0.6	15.7	0.92
BB626	23.7	0.3	0	24.6	0.99
BB627	62.7	1.9	0.3	65.3	0.98

* nMoles of adenylate x g. dry wt.$^{-1}$.

Table 10. The effects of crude oil on the uptake and respiration of glucose and glutamic acid by natural marine microbial populations found in water and sediment samples taken from the Lower Cook Inlet and the Beaufort Sea. The percent reduction is reported as the mean value for all observations.

A. WATER

		GLUCOSE		GLUTAMIC ACID	
Study Area	Time	Percent Reduction	Number of Observations	Percent Reduction	Number of Observations
Beaufort	1/78	[c]45	8		
Beaufort	4/78	0	3	0	2
Beaufort	9/78	52	40		
Lower Cook	11/77	[c]41	21		
Lower Cook	4/78	45	32	33	35

B. SEDIMENT

Beaufort	9/77	[c]35	20	[c]33	20
Beaufort	4/78	24*	5	7*	5
Beaufort	9/78	32*	30		
Lower Cook	4/78	14*	26	18*	7

[c]These values are for average percent reduction in respiration only.

*These differences were not significant at the 0.05 level.

In the Beaufort Sea studies, Prudhoe Bay crude oil was used and in the Lower Cook Inlet study, Lower Cook Inlet crude oil was used.

Table 11. The effects of crude oil, Corexit 9527, and crude oil plus Corexit 9527 on the uptake and respiration of glucose and glutamic acid in water and sediment samples collected in the Beaufort Sea and the Lower Cook Inlet. The final concentration of Corexit in these experiments was 15 ppm.

A. WATER

Study Area	Time	Number of Observations	Substrate	AVERAGE PERCENT REDUCTION Crude Oil	Corexit 9527	Crude Oil + Corexit
Beaufort	9/78	14	glucose	52*	58*	76*
Lower Cook	4/78	2	glucose	30	83	80
Lower Cook	4/78	5	glutamate	40	47	74
B. SEDIMENT						
Beaufort	4/78	2	glucose	52	65	80
Beaufort	4/78	2	glutamate	12	26	38
Beaufort	9/78	34	glucose	32	15*	40*
Lower Cook	4/78	4	glutamate	4	0	8
Lower Cook	4/78	1	glucose	13	0	0

*These were the ONLY differences that were significant at the 0.05 level.

Figure 1. The location of stations where samples were collected during the summer, 1978 Beaufort Sea cruise.

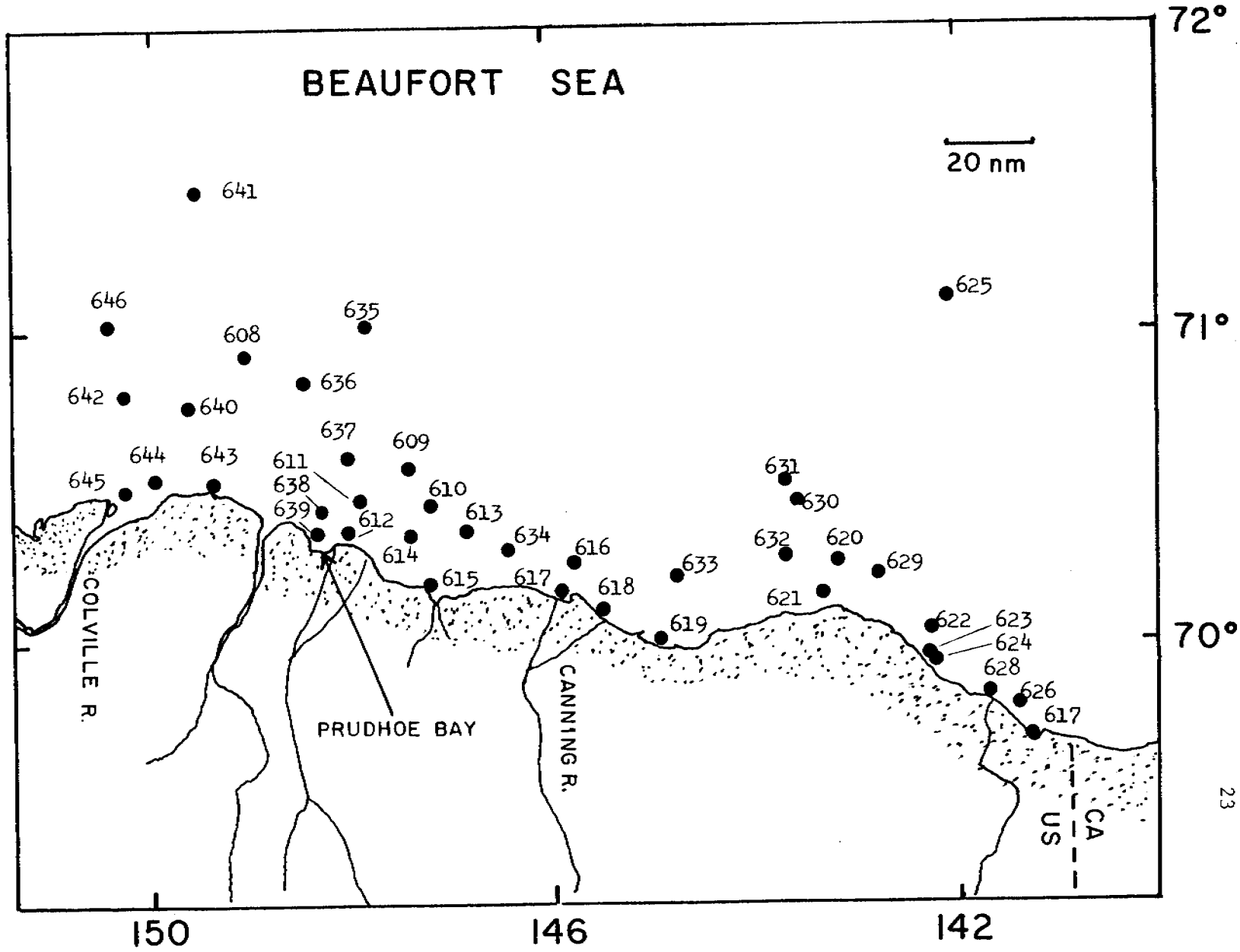


Figure 2. The rate of glucose uptake observed in water samples reported in ng/ g dry wt./h.

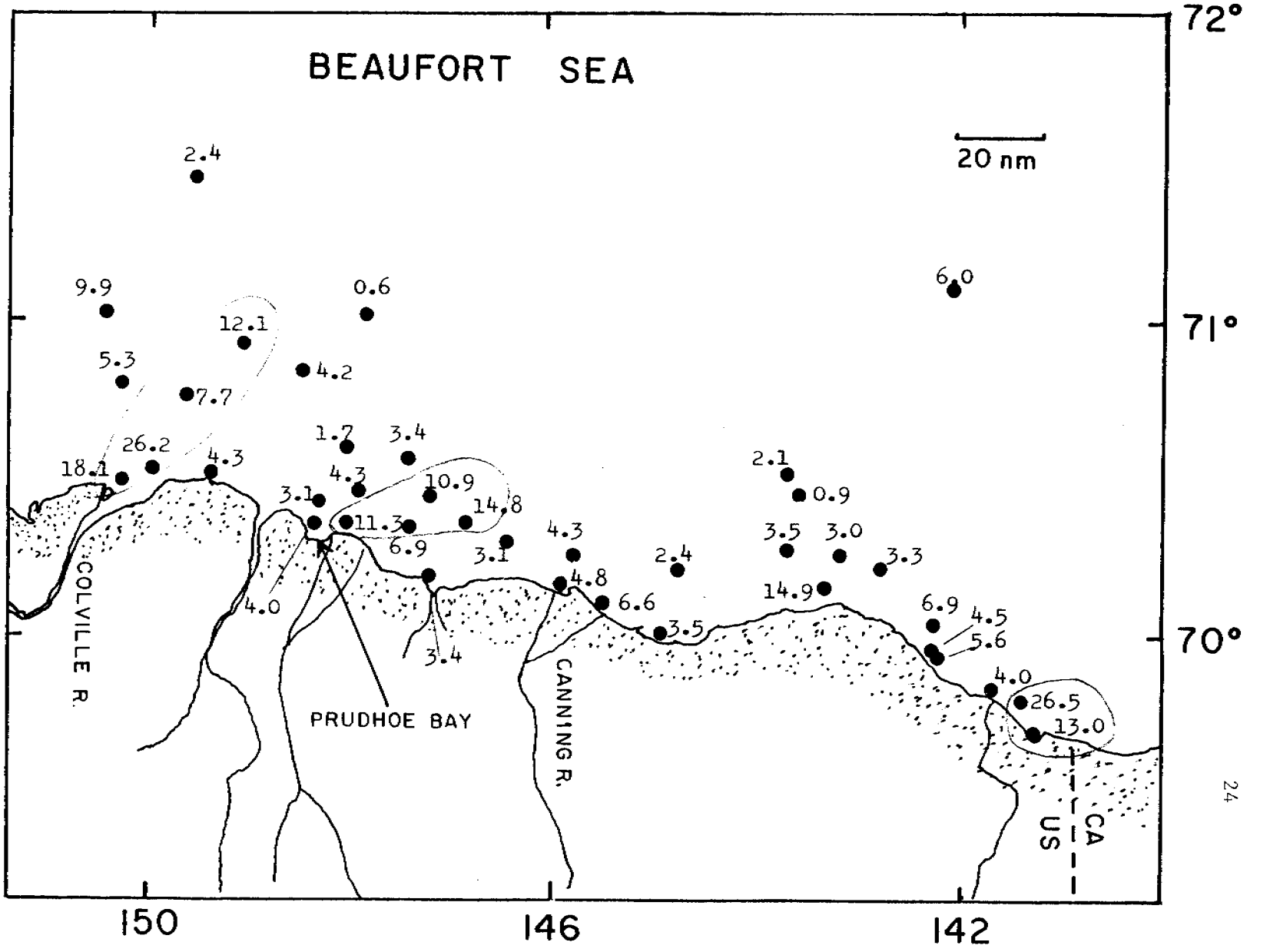


Figure 3. The rate of glutamic acid uptake observed in water samples reported in ng/ g dry wt./h.

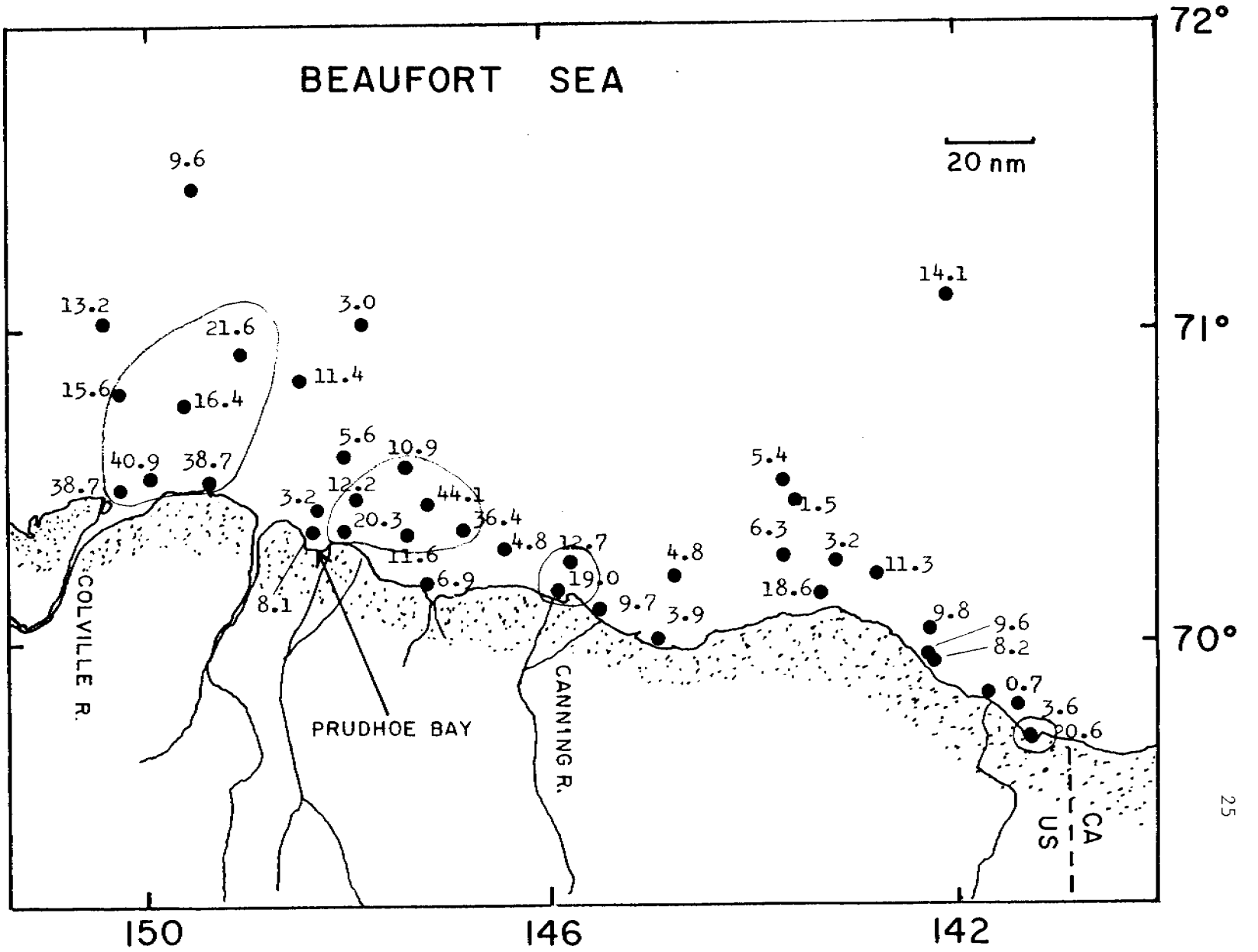


Figure 4. Percent respiration observed in water samples exposed to glutamic acid.

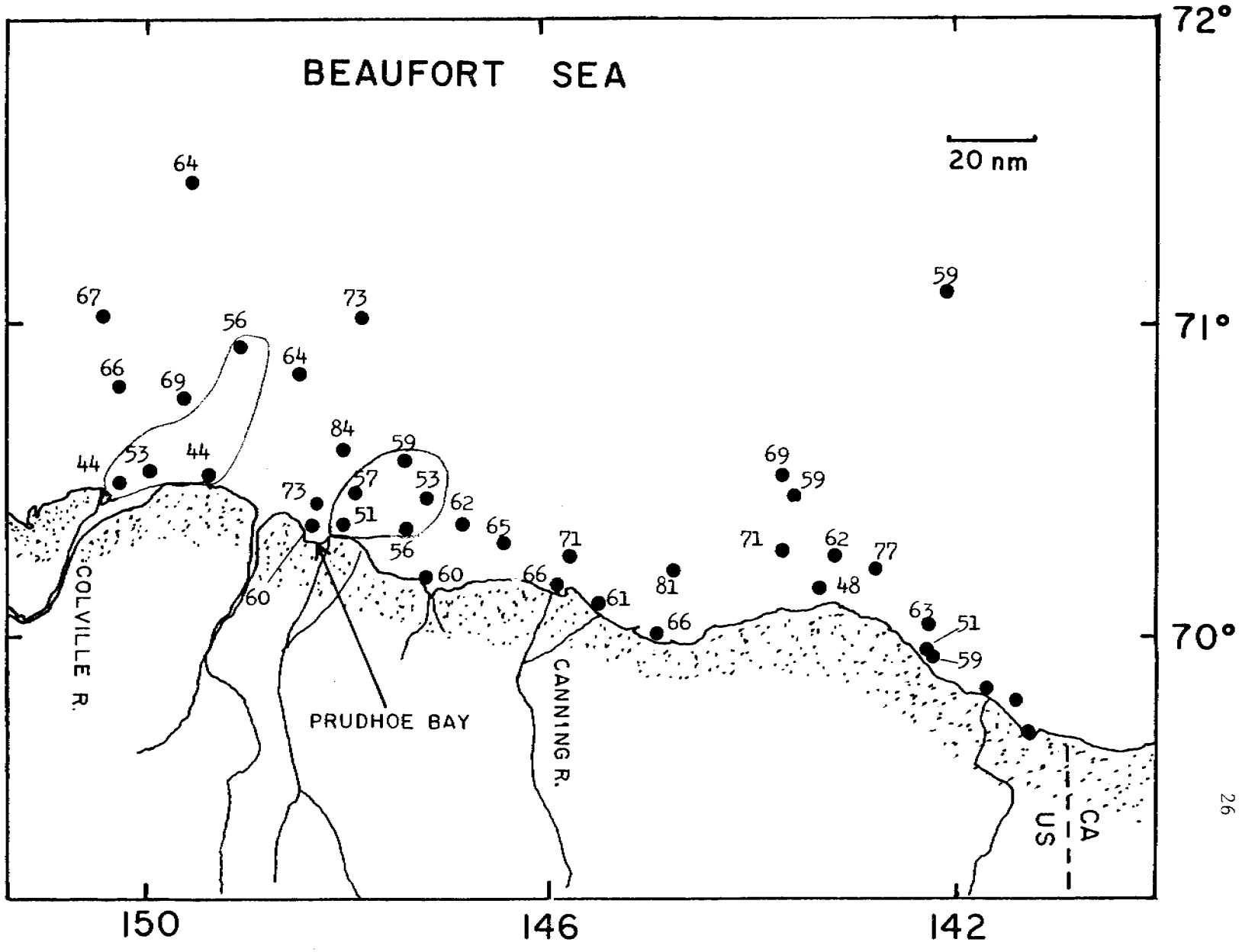


Figure 5. Percent respiration observed in water samples exposed to glucose.

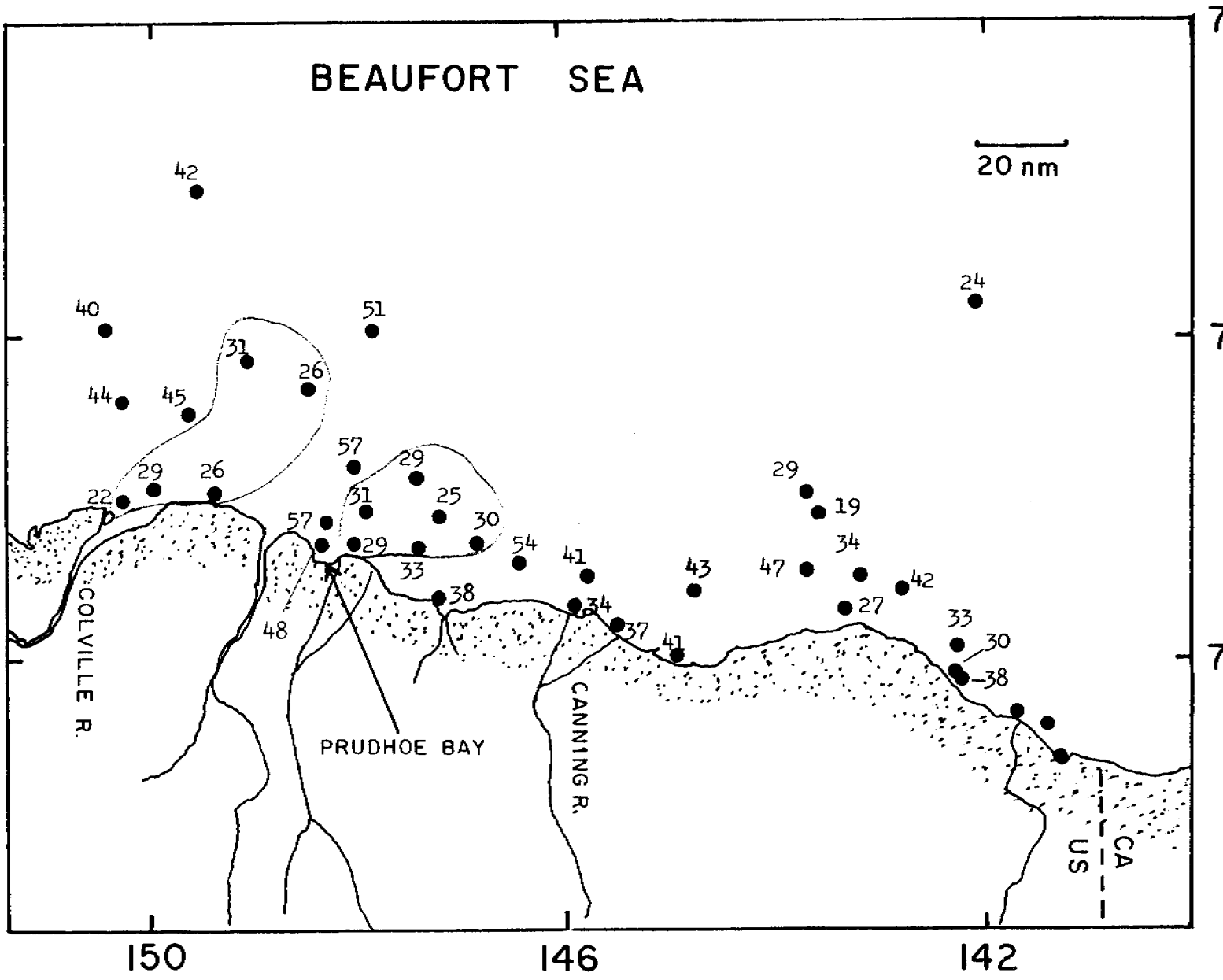


Figure 6. The rate of glutamic acid uptake observed in sediment samples reported in ng/g dry wt./h.

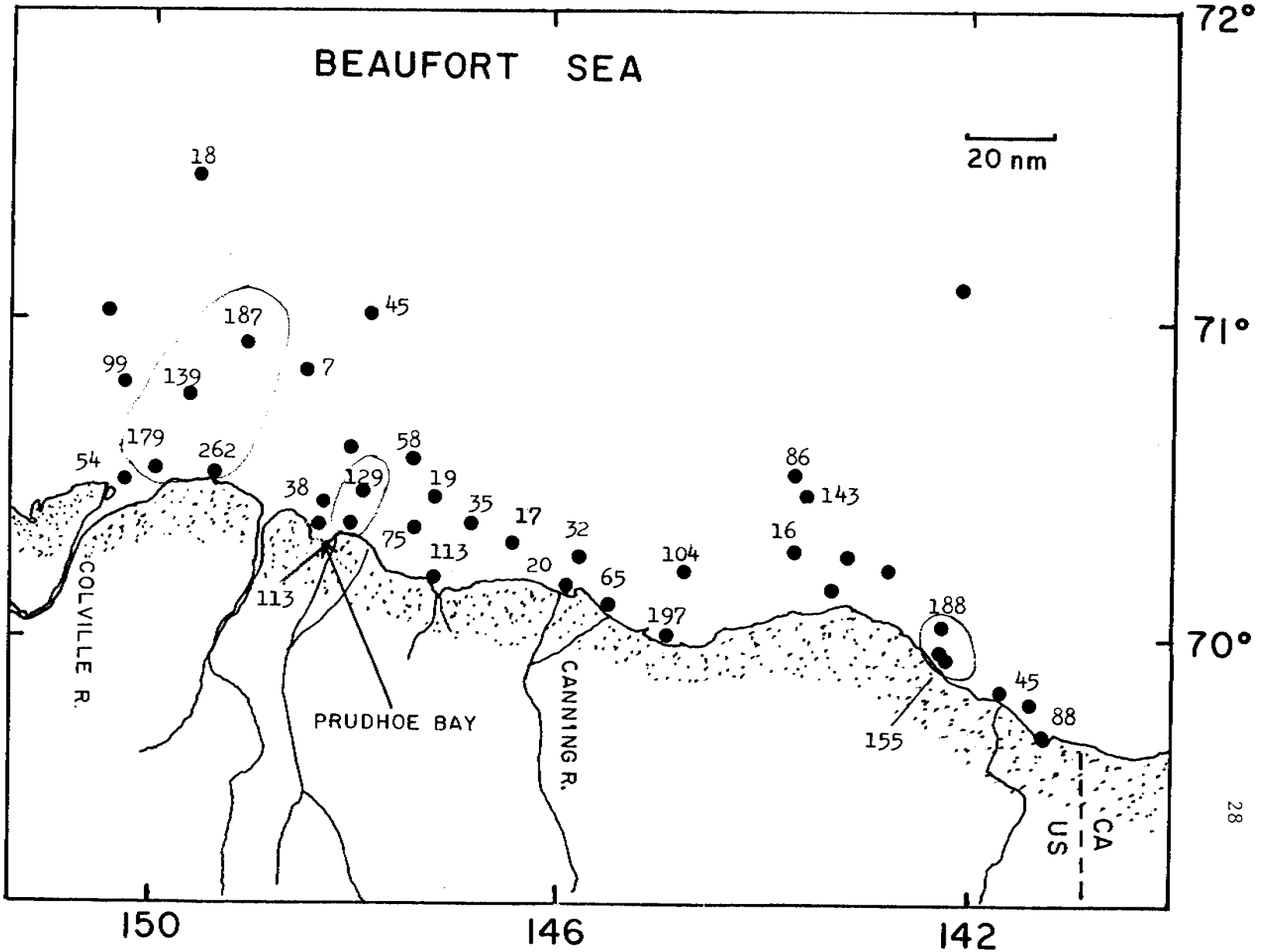


Figure 7. The rate of glucose uptake observed in sediment samples reported in ng/g dry wt./h.

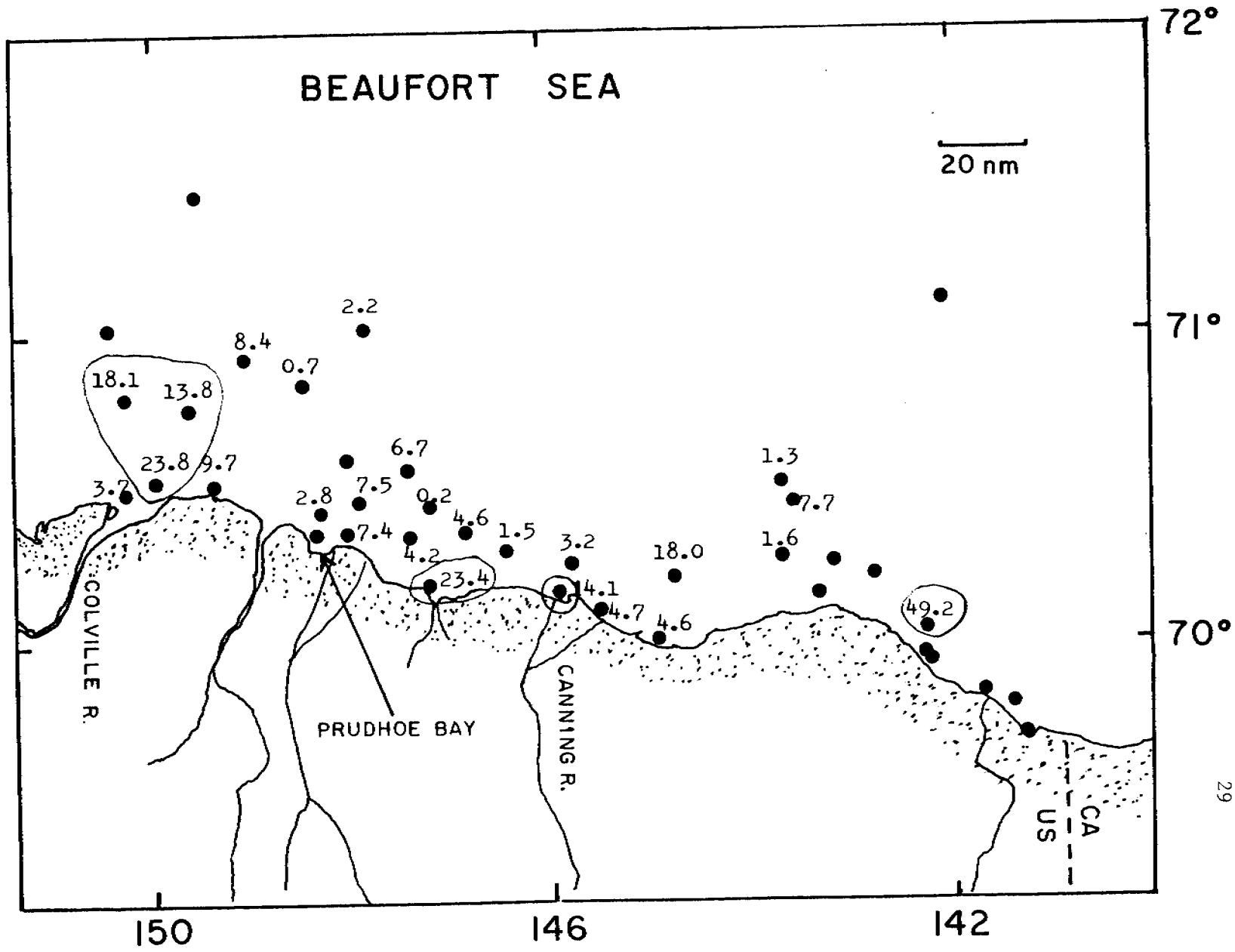


Figure 8. Percent reduction in the rate of glutamic acid uptake in water samples exposed to Prudhoe Bay crude oil when compared to nonoiled samples.

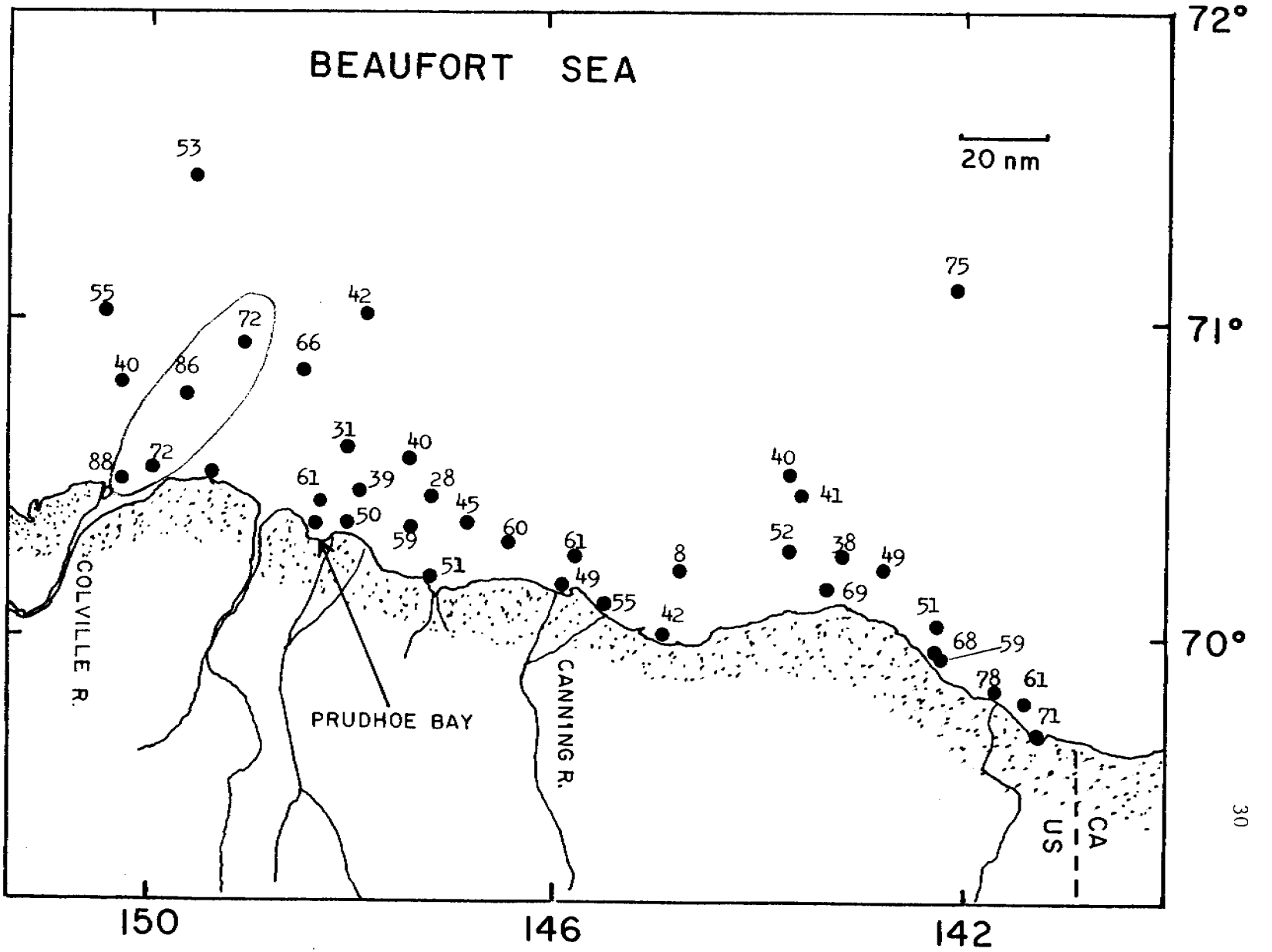
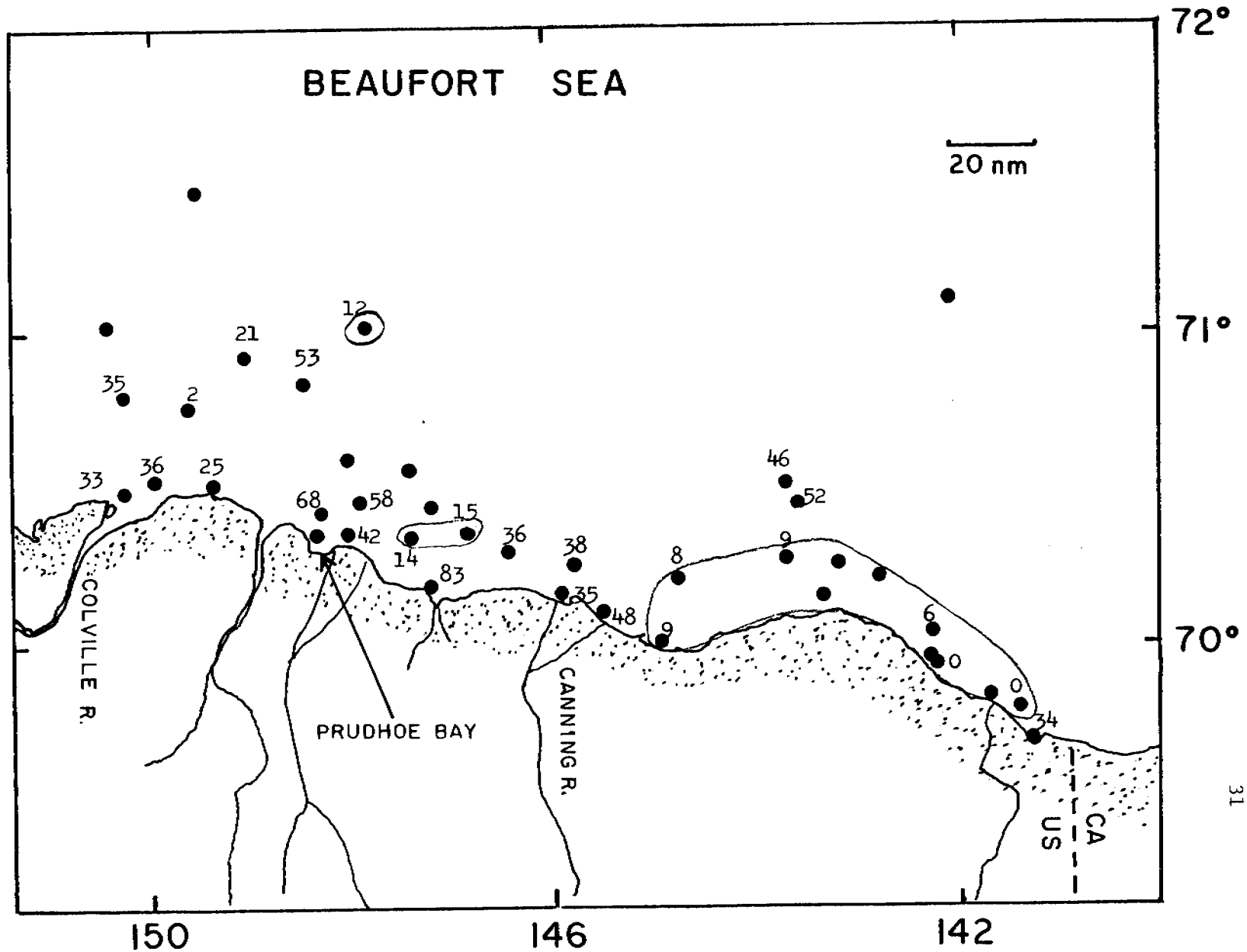


Figure 9. Percent reduction in the rate of glucose uptake in water samples exposed to Prudhoe crude oil when compared to nonoiled samples.



Research Unit 500

SIXTH QUARTERLY REPORT
(Covering the period of July 1 to September 30, 1978)

on

ACTIVITY-DIRECTED FRACTIONATION OF PETROLEUM SAMPLES

to

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

November 20, 1978

by

J. S. Warner and J. W. Anderson

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

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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 reserach 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

In Vivo Biological Screening Studies
(Performed by Jack Anderson, Battelle Pacific Northwest Laboratories)

Materials and Methods

In vivo bioassays of selected solutions were conducted to determine the toxicity of the samples to mysids at 100, 40, 10 and 4 µl/l, and 1000, 400, 100, 40 µl/l for solvents used as carriers. The samples included fractions from vac-stripped fresh Prudhoe Bay crude oil, weathered PBC, residuals, volatiles, and some specific aromatic hydrocarbons. Except where solvents were tested alone, all solutions contained 100 mg/ml of material in a 1:4 cyclopentanol-monoolein base.

Aliquots of sample solutions were added via microliter pipet and syringe to 250 ml of seawater. This was whipped to a dispersion for 30 seconds in a stainless steel Waring blender followed by two 250 milliliter seawater rinses in the blender to remove any residual solution. Each rinse was also whipped for 30 seconds and then poured into the bioassay aquarium containing 2250 ml of seawater for a total of 3 liters. All methods and materials were otherwise unchanged from previous bioassay procedures.

Results

The results of the bioassays are given in Table 1. Although mysids seem to be insensitive to most of the fractions from vac-stripped fresh Prudhoe Bay crude oil, samples 33850-39-2, 4, 5, 7 were not large enough to permit verification by repeated testing. No LC50 for 24 or 48 hour periods was ascertained for weathered Prudhoe Bay crude oil, volatiles or residuals.

The second bioassay of sample 39-13, a cyclopentanol-monoolein blank, indicated that mortalities due to this solvent carrier appear to be negligible. However, insufficient sample size prevented further testing for verification. Bioassays using cyclopentanol alone were conducted and the range of toxic concentrations was between 10 and 68 ppm. Using the present bioassay procedure, monoolein alone was found to be too insoluble in seawater to permit testing.

TABLE 1. TOXICITY OF PBC FRACTIONS TO NEOMYSIS

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time	
			24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
	33850-39-1 Vac-Stripped Fresh PBC Oil			
	24 hr	48 hr		
Control	70%	70% *	*Control mortality too high for LC50 determination.	
.1	100%	80%		
.4	90%	90%		
1.0	90%	60%		
4.0	--	--		
10.0	100%	80%		
	33850-29-2 Fraction From Vac-Stripped Fresh PBC Oil			
Control	100%	70% *		.700
.1	100%	80%		
.4	90%	70%		
1.0	67%	44%		
4.0	80%	60%		
10.0	70%	60%		
Control	100%	100%	None	None
.1	90%	80%		
.4	90%	90%		
1.0	100%	100%		
4.0	90%	80%		
10.0	100%	100%		
Control	70%	70% *		
.1	90%	80%		
.4	90%	90%		
1.0	100%	100%		
4.0	100%	90%		
10.0	100%	--		
	33850-39-3 Vac-Stripped Fresh PBC Oil			
Control	90%	70% *		
.1	100%	70%		

TABLE 1. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time	
			24 hr $\bar{x}$ S.D.	48 $\bar{x}$ S.D.
.4	90%	90%		
1.0	80%	70%		
4.0	90%	80%		
10.0	100%	90%		
	33850-39-5 Vac-Stripped Fresh PBC Oil			
Control	70%	50% *		
.1	90%	80%		
.4	90%	60%		
1.0	90%	90%		
4.0	60%	50%		
10.0	60%	10%		
Control	80%	80%	None	None
.1	100%	100%		
.4	100%	90%		
1.0	100%	100%		
4.0	100%	90%		
10.0	100%	90%		
Control	100%	90%	None	None
.1	100%	90%		
.4	100%	90%		
1.0	100%	100%		
4.0	100%	100%		
10.0	100%	70%		
	33850-39-6 Vac-Stripped Fresh PBC Oil			
Control	100%	60% *		
.1	80%	70%		
.4	60%	40%		
1.0	90%	70% **	** Relatively high survival	
4.0	90%	70% **	at highest concentrations	
10.0	70%	60% **	indicated low toxicity.	

TABLE 1. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
	33850-39-7 Vac-Stripped Fresh PBC Oil			
Control	100%	70% *		
.1	80%	70%		
.4	80%	60%		
1.0	70%	60%		
4.0	80%	40%		
10.0	80%	70%		
Control	90%	90%	None	None
.1	90%	80%		
.4	100%	100%		
1.0	100%	100%		
4.0	80%	70%		
10.0	100%	100%		
	33850-39-8 Fraction From Weathered PBC Oil			
Control	80%	60% *		
.1	80%	80%		
.4	90%	70%		
1.0	90%	70% **		
4.0	90%	80% **		
10.0	100%	80% **		
	33850-39-9 Fraction From Weathered PBC Oil			
Control	80%	60% *		
.1	100%	100%		
.4	90%	70%		
1.0	100%	100% **		
4.0	90%	90% **		
10.0	90%	90% **		
	33850-39-10 Fraction From Weathered PBC Oil			
Control	100%	70% *		
.1	80%	60%		

TABLE 1. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
.4	90%	90%		
1.0	80%	70%		
4.0	80%	80% **		
10.0	90%	80% **		
	33850-39-11 Fraction From Weathered PBC Oil			
Control	90%	70%		
.1	90%	70%		
.4	90%	90%		
1.0	90%	90%		
4.0	90%	80% **		
10.0	90%	90% **		
	33850-39-12 Fraction From Weathered PBC Oil			
Control	100%	100%	None	None
.1	80%	80%		
.4	100%	80%		
1.0	100%	90%		
4.0	80%	70%		
10.0	100%	70%		
Control	100%	90%	None	None
.1	100%	90%		
.4	80%	60%		
1.0	90%	80%		
4.0	100%	100%		
10.0	100%	90%		
	33850-39-14 1, 2, 4-Trimethylbenzene			
Control	90%	90%	None	None
.1	90%	80%		
.4	80%	70%		
1.0	75%	60%		
4.0	70%	40%		
10.0	100%	100%		

TABLE 1. (Continued)

Concentration	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
Control	100%	80%	10.0	7.4
.1	100%	90%		
.4	80%	80%		
1.0	100%	100%		
4.0	80%	70%		
10.0	50%	40%		
Control	100%	90%	6.4	6.0
.1	100%	90%		
.4	90%	80%	8.2 ± 2.55	6.7 ± .99
1.0	100%	100%		
4.0	100%	90%		
10.0	0%	0%		
	33850-39-15 2-Methylnaphthalene			
Control	100%	90%	.63	.67
.1	90%	70%		
.4	100%	100%		
1.0	10%	0%		
4.0	0%	0%		
10.0	0%	0%		
	33850-39-17 1-Methylpyrene			
Control	90%	80%	.4	.17
.1	80%	80%		
.4	50%	0%		
1.0	10%	0%		
4.0	10%	0%		
10.0	30%	0%		
	33850-39-18 4-Methylphenol			
Control	100%	90%		
.1	100%	64% ***	*** Unusual Response	
.4	100%	80%		
1.0	100%	100%		
4.0	90%	50%		
10.0	100%	100% ***		

TABLE 1. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
Control	90%	90%	7.42	5.2
.1	80%	70%		
.4	90%	90%		
1.0	90%	80%		
4.0	70%	70%		
10.0	40%	0%		
Control	100%	100%	10.0	2.0
.1	100%	100%	8.71 ± 1.82	2.61 ± 2.28
.4	90%	90%		
1.0	100%	70%		
4.0	100%	30%		
10.0	50%	0%		
	33850-39-20 Dibenzothiophene			
Control	80%	60% *	2.0	2.0
.1	80%	80%		
.4	100%	70%		
1.0	100%	100%		
4.0	0%	0%		
10.0	0%	0%		
Control	90%	80%	1.85	1.85
.1	80%	70%		
.4	100%	100%	1.93 ± .11	1.93 ± .11
1.0	90%	90%		
4.0	0%	0%		
10.0	0%	0%		
	33850-39-22 Residuals/Fresh PBC Oil (b.p. >150 c/o .1mm)			
Control	100%	80%	None	2.3
.1	100%	80%		
.4	80%	70%		
1.0	100%	80%		
4.0	70%	30%		
10.0	90%	10%		

TABLE 1. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
Control	90%	90%	None	None
.1	100%	80%		
.4	100%	90%		
1.0	100%	90%		
4.0	90%	90%		
10.0	70%	70%		
Control	100%	90%	None	None
.1	100%	100%		
.4	100%	100%		
1.0	90%	70%		
4.0	80%	80%		
10.0	90%	80%		
	33850-39-23 Volatiles From Fresh PBC Oil (b.p. <150° C/o.1mm)			
Control	70%	30% *		
.1	80%	80%		
.4	90%	70%		
1.0	--	--		
4.0	85%	65%		
10.0	80%	60%		
Control	100%	100%	None	None
.1	100%	70%		
.4	100%	100%		
1.0	100%	100%		
4.0	100%	100%		
10.0	90%	90%		
	33850-39-13 Blank			
Control	90%	70% *		
.1	90%	80%		
.4	60%	50%		
10.0	90%	90%		
40.0	100%	90%		
100.0	90%	50%		

TABLE 1. (Continued)

Concentration	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
Control	90%	90%	None	None
1.0	100%	100%		
4.0	100%	90%		
10.0	100%	100%		
40.0	100%	80%		
100.0	100%	100%		
	Cyclopentanol Solvent			
Control	80%	80%	None	10
1.0	90%	90%		
4.0	100%	90%		
10.0	70%	50%		
40.0	80%	70%		
100.0	80%	60%		
Control	90%	90%	None	68
1.0	90%	90%		
4.0	100%	100%		
10.0	100%	90%		
40.0	100%	90%		
100.0	60%	20%		
	33850-39-4 Vac-Stripped Fresh PBC Oil			
Control	100%	60% *		
.1	80%	80%		
.4	80%	60%		
1.0	90%	80%		
4.0	60%	40%		
10.0	80%	60%		

Table 2 lists the fractions, which are actually specific hydrocarbons, that produced significant mortality and, therefore, LC50 values. The reproducibility of the LC50 values for these compounds gives evidence of the usefulness of these tests. Unfortunately, there were no consistent findings on the toxicity of fractions containing a mix of unknown components. We have pointed out the problem with insoluble components, which tends to confuse the measurement of actual LC50 values. These components are not really available to the organisms, as they move to the surface after various periods ot time. The calculated or nominal concentration is, therefore, quite a bit greater than the actual amount "seen" by the mysids. All possible methods should be explored to remove these insolubles from fractions before testing the toxicity for mysids.

As we have demonstrated toxicity by specific components which are included in one or more of the fractions, we know that at a given concentration the latter should produce mortality. As noted, in the original proposal, there is a problem of dilution from other components in the fraction. This means that there must be some sort of enrichment of the toxic material or the sensitivity of the text must be increased. Removal of insolubles will aid in the first aspect, and we will be attempting to test a more sensitive biological approach. Mysids which are "healthy" tend to orient toward the current in holding tanks. We are testing the reproducibility of this response and the possibility of altering the response by pre-exposure to specific compounds at sublethal levels.

Solvent Extraction

As discussed in the last report, our studies have indicated that those components of oil that are insoluble in dimethyl sulfoxide (DMSO) or acetone can not be effectively dispersed in water for bioassay except at extremely low levels. The insoluble components in oil fractions also interfere with the bioassay of the more readily dispersible components. Consequently we have reconsidered our original objective of studying all components of oil including the highly insoluble components. One can rationalize, with considerable justification, that if a component is insoluble in dimethyl sulfoxide or acetone (solvents suitable for the Ames test) it is very unlikely that the material can be absorbed into a biological system and exert an effect. We are, therefore, now

TABLE 2. TOXICITY OF REFERENCE COMPOUNDS TO NEOMYSIS

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time	
			24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
	33850-39-14			
	1, 2, 4-Trimethylbenzene			
	24 hr	48 hr		
Control	90%	90%	None	None
.1	90%	80%		
.4	80%	70%		
1.0	75%	60%		
4.0	70%	40%		
10.0	100%	100%		
Control	100%	80%	10.0	7.4
.1	100%	90%		
.4	80%	80%		
1.0	100%	100%		
4.0	80%	70%		
10.0	50%	40%		
Control	100%	90%	6.4	6.0
.1	100%	90%		
.4	90%	80%	8.2 ± 2.55	6.7 ± .99
1.0	100%	100%		
4.0	100%	90%		
10.0	0%	0%		
	33850-39-15			
	2-Methylnaphthalene			
Control	100%	90%	.63	.67
.1	90%	70%		
.4	100%	100%		
1.0	10%	0%		
4.0	0%	0%		
10.0	0%	0%		
	33850-39-17			
	1-Methylpyrene			
Control	90%	80%	.4	.17
.1	80%	80%		

TABLE 2. (Continued)

Concentration (ppm)	% Survival of Test Animals		LC50, ppm For Given Exposure Time 24 hr $\bar{x}$ S.D.	48 hr $\bar{x}$ S.D.
.4	50%	0%		
1.0	10%	0%		
4.0	10%	0%		
10.0	30%	0%		
	33850-39-18 4-Methylphenol			
Control	100%	90%	None	None
.1	100%	64%		
.4	100%	80%		
1.0	100%	100%		
4.0	90%	50%		
10.0	100%	100%		
Control	90%	90%	7.42	5.2
.1	80%	70%		
.4	90%	90%		
1.0	90%	80%		
4.0	70%	70%		
10.0	40%	0%		
Control	100%	100%	10.0	2.0
.1	100%	100%		
.4	90%	90%	8.71 ± 1.82	3.61 ± 2.28
1.0	100%	70%		
4.0	100%	30%		
10.0	50%	0%		
	33850-39-20 Dibenzothiophene			
Control	80%	60%	2.0	2.0
.1	80%	80%		
.4	100%	70%		
1.0	100%	100%		
4.0	0%	0%		
10.0	0%	0%		
Control	90%	80%	1.85	1.85
.1	80%	70%		
.4	100%	100%	1.93 ± .11	1.93 ± .11
1.0	90%	90%		
4.0	0%	0%		
10.0	0%	0%		

concentrating our efforts on the study of oil fractions that are soluble in DMSO or acetone.

DMSO has been used by various workers to extract aromatic components, especially polynuclear aromatic hydrocarbons (PAH) from oil dissolved in a saturated hydrocarbon solvent. The method also works well for separating PAHs from extracts of environmental samples. Other highly polar hexane-immiscible organic solvents such as nitromethane or ethylene glycol have been used effectively in place of DMSO.

We extracted fresh Prudhoe Bay crude oil with DMSO by dissolving 10 g of oil in 90 ml of hexane and extracting with 100 ml portions of DMSO. The DMSO extracts were then treated with three volumes of water and backextracted with methylene chloride. The methylene chloride extract was washed with water to remove traces of DMSO and dried over anhydrous sodium sulfate. Five repetitive extractions with DMSO yielded 4.2, 3.6, 1.5, 1.1, and 0.6 per cent of the oil, respectively, as extractable material for a total of 11.0 per cent extractables.

Acetonitrile was used in place of DMSO to extract both fresh and weathered Prudhoe Bay crude oil in a similar manner. Because acetonitrile is quite volatile, the solvent could be stripped off directly without dilution with water and back extraction. The amount of extractables recovered was 10.4 per cent for the fresh oil and 9.9 per cent for the weathered oil. Thus, from a total recovery standpoint, the use of acetonitrile appeared to give about the same results as DMSO. Since the two solvents are similar in many respects, it is very likely that extracts are also qualitatively similar.

A third solvent that was studied was acetone. In this case, 10 g of oil was shaken with 100 ml of acetone. About 40 per cent of the oil dissolved.

The soluble fractions obtained by the above methods should be much easier to work with than the whole oil because the major intractable components have been removed. The soluble fractions will be subfractionated by gel permeation chromatography (GPC) and adsorption chromatography followed by bioassay. GPC studies were conducted using Bio Beads SX-8 with methylene chloride as the mobile phase. The method worked very well for separating the oil into at least 10 discreet fractions in which aromatic hydrocarbons were well separated from paraffinic hydrocarbons. It was

also of interest to note that nearly all of the color was associated with high-molecular-weight material.

Acid Extraction

The acid-soluble components in oil are the nitrogen-containing bases, e.g. quinolines and carbazoles, which are relatively toxic and/or mutagenic. The acid-soluble fraction of fresh Prudhoe Bay crude oil was obtained by dissolving 100 g of oil in 400 ml of hexane, and extracting with 500 ml of 2N H_2SO_4 by equilibration for 20 hours. The aqueous acid extract was neutralized and backextracted with methylene chloride. The acid extractables amounted to only 0.04 per cent of the oil.

In Vitro Biological Screening Studies

The DMSO-extractable and acid-extractable fractions from fresh Prudhoe Bay crude oil were dissolved in DMSO to give solutions containing 125 mg/ml and 25 mg/ml, respectively. These solutions were then studied using the Ames Salmonella mutagenicity assay with activated microsomes. The results are given in Table 3. Both fractions were very toxic in the assay at levels above 0.5 mg per plate which represents about 200 ppm in the assay media. Despite the toxicity significant numbers of revertants were obtained indicating mutagenicity. The fractions will be assayed at lower levels, 0.01 to 0.1 mg/plate, to obtain a more valid assessment of mutagenicity.

The fact that both toxicity and mutagenicity were detected by the in vitro screening of the crude extracts is very encouraging becuase it means that we now have a reference point for following subsequent subfractionations. The originally proposed "activity-directed" fractionation can be applied to such fractions. This was not true for the whole oil for which no biological activity could be detected using the screening assay.

TABLE 3. MUTAGENICITY OF PRUDHOE BAY CRUDE OIL EXTRACTS

Salmonella Strain	Dose, mg Per Plate	Toxicity: Colonies Per Plate	Toxicity: Toxicity Factor[a]	Mutagenicity: Revertants Per Plate	Mutagenicity: Relative Mutagenicity[b]
		Acid Extractables			
98	2.5	0	>20	42	>20
	0.5	25	10.8	44	11
	0.1	106	2.5	53	3
	0	270	1.0	43	1
100	2.5	4	>20	0	--
	0.5	1	>20	32	>7
	0.1	21	5.5	52	3
	0	116	1.0	93	1
1537	2.5	0	>20	0	--
	0.5	0	>20	4	>13
	0.1	23	3.5	10	6
	0	81	1.0	6	1
		DMSO Extractables			
98	12.5	0	>20	0	--
	2.5	5	>20	34	>16
	0.5	33	8.2	67	13
	0	270	1.0	43	1
100	12.5	0	>20	0	--
	2.5	0	>20	41	>9
	0.5	1	>20	82	>18
	0	116	1.0	93	1
1537	12.5	0	>20	0	--
	2.5	0	>20	4	>13
	0.5	0	>20	11	>37
	0	81	1.0	6	1

a. $\frac{\text{Colonies in control}}{\text{Colonies in sample}}$

b. $\frac{\text{Revertants in sample}}{\text{Revertants in control}} \times$ Toxicity factor

FUTURE WORK PLANS

Our efforts during the next report period will include:

1. Fractionation of DMSO-soluble and acetone-soluble fractions from fresh and weathered oil by gel permeation chromatography using Bio Beads and/or Sephadex LH-20.
2. *In vitro* bioassay of fractions using the Ames mutagenicity assay and prescreen confluency assay for mammalian cell toxicity.

QUARTERLY REPORT

Contract # 3-5-022-56
Research unit 537
Task Order 32
Report Period 10/1/78 - 1/1/79
Number of pages: 4

NUTRIENT DYNAMICS IN NEARSHORE UNDER-ICE WATERS OF THE ALASKAN BEAUFORT SEA

Dr. Donald M. Schell

Institute of Water Resources
University of Alaska
Fairbanks, Alaska 99708

I. TASK OBJECTIVES

The overall objectives of this research unit are to investigate the trophic system dynamics of the primary producers in the nearshore waters of the Beaufort Sea, and to relate the observed nutrient regimes with the *in situ* primary production and the secondary production arising from the input of terrestrially derived carbon, nitrogen, and phosphorus. This work has been extended temporally to include winter aspects. The spatial coverage has been expanded eastward from Simpson Lagoon to the Stefansson Sound area in response to the upcoming Beaufort Sea oil and gas lease sale. Data gaps in the nutrient, salinity, and ice thickness information during late autumn were filled by this research unit as part of the Arctic Project Office's integrated winter studies program. The individual tasks, undertaken during the last quarter, can be summarized as follows.

1) Water samples and ice thickness measurements were collected for 21 stations between Foggy Island Bay and the Colville River delta. Stations were occupied within the lagoon systems and outside of the barrier islands at the edge of the shorefast ice.

2) Ammonia regeneration experiments were set up on the lagoon bottom at the intensive study site in Stefansson Sound utilizing divers with the RU 356 program.

3) Process studies were undertaken with water and epifaunal samples from Elson Lagoon to determine the rate of vegetative detritus oxidation. This work was performed at the Naval Arctic Research Laboratory at Point Barrow, Alaska.

II. FIELD ACTIVITIES

As part of the integrated winter studies program, personnel from this research unit participated in the nearshore sampling effort during 8-10 November 1978. Logistic support was provided by a NOAA helicopter and chartered helicopters. Figure 1 shows the station locations occupied during the sampling period. Station BP near Foggy Island Bay is the approximate location of RU 356's intensive study site and was chosen for the *in situ* ammonia regeneration experiments. The sampling efforts were aided by very favorable weather for this season and the entire

projected station list was sampled. At each station the ice was drilled using a 20cm diameter power auger and the drill chips noted for the presence or absence of incorporated detrital material. After completion of the hole, the ice thickness was measured and the water column sampled. In waters less than 3m, samples were taken just beneath the ice and at the bottom. In deeper offshore waters, samples were taken at approximately 4m intervals from surface to bottom.

Process studies to measure the rate of cellulose biodegradation in the under-ice waters of the Beaufort Sea were undertaken at the Naval Arctic Research Laboratory at Barrow. Water samples were collected at stations in Elson Lagoon, Smith Bay and Dease Inlet. A big-tired truck was used for transportation on Elson Lagoon and a Cessna 180 ski-equipped aircraft was used to sample the latter two locations.

A baited trap was set overnight in Elson Lagoon and, upon retrieval, approximately 200 amphipods were captured. These animals were used to investigate their ability to digest cellulose through a series of experiments employing ^{14}C -labeled cellulose mixed with peat samples obtained from Simpson Lagoon.

III. LABORATORY ACTIVITIES

Carbon isotope studies. Specimens of fauna and basal peat samples from the Simpson Lagoon area were analyzed for ^{14}C and $^{13}C/^{12}C$ isotope ratios. Depressions in the radiocarbon age were found for four-horn sculpins, amphipods, mysids, and saduria obtained from the lagoon. This indicates a movement of eroded peat carbon following microbial consumption up the food chain into higher organisms. The anadromous fish dated yielded modern ages which has inferences concerning their utilization of the lagoon epifauna as a primary food source. Final interpretation of carbon isotope results is pending the receipt of replicate sample dates and additional basal peat ages.

The microbial activity in the detrital peat materials was investigated at the Naval Arctic Research Laboratory at Point Barrow. Samples of seawater were incubated with ^{14}C-labeled cellulose and aliquots were taken at approximately 12- hour intervals. These aliquots were acidified and stripped with nitrogen to remove the carbon dioxide

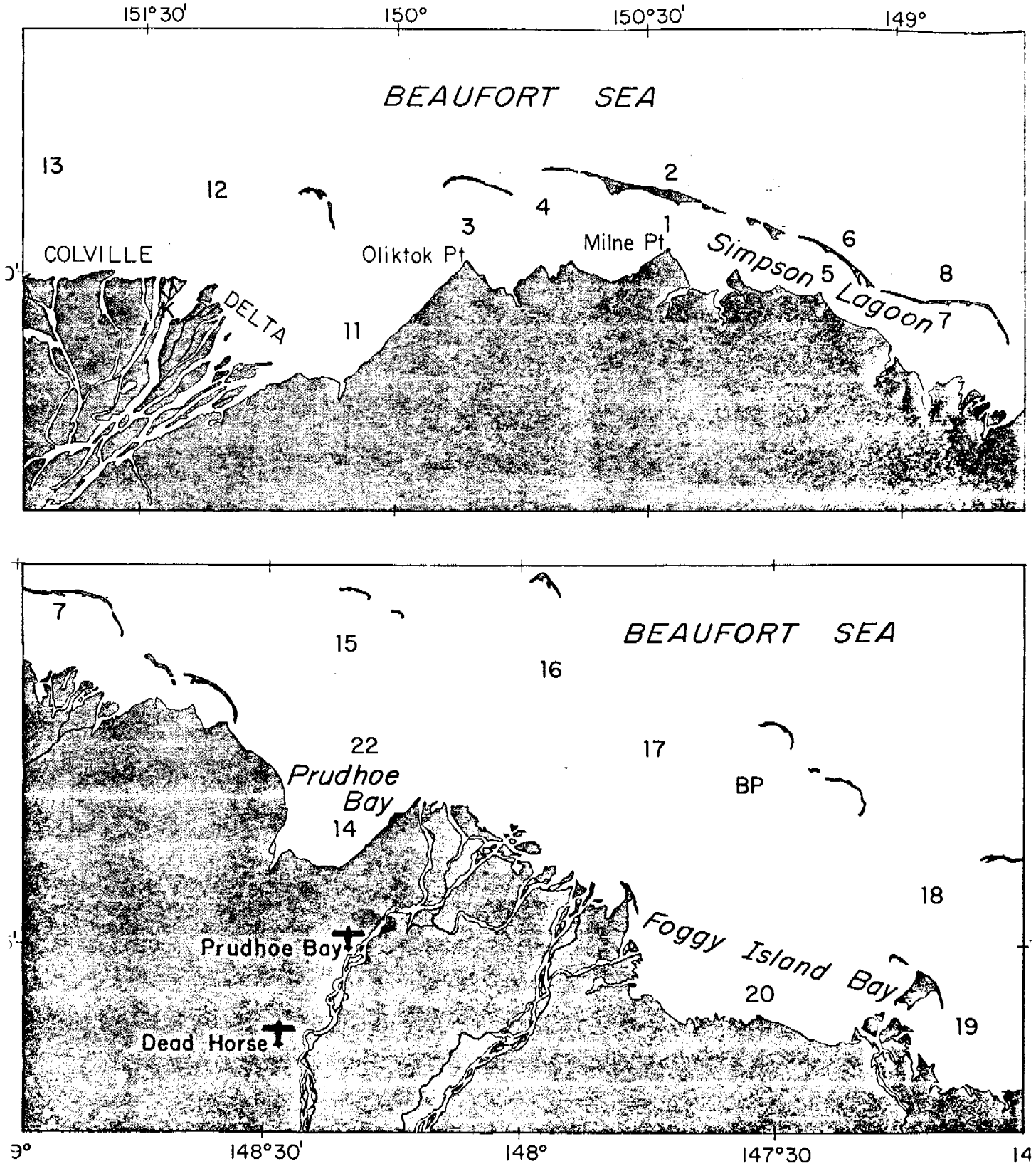
fraction, which was subsequently absorbed in phenethylamine liquid scintillation cocktail. These experiments, conducted at 0° and 20°, showed active microbial decomposition and oxidation of the labeled cellulose, with the fastest rates occuring at 20°.

To test the hypothesis that amphipods might possess intestinal microflora which would be active cellulose degraders (and thus be able to symbiotically contribute to the nutrition of the amphipods), an experiment was conducted using freshly captured animals fed on radio-labeled cellulose. Animals were offered both carrier-free and a mix of labeled cellulose and peat aged in seawater. A control of peat plus labeled cellulose without amphipods was used to determine the oxidation rate due to microflora alone. At 12 hour intervals, animals were sampled and aliquots of seawater stripped for radiolabeled carbon dioxide as described above. The results of these experiments indicated that no oxidation of cellulose could be ascribed to the amphipods tested or to associated microflora. Substantial oxidation rates were observed in the peat-only sample and there appeared to be some depression of this activity in the sample containing amphipods and peat. This may be due to grazing of meiofauna and microflora by the amphipods, which were observed to be actively feeding during the course of the experiment.

IV. PROBLEMS ENCOUNTERED

No problems were encountered in either field data collection or laboratory experimental work.

8-10 NOV. WINTER 1978



OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: December 31, 1978

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 32 R.U. NUMBER: 537

PRINCIPAL INVESTIGATOR: Dr. D. M. Schell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan

Cruise/Field Operation	Collection Dates From	Collection Dates To	Estimated Submission Dates[1] Batch 1		
Dease Sampling Trip 1	3/31/77		6/30/78		
Elson Lagoon Sampling Trip 1	5/23/77		6/30/78		
Simpson Lagoon Sampling Trip	4/78 - 8/78		3/31/79		
Simpson Lagoon Stefausson Sound	11/78		6/30/79		
Smith Bay Dease Inlet, Elson Lagoon	11/78		6/30/79		

Fiscal Report

Contract: 03-5-022-56

Task Order: #32

Date: December 22, 1978

Category	Billed this Quarter	Cumulative Billed
Salaries and Wages	$4,358.38	$35,158.27
Travel	250.50	409.05
Equipment	416.80	663.56
Other	538.22	1,243.90
Staff Benefits	671.17	6,218.45
Overhead	2,179.19	17,579.14
Total Billed	$8,414.26	$61,272.37
Total Award		$133,412.00
Total Unbilled		72,139.63

These data are taken from University of Alaska vouchers submitted in the three months prior to the above date.

EFFECTS

Contents

October 1-December 31, 1978
Research Unit # 72

Quarterly Report

Sensitivity of 39 Alaskan Marine Species To Cook Inlet Crude Oil and No. 2 Fuel Oil

Stanley D. Rice et al.
NOAA/NMFS/NAFC
Auke Bay, Alaska

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Auke Bay Fisheries Laboratory
P. O. Box 155, Auke Bay, Alaska 99821
(907) 789-7231

Date : January 4, 1979

Reply to Attn. of: F11x9

To : Dr. Herbert E. Bruce, Manager, Juneau Project Office, OCSEAP

From : Dr. William A. Smoker, Director

Subject: Quarterly Report--RU 72, October-December 31, 1978

The current OCSEAP contract calls for bioassays of arctic animals. All experimental bioassays are scheduled for the second half of FY 79. We have begun planning for the upcoming research effort and have begun arrangements for logistics to collect arctic animals. R and D is continuing as we are continuing experiments under internal NMFS funding to refine our flow-through systems.

Some experiments started in FY 78 under OCSEAP funding are continuing under NMFS funding in FY 79. These projects will be reported in greater detail in the annual report due next quarter.

Attached is a manuscript, "Sensitivity of 39 Alaskan Marine Species to Cook Inlet Crude and No. 2 Fuel Oil" by Rice, Moles, Taylor, and Karinen, that has been accepted for presentation and publication at the 1979 Oil Spill Conference in Los Angeles (March 19-22).

Enclosure

cc: Murray Hayes
Merrell
Rice
Karinen

SENSITIVITY OF 39 ALASKAN MARINE SPECIES TO COOK INLET CRUDE OIL AND NO. 2 FUEL OIL

by

Stanley D. Rice, Adam Moles, Tamara L. Taylor, and John F. Karinen

Northwest and Alaska Fisheries Center Auke Bay Laboratory

National Marine Fisheries Service, NOAA

P.O. Box 155, Auke Bay, AK 99821

ABSTRACT

Sensitivities were determined for 39 subarctic Alaskan species of marine fish and invertebrates to water-soluble fractions of Cook Inlet crude oil and No. 2 fuel oil. This is the largest group of animals ever tested under similar test conditions with the same petroleum oils and analytical methods. Organisms bioassayed represent several habitats, 6 phyla, and 39 species including fish (9), arthropods (9), molluscs (13), echinoderms (4), annelids (2), and nemerteans (2). Sensitivities were determined by 96-h static bioassays. Concentrations of selected aromatic hydrocarbons were determined by gas chromatography; concentrations of paraffins were determined by infrared spectrophotometry.

Although sensitivity generally increased from lower invertebrates to higher invertebrates and from higher invertebrates to fish, sensitivity was better correlated to habitat. Pelagic fish and shrimp were the most sensitive animals to Cook Inlet crude oil with 96-h TLm's from 1-3 mg/l total aromatic hydrocarbons. Benthic animals, including fish, crabs, and scallops were moderately tolerant (TLm's to Cook Inlet crude oil of 3-8 mg/l total aromatic hydrocarbons). Intertidal animals, including fish, crabs, and starfish, and many molluscs, were the most tolerant forms to water-soluble fractions of

petroleum (TLm's greater than 8-12 mg/l of total aromatic hydrocarbons). Most of the intertidal animals were not killed by static oil exposures. No. 2 fuel oil was more toxic to most species than Cook Inlet crude oil.

Sensitive pelagic animals are not necessarily more vulnerable to oil spills than tolerant intertidal forms--oil may damage intertidal environments more easily and adverse effects may persist longer than in damaged pelagic environments.

INTRODUCTION

In nearshore and offshore marine waters of Alaska, exploration, extraction, refinement, and transportation of oil will increase. To make objective decisions about where and under what environmental conditions future offshore lease sales should be held, as well as oil transport logistics, managers will need hydrocarbon toxicity information that identifies sensitive species, life stages, and habitats in Alaskan marine waters.

There are three major problems in applying information in the literature on oil toxicity to the Alaskan environment: (1) Much of the literature prior to 1973 does not present chemical analyses of oil-water solutions; thus, it is impossible to compare oil toxicities and animal sensitivities in different studies. (2) More recent literature is usually quantitative, but the studies generally emphasize animals from warmer environments (>12°C) that are not characteristic of Alaskan waters. Results from quantitative studies in warmer environments are not applicable to colder environments because temperature is known to affect both the toxicity of oil through increased persistence of soluble aromatic fractions and the sensitivities of animals (Rice et al. 1976, 1977; Korn et al. 1979). Extrapolating oil toxicity data from warmer environments to colder environments is tenuous at best. (3) Studies cannot be compared when water-soluble oil concentrations are determined by different

analytical methods. For example, oil concentrations measured by infrared (IR) spectrophotometry are not equivalent to concentrations measured by gas chromatography (GC) because each method is measuring different compounds within the mixture. No single analytical tool can adequately quantitate all of the individual compounds or classes of compounds in oil-water solutions because oil is a complex mixture of many hydrocarbon compounds of varying size, solubility, and vapor pressure. Comparisons of toxicities within a study are usually valid because the same analytical method has been used; thus, the method will provide a relative index of oil concentration and toxicity even if it does not measure the entire toxic fraction.

The objective of this study was to determine and compare the sensitivities of 39 Alaskan marine species tested statically with the water-soluble fraction (WSF) of Cook Inlet crude oil and No. 2 fuel oil. Our data are intended to provide environmental managers with a large information base on oil toxicity that can be used to compare the vulnerability of different Alaskan species collected from several different habitats. These data are not intended for direct extrapolation to possible ecological effects of oil spills, which would require controlled field toxicity experiments.

The WSF was measured with a gas chromatograph because GC analyses quantify the aromatic hydrocarbons, the most toxic fraction of crude oil (Neff et al. 1976; Rice et al. 1977). We included oil-water measurements by IR because in earlier research this method was used extensively; although, it primarily measures the relatively non-toxic paraffin fraction of the WSF.

METHODS

Test animals were collected in southeast Alaska by beachcombing, beach seining, diving, trawling, or in shrimp pots. All animals were adults or, in a few cases, they were juveniles if the adults are large (e.g., king crab,

pink salmon fingerlings, flounders). Prior to testing, animals were held for 3 days to 3 weeks in flowing seawater at 4° to 8°C and salinities of 26 to 30°/$_{oo}$ depending on the season. All animals were fed during acclimation, but not during the tests.

Animals were exposed to static dilutions of the WSF of Cook Inlet crude oil and No. 2 fuel oil. The WSF's were prepared by mixing 1% oil in seawater for 20 h. The mixture was allowed to settle for 3 h before the water-soluble portion was siphoned from under the slick (Taylor and Karinen 1977). The glass test containers received dilutions of the WSF's and no more than 1 gram of tissue per liter of WSF. All WSF concentrations were analyzed at the beginning of each test. Static concentrations declined in 96 h, by evaporation and biodegradation, to about 20% of the initial concentration. Test solutions were aerated slowly (one bubble/second), and depending on season, their temperatures were held at 4° to 8°C. Mobile intertidal animals were restrained from leaving the water by holding them in perforated polyethylene boxes suspended in the water. The test animals were transferred to uncontaminated flowing water after 96 h of oil exposure and held for 24 h before final mortalities were checked. Death was defined as no movement when prodded.

Ninety-six hour median tolerance limits (96-h TLm--concentration that killed 50% of the animals after 96 h) were calculated by logit analysis (Silverstone 1957); associated 95% confidence limits were derived from the variance.

Concentrations of the WSF's were measured by infrared spectrophotometry and gas chromatography. Water samples for IR analysis

were extracted with Freon[1] and the absorbance of the extracts was measured at 2930 cm^{-1} with an IR spectrophotometer (Gruenfeld 1973). Results are expressed as mg/l of oil.

Water samples for GC analyses were extracted with methylene chloride. A small aliquot of the extract was analyzed for mono-aromatic hydrocarbons. The analyses for di-aromatic hydrocarbons required increased sensitivity; consequently, the remainder of the extract was concentrated by evaporation with nitrogen after the addition of n-decane and n-hendecane as internal standards.

The GC analyses of the soluble aromatic hydrocarbons were performed with a Tracor[1] Model 550 gas chromatograph. Sample-run conditions were as follows: 10 ft by 1/8 in. stainless steel column with 10% SP-2100 on 100/120 Supelcoport[1], flow-rate 20 ml/min N_2, flame ionization detector, sample size 1.5 µl, inlet temperature 225°C, outlet temperature 300°C, detector temperature 350°C. Column temperature for mono-aromatic hydrocarbons was 50°C for 4 min, then 6°C/min up to 80°C. Column temperature for di-aromatic hydrocarbons was isothermal at 140°C. The concentrations of benzene, toluene, o-, m-, p-xylene, 3-C benzene, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, and dimethylnaphthalenes were added to give a fairly precise estimate of the "total" aromatic hydrocarbons in solution.

COMPARISON OF SENSITIVITIES TO COOK INLET CRUDE OIL

Some species were sensitive to 96-h exposures of oil, while others were not (Table 1). We have arbitrarily identified three gradations of sensitivity. Highly sensitive species, which included most of the pelagic fish and shrimp,

[1] Reference to trade names does not imply endorsement by National Marine Fisheries Service, NOAA.

had TLm's less than 3 mg/l "total" aromatic hydrocarbons. The moderately sensitive species had TLm's of 3 to 8.45 mg/l "total" aromatic hydrocarbons and included one shrimp, one bottom fish, two crabs, a scallop, and one lower intertidal limpet. Tolerant species were resistant to 4-day exposures and did not die in the highest concentrations we could generate (8-12 mg/l "total" aromatic hydrocarbons). Tolerant species included one bottom fish, two intertidal fish, and most of the intertidal echinoderms, hermit crabs, limpets, chitons, clams, snails, and worms.

The most sensitive species were generally pelagic; the moderately sensitive species were either benthic or intertidal forms; and the tolerant species were predominantly from the intertidal zone. There were some exceptions, such as the tolerant subtidal amphipods and mysids. Fish were collected from several habitats, and demonstrated the correlation of sensitivity with habitat. Five species of pelagic fish were sensitive. One bottom fish (great sculpin) was moderately sensitive, while another (starry flounder) was tolerant. The two species of intertidal fish (crescent gunnel and high cockscomb prickleback) were collected under rocks at low tide and were quite tolerant (none died in the highest exposures--11.72 mg/l "total" aromatic hydrocarbons).

The intertidal species of all phyla are the most tolerant forms, indicating that tolerance is related to habitat adaptation rather than phylogenetic adaptation. The intertidal zone is a rigorous environment where animals must survive periodic desiccation, a wide range of air temperatures, varying salinities, and varying surf conditions. The severity of these stresses depends on elevations in the intertidal zone, tides, season, and weather. Most invertebrates in the intertidal environment minimize these stresses by temporarily isolating themselves from the environmental stress. For example,

the intertidal molluscs temporarily avoid the adverse conditions by closing the shell; other species may use behavioral adaptations, such as hiding in the moist sand under rocks. Most species decrease metabolic demands, and some shift to anaerobic metabolism (Zwann et al. 1976).

Many tolerant species were obviously affected, although they survived the higher exposures. At the highest concentrations tested (8-12 mg/l total aromatic hydrocarbons), the amphipods and mysids stopped swimming but continued to move; starfish, urchins, and subtidal snails could not remain attached to the glass exposure containers; the lined chiton could not right itself; and the hermit crabs left their shells. Many of these animals recovered within a few days after they were returned to clean water; but, if high exposures occurred in the natural environment, survival would be unlikely because these animals would be vulnerable to predation and buffeting by surf action. Several intertidal molluscs, such as the mussel, little neck clam, limpets, chitons, and snails, were not affected at the same high exposure levels.

Our study determined and compared the sensitivities of adult or juvenile animals, but not eggs or larvae. We suspect that the sensitivities of larvae from intertidal animals are much greater than the sensitivities of adults because the larvae are probably not adapted to the rigorous intertidal environment during their pelagic life stages. However, generalizations about untested life stages should be avoided because sensitivities of larvae have been found to vary considerably between life stage (Neff et al. 1976; Rice et al. 1977). Consequently, our data on adult or juvenile sensitivities should not be used to guess the potential vulnerability of larval fishes and invertebrates.

Although static tests are the most practical when used to compare numerous species, static oil tests are not the best method for comparing sensitivities of sensitive pelagic species and tolerant intertidal species. In our static tests, oil concentrations declined in 96 h to approximately 20% of the initial concentrations. Tolerant species that "clam up" and decrease metabolic functions may not have sufficient time to accumulate toxic concentrations in their tissues. Brodersen (unpublished data) tested and compared the sensitivities of several tolerant and sensitive Alaskan species in static and flow-through tests with toluene and naphthalene. The differences between TLm's of static and flow-through tests were most different with the tolerant intertidal species. However, the sensitivities of tolerant species in flow-through tests never increased to the level where they were equivalent to the sensitivities of pelagic species. Consequently, we conclude that pelagic species are generally more sensitive to short-term oil exposures than tolerant intertidal species.

COMPARISON OF TOXICITY BETWEEN COOK INLET CRUDE OIL AND NO. 2 FUEL OIL

For the various types of animals the patterns of sensitivity for both Cook Inlet crude oil and No. 2 fuel oil were the same. Pelagic animals that were sensitive to crude oil were also sensitive to No. 2 fuel oil; tolerant intertidal species were tolerant to both oils (Table 2). For the sensitive species, No. 2 fuel oil was consistently more toxic than Cook Inlet crude oil, as shown by lower TLm's. When measured by GC, the TLm's for No. 2 fuel oil ranged from 10 to 59% of the TLm's for crude oil; when measured by IR, TLm's for No. 2 fuel oil were 18 to 36% of the TLm's for crude oil.

Parent crude oil and No. 2 fuel oil have different chemical compositions, and thus have WSF's of different composition and toxicity (Table 3). The

stock WSF of crude oil contained more aromatic hydrocarbons and had a different ratio of mono- to di-aromatic hydrocarbons than the stock WSF of No. 2 fuel oil (the crude oil WSF had a ratio of mono- to di-aromatic hydrocarbons of 15.7/1; the WSF of No. 2 fuel oil had a ratio of mono- to di-aromatic hydrocarbons of 1.1/1). The mono-aromatic hydrocarbons (benzene and derivatives) contribute to the toxicity of WSF's, but are about 1/10 as toxic as di-aromatic hydrocarbons (naphthalene) (Neff et al. 1976; Caldwell et al. 1977; Rice et al. 1977); however, mono-aromatic hydrocarbons compared to di-aromatic hydrocarbons are more soluble in water, and thus, produce higher concentrations in the WSF. TLm's of crude oil, measured as "total" aromatic hydrocarbons by GC, reflected concentrations of toxic solutions that consisted of a large percentage of the less toxic mono-aromatic hydrocarbons. In contrast, the observed toxicity of No. 2 fuel oil was probably caused by small concentrations of highly toxic di-aromatic hydrocarbons.

The relative contribution of each compound, or class of compounds, to the toxicity of a WSF is not known; although, WSF's with different hydrocarbon compositions have different toxicities. Understanding the toxicity of oil WSF's is greatly hindered because little is known about the mechanism of oil toxicity (the mechanism probably varies between classes of compounds) and because nothing is known about the toxicity of any of the aromatic hydrocarbons when associated with each other, with paraffins, or with other compounds present in the WSF (e.g., phenols, naphthols).

COMPARISON OF TLM'S FROM IR AND GC ANALYSES

Generally, whether oil concentrations were measured by IR or GC, the more tolerant animals had TLm's that were greater than TLm's of sensitive animals. The more toxic solutions of crude oil and No. 2 fuel oil contained

both more aromatics and more paraffins than less toxic solutions (Table 2, Fig. 1); however, TLm's determined by IR and GC for individual species do not correlate well. Oil concentrations determined by IR and GC analysis of the same toxic solutions of Cook Inlet crude WSF's had a significant correlation (r^2 = 0.644, $\underline{P}$ <0.01). Oil concentrations of No. 2 fuel oil WSF's, measured by IR and GC also had a positive trend (r^2 = 0.312); but, the correlation was not significant ($\underline{P}$ > 0.05). The differences between results measured by IR and GC occurred because the IR method measures paraffins, which are not the primary toxic components of a WSF. The ratio of paraffins to aromatic hydrocarbons varies between WSF's. When prepared from the same oil, WSF's are not simple proportional dilutions of the parent oil, but are water extracts of the oil. The ratio of paraffins to aromatics depends on several factors (temperature, mixing energy, and others) that affect hydrocarbon solubility and oil-droplet dispersion (Rice et al. 1977). Although there is a correlation between IR and GC measurements for Cook Inlet WSF in our study, the correlation is not appropriate for any other oil, or for Cook Inlet crude oil mixed under conditions different from ours. Bean et al. (1978) also found differences between IR and GC measurements of oil-water solutions and concluded that IR analyses provide no useful information on actual levels of hydrocarbons in mixtures with a preponderance of water-soluble aromatic hydrocarbons.

Managers using results from laboratory studies on oil toxicity should be cautious about comparing sensitivities of animals that were tested in different studies. Comparisons between studies using different analytical methods are inappropriate. For example, mg/l of oil measured by IR are not equivalent to mg/l of aromatic hydrocarbons measured by GC. Even studies that appear to use the same analytical methods may not be comparable. For example, IR

measurements have been used extensively in past studies (reviewed by Craddock 1977), but each study used different oils or mixing procedures, which would affect the paraffin/aromatic-hydrocarbon ratio. Even in analyses by GC, which measure the toxic aromatic fraction, the techniques are not uniform and some procedures are not effective at extracting and measuring the highly volatile mono-aromatics. If two GC procedures are not measuring the same aromatic hydrocarbons with equal effectiveness, then comparisons between studies will be invalid. Consequently, there is little point in comparing animal sensitivities derived from experiments of different investigators, although the comparisons and conclusions within a study are usually valid.

SENSITIVITY VERSUS VULNERABILITY OF ALASKAN SPECIES TO OIL

Pelagic animals were the most sensitive of species tested with oil, but they may not be the most vulnerable to oil spilled in the environment. These species are mobile, and can avoid a spill. Even if these species could not avoid an oil spill or oily effluent, they would probably survive because the oil and water would have to be mixed violently and possibly in a semi-enclosed environment, as in a bay, to produce a significantly toxic concentration. Alhough we could determine that the pelagic habitat was contaminated, we could not demonstrate actual damage to the habitat.

Although benthic and intertidal species were more tolerant to short-term exposure, the potential for high concentrations of toxicity occurring during exposure is greater because of mixing and entrainment of the oil in the shallow nearshore waters. Furthermore, habitats of benthic and intertidal species are particularly susceptible to physical oil contamination. Habitat that is coated with oil may erode or provide unsuitable substrate for grazing or for settling of larval stages. Oil on a polluted substrate may persist for a

long time and subsequently release toxicants continously. There presently are no comparative data on the sensitivity of pelagic, benthic, or intertidal species to chronic oil exposures.

The pelagic species in this study were more sensitive to short-term exposures of oil; the benthic and intertidal species were more tolerant to oil exposure. However, deciding which species are more vulnerable is a complex question that requires consideration of the species, life stage, amount and length of exposure, and interaction of the oil and animal with the physical and biological environment. Environmental managers should be aware of the limitations of the data from individual experiments and not make oversimplified conclusions.

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FIGURE LIST

1. Linear relationship of oil-water concentrations of the same toxic solutions of Cook Inlet crude oil and No. 2 fuel oil measured by infrared spectrophotometry and gas chromatography. For Cook Inlet crude oil, the equation is $y = 1.656 + 0.56x$ (correlations coefficient of $r^2 = 0.644$, $P < 0.01$). For No. 2 fuel oil, the equation is $y = 0.023 + 1.18x$ (correlation coefficient of $r^2 = 0.312$, $P < 0.1$).

Table 1. Sensitivities of 38 Alaskan Marine Species to Cook Inlet crude oil. 96-h TLm's are in mg/l of total aromatics determined by GC, with 95% confidence intervals in parentheses.

Scientific Names	Common Names	Habitat	°96 h TLm total aromatics
Fish			
1. Clupea pallasi	Pacific herring	pelagic	1.22 (0.88-1.56)
2. Salvelinus malma	Dolly Varden	pelagic	1.55 (1.30-1.80)
3. Oncorhynchus gorbuscha	pink salmon	pelagic	1.69 (1.47-1.83)
4. Theragra chalcogrammus	Walleye pollock	pelagic	1.73 (1.37-2.09)
5. Aulorhynchus flavidus	tubesnouts	pelagic	2.55 (2.06-3.03)
6. Myoxocephalus polyacanthocephalus	great sculpin	benthic	3.96 (3.52-4.40)
7. Platichthys stellatus	starry flounder	benthic	>5.34
8. Pholis laeta	crescent gunnel	intertidal	>11.72
9. Anoplarchus purpurescens	cockscomb prickleback	intertidal	>11.72
Crustaceans			
10. Crangon alaskensis	grass shrimp	subtidal	0.87 (0.83-0.91)
11. Pandalus goniurus	humpy shrimp	subtidal	1.79 (1.53-2.04)
12. Eualus suckleyi	kelp shrimp	subtidal	1.86 (1.66-2.07)
13. Pandalus borealis	pink shrimp	subtidal	4.94 (3.20-5.60)
14. Paralithodes camtschatica	king crab	benthic	3.69 (2.65-4.73)
15. Hemigrapsis nudus	purple shore crab	intertidal	8.45 (8.32-8.58)
16. Pagurus hirsuiticulus	hairy hermit crab	intertidal	>10.58
17. Orchomene pinguis	amphipod	planktonic	>7.98
18. Acanthomysis pseudomacropsis	mysid	planktonic	>9.02
Echinoderms			
19. Cucumaria vega	tarspot	intertidal	>6.84
20. Strongylocentrotus drobachiensis	green sea urchin	intertidal	>10.58
21. Leptasterias hexactis	six-armed starfish	intertidal	>10.58
22. Eupentacta quinquesimita	white cucumber	intertidal	>12.29
Mollusks			
23. Chlamys hericus	pink scallop	benthic	3.94 (3.52-4.39)
24. Mytilus edulis	blue mussel	intertidal	>8.97
25. Protothaca staminea	little neck clam	intertidal	>6.84
26. Collisella scutum	plate limpet	intertidal	8.18 (6.14-10.96)

Table 1. continued.

Scientific Names	Common Names	Habitat	°96 h TLm total aromatics
27. Notoacmaea pelta	shield limpet	intertidal	>8.46
28. Katharina tunicata	leather chiton	intertidal	>8.46
29. Tonicella lineata	lined chiton	intertidal	>8.46
30. Mopalia cilliata	ciliated chiton	intertidal	>8.46
31. Margarites pupillus	purple margarite	intertidal	>8.46
32. Littorina sitkana	Sitka periwinkle	intertidal	>8.46
33. Thais lima	file periwinkle	intertidal	>8.46
34. Colus halli	Hall's colus	benthic	>8.98
35. Neptunea lyrata	ridged whelk	benthic	>10.58
Annelids			
36. Nereis vexillosa	mussel worm	intertidal	>10.58
37. Harmothoe imbricata	scale worm	intertidal	>10.58
Nemerteans			
38. Paranemertes peregrina	purple ribbon worm	intertidal	>10.58
39. Lineus vegetus	brown ribbon worm	intertidal	>10.58

Table 2.--96-h TLm's (with corresponding 95% confidence interval) for Alaskan marine species sensitive to Cook Inlet crude oil and No. 2 fuel oil. TLm's are reported in mg/l total aromatics as measured by gas chromatography and mg/l total hydrocarbons are measured by infrared spectrophotometry.

Species	Cook Inlet Crude Oil		Fuel Oil	
	96-h TLm IR (mg/l)	96-h TLm total aromatics (mg/l)	96-h TLm IR (mg/l)	96-h TLm total aromatics (mg/l)
Fish				
1. Oncorhynchus gorbuscha	1.50(1.29-1.71)	1.69(1.47-1.83)	0.54(0.52-0.55)	0.97(0.90-1.06)
2. Salvelinus malma	2.27(1.94-2.60)	1.55(1.30-1.80)	0.72(0.67-0.78)	0.15(0.14-0.16)
3. Myoxocephalus polyacanthocephalus	3.82(3.51-4.13)	3.96(3.52-4.40)	2.41(2.15-2.67)	1.31(1.25-1.37)
4. Platicthys stellatus	>4.69	>5.34	>1.72	>0.97
5. Pholis laeta	>5.89	>11.72	>1.72	>0.97
Crustaceans				
6. Orchomene pinguis	>7.40	>7.98	>0.48	>1.74
7. Acanthomysis pseudomacropsis	>9.12	>9.02	>0.45(0.36-0.57)	2.31(1.85-2.88)
8. Eualus suckleyi	3.94(3.49-4.39)	1.86(1.66-2.07)	0.59(0.41-0.77)	1.10(0.90-1.30)
9. Crangon alaskensis	2.19(2.08-2.30)	0.87(0.83-0.91)	0.43(0.38-0.49)	0.36(0.31-0.41)
10. Pagurus hirsuiticulus	>6.94	>10.58	>8.19	>3.36
11. Paralithodes camtschatica	4.70(4.10-5.30)	3.69(2.65-4.73)	0.81(0.72-0.90)	1.02(0.93-1.11)
Mollusks				
12. Collisella scutum	3.65(2.62-5.08)	8.18(6.14-10.96)	>8.19	>3.36
13. Chlamys hericus	5.20(4.11-6.29)	3.94(3.52-4.39)	>8.19	>3.36
14. Katharina tunicata	>8.72	>8.46	>8.19	>3.36
15. Mytilus edulis	>7.41	>8.98	>4.19	>1.25
16. Thais lima	>8.72	>8.46	>8.19	>3.36
Annelids				
17. Nereis vexillosa	>6.94	>10.58	>8.19	>3.36
Nemertean				
18. Paranemertes peregrina	>6.94	>10.58	>8.19	>3.36
Echinoderms				
19. Leptasterias hexactis	>6.94	>10.58	>8.19	>3.36

Table 3. Differences in the mono- and di-aromatic hydrocarbon composition of typical water soluble fraction stocks of Cook Inlet crude and No. 2 fuel oil.

	Cook Inlet Crude mg/l	No. 2 Fuel Oil mg/l
Benzene	2.58	0.11
Toluene	2.32	0.17
o-Xylene	0.42	0.12
m-p Xylene	0.91	0.17
3-C Benzenes	0.28	0.18
Naphthalene	0.17	0.15
1-Methylnaphthalene	0.06	0.13
2-Methylnaphthalene	0.11	0.25
Dimethylnaphthalene	0.06	0.14
Total mono-aromatic hydrocarbons	6.51	0.75
Total di-aromatic hydrocarbons	0.40	0.67
Ratio of mono-/di-aromatic hydrocarbons	15.7/1	1.1/1
Total aromatic hydrocarbons - GC	6.91	1.42
Total hydrocarbons - IR	9.76	1.26

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SUBLETHAL EFFECTS OF PETROLEUM HYDROCARBONS AND TRACE METALS, INCLUDING BIOTRANSFORMATIONS, AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, PATHOLOGICAL, AND BEHAVIORAL INDICES

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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 hydrocarbons and trace metals.

Behavior

Studies concerning avoidance of sediment containing Prudhoe Bay crude oil (PBCO) by juvenile English sole (Parophrys vetulus) and Dungeness crabs (Cancer magister) have been completed. Previously reported one-day tests with flatfish indicated no avoidance of oiled sediment which contained 2.5% PBCO (initial concentration, v/v). In the current 15-day test with oiled sediment containing 5% PBCO, there was also no evidence of avoidance; however, there were some flatfish mortalities. Juvenile Dungeness crabs did not avoid the surface of oil-contaminated sediment and suffered no mortalities. However, in contrast to their behavior on unoiled sediment in which they frequently buried themselves, the crabs did not bury in oiled sediment unless alarmed.

Pathology

Further investigations on the effects of exposing starry flounder (Platichthys stellatus) to sediment contaminated with 0.5% (v/v) PBCO were performed. In an experiment described in the previous quarterly report, no substantial differences were detected between control and oil-exposed starry flounder after 62 days of exposure. Both groups had similar degrees (ranging from normal to severe) of hepatocellular vacuolization during the course of the experiment, which after extensive histochemical analyses performed during the present quarter has been demonstrated to be lipid vacuolization. No differences were detected between the staining characteristics or morphology of the hepatocellular vacuoles of oil-exposed and control fish. A three- to four-month experiment employing a similar protocol was recently initiated in which young-of-the-year English sole are being exposed to "high-silt" sediment contaminated with 1% (v/v) PBCO.

Morphology

Studies on the structure of eggs from several teleosts have revealed great differences among the surfaces as well as differences in the internal structure of egg membranes.

It was observed in laboratory tests that microscopically detectable petroleum droplets adhered to the surface of herring (Clupea harengus pallasi), but nottothe surface of walleye pollock(Theragra chalcogramma) eggs. Possible relationships between egg membrane structure and damage from petroleum will be explored, as experiments on effects of petroleum on developmental biology of fishes are continued.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Lowering of seawater temperature (4^{o} vs. 12^{o}C) resulted in significant ($p<0.05$) increases in both the concentrations and residence times of naphthalene and its metabolites in tissues of starry flounder fed tritiated naphthalene. The magnitude of increased concentrations was much greater for naphthalene than for metabolites, probably because bioconversion of naphthalene was considerably less at the lower temperature. No marked difference was observed between the patterns of metabolites accumulated in tissues at 4^{o} and 12^{o}C.

Biotransformation of Petroleum Hydrocarbons

Work was continued on the food-web transfer of petroleum hydrocarbons. Data were collected, at two feeding times, on levels of the major metabolites of 2,6-dimethylnaphthalene (2,6-DMN) in the digestive tract and gonads of sea urchins (Strongylocentrotus droebachiensis) feeding on seaweed (Fucus districhus) containing 2,6-DMN. In addition, the total radioactivity contained in the urchin test (i.e., shell) and the spines, but not released by solvent extraction, was determined for the two feeding periods. Major metabolites in both the digestive tract and gonads were conjugates of 2,6-DMN and ranged in concentrations from nanograms per gram of dry tissue to fractions of a nanogram per gram of dry tissue.

OBJECTIVES

This interdisciplinary study has a series of objectives designed to evaluate the effects of petroleum on marine organisms. The specific objectives of work performed during the current quarterly period of October 1, 1978, to December 31, 1978, are as follows:

Behavior

To determine if flatfish and crab avoid PBCO-contaminated sediment.

Pathology

To define the uptake and disposition of petroleum hydrocarbons by flatfish exposed to crude-oil-contaminated sediments, and to characterize possible pathological effects resulting from long-term exposure.

Morphology

1. To define degrees and types of variations in membrane structure of teleost fish eggs for use in assessing relationships between membrane structure and susceptibility to petroleum. 2. To determine if petroleum droplets adhere to teleost fish eggs.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

To assess influence of environmental temperature on metabolism and dispo-

sition of naphthalene in starry flounder.

Biotransformation of Petroleum Hydrocarbons

(1) To delineate the formation of individual metabolites of 2,6-DMN in the digestive tract and gonads of urchins feeding on Fucus exposed to 2,6-DMN in seawater (our earlier work showed no evidence for the bioconversion of this compound in Fucus; (2) to determine the accumulation of 2,6-DMN and/or its total metabolites (radioactivity not extracted by solvents) in the test plus spines at two feeding periods (three days and 14 days); (3) to ascertain if thin-layer chromatography (TLC) profiles for metabolites were different at the two feeding periods, and (4) to ascertain if the level of "bound" radioactivity in the solvent-extracted test plus spines was different at the two feeding periods.

FIELD OR LABORATORY ACTIVITIES

SHIP OR FIELD TRIP SCHEDULE - N/A

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; physiological and pathological studies
N. Karrick	Principal investigator; chemical investigations
D. Weber	Principal investigator; behavioral studies
E. Gruger, Jr., PhD	Coordinator of chemical analyses and reports to OCSEAP
W. Roubal, PhD	Research chemist; hydrocarbon metabolism
D. Federighi	Chemist; assistant to Dr. Roubal
U. Varanasi, PhD	Research chemist; metal/hydrocarbon studies
D. Gmur	Chemist; assistant to Dr. Varanasi
W. Reichert, PhD	Research chemist; metal/hydrocarbon studies
J. Parker	NOAA Corps Officer; assistant in pathology studies
T. Scherman	Physical science technician; part-time assistant in pathology and behavioral studies
B. McCain, PhD	Microbiologist; effects of petroleum in sediments on flatfish, coinvestigator with Dr. Hodgins
W. Gronlund	Fishery research biologist; assistant in pathology and behavior studies
W. Ames	Fishery research biologist; assistant to Dr. McCain
L. Rhodes	Biological aide; part-time assistant to Dr. McCain

J. Hawkes, PhD — Fishery research biologist; electron microscopy
C. Stehr — Technician; assistant to Dr. Hawkes

METHODS

Behavior

The testing apparatus designed to evaluate avoidance of PBCO-contaminated sediment by flatfish and crabs was described in the previous OCSEAP Quarterly Report (July 1 to September 30, 1978). In the current tests, the experimental procedure was the same except PBCO in the sediment was increased to 5% (v/v), and the sediment was rinsed for only five hours before releasing the fish on the non-oiled side. The group of 20 flatfish was checked on days 1, 2, 3, 4, 7, 9, and 15 to determine the numbers of fish on the oiled or non-oiled sediment. Upon termination of the flatfish testing, six juvenile Dungeness crabs (average 8.5cm in carapace width) were placed on the same sediment, and their activity and feeding behavior were monitored for one week. Ten juvenile coon-stripe shrimp (Pandalus danae), a nonburrowing crustacean, were also present in the apparatus during all tests.

Pathology

The procedures for exposing starry flounder to sediment contaminated with 0.5% PBCO and for assessing possible pathological effects are described in the previous quarterly report. Briefly, 50 fish each were in the oil-exposed and control groups. At 0-time and 13, 28, and 62 days, all fish were weighed and measured, and a subsample was sacrificed and tissue samples were taken for histology, hematology, electron microscopy, and analytical chemistry. Additional histochemical procedures used on cryostat sections of liver tissue included the oil red-O and Sudan black stains for lipid. Glycogen-specific stains used were Best's Carmine and periodic acid-Schiff (PAS) (Armed Forces Institute of Pathology, 1968). In a recently-initiated experiment, employing the same facilities and sampling procedures as above, juvenile English sole were placed on a high-silt-content sediment containing PBCO at an initial concentration of 1% (v/v).

Morphology

Herring or pollock eggs were placed in one-liter glass jars with surface areas of 210mm^2 each. Seawater, to which 0.1ml PBCO was added, was placed in each jar which was then gently agitated. In one experiment, samples were taken after one hour of exposure to the petroleum and, in another, 24 hours after exposure. Eggs were removed from the containers in such a manner that they did not pass through the oil slick. In each case, samples were taken from four containers, two aerated and two not aerated. Control eggs which were not exposed to oil, but which were otherwise similarly treated, were also examined.

In another experiment, clusters of herring eggs which were attached to eel grass were transferred from a jar which contained oil to one with sea water without oil. In this experiment, the transferred eggs were passed through the oil slick. After one hour, and again after 24 hours, eggs were removed for examination.

In all experiments, the number of eggs, the number and size of adhered

petroleum droplets and the developmental stage of the embryo were recorded.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Two groups of starry flounder were acclimatized at either 4^{o} or 12^{o}C for two weeks prior to naphthalene exposure. Fish were force-fed 56μCi each of ^{3}H-1-naphthalene and maintained in flowing sea water. Three to six fish were analyzed at 24 and 168 hours for concentrations of naphthalene and its metabolic products in various tissues and body fluids by previously described methods (Varanasi, et al., 1978a). Individual metabolite classes were characterized by TLC, as described previously (Varanasi, et al., 1978b).

Influence of environmental temperature on the disposition and metabolism of dietary naphthalene in starry flounder was studied by determining (a) retention of naphthalene in tissues of fish fed an equal dose (56μCi each) of ^{3}H-naphthalene and held at 4^{o} and 12^{o}C in flowing sea water; (b) extent of bioconversions of naphthalene (measured by solvent-partitioning using hexane and NaOH) at 4^{o} and 12^{o}C; and (c) types and concentrations of metabolite classes (characterized by thin-layer chromatography) accumulated in liver, muscle, and bile of fish held at 4^{o} and 12^{o}C.

Biotransformation of Petroleum Hydrocarbons

The metabolites of 2,6-DMN were isolated from whole digestive tract (with contents) and gonads from sea urchins, as follows: a sample (≈10g) was homogenized with 50ml of methanol and filtered. The residue was then rehomogenized (and filtered) 4-5 times with 110-15ml portions of boiling methanol. The filtrates were combined and concentrated to 1-3ml at 10^{o}C in a rotary evaporator. The concentrate was then applied to a 26cm x 1.8cm LH-20 Sephadex column, and 50ml of 60:40 (v/v) benzene:methanol was passed through to remove lipids and pigments. This elution was followed with 50ml of 40:60 (v/v) benzene:methanol in order to recover the metabolites of 2,6-DMN. Metabolites were resolved by the application of two TLC systems described earlier (Roubal, et al., 1977).

The combined test plus spines from each urchin were individually assayed for radioactivity by extracting samples with 15ml portions of hot methanol until no more radioactivity was released (3-4 times). The radioactively-labeled substances remaining in the extracted residue were assayed by liquid-scintillation spectrometric techniques. Residues from extracted digestive tract and gonads were also analyzed for remaining radioactivity.

SAMPLE COLLECTION LOCALITIES

Behavior

Juvenile English sole, Dungeness crabs, and coonstripe shrimp were collected in Puget Sound on the west side of Whidbey Island with a 10m beach seine. Sediments were from a beach known to have low levels of hydrocarbon contamination near Sequim, Washington.

Pathology

Starry flounder were collected from the mouth of the Columbia River, and sediment was obtained from the same site described in the Behavior section. English sole were captured at Point Pully in Puget Sound, and "high-silt" sediment was obtained from a beach at the Battelle Northwest facility near Sequim, Washington.

Morphology

Herring and pollock eggs were collected from Puget Sound and cultured in the laboratory.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Sexually-immature starry flounder were obtained from the mouth of the Columbia River and maintained at NMFS Mukilteo facility.

Biotransformation of Petroleum Hydrocarbons

The sea urchins used in this portion of the study were collected from Puget Sound.

DATA COLLECTED AND/OR ANALYZED

Behavior

Sediments, interstitial water, and above-sediment water were taken during the testing period. Twenty-eight of these samples were analyzed for total extractable petroleum hydrocarbons (TEPH), and 30 samples for aromatic hydrocarbons by gas chromatography (GC).

At the termination of testing of English sole for avoidance of oil-contaminated sediment, the fish were preserved for histopathology and for analysis of petroleum hydrocarbons in tissues.

Pathology

(1) Number and types of samples: Tissue samples for histology (121); blood for hematology (8); sediment for hydrocarbon analyses (2); interstitial water samples for hydrocarbon analyses (2); tissues for hydrocarbon analyses (14).

(2) Number and type of analyses: Microscopic examination of histological specimens (146); hematology (hematocrit, hemoglobin, total blood cell count, differential white cell count) (50); sediment and water samples for total extractable petroleum hydrocarbons (TEPH) analyses (4); tissues for hydrocarbon analyses (0).

Morphology

Number of samples: 598 eggs were examined.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

(1) Number and type of samples: Three to six fish were analyzed at each of two time intervals and at two experimental temperatures. Samples were analyzed in triplicate for naphthalene and metabolite concentrations. More than 1,000 samples were processed for liquid scintillation spectrometry.

(2) Number and type of analyses: Tissue samples were digested in NaOH and hexane for partitioning of the parent hydrocarbons and its metabolic products. Extracts of liver, muscle, and bile were also processed for thin-layer chromatography to identify metabolite classes.

Biotransformation of Petroleum Hydrocarbons

(1) Types of samples: Samples of digestive tracts and gonads from sea urchin exposed to 1,6-DMN, in separate tests, were analyzed for the presence of major metabolites of 1,6-DMN. The combined test (i.e., shell) plus spines from each urchin were analyzed for radioactivity of tritium-labeled 2,6-DMN not released by solvent extraction (i.e., bound 2,6-DMN and/or its bound metabolites).

(2) Type and number of analyses: The digestive tracts and gonads were analyzed for trans-3,4-dihydro-3,4-dihydroxy-2,6-dimethylnaphthalene, 3-hydroxy-2,6-dimethylnaphthalene, and the mercapturic acid and sulfate/glycoside conjugates, after 3 and 14 days from the onset of feeding by urchins on treated Fucus. The latter two metabolites were not resolved by the TLC system used.

Three sea urchins were analyzed at two feeding periods (three days and two weeks), for a total of six digestive tracts and six gonad samples. A total of six test plus spines samples were analyzed for bound radioactively-labeled compounds. Likewise, six solvent-extracted digestive tracts and six solvent-extracted gonads were analyzed for residual radioactivity.

RESULTS

Behavior

There was no significant difference ($p=0.05$) between the number of English sole on 5% (v/v) oil-contaminated sediment and the number of fish on sediment without added oil. During the two-week test, 15% (3 of 20) of the flatfish died, and at the termination of the test, an additional 24% (4 of 17) did not appear to be feeding.

The crabs, as did the flatfish, frequently crossed between the oil-contaminated and non-oiled sediment chambers and readily located and consumed food on the oiled side. However, in contrast to the flatfish behavior, the crabs did not bury themselves in the oiled sediment unless alarmed. Analysis of the total data on daily observations of crab distribution showed that of the six individuals in the test apparatus an average of 1.1 were on the non-oiled sediment surface, 3.4 were buried in the non-oiled sediment, and 1.5 were on the surface of the oiled sediment; none were buried in the oil-contaminated sediment.

The average TEPH in the oil-contaminated sediment over the 15-day test period was 8700 ± 1300µg/g, whereas on the non-oiled side, similar extractable material from sediment using the same procedure averaged 28 ± 4µg/g. In water above the sediment on the oil-contaminated side, the concentration of petroleum hydrocarbons averaged 96ηg/g, and in water above the non-oiled sediment side averaged 28ηg/g.

Throughout the experiment, coonstripe shrimp were equally distributed in the water column above the sediment. They did not avoid oil droplets in the water caused by crab or flatfish activity, nor did they exhibit a reduction in feeding response or ability to locate food.

Pathology

The exposure of starry flounder to oiled sediment was terminated after 65 days due to an interruption of seawater flow to the control aquarium and the resulting high number of mortalities. During the course of the experiment, the test fish were exposed to sediments containing an initial TEPH concentration of 1960µg/g in the top 2cm. The TEPH remained at approximately 400µg/g during the first month. At one month, the fish were removed and the sediment redistributed, yielding a surface layer with 770µg/g TEPH. After two months, the TEPH in the surface of the sediment was 180µg/g. The three aromatic hydrocarbons detected in highest levels in the sediment were the 1-,2-, and 2,6-methyl-naphthalenes.

The microscopic structure of the livers of both control and oil-exposed starry flounder sacrificed at two weeks was essentially normal, but at one month, livers of both groups had severe hepatocellular vacuolization. By two months, only one case (one of four fish) of severe vacuolization was observed in the oil-exposed group. The remainder of this group and all of the controls had hepatocellular vacuolization ranging from normal to moderate. Preliminary evidence from light microscopic examination of sections of plastic-embedded liver tissues which had been processed for electron microscopic examination suggested that the vacuoles contained glycogen. However, extensive histochemical tests of tissue sections from both paraffin-embedded and frozen (sectioned by cryostat) liver tissue has confirmed that the vacuoles actually contained lipid.

Data from the ongoing experiment involving long-term exposure of juvenile English sole to PBCO-contaminated sediments are not yet available.

As part of a cooperative effort with the members of the Behavioral Section concerned with avoidance of crude oil-contaminated sediments by English sole, three fish which had been exposed to sediments containing very high levels (5% v/v) of PBCO for 15 days were examined histologically. All three had mucous cell hyperplasia in the olfactory epithelium associated with excessive mucous production. Two of the three had severe hepatocellular lipid vacuolization (HLV).

Morphology

Microscopically detectable petroleum droplets adhered to herring eggs and did not adhere to pollock eggs. When herring eggs were gently agitated in jars with an oil slick on the surface, 6-23% of the eggs had adherent oil droplets after a one-hour exposure (n = 158). After 24-hour exposure, 49% of the eggs were similarly oiled (n = 92). When herring eggs which were attached to eel grass were passed through the oil slick, 41% had adherent oil droplets after one hour

in clear seawater (n = 44). The droplets of oil varied in diameter from 6μm to 100μm, with the mode at 40μm.

Starry flounder and pink salmon (Oncorhynchus gorbuscha) eggs were examined with scanning and transmission electron microscopy to determine differences in egg membrane structure. The starry flounder egg membrane constituted 1.5 - 2% of the egg diameter, whereas the pink salmon egg membrane was 8.5% of the diameter. The interior membrane structure obviously differed between the two species. In the flounder, there were six continuous horizontal lamellae, but in the salmon there were very short, discontinuous lamellae which were pierced by pore canals.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Retention of naphthalene in most tissues (liver, muscle, skin, brain) at 24 hours after the initiation of naphthalene-exposure, was substantially greater (two to seven times) at 4° than at 12°C. The decline in naphthalene concentration from 24 to 168 hours was slower at 4° than at 12°C. As much as 34% of total administered radioactivity was present in the entire gastrointestinal (GI) tract of fish at 12°C. At both 24 and 168 hours, radioactivity associated with the metabolites was about 1.5 to three times as much in tissues at 4°C than at 12°C.

No marked difference was observed in the profiles of metabolites (characterized by TLC) accumulated in tissues at 4° or 12°C. At 24 hours, liver and muscle of fish at both temperatures contained primarily the non-conjugates (e.g., the dihydrodiols, 1- and 2-naphthols); from 24 to 168 hours there was a significant decrease ($p<.05$) in the dihydrodiol fraction and an increase in the conjugates (glucuronides, sulfates, mercapturic acids). Metabolites in bile were primarily conjugates, with glucuronides as the major metabolites.

Biotransformation of Petroleum Hydrocarbons

The recovery efficiencies for some of the metabolites of 2,6-DMN at various steps in analysis are being reevaluated. The data listed below for concentrations of metabolites in tissues are tentative; however, the levels of all accumulated metabolites in the sea urchin digestive tract and gonads are low, e.g., parts-per billion.

The digestive tract from urchins that fed for three days on treated Fucus contained less than 0.01ng/g dry tissue of a compound corresponding to 3,4-dihydro-3,4-dihyroxy-2,6-DMN on TLC plates. No 3-hydroxy-2,6-DMN was detected in the digestive tract. The major nonconjugated metabolite of 2,6-DMN in the digestive tract and gonads is an unidentified compound (probably less than 0.03 ng/g dry tissue). The low R_f value of this compound (0.16 ± 0.01) indicates that this metabolite is more polar than the 3-hydroxy and dihydrodihydroxy compounds.

The major metabolites in the digestive tract had R_f values corresponding to naphthyl sulfate and glycoside (∿1.25ng/g dry tissue). A second conjugate with an R_f corresponding to a naphthyl mercapturate (∿0.01ng/g dry tissue) was also present in the digestive tract.

No nonconjugated metabolites typical of the 3-hydroxy and dihydrodihydroxy

derivatives were detected in the gonads of urchins that had fed for three days on treated Fucus. The major metabolite in the gonads had an R_f corresponding to the sulfate/glycoside (∿0.02ng/g dry tissue). A minor metabolite with an R_f corresponding to the mercapturate was present in the samples, but varied from sample to sample.

After 70% of the accumulated total radioactivity in urchins which had fed for three days on treated Fucus remained in residues of test plus spines after methanol extraction. This radioactivity was not released when portions of the tissue residue were treated with water, diethyl ether, aqueous EDTA, dilute HCl, or treated with a broad-spectrum proteolytic enzyme which digested the protein coat from the inside and outside surfaces of the urchin test.

In comparison to tissue residues from the test plus spines, radioactivities in the solvent extracted tissues of digestive tract and gonads were 0.47% and 0.80% of the total.

About 10% of the radioactivity from tritiated 2,6-DMN in the test plus spines was released into solution when the material was ground up in concentrated ammonium hydroxide and allowed to stand in contact with ammonium hydroxide, a single radioactive component with an R_f of 0.06, which did not correspond to any known standard. The low R_f indicates that the ammonium hydroxide-extractable material is more polar than the conjugates of naphthalene investigated previously (Roubal, et al., 1977).

The quantification of metabolites in tissues of urchins which fed for 14 days on treated Fucus is not complete. Based on a visual examination of TLC chromatograms, we observed that the dihydrodiol derivative of 2,6-DMN was present in both digestive tract and gonads. Moreover, a component with an R_f corresponding to 3-hydroxy-2,6-DMN is present in the digestive tract. However, major metabolites in both organs have R_f values corresponding to a mercapturate and a sulfate or glycoside (or both). Residual radioactivity in the combined test plus spines, not released by solvent extraction, was less than in the 14-day experiment (by more than an order of magnitude).

PRELIMINARY INTERPRETATION OF RESULTS

Behavior

Observations on flatfish feeding in the avoidance apparatus indicate that juvenile English sole respond to food primarily by visual cues. For the majority of flatfish, their rapid response time and ability to locate food on oiled sediment suggests that non-avoidance of contaminated sediment is not likely due to narcosis. There was concern, however, that lack of avoidance by flatfish could be an inability to detect oil resulting from acute water soluble hydrocarbon disruption of the chemosensory system. The coonstripe shrimp, which is primarily a chemosensory feeder, was used as in indicator for disruption of this sensory modality. Over a three-week period, observations on shrimp in the test apparatus indicated no change in their ability to locate food.

The results of these experiments suggest that juvenile English sole do not discriminate between oiled and non-oiled sediment, even at oil concentrations which cause mortality. Also, Dungeness crabs do not avoid the surface of heavily

oiled sediment, but there is no information, to date, on the effect of chronic exposure for these crustacea. These results are in contrast to statements in the literature in which it is generally assumed that mobile marine organisms avoid oil contaminated areas.

Pathology

Although starry flounder were exposed to sediments with PBCO at concentrations which had previously been shown to cause severe HLV in English sole exposed for a similar period (McCain, et al., 1978) no identifiable oil-related effects were found. The observation that both control and oil-exposed starry flounder had similar levels of HLV suggests that, at least in this species, this condition is not reflective solely of crude-oil exposure. The severe HLV which was observed in starry flounder was probably caused by diet or stress-related factors.

Only very preliminary interpretation is possible in the case of the abnormalities observed in the olfactory epithelium of English sole used in avoidance experiments for the following reasons: (1) the fish were exposed to extremely high initial levels of petroleum hydrocarbons; (2) only three fish were examined histologically; and (3) the length of time each fish was exposed to the oiled sediment is not known even though the fish were in the double-chambered system for 15 days. Crude-oil-seawater mixtures (0.14mg/l) have been reported to cause abnormalities in the olfactory organs of Menidia menidia (Atlantic silverside) (Gardner 1975). The abnormalities included hyperplasia of the olfactory sustentacular cells, or supporting epithelium. Atlantic silversides with such lesions appeared to be disoriented during the experiments. The olfactory abnormalities observed in English sole were much less severe, and their influence on the ability of these fish to avoid crude oil-contaminated sediments is not known.

Morphology

One of the observations that was made on samples taken after the Argo Merchant oil spill was that oil droplets adhered to egg surfaces. In studies reported by Longwell (1978), oil was found to occur on the surface of eggs collected at the Argo Merchant spill site of both cod (Gadus morhua) and pollock (Pollachius virens). The conditions under which the samples were taken, however, involved dragging netted eggs through the surface slick. The question remained unanswered as to whether or not adherence of oil to the eggs occurred in the absence of sampling damage.

We detected petroleum droplets adherent to herring egg, but not to walleye (Pacific) pollock egg surfaces. The surface morphology of these two eggs, moreover, was quite different. The herring egg had a coating over the membrane surface which was amorphous in appearance as visualized in the scanning electron microscope. The pollock egg was smooth-surfaced except for occasional pores, and lacked coating. Of course, these structural differences may not directly reflect differences in membrane permeability to petroleum.

It is anticipated that relationships between the structure of egg membranes of teleost fishes of several species and vulnerability to petroleum will be better defined as experimental research progresses on effects of oil and egg and larval development (see proposed studies on effects of weathered oil on salmon and flatfish egg and larval development in the R.U. 73 proposal for FY 79).

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Lowering seawater temperature influenced retention of both naphthalene and its metabolic products. Slow decline in naphthalene concentrations of tissues of fish at 4° may be due, in part, to the fact that a considerable amount of naphthalene was still present in the entire GI tract of these fish at 24 hours after the initiation of exposure. At the end of one week, tissues of fish at 4° contained 30 to 40 times as much naphthalene--a potential source of oxygenated metabolites--as that present in tissues of fish at 12°C. Interestingly, metabolite concentrations were only twice as high in fish at 4°C, compared to metabolite concentrations in fish at 12°C. Thus, lowering of environmental temperature resulted in significant increases in both concentrations and resident times of naphthalene and its metabolites in tissues of starry flounder exposed to dietary naphthalene; however, the increase in concentration was much greater for naphthalene than for the metabolites, indicating the bioconversion of naphthalene was considerably less at the lower temperature.

Biotransformation of Petroleum Hydrocarbons

The results enumerated here, together with those presented in previous reports, demonstrate that (1) 2,6-DMN is transferred from seawater to Fucus and then to sea urchins, (2) there was no evidence for the bioconversion of 2,6-DMN in the intermediate stage of the transfer, (3) significant amounts of metabolites of 2,6-DMN accumulate in sea urchins receiving 2,6-DMN via the food chain, and (4) the important finding that urchins receiving 2,6-DMN via their food sequester the bulk of the radioactivity they receive in the test plus spines. The tendency of urchins to sequester large proportions of the hydrocarbon from the diet into the test plus spines may decrease the pollution burden on soft tissues. The lower accumulated radioactivity in the test plus spines in urchins feeding for much longer than three days (e.g., 14 days) may indicate that hydrocarbons/metabolites are slowly released from the test plus spines after exposure to petroleumn.

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Oral Presentations

None.

ESTIMATE OF FUNDS EXPENDED

Funds expended for the quarter ending on December 31, 1978, are 61.0K. (Actual cut-off date for calculating this figure was December 15, 1978.)

Research Unit 417

ECOLOGICAL STUDIES OF INTERTIDAL AND SHALLOW SUBTIDAL HABITATS IN LOWER COOK INLET

Prepared for

NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

Prepared by

DAMES & MOORE

Dennis Lees

January 1979

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January 25, 1979

National Oceanic and Atmospheric Administration
OCSEAP Office
P.O. Box 1808
Juneau, AK 99802

Attention: Ms. Susie Swanner

Dear Ms. Swanner:

Quarterly Report
R.U. #417
Ecological Studies of Intertidal
and Shallow Subtidal Habitats in
Lower Cook Inlet

This administrative summary reports the status of this study after the fall quarter. During this period, we completed field operations in Lower Cook Inlet, submitted a preliminary report on the soft intertidal habitats examined in Lower Cook Inlet, and commenced preparation of the final summary report for this research unit.

At this time, processing of the core samples from mud and sand substrates is nearly complete. Data processing awaits a piece of computer hardware.

Except for a survey in NEGOA that was cancelled for logistical and weather reasons, the planned schedule is complete. If you have any questions, please contact me at the Homer office.

Very truly yours,

DAMES & MOORE

Dennis C. Lees

Dennis C. Lees
Principal Investigator

DCL/ms

QUARTERLY REPORT

I. Task Objectives

The main purpose of the study is to describe some of the important features of the principal intertidal and nearshore assemblages in Lower Cook Inlet and Prince William Sound. Specific overall objectives are to obtain information on patterns of trophic dynamics and succession, and to develop preliminary estimates of primary and secondary production in the assemblages examined. Considerable effort is being placed in obtaining biomass and production estimates for the algal assemblages in the rocky intertidal and subtidal region on the south side of Kachemak Bay.

II. Field and Laboratory Activities

A. Ship or Field Trip Schedule

1. 15 October--Gull Island--intertidal--via NOAA-chartered vessel, M/V Humdinger
2. 16 October--Homer Spit--intertidal--via personal car
3. 17 October--Seldovia Point--intertidal--via NOAA-chartered vessel, M/V Humdinger--aborted trip
4. 18 October--Seldovia Point--intertidal--via NOAA-chartered vessel, M/V Humdinger
5. 18-19 October--Chinitna Bay--intertidal--via NOAA-chartered float plane
6. 26 October--Jakolof Bay--subtidal--via Dames & Moore skiff
7. 30 October--Seldovia Point--subtidal--via M/V Searcher
8. 31 October--Seldovia Point--subtidal--via M/V Searcher
9. 2 November--Deep Creek--intertidal--via personal car
10. 8 November--Seldovia Point--subtidal--via M/V Searcher

B. Scientific Party

1. Deborah Boettcher, Dames & Moore, Assistant Biologist
2. William Driskell, Dames & Moore, Assistant Biologist
3. David Erikson, Dames & Moore, Assistant Biologist
4. Dr. Jonathon Houghton, Dames & Moore, Project Marine Biologist
5. John Isakson, Dames & Moore, Project Marine Biologist
6. Dennis Lees, Dames & Moore, Principal Investigator, Project Manager
7. Thomas Rosenthal, Contract Labor

C. Methods

1. Field Sampling

a. Soft Substrates

(1) A profile of beach elevations is established.

(2) A stratified random sample design is being utilized.
(3) Ten cores 10 cm in diameter and about 30 cm long are collected randomly at each of at least three levels of the beach below mean sea level.
(4) Samples are individually bagged and labelled.
(5) When weather permits, the fresh samples are screened in seawater through a 1 mm sieve to remove the sand. The sample remaining in the screen is rebagged with its label and fixed with a 10 percent formaldehyde-seawater solution.

b. Rock Substrates

(1) A stratified sampling design is being used.
(2) Levels being occupied at Seldovia Point are about +8 ft, +2 ft, -1 ft, -20 ft, -40 ft and -60 ft elevations.
(3) Levels being occupied at Gull Island are about +12 ft, +5 ft, MLLW and -1 ft elevations.
(4) Ten-1/4 m^2 quadrats are placed randomly at each level; within each quadrat the number and/or relative cover of each plant taxon are recorded and all plants attached within the frame are removed and bagged. Additionally, the number and/or relative cover of conspicuous invertebrates and fish are recorded.
(5) Additional quadrats (from 1/16 m^2 to 25 m^2) are utilized at each level to obtain better estimates of density and cover for the plants and animals in the study area.
(6) Feeding observations are recorded.
(7) Samples of many invertebrates are collected to establish size distributions.
(8) At Jakolof Bay, tagged individual plants of Laminaria groenlandica, Agarum cribrosum, and Alaria fistulosa, were measured for the last time in such a manner as to allow the determination of growth rates.

2. Laboratory Procedures

a. Soft Substrates

(1) In the laboratory, the samples are sorted and the organisms identified to the lowest practical taxon and counted.
(2) Aggregate drained wet weights are measured for each species, where practical, or for major taxa.
(3) Representative specimens are sent to taxonomic specialists for identification for verification.

b. Rock Substrates

(1) Plant samples from each level are handled and recorded individually.
(2) Drained wet weight and length are measured for each laminarian; aggregate drained wet weights are measured for all other algae.
(3) Sizes are measured for various invertebrate species to establish size distributions.
(4) Fish and selected invertebrate species are dissected in order to examine stomach contents and develop food webs.

D. Sample Localities

1. Soft Substrates

a. Deek Creek--1-1/2 miles south of beach access at beach park (Figure 1); transect based on very large triangular boulder at base of cliff.
b. Homer Spit--2-1/2 miles south of Kachemak Drive, off beach access ramp on west side of Spit (Figure 1).
c. Chinitna Bay--the transect line extends normal to the shoreline from an intertidal boulder in front of Wayne Byer's home site (Figure 1).

2. Rock Substrates

a. Gull Island, in Kachemak Bay--Gorilla Rock at west end of island (Figure 1);
b. Jakolof Bay, in Kachemak Bay--on the reef at the mouth of Jakolof Bay, under the overhead high tension wires (Figure 1);
c. Seldovia Point, in Kachemak Bay--directly at the point; transect based on a very large boulder, marked by a pointed arrow, at the base of the cliff (Figure 1).

E. Data Collected or Analyzed

1. Soft Substrates

a. Homer Spit (16 October 1978)--Thirty core samples collected, sorted, identified, measured and weighed
b. Chinitna Bay (18-19 October 1978)

(1) Thirty core samples collected, sorted
(2) 1/16 m^2 square quadrats for Mya spp. siphon counts--75

c. Deep Creek (2 November 1978)--Thirty core samples collected, sorted, identified, measured and weighed

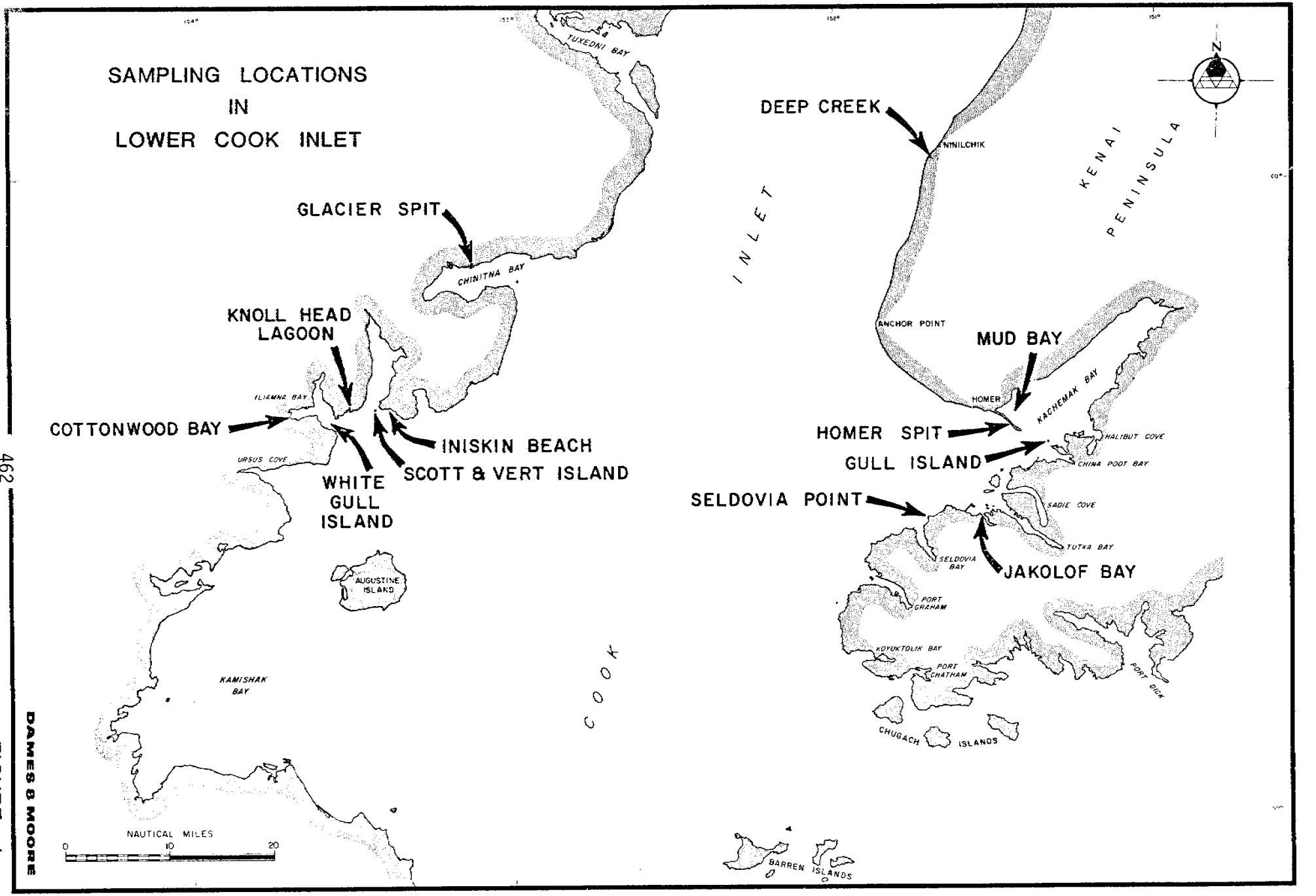

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FIGURE 1

DAMES & MOORE

2. Rock Substrates

a. Gull Island Intertidal Survey (15 October 1978)

(1) 1/4 m^2 square quadrats for cover and density of plants and animals--34
(2) Size distribution for two species

b. Seldovia Point Intertidal Survey (18 October 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--28
(2) Size distribution for three species
(3) Feeding observations--6

c. Jakolof Bay Subtidal Studies (26 October 1978)

(1) Large quadrats for large invertebrates

1 x 30 m - 5

(2) Tagged plants measured:

Agarum cribrosum--14
Alaria fistulosa--8
Laminaria groenlandica--14

d. Seldovia Point Subtidal Survey (30, 31 October and 8 November 1978)

(1) Large quadrats for phaeophytes and fish

1 x 5 m - 4
0.5 x 20 m - 1
1 x 30 m - 1
2 x 30 m - 2

(2) 1/4 m^2 square quadrats for plant cover, density and biomass--20
(3) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--9
(4) 1/4 m^2 square quadrats for cover and density of plants and animals--12
(5) Tagged plants measured:

Agarum cribrosum--7
Laminaria groenlandica--1

(6) Size frequency for two species
(7) Feeding observations--3

F. Milestone Chart and Data Submission Schedule--The projected schedule (Figure 2) is generally on schedule.

1. Lower Cook Inlet

a. Field Survey--all field work has been completed.
b. Lab Analysis--laboratory work will be completed on schedule.
c. Final Report Preparation--data reduction and analysis has commenced in all areas of research.
d. Digital Data Processing--data processing is awaiting completion of an internal computer system. That system is nearing completion. The main problem now is obtaining a new piece of hardware to connect the computer to the printer.

Computer checks of past data submissions have uncovered a problem in our source file for taxonomic codes. This problem is being discussed with the Juneau project office.

NEGOA--Field activities scheduled for November were cancelled due to weather problems and support difficulties. The vessel that we chartered sprang some planks while crossing Hinchinbrook Entrance on its way to pick us up. It was subsequently grounded and burned. We were then unable to obtain a suitable vessel to conduct the survey.

III. Results

A preliminary report covering FY77 sampling periods on soft intertidal substrates was submitted in December. This report discusses species composition, zonation, seasonal patterns, community structure and potential sensitivity of the soft intertidal habitats to contamination by oil.

IV. Preliminary Interpretation of Results

See Dames & Moore, 1978. Ecology of Unconsolidated Beaches in Lower Cook Inlet. Prepared for NOAA OCSEAP Project Office, Juneau, Alaska, 184 pp.

V. Problems Encountered

These have been noted briefly above.

A. Computer checks of previous data submissions for NEGOA and Lower Cook Inlet have indicated use of a number of invalid taxonomic codes. Further examination of the situation indicates that we were only provided with an obsolete taxonomic code, which we have unwittingly used to code several sets of data. This problem is being reviewed.

B. Field activities scheduled for NEGOA in December were cancelled as a consequence of the loss of our chartered vessel. While

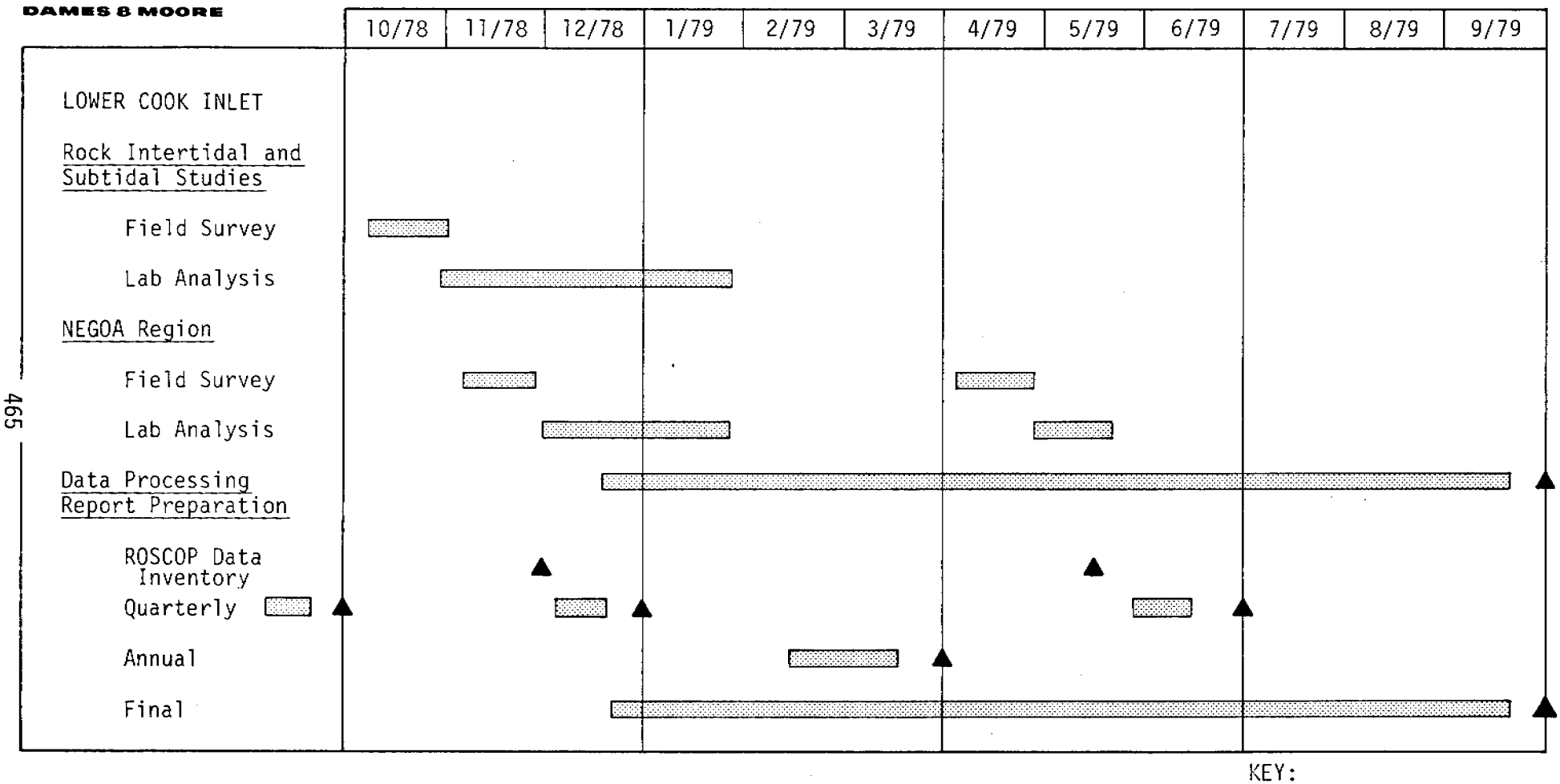

FIGURE 2

XII. MILESTONE CHART

PI: Dennis C. Lees

R.U. #417

running in moderate seas across the Hinchinbrook Entrance to Prince William Sound, enroute from Cordova to Whittier to pick us up, the vessel sprang some planks and began taking water. In an effort to save the vessel, the skipper attempted to run her dry on the beach. Instead, the vessel was gored on a rock and severely damaged. She was subsequently refloated with barrels, moved to a nearby island, beached, stripped and burned. We were subsequently unable to obtain a suitable vessel with which to conduct the survey safely in the poor weather that characterized this season.

VI. Estimate of Funds Expended

$40,000

Quarterly Report
October-December 1978
Research Unit #423

Influence of Petroleum on Egg Formation and Embryonic Development in Seabirds

C. R. Grau[1], David G. Ainley[2], T. Roudybush[1], S. Morrell[2]

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2. Point Reyes Bird Observatory, 4990 Shoreline Highway, Stinson Beach, CA 99802

January 17, 1979

During the last three months data have been obtained which have caused us to re-evaluate some of our preliminary conclusions from 1977 and 1978. Feeding of dyes in a nonrepeating sequence to auklets after removal of their first eggs allowed us to obtain auklet eggs with rings of yolk with known times of deposition. This enabled us to determine the date of completion of yolk deposition. The time between the completion of yolk deposition and oviposition was calculated and found to be four days in the five clear examples we obtained. We had earlier assumed this to be just one day in auklets as it is in species in which this time is known. While this three day difference in the timing of oviposition in relation to onset of rapid yolk deposition may appear to be small, it caused us to plot breeding success against number of days between dosing and oviposition (Figures 1-5). Although we had expected auklets, like our laboratory model the Japanese quail, to be vulnerable to oil toxicity during the latter part of yolk formation, auklets responded to oil dosing with a decrease in reproductive success 10 to 14 days after dosing. This indicates that auklets are vulnerable to the doses of oil we used for about 5 days - from 2 days before the onset of rapid yolk deposition to about three days after the onset of rapid yolk deposition.

The stage of the auklets reproductive effort which appears to be interrupted by oil ingestion is egg production. This conclusion, however, is tentative and must await further analysis of the data from both 1977 and 1978 for confirmation.

Data from the last ten years obtained by PRBO have shown a correlation between fledging and the phase of the moon. These data have only recently been summarized in enough detail to show this correlation. No correlation between time required for fledging and the phase of the moon has been found,

however. Correlations between hatching time, time of oviposition, and phase of the moon have not been made. These correlations are important, because dosing of auklets with oil is necessarily correlated with the phase of the moon. Auklets come ashore in substantially reduced numbers on moonlit nights compared to moonless nights. An adequate analysis of the data must include an attempt to account for effects of the phase of the moon on the results of our experiments. Such work is in progress.

In a set of experiments in 1978 auklets which laid before they could be dosed with oil had their eggs removed and were allowed to lay second eggs. Between the time of egg removal and laying of the second egg auklets were either dosed with 1g of Bunker C oil or were smeared on the brood patch with 100 mg Bunker C oil. If second eggs were not laid within one week of the first treatment with oil, attempts were made to redose the auklets. Even though only 100 mg of Bunker C oil was used on the smeared auklets and the time and trauma of smearing an auklet was much less than that of dosing orally, smeared auklets had impared reproduction compared to controls (significant at $P < .001$) while orally dosed auklets differed only at $P < .05$. While these conclusions must again be considered tentative pending further analysis of the data and submission of the final report, smearing oil on auklet brood patches appears to be more effective in reducing reproductive success in auklets than oral ingestion of oil. Again the part of the auklet's reproductive effort which is interrupted by oil smearing appears to be egg production.

Relation to OCS Oil and Gas Development

Reproducing auklets are vulnerable to small oral or dermal doses of oil. Even though in the first analyses, no effect of oil on auklet reproduction was noted in 1977, re-examination of the data showed that ingestion of as little as 600 mg of Bunker C oil caused a reduction in egg laying ten to 14 days after dosing. Statistical evaluation of the effect of 300 mg of Bunker C oil on egg laying in auklets is not yet complete, but it appears that even 300 mg of Bunker C oil reduced egg laying to half of what would otherwise be expected.

Another factor which makes auklets very vulnerable to oil contamination is their sensitivity to oil even before the onset of rapid yolk formation. This allows a lag time of as long as 14 days from time of exposure to possible observation of the effect of oil on egg laying. In the case of chronic small oil spills in the area where breeding auklets feed, severe damage could occur before it could be detected.

Cassin's Auklets

Cmy BC Egg Production 1977

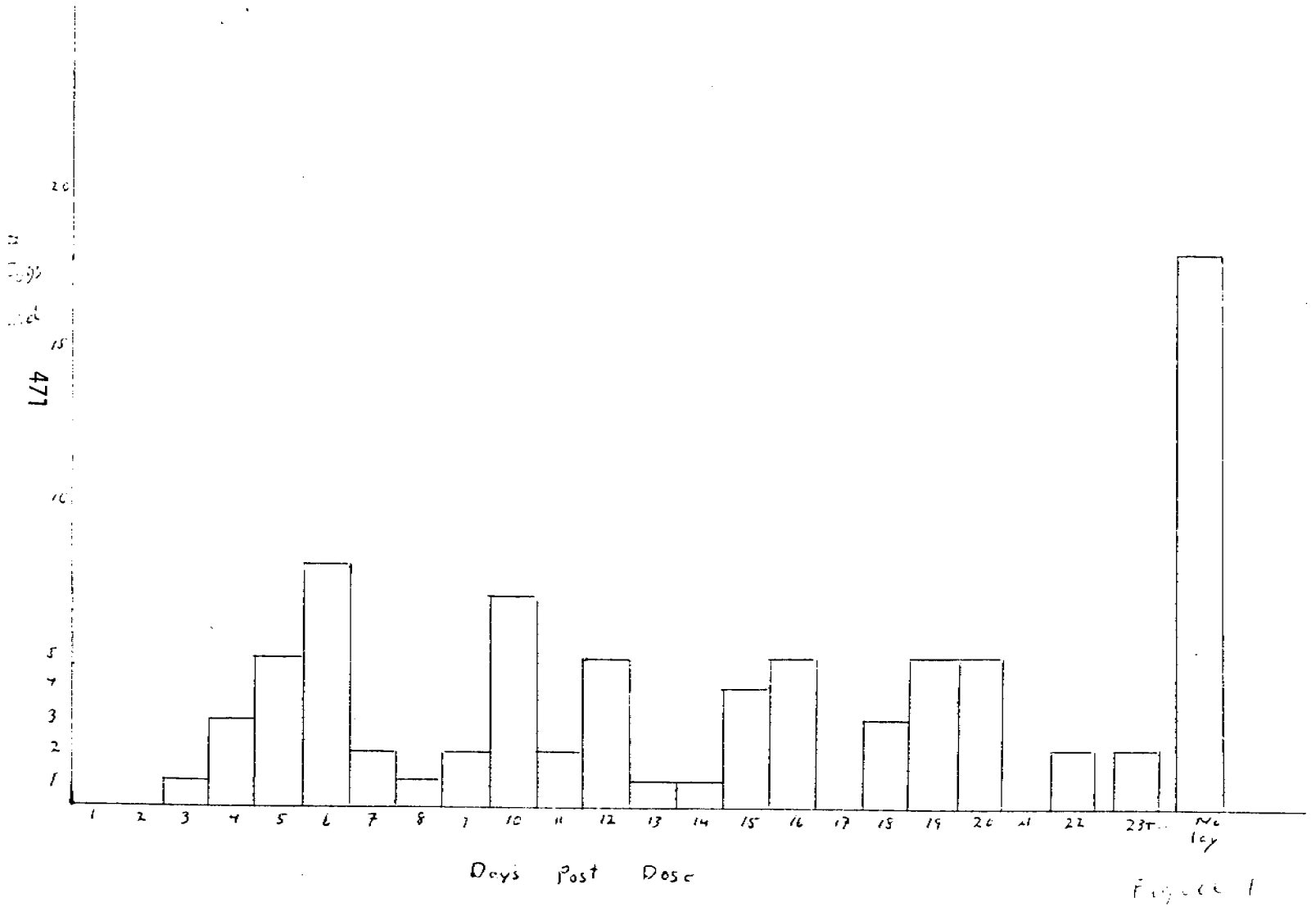


Figure 1

1-2-79

Cassin's Auklet

Egg Reduction 1977

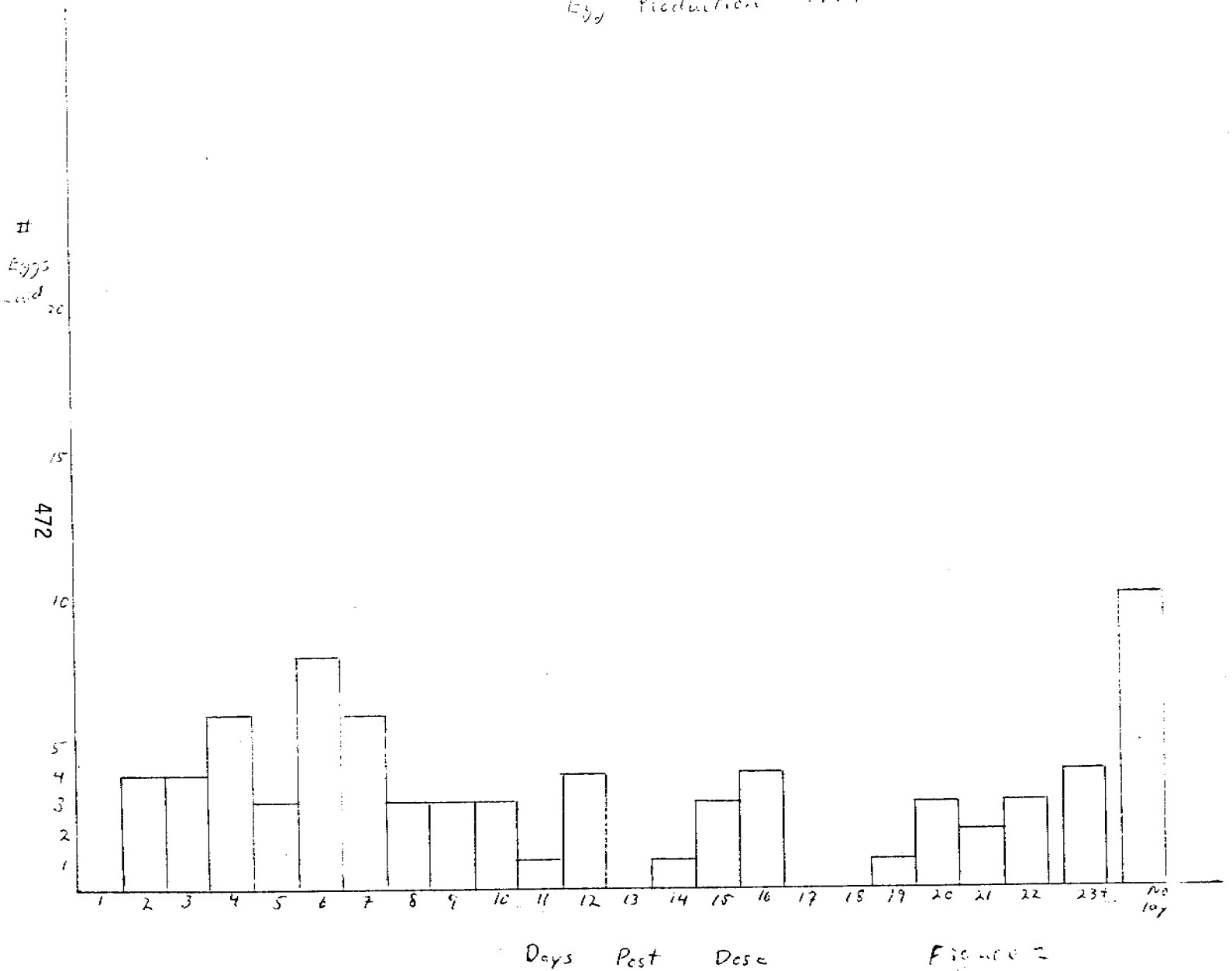
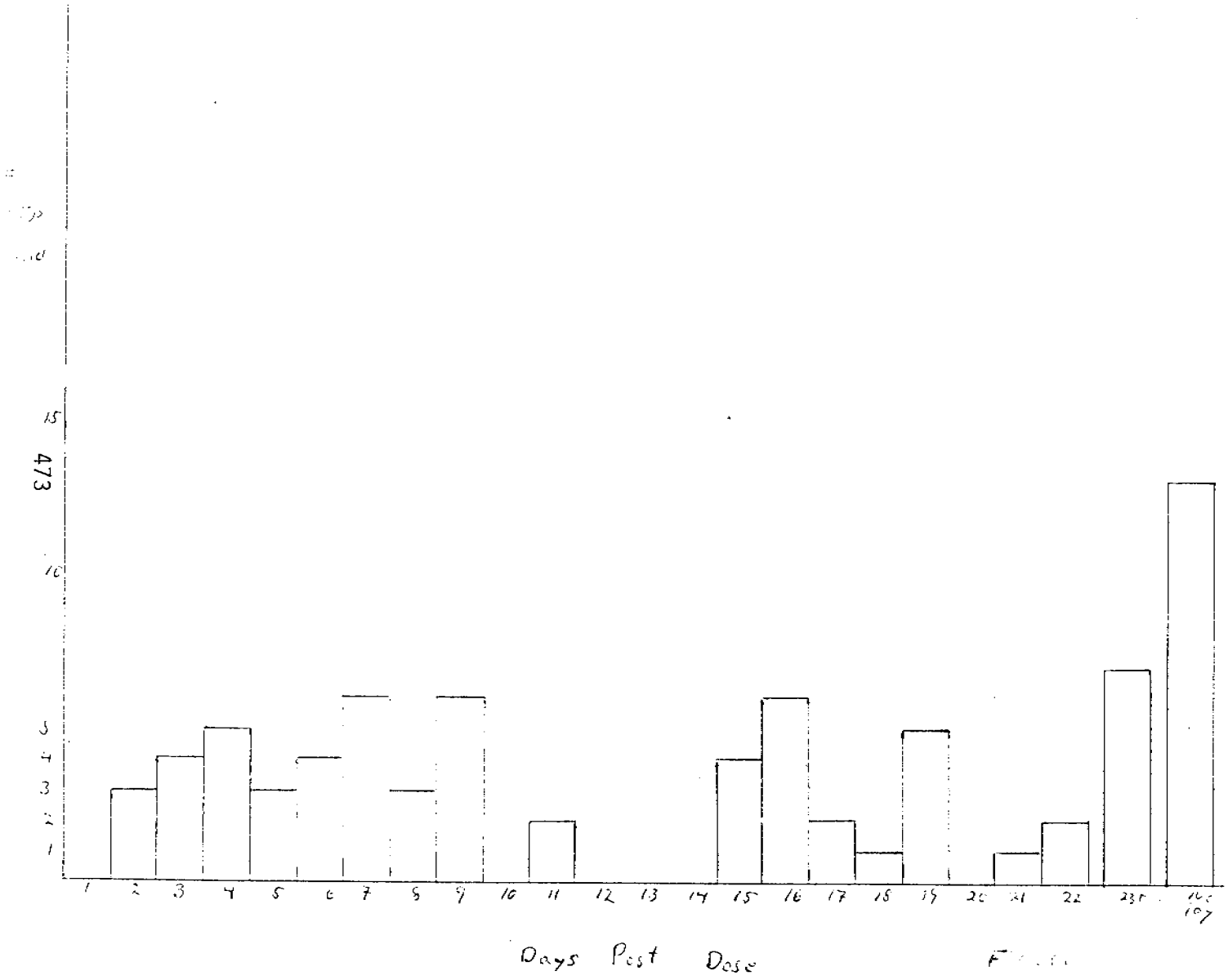


Figure 2

1-2-77

Cassin's Auklet

Egg Production 1977



Fledging Success - Bunker C -1978

Known Birds Still on Burrows When Checked

Plus Burrows with No Eggs

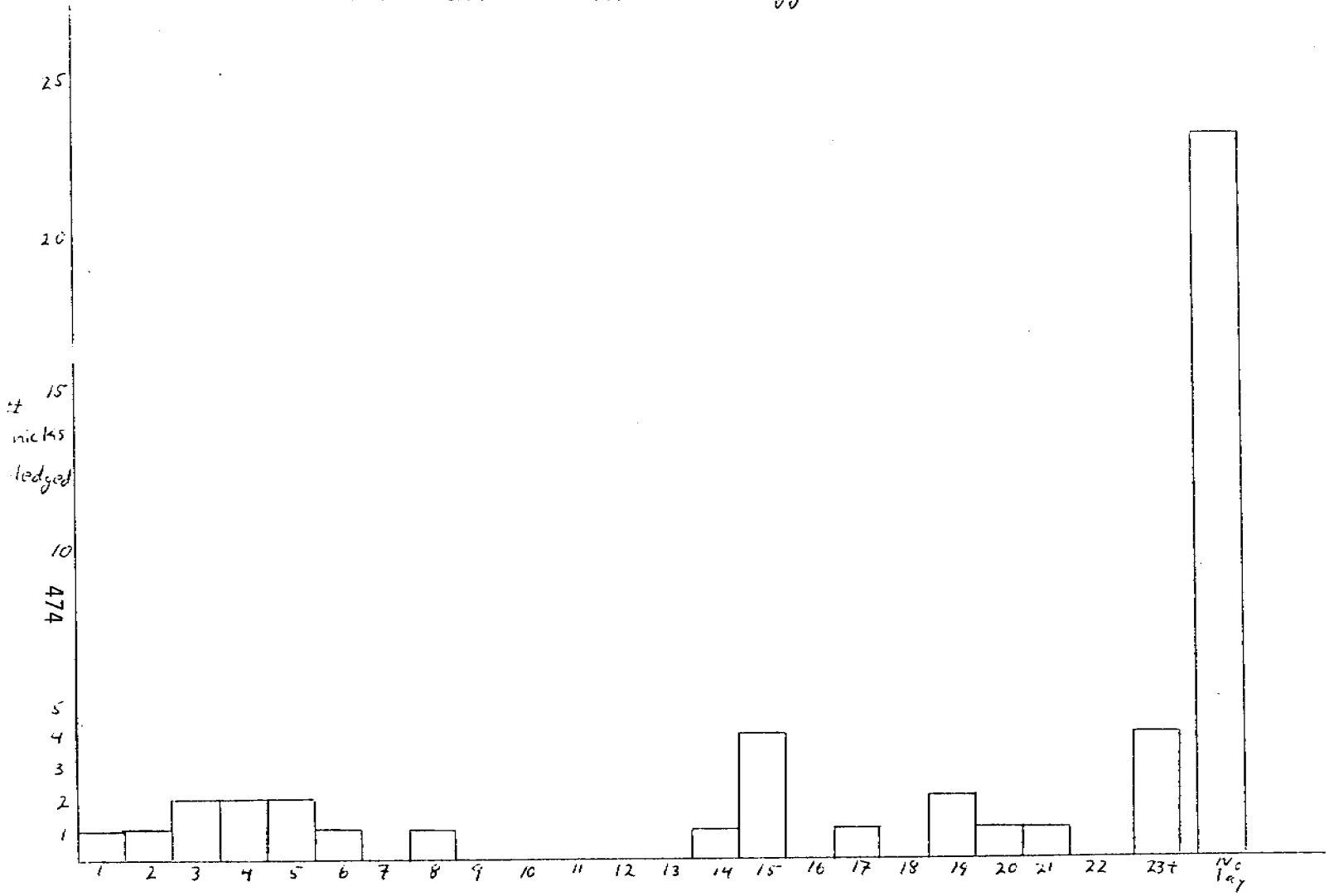
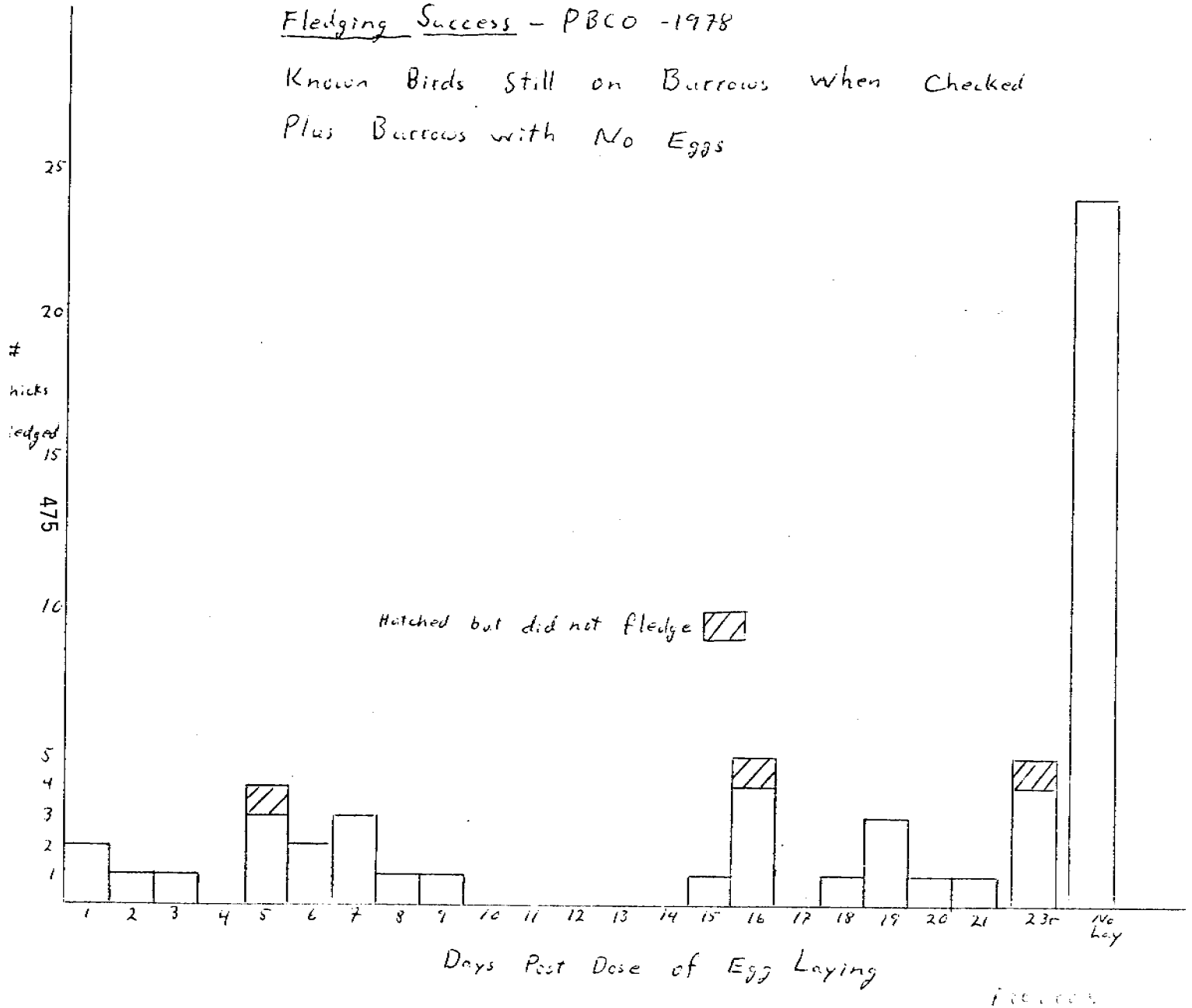


Figure 11


Fledging Success – PBCO -1978
Known Birds Still on Burrows when Checked
Plus Burrows with No Eggs
chicks fledged
25
20
15
10
5
4
3
2
1
475
Hatched but did not fledge
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 23+ No Lay
Days Post Dose of Egg Laying

QUARTERLY REPORT

Contract # 03-5-022-67-TA8 #4
Research Unit # 424
Reporting Period: 1 OCT 78 - 31 DEC 78
Number of Pages: 13

Lower Cook Inlet Meroplankton

T. Saunders English
Department of Oceanography
University of Washington

1 January 1979

Departmental Concurrence: Richard W Sternberg for
George C. Anderson
Associate Chairman for Research

REF: A78-28

I. Task Objectives

Our main objective is to conduct a quantitative survey to determine the seasonal distribution of commercially or ecosystem important species of ichthyoplankton, crab and shrimp larvae in Lower Cook Inlet, Alaska.

II. Field or Laboratory Activities

A. Ship or Field Trip Schedule

None in this quarter.

B. Scientific Party

None in this quarter.

C. Methods

The methods of laboratory analysis are unchanged from earlier reports.

D. Sample Localities

See Figure 1 and 2, Table 1 and 2.

E. Data Analyzed

Samples from nine cruises (19 May to 30 June 1978) were analyzed, representing fifty-seven bongo tows taken at thirty stations. All nine cruises were aboard the *Humdinger* and all samples were taken with a 60 cm bongo net (Table 3).

Samples were taken during three additional cruises (28 August, 3 September and 27 September) at four stations at the request of BLM (Figure 2, Table 2). They have been analyzed and represent four bongo and four neuston tows (Table 4).

F. Milestone Chart and Data Submission Schedule

The Milestone Chart (Table 5) covers the contract period from October 1978 to October 1979.

III. Results

Fish eggs, fish, crab and shrimp larvae from fifty-seven bongo hauls at thirty-one stations on nine cruises have been analyzed and the data submitted concurrently with this report as Fortran data cards. All data are in its complete form and should need no further changes. Further computer analyses will appear in future reports.

The fish eggs, fish, crab and shrimp larvae from four bongo and four neuston hauls taken at four BLM stations on three cruises have been analyzed and summarized (Table 4). Data have been submitted con-

currently with this report as Fortran data cards. All data are in its complete form and should need no further changes.

IV. Preliminary Interpretation of Results

Further computer analysis of data will enable us to give an interpretation to the results.

V. Problems Encountered

A few sorted samples from the 505 µm bongo nets were lost or broken during shipment from the field to the University of Washington. Replicate samples of the 333 µm mesh nets were analyzed and reported instead.

The funds for FY 79 have not been received by the University yet, nor has NOAA yet made a binding commitment that any or all of the funds agreed upon will eventually appear. This annual problem continues to be seriously disturbing to the University, the Department, the principal investigator and the employees on the contract.

VI. Estimate of Funds Expended

It is estimated that 36.75% of the funds agreed upon for FY 79 have been expended.

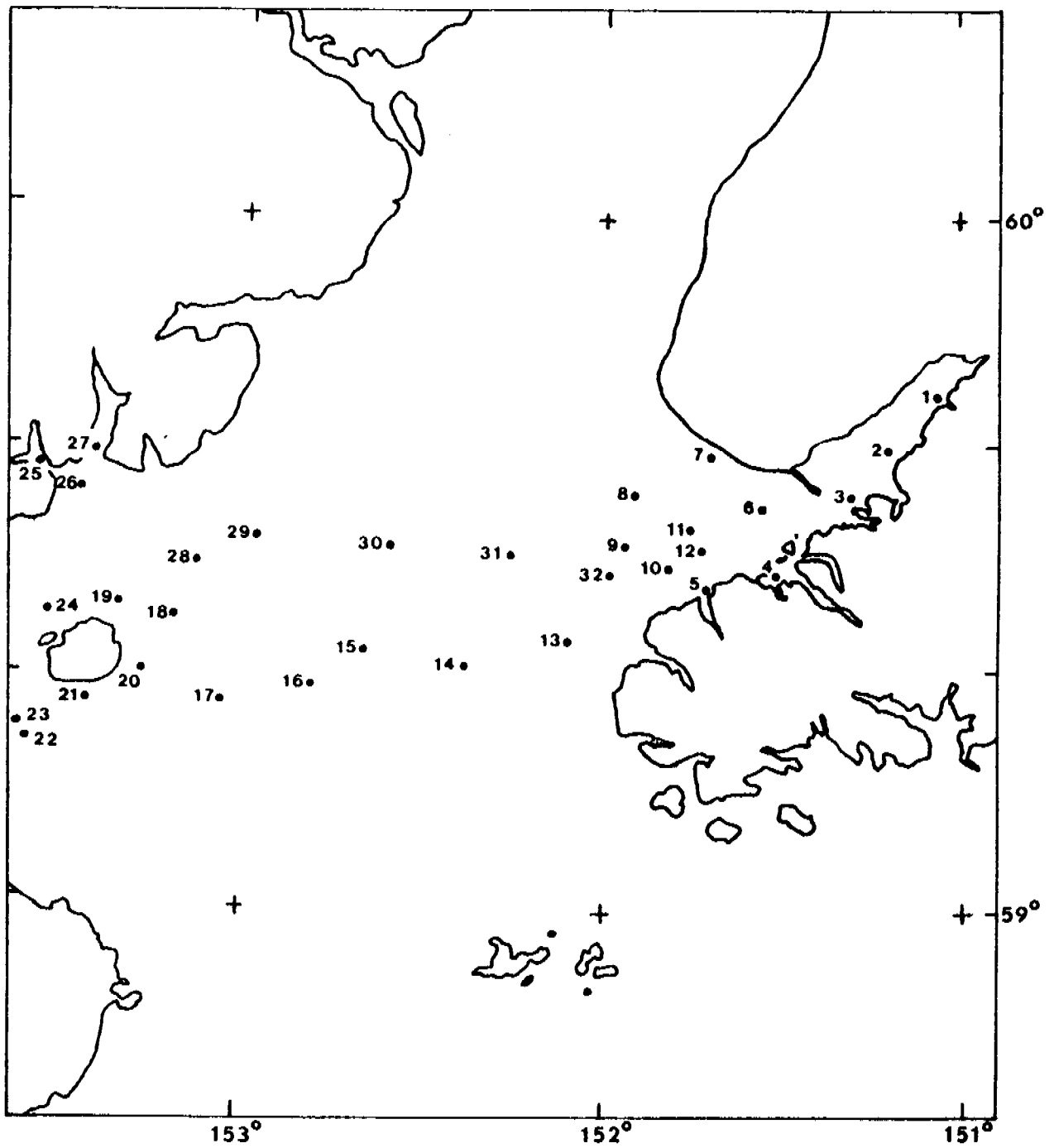


Figure 1. Station locations, Lower Cook Inlet.

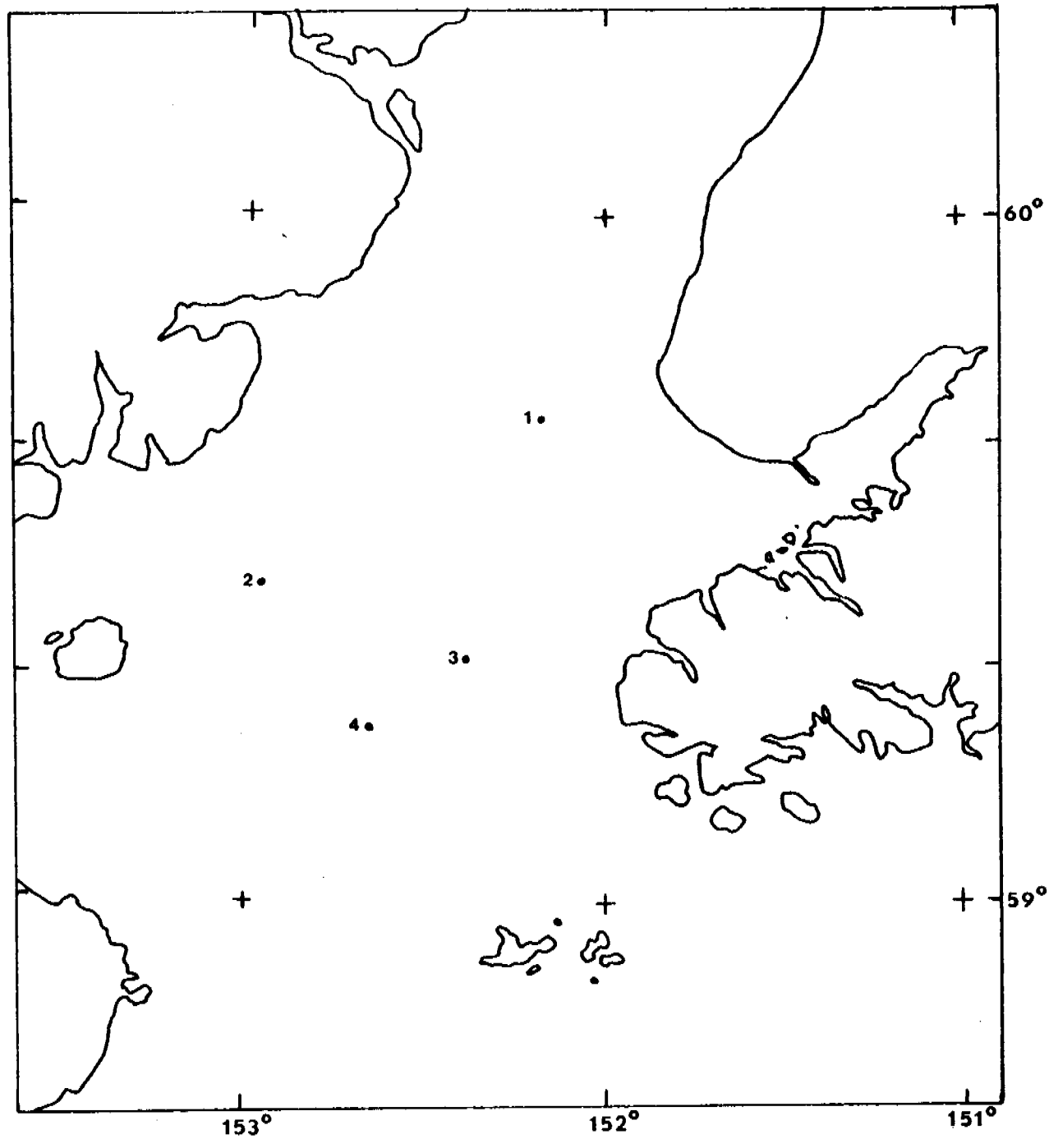


Figure 2. BLM station locations, Lower Cook Inlet.

Table 1. Station locations

Station	Latitude (N)	Longitude (W)	Depth (m)	Location
1	59° 44.0'	151° 04.0'	36	Inner Kachemak Bay
2	59° 40.0'	151° 12.0'	64	Inner Kachemak Bay
3	59° 36.0'	151° 18.0'	79	Inner Kachemak Bay
4	59° 28.5'	151° 32.0'	18	Jakalof Bay
5	59° 28.0'	151° 44.5'	18	Seldovia
6	59° 34.0'	151° 32.5'	73	Outer Kachemak Bay
7	59° 39.0'	151° 48.0'	29	Outer Kachemak Bay
8	59° 37.0'	151° 52.0'	26	Outer Kachemak Bay
9	59° 33.0'	151° 55.0'	35	Outer Kachemak Bay
10	59° 29.0'	151° 51.0'	60	Outer Kachemak Bay
11	59° 34.0'	151° 44.0'	73	Outer Kachemak Bay
12	59° 31.0'	151° 45.0'	84	Outer Kachemak Bay
13	59° 23.0'	152° 06.0'	53	Lower Cook Inlet
14	59° 20.0'	152° 22.0'	79	Lower Cook Inlet
15	59° 22.5'	152° 40.0'	59	Lower Cook Inlet
16	59° 16.3'	152° 49.5'	88	Lower Cook Inlet
17	59° 15.9'	153° 08.5'	53	Lower Cook Inlet
18	59° 26.0'	153° 14.0'	37	Lower Cook Inlet
19	59° 27.5'	153° 22.0'	27	Kamishak Bay
20	59° 20.0'	153° 14.0'	48	Kamishak Bay
21	59° 17.0'	153° 26.0'	26	Kamishak Bay
22	59° 14.0'	153° 40.0'	29	Kamishak Bay
23	59° 15.9'	153° 41.0'	27	Kamishak Bay
24	59° 27.0'	153° 34.0'	20	Kamishak Bay
25	59° 38.0'	153° 35.0'	5	Cottonwood Bay
26	59° 36.0'	153° 29.0'	5	Iliamna Bay
27	59° 39.0'	153° 26.0'	5	Iniskin Bay
28	59° 30.0'	153° 10.0'	35	Lower Cook Inlet
29	59° 32.0'	152° 58.0'	41	Lower Cook Inlet
30	59° 31.0'	152° 36.0'	60	Lower Cook Inlet
31	59° 33.0'	152° 14.0'	48	Lower Cook Inlet
32	59° 28.0'	151° 58.0'	66	Lower Cook Inlet

Table 2. BLM station locations

Station	Latitude (N)	Longitude (W)	Depth (m)	Location
BLM-1	59° 42.5'	152° 09.0'	37	Lower Cook Inlet
BLM-2	59° 27.0'	152° 59.0'	46	Lower Cook Inlet
BLM-3	59° 20.0'	152° 22.0'	84	Lower Cook Inlet
BLM-4	59° 11.0'	152° 39.0'	93	Lower Cook Inlet

Table 3. Haul summary sheet 19 May - 30 June 1978.

Cruise	Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
HU I	19 MAY	2159	1	1	60 cm bongo	46
		2359	2	2	"	39
	20 MAY	0049	3	1	"	52
HU II	28 MAY	2111	6	1	60 cm bongo	66
		2128	6	2	"	30
	29 MAY	0914	6	1	"	72
		0932	6	2	"	32
HU III	1 JUN	2018	12	1	60 cm bongo	65
		2103	10	1	"	66
		2154	9	1	"	26
		2234	8	1	"	18
		2311	7	1	"	24
	2 JUN	0002	11	1	"	70
		0101	6	1	"	67
HU IV	4 JUN	2057	13	1	60 cm bongo	35
		2207	14	1	"	86
		2354	15	1	"	48
	5 JUN	0114	16	1	"	76
HU V	8 JUN	2054	24	1	60 cm bongo	6
		2128	23	1	"	8
		2203	22	1	"	19
		2327	21	1	"	10
	9 JUN	0032	20	1	"	38
		0125	18	1	"	29
		0209	19	1	"	20
HU VI	9 JUN	1625	28	1	60 cm bongo	23
		1734	29	1	"	33
		1924	30	1	"	41
		2140	31	1	"	38
		2214	32	1	"	71
HU VII	26 JUN	1627	25	1	60 cm bongo	5
		1723	27	1	"	3
		1747	26	1	"	11
		1910	19	1	"	16
		2006	24	1	"	18
		2153	23	1	"	21
		2219	22	1	"	23
		2345	21	1	"	20
	27 JUN	0055	20	1	"	42
		0144	17	1	"	49

Table 3. (cont.)

Cruise	Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
HU VII	27 JUN	0318	16	1	60 cm bongo	85
		0433	15	1	"	52
		0559	14	1	"	70
		0658	13	1	"	50
		0910	10	1	"	49
HU VIII	28 JUN	2249	6	1	60 cm bongo	70
	29 JUN	0022	11	2	"	69
		0128	7	1	"	23
		0157	8	1	"	20
		0302	9	1	"	35
		0406	12	1	"	81
		0516	4	1	"	10
HU IX	29 JUN	1744	2	1	60 cm bongo	44
		1853	1	2	"	37
		2016	3	1	"	52
		2121	6	1	"	87
	30 JUN	0922	6	1	"	85
HU XXII	28 AUG	2318	BLM-3	1	60 cm bongo	76
		2325	BLM-3	2	neuston	surface
HU XXV	3 SEP	0009	BLM-1	1	60 cm bongo	32
		0022	BLM-1	2	neuston	surface
		0440	BLM-2	1	"	"
		0450	BLM-2	2	60 cm bongo	41
HU XXVIII	27 SEP	0057	BLM-4	1	neuston	surface
		0110	BLM-4	2	60 cm bongo	105

Table 4. Lower Cook Inlet-BLM stations (1978)

Date (GMT)	Station	Time (GMT)	Mesh Size (μm)	NODC Code No.	Species	Size (mm) or Stage	% Sample	No.	No. /m^3	Net
3 SEP	BLM-1	0009	333	8755030201	*Mallotus villosus*	5.6, 7.1	100%	2	0.054	bongo
				6183	anomurans	zoea		3	0.081	
				61880301	*Cancer* spp. (not *magister*)	V		5	0.135	
				61880301	" "	meg.		40	1.081	
				6184	brachyurans	zoea		5	0.135	
				617916	hippolytids	zoea		12	0.324	
		0009	505	8755030201	*Mallotus villosus*	15	100%	1	0.027	bongo
				6183	anomurans	zoea		7	0.189	
				6183	anomuran	meg.		1	0.027	
				61880301	*Cancer* spp. (not *magister*)	I		2	0.054	
				61880301	" "	V		12	0.324	
				61880301	" "	meg.		45	1.216	
				6184	brachyurans	zoea		4	0.108	
				617916	hippolytids	zoea		10	0.270	
		0022	505	6188030104	*Cancer magister*	II	100%	1	0.014	neuston
3 SEP	BLM-2	0450	333	8755030201	*Mallotus villosus*	7.0, 7.4	100%	2	0.050	bongo
				6183	anomurans	zoea		16	0.400	
				6188030104	*Cancer magister*	II		1	0.025	
				61880301	*Cancer* spp. (not *magister*)	meg.		3	0.075	
				6184	brachyurans	zoea		3	0.075	
				617916	hippolytids	zoea		35	0.875	

Table 4. (cont.)

Date (GMT)	Station	Time (GMT)	Mesh Size (μm)	NODC Code No.	Species	Size (mm) or Stage	% Sample	No.	No. /m^3	Net
3 SEP	BLM-2	0450	505	8755030201	*Mallotus villosus*	6.8, 14	100%	2	0.050	bongo
				6183	anomurans	zoea		16	0.400	
				61880301	*Cancer* spp. (not *magister*)	V		1	0.025	
				61880301	" "	meg.		1	0.025	
				6184	brachyurans	zoea		4	0.100	
				6184	brachyurans	meg.		1	0.025	
		0440	505	8818910101	*Gasterosteus aculeatus*	12-25	100%	9	0.127	neuston
				88270101	*Hexagrammos* sp.	7.7-8.1		4	0.056	
				61880301	*Cancer* spp. (not *magister*)	meg.		2	0.028	
28 AUG	BLM-3	2318	333	8755030201	*Mallotus villosus*	5.7	100%	1	0.016	bongo
				88260101	*Sebastes* sp.	3.8		1	0.016	
				6183	anomurans	zoea		13	0.210	
				6188030104	*Cancer magister*	V		2	0.032	
				61880301	*Cancer* spp. (not *magister*)	III		1	0.016	
				61880301	" "	IV		1	0.016	
				61880301	" "	V		21	0.339	
				61880301	" "	meg.		2	0.032	
				6184	brachyurans	zoea		3	0.048	
				617916	hippolytids	zoea		107	1.726	

Table 4. (cont.)

Date (GMT)	Station	Time (GMT)	Mesh Size (μm)	NODC Code No.	Species	Size (mm) or Stage	% Sample	No.	No. /m^3	Net
28 AUG	BLM-3	2318	505	88310204	*Artedius* sp. (Type 1)	3.6	100%	1	0.016	bongo
				8755030201	*Mallotus villosus*	6.7- 17		3	0.047	
				884003	Bathymasteridae	6.1		1	0.016	
				875503	Osmeridae	5.8		1	0.016	
				6183	anomurans	zoea		10	0.156	
				6183	anomurans	meg.		2	0.031	
				6188030104	*Cancer magister*	V		1	0.016	
				61880301	*Cancer* spp. (not *magister*)	II		1	0.016	
				61880301	" "	III		1	0.016	
				61880301	" "	IV		2	0.031	
				61880301	" "	V		11	0.172	
				61880301	" "	meg.		4	0.062	
				6184	brachyurans	zoea		11	0.172	
				617916	hippolytids	zoea		95	1.484	
		2325	505	8818010101	*Gasterosteus aculeatus*	19	100%	1	0.014	neuston
				88270101	*Hexagrammos* sp.	9.1-13		14	0.197	
				8755030201	*Mallotus villosus*	23-27		4	0.056	
				884003	Bathymasteridae	6.8, 7.7		2	0.028	
				875503	Osmeridae	7.4-35		30	0.422	
				6188030104	*Cancer magister*	meg.		4	0.056	
27 SEP	BLM-4	0110	333	61880301	*Cancer* spp. (not *magister*)	meg.	100%	4	0.043	
				6184	brachyurans	zoea		1	0.011	
				617916	hippolytids	zoea		12	0.130	

Table 4. (cont.)

Date (GMT)	Station	Time (GMT)	Mesh Size (μm)	NODC Code No.	Species	Size (mm) or Stage	% Sample	No.	No. /m^3	Net
27 SEP	BLM-4	0110	505	8831090506	*Eumicrotremus orbis?*	9.0	100%	1	0.011	bongo
				61880301	*Cancer* spp. (not *magister*)	meg.		6	0.067	
				617916	hippolytids	zoea		12	0.135	
		0057	505	88270101	*Hexagrammos* sp.	5.6	100%	1	0.028	neuston
				879103	Gadidae	6.2		1	0.028	

Table 5. Milestone chart and data submission schedule.

O - Planned Completion Date

X - Actual Completion Date

RU # 424 PI: T. Saunders English

Major Milestones: Reporting, 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
Planning Workshops: LCI Synthesis	⊢	—	⊣										
Data Processing	⊢	—	—	—	—	—	—	—	—	—	—	⊣	
Quarterly Report				X									
Submit Spring 78 Data (55 bongo)				X									
Annual Report							O						
Quarterly Report										O			
Submit Summer 78 Data (42 bongo + 57 neuston)										O			
Final Report													O

QUARTERLY REPORT

Research Unit #425

Reporting Period: October 1-December 31, 1978

ORGANIC DETRITUS AND PRIMARY PRODUCTIVITY IN LOWER COOK INLET

Principal Investigator: Jerry D. Larrance

Report Prepared By: Alex Chester

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National Oceanic and Atmospheric Administration
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January 2, 1978

I. ABSTRACT

Analyses of sediment trap and water colmn data collected during the 1978 field season have progressed on schedule. Computer punch cards containing pigment, primary productivity, nutrients, and sunlight information (file type 029) have been prepared for all five cruises and forwarded to the OCSEAP project office. Enumeration of phytoplankton samples is complete and keypunching and computer analysis will commence shortly. Work on sediment trap samples has proceeded and preliminary information on carbon and nitrogen content is available.

Sediment trap samples obtained from each of three stations during four of the five cruises to Cook Inlet have yielded information on input of organic material to the seafloor (see Fig. 1 for station locations and area chart). Downward daily fluxes of total particulate matter ranged from 2 to 22 g/m^2, except for an extreme value of 72 g/m^2 in an area and period of high runoff. By analysis of chlorophyllous pigments in the sediment traps and in the water column, it is estimated that an average of 8% of this loss is attributable to grazing and subsequent fecal pellet production by herbivorous zooplankton.

Analyses of chlorophyll, productivity, and related parameters give results that are in general agreement with patterns perceived in 1976. Kachemak Bay is the site of the initial plankton bloom in early May (Chl. *a* 200 mg/m^2; production = 7-8 gC/m^2-day). The bloom in Kamishak Bay is delayed by about one month. Standing stocks of phytoplankton do not increase in the central portion of Cook Inlet until well into the summer. This information will be combined with data on water circulation, water column stability, and suspended sediment concentrations to further characterize

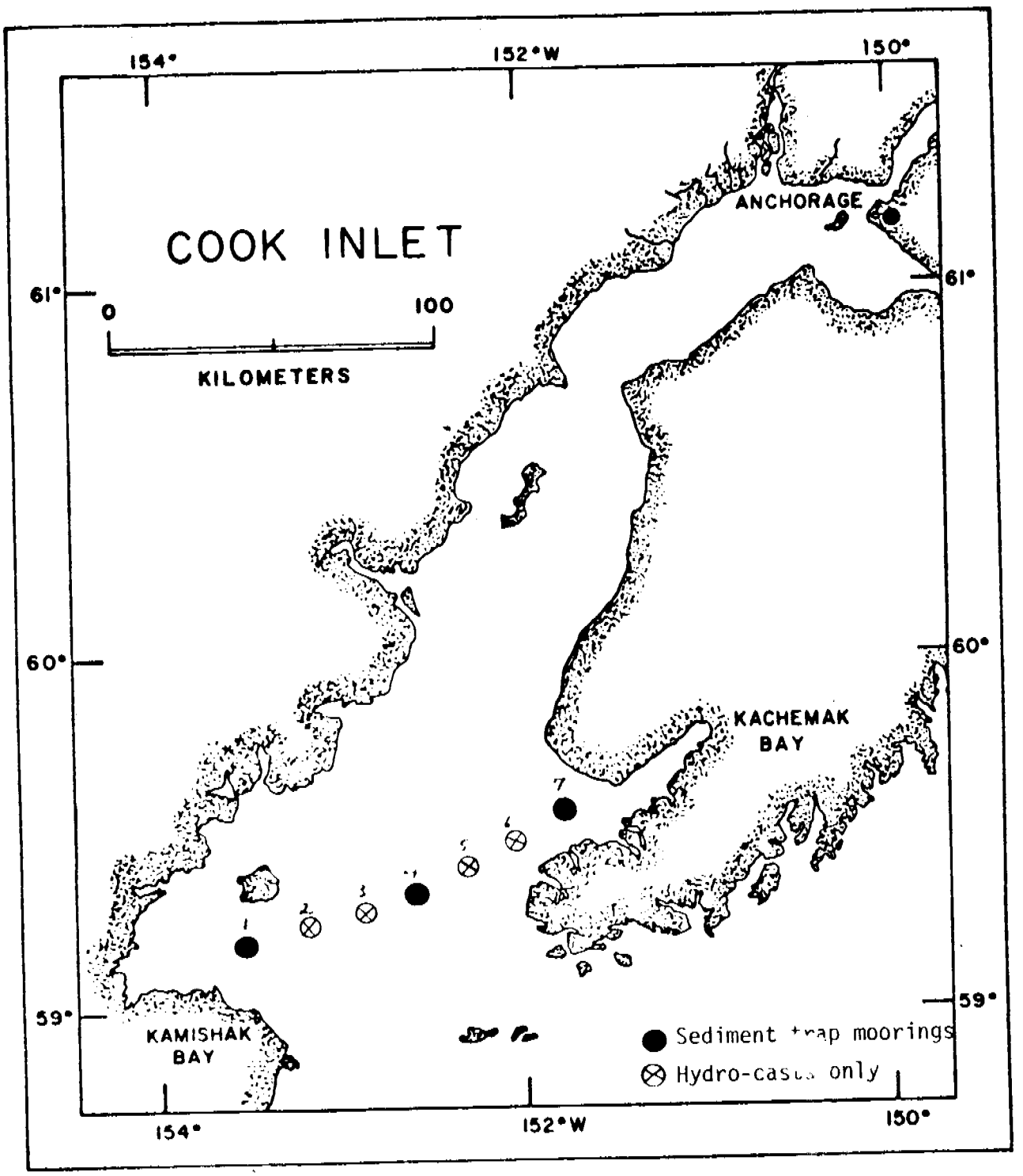


Figure 1. Station locations, lower Cook Inlet, 1978.

the bio-physical environments of Cook Inlet with respect to the production and input of organic material to the sea floor.

II. TASK OBJECTIVES

Specific objectives for the period October through December were:

1. To complete preliminary analysis of chlorophyll, primary productivity, and nutrient samples, and commit the data to keypunch cards in NODC formats for delivery to OCSEAP;

2. To complete the enumeration of selected phytoplankton samples and prepare data in NODC formats;

3. To continue analysis of sediment trap samples including total and organic carbon and nitrogen determinations, microscopical scanning for fecal pellets and other recognizable organic debris, and preliminary electron microscope observation of selected fecal material;

4. To begin data synthesis of environmental variables.

III. LABORATORY ACTIVITIES

Specific laboratory activities included:

1. liquid scintiallation counting of ^{14}C primary production experiments;

2. analysis of remaining nutrient samples;

3. enumeration of phytoplankton species in preserved samples;

4. inspection and counting of selected organic particles collected from sediment traps by light and electron microscopes;

5. determination of total and organic carbon and nitrogen content of sediment trap samples;

6. preparation of data for delivery to OCSEAP;

7. preliminary computer processing of data;

8. preparation of data in graphic and tabular formats suitable for reporting and data synthesis.

IV-V. RESULTS AND INTERPRETATION

A. Particulate matter sampled by sediment traps

The available information on material caught in the sediment traps is summarized in Table 1. The downward flux of particles ranged between 2 and 22 g/m^2-day except for a value of 72 g/m^2-day in May in Kamishak Bay (Sta. 1). At that time the water was noticeably much more turbid than at other areas and times, and contained heavy loads of terrestrial particulate matter. The overall mean daily flux was 19.4 g/m^2, but was 13.5 g/m^2 if the high May value at station 1 is omitted. With the omission of that value, the largest mean daily (19.1 g.m^2) flux occurred in Kachemak Bay (Sta. 7) as compared to a mean of 10.8 g/m^2 at both stations 1 and 4.

The highest chlorophyll and fecal pellet content was also found in the Kachemak Bay samples. The chlorophyll equivalent values given in Table 1 include pheopigment concentrations which have been adjusted for the molecular weight differences between chlorophyll and pheophorbide in order to obtain estimates of chlorophyll lost from the water column by grazing (Shuman and Lorenzen, 1975). The pigment concentrations in sediment trap samples were distinctly greater at station 7 (Kachemak Bay) than at stations 1 and 4 for all sampling periods. The mean flux at station 7 was 14.3 mg/m^2-day contrasting with means of 2.6 and 2.4 mg/m^2-day for stations 1 and 4. The mean numbers of fecal pellets were 421, 780, and 1470 x 10^3/m^2-day for stations 1, 4, and 7, respectively. These pigment and fecal pellet fluxes reflect the high biological production in Kachemak Bay.

Table 1. Daily fluxes of total particulate matter, plant pigments, zooplankton fecal pellets, and derived estimates of losses from overlying phytoplankton populations, lower Cook Inlet, 1978.

Station	Month	Total Particulate Matter (TPM) g·m⁻²-day	Chloropnyll Equivalents mg·m⁻²-day	Standing Stock Lost %	Grazing Loss %	Fecal Pellets $10^3/m^2$-day
7	May	17.3	17.2	8.5	79	360
	June	22.1	14.4	5.7	81	930
	July	-	-	-	-	-
	August	18.0	11.3	7.6	89	3110
4	May	9.4	1.9	4.1	89	250
	June	22.1	5.0	18.2	85	2010
	July	1.9	1.0	2.6	88	79
	August	9.6	1.5	1.6	87	120
1	May	72.0	1.6	9.9	90	92
	June	-	-	-	-	-
	July	6.4	3.0	7.2	61	750
	August	15.2	3.1	9.2	81	1830

The relationship between estimated chlorophyll grazed and fecal pellets found in the trap was explored. While no positive correlation was found between chlorophyll grazed and numbers of fecal pellets counted in the samples (Fig. 2), the correlation was significant (r^2=.69) when fecal pellet volumes were used (Fig. 3). That the three values from station 7 fall above the regression line, indicates that fecal pellets produced in Kachemak Bay may be richer in phytoplankton remains than those at stations 1 and 4. This view is consistent with data showing higher TSP: Chlorophyll ratios in the sediment traps at stations 1 and 4 and suggests that zooplankton grazers may be ingesting relatively more inorganic (non-chlorophyll bearing) particles there than at station 7.

By comparing the pigment fluxes with chlorophyll concentrations in the overlying waters, an estimate was made of the portion of the phytoplankton population lost each day by sinking of algal particles which include whole cells, cell fragments, and zooplankton fecal pellets. The percentage loss ranged between 2 and 24% with a mean of 7.5%. The pheopigment fraction of the total pigment flux is listed in Table 1 as grazing loss. Of the total plant biomass lost from the water column, an average of 83% could be attributed to grazing and fecal pellet production. The assumption was made that chlorophyll is converted to pheophorbide only within the guts of grazers (Shuman and Lorenzen, 1975).

We have completed initial light-microscope scans of the sediment-trap samples. In addition to numerous fecal pellets, amorphous fecal material, intact diatom cells, zooplankton molt material,

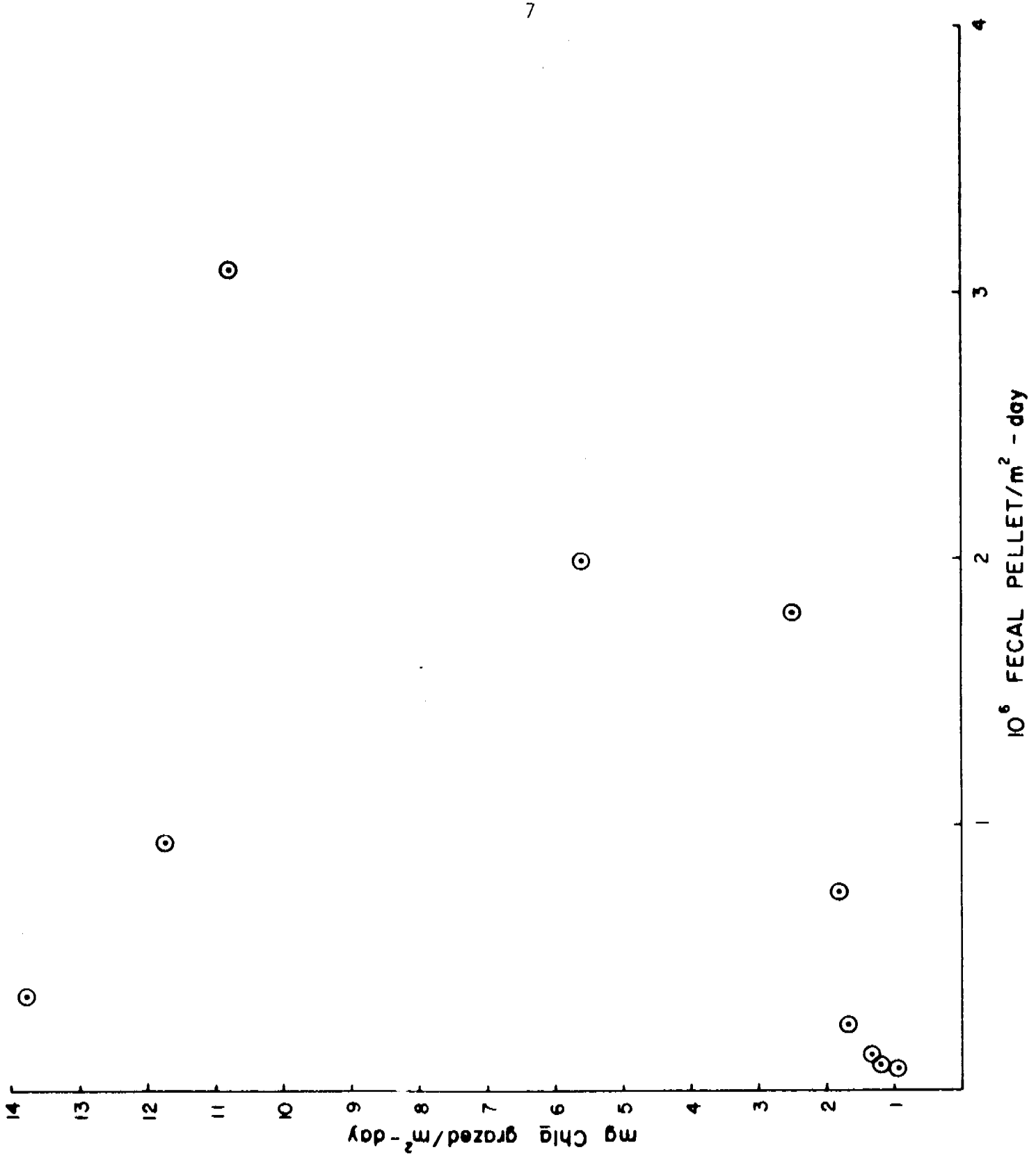


Figure 2. Estimated chlorophyll grazed as a function of fecal pellet numbers caught in sediment traps, lower Cook Inlet, 1978.

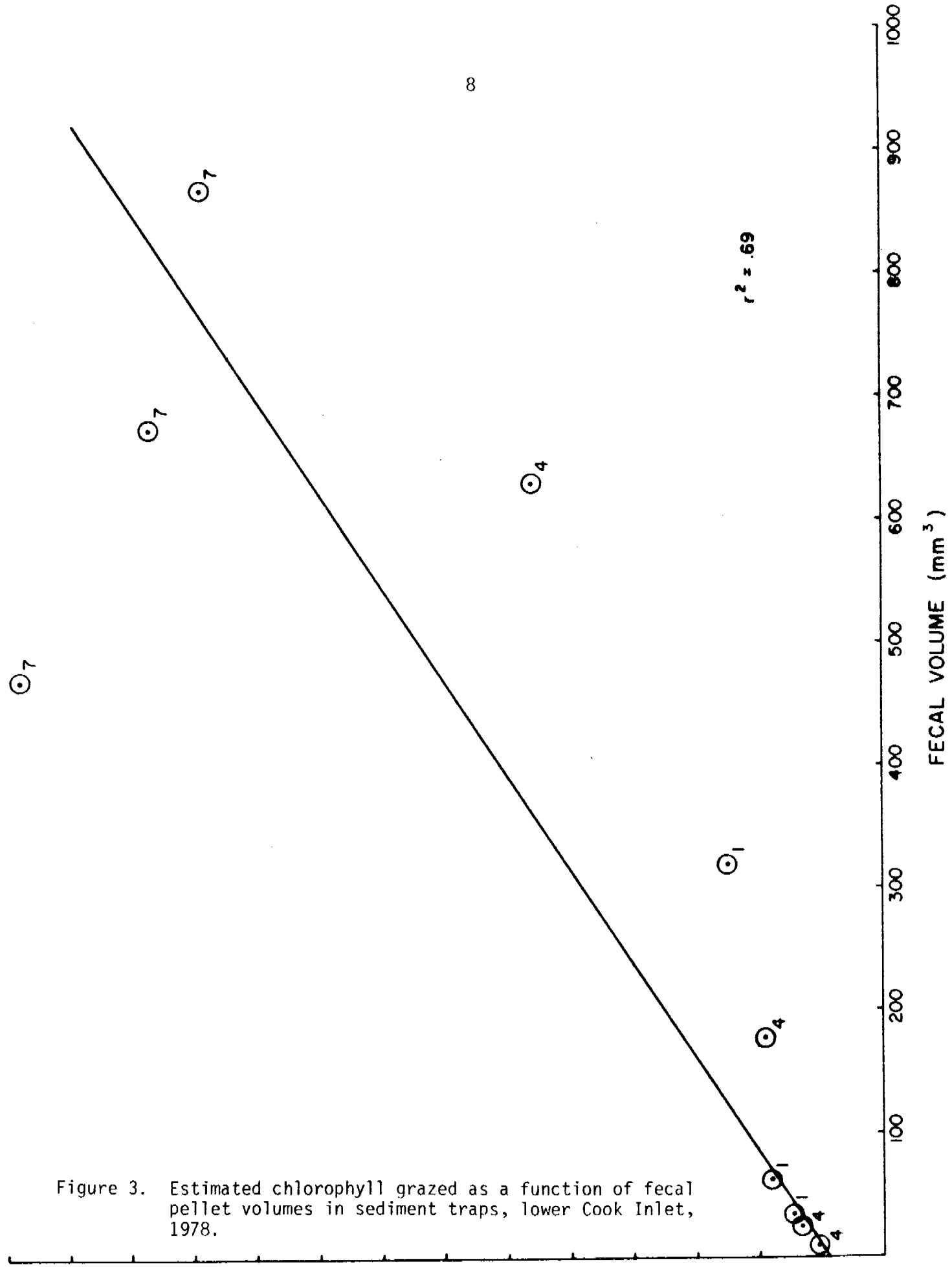


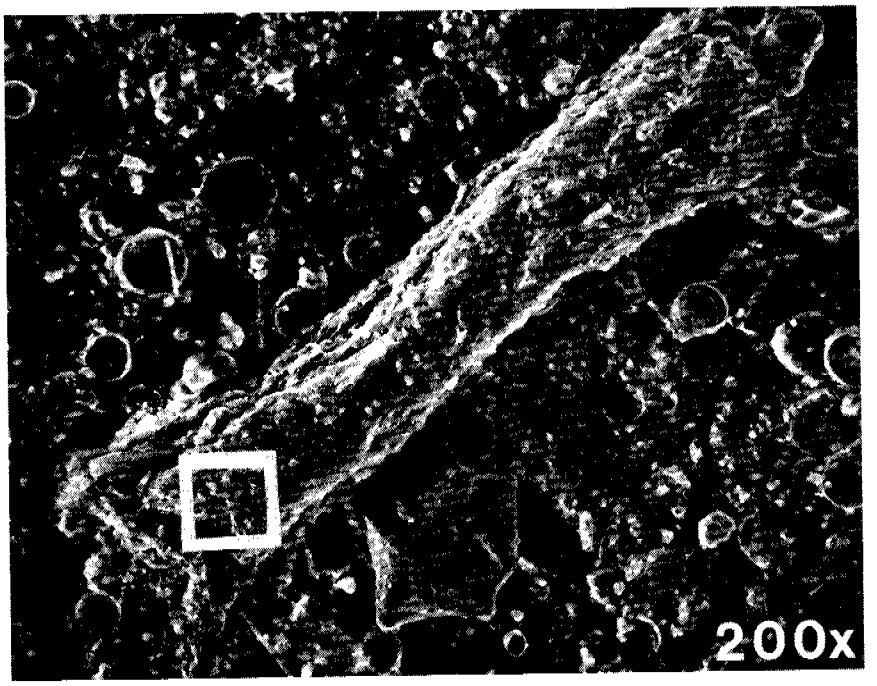
Figure 3. Estimated chlorophyll grazed as a function of fecal pellet volumes in sediment traps, lower Cook Inlet, 1978.

and larvae of various bottom settling invertebrates such as polychaete worms, barnacles, clams, snails, and crabs were commonly seen. Scanning electron micrographs of representative fecal pellets clearly show the presence of broken diatom frustules (Fig. 4).

Preliminary determinations of organic carbon and nitrogen content of the sediment trap material is not complete, but initial analysis emphasizes the small quantity of usable organic matter present in the sediment trap samples. Even in the biologically active area of Kachemak Bay, carbon accounted for only about 3% of the sediments by weight. Analysis of these samples is continuing, and implications for the benthic food web will be considered later.

B. Water column data

Although most of the data obtained from water column sampling has been analyzed, extensive integration of the information has not been completed. Still, some broad characterizations can be made regarding the patterns of phytoplankton distribution and productivity. Typical cross sectional plots of chlorophyll (Fig. 5) show highest values generally at station 7 and usually lower values at mid-channel. These distributions are consistent with temperature and circulation information which indicates deep water rising toward the surface at mid-channel. This deep water contains low concentrations of chlorophyll. Figure 6 shows the average values of chlorophyll _a_ (integrated to 50 m, except to 25 m at stations 1 and 2) for the seven station transect across lower Cook Inlet. Values were uniformly low during late March. The spring bloom began in Kachemak Bay by the early part of May, but was not



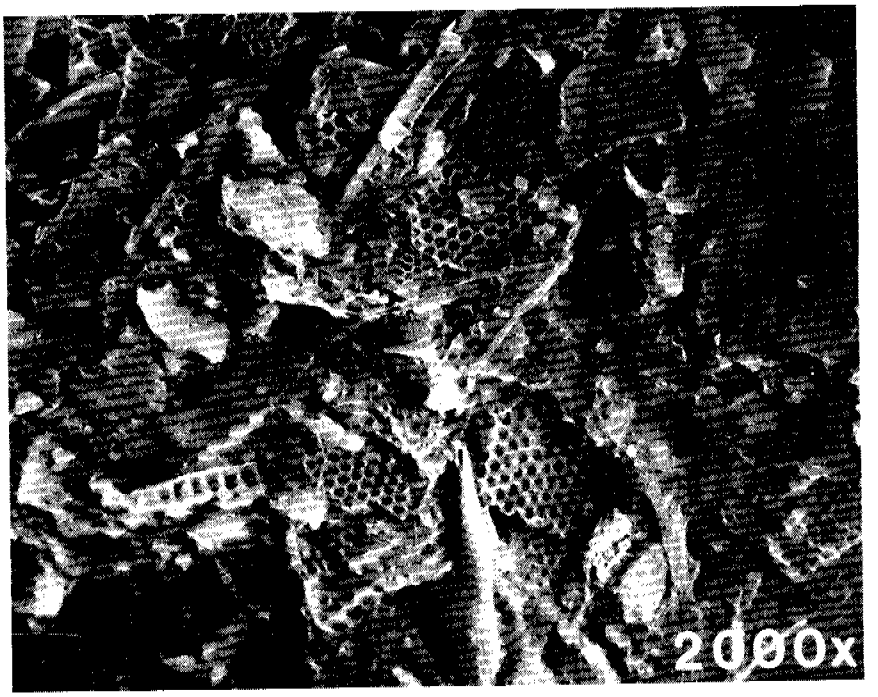


Figure 4. Electron micrographs of a typical fecal pellet.

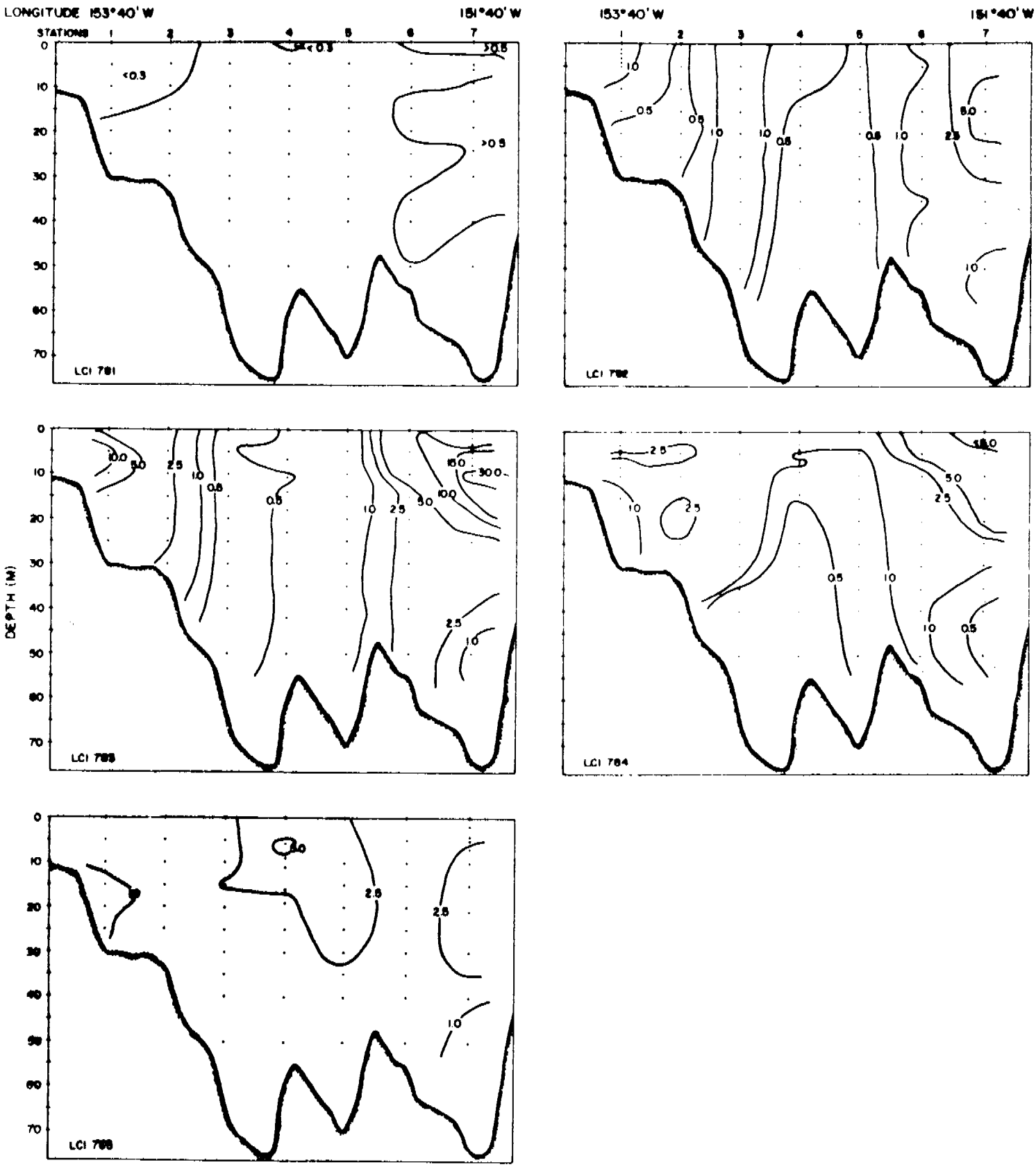


Figure 5. Representative chlorophyll section plots, lower Cook Inlet, 1978. Chlorophyll a in mg/m^3.

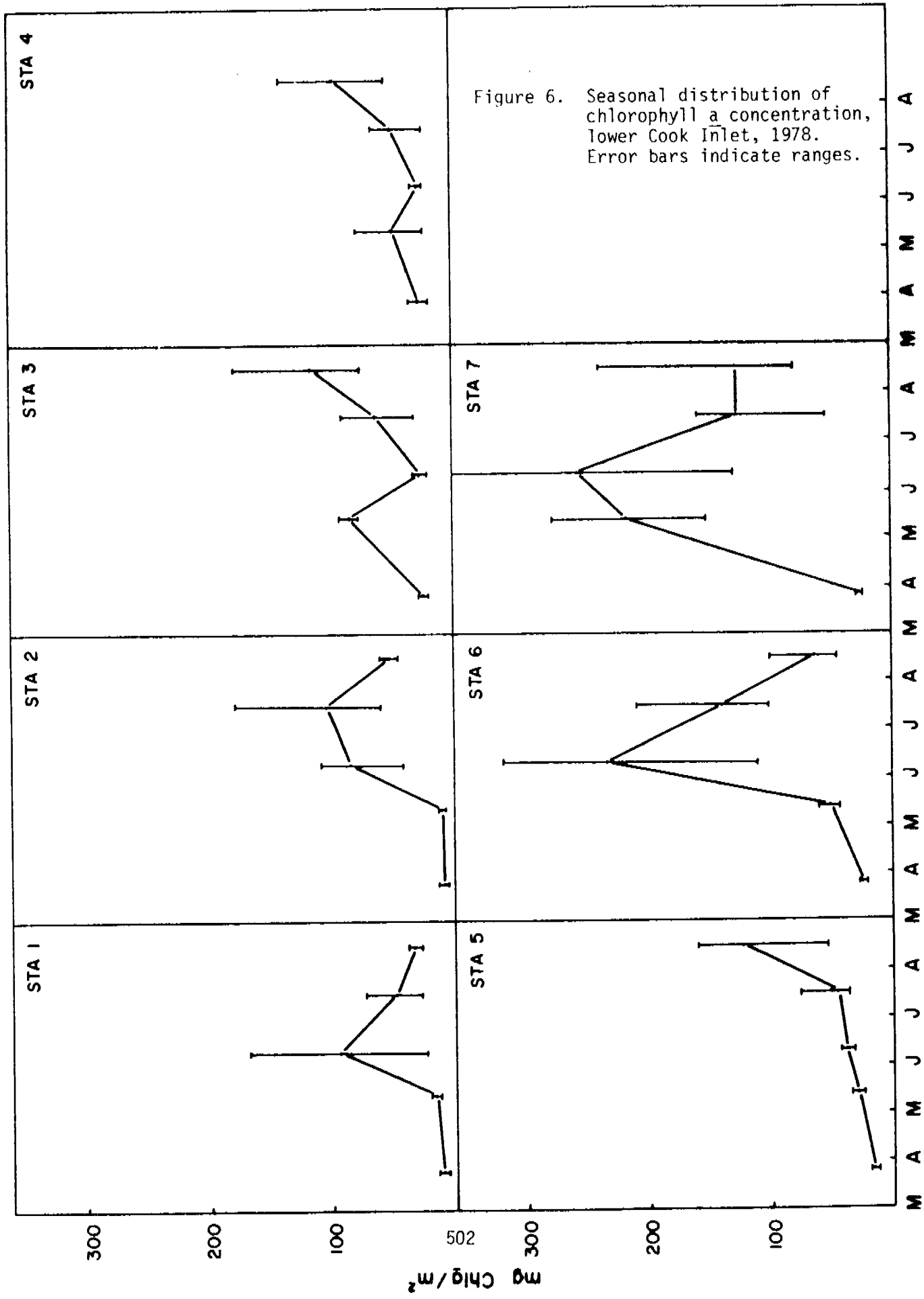


Figure 6. Seasonal distribution of chlorophyll a concentration, lower Cook Inlet, 1978. Error bars indicate ranges.

apparent elsewhere in the inlet. In June, the bloom was in evidence in both Kachemak (Sta. 6-7) and Kamishak (Sta. 1-2) Bays, with little activity noticed at the three central inlet sites. Phytoplankton biomass levels in these bays remained relatively high through July and August, though somewhat reduced from June peaks. No substantial increase in phytoplankton standing stock was observed in the central portion of the inlet until August. Information on primary productivity generally supports biomass observations (Fig. 7). Station 7, in Kachemak Bay, was most productive in May and maximum productivity rates in Kamishak Bay (Sta. 1) occurred in June. High production levels in the central inlet were not observed until August.

Water transparency as indexed by Secchi Disk depth is a useful parameter for evaluating cross inlet differences between Kachemak Bay, Kamishak Bay, and the central basin of Cook Inlet (Fig. 8). High loads of terrestrially derived sediments carried by water exiting along the western side of Cook Inlet cause highly turbid waters in the Kamishak Bay region during the early spring. The decreased submarine light levels which result may explain why the Kamishak Bay bloom is delayed until June. Water transparency was greater in June even though suspended matter derived from phytoplankton was greater. Transparency was greater in the central inlet, and Secchi Disk depths increased from west to east as cleaner inflowing ocean water was encountered. Transparency in the central inlet did not decrease until July and August when productivity increased. In the Kachemak Bay region (Sta. 6-7), transparency was high in the early spring, but rapidly declined

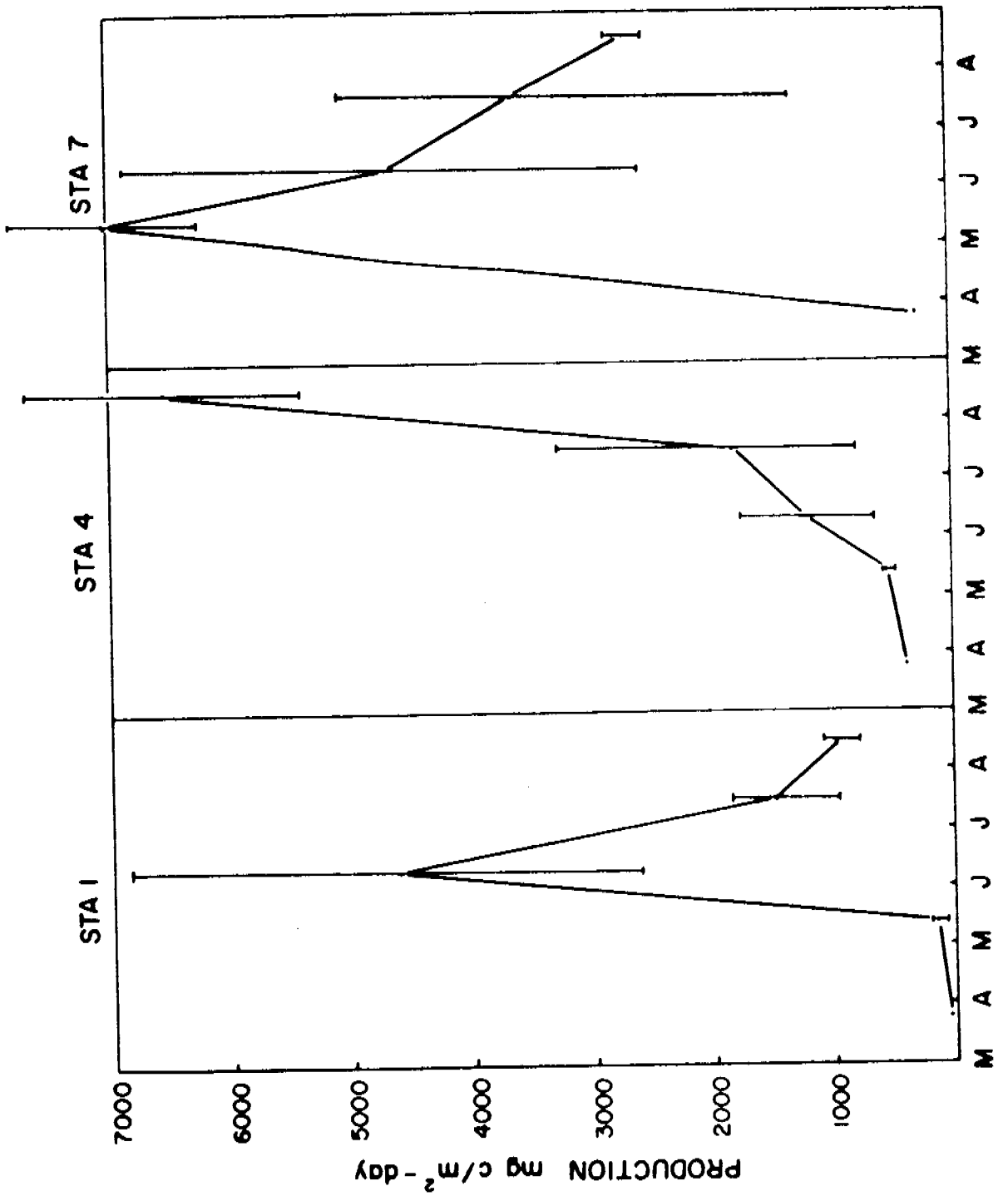


Figure 7. Seasonal distribution of primary production, lower Cook Inlet, 1978. Error bars indicate ranges.

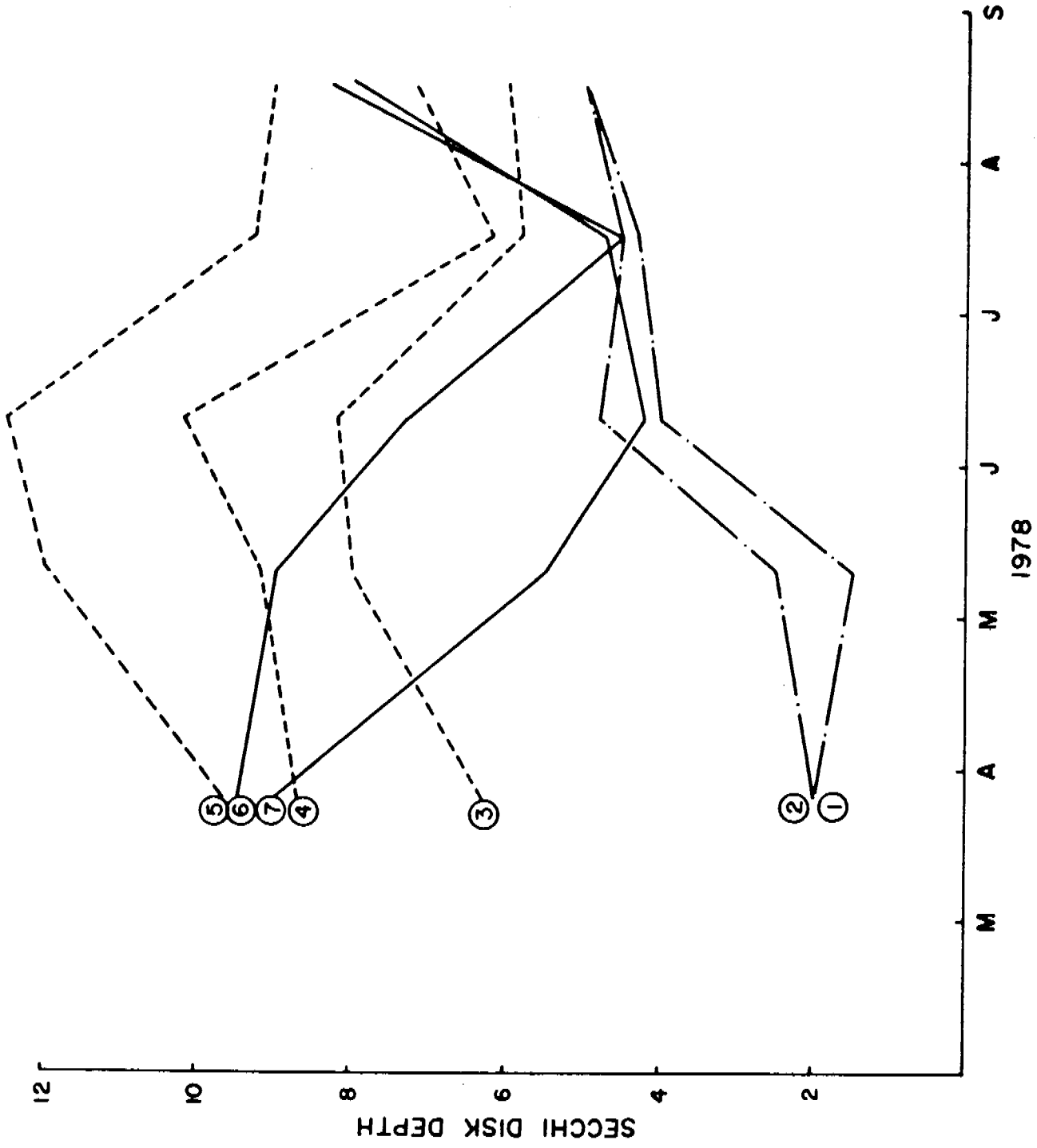


Figure 8. Average Secchi Disk measurements during five cruises, lower Cook Inlet, 1978.

as the bloom developed through May, June, and July. Clearer water was encountered in August. These water clarity observations are consistent with our general notions of Cook Inlet circulatory and biological patterns and help ellucidate the different bio-physical areas of lower Cook Inlet.

VI. REFERENCES

Shuman, F. R., and C. J. Lorenzen (1975). Quantitative degradation of chlorophyll by a marine herbivore. Limnol. Oceanogr., 20(4): 580-586.

VII. ESTIMATE OF FUNDS EXPENDED: $19,500.00

QUARTERLY REPORT

ON RESEARCH UNIT 454

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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FIRST QUARTER OF FY1979

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OCSEAP Office
P. O. Box 1808
Juneau, Alaska

Contract No. 2311102778

January, 1979

UPTAKE OF TRACE METALS FROM CLEAN AND OIL-CONTAMINATED DETRITUS

METHODS

Previous experiments have indicated that the presence of oil has little or no effect on the availability of trace metals from sediment. A final experiment has been conducted, using longer periods of exposure and depuration and examination of a larger number of isotopes. Detritus was collected from the laboratory seawater system head tanks, dried, subjected to neutron activation for two hours at a neutron flux of approximately 1 X 10^{13} n cm^{-2} sec^{-1}, and aged for 3 months to reduce its activity. Six g dry weight of neutron activated detritus was added to 100 g wet weight of "cold" detritus and 1 liter sea water, which was then shaken by hand for 1 minute. The resulting slurry was aerated and held in a water table five days, then filtered onto #42 Whatman paper and divided into two portions. One received 100 ml sea water and 1 ml ether containing enough Prudhoe Bay crude oil to produce a concentration of 1000 ppm oil in the sediment. The other received only sea water and ether. The detritus was shaken 4 minutes and filtered again, and a sample of oiled detritus was removed for gamma counting.

Two liters of sea water were placed in each side of two two-sided aquaria which were surrounded by a water bath at 13°C. Oiled or non-oiled detritus was placed in one side of each aquarium and allowed to settle to the bottom and thirty Macoma inquinata were placed in each of the four compartments. Water was pumped out of the detritus-containing sides, passed through a 100 μ mesh nylon screen and transferred to the other side, from which it returned by flowing over the dividing barrier. This system allowed for the aeration of both sides without agitating the detritus enough to suspend it in the

water column. Thus only metals dissolved in water or on particles less than 100 μ in diameter could reach the animals on the filtered side of the aquarium. When necessary small amounts of detritus which had accumulated on the bottom of the filtered side were removed by gentle suction and returned to the detritus side.

Groups of five clams were removed from each compartment after 2, 4, 8, and 15 days of exposure and shucked, and the meat and shells were rinsed in fresh sea water. Shells were scrubbed if needed, to remove adhering detritus. The meat and shells of each group was dried to constant weight at 80°C. One-hundred ml samples of filtered sea water were taken after 2, 8, and 15 days and evaporated to dryness for counting. Samples of oiled and non-oiled detritus were removed and dried on the 15th day of exposure, for gamma counting.

After 15 days of exposure the remaining clams were transferred to depuration tanks with clean water and detritus, which was replaced after two and four days. Groups of five clams were removed after 2 and 8 days of depuration and prepared for counting. The gamma activity of samples of detritus, meat, shells, and residue from evaporated sea water was measured on a Ge(Li) diode.

RESULTS

The numbers of net counts at energy levels corresponding to ^{51}Cr, ^{152}Eu, ^{46}Sc, ^{59}Fe, ^{65}Zn, and ^{60}Co were calculated and corrected for the rates of decay of each isotope to determine the count rate/g d.w./1000 minutes at the time each sample was removed from the experiment. The relation between the corrected isotope count and the actual amount of metal present was established by reference to the known metal content of the detritus. These values had been established in this laboratory for K, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Se,

Pb, and As, and for all these there was good agreement with the trace metal concentrations in shale as reported by Krauskopf (Introduction to Geochemistry, pp. 639-640, McGraw-Hill, New York, 1967; taken from Vinogradov, Geokhimiya, Vol. 1962, pp. 560-561). Therefore, it seemed quite probable that the elemental composition of the collected detritus was similar to that of shale and the levels of Eu, Sc, and Co in shale were accepted as those present in the detritus.

It was thus possible to determine for each sample the amount of metal present per g or per ml sea water. However, since the clams were not depurated to purge their intestinal tracts before they were shucked and dried it was necessary to determine how much of their total sample isotope content was incorporated into their tissue and how much was only in transit through their guts. Since scandium is known to be associated only with detritus and not incorporated into tissue its concentration was used to calculate the amount of detritus present per g d.w. of the total Macoma samples. This amount was multiplied by the known detrital or shale concentration of each of the other metals present, and the products were subtracted from the total amounts. The differences corresponded to the tissue concentration of each metal.

One example of this treatment of the data is given here:

Metal	Concentration in shale	Concentration in detritus	Corrected Counts /1000 mins./g d.w. detritus	Corrected Counts /1000 mins/ g d.w. Macoma (non-oiled, 4 days)
Sc	10 µg/g		287,907	4086
Zn	80 µg/g	88 µg/g	3,493	90

$\frac{3493}{88} = \frac{90}{x}$ $\quad x = 2.27$ µg Zn/g d.w. total Macoma sample.

$\frac{287,907}{10} = \frac{4086}{y}$ $\quad y = .142$ µg Sc/g d.w. total Macoma sample.

$\frac{10}{10^6} = \frac{.142}{z}$ $\quad z = 14,200$ µg = 14.2 mg detritus/g d.w. total Macoma sample.

$\frac{14.2 \times 88}{1000}$ = 1.25 µg Zn/g d.w. sample, associated with detritus.

2.27 - 1.25 = 1.02 µg Zn/g d.w. sample, incorporated into tissue.

The only metal which appeared consistently at detectable levels in sea water was cobalt. As shown in Table 1, the amount of Co given up by oiled and non-oiled sediment did not differ.

Table 1. Co content of filtered sea water (µg x 10^{-5}/ml).

Days Exposure	Oiled	Non-oiled
2	5.1	4.5
8	4.15	no sample
15	6.0	5.5

Cr, Eu and Sc appeared sporadically in sea water and Fe and Zn did not appear.

The detrital contents, calculated from the scandium levels of the samples, indicate that the clams fed in the first two days of direct exposure to detritus, and the net amount of food in their digestive tracts declined thereafter. Initially about 2½% of the body dry weight was composed of detritus in the absence of oil. In the presence of oil only one half as much food was taken in initially, and it was lost at a greater rate. On the filtered side of the aquaria, less than one tenth as much non-oiled detritus was taken up initially, as compared to the side containing the bulk of the detritus. This level changed less during the course of exposure. Clams receiving filtered water from oiled detritus took in about as much as the non-oiled controls. Table 2 and Figure 1 illustrate these results.

Figure 1. Detritus (mg/g) ingested by Macoma inquinata.

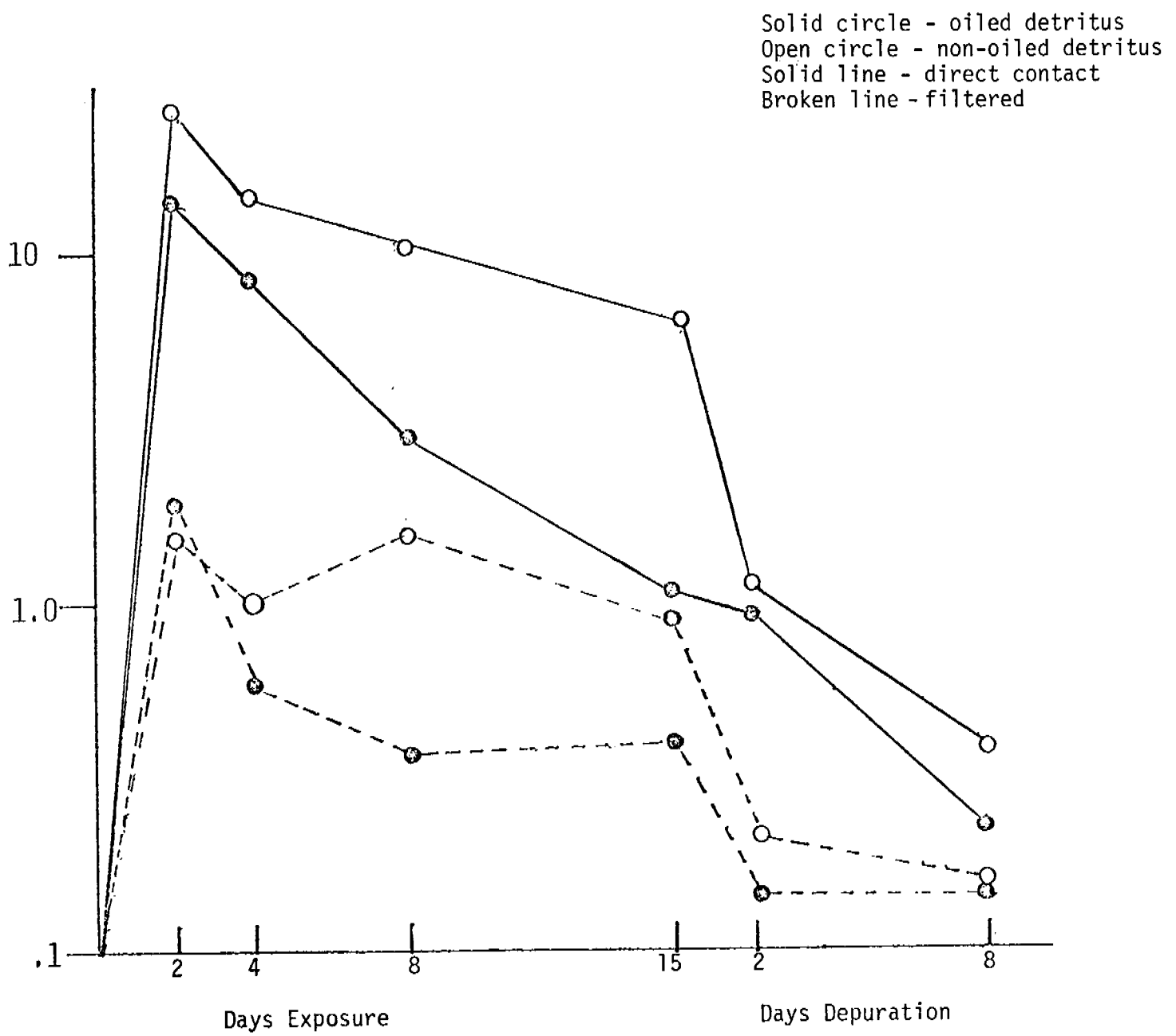


Table 2. Detritus (mg/g d.w.) ingested by Macoma inquinata.

Days Exposure	Non-oiled	Oiled	Non-oiled (filtered)	Oiled (filtered)
2	25.7	13.5	1.53	1.99
4	14.2	8.31	.96	.57
8	10	2.97	1.52	.37
15	6.2	1.07	.88	.38
Days Depuration				
2	1.1	.88	.22	.14
8	.37	.24	.15	.14

Table 3 shows the amounts of metal per g d.w. incorporated into Macoma tissue. Evidence for the incorporation of metals from detritus into tissue was found only for Co and Zn. Cr was detected in only three clam samples, though it was present in the detritus. Eu was accumulated at barely detectable levels, and no labelled Fe remained in the tissue longer than eight days.

Figures 1 and 2 show the amounts of Co and Zn incorporated into Macoma tissues during two weeks exposure to labelled detritus and one week depuration. Those organisms which received their metal through the water column or on very fine particles incorporated nearly identical amounts whether oil was present or absent. Those which had direct access to detritus incorporated the same amounts early in the exposure period, but later the oiled animals took in less. This difference is probably due to the fact that less oiled than non-oiled detritus was ingested and, therefore, a smaller amount of labelled metal was available for absorption across the walls of the intestinal tract.

The labelled-metal content of the shells has not yet been determined.

Table 3. Metals (μg/g d.w.) incorporated into Macoma inquinata exposed to oiled and non-oiled detritus.

	Eu				Fe			
Days Exposure	NO	O	NOF	OF	NO	O	NOF	OF
2	0	.013	0	-	0	130	16.8	13
4	.001	.0083	.0001	-	131	22	0	-
8	.004	.0083	.0002	-	85	16	11	-
15	.001	.00107	.0003	-	0	-	0	-
Days Depuration								
2	.001	.00089	.0004	-	0	0	-	-
8	0	.00084	.0003	-	-	-	-	-

	Zn				Co			
Days Exposure	NO	O	NOF	OF	NO	O	NOF	OF
2	.24	.288	.257	-	.024	.059	.009	.019
4	1.02	1.38	.318	-	.070	.112	.025	.043
8	1.18	1.09	.572	.952	.175	.108	.049	.043
15	3.41	1.38	1.054	.873	.140	.067	.042	.054
Days Depuration								
2	2.23	.626	.937	1.01	.216	.130	.043	.041
8	2.10	.99	1.095	1.32	.133	.080	.037	.0455

O = oiled
NO = not oiled
F = filtered
0 = no net incorporation into tissue
- = no metal present in sample

Figure 2. Incorporation of zinc into Macoma tissue.

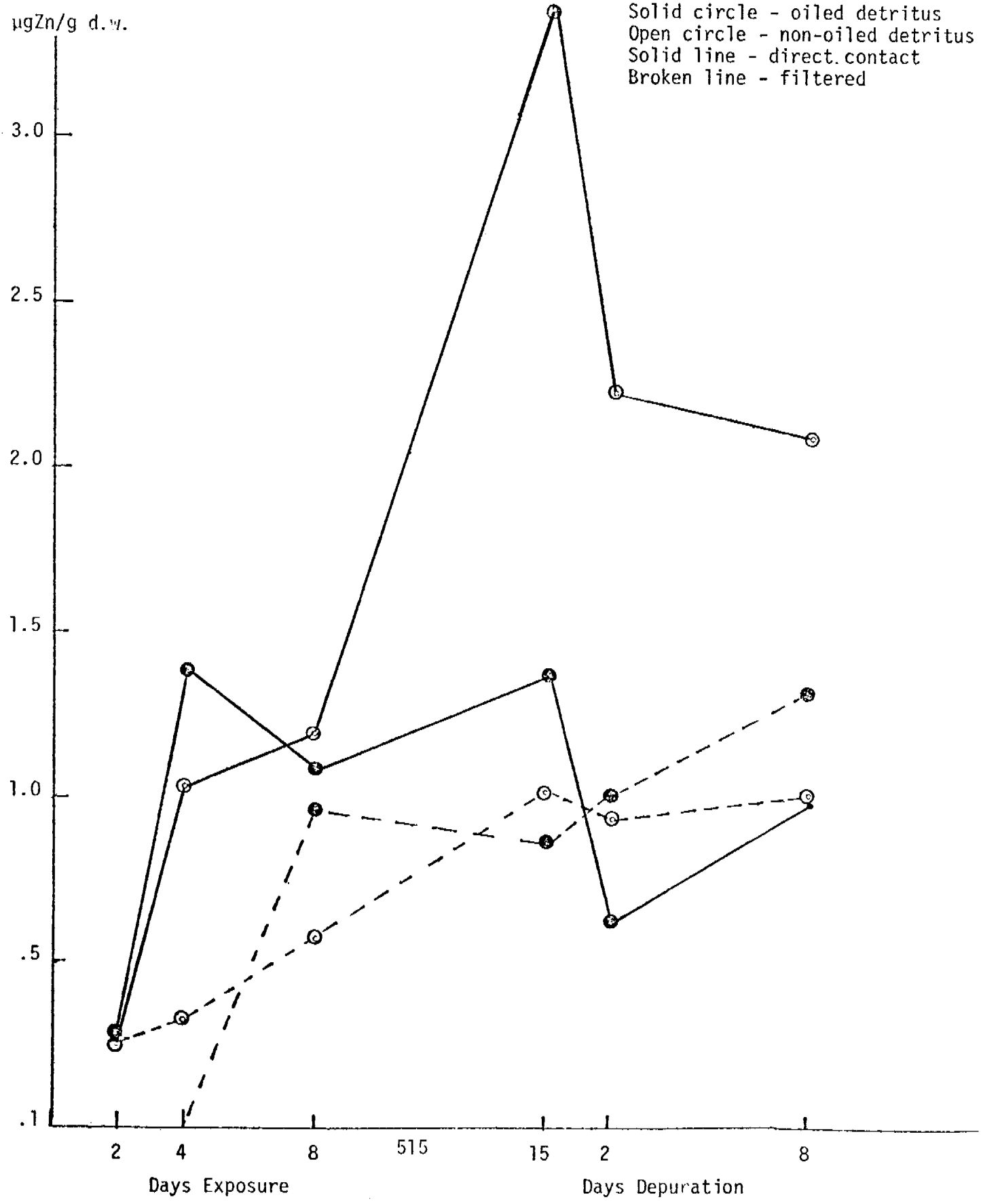
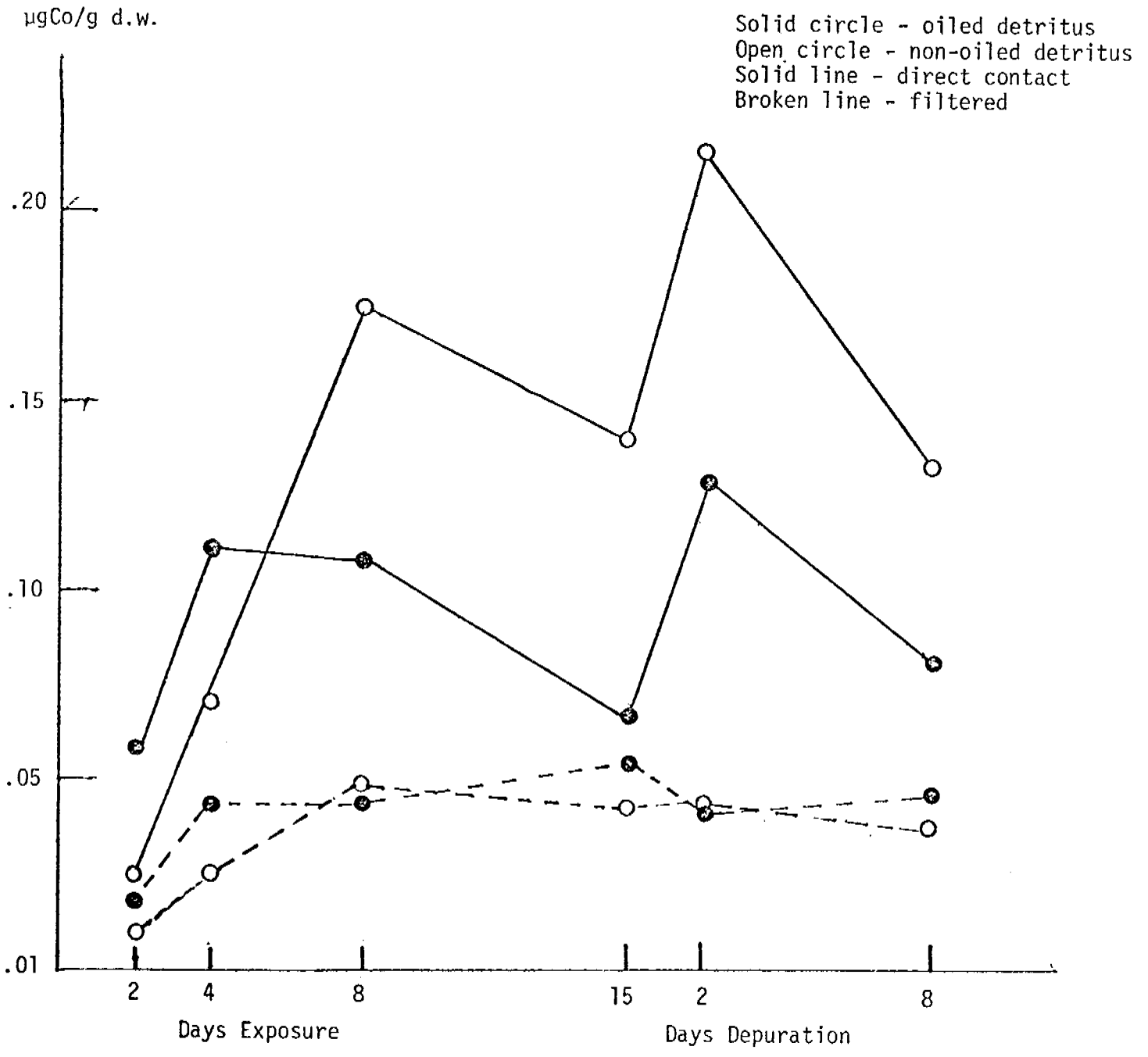


Figure 3. Incorporation of cobalt into Macoma tissue.



DISCUSSION

The detritus on which the clams fed in this experiment was the same material they ingest in nature. There is, therefore, no reason to believe that the concentrations of metals in their food were any higher during than before the experiment or to expect a net increase in metal concentration in the control animals exposed to non-oiled detritus. The fact that labelled Zn and Co appeared in the controls indicates that a more or less rapid exchange takes place between the metals in the tissue and in the environment.

The tissue zinc concentration of Macoma is about 200 ppm. The cobalt concentration is not known, but probably resembles that of other bivalves from unpolluted waters, which is on the order of 0.5 ppm. Thus, the amount of labelled zinc and cobalt taken in by control Macoma in two weeks, presumably replacing metal lost to the environment, amounts to about 1% and 30%, respectively, of their normal metal pool. If hydrocarbons enhanced the rate of uptake of metal from normal environmental concentrations, then oil-exposed animals would be expected to accumulate metals from the environment at a faster rate than that at which they lost them to the environment and so to exhibit a greater increase in radioactivity than is found in the controls. This is not the case, since the net amount of radioactivity incorporated into the tissues of oil-exposed animals over time was less than that in the controls.

This reduction, however, does not imply that PHC's reduce the ability of Macoma to absorb metals from detritus. In fact, comparison of the zinc and cobalt concentration of the gut contents after two and fifteen days exposure shows a 92 and 94% decline, respectively, between the initial and final sample. In control animals the concentration goes down by 78% over the same period. This difference can also be attributed to the maintenance of a higher feeding rate by control clams, which would bring in larger quantities of labelled metal.

There seem to be no grounds for believing that exposure to 1000 ppm PBC either increases or decreases the rate at which Macoma absorbs metals, except through a reduction in the rate of food intake. This conclusion is supported by the fact that on the filtered side of the aquarium, where the absolute differences between food intakes of oiled and non-oiled animals were less and where more of the metals may have been taken in via the water column, the amounts incorporated by the two groups were quite similar.

CONDITION INDEX AND FREE AMINO ACID LEVEL OF *PROTOTHACA STAMINEA* EXPOSED TO OIL-CONTAMINATED SEDIMENT

Roesijadi and Anderson (1978, in press) exposed *Macoma inquinata* to sediment contaminated with 1100 ppm Prudhoe Bay crude oil for 38 days, beginning in June 1977. They observed a 16% reduction, significant at the .001 level, in condition index and a 27% reduction, significant at the .01 level, in the free amino acid concentration of the gills, mantle, and adductor muscle in exposed *Macoma*, compared to control animals. Two-thirds of the decrease in FAA was due to a 38% decrease in glycine. A similar experiment was carried out on a larger scale, beginning in January 1978, in which two detritivores, the clam *Macoma*, and the sipunculid worm *Phascolosoma agassizi*, and one suspension feeder, the clam *Protothaca staminea*, were exposed for 54 days.

METHODS

Ninety-eight mls PBC was emulsified in a blender with two 500 ml volumes of sea water. The oil and one liter sea water were added to 42 kilograms of coarse, sandy sediment and mixed for one hour in a cement mixer. The oiled sediment was flushed three times with sea water and left in a sea table overnight. Cores for IR analysis of total hydrocarbon content were then taken. One hundred and ninety *Protothaca*, sixty *Macoma*, and seventy *Phascolosoma* were collected from the intertidal region of Travis Spit, near the Battelle Laboratory on Sequim Bay, Washington State, U.S.A. Initial control groups of the two clams were taken for condition index and free amino acid determination by the methods of Roesijadi and Anderson (1978, in press), and a group of sipunculids were taken for free amino acid determination. The remaining animals were distributed in mesh-bottomed trays, containing oiled or clean control sediment, which were replaced in the Travis Spit intertidal on January 11, 1978.

On March 6, 1978 the trays were removed. The five surviving oil-exposed Macoma, five exposed Protothaca, and five controls of both species were taken for hydrocarbon analysis. Condition indices and FAA contents of exposed and control Protothaca were determined by the methods of Roesijadi and Anderson (1978, in press). Condition indices were calculated by the formula:

$$C.I. = \frac{\text{g ash-free dry weight}}{\text{cm shell length}^3} \times 1000$$

FAA determinations of control Macoma and Phascolosoma and HC analyses of the clams have not been completed.

RESULTS

At the start of the experiment the oiled sediment contained 1237 ± 112 ppm hydrocarbon, measured by IR analysis, and the control sediment 10 ± 11 ppm. After 54 days the HC level in oiled sediment had fallen to 850 ± 17 ppm.

In the control trays, 82 out of 90 Protothaca (91%), 20 out of 20 Macoma (100%), and 11 out of 30 Phascolosoma (37%) were alive and present. In the trays containing contaminated sediment 77 out of 90 Protothaca (85%), but only 5 out of 30 Macoma (17%) and none out of 30 Phascolosoma remained. The more mobile sipunculid worms may have migrated from the oiled environment, but the missing Macoma presumably died. The data on condition index are summarized in Table 4.

Table 4. Condition indices of initial control, field control, and exposed Protothaca staminea.

	$\bar{x}$	s.e.		n
Initial Control	19.3	± .36		10
Field Control - 54 Days in Clean Trays	18.2	± .20	n.s.	59
Exposed - 54 Days in Contaminated Trays	17.1	± .17	**	64

n.s. Not significantly different at .10 level from initial control.

** Significantly different from field control at .01 level means compared by student's t test.

The concentration of free amino acids in the mantle, gills, and adductor muscle of Protothaca staminea is shown in Table 5.

DISCUSSION

The condition index of Macoma inquinata, exposed to oil contaminated sediment for 38 days in June 1977, was 16% lower than that of control animals. Fifty-nine percent of the exposed animals survived, compared to 92% of the controls. When exposed for 54 days, beginning in January, 1978 only 17% of the Macoma survived. By contrast, 85% of the Protothaca exposed to oiled sediment in January, 1978 survived for 54 days, and the condition index of the survivors was only 6% less than that of the controls. The contrasting survival pattern of the two species in the same experiment clearly shows that Protothaca is under less stress than Macoma under these conditions.

The difference in percent decrease in condition index may also be significant, although it must be viewed more cautiously since the measurements on Macoma and Protothaca were made at different seasons. Since it is not likely that the shell lengths of any individual animal changed significantly during the course of the experiment, the condition indices are directly proportional to the ash free dry weights. These declined by only one third as large a percentage, compared to the controls, in exposed Protothaca as in exposed Macoma, indicating that the former were not forced to draw on their stored reserves for nutrition to as great an extent as the latter. This also points to a lesser degree of stress suffered by the suspension feeders than by the deposit feeders.

Table 5. Free amino acid concentration in gills, mantle, and adductor muscle of Protothaca staminea (μmoles/g).

	Initial Control	Field Control	Field Exposed
Alanine	9.47 ± 1.48	6.47 ± 2.23††	4.01 ± 2.3*
Arginine	2.84 ± .56	2.75 ± .85	1.92 ± 1.31
Aspartic Acid	1.30 ± .65	1.15 ± .47	.56 ± .50*
Glutamic Acid	3.89 ± 1.57	3.26 ± .88	1.99 ± 1.32*
Glycine	26.7 ± 6.5	21.9 ± 7.8	18.33 ±12.6
Histidine	.21 ± .06	.11 ± .03††	.34 ± .70
Isoleucine	.27 ± .05	.24 ± .10	.15 ± .10
Leucine	.43 ± .10	.24 ± .11††	.31 ± .16
Lysine	.34 ± .12	.37 ± .11	.21 ± .11**
Methionine	.08 ± .02	0	0
Phenylalanine	.31 ± .08	.22 ± .07†	.22 ± .17
Proline	.26 ± .08	.16 ± .10†	.10 ± .09
Serine [1]	1.17 ± .30	.91 ± .18†	.93 ± .67
Threonine	.36 ± .13	.28 ± .08	.21 ± .13
Tyrosine	.28 ± .06	.25 ± .08	.21 ± .22
Valine	.37 ± .07	.33 ± .10	.23 ± .15
Taurine	33.6 ±10.6	43.3 ±17.1	18.36 ±13.05**
Total	79.94 ±17.96	85.56 ±26	47 ±24.5 **
Taurine:Glycine	1.23 ± .28	2.04 ± .54	1.38 ± .78

† significantly different from initial control at .05 level; student's t test

†† significantly different from initial control at .01 level; student's t test

* significantly different from field control at .05 level; student's t test

** significantly different from field control at .01 level; student's t test

[1] serine, glutamine, and asparagine co-chromatograph

The changes found in free amino acid levels in the tissues of Protothaca differ from those reported in other bivalve species under stress. Roesijadi and Anderson (1978, in press) found a pattern in Macoma resembling the stress syndrome described by Bayne et al. (1976) in Mytilus edulis. In their exposed animals the average level of glycine was reduced to 62% of that in the controls, while the taurine level stayed constant, leading to an increase in the taurine:glycine ratio. Jeffries (1972) reported a drop in glycine level in stressed Mercenaria mercenaria accompanied by an increase in taurine levels, again leading to an elevated taurine:glycine ratio.

In Protothaca the situation was reversed. The mean glycine level of exposed clams did not differ significantly from that of controls, but the mean level of taurine was reduced by 58%, leading to a decline in the taurine:glycine ratio. The significance of this decline is not clear at this time, since the only known role of taurine in the metabolism of marine invertebrates is to function in osmoregulation. There is no reason to suspect any difference between the salinity level of the water surrounding the oil-exposed and the control groups. However, there is some evidence to indicate that the taurine levels of Protothaca tissue may fluctuate as a result of conditions not related to stress or osmoregulation. Roesijadi (1979, in press) reported that holding Protothaca in the laboratory for 26 days under constant temperature and salinity resulted in a significant decrease in the taurine level of the gills while the glycine levels remained constant. Stress, in the form of addition of up to 155 µg/l of Na hypochlorite led to a significant decrease in the concentration of glycine but not of taurine.

In view of these data, which indicate that taurine levels may change in this species for unknown reasons, it may be more useful to consider the changes in other free amino acids, especially glycine, as indicators of stress. There

is only a slight, statistically insignificant, decrease in the glycine levels in the oil-exposed Protothaca. This response, together with the smaller decrease in condition index and the higher rate of survival, all support the conclusion that the suspension feeder Protothaca is less vulnerable to oil-contaminated sediment than the deposit feeder Macoma.

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DISTRIBUTION AND BIOAVAILABILITY OF POLYNUCLEAR AROMATICS WITHIN A DETRITUS EXPOSURE SYSTEM

In a previous quarterly report (July, 1978) an analytical scheme was described for monitoring the uptake and fate of ^{14}C phenanthrene, ^{14}C chrysene and ^{14}C benzo(a)pyrene in the tissue of the intertidal detritivore, Macoma inquinata, exposed to oil-contaminated sediment. Since this report, research has been conducted and the scheme has been expanded to include the analysis of the sediments and interstitial waters containing these ^{14}C species to which the clams were exposed. Stress this quarter has been placed on using the scheme to account for the formation of degradation products other than CO_2 as a result of microbial activity or metabolism within the clams. The expanded scheme is shown in Figure 4 and the details of the extraction and liquid chromatography procedures are reported in an appendix at the end of this report.

RESULTS AND DISCUSSION

No degradation or metabolic products were observed in the tissue of Macoma inquinata or in the associated sediment for all three ^{14}C species after 30 days. Our findings show that: (1) separation of day 30 tissue and sediment extracts by gel permeation chromatography resulted in the generation, in each case, of one radioactive peak which had a retention time identical to that of the parent compound; (2) separation of day 30 tissue and sediment extracts by reverse phase high pressure liquid chromatography resulted in the same situation described above in (1), and; (3) recoveries of substrate radioactivity in tissue and sediment extracts from the GPC and reverse phase chromatography steps were high, indicating the absence of unaccounted for activity which could be ascribed to polar compounds (Table 6).

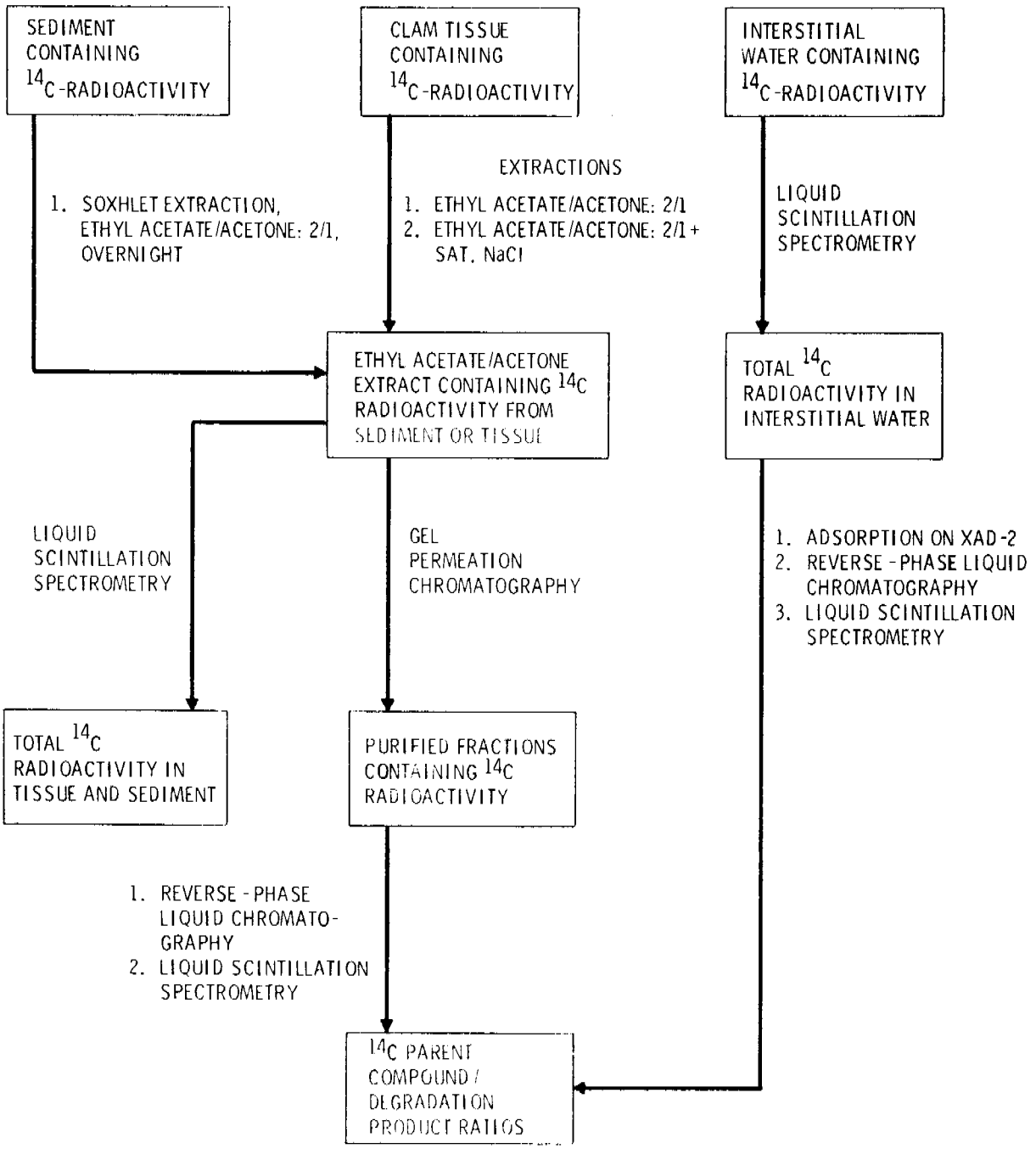

Figure 4. Flow diagram for analyses of ^{14}C-compounds.

Table 6. Percent recovery of ^{14}C radioactivity from tissue and sediment extracts chromatographed on GPC and reverse phase liquid chromatographic systems.

Chromatography	Compound	Tissue[1]	Sediment[1]
GPC	Phenanthrene	101.5	97.6
	Chrysene	114.6	99.3
	Benzo(a)pyrene	102.1	102.6
Reverse-Phase	Phenanthrene	96.9	85.6[2]
	Chrysene	103.8	101.4
	Benzo(a)pyrene	87.3[2]	89.9[2]

[1] % recovery of activity injected on column system.

[2] Due to the low count levels in these samples, the lower recovery values can be accounted for in the greater counting error which ranged from 10-30% for these samples.

Differences in the water solubility and adsorptivity of phenanthrene, chrysene and benzo(a)pyrene affect their distribution between sediment and interstitial water, thereby affecting the level of availability of these compounds to tissue and their retention in sediment. The percent distributions of these compounds in interstitial water were calculated and are listed in Table 7. In all three cases, the level of activity associated with the interstitial water was extremely low. Phenanthrene appeared to be the most soluble component with 0.42 to 2.80% of the activity present in the interstitial water. For chrysene and benzo(a)pyrene, these ratios were lower by one to two orders of magnitude.

The possibility that the ^{14}C-radioactivity associated with the interstitial water was due, in part, to degradation products was next explored. Phenanthrene has the greatest potential for microbial degradation (McKenna and Heath, 1976) and in these experiments produced the highest levels of activity in the interstitial water. We chose to subject a 30-day phenanthrene interstitial water sample to the following experiment. Eighty-eight milliliters of the interstitial water was passed through two series coupled stainless steel columns (22 cm X 1 cm O.D.) containing XAD-2 macroreticular resin. These resins are known for their ability to adsorb aromatic hydrocarbons efficiently (Junk et al., 1974). The second column was present in case the capacity of the first column for phenanthrene was exceeded. Results showed that 97.9% of the recovered ^{14}C activity in the initial sample was not retained by the XAD-2 resin. This was in marked contrast to the adsorption characteristics of ^{14}C-phenanthrene on this column system where 99.9% of the total recovered activity was retained by the first column. These results (Table 8) support preliminary studies in which it was found that the majority of ^{14}C activity from interstitial water samples (phenanthrene exposure) could not be extracted by use of hexane, benzene or chloroform as extraction solvents.

Table 7. ^{14}C phenanthrene, chrysene and benzo(a)pyrene interstitial water-sediment distributions. % water in experimental sediments, 15.7 ± 1.2, n = 43.

Compound	Day	^{14}C activity (DPM) in water from 1 gram sediment (wet wt.)	^{14}C activity in sediment DPM/gram wet wt.	% distribution[2] of ^{14}C activity in interstitial water from 1 gram of sediment (wet wt.)
Phenanthrene	1	33	7,740	≲0.42
	3	26	7,036	≲0.37
	7	61	7,132	≲0.85
	15	77	3,896	≲1.97
	30	23	1,959	≲1.22
	59	17	609	≲2.80
Chrysene	1	3	10,711	≲0.03
	3	2	10,975	≲0.02
	7	2	10,318	≲0.02
	15	1	10,816	≲0.01
	30	4	8,106	≲0.01
	59	5	7,548	≲0.07
Benzo(a)pyrene	1	0	8,072	~ 0
	3	1	7,095	≲0.01
	11	1	7,215	≲0.01
	20	0	8,353	~ 0
	35	1	6,601	≲0.02
	60	1	6,340	≲0.02

[1] Calculation of distribution ratio assumes that the trace levels of ^{14}C activity in the interstitial water samples is present as parent substrate.

[2] $$\% \ ^{14}C \text{ activity} = \frac{^{14}C \text{ activity in water}}{^{14}C \text{ activity in sediment} - {}^{14}C \text{ activity in water}} \times 100$$

Table 8. Adsorption characteristics of ^{14}C phenanthrene and ^{14}C activity from 30 day phenanthrene interstitial water sample on XAD-2 resin.

Sample	% Activity on Top Column	% Activity on Bottom Column	% Activity In Aqueous Column Effluent
^{14}C Phenanthrene[1]	99.9	0.1	0.1
^{14}C Activity from ^{14}C Phenanthrene Interstitial Water Sample[2]	2.0	0.2	97.9

[1] 93% of the total activity recovered.

[2] 96% of the total activity recovered.

Since no degradation products could be observed in tissues or sediments during the 60-day experiments, the total ^{14}C-activity associated with the tissue and sediment was that of the parent compound. Figures 5-7 show the uptake of these compounds in tissue and retention in sediment during the 60-day experiments. The amount of phenanthrene in clam tissue increased during the first 3 days and then decreased exponentially to 5% of the 3 day value at 60 days. A similar decrease in the amount of phenanthrene was observed in sediment where only 8% of the phenanthrene present at day 1 remained after 60 days. The amount of chrysene in clam tissue increased for the duration of the experiment with ten times as much chrysene present in the tissue at 60 days as at day 1 (Figure 6). The amount of chrysene in sediment had decreased by 30% in 60 days. The amount of benzo(a)pyrene in tissue also increased over the entire length of the experiment with 7 times as much benzo(a)pyrene present in the tissue at 60 days as at day 1. The amount of benzo(a)pyrene in sediment decreased by 21% in 60 days (Figure 7).

CONCLUSIONS

The purpose of these experiments was to determine the fate of ^{14}C-phenanthrene, chrysene, and benzo(a)pyrene in oil-impacted sediments, in terms of their distribution in association with sediment particles, in interstitial and surface water, and in detritivorous organisms, as well as their chemical alteration as a result of degradation processes within the experimental systems. This quarter, we have investigated extensively the tissue and sediment systems associated with these experiments using high pressure liquid chromatographic techniques in combination with ^{14}C-labelled compounds. Within the detectability limits of the techniques, we were not able to detect the presence of significant levels of degradation products within these systems after 30 days. It is possible that slow microbial

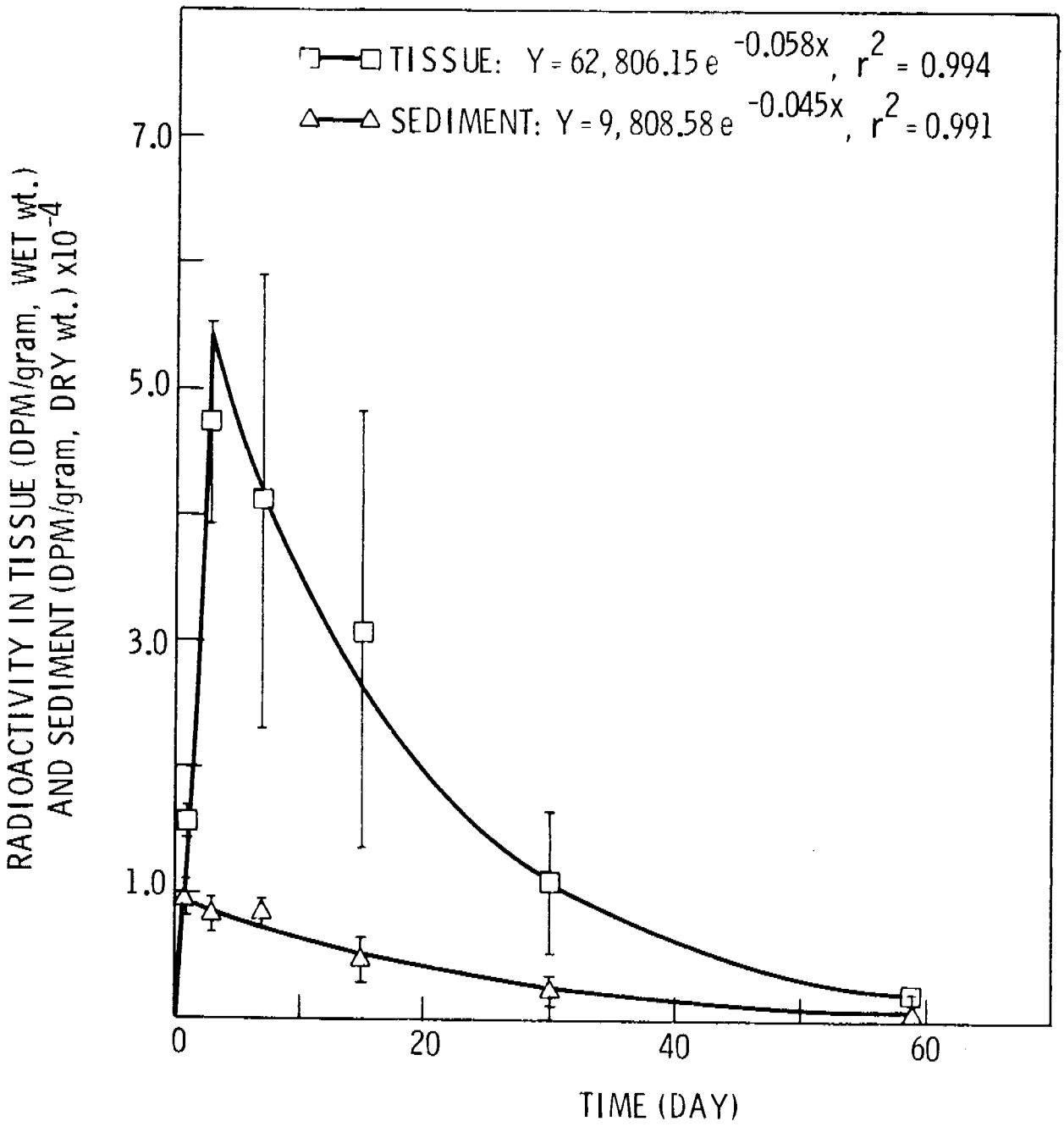

Figure 5. ^{14}C-radioactivity in tissue and sediments from phenanthrene exposure (n = 3).

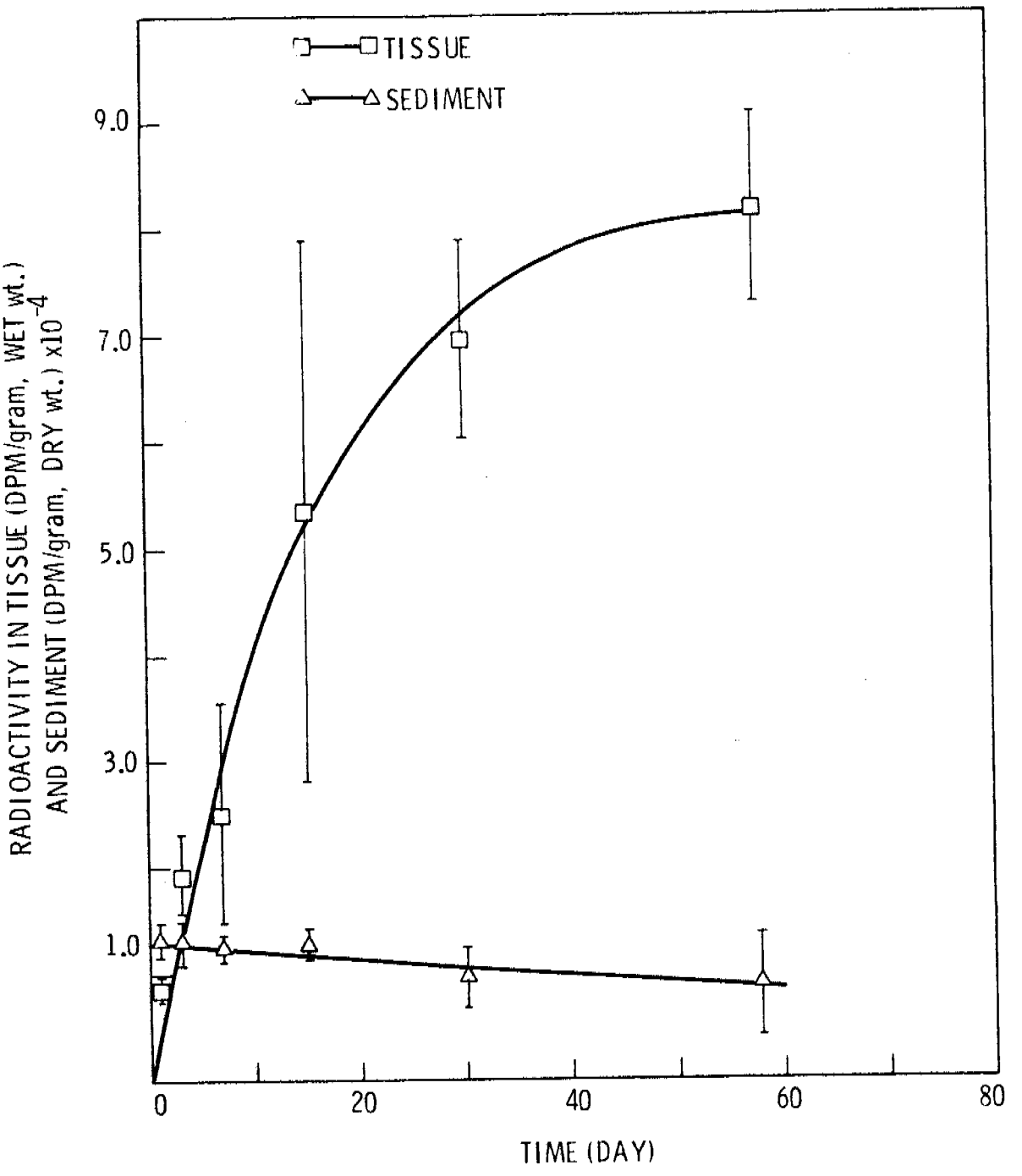

Figure 6. ^{14}C-radioactivity in tissue and sediments from chrysene exposure (n = 3).

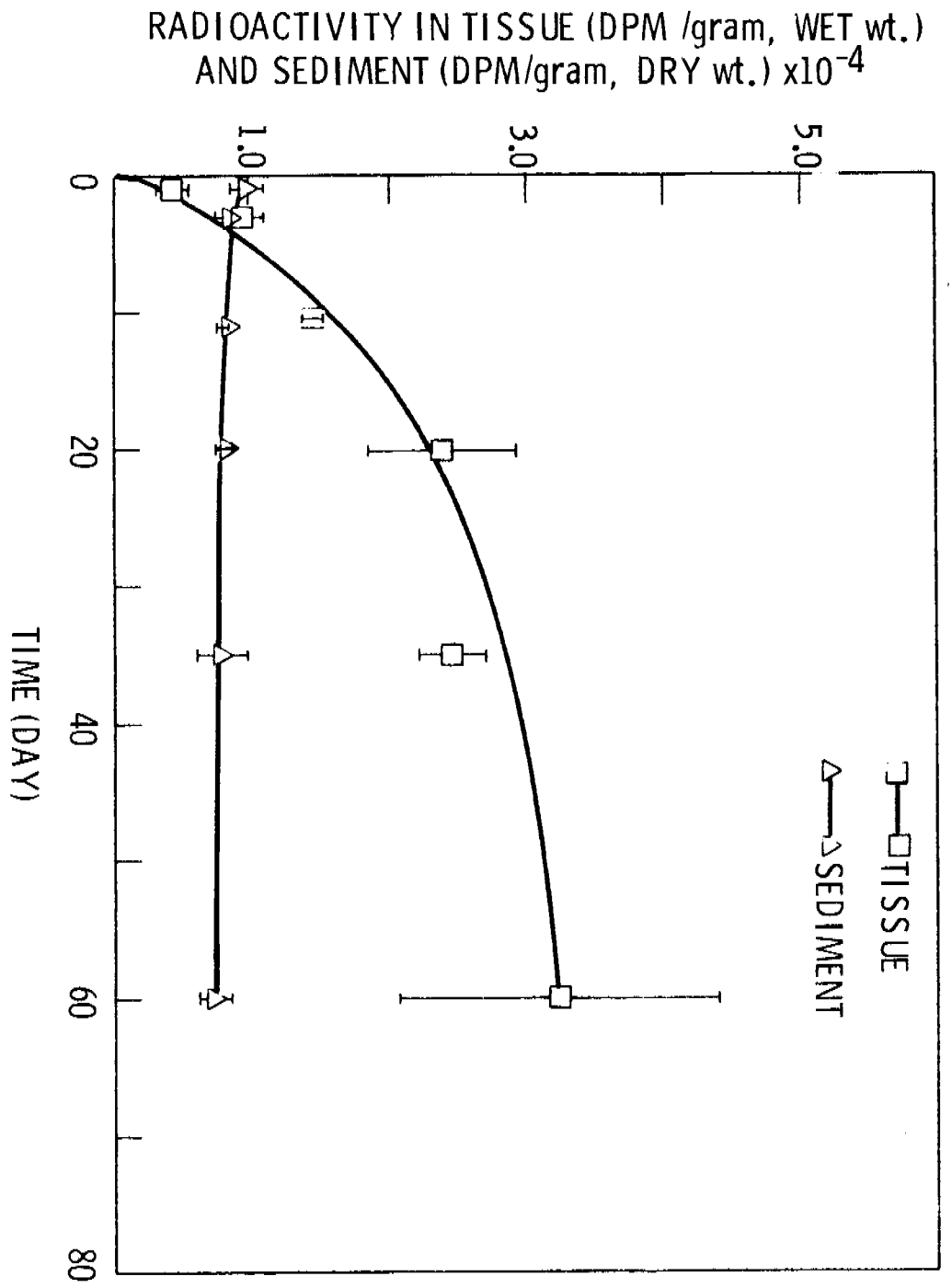

Figure 7. ^{14}C-radioactivity in tissue and sediments from benzo(a)pyrene exposure (n = 3).

degradation is occurring and the compounds of interest are transient intermediates which never accumulate during the total degradation of these molecules to CO_2. Another possibility is that microorganism populations in the sediment preferentially metabolize compounds in the oil other than aromatic hydrocarbon further protecting the latter from degradation.

Our preliminary investigations of an interstitial water sample from the phenanthrene study suggests that over 90% of the ^{14}C-activity is not associated with phenanthrene, but with more water-soluble polar components. These results suggest that the availability of this hydrocarbon along the pathway of release from sediment to interstitial water to Macoma is even more significant than previously reported (Roesijadi et al., 1978). The interstitial water samples will be studied more extensively in the next quarter.

Uptake of ^{14}C-phenanthrene, ^{14}C-chrysene, and ^{14}C-benzo(a)pyrene follow the general pattern previously described for these compounds in clams (Roesijadi et al., 1978). Substantial differences were observed in the accumulation of phenanthrene vs. chrysene and benzo(a)pyrene in tissues and the amounts of these components in sediments. The rapid depuration of phenanthrene from clam tissue correlates with the rapid loss of this compound from sediment to interstitial water with subsequent loss from the system due to periodic tidal flux. This chain of events is, in part, a result of the higher solubility and lower lipophilicity of phenanthrene. Similarly, the increased lag time associated with the accumulation of chrysene and benzo(a) pyrene in tissue appears to correlate with the greater persistence of these compounds in sediment. Their greater persistence, in part, is a result of their greater lipophilicity and lower solubility in water. It would appear that Macoma would continue to accumulate these latter compounds over longer exposure periods. The uptake exhibited cannot be separated clearly

into that from interstitial water and that related to ingestion of detrital particles. We have shown that chrysene and benzo(a)pyrene are biologically available, but the exact route of entry cannot easily be ascertained with this species. Future experiments with the polychaete Abarenicola will allow quantitation of ingestion, which can then be correlated with the extent of bioaccumulation.

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APPENDIX

Preparation of Tissue Extracts for GPC Analysis

Tissues[1] from individually shucked clams containing ^{14}C hydrocarbons were patted dry and weighed into 25 ml corex centrifuge tubes. To each tube was added a solution of ethyl acetate/acetone, 2/1 (3 ml/2.5g tissue, wet weight). The samples were homogenized using a Tekmar Tissumizer and then centrifuged at 5000 rpm for 10 minutes. The organic layer (top) from each sample was transferred to calibrated 15 ml glass stoppered centrifuge tubes with pasteur pipettes. The extraction sequence was repeated using ethyl acetate/acetone 2/1 (2 ml/2.5g of tissue) and saturated sodium chloride (1.0 ml/2.5g of tissue). The organic extracts (two from each tissue sample) were combined and the volume recorded. An aliquot of the samples were analyzed for total ^{14}C radioactivity by liquid scintillation spectrometry. The remaining portion of each sample was concentrated to 1.0 ml under a stream of nitrogen and injected onto the μ-Styragel columns.

Preparation of Sediment Extracts for GPC Analysis

Samples of sediment from cores (~ 15 to 30 grams, wet weight) containing ^{14}C-radioactivity were soxhlet extracted with 50 ml of ethyl acetate/acetone 2/1 overnight. The soxhlets were cooled in such a manner as to retain as much of the solvent as possible in the soxhlet cup. The concentrated organic extract from each sample was transferred to calibrated glass stoppered centrifuge tubes and the volume recorded. An aliquot of each sample was analyzed

[1] Wet weight of tissue of individual clams used in these experiments was 4.37 ± 1.16 grams.

for total ^{14}C-radioactivity. The remaining portions of the samples were concentrated to 1.0 ml under a stream of nitrogen and injected onto a μ-Styragel column. The extracted sediments were dried at 110° and their dry weight determined.

Analysis and Simplification of Tissue and Sediment Extracts by Gel Permeation Chromatography (GPC)

The concentrated tissue and sediment extracts were chromatographed on three series coupled μ-Styragel columns with the following pore sizes: 10^3Å, 500Å, and 100Å. The dimensions of each column were 7.9 mm x 30.0 cm. The following liquid chromatographic parameters were used:

Mobil Phase: Methylene Chloride

Flow Rate: 2.0 ml/min

Pressure: ~400 psi

UV at 254 nm, Attenuation, 0.04 to 2.10 Absorbence Units

The column system was calibrated using polystyrene standards and compounds of interest in our experiment. Retention volumes for these compounds are listed below:

Compound	Mol. Wt.	Log MW	Retention Volume
Benzene	78	1.89	31.73
Naphthalene	128	2.11	31.73
1-Naphthol	144	2.16	35.67
Phenanthrene	178	2.25	31.73
Chrysene	228	2.36	31.89
Benzo(a)pyrene	252	2.40	32.0
Benzo(a)pyrene trans 7,8 dihydrodiol	286	2.46	32.0
Polystyrene	2,900	3.46	20.63
Polystyrene	15,000	4.18	17.40

It should be noted that, due to limitation on manufacturer quality control, retention volumes for a similar set of columns could be slightly different.

Aliquots of 2.0 ml fractions collected were analyzed for total ^{14}C-radioactivity. Those containing ^{14}C-radioactivity were appropriately combined, concentrated, and analyzed in more detail by reverse-phase high pressure liquid chromatography.

ANALYSIS OF GPC PURIFIED EXTRACTS BY REVERSE-PHASE LIQUID CHROMATOGRAPH

One milliliter methylene chloride tissue and sediment extracts containing radioactive compounds were solvent exchanged by the addition of 1 ml of acetonitrile. The tissue and sediment extracts were chromatographed in two series coupled y-Bondapak C-18 columns (7.9 mm x 30.0 cm each) using the following liquid chromatographic parameters:

Mobile Phase:	Acetonitrile/water
Solvent Program:	Acetonitrile/water: 60/40 ——> 80/20, 20 min.
Flow Rate:	2.0 ml/min
UV:	254 nm

Aliquots of 2.0 ml fractions collected were analyzed for total ^{14}C-radioactivity.

QUARTERLY REPORT

Analysis of potential effects of OCS development on the Barrier Island-lagoon ecosystems of the Beaufort Sea

Research Unit No. - 467

Reporting Period - 1 October - 31 December 1978

Number of Pages - 14

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I. Highlights

This quarterly report summarizes new research findings of RU 467. A brief description of all research conducted since the submission of the 1977 Annual Report in April is included to put into perspective this quarter's research, which has been primarily analysis of data collected during the summer.

A. Invertebrates

Important new information is emerging about the life cycles and secondary production of key invertebrate species. Amphipods appear to be able to remain in the lagoon year-round and to complete their life cycles there. Mysids appear to use the lagoon in summer as a rearing area for young, but moved to deeper waters in winter, presumably because of the high under-ice salinities in the lagoon in winter. Very high growth rates of young mysids in the lagoon from July-September resulted in a large secondary productivity at the invertebrate level.

B. Fish

Key species of anadromous fish did not greatly change their diet from the epibenthic invertebrates that they ate in 1977. Their utilization of nearshore habitats was highest near mainland beaches as it was in 1977. Seven new fish species were caught in nearshore waters in 1978; arctic cod abundance in late August was many times the estimated abundance of cod in the nearshore in 1977. The cod were so abundant (an estimated several million in Simpson Lagoon) that they may have significantly depleted the food supply (chiefly mysids) that existed before their arrival. Winter studies showed that nearshore habitats may be more important than previously thought as overwintering area for marine fish.

C. Birds

In general, both the foods that birds (oldsquaws and phalaropes) ate and the use of the nearshore region by these birds were similar to these processes as they were encountered in 1977, although a few differences were evident. Oldsquaws ate principally mysids and some amphipods; phalaropes ate copepods. Island-nesting birds showed higher nesting densities in 1978 than in 1977; arctic foxes on the islands in 1978 were correspondingly less numerous. Juvenile phalaropes congregated and fed along island and mainland beaches in late summer, but in lower numbers than last year. Oldsquaw use of the lagoon for molting and feeding in late summer during 1978 was spatially and temporally similar to 1977; however, September densities of oldsquaw were lower than they were at that time in 1977. Surveys of the coast east to the Canadian border showed that oldsquaws congregated in all the major lagoon systems during summer, but were not as numerous in coastal non-lagoon areas.

II. Task Objectives

This program was originated to design and carry out a series of integrated ecological process studies in a barrier island-lagoon ecosystem on Alaska's Beaufort Sea coast. The program's broad objectives are to:

(1) Identify and analyze the importance of selected ecosystem components and processes contributing importantly to the structure and productivity of nearshore ecosystems.

(2) Evaluate the feasibility of detecting and quantifying temporal changes in those ecosystem components and processes identified as important.

(3) Identify mechanisms by which those components and processes could be tested for their sensitivity to man-caused change, and, therefore which might be used to predict and analyze impacts of OCS petroleum development.

This program is being implemented in conjunction with the research efforts of OCSEAP Research Units No. 526, 527, 529, 530, and 531, (nutrient dynamics, oceanography, geomorphology, and sedimentology).

It is the responsibility of LGL Limited to conduct studies in aquatic ecology and ornithology, to administer the integration of the above Research Units into the entire barrier island-lagoon program, and to synthesize information from all related research disciplines to make an assessment of the impact of petroleum development activities on the nearshore ecological processes of the Beaufort Sea.

Modeling workshops conducted during the course of the program function to create a common base for communication among PI's, program managers, and NOAA and BLM coordinators. Each stage of computer simulation of selected physical and biological processes in the barrier island-lagoon system represents the current level of understanding of these processes. In successive interdisciplinary workshops investigators critically examine each research effort in light of data gaps revealed through in-depth workshop discussions and through evaluation of the key processes represented by the model.

Specific task objectives of RU 467 are as follows:

1) To clarify the food web and energy flow processes (to include all trophic levels from the ultimate food base to the key bird and fish species) which support important vertebrates in the barrier island-lagoon system. (Schell, RU 527, is the PI for processes in the lower trophic levels.)

2) To assess food sources and feeding dependencies of fishes and invertebrates in the lagoon and nearshore marine waters.

3) To document movements and residency behavior of fish and invertebrates in the lagoon habitat.

4) To characterize the manner in which selected bird species utilize the barrier island-lagoon system for feeding, resting, nesting, and/or molting.

5) To describe the feeding and habitat dependencies of the bird and fish species studied as these dependencies may be disrupted by OCS-related development.

6) To evaluate the importance of those habitat features (which may potentially be altered by petroleum development activities) to the breeding and feeding activities of birds and fish.

7) To investigate mechanisms of over-wintering by fish and invertebrates.

8) To document the dependencies of biotic communities on coastal dynamics, geochemical processes, and nearshore circulation patterns through active coordination with Research Units No. 526, 527, 529, 530, and 531. Simulation modeling will play an important role in addressing this objective.

9) To use simulation modeling in a workshop context to assist in the accomplishment of #8 (above) and to evaluate the sensitivities of selected system processes and components to predicted development activities.

10) To prepare a detailed modeling report that will explicitly outline the mathematical bases for the systems model which has been developed and the logic behind its predictions. This report will also examine the predictions of the model and point out areas where predictions are limited by data gaps and by uncertainties about temporal and spatial variability.

III. Activities

A. Field Work, Laboratory Analyses, Workshops

Field research on fish and invertebrates commenced in April with a short sampling effort for fish and invertebrates in the Simpson Lagoon and Colville River delta areas. More extensive sampling efforts for invertebrates, fish, and birds were conducted from early June to late September from a field camp at Milne Point on Simpson Lagoon. Fish and invertebrates were again collected in Simpson Lagoon (as well as in areas outside the study area) during a short period in November.

Laboratory analyses of invertebrate samples and fish and bird stomach contents (which were composed primarily of invertebrates) commenced in July and are as yet incomplete. Invertebrates were identified, weighed, measured and/or sexed according to the specific purpose of each sample.

Workshops held included three meetings of LGL biologists and invited consultants for the purposes of (1) reviewing the sampling designs and techniques proposed for 1978 research (May 1978), and (2) planning analytical strategies for the data collected during the 1978 summer season (October 1978 and November 1978). There have also been two large-scale interdisciplinary modeling workshops held at the University of British Columbia (April and December 1978); investigators of RU 467 and all related Research Units attended these.

B. Scientific Party

The scientists involved in this program and their roles and affiliations are listed below.

Name	Affiliation	Project Role
Joe Truett, Ph.D.	LGL Limited - U.S., Inc.*	Project Director
Peter Craig, Ph.D.	LGL Limited**	PI, Aquatic Ecology (fish)
William Griffiths, M.S.	LGL Limited***	PI, Aquatic Ecology (invertebrates)
Lewis Haldorson, Ph.D.	LGL Limited - U.S., Inc.*	Aquatic Ecology
Howard McElderry, B.S.	LGL Limited - U.S., Inc.*	Aquatic Ecology
Stephen Johnson, Ph.D.	LGL Limited***	PI, Avian Ecology
Robert Dillinger, B.S.	LGL Limited***	Laboratory Analysis (invertebrates)

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C. Methods

General methods used for the several areas of research are presented below:

Invertebrates

The invertebrate field sampling program was conducted from early June through late September. Stations, in the lagoon and on the ocean side of the barrier island, were sampled at various frequencies and with several types of gear; sampling frequency and gear type used depended on the objectives of the sampling (see below).

Sampling Device	Locations Sampled	Sampling Frequency	Purpose of Sample
Drop net	Lagoon, marine	Every 14 days	Density and seasonal growth estimates; evaluation of movement patterns of epibenthic invertebrates.
Faber net	Lagoon, marine	Every 14 days	Density estimates of invertebrates in the water column; evaluation of movement patterns of epibenthic invertebrates.
Baited trap (under ice)	Lagoon	Daily	Presence - absence determinations of epibenthic invertebrates prior to break-up.
Baited trap	Lagoon	Every 7 days	Growth estimates for amphipods
Bottom dredge	Opportunistic	Every 7 days	Growth estimates for mysids and amphipods
Drift nets	Passes between barrier islands	Every 7 days	Documentation of movements of epibenthic invertebrates into and out of lagoon.
Diver transects	Lagoon, marine	Opportunistic at intervals during open-water season	Density estimates of mysids and behaviorial observations of mysids and other organisms.

...cont'd

Sampling Device	Locations Sampled	Sampling Frequency	Purpose of Sample
Airlifts	Lagoon, marine	Opportunistic	Density estimates of amphipods and bivalves.
Core samples	Lagoon, marine	Opportunistic	Density estimates of all inbenthic invertebrates.

Fish

Fish populations were sampled throughout the open water season (June-September) and under the ice in April and November. Techniques used and purpose of sampling were as follows:

Sampling Device	Locations Sampled	Sampling Frequency	Purpose of Sample
Fyke net	Lagoon	Continuous; checked daily	Evaluate directional movements of fish; tag and measure fish.
Gill nets	Lagoon, marine	Continuous for short periods	Obtain life history data and feeding information.
300' beach seine	Lagoon beaches	Opportunistic	Determine nearshore densities of fish.
Faber net	Lagoon, marine	Every 14 days	Collect larval fish.
Gill nets (under ice)	Lagoon, marine	Continuous for short periods	Presence-absence of fish in winter

Avian Ecology

Birds were studied in several ways from late June to late September. Techniques of study and purposes of the techniques are as follows:

Technique	Time	Purpose
Visual observations of migrating birds	Late spring, midsummer, early fall.	Study the spring migration, molt migration, and fall migration of sea ducks.
Surveys of breeding bird plots on mainland and island	Early summer to mid-summer.	Determine nest densities and nesting success of selected species.
Aerial surveys of coastal transect strips	10-day intervals, 20 June - 20 September.	Determine the distribution, densities, and apparent habitat preferences of sea ducks along the Beaufort Sea coast.
Collections of old-squaws and phalaropes	At regular intervals throughout the summer.	Determine the feeding preferences of the species collected.

D. Sample Localities

All invertebrate and fish samples were collected in or near Simpson Lagoon. (Invertebrates were routinely collected at five lagoon and 2 marine stations; fish were collected at fewer stations.) Bird surveys were made in the nearshore waters in the vicinity of Simpson Lagoon and Harrison Bay as well as eastward along the coast to the Canadian border. Surveys for nesting birds were also made on the barrier islands and on the nearshore mainland.

E. Data Analyzed

Analyses of data collected since April 1978 are incomplete and statements of results are correspondingly tentative. Analyses are expected to be concluded next quarter.

IV. Results

Preliminary results of the research are presented below. Many of these results are incomplete so should be viewed as tentative.

A. Invertebrate Ecology

1. Several species of amphipods (especially *Onisimus glacialis*) were found in all samples collected under the ice in March, April and June and therefore probably live year-round in the lagoon. There is sufficient water between the ice and the lagoon bottom throughout the winter to enable these euryhaline species to survive, although the high salinity of the water in late winter probably excludes many other organisms.

2. Diver observations on 28 June indicated that small mysids 2.0-3.0 mm were present in large numbers in open-water leads along the mainland shore and along both shores of the barrier islands. Mysids appeared to be very scarce in the central portion of the lagoon at this time; divers observed only one in the deeper waters away from the areas near the shore.

3. Bottom dredge samples collected in the lagoon on 7 July contained several female mysids 11-16 mm in length that were brooding young mysids 2-3 mm in length. The number of young per adult varied from 4-16. None of the samples taken at other times contained female mysids brooding young.

4. Drop net samples and diver transects indicated that the densities of invertebrates used by birds and fish as key food organisms (amphipods and mysids) were of the same order of magnitude in 1978 as they were in 1977.

5. Drop net samples and diver observations indicated that mysids began to decline in numbers around the middle of August. (This decrease in abundance coincided with a large influx of an estimated several million arctic cod into the lagoon.) The number of amphipods did not show a corresponding decline in late summer.

6. No obviously gravid female mysids or amphipods were found in the latest (September 23) samples taken during the open-water period. However the male mysids in these late samples were in breeding condition.

7. Faber net results indicated that many amphipods and mysids were suspended in the water column at any given time and were thus presumably susceptible to transport into or out of the lagoon by currents.

8. Drift samples taken in the passes between the barrier islands indicated that there was a large-scale exchange of epibenthic organisms between the lagoon and the marine environment through these passes.

B. Ecology of Fish

Data gathered during this field season substantiated some previous findings, refined others, and provided a minimum estimate of the magnitude of year-to-year variability that might be expected to occur in lagoon fish populations. In addition, several observations made in 1978 have substantially broadened our concept of fish utilization of nearshore Beaufort Sea waters.

(1) In 1978 as in 1977, arctic cisco, least cisco, arctic char, arctic cod, and fourhorn sculpin were found to be the most common fish species in the lagoon system.

(2) In both years these fish relied almost exclusively on epibenthic invertebrates (mysids, amphipods, copepods) for their food supply, although species composition of prey organisms differed between years.

(3) Densities of fish in 1978, as in 1977, were highest along the mainland shoreline (0.01 fish/m^2, species combined), averaging 3.6 and 24 times greater, respectively, than densities of fish along lagoonside and oceanside shorelines of the barrier islands.

(4) In 1978 seven new fish species were encountered, that were not caught in 1977. Included was a small run of pink salmon.

(5) In 1978 large numbers of arctic cod, estimated to be in the millions (far greater than in 1977), entered Simpson Lagoon in mid-August.

(6) Winter studies showed that nearshore areas may provide important overwintering habitat for fish during winter months. In late winter (April), both anadromous and marine fishes (arctic cisco, least cisco, fourhorn sculpin, boreal smelt, saffron cod) were caught in the brackish water of the lower Colville Delta (-1.5°C; 22°/oo). In early winter (November), four marine fishes (arctic cod, boreal smelt, fourhorn sculpin, saffron cod) were caught under the ice in the Prudhoe Bay-Simpson Lagoon region.

C. Avian Ecology

Tentative findings of the 1978 research in avian ecology are as follows:

(1) The volume, timing and directions of movements of migrating birds during 1978 were similar to that observed during 1977.

(2) The estimated density of breeding birds in tundra situations on that mainland was approximately three times greater than estimated densities in similar barrier island habitats. The bird species diversity was similarly greater on the mainland tundra.

(3) No Arctic Foxes were seen on any of the barrier islands during 1978, which contrasts with the situation found in 1977. At the same time in 1978, production of eggs and young by those bird species unique to barrier islands within the study area (eiders, gulls, and terns) was markedly higher than in 1977. However, this increased production was still much lower than that observed on a barrier island (Thetis Island) which historically has no Arctic Foxes in summer and high bird production.

(4) Preliminary analyses indicate that the density of shorebirds, (mainly phalaropes) on coastlines in the Jones Islands-Simpson Lagoon study area was lower during August 1978 than during August 1977. The data have not been fully analyzed.

(5) Preliminary analyses indicate that the density of oldsquaws present in Simpson Lagoon was generally the same during 1978 as during 1977, except that the late season influx of females and young-of-the-year birds recorded in 1977 was not noted during 1978. As a consequence the dramatic increase in oldsquaw abundance noted during late September 1977, was not evident during 1978. The data have not been fully analyzed.

(6) The diets of phalaropes and oldsquaws during 1978 remained generally unchanged from 1977 diets. Phalaropes preyed most heavily on copepods. Oldsquaws preyed most heavily on mysids and amphipods, although bivalves comprised a significant proportion of their early-season diet.

D. Workshop Results

The modeling workshop held on 11-12 December at the University of British Columbia focused on revising and refining the existing model and defining the kinds of development scenarios which would

be amenable to treatment by the use of modeling for assessing impacts. Investigators provided new information which in some cases revised the existing concepts about the food chains and vertebrate consumers in the nearshore environment. (Immediately following the workshop, the modelers made some preliminary revisions of the existing model which cast some doubt upon the idea generated by last year's research that the vertebrate consumers had unlimited food supplies.) Petroleum industry representatives from Atlantic Richfield Company assisted in generating reasonable scenarios of petroleum exploration and development for the nearshore region.

Schell (RU 527) presented evidence to indicate that most of the carbon that supports the invertebrates, fish and birds is "modern" (e.g., non-peat). His results also indicate that the source of this "modern" carbon is marine rather than terrestrial. The nature of circulation that might allow this postulated source of production to be delivered in quantity to the lagoon system is still unclear. The secondary production by invertebrates (primarily mysids) in the lagoon is very high in July, August, and September because of the high standing crops and rapid growth of the organisms during this period; however, there was some indication that heavy cropping by consumers this year might have been able to outstrip this productivity. (If such was the case, food could, under some circumstances, become limiting to the growth or state of health of the bird and fish consumers.) However, the biologists thought that populations of the key species of both birds and fish are normally limited elsewhere in their ranges and/or life cycles.

It was made clear during the workshop that the model is most useful for prediction of those impacts which act indirectly through the food chain. Such direct impacts as oil on birds, increases in fishing pressures, and removal of portions of habitat must (and can) be defined directly. Therefore, the types of development activities that can be examined for potential impact via use of the model are those that would interrupt the transport, processing, or availability of nutrients and/or carbon. Specific samples of such development

scenarios are causeways which would block or otherwise alter the input of nutrients or carbon, changes in nearshore circulation patterns with resulting alterations in the current-dependent movements of invertebrates, and alterations in the nearshore water temperature regimes upon which the rates of secondary production might depend. Several scenarios of specific exploration and development activities were discussed in relation to potential impacts. These discussions served as preliminary test cases for the more extensive "predictive" attempts planned for the nest modeling workshop.

As the workshop session concluded, it was not clear whether the predicted levels of selected kinds of development (e.g., causeway construction, artificial island construction, extensive industrial use of existing barrier islands) would have measurable impacts on critical processes in the nearshore region. It was clear, however, that any conclusions at this time can only be based on very preliminary data (or in many cases 'best guesses' only) and final judgement must be reserved until the data have been more fully analyzed and interpreted.

V. Preliminary Interpretations of Results

Few extensive interpretations of results can be made at this time. Some early indications, however, are as follows:

(1) Amphipods appear to be able to complete their entire life cycle in the lagoon. Mysids appear to be absent from the lagoon in spring (March-June) and repopulate the system in late June and early July, appearing first along the nearshore leads and then moving into the central portion of the lagoon, indicating that the lagoon may serve as a rearing area for small mysids but not as an overwintering area for any mysid age classes.

(2) Because large numbers of amphipods and mysids are suspended in the water column at any given time, they are probably susceptible to transport into or out of the lagoon by currents.

(3) It appears possible that the large influx of arctic cod into Simpson Lagoon in 1978, coupled with the daily food requirement of cod of approximately six percent of body weight per day (determined in field tests), may have been responsible for the substantial reduction in the numbers of mysids (favored food of the fish) which occurred about this time in the lagoon. If this is true, the abundance of fish food which apparently occurred in Simpson Lagoon in 1977 may not be a representative condition in nearshore areas in years of high arctic cod abundance.

(4) It appears that nearshore coastal waters are used in the winter by some marine fish species for feeding and/or spawning, and selected coastal sites are used in winter by anadromous fish for feeding and overwintering. With the exception of shallow-water areas which freeze solid or become hypersaline, the nearshore coastal environment is probably best viewed as an area which supports populations of fish throughout the year, though species composition and distribution may differ between summer and winter periods.

(5) The presence of Arctic Foxes on the barrier islands may depress the nesting success of island-nesting birds.

(6) All coastal lagoons from the study area eastward to the Canadian border appear to be good habitat for oldsquaws in summer for molting and feeding; these birds seldom concentrate in non-lagoon coastal areas.

(7) The migratory, molting, staging, and feeding behaviors of oldsquaws and phalaropes were qualitatively similar in 1977 and 1978; important quantitative differences may exist, however.

VI. Auxiliary Material

None submitted.

VII. Problems Encountered/Recommended Changes

No major problems have been encountered. There are no recommended major changes in research objectives.

VIII. An estimated 83% of 1978 project funds have been expended.

CONTAMINANT BASELINES

Contents

Quarterly Report

Research Unit: 152
Reporting Period: 10/1/78-12/30/78
Number of Pages: 28
Principal Investigator: Richard A. Feely

Composition, Transport, and Deposition of Suspended Matter in Lower Cook Inlet and Shelikof Strait, Alaska

Prepared by

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December 30, 1978

I. Task Objectives

The major objectives of the Lower Cook Inlet suspended matter program include: (1) determination of the variability of the vertical fluxes, the distribution and the composition of suspended particulate matter in areas of contrasting sedimentation and productivity; and (2) determination of trace element associations with specific particulate phases in suspended matter from Lower Cook Inlet.

II. Field and Laboratory Activities

A. Field Activities

1. Ship Schedule

a. DISCOVERER Cruise RP-4-DI-78A-III (4-17 May 1978)

b. MILLER FREEMAN Cruise RP-4-MF-78A-II (19 May-4 June 1978)

c. DISCOVERER Cruise RP-4-DI-78B-II (22 August-6 September 1978)

d. DISCOVERER Cruise RP-4-DI-78C-V (2-20 October 1978)

2. Participants from PMEL

a. Dr. Richard Feely, Oceanographer

b. Mr. Gary Massoth, Oceanographer

c. Ms. Jane Hannuksela, Oceanographer

d. Mr. William Landing, Research Assistant, UW

e. Mr. Randy Dyer, Research Aid, UW

f. Mr. Anthony Paulson, Oceanographer

3. Methods

a. Particulate Matter - Water samples were collected in General Oceanics 1070 10L PVC Top-Drop Niskin bottles from preselected depths. Nominally these included: 0-2 m, 10 m, 20 m, 40 m, 60 m, 80 m, and 5 meters above the bottom. Aliquots were drawn within one-half hour after collection

from each sample and vacuum filtered through preweighed 0.4 µm pore diameter Nuclepore polycarbonate filters for total suspended matter concentration determinations and multielement particulate composition analysis. Samples were also filtered through 0.45 µm pore diameter Selas silver filters for particulate carbon and nitrogen analyses. All samples were rinsed with three 10 mL aliquots of deionized and membrane filtered water, placed in individual petri dishes with lids slightly ajar for a 24-hour desiccation period over sodium hydroxide and then sealed and stored (silver filters frozen) for subsequent laboratory analysis.

b. Bottom Sediment - Bottom sediment samples were collected with a Shipek grab sampler, a three-inch gravity corer equipped with a plastic core liner, and a HAPS corer. Twelve gravity corer samples and all HAPS corer samples were sectioned into 1 cm segments upon collection and frozen in individual plastic bags. All remaining bottom sediment samples were immediately frozen and returned to the laboratory intact.

c. Nephelometry - The vertical distribution of suspended matter was determined with a continuously recording integrating analog nephelometer. The instrument was interfaced with the ship's CTD system using the sound velocity channel (14-16 KHz). Continuous vertical profiles of forward light scattering were obtained in analog form on a Hewlett Packard 7044 X-Y recorder.

d. Conductivity (Salinity), Temperature, and Depth - These standard hydrographic data were acquired with a Plessy Model 9040 Environmental Profiling System (CTD probe) and a Model 8400 digital data logger using 7-track, 200 B.P.I. magnetic tape. Temperature and salinity calibration data were provided by NOAA ship personnel from discrete water samples utilizing reversing thermometers and a bench salinometer, respectively. Signals from the CTD system and the nephelometer were also simultaneously interfaced with the ship's data acquisition system. This resulted in computer listings of continuous (uncorrected) data for conductivity, temperature, depth, salinity, sigma-t, and light scattering for all vertical sampling stations.

e. Sediment Trap/Vertical Particulate Flux Studies - During Cruise RP-4-MF-78A-II (19 May-4 June 1978) three moorings, each supporting one set of tandem sediment traps located 10 m above the bottom, were deployed along a transect line extending from Kamishak Bay to Kachemak Bay in Lower Cook Inlet. The sediment trap capture period was set (trap closure to be activated by self-contained timers approximately 85 days after deployment) to obtain a long-term average of the particulate vertical flux mass (rate) and composition. Recovery of the sediment traps occurred in October 1978 (DISCOVERER Cruise RP-4-DI-78C-V).

4. Station Locations

Figure 1 shows the locations of suspended matter stations occupied during Cruise RP-4-DI-78A-III (4-17 May 1978) and RP-4-MF-78A-II

(19 May-4 June 1978) in Lower Cook Inlet. Stations ST-1, ST-2, and ST-3 were the only positions occupied during the latter cruise which was conducted entirely for sediment trap deployment operations. The station locations for the late summer cruise (RP-4-DI-78B-II, 22 August-6 September 1978) in Lower Cook Inlet and Shelikof Strait are shown in Figure 2. The additional stations in Shelikof Strait were occupied to identify the regions where suspended matter from Lower Cook Inlet is deposited.

5. Samples and Data Collected

We have completed both interdisciplinary cruises scheduled for FY 78 in Lower Cook Inlet. During the first cruise (RP-4-DI-78A-III, 4-17 May 1978), 283 suspended particulate matter samples, five gravity and HAPS corer samples, 59 nephelometer profiles, and 72 CTD profiles were collected. In addition, nine suspended matter samples were processed in support of hydrocarbon studies conducted in Upper Cook Inlet (Cline: RU 153). A total of 12 stations were occupied, including two 48-hour time series studies at stations CB-7 and CB-9 (Fig. 1). During the summer cruise (RP-4-DI-78B-II, 22 August-6 September 1978), a total of 22 stations were occupied in Cook Inlet and Shelikof Strait and 280 suspended matter samples and 7 sediment cores were collected. A single time-series station was occupied at station CB-10 (Fig. 2).

B. Laboratory Activities

1. Methods

The suspended matter samples from Lower Cook Inlet are being analyzed for extractable Al, Fe, Mn, Cr, Cu, Ni, Zn, and Pb using a combination of two extraction treatments followed by flameless

atomic absorption spectrophotometry. The first extraction procedure involves the use of hydrogen peroxide to release organically-bound trace metals. The second treatment utilizes 0.3 N hydrochloric acid to release trace metals which are weakly bound to inorganic phases. The details of the procedures are outlined below.

a. H_2O_2 Treatment. Dilute 30% ULTREX (J. T. Baker) hydrogen peroxide to 10% with the addition of quartz distilled water (Q-H_2O). Combine 5 mLs of 10% H_2O_2 with 100-500 mg of sample material in a precleaned centrifuge tube equipped with a nonsealing cap. The volume and mass of extractant and sample, respectively, may vary within the above limits depending on the relative magnitude of the organic fraction in the sample. We are currently using polypropylene centrifuge tubes and caps. Heat the extractant-sediment solution in a water bath at approximately 50°C for 48 hours. During the final 24 hours of heating, vigorously sonicate the solution to assist in dispersal and breakdown of the organic matter. Centrifuge the tube contents at 2000 rpm for 1 hour. Decant the supernate into a precleaned and tared polyethylene (CPE) bottle. Rinse the residual particulate matter with one 10 mL aliquot of quartz-distilled water. Centrifuge, as above, after each rinse and combine all supernates in the polyethylene bottle. Since the centrifugation separation is not complete, filter the samples through a 0.4 µm Nuclepore filter. Determine the weight of the supernate by difference.

b. 0.3M HCl Treatment. Dilute Ultrex® (J. T. Baker) HCl to 0.3M with Q-H_2O. Add 8 mLs of 0.3 M HCl to 100-500 mg of sample which has been treated with H_2O_2. Heat the mixture to 75°C for 24 hours while sonicating. Centrifuge the mixture at 2000 rpm for 1 hour. Decant the supernate into a precleaned and tared polyethylene bottle. Add 8 mLs of 0.3M HCl to the residual sediment. Shake this mixture, then centrifuge as above and decant the supernate into the bottle. Repeat the rinsing of the residual sediment once. Filter the combined supernates through a 0.4 μm Nuclepore® filter. Determine the weight of the final supernate by difference.

2. Sample and Data Status

The suspended matter distributions and vertical fluxes have been determined and will be discussed in the following section of this report. The chemical analyses of the suspended matter samples from the time-series stations and sediment traps are underway and will be discussed in a future report.

III. Results and Discussion

A. Particulate Matter Distributions and Transport

To date we have completed both cruises in Lower Cook Inlet and Shelikof Strait which have been scheduled for FY 78. The first cruise was conducted during the spring of 1978 (4-17 May) and the second cruise was conducted in late summer of the same year (22 August-6 September). The station locations for the two cruises are shown in Figures 1 and 2. Vertical distributions of temperature, salinity, and suspended matter concentrations were obtained along eight stations extending from Kamishak Bay to Kachemak Bay and seven stations along the longitudinal

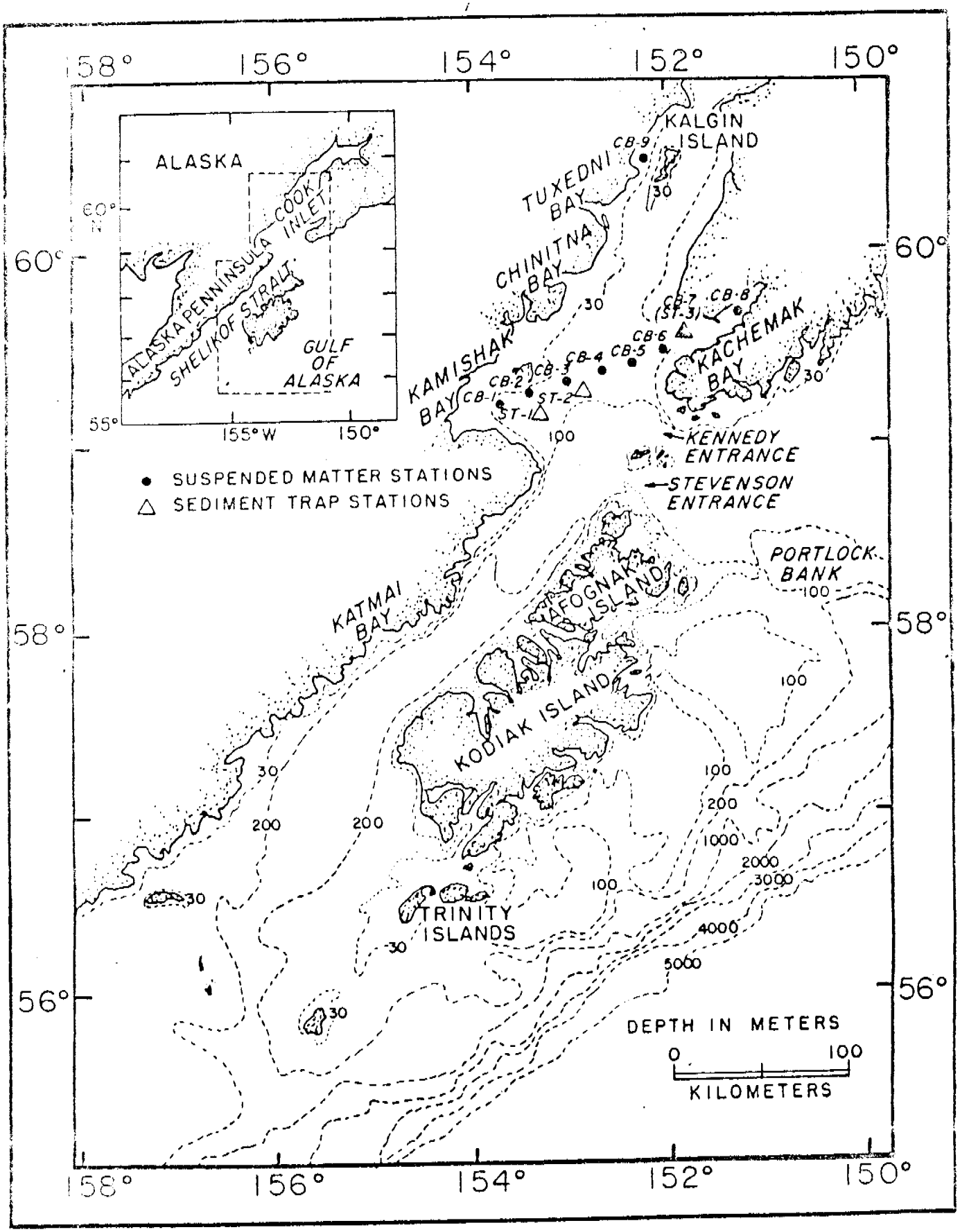

Figure 1. Locations of suspended matter and sediment trap stations occupied in lower Cook Inlet (Cruises RP-4-Di-78A-III, 4-17 May 1978 and RP-4-MF -78A-II, 19 May - 4 June 1978).

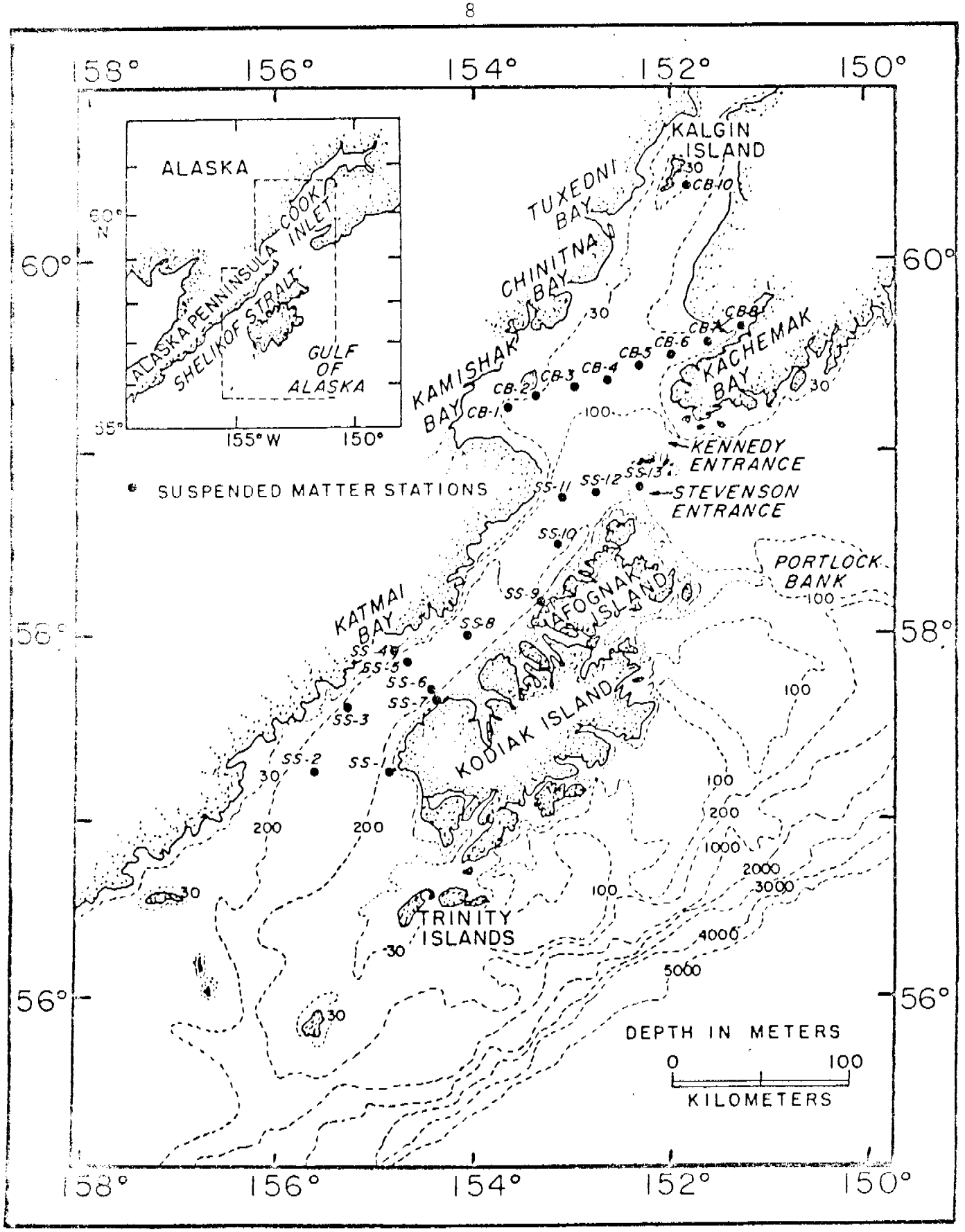

Figure 2. Locations of suspended matter stations occupied in lower Cook Inlet (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

axis of Shelkof Strait. Figures 3 and 4 show vertical sections of the data for the cruises in Lower Cook Inlet and Figures 5 and 6 show the vertical sections for the Shelikof Strait data which was taken on the summer cruise.

The data from Lower Cook Inlet show significant cross-channel variations which can be utilized to identify three distinct water masses. On the west side (stations CB1 through CB3) the water properties are low salinity (30.0-31.6°/oo) and high suspended matter concentrations (0.9-3.6 mg/L). The water is virtually unstratified from top to bottom. These properties are characteristic of the outward flowing brackish water which originates from upper Cook Inlet and flows south along the western coast. This water mass contains significant amounts of terrigenous rock debris from the rivers which drain into upper Cook Inlet. The central region (stations CB5 and CB6) contain water which is more saline (31.4-31.8°/oo) and less turbid (0.4-1.4 mg/L). This water is characteristic of the inflowing Gulf of Alaska which flows north along the east side of the Inlet. This water is only slightly more stratified than the outward flowing brackish water. In Kachemak Bay (stations CB7 and CB8) the waters are relatively warm (5.6-12.3°C), less saline (27.3-31.4°/oo) and moderately turbid (0.9-2.8 mg/L) These waters are moderately stratified, with the fresh water from the Fox and Martin Rivers extending outward as far as station 7.

The April and August-September data show some patterns which are consistent with the data from the previous year.. First, the outward flowing brackish water on the western side is colder in April and warmer in August-September than the inward flowing Gulf of Alaska water. This feature is consistent with data obtained in April and July 1977 (Figs. 7

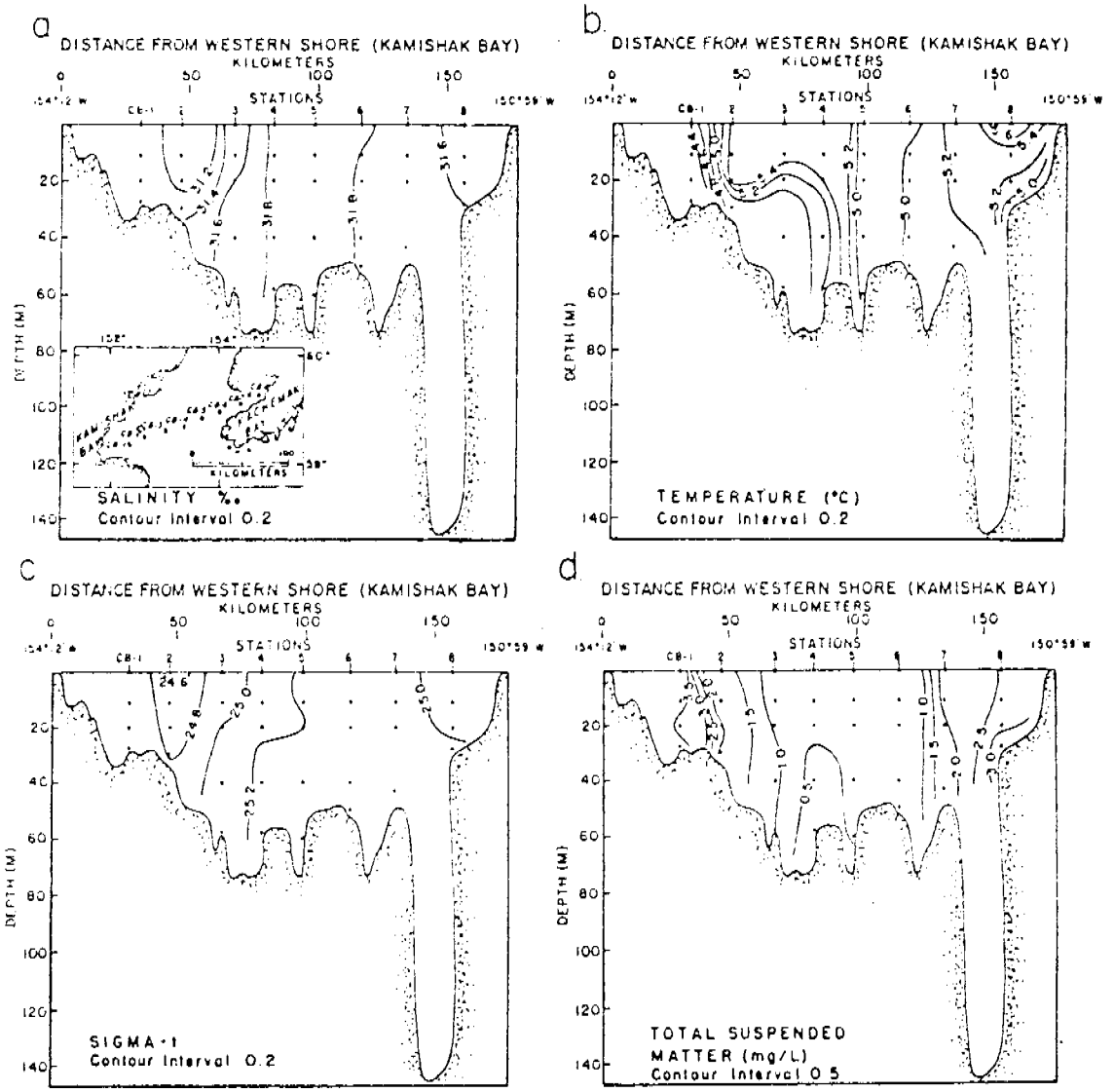

Figure 3. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations CB1 thru CB8 in Lower Cook Inlet (Cruise RP-4-Di-78A-III, 4-17 May 1978).

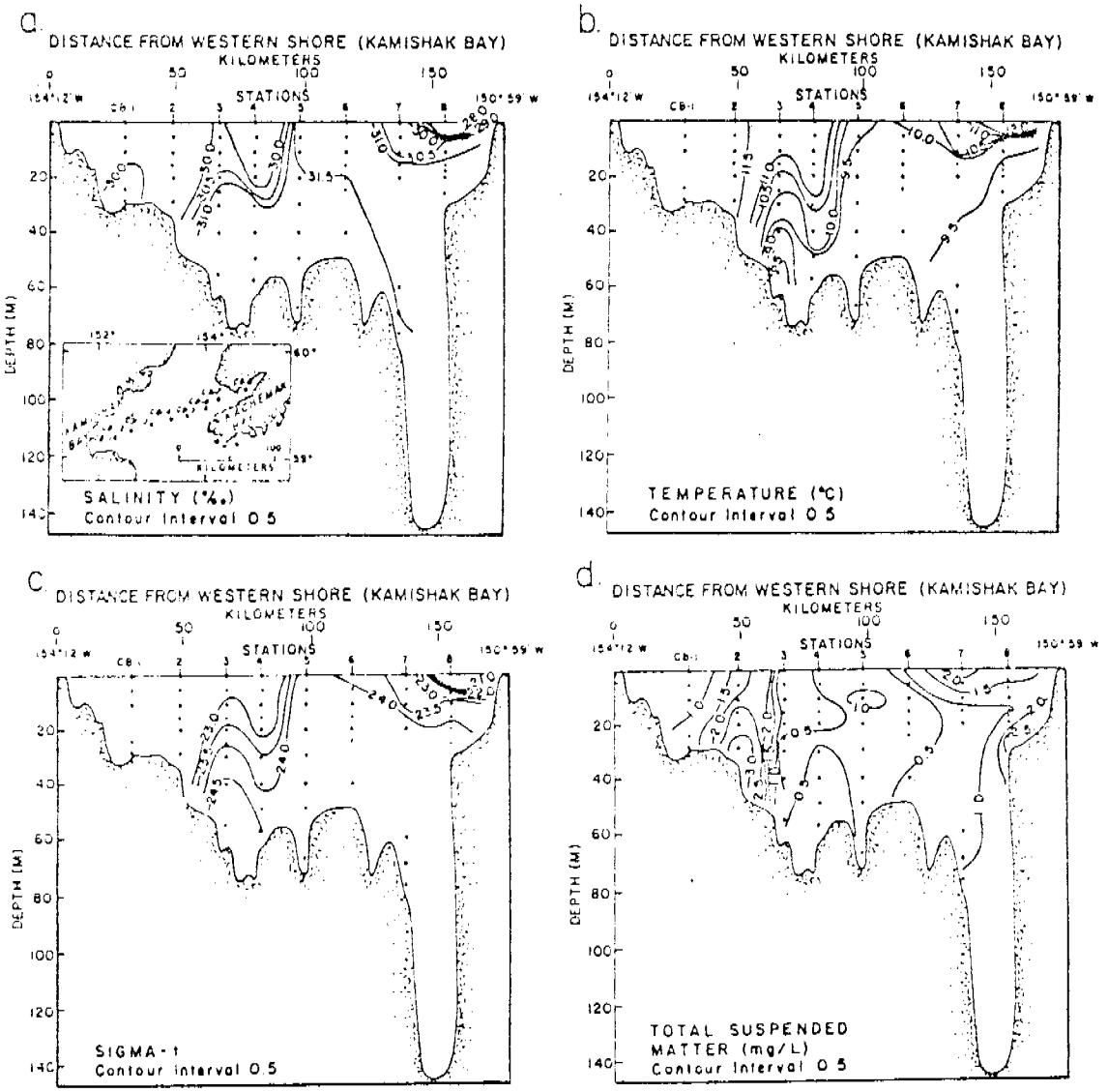

Figure 4. Vertical cross sections of the distributions of : a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations CB1 thru CB8 in Lower Cook Inlet (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

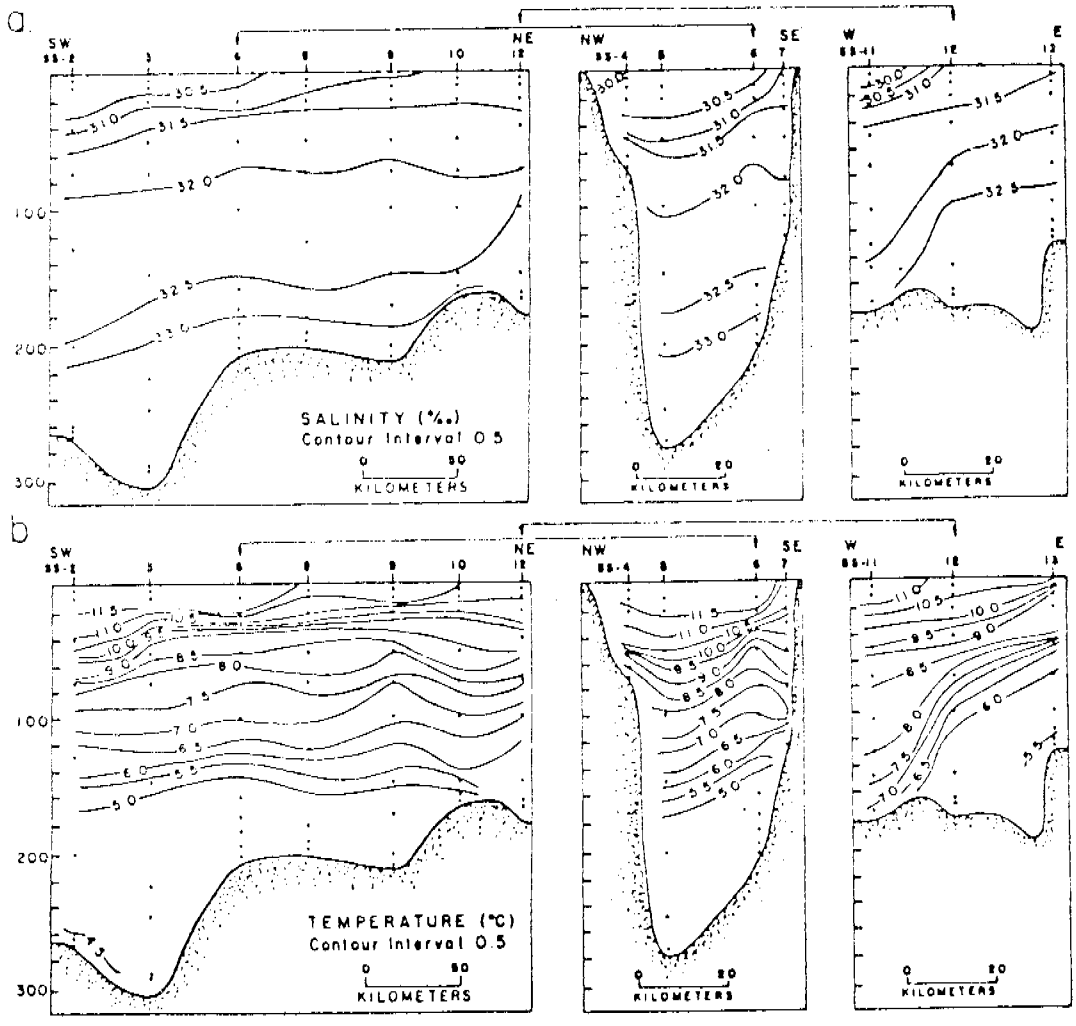

Figure 5. Vertical cross sections of the distributions of: a. salinity; and b. temperature for stations SS2 thru SS13 in Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

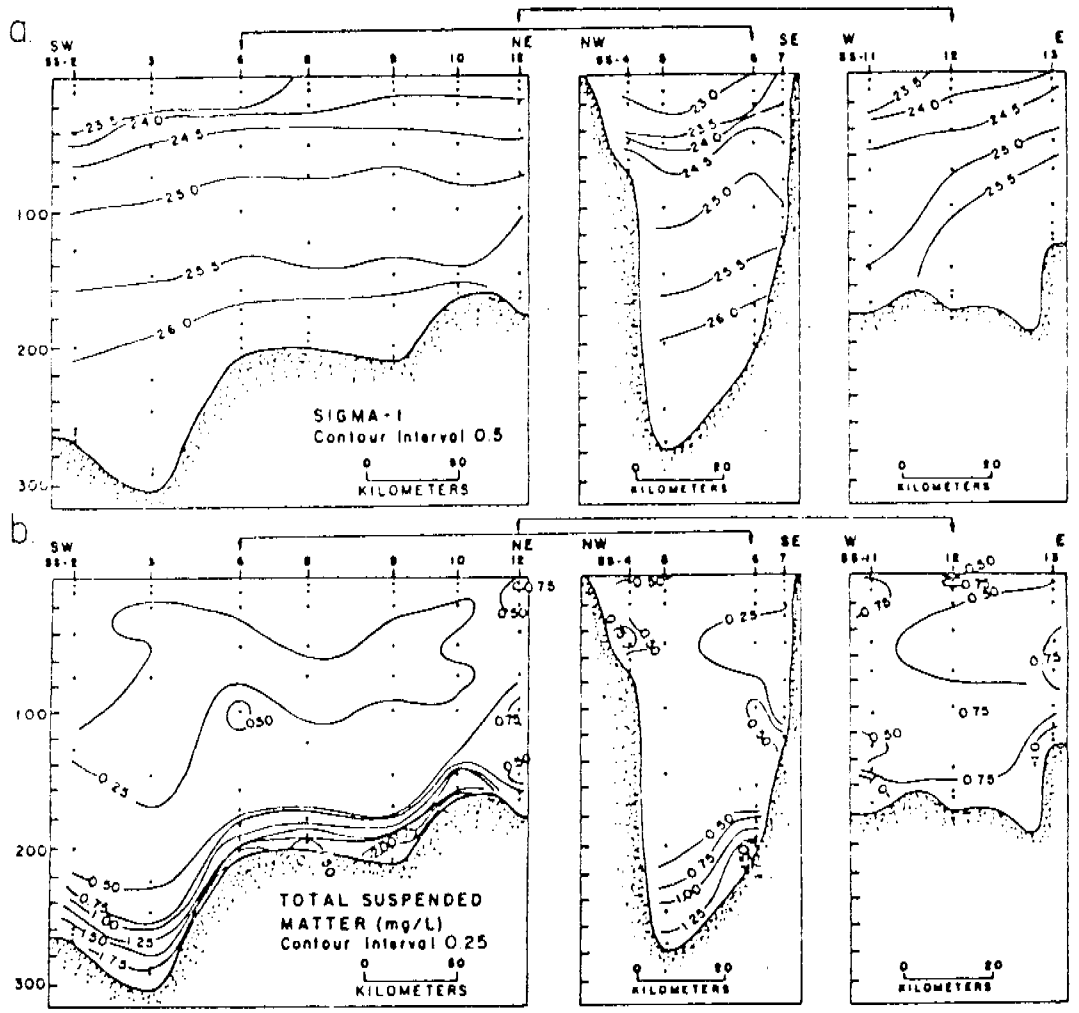

Figure 6. Vertical cross sections of the distributions of: a. sigma-t; and b. total suspended matter for stations SS2 thru SS13 in Shelikof Strait (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

and 8) and appears to be related to temperature of the inflowing river water which shows larger seasonal variations due to the larger fluctuations of temperature over the continental land masses. Furthermore, suspended matter concentrations are higher in April than in late summer even though there is more freshwater input into Cook Inlet during the late summer. A possible explanation for this phenomenon is that April is usually the time when most of the ice breakup occurs in upper Cook Inlet. Resuspension and transport of previously deposited sediments may occur as a result of ice movement. Another possibility is that if the currents are stronger in April, there is less time for mixing and dilution of ambient suspended matter. This is probably the case for the April 1977 data as the suspended matter concentrations are the highest of the five cruises in the Kamishak Bay region, with corresponding salinities being the lowest of the five cruises. This suggests that more riverborne suspended matter is transported out of the Inlet and into Shelikof Strait during this time of the year.

Figures 5 and 6 show vertical cross-sections of temperature, salinity, total suspended matter, and sigma-t for stations located in Shelikof Strait. The data were obtained on the August-September cruise. Stations 2 thru 12 represent a longitudinal cross-section along the axis of the strait. Stations 4 thru 6 and 11 thru 13 represent transverse cross-sections at mid-channel and at the upper mouth, respectively. The data show cross channel gradients of temperature, salinity, and suspended matter which are consistent with the cross channel gradients in Lower Cook Inlet. This is the strongest evidence to date which suggests that riverborne suspended matter from upper Cook Inlet is being received into Shelikof Strait. There is also evidence for a near-bottom nepheloid

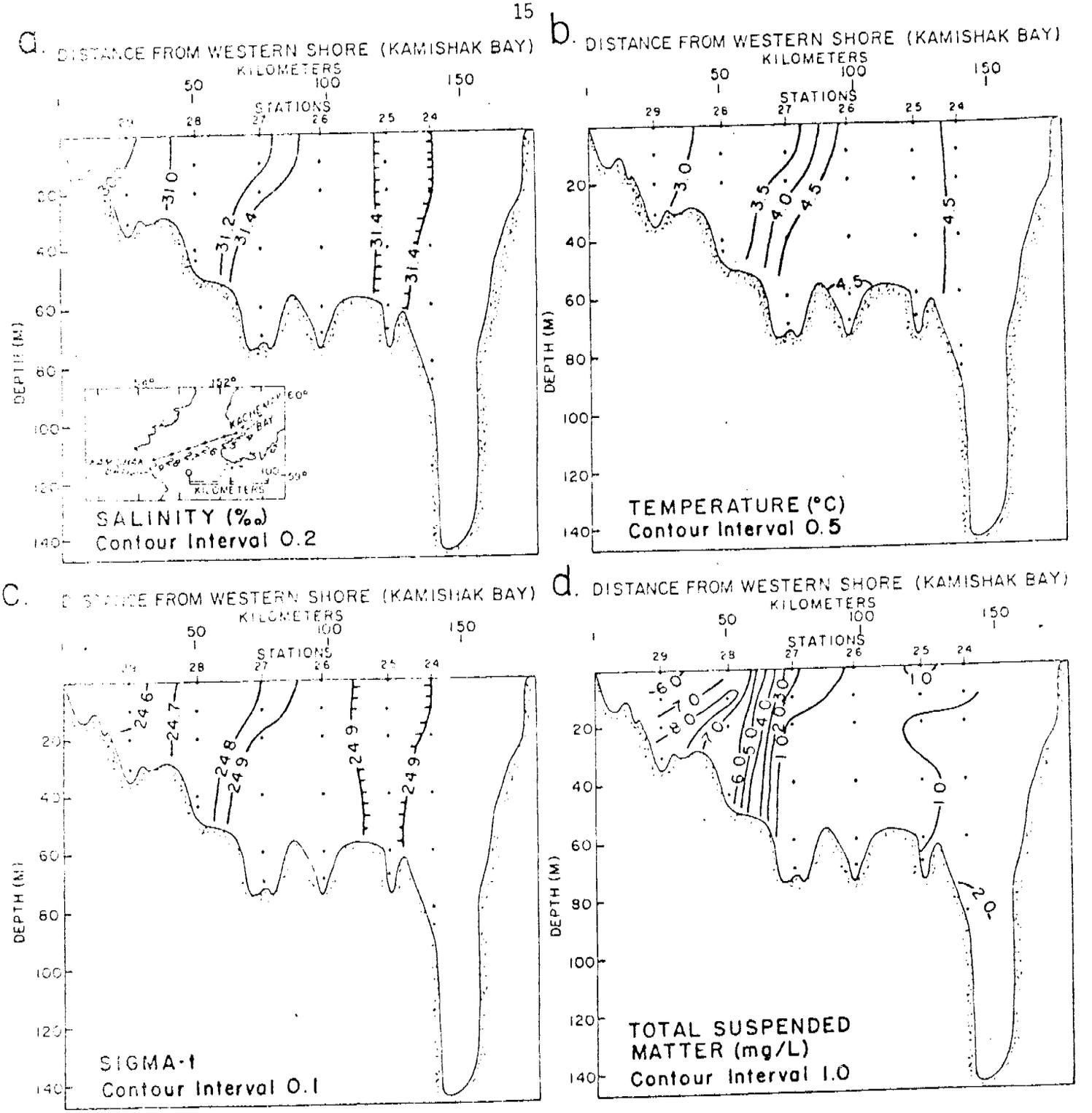

Figure 7. Vertical cross sections of the distributions of: a. salinity: b. temperature; c. sigma-t; and d. total suspended matter for stations 25 thru 29 in Lower Cook Inlet (RP-4-Di-77A-IV, 4-16 April 1977).

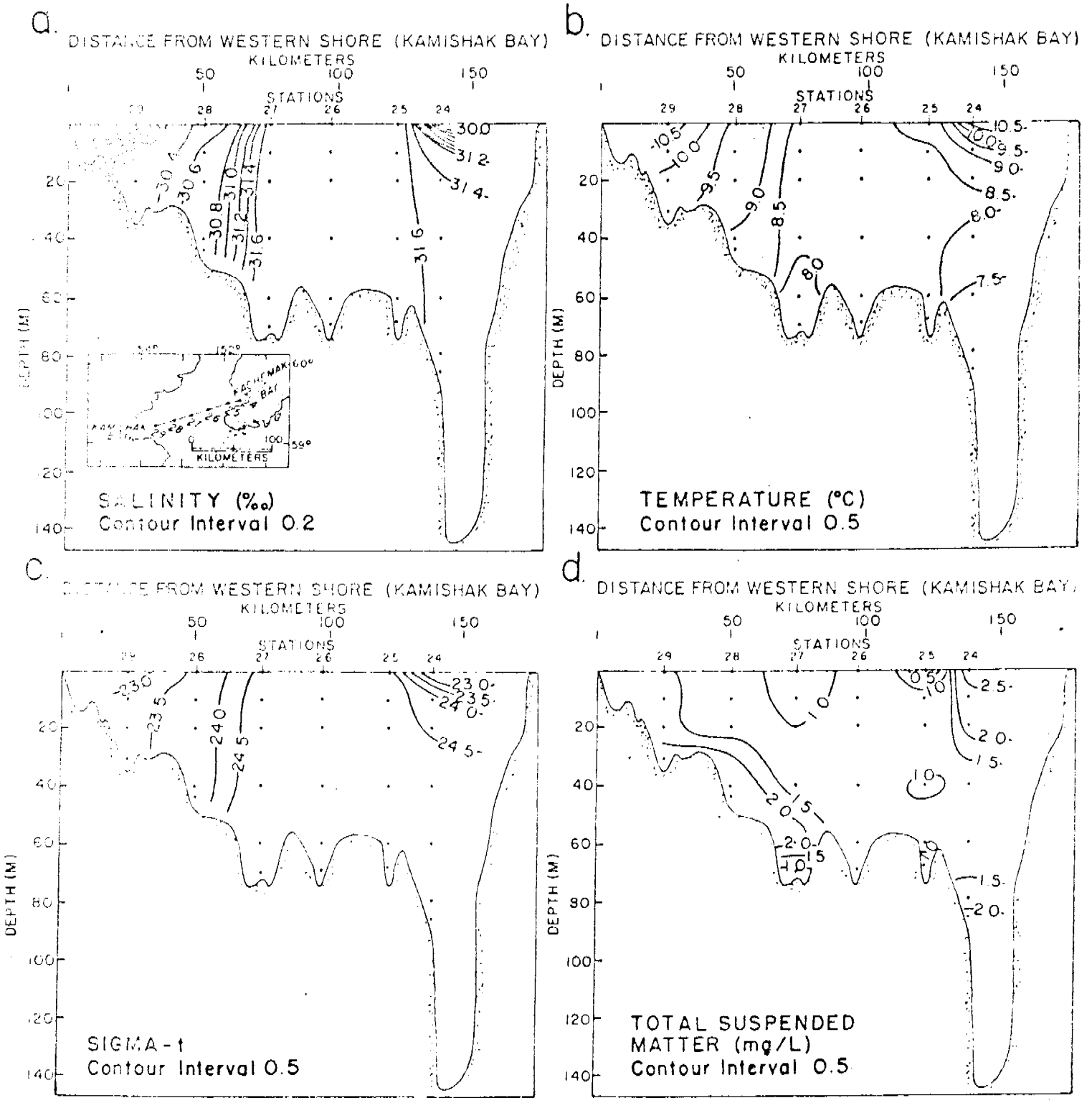

Figure 8. Vertical cross sections of the distributions of: a. salinity; b. temperature; c. sigma-t; and d. total suspended matter for stations 24 thru 29 in Lower Cook Inlet (Cruise Acona-245, 28 June - 12 July 1977).

layer in the Strait which exists in the bottom 50-60 meters of the water column. Since there are no corresponding large changes in temperature and salinity which would tend to hold up suspended material from settling, the bottom nepheloid layer in this region is probably due to resuspension of bottom sediments. This suggests that sediments and/or contaminants probably get redistributed in the Strait before final deposition occurs. The chemical studies of the near-bottom suspended matter will probably provide more insight to this problem.

B. Chemical Composition of the Suspended Matter

While trace metal analyses of the suspended matter from Lower Cook Inlet are still under way, the particulate carbon analyses are complete and salient results are briefly described below. Figures 9 and 10 show the distribution of particulate carbon for the April and August-September cruises in Lower Cook Inlet. Large cross channel gradients occur in both spring and summer data, with the highest concentrations and vertical gradients of particulate carbon occurring at stations located in Kachemak Bay. Larrance et al. (1977) state that phytoplankton productivity and standing stocks of chlorophyll *a* are highest in Kachemak Bay and decrease steadily to low values in the middle of the Inlet. These data suggest that the observed variations of particulate carbon are directly related to production of marine organic matter in the Inlet, with Kachemak Bay being the most productive. This is probably the result of a number of factors, including: (1) upwelling of nutrient-rich subsurface waters in the region northwest of the Chugach Islands (Burbank, 1977); (2) stratification and stabilization of the surface waters due to formation of two gyre systems (Burbank, 1977 and Larrance et al., 1977); and (3) deeper light penetration due to input of relatively nonturbid oceanic water from the Gulf of Alaska (Feely et al., 1978).

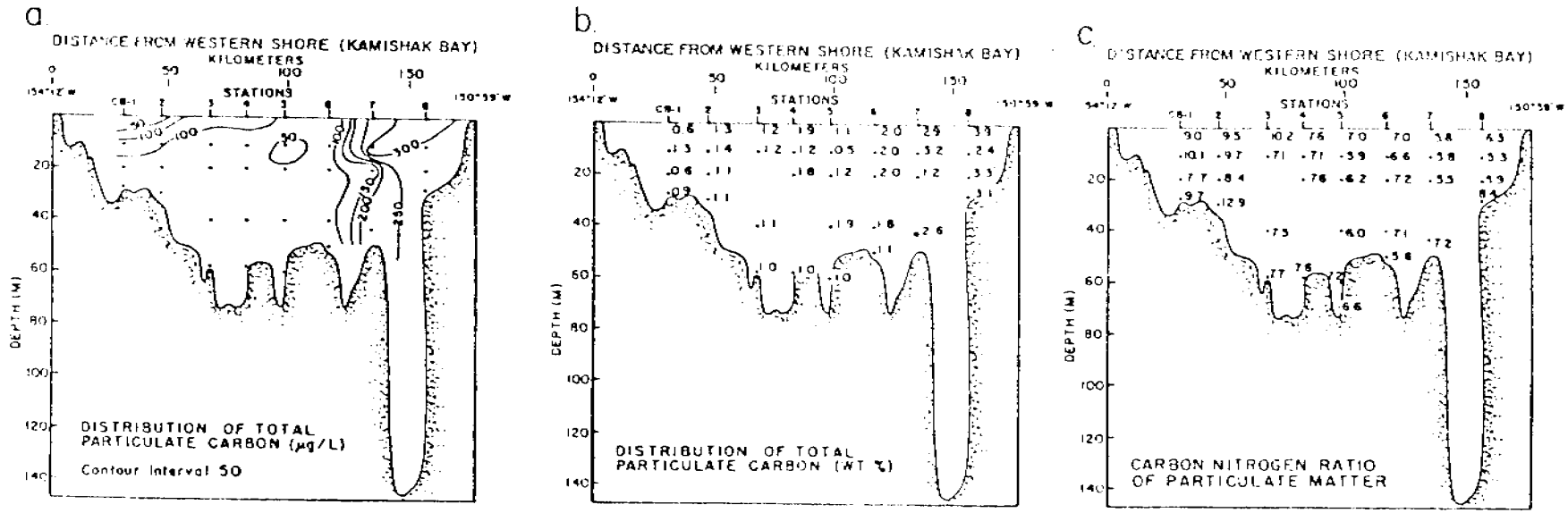

Figure 9. Vertical cross sections of the distributions of: a. particulate carbon in units of ug/l; b. particulate carbon in weight percent of the suspended matter; and c. carbon to nitrogen atom ratios for stations CB1 thru CB8 in Lower Cook Inlet (Cruise RP-4-Di-78A-III, 4-17 May 1978).

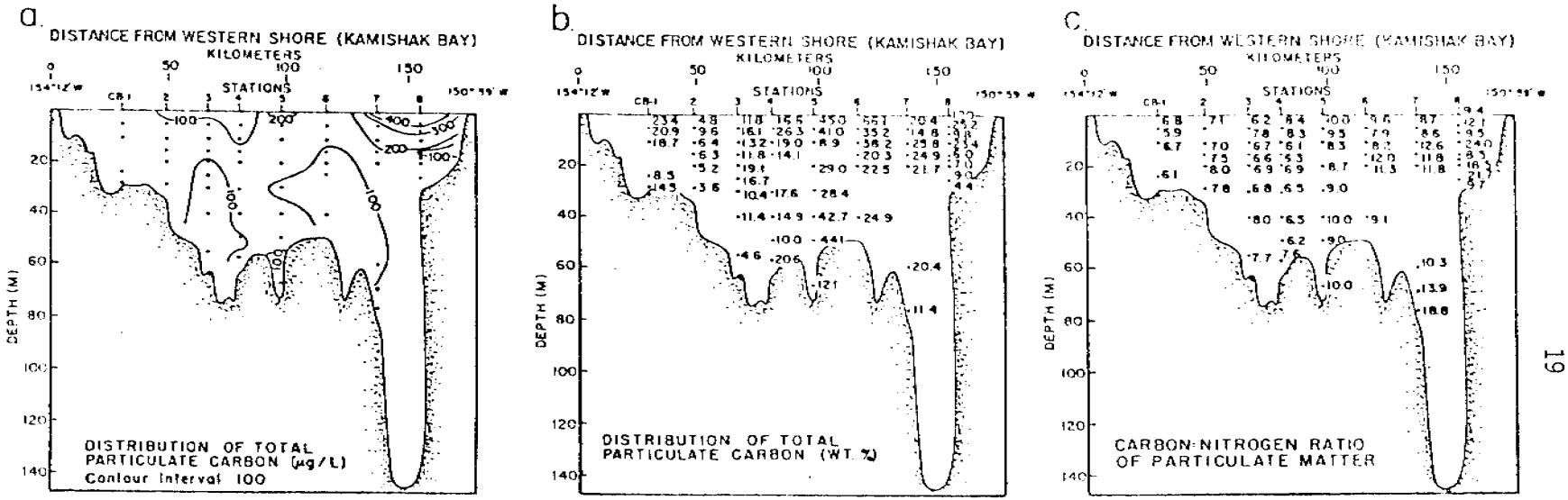

Figure 10. Vertical cross sections of the distributions of: a. particulate carbon in units of ug/l; b. particulate carbon in weight percent of the suspended matter; and c. carbon to nitrogen atom ratios for stations CB1 thru CB8 in Lower Cook Inlet (Cruise RP-4-Di-78B-II, 22 August - 6 September 1978).

Undoubtedly, some of the organic matter that is produced in the Kachemak Bay region settles to the sea floor and gets buried within the sediments. However, since the net circulation is to the north and back again to the southwest into Shelikof Strait, a significant fraction of the organic matter produced in Kachemak Bay probably gets deposited in Shelikof Strait. This means that the two regions are linked by physical, chemical, and biological processes. If any of the processes occurring in Kachemak Bay are altered, either by natural or artificial means, the major effect might be observed in Shelikof Strait, which is less dynamic and more stable than Lower Cook Inlet. If this is the case, then environmental parameters monitored in Shelikof Strait may be sensitive indicators of subtle changes occurring in the Inlet.

C. Temporal Variability of Suspended Matter

In order to obtain some information about high frequency (hourly) fluctuations of particulate concentrations in Lower Cook Inlet, three time series experiments were conducted during the April and August-September cruises. In April, 48-hour time series experiments were performed at station CB-7 in Kachemak Bay and CB-9, just west of Kalgin Island. A single time series experiment was conducted at CB-10, due east of Kalgin Island, during the August-September cruise. Water samples were collected and filtered every two hours from the surface and 5 meters above the bottom. The results of these experiments are shown in Figures 11 thru 13. The high and low tides are represented in the figures by arrows. The reference points for the tidal data are indicated in the figure captions. At the two stations on either side of Kalgin Island, suspended matter concentrations are highly variable both at the surface and near the bottom. At the surface, particulate concentrations

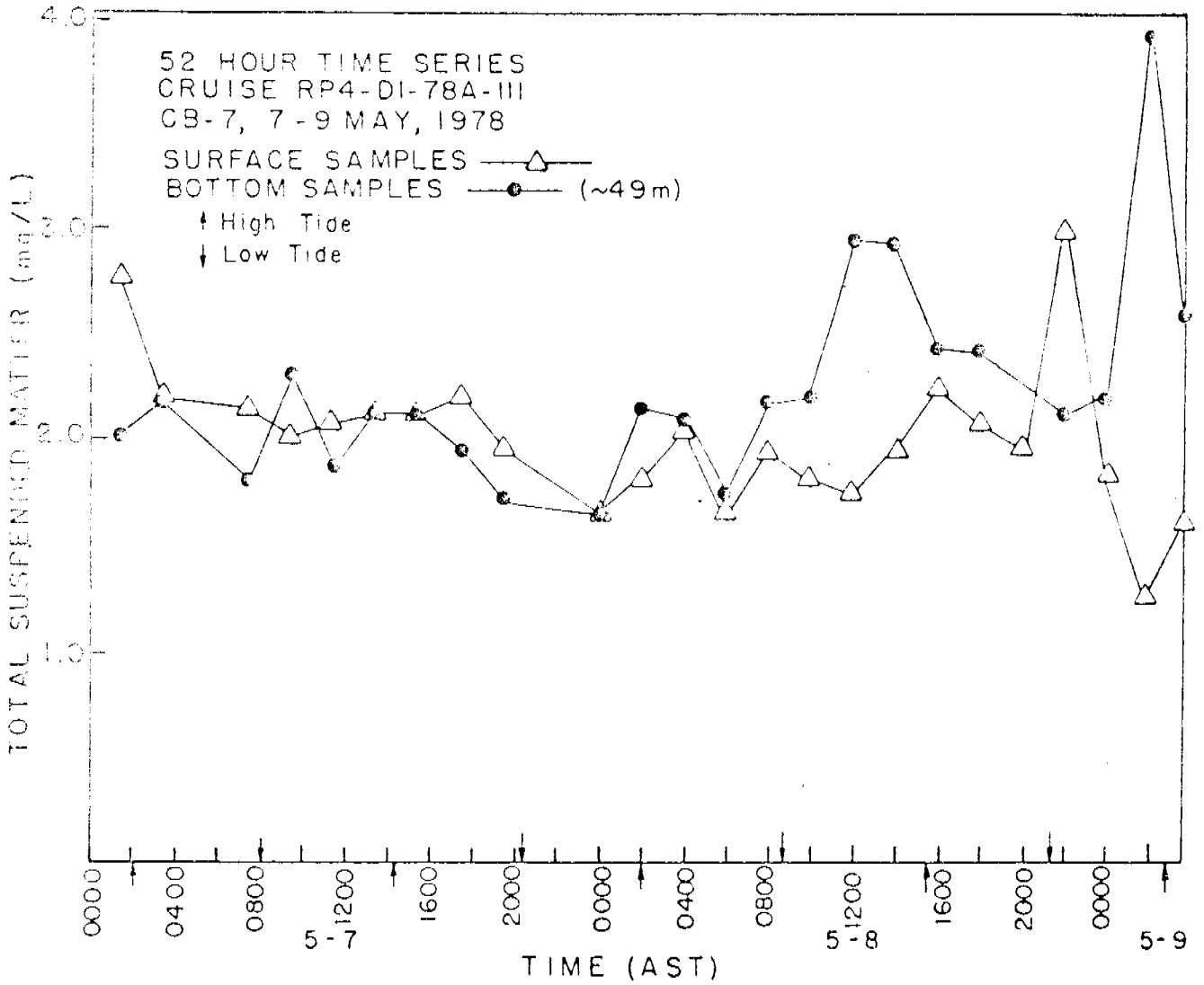

Figure 11. Temporal variability of total suspended matter at the surface and 5m above the bottom at station CB7 in Lower Cook Inlet (Cruise RP-4-Di-78A-III, 4 - 17 May 1978). The reference point for the tidal data was Homer, Alaska.

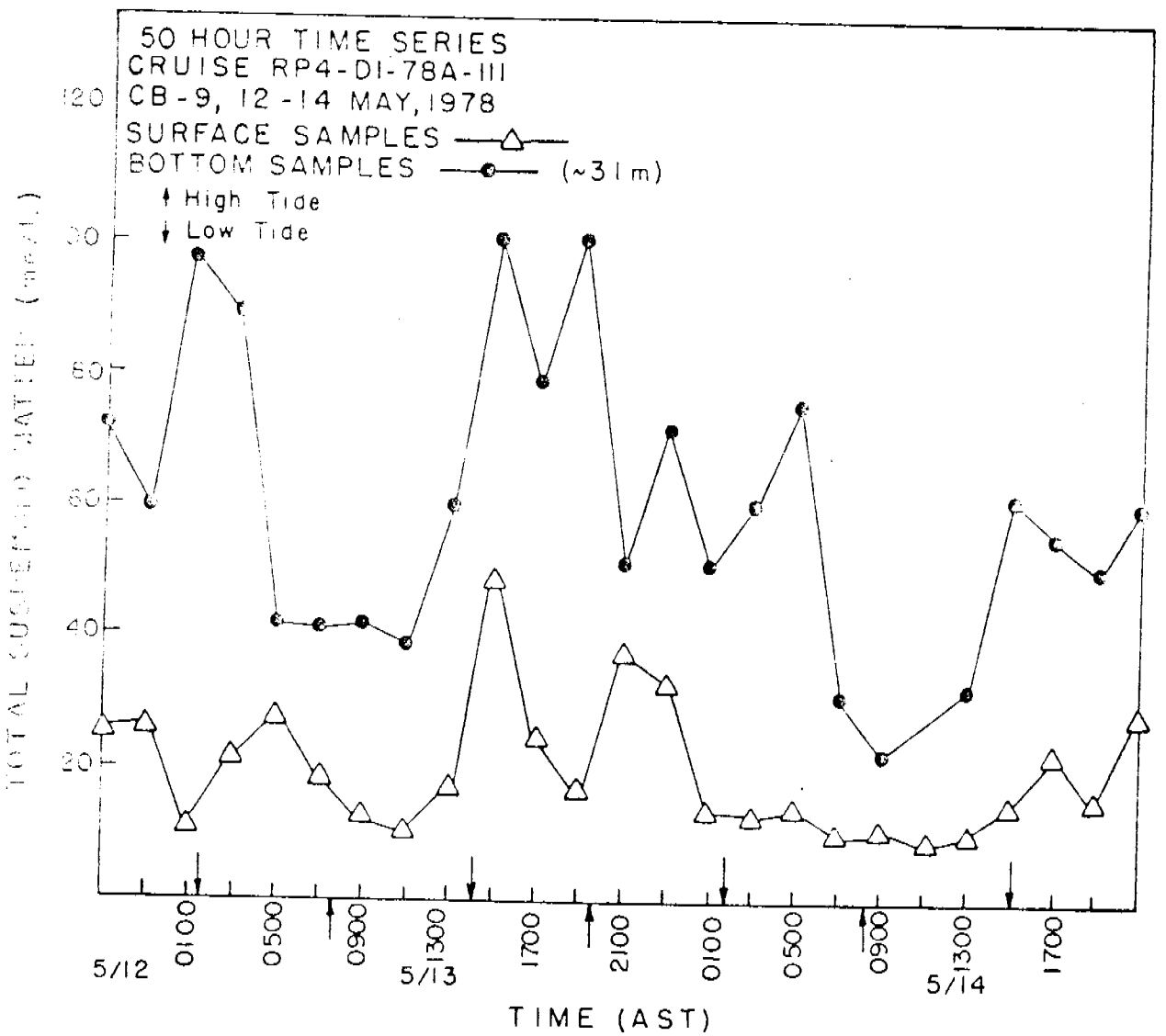

Figure 12. Temporal variability of total suspended matter at the surface and 5 m above the bottom at station CB9 in Lower Cook Inlet (Cruise RP-4-Di-78A-III, 4 - 17 May 1978). The reference point for the tidal data was Drift River Terminal tide station.

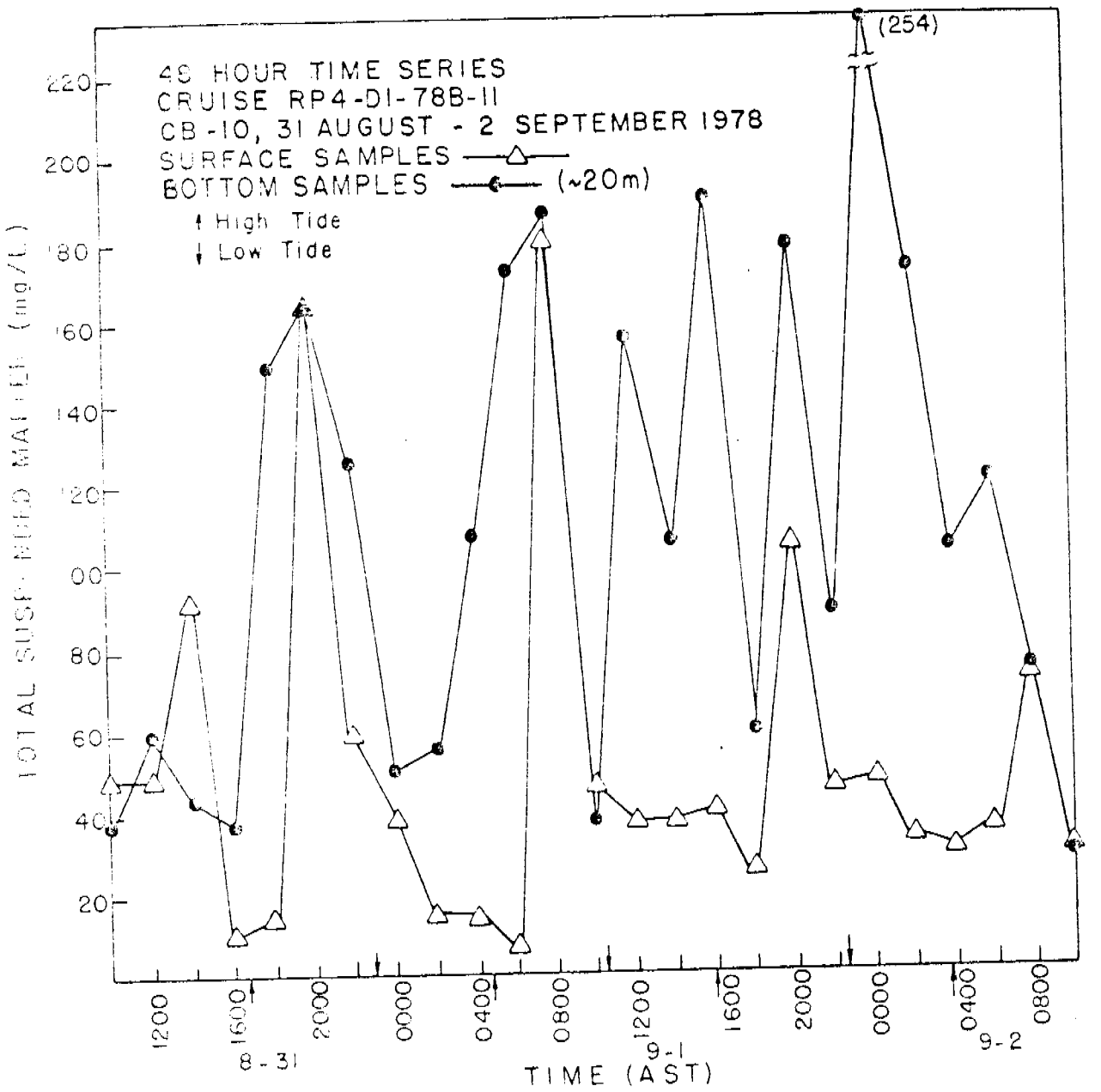

Figure 13. Temporal variability of total suspended matter at the surface and 5 m above the bottom at station CB10 in Lower Cook Inlet (Cruise RP-4-Di-78A-II, 22 August - 6 September 1978). The reference point for the tidal data was Kenai City Pier.

range from 10-50 mg/L at CB-9 and 10-180 mg/L at CB-10. The surface maxima have a 12-hour period and appear to reach their peak shortly after the ebb current reaches maximum velocity. Near the bottom the suspended matter concentrations are more variable and reach concentrations in excess of 250 mg/L. The near-bottom particulate maxima do not show a consistent periodicity pattern, but peaks associated with both the ebb and flood currents are evident. Furthermore, near-bottom suspended matter concentrations generally are higher than at the surface, indicating that when the tidal currents reach maximum velocity the bottom sediments are being resuspended.

While the time series data for the Kachemak Bay station show evidence for greatly reduced concentration fluctuations, the general trend of particulate maxima occurring shortly after the ebb current reaches maximum velocity still exists. These data suggest that throughout the Inlet tidal currents are a major cause of high frequency fluctuations of suspended matter distributions. It appears that during ebb current, the turbid brackish water from the north moves southward, elevating the ambient suspended load. In near-bottom waters this process is augmented by local resuspension of bottom sediments, if the bottom currents reach some threshold velocity. These conclusions are consistent with the general conclusions of Gatto (1976), who stated that from observations of LANDSAT images of Lower Cook Inlet, it appeared that turbid plumes were more prominent in the southern and central part of the lower Inlet just after the ebb current.

D. Sediment Trap Studies

During cruise RP-4-MF-78A-II (19 May-4 June 1978), three moorings, each supporting one set of tandem sediment traps located 10 meters above

the bottom, were deployed along a transect line extending from Kamishak Bay to Kachemak Bay in Lower Cook Inlet (Fig. 1). The purpose of the traps was to obtain long-term averages of the vertical fluxes of suspended matter in selected regions of Lower Cook Inlet. The sediment trap capture period was set for closure approximately 85 days after deployment, which occurred on May 27, 1978. Of the six sediment traps deployed, four were recovered. The two sediment traps from station ST-3 were accidentally dredged up by the fishing vessel, Columbia, and the samples were lost. In addition, most of the sample from one of the sediment traps at ST-2 was also lost due to breakage of the sodium azide diffusion cap during recovery. Table 1 summarizes the particulate matter fluxes obtained by gravimetric analysis of the material captured by the traps. Also included are the mean particulate fluxes obtained by Larrance (1978) for short-term sediment trap deployments at CB-1, CB-4, and CB-7. The long-term flux at ST-1 is about the same as the mean value obtained by Larrance for traps deployed at CB-1 (20.8 g m^{-2} day^{-1} vs. 22.0 g m^{-2} day). This suggests that the two locations are very similar in their sedimentation characteristics and the data from the two sets of traps can be intercompared. The long-term sediment flux at ST-2 was 2.4 times greater than the mean of the sediment fluxes at CB-4 (28.5 g m^{-2} day^{-1} vs. 12.0 g m^{-2} day). While these stations were less than 15 nautical miles apart (Fig. 1), these differences are probably real because station ST-2 is within the region dominated by the outflowing brackish water and station CB-3 is in the region influenced by the inward flowing Gulf of Alaska water. Presumably, a significant fraction of the suspended matter in the outward flowing brackish water settles out in Kamishak Bay. Just how much of this material gets buried within the

Table 1. Sedimentation rates of suspended materials collected by sediment traps deployed on moorings approximately 10 m above the bottom at selected locations in Lower Cook Inlet

Station Location	Time Open (hours)	Average Flux ($g\ m^{-2}\ day^{-1}$)
CB-1*	120	22.0 ± 25
CB-4*	120	12.0 ± 8
CB-7*	120	28.8 ± 2
ST-1	2040	20.8 ± 7
ST-2	2040	28.5

*Data from Larrance (1978).

sediments below the zone of resuspension cannot be determined until the sediment trap flux data are compared with the sediment accumulation data, which will be determined by ^{210}Pb dating of sediment cores from the same region.

III. Problems Encountered

We have no significant problems to report at this time.

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VI. Estimate of Funds Expended	Allocated	Expended	Balance
Salaries and Overhead	$79.7 K	$40.7 K	$39.0 K
Travel and Shipping	3.8	0.8	3.0
Equipment	0	0	0
Logistic Support	1.2	0	1.2
Publications, Reports and Data Processing	2.6	0.7	1.9
Other Direct Costs	4.3	3.7	0.6
Indirect Costs	3.4	0	3.4
Totals	$95.0 K	$45.9 K	$49.1 K

QUARTERLY REPORT

Research Unit: 153

Reporting Period: October 1-December 31, 1978

IDENTIFICATION OF NATURAL AND ANTHROPOGENIC PETROLEUM SOURCES IN THE COOK INLET UTILIZING LOW MOLECULAR WEIGHT HYDROCARBONS

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January 1979

I. Task Objectives

The proposed studies for FY 79 will focus on two marine environments characterized by the inputs of natural and anthropogenic hydrocarbons. They are Norton Sound and Cook Inlet. In each of these environments the long-range goal is to develop procedures by which the introduction of oil can be reliably documented and to use these methods to investigate the fate of petroleum under natural conditions. These studies were initiated this year in Cook Inlet and will be expanded during FY 79.

In support of our program to understand the fate of oil under arctic and subarctic conditions, we will continue the oil-suspended matter interaction studies with emphasis on the dynamics. The specific objectives of the program in each lease area are described below.

The program for FY 79 will expand upon the framework developed this year. One phase of this expansion includes more detailed analysis of aromatics, both the light and heavy compounds. Because aromatics are more toxic than the paraffins, and because of their ubiquitous presence in crude oils and refined products, the occurrence and fate of these compounds is of paramount importance. The program outlined for next year involves the analysis of waters, and suspended sediments for aromatics. In addition, our absorption experiments involve partitioning of hydrocarbons between oil and sediments, with particular emphasis on aromatics.

While these experiments have been useful in defining the loading characteristics of Cook Inlet suspended matter, they do not address questions of dynamics. In Cook Inlet, the suspended loads are substantial (~ 100 mg/ℓ upper end of Inlet), providing a large scavenging potential for oil. When oil is spilled on the surface, turbulence transports suspended solids to the

lower surface of the slick, where continuous scavenging may take place.

A. Cook Inlet

This year's studies have shown rather conclusively that the region north of The Forelands is a source of petroleum hydrocarbons, presumably originating from the production region of Trading Bay. These conclusions are largely derived from the abundance of alkanes versus alkenes and the occurrence of soluble LMW aromatics. The methodology employed for the detection of aromatics was not quantitative, but served to identify the presence of aromatics. With this knowledge in hand, next year's study will focus on compound identification and quantification of LMW aromatics using glass capillary chromatography and GC-MS characterization. Considerable attention will be given to the identification of unique aromatic compounds present in crude oils and their abundance in Cook Inlet.

Our current studies will continue into the biological production of LMW aliphatics, both in the water column and in the sediments. Laboratory experiments were initiated this year in an attempt to more fully understand the conditions under which LMW alkenes are produced. Preliminary results indicate that light is an important factor, but we have not ruled out the importance of microorganisms.

Where possible, attempts will be made to determine the composition and fluxes of LMW aliphatics from the sediments. We are interested in elucidating the significance of sedimentary hydrocarbon production toward the HC budget of Cook Inlet. Efforts are currently underway to develop a simple compartment model describing the mass flow of hydrocarbons from Cook Inlet. Several models are currently being explored, but preliminary results are at least one year away.

Specifically, next year's objectives will be:

1. Investigate the time variation of LMWH (aliphatics and aromatics) in the water at two 48-hr. time series stations in the spring of 1979.

2. Investigate the distribution of adsorbed hydrocarbons on suspended matter at the same time series stations. These are the heavy hydrocarbons ($\geq C_{12}$) collected by high speed centrifugation.

3. Determine the vertical distribution of LMW aliphatics in the interstitial pore waters at the time series station in Kachemak Bay. We will compare the gas harpoon to conventional gravity coring techniques.

4. Determine the abundance and content of petroleum-like hydrocarbons associated with suspended matter collected in sediment traps (Dr. Feely, R.U. 152). This study is designed to evaluate the vertical transport of petroleum hydrocarbons associated with suspended matter. The responsibility for sediment acquisition falls under R.U. 152.

5. Participate in continuing intercalibrations and methods evaluation programs for both light and heavy hydrocarbons.

B. Norton Sound

The objectives of this phase of the work are largely the same as proposed two years ago, but not implemented. At the present time, our knowledge of the Norton Sound gas seep is restricted to the analysis of water for LMW aliphatics. These data suggest that the hydrocarbons are of thermogenic origin and presumably are associated with the heavier fractions. Since these hydrocarbons are not anthropogenic in origin, the general strategy is to characterize the hydrocarbons associated with gas seep and determine their areal extent. This includes the dissolved fraction (LMWH) as well as the adsorbed material. These data are to be used to investigate suitable hydrocarbon components as tracers from a bottom source and to evaluate their dispersion and transport characteristics. Specifically, we intend to:

1. Assess the composition of LMW aliphatics and aromatics in the water near the seep and evaluate the dispersion characteristics

of the plume. This will be coordinated with R.U. 435.

2. Determine the vertical profile of LMW aliphatics in the interstitial waters near the locus of the seep and compare it to distributions found to the east (upstream). The gas harpoon and conventional gravity coring will be attempted, but may not be successful due to the high impermeability of the bottom. Also, an attempt will be made to characterize the LMW aromatic fraction in pore waters to the extent sampling is successful.

3. Determine the composition and concentration of petroleum-like hydrocarbons associated with suspended matter. Suspended solids will be obtained with a high speed centrifuge. Analysis of the heavy fractions will include both aliphatic and aromatics. Two 24-hr. time series stations will be occupied for the purpose of acquiring sufficient sediment for HC analysis. One of these stations will be a control.

These objectives will be carried out during a summer cruise to Norton Sound.

II. Field or Laboratory Activities

A. Ship and Field Activities

No field activities were scheduled or carried out during this period of time.

B. Scientific Party - N/A

C. Methods - N/A

D. Sample Locality - N/A

E. Data Collected or Analyzed

All water samples taken during the May cruise has been analyzed and reported previously. Dissolved LMW hydrocarbon samples taken in August-September have been analyzed and the data submitted to NODC. The synthesis of these data will be reported in April 1979. Suspended matter collected with the centrifuge and in the sediment traps has been extracted and is currently undergoing G.C. analysis. These analyses have been interrupted by gas chromatographic difficulties.

III. Results

The dissolved LMW hydrocarbon data taken during the August-September cruise has been reduced to hard copy form, but is not available in graphical form. These data will be included in the comprehensive annual report submitted in April, although if the data are required earlier, it could be submitted.

As stated earlier, all sediment samples, including the marsh samples taken by SAI, have been extracted and await chromatographic analyses. Chronic electronic difficulties have precluded the finalization of these results. These data will be available by the April reporting schedule.

Work is continuing on the oil adsorption studies. Several months effort was devoted to improving extraction efficiencies and oil quantification procedures. Having accomplished this, the next phase of the work, which will begin this month, will be to investigate the efficiency and kinetics of particle sorption from a surface oil layer. The oil will be allowed to "weather" during the coarse of the experiment.

IV. Problems Encountered

Major difficulties were encountered in the analysis of seawater for LMW aromatic compounds. Major areas of concern included carrier gas contamination, poor stripping efficiency, and inadequate chromatography. Because of the complexity and abundance of volatile organics present in seawater, procedures adopted for both the May and August cruises were inadequate to resolve the components. Progress has been made on identifying and correcting the sources of contamination. Studies on the purging and trapping efficiencies is currently underway. In parallel with these activities, component resolution on

a 10 m glass capillary column (SE-54) is being checked. Packard model 5992 has been set up and is currently undergoing checkout procedures. It will be installed on the R/V DISCOVERER next April prior to the Alaskan field season.

V. Budget Expenditures

	Allocated	Expended to Date	Balance
Salaries	$112,982	$26,300	$86,682
Travel	5,552	-0-	5,552
Logistics	1,000	-0-	1,000
Publications	2,800	-0-	2,800
Other Direct Costs	5,650	3,700	1,950
	$127,984	$30,000	$97,984

QUARTERLY REPORT

Contract: #03-5-022-56
Research Unit: 162
Task Order: #12
Reporting Period: 10/1/78-12/31/78
Number of Pages: 17

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

December 1978

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

Resurrection Bay

R/V *Acona* No. 267, 9 October 1978

Personnel: D. C. Burrell
T. Owens
M. Robb
D. Weihs
C. Cremo

Full survey of hydrography, nutrient distributions, and other chemical parameters is shown in Table I. Closed spaced water column and interstitial water samples were taken. The primary objective of this cruise was to research the distribution and flux of metals across the sediment-water interface.

TABLE I

RESURRECTION BAY

R/V *Acona* 267 - 9 October 1978

Operations

Station	Depth (m)	Operations
RES 2.5	287	Water column samples: T, S, O_2, nutrients, POC, DOC, SL, particulate sediment sizing, sampling for dissolved Ca, Cu, Mn and V and particulate Al, Mn and V.
		Benthos core: Interstitial H_2S, SO_4, TM, Cl, alk, DOC, Eh, pH, samples for dissolved Ca, Mn, Cu. Sediment samples retained for size analysis, POC, chemical extracts for TM.
RES 4	261	T, S, O_2.

B. Scientific Parties

As noted above.

C. Field Collection Method

As discussed in 1977-78 Annual Report.

D. Sample Localities

Standard stations as discussed previously.

E. Laboratory Analysis Program

No new techniques employed this quarter. Methods as given in previous reports.

III. RESULTS

A. Lower Cook Inlet - Time Series Data

Additional geochemical data for Stations CB-7 and CB-9 occupied on the *Discoverer* cruise 4-16 May 1978 are given in Tables II and III. Additional geochemical data for Stations CB-10 taken on the *Discoverer* cruise of 29 August-2 September 1978 are given in Table IV.

B. Natural Flux of Heavy Metals at NEGOA Specific Study Sites

Additional geochemical data for the time periods April and July 1978 are given in Tables V and VI and Figure 1.

C. Heavy Metal Contents of Sediment Extracts

Additional organic and inorganic sediment extraction data for NEGOA specific study site and for lower Cook Inlet are given in Tables VII-IX and X-XI respectively.

TABLE II

LOWER COOK INLET

OSS *Discoverer* - 4-16 May 1978

Water Column Chemistry at Time Series

Station CB-7, Kachemak Bay

Hour	Depth	DOC (mg C/ℓ)
0	surface	> 3.80
0	deep	2.99 ± 0.04
6	surface	2.31 ± 0.31
6	deep	2.52 ± 0.36
12	surface	3.10 ± 0.09
12	deep	2.50 ± 0.18
18	surface	2.65 ± 0.26
18	deep	2.55 ± 0.10
24	surface	2.86 ± 0.10
24	deep	1.76 ± 0.02

TABLE III

LOWER COOK INLET

OSS *Discoverer* - 4-16 May 1978

Water Column Chemistry at Time Series

Station CB-9, Redoubt Bay

Hour	Depth	DOC (mg C/ℓ)
0	surface	2.43 ± 0.26
0	deep	2.27 ± 0.42
6	surface	2.22 ± 0.55
6	deep	2.14 ± 0.13
12	surface	1.76 ± 0.17
12	deep	1.91 ± 0.10
18	surface	2.57 ± 0.84
18	deep	1.95 ± 0.34
24	surface	2.09 ± 0.07
24	deep	2.23 ± 0.36

TABLE IV

LOWER COOK INLET

OSS *Discoverer* - 29 August-2 September 1978

Water Column Chemistry at Time Series
Station CB-10

Hour	Depth	DOC (mg C/ℓ)
0	surface	1.87 ± 0.23
0	deep	1.9
6	surface	1.73 ± 0.31
6	deep	1.3
12	surface	1.47 ± 0.07
12	deep	2.11 ± 1.08
18	surface	1.28 ± 0.29
18	deep	1.47 ± 0.42
24	surface	2.0
24	deep	1.20 ± 0.26

TABLE V

NEGOA SPECIFIC STUDY SITE: RESURRECTION BAY

R/V *Acona* 260 - April 1978

Water Column Chemistry at

Station Res 2.5

Depth (m)	DOC (mg C/ℓ)
10	2.3
30	1.15 ± 0.12
70	1.68 ± 0.76
110	1.45 ± 0.33
170	0.89 ± 0.05
190	1.06 ± 0.08
210	1.45 ± 0.45
230	1.13 ± 0.03
250	1.08 ± 0.02
260	1.34 ± 0.02
270	1.12 ± 0.09
280	0.98 ± 0.05
285	1.44 ± 0.45

TABLE VI

NEGOA SPECIFIC STUDY SITE: RESURRECTION BAY

R/V *Acona* 202 - July 1978

Water Column Chemistry at

Station Res 2.5

Depth (m)	DOC (mg C/ℓ)
10	> 4.0
30	1.04 ± 0.49
70	0.75 ± 0.13
110	1.17 ± 0.06
170	1.09 ± 0.30
190	0.78 ± 0.05
210	0.76 ± 0.22
230	0.52 ± 0.03
250	0.69 ± 0.06
260	0.58 ± 0.12
270	0.79 ± 0.35
280	1.58 ± 0.23

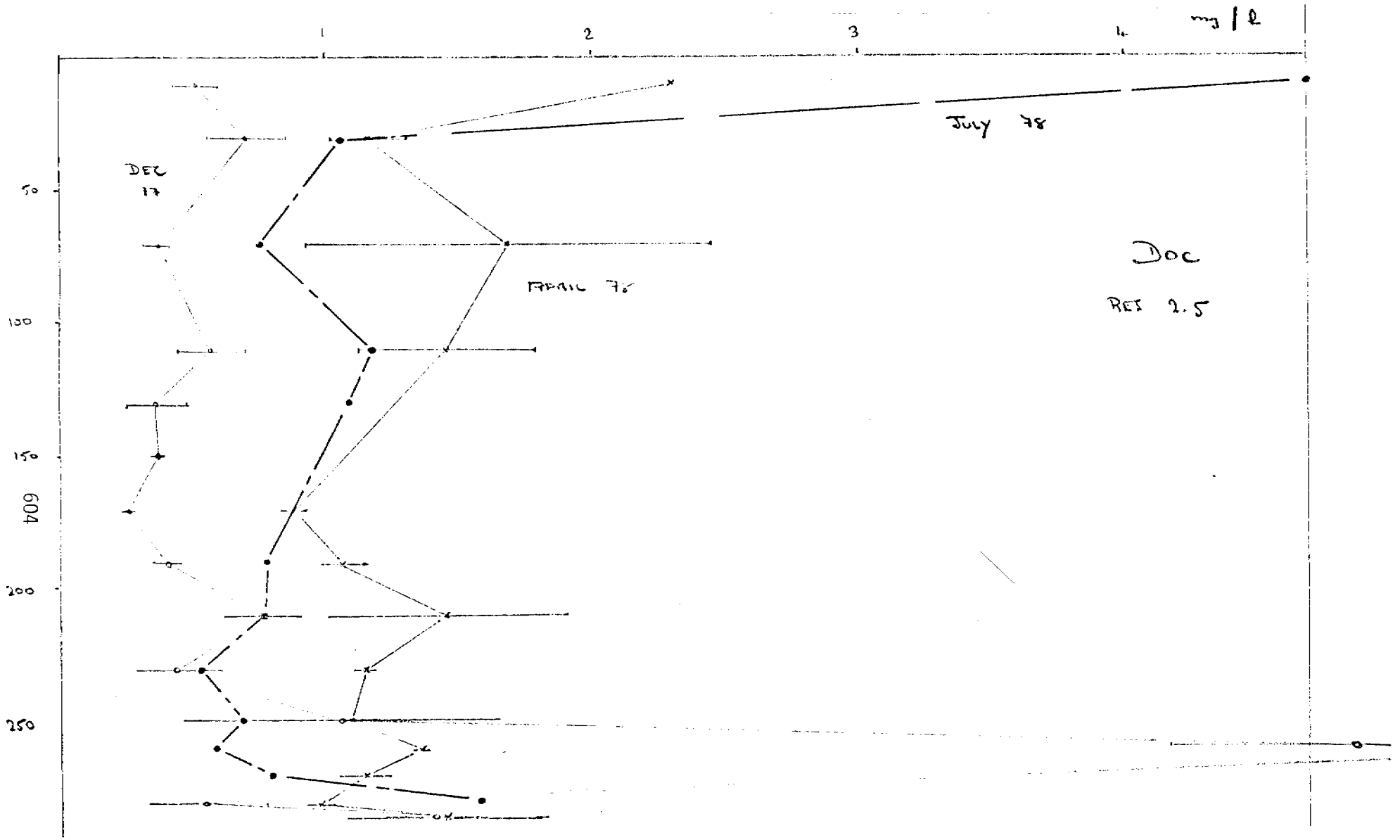

Figure 1. Seasonal DOC at Res 2.5.

TABLE VII

RESURRECTION BAY

R/V *Acona* 260 - April 1978

Heavy Metal Contents of Organic Matrix Extractions
of Core Sediment (µg/g Dry Sediment)
Station Res 2.5

Sample Depth (cm)	Cu	Mn	Fe	Zn	Ni
0 - 5.5	5.9 ± 1.8	15.0 ± 0.1	<1.5	<0.6	<0.3
14.5 - 19.5	4.5 ± 0.6	7.8 ± 1.5	<1.5	<0.6	<0.3
19.5 - 24.0	7.1 ± 1.1	5.0 ± 0.3	<1.5	<0.6	<0.3
50.0 - 54.5	6.0 ± 1.3	2.6 ± 0.7	<1.5	<0.6	<0.3

TABLE VIII

RESURRECTION BAY

R/V *Acona* 260 - April 1978

Heavy Metal Contents of Inorganic Matrix Extractions of
Core Sediments (µg/g; ppm dry weight)
Station Res 2.5

Sample Depth (cm)	Cu	Mn	Fe	Zn	Ni
0 - 5.5	38 ± 11	443 ± 10	$> 10^4$	-	30 ± 6
14.5 - 19.5	73 ± 7	233 ± 29	$> 10^4$	-	21 ± 7
19.5 - 24.0	66 ± 7	223 ± 40	$> 10^4$	-	26 ± 5
50.0 - 54.5	74 ± 7	278 ± 39	$> 10^4$	-	35 ± 6

TABLE IX

RESURRECTION BAY

R/V *Acona* 270 - October 1978

Heavy Metal Contents of Organic Matrix Extractions
of Core Sediments (µg/g dry sediment)

Sample Depth (cm)	Cu	Mn	Fe	Cd
0 - 10	1.65 ± 0.05	18.5 ± 2.7	<3	0.22 ± 0.05
10 - 20	1.3 ± 0.1	11.0 ± 0.3	<3	0.23 ± 0.06
20 - 30	1.0 ± 0.2	6.1 ± 0.3	<3	0.15 ± 0.03
30 - 40	1.6 ± 0.8	7.1 ± 1.6	<3	-
40 - 50	0.9 ± 0.1	4.9 ± 0.3	<3	0.15 ± 0.02
50 - 60	0.9 ± 0.1	3.2 ± 0.6	<3	0.19 ± 0.02
80 - 85	0.95 ± 0.05	3.9 ± 0.5	<3	0.20 ± 0.03

TABLE X

LOWER COOK INLET

R/V *Acona* - 21-26 June, 1977

Heavy Metal Contents of Organic Matrix Extractions
of Surface Haps Core Samples (µg/g)

Station No.	Cu	Mn	Fe	Zn	Ni
CI - 16	6.0 ± 0.7	2.1 ± 0.2	<1.5	<0.6	<0.3
CI - 12	3.7 ±0.7	-	<1.5	<0.6	<0.3

TABLE XI

LOWER COOK INLET

R/V *Acona* - 21-26 June, 1977

Heavy Metal Contents of Inorganic Matrix Extractions of Surface Haps Core Samples (μg/g)

Station No.	Cu	Mn	Fe	Ni
CI - 15	15 ± 2	240 ± 16	>5000	5 ± 1
CI - 16	32 ± 2	200 ± 60	$>10^4$	24 ± 5
CI - 12	6	120	>5000	6

IV. PRELIMINARY INTERPRETATION

Not included in the quarterly report, which contains comparatively few new data; most of this quarter's work is not yet in final format.

V. PROBLEMS ENCOUNTERED

A. Equipment problems reported for the previous quarter continued into the current reporting period but are now largely solved. In particular, the plasma furnace is now again working satisfactorily although it took repeated correspondence from ourselves, the Institute and finally, the University authorities to the manufacturers to get satisfaction. We suspect that the spectra size analyser will never function to the claimed degree of accuracy and precision but we are continuing to work on this. The atomic absorption spectrophotometers have also now been serviced.

B. Activation analysis planned for October had to be delayed a second time because of further malfunctions with the U.C. Irvine reactor. We were able to run through a fairly large batch in mid-December (these data are not yet available in report form) but at least one further session will be required.

C. The sediment extraction scheme developed and reported in the previous quarterly report has been operated throughout this current quarter but is incredibly time consuming. The data reports above were the efforts of one full time technician over this time period. We have acceded to OCSEAP requests to utilize a common scheme with PMEL Seattle but believe that since any extraction scheme is arbitrary, the effort and expense are unjustified.

D. Irreparable damage to our special trace metal sampling bottles was reported previously. It should be recorded here that this was due to no fault of any of the personnel from this R.U. It will be necessary for us to request an internal budget transfer to replace this equipment.

E. OCSEAP Boulder cannot apparently assign further cruise time for the NEGOA specific study site program. Although such management problems are fully appreciated it should be recorded here that the Yakatat Bay data collected to date will be of little use unless more seasonal coverage is obtained.

Fiscal Report

Contract: 03-5-022-56

Task Order: #12

Date: December 22, 1978

Category	Billed this Quarter	Cumulative Billed
Salaries and Wages	$21,750.33	$276,084.71
Travel	791.42	19,508.75
Equipment	3,070.73	52,827.44
Other	8,385,86	207,005.94
Staff Benefits	3,357.13	45,711.63
Overhead	10,819.96	144,606.42
Total Billed	$48,175.43	$745,744.89
Total Award		$880,717.00
Total Unbilled		134,972.11

These data are taken from University of Alaska vouchers submitted in the three months prior to the above date.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: December 31, 1978

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 12 R.U. NUMBER: 162/163/288/293/312

PRINCIPAL INVESTIGATOR: Dr. D. C. Burrell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches are identified as foot notes. Only data due are listed.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates		
	From	To	Batch 1	2	3
Acona	6/21	6/26/77		6/30/79*	
Discoverer	5/25	6/5/77		6/30/79*	6/30/79*
Acona 246	7/25	7/30/77	6/30/79*		
Volna	7/77	8/77	6/30/79*		
Surveyor	3/31	4/27/77			6/30/79*
Surveyor	11/3	11/17/77		6/30/79	6/30/79*
Acona 254	11/20	12/4/77		6/30/79*	
Acona 260	4/22	4/26/78		6/30/79*	
Discoverer	5/4	5/17/78	6/30/79*	6/30/79*	
Acona 262	7/10	7/11/78	6/30/79	6/30/79	
Discoverer	8/29	9/2/78	6/30/79	6/30/79	
Acona 270	10/78	10/78		6/30/79*	

Data Batch 1 Trace elements in water column
Data Batch 2 Trace elements in sediment or sediment extracts
Data Batch 3 Trace elements in biota

* Data appear in quarterly and annual reports, but still to be submitted on tape.

QUARTERLY REPORT

Contract: #03-5-022-57
Research Unit: #275
Task Order: #5
Reporting Period: 9/30/78-12/31/78
Number of Pages: 2

HYDROCARBONS: NATURAL DISTRIBUTION AND DYNAMICS ON THE ALASKAN OUTER CONTINENTAL SHELF

Principal Investigator

D. G. Shaw

Institute of Marine Science
University of Alaska
Fairbanks, Alaska

December 1978

I. FIELD ACTIVITIES

None since the last quarterly report.

II. LABORATORY ACTIVITIES

Analysis of samples from Cook Inlet and the Beaufort Sea are proceeding without any major problem. Some effort is also being devoted to the development of a solid resin (Tenax) based seawater extraction system for use during next springs Cook Inlet cruise.

III. RESULTS

This research units quarterly report for the spring of 1978 contained the statement "[Cook Inlet water extracts] showed a steady series of normal alkanes characteristic of petroleum". This statement is correct; however its implications probably are not. Further analysis has shown that, 1) these samples do not contain cycloalkanes or a UCM; and, 2) these samples do not contain aromatic hydrocarbons characteristic of petroleum. Based on all available data to date it appears that the normal alkanes may be of bacterial origin.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: December 31, 1978

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 5 R.U. NUMBER: 275/276/294

PRINCIPAL INVESTIGATOR: Dr. D. G. Shaw

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Batch	Estimated Submission Dates[1]		
	From	To		1	2	3
Silas Bent Leg I #811	8/31/75	9/14/75	None	submitted	submitted	
Discoverer Leg III #810	9/12/75	10/3/75	None	None	submitted	
Discoverer Leg IV #812	10/3/75	10/16/75	Submitted	None	submitted	
Surveyor #814	10/28/75	11/17/75	None	submitted	None	
North Pacific	4/25/75	8/7/75	submitted	None	None	
Contract 03-5-022-34	Last	Year	submitted	submitted	submitted	
Moana Wave MW 001	2/21/76	3/5/76	None	submitted	submitted	
Miller Freeman	5/17/76	6/4/76	submitted	None	None	
Glacier	8/18/76	9/3/76	None	submitted	None	
Discoverer	9/10/76	9/24/76	None	submitted	submitted	
Moana Wave	10/7/76	10/16/76	None	submitted	submitted	
Acona	6/25/76	7/2/76	submitted	submitted	submitted	
Discoverer	5/20/77	6/11/77	submitted	None	None	
Acona	6/22/77	6/27/77	submitted			
Surveyor	11/03/77	11/17/77	submitted	None	None	
Discoverer	5/4/78	5/17/78	3/31/79	None	None	

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Discoverer	8/29	9/2/78	3/31/79	3/31/79	None
Alumiak	8/3	9/2/78	3/31/79	None	None

Note: [1] Data Management plan has been approved and made contractual.

Fiscal Report

Contract: 03-5-022-56

Task Order: #5

Date: December 22, 1978

Category	Billed this Quarter	Cumulative Billed
Salaries and Wages	$25,082.74	$344,085.61
Travel	1,244.14	14,841.94
Equipment	(610.00)	136,664.12
Other	2,329.09	162,838.10
Staff Benefits	3,531.79	55,648.75
Overhead	12,433.82	175,302.82
Total Billed	$44,011.58	$889,381.34
Total Award		$1,124,551.00
Total Unbilled		235,169.66

These data are taken from University of Alaska vouchers submitted in the three months prior to the above date.

Quarterly Report
October to December, 1978
Research Unit R.U. No. 480

Characterization of Organic Matter in Sediments from Cook Inlet

Contract No. 03-6-022-35250

I.R. Kaplan, M.I. Venkatesan and J. Bonilla

Institute of Geophysics and Planetary Physics

University of California

Los Angeles, California 90024

December, 1978

Field Activity:

The locations of the sampling stations in spring and summer, 1978 cruises are represented in Fig. 1

Laboratory Activity:

1. All 17 spring samples and a replicate of one of the samples have been column chromatographed and the aliphatic fractions have been run on gas chromatograph.

The completed gravimetric and gas chromatographic data and characteristic parameters of the hydrocarbons are presented in Fig. 2 and Tables 1 and 4-5.

2. All 17 summer samples, including two Coal Oil Bay samples, have been extracted and column chromatographed into aliphatic and aromatic fractions. Data on non-saponifiable fractions are represented in Fig. 2. Gravimetric data is summarized in Table 2.

Sediments were also analyzed for total and organic carbon contents (Table 3)

3. Interlaboratory calibration samples have been analyzed and the data will be sent to Dr. D. W. Brown.

Table 1. Cook Inlet Sediment Samples (1978 - Spring Cruise)

Station No.*	Latitude (N)	Longitude (W)	Depth (m)	Nonsapon. Fr. (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
201	59°12.5'	153°52.6'	22	39.09	4.49	3.24
203	59°05.8'	153°29.5'	38	13.81	1.24	1.05
204	59°13.7'	153°39.4'	34	44.51	2.12	1.91
211	59°26.1'	153°37.5'	19	20.41	1.27	1.26
212	59°32.6'	153°20.9'	26	20.09	1.58	1.42
213	59°29.9'	153°14.0	33	16.06	1.14	1.27
214	59°17.9'	153°13.2'	53	25.83	1.41	1.35
233	59°48.9'	152°55.6'	14	32.24	2.27	2.06
233R	59°48.9'	152°55.6'	14	32.67	2.70	2.45
234	59°38.2'	152°56.4'	38	13.86	0.99	0.61
245	60°07.8'	152°16.7'	46	11.01	1.17	1.01
247	59°58.3'	152°34.1'	20	7.97	1.02	0.87
255	60°18.8'	151°37.0'	42	57.07	1.45	14.10
265	60°34.7'	151°49.5'	16	95.09	28.81	8.74
370	58°17.0'	154°02.6'	112	51.76	3.09	3.66
380	58°38.4'	153°26.0'	57	24.85	2.91	1.72
390	58°53.5'	153°11.0'	170	27.77	2.13	2.56
394	58°51.3'	153°08.2'	171	42.59	2.06	3.83

* All samples are 0-2 cm.

R - Replicate

Table 2. Cook Inlet Sediment Samples (1978 - Summer Cruise)

Station* No.	Latitude (N)	Longitude (W)	Depth (m)	Nonsapon. Fr. (ppm)	Aliphatic Fr. (ppm)	Aromatic Fr. (ppm)
378	58°01.9'	153°28.2'	92	38.10	1.26	2.61
388	58°27.4'	152°56.1'	214	108.60	5.81	9.97
384	58°30.5'	153°14.5'	176	48.39	2.00	3.66
390	58°53.6'	153°10.8'	165	32.15	1.97	1.89
204	59°13.8'	153°39.7'	33	25.12	1.42	1.48
206	59°09.5'	153°06.5'	90	26.65	0.88	1.86
215	59°22.4'	152°48.3'	78	7.73	0.48	0.63
217	59°21.7'	152°22.8'	71	16.51	0.44	0.42
212	59°32.0	153°21.0'	24	23.99	2.14	1.54
398	58°49.3'	152°12.0	-	84.04	0.07	2.48
205	59°06.7'	152°40.4'	138	38.88	1.14	1.06
234	59°38.3'	152°55.7'	39	34.09	1.94	0.96
UC100	59°01.2'	152°28.8'	150	21.67	0.99	0.75
UC200	59°01.0'	152°32.4'	150	33.03	1.24	1.35
UC300	58°28.3'	153°45.6'	101	94.82	4.55	5.16
CB8	59°39.4'	151°16.6'	-	117.95	13.08	7.24
CB8R	59°39.4'	151°16.6'	-	90.05	9.43	7.68

* All samples are 0-2 cm

R - Replicate

TABLE 3

Sample	TOC (% C)	TC (% C)
SPRING SAMPLES		
201	0.61	0.94
203	0.55	0.80
204	0.45	0.69
211	0.33	1.26
212	0.42	0.69
213	0.59	0.65
214	0.45	0.54
233	0.41	0.58
234	0.35	0.93
245	0.42	0.63
247	0.20	0.41
255	0.25	0.78
265	0.15	0.35
370	0.71	0.91
380	0.63	0.83
390	0.47	0.61
394	0.72	1.11
SUMMER SAMPLES		
388	1.16	1.57
384	0.73	0.89
390	0.57	0.80
204	0.67	0.82
206	0.38	0.60
215	0.49	0.51
217	0.25	0.34
212	0.61	1.10
398	0.44	6.22
205	0.42	1.23
234	0.30	0.89
UC100	0.31	1.02
UC200	0.38	1.56
UC300	0.69	1.02
CB8	0.93	1.53

Table 4. Aliphatic Hydrocarbon Concentrations (ng/g)

in Cook Inlet Sediment Samples, Spring 1978.

Station*	n-C_{15}	n-C_{16}	n-C_{17}	Pristane	n-C_{18}	Phytane	n-C_{19}	n-C_{20}	n-C_{21}	n-C_{22}	n-C_{23}
201	15.0	5.1	11.8	11.6	8.9	3.5	13.9	12.7	28.3	23.6	62.1
203	n.d.	n.d.	0.6	0.6	0.9	0.2	2.1	2.7	6.4	5.5	14.7
204	0.7	1.2	3.3	3.2	3.9	1.0	7.5	6.6	14.4	13.0	32.7
211	2.4	2.5	4.7	5.7	4.6	1.7	7.9	7.9	16.1	12.7	31.4
212	n.d.	n.d.	0.6	0.8	1.2	0.3	2.9	3.4	7.3	6.0	14.9
213	0.3	0.5	1.3	1.3	1.6	0.4	2.8	2.9	6.4	5.4	14.0
214	1.1	1.4	2.8	2.7	3.7	0.7	6.2	5.5	9.8	8.3	19.6
233	4.0	4.6	6.6	7.7	7.3	1.6	11.0	10.5	18.6	15.4	34.1
233R	0.4	1.1	3.2	3.4	4.4	1.0	9.4	8.7	19.6	14.1	31.5
234	0.4	0.4	0.8	0.7	0.8	0.2	1.2	0.9	1.2	1.3	1.8
245	n.d.	n.d.	0.4	0.5	0.7	n.d.	1.3	1.5	5.8	2.7	6.7
247	n.d.	0.3	0.9	2.2	1.4	0.8	2.5	2.4	3.5	3.7	5.7
255	1.3	1.2	2.0	2.6	1.7	0.5	2.6	2.5	4.6	3.8	7.9
265	8.0	13.0	27.3	14.9	42.3	19.4	65.2	75.1	50.2	38.6	35.2
370	23.3	50.2	20.4	26.3	18.9	6.2	28.9	23.2	49.0	31.7	76.0
380	0.2	0.4	1.0	1.4	1.0	0.3	1.9	2.3	5.7	4.7	12.7
390	1.6	1.8	3.2	5.9	3.7	1.2	6.5	6.2	10.7	9.1	19.3
394	11.4	12.0	18.7	32.9	19.7	6.8	26.4	23.0	31.8	22.8	32.7

* All samples are 0-2 cm, R = replicate, n.d. = too low to be determined accurately

Table 4 (continued)

Station*	n-C_{24}	n-C_{25}	n-C_{26}	n-C_{27}	n-C_{28}	n-C_{29}	n-C_{30}	n-C_{31}	n-C_{32}	n-C_{33}	n-C_{34}
201	28.4	103.9	28.3	282.8	30.2	178.8	18.1	139.7	12.4	52.4	4.9
203	6.2	24.4	6.7	67.9	6.9	42.7	2.8	32.0	2.7	12.0	1.4
204	14.3	51.5	14.4	105.4	12.9	80.5	13.5	55.6	10.0	20.6	1.8
211	14.9	50.6	17.9	138.8	12.8	73.9	10.5	48.9	4.5	15.3	1.0
212	7.3	24.2	7.4	47.4	6.3	32.1	7.0	24.6	4.1	8.6	0.8
213	6.6	25.5	7.0	56.2	7.0	44.2	3.9	30.5	3.2	12.0	1.5
214	9.4	33.0	9.9	62.9	7.9	46.8	8.2	28.3	4.5	7.8	0.7
233	15.6	51.2	14.4	113.1	12.3	78.8	9.8	49.9	5.6	18.3	1.3
233R	16.2	47.7	13.0	92.7	10.0	47.1	12.7	31.7	5.3	9.2	0.9
234	0.9	2.4	0.6	4.8	4.1	5.4	0.1	3.8	1.2	0.4	n.d.
245	3.3	13.6	4.2	28.3	3.6	21.8	2.1	15.0	4.6	1.3	0.9
247	4.8	10.0	5.8	21.2	5.9	17.9	3.8	12.2	2.4	5.2	1.5
255	4.2	12.2	4.5	22.8	3.6	18.8	3.5	13.9	4.1	5.0	0.5
265	22.8	51.2	42.0	40.5	30.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
370	37.1	133.0	36.9	388.7	34.4	221.3	35.9	171.9	16.8	65.1	7.6
380	5.7	23.8	6.6	69.9	7.3	43.1	3.8	31.0	2.7	11.8	1.2
390	12.3	30.5	9.7	70.4	10.5	47.9	8.7	33.4	3.4	11.2	2.1
394	23.7	45.4	34.3	95.7	33.2	79.0	28.6	71.0	12.8	27.7	6.7

* All samples are 0-2cm, R = replicate, n.d. = too low to be determined accurately

Table 5. Characteristic Parameters for Cook Inlet Hydrocarbons (Spring, 1978)

Station	Nonsap. Fr. / O.C. ($\times 10^{-4}$)	Alkanes / O.C. ($\times 10^{-4}$)	Pr. / $n\text{-}C_{17}$	Phy. / $n\text{-}C_{18}$	Pr. / Phy.	Odd / Even
201	64.08	1.74	0.98	0.39	3.34	5.15
203	25.11	0.44	1.07	0.24	2.66	5.66
204	98.91	1.02	0.97	0.27	3.01	4.06
211	61.85	1.45	1.22	0.37	3.34	4.36
212	47.83	0.50	1.34	0.26	2.56	3.74
213	27.22	0.40	0.95	0.28	2.86	4.93
214	57.40	0.62	0.97	0.20	3.66	3.67
233	78.63	1.17	1.17	0.21	4.96	3.93
233R	--	--	1.06	0.22	3.48	3.39
234	39.60	0.09	0.87	0.20	4.09	2.09
245	26.21	0.29	1.25	0.22	2.50	3.99
247	39.85	0.55	2.52	0.57	2.79	2.47
255	228.28	0.48	1.33	0.32	4.87	3.02
265	633.93	3.60	0.55	0.46	0.77	1.06
370	72.90	2.07	1.29	0.33	4.28	4.03
380	39.44	0.38	1.45	0.28	4.99	5.65
390	59.09	0.64	1.85	0.33	4.87	3.48
394	59.15	0.92	1.76	0.34	4.88	2.03

R = Replicate

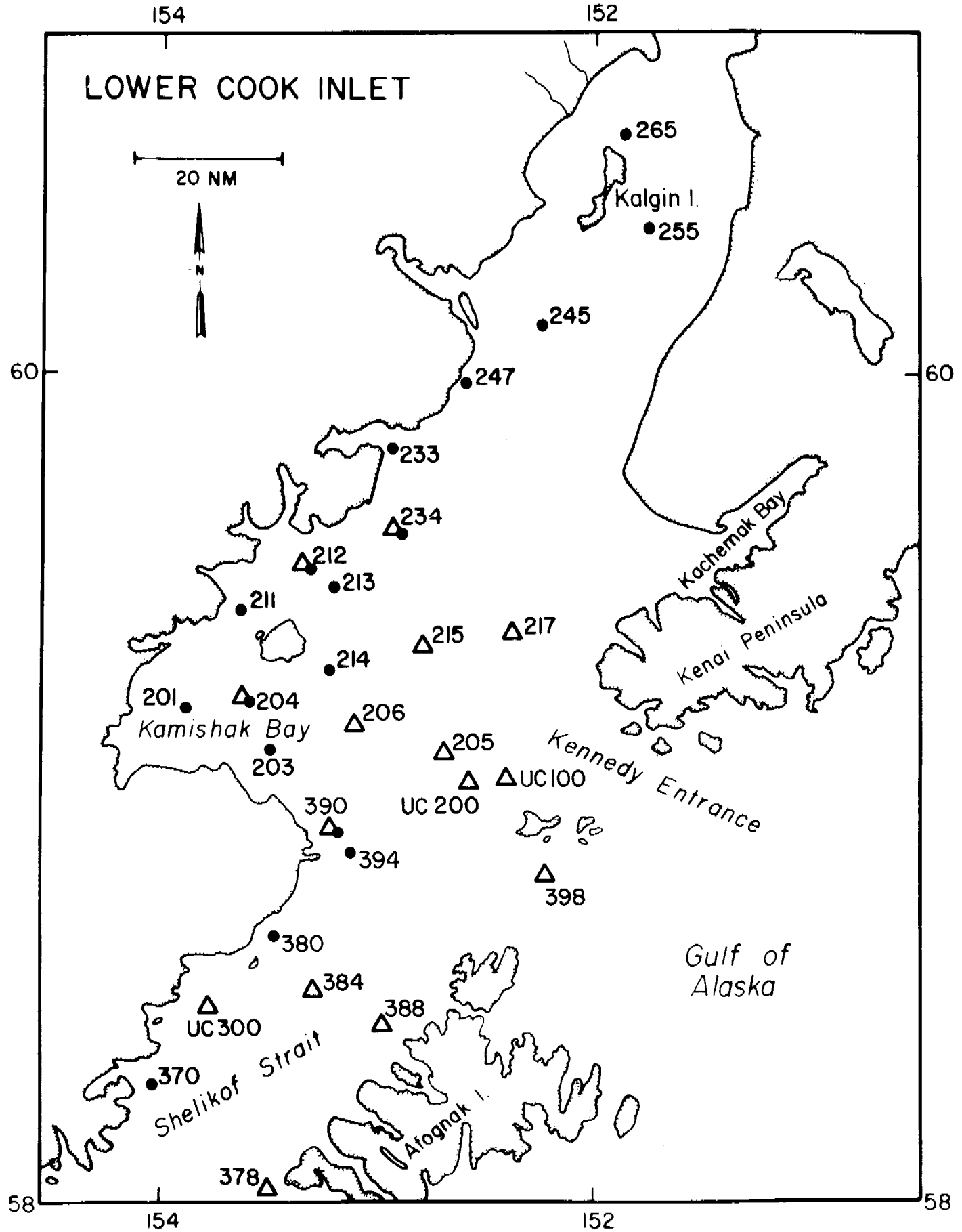

FIG. 1. ● 1978 SPRING SAMPLES, △ 1978 SUMMER SAMPLES

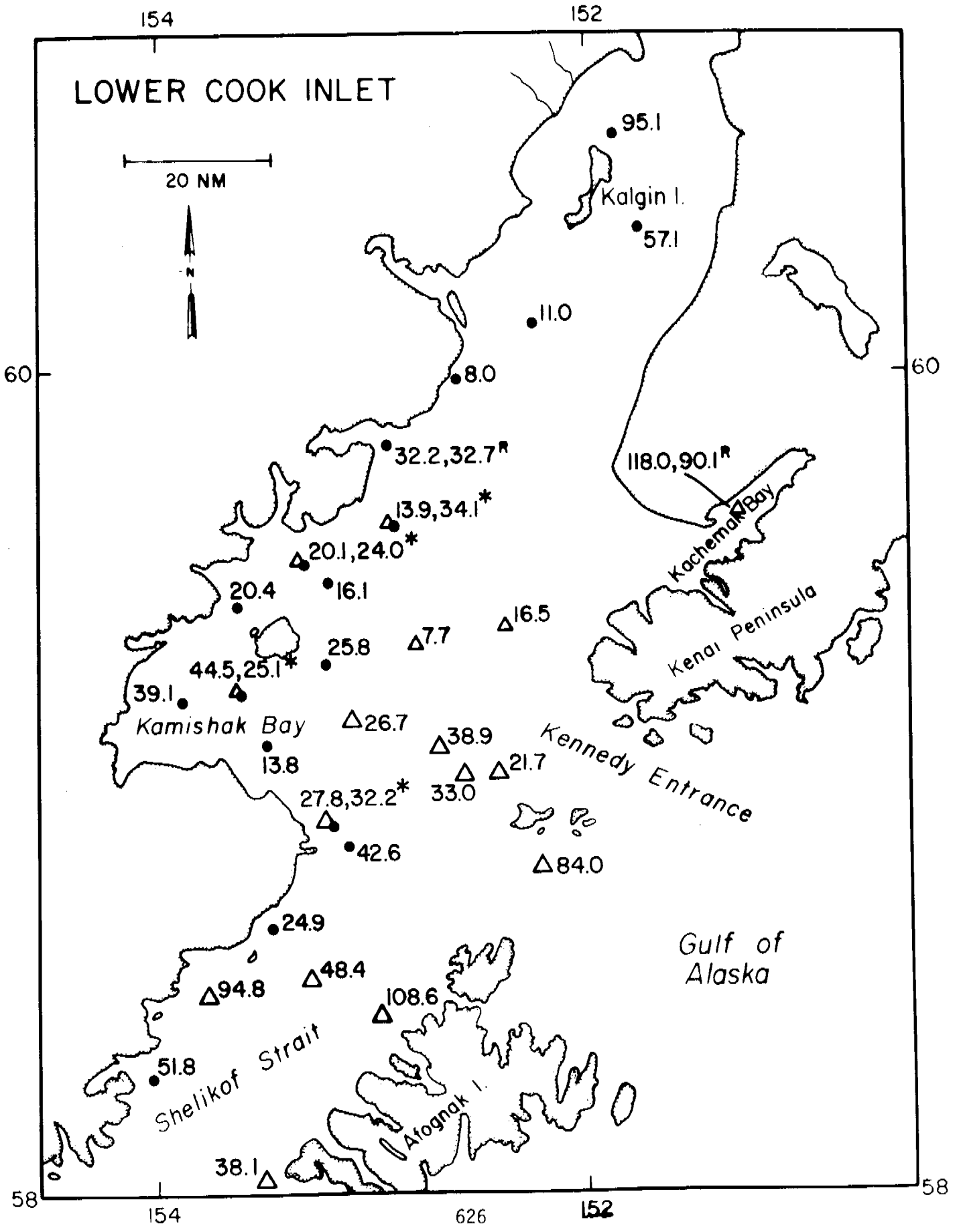

FIG. 2. NONSAPONIFIABLE FRACTIONS IN PPM.

* = SUMMER SAMPLES; R = REPLICATE

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